Managing environmental and energy transitions for regions and cities

The Circular Economy: What, Why, How and Where

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Background information

This paper was prepared as a background document for an OECD/EC high-level expert workshop on “Managing the transition to a circular economy in regions and cities” held on 5 July 2019 at the OECD Headquarters in Paris, France. It sets a basis for reflection and discussion. The background paper should not be reported as representing the official views of the European Commission, the OECD or one of its member countries. The opinions expressed and arguments employed are those of the author(s).

Managing environmental and energy transitions for regions and cities

The workshop is part of a five-part workshop series in the context of an OECD/EC project on “Managing environmental and energy transitions for regions and cities”. The five workshops cover “Managing the transition to a climate-neutral economy”, “Managing environmental and energy transitions in cities”, “Managing the transition to a circular economy”, “Managing environmental and energy transitions in rural areas”, and “Financing, scale-up and deployment”. The outcome of the workshops supports the work of the OECD Regional Development Policy Committee and its mandate to promote the design and implementation of policies that are adapted to the relevant territorial scales or geographies, and that focus on the main factors that sustain the competitive advantages of regions and cities. The seminars also support the Directorate-General for Regional and Urban Policy (DG REGIO) of the European Commission in work of integrating sustainability transitions in the next generation of European Union Cohesion Policy programmes 2021-2027, as well as to support broader discussion with stakeholders on managing long-term environmental and energy goals in regions and cities. The financial contributions and support from DG REGIO are gratefully acknowledged.

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Contents

1 PART I: THEORETICAL AND CONCEPTUAL FOUNDATIONS

1. Historical Background (Paul Ekins)

The idea of the circular economy has two long strands, the first relating to the flow of materials through an economy, and the second concerned with thinking about the economic conditions that might bring about such a flow. These two conceptual streams go back to the early days of the modern environmental movement in the 1960s and 1970s and have a subsequent symbiotic relationship with it.

The materials strand developed out of the concept of 'industrial ecology', a term that, along with the related term 'industrial symbiosis' was used in economic geography in the 1940s to describe the determinants of the location of industries in order to make efficient utilisation of resources and avoid waste. By 1970 these ideas had acquired a normative element, as shown in a remarkable passage from the address of a President of the American Association for the Advancement of Science: "The object of the next industrial revolution is to ensure that there will be no such thing as waste, on the basis that waste is simply some substance that we do not yet have the wit to use... In the next industrial revolution there must be a loop back from the user to the factory, which the industry must close. … If American industry should take upon itself the task of closing this loop, then its original design of the article would include features facilitating their return and remaking." (Spilhaus, 1970: 1673) Earlier, and even more remarkably, Spilhaus had written: "Ideally, the system would be completely closed. All water would be purified and reused; all solid wastes would be sent back as resources for making more things." (Spilhaus, 1966: 488).

It was a full twenty years before these ideas became a central part of the emerging research discipline of industrial ecology as articulated in a paper by Frosch and Gallopoulos for *Scientific American*: "The traditional model of industrial activity in which individual manufacturing processes take in raw materials and generate products to be sold plus waste to be disposed of should be transformed into a more integrated model: an industrial ecosystem. In such a system the consumption of energy and materials is optimized, waste generation is minimized and the effluents of one process … serve as the raw material for another process. The industrial ecosystem would function as an analogue of biological ecosystems." (Frosch and Gallopoulos, 1989: 144)

Later in the article Frosch and Gallopoulos (1989: 152) write: "The concepts of industrial ecology and system optimization must be taught more widely. … [They] must be recognized and valued by public officials, industry leaders and the media. They must be instilled into the social ethos and adopted by government as well as industry." [1]

Clearly this wider dissemination of industrial ecology ideas has not (yet) happened, but at least academe took seriously this call to mobilisation, and increasing academic interest in the topic led in 1997 to the foundation of the *Journal for Industrial Ecology*, one of the major journals in which articles about the circular economy now find a home (the other English-language journals which are important outlets for this literature are *Journal of Cleaner Production* [by a large margin], *Resources, Conservation and Recycling* and *Sustainability* [see Geissdoerfer et al., 2017, Figure 3: 762 for the full list]). In 2001 the International Society for Industrial Ecology (ISIE) was founded. Yet despite the early articulation of circular economy principles as cited above, and a detailed discussion of the concept in a well-known environmental economics textbook in 1990, as will be seen below, a 'history' of industrial ecology published in 1997 (Erkman, 1997) did not even mention the term 'circular economy'.

The seminal text in the economic strand of work in this area is unquestionably Boulding (1966). It is truly astonishing how this single brief paper (with just five references) set out most of the insights on which current circular economy thinking is now based, and little less astonishing how long these insights took to become more firmly entrenched in thinking about the environment, resources and the economy. It is worth identifying these insights in detail, for they provide both the philosophical and practical basis on which the burgeoning circular economy literature implicitly or explicitly draws.

Boulding's paper opens with a discussion of the difference between open and closed systems, particularly in respect of the three essential elements of existence: materials, energy, and information/knowledge. These elements also underpin the economy, which Boulding calls 'the econosphere', which he sees "as a material process involving the discovery and mining of fossil fuels, ores, etc., and at the other end a process by which the effluents of the system are passed out into noneconomic reservoirs." In other words, what is now called the 'take-make-dispose' linear economy. Boulding then turns to the concept of entropy, giving a description of the thermodynamics of a circular economy, stressing the importance of both energy and information.

Having established, in different words, the physical system conditions for the circular economy, Boulding turns to its philosophical, ethical and economic dimensions. Here again he is astonishingly prophetic. He begins by drawing his now famous distinction between 'cowboy' and 'spaceship' economies: the former associated with "the illimitable plains and also associated with reckless, exploitative, romantic, and violent behaviour, which is characteristic of open societies", the latter recognising that "the earth has become a single spaceship, without unlimited reservoirs of anything, either for extraction or for pollution, and in which, therefore, man must find his place in a cyclical ecological system which is capable of continuous reproduction of material form even though it cannot escape having inputs of energy."

Boulding notes that in a 'cowboy' economy it may be not unreasonable to link human welfare to throughput, as measured by GNP (but even then argues for a distinction between capital and income accounting, and accounting for environmental externalities, that is even today at the cutting edge of environmental-economic accounting and more honoured in the breach than the observance). More relevant here is Boulding's insistence that the 'spaceman' economy must be primarily concerned with "stock maintenance", in contrast to the economists of his day (and mostly in ours) who "continue to think and act as if production, consumption, throughput, and the GNP were the sufficient and adequate measure of success".

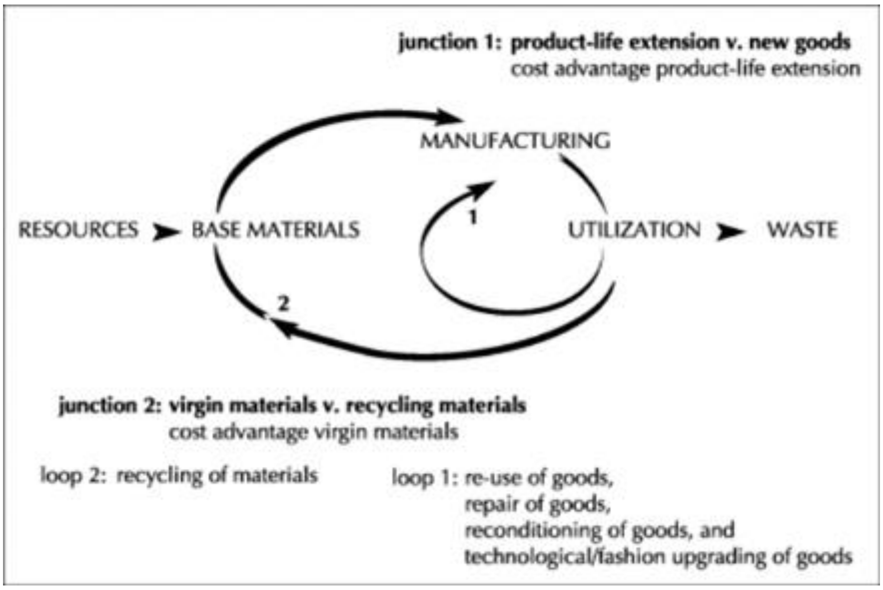
Finally, Boulding wonders why those now living should worry about the spaceman economy when it "is still a good way off (at least beyond the lifetimes of anyone now living)", encouraging the attitude "so let us eat, drink, spend, extract and pollute, and be as merry as we can, and let posterity worry about spaceship earth". One reason, he thinks, is frankly ethical, involving a concern for future generations that was to be put at the heart of sustainable development in the Brundtland Report (WCED, 1987) twenty years later.

But Boulding also sees a less normative reason for concern about cowboy economics, noting (even in 1966) that "The shadow of the future spaceship, indeed, is already falling over our spendthrift merriment. Oddly enough, it seems to be in pollution rather than in exhaustion that the problem is first becoming salient. … . The problems which the spaceship earth is going to present, therefore, are not all in the future by any means, and a strong case can be made for paying much more attention to them in the present than we do now."

No belittlement is intended of subsequent authors in this field by saying that most of their work develops Boulding's insights in these areas rather than adding substantively to them, as the following brief survey should make clear.

The Club of Rome's early computer simulation of limits to growth (Meadows et al., 1973) suggested that, indeed, an unreformed cowboy economy was headed for 'overshoot and collapse' within a century (a prognosis that it is certainly too early to declare false). Stahel and Reday-Mulvey (1981) took a different tack, at a time of the oil price shocks and high unemployment in Europe, and noted that jobs could be created by substituting human labour for fossil energy and materials, positing cost advantages from both product-life extension and reconditioning compared to new goods, and from using recycled compared to virgin materials. This is a recurrent theme in the modern circular economy literature though it is very far from clear that it is a general truth. This publication contains perhaps the first diagrammatic portrayal of a circular economy, as shown in Figure 1.1.

Figure 1.1. An early depiction of a circular economy



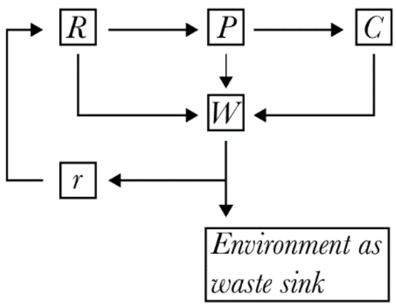
Source: Based on Stahel and Reday, 1981: 70 (figure supplied by Stahel, personal communication, May 2019)

Stahel developed his ideas with a prize-winning essay in 1982 that identified "the extension of the use-life of goods" as "a sensible point at which to start a gradual transition towards a sustainable society in which progress is made consistent with the world's finite resource base", which Stahel called a "spiral-loop system that minimises matter, energy-flow and environmental deterioration without restricting economic growth or social and technical progress" (Stahel 1982: no page numbers) through reuse (loop 1), repair (loop 2), reconditioning (loop 3) and recycling (loop 4). This may serve as an early definition of the circular economy, without being called such, although it is not made clear in the paper, nor has it been clarified subsequently, how a no trade-off economy of this sort can be realised in practice. Some of the relevant trade-off issues relating to matter, energy, environmental deterioration, economic growth and social and technical progress will be returned to later in this paper.

In his 1982 paper Stahel himself turns from theoretical exposition to practical matters, the various processes in different economic sectors through which the four loops can be realised, the business opportunities that these present, including the opportunities for innovation, and the obstacles and barriers to these opportunities being realised. All these topics will be discussed in subsequent sections of this paper.

It is not until 1990 that the circular economy is fully defined and described as such in economic terms. This is in the environmental and resource economics textbook Pearce and Turner 1990 (pp.35-41). It is striking that the concept is absent from the popular book published only one year earlier, *Blueprint for a Green Economy* (Pearce et al. 1989), which leads to the speculation that perhaps Kerry Turner should be credited with the invention of the term. However that may be, Pearce and Turner (1990) contrast (circular) natural systems with (linear) economic systems, distinguish between capital stocks and the flows from them, and go back to Boulding's paper to emphasise the importance of the laws of thermodynamics. They write (p.37): "Boulding's essay was pointing to the need to contemplate Earth as a closed economic system: one in which the economy and environment are not characterised by linear interlinkages, but by a *circular* relationship. Everything is an input into everything else." (original emphasis). Pearce and Turner's simple circular economy diagram is shown in Figure 1.2, which may be responsible for later authors considering recycling as the major or dominant process underlying circularity, which some authors have since found problematic, as will be seen in the next section.

Figure 1.2. A circular economic system



Note: Key: R=resources, P=production, C=consumption, U=utility, W=wastes, r-recycling
Source: Pearce and Turner 1990: 38

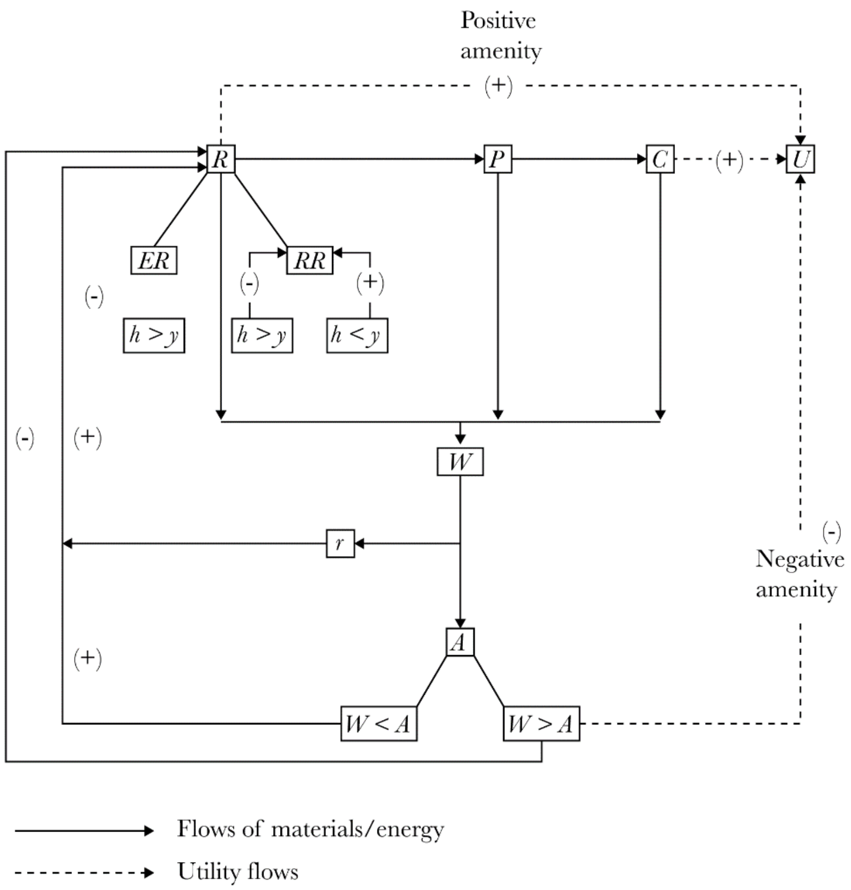
Pearce and Turner (1990) also give space to other considerations that are often omitted in later accounts of the circular economy. First they point to the Second Law of Thermodynamics to stress the technical infeasibility of 100% recycling even of materials (their example is the lead emissions arising from the combustion of leaded petrol) and the physical impossibility of recycling energy (for example, the heat from fossil fuel combustion can never return to its original concentrated form). Moreover, the energy penalty of increasing recycling once it has already reached very high levels is likely to be prohibitive in terms of cost. In this sense, a fully circular economy can never be achieved – the 'environment as waste sink' box in Figure 1.2 will always have something in it.

However, Pearce and Turner (1990) point out that the environment has 'assimilative capacity' which allows some wastes to be harmlessly reabsorbed into the environment and perhaps even become useful products. Many emissions to air and biologically degradable wastes fall into this category. Such wastes can become part of a larger circular system that includes the natural environment. However, if the assimilative capacity is exceeded, then wastes become pollution, which can damage both natural systems and human health and welfare.

Pearce and Turner (1990) also draw a distinction between exhaustible and renewable resources. Any use of the former will deplete stocks of those resources, but renewable resources have the capacity to renew themselves. If used within that capacity, renewable resources will not deplete and may increase, weakening the 'finite resource base' arguments for a circular economy such as that employed by Stahel cited above.

Such considerations lead to Pearce and Turner (1990)'s 'complete picture' of a circular economy, which is reproduced in Figure 1.3.

Figure 1.3. The 'complete picture' of a circular economy



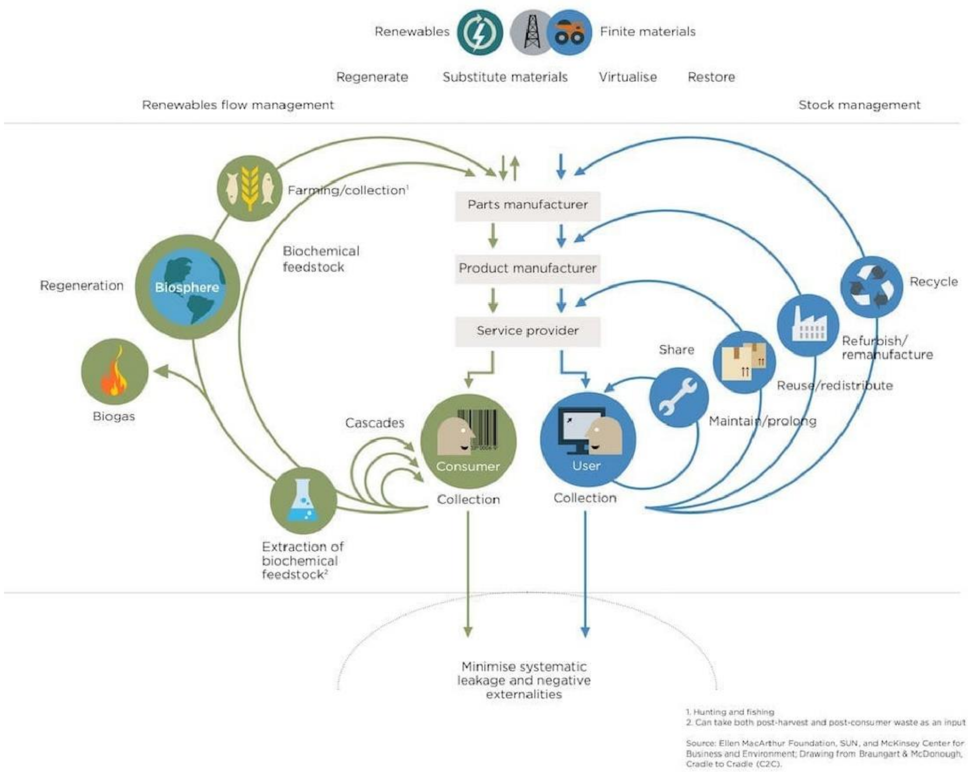
Note: Key: R=resources, ER =exhaustible resources, RR= renewable resources, P=production, C=consumption, U=utility, W=wastes, A=assimilative capacity, r-recycling, h=harvest, y=yield (=0 for ER)
Source: Pearce and Turner, 1990, Figure 2.4: 40

Given the wide use of the Pearce and Turner textbook, and further coverage of the topic under 'Ecocapital' in an illustrated book of 1992 (Ekins et al., 1992) it might have been thought that the idea of circular economy was poised for take-off. It didn't happen. By 2016, the economics journal most likely to have picked it up – *Ecological Economics*, founded in 1990 – had fewer than three articles on the topic (Geissdoerfer et al., 2017: 762), and no other economics journal did either. Clearly the time was not right.

The idea went to sleep for close on twenty years, both in terms of use of the phrase, and intellectually. Since 1990 there has been very little fundamental conceptual development of the circular economy concept, although a number of authors, particularly in the popular literature, have embellished it, with the nature of the embellishments evident in the title. Examples are *Biomimicry* (Benyus, 1997), and *Cradle to Cradle* (McDonough and Braungart, 2002). It is remarkable that, as with the Erkman, (1997) paper, neither of these less academic treatments of the topic refer explicitly to the circular economy, although they clearly are concerned with the substance of the concept.

And then Ellen MacArthur came on the scene. Famous from breaking the world record time for sailing solo non-stop round the world in 2005, she set up the Ellen MacArthur Foundation (EMF) in 2010. Partnering with a number of large companies and the McKinsey consultancy, EMF produced in 2013 three publications 'Towards The Circular Economy', the first of which contained the celebrated 'butterfly' diagram, which is reproduced in Figure 1.4[2]. The four people credited in Volume 1 of 'Towards The Circular Economy' are Braungart, Stahel and Benyus (all mentioned above), and Roland Clift, then Executive Director of ISIE (EMF, 2013: 26). None are economists. The Foreword to this volume is by Janez Potocnik, then European Commissioner for the Environment. In mid-2015 Potocnik introduced his Circular Economy Package from the European Commission, by when it was clear that the concept had arrived in the mainstream – in business (through EMF) and politics. Academe, which had introduced the basic ideas half a century before, is still trying to catch up.

Figure 1.4. The 'butterfly' circular economy diagram



Source: EMF 2013 : 24, https://www.ellenmacarthurfoundation.org/circular-economy/infographic

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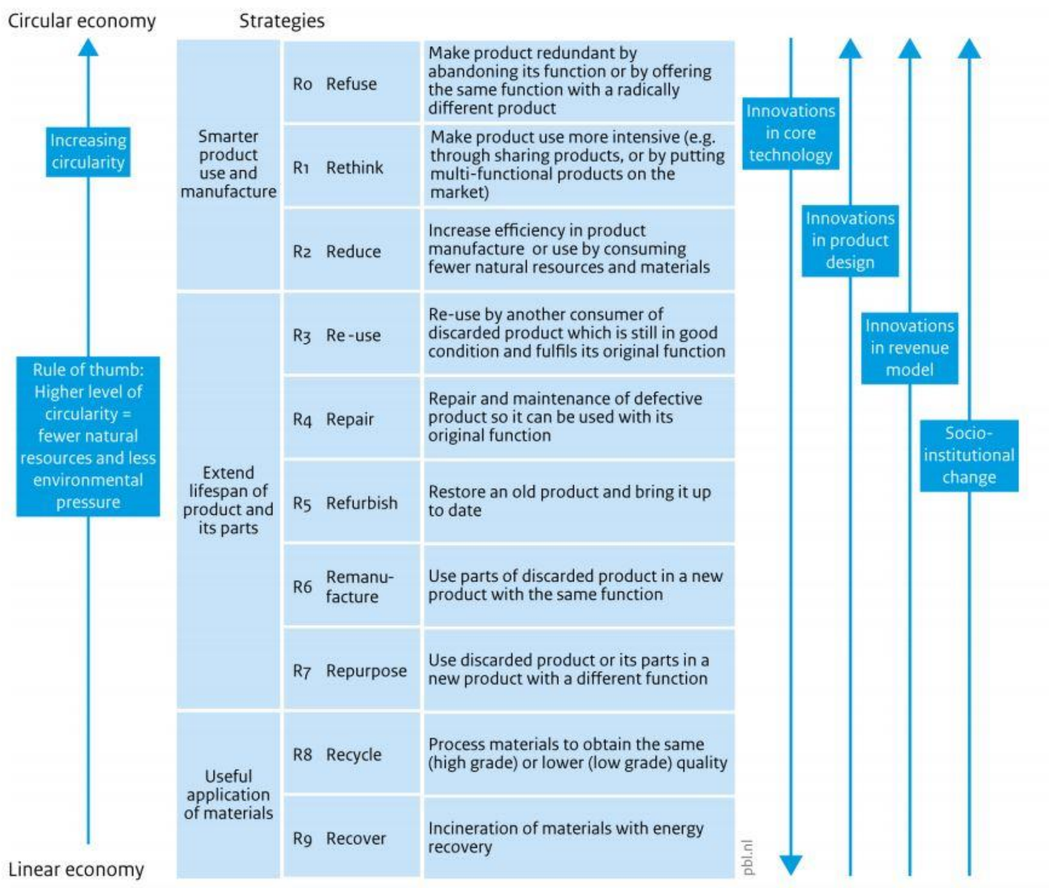
2. Definitions and related concepts (Paul Ekins)

Both Pearce and Turner (1990) and Ekins et al. (1992) cited in the previous chapter rely on their diagrams to convey the meaning of 'circular economy' and do not give a verbal definition of it. Such is not the case for subsequent authors. By 2017 Kirchherr et al. were able to identify 114 definitions.

Much of the content of these definitions has been pre-figured in the discussion in the previous section. Given the importance of the Ellen MacArthur Foundation in the current discourse, it seems appropriate to quote their definition: "A circular economy is an industrial system that is restorative or regenerative by intention and design. … It replaces the 'end-of-life' concept with restoration, shifts towards the use of renewable energy, eliminates the use of toxic chemicals, which impair reuse, and aims for the elimination of waste through the superior design of materials, products, systems, and, within this, business models." (EMF, 2013: 7)

It can be seen from Figure 1.3 that recycling was a key element in circular economy thinking from the start. As time has gone on the number of 'R's has multiplied. The Japanese Government's '3R Initiative' (reduce, reuse, recycle) dates from 2004[3]. The European Union's waste hierarchy in its 2008 Waste Framework Directive[4] has four Rs (reduce, reuse, recycle, recover). By 2017 nine separate Rs contributing to circularity had been identified (Figure 2.1).

Figure 2.1. Circularity strategies within the production chain, in order of priority



Source: Potting et al. (2017), Figure 1 : 5

Following their review of the 114 definitions extant at the time of their publication, Kirchherr et al. (2017) synthesise these definitions into their own: "circular economy describes an economic system that is based on business models which replace the 'end-of-life' concept with reducing, alternatively reusing, recycling and recovering materials in production/distribution and consumption processes, thus operating at the micro level (products, companies, consumers), meso level (eco-industrial parks) and macro level (city, region, nation and beyond), with the aim to accomplish sustainable development, which implies creating environmental quality, economic prosperity and social equity, to the benefit of current and future generations." (Kirchherr et al. 2017: 224-225)[5].

Those who want a concept-by-concept analysis of the different definitions above are referred to Kirchherr et al.'s paper. Here only the following points will be noted.

The EMF definition uses more organic language ('restorative and regenerative') in keeping with the ideas of ecology and symbiosis that were at the root of the concept in its early days, and it identifies some of the main elements and objectives of a circular economy (renewable energy, elimination of toxic chemicals and waste, superior design and business models). It shifts the focus of attention upstream. It does not even mention recycling.

Kirchherr et al.'s definition identifies the circular economy as an economic system (and not just an industrial system, as in EMF), and mentions four of the nine Rs (though note that even Potting et al.'s nine Rs do not include restoration and regeneration, which are in EMF's definition). It introduces two crucial components – the idea of level or scale, and sustainable development – both of which are discussed further below and the latter of which is made Kirchherr et al.'s aim of the circular economy. The definition in footnote 5 is frankly utopian. No known economy has ever been successful in "simultaneously creating environmental quality, economic prosperity and social equity, to the benefit of current and future generations", though there may be no harm in having that as an objective, which in any case resonates with the multi-dimensional aspirations of sustainable development, as discussed further below. Finally, the footnote 5 definition also identifies two enablers: business models (which also appear in the EMF definition) and 'responsible consumers'. A notable omission from the enablers is public policy. It is not at all clear that a circular economy is remotely likely to be achieved without sustained and determined public policy, some of the elements of which are explored in section 7 of this paper.

In their attempt to pull together some of these disparate ideas, Blomsma and Brennan (2017: 606) refer to the circular economy as an 'umbrella concept' essentially rooted in concerns around resource and waste management, with circular economy strategies, called resource life-extending strategies (RLESs), "predominantly and increasingly" seeking "to extend resource life, for example: reuse, recycling, remanufacturing, servitization, repair, waste-to-energy, product longevity approaches, and the cascading of substances (i.e., the transformation of materials through various use phases)." More broadly, they write: "[The circular economy] articulates (more clearly) the capacity to extend the productive life of resources as a means to create value and reduce value destruction." (Blomsma and Brennan 2017: 609).

The characterisation is both true and useful, but it begs the further question: why? What are the purposes behind the RLESs? Are such strategies just good in themselves, or are they instrumental in achieving other goals? Blomsma and Brennan (2017: 608) find the roots of these concerns in the "toxicity and scarcity" problematique explored by the literature of the environmental movement in the 1960s and 1970s, and this is in accordance with this paper's own tracing of the genesis of the circular economy outlined in section 1.

But further questions are raised if addressing 'toxicity and scarcity' are the ultimate goals of RLESs: for example, should society be concerned with, and therefore seek to apply circular economy thinking and resource life extension to, materials that are *not* scarce? And how should such scarcity be defined and monitored? And in respect of 'toxicity', do all RLESs deliver net environmental benefits? In many cases, the answer to such a question can only be revealed through painstaking life cycle assessment of the RLES compared to the less extended resource life it is seeking to replace. Yet this is often not acknowledged in much of the literature in this field that tends to treat circular economy as an end in itself.

Rather than seeking to define a circular economy in so many words, it may be described through its characteristics. This is the approach adopted by the OECD (McCarthy et al., 2018) which identified the following key features of a circular economy: increased product repair and remanufacture, increased material recycling, more robust long-lived products through design, increased produce re-use and repair, increased material productivity, improved asset utilisation, and modified consumer behaviour. The intended effects of these features are listed as: decreased demand for new goods (and virgin materials), substitution of secondary raw materials in production, expanded secondary sector, more durable and repairable products, and expanded sharing and service economies (McCarthy et al., 2018, Figure 1: 15).

Another review of the issues underlying the circular economy idea is that by Geisendorf and Pietrulla (2018), who assess a number of concepts related to the circular economy, many of which were mentioned in section 1, against different ‘categories and characteristics’ that are explicitly identified with these concepts.

Table 2.1 indicates how the concepts they have reviewed (along the top row) incorporate these categories and characteristics. Both the concepts and the categories and characteristics are heterogeneous in nature and scope. For example, circular economy and cradle-to-cradle may be thought to encompass closed supply chains, regenerative design and reverse logistics. And the categories and characteristics range from the very specific (e.g. business models and customer relationship management) to very general (e.g. a whole-economy perspective).

Table 2.1. Categories and characteristics of circular economy concepts

		Concepts									
Categories	Characteristics	Circular economy	Cradle to cradle	Closed supply chains	Regenerative design	Blue economy	Industrial ecology	Reverse logistics	Performance economy	Natural capitalism	Bio-mimicry
Motivation(s)	Focus on environment	●	●	●	●	●	●	●	●	●	●
	Focus on profitability			●				●			
	Including social aspects	●	●		●	●			●	●	
Proposition for waste management	Efficiency and waste reduction	●	●	●	●	●	●	●	●	●	●
	Zero waste	●	●		●						
	Technological/ biological substances	●	●								
Guidelines and tools	Business model perspective	●	●			●				●	
	Focus on operations		●	●	●		●	●			
	Measurability	●	●	●		●	●	●	●	●	
	Policy	●		●			●				
Economic sectors covered	Primary sector	●	●		●	●	●			●	
	Secondary sector	●	●	●	●	●	●	●	●	●	●
	Tertiary sector	●	●		●	●			●	●	
Economic scope	Macro-economic perspective	●				●			●	●	
	Meso-economic perspective		●	●			●				
	Micro: company level	●	●	●	●		●	●			
	Micro: product level	●	●		●			●			●
Activities during life cycle stages: Circular design of ...	Product development	●	●	●	●	●			●	●	●
	Raw material sourcing	●	●	●							●
	Production processes	●	●	●		●	●	●			●
	Use	●	●						●		●
	CRM							●	●		
	End of life/ disposal	●	●	●	●	●	●	●	●	●	●
	Transportation	●	●	●	●	●	●				

Note: CRM stands for customer relationship management
Source: Geisendorf and Pietrulla 2018, Table 1: 777 (for the citations underlying the assessments in this table, please see the source)

It can be seen that only four characteristics are common to all the concepts: focus on the environment (which presumably also includes natural resources), efficiency and waste reduction, coverage of the secondary (manufacturing) sector, and end-of-life disposal. A definition that would therefore cover all these concepts, at least in part, would seem to be: The circular economy is one that has low environmental impacts and that makes good use of natural resources, through high resource efficiency and waste prevention, especially in the manufacturing sector, and minimal end-of-life disposal of materials.

The inclusion of levels and scale (micro, meso and macro) in both Kirchherr et al. (2017)'s definition and Geisendorf and Pietrulla (2018)'s characteristics arises from an awareness in the academic literature of the importance of these dimensions in attempts to put the circular economy into practice. In their review of the literature to 2016, Ghisellini et al. (2016) explicitly divide up the studies on implementation into the micro (cleaner production), meso (eco-industrial systems and industrial symbiosis districts and networks) and macro (regional eco-industrial networks and productions, eco-cities, urban symbiosis and collaborative consumption) levels. In this paper these meso and macro levels are discussed in more detail in section 11.

The relationship between the circular economy and sustainability is the topic of Geissdoerfer et al. (2017). Annoyingly, this paper fails to distinguish consistently between 'sustainability' and 'sustainable development', even identifying the famous Brundtland definition of the latter as a definition of the former (p.758). This is not mere semantic nit-picking. The word sustainability cannot be sensibly discussed until the question 'sustainability of *what*?' has been answered. Sustainable development answers that question with the word 'development', itself a difficult and complex concept. Sustainable development is usually identified as having three dimensions – economic, social and environmental. It is clear that economic, social and environmental sustainability are quite distinct, conceptually and in terms of indicators, and by no means necessarily well aligned. A simple example illustrates this. Economic sustainability may be thought to involve a non-declining Gross Domestic Product (GDP), but it is sometimes considered that environmental sustainability will require a declining GDP ('degrowth'). Using the words 'sustainability' and 'sustainable development' synonymously, as is unfortunately common in the literature, completely obscures these crucial distinctions which are in continual tension and at the heart of much environmental discourse.

This paper seeks to distinguish rigorously between environmental sustainability (the maintenance of important environmental functions), economic sustainability (maintenance of the capital stock, sound money, corporate profitability) and social sustainability (maintenance of social cohesion). The concept of sustainable development, the main objectives, targets and indicators of which can be found in the Sustainable Development Goals (SDGs), seeks to integrate and achieve all three of these 'sustainabilities'.

Looking back at the EMF 'butterfly' diagram in Figure 1.5, it is clear that its conception of the circular economy puts most emphasis on environmental sustainability: its focus is overwhelmingly on making circular use of natural resources and reducing environmental impacts. Elsewhere in EMF literature there is also a strong focus on the economic benefits of a circular economy (EMF 2015, 2016), as will be seen in section 8. However, the notion that 'closing the loop' of the circular economy is always going to lead to economic benefits is clearly fanciful. As Sauvé et al. (2016: 54) point out: "At some point, the extra cost of improving and refining further a circular material flow will exceed the corresponding benefits to society, and this is true for any kind of environmental protection. Specifically, a circular economy must promote loops when socially desirable and efficient … i.e. as long as the benefit is greater than or equal to the cost. … e.g. should we invest in a new infrastructure to recycle a specific material in order to reduce waste and preserve the resource, or should we keep exploiting the raw material at cheaper cost, use the short term benefits to build a school and educate our children? When is the benefit greater than the cost?" Most of the circular economy literature is remarkably reticent about such questions.

The same can be said about the social dimension of a circular economy. Clearly a wide range of social arrangements (in terms of diversity, inclusion, income and wealth distribution, employment and working conditions) are possible in a material economy with the characteristics of Figure 1.5. Would some social arrangements allow a certain economy with Figure 1.5 material characteristics to be identified as ‘circular’, while another with exactly the same material characteristics but different social arrangements was not seen as ‘circular’? The definition above of Kirchherr et al. (2017) to the effect that a circular economy must create ‘social equity’ would suggest so. But this is far from intuitive, and bound to be contested.

Finally, to the environmental dimension, even this turns out not to be straightforward. As Sauvé et al. (2016: 55) make clear: “There needs to be care in evaluating the options that might reduce environmental impacts in one stage of the life cycle of the product, but would increase these elsewhere. … A life cycle approach is therefore an indispensable tool of eco-design and essential to properly compare different options to be implemented within a circular economy approach.” Sometimes, no doubt, the environmentally preferred option for a particular material in particular circumstances would not be circularity, but disposal. Such considerations make it imperative that enthusiasm for a circular economy does not obscure its objectives, which are the subject of the next section.

The work of Geng and Doberstein (2008) shows how these ideas are being applied in China, where the circular economy[6], by which is meant “the realisation of a closed loop of materials flow in the whole economic system”, was formally adopted in 2002 as the new model of sustainable development (Geng and Doberstein, 2008: 232). In China by then the organisation of the circular economy was already being conceptualised at three levels: the micro, where it was largely equated to cleaner production in the firm, the meso, where it was identified with the many ‘Eco-Industrial Parks’ that were springing up round the country, and the ‘macro’, which involved region-wide circular economy thinking and planning. The important experience of China in this area is explored further in section 9 of this paper. Sauvé et al. 2016 (p.55) write: “At the macro level, the incentives for circular economy must be phased in with societal and stakeholder interests. Under Geng and Doberstein's classification, this is where circular economy could meet with sustainable development.”

However, this identification of circular economy with sustainable development is by no means universal. It can be seen from Table 2.1 that the social dimension is entirely absent from some circular economy concepts, and it is very scantily treated in many others. In their review of the relationship between the circular economy and sustainability, Geissdoerfer et al. (2017) show that a circular economy is normally seen to be broadly supportive of sustainability, but perceptions differ greatly as to the strength of this relationship, and in some cases trade-offs can be identified (see Table 2.2).

Table 2.2. Relationships between the circular economy and sustainability

Relationship types between the Circular Economy and sustainability.

General direction	Type of relationship	Short description Circularity/closed loop systems are seen as …
Conditional	Conditional relation	One of the conditions for a sustainable system
	Strong conditional relation	The main solution for a transformation to a sustainable system
	Necessary but not sufficient conditional relation	A necessary but not sufficient condition for a sustainable system
Beneficial	Beneficial relationship	Beneficial in terms of sustainability, without referring to condition-ality or alternative approaches
	Subset relation (structured and unstructured)	One among several solutions for fostering a sustainable system
	Degree relation	Yielding a degree of sustainability with other concepts being more and/or less sustainable
Trade-off	Cost-benefit/trade-off relation	Having costs and benefits in regard to sustainability, which can also lead to negative outcomes
	Selective relation	Fostering certain aspects of sustainability but lacking others

Source: Geissdoerfer et al., (2018), Table 4: 766 (for the full references of the Examples in literature column, please see the source)

This review of some of the literature that has analysed concepts and definitions underlying or contributing to the thinking around the circular economy permits a synthesis of its purposes and the principal means through which it can be promoted. These are the subjects of the next section.

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3. Purpose of a circular economy (Paul Ekins)

The previous section has shown a wide variation in perceptions as to how the circular economy is conceived, how it is defined, and what it is intended to achieve. This is very much an echo of the findings of the systematic review by Merli et al. (2018). This section seeks to pull together the ideas in the previous sections into a single narrative, many of the elements of which will be explored further in the rest of this paper.

Most importantly, the purpose of moving towards a circular economy is to slow depletion of scarce natural resources, reduce environmental damage from extraction and processing of virgin materials, and reduce pollution from the processing, use and end-of-life of materials. The main means of achieving this is through increasing the efficiency and productivity of resource use and reducing the quantity of material disposed of. This in turn will require new business models (section 5) that are part of a whole-system perspective on resource use, and incorporate closed supply chains, regenerative design, and reverse logistics that increase the life of products, thereby maintaining for a longer period the value in their materials and the overall value derived from them, so that fewer materials end up as wastes. Such business models need to be financially sustainable, the achievement of which is currently constrained by many barriers (section 6). Removing these will require fundamental changes in the economic landscape in which they operate, changes that will need to be brought about through public policies of many kinds (section 7), as well as through changes in business organisation.

There are anecdotal reports of business models of this kind being more profitable than those they replace, but such models remain marginal to business activity more generally. Nevertheless there are estimates of large economic gains (at corporate, sectoral and macroeconomic levels) to be made from moving systematically towards a circular economy (section 8), with associated improved competitiveness and employment for businesses and the national economy. In the limit this could make a substantial contribution to sustainable development, as defined by the targets of the SDGs. These benefits are on top of the environmental and resource benefits that provide the primary rationale for the circular economy (also section 8).

At the macro scale the main example of systematic policy attempts to move towards a circular economy may be seen in a number of countries, including China (section 9), some Member States of the European Union and the European Union as a whole (section 10), and a number of regions and cities (section 11). However, the assessment of progress towards a circular economy depends on the development and use of appropriate indicators, and it is to this topic that this paper turns next.

Reference

Merli, R., M. Preziosi and A. Acampora (2018), 'How do scholars approach the circular economy? A systematic literature review', *Journal of Cleaner Production*, Vol.178, pp.703-722

4. Indicators of a circular economy (Teresa Domenech)

As for any concept that proposes a transition from the current state to a different 'desirable' vision, as is the case of the circular economy (CE), there is a need to identify: a) what is the 'desired' end state (i.e. main dimensions and desirable objectives), b) how can we intervene in current systems to induce change (strategies and policies) and, c) derived from the above, how can we measure and track progress towards it, as a way to review the effectiveness of current strategies, and introduce, if necessary, corrective or preventive measures. What Meadows et al. (1998: 2) already emphasised for indicators of sustainability is also valid for CE indicators. Indicators 'arise from values (we measure what we care about) and they create values (we care about what we measure)'. Although as shown in earlier chapters, the concept of CE is not new, its incorporation into the mainstream policy discourse is, and, therefore, the process of definition of indicators becomes critical, as it is likely to shape how we think about it and what aspects or dimensions are emphasised. The choice of indicators is of crucial importance as it becomes 'a critical determinant of the behaviour of a system' (Meadows et al., 1998: 5). Indicators generally have two main purposes: 1) one forward looking to provide guidance and 2) another backward looking to provide feedback and review performance. Therefore, quantitative indicators are required for guiding and reviewing CE policies.

Interest in the concept of CE from both policy making and businesses has induced an exponential growth in the development of CE indicators (Saidani et al., 2018). The need for indicators is acknowledged in the European Commission (EC)'s Circular Economy Package: 'In order to assess progress towards a more circular economy and the effectiveness of action at EU and national level, it is important to have a set of reliable indicators'. Scholars, such as Elia et al. (2017: 2741) also highlight that 'deep research on CE assessment and indicators is still lacking', especially with regard to the scope of the indicator and dimensions they include.

In an attempt to provide clarity and synthesise systems of indicators, recent reports and papers have reviewed existing sets of CE indicators. A report on CE indicators by EASAC (2016), commissioned by the EC, provides an overview of existing sets of indicators related to resource efficiency and green growth, and how they could align or provide the basis for the development of a CE indicator system. The review includes, among many others, the World Bank indicator set to measure progress towards the SDGs and the OECD (2014) system of indicators for green growth. In parallel, UNEP has developed Sustainable Consumption and Production Indicators for the Future relating to SDGs (2015) and there is on-going work at the OECD to further refine measurement of consumption based indicators as part of the Material Flow Accounting framework in collaboration with Eurostat and UNEP's International Resource Panel (IRP) and work led by the United Nations Economic Commission for Europe (UNECE) to revise waste indicators to better reflect circularity aspects. At the EU level, the report identifies existing targets derived from the revised waste directives as well as non-binding monitoring systems, including the EU Resource Efficiency Scoreboard, which is organised using a three-tiered approach from more general to more concrete (thematic) indicators, and has Raw Material Consumption as the lead indicator, and a critical raw materials indicator system. Focusing specifically on CE indicators, Saidini et al. (2018) conducted an extensive literature review, identifying 55 circularity indicator sets, at three implementation levels: global, meso and micro. To make sense of existing indicator sets, the authors propose a taxonomy along 10 key criteria, which are included in Table 4.1 below:

Table 4.1. Categories for the proposed taxonomy of circularity indicators

Categories for the proposed taxonomy of C-indicators.

Categories *(criteria)*	#1 - **Levels** *(micro, meso, macro)*	#2 - **Loops** *(maintain, reuse/ reman, recycle)*	#3 - **Performance** *(intrinsic, impacts)*	#4 - **Perspective** *(actual, potential)*	#5 - **Usages** *(e.g. improvement, benchmarking, communication)*
	#6 - **Transversality** *(generic, sector-specific)*	#7 - **Dimension** *(single, multiple)*	#8 - **Units** *(quantitative, qualitative)*	#9 - **Format** *(e.g. web-based tool, Excel, formulas)*	#10 - **Sources** *(academics, companies, agencies)*

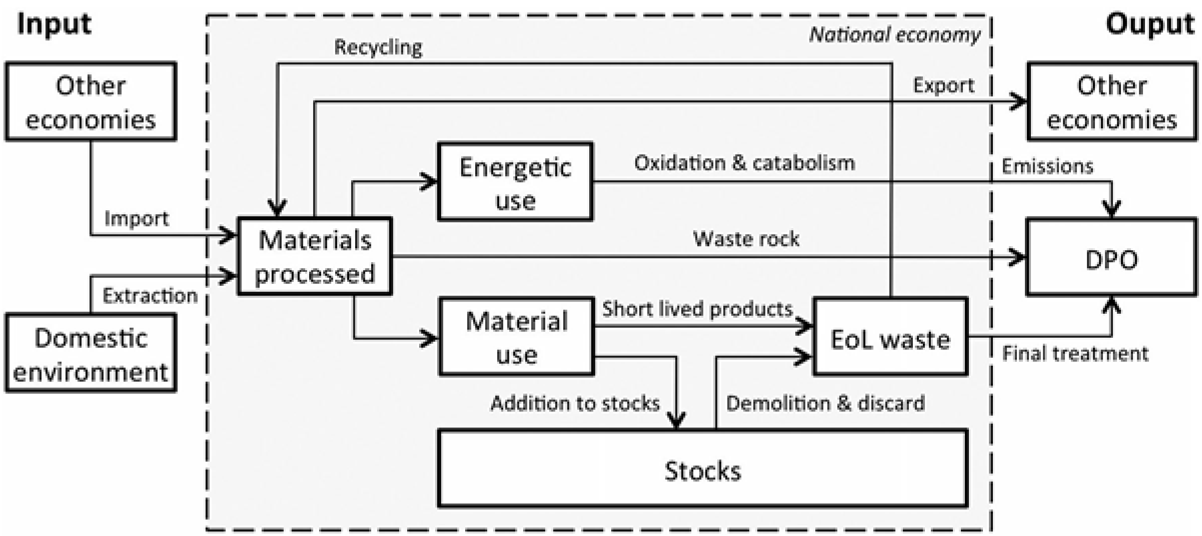
Source: Saidani et al. (2018: 549)

Saidani et al. (2018) and their supplementary selection tools is a good reference to specific sets of circularity indicators. As one would expect most of these indicators sets have their origin in Europe and China, where CE has become a prominent part of the policy discourse and there are active policy programmes that seek to promote the transition towards it. While these compilation reviews are certainly useful, and highlight the myriad of CE monitoring systems that already exist, one critical element that is not examined in great detail is the actual CE conceptualisation embedded in the monitoring frameworks. This is of utmost importance as it refers to the key question of 'circularity of what' which underlies any measurement exercise. In Saidani et al. (2018), the only category that provides an indication of what the indicators are measuring is one referring to 'loops'. Their interpretation thus of the concept of CE is very closely related to that of the 3 Rs and their further development into 9 Rs. However, as highlighted by McDowall et al. (2017), while that may be the prevalent lens in which the CE is thought of in Europe, CE in China has a broader scope, incorporating pollution and going beyond the areas of resources and waste, reflecting also the differing realities in both regions, levels of development and historical evolution of policy making in the area of sustainability.

As policy intervention and analysis have gravitated around the application of CE at different levels and in some cases with different sectorial focus (i.e. CE in buildings, CE for plastics, etc), most of the indicator sets have also been developed with specific foci in mind. For clarity, this section has organised the review of monitoring systems at the macro, meso and micro levels.

At the macro level, which includes global, supranational and national levels, most of the existing indicator sets apply to one single region (e.g. EU) or country, and, in many cases are linked to specific policies to promote the transition towards the CE. However, there are few attempts to globally assess the current circularity of the system. Measuring the CE at the global level is challenging and faces numerous data limitations, so most of these attempts rely on a single indicator or index. Grounded in Material Flow Accounting, Haas et al. (2015) measure the circularity of the global economy as the 'share of actually recycled materials in total processed materials'. Using this indicator, the authors conclude that current levels of circularity globally are very low at 6%, while most of the processed output of the economy leaves the economy as waste and emissions (66%) and also a large fraction is added to the stock (27%). Using the same methodology, Haas et al. also estimate the degree of circularity of the EU. Despite advanced recycling in the EU, which accounted to almost 2.0 t/pc/year or 41% of the total end of life waste, the degree of circularity, as the share of recycled materials in total processed output' is, although significantly higher than the global level at 13%, still far from what recycling rates may suggest. Interestingly the analysis also highlights the overall size of the industrial metabolism, for example, circular flows, defined as all biomass flows[1] plus recycled material that goes back into the productive system, in the EU amount to 6.8 t/cap/yr compared to 3.5 t/cap/yr in the global economy, while also non-circular flows, all non-renewable materials which are not recovered at the end of life, are larger, at 6.4 t/cap/yr, as compared to 3.4 t/cap/yr globally. The authors thus conclude that there is a need for 'downscaling the overall size of social metabolism, in particular, in industrial countries in addition to advancing the degree of circularity' (Haas et al., 2015: 771).

Figure 4.1. Model for the estimation of circularity at the macro scale



Note: DPO = Domestic Processed Outputs
Source: Haas et al. (2015: 769)

Similarly, Circle Economy, a think tank in the area of CE, publishes since 2018 a yearly 'circularity gap report', which building on Material Flow Accounting, attempts to estimate the degree of circularity of the global economy. In this case, circularity is measured as 'cycled materials' as a share of the total resources entering the economy, which they estimate at 9% globally. The results are close enough to Haas et al. (2015), but as a non-academic exercise the description of the model is less well specified in terms of system boundary definition and assumptions. The circularity is calculated as recycled materials as a proportion of overall resources entering the global economy but it is unclear whether this refers merely to processed materials or also considers unused or unprocessed extraction (i.e. tailings from mining). The report also proposes a Mass-Value-Carbon nexus, as a way to connect material consumption, carbon emissions and value generation, and identifies potential synergies as well as trade-offs between the three

[1] As remarked by Haas et al. (2015) all biomass production cannot be regarded as fully circular but for simplification this analysis considers all biomass flows in the definition of circular flows, as under certain parameters, they can potentially be regenerated.

core dimensions, connecting with the idea of decoupling. Based on the analysis of historical trends, pathways of development towards the future are proposed.

At the supranational level, the EU has developed a CE monitoring tool to track progress of the performance of the policy instruments introduced by the CE package. The so-called 'monitoring framework' comprises 15 indicators, classified in four main dimensions: 1) production and consumption; 2) waste management; 3) secondary raw materials and 4) innovation and competitiveness. Indicators in each of these categories are summarised in table 4.2.

Table 4.2. Circular economy monitoring framework

Production and consumption		
EU self-sufficiency for raw materials	Import Reliance (IR) = (Net Import)/(Apparent Consumption) = (Import – Export)/(Domestic production + Import – Export)	36.4%
Green public procurement	N/A	N/A
Waste generation		
Generation of municipal waste per capita (kg per capita)	Eurostat, Municipal waste by waste operations (env_wasmun), collected via a subset of the OECD/Eurostat Joint Questionnaire,	486
Generation of waste excluding major mineral waste per unit of GDP (kg per 1000 EUR)	Eurostat. Generation of waste by waste category, hazardousness and NACE Rev. 2 activity (env_wasgen)	65
Generation of waste excluding major mineral waste per domestic material consumption (%)	Eurostat. Generation of waste by waste category, hazardousness and NACE Rev. 2 activity (env_wasgen)	13.5
Food waste (million tonnes)	Eurostat. Estimates based on generation of waste by waste category, hazardousness and NACE Rev. 2 activity (env_wasgen)	80
Waste management		
Recycling rates		
Recycling rate of municipal waste (%)	Eurostat. Municipal waste by waste operations (env_wasmun) collected via a subset of the OECD/Eurostat Joint Questionnaire.	46.4
Recycling rate of all waste excluding major mineral waste (%)	Eurostat. Management of waste excluding major mineral waste, by waste operations (env_wasoper)	57
Recycling and recovery of specific waste streams		
Recycling rate for overall packaging (%)	Eurostat. Packaging waste by waste operations and waste flow (env_waspac),	67
Recycling rate of plastic packaging (%)	Eurostat. Packaging waste by waste operations and waste flow (env_waspac)	42.4
Recycling rate of wooden packaging (%)	Eurostat. Packaging waste by waste operations and waste flow (env_waspac)	39.8

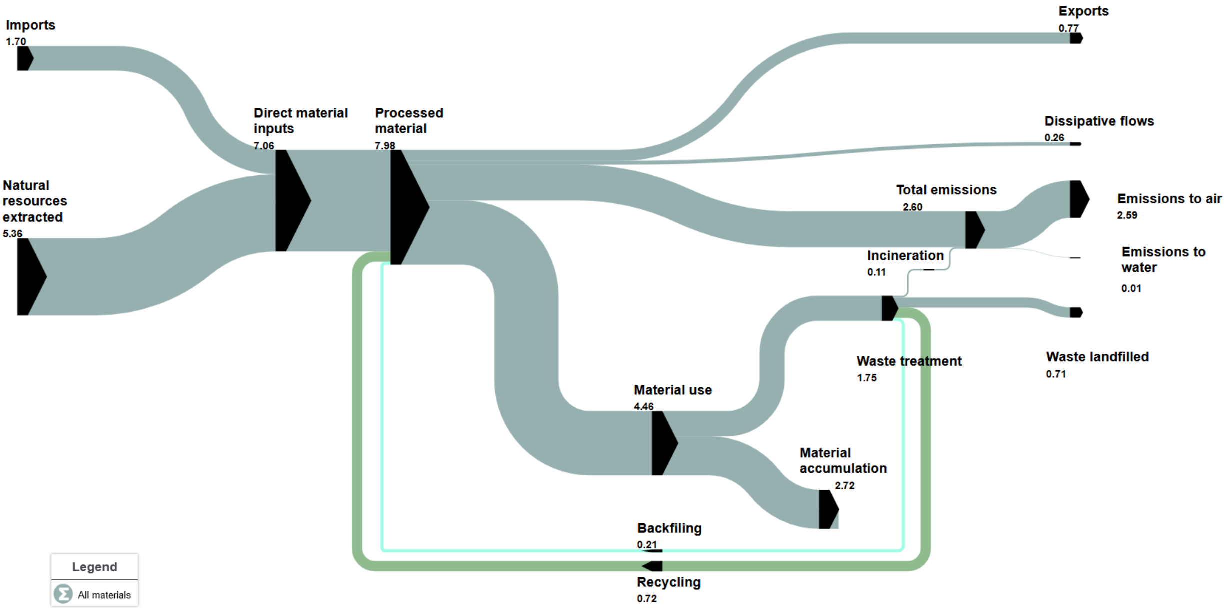
Recycling rate of e-waste (%)	Eurostat. Waste electrical and electronic equipment (WEEE) by waste operations (env_waselee),	41.2
Recycling of biowaste (Kg per capita)	Eurostat. Municipal waste by waste operations (env_wasmun) collected via a subset of the OECD/Eurostat Joint Questionnaire	81
Recovery rate of C&D waste (%)	Eurostat. Treatment of waste by waste category, hazardousness and waste operations (env_wastrt)	89
Secondary Raw Materials		
Contribution of recycled materials to raw materials demand		
End of life recycling input rates (EOL-RIR) (%)	This indicator measures recycling's contribution to materials demand per type of material. Data source: European Commission DG GROW. Study on the review of the list of Critical Raw Materials - Final Report (2017).	12.4
Circular material use rate (%)	The indicator measures the share of material recovered and fed back into the economy - thus saving extraction of primary raw materials - in overall material use. The circular material use (CMU) rate is defined as the ratio of the circular use of materials to the overall material use. Source: Eurostat. Several databases: env_wastrt), (env_ac_mfa), international trade in goods statistics (comext).	11.7
Trade in recyclable raw materials		
Imports from non-EU countries (tonnes)	Eurostat. International trade in goods statistics (comext).	5,905,135
Exports to non-EU countries (tonnes)	Eurostat. International trade in goods statistics (comext).	36,934,824
Intra EU trade (tonnes)	Eurostat. International trade in goods statistics (comext).	53,035,741
Competitiveness and innovation		
Gross investment in tangible goods (% of GDP at current prices)	Eurostat. Structural business statistics (SBS).	0.12
Persons employed (% of total employment)	Eurostat. Structural business statistics (SBS).	1.73
Value added at factor cost (% of GDP at current prices)	Eurostat. Structural business statistics (SBS).	0.98
Number of patents related to recycling or secondary raw materials	European Commission Joint Research Centre (JRC): Analysis of the online database PATSTAT which is the statistical database of the European Patent Office.	338.17

Note: *Indicators based on latest data available for each indicator [2014-2018]
Source: EC (https://ec.europa.eu/eurostat/web/circular-economy/indicators/monitoring-framework)

As can be seen, the monitoring framework provides a comprehensive system of indicators that goes beyond material cycles to also consider supply chain implications, reliance on primary raw materials, trade in raw materials, and economic indicators measuring private investment, gross value added and job generation in CE-related activities. The framework is also meant to be complemented by the resource efficiency (RE) scoreboard and the raw material scoreboard, providing a complex but robust system monitoring CE performance. However, interestingly, indicators related to the scale of the socio-economic metabolism and apparent and real consumption are not included, although the RE scoreboard includes a scale indicator as lead indicator, which is Raw Material Consumption.

In Figure 4.2 a Sankey diagram for Europe visually describes the flow of materials in the EU economy, highlighting that emissions, dispersion and disposal of waste are still very relevant. The Sankey diagram also highlights the growth of the industrial metabolism with significant additions to the stock yearly.

Figure 4.2. Flow of material through the European Union economy



Source: EC, Material Flows EU 2017 in Gt/year (billion tonne per year) (https://ec.europa.eu/eurostat/web/circular-economy/material-flow-diagram)

In parallel to the development of the official EC 'monitoring framework', a number of academic contributions have proposed alternative frameworks for measuring the circular economy in the EU. Following Haas et al. (2015), Mayer et al. (2019) use material flow analysis to review the degree of circularity of the EU. The authors criticise partial approaches to CE, which focus on increasing recycling or on partial/sectoral improvements of circularity which overlook the implications of those improvements at a broader scale. More importantly, the authors conclude that absolute reductions in resource extraction and consumption are needed (Mayer et al., 2019). Building on previous contributions (Haas et al., 2015 or Nuss et al., 2017), the authors perform a comprehensive economy-wide material flow analysis (MFA), which includes all biomass, metals, non-metallic minerals, and fossil energy carriers and reconcile different datasets. Based on the analysis, six pairs of indicators are developed, distinguishing between scale indicators, which measure the scale of the overall socio-economic metabolism, and circularity rate indicators, which measure cycling of flows. The MFA-derived indicators are classified as input or output indicators, as shown in Table 4.3. Results of the analysis differ slightly from previous contributions but are consistent with those of the official monitoring framework. Overall, consumption of raw materials in the EU28 is estimated to have amounted to 5.8 Gt and from those only 0.7Gt came from secondary materials. Processed materials were mainly used for producing energy (3.1 Gt) and maintaining the current stocks (3.5 Gt). Also, even though recycling rates were high for end-of-life waste, the output socioeconomic cycling rate (OSCr), that is the share of secondary materials in interim output, was still remarkably small at around 14.8%, or 9.6% if only those reprocessed and used in the domestic economy are considered. This suggests, in line with previous contributions, that measuring the CE through recycling rates or even recirculation/ cycling of materials, may provide a partial understanding of the circularity of the system as a whole and that the scale dimension needs also to be assessed.

Table 4.3. Circular economy indicators

	Dimension	Input-side indicator	Output-side indicator
Scale indicators (t)	In and output flows	Domestic material consumption **DMC**	Domestic Processed outputs **DPO**
	Consumption based perspective	Raw material consumption **RMC**	n.d.
	Interim flows	Processed materials **PM** = DMC + secondary materials	Interim outputs **IntOut** = EoL waste + DPO emissions
Circularity rates (%)	Socioeconomic cycling SC	Input socioeconomic cycling rate **ISCr** = Share of secondary materials in PM	Output socioeconomic cycling rate **OSCr** = Share of secondary materials in IntOut
	Ecological cycling potential EC	Input ecological cycling rate potential **IECrp** = Share of DMC of primary biomass in PM	Output ecological cycling rate potential **OECrp** = Share of DPO biomass in IntOut
	Non-circularity NC	Input non-circularity rate **INScr** = Share of eUse of fossil energy carriers in PM	Output non-circularity rate **ONCr** = Share of eUse of fossil energy carriers in IntOut

Note: eUse stands for energetic use
Source: Mayer et al. (2019: 67).

China has also been a pioneer in the adoption of CE policies. In fact, it was the first country to introduce CE at the core of its policy making. The 11th five-year plan, between 2006-2010, already contained a whole chapter highlighting the opportunities of the circular economy and powerful policy mechanisms such as the 2008 Law for the Promotion of the Circular Economy and industrial park demonstration programmes (Matthew and Tan, 2016). The following five-year plans, 12th (2011-2015) and 13th (2016-2020), have consolidated the policy relevance of the CE in China. In 2013, the Circular Economy Development Strategies Action Plan acknowledges three main levels for the implementation of CE corresponding to the organisation (micro), industrial park (meso) and city/ region (macro). The rapid policy development has also been accompanied with ambitious targets that cover waste recovery, reduction of certain pollutants, use of water and emissions and the development of a two-tiered set of indicators that cover macro and meso (eco-industrial park) levels. The macroeconomic system of indicators in China includes 22 indicators across four main categories: resource output, resource consumption, integrated resource utilization, and waste disposal/pollutant emission indicators (Geng et al., 2012), as shown in Table 4.4.

Table 4.4. Circular economy indicators in China

Circular economy evaluation indicator system (at macro level).

Groups	NO.	Indicators
1. Resource output rate	1.1	Output of main mineral resource
	1.2	Output of energy
2. Resource consumption rate	2.1	Energy consumption per unit GDP
	2.2	Energy consumption per added industrial value
	2.3	Energy consumption of per unit product in key industrial sectors
	2.4	Water withdrawal per unit of GDP
	2.5	Water withdrawal per added industrial value
	2.6	Water consumption of per unit product in key industrial sectors
	2.7	Coefficient of irrigation water utilization
3. Integrated resource utilization rate	3.1	Recycling rate of industrial solid waste
	3.2	Industrial water reuse ratio
	3.3	Recycling rate of reclaimed municipal wastewater
	3.4	Safe treatment rate of domestic solid wastes
	3.5	Recycling rate of iron scrap
	3.6	Recycling rate of non-ferrous metal
	3.7	Recycling rate of waste paper
	3.8	Recycling rate of plastic
	3.9	Recycling rate of rubber
4. Waste disposal and pollutant emission	4.1	Total amount of industrial solid waste for final disposal
	4.2	Total amount of industrial wastewater discharge
	4.3	Total amount of SO_2 emission
	4.4	Total amount of COD discharge

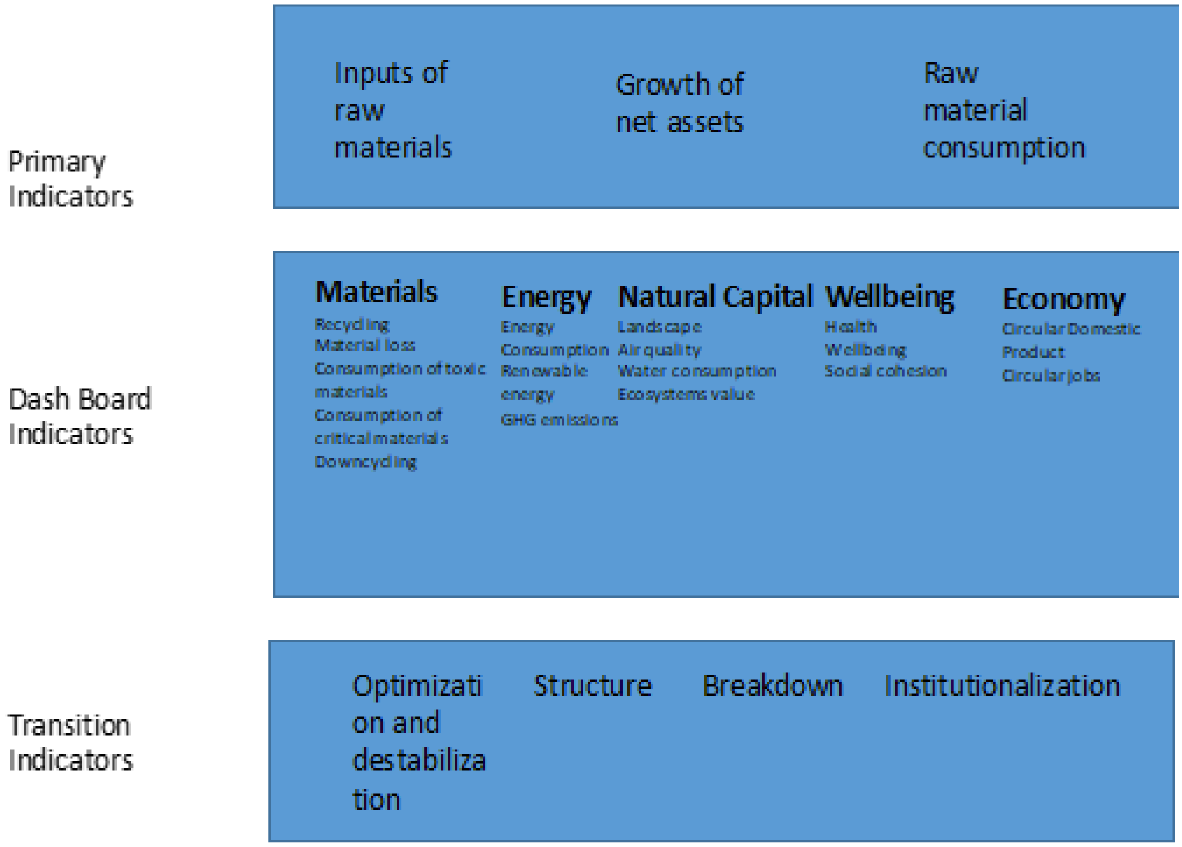
COD means chemical oxygen demand

Source: Geng et al. (2012: 219).

In contrast with Europe, where the monitoring framework focuses mainly on material consumption and solid waste, the indicator set for China's cities and regions covers energy and water consumption and pollutant emissions. Compared to the monitoring system in Europe, the Chinese set for city and regional levels does not capture the 'cycling of materials' and their use as secondary materials (e.g. contribution of recyclates to total demand per type of material). In addition, the Chinese set does not include indicators that monitor the scale of the socio-economic metabolism as proposed in the literature (Haas et al, 2015; Mayer et al., 2019). Also economic indicators of competitiveness and innovation are not part of the Chinese CE system of indicators. These disparities are a reflection of the differences in how CE is conceptualised in Europe and China (McDowall et al., 2017).

While the system of indicators in China at the macro level applies to cities and regions, there is no parallel in Europe of an agreed system to review performance of CE at the city level. However, municipalities have been particularly active in this respect and there is a large and increasing number of cities that have adopted CE strategies. Pioneering this process is the municipality of Amsterdam with an ambitious CE strategy focusing on circular construction and circular cascading of organic waste. Indicators are used to monitor impact associated with the strategies across four axes: value creation; jobs growth; material savings, measured as reduction in Domestic Material Consumption (DMC), and CO2 reductions (Circle Economy et al., 2016). Following this, and in a context of very active policy making in the area of CE, Amsterdam and other municipalities of its metropolitan area, developed a dashboard of indicators to monitor progress towards the CE. The dashboard has three tiers: 1) primary indicators on raw materials; 2) dash board of indicators in thematic areas covering recycling, energy and biodiversity and 3) transition indicators that reflect institutional change, see Figure 4.3.

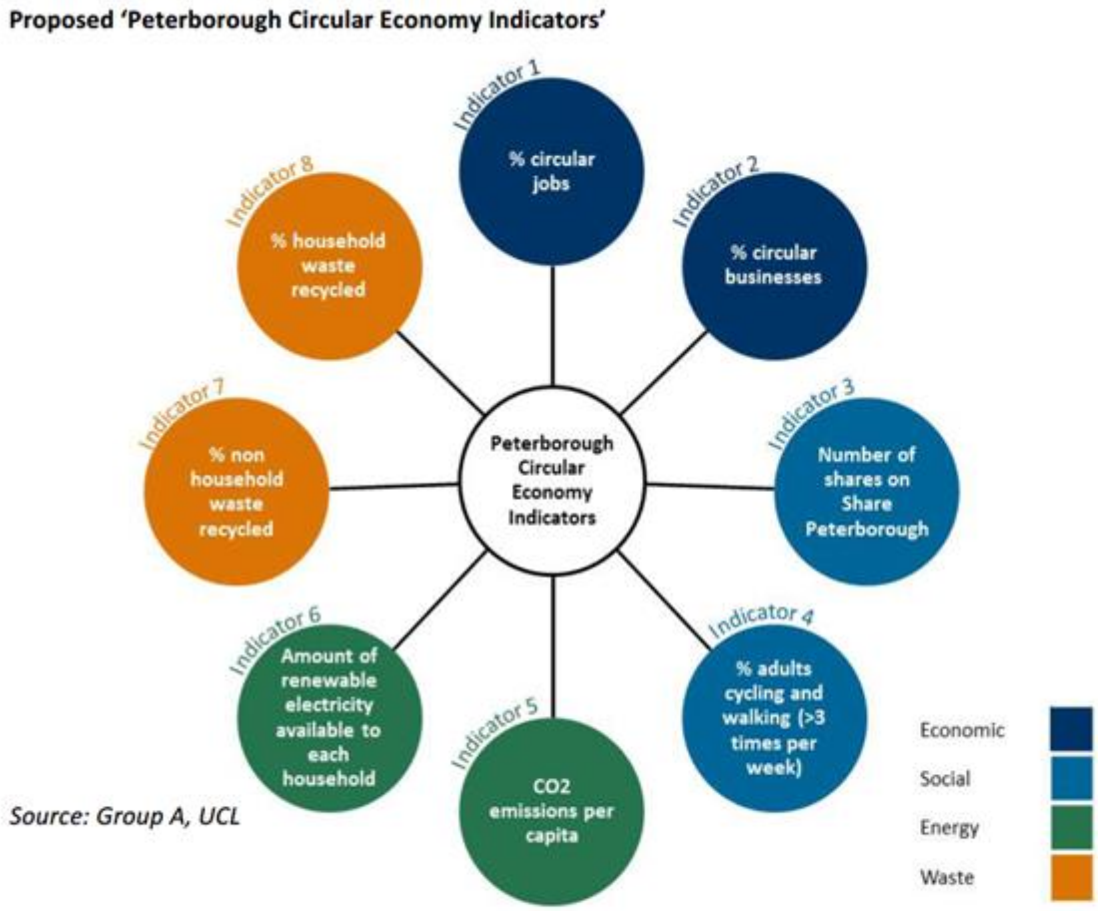
Figure 4.4. Circular economy indicators for Amsterdam



Source: Adapted from Metabolic (2018)

A recent report from Climate KIC C40 cities (2019), based on a purposive sample, identifies 12 case studies of municipalities in Europe pioneering CE initiatives, including Amsterdam, Brussels, Copenhagen and Helsinki to name just a few. The report also lists an important number of municipalities which have developed CE strategies in specific areas such as construction, procurement or utilities. Other cities such as London, Porto, Barcelona or Peterborough also have city-wide dedicated CE roadmaps and ambitious programmes to increase circularity at the urban scale. Petit-Boix and Leipold (2019) report almost 60 municipalities in Europe with dedicated CE strategies although varying in scope and stage of development. As part of their CE strategies, many of these municipalities have developed monitoring frameworks or systems of metrics at the urban level. In general, they tend to be less comprehensive than the Dutch framework and, in many cases, focus on specific aspects such as recycling of construction and demolition (C&D) waste and food waste while others also include aspects such as jobs and private investment, see, for example Figure 4.4, the indicator system associated with the CE strategy at Peterborough (UK).

Figure 4.5. Circular economy indicators for Peterborough



Source: Peterborough Opportunity and UCL (2018: 3).

Also, in their review of CE strategies at the city level, Petit-Boix and Leipold (2018) report MFA and LCA or hybrid approaches as the main assessment frameworks for CE-related strategies, although they do not consider indicator systems as such.

Beyond cities, Avdiushchenko (2018) argues for the need for monitoring frameworks at the regional scale, suggesting this may be an adequate scale to measure some dimensions of circularity, such as CE entrepreneurship, waste management or sharing initiatives, because it is a meaningful policy and institutional level with a number of structural, cohesion and investment funds operating at this level. Flanders have published guides for the development of CE indicators, which review different frameworks and methodologies of calculation, although the region has not developed indicator systems per se (Vito, 2016). In this line, Avdiushchenko (2018) proposes a CE regional framework and identifies key evaluation aspects for each of the 12 identified core pillars, including aspects such as 'economic prosperity or 'energy efficiency and renewable energy'. The proposed system also gives prominence to aspects less well covered in other monitoring systems at national level in terms of social impacts beyond just employment.

The industrial park/estate has also received considerable attention as a main implementation level of the CE. Although this has been a traditional focus area of industrial ecology and industrial symbiosis perspectives, the relevance played by industrial areas in the CE policy in China and other economies in Asia has resulted in important developments in terms of implementation and monitoring frameworks. In 2017 the United Nations Industrial Development Organisation (UNIDO), the World Bank Group, and Deutsche Gesellschaft für Internationale Zusammenarbeit GmbH (GIZ) published an International

Framework for Eco-Industrial Parks (EIPs) summarising the main requirements and expected performance of EIPs, providing guidance in the transition process from conventional productive areas to EIPs. The framework identifies four core elements (resource management, infrastructure and service management, sustainable engineering technology and economic performance) and a number of aspects within each of those categories. The framework, though, does not identify a system of indicators as such but proposes a credits/ accreditation system depending on the level of implementation or adoption of the main requirements. In China, the development of EIPs is well established in policy making and constitutes a critical element of its CE strategy. Reported performance of EIPs across different environmental dimensions seems to consistently exceed performance of other industrial areas (Tin et al., 2014 and Huang et al., 2019). However, comparison across case studies has proven difficult given disparities in the definition and operationalization of EIPs in the regional policy. This led to the definition of a national standard for EIPs that aimed at providing clarity of the main requirements of EIPs as well as harmonising the monitoring of performance. The system of indicators proposed has evolved through a number of iterations, the first discussions taking place as early as 2006, with the first standard adopted in 2009. Huang et al. (2019) review in detail the new national demonstration EIP standard (HJ/T274-2015) in China approved in 2015, under the leadership of the MEP (Ministry of Environmental Protection). Compared to previous standards, the new standard provides a more comprehensive evaluation of a number of environmental aspects including waste management and pollutant emissions and also gives more emphasis to promotion of industrial symbiosis opportunities and more clarity in calculation methods (Huang et al., 2019). The standard is rather comprehensive and, in fact, much more insightful than the Chinese system of CE indicators at the macro (city/region) level. It contains 32 indicators across five main categories: 1) economic development; 2) industrial symbiosis; 3) resource conservation; 4) environmental protection and 5) information disclosure. Interestingly, it also includes quantitative benchmarks and, in most cases, minimum level of performance required. Although there may still be a number of issues in terms of harmonisation of calculation methods, data quality and data gathering procedures, the standard breaks new ground in terms of establishing frameworks at any level (micro, meso and macro) with benchmarks and minimum required performance levels.

Finally, the micro level has also received considerable attention in terms of the development of monitoring tools. Most contributions refer to two main units of intervention: the individual organisation (e.g. businesses) and the supply-chain and sector of activity. Genovese et al. (2017) use a hybrid approach combining Economic Input-Output (EIO) analysis and life cycle analysis (LCA) to assess the degree of circularity in supply chain with case studies in the food and chemical supply chains. Their analysis focuses on the calculation of the Total Emissions Impact traced along the whole supply chain combining multi-region IO analysis with LCA databases. Based on the hybrid framework, the authors calculate the impact of CE strategies for two case studies selected. In the case of the chemical sector, the CE strategy selected is the substitution of ferric chloride, produced in a linear way, by ferrous sulphate, obtained as a by-product from titanium dioxide production. The model calculates three times less emissions of CO2 eq in the CE scenario compared to the linear production. The results also capture the avoided impacts generated by the prevention of the disposal of the residue from Titanium Dioxide. Similarly, the model reports also important savings in the use of waste vegetable oil in the production of bio-diesel compared to the linear scenario. This and other contributions at the supply chain level seem to suggest that changes at the product level may indeed have relevant implications at the system level and that monitoring frameworks need to adequately capture system level implications of CE product-focused strategies. Similarly, WBCSD (2020) argues for a harmonised measurement framework for circularity metrics in business organisations and proposes a system of seven indicators at the organisation level across three categories: 'close the loop', 'optimise the loop' and 'value the loop'. Elia et al. (2017) review the use of indexes and systems of indicators as monitoring frameworks for the Circular Economy at the micro-level. The proposed taxonomy of index-based approaches to measure the CE considers indicators across four main parameters or dimensions, 'material flows', 'energy flow', 'land use and consumption' and 'other life-cycle based' and reviews existing contributions to assess what areas of the CE, or 'CE requirements' are addressed by different systems. The report identifies five main CE requirements, based on the literature review: 1) reducing input use of natural resources; 2) increasing the share of renewables and recyclates; 3) reducing emissions; 4) reducing valuable material losses and 5) increasing the value and durability of products. Based on the literature review, it also concludes that while most of the contributions focus on developing monitoring systems at the macro level, the meso and micro levels are still relatively unexplored.

At the organisational level, a number of measures to assess CE in organisations or products exist. The first, probably most widely known, is the index developed by EMF (2015). The proposed measure is called the Material Circularity Indicator (MCI) which can be applied to single products but also provides a framework for aggregation at the organisational level. The is calculated as MCI= 1-LFI*Fx, where LFI stands for Linear Flow Index, calculated as a function of reused or recycled content in the product and production of unrecoverable waste and where Fx is a function of the degree of intensity of use of the product. The MCI index varies between 0 and 1, as the restriction MCI=max (0,MCI) applies to avoid negative numbers. The closer to 1 the MCI is, the more circular the product is. This index is accompanied by a battery of complementary indicators that measure risk and impact. This may include raw material price variations, material security and scarcity, toxicity and impact indicators such as CO2 emissions. Di Maio et al. (2015) propose the 'Circular Economy Index' as a ratio of recycled output to recycling input, providing a measure of efficiency of recycling systems. Park and Chertow (2014) refer to the 'Reuse Potential Indicator' as a way to measure the actual technical recyclability and actual cycling potential of specific materials. Linder et al. (2017) provide a financial circularity index that compares the economic value of recirculated end-of-life (EOL) products to total product value. Scheepens et al. (2016) propose a measure that captures the relationship between the costs associated with environmental pollution and the market value of the products and services provided. More recently, Pauliuk (2018) reviews the proposed BSI 8001 CE implementation framework and argues that there is still a knowledge gap to develop relevant and reliable indicators at the organisation and product levels. The author proposes a dashboard of CE indicators, compiled from the literature and organised across 4 main axes (CE, Resource Efficiency, Climate & Energy, Stocks and Sufficiency) as a selection tool for organisations. However, it is stressed that indicators at the organisational level run the risk of losing sight of the system implications of the implemented strategies if these are not monitored using a 'systems perspective' using available methods of MFA and LCA to assess flows of resources and their impacts. Table 4.5 provides a summary of the main relevant CE-monitoring frameworks reviewed in this chapter.

Table 4.5. Summary of relevant CE indicator/s at different levels of governance

Dimension	Indicators	Source
Global/Macro	MFA based circularity indicator: 'share of recycled materials in total processed materials', Figure 4.1	Haas et al. (2015)
	Circularity Gap Cycled Materials: 'Percentage of recycled materials in overall resource consumption' Mass-Value-Carbon Nexus framework	Circularity Gap Report (2019)
	EU 'CE monitoring framework' 15 indicators across 4 main dimensions, Table 4.2	EC
	'scale indicators' and 'circularity rate indicators' MFA-based, Table 4.3	Mayer et al. (2019)
	Chinese 'macroeconomic system of indicators for CE', Table 4.4	Geng et al. (2014)
Meso	Amsterdam and metropolitan area CE indicator framework 'primary resource indicators', 'dashboard indicators' and 'transition indicators', Figure 4.3	Circle (2016)
	Peterborough CE indicators dashboard, Figure 4.4	Peterborough, n.d.
	Eco-Industrial Park framework 'resource management', 'infrastructures and services', 'sustainable engineering technologies', 'economic performance'	UNIDO, WB, GIZ (2019)
	Chinese EIP standard	Huang et al., 2019

	32 indicators across five categories	
Micro	Supply chain indicators based on combined IO and LCA analysis	Genovese et al. (2017)
	Material Circularity Indicator (MCI)	EMF (2015)
	Circular Economy Index	Di Maio et al. (2015)
	Reuse Potential Indicator	Park and Chertow (2014)
	Financial circularity index	Linder et al. (2017)
	Dashboard of CE indicators based on BSI 8001 (Resource Efficiency, Climate & Energy, Stocks and Sufficiency)	Pauliuk (2018)

Source: Author's compilation.

In conclusion, the rapid development of the policy agenda for the CE in different world regions has highlighted the need for indicators and monitoring frameworks to assess the effectiveness of the adopted policies and instruments at different levels. However, the development of monitoring frameworks faces a number of challenges. First and foremost, there is no agreed precise definition of CE, and different regions (e.g. EU and China) have significantly different conceptualisations of what a CE is, which inevitably results in different ways of measuring it. Secondly, the review of indicator systems undertaken here suggests a lack of integration between the micro-, meso- and macro-levels with the risk of leading to conflicting strategies to achieve circularity at the system level. Future research thus needs to address the necessary alignment of CE strategies at the micro-meso-macro levels, through a complex monitoring system that traces system level implications from bottom-up and top-down initiatives, in line with Pauliuk (2018) and Mayer et al. (2019). Third, and related to the above, there is still limited understanding of rebound effects of CE strategies (Zink and Geyer, 2017). This relates to what the assumptions around displacement of primary materials by secondary material are as well as price effects. For example, Geyer and Blass (2010) found that the environmental benefits associated with the use of refurbished phones are likely to be low as they would normally be consumed in developing economies, by people who would not otherwise own a phone, adding to the overall number of mobile phones rather than displacing primary consumption. Similarly, Haupt et al. (2017) found that commonly used indicators of circularity such as collection rate and recycling rate may give a misleading indication of progress, as recycling rates indicate inputs into the recycling processes, rather than an indication of efficiency of recycling processes and how much those flows have displaced actual primary consumption of materials.

Most of the indicator systems reviewed have at their core indicators related to higher levels of reuse, remanufacturing and recycling, operationalised through the concept of 3R or 9Rs assuming that this would necessary lead to a greater level of circularity and ultimately would mitigate pressures on environmental systems. However, some of the assumptions behind the 3Rs approach may need revision or to be complemented with further analysis. A critical one refers to the role of recycling and its socio-technical limitations. Some studies have recently suggested that in some instances recycling may indirectly increase the use of materials and energy compared to primary use (e.g. Cullen, 2017; Behera et al., 2014). Also, importantly, MFA-based analyses reviewed here have highlighted that despite high recycling rates of EOL products, the overall degree of circularity in advanced economies is still very low, with high reliance on fossil fuels (and associated emissions and pollution) and significant additions to the stock, which substantially reduces the scope of change induced by CE strategies. This, thus, results in high consumption of primary resources and generation of waste and emissions. And, as demonstrated by Haas et al. (2018) and Fellner et al. (2017) even a 100% cycling of EOL waste as secondary materials in Europe would only cover a small fraction of overall material consumption. In addition, while generally closed loop recycling is assumed to be superior to open loop recycling, as a way to reduce dissipation, some authors have questioned this (e.g. Geyer et al., 2016), stressing the need for further research in this area.

A consequence of all the above, is that system- wide approaches are required to effectively monitor the CE. The monitoring system needs to reflect not only the circularity of the flows in the system but also the scale of the socio-economic metabolism. The system level is also required to ensure a better understanding of rebound effects and the system implications of CE strategies. However, the analysis has shown that in most cases, policy driving monitoring systems lack indicators that measure the scale of the system and do not include indicators that could induce more efficient use of the material stocks, such as prolonging the life of products or increase intensity in the use of stocks. The MFA analyses also indicate that the transition to a low-carbon economy is or should be a critical element of a CE and, thus, more efforts to integrate both low-carbon and circular strategies are needed to enhance consistency between both pathways and promote synergies. Beyond conceptual issues, data gaps and inconsistency in statistical reporting is a hurdle that any monitoring system faces, especially as some of the dimensions of the CE have not historically been reflected in statistical databases. The problem is significantly aggravated if we look beyond Europe, where data sources have not been developed in consistent ways, raising issues around data availability, harmonisation and standardised procedures of calculation.

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PART II: ACHIEVING THE CIRCULAR ECONOMY

5. Business models in the circular economy (Paul Ekins)

A business model describes an organisation's means of value creation, value realisation and value distribution. Lahti et al. (2018: 2) write: "The features of a business model define the company's customer value proposition and pricing mechanism, indicate how the company organizes itself and whom it partners with to produce value, and specify how the company structures its supply chain." In a private organisation operating in a competitive environment which is expected to maximise the returns to those who have lent it money, like most businesses, there is an obvious incentive to externalise environmental and social costs. Where this is permitted by the regulatory environment, it can even be argued that this is a business imperative, if the business is not to be undercut by competitors.

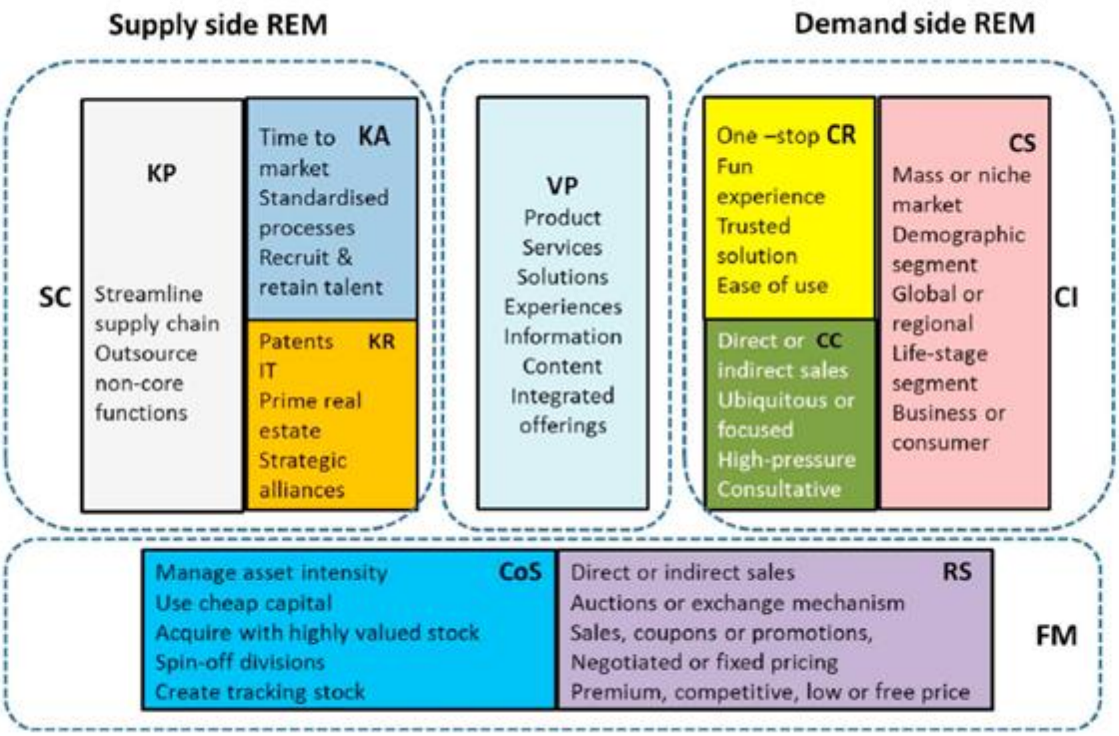
It has been established in sections 1-3 of this paper that one of the principal purposes of a circular economy is to reduce environmental damage, which is well understood to be one of the areas most prone to cost externalisation. This emphasises the importance of public policy to internalise these costs to the companies causing them, if circular economy companies and business models are to flourish.

However, this does not mean that all moves towards a circular economy at business level lead to competitive disadvantage, and there is now a considerable literature as to how some companies have sought to use circular economy thinking for commercial benefit, or found that it has delivered such benefits when pursued for environmental reasons. Obvious potential benefits from circularity may arise from resource efficiency savings on purchased inputs or waste disposal costs, from improved internal or supply chain management processes, or from increased employee morale and customer reputation that can arise from perceived corporate social responsibility involving an emphasis on greater circularity. This section explores some of the theory and thinking that leads to business models of this kind. The next section will discuss some of the barriers to putting this thinking into practice and how these barriers may be overcome.

Lahti et al. (2018: 3) consider that: "A circular business model is designed to create and capture value while helping achieve an ideal state of resource usage (e.g., finding a model that most closely resembles nature and comes close to achieving the complete cycling of materials). Accordingly, the goal of the business model shifts from making profits through the sale of products or artefacts to making profits through the flow of resources, materials, and products over time, including reusing goods and recycling resources. This reasoning implies that companies can reduce negative impacts on the environment by delivering and capturing value through this alternative value proposition." And this gets to the heart of the problem. Circular business models seek fundamentally to reconfigure a company's use of material resources in order to effect environmental improvement, in a context in which the value of such improvement is usually unrecognised in the private returns to the company. Any costs incurred in the reconfiguration will therefore either imply a reduction in profitability, or will need to lead to reduced costs, or increased opportunities, elsewhere.

Diaz et al. (2019) have used the 'business model canvas' they attribute to Osterwalder and Pigneur (2010) to locate in the geography of a firm's business model the main 'resource efficiency measures' (REMs) they have identified in the literature. Figure 5.1 shows their diagram of the business canvas model, with the four elements that can be affected by Business Model Change (BMC), to which they add the further element of Internal Processes (IP).

Figure 5.1. Resource efficiency measures and business model changes



Note: Key: The four main elements of the business model canvas: SC = supply chain; VP = value proposition; CI = customer interface; FM = financial model. The components of these main elements: KP = key partners; KA = key activities; KR = key resources; CR = customer relations; CS = customer segments; CC = customer channels; CoS = cost structure; RS = revenue stream
Source: Diaz et al. 2019, Figure 5 : 24

Table 5.1 briefly describes the different REMs and relates them to the business model changes (BMCs) with which they are generally associated. Clearly there is substantial overlap between the various categories. It is interesting that the authors class 'circular economy' as a REM, whereas it was seen that resource efficiency was generally taken to be the principal purpose of a circular economy, a further example of the fluidity of categorisation that is still characteristic of this literature.

Table 5.2. Relationships between resource efficiency measures and business model changes

Resource efficiency measure	No. of case studies	Description	Related business model change (BMC)
Demand side			
Green products	29	New product introduction	VP, SC, IP
Green services	32	'X as a service'; services in value chains	VP
Service substitutes	1	Refillable packaging	VP, CI
Services instead of products	12	Sharing and renting, sometimes with insurance and TBM	VP, FM
Functional sales	9	Renting and leasing; performance contracting	VP, FM

Take-back management (TBM)	21	Reusable packaging; equipment for re-use or refurbishing	SC, CI
Supply side			
Pollution control	1	Pollution control (cf cleaner production)	SC, IP
Waste management	9	Effective collection of waste streams	IP
Cleaner production	8	Cleaner production (cf pollution control)	SC, IP
Eco-efficiency	12	Less input material or material substitution	IP, SC, VP
Green supply chain management	23	Source green materials; code of conduct, co-operation between suppliers; benefits sharing	SC, VP
Life cycle			
Cradle-to-Cradle (C2C)	20	C2C products or services; bio-processing	SC, IP, VP
Industrial symbiosis	23	Platforms/places that connect supply and demand of residual streams	SC, VP
Circular economy	49	As discussed in this paper	Most elements of business model

Source: Adapted by the author from Diaz et al. (2019), Tables 5, 6, 7: 26, 29, 30

The OECD (2019) typology of circular business models singles out five models for special analysis: circular supply models, which replace traditional inputs with renewable, bio-based or recovered inputs; resource recovery models, which use waste streams to produce secondary materials; product-life extension, through making more durable products, or products which can be re-used, repaired, refurbished and remanufactured; sharing models, through which under-utilised consumer goods are used more intensively by being shared in use; and product-service systems (PSS), the business model that has had easily the most analysis in the literature, and in Table 5.1 is called ‘Services instead of products’.

PSS was in fact the subject of Stahel (1982) (though it was there referred to as ‘Product-Life Extension’), which was seen in section 1 to have generated the first diagram of a circular economy. Since then PSS has been the subject of hundreds of research papers across a wide range of disciplinary fields, including Information Systems, Business Management, and Engineering and Design, as well as, more recently, the circular economy. This has led to a number of review papers and journal special issues on the topic. One of the most recent review papers is Tukker (2015), which is part of the special issue of the *Journal of Cleaner Production* entitled ‘Why have Sustainable Product-Service Systems not been widely implemented?’, a pertinent question given the quantity of academic attention they have received. This special issue was followed in 2017 by a 400-page conference compendium of the 9th CIRP Industrial Product/ Service-Systems Conference (McAloone et al., 2017).

Tukker (2015) closely followed another review of PSS by Boehm and Thomas (2013), and approvingly cites Boehm and Thomas (2013)’s definition of PSS that they synthesised from the literature they review: “A Product-Service System (PSS) is an integrated bundle of products and services which aims at creating customer utility and generating value.” (Tukker, 2015: 2, citing Boehm and Thomas, 2013). Tukker (2015) builds on his earlier review (Tukker, 2004) by identifying three different types of PSS:

- *Product-oriented services*: where some additional services are added but the main business model is still selling products;
- *Use-oriented services*: where the product is still central, but its ownership remains with the provider and the product is leased, shared, rented or pooled;
- *Result-oriented services*: where payment is by pre-defined and agreed result, i.e. pay per service unit delivered

The core of the analysis in Tukker (2015) focuses on the business and environmental (dis)advantages of PSS. The environmental side of this is discussed in section 9 of this paper, but Tukker’s conclusion on the business dimension is not reassuring for those eager to see PSS becoming more widely established: “Products for which a PSS business model will work are typically expensive, technically advanced, requiring maintenance and repair, easy to transport, used infrequently by customers, and not heavily influenced by branding, fashion, etc. There is also a clear difference in the success of PSS between the consumer and business markets because consumers attach far greater value to owning the products they use and having full control over how to use them. It is therefore not surprising that various authors argue convincingly that legal and political changes are essential if sustainable PSS are to break through in the market." (Tukker, 2015: 86)

In his answer to the question 'Why have Sustainable Product-Service Systems not been widely implemented?', Tukker (2015: 88) notes (quoting the earlier review Tukker and Tischner, 2006, in italics): "Certainly, in various cases PSS can provide higher tangible and intangible value to the user, can be created with lower system costs, and can improve a firm's position in the value chain – and hence its competitive advantage. However, as we already concluded in 2006 (Tukker and Tischner, 2006): *"...PSS do not deliver such bonuses by definition. Particularly in a B2C context, product ownership contributes highly to esteem and hence intangible value. Access to the product is [in PSS] often more difficult, creating tangible consumer sacrifices. Costs can be higher, if the PSS has to be produced with higher priced labour or materials, or when the often more networked production systems generate high transaction costs. And sometimes a switch to PSS may weaken the position in the value chain. In industries where excellence in product manufacturing and design form the key to uniqueness and hence power in the value network, diverting focus to an issue such as PSS development is a recipe to lose rather than win the innovation battle."*

"In our view, the limited diffusion of sustainable PSS, in particular, such as car sharing systems, shared use of do-it-yourself tools, and washing services, can be explained simply by the factors mentioned in the above quote."

This is a far cry from the optimism expressed in Stahel (1982), who foresaw that "the private sector, whether R&D, manufacturing or finance, will find innumerable business opportunities in product-life extension activities … [W]hile increasing the number of skilled jobs available and reducing our dependence on strategic materials, such activities will provide the private sector with fresh impetus to make cheaper goods available as part of a self-replenishing economy built on a spiral-loop pattern which allows a substitution of manpower for energy." (Stahel, 1982, Abstract).

The next section explores whether and how the cost and other barriers to PSS and other circular economy business models can be removed so that Stahel's vision may come closer to being realised.

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6. Barriers to and drivers of a circular economy (Nicholas Hughes, Lorenzo Lotti)

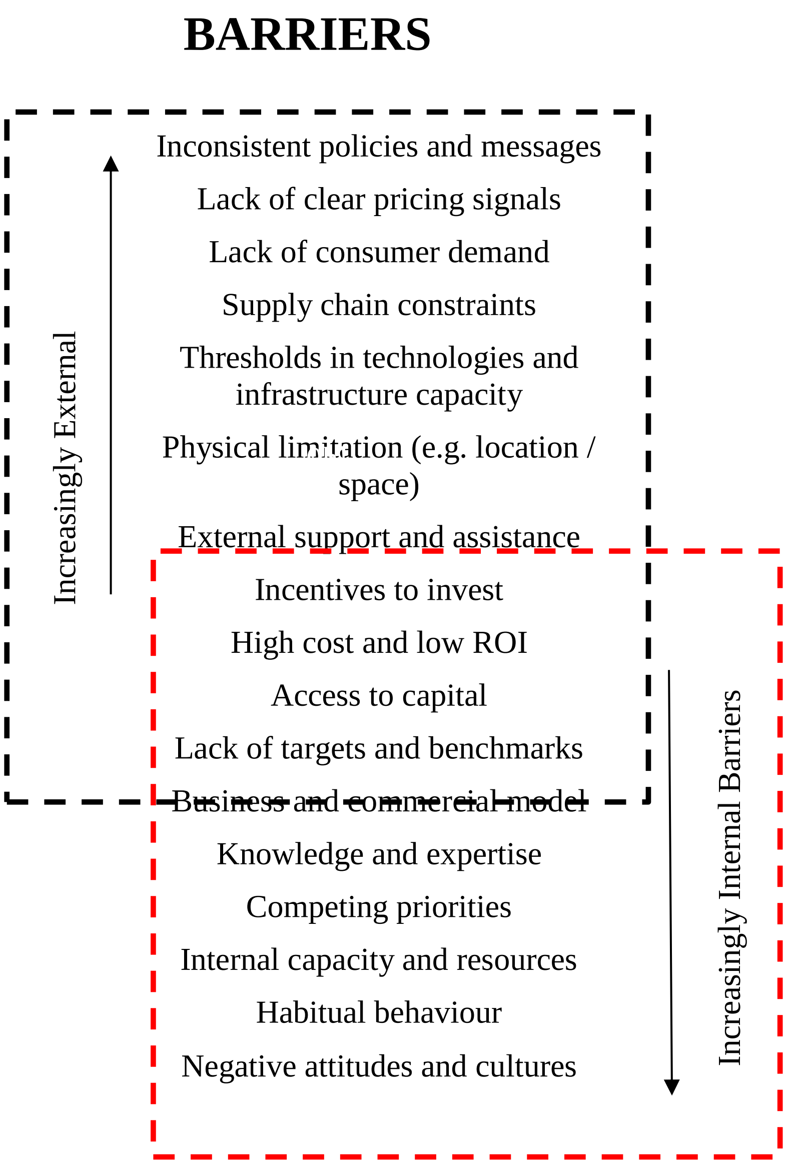
As described in other sections of this report, CE practices already occur in certain businesses and contexts. At the same time, it is clear that CE practices are not ubiquitous. It can be inferred from this that there are drivers for CE practices which are causing or enabling them to occur in certain circumstances, but there are also barriers which prevent their wider adoption. Examining both drivers and barriers to CE provides a useful platform from which to propose measures to enhance CE, by removing barriers and sharpening or enhancing drivers – this will be the task of section 7. In the current section some recent categorisations of barriers and drivers to CE and resource efficiency (RE) are considered. Their similarities and differences are observed, and some broad principles drawn out.

One useful distinction to draw out in considering barriers and drivers, is between those that are internal, and those that are external. Barriers and drivers that are internal to companies or to the practices of individuals, reflect something about the strategies and decisions made within that company or by that individual, and thus typically are connected with actions over which the company or individual has some control. External drivers and barriers reflect the context in which the company or individual operates. As such the company or individual has less direct control over such factors, and correcting or enhancing them may be a matter for policy intervention. This distinction between internal and external barriers from the business perspective is represented in Figure 6.1, below, adapted from a report on *the opportunities to business of improving resource efficiency*, by AMEC and BioIs (2013).

Amongst the external barriers that companies might face, as listed in Figure 6.1, 'inconsistent policies and messages', and 'lack of clear pricing signals', are clearly problems whose resolution would require the intervention of policy makers. Other barriers such as 'supply chain constraints', and 'thresholds in technologies and infrastructure capacity', may more directly concern interactions with other companies; however, the role of policy in coordinating actors and supporting technological innovation may still be significant.

Amongst the internal barriers, choices about the 'business and commercial model', 'knowledge and expertise', 'competing priorities', 'internal capacity and resources', 'habitual behaviour', 'negative attitudes and cultures', are all things which it would be within the remit of a company to improve or resolve within its own organisation. However, the motivation to do so would be affected by external factors – if there is a 'lack of consumer demand' for the kinds of products that would be consistent with the CE – such as products designed with recycling or remanufacturing in mind – or if 'policies' or 'pricing signals' are absent, then there would clearly be limited motivation for a company to act to remove its internal CE barriers, unless such barriers also happened to be barriers to profit. Financial barriers such as 'high upfront costs', 'low returns on investment', and constrained 'access to capital', whilst being reflective of internal conditions in the company, are also strongly related to external conditions, and thus could also be improved by policy measures, for example, to provide low-cost financing, or to reduce the cost of commercial financing by providing clear and stable long-term policies.

Figure 6.1. Barriers to business becoming more resource-efficient



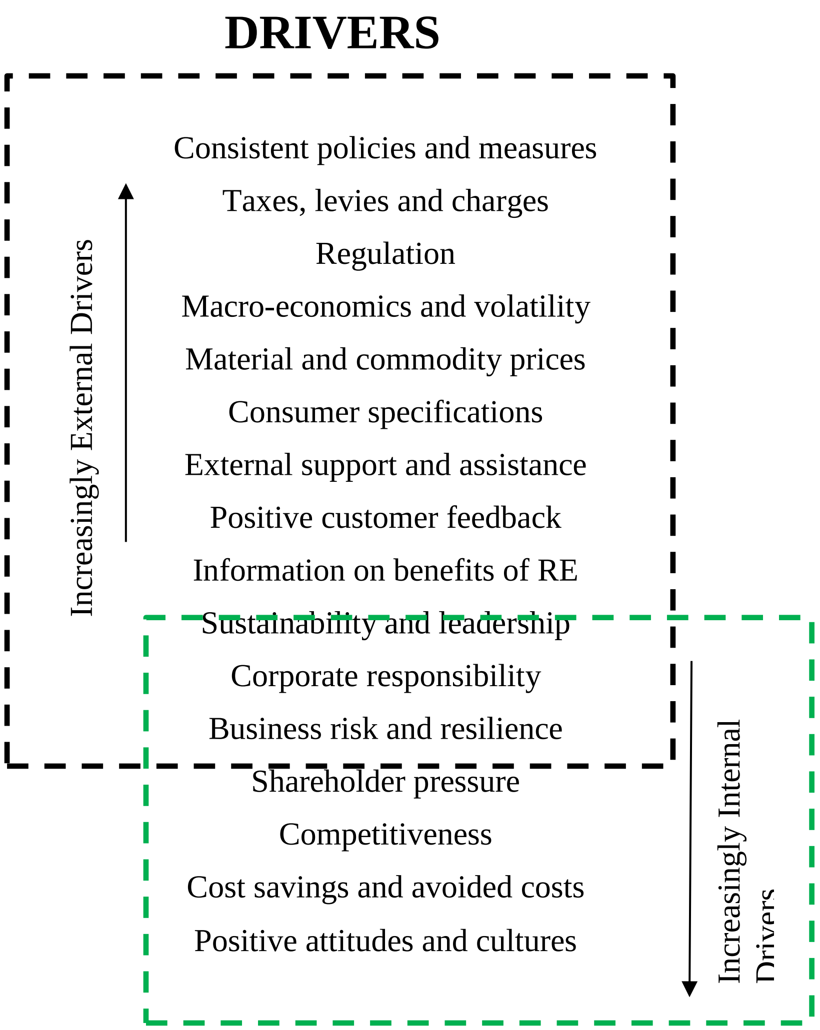
Source: Adapted from AMEC and BioIS (2013), Figure B9: 83

Several of these external and internal barriers could also with minimal strain be interpreted from the point of view of the individual. Individuals' habitual behaviour can be a powerful inhibiting factor limiting CE practices – however it must also be acknowledged that habits themselves are usually cultivated, at least originally, due to external conditions, in particular the lack of alternative options. Individuals are also generally sensitive to high upfront costs and low rates of return.

In order to enhance the transition between the linear and circular economy, it is also important to consider insights from behavioural economics, which are related to both internal and external barriers. Widely used neoclassical theories assume fully rational and self-interested economic agents, directly affecting policy expectations in terms of effectiveness and efficiency. However, a large literature has challenged neoclassical models, supported by strong evidence on observed behaviours: individuals often deviate from self-interest and full-rationality assumptions. Behavioural economics has identified deviations with respect to preferences (time inconsistency, the effect of social preferences and altruism, reference dependence, incorrect probability weighting), beliefs (individuals project current preferences into the future) and decision making (the effect of framing, inertia, limited attention and use of heuristics); these deviations affect individuals, firms and ultimately pricing signals and policies.

An integration of psychology and economics as in behavioural economics can lead to better predictions of economic behaviour and, subsequently, to better policy descriptions (Camerer 1999). Figure 6.2, below, also adapted from AMEC and BioIS (2013), is a corresponding figure to Figure 6.1, this time showing the drivers, but also drawing the distinction between the external and internal.

Figure 6.2. Drivers to stimulate businesses to become more resource-efficient



Source: Adapted from AMEC and BioIS (2013), Figure B9: 83

The external drivers include several which are already indicative of policy measures in response to some of the ‘barriers’ set out in the previous figure, for example, consistent policies and measures, and the use of taxes, levies and charges, and of regulation, to address a lack of clear pricing signals. Policy makers can also assist with providing information on the benefits of resource efficiency and the CE. Customer specifications and positive customer feedback in support of CE practices and products are clearly external to businesses, but would themselves be dependent on other broader social trends, within which governments could play a role.

Internal drivers such as cost savings and avoided costs, increased competitiveness, and considerations of business risk and resilience, are in some senses the most purely internal, in that they would reflect the adoption of CE practices due to their contribution to the financial health and long-term resilience of the company. However, the importance of drivers such as sustainability and leadership, corporate responsibility, shareholder pressure, and positive attitudes and cultures, would be dependent on how widely and deeply CE values have taken root in the company’s customer base and in society more broadly – a company whose customers and shareholders had no interest in CE, would correspondingly feel no impetus from such potential drivers.

An important general observation arising from considering these internal and external barriers and drivers, is that barriers and drivers are frequently not isolated, but operate in a context, and in combination with other drivers and barriers, both internal and external. This is why Kemp et al (2014: 52) develop the concept of the ‘web of constraints’ – and a corresponding ‘web of drivers’ – rather than considering individual barriers and drivers operating independently.

Diaz Lopez et al. (2019) explore relationships between resource efficiency measures, CE business model changes, and implementation barriers in 143 cases. They adopt a categorisation of implementation barriers, as shown in Table 6.1.

Table 6.1. Main categories of Implementation Barriers for resource efficiency

Barrier type	Definition	Examples
Institutional	Barriers caused by (e.g. political) institutions framing the “rules of the game”.	Regulations and laws, fiscal measures, conditions for investment
Market	Market conditions, economic climate, and value network conditions	Monopolies, lack of information, subsidies, supplier leverage, relative cost of labour, materials and energy, etc.
Organisational	Firms as social systems influenced by goals, routines, organisational structures, etc.	Company strategy or focus, lack of funds, lack of management systems, etc.
Behavioural	Individuals' values and attitudes within companies	Lack of attention, lack of perceived control, lack of information, risk averse nature of existing market actors, etc.
Technological	Availability or lack of knowledge, technical artifacts or knowhow.	Lack of equipment or other tools, undeveloped technology from the market, cost of technology, unable to support technology, etc.

Source: Diaz Lopez et al (2019), Table 3 : 24; drawing on Bastein et al. (2014), Michaelis and Carey (1973), Weber (1997), Ashford (1993), Montalvo (2002), and von Weiszäcker et al. (2009).

These categories can also be usefully considered in terms of their position on the internal-external scale. Institutional barriers, such as regulations, laws and fiscal measures, and market barriers, such as subsidies, and relative costs of materials, labour and energy, would be largely outside the control of a company or individual. As with the AMEC BioIS list of external barriers, they also infer policy actions that governments could take to remove or reduce such barriers. Organisational barriers, such as company strategy or management systems, and behavioural barriers such as values, attitudes or lack of information, are both more internal categories – however, as observed in the AMEC and BioIS list, the link to external barriers is strong, as the willingness and capability of both companies and individuals to address such barriers could be strongly supported by CE-conducive changes to external conditions. Technological barriers also have both internal and external characteristics. Technologies can be developed internally by firms, as part of their innovation processes. However, state-funded R&D programmes can also provide crucial impetus to technological innovation, and the institutional conditions established by policies are also crucial for providing fertile ground for private sector innovation.

The review of Diaz Lopez et al. (2019) finds some limited evidence of relationships between types of resource efficiency measures (REMs) and types of resource efficiency business model changes (BMCs), and the categories of implementation barriers. For example, technical barriers appeared most significant to resource efficiency measures directed at the supply side, whereas market barriers were more significant to measures directed at the demand side, and to life cycle measures. In terms of business models, supply chain business model changes were mainly related to organisational challenges, and financial model business model changes were mainly related to behavioural barriers. However, these relationships are relatively weak, and the firmer conclusion is that 'in general most Implementation Barriers play a role in all types of REMs and BMCs' (Diaz Lopez et al., 2019: 20). The conclusion that multiple types of barriers can interact and operate at the same time, reflects the concept of the 'web of constraints' – and a corresponding 'web of drivers' – as described by Kemp et al (2014) as being a more useful way of understanding drivers and barriers than as isolated and exclusive phenomena.

It is also important to recall that both the AMEC and BioIS, and the Diaz Lopez et al categorisations are from the point of view of firms. It has been noted that some correspondences can be drawn between barriers and drivers as faced by firms and by individuals, however there will also be some differences. Further, there is also the broader societal-level perspective, as explored in section 3 of this paper, which investigates the purpose of the CE and what problems it is intended to address. The reduction of pollution and avoidance of resource depletion are societal-level concerns, which are as important to the rationale of the CE as firm-level and individual-level concerns. The fact that the benefits of such drivers are not always priced in to individual and firm-level decisions, can from the societal perspective be considered a market failure, which it is the job of policy to address, as will be discussed in section 7.

Govindan and Hasaganic's (2018) clustered classification of drivers and barriers includes factors which extend to the individual consumer level, as well as to the societal level. Important additions in this classification, which received less attention in the previous typologies, include the role of 'culture and social' issues, which can include firms' relationships with other firms, as well as individuals' values and beliefs, such as the 'thrill of newness' or negative perceptions of refurbished or remanufactured products, as being a potential barrier to the uptake of such products. The authors also include broader societal goals amongst their drivers, such as environmental protection, economic growth and job creation. As will be discussed further below, the evidence for such broader benefits is not entirely straightforward, due to the possibility of some economic 'losers' in a CE transition, and to factors like the 'rebound effect'. Govindan and Hasaganic's (2018) clustering of barriers is summarised in Table 6.2, with the drivers summarised in Table 6.3.

Table 6.1. Summary of clusters of barriers as analysed by Govindan and Hasaganic (2018)

Barrier cluster	Examples of barriers
Governmental issues	Ineffective, insufficient or unsupportive policies; lack of performance indicators; unclear vision
Economic issues	Weak incentives, lack of internalisation of external costs; high upfront costs and insufficient short-term benefits prevents investment; resource-efficient options can be more expensive
Technological issues	Product complexity inhibits separation of materials making recycling harder; challenges monitoring product quality throughout the lifecycle, and maintaining product quality with recovered or remanufactured materials; lack of accurate information in tracking material composition of products to enable recycling and remanufacturing
Knowledge and skills issues	Lack of public information and awareness to support participation in reuse / recycle / remanufacturing; lack of necessary skills in workforce; consumer awareness about refurbished or remanufactured products – perception that quality is lower

Management issues	Lack of interest or leadership on circular economy within firms at management level; higher priority given to other supply chain issues; organisational structures within firms inhibit implementation of CE practices
Circular economy framework issues	Lack of successful business models; complexity of transnational supply chains, including for waste management; tendency to focus on recycling when other CE practices might be more beneficial
Culture and social issues	Lack of good relationships in supply chain; linear technologies and practices deeply rooted; negative customer perceptions of remanufactured products; 'thrill' of newness
Market issues	Challenges to operating take-back systems with multiple companies involved, and legal problems for service providers retaining the sold product; lack of standards and variable quality of refurbished products; lack of consumer acceptance of 'service' rather than ownership models; remanufacturing requires experience and knowledge

Source: author's adaptation of Govindan and Hasaganic (2018) Table 5: 296-299.

Table 6.2. Summary of clusters of drivers as analysed by Govindan and Hasaganic (2018)

Driver cluster	Examples of drivers
Policy and economy	Government laws and policies compel firms to act; potential for increased revenues due to increased efficiencies may encourage firms to act
Health	Public and animal health is compromised by pollution – to the extent that CE can reduce pollution it will have health benefits
Environmental protection	Environmental damage is caused by consumption of energy and extraction of the Earth's resources. To the extent that CE enables the more efficient use of the Earth's resources it can reduce such damages
Society	CE is required to support increasing population, and increasing urbanisation, sustainably; CE will create jobs; customers increasing knowledge and demands for sustainable products
Product development	CE will improve efficiency of material and energy use in the supply chain; longer lasting products will be higher quality and therefore increase their value

Source: author's adaptation of Govindan and Hasaganic (2018) Table 3: 288

Hughes and Ekins (2018) draw attention to the difference between removing barriers that would enable private firms and actors to do things that are in their own financial interest; and occasions where the barrier is precisely that the CE action is not in the financial self-interest of the individual actor or organisation. For example, if a CE measure would bring about an increased labour cost which is greater than the value of the materials saved as a result of the increased material efficiency of the process, then it would simply not be in the financial interest of a rationally self-interested company or other actor to put the measure in place (Allwood, 2014: 456-457). In such cases, removing the barrier – or turning the barrier into a driver – requires a more fundamental restructuring of incentives, such as fiscal intervention, or regulatory intervention to prohibit the undesired behaviours or realign responsibilities for CE-conducive behaviour.

This distinction informs the way that Hughes and Ekins (2018) choose to set out barriers to resource efficiency, an adaptation of which is set out in Table 6.4. As shown, the barriers can be divided into those impeding a resource-efficient decision which would be in the financial self-interest of the firm or actor (in other words, removing such barriers is likely to result in a 'win-win' situation for the private actor and for society, both in environmental and financial terms); and those in which the barrier is the fact that resource efficiency is not in the financial self-interest of the actor concerned (in other words, removing such barriers may not result in a 'win-win' situation as some actors may end up being 'losers' relative to their position under the status quo). The final category then can be considered as 'secondary' barriers, that may arise as outcomes of addressing barriers in either of the first two categories, creating new barriers through the opposition of 'losers' from the overall RE increase – addressing these barriers can be seen as 'managing the transition'.

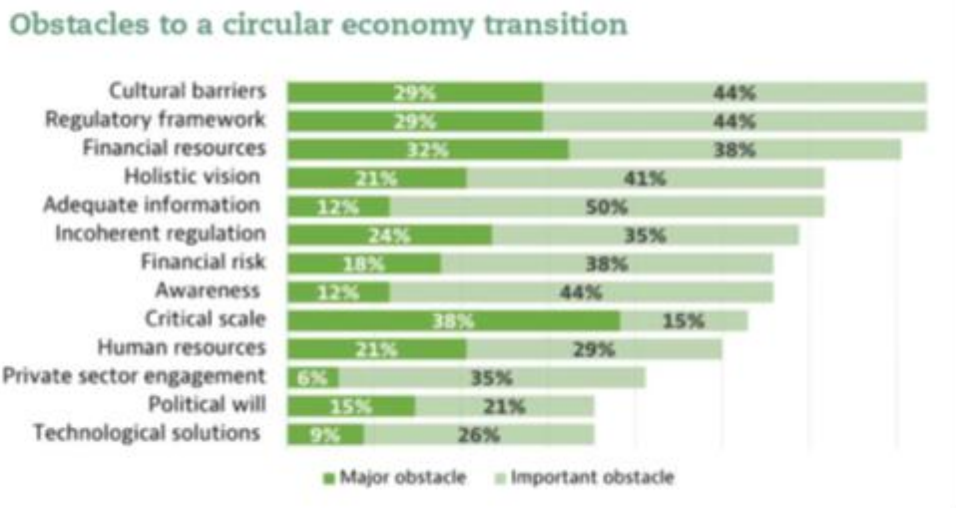
Table 6.3. Barriers to resource efficiency / circular economy

Barriers that inhibit otherwise financially positive resource efficiency actions	
Barrier	Notes / examples
Lack of information, or imperfect information	Consumers with incomplete information on efficiency of e.g. energy-consuming appliances, are impeded from making what would be a rational economic, as well as resource-efficient, choice
High upfront costs and financial risk	Some resource-efficient investments might be financially positive in the long run, but are not made because the upfront costs cannot be met, or the rate of return is not high enough
Habits, lack of pre-existing relationships	Some resource efficiency gains can be achieved by maximising synergies and coordinating materials and supply chains between multiple actors – but pre-existing habits and lack of relationships can inhibit identification of such opportunities
Barriers because of which resource efficiency actions would not be to the private financial benefit of the actors concerned	
Barrier	Notes / examples
Split incentives	In such cases, the actor who is in the position of being able to make a resource-efficient decision or investment, would not personally stand to benefit financially, even though others would. Examples include landlords not having the incentive to provide energy-efficient properties, in cases where tenants pay the energy bills; or manufacturers not having the incentive to design products amenable to recycling or remanufacturing, because they are not exposed to the costs of waste disposal
Incomplete pricing of externalities	Even if resource-efficient behaviour may be to the larger benefit of society and the environment, by reducing pollution and resource depletion, if such negative impacts do not have a financial price, then resource-efficient behaviour may not be in the financial interest of a private actor. If the cost of labour is high relative to the cost of materials, this can also mean that resource-efficient choices are not financially efficient to individual actors
Risk perception associated with long-term investments	Investments in new and innovative resource- efficient processes and technologies may not make sense in the short term, assuming that the status quo of current economic structures remains in place; however such investments would be rewarded under a future, fundamentally restructured system. Such investments would then require for their justification some level of faith in the forthcoming evolution of such a broader system, and would be inhibited by the risk perception of such wider changes not coming about.
Secondary barriers: 'managing the transition'	
Barrier	Notes / examples
The potential for 'losers' as a result of the CE	Even though CE may deliver economic benefits through savings of material costs, benefits may not be evenly spread. Sectors, regions or countries dependent on extractive industries would stand to lose, as would actors who would be required to make efficiency investments from which they are spared in the status quo, due to split incentives. Such 'losers' may therefore resist the transition, creating a secondary barrier which will also need to be negotiated.
The 'rebound effect'	If CE measures result in cost savings, it is possible that the extra money could be spent by actors on other resource- or energy-intensive products that would negate the original material or energy efficiency savings.

Source: Source: author's own, summarising Hughes and Ekins (2018)

OECD (2019) surveyed 34 cities and regions, and uncovered a list of perceived 'obstacles to a circular economy transition' (Figure 6.3), which identifies themes comparable with many of those identified by the other studies presented here. Cultural barriers, regulation and financial challenges are widely cited as obstacles. Information, awareness and engagement also rank highly, as do political will and having a holistic vision.

Figure 6.3. Obstacles to a circular economic transition – survey data from 34 cities and regions



Source: OECD (2019)

Conclusion

Barriers and drivers to the CE have been considered by a number of authors, and categorised in different, though complementary ways.

For any given actor or organisation, barriers and drivers can be internal – relating to internal processes and decisions; or external – relating to external conditions over which they have less direct control. For example, internal conditions could include, for a company, decisions about business models, priorities or operational culture, and for an individual, financial priorities or choices about resorting to or breaking out of habitual behaviour. External conditions for any actor or organisation would include policies or pricing incentives set by governments, or the demands, practices or activities of other actors, such as customers or organisations in the supply chain. However, as every internal decision is made within an external context, there are clear links between these two domains.

Accordingly, some categorisations of barriers and drivers focus less on the internal-external divide, and take a more thematic approach to understanding barriers and drivers. Though there are differences between the various categorisations presented in this section, the following broad types of barrier-driver categories tend to recur: economic, institutional, technological, organisational, knowledge and skills, habits and culture.

Economic barriers and drivers are often significant. CE measures can sometimes result in direct cost savings for the actors implementing them, in which case the economics are providing a driver. However, this is by no means always the case. Sometimes CE measures are simply not cost-effective due to the relative costs of materials and labour, or due to unpriced externalities; in other cases they are impeded by split incentives, or by high upfront investment costs and insufficiently high rates of return on investment. In such cases the economics provide a barrier.

Non-economic factors may also be significant both as drivers and barriers. **Institutional** conditions such as material management regulations could either enable or inhibit recycling or remanufacturing.

Technological and infrastructure factors can enable or limit the options available to companies or individuals who might wish to participate in the CE.

Knowledge and organisational practices have significant impacts on the ability of organisations and individuals to undertake CE measures, and the existence of pre-existing relationships with other actors, for example to facilitate industrial symbiotic relationships, can be significant drivers, with the absence of such relationships correspondingly having the potential to create barriers.

Habits and culture are also significant shapers of the behaviours of both organisations and individuals. In companies, commitment and leadership in developing a CE-conducive culture is crucial, and for individuals a value-based commitment to CE principles may be important to taking steps which might at first seem less convenient than the habits established within a 'throw-away' culture.

All of the categorisations summarised in this chapter provide useful ways of examining the various kinds of barriers and drivers. However, an important overall message is not to view the various barriers and drivers in isolation from each other, but in terms of what Kemp et al (2014: 52) have called a 'web of constraints' and correspondingly a 'web of drivers'. Important synergies reach across the various barrier / driver categories, across the internal / external distinction, and between the firm-level, individual-level and government perspective. For example, economic incentives are made more effective by the availability of appropriate alternative technologies; technological innovation can be stimulated by clear regulation and consistent long-term policy. An apparently internal decision such as the rate of return on investment needed to justify a CE investment can be substantially influenced by external conditions which affect available interest rates and the cost of financing. Similarly, there are fluid synergies between individual, firm-level and government perspectives, as attitudes of individuals add up to demonstrate to companies that there is demand for CE products, and government signals affect their confidence in the long-term existence of markets for them. Individuals' own capacities and willingness to act is also affected by their perceptions of the availability of genuine CE-conducive choices, and their belief in the good faith of commercial and government actors in supporting and backing up their decisions.

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7. Policies for a circular economy (Paul Drummond, Lorenzo Lotti)

Public policy interventions may be defined and classified in a variety of ways, depending on the purpose and interest of the classifier. One approach is to group interventions by their *modus operandi*, particularly using three broad categories well-established in the environmental policy literature – regulatory (i.e. setting requirements or prohibitions), 'market-based' (i.e. altering economic incentives), and 'information' (i.e. providing actors in the economy or society with information with which to make informed choices). These categories match and seek to address classic market failures, and are an important, but insufficient, set of tools to stimulate radical innovation and transformation, instruments for which are included in the EMF 'toolkit' discussed next). Another approach is to categorise by the sector, or the stage of the value chain (or circularity strategy), which the intervention seeks to address (or encourage), as illustrated by Figure 2.1. However, such an approach can be cumbersome, with many interventions having an impact across different sectors or elements of the value chain.

In 2015, the EMF published *Delivering the Circular Economy: A Toolkit for Policymakers*, aimed at supporting 'policymakers who have decided to transition to a circular economy in designing a strategy to accelerate this process' (EMF, 2015: 39). Although designed primarily for national policy makers, the authors stress that this toolkit is applicable to policymakers at all levels, from municipal to supranational. The Toolkit includes six categories of policy intervention, adapted into five for the purposes of this section, as presented in Table 7.1, below. This categorisation reflects the three categories that seek to address classic market failures, but supplements these with categories of intervention that seek to further stimulate and support innovation, and bring them to market. This section will provide a brief overview of the main policies within these categories that have been used to encourage a circular economy, and evidence of their impact from the literature.

Table 7.1. Five categories of policy intervention

Policy Intervention Category	Examples
Regulatory Frameworks	Strategies and targets for resource efficiency/productivity; product regulations (e.g. material requirements, product warranties); waste regulation (e.g. landfill bans, recycling requirements, Extended Producer Responsibility)
Fiscal Frameworks	Material use taxes, waste or landfill taxes and charges, subsidies or tax reduction for resource-efficient or circular products or activities
Education, Information & Awareness	Communication and information campaigns, requirements or resources targeted at businesses or the public
Public Procurement & Infrastructure	Inclusion of resource efficiency elements in public procurement criteria, investment in enabling infrastructure.
Innovation Support Schemes & Collaboration Platforms	RD&D programmes, public-private partnerships, financial, technical and training support to business, voluntary business collaboration platforms

Source: Adapted from: EMF, 2015: 47

Setting overarching strategies for transitioning towards resource efficiency and circularity, and associated targets (from the general, such as resource productivity, to the more specific, such as municipal waste recycling targets), helps guide the direction and ambition of policy and other action, at all levels of governance. Key strategies and associated targets as developed and applied by China and the EU are discussed in sections 9 and 10, respectively. However, effective policy instruments must be introduced to achieve them.

The use of regulatory instruments has been central to resource efficiency and circular economy policy making to date, particularly with regard to waste disposal and pollution. Over recent decades, many countries and jurisdictions around the world have instituted bans on disposing different types of waste streams into landfill, requiring instead alternative disposal, treatment or material re-use. The EU is a key example, in which landfill diversion and recycling targets (described further in section 10) led 19 member states to institute landfill bans for certain (non-hazardous)[7] waste streams by 2017 (CEWEP, 2017), usually in combination with landfill taxes for other waste streams. In combination, these instruments have driven a reduction of municipal waste to landfill from 55% in 2000 to 23% in the EU28 in 2017 (Eurostat, 2019). However, the destination for the diverted waste has depended on the wider policy landscape, with incineration a popular option in many countries (supported by the possibility of subsidies for the biodegradable fraction, considered a renewable resource that may contribute to EU renewables targets, when combined with energy recovery) (Domenech & Bahn-Walkowiak, 2019; EEA, 2009). There is also little evidence to suggest such interventions reduce the generation of waste in the first place (EEA, 2009).

Largely in order to increase recycling rates, the concept of ‘Extended Producer Responsibility’ (EPR), which emerged in the early 1990s and is defined as an approach in which ‘a producer’s [financial or physical] responsibility for a product is extended to the post-consumer stage of a product’s life cycle’ (OECD, 2001: 9), has been applied in most OECD countries, and many emerging economies, largely for electric and electronic equipment (particularly small consumer electronics and batteries), packaging, vehicles and tyres. Product ‘take-back’ requirements, according to which the producer or retailer must collect the product at the post-consumer stage, account for over three quarters of EPR regulations in the OECD (with advanced disposal (or recycling) fees and deposit-refund systems, discussed below, accounting for the majority of the remainder). The evidence suggests that EPR schemes have generally contributed to a reduction in landfilling and an increase in rates of material recycling (to varying degrees), and whilst they have contributing to improving the eco-design of products in some countries, they rarely serve as the principal driver (OECD, 2014; 2016a; 2016b). The OECD’s *Extended Producer Responsibility: Updated Guidance for Efficient Waste Management* presents various proposals for increasing the incentive for eco-design through EPR schemes, including ensuring fees appropriately cover the full cost of end-of-life management of the product, the use of modulated fees linked to specific design features, such as the presence or absence of standardised components (instead of a fixed unit or weight-based fee commonly used), reduced use of exemptions, and greater international harmonisation of EPR schemes (OECD, 2016b).

There are relatively few instances of regulatory requirements on the eco-design of products that seek to promote material efficiency or circularity. Instead, eco-design requirements tend to focus on the energy efficiency or pollution generated by the 'in-use' phase of a product, such as the requirements under the EU's Ecodesign Directive and Japan's Top Runner Programme, and CO_2 and local air pollutant emission regulations for new vehicles in place in many OECD and other countries. Although these instruments have had varying success in achieving their stated objectives (Inoue & Matsumoto, 2019; Mikler, 2005), their effect on material efficiency, even where 'lightweighting', for example, may contribute to reducing energy consumption or pollution (e.g. vehicles), has been low, often due to the design of such instruments reducing this incentive (e.g. in the EU, CO_2 limits are based on the average vehicle weight of a manufacturer's fleet, with increasing weight allowing increased CO_2 limits) (Hooftman et al., 2018). However, 'right to repair' requirements, which afford consumers (or professional repairers) the right to access spare components and the ability to repair faulty goods (largely vehicles and electronic goods) and thus increase their lifespan, is of increasing interest in the United States and EU, in particular. In October 2019, the European Commission adopted, under the Ecodesign Directive, rules that from 2021 require manufacturers of refrigerating appliances and household washing machines, driers and dishwashers, to *inter alia*, provide a 7-10 year minimum availability of spare parts after purchase, allow replacement of these parts with commonly used tools by professional repairers, and ensure the availability of relevant information to such professionals (European Commission, 2019).

A range of countries and jurisdictions have employed outright bans on the manufacture, sale or use of certain products or materials, particularly single-use plastic bags (and more recently, microbeads), in order to decrease material use and prevent (particularly marine) pollution. The specific design and scope of these bans is highly varied, as is the available evidence on their effectiveness, with bans on plastic bags having a negligible effect in Bangladesh (due to a lack of appropriate enforcement), to delivering (in combination with a levy on paper bags) a nearly 90% reduction in the use of all types of single-use bags in Santa Barbara, California (Nielsen et al., 2019).

Instruments to alter the fiscal framework concerning the lifecycle of materials in the economy are also widely used, again with a substantial focus on waste disposal and pollution. Landfill taxes to incentivise the diversion of waste streams have become widespread across the EU and other OECD countries in recent years (OECD, 2016a), often in combination with landfill bans, with the effectiveness of these instruments discussed above. Incineration taxes, introduced to instead encourage the recycling of waste material, are also being increasingly applied (although to a far lesser extent than landfill taxes) (OECD, 2016a). However, they are usually at lower effective rates than landfill taxes in the same countries, and thus have had relatively little impact on encouraging material reuse or recycling (Xevgenos et al., 2015).

There is substantial literature debating the theoretical merits of both advanced disposal (or recycling) fees (ADF or ARF), in which fees are levied on products at the point of purchase, based on estimated costs of collection for disposal or recycling. Such instruments have been applied in various OECD countries and jurisdictions, largely on electrical and electronic products, but there is little empirical evidence of their effectiveness in encouraging recycling or effective eco-design. Deposit-refund systems, in which a deposit is made at the point of sale of a product and refunded upon its return, are generally concentrated in the used beverage container and lead-acid battery markets (Kaffine & O'Reilly, 2015). The evidence suggests that such instruments lead to high return rates and a reduction in littering, but often come with substantial handling and administration costs (Linderhof et al., 2019), and again, little empirical evidence exists on other value chain implications of such systems, such as improving the design of the original products. Taxes on the extraction or use of virgin materials (excluding energy products), regardless of motivation, are relatively scarce. Where they have been introduced, such as on aggregates in Sweden, Denmark and the UK, they have had limited effect on encouraging more efficient resource use and recycling of secondary materials due to low tax rates, relative price inelasticity, and sectoral exemptions (Söderholm, 2011).

Between 1970 and 2012, 544 environmental labelling and information schemes (ELIS) were introduced across 197 countries, with rapid growth experienced since the late 1990s, with around 40% related to natural resources and waste. The vast majority of these of these are voluntary schemes, operated by private or non-governmental organisations at national levels, and generally concern the processes and methods of production (Gruére, 2013). However, the existence of overlapping schemes, many with opaque methodologies, often produces confusion among consumers, leading to concerns of false claims and 'greenwashing', and ultimately brings into question the effectiveness of such instruments introduced thus far (Prag et al., 2016). Governments have attempted to tackle these issues through a variety of means, including the use of regulation and enforcement action against misleading or false claims (with associated prosecutions increasing in OECD countries overtime, although it is not clear if this is due to improved regulation and enforcement, or an increase in the number of false claims), and the use of approved labels (either mandatory or voluntary), either directly or through adoption of the criteria that underpin them, in public procurement criteria (Klintman, 2016).

Public procurement accounts for around 12% of GDP, and one third of public expenditures, in OECD countries. In 2016, 84% of OECD countries had green public procurement (GPP) policies at central government level, however few include resource efficiency considerations (OECD, 2016a). GPP is widely recommended as an effective policy for providing a market for products and services with high environmental performance, however the evidence for such schemes achieving their objectives, both in terms of direct environmental benefits and stimulating innovation, remains limited (albeit largely positive) (Cheng et al., 2018).

Governments around the world, from city to supranational, have provided various degrees and forms of public support for research, development and demonstration (RD&D) of new technologies, practices and business models for a circular economy, and encouraged their diffusion through financial, technical and training support (Prendeveille et al., 2018). However, tracking such activities to outcomes, and drawing clear, generalisable conclusions, is a highly difficult task, with many such activities – such as the actual level of public support for resource efficiency innovation – often not measured (OECD, 2016a). A common approach to support such innovation, however, has focused on industrial symbiosis, particularly through the creation of eco-industrial parks (as discussed elsewhere). In 2016, 250 eco-industrial parks existed around the world, with two-thirds in non-OECD countries (particularly China). Of those for which data was available, 45% engaged in industrial symbiosis, whilst 51% engaged in other waste management measures, and 35% in other resource efficiency activities, often generating substantial savings and efficiencies (Kechichian & Jeong, 2016).

Governments and regulators are also currently reviewing their policies in the light of insights from behavioural economics, which may suggest changes in policy design. For instance, if consumers do not fully rationally react to price changes (and do not take into account the cost of such behaviour) because of inertia, status-quo bias, limited attention and inconsistent time discounting, then default options may be more effective in promoting pro-CE behaviour than price instruments. Another example relates to heuristics in decision-making: framing is relevant for the evaluation of tax policy (McCaffery & Baron 2006). According to "Tackling Environmental Problems with the Help of Behavioural Insights" (OECD, 2017), there are at least six main areas in which behavioural insights could be effectively adopted: to promote energy efficiency and investments in energy saving tools and products (cars included); to reduce waste production; to promote environmental compliance; to incentivize sustainable food consumption; and to enhance the conservation of water (OECD, 2017).

Altruism and social pressure could also result in greater and earlier adoption of pro-CE behaviours, driven by households which have a stronger concern for future generations or the environment, or firms which engage in more sustainable behaviours, either unilaterally or because of social pressure. With respect to businesses, Gunningham (2004) focuses on corporations' 'social licence to operate', whereby their activities are influenced by societal expectations whether or not these are included in policies or laws, leading them to go beyond strict compliance.

A tool which is often used in parallel with standard policies is ‘nudges’, defined by Thaler & Sustein (2009: 6) as “any aspect of the choice architecture that alters people's behaviour in a predictable way without forbidding any options or significantly changing their economic incentives”.

Shogren & Taylor (2008) have described bounded rationality as an additional market failure that needs to be taken into account: according to this perspective, CE-related policies should then address two failures, the negative externality plus the behavioural one.

Building a circular economy is a complex, multifaceted challenge, needing to be addressed by appropriate policy mixes. There is no ‘one size fits all’ policy mix, however to be effective the underlying interventions must be coherent in their operation (within and between governance levels), consistent in their objectives, and credible enough to engender confidence among actors in the economy (Wilts & O’Brien, 2019). Learning and disseminating lessons from past experience, such as through the OECD’s *Policy Guidance on Resource Efficiency* (OECD, 2016a), is key. However, in the increasingly interconnected global economy, establishing circularity at the rate and to the degree required will involve substantial international co-operation in data and knowledge gathering and sharing, investment and policy co-ordination. Specifically, Geng et al. (2019) propose five priority actions to facilitate ‘globalising’ the circular economy: (1) establish a global database to capture links between resource uses; (2) establish a global platform to share knowledge about the circular economy; (3) establish international alliances to promote large-scale experimentation; (4) develop international standards for performance measurement, reporting and accounting for key products; and (5) develop approaches to enforcing regulations, settling disputes and implementing sanctions. They suggest that ultimately, these efforts should cohere to form an international agreement on sustainable resource management.

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8. Environmental, resource, economic and social implications of a circular economy (Paul Ekins)

Environmental and resource implications

In the OECD’s ‘baseline approach’ projection of resource use to 2060, total resource use is projected to grow from 79 gigatonnes (GT) in 2011, to 167 GT in 2060. As the OECD Secretary-General said in the Foreword to the report, such growth “coupled with the environmental consequences of extraction, processing and waste, is likely to increase the pressure on the resource bases of our economies and jeopardise future gains in well-being”. (OECD, 2019) Such concerns explain policy makers’ heightened interest in the increased resource efficiency promised by moving towards a circular economy.

It is intuitively plausible that increasing the length of time that materials stay in the economy will reduce the extraction of virgin materials below what they would otherwise have been. Where virgin material extraction is associated with environmental impacts, which is often the case, it is also plausible that this reduction in extraction will reduce environmental impacts.

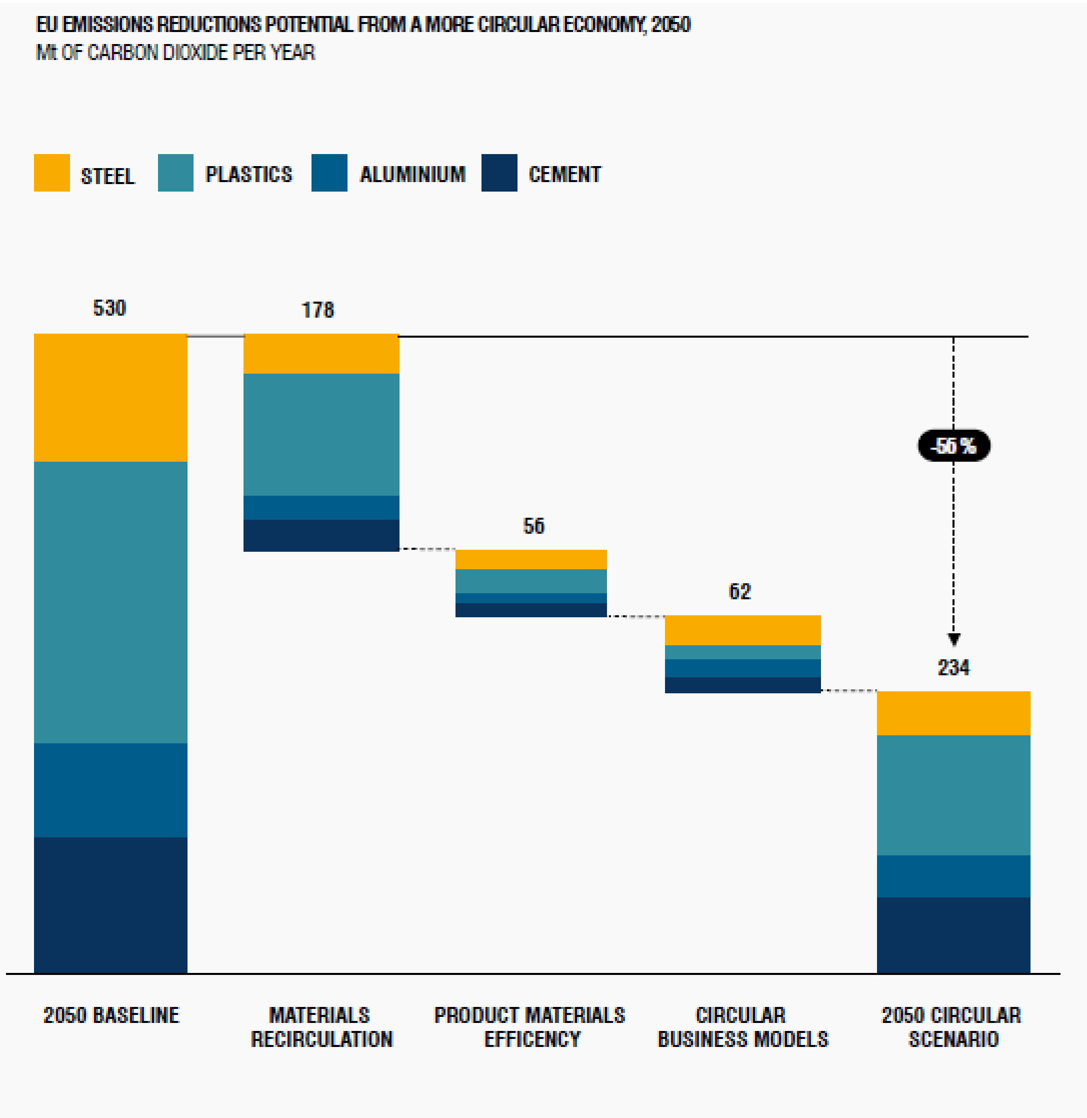
It is also plausible that reducing waste disposal to landfill through increased delivery of some subset of the 9Rs described in section 2 will reduce the environmental impacts of landfill, although this can also be achieved through better engineering of landfill sites. Whether increased recycling (to take just one of the 9Rs) produces net environmental benefits depends on the environmental impacts of the recycling process, as well as on the avoided disposal route, and this can only be determined, as stated earlier, through detailed life cycle analysis (LCA). LCA results are very dependent on their input assumptions so that it is often not easy to arrive at definitive conclusions about the best environmental option for particular material procedures (as an example of the complexities involved, see Aumonier and Collins 2005 for a comparison between disposable and re-usable (home or commercially laundered) baby diapers; the conclusions were “For the three nappy systems studied, there was no significant difference between any of the environmental impacts – that is, overall no system clearly had a better or worse environmental performance.” (Aumonier and Collins 2005: 7))

It is, however, well established that recycling iron and steel and aluminium leads to large energy savings compared with the primary production of those metals. For carbon emissions there is analysis that shows that moving to a circular economy could lead to substantial reductions: for example, 56% by 2050 in the European Union (EU) from the steel, plastics, aluminium and cement sectors (see Figure 8.1).

It should be noted that the emissions reductions in Figure 8.1 do not include those from increased energy efficiency of the energy system. ‘Materials recirculation’ essentially incorporates the 9Rs; product materials efficiency involves wasting less materials in production and reducing over-specification; and circular business models mainly involve making much more intensive use of buildings and vehicles, through sharing business models.

A similar level of emissions reduction emerged from the analysis of 'harder-to-abate' sectors by the Energy Transitions Commission (ETC) which found that demand management (broadly the materials recirculation, product materials efficiency and circular business models categories of the Material Economics study) and energy efficiency improvements could cut global carbon emissions from heavy industry (cement, steel, plastics) and heavy transport (heavy road transport, shipping, aviation) by 55% by 2050 (ETC 2018, Exhibit 11: 31). While the total emissions reduction from demand management are not reported separately, it is clear that it is substantially below that estimated from the Material Economics study.

Figure 8.1. Emissions reduction potential from a more circular economy from four sectors in the EU



Source: Material Economics 2018, Exhibit 1.5: 19

In one of the most ambitious modelling exercises of its kind to date, IRP 2019 compared a Towards Sustainability scenario with Historical Trends to 2060. The Towards Sustainability scenario sought to estimate the joint results of four suites of policy measures: resource efficiency policies, climate policies,

policies to protect landscapes and life on land, and policies for healthy diets and reduced food waste. The results of the modelling are shown in Table 8.1.

The IRP study did not estimate the broader environmental benefits from the resource use changes in the Towards Sustainability scenario compared to Historical Trends. However, there is no doubt that the 90% decrease in greenhouse gas emissions from 2015 levels would lead to substantial improvements in local air quality, given that so much air pollution results from fossil fuel combustion. Similarly, with agriculture the major global cause of biodiversity loss and water use, the reduction in agricultural and pasture land should reduce pressure on biodiversity, while the increase in forests should give opportunities for biodiversity increase. The impact on water resources cannot really be inferred from this analysis as it will depend far more on the extent and nature of any expansion of irrigation on remaining farmland. In respect of material extraction, doubtless the 47 billion tonne reduction in 2050 in Towards Sustainability compared to Historical Trends will significantly reduce the environmental impacts of the extractive industry, but material extraction on Towards Sustainability is still projected to be 51 billion tonnes higher than in 2015, so that reductions in the environmental impacts of mining remain imperative.

Table 8.1. Environmental and resource impacts from two scenarios

Impact	Historical trends	Towards sustainability
Material extraction	190 billion tonnes by 2060, more than double the 2015 level of 92 billion tonnes	143 billion tonnes, 25% lower than under Historical Trends
Greenhouse gas emissions	43% increase from 2015 to 70Gt CO_2e p.a. by 2060	90% decrease from 2015 to 4.8Gt CO_2e p.a. by 2060
Global pasture land	25% increase from 2015 by 2060	30% reduction compared to Historical Trends by 2060
Agricultural land	20% increase from 2015 by 2060	9% reduction compared to Historical Trends by 2060
Forests and other habitat	10% reduction in forests, and 20 % reduction in other habitat, from 2015 by 2060	11% increase in forests and other habitat from 2015 by 2060, with 13 million km^2 forest loss prevented and 4.5 million km^2 restored

Source: Author's compilation from IRP 2019, Section 4.5: 111-118

This section should end on a note of caution. None of these reductions in environmental impact from reduced resource use can be taken for granted, and all will have to be supported by policies that go beyond circularity if they are to be assured. This is most obviously true in the case of rebound effects. If moves to circularity through greater resource efficiency save large amounts of money, through lower production costs and cheaper products, as is widely estimated (see the next section), then these financial savings may be re-spent in more or less environmentally damaging ways, which will reduce to a greater or lesser extent the environmental benefits of circularity. No estimates of these effects have been found for rebound effects from material efficiency increases, but there is a large literature on rebound effects from increases in energy efficiency, which shows that these effects can be very substantial.

Economic and social implications

It is widely assumed that moves towards circularity will bring substantial economic benefits, in terms of cost savings to firms and consequent improvements to their competitiveness, stimulation of innovation and new industrial opportunities, and macro-economic benefits in terms of increased output and employment. Fairly typical language is the following: "The European Commission adopted an action plan in 2015 to help accelerate Europe's transition towards a circular economy, boost global competitiveness, promote sustainable economic growth and generate new jobs."[8]

There have been numerous quantitative estimates of the economic opportunities presented by increased resource efficiency. One of the earliest was by the McKinsey consultants Dobbs et al. (2011), who wrote that implementing all the resource efficiency technologies they considered would save private investors

US$2.9 trillion per year by 2030, with 70 percent offering a rate of return greater than 10 percent per year. Moreover the US$2.9 trillion from a private-investor perspective increases to US$3.7 trillion from a social perspective if financial subsidies to energy, agriculture and water, and energy taxes were removed and carbon was priced at US$30 per tonne (Dobbs et al. 2011: 10). The US$900 billion investment required to realise the savings “could potentially create 9 million to 25 million jobs. Over the longer term, this investment could result in reduced resource price volatility that would reduce uncertainty, encourage investment, and also potentially spur a new wave of long-term innovation” (Dobbs et al., 2011: 12). However, it should be noted that this is an estimate of gross jobs created that does not take account of likely job losses in resource-intensive sectors.

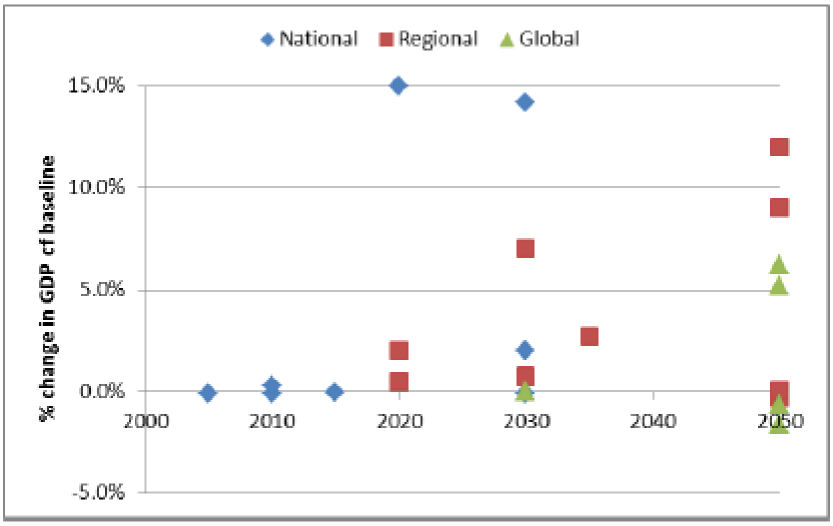
The Ellen MacArthur Foundation (EMF) has also estimated substantial benefits from moving towards circularity. Their ‘circular scenario’ “could reduce annual net European resource spend in 2030 as much as 32 percent, or €0.6 trillion versus today”, with a further €0.7 trillion generated by economic multiplier effects and another €0.5 trillion from reduced externalities (EMF 2015: 14) In the same vein, EMF (undated: 8) talks of a €320 billion ‘circular economy investment opportunity’ for Europe up to 2025. Clearly these resource cost savings, and the returns on the investment required to generate them, are very sensitive to assumptions about resource and material prices.

Economic modelling is required to estimate how these reduced resource costs are converted into GDP gains, and that done by EMF 2015 suggests “European GDP could increase as much as 11 percent by 2030 and 27 percent by 2050 in a circular scenario, compared with 4 percent and 15 percent in the current development scenario, driven by increased consumption due largely to correcting market and regulatory lock-ins that prevent many inherently profitable circular opportunities from materialising. Thus, in a circular scenario, GDP could grow with 7 percentage points more by 2030 than the current development path and could increase the difference to 12 percentage points by 2050.” (EMF 2015: 33). Most recently, modelling from UN Environment’s International Resource Panel finds that “implementing an integrated package of resource efficiency, sustainability, and climate policy actions results in net economic benefits globally from 2030 onwards, with global GDP 8 per cent above *Historical Trends* in 2060, as projected economic gains from resource efficiency outweigh[ing] the near-term economic costs of achieving ambitious reductions in net greenhouse gas emissions.” (IRP 2019:117)

The OECD (McCarthy et al., 2018) has assessed the extant modelling studies of the GDP impacts of moving towards a circular economy. Figure 8.2 shows the outcome of this assessment.

Figure 8.2. GDP results for model studies of moves towards a circular economy

Figure 5. Headline modelling results in the studies considered in this review: GDP with respect to baseline



Note: Geographic coverage – national, regional, global – refers to the area that results were reported for. Some models have global coverage but only report results for a particular region.

Source: McCarthy et al., 2019, Figure 5 : 40

Figure 8.2 shows that most of the models show a GDP change of less than 5%, but most of these are positive rather than negative. Seven of the results, however, shows GDP gains of 5% or more, and three have gains of more than 10%.

Elsewhere (Ekins and Hughes et al., 2017: 99-110) the assumptions that go into the models that produce these kinds of GDP results have been discussed. In addition to the nature and level of the estimated resource cost reductions, the results are dependent on the kind of economic model used (computable general equilibrium, macro-econometric, system dynamic), the treatment of investment (the extent of crowding out that is assumed), the level of unused resources (especially labour) in the economy, the skills required by more circular activities and their level of availability, and the nature of the policy used to achieve the increased resource efficiency (an environmental tax reform turns out to be particularly economically beneficial). In addition, a significant feature underlying positive GDP results is that policy making is assumed to be both consistent and efficient. The OECD's much longer discussion of these issues in McCarthy et al. (2018) goes into much more detail as to how the assumptions made about them affect the modelling outcomes.

Fewer of the models generate results for employment and these are not reviewed in McCarthy et al. (2018). Nor does there seem to be a comparable comparative study of employment results. Some of the most optimistic impacts of greater circularity on employment have been generated by the modelling of several European countries in Wijkman and Skånberg (undated, but probably 2016), who write: "unemployment rates — compared to today — could be cut by a third in Sweden and the Netherlands, and possibly more, maybe even cutting unemployment in half — provided that some of the likely trade surplus gains would be used for investments domestically. In Spain the unemployment rate is likely to be reduced from the current over 20% to somewhere close to 15%, in Finland unemployment would be cut by a third, and in France by almost a third, provided that some of the likely trade surplus gains would be used for investments domestically" (Wijkman and Skånberg, undated: 39).

More moderately, the European Commission study of the impact of circular economy policies on the labour market in Europe (Cambridge Econometrics et al., 2018) found that such policies could increase employment by around 0.3% (650,00-700,00 jobs) by 2030 (compared to a 0.5% increase in GDP by the same date). Sectoral outcomes differ: for example, employment increases in the sewerage and waste and repair and maintenance of machinery sectors, but reduces in the construction and electronic equipment sectors. One of the most interesting aspects of this study is its analysis of the skills requirements underlying this employment shift, an aspect that is often not considered in studies of this kind.

Despite the fact that some of the definitions of the circular economy emphasise the social dimension, and in particular social equity, no literature has been found that seeks to explore this dimension apart from the impacts of circularity on employment. Nor are the policies that might lead to more, as opposed to less, equitable circularity anywhere discussed. This is therefore a major gap in the literature if it is indeed considered that the social dimension of circularity is of importance.

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PART III: THE CIRCULAR ECONOMY IN SPECIFIC PLACES

OECD (2019) has noted that a number of countries (China, European Union, Finland, France, Netherlands, Scotland) have introduced ‘circular economy roadmaps’, and some other countries have introduced strategies with similar intent but with another name (e.g. Japan and the United States). The next two sections describe two of the most important such efforts, in China and the European Union.

9. The circular economy in China (Raimund Bleischwitz)

China is widely seen as a leader in the circular economy. This section will identify the major themes in the Chinese CE literature with a focus on cities and regions and their differences from CE emphases in other regions and countries.

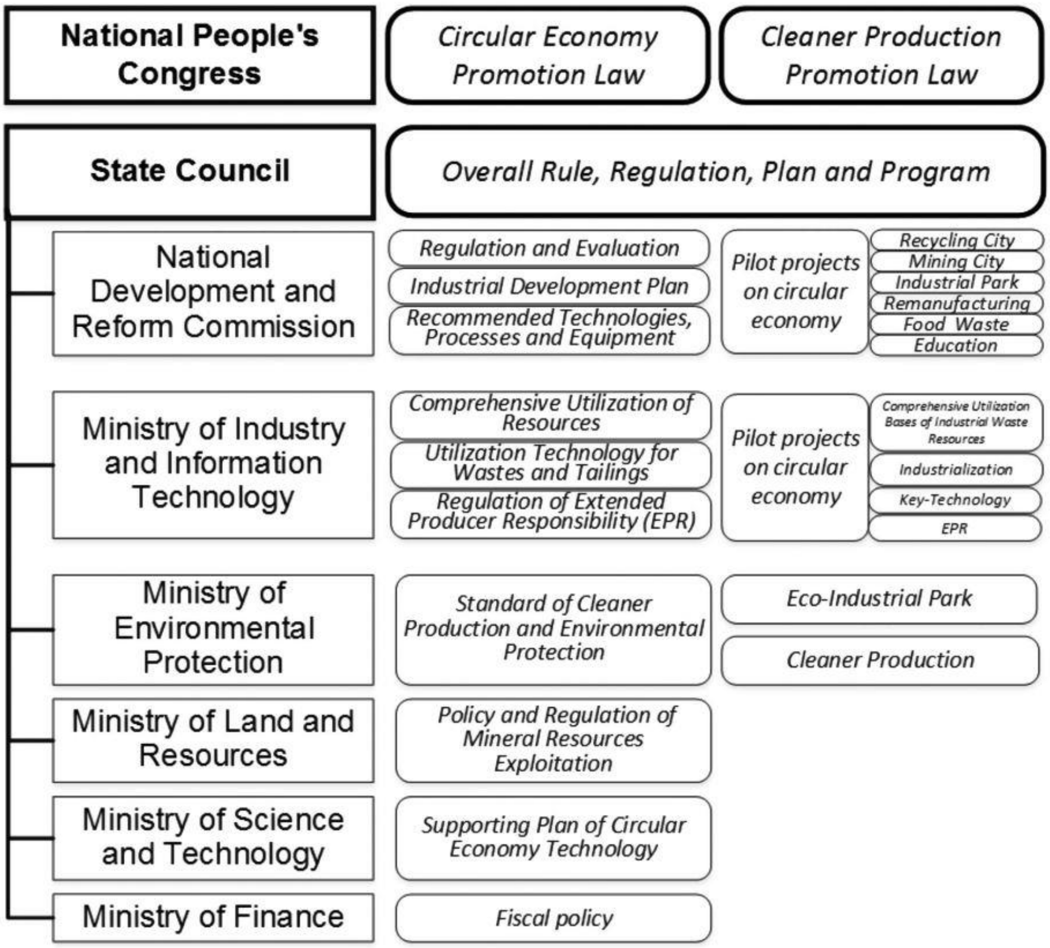
The circular economy concept started to emerge in China in the 1990s with its origins in cleaner production, industrial ecology, and ecological modernization thinking. Inspired by Europe and Japan, the central government moved forward and formally accepted the concept of a CE as a new development strategy in 2002. China’s main national-level framework for pursuing the CE is the ‘Circular Economy Promotion Law’, which came into force in 2009. Various action plans provide further details for specific sectors and clarity on the implementation. The 2017 ‘Circular Development Leading Action Plan’ builds on this foundation by taking steps towards addressing environmental and societal externalities. The Action Plan also stresses opportunities in new digital solutions, the potential to integrate circular economy principles at the design stage of products, and to develop new circular economy business models (EMF 2018: 20).

China considers the circular economy key for its wider ambitions to achieve an ‘ecological civilisation’ and puts emphasis on “the realisation of a closed loop of materials flow in the whole economic system” (Geng and Doberstein 2008: 232; Zhu et al. 2018: 111), much in line with the early thinkers analysed in section 1 of this paper. Compared with the EU and OECD member states, however, China is an emerging economy and faces severe challenges of pollution as a consequence of its fast development pathway since the early nineties under its leaders Deng Xiaoping, Jiang Zemin, Hu Jintao, and Xi Jinping. This explains why, in comparison, the Chinese CE agenda covers (a) a range of broad environmental indicators (e.g. including pollution and water) and (b) addresses key issues of growth and development.

In line with its planning-oriented policy system, China places great attention to scale, through a multilevel system of governance at three levels: the micro, where it was largely equated to cleaner production in the firm, the meso, where it was identified with the many ‘Eco-Industrial Parks’ that were springing up round the country, and the ‘macro’, which involved region-wide circular economy thinking and planning at the level of provinces and the country as a whole.

China’s CE policy is place-oriented. It includes an explicit concern for the integration of CE principles into land-use planning (see, e.g., Articles 29 and 37 of the CE Promotion Law). One reason for this is China’s ongoing rural-urban transition: The growth of new urban and industrial areas has created challenges for land-use planners. The focus of CE policy on environmentally sensitive spatial integration of residential, agricultural, and industrial activities reflects those concerns. This is very different from the situation in Europe and elsewhere, where urban development is not occurring on the same scale.

Figure 9.1. The operational framework of a CE in China



Source: Zhu et al. 2018 : 114

A distinctive feature of China's CE policies can be characterized as 'experimentation under hierarchy'. It involves the designation and funding of specific provinces, cities, or zones (such as industrial parks) as CE pilots or demonstrations (Geng et al. 2012; Huang et al. 2019; Mathews and Tan 2016). This approach spans geographical scales: from cities to individual enterprises that all can qualify as 'CE demonstrators'. It is a key to Chinese efforts to upscale a CE: municipal or industrial park authorities (or managers, in the case of enterprises) can apply to the National Development and Reform Commission (NDRC) and others for a designation and are then assessed against key performance targets. Designated entities receive substantial funding from the NDRC and other sources and seeking such designations can be an important part of local economic strategy.

Designation of regional pilot zones is a frequently used governance tool in China (Zhao et al. 2016) used by both central and provincial governments. It leads to an array of special zones (low carbon, eco-industrial, circular economy, etc.), with areas often receiving multiple designations. Most of these zones are substantially larger than any case in the Western world. The Suzhou New District (SND), for instance, hosted in 2014 more than 16,000 enterprises and almost 4,000 manufacturing firms, many in IT, electronics, biotech and medical-device manufacturing. Lessons from designated experimental zones are then used as a basis for informing future policy making; policy documents refer to lessons learnt from numerous CE pilots.

Implementation gaps exist due to economic imperatives at the provincial level, bonus systems for policy makers if they meet their respective planning goals, a tax system favouring growth and budget issues over environmental concerns, and prevalence of environmentally-intensive 'zombie industries' that are kept alive due to social concerns.

Discussions are under way how the central government can designate zones and the associated funds in a way that enables barriers to be overcome and would provide stronger incentives to meet CE goals. Such analysis is strengthened by the fact that industrial parks in general account for a large share of Chinese manufacturing output (around 50% according to Mathews and Tan 2016), and upscaling experiments piloted in designated parks could provide a mechanism for wider application. China's Circular Economy Promotion Law requires the establishment of target responsibility systems in support of the CE, and notes that progress against indicators should be used in the performance evaluations of senior officials.

Ongoing research addresses both cities and industrial parks and seeks to establish evidence how designated regions show improvements against relevant performance indicators, what gaps remain, and what lessons can be learned. Huang et al. (2019) provide an analysis of the new national demonstration EIP standard (HJ/T274-2015), which is said to be more consistent and more comprehensive, strengthening industrial symbiosis, and offering some adaptive flexibility.

In a recent report from the Ellen MacArthur Foundation (EMF 2018), cities in China are praised for holding the most promise to realise future circular economy potential. China's cities are said to host a broad range of talents, customers, technology-savvy markets, and high concentrations of material flows, which, in combination, make them potential incubators of innovative circular solutions at scale. The sharing economy in particular has enjoyed great momentum in recent years and is predicted to account for over 10% of GDP by 2020. This momentum has been largely enabled by China's recent digitalisation boom, which has made it the world's largest e-commerce market, accounting for more than 40% of global e-commerce transactions, and home to mobile payment transactions with a value 11 times those in the United States. Potentially, this would allow large-scale experiments and upscaling of a CE in areas such as e-mobility and car sharing, infrastructure development and housing, food and nutrition, textiles and fashion. These circular economy opportunities for China's cities have the potential to yield savings of CNY 32 trillion (USD 5.1 trillion) in 2030 and CNY 70 trillion (USD 11.2 trillion) in 2040, compared with the current development path. To put this into perspective, these cost savings amount to around 14% and 16% of China's projected GDP in 2030 and 2040 respectively. These savings are expressed as a reduction in the total cost of access (TCA), a concept closely aligned with the total cost of ownership but applied to cases where the user does not necessarily own the relevant goods or assets.

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10. The Circular Economy Package of the European Union (Paul Drummond)

The concept of the circular economy gained prominence only recently among European policy makers, in large part following concern over high commodity prices (McDowall et al., 2017). In response, in 2011 the European Commission launched its 'Flagship initiative on resource efficiency', operationalised through its 'Roadmap to a Resource Efficient Europe' published later the same year. In July 2014, the Commission adopted the communication 'Towards a circular economy: a zero waste programme for Europe', which alongside a review of targets in six waste management directives, formed the EU's first 'Circular Economy Package' (CEP). The key objectives of the CEP were to boost recycling and prevent the loss of valuable materials, create jobs and economic growth, demonstrate how new business models, eco-design and industrial symbiosis can contribute to the transition to 'zero waste', and to reduce GHG emissions and other environmental impacts. It also proposed setting a (non-binding) headline target to increase material productivity by 30% between 2014 and 2030 (measured as GDP per unit of raw material consumption), along with introducing and tightening existing waste-related targets (Domenech & Bahn-Walkowiak, 2019).

However, in December 2014 the Commission withdrew the CEP stating that it would instead present a new, more ambitious package by the end of 2015, and one which would cover the full economic cycle, rather than focusing on waste reduction. Consequently, in December 2015 the Commission adopted the revised CEP, entitled 'Closing the Loop – An EU action plan for the circular economy', with the overall objectives of contributing 'to the EU's efforts to develop a sustainable, low carbon, resource efficient and competitive economy' (European Commission, 2015: 2) to be delivered by 54 'actions' to be carried out by 2020. This section will describe the main elements of the revised CEP using the policy intervention classification presented in section 7, and discuss progress with their implementation and their effectiveness in achieving their objectives.

The main regulatory requirements resulting from the CEP are binding targets on landfilling and recycling, introduced via the introduction and revision of various directives, which entered into force in July 2018. The targets include common requirements for 65% of municipal waste to be recycled by 2035, and 70% of packaging waste by 2030 (with sub-targets for specific packaging materials, from 30% for wood to 85% for paper and cardboard), with intermediate targets for both, and a maximum of 10% of municipal waste to be sent to landfill by 2035 (with waste suitable for recycling or other recovery prohibited from landfill by 2030) (European Commission, 2019a). As with pre-existing waste-related targets, member states are largely free to select the specific policy instruments and mixes appropriate to achieve these targets. However, they must adhere to a range of other new requirements, including the obligation to establish separate collection for paper, metal, plastic and glass waste, and the establishment of EPR schemes for all packaging by the end of 2024 (with new minimum operating requirements). Although a key element of the original CEP, the proposal for an EU-wide resource productivity target was excluded from the revised Package (however, a number of member states have set unilateral targets) (Domenech & Bahn-Walkowiak, 2019).

In 2017, 30% of total municipal waste in the EU28 was recycled. This is a substantial increase from 11% in 1995 (Eurostat, 2019a), but is a long way below the 2020 target of 50% set by the 2008 Waste Framework Directive, with 14 member states at risk of non-compliance (European Commission, 2018). 67% of all packaging waste was recycled in 2017 (varying from 40% in Malta to 82% in Belgium), with most member states meeting the target of 55% to be achieved by 2008-2015, and 17 already achieving the new 2025 target of 65% (and 6 even achieving the 2030 target) (Eurostat, 2019c). Around 23% of municipal waste in the EU27 was sent to landfill in 2017– nearly half the value experienced ten years prior (but with substantial variation between member states, ranging from less than 1% in the top five, and above 70% in the lowest five) (Eurostat, 2019a). As such, although broad trends are promising, meeting the targets set in 2018 – particularly for total recycling and landfilling - will require substantial further policy effort in many member states.

The CEP also aimed to increase emphasis on circular economy aspects in requirements set under the Ecodesign Directive, including standards on material efficiency (European Commission, 2015). Various ecodesign regulations adopted in October 2019, including for washing machines, dishwashers and refrigerators, include circular economy-related requirements, and, following a request by the Commission, standards on material efficiency aspects, including durability, repairability (discussed in Chapter 7) and recyclability, informed by the three European Standards Organisations[9]. Other EU-wide regulatory ambitions proposed by the CEP, including minimum requirements for water reuse in agricultural irrigation and standards for secondary raw materials and material-efficient recycling for electronic waste and related products, are at various stages of development (European Commission, 2019b).

Setting the appropriate fiscal framework through the use of economic instruments is promoted as a core objective to encourage the development of resource efficiency and circularity in the EU. However, as Article 192 of the Lisbon Treaty requires environmental measures 'primarily of a fiscal nature' instituted at the EU level to be enacted by unanimous vote in the European Council[10], such instruments are left largely to competence of member states (an exception is the Energy Tax Directive, which seeks to set minimum tax rates for energy products across the EU to reduce competitive distortions; however its influence is limited, as minimum rates are low, and a range of derogations and exemptions were and are available) (Domenech & Bahn-Walkowiak, 2019).

Environmental taxes, a cornerstone instrument in efforts to set the appropriate fiscal framework through pricing the externalities associated with resource extraction and use, accounted for just 6.1% of total revenues from taxes and social contributions in the EU28 in 2017 (ranging from 4.4% in Luxembourg, to 10.2% in both Greece and Slovenia). The vast majority (77%) of these revenues were raised through taxes on energy products, with taxes on resource extraction and pollution (excluding GHG emissions, but including waste management levies) together accounting for just 1% of total environmental tax revenue (Eurostat, 2019b). The generally weak environmental fiscal position in the EU is further illustrated by the presence of environmentally harmful subsidies (EHS), with debate most often focused on fossil fuel subsidies in the context of the need for climate change mitigation. In the EU, such subsidies were estimated to be worth €55 billion in 2016 (European Commission, 2019c).

Although not directly tackled as part of the CEP, both these elements are addressed in the 2011 Roadmap, which proposes that member states should 'shift taxation away from labour to environmental impacts', with 'a major shift' achieved by 2020, and 'prepare plans and timetables to phase out EHS', with a phase out achieved by 2020 (European Commission, 2011: 11). The values presented above remain similar to those present when the Roadmap was published, so that these aspirations have not come close to being achieved.

Education, information and awareness interventions proposed by the CEP may be grouped into three broad categories. The first category are those that seek to improve the collection and availability of data, including the further development of the EU Raw Materials Information System (RMIS), the development of a common methodology and indicators to measure food waste, and the development of a monitoring framework for the circular economy. Progress has been made on all these fronts. The RMIS was launched in November 2017, and presents data and other information across 12 thematic blocks (drawn in part from the Raw Materials Scoreboard, launched in 2016 and published every two years) covering, *inter alia*, critical raw materials, secondary raw materials, and environmental and social sustainability. A common methodology to measure food waste was adopted by the Commission in May 2019, whilst the overarching circular economy monitoring framework, composed of a set of 15 indicators across the value chain and associated aspects (e.g. competitiveness, employment), was first published in January 2018 (European Commission, 2019b), as discussed in section 4.

The second category of interventions are those that seek to promote best practice amongst businesses (particularly in waste management). This includes the inclusion of circular economy aspects into Best Available Technique Reference (BREF) documents, published as part of the Industrial Emissions Directive (achieved for five industrial sectors), the issuing of best practice guidance for mining waste management (published in January 2019), the promotion of industry-led certification for waste and recyclate treatment facilities (expected by the end of 2020), and the identification and dissemination of good practices in waste collection systems (to be adopted by the end of 2019) (*ibid*).

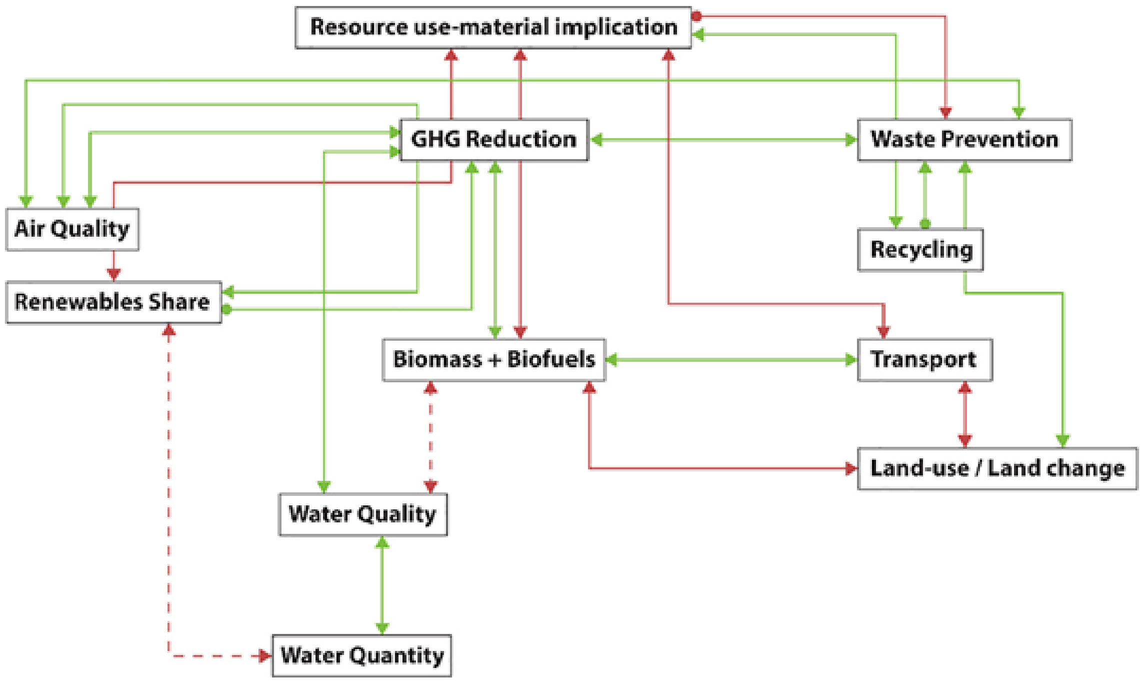
The third category are those that seek to provide information to the consumer. This includes presentation of circular economy-related information on product energy labelling (information on availability of spare parts, ease of repair, and facilitating end-of-life treatment is now available on such labels for various products); a 'fitness check' for the EU's Ecolabel (awarded to products and services meeting high environmental standards across their lifecycle) with implementation of any recommendations (the 'fitness check' was completed in June 2017, with recommendations under implementation); exploration into the possible use of Product Environmental Footprints to measure and communicate environmental information (rules have been set on a range of product categories, valid until the end of 2020); and action on false 'green' claims and 'planned obsolescence' (revised guidance to application of the Unfair Commercial Practices Directive and the Directive on Unfair Obsolescence Practices was published in May 2016) (*ibid*).

The CEP proposed action to enhance the integration of circular economy requirements into its voluntary GPP criteria, and support a greater uptake of these criteria across member states, and in the EU's own institutions (European Commission, 2015). Circular economy requirements are now included for various product categories, with the 3rd edition of the 'Buying Green' handbook and the brochure 'public procurement for a Circular Economy' published to support uptake. Training 'toolkits' are undergoing revision, and training schemes across member states will take place across 2019 (*ibid*). GPP is included as a metric in the monitoring framework (in terms of the share of total public procurement that may be considered GPP), however data has not yet been reported against it for any member state (Eurostat, 2019d).

Various innovation support and collaboration platform interventions were proposed by the CEP. Principal among these is a focus on circular economy issues under 'Horizon 2020', the EU's research and innovation programme for 2014-2020. Between 2016 and 2018, over 250 research projects related to the circular economy were financed, including those directly contributing to the actions described above, with public funding of over €1.2 billion (European Commission, 2019d). An additional €950 million is available for projects in 2018-2020 (European Commission, 2019b). In addition, CEP 'actions' included establishing a pan-EU network of technological infrastructures for SMEs to adopt advanced manufacturing (a pilot phase is underway, with the objective of creating a self-sustaining platform by 2020 (KET4CP, 2018)), improving the exchange of information between manufacturers and recyclers of electric products (in February 2018 the online Information for Recyclers Platform – I4R – was launched, to facilitate such information sharing as required by the WEEE Directive), and an assessment of the possibility of launching a joint platform with the European Investment Bank (EIB) and national banks to support the financing of the circular economy (a Circular Economy Finance Support Platform was launched in January 2017) (European Commission, 2019b).

All 54 'actions' proposed by the CEP have been delivered or are being implemented. However, it is difficult to determine whether these actions have been effective in delivering the overall objectives of the CEP as described at the beginning of this section. This is in part due to the short timeframes concerned, but also a result of the lack of any quantitative targets against which to measure their achievement. Regardless, given the breadth of the objectives of the CEP, and the complexity of interactions between them, it is likely that some goals and associated actions will be synergistic, whilst others will be in conflict. Figure 10.1, below, illustrates examples of such relationships.

Figure 10.1. Synergies (green lines) and conflicts (red lines) between different objectives within a low-carbon, resource-efficient economy



Source: Domenech & Bahn-Walkowiak (2019) "Transition Towards a Resource Efficient Circular Economy in Europe: Policy Lessons from the EU and the Member States", https://doi.org/10.1016/j.ecolecon.2017.11.001

Maximising synergies and minimising conflict between these objectives is essential to their mutual advancement, with policy mixes that are coherent, consistent and credible (Wilts & O'Brien, 2019), across both member states and governance levels, from the EU level, to individual cities.

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11. The Circular Economy in Cities and Regions (Teresa Domenech)

Urban areas concentrate half of the world's population and consume 70% of the resources and one third of the energy globally (UNEP, 2016). It is expected that by 2050, 70% of the world's population will live in urban areas. Future cities are also faced with the challenges of becoming more resilient in the face of problems such as climate change, and increasing the efficiency with which energy and resources are being consumed, while trying to solve existing social imbalances and support human wellbeing. Although the adoption of CE strategies at the urban level has been the focus of considerable policy innovation and experimentation, the topic has only been recently addressed in the literature, providing a reflective standpoint by which practice can be assessed, critically evaluated and, if necessary, redirected.

Although the concept of a circular city is relatively new, it builds on the extensive body of research on urban metabolism and the more recent concept of the 'resource nexus', which looks at the connections between systems of materials, energy, water and land, but interestingly also expands it to the analysis of additional dimensions including innovation capacity, enabling technologies and new business models. The reasons for the enthusiastic uptake of CE by municipalities are unclear but may be related to the close linkage between the opportunities portrayed by the approach and current concerns and challenges experienced by municipalities linked to use of resources (e.g. built environment and infrastructures), generation of waste (e.g. including food waste and other key priority waste streams including textiles, electrical and electronic equipment (EEE), C&D waste) and sustainable livelihoods (including aspects such as mobility, consumption and production, and social integration). Action has been activated through powerful networks such as the CE City and Government members of the EMF CE100 network, the C40 network and ICLEI. Large-scale pilot programmes in China have also encouraged eco-industrial and eco-city developments with CE principles at their core.

In a context where action has in many cases preceded rigorous academic analysis and reflection, it is unsurprising that existing literature reveals important differences in how the term ‘circular economy’ is understood and operationalised at the city and regional levels (Petit-Boix, 2018; Prendenville et al., 2018). In 2016, the EMF launched the Cities Network as an attempt to bring together city governments to leverage action towards the CE. Since then a large number of cities in Europe have adopted general or sector specific plans to increase circularity. The emerging myriad of CE policy strategies introduced at the urban level includes roadmaps, pathways and plans (see for example the CE strategies of Amsterdam, London or Paris, just to mention a few). However, consistent foundational frameworks on what CE means for cities and ways to attain it are still largely absent. Petit-Boix and Leipold (2018) identify 83 municipalities globally, of which 57 in Europe, with defined and implemented action plans around the CE. Based on a bibliographic analysis, the same authors classify city level strategies for the CE according to four main areas of intervention: infrastructures, social consumption, industries and businesses, and urban planning, to conclude that most city level CE strategies have infrastructures as their main focus of intervention and, within this category, strategies on ‘energy production, recovery and efficiency’ and ‘efficient waste management infrastructure’ are predominant (see Table 11.1). The focus areas tend to coincide with areas of competence traditionally associated with the local level. While city government may have little capacity to drastically change economic drivers or framework conditions through regulation, they generally have greater levels of control over infrastructures, especially those related to distributed production of energy and management of waste, and regulation of local economic activities. The review also suggests that strategic areas within urban policy such as ‘urban planning’ are currently largely unexplored both theoretically and at an operational level in CE strategies. Exceptions to this include the addition of CE considerations in the New London Plan and innovative planning instruments adopted by Amsterdam (with a focus on localised use/reuse of resources) and Barcelona (maker-labs and spaces for social co-production). Also, changes to urban planning approaches tend to be associated with long processes of consultation and, therefore, may take time to be embedded into practices, although sustainability concerns have been at the core of urban planning development for the past 20 years.

Table 11.1. Features of CE Strategies in Urban Areas of Different Population Size

Features of the CE strategies	Population size (number of inhabitants)	Total	≤20,000	(20,000 - 50,000]	(50,000 - 100,000]	(100,000 - 250,000]	(250,000 - 500,000]	(500,000 - 1,000,000]	(1,000,000 - 5,000,000]	> 5,000,000
Number of municipalities (n)		83	5	10	6	15	9	19	15	4
Number of local strategies		210	6	13	6	26	22	61	53	23
Infrastructure (47%)	Local food production	5%					•	•	•	•
	Energy production, recovery and efficiency	10%		•		•	•	•	•	•
	Efficient waste management infrastructure	12%	•	•	•	•	•	•	•	•
	Green construction and materials	9%		•	•	•	•	•	•	•
	Water conservation and reuse	4%	•				•	•	•	•
	Smart IT	4%				•	•	•	•	•
	Green mobility	3%				•	•	•	•	•
Social consumption (24%)	Product repair and (waste) reuse	8%	•	•	•	•		•	•	•
	Food waste management	5%	•		•	•	•	•	•	•
	Sharing initiatives	4%				•	•	•	•	•
	Disposable products reduction	7%		•	•	•	•	•	•	•
Industries and businesses (22%)	Industrial symbiosis	4%	•				•	•	•	
	Use of recycled materials	2%						•	•	
	Remanufacturing	1%						•		•
	Product eco-design/cradle-to-cradle principles	2%				•		•	•	•
	Material, nutrient and energy recovery	2%						•	•	
	Upgraded technologies	2%						•	•	
	Waste/product reuse and cascading	6%		•			•	•	•	
	Green procurement	3%		•		•	•		•	
Urban planning (8%)	Land occupation and zoning	4%		•		•		•	•	•
	Sustainable planning	4%	•				•	•	•	•

Source: Petit-Boix and Leipold (2018 : 1274)

A number of questions arise from the above discussion: 1) how can cities contribute to the CE on a broader scale; 2) are there any particularities of cities, or the urban level, that facilitate or, on the contrary, restrict achievement of CE principles and 3) if so, what are the main characteristics of a Circular City and what might be its role in managing the transition towards the CE. Existing literature on CE and cities mostly focuses on case study reviews and comparisons, generating limited understanding on any of the questions above. The OECD programme on Circular Cities and Regions emphasizes three main critical roles played by cities in the transition to the CE. First, their areas of policy competences cover core dimensions of CE such as waste, construction and transport. Second, they are spaces for innovation and experimentation and, thirdly, they are responsible for around 60% of the public budget in OECD countries (OECD, 2019).

With regard to the first question 'how can cities contribute to CE at a larger scale?', aspects to consider relate to urbanisation trends at global level and, closely linked, concentration of the use of resources, energy and generation of waste in cities. As mentioned above, about 70% of resources are currently consumed in cities and around 60% of waste is generated by cities, which also produce around 60-80% of global GHG emissions (UNEP, 2016). In addition, global urban land is expected to increase through 2030, as a large proportion of urban spaces are yet to be built (Elmqvist et al., 2013; Seto et al., 2011 cited in Larondelle et al., 2014). This means that how resources are managed in cities is going to crucially influence overall resource consumption, generation of waste and carbon emissions. Cities though do not exist in isolation but are embedded in larger systems, which include peri-urban areas and rural areas and are connected through trade flows to even remote rural parts of the world. The concept of hinterland of cities is useful to understand these dynamics. The concept refers to the terrestrial and aquatic ecosystems the cities rely on for the consumption of resources, production of energy, discharge of waste and sequestration of emissions. With increased globalised flows of materials, the hinterland of the city is not necessarily the areas adjacent to the city perimeter but may well extend to other parts of the world, which provide resources to the city and act as sink for its emissions and waste. Cities largely depend on ecosystem services provided by their hinterland in the form of water, food, clean air and natural space (Larondelle et al., 2014). In most cases, thus, the hinterland of cities is not related to local or regional 'biophysical capacities' but dependent on goods and services that exist beyond the boundaries of the city in regions all over the world, in many cases rural and virgin forest areas (Kissinger and Haim, 2008). Global food systems are a good example of this, with food consumption being supported by agricultural production in different regions in the world. Kennedy et al. (2007) estimate that hinterland areas supporting cities are one to two orders of magnitude larger than the city territory itself and Seto et al. (2012) expect that urban footprints will triple over the years up to 2030. Traditional policy boundaries addressing local/regional/national and supranational levels as separate levels thus need to be rethought to recognise the interaction across different levels and harmonised frameworks to transition towards greater levels of circularity.

Pressure on ecosystem services, exacerbated by urbanisation trends globally, thus may contribute to aggravate issues such as urban resource scarcity issues in the areas of food, access to energy and water. In fact, almost half of the world population live in cities that experience levels of water stress (Richter et al., 2013 as cited in Williams, 2019) and cities in the Global South may experience important issues related to access to energy and food security, with a greater reliance on global food production markets to the detriment of local production. Also, interestingly, cities have made little effort to close the nutrient cycle, by returning nutrients to agriculture and forest areas, something that will be briefly addressed later.

Going back to the initial question of whether cities can contribute to the CE at a larger scale, one may conclude that cities have a particularly important role to play in any CE transition due to the current linearity with which resources are consumed in cities and then disposed of (mainly outside them), their scale in terms of their share of resources consumed and waste generated, and their role in setting consumption patterns and connections to global trade. Also importantly, the accumulation of material stocks in the techno-sphere of urban areas (as demonstrated in section 4) suggests cities could become resource reservoirs in the future (Williams, 2019), providing opportunities to shift towards more sustainable pathways of consumption of primary raw materials.

Although the above indicates a relevant role for cities in the CE, there is still limited discussion about the specific traits that make cities a suitable area of intervention for the CE transition. Further insights about this may come from developments in the economic geography literature which explores issues of localisation and innovation theory. From this perspective, cities are shaped by a number of tensions related to economies and counterpart diseconomies of scale and agglomeration. These concepts date back to economists like Weber (1909) and the localisation theories of Ohlin (1933), who distinguishes between large-scale economies, localisation and urbanisation economies and, generally, provides a theoretical foundation for later contributions throughout the 1950s and 1960s.

This is later picked up by the 'new economic geography' in the late 1990s and 2000s (Parr, 2002), with a focus on regional development. Chertow et al. (2008) use the term 'environmentally related agglomeration economies' to refer to opportunities to optimise flows of water, energy, materials, and by-products across firms in geographic proximity, through industrial symbiosis relationships. These types of economies of agglomeration, which as noted by Parr (2002) vary in their degree of complexity, scope and scale, can be found in cities at different levels and can be internal or external to firms. Due to the concentration of activities and resources (and waste), cities are likely to generate economies of agglomeration that are external to the firm and emerge from collective action or built infrastructure (including logistics). These are generally referred to as 'urbanisation economies'. They include the access to a pool of resources (labour, material inputs or energy) as well as infrastructures, public utilities, transport services and specialised supporting services (financial, knowledge, IT, R+D, etc). In most cases, these are provided by the state or the market or a combination of both (Parr, 2002).

Most of the opportunities for the articulation of CE in cities derive from or are connected to urbanisation economies, as they provide adequate spatial and socio-economic conditions to favour opportunities around the tighter loops of the CE butterfly diagram. For example, in line with the work of Chertow et al. (2008), they may provide a suitable infrastructural basis but also the necessary scale to optimise utilisation of water, energy and material resources. This is especially relevant for the biological cycle, where opportunities to cascade nutrients or energy may be restricted by geographical proximity. For example, there are technical constraints to the spatial radius for steam and district heat distribution. This is also true for grey water collection systems, water treatment and filtration facilities and extraction and recovery of nutrients and heat from wastewater treatment plants. Opportunities to generate energy from organic waste in anaerobic digestion (AD) plants and produce digestate to replace chemical fertilisers are also place-dependent. Transportation of biological waste over long distances is discouraged both from the point of view of transport costs (and associated emissions) as well as distribution and fairness issues.

The opportunities of geographical proximity are less evident in relation to the technical cycle in a context of a highly globalised economy. Brooks et al. (2018) report that in 2016, of all plastic intended for recycling, half (around 14.1 million tonnes, mt) was exported and around half of this (7.35 mt) had China as its recycling destination. The introduction of import bans on low quality plastics has since changed the geographical distribution of waste recipients, but still demonstrates the global reach of markets for secondary materials. Leaving aside environmental and social concerns related to the standards of recycling and safety of disposal in current trade flows of materials, this also highlights that while global markets may arguably play a role in promoting the outer circle of CE interventions, associated mostly with recycling, preferable tighter loops including remanufacturing, maintenance and repair may be better facilitated in an effective and economic manner, in urban areas, where scale, access and proximity may reduce the transaction and transport costs associated with these activities.

However, although some of the above points seem to suggest an important role of cities in the transition to the CE, one should not overlook diseconomies of agglomeration which may result from the concentration of activities in the space (e.g. increased pollution from sources including waste treatment/ recycling activities) as well as competition for land uses, which may restrict opportunities to realise some of the CE-related synergies. Williams (2019) distinguishes between two extremes in the spectrum of cities: shrinking urban areas and hedge cities. These two distinct types of cities face different challenges related to localisation economies. In the case of shrinking cities, the main challenges to increase circularity may be associated with the underutilisation of infrastructures, leading to what is called structural waste, and reduced opportunities to create agglomeration economies. At the other end of the spectrum, hedge cities face the challenges associated with competition between different land uses, which may displace activities with lower added value by spatial unit, such as productive spaces, recovery/repair activities or waste management facilities, compared to premium residential and commercial spaces. It may also create pressures on green and blue infrastructure that provides ecosystem services to the cities (Williams, 2019).

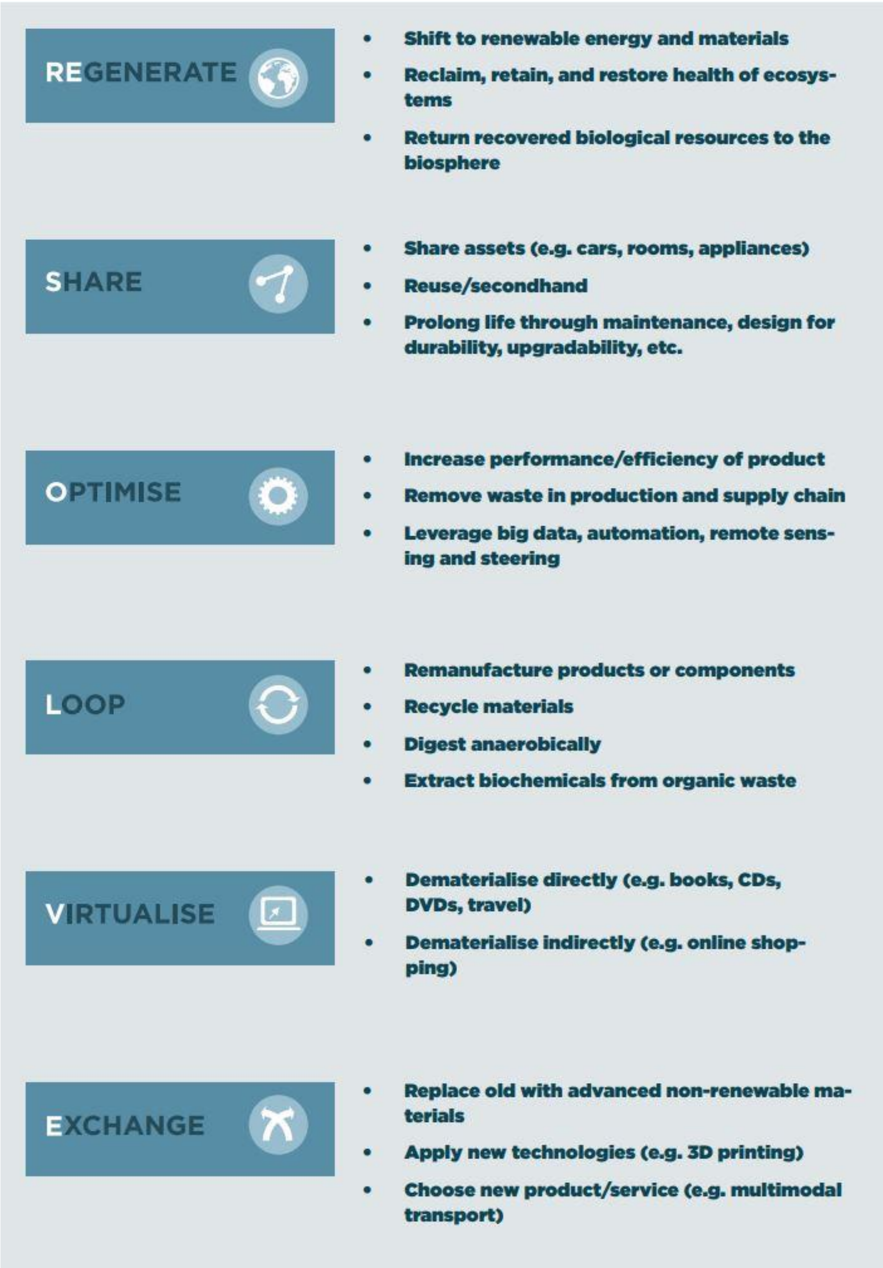
Building on this, one could derive lessons related to which areas of intervention could be adequate to leverage change at the city level towards CE. The city scale may generate environment-related benefits emerging from scale and proximity, especially with regard to the flows of matter and energy with low economic value (e.g. C&D waste, food waste, etc) and may provide opportunities to promote activities in the tighter loops of both biological and technical cycles. EMF (2019) proposes closed loop systems for food in cities where food waste is cascaded, and nutrients are recovered and used to increase yields of local food production which is then consumed by the city. While there are indeed small-scale examples where this has been applied with relative success (e.g. an abattoir project in Brussels where food waste from the market is used to produce compost and energy which is then used with hydroponic techniques to grow vegetables that are sold in the market), one should not forget that cities are open systems with high reliance on their hinterland and subjected to the market and system dynamics of wider systems and therefore rely on framework conditions defined at a wider level, where local governments' ability to influence are limited (e.g. global food supply systems).

While the infrastructural level of the city is very relevant, which has also been emphasised in Petit-Boix and Leipold (2018) as one of the key areas of intervention related to CE urban strategies, cities have a potentially greater role than this. As highlighted by Williams (2019) cities are complex urban environments characterised by ‘a wide diversity of actors, operating across different sectors at a variety of scales all with different motivations’. The field of urban metabolism brings the idea of cities as systems of systems, where localised interactions between the supporting natural system, the built environment, including infrastructures, and the socio-economic system, with accepted behaviours, social practices and economic incentive structures help shape the behaviour of actors. The complex interactions among these three systems define how the city behaves and the resource flows associated with that behaviour. Transitions to new forms of urban environments thus require simultaneous transformations in all the systems and their interactions. While having the right set of infrastructures to recover materials, reduce structural waste and promote more circular use of resources is essential, cities have the strategic role to leverage new behaviours among citizens and firms, which in turn requires a new governance setting.

Cities have been at the forefront of innovation in CE. Cities as ‘urban labs’ have been adopted to test different ways of interaction between citizens, firms and government to increase collaboration in Europe. It has been suggested that cities can act as ‘facilitators’ promoting collaboration across actors and systems to promote new business models from a co-creation and co-implementation perspective (EC, 2017). A recent report from the European Commission (2017), evaluating the impact of CE strategies at the urban level mediated by ‘urban lab’ approaches, identified a number of critical aspects that are needed to generate systemic change including ‘improved coordination across multiple levels of government’, promotion of city-level and inter-city networks to help with capacity building and knowledge sharing, facilitated by open-source and detailed digital data of flows of resources and a harmonised framework for the assessment of intervention. This implies that new forms of governance in cities have to emerge to promote multi-stakeholder collaboration, data-rich environments, and spaces for experimentation, which may include promotion of distributed manufacturing and sustainable lifestyles. Cities thus could create the mechanisms and conditions for adoption and piloting of new business models that test and validate novel approaches, covering both technical and social innovations, providing the space for business to ‘make’ using new forms of advanced digital and distributed manufacturing and providing opportunities and scale for early adopters to scale up. Cities may also have an essential role in knowledge dissemination, acting in larger city networks. Here, agglomeration economies have been key in facilitating new forms of the sharing economy and opportunities to exploit performance and use business models. In contrast, China has adopted more top-down models such as ‘City Pilot Programmes’.

The next question is how can cities initiate and manage the transition towards the CE. The enthusiasm with which the concept of CE has been embraced by municipalities, both in Europe and China, has also resulted in a number of frameworks to mobilise action, mainly developed by consultants. One of the most widely adopted methods is the RESOLVE framework proposed by EMF (2015). The framework proposes six areas of action: Regenerate; Share; Optimise; Loop; Virtualise; and Exchange, as shown in Figure 11.1, which has been used by governments and organisations to initiate change towards the CE (Lewandowski, 2016). The framework is supposedly underpinned by the three principles for circularity (EMF, 2015: 1) ‘Preserve and enhance natural capital by controlling finite stocks and balancing renewable resource flows’; 2) ‘Optimise resource yields by circulating products, components and materials at their highest utility and value’ in both technical and biological cycles and 3) ‘Foster system effectiveness designing out negative externalities’.

Figure 11.1. The RESOLVE framework



Source: EMF (2015)

Following an increased interest in cities and the role of urban areas for the CE, in 2019, EMF launched a new series of resources for the implementation of CE principles in cities. This articulates a vision for a circular city with the following main pillars: 1) new ways of planning that encourage better use of space and resources; 2) introduction of new business models that promote access over ownership of products; 3) sustainable urban mobility; 4) circular built environment, with buildings and infrastructures designed to be adaptable, modular and easy to maintain; 5) use of local materials and 6) role of local networks to increase reparability and maintenance of products and buildings (EMF, 2019). The framework proposes three core focus areas for cities: buildings, products and mobility, with a fourth, food, addressed separately in a different report, EMF (2017). The new urban framework is organised in five areas of intervention across the three core themes: planning, designing, making, accessing, and operating and maintaining, as summarised in Table 11.2 below. The framework is essentially different to the RESOLVE framework as it is organised by project life stage rather than impact stage. In this sense, it aligns well with the implementation framework proposed in the BSI 8001: 2017 '*Framework for implementing the principles of the circular economy in organizations*'. The main focus of EMF 2019 is to highlight the economic opportunities unleashed in any of the life stages of CE interventions across the three themes (Buildings, Products and Mobility), with little acknowledgement of the associated costs and challenges.

Table 11.2. Areas of Intervention in Different Sectors

Phase	Buildings	Products	Mobility
PLANNING	1. Planning compact cities – dense, mixed-use, and transit-oriented 2. Planning for local circular material flows	1. Supporting and incentivising better production (upstream) 2. Providing resource management infrastructure (downstream)	1. Compact city development for effective mobility 2. Urban freight strategies for effective reverse logistics and resource flows 3. Infrastructure for zero-emission vehicles and energy storage 4. Using big data solutions to optimise mobility systems
Designing	1. Designing for adaptable and flexible use 2. Using collaborative design processes 3. Integrating material choices into design 4. Taking inspiration from nature	1. Designing for reuse and multiple cycles 2. Designing to support efficient operation and maintenance 3. Designing in transparency in supply chains and products 4. Open-source design to accelerate innovation, uptake, and customisation	1. Designing vehicles for adaptable and shared use 2. Design for zero-emission transport vehicles and energy grids 3. Designing transport infrastructure for adaptable use 4. Designing regenerative and energy-positive, mobility infrastructure
Making	1. Sourcing materials strategically 2. Building with resource-efficient construction techniques 3. Building 'buildings as material banks' (BAMB)	1. Sourcing locally abundant materials 2. Aligning digital manufacturing with circular economy principles 3. Increasing the distribution of manufacturing in line with circular economy principles	1. Sourcing infrastructure materials strategically 2. Manufacturing vehicles using resource-effective techniques 3. Building infrastructure with new construction techniques
Accessing	1. Accessing residential space through shared-use schemes 2. Accessing commercial space through shared-use schemes 3. Increasing the use of space through design features	1. Accessing products through product-as-a-service business models 2. Accessing pre-owned products through peer-to-peer models	1. Alternative solutions that reduce transport needs 2. Active and low-impact mobility solutions 3. Multimodal transport as an integrated service 4. Optimising freight capacity through shared solutions and distributed centres
Operating and maintaining	1. Using smart technology to run buildings effectively 2. Using product-as-a-service models for building fit-outs 3. Adapting buildings for alternative uses 4. Refurbishing buildings to run them efficiently	1. Empowering repair initiatives to extend product cycles 2. Refurbishing products for reuse	1. Minimising trip length, duration, and operational energy use via digital solutions 2. Mobility assets operated and maintained in new business models 3. Refurbishing and repairing vehicles to extend material cycles 4. New techniques for infrastructure operation and maintenance

Source: Adapted from EMF (2019)

In general, the academic literature has looked at these frameworks from a more critical perspective. While generally reports tend to highlight examples of successful business models that have exploited opportunities in each of the framework areas, integrated action across areas, especially through consistent and well-conceived policy mixes, is still rare. Williams (2019) notes that current urban approaches to circularity do not fully capture the complexity of urban systems, highlighting important shortcomings of the application of this type of framework at the city level. The frameworks are action-oriented and fail to recognise the different nature, scale and multiplicity of interactions between the natural and built environments, and socio-economic environments in constant change and evolution. It also lacks specificity with regard to the role of consumption and patterns of use of resources, which may compromise the ability of cities, as consumption hubs, to recover resources and maintain them in the productive cycle, through manufacturing and recovery activities. Other relevant dimensions such as the role of land, and competitive uses of land, and existing built infrastructure (and consequently potential lock-ins) are not captured by simplified frameworks such as RESOLVE (Williams, 2019) or the new 5-stage framework proposed by EMF (2019).

Gaps in the understanding of transitioning processes are also identified in the literature. De Jong et al. (2015) mention 12 distinct concepts that entail different approaches to transitioning to sustainable cities (e.g. eco-cities, zero-waste cities, smart cities, etc), and highlight lack of clarity in terms of the vision and limited tool-set to manage the transition. Prendeville et al. (2018) consider that the CE concept is 'over-hyped' and 'ill-defined', and propose a reflective investigation to understand what the CE agenda means for cities, including an interesting historic overview of the field of urban sustainability to identify what propositions are different from previous '*trends*' and to what extent those differences may or may not provide a better framing of how to transition towards more sustainable cities or sustainable ways to use resources in cities. Limited literature on circular cities, drawing in many cases from interventions in China, point to barriers such as the limited scale of the interventions (Yu et al., 2015) or lack of public engagement and limited opportunities of participation (Geng et al., 2009). Prendeville et al. (2018) propose a conceptual framework of circular cities which combines top-down institution-driven initiatives and bottom-up change, which may also be stimulated by local governments, and categorise them according to the 5 areas of intervention proposed by the RESOLVE framework, as per Figure 11.3.

Figure 11.2. Circular City Principles

Circular city principle	Top-down example	Bottom-up example
Regenerate	Utilizing rooftops as solar fields, developing green space for biodiversity and to improve air quality.	Personal acquisition of renewable energy; solar panels, urban farming, electric or biogas fuelled mobility.
Share	Policy innovation to support the collaborative economy, regulate sharing, tax and fiscal measures incentivizing sharing.	Car sharing, appliance sharing (washing machines, tools), repair (repair cafes), reuse (clothing, furniture, vehicles, appliances).
Optimize	By using gathered data on traffic flows, the efficiency of cities' major transportation can be optimized, decreasing congestion. Installing smart LED lighting throughout the city to save energy. Retrofitting old buildings to increase their energy efficiency.	Smart citizen labs, Fab Labs, smart grids, smart communities.
Loop	Waste separation and recycling, district heating, bio-based economy, reverse logistics.	Community recycling initiatives, upcycling initiatives, community bio-digesters.
Virtualize	Virtual city hall counters. Autonomous public transportation and semi-private transportation like taxis. Virtualization of public libraries, archives, legal information. A paperless municipality.	Community-led digital platforms, citizen-science climate monitoring.
Exchange	Circular construction/demolition materials and processes, electric powered public transportation, procurement of circular office furniture.	Electric mobility, organic and locally-sourced (super)markets, eco-fashion, e-readers.

Source: Prendeville et al. (2018: 174)

While interesting, generally relatively niche initiatives provide some guidance on actions and areas of intervention of CE in cities, there is still a need to better understand the connections and mutual implications between the different building blocks and have a more holistic understanding of what a circular city is or aims to achieve. In the comparison of pioneering CE cities, Prendeville et al. (2018) observe a number of patterns which although general provide some guidance on the sort of framework conditions that may favour cooperation for the CE. Increasing data-rich knowledge of the city, including understanding of the urban metabolism needs to be partnered with public-private alliances that encourage business-led innovation and connections between city stakeholders. Many existing measures, though, as noted by

Predenville et al. can be labelled as incremental while ‘major investments’ to transform baseline linear systems are largely absent. Areas of experimentation, such as the Amsterdam ‘Free Zones’ may provide suitable spaces to test and pilot new system and stakeholder collaborations.

EMF (2019) points to a number of policy levers to induce change. Among these, they include a number of general recommendations such as road-mapping and design of strategies, convening and partnering, capacity building and awareness raising, but also more specific actions in the area of urban planning and asset management. This is interesting because despite being an area of competence that traditionally falls into municipalities, it has been largely overlooked in the literature. Here recommendations include proactive use of urban planning to ensure dense and compact cities, with access to good public transport systems but also more concrete action potentially imposing requirements in use of material and generation of waste for design of spaces, buildings and infrastructures. In terms of asset management, use of publicly owned assets and land can also offer opportunities to increase circularity in conjunction with urban planning such as using city-owned land to facilitate exchange of materials and storage between deconstruction and construction projects, traditionally an important barrier to higher levels of C&D waste utilisation.

In summary, ‘circular cities’ is a relatively new concept that fits in the crowded space of urban sustainability. The application of CE principles to cities has been enthusiastically adopted by an increasing number of municipalities although the actual agenda is still ambiguous and lacks reflection about the interaction between local, meso and global levels. Most of the initiatives to increase circularity in cities have started with some sort of road-mapping and identification of opportunities, usually based on sectoral approaches with some degree of application generally at niche or reduced scale. There may be potential benefits associated with agglomeration economies in cities that may facilitate re-utilisation of waste flows. However, there are limitations to this. While most of the waste is globally generated in cities, the predominance of residential and commercial uses limits the ability of cities to cycle back recovered resources into the system at the urban and regional scale. The limited manufacturing base of modern cities means that CE loops on the technical side (remanufacturing, recycling) tend to be constrained. Similarly, on the biological side, it can be difficult to utilise recovered nutrients as productive land in cities is very limited or non-existent, creating again a problem of displacement between supply and demand. Systematic literature reviews (e.g. Petit-Boix and Leipold, 2018) suggest that CE initiatives are relatively constrained to the areas of energy and waste infrastructures and management, while far-reaching intervention through urban planning, which plays a very important role in how activities in the space are organised, how activities, people and networks interact and, ultimately, how resource and energy flow in a city, are still limited. Therefore, further examination of the spatial dimension of material flows could certainly contribute to enhance opportunities as well as reveal limitations to promote CE loops at the city level together with a better understanding of the integration of local, meso and global levels.

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12. Conclusions

After having lain effectively dormant for many years, it is remarkable how quickly the idea of the circular economy has become established in mainstream business and policy thinking, something which outside China, at least, dates from the first publications of the Ellen MacArthur Foundation in 2013. In China, as was seen above, the idea took root a decade or so earlier.

However, the speed of the general acceptance of the idea has not led to a common understanding of the meaning of the term. On the contrary, it could be argued that one of the reasons for its general acceptance is that it has now come to mean pretty much all things to all people. In this, it resembles the concept of ‘sustainable development’ and indeed, as was seen earlier, the circular economy is now sometimes equated with sustainable development.

This is noteworthy because, unlike sustainable development, the circular economy started off by being quite clearly described, by the Pearce and Turner book in 1990, and in the 1960s by Kenneth Boulding and a strand of thinking that later came to be called industrial ecology. In these conceptions of the circular economy the idea dealt with flows of physical resources, and its purpose was to reduce the potential impacts of resource depletion and the environmental impacts of resource extraction, use and disposal. This core idea was expressed earlier in this paper through the definition: The circular economy is one that has low environmental impacts and that makes good use of natural resources, through high resource efficiency and waste prevention especially in the manufacturing sector, and minimal end-of-life disposal of materials.

Neither Boulding nor Pearce and Turner speculated what the broader economic implications would be of moving towards a circular economy, but this was not the case in Stahel’s early seminal writings on the issue (he writes “Extending product-life … builds on and increases wealth … while increasing the number of skilled jobs available… In this way, unemployment and poverty may be substantially reduced [Stahel 1982, Abstract]). His 1981 book with Reday-Mulvey, based on a 1977 report for the European Commission, was entitled *Jobs for Tomorrow*. Stahel has expanded on this at some length in his book *The Performance Economy*, which is the circular economy by another name, which will “produce higher wealth and economic growth … [and] create more manual and skilled jobs” both with greatly reduced resource consumption (Stahel 2010: 1).

This optimistic view of the economic implications of moving to a circular economy forms an essential part of both the business and policy narratives on the topic, as exemplified by the Ellen MacArthur Foundation publications, and the circular economy rhetoric of the European Union. The view is based mainly on consultancy studies for EMF, the European Commission and others that look at the resource costs and benefits of introducing particular technologies, the experiences of particular firms, the aggregation of these estimates across sectors, and their input into macro-economic models. The estimates are, of course, very dependent on the various assumptions that have been made. In general, these seem not implausible, although perhaps the least persuasive element of this positive narrative concerns the estimates of much increased employment. Clearly this would be very dependent on the employment conditions, labour markets and skills base of the economy under consideration, and yet all too often in estimates of ‘more jobs’ these seem underspecified. The brief survey of these issues in section 8 seemed to indicate that, at worst, moving towards a circular economy would be neutral in terms of output and employment (though there could be significant sectoral changes), and on optimistic assumptions the outcomes could be significant income and employment growth.

The other social implications of greater resource circularity are even less clear than in the case of employment. Indeed there seems little reason to imagine that a more circular economy in terms of resource use will necessarily be more equitable, or less unequal, than a linear economy. The social outcomes of greater circularity are likely to depend on the social policies that accompany policies to increase circularity rather than the circularity policies *per se*. And whether an economy that is circular in resource use, but unequal in terms of income and wealth distribution, should count as a ‘circular economy’ is a matter of semantics and definitions. In general, though, it does not seem helpful to equate the circular economy with sustainable development, thereby obscuring its essential focus on the use of physical resources and consequent environmental impacts.

If the relationship between the circular economy and sustainable development is not obvious, this is even more true for the concept of sustainability which is now used with an even broader set of meanings. It is clearly intended that a circular economy would be more environmentally sustainable than a linear economy and, while this is intuitively plausible, the question of which particular uses, re-uses or recycling of materials are environmentally preferable need to be determined through specific analysis, using methods such as LCA. Similarly, it is plausible that reducing the extraction of virgin materials in favour of secondary materials will relieve potential bottlenecks in material supply and reduce the environmental impacts of extraction, but again the existence of the former and the achievement of the latter need to be evaluated on a case by case basis.

With regard to the other meanings and dimensions of ‘sustainability’ (e.g. economic, social, ethical), the implications of just the circular flow of materials seem quite unresolved. A zero-waste or circular economy could be organised in many different ways, with many different social and economic outcomes. There seems to be no clear reason at all why a political economy should be defined by the mere fact of a circular material flow.

On the question of scales, it is clear that circular economy thinking is applicable at the micro, meso and macro scales. The ability to which actors at the micro scale (firms and households) are able to embrace circularity will depend greatly on the wider context – particularly the provision of infrastructure and the relative costs of circular and linear behaviours. Actors at the meso scale (cities, regions and industrial parks) are likely to have more freedom of action, but this too will depend critically on their powers and the institutional framework within which they operate. They are also meshed into the global trade and flow of material resources, including food, over the dynamics of which they generally have little influence. They may also have little capacity to engage in large-scale re-purposing of materials once they have reached the end of their first life.

The Chinese model of regional governance goes beyond the large-scale demonstrations funded by Europe’s Horizon 2020 programme, and it is more coordinated than the experimentation that occurs among EU or OECD member states. It appears to be more geared toward upscaling successes. In its focus on creating arenas for transition experiments, focused on leading firms and institutions, the Chinese approach bears some resemblance to the prescriptions of transition management and attempts at green innovation-led development in transition regions. The blend of coordinated administration, as well as encouragement and facilitation of local experimentation provide a governance model that could provide important lessons for the structuring of large-scale demonstrations or sociotechnical experiments within the European context. This is particularly relevant in Europe, given a recognized need to move beyond fostering best practice in “niches” toward upscaling and mainstreaming promising innovations.

It would be very useful to consider the establishment of a global platform for sharing knowledge about the circular economy at urban and regional scales; this could also help to establish new standards and key performance indicators, as well as new alliances with corporate and other actors to promote, large-scale experiments and upscaling. Lessons learned from the EBRD’s ‘Green Cities’ programme might also be useful.

At the macro scale, national governments have the usual policy instruments available to them to change incentives, influence behaviours, create infrastructures and supporting institutions, and engage directly in markets. So far, national governments’ use of these instruments to promote circularity, with the possible exception of China, has been limited, despite the supportive rhetoric. Whether the circular economy becomes more than a passing fashion will depend on the extent to which governments use the powers at their disposal more systematically to promote it.

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Endnotes

[1] The website http://isfie.onefireplace.com/resources/Documents/Strategies_For_Manufacturing_Sci_American_1989.pdf which reproduces this article notes: “The original title proposed by the authors was "Manufacturing -- The Industrial Ecosystem View", but was not accepted!”

[2] Interestingly, the drawing is credited to McDonough and Braungart, *Cradle to Cradle*, but no such diagram appears in their book of that name published over ten years before.

[3] See http://www.env.go.jp/recycle/3r/initiative/en/index.html

[4] See http://ec.europa.eu/environment/waste/framework/

[5] Note that this is subtly different from the definition that appears in the Conclusions to Kirchherr et al.’s paper: “[A circular economy is] an economic system that replaces the ‘end-of-life’ concept with reducing, alternatively reusing, recycling and recovering materials in production/distribution and consumption processes. It operates at the micro level (products, companies, consumers), meso level (eco-industrial parks) and macro level (city, region, nation and beyond), with the aim to accomplish sustainable development, thus simultaneously creating environmental quality, economic prosperity and social equity, to the benefit of current and future generations. It is enabled by novel business models and responsible consumers.” (Kirchherr et al. 2017: 229)

[6] Interestingly, Geng and Doberstein (2008) feel the need to qualify their use of the term by saying “The terminology may not be very familiar to Western readers”, which shows that the phrase was not in widespread scientific use even in 2008.

[7] Waste that may be classified as hazardous, including flammable, explosive, medical and toxic waste, have been banned from landfill in the EU since 2001 (European Commission, 2019a).

[8] https://ec.europa.eu/commission/priorities/jobs-growth-and-investment/towards-circular-economy_en

[9] The European Committee for Standardization (CEN), the European Committee for Electrotechnical Standardization (CENELEC), and the European Telecommunications Standards Institute (ETSI).

[10] However, in January 2019 the Commission published a proposal to gradually transition towards qualified majority voting for such matters (European Commission, 2019e).