Circular economy in Europe

Developing the knowledge base

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European Environment Agency

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Foreword

The European Environment Agency (EEA)'s publication *The European environment — State and outlook 2015* highlights 'stimulating resource-efficient, low-carbon economic and social development' as essential to achieving the 2050 vision of 'living well within the limits of the planet' as set out in the European Union (EU)'s 7th Environment Action Programme.

This requires Europe and the rest of the world to move away from the current linear economic model of take-make-consume-dispose, which relies on large quantities of easily accessible resources and energy, to a circular model in which planetary boundaries are respected through resource conservation and by maximising the use of resources already available within the economy.

The concept of a circular economy has recently gained traction in European policymaking as a positive, solutions-based perspective for achieving economic development within increasing environmental constraints. This is reflected in the 7th Environment Action Programme, which identifies the 'need for a framework that gives appropriate signals to producers and consumers to promote resource efficiency and the circular economy'. It is also increasingly seen as a business opportunity, for example through the efforts of the Ellen McArthur Foundation. Moreover, European countries increasingly indicate the circular economy as a political priority.

In December 2015, the European Commission published *Closing the loop — An EU action plan for the circular economy*, a new strategy that aims to support the transition to a circular economy in the EU. The action plan sets out a large number of initiatives that address all stages of the life cycle, combined with concrete targets on waste and the development of a monitoring framework in cooperation with the EEA. In this way, it takes important steps towards a circular economy in Europe.

When I was appointed as Executive Director in 2013, I made a commitment for the EEA to help Europe achieve its long-term policy vision by focusing on plausible transition pathways. Therefore, I am pleased with the transitions perspective in the new strategy on the circular economy, recognising that what lies ahead of us is no less than a fundamental systemic change. The EEA is prepared to support this transition through analysis and assessments, in cooperation with the European Commission, the European Environment Information and Observation Network (Eionet) and other stakeholders.

But what are the benefits of a more circular economy and how can these, as well as potential negative effects, be assessed? What needs to be done to turn theory into practice, and what hurdles need to be overcome? And how can current policies, alongside business and civil society initiatives, contribute to the transition? Answers to such questions can help policymakers, investors, businesses, consumers and civil society to find the most promising transition pathways.

The current knowledge base, however, is rather fragmented. Better insight is needed into various aspects of system dynamics, such as production structures and functions, consumption dynamics, finance and fiscal mechanisms, and triggers and pathways for technological and social innovations.

Through this new series of circular economy reports, the EEA aims to provide answers to some of these questions and bridge knowledge gaps. The series mainly targets policymakers at the EU and national levels, but it also targets businesses and civil society.

This report draws on a wide range of knowledge sources, both internal and external to the EEA. Through compiling and interpreting the available information, it touches on four dimensions of a circular economy: the concept and benefits; the main enabling factors and transition challenges; metrics for measuring progress; and contextual issues that would require attention from research or policy. In this way, the EEA seeks to support policymaking by furthering the understanding of the circular economy concept and its implementation.

Hans Bruyninckx, Executive Director

Summary: a circular economy — essential for Europe

Europe is bound to the rest of the world through multiple systems that enable two-way flows of materials, financial resources, ideas and innovation. As a result, Europe's economic, ecological and societal resilience is and will continue to be significantly affected by a variety of global and interdependent social, economic, political, environmental and technological trends.

Global material resource use in 2030, for example, is expected to be twice that of 2010 (SERI, 2013), while the most recent United Nations forecast suggests that the global population is likely to exceed 11 billion by the end of the 21st century (UN DESA, 2015). With 7.2 billion people today, however, the planet is already struggling to meet humanity's demands for land, food and other natural resources, and to absorb its wastes. Indeed, there is evidence that some planetary boundaries, which define a safe operating space for human development, may already have been transgressed. These include the biosphere's integrity, nitrogen and phosphorus cycles, climate change and land system changes (Steffen et al., 2015).

The pace of technological change, particularly in the fields of information, communication, nano- and biotechnologies, is unprecedented. These innovations may help to reduce humanity's impact on the environment and reliance on non-renewable natural resources, but the uptake of new technologies is often associated with uncertainty and risk.

In the face of these challenges and opportunities, the EU aims to evolve its economic and social systems so that its citizens will, by 2050, live well but within the limits of the planet (EU, 2013).

A circular economy can contribute to this. Unlike the traditional linear take-make-consume-dispose approach, a circular economy seeks to respect planetary boundaries through increasing the share of renewable or recyclable resources while reducing the consumption of raw materials and energy and at the same time cutting emissions and material losses. Approaches such as eco-design and sharing, reusing, repairing, refurbishing and recycling existing products and materials will play a significant role in maintaining the utility of products, components and materials and retaining their value.

The benefits for Europe could be considerable, reducing environmental pressures in Europe and beyond and minimising the continent's high and increasing dependence on imports, which could potentially become vital as other regions develop and international competition for resources increases. Circular economy strategies could also result in considerable cost savings, increasing the competitiveness of Europe's industry while delivering benefits in terms of job opportunities.

The concept of a circular economy is relatively new at the European level, and its overall economic, environmental and social effects have yet to be fully assessed. The concept has its roots in sustainable development, and the term 'circular economy' has been used by countries such as Germany and China for a number of years. Some aspects of current policy development, particularly in terms of waste and new business practices in several sectors, are moving tentatively towards circularity, but not necessarily in a systematic or coordinated way. More information is needed to inform decision-making and combine thinking about environmental, social and economic impacts.

Inter-sectoral and political tensions are likely to develop in the course of a transition, as there will inevitably be winners and losers. While Europe remains a powerhouse of knowledge and innovation, some of its traditional businesses and their employees are likely to suffer in the transition to a circular economy.

The overall aim is to manage all natural resources efficiently and, above all, sustainably. The transition to a circular economy will be multifaceted and will therefore need to involve all stakeholder groups: governments, businesses and finance, civil society and citizens. It will require different business, finance and even fiscal models, together with technological and social innovation and the acquisition of new skills and knowledge through education. The European Commission's 2015 circular economy package (EC, 2015a) should play an important role in bringing this about.

Charting progress

In parallel with the need to increase understanding of the circular economy, it will also be important to chart progress and identify where more work is needed to achieve change. Some existing indicators are already useful, but others will be needed to help guide the development of supportive and flexible policies.

The transition to a circular economy will be evolutionary. Innovation and change will bring benefits but also create challenges. The development of complex plastics and alloys — increasingly used in electrical and electronic products, as well as in vehicles — is a good example. Science, businesses and governments are only beginning to understand how to recycle them, avoiding the waste of valuable and increasingly rare materials, while keeping potentially hazardous substances out of the biosphere, where they could affect ecosystems and human health.

The series of circular economy reports to be published by the EEA in the coming years — based on growing insights from science and innovation, as well as other knowledge sources — aims to support efforts to make Europe's economy more circular and thereby realise its full potential.

The knowledge base needed for a circular economy and the EEA's role

The transition to a circular economy is a complex process involving fundamental changes to production-consumption systems that affect the environment. These include financing mechanisms, consumer behaviour, government intervention such as tax policy, and technological, social and business innovation. Monitoring and assessing the related environmental pressures and impacts is a core EEA activity.

Managing the transition will also require a better understanding of broad societal trends and the drivers of production and consumption patterns. Prospective analysis and foresight techniques such as scenario-building or horizon scanning can help identify possible triggers for the desired systemic changes. Such analytical techniques can also factor in shocks and resilience, and allow institutions and decision-makers to prepare for the unexpected and undesired. These techniques will have to be adapted to the process of transition towards a circular economy.

Examples of good practice that can be applied at broader scales can also inform analyses of policy options and effectiveness. Obtaining relevant information from all actors involved will require cooperation across different sectors and between organisations, a process to which the EEA intends to contribute.

All of this implies a substantial expansion of the evidence base, and while some indicators and assessments already exist, there is much to be done to develop a comprehensive analytical framework. The analytical approach described in Figure 1.1 can be applied at the European, national or local levels, as well as to specific sectors or materials. The EEA aims to contribute to this knowledge base in cooperation with its relevant partners and networks, including Eionet.

1 The circular economy and its benefits

1.1 The need for action

The concept of the circular economy reflects the recognition that European systems of production and consumption need to be fundamentally transformed to achieve the EU's 2050 vision of 'living well within the limits of our planet' (EU, 2013) (Box 1.1).

In the last hundred years, the shift of an increasing number of countries from low to high levels of human development has brought an unprecedented increase in natural resource use. Driven initially by economic development in Europe and North America, and subsequently elsewhere, world gross domestic product (GDP) has increased 25-fold since 1900, bringing a 10-fold rise in global resource extraction (Krausmann et al., 2009; Maddison, 2013).

These trends are likely to continue in the coming decades, as growing populations in Asia and elsewhere increasingly adopt the consumption patterns of developed regions. Global economic output is projected to triple between 2010 and 2050 (OECD, 2014) and resource use may double by 2030 (SERI, 2013). For Europe, these developments raise major concerns relating to the security of access to natural resources and the wider environmental impacts of escalating global resource use.

Europe's economy depends on an uninterrupted flow of natural resources and materials, including water, crops, timber, metals, minerals and energy carriers, with imports providing a substantial proportion of these materials in many cases. Increasingly, this dependence could be a source of vulnerability, as

Box 1.1 Living well within the limits of the planet makes economic transition imperative

In March 2015, the EEA published *The European environment — State and outlook 2015* (SOER 2015) (EEA, 2015a), which provides a comprehensive assessment of the European environment and sets it in a global context. It informs European environmental policy implementation and analyses the opportunities of achieving the EU's 2050 vision of 'living well within the limits of the planet'. The report's three key conclusions are highly relevant to helping frame priority areas for action on the circular economy.

First, EU environment and climate policies have delivered substantial benefits not only to the environment, but also to the economy and human well-being. The European environment has seen marked reductions in emissions to air and water, with, for example, the EU on track to meet its 2020 targets for greenhouse gas emission reductions. Meanwhile, the industrial sector that manages natural resources and produces goods and services that reduce environmental degradation grew by more than 50 % between 2000 and 2012 (Eurostat, 2015a), one of the few sectors to have flourished since the 2008 financial crisis.

Second, and despite some successes, Europe faces both persistent and emerging challenges linked to its production-consumption systems and a rapidly changing global context, as shown by a range of social, technological, economic, environmental and political megatrends.

Third, achieving the 2050 vision requires fundamental transitions, especially in the systems that contribute most to environmental pressures and impacts — food, energy, mobility and housing — along their entire value chain. This also implies that wide-ranging changes to the enabling finance and fiscal systems will be required.

SOER 2015 also highlights that achieving the 2050 vision will depend on action taken and investments made today across the key systems, and that the criteria for long-term systemic change should deliver decent employment and salaries and be equitable, while respecting environmental limits.

growing global competition for natural resources has contributed to marked increases in price levels and volatility. Even if not scarce in absolute terms, many natural resources are unevenly distributed globally, making access and prices more volatile and exacerbating the potential for conflict (EEA, 2015b). Uncertain and unstable prices can also disrupt the sectors that are dependent on these resources, forcing companies to lay people off, defer investment or stop providing goods and services.

At the same time, rapid increases in extraction and exploitation of natural resources are having a wide range of negative environmental impacts in Europe and beyond (EEA, 2014a). Air, water and soil pollution, acidification of ecosystems, biodiversity loss, climate change and waste generation put immediate, medium- and long-term economic and social well-being at risk. While resource use in Europe has become more efficient in recent years, resulting in absolute reductions in emissions of greenhouse gases and pollutants, the continent's burden on global ecosystems remains considerable, particularly if pressures in the countries of origin of imported products and materials are taken fully into account (EEA, 2015a). In addition, Europe's overall gains in resource efficiency may not be sustained when the economic development of countries hit by recent recession recovers.

Creating a circular economy in Europe can help to address many of these challenges, and further improving the efficiency of resource use has obvious economic benefits, reducing costs and risks while enhancing competitiveness. European leadership in the transition to a circular economy also offers opportunities to drive innovation in new materials and better products and services, creating new jobs and securing first-mover advantages in the global economy (EMF, 2012; Accenture, 2014).

1.2 What is a circular economy?

In essence, a circular economy represents a fundamental alternative to the linear take-make-consume-dispose economic model that currently predominates. This linear model is based on the assumption that natural resources are available, abundant, easy to source and cheap to dispose of, but it is not sustainable, as the world is moving towards, and is in some cases exceeding, planetary boundaries (Steffen et al., 2015).

The Ellen MacArthur Foundation defines a circular economy as one that is restorative, and one which aims to maintain the utility of products, components and materials and retain their value (EMF, 2015a). It thus minimises the need for new inputs of materials and energy, while reducing environmental pressures linked to resource extraction, emissions and waste. This goes beyond just waste, requiring that natural resources are managed efficiently and sustainably throughout their life cycles. A circular economy thus provides opportunities to create well-being, growth and jobs, while reducing environmental pressures. The concept can, in principle, be applied to all kinds of natural resources, including biotic and abiotic materials, water and land.

Eco-design, repair, reuse, refurbishment, remanufacture, product sharing, waste prevention and waste recycling are all important in a circular economy. At the same time, material losses through landfill and incineration will be reduced, although these may continue to play a much-reduced role in safely removing hazardous substances from the biosphere and recovering energy from non-recyclable waste.

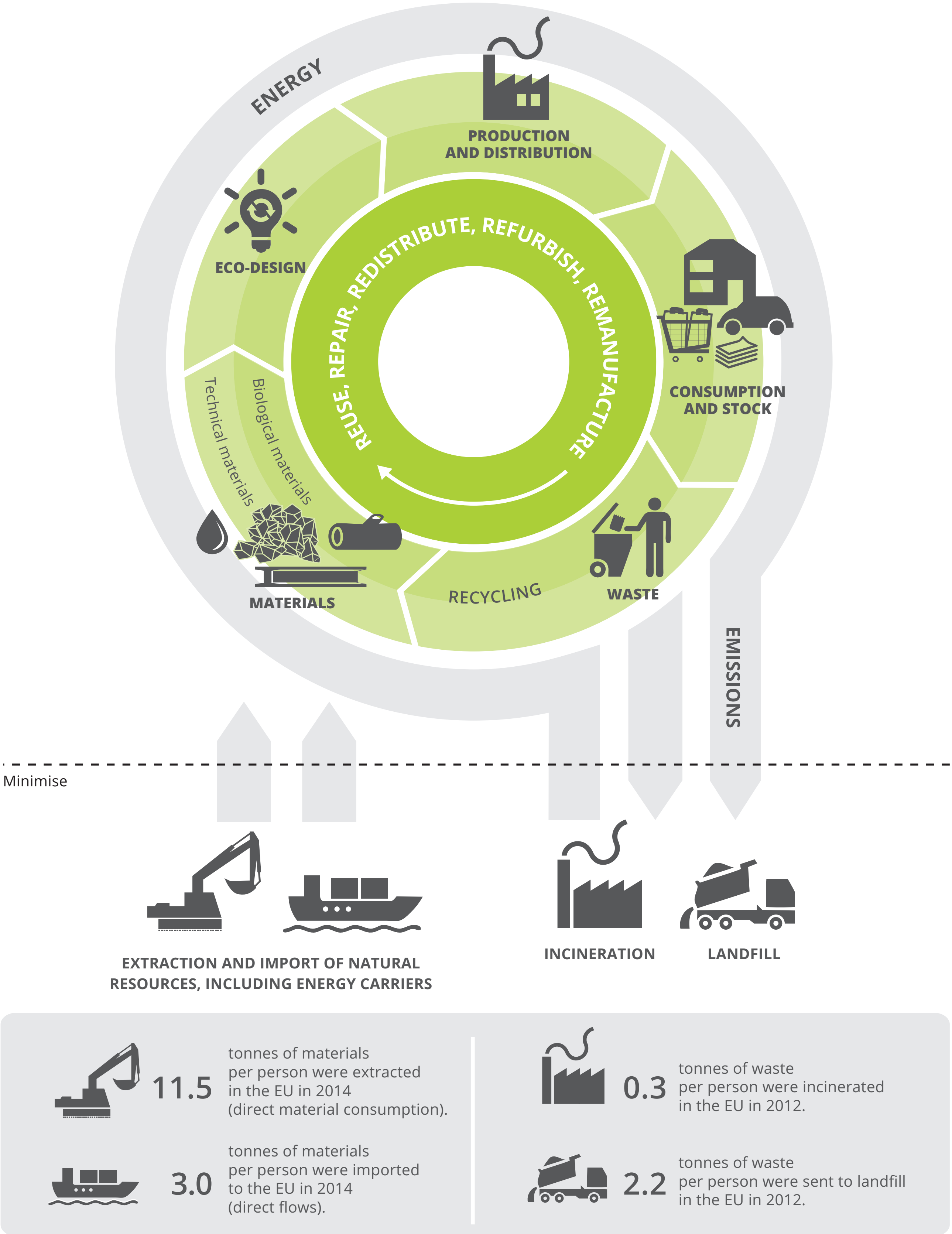
Several concepts and visualisations of a circular economy exist; Figure 1.1 shows a simplified model. The main idea is that waste generation and material inputs are minimised through eco-design, recycling and reusing of products. This will create economic and environmental co-benefits, as the dependency on extraction and imports declines in parallel with a reduction in the emissions to the environment caused, for example, by extraction and processing of materials, incineration and landfill.

The outer circle represents the overall energy flows. Relevant parameters are the total energy efficiency and the share of renewables, which should both increase compared with the linear model. The implications for incineration are not straightforward. While energy recovered through incineration can partly compensate for (fossil) fuel use, incineration is to be minimised, as the energy from incineration can be used only once and thus removes materials from the loop.

The middle circle represents the material flows in the recycling loop, distinguishing between abiotic technical materials (such as metals and minerals) and biological materials. An increased share of the latter would, in principle, be beneficial, as they are truly renewable, whereas technical materials are not. In practice, technical and biological materials are often mixed, which has implications for biodegradability and recyclability. Furthermore, using more biological materials may exert additional pressure on natural capital, with impacts on ecosystem resilience (Chapter 4).

The inner circle represents reuse, redistribution, repair, remanufacture and refurbishment, bypassing waste generation and recycling and thus requiring minimal

Figure 1.1 **A simplified model of the circular economy for materials and energy**



Source: EEA based on Eurostat, 2015b, 2015c.

resource input. These approaches retain the value of products, components and materials at the highest possible level.

Box 1.2 lists the main characteristics of a circular economy and a number of technical, economic or social enabling factors required to effect the transition to such an economy. The main characteristics will differ for different types of system, for example for food that is consumed, metals that can be recycled or water used in processing that can be recycled. Similar principles, however, apply and some key characteristics and enabling factors can be defined. While the list of enabling factors is not exhaustive, it demonstrates the wide range of changes that will be needed to trigger or advance the transition.

Box 1.2 Key characteristics and enabling factors of a circular economy

Key characteristics	Enabling factors
Less input and use of natural resources • minimised and optimised exploitation of raw materials, while delivering more value from fewer materials; • reduced import dependence on natural resources; • efficient use of all natural resources; • minimised overall energy and water use. ***Increased share of renewable and recyclable resources and energy*** • non-renewable resources replaced with renewable ones within sustainable levels of supply; • increased share of recyclable and recycled materials that can replace the use of virgin materials; • closure of material loops; • sustainably sourced raw materials. ***Reduced emissions*** • reduced emissions throughout the full material cycle through the use of less raw material and sustainable sourcing; • less pollution through clean material cycles. ***Fewer material losses/residuals*** • build up of waste minimised; • incineration and landfill limited to a minimum; • dissipative losses of valuable resources minimised. ***Keeping the value of products, components and materials in the economy*** • extended product lifetime keeping the value of products in use; • reuse of components; • value of materials preserved in the economy through high-quality recycling.	***Eco-design*** • products designed for a longer life, enabling upgrading, reuse, refurbishment and remanufacture; • product design based on the sustainable and minimal use of resources and enabling high-quality recycling of materials at the end of a product's life; • substitution of hazardous substances in products and processes, enabling cleaner material cycles. ***Repair, refurbishment and remanufacture*** • repair, refurbishment and remanufacture given priority, enabling reuse of products and components. ***Recycling*** • high-quality recycling of as much waste as possible, avoiding down-cycling (converting waste materials or products into new materials or products of lesser quality); • use of recycled materials as secondary raw materials; • well-functioning markets for secondary raw materials; • avoidance of mixing and contaminating materials; • cascading use of materials where high-quality recycling is not possible. ***Economic incentives and finance*** • shifting taxes from labour to natural resources and pollution; • phasing out environmentally harmful subsidies; • internalisation of environmental costs; • deposit systems; • extended producer responsibility; • finance mechanisms supporting circular economy approaches. ***Business models*** • focus on offering product–service systems rather than product ownership; • collaborative consumption; • collaboration and transparency along the value chain; • industrial symbiosis (collaboration between companies whereby the wastes or by-products of one become a resource for another). ***Eco-innovation*** • technological innovation; • social innovation; • organisational innovation. ***Governance, skills and knowledge*** • awareness raising about changing lifestyles and priorities in consumption patterns; • participation, stakeholder interaction and exchange of experience; • education; • data, monitoring and indicators.

Central to achieving the necessary systemic changes, however, will be to find synergetic economic and social incentives, for example through financial mechanisms that encourage consumers and producers to hire rather than buy a product, while at the same time stimulating the eco-design of the product.

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. Integration between policy levels and policy domains, as well as within and across value chains, is also essential. Action will be needed at all levels, from the European to the local, and by all stakeholders, including governments, businesses, researchers, civil society and citizens.

While the EEA's analytical focus will mainly be on the environmental effects of the transition, relevant economic and social factors will also be analysed to support the process. This is essential because of the strong links between the use of natural resources, human health and well-being, and the functioning of ecosystems in Europe and globally through trade in goods and services.

1.3 What are the benefits?

The EU's waste policies already contribute to the development of a circular economy, mainly through policy measures that favour recycling. But there are benefits of a more extensive transition to a circular economy in four areas: resource use, the environment, the economy and social aspects such as job creation (Figure 1.2). The transition process, however, necessarily requires profound changes and thereby also creates transition costs.

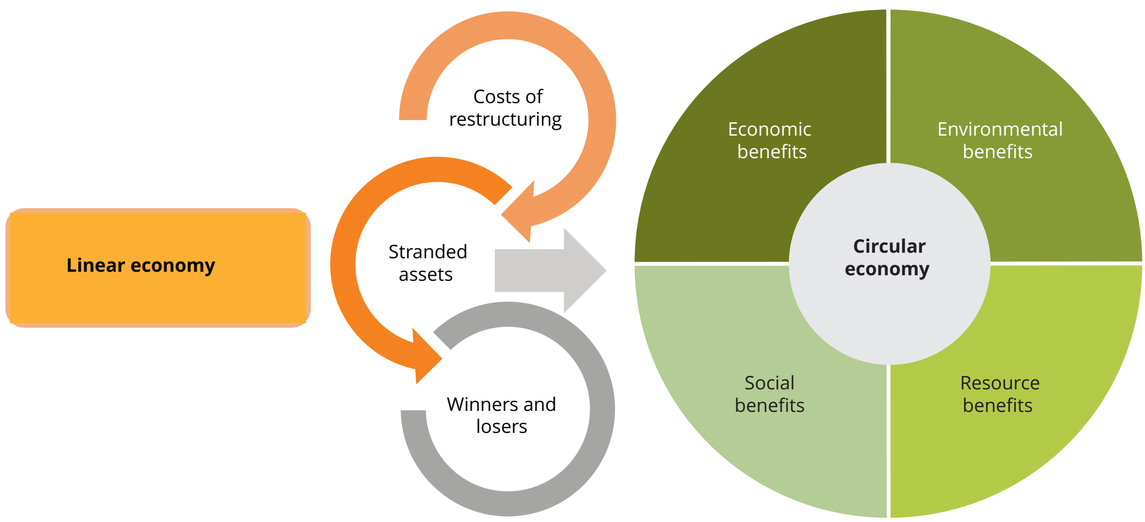
1.3.1 Resource benefits: improving resource security and decreasing import dependency

A circular economy could increase the efficiency of primary resource consumption in Europe and the world. By conserving materials embodied in high-value products, or returning wastes to the economy as high-quality secondary raw materials, a circular economy would reduce demand for primary raw materials. This would help to reduce Europe's dependence on imports, making the procurement chains for many industrial sectors less subject to the price volatility of international commodity markets and supply uncertainty due to scarcity and/or geopolitical factors.

An estimated 6–12 % of all material consumption, including fossil fuels, is currently being avoided as a result of recycling, waste prevention and eco-design policies; the maximum potential using the existing technology is estimated to be 10–17 % (EC, 2011a). Using innovative technologies, resource efficiency improvements along all value chains could reduce material inputs in the EU by up to 24 % by 2030 (Meyer, 2011).

A recent study of the impacts of a switch to a circular economy in the food, mobility and built environment

Figure 1.2 Transition from a linear to a circular economy



sectors estimated annual savings of primary resource inputs of EUR 600 million in the EU-27 ([1]) by 2030. Achieving this would require systemic changes in these sectors. For example, in the area of mobility, changes would entail more sharing of cars and better integration of transport modes, light-weight and remanufactured cars, electrification of transport based on renewables and self-driving vehicles. For the food system, the study mentions more resource-efficient and regenerative farming practices such as organic or no-till farming, closing nutrient loops (for example, phosphorus recovery from meat and bone meal) and reducing food waste. Moreover, in the built environment, systemic changes would include factory-based industrial processes in construction, smart urban planning, sharing of residential and office space, and energy-efficient buildings (EMF and McKinsey Center for Business and Environment, 2015).

1.3.2 *Environmental benefits: less environmental impact*

The absolute decoupling of economic output and social well-being from resource and energy use, and from related environmental impacts, is the main objective of the EU's resource-efficiency policy (EU, 2013). Indeed, although current waste policies already contribute to this, the European Commission estimates that different combinations of more ambitious targets for recycling of municipal and packaging waste and reducing landfill could lead to a reduction in greenhouse gas emissions of around 424–617 million tonnes of carbon dioxide equivalent over 2015–2035, on top of reductions through the full implementation of existing targets (EC, 2015b).

Measures beyond waste recycling, however, could further reduce greenhouse gas emissions. It has been estimated, for example, that, in the food and drink, fabricated metals and hospitality and food services sectors, resource efficiency measures could avoid around 100–200 million tonnes of carbon dioxide equivalent emissions annually (AMEC Environment & Infrastructure and Bio Intelligence Service, 2014). Keeping materials in the loop would also help to enhance ecosystem resilience and the environmental impacts of mining primary raw materials, often outside Europe.

The study of the potential in the food, mobility and built environment systems mentioned above estimates a prospective reduction in greenhouse gas emissions of 48 % by 2030 and 83 % by 2050 compared with 2012 levels, and a reduction in externality costs ([2]) of up to EUR 500 million by 2030 (EMF and McKinsey Center for Business and Environment, 2015).

1.3.3 *Economic benefits: opportunities for economic growth and innovation*

The linear take-make-consume-dispose approach exerts great pressure on the environment and human health, and can also reduce opportunities for increasing the competitiveness of several sectors of European industry. A circular economy, on the other hand, could offer a platform for innovative approaches, such as technologies and business models to create more economic value from fewer natural resources.

A circular economy could provide significant cost savings for various industries. For example, implementation of circular economy approaches in the manufacture of complex durable goods with medium lifespans is estimated to result in net material cost savings of USD 340–630 billion per year in the EU alone, roughly 12–23 % of current material input costs in these sectors (EMF, 2012). For certain consumer goods — food, beverages, textiles and packaging — a global potential of USD 700 billion per year in material savings is estimated, that is, about 20 % of the material input costs in these sectors (EMF, 2013).

Another study estimates the annual net benefits for EU-27 businesses of implementing resource-efficiency/ circular economy measures such as waste prevention, the recovery of materials, changing procurement practices and the re-design of products. These range from EUR 245 billion to EUR 604 billion, representing an average of 3–8 % of annual turnover (AMEC Environment & Infrastructure and Bio Intelligence Service, 2014).

1.3.4 *Social benefits: sustainable consumer behaviour and job opportunities*

Social innovation associated with sharing, eco-design, reuse, recycling and other developments can be expected to result in more sustainable consumer behaviour, while contributing to human health and safety.

([1]) EU-28 countries excluding Croatia.
([2]) Externalities include carbon dioxide (EUR 29 per tonne), traffic congestion, non-cash health impacts of accidents, pollution and noise, land opportunity costs, opportunity costs related to obesity, adverse health effects due to the indoor environment and transport time (related to urban planning).

A circular economy is also expected to create job opportunities. Indeed, according to the European Commission's impact assessment on a legislative proposal on waste, increased recycling targets, the simplification of legislation, improved monitoring and the diffusion of best practice to achieve increased recycling/preparing for reuse targets for municipal and packaging waste, in combination with reduced landfill of waste, could result in the creation of up to 178 000 new direct jobs by 2030 (EC, 2015b).

The development of fully circular value chains might have significantly greater potential. Estimates for the United Kingdom suggest that around 500 000 jobs could be created in a circular economy. While some sectors may diminish, a net creation of jobs by 2030 is projected (Morgan and Mitchell, 2015). This study also demonstrates how differing circular strategies could generate different types of jobs. For example, labour-intensive strategies, such as the preparation and sorting of products and materials for reuse or recycling, would mainly yield jobs for low-skilled people; medium-skilled jobs are expected to be created in closed-loop recycling and remanufacturing, and high-skilled jobs in bio-refining.

Replacing products with services could also provide jobs for people with all levels of education. A recent study (Ministère de l'Economie et al., 2015) estimated that 2 200 new jobs, mainly for blue-collar workers, could be created by 2030 by applying circular economy practices in Luxembourg's construction, automotive, manufacturing, financial, logistics, research and development, and administrative sectors, providing opportunities for unemployed young people.

Finally, a meta-study reviewing 65 studies on employment and the circular economy found generally positive employment effects as a result of moving towards a circular economy. The studies mainly addressed energy and material savings; studies on employment effects of sharing, recycling and further approaches are scarce (Horbach et al., 2015).

1.4 Challenges

While the order of magnitude of expected environmental, resource-related and socio-economic benefits of a transition to a circular economy are reasonably reliable, the exact numbers in existing studies need to be treated with some caution, owing to methodological and data limitations.

As in all transition processes, benefits will not be evenly distributed: some industrial sectors, businesses, regions and societal groups are likely to lose, while others will benefit. For example, jobs in industries producing virgin materials or low-quality consumer goods, often outside Europe, could be lost through such strategies. Policies will be needed to manage these effects.

Realising the benefits will also depend upon how well and quickly adequate skills and education for the circular economy can be developed and rolled out.

2 Enabling factors

2.1 Introduction

The transition to a circular economy requires fundamental changes in many different areas of the current socio-economic system. Although it is a complex process that is difficult to predict, several crucial areas of change can be identified in technical, economic and social domains, with a focus on the enabling factors that guide and accelerate the transition process (Box 1.2). These factors need to act simultaneously in order to create reinforcing effects, and, critically, they all require the support of adequate policy frameworks and interventions.

Forward-looking governments and business organisations are increasingly analysing policy options and their potential impacts, aiming to create favourable conditions for a circular economy (De Groene Zaak, 2015; EMF, 2015b). At the EU level, the European Commission's recent circular economy package (EC, 2015a) and the European innovation partnership on raw materials (EC, 2012a) both aim to enable circular economy approaches, while the EU's Horizon 2020 research and innovation programme is set to invest around EUR 670 million throughout 2016–2017 into the EU's industry, with the aim of supporting circular economy approaches (EC, 2015c).

One of the most powerful enablers of a circular economy is business model innovation ([3]): business models that successfully incorporate circular economy principles have a direct and lasting effect on the economic system. Without the adaptation of policy frameworks, however, many innovative business models will not be able to compete with existing linear ones, or they might lose some or all of their benefits when scaling up.

Eco-design, because it acts at the start of the value chain, is a second important enabler, but, because the current economic system does not reward eco-designed products, policies will need to provide the necessary incentives to improve the circularity of products, extending lifetimes, repair, reuse and recycling.

Reuse and repair are enablers whose relevance has recently grown, with the rise of second-hand markets and online repair communities complementing smart policy interventions that stimulate reuse by simultaneously tackling labour-cost barriers and low-skilled employment challenges.

Waste prevention is an important strategy that cuts across different areas of change, rather than being one single enabler.

2.2 Innovative business models

2.2.1 Service- and function-based business models

These models relate to the functions of a product instead of its physical ownership (Ölundh and Ritzén, 2001; Mont, 2007). Various types can be distinguished: **product-oriented services**, which are centred on product sales, including additional services such as maintenance and take-back agreements; **user-oriented services**, which are based on product leases, rentals, sharing and pooling; and **result-oriented services**, which provide specific outcomes, such as the creation of a pleasant climate in offices (Tukker and Tischner, 2006).

From an economic perspective, these models can improve customer loyalty, increase market share through product differentiation, scale up the value of used products leading to reduced costs, and bring new technologies to the market (Baines et al., 2007; FORA, 2010; EMF, 2013). In addition, service-based business models provide transparency for customers about the costs of the whole use phase, whereas uncertainties exist about costs of maintenance, repair and replacement in purchase-based models (FORA, 2010). Nevertheless, these models may trigger negative economic and social impacts on traditional value chains, as they reduce the need for new materials and products. Environmental benefits can be observed in terms of reducing resource use and environmental impacts through the substitution of products with services.

([3]) Different typologies of circular business models have been developed (for example, ETC/SCP and ETC/WMGE, 2014; van Renswoude et al., 2015).

Box 2.1 Service- and function-based business models in action

In 2010, Xerox, a producer of copying machines, ventured into the managed service sector by enabling customers to lease printing and copying machines, paying per print or copy made, with maintenance costs included in the cost per click. The managed print services business model has been so successful that, by 2011, it accounted for nearly 50 % of the company's revenue (Xerox, 2015).

Rolls-Royce decided to offer performance-based power-by-the-hour contracts in its civil aviation business under which customers paid a fixed maintenance price that guaranteed engine availability to lessees. By 2011, Rolls-Royce's revenue from this service reached GBP 6.02 billion, that is, 53.4 % of its total revenue (Smith, 2013).

Rebound effects, such as increased demand for a service because it costs less than ownership, could, however, arise.

2.2.2 Collaborative consumption

Collaborative consumption is based on sharing, swapping, bartering, trading or leasing products and other assets such as land or time (Botsman and Rogers, 2010). While such peer-to-peer interactions have long been practised on a local scale, they have developed into a different dimension through the use of online **sharing marketplaces**, through which the demand for certain assets, products or services is matched with their supply, usually through consumer-to-consumer (C2C) channels.

Some — for example the hugely successful Airbnb model, which allows people to rent rooms and apartments — involve fees for individual transactions, while others are only open to registered fee-paying members, and some, typically smaller and often local schemes, are cost-free for users. A 2014 global online survey showed that 54 % of European respondents were willing to share or rent out their possessions for money, while 44 % were happy to rent goods and services from others (Nielsen, 2015), suggesting that this model has considerable potential.

Positive economic effects include consumer access to a broader selection of products and services without incurring the liabilities and risks associated with ownership. While outcomes for citizens are generally positive, traditional businesses could experience losses in the form of lower sales, while governments might have to re-examine fiscal rules to guard against diminishing tax revenues.

Environmental benefits include a decrease in the use of natural resources, energy and emissions throughout production and consumption cycles based on longer or more intensive use of existing products (FORA, 2010). That, however, might trigger negative environmental impacts by promoting the longer use of inefficient appliances, or an increase in mobility (Leismann et al., 2013) through, for example, car sharing or low-price access to holiday accommodation.

Social effects can be measured through enhanced social interaction and cohesion, as well as job creation. While the net effect on the creation of new jobs is unknown, companies organising collaborative consumption stimulate micro-entrepreneurship among the general public (Dervojeda et al., 2013). The rapid growth of some internet-based C2C platforms has sparked discussion about fair competition, safety, risk allocation and workers' rights, triggering the creation of specific legislative frameworks. Issues of concern

Box 2.2 Collaborative consumption in action

Peerby is an online platform that matches people in temporary need of a specific object with those who have the object and are willing to lend it, free of fees. From its inception in 2011, Peerby has enabled 300 000 lending and borrowing transactions between its 100 000 members, leading to a net decrease in the need for new products (Financial Times, 2014).

Operating with a similar C2C business model, the originally Dutch platform Thuisafgehaald (Shareyourmeal) makes it possible for people to share spare homemade food. So far, the meal-sharing website has enabled people in eight European countries to share around 133 000 meals (Thuisafgehaald, 2015), reducing food waste and strengthening social ties between neighbours.

that might require regulation when collaborative consumption is scaled up include taxation, property rights, avoiding the creation of informal sectors in the economy, and insurance.

Uptake of collaborative consumption is also influenced by cultural factors, for example historic experiences of forced collectivisation, and increased personal wealth providing more assets to share, although interest in sharing might, for economic reasons, be higher in less well-off regions of Europe. Overall, the effects of collaborative consumption business models depend on the exact set-up of the model, including whether they are oriented towards profit or non-profit.

2.2.3 Waste-as-a-resource business models

Business models aiming to use waste as a resource promote cross-sector and cross-cycle links by creating markets for secondary raw materials. These can reduce the use of energy and materials during production and use, and also facilitate locally clustered activities to prevent by-products from becoming wastes: industrial symbiosis.

Positive economic effects can arise from the availability of cheaper materials diverted from waste as an alternative to virgin materials (OECD, 2013), including avoiding the costs of waste disposal and capturing the residual economic value of existing material streams (ETC/SCP, 2013). Positive environmental effects can be measured as a net reduction in environmental pressure from waste disposal and the production of virgin materials.

Social effects include the reduction of municipal waste disposal and other environmental costs (EMF, 2012). Recycling chains that meet environmental and worker safety standards have positive social impacts, but lock-in effects can occur if the demand for waste as an input reduces the incentive for waste prevention.

2.2.4 Finance mechanisms for innovative business models

Circular business models require adapted finance mechanisms. For example, with a changed perspective on selling services rather than products, the property rights of products are no longer transferred to the consumer (buyer), but will be kept by the producing company. Businesses will not receive payment at the beginning of the product's life cycle, but will receive payments during their period of use. The timing of cash flow is therefore pivotal for new business models in the circular economy. The relatively new, green-bond market appears well-suited for this purpose (EEA, 2014b).

Moving some of the tax burden from traditional sources (for instance, personal income taxes or social security contributions) to activities damaging the environment can also accelerate the transition from the linear to a circular economic model. Environmental taxes can lead to a reduction in labour costs and thereby encourage labour-intensive activities such as remanufacturing and repair, thus creating a more level playing field between the innovative and traditional business models (EEA, 2014b).

Insight into the development and use of these financing mechanisms and tax-based instruments, and the market penetration of new business models, will thus be crucial for analysing the transition process.

2.2.5 The importance of policy innovation

A common feature of most innovative business models is their disruptive nature. This is positive, as

Box 2.3 Waste-as-a-resource business models in action

The National Industrial Symbiosis Programme (NISP) in the United Kingdom is a network of more than 15 000 participating industrial companies that identifies mutually profitable transactions between companies to optimise the use of underused or undervalued resources, including energy, water, waste and logistics. So far, NISP has enabled its members to divert 47 million tonnes of industrial waste from landfill, generated GBP 1 billion in new sales and created and safeguarded more than 10 000 jobs (International Synergies, 2015).

Kalundborg is a medium-sized Danish town that, since 1970, has developed a symbiotic relationship between public authorities and private companies to buy and sell waste, including steam, gas, water, gypsum, fly ash and sludge. The benefits from this collaborative network include heat recovery equivalent to the annual electricity consumption of more than 75 000 families, avoiding 240 000 tonnes of carbon dioxide emissions and saving 3 million cubic metres of water through recycling and reuse (Jacobsen, 2008).

system change requires nothing less than disruptive action, but new business models can also have negative effects because, for example, no taxes are paid or safety regulations are not met. These negative effects are the result of existing policy frameworks not keeping up with changing social, technological and economic contexts. Policy innovation should tackle this problem by finding solutions to eliminate any potentially negative social consequences of innovative business models while safeguarding or even strengthening their positive environmental and economic outcomes.

2.3 Eco-design

Eco-design delivers products made with fewer resources, using recycled and renewable resources and avoiding hazardous materials, as well as with components that are longer lasting and easier to maintain, repair, upgrade and recycle. Two approaches can be distinguished: product redesign based on incremental improvements to existing products and new product design representing the development of new resource-efficient products that can be repaired, upgraded and recycled (UNEP and TU, 2009).

From an economic point of view, eco-design can reduce production costs leading to increased purchasing power for consumers, which in turn can improve their welfare (EMF, 2013). If products are designed to last longer and can be easily repaired or upgraded by product owners or professional repair facilities, the value is retained in society for much longer than if the product is discarded, even if the materials are recycled.

Environmentally, eco-design can contribute to the decoupling of economic growth from resource consumption through a decreased use of materials and energy, higher recycling rates and reduced waste generation (EMF, 2013). Environmental rebound effects, such as the longer use of relatively inefficient products, however, could occur, but depend strongly on patterns of use (Gutowski et al., 2011).

Social effects include job creation and increased consumer trust in sustainable products and services (Fiksel, 2003).

The Ecodesign Directive requirements for energy-related products provide a framework for setting minimum environmental standards and energy efficiency requirements for energy-related products (EU, 2009). Although it has, in practice, been used mainly to set energy efficiency performance criteria, it could also be used more intensively to stimulate circular product design, for example by ruling out design strategies that hinder repair or exchange of faulty parts (EEA, 2014a).

2.4 Extending the lifetime of products through reuse and repair

Extending the lifetime of products is a central enabler of the circular economy, and reusing products and their components, as well as remanufacturing, is one of its key strategies. Reuse conserves the physical assets of raw materials as well as the energy embedded in products or components. Among others, the 7th Environment Action Programme calls for measures to address product durability, reparability, reusability, recyclability, recycled content and product lifespan (EU, 2013).

The roles of reuse and preparation for reuse have been significantly strengthened by the 2008 Waste Framework Directive (EU, 2008), which established a five-step waste hierarchy. Its first priority is to prevent waste from being generated, followed by preparation for reuse, recycling, recovery and, finally, disposal. The Directive provides basic definitions for reuse and preparation for reuse:

- **reuse** means any operation by which products or components that are not waste are used again for the purpose for which they were conceived;

Box 2.4 Eco-design in action

Houdini Sportswear AB, Sweden, designs long-lasting products and also offers repair services, rental of outer garments and own-brand second-hand clothes at its shops. The company started to use recycled polyester fibres in its products and reached a proportion of 58 % recycled materials in items sold in 2012/2013. At the same time, it is partnering with other outdoor garment producers to phase out persistent, toxic and bio-accumulative per- and poly-fluorinated chemicals (Houdini, 2013; Kiørboe et al., 2015).

PUMA, another sportswear corporation, designed Clever Little Bag packaging for its shoes. This reduced cardboard use by about 65 % and is saving 20 million megajoules of electricity, 0.5 million litres of diesel and 1 million litres of water per year — and the bags can be reused (Daily Telegraph, 2010).

- **preparing for reuse** means checking, cleaning, repairing or recovery operations by which products or components that have become waste are prepared so that they can be reused without any other pre-processing.

Reuse and repair might still be more widely applied in lower income countries in Europe for economic reasons and because of past experiences of limited access to resources. However, these patterns are being challenged by the increasing complexity of products together with shorter innovation cycles and rapidly changing market fashions, which lead to a rapid loss in the value of products over time. Recently, however, interest in reuse has increased significantly, illustrated by civil society initiatives such as repair cafes and the booming internet-based market places that match sellers of used goods with buyers. Emerging business models (Box 2.5) demonstrate a variety of ways of prolonging the life of products or components, saving costs and materials while creating new jobs.

2.4.1 Policy incentives for reuse

New and innovative business models often require carefully designed policy interventions to become mature, competitive and economically viable, while at the same time avoiding market distortions. Reuse initiatives, for example, are often supported by specific policy initiatives, such as the establishment of local and regional reuse networks, the development of binding quality standards and warranty regulations for second-hand products, or first attempts to ensure the reparability of products. In France, for example, manufacturers and retailers are obliged to inform consumers about the period for which spare parts will be available and manufacturers are obliged to provide the repair sector with spare parts.

One successful type of policy intervention is the linking of reuse to social employment policies, offering jobs to lower skilled or long-term unemployed workers. These kinds of synergies are demonstrated by, inter alia, the Kringloop Reuse Centres in Flanders, Belgium.

Based on a Dutch model, Flanders introduced a network of reuse centres in 1992 (EC, 2009) with the primary goal of preventing waste by reselling discarded products. In more than 140 second-hand shops grouped into 31 reuse centres, products such as textiles, electronics, furniture, kitchen appliances, books, records and bicycles are sorted, repaired and resold (OVAM, 2014). Apart from saving 4 kilograms of waste per inhabitant per year, the network also guaranteed employment to more than 3 800 workers in 2012 (full-time equivalent). The majority of these have been long-term unemployed or have received only limited education, and the network's reuse centres provide them with both a stable income and practical workplace experience. Added to this, the network enables those with limited resources to obtain goods they could otherwise not afford.

Preparation for reuse and repair is generally employment-intensive and often in the hands of craftsmen and small companies, creating jobs at the local level. Synergies with employment policies therefore highlight the cross-cutting nature of this topic, although additional measures aiming to lengthen product life, diminish single-use products and reduce waste will still be needed.

There is also a global dimension to reuse as an enabling factor for a circular economy. After first use, many products, including electronic devices, cars and textiles, are exported to developing countries where, due to lower labour costs, manual sorting, repair and further preparation for reuse are cheaper than in Europe and demand for used products is higher. This has a

Box 2.5 Reuse as part of the business model

An example of reuse being integrated into the business model of companies is the Aircraft Fleet Recycling Association (AFRA), a not-for-profit association originally formed by 11 airlines to present a perspective on aircraft sustainability by developing best practice and technologies for the management of the world's older fleet (Glueckler and Dickstein, 2015). The organisation has published a best-management-practice auditable standard and provides training for its 28 accredited members.

In 2013, 470 planes were disassembled, returning more than 6 000 tonnes of components to service (Glueckler and Dickstein, 2015). In 2014, the value of parts recovered and reintroduced to the market amounted to USD 3.2 billion. Other projects, including PAMELA (Process for Advanced Management of End of Life of Aircraft), which is co-funded by the EU, also aim to demonstrate that an aircraft can be dismantled safely and its components prepared for reuse in aviation or other sectors (EC, 2011b).

significant potential to develop global closed cycles, resulting in economic, social and environmental gains. However, it also presents challenges with regard to ensuring that products are actually repaired or recycled without damaging effects on human health and the environment, and that such exports for reuse and recycling are not just a way of circumventing national, regional and international agreements on dealing with wastes, including hazardous ones.

2.5 Waste prevention programmes

One of the established policies that supports the move towards a circular economy is the EU's five-step waste hierarchy established in the 2008 EU Waste Framework Directive, prioritising the prevention of waste generation. The Directive required EU Member States to adopt waste prevention programmes by December 2013, and many countries included measures to foster innovative business models, repair, reuse and eco-design in their programmes.

Policy measures aiming to reduce waste also decrease the overall need for raw materials and avoid both waste and the emissions created along the value chains of materials and products. They also offer a variety of opportunities to reduce costs, from the purchase of raw materials to the treatment and disposal of wastes.

Despite its undisputed potential, waste prevention seems to be one of the most challenging strategies: in 2012, more than 2.5 billion tonnes of waste were discarded in the EU, 101 million tonnes of which were hazardous (Eurostat, 2015d).

Waste prevention interacts with a wide range of environmental and non-environmental policy areas and covers a broad range of different activities along the whole value chain, including all upstream and downstream elements. Waste can be prevented in the production phase by improving material efficiency, using processes that generate less waste, and product and service innovation (EC, 2012b). In the distribution phase, waste can be prevented, for example by good planning of supplies and stocks, waste-reducing marketing strategies, including avoiding buy-one-get-one-free offers that tend to generate waste by incentivising the purchase of un-needed food, and using less waste-intensive packaging. Waste can also be prevented during the consumption phase, for example by using products that are less waste-intensive over their life cycles, keeping products in use for longer, repairing, sharing or hiring products, and reducing levels of consumption (EC, 2012b). Box 2.6 and Box 2.7 illustrate two different examples of waste prevention policies applied in European countries.

Article 29 of the Waste Framework Directive obliged all EU Member States to develop national waste prevention programmes by the end of 2013. A review of the first 27 programmes revealed, inter alia, that countries/regions use a wide variety of indicators, and 17 have set quantified targets, but with limited use of monitoring systems. Around two-thirds of policy instruments focus mainly on information and awareness raising, with regulatory and economic instruments accounting for only around one-third (EEA, 2014c). The programmes outline the status quo and future objectives, together with specific measures needed to reach them. Based on their specific framework conditions, countries and regions have chosen different key sectors, waste streams and policy approaches for the implementation of their programmes.

The EEA's reviews of progress in Europe in 2013 and 2014 also highlighted a clear need to improve the insight on implementation of waste prevention measures (EEA, 2014c, 2015c). Future EEA analyses will therefore focus on the impacts of specific measures and initiatives for selected waste types or specific waste-generating sectors, for example hazardous waste, food waste or reuse systems (EEA, 2015c).

Box 2.6 Waste prevention in the construction sector in Austria

The Austrian waste prevention programme identified construction and infrastructure development as one of the key sectors for waste prevention and developed a building-passport concept as part of a building material information system (Reisinger et al, 2014). This aims to connect architects, suppliers and statistical registers to enable the careful, selective demolition of buildings, enabling reuse and high-quality recycling of building materials, and to support the prevention of waste by extending the use of houses through improved maintenance schemes.

The building passport includes all of the necessary information for the waste-light operation of buildings, and records all building activities, incorporated materials and technical equipment (Rechberger and Markova, 2011). Following several pilot projects, the Austrian waste prevention programme is now working to standardise building passports and increase their use.

Box 2.7 Food waste prevention in Spain

A study on food waste in Spain indicated that national average food loss and waste amount to around 176 kilograms per person per year. Alerted by the fact that Spain is ranked seventh in Europe in terms of volume of food loss and waste (7.7 million tonnes), the country has taken a proactive approach and adopted the More Food, Less Waste strategy (MAGRAMA, 2013). The programme aims to reduce food loss and waste through the whole food supply chain, starting with agriculture, through food processing and distribution, to consumption in households and the hospitality sector, and food waste valorisation.

The strategy includes carrying out studies to understand where, how, why and what type of food loss and waste are generated (MAGRAMA, 2015); promoting and sharing good practice and raising awareness; analysing and reviewing regulatory aspects; collaborating with relevant actors; and promoting the development of new technologies. The implementation period runs over three years.

3 Monitoring progress towards a circular economy

At present, there is no recognised way of measuring how effective the EU, a country or even a company is in making the transition, nor are there holistic monitoring tools for supporting such a process.

A monitoring framework, as well as individual indicators, across multiple levels would facilitate policy development, measure environmental performance and policy effectiveness, benchmark products, sectors and countries, and improve business investment decisions. Such a framework should provide meaningful answers to policy questions covering all relevant dimensions of the transition: resource use and material flows, environmental impacts, economic parameters, social well-being, financing flows and policy effectiveness. Because of the complex dynamics governing the transition, the monitoring framework needs to be flexible, allowing the adaptation of indicators and focus areas to maintain its effectiveness throughout the evolution of the transition.

This chapter looks at the challenges and solutions related to developing such a framework to enable the measurement of progress in the transition. In this report, the focus is on the material side of the circular economy, analysing which policy questions and indicators would give insight into whether or not the European economy is becoming more circular.

Indicators, however, have clear limits for giving directions. Qualitative assessments are therefore needed to complement them in the process of monitoring progress towards a circular economy.

3.1 Policy questions related to the material aspects of a circular economy

Table 3.1 lists a set of policy questions that are relevant when assessing progress towards a circular economy with a focus on materials.

Some of these can be answered by using existing indicators, whereas data and robust indicators do not yet exist to answer others. Some indicators, such as those relating to eco-design, can be better used at the product level; others, such as those based on material flows, can be used at a macro-economic level. Overall, indicators related to material use and recycling cut across all stages of the cycle listed in Table 3.1.

Tables 3.2–3.6 match the questions in Table 3.1 to indicators that can answer policy-relevant questions on progress towards a circular economy; some are already available, but others still need to be developed. Priorities will have to be identified for investment in filling the gaps and linking indicators to qualitative assessments. The set is by no means exhaustive and should be considered dynamic.

Table 3.1 Policy questions related to progress towards a circular economy from a materials perspective

Material input	Are Europe's primary material inputs decreasing?
	Are material losses in Europe decreasing?
	Is the share of recycled materials in material input increasing?
	Are the materials used in Europe sustainably sourced?
Eco-design	Are products designed to last longer?
	Are products designed for disassembly?
	Are recycled materials included in product design?
	Are materials designed to be recycled, avoiding pollution from recycling loops?
Production	Is Europe using fewer materials in production?
	Is Europe using a lower volume and number of environmentally hazardous substances in production?
	Is Europe generating less waste in production?
	Are business strategies shifting towards circular concepts such as remanufacture and service-based offers?
Consumption	Are Europeans switching consumption patterns to less environmentally intensive types of goods and services?
	Are Europeans using products for longer?
	Is European consumption generating less waste?
Waste recycling	Is waste increasingly recycled?
	How far do materials keep their value in recycling processes, avoiding down-cycling?
	How far is the recycling system optimised for environmental and economic sustainability?

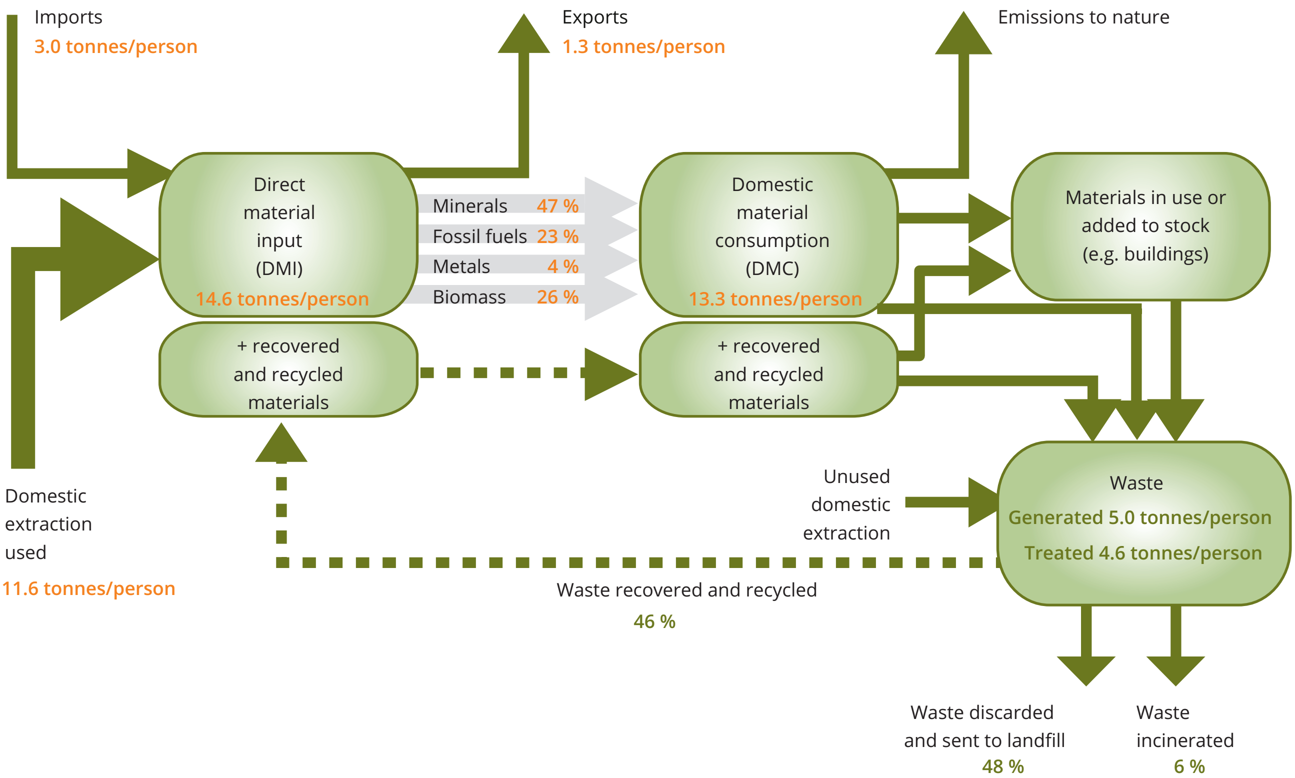
3.2 Material input

Established indicators already exist to measure primary material inputs. While data on domestic material consumption (DMC) are most widely available, raw material consumption (RMC) is a modelled indicator that includes indirect material flows associated with imports and exports and thus reflects Europe's overall material impact better than DMC. Indicators to answer the policy questions on material losses, on the share of recycled materials and on the sustainable sourcing of materials still need further work, and only limited data are available (Table 3.2). The EEA's estimates of the share of recycled materials in EU consumption of selected materials range from 42 % for iron and steel to just 2 % for plastics in 2006 (EEA, 2011). Development work focusing on material flows in a circular economy, on the contribution of recycling to material demand and on supply risks is currently under way at the European Commission under its activity for creating a Raw Materials Scoreboard in support of the European Innovation Partnership on Raw Materials (EC, 2014).

The challenges in answering the final three policy questions in Table 3.2 are illustrated by the example of material losses, with minimising such losses being one of the key characteristics of a circular economy (Box 1.2). The discrepancy between material input, waste generation and recycling flows, shown in Figure 3.1, demonstrates that adequate data are currently not available to enable macro-level monitoring of the main losses and sinks. Of the waste treated, less than half is recovered or recycled.

Loops are unlikely to close fully, partly because some processed material is used to provide energy and is thus not available for recycling. Another reason for losses is the increasing complexity of products and materials, for example plastic and metal alloys, which are technically challenging to recycle.

Figure 3.1 Material flows and waste in the EU-28, 2012–2014



Note: For waste statistics, latest data are from 2012 (dark green figures); for material flows, data are from 2014 (orange figures).

Source: EEA, based on Eurostat 2015b, 2015c, 2015d.

Table 3.2 Policy questions and indicators for material input

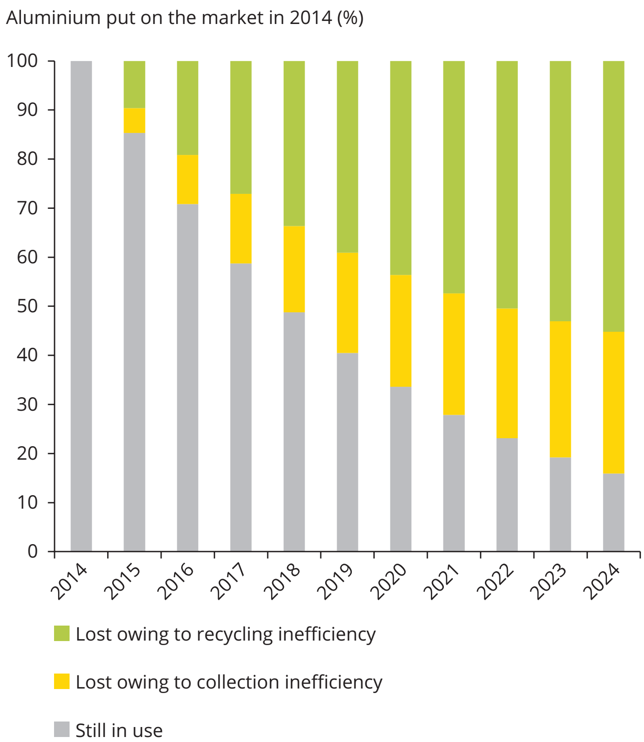
Policy questions	Possible indicators	Data availability
Are Europe's primary material inputs decreasing?	DMC or RMC	++
Are material losses in Europe decreasing?	Proportion of material losses in key material cycles	+
	Diversion of waste from landfill (EEA indicator WST006, under development)	++
Is the share of recycled materials in material input increasing?	Share of secondary raw materials in material consumption	+
Are the materials used in Europe sustainably sourced?	Share of sustainability-certified materials in material use (by key materials)	+

Note: ++, data readily available and/or indicator exists; +, limited data available that could be used to develop the indicator or experimental indicator; –, no data currently available to create the indicator.

While information is available on material inputs measured as DMC or calculated as RMC, including the amount of raw materials that need to be extracted to produce traded goods, stocks are currently not measured in the EU's statistical system and are much more difficult to assess. Losses are, to some extent, addressed in the EU's waste statistics, but the two statistical systems of material flows and waste are not compatible and thus cannot easily be used for balancing inputs, stocks and losses. To reduce losses, better information about where they actually happen is needed. Eurostat is currently exploring possibilities for linking waste data to material flow data.

As an example of material losses, Figure 3.2 shows cumulative material losses related to the use of aluminium cans in Flanders, calculated with a Weibull-based partitioning model with parameters chosen to mimic an average use phase of six months (OVAM, forthcoming). The figure shows that, even in a very circular system, with collection and pre-processing rates of 97 % each and recycling process efficiencies delivering 97 % recovery in the smelting process, only 16 % of the aluminium remains in the cycle after 10 years.

Figure 3.2 The cumulative loss of aluminium from the hard packaging cycle in Flanders over time



Source: Modelled by VITO, based on data from OVAM (forthcoming).

3.3 Eco-design

Eco-design is a strategic management approach that considers the environmental impacts of the full life cycles of products, processes, services, organisations and systems. Eco-design strategies, such as design for recycling or disassembly, can facilitate remanufacturing and closed loops in general, while also making products suitable for servicing, leasing and hiring. Products may include buildings and infrastructure, as well as consumer products.

While eco-design is a key approach in a circular economy, macro-level indicators that could answer the policy questions listed in Table 3.3 barely exist; regular data are not available for any of the possible indicators listed. As a whole, progress in eco-design strategies can best be monitored at the company and product levels. Developing indicators that can monitor progress towards eco-design at the EU or country level is a significant challenge.

The material circularity indicator, developed by the Ellen MacArthur Foundation (EMF and Granta Design, 2015), combines aspects of lifetime and intensity of use with the proportion of recycled material and the share of materials in a product that can be recycled in a single indicator, applicable at the product or company level.

Durability is influenced by a number of factors, such as the resilience of materials and components, design that enables repair and refurbishment, and fashion, while lifetime also depends on patterns of use. Indicators for design for recycling and disassembly are less straightforward than, for example, the use of specific materials in products. Design for disassembly enables a decrease in the cost of dismantling a product, which can in turn lead to enhanced recycling and reuse of the product itself or its components. As a consequence, waste flows associated with the product are reduced and impacts associated with the production of new products or parts are avoided. Absolute figures are very product- and process-specific.

Table 3.3 Policy questions and indicators for eco-design

Policy questions	Possible indicators	Data availability
Are products designed to last longer?	Durability or lifetime compared with an industry average for a similar product	–
Are products designed for disassembly?	Time and number of necessary tools for disassembly	–
Are recycled materials included in product design?	Proportion of recycled material in new products	–
Are materials designed to be recycled, avoiding pollution from recycling loops?	Share of materials where safe recycling options exist	–

Note: ++, data readily available and/or indicator exists; +, limited data available that could be used to develop the indicator or experimental indicator; –, no data currently available to create the indicator.

3.4 Production

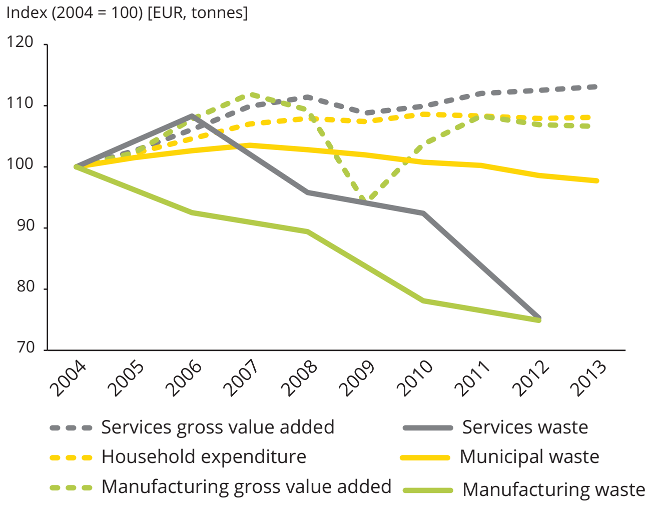
A circular economy aims for production processes that minimise material inputs and limit the output of non-recyclable or hazardous waste.

Some data are available on material use in production in different sectors, based on environmental-economic accounting (Table 3.4). Work is under way to consolidate the methodology and data and this should provide a more robust basis for indicators. Meanwhile, established indicators exist for the generation of waste in production by sector in Europe. Figure 3.3 shows that, since 2004, the manufacturing and service sectors have generated less waste in absolute terms, despite their economic growth. A similar indicator could be created for hazardous waste, based on existing data.

There are currently few means of monitoring clean production directly from a material cycle perspective. Data are regularly assembled on the production of hazardous substances, including amounts produced for export from Europe, but not on the amount actually used in Europe, including imports.

Developments at the macro-level, such as a decline in material input or waste generation, are often difficult to interpret and changes could, for example, be due to structural changes in the economy rather than any movement towards a circular economy. Monitoring progress, therefore, should include developments towards more circular business strategies. Examples of how this could be measured include the involvement of companies in circular economy networks and the share of remanufacturing in the economy. Remanufacturing, for example, uses existing products or components to create new ones with the same properties as those made from scratch, and is thus a way of minimising the environmental impacts of production. The European remanufacturing landscape is only now being mapped (ERN, 2015), so further studies will be needed to quantify the current size and structure of the remanufacturing industry.

Figure 3.3 Waste generation by production and consumption activities in Europe



Notes: Generated waste refers to waste excluding major mineral waste such as mining waste or mineral waste from construction and demolition. The geographical coverage for manufacturing and services waste, and manufacturing and services gross value added (in constant prices), is the EU-28 plus Norway; for municipal waste generation and household expenditure, it is the EEA-33. Values for Croatia are missing in manufacturing and services waste generation for 2006.

Source: EEA indicator CSI041/WST004, based on Eurostat data.

Table 3.4 Policy questions and indicators for production

Policy questions	Possible indicators	Data availability
Is Europe using fewer materials in production?	Material use for production compared to GDP (potentially by sector)	+
Is Europe using a lower volume and number of environmentally hazardous substances in production?	Input of substances that are classified as hazardous	+
Is Europe generating less waste in production?	Waste generation (production activities) (EEA indicator CSI041/WST004)	++
	Generation of hazardous waste in production processes	++
Are business strategies shifting towards circular concepts such as remanufacture and service-based offers?	Involvement of companies in circular company networks	–
	Share of remanufacturing business in the manufacturing economy	–

Note: ++, data readily available and/or indicator exists; +, limited data available that could be used to develop the indicator or experimental indicator; –, no data currently available to create the indicator.

3.5 Consumption

Consumption choices by citizens, governments and businesses have a considerable influence on the realisation of a circular economy through their choice of products and services, patterns of use, disposal options and behaviour.

Indicators such as the environmental footprint of consumption in Europe and the generation of municipal waste in Europe will reflect, on a macro-level, the effects of making more circular choices such as sharing existing assets, choosing longer-lasting products or reusing, repairing and refurbishing products instead of buying new ones. These indicators will show the net effects of such consumption developments on a macro-level. They balance material inputs and waste avoided through more circular consumption modes against additional environmental pressures that result when, for example, people spend income they have saved by renting instead of owning on other goods and services. Such macro-level indicators, however, cannot allocate the net effects to specific changes in consumption behaviour.

The trends in material footprint per euro spent would be more difficult to interpret; for example, a shift to longer-lasting products and repair instead of buying new would reduce environmental pressures per euro spent if the expenditure stays the same or increases for the same product or service unit.

Methods for calculating the environmental footprints of household consumption, using environmentally extended input-output tables or life-cycle analyses, are available, but data availability is still limited and subject to delays.

However, for monitoring the effects of different circular consumption strategies and revealing their relevance and effects, more specific indicators are needed. For example, measuring the actual lifetime of products or the market share of services that prepare for reuse and repair could help answer the question of how long products are actually used before being replaced with new ones. Regularly produced data for such indicators, however, do not currently exist.

A useful and established indicator for consumption is the generation of municipal waste (Figure 3.3). This decreased by 2 % in Europe (EU-28 plus Iceland, Liechtenstein, Norway, Switzerland and Turkey) between 2004 and 2012, and is decoupled from household expenditure (EEA, 2015d).

Table 3.5 Policy questions and indicators for consumption

Policy questions	Possible indicators	Data availability
Are Europeans switching consumption patterns to less environmentally intensive types of goods and services?	Environmental footprint of consumption (including materials) in Europe	+
	Material footprint per euro spent (EEA indicator SCP013)	+
Are Europeans using products for longer?	Actual average lifetime of selected products	–
	Market share of preparing for reuse and repair services related to sales of new products	–
Is European consumption generating less waste?	Waste generation (consumption activities) (EEA indicator CSI041/WST004)	++

Note: ++, data readily available and/or indicator exists; +, limited data available that could be used to develop the indicator or experimental indicator; –, no data currently available to create the indicator.

3.6 Waste recycling

One of the central pillars of a circular economy is feeding materials back into the economy and avoiding waste being sent to landfill or incinerated, thereby capturing the value of the materials as far as possible and reducing losses.

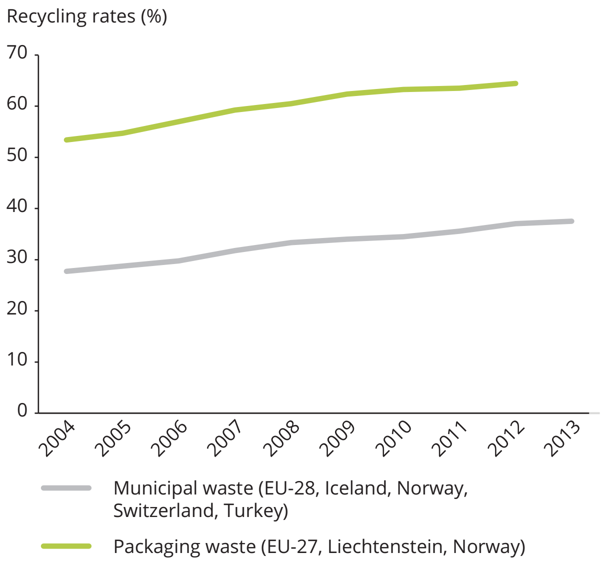
Recycling rates — the amount of waste recycled as a share of waste generated — can be calculated from regularly reported European waste data for several waste streams. Recycling rates of municipal and packaging waste, for example, have steadily increased over the past 10 years in Europe (Figure 3.4), mainly triggered by legally binding recycling targets. Some of the data, however, might include rejects from sorting and processing. Moreover, data include all forms of material recovery, with no distinction between down-cycling, recycling or up-cycling.

Indicators measuring how far materials keep their value in recycling processes, and how far the recycling system is optimised for environmental and economic sustainability, are more difficult to calculate. In practice, only a limited number of materials can currently be recycled without a loss of quality. Reasons include material mixes and additives that technically cannot be separated, contamination and dissipative use. Even materials that, in principle, can be recycled without a loss of quality, such as metals and glass, can be downgraded by contamination and the high cost of processing.

Attention therefore needs to be paid to extending the quality and value of recycled material, starting from the design of materials and products. More innovation and increased efficiency are also required at all stages of the recycling system: collection, pre-treatment and processing. The turnover of recyclables in Europe could give some indications of their value, and the European reference model on municipal waste (ETC/WMGE, 2015) could be used to calculate environmental effects and costs/revenues of recycling systems for municipal waste. However, this model does not allow for calculation of trends back through time.

Indicators of quality would have to be set separately for different materials. Innovative approaches are needed to capture both the material quality and the suitability of recycled materials for replacing virgin materials.

Figure 3.4 Recycling rate of municipal solid waste and packaging waste in Europe



Notes: Recycling rates are related to waste generated. Recycling of municipal waste includes material recycling and composting/anaerobic digestion. Gap filling of data for municipal waste was applied for Croatia and Iceland for several years. Gap filling of packaging waste data was applied for several years for Bulgaria, Liechtenstein, Norway and Romania.

Source: Draft EEA indicator WST005, based on Eurostat data (Eurostat, 2015e, 2015f).

Table 3.6 Policy questions and indicators for waste recycling

Policy questions	Possible indicators	Data availability
Is waste increasingly recycled?	Recycling rates for different types of wastes/materials (EEA indicator WST005, under development)	++
How far do materials keep their value in recycling processes, avoiding down-cycling?	Recycled material quality compared with virgin material quality	–
	Turnover of key recyclables	+
How far is the European recycling system optimised for environmental and economic sustainability?	Environmental effects and cost/revenues of municipal waste management in Europe	+

Note: ++, data readily available and/or indicator exists; +, limited data available that could be used to develop the indicator or experimental indicator; –, no data currently available to create the indicator.

3.7 Conclusion

Current work on indicators that track progress towards a circular economy has been driven, to a large extent, by developments in material resource efficiency and waste management. Such measures of eco-efficiency classify resource flows according to the main categories identified in material flow accounts and waste statistics. While these are useful, the statistics fall short of providing a basis for assessing some particularly relevant aspects of a circular economy, such as material losses and the qualitative aspects of recycling.

In addition, looking at the elements of a circular economy holistically, challenges and large knowledge gaps persist. More robust data are needed on new business trends and sustainable consumption relating, for example, to eco-design, the sharing economy, and repair and reuse. Better descriptive social indicators, indicators for industrial symbiosis and waste prevention indicators would also provide greater insights on progress.

4 Circular economy in a wider context

4.1 Circular and green economy

For the circular economy to realise its full potential, it is important to consider how it resides within the wider policy context, in particular the EU's 7th Environment Action Programme. Recognising that environmental, economic and social objectives are essentially interlinked, the programme's three key objectives are to:

1. protect, conserve and enhance the EU's natural capital;

2. turn the EU into a resource-efficient, green and competitive low-carbon economy;

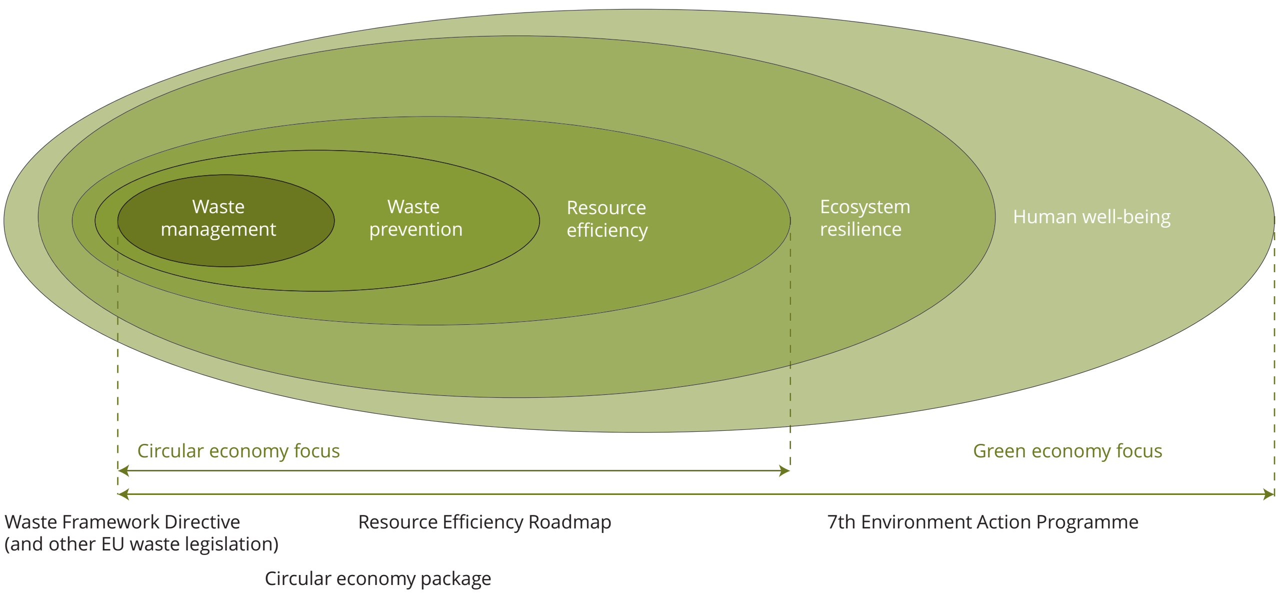
3. safeguard the EU's citizens from environment-related pressures and risks to health and well-being.

Taken together, these objectives reflect a 'green economy' policy concept, with 'green growth' and 'sustainable development' related but not synonymous concepts. In essence, economic growth should be decoupled from environmental pressures in order to maintain ecosystem resilience and prevent impacts on human well-being. Resource efficiency gains would be central to achieving this.

While a circular economy aims to increase resource efficiency, and is thus instrumental in realising the second key objective of the 7th Environment Action Programme, it does not fully address preservation of natural capital and prevention of environmental risks to human health and well-being. In fact, the circular economy can be represented as the core of a green economy perspective that widens the focus from waste and material use to ecosystem resilience and human health and well-being (Figure 4.1).

This wider interpretation calls for integrated analysis of the performance of production-consumption systems that goes beyond the 'core' circular aspects, as outlined in the previous chapters. Some further issues that merit broader assessment and policy attention are discussed below.

Figure 4.1 Circular economy and green economy



Source: EEA.

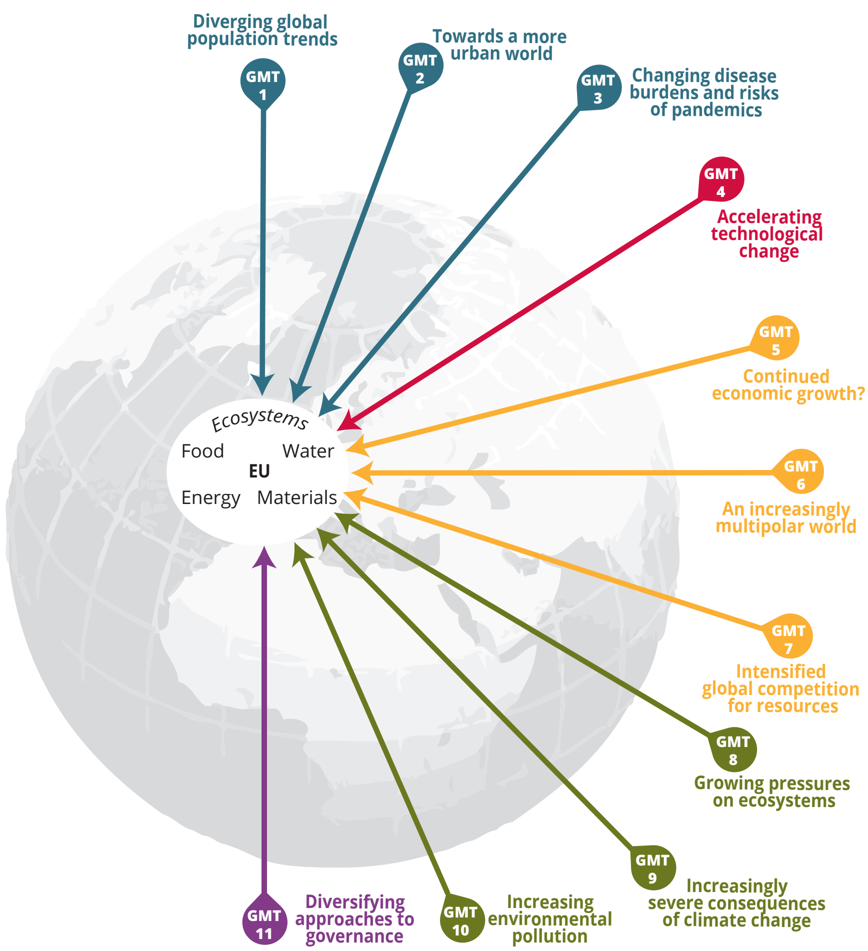
4.2 Global aspects

Decreased dependency on imports of strategic resources may be an explicit objective of the circular economy, but European production-consumption systems depend on such imports and will not operate in isolation. It is crucial to understand the environmental pressures that arise along the value chain, where these pressures will be critically felt and how a transition to a circular economy may influence those pressures. Only then can policy efforts be targeted at resources and actors for which the economic, environmental and social benefits of circular approaches are greatest.

The main resource categories relevant to the environment and human well-being are food, water, energy and materials (including chemicals), with the food, mobility and housing systems creating the dominant pressures (Figure 4.2). All are influenced by global megatrends (EEA, 2015b). Understanding these global megatrends and their possible impact on European production-consumption systems will require further study. In addition, the environmental and social implications of changes in supply chains, both in Europe and abroad, should be understood. A circular economy, if widely applied on a global level, in turn bears the potential to influence some of these megatrends.

European policies are mostly targeted at impacts that occur within Europe and at the production and end-of-life stages of systems. As international trade law limits intervention options, policy generally relies on consumption-oriented approaches, such as eco-labels, to influence the impacts of production abroad. European and global businesses increasingly work towards sustainable value chains. The United Nations' Sustainable Development Goals (UN, 2015), especially the goal to ensure sustainable consumption and production patterns, can be expected to give new impetus to public and private initiatives in this

Figure 4.2 Global megatrends (GMTs) and European production-consumption systems



Source: EEA, 2015b.

area. Coherence between (policy) interventions on the production and consumption side will be key to achieving this.

4.3 Ecosystem considerations

Tackling systemic challenges such as climate change and biodiversity loss requires an integrated approach to ensuring food, water and energy security, as well as fundamental changes in the production-consumption systems involved. Trade-offs are numerous, however, and should be carefully considered.

The objective of replacing non-renewable with renewable resources in a circular economy, for example, may increase competition for land and thereby increase pressures on natural capital. Bio-based materials compete with production of both food and biomass for energy generation, as well as with land use for other purposes. In general, biomass is best used in a cascade in which energy generation is the last step rather than the first.

But even if biomass is primarily used for durable products, environmental impacts are not straightforward. A key example is wood as a construction material. The benefits of this renewable resource should be offset against the biodiversity impacts of increased wood harvest, with current harvesting rates in Europe already reaching 65 % of the annual increment (EEA, 2015e). Analogous to the debate on bio-energy, the potential for uptake of bio-based materials should be critically analysed in view of overall biomass production and ecosystem resilience.

Overall, in the transition to a circular economy, it will be crucial to monitor how far the environmental benefits of circular approaches are realised or countered, for example by rebound effects.

4.4 Risks to human health and well-being

The assessment and governance of risks to human health and well-being cut across all dimensions of the green economy, and may deal with anything from exposure to air, soil and water pollution to loss of ecosystem services and impacts of climate change.

Of particular concern in the context of a circular economy is our increasing reliance on chemicals. When closing material loops, accumulation of hazardous substances should, in principle, be prevented. A key challenge in this respect is striking the right balance between the quantities of materials to be recycled and their (non-toxic) quality.

In the short term, clean material cycles will require keeping potentially contaminated waste materials apart and identifying waste types, products and materials that should not be recycled. To increase the recycling potential over time, the use of hazardous substances in products and processes would have to be minimised through eco-design. Reducing the accumulation of hazardous substances in material cycles is already an important goal of EU waste prevention policies.

There is also uncertainty about the impacts of new products and technologies in a circular economy. Policymakers will face difficult decisions, particularly when dealing with commercial interests and socio-economic trade-offs. Well-balanced precautionary approaches need to be developed to reap the benefits of innovation while minimising the risk of harming ecosystems and human health and well-being.

4.5 Socio-economic issues

The prevailing linear economic system and the rules governing it have been developed and matured over many years. As new circular approaches emerge, frictions between the existing linear system and the new approaches are bound to arise. These may be perceived as threats by some stakeholders, but as opportunities by others.

Overall, the way socio-economic benefits and risks are distributed, and how they are perceived by stakeholders, will be crucial for the transition to a circular economy in Europe. While several studies underline the potential of the circular economy in terms of creating employment, more attention needs to be given to net employment benefits and to the distribution of benefits and transition costs across different segments of the population, as well as across regions.

For example, little is known about the quality of new jobs that might be created in the circular economy and the skills needed in employees. Remanufacturing might bring industrial jobs back to Europe, but a move to product-service systems could also replace highly paid industrial jobs with lower paid service jobs. Similarly, collaborative consumption might improve social cohesion within a group of citizens, but it might also discriminate against other societal groups.

Overall, it will be important to increase research efforts to develop models and other tools for analysing socio-economic and environmental interactions and trade-offs.

References

Accenture, 2014, *Circular advantage — Innovative business models and technologies to create value in a world without limits to growth*, Dublin.

AMEC Environment & Infrastructure and Bio Intelligence Service, 2014, *The opportunities to business of improving resource efficiency — Final report on behalf of the European Commission*, Contract Ref. 070307/2011/610181/ETU/F.1., Northwich.

Baines, T. S., Lightfoot, H. W., Evans, S., Neely, A., Greenough, R., Peppard, J., Roy, R., Shehab, E., Braganza, A., Tiwari, A., Alcock, J. R., Angus, J. P., Bastl, M., Cousens, A., Irving, P., Johnson, M., Kingston, J., Lockett, H., Martinez, V., Michele, P., Tranfield, D., Walton, I. M. and Wilson, H., 2007, 'State-of-the-art in product-service systems', *Proceedings of the Institution of Mechanical Engineers, Part B: Journal of Engineering Manufacture*, 221(10), 1 543–1 552.

Botsman, R. and Rogers, R., 2010, *What's mine is yours: The rise of collaborative consumption*, Harper Collins Publishers, New York.

Daily Telegraph, 2010, 'Puma ditches the shoe box for a greener "Clever Little Bag"' (http://www.telegraph.co.uk/finance/newsbysector/retailandconsumer/7587375/Puma-ditches-the-shoe-box-for-a-greener-Clever-Little-Bag.html) accessed 18 March 2015.

De Groene Zaak, 2015, *Governments going circular — A global scan by De Groene Zaak*, Dutch Sustainability Business Association, Breda.

Dervojeda, K., Verzijl, D., Nagtegaal, F., Lengton, M., Rouwmaat, E., Monfardini, E. and Frideres, L., 2013, *The Sharing Economy — Accessibility Based Business Models for Peer-to-Peer Markets. Case Study 12*, European Commission, Directorate-General for Enterprise and Industry.

EC, 2009, 'Waste prevention — best practices' (http://ec.europa.eu/environment/waste/prevention/practices.htm) accessed 5 November 2015.

EC, 2011a, Commission staff Working Paper — Analysis associated with the Roadmap to a Resource Efficient Europe, Part II, accompanying the document Communication from the Commission to the European Parliament, the Council, the European Economic and Social Committee and the Committee of Regions 'Roadmap to a resource efficient Europe' (SEC(2011) 1067 final).

EC, 2011b, 'End-of-life aircraft recycling offers high grade materials' (http://ec.europa.eu/environment/ecoap/about-eco-innovation/good-practices/eu/719_en.htm) accessed 30 November 2015.

EC, 2012a, Communication from the Commission to the European Parliament, the Council, the European Economic and Social Committee and the Committee of the Regions: Making raw materials available for Europe's wellbeing — Proposal for a European innovation partnership on raw materials (COM(2012) 82 final of 29 February 2012).

EC, 2012b, *Preparing a waste prevention programme — Guidance document*, European Commission, Directorate-General Environment.

EC, 2014, Monitoring and evaluation scheme for the European innovation partnership — Strategic implementation plan on raw materials (final of 26 March 2014).

EC, 2015a, Communication from the Commission to the European Parliament, the Council, the European Economic and Social Committee and the Committee of the Regions — Closing the loop — An EU action plan for the Circular Economy (COM(2015) 614/2 of 2 December 2015).

EC, 2015b, Commission staff working document, Additional analysis to complement the impact assessment SWD (2014) 208 supporting the review of EU waste management targets Accompanying the document Proposal for a Directive of the European Parliament and of the Council amending Directive 2008/98/EC on waste Proposal for a Directive of the European Parliament and of the Council amending Directive 94/62/EC on packaging and packaging waste Proposal for a Directive of the European Parliament and of the Council amending Directive 1999/31/EC on the landfill of waste Proposal for a Directive of the European Parliament and of the Council amending Directives 2000/53/EC on end-of-life vehicles, 2006/66/EC on batteries and accumulators and waste batteries and accumulators, and 2012/19/EC on waste electrical and electronic equipment SWD(2015) 259 final.

EC, 2015c, *Commission invests €16 billion in funding for research and innovation over next two years*, Press release 13 October 2015 IP/15/5831, European Commission, Brussels.

EEA, 2011, *Earnings, jobs and innovation: the role of recycling in a green economy*, EEA Report No 8/2011, European Environment Agency.

EEA, 2014a, *Environmental indicator report 2014: Environmental impacts of production-consumption systems in Europe*, European Environment Agency.

EEA, 2014b, *Resource-efficient green economy and EU policies*, EEA Report No 2/2014, European Environment Agency.

EEA, 2014c, *Waste prevention in Europe — The status in 2013*, EEA Report No 9/2014, European Environment Agency.

EEA, 2015a, *The European environment — State and outlook 2015: Synthesis report*, State of the environment report, European Environment Agency.

EEA, 2015b, *The European environment state and outlook 2015 — Assessment of global megatrends*, European Environment Agency.

EEA, 2015c, *Waste prevention in Europe — The status in 2014*, EEA Report No 6/2015, European Environment Agency.

EEA, 2015d, 'Waste generation (CSI 041/WST 004) — Assessment published Mar 2015' (http://www.eea.europa.eu/data-and-maps/indicators/waste-generation-1/assessment) accessed 26 November 2015.

EEA, 2015e, 'The European Environment — State and outlook 2015: European briefing on forests' (http://www.eea.europa.eu/soer-2015/europe/forests#tab-based-on-indicators) accessed 16 November 2015.

EMF, 2012, *Towards the circular economy — Economic and business rationale for an accelerated transition*, Volume 1, Ellen MacArthur Foundation, Isle of Wight.

EMF, 2013, *Towards the circular economy: Opportunities for the consumer goods sector*, Ellen MacArthur Foundation, Isle of Wight.

EMF, 2015a, 'Circular economy overview' (http://www.ellenmacarthurfoundation.org/circular-economy/overview/concept) accessed 5 November 2015.

EMF, 2015b, *Delivering the circular economy — A toolkit for policymakers*, Ellen MacArthur Foundation, Isle of Wight.

EMF and Granta Design, 2015, *Circularity Indicators — An approach to measuring circularity — Project Overview*, Ellen MacArthur Foundation and Granta Design, Isle of Wight and Cambrigde.

EMF and McKinsey Center for Business and Environment, 2015, *Growth within: A circular economy vision for a competitive Europe*, Ellen Mac Arthur Foundation and McKinsey Center for Business and Environment, Isle of Wight.

ERN, 2015, 'European Remanufacturing Network' (http://www.remanufacturing.eu) accessed 30 November 2015.

ETC/SCP, 2013, *Approaches to using waste as a resource. Lessons learnt from UK experiences*, ETC/SCP Working Paper No 5/2013, European Topic Centre on Sustainable Consumption and Production, Copenhagen.

ETC/SCP and ETC/WMGE, 2014, *Reflections and lessons learnt from EEA's work on sustainable lifestyles*, ETC/SCP and ETC/WMGE Working Paper, European Topic Centre on Sustainable Consumption and Production and European Topic Centre on Waste and Materials in a Green Economy, Copenhagen and Mol.

ETC/WMGE, 2015, 'European reference model on municipal waste' (https://etc-wmge.vito.be) accessed 30 November 2015.

EU, 2008, Directive 2008/98/EC of the European Parliament and of the Council of 19 November 2008 on waste and repealing certain Directives (OJ L 312, 22.11.2008, pp. 3–30).

EU, 2009, Directive 2009/125/EC of the European Parliament and of the Council of 21 October 2009 establishing a framework for the setting of ecodesign requirements for energy-related products (OJ L 285, 31.10.2009, pp. 10–35).

EU, 2013, Decision No 1386/2013/EU of the European Parliament and of the Council of 20 November 2013 on a General Union Environment Action Programme to 2020 Living well, within the limits of our planet (OJ L 354, 20.12.2013, pp. 171–200).

Eurostat, 2015a, 'Environmental goods and services sector (env_egs)' (http://ec.europa.eu/eurostat/web/

environment/environmental-goods-and-services-sector/database) accessed 22 October 2015.

Eurostat, 2015b, 'Material flow accounts (env_ac_mfa)' (http://ec.europa.eu/eurostat/data/database#) accessed 26 November 2015.

Eurostat, 2015c, 'Treatment of waste (env_wastrt)' (http://ec.europa.eu/eurostat/web/waste/data/database) accessed 26 November 2015.

Eurostat, 2015d, 'Generation of waste by waste category and hazardousness (2012)' (http://ec.europa.eu/eurostat/tgm/table.do?tab=table&init=1&language=en&pcode=ten00109&plugin=1) accessed 23 July 2015.

Eurostat, 2015e, 'Packaging waste (env_waspac)' (http://ec.europa.eu/eurostat/web/waste/data/database) accessed 4 November 2015.

Eurostat, 2015f, 'Municipal waste (env_wasmun)' (http://ec.europa.eu/eurostat/web/waste/data/database) accessed 4 November 2015.

Fiksel, J., 2003, 'Designing resilient, sustainable systems', *Environmental Science & Technology*, 37, 5 330–5 339.

FORA, 2010, *Green business models in the Nordic Region*, Green paper, FORA, Copenhagen.

Financial Times, 2014, 'Insuring the sharing economy' (http://www.ft.com/intl/cms/s/0/b36efb60-7675-11e4-9761-00144feabdc0.html#axzz3ghmBV0AO) accessed 18 March 2015.

Glueckler, E. and Dickstein, J., 2015, 'Promoting aircraft parts reuse in an environmental management paradigm', presentation given at: Bilateral meeting on activities of the Aircraft Fleet Recycling Association at the EEA, Copenhagen.

Gutowski, T. G., Sahni, S., Boustani, D. and Graves, S. C., 2011, 'Remanufacturing and energy savings', *Environmental Science & Technology*, 45(10), 4 540–4 547.

Horbach, J., Rennings, K. and Sommerfeld, K., 2015, *Circular economy and employment*, Lichtenfels, Mannheim (https://sunstiftungsfonds.files.wordpress.com/2015/06/ce_employment_13052015.pdf) accessed 5 November 2015.

Houdini, 2013, *GRI-Rapport — Maj 2013 — April 2013*, Houdini Sportswear AB, Nacka.

International Synergies, 2015, 'National Industrial Symbiosis Programme (NISP)' (http://www.international-synergies.com/projects/national-industrial-symbiosis-programme/) accessed 23 July 2015.

Jacobsen, N. B., 2008, 'Industrial symbiosis in Kalundborg, Denmark: A quantitative assessment of economic and environmental aspects', *Journal of Industrial Ecology*, 10(1–2), 239–255.

Kiørboe, N., Sramkova, H. and Krarup, M., 2015, *Moving towards a circular economy — Successful Nordic business models*, Nordic Council of Ministers, Copenhagen.

Krausmann, F., Gingrich, S., Eisenmenger, N., Erb, K.-H., Haberl, H. and Fischer-Kowalski, M., 2009, 'Growth in global materials use, GDP and population during the 20th century', *Ecological Economics*, 68(10), 2 696–2 705.

Leismann, K., Schmitt, M., Rohn, H. and Baedeker, C., 2013, 'Collaborative consumption: Towards a resource-saving consumption culture', *Resources*, 2(3), 184–203.

Maddison, A., 2013, 'Maddison project database' (http://www.ggdc.net/maddison/maddison-project/home.htm) accessed 20 March 2015.

MAGRAMA, 2013, *Estrategia 'Más alimento, menos desperdicio' — Programa para la reducción de las pérdidas y el desperdicio alimentario y la valorización de los alimentos desechados*, Ministerio de Agricultura, Alimentación y Medio Ambiente, Madrid.

MAGRAMA, 2015, 'Información de interés — Estrategia "Más alimento, menos desperdicio" — Alimentación' (http://www.magrama.gob.es/es/alimentacion/temas/estrategia-mas-alimento-menos-desperdicio) accessed 21 September 2015.

Meyer, B., 2011, *Macroeconomic modelling of sustainable development and the links between the economy and the environment — Final report*, ENV.F.1/ETU/2010/0033, Osnabrück.

Ministère de l'Economie, Ministère du Développement durable et des Infrastructures and Luxinnovation, 2015, *Luxembourg as a knowledge capital and testing ground for a circular economy* (http://www.innovation.public.lu/fr/brochures-rapports/e/ecomie-circulaire/index.html) accessed 30 November 2015.

Mont, O., 2007, 'Consumption and ecological economics: Towards sustainability', in: Pertsova, C. C. (ed.), *Ecological economics research trends*, Nova Science Publishers, New York, pp. 13–44.

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

Nielsen, 2015, 'Global consumers embrace the share economy' (http://www.nielsen.com/apac/en/press-room/2014/global-consumers-embrace-the-share-economy.html) accessed 9 April 2015.

OECD, 2013, *Why new business models matter for green growth*, Green paper 2013/01, Organisation for Economic Co-operation and Development, Paris.

OECD, 2014, 'All statistics — OECD iLibrary' (http://www.oecd-ilibrary.org/statistics) accessed 17 July 2013.

Ölundh, G. and Ritzén, S., 2001, 'Functional sales as a further approach to environmental product development - a case study', in: Proceedings of the Second International Symposium on Environmentally Conscious Design and Inverse Manufacturing, Tokyo.

OVAM, (forthcoming), *Monitoring material losses from the material cycle*, Openbare Vlaamse Afvalstoffenmaatschappij, Mechelen.

OVAM, 2014, *De kringloopcentra in het Vlaamse Gewest — Opvolgingsverslag 2012*, Openbare Vlaamse Afvalstoffenmaatschappij, Mechelen.

Rechberger, H. and Markova, S., 2011, *Entwicklung eines Konzeptes zur Förderung der Kreilaufwirtschaft im Bauwesen: Materieller Gebäudepass und Design for Recycling für das Bauwesen*, Technische Universität Wien, Vienna.

Reisinger, H., Buschmann, H., Walter, B., Lixia, R., Daxbeck, H., 2014, *Gebäudepass — Erarbeitung von Grundlagen für die Standardisierung von Gebäudepässen als Gebäudematerialinformationssystem*, Umweltbundesamt and Resourcen Management Agentur, Vienna.

van Renswoude, K., ten Wolde, A. and Joustra, J. D., 2015, *Circular Business Models — Part 1: An introduction to IMSA's circular business model scan*, IMSA, Amsterdam.

SERI, 2013, 'SERI Global Material Flows Database' (http://www.materialflows.net/home/) accessed 2 December 2013.

Smith, D., 2013, 'Power-by-the-hour: the role of technology in reshaping business strategy at Rolls-Royce', *Technology Analysis & Strategic Management*, 25(8), 987–1007.

Steffen, W., Richardson, K., Rockström, J., Cornell, S. E., Fetzer, I., Bennett, E. M., Biggs, R., Carpenter, S. R., de Vries, W., de Wit, C. A., Folke, C., Gerten, D., Heinke, J., Mace, G. M., Persson, L. M., Ramanathan, V., Reyers, B. and Sörlin, S., 2015, 'Planetary boundaries: Guiding human development on a changing planet', *Science*, 347(6223), 1259855.

Thuisafgehaald, 2015, 'Over ons' (http://www.thuisafgehaald.nl/over-ons/item42196) accessed 23 July 2015.

Tukker, A. and Tischner, U., 2006, 'Product-services as a research field: past, present and future. Reflections from a decade of research', *Journal of Cleaner Production*, 14(17), 1552–1556.

UN, 2015, *Transforming our world: the 2013 agenda for sustainable development*, A/RES/70/1, United Nations.

UN DESA, 2015, *World Population Prospects: The 2015 Revision, Key Findings and Advance Tables*, Working Paper No ESA/P/WP.241, United Nations, Department of Economic and Social Affairs, Population Division, New York.

UNEP and TU, 2009, *Design for sustainability — A step-by-step approach*, United Nations Environment Programme and Delft University of Technology, Paris and Delft.

Xerox, 2015, 'Xerox 2011 report on global citizenship — Company profile' (http://www.xerox.com/corporate-citizenship/2011/company-profile.html) accessed 1 December 2015.

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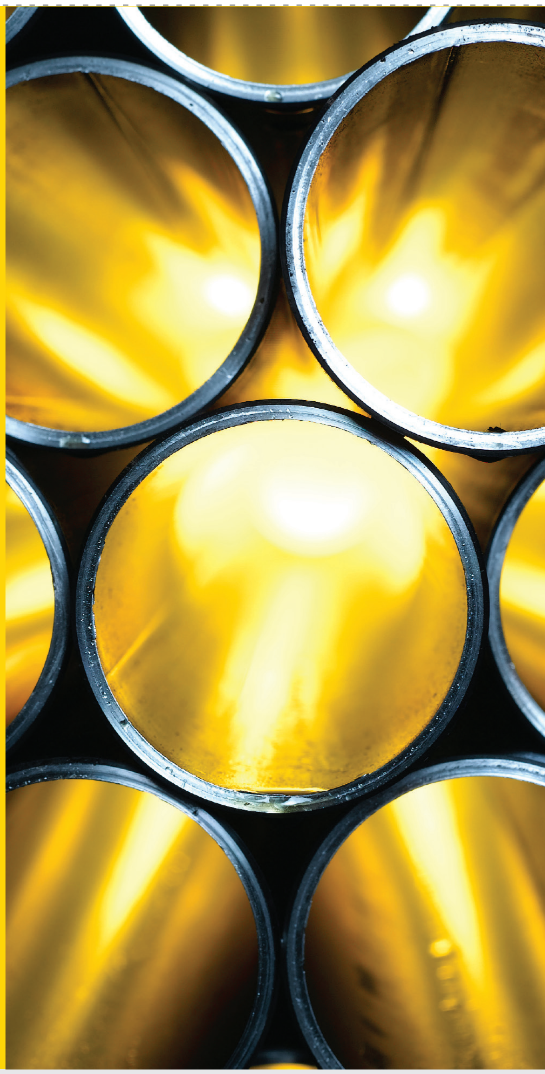

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