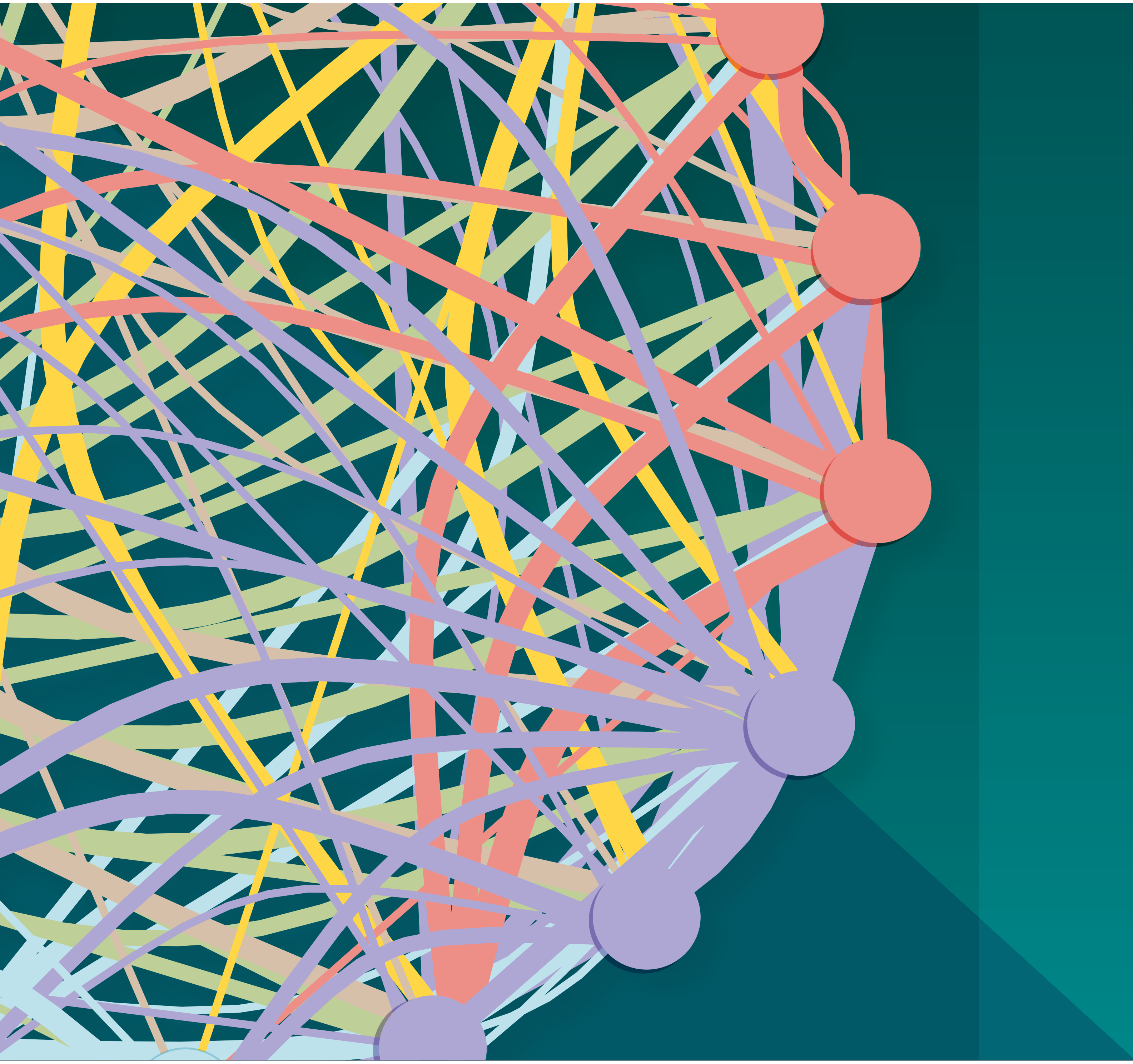
EEA Report | No 25/2019

Drivers of change of relevance for Europe's environment and sustainability

ISSN 1977-8449



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European Environment Agency

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Cover design: EEA
Cover photo: © EEA
Layout: Rosendahls a/s

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Luxembourg: Publications Office of the European Union, 2020

ISBN 978-92-9480-219-4
ISSN 1977-8449
doi:10.2800/129404

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Feedback from and discussions with the European Environment Information and Observation Network (Eionet) Eionet — via National Focal Points (NFPs) and NRC-FLIS from the EEA's 33 member countries and six cooperating countries.

Feedback from the colleagues from the European Commission — Environmental Knowledge Community (EKC): Directorate-General (DG) Environment, DG Climate Action, and Joint Research Centre

Foreword

The EEA's mission is to provide sound, independent and timely information on the environment to European citizens and policymakers, with the overall aim of supporting sustainable development in the EU and EEA member countries. As stressed in the EEA Regulation (EU, 2009), a key task of the EEA is to report on the state of, trends in and prospects for the environment on a regular basis. The publication of *The European environment — state and outlook* report (SOER) every 5 years fulfils this function, based on environmental data and indicators as well as the key findings of other environmental and sustainability assessments.

It is increasingly recognised that reporting on the environment in Europe, in particular regarding the prospects for its future evolution, cannot rely solely on environmental information. Indeed many 'drivers of change' that impact the environment and sustainability in Europe are not of an environmental nature and of European origin, as the world is becoming increasingly interconnected. They are however of crucial importance in determining Europe's long-term environmental and sustainability outlook (EEA, 2015b, 2019e). Furthermore, the knowledge base supporting environmental policymaking, traditionally rooted in quantitative analyses and modelling around specific issues, is now increasingly integrating qualitative approaches such as systems thinking, foresight and horizon scanning.

The EEA has been a key player in fostering a broader, more global and more systemic perspective in integrated environmental assessments through the publication of two assessments of global megatrends supporting SOER 2010 and SOER 2015 (EEA, 2010, 2015d) and in disseminating the culture of anticipation and preparedness within the European Environment Information and Observation Network (Eionet) across national environmental ministries and agencies, as reflected by the uptake of global megatrend assessments in countries' reporting activities (EEA, 2019e). By building on the experience of both the EEA and Eionet, this report aims to further expand the EEA knowledge base on key 'drivers of change' and potential futures for Europe's environment and sustainability. It presents a synthesis of global and European megatrends with illustrations of key emerging trends, wild cards and uncertainties, with the aim of informing about on-going, emerging and potential future developments, as well as raising awareness and contributing to the diffusion of anticipatory thinking.

Such endeavour is not an easy one. The future cannot be known a priori, all the more in today's world characterised by increasing volatility, uncertainty, complexity and ambiguity (VUCA) (Bennis and Nanus, 1985). However, it can be imagined. More precisely, alternative futures can be imagined, debated and pursued by actors. Identifying key drivers of change for the environment and sustainability in both a systematic and systemic way — as pursued by this report — provides a more accurate and sound knowledge base to ensure the plausibility of these different pictures of the future. Yet, the implications of future developments are perceived differently across societal groups and stakeholders, and often they are equally plausible (EEA, 2015d; EEA and Eionet, 2017). In order to ensure relevance, saliency and legitimacy — the three pillars of integrated environmental reporting according to the EEA (Eckley et al., 2001) — the report has been developed by engaging with several experts and stakeholders, including EEA staff, the National Reference Centres for Forward-looking Information and Services (NFC FLIS) network and external experts, as well as by establishing a Technical Advisory Board, and by building on institutional interactions within Eionet and the Environmental Knowledge Community.

The EEA, by increasingly adopting foresight and systems thinking approaches, plans to build further on this work, with the aim of improving the understanding of potential implications for systems of production and consumption in Europe, in the light of the ambitions recently introduced by the European Commission, such as the European Green Deal and other policies fostering transitions towards sustainability. By analysing 'drivers of change', this report already contributes to the understanding of potential changes relevant to Europe's environment and sustainability and provides insightful information concerning possible future scenarios and implications, so to better support policymakers in anticipating issues, managing risks and chasing opportunities.

Executive summary

Drivers of change

The world is becoming increasingly interconnected through flows of information, resources, goods and services, people and ideas, and this implies that changes occurring in one part of the world are likely to have a ripple effect on others. Europe, apart from having played a pivotal role in shaping global changes over the last centuries, is today highly intertwined with the rest of the world much more than ever before. Many '**drivers of change**' that impact the environment and sustainability in Europe are actually not of an environmental nature and of European origin, but they are crucially important in determining Europe's long-term environmental and sustainability outlook (EEA, 2015b, 2019e). As a result, there has been growing interest for systems thinking and anticipatory knowledge within EU institutions in view of designing better informed and ultimately more effective policies. The future of Europe's environment and sustainability is likely to be highly influenced by developments of societal, technological, economic, environmental and geopolitical natures, as well as changes in values and lifestyles. These 'drivers of change' differ from each other in relation to their origin, nature, likelihood, significance, geographical scale and timescale. Although some of them are well established and well known, some have just emerged, and their effects have not yet unfolded or are still unknown.

A variety of 'drivers of change' are characterised in this assessment with the aim of providing a 'rich picture' of the changes occurring at the global/European interface. These include **global megatrends** (i.e. global, long-term trends that are slow to form but have a major impact), **European trends** (i.e. well-established trends characterising Europe in particular), **emerging trends** (i.e. developments that are only emerging but are not yet well-established) and **wild cards** (i.e. unlikely but potentially disruptive future developments). Uncertainties concerning potential future developments, scenarios, projections, assumptions and narratives, are also accounted for in the assessment. Together, they represent a network of 'drivers of change' that are highly interlinked, as one development often co-evolves with others. Although it is difficult to disentangle them fully, a set of thematic clusters has been developed with the goal of exploring their characteristics, interactions and potential implications. As a result, this report spans the following thematic clusters:

- Cluster 1 — Growing, urbanising and migrating global population.
- Cluster 2 — Climate change and environmental degradation worldwide.
- Cluster 3 — Increasing scarcity of and global competition for resources.
- Cluster 4 — Accelerating technological change and convergence.
- Cluster 5 — Power shifts in the global economy and geopolitical landscape.
- Cluster 6 — Diversifying values, lifestyles and governance approaches.

The report provides an in-depth characterisation of these clusters, their components and interactions within and across clusters. A synthesis of the key findings and insights is provided below.

'The Great Acceleration' megatrends

From an historical perspective, since the onset of the Industrial Revolution in Europe in the second half of the 18th century, megatrends like technological development and increased access to natural resources, economic growth, improvement standards of living and consequent population growth, have mutually reinforced each other, contributing to growing demand for resources and environmental pollution. This pattern has been further strengthened since then and it has expanded to the global scale, leading to unprecedented growth in population, economy, demand for resources and environmental pollution. For example, the **world population** had increased dramatically from the year 1800 when 1 billion people were registered, reaching 7.7 billion in mid-2019 (UN DESA, 2019). **Global energy consumption** has grown 25 times from 1800 to the present day and has been largely based on non-renewable fossil fuels (85 % to 90 %). Similarly, the global **use of materials** (i.e. metals, fossil fuels, minerals and biomass) increased tenfold between 1900 and 2009 (Krausmann et al., 2009). From 1950 onward, the pace of growth in population, economic activity and resource consumption increased further. For example, the **global economic output** increased about 12-fold between 1950 and 2016 (Bolt et al., 2018), leading to enormous improvements in living standards and well-being for hundreds of millions of people, especially in Europe and other highly industrialised world regions. As a result, from the 1950s to the present day the world population experienced a fourfold increase, thanks to a combination of factors that led to a significant reduction in mortality rates.

Consequently, the sheer size of global population growth and the intensity of human activities has caused **tremendous pressures on the Earth's life support systems** through climate change, biodiversity loss, and changes in the chemical composition of the atmosphere, oceans and soil among others. The period after the 1950s marked a unique period in human history with **unprecedented and accelerating human-induced global change**. This has become known as **'the Great Acceleration'** (Steffen et al., 2011, 2015). Change is occurring on such a scale that human activities have now significantly altered the Earth's system from the stable Holocene to a new human-dominated epoch referred to as the Anthropocene (Waters et al., 2016). Human activities are estimated to have caused approximately 1.0 °C of global warming above pre-industrial levels, and global warming is likely to reach 1.5 °C between 2030 and 2050 if current rates continue in the future (IPCC, 2018). As a consequence of the pressures exerted on ecosystems, the Earth is experiencing an **exceptionally rapid loss of biodiversity**, and more species are threatened with extinction now than at any other point in human history (IPBES, 2019). Anthropogenic activities have unleashed a mass extinction event, the sixth in roughly 540 million years, wherein many current life forms could be annihilated or at least condemned to extinction by the end of this century (Ripple et al., 2017). In the last 50 years growing **global material demand** has led to nearly 90 % of biodiversity loss and water stress and approximately half of climate change pressures (IRP, 2019).

Climate change, loss of natural capital and **biodiversity**, and **pollution** are **highly interconnected** and mutually reinforcing. For example, climate change and growing pollution are likely to further increase the loss of natural capital and biodiversity by impacting natural and productive terrestrial and marine systems globally (IPCC, 2018, 2019a, 2019b); in turn, the loss of natural capital and related carbon stocks increases Greenhouse gas emissions (GHG), leading to climate change. While **tipping points** are fundamentally uncertain, exceeding them might lead to catastrophic consequences for the functioning of the planet's ecological system, including the human species (e.g. a loss of pollinators). In the most recent *The global risks report 2019* by the World Economic Forum, **environmental risks** accounted for three of the top five risks ranked by likelihood and four of the top five risks ranked by impact (WEF, 2019). Despite international agreements — such as the Paris Agreement, Aichi biodiversity targets and the Sustainable Development Goals (SDGs) — current trends indicate that these challenges are likely to worsen in the future, unless a fundamental reconfiguration of production and consumption systems occurs at the global scale.

Recent trends and outlooks: between challenges and opportunities

Many global developments in recent decades increase the likelihood of a continuation of these 'Great Acceleration' megatrends. Others, however, both at global and European scale, are less certain in their implications for the environment and sustainability, as the interactions between different developments bring an additional layer of complexity. An overview of such developments is provided below.

The role of demography and migration

According to the recent United Nations Department of Economic and Social Affairs (UN DESA) scenarios, the **global population is expected to increase** from its current figure of 7.7 billion to reach 8.5 billion in 2030, 9.7 billion in 2050 and 10.9 billion in 2100, with most of the projected growth expected in **urban areas** of developing countries (Cluster 1). In the long-term, the pace of population growth is expected to slow further, reaching a plateau or even decreasing towards the end of the century. Recent trends have shown that a large share of this increase was associated to **socio-economic development** (e.g. health care, wealth and education) which led to decreasing mortality rates, including child mortality, and consequent rise in global life expectancy, although gaps between regions remain. Similalry, fertility has been declining globally, a trend that in combination increased life expectancy, has led to an overall **ageing** of the global population. In fact, for the first time in the world's history, there are now more people aged 65 years or above than children under 5 years of age (Cluster 1).

The largest share of projected population growth is expected to occur mainly in sub-Saharan Africa, Northern Africa, Central and South-East Asia (with India becoming the most populous country in the world), although with important regional differences. Instead, East Asia and Europe are expected to observe stabilisation and subsequent decrease. For example, Europe is projected to have a **stable or declining population** in 2050, compared with 2019, as it is confronted with an ageing population (also occurring in China and Japan), with people older than 65 years representing 42 % of the total population in 2070 in comparison with 14 % in 2016 (Cluster 1).

The implications of these trends are multiple. While population growth in developing countries can be significantly limited by a **lack of access to basic resources** (e.g. water, food) and sanitation (Cluster 3), unless global inequality issues would be addressed, and jeopardize the achievement of the Sustainable Development Goals (e.g. eradication of hunger), **ageing might reduce public revenues** and create challenges for governments in developed countries. In the European Union, given low fertility rates and in the absence of migration, a declining and ageing population raises questions about a shortfall of working-age adults and **increased dependency ratio**, and poses challenges for social stability, taxation and public health systems (EEA, 2019e). On the other hand, this trend might create opportunities for **rethinking taxation** (e.g. shift from labour to environmental taxation) (Cluster 6).

Demographic aspects have also implications on international migration. In fact, some areas of the world, particularly where fertility rates are still high, are likely to experience **youth bulges** in the short term, which result in high shares of children and young adults, bringing both opportunities for economic growth (e.g. 'demographic dividend') and challenges for social cohesion if jobs are lacking (Cluster 1). This trend, alongside with continued global inequality between regions, and geopolitical tensions, is contributing to the increase of **international migrants** (Cluster 1). While at the global scale it concerns only 3 % of the population and it has mainly an intra-continental character, world regions have witnessed very different patterns, with high-income countries absorbing the majority of the net increase in the last few decades. While Europe is a key destination for **refugees**, especially because of geographical reasons and proximity of recent conflicts, Asia is becoming increasingly attractive as a destination for migrants, as a result of increased economic development. **Irregular migration** is unfortunately associated with high public's concern, contributing to xenophobia, populism and right-wing movements gaining ground across Europe. In the coming decades, environmental degradation and climate change are expected to become increasingly important drivers of migration globally (Cluster 2); however, future migration volumes remain highly uncertain (IPCC, 2018), as the main determinant of international migration is often geopolitical instability and insecurity.

The major shift in global economic power

Many of the demographic trends described above have been determined by **socio-economic change** and by the **shift in global economic power** (Cluster 5). Since the 1990s, much of global economic growth has been driven by **emerging economies**, such as Brazil, China and India, and translated in growing affluence in these regions. For example, **China's economy** grew on average 9.5 % annually between 1990 and 2017, compared with 1.7 % in the euro area (World Bank, 2020a). Moreover, measured in purchasing power parity (PPP), China's gross domestic product (GDP) surpassed the United States' GDP in 2013 (OECD, 2018b) (Cluster 5).

The fact is that China and many other developing countries are benefiting from a competitive advantage in labour-intensive manufacturing as a result of a cheaper workforce. Moreover, they are also massively investing in research and development. Together with access to integrated global production networks fostered by trade liberalisation and digitalisation, this has led to the rapid emergence of China and other Asian countries as the new '**workshop of the world**' (WTO, 2018a) (Cluster 5). In contrast, the EU's share of the global economy (in PPP terms) is shrinking and could be halved between 2000 and 2050, dropping from 28 % to 14 % (OECD, 2018b). More recently China emerged as a **global technological power** and overcome the EU concerning research and development investment rates (Clusters 4 and 5). From a geopolitical perspective, developed economies are no longer alone in investing in research and development (R&D). China, in particular, has already overtaken the EU in terms of R&D intensity and is rapidly emerging as a technological power (Cluster 5). Overall, R&D remains highly concentrated, as a small number of countries, companies and sectors account for a large share of the total R&D investment, pointing to potential issues concerning concentration of power. **Europe is lagging behind the United States and China in ICT-related innovation**. While R&D investments in China and other non-OECD countries are expanding, Europe is experiencing a stagnation in R&D intensity (Cluster 4).

From a **geopolitical perspective**, the United States remains the world's dominant power because of its economic and, above all, military and technological primacy. However, US dominance is not hegemonic, and a number of contesting powers are rising, and geopolitical power is increasingly defined outside the traditional battlefields (Cluster 5). As **economic power shifts**, emerging countries and regions may also seek to increasingly translate their economic gains into global influence.

Overall, the rapidly changing landscape of global economic power has led to increasing **geopolitical uncertainties** and **tensions in the global multilateral system** (ESPAS, 2015). This is seen in a waning of the consensus on the benefits of globalisation and trade liberalisation, resulting in countries turning away from multilateral agreements and increasing protectionist measures (EPSC, 2018b). Therefore, the future of **international trade** has become more uncertain in recent years, as a result of political elections in Western countries and China's reorientation towards its internal market (Cluster 5). For Europe, where exports represented more than 50 % of GDP in 2018, this is of great concern (EPSC, 2018b). Access to strategic resources (e.g. energy carriers and materials) (Cluster 3) is fundamental to sustaining competitive economies; given the uneven distribution of resources across the globe, much of the future geopolitical challenges will revolve around **trade agreements** and access to raw materials and international markets.

At the global scale, **rapid economic growth in developing regions** has lifted millions of people out of poverty in recent decades, and allowed a number of countries to reach middle-income status. In particular, emerging economies have been the main driver of a **fast-growing global middle class**, which reached 3.2 billion people in 2016 (Kharas, 2017) (Custer 5). Economic development has increased revenues for households and allowed governments to invest in social infrastructure and services (e.g. education, health and social security), contributing positively to increased life expectancy (Cluster 1). Nevertheless, **extreme poverty still exists**; for example in 2018, 6.2 million children died before reaching the age of 14 years, which is equivalent to more than the population of Denmark (World Bank, 2019b). From the perspective of consumption levels, Western societies are still better off than emerging economies. For example, when looking at GDP per capita, it is expected that China will remain just below 50 % of the EU value until 2035, suggesting that if the speed of structural convergence between economies is high, the gap itself will remain substantial for a long time.

The improvement of living conditions for a significant part of the world, alongside with maintained consumerism in Western societies, have occurred at a **significant cost to the environment**. While **international trade**, facilitated by liberalisation (e.g. limited tariffs) and digitalisation, has been one key factor behind the rebalancing of global economic output, its rapid expansion is associated with growing environmental pressures and resource consumption (Clusters 2 and 3). Industrialising countries, a rising global middle-class and international trade, are largely at the core of this mechanism.

The changing geography of resource demand and environmental pressure

In fact, newly **industrialising countries** build new infrastructure for accommodating a growing urban population and increase their manufacturing capacity, while high-income countries outsource the more material- and energy-intensive stages of production and subsequently import intermediate and final products. As a consequence of that, emerging economies have been responsible for most of the direct increase in **global consumption of metals** and two thirds of the **increase in energy consumption** over the past 20 years, with China on its own accounting for 83 % of the global increase in metal consumption and 48 % of the increase in energy consumption (World Bank, 2018).

Developed countries exert significant share of their environmental pressures and impacts abroad, through trade. For example, in 2011 nearly one third of Europe's energy footprint and nearly two-thirds of its land use footprint were occurring in other parts of the world. Similarly, recent estimates indicate that the EU carbon footprint is 27 % higher than GHG emissions associated with production in the EU (Wood et al., 2019). The **externalisation** of a share of environmental pressures to the other parts of the world may hinder the achievement of the Sustainable Development Goals, as this often occurs in countries where environmental regulation and governance is less effective than in the EU.

Future outlooks indicate that **global resource consumption** is expected to continue. Projections suggest that there will be a doubling of demand for materials by 2060 (IRP, 2019), raising concerns about access to key primary and secondary raw materials and posing a challenge to economies that are highly dependent on materials from international markets, such as Europe (Alessandrini et al., 2017). According to the IRP scenario 'Towards sustainability', which sees the implementation of resource efficiency and sustainable consumption and production policies to promote stronger economic growth, improve well-being, help to support a more equal distribution of income and reduce resource use across countries, long-term resource demand would be reduced by 25 % compared with the 'Historical trends' scenario, while GDP would still grow by 8 % (IRP, 2019). However, recent findings challenge the assumption that green growth and relative decoupling could be enough to reduce resource consumption and related environmental pressures, unless consumption levels are limited at the same time. Other projections in resource demand point towards additional challenges.

Demand for oil is expected to increase further and the potential mismatch between supply and demand is likely to create significant risks around 2025, as the expansion of oil shale gas will not be enough to compensate for the continued absence of new conventional oil projects. Meeting oil supply demand in the coming decades, because of rising petrochemicals, trucking and aviation demand worldwide, would require a twofold increase in new conventional oil, a rather unlikely possibility (IEA, 2019a). At the same time, the **electricity sector** is experiencing a fundamental transformation because of the declining costs of renewable energy technologies and increased digitalisation, and power generation through renewable energy is projected to grow further (Cluster 4).

The **global demand for land** is projected to grow, particularly as 25 % to 100 % more food may be required globally by 2050, depending on socio-economic and technical assumptions (Hunter et al., 2017). Demand for biofuels is also expected to rise (OECD and FAO, 2018) and agriculture is projected to be increasingly compromised by the combined effects of climate change and soil degradation (UNCCD, 2017). Moreover, changes in lifestyles and affluence in the East are contributing significantly to increased demand for agricultural land and pastures, in response to increased consumption of meat. Projections indicate that such expansion is likely to occur at the expense of natural ecosystems and biodiversity hotspots and also as a result of international 'land grabbing'. The **global demand for water** is projected to rise by 55 % by 2050, assuming a continuation of current policies and socio-economic trends (OECD, 2012). Today, 1.9 billion people live in severely **water-scarce regions**, and this number could increase to 5.7 billion by 2050 (UN Water, 2018b). Because of climate change, water scarcity could impact southern Europe in particular (Veldkamp et al., 2017). Environmental degradation worldwide creates social and economic impacts and contributes to **increasing inequalities** (Cluster 5) as well as regional and international migration (Cluster 1), influencing people's quality of life and health as well as their experience and interaction with nature (Cluster 6).

The **geography of environmental pollution** is also changing as a result of global shifts in economic power. For example, **air pollution**, the main environmental contributor to the global burden of disease contributing to 6 to 7 million premature deaths annually, has improved in developed economies, albeit at different paces, while emissions have been on the rise in developing countries and emerging economies in the last decade. The highest **death toll** is in East Asia and South Asia, as cities in these regions have a very large population and high levels of pollution. Although in recent years emissions of SO_2 and nitrogen oxides (NO_x) have begun to decline in East Asia, the dynamics governing rapid development and urbanisation, coupled with insufficient environmental governance, are likely to worsen air pollution in the future, unless additional policy interventions are put in place. **International agreements** have a fundamental role in addressing specific pollutants and chemicals. While successful in some cases, such as the Montreal Protocol, whose implementation led to the decline in emissions of ozone-depleting substances by more than 99 % between 1990 and 2016 (UN Environment, 2019c), there is still much to be done to curb the highest death toll associated with air pollution.

Pollution increasingly affects water quality too. Although 1.5 billion people gained access to basic drinking water services over a 15-year period from 2000 to 2015, nearly 2.3 billion people still lack **access to safe sanitation**, (UN Environment, 2019b). This has led to 1.4 million deaths annually from preventable diseases associated with pathogen-polluted drinking water and inadequate sanitation. Remarkably, **water quality** has worsened in most of the world's regions since 1990, mainly because of organic and chemical pollution, including pathogens, nutrients, pesticides, sediments, heavy metals, plastic and microplastic waste, persistent organic pollutants and salinity (UN Environment, 2019). Pollution from plastic waste is also a growing issue. For example, marine litter is now found in all oceans and at all depths, while e-waste is becoming a growing concern.

Growing emissions of pollutants to air, soil and water, as well as demand of resources such as land, biomass, minerals, metals and fossil fuels, are increasingly affecting **natural capital, biodiversity and climate change,** which create, in turn, growing impacts to humans. For example, **rising global temperature** alters weather patterns and in turn has impacts on the environment, the economy and society, threatening the livelihoods, health, water, food and energy security of populations (UN Environment, 2019c). Many land and ocean ecosystems and some of the services they provide have already changed because of global warming (IPCC, 2018). The continued loss and rapid decline of coastal marine ecosystems, which are among the most productive systems globally, reduce their ability to protect shorelines and the people and species that live there from storms, as well as their ability to provide sustainable livelihoods (IPBES, 2019).

Overall, **environmental degradation worldwide** creates social and economic impacts and contributes to increasing inequalities (Cluster 5) as well as regional and international migration (Cluster 1). Environmental degradation influences people's quality of life and health as well as their experience and interaction with nature but it also leads to increased awareness about these issues (Cluster 6).

Without drastic emissions abatement measures globally, in the coming two to three decades, continued global warming is expected to increase the likelihood of severe, pervasive and irreversible consequences, such as the collapse of natural ecosystems (the Arctic, coral reefs, the Amazon rainforest), the erosion of global food security and the displacement of people at unprecedented scales (EEA, 2019e). Despite the establishment of the Paris Agreement, at the global scale, governments are planning to produce about 50 % **more fossil fuels by 2030 than would be consistent with a 2 °C pathway** and 120 % more than would be consistent with a 1.5 °C pathway (SEI et al., 2019). These values also surpass production levels consistent with the implementation of the national climate policies and ambitions underpinned by nationally determined contributions at the heart of the **Paris Agreement** (SEI et al., 2019) (Cluster 2). At the same time, **increase in global meat consumption** (Clusters 5 and 6), conversion of land for cattle grazing and animal feed production and the intensification of the global food system (e.g. reliance on high inputs of chemical fertilisers, pesticides and preventive use of antibiotics) are expected to impact terrestrial ecosystems, leading to further soil erosion and compaction, reduced water filtration and availability, and biodiversity decline.

All of the trends above point towards a growing amount of challenges that might prevent the achievement of the Sustainable Development Goals, in Europe and globally, unless major actions are taken at the international scale. However, the trends described above are not the only ones influencing future developments and the potential to achieve SDGs. **Changes in technologies, values, identities, work and governance,** which are more complex to characterise and uncertain in their implications, bring about challenges, risks but also opportunities for sustainability.

Technological innovation: between challenges and opportunities

According to several authors, **technological innovation** is currently accelerating, mainly fuelled by the **widespread digitalisation** of economies and societies worldwide (Cluster 4). For example, while electricity took almost half a century to reach 25 % of the US population, the worldwide web and smartphones took less than 10 years to achieve similar market penetration (Kurzweil, 2005). Our world is now **hyperconnected**, and all individuals, firms and markets are affected by the digital transformation, although adaptation remains unequal.

Widespread digitalisation is the key enabler of the **'Fourth Industrial Revolution'**, which fuses digital technologies with the physical and biological worlds — a trend referred to as 'technology convergence' (Cluster 4). Largely enabled by the Internet of Things (IoT), this is expected to provide **opportunities** for more integrated and efficient industrial processes, personalised production, **new jobs and economic growth**. However, digitalisation is currently **changing the nature of jobs**, creating new opportunities and risks, and requiring the development of new skills (Cluster 6). There is a real risk that, because of further automation, more jobs will be lost than created, and that job losses and creations will affect occupations, sectors and countries unequally. Alongside with automation, it might contribute to weakening the welfare system (Cluster 6). The development of **digital platforms**, alongside with the diffusion of smart devices and the emergence of the **'on-demand' economy**, has enabled the diffusion of business models whose success is largely dependent on their ability to escape fiscal or social regulations (e.g. taxation and social contribution), leading to **precarious forms of work**, low wages and job insecurity (Cluster 6), besides opportunities for economic development and creation of new jobs.

Other **enabling technologies**, such as additive manufacturing, nanotechnology and biotechnology, continue to develop, and concerns for human health and the environment are still significant (Cluster 4).

Emerging digital technologies, such as big data analytics, artificial intelligence and blockchain (Cluster 4), offer tremendous opportunities in each aspect of everyday life, however implications from an ethical, **privacy and security** perspective are significant and are causing increasing concerns within society. Today, **data ownership** is concentrated, with international bandwidth use shifting towards giant content providers such as Amazon, Google, Facebook and Microsoft (OECD, 2019d). However, the key issue is how data are used. Concerns are being raised regarding issues such as illegal social media manipulation for influencing results of political elections (e.g. in Europe and the United States); the use of big data analytics for mass surveillance; protection and security of sensitive data. A hyperconnected world, increasingly relying on smart infrastructure (Cluster 4), is also more vulnerable to massive **cyberattacks** that can disrupt energy provision, business activities and electoral processes alike. Cybersecurity specialists refer to government-sponsored cyberattacks as advanced persistent threats.

Technological developments such as digitalisation, hyperconnectivity and the ever-increasing penetration of **social media** in all aspects of life, information have also contributed to new socio-political phenomena regarding **access to information**, the diffusion of **'fake news'** and the polarisation of public opinion (Cluster 6). Hence they play a fundamental role in matters of security and democracy, raising serious ethical concerns and creating also new challenges for the governance of sustainability transitions.

Overall, **the sustainability outcome of technological innovation is difficult to anticipate**. 'Sustainability-driven' technologies are potentially beneficial to the advancement of sustainability (Clusters 2 and 3). However, because of their non-linear character, technological 'solutions' to complex problems (e.g. GHG emissions) may lead to **unintended consequences** when scaled up at the system levels (e.g. indirect land use change, loss of biodiversity and increased competition for land resulted from biofuels production). The governance of innovation through principles and approaches such as the **precautionary principle** and **responsible research and innovation**, alongside with foresight, could help in anticipate potential challenges.

Technological development (Cluster 4) can help to **mitigate local impacts**, but at the global scale increased efficiencies have historically contributed to further economic growth (Cluster 5), demand for resources and global environmental impacts (Clusters 2 and 3). For example, the **digital economy** may turn out to be more resource intensive than expected, particularly because of energy consumption associated to IT infrastructure and the widespread use of **personal electronic devices**. While these devices might contribute to reduce direct energy demand locally, **global energy demand** could increase driven by ICT infrastructure and growing production of households' electronic objects (Hittinger and Jaramillo, 2019). Digitalisation is also contributing to a significant increase in **extraction of raw materials**, new dependencies (e.g. CRMs) and to a rapid increase in **waste** electrical and electronic equipment (WEEE), leading to significant environmental and social implications in Europe and elsewhere. Instead, lowering **material standards of living** could lead to lowering overall demand for resources and emissions, but such changes would require a fundamental rethinking of society and lifestyles, which are currently entrenched in consumerism (Cluster 6).

Global changes in identities, values and culture

Besides technological change, in the last few decades **identities, values and cultures** have changed as a consequence of **globalisation**, trade liberalisation (Cluster 5) and digitalisation (Cluster 4). In emerging economies, this has been accompanied by increasing income (Cluster 5) and the adoption of Western lifestyles (e.g. **consumerism**). In contrast, in developed economies, such as Europe, ageing populations (Cluster 1) in combination with weak economic growth (Cluster 5) and rising national debts in the aftermath of the 2008 financial crisis (Eurostat, 2018a) have posed **unprecedented challenges for welfare systems** and created **discontent and inequality**, which in turn has become one of the largest obstacles to environmental sustainability (UN Environment, 2019c). For example, in most of the EU countries **the middle class has contracted**, as a result of the 2008 financial crisis and structural labour market changes (ILO, 2016). Moreover, despite corrective measures have been taken after the 2008 financial crises, the international financial system remains a source of concern for future economic development, as global debt continues to grow.

At the same time, **inequalities within countries** have been rising in Europe and emerging economies (OECD, 2015b). The prospects for the global middle class are highly uncertain, with some studies suggesting that their share of global wealth might decline in the coming decades, whereas the wealth of the top 1 % of the global population, which captured 27 % of total income growth during the period 1980-2016, might increase further (WIL, 2017). There is a risk that the younger people in Europe today could be less well off than their parents, with **unemployment among young people** (under 25 years), at 18.6 % in 2017, being markedly higher than the overall unemployment percentage (8.2 %) (EC, 2017j). These inequalities can jeopardise the collective efforts required to achieve the Sustainable Development Goals. In parallel, **new work patterns and lifestyles** are emerging. With rapid and pervasive technological change, more jobs are likely to be automatised (Cluster 4), and demand for high-skilled qualifications is expected to rise (IPPR, 2015). While **creating new opportunities, this poses challenges for individuals**, such as increasing mobility needs, and for governments, such as the need to prevent mass unemployment and job insecurity. The gig economy and the benefits of working flexibly also have the potential to adversely affect workers' rights, health, safety and mental well-being. For example, more than 50 % of independent workers in Europe are not covered by unemployment benefits (OECD, 2017b).

Several of the trends described above, such as the **erosion of the European social model**, the 2008 financial crisis, unemployment, migration, social and economic inequalities (real or perceived), worries about the downgrading of the West, higher individual expectations and fundamental disruptions brought about by technological advancements in values, identities and social norms have contributed to a **rapidly changing political landscape** among Western societies. Consequently, the inability of existing political parties to respond efficiently to these concerns and challenges has largely fostered the rise of **populist movements** and growing **distrust in institutions**. In connection to that, the values and founding principles of our society are also challenged by the emergence of the so-called **'post-truth'** trend. Standards of public communication based on truth telling, which societies have taken decades or even centuries to establish, are becoming increasingly vague and negotiable (NIC, 2017). Together with the increased role of **social media** in our lives (Cluster 4), the spread of **fake news** has contributed to the **polarisation of debate** and the creation of 'echo chambers' in which interest groups largely interact only with people with similar views (Calais Guerra et al., 2013).

As a result of the above trends, **governance systems** at all levels (global, national, and regional) are under increased pressure because of mounting challenges. Concerning environment and sustainability aspects, the effectiveness of intergovernmental collaboration has often been questioned, in particular in relation to the non-enforcement of agreed rules or international commitments. This is creating a need for new forms of governance and institutions at local, regional and global levels.

At the same time, other **non-state actors**, such as non-governmental organisations and multinational firms, are increasingly challenging traditional power relations (Ruggie, 2018). In particular, the **power of transnational companies** (Cluster 5) has risen significantly, compared with the power of governments, and has reached a point at which around 10 % of the world's corporations generate 80 % of all profits globally, with a handful of companies controlling, for example, nearly 90 % of the information technology sector, as reported by Folke et al. (2019). Such **concentration of power** increases their influence in shaping standards and norms, limits the ability of governments to respond to global sustainability challenges through national regulations, and creates imbalances concerning research and knowledge production, influencing public discourse and policymaking.

'Glocalisation', an emerging phenomenon in governance, is seeing in particular an increased role for global governance and institutions and local governments, with a declining and secondary role for national and provincial levels of government. In fact, there is a wider trend in the **empowerment of city governance** (Cluster 1) with cities, and particularly megacities, gaining autonomy, setting social and economic standards, and becoming increasingly important subnational actors. For example, **city networks** and associations already have a recognised role in shaping global agreements, including climate and sustainability (Vandecasteele et al., 2019). At the same time, cities harbour numerous forms of **emerging social innovations**, such as the sharing economy, community-oriented forms of living, 'prosumerism' and slow-food movements. **Experimentation activities** in cities, such as establishing a network of 'European living labs', have been suggested as a useful way to test innovative mobility solutions with the direct involvement of people. This would allow decision-making to explicitly take into account citizens' visions and needs (Alonso Raposo et al., 2019), including moral, ethical, environmental and legal concerns associated with the uptake of new technologies in cities (e.g. driverless mobility).

Together with the experimentation of governance approaches, **sustainable lifestyles** are also increasingly embraced by people in Western societies, especially by younger generations (e.g. 'millennials'), often motivated by climate and environmental concerns. The **dominant economic paradigm** is also increasingly questioned in relation to sustainability and alternative narratives exploring sufficiency as a complement to efficiency are being discussed in society. Nevertheless, tensions exist between people's motivations and their actual behaviours because of a number of social, cultural, economic and psychological lock-ins (e.g. consumerism), as well as institutional, legal and infrastructural constraints. The dominant system of socio-economic organisation worldwide, the neoliberal market capitalism, has a significant role in preventing fundamental reconfigurations of consumption and production. According to (Kemp et al., 2016), while 'governments are **locked-in to the economic growth paradigm** socially and environmentally harmful, partly because of the need to maintain employment levels and finance the welfare state', 'individuals are locked into a cycle of 'work and spend' by consumption competition and labour market rigidities that prevent people working shorter hours'.

Reflections on Europe's ambition for a sustainable future

The trends above point to the changing global/European landscape, the existence of persistent sustainability challenges and new risks, as well as to the many opportunities. Their implications for the achievement of Europe's sustainability ambitions are likely to be major ones. In fact, the desired transformations towards sustainability will not occur in a vacuum. Policies aimed at transforming production and consumption systems, such as the foundations for a sustainable future in Europe (EC, 2019f), will need to take into consideration the **changing landscape** of global relations, the emergence of social and technological innovations, and the concerns of European citizens. All of these generate not only new challenges and opportunities for sustainability but also — within an increasingly complex and interconnected world — many uncertainties.

Although many **uncertainties** concerning the direction of such changes remain, one message clearly stands out for Europe: **its role in the global arena is changing**, and this creates new risks and opportunities of an environmental, social, economic and strategic nature. At the same time, Europe is faced with internal challenges, as the European project is being challenged more so than ever before.

Regarding the environment, while progress in reducing some key environmental pressures has been made (e.g. some emissions to air), policies have had a clearer impact in reducing environmental pressures than in protecting ecosystems and biodiversity, human health and well-being (EEA, 2019e). The outlook towards 2030 is not positive in many areas, particularly in relation to natural capital. Moreover, the prospects for meeting policy objectives and targets show that Europe is either not on track or only partially on track to achieve the majority of objectives and targets (EEA, 2019e). New implications concerning health and well-being, the security of the resource base underpinning Europe's economy and the ability to protect nature and biodiversity are likely to unfold because of multiple drivers of change.

The EU has the **opportunity to reposition itself** in front of the upcoming environmental, sustainability and strategic challenges and chase the opportunities that lie ahead. European citizens and their representatives, as well as a variety of actors across society, including citizens, civil society and entrepreneurs, are called to action to respond to the challenges, chase opportunities and anticipate and mitigate risks. However, **sustainability policies** in the EU will have only a limited impact on the planet if others pursue opposing strategies (e.g. the EU currently contributes 8.5 % of global emissions of GHGs), and, therefore, **international cooperation** will become ever more important. **Citizens and civil society** now have greater opportunities to not only engage in societal innovations, through experimentation with different behaviours and lifestyles but also re-discuss established framings and contribute to redefining priorities.

Although the EU is responding to these challenges with established policy frameworks and by pursuing international environment and sustainability stewardship through the Green Deal (EC, 2019c), many of these **persistent problems** resist traditional policy responses, as they are intrinsically linked to unsustainable but well-established patterns of production and consumption. If Europe is to achieve the SDGs, the Paris Agreement and the 2050 vision, it needs to fundamentally transform its core production and consumption systems, in particular those related to food, energy, and mobility (EEA, 2019e), as well as the built environment (EC, 2019f). This requires rethinking not just technologies and production processes but also **consumption levels and social practices** (EEA, 2019e). Furthermore, the scale, depth and speed of change needed imply that careful attention should be paid to **the social implications** of these transformations, in particular distributional aspects (EC, 2019f).

The paradigm of 'infinite growth' is being increasingly challenged. Protesters are putting pressure on policymakers by calling for urgent actions and change in priorities and demanding a stepping-up of efforts concerning protection of the Earth's climate and ecosystems. However, the perspective of reductions in consumption may not be particularly appealing to a significant share of the population, especially those suffering because of inequality and a lack of opportunities. Transitions to sustainability must be **'just' and 'fair' transitions** for people, else they will fail. European policymakers will have to balance between these instances while navigating a more uncertain and complex global landscape.

1 Setting the scene

1.1 The changing landscape

1.1.1 Europe in an increasingly complex and uncertain world

Europe has played a pivotal role in shaping global changes over the last centuries and is today highly intertwined with the rest of the world in numerous ways, for example through trade, financial flows and geopolitical processes, flows of information, resources, goods and services, people and ideas (EEA, 2015d, 2019e). This means that production and consumption systems in Europe are not isolated from one another or the rest of the world. Instead, they are influenced by multiple 'drivers of change'. For example, global population growth accompanied by the rise of a global middle class are intensifying many environmental challenges, while rapid technological change carries new opportunities, risks and uncertainties. At the same time, Europe contributes to environmental pressures in other parts of the world, for example through globalised supply chains that satisfy the patterns and levels of consumption of European citizens. Several drivers of change that impact the environment and sustainability in Europe are actually not of an environmental nature or of European origin, but they are of crucial importance in determining Europe's long-term environmental and sustainability prospects (EEA, 2015b, 2019e). Sometimes these drivers of change are well established and well known; sometimes they have just emerged, and their effects have not yet unfolded or are still unknown. Recent years have been a profound reminder of this. Indeed, a number of new and unexpected developments have occurred recently at both European and global scales. These include the 2008 financial crisis, 'Brexit' (for the very first time one of the Member States has left the EU), the rise of populism in the West, terrorist attacks in the heart of Europe, migration to Europe, disruptive technological developments and growing citizen engagement with climate action. From a European perspective the world may seem increasingly complex, uncertain and 'ambiguous', as the claim of 'the end of history', supposedly established by an irreversible mainstreaming of the Western liberal democracy model across the globe (Fukuyama, 1989), is clearly buried. Far from this situation, the world is entering a new phase full of uncertainties, in which the resilience of Western democracies is challenged.

1.1.2 A growing anticipatory culture within EU institutions

Against this backdrop there has been growing interest in anticipatory knowledge within EU institutions. The recognition of the changing global landscape, the acceleration of technological change and growing unknowns have led EU policymakers to develop literacy and capacity in foresight, horizon scanning and other forward-looking assessments (see, for example, the EU better regulation guidelines; EC, 2015a, 2019a). This has also been translated into the establishment of a number of dedicated services, including the European Strategy and Policy Analysis System (ESPAS), the Scientific Foresight and Global Trends units of the European Parliamentary Research Service (EPRS), the European Political Strategy Centre (EPSC), the EU Policy Lab of the Joint Research Centre of the European Commission (JRC), as well as other foresight units across EU institutions (such as the EEA), besides the long-established Panel for the Future of Science and Technology of the European Parliament (STOA). Very recently, the nomination of a Vice-President of the European Commission for 'interinstitutional relations and foresight' has reaffirmed the strategic importance of anticipatory knowledge.

As a result, the knowledge base underpinning policy analysis and decision-making is evolving. For example, two recent high-level policy documents of the European Commission — the reflection papers *White paper on the future of Europe and the way forward* (EC, 2017i) and *Towards a sustainable Europe by 2030* (EC, 2019f) — refer explicitly to global megatrends and make use of scenario analysis. Similarly, the definition of Horizon Europe — the EU framework programme for research and innovation 2021-2027 — was informed by the *BOHEMIA* study, which provided a long-term view on the challenges and opportunities for research and innovation in Europe (EC, 2018m). The JRC has developed an online, dynamic and collaborative repository of information on global megatrends (EC, 2018l), as well as a stakeholder engagement tool to foster foresight literacy in policymakers. Finally, recent policy initiatives within EU institutions, such as the FORENV project ([1]), point towards an increased interest in foresight as a means of exploring the implications of a wide range of drivers of change on environment and sustainability.

The knowledge base supporting environmental policymaking, traditionally rooted in quantitative analyses and modelling around specific issues, is also integrating more qualitative approaches. In this context, the EEA has been a key player in fostering a broader, more global and more systemic perspective in integrated environmental assessments through the publications of two assessments of global megatrends supporting *The European environment — state and outlook* report (SOER) 2010 and SOER 2015 (EEA, 2010, 2015d). Moreover, a methodological toolkit for assessing the implications, risks and opportunities of global megatrends for the environment (EEA and Eionet, 2017) was developed through cooperation between the EEA and the National Reference Centres for Forward-looking Information and Services (NRC FLIS) ([2]). The application of this approach at regional and country levels has contributed to disseminating the culture of anticipation and preparedness within national environmental ministries and agencies, as reflected by the uptake of forward-looking perspectives in many of their reporting activities (EEA, 2019e). By building on this experience, this report aims to further expand the EEA's knowledge base on potential futures for Europe's environment and sustainability to better support policymakers in anticipating issues, managing risks and chasing opportunities. The report has also the objective of complementing the preliminary findings introduced in SOER 2020 (EEA, 2019e).

1.2 Objectives, approach and limitations of the assessment

1.2.1 Objectives

The EEA's mission is to provide sound, independent and timely information on the environment to European citizens and policymakers, with the overall aim of supporting sustainable development in the EU and EEA member countries. As stressed in the EEA Regulation (EU, 2009), a key task of the EEA is to report on the state of, trends in and prospects for the environment on a regular basis. The publication of the SOER every 5 years fulfils this function, based environmental data and indicators as well as the key findings of other environmental and sustainability assessments.

This work has the overall objective of better understanding the changing global/European context and identifying drivers of change of potential relevance for Europe's environment and sustainability, by further developing the EEA's previous work, notably its assessments of global megatrends (EEA, 2010, 2015d). In particular, it has the further ambition of including in the assessments a wider set of drivers of change that interact with global megatrends, such as more European-specific trends, emerging trends and wild cards (see section 2.1). Overall, it provides a 'rich picture' of the landscape of drivers of change that are likely to influence Europe in the decades to come, and it facilitates the analysis of potential implications for Europe, such as challenges and opportunities for meeting sustainability objectives. As indicated in Figure 1.1, while this assessment focuses on the characterisation of drivers of change, it already points towards potential implications for Europe's environment and sustainability goals.

1.2.2 Approach to the assessment

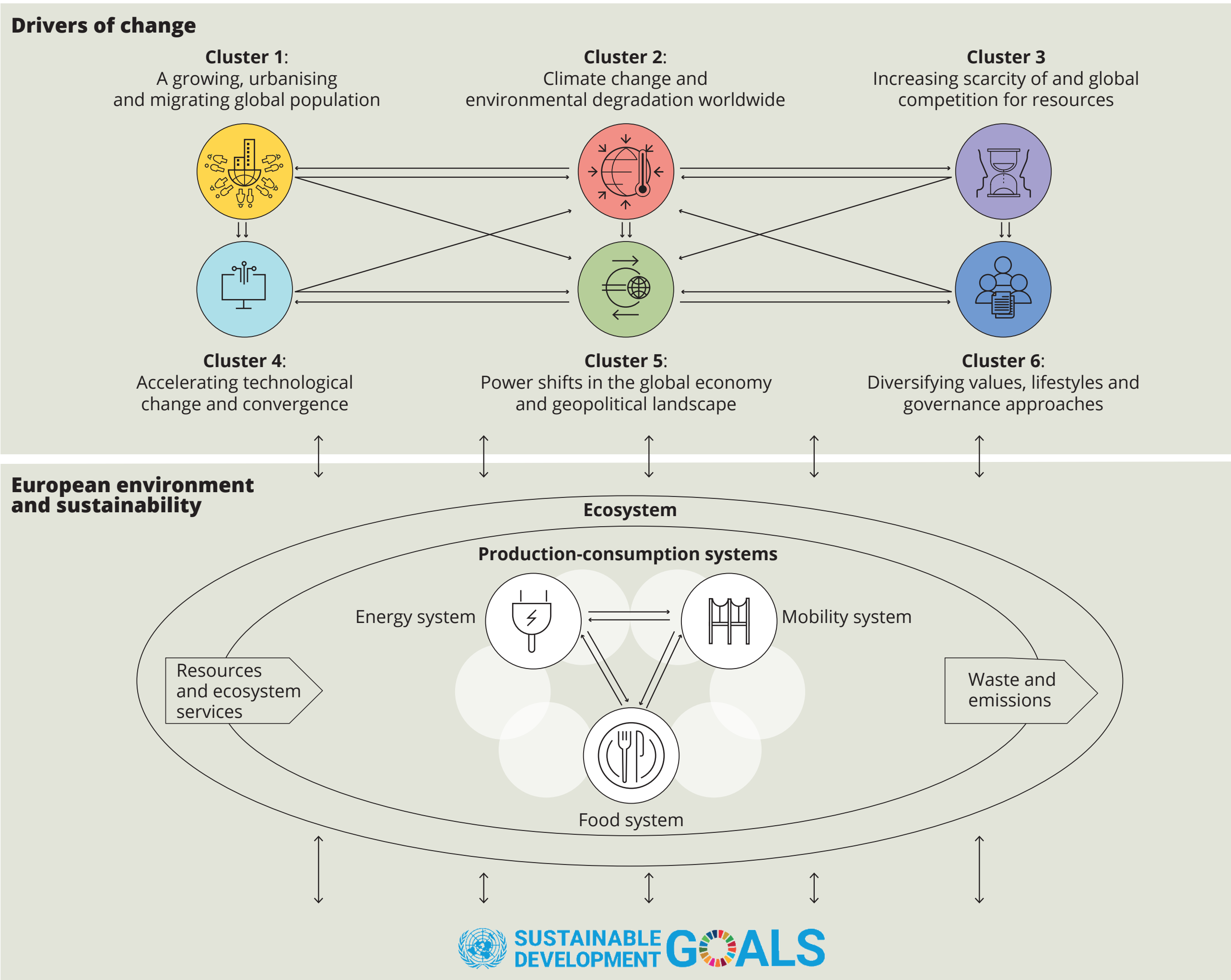
The approach adopted in this assessment relies primarily on foresight and systems thinking, as they are appropriate tools for dealing with the volatile, uncertain, complex and ambiguous (VUCA) nature of real-world situations and for the exploration of potential developments (Bennis and Nanus, 1985). In fact, the future cannot be known a priori, it can only be perceived and imagined in different ways, while the implications of such 'imagined futures' are perceived differently across societal groups and stakeholders (EEA, 2015d; EEA and Eionet, 2017).

In operational terms, the approach combines desk research and participatory processes (i.e. workshops and engagement of institutional stakeholders). To ensure, relevance, saliency and legitimacy — the three pillars of integrated environmental assessment according to the EEA (Eckley et al., 2001) — the report has been developed by engaging with several experts and stakeholders, including EEA staff, the NRC FLIS, external experts and contractors commissioned by the EEA, as well as by establishing a Technical

([1]) FORENV is a participatory horizon-scanning initiative of the European Commission, in cooperation with the EEA and the NRC FLIS (see below), that aims to identify, characterise and communicate emerging environmental issues.

([2]) NRC FLIS is part of the European Environment Information and Observation Network (Eionet), a partnership network of the EEA and its member and cooperating countries.

Figure 1.1 Logic of the assessment



Source: EEA.

Advisory Board, composed of additional EEA staff, experts from the Scientific Committee of the EEA, members of the European Commission's JRC and the Directorate-General of the Environment and Eionet and NRC FLIS members. Moreover, as for all EEA reports, this document was subject to Eionet review — a process that allows EEA member countries and other EU institutions to provide feedback useful for revision of the content — as well as a review within the Environmental Knowledge Community ([3]).

As the knowledge base underpinning global and European trends has grown substantially in recent years, and in consideration of the deep uncertainty or 'ignorance' characterising our limited understanding of complex issues, the identification and characterisation of drivers of change draws upon very heterogeneous sources that differ in terms of their nature (i.e. foresight processes, model-based assessments, integrated assessments, scientific articles, reports, research projects, opinion pieces and other literature sources), time-scales (ranging from historical trends to future scenarios) and viewpoints (ranging from consensus-based experts opinions to individual opinion pieces). While heterogeneity might sometimes limit their comparability this should not be considered as a fundamental limitation of the assessment, as 'knowing' is not the only objective of foresight.

([3]) The Environmental Knowledge Community (EKC) is an informal group composed by five services of the European Commission (DG Environment, DG Clima, DG Research and Innovation, DG Estat and the Joint Research Centre) and the European Environment Agency, which aims at improving the way environmental knowledge is generated and shared for EU policies. See also: https://ec.europa.eu/environment/integration/research/environment_knowledge_en.htm

On the contrary, the value of foresight is as much in the psychological processes (e.g. 'thinking', 'perceiving', 'feeling' and 'imagining') as in the substantive cognitive product and thus there is less of the traditional demand to be 'factually correct' about potential future developments and more demand to be 'practically useful' (e.g. point to issues of potential relevance and plausible mechanisms). This approach is fully in line with requirements and quality criteria for foresight for sustainability transitions (Jakil, 2011).

Nevertheless, it is important to recognise that the tension between the broad scope of the analysis and the production of a concise report has inevitably led to a limited selection of themes. Although any selection can be questioned, this report has relied largely on previous synthesis works to ensure a comprehensive overview. Moreover, examples, illustrations and case-studies are used to describe cascades of drivers with direct and direct drivers acting on each other in complex ways, which would be inherently difficult to characterise fully. By challenging current assumptions and world-views in some of its parts, this assessments invites the readers to think differently about what they know, what they think they can know and how they know, as its value rests in its quality of 'knowledge product' as much as in its ability to stretch thinking, creativity, etc.

2 Drivers of change

2.1 Overview

As the world is becoming increasingly interconnected through flows of information, resources, goods and services, people and ideas, changes occurring in one part of the world are likely to have a ripple effect on others. As a consequence, the future of Europe's environment and sustainability is likely to be increasingly shaped by a multiple factors that interact in a complex and largely unpredictable way.

These factors altogether are referred in this assessment as '**drivers of change**'. They differ from each other in terms of their origin, their nature, their likelihood, their significance, their geographical scale and their timescale. They can be, for example, of societal, technological, economic, environmental and geopolitical natures as well as originate from shifts in values and lifestyles. While some are well established and well known, they have sometimes just emerged, and their effects have not yet unfolded or are still unknown. Considered together they constitute a network of highly interlinked, co-evolutionary phenomena. Grouping them in different categories, while representing a simplification, is useful to facilitate their characterisation. In this assessment, four categories of drivers of change are identified, as defined below:

- **Global megatrends** are global, long-term trends that are slow to form but have a major impact once in place (EEA, 2015d). They are the great forces that are likely to affect the future in all areas throughout the world over the next 10 to 15 years. Furthermore, they are often strongly interconnected.

- **European trends** are mid- to long-term trends specific to Europe and, contrary to global megatrends, not all of them are likely to have major implications at global scale. They are directly or indirectly interconnected between them and with global megatrends and their direction of change can be aligned or contrasting global megatrends (e.g. a stagnating European population in contrast to a growing global population).

- **Emerging trends** represent emerging developments that are occurring at a fast pace but are not yet fully established over mid- to long-term timescales, and for this reason their potential implications are not yet well understood. Depending on their evolution, they might lead to the establishment of new European trends or global megatrends.

- **Wild cards**, instead, are developments that may seem unlikely or very unlikely at present but could occur in the future, and, if they do, they are likely to bring about disruptive changes.

Although the categories above can help navigating the complex landscape of drivers of change, the future evolution of these drivers remains fundamentally uncertain. Drivers of change are characterised by different underlying mechanisms whose predictability can differ significantly. For example, biophysical and chemical processes are often more predictable than socio-economic, political or technological phenomena, as the latter are generally more volatile and subject to rapid changes. However, the mutual influence and interconnectedness that characterise drivers of change, lead to the emergence of new systems configurations and largely unpredictable future outcomes. This implies, for example, that despite demographics being a rather stable and predictable evolution, sudden social, economic or political shifts may have fundamental implications for demography and completely change its trajectory.

This characteristics points to the inadequacy of our knowledge base and cognitive abilities when it comes to make full sense of complexity and therefore to the need of recognising the presence of '**deep uncertainty**'. Against this background, 'uncertainty' text boxes are introduced in the assessment with the aim of reflecting on both quantitative uncertainty (e.g. scenario modelling and projections) and epistemic uncertainty (e.g. framings and narratives), as antidote to hypocognition (Lakoff, 2010).

Although it is often difficult or impossible to disentangle these phenomena because of their high interconnectedness, a set of **thematic clusters** has

Box 2.1 Clustering drivers of change

The knowledge base on global megatrends, European trends and other drivers of change keeps expanding. In this assessment a broad set of recent horizon scanning initiatives and 'synthesis' studies was reviewed in order to define a set of thematic clusters. The sources considered were: *Global trends to 2030* (ESPAS, 2015, 2019); *Global trends to 2035* (EPRS, 2017a, 2018a); *The EC megatrends hub* (EC, 2018l); *Assessment of global megatrends* (EEA, 2015a, 2015d); *An OECD horizon scan of megatrends and technology trends in the context of future research policy* (OECD and DASTI, 2016). The global megatrends included in the above documents were allocated to the different categories of the STEEPV framework (i.e. society, technology, economy, environment, politics and values) (Fowles, 1978), according to thematic relevance. This ensured that the full breadth of relevant topics included in other synthesis works were covered. The STEEPV categories were subsequently modified through iterations, to best reflect goals and narratives of this assessment. Compared to the STEEPV categories in the final set of thematic clusters the social dimension was split into two main components, focusing on demographic aspects on the one hand (Cluster 1) and societal change on the other — health and lifestyles were joined together with values and norms, leading to Cluster 6. Moreover, the environmental aspects were differentiated into two separate clusters — with Cluster 2 referring to 'pollution, biodiversity and climate change' and Cluster 3 to 'resources' — to better distinguish between their nature, also in consideration of the environment and sustainability focus of this assessment. Once the main structure of clusters and global megatrends was in place, an in-depth analysis of literature was carried out to further identify relevant thematic European trends, emerging trends and wild cards, which populated the clusters with further content.

been developed to facilitate the description and exploration of this network and their interactions. The starting point of the clustering was the society, technology, economy, environment, politics and values (STEEPV) framework (Fowles, 1978), a systematic approach to scanning and analysing potential drivers of change. These categories were modified to better reflect the outcomes of the literature review (see Box 2.1). The result led to the identification of the following clusters:

- Cluster 1 — A growing, urbanising and migrating global population.
- Cluster 2 — Climate change and environmental degradation worldwide.
- Cluster 3 — Increasing scarcity of and global competition for resources.
- Cluster 4 — Accelerating technological change and convergence.
- Cluster 5 — Power shifts in the global economy and geopolitical landscape.
- Cluster 6 — Diversifying values, lifestyles and governance approaches.

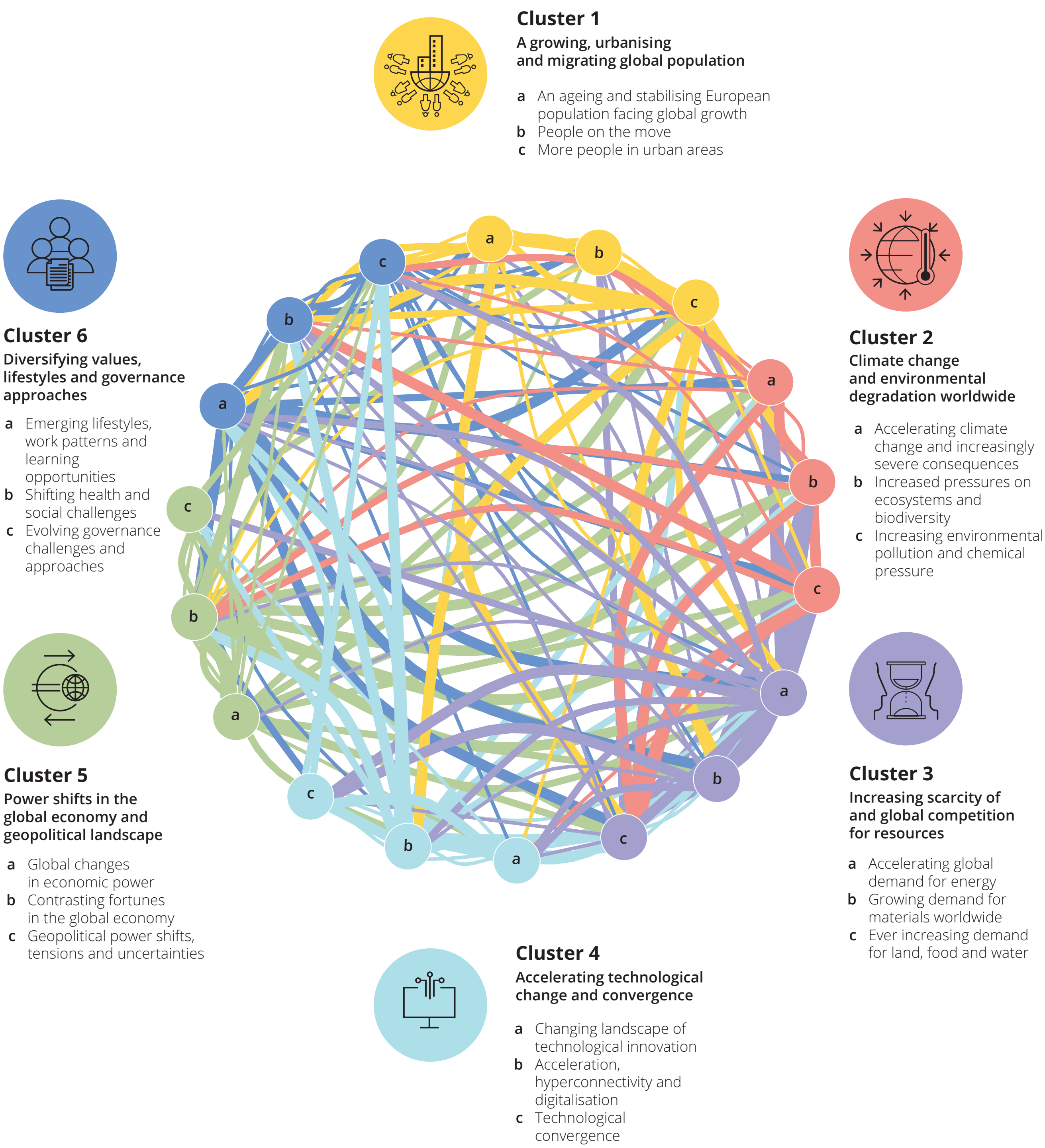
Table 2.1 provides an overview of the thematic clusters and their main components, while Figure 2.1 illustrates them as **'network of clusters'** by highlighting the interlinkages existing between components, both within and across the clusters.

Understanding and treating drivers of change as a network of clusters rather than individual clusters is of fundamental importance, as the interactions occurring between them provide significant insights on potential future developments. For example, the nearly exponential trajectory of human activity (e.g. population, economy and consumption levels) and the concurrent growth of environmental pressures that characterise 'the Great Acceleration' ([4]) (Steffen et al., 2011, 2015) (Figure 2.2), indicate strong interconnections between them, and more specifically mutually reinforcing feedbacks. The observed dynamic also brings to mind the 'overshoot and collapse' behaviour, according to which exponential growth is followed by rapid decline associated with the depletion of non-renewable resources (Breierova, 1997), as already highlighted by Meadows et al. (1972), indicating that humanity may well be on its path towards an ecological overshoot.

For example, changes in prices of natural resources and energy in Europe are generally associated with strong implications for both the production and the consumption of goods and services as well as habits and routines. Prices of energy commodities are, to a large extent, influenced by demographic, economic and geopolitical developments often occurring elsewhere, given that Europe is a relatively resource-scarce continent (EEA, 2015d). Pressures and impacts on human and ecosystem health are increasingly determined by global interconnections, for example environmental pollution in other regions can impact Europe directly through long-range transport

([4]) 'The Great Acceleration' is the period after the 1950s that marked a unique moment in human history, with unprecedented and accelerating human-induced global change.

Figure 2.1 Thematic clusters and their interactions



Note: Connectors' width illustrates a qualitative estimation of the strength of interaction among drivers of change.

Source: EEA.

Figure 2.2 Indicators for global socio-economic development and the structure and functioning of the Earth's system (cont.)

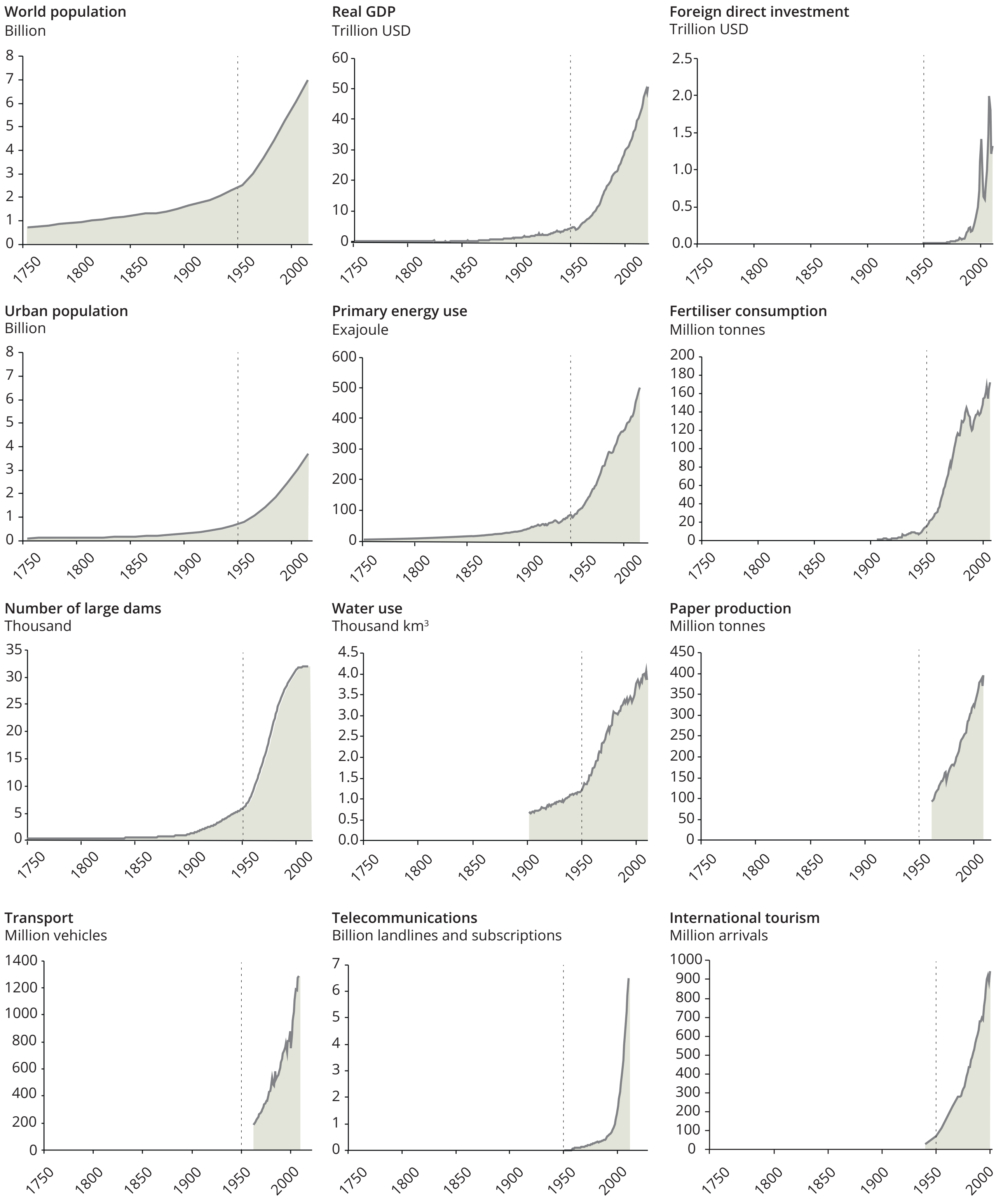
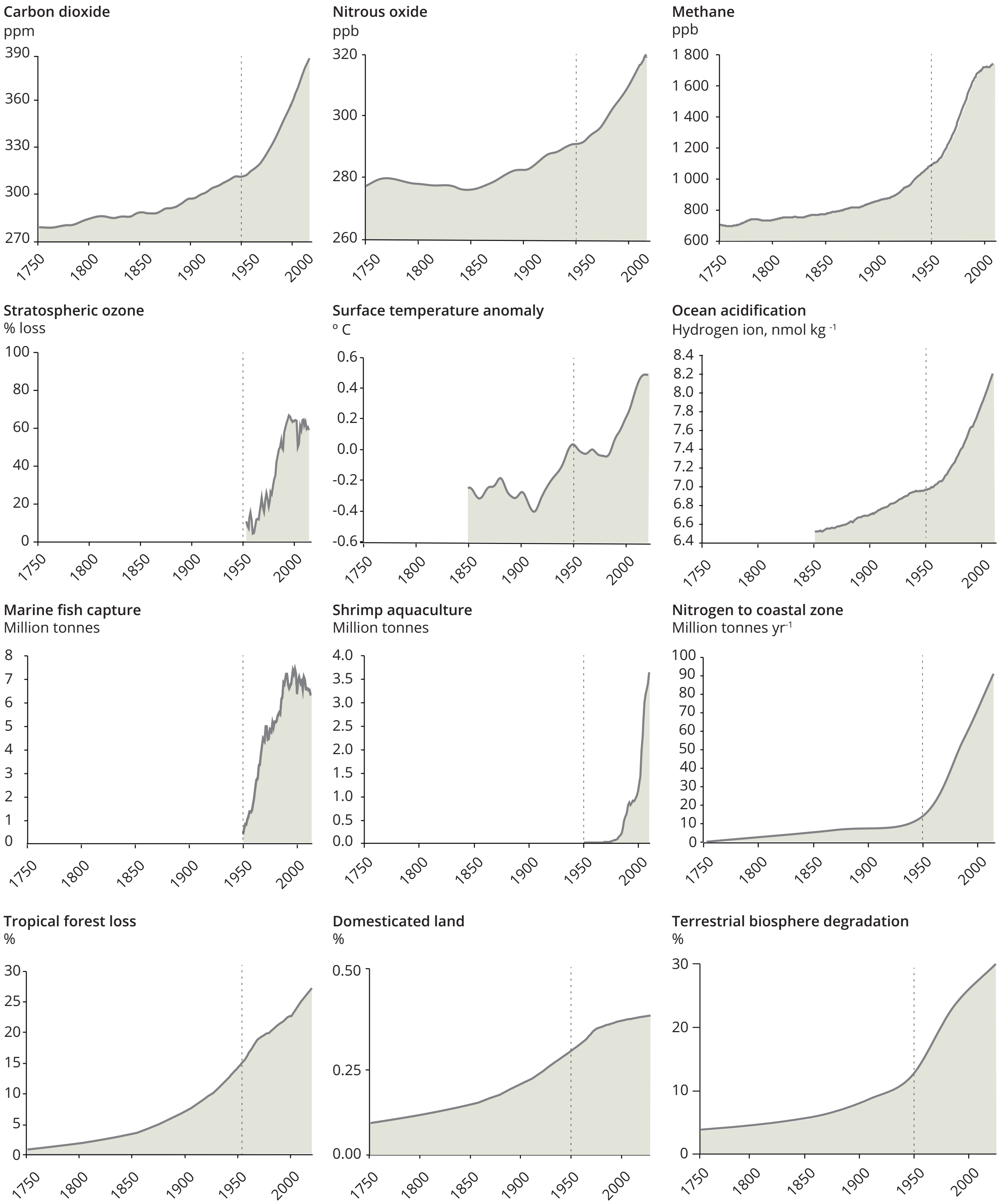


Figure 2.2 Indicators for global socio-economic development and the structure and functioning of the Earth's system (cont.)



Note: GDP, gross domestic product.

Source: Steffen et al. (2015).

of precursor gases from other parts of the world and largely depend on models of economic development pursued by other regions, while Europe indirectly contributes to environmental pressures in other parts of the world through globalised supply chains and growing externalisation (EEA, 2015d, 2019e).

By adopting system thinking and foresight, this assessment attempts to explore the interconnections existing between drivers of change across global and European scales and to reflect on their implications for the achievement of environmental and sustainability goals.

Table 2.1 Overview of the six clusters and their main components (cont.)

Cluster 1 — A growing, urbanising and migrating global population		
a) An ageing and stabilising European population facing global growth	**b) People on the move**	**c) More people in urban areas**
• **Global megatrend:** A growing world population • **EU trend:** Population stabilisation and decline in Europe • **Global megatrend:** Ageing worldwide • **Uncertainty:** Assumptions associated with population projections	• **Global megatrend:** Increasing migration across the world • **Emerging trend:** Climate and environmental change and international migration • **EU trend:** Europe at the forefront of international migration • **EU trend:** The effect of migration on Europe's population prospects	**Global megatrend:** Continuing urbanisation worldwide **Emerging trend:** Challenges of migration in urban areas **EU trend:** Increased mobility, urban sprawl and regional diversification within the European Union **Wild card:** Social and technological innovation in cities
Cluster 2 — Climate change and environmental degradation worldwide		
a) Accelerating climate change and increasingly severe consequences	**b) Increased pressures on ecosystems and biodiversity**	**c) Increasing environmental pollution and chemical pressure**
• **Global megatrend:** Unprecedented increase in GHGs concentration • **Uncertainty:** Geoengineering climate solutions opportunity or risk? • **Uncertainty:** modelling climate change and its impacts	• **Global megatrend:** Growing pressures on ecosystems • **Global megatrend:** Unprecedented loss of biodiversity • **Wild card:** Entomofauna, pollinators and risks for global food supply	• **Global megatrend:** Increasing environmental pollution and chemical pressure worldwide • **EU trend:** Air quality in Europe • **Emerging trend:** Microplastics in the food chain
Cluster 3 — Increasing scarcity of and global competition for resources		
a) Accelerating global demand for energy	**b) Growing demand for materials worldwide**	**c) Ever increasing demand for land, food and water**
• **Global megatrend:** Fossil fuels keep dominating world energy supply • **EU trend:** Import dependency, energy and critical raw materials in Europe	• **Global megatrend:** Unprecedented use of materials • **Uncertainty:** Beyond green growth and decoupling • **Uncertainty**: How circular can the EU economy be?	• **Global megatrend:** Growing middle-class drives food demand • **Global megatrend:** Increasing demand for land • **Emerging trend:** 'Land grabbing' • **Global megatrend:** Unprecedented rates of water consumption

Table 2.1 Overview of the six clusters and their main components (cont.)

Cluster 4 — Accelerating technological change and convergence		
a) Changing landscape of technological innovation	**b) Acceleration, hyperconnectivity and digitalisation**	**c) Technological convergence**
Global megatrend: Emergence of China as technological power **Global megatrend:** Concentration of technological development in few countries	**Global megatrend:** Accelerating technological change **Global megatrend:** Digitalisation and key digital technologies **Uncertainty:** The risk of a digital divide in a hyperconnected world **Uncertainty:** Ethical, privacy and security issues associated with digital technologies	**Emerging trend:** Fourth industrial revolution? **Emerging trend:** 'Sustainability'-driven technologies **Emerging trend:** Key emerging applications **Uncertainty:** Challenges associated with synthetic biology **Uncertainty:** Artificial meat: an uncertain potential for climate change mitigation **Uncertainty:** The limited contribution of efficiency gains in technological innovation
Cluster 5 — Power shifts in the global economy and geopolitical landscape		
a) Global changes in economic power	**b) Contrasting fortunes in the global economy**	**c) Geopolitical power shifts, tensions and uncertainties**
• **Global megatrend:** Continued global growth, shifting to the South and East • **Global megatrend:** Structural change of the global economy • **EU trend:** European imports' negative spill-over effect • **Global megatrend:** Growing debt and systemic financial risks • **EU trend:** The effects of financialisation and the financial crisis on Europe's economy, society and environment	• **Global megatrend:** Poverty reduction but not everywhere • **Global megatrend:** A middle class growing, but shrinking in the West • **Global megatrend:** Rising inequality within countries	• **Global megatrend:** A vulnerable globalisation and multilateralism • **Emerging trend:** Changing power distribution in the international system • **Emerging trend:** Evolving security challenges and the new warfare • **Uncertainty:** Emerging security challenges around the Arctic
Cluster 6 — Diversifying values, lifestyles and governance approaches		
a) Emerging lifestyles, work patterns and learning opportunities	**b) Shifting health and social challenges**	**c) Evolving governance challenges and approaches**
• **Global megatrend:** Changing values and emerging lifestyles in a more consumerist orld • **Global megatrend:** Changing nature of work and increasing vulnerability • **Emerging trend:** New forms of education and learning	• **Global megatrend:** Changing disease burdens • **Global megatrend:** Social and health inequalities • **EU trend:** Social vulnerability and environmental health hazards in Europe • **EU trend:** Welfare systems under pressure in Europe • **EU trend:** Ageing and the erosion of the fiscal base in Europe	• **EU trend:** Distrust in institutions in Western democracies • **Uncertainty:** Science, evidence and trust in public institutions — is there a crisis? • **Emerging trend:** Innovation in governance

2.2 Cluster 1 — A growing, urbanising and migrating global population

Key messages (cont.)

An ageing and stabilising European population facing global growth

- According to the recent United Nations Department of Economic and Social Affairs scenarios (UN DESA, 2019), the global population is expected to increase from its current figure of 7.7 billion to reach 8.5 billion in 2030, 9.7 billion in 2050 and 10.9 billion in 2100. Most of the projected growth is expected in developing countries, especially in Africa, although population growth in such countries can be significantly limited by a lack of access to basic resources (e.g. water, food) and sanitation (Cluster 3).

- Mortality rates, including child mortality, are decreasing globally, leading to a rise in global life expectancy. At the same time, fertility has been reducing globally, leading to ageing. For the first time in the world's history, there are now more people aged 65 years or above than children under 5 years of age.

- Europe is projected to have a stable or declining population by 2050, compared with 2019, as it is confronted with an ageing population (which is also occurring in China and Japan), with people older than 65 years representing 42 % of total population by 2070, in comparison with 14 % in 2016. Given low fertility rates and in the absence of migration, this raises questions about a shortfall in workingage adults and poses challenges for social stability, taxation and public health systems (EEA, 2019e).

People on the move

- The characteristics of demography allow to project population growth for decades into the future with some degree of confidence in the results, given the dependence on relatively stable biological characteristics (e.g. fertility and mortality). However, it is very often the case that demographic scenarios assume a continuation of past trends, while less focus is given to factors that are not strictly demographic and 'surprise' events with a potentially high influence. For example, migration, given its dependence on abrupt geopolitical shifts and environmental challenges, is the most difficult to project with confidence.

- International migration is a relevant phenomenon, but its proportions are often misunderstood. At the global scale, it concerns only 3 % of the population, and it has mainly an intracontinental character. While Europe is a key destination for refugees, Asia is becoming increasingly attractive as a destination for migrants. In the coming decades, environmental degradation and climate change are expected to become increasingly important drivers of migration globally; however, future migration volumes remain highly uncertain (IPCC, 2018).

- Migration is very much influenced by geopolitical situations and armed conflicts (Cluster 5), which are the root cause of mass migration of refugees. Irregular migration, a significant phenomenon in Europe, is unfortunately associated with much of the public's concern about immigration (IOM, 2018), influenced, in turn, by misinformation (Cluster 6). The upsurge in refugees in Europe — while it is fighting terrorism and experiencing other socioeconomic challenges — has contributed to xenophobia, populism and rightwing movements gaining ground across Europe (see also Clusters 5 and 6).

More people in urban areas

- Urbanisation is expected to further increase globally, especially in Africa and Asia, with a projected 68 % of the world's population living in cities by 2050, compared with 55 % today (UN DESA, 2018a). In Europe, urban growth is expected to be slower, and, while most capital cities are likely to grow sensibly, other cities might contract by up to 30 % (Eurostat, 2016).

- Demography, urbanisation and migration are fundamentally interconnected, as population growth is very often associated with the expansion of urban areas and migration, often driven by better job opportunities and standards of living in cities (Cluster 5). Cities are also where the biggest contrasts in living standards can be observed, both globally and in Europe (Cluster 5), and where health challenges are more often pronounced, especially among the most vulnerable people.

Key messages (cont.)

- Apart from being where the majority of economic activity is concentrated, cities also have a primary role in pushing forward societal change, harbouring the circulation of ideas and encouraging the experimentation of social and technological innovations and changes in values, lifestyles and approaches to governance (Clusters 4 and 6).
- Overall, over half of European cities are expected to see their population decline in the future, and at the same time European urban areas are expected to cover greater areas than in the past (Vandecasteele et al., 2019). The shift in population from rural to urban areas as well as from eastern and southern regions to northern and western Europe, motivated by the search for better economic opportunities, is likely to lead to further competitiveness and cohesion issues within and across countries. Substantial disparities in economic development across EU regions and growing vulnerabilities would deserve increased policy attention.

2.2.1 *An ageing and stabilising European population facing global growth*

2.2.1.1 A growing global population

Human population growth is a very recent phenomenon from a historical perspective, as it has occurred only in the last two to three centuries (Roser et al., 2019). Since 1 billion people were registered around the year 1800, the pace of growth has increased dramatically, reaching 7.7 billion in mid-2019, according to the latest estimates (UN DESA, 2019); only from the 1950s to the present day has the world population experienced a fourfold increase. Such a leap forward has heavily depended on a number of factors that have led to a reduction in mortality rates. This has been largely due to **scientific and technological developments** that have translated into major benefits for humankind, living standards and longevity. However, this has also generated unprecedented pressure on our environment and resources, causing the Earth to enter a geological phase currently known as the 'Anthropocene' (see Clusters 2 and 3).

The growth rate of the **global population** reached its maximum around the 1960s and has been declining ever since, indicating a continued but slower growth. According to recent United Nations Department of Economic and Social Affairs (UN DESA) medium-variant projections, the global population is expected to reach **8.5 billion in 2030, 9.7 billion in 2050** and **10.9 billion in 2100** (UN DESA, 2019), while the pace of growth is projected to slow further, reaching a plateau or even decreasing towards the end of the century, although there is high uncertainty regarding long-term estimates (see Box 2.2).

World regions are expected to experience the region- and country-specific demographic trends illustrated in Figure 2.3. Under the UN DESA medium-variant projections (2019), **the population in Africa is projected to nearly to double** from its current figure of 1.3 billion to 2.5 billion by 2050, the majority of which is expected to occur in sub-Saharan Africa ([5]) and account overall for nearly 50 % of global population growth. In northern Africa, the population is likely to increase by 40 million by 2030 and 130 million by 2050 (UN DESA, 2019), showing a continued population increase in the region, even though it is slower than in the recent past (ESPAS, 2019). Asia's population is expected to increase from 4.6 million people to 5.3 million, with two distinct trends. Central Asia and South East Asia will experience, overall, a significant population growth, accounting for nearly 23 % of global population growth by 2050 (UN DESA, 2019). India is likely to become the most populous country by the end of the 2020s, surpassing China. In fact, East Asia and South East Asia will observe an overall decrease, as a result of an expected population reduction in China, Japan and Korea that will outrun sustained population growth in Indonesia and the Philippines (UN DESA, 2019). China's population is expected to stabilise at around 1.4 billion inhabitants by 2050, as a result of a population reduction close to 3 %. According to the UN DESA medium-variant projections (2019), the populations in Latin America and the Caribbean, North America and Oceania are expected to increase by 17 %, 15 % and 34 %, respectively, accounting for an increase of 180 million

([5]) Sustainable Development Goal region, as defined in the UN DESA world population projection (UN DESA, 2019).

people — roughly 10 % of expected population growth by 2050, **while Europe's population is projected to decrease by 2050** (UN DESA, 2019). Overall, at the global scale, a few countries will account for the majority of global population growth, while a growing number of countries is currently experiencing a decrease in population due to low levels of fertility or high rates of emigration (UN DESA, 2019).

2.2.1.2 Population stabilisation and decline in Europe

Several estimates of long-term population trends in the 28 EU Member States (EU-28) have been developed (Lutz et al., 2018, 2019; EC, 2017f; Eurostat, 2017; UN DESA, 2019, 2017b). Despite significant differences concerning **mortality, fertility and migration rates**, scenarios based on 'central' or 'medium' assumptions on migration and fertility rates ([6]) indicate that the EU-28 is likely to experience moderate population growth for the next two to three decades, followed by stabilisation and a likely decline. According to the most recent estimates, if current trends were to continue then the EU-28 population would amount to 521 million people by 2060 (Lutz et al., 2019), while, according to UN DESA, the population of the European continent is projected to decrease by 5 % by 2050, with significant differences among sub-regions. The most relevant reduction is expected to occur in eastern and southern Europe (roughly -10 %), while a stable population is projected for western Europe and a slight increase for northern Europe (+8 %) (UN DESA, 2019).

Significant increases in migration flows and/or fertility rates would be needed to counterbalance this trend (see Lutz et al., 2019).

2.2.1.3 Ageing worldwide

The global population is **ageing** because of **decreasing fertility levels** and **increasing life expectancy** (UN DESA, 2019). This is the result of a number of positive developments that have occurred at the global scale, mainly related to health care, wealth and education (ESPAS, 2019; Lutz et al., 2019). According to the medium-variant projection, the global fertility rate is expected to be as low as 2.2 by 2050, which is just above the level needed to maintain the same population size (UN DESA, 2019); however, this assumption depends on continued economic growth, on average. Along similar lines, despite marked differences globally, fertility rates are expected to converge further across world regions, with slight increases in developed countries, and other regions continuing to decline, particularly in sub-Saharan Africa. However, access to education for girls and young women will be a pre-condition to curbing fertility rates in developing countries, as **female education and empowerment** are closely connected to family planning and are able to reduce fertility rates by creating a virtuous circle, leading to increased skills, job opportunities and better health (Lutz et al., 2019), stimulating female education, women's empowerment and self-determination (e.g. through rights, land ownership).

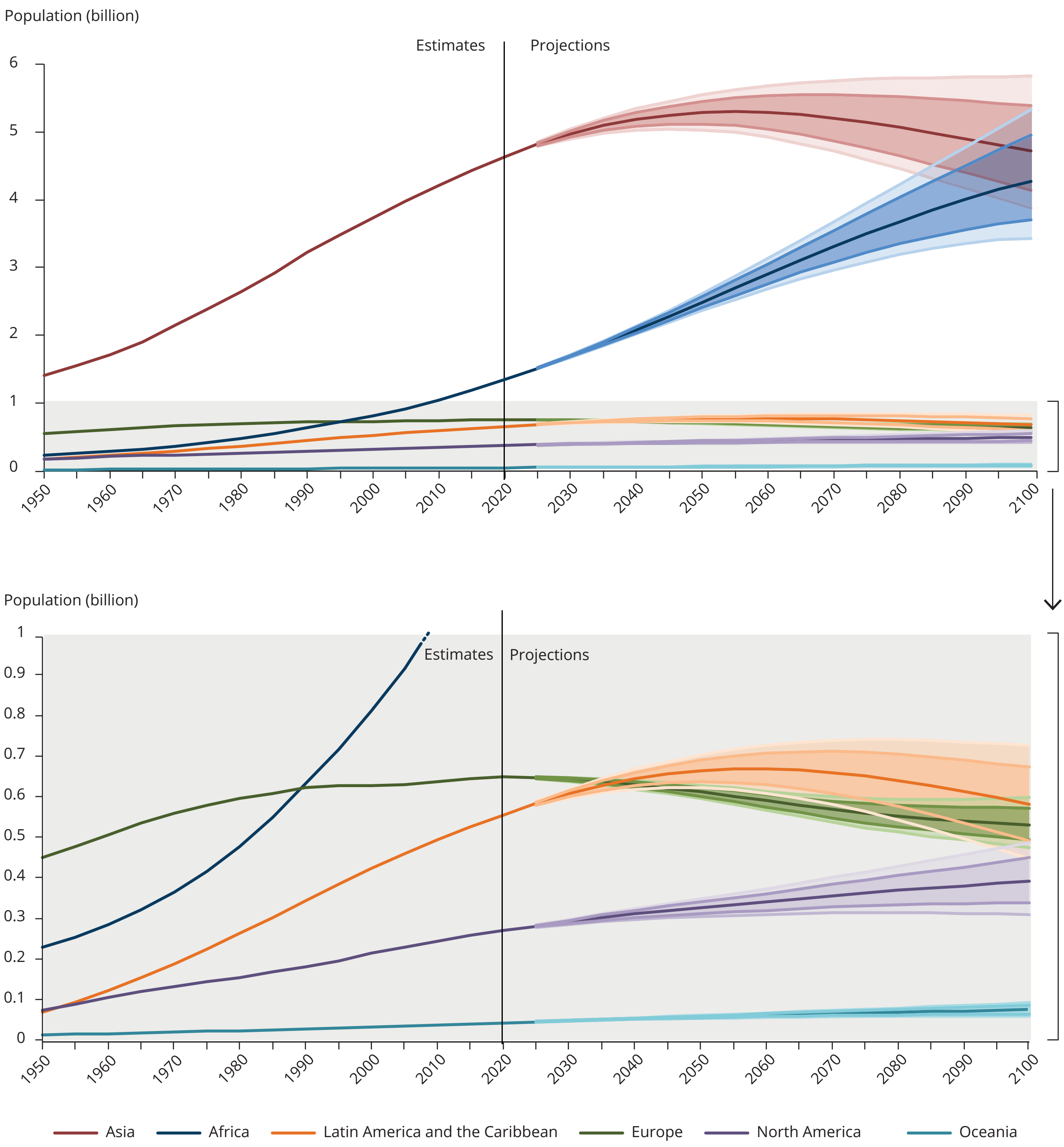
Box 2.2 Uncertainty and assumptions associated with population projections

Population size and age structure are directly determined by the interaction between fertility, mortality rates and net migration. Because of the inertia of demographic processes, projected changes in population size and structures can be made for decades in the future (Lutz et al., 2019), with some degree of confidence in the results. For example, according to UN DESA (2019), two thirds of the projected growth of the global population by 2050 will be determined by current age structures.

However, the evolution of fertility, mortality and migration rates over time builds on a series of assumptions, which turn out to be more or less accurate in time. Multiple scenarios are often developed to estimate an array of future population sizes and age structures, reflecting different assumptions (Lutz et al., 2019, 2018; UN DESA, 2019; EC, 2017f). However, it is very often the case that scenarios assume a continuation of past trends, while less focus is given to factors that are not strictly demographic, 'surprise' events and bottlenecks. For instance, UN DESA's long-term projections (2019) assume that Africa's population will triple, from 1.3 billion to more than 4.2 billion, between 2015 and 2100, without reflecting on the implications of growing resource demand (e.g. food, water, energy, land) and access to sanitation, which are increasingly put under stress by global change (Cluster 2) and power shifts in the global economy (Cluster 5). These might have dramatic effects on population and limit sensibly the soundness of such long-term estimates. International migration is also contributing sensibly to uncertainty, given its volatile character (IOM, 2018), i.e. migration is often associated with abrupt geopolitical changes, including wars, which cannot be easily anticipated.

([6]) Typical assumptions for medium/central scenarios for the EU-28 are the following: a recovering fertility rate, decreasing mortality rates and rather stable levels of migration.

Figure 2.3 **World population by regions, 1950-2100, medium-variant projections 80- and 95- uncertainty ranges**



Source: UN DESA (2019).

Mortality rates are decreasing globally, including child mortality, and **global life expectancy is rising** (UN DESA, 2017b, 2019). Global life expectancy at birth reached approximately 73 years in 2019 and is expected to reach 77 years by 2050 (UN DESA, 2019). Considerable progress has been made concerning mortality and longevity, especially in sub-Saharan Africa, although the gaps between countries around the world remain wide. **Disparities in the average length of life** can reach up to 30 years and are largely driven by child and maternal mortality, conflicts and HIV-related mortality (UN DESA, 2019). Overall, in 2018, at the global scale, there were more people aged 65 years or above than children under

5 years of age, registering an all-time record in world history (UN DESA, 2019). The ageing of the world population trend is expected to continue further, as the proportion of the 65-years-and-over age group over total population is projected to increase in virtually all countries (UN DESA, 2019) (Figure 2.4). Europe and North America are the regions where this trend is expected to manifest more strongly, with one person in every four aged 65 years or over by 2050 (UN DESA, 2019).

Despite generalised ageing, substantial differences will persist among regions in terms of demographic structure. For instance, Europe, Africa and Asia show the diverging trend in age profiles: in 2050 more than 50 % of Africa's population is expected to be 24 years old or younger, whereas in Europe this figure will be around 25 %; for older people (60 years and over) less than 10 % of Africans will be in this age group, compared with almost 35 % of Europeans. In 2050, significantly more Europeans will be over 60 years old than under 24 years old (UN DESA, 2017b).

Some areas of the world, particularly where fertility rates are still high, are likely to still experience **youth bulges** in the short term, which result in high shares of children and young adults (ESPAS, 2019; UN DESA, 2019). This might bring new opportunities for economic growth (i.e. 'demographic dividend') but could also create new challenges for social cohesion if jobs are lacking. This trend is also likely to characterise Europe's southern neighbourhood, although to a lesser extent (ESPAS, 2019).

Influenced by dynamics in fertility, life expectancy and migration, the projections for the EU show that the population will age significantly, with people older than 65 years representing 42 % of total population by 2070, in comparison with 14 % in 2016 (EC, 2017g). This is despite a slight increase in fertility rates in the EU, from nearly 1.5 live births in 2001 to 1.6 in 2016 (Eurostat, 2018d). Fertility rates are assumed to reach 1.8 live births per woman by 2070 (EC, 2017g) as a result of the continuation of recent trends; these rates will be insufficient to reach the level required to keep the population size constant in the absence of migration (Eurostat, 2018g). Russia and China are expected to follow an ageing pattern similar to that in Europe (ESPAS, 2019).

Overall, the ageing of some of the world's populations will lead to an **increased dependency ratio**, implying that, globally, there will be fewer working-age people (25 to 64 years) than the number of older people (65 years and over) (UN DESA, 2019). The implications of this trend for the **EU's public finances** are likely to be significant, particularly for what concerns public health and pension expenditure, as well as investment capacity necessary for responding to environment and sustainability challenges (EEA, 2019d). On the contrary, developing regions will be characterised in the medium term by high numbers of children and young people, translating into increased demand for health care, education and subsequently employment, a demand that will be difficult to meet and that will likely trigger political and social instability unless countermeasures are taken (UN DESA, 2017b).

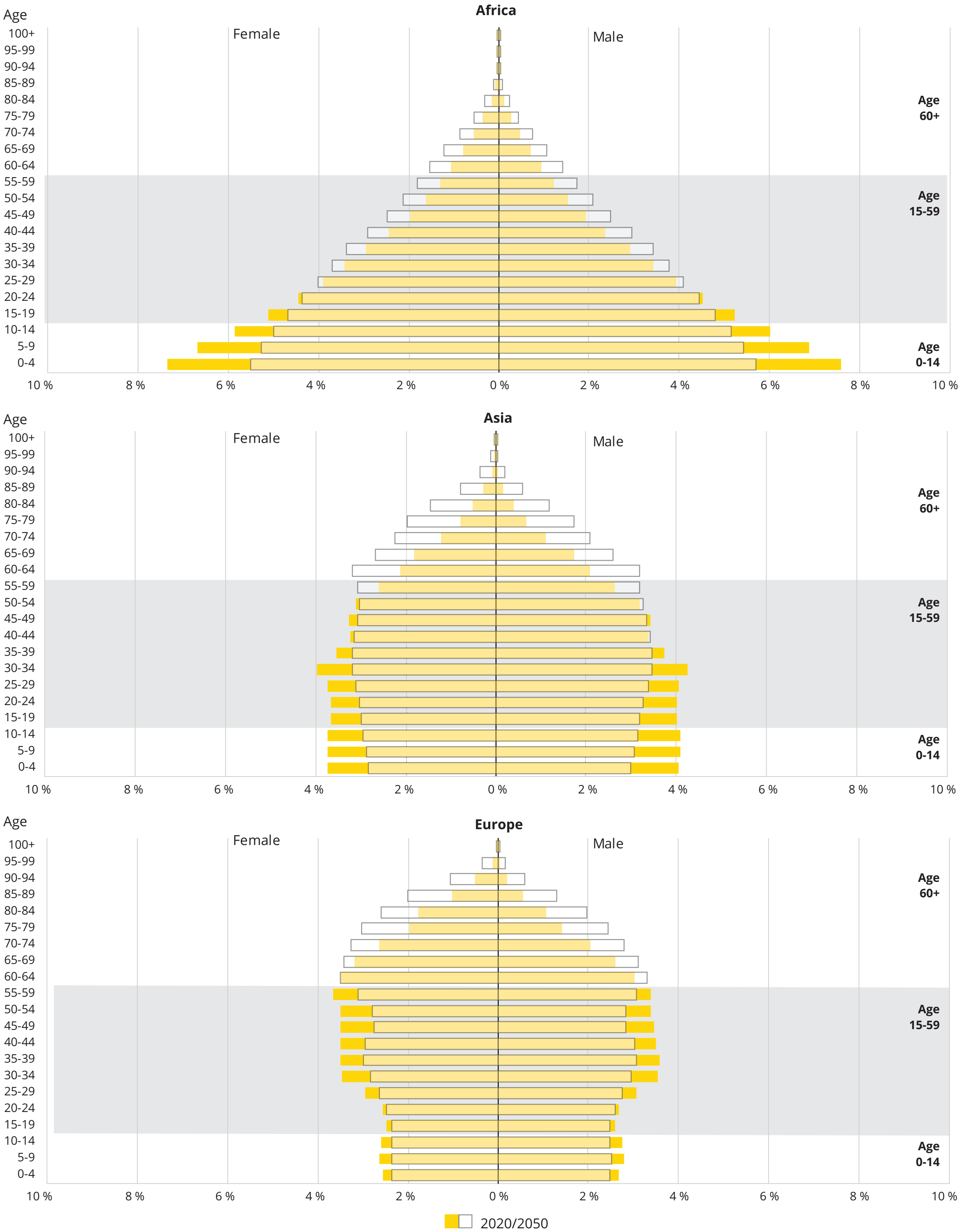
2.2.2 People on the move

2.2.2.1 Increasing migration across the world

Migration is a complex phenomenon that involves a multiplicity of social, economic, environmental and political factors (IOM, 2018). The number of international migrants (i.e. the absolute number of people living outside their country of birth) increased — from 170 million in 2000 to 258 million in 2017 (UN DESA, 2017a) — proportionally to an expanding global population (EPSC, 2017). Despite being a significant phenomenon, especially because of its social and political implications, international migration concerns slightly more than 3 % of the global population, indicating that, at the global scale, the vast majority of people grow up and live their lives in the country where they were born (IOM, 2018). **International migration flows** have largely remained stable in the last two decades, after peaking between 1995 and 2000, and the majority of international migration is **intra-continental** (EPSC, 2017). However, world regions have witnessed very different patterns, with high-income countries absorbing the majority of the net increase in international migration in the last few decades (ESPAS, 2018). Northern Africa and western Asia have become net receivers only recently, and other world regions continue to be net senders (UN DESA, 2019). However it is important to consider that these changes follow major economic and geopolitical shifts; in fact, not more than two generations ago most European countries and regions — now net receivers of international migration — had a lot more emigrants than immigrants (ESPAS, 2018). More recently, between 2000 and 2017, Europe had 22 million international migrants, following Asia, which had the largest migration inflow among all of the world's regions of about 30 million people (UN DESA, 2017a). Among the 20 largest migration destination countries worldwide, nine were in Europe (UN DESA, 2017a).

Migration has historically helped to improve lives, offering opportunities for better lives abroad and creating benefits for both home and host countries, as well as challenges for both migrants and receiving

Figure 2.4 **Distribution of the population by age and sex by region, 2020 and 2050**



Source: UN DESA (2019).

countries (IOM, 2018). Migrants increasingly finance the economic development of their home countries; for instance, world-scale remittances are significantly higher than official development assistance (EPSC, 2017). However, migration is also associated with personal challenges and distress for migrants, often because of 'lack of preparedness, difficulties in adjusting to the new environment, the complexity of the local system, language difficulties, cultural disparities and adverse experiences' (Virupaksha et al., 2014). Although most international migration is **voluntary** and driven by socio-economic aspects (i.e. labour opportunities, demand for education or personal motives), **forced migration** associated with displacements because of persecution, armed conflicts, environmental degradation, natural disasters and a deep lack of security and opportunity is increasing (IOM, 2018), although the line between voluntary and forced migration is often blurred. By the end of 2018, the population of forcibly displaced people reached almost 70.8 million individuals, having increased by more than 60 % since 2009. This record high is equivalent to 37 000 people being forced to flee their homes every day in 2018 (UNHCR, 2019).

Migration patterns are changing with economic development and **employment opportunities**, meaning that developing regions are becoming increasingly attractive to voluntary migrants, with Asia and particularly China expected to be potential **major destinations** by 2050 (OECD and DASTI, 2016), although this would also require major policy changes in receiving countries. Migration is often used as a diplomatic bargaining chip to ensure access to primary resources (e.g. China's approach to visas and cooperation in Africa and Central Asia) or to extend a sphere of influence (e.g. Russia's labour remittances in neighbouring countries) (ESPAS, 2019). Africa is also expected to attract more people as economic development increases (OECD and DASTI, 2016). However, economic growth in developing countries triggers further international migration, when translated into enough income and international sensibility for individuals (ESPAS, 2019; Lutz et al., 2019). Under extremely poor conditions, it is not possible for people to afford the high costs of travel, so migrants tend to move to nearby countries; only when economic development progresses further will emigration rates fall again (ESPAS, 2019; Lutz et al., 2019).

Quantitative migration flows are the most difficult trends to estimate, as they generally result from significant shifts in international order or conflicts that cannot be easily anticipated. However, given Europe's geographical and geopolitical location and socio-economic levels of development, the fact that this trend will further affect Europe cannot be excluded (ESPAS, 2018). In particular, 'youth bulges' in Africa could lead to **unemployment and further migration** if developing economies are not able to accommodate a growing labour force (Lutz et al., 2019). In addition, drivers of change, such as climate change and global environmental change (Clusters 2 and 3), and recognised drivers of regional and international displacement are expected to have a growing influence in the decades to come, although the implications for Europe are unclear (see Box 2.3).

Box 2.3 Emerging trend — Climate change, environmental change and international migration

Climate change and environmental change have been increasingly identified as important drivers of international and urban migration, as they threaten peoples' livelihoods, e.g. by limiting access to food and sanitation (ICMPD, 2011; Foresight, 2011a, 2011b; IOM, 2015; EEA, 2015d; EPSC, 2017; ESPAS, 2019; Lutz et al., 2019). For example, droughts and water shortages attributed to climate change have been identified as a contributing factor to the outbreak of conflicts in western Asia between 2010 and 2012, as repeated crop failures and migration to urban centres possibly led to increased unemployment and political unrest (Abel, 2017; Lutz et al., 2019), although role of climate in determining conflicts cannot be seen as preponderant (Raleigh et al., 2008).

As reported in *The European environment — state and outlook 2020* integrated assessment (EEA, 2019e), in the coming decades, environmental degradation and climate change are expected to become increasingly important drivers of migration (Missirian and Schlenker, 2017). However, because of the complex social, economic and environmental factors underlying migration, estimates about future migration volumes remain highly uncertain (IPCC, 2018). The impact of climate change on international migratory flows to Europe is considered limited and context specific (Lutz et al., 2019). The environment has always influenced migration; however, this relationship is a complex and multifaceted one, as factors such as population growth, poverty, inequality, governance, adaptation capacity, security and conflict determine how societies can react to extreme events and emergencies, as well as long-term challenges (IOM, 2015). While climate variability and extremes can increase migration, they could also prevent it by limiting the availability of resources necessary for emigration, so the net effect is unclear (Lutz et al., 2019). The effects of climate change are likely to result in an increase in existing historical migration from rural areas to cities in developing countries (ESPAS, 2019) or migration over short distances (Lutz et al., 2019) rather than to Europe.

Box 2.4 Uncertainty — The effect of migration on Europe's population projections

Europe's population projections suggests that, without a major restructuring of the economy and welfare policy, increasing immigration of working-age people may be necessary to support an ageing population. Since 1950, migration has contributed to population growth in Europe and has, since the period 1990-2000, offset a population decline. Moreover, the size of the total population would have declined during the period 2000-2015 in the absence of migration (UN DESA, 2017a). However, it is unclear whether in the next two to three decades Europe's population will continue to decline or will stabilise, as the projected net inflow of immigrants is characterised by large uncertainties (EC, 2017f; Lutz et al., 2019) and fluctuations in the political orientation of EU governments. The future of migration in Europe will also depend on international stability and EU action, such as the control of arrivals and entry, asylum procedures, resettlement and return mechanisms (ESPAS, 2018). It has been suggested that migration flows would be more predictable if the EU were to exert its influence abroad, asking for reforms and border controls (ESPAS, 2019).

2.2.2.2 Europe at the forefront of international migration

In the last two decades, the number of migrants living in what is now the EU-28 has increased from 34 million in 2000 to 57 million in 2017, growing from nearly 7 % to 11 % of the total population (ESPAS, 2018). Out of these, roughly 20 million people are from another country of the EU-28, while 37 million are migrants from third countries (ESPAS, 2018). The vast majority of immigration to Europe occurs through regular permits, and it has been rather stable for the last decade — almost 2 million people per year looked for opportunities to reunite with family, to study or to work. In the light of demographic projections, Europe may need to increasingly embrace migration; however, the future of migration in Europe is characterised by several uncertainties (see Box 2.4).

However, in recent years Europe has been at the forefront of **large-scale migration flows** arising from conflicts in the Middle East and North Africa. This humanitarian crisis is largely affecting the European neighbourhood, with Syrian refugees comprising the biggest refugee population from a single conflict in a generation (6.3 million in 2017; UNHCR, 2017). During the period 2013-2016, the flow of asylum seekers into Europe was largely associated with irregular arrivals through the Mediterranean and Western Balkan routes, often those of refugees and forced migrants, while in 2017 and 2018 this was no longer the case (ESPAS, 2018). While international migration can positively influence economic and social development by rebalancing labour markets, only a fraction of migrants at present enter the EU for employment, compared with those who enter for family reunification and humanitarian reasons; moreover, Europe attracts a smaller share of highly skilled migrants than North America (EPSC, 2017).

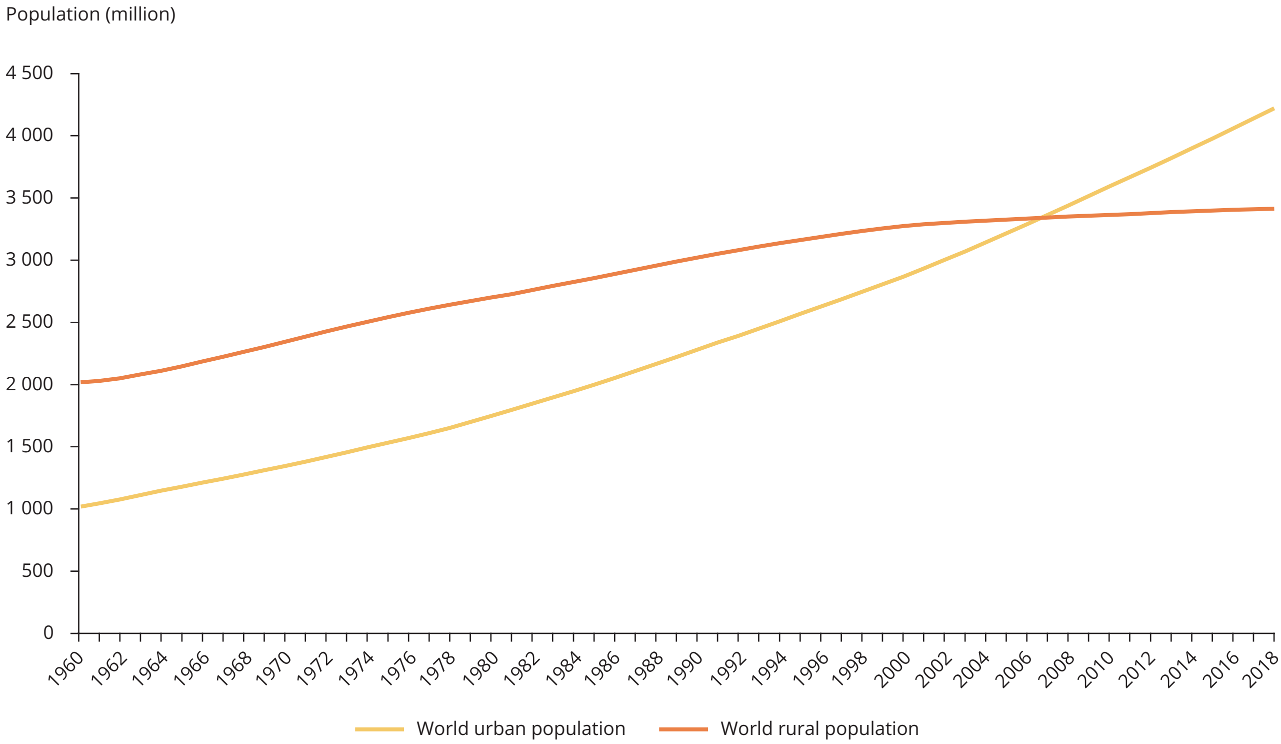
Irregular migration is unfortunately associated with much of the public's concern about immigration (IOM, 2018). The upsurge in refugees in Europe — while it is fighting terrorism and facing other socio-economic challenges (e.g. weak labour market, economic conditions and the questionable unity of the EU) — is contributing to xenophobia, populism and right-wing movements gaining ground across Europe (see also Clusters 5 and 6). In Europe, irregular migration has appeared on the list of top concerns among citizens since 2014, peaking at the end of 2015, consistent with the spike in irregular arrivals through the Mediterranean and Atlantic shores. Despite the fact that the current situation has improved (e.g. arrivals dropped from 360 000 in 2016 to 160 000 in 2017), the perception of poorly managed processes remains; this may also be because of a very likely misperception regarding actual figures, often driven by misinformation (see Cluster 6), that overestimate the size of the immigrant population within European countries (EPSC, 2017).

2.2.3 More people in urban areas

2.2.3.1 Continuing urbanisation worldwide

Urban living is a rather new development in human history, as it was not until the end of the 19th century that **urban areas began to rapidly increase across the world** and populations increasingly moved away from rural settlements (Ritchie and Roser, 2018b). This was largely a result of industrialisation, agricultural mechanisation, environmental change and especially population growth (EEA, 2015d). In 1800, nearly 7 % of the global population lived in urban areas, and by 1900 this share had increased to 16 % (Ritchie and Roser, 2018b). Urban areas have grown particularly fast in Europe, North America, Australia and Japan since the early 20th century, leading to large urban populations. In the last 50 years, urbanisation has increased rapidly across many low- and middle-income countries, while in 1950 only 30 % of the world's population lived in urban areas, a proportion that had grown to 55 % by 2018 (UN DESA, 2018b), as illustrated in Figure 2.5.

Figure 2.5 Global urban and rural population, 1960-2018



Source: World Bank (2019d, 2019f).

According to the latest estimates, in 2018 about 55 % of the world's population lived in urban areas, and by 2050 this is expected to increase to 68 % (UN DESA, 2018a). According to UN DESA (2018a), the most urbanised regions at present are North America (with 82 % of its population living in urban areas), Latin America and the Caribbean (81 %), Europe (74 %) and Oceania (68 %). While the urbanisation level in Asia is about 50 %, Africa is still mostly rural, with 43 % of its population living in urban areas (UN DESA, 2018a). Despite Asia being relatively less urbanised than other regions, 54 % of the world's urban population lives there, as a result of the total population size; Asia is followed by Europe and Africa, which account for 13 % each (UN DESA, 2018a).

By 2050, Africa and Asia together are likely to account for almost 90 % of the projected 2.5 billion increase in the global urban population (UN DESA, 2018a), with India, China and Nigeria together projected to account for 35 % of the total increase in the world's population (UN DESA, 2018a). Based on past trends and assessments (UN Habitat, 2016; IOM, 2018), it is likely that a significant share of urban population growth will happen in **slums**, especially in 'megacities', as this phenomenon has been a central characteristic of rapid urbanisation in the Global South and is expected to continue well into the future (IOM, 2018). Europe can also expect **rising levels of urbanisation**, although at a much slower pace. Globally, the fastest growing urban settlements are expected to be cities with populations smaller than 1 million, with small to medium-sized cities growing twice as much as megacities (ESPAS, 2019). **Trade and industry grow cities and drive urbanisation in developing countries**, as industries attract other industries and a workforce and create the need for products and services. This is currently occurring at a faster pace in developing countries than in developed ones (EEA, 2015d). At the same time, industrial agriculture requires a smaller work force, reduces wages and drives people to seek jobs in towns and cities (Andzio-Bika and Wei, 2005), contributing further to the growth of urbanisation. Overall, metropolitan areas are the prime engine of growth, while megacities account for 70 % of the world's gross domestic product (GDP) (OECD and DASTI, 2016); in the Organisation for Economic and Co-operation Development (OECD) area, more than half of economic growth and job creation occurred in the 275 metropolitan areas with over 500 000 inhabitants (OECD, 2013).

Cities also have an important role to play in pushing forward societal change, as they are very often where **social and technological innovation** are experimented with and put into practice, thanks to the concentration

Box 2.5 Emerging trend — Challenges of migration in urban areas

Although well-managed urbanisation can help to maximise benefits while minimising the environmental degradation associated with the growing number of city dwellers (UN DESA, 2018), poorly planned, dense urban settlements bring congestion, overcrowding and pressures on infrastructure and the environment, undermining health and making it easier for diseases to spread (EEA, 2015a). Trends such as growing migration, inequality of opportunity and tensions associated with international and European migration point towards an increasingly vulnerable European society (see Cluster 6) if current trends continue further and proper responses are not provided by the EU and its countries. According to the European Strategy and Policy Analysis System (2019), uncontrolled urban growth often leads to urban sprawl, low productivity, segregation, congestion and crime. Social tension and riots have been observed in the recent past on the peripheries of some of the major European cities, as a result of segregation. Slums are associated with governance and security issues and lead to risks of disease, violence and a lack of education and other opportunities for human development, as a result of inadequate, crowded and unsafe housing, and a lack of basic infrastructure and public utilities (IOM, 2018). The established migrant camps at the gates of Europe and between its countries, as well as slums within its cities or informal settlements in its rural areas, are an emerging issue in Europe.

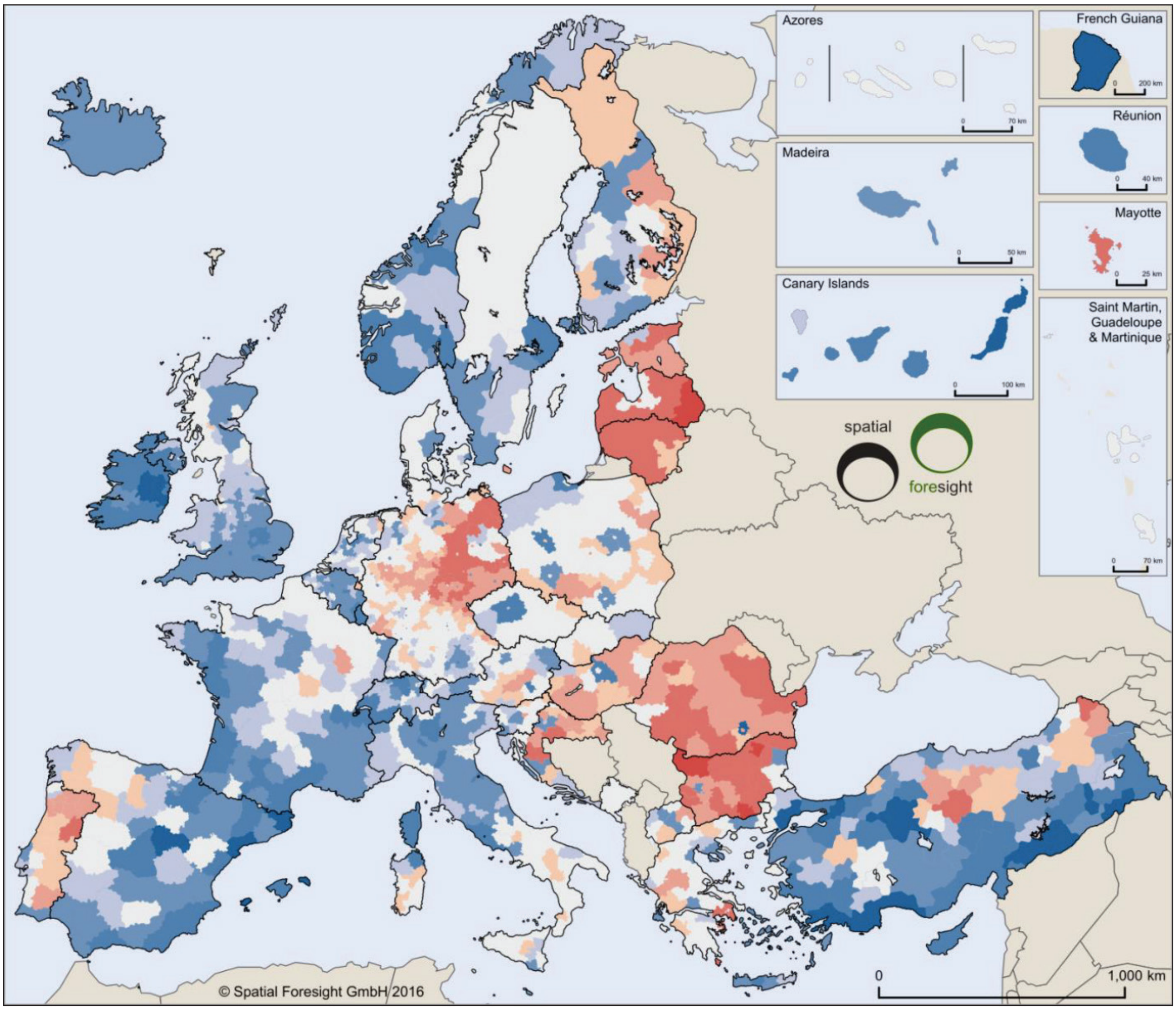
of people, ideas and resources (Vandecasteele et al., 2019). However, several challenges materialise in association with urbanisation, as cities are also the theatres in which migration, political discontent, conflict, terrorism and crime occur (ESPAS, 2019). It has been suggested that, by 2030, urban living will be the way of life for society as a whole (ESPAS, 2019). However, the United Nations (UN) has warned that many cities across the world are poorly prepared for the **multidimensional challenges of growing urbanisation** (UN Habitat, 2016), including poverty, migration, the need for services and environmental issues (see Box 2.5). Cities are also where the majority of environmental pressures originate, as 60-80 % of all resource consumption and energy use and nearly half of CO_2 emissions and ecosystem degradation can be attributed to cities (EEA, 2015d). According to the International Resource Panel (IRP) (2018), if changes are not made to how cities are built and designed, the annual amount of resources used by urban areas at the global scale could grow from 40 billion tonnes in 2010 to 90 billion tonnes by 2050, an increase of 125 % (Cluster 3). Moreover, alongside with global warming (Cluster 2), urbanisation can enhance warming in cities and their surroundings (heat island effect), especially during heat related events (e.g. heat waves), with stronger impact on night-time temperature, overall leading to **increased risks for health** (IPCC, 2019a). Despite shifts in mainstream urban planning practice towards compact cities and densification strategies, more dispersed models of urbanisation, such as suburbanisation, peri-urbanisation and urban sprawl, prevail all over the world and in particular in developing countries (UN Habitat, 2016).

2.2.3.2 Increased mobility, urban sprawl and regional diversification within the EU

Overall, **intra-EU mobility** has facilitated population changes within the EU in recent decades and has been largely driven by pre-existing economic disparities between Member States, as the gaps in wages and living standards create a strong attraction to western and northern countries (Lutz et al., 2019). The population of the EU increased from 476 million to 508 million between 1991 and 2015, and, despite low fertility, both western and southern Europe experienced a substantial population increase (Lutz et al., 2019). This was largely due to significant migration within and outside the EU.

Overall, during the decade 2010-2020, for eight countries in the EU negative net migration exacerbated the decreasing population size, leading to reductions of between 1 % and 13 % in total population. These countries were Bulgaria, Croatia, Greece, Poland, Portugal, Latvia, Lithuania and Romania (UN DESA, 2019). Demographic trends at a subnational scale between 2000 and 2014 (Map 2.1) confirmed population decline across large parts of eastern Europe, with the exception of capitals and metropolitan cities (Gløersen et al., 2016). While statistics on intra-EU bilateral flows of migration are still characterised by limited accuracy, it has been estimated that the trend was largely driven by immigration from EU Member States that joined the EU in 2004 (Lutz et al., 2019), leading to a phenomenon defined as east-west polarisation (Gløersen et al., 2016). Overall, according to Eurostat (2018c), demographic change in Europe can be summarised according to the following main trends: **capital city region effect** (i.e. continued expansion in areas around capital cities); **urban-rural split; north-south split** between EU Member States (i.e. a high proportion of the population in northern Member States is single and is living alone, contrary to the situation in Mediterranean countries); **regional divergences** within individual EU Member States (e.g. between eastern and western regions of Germany and northern and southern regions of Belgium, Italy and the United Kingdom).

Map 2.1 Population change between 2000 and 2014 by NUTS 3 regions



Annual average population change from 2000 to 2014 in percentage

%: -3 to -2 | -2 to -1 | -1 to -0.5 | -0.5 to -0.25 | -025 to 0.25 | 0.25 to 0.5 | 0.5 to 1 | 1 to 2 | 2 to 4.5

* Data for AT, IT, LV, HR, HU and MT from 2001-2014.
* Data for SK, ES, CZ, UKD6, UKD61, UKD62, UKD63, UKD71, UKE44, UKE45, UKF24, UKF25, UKG36, UKG37 UKG38, UKG39, UKH24 and UKH25 from 2002-2014.
* Data for NL, SI and IS from 2003-2014.
* Data for BE335 and BE336 from 2004-2014.
* Data for NO011 and NO012 from 2005-2014.
* Data for DK from 2007-2014.
* Data for TR from 2008-2014.
* Missing data for parts of DED2, DED4, DED5 and DEE0 was substituted with data from the next higher NUTS level.

Notes: Administrative boundaries: Spatial Foresight and University of Geneva based on material from Eurostat GISCO, the GADM database and the EEA. Data: Eurostat (demo_r_pjangrp3). NUTS, Nomenclature of Territorial Units for Statistics.

Source: Spatial Foresight, as in Gløersen et al. (2016).

As reported by the European Strategy and Policy Analysis System (ESPAS) (2019), most Europeans live in cities of between 100 000 and 1 million people, while only 7 % of the population lives in cities larger than 5 million (Dijkstra et al., 2016). Besides this, the move from the inner city to suburban and peri-urban areas has been a continuous trend in Europe since the mid-20th century, and the divide between urban and rural areas is becoming increasingly blurred (Eurostat, 2016). Europe has also been experiencing a trend of 'rurbanisation'

(Roberts, 2014), which essentially entails two types of urban development: rural-urbanised lifestyle living areas — rural residential — in the hinterland of cities in developed economies; and — especially relevant to Europe — areas where non-residents and foreigners are acquiring property in small rural towns and villages (Roberts, 2014). This not only brings construction and job opportunities to small rural towns and cities but also creates risks for rural property and land markets (e.g. locally unaffordable housing and land) and societal division (e.g. fenced off communal areas; Roberts, 2014).

Recent trends (2000-2014) have indicated that the economic downturn has accentuated the polarisation in trends in Europe and within Member States; contrasts are accentuated between regions that are perceived as offering **attractive living environments**, including metropolitan areas and areas in decline (Gløersen et al., 2016). Over half of European cities are expected to see their population decline in the future, and at the same time European urban areas are, overall, expected to cover greater areas than in the past (Vandecasteele et al., 2019). In particular, **capitals** and their adjoining urban regions are expected to see urban growth, particularly in northern and western Europe, while some cities are projected to contract by 20-30 % in countries such as Greece, Latvia, Poland and Portugal (Eurostat, 2016). Alternative scenarios departing from those that have been illustrated above might unfold as a result of multiple interactions among factors such as governance and social and technological innovation, leading to very different trends in the mid- to long term (see Box 2.6).

Intra-EU migration is also expected to lead to increased social vulnerability and inequality across Europe, reinforcing the trends observed in Cluster 6. The EU could face further differentiation between western and northern Member States and eastern and southern regions because of increased migration with the EU, associated with economic disparities and a lack of opportunities (Lutz et al., 2019). A **decline in population** in some areas is due to Europe's demographic trends, and in other areas it is more importantly determined by internal migration (UN DESA, 2019). Western European regions experience more limited demographic decline than is observable at the regional level (Gløersen et al., 2016). To some extent, this trend has affected European southern regions too, particularly Greece, Portugal, Spain (eastern regions) and Italy (southern regions), as many young adults left these countries as a result of the recent financial crisis, further **aggravating issues of ageing** and the old-age dependency ratio in these regions (Lutz et al., 2019). Although this may have led to overall economic growth at the EU scale, the benefits for the sending Member States are less clear, as large emigration contributes to lower economic growth and a loss of talent and innovation (Atoyan et al., 2016). Moreover, it has been indicated that the flows of profits generated in eastern EU countries are mainly benefiting western-EU investors, who now possess a considerable proportion of the capital of the ex-eastern European countries (i.e. roughly a quarter of the complete stock of fixed capital and over half of the capital stock of firms) (Piketty, 2018). Between 2010 and 2016, the flows of profits that owners of the firms received exceeded by far the European transfers going to eastern EU countries and reduced commensurately the national income of these countries, an argument often used to indicate that investors take advantage of their position of strength to keep wages low and maintain excessive

Box 2.6 Wild card — Social and technological innovation in cities

There is a trend towards the empowerment of city governance, through which powers are devolved from national to local level (OECD and DASTI, 2016; UN Habitat, 2016) (Cluster 6). Cities, and particularly megacities, are gaining autonomy, setting social and economic standards and becoming increasingly important subnational actors, and the achievement of the Sustainable Development Goals will greatly depend on what will happen at the city scale. Cities are likely to play a central role in social innovation, including new governance approaches, because of the proximity of stakeholders (Vandecasteele et al., 2019). New forms of urban governance and greater citizen engagement in policy processes are already being stimulated in many cities in Europe. The co-creation of strategies to tackle urban challenges involving citizens' perspectives are expected to provide a broader range of perspectives and potential solutions (Vandecasteele et al., 2019).

With the uptake of new technological developments such as the Internet of Things (see Cluster 4), cities in mostly advanced economies may become 'smart cities', as their transport and utility infrastructure and other systems become increasingly interconnected. It is often suggested in the literature that enabling smart technologies could lead to increased efficient use of energy and resources (OECD and DASTI, 2016), although such a transition is also subject to uncertainties, especially in relation to resource and energy consumption implied by the transition to smart cities in the light of climate policies and resource scarcity (see also Cluster 3). On the contrary, with technological developments leading to improved logistics, especially telecommunication and internet services, and the transition to a digital society (e.g. digitisation of business, flexible ways of working — Clusters 4 and 6), rural areas could become increasingly attractive places to live, and the depopulation of regional peripheries could be reduced.

margins (Piketty, 2018). Scenarios for 2060 indicate that further concentration of population is likely to occur in western Europe at the expense of a **decline in population in eastern Member States**, the extent of which is likely to depend on future convergence among EU regions concerning aspects such as living standards, labour and wages, and opportunities for higher education (Lutz et al., 2019). This may lead to further **congestion of people in cities** and in western Europe, and increasing abandonment of rural areas in the east of Europe, which may then lead to demographic imbalances that aggravate a decline in population associated with low fertility rates and limit economic growth. According to the Joint Research Centre of the European Commission (JRC) (Batista e Silva et al., 2016), if current trends on sectoral gross value added and employment continue in the future, consistent with the demographic and overall macro-economic scenario defined by the Directorate-General for Economic and Financial Affairs (DG ECFIN) and Eurostat (EC, 2017f), **disparities in economic development across EU regions** will be on the rise. If not properly managed, a population decline and shrinking may lead to challenges concerning maintenance of infrastructure and public services, leading to a territory more vulnerable to natural hazards. Moreover, investments in high-tech, large-scale farms may substitute those in small to medium-sized farms and change the cultural landscape of some European regions. Instead, attracting residents and visitors may be more beneficial for local development than actions promoting competitive, export-oriented industries (Gløersen et al., 2016). European policies will need to find a balance between regional development, social inclusion, protection of natural capital and management of natural hazards, particularly in the light of a changing climate and more severe implications (see Cluster 2).

2.3 Cluster 2 — Climate change and environmental degradation worldwide

Key messages (cont.)

The period after the 1950s marked a unique period in human history with unprecedented and accelerating humaninduced global change, which has become known as 'the Great Acceleration' (Steffen et al., 2011, 2015). Such development has delivered enormous improvements in living standards and wellbeing for hundreds of millions of people, especially in Europe and other highly industrialised world regions.

At the same time, the sheer size of global population growth and the intensity of human activities has caused tremendous pressures on the Earth's life support systems through climate change, biodiversity loss, changes in the chemical composition of the atmosphere, oceans and soil, etc. Environmental change is occurring at such a scale that human activities have now significantly altered the Earth's system from the stable Holocene to a new humandominated epoch referred to as the Anthropocene (Waters et al., 2016).

Accelerating climate change and increasingly severe consequences

- Human activities are estimated to have caused approximately 1.0 °C of global warming above preindustrial levels, and global warming is likely to reach 1.5 °C between 2030 and 2050 if current rates continue in the future (IPCC, 2018). Rising global temperature alters weather patterns and in turn has impacts on the environment, the economy and society, threatening the livelihoods, health, water, food and energy security of populations (UN Environment, 2019c).

- Global climate change implications, such as changing species patterns, the presence and resilience of invasive species, increased frequencies of floods and droughts, wildfires, heatwaves, extreme weather events, increased melting and related water availability, all have the potential to impact natural and productive terrestrial and marine systems globally (IPCC, 2018, 2019a, 2019b). In the most recent The global risks report 2019 by the World Economic Forum, environmental risks, including climate change, accounted for three of the top five risks ranked by likelihood and four of the top five risks ranked by impact (WEF, 2019) and current trends indicate that these challenges are likely to worsen in the future.

- Globally, there has been growing political commitment to limit global GHG emissions, as reflected in the policy ambitions at all governance levels to pursue ambitious climate change targets, including the ratification of the United Nations Framework Convention on Climate Change (UNFCCC) Paris Agreement of December 2015 (UNFCCC, 2015). It has been recently estimated that, at the global scale, governments are planning to produce about 50 % more fossil fuels by 2030 than would be consistent with a 2 °C pathway and 120 % more than would be consistent with a 1.5 °C pathway (SEI et al., 2019).

Increased pressures on ecosystems and biodiversity

- The Earth is experiencing an exceptionally rapid loss of biodiversity, and more species are threatened with extinction now than at any other point in human history (IPBES, 2019). Anthropogenic activities have unleashed a mass extinction event, the sixth in roughly 540 million years, wherein many current life forms could be annihilated or at least condemned to extinction by the end of this century (Ripple et al., 2017).

- Currently, 75 % of the terrestrial environment and 40 % of the marine environment are now severely altered globally (EEA, 2019e; IPBES, 2019), while global indicators of ecosystem extent and condition have shown a decrease of an average of 47 % in their estimated natural baselines, with many continuing to decline (IPBES, 2019). The direct drivers explaining most of the decline in terrestrial, freshwater and marine ecosystems are — to different degrees — changes in land and sea use, direct exploitation of organisms, climate change, pollution and invasion of alien species (IPBES, 2019), while indirect drivers are growing population, urbanisation and consumption levels (see Clusters 1, 3, 5 and 6).

- Climate change, loss of natural capital and biodiversity, and pollution are highly interconnected and mutually reinforcing. For example, climate change and growing pollution are likely to further increase the loss of natural capital and biodiversity; in turn, the loss of natural capital and related carbon stocks increases greenhouse gas emissions leading to climate change. While tipping points are fundamentally uncertain, surpassing them (e.g. loss of pollinators) might lead to catastrophic consequences for the functioning of the planet's ecological system, including the human species.

- Environmental degradation worldwide creates social and economic impacts and contributes to increasing inequalities (Cluster 5) as well as regional and international migration (Cluster 1). Environmental degradation influences people's quality of life and health as well as their experience and interaction with nature but it also leads to increased awareness about such issues (Cluster 6).

Key messages (cont.)

Increasing environmental pollution and chemical pressure

- Air pollution is the main environmental contributor to the global burden of disease (Cluster 6). This translates into 6 to 7 million premature deaths and significant welfare losses. Although emissions trends have declined in western countries, albeit at different paces, rapidly developing countries and emerging economies have been on the rise in the last decade, reflecting geopolitical and macro-economic changes (Cluster 5) and continued urbanisation (Cluster 1). The highest death toll is in East Asia and South Asia due to high density of population and exposure to high levels of pollution.

- Water quality has worsened in most of the world's regions since 1990, mainly because of organic and chemical pollution, including pathogens, nutrients, pesticides, sediments, heavy metals, plastic and microplastic waste, persistent organic pollutants and salinity (UN Environment, 2019b). One of the fastest growing concerns related to water quality is antibiotic-resistant bacterial infections, projected to become the main cause of death worldwide by 2050 (UN Environment, 2019b).

- Pollution from plastic waste is also a growing issue increasingly affecting all oceans, while e-waste is becoming a growing concern. In 2016, Europe was the second largest generator of e-waste per person (around 16-17 kg) (Baldé et al., 2017). While international agreements have been successful in addressing specific chemicals, new chemical risks are emerging (UN Environment, 2019a). The spread of large quantities of hazardous chemicals and other pollutants throughout global ecosystems has been increasing at rates significantly outpacing those of other drivers of global environmental change, however, not enough attention is given to their potential impacts (Bernhardt et al. 2017).

2.3.1 Increasingly severe consequences of climate change

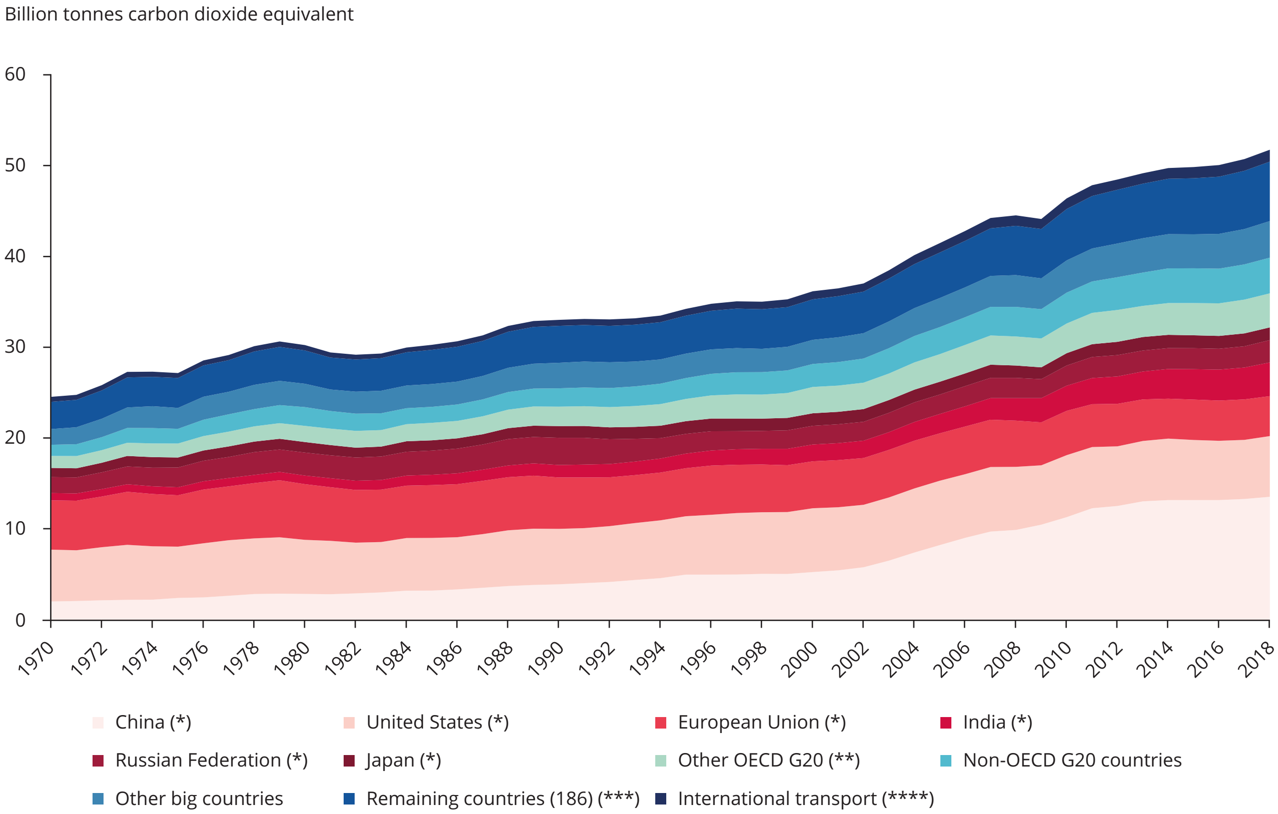
2.3.1.1 Unprecedented increase in greenhouse gases concentration and global temperature

Many of the changes in the global climate system are unprecedented over decades to millennia and are largely caused by human activities, such as GHGs emissions from fossil fuel burning, agriculture and deforestation. In fact, the onset of the Industrial Revolution around 1760 was accompanied by an increasing pace of change in human development and associated environmental degradation. In particular, the period after the 1950s marked a unique period in human history with unprecedented and accelerating human-induced global change, which has become known as **'the Great Acceleration'** (Steffen et al., 2011, 2015). Global annual emissions of greenhouse gases (GHGs) have risen steadily in the last couple of centuries, and only in the last 50 years emissions have reached a 2-fold increase, although different paces have been observed among world regions (see Figure 2.6).

Overall, human activities are estimated to have caused approximately 1.0 °C of **global warming above pre-industrial levels, and global warming is likely to reach 1.5 °C between 2030 and 2050** if current rates continue in the future (IPCC, 2018). For example, atmospheric concentrations of carbon dioxide (CO_2) and methane (CH_4) have increased by about 40 % and 150 %, respectively, since 1750 and are projected to rise further (IPCC, 2013). **The observed global mean temperature is continuing to rise**, as each of the last three decades has been successively warmer than any preceding decade since the mid-19th century, while the frequency and magnitude of extremes in temperatures and global distributions of climate patterns and their impacts are shifting (IPCC, 2018) (Figure 2.7). Arctic regions are undergoing the strongest warming trends, with increases ranging between two and three times the mean global temperature rise (IPCC, 2018; UN Environment, 2019c), leading to widespread **shrinking of the cryosphere**, with mass loss from ice sheets and glaciers, reductions in snow cover and Arctic sea ice extent and thickness, and increased permafrost temperature (IPCC, 2019b). The alteration of the polar climate system is likely to have global repercussions, such as accelerated global sea level rise and the disturbance of climate and weather patterns (UN Environment, 2019c), a trend that is expected to continue for many centuries or even millennia, even after the climate has stabilised as a result of the thermal inertia of the deep ocean. **Land use change** associated to the expansion of areas under agriculture and forestry (see Cluster 3), has contributed to increasing net GHG emissions, besides determining significant loss of natural ecosystems and declining biodiversity (IPCC, 2019a).

However, despite international commitment to reduce GHG emissions (e.g. the UNFCCC Paris Agreement; UNFCCC, 2015), it has been recently estimated that, at the global scale, governments are planning to produce about 50 % more fossil fuels by 2030 than would be consistent with a 2 °C pathway and 120 % more than would be consistent with a 1.5 °C pathway (SEI et al., 2019). These values also surpass production levels

Figure 2.6 Total annual emissions of GHGs, by world region



Notes:
* Member of Group of Twenty (G20). The EU(28) in its entirety is also a member.
** 'Other OECD countries G20' exclude six not listed OECD countries which total emissions comprise about 10% of this group: Chili, Iceland, Israel, New Zealand, Norway, and Switzerland.
*** Total emissions of 'Remaining countries (186)' is the sum of all countries minus G20 and minus the six 'Other large countries'. Includes six not listed small OECD countries mentioned in note 2.
**** Total emissions from international marine and aviation bunkers (international water and air transport).

Source: Olivier and Peters (2020), in turn based on multiple sources.

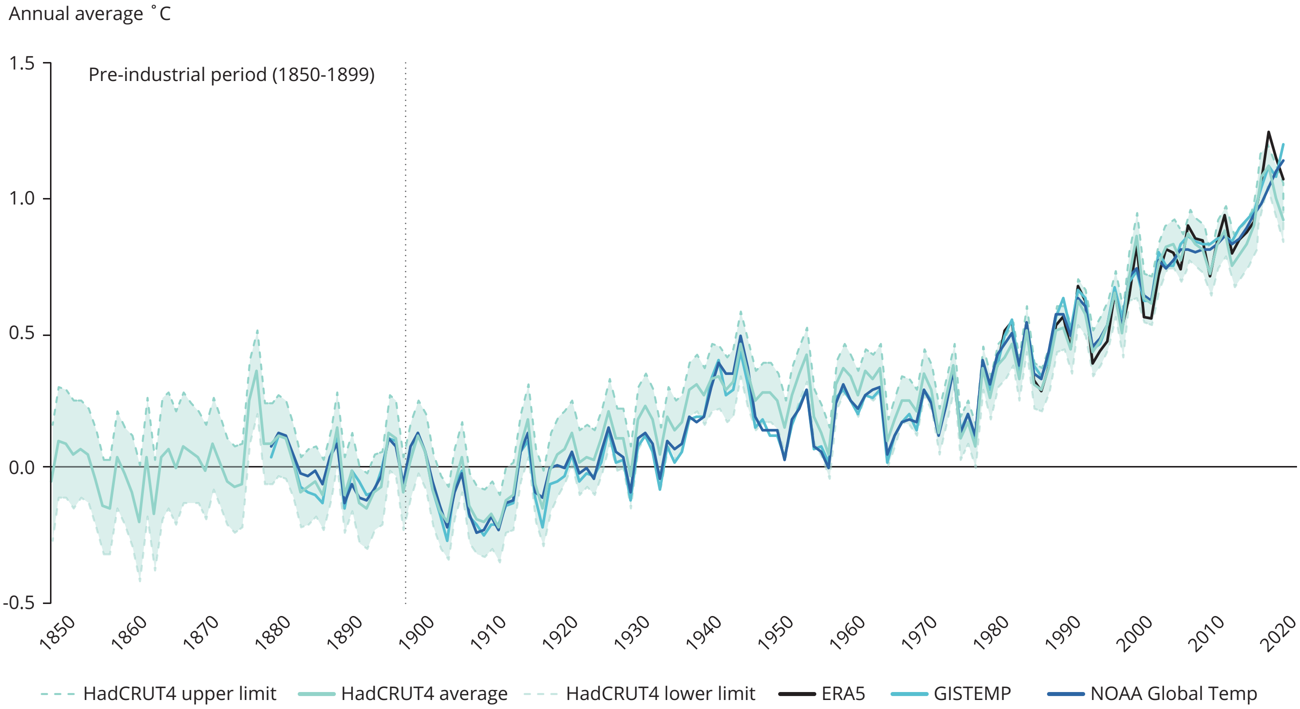
consistent with the implementation of the national climate policies and ambitions underpinned by nationally determined contributions at the heart of the Paris Agreement (SEI et al., 2019) (see also Cluster 3).

2.3.1.2 Increasingly severe impacts on well-being and ecosystems

Rising global temperature alters weather patterns and in turn has impacts on the environment, the economy and society, threatening the livelihoods, health, water, food and energy security of populations (UN Environment, 2019c). For example, as **temperatures increase**, heatwaves are expected to become more frequent; nevertheless, future climate-related risks depend on the rate, peak and duration of the warming (IPCC, 2018). In a high GHG scenario, in many regions (e.g. Asia, Australia, Europe), **extreme heat events** are likely to occur more frequently, with the highest increases in the tropics (IPCC, 2018). In many world regions, including Europe, increases in the frequency and intensity of extreme climate events such as droughts and heavy precipitation have been already observed (EEA, 2019e). Moreover, many **land and ocean ecosystems** and some of the services they provide have already changed because of global warming (IPCC, 2018).

Variations in precipitation patterns indicate more frequent, intense rainfall and storms in some regions, leading to **increased risk of flooding** and **excessive droughts** in others. For example, the Mediterranean and parts of Africa are increasingly experiencing intense droughts (IPCC, 2014), increasing evapotranspiration and the risk of desertification in southern Europe (EEA, 2017a). In a 1.5 °C to 2 °C warmer world the duration and intensity of drought risks would increase in many historically drought-prone regions and in regions such as the Amazon, north-eastern Brazil and central Europe (Liu et al., 2018).

Figure 2.7 Global average near surface temperatures relative to the pre-industrial period



Notes: HadCRUT4: Met Office Hadley Centre and Climatic Research Unit; GISTEMP: NASA Goddard Institute for Space Studies; NOAA Global Temp: National Centers for Environmental Information; ERA5: Copernicus Climate Change Service by ECMWF.
Light blue area: 95 % confidence interval of HadCRUT4 data set.

Source: EEA (2019b).

Global climate change implications, such as changing species patterns, the presence and resilience of invasive species, increased frequencies of floods and droughts, wildfires, heatwaves, extreme weather events, increased melting and related water availability, all have the potential to impact natural and productive terrestrial and marine systems globally (IPCC, 2018, 2019a, 2019b). The impacts on and risks for selected natural, managed and human systems in the case of an increase in temperature have been assessed by IPCC (2018). For example, **warm water corals**, very important ecosystems and nurseries for fish, as well as biodiversity hotspots, are particularly at risk, alongside Arctic regions and coastal systems (IPCC, 2018). Similarly, the shrinking cryosphere in the Arctic and high-mountain areas and the thawing of permafrost could pose risks to the environment and the food chain, through the release of mercury, increasing erosion, landslides, ground subsidence, floods, extreme sea levels, coastal erosion and changes in plant species composition at high latitudes, with impacts on health and well-being unequally distributed across populations and regions (IPCC, 2019b).

There are a number of climate change impacts that could be avoided by limiting global warming to 1.5 °C compared with 2 °C, or more (IPCC, 2018) urgent and unprecedented changes would be needed to meet this objective. Without drastic **emissions abatement measures** globally, in the coming two to three decades, continued global warming is expected to increase the likelihood of severe, pervasive and irreversible consequences, such as the collapse of natural ecosystems (the Arctic, coral reefs, the Amazon rainforest), the erosion of global food security and the displacement of people at unprecedented scales (EEA, 2019e). The effect of climate change is expected to show significant **regional differences** and might be positive under specific circumstances and locations (see EEA, 2017a for impacts and vulnerability in Europe). The future level of risk posed by climate change will depend on the severity of warming as well as on factors like population dynamics (Cluster 1), affluence, consumption and lifestyles (Clusters 5 and 6), production and technological development (Clusters 3 and 4), and on the extent to which mitigation and adaptation responses are effectively implemented (IPCC, 2018, 2019a). Among several **mitigation options**, geoengineering is often advocated as a potential solution of climate change, however some of the technological options grouped under geoengineering are characterised by **major uncertainties** concerning effectiveness, feasibility and risks (see Box 2.7).

Box 2.7 Uncertainty — Geoengineering climate solutions: opportunity or risk?

The risk of increasing climate implications could boost an interest in geoengineering in the future. The two most discussed groups of technologies are solar radiation management and the removal of CO_2 from the atmosphere. The latter in combination with large-scale biomass cultivation to produce energy carriers (i.e. bio-energy with carbon capture and storage, BECCS) is a recurring option in the Intergovernmental Panel on Climate Change long-term scenarios (Spangenberg and Polotzek, 2019). However, such major interventions are characterised by high uncertainty concerning their ability to achieve a net removal of CO_2 from the atmosphere (EASAC, 2019) and are likely to bring risks regarding their environmental impacts and unintended consequences (Curvelo, 2015; NIC, 2017). For example, solar radiation reduction will not help reduce ocean acidification, and the removal of CO_2 through carbon capture and storage (CCS) is likely to threaten biodiversity (EEA, 2006; Spangenberg et al., 2014; Smith et al., 2016; Williamson and Bodle, 2016). As reported in *The European environment — state and outlook 2020* (EEA, 2019e), among other technical and social challenges (e.g. safety and acceptance), CCS-equipped power plants are estimated to require approximately 15-25 % more energy and thus need more fuel than conventional plants. This would lead to increased direct emissions of air pollutants from CCS plants, including particulate matter and nitrogen dioxide (EEA, 2011).

Globally, there has been **growing political commitment** to limit global GHG emissions, as reflected in the policy ambitions at all governance levels to pursue ambitious climate change targets, including the ratification of the United Nations Framework Convention on Climate Change (UNFCCC) Paris Agreement of December 2015 (UNFCCC, 2015). Moreover, concerns regarding the future of the climate are mounting among citizens and young age groups in particular, thanks to growing exposure on social media (see Cluster 6), calling for urgent action to halt global environmental challenges.

The pathways reflecting the full implementation of current mitigation ambitions, as submitted by all countries globally under the Paris Agreement, imply a global warming of around 3 °C by 2100. If this 'emissions gap' is not closed by 2030 through strong emission reductions, the goal of a well below 2 °C global temperature increase will be out of reach (IPCC, 2018; UNEP, 2018). Recent estimates indicate that **the gap is likely to widen further** because of planned fossil fuel-based power plants, and so it is likely to increase further (SEI et al., 2019). In this context, the recent EU strategy for a climate-neutral economy by 2050 in Europe (EC, 2018i) forms an important contribution, although Europe contributes directly to around 8 % of global GHG emissions.

According to the Intergovernmental Panel on Climate Change (IPCC) (2018), limiting global warming to 1.5 °C would require investing about USD 2.4 trillion in the global energy system every year between 2016 and 2035, or about 2.5 % of the world's GDP. However, cost-benefit analysis or risk-based analysis based on integrated assessment models (IAMs) should probably not be at the core of political decisions, given their limited reliability and substantial inability to address complex systems' uncertainties and non-linearity (e.g. tipping-points — see Box 2.8).

2.3.2 Increased pressures and impacts on ecosystems and biodiversity

2.3.2.1 Growing pressure on terrestrial, freshwater and marine ecosystems

Nature supports the existence of human life on Earth through provision of services, food and feed, fibre, energy, medicines and genetic resources; regulation of the quality of air, freshwater and soils; regulation of climate, pollination and pest control; and a reduction in the impacts of natural hazards; and provision of inspiration and learning, and physical and psychological experiences (IPBES, 2019).

However, nature and its **vital contributions to people** are deteriorating worldwide at an alarming pace because of human activities (IPBES, 2019; UN Environment, 2019c), as the rate of global change in nature induced by humans in the past 50 years is unprecedented in human history (IPBES, 2019). Currently, **75 % of the terrestrial environment and 40 % of the marine environment are now severely altered globally** (EEA, 2019e; IPBES, 2019), while global indicators of ecosystem extent and condition have shown a decrease of an average of 47 % in their estimated natural baselines, with many continuing to decline (IPBES, 2019).

The direct drivers explaining most of the decline in terrestrial, freshwater and marine ecosystems were — to different degrees — changes in land and sea use, direct exploitation of organisms, climate change, pollution and invasion of alien species (IPBES, 2019), as reported in Figure 2.8. Indirect drivers underpinning global change were identified as growing population, urbanisation and consumption levels (see Clusters 1, 3, 5 and 6).

Box 2.8 Uncertainty — Modelling climate change and its impacts for policy

Despite the existence of significant uncertainties in modelling climate change impacts (EEA, 2017a), often associated to the existence of non-linear responses (e.g. melting of ice and snow and the thawing of permafrost, local to regional feedback mechanisms) it has been recently estimated that the climate models developed in the past five decades to replicate the physics of the climate 'were [overall] skilful in predicting subsequent changes in global mean surface temperature, as projections were consistent with observations, particularly when mismatches between model-projected and observationally estimated forcing [i.e. rates of anthropogenic emissions] were taken into account' (Hausfather et al., 2020). Unfortunately, the same thing cannot be said of emission scenarios and integrated assessment models (IAMs).

Models of the costs and benefits associated with climate change, like IAMs, are seen by many as a key ingredient in policy action and in advocacy for urgent action (Stern, 2015), or inaction (Nordhaus, 2007). However, given the impossibility of predicting meaningfully both socio-economic and ecological developments decades away from the present, these models are particularly vulnerable to deconstruction (Saltelli et al., 2015). Although these studies may be seen as academically legitimate, and even useful for policy simulation, their use for policy formulation should give rise to some concerns.

For example, integrated assessment models (IAMs), very often at the base of climate policy, are inherently unable to appropriately reflect non-linear dynamics, either economic or ecological, that can have large impacts on system structure and behaviour. This implies their inability to describe long-term developments and to take into account the structural uncertainty of complex systems. Therefore they are bound to failure in the real world (Spangenberg and Polotzek, 2019). Moreover, while IAMs are often seen as descriptive and 'objective' representations of reality, they actually embed normative assumptions, such as maximisation of the social utility function (e.g. often measured as gross domestic product) being inherently tied to specific concepts of welfare (Spangenberg and Polotzek, 2019). For example, all four Intergovernmental Panel on Climate Change illustrative model pathways (IPCC, 2018) assume that continuous economic growth leads in all cases to a potential transgression of the 1.5 °C threshold, making their ability to prevent higher levels of warming entirely dependent on the use of CO_2 removal, which, for three out of four pathways requires negative emission technologies, such as bioenergy with carbon capture and storage. In contrast, alternative pathways, such as discontinuing economic growth in affluent countries, are simply neglected (Spangenberg and Polotzek, 2019).

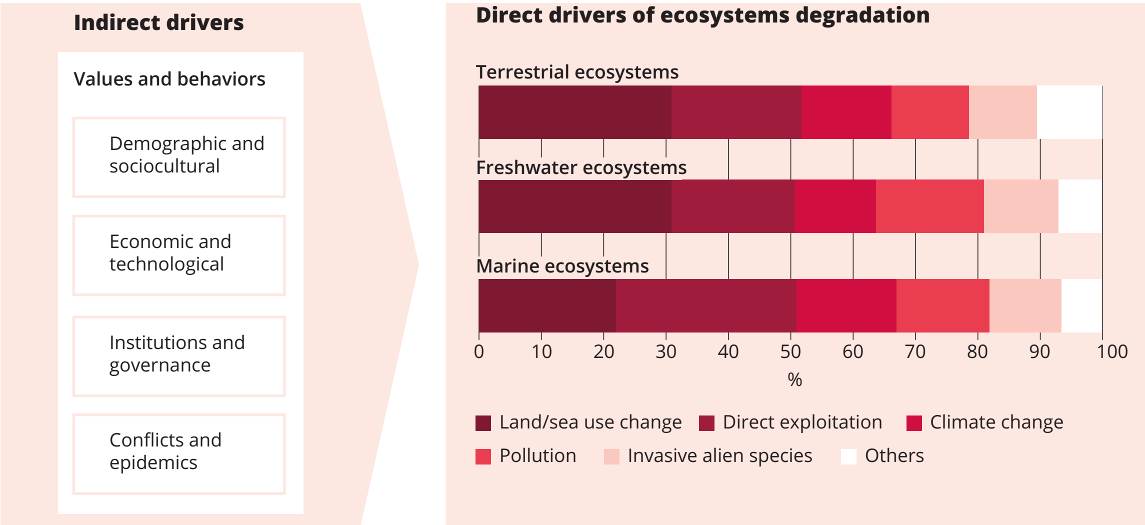
Therefore, any cost-benefit analysis explicitly assessing the costs of climate change based on IAMs and discount rates turns out to be very fragile, as, for example, the basis of the dispute between Stern (2007) and Nordhaus (2007) concerning future costs of climate change, as highlighted by Saltelli and D'Hombres (2010). In correspondence published in *Nature* (Saltelli, 2016) it was noted that 'models that predict higher costs of climate change might make political intervention more palatable. But prescribing models that generate more precisely quantified estimates of a desired output is a political programme, not a scientific one. Responsible research requires responsible quantification and responsible acknowledgement of uncertainty.'

Therefore, extreme caution should be exercised in the use and interpretation of the economics of climate change, especially when used to orient societal debate and policy. Moreover, the knowledge base should overcome the mechanistic world view embedded in IAMs and replace it with one based on a physical economy of matter and energy flows, switching from equilibrium thinking and modelling to evolutionary approaches (Spangenberg and Polotzek, 2019) as well as foresight and systems thinking.

Almost half of the global habitable land resource has already been converted for human use (UNCCD, 2017). While the **net rate of forest loss** has halved since the 1990s, it is now approximately 68 % of the estimated pre-industrial level, and terrestrial 'hotspots' of endemic species, including the tropical rainforest, have been affected more severely (IPBES, 2019). Land use changes associated with seizing biomass mainly occur in Africa, the Middle East, eastern Europe, central Asia and Russia, whereas consumption (e.g. of crops or timber) is the motive for most of the land take in western industrial countries and Asia (UNCCD, 2017).

Increasing global meat consumption (Clusters 5 and 6) and conversion of land for cattle grazing and animal feed production is a key driver of land use change and environmental degradation globally (Heinrich Böll Foundation and Friends of the Earth Europe, 2013). Moreover, agricultural land and water management as well as production practices have led to **soil erosion and compaction**, reduced water filtration and availability, **biodiversity decline** (both above and below ground) and a reduction in the Earth's vegetated surface productivity by approximately 20 % (UNCCD, 2017). In addition to this, driven at least in part by intensification, the global food system is increasingly reliant on **chemical fertilisers, pesticides and preventive use of antibiotics** (IPES Food, 2016), which has negative implications for soil fertility and crop quality, disrupt ecological processes and contaminate surface water and groundwater (Bernhardt et al., 2017). These trends are likely to

Figure 2.8 Drivers of pressure and impacts underpinning global declines in nature



Source: EEA, based on IPBES (2019).

further exacerbate loss of ecosystems and biodiversity if consumption levels continue to increase as a result of growing affluence (e.g. expanding global middle class — see Clusters 3 and 5).

Marine ecosystems — from coastal to deep sea — are also increasingly affected by human actions as a result of the **cumulative impacts of resource extraction and pollution** (IPBES, 2019). The continued loss and rapid decline of coastal marine ecosystems, which are among the most productive systems globally, reduce their ability to protect shorelines and the people and species that live there from storms, as well as their ability to provide sustainable livelihoods (IPBES, 2019). Notably, seagrass meadows decreased in extent by over 10 % per decade from 1970 to 2000, while live coral cover on reefs has nearly halved in the past 150 years (IPBES, 2019). The latter has been significantly influenced by increased water temperatures and ocean acidification due to climate change, which has interacted with and further exacerbated other drivers of loss (IPBES, 2019). Globally, more than 30 % of marine **fish stocks** are estimated as being overfished, thus increasingly threatening the global marine ecosystems (IPBES, 2019), raising substantial concerns regarding food availability in coastal communities (see Cluster 3).

2.3.2.2 Unprecedented global biodiversity loss: towards the sixth mass extinction?

In response to the pressures exerted on ecosystems, the Earth is experiencing an exceptionally rapid loss of biodiversity, and more species are threatened with extinction now than at any other point in human history (IPBES, 2019). **The global rate of species extinction** is already, at least, 10 to 100 times higher than the average rate over the past 10 million years, and it is accelerating (IPBES, 2019). The abundance of wild species has declined drastically, both globally and in Europe — a phenomenon referred to as the **'Anthropocene defaunation'** (Dirzo et al., 2014; McCauley et al., 2015). The mass of humans today is an order of magnitude higher than that of all wild mammals combined (Bar-On et al., 2018). Overall, evidence suggests that a sixth mass extinction of Earth's biota is already under way (Leakey and Lewin, 1996; Ceballos et al., 2015). Moreover, the threat of extinction has been shown to have accelerated in the last 40 years, as indicated by estimates based on the best-studied taxonomic groups (IPBES, 2019).

On average, **nearly 25 % of species are threatened with extinction** across well-studied species groups, according to the International Union for the Conservation of Nature's Red List (IUCN, 2019). The proportion of insect species threatened with extinction is a key uncertainty, but available evidence supports a tentative estimate of 10 %. These proportions suggest that, of an estimated 8 million animal and plant species (75 % of which are insects), around 1 million are threatened with extinction (IPBES, 2019). Estimates based on habitat loss and deterioration provide a similar order of magnitude, suggesting that many terrestrial species are condemned to extinction within decades, unless their habitats are restored (IPBES, 2019).

Overall, the **loss of genetic and species diversity** is a challenge for natural and agricultural ecosystems' resilience to threats, such as pests, pathogens and climate, which threaten food security and have implications for public health (IPBES, 2019). Fewer varieties and breeds of plants and animals are in fact being cultivated and maintained globally (UN Environment, 2019c). As 70 % of people living in poverty directly depend on natural resources for their livelihood, biodiversity loss should also be considered an equity issue, not just an ecological one (UN Environment, 2019c). If current rates of decline continue, future generations will be deprived of the health benefits of biodiversity, with disproportionate impacts likely to be suffered by the most vulnerable part of the population (e.g. poorer people, women and children) (UN Environment, 2019c).

2.3.2.3 Systemic risks stemming from continued acceleration

Environmental systems are deeply intertwined with societal needs, such as food production, energy security and freshwater supply, and the resulting pressures have led to a plethora of systemic environmental challenges, such as ecosystem degradation and biodiversity loss, climate change and pollution loads (EEA, 2019e). Given their systemic nature, these challenges are linked through **feedback loops** occurring at multiple scales, further complicating their governance. This implies, for example, that increasing levels of global warming might exacerbate biodiversity loss and further erode the resilience of ecosystems, while pressure on land resources is likely to accelerate climate change even further through aridification and loss of vegetated cover (EEA, 2019e).

As reported in SOER 2020 (EEA, 2019e), the continuation of the 'Great Acceleration' with rising consumption levels driven by a growing population and a global middle class (see Clusters 3 and 5) raises the critical questions of whether and at what point human-induced pressures exceed **environmental limits or tipping points**. According to the planetary boundary framework, climate change and biodiversity loss are identified among the issues of most serious concern for the Earth's life support systems (EEA, 2019e). Along similar lines, in the most recent *The global risks report 2019* by the World Economic Forum, environmental risks accounted for three of the top five risks ranked by likelihood and four of the top five risks ranked by impact (WEF, 2019). In fact, persistent exposure to multiple and cumulative factors can lead to large changes that are costly to reverse (if reversible at all) and unpredictable, abrupt and persistent modifications (i.e. regime shifts) in the structure and function of social-ecological systems, affecting the variety of **ecosystem services** they provide. For example, the cumulative effect of climate, economic and societal pressures, including overfishing, bycatch and (plastic) waste, is altering the marine environment in fundamental ways through changes in physico-chemical characteristics. These changes include ocean acidification, ocean warming, changes in salinity and nutrient availability, and local stressors, such as pollution and eutrophication. Together, these factors could exacerbate a decline in global marine biodiversity and lead to a global redistribution of marine species, impacting fisheries' productivity and the provision of other ecosystem services.

Similarly, **species' extinction** or decline may further lead to **cascading and catastrophic co-extinctions** (Sodhi et al., 2009; Schleuning et al., 2016). It is important to consider that most of nature's contributions to humans are not fully replaceable and that some contributions are irreplaceable (IPBES, 2019). For example, warnings of a **potential global collapse of entomofauna** and related catastrophic effect on food production have been raised as well (Hallmann et al., 2017; Sánchez-Bayo and Wyckhuys, 2019) (see Box 2.9). If current trends and trajectories concerning increasing land and sea use change, exploitation of organisms and climate change were to continue in the future, both the 2030 agenda for sustainable development and the Aichi biodiversity targets for nature conservation and sustainable use would not be met (IPBES, 2019). Only transformative changes and system-wide reorganisation, encompassing economic, social, political and technological factors (Clusters 4, 5 and 6), including paradigms, goals and values (Cluster 6), could contribute to their achievement (IPBES, 2019). This means that society will need to fundamentally **rethink global production and consumption systems**, the underpinning economic models and standards of life, and their unequal global distribution. Foresight approaches and system thinking could help in systematically exploring alternative futures and sparking debate around their feasibility and viability, as well as wider societal desirability.

2.3.3 Increasing environmental pollution, waste production and chemical pressure

2.3.3.1 Air pollution: high burden of disease and changing geography

A clean environment is essential for human health and well-being. Current levels of pollution are detrimental to human health, with approximately **19 million premature deaths** estimated to occur annually as a result of pollution of air, soil, water and food globally (UNEP, 2017). Major drivers of increased pollution are agriculture and food, energy, industry manufacturing, services, transport and waste (UNEP, 2017). In addition, noise is an emerging human health issue, while climate

Box 2.9 Wild card — Entomofauna, pollinators and risks for global food supply

Recent studies have confirmed rapid global insect declines (Seibold et al., 2019) that have been termed by some as 'insectageddon' (Monbiot, 2017). It has been observed over the last two to three decades that both wild and domesticated insect pollinators are in dramatic decline, which means that the existence of species and ecosystem resilience are at stake, as pollinators have a very important ecological role. In fact, globally nearly 90 % of wild flowering plant species and their ecological services (providing food, forming habitats and providing other resources for a wide range of other species) depend, at least in part, on the transfer of pollen by animals (IPBES, 2016). Moreover, more than three quarters of major food crops depend on animal pollination globally, accounting, together, for 35 % of the world's food production volume (IPBES, 2016).

The present pollinator crisis threatens global and local food security, may worsen the problems of hidden hunger, will erode ecosystem resilience and may destabilise ecosystems that form our life support system (van der Sluijs and Vaage, 2016). The decline in entomofauna (including pollinators) is the likely result of the combination of biocides interacting with other environmental drivers, such as habitat fragmentation, nitrogen deposition, invasive alien species, pathogens and climate change, which could potentially cause ecosystem collapses (IPBES, 2016; Potts et al., 2016), potentially leading to catastrophic consequences over a rather short transient. Despite the existence of huge uncertainty around where tipping points are (Oliver, 2016), insect-mediated ecosystem services such as pollination, soil and freshwater functions, fisheries and biological pest control are essential to ecosystem functioning and global food security, providing an irreplaceable contribution to people.

Among other drivers, the most widely used and fastest growing class of insecticides globally, neonicotinoids — a class of persistent organochlorine compounds of growing concern — has been indicated as one of the key drivers of this global collapse of insect populations, through its interaction with other drivers. For example, strong evidence exists that neonicotinoid pollution has dramatically reduced the abundance of aquatic insects in polluted surface water (Van Dijk et al., 2013). Because most flying insects start their life cycles as larvae in surface water, it is not a surprise that the collapse in abundance of insectivorous birds correlates geographically with areas of high imidacloprid pollution (Hallmann et al., 2017). Combined with their very high toxicity to insects, their wide prophylactic application, persistence in soil and water and potential for uptake by succeeding crops and wild plants make neonicotinoids bioavailable to pollinators at sub-lethal concentrations for most of the year (van der Sluijs and Vaage, 2016). According to the Intergovernmental Science-Policy Platform on Biodiversity and Ecosystem Services (IPBES, 2016), recent research shows evidence of lethal and sub-lethal effects on bees and some evidence of impacts on the pollination they provide, particularly for wild pollinators' survival and reproduction during actual field exposure (Rundlöf et al., 2015), while evidence of the effect on managed honey bee colonies is conflicting. As suggested by van der Sluijs and Vaage (2016), an integrated approach that simultaneously addresses the key drivers is needed. This includes creation and restoration of floral and nesting resources, a global phase-out of prophylactic use of neonicotinoids and fipronil, an improvement in test protocols on authorisation of agrochemicals, and restoration and maintenance of independence in regulatory science. While the EU has acted with a moratorium on certain uses of the three most toxic neonicotinoids, further actions are needed to limit their widespread use (e.g. in greenhouses, cattle breeding) and to prevent a shift towards the use of other neonicotinoids still allowed in Europe. These measures are largely opposed by the agro-chemical sector.

change, depletion of stratospheric ozone, loss of biodiversity, etc., also adversely affect human health. Children, the elderly, disabled and poor people are particularly **exposed and vulnerable** to environmental pollution (UNEP, 2017).

Emissions generated by human activity continue to alter the composition of the atmosphere, leading to air pollution, climate change, stratospheric ozone depletion and exposure to persistent, bioaccumulative and toxic chemicals (UN Environment, 2019c). As reported by the EEA (2019e), **exposure to air pollution** may lead to adverse health impacts, such as premature mortality and morbidity, mainly related to **respiratory and cardiovascular diseases** (WHO, 2015). Air pollution in general and particulate matter as a separate component of air pollution mixtures have been classified as **carcinogenic** (IARC, 2013).

Globally, air pollution is the main environmental contributor to the **burden of disease**. This translates into 6 to 7 million premature deaths and welfare losses close to USD 5 trillion annually (UN Environment, 2019c). Exposure to **particulate matter** is highest for residents in urban areas, particularly those in countries undergoing rapid economic development and the 3 billion people who depend on burning fuels, such as wood, coal, crop residue, dung and kerosene, for cooking, heating and lighting (UN Environment, 2019c). Another important source of air pollution, specifically SO_2 and non-methane volatile organic compounds, are sectors involved in the production and consumption of fossil fuels as well as fossil fuel-based electricity production (IPBES, 2019; UN Environment, 2019c).

Overall, there is an ongoing change in the geography of environmental pollution, which fundamentally reflects geopolitical and macro-economic changes (Cluster 5) as well as the continuation of long-established trends such as urbanisation (see Cluster 1). Although **emissions trends have declined in western countries**, albeit at different paces (see Box 2.10), those in rapidly developing countries and emerging economies have been on the rise in the last decade. For instance, SO_2 emissions are among the few air pollutants to have declined globally, as a result of two main trends: a reduction of more than 75 % occurred between 1990 and 2016 because of North America and Europe, partially offset by an increase of more than 50 % in Asia. **Globally, the highest death toll is in East Asia and South Asia**, as cities in these regions have very large populations and high levels of pollution (with high levels of particulate matter with a diameter of 2.5 µm or less, $PM_{2.5}$, and ground-level ozone in urban areas). Such high health burdens are also caused by significant production of goods consumed primarily in western Europe and North America (UN Environment, 2019a). Although in recent years emissions of SO_2 and nitrogen oxides (NO_x) have begun to decline in East Asia, the dynamics governing rapid development and urbanisation, coupled with insufficient environmental governance, are likely to worsen air pollution in the future, unless additional policy interventions are put in place. International agreements have a fundamental role in addressing specific pollutants and chemicals. While successful in some cases, such as the Montreal Protocol, whose implementation led to the decline in emissions of ozone-depleting substances by more than 99 % between 1990 and 2016 (UN Environment, 2019c), there is still much to be done to curb the highest death toll associated with air pollution.

2.3.3.2 Worsening water pollution

Water quality has worsened in most world regions since 1990, mainly because of organic and chemical pollution, including pathogens, nutrients, pesticides, sediments, heavy metals, plastic and microplastic waste, persistent organic pollutants and salinity (UN Environment, 2019b). Although 1.5 billion people gained access to basic drinking water services over a 15-year period from 2000 to 2015, nearly 2.3 billion people still lack access to safe sanitation

Box 2.10 European trend — Air quality in Europe

In Europe, strong reductions in air emissions or peak ozone exposure have been achieved, but background concentrations of ozone, mercury and some persistent organic pollutants are not declining (UNECE, 2016). These concentrations are highly influenced by air pollution in other parts of the world via long-range transport and can only be reduced through internationally coordinated action (UNECE, 2016). As reported in *The European environment — state and outlook 2020* (SOER 2020) (EEA, 2019e), the latest estimations for Europe indicate an alarming number of premature deaths is still due to exceedances of EU air quality targets. In particular, exposure to particulate matter with a diameter of 2.5 µm or less ($PM_{2.5}$) is responsible for around 400 000 premature deaths in Europe every year, while exposure to nitrogen oxides and ozone were responsible for around 70 000 and 15 000 premature deaths in 2017, respectively. As reported in SOER 2020, the emissions of most of the main air pollutants decreased in general in Europe over the period 2000-2017, however this decrease did not happen at the same pace in all countries/regions and in all sectors. While SO_2 emissions have decreased substantially, reductions were comparably less for fine particulate matter — the pollutant that poses the greatest threat to human health — and polycyclic aromatic hydrocarbons, which can have carcinogenic and mutagenic effects. The reduction in emissions has brought about a decrease in air pollutant concentrations and a general improvement in air quality, with concentrations generally below the EU standards for SO_2, carbon monoxide, lead and benzene. However, there are still exceedances of EU air quality health standards for particulate matter, NO_2 and ozone; EU vegetation standards for ozone; World Health Organization health guidelines; and critical loads of nitrogen in many ecosystems.

In the future, an increased uptake of information and communications technology and automation in industry is likely to increase electrification within the European economy and encourage a shift away from combustion-based end-of-pipe technological applications (see Cluster 3). As recently observed by the EEA (2019a), increased economic activity, together with the shift towards electrification — a trend observed across all economic sectors — has led to a rising demand for electricity. If considered alone, these trends would have also led to higher emissions of air pollutants. Instead, a significant reduction in sulphur oxides (-80 %), nitrogen oxides (-40 %), dusts (-75 %) and CO_2 (-6 %) was observed in Europe, because factors such as change in electricity mix generation, adoption of abatement equipment and cleaner technologies introduced through the Large Combustion Plants Directive and the EU Emissions Trading System (EEA, 2019a) have compensated for growing electricity demand (including combustion) at the European scale. Whether the likely increase in energy demand driven by digitalisation and related technological applications (see Cluster 5) will lead to additional emissions to air will depend very much on whether new energy supply will be provided by deploying renewable energy sources instead of fossil-based ones (see Cluster 3).

Source: Adapted from EEA (2019e, 2019a).

(UN Environment, 2019b). This has led to 1.4 million deaths annually from preventable diseases associated with pathogen-polluted drinking water and inadequate sanitation (IPBES, 2019; UN Environment, 2019c). It has been estimated that the total global disease burden could be reduced by 10 % if drinking water quality and access, sanitation and hygiene are improved alongside integrated water resources management (UN Environment, 2019b).

One of the fastest growing concerns related to water quality is **antibiotic-resistant bacterial infections**, projected to become the main cause of death worldwide by 2050 (UN Environment, 2019b). Another emerging issue is represented by new pollutants not easily removed by current waste water treatment technologies (e.g. pharmaceuticals, pesticides, antimicrobial disinfectants, flame retardants, detergent metabolites and microplastics) (UN Environment, 2019b). In particular, various **endocrine-disrupting chemicals** are now widely distributed through the freshwater system on all continents, with long-term impacts on foetal underdevelopment and male infertility (UN Environment, 2019c). Without effective counter-measures, these trends are likely to continue in the future. In particular, the growing demand for consumer goods and lifestyles being embraced by a growing global middle class are likely to further exacerbate these issues (Cluster 5). Moreover, population growth, migration and especially urbanisation trends (Cluster 1) are likely to increase the number of people vulnerable to water-related diseases if urban growth and related infrastructural developments are not properly managed.

2.3.3.3 Growing waste production, plastic pollution and the use of chemicals

Growth in global population and in the middle class are combining to change consumption patterns and levels, leading to increased resource use and causing waste generation rates to rise globally. With rapid population growth and urbanisation, annual **waste generation** is expected to increase by 70 % from 2016 levels to 3.40 billion tonnes by 2050 (World Bank, 2019e), under a business-as-usual scenario. Waste that is poorly collected or improperly disposed of can have detrimental impacts on the environment and human health through contamination of groundwater and surface water as well as air pollution from burning of waste.

Pollution from plastic waste is also a growing issue. For example, marine litter is now found in all of the oceans and at all depths and is at such a scale that it has attracted increasing media attention. Recent estimations indicate that approximately 32 % of plastic packaging escapes collection systems, ending up in oceans and clogging urban infrastructure (WEF et al., 2016), with plastics making up 80-85 % of marine litter on European beaches in 2018 (EPRS, 2018b). Despite the fact that limited knowledge is available on the subject, estimates indicate that the input of plastic marine litter from domestic waste mismanagement in coastal areas amounts to some 8 million tonnes annually, largely generated from land-based sources (UN Environment, 2019c). By 2050, there could be as much plastic (by weight) as fish in the world's oceans (WEF et al., 2016). Although characterised by uncertainty and knowledge gaps, microplastics have been associated with potential adverse effects on marine organisms and humans (Box 2.11) (UN Environment, 2019c).

E-waste production is emerging as an increasing risk for ecosystem health, as it contains substantial levels of hazardous toxins, such as mercury, cadmium, chromium and ozone-depleting chlorofluorocarbons. With an annual growth rate of 4-5 % ([7]), there was approximately 50 million metric tonnes of e-waste projected to be disposed of worldwide in 2018 (EEA, 2019e). In 2016, Europe was the second largest generator of e-waste per person (around 16-17 kg) (Baldé et al., 2017). The negative effects of persistent, bioaccumulative and toxic substances are increasingly recognised, but their effects on humans and ecosystems are still not well understood (EEA, 2019e).

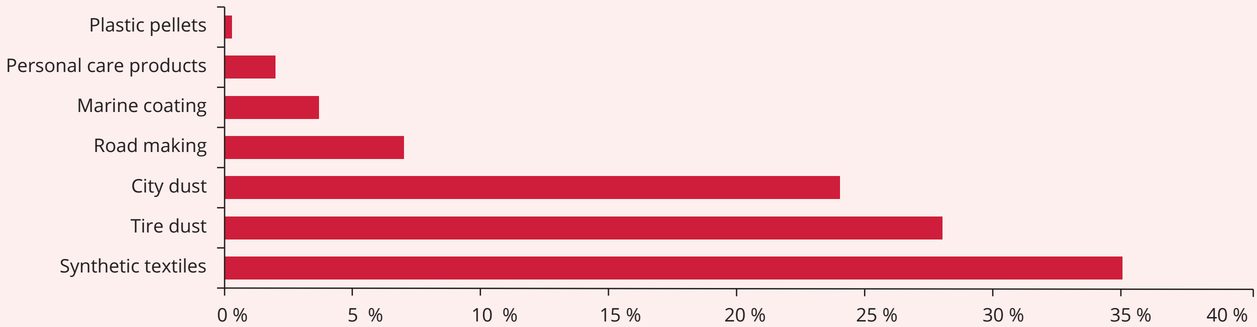
Chemicals have brought many benefits to humanity; however, the pollution associated with them has now created a global problem, as **toxic substances can spread to the most remote environments**, including receiving water systems worldwide (UN Environment, 2019c). The size of the global **chemical industry** exceeded USD 5 trillion in 2017, and it is projected to double by 2030, because the rapid growth of emerging economies is expected to increase both production and consumption (Cluster 5) (UNEP, 2019). Moreover, supply chains and the trade of chemicals and products are becoming increasingly globalised and complex, creating further challenges for the development and enforcement of international regulations.

([7]) The assumptions behind this growth rate are not known, and it may be challenged by other outlooks of, for example, resource scarcity, which could feed back through changing price structures to reduce this assumed growth.

Box 2.11 Emerging trend — Microplastics and the impact on the food chain

Alongside concern about visible plastic waste in the environment, recent research indicates a growing presence and abundance of microplastics in marine environments. One study has estimated that, on average, every square kilometre of the world's oceans has 63 320 microplastic particles floating on the surface, with significant regional variations; for example, concentrations in East Asian seas are 27 times higher than average (Eriksen et al., 2014; Isobe et al., 2015). Between 69 % and 81 % of microplastics in the marine environment come from 'secondary microplastics' that originate from the degradation of larger plastics (WEF et al., 2016), while the main 'primary microplastics released in the ocean mainly originate from land activities' (Boucher and Friot, 2017) (Figure 2.9).

Figure 2.9 Primary microplastics in the oceans according to IUCN



Note: IUCN, International Union for the Conservation of Nature.

Source: EC (2017e), in turn based on Boucher and Friot (2017).

In the food chain, the impacts of microplastics on both wildlife and the human population are not yet well understood (EC, 2017e). While current knowledge does not provide a complete explanation of how microplastic contaminants interact chemically and physiologically with various organisms at different trophic levels, recent studies indicate that plastic nanoparticles (i.e. a finer fraction of particle composing microplastics) are associated to reduced survival of acquatic zooplankton and to behavioural disorders in fish, given their ability to penetrate the blood-to-brain barrier (Mattsson et al., 2017). While risks microplastics pose to human health through the consumption of contaminated food are difficult to determine, exposure is growing fast. Studies have identified that a quarter of samples of fish from markets in Indonesia and the United States were found to have plastic debris in their guts, and new evidence includes microplastics and synthetic fibres being detected in a range of food products for human consumption, including drinking water, beer, honey, sugar and table salt (Liebezeit and Liebezeit, 2013, 2014; Rochman et al., 2015; Yang et al., 2015). These developments call for increased attention, monitoring and precautionary strategies to reduce potential impact on human and ecosystems health.

Source: Adapted from UNEP (2016).

As a consequence, **hazardous chemicals** and other pollutants (e.g. plastic waste and pharmaceutical pollutants) continue to be released in large quantities (UNEP, 2019). In particular, as stated by Bernhardt et al. (2017), the diversity and quantity of synthetic chemicals generated, released and spread out through global ecosystems have been increasing at rates significantly outpacing those of other drivers of global environmental change (i.e. rising concentrations of atmospheric CO_2, biodiversity loss, habitat loss and nutrient pollution). However, there is little attention given in ecology to the evaluation and assessment of this sort of pollution (Bernhardt et al., 2017).

Nowadays, chemicals are ubiquitous in humans and the environment and are accumulating in material stocks and products, leading to an estimated burden of disease from selected chemicals equal to 1.6 million lives in 2016, a value that is likely to be underestimated (UNEP, 2019).

Chemicals that enter the environment are often mixed with other chemicals, producing breakdown products, by-products or reactions to form new substances in the waste stream or in the environment. There is a range of adverse effects of chemical pollution on the environment, including a decline in soil fertility and the quality of crops, contamination of surface water and groundwater quality, and disruption of ecological processes. However, for new and novel chemical mixes and their interactions in and with the environment, **many effects are uncertain**, especially in the longer term. For example, the use of three of the main fertiliser nutrients (N, P_2O_5 and K_2O) is expected to grow in the future (FAO, 2017b). Their use, alongside **synthetic pesticides**, has negative impacts on ecosystems and the services they provide, biodiversity and in particular freshwater quality if they leach into groundwater or surface waters. Although the effects of chemical pollution on ecology are often uncertain, it is known to cause a variety of adverse environmental effects all of which have **negative implications** for the food system and in particular food production.

International agreements have been successful in addressing specific chemicals, but new chemical risks are emerging (UN Environment, 2019a). For example, environmental concentrations of the most-studied persistent organic pollutants (POPs) have been reduced in Europe, North America, Asia and the Pacific regions, and the Arctic because of regulations including the Stockholm Convention (UN Environment, 2019a). However, considerable gaps in emission data for POPs remain, and unregulated POP emissions may be increasing, because many commercial products contain unknown quantities and types with unknown effects (UN Environment, 2019a).

However, significant gaps still exist concerning the assessment and regulation of harmful chemicals (UN Environment, 2019c), from both knowledge and governance perspectives. Besides this, several **emerging issues** (e.g. endocrine disruptors, nanoparticles) are characterised by substantial unknowns concerning distribution and effects. More science-based information and risk assessments as well as the adoption of the precautionary principle would be needed to ensure environmental protection.

According to the UN, addressing legislation and capacity gaps in developing countries and emerging economies remains a priority, given their growing role in the consumption and production of goods (UNEP, 2019). However, consumer demand (Clusters 5 and 6) as well as green and sustainable chemistry education and innovation (Cluster 4) are among the important drivers of change that may reorient the production of chemicals towards more sustainable processes, alongside the uptake of production processes with lower environmental impacts (UNEP, 2019).

2.4 Cluster 3 — Increasing scarcity of and global competition for resources

Key messages (cont.)

Trends and outlooks

The existence of energy gradients and the availability of materials enables life on Earth as well as human activity, across all aspects of life, and underpins the development of complex societies. Throughout the 20th century, socioeconomic trends, including population (Cluster 1) and economic growth, as well as affluence (Cluster 5), have rapidly accelerated, requiring overall large amounts of natural resources to fuel improvements in human wellbeing (IRP, 2019). In the last few decades, economic growth and increased affluence in middle-income countries has been the key factor behind growing resource demand.

Accelerating global demand for energy

- Overall, global energy consumption has grown 25 times from 1800 to the present day and has been largely based on fossil fuels (85 % to 90 %). Emerging economies have been responsible for two thirds of the increase in energy consumption over the past 20 years, with China on its own accounting for 48 % of the increase (World Bank, 2018). Despite the existence of international agreements on greenhouse gas (GHG) reduction, the global energy mix has not changed significantly in the last 20 years, moreover, future GHG emission estimates based on shortterm energy plans at the global scale are 120 % higher than emissions consistent with a 1.5 °C pathway (SEI et al., 2019).

- Rising incomes and an extra 1.7 billion people largely expected to live in urban areas of developing economies are projected to raise global gross energy demand by more than 25 % in 2040 (Clusters 1 and 5). Such an increase is likely to create a significant risk for the global supply of oil around 2025, as the expansion of oil shale gas will not be enough to compensate for the continued absence of new conventional oil projects. In the mid-term, uncertainty concerning the viability of shale oil and shale gas is likely to play a fundamental role, influencing market prices.

- Supply from renewable energy sources is on the rise, as the electricity sector is experiencing a fundamental transformation associated to lowering costs of renewable technologies and digitalisation. However, issues like high costs associated with the upgrade of infrastructures (e.g. networks and storage), may hinder its expansion. The uptake of renewable energy and digital technologies (Cluster 4) is likely to face the challenge of security of supply for certain materials (e.g. CRMs), an issue particularly relevant for Europe, given the EU's ambition towards climate neutrality.

Growing demand for materials worldwide

- Global use of material resources increased 10fold between 1900 and 2009 (Krausmann et al., 2009), and it has continued to rise in recent years. Two main dynamics characterise the latest trends: newly industrialising countries are building new infrastructure, and highincome countries are outsourcing the more material and energyintensive stages of production (Cluster 5). Projections suggest that there will be a doubling of demand for materials by 2060 (IRP, 2019), raising concerns about access to key primary and secondary raw materials and posing a challenge to economies that are highly dependent on materials from international markets, such as Europe (Alessandrini et al., 2017).

- The extraction of materials is associated with high impacts on ecosystems, biodiversity loss and climate change. In the last 50 years growing global material demand has led to nearly 90 % of biodiversity loss and water stress and approximately half of climate change pressures, as well as contributing to exacerbating inequalities within and across countries (IRP, 2019).

- While between 1970 and 2000 population growth was the main driver behind material extraction at the global scale, from 2000 onwards increased affluence (Cluster 5 and 6) became the strongest force underpinning global resource extraction (IRP, 2019). While decoupling has been pursued as the main strategy for reducing resource demand and environmental burdens from economic growth, there is no empirical evidence that an absolute, permanent and sufficiently fast decoupling is occurring at all at the global scale (Parrique et al. (2019).

- The principle of 'sufficiency', in conjunction with sustainable management of resources, is gaining increasing international resonance as a complement to 'efficiency', although at odds with the current neo-liberal economic model. The sole increase of circularity of materials within ever expanding economic systems may not be compatible with the goal of reducing environmental pressures and protecting natural capital.

Key messages (cont.)

Ever increasing demand for land, food and water

- A growing population over the coming decades (Cluster 1), combined with increased income and changes in consumption patterns (Clusters 5 and 6), is likely to result in an increased demand for food, feed and water by 2050 (IPCC, 2019a).The expansion of the middle class in the developing world, driven by rising disposable incomes, is expected to enable global consumers to switch to foods with higher fat and protein contents, such as animal products, leading to increased global demand for land.
- Changes in lifestyles and affluence in the East, alongside with growing global demand for biofuels, are contributing to increased demand for agricultural land and pastures which are likely to lead to the expansion of international 'land grabbing', at the expense of natural ecosystems and biodiversity hotspots. At the same time, agriculture is projected to be increasingly compromised by the combined effects of climate change and soil degradation (UNCCD, 2017), while water demand is on the rise.
- The choices made today concerning urban design, spatial planning and infrastructure, as well as urban governance, will be crucial in defining the future resource demand and the overall pressure on health and the environment, given that the majority of consumption occurs in cities. Change in lifestyles and reduction of consumption levels could play a key role in reducing resource demand.

2.4.1 Accelerating global demand for energy

2.4.1.1 Fossil fuels keep dominating global energy supply

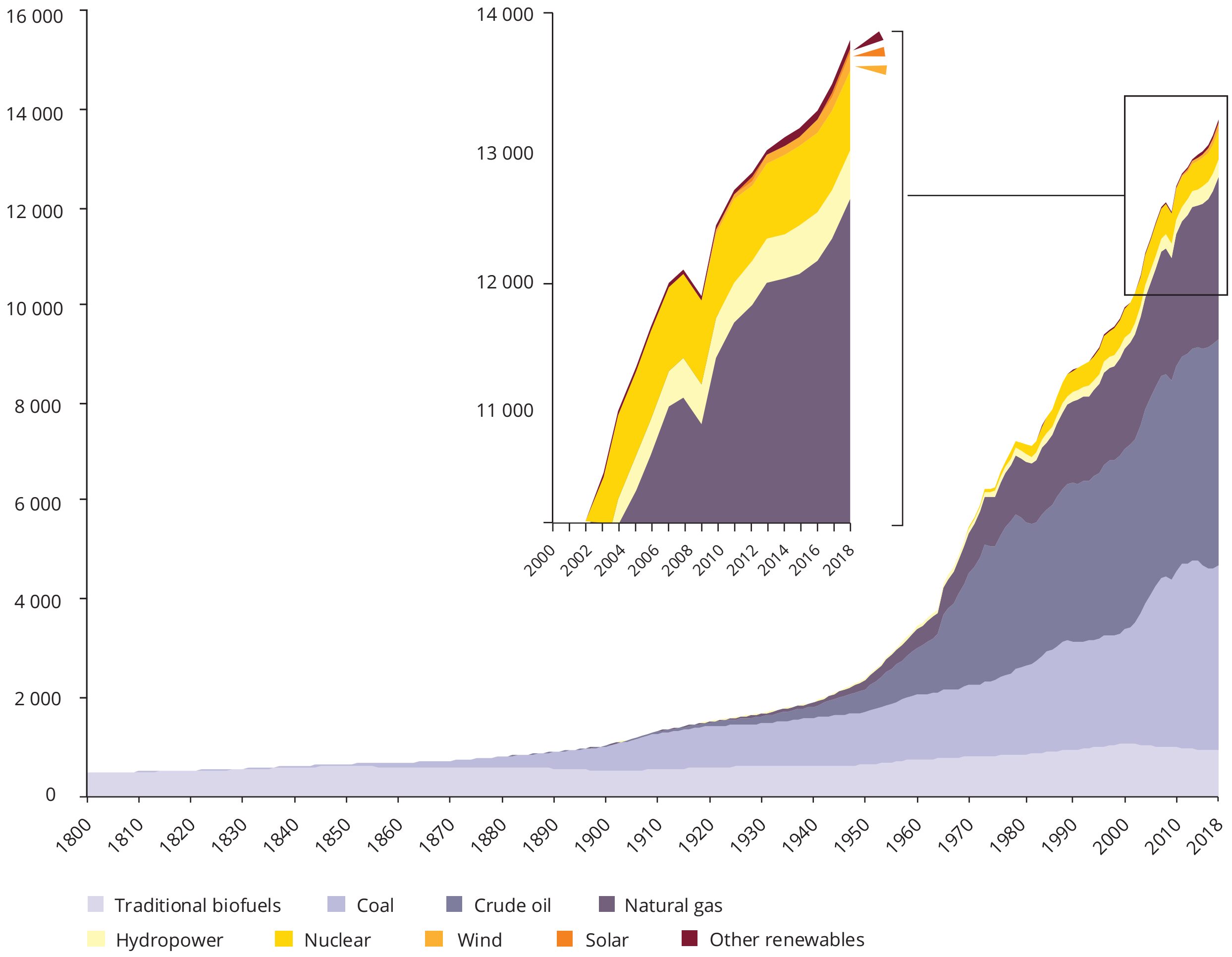
The existence of energy gradients enables life on Earth as well as human activity, across all aspects of life, and underpins the development of complex societies. Energy needs co-evolve alongside the types of energy sources that human society is able to exploit, by transforming them into carriers that meet specific applications. Before the advent of the Industrial Revolution in the 19th century and the discovery of fossil fuels (e.g. coal mainly), **traditional biofuels** were nearly the only source of energy available to humans, apart from human and animal power, windmills and watermills (Ritchie and Roser, 2018a). After this major breakthrough, **coal use** grew very fast and remained the main energy carrier, together with wood, for nearly a century, after which **oil, natural gas and hydroelectric power** started making a dent and then increased exponentially (see Figure 2.10). Together with nuclear power, the energy mix in 2017 was rather different from what it was a century ago, although relative shares have been rather constant in the last 10 to 20 years. This indicates that global energy transitions are long-term processes, especially when they require major investments in infrastructure. The main difference registered during that period is the growing exploitation of **renewable sources** (i.e. modern biofuels, wind, solar), which accounted for nearly 3.6 % in 2017 and 10.5 % when summed with hydroelectricity (BP, 2019).

The growth in global energy demand experienced in the last two centuries is staggering: between 1800 and the present day, world energy consumption has grown roughly 25 times (Ritchie and Roser, 2018a). In the last 50 years, global total primary energy supply increased more than 2.5 times, with major changes in the shares of oil and gas. Today, oil covers a lower share of primary energy supply than it did in the 1970s, mainly thanks to the expansion of natural gas, nuclear energy and renewables to a lesser extent (IEA, 2018a). However, **regional differences** characterise the energy mix, for example the share of renewable energy in gross final energy use in the EU was expected to have reached 17.4 % in 2017 (EEA, 2018d), while in the United States it is slightly more than 7 %, and in China it is approximately 12 % (BP, 2019). At the global scale, although the high in capacity for fossil fuel electricity generation that occurred in the last 50 years has increased affordable energy globally, it has also led to trade-offs with health and the environment (IRP, 2019), leading to **unprecedented emissions of GHGs** and the release of pollutants (Cluster 2).

The geography of **energy production** indicates high levels of concentrations among all fuels, with some variations. China produced almost half of world's coal in 2017, and almost a third of hydroelectric power, while the United States and France combined produced almost 50 % of all nuclear power. Saudi Arabia, Russia and the United States contributed slightly less than 40 % of the world's crude oil, while Russia and the United States also accounted for 40 % of world's natural gas (IEA, 2018a). Until 2012, the EU was the region with the most investments in renewable energy; however, in 2013 this was surpassed by China, which has established itself as a clear market leader since then (EEA, 2017d). In 2016, the EU came second after China in terms of installed renewable energy capacity,

Figure 2.10 Global primary energy consumption

Million tonnes of oil equivalent



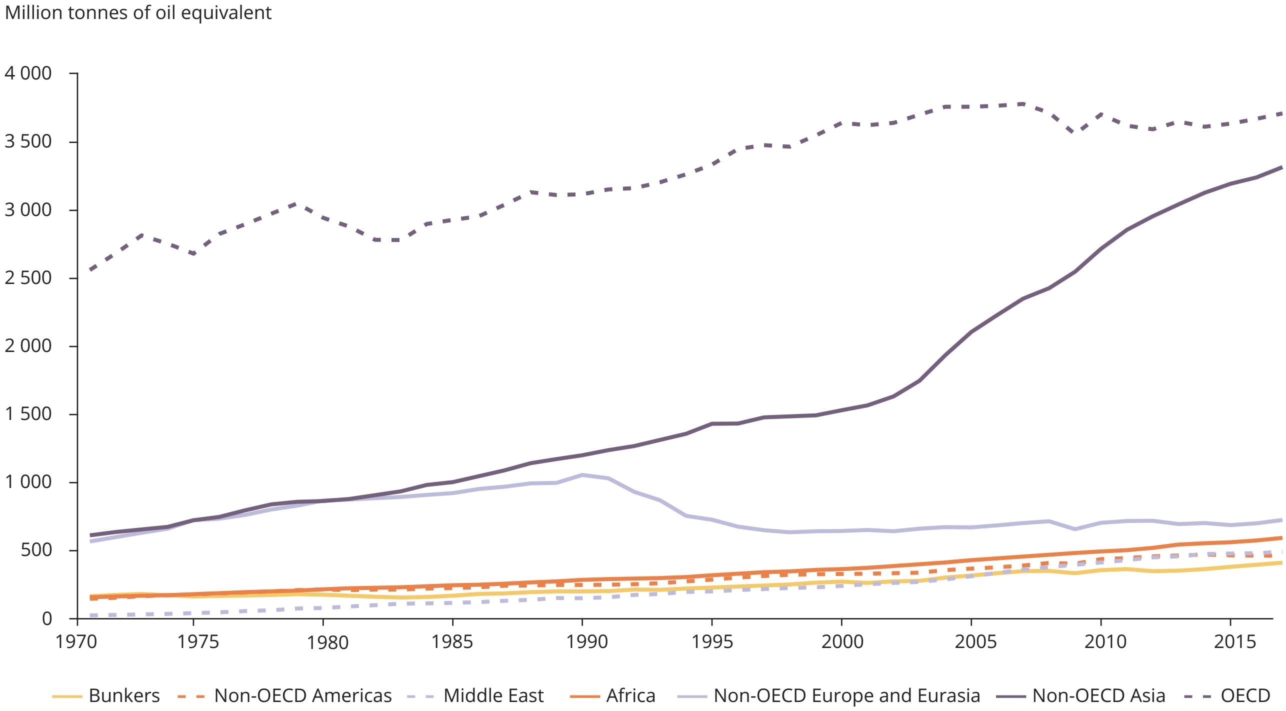
Source: Adapted from Ritchie and Roser (2018a), in turn based on Smil (2016) and BP (2019).

while it still has the largest solar photovoltaic (PV) and wind capacity in the world (followed by China and the United States). However, China is likely to take the lead in wind energy (EEA, 2017d). In terms of transforming its energy resource base, the EU is outpacing the other world regions with a growth rate of 7.4 % in renewable energy capacity.

The geography of final **energy consumption** has changed quite substantially in recent years (see Figure 2.11). The OECD's share of global total primary energy supply fell from 61 % in 1971 to 38 % in 2017 and is now almost on a par with non-OECD Asia, where energy demand has grown sevenfold (IEA, 2018a). The generally increasing trend in the OECD came to an end with the 2008 global economic crisis, with total final consumption staying steady around a plateau for a number of years (IEA, 2018a), and it picked up again in 2014. **Total final consumption has soared in non-OECD Asia** (which includes China) since the early 2000s, accounting for over one third of global total final consumption in 2017 (IEA, 2018a).

Global energy consumption keeps increasing. In 2018, it increased by 2.3 %, at nearly twice the average rate of growth since 2010, driven by a robust global economy and higher heating and cooling needs in some parts of the world. China, the United States and India, together, accounted for nearly 70 % of the rise in energy demand (IEA, 2019a). Weather conditions in 2018 were also responsible for almost a fifth of the increase in global energy demand, as average winter and summer temperatures in some regions approached or exceeded historical records (IEA, 2019a). In 2018, the demand for all fuels increased, led by natural gas, even as solar and wind power posted double digit growth. The United States had the largest increase in oil and gas demand worldwide. Gas consumption jumped 10 % from the previous year's figure, equivalent to the United Kingdom's current gas

Figure 2.11 World total final energy consumption by region



Note: Bunkers: energy consumption of ships and aircraft on international routes.

Source: IEA (2018c), https://www.iea.org/data-and-statistics/charts/world-total-final-consumption-by-region-1971-2017.

consumption. Renewables, which grew by over 4 %, met around one quarter of the growth in total primary energy demand. This was largely due to the expansion in **electricity generation**, where **renewables** accounted for 45 % of the growth in 2018 (IEA, 2019a). Nuclear power also grew by 3.3 % in 2018, mainly as a result of the new capacity in China and the restarting of four reactors in Japan. Worldwide, nuclear generation met 7 % of the increase in energy demand.

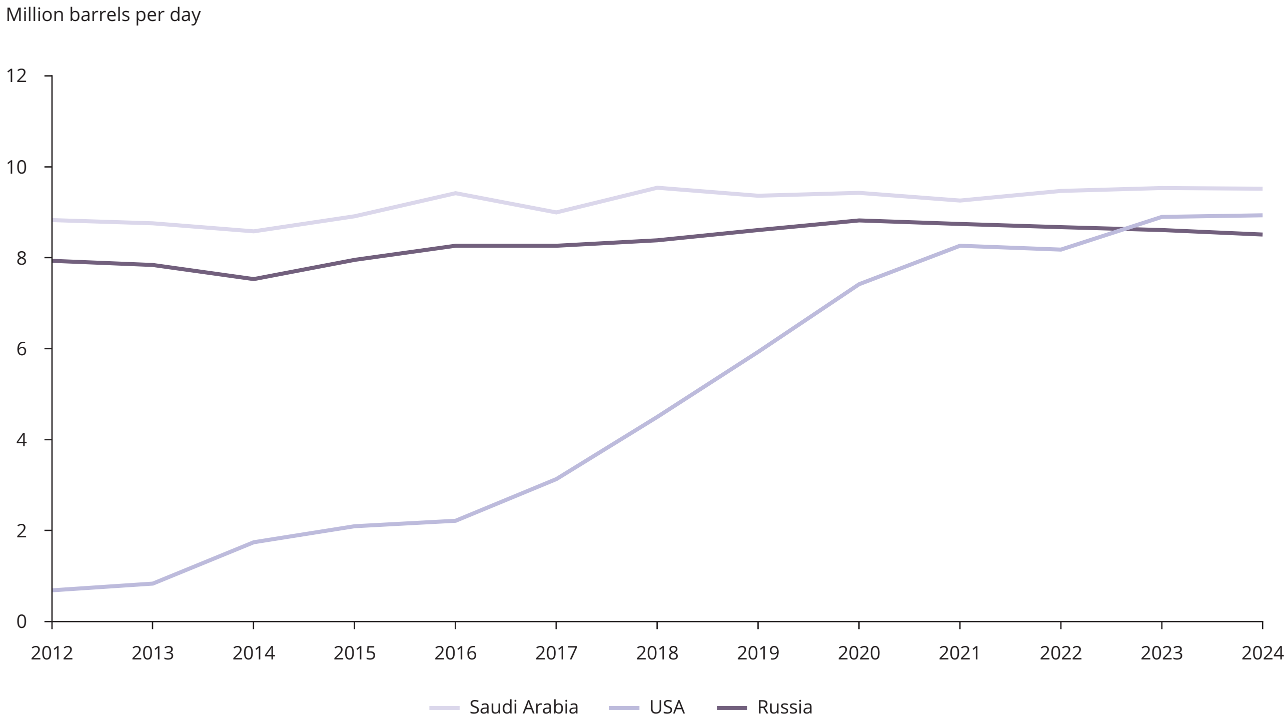
2.4.1.2 Future energy demand: between shale oil, gas and renewables

According to the International Energy Agency (IEA) (2018b), while the geography of energy consumption continues its historic shift to Asia, there are mixed signals on the pace and direction of change. Oil markets, for instance, are entering a period of renewed **uncertainty and volatility**, including a **possible supply gap** in the early 2020s. Demand for natural gas is on the rise, as China emerges as a giant consumer, while solar PV is growing, other low-carbon technologies still require fundamental investment.

According to the IEA, **rising incomes** and an extra 1.7 billion people largely expected to live in urban areas of **developing economies** are projected to increase global energy demand by more than 25 % in 2040 (IEA, 2019c) (see Cluster 1). By the same year, Asia is likely to overtake Europe and North America, accounting for more than 40 % of global energy demand, leading to an expected change in the geography of international energy trade flow (IEA, 2019c). **Rapid technological innovation** is leading to increased extraction of unconventional fuels (e.g. shale gas, oil sands and oil shale) by making them economically more viable (Weijermars, 2015; Neville et al., 2017), transforming global oil markets (IEA, 2019b). Hydraulic fracturing or **'fracking'**, developed in the United States in 2000, set the stage for further exploitation of fossil fuels that were previously inaccessible, which is reordering the geographies of production and trade, and although most shale gas exploration takes place in the United States and Canada, production is also under way in Argentina and Chile (Neville et al., 2017).

According to the IEA's forecasts, in the next 6 years the United States is likely to lead oil supply growth, exporting more oil than Russia and close to Saudi Arabia's production (IEA, 2019b), indicating that nearly every fifth barrel of oil and every fourth cubic metre of gas in the world come from the United States (Figure 2.12). Nevertheless, **conventional oil production** peaked in 2008 and has declined ever since, a trend that is not expected to be interrupted

Figure 2.12 Oil gross export trends and forecasts



Source: IEA (2019b).

in the short term. In this case, meeting oil supply demand in the coming decades, because of rising petrochemicals, trucking and aviation demand, would require a twofold increase in new conventional oil, a rather unlikely possibility (IEA, 2019a). This is likely to imply a significant risk for the global supply of oil around 2025, as the expansion of oil shale gas will not be enough to compensate for the continued absence of new conventional projects (Auzanneau, 2019), based on the IEA's forecasts (2019b). Moreover, shale oil fields are often associated with high **financial interests** and revenues but affected by a rapid decline in oil production, leading to a situation in which new wells must be constantly drilled to maintain extraction and revenue levels; therefore, doubts have been raised concerning its mid-term viability (Auzanneau, 2019). Overall, the outlooks presented here are in stark contrast with the implementation of the national climate policies and ambitions underpinned by nationally determined contributions at the heart of the Paris Agreement (SEI et al., 2019).

Regarding other energy sources, the United States is expected to be surpassed by China concerning **nuclear energy production** (IEA, 2019c), as Europe, Japan, Russia and the United States are planning to decommission almost 200 operational reactors (out of 434 operating in 2013) by 2040 (OECD and DASTI, 2016). Much of the future of global nuclear energy production will therefore depend on whether new nuclear capacity will be built to replace these retirements. Several countries in northern, western and southern Europe have announced a phase-out of nuclear power, whereas nuclear electricity production in eastern European countries is projected to continue to rise, leading to a likely change in the coming years (IAEA, 2017).

The **electricity sector** is experiencing a fundamental **transformation**, given the convergence of cheaper renewable energy technologies and growing digital applications (IEA, 2019c) (see Cluster 4). These trends have led to electricity covering 20 % of total final consumption, with a prospect of continued increase (IEA, 2019c). New technologies including the Internet of Things (IoT), cryptocurrencies, cloud computing, supercomputers and other electronics-related technologies could also be some of the main sources of increasing electricity consumption (OECD and DASTI, 2016) (see Cluster 4). Whether electricity consumption will continue this rise in the future will depend on several factors, including socio-technical, socio-economic and political factors. Consumption areas that are critical for future developments are domestic and public heating and power for transport (IEA, 2019c). According to the IEA, a stronger push for electric mobility, electric heating and electricity access could lead to an unprecedented **rise in energy demand**, equalling, by 2040, an additional amount that is nearly twice the United States' present demand (IEA, 2019b). This scenario will have substantial implications for other resources and, in particular, the raw materials needed to upgrade the energy infrastructure (see Box 2.12).

In advanced economies, the growth in power demand is more modest than in developing countries, largely because of the huge costs associated with an infrastructure upgrade, which is essential to ensure a high degree of flexibility of the system, to provide a continuous and reliable energy supply (IEA, 2019c). In fact, most renewable energy technologies are **'intermittent'** in character, meaning that they do not provide continuous electricity supply, as the availability of wind and sunlight follows specific daily patterns. This requires infrastructural adjustments on a very large scale, such as increased interconnectivity, battery storage capacity and backup from **flexible power technologies** (e.g. natural gas, oil, nuclear). The latter currently remains the main source of system flexibility,

Box 2.12 European trend — Import dependency, energy and critical raw materials (cont.)

Europe is relatively resource poor and vulnerable to competition to imports. Overall, trade in natural resources highlights the EU's high dependency on metal ores and fossil fuel resources from the rest of the world. Europe imports a large quantity of primary materials, such as fuels, as well as intermediate and final products, while it exports primarily processed goods for final and industrial consumption (Eurostat, 2018f). Overall, imports equal three to four times the amount of exports. This imbalance differs among types of resources: while Europe is almost self-sufficient in biomass (11 %) and non-metallic minerals (i.e. construction materials) (2 %), it is clearly dependent on imports of metal ores and fossil fuels, having shown a dependency ratio of 54 % and 64 %, respectively, of imports over total material inputs in 2017 (Eurostat, 2018f), only considering direct material requirements. When considering the whole supply chain of imported goods and services in the 28 EU Member States (EU-28), the figure increases sensibly. In 2016, imports covered 40 % of material inputs in the economy of the EU-28, implying an import dependency on fossil materials and energy equal to 72 % and on metal ores equal to 87 %, while for biomass and non-metallic minerals, import dependency reached 13 % each (Eurostat, 2019c).

This means that the European economy has an enormous pulling power, but at the same time this puts the EU at potential risk of supply disruption. Political unrest or changes in economic policy in exporting countries could lead to potential risks, in terms of global security of supply and price volatility, in the short term. In addition, sudden changes in demand for these resources could also add to the uncertainty of supply, as resource extraction often cannot easily respond to such changes. A reliable access to raw materials is becoming a growing concern in the EU, as some of these materials are crucial to Europe's economy, across all industrial supply chain stages, or underpin high-tech products and emerging innovations such as information and communications technology applications and renewable energy (e.g. solar panels, wind turbines, electric vehicles and energy-efficient lighting) (EC, 2018j).

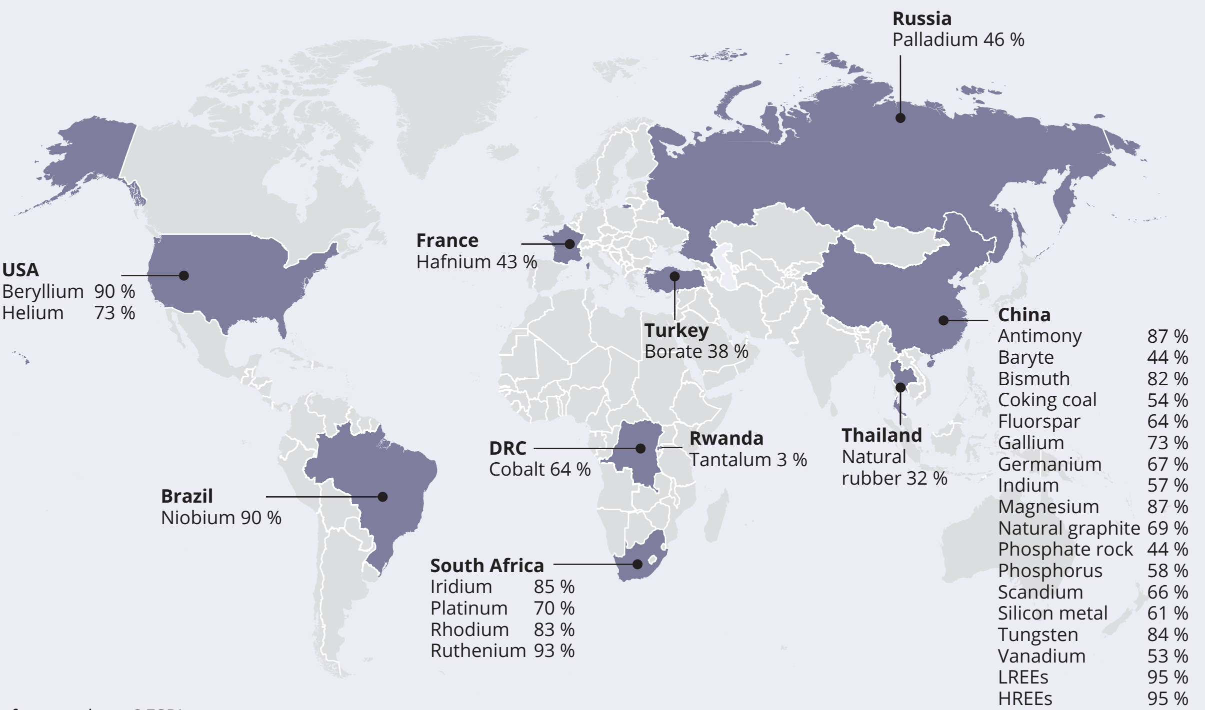
Within the global business community, geopolitical and domestic political instability are seen as the main risks causing uncertainty for resource access and supply (Salam et al., 2017). EU industrial regions already face a number of challenges regarding access to both primary and secondary raw materials from international markets, particularly concerning unprocessed minerals and metals (Alessandrini et al., 2017). For example, Knobloch et al. (2018) found that, out of 27 examined metals, the applications associated with the highest vulnerability of resource supply for the automobile industry were autocatalysts (Rh), electric motors of electric vehicles (Dy, Nd, Tb and Pr) and emerging light-emitting diode (LED) applications (Eu). A special concern is posed by metals (Lithium, Cobalt, Neodymium, Copper and others) needed for the construction of batteries, e.g. to electrify the transport sector, which appear insufficient to meet a global demand (Herrington et al., 2019).

The European Commission has created and recently updated a list of critical raw materials (CRMs) (EC, 2017b) to identify which and how many should be considered 'critical' to the EU industry and especially high-tech products and emerging innovations. In fact, the European Commission's vision to achieve a climate-neutral economy by 2050 is also inseparable from resource security issues concerning energy and raw materials. For example, although substitute materials may be available in future, CRMs are currently irreplaceable in solar panels, wind turbines, electric vehicles and energy-efficient lighting. Most of the production of these 27 most critical resources takes place in a handful of countries (e.g. China, Russia, Brazil, the United States, South Africa), granting them significant market power over the price and supply (see Figure 2.13) (EC, 2018d).

Moreover, the EU is currently attempting to ease resource scarcity in consideration of the strategic importance of raw materials for the EU manufacturing industry, by investing in recycling capacity and new business models under the umbrella of the 'Circular Economy package' (EC, 2018e, 2018f, 2018g), in synergy with the renewed EU industrial policy strategy (EC, 2017c). According to the European Commission, the circular economy should be made the backbone of EU industrial policy, in which boosting the market for secondary raw materials should be a priority.

Box 2.12 European trend — Import dependency, energy and critical raw materials (cont.)

Figure 2.13 Contribution of primary global suppliers of critical raw materials, average from the period 2010-2014



Reference data: ©ESRI

Source: EC (2018d).

combined with new interconnections, storage and demand-side responses. Regional integration also has strong potential, as in the case of the EU and its 'Energy Union' (IEA, 2019c).

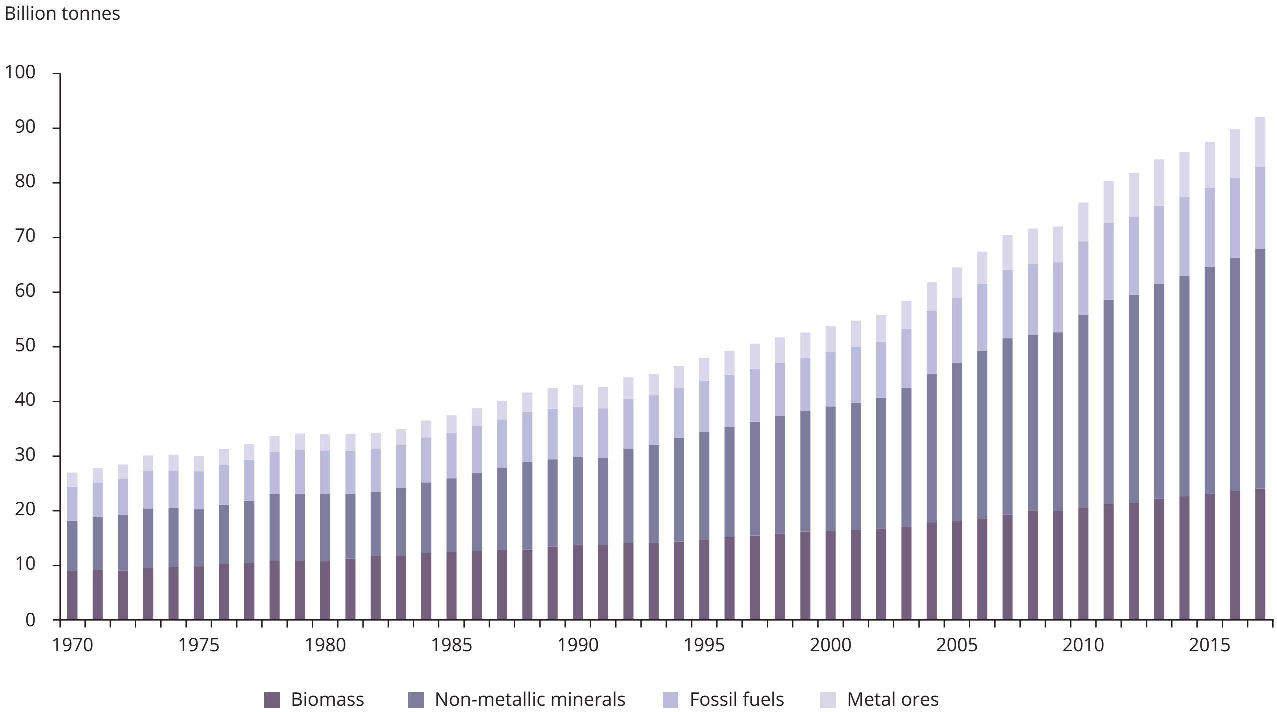
According to the IEA, by 2040 **renewables** will have become the technology of choice for power, making up nearly two thirds of global capacity additions, leading to a share in power generation of 40 % compared with 25 % registered today (IEA, 2019c). However, according to the same scenario, coal and gas will still be the first and second largest sources of power by 2040, jeopardising the achievement of the Paris Agreement. Similarly, according to recent estimates, current plans concerning **new energy capacity** development by 2030 at the global scale still rely substantially on **fossil fuels** and imply that GHG emissions will be 50 % higher than would be consistent with a 2 °C pathway and 120 % higher than would be consistent with a 1.5 °C pathway (SEI et al., 2019).

2.4.2 Growing demand for materials worldwide

2.4.2.1 Unprecedented use of materials

Materials underpin the majority of the gross national product of the industrialised nations — in one way or another — and are therefore vital to the economy. By mitigating regional imbalances in material resource availability, global markets and supply chains for many materials are **now strategically important** for production systems (IRP, 2019). The extraction of non-renewable materials inevitably reduces the global stocks of these materials available for future use, as the share of recycled materials within the global economy is estimated to be only 6 % of total processed materials (Haas et al., 2015). The majority of resources used today are non-renewable (e.g. fossil fuels and minerals), which has led to global supply levels continuing to approach and reach the limits at which they can be extracted cost-effectively (with current technologies) (Capellán-Pérez et al., 2019).

Figure 2.14 Trends in global domestic extraction of materials, 1970-2017

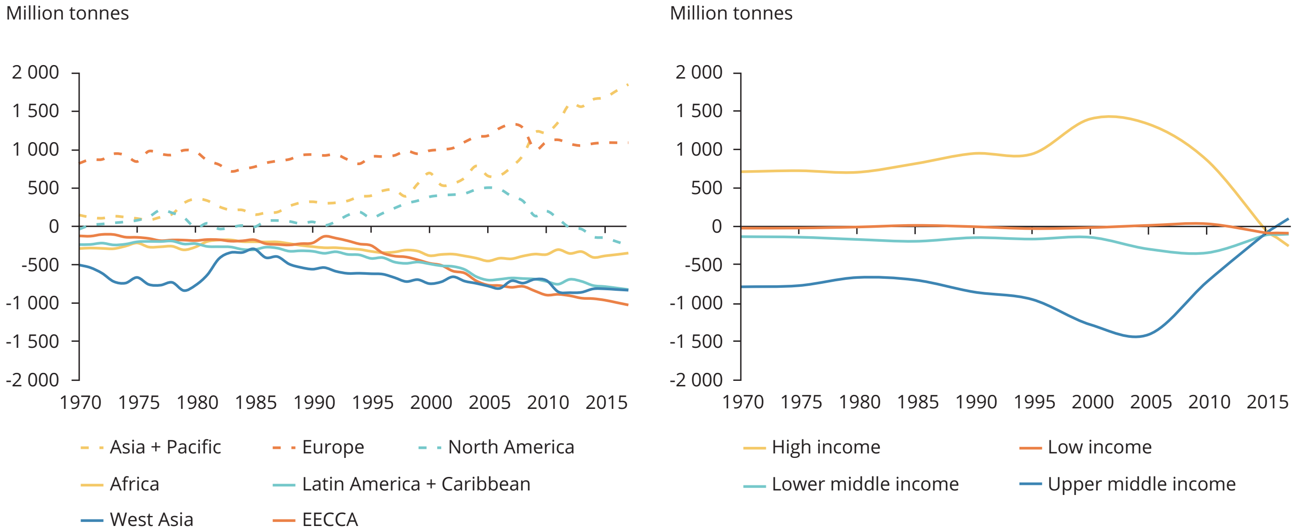


Source: WU Vienna (2018).

Throughout the 20th century, socio-economic trends, including population (Cluster 1) and economic growth as well as levels of consumption (Cluster 5), have rapidly accelerated, requiring overall large amounts of natural resources to fuel improvements in human well-being (IRP, 2019). **Global material use** is estimated to have increased almost 10-fold between 1900 and the early part of the 20th century, accelerating from an annual growth of 1.3 % during the period 1900-1949 to 2.6 % during the period 1950-1999, and 3.6 % annually during the period 2000-2009 (Krausmann et al., 2009). In the last 50 years, global material demand has increased almost continuously, leading to nearly 90 % of biodiversity loss and water stress, and approximately half of climate change pressures, as well as having contributed to exacerbating inequalities within and between countries (IRP, 2019). Since 1970, global extraction has tripled largely because of a surge in the mining of non-metallic minerals that are critical for economic development, especially in the technology sector. Moreover, the manufacturing of e-products demands increasing access to non-renewable resources. Recent trend data show that the **global demand for materials is continuing to rise dramatically** (Figure 2.14) (WU Vienna, 2018), with biomass and non-metallic minerals showing particular increases in extraction between 2003 and 2017. Projections based on current practices and efficiency rates suggest that material resource demand may more than double from 2015 to 2050 (IRP, 2019).

Over the past 20 years, the rapid growth in emerging economies has boosted global demand for resources (e.g. raw materials, energy), and seven countries representing the largest **emerging economies** (China, India, Brazil, Russia, Mexico, Indonesia and Turkey) were responsible for most of the increase in the global consumption of metals and two thirds of the increase in energy consumption over this period, with China on its own accounting for 83 % of the global increase in metal consumption and 48 % of the increase in energy consumption (World Bank, 2018). While between 1970 and 2000, **population growth** was the main driver behind material extraction at the global scale, from 2000 onwards **increased affluence** became the strongest force underpinning global resource extraction (IRP, 2019). Since the 2000s, major investments in infrastructure and higher material living standards in upper-middle-income countries — in Asia in particular — drove global extraction rates (IRP, 2019). Per-capita levels of direct material consumption of middle-income countries surpassed those of high-income countries in 2012, which is in essence the result of two main dynamics: (1) newly industrialising countries are building new infrastructure; and (2) high-income countries are outsourcing the more material- and energy-intensive

Figure 2.15 Physical trade balance by world regions and national income bands, 1970-2017



Notes: EECCA: Eastern Europe, Caucasus, and Central Asia region.

Source: UNEP and IRP (2018), as presented in IRP (2019).

stages of production and the related environmental impacts to middle- and low-income countries (IRP, 2019). Therefore, when calculated across the full supply chain, the material footprint of high-income countries is 60 % higher than that of middle-income countries and 13 times higher than that of low-income groups (IRP, 2019).

The demand for materials increased substantially in the new millennium because of **the economic growth and industrialisation of upper-middle-income countries**, which reached such a point that Asian and Pacific countries now have a higher **trade balance** than Europe (IRP, 2019). In contrast, high-income countries have experienced a continuous reduction in trade balances, mass-wise, since 2009, reaching negative values during the period 2015-2017, indicating that exports amount to more than imports, while the opposite trend is observed for upper-middle-income countries (IRP, 2019). This indicates that several high-income countries now find exporting some primary products economically viable, because of higher prices of commodities being driven by the rise in global demand (see Figure 2.15).

2.4.2.2 Future demand for material driven by emerging economies

The world's population has quadrupled over the last century, and the 21st century could see the global population reach 9.7 billion by 2050, compared with 7.6 billion in 2017 (UN DESA, 2019) (see Cluster 1). Moreover, although continued relatively slow growth in the global economy (Cluster 5) could ease (or at least slow the increase in) some resource use pressures, global growth outlooks for 2020 indicate an annual global growth of 2.9 %, with 4.7 % annual growth forecast in emerging economies (World Bank, 2018). This suggests that the projected population and economic growth in association with rising consumption levels (Cluster 5) are likely to further increase the global demand for resources, although demand for specific resources is subject to significant uncertainty. Much will depend on the **prospects for economic development**, affluence and consumption patterns, and structural economic changes, as well as technological innovation. The projected increase in urban areas in the South and in the East (see Cluster 1) is likely to be a key factor in defining future demand for resources associated with new infrastructure as well as direct consumption of resources (e.g. energy carriers and water) (IRP, 2018). A large share of **future resource requirements** is likely to be associated with the expansion of **cities**, to accommodate the increase in the global urban population (IRP, 2018). Given the current pace of urbanisation, the choices made today concerning urban design, spatial planning and infrastructure, as well as governance, will be crucial in defining the future metabolism of cities and their pressure on health and the environment.

Increasing **consumption levels**, driven by growing affluence (Cluster 5), leads to a growing global demand for energy and resources and increased competition. To foster their economies, national governments and businesses are likely to increasingly compete for scarce resources including land, water and materials. In turn, this translates into changes in international power balances (Cluster 5), tensions concerning trade practices and uncertainty regarding new agreements, leading to an increased risk for security of supply of strategic resources, particularly for resource-scarce regions (Alessandrini et al., 2017). For example, **imports of raw materials** could be subject to restrictions from exporting countries. Moreover, as indicated in Cluster 5, the future of **global trade agreements** and related institutions appears quite uncertain and increasingly characterised by erosion of the consensus regarding the benefits of globalisation and free trade (EPRS, 2018a; EPSC, 2018b). Under this scenario, it is likely that bilateral agreements will be increasingly important — especially for relatively resource-scare regions, such as Europe — to secure the supply of strategic resources and access to growing markets for export.

The IRP has developed two main scenarios for resource demand in 2060. The 'Historical trends' scenario — which essentially projects a continued increase in pressures driven by continued economic growth and the need for buildings and infrastructure — leads to a growth in resource use reaching 190 billion tonnes and over 18 tonnes per capita by 2060, compared with 92 billion tonnes and 12 tonnes per capita in 2017 (IRP, 2019). Given the impacts associated with the extraction or production of raw materials, such an increase would translate into growing GHG emissions (+43 % compared with 2015), water withdrawals (+100 % compared with 2010) and agricultural land (+20 %), as well as a reduction in forested areas (-10 %) and other habitats (-20 %) (IRP, 2019), adding to the unprecedented levels of pressures on natural capital and biodiversity, climate and human health described in Cluster 2, despite additional stress on resource supply systems (IRP, 2019). In addition, this scenario points towards bottlenecks and issues concerning **food security**, as projected increases in yield will not be enough to compensate for the increased demand for food, especially in Africa, natural areas could be further clear cut to ensure food production (IRP, 2019), and **climate change** is likely to further affect the ability to grow food in certain areas (see Cluster 2). Therefore, demographic projections presented in Cluster 1 may not be fully compatible with such a scenario.

Instead, according to the IRP scenario 'Towards sustainability', which sees the implementation of resource efficiency and sustainable consumption and production policies to promote stronger economic growth, improve well-being, help to support a more equal distribution of income and reduce resource use across countries, long-term resource demand would be reduced by 25 % compared with the 'Historical trends' scenario, while GDP would still grow by 8 % (IRP, 2019). According to IRP, these measures would also ease the emissions of GHGs and the demand for pasture and agricultural land, and forests and other natural areas would increase compared with today's situation (IRP, 2019). This scenario assumes that **decoupling natural resource use** and environmental impacts from economic growth and human well-being is an essential element in the transition towards a sustainable future, in the context of an increase in GDP. However, recent findings challenge the assumption that **green growth** and relative decoupling could be enough to reduce resource consumption and related environmental pressures, unless **consumption levels** are limited at the same time (see Box 2.13). Similarly, recent findings indicate that there might be substantial limits to **'circularity'** as a

Box 2.13 Uncertainty — Beyond green growth and decoupling

The green growth paradigm relies on the assumption that continued economic growth could be achieved by reducing pressures and impacts on the environment, in relative or absolute terms. The situation known as 'relative decoupling' indicates a decrease in environmental pressure or impact relative to gross domestic product (GDP) (i.e. both GDP and environmental pressure or impact grow, but GDP grows faster than pressures), while 'absolute decoupling' points to a situation in which GDP increases, but overall pressure or impact decreases. According to a recent review of the studies underpinning the narrative of green growth and decoupling, there is no empirical evidence that an absolute, permanent and sufficiently fast decoupling is occurring at all at the global scale. Instead, local, temporary and relative decoupling is often observed, sometimes on the basis of partial, if not ill-defined, accounting schemes (e.g. focusing only on the territorial scale and omitting trade).

Although this evidence does not exclude the occurrence of a hypothetical 'absolute, global and fast decoupling', several factors make such a development extremely unlikely and raise the question of how far this narrative can actually suffice in bringing humanity closer to 'solutions' to global environmental challenges. Several factors make the decoupling hypothesis inadequate: rising energy expenditure, the rebound effect, problem shifting, the underestimated impact of services, limited potential for recycling in a growing economy, insufficient and inappropriate technological change, and cost-shifting. It is therefore suggested that the narrative should shift towards 'sufficiency' (i.e. reducing overall levels of consumption), especially in the West, as opposed to growth, and complementary to resource efficiency. However, such fundamental reconfiguration of the economy is at odds with the current neoliberal approach to economics and financing.

Source: Based on Parrique et al. (2019).

strategy to reduce overall resource demand (direct and indirect), unless overconsumption is tackled at the same time (Box 2.14).

2.4.3 Ever-increasing demand for food, land and water

2.4.3.1 Growing global middle class drives an increase in food demand

A growing population over the coming decades (Cluster 1), combined with increased income and changes in consumption patterns (Clusters 5 and 6), is likely to result in an **increased demand for food**, feed and water by 2050 (IPCC, 2019a), which, according to the Food and Agriculture Organization of the United Nations (FAO) (2017a) could increase by 50 % compared with 2013. While food demand may fall in Europe, Japan and Russia as a result of population and consumption declines and ease global demand, the expansion of the middle class in the developing world, driven by rising disposable incomes, enables consumers to switch to **foods with higher fat and protein contents**, such as animal products, when these are available. The growing global middle class (see Cluster 5) could lead to an additional demand for more resource-intensive types of food, such as meat (OECD and DASTI, 2016), and increase both challenges and opportunities for meat production in Europe (see Box 2.15). Growing demand could in turn lead to increased production and pressure to intensify agriculture, and, combined with land management practices, would have implications for **land use change**, food insecurity, water scarcity, terrestrial GHG emissions, carbon sequestration potential and biodiversity (IPCC, 2019a) (see also Cluster 2). Cropland expansion, for instance, is likely to result in large **declines in biodiversity** (IPCC, 2019a), adding to already unsustainable levels of environmental pressure.

The global demand for **fishery products** is also currently increasing, and more than 30 % of global marine fish stocks are being overfished (WWF, 2018),

Box 2.14 Uncertainty — How circular can the EU economy be? (cont.)

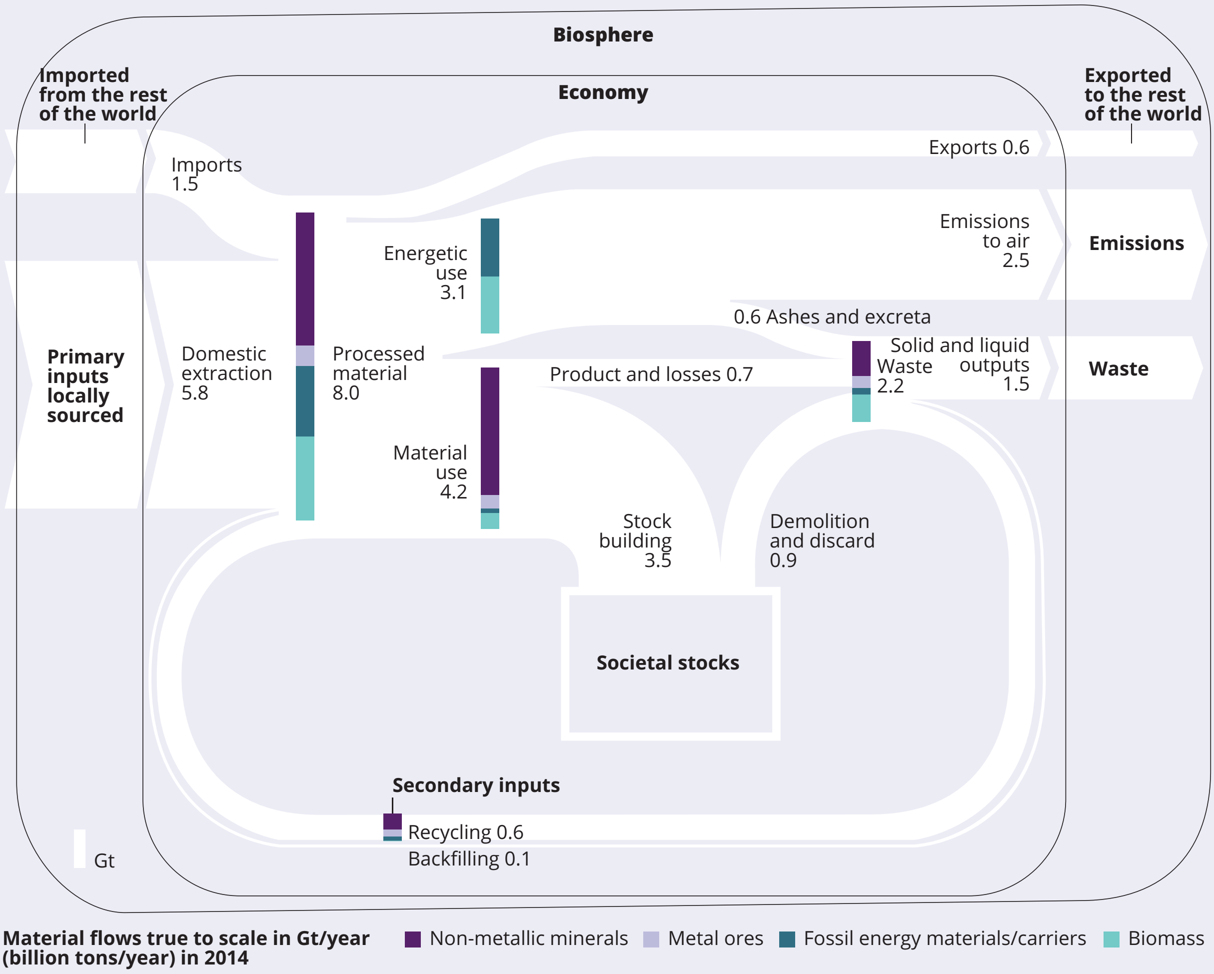
The concept of the 'circular economy' has become prominent in both EU and Chinese policymaking as a way to pursue a more sustainable use of natural resources (McDowall et al., 2017). In fact, there is growing recognition that a linear economic model — 'produce, consume, dispose' — is fundamentally unsustainable, as it relies on ever-growing imports of natural resources and generating waste and emissions (McDowall et al., 2017). Instead, the circular economy is based on the idea of closing material loops, aiming to maintain the value of products, materials and resources for as long as possible within the economy by returning them into the product cycle at the end of their use while minimising the generation of waste.

According to the European Commission (EC, 2019f), apart from creating a competitive advantage and benefiting the European environment and the economy, the development of a circular economy would help to decrease the EU's indirect pressures globally as well as increase its strategic autonomy, given its heavy reliance on resources from other parts of the world. The first steps in this direction have already been made, through the establishment of the circular economy action plan (EC, 2015b), the revised EU Bioeconomy Strategy (EC, 2018a) and the EU Plastics Strategy (EC, 2018e). As a result of this, as reported by Eurostat (2019f), the recycling rates and use of recycled materials in the EU are steadily growing. While the overall recycling of all waste remained at similar levels between 2010 and 2016 (i.e. 53 % and 55 %), waste recovery from specific streams, such as construction and demolition, plastic packaging, municipal waste and waste of electrical and electronic equipment (e.g. computers, televisions, fridges and mobile phones), grew substantially, reaching recycling levels equal to 46 % of municipal waste, 67 % of overall packaging, 42 % of plastic packaging, 41 % of e-waste and 89 % of construction and demolition waste. In spite of these high recycling rates, on average only 12 % of material resources used in the EU in 2016 came from recycled products and recovered materials (Eurostat, 2019f).

However, current levels of recycling are very limited compared with the material flows at the scale of the overall economy of the 28 EU Member States (Mayer et al., 2019), accounting for nearly 10 %. This depends on the fact that a very large share of the material flows in the economy cannot be recycled, as they are used for energy and then transformed into emissions to air, water and soil, or converted into long-term stocks (e.g. in buildings and infrastructure) (see Figure 2.16). Although secondary inputs such as processed minerals and metals, paper and glass can be kept for longer in the economy or recycled, the primary inputs provided by the biosphere, such as water, food and energy, are degraded in an irreversible way and cannot be recycled by human activities (Haas et al., 2015). For example, petrol becomes a mix of emissions, food becomes a quantity of faeces, and water loses its original useful attributes after use.

Box 2.14 Uncertainty — How circular can the EU economy be? (cont.)

Figure 2.16 Material flows in the EU-28 economy



Source: Adapted from Mayer et al. (2019).

Thus, in a circular economy context, recycling secondary inputs is conditional on the provision of primary inputs and sink capacity by the biosphere, as the circulation of resource flows in the economy is overall guaranteed by processes outside human control (e.g. cycling of nutrients, water, biomass production), although a marginal improvement can also be achieved by reusing water or recycling bio-waste. However, only a very limited fraction of the material input can be recycled, compared with the overall material processed in the EU (Giampietro, 2019). Therefore, the provision of primary inputs is much more dependent on healthy ecosystems and the existence of stocks of energy sources than the recycling occurring within the economy. This means that, even if circularity rates were to increase more for selected waste streams, the whole economy is likely to be still largely dependent on nature's provisioning services.

In a growing economy, the processes needed also required to increase circularity significantly would imply an additional demand for ecosystems' supply and sink services (e.g. cycling of nutrients, water, biomass production), which already now surpasses ecosystems' sustainable carrying capacity (Giampietro, 2019). The loads are already too high for ecosystems, as demonstrated by the unprecedented levels of pressure and degradation in Europe and worldwide (see Cluster 2). For instance, if Europe were to increase its reliance on biomass exploitation of global or European forests, pastures or agricultural lands to reduce its dependence on imported fossil fuels by increasing yields, this might translate into further loads on terrestrial ecosystems in Europe or elsewhere, further contributing to the reduction in ecosystems' quality and biodiversity. Therefore, unless a reduction in the demand for goods occurs, actions targeting the circularity of industrial processes are unlikely to reduce significantly the burden on the environment at the EU/global interface. Tackling these challenges would require a fundamental rethink of the concept of wellbeing and a shift towards lower consumption levels, alongside with circular economy measures. However, this path is fundamentally at odds with consumerism, the dominant economic paradigm, and change might be difficult to occur at a significant scale (see Cluster 6).

while projections suggest that 88 % of fish stocks will be **overfished** and well below their target biomass by 2050 (Worm, 2016). Overfishing, in combination with climate change (Cluster 2), is pushing fish stocks all over the world to the verge of collapse (Laffoley and Baxter, 2016). This is likely to have severe repercussions, given the fundamental role that fish have in the global population's intake of proteins, as it was estimated that, in 2013, fish accounted for almost 17 % of the global population's intake of protein, and in some coastal and island countries the figure was as high as 70 % (FAO, 2016, 2018). Reduced wild catches from unsustainable fishing practices could also increase demands for farmed fish, which will put pressure on terrestrial ecosystems, given the associated need for crop-based feed (Fry et al., 2016).

Overall, meeting rising levels of **global food demand** may not be possible if distribution follows purchasing power, neglects unequal distribution of food resources and food insecurity aspects. Globally, more than 820 million people — nearly one in nine — have not enough to eat, while at the same time not a world region is exempt from the epidemic of overweight and obesity (WHO, 2018a), pointing at inequality as a major driver for hunger and food insecurity. In addition to that, pressures from climate change and loss of soil quality and productivity, as well as increased exploitation of agro-ecosystems (Cluster 2), may mean that food production cannot keep pace with population growth and that, as a result, regional food shortages could become more likely, with impacts on conflicts, migration and well-being. **Future climate projections** alone (e.g. under the high-emissions and no-adaptation scenarios) suggest that, by 2050, large parts of sub-Saharan Africa could be highly vulnerable to food insecurity (IPCC, 2019a). This would reinforce global food insecurity, worsen an already critical situation that sees hunger again on the rise despite global commitment to the Sustainable Development Goals (SDGs) (FAO, 2019).

While **food insecurity** could be mitigated with increased productivity in the short term, the long-term effects of **intensification** are detrimental to soils and make agriculture even more dependent on external inputs, such as fertilisers, pesticides and fuels for agricultural machinery, locking the agricultural sector into an ever-growing dependence on fossil fuel resources and growing external inputs. Food production is also affected by the potential **volatility of the fossil fuels market** because of increased competition for energy resources and the location of much of the supply in a small number of and/or in geopolitically less stable regions, with potential further repercussions on food prices. Similarly, the expansion of biofuels and the increased use of biomass as an alternative feedstock to fossil-based chemicals, also referred as **'bioeconomy'**, might lead to increased competition for land and rise in food prices, as already manifested in the recent past (EEA, 2019e).

The global food production system and consequent global food security are also highly dependent on the supply of commercial phosphorus fertilisers (Chowdhury et al., 2017). As a resource, phosphorus, mainly acquired from phosphate rock, is 'finite, non-substitutable, non-renewable, and geographically restricted' (Chowdhury et al., 2017). The outlook suggests that, with the increase in the global middle

Box 2.15 Wild card — Animal-based food production, environment and health risks

Increased global demand for meat driven by an expanding global middle-class (Cluster 5) could lead to maximising production of animal-based food and intensifying livestock production in countries outside the EU (such as China; Fischer et al., 2012) and potentially lowering environmental standards and ethical concerns globally. Recent examples are the mad cow disease as well as epidemics like swine fever and bird flu. If production expands in countries with lower environmental, animal welfare and food production hygiene standards compared to the ones in place in the EU, this development might lead to increased risks for health and the environment. The ongoing outbreak of coronavirus COVID-19 has started in China towards the end of 2019 and has presumably originated from wildlife (bats) in a wet market, similarly to the SARS outbreak (Woodward, 2020b, 2020a). Since then, the disease has been spreading in the rest of the world, leading to more than 130 000 cases and led to nearly 5 000 deaths as of 13th March 2020 (ECDC, 2020). This is creating unprecedented challenges for healthcare systems across the world, affecting profoundly the way people interact, move and work in Europe, as a consequence of the emergency measures taken by governments to slowing-down the spread of the disease.

Overall, infectious zoonoses, food-related or not, 'emerge from complex interactions among social and ecological systems' (Waltner-Toews, 2017) and while they are usually seen as 'one off', 'they are likely to be more of a problem in future, as climate change and globalisation alter the way animals and humans interact' (Benton, 2020). Factors like a fast-growing urban middle class, growing consumption and disturbance of ecosystems, increasing city living and inequality, as well as growing international travel, suggest that these diseases might be more common in the future (Benton, 2020).

class in the coming decades, the **demand for phosphorus will increase** and, together with depleting reserves and geopolitical limitations, lead to higher phosphorus prices, which may eventually restrict the access of many countries, including those in Europe, to phosphorus fertilisers (Chowdhury et al., 2017). All these uncertainties and the potentially increased cost of resources used in food production, distribution and retail are also likely to affect the global food system in the future.

Pathways towards the achievement of global food demand, health and natural protection objectives are not uncommon in the literature (e.g. Bahadur et al., 2016). It has been estimated that response options throughout the food system, from production to consumption, including food loss and waste, can be deployed and scaled up and can also advance adaptation to and mitigation of climate change, by adding, globally, to significant carbon sequestration and avoiding GHG emissions (e.g. through dietary changes) (IPCC, 2019a). However, it is often the case that scenarios rely on implausible and often controversial assumptions, as well as oversimplifications concerning the viability of future technologies (Saltelli and Lo Piano, 2017). Moreover, **global imbalances and injustices** between the Global South and the Global North, as well as asymmetries in the political power of trade patterns, arguably at the root of the issue of diets, are often overlooked (see Saltelli and Lo Piano, 2017).

At the global scale, a growing population would not represent the fundamental problem per se. Instead, the **uneven distribution of food** and related consumption levels see nearly 815 million people worldwide suffering from hunger and 2 billion adults being overweight globally (including 50 % of the EU population) (FAO et al., 2017; IPCC, 2019a), and the growing demand for meat and dairy products driven by an expanding global middle class (Kharas, 2017) represent the two main reasons for concern. Similarly, adequately feeding 10 billion people by 2050 would require an increase of 50 % in food production; however, some 33 % of global edible food is lost or wasted (UN Environment, 2019c). Reducing **food waste** would help to mitigate rising demand. Approximately 56 % of global food loss and food waste occurs in developed countries (UN Environment, 2019c), including the EU, where food waste per capita ranges between 158 kg and 298 kg per year (Philippidis et al., 2019). A fundamental reconfiguration of the global food system is therefore urgently needed, including aspects such as trade, consumption levels and health considerations alongside efficiencies.

2.4.3.2 Increasing demand for land

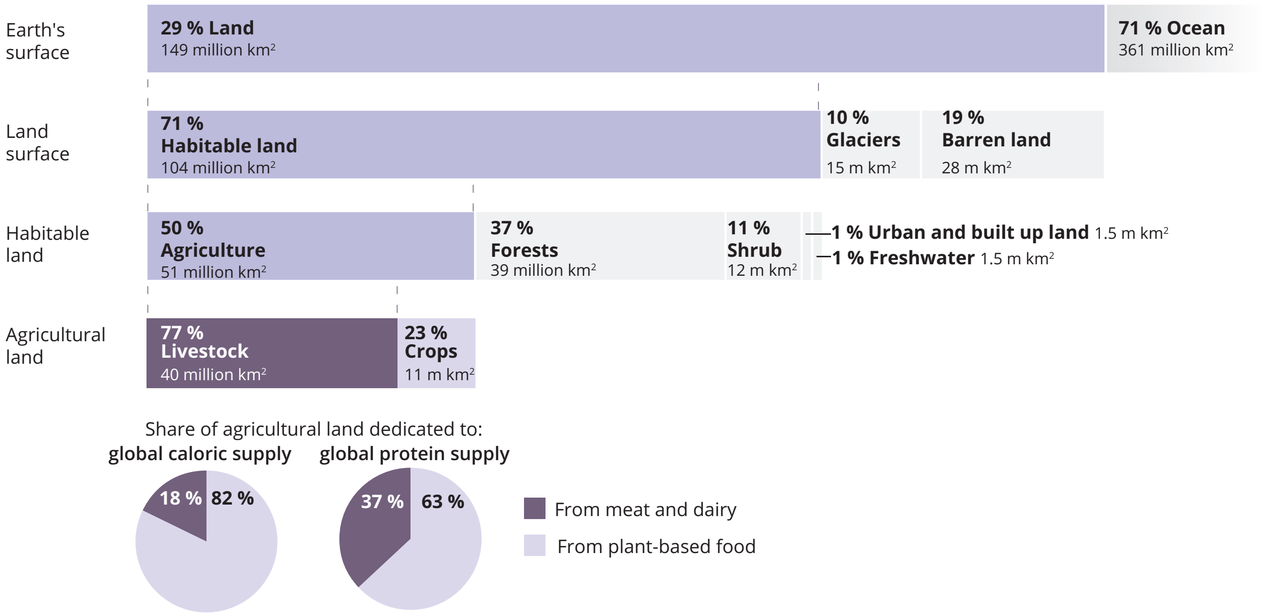
Land provides the principal basis for human livelihoods and well-being, including the supply of food, freshwater and multiple other ecosystem services, as well as biodiversity, beside playing an important role in the climate system (IPCC, 2019a). Although the expansion of areas under agriculture and forestry together with increased productivity has supported the increasing global demand for food, feed, fibre, timber and energy associated with global population growth, consumption levels and shifting demand (Clusters 1 and 5), it has led to unprecedented rates of land and freshwater use (IPCC, 2019a).

Changes in land use and land cover represent an important **driver of change** for the global climate as well as biodiversity, as they alter the Earth's energy balance, biochemical cycles, and ecosystems and their services (Song et al., 2018). For example, urban sprawl affects the hydrological cycle and soil functions, causing urban heat islands (UN Environment, 2019c). At the regional scale, land use and land cover changes can influence the intensity, frequency and duration of extreme events (IPCC, 2019a), while at the local level they increase societal vulnerability to extreme events, as a result of land use planning and management.

Currently, **food production is the largest anthropogenic use of land**, using 50 % of habitable land (Figure 2.17). Livestock production uses 77 % of agricultural land for feed production, pasture and grazing, while urban areas have grown from 2.5 % of global land to 7.6 % (UN Environment, 2019c). According to recent studies (Song et al., 2018), tree cover increased by more than 7 % during the period 1982-2016, as net losses in the tropics were outweighed by net gain in the extratropics. Globally, arid and semi-arid ecosystems have lost vegetation cover, while montane systems have increased tree coverage during the same period (Song et al., 2018), with 60 % of the changes due to human activity and 40 % due to climate change.

Growing demand for food, feed, wood and bioenergy can often prompt **changes in land use**. Fuelled by population and consumption trends, global demand for land is steadily increasing. According to the IPCC (2019a), the supply of vegetable oils and meat per capita has more than doubled globally since 1961, while the supply of food calories per capita has increased by about one third. This is projected to continue, particularly since 25 % to 100 % more food may be required globally by 2050, depending on socio-economic and technological assumptions

Figure 2.17 Global surface area allocation for food production



Source: Ritchie and Roser (2019), in turn based on FAO.

(Hunter et al., 2017). Dietary changes and rising income levels globally are expected to cause an increase in meat consumption by 2050, contributing to increased demand for land and water, given the high requirements of meat production compared with plant-based food, on average ([8]) (FAO, 2012).

According to the IRP (IRP, 2019), if current trends were to continue in the future, **global cropland** is likely to increase by nearly 20 % by 2060, particularly in Africa, Europe and North America, while **global pasture areas will increase by 25 %**, with the highest growth in Africa and Latin America. Overall, it is expected that improved yields will not be able to compensate for the expected surge in global demand based on current demographic scenarios. Therefore, arable land availability is also likely to add to the intensified competition for resources, as the **pressures of climate change** and **soil degradation** will further affect the amount of land available for productive agriculture. Annually, approximately 12 million hectares of productive land are eroded, with almost half of the world's agricultural land already being affected by moderate-to-severe degradation due to desertification and drought (OECD and DASTI, 2016). Coupled with current soil erosion rates from agricultural fields two to three orders of magnitude higher than soil formation rates (IPCC, 2019a), it is likely that the decline in fertile land will put increased pressure on agricultural productivity.

Additional drivers are likely to intensify competition for land, resulting in **rising prices of agricultural products** (Haberl, 2015). For example, future urban expansion in response to a growing population and urbanisation (Cluster 1) is likely to lead to conversion of cropland, affecting peri-urban food production (IPCC, 2019a). At the same time, **demand for biofuels** is also expected to rise, particularly in developing regions (OECD and FAO, 2018), and agriculture is expected to be increasingly compromised by the combined effects of climate change and soil degradation, especially in sub-Saharan Africa (UNCCD, 2017). Typically, the expansion of biofuel/hydropower production and agricultural land occurs at the expense of forests and other natural vegetation (EEA, 2015a). Altogether, pressures on land due to increasing demand for food, fodder and biomass, combined with land degradation, are causing a scarcity of good quality land and giving rise to the phenomenon of international land acquisition, also known as **'land grabbing'** (see Box 2.16).

([8]) The environmental impacts associated with the consumption of products vary significantly across individual products, depending on production phases and the length of the supply chain.

Future projections indicate that sub-Saharan Africa, the Middle East and North Africa, South Asia and, to a lesser extent, South East Asia are the main regions that will be confronted by rapidly increasing pressure on the remaining land resources. **Land use outlooks** show that, under all shared socio-economic pathways (SSP) scenarios (with the exception of sustainability — SSP 1), land is projected to be converted from natural land and forests to pastures, energy crops and food and feed, which will be most obvious in sub-Saharan Africa (UNCCD, 2017). Overall, at the global scale it is expected that important natural ecosystems harbouring large parts of **terrestrial biodiversity**, such as grasslands, shrub land and savannahs, will decrease by 20 %, with the largest losses occurring in Africa, Latin America and Europe (IRP, 2019).

Sustainable land management can prevent, reduce and sometimes reverse land degradation, and maintain productivity while providing co-benefits for climate adaptation and mitigation (e.g. through carbon sequestration) (IPCC, 2019a). Although these actions are likely to deliver benefits to communities and support several SDGs (IPCC, 2019a), land management alone will not be able to accommodate both ever-growing consumption levels and ecosystem conservation goals. Therefore, actions targeting the reduction of demand would be a fundamental complement to sustainable land management.

2.4.3.3 Unprecedented rates of water consumption

Globally, **per capita availability of freshwater is decreasing** because of requirements associated with agriculture, industry and energy production, in the face of a growing population, as well as climate change impacts, such as droughts, water scarcity, desertification and famine in many areas (UN Environment, 2019b). There is a clear interaction here between climate change and environmental degradation, as climate change is expected to lead to significant degradation of productive land and water scarcity, globally and in Europe (EEA, 2019e) (see also Cluster 2).

Overall, this translates into an increasing number of people at risk, increased migration and social conflicts, also because of increased competition for access to water resources and food (UN Environment, 2019b). In 2016, it was estimated that two thirds of the world's population lived in areas that experience **water scarcity** for at least one month a year (Mekonnen and Hoekstra, 2016) and that a third of the world's biggest groundwater systems are already in distress (Richey et al., 2015), suggesting significant long-term risks to water availability. Countries in sub-Saharan Africa, as well as regions in India and China, are particularly afflicted by water stress. Based on current climate projections, by 2030, water scarcity in some arid and semi-arid places is likely to displace between 24 million and 700 million people (UN Water, 2018a). At present, 1.9 billion people already live in severely water-scarce regions, and nearly half of the global population lives in regions with potential water scarcity for at least one month per year. These numbers could increase to 3.2 billion and 5.7 billion, respectively, by 2050 (UN Water, 2018b). Water scarcity could impact in particular southern Europe (Veldkamp et al., 2017). Water scarcity is also caused by a lack of access to clean water. Globally, every year millions of people are

Box 2.16 Emerging trend — 'Land grabbing'

Since 2000, the growing global competition for arable land, freshwater and energy has been apparent because of a sharp increase in large-scale transnational land acquisitions, primarily in Africa, by foreign investors from Europe, China, the Middle East and North America. As a result, large-scale monocultures (e.g. for palm oil production) often replace smallholder tenure and local access to land and water and leave little opportunity for alternative practices that provide ecosystem services and support biodiversity (UNCCD, 2017). This phenomenon is also known as 'land grabbing' and indicates a situation in which large-scale transnational acquisitions of land, mostly in developing countries, are evicting people or taking away access to land, water and other related resources for the rural poor (UNCCD, 2017). This is contributing to intensification of conflicts and risks to food security around the world (GRAIN, 2016).

The United Nations Convention to Combat Desertification (UNCCD, 2017) reports that 'land grabs' have increased dramatically since 2000, covering more than 42 million hectares dedicated to food, timber and biofuel crops, primarily in Africa. As a result, about 25 % of global cropland area, and its associated use of water and other inputs, now produces commodities that are exported to land-poor but cash-rich countries (UNCCD, 2017). Often land grabbing is part of a broader corporate strategy to profit from carbon markets, mineral resources, water resources, seeds, soil and environmental services (GRAIN, 2016). Mainly corporations and governments from Europe, the Middle East, North America and South-East Asia are responsible for 'grabbing' land (GRAIN, 2016). Based on outlooks for socio-economic development and food, fodder and bio-energy demand (driven by increased demand in emerging economies), it seems very likely that, in the absence of new regulation or international agreements, global land acquisitions will continue and potentially increase in scale.

affected (often lethally) by diseases associated with inadequate access to safe water supply, sanitation and hygiene (United Nations, 2018).

Water availability is therefore a further key area of potential conflict and trade-off, in which food production and consumption will be affected by other demands for water (e.g. industry) (EEA, 2017a). For example, in the IRP 'Historical trends' scenario, global water withdrawals for industries and municipalities are expected to rise because of **urbanisation and economic growth**, and climate change would create uncertainties related to the **supply and distribution of water**, most likely affecting agriculture (IRP, 2019). In turn, projections show that the absolute agricultural intensification needed to meet future food demand could lead to severe water stress in many world regions. As a result, water security and the functioning of ecosystems and their capacity to provide essential services could be compromised. Moreover, groundwater constitutes just under a third of global freshwater use and is being exploited faster than it can be recharged across many parts of the world (Lo et al., 2016), mainly because of over-abstraction for irrigation, drinking water, and industrial and mining uses (UN Environment, 2019c). Excessive extraction for irrigation, whereby groundwater is slowly renewed ('water mining'), is the main reason for decreasing resources (exacerbated by an increased demand for agricultural products). Future risks of **groundwater depletion** could particularly affect irrigated agriculture and subsequently global food security and urban water supplies, particularly in the context of climate change (Cluster 2); it has been observed that change in precipitation patterns is associated with groundwater depletion in numerous global aquifers (Thomas and Famiglietti, 2019), often leading to saltwater intrusion. With water scarcity an increasing problem globally, desalination is increasingly considered a viable option for meeting water needs. Currently, desalination provides only 1 % of the world's drinking water (UN Water, 2017); however, it is projected that by 2025 almost 14 % of the world could rely on desalination. Alongside with technological solutions, promoting water management (including efficiency, recycling, rainwater harvesting and desalination) is becoming increasingly important to ensure greater water security and more equitable water allocation for different users and uses (UN Environment, 2019c).

2.5 Cluster 4 — Accelerating technological change and convergence

Key messages (cont.)

Acceleration, hyperconnectivity and digitalisation

- Technological progress is a fundamental characteristic of human societies that has allowed humans to prosper through achievements such as farming, cities, culture, industrialisation and medical advances. Technological innovation co-develops with societal needs and lifestyles (Cluster 6), economic development and wealth (Cluster 5), and it is shaped by financial investments, the up-scaling and diffusion of technological applications within society, and, not lastly, by research and innovation policies.

- Given the highly uncertain and evolutionary character of technological innovation, both the pace of uptake and the nature of impacts of new technologies on society (e.g. sustainability outcomes) can hardly be forecasted. For example, efficiency gains coupled with a globally expanding demand for goods and services, have enabled an ever-increasing exploitation of biotic and non-biotic resources, leading to fundamental modifications of the environment and landscapes, as well as growing pollution worldwide (see Clusters 2 and 3).

- Today, the global landscape of technological innovation is under rapid transformation. According to several authors, technological innovation is currently accelerating, mainly fuelled by the widespread digitalisation of economies and societies worldwide. For example, while electricity took almost half a century to reach 25 % of the US population, the worldwide web and smartphones took less than 10 years to achieve similar market penetration (Kurzweil, 2005). Our world is now hyperconnected, and all individuals, firms and markets are affected by the digital transformation, even though adaptation remains unequal.

- Emerging digital technologies, such as big data analytics, artificial intelligence and blockchains, offer tremendous opportunities in each aspect of everyday life, however implications from an ethical, privacy and security perspective are significant and are causing increasing concerns within society. Today, data ownership is concentrated, with international bandwidth use shifting towards giant content providers such as Amazon, Google, Facebook and Microsoft (OECD, 2019d). Concerns are also being raised regarding issues such as illegal social media manipulation for influencing results of political elections (e.g. in Europe and the United States); the use of big data analytics for mass surveillance; protection and security of sensitive data.

- From an environment and sustainability perspective, the digital economy may turn out to be more resource intensive than expected. While personal electronic devices might contribute to reduce direct energy demand locally, global energy demand could increase driven by ICT infrastructure and growing production of households' electronic objects (Hittinger and Jaramillo, 2019). Digitalisation is also contributing to a significant increase in extraction of raw materials and to a rapid increase in waste electrical and electronic equipment (WEEE), leading to environmental and social implications in Europe and elsewhere.

Technological convergence

- Widespread digitalisation is the key enabler of the 'Fourth Industrial Revolution', which fuses digital technologies with the physical and biological worlds. Largely enabled by the Internet of Things, this is expected to provide opportunities for more integrated and efficient industrial processes, personalised production, new jobs and economic growth.

- Technology convergence fuelled by digitalisation (e.g. automation, efficient industrial processes) is currently changing the nature of jobs, creating new opportunities and risks, and requiring the development of new skills (Cluster 6). There is a real risk that, because of further automation, more jobs will be lost than created, and that job losses and creations will affect occupations, sectors and countries unequally. Alongside with automation, it might contribute to weakening the welfare system, leading to precarious forms of work, low wages and job insecurity (Cluster 6).

- According to the European Commission, key enabling technologies, such as advanced manufacturing, nanotechnology, biotechnology and advanced materials, provide the basis for innovation in a range of products across all industrial sectors (EC, 2016b). While these technologies continue to develop, offering prospects for societal advancements and economic benefits (e.g. personalised production, personalized medicine, enhanced human performance), concerns for human health and the environment are still significant (e.g. risk associated to nanomaterials and genetically modified organisms).

Key messages (cont.)

- In the EU, research and innovation policies like Horizon Europe aim to address directly societal challenges, such as environmental protection, climate change mitigation and adaptation, and other sustainability considerations. In particular, 'Sustainability-driven' or 'green' technologies have increasingly become the focus of policymakers in the EU and also in China. Many developments relate to the transformation of the energy, mobility and food systems, and are aimed generally at achieving a more circular, bio-based, climate-neutral and non-toxic economy.

- The outcomes of the up-scale of technological innovations is difficult to anticipate. From an environmental perspective, together with increasing consumerism (Clusters 5 and 6), technological progress is also the root cause of many of the environmental challenges that we face today. Whether emerging technologies — and which of these in particular — will contribute to easing or worsening environmental and sustainability challenges cannot be known a priori. Much will depend on the ability to anticipate and govern potential risks as well as benefits. The precautionary principle, responsible research and innovation, adaptive governance, and foresight and horizon scanning represent important tools, in the hands of public authorities, for achieving this goal.

Changing landscape of technological innovation

- From a geopolitical perspective, developed economies are no longer alone in investing in research and development (R&D). China, in particular, has already overtaken the EU in terms of R&D intensity and is rapidly emerging as a technological power (Cluster 5). In particular, Europe is lagging behind the United States and China in ICT-related innovation and the EC is currently focusing on closing this gap with the implementation of the European Digital Strategy. Overall, R&D remains highly concentrated, as a small number of countries, companies and sectors account for a large share of the total R&D investment, pointing to potential issues concerning concentration of power.

2.5.1 Acceleration, hyperconnectivity and digitalisation

2.5.1.1 Accelerating technological change

Technology has a **fundamental role in human history**, as the development of new tools and applications, such as farming, cities, culture, industrialisation and medical advances — one of the most distinctive characters of the human species — has enabled massive exploitation of biotic and non-biotic resources, and fundamental modifications of the environment and landscapes, ultimately allowing humans to develop in complex societies and thrive. At the same time, together with increasing consumption levels (Clusters 5 and 6), technological progress is also the root cause of many of the environmental challenges that we face today (see Clusters 2 and 3).

Technological progress is largely an unpredictable process, as the interaction among multiple factors, ranging from biophysical, social, cultural and financial to political, regulatory and strategic ones, determine the success of a specific technology. In particular, the **uptake of new technologies** and related diffusion often shows an **'emergent' character**, as rapid evolution often follows right after enabling innovations. For example, the evolution of the mobility system towards cars being a dominant form of land-based transport is the result of a century-long process across multiple factors such as: knowledge and infrastructure for car production, private investments in skills, public investments in road infrastructure, emergence of industries complementary to manufacturing, delivery of fuel, tyres and other accessories, adaptation of urban design to the car, as well as changes in behaviour, expectations and cultural values linked to car ownership (EEA, 2017c). At the same time, the favourable chemical-physical properties of petrol (i.e. high-energy density at a relatively low risk of explosion) and the abundance of easily accessible oil resources made petrol a perfect energy carrier and enabled cars to become the dominant technology in the mobility systems of the 20th century.

Empirical observations (see Figure 2.18) indicate that technological progress, often measured through efficiency or functionality gains, is the result of positive reinforcing feedback between increasing performance, investment, upscaling and increased economic return. However, several 'promising' technologies have never achieved a stage of maturity, despite substantial investments — e.g. while research into fusion reactors began in the 1940s, to date no design has produced more fusion power output than the electrical power input, defeating the purpose (WNA, 2015). Given its **highly uncertain character**, technological progress can hardly be projected beyond the short term; consequently, the exploration of technological futures becomes a matter of scenario analysis and related socio-technical imaginaries.

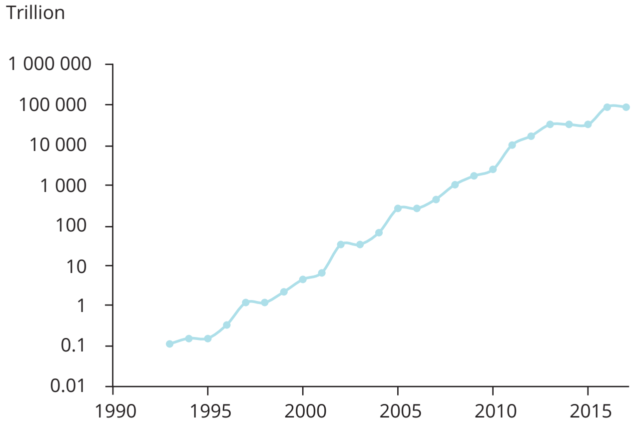
The analyses of most international organisations (European Parliamentary Research Service, or EPRS, JRC, OECD, World Economic Forum, World Bank) and many renowned experts (Diamandis, Kurzweil, Brynjolfsson and McAfee) point to an **acceleration in technological change**. While electricity took almost half a century to reach 25 % of the US population, the worldwide web and smartphones took less than 10 years to achieve similar market penetration (Kurzweil, 2005). For some, acceleration is actually inherent in technological progress, as 'an analysis of the history of technology shows that technological change is exponential' because of accelerating returns in a number of factors (Kurzweil, 2001), as well as self-reinforcing loops with economic development (Cluster 5), urbanisation (Cluster 1) and more educated and informed societies (Cluster 6). According to the Global Innovation Index 2019, 'amid economic slowdown, innovation is blossoming around the world' (Cornell University et al., 2019). Today, the world is witnessing a **mass acceptance of innovative products** and services and a mainstreaming of a technology-driven culture valuing numeracy, problem-solving, information and communications technology (ICT) and creative skills (OECD, 2017f).

Demonstrating this acceleration across the board and through quantitative data is, however, more difficult. Available **computing power**, often considered as the best proxy to measure it (as computers are embedded in almost all modern technologies), has been accelerated since the 1970s, benefiting from increased miniaturisation and storage capacity. Similarly, growth in the power of supercomputers, which can solve increasingly complex problems, has doubled every 1.2 years since 1994 (Kurzweil, 2005), and it is expected that parallel computing, quantum computing and biocomputing will further contribute to this acceleration (EPRS, 2018a). Other indicators support this claim. **Global R&D expenditure** has been growing faster than the global economy, more than doubling between 1996 and 2016 (Cornell University et al., 2019). Companies worldwide have been significantly increasing their R&D investments for eight consecutive years. Patent applications under the International Patent Classification (IPC) more than doubled between 1999 and 2013, although the number of patents actually granted has declined since the early 2000s, at least in the United States and in the EU (EPRS, 2018a).

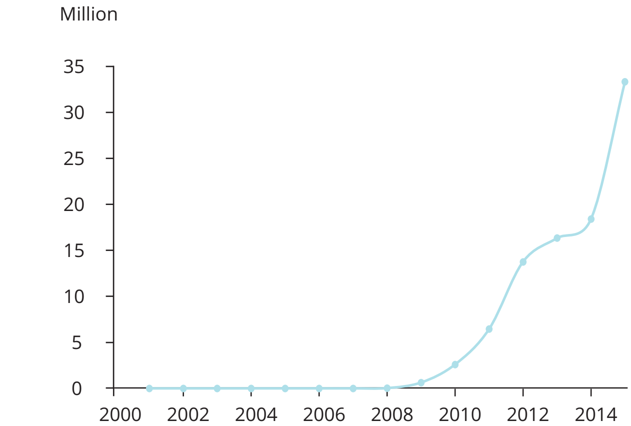
The acceleration of technological change is perhaps best reflected in the fast and recent trends in global ICT developments that have led to a **hyperconnected world**. More than half of the world's population, or 3.9 billion people (51.2 %), are now using the internet (ITU, 2018). In developing countries, the increase rose from 7.7 % in 2005 to 45.3 % at the end of 2018, with most new users in the Asia Pacific region and the strongest growth in Africa (ITU, 2018). In OECD countries, the share of people who use the internet

Figure 2.18 Evolutionary paths in performance of selected technologies

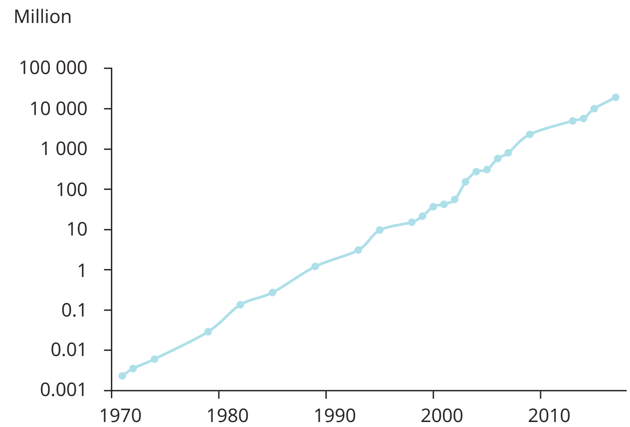
Floating-point operation per second (FLOPS)



Number of human genome base pairs sequenced per US$



Transistors per microprocessor (transistors per chip)



Note: The time scales differs between charts.

Source: Our World in Data (Roser and Ritchie, 2019), in turn based on TOP500 Supercomputer Database (2019), Rupp (2019) and NHGRI Genome Sequencing Program (Wetterstrand, 2017).

has grown by 30 percentage points over the last 10 years (OECD, 2019d). Europe is the most connected continent, with almost 80 % of the population using the internet (ITU, 2017). In 2017, 71 % of internet users were people aged 15 to 24 years, indicating that young people are leading internet adoption (ITU, 2017). Over 50 % of 16- to 74-year-olds in Brazil, China and South Africa use the internet today, and the gap with OECD countries is narrowing (OECD, 2017d). Mobile broadband subscriptions worldwide increased from 825 million in 2010 to 4.6 billion in 2017, and 90 % of the global population can access the internet through a 3G or higher quality network (ITU, 2018). All this has been favoured by increasingly cheap ICT products, with prices of communication-related products having decreased by more than 20 % in the OECD area between 2000 and 2018, at a time when consumer prices were increasing by about 45 % on average (OECD, 2019d). The commercial price per gigabyte diminished from about USD 10 in 2000 to below USD 0.3 in 2018 (OECD, 2019d).

2.5.1.2 Digitalisation

This nearly worldwide connectivity and pervasive computing has led to the emergence of a **wide-ranging digitalisation** of economies and societies, supported and driven by unprecedented data generation and use, and affecting all economic sectors (OECD, 2018f). From a societal perspective, the internet and web-based applications have become a crucial **part of everyday life** for most individuals. Content production hosted on the internet has boomed worldwide, with the total number of websites growing from about 100 million in 2006 to more than 1.6 billion in 2018 (Netcraft, 2018). In Europe, the average individual allocated more than 3 hours per day to internet use in 2016 (OECD, 2019d). A number of services and functions, including mailing, banking, shopping, learning, translation services, news provision, data access and many more, are now largely accessed through online paths. In 2017, 65 % of people aged 16 to 74 years in the OECD area used the internet to access news content, and 90 % of young people aged between 16 and 24 years used it for social networking (OECD, 2019d). On average, 64 % and 66 % of internet users in the OECD area used **online shopping** and online banking in 2018, respectively (OECD, 2019d). However, there can be considerable differences in internet uptakes between different groups in society (see Box 2.17).

From a business perspective, 'all firms and markets are affected by the digital transformation, although the pace of change differs' between countries, sectors, organisations and places' (OECD, 2019d). Almost no business today is run without digital technologies, which are increasingly affordable, even for smaller businesses. However, not all businesses have achieved their full potential because of the investments required in **reskilling** and updating business models (OECD, 2019d). Besides, businesses face not only the challenges of integrating digital technologies into their own processes but also the **disruption** brought about by newcomers in their respective fields. In particular, many existing business models have been challenged by the 'platformisation' of the internet over the last decade. Only a few years were needed for digital platforms, such as Uber and Airbnb, to gain growing shares of markets, competing against well-established taxi companies and hotels. However, the existence of a flexible international online market for product development (e.g. sales through internet, easy connections with investors and financial markets), allows start-ups to grow quickly without big investments in IT systems. They can also raise capital through online crowdfunding and reach markets through social networks. In terms of job creation, of the 38 million jobs added to the OECD area between 2006 and 2016, around 40 % were in highly digital-intensive sectors (OECD, 2019d). In 2016, information industries (i.e. 'ICT sector' and 'content and media sector') accounted for 3.7 % of employment across OECD countries (OECD, 2019d).

Box 2.17 Uncertainty — The risk of a digital divide in a hyperconnected world

Although connectivity is increasing, there are indications of a digital divide. In comparison with the Organisation for Economic Co-operation and Development (OECD) area, developing countries have slower and less affordable broadband connections (ITU, 2017). Although the strongest growth in deployment occurs in developing countries, less than 25 % of Africans use the internet, which deprives them of trade, business and learning opportunities. A global gender digital divide also exists, as the proportion of women worldwide using the internet remains 12 % lower than men (ITU, 2017). Even in developed countries, there are signs of a digital divide among several societal groups. The generational gap in internet use often remains pronounced in OECD countries, along with limited coverage of fixed broadband in rural households (OECD, 2019d). Beyond access, opportunities for digital training are also unequal among workers, as those who are most in need of training are less likely to benefit from a session given by their company (OECD, 2019d). This might create challenges for workers in need of training to adjust to the changing nature of work and education (see Cluster 6).

On the other hand, the development of **digital platforms**, alongside with the diffusion of smart devices and the emergence of the 'on-demand' economy, has enabled the diffusion of business models whose success is largely dependent on their ability to escape fiscal or social regulations (e.g. taxation and social contribution). Such business models are often considered unfair by traditional operators and characterised by precarious forms of work, low wages and job insecurity (see Cluster 6, section 2.7.1).

Overall, it is still too early to understand fully the broad impacts of digitalisation on the economy, society and the environment. Many considerations are a matter of socio-technical imaginaries and supporting narratives, such as the 'Fourth Industrial Revolution' (see Section 2.5.2.1). However, some implications of digitalisation are already visible and will undoubtedly require adjustments from society, governments and businesses. For instance, no matter which pathway it follows, **'training and upskilling are a must** for thriving in the digital transformation' (OECD, 2019d). Cognitive and problem-solving skills related to science, engineering, mathematics and ICT are obviously particularly needed. In 2018, 40 % of EU workers had to learn to use new software or ICT tools (OECD, 2019d). However, this set of skills is not sufficient, as non-cognitive and social skills (e.g. communication, creativity) appear to be just as crucial for workers to be fully rewarded in the emerging digital economy (OECD, 2017d). Secondly, a number of health and well-being issues are emerging, along with digital lifestyles (see Cluster 6). Digital addiction is of particular concern, as many young adults now follow an **'always-on lifestyle'** and spend at least a quarter of their day online (OECD, 2017a). According to the results of the 2015 OECD programme for international student assessment (PISA), about 80 % of 15-year-olds in France, Greece, Portugal and Sweden reported feeling bad if no internet connection was available (OECD, 2018d). A third kind of implication relates to governance broadly speaking, as digitalisation has already started to disrupt existing systems of information, scientific production and policymaking (see Cluster 6). Digitalisation has the potential to improve transparency but brings concerns for privacy and security, as well as ethical challenges (see Box 2.18).

Finally, digitalisation seems to carry a lot of **hopes and concerns for the environment**, particularly regarding overall energy consumption, and ICT and electronic goods now represent the main component of electronic waste. Increased digitalisation has led, among other things, to growth in what is referred to as the 'on-demand economy', which has led to the expectation of an almost instant delivery of services, including transport (e.g. Uber, Lyft, Hailo), as well as goods (e.g. Amazon), increased internet shopping and the expectation of fast at-home deliveries (e.g. same or next day; Joerss et al., 2016; Bauer et al., 2017). In Europe, the same-day and fast delivery of goods has already transformed transport logistics and associated technologies, for example those seen in huge distribution warehouses and delivery networks. Further expansion of such services (internationally and locally) is likely to require additional transport, and faster transport implies (potentially) less sustainable modes, including aviation, and perhaps even drones (Joerss et al., 2016).

Overall, the widespread increase in the number and use of **personal electronic devices** associated with ubiquitous digitalisation in all aspects of life (e.g. IoT), a figure that might reach up to 30 billion of objects connected to the Internet by 2020 (Nordrum, 2016), might have substantial implications on demand for energy (Hittinger and Jaramillo, 2019). While these devices might contribute to reduce direct energy demand locally (e.g. through process and systems optimisation as well as by favouring behavioural change), global **energy demand** could increase driven by ICT infrastructure (e.g. cloud computing, data centres, and cell phone infrastructure) and growing production of households' electronic objects that is likely to outpace efficiency gains (Hittinger and Jaramillo, 2019; see also Box 2.21). The rapid development and uptake of ICT and increasingly higher replacement rates of ICT devices are also contributing to a significant increase in extraction of raw materials and to a rapid increase in waste electrical and electronic equipment (WEEE), also called e-waste (Baldé et al., 2017), leading to significant environmental and social implications, including concerns regarding security of supply (see Box 2.12).

2.5.1.3 Key digital technologies

Digital technologies are an example of **fast-accelerating technologies**. Because of their general-purpose nature, their acceleration sustains itself over time as they find new areas of application (OECD, 2019d). Cloud computing and big data analytics have already materialised in practice, whereas artificial intelligence, quantum computing, biocomputing and blockchain are only emerging.

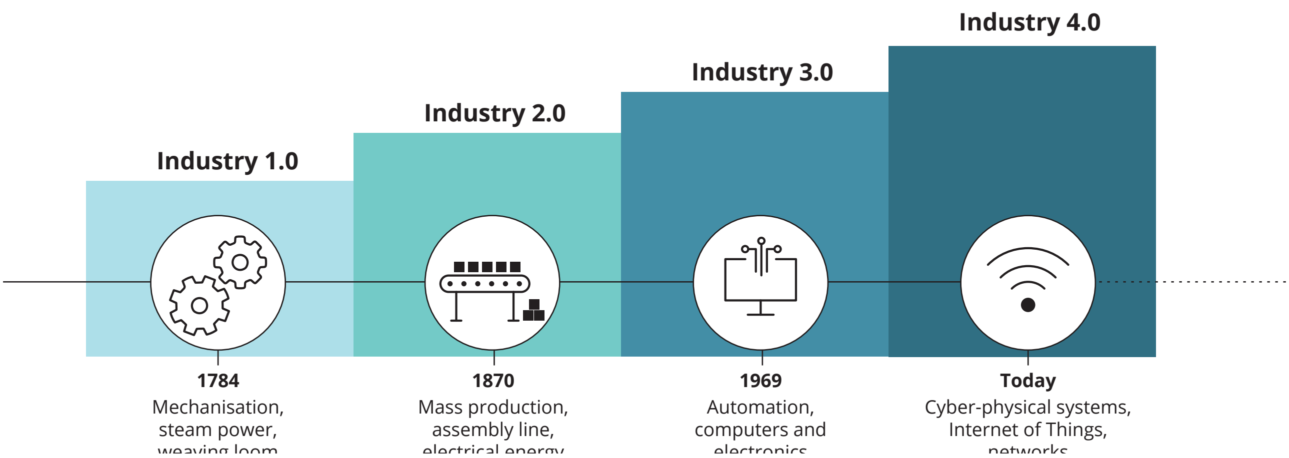
The transition towards cloud-based ICT is ongoing. In parallel with the diffusion of high-speed fibre broadband, the construction of giant data centres and improvements in data-processing technologies, **cloud computing services** registered the fastest increase in uptake of a number of ICT-related activities between 2014 and 2018 (OECD, 2019d). Declining data storage and processing costs have also facilitated the collection of large volumes of data, also referred to as 'big data'. Between 2002 and 2009, data traffic grew 56-fold compared with a corresponding 16-fold increase in computing power (Craglia et al., 2018). With data becoming a main input of innovative activities (OECD, 2018f), this has pushed the adoption of **big data analytics**, which is now performed by 12 % of businesses and one third of large businesses in OECD countries (OECD, 2019d). The need to access sufficiently large volumes of data can favour larger firms, but all organisations can acquire data from other sources (OECD, 2019d). Integrating big data analytics into businesses, however, requires the development of appropriate skills (e.g. parallel processing, visualisation) and changes in organisational practices, as well as ensuring compliance with data protection rules.

This exponential growth in the volume and variety of digital data, combined with increased processing power and improvements in algorithms, has resulted in recent developments in the field of **artificial intelligence** (AI). AI 'refers to machines or agents that are capable of observing their environment, learning, and based on the knowledge and experience gained, taking intelligent action or proposing decisions' (Craglia et al., 2018). In short, AI describes 'machines performing human-like cognitive functions' (OECD, 2019d), but the ideal still for many is to create 'machines that can "think"' (Turing, 1950). While work began in the 1950s, recent developments — and in particular major breakthroughs in the last 7 years — have boosted expectations (Craglia et al., 2018). Some claim that AI will reach human brain capacity in the next few decades (OECD and DASTI, 2016). Among these developments, **machine learning**, which consists of a statistical approach to identifying patterns in large data sets, is now the most widely used (Craglia et al., 2018). Coupled with big data analytics, cloud computing, machine-to-machine communication, robotics and the IoT (see Section 2.5.2), these developments are now strengthening the potential impact of AI (OECD, 2019d). In fact, AI applications have already entered our everyday lives in fields such as machine translation, image recognition and music generation, and this should soon be the case in medical diagnostics and connected and autonomous vehicles (Craglia et al., 2018). Globally, the EU and the United States are still responsible for the greatest shares of highly cited AI-related publications, but those shares have declined over the last decade because of increased engagement from China and other countries (OECD, 2019d). Today, the EU, the United States and China each account for about one quarter of all key AI research and industry players worldwide, and China aims to lead by 2030. Overall, AI has the potential to revolutionise **industrial production** (see Section 2.5.2), while its overall effect on global challenges related to health, energy, mobility and the environment cannot be known a priori, as much will depend on the scale of its deployment as well as the potential trade-offs it might generate. The future of AI and digitalisation is not entirely open — given that the past shapes it — and much of it will fundamentally depend on their governance (Floridi, 2019). In fact, as for other digital technologies, AI raises a number of **ethical, security and even existential issues for humanity** (see Box 2.18), apart from having uncertain implications for the environment.

For example, AI systems and the IoT combined with 'smart' capabilities, such as domestic energy management to automatically control appliances (e.g. Rehman et al., 2016) and big data analysis, could enable energy systems to transition from supplying energy to matching demand, reinforcing the growing demand for electrical energy (see Cluster 3). According to some authors, these technologies could lead to progress in the development of smart grids and more efficient networks, supporting the uptake of renewables and enhancing efficiency, resulting in a continuous joint optimisation of demand and supply in all walks of life (e.g. Roland Berger, 2018). However, such a transformation would require the interconnection of energy production (e.g. from renewables) with improved energy storage and possibly a growing amount of critical raw materials (CRMs) (see Box 2.12). Other authors (Kovacic and Giampietro, 2015) warn against the promises of smart grids, given the high uncertainty associated with the many challenges that this technology is facing (e.g. acceptance, rebound effects), as well as considering the ambiguity associated with multiple envisioned purposes (e.g. a way to change the metabolic pattern of societies and maintain current lifestyles).

Similarly, another potentially disruptive digital technology is **blockchain**, which is 'a public ledger consisting of all transactions taken place across a peer-to-peer network', allowing its participants 'to make transactions without the needed of a trusted central authority and at the same time relying on cryptography to ensure the integrity of transactions' (ENISA, 2018). Introduced in 2008 to serve as a public ledger for the cryptocurrency Bitcoin, blockchain has given rise to hundreds of cryptocurrencies (e.g. Ethereum, Ripple, NEO, Litecoin) as well as other emerging applications in many fields, such as supply chains, digital content, patents, smart contracts, governance and e-voting (EPRS, 2017b). Indeed, by 'cutting the middleman' while remaining trustworthy and secure by design, blockchain can lead to strong efficiency gains (EP, 2018) and foster more participatory, transparent and decentralised

Figure 2.19 The four industrial revolutions



Source: BMBF (2013).

governance systems (EPRS, 2017b). So far, however, the current standard process of transaction verification is extremely energy intensive, as the underlying 'mining' based on the 'proof-of-work' algorithm requires a huge amount of processing power, and therefore electricity, to run associated computer calculations (de Vries, 2018). Other emerging technological developments in **quantum computing**, which uses the property of quantum effects to boost performance exponentially, and **biocomputing**, which uses complex molecules such as DNA to perform operations, may require less energy input per operation (EPRS, 2018a).

2.5.2 Technology convergence

2.5.2.1 The Fourth Industrial Revolution?

Driven by widespread digitalisation, **technology convergence** is a key aspect of what has been called the 'Fourth Industrial Revolution' (Schwab, 2017), 'Industry 4.0' or the 'Next Production Revolution' (OECD, 2017f), which fuses **digital technologies** (such as big data analytics, AI and blockchain presented in Section 2.5.1.3) with the **physical and biological fields**. In fact, as illustrated in Figure 2.19, the distinctive character of the 'Forth Industrial Revolution' compared to the previous 'industrial revolutions' consists in the **greater integration** (or 'more seamless' connection) between the digital and physical world.

A number of recognised organisations consider that the next drivers of innovation and growth will be concentrated around a number of key emerging technologies, in particular the IoT, additive manufacturing, robotics, smart materials, biotechnologies, nanotechnologies and space technologies (EC, 2016a; OECD and DASTI, 2016; Craglia et al., 2018; OECD, 2018e). It is estimated that there are over 100 technologies that can be described as 'emerging', and their development is often dependent on one other (OECD and DASTI, 2016; Park, 2017), which makes technology convergence significant and calls for cross-disciplinary environments. This could also explain why the Fourth Industrial Revolution so far has yet to materialise. Assuming policy structures are put in place to support it, technology convergence could generally provide opportunities, such as more **efficient industrial processes and personalised production** (EC, 2016a; OECD, 2018e), and boost the currently mature and relatively sluggish economies of Europe, the United States and Japan by creating new jobs, markets and demand (Park, 2017).

One major implication of the announced industrial transformation remains unclear: **its overall impact on employment**. There is a real risk that, because of further automation, more jobs will be lost than created, and that **job losses and creations** will affect occupations, sectors and countries unequally. Projections are diverging because of diverse assumptions on the displacement effect, through which robots directly replace workers in specific tasks, and the productivity effect, which can expand labour demand, thanks to more efficient industrial processes. Much of this depends on the cumulative impact of IoT, AI, big data analytics, advanced manufacturing and robotics, which will eventually decide how much robots are able to adapt to new working environments without the need for humans to re-programme them (OECD and DASTI, 2016). Recent studies find that the displacement effect dominates in Europe: one additional robot per 1 000 workers reduces the employment rate by 0.16-0.20 % (Chiacchio et al., 2018). Globally, up to 30 % of the hours worked could be automated by 2030, depending on the speed of adoption (McKinsey & Company, 2017). Some estimations suggest that, for 14 % of workers in OECD countries, there is a high risk of their **tasks being automated** in the next 15 years, while another 32 % have a 50-70 % chance of facing significant changes in the set of tasks and skills required in their job (OECD, 2018f; Nedelkoska and Quintini, 2018). Manufacturing, transport and storage are the sectors with the highest risk of job losses, and they are also those with a traditionally high share of employment (PwC, 2018).

2.5.2.2 Key emerging applications

Among key emerging applications merging these two worlds, the IoT represents 'the next step in convergence between ICT and economies and societies on an unprecedented scale'(OECD, 2018c). With reference to 'the connection of an increasing number of devices and objects over time to the Internet', the IoT is expanding exponentially to form a ubiquitous network of sensors and actuators that report on their status and their surrounding environment or act on it (OECD, 2018c). Currently, for every person there are about five devices connected to the internet (OECD and DASTI, 2016), and it is estimated that by 2020, 8 billion people and 25 billion active 'smart' devices could be interconnected through one single information network (Marquier et al., 2016), a 'superorganism' in which the internet represents the nervous system. **Machine-to-machine communication** (M2M), a subset of the IoT, is key to unleashing the full potential of the IoT, as it allows autonomous data communication between machines, with little or no human interaction (OECD, 2015a). In June 2017, China accounted for 44 % of worldwide M2M SIM card subscriptions — three times the share of the United States (OECD, 2017d). IoT devices can be located equally in homes, workplaces, public spaces, industry or the natural world, and their applications relate to energy management (e.g. smart metering), security (e.g. infrastructure control), transport (e.g. autonomous and connected vehicles, delivery drones), agriculture (e.g. precision farming), health (e.g. human body monitoring), manufacturing (e.g. real-time logistics) and many other sectors. Obviously, many privacy and security concerns are raised by the pervasive deployment of sensors collecting data everywhere all the time (see Box 2.18).

In Europe, much of the focus is being put on modernising the industrial base with a view to achieving the EU's objective of bringing industry's contribution to the economy to 20 % of GDP. According to the European Commission, **key enabling technologies**, such as advanced manufacturing, nanotechnology, biotechnology and advanced materials, provide the basis for innovation in a range of products across all industrial sectors (EC, 2016b). Among advanced manufacturing technologies, **additive manufacturing** (also known as 3D printing) refers to the 'various processes used in the manufacture of products, by depositing or fusing materials layer by layer' (EC, 2017h), instead of subtracting them, as in traditional manufacturing. 3D printing could disrupt consumption and production patterns, particularly by strengthening the role of local production, and subsequently trade relations, by reshoring manufacturing. **Nanotechnology** refers to science and engineering areas at the nanometre scale of atoms and molecules. Manufactured nanomaterials and related devices and structures are 80 000 times smaller than the diameter of a human hair, and some desirable properties include greater reactivity, unusual electrical properties and enormous strength per unit of weight. There are promising applications in electronics, medicines and a variety of everyday products, such as food, cosmetics and personal care products (see also Cluster 2 in relation to microplastics in the food chain). Along with the excitement about the opportunities that nanomaterials might provide (e.g. nanodiamonds that can penetrate the blood-brain barrier, allowing the targeted delivery of remedies to cancerous tumours), there is also concern and significant gaps in our knowledge about what nanomaterials could do to the environment (and health) and about their safety, especially in the long term. **Biotechnology** refers, broadly, to the application of science and technology to living organisms (OECD, 2005), in particular their genomes. Biotechnology has already contributed to a broad range of existing applications, including agriculture and food, medicines, health diagnostics and treatments, and enzymes for a variety of industrial applications. Recent developments include **synthetic biology** (see Box 2.19), **bioplastics** and applications for **personalised medicine** — with approaches adjusted to the biological and genetic makeup of a single individual — which seem promising for changing diagnosis, intervention and prevention processes (NIC, 2017). Progress in biology, ICT, cognitive sciences and pharmacology could blur the boundaries between natural and **enhanced human performance**, even for very basic functions such as memory, strength, hearing and vision (NIC, 2017). New materials, such as nanomaterials, biomaterials, graphene and smart materials, are also emerging areas of technological development.

Box 2.18 Uncertainty — Ethical, privacy and security issues associated with digital technologies

Although digital technologies have the potential to foster the democratisation of innovation, information and governance in general (as they did during the Arab Spring, for example), their implications from an ethical, privacy and security perspective are significant and are causing increasing concerns within society. If data are the new oil of the 21st century, those who own the data already have a critical advantage. Today, data ownership is concentrated, with international bandwidth use shifting towards giant content providers such as Amazon, Google, Facebook and Microsoft (OECD, 2019d). However, the key issue is how data are used. Unlike oil, data will not become scarce, and their real value originates from the insights generated through analytics (WEF, 2018c). Some argue that those who own the algorithms own the future (Lanier, 2014), while others fear the insurgence of 'Surveillance Capitalism' (Zuboff, 2018). So far, the transparency of algorithms used in search engines, social networks or online marketing has been very limited, for example 'current machine learning algorithms display some of the characteristics of a black box' where we 'do not understand fully what happens in-between, and how certain outputs, including decisions and actions, are derived' (Craglia et al., 2018). Concerns are also being raised regarding issues such as illegal social media manipulation for influencing results of political elections (e.g. in Europe and the United States); the use of big data analytics for mass surveillance (e.g. WikiLeaks and control of citizens in China); and the difficulty that national institutions encounter in ensuring protection and security of sensitive data and network communications in a hyperconnected and globalised world. More insidiously, there are increasing concerns about social media driving the emergence of a 'post-truth world', in which standards of public communication (e.g. truth telling) — which modern societies have taken decades or even centuries to establish — are becoming increasingly vague and negotiable (see Cluster 6).

Overall, the implications of digital technologies need to be assessed to ensure their safe, fair and beneficial deployment for society, but they also should be understood and discussed by all, not only a handful of experts with the best available knowledge. Today, ordinary citizens and policymakers find it difficult to keep up with these developments and what they mean for daily life as well as the future of humankind (Kiiski Kataja, 2016; OECD, 2018f). Literacy, education and public engagement are needed to shift the debate from a utilitarian view of 'what can AI and digital technologies do?' to an ethical perspective on 'what should AI and digital technologies do?', perhaps in view of developing a global treaty on digital ethics (Leonhard, 2016).

Box 2.19 Uncertainty — Challenges associated with synthetic biology

Within the broader field of biotechnology, synthetic biology refers to an interdisciplinary area that consists of 'the application of science, technology and engineering to facilitate and accelerate the design, manufacture and/or modification of genetic materials in living organisms' (SCENIHR et al., 2015a, 2015b). Different from earlier molecular biology and genetic engineering techniques, synthetic biology involves the assembly of entirely new sequences of DNA and entire genomes, not only the transfer of individual genes. Some of its proponents consider it an attempt to 'design life according to humanity's need' (Engelhard, 2016), which will have major impacts on society, the economy and the environment. So far, it remains an emerging field, although related technologies are already applied in the pharmaceutical, chemical, agricultural and energy sectors. Noticeable applications include the engineering of yeast or microalgae to produce pharmaceuticals, biofuels or flavourings as alternatives to naturally occurring or petroleum-based molecules. From an environmental perspective, developers stress its potential to reduce the impact of human land use on biodiversity (e.g. through genetically modified crops, which allow a reduction in pesticide use), to facilitate the bioremediation of polluted industrial sites (e.g. through the use of synthetically engineered microbes, which can degrade persistent chemicals) and to detect pollution (e.g. through biodetectors sensing the presence of micro-pollutants) among other things (Science for Environment Policy, 2016).

However, synthetic biology also carries a new kind of risk to the environment, characterised by high unpredictability and potential irreversibility. Indeed, as it has become increasingly cheap and quick to edit genes, thanks to gene drives (such as CRISPR/Cas9 ([9])), new applications are being developed to shape and transform nature at a large scale, for example in view of the desire to eradicate malaria-carrying mosquitoes. Designed to operate autonomously in nature and spread the modified DNA among entire populations, gene drives have 'the potential to overcome the natural pattern of heredity' (Liebert et al., 2017). Some scientists have warned that such technologies represent 'a new stage and depth of the power and intervention into ecosystems', potentially driving these ecosystems beyond their tipping points in irreversible ways (Liebert et al., 2017). Such applications of synthetic biology raise the following concerns: How will genetically engineered mosquitoes affect the rest of the ecosystem? Is it possible for the gene drive to mutate and affect other species? Will we be able to recognise, monitor and control modified organisms after their release into the environment? How do we decide if the application is safe to use or even to test? How do we factor in inevitable human errors and ignorance? (Redford et al., 2019; Liebert et al., 2017; Science for Environment Policy, 2016).

Note: Based on 'EEA/Eionet FLIS *Brief on emerging trends — synthetic biology and the environment*'.

([9]) CRISPR, clustered regularly-interspaced short palindromic repeats; Cas9, CRISPR-associated protein 9.

The evolution of production and consumption systems and sustainability outcomes is inherently unpredictable and deeply uncertain, with technologies being just one factor among many, whereas cause-and-effect interactions cannot be traced in linear or isolated causal trajectories (Preiser et al., 2018). Therefore, the extent to which emerging technologies — and which of these in particular — will contribute to easing or worsening environmental and sustainability challenges cannot be known a priori. Much will depend on the ability to anticipate and govern potential risks as well as benefits. The precautionary principle, responsible research and innovation, adaptive governance, and foresight and horizon scanning represent important tools, in the hands of public authorities, for achieving this goal (see EEA, 2013, 2019c).

2.5.2.3 'Sustainability'-driven technologies

A number of technological developments are driven by **innovation policies** (e.g. Horizon Europe in the EU) aiming to address directly societal challenges, such as environmental protection, climate change mitigation and adaptation, and other sustainability considerations. When considered together with more traditional competitiveness and growth objectives, 'green technologies' that are potentially beneficial to the advancement of sustainability have increasingly become the focus of policymakers, particularly in the EU but also in China. Many developments relate to the transformation of the energy, mobility and food systems, and are aimed generally at achieving a more circular, bio-based, climate-neutral and non-toxic economy.

The decarbonisation of energy systems pushes for innovation in **renewable energy technologies** (e.g. wind, solar, bioenergy, hydrogen) and **carbon capture and storage** (CCS). Because of the intermittence of renewable energy sources, innovation is also directed at **smart grids** and **smart meters and batteries** with a view to deploying smart and decentralised energy systems. In the EU, the share of renewable energy in 2016 (17.0 %) was almost twice as high as that in 2005 (9.0 %) (EEA, 2018c). Similarly, the decarbonisation of mobility systems stimulates innovation in electric vehicles, hydrogen technology (in particular in Japan) and connected and autonomous vehicles. Although electric vehicles constituted only around 1.5 % of all new car registrations in the EU-28 in 2017 (EEA, 2018a), adoption is on the rise, with an increase in registrations of battery electric vehicles of 51 % in 2017 (EEA, 2018b). In combination with space-based technologies (for remote sensing, geo-mapping and positioning) and the automated steering system of machinery (for tractors, etc.), the IoT is expected to boost developments in **precision farming** (CEMA, 2018b), with the ambition of producing more food on less land with less input (CEMA, 2018a). **Artificial meat** is also associated with the ambition of reducing environmental burdens, particularly concerning climate change; however, its implications are ambiguous (see Box 2.20).

However, the overall effect of the upscaling of many of these new technologies developed to 'solve' sustainability problems as well as for many key emerging applications (Section 2.5.2.2) is often uncertain and ambiguous, as trade-offs and unexpected consequences may often manifest. As indicated in Section 2.5.1.1, the uptake of technological development or 'niches' is not the result of a linear process; on the contrary, the diffusion of certain technologies tends to follow near exponential growth pathways. Because of such non-linear dynamics and the interconnectedness between social, technological and ecological systems, technological 'solutions' (e.g. biofuels) to a problem (e.g. GHG emissions) may lead to **new challenges** (e.g. indirect land use change, loss of biodiversity and increased competition for land). Many of these technologies place a new demand on resources, especially scarce CRMs (see Box 2.12), which may exacerbate geopolitical tensions (Clusters 3 and 5), apart from potentially representing a barrier to their adoption. Similarly, marginal efficiency gains in established technologies may lead to increased resource demand or emissions, contrary to initial expectations (see Box 2.21). As for digital technologies and emerging technological applications, the governance of sustainability-driven technologies should ensure that risks and unintended consequences stemming from their up-scaling would not offset benefits and opportunities. Approaches like the **'precautionary principle'** and frameworks such as **'responsible research and innovation'**, with the latter being also implemented in the EU Horizon 2020 scheme, could be useful to guide further research and innovation, ensure societal participation and deliberation on ethical and other sustainability aspects and properly inform regulatory measures.

2.5.3 Changing landscape of technological innovation

2.5.3.1 The emergence of China as a technological power

The global landscape of technological innovation is evolving. Economic growth in developing regions (Cluster 5), together with rising education levels enhancing human capital and boosting innovation activities (Samir et al., 2010), is creating new centres of research, innovation and development (EEA, 2015d). Today, developed and developing economies of all types promote innovation to achieve economic and

Box 2.20 Uncertainty — Artificial meat: an uncertain potential for climate change mitigation and healthy diets

A strong growth in animal-based food consumption at the global level is expected in the next few decades because of the rise a global middle class with changing eating habits, especially in Asia. Overall, global demand for meat and dairy products is expected to grow by 73 % and 58 %, respectively, by 2050, compared with 2010 levels (FAO, 2011). As livestock farming is responsible for a significant share of environmental pressures and greenhouse gas (GHG) emissions, these projections are worrying. In particular, livestock supply chains are estimated to be responsible for 14.5 % of all anthropogenic GHG emissions, according to the United Nations Food and Agriculture Organization's global life cycle approach (Gerber et al., 2013). Responses to mitigate these environmental pressures include incremental improvements in livestock production efficiency and manure management practices, but some stakeholders have started thinking beyond the 'livestock farming box'. One idea is to propose to consumers a food product that is not traditional meat but that has a similar nutrient value and taste. Artificial meat, which refers to meat cultivated *in vitro* from stem cells of living animals, is presented by its developers as a novel and more environmentally friendly alternative to livestock breeding.

One particular study — the results of which have been cited extensively — has been particularly key to mainstreaming this perspective (Mattick et al., 2015). Published in 2011, an anticipatory life cycle analysis shows that, 'in comparison to conventionally produced European meat, cultured meat involves approximately 7-45 % lower energy use (only poultry has a lower energy use), 78-96 % lower GHG emissions, 99 % lower land use, and 82-96 % lower water use depending on the product compared' (Tuomisto and Teixeira de Mattos, 2011). However, these results remain subject to huge uncertainty, as the assumptions on this emerging technology, its associated production processes and related systemic effects are highly speculative. Other studies show that artificial meat production could lead to more global warming than cattle production if energy for *in vitro* production systems is still generated by fossil fuels (Lynch and Pierrehumbert, 2019). As for many technologies, much of the reduction in its climate impact depends on the use of renewable energy sources. Environmental policymakers should be involved in technological development processes related to artificial meat, to ensure that future production processes are sustainable. This includes the need for more systemic assessments of this technology, based on life cycle analysis and monitoring as to mitigate unintended environmental consequences.

At the same time, concerns have been raised on potential risks for health associated with artificial meat consumption, potentially stemming from hormones and endocrine disruptors migrating into food from in vitro cultivation (Muraille, 2019), however, at the moment there is virtually no evidence about the effects of artificial meat consumption.

Note: Based on 'FLIS *Brief on emerging trends — Artificial meat and the environment*'.

social development (Cornell University et al., 2019). Many governments from non-OECD countries have set the objective of boosting national R&D investment (e.g. Government of India, 2013; Brazil; China). Considering the population size of some of these players, this is expected to be highly impactful in the mid- to long term. In India for example, there are almost 600 000 tertiary ICT graduates a year, about five times as many as in the United States (OECD, 2019d). So far, however, the shift in the global R&D landscape has mainly been influenced by China.

China unambiguously wants to become a world leader in science and technology by 2050 (China State Council, 2015). China overtook the EU in R&D intensity ([10]) in 2013 (see Figure 2.21) and already features among the top countries regarding emerging ICT patents (OECD, 2017d). It spent about USD 496 billion ([11]) (2.1 % of GDP) on R&D in 2017, which is only 10 % less than the United States but 15 % more than all EU countries together (OECD, 2019b). China has become the second largest scientific powerhouse after the United States, as measured by its share of the top 10 % most-cited publications (OECD, 2017e). According to the Global Innovation Index 2019, China has already established itself in the group of leading innovative nations by entering the top 15 in 2019 (Cornell University et al., 2019). According to the JRC, Chinese firms are also expanding their knowledge base through the acquisition of foreign companies (Preziosi et al., 2019).

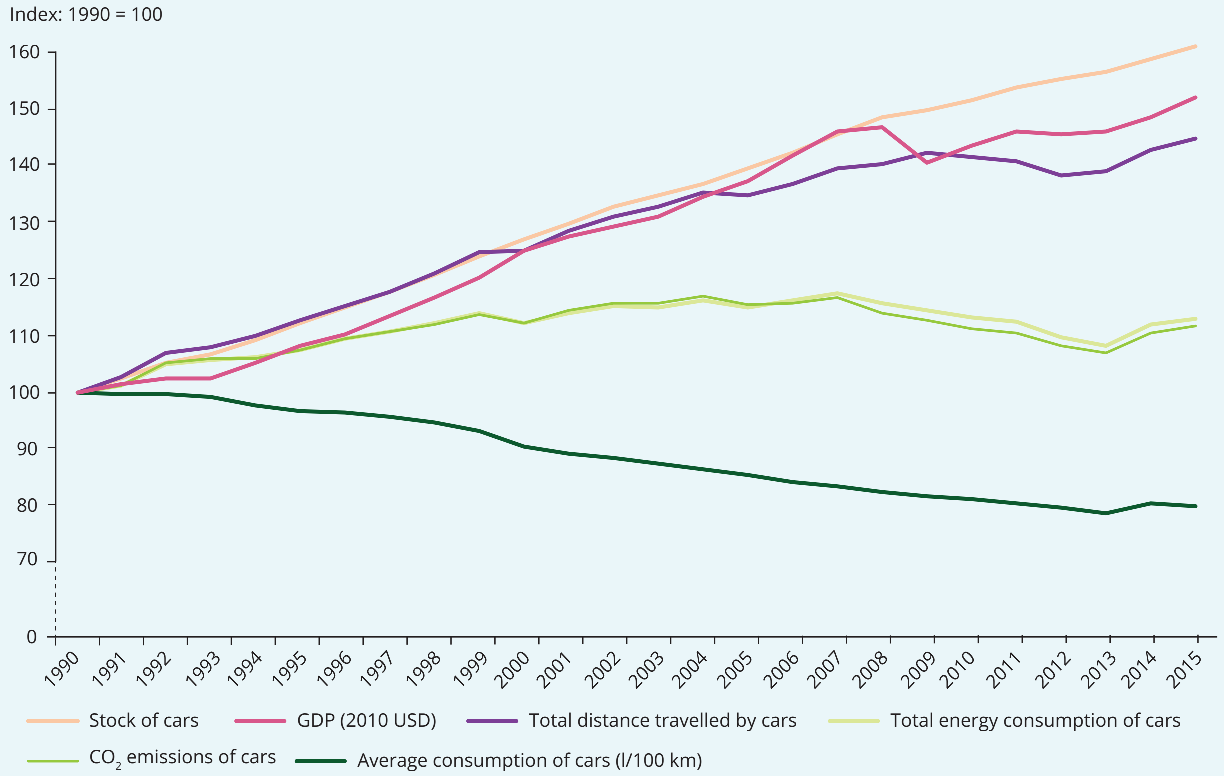
While R&D investments in China and other non-OECD countries are expanding, Europe is experiencing a stagnation in R&D intensity, which only slightly increased in 2017 to reach 1.97 % of GDP (OECD, 2019b). This remains very far from the target set by the European Commission to invest 3 % of the EU's GDP in R&D by 2020 (EC, 2010). As of today, only four EU countries (Austria, Denmark, Germany and Sweden) exceed this threshold (OECD, 2019b). More

([10]) Percentage of R&D spending as a percentage of GDP.
([11]) 2010 USD, constant prices and purchasing power parity (PPP).

Box 2.21 Uncertainty — Technological innovation and the limited contribution of efficiency gains

Technology-driven gains in efficiency introduced by sustainability-driven technologies may be undermined by lifestyle changes and increased consumption and production, partly because improvements in efficiency tend to make a product or service cheaper and thus lead to increased production and consumption. This phenomenon, known as 'Jevons' paradox' — first identified by Jevons (1866), who observed how efficiency gains in coal extraction technologies led to growing coal extraction — has now been observed among numerous technologies, resources and pollutants. This phenomenon is also known as the 'rebound effect'. Examples of this challenge can be found across the food, energy and mobility systems. For example, increased water savings in agriculture have been associated with an expansion of irrigated areas, a shift towards more intensive and higher value crops and more frequent irrigation events (Font Vivanco et al., 2018). The benefits associated with improvements in energy efficiency in buildings (e.g. thermal insulation, efficient boilers and lighting) are often offset at the macro-economic scale by the resulting savings being spent elsewhere in the economy (Font Vivanco et al., 2018). Moreover, interlinkages between resource-specific rebound effects are known to exist (e.g. energy and material), but are less understood as often assessed in isolation (Font Vivanco et al., 2018).

Figure 2.20 Fuel efficiency and fuel consumption in private cars, 1990-2015

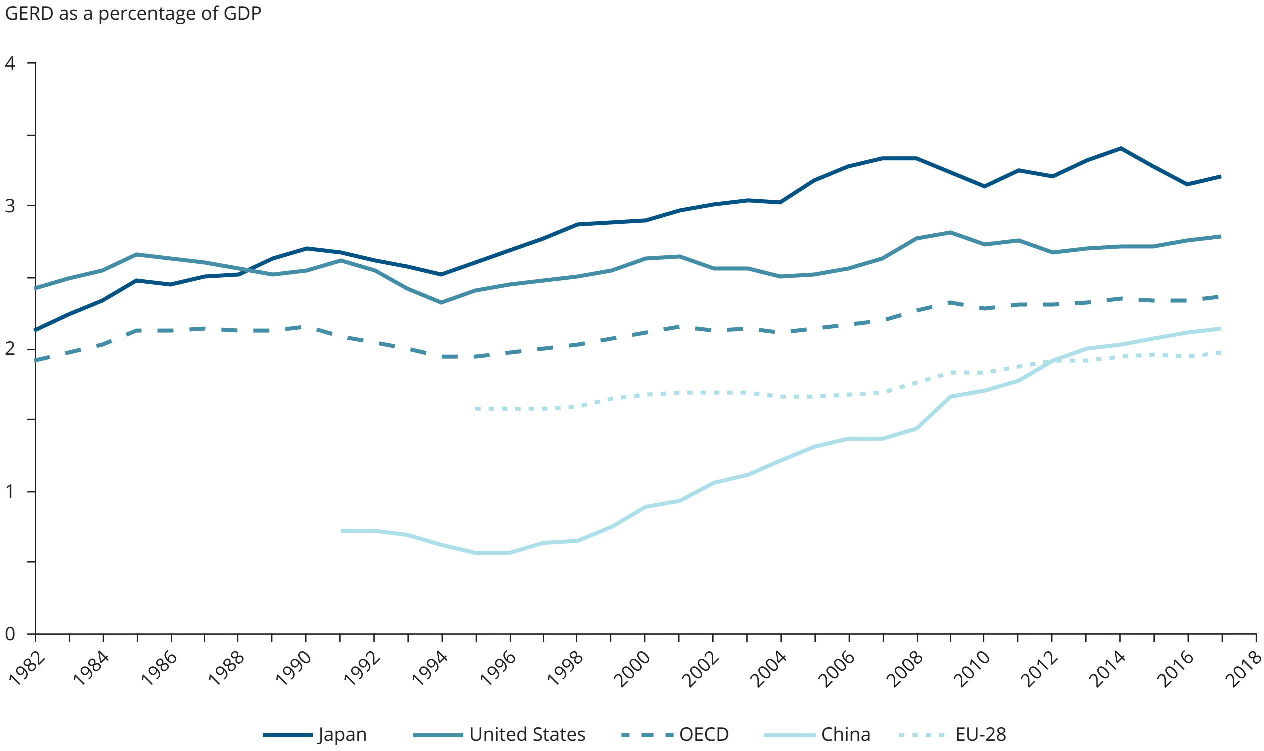


Sources: Enerdata (2019); World Bank (2019a).

For example, improvements in fuel efficiency in cars have not led to a reduction in fuel consumption or greenhouse gas emissions because of increased car ownership and the distances driven (Figure 2.20). Similarly, the environmental benefits of replacing car journeys with cycling or reducing food waste will depend in part on whether consumers use the money saved to increase their consumption of other goods or services. In addition to highlighting challenges for governance, these examples highlight the importance of focusing on transforming whole socio-technical systems, rather than seeking to alter specific aspects of production or consumption, such as efficiency improvements in this case. This suggests that sustainability challenges cannot be solved by pure technological innovation: a change in behaviour as well as overall consumption levels is needed to reduce environmental burdens.

Sources: Adapted from EEA (2019e).

Figure 2.21 R&D intensity in OECD countries and other economies



Note: GERD, Gross Domestic Expenditure on Research and Development.

Source: OECD Main Science and Technology Indicators (2019c), https://stats.oecd.org/Index.aspx?DataSetCode=MSTI_PUB#.

fundamentally, a long-lasting issue of concern for Europe remains the gap between the basic discovery research and the actual commercialisation of new products and services, known as the **'Valley of Death'**, as many innovations never succeed commercially (Jucevicius et al., 2016; EC, 2018b). Furthermore, although EU institutions consider key enabling technologies ([12]) to be central to modernising Europe's industrial base and driving the development of new industries (EC, 2009, 2016b), the majority of the EU manufacturing firms are today failing to use advanced manufacturing technologies (EC, 2017a).

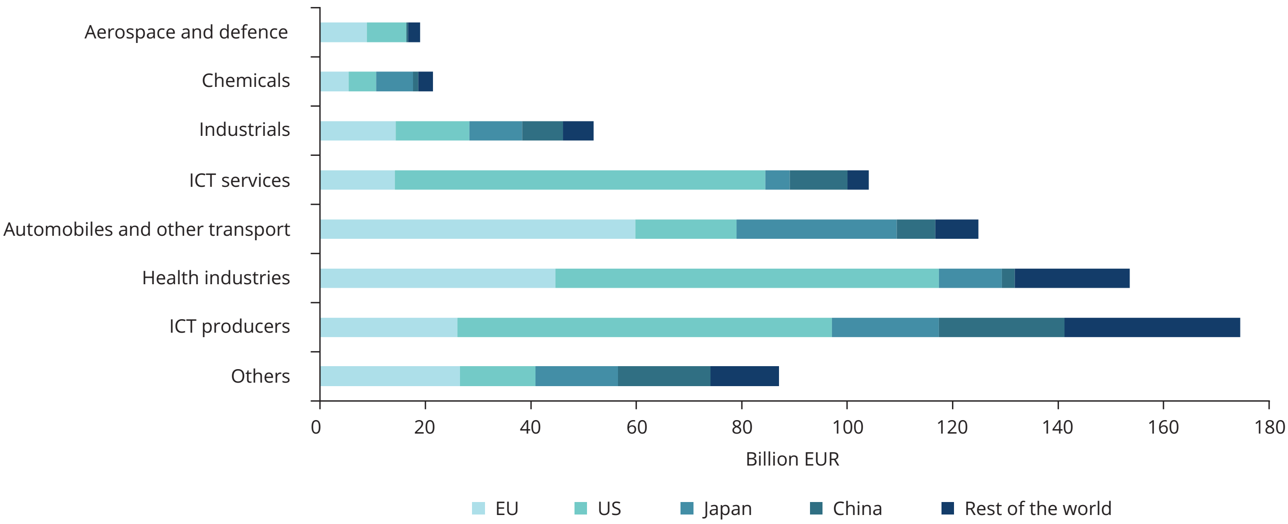
2.5.3.2 High concentration of technological innovation

R&D is highly concentrated, as a small number of countries, companies and sectors account for a large share of the total R&D investment. According to the 2018 EU Industrial R&D Investment Scoreboard (Hernandez Guevara et al., 2018), out of the 2 500 companies investing over EUR 25 million in R&D across the world in 2017/18, which overall account for 90 % of the world's business-funded R&D, 88 % are based in four main regions: the United States (37 %), the EU (27 %), Japan (14 %) and China (10 %). Furthermore, the top 100 R&D investing companies account for more than half of the total R&D investments, and the four largest R&D investing sectors (ICT producers, health industries, automobiles and other transport, and ICT services) account for more than three quarters (Hernandez Guevara et al., 2018).

Considering the distribution of patents worldwide leads to similar conclusions while highlighting the dynamism of Chinese R&D. In 2017, five intellectual property (IP) offices dealt with almost 85 % of patent applications worldwide (WIPO, 2019). China's IP office received 43 % of them, followed by IP offices in the United States (19 %), Japan (10 %), South Korea (6 %) and the EU (5 %). From a firm perspective, the top 250 R&D investors account for 67 % of patents, 57 % of designs and 41 % of trademarks of all IP rights owned by the top 2 000 R&D investors (Daiko et al., 2017). Overall, this represents **a significant concentration**

([12]) Micro- and nanoelectronics, nanotechnology, industrial biotechnology, advanced materials, photonics, and advanced manufacturing technologies (as prioritised by the European Commission in 2009).

Figure 2.22 R&D investment by industry and region



Notes: R&D investments relate to the 2 500 companies investing over EUR 25 million in R&D across the world in 2017/18, as per the methodology defined in the 2018 edition of the EU Industrial R&D Investment Scoreboard (Hernandez Guevara et al., 2018).

Source: The 2018 EU Industrial R&D Investment Scoreboard (Hernandez Guevara et al., 2018).

of power related to technology development, with implications for how it may influence global social and economic development (Clusters 5 and 6).

2.5.3.3 Regional differentiation in R&D specialisations

From a sectoral perspective, the R&D specialisations of these main regions are also evolving. Worldwide R&D growth in 2017/18 was driven by the ICT sector (both services and producers), followed by the health sector, but there are increasingly marked differences between regions (Hernandez Guevara et al., 2018). In a nutshell, US and Chinese companies have increased their share of the global ICT service sector while the EU's share has declined, whereas EU companies' share of the automotive sector has increased while the United States' share has decreased (Hernandez Guevara et al., 2018). Although the United States and China dedicate 51 % and 48 %, respectively, of their R&D to ICT, the EU only reaches 20 %, and its largest software firm ranks only 27th (Hernandez Guevara et al., 2018) (Figure 2.22).

Europe is lagging behind the United States and China in ICT-related innovation. Over the period 2013-2016, China, Japan, South Korea, Taiwan and the United States were responsible for developing between 70 % and 100 % of the top 25 cutting-edge digital technologies, whereas only a few EU countries (France, Germany, Sweden) featured among the top five players in a few emerging digital technologies (OECD, 2019d). Today, the ICT giants are American (e.g. Google, Apple, Facebook, Amazon, Microsoft) or Chinese (e.g. Alibaba, Baidu, Tencent, Xiaomi), rarely European. This worrying picture for European competitiveness in the field of high-tech ICT-related innovation is only reinforced when looking at cutting-edge hardware developments, such as quantum computing, the United States and China are 'competing neck and neck', with the EU falling behind (EPRS, 2017a). The EC is currently focusing on closing this gap with the implementation of the European Digital Strategy (EC, 2020b) and the new industrial strategy for Europe (EC, 2020a), which together take 'an ambitious approach toward digital technological development, as well as toward the ways in which technology will be used to meet climate-neutrality objectives' (White & Case, 2020).

2.6 Cluster 5 — Power shifts in the global economy and geopolitical landscape

Key messages (cont.)

Global changes in economic power

- Global economic output increased about 12-fold during the period 1950-2016 (Bolt et al., 2018), leading to increase in wellbeing for a large share of the global population, but also increasing environmental pressures (Cluster 2) and demand for resources (Cluster 3). Since the 1990s, much of this global growth has been driven by emerging economies, such as Brazil, China and India, reflecting a shift in economic power from mature economies to emerging ones. For example, China's gross domestic product (GDP) surpassed US GDP in 2013 (OECD, 2018b), while the growth rate registered between 1990 and 2017 by the Chinese economy was five time higher than EU's economic growth.

- One key factor behind the rebalancing of global economic output has been trade liberalisation that, together with technological development (Cluster 4), globalisation of supply chains and cheap labour, has led to the rapid emergence of China and other Asian countries as the new 'workshop of the world' (WTO, 2018a). While continued globalisation of trade was observed for the last decade, its future prospects are now unclear due to growing international tensions on tariffs and trade agreements.

- International trade has contributed substantially to global economic growth but also to growing global environmental pressures and resource consumption. In particular, the rebalancing of economic activity worldwide has led to the externalisation of significant shares of environmental pressures from richer economies to emerging economies. While offering economic opportunities, this trend hindered health and natural capital protection in most vulnerable countries (Clusters 2 and 3). In Europe, a significant part of the environmental pressures associated with consumption is externalized to other parts of the world. This figure ranged from 31 % (energy use) to 61 % (land use) in 2011, while recent estimates indicate slightly less than one-third of the carbon footprint associated to consumption in the EU is occurring outside the EU borders (Wood et al., 2019).

- The 'financialisation' of the economy and growing international debt are associated with systemic risks which can materialise in the form of international contagion effects that spread across institutions and markets, and ultimately to the real economy. Despite corrective measures have been taken after the 2008 financial crises the international financial system remains a source of concern for future economic development, as global debt continues to grow. 'Financialisation' has direct implications for public finances and inequality (Cluster 6).

Contrasting fortunes in the global economy

- At the global scale, rapid economic growth in developing regions has lifted millions of people out of poverty in recent decades, by generating revenues for households and allowing governments to invest in social infrastructure and services (e.g. education, health and social security). Nevertheless, extreme poverty still exists; for example in 2018, 6.2 million children died before reaching the age of 14 years, which is equivalent to more than the population of Denmark (World Bank, 2019b).

- Emerging economies have also been the main driver of a fast-growing global middle class, which reached 3.2 billion people in 2016 (Kharas, 2017), while in most of the EU countries the middle class has contracted, as a result of the 2008 financial crisis and structural labour market changes (ILO, 2016). The stark contrast between GDP per capita figures in emerging and mature economies suggests that, if the speed of structural convergence between economies is high, the gap itself will remain substantial for a long time.

- Inequalities within countries have been rising in Europe and emerging economies (OECD, 2015b). While the prospects for the global middle class are highly uncertain, some studies suggest that their share of global wealth might decline in the coming decades, whereas the wealth of the top 1 % of the global population, which captured 27 % of total income growth during the period 1980-2016, might increase further (WIL, 2017). As a consequence of that, there is a risk that the younger people in Europe today could be less well off than their parents, with unemployment among young people (under 25 years), at 18 % in 2017, being markedly higher than the overall unemployment rate (8 %) (EC, 2017j).

Key messages (cont.)

Geopolitical power shifts, tensions and uncertainties

- Geopolitical uncertainties and tensions in the global multilateral system are increasing (ESPAS, 2015). This is seen in a waning of the consensus on the benefits of globalisation and trade liberalisation, resulting in countries turning away from multilateral agreements and increasing protectionist measures (EPSC, 2018b). For Europe, where exports represented more than 50 % of GDP in 2018, this is of great concern (EPSC, 2018b). As access to strategic resources (e.g. energy carriers and materials) (Cluster 3) is fundamental to sustaining competitive economies, many of the future geopolitical challenges are expected to revolve around trade agreements, access to raw materials and international markets.

- The United States remains the world's dominant power because of its economic and, above all, military and technological primacy. However, US dominance is not hegemonic, and a number of contesting powers are rising, and geopolitical power is increasingly defined outside the traditional battlefields. As economic power shifts, emerging countries and regions may also seek to increasingly translate their economic gains into global influence.

- Warfare has also become more asymmetric through the use of 'hybrid warfare' tactics directly targeting governments and populations. A hyperconnected world, increasingly relying on smart infrastructure (Cluster 4), is indeed more vulnerable to massive cyberattacks that can disrupt energy provision, business activities and electoral processes alike. Cybersecurity specialists refer to government-sponsored cyberattacks as advanced persistent threats.

- Non-state actors, such as non-governmental organisations and multinational firms, are increasingly challenging traditional power relations (Ruggie, 2018). The power of transnational companies has risen significantly, compared with the power of governments. It has reached a point at which around 10 % of the world's corporations generate 80 % of all profits globally, with a handful of companies controlling, for example, nearly 90 % of the information technology sector (Folke et al., 2019). Such concentration of power increases their influence in shaping social and environmental standards and norms, influences public discourse and policymaking and limits the ability of governments to respond through national regulations. This asymmetry of power also characterise scientific research and knowledge.

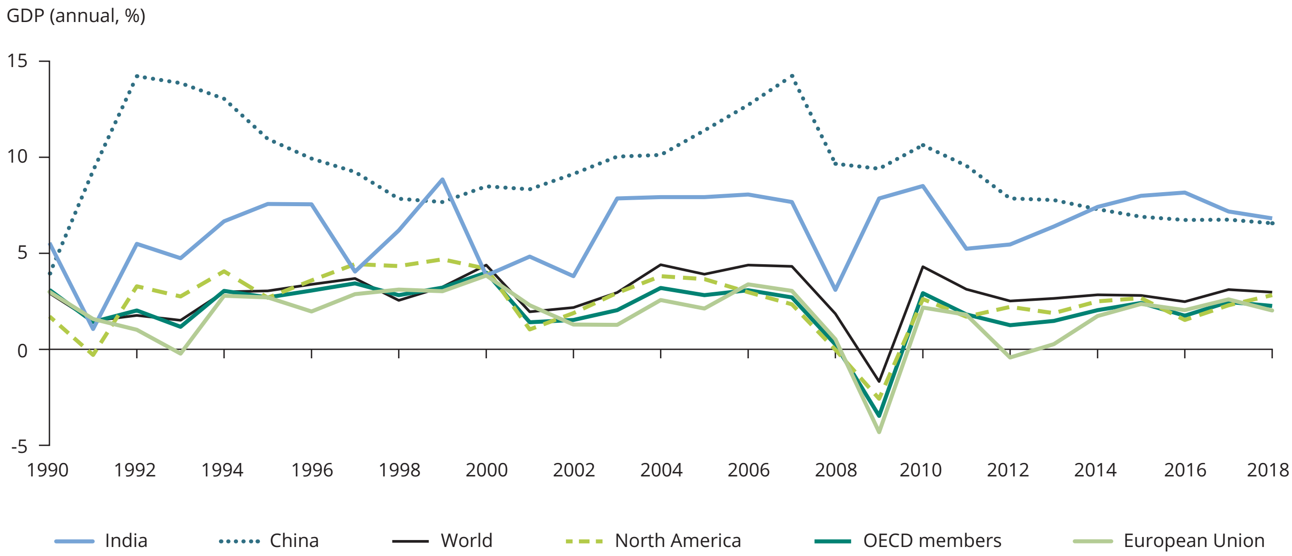
2.6.1 Global changes in economic power

2.6.1.1 Continued but uneven global economic growth shifting towards the South and the East

Rapid economic growth has been a key feature since the 1950s, with global economic output increasing about 12-fold during the period 1950-2016 (Bolt et al., 2018). Since the 1990s, much of this global growth has been driven by a strong expansion of emerging economies, in particular very large countries such as Brazil, China and India, reflecting a **shift in economic power towards the East and the South**. China's economy grew on average 9.5 % annually between 1990 and 2017, compared with 1.7 % in the euro area (World Bank, 2018). Measured in purchasing power parity (PPP), which corrects for price differences between countries, China's GDP surpassed the United States' GDP in 2013 (OECD, 2018b). In terms of nominal GDP (i.e. prices at market exchange rates), some projections suggest that China could be the largest world economy before 2030 (PwC, 2017). In its early stage, the rebalancing of global growth has, in a large way, reflected developing economies' ability to import knowledge, practices and technologies, rather than going through the slower process of developing them domestically (EEA, 2015d). More recently China emerged as a global technological power and overcome the EU concerning research and development investment rates (see section 2.5.3.1). With relatively abundant natural resources and working-age populations, their economic transition has been much faster than the economic transition that was seen in now developed countries in the 19th and 20th centuries.

The years following the financial crisis of 2008 saw economies in developed and developing regions experience a recession or slowed growth; however, the resilience and continued higher growth in developing economies compared with **relative stagnation in developed economies**, including Europe, have

Figure 2.23 Gross domestic product (GDP) growth



Source: World Bank (2020b), https://data.worldbank.org/indicator/NY.GDP.MKTP.KD.ZG.

rapidly advanced a global rebalancing of economic production across the world (EEA, 2015d). As shown in Figure 2.23, the rate of growth in China and India has been consistently between 5 % and 10 %, which is considerably higher than in Europe or North America (World Bank, 2020a). In the short term, this clear difference in growth rates between developed and developing economies is likely to continue (World Bank, 2020a). Even if China's economic growth falls slightly, South Asia and notably India, together with sub-Saharan Africa, are expected to see faster growth (World Bank, 2018). In contrast, despite efforts to foster stronger economic growth, Europe and other developed economies are faced with several constraints: shrinking workforces (see Cluster 1), diminishing productivity gains (below 1 % per annum since the turn of the century; EPRS, 2018a), high debt levels, weak demand, political uncertainty (such as Brexit for the EU) and doubts about globalisation (NIC, 2017).

According to the OECD (OECD, 2019a), in the longer term developing economies are expected to become increasingly important economically if current trends continue further. They could account for half of global economic output by 2030, with shares potentially increasing further to around 70 % by 2050. It is likely that **by 2030 China alone may have the largest economy**, surpassing the United States. India's GDP is expected to surpass the size of the euro area's GDP sometime in the early 2020s, and by 2050 its total GDP will be double that of the euro area (OECD, 2019a). In contrast, the EU's share of the global economy (in PPP terms) could be halved between 2000 and 2050, dropping from 28 % to 14 % (OECD, 2019a). Overall, these GDP considerations are key from a geopolitical perspective, since, when associated with population size, military spending and technological investments, they emphasise how Asia could surpass North America and Europe combined in terms of global power.

However, when looking at **GDP per capita**, it is expected that China will remain just below 50 % of the EU value until 2035, suggesting that if the speed of structural convergence between economies is high, the gap itself will remain substantial for a long time (EPRS, 2018a). This also opens up a broader discussion on growth versus progress — in view of the social (e.g. inequalities) and environmental (e.g. pollution, CO_2 emissions) harm that can accompany economic growth — and the limitations of GDP as a measure of human well-being. For example, different conceptualisations of the economy have been proposed, including the circular economy, the sharing economy, green growth (UNEP, 2011), 'doughnut' economics (Raworth, 2013) and 'beyond GDP' approaches, as well as the UN's SDGs, and have found some traction among policymakers (EC, 2019b). However, more fundamental challenges to the economic orthodoxy, such as degrowth (D'Alisa et al., 2014) and the steady-state economy (Daly, 1991), did not raise the same interest within policy circles.

Despite the existence of multiple attempts to make mid- to long-term projections concerning global economic growth, future developments cannot be projected with any accuracy, as economic development is fundamentally uncertain and dependent on many other factors. In fact, economic growth depends on a number of factors, such as population growth (Cluster 1), technological development (Cluster 4), the availability of resources (Cluster 3), geopolitical shifts (Cluster 6), international agreements (e.g. trade agreements), and fiscal and financial policies. Moreover, in the future environmental challenges, such as climate change and loss of biodiversity, natural capital and ecosystem services (Cluster 2), could increasingly affect the ability of human societies to meet their needs, especially if ecological tipping points are surpassed (see Section 2.3.2.3) or in the case of increased competition for strategic resources. In this case, the effects on the economic system could be so profound that its meaning and our understanding of it could change dramatically.

2.6.1.2 Structural change of the global economy

One key factor behind the rebalancing of global economic output has been **trade liberalisation**, together with technological development (Cluster 4). Access to export markets has been facilitated by very limited tariffs and significant reductions in the costs of engaging in international trade as a result of digitalisation (OECD, 2019d). This has changed both how and what is traded (González and Jouanjean, 2017) and has promoted **structural economic change**, as national production is no longer limited by domestic demand. In developing countries, benefiting from a competitive advantage as a result of a cheaper workforce has often meant increasing labour-intensive manufacturing. Together with access to integrated global production networks, this has led to the rapid emergence of China and other Asian countries as the new 'workshop of the world' (WTO, 2018a). Asia is already the world's largest trading region and has the highest continuous rate of growth in trade (WTO, 2018a). 'South-south' flows between emerging markets doubled their share of global trade during the decade 2005-2015 (McKinsey & Company, 2015).

Overall, international trade has increased environmental pressure globally (Wood et al., 2018), and Europe has also significantly contributed to this (see Box 2.22). There is, however, **uncertainty in trade outlooks**, as policy choices and economic conditions influence trade, with the slowdown in trade growth in 2018 (WTO, 2018b) connected to growing trade tensions globally (notably between the United States and its trading partners). For many, 'it is doubtful that world trade can sustain past trend annual growth rate of as much as 6-7 % in volume and 10 % in value terms' (EPRS, 2018a) around twice the typical GDP growth, as those rates can be largely explained by the rapid and unique increase in exports of manufactured goods from China. China's slowdown in investment and ongoing transition from export-led to consumption-led growth might confirm in coming years the recent downturn in global trade growth (IMF, 2016). Other factors will also need to be considered in the future, such as trade goods maturing and the shift to services (EPRS, 2018a). Indeed, the maturing of global supply chains, the increasing significance of customisation and on-demand business, technological developments such as 3D printing and automation (see Cluster 4), more stringent climate change mitigation policies, and the growth of the US shale and gas sector may all foster reshoring or less demand for offshore manufacturing (EPRS, 2018a). Besides, 'advanced economies are moving towards services as the main source of economic value', which could curb their demand for imports (EPRS, 2018a).

Despite the uncertainty, outlooks suggest that the changes in global economic power will be mirrored in trade patterns, for example one outlook expects exports from non-OECD economies to rise from 35 % of world exports in 2012 to 56 % by 2060 (NIC, 2017). By 2030, developing countries could be contributing to two thirds of global growth and half of global output, and could be the main destinations of world trade (OECD and DASTI, 2016). The rising middle class of developing countries will indeed demand imported goods (EPRS, 2018a). Another important driver of the shift in global economic power is **foreign direct investment** (FDI), which refers to investment in businesses, facilities, production capacity, etc., in one country by an entity from another. Short-term FDI trends are influenced by fiscal policy decisions. However, looking at global FDI trends, there are indications that global economic power is shifting, for example in 2016 China became a net outward direct investor for the first time, following a trend of increasing FDI outflows since 2005 (indicating that China had been increasingly investing in foreign countries) (OECD, 2018a).

At the same time, **non-state actors** are increasingly challenging traditional power relations (Ruggie, 2018). Multinational firms, non-governmental organisations, sovereign wealth funds, major cities, academic institutions, think tanks and foundations endowed with global reach are playing increasingly influential roles. In some cases, they may even prove instrumental in creating new alliances and coalitions that have wide public support to tackle some of the global challenges facing the planet, such as poverty and environment and security issues (NIC, 2017). However, **the power of transnational companies** has risen significantly, compared with the power of governments, and has reached a point at which around 10 % of the world's corporations generate 80 % of all profits globally, as reported by Folke et al. (2019), with a handful of

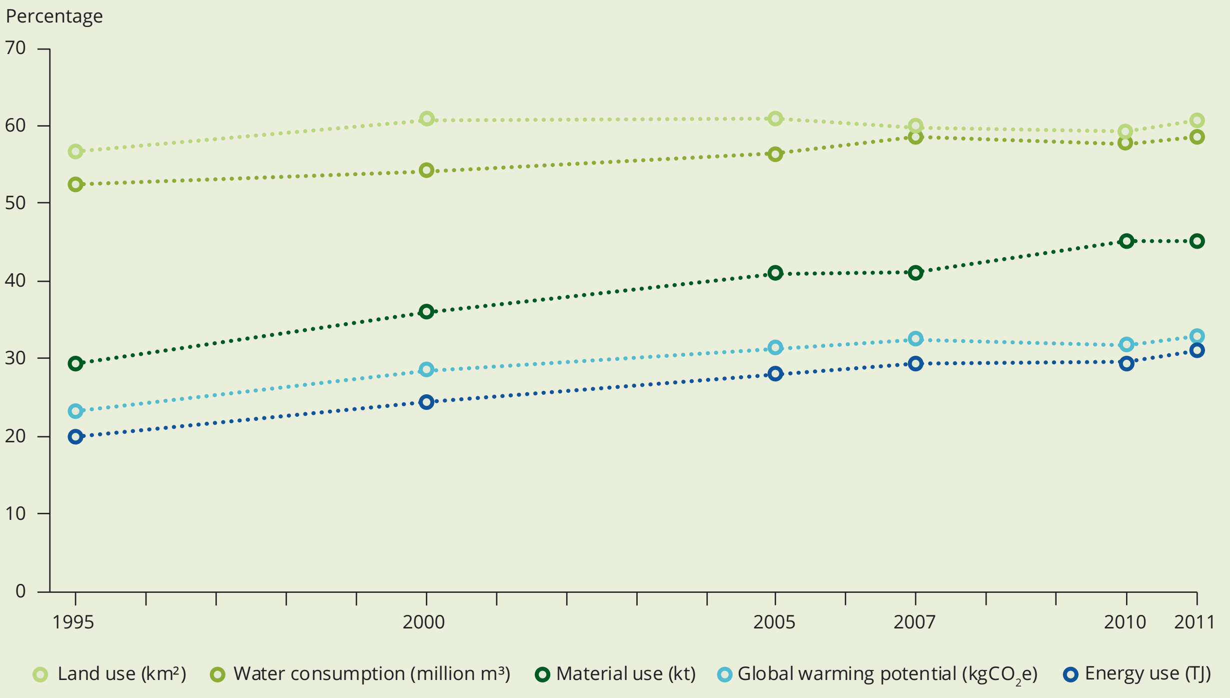
Box 2.22 EU trend — European imports' negative spill-over effect

The 28 EU Member States (EU-28) are the second largest exporter and importer of goods in the world; their economy accounted for slightly less than 16 % of global exports and 15 % of global imports in 2018 (Eurostat, 2019b), with their main commercial partners being China and the United States. In particular, China was the origin of nearly 20 % of all goods imported into the EU-28 in 2018, followed by the United States, Switzerland, Norway, Turkey and Japan (Eurostat, 2019b).

As reported in *The European environment — state and outlook 2020* report, European production and consumption patterns also have implications for environmental pressures and degradation in other parts of the world, as key production-consumption systems, such as energy, mobility and food, operate across and beyond European borders. Europe is highly dependent on resources extracted or used outside Europe, such as water, land use products, biomass and other materials, to meet its high consumption levels. The pressures associated with final consumption in Europe are higher than the world average, and recent research suggests that the EU is indeed a net importer of environmental impacts (Wood et al., 2018; Sala et al., 2019). This means that a large part of the environmental impacts associated with European consumption occurs in other parts of the world. In 2011, this figure ranged from 31 % (energy use) to 61 % (land use) (Figure 2.24). Recent estimates confirmed that the European carbon footprint associated with EU-28 consumption was 27 % higher than emissions associated with production in 2015 (Wood et al., 2019), while other studies have assessed multiple environmental impacts stemming from EU trade (Beylot et al., 2019; Corrado et al., 2020).

While trade liberalisation has led to growing economic opportunities for emerging economies (see Section 2.6.1.2), it has also led to growing environmental pressures. In fact, the prices of internationally traded goods rarely incorporate the costs of environmental externalities, i.e. the embedded impact of the land and water used, the greenhouse gases emitted or the biodiversity affected. In particular, many internationally traded goods are produced in world regions with high returns on investment but low environmental costs or weak environmental regulation.

Figure 2.24 Share of Europe's final demand footprint exerted outside European borders



Note: Geographical coverage: EU-28 plus Norway, Switzerland and Turkey.

Sources: EEA-ETC/WMGE own calculations based on EXIOBASE 3; Stadler (2018).

In fact, from a European perspective trade has largely contributed to environmental leakage and an overall increase in the global consumption of energy and materials, as a result of the restructuring of international supply chains and shifts in consumption patterns (Wood et al., 2018). Moreover, Europe is a major contributor to pressures on fish stocks, as the EU is the largest importer of seafood and fish products in the world, with a market share of 20 % of total global imports of seafood, while it was responsible for around 6 % of total global exports between 2013 and 2015 (FAO, 2016).

Box 2.22 EU trend — European imports' negative spill-over effect (cont.)

While trade policies have contributed to economic growth globally they have also been criticised for largely benefiting the appropriating party only, thus having spill-over effects on the prices and living conditions of small farmers, land grabbing, depletion of fish stocks and export of toxic substances, as well as debt, tax and finance in the Global South (SDG Watch Europe, 2019). Moreover, trade liberalisation has been indicated as one of the mechanisms that contribute to heighten the gap existing between poor countries and rich ones, as the proponents fundamentally ignore that rich countries developed through a combination of government intervention, protectionism, and strategic investment rather than free trade (Reinert, 2007).

Decision-makers and consumers in importing countries are often not fully aware of these displacement effects, partly because of increasingly globalised and complex supply chains that limit awareness concerning the full social, economic and environmental implications of their purchasing decisions (EEA, 2015d). In addition, as in other regions, Europe's demand for goods and services is growing in proportion to rising levels of affluence (Sala et al., 2019). A consequent increase in global trade would therefore contribute negatively to the achievement of international agreements on climate and biodiversity protection, as it would lead to increased global use of energy and material use and growing environmental impacts (Ekins et al., 2017; Wood et al., 2018). Therefore, from a policy perspective, focusing solely on the environmental pressures occurring within Europe, without further consideration of additional environmental impacts abroad, can result in an overly positive perception of Europe's sustainability. These aspects may hinder substantially the achievement of the Sustainable Development Goals' (SDGs') agenda; therefore, reforms that include impacts associated with trade and trade policies should be included more prominently in the EU's political agenda to address this issue and contribute to the achievement of the SDGs (SDG Watch Europe, 2019). The introduction of a carbon tax at the EU border was suggested by the President of the European Commission in her political guidelines (Von der Leyen, 2019).

promoted the benefits that advocates claim, given their prominence, leading to a biased public debate (Gelinsky and Hilbeck, 2018). Such an imbalance is not expected to improve without action at country, European and international levels, and it might fundamentally shape the perception of public opinion regarding risks and opportunities.

However, such concentration of power could turn into an important lever. For example, the development of corporate biosphere stewardship could represent an important lever for ensuring the long-term viability of the planet (Folke et al., 2019).

2.6.1.3 Growing debt and systemic financial risks

The financial sector is an increasingly important factor in the global economy, with growth in traded goods expected to potentially decline in the coming years, while trade in services and investment flows could increase (ESPAS, 2015). However, **the 2008 financial crisis** seriously challenged the resilience of the international financial system and raised concerns about the risks of speculation and opportunities for further regulatory measures. Starting with a collapsing, debt-fuelled bubble in residential real estate (i.e. subprime mortgage market) in the United States, it eventually led to the most serious global economic recession since the Second World War. The highly interconnected and complex nature of the global financial system implies the existence of systemic risks, which can materialise in the form of international contagion effects that spread across institutions and markets and ultimately to the real economy (IRGC, 2018).

Although these **cascading failures** have been analysed thoroughly (see IRGC, 2018), and corrective measures have since been taken (such as the Basel III capital and liquidity standards), the international financial system remains a source of concern for future economic development. However, banks are better capitalised, volatile short-term lending across borders has been cut sharply, and opaque securitisation products have been largely phased out, making the global financial system overall more resilient and less exposed to contagion effects (McKinsey & Company, 2018). Nevertheless, **global debt continues to grow** (IMF, 2018; Mbaye et al., 2018). In 2016, global debt was estimated at 225 % of global GDP, exceeding the previous record of 213 % in 2009 (WEF, 2018b). The most indebted economies in the world are also the richest ones. In particular, public debt has soared in advanced economies since the 2008 financial crisis. Corporate debt in developing countries and China's debt are also increasing (OECD, 2019e). As real-estate prices have soared in many megacities across the world, this leads to uncertain but potentially significant consequences for the real economy (McKinsey & Company, 2018). An overview of the trends in and implications for Europe is provided in Box 2.23.

2.6.2 Contrasting fortunes in the global economy

2.6.2.1 Poverty reduction but not everywhere

At the global scale, rapid economic growth in developing regions has lifted **millions of people out of poverty** in recent decades, by generating revenues

Box 2.23 EU trend — The effects of financialisation and the financial crisis on Europe

Financialisation, apart from having created the preconditions for the economic crisis that hit Europe in 2008, has also had wider socio-economic implications. Although a well-functioning financial system is vital for economic development, financialisation is associated with several adverse effects for both firms and overall economic growth, leading to financial instability, increased inequality (e.g. wages and taxation) (Kus, 2012) and the burdening of public budgets (e.g. bailout of financial institutions) (Battiston et al., 2018). In Europe, this has led to increased taxation, reduced public expenditure and money borrowing in international markets, affecting households' disposable income (WEF and The Conversation, 2015).

Financialisation has also had important effects on firms and labour, by substantially influencing the business models adopted by non-financial economic activities (Battiston et al., 2018). As non-financial firms are sensibly increasing their share of property income and financial assets over revenues from production to maximise short-term shareholders' value, resources are diverted from long-term investments, such as research and development and capacity expansion (Battiston et al., 2018). Financialisation has also had implications for the reduction in net wages in non-financial sectors, the cut in labour costs and the rewards of top executives, increased short-termism and the weakening of institutions and policies focusing on containing income disparity (Kus, 2012). Apart from this, the financial and then economic crisis in Europe had structural effects on production. Industry and construction were the sectors that experienced the sharpest and longest lasting decline in economic turnover, while services such as real estate, public administration, health and social work did not register any contraction (Eurostat, 2019d). These structural changes have also resulted in manufacturing activities, and some services (e.g. assistance provided by call centres) being moved to lower labour cost regions, both within and outside the EU (Eurostat, 2019d), creating challenges for employment and social cohesion. The EU has recently developed a European Globalisation Adjustment Fund, which is expected to support European workers who have lost their jobs, because of the relocation of firms to other countries, through training and employability measures (EC, 2019d).

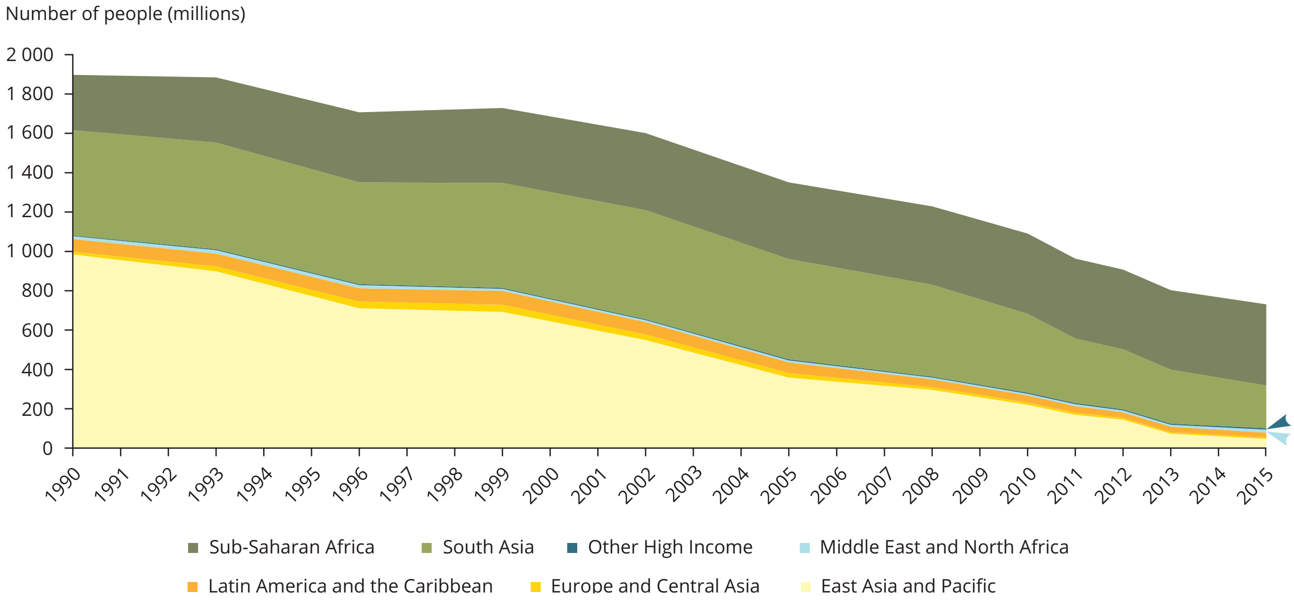
Structural changes induced by financialisation and the restructuring of the international supply chains have also shaped the real economy and the demand for resources as an input into industrial processes. The financial intensity and energy intensity of the economy are anti-correlated: while financial intensity grew sensibly, energy intensity declined (Kovacic et al., 2018). Therefore, increased financialisation has contributed to reducing energy intensity in Europe and decoupling energy and resource use from gross domestic product, as it has enabled a shift in non-financial corporate sectors towards rent-seeking activities, which are less resource intensive. This has increased the profits of firms, despite growing deindustrialisation, stagnating investment and slow economic growth, allowing for externalisation to become economically viable (Kovacic et al., 2018). Although the shift towards services, including financial activities, is often suggested as a viable strategy for reducing environmental pressures occurring within an economy, their overall environmental footprint may not be lower than manufacturing, when assessed across the full supply chain (EEA, 2014b). This is because services rely on inputs from other sectors, such as food, machinery and electricity (EEA, 2014b). As a consequence, while demand for resources and emissions can be eased within one region (e.g. Europe), at the global scale this might translate into increased environmental pressures, as a result of increased trade (see Box 2.22).

for households and allowing governments to invest in social infrastructure and services (e.g. education, health and social security). In 2015, 10 % of the world's population lived below the international poverty line (revised to USD 1.90 a day in 2015), which is almost a 36 % reduction compared with 1990 (World Bank, 2019b). This means that nearly 1.1 billion fewer people are living in extreme poverty than in 1990. This progress has been accompanied by strong progress in reducing child mortality, maternal mortality and hunger. For example, the global under-5-years mortality rate declined by 59 % between 1990 and 2018, reaching 39 deaths per 1 000 live births (Unicef et al., 2019).

However, while poverty rates have declined in all regions, progress has been uneven. If the world achieved the first Millennium Development Goal target — to cut the 1990 poverty rate in half by 2015 — 5 years ahead of schedule, it is largely because of the 'performance' of Asian countries. East Asia and the Pacific regions, Europe and Central Asia have reduced extreme poverty to below 3 % (World Bank, 2019b). Many of these countries have even reached middle-income status, with improvements in living standards for a large part of their population (World Bank, 2019b). In contrast, the number of poor people in sub-Saharan Africa increased by 9 million during the period 1990-2015, meaning that the region had more people in extreme poverty (413 million) than all the other regions combined (World Bank, 2019b). If the trend continues, by 2030, nearly 9 out of 10 people in extreme poverty will be in sub-Saharan Africa.

This results in a world where **extreme poverty persists**. In 2015, 736 million people were still extremely poor. In 2018, 6.2 million children died

Figure 2.25 Number of people in extreme poverty



Note: Extreme poverty is defined as people living under USD 1.9 a day using 2011 PPP (power purchasing parity).

Source: Our World in Data (Roser and Ortiz-Ospina, 2019), in turn based on World Bank (2019c).

before reaching the age of 14 years, which is equivalent to more than the population of Denmark (World Bank, 2019b). Overall, considering the forecasts for slowed global growth and the difficulty of reaching those in extreme poverty, who often live in fragile countries and remote areas, it is unlikely that the first SDG to eradicate poverty by 2030 will be reached. Furthermore, measuring poverty in monetary terms, such as a person's consumption, presents serious limitations. This is why, in addition to accounting for cross-country differences in purchasing power, international organisations and countries increasingly use a multidimensional approach, in which other aspects such as education, access to basic utilities, health care and security are included. This reveals, however, a darker picture in which the share of the poor becomes almost 50 % higher (World Bank, 2019b). Finally, financial crises (Section 2.6.1), food prices volatility (Cluster 3) and climate change (Cluster 2) are threatening those vulnerable households that have just moved out of poverty.

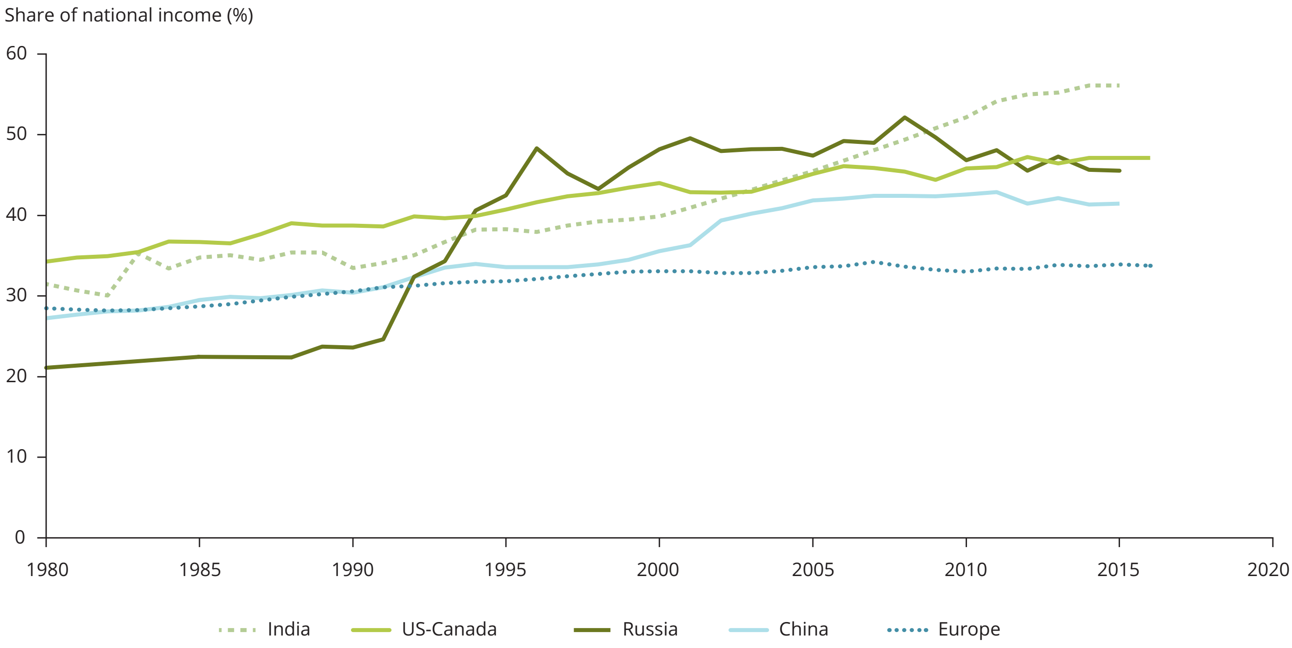
2.6.2.2 A middle class growing globally but shrinking in the West

Global population growth (Cluster 1) and rapid economic growth (Section 2.6.1) have led to the rise of a fast-growing global middle class, driven by emerging economies in Asia. Kharas (2017) has calculated that the rate of increase in the global middle class ([13]) in absolute numbers was approaching an all-time peak, with around 140 million people achieving middle class status annually in 2016 and a rise to 170 million annually likely by the period 2020-2021. In 2016, the global middle class reached 3.2 billion people, with an estimated 88 % of the new entrants living in Asia, in sharp contrast with a **stagnation of the European and North American middle class** (Kharas, 2017). Indeed, since the 2008 financial crisis, Europe's middle class has contracted in most countries because of increased levels of unemployment, changing working arrangements (e.g. increase in temporary contracts) and the erosion of earnings in traditionally middle-class jobs, such as teaching and public administration (ILO, 2016).

Projections suggest a further increase to more than 5 billion by 2030 (Kharas, 2017), with likely associated increases in consumption levels and environmental impacts, not least carbon emissions. This depends largely on the evolution of consumption patterns, as it is often indicated that 'millennials' (i.e. the generation of those born between 1980 and 1996) may be more willing and able to demand and change behaviour towards more sustainable lifestyles (Gallup, 2019;

([13]) Kharas defines the middle class as comprising those households with per capita incomes between USD 10 and USD 100 per person per day in 2005 PPP terms.

Figure 2.26 Income shares of the top 10 % in a set of countries/regions, 1980-2016



Source: World Inequality Lab (2019).

Cheng, 2019), although there is no systematic analysis supporting such claim. A growing and more affluent middle class also represents new market opportunities for Europe for the export of its goods and services and as a tourist destination, with significant implications for Europe's environment and sustainability.

2.6.2.3 Rising inequalities within countries

The general trend in and outlooks for global growth and expansion of the middle class do not necessarily mean that the benefits of growth or levels of income are distributed evenly. While global economic development has brought about undoubted benefits and helped reduce **inequalities in global living standards, inequalities are often increasing within countries**. Figure 2.26 shows how the latter increased in major economies during the period 1980-2016 (World Inequality Lab, 2019). Although Europe remains home to the most equal societies globally (EC, 2017j), inequalities have nonetheless been rising too, though at a slower rate than in other regions. In 2015, in OECD countries the **gap between rich and poor** was at its highest level for more than 30 years, with the richest 10 % of the population having an earnings ratio of 10:1 compared with the income of the poorest 10 %, whereas this ratio was 7:1 in 1980 (OECD, 2015b).

In Europe, the legacy of the 2008 financial crisis is still felt, and, while across the EU the economy is generally more stable and unemployment is falling, there are geographical and intergenerational inequalities (EC, 2017j). In particular, there is a risk that younger people in Europe today could be less well off than their parents, with **unemployment among young people** (under 25 years), at 18.6 % in 2017, which is markedly higher than the overall unemployment percentage (8.2 %) (EC, 2017j). Looking to the future, the convergence of new technologies, while bringing potentially huge opportunities, will also transform economies and society, with a potential for societal disruptions including, for Europe, further rises in unemployment, increasing inequalities and the impoverishment of the middle classes (ESPAS, 2015). Growing inequalities in access to resources (including education and health services) may also trigger social discontent and represents wasted potential and reduced social mobility (OECD, 2015b; ESPAS, 2015). The majority of the global poor live in rural areas and are poorly educated, employed in the agricultural sector and under 18 years of age (World Bank, 2019b).

2.6.3 Geopolitical power shifts, tensions and uncertainties

2.6.3.1 A vulnerable globalisation and multilateralism

The end of the 20th century and first two decades of the 21st saw much engagement in multilateral cooperation, including in recent years the Paris Agreement on climate change (UNFCCC, 2015) and the UN's 2030 agenda for sustainable development (UN, 2015). Today, however, there are signs of strain in the global order, with interdependence and the need for collective action conflicting with tensions in the existing multilateral system (ESPAS, 2015). This is reflected in a **waning of the consensus** on the benefits of **globalisation and free trade**, leading to countries turning away from multilateral agreements towards bilateral or regional trade deals and an increase in protectionist measures (EPSC, 2018b).

The current waning of the consensus on the benefits of globalisation and free trade (NIC, 2017) may also lead to the undermining of current — and act as a barrier to future — cooperation and agreement on international environmental standards and goals (EPSC, 2018b). The creation of **tariffs and other trade barriers** in response to protectionist measures is a growing phenomenon, also known as 'trade wars'. At the same time, global competitors are using unfair trade practices, such as dumping and subsidies to gain advantage on international markets. Indeed, the term 'globalisation' has become increasingly contentious, at least in advanced economies (EPRS, 2018a), particularly because of the generalised sentiment of insecurity it produces, as a growing number of tasks of the value chain — not a few sectors or occupations — can now be offshored (Baldwin, 2016). Together with the fear of downgrading from Western societies, this has been fertile ground for bolder criticisms and actions against the existing multilateral system.

Notably, 2018 has seen the United States withdrawing from the Trans-Pacific Partnership, harsh renegotiations of the North American Free Trade Agreement (NAFTA), the imposition of tariffs on steel, aluminium and other imports, and the explicit threat of a trade war with China and also other trading partners, including the EU (EPSC, 2018b). Trade tensions have always existed, and trade wars are not a new phenomenon. However, while in recent decades such disputes have been settled through clearly defined rules set out under the World Trade Organization (WTO), the disregard for the WTO rules expressed by the current US administration, together with heightened global power rivalries, indicates a risk higher than ever before of escalation and 'economic war' (EPSC, 2018b).

Rivalry and the potential for escalation in **protectionism** is of great concern to Europe, which has an economy in which one in seven jobs are dependent on exports (EPSC, 2018b) and which has in recent decades been increasingly driven by export growth, with exports representing more than 50 % of GDP in 2018 (EPSC, 2018b). The challenges faced by Europe do not stop here, as criticism of existing multilateral institutions did not spare the European project and materialised eventually in Brexit.

2.6.3.2 Changing power distribution in the international system

Following the collapse of the Union of Soviet Socialists Republics (USSR), the immediate post-Cold War international system was dominated by the sole US 'hyperpower' (as popularised by Védrine; International Herald Tribune, 1999). Today, the United States remains the **world's dominant power** because of its economic and, above all, military and technological primacy. In particular, thanks to its air force, naval fleets and space capabilities, the United States is the only power that can launch and sustain major military operations around the world (EPRS, 2018a). In 2015, US defence spending was still outstripping that of China, Russia, the United Kingdom, France, Japan, Saudi Arabia and India combined (SIPRI, 2017). However, US dominance is not hegemonic, and a number of contesting powers are rising, and geopolitical power is increasingly defined outside the traditional battlefields. Indeed, security challenges are evolving quickly (see Section 2.6.3.3).

In particular, China has the potential to become a serious rival. With a population four times the size of the United States, the size of its economy (by GDP) is likely to overtake the United States before 2030. China also increased its **military spending** by 83 % over the past decade, while US spending decreased by 17 % (EC, 2018n), with the clear ambition of having 'fully-modernised armed forces by 2035, and a fully-fledged top-tier military by 2050 that is capable of fighting and winning wars' (Nouwens, 2018). Besides, China is advancing its Silk Road Economic Belt from China to Europe through Central Asia. By connecting 60 nations, 70 % of the global population and close to 75 % of the world's energy resources through land and sea, the new Silk Road has the ambition of strengthening China's global position both economically and politically. Finally, China is becoming a technological leader, with massive investments in AI and cyber-physical systems (Cluster 4), which could give it a strategic geopolitical advantage in the coming decades.

As for Europe, **the EU remains the world's second-largest economic power** (by GDP), the world's largest single market area and a major source of influence in international negotiations, thanks to the soft power of individual countries (in particular France, Germany and the United Kingdom). Military-wise, most EU Member States do not fulfil the North Atlantic Treaty Organization (NATO) guidelines of allocating at least 2 % of GDP to defence expenditure. Whether the EU will be a strong pole in the new multipolar world depends largely on the resolution of its internal challenges and the further consolidation of its union (such as a defence union). Brexit appears a particular setback in this regard.

Other **emerging economies** are rising, either as new international powers, such as India (considering its population size, economic potential and growing investments in defence and innovation), or regional powers, such as Brazil in South America. As economic power shifts, emerging countries and regions may also seek to increasingly translate their economic gains into global influence, as reflected in the formation of the G20 (group of 20 of the world's most advanced and emerging economies) in 1999, alongside the G7/G8 (group of seven or eight of the world's most advanced economies) in 1975 (OECD and DASTI, 2016). Meanwhile, more traditional players are far from being powerless in contesting the United States' particular geopolitical interests. Russia in particular has remained a strong player in influencing the state of international affairs, especially in Eurasia and the Middle East. It also took advantage of hybrid warfare, making military power irrelevant through alleged cyberattacks on critical infrastructure, the manipulation of information and interference in elections in Europe and the United States. In the Middle East, and despite the impact of international sanctions, Iran remains a key regional power playing a crucial role from Syria to Yemen.

2.6.3.3 Evolving security challenges and the new warfare

The diversification of threats and actors is generating new security challenges for the defence and security communities, as well as society as a whole (JRC, 2018). While the sources of conflicts remain unchanged (i.e. fight for power, religious ideas, territories, resources and energy), the ways they materialise have evolved.

Recent military interventions, often in the form of **international coalitions**, have mostly taken place in rogue and failing states, such as Afghanistan, Iraq, Libya, Syria and Yemen (EPRS, 2018a), threatening the international order or existing interests of larger powers. However, coalitions are less coordinated by traditional bodies such as NATO and more by ad hoc alliances, sometimes driven by regional powers, as reflected by the Libya intervention in 2011 (with the involvement of the Arab League) and the Syrian conflict (EPRS, 2018a). Such regional powers are expected to increasingly run their own policy operations in their neighbourhood in the next decade (EPRS, 2018a).

Fuelled by continuous instability in the Middle East and radicalisation over the internet, **violent extremism** has grown since the 9/11 terrorist attacks, with Europe paying a heavy price during the last decade. Although it remains a relatively free and stable place to live, with 15 of the worlds' 25 most peaceful countries being in the EU (Vision of Humanity, 2019), terrorist attacks in recent years, including 'home-grown' terrorist threats, are changing the way people think about security and borders. Combined with migration to Europe, particularly the refugee crisis, this has fuelled debate and tensions in European countries and is challenging the solidarity of the EU (EC, 2017j). Such forces may be fuelling dissatisfaction with and distrust of mainstream politics and institutions at all levels, and create a vacuum that can be filled by populist and nationalist rhetoric (see Cluster 6) (EC, 2017j).

Warfare has also become more asymmetric through the use of 'hybrid warfare' tactics directly targeting governments and populations. A hyperconnected world, increasingly relying on smart infrastructure (Cluster 4), is indeed more vulnerable to massive **cyberattacks** that can disrupt energy provision, business activities and electoral processes alike. Cybersecurity specialists refer to government-sponsored cyberattacks as advanced persistent threats, indicating an emerging trend that is likely to continue and more broadly a changing security paradigm. Besides, China's lead in developing the next 5G network infrastructure raises concerns as regards data privacy and the security of sensitive communications. Transnational organised crime organisations are also seizing new opportunities offered by digitalisation to traffic illegal substances and weapons through the 'dark web', spy on institutions (sometimes on behalf of foreign powers) and blackmail individuals and companies through hacking techniques (e.g. phishing).

As highlighted by annual global risks perception surveys (WEF, 2018a), the other rising sources of concern for key decision-makers worldwide relate to climate and environmental risks (Clusters 2 and 3). Climate change has the potential to alter security threats worldwide, with potentially unexpected consequences the world over. In particular, the increased likelihood of more frequent extreme weather events would directly threaten **critical infrastructure** and national security in terms of supplies of energy, food and financial resources. The diverse impacts of climate change can also contribute to further conflicts and large-scale migration from island nations or increasingly food-insecure countries (see Cluster 1 and 2). Out of almost 1 billion people living in areas with high or very high exposure to climate hazards, 41 % reside in countries that already have low levels of peacefulness (Vision of Humanity, 2019). Climate threats challenge existing security approaches, as climate change is a global megatrend, but its impacts can be local, acute and unpredictable 'black swans'. The Arctic is expected to continue warm rapidly, leading to new geo-political scenarios (see Box 2.24).

Although space has been characterised by successful civilian **international cooperation**, as illustrated by the strong Russia-US cooperation on the International Space Station, the joint European-Russian ExoMars mission and the Brazilian-Chinese joint development of remote sensing satellites, space is increasingly subject to strengthened geopolitical, security and military competition (EPRS, 2018a). Almost 50 years after the end of the US Apollo programme, the United States plans to return astronauts to the moon in 2024 as an intermediate step towards a future crewed mission to Mars, with China having similar ambitions and the EU, India and Russia continuing their space exploration efforts. Unlike the Apollo era, private companies have entered the game, in particular in the United States, with SpaceX and BlueOrigin. The militarisation of space is expected to increase through further applications in surveillance and data collection and the clear ambition of the United States to secure US dominance in space (The White House, 2018).

Box 2.24 Uncertainty — Security challenges around the Arctic

The Arctic is expected to continue to warm more rapidly than global averages (IPCC, 2019b) (see Cluster 2), and according to a number of projections, the Arctic Ocean will be nearly ice free before 2050, which means that both the North-West Passage and the Northern Sea Route will be open to shipping well before then (EPRS, 2018a). A number of countries — Russia, Canada, Denmark — have recently made competitive claims to the United Nations Commission on the Limits of the Continental Shelf on the same territory, which may contain 13 % of the world's undiscovered conventional oil and 30 % of its undiscovered conventional natural gas, as well as mineral deposits (USGS, 2008). Moreover, China has identified itself as a 'near-Arctic state' and is likely to exert influence in the governance of the Arctic.

Future exploitation of the Arctic reserves is likely to be a source of potential international tension in terms of access to resources as well as shipping routes connecting Asia to Europe. The future of diplomacy will be important for regional security and peace. Moreover, using the fossil fuel stocks of the Arctic, if economically viable, would jeopardise any serious attempt to reduce greenhouse gas emissions, adding another layer of complexity to the diplomacy of the region.

2.7 Cluster 6 — Diversifying values, lifestyles and governance approaches

Key messages (cont.)

Emerging lifestyles, work patterns and learning opportunities

- In the last few decades, identities, values and cultures have changed as a consequence of globalisation, trade liberalisation (Cluster 5) and digitalisation (Cluster 4). In emerging economies, this has led to increasing income, the rise of a global middle class and the adoption of Western lifestyles (e.g. consumerism), with associated demand for resources (Cluster 3) and, ultimately, growing environmental pollution (Cluster 2).

- At the same time, numerous forms of social innovation, such as the sharing economy, community-oriented forms of living and slow-food movements, are emerging often facilitated by digital technologies (Cluster 4). Sustainable lifestyles are increasingly embraced by people in Western societies, especially by younger generations (e.g. 'millennials') which are often motivated by climate and environmental concerns. Nevertheless, tensions exist between people's motivations and their actual behaviours, as multiple lock-ins (e.g. social, cultural, economic and psychological) prevent change.

- New work patterns and lifestyles are emerging as a result of rapid and pervasive technological change (Cluster 4), creating both challenges and opportunities in Europe and in the rest of the world. While creating opportunities for economic growth, digitalisation — together with automation — and the gig economy, have the potential to adversely affect workers' rights, health, safety and mental well-being because of growing job insecurity. As a consequence, governments are likely to face new challenges associated to the risk of massive unemployment, reskilling of the working population, 'non-standard' forms of work and social vulnerabilities.

- New job opportunities could be created in the field of climate mitigation and adaptation. For example, the implementation of the long-term goal of the 2015 Paris Agreement is expected to have positive effect on job numbers, as job losses in certain sectors as carbon- and resource-intensive industries are expected to be more than offset by new job opportunities, particularly in sectors like energy supply, manufacturing of electric vehicles, and in the construction sector (ILO, 2018a), provided that policies facilitating the reallocation of workers and re-skilling would be implemented. However, uncertainties remain concerning the overall implications of the scaling-up of technologies (Clusters 3 and 4).

- Life-long learning is becoming the norm and is increasingly supported by a diversification of educational opportunities (OECD, 2017c), favoured by digitalisation, among other factors. While the global workforce is increasingly skilled and educated (e.g. 65 % of world's population has at least lower secondary education; EPSC, 2019b), access to and participation in education remain an issue for many developing countries that lack basic infrastructure and the facilities to provide effective learning environments.

Shifting health and social challenges

- Health and social inequalities persist around the globe. The global disease burden is shifting from communicable to non-communicable diseases, accounting for 71 % of all deaths globally in 2016 (WHO, 2018c). Major lifestyle-related human health challenges remain, such as cardiovascular diseases, obesity and cancer.

- The quality of the environment (Cluster 2) matters substantially. For example, air pollution is still the greatest environmental health risk in Europe, being responsible for a lower quality of life and an alarming number of premature deaths, around 400 000 in the EU in 2017, while climate change is expected to create additional health risks globally.

- Gender-based violence remains a harsh reality. It is estimated that 35 % of women worldwide have experienced either physical and/or sexual intimate partner violence or sexual violence by a non-partner at some point in their lives (UN Women, 2019). In the EU, 1 in 10 women has experienced sexual harassment or stalking through new technologies (EC, 2019e). Inequality also affects people's ability to access healthcare. In the EU as in the rest of the world, groups of lower socio-economic status tend to be more negatively affected by environmental health hazards.

Key messages (cont.)

- **Evolving governance challenges and approaches**

- Governance systems at all levels (global, national and regional) are under increased pressure because of mounting challenges. For example, in Europe, ageing societies (Cluster 1), the growing burden of disease and additional investment needs driven by globalisation, innovation and competition (Clusters 4 and 5) demand larger public expenditures. A the same time, sluggish economic growth, growing debt and financial crises (Cluster 5), as well as a narrowing fiscal base due to ageing (Cluster 1), reduce public revenues.

- In Europe, ageing represents one of the most prominent challenges, as an increased number of elderly people will depend on a smaller working population. The elderly will probably have to work longer, while the shortfall in the workforce might have to be replaced by immigrants and automation (Clusters 1 and 4), unless new approaches to fiscal policy will be developed (e.g. shift in the tax base).

- Moreover, the erosion of the European social model, unemployment, migration, social and economic inequalities (real or perceived), higher individual expectations and fundamental disruptions brought about by technological advancements (Cluster 4) in values, identities and social norms have all contributed to a rapidly changing political landscape among Western societies. The inability of existing political parties to respond efficiently to these concerns and challenges has largely fostered the rise of populist movements.

- At the same time, the values and founding principles of our society are being challenged with the emergence of the so-called 'post-truth' trend, as standards of public communication based on truth telling, which have taken societies decades or even centuries to establish, are becoming increasingly vague and negotiable (NIC, 2017). Together with the increased role of social media in our lives (Cluster 4), the spread of fake news has contributed to the polarisation of debate and the creation of 'echo chambers' in which interest groups largely interact only with people with similar views (Calais Guerra et al., 2013). In addition, the growing influence of non-state actors (Cluster 5) might potentially threaten democratic processes, as they are often unelected and unaccountable, and not always transparent (EEA, 2015a).

- The effectiveness of intergovernmental collaboration concerning environmental and sustainability challenges has often been questioned, in particular in relation to the non-enforcement of agreed rules or commitments (EEA, 2015b). However, new forms of governance and institutions at local, regional and global levels, are emerging. In particular, the growing 'glocalisation' of governance is expected to offer new opportunities for contributing to the achievement of sustainability objectives, empowered by the increasing autonomy of cities and technologies that favour decentralized governance of systems (e.g. energy communities).

2.7.1 Emerging lifestyles, work patterns and learning opportunities

2.7.1.1 Changing values and emerging lifestyles in a more consumerist world

The rise of a global middle class (Cluster 5) and the diffusion of Western lifestyles in many emerging economies, boosted by international trade (Cluster 5), digitalisation (Cluster 4), and globalised media and marketing, has been extending **consumerism** around the globe. This has actually had a much more profound impact on cultures and values in many developing countries than in advanced economies, which have experienced the consumer society for several decades. Identities and social norms have also been shaken up around the world through the diffusion and sometimes confrontation of more liberal ideas and practices. Nevertheless, stark contrasts still characterise our society. As indicated in Clusters 3 and 5, while more than 820 million people have not enough to eat, now overweight affects 2.1 billion adults globally (WHO, 2018a).

Counter-trends to consumerism have also been emerging, particularly in advanced economies where achieving the high watermark in material well-being is creating a 'good enough' trend in thinking, at least in prosperous, urban and young segments of their populations. In such *milieu*, well-being is no longer increased by accumulating more material things but by limiting them, and the emphasis is shifting towards the value of a good life. Climate and environmental concerns are also pushing towards more **sustainable lifestyles**, sometimes frugal. For example, although limited empirical evidence is available, there are some indications that moving to a vegan or vegetarian diet appears to be an increasing trend in many Western societies (e.g. among 'millennials', see Cluster 5); according to recent estimates, the share of European consumers avoiding red meat and beef has grown significantly, reaching 13 % of total population (Statista, 2019).

As reported by Kemp et al. (2016), neoliberal market capitalism, the dominant system of socio-economic organisation worldwide, has a significant role in preventing fundamental reconfigurations of consumption and production. While 'governments are **locked-in to the economic growth paradigm** socially and environmentally harmful, partly because of the need to maintain employment levels and finance the welfare state', 'individuals are locked into a cycle of 'work and spend' by consumption competition and labour market rigidities that prevent people working shorter hours'. In fact, tensions exist between people's motivations and their actual behaviours because of a number of social, cultural, economic and psychological lock-ins, as well as institutional, legal and infrastructural constraints. Overall, the **emergence of new behaviours and lifestyles** depends on their complex set of interactions. For example, concerning food consumption, more flexible working and leisure time driven by digitalisation and hyperconnectivity (Cluster 4) is known to increase the demand for more flexible food consumption (on-the-go, to-go, delivered), which could lead to a higher consumption of convenience food and food on demand. Such products are generally highly processed and unhealthy, contributing to obesity and non-communicable diseases (e.g. 'empty calories'), besides being the result of extended and industrialised food chains and increasing the environmental burden of distribution and retail (e.g. vending machines, deliveries). Opposite to this, increased awareness on issues such as global environmental change, negative health effects of meat and dairy consumption and production (including multi-resistant bacteria) and food scandals may lead to wider behavioural changes and cause trickle-down effects. However, at the global scale, the above trend should be seen against the wider trend of increasing demand for meat and dairy globally, driven, for example, by the rising global middle class (Cluster 5) (EPSC, 2018a).

In the past 15 years, there has been an increased interest in **social innovation**, referring to 'innovative activities and services that are motivated by the goal of meeting a social need and that are predominantly diffused through organisations whose primary purposes are social' (Mulgan et al., 2007). In particular, a number of new economic models have emerged recently. Among them, the **'do-it-yourself economy'** (DIY) is driven by many factors, such as economic rationalisation, choice, identity seeking, and economic and market necessity, and is further facilitated by the internet with the open source and design movements (Zweck et al., 2017). Technology has also facilitated the emergence of social innovation, such as the 'sharing economy' and the 'on-demand economy' (Zweck et al., 2017; World Economic Forum, 2018) (Cluster 4). In the **sharing economy**, assets are shared via digital platforms in a manner aiming to create economic, social, environmental and practical benefits (Zweck et al., 2017; World Economic Forum, 2018). In the **on-demand economy** (also called 'gig', 'collaborative' or 'platform' economy), products and services are selected on an ad hoc and almost real-time basis through online platforms (e.g. Uber, Airbnb, TaskRabbit) adjusted to the immediate user's interests. The opportunities and risks unleashed by these models are discussed in Cluster 4. In addition to that, it is important to consider that Internet and communication technologies such as the IoT and 'smart home devices' (Cluster 4), which are at the basis of the sharing economy and the on-demand economy, are having implications on behaviour and consumption patterns, as purchase choices are heavily influenced by the environment surrounding them (EEA, 2017b). For what concerns food production and consumption, new market opportunities are pursued through digitalisation and big data analytics, enabling direct marketing, online food delivery services alongside with green applications for tablets and smartphones. Some of these developments could enable behavioural change and encourage green consumerism, the reduction of waste, and the adoption of healthier diets by giving access to large amounts of environmental information (e.g. product performance) and dietary recommendations. Oppositely, the opportunities offered by big data analytics could be deployed by private actors for profit maximisation only, through consumer profiling. The extent to which this will turn into an opportunity for the environment will largely depend on future policy actions.

2.7.1.2 Changing nature of work and increasing vulnerability

The digitalisation of economies and societies (Cluster 4), together with the already long-established shift from manufacturing to services in advanced economies (Cluster 5), is having pervasive impacts on the role of labour and the nature of work itself, not limited to a **shift in jobs** from one economic sector to another (EPSC, 2019b). In Europe in particular, the transition away from middle-skilled jobs to low- and high-skilled employment, driven by increasingly ubiquitous automation of routine tasks in all economic sectors, has led to a **need for massive reskilling** of the working population. Jobs are being lost and others are being created, but in the near term the skill gap for many workers, among other factors, prevents them from accessing a secure job position (EPSC, 2019b).

Within this changing landscape, social innovation is bringing **new income-generating opportunities** of a nature different from traditional jobs. In particular, the on-demand economy has the potential to meet demands of seasonal (e.g. hospitality workers during summer or winter periods) and high work demand periods (e.g. in hospitals), replacing traditional agencies offering temporary employment. Digital platforms such as Airbnb, Uber, Deliveroo and TaskRabbit (see Cluster 4) offer anyone who owns a flat, car or bike or has a particular skill the opportunity to generate income. These new ways of work engagement are transforming employment procedures and introducing new working patterns (Gerards et al., 2018). Work is becoming more time as well as space flexible, as technology is enabling people to work remotely (Gerards et al., 2018), as well as collaboratively across various countries and time zones, cooperatively, and in technology-dependent and decentralised ways (Susskind and Susskind, 2015).

According to recent data, the number of people that are engaged in independent work, are self-employed, have a part-time job or even multiple part-time jobs (so-called 'slashers') is increasing in Europe and globally. It has been estimated that independent workers represent 30 % of the working-age population in Germany while in the United Kingdom they represent 26 % (McKinsey & Company, 2016), while in France 16 % of workers are slashers (Machuron, 2016). The share of part-time employment in EU countries today is around 19 %, while temporary employment represents about 14 % of the total number of EU employees (Eurostat, 2018b). As reported by the European Political Strategy Centre of the European Commission (EPSC, 2019b) some 40 % of the European workforce is engaged in **'non-standard' forms of work** ([14]), a trend that concerns particularly younger, female and migrant workers. This could be partially related to the pursuit of self-fulfilment, driven by entrepreneurial spirit and an increased desire for one's time sovereignty, reflected in the need to balance family, leisure time and work (Zweck et al., 2017). Although constituting a minority among an independent workforce, millions of people in the EU and the United States are independent out of necessity, driven by economic circumstances and labour market conditions (McKinsey & Company, 2016). The 2008 financial crisis and subsequent recession and austerity policies in Europe perhaps also have something to do with this phenomenon, as it has become difficult, particularly for young people in the EU, to find 'full-time permanent' employment. It has been suggested that the on-demand and DIY economy and self-employment are an attempt to bridge this shortfall in 'permanent jobs' (e.g. in Greece, Spain) (Zweck et al., 2017).

The gig economy and the benefits of **working flexibly** have the potential to adversely affect workers' rights, health, safety and mental well-being (Howard, 2017) and to contribute to increasingly vulnerable forms of employment, in 2017 accounting for about 1.4 billion people globally (ILO, 2018b). This number was projected to grow by 17 million annually in 2018 and 2019 (ILO, 2018b). Thus, the platform economy also raises questions about workplace protection and what a decent job will be like in the future (NIC, 2017), as well as longer term social support concerns, for example those relating to pension provision and housing. In Europe, 'more and more jobs are being created at the boundary between independent and dependent employment', reflecting 'a growing trend by businesses to resort to dependent self-employment', a model that reduces labour costs for the employer and shifts risks and responsibility to the individual worker (EPSC, 2019b). Moreover, 'workers on non-standard contracts generally do not benefit from social protections offered under national law' (EPSC, 2019b) and it has been estimated that **more than 50 % of independent workers in Europe are not covered by unemployment benefits** (OECD, 2017b). The rise of digitalisation, automation and the on-demand economy are also fuelling discussions about the universal basic income, an idea that is supported by nearly two thirds of Europeans (Lam, 2016) but raises significant questions about how governments could raise revenue and support such schemes, particularly with fewer people in traditional forms of employment, which could undermine tax revenues.

In Europe, the growing penetration of digitalisation into all areas of the economy and society is likely to increase demand for both basic and advanced digital skills, to enable work flexibility (e.g. teleworking), as well as to increasingly blurred boundaries between work and leisure, leading both to opportunities for lifelong learning, as well as challenges for mental health, private and family life (EPSC, 2019b). At the same time, middle-paying jobs are declining as a result of multiple stressors like the financial and economic crisis, employment cuts in the public sector as well as gradual labour market deregulation, while prospects point a continued increase of the 'silver workforce' (i.e. people aged 55 to 64 in employment) (EPSC, 2019b).

([14]) Non-standard work includes self-employment, part-time or temporary work, contractors, freelancers, agency work and on-demand or 'zero-hour' contracts (EPSC, 2019b).

According to the International Labour Organisation (ILO), the implementation of the long-term goal of the 2015 Paris Agreement (i.e. to keep the increase in global average temperature to less than 2 °C above pre-industrial levels), is likely to affect the future of work. Recent estimates indicate that a **transition to a green economy** is likely to have positive effect on job numbers, as 'job losses in certain sectors as carbon-and resource-intensive industries will be more than offset by new job opportunities', particularly in sectors like energy supply, manufacturing of electric vehicles, and in the construction sector (i.e. energy efficiency of existing and future buildings) (ILO, 2018a). However, ILO warns that 'policies that facilitate the reallocation of workers, advance decent work, offer local solutions and support displaced workers' will be needed to ensure meeting social, economic and environmental goals (ILO, 2018a). At the same time, the likely negative effects of climate change (Cluster 2) will put jobs at risks, agriculture in particular, given the likely increase in frequency of human-induced natural disasters. As a result, **new job opportunities** could be created in the field of climate mitigation and adaptation.

2.7.1.3 New forms of education and learning

In knowledge-based, increasingly data-driven societies and economies, good-quality education and learning are becoming even more crucial for individuals to secure an income and defend their rights and for countries to ensure their competitiveness worldwide.

The **global workforce is increasingly skilled and educated**, as 65 % of the world's 16+ population has at least lower secondary education and enrolment in tertiary education around the world has doubled in about three decades reaching now 29 % (EPSC, 2019b). However, despite considerable progress over recent years, **access to and participation in education remain an issue for many developing countries** that lack basic infrastructure and the facilities to provide effective learning environments (UN, 2019). Overall, 262 million children and young people aged 6 to 17 years were still out of school in 2017, and more than half of children and adolescents are not meeting minimum proficiency standards in reading and mathematics (UN, 2019). Some 750 million adults — two thirds of them women — were illiterate in 2016. Half of the global illiterate population lives in South Asia, and a quarter lives in sub-Saharan Africa (UN, 2019). Nevertheless, it is expected that 'by 2030, developing economies will become home to 3 times more skilled workers than high-income (OECD) countries', with 'China and India already home to the highest numbers of university and graduates in Science, Technology, Engineering and Mathematics' (EPSC, 2019b).

Life-long learning is also becoming the norm and is increasingly supported by **diversification of educational opportunities**, which are becoming more open, online and transboundary and enabled by digitalisation. There is an increase in peer-to-peer learning, use of bite-sized learning in workplaces and personal environments and growing home-schooling, which is creating a risk of so-called 'educational bubbles', caused by internet-based personalised learning — in practice meaning that children only receive information based on their pre-existing knowledge and interests (an educational equivalent of the social-media 'echo chambers' of interest groups) (EC, 2017d). The emergence of online and mass education has also profoundly influenced higher education (van der Zwaan, 2017). There is a huge increase in easily accessible internet teaching and learning resources through OpenCourseWare and massive open online courses (MOOC List, 2018). Moreover, the **'democratisation of expertise'** (Maasen and Weingart, 2005) is further blurring the lines between education, public engagement and professional research.

2.7.2 Shifting health and social challenges

2.7.2.1 Changing disease burdens

Because of basic healthcare improvements, scientific advancements and ageing populations in many world regions (Cluster 1), the global disease burden is shifting from communicable to non-communicable diseases, accounting for 71 % of all deaths globally in 2016 (WHO, 2018c). However, many developing countries have to deal with a 'dual burden' of disease: continuing to prevent and control infectious diseases while addressing the increasing prevalence of chronic and degenerative diseases and environmental health risks. In Europe, the leading causes of disabilities and deaths are now **cardiovascular diseases, cancer, diabetes and respiratory diseases**, together accounting for 77 % of disease burden and 86 % of premature mortality (WHO Europe, 2014). A growing health issue affecting Europe is **obesity**, causing about 2.8 million deaths per year and absorbing 7 % of the EU's health budget (FAO et al., 2017). In 2014, more than half of the EU's population was estimated to be overweight (Eurostat, 2018e), as well as one in three children in Europe (FAO et al., 2017), because of high-calorie diets and inactive lifestyles.

If much of the burden of disease is related to unhealthy lifestyles, **air pollution** is still the greatest environmental health risk in Europe, being responsible for a lower quality of life and around 400 000 premature deaths in the EU in 2017, particularly because of harmful road transport emissions (EEA, 2019e) (see Cluster 2). Furthermore, **climate change** is expected to create additional health risks worldwide as a result of heat stress, diarrhoea, malaria and childhood undernutrition (WHO, 2014). Health concerns also relate to drug-resistant disease strains potentially leading to a **post-antibiotic world**, in which antibiotics are ineffective, as well as increased risk of new epidemics or even a global **pandemic**, fostered by increased global mobility and potential biotechnology attacks.

The changes in society, including digitalisation and **changing work patterns**, affect **mental health**, with over 300 million people worldwide known to suffer from depression and 260 million from anxiety; many of these suffer from both (WHO, 2017). The increased focus on self-fulfilment (Zweck et al., 2017) may reflect a wider trend in narcissism and self-reflection among the first generations raised in a hyperconnected and online world: Generation Me (Twenge, 2014). Technology, along with changing educational demands and expectations of young people and urbanisation/indoor living trends with a lack of access to nature (Louv, 2011), lead to people being overly connected. This can have a psychological impact on concentration, expectation of instant gratification, **digital addiction**, anxiety associated with social media presence and depression, as well as negative repercussions for physical health (WFMH, 2018).

There are, however, more optimistic emerging trends. Moving to **vegan or vegetarian diets** appears to be increasing in many Western societies (Hancox, 2018), mainly for ethical and philosophical reasons related to protecting animal rights and sustainability concerns (Heinrich Böll Foundation and Friends of the Earth Europe, 2013). So far, however, only between 2 % and 10 % of Europeans describe themselves as vegetarian, compared with 31 % of Indians, who do not eat meat for religious reasons (Heinrich Böll Foundation and Friends of the Earth Europe, 2013). The key uncertainty there, as well as in other Asian and African countries, is whether such diets will survive the rise of the global middle class (Cluster 5), which is often accompanied by increased consumption of meat and dairy products. Shifting to a technological perspective (Cluster 4), a range of wireless sensors (e.g. smartwatches) and associated applications are making **digital fitness tracking** increasingly popular, fostering the shift to more active lifestyles. New generation devices, in the form of wearables, implants or ingestible pills, are also able to monitor and affect a particular body function (Harvard Health, 2018). This can support a shift to more preventive medicine, thanks to more convenient, regular and relevant transmission of information to healthcare professionals. However, it is too early to say whether the resulting health benefits are worth the increasing concerns about privacy and security in communicating such sensitive information.

2.7.2.2 Persisting social and health inequalities

Whereas much progress has been made globally in improving the health of millions of people, and although people in advanced economies have more opportunities to look after and improve their health thanks to technologies, health and well-being may be one of those dimensions that is increasingly separating and dividing different parts of the population in most countries. Globally, 90 % of all health R&D expenditure is targeted at problems that affect only 10 % of the world's population (WHO, 2018b). In advanced economies, access to increasingly sophisticated and expensive health infrastructure is also a segregating factor, especially in countries without universal social security. In the EU, groups of lower socio-economic status tend to be more negatively affected by environmental health hazards (such as the impacts of air pollution, noise and extreme temperature), as a result of both their greater exposure and their higher vulnerability (EEA, 2018e) (see also Box 2.25).

The **urban-rural divide** is another source of concern for inequalities in both developed and developing countries. Rural areas suffer from a number of socio-economic issues, in particular depopulation due to urbanisation (Cluster 4). Globally, the share of rural population worldwide fell from 67 % to 45 % between 1960 and 2017. In the EU, 28 % of the population lives in rural areas, which cover 44 % of the territory. The urban-rural divide relates largely to differences in opportunities, which explains a general sense of 'being left behind' in rural populations. As cities are the nodes of the globalised economy, more innovation occurs there, more new jobs are created and more and more resources are flowing into them (ScienceDaily, 2019). As rural areas host more people inclined to leave education or training early (12.2 % against 9.8 %) and fewer people with a tertiary level of educational attainment (27.9 % against 48.1 % for the 30- to 34-year-old segment), they are less and less attractive for new knowledge-driven businesses. The EU landscape of **inequalities** is mixed, with variation between groups of countries (especially north/west versus east). On the one hand, the EU-28 unemployment rate in rural areas was 9.1 % in 2015, which was somewhat lower than the rate in cities (10.0 %), and the share of people overburdened ([15])

([15]) The housing cost overburden rate is defined as the share of the population that is living in a household where total net housing costs are greater than 40 % of disposable income.

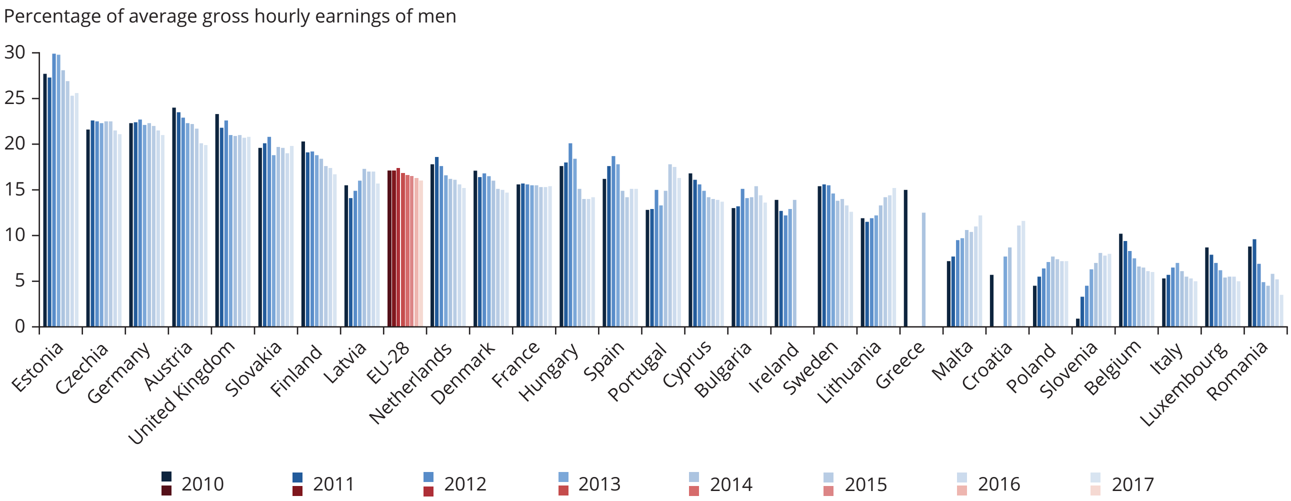
by housing costs was also lower (9.1 %) compared with cities (13.3 %). Besides, income inequality was reduced overall in the EU between 2000 and 2018 when adjusted for standard of living (Allianz, 2019). On the other hand, a larger part of rural populations has more limited access to a number of services (top-level education, health services, fast access to internet) and are more at risk of poverty or social exclusion compared with city dwellers (Eurostat, 2019g). What is clear is that regional inequalities and rural depopulation have been key voter concerns in recent elections, such as Brexit, and social movements, such as France's Yellow Vest movement. Counter-trends to rural depopulation exist, particularly because of increased possibilities of teleworking, housing cost overburden in cities and emerging economic opportunities linked to renewable energy production. However, it is unclear whether they could counterbalance the megatrend in the long run.

Despite significant progress, **gender inequality** persists. Globally, over 50 % of 10-year-olds live in countries with high levels of gender inequality (UNFPA, 2019). Worldwide, women account for only 24.3 % of parliamentary positions (IPU, 2019). In the EU, despite strong variations between countries, the gender pay gap has been stagnating for several years (see Figure 2.27), with women's gross hourly earnings on average having been 16 % below those of men in 2017 (Eurostat, 2019a). This has also been reflected

Box 2.25 EU trend — Social vulnerability and environmental health hazards

Despite Europe's environment improving over recent decades (see Cluster 2), air pollution and noise as well as extreme temperatures continue to contribute to serious illnesses and premature deaths (EEA, 2018e). These impacts are not suffered equally across the European population, as socio-demographic differences influence significantly the impacts of these stressors on citizens' health. While individual characteristics and habits — such as health status, age, stress and fitness — define individuals' sensitivity to such pressures, their socio-economic status affects their ability to cope with such environmental health hazards, influencing for instance their ability to relocate to reduce their exposure to pollutants (EEA, 2018e). In 2017, slightly more than 22 % of the EU population was living in households at risk of poverty or social exclusion, and, despite the fact that the level of disposable income of households had increased in nearly all Member States, the goal of reaching pre-crisis levels is still unfulfilled in some (Eurostat, 2019e). Overall, at the EU-28 scale, the current figure (112.8 million in 2017) is still very distant from the target set by the EU for 2020 (96.2 million). It has been recently observed that, in many European regions — particularly southern and eastern Europe — social vulnerability overlaps with high levels of environmental health hazards, leading to negative health outcomes (EEA, 2018e). The effect of inequality is particularly visible at the city level, where affluent communities that enjoy a healthy environment are located next to neighbourhoods where health is heavily impacted by pollution (EEA, 2018e). Overall, the situation in the mid- to long term is not expected to improve, unless actions are taken. For example, pressures on water in cities are likely to increase, as a result of a combination of an increased urban population, over-abstraction, chemical pollution and increasing effects of climate change (Vandecasteele et al., 2019).

Figure 2.27 EU trends in gender pay gap in adjusted form, 2010-2017



Source: Eurostat (2020).

in a small improvement in the EU Gender Equality Index over the years (EIGE, 2019). **Gender-based violence** remains a harsh reality. It is estimated that 35 % of women worldwide have experienced either physical and/or sexual intimate partner violence or sexual violence by a non-partner at some point in their lives (UN Women, 2019). In the EU, 1 in 10 women has experienced sexual harassment or stalking through new technologies (EC, 2019e).

2.7.2.3 Welfare systems under pressure in Europe

In addition to persistent inequalities, a combination of demographic and economic factors is creating a perfect storm, jeopardising the sustainability of the European social model, which has become a fundamental part of European identity. Offering generous social protections and insurance against risks through income redistribution, unemployment benefits, universal health care, free education and retirement pensions, European welfare systems were largely put in place during the post-war boom, characterised by high growth, cheap energy, reconstruction and an optimistic mood. Today, however, the landscape has completely changed. On the one hand, ageing societies (Cluster 1), the **growing burden of disease** and additional investment needs driven by globalisation, innovation and competition (Clusters 4 and 5) demand **larger public expenditures**. On the other hand, sluggish economic growth, growing debt and financial crises (Cluster 5) as well as a narrowing fiscal base due to ageing (Cluster 1) reduce possible public revenues.

In Europe, **ageing** represents the most prominent demographic challenge (Lutz et al., 2019) (see Cluster 1). This means that a higher share of the population will be aged 65 years and above, while the share of the population aged between 20 and 65 years will reduce over time, leading to a situation in which an increased number of elderly people will depend on a smaller working population. The European Commission's projections suggest that the working-age population (people aged 15 to 64 years) will decrease from 65 % in 2016 to 56 % by 2070, with about two working-age people for every person over the age of 65 years (EC, 2017f). The **economic old age dependency ratio** (inactive 65-year-olds and over versus the employed aged 20 to 64 years) is projected to rise significantly from approximately 43 % in 2016 to approximately 68 % by 2070 in the EU (EC, 2017f), though with noticeable differences among Member States. An ageing population will pose a major challenge to the long-term sustainability of public finances related to public health and pension expenditure (Council of the European Union, 2018). At the same time, demand for infrastructure and services in cities, particularly concerning health care, mobility, education, housing, decent work and a safe environment and social policy, are likely to increase, brought about by an ageing EU population as well as the urban poor and vulnerable groups (e.g. migrants) (Lutz et al., 2019; UN DESA, 2018b), as well as by investments for climate mitigation and adaptation. However, for local and regional authorities, depopulation (see Cluster 1) entails major challenges, even more so than ageing (Gløersen et al., 2016). If not properly managed, population decline and shrinking may lead to challenges concerning maintenance of infrastructure and public services, leading to a territory more vulnerable to natural hazards.

In ageing economies, the elderly will probably have to work longer, and the shortfall in the workforce might have to be replaced by immigrants and automation (PwC, 2013), unless a shift in the tax base occurs. According to the European Commission projects that, in the long term, the net migration flows to Europe will not offset the trends in the shrinking of the working-age population in the EU (EC, 2017f). Neither increased migration nor increased fertility — along with support for larger families — both suggested as a remedy to the issue of ageing and workforce reduction, will stop population ageing (Lutz et al., 2019). Instead, rising labour force participation rates could offset the decline in the working-age population in the short term (less than 5 years), but total employment would start to fall after that date (EPRS, 2018a).

A reduction in **public revenues** could also be amplified by the increased automation and robotisation of the manufacturing sector, enabled by the uptake of ICT (see Cluster 4), and the consequent risk of technological unemployment (EEA, 2019d). This trend suggests that a shift in the tax base from labour towards resource use and/or pollution (e.g. increased tax in diesel fuel) could therefore be increasingly necessary in Europe, However, there is growing societal resistance to measures such as increased fuel taxation (e.g. Yellow Vests in France) because of their distributional effects, often penalising consumers and potentially leading to increased **inequality**. These aspects should be taken in consideration for ensuring the achievement of a 'just transition'.

2.7.3 Evolving governance challenges and approaches

2.7.3.1 Distrust in Western democracies and their institutions

The erosion of the European social model, the 2008 financial crisis, unemployment, migration, social and economic inequalities (real or perceived), worries about the downgrading of the West, higher individual expectations and fundamental disruptions brought about by technological advancements in **values, identities and social norms** have all contributed to a rapidly changing political landscape in Western societies. Together with the fragmented response provided by Member Countries and EU institutions on migration, alongside the long-lasting effects of the economic crisis, social inequalities (slightly less than one in four EU citizens are at risk of poverty or social exclusion), have created the conditions for the spread of societal delusion. In particular, the inability of existing political parties to respond efficiently to these concerns and challenges has largely fostered the **rise of populist movements** that promise to deliver better results. More fundamentally, a repolarisation of the partisan divide is emerging, with an ongoing shift from the traditional left versus right opposition towards a confrontation between nationalists (or self-proclaimed 'patriots') and 'globalists' (Haidt, 2016).

At a structural level, 'an information economy is likely to lead to the creation of **new voting blocs** [which] may become crucial elements of winning electoral coalitions' in Europe and elsewhere (EPRS, 2018a). Some likely voting blocs include newly upper-middle class professionals, former industry workers (including lorry and taxi drivers losing their jobs because of technological innovation), on-demand economy workers experiencing similar precarious working arrangements, rural voters (even though they will not be numerous), and the elderly, who will grow rapidly in numbers in the next decade (EPRS, 2018a).

The growing distrust of institutions is, however, not limited to political parties. The values and founding principles of our society are also challenged by the emergence of the so-called **'post-truth' trend**. Standards of public communication based on truth telling, which societies have taken decades or even centuries to establish, are becoming increasingly vague and negotiable (NIC, 2017). There is a clear argument that such behaviours have always existed, but recently they may have become increasingly recognised as 'digital technologies and social media are fundamentally reshaping the media landscape worldwide' (EPSC, 2019a). The acceleration of the information cycle has led to reduced time available for in-depth research and quality news, contributing to the explosion of dubious information and making it harder for citizens to distinguish between fact and fiction (EPSC, 2019a). For example, in Europe media amplification and overexposure of migration issues has also contributed to the development of misconceptions regarding the scale of this phenomenon. In 19 out of the 28 EU Member States, citizens estimate that the proportion of immigrants in the population is at least twice the actual proportion, while in some countries the ratio is much higher (EC, 2018k). Fast-spreading misinformation and **'fake news'** are posing a threat to democracy and efficient governance (NIC, 2017; Vosoughi et al., 2018), partly because false news appears to be spreading significantly 'faster, deeper and more broadly' than the true news, according to empirical evidence (Vosoughi et al., 2018). For example, an estimated two thirds of tweeted links to popular websites are posted by automated accounts — not human beings (Pew Research Center, 2018). Another aspect of the influence of pervasive social media in political and social discussion is the polarisation of debate and the creation of 'echo chambers' in which interest groups largely interact only with people with similar views (Calais Guerra et al., 2013), a trend which is growingly affecting academia as well, as search engines offer only a limited set of information to scholars. The influence of social media and the post-truth trend (real or perceived) is challenging the role of expertise, as well as the credibility of and trust in other established sources of authority (e.g. governments, policies, scientists) (NIC, 2017). Together with scientific misconduct and related scandals, the existence of power asymmetries in the production and use of evidence, has led to a legitimacy crisis in science for policy that calls for remediation (see Box 2.26).

2.7.3.2 Innovation in governance

Clearly, governance systems at all levels (global, national, and regional) are under increased pressure. Emerging economies and least-developed countries face their own challenges related to poverty reduction, conflicts and the advancement of democracy, and all countries are confronted with planetary issues such as climate change, environmental degradation and technological displacement. There is a **mismatch of scale** between the increasingly long-term, systemic and often transboundary challenges facing societies and the more limited focus and powers of governments. Existing approaches to governance tend to rely on simplicity, narrow issue focus and short-termism, which are inadequate to address sustainability issues (EEA, 2019e). Furthermore, whereas recent years have given birth to ambitious international agreements, including the Paris Agreement on climate change and the 2030 agenda for sustainable development, putting them into practice remains the key challenge. So far, the effectiveness of intergovernmental collaboration has often been questioned, in particular in relation to non-enforcement of agreed rules or commitments (EEA, 2015d). This is creating a need for new forms of governance and institutions at local, regional and global levels. As a response, governance systems are multiplying and diversifying. This is particularly because of the growing influence of **non-state actors**, such as non-governmental organisations, multinational firms,

Box 2.26 Uncertainty — Science, evidence and trust in public institutions: is there a crisis?

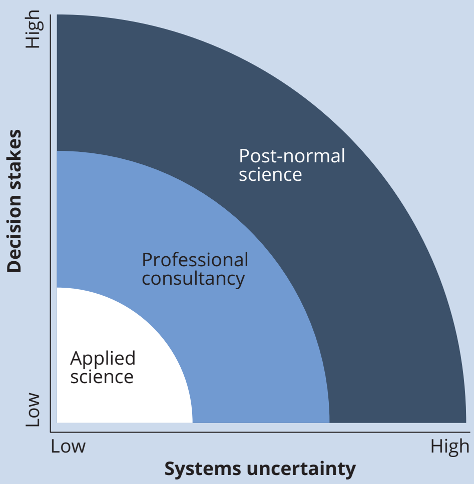
A legitimacy crisis is affecting science and the production and use of evidence for policy (Saltelli and Funtowicz, 2017). The inability to foresee the economic crisis and its devastating effects, as well as the multiple cases of corruption and malpractice in scientific research and policy, has negatively influenced the perception of the role of experts, expertise, and science and its institutions within society. As a result, trust in science and its institutions has inevitably eroded, along with trust in the underpinning mechanism of legitimation of political elites. While this has created opportunities for critical reflections and reformation, it has also led to attacking the foundations of Western democracies. In response to this, there is an increased attitude adopted by institutions and the public in defending the role of science and the underpinning mechanism of knowledge production at all costs, without recognition of internal inconsistencies and fallacies (Saltelli, 2018). These trends resulted in increased polarisation in society, often between 'science deniers' and 'science believers' (Saltelli, 2018).

From a science-for-policy perspective, it is important to recognise that, while science has a fundamental role to play, 'evidence-based policy' is largely based on a paradigm that 'seeks to understand the world in order to be better able to predict and control a volatile and uncertain external environment and in doing so, assume an objective or detached position in relation to the phenomena under observation' (Preiser et al., 2018). However, this assumption of objectivity marginalises considerations of values and subjective experience (Hammond, 2005) that is proper of sustainability challenges. Decisions regarding climate change, vaccines, biodiversity loss, genetically modified crops and environmental health risks, are often contested, as these challenges are characterised by uncertain facts, values in dispute, high stakes and urgent decisions (Funtowicz and Ravetz, 1993). Under these circumstances it is problematic to make truth claims from the assumption of objectivity (Rogers et al., 2013), as there is no purely 'scientific' solution to such problems. In fact, the suitability of one particular solution is often dependent on the perspective of the observer (Funtowicz and Ravetz, 1993; Funtowicz et al., 1999) as scientific findings and insights alone cannot resolve ethical questions surrounding sustainability issues. Only people can on the basis of their world views, values and beliefs (Vries, 2013). Scientists and their institutions make no exception to this.

In recognition of these issues, the 'Post-Normal Science' paradigm (Funtowicz and Ravetz, 1993) (see Figure 2.28), has been proposed as a useful concept to ask pertinent questions at the science-policy interface under conditions of high uncertainty and complexity, as it warns 'against the reduction of political/practical problems to technical ones, and against the artificial separation of facts and values at the science-policy interface', while promoting problem-solving by deliberative extended peer communities where different kinds of actors and knowledge are brought to bear (Saltelli, 2018).

As reported by Saltelli (2018), in order to reconcile the divide that has grown within society and remedying the ongoing drift in trust, science and policy institutions should probably consider to: 1) 'rebalance power asymmetries in the use of evidence' (Laurens, 2017) in order to avoid that 'the actors with the deepest pockets buy the science they need, frame issues according to specific agendas and enforce these on the rest of society', as currently occurring (Drutman, 2015; Laurens, 2017; Saltelli and Giampietro, 2017); 2) as well as increase transparency and accountability by engaging in debate and dialogue with an 'extended peer community' (Funtowicz and Ravetz, 1997), composed indeed of experts and key stakeholders, but also as citizens and civil society at large.

Figure 2.28 The Post-Normal Science diagram



Source: Funtowicz and Ravetz (1993).

digital communities, transnational networks and social media platforms, which are creating new rules and expectations in society in spheres of accountability and transparency (Scherer and Palazzo, 2011; Flew, 2015). Social networks are empowering these actors — for better or for worse — as social media potentially creates platforms for mass manipulation (Confessore et al., 2018). Another downside is that non-state actors are potentially threatening democratic processes, as they are often unelected and unaccountable, and not always transparent (EEA, 2015a).

Another emerging phenomenon is the **increasing 'glocalisation' of governance**, which is seeing in particular an increased role for global governance and institutions and local governments, with a declining and secondary role for national and provincial levels of government. **City networks** and associations already have a recognised role in shaping global agreements, including climate and sustainability (Vandecasteele et al., 2019). This is reflected in Europe through, for example, the Covenant of Mayors in Europe — a transnational European grouping of local government (city level) established to better implement EU level climate and energy policies (Covenant of Mayors, 2019). There is a wider trend in the **empowerment of city governance** (Cluster 1) with cities, and particularly megacities, gaining autonomy, setting social and economic standards, and becoming increasingly important subnational actors. The concept of 'polycentric governance', which consists of multiple governing bodies interacting to make and enforce rules across scales, is gaining traction in the context of collective actions for fighting climate change (Jordan et al., 2018). In Europe, with growth in **decentralised energy solutions**, cities and neighbourhoods could become more important in collective decisions about energy production, supply and consumption, potentially leading in the future to the emergence of city-level energy networks. Also, experimentation activities in cities, such as establishing a network of 'European living labs', have been suggested as a useful way to test innovative mobility solutions with the direct involvement of people. This would allow decision-making to explicitly take into account citizens' visions and needs (Alonso Raposo et al., 2019), including moral, ethical, environmental and legal concerns associated with the uptake of new technologies in cities (e.g. driverless mobility).

3 Reflections on Europe's ambition for a sustainable future

3.1 What could this mean for Europe?

The global-European landscape is changing significantly. Continued economic growth, along with technological innovation, has led to substantial benefits, such as lifting millions of people out of poverty in China and India, reducing child mortality and allowing the world population to grow older than ever before. However, increased production and consumption of goods and services, especially through international trade, has led to growing consumption of resources, loss of global biodiversity and natural capital, widespread pollution of the environment and increasingly severe impacts of climate change, despite the establishment of international agreements. The world is not becoming less unequal, poverty and famine are still affecting a large share of global population, and wars, terrorism and displacement are still a daily reality for many. Sustainable Development Goals (SDGs) and related targets for 2030 appear to be far from reach.

Although many uncertainties concerning the direction of such changes remain, one message is clear for Europe: its role in the global arena is changing, and this creates new risks and opportunities of an environmental, social, economic and strategic nature. At the same time, Europe is faced with internal challenges, as the European project is being challenged as it never has been before. A number of factors are contributing to this, including the rise of populism in the West; persisting social inequality and the long-lasting effects of the financial crisis; the shrinking role of the European economy, compared with new economic powers; sluggish economic growth and tensions associated with trade wars; increased old-age dependency ratio and new health challenges; the emergence of a regime of socially contested facts (e.g. 'post-truth') and growing polarisation across society; potential instability in neighbouring regions (e.g. eastern European countries, southern Mediterranean regions and the Middle East); and the accelerating role of technology, digitalisation and connectivity in all spheres of life.

Concerning environmental aspects, while environment and climate policies of the EU have delivered substantial benefits since their inception in the 1970s, Europe faces persistent problems in areas such as biodiversity loss, resource use, climate change and environmental risks to health and well-being, as recently emphasised by *The European environment — state and outlook 2020* (SOER 2020) report (EEA, 2019e). Although progress in reducing some key environmental pressures has been made (e.g. some emissions to air), policies have had a clearer impact on reducing some environmental pressures than on protecting ecosystems and biodiversity, human health and well-being (EEA, 2019e). The outlook towards 2030 is not positive in many areas, particularly in relation to natural capital; moreover, the prospects of meeting policy objectives and targets show that Europe is either not on track or only partially on track to achieving the majority of objectives and targets (EEA, 2019e). New implications for health and well-being, the security of the resource base underpinning Europe's economy and our ability to protect nature and biodiversity are likely to unfold because of multiple drivers of change.

Along with the challenges described above, there is growing recognition that the prevailing model of economic development — globally and particularly in Western societies — cannot be sustained indefinitely, given the high pressures and the impact that they generate, and that fundamental transformations of our systems of production and consumption are needed (EEA, 2014a, 2015c, 2019e). Europe has the opportunity to respond to this call.

3.2 Responding to sustainability challenges

The EU is among the strongest economic powers in the global arena, exerting substantial influence on regional and global developments. Together with its Member States, it has the opportunity to respond to the challenges of a changing global and European landscape and secure its citizens' standard of living, including socio-economic development and job creation. However, the effectiveness of the responses will largely depend on which choices are made, now and in the long term. European citizens and their representatives, as well as a variety of actors across society, including citizens, civil society and entrepreneurs, are called to action to respond to the challenges, chase opportunities and anticipate and mitigate risks.

Policymakers, by establishing policy frameworks and regulations, as well as by orienting fiscal instruments and international cooperation, can act in anticipation to prevent issues and unintended outcomes and to contribute to reducing environmental pressures associated with European production and consumption that occur in Europe or elsewhere. Similarly, citizens and civil society now have greater opportunities not only to engage in societal innovations, through experimentation with different behaviours and lifestyles but also to re-discuss established framings and contribute to redefining priorities. New business models and social innovations driven by environmental concerns are also emerging. These concern initiatives such as self-production of food and energy, the sharing economy and achieving lower consumption levels (e.g. sufficiency). It appears that 'green' considerations are much more widespread among new generations. Nevertheless, these new norms are often largely confined to niches. Some of these new models also entail risks, trade-offs and burden-shifting when scaled up beyond local initiatives, and their overall social and environmental benefits become less clear (e.g. the rise in travel associated with cheaper accommodation, achieved through house-sharing platforms).

The EU could decide to continue its efforts in pursuing sustainability leadership in the international arena, contributing to pushing forward societal change by leading by example on addressing environmental issues. Nevertheless, policies in the EU will only have a limited impact on the planet if others pursue opposing strategies (e.g. the EU contributes 8.5 % of global emissions of greenhouse gases; Olivier and Peters, 2020), and therefore international cooperation will be increasingly important. At the same time, Europe also causes significant spill-over effects outside its territory, for example through trade, leading to environmental degradation and social impacts, which may hinder the achievement of the SDGs at the global scale and should therefore be mitigated.

Moreover, Europe is a continent with a broad variety and diversity of cultural heritage and social practices, characterised by a significant variety of landscapes and ecosystems. The relative magnitude of implications for countries will largely depend on the variability and specificity of local environmental, economic and social conditions. Some trends might have a strong regional or local connotation, and implications may necessitate a regional- or country-specific response, often of a territorial character (e.g. climate change adaptation plans, infrastructural investments, land use planning).

However, the ability of individual countries to respond will be limited in the face of major developments (e.g. concerning technological innovation — synthetic biology, artificial intelligence, robotisation, big data) and will benefit from coordinated European responses (e.g. regulation of innovation). In fact, sustainability challenges, because of their systemic nature, cannot be tackled in isolation. Economic, social and environmental challenges — such as growing economic inequality, climate change and environmental degradation, geopolitical tensions and governance of the digital transformation of the economy — are increasingly complex and interconnected and cannot be tacked other than through international cooperation (see also WEF, 2019).

The EU has largely recognised these issues and in response has committed to a number of long-term and ambitious environmental and sustainability goals. It has set itself an ambitious vision for 2050, with the aim of 'living well, within the limits of our planet' (EU, 2013). Moreover, alongside the vast majority of countries worldwide, it has committed to achieving the SDGs by 2030 as well as ambitious targets for climate, biodiversity and resource use (EEA, 2019e). These goals and related targets are now increasingly integrated into EU policymaking (EC, 2019f). Policy frameworks such as the Carbon-neutral Economy (EC, 2018i), the Circular Economy Action Plan (EC, 2015b) and the Circular Economy package (EC, 2018d, 2018e, 2018g, 2018h) and the Bioeconomy Strategy (EC, 2018a), apart from ensuring a reliable resource base for a competitive European economy, hold the promise of reducing environmental pressures in Europe and elsewhere, contributing to achieving the SDGs. Similarly, both the political guidelines of the European Commission's new president (Von der Leyen, 2019) and the Commission's Green New Deal (EC, 2019c) indicate that environment and sustainability stewardship is a priority for the EU, as confirmed by the Commission's new president , Ursula von der Leyen, who indicated that 'the European Green Deal is our new growth strategy' (Euractiv, 2019).

Yet, many of these persistent problems resist traditional policy responses, as they are intrinsically linked to unsustainable but well-established patterns of production and consumption. If Europe is to achieve the SDGs, the Paris Agreement and the 2050 vision, it needs to fundamentally transform its core production and consumption systems, in particular those related to food, energy and mobility (EEA, 2019e), as well as the built environment (EC, 2019f). This requires rethinking not just technologies and production processes but also consumption levels and social practices (EEA, 2019e). Furthermore, the scale, depth and speed of change needed imply that careful attention should be paid to the social implications of these transformations, in particular the distributional aspects (EC, 2019f).

Moreover, the analysis of the drivers of change suggests that a reconciliation between well-being and environmental goals may not be achievable without a fundamental reconfiguration of the economic system and consumption patterns, as well as a reduction in overall consumption levels. In fact, a growing economy is directly or indirectly associated with a growing demand for resources and environmental pressures. There is no empirical evidence that an absolute, permanent and sufficiently fast decoupling is occurring at all at the global scale. Instead, a fundamental change in the dominant socio-economic paradigm would be needed to 'bend the trends', given the scale of the challenges. Moving away from efficiency and decoupling and embracing sufficiency as a guiding principle could be a fundamental ingredient in reducing environmental pressures.

Such radical change is fundamentally at odds with the dominant socio-economic paradigm underpinning Western standards of living. In contrast, innovation in social practices targeting a reduction in consumption levels, such as sharing goods, reusing and repairing them, and a shift towards healthier and more sustainable diets and sober lifestyles away from consumerism, would be needed to sensibly reduce environmental pressures and reverse the trends. Unless pursued at the international level, this change in orientation will not naturally occur, as economic growth remains by far the main preoccupation of governments. Nevertheless, the paradigm of 'infinite growth' is being increasingly challenged and presented as both a physical impossibility and an inadequate response to societal and environmental challenges. Protesters are putting pressure on policymakers, by calling for urgent actions and a change in priorities and requiring a stepping-up of efforts to protect Earth's climate and ecosystem, as well as for the protection of the most vulnerable components of the society. The perspective of reducing consumption may not be particularly appealing to a significant share of the population, especially those suffering because of inequality and a lack of opportunities. Sustainability transitions should be just and fair ones, not only aiming for reduced environmental impacts in Europe. European policymakers will have to balance these perspectives towards a sustainable and just transitions, while navigating the more uncertain and complex global landscape.

3.3 Looking ahead

All of the changes described in the previous chapter, being of a demographic, social, economic, technological, geopolitical or environmental character, are likely to lead to both challenges and opportunities for the EU and its Member States. Their nature and likelihood is, however, rather uncertain, complex and controversial. The success or failure of European policy in addressing sustainability issues, including achieving Europe's ambition to 'live well, within the limits of our planet', will depend, among other things, on its ability to respond to global-European changes by anticipating potential future issues and providing timely responses. Identifying potential implications associated with drivers of change, and particularly their effect on environmental, social and economic components, is and will be of crucial importance.

The EEA, by further building on foresight, systems thinking and its established forward-looking activities, as well as increasing cooperation with institutional actors and stakeholders, and its network of countries (European Environment Information and Observation Network, Eionet), will pursue its exploration of the potential implications of drivers of change, to contribute to expanding the knowledge base and raising awareness among European policymakers.

In particular, future EEA activities will continue the exploration of implications initiated in this report, by focusing on the key priority areas identified by the European Commission's vision of a sustainable Europe by 2030 (EC, 2019f), namely 'From linear to circular economy'; 'Sustainability from farm to fork'; 'Future-proof energy, buildings and mobility'; and 'Ensuring a socially fair transition', with the aim of supporting the development of robust, coherent and adaptive policies aimed at achieving Europe's environment and sustainability goals.

Abbreviations

AI	Artificial intelligence
CCS	Carbon capture and storage
CRM	Critical raw material
EEA	European Environment Agency
EEA-33	33 EEA member countries (the 28 EU Member States plus Iceland, Lichtenstein, Norway, Switzerland and Turkey)
Eionet	European Environment Information and Observation Network
EPRS	European Parliamentary Research Service
EPSC	European Political Strategy Centre
ESPAS	European Strategy and Policy Analysis System
EU-28	28 EU Member States
FDI	Foreign direct investment
GDP	Gross domestic product
GHG	Greenhouse gas
IAM	Integrated assessment model
ICT	Information and communications technology
IEA	International Energy Agency
IoT	Internet of Things
IRP	International Resource Panel
IP	Intellectual property
JRC	Joint Research Centre of the European Commission
NATO	North Atlantic Treaty Organization
NO_x	Nitrogen oxides
NRC FLIS	National Reference Centres for Forward-looking Information and Services

NUTS	Nomenclature of Territorial Units for Statistics.
OECD	Organisation for Economic and Co-operation and Development
POP	Persistent organic pollutant
PPP	Purchasing power parity
R&D	Research and development
SDG	Sustainable Development Goal
SOER	The European environment — state and outlook report
STEEPV	Society, technology, economy, environment, politics and values (framework)
UN	United Nations
UN DESA	United Nations Department of Economic and Social Affairs
WEEE	Waste electrical and electronic equipment
WTO	World Trade Organization

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European Environment Agency

Drivers of change of relevance for Europe's environment and sustainability

2020 — 133 pp. — 21 x 29.7 cm

ISBN 978-92-9480-219-4
doi:10.2800/129404

TH-AL-20-008-EN-N
doi:10.2800/129404

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