Paving the way for a circular economy: insights on status and potentials

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Executive summary

Previous European Environment Agency reports on the circular economy have focused on the overarching concept as well as on specific aspects, such as waste prevention and reuse, products, plastics, chemicals, clean material cycles and policy initiatives. Circular material use may bring economic and environmental co-benefits, and is therefore a promising tool for sustainable development. Preliminary evidence suggests that the reductions in greenhouse gas emissions because of circular approaches can be substantial. However, it is too early to evaluate the overall economic and environmental impacts of the circular economy. Initiatives are young and diverse, and relevant harmonised European-level statistics are still largely lacking.

Fostering circular material use requires a broad system perspective and extensive stakeholder involvement. The entire product lifecycle — including the design, production, consumption and waste phases — needs to be addressed in a coherent way. The enablers of and barriers to circular business models need to be well understood and addressed before innovation and competitiveness can be enhanced. There is no silver bullet, though. The complexity of products and production-consumption systems, as well as the variety of material-specific issues call for tailor-made solutions. A mix of measures at different scales will generally be needed to involve the right stakeholders and to support and upscale promising local initiatives.

The available statistics on material flows and waste generation show that the circular economy is still in its infancy. At macro level, only around 10 % of the materials used in the European economy are recovered and reused. This circularity rate varies from less than 1 % for materials like lithium and silicon to more than 50 % for silver and lead. Waste volumes went up by 3 % between 2010 and 2016, but the share of recycled waste also grew (50-54 %) as did that of waste incinerated with energy recovery (12-18 %). Landfilling decreased from 29 % to 24 %. Although large differences between individual countries exist, these overall shifts in waste management are in line with the principles of the waste hierarchy as laid down in the EU Waste Framework Directive.

To avoid waste generation in the first place, national waste prevention initiatives exist to make products more durable and extend their effective lifespan. These include incentives for product design, promoting repair and reuse, and changing consumption patterns. Their net effects are difficult to assess, however, as they cannot be derived from the available waste statistics.

The available data suggest that circular business models are increasingly adopted, with operational efficiency and waste reduction receiving most attention. One in four companies for which information is available report that they have changed their product design to improve reuse, repair or maintenance. The shift from product-based to service-based business models is a promising development that may promote shared use, and product durability and reparability. The biggest obstacles to circular business models appear to be corporate culture, market factors and system complexity. Traceability of materials and keeping material cycles clean from hazardous substances is also very important in this respect. Trust in material performance and safety, in addition to price, will largely determine whether manufacturers will be willing to use recycled materials and whether consumers will be prepared to buy products made from them.

An EEA country survey has shown that policy support at national level is extensive. Of 32 responding EEA member countries, 21 reported circular economy initiatives, often within a wider resource efficiency approach. The reported measures generally reflect EU policy priorities, with a comparatively strong focus on energy efficiency and waste. Regulation and market-based instruments are mainly focused on the end-of-life phases (recycling, energy, waste), while eco-design, consumption and reuse are typically targeted with softer policy instruments. The latter would need more attention to tackle the systemic aspects of circular material flows.

Potential synergies between circular material use, climate change mitigation and the halting of biodiversity loss are increasingly recognised. However, such synergies require further integration within and between climate-neutral, bio- and circular economy policies. Monitoring progress also needs further investment as many relevant data — for example, on the production and consumption phase of product lifecycles — are not readily available in established information systems (e.g. statistical systems) that support such policies.

1 Introduction

1.1 About this report

The EEA started a series of consistent activities around the circular economy in 2014. The work, supported by the European Topic Centre on Waste and Materials in a Green Economy (ETC/WMGE), has involved conceptual framing and dedicated studies on selected aspects of the circular economy. Outputs have focused on the characteristics of a circular economy (EEA, 2016a), waste prevention and reuse (EEA, 2018d), chemicals (EEA, 2018a), products in a circular economy (EEA, 2017), clean material cycles and plastics (EEA, 2019a), and national policy initiatives in a wider resource efficiency context (EEA, 2016b, 2019b). This report, published towards the end of the current EEA multiannual work programme 2014-2020, takes stock of the insights gained and highlights issues needing further attention in the coming years.

Altering current trends in material resource use and waste management lies at the heart of circular economy thinking and actions; achieving this requires insight into policy action, technological innovation, the emergence of new business models and trends in consumer behaviour, among other things. The barriers to the transition to a circular economy and the governance measures and policies needed to tackle them also need to be understood. In addition, throughout the transition, progress must be analysed to ascertain whether the circular economy is delivering on its promise of economic and environmental co-benefits. Inevitably, in the current initial stages of the transition, evidence of progress is limited, so this report focuses on the information available on material cycles, enablers of the transition to a circular economy and dedicated policy measures.

Against this backdrop, Chapter 2 provides an overview of the state of knowledge on flows and stocks of materials, products and waste. From this overview, it is clear that the circularity of Europe's economy can be only partially assessed at present, as there are few data on the management of products — reuse, repair and remanufacturing. The available data at macro-level show that Europe is still far from being a circular economy and that available knowledge focuses on the waste phase.

Drawing on insights from research on transitions, Chapter 3 explores a number of priority areas in which innovation is needed and policy interventions could stimulate the transition to a circular economy. It discusses integrating the principles of circularity into innovation processes, promoting design principles, and working to change consumer behaviour and lifestyles, finance, fiscal policy and infrastructure.

Chapter 4 builds on this discussion by exploring opportunities and challenges in governing complex, multi-stakeholder processes of systemic change. It reviews policy measures in EEA member countries and discusses strategic frameworks at different scales of governance aimed at systemic change. Finally, it explores the synergies and trade-offs that arise through the interaction between these strategies.

Recognising that new knowledge is needed to understand and support the transition to a circular economy, Chapter 5 explores the limitations of existing knowledge systems and the opportunities to make them fit for the 21st century.

1.2 The broader context for circular economy policy

In the last 50 years the world has seen a continuous and unprecedented increase of material demand (IRP, 2019). In this period, the global production of goods has doubled, the extraction of materials has tripled and economic development, as measured by gross domestic product (GDP), has quadrupled. This expansion of activity has been responsible for more than 90 % of biodiversity loss and water stress and for approximately half the drivers of climate change. And, looking ahead, global material use could rise from 92 billion tonnes today to around 190 billion tonnes by 2060, while greenhouse gas emissions could increase by 43 % (IRP, 2019). Material use is still expected to grow in EU Member States as well, while resource efficiency is projected to increase (IRP, 2019; OECD, 2019).

The circular economy aims to reduce resource use by recycling of materials and reusing products, extending their lifespan and maintaining their economic value. This has both economic and environmental benefits (EEA, 2016a). Creating a circular economy requires fundamental changes throughout the value chain, from product design and technology to new business models, new ways of preserving natural resources (extending product lifetimes) and turning waste into a resource (recycling), new modes of consumer behaviour, new norms and practices, and education and finance.

In 2015, the EU launched its circular economy package in response to the sustainability challenges linked to global overuse of natural resources and related waste production and harmful emissions. The EU action plan for the circular economy (EC, 2015a) establishes a concrete and ambitious programme of action, with measures extending from consumption and production to waste management and markets for secondary raw materials. Collectively, these measures will contribute to increasing product and material life cycles through greater reuse and recycling, thereby bringing benefits to both the environment and the economy (EC, 2019b).

Action will be needed at many levels, from European to local, and by all stakeholders, including governments, businesses, researchers, civil society and citizens (EEA, 2016a). Because of the many interactions between scales and policy areas, transforming the economy is a highly complex matter. There are no simple solutions. Promoting experimentation with innovative approaches is important, and this normally requires an enabling policy framework — including creating room to fail. Integration between policy levels and policy domains, as well as within and across value chains, is also essential.

1.2.1 Economic transformation

The emergence of the circular economy concept can be understood as part of a broader shift in research and policy that emphasises the need to transform the economic system. In the EU context, this is expressed through the adoption, during the last decade, of detailed strategic frameworks and action plans addressing the low-carbon economy, the climate-neutral economy ([1]), the circular economy and the bioeconomy (EC, 2011, 2012, 2015a, 2018a, 2018b).

These new frameworks are based on a shared understanding that the ecosystems that ultimately sustain our society and economies have a finite capacity to provide resource inputs and absorb waste and harmful emissions. As acknowledged by research and policies dating back at least to the Brundtland report (World Commission on Environment and Development, 1987), the prosperity and well-being of current and future generations critically depends on preserving this natural capital base. At present, however, the opposite is happening. The great acceleration of economic and social activity that occurred during the 20th century brought with it huge increases in resource use and pollution (Steffen et al., 2011, 2015). As developing regions increasingly shift towards the lifestyles of advanced economies, the pressures on ecosystems look set to grow.

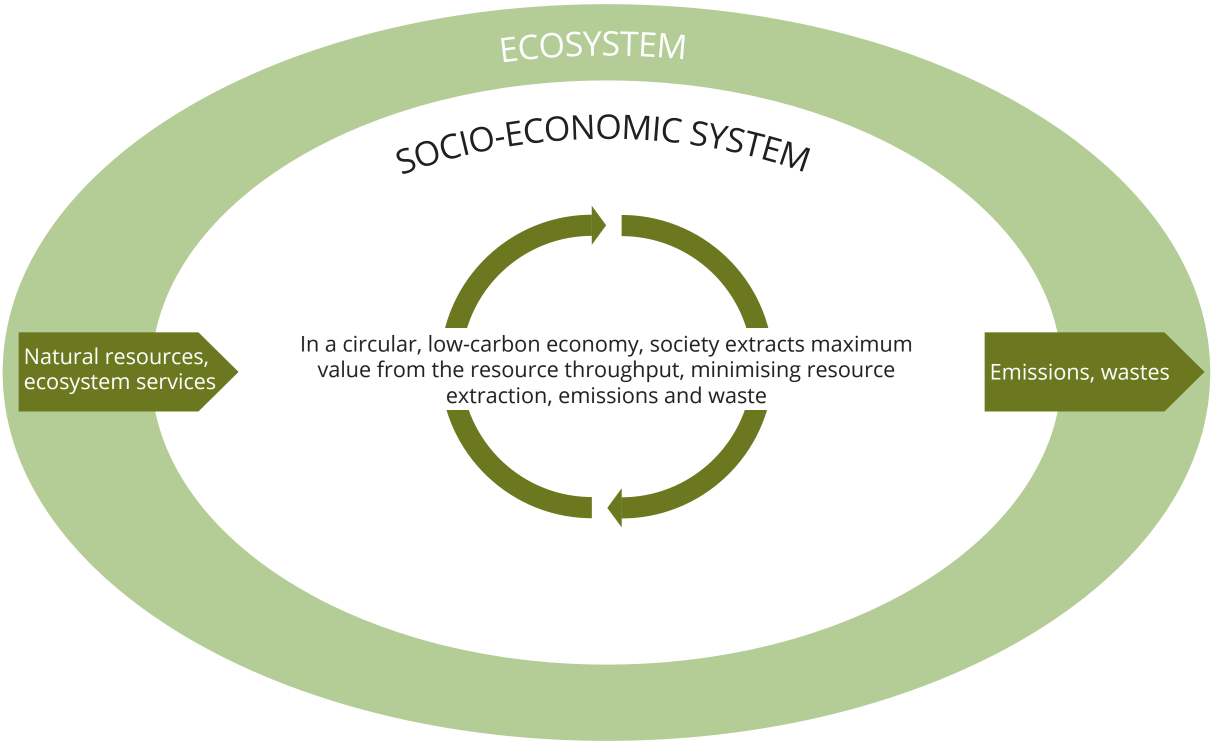
To achieve its 2050 vision of living well, within the limits of the planet (EC, 2013), the EU will need to substantially reduce environmental pressures. This will mean decarbonising and dematerialising Europe's consumption and production patterns, and shifting away from non-renewable resource use and towards the sustainable use of renewable, bio-based resources. These objectives are covered in separate EU strategies addressing climate neutrality, circularity and the bioeconomy; in reality, these are closely connected, reflecting different dimensions of the same problem. For example, 60 % of greenhouse gas emissions arise from the production and use of goods (US EPA, 2015; IRP, 2019).

Sustaining and enhancing living standards while operating within environmental limits means extracting the maximum social and economic value from a greatly reduced resource throughput (Figure 1.1). As emphasised in the new generation of EU frameworks, this implies the need for economic transformation, meaning fundamental reconfiguration of production and consumption systems. The EU's circular economy action plan (EC, 2015a), for example, highlights both the interdependence of these frameworks and their focus on transformative change:

> 'The transition to a more circular economy … is an essential contribution to the EU's efforts to develop a sustainable, low carbon, resource efficient and competitive economy. Such transition is the opportunity to transform our economy and generate new and sustainable competitive advantages for Europe.'

([1]) Before the publication of the 2018 EU strategy for a climate-neutral Europe, *A Clean Planet for All*, the term 'low-carbon' was commonly used. This report uses both terms interchangeably.

Figure 1.1 The logic of the circular, low-carbon economy



Source: Based on EEA, 2014.

1.2.2 Production-consumption systems

Alongside the cross-cutting frameworks addressing economic transformation, research and policy increasingly target specific production-consumption systems, such as those concerning mobility, energy, shelter and food. In addition to addressing basic human needs, these systems also account for most of society's resource use, waste and emissions (Figure 1.2). Since 2015, the EU has developed broad strategies addressing the energy and mobility systems, notably the Energy Union and the 'Europe on the Move' agenda (EC, 2017; 2015b). There are also growing calls for the EU to develop a common food policy (IPES Food, 2018; EESC, 2017). Focusing on systems, rather than individual sectors or actors, is important to avoid rebounds and undesired side-effects, lock-ins and trade-offs.

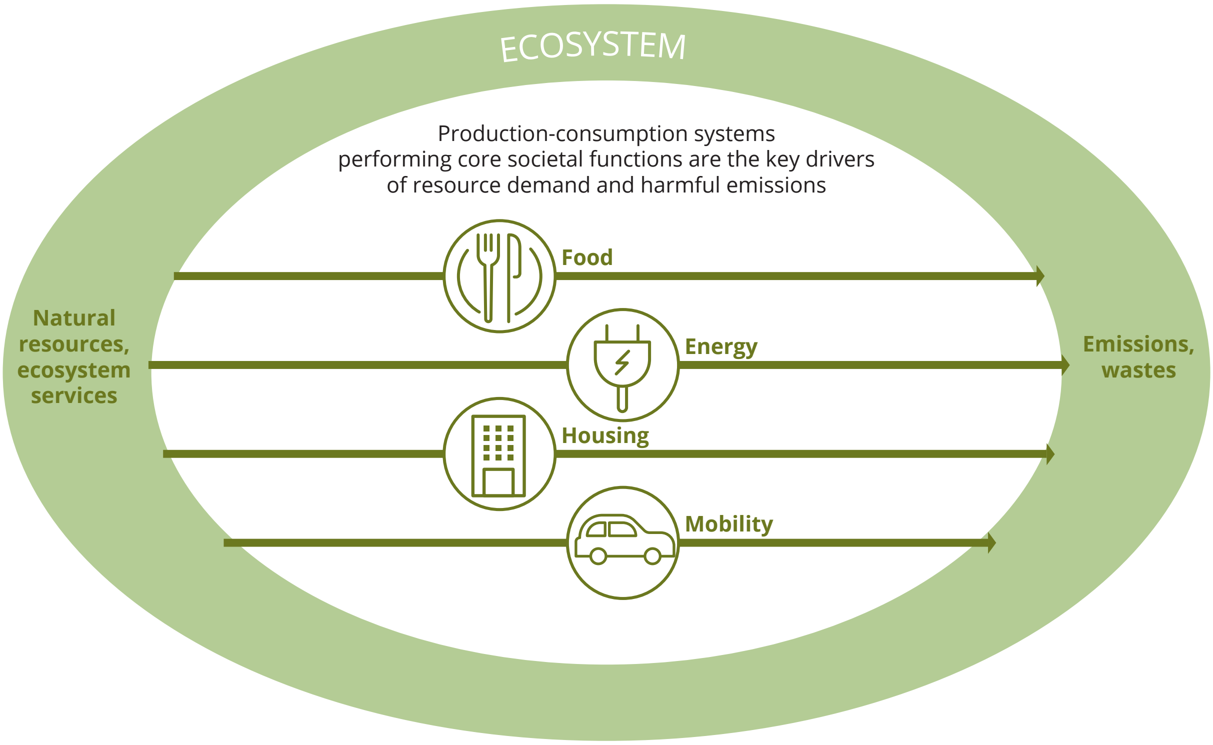
Transforming these systems cannot be achieved simply through technological fixes or incremental efficiency improvements. Transitions also require new business models, social practices, cultural norms and lifestyles, which not only offer opportunities for new jobs and growth but also imply major challenges linked to the phasing out of established structures and norms. The inherent unpredictability surrounding the emergence and impacts of new modes of consuming and producing means that transitions are highly complex and uncertain processes.

1.2.3 Knowledge needs

Creating a circular economy in Europe requires new knowledge in several areas. These include raw materials cycles and the role of producers, designers, manufacturers, consumers, and recycling companies. Innovative technologies, such as blockchain and big data analysis, may allow tracing of materials and better understanding the socio-economic processes involved. New forms of collaboration and co-creation between different stakeholders are also needed.

Within the framework of the EU circular economy package (EC, 2015a), the European Commission has developed a monitoring framework 'composed of a set of key, meaningful indicators that capture the

Figure 1.2 Key systems driving society's demands on natural capital



Source: Based on EEA, 2014.

main elements of the circular economy (EC, 2018c), which aims to gather knowledge to help 'set new priorities towards the long-term objective of a circular economy'.

The EEA supports this knowledge development. In 2016, it published its first report on the circular economy, *Circular economy in Europe — Developing the knowledge base* (EEA, 2016a). This explains the concept of a circular economy, addressing key characteristics, benefits, enabling factors and its representation in established monitoring systems. It emphasises the need to chart progress and identify where more work is needed — some existing indicators are useful, but others will be needed to help guide the development of supportive and flexible policies.

The EEA's second circular economy report, *Circular by design — Products in a circular economy* (EEA, 2017), addresses the importance of product-related aspects and the systemic drivers of product design and use. The report highlights the importance of smarter product design and the environmental and social benefits of increasing reuse, repair, redistribution, remanufacturing and refurbishment. It identifies the need for better knowledge about the link between products, underlying business models and the societal infrastructure and governance that influence life cycles. In particular, it emphasises that there are no one-size-fits-all solutions for the better design of products for circular use.

The third report, *The circular economy and the bioeconomy — Partners in sustainability* (EEA, 2018c), addresses the sustainable use of renewable natural resources and the circularity of bio-based products within a broader systemic approach. As the report explains, a sustainable and circular bioeconomy would keep resources at their highest value for as long as possible through the cascading use of biomass and recycling, while ensuring that natural capital is preserved. This requires coordinated action and careful consideration of possible trade-offs. Policy interventions should aim to reduce environmental pressures along entire product life cycles. Technological innovation should be embedded in wider system innovation that also tackles consumer behaviour, product use and waste management.

2 Waste and material flows and circularity

2.1 Introduction

The available data on circularity reflect the historically predominant policy focus on downstream, end-of-pipe solutions. For the most part, EU legislation and policies have been developed to manage waste; they set out tangible objectives and a clear framework, thereby providing legal certainty for investment. This chapter covers a few examples of the type of information that is available, mostly developed by Eurostat.

However, a circular economy (Box 2.1) goes well beyond waste reduction, encompassing aspects such as resource access, use and impacts; sustainable design; consumption patterns and production processes; and repair and remanufacturing (Figure 2.1). It transcends solely technical aspects, as economic and social aspects also play an important role. For example, who owns raw materials and are the owners responsible for keeping the raw materials in the economic value cycle? What is the role of consumers? Will there be a wider change, from ownership to use of products and services? These questions illustrate the range of issues for which new data and knowledge are needed.

2.2 Key trends for waste

To monitor the implementation of the EU's policy on waste (EU, 2002), Eurostat collects data every 2 years from EU Member States and neighbouring countries on the production of waste from all economic sources, including businesses and private households, and its management.

2.2.1 Waste statistics

In 2016, the total waste generated in Europe ([2]) by all economic activities and households amounted to 2 678 million tonnes. Mineral waste from, for example, the construction and demolition sector or the mining and quarrying sector represent the largest category — about 70 % of all waste generated. Major mineral wastes are somewhat uncertain and are therefore not included in this analysis.

Although data on EEA countries other than the 28 EU Member States are sometimes available in Eurostat, not all databases have full coverage. The graphs in this chapter therefore only include EU Member States plus Norway to maintain consistency throughout the chapter.

Figure 2.2 shows the distribution of waste types, excluding major mineral waste, for 2016, which amounted to 749 million tonnes. Overall, 41 % of the total waste generated is mixed, with household and similar waste accounting for about 54 % of this. Recyclable waste — metals, paper, glass, rubber, plastic, wood and textiles — amount to 249 million tonnes or one third of all waste generated.

Figure 2.3 shows that the total amount of waste generated in Europe between 2010 and 2016 increased by 5 %, while the gross domestic product (GDP) for the same group of countries increased by 16 % (Eurostat, 2019c). This represents a relative decoupling of waste generation from economic growth but no absolute decline in waste generation.

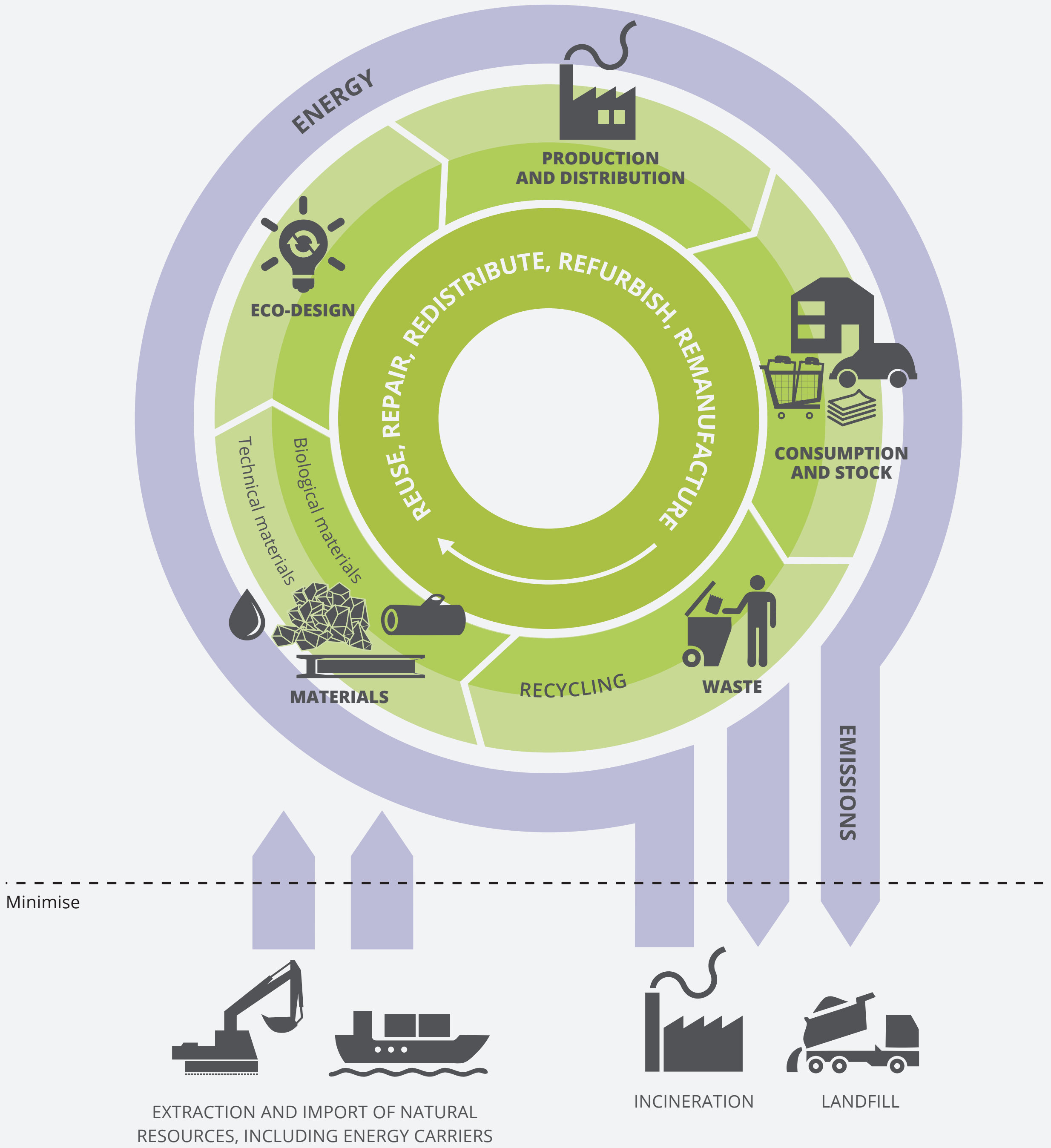
Waste treatment data for the EU plus Norway reveal that, between 2010 and 2016, there was a 3 % increase in the volume of waste sent for treatment, from 717 million tonnes in 2010 to 740 million tonnes in 2016. Figure 2.4 shows that, during this period, the proportion of waste that was recycled increased from 50 % to 54 % and the share of waste incinerated with energy recovery increased from 12 % to 18 %. Landfilling of waste decreased from 29 % to 24 % and the proportion incinerated without energy recovery

([2]) EU Member States and the other EEA member countries for which data are available — Iceland, Liechtenstein, Norway, Montenegro, North Macedonia, Serbia and Turkey.

Box 2.1 The concept of a circular economy

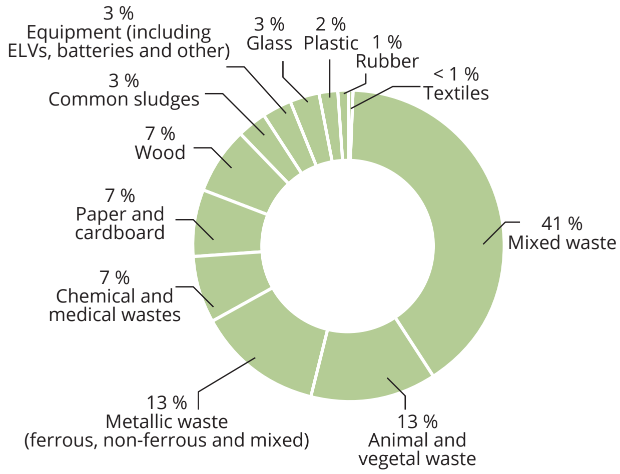
Several graphical representations of the circular economy exist; the EEA uses this simplified one (Figure 2.1). Waste generation and material inputs are minimised through eco-design, the reuse of products and the recycling of waste. Reuse, repair, redistribution, refurbishment and remanufacturing are at the core of this approach (inner circle). The middle circle represents material flows in the recycling loop, distinguishing between abiotic technical materials, such as metals and minerals, and biological materials. The outer circle represents overall energy flows.

Figure 2.1 The EEA's circular economy concept



Source: EEA, 2016a.

Figure 2.2 **Waste generation in the EU + Norway from economic activities and households by waste type for 2016 (excluding major mineral waste)**



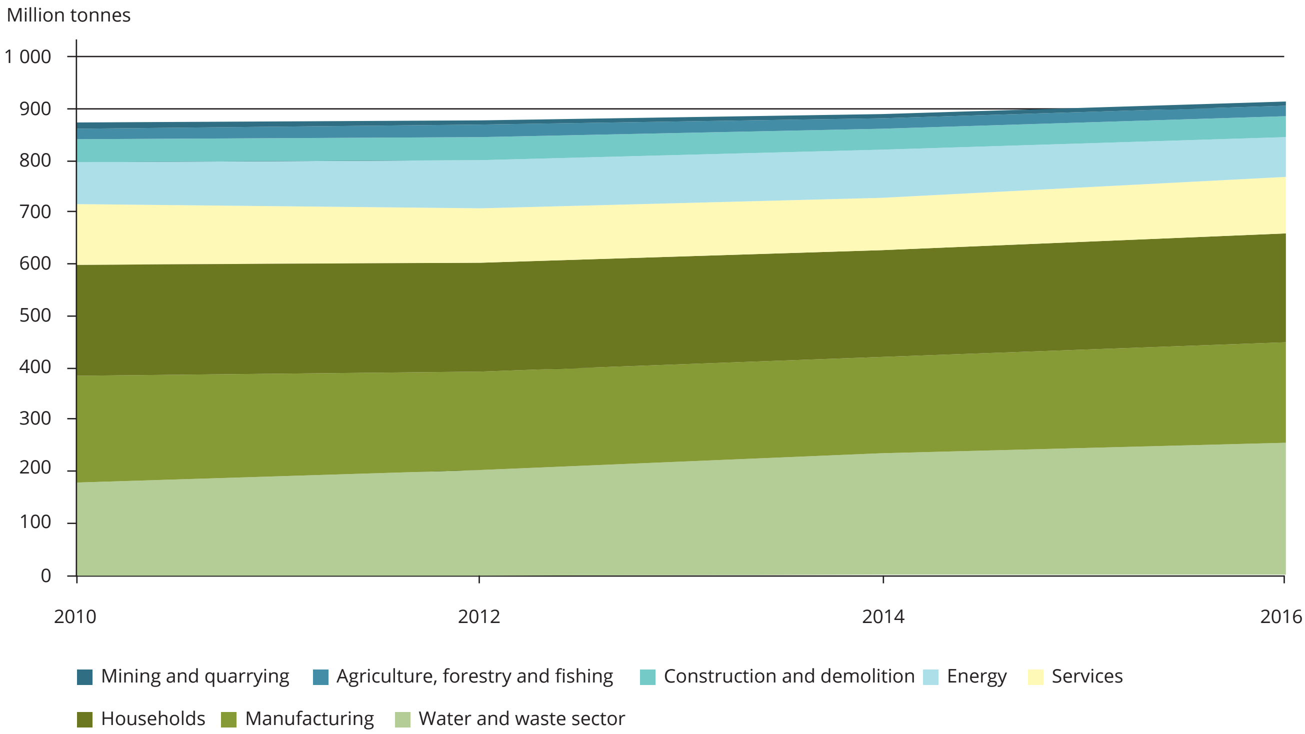
Source: Eurostat, 2019d.

fell from 6 % to 3 %. Although large differences between individual countries exist, these overall shifts in waste management are in line with the principles of the waste hierarchy as laid down in the EU Waste Framework Directive.

These favourable trends have been strongly driven by improvements in municipal solid waste (MSW) management, which accounts for about one third of total waste, excluding major mineral waste. This is consistent with the fact that many policies on waste management focus on MSW or specific waste included within it.

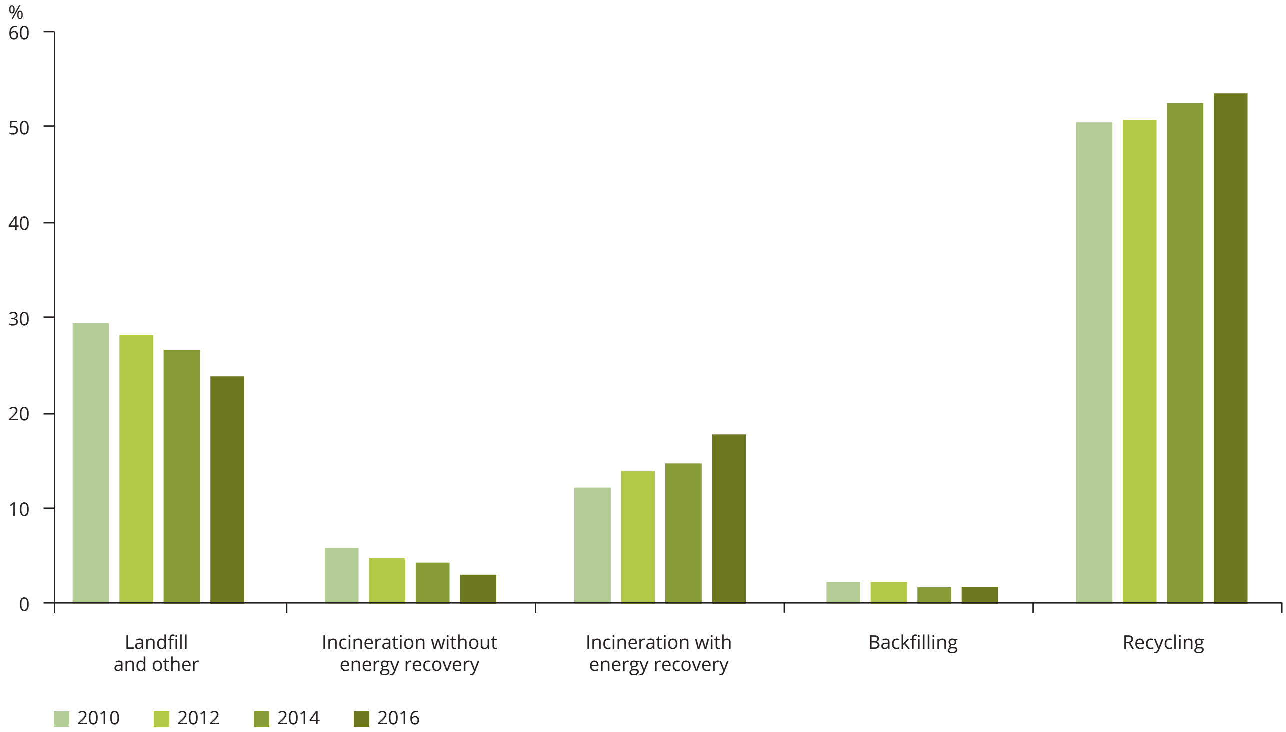
Although MSW generation per person increased in some Member States, overall EU statistics show a decrease from 523 kilograms per capita in 2007 to 486 kg/capita in 2017 (Eurostat, 2019i). During this period, the absolute amount of MSW treated stayed relatively stable at around 250 million tonnes (Figure 2.5) but there was a significant reduction in landfilling (− 46 %) and incineration without energy recovery (− 76 %), implying a shift towards recovery activities — incineration with energy recovery (+ 88 %), material recycling (+ 24 %) and composting (+ 30 %).

Figure 2.3 **Waste generation in the EU + Norway by economic activity and households, 2010-2016 (excluding major mineral waste)**



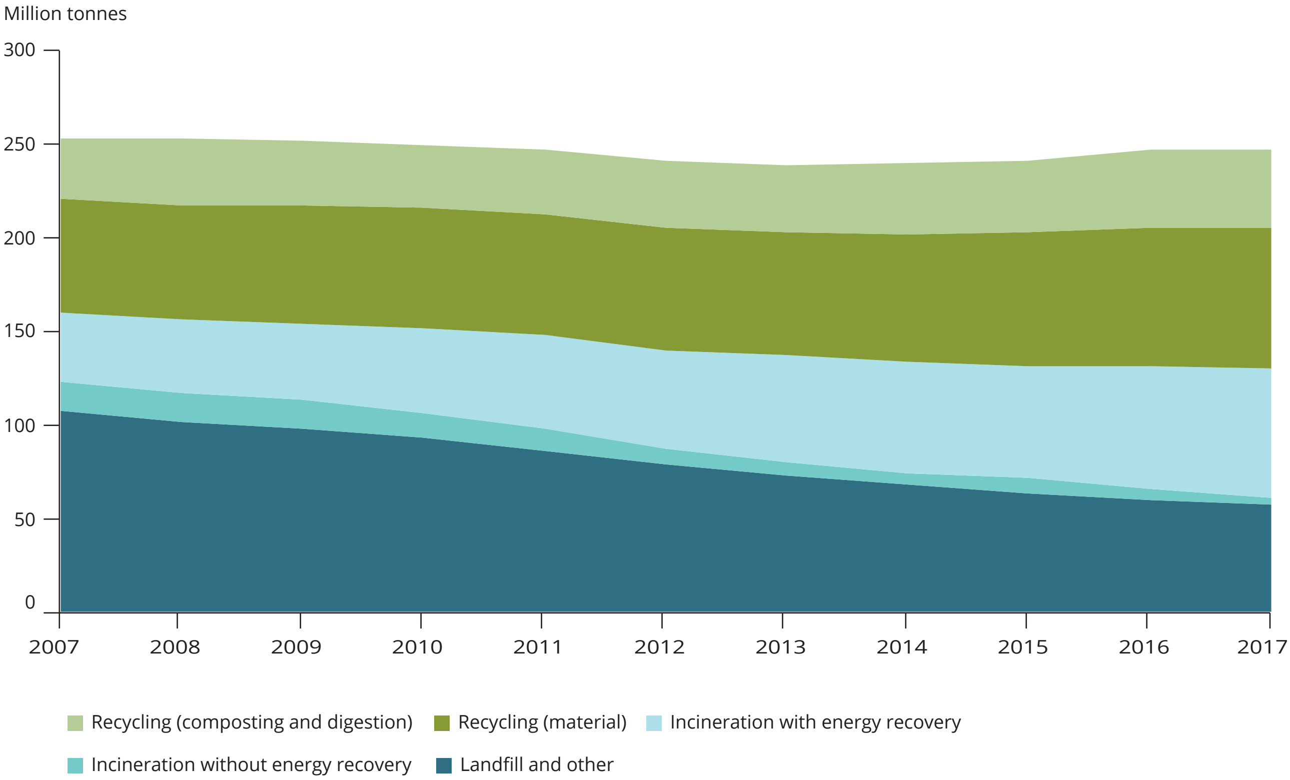
Source: Eurostat, 2019d.

Figure 2.4 Waste treatment in the EU + Norway, 2010-2016 (excluding major mineral waste)



Source: Eurostat, 2019j.

Figure 2.5 Municipal solid waste treatment in the EU + Norway, 2007-2017



Source: Eurostat, 2019i.

On top of MSW data, in line with specific EU directives, data are also available for specific waste streams, such as packaging, waste electrical and electronic equipment (WEEE), end-of-life vehicles (ELVs) and batteries. In the future, data on food waste prevention will be also available.

2.2.2 What do waste statistics say about achieving a circular economy in Europe?

The WFD defines the waste hierarchy — a ranking of waste management options based on assumed environmental impacts — as an overarching principle of EU and national waste policy. It prioritises waste prevention, followed by preparation for reuse, recycling, other types of recovery and disposal, with landfilling as the least desirable option. When followed, it should result in improved resource and energy efficiency, reduced use of virgin materials and reduced greenhouse gas emissions and pollution.

The strength of the waste hierarchy is that it is a clear and practical tool for decision-makers, with well-defined measures at each tier. Thanks to both its clarity and specific waste management targets following the hierarchy, its implementation has been successful. The EU statistics on MSW show a clear shift away from disposal and towards recycling and energy recovery (Figure 2.5). Furthermore, the implementation of the waste hierarchy has led to a mature waste management sector, creating new jobs and economic growth. The number of people employed in the waste sector in the EU has increased from almost 840 000 in 2011 to around 950 000 in 2016; more than 50 % of these people are active in waste collection. Over the same period, the value added created within the waste sector increased by 15 % to EUR 52 billion in 2016 (Eurostat, 2019e).

Although recycling percentages have increased significantly at the expense of landfilling, there is no distinction in the statistics between open- and closed-loop recycling, or between high- and low-value recycling. Furthermore, waste statistics focus on sectors of origin — mining, construction, household waste, etc. — or waste type, such as paper, metals, plastics, and provide only limited information at the product level. But it is the product level that plays an important role in capturing the benefits of the circular economy, as the most value can be preserved by creating inner circles (Figure 2.1) through reuse, repair and remanufacturing. Quantitative data about reuse, repair and remanufacturing of products are largely absent from waste statistics, as these products never actually become waste.

2.2.3 The role of waste prevention

Waste prevention is an integral part of the circular economy. The systems thinking of prevention and its aim of avoiding waste generation, which in many cases can be translated as keeping products in the economy for as long as possible, is similar to the broader objectives of the circular economy. Specific waste prevention measures — for example promoting repair and reuse, selecting durable materials for product development and considering lifespan in product design — can contribute to the transition to a circular economy.

The EEA has recently published its latest annual waste prevention reports (EEA, 2019a), with a focus on preventing plastic waste. Plastic products' life cycles are, in many cases, contrary to the circular economy principles (Figure 2.1). Moreover, while the demand for plastic products is increasing globally, their recycling, including in Europe, remains low compared with other common materials.

The EEA's 2019 waste prevention report tried to map the actions that countries in Europe are taking to prevent the generation of plastic waste. In total, 173 national or regional measures were identified, most of which are voluntary agreements between various stakeholders or information campaigns. A lot of measures have been quite successful. Examples include Italy's efforts to promote package-free products that are sold loose or in bulk. One widely successful measure is the introduction of charges for single-use plastic carrier bags in many countries (mandated by EU legislation) that has brought about an impressive reduction in the amount of bags consumed. In Greece, the measure took effect in January 2018 and has led to an 80 % reduction in lightweight carrier bag consumption in larger stores, such as supermarkets. A similar levy in Portugal, as of 2015, has reduced plastic bag consumption by more than 90 %. Switzerland achieved a reduction of 84 % within a year of the levy being implemented. In Switzerland, other types of plastic bags were already chargeable in grocery stores, which indicates that a potential shift from lightweight to thicker bags may have been avoided.

With the notable exception of plastic carrier bags, prevention measures are, in general, difficult to monitor and evaluate in terms of their success. Prevention is normally reflected in waste generation, which is a parameter influenced by other socio-economic developments, such as economic and population growth.

The report concludes that more effort is needed in the so far unexploited areas of reducing hazardous substances in plastic products and innovations in their design (both are forms of waste prevention). However, more specialisation of measures is needed: specific polymers or plastic products whose use is currently not in line with the circular economy (single-use plastics, most environmentally impactful plastic types) should be targeted. In this respect, the recent adoption of the Single-Use Plastics Directive (EU, 2019) is an important step in that direction.

Recently, the European Commission has also identified textiles (apparel and fabrics) as a priority product category for the circular economy (EC, 2019d). Europeans purchase on average 26 kg of textiles per person per year.

The system of production and consumption of textiles has huge environmental, climate and social impacts. The EEA (EEA, 2019) has identified resource use, land use, climate change and chemicals as among the environmental and climate hot spots for textiles. From a consumption perspective — looking at the pressures from the supply side for consumption in the EU — clothing, footwear and household textiles is the fourth highest impact category for resource use and water use (after food, housing and transport); the second highest for land use; and the fifth highest for greenhouse gas emissions (EEA, 2019). Pressures from the upstream supply chain for EU-28 consumption of clothing, footwear and household textiles include 1.3 tonnes primary raw materials; 104 m^3 water use; 703 m^2 land use; and 654 kg CO_2 equivalents per capita (EEA, 2019d).

A circular system of textiles would be beneficial from economic, environmental, climate and social perspectives. It requires innovative production methods, new business models, circular behaviour and supporting policy measures in all stages of the life cycle.

2.3 Resource flows and efficiency

Tools for monitoring of material flows at macro-level look at the circular economy from an economy-wide perspective. These can help capturing system-wide effects and assessing whether absolute reductions in resource use and waste flows have been achieved (Geyer et al., 2016; Mayer et al., 2019).

Over the past few years, an increasing body of work has provided insights into the flows and stocks of products, materials and waste (EEA, 2019b, 2016b). Data on material use, waste and recycling are being collected through Eurostat, and academics and the Joint Research Centre (JRC) of the European Commission have studied these data to produce material flow analyses and Sankey diagrams that provide visual snapshots of the material state of Europe's economy. Waste data, which have become increasingly available over time as a result of the development of European waste policy, are a second source of information on the circularity of the European economy. In the near future, the newly adopted revised WFD (2018/851) will make available new data, as it includes reporting obligations for reuse. The European Commission is currently developing the reporting guidelines and calculation rules, while progressive reuse and recycling targets for MSW have been adopted for 2025, 2030 and 2035. The European Commission is mandated to propose targets for preparing MSW for reuse by 2024, as well as preparing for reuse and recycling targets for a number of specific waste types.

2.3.1 Aggregated material flows

Data on aggregated material flows provide a birds-eye view of the state of circularity of the economy. Based on data from Mayer et al. (2019), the following overall picture can be constructed at the level of four aggregated material types: non-metallic minerals, metal ores, biomass and fossil fuel energy materials/carriers (Figure 2.6).

On the input side, it is clear that domestic extraction is very important for non-metallic minerals and biomass. For both of these, more than 80 % of the materials that enter the European economy are sourced within the EU. However, metal ores and fossil fuel materials are mainly imported, highlighting Europe's import dependency for these. In the case of metal ore, domestic extraction generates large volumes of waste. During the extraction of 0.02 gigatonnes per year (Gt/year) of metals, almost a 10-fold amount of waste is generated (0.17 Gt/year), which does not enter the material cycle but is disposed of immediately.

Europe also exports processed materials. In the case of the minerals and biomass exported, quantities fall within the same range of magnitude as those for imports. For metal ores and fossil fuel materials,

Figure 2.6 **Material flows through the EU economy, plotted on the EEA circular economy framework (gigatonnes per year), 2014**

Source: Data from Mayer et al., 2019, based on Eurostat, 2019f, 2019g, 2019h.

exports are lower than imports. The export of processed metal ores is, however, significant, as about one third of all processed metal ores are exported, e.g. as vehicles or machinery.

Metals and minerals are used solely as materials, while the majority of biomass and fossil fuel materials are processed for energy production. For biomass, only 19 % are used in material applications, whereas only 3 % of fossil materials are used as materials in, for example, producing chemicals and plastics. The prevalence of energy applications implies that a large fraction of fossil fuel materials and biomass disappear from the material cycle and are no longer available for closing the loops in a circular economy.

Materials that are used in material applications often stay for a time in the economy as societal in-use stock. This stock building is especially important in the case of minerals and metals for which 94 % and 78 %, respectively, are added to stock in the form of buildings, infrastructure and durable products, for example. The remainder ends up as waste within a short time frame. In the case of biomass and fossil fuel products, only 50 % of the material applications are added to stock, while the other 50 % are lost through emissions and waste.

Nevertheless, for all four material types, there is a net build-up of stock, as the amount of material that is discarded annually from stock is smaller than the amount added. The total volume of materials present within societal stock cannot be assessed based on the material flow data. In recent years, several efforts have been made to estimate societal in-use stocks for different types of materials (Graedel, 2010; Krausmann et al., 2017) and products, such as ELVs, WEEE and batteries (Huisman et al., 2016). Although challenging to measure and estimate, this information can be useful in generating scenarios of future use intensity, expected waste flows, and reuse and recycling potential.

Of the waste that is generated, only a limited fraction is recycled. Overall, about one third of mineral, biomass and fossil fuel waste is recovered by recycling, but there is a big difference between these material types. In the case of minerals, the material mass that is lost from the material cycle is mainly added to societal stock and will remain in use for years or even decades, before ending up in future waste flows and potential recycling cycles. In the case of biomass and fossil fuel materials, losses are mainly because their use in generating energy and recycling accounts for only 9 % and 3 %, respectively, of the total processed material. In the case of metal waste, recycling is more prevalent, as two thirds of metal waste is recycled. The remaining waste is disposed of, either by incineration or landfilling.

At aggregated macro-level, across all product types, the EU economy has a yearly virgin material input of 5.8 Gt primary domestic extraction and imports 1.5 Gt. Only 0.7 Gt of materials is recycled and reused as secondary material input (Mayer et al., 2019). The circular material use (CMU) rate is an indicator that measures the share of recovered materials used in the economy, thus saving the extraction of primary materials. It is defined as the ratio of circular use to overall material use. The CMU rate of the EU economy in 2016 was 11.7 % (Eurostat, 2019a).

The understanding that the current economy is far from circular serves as a call for action to all stakeholders involved. At the same time, however, such insight is not sufficient to determine what kind of action is needed and where, mainly because these aggregated data represent a snapshot of the economy at a specific time, often many years in the past, and at a level of aggregation that does not allow us to identify the levers for change.

2.3.2 Individual materials

Next to data aggregated over different materials and products, material flow data are also available for individual materials. BIO by Deloitte (2015) and Passarini et al. (2018) have developed a comprehensive overview of material flow Sankey diagrams for a wide range of (critical) raw materials. Such diagrams provide insights into the level of imports, use, recycling, losses and exports of individual materials at EU level. They show that:

- There is a wide variety in material flows between different materials within one material domain.
- The degree of functional recycling — retaining the full function of the material in the next use — of different critical materials ranges significantly, from, for example, 0 % for dysprosium to 29 % for europium.
- For certain materials, such as phosphorus, Europe exhibits a strong linear consumption pattern, with European soils serving as a final sink for around 81 % of the material used.

Box 2.2 indicates that real availability of a material, can only be assessed by combining information on the supply risk and recycling input rates.

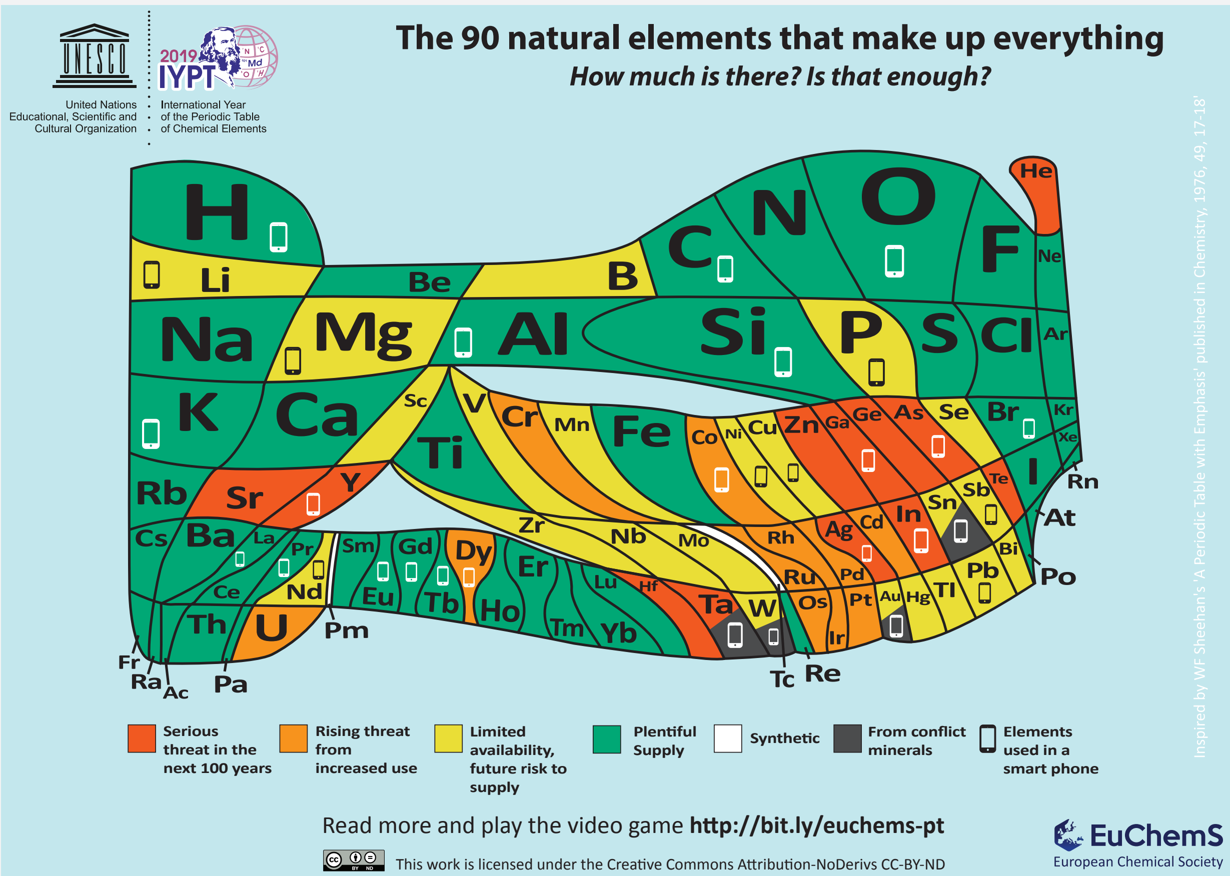
2.3.3 Going beyond material flows

While material flow statistics point to the most prominent circularity gaps, it is still difficult to translate such insights into action. An important reason for this is that material flow statistics do not convey information about the products in which the materials are used. Material flow statistics also do not include several key stages of the circular economy, such as reuse, remanufacturing or repair of products. Furthermore, they provide little insight into the build-up of or decrease in material stocks within the economy, which is an important factor if our economic system's ability to close material loops is to be understood. Circularity metrics at the level of product flows and stocks are one important data gap in this respect (Parchomenko et al., 2019). For construction materials, for example, it is clear that the growth in building stocks does not allow the sourcing of all materials needed from recycled waste. In addition, there is a lack of information on waste composition.

Box 2.2 Differences in circularity of metals

A combination of information on supply risk (Figure 2.7) and on recycling input rates (Figure 2.8) gives a better insight into real availability.

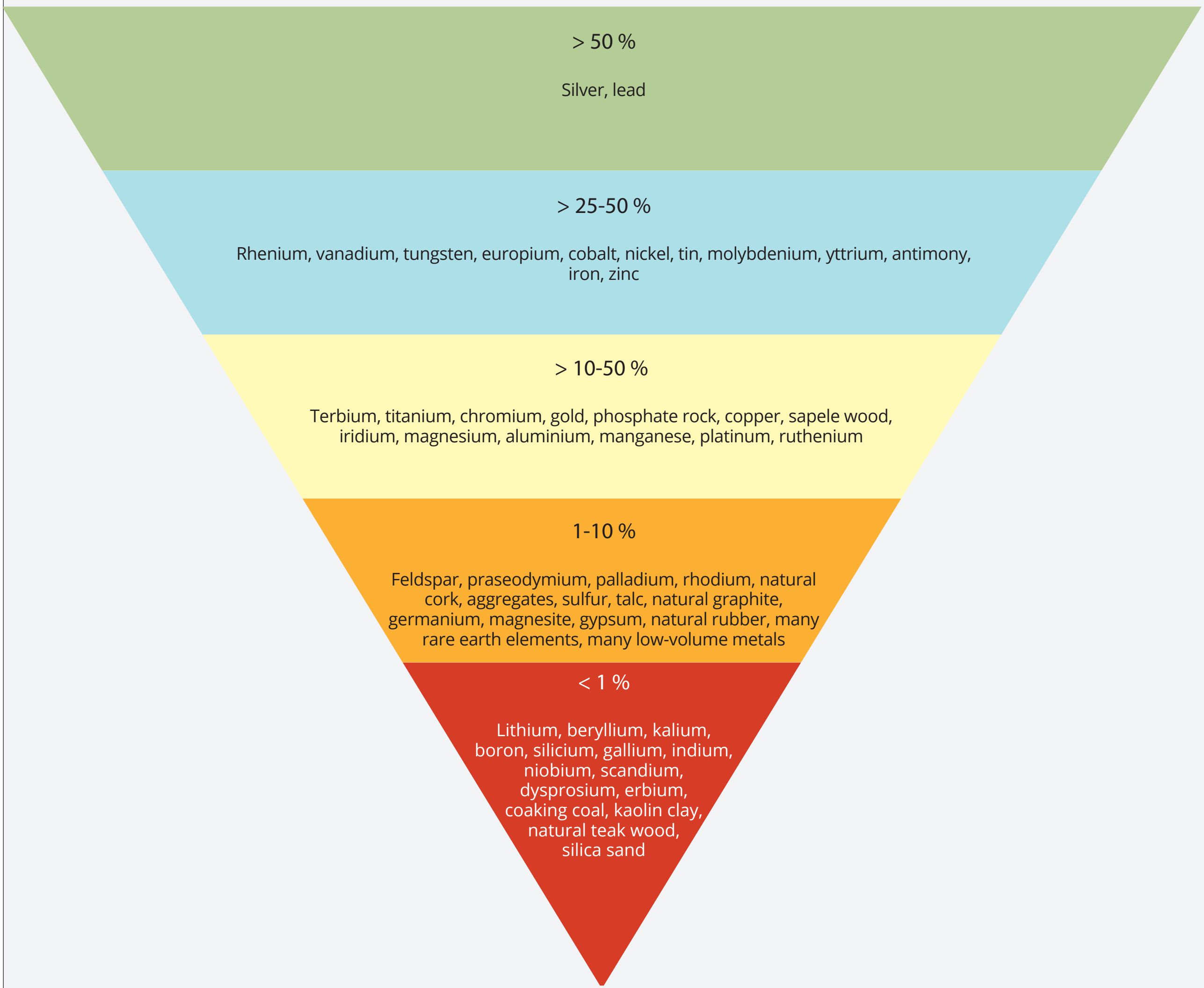
Figure 2.7 Mendeleev's periodic table of 90 natural elements adapted to reflect their availability and supply risk



Source: European Chemical Society, 2019.

Box 2.2 Differences in circularity of metals (cont.)

Figure 2.8 End-of-life recycling input rates for selected materials (2018)



Source: EEA own elaboration based on Eurostat, 2018.

3 Enabling the transition

Moving away from a centralised, optimised, linear economic system towards a more experimental and decentralised circular economy faces many barriers. Consumer behaviour, industrial ecosystems, infrastructure, financing schemes and policies have co-evolved over decades, based on decisions and efficiency improvements reflecting a linear logic. These system elements are closely intertwined and aligned with each other, creating strong lock-ins (World Economic Forum, 2014). The need to transform production-consumption systems in ways that reconcile economic prosperity with environmental limits presents a major governance challenge. Although Europe's core societal systems have undergone fundamental transitions in the past, such changes were seldom the outcome of sustainably driven processes.

Transitions are society-wide processes, engaging multiple stakeholders and depending critically on the emergence of innovation in technologies, social practices, organisational forms and business models. The complexity and uncertainty of systemic change means that governments cannot simply plan and implement transitions. However, they play an essential enabling role, for example by promoting experimentation and learning; by facilitating structural change through education and welfare policies; and by providing direction and coherence to society-wide processes by developing visions, strategies and targets.

3.1 Integrating circularity principles into business innovation processes

From the introduction of the circular economy in the European policy debate, the concept of a circular economy was framed as a business-oriented response to resource and environmental challenges (EMF and MCBE, 2015; EC, 2015a). The business potential of a circular economy has been the topic of many reports over the last 5 years. There is less evidence, however, on implementing circular business opportunities and circular business transformations.

Data from Eurobarometer surveys provide some insights into the focus of business action related to the circular economy. A survey on resource efficiency carried out in 2016 found that minimising waste, saving energy, and reducing material and water use are significant actions being undertaken by small and medium-sized enterprises (SMEs) across Europe, but this is mainly because they reduce internal production costs (TNS Political & Social, 2016). Table 3.1 shows that, in 2017, a large majority of companies reported taking action to minimise waste, but only one in four companies reported that they have changed their product design to improve reuse, repair or maintenance. Although these numbers had increased by 2 to 4 percentage points compared with 2015, SMEs still appear to be taking less action than large companies.

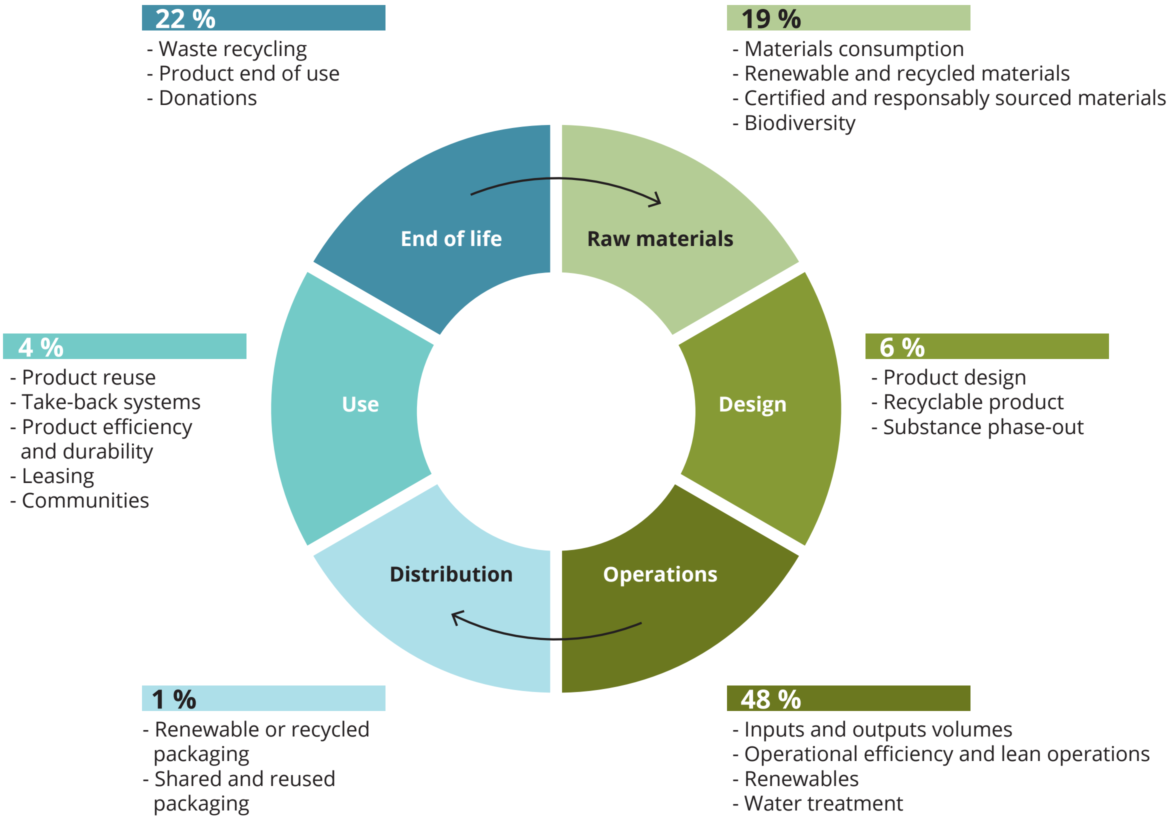
The fact that most companies still focus on waste and internal processes in their innovation efforts related to materials and circularity can also be observed in a survey on circularity metrics, carried out by the World Business Council on Sustainable Development (WBCSD), based on interviews with 39 companies in 2017-2018 (WBCSD, 2018). While 76 % of respondents were effectively monitoring circularity aspects related to their company, almost 48 % of the circular metrics identified related to the internal operations or processes of the business (Figure 3.1). The end-of-life and raw materials phases accounted for another 41 % of the metrics identified. The design, distribution and use phases are rarely looked into by companies.

Table 3.1 Action related to circularity taken by small and medium-sized enterprises and large companies, based on a Eurobarometer survey, 2017

Action	Percentage of companies	
	SMEs	Large companies
Minimise waste	65	80
Reuse waste within the company	42	59
Improve design for maintenance, repair or reuse	25	27
Sell scrap materials to other companies	21	30

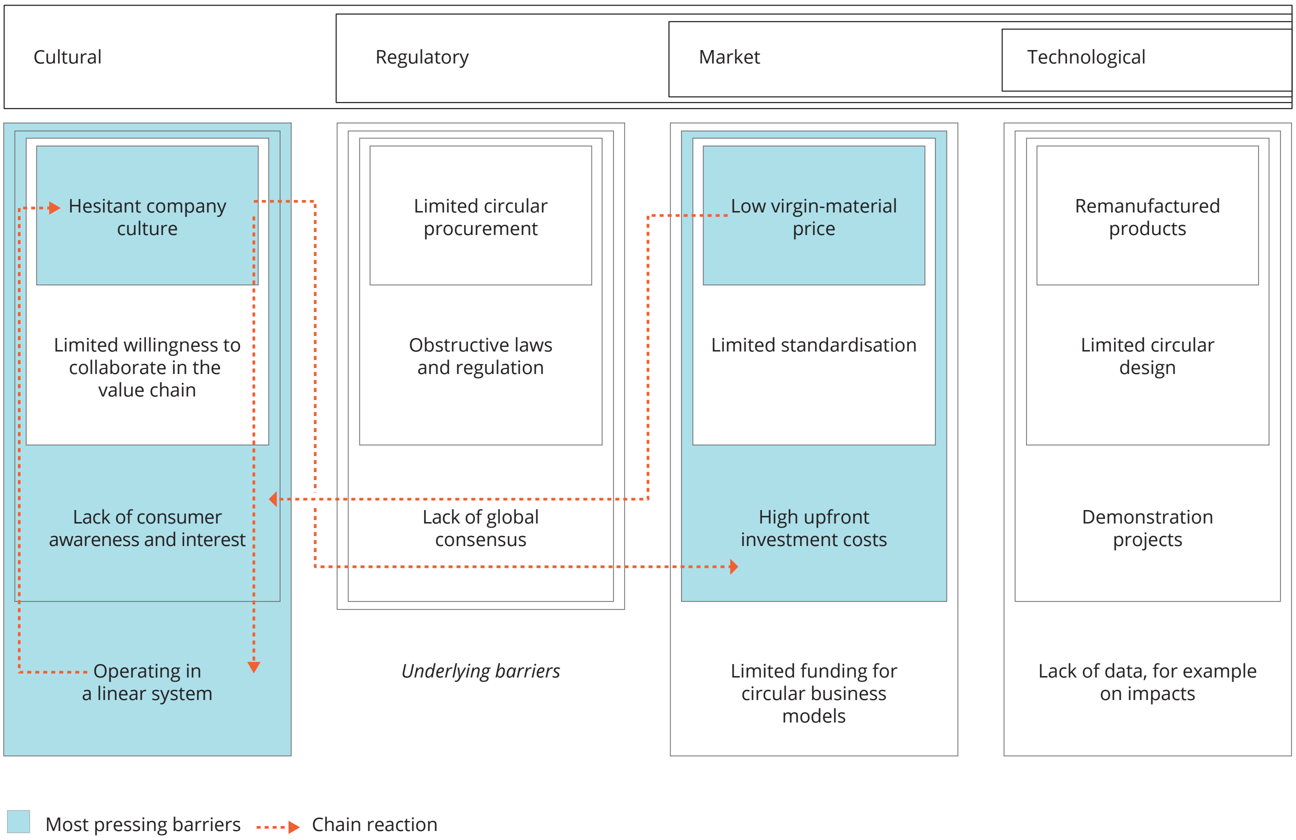
Source: TNS Political & Social, 2018.

Figure 3.1 Overview of circularity metrics used by companies, 2017-2018



Source: WBCSD, 2018.

Figure 3.2 Key circular economy barriers and their interactions



Source: Kirchherr et al., 2018.

Eurobarometer surveys identified some operational barriers for companies to adopt circular business models, such as complex administrative or legal procedures, the cost of meeting regulations or standards, and difficulties in accessing finance. However, more in-depth stakeholder has revealed that the most prominent obstacles are corporate culture, market factors and system complexity. Kirchherr et al. (2018) found that technological barriers were the least pressing obstacles identified by businesses and policymakers, whereas a hesitant company culture and a lack of consumer interest and awareness were the most significant (Figure 3.2).

Rizos et al. (2016) also found that the most frequently mentioned enabler of implementing circular economy business models was the company culture of staff and managers. The Ellen MacArthur Foundation (2017) found four major reasons for the difficulties encountered in the growth and mainstreaming of circular models.

1. The systemic nature of the circular transition and its associated transition costs. A circular business model nearly always necessitates redefining roles along the value chain, for both suppliers and customers.

2. Mindsets and a lack of awareness. In many cases, companies are still not aware of the costs and benefits that a shift towards a circular business model would bring.

3. Uncertainty about the direction of the transition. Those companies that do see the potential benefits are not confident that the transition will happen.

4. Policy barriers. Existing laws and regulations obstruct novel business models and limit the scaling up of circular business models, but they are less relevant when it comes to initiating innovation.

In summary, cultural and systemic factors rather than technological ones appear to be the main barriers to

Box 3.1 Business drivers — smartphone repair shops in Denmark

In their 2016 study, Riisgaard et al. (2016) reported that 90 companies in Denmark operate viable businesses repairing smartphones that are driven by both cost savings and smartphone owners' ease of accessing repair services. Smartphone manufacturers have no incentive to stimulate repair activities, as their business models are based on selling as many units as possible. Additional advantages of the repair economy are that it generates local jobs while creating environmental benefits by extending the smartphones' lifetimes.

the circular business transition. Therefore, it is not surprising that established companies — both SMEs and large enterprises — encounter difficulties when trying to successfully initiate and scale up circular business models. Most circular business innovations are not currently initiated by companies within a certain sector (Box 3.1) but are driven by start-ups that do not have a legacy of existing customers, shareholders, employees, capabilities, etc. (Rizos et al., 2016). However, digital technologies can be an important enabler in facilitating companies to make the transition to circular business models by, for example, providing transparency throughout the value chain.

3.2 Design for systemic change

3.2.1 Circular by design

To preserve the value of products for as long as possible, their design stage is crucial (EEA, 2017). Decisions made during the design stage — for example on material use and assembly methods — determine to a large extent the product's environmental impact, durability, reparability, suitability for refurbishment or remanufacturing and recyclability. Eco-design is a systematic approach aimed at designing products in such a way that the environmental impacts during their life cycle are reduced (Maris et al., 2014). Many different eco-design strategies exist, focusing on different stages of a product's life cycle: choosing materials with less impact, reducing the amount of material used in a product, improving production processes, reducing transport and packaging, improving energy efficiency during use, etc. In addition, there are many eco-design principles that focus on improving the product's end-of-life potential, including designing for remanufacturing, designing for repair, designing for recycling and designing for biodegradability (Go et al., 2015). This multitude of design principles and strategies are often referred to as 'design for X' (Kuo et al., 2001).

Today, however, design puts more emphasis on a product's attractiveness — for example, its low price and fashionable features — than on its circularity potential. The number of products sold increases every year, fuelled by the availability of relatively abundant and cheap natural resources and energy, and by technological advances in mass production and automation. At the same time, product lifetimes continue to decrease, as a result of both a reduction in the technical lifespan of cheap consumer products and a trend in consumer behaviour towards seeking replacements more frequently (Wang et al., 2013; Wieser et al., 2016).

By designing products in a smarter way, their useful lives can be extended and circular end-of-life options can be anticipated and facilitated. To enable an efficient recovery of products, parts and materials, end-of-life strategies need to be planned early on in the design process and product features need to be adapted accordingly. Design strategies targeting the product's end of life can be divided into two categories, which can be combined: (1) strategies aimed at extending product lifetimes through maintenance, repair or refurbishment; and (2) strategies aimed at reusing products, parts and materials through remanufacturing, harvesting parts and recycling (Bakker et al., 2014). All strategies require product cleaning and checking and their non-destructive disassembly or reassembly, the feasibility of which is highly dependent on the product's design and configuration.

Circular strategies targeting inner circles, such as reuse, repair, remanufacturing and refurbishment, have so far received less attention than outer-circle strategies, such as recycling and waste disposal (Figure 2.1). As a result, inner-circle strategies are less mature. Nonetheless, circular product strategies offer significant environmental and economic benefits. For example, using products for a longer period avoids the use of natural resources and the environmental impacts associated with producing replacement products. It is therefore crucial that product design choices reflect both consumer preferences and circular end-of-life considerations.

During the design phase, attention also needs to be paid to a product's role within society and whether consumers need such a product or its services. The shift from product-based to service-based business models is a promising development that may promote shared use and product durability and reparability. However, increased access may also lead to increased consumption, while a reduced sense of ownership may result in fewer incentives for users to maintain and look after their products.

Circular product design needs to be supported by a well-tailored governance system and suitable infrastructure; there is little value in designing a product that can be recycled if the necessary infrastructure for collecting and processing recyclate is lacking (EEA, 2017). Suitable business models, as described by Bocken et al. (2016), also need to be in place. The probability, for example, that a washing machine designed for easy repair will actually be mended is highly dependent on the convenience and cost of repair services versus the purchase price of a new product. As a result, in a country with low labour costs and a high availability of technically skilled workers, these washing machines will have a higher chance of being repaired than the same machines sold in another country in which a repair sector is largely absent.

Careful monitoring and assessment of the impacts and benefits in different contexts will be essential throughout the transition process, as there is no one-size-fits-all solution for the creation of circular product cycles. Rebound effects, burden shifting or other trade-offs may result in undesired outcomes. For example, although the trend towards increasingly complex and multi-functional products may lead to lower material consumption, as one product can fulfil multiple needs, increasing miniaturisation and product complexity hampers disassembly and thus the potential for reuse and recycling.

The high degree of uncertainty over the effects of new business models, policy measures or design approaches underlines the need for experimentation to become part of the innovation process while effects are monitored throughout the whole system and adapted along the way.

3.2.2 Clean material cycles

An important barrier to the circular economy transition is the presence of hazardous or persistent substances in waste streams, which pose potential risks to human health or the environment when they re-enter the product cycle through recycling. This may lead to the accumulation and unintended spreading of chemical substances in secondary materials, which will negatively affect their market value, restrict downstream applications and result in potential risks to health and the environment (Bodar et al., 2018). An example is additives, such as plasticisers in packaging materials (Groh et al., 2019) and textiles (Rovira and Domingo, 2019). Legacy substances — chemicals that are prohibited or severely restricted by product law, although they may still be present in older products — require special attention, as they can re-enter the material loop through the recycling system. Examples include certain brominated flame retardants and heavy metals in waste electrical and electronic equipment (WEEE) (Chen et al., 2012), cadmium pigment in consumer plastics (Turner, 2019) and asbestos in construction and demolition waste (Gualtieri, 2013). Furthermore, modelling of paper recycling showed that, even if the use of bisphenol A in thermal paper were banned completely, the chemical would remain present in recycled paper for an estimated 31 years (Pivnenko and Fruergaard, 2016). Hazardous substances in recycled waste streams may also lead to new risks, as the exposure and environmental emission routes through a new product's application may be different from those of the original product. This calls for appropriate risk management tools to control the resulting risks (Bodar et al., 2018).

To prevent chemicals of concern from (re-)entering the material stream, measures can be taken at the end-of-life stage by, for example, improved physical sorting of waste and chemical contaminant removal (Bernard and Buonsante, 2017). Bodar et al. (2018) suggest including obligations in the EU's Registration, Evaluation, Authorisation and Restriction of Chemicals (REACH) Regulation that require the manufacturers of new chemical products to explicitly address the re-entrance of chemicals into material loops, anticipating exposure pathways and scenarios that might emerge in a circular economy. Eventually, such restrictions may trigger innovation efforts to phase out harmful chemicals and develop safe, non-toxic and more sustainable alternatives. For example, products that have a high risk of being spread in the environment could be made either from materials that biodegrade or into non-toxic degradable products (WEF et al., 2016). Creating products that are safe by design not only reduces health risks during production and use but also facilitates the future use of recovered materials in a circular economy. This, again, emphasises the importance of the design phase.

Clean material cycles — those that are free from undesired contamination — are crucial for maintaining material quality in recycling processes. Trust in material performance and safety, in addition to the price, will largely determine whether or not manufacturers will be willing to use recycled materials and consumers will be prepared to buy products made of them. Access to sufficient information on the presence and concentration of contaminants in recycled materials is crucial for customer acceptance as well as compliance with legal health and environmental requirements.

3.3 Changing consumer behaviour

Consumer behaviour is one of the key levers for enabling the transition to a circular economy. It is both a strong and a challenging lever. Many businesses typically follow mainstream consumer behaviour and attitudes to identify market potential for new products and services. Similarly, consumer behaviour also determines the space available for policy initiatives stimulating sustainable and more circular behaviour. According to this reasoning, public interest in a more sustainable or circular society is crucial for the viability of new business models or policy measures that stimulate shared use, reuse, repair or recycling.

3.3.1 Availability of data on consumer behaviour

Although few data are available about consumer behaviour related to the circular economy, European citizens regard resource efficiency in general as very important. For example, a 2014 Eurobarometer survey showed that a large majority of respondents believe that a more efficient use of resources would be beneficial for quality of life, economic growth and employment opportunities (TNS Political & Social, 2014). The results of this survey include the following.

- Almost 9 out of 10 respondents agreed that their country generates too much waste.
- A similar number of respondents take action to reduce the amount of household waste they generate and only 43 % believe that their household generates too much waste.
- The most common action that respondents mentioned taking to reduce the amount of waste generated by their household is avoiding food and other types of waste by buying exactly what they need (83 %).
- Among the respondents who said they do not make any effort to reduce their household waste, the most frequently mentioned reasons are related to the belief that it is the responsibility of the producers to reduce waste, not theirs (41 %), or that they tend to throw things away, as it is difficult or too expensive to get them repaired (39 %).
- About half of the respondents have tried one of the following alternatives to buying brand new products: buying a remanufactured product (35 %), using sharing schemes (27 %) or leasing/renting a product instead of buying it (21 %).
- More than three quarters of respondents (77 %) would rather repair their goods than buy new ones, but ultimately they have to replace or discard them because they are discouraged by the cost of repair and the level of service provided.

An earlier Eurobarometer survey from 2011 (Gallup Organization, 2011) provides additional data on consumers' attitudes to circular solutions.

- Almost 7 out of 10 (68 %) EU citizens said that they were willing to buy products such as furniture, electronic equipment and textiles second hand.
- In almost all EU Member States, respondents were more likely to say that they would buy second-hand furniture than that they would buy second-hand electronic equipment or textiles.
- Almost 6 out of 10 (57 %) EU citizens who would not buy certain items second hand said that their concerns about quality and usability prevented them from doing so. One out of two interviewees mentioned health and safety concerns.
- More than 8 out of 10 (86 %) EU citizens said they would buy products made of recycled materials. A slight majority (51 %) of EU citizens who were willing to buy products made from recycled materials selected 'quality' or 'usability' as the most important factor in their decision-making.

These data provide some insights into why the share of reuse, repair, remanufacturing or even recycling is much lower than one would expect, given the overall positive attitude of people towards waste prevention and resource efficiency. There seems to be a considerable gap between attitudes and actual behaviour, driven by perceptions that circular solutions are more expensive, less convenient or of lower quality and that it is up to companies and governments to act.

3.3.2 Users' needs and consumption patterns

The key challenge for developing successful circular solutions is identifying and addressing user needs and linking these to circular strategies, such as integrated repair or reuse. Such an approach is common in start-ups, where user-centred design is one of the main entry points for the business development process (Ries, 2011). Camacho-Otero et al. (2018) show that the motives for adopting circular products or services are not necessarily related to personal attitudes on environmental issues. Integrating knowledge and values about the circular economy and sustainability into increasingly abundant start-up incubators would greatly spur business innovation that supports a circular economy.

In a circular economy, consumption patterns will be markedly different from those of today, with increased 'usership' instead of ownership (EMF, 2013; ING, 2015; EEA, 2017). The social implications of such changes are still poorly understood. The literature mentions several aspects that could define consumption in a circular economy and that warrant further research: anonymity, because products no longer define the identity of consumers; connectedness, among consumers in communities and between consumers and companies; multiplicity of values, as consumption will still be defined not only by utility but also by emotional value; political consumerism, as dematerialised consumption is a form of political statement against mainstream consumption; and uncertainty, because the liquid nature of ownership in a circular economy creates trust and risk issues (Camacho-Otero et al., 2018). Communication will be key to help. Developing knowledge on usership and the communication of its benefits, would enable citizens to make better consumption choices to drive the transition to a circular economy.

3.4 Economic incentives

3.4.1 Financing

The transition to a climate-neutral, resource-efficient and circular economy is critical for the EU economy overall, for EU's competitiveness and sustainable growth. However, reports and studies illustrate that the economies are far from being climate-neutral and resource-efficient, although progress in reducing greenhouse gas emissions and decoupling resource use from economic activities has been made in recent years. It is therefore self-evident that substantial investment in the circular economy transition is required; this will have to be funded by the public and private sectors, including financial institutions.

Responding to these needs, the European Commission has taken action to promote both sustainable finance in general and more specifically investment in the circular economy. In 2016, it created the High-Level Expert Group on Sustainable Finance 'to provide recommendations to hardwire sustainability into the EU's regulatory and financial policy framework, as well as to accelerate the flow of capital towards sustainable development objectives' (High-Level Expert Group on Sustainable Finance, 2018). Building on the group's work, the European Commission produced an action plan, *Financing sustainable growth*, in March 2018 (EC, 2018d) and adopted a package of implementation measures in May 2018.

A key recommendation by HLEG and subsequent legal proposal by the European Commission is to develop a taxonomy for what constitutes an economic sustainable activity for investment purposes. Circular economy is integrated as a key environmental objective of the proposed regulation on the establishment of a framework to facilitate sustainable investment (EC, 2018f). The European Commission set up a Technical Expert Group (TEG) in 2018 to propose technical screening criteria for sustainable economic activities as per the proposed regulation. The initial focus has been climate change but the circular economy dimension has also been part of the TEG's deliberations to ensure that economic activities contributing substantially to climate mitigation does not significantly harm circular economy objectives.

The European Commission also set up a Circular Economy Finance Support Platform to support the EU's circular economy action plan. The platform was intended to boost investment in the circular economy by drawing on both public and private resources and utilising tools such as the European Fund for Strategic Investments (EFSI).

Estimating the investment need for the transition to a circular economy is very challenging, because the circular economy concept encompasses a broad range of environmental dimensions and economic sectors. It is therefore not surprising that many different definitions of what is understood under the circular economy concept exist ([3]). In contrast, the climate and energy field is characterised by clear targets and definitions established in the European Commission's Clean energy for all Europeans package (EC, 2019a; High-Level Expert Group on Sustainable Finance, 2018).

Table 3.2 sets out the variety of economic sectors that the European Investment Bank (EIB) used to classify its circular economy lending portfolio.

The total amount lent is low when compared with the EIB's total signed financing activities to EU Member

([3]) For example, Kirchherr et al. (2017) found a total of 114 definitions of a circular economy in the literature. The growth in the topic is reflected in the increase in the amount of peer-reviewed articles being published: 30 articles in 2014 compared with more than 100 in 2016. In addition, it should be noted that the concept of the circular economy was more or less developed and led by practitioners and not by academia (Korhonen et al., 2018).

Table 3.2 European Investment Bank circular economy lending by sector, 2013-2017

Sector	Amount lent (EUR million)	Share (%)
Industry and service	706	33
Water management	554	26
Agriculture and bioeconomy	366	17
Waste management	331	16
Mobility	95	5
Urban development	50	2
Energy	14	1
Total circular economy lending	2 116	100

Source: EIB, 2019.

States, which amounted to EUR 332 billion in the period 2013-2017 (EIB, 2018), with financing of climate action in 2017 alone amounting to EUR 19.4 billion (EIB, 2018). The reasons for the limited scale of circular economy investment arises, in part, from the innovative character of the circular economy concept as well as the relatively small scale of circular economy projects.

The circular economy concept seems to be quite new and innovative in the political context. However, investment by SMEs in circular economy activities, such as waste water treatment, waste recycling or reuse, are not new at all. A 2016 Eurobarometer briefing note found that 73 % of companies had taken some circular economy-related activities during the previous 3 years (TNS Political & Social, 2016).

As one of the main stakeholders promoting the circular economy, the European Commission is also key in financing circular economy activities. Many different EU programmes are dedicated to funding the transition to a circular economy, including the European structural and investment funds ([4]), projects under Horizon 2020 ([5]), the EU programme for competitiveness of enterprises and small and medium-sized enterprises (COSME) ([6]), the LIFE programme ([7]), the Connecting Europe Facility ([8]) and the EFSI ([9]) ([10]).

Apart from funding circular economy activities, the EIB provides support for investment projects through the European Investment Advisory Hub ([11]) and InnovFin Advisory ([12]). These support activities carried out by the EIB are noteworthy because, as the circular economy concept is often innovative, they may lead to new models of economic production by creating new conditions for businesses, consumers and natural resource use (EIB, 2019).

3.4.2 *Financial aspects of circular business models*

Business model innovations associated with the transition to a circular economy can encounter challenges in securing finance. The concept of a product as a service has, for example, a different risk profile from the established model of buying and owning a product, and therefore it requires financial institutions (ING, 2015, 2016) and companies shifting from a sales-based model to a service-based one to rethink.

Recently, financial institutions as well as traditional asset leasing firms have started to explore how existing financial leasing solutions should be adapted to enable circular service-based models (ABN Amro et al., 2018;

([4]) https://ec.europa.eu/info/funding-tenders/funding-opportunities/funding-programmes/overview-funding-programmes/european-structural-and-investment-funds_en
([5]) https://ec.europa.eu/programmes/horizon2020/en
([6]) https://ec.europa.eu/growth/smes/cosme_en
([7]) https://ec.europa.eu/easme/en/life
([8]) https://ec.europa.eu/inea/en/connecting-europe-facility
([9]) https://ec.europa.eu/growth/industry/innovation/funding/efsi_en
([10]) For further information on the amounts available under the different programmes during the current programming period, see Appendix 1 of Vasileios et al., 2018.
([11]) http://eiah.eib.org
([12]) http://www.eib.org/en/products/blending/innovfin/index.htm

Janssens, 2019). Some of the important challenges identified in these reports are:

- the need for a clear understanding of what circular business models are or a framework outlining this;
- the financial implications for producers of managing products as assets instead of selling them;
- the need for finance providers to be able to understand the financial and operational risks, as well as the residual value after a product's first life;
- the need to work out clear contractual agreements between the circular service provider and the financing party that assign roles and responsibilities concerning the management and ownership of the products involved.

While all this requires quite some effort from both companies and financing parties, it is noteworthy that the often-mentioned financial barrier to circular business appears to be mainly a knowledge and communication obstacle between stakeholders that, until recently, operated in different business areas. By creating a shared understanding and clear standards for circular business financing, it can be expected that the adoption of circular service models will grow significantly in the coming years.

Another challenge is related to the fact that many initiatives on the circular economy are small scale and therefore not likely to attract financing; the EIB tries to overcome this by grouping several (similar) initiatives.

3.4.3 Fiscal instruments

Fiscal policy instruments are also important tools for promoting the circular economy by adjusting incentives for consumption expenditure and investment. The elimination of environmentally harmful subsidies is the first step towards fostering a policy framework that will champion circular economy approaches, compared with the current widespread linear economic model. Stimulating a level playing field between different business models and raw versus secondary/recycled resources and materials may require further fiscal policy instruments, such as material/resource taxes.

The motives for introducing resource taxation schemes are diverse, ranging from reducing the dependency on raw materials and stimulating alternative technologies and eco-innovation to changes in relative prices. The latter may also tackle the existence of external effects by internalising these environmental and resource costs, which are not reflected in current prices.

Furthermore, taxes levied on natural resources can stimulate increases in resource efficiency and the substitution between different types of resources (Vasileios et al., 2018; Milios, 2016). However, the actual design of material resource taxation schemes is far from trivial (ETC/SCP, 2012; ETC/SCP et al., 2015).

This type of environmental tax can be implemented at different stages of the value chain:

- at the extraction stage;
- at the input of the material to its first industrial use;
- at the final consumption of products including the material.

All three approaches have advantages and disadvantages in terms of improving resource efficiency, requirements related to administration, uncertainties, and side effects and issues related to international trade (ETC/SCP, 2012; ETC/SCP et al., 2015).

In the case of implementing a domestic resource tax, further policy issues, such as the need for border tax adjustments for imported materials, intermediate or final products, may be needed to serve as counter-balancing measures to protect the competitiveness of domestic industry and therefore may hinder the implementation of the tax in general. Although the rationale for introducing resource taxes is rather convincing, the actual design of the fiscal instruments must weigh up the pros and cons associated with the stages of the value chain at which the tax is introduced.

Another regularly mentioned fiscal policy measure is a reduction in the value added tax (VAT) rate for secondary materials and/or products designed and produced with the circular economy in mind. China makes use of the differentiation between VAT rates for goods produced from recycled materials (Vasileios et al., 2018). In addition, VAT differentiation also has potential for promoting repair services (Milios, 2016).

Extended producer responsibility (EPR) schemes are part of the EU environmental policy culminating in EPR legislation for specific waste streams — end-of-life vehicles, WEEE, and waste batteries and accumulators — as well as legislation on packaging waste, which resulted in EPR schemes being implemented across several EU Member States (ETC/WMGE, 2017). These schemes can be portrayed as fiscal/environmental policy measures allocating financial and physical responsibilities to producers to deal with products at the post-consumer stage.

Recent research concluded that 'there is mounting evidence from the empirical literature about the relationship between the advent of EPR and the observed increases in separate collection and recycling of the addressed waste streams (also fostered by waste targets set by the EU legislation)', and that 'the main conclusions point to a significant role of these approaches in pushing the industrial material system to establish system-level loops for reuse/recycling/recovery, thus pushing to achieve the policy targets through increasing circularity' (ETC/WMGE, 2017). The new Waste Framework Directive also sets requirements for EPR schemes.

4 Policies and governance

Transforming systems for sustainability is challenging, with many policies and incentives operating at different governance levels. It also requires experimentation and learning, based on interactions among multiple stakeholders, including businesses, users, scientific communities, policymakers, social movements and interest groups.

This complexity calls for extensive e breadth of activities across policy areas and levels of governance and creates the need for coordination and direction. Public institutions have a key role to play in ensuring horizontal coherence across policy areas and vertical coherence at local, national and international levels. Governments can facilitate networking and knowledge sharing by providing resources and creating necessary infrastructure or institutions. By recognising that sustainability transitions also imply normative choices between alternative visions of the future and how to get there, public authorities can contribute by creating processes to engage the public and enable consultation and deliberation. Governments can facilitate networking and knowledge sharing by providing resources and creating necessary infrastructure or institutions.

This chapter explores some of these governance challenges in relation to the circular economy transition. It maps the use of policy instruments in EEA member countries to address circular economy life cycle phases and then discusses the growing use of strategic frameworks at different levels of governance to coordinate and orient systemic change. Finally, it explores the synergies and trade-offs that arise through the interaction between these strategies.

4.1 Policy initiatives related to the circular economy

Policy plays a key role in enabling or constraining the transition to a circular economy. Although the circular economy has become a mainstream political topic with the adoption of the EU's circular economy action plan and the implementation of related policies at EU and national levels (EEA, 2019b) there is little analysis of the number of policies addressing different phases of the circular economy life cycle and what types of instruments are used.

To improve the understanding of national policies addressing different areas and stages of the circular economy, a meta-analysis of approximately 300 policy initiatives within EEA countries was conducted. The initiatives used in the analysis were taken from the country reports of the 2016 and 2019 *More from less* reports (EEA, 2016b, 2019b). They were categorised along different axes: the stage(s) of the circular economy that they targeted (Figure 2.1); the primary driver of the initiative — economic, environmental or the circular economy; and the type of policy instrument(s) used within the initiative — regulation, market-based or awareness-raising. This analysis produced the following observations about Europe's circular economy policy landscape:

- Overall, market-based instruments are the most frequently used policy type for all life cycle phases other than the extraction and import phases for which regulation is the dominant policy type (Figure 4.1).

- Of all life cycle phases, the production and distribution phases seem to attract the most attention from policymakers, closely followed by the recycling and waste phases (Figure 4.1). When separating policy initiatives that have an environmental focus from those with an economic agenda (Figure 4.2 and Figure 4.3), it becomes clear that environment-related policies focus much more on the end-of-life stages than economically inspired initiatives, which focus on production and distribution.

- When looking at the relative share of the different policy types affecting a certain life cycle phase (Figure 4.4), it appears that the eco-design, consumption and inner circle (Figure 2.1) phases have the highest percentages of soft policy instruments, such as awareness raising.

Figure 4.1 Circular economy life cycle phases affected by various policy instruments in EEA member countries

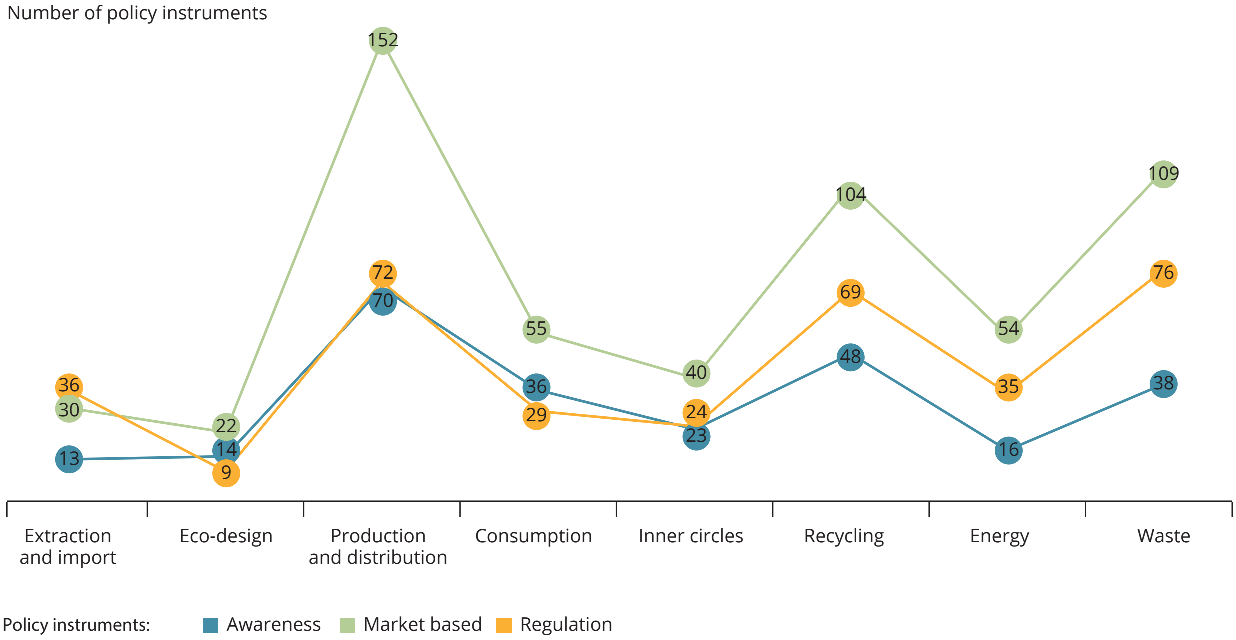


Figure 4.2 Circular economy life cycle phases affected by various policy instruments in EEA member countries — policy initiatives with an environmental focus

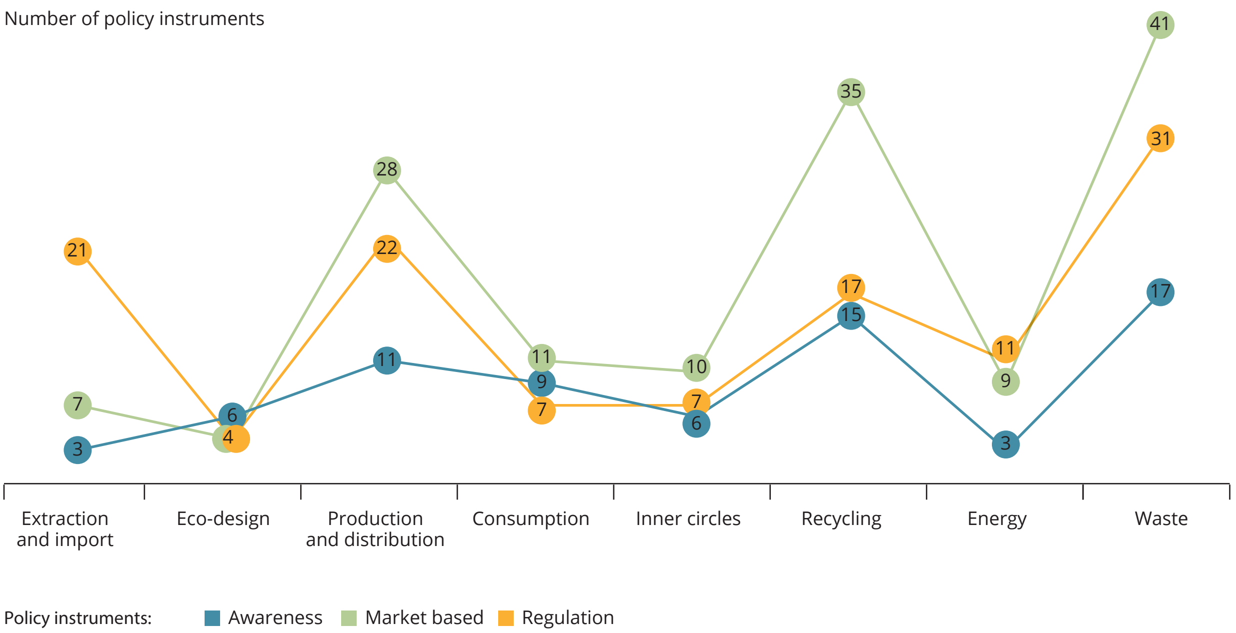


Figure 4.3 Circular economy life cycle phases affected by various policy instruments in EEA member countries — policy initiatives with an economic focus

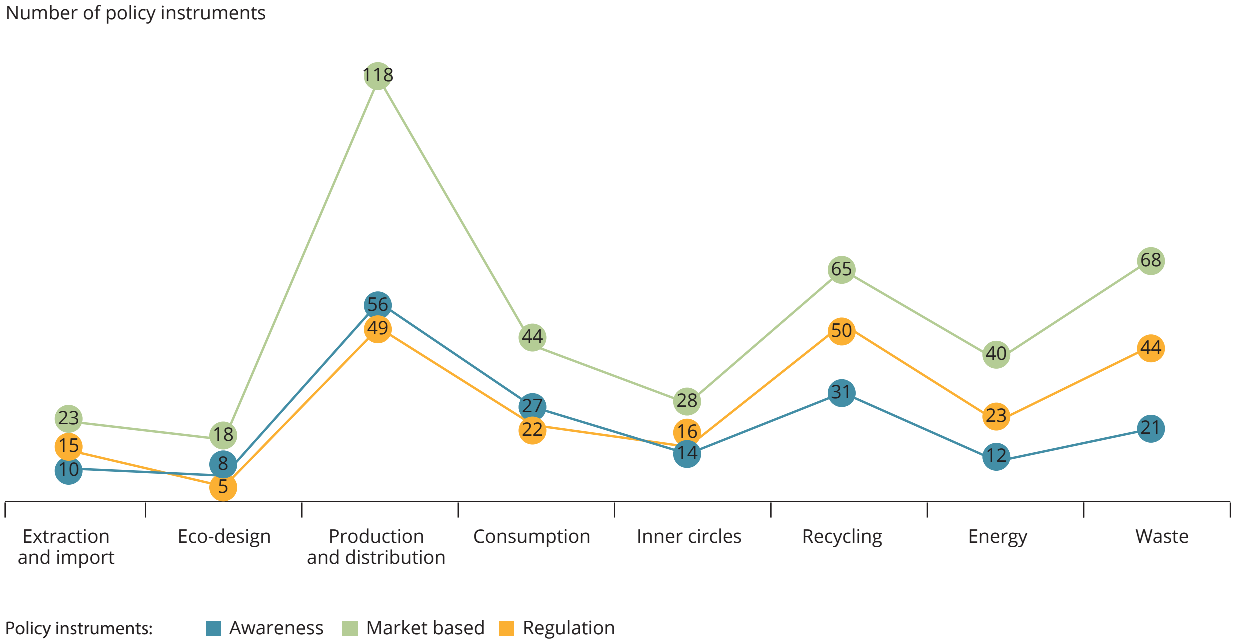
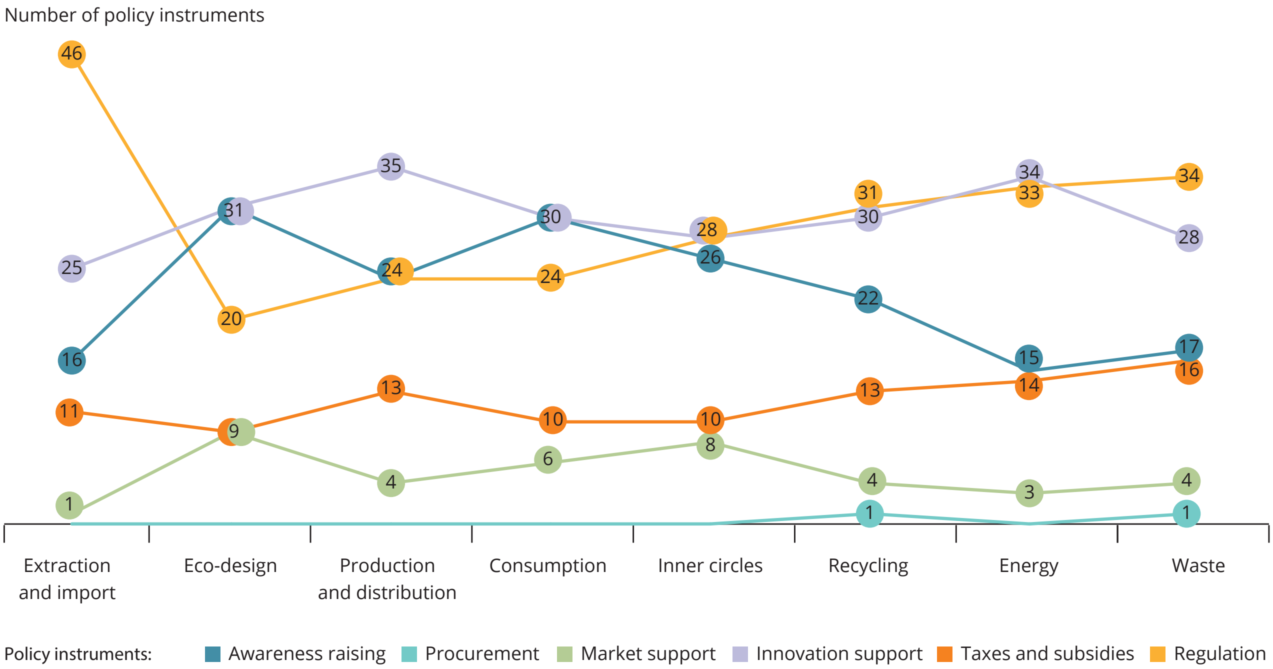


Figure 4.4 Proportional distribution of policy instruments per circular economy life cycle phase in EEA member country policies



The current EU approach to sustainable material use has two major foci. Firstly, to address global resource risks, attention is being paid to resource efficiency measures aimed at optimising production processes that are still predominantly linear. Secondly, there is a focus on products' end of life through EU waste management policies. Their objective is to minimise the environmental and health impacts of waste and that it is used as a resource whenever possible, adding to the EU's resource efficiency.

These two perspectives are reflected in the implementation of circular economy policies at a national level. Hard policy instruments, regulation and market-based instruments, driven by environmental concerns, are mainly focused on the end-of-life phases — recycling, energy, waste — while the first life cycle stages are predominantly addressed by soft instruments created for eco-design, consumption and inner circle phases (Figure 2.1), unless they serve an economic purpose, for example for extraction and import, and production and distribution.

A shift from soft to harder policy instruments in the early stages of the life cycle would be beneficial to tackle the barriers faced by companies (see Section 3.4).

4.2 Strategies and roadmaps

The mix of policies that influence transitions is highly complex, encompassing areas such as innovation, industry, sectors, education, employment and trade. Because such policies are normally developed in distinct departments with contrasting objectives and expertise, misalignments are common. As a result, there may be tensions or even contradictions between policy incentives and signals.

Policy misalignments can also arise between different levels of governance. As acknowledged in the EU's circular economy action plan, 'making the circular economy a reality will ... require long-term involvement at all levels, from Member States, regions and cities, to businesses and citizens.' Governance of the circular economy transition therefore depends, in part, on finding ways to ensure vertical coherence between policies. It also requires mechanisms to engage and interact with stakeholders — partly because of the need to learn from the successes and failures of local innovation and experimentation.

The emergence of transformative EU frameworks for a circular, climate-neutral and bio-based economy represents a response to this need to promote policy coherence. In articulating overarching visions and targets, these frameworks help to orient and coordinate action across scales. And the emergence of new platforms for networking and communication — including the European Circular Economy Stakeholder Platform — provides a novel means of sharing best practice and knowledge. However, as noted by the European Commission, the efficacy of the EU frameworks requires that they are translated into strategies, policies, targets and action at national and local levels (EC, 2019e):

> 'If we are to succeed, we must pull in the same direction at all levels. It is therefore of the utmost importance that all actors in the EU prioritise the sustainability transition. They must further develop the cross-cutting policy agendas that have been adopted at the EU level in recent years.'

This is clearly happening in the circular economy area. A recent EEA review of experience of and lessons learned from developing circular economy policies (EEA, 2019b) shows that 21 of the 32 participating countries have initiated work on national policy documents related to the circular economy. Cities and regions are increasingly adopting their own strategies and roadmaps (C40 Cities and EIT Climate-KIC, 2018; EC, 2019c). As they are not under any legal obligation to create such strategies, this is impressive progress just three years after the publication of the EU action plan for the circular economy in December 2015.

The EEA review reveals several common threads between the front-runner countries. Developing circular economy policies should involve a broad range of stakeholders. In several countries, the government not only assumes the role of regulator and enforcer in this process but is increasingly playing the role of facilitator and moderator. Some action relies on voluntary approaches, underpinned by a clear business case. Several governments have estimated the benefits for their country's economy from implementing the circular economy. Finally, some governments, for example the Government of Flanders, have applied a broad definition of resources to be used in closed cycles: raw materials, water, space, food and excavated soil.

4.3 Interactions between transformative policy frameworks

The new strategic policy frameworks emerging at the EU level, addressing the climate-neutral economy, the circular economy and the bioeconomy, and mobility and energy, etc., are essential for promoting direction and coherence across policy areas and scales. Yet, they provide only a partial response to the governance challenge. In terms of promoting policy coherence, the frameworks are characterised by their own synergies and trade-offs.

Climate, resource efficiency and biodiversity goals must be aligned and directed towards integrated sustainability and towards consumption and production systems through integrated policies. Unfortunately, they are often approached in isolation in policy, in technology, and in research and innovation. That is why more attention needs to be paid to finding synergies between them and ways in which they can support and reinforce each other.

4.3.1 The circular economy and the bioeconomy

The circular economy approach is linked with the EU bioeconomy strategy. In combination, they aim to keep the value of products and materials for as long as possible; to develop clean material cycles; to ensure food security; to transform the fossil fuel-based economy into a bioeconomy; and to respect the environmental limits of the planet (EEA, 2018c).

They can be dovetailed further by applying the following system-design principles.

1. Policy interventions should be geared towards the reduction of environmental pressures along the entire value chain. This requires explicit sustainability targets, recognition of trade-offs and coherent measures aimed at producers and consumers.

2. Bio-based approaches should be tailored to the relevant use context, specifically:

    i. Innovation that diminishes material and energy use and keeps products and materials in circulation should, wherever possible, be prioritised, as this helps to decrease pressure on biomass production and prevents the unwanted dissipation of technical materials in the environment.

    ii. Bio-based, non-biodegradable materials should be used only when they can be effectively recycled at the end of their lives.

    iii. Bio-based, biodegradable materials should be used when the risk of dispersion into the natural environment is high, such as lubricants, materials subject to wear and tear and disposable products.

3. Technological innovation should be embedded in wider system innovation that also tackles consumer behaviour, product use and waste management. This will greatly enhance the success of sustainable innovation and will help anticipate scaling problems and unintended consequences. Questions about the impact of a bio-based innovation on the local and/or global biocycle when it is applied in a specific context and when it is applied at scale should be asked. Life cycle thinking, when properly applied, can be of great help in tackling such questions.

4.3.2 The circular economy and the climate-neutral economy

Resource efficiency and the low-carbon economy are central themes in global discussions on the transition to a green economy (OECD, 2014; UNEP, 2014). The EU's Seventh Environment Action Programme (EU, 2013) states that it is necessary to 'turn the [European] Union into a resource-efficient, green, and competitive low-carbon economy' (EC, 2011). By 2050, the EU aims to cut its carbon dioxide emissions by 80-95 % compared with levels in 1990. Moreover, in 2018, the European Commission adopted the goal of moving to a climate-neutral economy by 2050.

If all current and planned climate policies are realised, global greenhouse gas emissions will be reduced by 11-13 billion tonnes of carbon dioxide equivalent by 2030, resulting in a shortfall in the reduction required to keep to the 1.5 °C pathway of 15 billion tonnes carbon dioxide equivalent (Circle Economy and Ecofys, 2016). To make up this shortfall, additional action is needed. Nowadays, climate mitigation action is primarily focused around energy efficiency and a shift to renewable-energy sources. Currently, one of the underlying drivers of high energy demand is high material consumption as a consequence of the current linear economy. The framing of the climate challenge as an energy and materials challenge offers new insights and solutions. Box 4.1 gives several examples of countries, looking for consistency in climate, circular economy and economic policies.

Material consumption contributes significantly to global greenhouse gas emissions. The United Nations Environment Global Resources Outlook for 2019 estimates that more than 50 % of total greenhouse gas emissions come from raw material extraction and

Box 4.1 Creating consistency in climate, circular economy and economic policies

Several countries are investigating ways of creating consistency between climate, circular economy and economic policies at a governance level.

Flanders, Belgium

In the draft 2021-2030 climate plan for Flanders, the transition to a green and circular economy is inserted as a transversal strategy to reduce greenhouse gas emissions. Several policy measures are mentioned, such as implementing a circular economy roadmap with concrete targets for resource use that clearly link the circular economy and climate policy. Further circular measures in the climate plan include developing a strategy for the collaborative economy; establishing a network of repair services; developing material passports for buildings; investigating a circular tax shift; and establishing circular priority rules in the criteria for public procurement.

Netherlands

The transition to the circular economy in the Netherlands is shaped by the nationwide circular economy programme, Netherlands Circular in 2050 (Rijksbrede Programma Circulaire Economie (RPCE)), and the five circular economy transition agendas. In 2018, a study by the Netherlands Organisation for Applied Scientific Research (TNO) calculated what the contribution to emissions reduction would be if the quantitative targets in the RPCE and the transition agendas are achieved. Reaching these targets could lead to an additional reduction in greenhouse gas emissions of about 7.7 million tonnes of carbon dioxide equivalent per year in 2030, about one fifth of the policy goal of a 49 % reduction, and about 13.3 million tonnes per year by 2050.

This calculation is a conservative estimate with only the effects of quantitative targets included — rebound effects, price changes and shifts in imports and exports are taken into account and lower the impacts on greenhouse gas emissions.

Germany

The German Federal Environment Agency (UBA) has been looking into systematically addressing the circular economy and climate policies together. A 2017 study showed that it is possible for Germany to become both greenhouse gas neutral and resource efficient. An integrated scenario demonstrated the possibility of reducing greenhouse gas emissions in 2050 by 95 %, compared with 1990 levels, and raw material consumption by almost 60 %, compared with 2010 levels, by balancing greenhouse gas and raw material savings from the move away from fossil fuel energy carriers with increased raw material used in constructing a renewable energy system. The study also shows that related ambitious climate and resource efficiency policies help achieve both goals.

processing (IRP, 2019). Figure 4.5 shows the importance of material-related greenhouse gas emissions in the consumption patterns of four countries. Material-related processes — material extraction, production of food, goods and fuel, transport and storage, and waste processing — account for 50-65 % of the total greenhouse gas emissions.

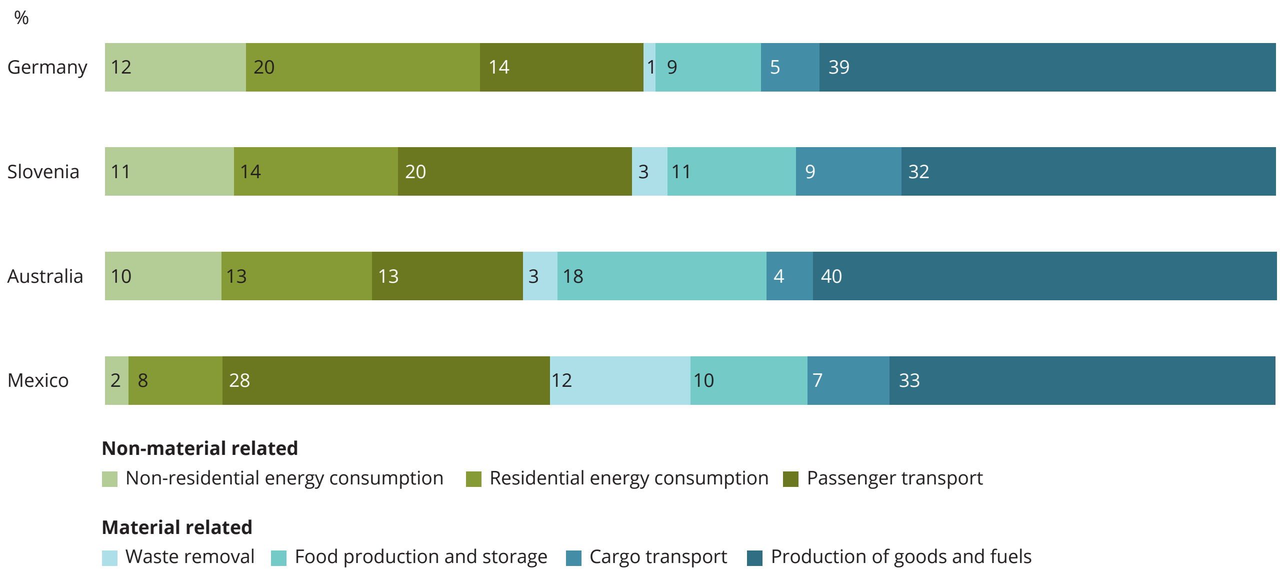
Acknowledging that more than 50 % of greenhouse gas emissions are related to materials management, making more efficient use of materials is a sound greenhouse gas mitigation strategy.

Although resource efficiency focuses on doing more with less, efficiency alone is not sufficient to bring about a significant reduction in environmental pressures. Efficiency measures need to be complemented by strategies to reduce resource use in absolute terms.

Creating a circular economy, by improving waste prevention and by encouraging longer use, reuse and recycling enables society to maintain the value of products and materials while increasing the lifetime and use intensity of products. In doing so, the demand for new products and virgin resources is reduced, thereby avoiding related energy use and environmental impacts (EEA, 2015).

In recent years, several research reports have discussed the contribution of resource efficiency and the circular economy to reducing carbon emissions. These studies have different assumptions, but the general conclusion is that the carbon gains from circular strategies are high (Material Economics, 2018). According to Circle Economy and Ecofys (2016), circular economy strategies, recovery and reuse, lifetime extension, sharing and service models, circular design, and digital platforms could cover

Figure 4.5 National greenhouse gas emissions from four countries, categorised by activity



Source: OECD, 2012.

half the gap between national climate mitigation targets and climate action taken by citizens and companies. Material Economics (2018) explored a broad range of circular strategies within the car manufacturing and building sectors, including extensive car-sharing systems and electrification, and calculated that a radical shift to circular business models and low-carbon technology would allow the EU to reduce its industrial emissions by 56 %, that is, 300 million tonnes annually, by 2050, more than half of what is necessary to achieve net zero emissions. Such a shift would, however, require significant effort from both producers and consumers.

A study by Green Alliance in the United Kingdom (2018) shows that five industrial sectors offer significant opportunities for cutting carbon dioxide emissions by improving resource efficiency, including the construction sector (e.g. by using lower carbon building materials and increasing reuse), vehicles (e.g. by encouraging people to use and keep efficient cars such as electric vehicles and hybrids for a few more years), and food and drink (e.g. by reducing avoidable food waste).

Lifetime extension strategies can also contribute significantly to reductions in greenhouse gas emissions. A study carried out by the European Environmental Bureau (EEB, 2019) calculated that, by carrying out a range of simple, already feasible design principles to extend the lifetime of washing machines, notebook computers, vacuum cleaners and smartphones by 5 years, would lead to a saving of 12 million tonnes of CO_2.

Table 4.1 The effect on climate impacts of extending the lifetime of products in the EU

Product	Annual climate impact of EU stock — use and non-use phases (million tonnes of CO_2 equivalent)	Expected lifetime (years)	Effect of extending the lifetime of all available products in the EU (million tonnes CO_2 per year)		
			1 year extension	3 years	5 years
Washing machine	17.62	11.5	1.6	3.7	5
Notebook computer	12.82	4.5	1.6	3.7	5
Vacuum cleaner	4.2	6.5	0.1	0.3	0.5
Smartphones	14.12	3	2.1	4.3	5.5

Source: EEB, 2019.

There are several examples of how circular strategies can contribute to lower greenhouse gas emissions. Greenhouse gas savings from circular economy actions usually result from a reduction in (virgin) material demand and subsequent reduction of greenhouse gas emissions from extraction, refining and transport of materials as well as production and transportation of goods. A review of the existing body of literature identified highest reduction potentials in the EU for materials such as plastics, metals, cement and food; as well as construction/housing and mobility (Trinomics et al., 2018). As summarised by Trinomics et al. (2018), estimates of potential greenhouse gas emission reductions from combinations of circular economy actions totalled 80-150 million tonnes CO_2 equivalents per year by 2030 (Club of Rome, 2011; Cambridge Econometrics, 2014; WRAP, 2016) and 300-550 million tonnes by 2050 (Deloitte, 2016; Material Economics, 2018). This corresponds to 2.1-4.0 % and 7.5-13.7 % of the total EU greenhouse gas emissions in 2016.

Box 4.2 provides an example of how circular strategies can profoundly change the mobility system and its carbon intensity.

From Box 4.2, it is clear that a combination of various circular strategies — efficiency increases, lifetime extension, etc. — supporting infrastructure and profound behavioural changes are needed to achieve significant greenhouse gas reductions. This will spur a true system change to a circular, low-carbon economy.

Box 4.2 A combination of circular strategies can radically change the mobility system

Today, several trends are challenging the current mobility system. More and more initiatives for sharing vehicles, and car or ride sharing, are being launched, pilot schemes have started to use self-driving cars and almost all car manufacturers are working on the production of electric vehicles. Internet applications that make peer-to-peer networks for car sharing and taxi services using self-driving cars possible are developing.

Each of these trends or strategies alone will have only a limited impact, but when strategies are combined they reinforce each other and bring about a new mobility system. Shared use combined with the technology of electric self-driving cars and internet applications can introduce a network of shared and self-driving vehicles that are available on call and can drastically reduce the number of vehicles needed. A better integration of different mobility modes, for example electric cars on call, trains, self-driving cars, will greatly reduce the number of vehicle kilometres and will result in fewer vehicles moving the same number of people and fewer greenhouse gas emissions. The added value comes from offering integrated mobility systems rather than producing cars.

In a report, Christis and Vercalsteren (2019) assess the climate impacts of various mobility scenarios, based on passenger car transport in Flanders (Figure 4.6). From the business-as-usual scenario, it is clear that greenhouse gas emissions from transport are expected to increase by about 5 % by 2030 in comparison with 2015 levels. A full electrification of passenger cars by 2030 would lead to a reduction in emissions of about 30 % between 2015 and 2030, which is not enough to reach the 51 % target set in the Flemish climate policy. It is also clear that the effect of electrification is much larger in Flanders — mainly as a result of reduced direct emissions during use — than on a global scale, which includes materials extraction and production of electric cars. This shows that territorial emission reductions are achieved at the expense of additional emissions in regions where the cars and batteries are produced.

The study also calculated what would be required to reach the objective of a 51 % reduction in Flanders' greenhouse gas emissions by 2030 compared with 2015 levels. It is clear that reaching climate targets will require a profound behavioural change. In the linear scenario, reductions will need to be achieved by reducing the kilometres driven by about half and improving the energy efficiency of vehicles. In the circular scenario, reductions can be achieved by a drastic intensification of car use and a radical shift towards car sharing — more kilometres per car and higher occupancy rates — rather than by reducing the kilometres driven. Both scenarios require significant investment in infrastructure to support them, including more public transport, and cycling, car sharing and carpooling systems, and improved urban planning to facilitate behavioural change.

It can be seen that, while emissions in Flanders remain the same, on a global scale, the circular scenario achieves greater greenhouse gas reductions than the linear one, as in a circular scenario fewer cars need to be produced, which happens outside Flanders.

Box 4.2 A combination of circular strategies can radically change the mobility system (cont.)

Figure 4.6 (a) Greenhouse gas emissions in Flanders

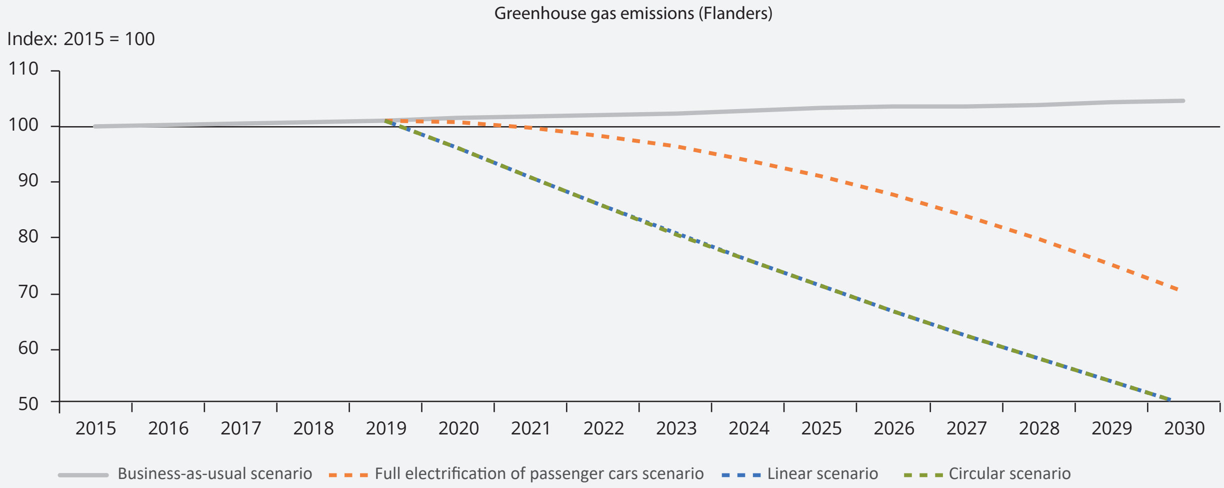
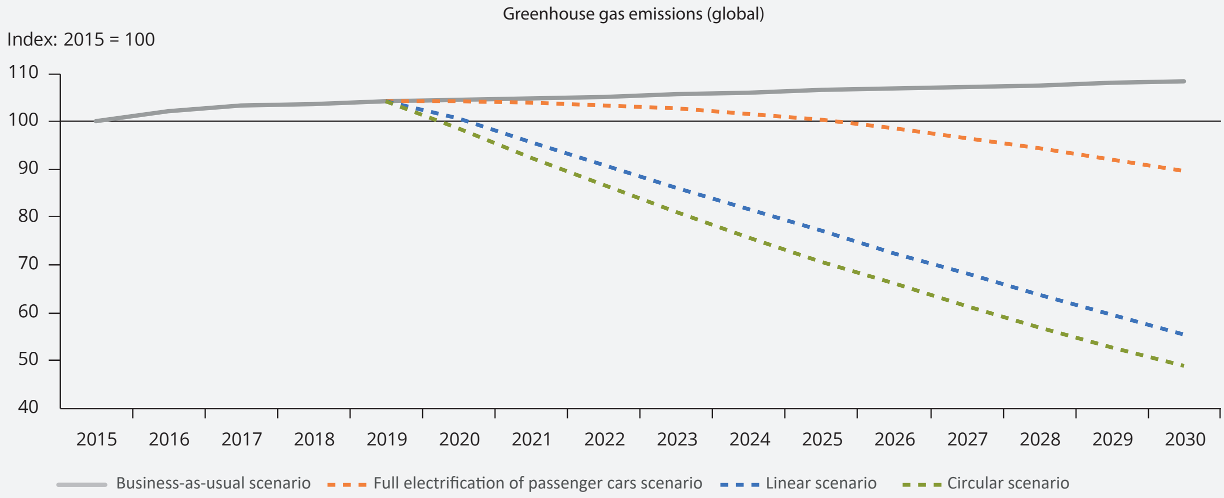


Figure 4.6 (b) Global greenhouse gas emissions in four mobility scenarios



Note: BAU, business-as-usual (scenario); TEC, full electrification of passenger cars (scenario); LCS, linear (scenario); CCS, circular (scenario).

Source: Christis and Vercalsteren, 2019.

Nevertheless, there are some trade-offs. Certain low-carbon or energy-efficient technologies require specific metals and minerals for the production of batteries or magnets, for example. A study by the International Resource Panel (IRP, 2017) calculated that low-carbon technologies require more than 600 million tonnes of additional metal resources, measured in iron-equivalent, by 2050 for additional infrastructure and wiring needs. Battery electric vehicles, for example, increase metal consumption by around 50 % compared with petrol vehicles. If this demand is not dealt with in a circular manner, it will lead to greater greenhouse gas emissions, which will affect climate change once again.

From these observations, it is clear that the realisation of a circular economy is a precondition for a successful climate policy.

5 Monitoring circularity in the 21st century

5.1 Introduction

The transition to a circular economy is a fast process with complex dynamics and multiple stakeholders. Monitoring approaches for following its development are lagging behind, and for good reason. Circularity is a highly diverse concept requiring policy development, action and monitoring at national, regional and local levels, across different sectors and over time.

The complexity and systemic perspective of the circular economy, and especially its logic in addressing economic, environmental and social objectives simultaneously, calls for a broad approach. Informing policymakers, financial markets, businesses and citizens about the progress of the transition to a circular economy requires both the harvesting of existing data and designing new approaches to data and indicators.

The outer and inner circles of the EEA concept for the circular economy (Figure 2.1) highlight the various types of knowledge needed to monitor progress.

5.2 Established knowledge: some opportunities and blind spots

5.2.1 The 'outer circle'

As illustrated in Chapter 2, current knowledge of the circularity of Europe's economy largely concerns trends in material flows and waste, in other words aspects related to the outer circle of Figure 2.1. In the framework of the EU circular economy package (EC, 2015a), the European Commission is developing a monitoring framework for a circular economy, 'composed of a set of key, meaningful indicators that capture the main elements of the circular economy' (EC, 2018c). It aims to gather knowledge that will help with 'setting new priorities towards the long-term objective of a circular economy'.

In a circular economy transition, indicators will remain valuable surveillance tools for policymakers to help them understand whether circularity action is turning trends in material flows and waste towards sustainability. There are some important gaps to address as well as opportunities to use existing data sources as proxies to inform key actions taken by policymakers and other stakeholders.

The waste and material statistics currently collected to support waste policy implementation, are volume based rather than value based (Hollins et al., 2017). The downside of this is that volume-based targets may encourage further investment in high-volume recycling of low-quality, low-value materials, possibly with a low environmental performance as well. However, the circular economy is about maintaining material and product values at the highest possible level for as long as possible, articulating the explicit need to look at waste and material recovery from the angle of value retention. It will require new waste metrics and targets to complement the volume-based targets with a more value-based approach.

Established EU waste statistics address the quantity of waste materials that are collected and enter the recycling process, but they do not specify whether this method of recycling implies closed- or open-loop recycling.

Furthermore, official waste statistics include neither details of the quantity and quality of recyclate that is produced nor the level of material functionality that is retained in the application of the recyclate. A proxy indicator to assess the quality of recycled materials is their market price. Eurostat's market prices for recyclate indicators provide information on glass, paper and board, and plastic waste, although they do not specify the type of material or the stage in the recycling process — after collection or before the use of recyclate in (new) production.

For plastic waste, for example, the average price per tonne reported in 2017 was EUR 314 (Eurostat, 2018). More detailed figures can be found in recycling industry media, which show that, depending on the type of plastic and its purity, the price can vary between GBP 10 and GBP 330 per tonne (Letsrecycle.com, 2019). Comparing prices of virgin and secondary plastics, it is clear that, on average, recycled plastics are much cheaper. Rather than indicating that recycled materials are more interesting for producers, this price differential suggests that the quality of recycled plastics does not (entirely) match the requirements of producers of plastics (Vanderreydt et al., 2019). Indeed, the lower quality or the variability in quality between batches of recycled plastics creates risks and/or the need for additional control measures in production processes, translating into a lower price for recycled plastics.

Existing indicators focus primarily on physical parameters, such as weight, that are more technology related. Indicators focusing on socio-institutional aspects, such as collection systems, are less well-defined and less frequently included in monitoring frameworks. A transition to a circular economy should not only be looked at from a material perspective but also include environmental considerations, such as climate change. Indicators monitoring environmental impacts already exist and can easily be combined and integrated into a set of indicators for monitoring the circular economy (Vercalsteren et al., 2018).

5.2.2 The 'inner circle'

A solid understanding of circularity requires insight into the flows and stocks of products and their value, which in turn requires knowledge of the extent of use, reuse, repair and the remanufacturing of products and components — the inner circle elements of Figure 2.1. Very few existing indicators capture the effects of strategies that relate to smarter product use and manufacturing or extending the lifespan of products.

Analysis of the data on the reuse of cars and electronics illustrates the current potential for informing policies and actions related to the inner circles (Figure 2.1). The electrical and electronic equipment (EEE) and automobile sectors both represent resource-intensive products but with different lifespans and ranges of economic value.

Eurostat data, for example, on the share of reuse in recycling exist for both the EEE and the automobile sectors, and thus allow a sectoral comparison. For EEE, data are also available on the share of reuse in products put on the market (Table 5.1). This represents shares of reuse in relation to the amount of newly sold products, while the indicator on the share of reuse in recycling shows the share of reused materials in products that have entered recycling facilities.

This different method of reporting is visible when comparing the two indicators for EEE: all countries show a higher share of reuse when assessed by the reuse in recycling indicator, because the reference base is the amount of registered waste EEE, although it excludes products put on the market but not collected in the official waste management value chain. This illustrates the complexity and limitations of existing statistics related to reuse, made even more complex by the sometimes questionable reliability of reported data. Alongside the upcoming monitoring obligations for reuse, as included in the amended Waste Framework Directive (WFD), there is a new opportunity to construct a monitoring structure for reuse that fits the circular economy concept.

5.2.3 Monitoring economic consequences of the transition

Next to the material/waste flows and environmental sustainability dimensions, the economic consequences of the transition to a circular economy also need to be monitored. This should include the economic significance of the growth in recycling, reuse, repair, etc., as well as the possible rebound and negative effects on the existing linear economy. There is, however, no robust and straightforward solution to this challenge.

The economic accounting structure, divided into primary, secondary and tertiary sectors that are each subdivided according to the products or services they deliver, does not allow the isolation of economic data representing circular activities — there is no circular sector. The waste management sector is visible in economic statistics, but this is, again, limited to companies labelled as waste management companies. All circular activities that happen within companies' upstream from the waste sector are embedded in the economic data of these companies. Only when the majority of a sector has shifted towards a circular model can the economic data related to it be identified as circular in the current economic accounting structure. Nevertheless, existing data can be used to obtain some insights into the economic potential and relevance of circular activities.

Analysing the reuse of products outside the waste management system, through second-hand trade conducted by consumers, second-hand retailers or reuse initiatives, provides additional insights. Combining data from different sources will be a key feature of monitoring circularity, as not all aspects can be addressed by official statistics, given limited public resources.

Table 5.1 Share of reuse in recycling or in products put on the market (POM) in the electrical and electronic equipment (EEE) and the automobile sectors in EEA countries, 2015 ([a])

Country	Share of reuse in recycling (percent by weight)		Share of reuse in products put on market (percent by weight)
	End-of-life vehicles	Electrical and electronic equipment	Electrical and electronic equipment
Belgium	25.02	3.9	1.2
Bulgaria	2.76	0.5	0.2 ([c])
Czech Republic	4.07	n/a	n/a
Denmark	n/a	0.3	0.1
Germany	4.79	2.6 ([b])	0.9 ([b])
Estonia	21.45	n/a	n/a
Ireland	0.90	1.6	0.6
Greece	n/a	n/a	n/a
Spain	25.84	1.0	0.2 ([b])
France	13.72	1.8	0.5
Croatia	0.39	n/a	n/a
Italy	18.91	n/a	n/a
Cyprus	54.39	4.8	1.1
Latvia	9.74	1.6	0.4 ([b])
Lithuania	42.74	n/a	n/a
Luxembourg	1.27	n/a	n/a
Hungary	25.72	n/a	n/a
Malta	n/a	n/a	n/a
Netherlands	n/a	1.0	0.3 ([c])
Austria	15.19	2.7	0.9
Poland	16.66	0.5	0.1
Portugal	n/a	n/a	0.0
Romania	n/a	n/a	n/a
Slovenia	n/a	n/a	0.0
Slovakia	4.17	n/a	n/a
Finland	7.26	1.5	0.8
Sweden	21.83	0.3	0.1
United Kingdom	1.74	3.7	1.1
Iceland	5.40	n/a	n/a ([b])
Liechtenstein	0.00	n/a	n/a
Norway	7.48	2.6	1.3

Notes: ELV, end-of-life vehicles; N/A, not available.

([a]) When using the indicators **share of reuse in POM** and **share of reuse in recycling** as proxies for reselling activities of collecting and recycling companies, the following have to be considered:
(1) Recycling and collecting companies also carry out further reselling activities, which do not relate to reuse. In fact, the reselling of **recycled** materials may often be more important to them. However, these proxy indicators do not cover the reselling of recycled materials, as they exclusively refer to aspects of reselling as a **reuse** activity in the sense that it is defined by the EEA (2018d).
(2) These indicators are measured in weight. As a result, heavier items have greater effects on the indicator value. However, this bias might be moderated, to a certain extent, by the fact that heavy items in the selected sectors may often be more expensive, such as sport utility vehicles (SUVs), than lightweight items, such as city cars, and therefore have a stronger effect on economic market shares.

([b]) Data from the year 2014.

([c]) Data from the year 2013.

Sources: EEA, 2018d; Eurostat, 2019b.

Table 5.2 Existing data for market shares of second-hand vehicles ([a])

State	Belgium	France	Germany
Share of second-hand vehicles	38 %	59 %	44 %
Calculated data	2014 data referring to average distance travelled	2015 data on share of second-hand vehicles (specifications on point of reference not indicated)	2017 data on economic turnover of second-hand automobile market by turnover of the total automobile market
Form of indicator	Proxy indicator	Unclear	Market share indicator

Note: ([a]) Only countries for which data are available (including proxy data) are listed.

Sources: ACEA, 2017, for Belgium and France. Statista, 2018, for Germany.

Difficult as it is to achieve a consistent view of the economic importance of product reuse, the relevance of the shared use of products and product repair or remanufacturing is even harder to assess. For example, recent studies related to the sharing economy have had to rely on rather anecdotal data or limited survey results to estimate the size of the sharing economy (EC, 2017a, 2018e). By analysing household consumption budgets, for example, it could be estimated that the potential economic relevance of sharing household consumer goods is rather low, as these account for less than 5 % of total household expenditure in Europe (EC, 2018e).

Product repair is embedded in a wide range of sectors and activities, making it virtually impossible to estimate the degree of repair in the economy. Gathering information on the number of new repair shops established over time or the trends in the turnover of such shops could, for example, be a simple proxy for assessing the trends in the economic relevance of repair. Finally, Eurobarometer surveys could be used to achieve a more in-depth understanding of the size of certain circular activities in the regular economy.

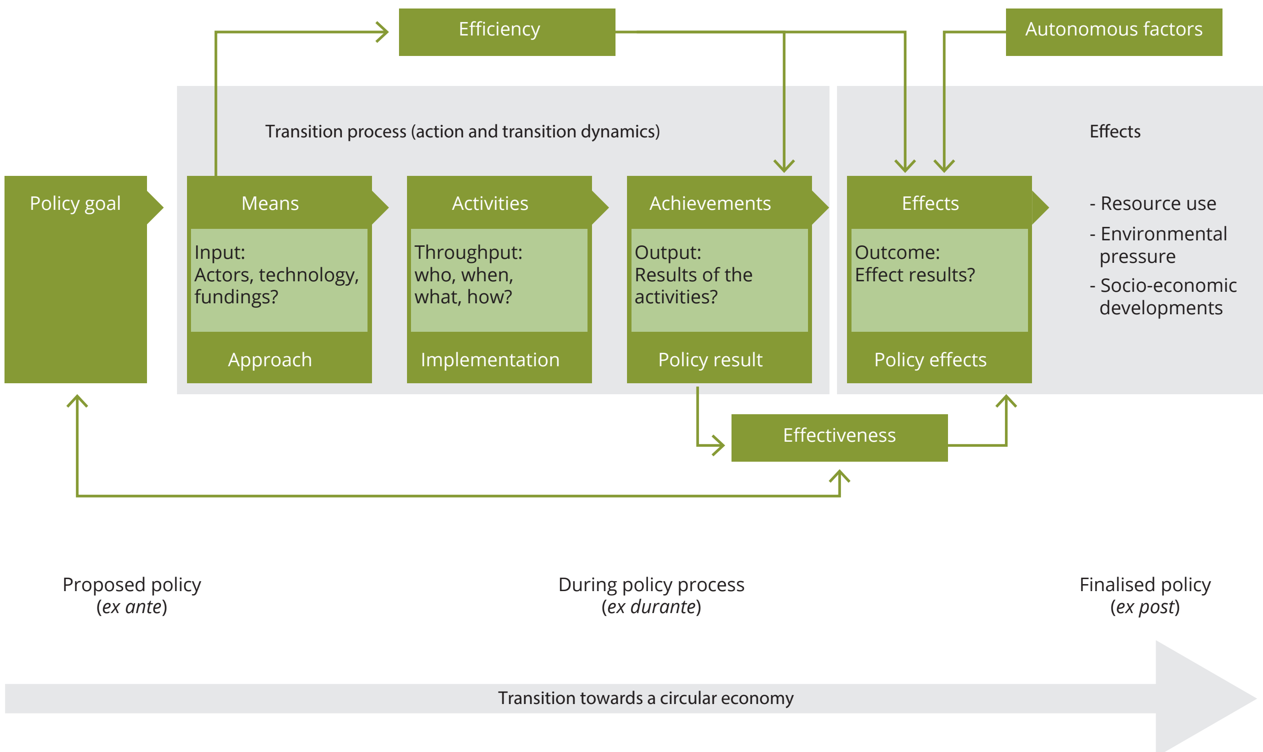
5.3 Monitoring in the 21st century

5.3.1 New approaches to monitoring transition governance

The European Network of the Heads of Environment Protection Agencies (EPAs) has analysed the gaps in current monitoring approaches that need to be filled to create an effective monitoring framework for the governance of the circular economy (EPA Network, 2017). This analysis recognises the blind spots discussed in Section 5.2, such as the need to shift monitoring efforts towards the inner circles (Figure 2.1) or to focus on product-level information complementary to aggregated material-level data. In addition, the work also highlights the lack of indicators related to the absolute decoupling of resource use from economic growth and those related to burden shifting to outside Europe (Section 4.3.2).

Furthermore, the EPAs emphasise the need to monitor the implementation of policy measures as well as the eventual outcomes of these measures. They argue that 'this differentiation is important, because the transition process may require a certain period, even years or decades, before a circularity strategy is achieved and its full effects on resource use, environmental pressure and socio-economic gain become apparent. Monitoring progress of the transition process can give an indication of whether the right things are happening and if the circular economy transition is on its way, or whether additional measures are needed' (EPA Network, 2017). A good example of this is given in the report *Single-use plastics: A roadmap to sustainability* (UNEP, 2018), which shows that the introduction of a single-use plastic ban has resulted in drastic reductions in plastic pollution in only 30 % of registered cases. Of the countries that have introduced national bans on plastic bags and have reported either no or little impact, the main issues seem to be a lack of enforcement and a lack of affordable alternatives. The ideas and concepts put forward by the EPA network in 2017 are being explored and developed further (Alaerts et al., 2018; Potting et al., 2018). These include a policy assessment framework that monitors direct effects — such as material consumption and waste generation — and indirect effects — such as contributions to climate change and other environmental impact factors — as well as the influence of implementation measures (Figure 5.1).

Figure 5.1 Policy assessment framework for measuring the progress of the transition to a circular economy



Source: Potting et al., 2018.

A second idea focuses on how to combine different levels of monitoring. The 2017 EPA study proposes using a combination of EU-, Member State- and product-level indicators, while Alaerts et al. (2018) propose working with macro-, meso- and micro-level indicators. The meso-level would focus on systems that fulfil societal needs (Figure 5.2), introducing the sustainability transitions view into the monitoring process. Adding micro-level indicators to the monitoring process would overcome the problem of niche developments during the early stages of a transition remaining invisible in macro-level societal indicators, such as national material flows or waste generation.

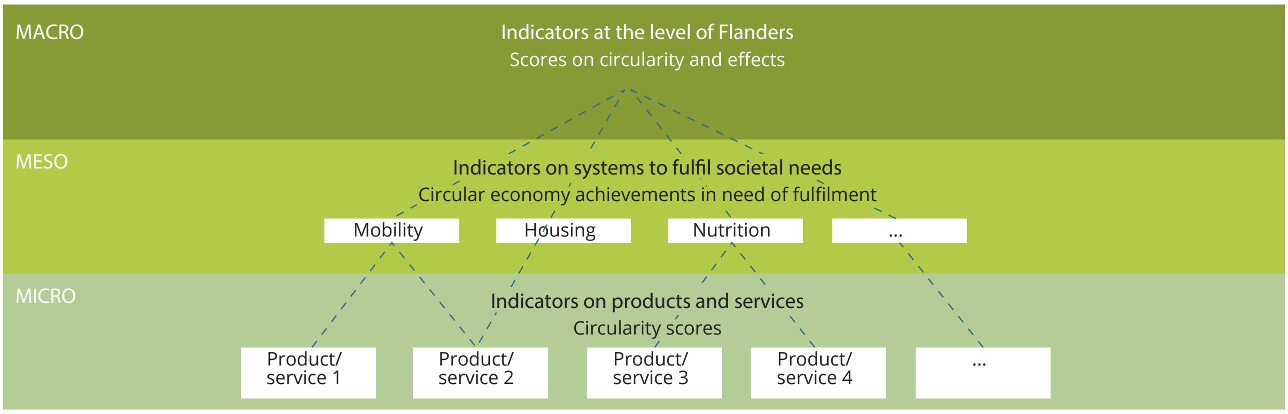
A third idea concerns approaches for assessing the shifts from outer circle to inner circle strategies (Figure 2.1). Without insights into the evolution of measures and effects of inner circle strategies, there is a high risk that the transition will remain locked into ineffective recycling routes (EPA Network, 2017). This goes together with expanding the focus on technology-related monitoring so it includes socio-economic aspects, such as adoption of business models and behavioural change (EEA, 2017).

These monitoring approaches highlight the need for new data analytics and new indicators (EEA, 2016a, 2017). It will be important to align development efforts with the needs of policymakers, the business community and citizens.

5.3.2 *Multi-stakeholder monitoring and the role of digital technologies*

Both large-scale businesses and small and medium-sized enterprises are key stakeholders in the transition from a linear to a circular economy, as they deliver products and services that drive consumers' choices while contributing to environmental and climate pressures. To measure progress in this field, we need to monitor the introduction and development of alternative (circular) business approaches that may start as small changes in the internal management of materials and waste but ultimately show up

Figure 5.2 Outline of the circular economy monitoring being developed by the Policy Research Centre Circular Economy



Source: Alaerts et al., 2018.

as an altered approach to customer interactions. Understanding more about innovative approaches to measurement at the business level and fostering their broad implementation should be another objective for monitoring circularity in the 21st century. The World Business Council on Sustainable Development is currently developing circularity metrics for companies (WBCSD, 2019). Significant synergies in terms of the need for data and the impact on learning can be generated when the conceptual logic of both policymakers and businesses are aligned.

The recent explosion in big data sources driven by digital technologies should be explored further for their potential to provide information on changing structures in society. The use of apps and interactive services for consumers allows the generation of unprecedented amounts of data on consumer preferences and behaviour.

Digital technologies can enable the upscaling of the circular economy. The internet of things, blockchain, artificial intelligence, material-flow models, interactive platforms, etc., can provide the basis for the management of materials and interactions along the value chain and for the provision of new services. All these interactions generate data or can leave digital traces. The monitoring, tracking and interpretation of these data will be essential for the assessment and monitoring of the implementation and growth of the circular economy.

Arguably, the single greatest monitoring challenge and opportunity revolves around tracking consumer choices and behaviour. People make product and service choices on a day-to-day basis, often based on information that is either incomplete or unclear. If public policymakers want to influence those choices, they will need to build partnerships with other stakeholders.

One example may be the harnessing of mobile technologies, such as phones and wearables, with big data sources — including choices and life cycle assessment data — and media channels, such as social media, in ways that help consumers adapt their choices from a linear to a circular way of thinking. Such actions can also contribute to the much-needed adjustment in price signals away from the linear economy and towards circular economy choices.

These types of 'knowledge to action' developments should be primarily focused on products that are at the core of the circular economy, on guiding business, and, on empowering citizens. This will doubtless bring additional challenges around confidentiality that will need to be set against the benefits with such knowledge to taking the next step on the transition to a circular economy.

Abbreviations

CMU	Circular material use
COSME	Competitiveness of Enterprises and Small and Medium-sized Enterprises
EEA	European Environment Agency
EEB	European Environmental Bureau
EEE	Electrical and electronic equipment
EFSI	European Fund for Strategic Investments
EIB	European Investment Bank
ELV	End-of-life vehicle
EPA	Environment protection agency
EPR	Extended producer responsibility
ESI	European Structural and Investment Funds
ETC/WMGE	European Topic Centre on Waste and Materials in a Green Economy
EU	European Union
GDP	Gross domestic product
Gt	Gigatonne
Gt/year	Gigatonnes per year
IRP	International Resource Panel
JRC	Joint Research Centre (of the European Commission)
MSW	Municipal solid waste
POM	Share of reuse in products put on the market
REACH	Registration, Evaluation, Authorisation and Restriction of Chemicals Regulation
SMEs	Small and medium-sized enterprises
TNO	Netherlands Organisation for Applied Scientific Research
VAT	Value added tax
WBCSD	World Business Council on Sustainable Development
WEEE	Waste electrical and electronic equipment

Glossary

Biodegradation	The transformation of a substance into new compounds through biochemical reactions or the actions of microorganisms such as bacteria.
Bioeconomy	Those parts of the economy that use renewable biological resources from land and sea — such as crops, forests, fish, animals and microorganisms — to produce food, materials and energy.
Blockchain	Blockchain is, inter-alia, the technology that underpins digital currency (Bitcoin, Litecoin, Ethereum, and the like). The use of the technology allows digital information to be distributed, but not copied.
Carbon dioxide equivalent	Carbon dioxide equivalency is a quantity that describes, for a given mixture and amount of greenhouse gas, the amount of carbon dioxide that would have the same global warming potential when measured over a specified timescale — generally, 100 years.
Climate-neutral economy	A climate-neutral economy is achieved if CO_2 emissions are reduced to a minimum and the remaining CO_2 emissions are offset with climate protection measures.
Closed-loop recycling	This results in recycled materials of the same quality and with the same application options as the original material.
Design for X	The use of a formal methodology to optimise a specific aspect of a design. The variable X represents the areas of focus.
Downcycling	See open-loop recycling.
Linear economy	The current 'take, make, dispose' economic model.
Material passports (for buildings)	Complete records of the materials used in buildings to facilitate their maintenance and the recycling/reuse of materials after demolition.
Natural capital	The world's stock of natural resources, which includes geology, soils, air, water and all living organisms.
Open-loop recycling	This results in recycled materials that have different, often inferior, material properties and applications from the original material (also known as downcycling).
Rebound effect	The reduction in expected gains from new technologies that increase the efficiency of resource use.
Sankey diagram	A specific type of flow diagram, in which the width of the arrows is proportional to the flow quantity.

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