01.

Assessing the global-European context and trends

Summary

- The period after the 1950s marks a unique period in human history in terms of human-induced global change and economic activity. This 'Great Acceleration' has delivered enormous improvements in living standards and well-being for millions of people.

- In turn, this has caused dramatic degradation of ecosystems and exceptionally rapid loss of biodiversity, including in Europe. Many of the changes observed in the global climate system since the 1950s are unprecedented over decades to millennia and largely caused by human activities. In addition, many known pollution problems persist, while new ones, such as certain types of chemical pollution, are emerging.

- In an increasingly interconnected world, Europe is influenced by multiple drivers of change. These can be characterised as global megatrends, more European-specific trends or emerging trends with potentially significant impacts. They include an ageing population in Europe, changing migration patterns, increasing inequalities, global competition for resources, the implications of accelerating digitalisation and other technological changes, and changing lifestyles. Many of these drivers have important influences on Europe's long-term environmental outlook.

- Through trade, European production and consumption patterns contribute significantly to environmental pressures and degradation in other parts of the world. Depending on the type of resource, the associated total environmental footprint of European consumption that occurs outside Europe is estimated to be in the range of 30-60 %.

- In conclusion, Europe, in common with other advanced economies, has achieved high levels of human development ('living well') but at the expense of being not environmentally sustainable. Europe currently does not live up to its 2050 vision of 'living within the limits of our planet'. This calls for fundamental changes in lifestyles, production and consumption, knowledge and education.

01.

Assessing the global-European context and trends

1.1 The Great Acceleration

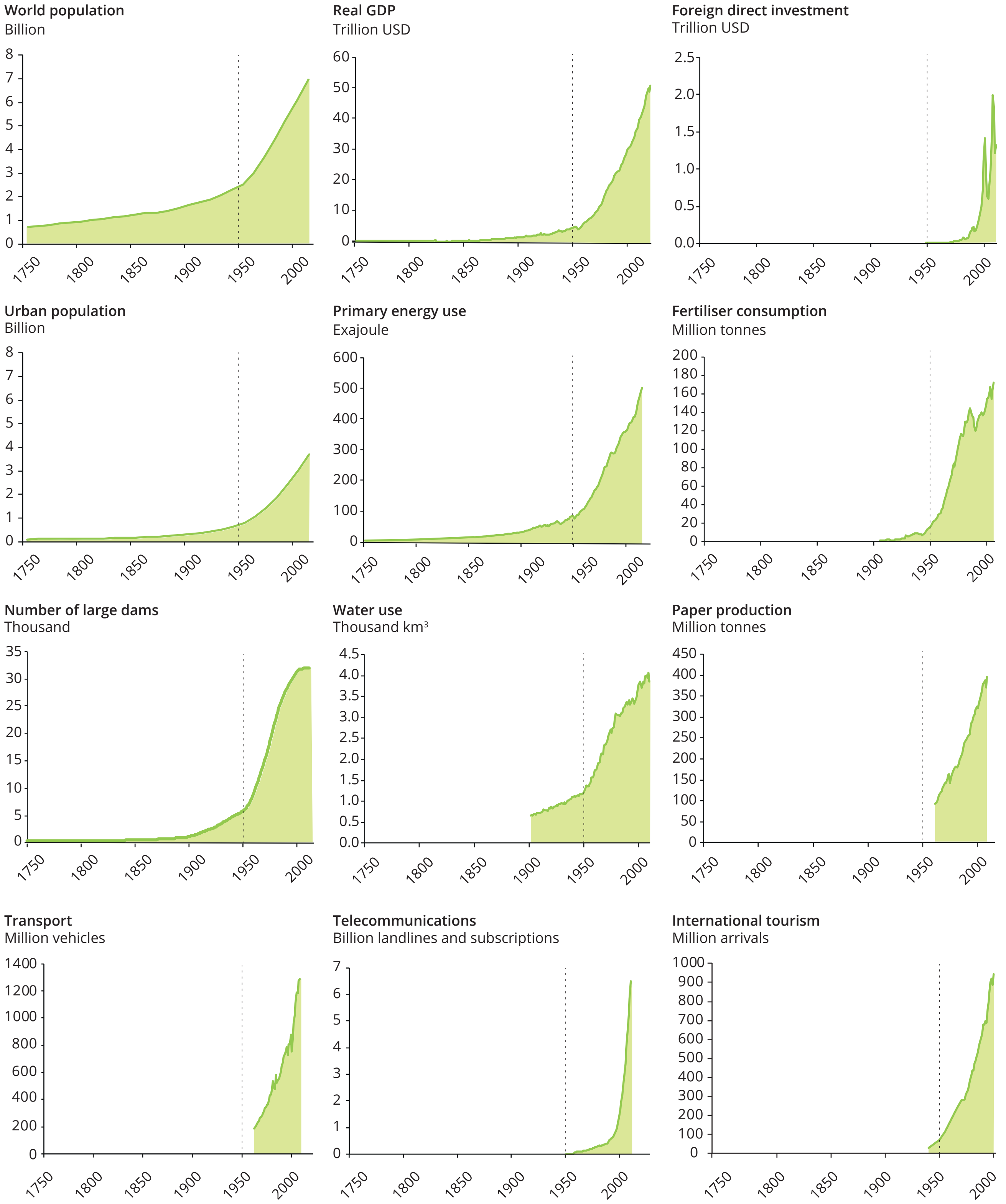
Many key human achievements — culture, farming, cities, industrialisation, medical advances — have happened during a period in which the Earth's natural regulatory systems, such as the climate, have been remarkably stable. This period spanning the last almost 12 000 years is referred to as the Holocene. However, the onset of the Industrial Revolution around 1760 was accompanied by an increasing pace of change in human development and associated environmental degradation and destruction.

In particular, the period after the 1950s marks 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, 2015b) (Figure 1.1). The global human population has tripled (from around 2.5 billion to some 7.5 billion today) (UNDESA, 2017c); the number of people living in cities has more than quadrupled (from less than 1 billion to more than 4 billion today) (UNDESA, 2018); economic output in terms of gross domestic product (GDP) expanded 12-fold between 1950 and 2016 (Bolt et al., 2018); fertiliser consumption of nitrogen, phosphate and potassium increased 12-fold between 1950 and 2010 (from 14.5 to 171.5 million tonnes in 2010); and primary energy use increased by almost a factor of five from 1950 to 2008 (from 112 to 533 exajoules) (Steffen et al., 2011, 2015b). In addition, as a result of increased welfare and prosperity, international tourism is now one of the largest and fastest growing economic sectors globally with a total of 1.18 billion international tourism arrivals in 2015 (UNWTO, 2017).

> Since the 1950s there has been unprecedented and accelerating human-induced global change, causing tremendous pressures on Earth.

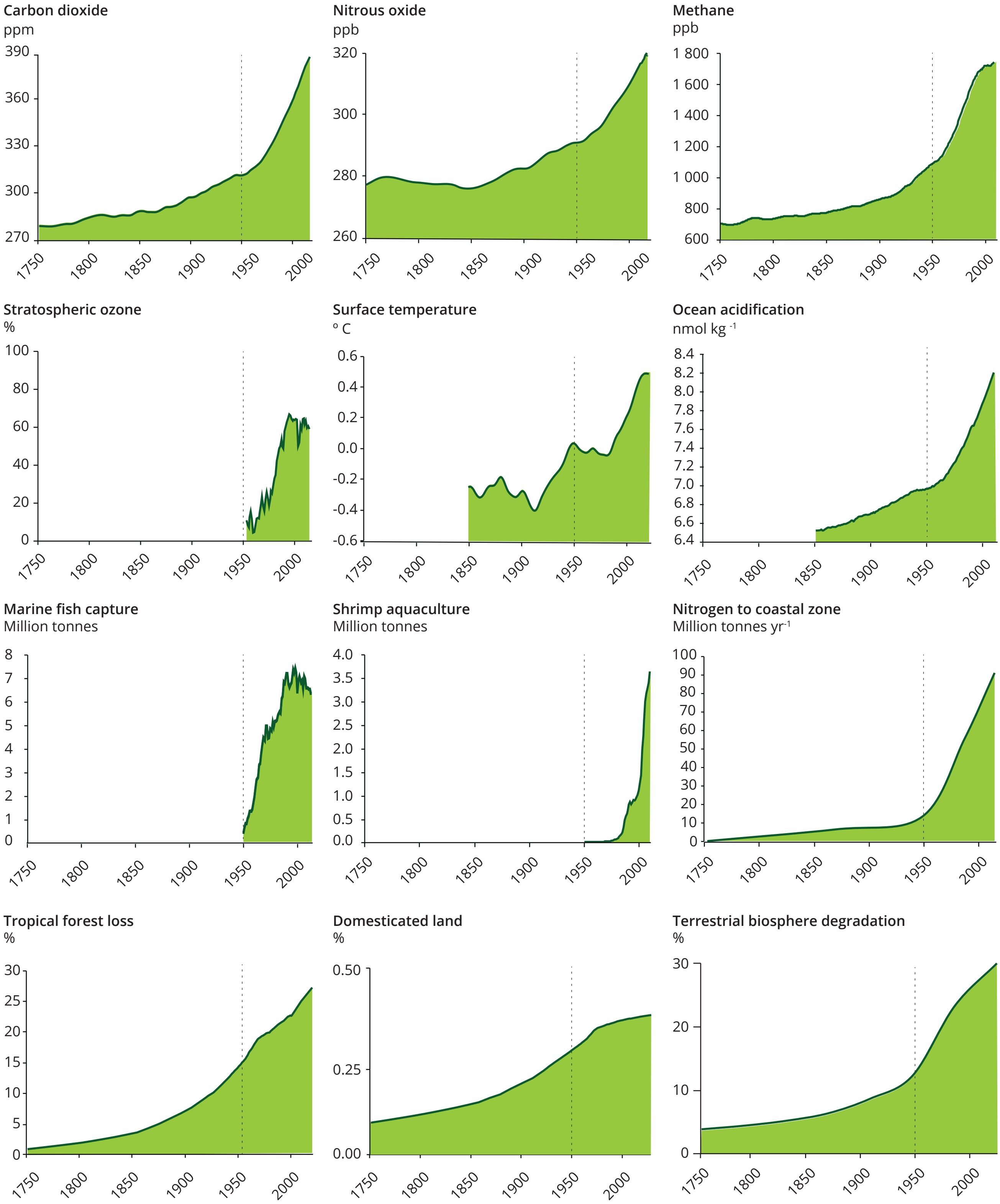
This exponential trajectory of human activity and economic growth has delivered enormous improvements in living standards and well-being for hundreds of millions of people, especially in Europe and other highly industrialised world regions. Other world regions have also benefited from this growth. For example, the percentage of the world's population living in extreme poverty (i.e. living on under USD 1.90 a day, based on the US dollar exchange rate of 2011) has dropped from 42 % in 1981 to about 10 % in 2013 (World Bank, 2018b). The prevalence of stunting among children under 5 years old due to malnutrition has dropped from almost 40 % in 1990 to 22 % in 2017 (World Bank, 2018c). However, at the same time the sheer size of the global population 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, etc. Change is occurring

FIGURE 1.1 Indicators for global socio-economic development and the structure and functioning of the Earth system



Note: GDP, gross domestic product.

Source: Steffen et al. (2015b).


Carbon dioxide
ppm
Nitrous oxide
ppb
Methane
ppb
Stratospheric ozone
%
Surface temperature
° C
Ocean acidification
nmol kg -1
Marine fish capture
Million tonnes
Shrimp aquaculture
Million tonnes
Nitrogen to coastal zone
Million tonnes yr-1
Tropical forest loss
%
Domesticated land
%
Terrestrial biosphere degradation
%
1750
1800
1850
1900
1950
2000

The loss and degradation of our natural capital is detrimental to human development.

at a scale at which human activities have now significantly altered the Earth system from the stable Holocene to a new human-dominated epoch referred to as the Anthropocene (Waters et al., 2016).

Twenty-five years after the first 'world scientists warning to humanity', 15 000 scientists recently issued a second warning, stating that:

Humanity has failed to make sufficient progress in generally solving these foreseen environmental challenges, and alarmingly, most of them are getting far worse. Especially troubling is the current trajectory of potentially catastrophic climate change due to rising greenhouse gas (GHG) emissions from burning fossil fuels, deforestation, and agricultural production — particularly from farming ruminants for meat consumption. Moreover, we have unleashed a mass extinction event, the sixth in roughly 540 million years, wherein many current life forms could be annihilated or at least committed to extinction by the end of this century (Ripple et al., 2017, p. 1026).

In the most recent *Global risks report 2019* by the World Economic Forum, environmental risks accounted for three of the top five risks by likelihood and four of the top five by impact (WEF, 2019).

1.2 Unprecedented pressures on planet Earth

Human activities have caused consistent widespread reductions in species populations and the extent and integrity of ecosystems (IPBES, 2019; UN Environment, 2019). The Intergovernmental Platform for Biodiversity and Ecosystem Services (IPBES) estimates that 75 % of the terrestrial environment and 40 % of the marine environment are now severely altered globally (IPBES, 2019). The Earth has experienced exceptionally rapid loss of biodiversity and more species are threatened with extinction now than at any other point in human history (IPBES, 2019). The abundance of wild species has declined drastically, both globally and in Europe (Chapter 3) — 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 the sixth mass extinction of Earth's biota is already under way (Leakey and Lewin, 1996; Ceballos et al., 2015). Across the oceans, the cumulative impacts of resource extraction and pollution have increased causing a decline in the health of marine ecosystems (IPBES, 2019). At present, 31 % of global fish stocks are overfished (FAO, 2016), and plastic pollution is increasing, with an estimated 4.8 to 12.7 million tonnes of plastic waste entering the ocean annually (Jambeck et al., 2015).

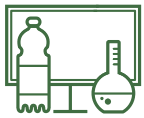
In addition to its intrinsic value, this unprecedented loss and degradation of Earth's natural capital ([1]) is detrimental to human development. Biodiversity and ecosystems and their services — the benefits people derive from nature — are fundamental for the existence of human life on Earth, through providing food and feed, fibre, energy, medicines, genetic resources; regulating the quality of air, fresh water and soils, regulating climate, pollination, pest control and reducing the impact of natural hazards; and providing inspiration and learning, and physical and psychological experiences (IPBES, 2019). Currently, degradation of the Earth's land surface through human activities is negatively impacting the well-being of at least 3.2 billion people (IPBES, 2018). The increasing demand for more food, energy and materials comes at the expense of nature's ability to provide such services in the future and frequently undermines many of the services that underpin almost every aspect of human well-being (IPBES, 2019). That means that humanity is running up an ecological debt that threatens the Earth system's ability to meet the needs of future generations and thereby jeopardises sustainable development, globally and in Europe. In 2020, it is envisaged that an ambitious post-2020 global biodiversity framework will be adopted in the context of the Convention on Biological Diversity to deal with these challenges.

Likewise, many of the observed changes in the global climate system since the 1950s are unprecedented over decades to millennia and largely caused by human activities such as GHG emissions from fossil fuel burning, agriculture and deforestation (IPCC, 2013a). For example, atmospheric concentrations

([1]) In this report, natural capital is used in line with the definition in the 7th EAP, i.e. it represents 'biodiversity, including ecosystems that provide essential goods and services, from fertile soil and multi-functional forests to productive land and seas, from good quality fresh water and clean air to pollination and climate regulation and protection against natural disasters'. A structured and complete definition of natural capital was developed under the EU MAES process. This distinguishes more explicitly abiotic natural capital and biotic natural capital (i.e. natural capital in the 7th EAP) and their respective components (see also Figure 1.1 in EEA (2018)).

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, 2013a). The Intergovernmental Panel on Climate Change (IPCC) confirmed that it is extremely likely that these increases in greenhouse gas concentrations due to human activities have caused most of the observed changes in the climate system (IPCC, 2013a). The global average annual near-surface temperature in the period 2006-2015 was 0.87 °C higher than the pre-industrial average (IPCC, 2018). The minimum extent of Arctic sea ice has declined by about 40 % since 1979. In many world regions, including Europe, increases in the frequency and intensity of extreme climate events such as droughts and heavy precipitation have been observed (IPCC, 2013b). Europe is also vulnerable to climate change impacts occurring outside Europe. In the coming decades, the economic effect on Europe of such impacts could potentially be very high, and Europe can expect to face challenges from increased climate-induced human migration and increased geopolitical and security risks in neighbouring regions (see EEA (2016) and Chapter 7).

Without drastic emission abatement measures in the coming two to three decades, continued global warming will increase the likelihood of severe, pervasive and irreversible consequences such as the collapse of natural ecosystems (the Arctic, coral reefs, the Amazon forest) (Box 1.1) and the erosion of global food security or displacement of people at unprecedented scales (Chapter 7). Pathways reflecting the full implementation of current mitigation ambitions, as submitted by all countries 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 reductions in emissions, the goal of achieving a global temperature increase well below 2 °C becomes out of reach (IPCC, 2018; UNEP, 2018). In this context, the recent EU strategy for a climate-neutral economy by 2050 in Europe (EC, 2018b) is an important contribution and step forward.



Many known pollution issues persist, while new ones are emerging.

Apart from continuing ecosystem destruction and the increasingly severe consequences of climate change, many known pollution issues persist while new ones are emerging. Pollution from plastic, electronic waste (e-waste) and chemicals are of increasing concern globally and in Europe (Chapters 9 and 10). By 2050, there could be as much plastic (by weight) as fish in the world's oceans (WEF et al., 2016), and the impact of microplastics on the food chain is expected to be substantial. E-waste, containing numerous hazardous toxins, has a current annual global growth rate of 3-4 %. In 2016, Europe was the second largest generator of e-waste per person (16.6 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 (Chapter 10).

A clean environment is essential for human health and well-being. Current levels of pollution are detrimental to human health, and approximately 19 million premature deaths are estimated to occur annually as a result of pollution of air, soil, water and food globally (UNEP, 2017b). In Europe, strong reductions in air emissions or peak exposure to ozone 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 through long-range transport and can be reduced only through internationally coordinated action (UNECE, 2016). While air quality has slowly improved in many of Europe's cities, many cities and regions still experience exceedances of the regulated limits (Chapter 8). In addition, noise is an emerging human health issue (Chapter 11), while climate change, depletion of stratospheric ozone, loss of biodiversity, etc., also adversely affect human health.

Moreover, human activities have substantially altered biogeochemical cycles. For example, the modification of the nitrogen cycle, mainly due to fertiliser use in agriculture, is far greater in magnitude than the modification of the global carbon cycle as a result of GHG emissions (OECD, 2018a). The release of excessive nitrogen into the environment contributes to eutrophication in freshwater bodies and coastal areas, and atmospheric emissions of nitrogen pose considerable human health risks (OECD, 2018a).

Ecosystem degradation and biodiversity loss, climate change, pollution loads and other global environmental challenges are intrinsically interlinked through numerous feedback loops at multiple scales. For example, increasing levels of global warming will exacerbate biodiversity loss and further erode the resilience of ecosystems. At the same time, global warming will increase the likelihood of extreme climatic events such as droughts and floods, which in turn amplify pressures on freshwater systems. These changes in turn put pressure on land resources through

When will human-induced pressures exceed environmental limits or tipping points?

aridification or increased loss of forest cover, which further contributes to accelerating climate change. These multiple interdependencies between environmental systems are intertwined with societal needs such as food production, energy security, and freshwater supply, adding an additional layer of complexity. For example, the food system is a major driver of biodiversity loss, land and soil degradation and GHG emissions and a polluter of air, freshwater and oceans through eutrophication (UN Environment, 2019). The systemic character of environmental challenges and their links to systems of production and consumption such as the food system will be explored further in Part 3.

The continuation of the Great Acceleration due to rising consumption levels by a growing population raises the critical questions of whether and at what point human-induced pressures exceed environmental limits or tipping points (Box 1.1). Are there certain critical limits — for example related to global resource use, levels of pollutants and emissions, or ecosystem degradation — beyond which resilience is eroded and abrupt changes in the Earth system can no longer be excluded? In this context, the planetary boundary framework examines the tolerance levels of the Earth's life support systems and has identified climate change and biodiversity loss as issues of serious concern (Box 1.2). Climate change and biodiversity loss are intrinsically linked, as they are influenced by many of the same indirect and direct socio-economic drivers. In turn, certain systemic responses such as ecosystem-based approaches are important for both climate change mitigation and adaptation as well as increasing ecosystem resilience (Chapter 17).

1.3 Drivers of change

Europe has played a pivotal role in shaping global changes over the last 50 to 70 years (Section 1.1) and is today intertwined with the rest of the world in numerous ways, for example through trade, financial flows or geopolitical processes. This means that Europe and its environment are influenced by multiple drivers of change at various scales. These can be characterised as global megatrends — large-scale and high-impact trends — (EEA, 2015), more European-specific trends or emerging trends with potentially significant impacts.

Some of the multiple and highly interconnected drivers of change are environmental and climate related, others are social, economic, technological or political. Many of the non-environmental drivers of change have strong impacts on the environment and climate and are of key importance in determining Europe's long-term environmental outlook. Therefore, drivers of change are an important part of the context for European environmental policymaking aimed at developing responses to today's systemic environmental challenges.

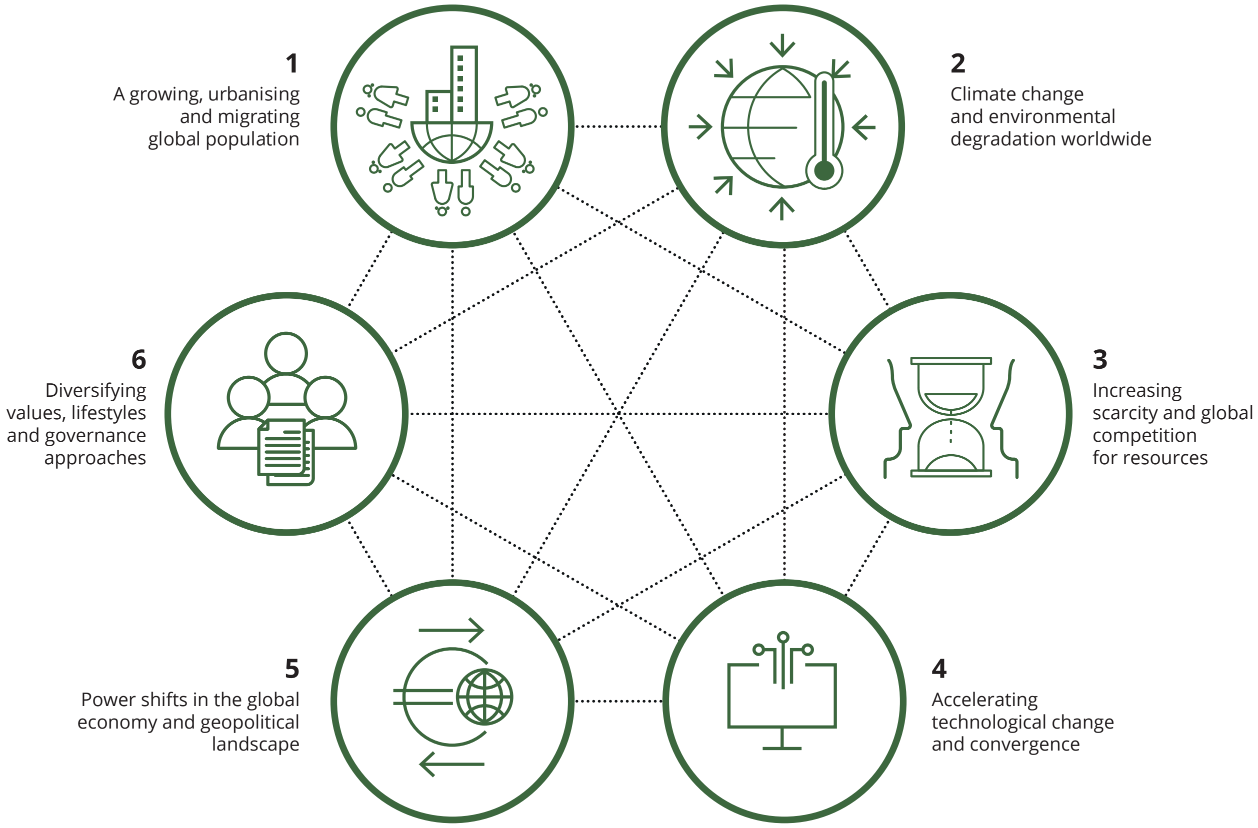
There are multiple options for identifying and grouping drivers of change into overarching thematic clusters, depending on the purpose and thematic emphasis. Possible foci can be technology (OECD/DASTI, 2016), economic aspects (WEF, 2017) or geopolitics (ESPAS, 2017). This report draws upon a synthesis of drivers of change from the perspective of Europe and its environment (EEA, forthcoming), which goes beyond previous EEA work on global megatrends (EEA, 2010, 2015) to include more European-specific trends and emerging trends. Six broad clusters of drivers of change have been distinguished (Figure 1.2). While aspects related to climate and global environmental degradation (cluster 2) are described in Section 1.3, the non-environmental clusters are briefly described below. A more detailed assessment, including potential implications on Europe's environment and society, be will provided in a forthcoming EEA report (EEA, forthcoming).

1.3.1 Cluster 1: A growing, urbanising and migrating global population

The world population exceeded 7.5 billion people in 2017, and it is projected to reach 9.8 billion by 2050 with most of the projected growth in developing countries (UNDESA, 2017c). In Africa, the population is projected to double from currently 1.3 billion to 2.5 billion by 2050 (Figure 1.5). On the contrary, Europe is confronted with ageing populations, albeit with differences in the projected trends among EU countries (EC, 2017b). In the 28 EU member States (EU-28), almost 35 % of the population is expected to be 60 or older in 2050 (UNDESA, 2017c). This raises questions about a shortfall in working-age adults and poses challenges for social stability, (environmental) taxation and public health systems.

Urbanisation and urban sprawl are expected to further increase globally, with a projected 68 % of the world's population living in cities by 2050 compared with 55 % today (UNDESA,

FIGURE 1.2 Clusters of drivers of change



Source: EEA.

2018). Africa and Asia together are projected to account for almost 90 % of the estimated 2.5 billion increase in global urban population by 2050 (UNDESA, 2018). In Europe, urban growth is projected to be slower than in Asia and Africa, and the share of Europeans living in cities is estimated to rise from currently 74 % to around 80 % in 2050. Most European capital cities are expected to see noticeable urban growth, while other cities might contract by up to 30 % (Eurostat, 2016).

Besides, international migration is on the rise and increasingly affects Europe. The number of international migrants increased from 170 million in 2000 to 260 million in 2017 (UNDESA, 2017a). Most international migration is voluntary and driven by economic opportunities and personal motives, but forced displacement due to armed conflicts or natural disasters is increasing. In 2017, Europe hosted about 2.6 million refugees and forced migrants (UNHCR, 2017). 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 of future migration volumes remain highly uncertain (IPCC, 2018).

1.3.2 Cluster 3: Increasing scarcity and global competition for resources

Global use of material resources increased 10-fold between 1900 and 2009 (Krausmann et al., 2009). It has continued to rise in recent years (Figure 1.6) with projections suggesting a doubling of demand by 2060 (IRP, 2019). This raises concerns about access to key primary and secondary raw materials and poses a challenge to

BOX 1.1 Tipping points, critical thresholds and resilience

A tipping point is when a system reaches a critical threshold at which a small change in conditions can lead to large, abrupt changes in the function and structure of a system, shifting it from one state to another. The existence of tipping points increases the risk of such shifts given ongoing environmental degradation. These shifts are difficult to reverse and can have drastic negative impacts on society.

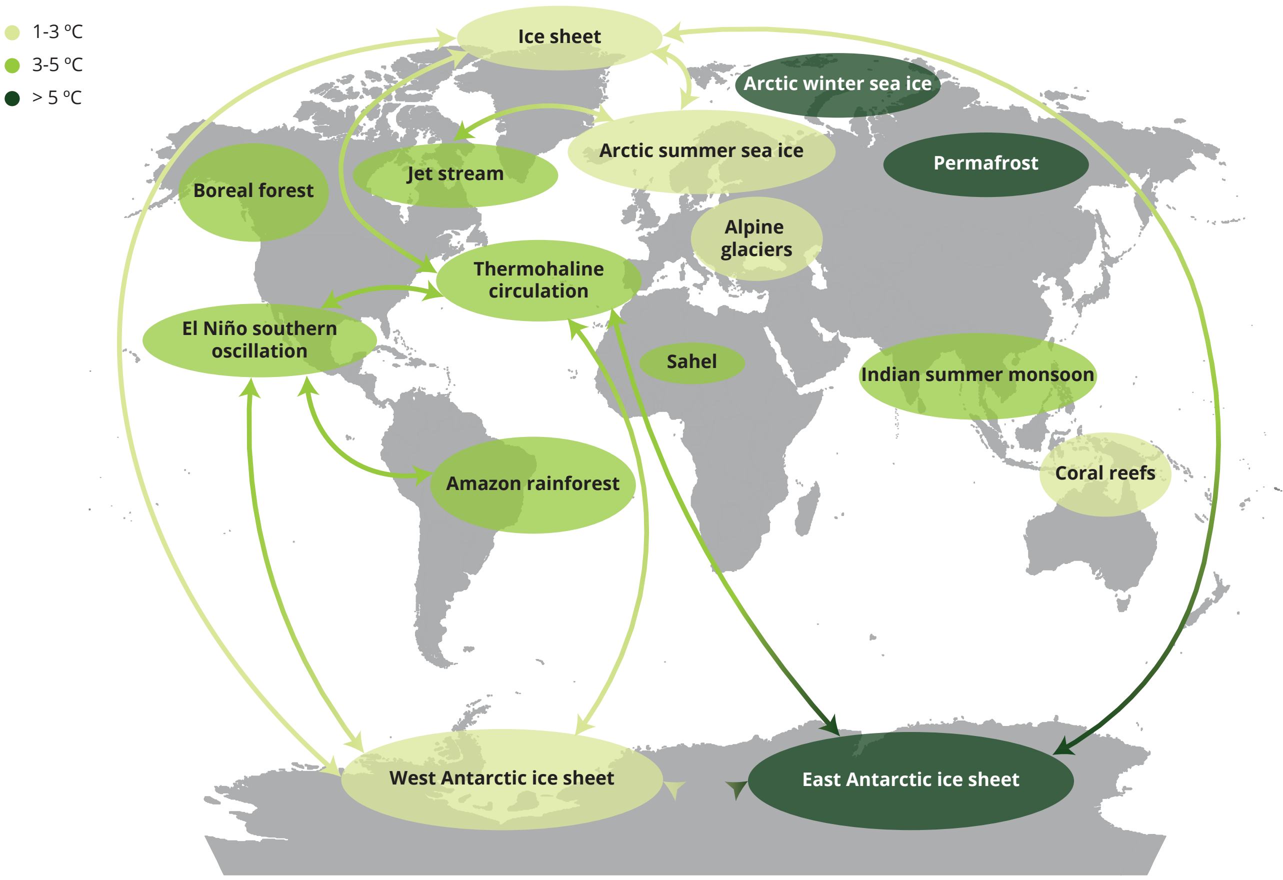
Resilience refers to the capacity of a system to absorb disturbance and reorganise while undergoing change so that it retains essentially the same function, structure, identity and feedbacks (Walker et al., 2004).

If a system has been degraded, e.g. ecosystem degradation through multiple pressures, its resilience is reduced, making the system more prone to shifting states.

The phenomenon of tipping points, critical thresholds and resilience can be found in many different systems, including natural, socio-ecological, and societal systems. An example is the collapse of the cod fishery in Newfoundland in the early 1990s, caused by a combination of overfishing and regional climatic variability (Patel et al., 2018).

In relation to climate change, several so-called 'tipping elements' have been identified (Figure 1.3), which are large-scale components of the Earth system, such as the Greenland ice sheet or the jet stream (Lenton et al., 2008; Levermann et al., 2012; Hansen et al., 2016; Steffen et al., 2018). The transgression of certain tipping points for these elements could trigger self-reinforcing feedback loops resulting in continued global warming even if human emissions were reduced to almost zero. It has been estimated that several of these tipping elements risk collapsing at temperature increases between 2 and 3 °C, although many uncertainties remain (Schellnhuber et al., 2016; Steffen et al., 2018). ■

FIGURE 1.3 Potential tipping elements and cascades according to estimated thresholds in global average surface temperature



Source: Steffen et al. (2018).

BOX 1.2 The planetary boundary framework

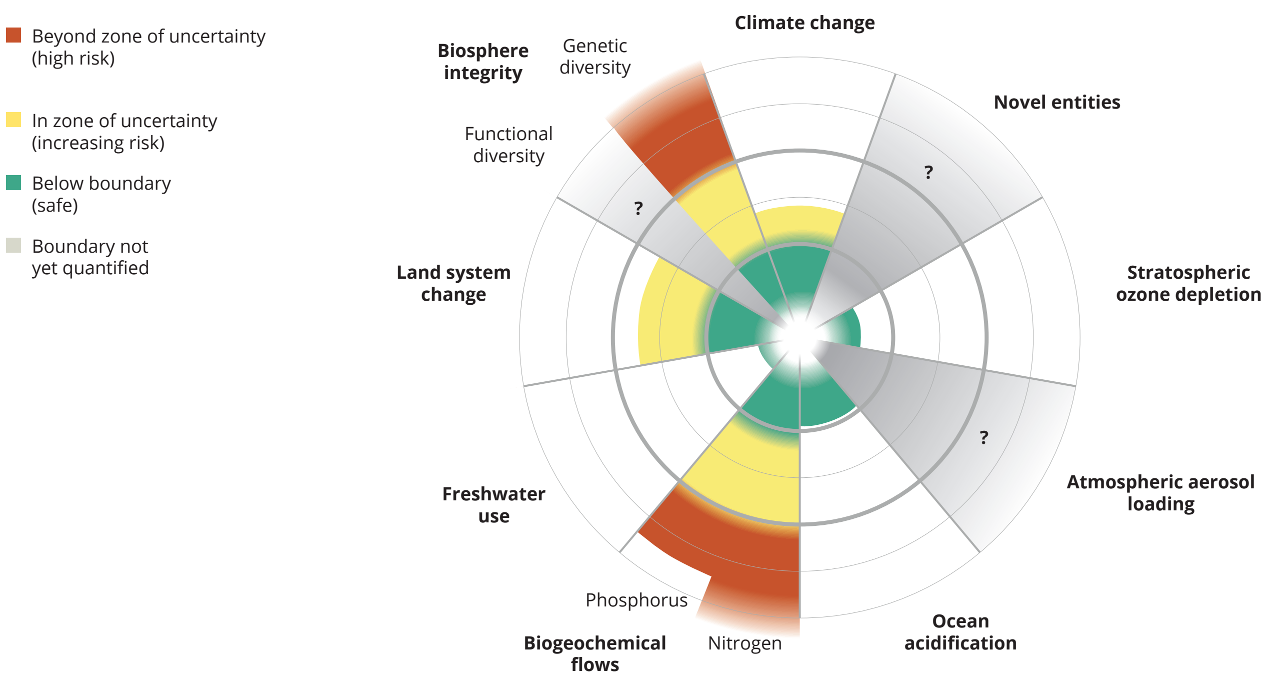
The planetary boundary framework identified nine processes that regulate the stability and resilience of the Earth system — 'planetary life support systems' (Rockström et al., 2009; Steffen et al., 2015a). The framework proposes precautionary quantitative planetary boundaries within which humanity can continue to develop and thrive, also referred to as a 'safe operating space'. It suggests that crossing these boundaries increases the risk of generating large-scale abrupt or irreversible environmental changes that could turn the Earth system into states detrimental or catastrophic for human development.

The nine planetary boundaries are: (1) climate change; (2) change in biosphere integrity; (3) stratospheric ozone depletion; (4) ocean acidification; (5) biogeochemical flows — interference with phosphorus (P) and nitrogen (N) cycles; (6) land system change; (7) freshwater use; (8) atmospheric aerosol loading; and (9) introduction of novel entities such as new substances or modified life forms (Figure 1.4). Loss of biosphere integrity relates to the widespread degradation of biodiversity and ecosystems with associated loss of ecosystem function, as described in Section 1.2. Two boundaries — climate change and biosphere integrity — have been identified as core boundaries, meaning that each of these has the potential on its own to drive the Earth system into a new state should they be substantially and persistently overshot and that the other boundaries operate through their influence on these two core boundaries (Steffen et al., 2015a).

Seven of the nine planetary boundaries have been quantified at the global scale by identifying control variables (e.g. atmospheric CO_2 concentration for climate change) and estimating specific limits that humanity should stay within. It is estimated that humanity has already overshot the limits that define a safe operating space for four planetary boundaries, namely those for biosphere integrity, climate change, land system change and biogeochemical flows (Steffen et al., 2015a).

Much uncertainty remains regarding some of the control variables, and the limits of the planetary boundaries represent estimates based on currently available scientific knowledge. These are likely to be further refined as scientific understanding evolves. For example, efforts to further define and quantify biosphere integrity are ongoing (Mace et al., 2014; Newbold et al., 2016). The planetary boundary work has been disputed by some scientists (e.g. Montoya et al.'s (2018) and Rockström et al.'s (2018) responses). ■

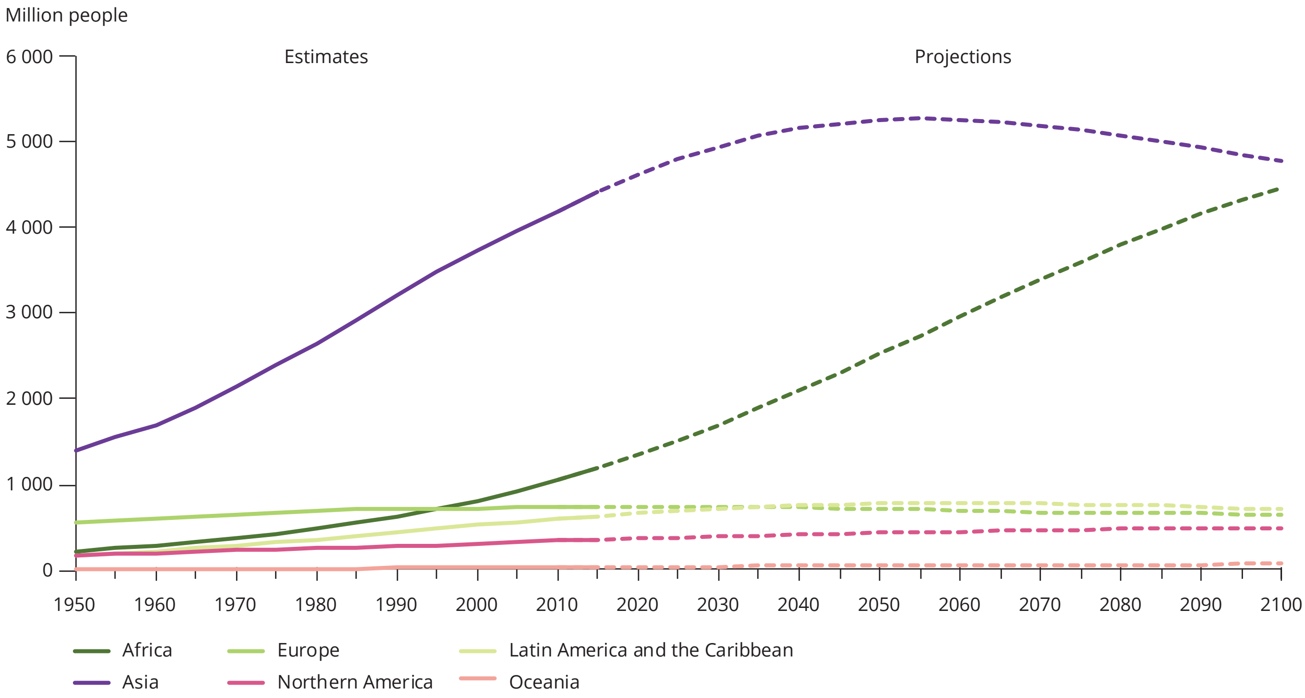
FIGURE 1.4 The status of the nine planetary boundaries



Note: BII, biodiversity intactness index; E/MSY, extinctions per million species-years.

Source: Steffen et al. (2015a).

FIGURE 1.5 **Trends in total population by world region, 1950-2100**



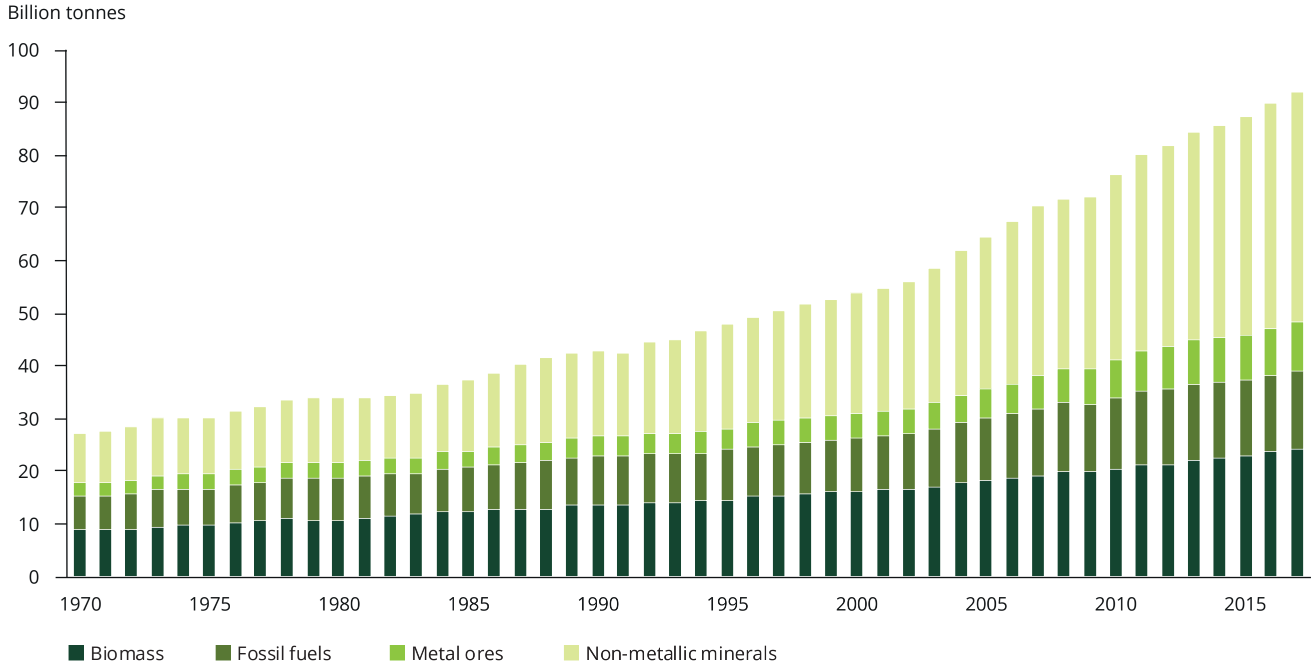
Source: UNDESA (2017b).

economies that are highly dependent on materials from international markets, such as Europe (Alessandrini et al., 2017). A list of 27 'critical raw materials' crucial for European industry — in particular green technologies — but with particular risks in terms of security of supply has been drawn up by the EU (EC, 2017a) (Chapter 9).

Likewise, global demand for land is projected to continue, in particular since 25-100 % more food would 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/FAO, 2018), and agriculture is projected to be increasingly compromised by the combined effects of climate change and soil degradation (UNCCD, 2017). Since 2000, the growing global competition for arable land is reflected in a sharp increase in large-scale transnational land acquisitions, primarily in Africa, by foreign investors from Europe, North America, China and the Middle East. As a result, large-scale monocultures (e.g. for palm oil production) often replace local access to land and water (UNCCD, 2017; IPBES, 018).

Similarly, global demand for water is projected to rise by 55 % until 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, 2018). Water scarcity could impact southern Europe in particular (Veldkamp et al., 2017). Likewise, global energy demand could increase by 30 % up to 2040, assuming an annual global economic growth rate of 3.4 % and increasing energy efficiency (IEA, 2017). Europe currently imports 54 % of all energy it consumes — and it is particularly dependent on imports of crude oil and natural gas (Eurostat, 2018b).

FIGURE 1.6 **Trends in global domestic extraction of materials, 1970-2017**



Source: WU Vienna (2018).

1.3.3
Cluster 4: Accelerating technological change and convergence

The global landscape of technological innovation is undergoing rapid transformation. Developed economies are not alone in investing in research and development (R&D). For example, China is expected to reach the same R&D intensity (i.e. R&D as a percentage of GDP) as an average Organisation for Economic Co-operation and Development (OECD) member country by 2020 (OECD, 2018c). In Europe, meanwhile, the stage between the basic discovery research and the actual commercialisation — known as the 'Valley of Death' — remains a particular challenge for fully exploiting the potential benefits of key enabling technologies (EC, 2018a).

Accelerating technological innovation is fuelled by the widespread digitalisation of economies and societies worldwide. While this can increase productivity and energy efficiency, it is not yet clear whether the energy and materials savings are enough to outweigh the negative sustainability impacts of information and communications technology (ICT) (UN Environment, 2019), such as its huge demand for critical raw materials (cluster 3). Apart from ICT, other technologies are increasingly penetrating societies and economies, such as artificial intelligence (AI) — the ability of machines and systems to acquire and apply knowledge and to simulate intelligent behaviour), the internet of things (IoT) — the connection over time of almost any device to the internet's network of networks — and big data and analytics. These technologies provide numerous applications and potential benefits, but they also pose risks and raise ethical concerns, for example in relation to privacy and cybersecurity.

Widespread digitalisation is also the key enabler of the 'Fourth Industrial Revolution', which fuses digital technologies with nanotechnologies, biotechnologies and cognitive sciences — a trend referred to as 'technology convergence' (OECD, 2017b; Schwab, 2017). This is expected to provide opportunities for more integrated and efficient industrial processes, personalised production, new jobs and economic growth (EC, 2016; OECD, 2018d). However, it has been suggested that about 14 % of workers are at a high risk of having most of their existing tasks automated over the next

15 years (OECD, 2018d). Concerns also exist over the implications for human health (especially from nanotechnologies and synthetic biology), and the implications for the environment are largely unknown (UNEP, 2017a).

1.3.4
Cluster 5: Power shifts in the global economy and geopolitical landscape

Global economic output increased about 12-fold in the period from 1950 to 2016 (Bolt et al., 2018). Since the 1990s, much of this global growth has been driven by emerging economies, such as Brazil, China or India, reflecting a shift in economic power. China's economy grew on average 9.5 % annually between 1990 and 2017 compared with 1.7 % in the euro area (World Bank, 2018d). Measured in purchasing power parity (PPP), which corrects for price differences between countries, China's GDP had already surpassed the United States' GDP in 2013 (OECD, 2018b). 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, 2018b).

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). In contrast, Europe's middle class has contracted in most EU countries as a result of the 2008 financial crisis and structural changes in the labour market (ILO, 2016). At the same time, inequalities within countries have been rising in Europe and emerging economies (OECD, 2015). Therefore, the prospects for the global middle class are highly uncertain, and 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 in the period 1980-2016, might increase further (WIL, 2017).

In addition, geopolitical uncertainties and tensions in the global multilateral system are increasing (ESPAS, 2015). This is seen in the 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, 2018). For Europe, where exports represented more than 50 % of its GDP in 2018, this is of great concern (EPSC, 2018). At the same time, other non-state actors such as non-governmental organisations (NGOs) and multinational businesses, are increasingly challenging traditional power relations (Ruggie, 2018).

1.3.5
Cluster 6: Diversifying values, lifestyles and governance approaches

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 consumption (cluster 5) and the adoption of Western lifestyles. 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 (EPRS, 2018), and the effects are already apparent in a shrinking middle class (cluster 5). This may lead to growing social discontent and inequality, which in turn is one of the highest obstacles to environmental sustainability (UN Environment, 2019).

In parallel, new work patterns and lifestyles are emerging. With rapid and pervasive technological change, more jobs are likely to be automated (cluster 4) and the demand for highly skilled qualifications is expected to rise (IPPR, 2015). Although this creates new opportunities, it poses challenges for individuals, such as increasing mobility needs, and for governments to prevent mass unemployment and job insecurity. Life-long learning is becoming the norm and is increasingly supported by a diversification of educational opportunities (OECD, 2017a). At the same time, numerous forms of social innovation, such as the sharing economy, community-oriented forms of living or slow food movements, are emerging. Yet, major lifestyle-related human health challenges remain, such as cardiovascular diseases, obesity and cancer. For example, more than half of the EU's population in 2014 was estimated to be overweight (Eurostat, 2018c). These trends are now global, with 71 % of all deaths in 2016 due to non-communicable diseases (WHO, 2018).

1.4
Europe's production and consumption

Global drivers of change have impacts on Europe, but, in turn, European production and consumption patterns also have implications for environmental pressures and degradation in other parts of the world. Key production-consumption systems — for example energy, mobility and food — operate across and beyond European borders. They contribute to meeting our fundamental needs, but at the same time they are the root causes of environmental and climate pressures both in Europe and abroad.

The European economy has gone through a series of major industrial transformations during the past two and a half centuries. Since the 1950s, the structure of the European economy has shifted from an industry-intensive towards a service-oriented economy. Alongside this, consumption patterns have also changed, with proportionally decreasing spending on basic needs — for example food — and relatively more on ITCs, recreation and health (Chapter 16). Overall, European consumption levels are high compared with many other world regions. For example, the average EU-28 citizen spends 3.4 times more on goods and services than the global average (World Bank, 2018a). In that context, imports are an important component in meeting final European demand for goods and services, and trade is fundamentally important for the European economy.

The environmental consequences of European production and consumption systems can be assessed from complementary perspectives ([2]). The territorial perspective includes environmental pressures exerted by human activities within the European territory. The production perspective expands this to include pressures arising from production by European residents (companies and households), irrespective of where geographically these activities take place, and is the methodology used in compiling European environmental-economic accounts. The consumption or footprint ([3]) perspective complements these by relating environmental pressures to final demand for goods and services. It includes the total environmental pressures resulting from consumption, irrespective of where geographically the production of these goods and services has resulted in environmental pressures. Therefore, the consumption perspective also includes the environmental pressures created around the world by European domestic consumption.

Europe's production and consumption patterns create environmental degradation in other parts of the world.

Reducing environmental pressures from the territorial perspective is the primary focus of most EU and national environmental and climate policies. At present, the territorial perspective is the only method accepted by international environmental law to account for a country's emissions and mitigation efforts. For example, commitments to limit or reduce GHG emissions under the Paris Agreement are implemented through 'nationally determined contributions' (NDCs). In the EU, these NDCs have to account for emissions on the territory of each Member State, thereby contributing to the collective effort to achieve the EU NDC. Similarly, such a territorial approach is also the basis for the regulation of pollution or the protection of ecosystems and biodiversity. Consequently, the territorial and production perspectives of Europe's environmental performance are captured in a large body of environmental indicators, accounts and assessments, providing an indispensable knowledge base to inform EU climate and environmental policymaking. The thematic chapters in Part 2 (Chapters 3 to 13) primarily take a territorial perspective, as they assess the environment's state, trends and prospects on the European territory.

Overall European environmental performance also has an influence beyond the borders of the EU. In an increasingly globalised world characterised by feedbacks, interdependencies and lock-ins in environmental and socio-economic systems, this is of continually increasing importance (Section 1.4). Over the last decade or so, substantial scientific progress has been made in quantifying the environmental footprints embodied in internationally traded products through approaches such as multiregional input-output databases (e.g. Lenzen et al., 2013; Timmer et al., 2015; Tukker et al., 2016) or life cycle assessment approaches (Frischknecht et al., 2018; Sala et al., 2019, forthcoming) Therefore, improved estimations of the environmental impacts of consumption in Europe are now available, providing a more comprehensive picture of environmental performance.

The pressures associated with final European consumption are higher than the world average, and recent research suggests that the EU is indeed a net importer of environmental impacts (Sala et al., 2019; Wood et al., 2018; Beylot et al., 2019). Many internationally traded goods are produced in world regions with low production costs and weak environmental regulation. The prices of internationally traded goods rarely incorporate the costs of environmental externalities, i.e. the embodied impact of the land and

([2]) There are three accounting perspectives: (1) territorial; (2) production; and (3) consumption. Detailed description of the concepts and methodologies behind these different perspectives can be found in an EEA report (EEA, 2013).

([3]) In this report, the term 'environmental footprint' indicates environmental pressures or impacts directly and indirectly associated with consumption of goods and services. It should not be confused with the 'product environmental footprint' or the 'organisation environmental footprint', which are specific assessment methodologies (EC, 2013).

water used, the GHGs emitted or the biodiversity affected. Decision-makers and consumers in importing countries are often not fully aware of these displacement effects. Focusing solely on the environmental impacts within Europe without considering the additional environmental impacts abroad can result in an overly positive perception of Europe's sustainability.

The volumes of water required for the production of a commodity traded for consumption in another region is often referred to as 'virtual water'. Estimates suggest that, for example, more than 40 % of the water needed to produce products consumed in Europe is used outside the EU territory (Tukker et al., 2016). Europe, with only about 7 % of the global population, was responsible for over 28 % of the imports of virtual water flows globally in 2009 (Serrano et al., 2016). Likewise, the EU countries rely heavily on 'virtual land' to meet their own consumption needs related to bioenergy and food production. Recent estimates suggest that more than half of the EU's land needs (arable land, pastures, forests) are based on land use abroad (Yu et al., 2013; Tukker et al., 2016).

Europe's impact on ecosystems outside its territory can also be illustrated by analysing the origin of biomass products consumed in Europe, such as food, fibre or bioenergy. One way to quantify the share of products from agriculture and forestry with non-EU origins is the 'embodied human appropriation of net primary production' (eHANPP) approach (Haberl et al., 2012). (Kastner et al., 2015) found that the share of biomass products with non-EU origins that are consumed in the EU increased from about 29 % in 1986 to 41 % in 2007. Moreover, this indicates

Depending on the type of resource, the associated total environmental footprint of European consumption that occurs outside Europe is estimated to be in the range of 30-60 %.

the EU's increasing dependence on Latin America as a main supplier. While the extent of associated environmental pressures at the places of origin has not yet been quantified, there is strong scientific consensus that international trade chains contribute to accelerating habitat degradation and that EU consumption exerts considerable pressure on many biodiversity hotspot areas globally (e.g. Moran and Kanemoto, 2017).

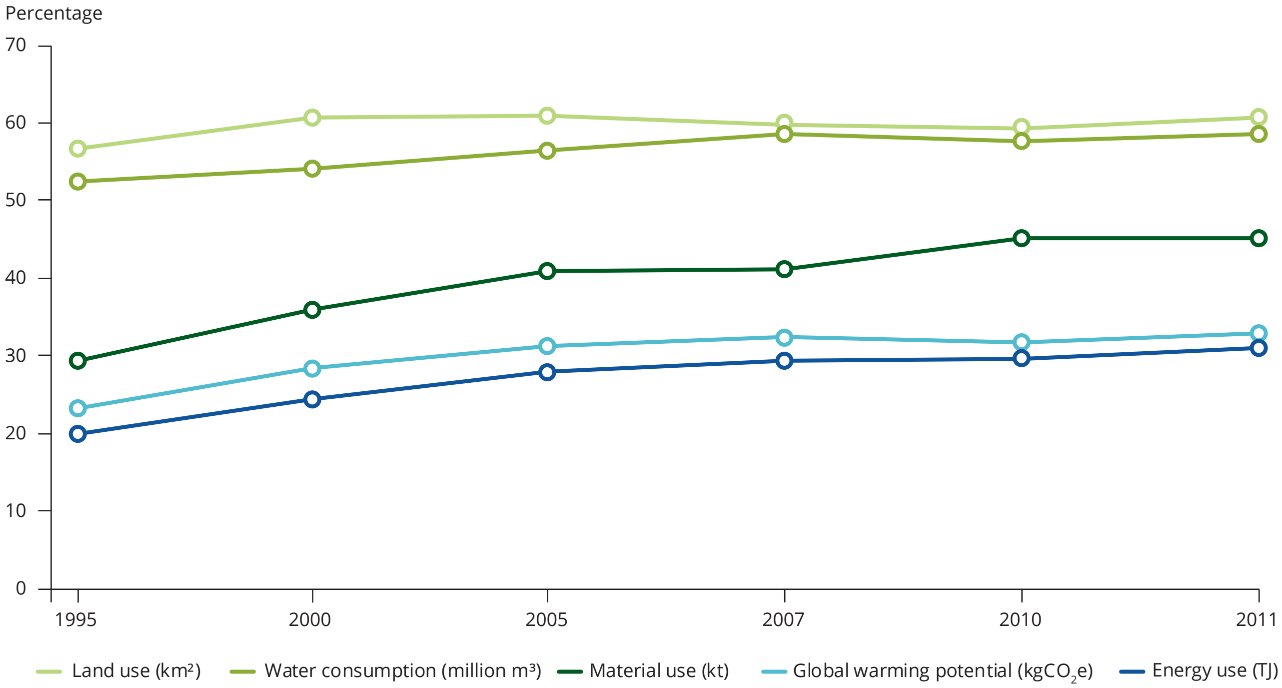
To summarise, it can be concluded that Europe is highly dependent on resources extracted or used outside Europe, such as water, land use products, biomass or other materials, to meet its high consumption levels. This means that a large part of the environmental impacts associated with European consumption is exerted in other parts of the world. In 2011, this ranged from 31 % (energy use) to 61 % (land use) (Figure 1.7). Between 1995 and 2011, Europe's footprint increased across all resource or impact categories, with the largest increases being for energy use and material use (Figure 1.7). Assessing Europe's environmental performance using different but complementary perspectives provides a more in-depth understanding of Europe's sustainability challenges and opportunities. The characteristics of these challenges and the opportunities to respond to them are explored further in Part 3.

1.5
Is Europe living within the limits of the planet?

The EU's Seventh Environment Action Programme (7th EAP) sets out the 2050 vision of 'Living well, within the limits of our planet' (Chapter 2), recognising that Europe's economic development and human well-being are intrinsically linked to a resilient and healthy natural environment. In general, advanced economies in Europe and elsewhere have achieved high levels of human development (living well) but at the expense of not being environmentally sustainable (i.e. living within environmental limits; Figure 1.8). Figure 1.8 uses the ecological footprint as a proxy for environmental limits, but there are other approaches. For example, a recent analysis of seven indicators of national environmental pressures and 11 indicators of social outcomes for over 150 countries found that no country meets the basic needs of its citizens at globally sustainable levels of resource use (O'Neill et al., 2018).

Regardless of which proxies and perspectives are used, assessing whether a region lives 'within the limits of our planet' is challenging. Several studies have explored this by applying the planetary boundaries framework to examine the environmentally safe operating space at sub-global scales: one study each for Sweden (Nykvist et al., 2013), South Africa (Cole, 2015) and Switzerland (Dao et al., 2018) and three studies for the EU (Hoff et al., 2014)

FIGURE 1.7 Share of Europe's final demand footprint exerted outside European borders



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

Source: EEA and European Topic Centre on Waste Materials in a Green Economy's own calculations based on Exiobase 3 (Stadler et al., 2018).

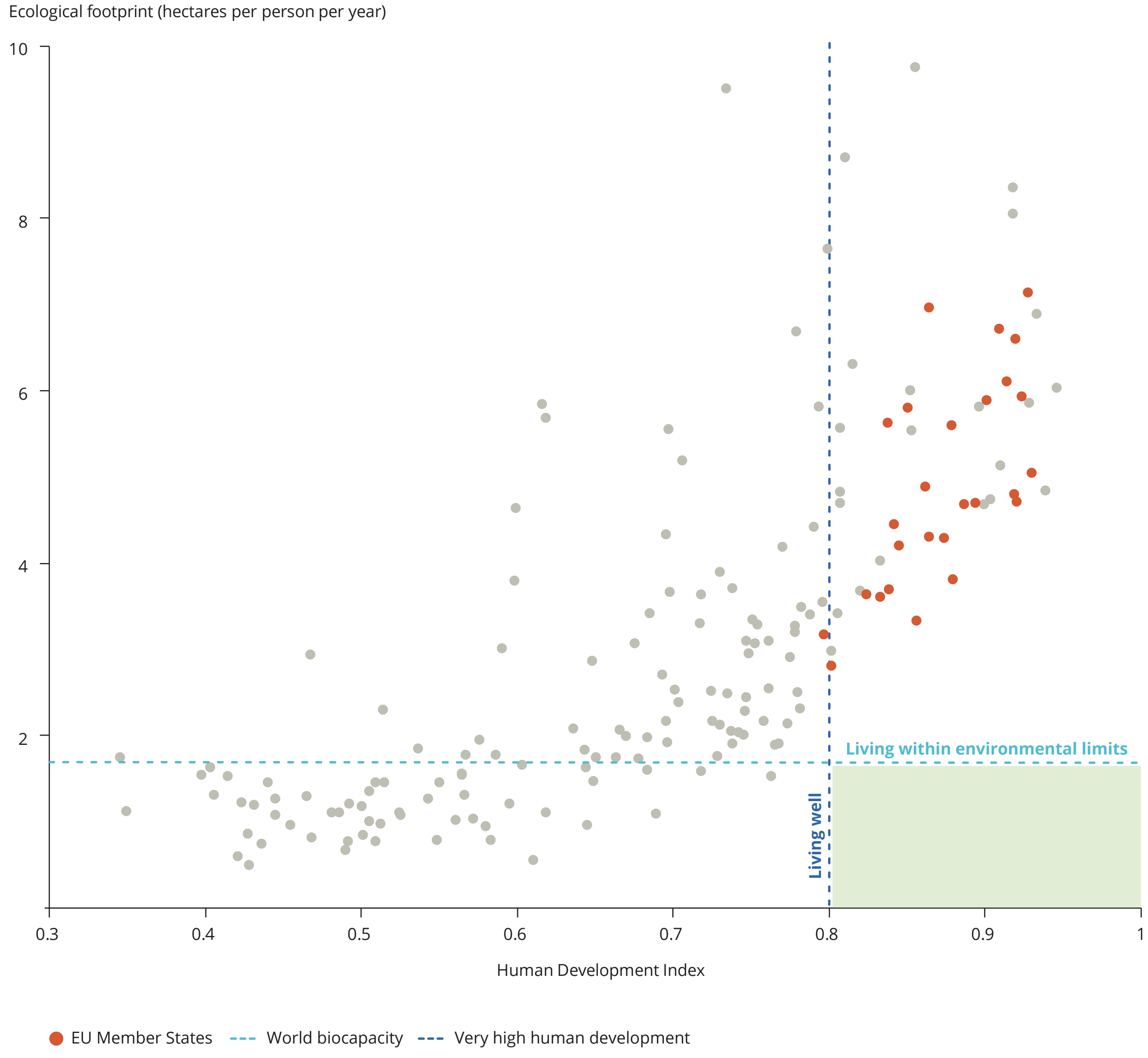
(Boxes 1.3 and 1.4). The first step in such an exercise is to disaggregate and allocate the globally defined limits of the planetary boundaries to specific national or European 'allowances', or 'shares', and then to measure the actual national or European performance against such 'down-scaled' allowances from a production- and/or consumption-based perspective.

Allocation of globally defined limits for planetary boundaries to national or European allowances is inevitably a normative process about responsibility for responding to and mitigating environmental degradation and about fair allocations of the global safe operating space. Most existing studies have applied a simple 'equal per capita' approach — which assumes the basic idea of equal rights for everyone — and have found large overshoots of the safe operating space for several planetary boundaries. However, there are alternative ways to define a safe operating space for a region depending on ethical and normative choices regarding aspects of fairness, (historical) responsibility, capacity to act, international burden sharing, or the right to economic development. As experiences with climate negotiations have shown, agreeing on allocations can be problematic and contentious.

Only a few attempts have been made to understand how multiple allocation principles will affect estimates of the safe operating space. A study from the Netherlands showed that, despite the large range resulting from multiple allocation approaches, most allocation results are lower than the current environmental footprints. Thus, the authors concluded that the Netherlands is not living within its safe operating space (Lucas and Wilting, 2018). Similar results have been found at the EU level based on an assessment of Europe's environmental footprint (Box 1.4).

The three studies that have applied planetary boundaries to the European scale (Hoff et al., 2014); Boxes 1.3 and 1.4) also concluded that Europe currently does not live 'within the limits of our planet'. Instead Europe overshoots its share of the global 'safe operating space' for several planetary boundaries, even under generous assumptions of what Europe's share of these global boundaries might be. The studies also suggest that

FIGURE 1.8 Correlation between ecological footprint and human development index



Note: The human development index (HDI) is calculated based on indicators of education, life expectancy at birth and wealth. It is expressed as a value between 0 and 1, from least to most developed countries. HDI scores between 0.8 and 1.0 are categorised as 'very high human development'. The ecological footprint measures how much land and water area a population requires to produce the resources it consumes and to absorb its waste. The world biocapacity is the global productive area available to produce resources and absorb waste. The HDI and ecological footprint data are from 2014.

BOX 1.3 Operationalising the concept of a safe operating space at the EU level — first steps and explorations

As a first step, the scientific evidence base for Europe for the following six planetary boundaries has been analysed: (1) climate change; (2) biosphere integrity; (3) land system change; (4) freshwater use; (5) biogeochemical flows (nitrogen and phosphorus); and (6) novel entities (chemical pollution). Subsequently, a simple 'equal per capita' disaggregation and allocation approach was followed for those planetary boundaries for which the global limits are available and can be quantified at the European scale (climate change, land system change, freshwater use, nitrogen flows and phosphorus flow). 'Equal per capita' assumes the basic idea of equal rights for everyone and means that the European critical limits were calculated simply as a function of Europe's share of the global population (approximately 7 %). A systematic compilation of Europe's current production- and consumption-based performance from scientific studies in relation to these planetary boundaries was used to assess whether the EU appears to be 'living within the limits of our planet'.

The study concluded that:

The EU does not appear to be 'living within the limits of our planet' for the majority of the boundaries analysed (based on equal per capita allocation approach).

Transgressions of the limits of planetary boundaries are generally higher in Europe than the global average.

Transgressions of the limits of planetary boundaries are generally higher for the consumption-based (footprint) perspective, reflecting that the EU is contributing to environmental pressures beyond its own territory due to goods imported into and consumed in the EU.

Trends over time show that decreases in Europe's territorial pressures are mostly outweighed by increasing environmental pressures in other world regions, thereby externalising the EU's environmental footprint. As a result, Europe's total consumption-based environmental performance does not show an improving trend for most planetary boundaries. ■

Source: Häyhä et al. (2018).

Fundamental changes in lifestyles, production and consumption, knowledge and education are needed for Europe to transition towards sustainability.

the European overshoots of the limits are greater than the global average for most planetary boundaries.

Other studies have looked at the EU's consumption from a life cycle perspective in a planetary boundary context and similarly conclude that EU consumption is environmentally unsustainable and not within limits of the planet (Sala et al., 2019). While there is considerable uncertainty on the limits of the planetary boundaries, numerous other studies employing input-output analysis largely confirm the findings that EU environmental footprints are above sustainable levels (Tukker et al., 2016; Wood et al., 2018).

Overall, this suggests that Europe still consumes more resources and contributes more to ecosystem degradation, both within and beyond its territory, than many other world regions. In addition, from a consumption-based perspective, Europe is more unsustainable than it is from a production-based perspective. In other words, Europe is, to an increasing degree, externalising its pressures on key environmental issues. This suggests that there is still a substantial gap between the EU's 2050 sustainability vision and current overall EU environmental performance, which will be examined in much more detail in Part 2.

This calls for fundamental and deep changes in relation to the functioning of Europe's socio-economic systems, lifestyles, education systems and institutions and to how knowledge is produced and used. Such sustainability transitions are inevitably complex and long term in character, but they require action now. Given Europe's embeddedness in globalised socio-economic structures and trade flows, new approaches and innovation will be needed. Part 3 assesses in more detail the challenges and opportunities to enable long-term transitions towards sustainability, as envisaged by the EU's 7th EAP and the Sustainable Development Goals.

BOX 1.4 Assessment of Europe's environmental footprint based on planetary boundaries

The study assessed whether Europe's environmental footprints are within the 'safe operating space' defined by the planetary boundaries framework by using a 'basket' of allocation approaches. It explored the implications of using four allocation principles proposed in the context of climate negotiations (e.g. Höhne et al., 2014), in addition to the equality principle:

Needs: people's different resource needs due to age, household size, location of residence.

Rights to development: resource needs proportional to development level (more resources to less developed countries to enable them to meet their development objectives).

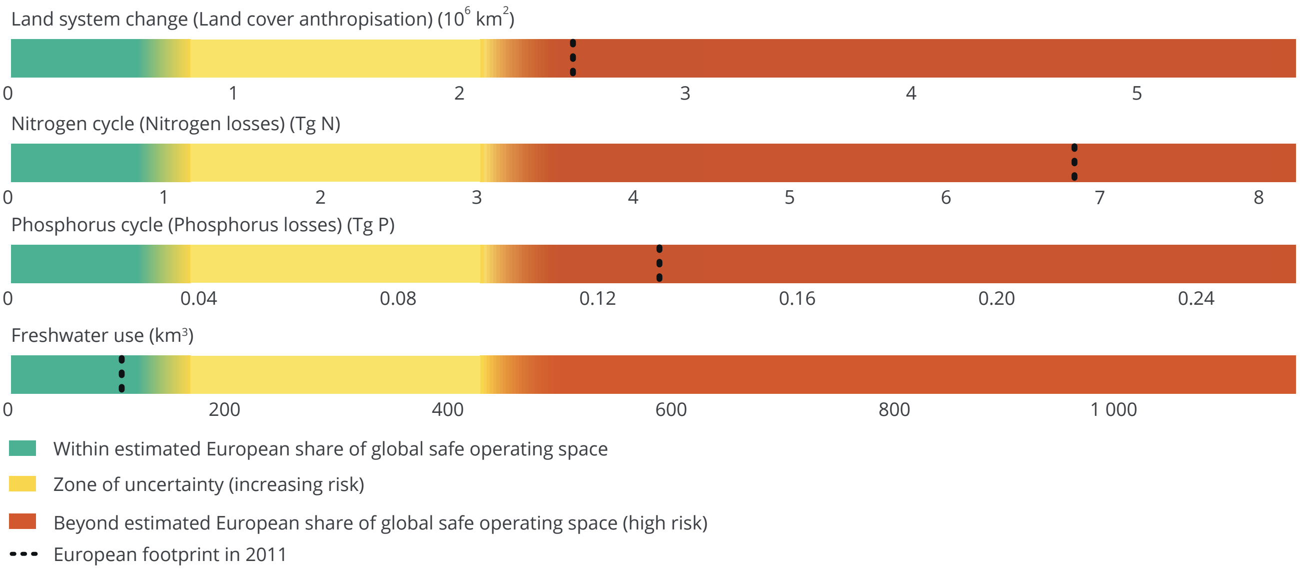
Sovereignty: resource needs as a function of economic throughput, biocapacity and land availability.

Capability: resource needs according to wealth and financial capability.

The principle of sovereignty results in the highest European share of the global safe operating space (median of 12.5 %), while the principle of rights to development results in the lowest share (median of 4.1 %). The yellow range in Figure 1.9 represents the average range across the five allocation principles, with a median of 6.9 %. This yellow range is defined as the 'zone of uncertainty' to reflect the normative process of defining a European safe operating space.

This basket of allocation approach has been tested at the European scale with consumption-based footprint data (Exiobase, version 3) for three planetary boundaries: (1) land system change; (2) biogeochemical flows (phosphorus, nitrogen, addressed separately); and (3) freshwater use. The results largely confirm the findings from Häyhä et al. (2018). European transgressions are substantial for phosphorus and nitrogen, regardless of which allocation principle is used. The land boundary is transgressed when applying the equality, needs, rights to development and capability principles but not when using the economically determined sovereignty principle (not seen in the averaged yellow range in Figure 1.9). The freshwater boundary is not transgressed in Europe as a whole, regardless of which allocation principle is applied. However, this does not mean that there are not severe regional water issues, especially in southern Europe. ■

FIGURE 1.9 European consumption-based performance for selected planetary boundaries



Notes: The yellow zone of uncertainty represents the average range across the six principles to allocate a European share of the global safe operating space.

The study takes a conservative approach, as it calculates the European share based on the lower end values of the global zone of uncertainty defined by Steen et al. (2015). For example, the global zone of uncertainty for freshwater is defined as 4 000-6 000 km^3 in Steffen et al. (2015). This study uses 4 000 km^3 as the basis for calculating the European share. In some cases (indicated in brackets) slightly different control variables have been used than in Steffen et al. (2015).

Source: EEA and FOEN (forthcoming).