World Health Organization
REGIONAL OFFICE FOR Europe

CIRCULAR ECONOMY AND HEALTH:
OPPORTUNITIES AND RISKS

ABSTRACT

The extensive use of natural resources threatens to exceed the carrying capacity of the Earth. The concept of a circular economy offers an avenue to sustainable growth, good health and decent jobs, while saving the environment and its natural resources. Further, the change from a linear economy (take, make, dispose) to a circular economy (renew, remake, share) is expected to support significantly the attainment of the Sustainable Development Goals (SDGs), particularly SDG 12 on responsible consumption and production. So far, however, the coverage of the health implications of a transition to a circular economy has been relatively limited. This report therefore aims to start to address this deficiency by framing the transition in a health context, to set the scene for further policy development, the assessment of research needs and stakeholder engagement in key health implications. It shows that the transition to a circular economy provides a major opportunity to yield substantial health benefits, such as direct benefits to health care systems and indirect benefits from reducing negative environmental impacts. There are also risks of adverse and unintended health effects, however, in processes involving hazardous materials, for example; circular economy strategies and particularly national, regional and local implementation plans need to be identify and address these risks.

KEYWORDS

CONSERVATION OF NATURAL RESOURCES
ENVIRONMENTAL HEALTH
ECONOMICS - TRENDS
ENVIRONMENTAL POLICY - TRENDS, ECONOMICS
RECYCLING - TRENDS, ECONOMICS
WASTE MANAGEMENT - TRENDS, ECONOMICS

ISBN 9789289053341

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Publications
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United Nations City, Marmorvej 51
DK-2100 Copenhagen Ø, Denmark

Alternatively, complete an online request form for documentation, health information, or for permission to quote or translate, on the Regional Office website (http://www.euro.who.int/pubrequest).

Layout: 4PLUS4.dk

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ACKNOWLEDGEMENTS

We thank Mike Holland (Ecometrics Research and Consulting (EMRC), United Kingdom), Joseph Spadaro (Researcher, Environmental Sciences, Bilbao, Spain), Maca Vojtech (Researcher, Environmental Economics and Sociology, Charles University Environment Centre, Prague, Czech Republic), Andy Haines (Dept of Social and Environmental Health Research, London School of Hygiene and Tropical Medicine, United Kingdom), Caroline Rudisill (Associate Professor of Health Economics, London School of Economics and Political Science, United Kingdom) and Klaus Kümmerer (Director, Institute for Sustainable and Environmental Chemistry, Leuphana University Lüneburg, Germany), for their extensive and helpful comments and suggestions. We gratefully acknowledge the managerial and technical support provided by staff of the WHO Regional Office for Europe's WHO European Centre for Environment and Health, in Bonn, Germany: Marco Martuzzi, Programme Manager, and Matthias Braubach, Technical Officer for Urban and Health Equity.

We are also grateful to a number of experts who were consulted and interviewed in the process of compiling this report, as follows: Bjorn Hansen (Head of Sustainable Chemicals Unit, European Commission Directorate-General for Environment), Michael Warhurst (Executive Director, Chemicals Health and Environment Monitoring Trust – CHEM Trust), Dustin Benton (Acting Policy Director, Green Alliance), Antonia Gawel (Lead, circular economy Initiative, World Economic Forum), Natacha Cingotti (Health and Chemicals Policy Officer, Health and Environment Alliance), Xenia Trier (Project Manager on Chemicals, Environment and Human Health, Integrated Environmental Assessments Programme, European Environment Agency), Joseph DiGangi (Senior Science and Technical Advisor, International POPs Elimination Network – IPEN) and Violeta Nikolova (Research Associate, United Nations University – Vice Rectorate in Europe, Sustainable Cycles Programme – UNU-ViE SCYCLE).

Valuable input and advice on the e-waste case study was given by Ruediger Kuehr (Head, SCYCLE, United Nations University) and Ms Vanessa Forti (Research Associate, United Nations University). The water reuse case study greatly benefited from comments from Oliver Schmoll (Programme Manager, Management of Natural Resources: Water and Sanitation, WHO Regional Office for Europe) and section 4.1 on the macroeconomic perspective benefitted from the close cooperation between WHO and Elisa Lanzi, (Economist and Policy Analyst, Organisation for Economic Co-operation and Development (OECD)).

Many thanks also to all participants of the WHO expert meeting convened in Bonn, Germany, in October 2017: "Circular Economy Meets Environment and Health – Opportunities and Risks". They discussed the first draft of this analysis and provided valuable and highly appreciated feedback and additional information that substantially helped to shape and improve the quality of this report.

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ABBREVIATIONS

ACES	Alliance for Circular Economy Solutions
AMR	antimicrobial resistance
BFRs	brominated flame retardants
BPA	bisphenol A
CFCs	chlorofluorocarbons
CHEM Trust	Chemicals Health and Environment Monitoring Trust
CLP Regulation	(EU) classification, labelling and packaging Regulation
CO_2	carbon dioxide
CSOs	civil-society organizations
DAKOFA	Waste and Resource Network Denmark
DALYs	disability-adjusted life-years
DEHP	diethylhexyl phthalate
DPSEEA framework	Driver, Pressure, State, Exposure, Effect, and Action framework
e-waste	electrical and electronic waste
EC	European Commission
ECHA	European Chemicals Agency
EHP	European Environment and Health Process
EIB	European Investment Bank
EMF	Ellen MacArthur Foundation
EU	European Union
EU27	the 27 countries belonging to the EU before July 2013
G7	Group of 7
GDP	gross domestic product
GHG	greenhouse gas
HEAL	Health and Environment Alliance
ISO	International Organization for Standardization
LIFE+	EU Financial Instrument for the Environment
MRI	magnetic resonance imaging
NGOs	nongovernmental organizations
PCBs	polychlorinated biphenyls
PFCs	perfluorinated chemicals
PVC	polyvinyl chloride
REACH	Registration, Evaluation, Authorisation and Restriction of Chemicals (EU)
REBMs	resource-efficient business models
ReSOLVE framework	Regenerate, Share, Optimise, Loop, Virtualise, and Exchange
RoHS Directive	Restriction of Hazardous Substances Directive
SDGs	Sustainable Development Goals
Sitra	Finnish Innovation Fund
SSPs	sanitation safety plans
STEP Initiative	Solving the E-Waste Problem Initiative
SVHCs	substance of very high concern
UNIDO	United Nations Industrial Development Organization
VAT	value-added tax
WEEE Directive	Waste Electrical and Electronic Equipment Directive
WRAP	Waste and Resources Action Programme

KEY MESSAGES

The extensive use of natural resources threatens to exceed the carrying capacity of the planet. The concept of the circular economy offers an avenue to sustainable growth, good health and decent jobs, while saving the environment and its natural resources. This concept has gained increasing prominence in recent years in policy development at the international, European Union and national levels of governance, and in business practices and consumer behaviour. Until now, the focus has been on the benefits of a transition to a circular economy from the point of view of efficient and sustainable production and consumption. Coverage of the health implications has been relatively limited.

This report aims to start to address this gap by framing the concept of the circular economy and its implementation in the context of health, to set the scene for further policy development, research and stakeholder engagement.

A transition to circular economy provides a major opportunity to yield potentially substantial health benefits while contributing to the attainment of a number of Sustainable Development Goals. The benefits are both direct, such as savings in the health care sector, and indirect, from reduced environmental impacts of production and consumption.

There are also risks of unintended adverse health effects in this transition, particularly related to managing risks from exposures to hazardous materials. Where such risks have been identified, they frequently affect vulnerable groups disproportionately, through, for example, informal work practices involving children and low-income groups.

The understanding of the health impacts of a transition to a circular economy – particularly in relation to chemicals of concern, water reuse, electrical and electronic waste, and distributional effects – shows significant gaps. Further research and evidence are essential to enable a more complete assessment of policy priorities for addressing the negative impacts and enhancing the positive ones.

Both policy discussions and national, regional and global strategies and action plans for a circular economy need to increase their coverage of and better integrate health benefits and risks. The health sector should therefore be actively involved in the transition process.

Policy priorities that have been identified for addressing areas of immediate concern include: appropriate regulation, monitoring and evaluation of circular economy initiatives; support for research; improved management of informal waste sites; and measures to raise public awareness. These should be addressed so that no reductions in support from the public and the policy community undermine progress in implementing the circular economy, including realizing potential health benefits.

All key stakeholders have important roles in securing health benefits and minimizing health risks, including intergovernmental organizations, governments of WHO Member States, the public sector, the business sector, nongovernmental and civil-society organizations, the research community, the mass media and the general public. Dialogue and cooperation between stakeholders, through agreed partnerships and action plans, are vital to drive progress in promoting the health benefits and addressing the health risks of the transition to the circular economy.

EXECUTIVE SUMMARY

This report explores the policy objective of a circular economy and its implications for human health. While the concept of the circular economy has recently gained increasing prominence in policy development at the national, European Union (EU) and global levels, and in business practices for the promotion of sustainable production and consumption, coverage of its health implications has been relatively limited. This report aims to start to address this gap by framing the concept of the circular economy and its implementation in the context of health, outlining the current evidence on health implications and setting the scene for further policy development, the assessment of research needs and stakeholder engagement.

Definitions of a circular economy have two main types: those that are resource oriented and focus on the need for closed loops of material flows and reduced consumption of virgin resources, and those that go beyond the management of material resources to incorporate additional dimensions, such as changing models of consumption. Implementation is therefore characterized by: reducing the use of primary resources, maintaining the highest value of materials and products, and changing utilization patterns. In practice, the actions needed to achieve this transition include: recycling; efficient use of resources; utilization of renewable energy sources; remanufacturing, refurbishment and reuse of products and components; the extension of product life; treating products as services; sharing of products; prevention of waste, including designing out waste in products; and a shift in consumption patterns. Alongside these actions, the phasing down of incineration and landfill as options for waste management is seen as a necessary requirement. To enable the actions and range of investments needed for such a transition, changes in perception and behaviour are needed at all levels, from consumers to producers and policy-makers.

A number of **global and European initiatives** are associated with the circular economy concept. In particular, circular economy principles have been identified as a means to address several of the Sustainable Development Goals (SDGs) (United Nations, 2018), notably SDG 12: "reduc[ing] waste generation through prevention, reduction, recycling and reuse (12.5), and "achiev[ing] the sustainable management and efficient use of natural resources". The circular economy concept is also strongly interlinked with and incorporated in the green economy concept, particularly in relation to its low-carbon and resource efficiency focus.

The **current state of play** in the implementation of the principles of the circular economy encompasses a great range of activities across the WHO European Region, although engagement with the concept is much greater in EU countries than non-EU countries. A key development in the EU is the adoption of the EU action plan for the circular economy (EC, 2015b), which sets out a timeline for action on production, consumption, waste management, the market for secondary raw materials, sectoral actions and innovation, with targets for the reduction of waste and a long-term path for waste management and recycling. These aim to continue recent trends towards a decline in waste generation per capita in the EU and an increase in recycled and composted municipal waste, along with decreases in landfilled waste. Business is seen to have a crucial role in progress towards the circular economy, particularly through developing innovative circular approaches to production and consumption. Waste management companies in Europe have widely adopted circular economy practices, and a variety of networks of businesses and nongovernmental organizations (NGOs) have been established to promote the gathering and sharing of knowledge and experience. Few of these, however, deal directly with health-related issues.

This report develops a **framework to categorize pathways** through which the implementation of circular economy models may affect human health and well-being. Based on a literature review and expert consultation, it identifies real and potential positive and negative health implications of circular economy processes, along with the economic sectors affected and issues related to distribution, focusing especially on impacts on vulnerable groups. To the extent possible, the framework draws on and adapts useful existing frameworks and classifications from the literature on environment and health, including from WHO initiatives.

General findings on the implications for human health from the implementation of circular economy models are as follows.

- Reducing the use of primary resources, maintaining the highest value of materials and products (through the recycling and reuse of products, components and materials) and moving towards greater use of renewable energy and energy efficiency have many **positive health implications**. In particular, direct and indirect benefits come from reducing the environmental impacts of manufacturing processes (and making cost savings in households and in the health sector).

- There is also potential for significant health benefits from changing utilization patterns, for example, through the health system introducing performance models in the procurement of equipment, and a wide range of health benefits, due to a reduction in environmental impacts, from shifts to product sharing and product-as-a-service models. The potential **negative health impacts** identified relate to risks in the recycling and reuse of products, components and materials. This refers in particular to the management of chemicals of concern, such as bisphenol A (BPA) and brominated flame retardants (BFRs) in a variety of products, and to emissions from the composting of waste. The report contains a number of case studies on these issues, including for chemicals of concern, electrical and electronic waste (e-waste), and food safety.

- Where negative impacts have been identified, their effects frequently fall disproportionately on **vulnerable groups** in Europe and globally. A key concern is the export of waste, such as e-waste, to dumping sites in developing countries, where the local population engaging in informal recycling is often more deprived than the general population. Conversely, the reduced global environmental pollution resulting from the circular economy will result in long-term health gains that may benefit disadvantaged groups, which are known to be disproportionately affected by environmental impacts. More detailed distributional assessment, however, is needed for each health impact identified.

- Research is underway that addresses the potential health impacts from a transition to circular economy; it considers, for example, chemicals of concern, water reuse and e-waste. Significant **knowledge gaps** exist, however, particularly those related to the nature of negative impacts (e.g. in the case of hazardous chemicals); the quantitative analysis of exposures and endpoints related to the identified potential health impacts could help build understanding of their relative significance. A small number of aggregate estimates of the potential benefits from specific circular economy policies are available, some of which suggest very significant potential benefits across a number of sectors and for the general population (e.g. EMF, 2015b; Ex'Tax et al., 2016). At best, these are order-of-magnitude estimates, however, and more detailed quantitative analyses for specific benefits and identified health impacts are needed. Thus, further research and evidence are essential for a more complete assessment of priorities for addressing negative impacts and enhancing positive impacts, in order to inform policy development.

A key **general conclusion** from this study is therefore that the transition to a circular economy could provide a major opportunity to yield substantial health benefits that will contribute to achieving the SDGs. Nevertheless, the transition also carries risks of adverse unintended health effects, for example, in processes related to hazardous materials; circular economy strategies and implementation plans need to identify and address these.

In view of these findings, and the relatively limited coverage of health issues in the transition to a circular economy, it is clearly necessary to increase the coverage of and better place health in national, regional and global policy discussions and future strategies, frameworks and action plans for a circular economy. To this end, the health sector and public health agencies such as WHO should be key stakeholders in supporting the transition process. In particular, they should actively support countries to define their strategies and translate them into national, regional and local action plans.

Further work is needed to identify and elaborate **priority actions** to maximize health benefits and minimize risks in the short and medium terms. Policy priorities identified in this report for addressing areas of immediate concern include:

1. further development of regulation for a number of direct negative health impacts;
2. better information flows on component materials in products to aid prevention and safe removal of harmful substances in recycled materials;
3. support for research where significant gaps exist, especially quantitative analysis of exposures, and endpoints related to identified potential health impacts, including distributional effects; and
4. actions to address health impacts of informal waste sites, including reducing risk of exposures to hazardous materials.

Urgent action to address these areas of concern is needed to ensure that no reductions in support from the public and the policy community resulting from these concerns undermine progress in implementing the circular economy and its potential for significant medium- and long-term health benefits.

Other identified policy priorities include the development of indicators for monitoring progress in realizing the health benefits and reducing the health risks of circular economy programmes, as well as promoting public awareness of the benefits of the circular economy, including those to health, and policy development on distributional issues informed by current research.

The conclusions (given in section 9) emphasize the important **role of key stakeholders**, including the policy and research communities, in achieving health benefits and addressing health risks. Business plays a crucial role in developing and implementing circular processes that can be the source of key direct and indirect benefits for both public and occupational health (e.g. by reducing air and water pollutant and GHG emissions in extraction, manufacturing and consumption processes). Business and NGOs also have a key role in addressing the potential unintended risks to public and occupational health of circular economy actions, including through the development of substitutes for hazardous materials.

In addition, civil society can become more engaged in the circular economy and thus contribute to healthy outcomes – for example, through contributions to lower production and consumption emissions – in a number of ways. These opportunities include promoting behavioural changes such as involvement in sharing platforms (e.g. car sharing) and consumer choices (e.g. recycling products and reused components).

Finally, while the report includes a number of key conclusions for key stakeholders, multistakeholder **partnerships and collaboration** between WHO Member States, NGOs, intergovernmental organizations, the private sector and academe, through agreed partnerships and action plans, are vital to drive progress in achieving the health benefits and addressing the health risks of the transition to a circular economy.

1

Overall aims of this analysis report

The WHO Regional Office for Europe commissioned this study as a background paper for its expert meeting, "circular economy Meets Environment and Health – Opportunities and Risks", held in Bonn, Germany in October 2017. The study's rationale was that, while the circular economy concept has gained increasing prominence in recent years, in the context of policy development and business practices for the promotion of sustainable production and consumption, coverage of its health implications has been relatively limited. The transition to a circular economy can have potentially significant health benefits through, for example, contributions to climate change mitigation and better air quality. If this transition does not adequately take account of the health implications, it also carries the risk of adverse health effects from, for example, processes related to hazardous materials.

This study therefore aimed to start to address this deficiency by framing the transition to a circular economy in a health context, and to set the scene for the further development of policy, assessment of research needs and engagement of stakeholders including business, NGOs and civil society in this important subject. The target groups are therefore the communities engaged in health, environmental and economic policy and research; the business sector; civil-society organizations; and the mass media. It should also be of interest to a more general readership.

As to the structure of this report, section 2 briefly explains definitions of the circular economy, related concepts, models of implementation and links to existing WHO programmes. Section 3 reviews the implementation of the circular economy concept, particularly countries in the WHO European Region. Section 4 provides an overview of the links between the transition to a circular economy in the broader macroeconomic and social context, and its implications for human health, including a discussion of distributional effects. Section 5 suggests a framework for reviewing, identifying and analysing the range of potential health impacts resulting from the transition to a circular economy. Section 6 uses this framework to outline the potential positive and negative health effects of moving towards a circular economy, including both direct and indirect effects, the stakeholders affected and distributional issues. It also presents and discusses the available quantitative evidence for these effects. Section 7 discusses a range of case studies on health issues related to the circular economy transition. These include a discussion of the health care sector, chemicals of concern, e-waste, food safety and waste-water reuse, along with broader outlines for the built environment, climate change and air pollution. Section 8 summarizes policy options for promoting the circular economy and addressing possible negative health risks. Finally, section 9 gives general conclusions on the positive and negative implications of the circular economy model for health, as well as specific conclusions on policy, research needs, business and NGOs. It also proposes ways to increase and better place health in the policy discussions and future national, regional and global strategies, frameworks and action plans for a circular economy.

The research for this report included a desk-based review of the relevant international literature, as well as consultations with experts on the circular economy and its implications for health and the environment.

2

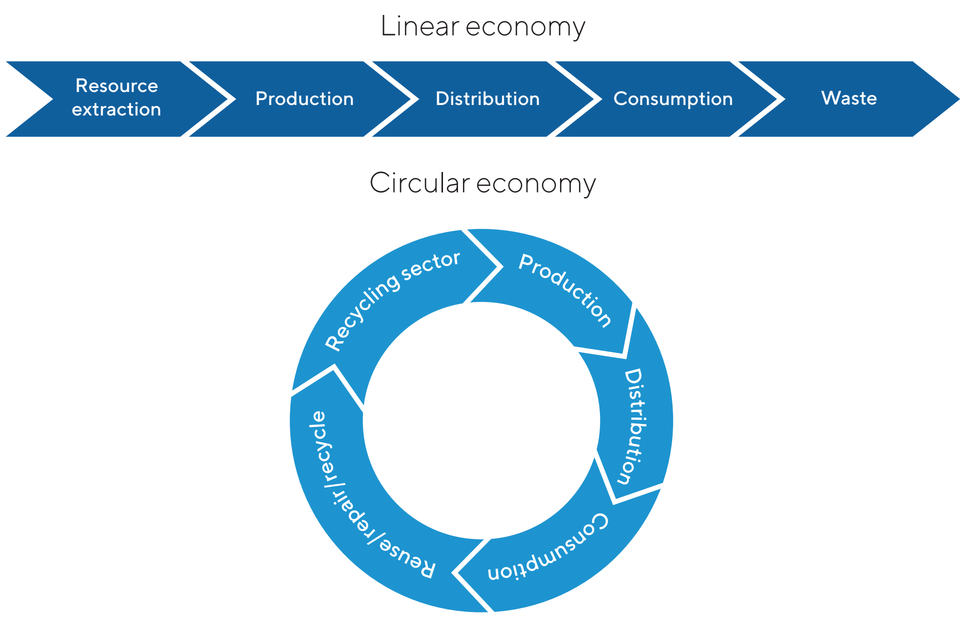
Outline of the concept of the circular economy and models of implementation

This section introduces the concept of the circular economy by discussing existing definitions and models of implementation. It also explains the linkages to a number of related concepts and global and European initiatives, and to WHO programmes and publications. It provides essential background to the subject and a foundation for the subsequent discussion and analysis of the health implications of the circular economy. Further detail and discussion on definitions, models and linkages can be found in Annex 1. Annexes 2 and 3 describe progress towards circular economy objectives and key national initiatives.

2.1 Definition

The circular economy is often presented in general terms as a transition from a linear (take, make, use, dispose) model to a circular (restorative and regenerative) model (EMF, 2015c) (Fig. 1). The literature, however, offers no single and ubiquitous definition, but a general consensus on the central concepts and aims of a circular economy. There are two kinds of definitions: those that are resource oriented and focus on the need for closed loops of material flows and reduced consumption of virgin resources, and those that go beyond the management of material resources to incorporate

Fig. 1. The linear economy and the circular economy

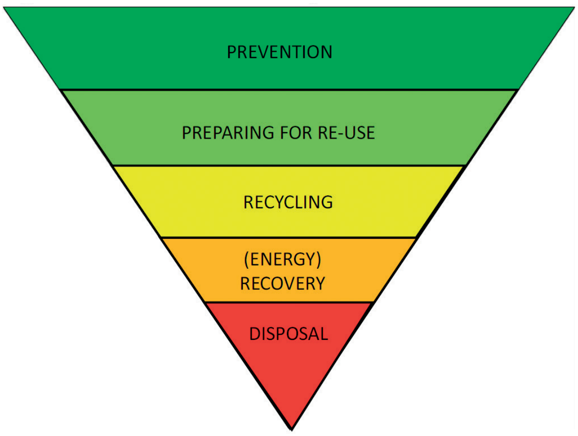


Source: AkzoNobel (2015).

additional dimensions, such as changing models of consumption (Rizos et al., 2017).

A frequently quoted definition by the Ellen MacArthur Foundation (EMF) sees 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, 2015c; EEA, 2016). The EU action plan for the circular economy describes a transition "where the value of products, materials and resources is maintained in the economy for as long as possible, and the generation of waste minimised" (EC, 2015b). A key focus is thus on minimizing the need for new inputs of materials and energy, and reducing the environmental pressures related to resource extraction, emissions and waste. A guiding principle for the minimization of waste in a circular economy is the waste hierarchy, in which actions to reduce and manage waste are given an order of preference (Fig. 2).

Fig. 2. The waste hierarchy



Source: Bourguignon (2017).

In simple terms, the types of processes needed for a transition to a circular economy can be categorized as: using fewer primary resources, maintaining the highest value of materials and products, and changing utilization patterns. In practice, the actions needed to achieve this transition include: recycling; efficient use of resources; utilization of renewable energy sources; remanufacture, refurbishment and reuse of products and components; extension of product life; product as service; sharing of products;[1] and waste prevention, including innovations to design out waste in products and a shift in consumption patterns (Rizos et al., 2017; EMF, 2015a). Alongside these actions, the phasing down of incineration and landfilling as options for waste management is seen as a requirement, although the best options for dealing with residual waste still need assessment.

The concept of the circular economy is often presented, including in the EU action plan, as enabling wider economic and social benefits, such as greater well-being, sustainable growth and employment. The main definitions reviewed for this report, however, did not explicitly mention health. Rizos et al. (2017) found that the existing conceptualizations of the circular economy do not include social aspects. A report from the European Environment Agency (EEA) (2016) gives a description that includes the potential for wider social benefits: "A circular economy thus provides opportunities to create well-being, growth and jobs, while reducing environmental pressures". An addition explicitly including health, alongside well-being, provides a useful definition for this report; it places health issues as integral to circular economy transition.

[1] Product sharing platforms take a variety of forms, including business to business, business to consumer and consumer to consumer; see the discussion in Frenken & Schor (2017).

2.2 Models

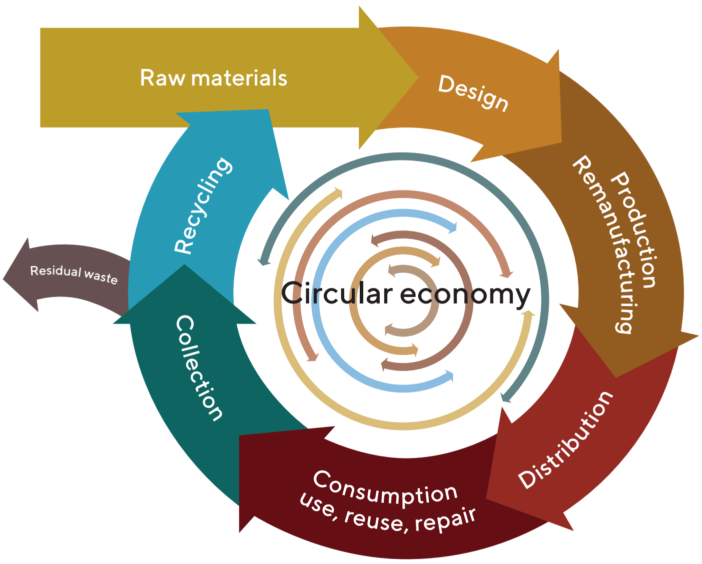
As with definitions, models of the circular economy vary in scope and sophistication. For example, Fig. 3 shows a simple circular concept, which describes a loop including production, consumption and reuse/repair/recycling. More complex representations include that developed by EMF (2015a), which outlines in greater detail the principles of:

1. preserving and enhancing natural capital by controlling finite stocks and balancing renewable resource flows;
2. optimizing resource yields by circulating products, components and materials at the highest utility; and
3. fostering system effectiveness by revealing and designing out negative externalities.[2]

Annex 1 provides a more detailed discussion of models of the circular economy.

A number of frameworks also set out processes and actions needed for a transition to a circular economy (Benton & Hazell, 2013; EMF, 2015c; Preston, 2012). For example, EMF uses the Regenerate, Share, Optimise, Loop, Virtualise, and Exchange (ReSOLVE) framework, which identifies six types of actions that businesses and governments can take. Such frameworks present a transition that requires an integrated effort by different stakeholders. These include a role for the state in setting strategy and regulatory and fiscal frameworks, and in funding some measures such as research and business support. Business plays a crucial role in implementing circular economy principles, including through innovation, while NGOs and business associations support this via promotion and knowledge sharing.

Fig. 3. Simple model of the circular economy



Source: EC (2015b).

[2] Negative externalities refer to any consequences of an economic activity that affect other parties without this being reflected in market prices. In this context, externalities with health implications include air, water, soil and noise pollution, and the release of toxic substances.

2.3 Related concepts and initiatives

A number of related concepts and associated global and European initiatives are linked with the circular economy concept. These include the following, outlined in greater detail in Annex 1.

The circular economy can be seen as a means of progressing towards **sustainable development** through achieving the SDGs (United Nations, 2018). The EU action plan for the circular economy (detailed in section 3) explicitly links the circular economy to the implementation of global commitments under the SDGs, particularly SDG 12 for ensuring sustainable consumption and production patterns (EC, 2015b). Some sources also see the transition to a circular economy as contributing to other SDGs, such as SDG 3 for good health and well-being (EMF, 2017a).

The working definition of a **green economy** provided by the United Nations Environment Programme (UNEP)[3] is "one that results in improved human well-being and social equity, while significantly reducing environmental risks and ecological scarcities" (UNEP, 2011). Thus, it is interlinked with the circular economy, in particular in its low-carbon approaches and resource efficiency, but has been interpreted as being wider in range, as it includes social and ecosystems dimensions. References to the circular economy in UNEP green economy documents focus mainly waste and the use of materials. The green economy is also closely linked to sustainable development and is seen as a tool for achieving sustainable development in the 2012 Rio+20 agenda (United Nations, 2012).

The **Batumi Initiative on Green Economy** (UNECE, 2016) is a set of voluntary commitments by European countries and organizations to undertake actions for a green economy. It includes actions for the circular economy, and serves to enable the Pan-European Strategic Framework for Greening the Economy 2016–2030 (Green Growth Knowledge Platform, 2018).

The circular economy is also closely linked to the concept of and initiatives on **resource efficiency**. The EU Resource Efficiency Roadmap (part of the Europe 2020 strategy) outlines the circular economy as an interlinked initiative in terms of sustainable materials management where waste becomes a resource (EC, 2011b). The EU action plan for the circular economy also links the circular economy to the implementation of global commitments under the Group of 7 (G7) Alliance on Resource Efficiency.

The transition towards a competitive **low-carbon economy** largely focuses on the supply side of economies. The European Commission (EC) roadmap for moving to a competitive low-carbon economy sets a target for the EU of cutting GHG emissions to 80% below 1990 levels by 2050, and outlines required contributions across all main sectors responsible for the EU's emissions (EC, 2011a). It foresees health benefits owing to improved air quality. Low-carbon approaches are included in the circular economy model (and the green economy concept) but have a narrower focus.

The **bioeconomy** is defined as the parts of the economy that use renewable biological resources from land and sea, such as crops, forests, fish, animals and micro-organisms, to produce food, materials and energy. The EC bioeconomy strategy proposes a comprehensive approach to address the ecological, environmental, energy, food supply and natural resource challenges faced by Europe (EC, 2012). This concept is the focus of a key element of the circular economy model, which includes optimizing resource yields in biological cycles, as well as technical cycles, as outlined in principle 2 of the circular economy model developed by EMF (see Fig. A1.2).

[3] UNEP launched the green economy initiative in 2008. It includes global research and country-level assistance aimed at motivating support for green economy investments as a way of achieving sustainable development.

2.4 Linkage to existing WHO programmes and publications

A number of key WHO initiatives and publications connect to and are affected by circular economy aims and policies, primarily in the area of the green economy, environment and sustainable development. These include the following.

WHO briefings on **health in a green economy** review the health effects of mitigation strategies for climate change and identify expected health co-benefits, including from waste management (WHO, 2018). They note that other effects may involve health risks or trade-offs.

The transition to a circular economy has implications for the stated priorities of **Health 2020,** the European health policy framework adopted by Member States in the WHO European Region in September 2012 (WHO Regional Office for Europe, 2013). These priorities include: tackling Europe's major disease burdens, strengthening people-centred health systems and public health capacity, and creating supportive environments and resilient communities. The circular economy may affect the burden of disease both positively (e.g. though reduction of air pollution due to transition to circular economy mobility and production modes; see section 5) and negatively (e.g. if hazardous chemicals are not managed to minimize health risks; see the case study in section 7). The circular economy can contribute to improving the delivery of public health and health care services by providing a range of cost-saving and efficiency measures (see the case study in section 7). The transition to the circular economy can promote supportive environments and resilient communities to the extent that this translates into improved well-being and quality of life (see the discussion on models of a circular economy and examples in the case study on the built environment in section 7). Successful health outcomes for the populations of Europe resulting from progress towards Health 2020 will also support a healthy workforce, which is required for successful development of a circular economy.

The most recent fruits of the **European Environment and Health Process (EHP)**, the EHP Roadmap towards the Sixth Ministerial Conference on Environment and Health (WHO Regional Office for Europe, 2015a) and the Declaration of the Conference (WHO Regional Office for Europe, 2017b), include a focus on waste. The Declaration states that progress on actions to improve the environment and health "can be accelerated and sustained by enhancing interdisciplinary research and supporting the transition to a green and circular economy as a guiding new political and economic framework". In particular, the objective to "prevent and eliminate the adverse environmental and health effects, costs and inequalities related to waste management and contaminated sites" includes "supporting the transition to a circular economy using the waste hierarchy as a guiding framework to reduce and phase out waste production and its adverse health impacts through reduction of the impact of substances of greatest concern" (WHO Regional Office for Europe, 2017b).

3

Review of the current implementation of the circular economy concept in the WHO European Region

This section briefly outlines current progress in implementing the circular economy concept in Europe. It includes information on action by the EU and countries, research programmes and business and NGO initiatives. It also includes basic data on the progress towards circular economy objectives that results from waste management practices. The aim is to provide further background on current developments in Europe and to review the extent to which they have included health issues.

The circular economy concept has achieved wide engagement from the academic, policy, business and NGO communities over recent years. The current implementation of its principles encompasses a great range of activities. Much of the information provided here refers to activities of both the EU and its Member States, although where possible the state of play in other countries in the WHO European Region is also given. In addition, key international organizations are very active in supporting projects and greater knowledge on the circular economy, including EEA (2016), OECD (2017), the United Nations Industrial Development Organization (UNIDO) (2018) and the World Economic Forum (2018). Table 1 presents an overview of policy options, and the discussion is continued in section 8.

Table 1. Overview of types of policy options for the circular economy

Policy types	Examples
Regulatory frameworks	EU and national strategies for Member States in the WHO European Region, including targets, e.g. the EU action plan on circular economy. Product standards and regulations, e.g. the Registration, Evaluation, Authorisation and Restriction of Chemicals (REACH) Regulation Waste regulations, e.g. the EU Waste Framework Directive, the EU Waste Electrical and Electronic Equipment Directive and related national legislation Industry and consumer regulations, e.g. on food safety
Economic instruments	Consumer incentives, e.g. reductions in value-added tax (VAT) for circular products Tax shift from labour to resources, e.g. landfill tax Financial support to business, e.g. subsidies, financial guarantee.

Table 1. contd.

Policy types	Examples
Education, information and awareness	Public communication and information campaigns Business collaboration platforms for information and best practice sharing, e.g. the Alliance for Circular Economy Solutions (ACES) Technical business support for advice, training and demonstration projects NGO information and awareness initiatives
Research and innovation policy	Research and development programmes, e.g. the EU Horizon 2020 projects on the circular economy, the European Cooperation in Science and Technology (COST) programme, the EU Circular Impacts project, projects of international development banks
Public procurement	Public investment in circular economy facilities, e.g. recycling collection and processing infrastructure Circular economy standards in procurement law or guidelines, e.g. strategy of the Danish Government for intelligent public procurement

Source: adapted from policy option categorization for the circular economy in the Circular Impacts project, EMF (2015a) and Preston (2012).

3.1 EU action plan for the circular economy

In policy terms, the **key European development** is the adoption of the EU action plan for the circular economy (EC, 2015b). This interprets the circular economy more broadly, seeing it as going beyond waste and environmental policy to include innovative forms of consumption and moving away from exclusive ownership, e.g. towards sharing/leasing products or infrastructure, and consuming services rather than products (EC, 2015b). The EC withdrew its earlier legislative proposals on the circular economy in 2014, and presented a new circular economy package in 2015 that covered the full economic cycle, not just waste reduction targets (European Parliamentary Research Service, 2016). The action plan sets out a timeline for actions in terms of:

- production, e.g. product requirements under the Ecodesign Directive, and guidance for industrial sectors in the reference documents on the best available techniques;
- consumption, e.g. the Regulatory Fitness and Performance Programme of the EU Ecolabel scheme, and action on green public procurement;
- waste management;
- the market for secondary raw materials;
- sectoral actions on plastics, food waste, critical raw materials, construction and demolition, biomass and bio-based materials;
- innovation; and
- investments and monitoring.

The legislative proposals set targets for the reduction of waste and establish a long-term path for waste management and recycling. Key targets for achievement by 2030 include: common EU targets for recycling 65% of municipal waste and 75% of packaging waste, and a binding target to reduce landfill to a maximum of 10% of municipal waste. The targets for municipal waste are mandatory, while others depend on translation or ratification in national law and vary between EU Member States.

Key legislative elements for waste include reviewing the targets in a number of directives (2008/98/EC on waste, 94/62/EC on packaging and packaging waste, and 1999/31/EC on the landfill of waste) and amending other 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). The report on the implementation of the circular economy action plan (EC, 2017b) sets out recent progress, and the ACES (2017) report card evaluated progress on the action plan independently. The action plan acknowledges that proposed options must "preserve the high level of protection of human health and the environment" but does not elaborate on the health-related aspects of the actions (EC, 2015b).

The EU action plan includes plastics among its key priorities and the EC recently adopted a "strategy for plastics in a circular economy" to protect the environment from plastic pollution while fostering growth and innovation (EC, 2018b). This includes explicit references to the potential threats to the environment and human health posed by plastic leakage.

3.2 National circular economy initiatives

A number of European countries – such as Denmark, Finland, Luxembourg and the Netherlands – have embarked on policy initiatives for a circular economy. Annex 4 outlines key national initiatives – including visions, roadmaps, strategies and action plans – in European countries and other global leaders, such as Canada, along with some examples of city and regional initiatives, such as those in Amsterdam and Brussels. In addition, a raft of national legislation on waste, resource efficiency and other relevant topics across European countries promotes circular economy principles without being assembled under this banner. For example, although Sweden does not currently have a roadmap or vision naming the circular economy, it strives to be a leader in innovative and sustainable industrial production through its "smart industry" vision, which includes encouraging circular economy business models (Government Offices of Sweden, 2016). Similarly, the German Resource Efficiency Programme includes developing and expanding the circular economy as a guiding principle.

A review of circular economy initiatives in the European Region indicates that most of the countries identified as leading in this field are EU Member States, particularly those in western and northern Europe. Evidence of high-level, dedicated circular economy initiatives in central and eastern European States is limited, although related actions are being developed in a number of different contexts. For example, among the countries participating in the Batumi Initiative on Green Economy, some in central and eastern Europe acknowledge the benefits to a circular economy from their proposed actions, although these do not principally focus on making the transition (Green Growth Knowledge Platform, 2018). Most of these countries are EU Member States; for example, Estonia names the transition towards a circular economy as a co-benefit of its low-carbon development strategy up to 2050. The policy on energy efficiency in the housing sector in Lithuania flags its relevance to the circular economy, and the revision of the natural resource tax system in Latvia includes specific requirements on waste management that are described as assisting the transition to a circular economy.

This study found few direct references to the circular economy in proposed actions among the non-EU countries participating in the Batumi Initiative, except in Azerbaijan, where it is mentioned in the context of strengthening the implementation of the environmental dimensions of the SDGs. In addition, the Regional Environmental Centre for the Caucasus is committed to wide-ranging action for the "promotion of circular economy in South Caucasus region", including a focus on "shifting consumer behaviours towards sustainable consumption patterns and developing clean physical capital for sustainable production patterns" (UNECE, 2016). Further research is needed to clarify the understanding of the reasons for the relatively limited current development of circular economy initiatives in central and eastern European countries and to identify more details of their government, business and NGO activity that are related to the circular economy.

In addition, while national initiatives (outlined in Annex 4) state the importance of health in in their visions for circular economies, they do not in general focus their analyses and actions on health in any detail. For example, a review found that Nordic Co-operation reports on the circular economy acknowledge health as an issue for consideration but give no further assessment or examples (e.g. Nordic Council of Ministers, 2015). One exception is the Luxembourg roadmap for a circular economy, which includes examples of the need for healthy materials and a section on health care (EPEA, 2014).

Outside Europe, Canada and China give key examples of national strategies for a circular economy. Japan is seen as a pioneer in recycling, although it does not have a circular economy strategy or vision, but focuses on waste management regulation, which often takes a product life-cycle approach (Ministry of Environment, 2018). The United States of America has no specific national policy to promote the circular economy, although there are a number of relevant measures at the state and local levels, such as the Green Building and Green Points Program for sustainable construction in Boulder, Colorado.

3.3 Research and innovation programmes

EC research programmes supporting the circular economy include: Horizon 2020, which includes a programme on the circular economy and sustainable process industries (EC, 2016c); Circular Impacts, an EU-funded research project; and the REBus project, pioneering resource-efficient business models for a circular economy.

The European Investment Bank (EIB) is a key player for circular economy investments in the EU, co-financing projects related to sustainable and economic growth, competitiveness and employment worth €2.4 billion in the last five years (EIB, 2018). Rizos et al. (2017), however, found that research on the circular economy is fragmented across various disciplines and often shows different perspectives on and interpretations of the concept and related aspects.

3.4 Business and NGO initiatives

As mentioned, business can play a crucial role in progress towards the circular economy, particularly by developing innovative circular approaches to production and consumption. In business, the term circular economy often emphasizes the engineering and design challenges for the relevant industry. Waste management companies in Europe (e.g. SITA United Kingdom and Veolia Environment) use the term widely, although many companies have implemented policies that are consistent with the concept but use different terminology (Preston, 2012).

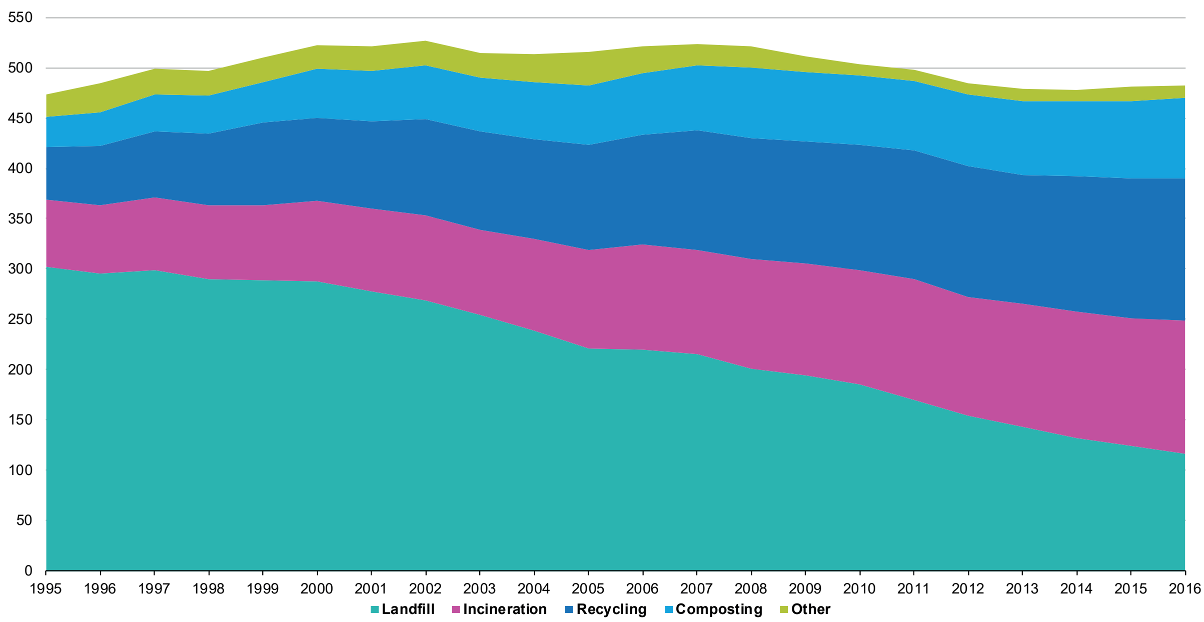
A wide variety of organizations and business and NGO networks have been established in recent years in Europe to promote, research and share knowledge and experience on the circular economy, such as EMF (United Kingdom), ACES, Circle Economy (the Netherlands), Circular Change (Slovenia), the Foundation for Circular Economy (Hungary), the Circular Economy Institute (France) and the Green Alliance (United Kingdom). Some of these, such as the Aldersgate Group (United Kingdom), also promote the circular economy at the policy level, particularly regarding the EU action plan. A review of these networks and organizations' work for the circular economy (see Annex 3) yielded very limited evidence of engagement in health-related issues. Organizations acknowledge human health as an issue in the transition to the circular economy, but with little elaboration or research. Organizations addressing health issues in the circular economy include the Health and Environment Alliance (awareness raising and advocacy on toxic substances, endocrine disrupting chemicals and disease prevention) and the Chemicals Health and Environment Monitoring (CHEM) Trust (chemical toxicity issues in the circular economy).

3.5 Progress towards circular economy objectives

As to practical progress towards circular economy objectives, the EU showed an overall decline in waste generation of about 7% in 2004–2013, with a decrease of 4% in municipal waste generation; caveats are needed, however, due to missing data, uncertainties and differences in waste calculation methods between countries (WHO Regional Office for Europe, 2016b). Fig. 4 shows overall trends in municipal waste treatment for the EU as a whole in 1995–2015: gradual declines in landfill and gradual increases in recycling, composting and incineration.

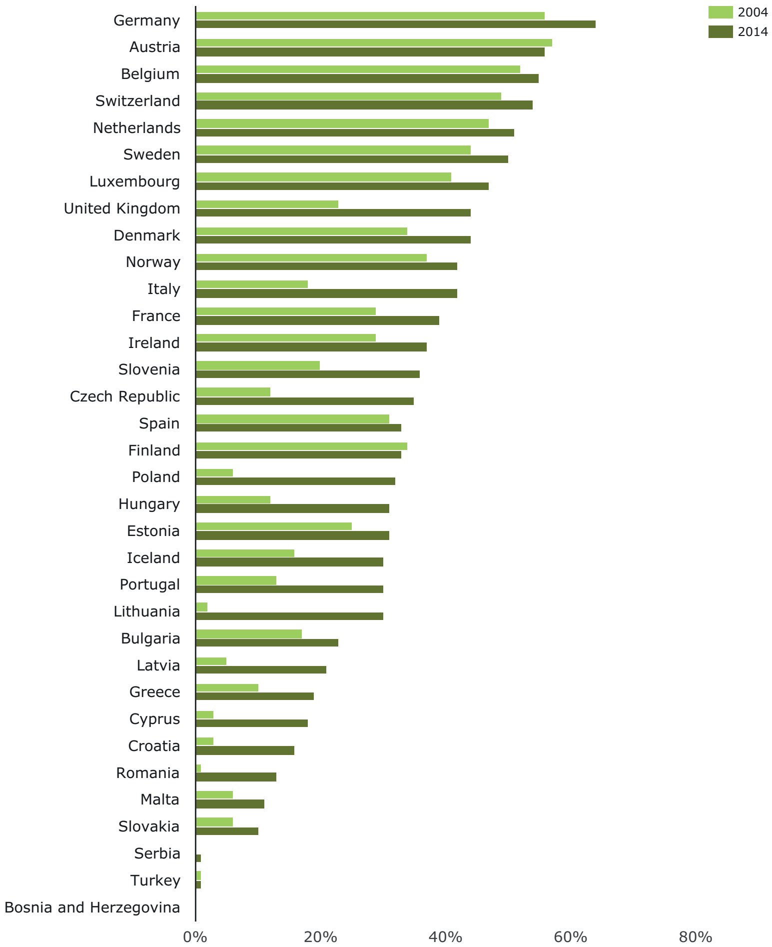
Countries vary significantly, however; many of those that more recently joined the EU have lower recycling and composting rates and much greater use of landfills, as shown in Fig. 5. A review by the WHO Regional Office for Europe (2016b) indicated large differences between and within European countries on waste management practices; some countries had old technologies and high levels of informal disposal, including open-air dumping and burning of waste. Annex 2 provides further details on the declining trends in municipal waste generation in most EU countries and the increases in the percentages of municipal waste recycled and composted in Europe over recent years (Eurostat, 2018b).

Fig. 4. Methods for municipal waste treatment in the EU (kg per capita), 1995–2015



Source: data from Eurostat (2018b).

Fig. 5. Comparison of municipal recycling and composting rates in European countries, 2004 and 2014



Source: EEA (2016b).

4

The circular economy and health: macroeconomic and distributional perspectives

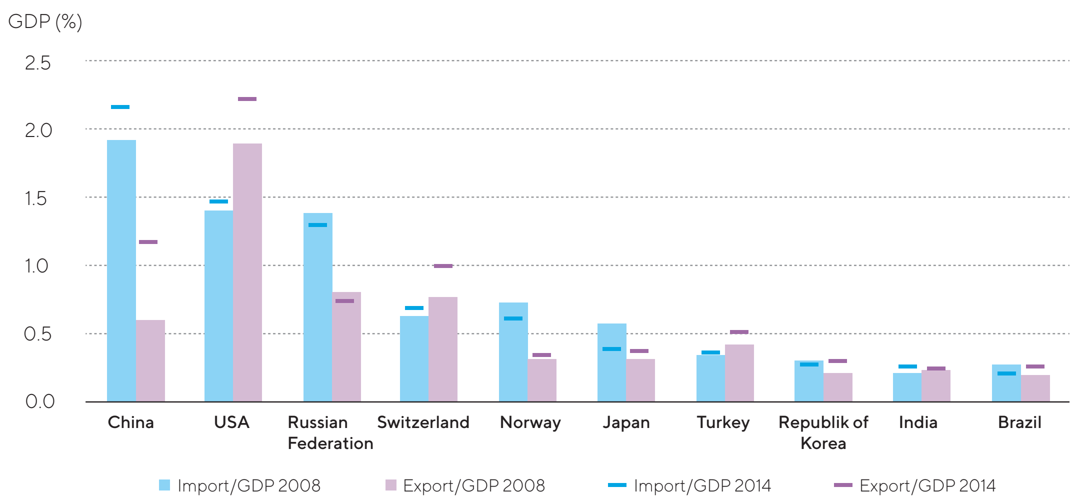
This section provides an overview of a number of the link between the operationalization of the circular economy in the broader economic and distributional context, and its implications for human health. It therefore provides the background for deriving a framework for the analysis of health effects relating to the circular economy (section 5) and for the identification of specific health effects (section 6).

4.1 Macroeconomic perspective

4.1.1 Global trends

At the macroeconomic scale, perhaps the most important trend to affect circular economy initiatives is globalization: the increased interdependence of countries and world regions for financial, human and material resources, as transport and communication costs have fallen. Fig. 6 provides evidence of this trend: trade between the EU and its 10 top trading partners increased as a share of gross domestic product (GDP) from 2008 to 2014 in almost all cases.

Fig. 6. EU trade in goods, imports and exports (% of GDP) for 10 main trading partners, 2008 and 2014



Source: data from Eurostat (2018a).

One likely consequence of this trend is that technological innovations that have arisen from strategies for resource reuse and reduction in circular economy initiatives in one country are more likely to be exported to others. As a result, economies of scale in manufacturing can be realized, further increasing the competitiveness of technologies. On the basis of this logic, EMF (2015b) estimates that, by 2030, the annual benefit of adopting advanced circular economy technologies, rather than current technologies, could be €1.8 trillion. This technological diffusion will then have broader health consequences than would otherwise be possible. The global adoption of digitization in communication and other technologies is likely to further amplify these trends.

The same advantages are likely to apply to the diffusion of technological innovations in pollution abatement that, when adopted, result in reducing the associated health impacts.

Other things being equal, the growth of world trade – including in technology that enhances the circular economy – would suggest that employment levels would also increase (Horbach et al., 2015). Higher employment in turn is understood to have both direct positive psychological and physical health benefits, and indirect benefits resulting from higher income, which allows the consumption of healthier food (see the case study in section 7) on food safety and healthy foods). Further health benefits associated with GDP growth resulting from globalization stem from the fact that increased expenditures on both public and private health care could be facilitated.

Contrary to this positive view of globalization and its relationship to circular economy initiatives and their health consequences, one tangible disadvantage of this trend is that comparative advantage encourages higher-income countries to export their waste – as well as polluting production – to lower-income countries. The case study on e-waste that is exported to dumping and processing plants in developing countries (section 7) illustrates the negative health consequences that may be associated with this trend. In addition, economic growth in countries dependent on exporting natural, nonrenewable resources could decline, resulting in lower levels of public health provision (OECD, 2017).

Further, globalization is likely to exacerbate the health impacts from emerging chemicals of concern (see case study in section 7) "by the increasing movement of chemical production to low-income and middle-income countries where public health and environmental protections are often scant. Most future growth in chemical production will occur in these countries" (Landrigan et al., 2017).

4.1.2 Macroeconomic indicators

A further positive trend that is particularly strong in higher-income countries relates to how the size of the economy is characterized. Specifically, awareness is growing that conventional measures of economic activity have a somewhat limited ability to capture other dimensions of human well-being and environmental constraints. For example, patterns of sustainable production (resulting in less material output) and sustainable consumption (in which fewer material products are consumed) are likely to be recorded as negative impacts on conventional measures such as GDP, even though they facilitate a transition to longer-term environmental and economic sustainability. Thus, the adoption and monitoring of a range of indicators of sustainable development, such as that undertaken by the EU statistical office, Eurostat (2015), as part of the EU Beyond GDP initiative, is an essential first step in better incorporating incentives for the circular economy in broad macroeconomic policy planning. Ultimately, given the extent of globalization, economic indicators and incentives need to be aligned at the international level, in order to avoid both pollution havens like those in the e-waste case study and overexploitation of natural resources more generally.

A further example of the rather limited value of GDP as a measure of welfare arises from the observation that pollution is often associated with health impacts that have both market and nonmarket costs. Market costs include those for health treatment, which would increase the GDP of the country in which people are treated but are effectively incurred to restore health after pollution affects it. Moreover, these costs are not trivial: Landrigan et al. (2017) estimate that health care spending on diseases caused by air pollution amounted to 3.5% of total health expenditure in high-income countries in 2013. In Sri Lanka, the only low- or middle-income country for which data are available, health care spending on diseases due to air pollution accounted for an estimated 7.4% of health care spending in 2013. The other main market cost associated with pollution is lost productivity arising from ill health. For this component, Landrigan et al. (2017) estimate that the costs from pollution-related disease account for 1.3–1.9% of GDP in low-income countries, and only 0.05–0.1% of GDP in high-income countries. Finally, the nonmarket component recognizes that health has an effect on peoples' welfare that is independent of GDP. When the component of willingness to pay to avoid premature mortality is added to the other two components, the total is estimated to be more than US$ 4.6 trillion, equivalent to 6.2% of global GDP.

Irrespective of the need to update macroeconomic indicators, a further positive development is the recent trend in the use of macroeconomic models to investigate how the structure of the macroeconomy might change as a result of a transition to a more circular economy. Studies to date indicate a tentative finding that, even with the adoption of traditional macroeconomic indicators, the shift to a circular economy will have either a neutral or positive effect in aggregate (OECD, 2017).

4.1.3 Conclusions

This discussion of the ways in which macroeconomic dynamics can differentially influence the resulting health outcomes implicitly highlights the roles public policy may play in maximizing the net health benefits. Specifically, on the one hand, the analysis indicates a role for the state in incentivizing the development and adoption of technology that is compatible with natural resource reuse and reduction. On the other hand, market forces need to be sufficiently well managed to ensure that market prices fully internalize associated external health and other costs, and that compensation mechanisms operate effectively.

The discussion of macroeconomic indicators highlights the inadequacies of existing measures, such as GDP, in capturing the natural resource constraints and the effects on well-being of the health effects of pollution. Again, this suggests a continued need to fully measure the size of pollution externalities so that they may be wholly internalized in public policy design and expressed in market prices. It also emphasizes the need for a renewed effort to promote the use of a wider, more inclusive set of sustainable development indicators in policy evaluation.

4.2 Distributional perspective

This section outlines the nature of distributional effects of a transition to a circular economy with specific reference to the environment and health.[4] It covers actual or potential inequalities in health exposures and effects among different groups, particularly vulnerable groups.

4.2.1 Context

The overall context for understanding the distributional effects of the implementation of circular economy actions is that, in general, environmental health risks in Europe and globally disproportionately affect vulnerable groups. The Lancet report on pollution and health concludes that "pollution disproportionately kills the poor and the vulnerable" and that "in countries at every income level, disease caused by pollution is most prevalent among minorities and the marginalised" (Landrigan et al., 2017). A WHO Regional Office for Europe (2010) review of evidence on environment

[4] This section uses the terms distributional effects and inequality to describe actual or possible positive or negative health impacts on vulnerable groups, rather than equity or fairness. This is because distributional effects represent inequality in terms of absolute quantitative differences between groups, while equity is defined as a relative term, and how changes to health impacts on vulnerable groups affect overall impacts relative to other groups is not known.

and health risks and social inequalities concluded that “people living in adverse socioeconomic conditions in Europe can suffer twice as much from multiple and cumulative environmental exposures as their wealthier neighbours, or even more”. Similarly, the review identified inequalities in exposure to environmental threats for vulnerable groups such as children and elderly people, low-education households, unemployed people, and migrants and ethnic groups (WHO Regional Office for Europe, 2010); key examples in various areas include the following.

Evidence indicates that more deprived populations tend to live closer to hazardous **waste management** sites and are more exposed to their emissions.

Although European evidence on poorer people’s exposure is mixed, in general, those of low socioeconomic status experience greater health effects from **air pollution**.

Residential location is strongly associated with exposure to environmental risks, with vulnerable groups (especially those with low income) having increased exposure. This includes environmental risks in dwellings (e.g. chemical contamination, noise and lack of sanitation) and residential environment, closeness to polluted sites or exposure to traffic-related pollution). Studies show that vulnerable groups (especially those with low income) have increased exposure to these risks. Differences between rural and urban areas depend on the type of risk; for example, higher health risks in general are associated with fewer household connections for water supply and sanitary equipment in rural areas (especially in eastern Europe and the Caucasus) but greater risks from air pollution and noise in urban areas.

In the **work environment**, the least skilled workers have the greatest exposure to harmful working conditions, including exposure to physical, chemical and microbiological toxins. Education, income, immigration status, ethnicity and gender influence which populations obtain low-skilled occupations.

Differences in the capacity to adapt to **climate change** (for example, due to differences in wealth, technical knowledge, information, skills and infrastructure) may increase inequalities, for example, through heat-related health impacts, flooding and food-, water- and especially vector-borne diseases.

The overall pattern, based on the available fragmentary data, is that **children** living in adverse social circumstances suffer from multiple and cumulative exposures, are more susceptible to a variety of environmental toxicants and often lack environmental resources or access to high-quality health care to reduce the health consequences of environmental threats.

As to **gender**, inequities in the environment and health due to biological and sociocultural differences have been identified in the issues of safe water and sanitation, human settlements, exposure to chemicals, clean air and safe working environments, and climate change (UNDP, 2013). The available evidence shows marked differences between men and women in exposure and vulnerability (WHO Regional Office for Europe, 2009, 2010).

4.2.2 Identified distributional effects

A key question in this context is to what extent circular economy actions do and will alleviate or contribute to the environmental health risks for the vulnerable populations listed above. As noted in section 6.1, the literature has limited coverage of the indirect economic and social impacts of the transition to a circular economy, including impacts on gender, skills, jobs, poverty and inequalities. Moreover, within its discussion of social impacts, this literature has not focused much on health issues and the related distributional effects of such a transformation (Rizos et al., 2017).

Possible distributional aspects of these health issues emerging from the current study include both direct impacts from specific actions and indirect longer-term impacts from combinations of actions. The rapid assessment of the implications for human health from the implementation of circular economy actions given in Table 3 (section

6) includes very preliminary indications of likely affected groups and distributional issues for identified health impacts. This is based on expert judgement as, while the literature on the circular economy identifies these issues in some cases, specific research on the distributional issues for the identified health impacts is limited.

4.2.3 Specific circular economy actions

Direct health consequences resulting from **specific circular economy actions** outlined in this report include those discussed in the case studies on chemicals of concern, e-waste and food safety (see section 7). As noted above, the negative effects identified frequently fall disproportionately hard on vulnerable groups in Europe and globally.

A key example is the effect of the **export of waste**, particularly e-waste (see case study in section 7.3), to unregulated and informal dumping sites in developing countries, where the local population and site workforce is often more deprived than the general population (WHO, 2016b) and thus less able to afford defensive action. Since the recycling of electronic products and components has increased in recent years, the level of health risks at these sites could be attributed in part to circular-economy-related actions that are not yet effective in minimizing health externalities. Policies to address this issue include implementing and enforcing health and safety standards at these sites and cutting the amount of toxic material that goes to them by improved tracking and routing to safer options.

The transition to a circular economy can also play a key part in reducing the total amount of harmful substances in the waste stream in the long term. If these actions succeed and their wider consequences (such as impacts on livelihoods) are taken into account, they will cut health impacts and could benefit the poor, since the local and worker populations of unregulated dump sites would disproportionately experience these benefits. The health benefits from these actions would be lower per unit of hazardous material from the remaining e-waste that goes to other regulated sites, although there is an unknown equity impact around the issue of hazardous material (thought to be from recycling) turning up in products.

The direct health consequences of recycling chemicals of concern, such as the BPA and BFRs being detected in products (see case study in section 7.2) is an area of scientific uncertainty and continuing research. This uncertainty includes distributional effects, since exposures and effects would depend on the demographic profile of the workers producing and the consumers buying the products in question, such as children's toys. Further specific circular economy actions may benefit the health of vulnerable groups, as identified in Table 3 (section 6), through the redistribution of edible food (given caveats on ensuring food safety standards), for example. Further research is needed in all the identified cases to improve the understanding of the implications for equity.

4.2.4 Indirect and longer-term impacts from combinations of circular actions

A successful transition to a circular economy would result in reduced global environmental pollution (including emissions to air, water and soil) from production and consumption processes. This in turn would produce long-term indirect health benefits to the extent that global environmental pollution is reduced.

The case studies on the built environment, climate change and air pollution in section 7 discuss examples of these benefits. Such benefits are likely to favour vulnerable populations because these groups are known to be disproportionately affected by environmental impacts due to inequitable environmental determinants of health, as outlined above. Further research is needed, however, to understand the distributional and equity implications in greater detail, including more precisely how circular economy processes affect the environmental conditions and health of poor people in more polluted locations in the world.

4.2.5 Conclusions

The human right to the highest attainable standard of health is enshrined in the WHO Constitution (WHO, 2017b) and the United Nations Convention on the Rights of the Child, which explicitly links the right to health with pollution and contamination (United Nations, 2016). This right underlines the importance of understanding the distribution of health impacts in the context of the circular economy. The negative health consequences of specific circular economy actions outlined in this report may disproportionately affect more vulnerable populations, as shown by the case on studies chemicals of concern, food safety and e-waste. On the other hand, the health benefits of the actions are likely to disproportionately favour vulnerable populations by addressing inequitable environmental determinants of health, such as air pollution and soil contamination. Given the importance of inequity in health in key initiatives, such as Health 2020 and the SDGs (WHO Regional Office for Europe, 2013; United Nations, 2016), the distributional issues outlined in this report require further emphasis in research and policy development, to minimize negative outcomes and promote positive outcomes for vulnerable populations.

5

Outline of a framework for assessing health impacts in the circular economy model

This section develops a framework to identify pathways through which implementation of circular economy models may affect human health and welfare. The framework is designed to describe the health and welfare impacts identified according to their key characteristics, including the type of effects (positive/negative, direct/indirect) and the economic sectors and groups affected (distributional issues). To the extent possible, the framework draws on and adapts existing frameworks and classifications from the environment and health literature, including from WHO initiatives.

The Driver, Pressure, State, Exposure, Effect, and Action (DPSEEA) framework is a useful tool for mapping links and causal relationships between the political, social and economic drivers of environmental pressures and states, and their effects on health exposures and impacts, as a basis for identifying policy actions for better health and environments. WHO developed the DPSEEA framework from a more general environment-based framework to focus specifically on links between the environmental and health (Corvalán et al., 2000; WHO, 2008).

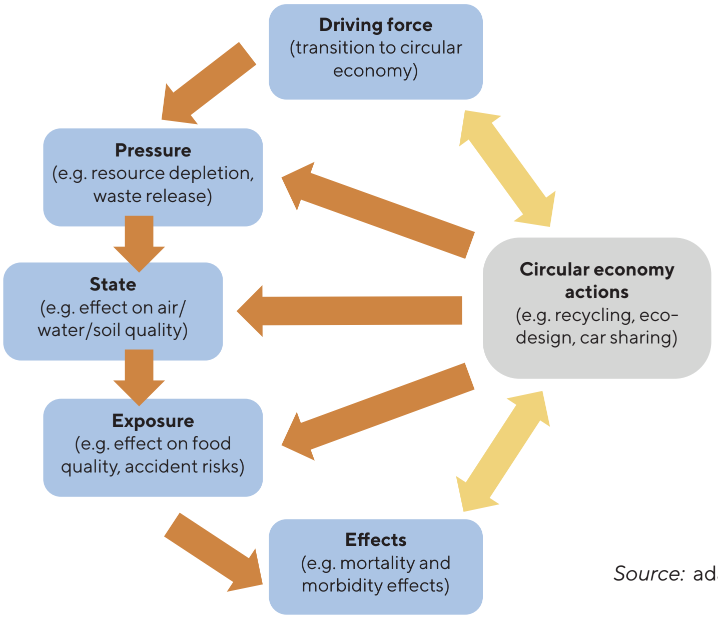
In the context of assessing the health implications of the transition to a circular economy, this framework can be adapted so that, rather than being used to identify policy actions, the range of possible processes needed for a transition to a circular economy (e.g. recycling, reuse, product sharing, etc.) is already defined.[5] The health impacts of implementing these processes can then be mapped according to their links with different elements of the framework, as shown in Fig. 7. Thus, some processes (such as recycling chemicals of concern) can be identified as directly affecting health exposures and effects, and others as doing so indirectly; an example of the latter could be when greater resource efficiency results in reduced environmental pressures from resource extraction and use, which then result in improved environmental conditions and reduced health exposures and effects. These impacts may appear far away from the areas where action is taken; for example, greater resource efficiency may have health implications in locations where source materials are mined, including in developing countries. Feedback loops may also occur: unintended negative health effects from circular economy processes can result in adjustments to policy on these processes. Similarly, initiatives for a circular economy drive the uptake of its processes, and their implementation can positively and negatively affect the overall drive for a transition to a circular economy.

The consideration and characterization of the possible implications for health of circular economy processes (section 6) uses the

[5] Note that this publication uses the term processes (as used in Rizos et al. 2017), as it focuses on the health implications of the increased use of these processes rather than the policy actions that might bring them about (e.g. regulation, economic incentives, awareness raising). The latter are discussed further in section 6.

framework described here. In particular, it aided the identification of where and how circular economy processes link to other elements in the DPSEEA framework and where there are real or potential health exposures and impacts as a direct or indirect result.

Fig. 7. The Drivers-Pressures-State-Exposure-Effects-Actions/DPSEEA framework is a framework for linkages between health, environment and development



Source: adapted from Corvalán et al., 2000; WHO, 2008.

Fig. 8 presents a framework for identifying and characterizing the potential health impacts of each circular economy process according to:

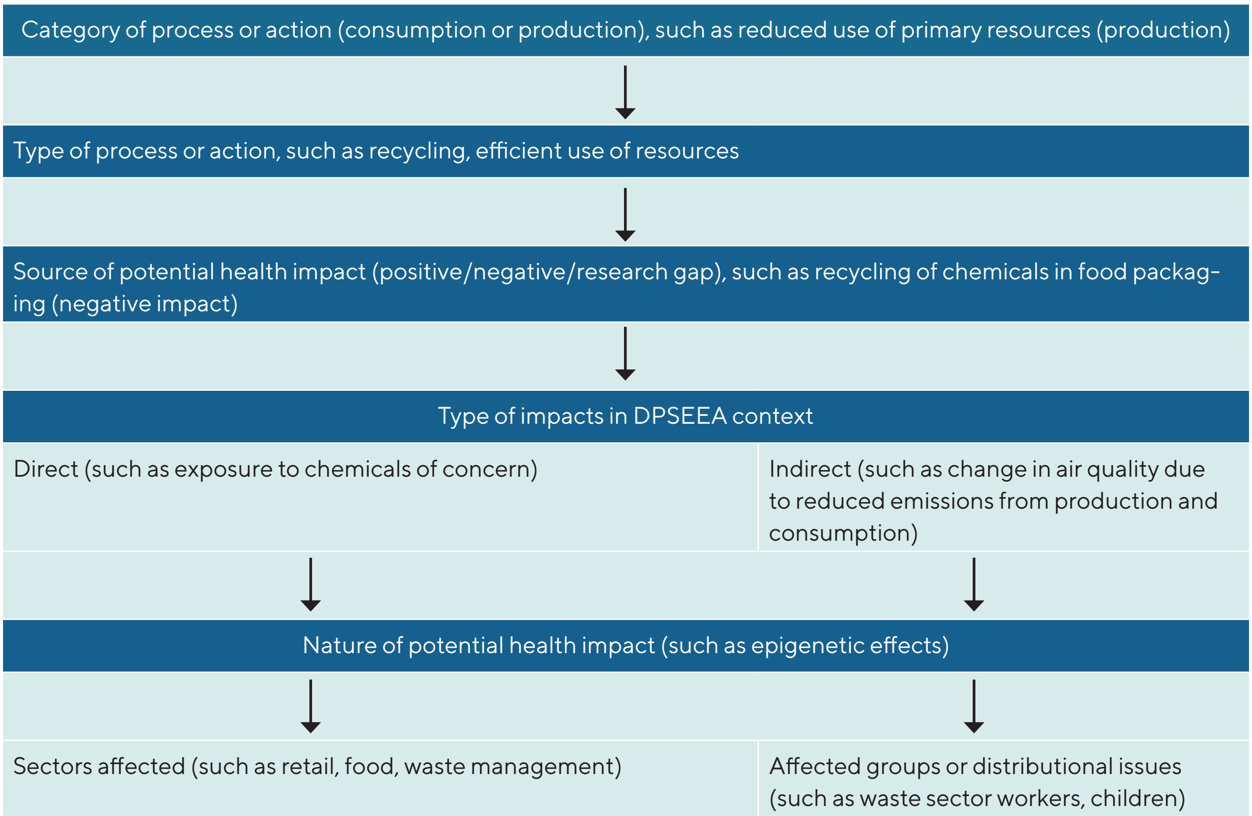
- the **category of the circular economy process or action (consumption or production)**, using categories defined in Rizos et al. (2017), as shown in Table 2;
- the **source of potential impact on or change in risk** and whether the change is positive or negative: for example, when recycling of chemicals of concern in food packaging (e.g. BPA, phthalates and perfluorinated chemicals – PFCs) causes a potentially negative impact;
- the **types of health impact**: characterizing health impacts of circular economy processes according to their causal links in the DPSEEA framework: that is, whether they result indirectly from changed environmental pressures and state (e.g. changes in air quality) or directly from health exposure (e.g. via pathways of inhalation or ingestion) and effect/endpoints (e.g. from direct exposure to chemicals of concern);[6]
- the **nature of the health impacts**: identifying real or potential positive and/or negative health endpoints (the epidemiological nature of health impacts[7]) and whether they concern occupational, public or consumer health;

[6] Where applicable, the relevant type of environmental links is identified, such as changes to air, water or soil quality; GHG emissions; and noise.

[7] Health impacts are defined with reference to the epidemiological categories used in the WHO study on preventing disease through healthy environments by Prüss-Üstün et al. (2016).

- the **economic sectors** in which the impact is associated with particular production processes or services, such as agriculture, industry or commerce (such as plastics, electronics, chemicals and food production), transport and housing or the built environment.
- the **affected groups and distributional issues**: indicating, where possible, race, poverty and inter- and intragenerational equity issues where there are specific occupational, public and consumer health impacts.

Fig. 8. Framework for identifying health impacts of the circular economy



Source: data from Rizos et al. (2017)

Table 2. Categories and types of circular economy processes and actions

Category (consumption or production)	Type
Reduced use of primary resources (production)	Recycling Efficient use of resources Use of renewable energy sources
Maintain the highest value of materials and products (production)	Remanufacturing, refurbishment and reuse of products and components Product life extension
Change utilization patterns (consumption)	Product as service Sharing models Shift in consumption patterns

Source: data from Rizos et al. (2017)

6

Health implications/ impacts of circular economy

6.1 Review of potential health impacts

This section presents a rapid assessment of the known and potential health implications of a transition to a circular economy based on a review of the literature. Table 3 gives an overview of real and potential health implications that have been identified by literature review and using the framework developed in section 5. This includes the identification of the most significant existing and potential health impacts, the stakeholders affected and distributional effects. Table 3 uses simple colour coding to indicate the positive and negative health implications identified in the literature. The existence and extent of identified impacts depend heavily on context, and research is limited in many cases, so no scaling of impacts is given. Table 3 also notes where the evidence of impacts remains inconclusive or limited. Thus, the rapid assessment is necessarily very generalized and not comprehensive; rather, it is intended to demonstrate the wide-ranging nature of potential impacts and whether the emerging literature has identified them as positive or negative. Further expert review is needed to assess the quality and extent of the available evidence per impact, and their relative importance.

Health issues are included in but not at the forefront of a number of the circular economy reports reviewed for this publication. Most studies on the circular economy issued to date focus primarily on the business case for enhanced resource efficiency (Wijkman & Skånberg, 2015). The review by Rizos et al. (2017) found limited information on the indirect effects on the economy and the social impacts of the transition to a circular economy, such as impacts on gender, skills, jobs, poverty and inequalities. Moreover, the reports that have looked at the social benefits that a transformation to a circular economy would entail focused mainly on other aspects, rather than directly on health impacts. For example, the report of the Green Alliance (2015) on the social benefits of a circular economy focuses on jobs and other economic benefits, but does not cover health. Similarly, the Club of Rome's reports on the benefits for society of a circular economy in Europe (Wijkman & Skånberg, 2015, 2016) focus on carbon emissions and employment benefits, with limited coverage of health.

Other literature covers the health effects of waste management options; publications of the WHO Regional Office for Europe (2007, 2016b) outline key issues, with reviews available on health impacts of waste treatment activities. The general conclusion given in WHO Regional Office for Europe (2016b), however, is that the health effects of waste management and disposal activities are only partly understood and definitive results, including accurate exposure information, are lacking in many cases. Much more comprehensive evidence is therefore needed to better inform the policy debate.

Table 3. Rapid assessment of human health and welfare implications from implementation of circular economy models

Process/Action	Source of potential health implications positive or negative	Health impact (direct or indirect)	Nature of potential health endpoint
Reduced use of primary resources (production)			
Recycling	Food waste: redistribution of edible food	Direct health effects	Reduced malnutrition and other poor diet related endpoints
	Food waste: composting	Direct health risks from inhalation of bioaerosols	Asthma or extrinsic allergic alveolitis
	Food waste: risk if food safety is compromised	Direct health effects	Food poisoning including diarrhoeal diseases (public health)
	Chemicals in food packaging (BPA, phthalates, PFCs)	Exposure to chemicals (direct)	Epigenetic effects
	Use of BFRs in manufacturing.	Exposure to chemicals (direct)	Endocrine, reproductive and behavioural effects
	E-waste recycling components (e.g. BFRs, PCBs)	Direct health effects and indirect impacts via soil, water and food, and toxic by-products	Contact with hazardous waste, increased risk of injury in recycling process
	Informal recycling	Occupational health risks at poorly regulated sites	Increased risk of accidents and exposure to hazardous materials
	Waste reduction and recycling in health sector	Direct impact on health sector via reduced costs	Reduced costs allow improved health services across all endpoints.
	Use of recycled materials in manufacturing processes	Indirect impact via reduced manufacturing air/water emissions	Cardiovascular and respiratory Heat-related conditions in climate change (long term)

Sectors affected	Groups affected or distributional issues	Notes	Example sources
Community	Low-income and vulnerable groups	Positive impact depends on safeguards on contamination and distribution of unhealthy foods.	Mabelis et al. (2016)
Waste management	Waste sector workers	–	Pearson et al. (2015)
Various including retail, catering, waste management	Vulnerable groups and community	Safety guidelines are available for food waste collection.	HSE (2018), WRAP (2016)
Retail, catering, waste management	Consumers, waste sector workers	CHEM Trust and the Health and Environment Alliance (HEAL) are working on this issue.	Chen et al. (2009), DiGangi & Strakova (2015), Genualdi et al. (2014), Rodgers et al. (2014), Rudel et al. (2011)
Plastics, retail, waste management	Consumers (eg children), waste plastics and sector workers	CHEM Trust is working on this issue.	–
Community, waste management	Waste site workers and children are especially vulnerable.	–	Kuehr & Magalini (2013)
Community, waste management	Disproportionately affects poor and vulnerable groups	This issue includes e-waste recycling sites and other waste sites and relevant to waste exports to countries outside Europe and any poorly regulated sites in Europe.	Ezeah et al. (2013)
Health, manufacturing	All health sector users	–	EC (2017b), EMF (2015c), REBus (2016a–c).
All sectors	Manufacturing sector workers, general population	Energy saving and lower emissions from using recycled materials in manufacturing process	EMF (2015a,b) includes analysis of carbon dioxide (CO_2) and pollution reductions,

Table 3. contd.

Process/Action	Source of potential health implications positive or negative	Health impact (direct or indirect)	Nature of potential health endpoint
Efficient use of resources	Use of sewage sludge in agriculture with contaminants (e.g. persistent industrial chemicals, pharmaceuticals, pesticides)	Change of soil/water quality	Wide range: eg typhoid, dysentery, diarrhoeal diseases
	Resource-efficient agricultural practices (including reduction in fertilizer and pesticide use), regenerative farming practices (including organic cultivation), closed loops of nutrients and other materials	Reduced pressures and states (indirect) and exposure (direct)	Reduction in poor-diet-related conditions, obesity, various cancers
Use of renewable energy sources	General move to renewable energy and energy efficiency in the circular economy across many sectors	Lower air pollutants and GHG (indirect)	Reduced cardiovascular and respiratory effects Reduced Heat-related impacts and exposure risks from extreme events from climate change
	Reduced energy recovery (incineration)	Reduced generation of pollutants during energy recovery process	Reduced cancers, respiratory and negative birth outcomes The evidence is not conclusive and research continues.
Maintain the highest value of materials and products (production)			
Remanufacturing, refurbishment, and reuse of products and components	"Circular buildings"	Improved indoor air quality and use of nontoxic materials	Various, including occupational health and safety issues, mental health and respiratory.
	Reuse of clothing and textiles	Reduced health risks, e.g. from cold or other harmful exposures	Lower risk from weather-related conditions

Sectors affected	Groups affected or distributional issues	Notes	Example sources
Agriculture, food production	Agricultural workers, consumers	There is potential risk but limited evidence of health impacts in the EU.	Risk & Policy Analysts Ltd et al. (2008)
Agriculture, food production, consumers	Consumers Further research needed on distributional issues need	Overall potential effect is consumers having greater access to high-quality food that would encourage healthier dietary choices (see discussion in case study).	EMF (2015b)
Multiple sectors	Positive for vulnerable groups, which are disproportionately affected by climate change and air pollution	The benefits should be balanced with any negative impacts, such as changes in land use, disposal of toxic materials from solar manufacturing.	EMF (2015b) and Deloitte (2016) focus of sources is on reducing CO_2 emissions.
Waste management, energy	Workers, vulnerable groups near incinerators	Although Incineration is defined as partially renewable, it is not a favoured the circular economy option in the circular economy literature. Assessment is needed of the pro and cons of options for treatment of residual waste flows consistent with the circular economy principles.	Ashworth et al. (2014), Health Protection Scotland (HPS, 2009)
Commercial and residential	Potential impacts for a wide range of groups	"Circular buildings" involve buildings made for looping, using renewable or recyclable healthy materials.	EMF (2015b, 2017b)
Textiles, voluntary sector	Poor and vulnerable groups	See example of reuse of workwear for humanitarian aid blankets. Positive impact depends on safeguards against infection transmission.	Circle Economy (2016)

Table 3. contd.

Process/Action	Source of potential health implications positive or negative	Health impact (direct or indirect)	Nature of potential health endpoint
Product life extension	Reduced waste generation and production emissions	Reduced indirect impacts from waste management (landfill, incineration, recycling, etc.) and from manufacturing air/water emissions	Various, including reduced cancer, negative birth outcomes, and respiratory risks
	Resource savings through extension of product life in hospitals	Direct impact on health sector via reduced costs	Reduced costs allow improved health services across all endpoints.
Change utilization patterns (consumption)			
Product as service	Performance models in health care sector and other sectors	Direct impact on health sector via reduced costs Indirect impact for various sectors (e.g. transport) via reduced manufacturing	Reduced costs allow improved health services. Conditions related to emissions from manufacturing are reduced.
Sharing models	Product- and service-sharing platforms (business to business, business to consumer and consumer to consumer), e.g. car sharing	Indirect impact via reduced manufacturing emissions Direct impacts on air quality and noise from car sharing	Reduced respiratory and cardiovascular conditions due to lower emissions
Shift in consumption patterns	Shift to healthier diets	Direct impact on health	Reduction in poor diet related conditions, obesity, cardiovascular diseases, cancers
	Shift from material to virtual products or services	Indirect impact for various sectors via reduced manufacturing	Reduced harmful conditions related to manufacturing emissions
Combinations of actions			
Efficient use of resources, Shift in consumption, new approaches.	Healthier food production	Direct impact on health Potential for indirect health benefits from reduced GHG and other emissions from changes in food production	Reduction in poor-diet-related conditions, obesity, cancers Reduction in harmful emissions.
Efficient use of resources, sharing models, Shift in consumption	Mobility	Indirect impacts from reduced air emissions Possible impacts on road safety	Respiratory, road accident deaths and injuries
Efficient use of resources, eco design, use of renewable energy.	Built environment	Improved indoor air quality and use of nontoxic materials	Various, including occupational health and safety issues, mental ill health and respiratory conditions

Sectors affected	Groups affected or distributional issues	Notes	Example sources
Waste management, manufacturing	Waste sector workers, manufacturing sector workers	The literature reviewed focuses on business and environmental benefits.	Montalvo et al. (2016)
Health	All health sector users	The health care case study (section 7) discusses the potential for sensor technology to aid replacement decisions.	EMF (2016a)
Health, manufacturing	All health sector users	Potential for worse treatment of shared goods by users (compared to with those owned) should be taken into account in overall impact assessment.	EMF (2015c), REBus (2016b)
General population	For car sharing, inner-city residents and low-income groups	Impact of car sharing also depends on extent of newer cars in schemes and rate of replacement.	EMF (2017a), Chen & Kockelman (2015) focus on environmental benefits.
Agriculture, food production, consumers	Consumers Distributional issues may need further research.	See resource-efficient agricultural practices (above) and healthier food production (below)	EMF (2015b)
Manufacturing, general population	Consumers	Broad area, for which impacts and distributional effects need further research	EMF (2016a)
Agriculture, food production, consumers	Consumers Distributional issues may need further research.	See also resource-efficient agricultural practices above and shifts to healthier diets (above).	EMF (2015b)
All sectors	Distributional issues may need further research.	–	EMF (2015b) gives a broad assessment of the circular economy implications for mobility.
Commercial and residential	Potential impacts for wide range of groups	–	EMF (2015b) gives a broad assessment of the circular economy implications for the built environment.

Table 3. contd.

Process/Action	Source of potential health implications positive or negative	Health impact (direct or indirect)	Nature of potential health endpoint
Recycling, efficient use of resources, shift in consumption	Reduced use of Landfill, and incineration	Reduced direct impacts from air, water and soil pollution and GHG emissions	Reduced cancer, negative birth outcomes, and respiratory diseases
Recycling, efficient use of resources, shift in consumption	Substitution and reduced use of hazardous materials resulting in reduced need for disposal of hazardous materials in long term	Reduced direct impacts from water and soil pollution	Multiple potential impacts including on cancers, birth outcomes, and diseases of the cardiovascular and nervous systems

6.2 Findings from the review of health impacts

Some general findings from the outline of human health and welfare implications from implementation of circular economy models given in Table 3 are as follows.

The potential and known **negative health impacts** identified relate to the general category of reduced use of primary resources (production), and particularly to managing risks in the recycling and reuse of products, components and materials. These impacts are very often the unintended consequences of such actions. Specifically, the impacts refer to the management of chemicals of concern, for example, e-waste, food packaging and fire retardants in a variety of products; and to emissions from the composting of waste. Managing these risks and impacts could be interpreted as a necessary part of the transition from a linear to a circular economy, during which chemicals of concern are ideally phased out of production processes.

The recycling and reuse of products, components and materials also have many **positive implications**, for example, in the context of savings in the health care sector and through the indirect health benefits of reducing environmental impacts (air, water and soil pollution, and GHG emissions) from manufacturing and extraction processes.

The identified health implications in the other broad categories of circular economy processes – maintaining the highest value of materials and products and changing utilization patterns – are also **largely positive**. In particular, performance models of utilization show potential for significant direct health benefits for the hospital/health care sector, and a wide range of indirect health benefits can result from the implementation of resource-efficient agricultural practices, the move towards greater use of renewable energy and energy efficiency, building using circular principles and shifts to new product-sharing and product-as-service models. All these processes are expected to reduce waste generation and result in improved resource efficiency, thereby cutting environmental impacts (e.g. emissions to air, water and soil) from economic activity across a number of sectors, with a corresponding reduction in the morbidity and mortality endpoint impacts.

Table 3 also includes some examples of **packages of circular economy measures** aimed at specific sectors or issues. For example, packages for the built environment, mobility and food production

Sectors affected	Groups affected or distributional issues	Notes	Example sources
Waste management	Poorer groups live closer to landfill sites.	Evidence of health impacts from landfill is not conclusive and research continues.	WHO Regional Office for Europe (2016b) gives a literature review relevant to action on contaminated sites (WHO Regional Office for Europe, 2017a).
Waste management	Potential impacts for a wide range of groups	Long-term benefit due to reduced use of hazardous materials in production	See examples in the context of the built environment (EMF, 2015b) and contaminated sites (WHO Regional Office for Europe, 2017a).

given in the literature (EMF, 2015b, 2017a) include a variety of measures that have a range of health implications related to pollution, climate change, occupation health and public health.

Table 3 also includes the reduction of **landfill and incineration** of waste, as these are seen as a consequence of following circular economy principles and concurrent with measures to reduce use of primary resources and maintain the highest value of materials and products. It will remain necessary, however, to assess the advantages and disadvantages of options for the treatment of residual waste flows consistent with circular economy principles.

Within **SDG 12**, to ensure "sustainable consumption and production patterns"; the identified areas requiring careful management of the health implications are mainly associated with achieving the targets for environmentally sound management of chemicals and all wastes throughout their life-cycles (SDG 12.4), and the reduction of food waste (SDG 12.3). In general, however, the potential for positive health outcomes from the circular economy model should greatly contribute to achieving SDG 12, particular by achieving sustainable management and the efficient use of natural resources (SDG 12.2) and substantially reducing waste generation (SDG 12.5).

Table 3 notes the potential and known **distributional effects** for specific health impacts. Where negative impacts are identified, their effects frequently fall disproportionately on vulnerable groups, as mentioned. Impacts on waste sector workers and the population living near waste management facilities also have distributional aspects to consider, since these people are often more deprived than the general population (WHO Regional Office for Europe, 2010). The positive indirect health impacts from reduced environmental pollution (including effects of GHG and air pollution emissions beyond the vicinity of waste management facilities) are likely to benefit the poor in that such people are known to be disproportionately affected globally. Nevertheless, more detailed distributional assessment is needed for each health impact identified. Indeed, Rizos et al. (2017) found that limited information was available on the social aspects of circular economy "such as gender, skills, occupational and welfare effects, poverty and inequalities". For further discussion on distributional effects see section 4.2.

The transition to a circular economy in the WHO European Region has a **global health footprint**. As noted under distributional effects, there are direct impacts on the local population and workers in informal waste management sites to which European waste is sent for disposal and/or recycling (see the case study on e-waste). There is also a wider question of the implications of this transition in Europe, in terms of changes in production and consumption, for the health of populations in other regions of the world. For example, how will the circular economy change the quantity and type of imports into Europe and what health implications for populations in the source countries would result from changes to environmental and social impacts of resource extraction and production (FoEE, 2014)?

Much current research addresses the potential health impacts of the transition to a circular economy, for example, in the context of chemicals of concern, water reuse and e-waste. Nevertheless, this review highlights many **knowledge gaps** in the understanding of the nature of these impacts (e.g. in the case of chemicals of concern), the severity and frequency of exposures and the extent of different health endpoints, along with the environmental residence time of the pollutants causing these impacts and the latency of onset. Thus, continuing research and further evidence are essential for a more complete assessment of priorities for addressing negative impacts and enhancing positive ones. In the context of waste management, the WHO Regional Office for Europe (2016b) recommends that "in general, methods and resources for cost-efficient health surveillance should be developed", and notes that some existing evidence is becoming less relevant for some countries in the WHO European Region, as the waste industry evolves and old facilities are phased out.

6.3 Quantification and valuation of health impacts

Methodologies for quantifying and valuing health impacts are well established. Quantitative estimates of the burden of disease attributable to different factors, including the environment, can combine comparative risk assessment, exposure and epidemiological data; transmission pathways; and expert opinion, as used in the global assessment of the burden of disease from environmental risks for WHO (Prüss-Üstün et al., 2016). Economic values for health impacts and policies that address or affect them impacts can be estimated using, for example, the cost-of-illness and damage-function approaches; the latter is commonly used in the context of air pollution. This includes assessing:

- resource costs, including aversive expenditures and direct medical and non-medical costs associated with treatment;
- opportunity costs, including the costs of loss of productivity and/or leisure time; and
- disutility costs, including pain, suffering, discomfort and anxiety (Hunt et al., 2015).

6.3.1 Potential health benefits

Available estimates of health impacts from specific policies or packages of policies for the circular economy suggest very significant potential benefits across a number of sectors and for the general population. These include the following.

The first is **health externality estimates for food, mobility and the built environment**. EMF (2015b) concludes that the "circular economy scenario could have a major impact on consumers' health and related health care costs and other societal costs, capturing a significant share of the more than 3 percent of GDP lost today to obesity by 2050." Under this scenario, the Foundation estimates that annual externalities in the 27 countries belonging to the EU before July 2013 (EU27) could decline by as much as €130 billion compared with the present day, and by about €10 billion compared with the current development scenario. These externalities include CO_2 (€29/tonne) and opportunity costs (e.g. productivity loss and loss of lives) related to obesity (EMF, 2015b).

Next is **savings in the health care sector**. The implementation report on the EU action plan on the circular economy includes estimates of the impact of amendments to the Directive restricting the use of certain hazardous substances in electrical and electronic equipment. The report suggests that the overall effect of enabling secondary market operations and increasing the availability of spare parts will reduce costs for public authorities, including a saving of about €170 million after 2019 for European hospitals due to the opportunities to buy and resell used medical devices (EC, 2017b). Other evidence on performance models in procurement suggests that hospitals in Denmark could save €70–90 million by 2035, with €10–15 million in savings annually by 2020 (EMF, 2015a).

An analysis for the Ex'Tax project by Cambridge Econometrics suggests that a **shift from labour- to resource-based taxes** in the period 2016–2020 would result in not only positive GDP and employment results in the EU27 but also health benefits from lower carbon emissions and pollution levels due to reduced energy, resource and water use, as well as increased well-being from employment effects. The cumulative value added for 2016–2020 (against baseline) is estimated as: €3.1 billion in avoided costs to society due to illness and premature death from air pollution exposure,[8] €4.9 billion in avoided costs due to human and ecosystem health damage associated with pollution of land and water with toxic chemicals and metals,[9] €0.7 billion in avoided costs due to human and ecosystem health damage associated with freshwater resources, and €2.2 billion in the value of healthy years of life gained by reduced unemployment[10] (Ex'Tax et al., 2016).

The EU action plan on the circular economy estimates that the measures being taken can reduce **GHG emissions** by more than 500 million tonnes between 2015 and 2035 (EC, 2015a). The health implications of this in the long term relate to possibilities for reduced impacts of extreme weather and heat-waves.

6.3.2 Problems in translating evidence into estimates

Many studies focus on the specific risks and exposures identified in Table 3. For instance, the WHO Regional Office for Europe (2016b) outlined the existing evidence on exposures and health effects from landfill and incineration of waste. There are a number of difficulties, however, in translating the available evidence into estimates of aggregate impacts, in quantitative or monetary terms, from specific identified health issues related to the circular economy.

In general, exposure assessment methods and data to assess the quantitative relationship between waste management and health effects are limited. Spinazzè et al. (2017) highlight the persisting concerns and uncertainties about potential environmental and health effects associated with exposure to emissions from waste management facilities. They conclude that most available studies have limitations related to poor exposure assessment and limited data on direct human exposures, and that harmonized exposure assessment strategies and techniques need to be developed. Thus, they see a comprehensive characterization of human exposure to waste management emissions as a continuing challenge.

Studies that have provided evidence on the presence of chemicals of concern in recycled materials, such the DiGangi & Strakova (2015) study on BFRs in plastics products, present sample

[8] Air pollution valuation based on disability-adjusted life-years (DALYs) due to changes in exposure (Desaigues et al., 2006, 2011).

[9] Land and water pollution valuat ion based on DALYs for human health (Desaigues et al., 2011) and the value of ecosystem services gained/lost for ecosystem health (De Groot et al., 2012).

[10] Based on value of quality adjusted life years gained/lost due to changes in unemployment related mortality (Desaigues et al., 2006, 2011).

data that cannot readily be scaled up to indicate the significance of the presence at the national, European or global level, to allow aggregate estimates for specific health exposures and endpoints.

The range of approaches that have been adopted hamper comparative assessment of the order of magnitude and significance of the identified health impacts. Rizos et al. (2017) found that available studies on the circular economy often "adopt different approaches when calculating the impacts which make the comparison of results from different sources challenging".

Many scientific studies on specific health risks and exposures are not in the context of how transition to a circular economy could or has changed these risks and exposures. For example, a recent study (Trasande et al., 2015) concludes that exposure to endocrine-disrupting chemicals, including those found in plastics, in the EU contributes substantially to disease and dysfunction, causing health and economic costs exceeding €150 billion per year, but further analysis is needed to identify by how much circular economy approaches affect this, as outlined in the case study on chemicals of concern.

In addition, the Lancet commission on pollution and health included the need for research on links between pollution and health as a key recommendation. In particular, it recommends that this include: the identification and characterization of the adverse health outcomes caused by new and emerging chemical pollutants, and the improvement of estimates of the economic costs of pollution and pollution-related disease (Landrigan et al., 2017).

6.3.3 Conclusion

In conclusion, aggregate quantitative and monetized estimates for the impacts of packages of action for the circular economy are available and indicate significant potential benefits. These should be seen as order-of-magnitude indications, due to the wide range of assumptions needed for the uncertainties about the progress and extent of the transition. The quantitative evidence for specific health concerns, for example, from hazardous chemicals in recycled materials, suffers from piecemeal availability and lacks consistent exposure assessments on which to base the quantification of aggregate impacts and understanding of their relative significance.

7

Case studies

This section presents a number of case studies on health impacts of the circular economy, in order to briefly outline and discuss the pathways through which the implementation of circular economy models may affect human health and well-being. The selection is not comprehensive, but is based on key issues arising in the literature review and consultations for this report and is intended to indicate the range of possible types of positive and negative health effects.

The authors included the example of hospitals to illustrate the potential direct savings to health services from circular economy actions. The subject of chemicals of concern in waste covers a broad area for which key issues are outlined here, with related examples given for e-waste and food waste. The case study on waste-water reuse also illustrates potential health issues relevant for policy development. The examples of the built environment/mobility, climate change and air pollution are included to show the potential for much wider indirect health benefits from a circular economy model.

7.1 Health care sector

Total health expenditure accounted for about 9.9% of GDP globally and 9.5% of GDP in the WHO European Region in 2014, and the global health workforce was over 43 million, with 12.7 million in European Region in 2013 (WHO, 2011d, 2016). Thus, the sheer size of the health sector indicates the potential for considerable cost and efficiency effects from any move towards circular economy principles.

The literature identifies significant direct cost savings for hospitals and health care services from the implementation of circular economy actions (e.g. EC, 2017b; EMF 2015a). The ageing of the population, technological development and increased expectations from patients increasingly drive health care costs. In this context, there is great potential for hospitals to use their scale and centralized management to maximize resource efficiency and minimize waste through prevention and recycling. A review of evidence by the WHO Regional Office for Europe (2016a) illustrates the potential benefits of fostering environmental sustainability in health systems in Europe. In the context of waste management, it found potential financial and environmental benefits from switching to reusable medical products and enhanced treatment of hospital waste-water. The implied health benefits would come to the extent that financial savings were or could be reinvested in health care services or used to lower service charges, among other options. There are also potential indirect health benefits from these actions to the extent that they also reduce health impacts from environmental media (i.e. air, soil and water pollution and GHG emissions) resulting from manufacturing processes.

A case study on hospitals in Denmark (EMF, 2015a) highlights considerable potential savings from the adoption of two key circular economy opportunities. The first is the use of **performance**

models in procurement. Performance models involve contracts in which the customer pays for the use of a product (e.g. via leasing) rather than the product itself. This helps to minimize total costs, since ownership may involve upfront investment costs, risks (repair, maintenance or obsolescence) and end-of-use treatment costs, while performance models can reduce purchasing and maintenance costs and maximize performance. Concurrently, the supplier can secure sustainable revenue streams, maximize resource use, and drive efficiency of use. This model may also give incentives to manufacturers to design products that are easier to maintain, repair and refurbish or remanufacture. The range of products that could be procured in performance models (EMF, 2015c) includes magnetic resonance imaging (MRI) scanners, radiation treatment equipment, laboratory instruments and (semi)durable goods such as scalpels and surgical apparel. The study calculates that performance models in procurement could save hospitals in Denmark around €70–90 million by 2035, and €10–15 million by 2020.

Second, hospitals could become leaders in **recycling and waste reduction** by supporting pilot and training programmes, and creating national guidelines and/or targets. While the purchase and preparation of food and drink are significant sources of waste in hospitals, recycling rates for packaging and organic waste are well below service sector targets: averaging below 20% compared with 2018 targets of 70% for packaging and 60% for organic waste. The Health Care Without Harm Europe coalition (2018) provides examples of waste and resource savings; for example, at the University Hospital in Freiburg, Germany, the introduction of waste minimization measures resulted in total annual savings of about €321 000.

EMF (2015a) suggests where using circular principles could reduce the considerable waste generated in the health care sector, with associated cost reductions, including virtualization such as technology-driven diagnosis (e.g. various applications for the use of information and communication technologies and mobile devices for health). The Foundation's report on intelligent assets in a circular economy (EMF, 2016a) also highlights further technology-driven resource savings by making decisions on the replacement of medical equipment in hospitals using sensor technology, which reveals its actual condition, rather than the current standard of equipment age and utilization. Decision-making on the timing of replacements of existing equipment would also need to take account of the benefits of any advances that have been made in the design of newer equipment.

Another example of such potential savings comes in a proposal to amend the Restriction of Hazardous Substances (RoHS) Directive (EC, 2017b), suggesting that:

> Fully enabling secondary market operations and increasing spare part availability for certain electrical and electronic equipment will have a positive economic impact by bringing market opportunities to the repair industries and secondary selling. It will reduce costs and administrative burden both for business, including [small and medium-sized enterprises], and for public authorities. For example, it will save European hospitals[11] approximately €170 million after 2019 due to maintaining the possibility to resell and buy used medical devices (which, without the proposal, would not be possible after the transitional period).

Other examples of the development of circular economy services and projects that offer resource savings and reduce costs to health care sector include the following programmes of particular businesses.

- Phillips' refurbishing solutions for MRI systems offer savings through the reuse of components, driving value creation in the circular economy.

[11] This seems to refer to EU countries, not all countries in the European Region.

- A pilot study of the MUJO medical technology company for the REBus project (2016c) showed that service agreements were good for health. MUJO manufactures specialized equipment to aid the rehabilitation of people with musculoskeletal disorders. The project offered the equipment under a leasing arrangement (performance model), in order to reduce the production of goods required for a given size of market. The results included a tenfold reduction in the volume of manufactured material. The benefit to customers is that they no longer have to buy capital equipment.

- Other pilot studies for REBus (2016a–b) addressed the use of remanufacture in the lifts market and the resulting environmental benefits, the resource efficient use and circular procurement of furniture at University Medical Centre Utrecht, The Netherlands.

- FLOOW2 Healthcare has developed a sharing marketplace for health care organizations to trade surplus capacity; this allows more intensive use of goods and equipment, resulting in more efficient use of raw materials and energy.

In addition, potentially significant indirect savings in health care costs could result if the implementation of circular economy models reduces the overall burden of disease by reducing pollution from production and consumption. The Lancet commission report on pollution and health highlights that pollution-related disease results in health care costs equivalent to about 1.7% of annual health spending in high-income countries and up to 7% in middle-income countries that are heavily polluted and rapidly developing (Landrigan et al., 2017). On the other hand, additional health care costs could result from a failure adequately to address potential health risks, for example, from chemicals of concern in recycling and reuse. The WHO Regional Office for Europe (2017c) strategic document on environmentally sustainable health systems builds on the evidence of the potential benefits of a circular approach outlined above, to propose types of actions that embed circular economy principles. These include: minimizing and adequately managing waste and hazardous chemicals; promoting an efficient management of resources; promoting sustainable procurement; and reducing health systems' emissions of GHGs and air pollution.

7.2 Chemicals of concern in products

The growth in the number and volume of new chemicals produced over recent decades provides the wider context for the existence of chemicals of concern in products. The report of the Lancet commission on pollution and health (Landrigan et al., 2017) states that over 140 000 new chemicals and pesticides have been synthesized since 1950 and that the 5000 produced in the greatest quantities have become widely dispersed in the environment, with associated widespread human exposure. Less than half of these have been tested for safety or toxicity, while rigorous evaluation of new chemicals before they are put on the market has occurred only in a few high-income countries. This has resulted in limited knowledge of the nature and extent of their effects on health and the environment, although some evidence has been emerged in recent years. Consequently, Landrigan et al. (2017) conclude that the contribution of chemical pollution to the global burden of disease is almost certainly underestimated.

In principle, the circular economy should entail the avoidance or phasing out of specific materials such as toxic substances, where these damage human health or the environment or where recycling or reuse is more technically complex and expensive, unless there is a compelling socioeconomic case for continued use, such as that applied in the REACH Regulation. In reality, however, hazardous chemicals can cause problems in the implementation of circular economy processes, especially in recycling, reuse and remanufacturing, owing to:

- long-lasting products containing chemicals that have been banned;

- the contamination of feedstock in production processes, as it is more difficult to control feedstock quality for recycled material than virgin material;

- the presence of chemicals whose use in manufacturing within the EU is illegal but not restricted in imported articles; and

- insufficient understanding of the toxicity of many chemicals that may be still in use (CHEM Trust 2015).

The EU action plan explicitly recognizes the issue of chemical substances that are identified as being of concern for health or the environment and may be not only present in recycling streams but also costly to detect and remove. It is thus committed to "the promotion of non-toxic material cycles and better tracking of chemicals of concern in products to facilitate recycling and improve the uptake of secondary raw materials" and the assessment of legislation on waste, products and chemicals in the context of a circular economy to address the presence of substances of concern and facilitate their traceability and risk management in the recycling process (EC, 2015b). At present the EC has noted that the lack of sufficient information about substances of concern in products, waste streams and recycled materials hampers the monitoring of the compliance of recycled materials (and articles produced with them) with legislative requirements (including the REACH Regulation, the classification, labelling and packaging (CLP) Regulation and the RoHS Directive). The EC also notes both the lack of a general framework to deal with the presence of substances of concern in recycled materials and difficulties in applying EU waste classification methodologies to the recyclability of materials. It is therefore developing analysis and proposed options on these issues that will feed into a future EU strategy for a nontoxic environment (EC, 2017a).

In general, circulating any products, components and materials that may be included as substances of very high concern (SVHCs) and subject to authorization under the REACH Regulation has health implications to be assessed. REACH Article 57 defines SVHCs as substances that have hazards with serious consequences, including those classified as carcinogenic, mutagenic or toxic for reproduction (category 1A or 1B). Listing a substance as one of the SVHCs by the European Chemicals Agency (ECHA) is the first step in the procedure for restriction of its use. The most recent list, from January 2018, included 181 SVHCs (ECHA, 2018a).

Three examples of chemicals of concern of relevance to circular economy processes (especially recycling, reuse and remanufacturing) and arising in current research and policy development are BPA, BFRs and polyvinyl chloride (PVC).

- BPA is used in polycarbonate plastics, food can linings and thermal paper (e.g. till receipts) and card (e.g. pizza boxes). It was listed in the candidate list of SVHCs in June 2017 owing to its endocrine-disrupting properties. Endocrine-disrupting chemicals are suspected of altering reproductive function; increasing the incidence of breast cancer, abnormal growth patterns and neurodevelopmental delays in children; and changes in immune function (UNEP & WHO, 2012). The ECHA Risk Assessment Committee concluded that the risk from BPA in till receipts is not "adequately controlled" (CHEM Trust, 2015). Trasande et al. (2015) concluded that exposure to endocrine-disrupting chemicals in the EU contributes substantially to health impacts, with health and economic cost estimates exceeding €150 billion per year, although the proportion associated with recycling is not assessed (EMF, 2016b). BPA was recently banned in thermal paper in the EU from 2020 under the REACH Regulation, classified as toxic for human reproduction (category 1B) under the CLP Regulation, restricted in materials in contact with food (such as infant feeding bottles) and limited in toys, with a current migration limit of 0.1 mg/l[12] and a proposal to lower the limit to 0.04 mg/l in 2018.

- BFRs are widely used in products including furniture, electronics and building products. The long life of these products increases their potential to contain banned chemicals by the time they enter the waste stream. Many flame-retardant chemicals have been identified as substances of concern for effects such us mutagenicity, endocrine disruption and carcinogenicity. In some products, such as furniture, people can be exposed to BFRs through not only direct contact but also dust released though use; there is particular risk to children, manufacturing workers and fire-fighters.[13] Some evidence has been found of BFRs in toys (Chen et al., 2009).

- PVC is a concern for recycling due to the presence of the softener diethylhexyl phthalate (DEHP) in some items such as footwear and floor coverings. This poses a reproductive toxicity threat to exposed workers. While the REACH Regulation bans DEHP, debate continues on EC proposals to authorize the recycling of plastics containing DEHP in new PVC products.[14]

The case studies on e-waste and food give other examples of chemicals of concern in products. In general, this is an area of scientific uncertainty that is undergoing extensive research. The difficulty of assessing complex long-term exposure and compounding effects further complicates the evidence on the health implications.

[12] European standards require that 10 cm² of material from a toy be extracted with 100 ml of water for one hour. Compliance with the specific limit value of 0.1 mg/l thus means that, during the extraction, a maximum of 0.01 mg BPA may migrate out of the toy material.

[13] HEAL (2016a) has made a case for flame-retardant-free furniture.

[14] Both the European Parliament (2015) and Breast Cancer UK (2016), for example, contributed to this debate.

7.3 E-waste

E-waste refers to all items of electrical or electronic equipment and its components that have been discarded without the intent of reuse (STEP Initiative, 2014). Global e-waste generation was estimated to be about 44.7 million tonnes in 2016, a figure forecast to increase to about 50.7 million tonnes by 2020. Europe (including the Russian Federation) generated the second largest quantity of e-waste on a per capita basis (16.6 kg per inhabitant) after Oceania (17. kg per inhabitant) in 2016 (Baldé et al., 2017).

The estimated economic value of raw materials contained in the estimated e-waste generated in 2016 is about €55 billion, which demonstrates the business potential of adopting circular business models. Although e-waste has high potential for recovery of precious metals, valuable materials, rare earths and plastics, with resulting economic benefits, official take-back systems are documented to collect and recycle only 20% of global e-waste. Europe has the highest rates of e-waste collection for recycling, including from households, business and institutions: around 35% in 2016. Countries in northern Europe performed better; their rate of 49% is the highest in the world. Other high-income regions, such as North America and Oceania, collect only 22% and 6%, respectively, of e-waste generated (Balde et al., 2017).

The fate of a large majority of global e-waste (34.1 tonnes in 2016) is unknown. In countries where a waste management system does not exist or is not yet well developed, e-waste is usually dumped, incinerated, traded or recycled under inferior conditions. In countries with e-waste policies and legislation and a well established infrastructure, however, the e-waste that is not reported as collected and recycled by the official take-back systems often ends up in residual or household waste. Much is also handled by metal recycling companies and waste traders, or shipped to economies in transition or developing countries, usually classified as second-hand items for reuse.

A key issue here is that a substantial portion is not reusable, and many developing countries lack adequate policies and legislation to set up the necessary infrastructure to manage e-waste in an environmentally sound way, so handling and disposal are frequently unregulated. A study conducted in 2015/2016 showed that EU Member States originated around 77% of used electric and electronic equipment imported into Nigeria, and China and the United States contributed 7.3% each (Balde et al., 2017). The Agbogbloshie area of Ghana has one of the largest informal e-waste dumping and processing sites in Africa, with about 215 000 tons of e-waste imported annually (Heacock, 2016).

Improper and unsafe treatment and disposal of the e-waste pose significant challenges to the environment and human health. Discarded equipment – such as refrigerators, telephones, laptops, washing machines, sensors, televisions and lamps – contain hazardous substances such as heavy metals (e.g. mercury, lead, cadmium, etc.) and chemicals (e.g. chlorofluorocarbons (CFCs) and various flame retardants). Improperly landfilled or incinerated e-waste poses significant contamination problems. In many developing countries, landfills leach toxins into groundwater and incineration is performed in unsafe ways that emit toxics, including dioxins. The hazardous materials contained in e-waste are volatile and not biologically biodegradable; through leaking, chemical reactions and vaporization, they contaminate soil and groundwater and can enter the food chain. Heavy metals are toxic to plants, animals and microorganisms. In humans, heavy metals can affect the organs, especially the brain, causing persistent effects on the nervous system. Chemicals such as some flame retardants can form corrosive or toxic fire gases and toxic decomposition products when burned. Releases of CFCs in the environment affect the human central nervous system and contribute greatly to the reduction of the planet's protective ozone layer.

E-waste can therefore contribute to adverse health effects through many possible routes. Health effects relate especially to the exposure of people working and living near informal e-waste processing sites via the contamination of air, soil, water and food, but may also affect populations away from these sites. Grant et al. (2013) concluded that the health consequences of e-waste exposure may include changes in thyroid function, altered cellular expression and function, adverse neonatal outcomes, cognitive and behavioural changes, and decreased lung function. Further, there are increased potential impacts for children, for whom exposure from contaminated food and dust, for example, may cause a high risk in neurotoxicity and adverse developmental effects (Zheng et al. 2013). In addition, recycling activities, such as dismantling electrical equipment, has the potential for increased risk of injury.

In addition, some studies suggest that evidence of hazardous materials in some products may be linked to recycled e-waste. For example, the survey by DiGangi & Strakova (2015) found that children's toys in six EU Member States contained octabromodiphenyl ether and decabromodiphenyl ether, which are used in plastics for electronics. Samsonek & Puype (2013) found flame retardants in plastic materials, such as thermo cups and kitchen utensils. Further research is needed to establish the source of these materials in products. Such substances are among those listed in the Stockholm Convention on Persistent Organic Pollutants that should not be present in children's products, consumer products, food contact materials, and other products. For example, the Persistent Organic Pollutants Review Committee has agreed that decabromodiphenyl ether is likely to lead to significant adverse effects on health and the environment.

A number of international initiatives are addressing global e-waste issues. WHO is working to identify the main sources and potential health risks of e-waste exposures, and to define successful interventions with support from the United States Environmental Protection Agency, the United States' National Institute of Environmental Health Sciences and the German Federal Ministry for

the Environment, Nature Conservation and Nuclear Safety. It has also launched the Initiative on E-waste and Child Health. The Solving the E-Waste Problem (STEP) Initiative (2014) aims to reduce dangers to human beings and the environment from inadequate treatment practices.
E-waste is subject to the Basel Convention on the Control of Transboundary Movements of Hazardous Wastes and Their Disposal, which bans the shipments of hazardous waste between developed and developing countries. Compliance is difficult to monitor, however, because reliable data are not available on the amount of exported electrical or electronic equipment that is accurately classified as e-waste (Heacock et al., 2016). Moreover, some commentators argue that current international law does not foster accountability over transboundary flows of e-waste and thus limits the potential to address impacts on vulnerable populations (Khan, 2016).

Key legislation in the EU of relevance to e-waste includes (Lundgren 2012):

- the Waste Electrical and Electronic Equipment (WEEE) Directive (2002/96/EC), which is intended to prevent e-waste generation, and to promote reuse, recycling and other forms of recovery and the improvement of the environmental performance in the life-cycle of this equipment;

- Regulation (EC) No. 1013/2006 on shipments of waste, which includes guidance on shipments of waste electrical and electronic equipment;

- the RoHS Directive (2002/95/EC and revised 2011/65/EU), which aims to contribute to the protection of human health and the environmentally sound recovery and disposal of e-waste;

- the REACH Regulation, which entered into force in 2007, to ensure a high level of protection of human health and the environment from the risks posed by chemicals;

- the EU Waste Framework Directive (2008/98/EC), which provides the legislative framework for the collection, transport, recovery and disposal of waste.

In the long run, adopting circular economy models should promote greatly reduced environmental and health impacts from e-waste. This can be achieved by substantially increased reuse and remanufacturing; these will reduce the proportion of devices reaching the ends of their useful lives that need to have their components recycled.
To this end the report on the implementation of the EU action plan on the circular economy includes proposals to amend the RoHS Directive in order to prolong the use of electrical and electronic equipment and postpone its end-of-life and disposal, thus avoiding the generation of additional hazardous waste (EC, 2017b).

Circular economy models also need to be adopted to recover the precious metals, including gold, silver, copper, platinum and palladium, contained in e-waste, and to recycle valuable bulky materials, such as iron and aluminium, along with plastics. In addition, the materials currently used – including hazardous compounds such as mercury lamps in liquid crystal display screens, PVC, flame retardants and other toxic additives in plastic components – and the design of electric and electronic equipment make recycling and reuse challenging. Circular solutions should therefore include the optimized design of electric and electronic equipment, to enable its disassembly, the reuse of components, the recovery of valuable and precious materials and the designing out of hazardous components. For example, the new generation of light-emitting diode screens is nonhazardous and easier to dismantle with automated systems (Hislop & Hill, 2011). Nevertheless, the existing environmental and health hazards associated with exports of e-waste to developing countries with inadequate and unsafe waste facilities still needs to be urgently addressed, while circular solutions are being developed (Benton et al., 2015).

7.4 Food safety and healthy foods

Health impacts from the circular economy model include both direct food safety issues and potential benefits related to healthy foods, from food waste policies and practices and, indirectly, from enabling healthier food choices.

7.4.1 Food safety

Significant household savings are envisaged for reducing the level of food waste. Reducing food waste in Denmark from 80–90 kg per capita to 40–50 kg per capita, for example, is estimated to enable households and businesses to save €150–200 million annually by 2035 (EMF, 2015a). The application of circular economy principles via adherence to the food waste hierarchy – with priority given to (in descending order) reducing waste, redistributing edible food, using food as animal feed, composting and anaerobic digestion, and finally disposal – should also entail health benefits if appropriate health and safety standards are respected (FoEE, 2014). For example, redistributing edible food to people in need and vulnerable groups should have positive health effects, given adherence to appropriate safeguards against contamination and the distribution of unhealthy foods, and there will be environmental health benefits to the extent that environmental impacts from food production and processing are reduced from current levels.

Nevertheless, finding chemicals of concern in recycled materials used in food packaging and kitchen items has raised some issues of food safety (see, for example HEAL, 2016b). Examples include the detection of chemicals such as BPA, phthalates and perfluorocarbons in recycled materials in pizza boxes in Denmark (Søndergaard, 2015) and e-waste recycled into plastic materials used in kitchen utensils, as mentioned above (Samsonek & Puype, 2013). The styrene monomer has been found in food packaging in the United States (Genualdi et al., 2014). There is also evidence of phthalates (suspected to be an endocrine-disrupting chemical) in packaging (EMF, 2016b; Rodgers et al., 2014; Rudel et al., 2011). The contamination of compost with harmful packaging or packaging components is a further issue of concern. Such components, such as heavy metals at high concentrations, could not only reduce compost quality but also allow these substances to enter the food chain and pose a risk to human health (EMF, 2016b; Lopes et al., 2011).

Even though research focuses on concerns about food contamination, information is not generally available on the extent of any health impacts. Potential types of impacts from BPA and phthalates include endocrine disruption and carcinogenicity, as described above.

The EU action plan on the circular economy acknowledges the issue of food safety in policy actions on food waste with a commitment "to clarify EU legislation relating to waste, food and feed and facilitate food donation and the use of former foodstuff and by-products from the food chain in feed production without compromising food and feed safety" (EC, 2015b). Moreover, the EU Platform on Food Losses and Food Waste (EC, 2018a) has a mission to support the achievement of the targets of SDG 12.3 (halving per capita food waste at retail and consumer level, and reducing food losses along the food production and supply chains by 2030) without compromising food safety, feed safety and/or animal health. A current policy concern is that the regulation of chemicals in food contact materials in the EU is not harmonized. While there are controls on the use of recovered plastics in food contact materials, there are no such requirements for other materials used, such as paperboard, ink and glue. Thus, while EU law requires the recycling of packaging, it does not address the chemical content in a consistent way (CHEM Trust, 2015).

7.4.2 Healthy foods

The literature also proposes that the implementation of the circular economy can promote the production and consumption of healthier foods. The report of a case study on the food system made by EMF (2015b) presents a circular economy vision that would address current issues of food waste, environmental externalities (e.g. in fertilizer use and GHG emissions from the food production chain) and unhealthy outcomes for consumers; it gives examples of digital solutions, such as smart refrigerators, on demand e-commerce delivery and wearable monitors.

This vision would (EMF, 2015b):

> restore and rehabilitate land and fish stocks and would reconnect nutrient and material loops to provide the needed input. The system would leverage digital solutions and greater proximity to consumers to avoid waste along the value chain. The distributed food would be non-toxic and healthy.

This would be achieved by the implementation of:

- resource-efficient agricultural practices, including reductions in fertilizer and pesticide use;
- regenerative farming practices to preserve natural capital and optimize long-term yields, including organic cultivation; and
- closed loops of nutrients and other materials: recovery of energy and nutrients from waste streams.

The literature on the circular economy and food production focuses primarily on these resource efficiency and environmental benefits, including from a switch away from meat production (e.g. Rabobank, 2014). A review of evidence on changes in GHG emissions, land use and water use resulting from shifting current western diets towards more sustainable dietary patterns (Aleksandrowicz et al. 2016) outlines the potential environmental benefits. Further, circular approaches are also seen as giving consumers greater ready access to fresh, high-quality food that would encourage healthier dietary choices. For example, a report for the Rockefeller Foundation–Lancet commission on planetary health (Whitmee et al., 2015) notes that benefits to health from a movement towards a circular economy include those resulting from changes in diet. Nevertheless, this requires continued raising of consumers' awareness of these issues; for example, a report (EC, 2014a) includes a case study on food waste that recommends actions to educate consumers on the negative health and environmental impacts of unsustainable food consumption.

This vision could be seen as not exclusively the result of implementing the circular economy concept but also interlinked with the wider agenda of the green economy and sustainable development. It nevertheless illustrates the potentially very significant health benefits that could be achieved, for example, in terms of decreased overweight and obese populations, to the extent that the circular economy model changes food demand patterns towards healthier choices. The McKinsey Global Institute (2014) estimated that overweight and obesity have a societal cost of 3.3% of European GDP.[15] The report of EMF (2015b) estimates a decline in negative externalities under a circular economy scenario of up to €130 billion by 2030 (as given in section 6), which includes opportunity costs (e.g. loss of productivity and lives) related to obesity.

7.5 Waste water reuse

This section summarizes the rationale, policy context and health implications of waste-water reuse in Europe, with a focus on the EU, as well as examples taken from other countries in the WHO European Region. The uses of recycled waste-water covered here include irrigation in agriculture, industry and aquifer recharge. Water reuse also includes direct and indirect potable reuse (WHO, 2017c). The section also briefly covers the use of sewage sludge as an agricultural fertilizer.

[15] This estimate of societal cost includes: (i) productivity losses using DALYs lost attributable to high body mass index; (ii) direct health care costs from WHO estimates; and (iii) investment in mitigating obesity via analysis of the research budgets in prevention programmes, and commercial weight management markets.

7.5.1 Rationale

A key rationale for reusing treated waste-water is to address the pressures of competing water demands, including for irrigated agriculture, industry, tourism and domestic uses. While waste-water reuse is already being widely practised in some parts of the WHO European Region, its significance is likely to grow in the context of the increasing severity of water scarcity and droughts due to climate change and increasing populations. Water reuse can also have other environment benefits, from relieving the pressure of discharges from urban waste-water treatment plants to sensitive areas and requiring less energy than alternative sources of water supply, such as desalination or water transfer.

As the pressures of urbanization, the demand for food and the scarcity of water increase, reusing sanitation waste is becoming more attractive and viable. Many authorities and enterprises are working on models of sanitation service chains that make beneficial use of nutrients, water and energy and offset the cost of service provision. These models can offer health benefits by removing excreta from the environment and increasing food production (WHO, 2016c).

7.5.2 Policy context

Treated waste-water reuse is widely acknowledged as an alternative source of water supply at the international, European and national levels. SDG 6, on ensuring access to water and sanitation for all, includes a target for a substantial increase in recycling and safe reuse of waste-water globally by 2030. Safe reuse is also a priority in the Declaration of the Sixth Ministerial Conference on Environment and Health (WHO Regional Office for Europe, 2017b), the strategic implementation plan of the European Innovation Partnership on Water (2012) and the Blueprint to Safeguard Europe's Water Resources (EC, 2018d).

In the EU, approximately 1 billion m^3 of treated urban waste-water is reused annually, but the potential figure is estimated to be around six times as large (BIO by Deloitte et al., 2015). The practice of waste-water reuse varies widely among the other countries in the WHO European Region. Some, such as Israel are leaders, in this field (TheTower.org Staff, 2016), while there is also much unplanned and informal reuse in other parts of the Region: for example, for irrigation in central Asia (Frenken, 2013). In Turkey, untreated waste-water reuse in agriculture has historically involved informal practices, although new urban waste-water treatment plants are enabling greater planned reuse in agriculture (Arslan-Alaton et al. 2011).

Existing regulations and standards on waste-water reuse include international guidelines, such as the WHO guidelines for the safe use of waste-water, excreta and greywater, International Organization for Standardization (ISO) standards, and EU and national regulations. (WHO, 2006; ISO, 2015; EC, 2016a, 2018d). To assist in the implementation of its guidelines, WHO promotes and recommends sanitation safety plans (SSPs), which use a step-by-step risk-based approach to systematically identify and manage health risks along the whole sanitation chain, including safe disposal and reuse of waste-water, to ensure the system is managed to meet health objectives (WHO, 2016b). The Ostrava Declaration suggests that policies and regulations use the SSP approach to systematically manage health risks (WHO Regional Office for Europe, 2017b).

In the EU, a number of guidelines and regulations relate to water reuse, including the Guidelines on integrating water reuse into water planning and management in the context of the Water Framework Directive (EC, 2016b) and the Urban Waste Water Treatment Directive. The EU has no common environmental or health standards for water reuse, although some countries within and outside it have defined standards. For example, Spain has implemented regulatory standards on quality of water in contact with food (BIO by Deloitte et al., 2015).

The use of treated sewage sludge as an agricultural fertilizer is subject to EU and national guidance and regulation. The Sewage Sludge Directive (86/278/EEC) seeks to encourage the use of treated sewage sludge in agriculture and to regulate its use to prevent harmful effects on the environment and health. This includes setting limit values for a number of heavy metals. As part of the EU circular economy package, the EC (2016a) has proposed a regulation that would significantly ease the access of organic and waste-based fertilizers to the EU single market; this would provide significant market opportunities for organic fertilizer products, including sewage sludge. The EC (2015a) circular economy package commits to a number of actions to promote the uptake of water reuse, including for better integration in water planning management, legislation on minimum quality requirements for water reuse in irrigation and aquifer recharge, industrial water reuse, support for research and innovation, and prioritization of investment.

Countries outside the EU vary widely in policies related to water reuse. For example, the review by Spinoza (2011) concluded that eastern Europe showed a great diversity in practices and legislation on sewage sludge management. For central Asian countries, a review of water-related health problems (Bekturganov et al., 2016) identified a lack of regulations to protect the environment and public health as a key factor affecting the spread of water-related diseases (Frenken, 2013). In Turkey, the policy aim is approximation of EU regulations on water reuse (Yaman, 2012), although Maryam & Büyükgüngör (2017) concluded that the lack of policies and laws is a main hurdle to waste-water reuse.

7.5.3 Health risks

Direct or indirect exposure to microbiological agents (viruses, bacteria, parasites and helminths) or chemical substances that may be present in reclaimed water can create risks to public and occupational health related to waste-water reuse (Amec Foster Wheeler Environment & Infrastructure UK Ltd et al., 2016). Possible exposure pathways include direct ingestion, dermal exposure and inhalation of contaminants in treated waste-water, as well as ingestion of microbiological and chemical hazards in food crops or fodder-fed animals.

Possible risks to human health from eating or contact with food irrigated with waste-water include exposure to pathogens (e.g. *Salmonella*, *Escherichia coli*), viruses (e.g. hepatitis A), parasites (e.g. *Cryptosporiduim*), potentially toxic contaminants and persistent organic contaminants (e.g. polychlorinated biphenyls – PCBs) (Amec Foster Wheeler Environment & Infrastructure UK Ltd et al., 2016). Inappropriate reuse practices may also contaminate surface and groundwater sources that are used for the production of drinking-water.

There is also a possible linkage between use of waste-water and the spread of antimicrobial agents in the environment. There is evidence of human risks associated with exposure to bacteria with antimicrobial resistance (AMR) and their AMR genes in environmental media via routes including water, waste-water and irrigated produce (WHO, 2014).

Health effects from reuse depend on the origin of waste-water, level and nature of treatment, and subsequent use (BIO by Deloitte et al., 2015). Salgot et al. (2006) and WHO (2006) further outlined the risks to human health and the environment associated with reclaimed water reuse. In addition, the reuse of treated waste-water may have beneficial environmental health effects to the extent that it reduces secondary effluent discharges to the environment (Amec Foster Wheeler Environment & Infrastructure UK Ltd et al., 2016).

Health risks associated with use of sewage sludge in agriculture concern the presence of viruses, bacteria, protozoa and helminths. The level of these risks depends on a number of factors, including how the sludge is treated and how it is used on the soil (and the effectiveness of risk management in these processes), and the type and uses of the crop concerned. For example, a number of countries in central Asia, the Caucasus and the Balkan area register soil-transmitted helminth infections due to poor sanitation and waste-water management. A study by Risk & Policy Analysts Ltd et al. (2008) found that "significant environment or health risks linked to the use of sewage sludge on land in the EU have not been widely demonstrated by observations or risk assessments in scientific literature since the directive has taken effect". Nevertheless, the EC is assessing whether the current Sewage Sludge Directive should be reviewed, including gathering further information are the presence of emerging pollutants in sewage sludge (EC, 2018c).

7.5.4 Research

A number of EU-funded research projects relate to water reuse, such as those on integrated concepts for reuse of upgraded waste-water (2002–2006) and the Innovation & Demonstration for a Competitive and Innovative European Water Reuse Sector project, to promote a wider understanding and awareness of water reuse practices among public administrations and end-users. Those with a specific focus on health risks include the project on safe food production using low-quality waters and improved irrigation systems and management. Its results included the finding that there were minimal microbiological health risks from eating tomatoes or potatoes irrigated with recycled water (SAFIR, 2009). Some studies have reviewed and compared levels of bacteria (e.g. *E. coli*) in products irrigated with treated waste-water and conventional irrigation water. For example, Forslund et al. (2013) found that tomatoes irrigated with treated waste-water (using membrane bioreactor technology and gravel filters) were free from *E. coli*.

The results cited above illustrate a general lack of current evidence for human health effects from water reuse in the EU. For example, Amec Foster Wheeler Environment & Infrastructure UK Ltd et al. (2016) note that the available literature "does not report cases of human diseases caused by reclaimed water in the EU". Further, the EC initiative for minimum quality requirements for reused water in the EU states that (EC, 2016d):

> The establishment of EU minimum quality requirements on water reuse is expected to have positive impacts on health and welfare as minimizing the risk of contamination with insufficiently treated reused water. This impact is however expected to be limited as no evidence has been found that current practices in the EU are causing health issues.

There is, however, a recognized need for more research in this area. The problem tree for optimizing water reuse in the EU, given by BIO by Deloitte et al. (2015), identifies "lack of information about actual risks" among informational needs. In particular, Amec Foster Wheeler Environment & Infrastructure UK Ltd et al. (2016) concluded that "there are very few health risk quantification studies and epidemiological studies on the reuse of reclaimed water".

In countries in the WHO European Region that do not belong to the EU, research on health impacts is more limited but shows different outcomes from EU-based research in some areas. For example, a review of water-related health problems in central Asia identified major factors affecting the spread of water-related diseases, including the use of untreated waste-water to meet water shortages, as well as a lack of infrastructure for waste-water treatment and discharge, of health awareness and proper handling of polluted water, and of regulations (Bekturganov et al., 2016; Frenken, 2013).

Current research challenges and uncertainties on waste-water reuse include the presence and impacts of "contaminants of emerging concern" (BIO by Deloitte et al., 2015). This covers a wide range of compounds, such as residues from pharmaceutical products, personal care products, pesticides and industrial chemicals, for which there is limited monitoring in conventional waste-water treatment systems. Specific areas of uncertainty and continuing research include the lack of comprehensive toxicological data on their potential impacts on human health and the environment. The Joint Research Centre published a watch list of emerging or little-known pollutants across the EU (Carvalho et al., 2015).

Differences between public health and occupational health risks from exposure to reclaimed water are also an area of uncertainty. Although agricultural and industrial workers involved in activities in which reclaimed water is used may face greater exposure to potential contaminants over longer periods than the public, they may also have a greater awareness of and implement risk control measures in these activities (BIO by Deloitte et al., 2015).

7.5.5 Conclusions

While there is no clear evidence that current practices in the EU for both reusing treated water and using sewage sludge in agriculture are affecting human health, the need for more research in this area is recognized, particularly the need to reduce uncertainties about the presence of pathogens and chemical pollutants of emerging concern. Further research in this area is particularly important in supporting the development of appropriate standards related to health and to inform public acceptance of water reuse; in particular, BIO by Deloitte et al. (2015) cite lack of public acceptance as a key reason for the current limited uptake of water reuse options in the EU.

Other countries in the WHO European Region vary much more in the policy context related to waste-water reuse; some have limited regulation, poor sanitation and waste-water management, and greater informal waste-water reuse. While more research is needed on the health impacts of water reuse practices in these countries, the need for further implementation of improved waste-water reuse management to address health risks is in general much greater than in EU countries.

7.6 Built environment

The literature on the circular economy includes broad visions of how the further introduction of circular principles into design, construction and urban planning could greatly improve the built environment over coming decades (e.g. ARUP, 2016; Cheshire, 2016; EMF, 2015b, 2017a). This case study outlines the key aspects of such visions, based largely on the work of EMF in this area, and discusses the types of health implications arising from such visions. The broad scope of the scenarios for urban development envisaged in the literature are interlinked with and play a key part in achieving the wider goals of smart cities, the green economy and sustainable development.
Growth within: a circular economy vision for a competitive Europe (EMF, 2015b) identifies four factors that account for the current structural waste in the built environment, summarized as: low productivity in construction; underutilization of some buildings (even though there is also over-utilization of some buildings and 11 million EU households (5%) live conditions defined as overcrowded or substandard); high energy consumption; and end-of-life waste and toxic materials. Much of the end-of-life waste is hard to separate, and contains toxic elements such as PVC (see case study above) and volatile organic compounds, some of which are suspected carcinogens and immune system disruptors.

The report (EMF, 2015b) then outlines six types of actions that could advance the built environment towards a less wasteful model based on circular principles:

1. moving construction towards factory-based industrial processes and three-dimensional printing, including use of renewable or recyclable and non-toxic materials;
2. better energy efficiency and distributed production of renewable energy: buildings becoming producers of energy for example in form of solar photovoltaic systems;
3. shared residential space, such as shared drying rooms and social areas;
4. shared office space and virtualization;
5. modularity and durability: greater flexibility in building and room configurations, such as via standardized interior components; and
6. urban planning such as promoting compact urban growth.

A development scenario based on these actions, with urban planning as a core element, is proposed that would create a circular built environment that would “lower household costs; protect land from degradation, fragmentation, and unsustainable use; reduce negative environmental impact; and make cities more liveable and convenient" (EMF, 2015b).

Minimizing negative externalities is a core aim of implementing circular principles in the built environment, including impacts on climate change, water, soil, noise and air pollution and implications for human health and well-being (ARUP, 2016). Although the sources reviewed do not assess or quantify in detail the health implications arising from their circular building visions, the main potential types of impact can be categorized as:

- health benefits from the use of non-toxic materials in new buildings and phasing out of toxic materials;
- improved air quality from, for example, reduced traffic congestion and expanded green infrastructure;
- health benefits associated with reduced GHG emissions (see case study on climate change) due to progress on energy efficiency and distributed production of renewable energy (the circular scenario described by EMF (2015b) projects that, by 2050, "neutral or positive energy buildings" could reduce CO_2 emissions by as much as 85% compared to current buildings in the EU27); and
- increasing well-being resulting from improvements in the quality of the urban environment due to the improving quality of public, work and residential areas and their buildings, and expanding green infrastructure (societal outcomes are described in terms of enhanced liveability including reduced noise).

Further research is needed to more fully explore the nature and extent of potential health benefits from the application of circular principles in the built environment. The contribution of circular economy principles to wider urban health goals, as measured by health indicators of sustainable cities (such as those for urban air quality and premature mortality from cardiorespiratory disease given by WHO (2012)), could then be more clearly assessed.

Networks such as the University College London (2018) Circular cities research hub and EMF (2018) Circular Cities Network are moving circular building design and construction forward. Arup, The Built Environment Trust and other partners have developed building prototypes made from reusable components, to demonstrate how circular economy principles can be applied to the built environment. In addition, a number of European cities, such as Peterborough, United Kingdom (Future of Peterborough, 2018) and Amsterdam, Netherlands, have embraced the circular city concept (see Annex 4).

7.7 Climate change

This section provides a brief overview of the health implications related to climate change mitigation resulting from a transition to a circular economy. The overall health effects of climate change have been assessed as largely negative and include:

- extreme heat contributing to the incidence of cardiovascular and respiratory diseases (including asthma);
- increased weather-related natural disasters and variable rainfall patterns, directly causing deaths and physical injuries, and increased risks of diarrhoeal and water-borne diseases; and
- changes to patterns of infection with diseases such as malaria.

Although there may also be some localized health benefits, such as decreased winter deaths in temperate climates, WHO (2017a) concludes that, even without taking account of all possible health impacts, climate change may cause almost a quarter of a million additional deaths per year between 2030 and 2050: 38 000 from heat exposure in elderly people, 48 000 from diarrhoea, 60 000 from malaria and 95 000 from childhood under nutrition. Thus, wide-ranging strategies and actions that successfully mitigate climate change by reducing GHG emissions could have significant future health benefits by preventing morbidity and mortality.

The circular economy is seen as a significant step towards a low-carbon, resource-efficient economy and therefore a key contribution to climate change mitigation (HEAL, 2015, Wijkman & Skånberg, 2015). The EU action plan (EC, 2015b) explicitly links action on the circular economy to other key priorities, including climate and energy. For example, the EC waste package (EC, 2014a) was estimated to have the potential to reduce GHG emissions by 443 million tonnes between 2014 and 2030.

Types of circular economy action that have potential to mitigate climate change that are identified in this report (see Table 3) include:

- the use of recycled materials in manufacturing processes that can foster overall energy savings and lower GHG emissions, depending on the recycled material and energy mix;
- the move towards more efficient use of resources in industrial sectors and agriculture resulting in reductions in GHG emissions; and
- the move towards renewable energy and energy efficiency across many sectors.

For example, progress on energy efficiency and the distributed production of renewable energy is expected to reduce GHG emissions in the built environment (see the previous case study). The circular scenario described by EMF (2015b) projects that, by 2050, "neutral or positive energy buildings" could reduce CO_2 emissions by as much as 85% in the EU27.

More research is needed to more fully identify and quantify the range of potential health effects resulting from circular economy actions that cut GHG emissions. An estimate of averted health impacts due to extreme heat was made for this report based on the estimate of a reduction of 500 million tonnes in GHG emissions during the period 2015–2035 due to circular economy actions, as given by the EC (2015a). These reductions would result directly from cuts in emissions from landfills and indirectly from recycling of materials, which therefore reduces resource extraction and processing emissions. The resulting averted heat-related mortality in EU Member States is estimated at 70 deaths, with a potential range of 20–130 deaths, and an economic benefit, with no discounting, of about US$ 150 million, or in a range of US$ 100–250 million (J. Spadaro, Researcher, Environmental Sciences, Bilbao, Spain, personal communication, August 2017).

While great uncertainties are attached to such quantitative and monetary estimates of the health benefits of climate change mitigation measures, these benefits are potentially significant for programmes of action related to the transition to a circular economy. In addition, benefits from reduced GHG emissions in Europe would also spread beyond its borders; in particular, as mentioned, such health benefits are likely to be especially felt by vulnerable groups that are disproportionately affected by climate change and air pollution globally.

Finally, actions related to the circular and green economies that mitigate climate change may have other co-benefits for health. WHO's briefings on health in the green economy (Hosking et al., 2011; Röbbel N, 2011; WHO, 2011a–c) identify a number of these, including occupational health gains from more energy-efficient building and transport infrastructure; for example, low-energy office buildings and workplaces that offer good daylight and natural ventilation can often improve workers' health and productivity. These actions may also bring increased health risks; for example, workers may be exposed to hazardous chemicals in the production of certain types of solar panel, which need to be mitigated (WHO, 2011c).

7.8 Air pollution

This section summarizes the broad range of effects on air pollution from a transition to a circular economy model, along with related health implications. Air pollution is a major worldwide risk to health, connected to a number of cardiovascular and respiratory diseases and other conditions, including lung cancer. A recent review by the royal colleges of Physicians and of Paediatrics and Child Health in the United Kingdom found that air pollution affects health throughout the life-course, and cited emerging, if not conclusive, evidence for obesity, dementia and diabetes as health impacts (RCP, 2016). WHO (2016a) estimates that outdoor air pollution caused about 3 million premature deaths globally in 2012, with 87% in low- and middle-income countries. Consequently, any programmes of action that significantly reduce air pollution can play an important role in tackling the associated health impacts.

The circular economy literature and action plans recognize that this model can help to address many environmental challenges (e.g. EC, 2015a; EEA, 2016). In particular, a range of circular economy actions and policies can support the reduction of air pollution. The types of such actions identified in this report include the following.

- The direct impacts of greater recycling and reuse of products, components and materials, as well as shifts towards product sharing and product as a service models, will **reduce the generation of non-recovered waste** and therefore its associated environmental impacts, including air pollution, of landfilling and incineration. While this has clear benefits for air quality in the EU, the requirements of the Industrial Emissions Directive (which limits emissions from, for example, incinerators) limits the scale of the benefit. Benefits will be perhaps substantially greater in countries with weaker emission standards.

- **Indirect impacts of recycling and reuse of products, components and materials** could result from reducing the environmental impacts from manufacturing processes, including air pollution, due to reduced resource extraction and processing emissions. For example, Grimes et al. (2008) estimated that energy savings of 90–95% can be achieved for secondary aluminium production, compared with primary production.

- **Shifts to product sharing and product-as-service models** also have the potential to reduce overall environmental impacts, including air pollution, from manufacturing processes and product use. Guidelines on appropriate product sharing are needed to guard against more intensive use of more polluting products.

- The move towards **greater use of renewable energy and energy efficiency** will reduce air pollutant emissions to the extent that there is a switch away from modes of energy production and transport with greater air emissions, especially fossil fuels.

Specific examples of where circular principles can affect air pollution cited elsewhere in this report include the following.

- The **implementation of circular building principles** is seen as resulting in safer construction conditions, due to the use of nontoxic materials and improved indoor air quality (see the case study on the built environment).

- There are potential air quality improvements from **car sharing** to the extent that more intensive use of vehicles could reduce overall traffic and pollutant emissions. The environmental impact of car sharing will also depend on the extent to which newer, less polluting cars are used in schemes and on the replacement rate.

- The third example is **e-waste disposal**, although one should recognize the increased risks from air pollution (and other environmental health risks) from unregulated recycling, such as at informal e-waste processing sites (see the case study on e-waste).

The link to climate change should also be noted here, since circular economy actions that reduce GHG emissions (as described in the case study on climate change) also lead to reduced air pollution emissions of particulate matter, sulfur dioxide and nitrogen oxides. An estimate of averted health impact from this decrease in air pollution is given above: the estimated reduction of 500 million tonnes in GHG emissions in the EU (EC, 2015a). The improved air quality from such actions is valued at about US$ 5.7 billion, which is an order of magnitude greater than that of the averted mortality from exposure to extreme heat given in the case study on climate change (J. Spadaro, Researcher, Environmental Sciences, Bilbao, Spain, personal communication, August 2017).

More research is needed to quantify the range of other potential health effects resulting from circular economy actions that reduce air pollution, and to consider more fully the distributional impacts of these actions. As in the case of climate change, these actions are likely to benefit vulnerable groups. For example, any health benefits from reducing vehicle emissions may have greater benefits for urban poor people who live close to congested areas, and lower emissions from landfill may benefit those who live near landfill sites.

8 Policy options

8.1 Overview of policy options for supporting the transition towards a circular economy

Table 1 in section 3 presented an overview of types of policy options for supporting the circular economy, including examples for regulatory frameworks; economic instruments; education, information and awareness; research and innovation policy; and public procurement. While the strategy and regulatory framework need to be set at the EU and national government levels, to create the conditions enabling circular economy initiatives to thrive, business and civil society have a crucial role in the transition. Key policy actions in support of a circular economy need therefore to be based on collaboration with business and civil society, with, for example, business supported via best practice knowledge sharing and pilot projects (Benton & Hazell, 2013). Section 3 gives details of the EU action plan and progress at the national, civil society and business levels.

The literature on policy options for this transition emphasizes the need for a mix of complementary instruments and approaches, including regulatory measures, economic incentives, education and awareness raising, and targeted funding for innovation and research (EC, 2014b; EMF, 2015c; Preston, 2012). It also highlights the barriers that need to be tackled for a successful transition, including the needs for: enhanced skills and investment in circular product design and production, investment in recycling and recovery infrastructure, economic incentives for efficient resource use and internalization of externalities, increased consumer and business acceptance of innovative consumption models (e.g. leasing rather than owning), increased information (e.g. on chemical composition of certain products) and sufficient waste separation at source (e.g. for food waste and packaging) (EC, 2014b).

An EC (2014b) study identifies a number of general policy priorities for accelerating the transition to a circular economy, focusing on those most relevant for EU policy. The priority materials given include: agricultural products and waste, wood and paper, plastics, metals and phosphorus. Priority sectors include: packaging, food, electronic and electrical equipment, transport, furniture, buildings and construction.

8.2 Policy options for addressing the health-related implications of circular economy policies

The most relevant policy options to address the most significant and direct identified potential health impacts from circular economy actions would seem to lie chiefly in the categories of regulation; education, information and awareness; and research given in Table 1. The precautionary principle could then be applied to enable policy responses where there is potential harm to human health, even though scientific research has not yet completely evaluated the risks, exposures and health endpoints, including distributional effects. The EC (2000) Communication on applying this principle highlights the need to find the correct balance so that "proportionate, non-discriminatory, transparent and coherent actions can be taken". Thus, some direct regulation might be justified where research gaps exist, but there is reasonable suspicion of serious health implications. Four key policy areas should be highlighted in this context.

- Revisions of EU legislation in relation to emerging health concerns continue the process of **regulation**. For example, the REACH Regulation recently banned BPA in thermal paper in the EU from 2020, owing to health concerns, as outlined in the case study on chemicals of concern in products. Amendments to the RoHS Directive are proposed to prolong the use of electrical and electronic equipment and postpone their end of life and disposal, thus avoiding additional generation of hazardous waste (EC, 2017b).

- Better flows of **information** on component materials in products are needed to better inform recyclers of the need for their safe removal and to help prevent the use of harmful substances in recycled materials. For example, the STEP Initiative supports work to identify and remove hazardous components in e-waste.

- Significant gaps in **research** exist, especially quantitative analysis of exposures and endpoints related to the identified potential health impacts. Continuing support for detailed research on specific identified health impacts will aid targeted regulation and information on chemicals of concern in waste flows. Research should also focus on finding less harmful substitute materials, as promoted in the work of a number of initiatives (e.g. EMF, 2015b).

- **Action on the informal waste sector** is needed because its activities in collection, treatment and disposal, and the illegal flows of hazardous waste are suspected to be significant, although complete information on this issue is lacking. For example, Europe exports high quantities of e-waste to developing countries that lack adequate waste management infrastructure, so that handling and disposal are frequently unregulated or health and safety regulations are not enforced. As shown in the case study, this directly and disproportionately affects the health of vulnerable and poor people working at and living near waste dumping sites. The implementation and enforcement of the Basel Convention through national and international legislation is central to tackling this issue (WHO Regional Office for Europe, 2016b).

In addition to tackling direct negative health effects, policy options can also be used to enhance positive effects. For example, a policy discussion on appropriate economic instruments in the circular economy model suggested a shift in taxation from labour to resources (Stahel, 2010). This would increase incentives to minimize waste, maximize resource productivity and encourage more labour-intensive circular business practices. Since about 6% of total tax revenues in Europe currently come from environmental taxes (including on pollution and resource extraction) and about 50% come from labour taxes and social contributions, this shift could represent a significant change (EMF, 2015c). An analysis for the Ex'Tax project (Ex'Tax et al., 2016) suggests that such a shift in 2016–2020 would produce positive results in the EU27, including a GDP 2% higher on average and employment 2.9% higher (an increase of 6.6 million) than the business-as-usual scenario. Sector analysis shows employment gains in most sectors except energy and utilities, with most gains in wholesale/retail, communication and basic manufacturing, and lower gains in agriculture. The study also highlights the potential for health benefits from this shift in tax policy in terms of lower carbon emissions and pollution levels due to reduced energy, resource and water use, as well as increased well-being from employment effects defined in terms of ensuring material needs, participation in society and social status (Ex'Tax et al., 2016).

This example of a shift in taxation policy illustrates that, while many policy actions related to the circular economy may not have originally and mainly been intended to secure health benefits, these actions have considerable co-benefits, as mentioned and discussed in sections 6 and 7. These include health co-benefits through reduced emissions from manufacturing processes and vehicles, cost savings in hospitals, improved occupational health and safety benefits from changes in the built environment, and a greater choice of healthy foods. As mentioned, however, there are potential negative health impacts or co-costs associated with circular economy actions, for example, in relation to chemicals of concern, e-waste and food packaging.

9 Conclusions

This section gives the key conclusions from this study, including both general conclusions; specific conclusions for various stakeholders: policy-makers, researchers, businesses/NGOs and civil society; and the conclusions from a recent WHO meeting.

9.1 General conclusions

- The circular economy concept has achieved prominence and wide engagement among the academic, policy, business and NGO communities over recent years. The current state of play for the implementation of its principles encompasses a wide range of activities, summarized for Europe in section 3, most noticeably in the waste sector.

- Assessments of health impacts from the circular economy (e.g. WHO Regional Office for Europe, 2016b) focus on the direct effects of waste management activities (landfill, recycling, etc.), but the full implementation of the wider definition of the circular economy may potentially have significant indirect health effects resulting from, for example, changes in environmental impacts from extraction, production, mobility and consumption.

- The assessment of health implications in this study found many existing and potential positive health implications related to the reduced use of primary resources" and "maintaining the highest value of materials and products, such as through the recycling and reuse of products, components and materials, and the move towards greater use of renewable energy and energy efficiency. In particular, these benefits come through cost savings in the health sector and the indirect health benefits of reducing environmental impacts on air, water and soil quality and GHG emissions from manufacturing processes.

- There are also potentially significant health benefits from changing utilization patterns through, for example, the health care sector's introducing performance models in the procurement of equipment, and a wide range of indirect health benefits due to the reduction in environmental impacts from shifts to product sharing and product-as-service models.

- The potential negative health impacts identified relate to the unintended consequences of recycling and reusing products, components and materials. This refers in particular to the management of chemicals of concern, such as those found in e-waste, food packaging and fire retardants in a variety of products, and to emissions from the composting of waste. The challenge for the circular economy in this context is the development of safer, effective and economically viable replacement materials. This is a key step in managing the transition from a linear to a circular economy.

- Although conclusions for key stakeholders are set out below, multistakeholder partnerships and collaboration between WHO Member States, NGOs, intergovernmental organizations, the private sector and academe through agreed partnerships and action plans are vital to drive progress in promoting the health benefits and addressing the health risks entailed in the transition to a circular economy.

9.2 Policy

- Policy priorities for addressing the areas of immediate concern identified in consultations for this report are:
- the further development of regulations for some direct negative health impacts, such as the recent banning of BPA in thermal paper in the EU from 2020;
- better information to inform recyclers and help prevent the use of harmful substances in recycled materials;
- support for research on the health impacts of recycling materials; and
- action to address health impacts at informal waste sites, including reducing the risk of exposure to hazardous materials.
- There are also broader priorities in terms of developing indicators for the monitoring of progress on the health benefits and on reducing the health risks of circular economy programmes, including taking account of distributional effects.
- Promoting public awareness of circular economy benefits, including health benefits, is also a key to progress. This includes changing perceptions of the quality and safety of remanufacturing, refurbishment and reuse of products and components (e.g. hospital equipment) and the benefits of shifts in consumption models (e.g. product sharing).
- The distribution of health impacts is of particular importance. More vulnerable populations may be disproportionately affected by both the negative health consequences of specific circular economy actions outlined in this report (as shown by the examples given in the case studies on chemicals of concern and e-waste) and the health benefits of circular economy actions (by addressing inequitable environmental determinants of health, such as air pollution and soil contamination). Thus, further policy development in this area, informed by ongoing research on distributional issues, is essential.
- Actions to address areas of concern are urgent, to prevent progress on the circular economy (and the potential for significant health benefits) being undermined by reduced public and policy community support resulting from these concerns.
- In view of this report's findings on the importance of health issues in the transition to a circular economy and the relatively limited coverage of these to date, it is clearly necessary to increase and improve the placement of health in policy discussions and future circular economy strategies, frameworks and action plans at the national, regional and global levels.
- To this end, WHO and the health sector should be active, key stakeholders in supporting the transition process. This would enable both positive and negative health considerations to be better integrated into circular economy strategies and national implementation plans. This involvement would also support concrete actions to address areas of health concern in the transition.

9.3 Research

- Much continuing research addresses the potential health impacts of a transition to a circular economy in the context of, for example, chemicals of concern, water reuse and e-waste. There are significant research gaps, however, especially in the quantitative analysis of exposures and endpoints related to the identified potential health impacts. It is also necessary to further develop the assessment of the effect on the environment and health of alternative policy options, for example, in the management of residual waste.

- Some aggregate estimates of potential benefits from circular economy policies are available, sometimes including health estimates (e.g. EMF, 2015b; Ex'Tax et al., 2016), but their authors acknowledge that these are order-of-magnitude estimates and that more detailed quantitative analyses of specific benefits and identified health impacts are needed. Further analysis to better understand potential health benefits could also be used to inform the development of policies and practices to enhance such benefits.

- There is also a priority need for more assessment of the health implications of a circular economy for the countries in the WHO European Region that do not belong to the EU. While this report aims to cover all the countries in the Region, the availability of consolidated data and analysis on a range of circular economy issues is much greater in EU countries. In addition, the business and policy communities in EU countries have greater engagement with the circular economy concept. More information is therefore needed on the state of play and progress being made on key circular economy issues and their health implications in countries outside the EU, including on waste management and resource efficiency. This would better inform an understanding of key policy priorities in these countries.

- Given the importance of inequity in health in key programmes such as Health 2020 and the SDGs (WHO Regional Office for Europe, 2013; United Nations, 2018), research and policy development need to give further emphasis to the distributional issues outlined in this report, in order to minimize the negative outcomes and promote positive outcomes for vulnerable populations.

9.4 Businesses/Civil-society organizations

- Business plays a crucial role in implementing circular principles, including through innovation, ecological design, resource efficiency and waste minimization, while civil-society organizations (CSOs) and business associations support this via promotion and knowledge sharing. Such approaches can be seen as integral to triple-bottom-line outcomes (that is, social, environmental and financial outcomes) for business.

- These actions can be the source of key direct positive health implications (e.g. via performance models and sharing platforms in procurement in the health care sector) and indirect implications via reducing environmental impacts (air, water and soil quality, and GHG emissions) in extraction, manufacturing and consumption processes.

- Business and CSOs can also play a key role in identifying and addressing the potential unintended consequences of circular economy actions. In particular, this refers to the challenges identified above in managing the presence of chemicals of concern in recycling and reusing products, components and materials, and developing safe substitute materials.

- A number of potential occupational health impacts from the circular economy transition have been identified. For example, health benefits are envisaged from using circular principles in the built environment to improve safety, air quality and mental health. Occupational health risks include those associated with use of chemicals of concern and poorly regulated e-waste sites. While further research is required to identify and assess these impacts, the active business and CSO networks for a circular economy can play a key role in promoting healthy outcomes and addressing potential occupational health risks.

- CSOs also have a key role in assisting and reviewing the development and implementation of policy related to the circular economy, identifying and reporting health-related issues and advocating changes in policy, business practice and consumer choices.

9.5 General public and the mass media

- Using circular principles can have a range of possible public health benefits, including improvements in safety, air quality and mental health in the built environment. There are also potentials gains to public health to the extent that savings in the health care sector (discussed in the case study in section 7) result in improvements in services. Indirect public health benefits may also occur through reductions in pollutant emissions from production and consumption processes.

- There are also public health risks from, for example, contact with chemicals of concern in products and components. These risks are an emerging area of research and require much more assessment.

- The general public and the mass media can become more engaged in the circular economy in a number of ways; this would enable them to inform, stimulate and contribute to healthy outcomes through, for example, lower production and consumption emissions. These opportunities include behavioural changes such as involvement in sharing platforms (e.g. car sharing) and consumer choices (e.g. recycling products and reused components).

9.6 Conclusions and recommendations of environment and health stakeholders

The following are the conclusions reached by the participants in a WHO meeting on the circular economy and environment and health, held in October 2017 in Bonn, Germany. The participants included representatives of the European Environment Agency, the United Nations Environment Programme, UNIDO, the United Nations Economic Commission for Europe, United Nations University, funding agencies such as the World Bank and the European Investment Bank, the Organisation for Economic Co-operation and Development, CSOs such as HEAL and EuroHealthNet, the private sector, young people's organizations and academe.

- Circular economy concepts and business models will increasingly replace the present dominant linear economy. The reasons for this change are manifold: the inefficient use of finite resources, limitations of GDP-focused economics, interest in indicators of well-being, internalization of the costs of climate change and awareness of planetary boundaries.

- Although largely absent from past discussions, the health sector should become actively involved as an enabler and key stakeholder in this transition process. Both positive and negative health considerations must be integrated into circular economy strategies and national, regional and local implementation plans.

- The transition to a circular economy can result in potentially significant net health benefits that will contribute to the attainment of the SDGs, particularly SDGs 3, 9, 11 and 12.

- WHO and the health and environment sector should promote a health-friendly transition to a circular economy and actively support countries in defining their strategies and translating them into national, regional, and local action plans.

- Joint action is required to ensure an effective and safe transition to a circular economy; every sector has to be engaged, including the public, to remove harmful substances (detoxify), to reduce emissions of GHGs (decarbonize) and other pollutants that affect air quality, to build the capacity of the ecosystem (enhance resilience), and to change lifestyles and use less resources (decouple).

- A circular economy can provide a major opportunity that could yield substantial health benefits, yet there are also risks of adverse effects that need to be identified, investigated, well communicated and integrated into circular economy strategies and implementation plans. Examples of such negative effects are specifically found in the areas of waste management, diffusion of hazardous chemicals and reuse of waste-water.

- Multistakeholder partnerships and collaboration among WHO Member States, CSOs, intergovernmental organizations, the private sector, the mass media and academe are vital to drive health and a sustainable circular economy forward through partnerships and action plans.

- The adoption of circular economy principles is an essential part of new business models and evidence suggests that it is expected to result in increased and sustainable growth, profits/taxes, employment and resilience for most private and state actors.

- All individuals – in their various economic and societal roles as consumers, producers, employees, educators, etc. – will have to change their lifestyles, attitudes and behaviour substantially over the next decades. If undertaken in a fair and equitable manner, this transition might enable the most effective and efficient societal transformation and significantly shorten the implementation phase, and thus help to overcome political and private sector concerns.

- Significant gaps in research remain in the area of the positive and negative links between a circular economy and health, particularly for the changing distributional effects. Additional research is needed to establish evidence of the benefits of a circular economy, which should then inform the political debate and implementation activities.

- A framework of environment and health indicators and metrics for human progress should be developed, along with a monitoring and evaluation system, to ascertain and optimize the expected benefits of a circular economy.

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ANNEX 1. CONCEPT OF THE CIRCULAR ECONOMY AND MODELS OF IMPLEMENTATION

This annex provides further detail and discussion on the definition and models of the circular economy, and links to related concepts and initiatives given in section 2.

A1.1 Definitions

The concept of a circular economy evolved over recent decades into its current form by building on earlier related concepts and frameworks, such as the functional service economy (performance economy), the cradle-to-cradle design philosophy and industrial ecology (EMF 2015a; Preston 2012). The literature gives no single definitive and ubiquitous definition of a circular economy, although it shows general consensus on the central concepts and aims. Rizos et al. (2017) identify two main types of definitions: those that are resource-oriented and focus on the need for closed loops of material flows and reduced consumption of virgin resources, and those that go beyond the management of material resources to incorporate additional dimensions, such as changing models of consumption.

In simple terms the types of processes needed for a transition to a circular economy can be categorized as: using fewer primary resources, maintaining the highest value of materials and products, and changing utilization patterns. In practice, the actions needed to achieve this transition include: recycling; efficient use of resources; utilization of renewable energy sources; remanufacturing, refurbishment and reuse of products and components; product life extension; product as service; product sharing; waste prevention, including designing waste out of products, and a shift in consumption patterns (Rizos et al., 2017; EMF, 2015a). Alongside these actions, the phasing down of incineration and landfilling as waste management options is seen as a necessary requirement, although a need remains to assess the best options for dealing with residual waste.

A frequently quoted definition by the Ellen MacArthur Foundation (EMF) sees 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; EEA, 2016a). A key focus is thus on minimizing the need for new inputs of materials and energy and reducing environmental pressures related to resource extraction, emissions and waste. The concept is also presented as enabling wider economic and social benefits, such as greater well-being, sustainable growth and employment. The main definitions reviewed for this report, however, make no explicit mention of health. Rizos et al. (2017) found that social aspects are often absent from the existing conceptualizations of the circular economy.

Definitions of the circular economy include a number of common themes:

- transition from linear (take, make, use, dispose) model to circular (restorative and regenerative) model (EMF, 2015a) (see Fig. 1).
- aims to keep products, components, and materials at their highest utility and value at all times (this requires the promotion of reuse, repair, reconditioning and recycling (Benton & Hazell, 2013), which contribute to keeping resources in use for as long as possible, extracting the maximum value from them whilst in use, and recovering and regenerating products and materials at the end of their service life (WRAP, 2018));

- closure of material loops;
- distinction between technical and biological cycles (see e.g. Fig. A1.2);
- system-wide innovation aiming to redefine products and services to design waste out and extend product life (see, for example, EEA, 2017), while minimizing negative impacts.

Definitions also include a tie-in of the circular economy model with addressing related economic, social and environmental challenges. These include: resource-related challenges for business and economies (for example, "it offers a model of sustainable growth fit for a world of high and volatile resource prices," according to Preston (2012)), sustainable growth, job creation and reduction in environmental impacts, including carbon emissions.

At a more conceptual level, definitions of the circular economy include aims:

- to decouple global economic development from finite resource consumption;
- to build economic, natural and social capital;[17] and
- to go beyond waste management alone to managing natural resources efficiently and sustainably throughout their life cycles.

At a practical level, the literature includes a number of categorizations for the types of actions or processes that can be undertaken by businesses and others to make the transition to a circular economy (EEA, 2016; EMF, 2015c; WRAP, 2018). For example, the Ellen MacArthur Foundation (EMF) developed the ReSOLVE framework (Regenerate (e.g. shift to renewable energy and materials), Share (e.g. sharing of assets and reuse of products), Optimise (e.g. removing waste in production), Loop (e.g. recycling and remanufacturing), Virtualise (dematerializing consumption) and Exchange (e.g. choosing new sustainable products)) (Fig. A1.1). This categorizes

[17] Definitions from EMF (2018) also include: "It is conceived as a continuous positive development cycle that preserves and enhances natural capital, optimises resource yields, and minimizes system risks by managing finite stocks and renewable flows" (EMF 2015a).

Fig. A1.1. The ReSOLVE framework

REGENERATE	• Shift to renewable energy and materials • Reclaim, retain, and restore health of ecosystems • Return recovered biological resources to the biosphere
SHARE	• Share assets (eg cars, rooms, appliances) • Reuse/secondhand • Prolong life through maintenance, design for durability, upgradability etc
OPTIMISE	• Increase performance/efficiency of product • Remove waste in production and supply chain • Leverage big data, automation, remote sensing and steering
LOOP	• Remanufacture products or components • Recycle materials • Digest anaerobically • Extract biochemicals from organic waste
VIRTUALISE	• Dematerialise directly (eg books, CDs, DVDs. travel) • Dematerialise indirectly (eg online shopping)
EXCHANGE	• Replace old with advanced non-renewable materials • Apply new technologies (eg 3D printing) • Choose new product/service (eg multimodal transport)

Source: EMF (2015c).

actions and processes based on the model in Rizos et al. (2017), which groups types of actions or processes under the headings of: reducing the use of primary resources, maintaining the highest value of materials and products and changing utilization patterns (see Table 2, section 5).

A1.2 Models

Models of the circular economy vary in scope and sophistication from the simple circular concept shown in Fig. 2 (section 2), which describe a production, consumption, reuse/repair/recycling loop, to the more complex outline based on three central principles given in Fig. A1.2 or applied to a specific industry in Fig. A1.3. The principles focus on

- preserving and enhancing natural capital by controlling finite stocks and balancing renewable resource flows:
- optimizing resource yields by circulating products, components, and materials at the highest utility at all times in both technical and biological cycles;[18] and
- fostering system effectiveness by revealing and designing out negative externalities.

Negative externalities are any consequences of an economic activity that affect other parties without being reflected in market prices. In this context, externalities with health implications include air, water, soil and noise pollution, and the release of toxic substances.

A number of frameworks also set out processes and actions needed for a transition to a circular economy (EMF, 2015c; Benton & Hazell, 2013; Preston, 2012). For example, uses the ReSOLVE framework identifies a set of six types of actions that businesses and governments can take. Circular economy models do not vary widely in terms of stakeholder roles for implementing such actions. Thus, there is a general understanding that a transition must include state intervention in setting strategy and funding some measures, such as research and business support, regulatory and fiscal frameworks supporting actions by business. There is also a key role for nongovernmental organizations (NGOs) and business associations in promotion and knowledge sharing. Due to the wide scope of what may be defined as circular economy actions, there are many examples of businesses, organizations and governments implementing policies that are consistent with the circular economy but use different terminology (Preston, 2012).

A1.3 Related concepts and initiatives

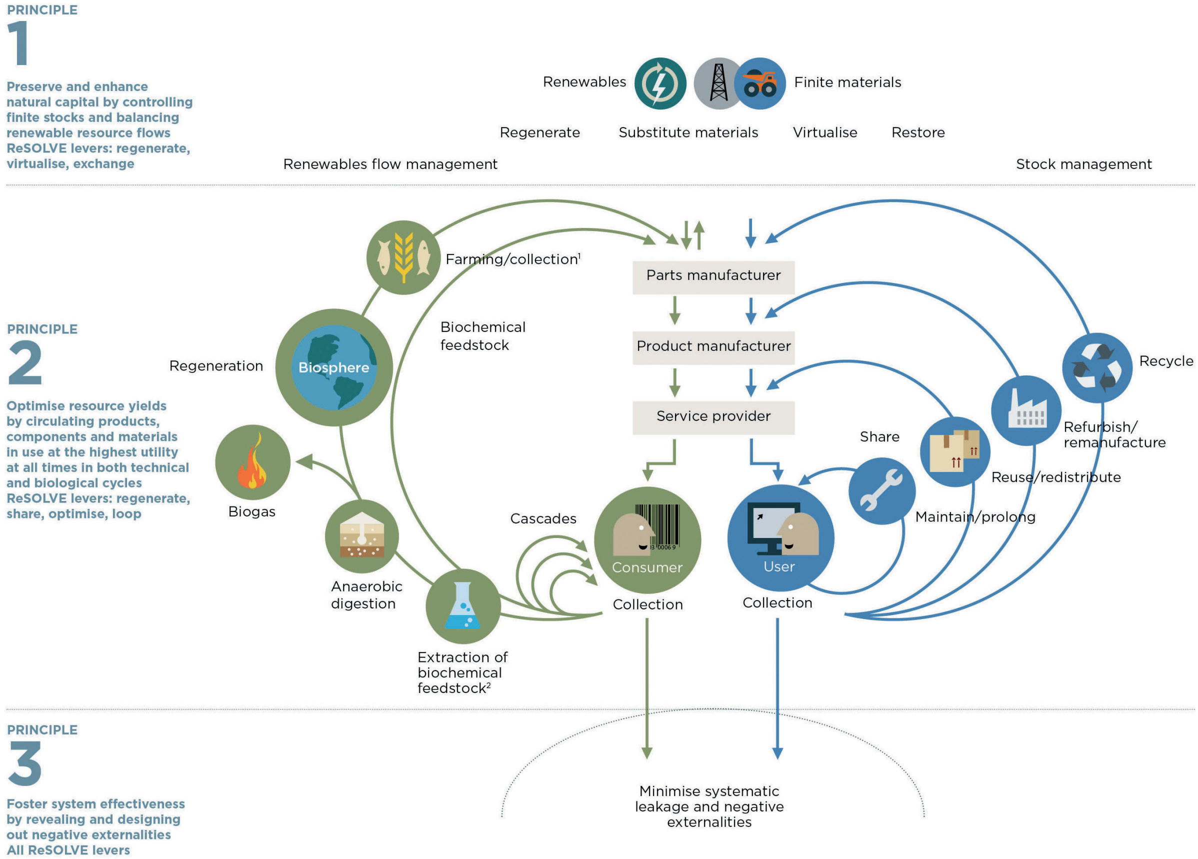
This section provides a brief outline of a number of related concepts and associated global and European initiatives, focusing on their links with the circular economy concept.

A1.3.1 Sustainable development and the Sustainable Development Goals (SDGs)

The circular economy can be seen as a means of progressing towards sustainable development through reaching the SDGs (United Nations, 2018). The European Union (EU) action plan for the circular economy (detailed in section 3) explicitly links the circular economy to the implementation of global commitments under the United Nations 2030 Agenda for Sustainable Development. It states that the action plan will be "instrumental in reaching the SDGs by 2030, in particular Goal 12 of ensuring sustainable consumption and production patterns" (EC, 2015).

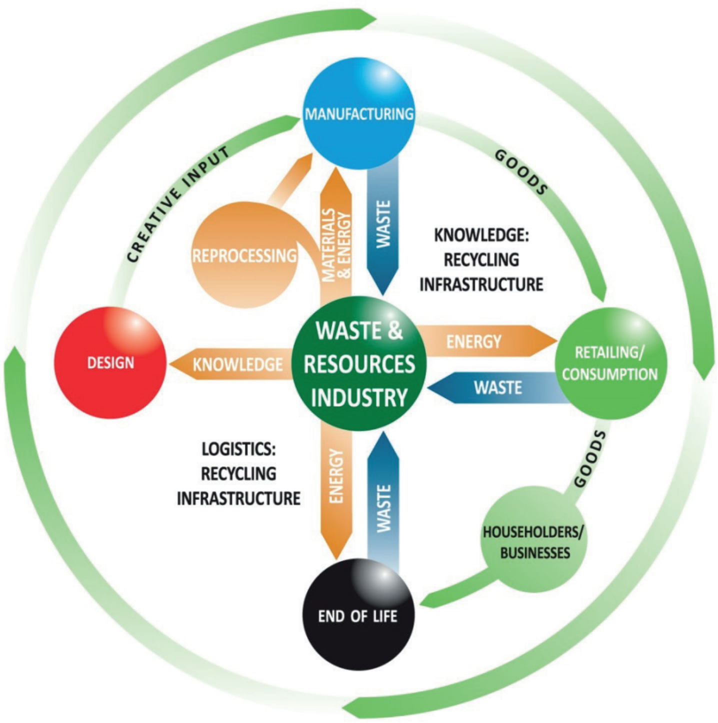
[18] In this model, a circular economy distinguishes between technical and biological cycles. The technical cycle involves the management of stocks of finite materials. Use replaces consumption. Technical materials are recovered and mostly restored. The biological cycle encompasses the flows of renewable materials. Consumption only occurs and renewable (biological) nutrients are mostly regenerated.

Fig. A1.2. Outline of circular economy according to three key central principles



Source: EMF (2015b).

Fig. A1.3. Modelling the circular economy with the waste and resource industry at the centre



Source: Environmental Services Association (2016).

The targets of particular relevance in SDG 12 are:

- to achieve the sustainable management and efficient use of natural resources (12.2);
- to halve per capita global food waste at the retail and consumer levels and reduce food losses along production and supply chains, including postharvest losses (12.3);
- to achieve the environmentally sound management of chemicals and all wastes throughout their life cycle, in accordance with agreed international frameworks, and significantly reduce their release to air, water and soil in order to minimize their adverse impacts on human health and the environment (by 2020) (12.4.); and
- to substantially reduce waste generation through prevention, reduction, recycling and reuse (12.5).

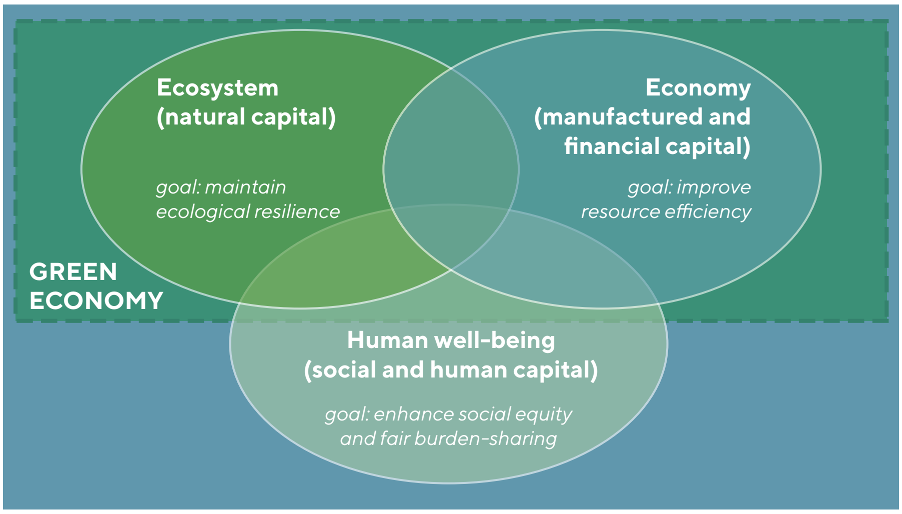
Some sources also see the transition to a circular economy as contributing to a number of the other SDGs. For example, EMF (2017) links the transition to helping to achieve SDGs 3 (on good health and well-being), 7 (on affordable and clean energy), 8 (on decent work and economic growth), 9 (on industry, innovation and infrastructure) and 11 (on sustainable cities and infrastructure).

A1.3.2 Green economy

The concepts of the green economy and the circular economy are closely interlinked. Indeed, the terms are sometimes used together to underline their interconnectivity. The working definition of a green economy used by the United Nations Environment Programme (UNEP)[19] is "one that results in improved human well-being and social equity, while significantly reducing environmental risks and ecological scarcities" (UNEP, 2011). Thus, this includes key features of a circular economy, particularly low-carbon approaches and resource efficiency, but has been interpreted as being wider in range in that it includes social and ecosystem dimensions. References to the circular economy in the UNEP Green Economy documents focus mainly on issues of waste and use of materials (Fig. A1.4). Nevertheless, some circular economy reports include the discussion of social and ecosystem benefits as part of a wider assessment of initiatives (e.g. EMF, 2015b). The green economy is also closely linked to sustainable development and, in the 2012 Rio+20 agenda, is seen as a tool for achieving sustainable development (United Nations, 2012).

[19] UNEP launched the Green Economy Initiative in 2008. It includes global research and country-level assistance aimed at motivating support for green economy investments as a way of achieving sustainable development.

Fig. A1.4. The green economy



Source: EEA (2016b).

A1.3.3 Batumi Initiative on Green Economy

The Batumi Initiative is a set of voluntary commitments by European countries and organizations to undertake green economy actions, including actions for the circular economy. It serves to enable the Pan-European Strategic Framework for Greening the Economy in the period 2016–2030 (UNECE, 2016b). Focus area 5 of the Strategic Framework is to "Develop clean physical capital for sustainable production patterns"; it explicitly refers to the circular economy approach in the context of encouraging closed-loop material cycles and eco-design of products. Focus area 4 is to "Shift consumer behaviours towards sustainable consumption patterns" including the circular economy aims of "efficient use of water, energy and materials, and the minimization of waste generation" (UNECE, 2016a). The Green Growth Knowledge Platform (2018) promotes the Batumi Initiative by providing information on the commitments of countries and organizations.

A1.3.4 Resource efficiency agenda

The circular economy is also closely linked to the concept of and initiatives on resource efficiency. The EU Roadmap to a Resource Efficient Europe (part of the Europe 2020 Strategy) outline the circular economy is as an interlinked initiative in terms of sustainable materials management where waste becomes a resource (EC, 2011). The European Resource Efficiency Platform (EC, 2018), which aims to provide high-level guidance to the European Commission, Members States and private actors on resource-efficiency, includes moving towards a circular economy in its manifesto (EREP, 2014). The EU action plan for the circular economy (EC, 2015b) also links the circular economy to the implementation of global commitments under the Group of 7 Alliance on Resource Efficiency.

A1.3.5 Low-carbon economy

This term refers to a transition towards a competitive low-carbon economy and largely focuses on the supply side of economies. The European Commission (EC) roadmap to a resource efficient Europe set a target for the EU to cut greenhouse gas (GHG) emissions to 80% below 1990 levels by 2050, and outlines required contributions across all main sectors responsible for Europe's emissions (EC, 2011). Health benefits are foreseen due to improved air quality. Low-carbon approaches are included in the circular economy model (and the green economy concept), but the concept is narrower in focus.

A1.3.6 The bioeconomy

The bioeconomy is defined as the parts of the economy that use renewable biological resources from land and sea (such as crops, forests, fish, animals and micro-organisms) to produce food, materials and energy. The EC bioeconomy strategy proposes a comprehensive approach to address the ecological, environmental, energy, food supply and natural resource challenges faced by Europe (EC, 2012). This concept is the focus of a key element of the circular economy model, which includes optimizing resource yields in biological cycles, as well as technical cycles, as outlined in principle 2 of the circular economy model developed by EMF (see Fig. A1.2).

A1.4 Linkage to existing WHO programmes and publications

While WHO programmes and publications make limited direct reference to the circular economy concept, some of its key health initiatives connect to and are affected by circular economy aims and policies, primarily in the area of the green economy, the environment and sustainable development.

A number of WHO briefings on health in the green economy (Röbbel, 2011; WHO, 2011b–d) review the health impacts of the strategies for mitigating climate change considered by the Intergovernmental Panel on Climate Change in its fourth assessment report (Pachauri & Reisinger, 2007). They identify expected health co-benefits from some of these strategies, including from the issue of waste management, and note that others may involve health risks or trade-offs. A number of WHO sector reports, including for health care, housing and transport, and other reports on household energy and occupational health identify opportunities for potential health and environment synergies (WHO, 2011a–d). The findings of these reports were used to inform the assessment of health impacts in section 6 above.

Health 2020 is the European health policy framework adopted by Member States of the Region in September 2012 (WHO Regional Office for Europe, 2018). It aims to support action across government and society to: "significantly improve the health and well-being of populations, reduce health inequalities, strengthen public health and ensure people-centred health systems that are universal, equitable, sustainable and of high quality" (WHO Regional Office for Europe, 2013).

The transition to a circular economy has various implications for the stated priorities of Health 2020 (WHO Regional Office for Europe, 2013).

As to tackling Europe's major disease burdens, the circular economy may affect the burden of disease positively (e.g. though reduction of air pollution due to transition to the circular economy mobility and production modes – see section 5) and negatively (e.g. if hazardous chemicals are not managed to minimize health risks – see the case study in section 7).

- As to **strengthening people-centred health systems and public health capacity**, the circular economy can contribute to improving the delivery of public health and health care services by providing a range of cost-saving and efficiency measures (see the case study in section 7).

- The transition to the circular economy can enhance **the creation of supportive environments and resilient communities** to the extent that this translates into improved well-being and quality of life (see discussion on models of a circular economy and examples in the case study on the built environment in section 7).

Further, successful health outcomes for the populations of Europe from progress towards Health 2020 will support the healthy workforce required for the successful development of a circular economy.

Waste was one of the eight themes of the **European environment and health process** roadmap to the Sixth Ministerial Conference on Environment and Health of the **European environment and health process** (WHO Regional Office for Europe, 2015). It was indicated as one of the key environmental and health issues not yet adequately explored and addressed by the Process. The WHO Regional Office for Europe held an expert consultation on the health effects of urban and hazardous waste in support of the Process (WHO Regional Office for Europe, 2016a).

Most recently, the Declaration of the Sixth Ministerial Conference on Environment and Health states that progress on actions towards improving the environment and health "can be accelerated and sustained by enhancing interdisciplinary research and supporting the transition to a green and circular economy as a guiding new political and economic framework" (WHO Regional Office for Europe, 2017).
In particular, the objective to "Prevent and eliminate the adverse environmental and health effects, costs and inequalities related to waste management and contaminated sites" includes "supporting the transition to a circular economy using the waste hierarchy as a guiding framework to reduce and phase out waste production and its adverse health impacts through reduction of the impact of substances of greatest concern" (WHO Regional Office for Europe, 2017).

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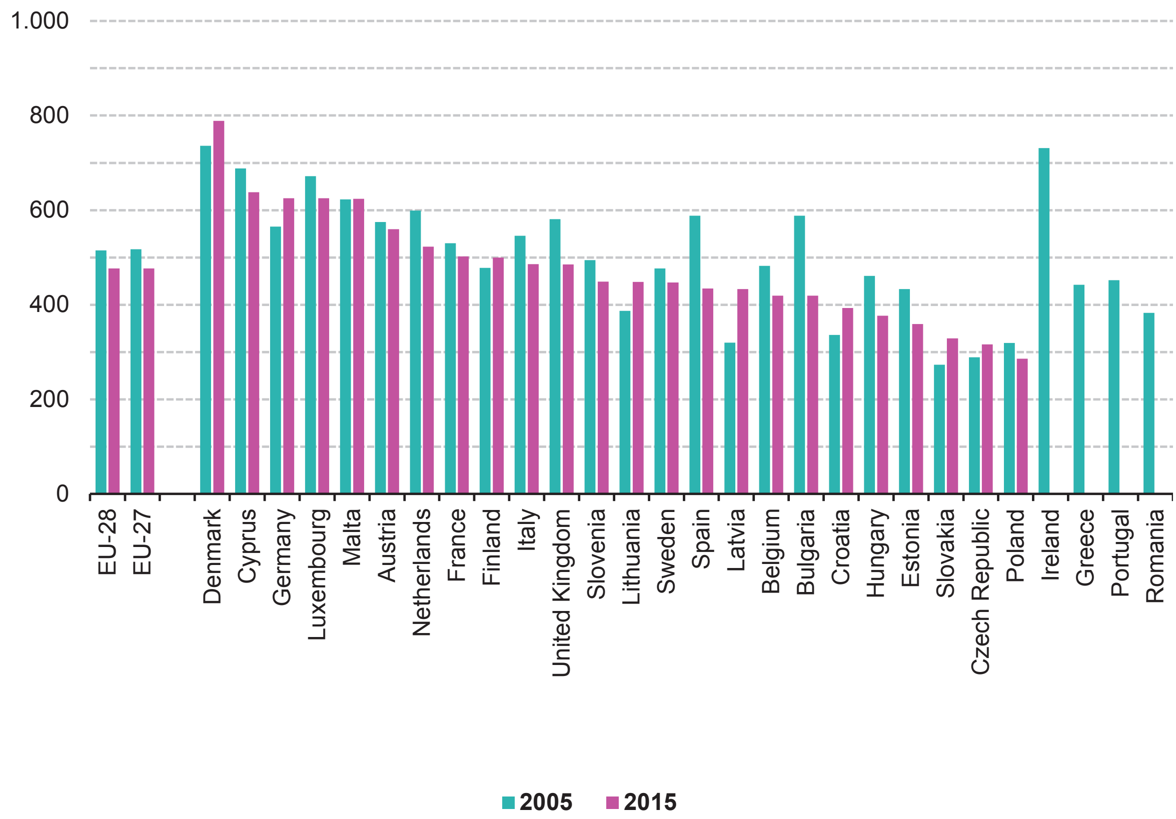
ANNEX 2. PROGRESS TOWARDS CIRCULAR ECONOMY OBJECTIVES

This annex provides further detail on the current state of play in progress towards a circular economy in Europe given in Section 3.

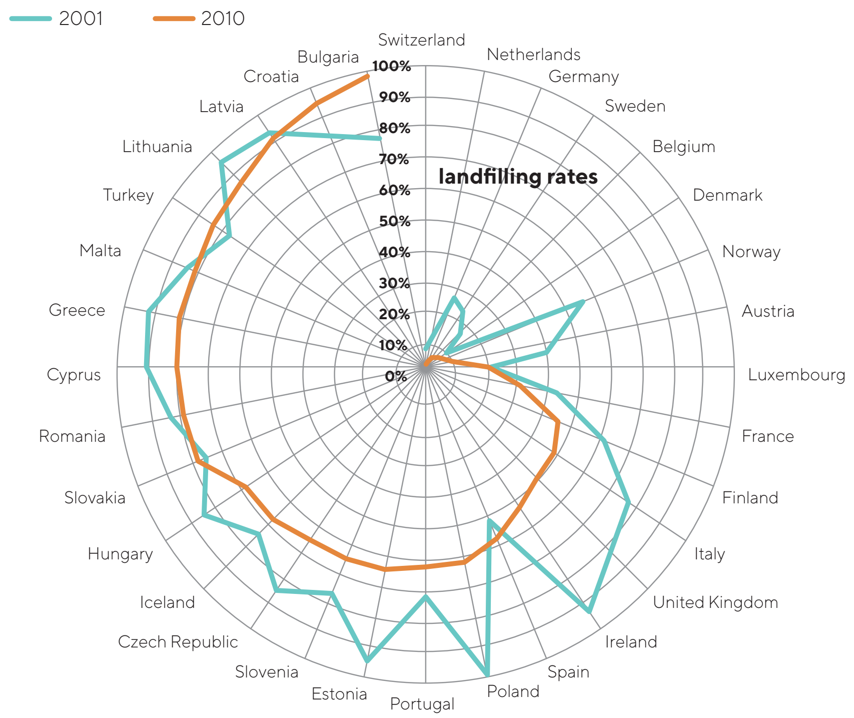
When one focuses on practical progress towards circular economy objectives, one notes an interesting overall trend towards declining waste generation per capita in the EU, where the overall decline was about 7% in the period 2004‒2013, with a decrease of 4% in municipal waste generation, although caveats are needed owing to missing data, uncertainties and differences in waste calculation methods between countries (WHO Regional Office for Europe, 2016). Fig. A2.1 shows municipal waste generation per capita declining in most EU countries, and in the averages for the 27 countries belonging to the EU between 1 January 2007 and 30 June 2013 (EU27) and the 28 belonging to it from 1 July 2013 (EU28), between 2005 and 2015. Progress was also made in waste management with, for example, increasing percentages of municipal waste recycled and composted across the WHO European Region (including some countries outside the EU) between 2004 and 2014 (see Fig. 5 in section 3). Fig. A2.2 shows landfilling rates for municipal waste and recycling rates for material and biowaste in 2001 and 2010 in 32 European countries.

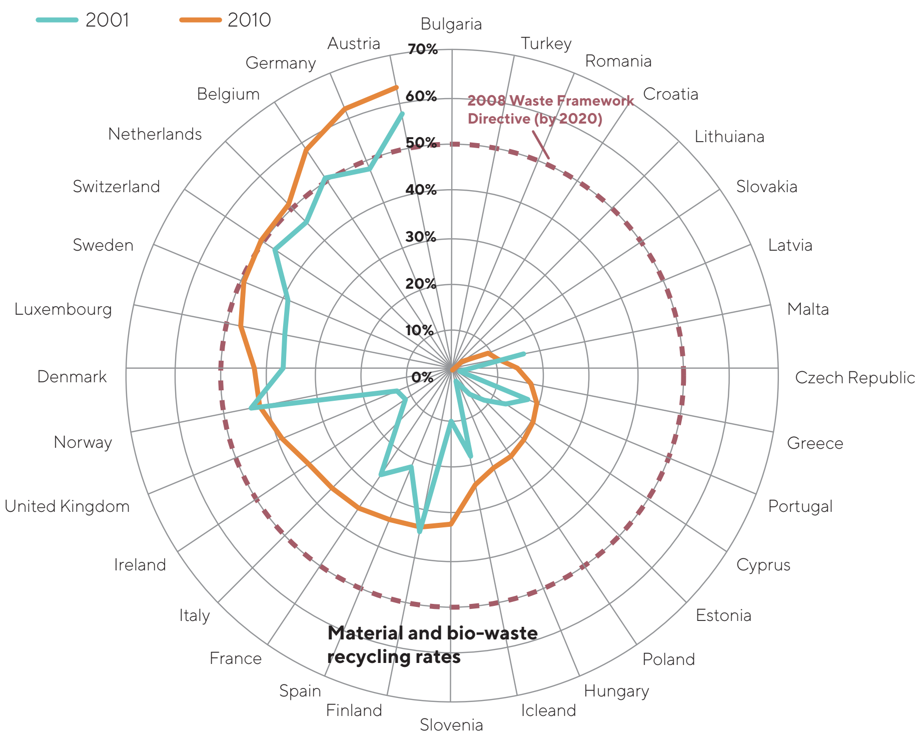
Fig. A2.1. Municipal waste generated by country in 2005 and 2015, sorted by 2015 level, kg per capita



Source: data from Eurostat, 2015.

Fig. A2.2. Landfilling rates for municipal waste and recycling rates for material and biowaste in 32 European countries, 2001 and 2010



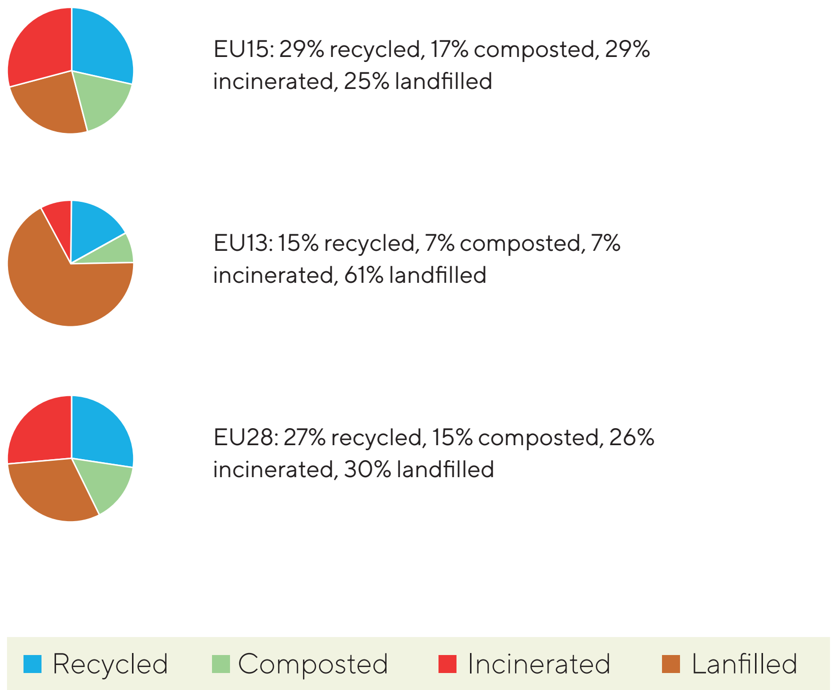


Source: EEA (2013).

Countries vary significantly, many more of that that recently joined the EU having lower recycling and composting rates and much greater use of landfills. Fig. A2.3 demonstrates such differences in these rates between the EU's 15 Member States before 2004 and the 13 that have joined since 2004 (EU15 and EU13, respectively).

The review by the WHO Regional Office for Europe (2016) notes the large differences between and within European countries in waste management practices; some countries have old technologies and high levels of informal disposal, including open-air dumping and burning of waste. Fig. 4 (section 3) shows overall trends in municipal waste treatment (kg per capita) for EU27 as a whole for the period 1995–2015, with gradual declines in landfill and gradual increases in recycling, composting and incineration.

Fig. A2.3. Comparison of rates of recycling, composting, incineration and landfill between EU15, EU13 and EU28 (note for WHO lay-out company: it would be better to have the percentages placed next to the various pie slices and to enlarge them a bit)



Source: data from Eurostat, 2013.

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[21] Electronic references were accessed on 17 April 2018.

ANNEX 3. KEY INITIATIVES FOR THE CIRCULAR ECONOMY AT THE NATIONAL AND OTHER LEVELS

Country	Initiative	Description
European countries		
Denmark	Circular Economy Hub	White Paper by State of Green and Danish Ministry of Environment and Food that describes issues and examples but does not give an action plan
Finland	Roadmap to a circular economy 2016–2025	Initiative of Sitra (Finnish Innovation Fund) with wide Government and stakeholder participation, that aims to clarify actions needed to achieve Government target of making Finland a global leader in the circular economy by 2025, and has five focus areas: a sustainable food system, forest-based loops, technical loops, transport and logistics, and joint actions
Luxembourg[a]	Circular economy roadmap, commissioned by the Luxembourg Ministry of the Economy	Study covering circular economy enabling mechanisms, commercial applications and potential roadmap
Netherlands	A circular economy in the Netherlands by 2050	Government-wide programme with priorities for biomass and food, plastics, manufacturing, construction and consumer goods
Scotland (United Kingdom)	Making things last: a circular economy strategy for Scotland	Strategy setting out priorities for moving towards a more circular economy: food and drink and the broader bioeconomy, remanufacture, construction and the built environment, energy infrastructure
European regions and cities		
Brussels Region	Regional Circular Economy Programme: 2016–2020	Objectives to transform environmental objectives into economic opportunities, anchor the economy to produce locally where possible, and help create employment
Amsterdam	Circular Amsterdam: A Vision and Action Agenda for the City and Metropolitan Area	Vision and strategy for circular construction chain and circular organic residual streams chain
Peterborough	Future Peterborough programme	Circular Peterborough Commitment supported by individuals, communities and businesses

	Health-related aspects	Key reports
	No explicit focus on health	State of Green (2016)
	Guiding principles acknowledge the need to manage any health and environmental risks associated with reuse and recycling. Diet issues are included in a focus area: sustainable food system.	Sitra (2016)
	Study includes several references to and examples of the need for healthy materials for a circular economy. It also includes a section on health care and concludes: "… so far none of the leading publications on the circular economy attempted to tackle the health care question despite the large implications for materials, jobs, cost savings and competitiveness" (EPEA, 2014).	EPEA (2014)
	Includes references to but no specific actions on: reducing exposure to substances that damage health; saving costs of health care; and dietary benefits	Government of Netherlands (2016)
	No health focus, except for reference to health and safety in section on skills in a circular economy	Scottish Government (2016)
	No specific health focus	Brussels Government (2016)
	No specific health focus	Circle Economy et al. (2015)
	No specific health focus	Future Peterborough (2018)

Country	Initiative	Description
Examples from countries outside the WHO European Region		
China	Circular Economy Development Strategy and Near-term Action Plan	Circular Economy Promotion passed in 2009, focusing on reducing resource use, reuse and recycling, and followed by a development strategy and action plan
Canada	New thinking: Canada's roadmap to smart prosperity	Broad vision and roadmap for transition, outlining goals and general actions

[a] Luxembourg was the 2017 hotspot for the circular economy under an initiative of the "Circle Economy" network, to exhibit the progress made over the previous two years (Government of Grand Duchy of Luxembourg, 2018).

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	Health-related aspects	Key reports
	No specific health focus found in sources	State Council of the People's Republic of China (2013)
	General statements promoting the circular economy as enhancing environmental and human health and improving workforce health in Canada	Smart Prosperity Secretariat (2016)

Smart Prosperity Secretariat (2016). New thinking: Canada's roadmap to smart prosperity. Ottawa: Smart Prosperity Institute (http://institute.smartprosperity.ca/sites/default/files/newthinking.pdf).

State Council of the People's Republic of China (2013). Notice of the State Council on issuing the circular economy development strategy and near-term action plan. Beijing: State Council of the People's Republic of China (http://www.gov.cn/zwgk/2013-02/05/content_2327562.htm) (in Chinese).

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ANNEX 4. KEY ORGANIZATIONS AND NETWORKS ACTIVE IN THE CIRCULAR ECONOMY

Organization/ Network	Description	Circular economy activities
Aldersgate Group (United Kingdom)	Alliance of leaders from business, politics and civil society that drives action for a sustainable economy	Work on resource efficiency includes a particular focus on engaging EU institutions around the design of the EU's new circular economy package. 2017 report includes a range of case studies (such as those taking part in the REBus project funded by the EU Financial Instrument for the Environment –LIFE+) and policy recommendations on the need for the circular economy package
Alliance for Circular Economy Solutions (ACES) (Europe)	New collaboration of businesses and think tanks committed to ambitious circular economy policy in Europe, including the Green Alliance, the Aldersgate Group, Dutch Sustainable Business (De Groene Zaak), the Ecologic Institute, the Institute for European Environmental Policy and UnternehmensGrün	Working to secure a European circular economy package that generates new jobs and revenues while driving product innovation, secondary raw material use and new business models
CHEM Trust (United Kingdom)	NGO aiming to prevent human-made chemicals from causing long-term damage to wildlife or human beings	Engagement with chemicals of concern in the circular economy
Circle Economy (Netherlands)	Social enterprise to accelerate the transition to circularity	Development of practical solutions, international communication and engagement
Circular Change (Slovenia)	Platform for stakeholder engagement focusing on the circular economy	Mission to inform, educate, recognize leaders, interpret best practice and co-create pioneering case studies in the transition from the linear to circular business models
Circular Economy Institute (France)	Aims to promote and accelerate the transition to the circular economy	Functions as a national multistakeholder think tank allowing the pooling of expertise and good practices
Circular Impacts (EU)	EU-funded research project involving the Ecologic Institute, the Centre for European Policy Studies and Wageningen Economic Research	Project measuring impacts of transition to the circular economy based on concrete data and macroeconomic, societal, environmental and labour market indicators

	Circular economy health-related activity	Key reports and websites
	Health issues not covered in the circular economy reports reviewed	Aldersgate Group (2017) Website (http://www.aldersgategroup.org.uk/blog/tag:circular-economy)
	Health issues not covered in the circular economy reports reviewed	ACES (2017) Website (http://www.green-alliance.org.uk/alliancefor_CEsolutions.php)
	Raising awareness of health/toxicity issues in the circular economy	Website (http://www.chemtrust.org.uk/home)
	No specific health focus but inclusion of health implications in case study on textiles	Website (http://www.circle-economy.com)
	No specific health focus among case studies	Website (http://www.circularchange.com)
	No specific health focus	Website (http://www.govsgocircular.com/cases/the-circular-economy-institute)
	Categorization of impacts includes health, although no detail yet available	Rizos et al. (2017) Website (http://circular-impacts.eu/start)

Organization/ Network	Description	Circular economy activities
Club of Rome (global)	Promotes understanding of global challenges and proposes solutions through scientific analysis, communication and advocacy, with a holistic, systemic and long-term perspective	Research on social benefits of the circular economy, particularly carbon emissions and employment
DAKOFA (Waste and Resource Network Denmark)	Primary task to prepare the Danish waste and resource sector for navigating in a dynamic society	Circular economy project that looks at opportunities from a country and policy-maker perspective
EMF (global)	NGO with mission to accelerate the transition to a circular economy	Global leader in placing the circular economy on the agenda of decision-makers across business, government and academe
European Commission (EC) (EU)	EU executive arm	Circular economy action plan
European Environment Agency (EU)	EU agency providing independent information on the environment	Publishing a series of circular economy reports
European Sustainable Business Federation (EU)	Network of national associations promoting sustainable economic policies	Promoting concepts and projects fostering the circular economy
Foundation for Circular Economy (Hungary)	Initiative to promote circular economy in Hungary and worldwide	Primary aim to create platform for knowledge, experience and practice related to circular economy
Friends of the Earth (global)	International NGO network campaigning on environmental issues	Part of group of NGOs lobbying EC circular economy plans
Green Alliance (United Kingdom)	Charity and independent think tank focused on leadership for the environment. Works with businesses, NGOs and politicians.	The Green Alliance convenes the Circular Economy Task Force: business-led group (including Waste and Resources Action Programme (see below)) that researches policy solutions to enable a more circular economy. The Green Alliance is a member of ACES.
Health and Environment Alliance (HEAL) (EU)	Non-profit-making organization addressing how the environment affects health in the EU	Part of group of organizations commenting on EU waste and circular economy policies
Mc Kinsey Center for Business and Environment (Global)	Centre intended to provide insights and solutions so that economies and the environment can thrive	Collaborating with EMF and the SUN Institute on, for example, circular economy report (EMF, 2015b)

Circular economy health-related activity	Key reports and websites
Health only indirectly referenced in circular economy reports through health impacts of unemployment and carbon emissions	Wijkman & Skånberg (2015, 2016) Website (https://www.clubofrome.org/a-new-club-of-rome-study-on-the-circular-economy-and-benefits-for-society)
Link to case study on hospitals in Denmark given by EMF (2015a)	Website (https://dakofa.com/element/test-article-last-week)
Estimates of reduced environmental and health externalities from the circular economy transition; some health implications analysis in sector reports, e.g. for food, mobility and built environment	EMF (2015b, 2017) Information website (http://circulatenews.org) Website (https://www.ellenmacarthurfoundation.org)
Action plan acknowledges that actions should preserve a high level of protection of human health and environment.	EC (2015, 2017) Website (http://ec.europa.eu/environment/circular-economy/index_en.htm)
Publications acknowledge importance of health protection.	Website (https://www.eea.europa.eu/publications/circular-economy-in-europe)
No specific health focus	Website (https://ecopreneur.jimdo.com)
No specific health focus	Website (http://circularfoundation.org/en)
Health issues not a focus in the circular economy materials reviewed	Friends of the Earth Europe (FoEE, 2014) Website (https://www.foe.co.uk/page/what-circular-economy)
–	Benton & Hazell (2013), Benton et al. (2015), Green Alliance (2015), Hislop & Hill (2011) Website (http://www.green-alliance.org.uk/resourcestewardship.php)
Active in raising awareness of health issues (e.g. toxic substances, endocrine-disrupting chemicals) in the circular economy context	HEAL (2015) Website (http://www.env-health.org)
Estimates of reduced environmental and health externalities from the circular economy transition in reports	Website (http://www.mckinsey.com/business-functions/sustainability-and-resource-productivity/our-insights/europes-circular-economy-opportunity)

Organization/ Network	Description	Circular economy activities
REBus project (Netherlands and United Kingdom)	EU LIFE+ funded project pioneering resource-efficient business models (REBMs) for a circular economy	Set up to test the REBM methodology in a number of business case studies the Netherlands and the United Kingdom and promote the development of a circular economy
SUN Institute Environment & Sustainability	Supports institutions, programmes and projects on environmental challenges and opportunities of globalization and enhanced cross-border activities	Collaborating with EMF and the McKinsey Center on, for example, circular economy report (EMF, 2015b)
Think20 Circular Economy Task Force	Part of Think20 network of research institutes and think tanks from the Group of Twenty	Focuses on what Group of Twenty governments can do to accelerate the transition, transform value chains, and realize the benefits for society, the environment and the economy.
Waste and Resources Action Programme (WRAP) (United Kingdom)	NGO working with governments, businesses and communities to deliver practical solutions to improve resource efficiency	Broad range of activities for circular economy, including on resource efficiency, waste reduction, recycling and alternative business models; member of Circular Economy Task Force (see above)
World Economic Forum (global)	International organization for public–private cooperation	Launched Platform for Accelerating the Circular Economy, led by the Global Environment Facility, Royal Philips N.V. and United Nations Environment Programme (UNEP)
Zero Waste Europe	Knowledge network and advocacy group across the EU that promotes elimination of waste in society	Aims including to redesign relationship with resources, adapt consumption patterns and think circular

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	Circular economy health-related activity	Key reports and websites
	Includes health care sector pilot projects for medical technology companies and medical centres	Website (http://www.rebus.eu.com)
	Estimates of reduced environmental and health externalities from the circular economy transition in reports	Website (https://www.sun-institute.org/en)
	No particular health focus	Website (http://www.t20germany.org/circular-economy)
	Health issues not covered in the circular economy material reviewed	Website (http://www.wrap.org.uk/about-us/about/wrap-and-circular-economy)
	Has no specific health focus, but has collaborated on EMF reports	Website (https://www.weforum.org/projects/circular-economy)
	Specific campaigning on issues of designing out toxic substances from products and bans on specific hazardous substances in EU	Website (https://www.zerowasteeurope.eu/category/waste/circular-economy)

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The WHO Regional
Office for Europe

The World Health Organization (WHO) is a specialized agency of the United Nations created in 1948 with the primary responsibility for international health matters and public health. The WHO Regional Office for Europe is one of six regional offices throughout the world, each with its own programme geared to the particular health conditions of the countries it serves.

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