The European environment — state and outlook 2020

Knowledge for transition to a sustainable Europe

European Environment Agency

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I.
Foreword

The *European environment — state and outlook 2020* (SOER 2020) comes at a crucial time. We face urgent sustainability challenges that require urgent systemic solutions. This is *the* unambiguous message to policymakers in Europe and globally. The overarching challenge of this century is how we achieve development across the world that balances societal, economic and environmental considerations.

This is the 6th SOER published by the European Environment Agency (EEA), and this 2020 edition identifies serious gaps between the state of the environment and existing EU near- and long-term policy targets. Citizens' expectations for living in a healthy environment must be met, and this will require renewed focus on implementation as a cornerstone of EU and national policies.

That being said, we do not only have to do more; we also have to do things differently. Over the next decade, we are going to need very different answers to the world's environmental and climate challenges than the ones we have provided over the past 40 years. This report aims to inform discussions on Europe's 2030 policies, including trajectories to 2050 and beyond.

These future policies must build on existing responses to our environmental and climate challenges — the *acquis* — and they must also respond to the most-up-to-date knowledge, which calls for fundamentally different approaches — both in terms of *what* we need to do, as well as *how* we need to do it.

The message of urgency cannot be overstated. In the last 18 months alone, major global scientific reports from the IPCC, IPBES, IRP and UN Environment [1] have been published, all carrying similar messages: current trajectories are fundamentally unsustainable; these trajectories are interconnected and linked to our main systems of production and consumption; and time is running out to come up with credible responses to bend the trend.

(1) Intergovernmental Panel on Climate Change (IPCC) reports on 1.5 °C Global Warming and Climate Change and Land; Intergovernmental Science-Policy Platform report on Biodiversity and Ecosystem Services (IPBES) Global Assessment Report on Biodiversity and Ecosystem Services; International Resource Panel (IRP) Global Resources Outlook report; UN Environment Global Environment Outlook 6.

The call for fundamental sustainability transitions in the core systems that shape the European economy and modern social life — especially the energy, mobility, housing and food systems — is not new. Indeed we made such a call in the 2010 and 2015 editions of SOER, and in recent years the EU has embedded this thinking in important policy initiatives such as the circular and bio-economy packages, the climate and energy policies for 2030 and 2050, and its future research and innovation programme. Furthermore, the EU's sustainable finance initiative is the first of its kind to ask serious questions about the role of the financial system in driving the necessary change.

However, it is one thing to change thinking and another to bring about actual change. The focus now must be on scaling up, speeding up, streamlining and implementing the many solutions and innovations — both technological and social — which already exist, while stimulating additional research and development, catalysing behavioural shifts and, vitally, listening to and engaging with citizens.

We cannot underestimate the social dimension. There are loud and understandable calls for a just transition, in which the potential losers from the low-carbon economy are given due care and attention. The unequal distribution of costs and benefits arising from systemic changes is now recognised by policymakers, but requires solid understanding, citizen engagement and effective responses.

Neither should we ignore the young people of Europe. They are increasingly making their voices heard to demand a more ambitious response to climate change and environmental degradation. Unless we manage to change current trends within the next decade, then their sense of fear for the future will prove to be well founded.

SOER 2020 does not provide all the answers to these complex challenges. Nonetheless, it is the EEA's most comprehensive integrated assessment to date, and the first to address rigorously our systemic challenges in the context of the sustainability transitions that we, as a society, must make. It builds on 25 years of experience with data, analysis and EU policy, drawing on the knowledge of our unique network of European member countries (Eionet).

We cannot predict the future, but we can create it. We are convinced that this report constitutes a solid, timely source of knowledge that can guide discussions on future EU environment and climate policies, and help shape European responses to the United Nations Agenda 2030 and Sustainable Development Goals (SDGs). Europe must lead the global transition to a healthy environment in a just and sustainable world. The idea of a European Green Deal — outlined as the number one priority in the Political Guidelines for the next European Commission 2019-2024 — has the potential to provide an excellent framework for action, allowing for the kind of systems-based thinking and innovation needed to achieve this transition and create a future we can all be proud of.

Hans Bruyninckx
Executive Director, European Environment Agency

II.
Executive summary

SOER 2020 in a nutshell

In 2020, Europe faces environmental challenges of unprecedented scale and urgency. Although EU environment and climate policies have delivered substantial benefits over recent decades, Europe faces persistent problems in areas such as biodiversity loss, resource use, climate change impacts and environmental risks to health and well-being. Global megatrends such as demographic change are intensifying many environmental challenges, while rapid technological change brings new risks and uncertainties.

Recognising these challenges, the EU has committed to a range of long-term sustainability goals with the overall aim of 'living well, within the limits of our planet'. Achieving these goals will not be possible without a rapid and fundamental shift in the character and ambition of Europe's responses. Europe needs to find ways to transform the key societal systems that drive environment and climate pressures and health impacts — rethinking not just technologies and production processes but also consumption patterns and ways of living. This will require immediate and concerted action, engaging diverse policy areas and actors across society in enabling systemic change.

Europe stands at a critical juncture in 2020. Its leaders have opportunities to shape future developments that will not be available to their successors. The coming decade will therefore be of decisive importance in determining Europe's opportunities in the 21st century.

These, in short, are the overarching conclusions of *The European environment — state and outlook 2020* (SOER 2020). The report provides a comprehensive assessment of Europe's environment to support governance and inform the public. Like all EEA reports, it is founded on the work of the European Environment Information and Observation Network (Eionet) — a partnership between the EEA and its 33 member countries and six cooperating countries.

Making sense of the European environment's state, trends and prospects requires an integrated approach that acknowledges the complex drivers and implications of environmental change. SOER 2020 provides just that, presenting the global context that shapes Europe's development (Part 1), European environmental and sectoral trends and outlooks (Part 2) and the factors constraining or enabling transformative change (Part 3). It concludes in Part 4 with reflections on how Europe can shift its trajectory and achieve a sustainable future.

Europe continues to consume more resources and contribute more to environmental degradation than other world regions.

SOER 2020 identifies many challenges and barriers. But it also sees reasons for hope. European citizens are increasingly voicing their frustration with the shortfalls in environment and climate governance. Knowledge about systemic challenges and responses is growing and is increasingly reflected in EU policy frameworks. In parallel, innovations have emerged rapidly in recent years, including new technologies, business models and community initiatives. Some cities and regions are leading the way in terms of ambition and creativity, experimenting with different ways of living and working and sharing ideas across networks.

All of these developments are important because they create space for governments to bring a new scale of ambition to policies, investments and actions. They also help raise awareness, encouraging citizens to rethink behaviours and lifestyles. Europe must seize these opportunities, using every means available to deliver transformative change in the coming decade.

Europe's environment in a changing global context

The environmental and sustainability challenges that Europe faces today are rooted in global developments stretching back over decades. During this period, the 'Great Acceleration' of social and economic activity has transformed humanity's relationship with the environment. Since 1950, the global population has tripled to 7.5 billion; the number of people living in cities has quadrupled to more than 4 billion; economic output has expanded 12-fold, matched by a similar increase in the use of nitrogen, phosphate and potassium fertilisers; and primary energy use has increased five-fold. Looking ahead, these global developments look set to continue increasing pressures on the environment. The world's population is projected to grow by almost one third to 10 billion by 2050. Globally, resource use could double by 2060, with water demand increasing 55 % by 2050 and energy demand growing 30 % by 2040.

The great acceleration has undoubtedly delivered major benefits, alleviating suffering and enhancing prosperity in many parts of the world. For example, the share of the global population living in extreme poverty has decreased sharply — from 42 % in 1981 to less than 10 % in 2015. Yet the same developments have also caused widespread damage to ecosystems. Globally, about 75 % of the terrestrial environment and 40 % of the marine environment are now severely altered. The Earth is experiencing exceptionally rapid loss of biodiversity, and more species are threatened with extinction now than at any point in human history. Indeed, there is evidence that a sixth mass extinction of biodiversity is under way.

Many of the changes in the global climate system observed since the 1950s are similarly unprecedented over decades to millennia. They largely result from greenhouse gas emissions from human activities, such as burning fossil fuels, agriculture and deforestation.

Both directly and indirectly, these pressures are inflicting tremendous harm on human health and well-being. The global burden of disease and premature death related to environmental pollution is already three times greater than that from AIDS, tuberculosis and malaria combined. But the continuation of the great acceleration could create even more far-reaching threats if pressures trigger the collapse of ecosystems such as the Arctic, coral reefs and the Amazon forest. Sudden and irreversible shifts of this sort could severely disrupt nature's ability to deliver essential services such as supplying food and resources, maintaining clean water and fertile soils, and providing a buffer against natural disasters.

As a pioneer of industrialisation, Europe has played a pivotal role in shaping these global changes. Today, it continues to consume more resources and contribute more to environmental degradation than many other world regions. To meet these high consumption levels, Europe depends on resources extracted or used in other parts of the world, such as water, land, biomass and other materials. As a result, many of the environmental impacts associated with European production and consumption occur outside Europe.

Collectively, these realities add up to a profound challenge for Europe and other world regions. The current trajectories of social and economic development are destroying the ecosystems that ultimately sustain humanity. Shifting onto sustainable pathways will require rapid and large-scale reductions in environmental pressures, going far beyond the current reductions.

Europe's environment in 2020

As the character and scale of global environmental and climate challenges has become clearer, policy frameworks have evolved. Europe's environmental policy framework — the environmental acquis — is increasingly shaped by ambitious long-term visions and targets. The overarching vision for Europe's environment and society is set out in the Seventh Environment Action Programme (7th EAP), which envisages that by 2050:

We live well, within the planet's ecological limits. Our prosperity and healthy environment stem from an innovative, circular economy where nothing is wasted and where natural resources are managed sustainably, and biodiversity is protected, valued and restored in ways that enhance our society's resilience. Our low-carbon growth has long been decoupled from resource use, setting the pace for a safe and sustainable global society.

EU environmental policies are guided by three thematic policy priorities in the 7th EAP: (1) to protect, conserve and enhance the EU's natural capital; (2) to turn the EU into a resource-efficient, green and competitive low-carbon economy; and (3) to safeguard the EU's citizens from environment-related pressures and risks to their health and well-being. In recent years, the EU has also adopted a series of strategic framework policies that focus on transforming the EU economy and particular systems (e.g. energy, mobility) in ways that deliver prosperity and fairness, while also protecting ecosystems. The United Nations (UN) Sustainable Development Goals complement these frameworks, providing a logic for transformative change that acknowledges the interdependence of social, economic and environmental targets.

Viewed against Europe's long-term vision and complementary policy targets, it is clear that Europe is not making enough progress in addressing environmental challenges. The messages from the SOER 2020 assessment of recent trends and outlooks is clear: policies have been more effective in reducing environmental pressures than in protecting biodiversity and ecosystems, and human health and well-being. Despite the successes of European environmental governance, persistent problems remain and the outlook for Europe's environment in the coming decades is discouraging (Table ES.1).

It is clear that natural capital is not yet being protected, conserved and enhanced in accordance with the ambitions of the 7th EAP. Small proportions of protected species (23 %) and habitats (16 %) assessed are in favourable conservation status and Europe is not on track to meet its overall target of halting biodiversity loss by 2020. Europe has achieved its targets for designating terrestrial and marine protected areas and some species have recovered, but most other targets are likely to be missed.

Policy measures targeted at natural capital have delivered benefits in some areas, but many problems persist and some are getting worse. For example, reduced pollution has improved water quality, but the EU is far from achieving good ecological status for all water bodies by 2020. Land management has improved, but landscape fragmentation continues to increase, damaging habitats and biodiversity. Air pollution continues to impact biodiversity and ecosystems, and 62 % of Europe's ecosystem area is exposed to excessive nitrogen levels, causing

SOER 2020 shows that despite the success of EU environmental policies, the outlook for Europe's environment is discouraging.

TABLE ES.1 **Summary of past trends, outlooks and prospects of meeting policy objectives/targets**

Theme	Past trends and outlook: Past trends (10-15 years)	Past trends and outlook: Outlook to 2030	Prospects of meeting policy objectives/targets: 2020	Prospects of meeting policy objectives/targets: 2030	Prospects of meeting policy objectives/targets: 2050
Protecting, conserving and enhancing natural capital					
Terrestrial protected areas	Green	Yellow	☑		
Marine protected areas	Green	Yellow	☑		
EU protected species and habitats	Yellow	Yellow	☒		
Common species (birds and butterflies)	Red	Red	☒		
Ecosystem condition and services	Red	Yellow	☒		
Water ecosystems and wetlands	Yellow	Yellow	☒		
Hydromorphological pressures	Red	Yellow	☒		
State of marine ecosystems and biodiversity	Yellow	Red	☒		
Pressures and impacts on marine ecosystems	Yellow	Red	☒		
Urbanisation and land use by agriculture and forestry	Red	Red			☒
Soil condition	Red	Red	☒		
Air pollution and impacts on ecosystems	Yellow	Yellow	☐	☐	
Chemical pollution and impacts on ecosystems	Yellow	Red	☒		
Climate change and impacts on ecosystems	Red	Red	☒		
Resource-efficient, circular and low-carbon economy					
Material resource efficiency	Green	Yellow	☑		
Circular use of materials	Green	Yellow		☐	
Waste generation	Yellow	Yellow	☐		
Waste management	Green	Green	☐		
Greenhouse gas emissions and mitigation efforts	Green	Yellow	☑	☒	☒
Energy efficiency	Green	Yellow	☐	☒	☒
Renewable energy sources	Green	Yellow	☑	☒	☒
Emissions of air pollutants	Yellow	Yellow	☑	☐	
Pollutant emissions from industry	Green	Yellow	☐		
Clean industrial technologies and processes	Green	Yellow	☐		
Emissions of chemicals	Yellow	Red	☒		
Water abstraction and its pressures on surface and groundwater	Green	Yellow	☒		
Sustainable use of the seas	Yellow	Yellow	☐		
Safeguarding from environmental risks to health and well-being					
Concentrations of air pollutants	Green	Yellow	☒	☑	
Air pollution impacts on human health and well-being	Green	Yellow		☑	
Population exposure to environmental noise and impacts on human health	Yellow	Red	☒		
Preservation of quiet areas	Yellow	Yellow	☒		
Pollution pressures on water and links to human health	Yellow	Yellow	☒		
Chemical pollution and risks to human health and well-being	Yellow	Red	☒		
Climate change risks to society	Red	Red	☐		
Climate change adaptation strategies and plans	Green	Green	☐		

Indicative assessment of past trends (10-15 years) and outlook to 2030	Indicative assessment of prospects of meeting selected policy objectives/targets
Green: Improving trends/developments dominate	Year ☑ Largely on track
Yellow: Trends/developments show a mixed picture	Year ☐ Partially on track
Red: Deteriorating trends/developments dominate	Year ☒ Largely not on track

Note: The year for the objectives/targets does not indicate the exact target year but the time frame of the objectives/targets.

EU policies have been more effective in reducing environmental pressures than in protecting natural capital and human health.

eutrophication. The impacts of climate change on biodiversity and ecosystems are expected to intensify, while activities such as agriculture, fisheries, transport, industry and energy production continue to cause biodiversity loss, resource extraction and harmful emissions.

Europe has made more progress in relation to resource efficiency and the circular economy. Material consumption has declined and resource efficiency improved as gross domestic product has increased. Greenhouse gas emissions declined by 22 % between 1990 and 2017, due to both policy measures and economic factors. The share of renewable energy sources in final energy consumption increased steadily to 17.5 % in 2017. Energy efficiency has improved, and final energy consumption has declined to roughly the level in 1990. Emissions of pollutants to both air and water have been reduced, while total EU water abstraction decreased by 19 % between 1990 and 2015.

More recent trends are less positive, however. For example, final energy demand has actually increased since 2014 and, if that continues, the EU's 2020 target for energy efficiency may not be met. Harmful emissions from transport and agriculture have also risen, and production and consumption of hazardous chemicals have remained stable. The outlook to 2030 suggests that the current rate of progress will not be sufficient to meet 2030 and 2050 climate and energy targets. In addition, addressing environmental pressures from economic sectors through environmental integration has not been successful, as illustrated by agriculture's continued impacts on biodiversity and pollution of air, water and soil.

Europe has achieved some success in protecting Europeans from environmental risks to health and well-being. For example, drinking and bathing water are generally of high quality throughout Europe. But, again, there are persistent problems in some areas and the outlook is worrying. For example, some persistent and mobile chemicals resist even advanced drinking water treatment. Similarly, although emissions of air pollutants have declined, almost 20 % of the EU's urban population lives in areas with concentrations of air pollutants above at least one EU air quality standard. Exposure to fine particulate matter is responsible for around 400 000 premature deaths in Europe every year, and central and eastern European countries are disproportionately affected.

Human health and well-being are still affected by noise, hazardous chemicals and climate change. Accelerating climate change is likely to bring increased risks, particularly for vulnerable groups. Impacts can arise from heat waves, forest fires, flooding and changing patterns in the prevalence of infectious diseases. In addition, environmental risks to health do not affect everyone in the same way, and there are pronounced local and regional differences across Europe in terms of social vulnerability and exposure to environmental health hazards. In general, the outlook for reducing environmental risks to health and well-being is uncertain. Systemic risks to health are complex and there are important gaps and uncertainties in the knowledge base.

Understanding and responding to systemic challenges

The persistence of major environmental challenges can be explained by a variety of related factors. First, environmental pressures remain substantial despite progress in reducing them. The pace of progress has also slowed in some important areas, such as greenhouse gas emissions, industrial emissions, waste generation, energy efficiency and the share of renewable energy. This implies a need to go beyond incremental efficiency improvements and to strengthen the implementation of environmental policies to achieve their full benefits.

The complexity of environmental systems can also mean that there is a considerable time lag between reducing pressures and seeing improvements in natural capital, and human health and well-being. Environmental outcomes, such as biodiversity loss, Societal systems of production and consumption (food, energy and mobility) must be transformed to achieve Europe's sustainable, low-carbon future.

are often determined by diverse factors, meaning that the effectiveness of policy measures and local management efforts can be offset by external factors. These include global developments such as growing populations, economic output and resource use, all of which influence the situation in Europe. Looking ahead, concerns are also emerging about drivers of change, such as technological and geopolitical developments that have unclear implications.

Perhaps the most important factor underlying Europe's persistent environmental and sustainability challenges is that they are inextricably linked to economic activities and lifestyles, in particular the societal systems that provide Europeans with necessities such as food, energy and mobility. As a result, society's resource use and pollution are tied in complex ways to jobs and earnings across the value chain; to major investments in infrastructure, machinery, skills and knowledge; to behaviours and ways of living; and to public policies and institutions.

The many interlinkages within and between societal systems mean that there are often major barriers to achieving the rapid and far-reaching change that is needed to achieve Europe's long-term sustainability objectives. For example:

- Production-consumption systems are characterised by lock-ins and path dependency, linked to the fact that system elements — technologies, infrastructures, knowledge and so on — have often developed together over decades. This means that radically altering these systems is likely to disrupt investments, jobs, behaviours and values, provoking resistance from affected industries, regions or consumers.

- Interlinkages and feedbacks within systems mean that change often produces unintended outcomes or surprises. For example, technology-driven gains may be undermined by lifestyle changes, partly because of 'rebound effects' when efficiency improvements result in cost savings that enable increased consumption.

- Production-consumption systems are also linked directly and indirectly, for example through their reliance on a shared natural capital base to provide resources and absorb wastes and emissions. This 'resource nexus' means that addressing problems in one area can produce unintended harm elsewhere, for example deforestation and increases in food prices due to biofuel production.

The systemic character of Europe's environmental challenges helps explain the limitations of established environmental governance approaches in delivering needed change. Although signs of progress have been observed across the food, energy and mobility systems, environmental impacts remain high and current trends are not in accordance with long-term environmental and sustainability goals.

A growing body of research and practice provides insights into how fundamental systemic change can be achieved. Such transitions are long-term processes that depend critically on the emergence and spread of diverse forms of innovation that trigger alternative ways of thinking and living — new social practices, technologies, business models, nature-based solutions, and so on. It is impossible to know in advance precisely what innovations will emerge, whether or how they will be integrated into lifestyles, and how they will affect sustainability outcomes. Transitions therefore involve numerous uncertainties, conflicts and trade-offs.

This understanding of systemic change has important implications for governance. First, the perceived role of government shifts from acting as a 'pilot', with the knowledge and tools to steer society towards sustainability, to a role as an enabler of society-wide innovation and transformation. Top-down planning still has a role in some contexts.

But governments also need to find ways to leverage the powers of citizens, communities and businesses.

Achieving this requires contributions across policy areas and levels of government towards common goals. Environmental policy tools remain essential. But enabling systemic change will require a much broader policy mix to promote innovation and experimentation, to enable new ideas and approaches to spread, and to ensure that structural economic change produces beneficial and fair outcomes. The complexity and uncertainty of transition processes means that governments will also need to find ways to coordinate and steer actions across society towards long-term sustainability goals and to manage the risks and unintended consequences that inevitably accompany systemic change.

Where does Europe go from here?

Taken together, the analysis in Parts 1-3 highlights the persistence, scale and urgency of the challenges facing Europe. Achieving the EU's 2050 sustainability vision is still possible, but it will require a shift in the character and ambition of actions. That means both strengthening established policy tools and building on them with innovative new approaches to governance. Drawing on the insights from across the report, Part 4 identifies a variety of important areas where action is needed to enable transitions.

Strengthening policy implementation, integration and coherence: Full implementation of existing policies would take Europe a long way to achieving its environmental goals up to 2030. Achieving full implementation will require increased funding and capacity building; engagement of business and citizens; better coordination of local, regional and national authorities; and a stronger knowledge base. Beyond implementation, Europe needs to address gaps and weaknesses in policy frameworks, for example in relation to land, soil and chemicals. Better integration of environmental goals into sectoral policy is also essential, as is improved policy coherence.

Developing more systemic, long-term policy frameworks and binding targets: The growing set of strategic policies addressing key systems (e.g. energy and mobility) and promoting the transformation to a low-carbon and circular economy are important tools for stimulating and guiding coherent action across society. But the coverage of long-term policy frameworks needs to be extended to other important systems and issues, such as food, chemicals and land use. Comparable cross-cutting strategies are also needed at other levels of governance — including countries, regions and cities. Engaging stakeholders in developing transformative visions and pathways is important to reflect the diverse realities across Europe and to maximise environmental, social and economic co-benefits.

Leading international action towards sustainability: Europe cannot achieve its sustainability goals in isolation. Global environmental and sustainability problems require global responses. The EU has significant diplomatic and economic influence, which it can use to promote the adoption of ambitious agreements in areas such as biodiversity and resource use. Full implementation of the UN's 2030 agenda for sustainable development in Europe and active support for implementation in other regions will be essential if Europe is to provide global leadership in achieving sustainability transitions. Using the Sustainable Development Goals as an overarching framework for policy development in the next 10 years could provide an important step towards realising Europe's 2050 vision.

Fostering innovation throughout society: Changing trajectory will depend critically on the emergence and spread of diverse forms of innovation that can trigger new ways of thinking and living. The seeds for this shift already exist. More and more businesses, entrepreneurs, researchers, city administrations and local communities are experimenting with different

> Achieving the EU's 2050 sustainability vision is still possible, but it will require a shift in the character and scale of actions.


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Sustainability needs to become the guiding principle for ambitious and coherent policies and actions across society.

ways of producing and consuming. In practice, however, innovations often encounter major barriers. Public policies and institutions therefore have a vital role in enabling systemic change. Environmental policies remain essential, but system innovation requires coherent contributions from diverse policy areas, ranging from research, innovation, sectoral and industrial policies to education, welfare, trade and employment.

Scaling up investments and reorienting finance: Although achieving sustainability transitions will require major investments, Europeans stand to gain hugely – both because of avoided harms to nature and society, and because of the economic and social opportunities that they create. Governments need to make full use of public resources to support experimentation, invest in innovations and nature-based solutions, procure sustainably, and support impacted sectors and regions. They also have an essential role in mobilising and directing private spending by shaping investment and consumption choices, and engaging the financial sector in sustainable investment by implementing and building on the EU's Sustainable Finance Action Plan.

Managing risks and ensuring a socially fair transition: Successful governance of sustainability transitions will require that societies acknowledge potential risks, opportunities and trade-offs, and devise ways to navigate them. Policies have an essential role in achieving 'just transitions', for example by supporting companies and workers in industries facing phase-out via retraining, subsidies, technical assistance or investments that help negatively affected regions. Early identification of emerging risks and opportunities related to technological and societal developments needs to be combined with adaptive approaches, based on experimentation, monitoring and learning.

Linking knowledge with action: Achieving sustainability transitions will require diverse new knowledge, drawing on multiple disciplines and types of knowledge production. This includes evidence about the systems driving environmental pressures, pathways to sustainability, promising initiatives and barriers to change. Foresight methods are an important way of engaging people in participatory processes to explore possible futures, outcomes and risks or opportunities. Generating, sharing and using relevant evidence to the full may require changes in the knowledge system linking science with policy and action, including developing new skills and institutional structures.

The next 10 years

Achieving the goals of the 2030 agenda for sustainable development and the Paris Agreement will require urgent action in each of these areas during the next 10 years. To be clear, Europe will not achieve its sustainability vision of 'living well, within the limits of our planet' simply by promoting economic growth and seeking to manage harmful side-effects with environmental and social policy tools. Instead, sustainability needs to become the guiding principle for ambitious and coherent policies and actions across society. Enabling transformative change will require that all areas and levels of government work together and harness the ambition, creativity and power of citizens, businesses and communities. In 2020, Europe has a unique window of opportunity to lead the global response to sustainability challenges. Now is the time to act.

PART 1

Setting the scene

00.
Reporting on the environment in Europe

00.

Reporting on the environment in Europe

A short history

For 25 years, the EEA has operated as a knowledge broker at the interface between science, policy and society in Europe. Today, there is widespread recognition that environmental issues touch on almost all aspects of society and have implications for the types of knowledge needed by policymakers and other stakeholders to underpin their actions. It is this backdrop that has guided the logic and contents of this report, the sixth in a series of European environment state and outlook reports (SOER) produced by the EEA since 1995, as mandated by its governing regulation (EU, 2009). The structure and focus of the six reports have reflected and informed the logic of the EU's environmental policy (Table 0.1). The reports have informed policy implementation by monitoring progress towards established targets, and identified opportunities for EU policy to contribute to achieving long-term objectives, notably the 2050 vision of 'living well, within the limits of our planet', as set out in the EU's Seventh Environment Action Programme, or 7th EAP (EU, 2013).

SOER 2020 marks 25 years of the EEA's reporting on the state of the environment

Like the previous reports, *The European environment — state and outlook 2020* (SOER 2020) provides relevant, reliable and comparable knowledge to support European environmental governance and inform the European public. It draws on the knowledge base available to the EEA and the European Environment Information and Observation Network (Eionet), which is the partnership network between the EEA's 33 member countries ([1]) and six cooperating countries ([2]). EU policies do not necessarily directly apply to the EEA's non-EU member countries and six cooperating countries; nevertheless, many of these countries follow the same or similar environmental and climate policy objectives, so they are included in the assessment as far as possible.

This report, SOER 2020, marks the 25th anniversary of state of the environment reporting at the EEA and more than 30 years of reporting at the European level (CEC, 1987). In parallel, state of the environment reporting at the national level has evolved rapidly, driven by the changing nature of environmental challenges and policy responses and the continuous drive for innovation in

([1]) The 28 Member States of the EU together with Iceland, Liechtenstein, Norway, Switzerland and Turkey.
([2]) Albania, Bosnia and Herzegovina, Montenegro, North Macedonia, Serbia and Kosovo (under United Nations Security Council Resolution 1244/99 and in line with the International Court of Justice Opinion on the Kosovo Declaration of Independence).

TABLE 0.1 The focus and context of SOERs 1995 to 2020

SOER	Focus	Input to EU environmental policy
1995	Addressed the Fifth Environment Action Programme (EAP) targets, focusing on trends and sectoral integration, in the context of a pan-European assessment	Report for the mid-term review of the 5th EAP (1993-2000)
1999	Addressed trends, outlooks and interconnections	Input to the assessment of the 5th EAP (1993-2000)
2005	Addressed trends and outlooks, core indicators, country scorecard analyses and long-term, flexible policymaking	Input to the mid-term review of the 6th EAP (2002-2012)
2010	Addressed 6th EAP priorities, focusing on trends and outlooks, the global context, complex challenges and governance	Input to the final assessment of the 6th EAP (2002-2012)
2015	Addressed 7th EAP priorities, focusing on trends and outlooks, systemic challenges, the need for transitions and governance	Input to implementing the 7th EAP and a baseline for evaluating progress
2020	Addresses 7th EAP priorities and other broad frameworks (including the Sustainable Development Goals), trends and outlooks, systemic challenges and sustainability transitions	Support to established EU environment policies and framing of future policies and programmes

Source: EEA.

assessment methods. Furthermore, the 1998 United Nations Economic Commission for Europe Convention on Access to Information, known as the Aarhus Convention, provided a strong incentive to anchor regular state of the environment reporting in national legislation in many countries. As a result, almost all Eionet countries now publish national state of the environment reports on a regular basis, and more than half of the EEA member countries plan to publish a new edition of their national report in 2019 or 2020 (Box 0.1).

SOER 2015 conclusions and follow-up

SOER 2020 builds on the conclusions of its predecessor published in March 2015. Based on a detailed analysis of the European environment's state and trends, the SOER 2015 synthesis report (EEA, 2015c) presented a mixed picture of policy successes and challenges. It demonstrated that, although implementation of environment and climate policies has delivered substantial benefits for the functioning of Europe's ecosystems and human well-being, the outlook in the coming decades is worrying. Europe faces major challenges in addressing persistent environmental problems that are tied in complex ways to systems of production and consumption. At the same time, in an ever more interconnected world, Europe's ecological and societal resilience is increasingly affected by a variety of global megatrends (EEA, 2015b).

On this basis, SOER 2015 concluded that achieving the EU's vision for 2050, as set out in the 7th EAP, requires fundamental transitions in the production-consumption systems driving environmental degradation, including the food, energy and mobility systems. It also stressed that neither environmental policies alone nor economic and technology-driven efficiency gains alone are likely to be sufficient. Such sustainability transitions will, by their character, entail profound changes in dominant institutions, practices, technologies, policies, lifestyles and thinking. They will inevitably involve uncertainties and disruption — impacting industries, investments, welfare systems and livelihoods. Yet they also present major opportunities to boost Europe's economy and employment and to put Europe at the frontier of science and innovation.

Improving the knowledge base for tackling sustainability transitions in Europe will require a greater use of anticipatory knowledge and understanding of the changing global context, in addition to interdisciplinary and participatory processes. Therefore, since the publication of SOER 2015, the EEA and Eionet have collaborated in a range of knowledge co-creation activities to bring together evidence from experiences across Europe and to develop transdisciplinary knowledge. Two of these EEA-Eionet cooperation processes are briefly introduced in Box 0.2.

SOER 2020 — an integrated assessment focused on sustainability

A plausible future requires a factual present (Snyder, 2018). Addressing trends across timescales is one of the key hallmarks of this report. Two other hallmarks are (1) bridging geographical dimensions in recognition that the environment has no borders and (2) providing integrated analysis across the many environmental, economic, social and governance dimensions needed to achieve sustainability.

This report comes at a time when political initiatives are challenged by false information and fake news. The need for sound scientific knowledge becomes even more important in this context (ESPAS, 2019). Linked to this, more people in Europe are questioning the value of established institutions, public policy and expertise in ways that undermine confidence in such structures and the value of the knowledge supporting them (ESPAS, 2019). This report makes every effort to acknowledge these realities by ensuring transparency through comprehensive referencing of scientific findings and an improved approach to appraisal and communication of aspects of quality and uncertainty, as well as of knowledge gaps. It also draws on stakeholders' knowledge and expertise (see also Section 0.2) and has been subject to extensive peer review (e.g. Eionet, EEA Scientific Committee, international experts). These steps are fundamental for ensuring the relevance, credibility and legitimacy of the report, particularly when the underpinning knowledge base and assessment characteristics are increasingly moving towards a systemic understanding of problems and possible pathways towards sustainability.

> SOER 2020 responds to the environmental challenges and the need to support fundamental transitions to sustainability.

Overall, SOER 2020 responds to the challenges presented by an evolving policy landscape and the need to support fundamental transitions to sustainability in Europe. It builds on the assessment approach of SOER 2015 and includes a range of assessments that support various stages of policy and decision-making. The report is structured into four parts (Figure 0.1).

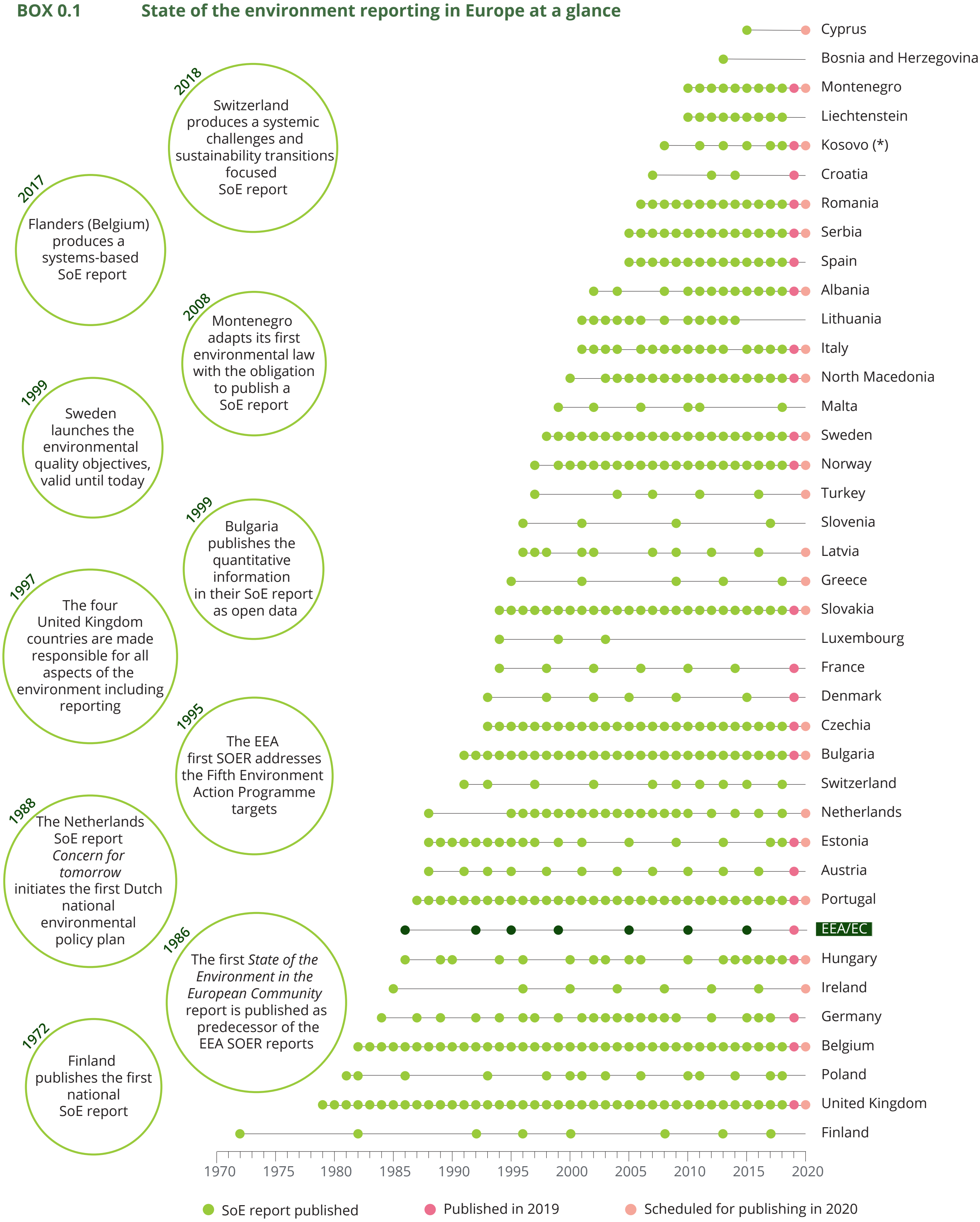
Part 1: **'Setting the scene'** comprises two chapters. Chapter 1 assesses the global-European context and trends that will shape Europe's efforts to achieve sustainability in the coming decades. Therefore, it mostly relies on data and findings from international organisations and processes and includes an analysis of global megatrends, European-specific trends and emerging issues. Chapter 2 provides an overview of Europe's policies and long-term sustainability goals that are currently in place to address environmental and climate challenges.

Part 2: 'Environment and climate trends' comprises 12 chapters that assess European trends over the past 10 to 15 years and provide an outlook for the coming 10 to 15 years. It provides an assessment of progress towards established EU environmental and climate policy goals, focusing particularly on objectives and targets in the 2020-2030 timeframe. Part 2 includes 10 thematic assessments (Chapters 3 to 12): biodiversity and nature; freshwater; land and soil; marine environment; climate change

FIGURE 0.1 Structure of the SOER 2020 report

PART 1 Setting the scene	PART 2 Environment and climate trends	PART 3 Sustainability prospects	PART 4 Conclusions
2 chapters addressing: · Assessing the global-European context and trends · Europe's policies and sustainability goals	*12 chapters addressing:* · 10 thematic assessments · Environmental pressures and sectors · Summary assessment of progress to 7th EAP objectives	*3 chapters addressing:* · Sustainability through a systems lens · Understanding sustainability challenges · Responding to sustainability challenges	*1 chapter addressing:* · Overall assessment of outcomes and reflections on implications

BOX 0.1 **State of the environment reporting in Europe at a glance**

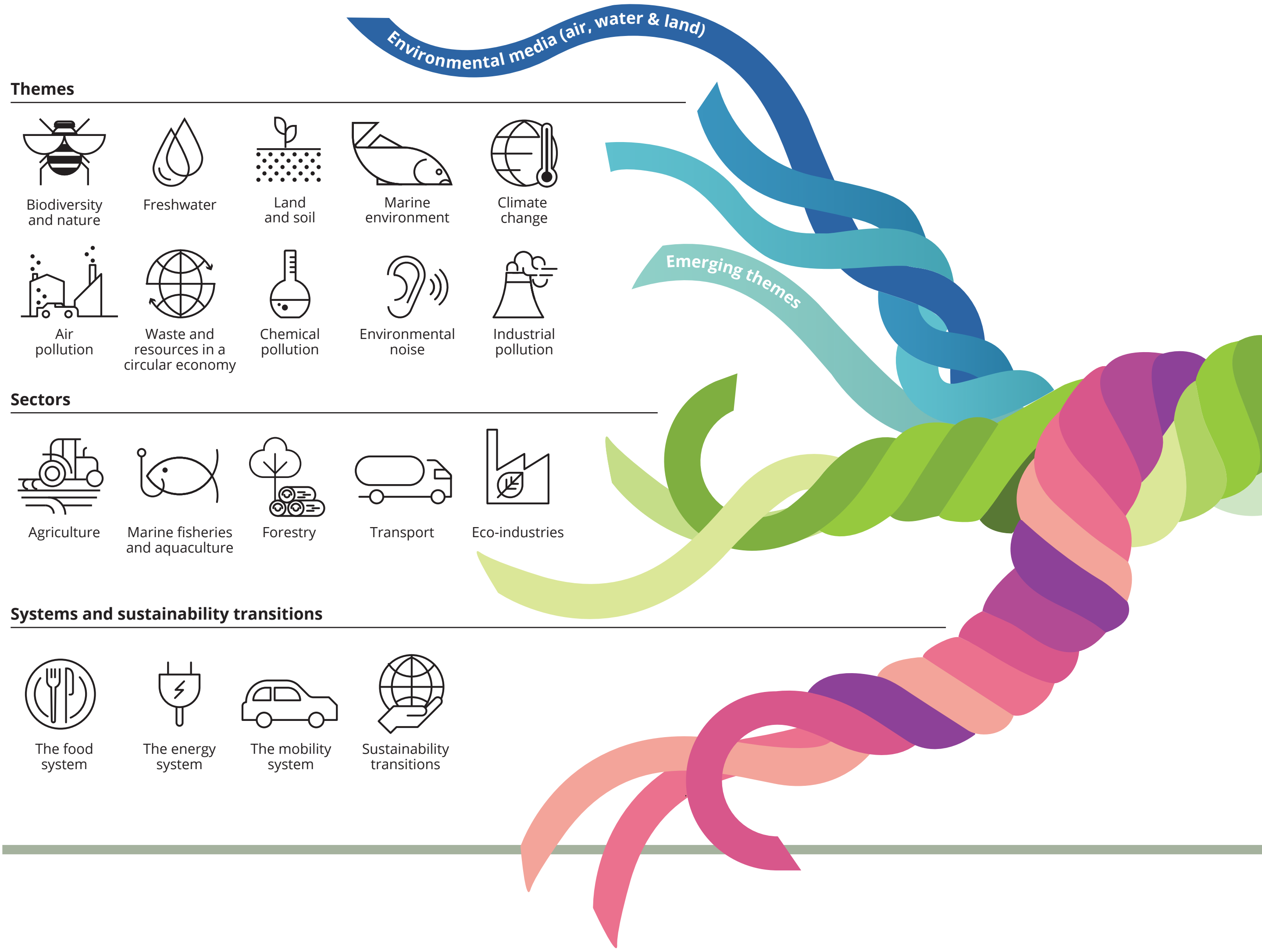


Notes: SoE, state of the environment; (*) Kosovo (under United Nations Security Council Resolution 1244/99 and in line with the International Court of Justice Opinion on the Kosovo Declaration of Independence).

Source: EEA and Eionet.


1972
Stockholm conference on the human environment
First Environmental Action Programme
1975
Wastewater Framework Directive
1976
Bathing Water Directive
1979
Birds Directive
1986
State of the Environment in the European Community published
Our Common Future published World Commission on Environment and Developments
1987
Regulation initiating the EEA and the European environment information and observation network (Eionet)
1990
1992
Convention on Biological Diversity
Framework Convention on Climate Change
Rio Declaration on Environment and Development
Directive on the Conservation of Natural Habitats, Fauna and Flora (Natura 2000)
1994
EEA/Eionet Establishment
First European Environment State and Outlook report published
1995
Europe's environment, the Dobris Assessment published
UNEP First Global Environmental Outlook published
1997
Kyoto Protocol
UNECE Aarhus Convention on Access to Environmental Information
1998
2000
Millenium Declaration and Millenium Development Goals
2003
Cartagena Protocol on Biosafety
2006
Directive Public access to Environmental Information
2008
Registration, Evaluation, Authorisation and Restriction of Chemicals (REACH)
2009
Marine Strategy Framework Directive
2010
2020 Climate & energy package
2011
Nagoya Strategic Plan for Biodiversity, including the Aichi Biodiversity targets
Biodiversity strategy to 2020
Energy roadmap 2050
2012
Bioeconomy strategy
Rio+20 Conference on sustainable development
2013
Adaptation strategy on climate change
7th Environment Action Programme
2015
Action Plan for the Circular Economy
Paris Agreement on Climate Change
2030 Agenda for Sustainable Development
Sendai Framework for Disaster Risk Reduction
2016
Quito New Urban Agenda
First Environmental Implementation Review
2017
2018
Action Plan on Sustainable Finance
European strategy for plastics in a circular economy
2019
UNEP 6th Global Environmental Outlook published
IPBES Global Assessment Report on Biodiversity and Ecosystem Services published
Global Resources Outlook 2019 published
The European environment — state and outlook 2020 (SOER 2020) published
United Nations milestones
European Union milestones
EEA milestones

BOX 0.1 State of the environment reporting in Europe at a glance (cont.)



> SOER 2020 provides a range of assessments that support the different stages of policy and decision-making.

mitigation and adaptation; air pollution; waste and resources; chemical pollution; environmental noise; and industrial pollution. In addition, Chapter 13 addresses the role of sectors in meeting environmental policy goals.

As in 2015, the thematic and sectoral assessments retain a strong focus on implementation. However, SOER 2020 provides a stronger analysis of the interlinkages across themes. In addition, country-level information is integrated to facilitate improved sharing of developments and approaches that offer wider potential. Part 2 also responds to the challenge of growing knowledge complexity by using summary assessments that take a consistent approach across the 10 thematic assessments. The summary assessments also include a new element on robustness to improve transparency regarding the quality of evidence, uncertainty and knowledge gaps. The final chapter of Part 2, Chapter 14, draws on the thematic and sectoral assessments to provide a summary assessment of past trends, outlooks and progress towards policy objectives and targets structured by the objectives of the 7th EAP.

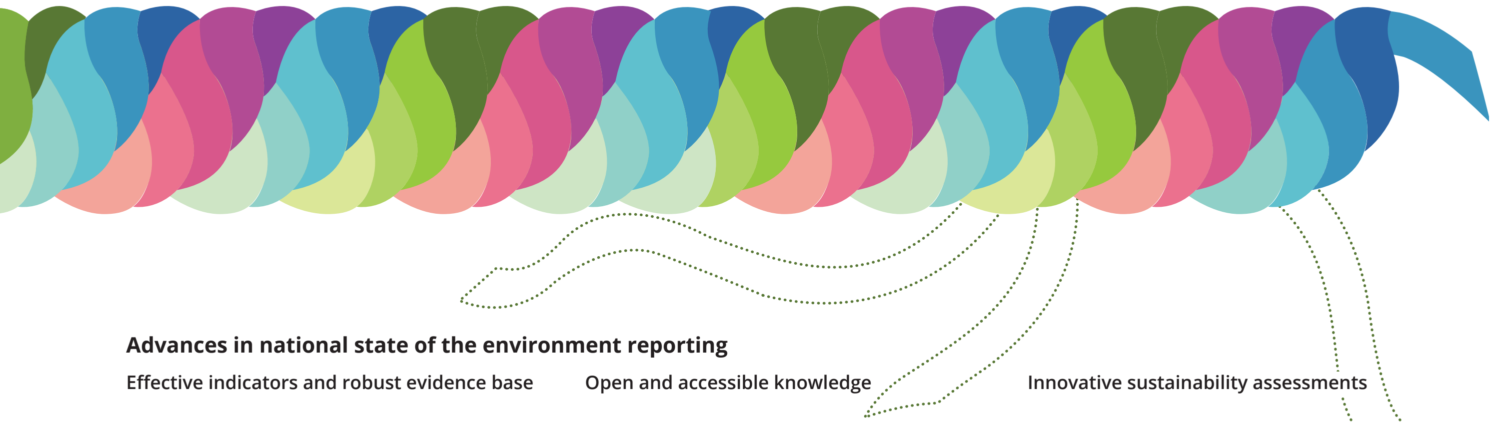
State of the environment: tools and building blocks

Data
from
- Environmental monitoring
- Key registers and databases
- Dedicated data sources and analysis

Indicators
showing environmental
- **D**riving forces
- **P**ressures
- **S**tates
- **I**mpacts
- **R**esponses

Scoreboards
giving insight into
- Environmental trends
- Policy progress

Assessments
providing knowledge on
- The state of the environment
- Trends and outlooks
- Systemic challenges and responses



Advances in national state of the environment reporting

Effective indicators and robust evidence base

that include the monitoring of emerging themes, sustainability transitions, and long term systemic challenges but also incorporate new data sources.

Open and accessible knowledge

with an emphasis on digital information and usage of different digital channels, interactive data visualisation and storytelling and provision of open data and models.

Innovative sustainability assessments

that address the challenges and prospects of long term sustainability transitions, broaden stakeholder participation, indicate barriers and levers for participatory solutions and links assessment knowledge to action.

Part 3: '**Sustainability prospects'** comprises three chapters and assesses long-term prospects (2030-2050), global interactions and opportunities for systemic transitions to achieve the EU's sustainability objectives. Chapter 15 introduces the shift to a broader sustainability and more systems-oriented perspective. Chapter 16 responds to the need for an increased focus on understanding and assessing the systemic character of today's environmental challenges, including key production-consumption systems such as energy, mobility and food. Finally, in response to the growing demand for knowledge on solutions and responses, Chapter 17 complements the analysis of environment, climate and sustainability challenges with a greater emphasis on how Europe can respond.

Part 4: 'Where do we go from here?' reflects on the implications of the findings of Parts 1, 2 and 3. This includes reflections on the current state of, trends in and outlook for Europe´s environment, opportunities for Europe's environmental governance, and broader enabling conditions to put Europe on a path to a prosperous and sustainable future.

Translating knowledge into action requires the involvement of a wide range of stakeholders. In response, the EEA has designed SOER 2020 as a process, extending over 2019 and 2020. The present SOER 2020 report, represents the first component in this process and provides the foundation for subsequent stakeholder interactions aimed at exploring its conclusions and their implications. The second component will be a set of stakeholder events that will inform the development of a 'knowledge for action' report that the EEA will publish in 2020.

BOX 0.2 EEA-Eionet cooperation in building anticipatory knowledge for sustainability transitions

E3I Sustainability transitions: now for the long term

Recognising the need to develop new knowledge to support environmental governance, the EEA and Eionet initiated the Eionet Improvement and Innovation Initiative (E3I) after the publication of SOER 2015. Focusing initially on the theme of sustainability transitions, E3I work combined two major functions. First, EEA and Eionet partners engaged in a shared learning process about sustainability transitions and related knowledge needs. Second, the work produced empirical evidence about transition activities across Europe, providing inputs to EEA work.

The E3I transitions activities were led by a working group of Eionet national focal points and EEA staff, who gathered case studies and inputs from 26 EEA member countries and five European topic centres. The work culminated in the publication of the first Eionet publication, *Sustainability transitions: now for the long term* (EEA and Eionet, 2016), which used case studies and interviews to explain and illustrate key concepts and to give a sense of the transformative activities already under way at local levels.

Mapping Europe's environmental future: understanding the impacts of global megatrends at the national level

Drivers of change, including global megatrends, are likely to bring risks and opportunities, whose relative magnitude largely depends on the variability and specificity of local environmental, economic and social conditions. The EEA and the National Reference Centre for Forward-Looking Information and Services (NRC FLIS) have engaged in a joint activity to develop a methodological toolkit to facilitate analysis of the implications of global megatrends at the national level (EEA and Eionet, 2017).

Many countries or regions in Europe have now investigated how global megatrends and other drivers of change may affect their environment and society (Table 0.2). The majority of these studies were prompted by the EEA's reporting on global megatrends (EEA, 2010, 2015a, 2015b) as well as the publication of the methodological toolkit. While differences exist in the focus and scope of these studies, climate change has been analysed most frequently, followed by pollution loads, population and urbanisation trends, and economic trends (Table 0.2).

Several countries (or regions) have included the findings of these studies in their national state of the environment reports. The global megatrends analysis for Switzerland (FOEN, 2016) is an example of clear articulation of these efforts. The study mainly followed the logic of the methodological toolkit (EEA and Eionet, 2017). One of the key findings used to inform the Swiss national state of the environment report (Swiss Federal Council, 2018) is that Switzerland's environmental challenges are all influenced by global megatrends. For example, the Swiss food production system is expected to be significantly affected by climate change, leading to both opportunities and risks. Additional in-depth studies confirmed that a longer growing season could be beneficial for agricultural production, but it might also lead to water resource conflicts. Heat waves, new diseases and water scarcity could also exert stress on dairy farming and meat production, both being very important economic activities. As only 60 % of Swiss food consumption is accounted for by domestic production, the country will be vulnerable to future price fluctuations in global food commodities triggered by climate change. Developing adaptation strategies will therefore be crucial to ensure ecological and societal resilience in Switzerland. ■

TABLE 0.2 Studies on implications of global megatrends at the national/regional scale and their thematic focus

		Focus of national/regional study											
		Environment						Resources		Environment and society			
EEA global megatrends		**Switzerland** (FOEN, 2016)	**Hungary** (MA, 2017)	**Slovenia** (SEA, 2018)	**Flanders** (BE) (Flemish Environment Agency, 2014)	**Slovakia** (Slovak Environment Agency et al., 2016)	**Sweden** (Naturvårdsverket, 2014)	**Western Balkans** (ETC/ICM, 2018)	**Northern Europe** ([a]) (Naturvårdsverket, 2014)	**Finland** (Valtioneuvoston kanslia, 2017)	**United Kingdom** (DEFRA, 2017)	**Netherlands** (PBL, 2013)	Frequency (%)
Social	Diverging global population trends	×	×		×	×	×		×	×	×	×	82
	Towards a more urban world	×	×		×	×	×		×	×	×	×	82
	Changing disease burdens and risks of pandemics		×		×	×	×		×		×		55
Technological	Accelerating technological change				×	×	×		×	×	×	×	64
Economic	Continued economic growth?	×	×		×	×	×		×	×	×	×	82
	An increasingly multipolar world				×	×	×		×	×	×		55
	Intensified global competition for resources			×	×	×	×	×	×		×		64
Environmental	Growing pressures on ecosystems	×	×		×	×	×	×	×		×		73
	Increasingly severe consequences of climate change	×	×	×	×	×	×	×	×	×	×	×	100
	Increasing environmental pollution	×	×		×	×	×	×	×	×	×		82
Political	Diversifying approaches to governance				×	×	×		×	×	×		55

Note: ([a]) 'Northern Europe' refers to a case study run for Germany and Sweden.

Source: EEA, based on NRC FLIS inputs.

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

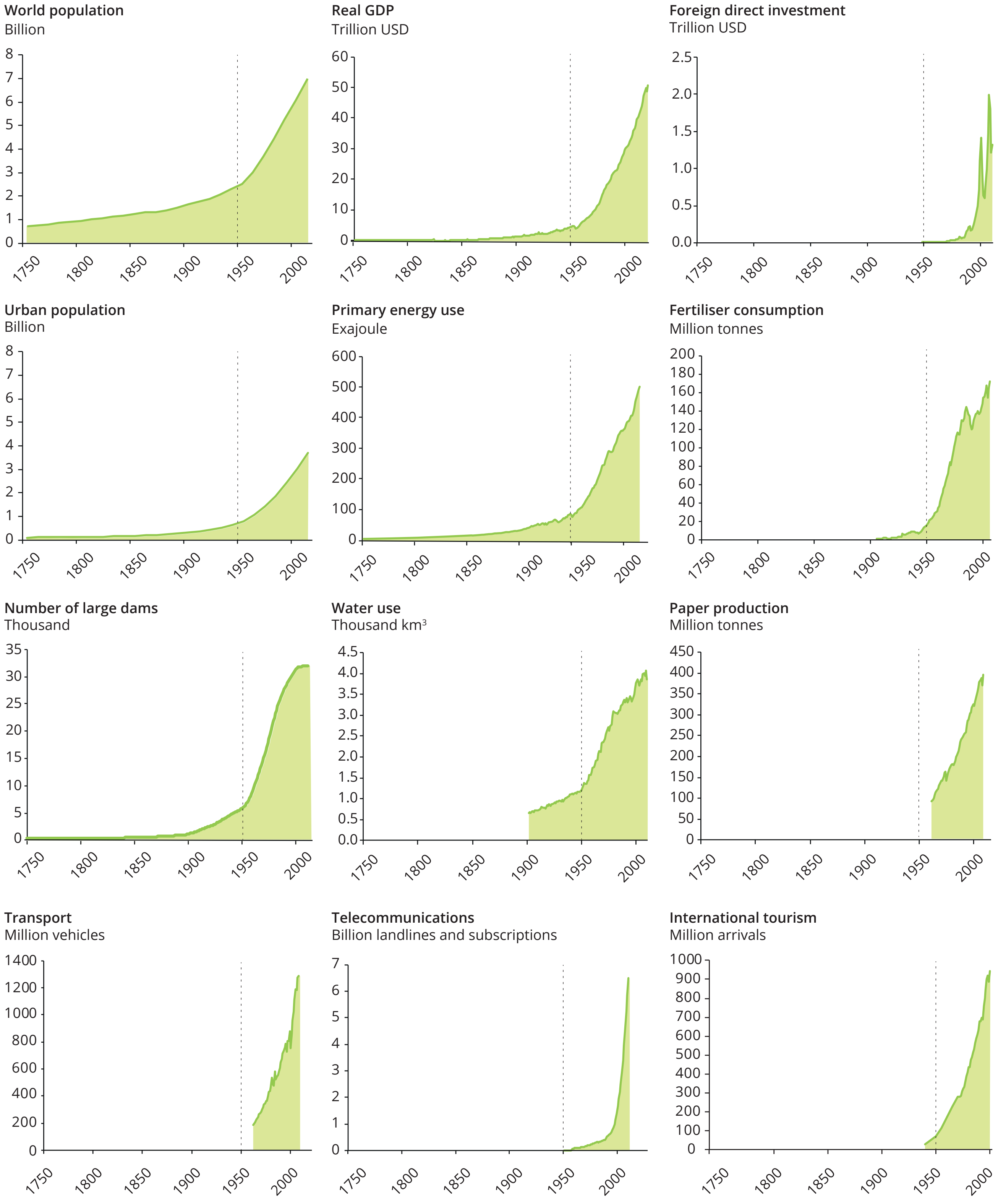
Many key human achievements — culture, farming, cities, industrialisation, medical advances — have happened during a period in which the Earth's natural regulatory systems, such as the climate, have been remarkably stable. This period spanning the last almost 12 000 years is referred to as the Holocene. 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.

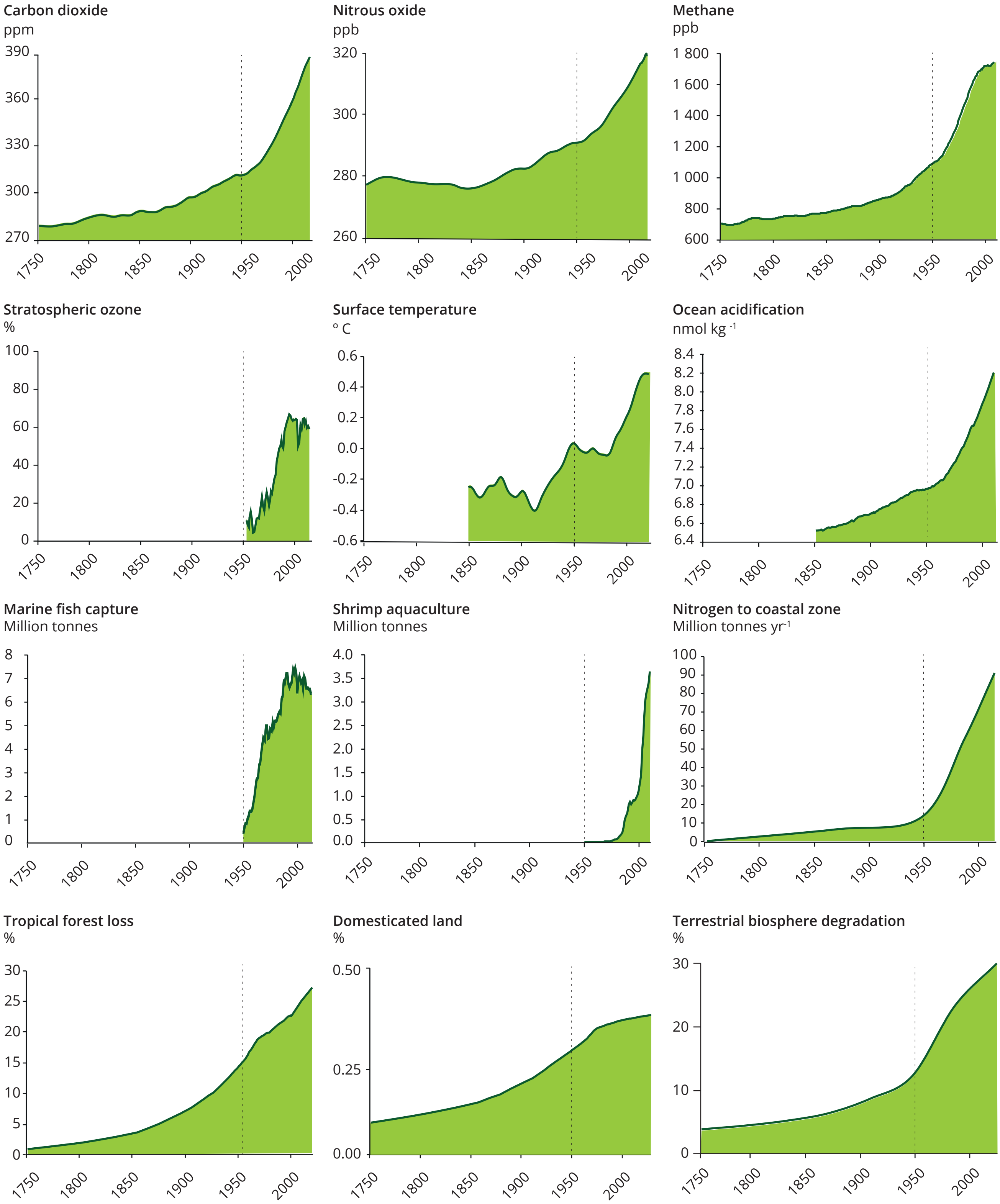
This exponential trajectory of human activity and economic growth has delivered enormous improvements in living standards and well-being for hundreds of millions of people, especially in Europe and other highly industrialised world regions. Other world regions have also benefited from this growth. For 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
390
360
330
300
270
1750
1800
1850
1900
1950
2000
Nitrous oxide
ppb
320
300
280
260
Methane
ppb
1 800
1 600
1 400
1 200
1 000
800
600
Stratospheric ozone
%
100
80
60
40
20
0
Surface temperature
° C
0.6
0.4
0.2
0.0
-0.2
-0.4
-0.6
Ocean acidification
nmol kg -1
8.4
8.2
8.0
7.8
7.6
7.4
7.2
7.0
6.8
6.6
6.4
Marine fish capture
Million tonnes
8
7
6
5
4
3
2
1
0
Shrimp aquaculture
Million tonnes
4.0
3.5
3.0
2.5
2.0
1.5
1.0
0.5
0.0
Nitrogen to coastal zone
Million tonnes yr-1
100
90
80
70
60
50
40
30
20
10
0
Tropical forest loss
%
30
25
20
15
10
5
0
Domesticated land
%
0.50
0.25
0.00
Terrestrial biosphere degradation
%
30
20
10
0

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).

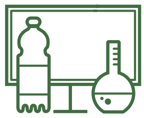
1.2 Unprecedented pressures on planet Earth

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)).



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

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.

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.

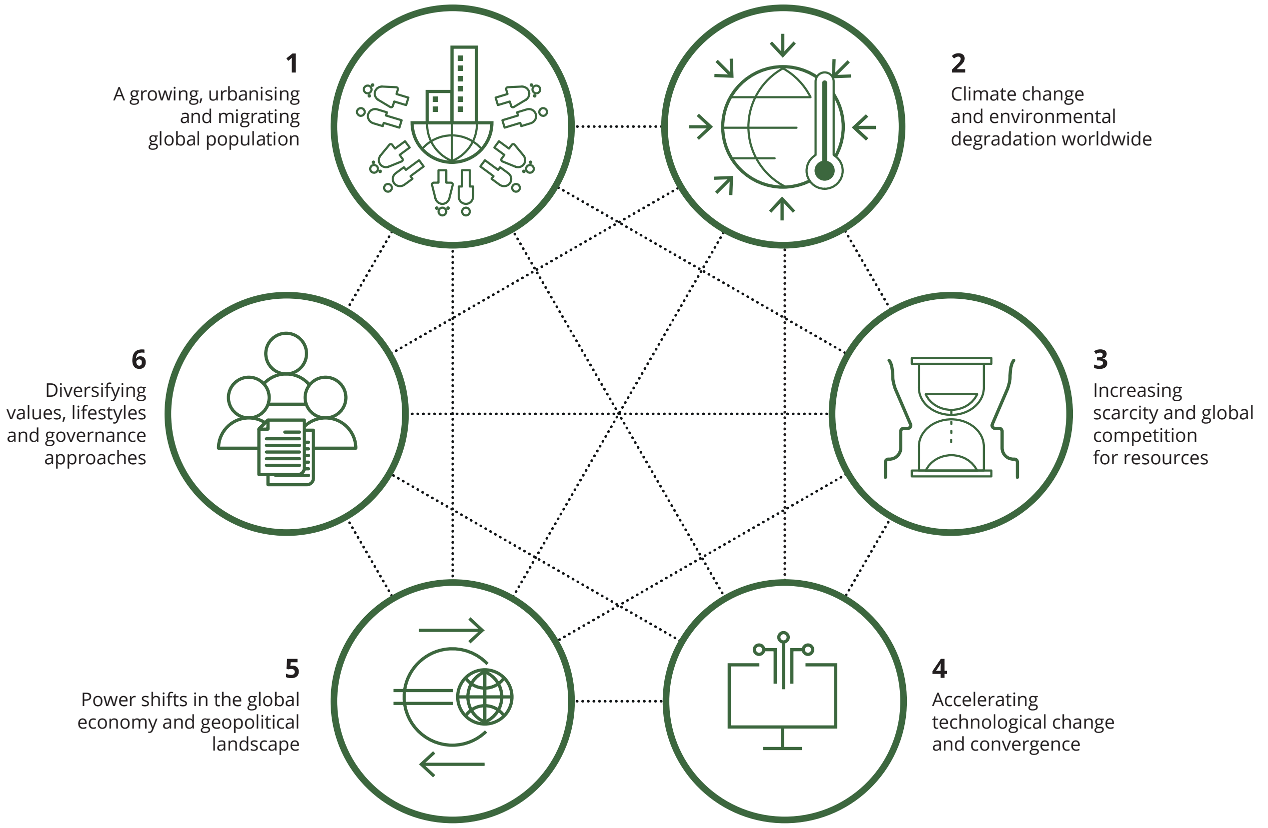
There are multiple options for identifying and grouping drivers of change into overarching thematic clusters, depending on the purpose and thematic emphasis. Possible foci can be technology (OECD/DASTI, 2016), economic aspects (WEF, 2017) or geopolitics (ESPAS, 2017). This report draws upon a synthesis 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.

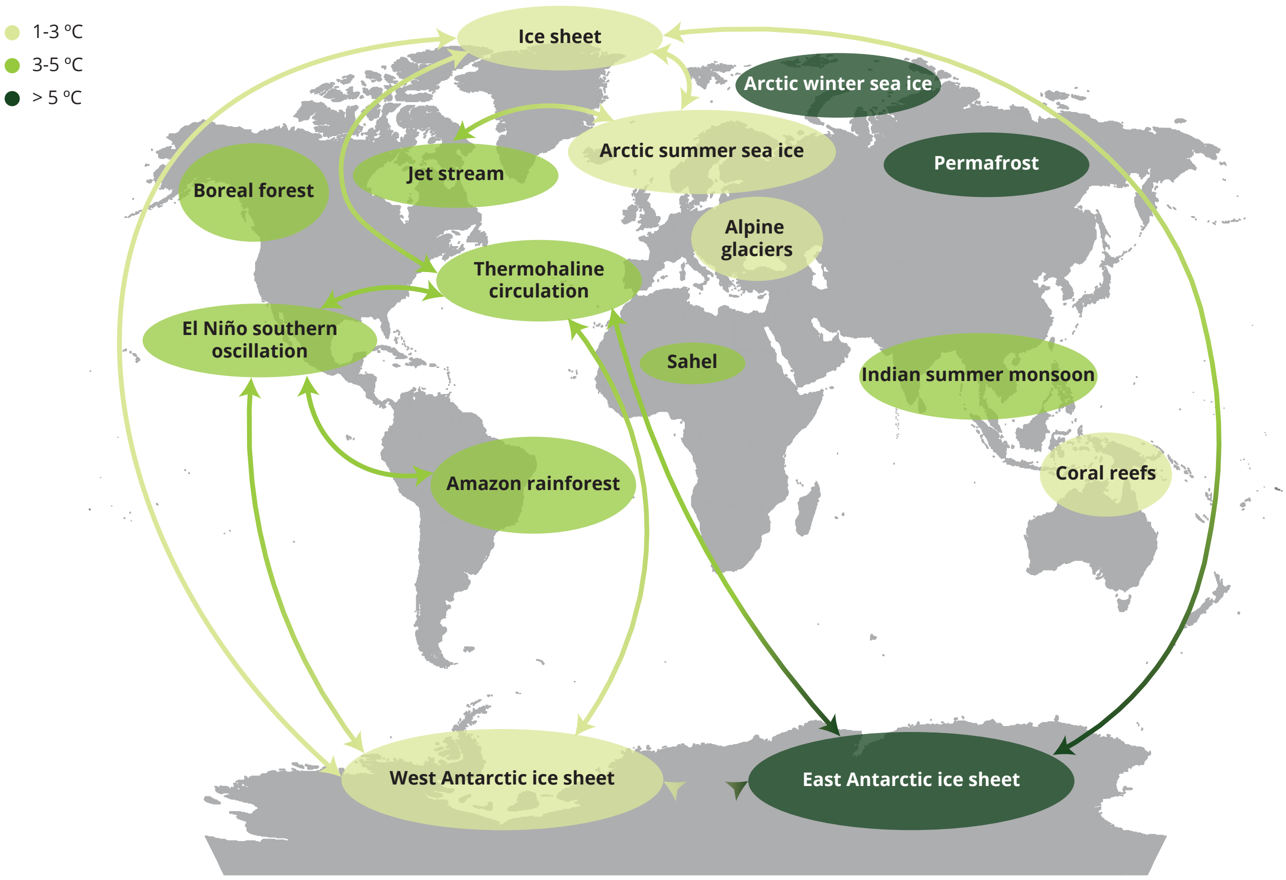
Resilience refers to the capacity of a system to absorb disturbance and reorganise while undergoing change so that it retains essentially the same function, structure, identity and feedbacks (Walker et al., 2004).

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

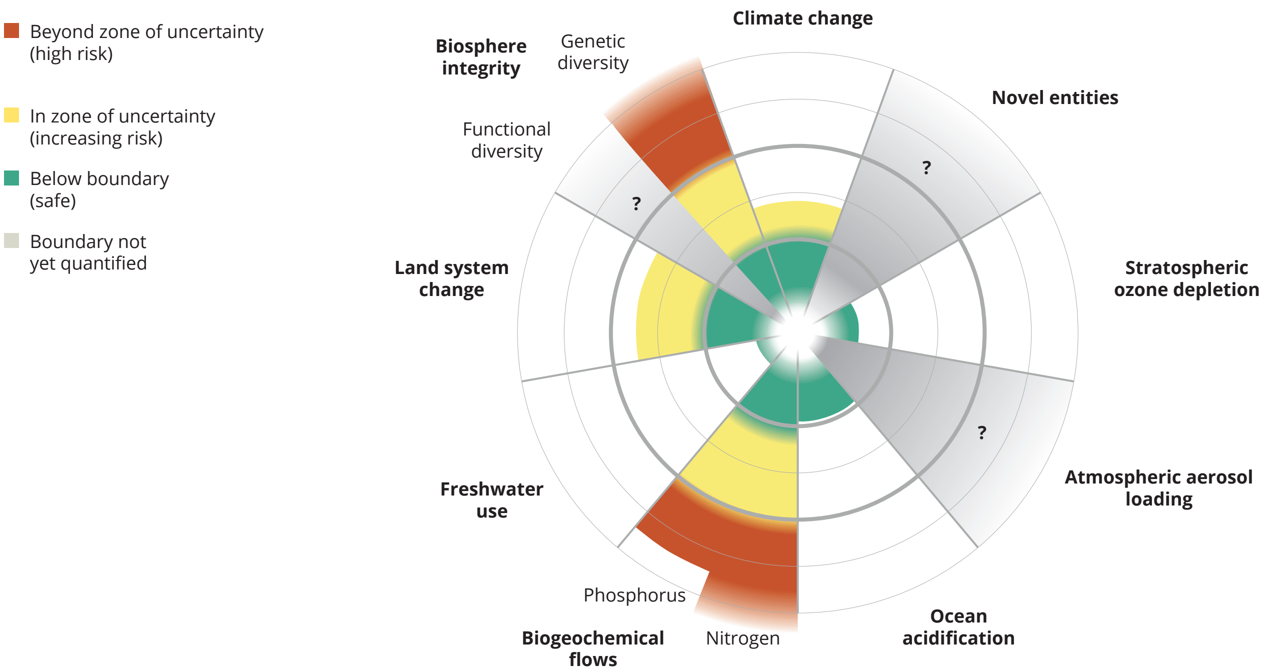
The planetary boundary framework identified nine processes that regulate the stability and resilience of the Earth system — 'planetary life support systems' (Rockström et al., 2009; Steffen et al., 2015a). The framework proposes precautionary quantitative planetary boundaries within which humanity can 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). ■

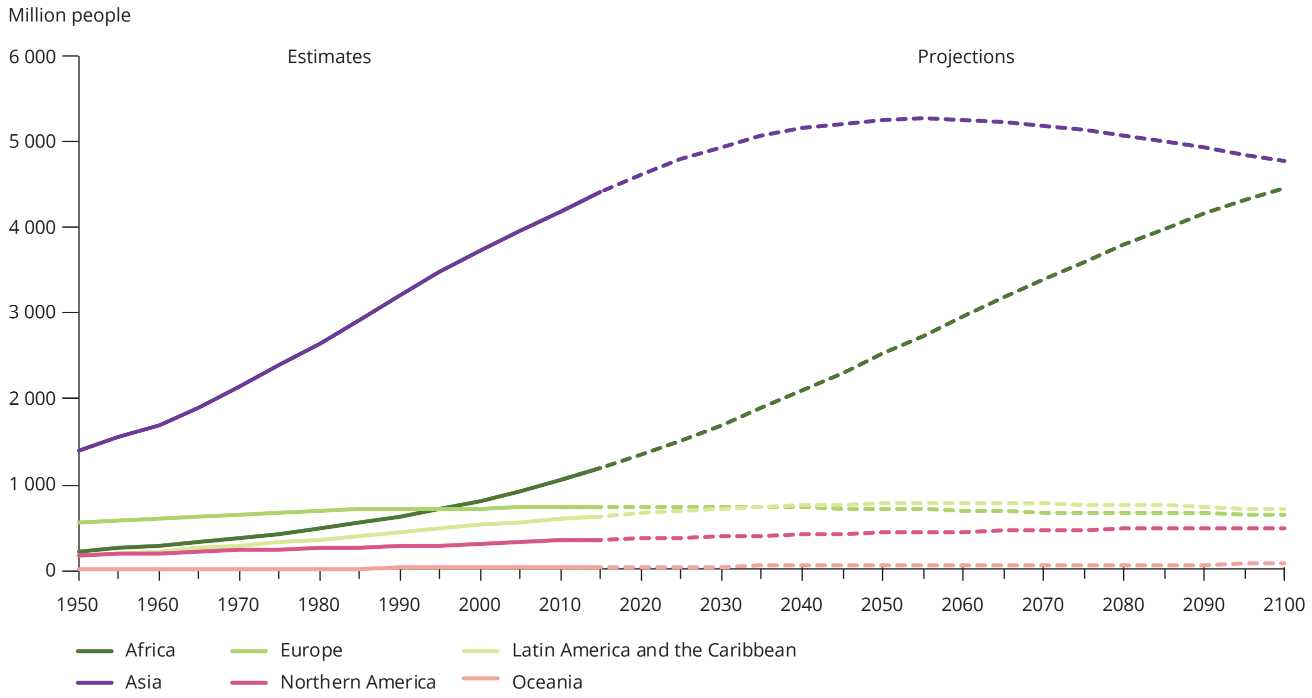
FIGURE 1.4 The status of the nine planetary boundaries



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**



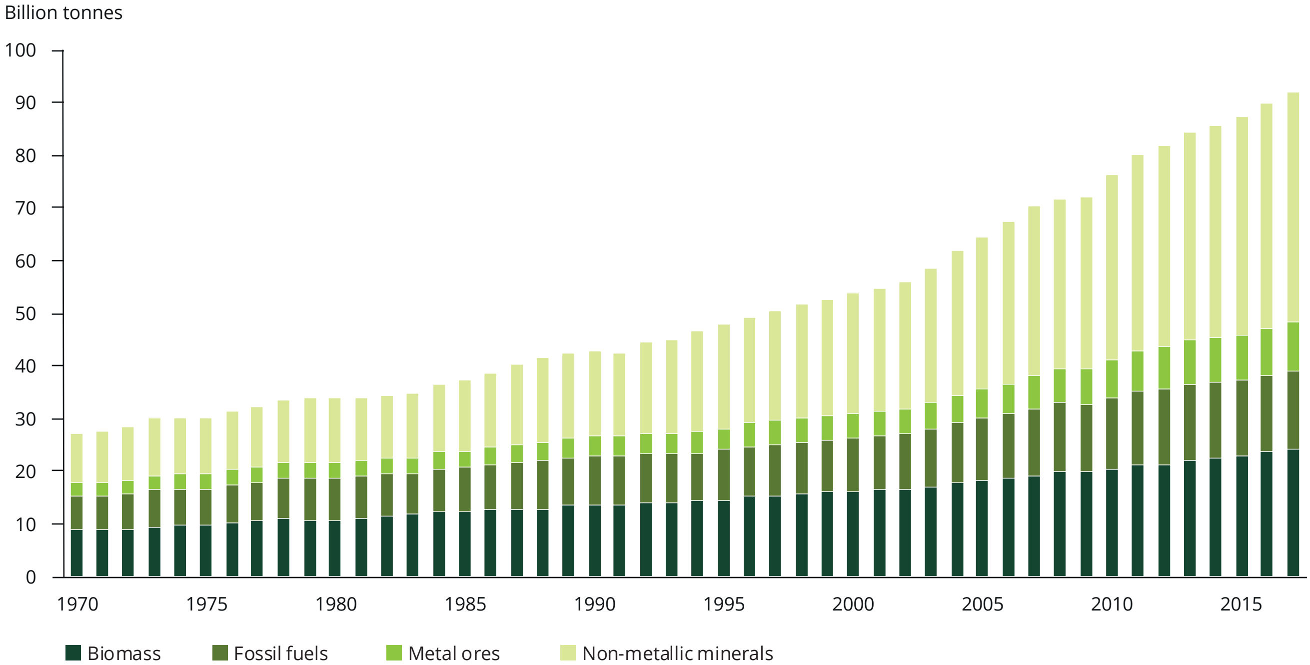
Source: UNDESA (2017b).

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).

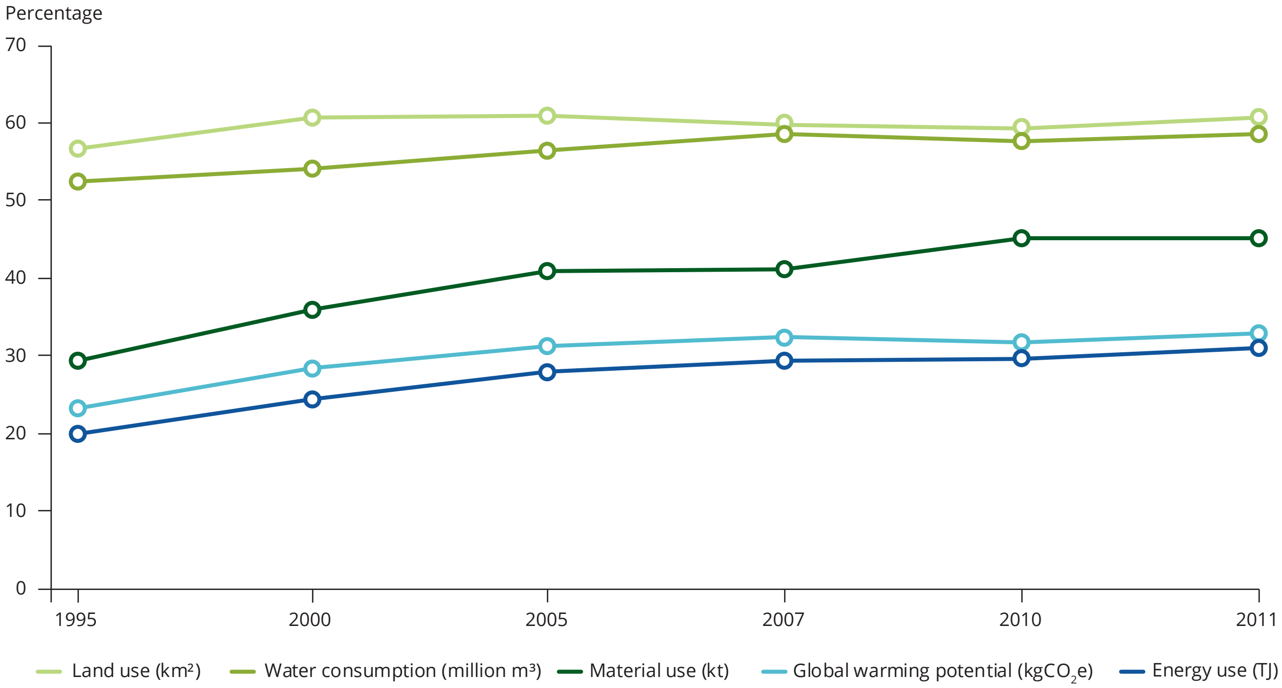
To summarise, it can be concluded that Europe is highly dependent on resources extracted or used outside Europe, such as water, land use products, biomass or other materials, to meet its high consumption levels. This means that a large part of the environmental impacts associated with European consumption 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).

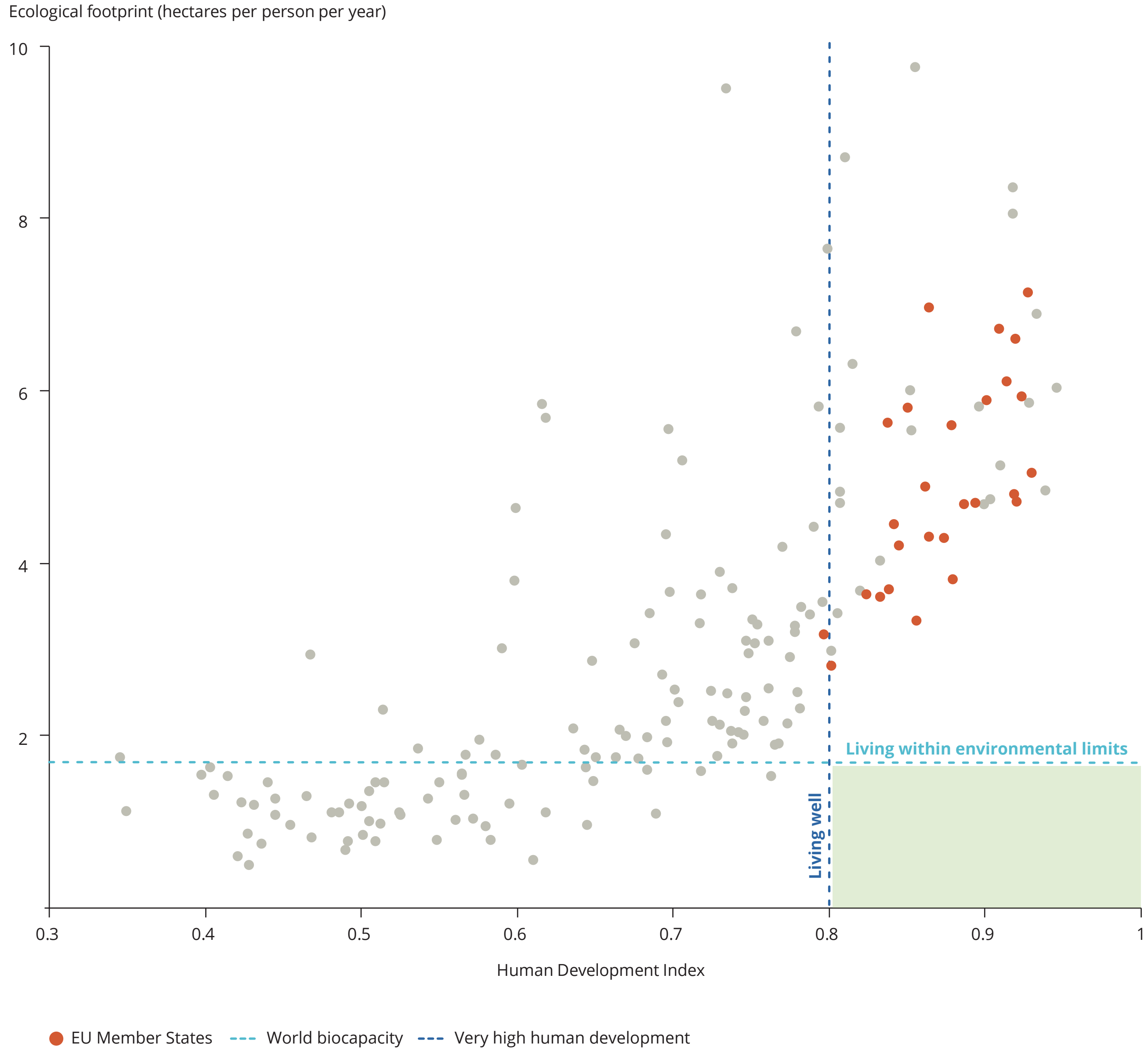
(Boxes 1.3 and 1.4). The first step in such an exercise is to disaggregate and allocate the globally defined limits of the planetary boundaries to specific national or European 'allowances', or 'shares', and then to measure the actual national or European performance against such 'down-scaled' allowances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

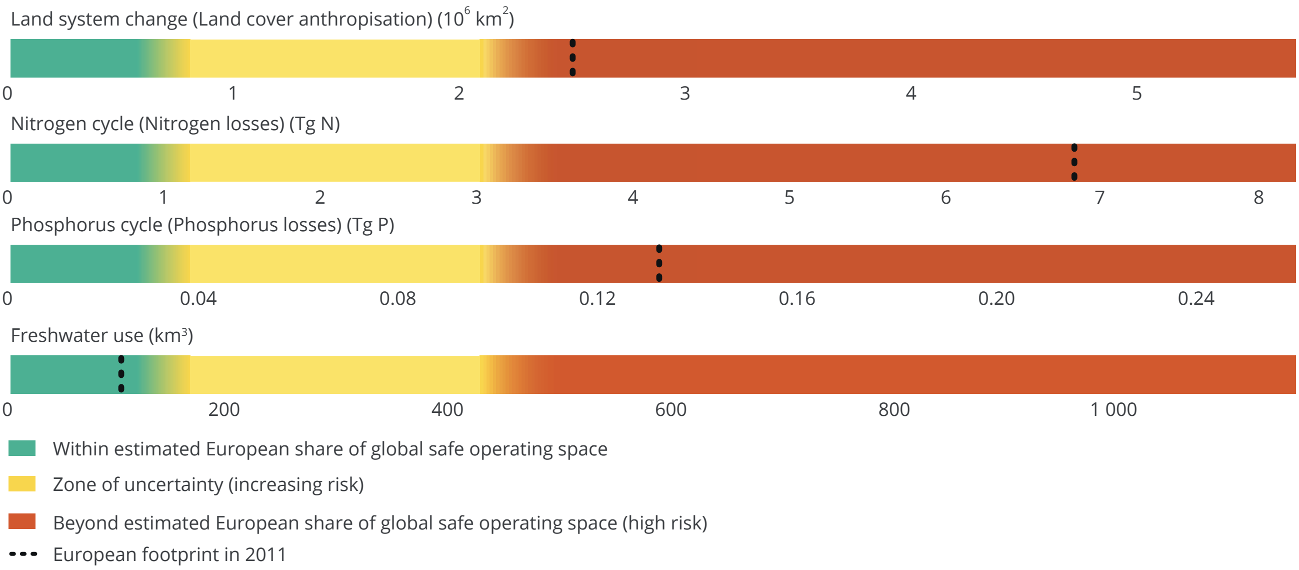
Sovereignty: resource needs as a function of economic throughput, biocapacity and land availability.

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).

02. Europe's policies and sustainability goals

Summary

- Recognising persistent environmental and climate challenges at European and global scales, European environmental and climate policymaking is increasingly driven by long-term sustainability goals, as embedded in the EU's Seventh Environment Action Programme (7th EAP) 2050 vision, the 2030 agenda for sustainable development and the Paris Agreement on climate change.

- The current European environmental and climate policy landscape reflects a diversity of approaches and instruments adopted since the 1970s. European policies have evolved from targeted regulatory interventions on specific issues to a stronger focus on integrating the environmental dimension into sectoral policies and, more recently, to macro-integrated policy packages with a broader sustainability perspective.

- EU environmental policies are mainly framed around three 7th EAP policy priorities: (1) to protect, conserve and enhance the EU's natural capital; (2) to turn the EU into a resource-efficient, green and competitive low-carbon economy; and (3) to safeguard the EU's citizens from environment-related pressures and risks to their health and well-being.

- Since *The European environment — state and outlook 2015* (SOER 2015) report was published, significant policy developments have occurred around the low-carbon economy and the circular economy frameworks, in particular with the adoption of the 2030 climate and energy framework and the 2018 circular economy package, and have been complemented by an update of the bioeconomy strategy.

- Environmental and climate action is also pursued through broader institutional arrangements, such as the climate-related expenditure accounting for at least 20 % of the EU's budget for 2014-2020 and the sustainable finance initiative.

- European citizens are highly supportive of environmental protection and climate action, while cities and other local actors are increasingly proactive in launching environmental and climate initiatives that support the achievement of the EU's objectives and targets.

02.

Europe's policies and sustainability goals

EU environment policy aims for a Europe that lives well, within the limits of our planet.

2.1 Europe's long-term sustainability goals

2.1.1 The 2050 vision of the Seventh Environment Action Programme

Europe has increasingly recognised in its policies the unprecedented pressures caused by human activities on planet Earth and the role played by the European economy in that regard (Chapter 1). In particular, European environmental policy is aimed at 'living well, within the limits of our planet'. In 2013, with the adoption of the Seventh Environment Action Programme (7th EAP), the EU endorsed the above long-term sustainability goal and turned it into a vision with a horizon of 2050 to guide its environmental action:

In 2050, we live well, within the planet's ecological limits. Our prosperity and healthy environment stem from an innovative, circular economy where nothing is wasted and where natural resources are managed sustainably, and biodiversity is protected, valued and restored in ways that enhance our society's resilience. Our low-carbon growth has long been decoupled from resource use, setting the pace for a safe and sustainable global society. (EU, 2013a)

The vision reflects a greater recognition that the prosperity, health and well-being of European citizens are intrinsically linked to a resilient and healthy natural environment in Europe and also at a planetary scale, as environmental degradation elsewhere can have negative effects in Europe in many ways (Chapter 1 and Part 3). It builds on the understanding that how we live, exchange, consume or produce is deeply interconnected with our environment through a complex web of interrelationships, related to what we extract from it (e.g. natural resources, energy), what we release into it (e.g. pollutants, chemicals) or what we disrupt in its functioning (e.g. climate, ecosystems, nutrient cycles). Addressing persistent environmental and climate challenges, such as the loss of biodiversity, climate change, the degradation of ecosystems, the unsustainable management of natural resources or the adverse effects of pollution on human health, will require fundamental changes in our society and economy (EEA, 2015a). By setting a distant time horizon, the vision recognises that important and sustained efforts will be required over several decades.

The 7th EAP 2050 vision is a true sustainability vision, which goes beyond environmental issues per se. It echoes the founding principles of the international Brundtland Commission

European environmental and climate policy is increasingly driven by long-term sustainability goals.

on sustainable development (WCED, 1987), reiterated by former United Nations (UN) Secretary-General Ban Ki-moon: 'At its essence, sustainability means ensuring prosperity and environmental protection without compromising the ability of future generations to meet their needs.' (Ban Ki-moon, 2014). Those principles have long since been at the heart of the European project, with sustainable development included in the Treaty of Amsterdam as an overarching objective of EU policies (EU, 1997). Article 3 of the Treaty on European Union currently in force states that, '[The Union] shall work for the sustainable development of Europe based on balanced economic growth and price stability, a highly competitive social market economy, aiming at full employment and social progress, and a high level of protection and improvement of the quality of the environment' (EU, 2007). The 7th EAP is one of the key policy frameworks to achieve this overall goal for the EU. Beyond setting its 2050 vision, it provides a more concrete overarching framework for shorter term objectives and targets the time horizon 2020/2030 (Section 2.3 and Part 2).

Besides, the 7th EAP vision is fully aligned with global objectives, such as the global recognition of the importance of protecting biodiversity and ensuring the provision of the ecosystem services on which human societies depend, as reflected in the 2020 Aichi biodiversity targets of the UN Convention on Biological Diversity. Since *The European environment — state and outlook 2015* report (SOER 2015) was published, two significant, long-term, global sustainability frameworks have been endorsed by the EU and complement the 7th EAP vision: the 2030 agenda for sustainable development and the Paris Agreement on climate change.

2.1.2 The 2030 agenda and the Sustainable Development Goals

In 2015, world leaders adopted the 2030 agenda for sustainable development, along with a set of 17 Sustainable Development Goals (SDGs) and 169 associated targets (UN, 2015b; Figure 2.1). Universal in scope, it applies to all countries at all levels of development, taking into account their 'different capacities and circumstances'. The setting of these goals built on the experience of the Millennium Development Goals (MDGs), which made an 'enormous contribution in raising public awareness, increasing political will and mobilising resources for the fight to end poverty' (EU, 2018g). Following up on the Rio+20 conference in 2012, the 2030 agenda expands the scope of the MDGs to address poverty eradication along with the economic, social and environmental dimensions of sustainability, as well as underlying issues related to institutions, governance, the rule of law, peace and international collaboration. In particular, the UN has stressed that the agenda should be viewed as an indivisible whole, in which all targets — be they of an economic, social or environmental nature — are equally important (Chapter 15).

Many SDGs embed a strong environmental dimension and have dedicated targets to progress on core environmental issues. In particular, SDG 13 promotes climate action, while SDGs 14 and 15 aim to advance the conservation of marine and terrestrial ecosystems and the sustainable use of their resources. Environmental sustainability is also sought in relation to agriculture (SDG 2), health (SDG 3), water (SDG 6), energy (SDG 7), tourism (SDG 8), infrastructure and industry (SDG 9), cities (SDG 11) and consumption and production patterns (SDG 12). Overall, 41 of the 169 targets address the quality of the physical environment either directly or indirectly.

Instrumental in shaping the 2030 agenda, the EU has expressed its ambition to play, together with its Member States, a leading role in its implementation (EU, 2018g). In 2016, the European Commission outlined its strategic approach and committed itself to integrating the SDGs in both its internal and its external policies (EC, 2016b). The first steps included the mapping of EU policies and actions for each SDG (EC, 2016a), the publication of an annual monitoring report on the EU's progress towards SDGs on the basis of 100 indicators (Eurostat, 2018), and the setting-up of a multi-stakeholder platform to support and advise the European Commission (EC, 2018h). In January 2019, the European Commission adopted the reflection paper 'Towards a sustainable Europe by 2030' to launch a forward-looking debate among EU citizens, Member States and other stakeholders on how to best progress on the SDGs (EC, 2019c).

Apart from the 2030 agenda, the year 2015 gave rise to several other international agreements in the field of sustainability, including the Addis Ababa Action Agenda of the Third International Conference on Financing for Development (UN, 2015c), which provides a global framework for mobilising public and private resources and investments for sustainable development, the Sendai Framework for Disaster Risk Reduction (UN, 2015a), which sets a new global approach to disaster risk management policy and operations, and, above all, the

FIGURE 2.1 **The Sustainable Development Goals**

Source: UN.

Paris Agreement on climate change (UNFCCC, 2015b).

2.1.3
The Paris Agreement

Only a few months after the adoption of the 2030 agenda, the 21st Conference of the Parties (COP 21) of the United Nations Framework Convention on Climate Change (UNFCCC) was held in Paris on 12 December 2015. In total, 196 countries adopted the first-ever universal, legally binding global climate agreement, commonly referred to as the Paris Agreement, with the aim of strengthening the global response to the 'urgent and potentially irreversible threat [of climate change] to human societies

The 2030 Agenda for Sustainable Development and the Paris Agreement are two examples of ambitious, international agreements on sustainability.

and the planet' (UNFCCC, 2015a). This responds in particular to the scientific evidence compiled and reviewed by the Intergovernmental Panel on Climate Change (IPCC) (Chapter 1).

The Paris Agreement sets the ambitious goal to '[hold] the increase in the global average temperature to well below 2 °C above pre-industrial levels and to pursue efforts to limit the temperature increase to 1.5 °C above pre-industrial levels'. Parties also agreed to '[increase] the ability to adapt to the adverse impacts of climate change' (UNFCCC, 2015b). To accomplish these goals, the Parties aim to reach a global peak in greenhouse gas (GHG) emissions as soon as possible and to achieve net zero emissions in the second half of this century.

In contrast to the previous international treaty, the 1997 Kyoto Protocol, which covered only about 12 % of global emissions (UNFCCC, 1997), all major emitters have adopted the legally binding obligations of the Paris Agreement. However, in 2017, the

United States announced its withdrawal from the Paris Agreement, which, in practice, may become effective in late 2021 (UNFCCC, 2017). In Europe, as required by the Agreement, the EU and its Member States have submitted their joint 'intended nationally determined contributions', which will be renewed and upgraded every 5 years. In addition to existing policies (Section 2.3), the EU supports Member States efforts through its European strategic long-term vision for a prosperous, modern, competitive and climate-neutral economy (EC, 2018c). The EU played an instrumental role in making the Paris Agreement operational during COP 24 (EC, 2018k).

The 2030 agenda and the Paris Agreement have considerably raised the ambition of international cooperation on sustainable development. The world, not just Europe, has recognised the importance and urgency of addressing a range of persistent environmental and climate challenges in a much more proactive and coordinated way. Although recognising and agreeing on long-term sustainability goals is essential, Parts 2 and 3 will highlight the challenges faced by Europe in delivering on these commitments, as well as the potential opportunities were its responses to the challenges to evolve more fundamentally.

2.2 Europe's environmental and climate policy

2.2.1 The evolution of European environmental and climate policy

While the 7th EAP 2050 vision, the 2030 agenda and the Paris Agreement are today increasingly driving European environmental and climate policymaking, the last dates back far before these long-term sustainability

European environmental and climate policy rests on solid foundations.

goals and frameworks were set up. At first, as reflected in the first two EAPs (1972-1981), European environmental policy consisted mainly of regulatory interventions focusing on specific issues such as water quality, air quality, waste disposal or species protection. The adoption of the Waste Framework Directive (EEC, 1975), the Bathing Water Directive (EEC, 1976) or the Birds Directive (EEC, 1979) represents this approach, based on the premise that targeted environmental legislation could lead to significant improvements in a range of environmental issues with relatively direct, well-identified cause-effect relationships. Since the 1970s, the replication of this intervention model led to a body of some 500 directives, regulations and decisions, which today forms the most comprehensive set of environmental standards in the world, commonly known as the environmental acquis. As a result, today European environmental policy rests on solid foundations (Box 2.1).

As documented by the five previous SOERs from 1995 to 2015, this has led over the years to a measurable and substantial improvement in the level of environmental protection in most parts of Europe (EEA, 2015a). Notable achievements include a significant reduction in emissions of pollutants to air, water and soil, the establishment of the world's largest network of protected areas under Natura 2000 (EEC, 1992), the recovery of many species previously on the brink of extinction, the provision of safe drinking water, and the reduction of exposure to hazardous chemicals.

However, by the 1980s, it had become increasingly clear that such targeted policies would be insufficient to address environmental problems that result from diffuse pressures from various sources, such as the unsustainable use of natural resources, environmental impacts on human health through pollution or chemical contamination or the loss of biodiversity. At a time when Europe had set itself the goal of creating a single market (EEC, 1987) and when the sustainable development concept began to be influential (UNCED, 1992), integrating environmental concerns into other EU sectoral policies, also known as environmental integration, became increasingly sought after (Table 2.1). A key mechanism for implementation in the 5th EAP (1993-2000), environmental integration was formally established as a requirement under the Treaty of Amsterdam (EU, 1997) following a European Council initiative (known as the Cardiff process). The first five target sectors were those contributing the most to environmental deterioration: (1) industry; (2) energy; (3) transport; (4) agriculture; and (5) tourism. This shift in approach was accompanied by an increasing use of non-legislative instruments, such as financial instruments (e.g. investment funds), economic instruments (i.e. market-based instruments to 'get the prices right'), horizontal approaches (e.g. information, education, research), and more coordination with stakeholders.

Environmental integration has been pursued to some extent through policy frameworks such as the common agricultural policy (CAP), the common fisheries policy (CFP), the cohesion policy or the EU's official development assistance, for example. Despite the soundness of this approach, and although some progress has been made (e.g. in the field of energy policy with the 2020 climate and energy package),

BOX 2.1 Fundamentals of European environmental policy

Environmental policy is an area of shared competence between the EU and the Member States, with the principle of subsidiarity determining the most effective level of action. The Treaties of the European Union established that EU environment policy should contribute to pursuing the objectives of 'preserving, protecting and improving the quality of the environment, protecting human health, [promoting] prudent and rational utilisation of natural resources, [and] promoting measures at international level [...] and [...] combating climate change' (EU, 2007).

EU environmental policy rests on four principles, as enshrined in the Treaties (EU, 2007):

- the precautionary principle, which is a risk management approach, 'whereby if there is the possibility that a given policy or action might cause harm to the public or the environment, and if there is still no scientific consensus on the issue, the policy or action in question should not be pursued' (EU, 2018c);

- the principle that preventive action should be taken, which means that environmental legislation should be adopted to prevent environmental harm and not as a reaction to environmental harm that has already occurred;

- the principle that environmental damage should as a priority be rectified at source, meaning that pollution, for instance, should be addressed where it occurs, e.g. by setting emission limit values;

- the polluter pays principle, stating that a company causing environmental damage is to be held financially liable for it and must take the necessary preventive or remedial action; this applies to operators of certain activities, such as transporting dangerous substances or managing extractive waste (EU, 2004).

EU environmental regulation also ensures that certain projects likely to have significant effects on the environment, e.g. the construction of a motorway or an airport, are subject to an environmental impact assessment (EIA). Equally, a range of public plans and programmes are subject to a similar process called strategic environmental assessment (SEA).

In addition, environmental policy in the EU is required to respect the Aarhus Convention (UNECE, 1998), which guarantees the right of all European citizens to access public environmental information and to participate in environmental decision-making as well giving them access to justice within the scope of environmental law.

In May 2016, the Commission launched the Environmental Implementation Review, a 2-year cycle of analysis and dialogue with Member States to improve the implementation of existing EU environmental policy and legislation (EC, 2017a, 2019a).

While EU policy frameworks do not necessarily directly apply to the non-EU member countries of the European Environment Agency (Iceland, Liechtenstein, Norway, Switzerland, Turkey) or the cooperating countries (Albania, Bosnia and Herzegovina, Kosovo under United Nations Security Council Resolution 1244/99, Montenegro, North Macedonia, and Serbia), many of these countries have the same or similar environmental and climate policy objectives, and they are included in the assessment as far as possible. ■

TABLE 2.1 The changing understanding of environmental challenges and the evolution of approaches to policy and assessment

Characterisation of key challenges	Key features	In policy since	Policy approaches (examples)	Assessment approaches and tools (examples)
Specific	Linear cause-effect, point source, local	1970s	Targeted policies and single-use instruments	Data sets, indicators
Diffuse	Cumulative causes	1990s	Policy integration, market-based instruments, raising public awareness	Data sets, indicators, environmental accounts, outlooks
Systemic	Systemic causes	2010s	Policy coherence, systemic focus (e.g. mobility system), long-term and multidimensional goals (e.g. SDGs)	Indicators, accounts, practice-based knowledge, systems assessment, stakeholder participation, foresight

Source: EEA.

BOX 2.2 The EU's Seventh Environment Action Programme

Since 1973, the European Commission has issued multiannual environment action programmes (EAPs) setting out forthcoming legislative proposals and goals for EU environment policy. In 2013, the Council and the European Parliament adopted the 7th EAP for the period up to 2020, under the title 'Living well, within the limits of our planet'. Building on a number of strategic initiatives, the programme identified three key thematic objectives:

1. to protect, conserve and enhance the EU's natural capital;
2. to turn the EU into a resource-efficient, green and competitive low-carbon economy;
3. to safeguard the EU's citizens from environment-related pressures and risks to their health and well-being.

Four priority objectives create an enabling framework to help Europe deliver on these goals:

4. better implementation of legislation;
5. better information by improving the knowledge base;
6. more and wiser investment in environmental and climate policy;
7. full integration of environmental requirements and considerations into other policies.

Two further priority objectives focus on meeting local, regional and global challenges:

8. to make the EU's cities more sustainable;
9. to help the EU address international environmental and climate challenges more effectively. ■

Source: Seventh Environment Action Programme (EU, 2013a).

this report indicates that this has led to mixed results, as have previous SOERs. Either environmental considerations have been insufficiently integrated into sectoral policies (e.g. for lack of incentives) or policy instruments have failed to deliver significant effects up to the scale and urgency of the challenges (Chapter 13).

Since the late 1990s, increased attention has been paid to better understanding the systemic interlinkages between the environment, society and the economy and understanding how policies could respond to them. This was reflected in the increasing orientation of the 6th and 7th EAPs (2002-2020) towards sustainability and in the search for more coherence among EU policies. This need has been reinforced with the recognition of the importance of climate change, which became the subject of a specific goal of the EU with the Treaty of Lisbon (EU, 2007).

Environmental integration into EU policy has had mixed results.

2.2.2 The current and developing EU environmental and climate policy landscape

Today, the 7th EAP (2014-2020) plays a central role and offers a coherent framework for EU environmental policies. The programme specifies an ambitious vision for 2050 (Section 2.1), sets out nine priority objectives to move towards this vision (Box 2.2) and defines a number of specific targets to be achieved by 2020 (as discussed in the chapters in Part 2). This framework builds on a number of strategic initiatives, directives and funding instruments covering almost all environmental thematic areas.

Among them, the EU biodiversity strategy to 2020 aims, through a set of six targets and 20 actions, to '[halt] the loss of biodiversity and the degradation of ecosystem services in the EU by 2020, and [restore] them in so far as feasible, while stepping up the EU contribution to averting global biodiversity loss' (EC, 2011b). The targets are aligned with the internationally agreed Aichi biodiversity targets of the Convention on Biological Diversity (CBD, 2013). For the marine environment, the ecosystem-based approach to management is further applied through the integrated maritime policy, the CFP and the Marine Strategy Framework Directive. A recent development in the field of nature and biodiversity is the adoption of the EU's first-ever initiative on pollinators to address their decline in Europe and worldwide.

As regards environment and health, one of the purposes of the REACH Regulation is to ensure a high level of protection of human health and the environment, in particular through better and earlier identification of the intrinsic properties of chemical substances (EU, 2013e). This is done through the registration, evaluation, authorisation and restriction of chemicals (REACH), and the Regulation's provisions, which are underpinned by the precautionary principle.

Environmental integration is still being pursued. For example in the agricultural sector, which is responsible for many environmental pressures (Chapter 13), environmental and climate considerations have been increasingly embedded within the CAP. For the period 2014-2020, this is being implemented through cross-compliance conditions for obtaining full direct payments, greening measures to make farmers deliver environmental and climate benefits beyond cross-compliance and voluntary commitments by farmers to get additional payments under agri-environment schemes (EU, 2013d, 2013e). CAP payments for agricultural development constitute 37.8 % of the EU overall budget in the multiannual financial framework for 2014-2020 (EC, 2013). Under its Pillar 2, supporting rural development programmes, Member States have to spend at least 30 % of the related budget on measures related to the environment and climate change mitigation. This represents almost 1 % of the EU budget, or EUR 25 billion for the period 2014-2020, making it a very important funding instrument, which may potentially influence the trends in environmental pressures from agriculture (Chapter 13).

The 7th EAP establishes a coherent policy framework for EU environmental policies.

Other funding instruments support the implementation of European environmental and climate policy. The LIFE programme is the EU's financial instrument supporting environmental, nature conservation and climate action projects throughout the EU (EU, 2013c). Since 1992, the LIFE programme has co-financed almost 5 000 small-scale projects developing innovative approaches for environment and climate action. For the period 2014-2020, the LIFE programme contributes approximately EUR 3.4 billion (EC, 2016c). EU funding instruments such as the European Regional Development Fund (ERDF) and the Cohesion Fund provide funding for the protection of the environment, although these instruments are primarily focused on other policy priorities. The European Maritime and Fisheries Fund has a strong focus on sustainable fish stocks, fuel-efficient fishing and reduced environmental impacts, among other priorities.

More recently, the ambition of the 7th EAP has been supported by a range of policy packages, which are more integrated at the macro-economic level and attempt to better address the long-term, systemic interlinkages between the environment, society and the economy. In particular, since the publication of the previous SOER, significant policy developments have arisen around three frameworks highly relevant for the environment and climate: (1) the low-carbon economy; (2) the circular economy; and (3) the bioeconomy.

In line with the Paris Agreement, the EU has set for itself ambitious climate- and energy-related targets in order to move towards a low-carbon economy by 2050. The long-term objective proposed by the European Commission is to achieve a reduction in GHG emissions of 80-95 % by 2050 compared with 1990 levels (EC, 2011a). In 2018, the European Commission raised its ambition with the publication of the European strategic long-term vision for a prosperous, modern, competitive and climate-neutral economy for 2050, which shows how Europe could lead the way to climate neutrality while ensuring a socially just transition (EC, 2018c). Building on the '20-20-20 targets' set for 2020, the EU has committed, through its 2030 climate and energy framework, to reduce GHG emissions to at least 40 % below 1990 levels by 2030, while improving energy efficiency by at least 32.5 % and increasing the share of energy from renewable sources to at least 32 % of final consumption (European Council, 2014; EU, 2018a, 2018b).

EU action relies on the EU Emissions Trading System (ETS), a 'cap and trade' mechanism for GHG emissions from nearly 11 000 installations (factories, power stations, etc.) across the EU, on the Effort Sharing Regulation (EU, 2018e), which sets binding annual targets for reducing GHG emissions for 2030 for each Member State in sectors not covered by the ETS (e.g. road transport, waste, agriculture and buildings), and on the LULUCF Regulation (EU, 2018d) committing Member States to ensure that GHG emissions from land use, land use change and forestry (LULUCF) are offset by at least an equivalent removal of CO_2 from the atmosphere in the period 2021-2030. These commitments are to be considered within the broader perspective of the Energy Union Strategy (EC, 2015b), which addresses

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environmental and climate dimensions along with issues of security, affordability, market integration, and research, innovation and competitiveness. The Regulation on the Governance of the Energy Union and Climate Action establishes a unique framework for cooperation between Member States and the EU, building on integrated national energy and climate plans, EU and national long-term strategies, and integrated reporting, monitoring and data publication (EU, 2018f). In addition, these mitigation efforts are complemented by the EU adaptation strategy on climate change (EC, 2013), which aims to make Europe more climate resilient by enhancing the preparedness and capacity to respond to the impacts of climate change (Chapter 7) and which has recently been evaluated positively (EC, 2018i). The online European Climate Adaptation Platform, Climate-ADAPT, plays a central role in improving informed decision-making for climate change adaptation across Europe (EEA and EC, 2019).

The concept of a circular economy has recently gained traction in European policymaking as a solutions-oriented perspective for achieving economic development within increasing environmental constraints (EEA, 2016). A circular economy aims to maximise the value and use of all materials and products, reducing the dependency on primary raw GHG emissions, thus contributing to moving towards a low-carbon economy. In 2015, the European Commission adopted its circular economy package, which includes an EU action plan for the circular economy (EC, 2015a), setting out a number of initiatives aiming at closing the loop of product life cycles, primarily through greater recycling. The package also led to the revision of six waste directives with new waste management targets regarding recycling and preparing for reuse and landfilling (Chapter 9). In 2018, the European Commission adopted complementary measures in its 2018 circular economy package, including a strategy for plastics that sets the goal that 'by 2030, all plastics packaging will have to be reusable or recyclable in an economically viable manner', and sets up a monitoring framework to record progress towards the circular economy at EU and national levels (EC, 2018a, 2018b).

> Major policy developments have occurred around the frameworks of the low-carbon economy, the circular economy and the bioeconomy.

While not being an environmental policy per se, a third framework of particular relevance to the environment and climate has gained momentum during the last decade. The EC (2012) defines the bioeconomy as 'the production of renewable biological resources and the conversion of these resources and waste streams into value added products, such as food, feed, bio-based products and bioenergy' and states that it aims to optimise the use of biological resources for ensuring food security, managing natural resources sustainably, reducing dependence on non-renewable resources, mitigating and adapting to climate change, and creating jobs and maintaining European competitiveness. The EU launched its bioeconomy strategy in 2012 to stimulate knowledge development, research and innovation, bring together stakeholders, create markets, and streamline existing policy approaches in this area (e.g. the CAP, the CFP, Horizon 2020, the Blue Growth initiative). Building on the conclusions of the 2017 review (EC, 2017b), the 2018 update of the bioeconomy strategy aims to accelerate the development of a sustainable circular bioeconomy, through strengthening, scaling up and spreading bio-based innovations across Europe, while paying more attention to ecological limitations (EC, 2018b).

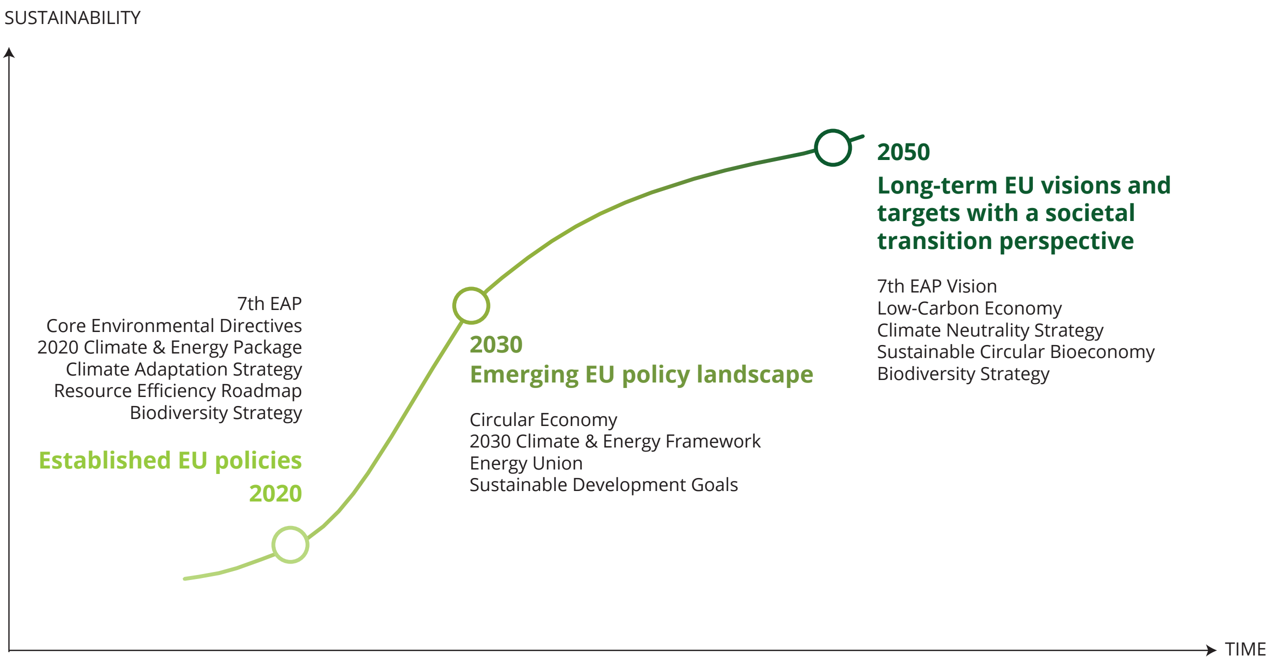
Overall, the EU environmental and climate policy landscape aims to address the short-, medium- and long-term time horizons through a range of policies, strategies and instruments that increasingly connect the environmental, social and economic dimensions of sustainability (Figure 2.2). However, the ambition of the 7th EAP vision and frameworks such as the low-carbon economy, the circular economy and the bioeconomy is such that it implies fundamental societal transitions to transform key production-consumption systems (Part 3). While policy interventions can trigger the change needed, such ambition will ineluctably question our collective ways of living and thinking. One positive sign is the increasing awareness and concern around environmental and climate challenges across society.

2.3 The context of Europe's governance

2.3.1 Environmental and climate mainstreaming in EU institutions

In addition to adopting policies, the EU institutions have started to embed environmental and climate dimensions in a number of ways, which reflects an increasing recognition of sustainability challenges. For instance, the multiannual financial framework, the EU's budget for 2014-2020, had the objective of ensuring that at least 20 % of the EU's budget is allocated to climate-related expenditure (EU and Euratom, 2013). Based on the current trend, climate-related spending is projected to amount to EUR 200 billion or 19.3 % of the EU's operational spending commitments (EC, 2018j), and climate change adaptation and mitigation have been integrated into all major EU spending programmes.

FIGURE 2.2 **The emerging EU environmental and climate policy landscape**



Source: EEA.

It remains difficult to monitor the EU's budget contribution to other environmental areas due to its degree of dispersion. It is, however, estimated that, for example, 8 % will be allocated to protect biodiversity over the period 2014-2020 (EC, 2018j).

EU regional policy, which is the EU's main investment policy with a budget of EUR 351.8 billion for the period 2014-2020, contributes to improving the environment and moving towards a low-carbon economy in Europe. For instance, EUR 40 billion from the ERDF and the Cohesion Fund are to be invested in the transition to a low-carbon economy in the period 2014-2020, twice the amount spent in the period 2007-2013. From a research and innovation perspective, Horizon 2020 reserves a significant part of its EUR 77 billion of funding available for the 2014-2020 period to tackle a number of societal challenges highly related to the environment (EU, 2013b). It has also established climate action and sustainable development as cross-cutting objectives and set expected expenditure levels of at least 35 % for climate action and at least 60 % for sustainable development.

The ambitious EU vision requires fundamental societal transitions.

Besides, the European Commission is increasingly looking at how to integrate sustainability considerations into its financial policy framework, in particular within the context of the Capital Markets Union. Indeed, it estimated that an investment gap of EUR 180 billion per year needs to be filled to achieve the EU's 2030 targets set out in the Paris Agreement (EC, 2017d). Following the recommendations of a high-level expert group, the Commission adopted an action plan on sustainable finance in March 2018, which was followed by the first set of measures to facilitate sustainable investments (EC, 2018d).

An initiative is also ongoing to 'green' the European semester. The European semester is a mechanism to improve the coordination of economic and budgetary policies in EU Member States. While it was created with the aim of monitoring the implementation of the Europe 2020 strategy (EC, 2010), which includes economic, social and environmental targets, the semester has mainly focused on macro-economic aspects, relying in particular on the GDP (gross domestic product) indicator. Following the integration of key social and employment indicators in the semester scoreboard, the ambition is now to embed environmental indicators to assess the sustainability of the progress made.

The EU has also set in motion Copernicus, its Earth observation programme (EC, 2017d). With seven dedicated satellites in orbit (so far), complemented by contributing missions, *in situ* sensors, numerical models and related services, it aims to provide full, free and open data daily to public and private users to allow a better understanding of and response to environmental and climate challenges. This includes monitoring of the atmosphere, the marine environment, land use and climate change.

2.3.2 Environmental and climate action across scales of governance

Environmental and climate action in the EU is not limited to the interventions of EU institutions and Member States. The scale of environmental and climate challenges calls for a whole-of-society approach in which all citizens and scales of governance across the EU have a role to play (EEA and Eionet, 2016). As annual Eurobarometer surveys show, support for environmental protection from European citizens has remained high across all Member States over the years, despite the socio-economic impacts of the 2008 financial crisis, and nearly 9 out of 10 Europeans (87 %) agree that they can play a role in protecting the environment (EC, 2017c). This allows more proactive environmental and climate interventions by EU institutions and Member States and closer engagement of citizens and local stakeholders in supporting their actions.

> European citizens are highly supportive of environmental protection and climate action.

It is increasingly recognised that 'cities are key players in implementing the EU's goals in terms of a low-carbon economy … and resource efficiency. They are crucial in improving waste management, public transport, water management and, through integrated urban planning, the efficient use of land.' (EEA, 2015b). Acknowledging this key role, the EU is supporting a range of initiatives fostering networking of cities and local authorities, in line with the eighth objective of the 7th EAP. Ten years after its launch in 2008, the Covenant of Mayors for Climate & Energy brings together more than 7 700 local and regional authorities representing more than 250 million citizens across Europe to help meet the EU climate and energy objectives (Covenant of Mayors, 2019). The initiative was embedded in the field of climate change adaptation with the setting up of Mayors Adapt, a subset of the Covenant of Mayors initiative, to engage cities in taking action to adapt to climate change (Mayors Adapt, 2015).

Other urban initiatives supported by the EU are the urban agenda for the EU, which includes the aim of strengthening the resilience of urban settings through preventing disaster and climate-related risks, in line with the UN new urban agenda (EU, 2016); the Reference Framework for European Sustainable Cities, which seeks to give all European cities practical support and a network to share information on moving towards sustainable urban development (RFSC, 2018); and the European Green Capital Award and European Green Leaf Award, which recognise and reward efforts to improve the environment, the economy and the quality of life in cities (EC, 2018g).

Companies are also increasingly concerned about environmental and climate challenges, because the latter can potentially disrupt their supply and value chains (e.g. through climate-related weather events), their profit margins can increase thanks to resource and energy efficiency, eco-innovation creates new markets or they are simply pushed to be more environmentally-friendly by their customers. Several approaches supported by the European Commission help companies that are willing to further integrate the environmental dimension into their business models. For instance, the EU Eco-Management and Audit Scheme (EMAS) is a management instrument for European companies and other organisations to evaluate, report and improve their environmental performance. As of April 2018, the EMAS Network counted 3 866 organisations and 9 004 sites (EC, 2018f). Through green public procurement, Europe's public authorities can also strengthen the demand for more sustainable goods and services, and therefore stimulate eco-innovation (EC, 2019b). Besides, corporate social responsibility, which refers to companies taking responsibility for their impact on society, also involves meeting environmental product requirements (EC, 2018e). The UN Global Compact, an initiative asking business to actively address environmental risks and opportunities, has a strong foothold in Europe where it has the largest total number of participants compared with other regions (UN Global Compact, 2018). Businesses, industries and their representatives are also key stakeholders within the Commission-led multi-stakeholder platform on the SDGs, the Circular Economy Stakeholder Platform, or the Bioeconomy Stakeholders Panel.

PART 2

Environment and climate trends

Introduction

Part 2, 'Environment and climate trends', provides an overview of the state of and outlook for the European environment. It assesses progress towards achieving established European environment and climate policy goals and focuses primarily on the 2020-2030 time frame. Ten environmental themes are assessed (Chapters 3-12), complemented by a concise assessment of environmental pressures and sectors (Chapter 13). Chapter 14 builds on these assessments to provide an integrated picture of the European environment's state, trends and outlook in relation to the priority objectives of the Seventh Environment Action Programme (7th EAP).

Summary assessments are used throughout Part 2 to present the content in a systematic, concise and accessible way. These are based on a combination of available evidence and expert judgement, including inputs from stakeholders during their development. More specifically:

- The assessment of trends is based on available indicators and other information as observed over the past 10-15 years.
- The assessment of outlooks is based on modelled estimates of future developments, where available, expected developments in drivers of change, and expert consideration of the effects of policies currently in place.
- The assessment of the prospects of meeting selected policy targets and objectives is based on distance to target assessments where available, and expert judgement.
- The assessment of the robustness of the evidence base also identifies key gaps and indicates the degree of expert judgement used.

The summary assessment tables use a range of colour coding and symbols (see below) and contain short explanatory texts justifying the allocation of the colour codes and symbols.

Each chapter in Part 2 contains a range of summary assessment tables by theme, for example the impacts of air pollution on human health. These are then compiled into a headline table presented at the beginning of each chapter, along with the key messages. Chapter 14 contains an overall summary assessment table incorporating these and structured in accordance with the priority objectives of the 7th EAP.

	Indicative assessment of past trends (10-15 years) and outlook to 2030	**Indicative assessment of prospects of meeting selected policy objectives/targets**		
(green)	Improving trends/developments dominate	Year	☑	Largely on track
(yellow)	Trends/developments show a mixed picture	Year	☐	Partially on track
(red)	Deteriorating trends/developments dominate	Year	☒	Largely not on track

Note: The year for the objectives/targets does not indicate the exact target year but the time frame of the objectives/targets.

03.
Biodiversity and nature

Key messages

- Biodiversity and nature sustain life on Earth, delivering numerous essential ecosystem services. They are a vital element of our cultural heritage and treasured for their recreational, spiritual and aesthetic values. As a result, biodiversity loss has fundamental consequences for our society, economy and for human health and well-being.

- Despite ambitious targets, Europe continues to lose biodiversity at an alarming rate and many agreed policy targets will not be achieved. Assessments of species and habitats protected under the Habitats Directive show predominantly unfavourable conservation status at 60 % for species and 77 % for habitats. Biodiversity loss is not confined to rare or threatened species. Long-term monitoring shows a continuing downward trend in populations of common birds and butterflies, with the most pronounced declines in farmland birds (32 %) and grassland butterflies (39 %).

- There has been progress in some areas, such as the designation of protected areas: the EU Natura 2000 network now covers 18 % of the EU's land area and almost 9 % of marine waters, making it the world's largest network of protected areas.

- Europe's biodiversity and ecosystems face cumulative pressures from land use change, natural resource extraction, pollution, climate change and invasive alien species. These have a severe impact on ecosystem services — nature's benefits to people — as illustrated by the recent alarming loss of insects, especially pollinators.

- The broad framework of EU biodiversity policy remains highly relevant and is fit for purpose but the challenge is urgent and interlinked with the climate crisis. Targets will not be met without more effective implementation and funding of existing measures in all European environmental policies, as well as greater policy coherence with respect to biodiversity in agricultural and other sectoral policies. The wider application of ecosystem-based and adaptive management in combination with increased public awareness of society's dependency on biodiversity and nature are important steps forward.

Thematic summary assessment

Theme	Past trends and outlook		Prospects of meeting policy objectives/targets
	Past trends (10-15 years)	Outlook to 2030	2020
Terrestrial protected areas	Improving trends dominate	Developments show a mixed picture	Largely on track
EU protected species and habitats	Trends show a mixed picture	Developments show a mixed picture	Not on track
Common species (birds and butterflies)	Deteriorating trends dominate	Deteriorating developments dominate	Not on track
Ecosystem condition and services	Deteriorating trends dominate	Developments show a mixed picture	Not on track

Note: For the methodology of the summary assessment table, see the introduction to Part 2. The justification for the colour coding is explained in Section 3.3, Key trends and outlooks (Tables 3.2, 3.3, 3.4 and 3.5).

03.
Biodiversity and nature

3.1
Scope of the theme

Biodiversity, or biological diversity, is the variety of life on Earth, within species, between species and of ecosystems (CBD, 1992). Biodiversity conservation is linked to its intrinsic value as well as the recognition that biodiversity and nature are a part of the natural capital (EC, 2011; EU, 2013) delivering numerous ecosystem services — or nature's contributions to people (IPBES, 2018). They are many and varied and include provision of food, pollination, carbon sequestration, mitigation of natural disasters, recreation and spiritual values, among many others (EU, 2013; EC, 2015; IPBES, 2018).

Europe's biodiversity has been shaped by human activity more than on any other continent and is continually under pressure as a result of our use of natural capital driven by human production and consumption (Chapter 1). The main drivers of biodiversity loss identified by the regional assessment report for Europe and Central Asia published by the Intergovernmental Science-Policy Platform on Biodiversity and Ecosystem Services (IPBES, 2018) are land use change, including habitat loss, fragmentation and degradation, as well as climate change, extraction of natural resources, pollution and invasive alien species.

The evidence of the negative impacts of biodiversity loss and the threats that unsustainable exploitation of our natural world poses for the food and water security of billions of people has been growing at European and global level over several decades and is exemplified by the recent IPBES report (IPBES, 2019) (Chapter 1). The conclusion is that destruction and loss of biodiversity and nature is as catastrophic as climate change.

The impact of Europe's alarming rate of biodiversity loss is as catastrophic as climate change.

3.2
Policy landscape

The targets and commitments within the EU biodiversity strategy to 2020 and the key role played by the nature directives in their delivery provide a means for meeting the requirements set by a range of international conventions and agreements, e.g. the Convention on Biological Diversity, or CBD (CBD, 1992), and the Bern Convention (Council of Europe, 1979). The strategy to 2020 reflects the commitments taken by the EU in 2010 at global level in the scope of the strategic plan for biodiversity 2011-2020, including 20 Aichi biodiversity targets.

The 2020 headline target is 'Halting the loss of biodiversity and the degradation of ecosystem services and restoring them in so far as feasible, while stepping up Europe's contribution to averting global biodiversity loss'. This headline target is broken down into six specific targets that address a number of critical policy areas including protecting (and restoring) biodiversity and ecosystem services and greater use of green infrastructure; sectors (agriculture, forestry, fisheries); invasive alien species; and EU impacts on global biodiversity. The Seventh Environment Action Programme (7th EAP) fully embraces the objectives of the EU biodiversity strategy to 2020 and its 2050 vision, and it states that, by 2020, the loss of biodiversity and the degradation of ecosystem services should be halted and that by 2050 biodiversity is protected, valued and restored in ways that enhance our society's resilience.

Other sectoral and territorial policies also have an important impact, e.g. Water Framework Directive, Floods Directive, Marine Strategy Framework Directive, common fisheries policy (CFP), common agricultural policy (CAP), National Emission Ceilings Directive, climate change-related policies, Europe's bioeconomy strategy and cohesion policy (Chapters 4-8 and 13). These encompass the marine and freshwater environments as well as terrestrial areas, and agricultural policy has proved to be particularly influential in shaping our European landscapes and the nature they contain.

Biodiversity and ecosystem services are key elements of the 2030 agenda for sustainable development and several of the Sustainable Development Goals (SDGs), whereby, in addition to 'protecting the planet' they underpin sustainable livelihoods and futures. Table 3.1 presents a selected set of relevant key policy objectives and targets that are addressed in this chapter.

Biodiversity loss has significant environmental, economic and social consequences.

3.3 Key trends and outlooks

3.3.1 Terrestrial protected areas

► See Table 3.2

Protected areas benefit species, ecosystems and the environment overall. They provide significant economic and societal benefits, including employment opportunities. In particular, they contribute to people's health and well-being and have significant cultural value.

Europe's protected areas are diverse in character, varying in size, aim and management approach. They are large in number but relatively small in size. Approximately 93 % of sites are less than 1 000 ha and 78 % are less than 100 ha (EEA, 2018b). This reflects the high pressure on land use, arising from agriculture, transport and urban development. Large-scale nature reserves occur mostly in countries with low population densities, such as Finland, Iceland, Norway and Sweden (EEA, 2018b).

The two most important European networks of protected areas are Natura 2000 in the EU Member States and the Emerald network outside the EU, established under the Bern Convention (Council of Europe, 1979). There are also other important international designations, such as UNESCO (United Nations Educational, Scientific and Cultural Organization) biosphere reserves, Ramsar and UNESCO World Heritage sites. The main goal of the Natura 2000 network is to safeguard Europe's most valuable and threatened species and habitats, listed under the Birds and Habitats Directives. Member States have to design and implement the necessary conservation measures to protect and manage identified sites: Special Areas of Conservation (SACs) under the Habitats Directive and Special Protection Areas (SPAs) under the Birds Directive.

Measuring progress in relation to designation and management of Natura 2000 sites is a central part of the EU 2020 biodiversity strategy headline target and 2050 vision as well as the global Aichi biodiversity target 11, which aims to conserve at least 17 % of terrestrial and inland water areas by 2020 and ensure that those areas are well connected and efficiently managed. Natura 2000 has stimulated a remarkable increase in the area protected in Europe, and presently the network covers 18% of the 28 Member States' (EU-28's) terrestrial area, with around 28 000 sites (EEA, 2018c). Together with marine Natura 2000 sites, the network encompasses nine terrestrial biogeographical regions and five marine regions (Figure 3.1) (EEA, 2018c).

There are various benefits stemming from Natura 2000. Common methodology and criteria adopted across the EU for the establishment of sites ensure better ecological coherence than if the network were organised within each Member State only. This helps, for example, migratory species and designation of sites across national borders. While the Natura 2000 network targets particular species and habitats, other species also benefit from the establishment of sites, in the so-called 'umbrella effect' (van der Sluis et al., 2016). It is estimated that there are between 1.2 and 2.2 billion

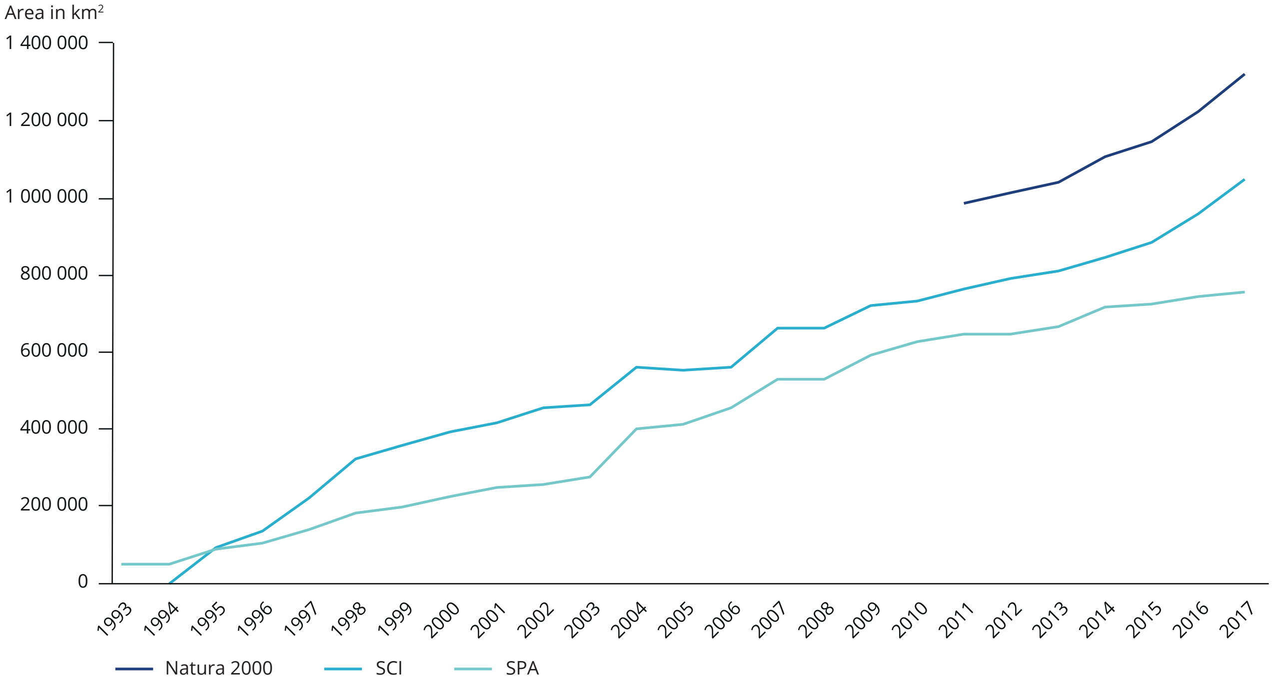
TABLE 3.1 Overview of selected policy objectives and targets

Policy objectives and targets	Sources	Target year	Agreement
Biodiversity and ecosystems			
Biodiversity and the ecosystem services it provides — its natural capital — are protected, valued and appropriately restored for their intrinsic value and essential contribution to human well-being and economic prosperity, and so that catastrophic changes caused by the loss of biodiversity are avoided	2050 vision of the EU biodiversity strategy to 2020	2050	Non-binding commitment
Protect species and habitats under the nature directives	Birds Directive, Habitats Directive (EU, national); EU biodiversity strategy to 2020, Target 1; Action plan for nature, people and the economy	2020	Legally binding and non-binding commitments
Maintain and restore ecosystems and their services	EU biodiversity strategy to 2020, Target 2; 7th EAP; SDG 15	2020	Non-binding commitment
Achieve more sustainable agriculture and forestry	EU biodiversity strategy to 2020, Target 3; 7th EAP	2020	Non-binding commitment
Make fishing more sustainable and seas healthier	EU biodiversity strategy to 2020, Target 5; 7th EAP;	2020	Non-binding commitment
Combat invasive alien species	Regulation on invasive alien species; EU biodiversity strategy to 2020, Targets 4, 5 and 6; 7th EAP	2020	Legally binding
Help stop the loss of global biodiversity	EU biodiversity strategy to 2020, Target 6; 7th EAP	2020	Non-binding commitment
Improve knowledge of pollinator decline, its causes and consequences; tackle the causes of pollinator decline; raise awareness, engage society at large and promote collaboration	EU pollinators initiative	2020	Non-binding commitment
Integrate green infrastructure (GI) into key policy areas, improving the knowledge base and encouraging innovation in relation to GI, improving access to finance including supporting EU-level GI projects.	Green infrastructure — Enhancing Europe's natural capital (GI strategy)	2020	Non-binding commitment

visitor days to Natura 2000 sites each year, generating recreational benefits worth between EUR 5 and 9 billion per year (Brink et al., 2013). The overall economic benefits of the Natura 2000 network stemming from the provision of various ecosystem services have been estimated to be in the order of EUR 200 to 300 billion/year (Brink et al., 2013).

An important characteristic is that Natura 2000 sites are not necessarily pristine areas, stripped of human impact. Their aim is not to exclude economic activity and, in fact, around 40 % of the Natura 2000 total area is farmland, and forests make up almost 50 %. The main objectives within Natura 2000 sites are to avoid activities that could seriously disturb the species or damage the habitats for which the site is designated and to take positive measures, if necessary, to maintain and restore these habitats and species to improve conservation. While this approach encourages sustainable management, the network can still be subject to significant pressures, such as the intensification or abandonment of traditional, extensive farming practices or even land abandonment, in particular in areas with natural constraints. Natural, old-growth forests are also subject to management intensification and their unique biodiversity and structural features are irreversibly lost. Management of the sites is therefore a decisive factor in achieving the conservation aims; however, we currently lack comprehensive information on how efficiently these sites are managed. Integration of Natura 2000 objectives into spatial planning is crucial. In particular, maintaining or improving connectivity between sites is of utmost importance. The Joint Research Centre

FIGURE 3.1 **Area of Natura 2000 sites designated under the EU Habitats and Birds Directives in 2017**



Note: The Natura 2000 network is composed of SPAs and SCIs. SPAs are Special Protection Areas, designated under the Birds Directive. SCIs include sites and proposed Sites of Community Importance and Special Areas of Conservation, designated under the Habitats Directive. Many sites are designated under both directives (as both an SCI and an SPA). The calculation of the Natura 2000 area taking this overlap into account is available only from 2011 onwards.

Source: EEA (2018c).

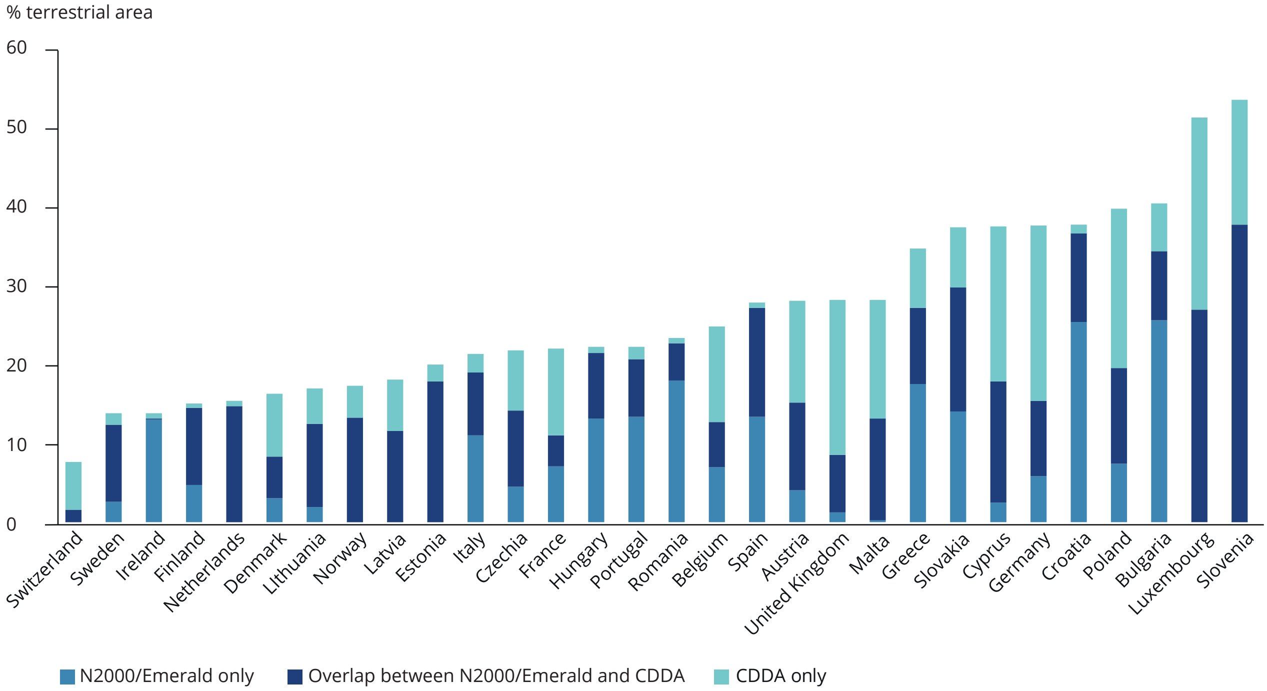
of the European Commission (JRC) has created an indicator of protected area connectivity (ProtConn) (JRC, 2019b) that quantifies how well networks of protected areas are designed to support connectivity and is based on assumed species distances between protected areas (Saura et al., 2018). In the EU, the indicator shows an average value of more than 18 % and therefore meets the connectivity element of Aichi biodiversity target 11. The ProtConn value varies, however, throughout Europe: it is lowest in the Netherlands (6.7 %), varies between 8 and 12 % in Finland, Ireland, Italy, Sweden and the Baltic States and is highest in Bulgaria, Croatia, Czechia, Germany, Poland and Slovenia (25 % or more) (Saura et al., 2018).

The Natura 2000 network covers 18 % of the EU's land area, with around 28 000 sites.

The Emerald network is an ecological network of areas of special conservation interest set up by the Contracting Parties to the Bern Convention. It is conceptually similar to Natura 2000, but it incorporates a wider group of countries. As the EU is a signatory to the Bern Convention, the Natura 2000 network is considered the EU Member States' contribution to the Emerald network. Outside the EU, the Emerald network is still in the early stages, and since December 2017 two European countries have officially adopted Emerald sites on their territories: Norway and Switzerland.

At the end of 2017, 14 Member States had designated more than 17 % of their land area as Natura 2000 sites: Bulgaria, Croatia, Cyprus, Estonia, Greece, Hungary, Italy, Luxembourg, Poland, Portugal, Romania, Slovakia, Slovenia and Spain (EEA, 2018c). The degree of overlap between Natura 2000 and national designations illustrates the extent to which countries have made use of their nationally designated areas to underpin Natura 2000 and to what extent Natura 2000 sites extend beyond national systems (EEA, 2018b) (Figure 3.2).

FIGURE 3.2 **Country comparison — share of country designated as terrestrial protected area and the overlap between Natura 2000 or Emerald sites and national designations**



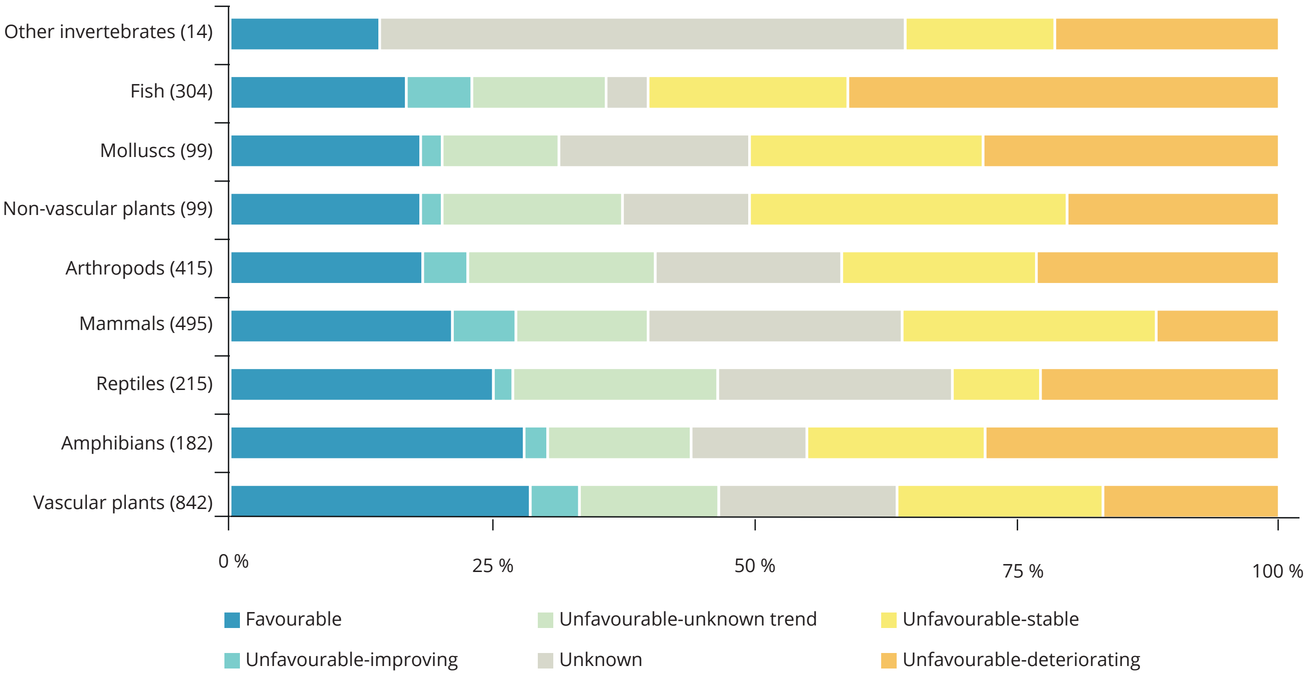
Note: A 'nationally designated protected area' (CDDA) is an area protected by national legislation. If a country has included sites designated under international agreements such as the EU Birds and Habitats Directives, or the Bern or Ramsar Conventions in its legislation, the corresponding protected sites, such as the Natura 2000 (N2000), Emerald or Ramsar sites, of this country are included in the CDDA.

Source: EEA (2018b).

TABLE 3.2 **Summary assessment — terrestrial protected areas**

Past trends and outlook		
Past trends (10-15 years)		There has been a steady increase in the cumulative area of the Natura 2000 network in EU Member States in the last 10 years, along with consistent growth in protected areas in all European countries.
Outlook to 2030		Designation of protected areas is not in itself a guarantee of effective biodiversity protection. Establishing or fully implementing conservation measures and management plans to achieve effectively managed, ecologically representative and well-connected systems of protected areas are crucially important and remain a challenge up to 2030.
Prospects of meeting policy objectives/targets		
2020	☑	The global Aichi biodiversity target 11 of 17 % of terrestrial areas conserved has been reached in Europe. In the EU, the Natura 2000 network already covers 18 % of the land area.
Robustness		Long-term data on the coverage of nationally designated protected areas in the EEA member countries and candidate countries (EEA-39) and consistent data on the Natura 2000 area are available. Information is lacking on the effectiveness of conservation measures in Europe's protected areas and how well biodiversity is protected there. The available outlook information is limited, so the assessment of outlook relies primarily on expert judgement.

FIGURE 3.3 **Trends in conservation status of assessed non-bird species at EU level**



Note: These are species from the Habitats Directive. The number of assessments is indicated in parenthesis. The total number of assessments is 2 665.

Source: EEA (2016e), based on conservation status of habitat types and species reporting (Article 17, Habitats Directive 92/43/EEC).

There are different patterns among countries and the differences in approaches reflect the diversity of historical, geographical, administrative, social, political and cultural circumstances (EEA, 2012).

In establishing Natura 2000, countries also have the flexibility to introduce new designation procedures, adapt existing ones or underpin the designation by other legislation. Some Natura 2000 sites nearly always overlap with national designations. This is particularly visible in Estonia, Latvia and the Netherlands and to a slightly lesser extent in Finland, Lithuania and Sweden. Countries that joined the EU most recently — Bulgaria, Croatia and Romania — have extended their protected areas very significantly by creating Natura 2000 sites, and in the past a similar process took place in Greece, Hungary, Ireland, Portugal and Slovakia. In other countries, there is moderate or little overlap, as in Denmark, France or Germany. Switzerland has a moderate overlap of Emerald sites with national designations, while in Norway the overlap is large.

> Designation as a protected area is not a guarantee of effective biodiversity protection; hence the need for management plans and conservation measures.

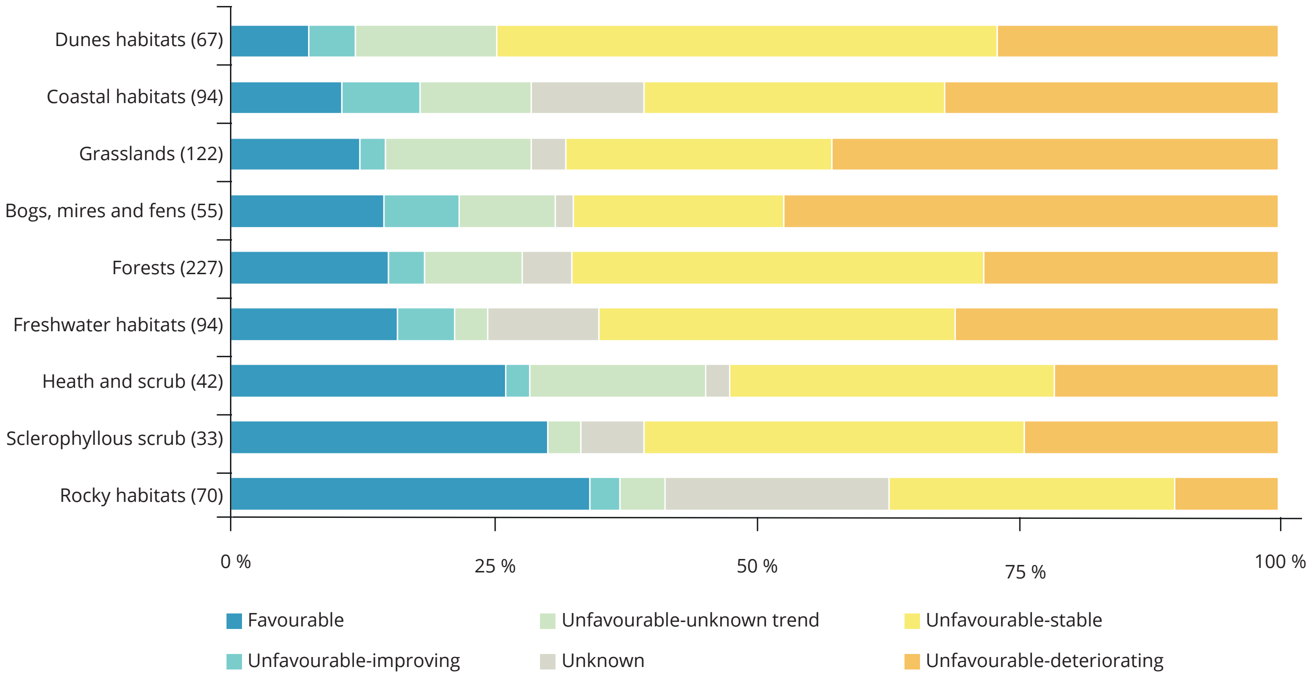
Independently of the scale and extent of the complementarity, it is clear, however, that the process of designing Natura 2000 sites, along with maintaining or extending nationally designated sites, benefits biodiversity and ecosystems and that Natura 2000 has very significantly increased the protected area coverage in Europe. The single designation of sites is not enough in itself to safeguard biodiversity and ecosystems, but it is a pre-condition to prevent species and habitats of European interest being lost forever.

3.3.2 EU protected species and habitats

▶ *See Table 3.3*

The EU Birds and Habitats Directives constitute the backbone of Europe's legislation on nature conservation. Member States are required to report on the status of species and habitats

FIGURE 3.4 Trends in conservation status of assessed habitats at EU level



Note: The number of assessments is indicated in parenthesis. The total number of assessments is 804.

Source: EEA (2016b), based on conservation status of habitat types and species reporting (Article 17, Habitats Directive 92/43/EEC).

covered by the Birds and Habitats Directives. Comprehensive data sets are therefore available in relation to, among others, conservation status, trends, pressures and threats, and conservation measures. Member States report on those directives every 6 years. The most recent results cover the period 2006-2012, and the outcomes of the next round of reporting, 2013-2018, will be available in 2020. Detailed information on how countries assess the conservation status of species and habitats under the Habitats Directive and population status under the Birds Directive is available on the EEA's website (EEA, 2015a). A parallel mechanism for reporting on the conservation status of species and habitats has been developed under the Bern Convention — Resolution 8. The first results from this reporting will also be available in 2020, which will contribute to a full pan-European perspective on their conservation status.

60 %

of species assessments show unfavourable conservation status.

Assessments of species and habitats protected under the Habitats Directive show predominantly unfavourable conservation status (EEA, 2015b). At the EU level, only 23 % of the assessments of species indicate favourable conservation status, while 60 % of species assessments are unfavourable. There are still significant gaps in knowledge, especially for marine species. Fish, molluscs and amphibians have a particularly high proportion of species that exhibit a deteriorating trend (EEA, 2016e) (Figure 3.3).

The conservation status of species varies considerably from one biogeographic region to another. At Member State level, more unfavourable assessments are declining than improving (EEA, 2016e).

Only 16 % of the assessments of habitats protected under the Habitats Directive have a favourable conservation status at the EU level (EEA, 2015b). Bogs, mires and fens have the highest proportion of unfavourable assessments, followed closely by grasslands (EEA, 2016b) (Figure 3.4). Conservation status trends

TABLE 3.3 Summary assessment — EU protected species and habitats

Past trends and outlook		
Past trends (10-15 years)		A high proportion of protected species and habitats are in unfavourable condition, although there have been some limited improvements in the last 10 years.
Outlook to 2030		The underlying drivers of biodiversity loss are not changing favourably so, without significant conservation efforts, current trends will not be reversed and pressures will continue to increase.
Prospects of meeting policy objectives/targets		
2020	☒	The EU is not on track to meet the 2020 target of improving the conservation status of EU protected species and habitats and the cumulative pressures remain high.
Robustness		Despite the increasing quality of information delivered by the nature directives reporting, data gaps remain, as a proportion of the assessments report unknown conservation status of species and habitats, unknown population status of birds and unknown trends for species or habitats assessed as unfavourable. The available outlook information is limited so the assessment of the outlook relies primarily on expert judgement.

are quite variable across biogeographic regions; however, more habitats are stable than decreasing in the terrestrial regions. There are still significant gaps in knowledge of marine habitat types. At the EU Member State level, the majority of assessments indicate low numbers of habitats with a favourable conservation status (EEA, 2016b).

Over half of the bird species in the Birds Directive are considered to be 'secure', i.e. they show no foreseeable risk of extinction and have not declined or been depleted (EEA, 2015b). However, 17 % of the bird species are still threatened and another 15 % are declining or depleted (EEA, 2016e).

The short-term trends of breeding birds in Member States indicate a high degree of change in their populations. There is no clear geographic pattern discernible in these trends. For wintering bird populations, assessments show an increasing trend for a relatively high proportion of wintering populations (EEA, 2016e).

The pressures and threats for all terrestrial species, habitats and ecosystems most frequently reported

The pressures on and threats to all terrestrial species, habitats and ecosystems most frequently reported by Member States are associated with agriculture.

by Member States are associated with agriculture (EEA, 2015b). For freshwater ecosystems, changes in hydrology, including overabstraction of water (Chapter 4) are most frequently reported as being important, although 'loss of habitat features or prey availability' is frequently reported for species, as is 'pollution to surface waters' for habitats.

The results of the nature directives' reporting are used to assess progress in implementing the EU biodiversity strategy to 2020, specifically, its Target 1, 'To halt the deterioration in the status of all species and habitats covered by EU nature legislation, and achieve a significant and measurable improvement in their status'. So far, progress towards the 2020 target of improving the conservation status of habitats covered by the EU Habitats Directive has not been substantial since 2010. Similarly, there has been little progress towards the target for bird populations under the Birds Directive in spite of some positive examples (Box 3.1). This indicates that significant additional conservation efforts need to be implemented to reverse current trends.

3.3.3 Common species (birds and butterflies) and interlinkages between the decline of birds and insects

► Table 3.4

Birds and butterflies are sensitive to environmental change and their population numbers can reflect changes in ecosystems as well as in other animal and plant populations. Trends in bird and butterfly populations can, therefore, be excellent barometers of the health of the environment.

The status of birds and butterflies has been the subject of long-term

BOX 3.1 The recovery of birds of prey in Europe

Historically many wildlife species in Europe have suffered dramatic declines in their numbers and distribution as a consequence of human activity. However, while Europe keeps losing biodiversity overall, there are also some positive examples of wildlife making a comeback (Deinet et al., 2013). These include birds of prey, e.g. red kite, white-tailed eagle, peregrine falcon or lesser kestrel. These success stories show that species can be brought back, even from the brink of extinction. This requires, however, well-designed conservation strategies, which are mainly a combination of factors: targeted species protection, reducing pressures (e.g. poaching or chemical pollution), specific site protection measures at the local level, such as Special Protection Areas in the Natura 2000 network, and targeted funding via LIFE projects. For example, with support from the LIFE programme, the Spanish imperial eagle population in the Iberian peninsula increased from 50 breeding pairs in 1995 to 520 pairs in 2017 (Ministerio para la Transición Ecológica, 2018; BirdLife International, 2019).

The success stories also work alongside social change and embracing the interactions between wildlife and people. The recovery of birds of prey and other wildlife is of great importance for ecosystem functioning and its resilience (Deinet et al., 2013). It also has implications for society and the economy: reconnecting people with nature increases their well-being and boosts local and regional economies. ■

monitoring in Europe, much of it via voluntary effort. The current data sets have good geographical and temporal coverage and are methodologically well founded, illustrating trends that can be linked to both policy and practice in terms of land use and management (EBCC, 2019; Eurostat, 2019). Both species groups resonate strongly with the interested public and are good examples of how the power of citizen science can be released through effective targeting (EEA, 2019a).

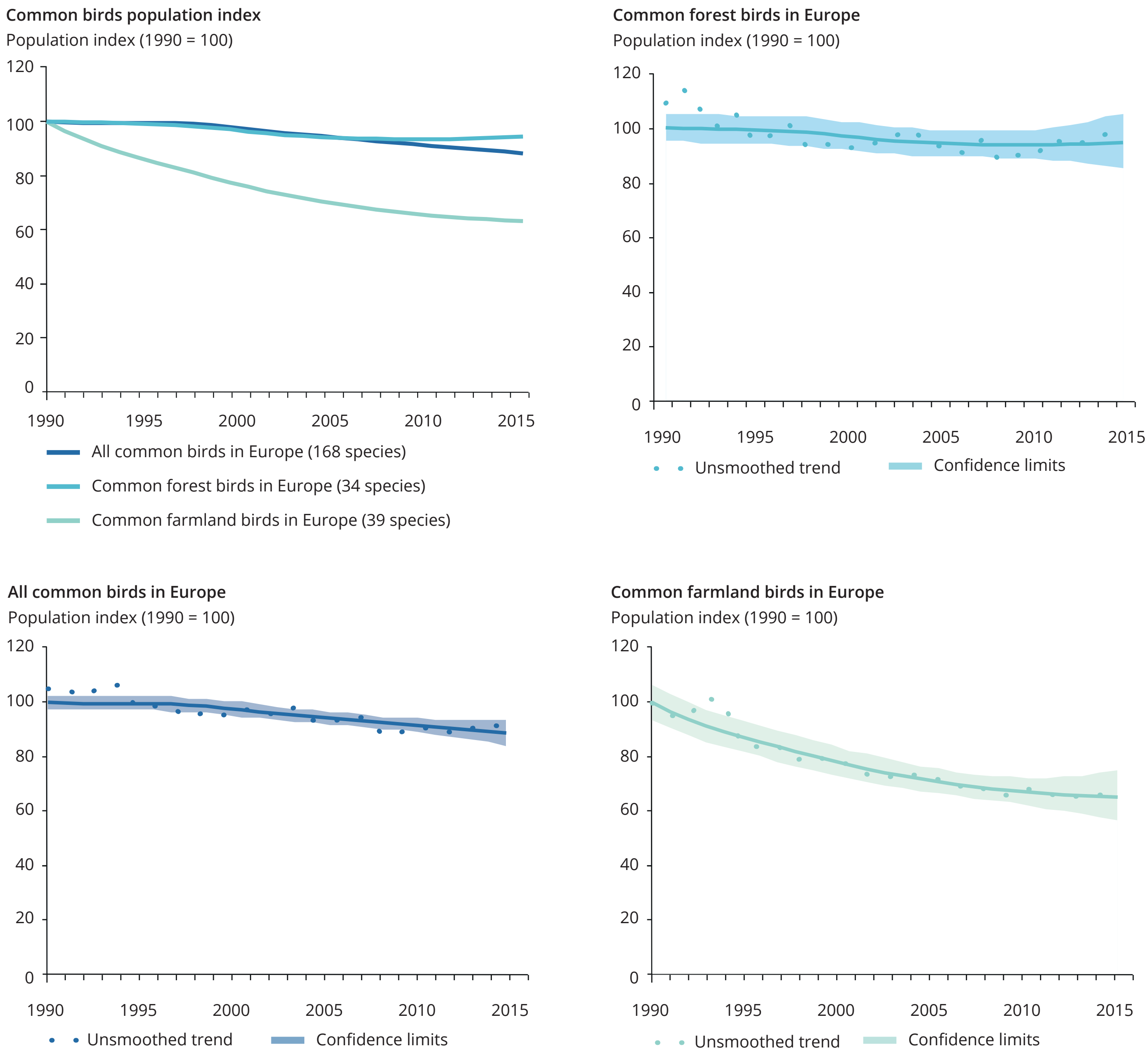
Long-term trends (over 25 years) from monitoring schemes of common birds (in particular farmland birds) and grassland butterflies show significant declines and no sign of recovery (EEA, 2019a). Figure 3.5 shows that, between 1990 and 2016, there was a decrease of 9 % in the index of common birds in the 26 EU Member States that have bird population monitoring schemes. This decrease is slightly greater (11 %) if figures for Norway and Switzerland are included. The decline in numbers of common farmland bird over the same period was much more pronounced, at 32 % (EU) and 35 % (EU plus Norway and Switzerland). The common forest bird index decreased by 3 % (EU) and 5 % (EU plus Norway and Switzerland) over the same period (EEA, 2019a). While this indicator takes 1990 as a starting point, it should be borne in mind that significant decreases had already occurred before that date.

The long-term trends in many bird and butterfly populations demonstrate that Europe has experienced a major decline in biodiversity.

In spite of year-to-year fluctuations, which are typical of butterfly populations, the index of grassland butterflies has declined significantly in the 15 EU Member States where butterfly population monitoring schemes exist (Figure 3.6). In 2017, the index was 39 % below its 1990 value in those countries. As with bird indices, the reductions observed since 1990 are on top of decreases occurring before that year (EEA, 2019a).

The long-term trends in farmland, forest and all common bird and grassland butterfly populations demonstrate that Europe has experienced a major decline in biodiversity. This has been primarily due to the loss, fragmentation and degradation of natural and semi-natural ecosystems, mainly caused by agricultural intensification (Donald et al., 2001; Van Dyck et al., 2009; Jeliazkov et al., 2016), intensive forest management (Virkkala, 2016; Fraixedas et al., 2015), land abandonment and urban sprawl (Chapters 5 and 13). For example, through habitat simplification (e.g. removal of hedgerows and treelines to make fields larger), loss and fragmentation, birds lose their nesting sites and food sources, which adds to population decline (Guerrero et al., 2012). Urban sprawl increases anthropogenic light levels as well as noise levels, which affects the behaviour of singing birds and impairs acoustic communication in birds (Chapter 11).

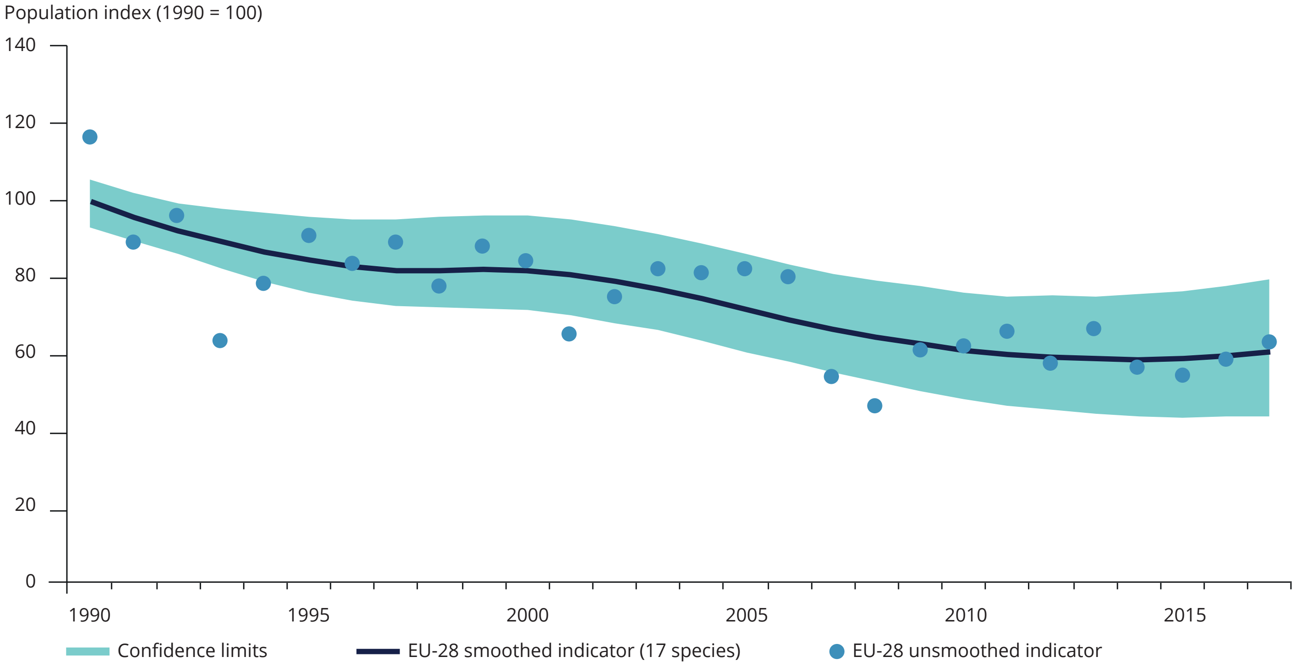
FIGURE 3.5 Common birds population index, 1990-2016



Note: The shaded areas represent the confidence limits. Geographical coverage: EU-28 Member States (except Croatia and Malta) and Norway and Switzerland.

Sources: EEA (2019a), European Bird Census Council, Royal Society for the Protection of Birds, BirdLife International and Czech Society for Ornithology.

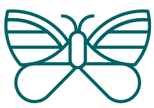
FIGURE 3.6 **Grassland butterflies population index, 1990-2017**



Note: The shaded area represents the confidence limits. Geographical coverage: Belgium, Estonia, Finland, France, Germany, Ireland, Lithuania, Luxembourg, the Netherlands, Portugal, Romania, Slovenia, Spain, Sweden, United Kingdom.

Source: EEA (2019a), Butterfly Conservation Europe, European Butterfly Monitoring Scheme partnership, Assessing Butterflies in Europe (ABLE) project.

Agricultural intensification can entail high inputs of agrochemicals, including pesticides. Their environmental impacts on the environment are described in Chapter 10. Increased use of pesticides results in reduced insect populations and seed production by plants, thereby reducing food for birds (Vickery et al., 2009; Musitelli et al., 2016). Apart from being an important source of food for birds and other animals, insects play a key role in ecosystem processes and provide various ecosystem services (Schowalter et al., 2018). Their most widely recognised role is pollination (Section 3.4.4 and Box 3.2) but they are also instrumental in developing soil nutrient cycling and providing pests, diseases and invasive alien species regulation (Noriega et al., 2018).



Grassland butterfly populations declined by 39 % in 15 EU Member States since 1990.

Recently, reports of dramatic losses of insects have been widely discussed. Hallmann et al. (2017) reported a decline of more than 75 % over 27 years in total flying insect biomass in protected areas in Germany. Declines concern pollinators too, including butterflies, as discussed earlier, but also honey bees and wild bees (Potts et al., 2010; EC, 2018b). An exhaustive global review of 73 reports of insect species declines (Sánchez-Bayo and Wyckhuys, 2019) concluded that habitat loss by conversion to intensive agriculture, followed by urbanisation, pollution (mainly pesticides and fertilisers), invasive alien species and climate change (to the least extent in moderate climatic zones) are the main drivers of decline. Moreover, there is increasing evidence that the use of pesticides such as neonicotinoid insecticides has a much wider impact on biodiversity, not only affecting non-target invertebrate (insect)

TABLE 3.4 Summary assessment — common species (birds and butterflies)

Past trends and outlook		
Past trends (> 25 years)		Since 1990 there has been a continuing downward trend in populations of common birds. Although this has levelled off since 2000 for some species, no trend towards recovery has been observed. The most pronounced declines were observed in farmland birds and grassland butterflies.
Outlook to 2030		The underlying drivers of the decline in common species are not changing favourably. Full implementation of a range of policy measures, including sectoral policies, is required to deliver improvements.
Prospects of meeting policy objectives/targets		
2020	☒	Europe is not on track to meet the 2020 target of halting biodiversity loss.
Robustness		Data collection methods are scientifically sound and the methods used by skilled volunteers are harmonised. However, wide monitoring schemes currently exist for only two species groups. The available outlook information is limited, so the assessment of outlook relies primarily on expert judgement.

species but also causing declines in bird populations. Neonicotinoids are applied as seed dressings to arable crops (Goulson, 2014) but only a very small percentage of this dressing (approximately 5 %) is absorbed by the growing plant. The rest accumulates in soils and leaches into surface and ground waters. Hallmann et al. (2014) used the Dutch long-term monitoring bird data and measurements of surface water quality to check to what extent water contamination by the most popular neonicotinoid, imidacloprid, correlated with bird population trends. They found that higher concentrations of imidacloprid in surface waters were consistently associated with decreases in bird numbers. The authors concluded that the declines are predominantly linked to changes in the food chain, namely the depletion of insect food resources for birds. It cannot be excluded, however, that declines in bird populations are also linked to trophic accumulation through consuming contaminated invertebrates or ingesting coated seeds (Hallmann et al., 2014).

It is difficult to forecast how soon biodiversity, as illustrated by the abundance of bird and grassland butterfly populations, will recover, as their state is influenced by a complex combination of environmental factors and policy measures. Potential positive impacts of CAP reform and the measures anticipated under the multiannual financial framework 2014-2020 on common species associated with farmland may become apparent in the period 2020-2030, as long as these policies are implemented thoroughly and on a large scale throughout the EU (EEA, 2019a). On the other hand, other factors that could adversely impact the outlook beyond 2020 include the negative impact of climate change on biodiversity and ecosystems, particularly on those specialist species groups that are dependent on non-intensive agriculture and forest ecosystems (EEA, 2019a). The increased competition for land could also intensify agricultural production in the EU, through land take via urbanisation as well as for producing renewable energy and biofuels.

3.3.4 Ecosystem condition and services

► *See Table 3.5*

The ability of ecosystems to deliver ecosystem services is inherently linked to their condition and provides an important pivot between their constituent species and habitats, and their abiotic components. Species and ecosystems are generally characterised by a capacity to cope with exploitation and disturbance. Beyond certain limits, or a 'safe operating space', however, species can decline in numbers or diversity and disappear or become extinct, and ecosystems can lose their capacity to deliver services (Birkhofer et al., 2018; Landis, 2017). Most biodiversity loss is ultimately anthropogenic and is driven by human production and consumption.

The IPBES regional assessment for Europe and Central Asia concluded (for IPBES sub-regions western Europe and central Europe) that there are decreasing trends (2001-2017) in biodiversity

BOX 3.2 EU Pollinators initiative

Pollinators are an integral part of healthy ecosystems. In Europe, pollinators are mainly insects such as bees (domesticated and wild bees), hoverflies, butterflies, moths and beetles. Without them, many plant species would decline and eventually disappear along with the organisms that depend on them. They are also important from an economic perspective: in the EU, around 84 % of crops and 78 % of temperate wild flowers depend, at least in part, on animal pollination and an estimated EUR 15 billion of the EU's annual agricultural output is directly attributed to insect pollinators (EC, 2018b).

In recent decades pollinators have declined dramatically and many species are on the verge of extinction (EC, 2018c). Existing evidence suggests that the main drivers of pollinator decline are land use change, intensive agricultural management and pesticide use, environmental pollution, invasive alien species, diseases and climate change (IPBES, 2016). Mitigating the decline will require actions across sectors, particularly in land management.

Acknowledging the urgent need to address pollinator decline, on 1 June 2018, the European Commission adopted a Communication on the first-ever EU initiative on pollinators. The initiative sets strategic objectives and a set of actions to be taken by the EU and its Member States to address the decline in pollinators in the EU and contribute to global conservation efforts. It sets the framework for an integrated approach to the problem and a more effective use of existing tools and policies now and in the following years under three priorities: (1) improving knowledge of pollinator decline, its causes and consequences; (2) tackling the causes of pollinator decline; and (3) raising awareness, engaging society at large and promoting collaboration (EC, 2018a, 2018b). ■

status for almost all terrestrial ecosystem types and that the majority of non-provisioning ecosystem services such as regulation of freshwater quality or pollination (Box 3.2) show declining trends (1960-2017) (IPBES, 2018).

Although reporting on ecosystem condition and services is a relatively new area and the coverage and availability of data and information is not comprehensive, it offers the potential for applying new technologies and innovation as well as providing an important benchmark with high policy relevance.

The EU biodiversity strategy to 2020, the global strategic plan for biodiversity 2011-2020 and many of the Sustainable Development Goals put ecosystems at the core of agreed objectives and targets. Target 2 of the EU biodiversity strategy explicitly aims to maintain and restore ecosystems and their services by including green infrastructure in spatial planning and restoring at least 15 % of degraded ecosystems by 2020. Action 5 in Target 2 of the EU biodiversity strategy to 2020 calls on Member States to map and assess ecosystems and their services in their national territory. This mapping and assessment of ecosystems and their services (MAES) process developed a common analytical framework to carry out the relevant assessment (Maes et al., 2013, 2018). Work at national level is complemented by an EU-wide assessment performed by the EEA and the JRC, which aims to provide the knowledge base for the other actions and targets of the strategy, e.g. green infrastructure, sustainable agriculture and forestry.

> Biodiversity targets will not be met without wider and more effective implementation of existing policies and stronger societal responses to biodiversity loss.

The final outcomes of the EU-wide assessment will be available by the end of 2019. The work done so far has looked at trends in five main categories of pressures (Section 3.1) in eight broad MAES ecosystem types in Europe (urban, cropland, grassland, heathland and shrub, woodland and forest, wetlands, freshwater and marine). Habitat change, including loss and fragmentation, as well as pollution, have had the greatest overall impact and they seem to be on the increase in more than 60 % of ecosystems assessed (EEA, 2016c). The effects of climate change on ecosystems are wide ranging and are considered one of the key risk factors for biodiversity decline and are projected to increase significantly across all ecosystems. A warming climate is leading to changes in species distribution and causing shifts in their ranges (EEA, 2017) as well as phenological changes, which may lead to decreased food availability and increased

TABLE 3.5 Summary assessment — ecosystem condition and services

Past trends and outlook		
Past trends (10-15 years)		Deteriorating trends have dominated with continued loss of valuable ecosystems and habitats as a result of land use change, particularly grasslands and wetlands, which has a severe impact on biodiversity and ecosystem services. Agricultural practices continue to have negative impacts on biodiversity and ecosystem services such as pollination.
Outlook to 2030		The underlying drivers of biodiversity loss are not changing favourably and increasing pressures from land use change, pollution, extraction of natural resources, climate change and invasive alien species are expected to further impact habitat quality and ecosystem condition. Ongoing initiatives triggered by policies, e.g. green infrastructure investments, the Pollinators initiative and restoration projects, are expected to deliver improvements.
Prospects of meeting policy objectives/targets		
2020	☒	Europe is not on track to meet the 2020 target of maintaining and enhancing ecosystems and their services by establishing green infrastructure and restoring at least 15 % of degraded ecosystems. While Natura 2000 areas have a positive effect on ecosystem condition and biodiversity in surrounding areas, pressures remain high and the conservation measures undertaken are still insufficient.
Robustness		Monitoring systems, models for assessing ecosystem services and data collection methods are scientifically sound but still improving in terms of completeness and appropriate spatial and temporal resolution. Significant improvements in data availability are expected, but the interconnection between ecosystem condition and service capacity still requires more research. Important data and information sources are natural capital accounting, the Copernicus programme and research initiatives. The available outlook information is limited, so the assessment of outlook relies primarily on expert judgement.

competition, and changes in species interlinkages and relationships. Climate change increases the importance of migration corridors between ecosystems and between protected areas. However, there are many barriers to movement, and not all species are able to move fast enough to keep up with the pace of climate change (EEA, 2017).

Another key pressure on biodiversity and ecosystems is invasive alien species IAS): animals and plants that are introduced accidentally or deliberately into a natural environment where they are not normally found, with serious negative consequences (Walther et al., 2009; Simberloff et al., 2013; Rabitsch et al., 2016). They spread through different pathways (Rabitsch et al., 2016), have a negative impact on ecosystem services and can increase the incidence of livestock diseases. Overall, they represent a major threat to native plants and animals as well as ecosystems in Europe, causing damage worth billions of euros to the European economy and to the health and well-being of Europeans every year. The EU Regulation on invasive alien species (EU, 2014) provides a set of measures to combat such species, ranging from prevention, early detection and rapid eradication to management of invasive alien species.

The core of the Regulation is the list of invasive alien species of Union concern, which is updated regularly and currently includes 49 species (EU, 2019). Information on their spatial distribution is now available for each of the species on the list (JRC, 2019a). This will serve as a baseline supporting the implementation of the Regulation and monitoring the evolution of IAS distribution in Europe. The initial findings indicate that several species are already quite widespread across the EU (e.g. *Impatiens glandulifera, Heracleum mantegazzianum, Ondatra zibethicus*) (JRC, 2019a), while others are not yet established in the European environment (e.g. *Microstegium vimineum, Parthenium hysterophorus, Sciurus niger)*. More information on invasive alien species is available through the European Alien Species Information Network (EASIN) (JRC, 2019c).

The outlook for ecosystem condition and services are difficult to assess mainly because of the complexity of the interactions and interdependencies between them, for example land use change affects the quantitative as well as the qualitative aspects of ecosystem services. Overall, various European initiatives and policies aim to counteract the deterioration in ecosystem condition and services. These are, among others, green infrastructure investments, the Pollinators initiative, LIFE projects, including rewetting of wetlands, renaturation of rivers and lakes, improving the Natura 2000 and Emerald networks and relevant activities in rural development programmes. However, the effects of many of those initiatives will be visible only in the medium or long term. Time lags in ecosystems' responses to environmental changes due to their buffering capacities may explain the lack of observed improvements in condition, but they are ambivalent, as they can also hide negative impacts due to ongoing high pressures.

The condition of ecosystems in Europe is increasingly under pressure from land use change, extraction of natural resources, pollution, climate change and invasive alien species.

3.3.5 Genetic diversity and soil biodiversity

Genetic diversity is crucial for food security, human health and the adaptation of species and ecosystems to environmental changes.

Apart from diversity of species and ecosystems, genetic diversity is the third key level of biodiversity; it describes the variability within a species, thus characterising the genetic pool, which enables organisms to better use, modify and adapt to changing environmental conditions. Plant and animal genetic resources for food and agriculture are an essential part of the biological basis for world food security (Martinez and Amri, 2008; FAO, 2015) and they contribute to human health and dietary diversity (Mouillé, et al., 2010). In addition to improving the quality of agricultural products, genetic diversity supports ecosystem-specific regulation processes, such as the suppression of pests and diseases.

While Europe is home to a large proportion of the world's crop varieties and domestic livestock breeds, it is also the region with the highest proportion of breeds classified as 'at risk'. At least 130 previously known cattle breeds are already classified as 'extinct' (Hiemstra et al., 2010; FAO, 2018). Modern plant breeding towards higher yields and minimal crop failure have reduced crop genetic diversity (Fu, 2015), and many traditional crop varieties and wild crop relatives are at risk too or have become extinct already.

The reasons for what is known as genetic erosion are similar to the pressures on biodiversity described earlier in this chapter and include in particular the intensification and industrialisation of animal and plant production, urbanisation, environmental degradation and land use change (e.g. loss of grazing land).

With climate change, the conservation and sustainable use of genetic diversity has become more critical than ever. For example, plants and animals that are genetically tolerant of high temperatures or droughts, or resistant to pests and diseases, are of great importance in climate change adaptation, which requires a diverse genetic basis (FAO, 2018). Preserving plant varieties and rearing endangered breeds is crucial for that purpose (FAO, 2019).

In order to properly address the critical value of genetic diversity, the European Commission, following an initiative by the European Parliament in 2013, commissioned a preparatory action on EU plant and animal genetic resources (EC, 2016b), that aimed to identify the actions needed to conserve and sustainably use genetic resources and to valorise the use of neglected breeds and varieties in an economically viable way .

Soil biodiversity maintains key ecosystem processes related to carbon and nutrient cycling and soil water balance.

Ecosystem services and functions rely on decomposition, which is the transformation of plant and animal residues into nutrients available to plants. This is possible only through burying, mixing, digesting and transforming of residues by soil animals including worms, mites, collembolans and bacteria. Soil organisms not only provide stability in the face of stress and disturbance, they also provide protection against soil-borne diseases (Brussaard et al., 2007).

One hectare of agricultural soil contains about 3 000 kg of soil organisms (Bloem et al., 2005), involving between 10 000 and 50 000 species (Jeffery et al., 2015). According to size and weight, earthworms dominate, whereas in terms of species richness, bacteria and fungi dominate (of which only 0.2-6 % are detected) (Orgiazzi et al., 2016).

Although soil biodiversity is difficult to investigate, there is evidence that pollution from metal and nanomaterials significantly reduces diversity (Gans et al., 2005), and species-diverse systems decompose more organic matter and produce more nitrogen compounds in the soil than species-poor soils (Setälä and McLean, 2004).

Soil biodiversity is increasingly under pressure, as a result of erosion, contamination and soil sealing, which may limit its capacity to deliver ecosystem services (Gardi et al., 2013; Orgiazzi et al., 2016) (Chapter 5).

3.4 Responses and prospects of meeting agreed targets and objectives

The recent fitness check of the EU nature legislation (EC, 2016a) concluded that, within the framework of broader EU biodiversity policy, the legislation remains highly relevant and is fit for purpose. However, full achievement of the objectives of the nature directives will depend on substantial improvement in their implementation in close partnership with local authorities and various stakeholders in the Member States to deliver practical results on the ground for nature, people and the economy in the EU. In response to the fitness check, the Commission produced an action plan for nature, people and the economy in 2017, including 15 actions to be carried out before 2020 that aim to rapidly improve the implementation of the nature directives (EC, 2017).

Other new policy instruments and initiatives, such as the National Emission Ceilings Directive, updated bioeconomy strategy, the Regulation on invasive alien species or the EU Pollinators initiative aim to help combat pressures and drivers of biodiversity loss.

Overall, however, policy responses, although successful in some areas, have been insufficient to halt biodiversity loss and the degradation of ecosystem services. Achieving significant progress towards biodiversity targets requires wider and more effective implementation of existing policies (EFSA, 2016). Improving coherence between different environmental policies, such as the EU biodiversity strategy, the Water Framework Directive, the Floods Directive and the Marine Strategy Framework Directive would make a positive contribution. For example, assessments of conservation status and pressures on freshwater habitat types under the Habitats Directive and assessments of the ecological status of water bodies under the Water Framework Directive run in parallel and there are not enough synergies between the two processes. A coordinated approach would result in co-benefits for both processes and improved management plans or programmes of measures (EEA, 2016a, 2018a).

Pressures on biodiversity and drivers of loss are mainly linked to a range of economic sectors and sectoral policies.

Financing mechanisms and other instruments included in sectoral and territorial policies have both direct and indirect impacts on biodiversity and ecosystem services to a very significant extent. While some of them may contribute to biodiversity conservation, many others affect it negatively through lack of coherence and conflicting objectives. For example, measures introduced in the CAP through agri-environmental schemes to reduce the environmental impact of agriculture have brought some positive outcomes. Overall, however, these have not been sufficient to halt biodiversity loss. The 2013 CAP reform introduced a payment for a compulsory set of 'greening measures', accounting for 30 % of the direct payments budget (EC, 2016c). These measures are intended to enable the CAP to be more effective in delivering its environmental and climate objectives, including those for biodiversity, soil quality and carbon sequestration, and at the same time to ensure the long-term sustainability of agriculture in the EU. However, a recent special report from the European Court of Auditors (2017) found the CAP greening measures ineffective, leading to positive changes in farming practices on only 5 % of EU farmland. Moreover, the report concluded that biodiversity and soil quality continue to be under increasing threat.

Another example is the production of renewable energy and biofuels, which may be of concern when it results in the conversion of natural or semi-natural ecosystems either for producing biofuels themselves or for producing other crops that have been displaced by biofuels.

While biodiversity in Europe is subject to many pressures and threats, the economic activities of Europe's nations have the potential to cause widespread depletion of natural capital and direct and specific damage to habitats and species well beyond Europe's regional boundaries. Europe's ecological deficit is considerable; its total demand for ecological goods and services exceeds what its own ecosystems supply (EEA, 2019b; Chapter 1). The implementation of Target 6 of the EU 2020 biodiversity strategy, aiming to help stop the loss of global biodiversity, continues to be of utmost importance.

Pressures on biodiversity and drivers of loss are mainly linked to a range of economic sectors and sectoral policies. Economic growth is generally not decoupled from environmental degradation and such decoupling would require a transformation in policies and tax reforms in the region (IPBES, 2018). Mainstreaming biodiversity concerns, in both the public and private sectors, and including them in sectoral policies is therefore crucial, especially for the post-2020 biodiversity agenda. These include trade, agriculture, forestry, fisheries, spatial planning, energy, transport, health, tourism and the financial sector, including insurance.

A more integrated approach across sectors and administrative boundaries would entail a wider application of ecosystem-based management and nature-based solutions. Green infrastructure, a strategically planned network of natural and semi-natural areas with other environmental features, is an example of such ecosystem-based management. Although biodiversity remains at the core of green infrastructure, it is much more than a biodiversity conservation instrument. Using a green infrastructure approach can improve the connectivity between and within protected areas and surrounding non-protected parts of the landscape, between urban and rural areas, and provide many other benefits such as increasing resilience to climate change, improving human health and well-being and flood regulation. The Natura 2000 network, which is a central part of European green infrastructure, is an excellent example of existing natural features (Section 3.4.1). There is a need, however, to ensure better protection and management of the sites (including their connectivity) and the condition of areas outside Natura 2000. National and regional frameworks to promote restoration and green infrastructure need to be further developed and implemented. Chapter 17 provides more information on the role of green infrastructure in the transition towards a sustainable society and economy.

In addition to policy, societal responses to biodiversity loss and the need for its conservation also play an important role; these include changes in the patterns of food consumption and consumption of other goods (Marquardt et al., 2019; Crenna et al., 2019). The results of the 2019 Eurobarometer survey show that Europeans' familiarity with the term 'biodiversity' has increased and that an overwhelming majority of the people interviewed are concerned about biodiversity loss and the state of the natural world (EEA, 2016d; EC, 2019).

Faced with the unprecedented and catastrophic loss of biodiversity and degradation of the Earth's ecosystems (IPBES, 2019), further efforts are needed to increase public awareness of the importance of biodiversity and ecosystem services for the livelihoods and well-being of Europeans, so that they may be more prepared to make personal efforts. This includes influencing decision-making with the aims of redefining priorities, achieving more coherent development of policies and stronger policy implementation, to contribute to sustainability transitions accepted by society.

04.
Freshwater

Key messages

- Water is an essential resource for human health, agriculture, energy production, transport and nature. Securing its sustainable use remains a key challenge globally and within Europe.

- Currently only 40 % of Europe's surface water bodies achieve good ecological status and wetlands are widely degraded, as are 80-90 % of floodplains. This has a critical impact on the conservation status of wetland habitats and the species that depend on them. Although point source pollution, nitrogen surpluses and water abstraction have been reduced, freshwaters continue to be affected by diffuse pollution, hydromorphological changes and water abstraction.

- Diffuse pollution and water abstraction pressures are expected to continue in response to intensive agricultural practices and energy production. This requires balancing societal demands for water with ensuring its availability for nature. Climate change is likely to change the amount of water available regionally, increasing the need for either flood protection or drought management and making this balance more difficult to achieve.

- Improved implementation and increased coherence between EU water-related policy objectives and measures is needed to improve water quality and quantity. Looking ahead it will also become increasingly critical to address and monitor the climate-water-ecosystem-agriculture nexus and connection with energy needs.

- It is on the river basin scale that effective solutions for water management can be found and essential knowledge is being developed through the implementation of river basin management plans under the Water Framework Directive. Solutions such as natural water retention measures, buffer strips, smart water pricing, more efficient irrigation techniques and precision agriculture will continue to grow in importance. An ecosystem-based management approach, considering multiple environmental objectives and co-benefits to society and the economy, will further support progress.

Thematic summary assessment

Theme	Past trends and outlook		Prospects of meeting policy objectives/targets
	Past trends (10-15 years)	Outlook to 2030	2020
Water ecosystems and wetlands	Trends show a mixed picture	Developments show a mixed picture	☒ Not on track
Hydromorphological pressures	Deteriorating trends dominate	Developments show a mixed picture	☒ Not on track
Pollution pressures on water and links to human health	Trends show a mixed picture	Developments show a mixed picture	☒ Not on track
Water abstraction and its pressures on surface and groundwater	Improving trends dominate	Developments show a mixed picture	☒ Not on track

Note: For the methodology of the summary assessment table, see the introduction to Part 2. The justification for the colour coding is explained in Section 4.3, Key trends and outlooks (Tables 4.2, 4.3, 4.4 and 4.5).

04.
Freshwater

4.1
Scope of the theme

Clean water is an essential resource for human health, agriculture, industry, energy production, transport, recreation and nature. Ensuring that enough water of high quality is available for all purposes, including for water and wetland ecosystems, remains a key challenge globally and within Europe. Europe's waters and wetlands remain under pressure from water pollution from nutrients and hazardous substances, overabstraction of water and physical changes. Climate change is expected to exacerbate many of these pressures, which depending on the pressure, may act on groundwater, rivers, lakes, transitional and coastal waters, as well as the riparian zone and wetlands. In return, this reduces the quality of the natural services provided by those ecosystems (Figure 4.1).

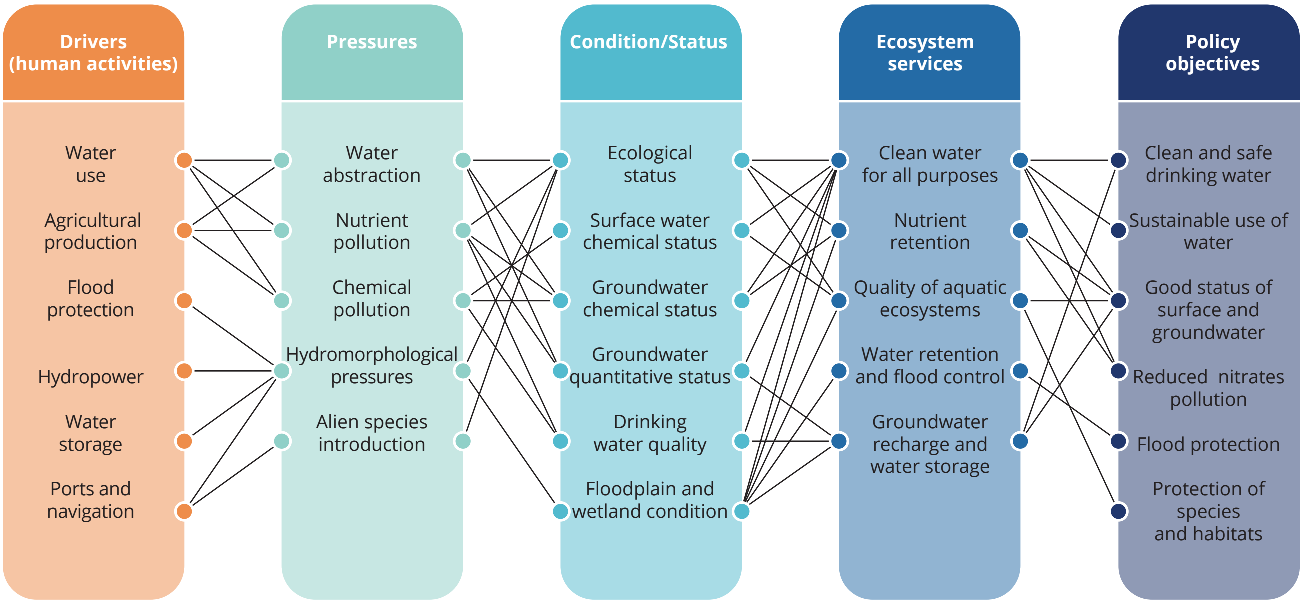
The remaining challenge is to further reduce the many pressures on water. These are linked to intensive agriculture, as well as other human uses that are economically important, but unfortunately also add large pressures to the environment. Improving water status will support improvements in biodiversity (Chapter 3) and in the marine environment (Chapter 6). Finally, Europe indirectly uses freshwater resources in countries outside its boundaries by importing goods with water-intensive production chains (Chapter 1).

Europe's waters are affected by pressures from pollution, overabstraction and physical changes.

4.2
Policy context

Europe's water policy has developed gradually over the last few decades. The first EU policies aiming to improve water quality date back to 1991, with the adoption of the Urban Waste Water Treatment and Nitrates Directives (EU, 1991a, 1991b), both targeting (among other things) reducing pollution pressures on water. In 2000, with the adoption of the Water Framework Directive (EU, 2000), an integrated ecosystem-based approach to managing water was introduced. Public safety and health objectives were secured by the Drinking Water, Bathing Water and Floods Directives (EU, 1998, 2006, 2007), and presently a proposal on the minimum requirements for water reuse is under discussion. While the directives tend to be very specific, the importance of water in relation to biodiversity and marine policies is pursued through the EU biodiversity strategy to 2020 (EC, 2011a) and the priority objectives of the Seventh Environment Action

FIGURE 4.1 **Selection of links between drivers, pressures, condition, ecosystem services and policy objectives**



Note: BOD, biological oxygen demand.

Source: Modified from Maes et al. (2018).

Programme, or 7th EAP (EU, 2013a). Water quantity remains an area of national competence, although issues linked to overall sustainable water use are of transboundary and thus European interest (EC, 2011b). EEA member countries that are not Member States of the EU also implement water policies inspired by the Water Framework and Floods Directives. Switzerland has set binding targets and requirements for its water policy and collaborates with its neighbours to achieve shared objectives through International Commissions for the Protection of the Rhine, Lake Constance and Lake Geneva. Turkey developed a national river basin management strategy for 2014-2023 with a view to ensuring the sustainable management of water resources in line with EU legislation. Iceland has adopted the Water Framework Directive, and it is working towards its implementation, albeit on a different timeline from the rest of the EU and Norway.

Europe's water policy also contributes to United Nations (UN) Sustainable Development Goal 6 (SDG 6) (UN, 2016) (Table 4.1) and to a range of other policies, for example in the areas of biodiversity and nature (Chapter 3), the marine environment (Chapter 6) and chemical pollution (Chapter 10). Conversely, another range of policies also influences freshwater: air pollution policies (Chapter 8), industrial pollution policies (Chapter 12), and sectoral policies (Chapter 13). An overview of environmental pressures stemming from agriculture is covered in Chapter 13. In the context of water it is important to mention that the common agricultural policy (CAP) includes requirements that support achieving environmental objectives. Funding provided under CAP Pillar II potentially supports the Water Framework Directive's objectives. Table 4.1 gives an overview of selected policies on freshwater addressed in this chapter.

4.3 Key trends and outlooks

4.3.1 Water ecosystems and wetlands

▶ See Table 4.2

In the context of European policy, surface water ecosystems are defined as rivers, lakes, and transitional and coastal waters. In addition many wetlands such as floodplains, bogs and mires depend on the availability of water for their existence. They are often found in the proximity of surface waters or depend on groundwater. These ecosystems provide important regulating ecosystem services, such as water purification, carbon capture

TABLE 4.1 Overview of selected policy objectives and targets

Policy objectives and targets	Sources	Target year	Agreement
Water ecosystems and wetlands			
Achieve good ecological status of all water bodies in Europe	Water Framework Directive (2000/60/EC)	2015	Legally binding commitment
Protect, conserve and enhance freshwater as well as the biodiversity that supports this natural capital	7th EAP, PO 1 (EC, 2013)	2050	Non-binding commitment
Protect and restore water-related ecosystems, including mountains, forests, wetlands, rivers, aquifers and lakes	SDG 6.6 (UN, 2016)	2020	Non-binding commitment
Hydromorphological pressures			
To assess and manage flood risks, aiming to reduce the adverse consequences for human health, environment and cultural heritage	Floods Directive (2007/60/EC)	2015	Legally binding commitment
Good hydromorphological status (quality element supporting good ecological status)	Water Framework Directive (2000/60/EC)	2015	Legally binding commitment
Pollution pressures on water and links to human health			
Achieve good chemical status of all surface and groundwater bodies	Water Framework Directive (2000/60/EC)	2015	Legally binding commitment
Reducing and further preventing water pollution by nitrates from agricultural sources	Nitrates Directive (91/676/EEC)	N/A	Legally binding commitment
To protect the environment in the EU from the adverse effects of urban waste water through collection and treatment of waste water. Implementation period depends on year of accession	Urban Waste Water Treatment Directive (91/271/EEC)	EU-15: 1998-2005 EU-13: 2006-2023	Non-binding commitments
To preserve, protect and improve the quality of the environment and to protect human health	Bathing Water Directive (2006/7/EC)	2008	Legally binding commitment
To protect human health from adverse effects of contamination of water for human consumption	Drinking Water Directive (98/83/EC)	2003	Legally binding commitment
Eliminate challenges to human health and well-being, such as water pollution and toxic materials	7th EAP, PO 3 (EC, 2013)	2050	Non-binding commitment
Improve water quality by reducing pollution	SDG 6.3 (UN, 2016)	2030	Non-binding commitment
Water abstraction and its pressures on surface- and groundwater			
Achieve good groundwater quantitative status of all groundwater bodies	Water Framework Directive (2000/60/EC)	2015	Legally binding
Water stress in the EU is prevented or significantly reduced	7th EAP; PO 2 (EC, 2013)	2020	Non-binding commitment
Water abstraction should stay below 20 % of available renewable water resources	Roadmap to a resource efficient Europe (EC, 2011b)	2020	
Substantially increase water use efficiency across all sectors and ensure sustainable withdrawals and supply of freshwater	SDG 6.4 (UN, 2016)	2030	Non-binding commitment
Implement integrated water resources management at all levels, including through transboundary cooperation as appropriate	SDG 6.5 (UN, 2016)	2030	Non-binding commitment

Note: EU-13, countries joining the EU on or after 1 May 2004; EU-15, countries joining the EU (or its predecessors) before 30 April 2004; PO, Priority objective; N/A, non-applicable.

and storage, and flood protection, in addition to providing habitats for many protected species. Hence, achieving good status of Europe's surface waters not only serves the objective of providing clean water but also supports the objective of providing better conditions for some of Europe's most endangered ecosystems, habitats and species, as listed under the Habitats and Birds Directives. Unfortunately, however, both surface water ecosystems and wetlands are under considerable pressure.

Trends in the ecological status of water

The quality of surface water ecosystems is assessed as ecological status under the Water Framework Directive.
The ecological status assessment is performed for 111 000 water bodies in Europe and it is based on assessments of individual biological quality elements and supporting physico-chemical and hydromorphological quality elements (definitions can be found in EEA, 2018b and Section 4.3.2). A recent compilation of national assessments, done as part of the second river basin management plans required under the Water Framework Directive (EEA, 2018b; EC, 2019), shows that 40 % of Europe's surface water bodies achieve good ecological status ([1]). This is the same share of water bodies achieving good status as reported in the first river basin management plans. Lakes and coastal waters tend to achieve better ecological status than rivers and transitional waters, and natural water bodies are generally found to have better ecological status than the ecological potential found for heavily modified or artificial ones. Across Europe, there is a difference between river basin districts in densely populated central Europe, where a high proportion of water bodies do not achieve good ecological status, and those in northern Scandinavia, Scotland and some eastern European and southern river basin districts, where more tend to achieve good ecological status (Map 4.1).

40 %

of the surface water bodies in Europe have a good ecological status.

The ecological status assessment is based on the 'one out, all out principle', i.e. if one assessed element of quality fails to achieve good status, the overall result is less than good status. Thus, the status of individual quality elements may be better than the overall status. Overall, for rivers, 50-70 % of classified water bodies have high or good status for several quality elements, whereas only 40 % of rivers achieve good ecological status or better. Since the first river basin management plans, many more individual quality elements have been monitored, improving the confidence of assessments, even if the variability of methods used by Member States remains so large that comparisons have to be made with caution (Table 4.2).

Trends in wetlands

Across Europe, wetlands are being lost. Between the years 2000 and 2018 the already small area of wetlands decreased further by approximately 1 % (Chapter 5). Many wetlands are found in undisturbed floodplains, the areas next to the river covered by water during floods. Scientific estimates suggest that 70-90 % of floodplains are degraded (Tockner and Stanford, 2002; EEA, 2016).

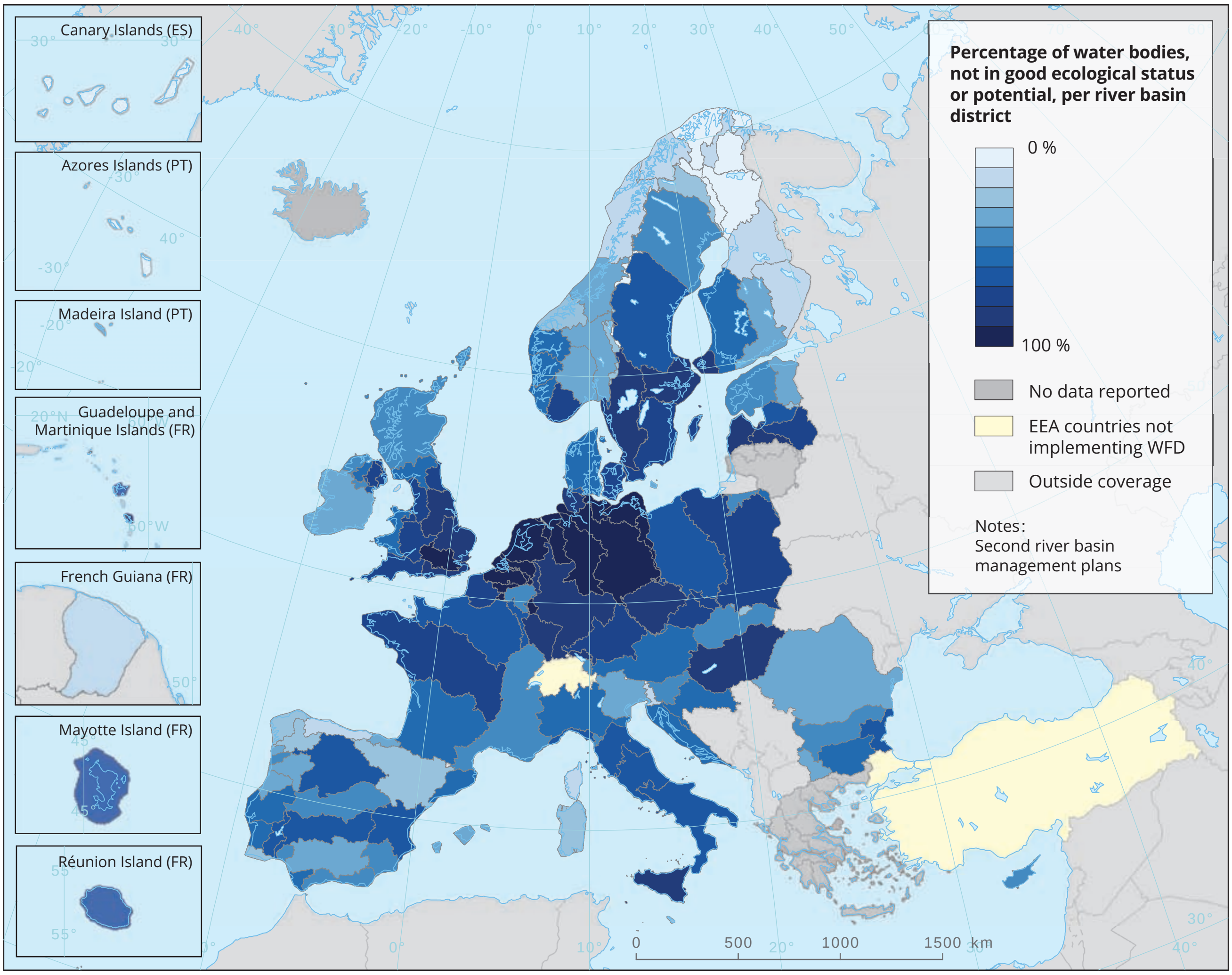
As a consequence, the capacity of floodplains to deliver important and valuable ecosystem services linked to flood protection and healthy functioning of river ecosystems has been reduced, ultimately reducing their capacity to support achieving good ecological and conservation status. The conservation status of many freshwater habitats and species listed in the Habitats and Birds Directives is not changing, and it remains predominantly unfavourable or bad (Table 4.2). The habitat group 'Bogs, mires and fens' (different wetland types) has the highest proportion of unfavourable assessments — almost 75 % (Chapter 3). The group 'Freshwater habitats' is also predominantly unfavourable, as are assessments of amphibians (Chapter 3).

Pressures and driving forces

The main reasons for not achieving good ecological status are linked to hydromorphological pressures (40 %), diffuse pollution (38 %) and water abstraction (Section 4.4). The understanding of the links between status and pressures has improved with the development of river basin management plans, and it is expected that the implementation of the Water Framework Directive will increasingly lead to a reduction in the most critical pressures and thus to improved ecological status of surface water bodies (Table 4.2). Freshwater habitats are subject to many of the same pressures as surface water bodies, and they are often very sensitive to overabstraction of water. In reporting under the Habitats Directive for freshwater habitats, changes in hydrology are most frequently reported as being important, as is 'pollution to surface waters' Chapter 3). In parts of Europe where groundwater abstraction is high, the pressure on wetlands

([1]) The WISE WFD database that underlies the WFD visualisation tool is subject to updates. This may lead to values in the visualisation tool differing from those presented in this chapter. The numbers in the text refer to values available on 1 January 2019. Recently, the database has been updated by Norway and Ireland, and these updates are captured in Map 4.1 and Map 4.2 but not in the values provided in the text.

MAP 4.1 **Country comparison — results of assessment under the Water Framework Directive of ecological status or potential shown by river basin district**



Notes: Caution is advised when comparing results among Member States as the results are affected by the methods used to collect and analyse data and often cannot be compared directly.
RBMP, river basin management plan.

Coverage: EU Member States, Norway and Iceland.

Source: EEA (2018e).

TABLE 4.2 Summary assessment — water ecosystems and wetlands

Past trends and outlook		
Past trends (10-15 years)		There has been mixed progress with 40 % of Europe's surface waters in good ecological status and some improvements in individual biological quality elements observed in the past 6 years. The conservation status of freshwater protected habitats and species is not changing, and remains predominantly unfavourable or bad.
Outlook to 2030		Continued progress is expected as implementation of the Water Framework Directive continues. Implementation of available provisions within the Water Framework, Floods, Habitats and Birds Directives to improve the conservation status of water-dependent habitats and species, by increasing the area of natural floodplains and wetlands, will be required to deliver improvements.
Prospects of meeting policy objectives/targets		
2020	☒	Europe is not on track to meet the objective of achieving good ecological status for all surface waters by 2020. Europe is not on track to meet the 2020 target of improving the conservation status of protected species and habitats (bogs, mires, fens, freshwater habitats and amphibians) and the cumulative pressures remain high.
Robustness		The EEA has collated EU Member States' assessments made under the Water Framework Directive. While each assessment is based on observations and can be considered robust, differences between approaches among EU Member States make comparisons challenging. The considerable loss of floodplains and wetlands is well documented. Outlooks are based primarily on expert judgement and assume that management implemented under EU policies will be effective and lead to some improvement. Knowledge gaps remain large for habitats and species not directly encompassed by EU legislation.

and freshwater ecosystems can be considerable. If they are designated as Natura 2000 sites, freshwater habitats and wetlands are protected through the associated management plans. An analysis of the share of inland surface water covered by protected areas showed that in the majority of European countries it is above the 17 % protection level set out in Aichi biodiversity target 11 (Bastin et al., 2019).

Europe is unlikely to achieve good ecological status for all surface waters by 2020.

4.3.2 Hydromorphological pressures

►See Table 4.3

Hydromorphology is considered a key parameter, because interaction between water, morphology, sediments and vegetation creates habitats that determine the river's ecological status. Hydromorphological pressures (2) are one of the main reasons that surface water bodies fail to achieve good ecological status; it is listed as a significant pressure for 40 % of surface water bodies (see sheet 'SWB pressures' in EEA, 2018e). Most of these pressures stem from physical alteration of river channels or of the riparian zone or shore or from dams, locks and other barriers.

These pressures occur because both the river and its floodplains are subject to a multitude of human uses that have altered their hydrology, morphology and connectivity as well as catchment land use over centuries. These uses are diverse and include increasing efforts to straighten rivers to make them navigable, drainage to gain agricultural land, urban development, and the need for ports, flood protection, water storage, hydropower and cooling water (Table 4.3). Transversal structures in particular (e.g. dams, weirs or locks) act as barriers for movement of sediment and biota. They also hamper the passage of fish, which is particularly important for the life cycles of eel, sturgeon or salmon because migration is part of their reproductive cycles. Fish are one of the biological quality elements assessed in rivers under the Water Framework Directive. Lateral

(2) Hydromorphology is the geomorphological and hydrological characteristic of a water body, which is also a condition for its ecosystem. Hydromorphological pressures are changes in the natural water body due to the human need to control flow, erosion and floods, as well as to drainage, river straightening and harbour construction.

TABLE 4.3 Summary assessment — hydromorphological pressures

Past trends and outlook		
Past trends (10-15 years)		Europe's water bodies have been subject to hydromorphological pressures for centuries. Although the Water Framework Directive has put in place initatives to reduce these pressures, they continue to affect 40 % of water bodies.
Outlook to 2030		Continued progress is expected as implementation of the Water Framework Directive continues. Full implementation of policies to restore rivers and put in place alternative flood protection methods, based on natural water retention measures, will be required to deliver improvements. Climate change may increase the magnitude and frequency of floods, leading to a greater demand for flood protection. It will also increase the demand for renewable energy generation, which is contributing to the expansion of hydropower in parts of Europe, resulting in increased hydromorphological pressures.
Prospects of meeting policy objectives/targets		
2020	☒	Europe is not on track to meet the objective of achieving good ecological status for all surface waters by 2020, and hydromorphological pressures are expected to continue to affect 40 % of Europe's surface waters.
Robustness		Hydromorphological pressures have been assessed by all EU Member States under the Water Framework Directive. While each assessment is based on observations and can be considered robust, differences in approaches make comparisons challenging, and a more detailed and comparable analysis at the European scale is lacking. The available outlook information is limited, so the assessment of outlook relies primarily on expert judgement and assumes that management implemented under EU policies will be effective and lead to some improvement.

connectivity between the river and its floodplain is also of critical importance, enabling floodplains to retain water for natural flood protection (EEA, forthcoming).

It is difficult to assess trends in hydromorphological pressures based on information reported under the Water Framework Directive because the categorisation of those pressures has changed between the reporting of the first and second river basin management plans, and no alternative method exists. However, EU Member States, Norway, Switzerland and Turkey are developing methods for assessing hydromorphological status (Kampa and Bussettini, 2018). At present, 55 different assessment methods are in use across Europe aiming to evaluate the impacts of hydromorphological pressures on the status of water bodies. Relevant measures needed to achieve good ecological status or potential are also considered as part of that work.

Drivers of change and solutions

Awareness is increasing of the important regulating ecosystem services provided by surface waters, floodplains and wetlands that have maintained their natural state to a high degree. Particularly important is the absence of barriers to fish migration, i.e. longitudinal connectivity, and the ability of floodplains to retain and filter water and nutrients, i.e. horizontal connectivity (Box 4.1). Fragmentation of rivers and of riparian habitats also has an impact on invertebrates and mammals. With the introduction of river basin and flood risk management plans, planning tools that support river restoration initiatives are in place and should ensure that more effort is made to restore Europe's rivers in the future. As restoration projects often involve using land differently, it is very important to involve citizens in the planning process. The results are, however, often seen as providing considerable added value, both because the resulting improved ecosystem services reduce management costs and because of the recreational opportunities that are achieved (Chapter 17).

4.3.3 Pollution pressures on water and links to human health

► *See Table 4.4*

Pollution of water with nutrients and harmful chemicals is of concern across

BOX 4.1 **Examples of solutions to hydromorphological pressures**

Removal of barriers

Barriers support hydropower production and water storage, and they may also help to control floods. They are, however, considered a hydromorphological pressure under the Water Framework Directive, and they are identified as one of the most common pressures on rivers in river basin management plans. Barriers disrupt the river ecosystem: they are not easily passable, and they alter flow regimes and sediment loads. The vast majority are small barriers, but the cumulative effects of many smaller barriers can be very large.

Many rivers in Europe have plans to restore populations of salmon, eel and sturgeon, which depend on migration to their headwaters for spawning. Several hundred thousand barriers are found in Europe's rivers, preventing migration. In the past, countries have implemented measures to make barriers passable for fish or to remove them altogether (EEA, 2018b, p. 73). In Estonia, the Cohesion Fund project 'Restoration of habitats in Pärnu river basin', aims to remove seven or eight dams on the river and its tributaries between 2015 and 2023, establishing a 3 000 km network of free-flowing water. In particular, removing the Sindi dam, located close to the river mouth, will make an important contribution to increasing spawning habitats. Many barriers are linked to hydropower production. In Iceland and Norway, most electricity is supplied by hydropower (73 % and 95 %, respectively). However, producing this energy has reduced the salmon population in the affected streams. According to the Norwegian Environment Agency, 23 % of Norway's salmon rivers have been negatively affected by river regulation schemes, the vast majority of which are for producing hydropower (NEA, 2018; Orkustofnun, 2018). Initiatives are in place to reduce the negative impacts, especially in relation to new projects (VRL, 2018). Barriers are also linked to reservoirs storing water between seasons to support crop production.

River restoration projects reconnecting rivers and floodplains

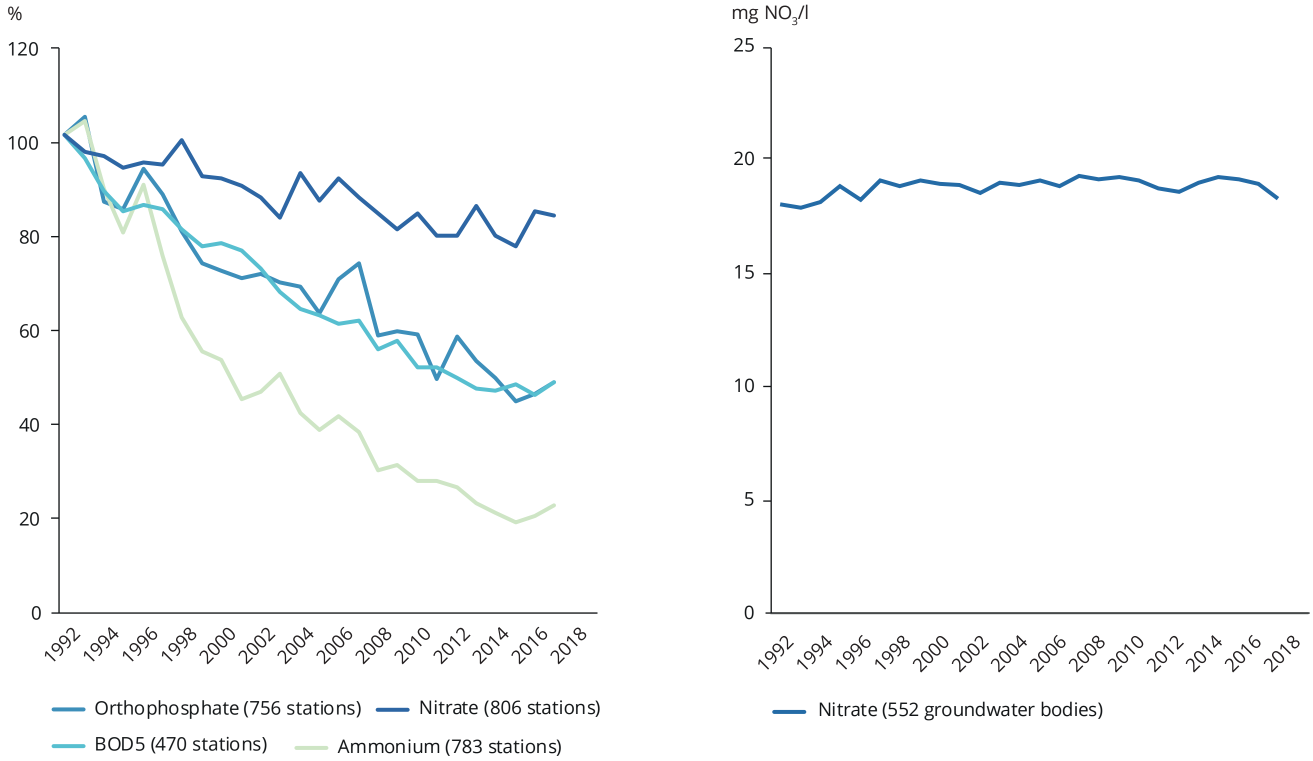
Because of the multiple benefits provided by natural floodplains, European policies encourage river basin management or conservation plans to favour restoration based on natural water retention measures, as well as conservation of existing natural floodplains. The need to change approaches to flood risk management because of the more uncertain future climate is often an underlying motivation; solutions based on natural properties are more cost-effective than structural measures in the long run (EEA, 2017a). Natural water retention measures refer to initiatives in which natural flood protection is provided at the same time as restoring the natural properties and functions of the floodplain, including its connection to the river. The measures can include structural changes to the river and floodplain and changes that involve managing how land is used within the floodplain (EEA, 2018c). Many examples of implemented natural water retention measures can be found on the European Natural Water Retention Measures Platform (NWRM, 2019). ■

Europe. The polluting substances stem from a range of activities linked to agricultural, industrial and household use. Emissions to water occur through both point source and diffuse pathways. Point sources refers to emissions that have a specific discharge location, whereas diffuse emissions have many smaller sources spread over a large area. Emissions into the atmosphere are spread, sometimes over large distances, eventually to be deposited on land or the sea surface (Chapter 8). Such pollutants can be transferred to rivers, lakes, and transitional, coastal and marine water as well as groundwaters. Transformation and storage may occur along the way, altering substances and creating multiyear timelags. Polluted water has an impact on human health and aquatic ecosystems. Faecal contamination from sewage is both unsafe and unpleasant, excess nutrients lead to eutrophication, which causes major disturbance of aquatic ecosystems, and chemicals that are harmful can, when limit values are exceeded, be a serious threat to both human and ecosystem health (Chapter 10).

Trends in nutrient concentrations

Declining concentrations of biological oxygen demand (BOD) and orthophosphate associated with industrial and urban waste water pollution are observed in most of Europe's surface waters (EEA, 2019c; Figure 4.2 and Table 4.4). A similar decline is also observed for other industrial emissions (Chapter 12) and nitrogen surplus has decreased (Chapter 13). However, concentrations of nitrates are declining much more slowly in groundwater and in rivers. These concentrations are more closely linked to agricultural diffuse pollution. The second river basin management plans showed that nitrate was the main pollutant affecting 18 % of the area of groundwater bodies, although 74 % of Europe's groundwater body area achieved

FIGURE 4.2 **Trends in 5-day biological oxygen demand (BOD5), orthophosphate and nitrates in rivers, and concentrations of nitrates in groundwater**



Note: Country coverage: EEA-39 (33 member countries and six cooperating countries).

Source: EEA (2019c).

good chemical status (EEA, 2018b and Table 4.4).

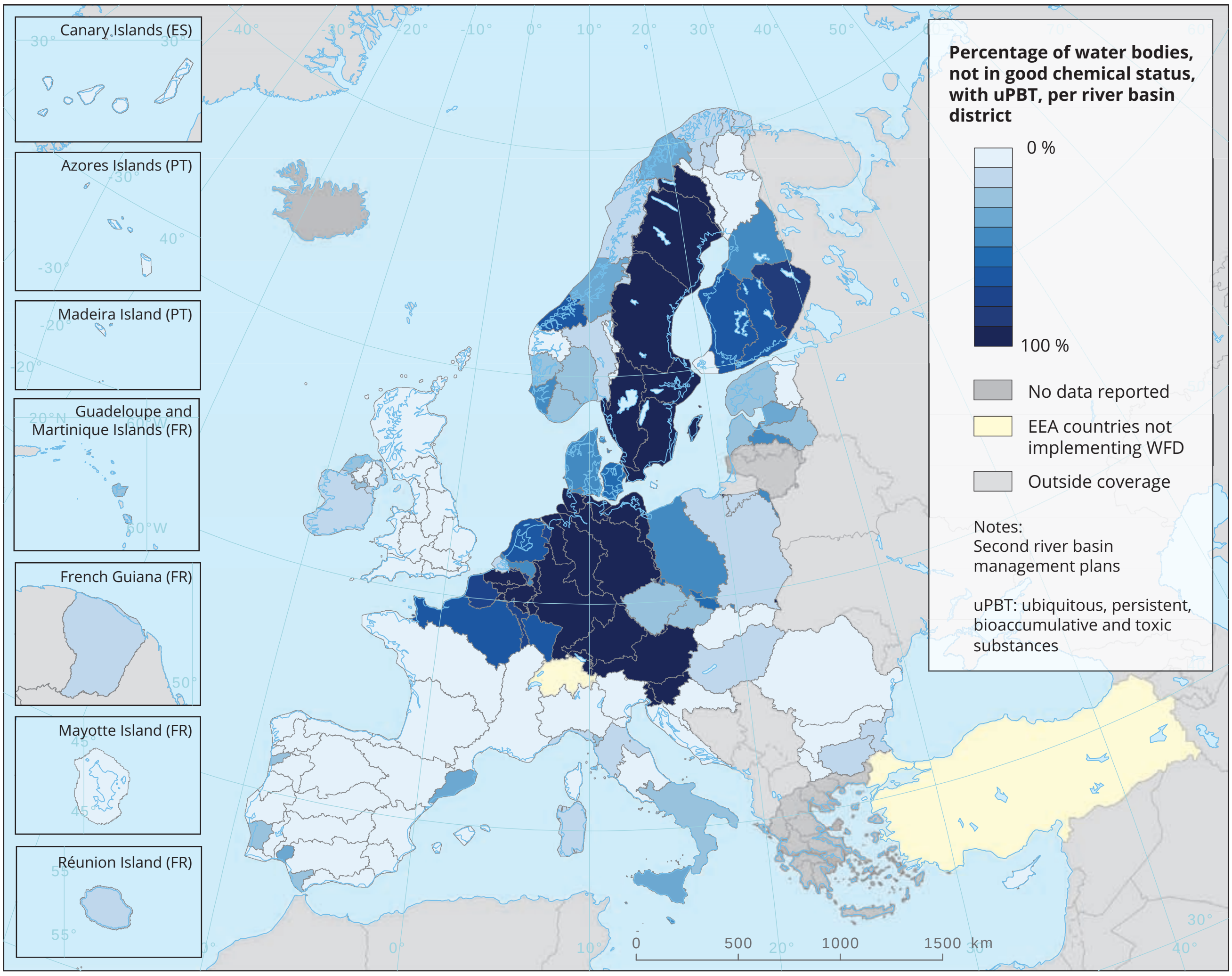
Trends in priority substances

In recent decades, legislation has helped ensure reduced emissions of certain hazardous substances (EU, 1976, 2000, 2010; EEA, 2018b). Under the Water Framework Directive, chemical status is assessed on a list of 33 'priority substances' that pose a significant risk to or via the aquatic environment, as set out in the Environmental Quality Standards Directive (EU, 2008b). The substances or groups of substances on the list include selected existing industrial chemicals, pesticides, biocides, metals and other groups such as polyaromatic hydrocarbons (PAHs), which are mainly produced by burning organic matter, and polybrominated diphenyl ethers (PBDEs), which have been used as flame retardants. While some priority substances occur naturally, most arise through human activities. To prevent further harm, their emissions must be reduced. The use of some of the most toxic substances, such as mercury and persistent organic pollutants, is heavily restricted, through both European legislation and international conventions.

> 38 %
>
> of the surface water bodies in Europe are in good chemical status.

In general, there is better knowledge about priority substances than more recently identified contaminants of concern (Chapters 5, 10, and 12).

MAP 4.2 **Country comparison — percentage of water bodies not achieving good chemical status**



Note: Assessment units are river basin districts. Caution is advised when comparing results among Member States, as the results are affected by the methods Member States have used to collect data and often cannot be compared directly.

Coverage: EU Member States, Norway and Iceland.

Source: EEA (2018d, SWB).

Concentrations in the environment of many 'legacy substances' — those that are no longer manufactured or used — are likely to continue to decline in water because their use has been phased out; however, new substances will emerge, and will need to be assessed and monitored for their risk to humans and the environment. A 2018 EEA report (EEA, 2018a) provides further information on chemicals in Europe's waters; see also Chapter 10 in this report for a broader discussion of chemicals in the environment.

Priority substances in water were assessed as part of the second river basin management plans by comparing the concentration of substances with their environmental quality standards. The assessment showed a relatively small number of substances that are responsible for most of the failures to achieve good chemical status: in particular, mercury, PBDE and PAHs are responsible for causing failure in a large number of water bodies. Overall, 38 % of Europe's surface water bodies achieved good chemical status (Map 4.2 and Table 4.4) (see also EEA, 2018a). The results, however, need to be interpreted with some caution. EU Member States have chosen different strategies for interpreting the results for mercury in their assessments. Mercury and PBDEs are ubiquitous, meaning that they are found everywhere, but only some countries have included them in their assessments. A subset of four of the priority substances and groups of substances, including mercury, is defined by the Environmental Quality Standards Directive as ubiquitous. Their concentrations will decline only very slowly, and their inclusion in chemical status under the Water Framework Directive may mask the trends in status of other substances. If these ubiquitous substances are omitted from the chemical assessment, only 3 % of Europe's surface waters fail to achieve good chemical status (EEA, 2018a, 2018e).

According to the information in the second river basin management plans, many of the priority substances listed do not exceed safety thresholds in the environment, which suggests that restrictions and emission controls, in particular, have been effective in preventing these substances from entering the environment. The chemical status of surface waters under the Water Framework Directive is assessed against a relatively short list of historically important pollutants — the priority substances. However, this misses the thousands of chemicals in daily use. There is a gap in knowledge at the European level over whether any of these other substances present a significant risk to or via the aquatic environment, either individually or in combination with other substances (EEA, 2018b). This discussion is further explored in Chapters 10 and 12, and in a 2018 EEA report (EEA, 2018a).

Drivers of change and solutions

The declining concentrations of BOD and nutrients in surface waters are associated

While water quality continues to improve, Europe is unlikely to achieve good chemical status for all water bodies by 2020.

with the considerable investments made in improving urban waste water treatment as a consequence of the Urban Waste Water Treatment Directive. There are still differences in the degree of urban waste water treatment among countries, but they are getting smaller (EEA, 2017b). The proportion of the population connected to urban waste water treatment plants in northern European countries has been above 80 % since 1995, and more than 70 % of urban waste water receives tertiary treatment. In central European countries, connection rates have increased since 1995 and are now at 97 %, with about 75 % receiving tertiary treatment. The proportion of the population connected to urban waste water treatment in southern, south-eastern and eastern Europe is generally lower than in other parts of Europe, but it has increased over the last 10 years and levels are now at about 70 % (EEA, 2017b). In spite of the implementation of urban waste water treatment, 15 % of surface water bodies fail to achieve good status due to point source pollution (see sheet 'pressures' in EEA, 2018e). Europe's bathing waters have also improved. In 2017, 95 % of bathing sites had good and excellent bathing water quality (EEA, 2019b). Water recreation such as beach holidays, swimming, kayaking, canoeing and rafting are of increasing interest to the European public and require safe bathing water. Areas with high ecological integrity have a higher potential for sustainable tourism.

Concentrations of some priority substances have decreased in surface waters as a result of improved emission controls (Chapter 12). However, although countries appear to have good knowledge of emissions, much of this knowledge does not extend to the European level. The EEA has found that emissions data, especially on emissions to water, reported under the Water Framework Directive or to the European Pollutant Release and Transfer Register (E-PRTR) or to the Water Information System for Europe (WISE), are incomplete and inconsistent, so there is no European-wide overview (EEA, 2018a).

Diffuse pollution remains a problem in Europe. It is mostly due to excessive emissions of nitrogen and phosphorus to water and to both historical and current emissions of mercury to the atmosphere and subsequently surface waters. Chemicals used as pesticides are also recognised as a source of diffuse pollution, although those used as biocides may reach urban waste water treatment plants. In the second river basin management plans, Member States identified that diffuse pollution is a significant pressure, affecting 38 % of surface water bodies and 35 % of the area of groundwater bodies (Table 4.4). The use of nitrogen-based fertilisers in agriculture is a primary cause of diffuse pollution (Chapter 13).

In recent decades, Europe has undertaken to reduce the use of mineral fertilisers in agriculture. As a consequence, the agricultural nitrogen surplus in the 28 EU Member States (EU-28) decreased by 18 % between 2000 and 2015 (EEA, 2019a) , but fertiliser application rates remain high, especially in those countries where agriculture is more intensive. In contrast, the phosphate surplus in the EU-28 increased by 14 % in the

TABLE 4.4 Summary assessment — pollution pressures on water and links to human health

Past trends and outlook		
Past trends (10-15 years)		Water quality has improved, although concentrations of nutrients in many places are still high and affect the status of waters. Drinking and bathing water quality continues to improve and some hazardous pollutants have been reduced.
Outlook to 2030		Continued progress in improving the chemical status of surface and groundwater is expected as implementation of the Water Framework Directive continues. Improvements in urban waste water treatment and industrial pollution will deliver improvements in pollution control, but diffuse pollution is expected to remain problematic. It is likely that pressures from newly emerging pollutants and mixtures of chemicals will be identified.
Prospects of meeting policy objectives/targets		
2020	☒	Europe is not on track to meet the objective of achieving good chemical status for all surface and groundwater bodies by 2020, with diffuse pollution expected to continue to affect 38 % of surface water bodies and 35 % of the groundwater body area. It is acknowledged that this result reflects that countries have taken differing approaches to interpreting the results for ubiquitous substances in their chemical status assessments.
Robustness		The assessment presented here is based partly on observations reported to the EEA as WISE-SoE data flows and partly on information provided as part of the Water Framework Directive reporting. While each assessment is based on observations and can be considered robust, differences in approaches make comparisons challenging, and a more detailed and comparable analysis at the European scale is lacking. The available outlook information is limited, so the assessment of outlook relies primarily on expert judgement and assumes that management implemented under EU policies will be effective and lead to some improvement. Countries have taken differing approaches tow interpreting the results for ubiquitous substances in their chemical status assessments.

shorter period between the reporting periods 2008-2011 and 2012-2015 (EC, 2018a). Today, Member States are implementing a number of measures, many of which are compulsory in nitrate vulnerable zones designated under the Nitrates Directive, both to reduce inputs and to reduce the impacts of a potential surplus. Those measures include farm-level nutrient management, standards for the timing of fertiliser application, appropriate tillage techniques, the use of nitrogen-fixing catch crops, crop rotation and buffer strips ([3]). Manure, and slurry storage and surplus management, as well as reducing the phosphate content of animal feed are also being implemented. In spite of these activities, the European Commission has concluded that further efforts to adapt measures to regional pressures are needed (EC, 2018a).

> 95 %
>
> of bathing sites in the EU met good and excellent bathing water quality standards in 2017.

4.3.4 Water abstraction and its pressures on surface and groundwater

► See Table 4.5

Europe's water abstraction of 243 000 million cubic metres can be split among four main sectors: (1) household water use (14 %); (2) industry and mining (18 %); (3) cooling water for electricity production (28 %); and (4) agriculture (40 %) (Figure 4.3). Geographically there are, however, large differences in the sectors using more water. In western Europe public water supply, cooling water and mining are responsible for the majority of water abstraction, whereas in southern Europe and in Turkey agriculture uses the largest share.

Water is abstracted from surface and groundwater resources (76 % vs 24 %). In total, 89 % of European groundwater bodies achieve good quantitative status. Overall, water abstraction has decreased by 19 % (1990-2015), and on average abstraction corresponds to 13 % of the renewable freshwater

([3]) Buffer strips are uncultivated strips along rivers and streams. They are used extensively across Europe as a response to the Nitrates Directive's requirement to reduce pollution. They reduce the movement of sediment, nutrients and pesticides from farmed fields. Their width varies depending on country and the severity of pollution problems.

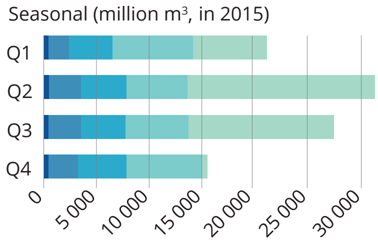
FIGURE 4.3 Water use in Europe by economic sector and by source

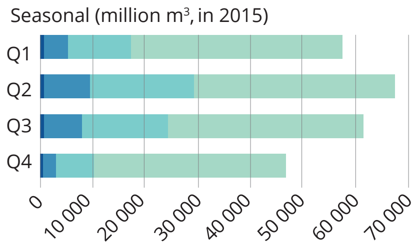
Annual water use by sectors (%, in 2015)

Service industries	2
Households	12
Mining and quarrying, manufacturing, construction	18
Electricity	28
Agriculture	40

Annual freshwater abstraction by source (%, in 2015)

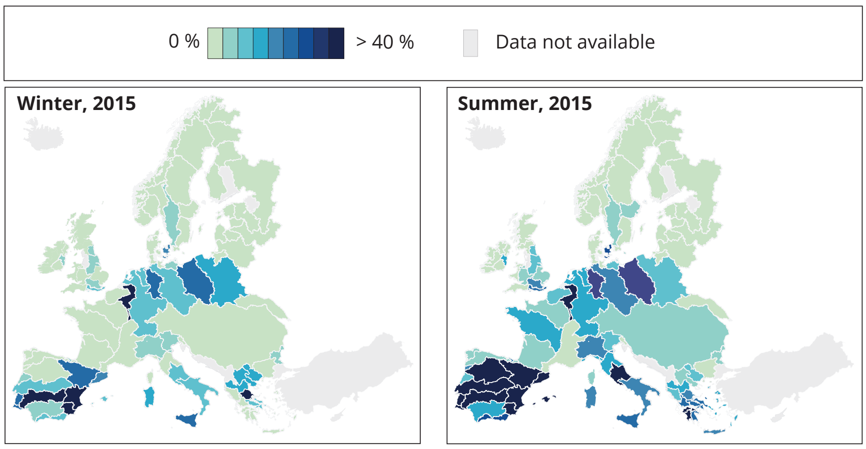
Lakes	1
Artificial reservoirs	10
Groundwater	24
Rivers	65





In Europe, around 243 000 million cubic metres of water per year are abstracted for different sectors. Around 60 % of the water abstracted is returned to the environment, but it has often been polluted in the process. Water resources and their uses are unevenly distributed across Europe, leading to large differences in water stress.

Water exploitation by river basin



Note: The water exploitation index (WEI+) is a measure of water stress. It measures level of water scarcity by comparing water use with the renewable freshwater resource available. A WEI+ of above 20 % implies that a river basin is under stress, and a WEI+ of more than 40 % indicates severe stress and clearly unsustainable resource use. In summer 2015, 19 % of Europe's area experienced water stress.

Source: EEA core set indicator 018: the use of freshwater resources (EEA, 2018c).

TABLE 4.5 Summary assessment — water abstraction and its pressures on surface and groundwater

Past trends and outlook		
Past trends (10-15 years)		Water abstraction is decreasing and 89 % of Europe's groundwater bodies achieve good quantitative status.
Outlook to 2030		Continued focus on maintaining and improving the quantitative status of groundwater is expected as implementation of the Water Framework Directive continues. However, water stress remains a concern in some regions and the future availability of water will be affected by climate change.
Prospects of meeting policy objectives/targets		
2020	☒	Europe is not on track to meet the objective of achieving good quantitative status of all groundwater bodies by 2020. Water abstraction currently exceeds 20 % of the renewable freshwater resource in 19 % of Europe's area.
Robustness		Good quantitative status is based on EU Member State assessments. While each assessment is based on observations and can be considered robust, differences in approaches make comparisons challenging. Water abstraction is recorded by Member States, whereas water use is attributed to sectors using a model. Outlook information is limited, so the assessment of outlook relies primarily on expert judgement and assumes that management implemented under EU policies will be effective and lead to some improvement.

resource (Table 4.5). These numbers, however, mask large geographical variations. Increasingly, in countries with limited freshwater resources, such as Cyprus, Malta, and Spain, freshwater is supplied by desalinating seawater. The milestone set in the EU Roadmap to a resource efficient Europe, namely that water abstraction should stay below 20 % of available renewable water resources in Europe, was not achieved in 36 river basins, corresponding to 19 % of Europe's territory, in summer 2015. Consequently, around 30 % of the European population was exposed to water scarcity in summer 2015 compared with 20 % in 2014 (EEA, 2018c). In addition, most of the 11 % of groundwater bodies that do not achieve good quantitative status are found in Cyprus, Malta, and Spain, although in the United Kingdom good groundwater quantitative status is not reached for more than 50 % of groundwater bodies for the Thames and Anglian districts (EEA, 2018d, groundwater quantitative status). In these areas more than 20 % of the renewable resource may be used.

89 %

of groundwater bodies in the EU are in good quantitative status.

Water storage and abstraction places considerable pressure on the environment. While the water used is less than the amount abstracted because some water is returned to the environment, water scarcity still occurs in parts of Europe, both in the summer and in the winter (Figure 4.3). The underlying causes of water scarcity, expressed by the water exploitation index, differ: in western Europe it is primarily linked to cooling water needed for energy production and industry; in southern Europe water scarcity is linked to agriculture.

Climate change projections suggest that Europe will face changes in the temperature of water and in precipitation in the future (Chapter 7). Dry parts of Europe will become drier, wet parts will become wetter, and the seasonality and intensity of precipitation may change. Flood frequencies could change in response to altered precipitation patterns. Europe is thought to have adequate water resources, but water scarcity and drought is no longer uncommon. In Europe, water scarcity can arise both as a consequence of the water demand for human activities and as a consequence of reduced meteorological inputs. Water scarcity is becoming increasingly frequent and widespread in Europe, and it is expected to get worse as changing seasonality precipitation decreases and temperatures increase in response to a changing climate. This will also make the environmental pressures of water abstraction worse, and the demand to better understand and manage the climate-water-ecosystem-agriculture nexus is likely to increase in the future.

4.4 Responses and prospects of meeting agreed targets and objectives

Enough water of good quality is a fundamental objective of Europe's environmental policy as well as for achieving the UN Sustainable Development Goals. In Europe this is supported through the comprehensive policy framework which includes setting legally binding objectives for Europe's water and for managing and reducing environmental pressures from hydromorphology, pollution and water abstraction. This policy framework will also support the delivery of Europe's contribution to SDG 6 on water.

In 2015, the second cycle of developing river basin management plans was finalised. Subsequently, the results were reported to the EU, and a comprehensive analysis of these results is presented in a 2018 EEA report (EEA, 2018b). A parallel process for the reporting of the first flood risk management plans under the Floods Directive has also taken place (EC, 2019). The European Commission is also developing a proposal for the Drinking Water Directive, to secure better protection of human health and to meet SDG 6, and an evaluation of the Urban Waste Water Treatment Directive, to align it with other policies to realise the potential for energy savings.

The Water Framework Directive and the Floods Directive operate on the scale of river basins. Water within a river basin is connected, and hence any decision that influences water quantity or quality in one part of the district can influence water in another part. Managing water quality and quantity requires detailed knowledge of water abstraction, land use and other pressures on the river basin scale. This knowledge is being developed as part of the implementation of river basin management plans under the Water Framework Directive and flood risk management plans under the Floods Directive. It is on this scale that effective solutions for water management can be found for Europe's 110 000 water bodies distributed across 180 river basins. River basin management plans already encompass transitional and coastal waters; they provide an effective means of regulating land-based pollution of the sea, especially with regard to nutrient and hazardous substance pollution.

Freshwaters remain significantly affected by diffuse pollution, hydromorphological changes and water abstraction.

Already, the process of developing river basin management plans has provided a better understanding of the status, the pressures causing failure to achieve good status, and the measures implemented to generate improvement. Member States have implemented measures that improve water quality and reduce pressures on hydromorphology. This knowledge is essential for achieving future improvements.

The analysis of the river basin management plans shows that Europe is on the way to achieving good status for water, but it also shows that the target of achieving good status for water in 2015 was not achieved. An initial analysis of flood risk management plans also shows that flood risk in Europe is being reduced and that many countries have plans for implementing natural water retention measures that will support hydromorphological improvements.

In recent decades, legislation has helped to ensure reduced emissions of certain hazardous substances (Section 4.4.3). However, there is a very large number of chemicals in use (Chapter 10) and only a few are listed as priority substances under the Water Framework Directive. The watch list, established under the Priority Substances Directive (EU, 2013b), provides a mechanism for gathering information on harmful substances for which information on concentrations in the aquatic environment is lacking.

One of the major successes for water quality has been the reduction of nutrient, certain hazardous substance and microbial pollution in rivers, lakes, and transitional and coastal waters following the implementation of urban waste water treatment, industrial emission controls and restrictions of chemicals. Although the Urban Waste Water Treatment Directive in particular is still not fully implemented in all countries, its effectiveness is clear. Where urban waste water treatment has been implemented, concentrations of nutrients, hazardous substances and microbial pollution in water have been reduced. This also supports achieving improved drinking water and bathing water quality, which in return support a high level of human health across Europe. Options for increased reuse of urban waste water are being considered by the European Commission (EC, 2018b). The EU supports the development of drinking water, urban waste water treatment and flood protection infrastructure through the European Regional Development Fund and the Cohesion Fund.

In contrast, it has proven much more complex to reduce diffuse pollution. The Nitrates Directive supports reducing diffuse nutrient pollution, which is one of the most commonly cited pressures on Europe's surface and groundwater bodies. In areas designated as nitrate vulnerable zones, the Nitrates Directive requires management of fertiliser use, and of manure and slurry storage and use, with the aim of reducing emissions. Efforts have, however, not yet been enough to sufficiently reduce diffuse pollution. Reducing diffuse pollution is a major societal challenge. It involves reducing atmospheric pollution and pollution from multiple small sources, and it applies to both nutrients and hazardous substances. Altering agricultural diffuse pollution requires steps to be taken at farm level to reduce pollution, which requires both farm-level investments and sometimes accepting reduced crop yields (Chapter 16). The new

CAP reform, which is currently being negotiated between the European Commission, Council and Parliament, contains several elements that could support achieving better progress to this end. For example, the proposed CAP reform requires EU Member States to increase their ambition to achieve the objectives of the Water Framework and Nitrates Directives compared with the 2014-2020 programming period, including by stimulating national coordination with environmental authorities. However, the final details of the new CAP could still change considerably (Chapter 13).

The EU Blueprint to safeguard Europe's water resources (EC, 2012) points to the insufficient use of economic instruments as one of several reasons for management problems not being adequately addressed. The fitness check of the Water Framework and Floods Directives, currently undertaken by the European Commission, includes the objective of enabling a discussion with all stakeholders. Input will encompass how the directives have brought about changes in the management of water and improvements in the state of water bodies and in the strategies to reduce the risk of flooding across the EU. The fitness check tackles both the functioning and the interactions of the directives, as well as the costs and benefits that the various stakeholders attach to them.

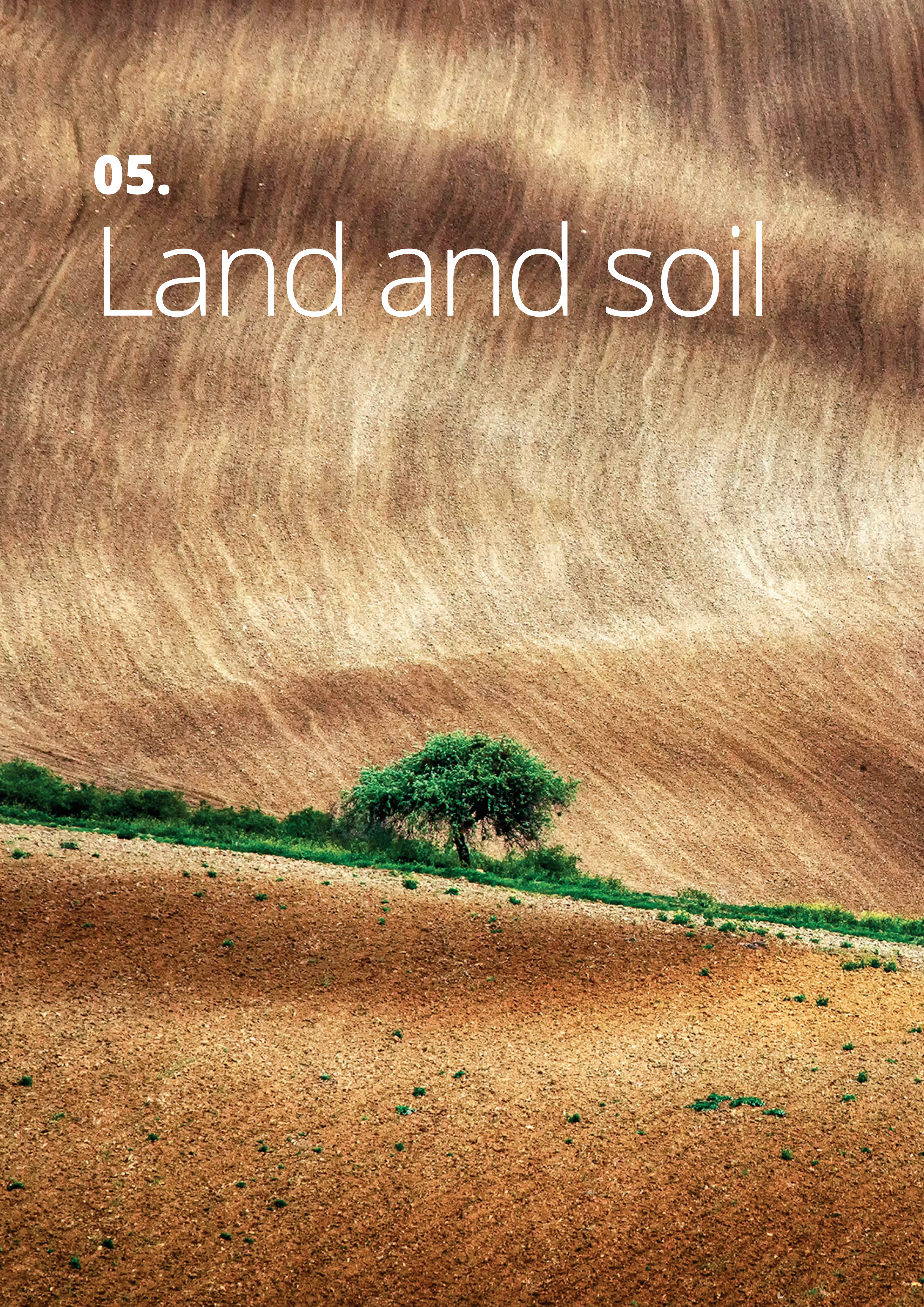
Chemical pollution remains an issue. Although legacy contaminants are declining, little is known about new substances. The large number of potentially hazardous chemicals makes monitoring programmes across Europe highly variable, and hence it is difficult to make a consistent assessment of chemical pollution on the European scale (Chapter 10).

Furthermore, the freshwater policy framework emphasises the integrated role of freshwater in achieving both biodiversity and marine environmental policy goals. Improving the status of water will also support achieving good conservation status of species and habitats under the Habitats and Birds Directives (EEC, 1979, 1992) and the good environmental status of marine waters under the Marine Strategy Framework Directive (EU, 2008a), especially for descriptors of eutrophication and hazardous substances. Many of the habitats and species protected under the Habitats and Birds Directives depend on the adequate availability of water and on good ecological and chemical status of surface waters. For example, 39 floodplain habitats and 14 bog, mire and fen habitats are listed in Annex I of the Habitats Directive. In many cases, the availability of surface- or groundwater is critical to achieving good conservation status. Thus, a clear link exists between the objectives of those directives. Similarly nutrient and chemical pollution in the marine environment often stems from land-based activities that need to be managed through river basin management plans under the Water Framework Directive. The Marine Strategy Framework Directive common implementation strategy has been very explicit on the need to develop this link to avoid having separate processes for the two directives, and this was further supported by Commission Decision (EU) 2017/848 on methodological standards (EU, 2017). However, while the requirements to link the directives are in place, and some coordination is likely to occur within Member States, the explicit outcome of this activity is not fully known at the European level. There are few mechanisms in place to insist on developing cross-policy strategies.

As it is anticipated that climate change impacts will increase towards 2030, water will also be affected, placing an additional demand on effective water management tools. Pricing and metering of household water are important instruments supporting the Water Framework Directive, and they need to be adapted to agricultural water abstraction to ensure efficiency gains such as those that can be obtained through optimising irrigation. It is also important to have a strategy in place for keeping saved water for the environment, rather than for increasing agricultural production. In parts of Europe, leakages from the public water supply system can be as much as 30 %, and reducing these is an obvious efficiency gain. As European policymakers strive to develop a sustainable strategy for water management, the development of new reservoirs or transfer of water between basins is only in line with the Water Framework Directive if their ecological status has not deteriorated (EU, 2000, Article 4.7). Instead, drought management strategies need to be developed, as part of river basin management and in response to climate change.

Projected climate change is likely to significantly affect water temperatures and quantities. Southern Europe is likely to struggle more with water scarcity and drought issues in the coming years, whereas precipitation is projected to increase in northern Europe. Thus, protecting people and their economic and cultural assets from flooding will continue to be of major importance. Improved flood risk management, as required by the Floods Directive, in combination with green infrastructure and nature-based solutions (Chapter 17), which both reduce flood risk and improve ecosystems, is a tool for achieving benefits and policy objectives for both people and nature. However, it remains unclear whether adaptation is happening fast enough to ensure sufficient capacity to cope with future climatic changes. As water has a profound influence on ecosystems, it will become increasingly critical to address and monitor the climate-water-ecosystem-agriculture nexus (Chapter 16), including in the light of other uses. It would be a missed opportunity for Europe not to consider the full extent of these links.

05.
Land and soil



Key messages

- Land and its soils are the foundation for producing food, feed and other ecosystem services such as regulating water quality and quantity. Ecosystem services related to land use are critical for Europe's economy and quality of life. Competition for land and intensive land use affects the condition of soils and ecosystems, altering their capacity to provide these services. It also reduces landscape and species diversity.

- Land take and soil sealing continue, predominantly at the expense of agricultural land, reducing its production potential. While the annual rate of land take and consequent habitat loss has gradually slowed, ecosystems are under pressure from fragmentation of peri-urban and rural landscapes.

- Land recycling accounts for only 13 % of urban developments in the EU. The EU 2050 target of no net land take is unlikely to be met unless annual rates of land take are further reduced and/or land recycling is increased.

- Soil degradation is not well monitored, and often hidden, but it is widespread and diverse. Intensive land management leads to negative impacts on soil biodiversity, which is the key driver of terrestrial ecosystems' carbon and nutrient cycling. There is increasing evidence that land and soil degradation have major economic consequences, whereas the cost of preventing damage is significantly lower.

- European policy aims to develop the bioeconomy but while new uses for biomass and increasing food and fodder consumption require increasing agricultural output, land for agricultural use has decreased. This leads to growing pressures on the available agricultural land and soil resources which are exacerbated by the impacts of climate change.

- The lack of a comprehensive and coherent policy framework for protecting Europe's land and soil resources is a key gap that reduces the effectiveness of the existing incentives and measures and may limit Europe's ability to achieve future objectives related to development of green infrastructure and the bioeconomy.

Thematic summary assessment

Theme	Past trends and outlook		Prospects of meeting policy objectives/targets	
	Past trends (10-15 years)	Outlook to 2030	2020	2050
Urbanisation and land use by agriculture and forestry	Deteriorating trends dominate	Deteriorating developments dominate		☒ Not on track
Soil condition	Deteriorating trends dominate	Deteriorating developments dominate	☒ Not on track	

Note: For the methodology of the summary assessment table, see the introduction to Part 2. The justification for the colour coding is explained in Section 5.3, Key trends and outlooks (Tables 5.2 and 5.4).

05.
Land and soil

5.1
Scope of the theme

Productive land and fertile soil are part of our shared natural capital. The management of land by owners and users is therefore fundamental for sustainable resource use and delivery of ecosystem services. These services include the provision of food, nutrient cycling, supporting all terrestrial biodiversity, water regulation and purification, and mitigating climate change by carbon sequestration. While the demand for food and the pressures on land and soil are increasing globally, biodiversity is visibly declining (UNEP, 2014; IPBES, 2018).

Current land use practices and observed land cover changes put significant pressure on the land system (EC DG AGRI, 2015; EEA, 2018c). The condition of land and soils is affected by loss of productive land because of land take and the type and intensity of land management. Europe's soils suffer from sealing, erosion, compaction, pollution, salinisation and carbon loss. Additional pressure on the land system comes from climate change. Shifting spring phenology, droughts, fires, storms and floods impact the condition of ecosystems and the food chain.

> Land-use management is vital for sustainable resource use and delivery of ecosystem services.

A complex pattern of pressures results from socio-economic drivers, expressed as the need for settlements, transport, clean water, food and fibre production, and tourism. Future scenarios and projections point to intensification of agriculture in northern and western Europe and extensification and abandonment in the Mediterranean region (Holman et al., 2017). More intensive land use will lead to a gradual decline in the levels of (soil) biodiversity (Schneiders et al., 2012; Tsiafouli et al., 2015).

5.2
Policy context

Prevention and restoration of land and soil degradation are addressed broadly in the European policy framework. Table 5.1 presents an overview of selected relevant policy targets and objectives. More details on policies related to agriculture and forestry are available in Chapter 13.

Regarding land and soil policies, binding targets are lacking at European level. The Seventh Environment Action Programme (7th EAP) and the EU Roadmap to a resource efficient Europe promote 'no net land take' in the EU by 2050, aiming to mitigate the effect of urban sprawl. 'No net land take' supports the land degradation neutrality target of the United Nations Convention to Combat Desertification (UNCCD), aiming to maintain the amount and quality of

TABLE 5.1 Overview of selected policy objectives and targets

Policy objectives and targets	Sources	Target year	Agreement
Land and soil			
EU policies help to achieve no net land take by 2050	7th EAP (EU)	2050	Non-binding commitments
Reduce soil erosion, increase soil organic matter, and promote remedial work on contaminated sites	Roadmap to a resource efficient Europe (EU)	2020/2050	
Prevent further degradation of soil, preserve its functions and restore degraded soil Integrate soil protection into relevant EU policies	Thematic strategy on the protection of soil	N/A	Non-binding commitment
Restore at least 15 % of degraded ecosystems; better integrate biodiversity into agriculture and forestry	EU biodiversity strategy to 2020	2020	Non-binding commitments
Targets 2.4 (food security), 3.9 (soil pollution), 15.2 (sustainable agricultural and forest management), and 15.3 (land degradation neutrality) Combat desertification and mitigate the effects of drought in countries experiencing serious drought and/or desertification	Global policies: SDGs, United Nations Convention to Combat Desertification	2030	Non-binding commitments
Sustainable management of natural resources and climate action: to ensure the long-term sustainability and potential of EU agriculture by safeguarding the natural resources on which agricultural production depends	Common agricultural policy (CAP)	N/A	Non-binding commitments
Ensure the monitoring of negative impacts of air pollution upon ecosystems (Article 9) (includes soils)	National Emission Ceilings Directive (Article 9)	2030	Binding commitment
Identify and assess sites contaminated by mercury, and address risks (includes soil contamination)	Minamata Convention on Mercury (Article 15)	N/A	Non-binding commitment
Ensure that emissions do not exceed removals in the LULUCF sector (no-debit rule)	LULUCF regulation (2018/841)	2025, 2030	Binding commitment

Note: 7th EAP, Seventh Environment Action Programme; LULUCF, land use, land use change and forestry; SDGs, Sustainable Development Goals; N/A, non-applicable.

land resources. Land degradation neutrality is promoted by Target 15.3 of the UN Sustainable Development Goals (SDGs), which, by 2030, strives to combat desertification and to restore degraded land and soil. SDG 2 (to eliminate hunger) connects soils, food production and healthy living. Land and soils are also bound to goals that address poverty reduction (SDG 1), health and well-being through reduced pollution (SDG 3), access to clean water and sanitation (SDG 6), the environmental impact of urban sprawl (SDG 11) and climate change (SDG 13).

The EU biodiversity strategy to 2020 calls for restoring at least 15 % of degraded ecosystems in the EU and to expand the use of green infrastructure, e.g. to help overcome land fragmentation. The UN Resolution on Soil Pollution (UNEP, 2017) requests countries to set norms and standards to prevent, reduce and manage soil pollution.

Although specific soil protection legislation is not in place in the EU, the 2006 soil thematic strategy promotes the inclusion of soil protection measures in various policy areas.

According to a study by Frelih-Larsen et al. (2017), 671 policy instruments related to soil protection exist in the 28 EU Member States (EU-28), and 45 % of them are linked to EU policies. For example, the National Emission Ceilings Directive aims to reduce the impact of emissions of acidifying substances (Chapter 8); the Industrial Emissions Directive seeks to prevent emissions from entering the soil (Chapter 12); several directives target avoiding soil contamination from waste disposal and chemicals (Chapters 9 and 10); and the Water

Framework Directive seeks to identify and estimate water pollution originating from soils (Chapter 4). Nevertheless, binding instruments and targets are mostly lacking, and not all soil threats and soil functions are covered.

5.3 Key trends and outlooks

5.3.1 Land cover change

Land use modifies the quality and quantity of ecosystem services (EEA, 2018c) by conditioning the potential of land and soil to provide these services. Unsustainable agricultural and forestry practices, urban expansion and climate change are the main drivers of land degradation, which according to the recent Intergovernmental Science-Policy Platform on Biodiversity and Ecosystem Services (IPBES) report (Scholes et al., 2018) have already resulted in loss of ecosystem services in many parts of the world. Accounting for the changes in land stocks, and for the processes driving these changes, may shed light on some pressures on Europe's land use (see the interactive land accounts viewer ([1])) that are impacting ecosystem services and our natural capital.

The 2018 mapping of Europe's land cover by the Copernicus Land Monitoring Service, recorded in the Corine Land Cover ([2]) data sets, indicates that the proportion of Europe's main land cover types are relatively stable (e.g. 25.1 % arable land and permanent crops, 16.6 % pastures, 34.4 % forests in the EEA's member countries and cooperating countries). The long-term changes over the period 2000-2018 show that the area of artificial surfaces has changed the most, increasing by 7.1 % (Figure 5.1). Although the latest period, 2012-2018, had the lowest increase, during the entire period 2000-2018, 921 km²/year of land was turned into artificial surfaces.

7.1 %

increase in the area of artificial surfaces between 2000 and 2018.

While the areas of arable land and permanent crops became smaller during the period 2000-2018 (by 0.5 %, 402 km²/year), in 2012-2018 there was no significant change in their extents. Firstly, the sprawl of economic and commercial sites decreased substantially in several countries (-91 % in Spain, -45 % in Germany, -35 % in France). Secondly, withdrawal from farming activities decreased (-87 % in Hungary) and so did the conversion from arable land into non-tilled agricultural land (-97 % in Germany, -93 % in Czechia, -79 % in Hungary). The small decrease in pastures and mosaic farmland mainly arose from a few countries, such as in Ireland as a result of afforestation and in France, Germany and Spain as a result of sprawl of urban and industrial areas. The loss of wetlands amounted to around 1 % over the last two decades. During 2012-2018 the most prominent decline was observed in Romania and Finland due to conversion to agriculture, to a lesser extent in the United Kingdom due to conversion to industrial sites and in Ireland due to afforestation. Forests and transitional woodlands (less than 0.1 % change) and natural grassland (less than 0.3 % change) had most stable land cover extents in Europe between 2000 and 2018.

5.3.2 Urban expansion and land use change

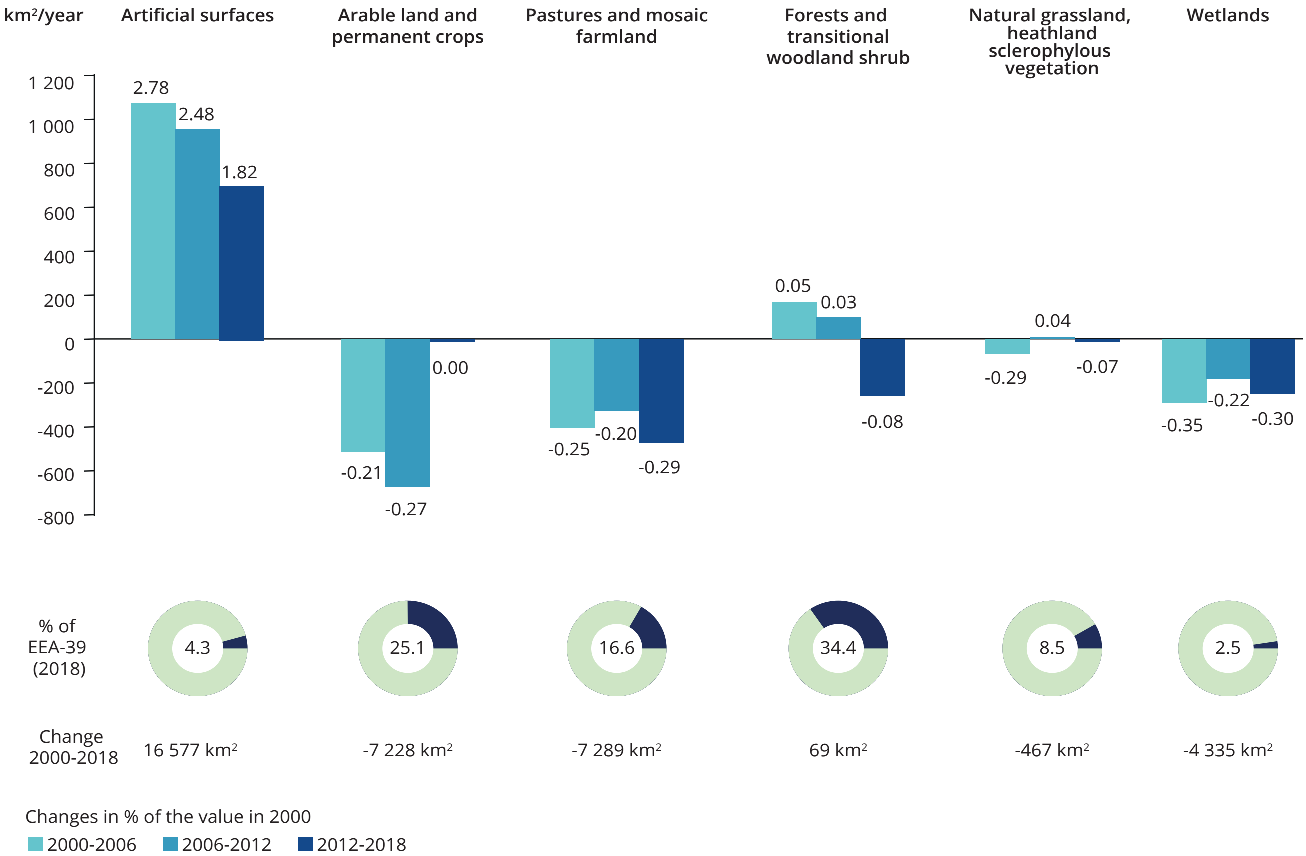
Seventy-two per cent of Europe's population lives in cities, towns and suburbs (Dijkstra et al., 2016). Urban agglomerations in the EU are expected to grow by 11 % (corresponding to 34 million people) by 2050 (Kompil et al., 2015), and artificial surfaces are predicted to increase by 0.71 % by 2050, leading to increasing land take and fragmentation (Lavalle and Barbosa, 2015; Lavalle and Vallecillo, 2015). Urban expansion is accompanied by a greater need for infrastructure (transport, water, waste and electricity), which decreases the long-term availability of productive land resources. Loss of fertile land caused by urban development decreases the potential of land to produce bio-based materials and fuels to support a low-carbon bioeconomy.

Land take

Land take is the process in which urban areas and sealed surfaces occupy agricultural, forest or other semi-natural and natural areas (EEA, 2017). The increase in artificial surfaces often impairs or disrupts valuable ecological functions of soils such as biomass provision, acting as soil biodiversity and a soil carbon pool, or water infiltration potential. This contributes to negative climate change

(1) https://www.eea.europa.eu/data-and-maps/dashboards/land-cover-and-change-statistics
(2) https://land.copernicus.eu/pan-european/corine-land-cover

FIGURE 5.1 **Change in six major land cover types in the EEA-39 during the period 2000-2018**



Note: Open spaces and water bodies are not shown, which is why the percentages do not add up to 100 %.

Source: EEA.

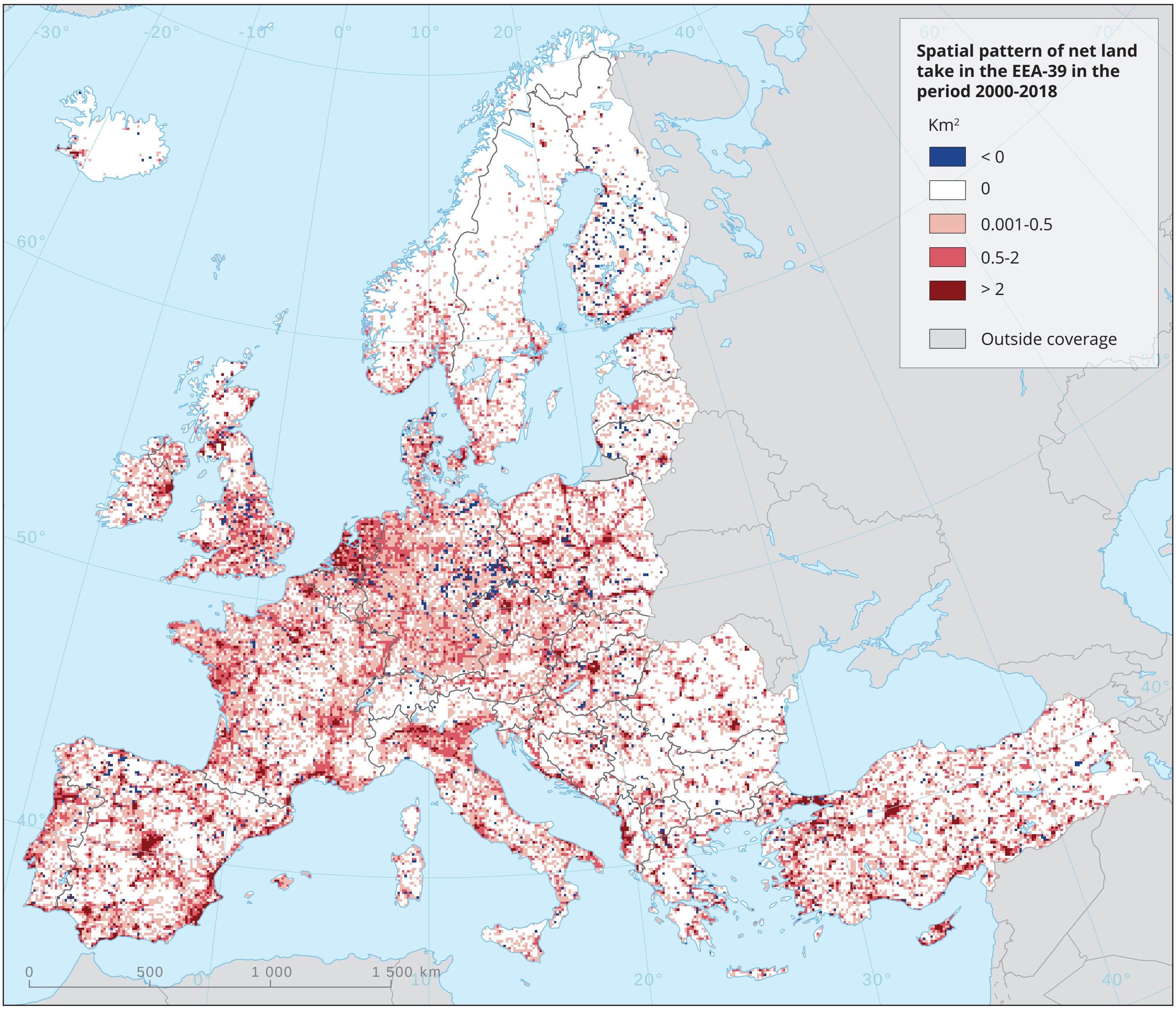
impacts by decreasing the potential for carbon storage and sequestration or increasing surface run-off during flooding (EC, 2014; Edenhofer et al., 2011).

Population and income growth have been widely reported to drive land take (Chapter 1), yet this relationship varies greatly across and within countries. In most developed countries, the demand for urbanised land grows faster than the population, or grows even without additional population, for example in Switzerland, the eastern part of Germany or the south of France (Colsaet et al., 2018). In some cases, artificial land is returned to other land categories (recultivation). The balance between taken and recultivated land is net land take — the concept behind the EU's 'no net land take' target (Map 5.1).

Calculated from the Corine Land Cover data set, annual net land take (see definition in EEA (forthcoming (a))) in the EU-28 continually decreased from 922 km²/year in the period 2000-2006 to 440 km²/year in the period 2012-2018 (see the interactive Land take data viewer ([3])). During the period 2000-2018, land take concentrated around larger urban agglomerations (Map 5.1), with 80 % of land taken at the expense of arable land and permanent crops (50 %) and of pastures and mosaic farmlands (almost 30 %). Nevertheless, while in that period some land was recultivated in the EU-28, 11 times

([3]) https://www.eea.europa.eu/data-and-maps/dashboards/land-take-and-net-land

MAP 5.1 **Spatial pattern of net land take in the EEA-39 in the period 2000-2018**



Source: EEA.

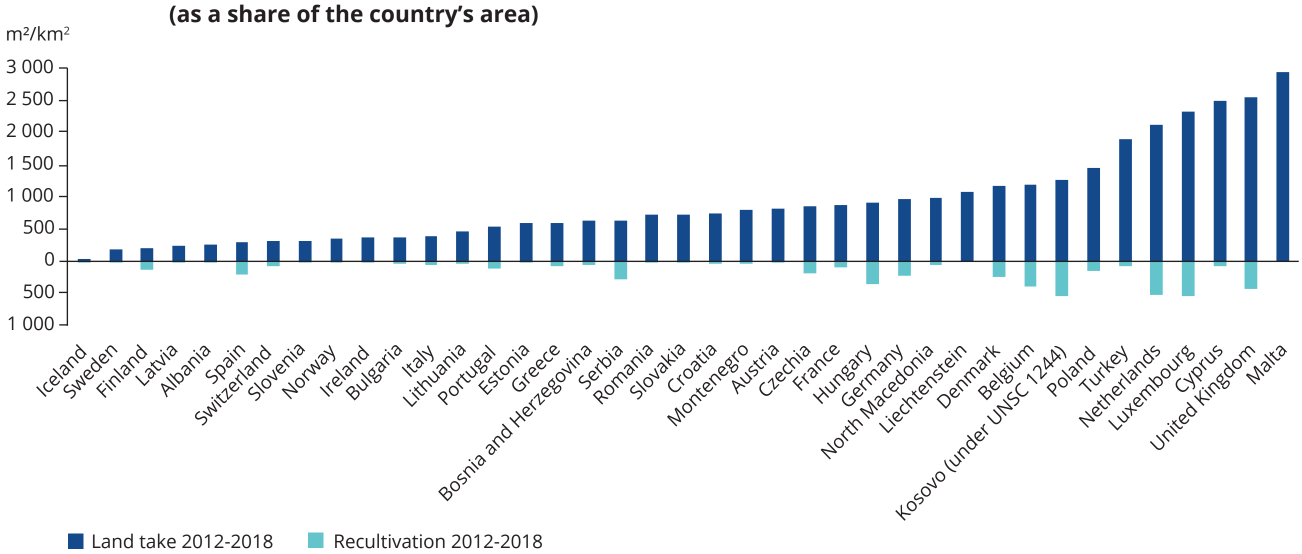
more land was taken (14 049 km² land take vs 1 269 km² recultivated land). Within functional urban areas (cities and their commuting zones) land recycling, the reuse of abandoned, vacant or underused urban land, is measured using the Copernicus Urban Atlas ([4]) data set. Land recycling is still low in most countries (see the Land recycling data viewer ([5]) — only 13 % of urban land development addressed the reuse of land in the period 2006-2012 (EEA, 2018b).

Loss of fertile land to urban development reduces the potential to produce bio-based materials and fuels to support a low-carbon bioeconomy.

Figure 5.2 presents land take in the EEA-39 during the period 2012-2018, as the share of the country's area, which allows comparison of countries of

([4]) https://land.copernicus.eu/local/urban-atlas
([5]) https://www.eea.europa.eu/data-and-maps/dashboards/land-recycling

FIGURE 5.2 **Country comparison — land take and land recultivation in the EEA-39 in the period 2012-2018 (as a share of the country's area)**



Note: Kosovo under United Nations Security Council Resolution 1244/99.

Source: EEA.

different sizes. Land take was highest in Malta, the United Kingdom, Cyprus, Luxembourg and the Netherlands. The large proportion of land take in Malta was mainly due to mining and urban sprawl. In the United Kingdom, Cyprus and Luxembourg, the main drivers were industrial and commercial activities and construction sites, the latter being the main reason in the Netherlands as well. Whereas in Malta there was no recultivation, and in Cyprus there was very little, in the Netherlands, Luxembourg and the United Kingdom, together with Kosovo ([6]), recultivation was the highest in the EEA-39 (see the interactive Land take data viewer ([7])).

A 2.6 % increase in land fragmentation occurred in the EEA-39 territory between 2012 and 2015, compared to a 6.2 % increase in the period 2009-2012.

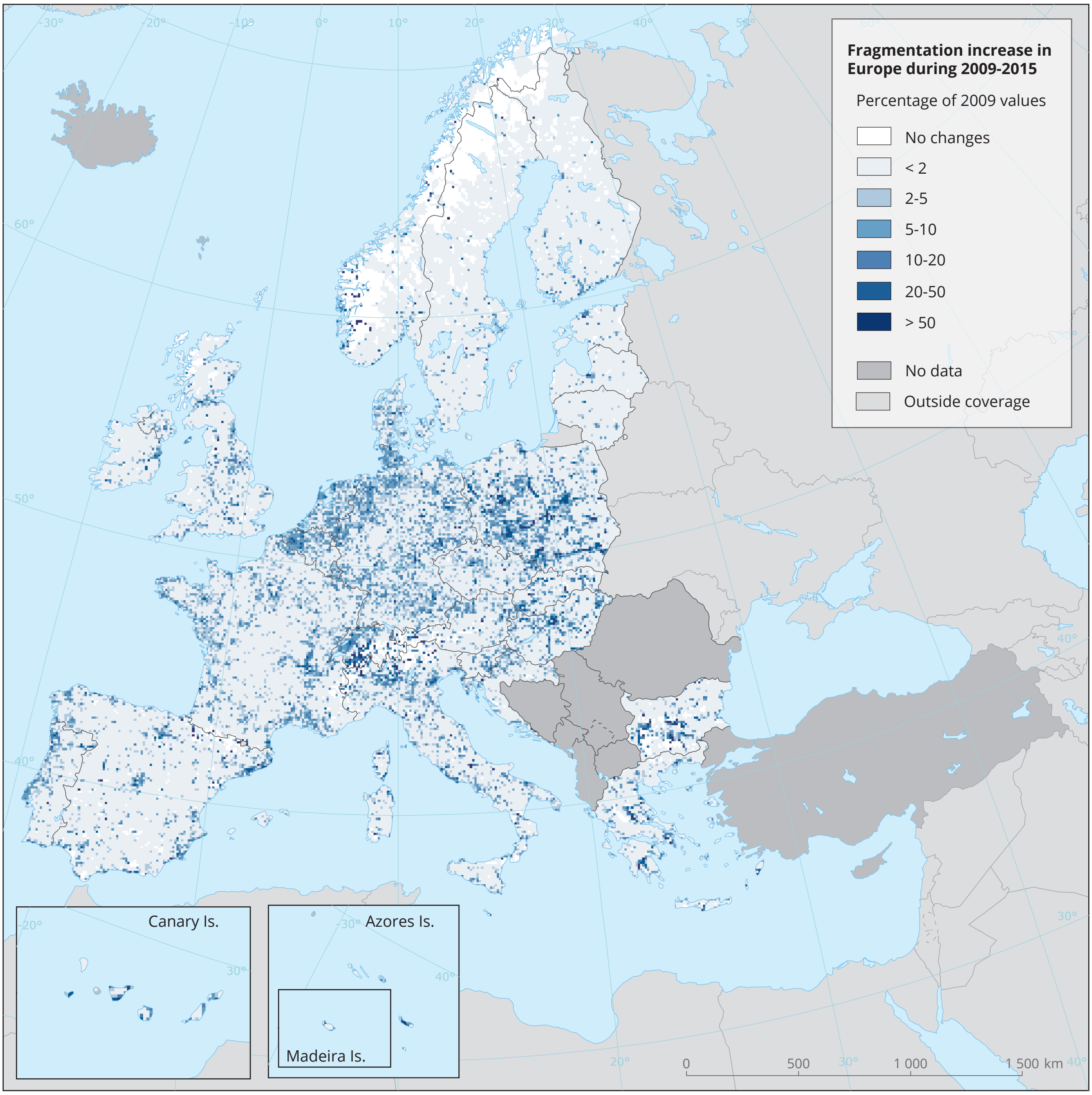
Landscape fragmentation

The expansion of urban areas and transport networks transforms large habitat patches into smaller, more isolated fragments, leading to habitat fragmentation. Fragmentation often jeopardises the provision of many ecosystem services and affects the stability and resilience of habitats. Although the EU biodiversity strategy to 2020 has a target to 'restore at least 15 % of degraded ecosystems in the Union and to expand the use of Green Infrastructure', there are only a few signs that pressure of land fragmentation has reached its peak.

Landscape fragmentation can be measured as the number of continuous, unfragmented areas (i.e. meshes) per 1 000 km² (Moser et al., 2007; EEA, 2018d). It increased by 6.2 % in the EEA-39 territory ([8]) between 2009 and 2012 but slowed down to a 2.6 % increase in the period 2012-2015 (EEA, forthcoming (b)). Compared with 2009, in 2015 the most rapid increase in fragmentation was observed in Poland (18 %) due to construction of motorways. Bulgaria, Greece and Hungary also showed rapid increases in fragmentation pressure (around 14 %). In absolute terms, indicating the highest density of meshes per 1 000 km², Switzerland and the Benelux states became the most fragmented in Europe (Map 5.2). In both measurement periods, mostly uninhabited areas and dispersed rural areas became more fragmented (more than a 5 % increase); these are areas with a relatively higher potential to

([6]) Under United Nations Security Council Resolution 1244/99.
([7]) https://www.eea.europa.eu/data-and-maps/dashboards/land-take-and-net-land
([8]) Excluding Albania, Bosnia and Herzegovina, Cyprus, Iceland, Kosovo, North Macedonia, Romania, Serbia and Turkey because of poor data coverage for transport infrastructure elements for this period.

MAP 5.2 **Increase in landscape fragmentation in Europe between 2009 and 2015**



Note: Landscape fragmentation as a result of an expansion in urban and transport infrastructure is monitored using the Copernicus Imperviousness ([9]) and the TomTom Multinet EUR (reference years: 2009, 2012, 2015) road network data sets ([10]). Data for Albania, Bosnia and Herzegovina, Cyprus, Iceland, Kosovo, North Macedonia, Romania, Serbia and Turkey are not available.

Source: EEA.

([9]) Under United Nations Security Council Resolution 1244/99.

([10]) Excluding Albania, Bosnia and Herzegovina, Cyprus, Iceland, Kosovo, North Macedonia, Romania, Serbia and Turkey because of poor data coverage for transport infrastructure elements for this period provide ecosystem services because of their lower degrees of urbanisation.

Fragmentation within Natura 2000 sites increased by 5.9 % in the period 2009-2012 and slowed down to a 1.6 % increase in the period 2012-2015 (EEA, forthcoming (b)). Urban and road infrastructure expansion may occur in Natura 2000 sites — depending on, if necessary, an assessment of their impacts in accordance with Article 6 of the EU Habitats Directive. This explains why fragmentation pressure was observed in the sites despite their protected status. Nevertheless, in all EU-28 countries, the increase in fragmentation was lower within Natura 2000 sites than in areas not protected by the EU nature directives.

5.3.3 Land use by agriculture and forestry

►*See Table 5.2*

Sectoral trends (Chapter 13) and high societal demand for agriculture and forestry outputs lead to pressures on land and soil. This has a range of negative environmental impacts, such as loss of biodiversity (Chapter 3), eutrophication pressures in freshwater ecosystems (Chapter 4) or air pollution (Chapter 8). Loss of arable land due to, for example, land abandonment in many cases causes loss of habitats for farmland species (Chapter 3). At the same time droughts, forest fires and floods are increasing threats, in particular in southern Europe. Sustainable management of our land and soil resources helps to maintain agricultural and forest productivity (e.g. Brady et al., 2015) while improving the potential of land and soils as a carbon sink, supporting biodiversity and storing and filtering water and nutrients.

Urban land take continues, consuming mostly agricultural land. There is however a slowing trend in urbanisation and the expansion of transport infrastructure.

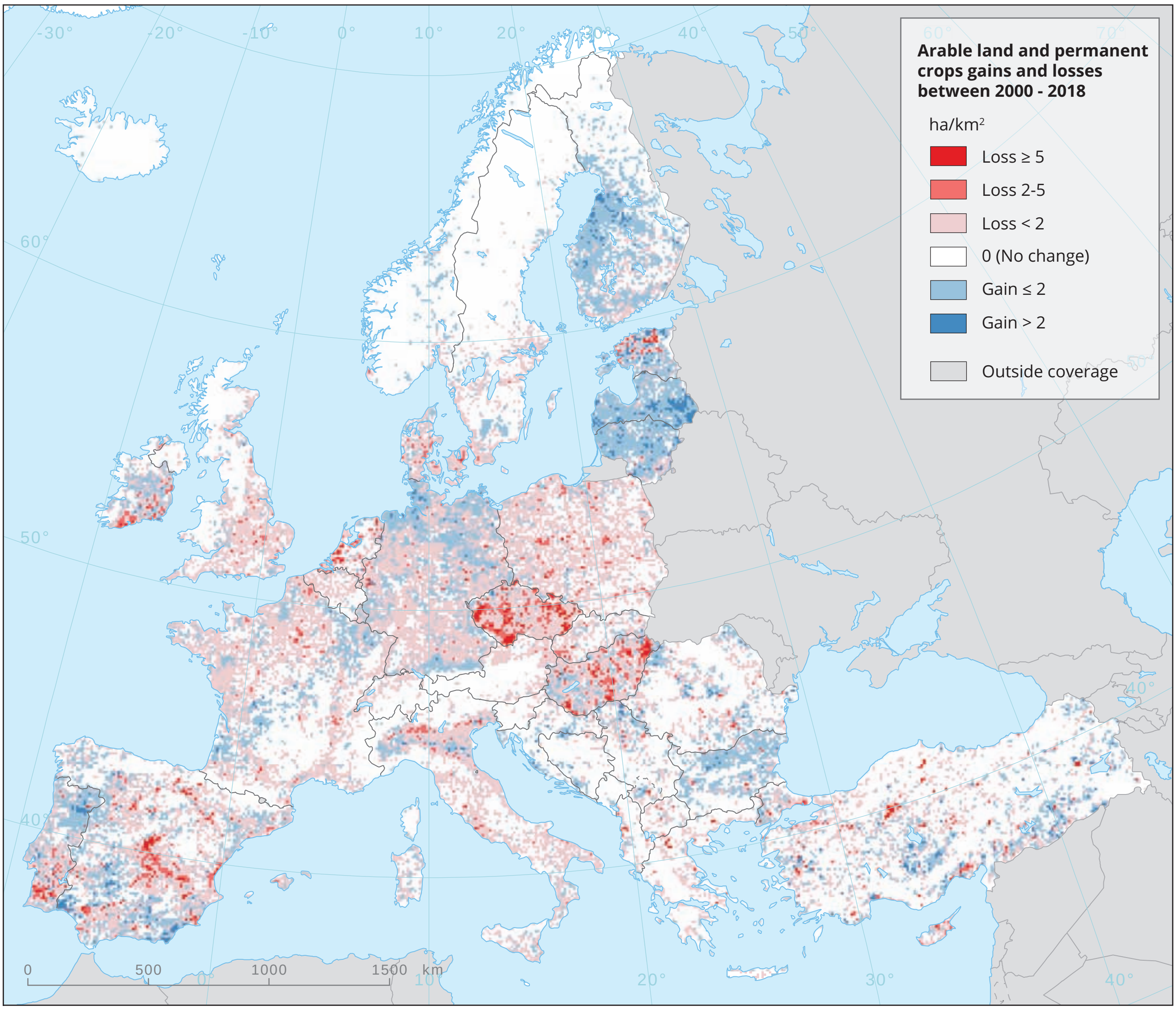
According to the Copernicus Corine Land Cover data sets ([11]), during the period 2000-2018, the largest losses of arable land and permanent crops were observed in Czechia, Hungary, the interior of Spain and southern Portugal (Map 5.3). While in Hungary and Portugal the main reason was withdrawal of farming and subsequent woodland creation, in Czechia the main driver was the extension of non-tilled agricultural land and pastures (see the interactive Land accounts viewer ([12])). In central Spain, the increase in construction and industrial sites was the main cause. The largest gains were observed in northern Portugal, the Baltic countries (in particular Latvia) and central Finland. While in Latvia and Lithuania arable land was created by converting pastures, in central Finland the gains were due to forest conversion.

Grasslands provide important ecosystem services, such as food provision, enjoyment of landscapes, storage of soil carbon, erosion control and flood regulation. They are among the most species-rich vegetation types in Europe with up to 80 plant species/m^2 (Silva et al., 2008). Grasslands are generally lost when extensive livestock farming is given up because of land abandonment or through conversion to cropland or increased fertilisation and mowing frequencies. The decline in grassland areas has negative consequences for pollinators and other insects as well as for birds (Assandri et al., 2019) (Chapter 3). Semi-natural grasslands are a core component of high nature value farmland in Europe, representing around 30 % of the EU's agricultural land (Paracchini et al., 2008). High nature value farmland exemplifies the pressures on agro-ecosystems from agricultural intensification as well as land abandonment (e.g. Henle et al., 2008; Renwick et al., 2013).

The forested area in Europe has been largely stable over the last two decades, and it only expanded because of afforestation programmes in some European countries and through spontaneous regeneration on abandoned agricultural land. Changes in forest land cover are now locally concentrated in a few European countries (Forest Europe, 2015). Despite the stable area and sustainable use of timber resources, forest ecosystems are subject to pressures (Section 13.4.2 in Chapter 13) and changes in their condition, which raises concern over their long-term stability and health (EEA, 2016, 2018a). Although the area of protected forests has slightly increased in the EEA-39 (EEA, 2019), the fragmentation of forests increased by 8 % between 2009 and 2015 (EEA, forthcoming (b)). In eastern and southern Europe (Bulgaria, Croatia, Greece, Hungary, and Poland), the increase in fragmentation of forests and woodlands was more than 15 %, and illegal logging is increasingly reported (e.g. in the Carpathian region).

([11]) https://land.copernicus.eu/pan-european/corine-land-cover
([12]) https://www.eea.europa.eu/data-and-maps/dashboards/land-cover-and-change-statistics

MAP 5.3 **Arable land and permanent crop losses and gains during the period 2000-2018**



Source: EEA.

TABLE 5.2 Summary assessment — urbanisation and land use by agriculture and forestry

Past trends and outlook		
Past trends (10-15 years)		Europe's land resources are exposed to intensive use at an accelerated rate. Land take continues, mostly at the expense of agricultural areas, although the yearly rate shows a tendency to slow down. The rate of reuse of developed land remains low. Landscape fragmentation has increased, impacting mostly uninhabited or dispersed rural areas and suburbs — areas with relatively greater potential to supply ecosystem services.
Outlook to 2030		Land take and resulting landscape fragmentation are projected to increase in forthcoming decades. Farming is likely to retreat further from marginal, biodiversity-rich areas and the intensive use of productive farmland is likely to increase, impacting the quality and ecosystem services of agricultural areas. Logging and consumption of wood for fuel will increase, which, together with increasing droughts, fires and storms, is expected to reduce forest ecosystem services.
Prospects of meeting policy objectives/targets		
2050	☒	Europe is at risk of not meeting the 7th EAP objective of managing land sustainably and reaching no net land take by 2050. However, slowing trends in the expansion of urban and transport infrastructure areas indicate that, if appropriate measures are taken, the targets could be reached. The increase in landscape fragmentation is lower within and in the areas surrounding Natura 2000 sites, hence protection policies seem to be effective in partially reaching the target set by the EU biodiversity strategy to 2020 to restore 15 % of degraded ecosystems.
Robustness		Data are based on regular and quantitative inventories of the Copernicus Corine Land Cover, Urban Atlas and Imperviousness data sets, using medium- and high-resolution remote sensing images. Interpretation and calibration are harmonised and quality assured and controlled by third party experts. While data quality is subject to sensor performance and weather impacts, and derived data still depend on human interpretation, remote sensing is the only tool that offers standardised and repeatable measurements on high spatial and temporal resolutions, at a large spatial scale and with continental to global coverage. The assessment of the outlook for and prospects of meeting policy objectives relies on models and on expert judgement.

Forest Europe (2015) reports that about 8 % of the forest area is intensively managed plantations. Intensive management operations involve clear-cutting, skidding damage to remaining trees and soil compaction. A study by Schelhass et al. (2018) underlines that little is known about harvesting processes in European forests. The current fellings/growth ratio is approximately 60-65 % of the annual forest increment harvested. Recent analysis of the wood resource balance (Camia et al., 2018) shows that this ratio is expected to be about 12 % larger as a result of underestimation of reported removals.

> Competition for land, unsustainable practices and pollution affect soil quality.

The climate targets of the Paris Agreement and the incentives offered under new EU policies, e.g. land-based carbon accounting (land use, land use change and forestry, LULUCF) will influence forest management. Energy policies already result in an increased demand for wood products and for bioenergy (Levers et al., 2014; Pricewaterhouse Coopers EU, 2017). As a consequence, the land used for intensively managed forests may increase to maximise the provision of biomass either from Europe's forests or by importing more biomass (e.g. wood pellets from North America).

Climate change, as well as economic and technological change, will continue to drive change in agricultural land management in the coming decades. Agricultural productivity in southern Europe will be particularly affected, and this is likely to involve a further retreat of farming from marginal but often biodiversity-rich areas as well as intensive use of productive farmland in central, western and northern Europe (Holman et al., 2017; Stürck et al., 2018). Europe's forests overall maintain their function as a carbon sink, but degradation of forest ecosystems may increase the risks of eroding the biodiversity and ecological condition of forests and of forest soils due to compaction, loss of nutrients and loss of forest soils (Bengtsson et al., 2000; Frelich et al., 2018). The sustainable management of ecosystems and soils under agricultural and forestry land use will continue to be an important challenge for conserving and enhancing Europe's natural capital.

5.3.4 Soil condition

► *See Table 5.4*

Pressures on European soils are increasing, and there is a risk that they will affect the services provided by properly functioning, healthy soils. Soil is a finite, non-renewable resource because its regeneration takes longer than a human lifetime. It is a key component of Europe's natural capital, and it contributes to basic human needs by supporting, for example, food provision and water purification, while acting as a major store for organic carbon and a habitat for extremely diverse biological communities. 'Soil formation and protection' is one of the ecosystem services known to be declining in Europe, according to the recent IPBES assessment (IPBES, 2018).

Soils are threatened by increasing competition for land, unsustainable practices and inputs of pollutants, causing their degradation in various forms. Exposure to chemicals (mineral fertilisers, plant protection products, industrial emissions), tillage and compaction, as well as soil loss through sealing from urban expansion, erosion and landslides, degrade soils physically, chemically and biologically.

Physical degradation of soils

Soil sealing causes the complete and irreversible loss of all soil functions. Urban expansion and infrastructure consume soils by physical removal or covering them with impermeable (impervious) artificial material (e.g. asphalt and concrete), though only part of the land that is defined as land take is actually sealed.

85 861 km^2

of land in the EEA-39 territory was sealed in 2015.

In 2015, 1.48 % of the total EEA-39 area was sealed (2.43 % of the EU-28 in 2012), totalling 85 861 km^2. The annual rate of soil sealing seems to have decreased since 2012 (annual sealing rate for the monitoring interval 2006-2009: 460 km^2; 2009-2012: 492 km^2; 2012-2015: 334 km^2). In certain densely populated countries with dense infrastructure, such as Belgium and the Netherlands, almost 4 % of the national territory is sealed.

Erosion describes the loss of soil by water (predominantly as rill or gully erosion) and by wind and harvest losses (i.e. soil adhering to harvested crops such as sugar beet and potato). Apart from the loss of productivity and soil function, erosion of agricultural soils is also critical because of their proximity to surface waters, leading to the transfer of soil material and pollutants into water systems (e.g. 55 % of soils in Switzerland have a connection to water bodies, (BAFU, 2017)).

Panagos et al. (2015) estimated the mean soil erosion rate by water to be about 2.46 t/ha per year in the EU (which is 1.6 times higher than the average rate of soil formation). Accordingly, 12.7 % of Europe's land area is affected by moderate to high erosion (soil loss rates > 5 t/ha per year). The total soil loss due to water erosion is estimated at 970 million tonnes per year (Panagos et al., 2016). The average annual soil loss by wind erosion is estimated to be about 0.53 t/ha per year (EU-28 arable land, 2001-2010; (Borrelli et al., 2017). Crop harvesting contributes to significant soil removal. Panagos et al. (2019) estimate that 4.2 million hectares of root crops (of 173 million hectares of utilised agricultural land in the EU) contribute to 14.7 million tonnes of soil loss. Although there is a declining trend due to a decrease in sugar beet cropping, crop harvesting practices may increase the overall soil loss rate in countries such as Belgium, Ireland and the Netherlands.

The annual cost of agricultural production (losses in crop yield) due to severe erosion in the EU is estimated to be EUR 1.25 billion (Panagos et al., 2018). Existing policy, in particular the cross-compliance requirements of the common agricultural policy (Chapter 13), may have reduced rates of soil loss over the past decade (Panagos et al., 2015). However, erosion rates can be expected to increase in the future as a result of more extreme rain events (Panagos et al., 2017), but sectoral changes, such as increased parcel size, heavier machinery and increased compaction, also play a role. Maintaining and/or increasing landscape features may reduce the risk of soil erosion.

Soil compaction is the result of mechanical stress caused by the passage of agricultural machinery and livestock. The consequences are increased soil density, a degradation of soil structure and reduced porosity (especially macroporosity). This causes increased resistance against root penetration and also negatively affects soil organisms, as their presence is restricted to sufficiently sized pores (Schjønning et al., 2015). Compaction is known to be a significant pre-cursor of erosion. Soil compaction may lower crop yields by 2.5-15 %, but it also contributes to waterlogging during precipitation events, which not only reduces the accessibility of fields to machinery but also negatively affects run-off, discharge rate and flooding events (Brus and van den Akker, 2018).

About 23 % of soils in the EU-28 are estimated to have critically high densities in their subsoils, indicating compaction (Schjønning et al., 2015). About 43 % of subsoils in the Netherlands exhibit compaction (Brus and van den Akker, 2018). Climate change (higher precipitation during the cold seasons), heavier machinery and increasingly narrow time windows for field operations are all factors that could increase the compaction hazard in the future. Although some countries have guidelines on access to land when the soil is wet, currently there is no European-level instrument to protect soils from severe compaction.

Chemical degradation of soils under intensive land use

Soils, with the help of various organisms, filter and buffer contaminants in the environment. Industrial activities, waste disposal and intensive land management have led to the dispersal of contaminants throughout the environment and eventually to their accumulation in soils. Sources of contaminants include the residues of plant protection products, industrial emissions, mineral fertilisers, biosolids (some composts, manures and sewage sludges), wood preservatives and pharmaceutical products.

Soil contamination can be diffuse and widespread or intense and localised (contaminated sites). Contaminants include heavy metals, persistent organic pollutants, residues of plant protection products and others. Depending on soil properties and their concentrations, contaminants in soil may enter the food chain, threaten human health and be toxic to soil-dwelling organisms (FAO and ITPS, 2017). Substances that are not readily degradable will eventually leach into surface and groundwaters or be dispersed by wind erosion (Silva et al., 2018).

There may be as many as 2.8 million contaminated sites in the EU, but only 24 % of the sites are inventoried.

According to Payá Pérez and Rodríguez Eugenio (2018), the dominating activities for contamination at local level are municipal and industrial waste sites (37 %) together with industrial emissions and leakages (33 %). In the EU-28, potentially polluting activities took place on an estimated 2.8 million sites (but only 24 % of the sites are inventoried). Currently, only 28 % of the registered sites are investigated, a pre-requisite to deciding whether remediation is needed or not (Payá Pérez and Rodríguez Eugenio, 2018). Considering the estimated extent of past and current pollution, and the uncertainties of reliable estimates, little progress has been made in the assessment and management of contaminated sites.

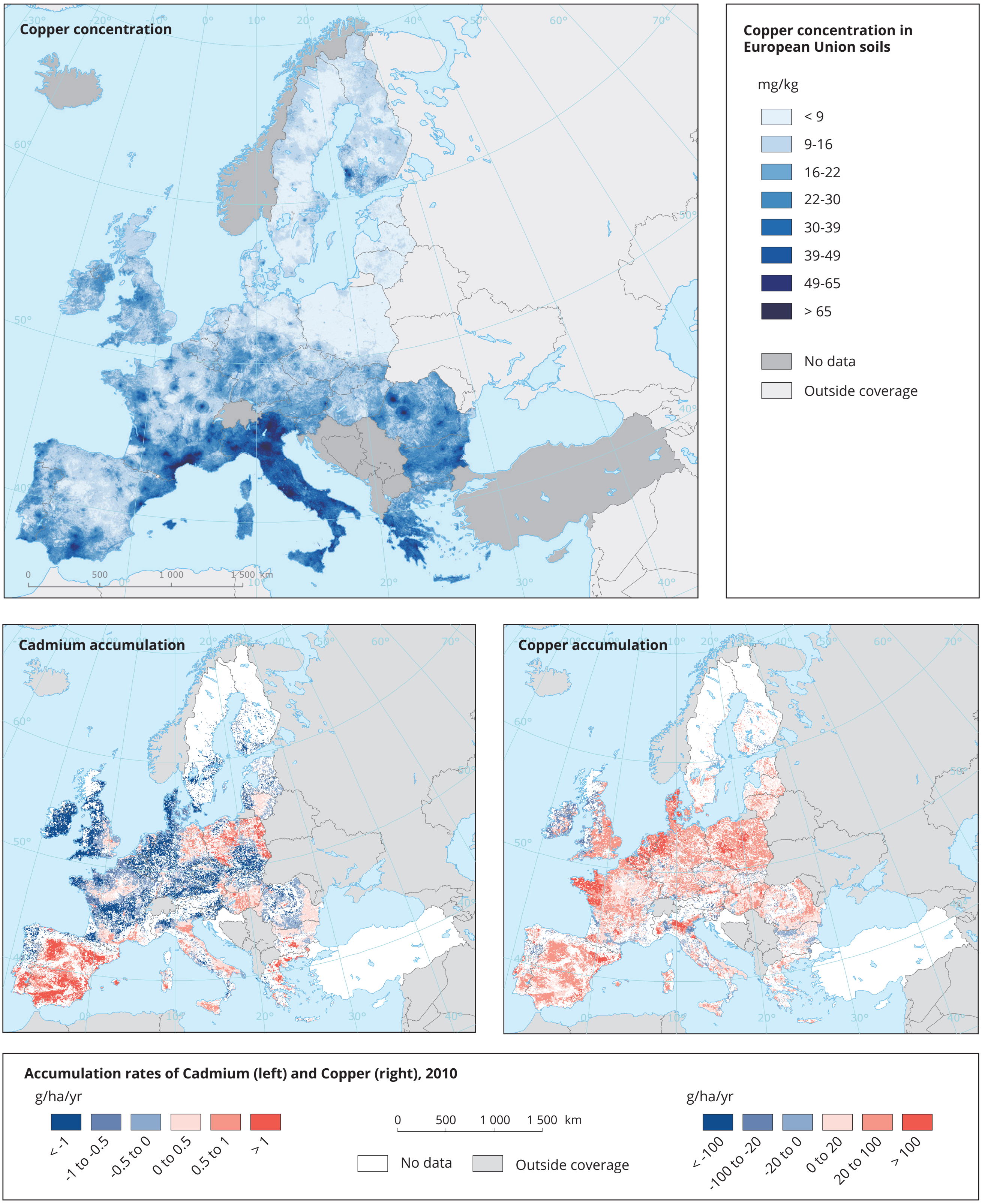
While diffuse contamination through large-scale atmospheric deposition is decreasing (lead by 87 % and mercury by 40 % since 1990, using concentrations in mosses as indicators (BAFU, 2017)), some metals such as cadmium and copper are accumulating in arable soils (Map 5.4). Once critical thresholds are exceeded, human health and ecosystem functioning is impacted, for example by the release of substances to groundwater (De Vries et al., 2007).

Cadmium — mainly originating from mineral phosphorus fertilisers — accumulates in 45 % of agricultural soils, mainly in southern Europe where leaching rates are low due to a low precipitation surplus (Map 5.4). In 21 % of agricultural soils, the cadmium concentration in the topsoil exceeds the limit for groundwater, 1.0 mg/m^3 (used for drinking water). Soils therefore need accurate monitoring of the fate of accumulating heavy metals in the seepage pathway through the soil to the groundwater.

While copper is an essential micronutrient, excess levels in soils are a source of concern. Copper has been widely used as a fungicide spray, especially in vineyards and orchards. Results from the Land Use and Coverage Area Frame Survey (LUCAS) soil sampling 2009-2012 show elevated copper levels in the soils in the olive and wine-producing regions of the Mediterranean (Map 5.4) (Ballabio et al., 2018). Animal manure is the largest source of copper in grassland, which together with zinc is added to animal feed and is introduced into the environment through manure spreading (De Vries et al., forthcoming).

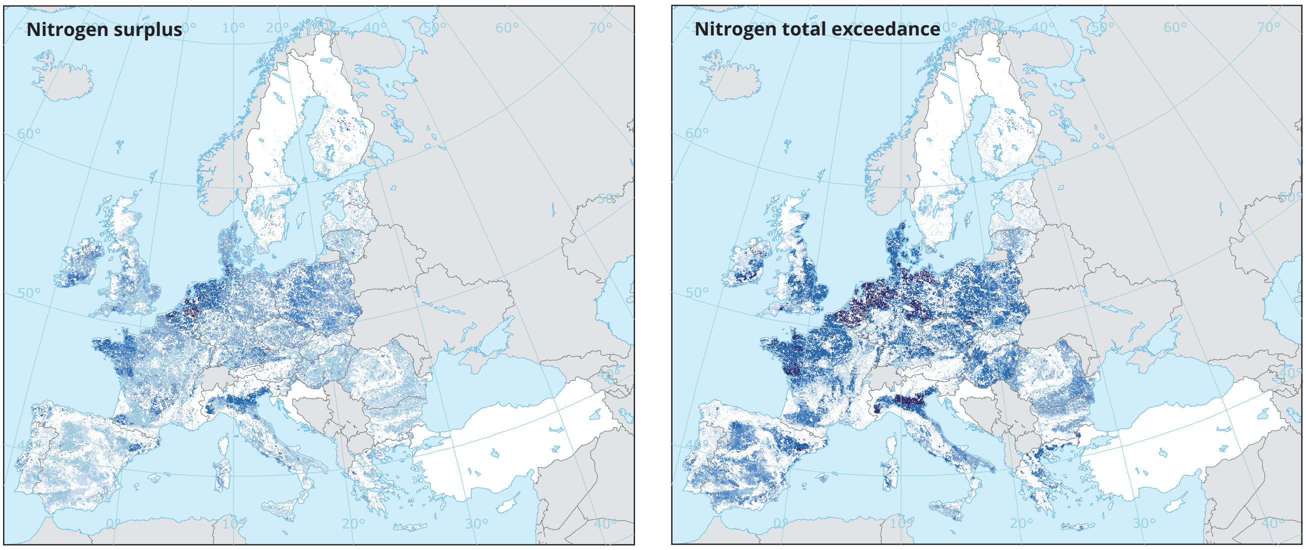
There is also increasing concern about the residence and accumulation of pesticide residues and their metabolites in soils (e.g. glyphosate and AMPA, or aminomethylphosphonic acid), and their potential release mechanisms, for example due to acidification and wind erosion (Silva et al., 2018). In the case of the Netherlands, in one third of the groundwater abstractions, pesticide concentrations can be found that exceed 75 % of the pesticide standards. Two thirds of the substances found are herbicides (Swartjes et al., 2016). In Finnish agricultural soils, 43 % of the samples contained pesticides, while quality standards were exceeded in 15 % of the groundwater bodies studied (Juvonen et al., 2017). In a pilot study with LUCAS soil samples, over 80 % of soils tested contained pesticide residues, with 58 % of samples containing mixtures of

MAP 5.4 Copper concentration in EU soils, and accumulation rates of cadmium and copper



Sources: Ballabio et al. (2018) (top); De Vries et al. (forthcoming) (lower left and lower right).

MAP 5.5 **Calculated nitrogen surplus (inputs vs outputs) (left) and exceedances of critical nitrogen inputs to agricultural land in view of adverse impacts on the environment (right)**



Nitrogen surplus and exceedances of critical nitrogen inputs to agricultural land in view of adverse impacts on water quality

kg/ha/year: < 25; 25 to 50; 50 to 75; 75 to 100; 100 to 200; > 200

0 500 1 000 1 500 km

No data; Outside coverage

kg/ha/year: < 0; 0 to 25; 25 to 50; 50 to 75; 75 to 150; > 150

Note: Statistical data refer to 2010 inputs; areas shown in white are non-agricultural soils.

Source: De Vries et al. (forthcoming).

Various soil contamination thresholds are already exceeded.

two or more residues in a total of 166 different pesticide combinations (Silva et al., 2019). These results indicate the accumulative effects of pollutants, and that mixtures of pesticide residues in soils are the rule rather than the exception.

In conclusion, contamination of soils is widespread, and various thresholds are already exceeded (e.g. cadmium), indicating that the filtering capacity of soils has been exceeded in some areas. However, the additive effects are still unknown for many substances in soils. In future attention needs to be paid to monitoring and investigating the effects of emerging contaminants such as microplastics, endocrine disruptors, antibiotics and flame retardants. Another source of concern is excessive nutrient inputs to soils through fertilisers, which leads to acidification and eutrophication (Chapter 1, Box 1.2 and Chapter 13). Europe is a global nitrogen hotspot with high nitrogen export through rivers to coastal waters, and 10 % of the global nitrous oxide (N_2O) emissions (Van Grinsven et al., 2013). Exceedance of critical loads for nitrogen is linked to reduced plant species richness in a broad range of European ecosystems (Dise, 2011) (see also Chapter 8, Box 8.2, for critical loads). For approximately 65-75 % of the EU-27 agricultural soils, nitrogen inputs

TABLE 5.3 Soil organic carbon by land use category in the period 2009-2015

Land use category	Number of samples	Mean SOC (g/kg)	
		2009	2015
Permanent grassland	2 230	42.0	43.8
Long-term cultivated land	5 018	17.9	17.3
Rice	5	22.8	19.2
Permanent crops	704	15.6	16.4
Natural vegetation	4 167	91.7	90.4
Wetlands	23	432.6	456.5

Source: Hiederer (2018).

through fertiliser, manure, biosolids and nitrogen-fixing crops exceed critical values beyond which eutrophication can be expected (e.g. critical ammonia, or NH_3, emissions to remain below critical loads, or 2.5 mg N/l in run-off to surface waters) (Map 5.5). On average across Europe, about a 40 % reduction in nitrogen inputs would be needed to prevent this exceedance (De Vries et al., forthcoming). Map 5.5 (left) presents the nitrogen surplus, being the difference between nitrogen inputs and uptake by plants, which is a measure of the potential pollution of air and water (De Vries et al., forthcoming).

Biological degradation and the decline in soil organic matter

Soils deliver key ecosystem services such as nutrient provision, water purification, filtering of pollutants and a habitat for soil organisms. Non-degraded soils provide these functions simultaneously and to a level needed for ecosystem performance (Chapter 3). Two closely connected indicators are the basis of soil multifunctionality, the soil organic carbon (SOC) pool and soil biodiversity. Carbon is one of the primary sources of energy in food webs; losses of carbon

The increased intensity of land use has negatively affected the species richness of earthworms, springtails and mites across Europe.

(through erosion, climate change, drainage of otherwise waterlogged soils) impact the supply of ecosystem services and reduce biodiversity (Stolte et al., 2016). Biologically mediated decomposition of organic material is the fundamental process for building the soil carbon stock, which, together with clay minerals, are important for nutrient retention and cycling.

Different forms of soil degradation (SOC loss, tillage, pollution, compaction and erosion) negatively impact the habitat available for soil organisms. In all regions across Europe, the species richness of earthworms, springtails and mites has been negatively affected by increased intensity of land use (Tsiafouli et al., 2015). Healthy soils contain active microbial (bacteria and fungi) and animal (micro to macro fauna) communities (Orgiazzi et al., 2016), of which bacteria and fungi are mainly responsible for nutrient cycling, which is essential for plant growth.

The dynamics of SOC vary according to land use and specific management practices. Forest soils currently act as a strong sink for carbon (30-50 % of the current sink by forest biomass) (Luyssaert et al., 2010). In a recent assessment covering 2009-2015, carbon in mineral cropland soils in the EU-28 was shown to be broadly stable or slightly declining (albeit at much lower levels compared with other land cover categories) (Table 5.3), while carbon in grasslands showed slight increases (Hiederer, 2018); similar results were also reported from national soil monitoring (e.g. Kobza, 2015; Kaczynski et al., 2017). It should be noted that the LUCAS sampling programme has only recently started, so the currently available 6-year interval is relatively short to demonstrate significant changes in SOC stocks.

The largest amounts of SOC are found in organic soils such as peat (Byrne and et al., 2004; spatial extend of peat and mires, see Tanneberger et al., 2017). Cultivation of organic soils causes large carbon dioxide (CO_2) emissions. Such carbon losses contribute significantly to the negative greenhouse gas balance

TABLE 5.4 Summary assessment — soil condition

Past trends and outlook		
Past trends (10-15 years)		Land cover change and management intensity significantly affect soil condition and levels of contamination. Progress in the remediation of polluted soils is slow. Despite recent reductions in soil sealing, fertile soils continue to be lost by continued land take. On intensively managed land, soil biodiversity is endangered. Soil loss as a result of sedimentation through erosion is still significant. The effects of soil compaction and historical and current losses of soil organic carbon are becoming increasingly visible under climate change.
Outlook to 2030		The underlying drivers of soil degradation are not projected to change favourably, so the functionality of soils is under even more pressure. Harmonised, representative soil monitoring across Europe is needed to develop early warnings of exceedances of critical thresholds and to guide sustainable soil management.
Prospects of meeting policy objectives/targets		
2020	☒	Europe is not on track to protect its soil resources based on the existing strategies. There is a lack of binding policy targets; and some threats to soil — compaction, salinisation and soil sealing — are not addressed in existing European legislation. There is a high risk that the EU will fail some of its own and international commitments such as land degradation neutrality.
Robustness		A consistent set of indicators and representative databases for all soil threats across Europe has not yet been established. Measurements and monitoring of soil threats are incomplete. For selected indicators, data on changes in the condition of topsoils can be derived from the LUCAS soil programme (pesticide and soil biodiversity components are currently being added). The assessment of the outlook for and prospects of meeting policy objectives relies primarily on expert judgement.

for some countries (Schils et al., 2008), and they are expected to continue to do so in the future: 13-36 % of the current soil carbon stock in European peatlands might be lost by the end of this century (Gobin et al., 2011).

5.4 Responses and prospects of meeting agreed targets and objectives

Several recent assessments consider land and soil critical yet finite natural resources, subject to competing pressures from urbanisation and infrastructure development and from increased food, feed, fibre and fuel production (FAO and ITPS, 2015; IPBES, 2018). While many European and national policies address land and soil to some extent, binding targets, incentives and measures are largely missing at the European level. The European Court of Auditors recommends establishing methodologies and a legal framework to assess land degradation and desertification and to support the Member States to achieve land degradation neutrality by 2030 (ECA, 2018).

Europe is at risk of not meeting the 7th EAP objective of managing land sustainably and reaching no net land take by 2050.

Meeting the 7th EAP objective of no net land take by 2050 would require investments in land recycling, as well as halting land take. Land recycling is one way to ensure that a growing urban population consumes less land per capita. Land recycling can be achieved by constructing between buildings (densification), by constructing on brownfield sites (i.e. already used sites, known as grey recycling) or by converting developed land into green areas (green recycling) (EEA, 2018b). Setting up green infrastructure is an important means of re-establishing and maintaining unsealed areas, thus allowing patches and networks of urban ecosystems to function in more sustainable cities (see Chapters 3 and 17 for more information on the role of green infrastructure). However, currently there is no legal framework or incentive to recycle urban land, despite funding being available for land rehabilitation under the EU cohesion policy.

> The absence of suitable EU soil legislation contributes to soil degradation within Europe.

Measures to halt land take vary considerably throughout European countries. Reducing land take is an indicative policy objective in Austria, whereas the target to achieve 'zero net land take by 2050' is integrated into national policies in France and Switzerland. In Germany, the national sustainable development strategy for 2020 sets a goal to limit the use of new areas for settlement and transport, whereas in Hungary the 2013 national spatial plan defines suitability zones for agriculture, nature protection and forest. The United Kingdom and Flanders (Belgium) aim to have 60 % of urban development on brownfield sites (Science for Environment Policy et al., 2016; Decoville and Schneider, 2016). However, new housing is needed in many urban conglomerates, and the 2050 objective of the 7th EAP continues to be challenging to meet.

There is currently no European legislation that focuses exclusively on soil. The absence of suitable soil legislation at the European level contributes to the continuous degradation of many soils within Europe (Virto et al., 2014; Günal et al., 2015).

Vrebos et al. (2017) found 35 different EU policy instruments that — mostly indirectly — affect soil functions, as suggested in the soil thematic strategy. Many of them have the potential to address various soil degradative processes (Frelih-Larsen et al., 2017). However, their effectiveness is unclear (Louwagie et al., 2011). For example, some of the common agricultural policy measures such as creating good agricultural and environmental conditions (GAEC) refer to only a specific set of practices, implemented in some areas for a limited period of time.

Glæsner et al. (2014) concludes that three threats to soil, namely compaction, salinisation and sealing, are not addressed in existing EU legislation and that targets to limit soil threats are hardly defined. A coherent coordination of the different existing policies could make soil protection at EU level effective. In addition, the multifunctionality of soil cannot be properly addressed through the existing heterogeneous policy environment. In order to progress, a revision of the existing soil thematic strategy (EC, 2006) is urgently needed, as well as agreements to improve Europe-wide harmonised soil monitoring and indicator assessments.

Societal discussion on soil protection needs to expand beyond economics and include the concept of land stewardship. This would complement the production-oriented and biophysical aspects of land management and aim to achieve more systemic solutions, such as land systems that encompass all processes and activities related to the human use of land (EEA, 2018c). A key element of better land stewardship will be a focus on ecosystem services. However, the services that landowners may supply as an obligation to the common good (land and soil) will need clear specifications (Bartkowski et al., 2018). The more systemic land systems approach may provide a holistic frame, but it needs to be complemented with relevant governance or legal measures. Technical solutions already known to practitioners still need criteria, thresholds and incentives to achieve the societal goal of more sustainable land use and to make its application on the ground part of everyday practice.

Diverse policies refer to soil pollution and the need for data on pollution sources (Water Framework Directive, Industrial Emissions Directive, National Emissions Ceiling Directive, Environmental Liability Directive, Mercury regulation, Sewage Sludge Directive); however, there is a lack of binding measures, e.g. to build and publish registers of polluted sites or to assess and apply harmonised definitions and critical thresholds for contaminants in soils.

With regard to land and soil, how can more sustainable use and proper preservation of the multifunctionality of land be achieved in the absence of direct policies? The 7th EAP has not been sufficient to create a common EU vision for sustainable land and soil use. Progress towards sustainable development in Europe (and globally) is possible only if land and soil resources are properly addressed.

06. Marine environment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Key messages

- Marine life is still under pressure across Europe's seas. Multiple pressures affect species and habitats, leading to cumulative impacts that reduce the overall resilience of marine ecosystems.

- Through joint efforts, European countries have managed to reduce selected pressures, and positive effects are starting to become visible. These cover the recovery of some marine species, including commercially exploited fish and shellfish stocks; where an increasing number of these stocks are now being fished at maximum sustainable yield. The target for designation of marine protected areas has been met.

- At the same time, the target of achieving good environmental status of European marine waters by 2020 is unlikely to be achieved in relation to key pressures such as contaminants, eutrophication, invasive alien species and marine litter.

- Changes observed across Europe's seas show that not all pressures are addressed adequately or fast enough and that knowledge of the cumulative effects of pressures remains limited.

- Looking ahead, the marine environment is under pressure from the development of the blue economy and climate change. In the face of this unprecedented amount of human activities competing to use the marine environment, the outlook for achieving the policy vision of healthy, clean and productive European seas is challenging. Transitions in the management of the marine environment to improve policy implementation, integration and cooperation are required.

Thematic summary assessment

Theme	Past trends and outlook		Prospects of meeting policy objectives/targets
	Past trends (10-15 years)	Outlook to 2030	2020
State of marine ecosystems and biodiversity	Trends show a mixed picture	Deteriorating developments dominate	☒ Largely not on track
Pressures and impacts on marine ecosystems	Trends show a mixed picture	Deteriorating developments dominate	☒ Largely not on track
Sustainable use of the seas	Trends show a mixed picture	Developments show a mixed picture	☐ Partly on track
Marine protected areas	Improving trends dominate	Developments show a mixed picture	☑ Largely on track

Note: For the methodology of the summary assessment table, see the introduction to Part 2. The justification for the colour coding is explained in Section 6.3, Key trends and outlooks (Tables 6.2, 6.3, 6.4 and 6.5).

06.
Marine environment

6.1
Scope of the theme

Throughout history, the use of Europe's seas — spanning from the Baltic Sea and North-east Atlantic Ocean to the Mediterranean and Black Seas — has played a crucial role in people's lives. This comprises the use of marine natural capital, including marine ecosystems and their biological diversity, which makes ecosystems function and underpins their capacity to supply ecosystem services, as well as the use of natural resources such as seawater, oil, sand or gravel.

People depend on the seas for transport, energy, food and income as well as for less obvious life-support functions, such as the oxygen in the air we breathe and climate regulation. How this core resource is managed is not only essential for the sea but also to meet people's basic needs and contribute to their well-being and livelihoods. As the seas are exploited, multiple pressures arise leading to cumulative impacts on marine ecosystems, which undermines their self-renewal and resilience, jeopardising the ecosystem services they can supply and upon which we depend.

Marine ecosystems and species remain under threat as Europe's seas continue to be exploited unsustainably.

This chapter explores the state of Europe's seas, the pressures and their effects and sustainable use in the context of 'living well, within the limits' of the sea.

6.2
Policy landscape

Earth is a blue planet. The health of the oceans is vital not only for the planet itself but also for humanity. Past and current human activities, and the cumulative pressures they exert, have reached a level where they not only impact marine species and habitats but are likely to jeopardise the essential structures and functions of marine ecosystems pushing against the limits for a safe operating space for humankind (Rockström et al., 2009; Steffen, et al., 2015) (Chapter 1).

Such progressive realisation has led to developing a comprehensive EU policy framework covering individual activities, whole sectors, pressures, species/habitats and ecosystems. The ecosystem-based approach to the management of human activities in the marine environment (i.e. ecosystem-based management) is at the centre of this framework (EC 2007; EU 2013; Table 6.1).

One of the main drivers for healthy, clean and productive European seas is the 2008 Marine Strategy Framework Directive (MSFD) (EU, 2008a). The MSFD aims to protect the marine ecosystems underpinning the supply of marine ecosystem services, upon which people and several maritime activities depend. It does so by enshrining ecosystem-based management into EU marine policy and requiring that EU marine waters achieve good environmental status by 2020. On the use of the sea, the EU integrated maritime policy seeks to provide a more coherent approach to maritime activities and issues, such as increased coordination between various policy areas, e.g. fisheries and maritime transport, in order to promote a sustainable blue economy. The work is further supported through the long-term efforts of the four Regional Sea Conventions (Helcom, the Baltic Marine Environment Commission; OSPAR, the Convention for the Protection of the Marine Environment of the North-East Atlantic; UNEP-MAP, the United Nations Environment Programme Mediterranean action plan; and the Bucharest Convention, known in full as the Bucharest Convention on the Protection of the Black Sea against Pollution).

UN Sustainable Development Goal (SDG) 14 is a global policy initiative raising awareness of the need to protect ocean health. It focuses on the conservation of, the reduction of pressures and their impacts upon, and the sustainable use of seas and oceans. The EU has adopted and embraced these goals, which are to be delivered through a series of EU policies and legislation pre-dating the adoption of SDG 14. Key among them are not only the MSFD and the integrated maritime policy but also the Seventh Environment Action Programme (7th EAP) (EU, 2013) and the EU biodiversity strategy to 2020 (EC, 2011). With all these instruments, the EU has committed to protecting, conserving and enhancing marine ecosystems. Finally, sustainability outcomes are influenced by other policies, including climate change, air pollution and industrial pollution (Chapters 7, 8, 12). Table 6.1 presents an overview of selected policy targets and objectives addressed in this chapter.

65 % +

of protected seabed habitats are in unfavourable conservation status.

6.3 Key trends and outlooks

Europe's seas are already influenced by centuries of human use, including the adverse effects from climate change, and may have limited, if any, untapped potential to offer. This is unless current management and protection measures are improved, coordinated and/or enforced. This section provides a snapshot of some of the key trends in the driving forces and the state of Europe's seas.

6.3.1 State of marine ecosystems, including their biodiversity

► *See Table 6.2*

Europe's seas, and their associated marine and coastal ecosystems, are very diverse in their geographical extent, structurally and in terms of their productivity. They range from shallow, semi-enclosed seas to vast areas of the deep ocean, and they include diverse coastal zones with prolific intertidal areas, lagoons and ancient seagrass beds (EEA, 2015c).

The Mediterranean and Baltic Seas illustrate such variation. The Mediterranean Sea is one of the world's hot spots for biodiversity. Its highly diverse ecosystems host around up to 18 % of the world's macroscopic marine biodiversity (Bianchi and Morri, 2000). In comparison, the Bothnian Bay in the Baltic Sea holds only approximately 300 species (Helcom, 2018a).

There is still much to discover about Europe's seas. It is estimated that at least 50 % of their total area (within 200 nautical miles) is more than 2 000 m deep and so in eternal darkness. This is an environment about which little knowledge is available and even less so regarding the impacts of human activities upon it.

Recognising such vulnerability as well as our dependency on marine and other ecosystems, the EU has put a strategic vision in place to halt the loss of biodiversity (EC, 2011). Core elements of this vision for 2020 are to achieve favourable conservation status for vulnerable marine species and habitats as well as good environmental status for marine biodiversity and marine ecosystems in general (EEC, 1992) (Table 6.1 and Chapter 3). Unfortunately, no progress reporting on the implementation of either directive has taken place since *The European environment — state and outlook 2015* (EEA, 2015b), and so other information sources have been used in this assessment.

Given the need to address many complex issues within a holistic perspective, it is challenging to come to a single conclusion on whether the loss of marine biodiversity has been halted and if Europe is on track to achieve healthy, clean and productive seas. It is possible, however, to look at long-term trends in the state of key ecosystem components. The trends in the state of widespread or common species show mixed developments.

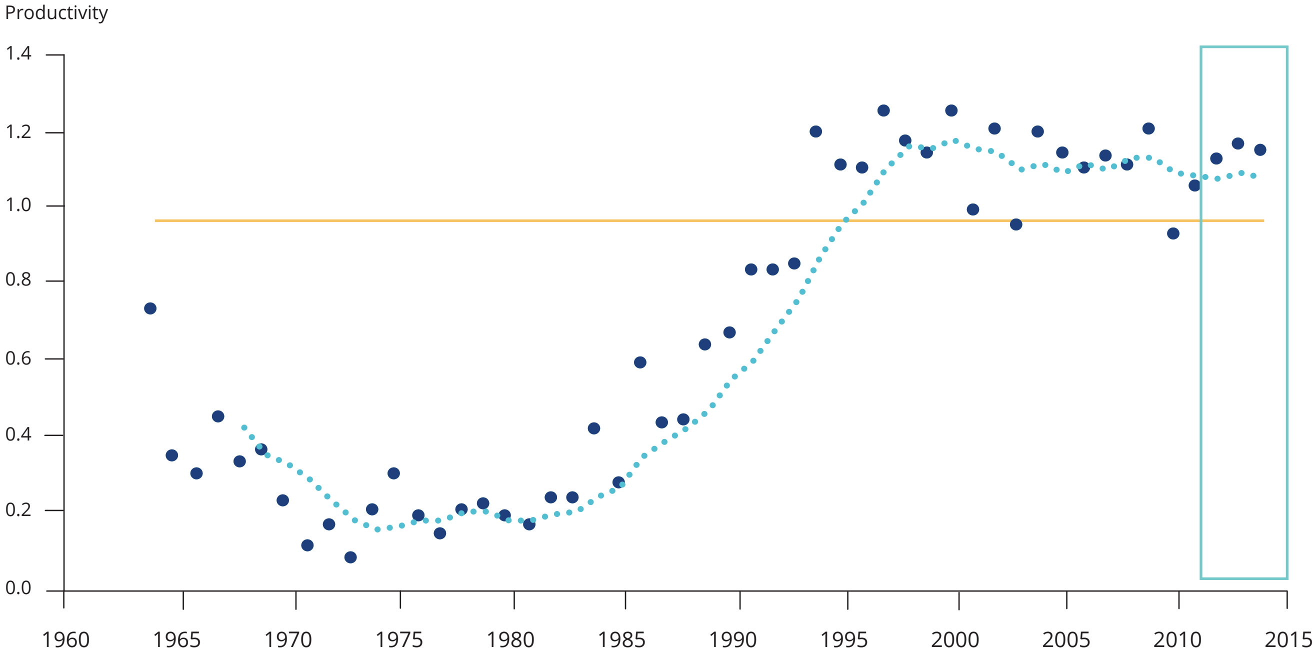
Most of the assessed commercially exploited fish and shellfish stocks in the North-East Atlantic Ocean (62.5 %) and the Baltic Sea (87.5%) were on track for meeting at least one of the GES criteria

TABLE 6.1 Overview of selected policy objectives and targets

Policy objectives and targets	Sources	Target year	Agreement
State of marine ecosystems and including their biodiversity			
Better protection and restoration of ecosystems and the services they provide	EU biodiversity strategy to 2020	2020	Non-binding commitment
Ensuring biodiversity through the conservation of natural habitats and of wild fauna and flora	Council Directive 92/43/EEC; Directive 2009/147/EC	N/A	Legally binding
The quality and occurrence of habitats and the distribution and abundance of species are in line with prevailing physiographical, geographical and climatic conditions	Directive 2008/56/EC as amended by 2017/845 and Decision 2017/848	2020	Legally binding
Minimise and address the impacts of ocean acidification	SDG 14.3	2030	Non-binding commitment
Pressures and their impacts			
Continuously reducing discharges, emissions and losses of hazardous substances and moving towards the target of their cessation within one generation	Fourth North Sea Ministerial Declaration 1995	2020	Non-binding commitment
Achieving concentrations in the marine environment near background values for naturally occurring hazardous substances and close to zero for man-made synthetic substances	Directive 2000/60/EC; SDG 14.1	2028	Legally binding
Keep concentrations of contaminants at levels not giving rise to pollution effects	Directive 2008/56/EC; Commission Decision 2017/848; SDG 14.1;	2020	Legally binding
Human-induced eutrophication is minimised, especially its adverse effects	2008/56/EC as amended by 2017/845 and Decision 2017/848; Directive 2000/60/EC	2020	Legally binding
Non-indigenous introduced species are at levels that do not adversely affect the ecosystems	Directive 2008/56/EC; Commission Decision 2017/848; EU biodiversity strategy to 2020	2020	Legally binding
Quantitative reduction of marine litter to a level that does not cause harm to the marine environment	Directive 2008/56/EC; Commission Decision 2017/848; 7th EAP; SDG 14.1	2020	Legally binding
Sustainable use of the seas			
Populations of all commercially exploited fish and shellfish are within safe biological limits	Directive 2008/56/EC; SDG 14.4	2020	Legally binding
Achieve maximum sustainable yields for European commercially exploited fish and shellfish stocks	EU common fisheries policy 2013; 7th EAP	2015-2020	Legally binding
Increase marine renewable energy production and exploration	EU integrated maritime policy — the Limassol Declaration	2020	Non-binding commitment
Support the development of a highly diversified and sustainable coastal and maritime tourism in Europe	EU integrated maritime policy — the Limassol Declaration	2020	Non-binding commitment
10 % of coastal and marine areas are conserved through systems of protected areas	CBD Aichi biodiversity target 11; SDG 14.5	2020	Non-binding commitment
Establish necessary measures to achieve or maintain good environmental status in the marine environment	Directive 2008/56/EC as amended by 2017/845 and Decision 2017/848; Directive 2000/60/EC	2020	Legally binding
Apply an ecosystem-based approach to the management of human activities	Directive 2008/56/EC; Directive 2014/89/EU	2020	Legally binding

Note: 7th EAP, Seventh Environment Action Programme; CBD, Convention on Biological Diversity; SDG, Sustainable Development Goal; N/A non-applicable.

FIGURE 6.1 Mean annual productivity of the white-tailed eagle in the Baltic Proper, Swedish coastal



Note: The productivity is estimated as the number of nestlings in the Baltic Proper from 1964 to 2014. Productivity is defined as the number of nestlings per checked territorial pair. The yellow line illustrates the threshold value of the Helcom core indicator.

Source: Helcom (2018a).

in the regions in 2017 due to better fisheries management (EEA, 2019c). In contrast, most of the assessed stocks in the Mediterranean Sea (94%) and Black Sea (85.7%) were subject to overfishing in 2016 (EEA, 2019c). Overall, 40 % of shark and ray species in Europe's seas show declining populations (Bradai et al., 2012; Nieto et al., 2015). In contrast, strong regulation to reduce fishing mortality has brought another top Mediterranean predator, bluefin tuna, back from the brink of collapse (in 2005-2007) to achieve sustainable levels of reproductive capacity in 2014 (Fishsource, 2018; based on ICCAT, 2017a, 2017b).

Average European seabird population trends are either stable or declining. Approximately 33 % are slightly declining and another 22 % are regarded as threatened (BirdLife International, 2015). In the Norwegian Arctic, the Greater North Sea and the Celtic Seas, there has been an overall drop of 20 % in seabird populations over the last 25 years for more than one quarter of the species assessed (OSPAR, 2017b). On a positive note, there are examples of recovery of individual species as a result of targeted management efforts, e.g. the banning of DDT (dichlorodiphenyltrichloroethane) and PCB. This includes the white-tailed eagle in parts of the Baltic Sea (Helcom, 2018b) (Figure 6.1).

Marine mammals are all protected by EU legislation or global policy, but their status is not fully understood due to complexities in monitoring. This has resulted in 72 % of Member States' reports on their status (ETC/BD, 2012) and 44 % of the International Union for Conservation of Nature (IUCN) assessments being data deficient (Temple and Terry, 2007). Some seal populations are relatively healthy and increasing in numbers or reaching carrying capacity (OSPAR, 2017c; Helcom, 2018a). Despite the increase in the population of grey seals in the Baltic Sea, their nutritional condition and reproductive status is not good (Helcom, 2018a). In the Mediterranean Sea, the number of monk seals appears to be stabilising, although this species is still at risk because of its small population size (Notarbartolo di Sciara and Kotomatas, 2016).

Recent studies of populations of killer whales show adverse effects of PCB on their reproduction, threatening > 50 % of the global population. This may result in the disappearance of killer whales from the most contaminated areas within 50 years, despite PCB having been banned for 30 years. This includes areas in the North-East Atlantic Ocean and around the Strait of Gibraltar (Desforges et al., 2018; Aarhus University, 2018).

Seabed habitats are under significant pressure across EU marine regions,

TABLE 6.2 Summary assessment — state of marine ecosystems and biodiversity

Past trends and outlook		
Past trends (10-15 years)	(yellow)	A high proportion of marine species and habitats continue to be in unfavourable conservation status or declining condition, although management efforts targeting individual species and habitats, or specific pressures, have led to improvements in their condition. However, this success is only partial, as recovery is not common to all biodiversity features or to all of Europe's seas.
Outlook to 2030	(red)	Many marine species or species groups still have declining populations or have failed to reach favourable conservation status. Nevertheless, several have achieved good condition, showing that some management efforts are working. However, the underlying climatic drivers of marine ecosystem degradation appear not to be improving, as related pressures are worsening. Legacy hazardous substances and heavy metals, non-indigenous species and marine litter will continue to impact marine ecosystems. The use of marine resources and space is expected to increase. Reaching agreed policy goals for the marine environment across all policies and mitigating climate change are essential to prevent further damage and/or achieve full recovery of marine ecosystems, thereby preserving their long-term resilience, if the outlook is to change.
Prospects of meeting policy objectives/targets		
2020	☒ (red)	EU marine regions are at risk of achieving neither the Marine Strategy Framework Directive's good environmental status for marine biodiversity nor the Habitats Directive's favourable conservation status for protected marine species and habitats by 2020.
Robustness		There is large variation in the availability of information on the state of marine species and habitats across marine regions and gaps in data remain. Formal reporting of progress on the implementation of EU marine environmental legislation is often delayed and/or inadequate. The available outlook information is limited, so the assessment of outlook relies primarily on expert judgement.

with over 65 % of protected seabed habitats reported as being in unfavourable conservation status 20 years after the entry into force of the Habitats Directive (EEA, 2015d). In another example, 86 % of the seabed assessed in the Greater North Sea and Celtic Seas shows evidence of physical disturbance by bottom-trawling gear (OSPAR, 2017a). In the Baltic Sea, only 44 % and 29 % of the soft-bottom seabed habitat area in coastal waters and in the open sea were in good status, respectively (Helcom, 2018a). However, the common dog whelk is recovering on the Norwegian coast as a direct response to banning TBT (tributylin) (see Schøyen et al., 2019, and Chapter 10).

To summarise, when considering the halting of marine biodiversity loss, there are several examples of recovery for some species and groups of species. These include the common dog whelk (Schøyen et al., 2019), assessed commercially exploited fish and shellfish stocks in the North-East Atlantic Ocean and Baltic Sea (EEA, 2019c), harbour seals in the Kattegat (OSPAR, 2017c; Helcom, 2018a), white-tailed eagle in the Baltic Sea (Helcom, 2018b) and the Mediterranean bluefin tuna (ICCAT, 2017a, 2017b).

Despite these examples, halting marine biodiversity loss remains a great challenge. Some marine populations and groups of species are still under threat, including copepods (UKMMAS, 2010; Edwards et al., 2016), pteropods (NOAA, 2013), Atlantic cod (Stiasny et al., 2019), seabirds (BirdLife International, 2015), assessed commercially exploited fish and shellfish stocks in the Mediterranean and Black Seas (EEA, 2019c), sharks and rays (Bradai, et al., 2012) and killer whales (Desforges et al., 2018). The same applies to seabed habitats (ETC/BD, 2012; OSPAR, 2017a; Helcom, 2018a). In addition, ocean warming (EEA 2016a), acidification (Fabry et al., 2008; NOAA, 2013) and deoxygenation (Carstensen et al., 2014; Breitburg et al., 2018; Schmidtko et al., 2017) continue to worsen.

These last examples indicate that various trophic levels could be impacted, which implies that the resilience of Europe's seas could be degrading and so significant systemic changes may be under way. Given the sometimes long response time for species to recover, e.g. 25-30 years for white-tailed eagle (Figure 6.1), or the even longer time taken for some trends in pressures on the ecosystem to reverse, e.g. eutrophication (Murray et al., 2019), the outlook for 2020 remains bleak. Therefore, marine ecosystems continue to be at risk, which could undermine the sea's capacity to supply the ecosystem services upon which humanity depends.

6.3.2
Pressures and their impacts

► *See Table 6.3*

Europe's seas and their ecosystems are perceived as the last wilderness with a large potential for increased exploitation. In reality, they are under various pressures from multiple human activities even in remote marine areas. Each human activity causes several pressures that often overlap (Jackson et al., 2001), and these overlapping pressures can cause cumulative adverse effects on marine ecosystems (Halpern et al., 2008; Micheli et al., 2013). But how to deal with these cumulative impacts has not yet been fully captured in management or planning processes.

Contaminants

Hazardous substances above agreed threshold levels are found across all of Europe's seas. While concentrations of specific substances and/or groups of substances have declined, some heavy metals and persistent substances are still found at elevated levels, at which — in the case of persistent substances, such as PCBs, or heavy metals, such as mercury — achieving politically agreed targets is jeopardised (Table 6.1). Furthermore, new substances are being developed and marketed faster than before. These may or may not pose a future threat (EEA, 2019b).

Contaminants in the marine environment can cause adverse effects on marine species but also potentially have an impact on human health (Chapter 10). For example, phthalates can cause reduced fertility in humans and they have been found in high concentrations in Europe's seas: from Bergen, Norway, to the German Bight, North Sea (AMAP, 2017). One phthalate (DEHP, or diethylhexyl phthalate) is listed as a priority substance under the EU Water Framework Directive (WFD), illustrating some of the existing efforts to reduce people's exposure to such substances (EU, 2000). Other substances, such as dioxins, have been recorded in oily fish, such as herring or salmon, in the Baltic Sea (Vuorinen et al., 2012). This has caused health authorities to advise restricting consumption of fish from the affected areas, especially by pregnant women. Dioxin can disrupt growth, cause cancer or adversely affect the immune system (Livsmedelsverket, 2018).

> The impacts of eutrophication on the marine environment and its ecosystems remain a problem in some European marine regions.

Eutrophication

Eutrophication, linked to nutrient pollution, remains a problem in some European marine regions. The forthcoming EEA assessment of eutrophication indicates that nutrient levels exceed threshold values in 40 % of the assessed sites.

Nutrient inputs have been reduced, but the Baltic Sea and the Black Sea remain eutrophic (Andersen, et al., 2017; Yunev et al., 2017). Thus, despite significant decreased inputs of nitrogen and phosphorus, more than 97 % of the Baltic Sea is still eutrophic (Helcom, 2018a) (Figure 6.2). Model results show that one Baltic basin may be non-eutrophic by 2030 or 2040 and more areas will have joined it by 2090. The Baltic Proper and Bothnian Sea may reach good eutrophication status only around 2200, and two areas may not be affected by eutrophication at all (Murray et al., 2019).

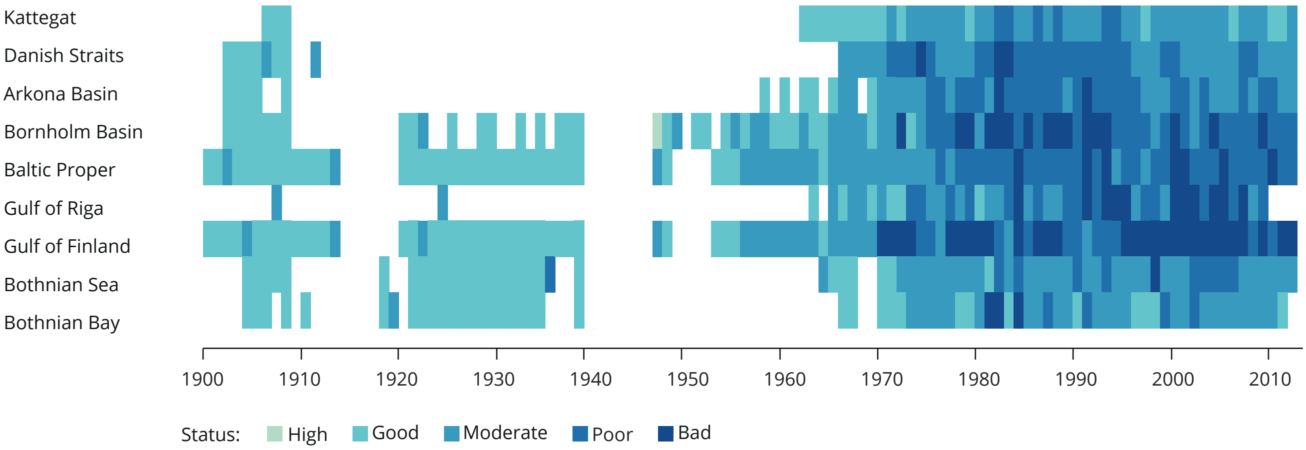
In the Black Sea, reduced nutrient inputs have translated into a 15-20 % reduction in primary production compared with 1992 levels. However, it remains mesotrophic compared with the pre-1960s oligotrophic levels, i.e. still eutrophic (Yunev et al., 2017).

Coastal water assessments under the WFD (EEA, 2018a) indicate that 55 % of the coastal waters assessed achieve its good ecological status objective regarding phytoplankton conditions (reflecting eutrophication status) as they are in either high or good status, although outcomes vary among EU marine regions. Good or high status is observed in the coastal waters of the Celtic Seas and the Bay of Biscay, the Macaronesian and most of the Mediterranean Sea. In contrast, 85 % and 76 % of the coastal waters assessed under the WFD in the Black and Baltic Seas were in less than good status, respectively. Nutrient inputs from point sources have significantly decreased, but inputs from diffuse sources have not, and the use of agricultural mineral fertilisers has even increased in some areas (EEA (forthcoming), 2019). Agriculture is the major driver of diffuse pollution with the highest inputs of nutrients and organic matter into aquatic environments (Chapter 13). The main driver of point source pollution is still urban waste water treatment and storm overflow (EEA, 2018c).

Reduced oxygen in seawater

Hypoxia is the extreme symptom of eutrophication, and deoxygenation is an increasing global challenge in coastal and open waters (Carstensen et al., 2014; Breitburg et al., 2018). It is a severe threat not only to the living conditions of biota but also for

FIGURE 6.2 **Long-term trends in eutrophication in the Baltic Sea**



Note: Long-term spatial and temporal trends are assessed for nine sub-basins of the Baltic Sea for the period 1901-2012 based on the HEAT multi-metric indicator-based tool and a broad range of *in situ* measured indicators.

Source: Andersen et al. (2017).

attempts to reverse the eutrophication process. Hypoxia in near-bottom water releases sediment-bound phosphorus in a readily utilisable form and enhances eutrophication, which may lead to a feedback loop (EEA (forthcoming), 2019). Deoxygenation may be exacerbated by increases in sea temperature (Carstensen et al., 2014; Breitburg et al., 2018).

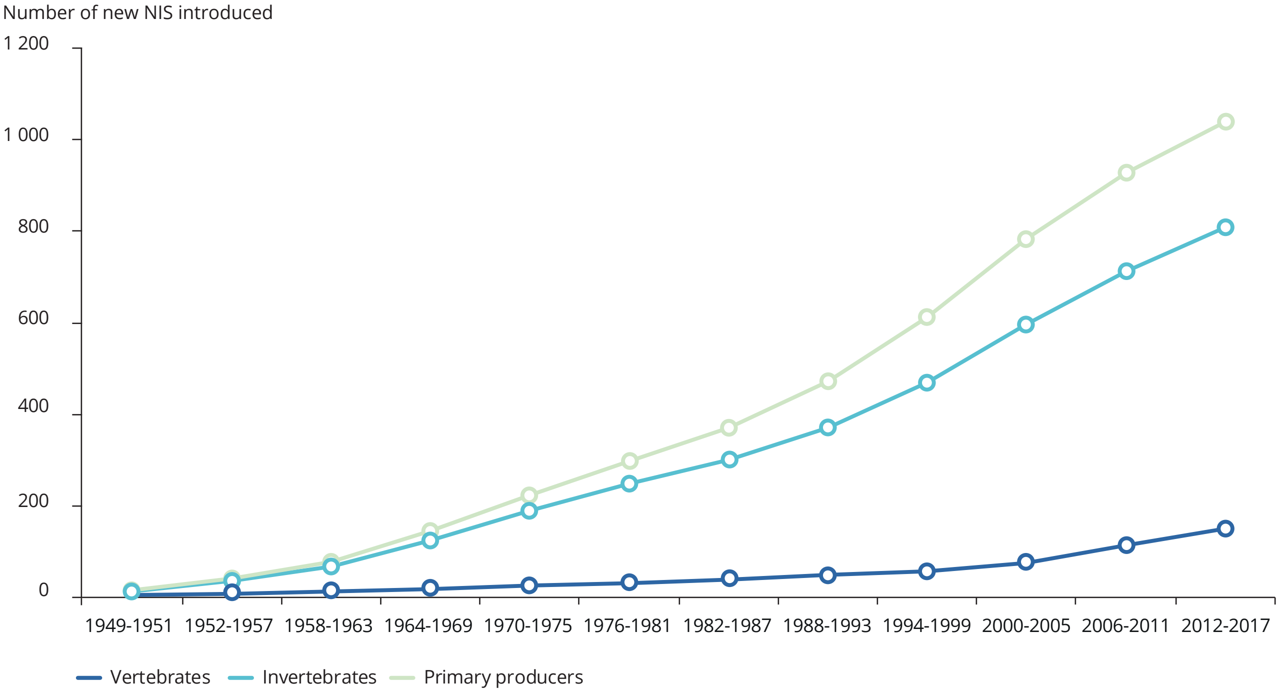
Widespread oxygen depletion occurs in the Baltic and Black Seas, although it is partly due to natural conditions (stratification) (EEA (forthcoming), 2019). The lower water layers of the Black Sea are naturally permanently anoxic, but the depth of the surface oxygenated layer has decreased from 140 m in 1955 to less than 80 m in 2016 (von Schuckmann, et al., 2016; Capet, et al., 2016). In the Baltic Sea, there was a 10-fold increase in the perennially hypoxic area during the 20th century, i.e. from 5 000 km^2 to > 60 000km^2 (Carstensen et al., 2014). In the Baltic Sea coastal zone, hypoxia has been steadily increasing since the 1950s (Conley et al., 2011). However, significant reductions in nutrient loads into the Baltic Sea in the last couple of decades have slowed the expansion of hypoxia, but the trend has not yet been reversed (Carstensen, 2019).

In the Greater North Sea, reduced oxygen concentrations are observed mainly at some stations in fjords in Denmark and along the Swedish and Norwegian coasts. Concentrations decreased at 9 % of the stations during the period 1990-2017, mainly in Danish fjords and at some points in the German Bight (EEA (forthcoming), 2019).

Fisheries

Commercial fisheries cover large areas of Europe's seas and are considered one of the human activities with the highest impact on the marine environment (Micheli et al., 2013; FAO, 2016; OSPAR, 2017b). Historically, many commercial fish and shellfish stocks have been overexploited, sometimes to the point that it may affect their reproductive capacity and, thus, their potential to recover from exploitation. Decreased fishing pressure in the North-East Atlantic Ocean and the Baltic Sea in recent years has led to signs of recovery of many stocks, meeting policy targets for fishing mortality or reproductive capacity or both in 2017 (EEA, 2019c). In contrast, most of the assessed stocks in the Mediterranean Sea (93.9 %) and Black Sea (85.7 %) were subject to overfishing in 2016 (EEA, 2019c; Section 13.3 in Chapter 13). A similar pattern is observed by Froese et al. (2018)) when looking across 397 stocks found in the Black Sea, Mediterranean Sea, Baltic Sea and the North-East Atlantic Ocean over the period 2013-2015. The abundance of sensitive species (sharks, rays, and skates) decreased by 69 % in heavily trawled areas (Dureuil et al., 2018). Bycatch of marine mammals, seabirds and non-commercial fish is still a major threat (OSPAR, 2017b).

FIGURE 6.3 Cumulative number of non-indigenous species in Europe's seas



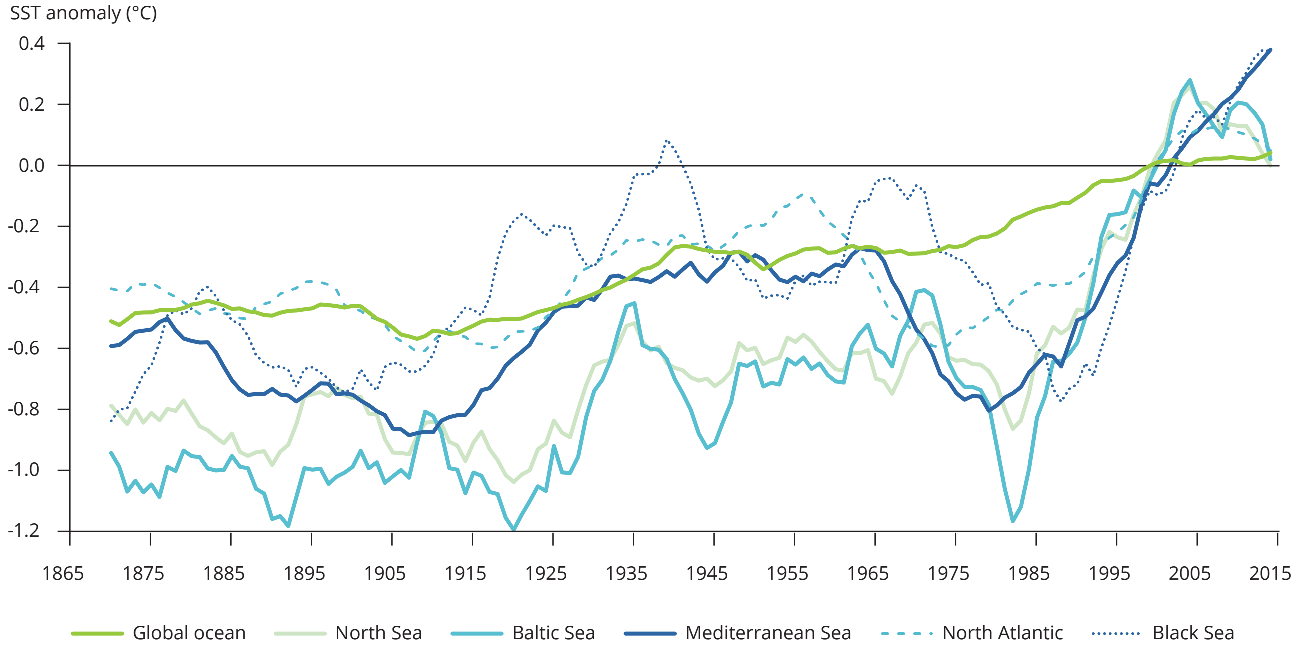
Note: Data file: MAR002_Trends in MAS_DATA-METADATA_v2.15.12.18.

Source: EEA (2015e).

Hydromorphological and other physical pressures

About 28 % of Europe's coastline is affected by pressures causing changes in hydrographic conditions, e.g. in seawater movement, temperature and salinity, according to the hydromorphological pressure assessments made in coastal waters under the WFD. Coastal developments modify natural hydrological conditions and impact habitats where hydrographical pressure is highest in the coastline of the Mediterranean and Black Seas. Reporting under the WFD also determined that about 19 % of the EU coastline is affected by permanent physical alterations in seabed habitats consistent with pressure from physical loss and due to, for example, urbanisation, port facilities, boating, flood protection infrastructures and land reclamation (EEA, 2019a) . In addition, about 25 % of the area of the coastal strip (up to 12 nautical miles from shore) is subject to seabed habitat loss due to construction of, for example, wind farms, oil and gas installations and ports, as well as exploitation of, for example, fish, shellfish and minerals. In offshore waters (from 12 to 200 nautical miles from shore), less than 3 % of seabed habitats are considered lost, although the extent of seabed habitat loss is region specific and highest in the Baltic Sea, where it affects 14 % of the seabed (ETC/ICM, unpublished data). In addition, about 16 % of Europe's seabed is under pressure from physical disturbance, which is mainly caused by bottom trawling and by shipping in shallow waters. Overall, 14 % of Europe's seabed was trawled at least once during the period 2011-2016, although this figure increases to 32 % when focusing on the coastal area (up to 12 nautical miles from shore). Up to 86 % of the Greater North Sea and Celtic Seas' seabeds have been physically disturbed by bottom trawling, of which 58 % is highly disturbed. Up to 40 % of seabed habitats in the Baltic Sea are physically disturbed and this is much higher in the sub-basins where bottom trawling is practised (OSPAR, 2017b; Helcom, 2018a). Shipping in shallow waters causes pressure from physical disturbance in 10 % of Europe's seabed overall, although regional extents can be much higher, reaching 57 % in the Baltic Sea (ETC/ICM, unpublished data).

FIGURE 6.4 **Average sea surface temperature (SST) anomaly (running average over 11 years)**



Note: Time series of annual average sea surface temperature (°C), referenced to the average temperature between 1993 and 2012, in the global ocean and in each of the European seas. Data sources: SST data sets from Copernicus Marine Environment Monitoring Service (Mediterranean Sea) and the Hadley Centre (HADISST1; global and other regional seas).

Source: EEA (2016b).

Non-indigenous species

All Europe's seas suffer from the introduction of non-indigenous species (NISs), with the highest number of introductions in the Mediterranean Sea. Currently, at least 1 223 marine NISs have been recorded. NISs appear to be introduced at a relatively constant rate (Figure 6.3) (EEA, 2019d). The main pathway of introduction is maritime transport, responsible for more than 50 % of NIS transfer via ballast water, tank sediments, hull fouling, corridors and other vectors (Tsiamis et al., 2018; EEA, 2019d) . The European sea with the highest pressure from NISs is the Mediterranean (Tsiamis et al., 2018). NISs are currently established in approximately 8 % of Europe's sea area. Of these, 81 NISs belong to the group most impacting species; these have the highest invasive potential. These invasive alien species are found across all of Europe's seas.

> 8 million
>
> tonnes of plastic waste ends up in the ocean every year putting pressure on the marine environment and its ecosystems.

Marine litter

Marine litter puts pressure on all marine ecosystems. For example, 8 million tonnes of plastic ends up in the ocean every year (EEA, 2018b). Plastic items are the most abundant and damaging components of marine litter because of their persistence, accumulation and toxicity, and they can have physical, chemical and biological impacts on marine biodiversity. Plastics constitute up to 95 % of the waste that accumulates on shorelines, the sea surface and the sea floor. The majority of plastic litter items are packaging, fishing nets and small pieces of unidentifiable plastic or polystyrene (Pham et al., 2014). Litter pollution harms marine animals through entanglement, clogging their digestive systems (following ingestion) and physiological changes, although the effects at population level are still not well investigated. Land-based sources contribute the largest proportion of litter, which is mostly transported by rivers or


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TABLE 6.3 **Summary assessment — pressures and impacts on marine ecosystems**

Past trends and outlook		
Past trends (10-15 years)		Where targeted management measures to address well-known pressures have been implemented consistently, negative trends are beginning to reverse, e.g. in nutrients and some contaminants. However, this success is only partial, as many trends in pressures have not changed. The underlying climatic drivers of marine ecosystem degradation appear not to be improving, as related pressures, such as sea surface temperature and ocean acidification, are worsening. The same is true of deoxygenation.
Outlook to 2030		Legacy hazardous substances and heavy metals, non-indigenous species, and marine litter will continue to impact marine ecosystems. Ocean acidification, deoxygenation and sea surface temperature all have worsening trajectories. The use of marine resources and space is expected to increase. Meeting agreed policy goals for the marine environment across all policies and mitigating climate change are essential to preventing further damage and/or achieving full recovery of marine ecosystems, preserving their long-term resilience and changing the outlook to 2030.
Prospects of meeting policy objectives/targets		
2020	☒	EU marine regions are at risk of not achieving the Marine Strategy Framework Directive's good environmental status for key pressures such as those on commercially exploited fish and shellfish stocks (in the Mediterranean and Black Seas), introductions of non-indigenous species, eutrophication, contaminants and marine litter by 2020.
Robustness		There is large variation in the availability of pressure-related information across marine regions and gaps in the data remain. Monitoring of key pressures should be improved and assessment threshold values established. Formal reporting of progress in the implementation of EU marine environmental legislation is often delayed and/or inadequate. The available outlook information is limited, so the assessment of outlook relies primarily on expert judgement.

directly discharged from coastal activities, e.g. tourism. The main marine sources of litter are fisheries, aquaculture and shipping (ETC/ICM (forthcoming), 2019).

Underwater noise

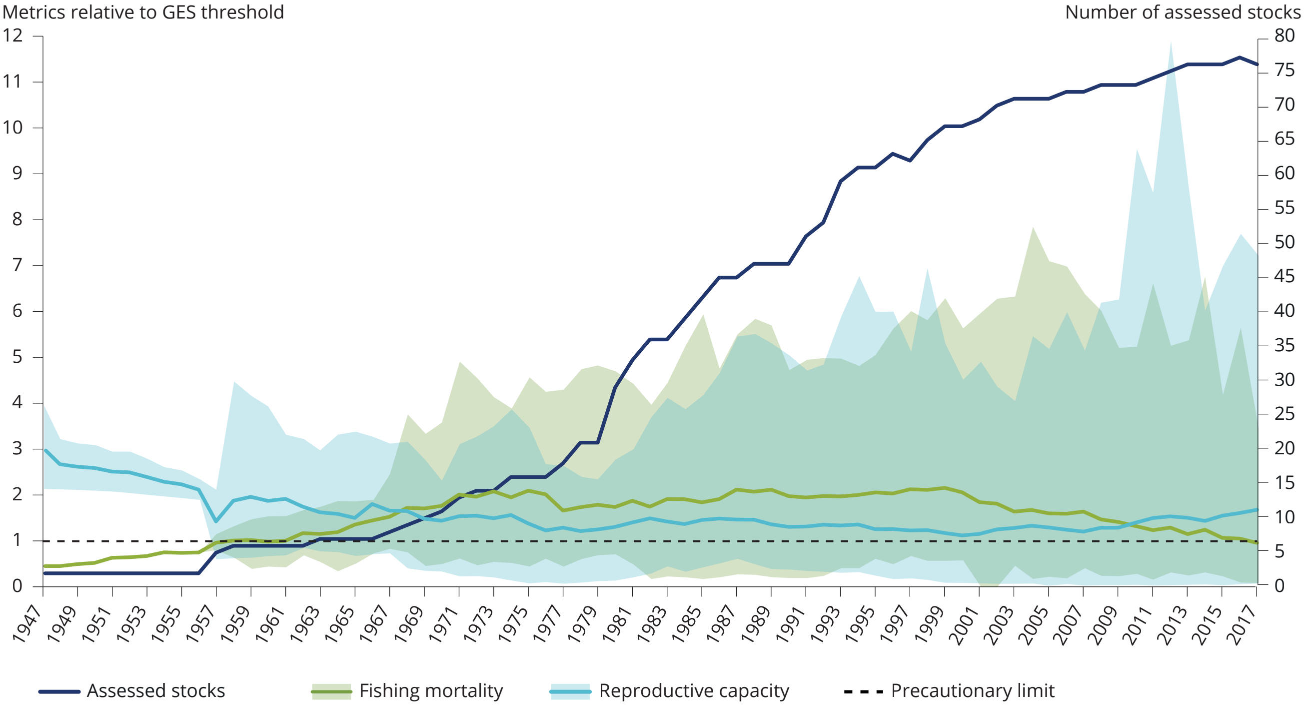
Underwater noise is a geographically widespread pressure. In the absence of a methodology for operational monitoring and of assessment thresholds, the severity of its effects on marine life cannot be determined. Anthropogenic sounds can lead to continuous underwater noise (mainly from marine traffic) and impulsive underwater noise, which is short pulses with high energy levels (arising mainly from impact pile driving, seismic exploration, explosions and sonar systems). The sources and spatial distribution of continuous and impulsive underwater noise are starting to be analysed in order to characterise the potential exposure of marine ecosystems to this pressure. According to the scientific literature, both types of underwater noise can affect marine animals, e.g. marine mammals, in various ways, ranging from changes in behaviour to death (ETC/ICM (forthcoming), 2019).

> Achieving the Marine Strategy Framework Directive's good environmental status across all EU marine regions remains unlikely by 2020.

Climate change

Anthropogenic climate change is a pressure causing changes to, for example, the temperature and acidity (pH) of Europe's seas. These have all warmed considerably since 1870, and this warming, which has been particularly rapid since the late 1970s, continues (Figure 6.4). Ocean surface pH has declined from 8.2 to below 8.1 over the industrial era and continues to do so (EEA, 2016a). Global mean sea level rose by 19.5 cm from 1901 to 2015, at an average rate of 1.7 mm/year, but with significant decadal variation. The rise in sea level relative to land along most European coasts is projected to be similar to the global average, with the exception of the northern Baltic Sea and the northern Atlantic coast (EEA, 2017). Whole marine ecosystem responses to these changes are largely unknown, although effects on individual species or species groups have been observed or projected (Fabry et al., 2008; NOAA, 2013; EEA, 2017). For example, in more acidic and food-limited conditions, cod larvae may experience reduced functionality or impairment of their organs as they expend more energy on growth and ossification of their skeletal elements (Stiasny et al., 2019). Impacts from seawater warming include the replacement of cold water species with warm water species, as observed in

FIGURE 6.5 **Trends in the number of assessed commercially exploited fish and shellfish stocks in the North-East Atlantic Ocean and Baltic Sea since 1945 and in the progress of these stocks towards achieving the MSFD's 'good environmental status' for descriptor 3, 'Commercial fish and shellfish', on the basis of their mortality and/or reproductive capacity**



Notes: This figure shows trends in the status of commercially exploited fish and shellfish stocks assessed between 1946 and 2016 expressed as two metrics: fishing mortality (F) and reproductive capacity (i.e. spawning stock biomass, SSB) relative to the MSFD thresholds for good environmental status (GES). These thresholds relate to the stocks' maximum sustainable yield (MSY), i.e. F_{MSY} and MSY $B_{trigger}$ (the biomass at the lowest level of the range around SSB_{MSY} able to produce MSY), respectively. For fishing mortality, 1 is the value ($F = F_{MSY}$) above which exploitation is unsustainable, while for reproductive capacity a value of 1 is a precautionary limit (SSB ≥ MSY $B_{trigger}$) below which there is a high risk that reproductive capacity will be impaired. The figure is based on 83 fish stocks in the North-East Atlantic Ocean and Baltic Sea for which F and/or SSB could be calculated against reference points in the period 1946-2016, i.e. stocks for which adequate information exists at the regional level to calculate one or the other metric or both. Both F/F_{MSY} and SSB/MSY $B_{trigger}$ could be calculated only for a maximum of 74 stocks. Note that the value of the metrics is determined by an increasing number of stocks and, therefore, part of the trend may be explained by new stocks being introduced into the analysis over the years. However, from 2013 onwards, the suite of stocks assessed remained stable.

Source: EEA (2019c).

copepods and fish in the North-East Atlantic Ocean (EEA, 2017). Sea level rise and the increased frequency of storm events add to the coastal squeeze and may have potentially severe effects (Gynther et al., 2016).

Marine ecosystems affected by climate change may also become more vulnerable to other anthropogenic pressures (ETC/ICM (forthcoming), 2019); Breitburg et al., 2018).

These assessments indicate that targeted management measures can serve to reduce pressures when the pressure-impact causality is clear and strong. They also indicate that, overall, management measures have either not yet taken effect or are insufficient to prevent, reduce or reverse marine ecosystem impacts or that they are not effective in the context of multiple pressures and cumulative impacts upon them. This implies that the resilience of Europe's seas could be degrading and so significant systemic changes may be under way.

6.3.3
From the past to the future — Europe depends on the seas

▶ *See Table 6.4*

Oceans and seas have been the foundation for the development of European societies

TABLE 6.4 Summary assessment — sustainable use of the seas

Past trends and outlook		
Past trends (10-15 years)		The use of Europe's seas continues to increase, with some established sectors declining or stagnating while new sectors are emerging. This puts marine ecosystems at risk and could undermine the sea's capacity to supply ecosystem services.
Outlook to 2030		It is envisaged that the use of Europe's seas will continue to increase in the light of the blue economy objectives. There is a mixed pattern of development for individual sectors. For example, oil and gas extraction has peaked in the North Sea, but offshore wind is growing. As competition for marine resources and space increases, coordination among stakeholders and policy integration will be needed to ensure that activities are sustainable.
Prospects of meeting policy objectives/targets		
2020	☐	Significant progress has been made in reaching maximum sustainable yields for commercially exploited fish and shellfish stocks in the North-East Atlantic Ocean and Baltic Sea. However, most assessed stocks in the Mediterranean and Black Seas are still overfished. Although commercial fisheries are very widespread and have a high impact, they represent just one of the uses of the sea. This means that other policy targets could be at risk from other uses and the cumulative impacts of multiple pressures.
Robustness		There is large variation in the availability of sector-related information across sectors and marine regions and gaps in the data remain. The available outlook information is limited, so the assessment of outlook relies primarily on expert judgement.

throughout history, and the mutually supportive relationship between oceans and humans has never been more widely recognised than it is today.

The maritime economy, often referred to as the 'blue economy', is a powerful driver of socio-economic growth in the EU. It is estimated that global maritime-related activities have an output of EUR 1.3 trillion — a figure set to double by 2030 (EC, 2017). Maritime activities include both traditional sectors, such as fishing, shipping, tourism and extracting resources, and emerging sectors, such as offshore wind, aquaculture and deep-sea mining (EU, 2017, 2014), as well as new ocean infrastructures, e.g. floating nuclear plants. All of these activities compete with each other for the use of marine resources and space. One of the solutions for realising the untapped potential of the seas will be ensuring that maritime spatial planning fully supports the achievement of good environmental status.

Of the more traditional uses of the seas, fisheries have faced significant challenges over the last couple of decades and have had significant impacts on the marine environment and coastal communities. In recent years, more assessed commercially exploited fish and shellfish stocks have been fished sustainably, i.e. at maximum sustainable yield, in the North-East Atlantic Ocean and Baltic Sea. Signs of recovery of the reproductive capacity of some of these stocks are also being seen (Figure 6.5; Chapter 13). Very few assessed stocks in the Mediterranean Sea (6.1 %) and Black Sea (14.3 %) are currently on track to being exploited at maximum sustainable yield (FAO, 2018; Froese et al., 2018; EEA, 2019c). In fact, in these seas there is 'no trend, to indicate any improvement in the exploitation since the implementation of the 2003 reform of the [common fisheries policy]' (Jardim et al., 2018, p. 48).

93.9 %

of assessed commercial fish and shellfish stocks in the Mediterranean Sea and 85.7 % in the Black Sea are still overfished.

Shipping, including maritime transport, has also been an important maritime activity for centuries. With the rise of globalisation and access to new markets, shipping traffic soared from the 1950s until the economic crisis in 2008 (WOR, 2010). In 2016, roughly 3 860 million tonnes of goods and commodities were handled in EU Member State (EU-28) ports, while passenger visits amounted to over 383 million people (EEA, 2016c; Eurostat, 2017). The sector contributes an estimated EUR 70 734 million in gross value added to Europe's economy, employing roughly 1.74 million people (COGEA et al., 2017).

Some industries, such as oil and gas extraction, are stagnating and declining in some regions, while other industries are emerging. An example of the latter

TABLE 6.5 Summary assessment — marine protected areas

Past trends and outlook		
Past trends (10-15 years)		In the period 2012-2016, the extent of marine protected areas (MPAs) almost doubled within EU marine waters to an area equal to that designated in the period 1995-2011.
Outlook to 2030		The challenge to ensure that EU MPA networks are coherent, representative and well-managed remains to deliver tangible benefits for biodiversity by 2030.
Prospects of meeting policy objectives/targets		
2020	☑	In 2018, the EU had met part of Aichi biodiversity target 11 and Sustainable Development Goal 14.5 relating to designating 10 % of its seas within networks of MPAs. Whether the MPA network will deliver measurable benefits for biodiversity remains to be documented.
Robustness		There is good information available on the spatial coverage of MPAs. There is little information available on how effective management measures are inside MPAs and, thus, whether they are as effective in protecting marine biodiversity as they could/should be.

The EU seas covered by the network of marine protected areas almost doubled from 2012 to 2016.

is the offshore wind industry's continued expansion into marine territory. Europe's installed offshore capacity reached 15 780 MW (= 4 149 grid-connected wind turbines) in 2017, the year by which 11 European countries had established 92 wind farms (including those under construction). Most of these are found in Denmark, Germany, Sweden and the United Kingdom (4C Offshore, 2018). Turkey has announced its intention to build first offshore windfarm projects as candidate renewable energy resource zones in the Aegean Sea, the Sea of Marmara and the Black sea.

Similarly, tourism is on the rise. Between 2006 and 2016, EU-28 (foreign) tourist arrivals increased by approximately 60 % (Eurostat, 2018). In 2014, Europe's coastal tourism accounted for 24.5 % of the EU's maritime economy, generating over EUR 86 436 million in gross value added (direct and indirect) and employing over 3.1 million people (COGEA et al., 2017). Such increases in tourism are dependent upon healthy coastal and marine ecosystems and simultaneously put pressure upon them.

Overall, the seas provide resources and space for a wide variety of human activities generating economic value as well as social and cultural benefits. As competing activities continue to increase, so will the cumulative impact on ecosystems already affected by centuries of use. Such expected growth, combined with the potentially degrading resilience of the ecosystems of Europe's seas, highlights the need for ecosystem-based management more than ever if Europe's seas and their limited resources are to be used in a sustainable manner.

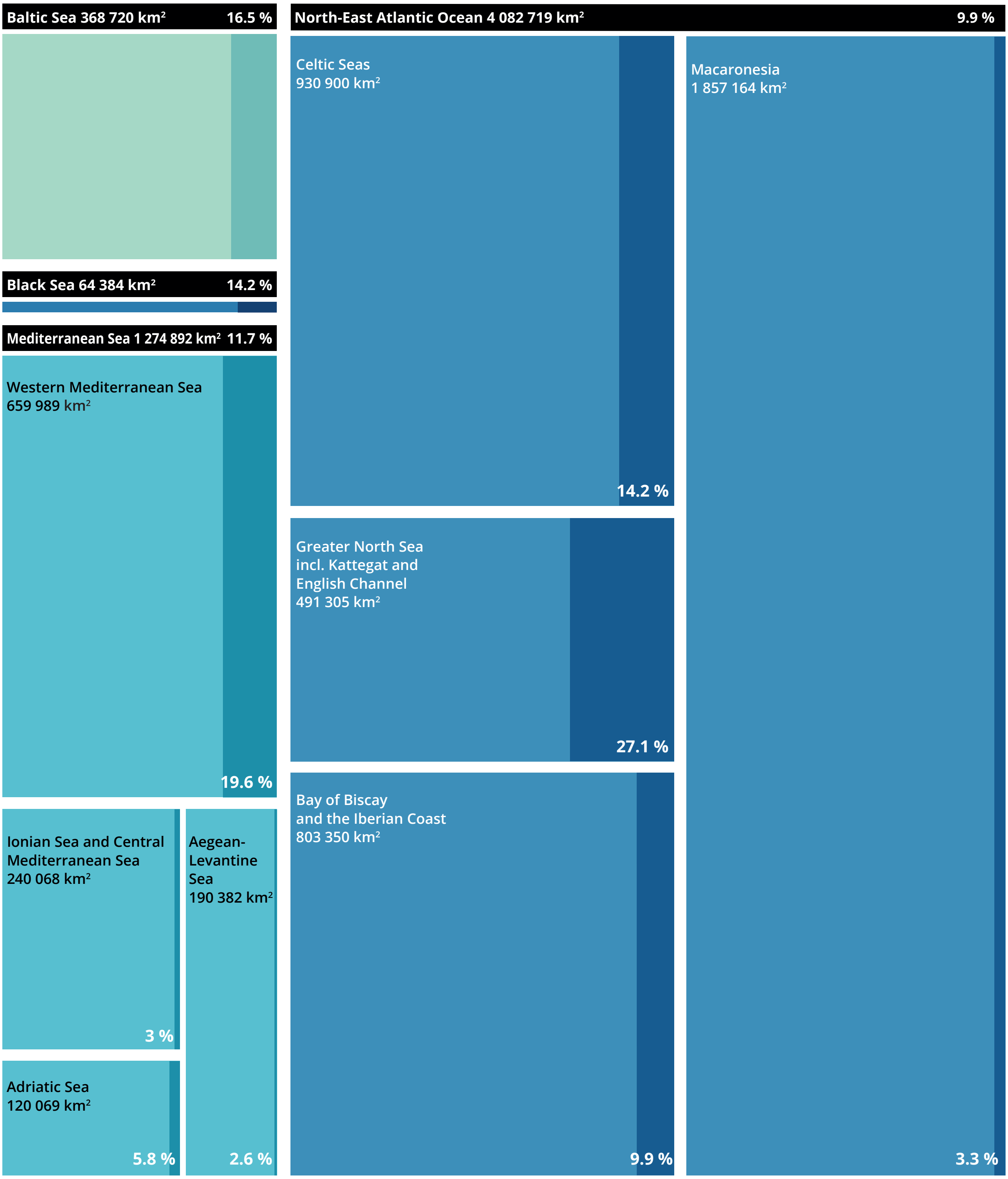
6.3.4 Marine protected areas — significant progress has been made

► See Table 6.5

Marine protected areas (MPAs) and networks of MPAs are a key measure for protecting the marine biodiversity of Europe's seas (EU, 2008a). MPAs are geographically distinct zones for which protection objectives are set. They constitute a connected system for safeguarding biodiversity and maintaining marine ecosystem health and the supply of ecosystem services. Networks of MPAs operate together at various scales and cover a range of protection levels, which work towards objectives that individual MPAs cannot achieve (EEA, 2015a, 2018c).

Approximately 75 % of EU MPAs are sites designated under the EU Habitats Directive (EEC 1992; Chapter 3) and the EU Birds Directive (EEC, 1979). These are an important element of the Natura 2000 network of protected sites — the largest coordinated network of protected areas in the world (EEA, 2018c). The remaining MPAs are sites designated only under national legislation (Agnesi et al., 2017). The next step is to make the Natura 2000 network coherent and representative ensuring adequate coverage of the diversity of the constituent ecosystems, in line with Article 13 of the MSFD.

FIGURE 6.6 The EU part of the regional sea surface area (km²) and the area covered by MPAs in 2016



Note: The quadrants illustrate the relative size of the EU part of each regional sea as well as the proportion of MPAs within them. The dark shading indicates the area covered by MPAs and the percentages are given in figures.

Sources: Agnesi et al. (2017) and EEA (2018c).

From 2012 to 2016, the EU almost doubled its network of MPAs. By 2018 it had reached Aichi biodiversity target 11 — protecting at least 10 % of its sea area within MPAs (United Nations, 2015) — albeit with some variation between the marine regions. Five out of 10 regional seas are still short of reaching the target of 10 % coverage of MPAs (EEA, 2018c; Figure 6.6).

With an entire MPA network designated across the marine territories of 23 EU countries, the next step is to ensure that they deliver the best possible benefits for marine biodiversity. This includes actions such as accurately measuring the degree to which MPAs and the network as a whole are achieving their intended purpose, including general protection of marine biodiversity (see also EEA (2018c)). It has been demonstrated that European MPA networks are being affected by commercial fisheries more than unprotected areas, which raises questions about the true benefit of the MPA network (Dureuil et al., 2018).

However, the establishment of MPA networks in EU waters remains a success story, showing the types of achievements that are possible when countries work towards a common goal, such as halting the loss of biodiversity. However, management efforts need to be improved.

6.4 Responses and prospects of meeting agreed targets and objectives

Overall, EU policy is set for both the long-term recovery and the sustainable use of Europe's seas. However, while the policy framework is among the most ambitious and comprehensive in the world, some of its objectives and goals, or variants thereof, have been in place for decades. These include the ambitions to cease emissions of hazardous substances, to achieve sustainable fisheries, and to establish a representative, coherent network of well-managed MPAs.

> Knowledge gaps remain in relation to the availability of quality information to evaluate progress.

Some targeted management measures, or other legal obligations, resulting from EU policy have been fully implemented and have been successful in reducing, or even removing, some well-known marine pressures. Other measures/obligations have not been implemented or implemented only in part and/or slowly and with limited success. The latter could also be because there is a time lag between implementing a strong pressure-impact causality measure and its having an effect. Furthermore, it could also be because the measures were not designed to deal with multiple pressures and their cumulative impacts. There are also large differences in progress in achieving policy targets within and between EU marine regions (e.g. Figure 6.6). Challenges remain with regard to the amount and quality of information available to evaluate progress. For example, no Member State had adequately reported the up-to-date state of its marine waters by the October 2018 deadline required by the MSFD. In addition, while Member States have established a few new measures, as well as measures integrating policy needs across several policies when implementing the MSFD, certain pressures are still addressed through fragmented, ineffective approaches.

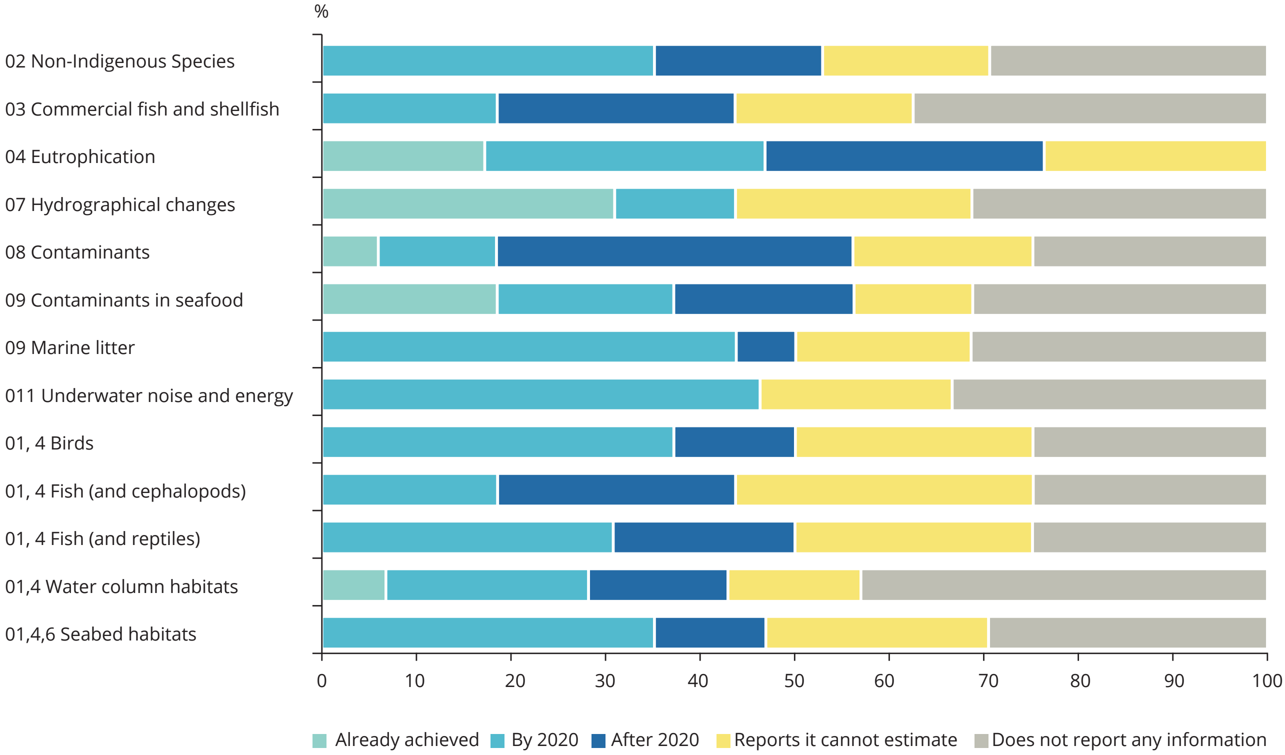
As a result, there seems to be a risk that the measures currently implemented across all policies are not sufficient to achieve the MSFD's good environmental status by 2020. The risk extends to whether they will be able to mitigate the additional adverse effects of the expected increase in maritime activities in forthcoming decades. The risk is compounded by having to achieve both good environmental status and the ambitions of the EU's blue growth strategy in a climate change context.

With many long-term policy commitments coming to fruition in the period 2018-2021, now is the time to make the most of the EU marine policy framework, including reflecting on what should be done differently in the next decade if the EU wants to achieve its long-term vision for clean, healthy, resilient and productive seas.

The implementation of this framework shows, at best, a mixed picture. There are several positive examples of recovery of specific biodiversity features across Europe's seas, reversing increasing pressure trends, and improved sustainability of some uses of the sea. However, these partial successes seem barely to register against the observed continued degradation and the expected increased use of the sea, as well as the observed and forecast worsening of climate change impacts on Europe's seas.

Overall, it seems that the knowledge and political vision to facilitate a change are available, but the question of whether Europe has the necessary resolve to act quickly and effectively enough remains. The root of most problems suffered by Europe's seas is not only the low rate and slow speed of policy implementation but also because there seems to be poor coherence and coordination between all the policies aiming to protect them. Thus, policymakers should all work towards ensuring that the limits to the sustainable use of Europe's seas, represented by achieving good

FIGURE 6.7 **Timelines for achieving good environmental status as reported by Member States**



Note: Member States integrated national, EU and international policies during their implementation of the MSFD to identify existing management measures and gaps in current management. New or additional measures were assigned to fill the gaps identified to address all relevant pressures on the marine environment. Assessment showed that many pressures had not been addressed in existing legislation and that additional efforts will be needed to achieve good environmental status. The timelines for achieving good environmental status therefore vary among topics.

Source: EC (2018a).

environmental status under the MSFD, are respected. Currently, some policies are giving an impetus for growth that does not seem to fulfil this premise.

When assessing the programmes of measures established under the MSFD, the European Commission concluded that, while EU Member States have made considerable efforts, it appears unlikely that good environmental status will be achieved by 2020 (Figure 6.7), as concluded in the present assessment. One of the reasons is that 'certain pressures of transboundary nature, the lack of regional or EU coordination potentially leads to a fragmented and ineffective approach to tackling the pressure' (EC, 2018a).

In conclusion, there may be less of a need to come up with specific new policies, or legislative initiatives, or to reiterate existing deadlines to meet legislation/policy, but rather a need to focus efforts on implementing and integrating existing policies and on fulfilling the intentions behind several thematic policy visions. In this respect, it seems that Europe is still learning: (1) about the limits to the sustainable use of its seas; and (2) how to address challenges of a transboundary or ecosystem-based nature.

A lot has been achieved since Europe first became aware of the effects of pollution on the marine environment, on marine biodiversity and on human health. However, ensuring that Europe's seas keep on supplying the ecosystem services upon which people's basic needs and well-being, and the economy, depend requires managing the unprecedented amount of human activities that are competing to use them — and to do so in the context of climate change. This will entail improved policy integration and a firm commitment to implementing already existing policies as well as increasing cooperation within Europe and with its neighbours.

07.

Climate change

Key messages

- Climate change is happening. Several climate variables, including global and European temperatures and sea level, have repeatedly broken long-term records in recent years. Climate change has substantially increased the occurrence of climate and weather extremes, including heat waves, heavy precipitation, floods and droughts, in many regions of Europe.

- Climate change is creating risks to, and in some cases opportunities for, the environment, the economy and people. The adverse impacts and risks are expected to intensify as the climate continues to change. Europe is also affected by indirect climate change impacts occurring outside Europe through various pathways, such as trade and migration. To limit the adverse effects of climate change, strong mitigation and adaptation measures are needed.

- EU greenhouse gas emissions have decreased by about 22 % in the past 27 years due to the combined result of policies and measures and economic factors. The carbon and energy intensity of the EU economy is lower now than it was in 1990 because of improvements in energy efficiency and the use of less carbon-intensive fuels, especially renewable energy sources. Transport remains one of the biggest challenges ahead to decarbonising the economy.

- Climate change adaptation is increasingly mainstreamed in EU policies, programmes, strategies and projects. Most EEA member countries now have a national adaptation strategy, and an increasing number of cities are adopting local adaptation strategies. The EU adaptation strategy adopted in 2013 has delivered on most of its objectives; however, its evaluation also identified areas where further action is needed.

- The EU is broadly on track towards meeting the target of spending at least 20 % of its budget for 2014-2020 on climate-related measures, but further efforts are needed. This target seems to have triggered a shift in climate-related spending in some policy areas (such as the European Regional Development Fund and the Cohesion Fund) but not in others (such as agriculture, rural development and fisheries).

- Looking ahead, a significant step-up in reductions is needed to achieve the EU's objective of an 80-95 % reduction in greenhouse gas emissions by 2050. While the EU is on track to achieve its 2020 targets on greenhouse gas emissions and renewable energy, progress on the energy efficiency target remains insufficient. Rising energy consumption trends and recent greenhouse gas projections from Member States indicate that the EU is not yet on track towards its 2030 climate and energy targets.

- The magnitude and pace of future climate change, and thus the long-term adaptation challenges, depend on the success of global mitigation efforts to keep the increase in global temperature to well below 2 °C compared with pre-industrial levels and to pursue efforts to limit the increase to 1.5 °C, as stated in the Paris Agreement.

Thematic summary assessment

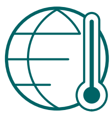
Theme	Past trends and outlook		Prospects of meeting policy objectives/targets		
	Past trends (10-15 years)	Outlook to 2030	2020	2030	2050
Greenhouse gas emissions and mitigation efforts	Improving trends dominate	Developments show a mixed picture	☑ Largely on track	☒ Largely not on track	☒ Largely not on track
Energy efficiency	Improving trends dominate	Developments show a mixed picture	☐ Partly on track	☒ Largely not on track	☒ Largely not on track
Renewable energy sources	Improving trends dominate	Developments show a mixed picture	☑ Largely on track	☒ Largely not on track	☒ Largely not on track
Climate change and impacts on ecosystems	Deteriorating trends dominate	Deteriorating developments dominate	☒ Largely not on track		
Climate change risks to society	Deteriorating trends dominate	Deteriorating developments dominate	☐ Partly on track		
Climate change adaptation strategies and plans	Improving trends dominate	Improving developments dominate	☐ Partly on track		

Note: For the methodology of the summary assessment table, see the introduction to Part 2. The justification for the colour coding is explained in Section 7.3, Key trends and outlooks (Tables 7.4, 7.5, 7.6, 7.7, 7.8 and 7.9).

07.
Climate change

7.1
Scope of the theme

Climate change is a key environmental, economic and social challenge globally and in Europe. On the one hand, most economic activities are contributing to climate change by emitting greenhouse gases or affecting carbon sinks (e.g. through land use change); on the other hand, all ecosystems, many economic activities and human health and well-being are sensitive to climate change.



Mitigation and adaptation are both necessary to limit the risks related to climate change.

This chapter gives an overview of the causes of climate change, of past and projected changes in the climate system and of selected impacts on the environment, the economy and people. Further information on climate change impacts is available in Chapters 3, 4, 5 and 6. This chapter also addresses the two fundamental policy areas to limit the adverse impacts of climate change: mitigation and adaptation. Both policies can be facilitated by targeted financing.

Mitigation of climate change means reducing the emissions of greenhouse gases and enhancing their sinks. Energy is also addressed in this chapter, as it is the key source of greenhouse gases. Climate change is a global problem, which requires global action. The global policy framework comprises the United Nations Framework Convention on Climate Change (UNFCCC), the Kyoto Protocol and the Paris Agreement. The EU and all EEA member countries have ratified these international treaties, and they are jointly responsible for their implementation.

Adaptation to climate change involves making adjustments to minimise the adverse impacts of climate change or to exploit any opportunities that may arise. Adaptation comprises a wide range of measures, including 'grey adaptation' (e.g. building coastal protection infrastructure in response to rising sea levels), 'green and green-blue adaptation' (e.g. planting trees in cities to reduce the urban heat island effect) and 'soft adaptation' (e.g. improving emergency management to deal with natural disasters).

7.2
Policy context

Mitigation and adaptation are both necessary to limit the risks related to climate change. However, the measures and policies are rather different.

Mitigation of climate change has a quantitative target that was agreed at the global level and is delivered through a set of climate and energy policies with specific targets and objectives for 2020, 2030 and 2050. The central aim of the Paris Agreement is to keep the rise in global temperature well below 2 °C above pre-industrial levels and to pursue

TABLE 7.1 Overview of selected policy objectives and targets

Policy objectives and targets	Sources	Target year	Agreement
Climate change mitigation including energy			
Limit human-induced global temperature rise to well below 2 °C (and pursue efforts to limit the temperature increase to 1.5 °C) above pre-industrial levels — building on the UNFCCC Treaty's ultimate objective to stabilise GHG concentrations at a level that would prevent dangerous anthropogenic interference with the climate system	Paris Agreement (UN)	Permanent	Binding international treaty
20 % cut in GHG emissions (from 1990 levels) 20 % of EU energy from renewable sources 20 % improvement in energy efficiency **To achieve the 20 % target:** EU ETS sectors would have to cut emissions by 21 % (compared with 2005) Non-ETS sectors would need to cut emissions by 10 % (compared with 2005) — this is translated into individual binding targets for Member States	EU 2020 climate and energy package	2020	Binding GHG target
At least 40 % cuts in GHG emissions (from 1990 levels) At least 32% of EU energy from renewable sources At least 32.5 % improvement in energy efficiency **To achieve the target of at least 40 %:** EU ETS sectors would have to cut emissions by 43 % (compared with 2005) — to this end, the ETS has been reformed and strengthened for its next trading period (2021-2030) Non-ETS sectors would need to cut emissions by 30 % (compared with 2005) — individual binding targets for Member States were adopted in May 2018	EU 2030 climate and energy framework	2030	Binding GHG target
By 2050, the EU's objective, in the context of necessary reductions by developed countries as a group, according to the IPCC, is to reduce GHG emissions by 80-95 % below 1990 levels Milestones: 40 % cuts in emissions by 2030 and 60 % by 2040	EU 2050 low-carbon roadmap and European Council conclusions of 29/30 October 2009	2050	Non-binding commitment
A climate-neutral economy: net zero GHG emissions by 2050	European Commission strategy: A Clean Planet for All: a European strategic long-term vision for a prosperous, modern, competitive and climate neutral economy	2050	Non-binding commitment
Overarching objectives: secure, competitive and sustainable energy Specific objectives: expand security of energy supply; develop a connected EU energy market; reduce energy demand and improve energy efficiency; decarbonise the energy mix; and increase research and development	Energy Union	2030, 2050	EU strategy
Climate change adaptation			
Decisive progress in adapting to the impact of climate change	7th EAP (EU) (EU, 2013a)	2020	Non-binding commitment
Strengthen resilience and the capacity to adapt to climate-related hazards and natural disasters in all countries	SDG target 13.1 (UN); Paris Agreement (UN) (UN, 2015; UNFCCC, 2015b)	2030	Non-binding commitment
Integrate climate change measures into national policies, strategies and planning	SDG target 13.1 (UN); Paris Agreement (UN) (UN, 2015; UNFCCC, 2015b)	2030	Non-binding commitment

TABLE 7.1 Overview of selected policy objectives and targets (cont.)

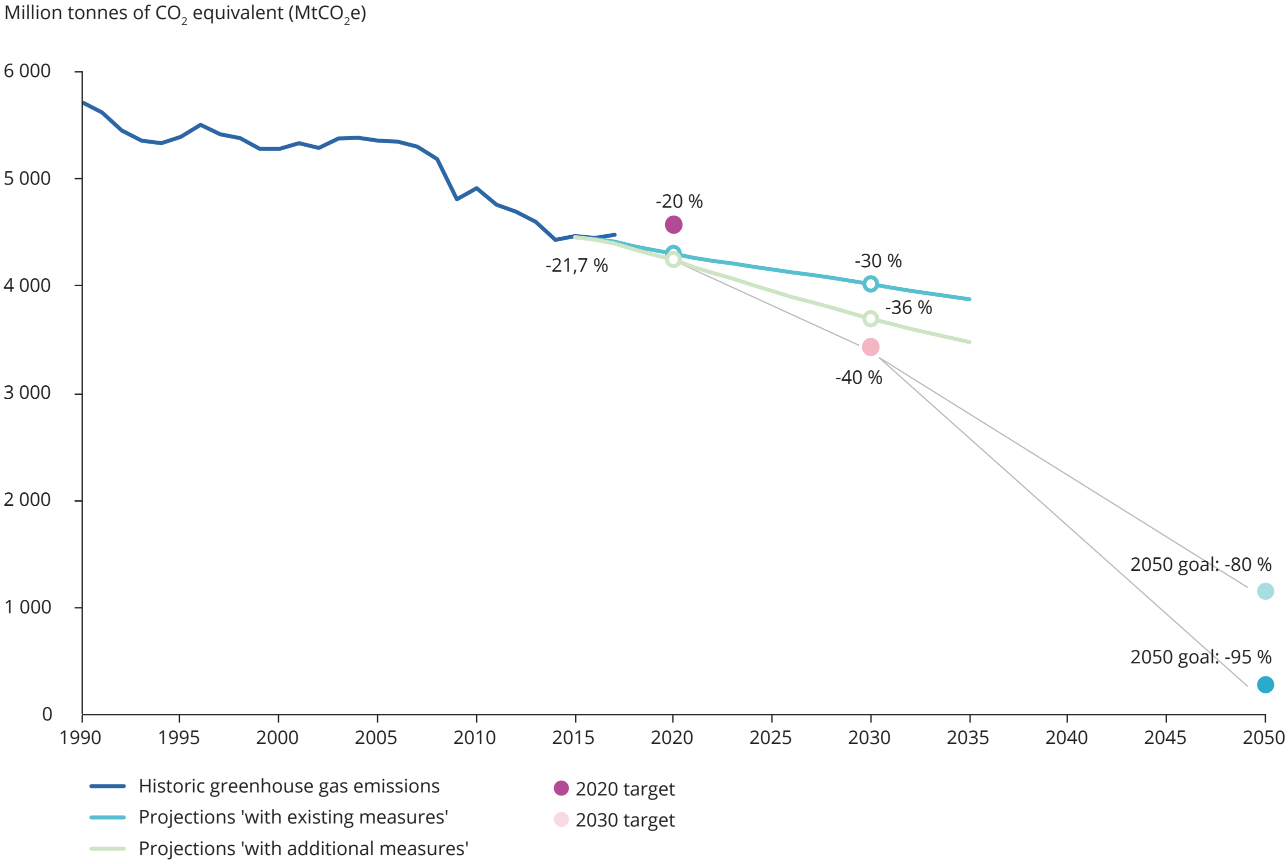
Policy objectives and targets	Sources	Target year	Agreement
Climate change adaptation			
All Member States are encouraged to adopt comprehensive adaptation strategies	EU strategy on adaptation to climate change (Commission Communication and Council Conclusions) (EC, 2013b; Council of the European Union, 2013)	2017	Non-binding commitment
Climate-proofing EU action: mainstream adaptation measures into EU policies and programmes	EU strategy on adaptation to climate change (Commission Communication and Council Conclusions) (EC, 2013b; Council of the European Union, 2013)	N/A	Non-binding commitment
Climate change finance			
Climate action objectives will represent al least 20 % of EU spending (in the period 2014-2020)	EU Multi-annual financial framework (Commission proposal, endorsed by Council and Parliament) (EC, 2011; European Council, 2013)	2014-2020	Non-binding commitment
Developed countries will jointly mobilise USD 100 billion annually to address the mitigation and adaptation needs of developing countries	Copenhagen Accord (UN), Paris Agreement (UN), SDG target 13.4 (UN) (UNFCCC, 2010, 2015b; UN, 2015)	2020	International treaty

Note: 7th EAP, Seventh Environment Action Programme; ETS, Emissions Trading System; GHG, greenhouse gas; IPCC, Intergovernmental Panel on Climate Change; SDG, Sustainable Development Goal; UN, United Nations; UNFCCC, United Nations Framework Convention on Climate Change; N/A, non-applicable.

efforts to limit the temperature increase to 1.5 °C. These global temperature targets correspond directly to remaining carbon budgets, i.e. to the amount of greenhouse gases that human activities can emit without exceeding a given level of warming. The EU has implemented many legislative acts aiming to reduce the emissions of the most important greenhouse gases and to enhance their sinks (see Table 7.1). One feature of the EU's domestic climate legislation is that it has the key objective of delivering on the international commitments agreed by heads of state. The other feature is the internal consistency between the quantified efforts required by Member States and the agreed international objectives binding the EU Member States and the EU as a whole. Specifically, with regard to the provision and use of energy, renewable energy and energy efficiency targets and objectives for 2020 and 2030 were included as headline targets in the Energy Union strategy (EC, 2015c), along with minimum targets for electricity interconnection (10 % by 2020 and 15 % by 2030), and flanked by objectives in other dimensions. The Energy Union and Climate Action Regulation of 2018 (EU, 2018b) sets out the legislative foundation that is meant to deliver a reliable, inclusive, cost-efficient, transparent and predictable governance of the Energy Union and climate action, for the purpose of ensuring that the 2030 and long-term objectives and targets of the Energy Union, in line with the 2015 Paris Agreement, are achieved.

In contrast, there is no single metric for measuring the success of adaptation to climate change. As a result, the policy targets for adaptation at the global and European levels are less quantifiable, and most monitoring activities so far focus on the adaptation process rather than on quantitative outcomes. In addition to the adaptation policies and targets mentioned explicitly in Table 7.1, climate change adaptation also requires 'mainstreaming' — or making part of everyday practice — in many other EU policies addressing climate-sensitive issues. Of particular relevance are policies for disaster risk reduction (e.g. EU Civil Protection Mechanism, EU action plan on the Sendai Framework for Disaster Risk Reduction), the common agricultural policy, the common fisheries policy, the Floods Directive, the Water Framework Directive, the forest policy, the nature directives, and policies related to public health. The effectiveness

FIGURE 7.1 Greenhouse gas emission trends and projections in the EU-28, 1990-2050



Note: The GHG emission trends, projections and target calculations include emissions from international aviation, and exclude emissions and removals from the LULUCF sector. The 'with existing measures' scenario reflects existing policies and measures, whereas the 'with additional measures' scenario considers the additional effects of planned measures reported by Member States.

Source: EEA, based on the final 2019 EU GHG inventory submission to the United Nations Framework Convention on Climate Change and projections reported by EU Member States under the EU Monitoring Mechanism Regulation.

of adaptation measures often can only be assessed after an extreme climate-related event. However, there is increasing evidence globally and in Europe that well-designed adaptation measures in response to extreme events have decreased the death toll caused by subsequent heat waves and the economic damage from subsequent river flooding (Fouillet et al., 2006; WMO and WHO, 2015; Thieken et al., 2016).

Mitigation and adaptation are facilitated by a suitable policy framework, earmarked financial resources, and targeted information and knowledge. There are quantified targets for climate change finance at the global and the European levels (see Table 7.1). Interestingly, none of these targets distinguishes between mitigation and adaptation. Further support for adaptation measures in Europe is provided by, among others, the Copernicus Climate Change Service (C3S) and dedicated research projects (e.g. under Horizon 2020 and JPI Climate).

7.3 Key trends and outlooks

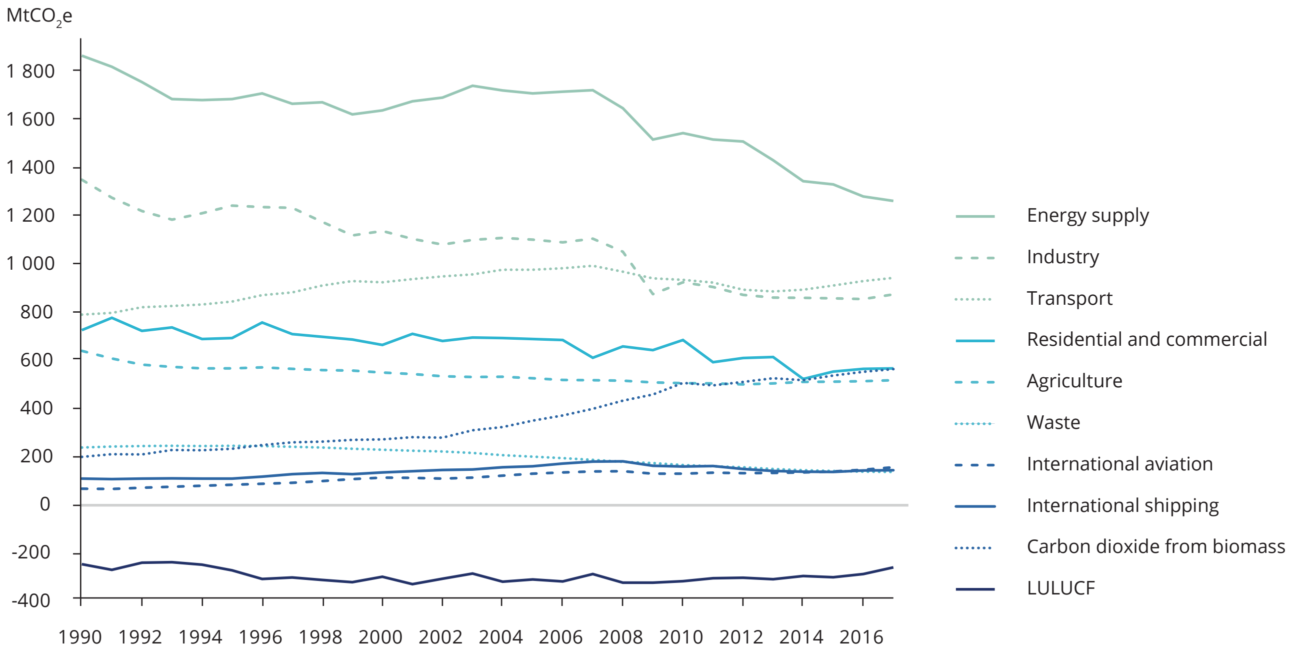
7.3.1 Emissions of greenhouse gases and climate change mitigation efforts

► *See Table 7.4*

Snapshot of the EU's greenhouse gas emission trends and projections

Figure 7.1 shows that the total greenhouse gas (GHG) emissions excluding land use, land use change

FIGURE 7.2 **Greenhouse gas emissions by main sector in the EU-28, 1990-2017**



Note: The sectoral aggregations are:
Energy supply CRF 1A1 (energy industries) + 1B (fugitives); industry CRF 1A2 (manufacturing industries and construction) + CRF 2 (industrial processes); transport CRF 1.A.3; residential and commercial CRF 1A4a (commercial) + CRF 1A4b (residential); agriculture CRF 1A4c (agriculture, forestry and fishing) + CRF 3 (agriculture); waste CRF 5 (waste); land use, land use change and forestry CRF 4 (LULUCF).
International aviation, international shipping and CO_2 biomass are memorandum items according to UNFCCC reporting guidelines and are not included in national GHG totals. International shipping is not included in any targets under the UNFCCC or the Kyoto Protocol. International aviation is included in the EU's 2020 and 2030 GHG targets. CO_2 from biomass is reported separately to avoid any double-counting of emissions from biomass loss in the LULUCF sector.

Source: EEA.

and forestry (LULUCF) and including international aviation declined by 1.2 billion tonnes of carbon dioxide equivalent (CO_2e) between 1990 and 2017. This represents a reduction of 22 % in the past 27 years.

The reduction in total GHG emissions since 1990 means that the EU remains on track to meet its 2020 target. However, according to the latest projections reported by Member States (EEA, forthcoming (a)), only the 2020 target is within reach. Significant efforts will therefore be needed to reach the 2030 target and, even more substantial efforts, to reach the 2050 objective (EEA, 2018j).

The EU is the sum of its Member States and most Member States have reduced emissions since 1990 (Table 7.3). About 50 % of the EU net-decrease was accounted for by Germany and the United Kingdom. The overall net GHG emission reductions achieved by most Member States were partly offset by higher GHG emissions in a few Member States.

On an aggregate level, Figure 7.2 shows that GHG emissions decreased in the majority of sectors between 1990 and 2017, with the notable exception of domestic and international transport. The largest decrease in emissions in absolute terms occurred in energy supply and industry, although agriculture, residential and commercial (i.e. buildings), and waste management have all contributed to the positive trend in GHG emissions since 1990. The figure also shows the strong increase in carbon dioxide (CO_2) emissions from

TABLE 7.2 Trends in EU emission-source categories between 1990 and 2017

Emission source category	$MtCO_2e$
Road transportation (CO_2 from 1.A.3.b)	170
Refrigeration and air conditioning (HFCs from 2.F.1)	93
Aluminium production (PFCs from 2.C.3)	-21
Agricultural soils: direct N_2O emissions from managed soils (N_2O from 3.D.1)	-22
Cement production (CO_2 from 2.A.1)	-26
Fluorochemical production (HFCs from 2.B.9)	-29
Fugitive emissions from natural gas (CH_4 from 1.B.2.b)	-37
Commercial/institutional (CO_2 from 1.A.4.a)	-38
Enteric fermentation: cattle (CH_4 from 3.A.1)	-43
Nitric acid production (N_2O from 2.B.2)	-46
Adipic acid production (N_2O from 2.B.3)	-56
Manufacture of solid fuels and other energy industries (CO_2 from 1.A.1.c)	-60
Coal mining and handling (CH_4 from 1.B.1.a)	-66
Managed waste disposal sites (CH_4 from 5.A.1)	-73
Residential: fuels (CO_2 from 1.A.4.b)	-115
Iron and steel production (CO_2 from 1.A.2.a +2.C.1)	-116
Manufacturing industries (excl. iron and steel) (energy-related CO_2 from 1.A.2 excl. 1.A.2.a)	-253
Public electricity and heat production (CO_2 from 1.A.1.a)	-433
Memo items:	
International aviation (CO_2 from 1.D.1.a)	89
International navigation (CO_2 from 1.D.1.b)	35
Total GHGs [excluding LULUCF, excluding international transport]	-1 327
Total GHGs [excluding LULUCF, including international aviation]	-1 237

Notes: The numbers in the table include the EU-28 and Iceland and show the change in emissions between 1990 and 2017. Only those emission sources that have increased or decreased by more than 20 million tonnes of CO_2 equivalent are shown in the table.

CH_4, methane; CO_2, carbon dioxide, N_2O, nitrous oxide.

Source: EEA, based on the final 2019 EU GHG inventory submission to the UNFCCC.

TABLE 7.3 Country comparison — climate mitigation variables and indicators by country: trends and projections

	Total GHG emissions in 2017 ($MtCO_2e$)	Change in total GHG emissions, 1990-2017 ($MtCO_2e$)	Change in total GHG emissions, 1990-2017 (%)	GHG emissions per GDP in 2017 (PPS, EU-28=100)	GHG emissions per capita in 2017, (tCO_2e per person)	Change in the carbon intensity of energy 1990-2017 (%)	Change in the total energy intensity of the economy 1990-2017 (%)
Austria	84.5	5.0	6.2	87	9.6	-20.0	-18.3
Belgium	119.4	-30.4	-20.3	103	10.5	-29.0	-27.1
Bulgaria	62.1	-40.5	-39.5	204	8.8	-6.1	-54.0
Croatia	25.5	-6.9	-21.3	114	6.2	-13.0	-20.5
Cyprus	10.0	3.6	55.7	156	11.6	2.7	-28.7
Czechia	130.5	-69.3	-34.7	157	12.3	-28.9	-48.4
Denmark	50.8	-21.3	-29.5	79	8.8	-32.9	-35.5
Estonia	21.1	-19.5	-48.0	232	16.0	-14.1	-64.8
Finland	57.5	-14.8	-20.5	109	10.4	-33.2	-24.5
France	482.0	-74.6	-13.4	79	7.2	-21.8	-25.5
Germany	936.0	-327.2	-25.9	105	11.3	-16.3	-40.1
Greece	98.9	-6.7	-6.4	156	9.2	-15.0	-13.0
Hungary	64.5	-29.7	-31.5	111	6.6	-25.5	-38.5
Ireland	63.8	7.3	12.9	84	13.3	-13.1	-66.1
Italy	439.0	-83.1	-15.9	86	7.3	-22.8	-10.8
Latvia	11.8	-14.8	-55.7	104	6.1	-31.4	-54.5
Lithuania	20.7	-27.9	-57.3	107	7.3	-23.6	-68.2
Luxembourg	11.9	-1.2	-9.2	90	20.0	-20.7	-51.0
Malta	2.6	0.3	12.2	65	5.5	-11.6	-63.3
Netherlands	205.8	-20.5	-9.1	107	12.0	-7.3	-34.2
Poland	416.3	-58.7	-12.4	178	11.0	-11.6	-61.7
Portugal	74.6	13.9	22.8	108	7.2	-8.0	-4.0
Romania	114.8	-134.1	-53.9	107	5.9	-18.1	-69.6
Slovakia	43.5	-29.9	-40.8	120	8.0	-35.2	-63.6
Slovenia	17.5	-1.2	-6.2	114	8.5	-19.0	-31.1
Spain	357.3	64.0	21.8	95	7.7	-14.6	-14.3
Sweden	55.5	-17.2	-23.7	52	5.5	-31.0	-39.8
United Kingdom	505.4	-304.4	-37.6	83	7.7	-24.7	-49.3
EU-28	**4 483.1**	**-1 239.8**	**-21.7**	**100**	**8.8**	**-20.5**	**-36.3**
Iceland	5.9	2.1	54.8	151	17.2	-40.3	13.4
Liechtenstein	0.2	0.0	-15.2	-	5.1	-	-
Norway	54.4	2.5	4.9	81	10.3	-10.0	-22.4
Switzerland	52.6	-4.1	-7.3	46	6.2	-	-
Turkey	537.4	317.6	144.5	116	6.7	-3.5	-12.8

Notes: The year 1990 is used as the reference year to show trends in GHG emissions on a comparable basis for all Member States and to assess progress towards the EU 2020 and 2030 targets. These data should not be used to assess the achievement of climate mitigation targets of individual Member States. GHG data are based on the final 2019 GHG inventory submissions to the UNFCCC (EEA, 2019c). GHG aggregates include international aviation and exclude the LULUCF sector. The source of GDP data is the European Commission's AMECO database (EC, 2019a). Where gaps were present, GDP was estimated based on trends in the data reported to the World Bank (Bulgaria, Croatia, Estonia, Hungary, Malta and Slovakia) (World Bank, 2019). Underpinning energy and population data are from Eurostat (Eurostat, 2019a, 2019b). For the Western Balkan countries, there is no requirement to report GHG inventories annually using the CRF Reporter as Annex I Parties to UNFCCC do. However, climate change information, including GHG inventories and mitigation actions, is available from the Parties' biennial update reports ([1]) to the UNFCCC and from European Commission projects such as the Environment and Climate Regional Accession Network (ECRAN ([2])).

Source: EEA.

([1]) https://unfccc.int/BURs
([2]) http://www.ecranetwork.org/Climate

biomass combustion, incentivised by the EU's policy on renewables and by the EU Emissions Trading Scheme (EU ETS) (EEA, 2019a). Although net removals from LULUCF increased over the period, the strong increase in CO_2 emissions from biomass combustion highlights the rapidly increasing importance of bioenergy in climate and energy responses across the EU. The pressures from these sectors are relevant not only to climate change but also to other environmental variables (Chapter 13).

On a more detailed level, Table 7.2 shows that the largest emission reductions ocurred in manufacturing industries and construction, electricity and heat production, and in residential combustion. The largest decrease in emissions in relative terms took place in waste management, due to reduced and better controlled landfilling. GHG emissions from hydrofluorocarbons (HFCs) and from road transportation increased substantially over the period 1990-2017.

This represents a challenge for Member States and for achieving the 2030 targets under the EU Effort Sharing Regulation, as transport accounts for about one third of emissions covered by the sectors in which national mitigation targets apply.

Currently, the EU's climate mitigation policy is based on a distinction between GHG emissions from large industrial sources, which are governed by the EU ETS (EC, 2019c), and emissions from sectors covered by the Effort Sharing Decision (EC, 2019b). For the ETS, there is an overall cap for the period 2013-2020, which puts a limit on emissions from installations by setting the maximum amount of emissions allowed during the 8-year period. For the sectors covered by the Effort Sharing Decision, there are binding annual GHG emission targets for Member States for the period 2013-2020.

Greenhouse gas emissions decreased in the majority of sectors between 1990 and 2017.

Between 2005 and 2017, emissions covered under the EU ETS decreased more rapidly than those from sectors not covered by the System. ETS emissions did increase faster than non-ETS emissions during the first phase of the EU ETS between 2005 and 2007, coinciding with a period of greater consumption of hard coal and lignite for power generation. Since then, however, ETS emissions have decreased at a faster rate than non-ETS emissions. In addition to the improvements observed in carbon intensity and energy efficiency in the heat and power sector, the economic recession that started in the second half of 2008 affected ETS sectors more than those outside the ETS (EEA, 2014b). The largest industrial installations are part of the EU ETS and the contraction in gross value added in industry appears to have led to a significant reduction in final energy demand and emissions in the sector. When emissions from energy supply were allocated to the end-user sectors, EEA figures showed that the largest emission reductions in the period following the economic recession were largely accounted for by industry as a whole (EEA, 2012).

Of the net EU reduction in total GHG emissions between 2005 and 2017, two thirds was accounted for by the ETS, and one third by the sectors not covered under the ETS. The sectors falling under the scope of the Effort Sharing Decision (soon to become the Effort Sharing Regulation) currently represent about 60 % of total greenhouse gas emissions in the EU, and they broadly include residential and commercial (buildings), transport, waste, agriculture and the part of industry not covered by the ETS. Of these sectors, improvements since 2005 have been more visible for buildings, non-ETS industry and waste management. For transport, emissions decreased between 2007 and 2013 but have increased consecutively in the last few years for both freight and passenger cars. For agriculture, emissions have increased in the past few years, both from livestock and from soils.

Analysis of key past and future trends and drivers

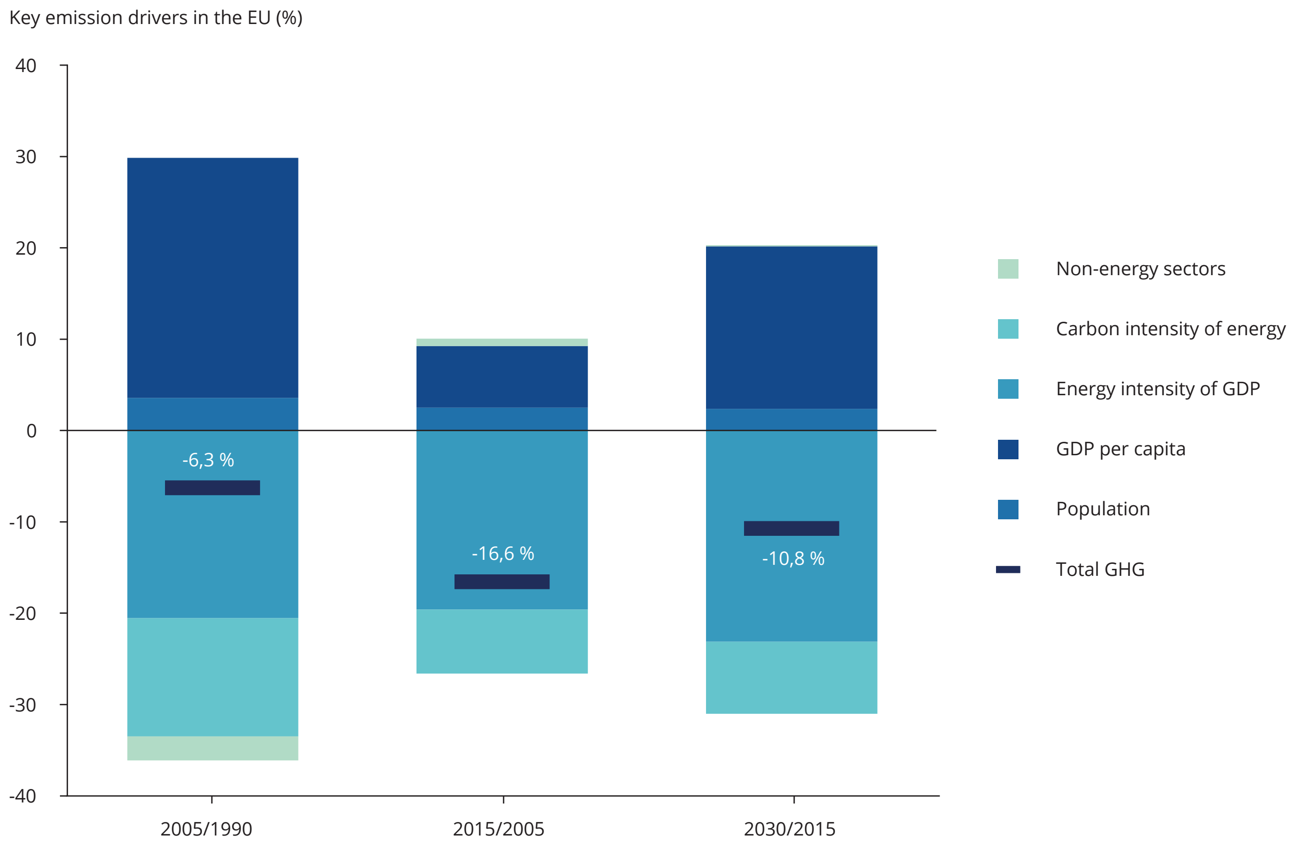
The speed of reduction in GHG emissions observed in the past will not be sufficient to meet the 2030 targets unless there are further improvements in both energy efficiency and carbon intensity (EEA, 2017a).

Figure 7.3 shows a comparison of key drivers underpinning GHG emissions in three different periods (1990-2005, 2005-2015 and 2015-2030), based on information reported by EU Member States.

Overall, the four main findings at EU level are:

1. Higher gross domestic product (GDP) would usually lead to higher GHG emissions, other factors being equal, because economic growth is still intrinsically linked to an energy system that remains heavily dependent on fossil fuels in most European countries (EEA, 2014b). Yet, the figure shows that emissions decreased and are expected to decrease further as GDP increases, confirming that attempts to mitigate climate change do not necessarily conflict with a growing economy.
In addition, the GHG intensities of Member States have both decreased since 1990 and converged (EEA, 2017a). One reason for this convergence is the strong growth in the use of renewable

FIGURE 7.3 Drivers of reductions in GHG emissions in the EU-28, 1990-2017



Note: Based on final GHG inventories to the UNFCCC and projections data reported under the EU Monitoring Mechanism Regulation by 29 May. The decomposition analysis is based on the logarithmic mean Divisia index (LMDI). The bar segments show the changes associated with each factor alone, holding the other factors constant. Projections at EU level have been aggregated based on Member States' submissions under EU reporting requirements. GHG emission projections in this figure refer to those in the 'with existing measures' scenario. The EU Reference Scenario 2016 from the European Commission (based on the PRIMES and GAINS models) was used to gap-fill incomplete reporting for specific Member States' parameters.

Source: EEA.

energy sources in most Member States and a clear move towards less carbon-intensive fuels. Due to this strong convergence, GHG emissions per capita and per GDP are more similar now across Member States than they were in 1990. Projections by Member States suggest a continued decoupling of GHG emissions alongside higher economic growth for the period 2015-2030. However, higher levels of renewables in the energy mix will be required to achieve complete decoupling between GHG emissions, energy and economic growth.

Fulfilling the 2030 targets requires further energy efficiency and carbon intensity improvements.

2. The lower carbon intensity of energy has been a key factor underpinning lower emissions, in spite of a decline in nuclear electricity production in recent years. This positive trend has been due both to the higher contribution from renewable energy sources in the fuel mix and to the switch from more carbon-intensive coal to less carbon-intensive gas.

The lower carbon intensity of energy (i.e. fewer emissions from producing and using energy) was, and is, expected to remain an important factor underpinning lower emissions in the future. According to Member States' projections, both an increase in renewable energy sources and a less carbon-intensive fossil fuel mix, with less coal than gas and lower oil consumption, are expected to drive reductions in emissions in the future.

≈80 %

of all EU greenhouse gas emissions come from fossils fuels.

3. The decrease in the energy intensity of GDP has been the largest contributing factor to lower GHG emissions from fossil fuel combustion in the past. The lower energy intensity of economic growth can be explained by improvements in energy efficiency (transformation and end use, including energy savings) and the strong uptake of renewables, as well as by changes in the structure of the economy and a higher share attributable to the services sector than to the more energy-intensive industrial sector (3). The decrease in the energy intensity of GDP is expected to remain a key factor in the transition to a low-carbon economy and, potentially, to carbon neutrality. This means continued improvements in energy efficiency — in both transformation and end use.

4. The largest emission reductions in the period 1990-2005 occurred in the non-energy sectors. In the period 2005-2015, energy-related emissions from both production and consumption decreased faster than non-energy emissions. Although the effects of the non-energy sectors shown in the decomposition analysis appear to be modest, the actual emission reductions observed in industrial processes, agriculture and waste management have been substantial since 1990. The largest emission reductions are projected to occur in the energy sector, although all sectors of the economy are expected to contribute to meeting climate mitigation objectives.

Overall, the same factors driving emission reductions in the past are also expected to play a key role in the future, although to a different degree. For the EU as whole, the projected overall estimates for reductions in GHG emissions by 2030 (with existing policies and measures), as reported by Member States, are consistent with a 30 % reduction compared with 1990 (excluding LULUCF and including international aviation). When additional measures are included, the gap closes to about a 36 % projected reduction compared with 1990. Whereas the EU is on track to achieve its 20 % GHG emission reduction target by 2020, more efforts to reduce GHG emissions will be needed to achieve its reduction target of at least 40 % by 2030 (EEA, 2018j) ([4]). These results suggest that efforts should, together with lower energy intensity and higher efficiency, concentrate on further improving the carbon intensity of energy production and consumption. The transport sector remains one of the key challenges to decarbonising the economy, although all sectors of the economy should contribute to the emission reductions that are required for the EU and Member States to meet their mitigation targets.

It is worth highlighting that, notwithstanding the different trends by country and region, warmer winters are another factor contributing to lower GHG emissions in Europe. In addition, there has also been lower fuel use due to the lower demand for space heating because of better insulation standards and retrofitting in buildings. There is a clear positive correlation between heating degree-days and fuel use and emissions from the residential sector. According to Eurostat data (Eurostat, 2019a), the current demand for heating in Europe is below its long-term average (defined as 1980-2004). An EEA analysis on heating and cooling showed that

([3]) There are various reasons for the lower share of industry in Europe's economy. Industry can close down, become more efficient and even relocate. Carbon footprint statistics (consumption-based approach) can be useful for assessing the impact of domestic economic activities abroad and for analysing emission trends. Yet, the assessment of progress towards GHG mitigation targets used here is consistent with how the targets have been defined and agreed both domestically and internationally (production-based approach). Also, while Europe may be indirectly generating some of the emissions elsewhere for final consumption in Europe — via imported products — a share of Europe's own emissions can also be linked to final consumption of European goods outside Europe — via EU exports.

([4]) In June 2019, the European Commission published its assessment of Member States' draft national energy and climate plans (NECPs) to implement the Energy Union objectives and the EU 2030 energy and climate targets. On aggregate, the projected emission reductions submitted in draft plans appear broadly consistent with the at least 40 % GHG reduction commitment under the Paris Agreement. The significant difference between the expected emission reductions in the draft NECPs and the 2019 projections reported by Member States under the EU Monitoring Mechanism Regulation can be explained by the different gap-filling methodologies that have been used when the 'with additional measures' (WAM) scenarios were not reported by Member States.

TABLE 7.4 Summary assessment — greenhouse gas emissions and mitigation efforts

Past trends and outlook		
Past trends (10-15 years)		The EU has reduced its GHG emissions by 22 % since 1990 primarily as a result of improved energy efficiency, higher shares of renewable energy and a less carbon-intensive fossil fuel mix. Other key factors, such as structural changes in the economy towards the services sector, the effects of the economic recession, and a lower demand for heat as a result of milder winter conditions and improved building insulation also played a role.
Outlook to 2030		The projected reductions in GHG emissions by 2030 (with existing policies and measures), as reported by Member States, are consistent with a 30 % reduction compared with 1990 (excluding LULUCF and including international aviation). When additional measures are included, the projected reductions would reach about 36 % relative to 1990.
Prospects of meeting policy objectives/targets		
2020	☑	The EU remains on track to achieve its 20 % 2020 targets compared with 1990.
2030	☒	Further mitigation efforts are required to meet the target to reduce GHG emissions by at least 40 % by 2030 compared with 1990.
2050	☒	Even faster rates of emissions reductions are required to meet the 2050 objective of a reduction in GHG emissions of 80-95 %.
Robustness		GHG historical data are based on GHG inventories reported to the UNFCCC and to the EU under the EU Monitoring Mechanism Regulation. Although there is uncertainty in emission estimates, GHG inventories undergo a thorough quality assurance/quality checking and review process on an annual basis. Outlooks are based on GHG projections data from Member States, as reported under the EU Monitoring Mechanism Regulation. The uncertainty in the projections is higher than that in GHG inventories, but the estimates for 2020 and 2030 at EU level are fully consistent with what Member States report to the EU.

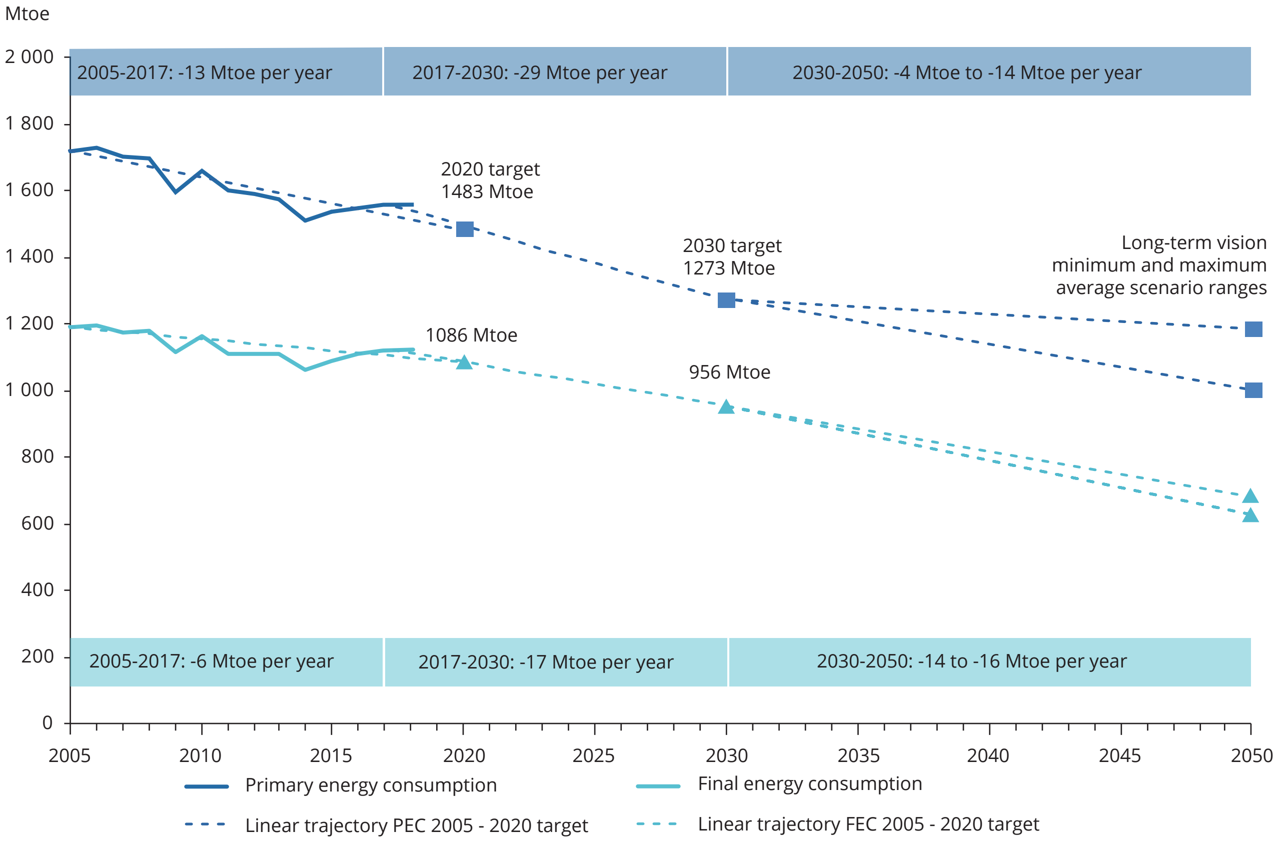
heating degree-days have decreased by about 0.5 % per year between 1981 and 2014, and particularly in northern and north-western Europe. In parallel, cooling degree-days increased on average by almost 2 % per year during the same period, particularly in southern Europe (EEA, 2019g). Because temperatures in Europe are projected to increase, the trends towards fewer heating degree-days and more cooling degree-days are also expected to continue — if not to accelerate.

In summary, the EU has so far managed to reduce its GHG emissions since 1990 due to a combination of factors, including:

- the effects of a number of policies (both EU and country-specific), including key agricultural and environmental policies in the 1990s, and climate and energy policies in the 2000s;
- the growing use of energy from renewable sources;
- the use of less carbon-intensive fossil fuels (e.g. the switch from coal to gas);
- improvements in energy efficiency;
- structural changes in the economy, with a higher share of total GDP accounted for by services and a lower share by more energy-intensive industry;
- the effects of economic recession;
- the milder winters experienced in Europe on average since 1990, which has reduced the demand for energy to heat buildings.

Finally, in spite of good progress in reducing GHG emissions and in decarbonising the EU economy, fossil fuels are still the largest source of energy and emissions in the EU. They contribute to roughly 65 % of the EU's final energy and to almost 80 % of all EU GHG emissions. There cannot be a complete decoupling of emissions from economic growth in a fossil fuel-based economy. This is because energy demand, which to date is mostly fossil fuel driven, remains connected to economic growth. This also implies that the higher the contribution from renewables, the easier it will be to break the link between economic growth, energy demand and GHG emissions. Most importantly, the more the EU reduces its total energy consumption through energy efficiency improvements, the less renewables need to be stepped up to replace fossil fuels.

FIGURE 7.4 **Primary and final energy consumption in the EU, 2005-2017, 2020 and 2030 targets and 2050 scenario ranges for a climate neutral Europe according to the EU strategic long-term vision for 2050**



Note: The 2020 target represents energy savings of 20 % from levels projected for 2020 in the Commission's energy baseline scenario of 2008. The indicative energy efficiency target for 2030 represents an improved energy efficiency of at least 32.5 % compared with 2030 projections in the same energy baseline scenario. The 2050 values represent indicative ranges for primary and final energy consumption that, combined with very high shares of energy from renewable sources in the energy mix, would allow the EU to reach carbon neutrality by 2050. The 2050 values are drawn from the carbon neutrality scenarios '1.5 TECH' and '1.5 LIFE' in the in-depth analysis accompanying the Commission's recent strategic long-term vision for a climate-neutral economy by 2050.

PEC, primary energy consumption; FEC, final energy consumption.

Sources: EC (2008, 2018c, 2018e); EEA (forthcoming (b), forthcoming (c)); European Council (2014); Eurostat (2019a).

Overall, the EU is reducing its energy consumption, but this trend has reversed since 2014.

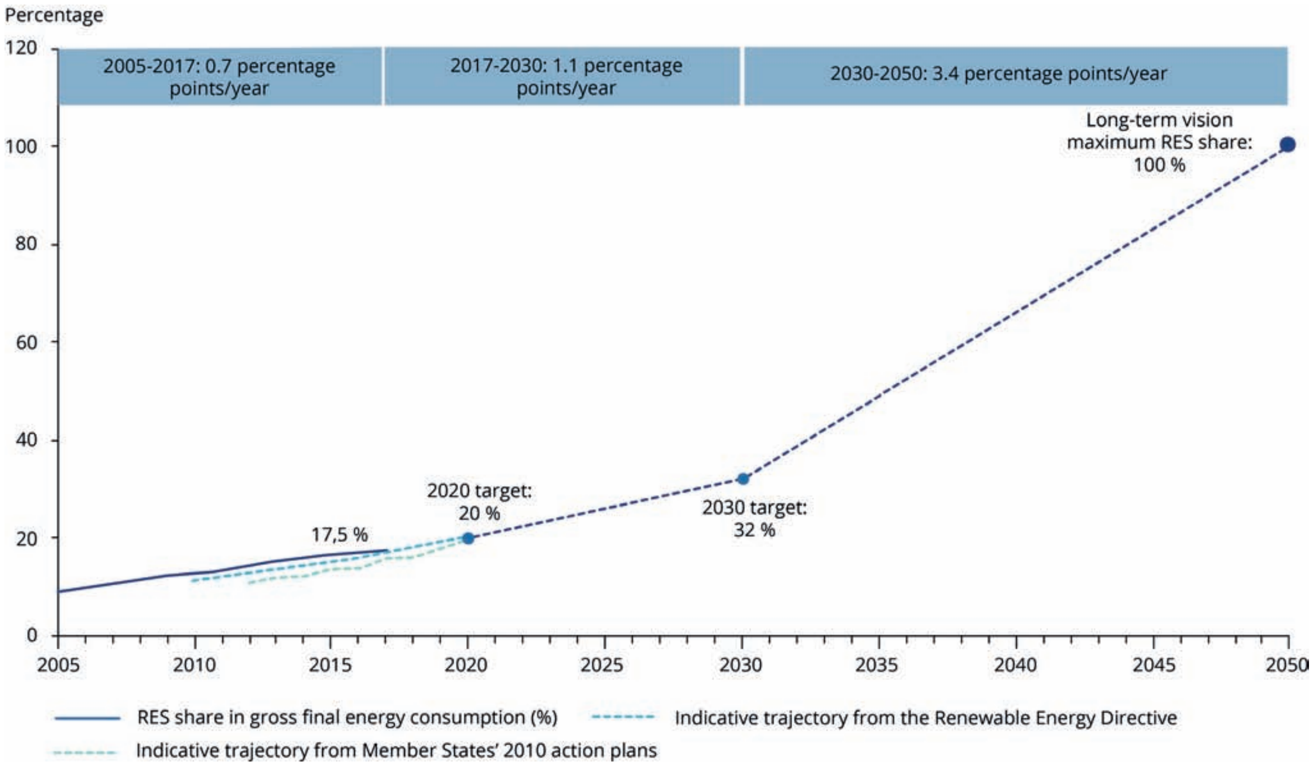
7.3.2
Energy efficiency and renewable energy sources

► *See Table 7.5 and Table 7.6*

Access to energy sustains the provision of key societal services, ranging from the temperature control and illumination of buildings to cooking, telecommunication, transport, agriculture, farming, mining and manufacturing of the goods we consume. However, supplying this energy at all times gives rise to many environmental risks and impacts, from global and long-term ones, such as climate change, to regional and local air pollution, the contamination of soils, surface waters and ground waters, and damage to sensitive ecosystems. The environment is showing signs of stress, as our energy consumption gives rise to approximately two thirds of all EU GHG emissions and as air quality declines to dangerous levels in certain areas, especially in regions that rely intensively on burning coal.

To make the provision and use of energy more sustainable and climate compatible, the EU and its Member

FIGURE 7.5 Share of energy from renewable energy sources in the EU's gross final energy consumption, 2005-2050



Note: Values for 2020 and 2030 represent legally binding targets for the minimum share of renewable energy sources in the EU's gross final energy use. The 2050 value represents the indicative share of renewable energy in the EU's gross final consumption that, combined with energy efficiency and other climate mitigation measures, would allow the EU to reach carbon neutrality by 2050. The 2050 value is consistent with the carbon neutrality scenarios '1.5 TECH' and '1.5 LIFE' in the in-depth analysis accompanying the Commission's recent strategic long-term vision for a climate-neutral economy by 2050. The renewable energy shares in the figure follow the accounting methodology put forward under Directive 2009/28/EC.

Sources: EC (2013a, 2013d, 2018c, 2018e); EEA (2018b); EU (2009); Eurostat (2019a).

States have agreed to progress towards the energy efficiency and renewable energy headline targets for 2020 and 2030 that were included in the Energy Union framework strategy, and to reform environmentally harmful subsidies, such as support for fossil fuels, limiting the exceptions to vulnerable social groups (EC, 2015c).

Energy efficiency

Overall, the EU is reducing its energy consumption, but this trend has reversed since 2014 (Figure 7.4). Compared with 2005, the EU's primary energy consumption in 2016 was 10 % lower as a result of decreases in final energy consumption, changes in the fuel mix used to produce electricity and heat (higher penetration of renewables and natural gas) and of improved efficiency in the conversion of primary energy sources (e.g. coal and gas) into final energy.

In 2017, final energy consumption in the EU was 6 % lower than in 2005 and 3 % higher than in 1990. The main drivers of the decrease since 2005 were the implementation of energy efficiency policies, structural changes in the economy towards less energy-intensive industrial sectors

Energy consumption gives rise to approximately 2/3 of EU greenhouse gas emissions.

TABLE 7.5 Summary assessment — energy efficiency

Past trends and outlook		
Past trends (10-15 years)		Overall, the EU has been reducing energy consumption and decoupling energy consumption from economic growth. However, this trend has reversed since 2014 and final energy consumption is increasing again, driven in part by economic growth (especially demand from the transport sector) and more energy use by households.
Outlook to 2030		Further improvements in energy efficiency are expected with implementation of current policies. However, the increasing trend in energy consumption since 2014 indicates that reversing this trend will require increased efforts and additional national policies and measures to address energy demand in all sectors, especially transport. Reducing energy consumption through efficiency improvements is cost-effective and has multiple health and environmental benefits. It supports meeting the EU's decarbonisation targets by lowering the demand for carbon-intensive fuels, making it easier for renewables to be substituted for them.
Prospects of meeting policy objectives/targets		
2020	☐	Despite past progress, the EU is at risk of not meeting the 20 % energy efficiency target for 2020 without new and renewed efforts. New measures to reduce energy consumption agreed under the recast of the Energy Efficiency Directive are expected to incentivise ambitious new reductions in the Member States. Without that, assuming that the current rate of progress continues, the EU is not on track to meet its minimum 32.5 % energy efficiency target for 2030 or to achieve its decarbonisation objectives for 2050.
2030	☒	Indicative EU energy efficiency targets beyond 2030 have not yet been defined. However, for the EU to achieve carbon neutrality by 2050, primary and final energy consumption across the EU would have to decrease by at least 31 % and 43 % by 2050 compared with 2005 levels, and possibly by as much as 42 % and 47 %, respectively, combined with very high shares of energy from renewable sources in the energy mix, in accordance with the in-depth analysis accompanying the Commission's recent strategic long-term vision for a climate-neural economy by 2050.
2050	☒	
Robustness		Energy indicators are robust, with energy production, consumption and import data being reported to Eurostat and to the European Commission. GHG and air pollutant emissions linked to energy production and consumption are well understood and quantified. Other environmental aspects related to energy efficiency (e.g. multiple social and health benefits) are less well captured. Outlook information is available and assumptions documented. The assessment of outlooks and the prospects of meeting policy targets also relies on expert judgement.

17.5 %

of the EU's energy came from renewable sources in 2017.

and the 2008 economic downturn. The biggest contributors to the decrease in final energy consumption were the industrial and household sectors (EEA, 2018g). Together these are responsible for approximately four fifths of the decrease since 2005.

Since 2014, levels of primary energy consumption increased again relative to the previous year. In 2017, primary energy consumption in the EU increased by 1 % compared with 2016, primarily due to increased energy demand in the transport sector and increases in the household and services sectors. As in 2016, in 2017 both primary energy consumption and final energy consumption were above the indicative trajectory towards 2020. This continued increase makes achieving the 2020 target increasingly uncertain. Increased efforts are needed from Member States to bring the EU back on track and reverse the trend towards increasing energy consumption.

Renewable energy sources

In 2016, the EU's share of energy from renewable sources (RES) was 17.0 %, increasing to 17.5 % in 2017. This gradual increase has occurred despite an increase in energy consumption from all sources, observed since 2014 across the EU. Steady progress in increasing the RES share indicates the EU has met its indicative trajectory for 2017-2018, as set out in the Renewable Energy Directive (Figure 7.5).

In absolute terms, the largest amount of renewable energy was consumed in the heating and cooling energy market sector, followed by

TABLE 7.6 Summary assessment — renewable energy sources

Past trends and outlook		
Past trends (10-15 years)		The EU has steadily increased the share of energy consumed from renewable sources. However, the annual increase has slowed down in recent years, especially due to increases in total final energy consumption.
Outlook to 2030		Further increases in the use of renewable energy sources are expected with the implementation of current policies. This requires further progress in energy efficiency and continuous further deployment of renewable energy sources along with an increase in their uptake in all sectors, especially in transport. Achieving this needs substantial investment across all sectors, including in industry, transport and the residential sector (also facilitating decentralised production and empowering renewable energy self-consumers and renewable energy communities).
Prospects of meeting policy objectives/targets		
2020	☑	The EU is overall on track to meet its 20 % renewable energy target in 2020. However, a continued increase in energy consumption poses risks for achieving the renewable energy target. The EU is not on track to meet the 10 % target for renewable energy use in transport by 2020. Achieving the minimum target of a 32 % share of gross final energy consumption from renewable sources by 2030 will require an increased pace of deploying renewables, together with efforts to tackle energy demand and increase investors' confidence. While renewable energy targets beyond 2030 have not yet been defined, achieving carbon neutrality by 2050 in accordance with the in-depth analysis accompanying the Commission's long-term vision for a climate-neutral economy would require significant improvements in energy efficiency and the transition to 100 % renewable energy sources in the energy mix (calculated according to the Renewable Energy Directive).
2030	☒	
2050	☒	
Robustness		Energy indicators are robust, with energy production, consumption and import data being reported to Eurostat and to the European Commission. These data allow tracking of energy flows from the production to the consumption side. GHG and air pollutant emissions linked to energy production and consumption are well understood. To some extent, they are quantified in relation to renewable energy sources. Outlook information is available and assumptions documented. The assessment of outlooks and prospects of meeting policy targets also rely on expert judgement.

the renewable electricity market sector (where the growth was mainly driven by wind power and solar photovoltaic systems). Insufficient progress has been achieved so far towards the EU's 10 % target for renewable energy consumption in the transport sector. In addition, average year-on-year RES growth across the EU has slowed since 2015, compared with the average annual pace of growth recorded between 2005 and 2014. With 2020 approaching, the trajectories needed to meet the national targets are becoming steeper. Increasing energy consumption, persistent legal/administrative constraints and further market barriers are hindering the uptake of an increased share of renewables in several Member States. These trends pose a risk for achieving the 2020 target.

7.3.3 Links between climate change mitigation and adaptation

The success of global efforts to reduce greenhouse gas emissions determines the magnitude and pace of climate change and consequently the need for adaptation to its impacts in the long term. Ambitious global mitigation measures are necessary to avoid the most dangerous impacts of climate change, because there are many limits and barriers to adaptation. At the same time, climate change is already occurring, and it will continue for many decades — and, in the case of sea level rise, many centuries — to come, even under the most stringent mitigation policies. Therefore, societies need to

18

of the 19 warmest years on record globally have occurred since 2000.

Since the 1950s, and in particular after 2000, Europe has increasingly experienced heat extremes and heat waves.

adapt to the unavoidable impacts of past and future climate change. In summary, the short-term adaptation challenges are largely independent of mitigation efforts, whereas the long-term climate challenge, and societies' ability to adapt to it, are strongly dependent on the success of global mitigation efforts.

There can be synergies as well as trade-offs between climate change mitigation and adaptation objectives. One strategy that often brings about mitigation as well as adaptation benefits is ecosystem-based adaptation. This is a nature-based solution that uses ecosystem services as part of an overall strategy to increase the resilience and reduce the vulnerability of communities to climate change (Secretariat of the Convention on Biological Diversity, 2009). Examples include natural water retention measures and green infrastructure (EC, 2013c; NWRM, 2019). Ecosystem-based adaptation can generate many environmental, social, economic and cultural benefits (EEA, 2017b; EC, 2018b). For further information, see the Climate-ADAPT platform [5]. Ecosystem-based adaptation can also contribute to climate change mitigation by reducing emissions caused by ecosystem degradation and/or by enhancing carbon stocks. An example of trade-offs between adaptation and mitigation is energy-intensive desalinisation or air conditioning based on fossil fuels.

7.3.4
Climate change and its impacts on ecosystems

► *See Table 7.7*

All ecosystems, many economic activities and human health and well-being are sensitive to climate variability and change. This section gives an overview of key changes in the climate system in the past and future, and of selected impacts on ecosystems. More detailed information on this topic is available in the EEA report *Climate change, impacts and vulnerability in Europe 2016 — an indicator based report* (EEA, 2017c). Specific information about the European climate in a particular year is available in the European state of the climate reports published annually by the C3S (C3S, 2018a).

Average temperature

Global average annual near-surface (land and ocean) temperature in the last decade (2009-2018) was about 0.91-0.96 °C warmer than the pre-industrial average (1850-1899) (Figure 7.6). The European land area has warmed by 1.6-1.7 °C over the same period, with significant regional and seasonal differences. Of the 19 warmest years on record globally, 18 have occurred since 2000 (EEA, 2019f).

All UNFCCC member countries have agreed on the long-term goal of keeping the increase in global average temperature to well below 2 °C compared with pre-industrial levels and have agreed to aim to limit the increase to 1.5 °C. About half of the maximum admissible warming under the Paris Agreement has already been realised. For the three highest of the four representative concentration pathways (RCPs, loosely known as emissions scenarios) considered by the Intergovernmental Panel on Climate Change (IPCC), the global mean temperature increase is projected to exceed 2 °C compared with pre-industrial levels during the 21st century, and most likely in the 2040s (IPCC, 2013; Vautard et al., 2014). 'Very deep and rapid global emissions reductions, requiring far-reaching transitions in all sectors of the economy, are necessary to keep the chance of limiting global mean temperature increase to 1.5 °C (IPCC, 2018).'

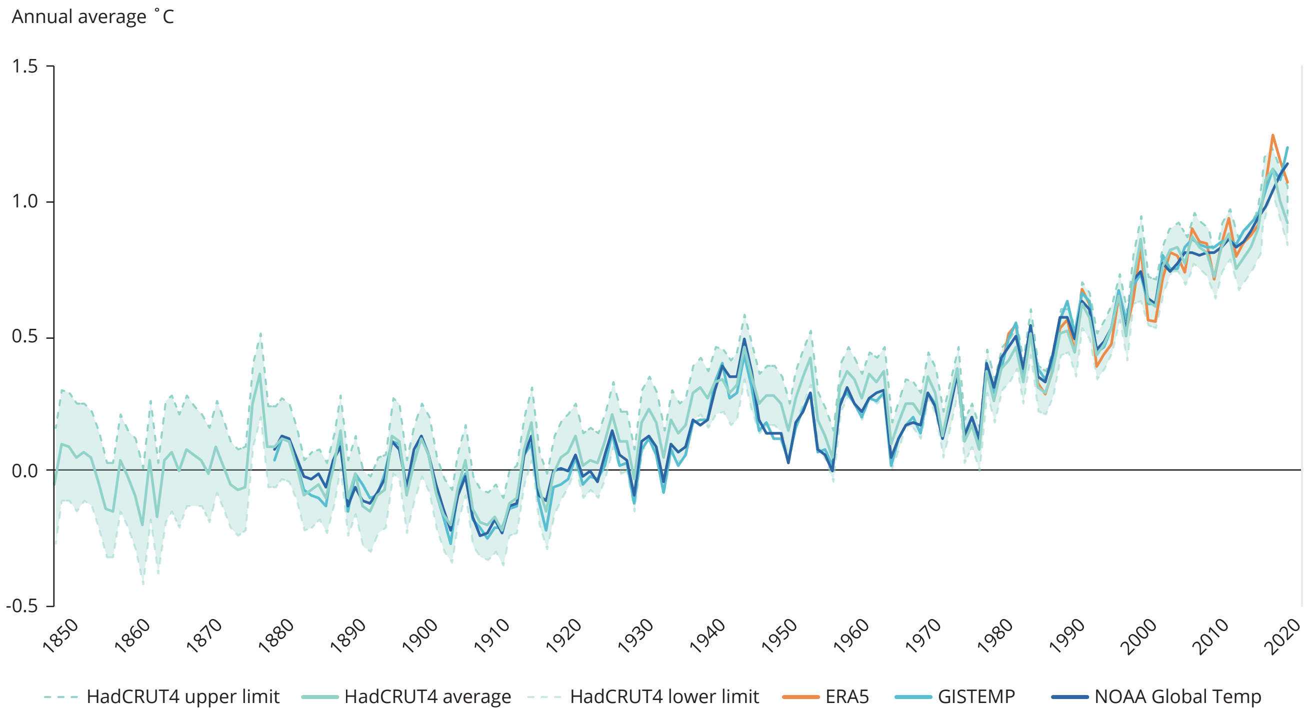
Heat extremes

Annually averaged land temperatures in Europe have increased considerably faster than global temperatures (see above), and daily maximum temperatures in Europe have increased much faster than annually averaged temperatures. This means that a given increase in global mean temperature is associated with a much larger increase in heat extremes in Europe.

Heat extremes and heat waves in Europe have increased considerably since the 1950s, and in particular after 2000. Since publication of the SOER 2015, all-time national temperature records were broken in eight EEA member countries (Poland in 2015, Spain in 2017 and Belgium, France, Germany, Luxembourg, the Netherlands and the United Kingdom in 2019), several of them with a large margin. In the same period, national records for the warmest night, which is particularly relevant from a human health perspective, were broken in nine countries (Austria in 2015, France and Slovenia in 2017, the Netherlands

[5] https://climate-adapt.eea.europa.eu/eu-adaptation-policy/sector-policies/ecosystem

FIGURE 7.6 **Average global near-surface temperature since 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, C3S by European Centre for Medium-Range Weather Forecasts. Light green area: 95 % confidence interval of HadCRUT4 data set. 'Pre-industrial period' refers to 1850-1899.

Source: EEA (2019f).

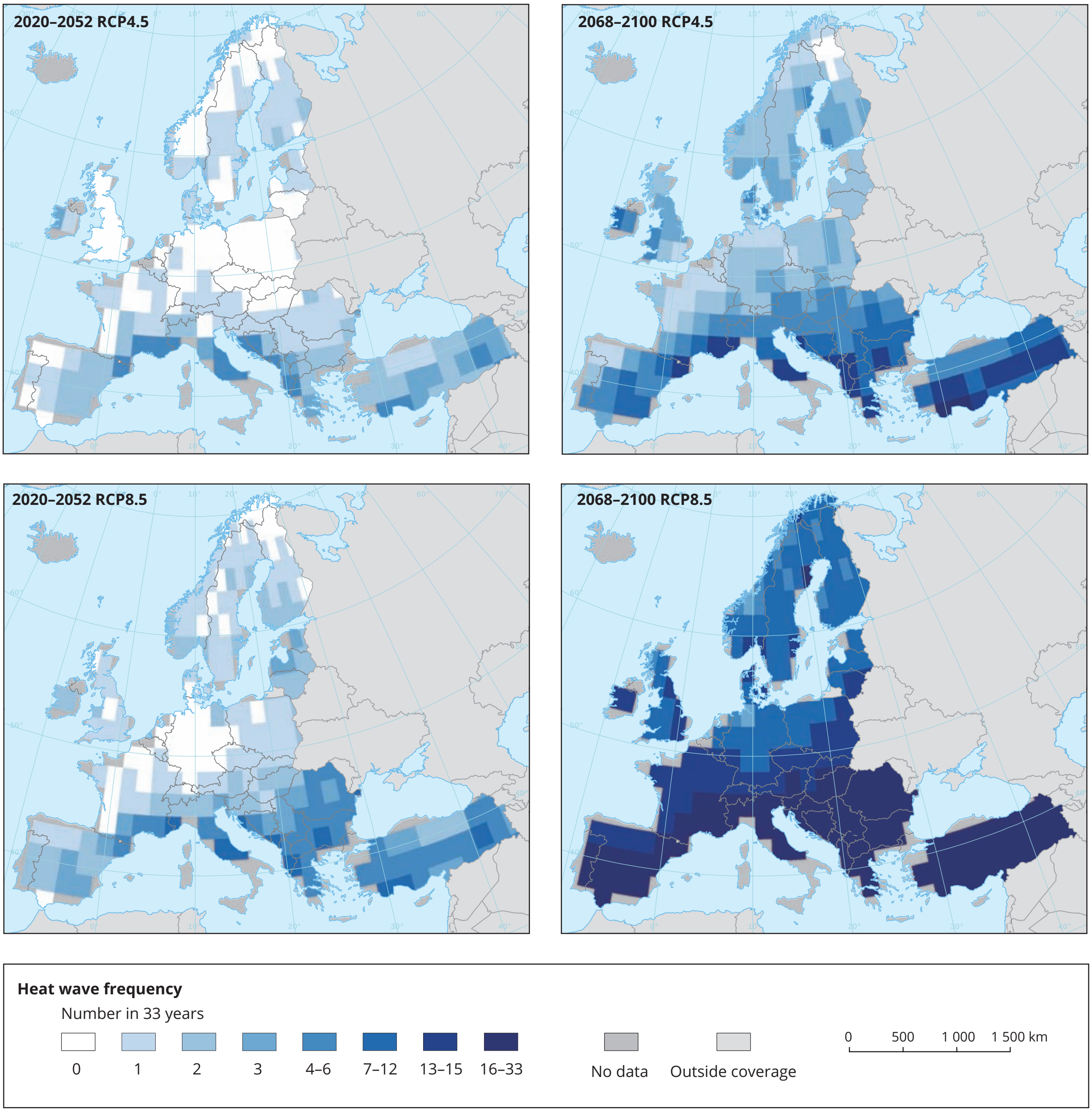
and Sweden in 2018 and Belgium, Luxembourg, Norway and the United Kingdom in 2019). Regional and/or monthly temperature records were broken in many more locations. Human-induced climate change made those unprecedented heat events in Europe, which already had considerable impacts on ecosystems, economic activities and human health, much more likely (typically around 10 to 100 times) than they would have been in an unchanged climate (EEA, 2019f; C3S, 2019; WMO, 2019; Vautard et al., 2019).

Heat waves are projected to become even more frequent and longer lasting in Europe. Under a high-emissions scenario, very extreme heat waves (more severe than the 2003 heat wave affecting southern and central Europe or the 2010 heat wave affecting eastern Europe) are projected to occur as often as every 2 years in the second half of the 21st century (Map 7.1). The projected frequency of heat waves is greatest in southern and south-eastern Europe (Russo et al., 2014). The most severe economic and health risks from heat waves are projected for low-altitude river basins in southern Europe and for the Mediterranean coasts, where many densely populated urban centres are located (Fischer and Schär, 2010). The effects of heat waves are exacerbated in large cities due to the urban heat island effect.

Total precipitation

Observed and projected changes in precipitation vary substantially

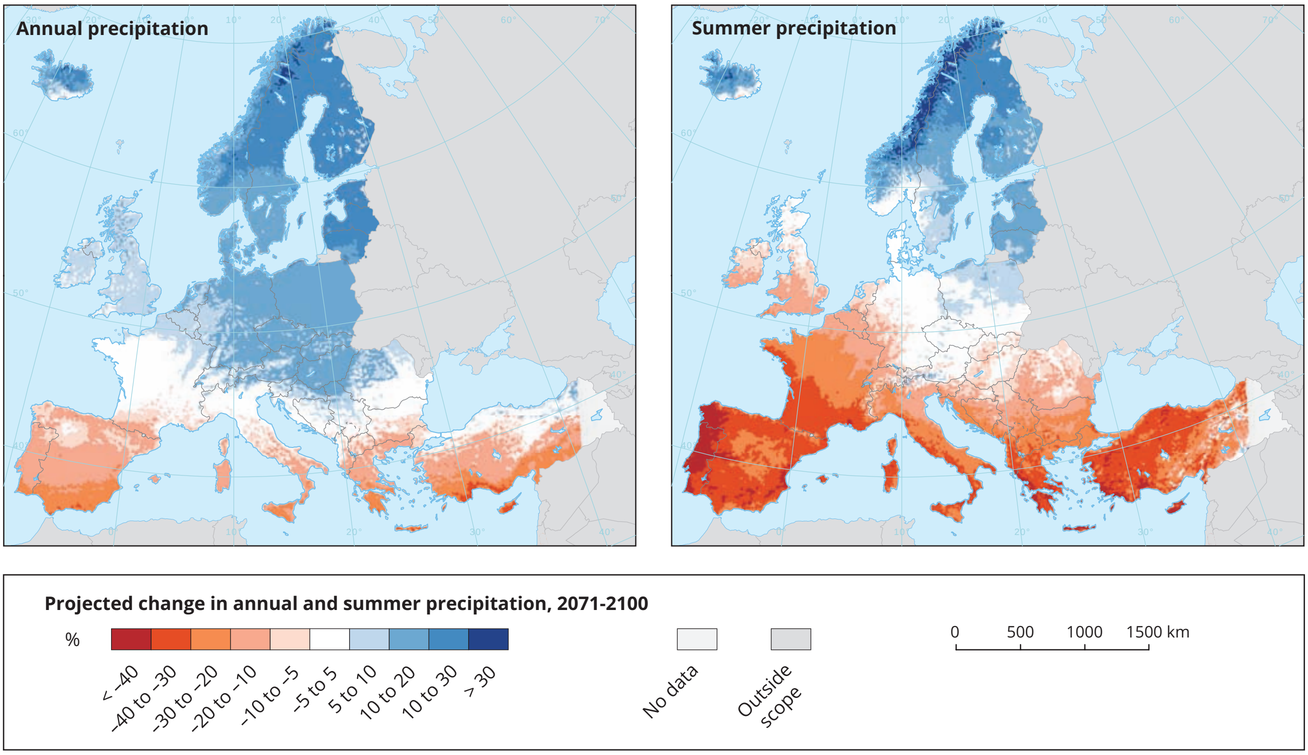
MAP 7.1 **Extreme heat waves in the future under two different forcing scenarios**



Note: RCP 4.5 corresponds to a medium-emissions scenario, whereas RCP 8.5 refers to a high-emissions scenario. Neither of these scenarios is compatible with the stabilisation target of the Paris Agreement.

Source: EEA (2019f), adapted from Russo et al. (2014).

MAP 7.2 **Projected changes in annual and summer precipitation**



Note: Projected changes in annual (left) and summer (right) precipitation (%) in the period 2071-2100 compared with the baseline period 1971-2000 for the forcing scenario RCP 8.5, which corresponds to a high-emissions scenario, based on the average of a multi-model ensemble of regional climate models.

Source: EEA (2017e), based on Euro-Cordex data.

across regions and seasons. Annual precipitation has increased in most parts of northern Europe and decreased in parts of southern Europe. These changes are projected to exacerbate in the future with continued climate change, and the projected decrease is greatest in southern Europe in the summer (Map 7.2) (EEA, 2017e).

Heavy precipitation and inland floods

The intensity of heavy precipitation events, which can cause floods, has increased in summer and winter in most parts of northern Europe. The largest increase has been observed for particularly strong precipitation events. Different indices show diverging trends for southern Europe. The intensity of heavy daily precipitation events is projected to increase over most of Europe, most strongly in north-eastern Europe (EEA, 2019h).

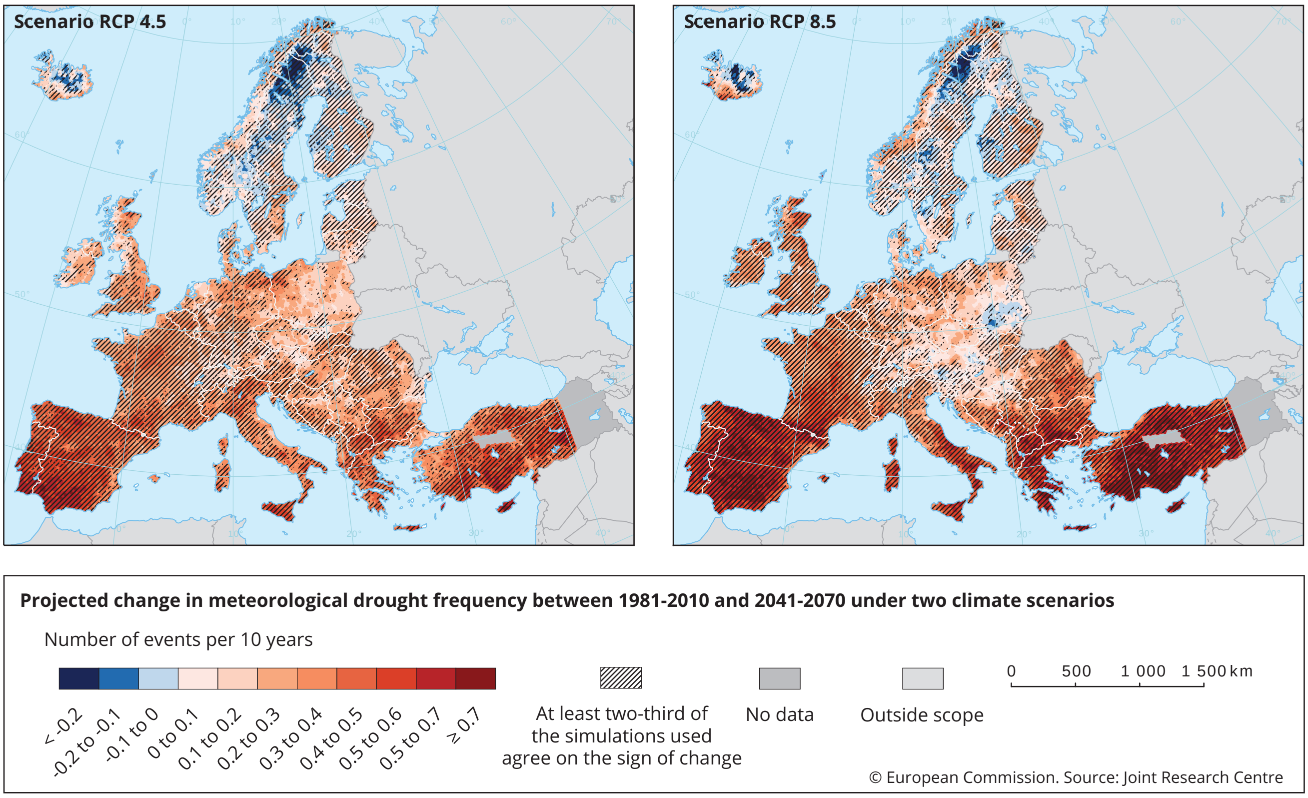
Heatwaves are projected to become more frequent and to last longer across Europe.

The number of very severe flooding events in Europe has increased in recent decades, but there is large interannual variability. Various European-wide studies project river flooding to become more frequent in north-western and central-western parts of Europe, whereas the results diverge in other regions (Kundzewicz et al., 2016, 2018). Pluvial floods and flash floods, which are triggered by intense local precipitation events, are likely to become more frequent throughout Europe (EEA, 2017f).

Droughts

Drought conditions have generally increased in southern Europe and decreased in northern Europe, but

MAP 7.3 **Projected changes in the frequency of meteorological droughts**



Note: The maps show projected changes in drought frequency (number of events per decade) by mid-century (2041-2070 relative to 1981-2010) for two different emissions scenario: RCP 4.5 (left) and RCP 8.5 (right). For an explanation of these scenarios, see Map 7.1.

Source: Adapted from Spinoni et al. (2018). Open access under CC BY 4.0.

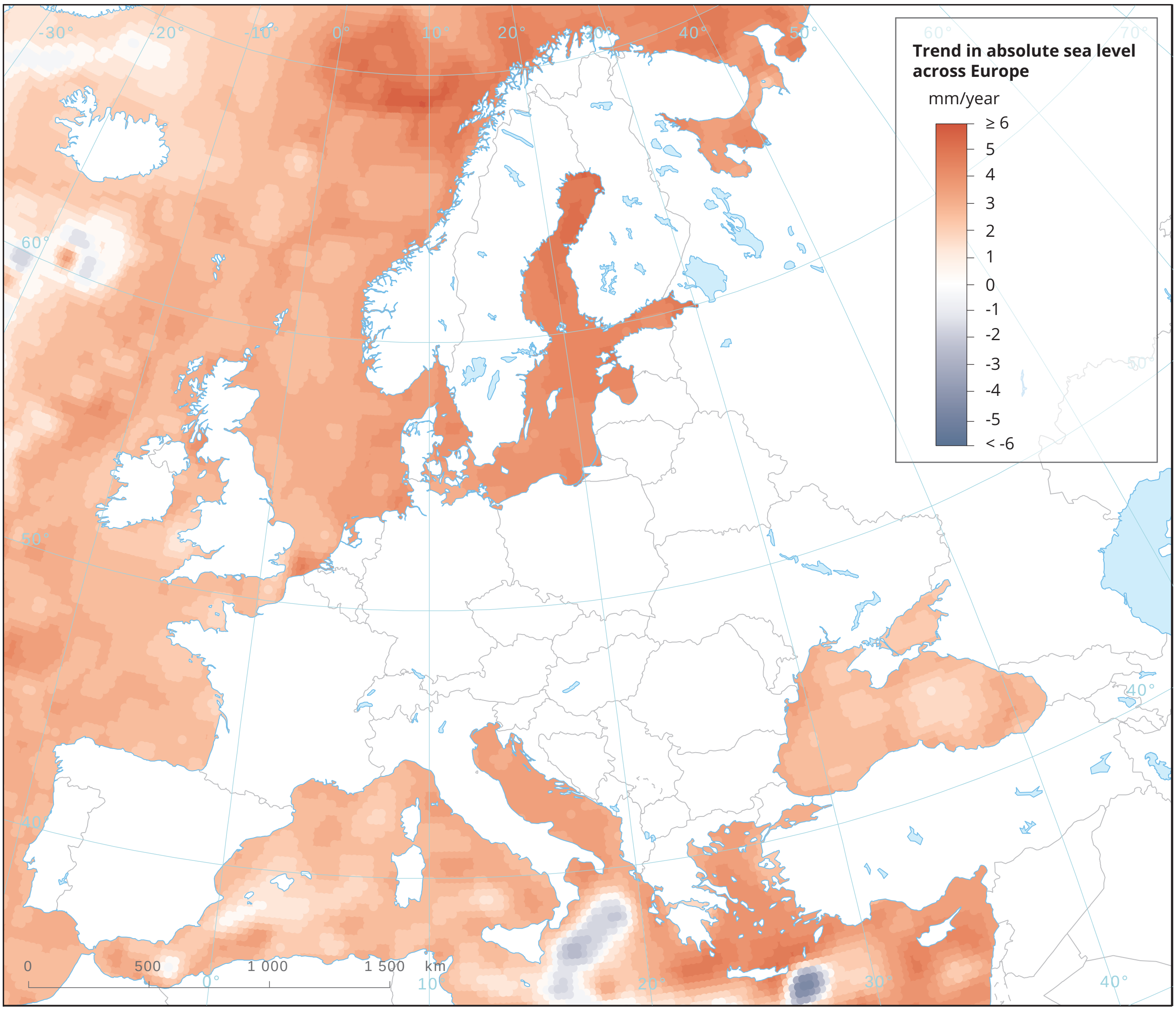
Severe floods have increased in recent decades in Europe, but with large interannual variability.

there are variations across seasons and some differences between various drought indicators. The increased droughts in southern Europe are driven by reductions in precipitation as well as by rising temperatures, which increases evapotranspiration. This pattern is projected to continue in the future (Map 7.3) (EEA, 2019i). Drought frequency is projected to increase everywhere in Europe in spring and summer, especially over southern Europe, and less intensely in autumn; winter shows a decrease in drought frequency over northern Europe (Spinoni et al., 2018). The observed and projected increase in drought conditions in southern Europe is increasing competition between different water users, such as agriculture, industry, tourism and households. For further information on freshwater systems affected by climate change, see Chapter 4.

Global and European sea level

Global mean sea level has increased by about 20 cm since 1900. The rise in global sea level has accelerated in recent decades as a result of human-induced climate change. The model simulations used in the IPCC Fifth assessment report (AR5) projected a rise in global sea level over the 21st century that is likely to be in the range of 28-98 cm (depending on the emissions scenario), but substantially higher increases in sea level were not ruled out. This range will be revised in the IPCC special report, The ocean and cryosphere in a changing climate, which is due to be published in September 2019. Several

MAP 7.4 **Trend in absolute mean sea level across Europe**



Note: Observed altimeter sea level trends (mm/year) from January 1993 to May 2017. The data have not been adjusted for glacial isostatic adjustment.

Source: CS3 (2018b).

recent model-based studies, expert assessments and national assessments have suggested an upper bound for 21st century global mean sea level rise in the range of 1.5-2.5 m. Further increases by several metres by 2300, and by many metres by 2500, are possible if the stabilisation goal of the Paris Agreement is not met (EEA, 2019e).

All coastal regions in Europe have experienced an increase in absolute sea level but with significant regional variation (Map 7.4). Extreme high coastal water levels have increased at most locations along the European coastline. The rise in sea level relative to land along most European coasts is projected to be similar to the global average, with the exception of the northern Baltic Sea and the northern Atlantic coast, which are experiencing considerable land rise as a consequence of post-glacial rebound. The increase in sea level and coastal flood levels is threatening coastal ecosystems, water resources, settlements, infrastructure and human

TABLE 7.7 Summary assessment — climate change and impacts on ecosystems

Past trends and outlook		
Past trends (10-15 years)		Anthropogenic climate change is ongoing and has led to increasing impacts on species and ecosystems. In some cases, such as sea level rise, changes have been accelerating.
Outlook to 2030		Climate change will continue in the coming decades, with increasingly severe impacts on species and ecosystems projected.
Prospects of meeting policy objectives/targets		
2020	☒	While there are no specific targets related to climate change and its impacts on species, habitats and ecosystems in Europe, the Seventh Environment Action Programme requires the mainstreaming of climate change adaptation into key policy initiatives and sectors in order to protect, conserve and enhance natural capital. Continuing climate change makes it more difficult to achieve other policy targets related to biodiversity protection, ecosystems and water quality.
Robustness		The qualitative and aggregated assessment presented here is based on a multitude of direct observations and quantitative modelling. It is considered robust, although there are considerable uncertainties for climate change and its impacts on specific ecosystems at the regional level.

lives (Chapter 6). Available studies project that the economic damage from coastal flooding in Europe would increase many fold in the absence of adaptation (Ciscar et al., 2018).

Further changes in the climate system

Climate change is also evident through melting glaciers (EEA, 2016e), decreasing sea ice (EEA, 2018c) and warming oceans (EEA, 2016h). Furthermore, the CO_2 emissions driving global climate change are making the oceans more acidic, which inhibits the growth of calcifying organisms (EEA, 2016f) (Chapter 6).

Climate change impacts on forests and other ecosystems

Climate change has caused widespread changes in the distribution of plant and animal species in Europe, both on land and in the sea. The migration has generally been northwards and, for and-based species, upwards to higher altitudes. The migration of many land-based species is lagging behind the changes in climate, which may lead to a progressive decline in European biodiversity (EEA, 2016b, 2016c). Climate change is also leading to changes in the seasonality of biological events, such as flowering of plants or hatching of birds (EEA, 2016g). Because these changes are not uniform across species, some animals no longer find sufficient food when they need it. Overall, these changes make it more difficult to achieve policy objectives related to preserving terrestrial and marine biodiversity in Europe (Chapters 3 and 6).

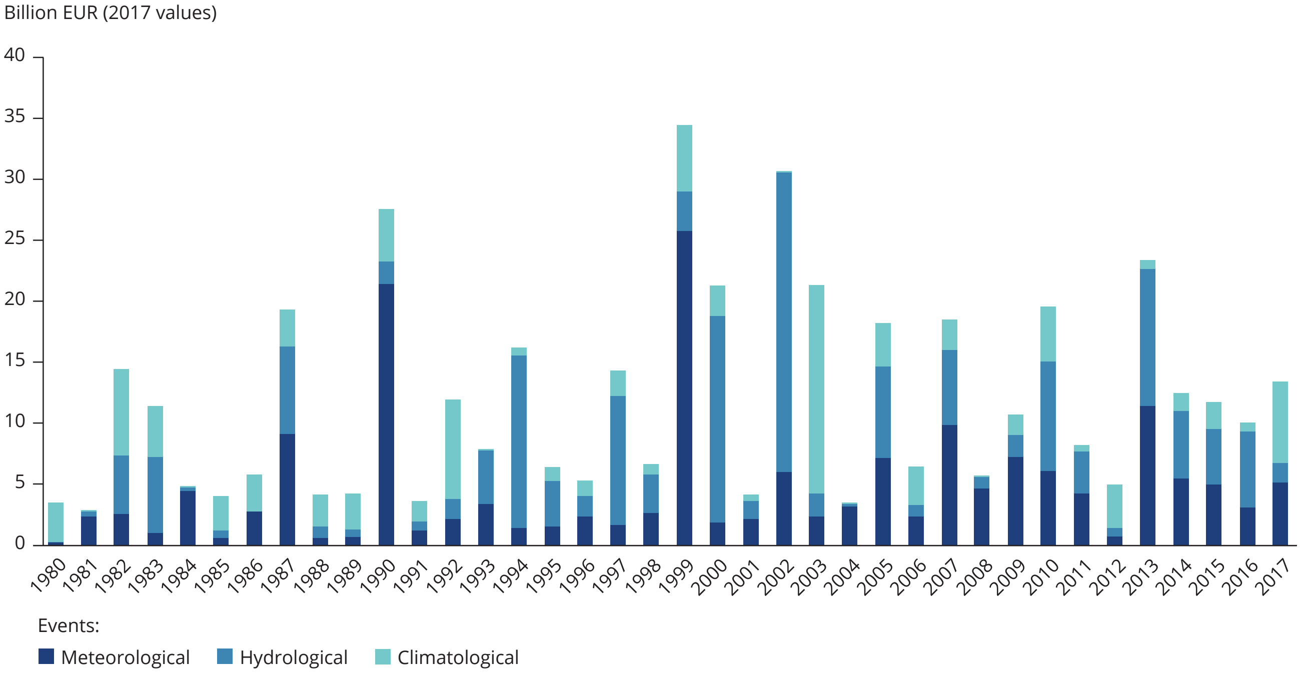
Forest growth is generally projected to increase in northern Europe and to decrease in southern Europe, but with substantial regional variation. At the same time, forest tree species are shifting towards higher altitudes and latitudes as a result of climate change (EEA, 2017d). More severe forest fire weather and, as a consequence, an expansion of the fire-prone area and longer fire seasons are projected across Europe in a warmer climate (EEA, 2019d). The impact of fire events is particularly strong in southern Europe, as exemplified by the extreme fires in Portugal in 2017 and in Spain and Greece in 2018. However, northern Europe can also be affected. For example, Sweden experienced unprecedented forest fires during extreme heat waves combined with droughts in 2014 and again in 2018. Climate change is also affecting the regional and spatial occurrence of forest pests and diseases. Forest insect pests are projected to increase in most regions of Europe (EEA, 2017c, Section 4.4.7). These combined impacts considerably affect forest structure and the functioning of forest ecosystems and their services (Chapter 13).

7.3.5 Climate change risks to society

► See Table 7.8

Climate change is affecting human health and well-being as well as many economic activities. This section gives an overview of selected climate change impacts on society. More detailed information on this topic is available in a 2017 EEA report (EEA, 2017c).

FIGURE 7.7 Economic damage caused by climate-related extreme events in EEA member countries



Note: Meteorological events: storms; hydrological events: floods and mass movement; climatological events: cold waves, heat waves, droughts, forest fires.

Source: Adapted from EEA (2019b), NatCatSERVICE provided by Munich Re.

Health impacts of climate change

Heat waves are the most deadly climate extremes in Europe. The 2003 summer heat wave alone is estimated to have caused around 70 000 premature deaths in Europe (Robine et al., 2008). The projected substantial increase in the frequency and magnitude of heat waves will lead to a large increase in mortality over the next few decades, especially in vulnerable population groups (the elderly, children, those in poor health), unless adaptation measures are taken. Urban areas are particularly affected due to the combined effects of higher temperatures as a result of the urban heat island effect, the frequent combination of heat with air pollution, including ground-level ozone, and high population density (EEA, 2016d). Different population groups are affected differently, depending on their age, general health and socio-economic status (EEA, 2019j).

Climate change is also affecting human health and well-being directly through floods and indirectly by changing the magnitude, frequency, seasonality and/or regional distribution of vector-, water- and food-borne diseases, pollen allergens and air pollution incidents. For example, extremely warm water temperatures in the Baltic and North Seas during recent heat waves were associated with unprecedented peaks in *Vibrio* infections in humans (EEA, 2017c, Section 5.2).

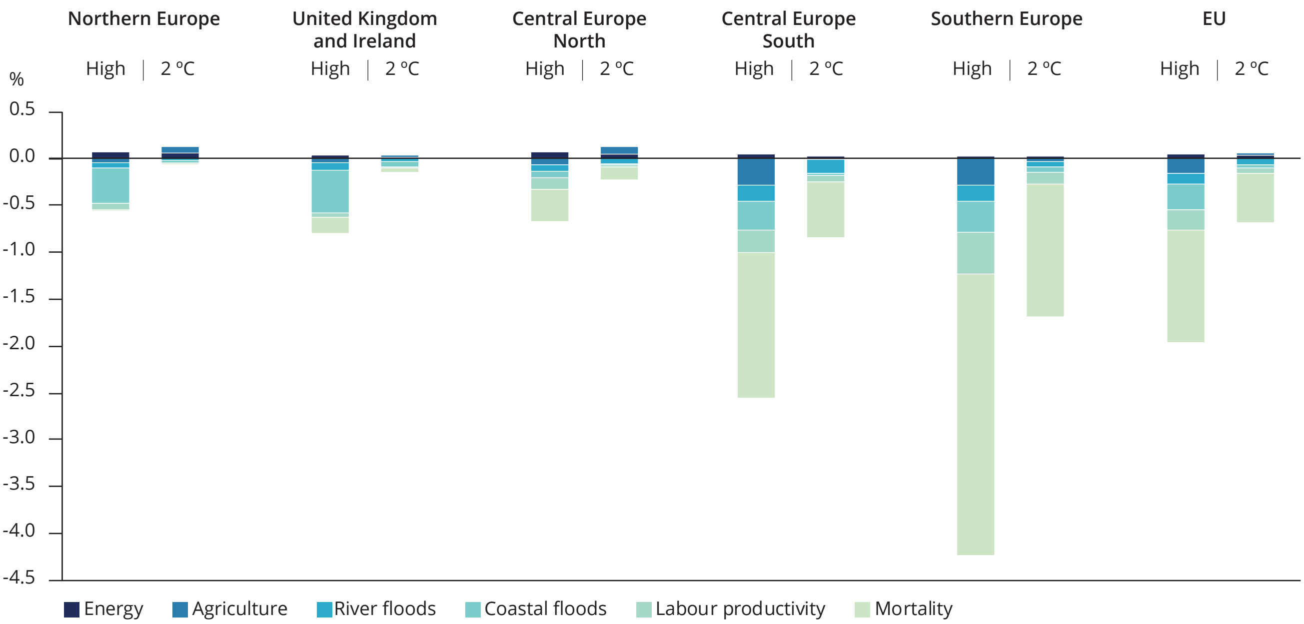
Economic losses from climate-related extremes

The direct economic losses caused by weather- and climate-related extremes in the EEA member countries amounted to approximately EUR 453 billion (in 2017 euro values) over the period 1980-2017 (Figure 7.7). The analysis of historical trends is difficult, because most of the losses were caused by a small number of very severe events (EEA, 2019b). Model simulations performed by the Joint Research Centre project large increases in most climate hazards in Europe and considerable economic damage. For example, in a hypothetical scenario without additional adaptation, impacts on critical infrastructure could rise 10-fold during the 21st century due to climate change alone (Forzieri et al., 2016, 2018).

Other economic impacts of climate change

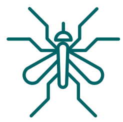
A changing climate is affecting a wide range of economic sectors and human activities, including agriculture, forestry, fisheries, water management,

FIGURE 7.8 **Projected welfare impacts of climate change for different EU regions and sectors for two warming scenarios**



Note: The country grouping is as follows. Northern Europe: Denmark, Estonia, Finland, Latvia, Lithuania and Sweden. UK & Ireland: Ireland and United Kingdom. Central Europe North: Belgium, Germany, Luxembourg, Netherlands and Poland. Central Europe South: Austria, Czechia, France, Hungary, Romania and Slovakia. Southern Europe: Bulgaria, Croatia, Cyprus, Greece, Italy, Malta, Portugal, Slovenia and Spain.

Source: Ciscar et al. (2018).



An increase in heat-related mortality and vector-and waterborne diseases has been observed across Europe.

coastal and flood protection, energy, transport, tourism, construction, and human health and wellbeing. Various research projects have assessed the multi-sectoral social and economic impacts of climate change across Europe or for specific European regions. The specific estimates depend strongly on the underlying climate scenarios; the sectors considered, including cross-border impacts; the assumptions regarding demographic and socio-economic developments, including adaptation; the treatment of uncertainties; and the economic valuation of non-market impacts and of impacts further in the future (EEA, 2017c, Section 6.3).

The Peseta III study by the Joint Research Centre has estimated the net welfare loss from climate change in the EU by the late 21st century at 1.9 % of GDP under a high warming scenario (RCP 8.5) and at 0.7 % under a 2 °C scenario (Figure 7.8). Southern and central-southern Europe are projected to suffer by far the highest losses as a percentage of GDP. Welfare losses in southern and central Europe are dominated by health-related impacts, in particular increased mortality from heat waves, but also reduced labour productivity. In contrast, welfare losses in northern and north-western Europe are dominated by coastal floods. The only sector with (small) positive net welfare impacts in the EU is the energy sector because of the reduced need for heating in a warming climate (Ciscar et al., 2018).

The Peseta III estimates are based on a limited number of sectors and climate change impacts. Other studies using different modelling frameworks and assumptions have arrived at both higher and lower estimates. Many impacts can be significantly reduced

TABLE 7.8 Summary assessment — climate change risks to society

Past trends and outlook		
Past trends (10-15 years)		Premature deaths due to heat waves and an increase in the incidence of several vector- and water-borne diseases have been observed in Europe. Forest fires facilitated by extreme heat and drought have led to considerable death tolls in recent years. There are no clear trends in the economic losses from extreme weather events.
Outlook to 2030		The past trends related to health impacts are projected to continue with ongoing climate change. The overall economic impacts of climate change on Europe are primarily negative, but there is substantial variation across regions and economic activities.
Prospects of meeting policy objectives/targets		
2020	☐	There are no specific targets for climate-related health risks, but the Seventh Environment Action Programme requires decisive progress to be made in adapting to climate change to safeguard from environment-related pressures and risks to health. There is some evidence that repeated climatic extremes affecting the same region (e.g. heat waves) lead to reduced health impacts because of adaptation.
Robustness		Data on past climate-sensitive health impacts originate from different sources, including mandatory reporting, official statistics and attribution analyses. The identification of trends is difficult because the most significant events are very rare. An overall assessment of the impacts of climate change on health is hampered by the lack of reliable estimates for cold-related health impacts. Data on economic losses from climate-related events are derived from insurance data, including estimates of uninsured losses. Attribution of trends is difficult because of the sparsity of the most costly events as well as concurrent developments in hazards, exposure and vulnerability.

by appropriate adaptation measures. However, adaptation generally comes at a cost, there may be trade-offs with other policy objectives, and residual impacts remain (EEA, 2017c, Section 6.3; EC, 2018b, Annex XIII).

Europe's vulnerability to climate change impacts occurring outside Europe

European societies are also affected by the indirect impacts of climate change occurring outside Europe through various pathways, such as international trade and migration (Figure 7.9). These 'cross-border impacts' can be triggered by a single extreme weather event (e.g. a temporary disruption of global supply chains due to damaged production or transport infrastructure following a flood), by prolonged periods of extreme weather (e.g. an extreme drought that increases world market prices of agricultural products) or by gradual climate change (e.g. flooding of densely populated coastal areas that triggers internal or international migration). The strongest evidence for Europe's sensitivity to cross-border impacts are the economic effects of global price volatilities, disruptions to transport networks and changes in the Arctic environment. European vulnerability to cross-border impacts of climate change is expected to increase in the coming decades, but quantitative projections are not yet available (EEA, 2017c, Section 6.4; Ciscar et al., 2018). Cross-border effects of climate change can be addressed by a combination of domestic and international policies.

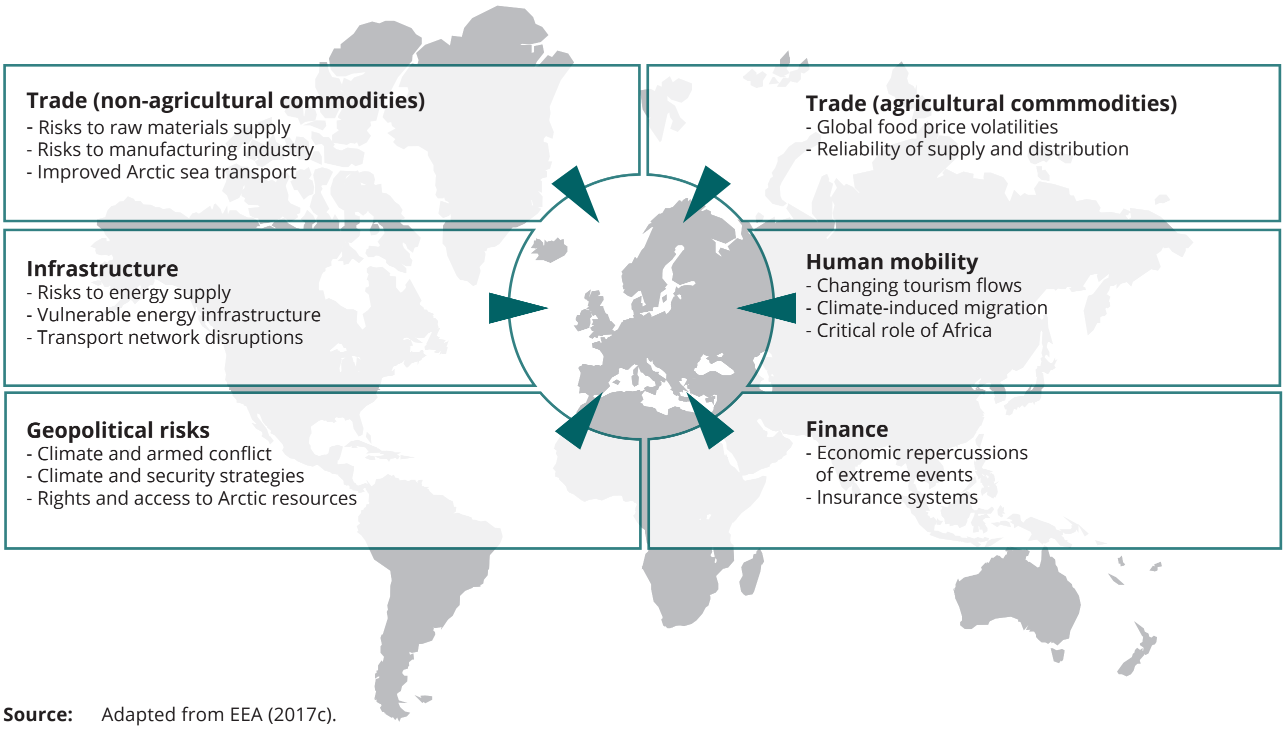
7.4 Responses and prospects of meeting agreed targets and objectives

7.4.1 Climate change mitigation

A number of policies have played an important role in reducing GHG emissions over the past 27 years (EEA, 2018e). In addition to the expected mitigation effects of climate policies, there have been positive indirect effects from other policies that were not aimed at reducing GHG emissions.

For instance, key EU polices such as the Nitrates Directive, the market reform of the common agricultural policy and the Landfill Directive have had a positive

FIGURE 7.9 **Overview of major pathways of indirect climate change impacts for Europe**



Source: Adapted from EEA (2017c).

impact on reducing greenhouse gas emissions from methane (CH_4) and nitrous oxide (N_2O). The Montreal Protocol on ozone-depleting substances has been one of the most successful multilateral environmental (and indirectly climatic) agreements to date, contributing to substantial reductions in GHG emissions in Europe and worldwide. This was because many of the substances addressed in the Montreal Protocol such as chlorofluorocarbons (CFCs) are also potent GHGs (Velders et al., 2007). The banning of CFCs, however, led to an increase in the consumption of substitute gases such as HFCs. In 2016, the Montreal Protocol was thus amended in Kigali, where countries committed to cutting the production and consumption of HFCs by over 80 % over the next 30 years.

Considerable co-benefits exist for air pollution and climate policies, not only at national but also at local level, although there are some trade-offs as well (Chapter 8). For instance, to stimulate the transition towards a more environmentally friendly future, the European Commission adopted the circular economy action plan (EC, 2015a). It includes measures covering the entire cycle from production and consumption to waste management. These actions should encourage greater recycling and reuse, and bring benefits for the environment, the economy and the climate (Chapter 9).

> Considerable co-benefits exist for air pollution and climate policies.

Moreover, the EU's Large Combustion Plant Directive has encouraged efficiency improvements and fuel switching from solid fuels to cleaner fuels and thus helped reduce emissions, not only of air pollutants but also of greenhouse gases (EEA, 2011, 2019a). Indeed, the EU has been able to reduce GHG emissions and air pollution, improve energy efficiency and achieve higher shares of energy from renewable sources and, at the same time, increase economic growth. Nevertheless, much remains to be done, and considering the co-benefits and trade-offs between climate policies and other policies, including environmental policies, in the design of new legislation would achieve maximum benefits.

In relation to direct effects, and the effectiveness of climate and energy policies, EEA analysis (EEA, 2016a) has shown that there is statistical evidence of a long-term relationship between GHG emissions, economic growth and use of energy from fossil fuels, and that GHG emissions can be predicted in the short term based on these two variables, with some variations due to, for example, particularly cold or warm years. A later analysis (EEA, 2017a) also showed that, based on projections reported by Member States, this long-term relationship becomes weaker as the years go by. This would suggest that climate change mitigation policies and measures, as a package if not individually, are gradually working and are expected to have a stronger effect over time both in Member States and at EU level.

Indeed, the increased use of energy from renewable sources since 2005 allowed the EU to cut its demand for fossil fuels by over one tenth in 2016 (EEA, 2018h). This is comparable to the fossil fuel consumption of the United Kingdom in that year, with coal being the fossil fuel most substituted across Europe (38 % of all avoided fossil fuels), followed by natural gas (at 36 %). The growth in the consumption of renewable energy after 2005 also helped the EU achieve an estimated gross reduction in CO_2 emissions of 9 % in 2016, compared with a scenario in which RES consumption stayed at the 2005 level (EEA, 2018h). This almost corresponds to the annual GHG emissions of France in that year. Most of these changes took place in energy-intensive industrial sectors under the EU ETS, as the increase in renewable electricity decreased the reliance on fossil fuels and made up roughly three quarters of the estimated total EU reductions.

Despite this recent progress, to meet the EU's 2030 and 2050 objectives there is a need to further improve energy efficiency and step up the use of renewables to reduce carbon intensity and completely decouple GHG emissions from energy use and economic growth.

Concerning energy, decarbonisation of the EU supply is possible. With full implementation of current energy efficiency solutions and the upscaling of low-carbon energy technologies, emissions of GHGs from the EU power sector can be reduced by 98 % or more (EC, 2018c). To make this possible, significant new investments in cost-efficient solutions, beyond diverting former fossil fuel investments to energy efficiency and renewables, are needed.

Meeting EU RES targets requires better RES deployment and more uptake, notably in transport.

Efforts to decommission conventional thermal generation (especially coal) also need to be intensified, because these technologies are by far the largest sources of climate and environmental pressures. Under such conditions, clean electricity can increasingly also foster low-carbon transitions within other sectors, such as industry, transport and buildings. Yet, to be successful, this transition also needs to be socially fair and inclusive. Not all new technological developments may ease pressures on the environment and challenges linked to deploying and upscaling new infrastructures need to be duly anticipated and addressed.

For the EU to remain on track towards its energy efficiency objectives, further implementation of energy efficiency measures across specific Member States is needed. To stay on track towards its RES targets, the EU needs to safeguard further RES deployment and to increase the pace of RES uptake in the transport sector.

A broad range of policies affect energy choices and planning and, as a result, environmental outcomes. These include energy security (subsidiarity element), finance and taxation, climate and energy policy at EU and national levels, and science and technology policies. Competencies are dispersed across EU, national, regional and municipal levels. Greater policy integration would improve the rate of progress: this includes continuing the mainstreaming of environmental objectives into key EU spending programmes in the energy area.

Taking a global perspective, although there have been strategies and various policies aimed at reducing GHG emissions in the EU since 2005, at the planetary scale the effect of such policies has been relatively modest. This is because the EU represents 8 % of global GHG emissions (EEA, 2017a). The 2020 EU climate and energy framework was partly designed to help the EU achieve its international 20 % reduction targets by 2020 under the UNFCCC as well as its 20 % emission reduction target under the Kyoto Protocol. The Paris Agreement, signed in 2015, raised the bar for everyone, with all UNFCCC member countries agreeing to keep the increase in global average temperature to well below 2 °C compared with pre-industrial levels and aiming to limit the increase to 1.5 °C (UNFCCC, 2015b).

In 2014, the European Council adopted the 2030 climate and energy framework (European Council, 2014), and the related legislation was adopted by the European Council and the European Parliament in 2018. The headline target of at least a 40 % reduction in GHG emissions by 2030 is consistent with the EU's nationally determined contribution (NDC) under the Paris Agreement. It is also consistent with the EU's longer term objective of the Roadmap for moving to a competitive low-carbon economy in 2050, agreed by the European Council in October 2009, in the context of the necessary reductions to be made by developed countries as a group, according to the IPCC, and re-affirmed thereafter, of reducing its GHG emissions by 80-95 % by 2050 compared with 1990, with milestones of 40 % by 2030 and 60 % by 2040. The EU ETS has been reformed and strengthened for the period 2021-2030 and will ensure that emissions in the sectors covered by the system are reduced by 43 % compared with 2005. For the sectors covered under the Effort Sharing Regulation, emissions would have to be reduced by 30 % compared with 2005, with individual binding targets for Member States. The climate change mitigation objectives are also part of the Energy Union framework strategy, which includes the strategic objectives of reducing energy demand, improving energy efficiency and decarbonising the economy. Finally, the European Commission published its strategic long-term vision for reductions of EU GHG emissions in November 2018, which embraces the target of net zero GHG emissions by 2050 and outlines feasible pathways for achieving this target with current technologies.

EU domestic legislation is in place to meet the Paris Agreement's objectives. It is, however, rather clear that the current NDCs by all signatories to the Paris Agreement are, to date, not consistent with the overall UNFCCC objective of avoiding dangerous anthropogenic interference with the climate system (UNFCCC, 1992), unless the current emissions gap is closed by 2030. According to the 2018 *Emissions gap report* by UN Environment (UNEP, 2018), pathways reflecting current NDCs imply global warming of about 3 °C by 2100. To close the gap, the level of global ambition should increase by 2030. The Paris Agreement requires each Party to prepare, communicate and maintain successive NDCs that it intends to achieve and to pursue domestic mitigation measures, with the aim of achieving the objectives of such contributions. The EU submitted its first NDC in 2015 (UNFCCC, 2015a). New or updated NDCs have to be submitted by all Parties by 2020. The Talanoa Dialogue and the Global Stocktake in 2023 are the mechanisms to ensure that the global community delivers on its objectives to curb emissions to a level consistent with the 2 °C and 1.5 °C targets.

The Paris Agreement also recognises the role of local and regional stakeholders in climate change mitigation. The Covenant of Mayors for Climate and Energy brings together local and regional authorities to implement the EU's climate and energy objectives on a voluntary basis (Covenant of Mayors, 2019b). In Europe, over 7 000 cities have already committed to this goal. Indeed, to address the big challenge and prevent the worst impacts from climate change, mitigation measures can and should be implemented at any level of government.

Climate adaptation is increasingly integrated into EU policies, programmes and strategies.

The challenge is big. Three out of four representative concentration pathways (the global emission scenarios used in the latest IPCC report) exceed 2 °C of global warming during the 21st century and most likely into the 2040s (IPCC, 2013; Vautard et al., 2014). Very rapid global reductions in emissions, and possibly the large-scale application of bioenergy combined with carbon capture and storage technologies, are necessary to keep the chance of limiting global mean temperature increase to 1.5 °C (IPCC, 2018).

7.4.2
Climate change adaptation

► *See Table 7.9*

A number of United Nations (UN) multilateral frameworks with relevance for climate change adaptation have been adopted since 2015. Apart from the Paris Agreement on climate change (UNFCCC, 2015b), these are the Sendai Framework for Disaster Risk Reduction 2015-2030 (SFDRR; UNISDR, 2015), and the 2030 Sustainable Development Agenda, including the Sustainable Development Goals (SDGs; UN, 2017). All these agreements have strong links to climate change adaptation. The Paris Agreement established the global goal on adaptation of 'enhancing adaptive capacity, strengthening resilience and reducing vulnerability to climate change, with a view to contributing to sustainable development and ensuring an adequate adaptation response in the context of the global temperature goal' (UNFCCC, 2015b, Art. 7) and thus linking adaptation and sustainable development. The SFDRR and SDGs also consider adaptation as crucial, pointing to possible synergies at the national level where these frameworks need to be implemented. Adaptation monitoring and evaluation is recognised as an important step in the process of adapting to climate change.

EU adaptation efforts

The EU strategy on adaptation to climate change (EC, 2013b) aims to contribute to a more climate-resilient Europe by enhancing the preparedness and capacity to respond to the impacts of climate change from a local to a European level. In November 2018, the European Commission published an evaluation of the EU adaptation strategy (EC, 2018a, 2018b, 2018g) based on the REFIT criteria (EC, 2012a) of the Commission's regulatory fitness and performance programme. In the absence of a specific monitoring and evaluation framework, the eight different actions defined in the strategy have been evaluated in their own right.

The evaluation of the EU adaptation strategy shows that each of the actions made progress between 2013 and 2018 and that they added value to national and sub-national measures. For example, climate change adaptation is increasingly mainstreamed into EU policies, programmes and strategies; the EU has co-funded many adaptation-related projects across Europe through LIFE and other programmes; most EEA member countries now have a national adaptation strategy; an increasing number of cities are adopting local adaptation strategies; and the Climate-ADAPT platform facilitates the exchange of knowledge relevant to adaptation across Europe. While the adaptation strategy promoted adaptation action plans, it was less effective in implementing, monitoring and evaluating those plans. Reflecting on lessons learned, the evaluation emphasises the needs for the following:

- applying the knowledge available for decision-making under uncertainty, e.g. through science-policy dialogues;

- improving the climate resilience of long-term infrastructure; better integration of the strategy's actions with each other and with the international dimension of adaptation;

- better monitoring of the implementation and effectiveness of national adaptation strategies and plans;

- encouraging the establishment of local adaptation strategies in all Member States;

- improving the analysis of the distributional effects of climate change impacts and adaptation measures.

Areas for improvement include, among others, exploiting synergies between climate change adaptation, climate change mitigation and disaster risk reduction; facilitating ecosystem-based adaptation; better mainstreaming into the EU maritime and fisheries policy; reinforcing the links between public health and adaptation; and better adaptation support to investors and insurers, including private investors (EC, 2018g).

Climate-proofing of EU action mainly includes mainstreaming adaptation into key vulnerable sectors. The adaptation strategy explicitly refers to the common agricultural policy,

Adaptation action plans need to be effectively implemented, monitored and evaluated.

the cohesion policy and the common fisheries policy, but progress has also been made in mainstreaming into disaster risk reduction, water, and urban and development cooperation policies (for a full list of EU policy initiatives where adaptation is mainstreamed, or is being mainstreamed, see EC, 2018b, Annex XI). Adaptation is also mainstreamed in the Energy Union and Climate Action Regulation, which was adopted in December 2018. This Regulation ensures that the national energy and climate plans to be submitted by the Member States in the future include climate adaptation components where applicable (EU, 2018b). A recent report by the European Court of Auditors found that the EU Floods Directive had positive effects overall but that the implementation of flood prevention measures suffers from weaknesses in allocating funding and that much fuller integration of climate change into flood risk management is needed (ECA, 2018).

Another objective of the EU adaptation strategy is 'better informed decision-making', with a central role for Climate-ADAPT ([6]). This is a web portal that aims to provide a common European knowledge base related to adaptation. In April 2019, it contained 2 191 database items and 90 case studies and had 3 715 subscribers to its newsletter across Europe. With a growing number of countries implementing adaptation action plans, the information provided by Climate-ADAPT is shifting to knowledge on the implementation and monitoring of adaptation and the development of appropriate indicator sets, e.g. by improving the Adaptation Support Tool ([7]). Climate-ADAPT is branded as a 'first-stop shop' for adaptation information in Europe, complementary to the national adaptation portals (EEA, 2018i).

C3S ([8]) makes an increasing amount of data on past and projected climate change freely available to scientists, policymakers and stakeholders. Of particular relevance for adaptation decision-makers is the C3S Sectoral Information System, which is currently under development.

Adaptation efforts of EEA member countries

The effectiveness and efficiency of many national adaptation policies can be assessed only in the long term, and even then an exact assessment is impossible due to the lack of a counterfactual situation. Consequently, there are no legally binding quantitative objectives and targets regarding adaptation at the European level. Apart from the requirements for the national communications to the UNFCCC, the only mandatory reporting for EU Member States on adaptation comes from the Monitoring Mechanism Regulation (EU, 2013b, Art. 15). From 2021 onwards, as mainstreamed in the Energy Union and Climate Action Regulation, integrated reporting on adaptation actions will be submitted every 2 years instead of every 4 years, in accordance with the requirements agreed upon under the UNFCCC and the Paris Agreement, including the Paris rulebook, adopted in December 2018 as part of the Katowice

([6]) https://climate-adapt.eea.europa.eu
([7]) https://climate-adapt.eea.europa.eu/knowledge/tools/adaptation-support-tool
([8]) https://climate.copernicus.eu

climate package (UNFCCC, 2015b, 2019; EU, 2018b).

Since 2013, there has been a steady increase in the number of national adaptation strategies (NASs) and national adaptation action plans (NAPs) being adopted by countries, and several countries have adopted a revised NAS. To date, 25 EU Member States and four other EEA member countries have adopted a NAS; 17 EU Member States and two other EEA member countries have also developed a NAP (EEA, 2018f; updated based on Eionet, 2019) (Map 7.5). Almost all of these NASs and NAPs are underpinned by climate change vulnerability and risk assessments (EEA, 2018d). Progress is expected to continue as the EU Member States currently lacking a NAS (Bulgaria, Croatia and Latvia) are in the process of drafting one. It is also expected that additional countries will adopt NAPs and that they will implement more specific adaptation policies and actions in line with their strategies and plans (EC, 2018b, Annex IX).

In the Western Balkans, Bosnia and Herzegovina adopted a climate change adaptation and low-emission development strategy in 2013 (Radusin et al., 2017) and is now starting work on a NAP (UNDP, 2018). Serbia is developing a national plan for adaptation (Ministry of Environmental Protection, 2017). In addition, a detailed list of proposed priority adaptation measures across sectors is available for North Macedonia (Zdraveva et al., 2014).

In the EU countries, most vulnerability assessments are made and adaptation options are identified for agriculture, health, biodiversity, forestry and energy. The main sectors in which national policy instruments promote adaptation are water, agriculture, biodiversity and forestry, whereas health and energy are lagging behind. Almost all EU Member States include transboundary cooperation on adaptation issues in the water sector, as required by the Water Framework Directive (EU, 2000) and the Floods Directive (EU, 2007), and highlighted in the Blueprint to safeguard Europe's water resources (EC, 2012b). For all other sectors, this is limited to one or a few countries only (EC, 2018b, Annex IX).

Over 1 900

local authorities in the EEA-39 countries have committed to take action to adapt to climate change.

A limited number of countries have started to monitor and/or evaluate adaptation policies and actions at national level, using mainly 'process-based' indicators. Some countries also use 'output-based' or 'outcome-based' approaches to assess if and how vulnerability has decreased and/or resilience has increased (e.g. Austria, Finland, Germany and the United Kingdom), but such approaches use complex methodologies and are resource intensive (EEA, 2014a; Mäkinen et al., 2018; EC, 2018b, Annex IX). It will not be possible to determine with any certainty whether or not decisive progress in increased resilience at EU level has been achieved by 2020.

Adaptation efforts in transnational regions

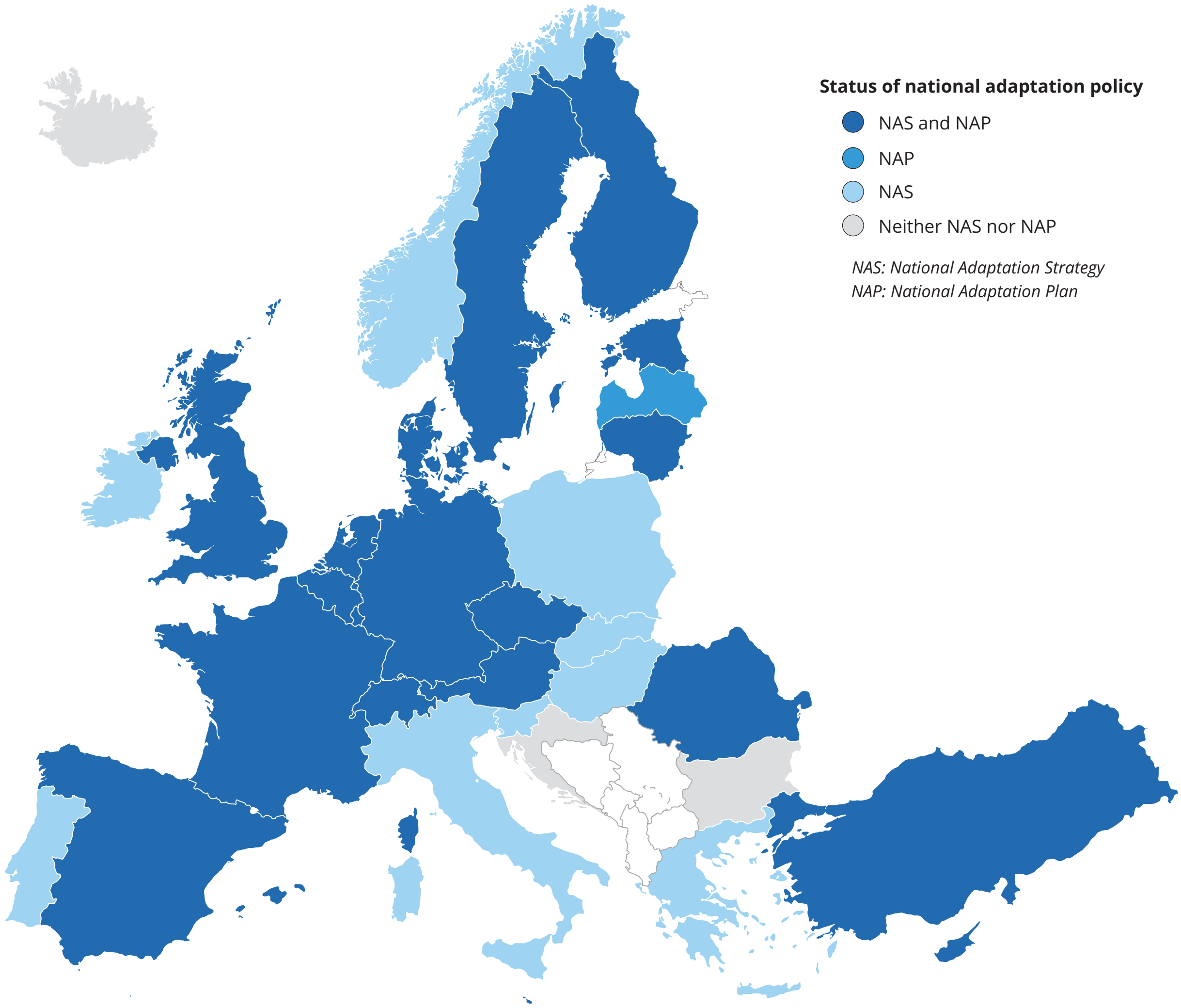
All European transnational regions are vulnerable to climate change to various degrees. Some of them, such as the Northern Periphery and Arctic, South West Europe and Mediterranean regions (which include large parts of the Adriatic-Ionian and Balkan-Mediterranean areas), as well as the mountainous part of the Alpine Space, have been identified as 'hot spots' (Ramieri et al., 2018; EEA, 2018a). Regions with geographically similar conditions address similar challenges, and the existence of shared resources typically requires common approaches (Rafaelsen et al., 2017; EEA, 2017c, 2018a).

Strategic objectives and actions related to adaptation are included in all four EU macro-regional strategies: for the Baltic Sea, the Danube, the Adriatic and Ionian, and the Alpine regions (EC, 2010, 2012c, 2014, 2015b). Common specific transnational adaptation strategies or action plans have also been developed in the North Sea, Northern Periphery and Arctic, Baltic Sea, Danube, Alpine Space and Mediterranean regions, but they have different levels of implementation. (Ramieri et al., 2018; EEA, 2018a).

Adaptation efforts in cities

Although the European and national levels provide the political, legislative and financial framework for adaptation, local adaptation actions address the specific situation of particular locations. The development of local adaptation strategies is increasing throughout Europe (Aguiar et al., 2018). As of April 2019, over 1 900 local authorities in the EEA member and collaborating countries have made commitments related to adaptation within the Covenant of Mayors for Climate and Energy. Among those signatories, 240 adaptation action plans have been submitted, and over 100 adaptation plans are at the monitoring stage (Covenant of Mayors, 2019a). Local authorities in Europe also join global initiatives relevant to adaptation, such as Making Cities Resilient (UN Office for Disaster Risk Reduction; over 650 participating local authorities in EEA member and collaborating countries), 100 Resilient Cities (Rockefeller Foundation; 14 European cities)

MAP 7.5 **Country comparison — overview of national adaptation policies**



Note: NAS, national adaptation strategy; NAP, national adaptation plan.

Sources: Adapted from EC (2018b) and EEA (2018f).

or C40 cities (8 European cities) (EEA, 2018k) ([9]). Involvement of cities in these initiatives may lead to longer-term commitment and action. Moreover, events and information platforms associated with the initiatives facilitate the exchange of knowledge through sharing of examples and lessons learnt (EEA, 2018k; Covenant of Mayors, 2019a). Many cities are already putting adaptation measures in practice. Frontrunner cities, such as Copenhagen or Rotterdam, are exemplars of how urban areas can be transformed to meet the adaptation challenge (Chapter 17). Others, such as Helsinki, are exploring how adaptation can be monitored (EEA, 2016i). In the absence of national strategies, cities can take the lead on adaptation within countries, as in the case of Belgrade (Ministry of Environmental Protection, 2017). Conversely, national leadership can ensure that adaptation planning follows the same standards in dozens of cities, as in the case of the 44MPA project in Poland (Ministry of the Environment, 2018).

([9]) The cities participating in these initiatives are mapped in the Urban vulnerability map viewer within the Climate-ADAPT platform (https://climate-adapt.eea.europa.eu/knowledge/tools/urban-adaptation).

TABLE 7.9 **Summary assessment — climate change adaptation strategies and plans**

Past trends and outlook		
Past trends (10-15 years)		The consideration of climate change adaptation at the EU level, the national level and in cities has increased in recent years. Most EEA member countries now have national adaptation strategies and/or action plans.
Outlook to 2030		Further action on climate change adaptation is ongoing or planned at European, national and subnational levels.
Prospects of meeting policy objectives/targets		
2020	☐	Most, but not all, EU Member States currently have a national adaptation strategy. Implementation of adaptation is still in its early stages in many countries because of a lack of funding or other barriers. Some countries have started to monitor the implementation of adaptation activities.
Robustness		Process-based information on the planning of adaptation at the national level is available from countries reporting to the EEA. Information on the implementation of adaptation at different levels is patchy at best. The assessment of outlooks relies primarily on expert judgement.

7.4.3 Climate change finance

Most measures for mitigating or adapting to climate change require financing, either initially or permanently. This section briefly reviews two financial targets related to EU domestic spending and to international spending.

EU budget targets and further EU activities

With the intention of mainstreaming climate action into the EU budget, the EU has agreed that at least 20 % of its budget for 2014-2020 should be spent on climate-related action (EC, 2011; European Council, 2013). Analyses by the Commission indicate that the EU is broadly on track towards the 20 % target, but further efforts are needed (EC, 2016). A report by the European Court of Auditors (ECA) acknowledged that ambitious work was under way and that the target has led to more, and better focused, climate action in the European Regional Development Fund and the Cohesion Fund. At the same time, the report highlighted a serious risk that the 20 % target will not be met and that there has been no significant shift towards climate action in the areas of agriculture, rural development and fisheries. The report also emphasised methodological weaknesses of the current tracking method, including the failure of tracking mitigation and adaptation spending separately. The ECA report also includes a detailed reply from the Commission addressing the ECA's observations and suggestions (ECA, 2016). Broadly similar conclusions have been reached, and various suggestions for improved climate mainstreaming in the next EU multiannual financial framework (2021-2027) were made in a recent study for the Commission (Forster et al., 2017).

The revised EU ETS Directive established new low-carbon funding mechanisms, in particular the Innovation Fund and the Modernisation Fund (EU, 2018a; EC, 2018f). The Commission action plan on sustainable finance intends to reorient capital flows towards sustainable investment in order to achieve sustainable and inclusive growth, manage financial risks stemming from climate change, environmental degradation and social issues, and foster transparency and long-termism in financial and economic activity (EC, 2018d).

International climate change finance

In the Copenhagen Accord under the UNFCCC, developed countries made the collective commitment to jointly mobilise USD 100 billion annually by 2020 to address the mitigation and adaptation needs of developing countries (UNFCCC, 2010). This commitment was reconfirmed and extended in the Paris Agreement (UNFCCC, 2015b). The Organisation for Economic Co-operation and Development (OECD) has reported that public climate finance from developed to developing countries increased from USD 37.9 billion in 2013 to USD 54.5 billion in 2017 (OECD, 2016). A submission by developed countries and the EU to the UNFCCC based on an earlier OECD study projected that aggregated funding levels for climate action in developing countries would reach more than USD 100 billion in 2020 (OECD, 2016; UNFCCC, 2016). These estimates and the underlying methodology have been criticised for their ambiguity in definitions and lack of transparency in reporting (AdaptationWatch, 2016).

08.
Air pollution

Key messages

- Air pollutants are emitted by a large range of economic activities (and from some natural sources). They can affect air quality far away from the source, and local effects also depend on local conditions. Air pollution is the single largest environmental health risk in Europe.

- The emissions of most main air pollutants decreased in Europe between 2000 and 2017. This decrease did not happen at the same pace in all countries and regions and not in all sectors. For instance, for the 33 EEA member countries, sulphur oxides from energy production and distribution decreased by 77 % (2000-2017), while ammonia emissions from agriculture decreased much less significantly and have even increased by about 3 % from 2013 to 2017. Reductions were comparably less for fine particulate matter, the pollutant that poses the greatest threat to human health.

- The reduction in emissions has led to a general improvement in air quality. However, there are still exceedances of EU air quality health standards for key pollutants such as particulate matter, nitrogen dioxide and ozone; EU vegetation standards for ozone; World Health Organization (WHO) health guidelines; and of critical loads of nitrogen in many ecosystems. These exceedances are expected to remain in 2020.

- With the full implementation of the current emission abatement policies, air pollutant concentrations above the WHO guidelines are expected to be almost completely eliminated by 2030. The current number of more than 400 000 premature deaths attributable to air pollution in the 28 EU Member States is expected to decline by more than a half by 2030, while the reduction in the impacts on ecosystems is expected to be smaller. Therefore there is still a need to substantially reduce the impacts on human health and ecosystems.

- To further improve air quality, additional measures are needed to reduce emissions, especially from agriculture, transport and domestic heating. The continuing contribution to poor air quality by these sectors is consistent with a need for systemic changes in the food, mobility and energy systems. Because of the transboundary character of air pollution, maintaining collaboration and coordinated action at international, national and local levels will be crucial to curb air pollution, in coordination with other environmental, climate and sectoral policies.

Thematic summary assessment

Theme	Past trends and outlook		Prospects of meeting policy objectives/targets	
	Past trends (10-15 years)	Outlook to 2030	2020	2030
Emissions of air pollutants	Trends show a mixed picture	Trends show a mixed picture	☑ Largely on track	☐ Partly on track
Concentrations of air pollutants	Improving trends dominate	Trends show a mixed picture	☒ Largely not on track	☑ Largely on track
Air pollution impacts on human health and well-being	Improving trends dominate	Trends show a mixed picture		☑ Largely on track
Air pollution and impacts on ecosystems	Trends show a mixed picture	Trends show a mixed picture	☐ Partly on track	☐ Partly on track

Note: For the methodology of the summary assessment table, see the introduction to Part 2. The justification for the colour coding is explained in Section 8.3, Key trends and outlooks (Tables 8.2, 8.3, 8.4 and 8.5).

08.
Air pollution

Air pollution is the single largest environmental risk to the health of Europeans.

8.1
Scope of the theme

The air we breathe and live in is a critical natural resource for humans, plants and animals. Good air quality is essential to protect not only human health and natural capital but also the built environment and therefore part of the cultural heritage.

Natural sources such as volcanic eruptions, sea salt or dust from wind erosion can contribute to air pollution. However, most pollutants are released as a result of human activities in economic sectors such as transport, agriculture, generation and use of energy, industry or waste management (Chapters 7, 9, 12, and 13).

Emitted pollutants, once released, undergo various physical and chemical processes (such as transport, reactions, absorption, and deposition on vegetation or with rain water), impacting ambient air quality, which can be analysed by measuring pollutant concentrations. Air pollution affects human health, vegetation and ecosystems, with particulate matter (PM), nitrogen dioxide (NO_2) and ground-level ozone (O_3) being the pollutants of greatest concern.

This assessment is primarily based on data officially provided by EU Member States and EEA member and cooperating countries under the obligations of the Convention on Long-range Transboundary Air Pollution (CLRTAP) protocols (UNECE, 2019), the National Emissions Ceilings (NEC) Directive (EU, 2016) and the Ambient Air Quality Directives (EU, 2004, 2008). In this last case, only measurement data from monitoring stations have been included (modelling data are not considered). The assessment focuses on the main, most harmful pollutants in ambient air and does not cover indoor air pollution.

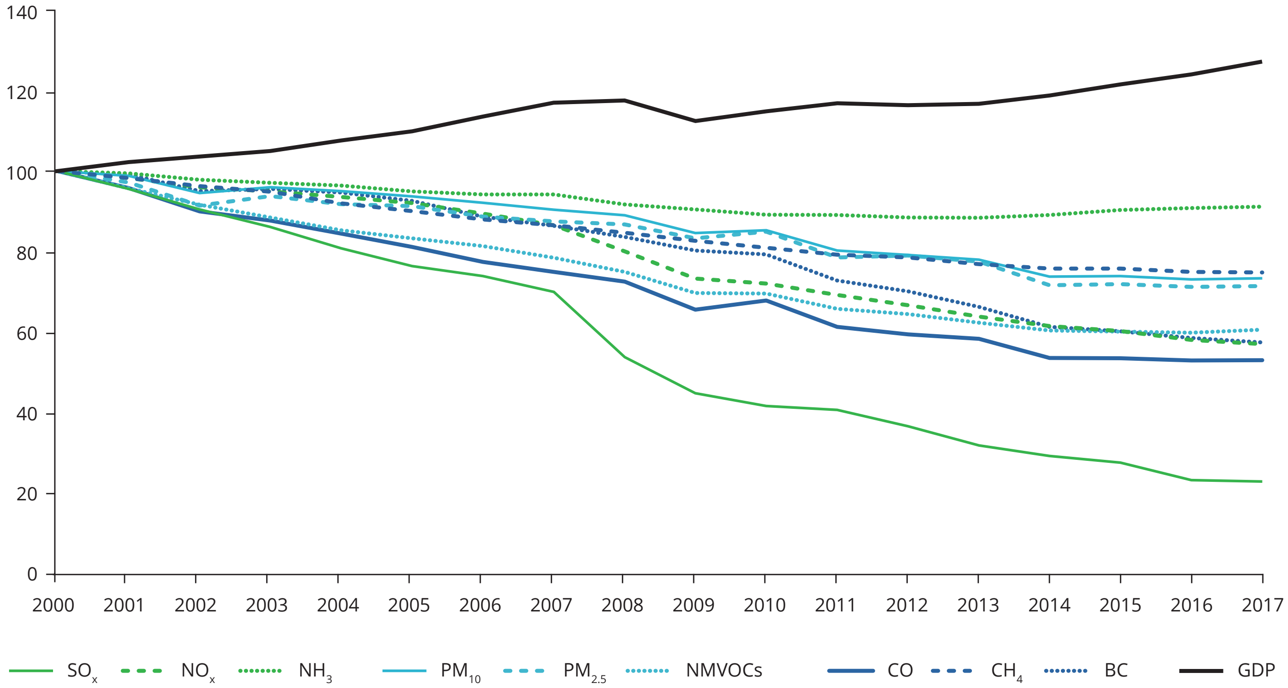
8.2
Policy landscape

Air pollution is a transboundary issue and therefore needs internationally concerted action to address it. The most significant international instrument to abate transboundary air pollution is the CLRTAP (UNECE, 1979), signed in Geneva in 1979, and its eight protocols to cut emissions of air pollutants. It has the overall objective of limiting and gradually reducing and preventing air pollution including long-range transboundary air pollution.

At the EU level, air pollution is a well-established environmental policy area, which has followed an approach based on three pillars (EC, 2018b):

1. it has implemented emission mitigation controls on national totals (via the NEC Directive (EU, 2016));

FIGURE 8.1 **Trends in the main air pollutant emissions and in gross domestic product in the EU-28**



Notes: Values for 2000-2017 are expressed as percentages of 2000 levels. Gross domestic product is expressed in chain-linked volumes (2010), as percentages of the 2000 level.
Methane (CH_4) emissions are total emissions (integrated pollution prevention and control sectors 1-7) excluding sector 5, land use, land use change and forestry. The present emission inventories include only anthropogenic non-methane volatile organic compound (NMVOC) emissions.
BC, black carbon.

Source: EEA (2019b).

2. it has set emission and energy efficiency standards for specific sources or sectors (e.g. the Industrial Emissions Directive, Euro regulations for vehicles, the Medium Combustion Plants Directive, the fuels and products directives, the Ecodesign Directive or the Nitrate Directive (EC, 2019b) (Chapters 7, 12, 13)); and

3. the two Ambient Air Quality Directives (EU, 2004, 2008) have set legal limits for ambient concentrations of air pollutants and the obligation to implement plans and measures when those limits are exceeded.

The objective of the most recent strategic policy directions such as the Seventh Environment Action Programme (7th EAP) (EC, 2013b) or the Clean Air for Europe Programme (EC, 2013a) is to achieve levels of air quality that do not give rise to significant negative impacts on, and risks to, human health and the environment.

Finally, the actions taken under other international environment and climate strategies, such as the Paris Agreement (UNFCCC, 2015) or the EU's Energy Union strategy (EC, 2015), are also expected to have a positive impact in reducing emissions of the main air pollutants. Table 8.1 presents an overview of selected policy objectives and targets on air pollution.

8.3 Key trends and outlooks

8.3.1 Emissions of air pollutants

► See Table 8.2

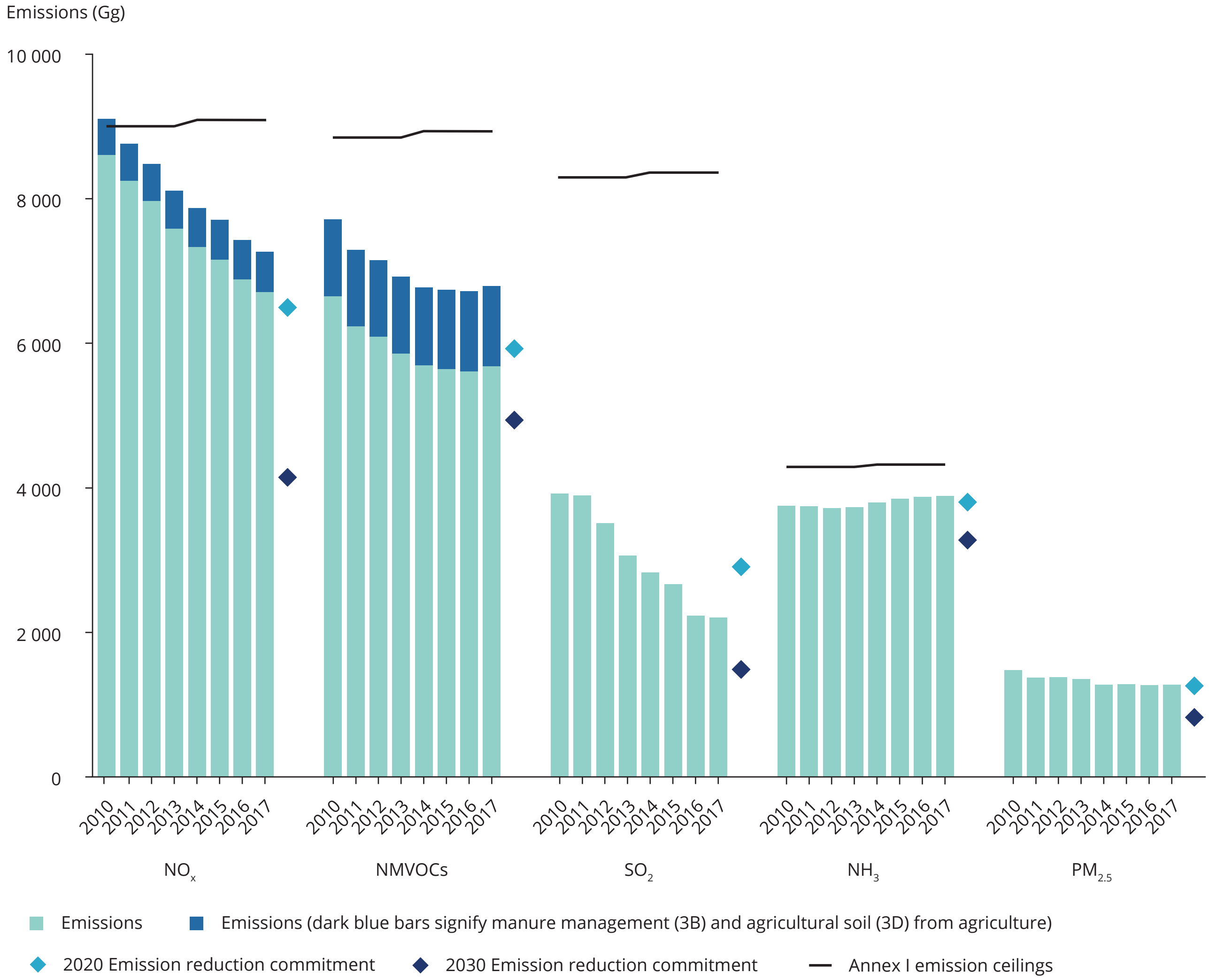
Figure 8.1 shows total emissions of the main air pollutants in the 28 EU Member States (EU-28), indexed

TABLE 8.1 Overview of selected policy objectives and targets

Policy objectives and targets	Sources	Target year	Agreement
Emissions of air pollutants			
Attain emission ceilings and reduction commitments for the main air pollutants SO_x, NO_x, NMVOCs, NH_3 and primary $PM_{2.5}$ (for the latter, only reduction commitments)	CLRTAP (UNECE, 1979) and protocols (UNECE, 2019), (particularly the 2012 amended Gothenburg Protocol)	Ceilings: 2010, remain applicable until 2019 Reduction commitments: 2020 and beyond	Legally binding to the Parties to the Gothenburg Protocol
	SDG 7 (Affordable and clean energy); SDG 13 (Climate action)	SDGs 2030	
Attain EU Member State and EU emission ceilings and reduction commitments for the main air pollutants SO_x, NO_x, NMVOCs, NH_3 and primary $PM_{2.5}$ (for the latter, reduction commitments only)	NEC Directive (EU, 2016) (transposes the reduction commitments for 2020 agreed by the EU and its Member States under the 2012 amended Gothenburg Protocol (CLRTAP); more ambitious reduction commitments agreed for 2030)	Ceilings for 2010, Annex I (and Annex II, environmental objectives for SO_x, NO_x and NMVOCs): remain applicable until 2019 Reduction commitments: 2020 and 2030	Legally binding (only Annex I ceilings)
	SDG 7 (Affordable and clean energy); SDG 13 (Climate action)	SDGs 2030	
Air quality			
Attain limit values for SO_2, NO_2, C_6H_6, CO, Pb, PM_{10} and $PM_{2.5}$; achieve target values for $PM_{2.5}$, O_3, As, Cd, Ni and BaP; the long-term objective for O_3; the national exposure reduction target and the exposure concentration obligation for $PM_{2.5}$; and critical levels for SO_2 and NO_x	Ambient Air Quality Directives (EU, 2004, 2008)	2005/2010/2013/2015/2020	Legally binding
	Clean Air Programme for Europe (EC, 2013a)	2020	
	SDG 11 (Sustainable cities)	SDG 2030	
Achieve levels of air quality that do not give rise to significant negative impacts on, and risks to, human health and the environment (in line with the WHO air quality guidelines)	7th EAP (EC, 2013b), Clean Air Programme for Europe (EC, 2013a)	N/A	Non-binding commitment
Impacts on human health and well-being			
By 2030, substantially reduce the number of deaths and illnesses from air pollution	SDG 3.9 (Ensure healthy lives and promote well-being for all at all ages)	2030	Non-binding commitment
By 2030, cut the health impacts of air pollution (in terms of premature mortality due to PM and O_3) by 52 % compared with 2005	Clean Air Programme for Europe (EC, 2013a)	2030	Non-binding commitment
Impacts on ecosystems			
No exceedances of the critical loads and levels	7th EAP (EC, 2013b)	N/A	Non-binding commitment
By 2030, reduce the ecosystem area exceeding eutrophication limits to 35 %	Clean Air Programme for Europe (EC, 2013a), NEC Directive (indirectly) (EU, 2016)	2030	Non-binding commitment

Note: As, arsenic; BaP, benzo[*a*]pyrene; C_6H_6, benzene; Cd, cadmium; CO, carbon monoxide; NH_3, ammonia; Ni, nickel; NMVOCs, non-methane volatile organic compounds; NO_2, nitrogen dioxide; NO_x, nitrogen oxides; Pb, lead; $PM_{2.5}$, fine particulate matter (≤ 2.5 µm diameter); PM_{10}, particulate matter ≤ 10 µm diameter; O_3, ozone; SDG, Sustainable Development Goal; SO_2, sulphur dioxide; SO_x, sulphur oxides; WHO, World Health Organization; N/A, non-applicable.

FIGURE 8.2 **EU progress towards meeting the 2010 emission ceilings set out in the NEC Directive and the 2020/2030 reduction commitments**



Note: Annex I lists the legally binding ceilings applicable for 2010-2019. To assess future attainment of 2020 and 2030 reduction commitments, NO_x and NMVOC emissions from two main agricultural activities — manure management (3B) and agricultural soils (3D) — are not considered. The magnitude of these emission sources is indicated by the blue bars on top of the NO_x and NMVOC columns. Only the lower part of the NO_x and NMVOC columns should be considered for comparison with the 2020 and 2030 reduction commitments.

Source: EEA (2019k).

as a percentage of their value in the reference year 2000. Emissions of all primary and precursor pollutants contributing to ambient air concentrations of the main air pollutants decreased between the years 2000 and 2017 in the EU-28. Generally, this decline was similar in the 33 EEA member countries (EEA-33), where sulphur dioxide (SO_2) emissions have decreased by 62 % since the year 2000, while ammonia (NH_3) emissions have decreased only slightly by 4 % but have increased in the agriculture sector since 2013 by about 3 % (EEA, 2019e).

While sulphur dioxide emissions declined by 62 % since 2000, ammonia emissions decreased by only 4 % in the EEA member countries.

The substantial reduction in SO_2 emissions occurred mainly in the energy production, distribution and use sectors (Chapter 12). Reductions in nitrogen oxides (NO_x) emissions, for example, have been achieved primarily as a result of fitting three-way catalytic converters to petrol-fuelled cars, driven by the legislative European emission standards (EEA, 2019d); emissions by economic sector are also shown in Chapter 12.

In 2017, the total emissions for the EU as a whole of four important air pollutants — NO_x, non-methane volatile organic compounds (NMVOCs), SO_2 and ammonia (NH_3) — were below the respective NEC Directive 2010 ceilings, which remain applicable until 2019 (EEA, 2019k).

However, 6 Member States continued to exceed their national emission ceilings for one or more pollutants in 2017: the Netherlands for NH_3 and NMVOCs; and Austria, Croatia, Germany, Ireland and Spain for NH_3. No Member State exceeded its NO_x or SO_2 ceilings.

Norway and Switzerland have signed and ratified the Gothenburg Protocol. Only Norway still exceeded its NO_x and NH_3 ceilings in 2017 (EEA, 2019e). Liechtenstein has signed, but not ratified, the Protocol, while Iceland and Turkey have not yet signed it (UNECE, 2018a).

After 2019, new commitments to reduce emissions for 2020 onwards, and later for 2030 onwards, are applicable under the NEC Directive. Every second year, Member States must report their emission projections for 2020, 2025 and 2030 for SO_2, NO_x, NH_3, NMVOCs, fine particulate matter (≤ 2.5 μm, $PM_{2.5}$) and, if available, black carbon (BC). These officially reported emission projections are used to assess whether or not Member States are on track to meet their reduction commitments for 2020 and 2030 (EU, 2016). Figure 8.2 summarises the EU's progress in meeting the ceilings and reduction commitments.

Besides general mitigation of air pollutant emissions in sectors such as road transport, residential households or agriculture, emissions in certain areas and during certain periods of the year also need consideration when planning regional and local mitigation measures (Box 8.1).

More efforts are needed for all pollutants to meet the EU's 2030 emission reduction commitments.

For the EU as a whole, the projections reported by the Member States in 2019 for the year 2030 show that additional efforts are needed to achieve the 2030 emission reduction commitments for all pollutants (EEA, 2019k). This means for NO_x a reduction of almost 40 % compared with 2017 emissions, for NMVOCs and NH_3 around 15 %, and for SO_2 as well as $PM_{2.5}$ more than 30 %.

The First Clean Air Outlook (EC, 2018c) is underpinned by a detailed study (Amann et al., 2018b), which includes *inter alia* a scenario analysis considering post-2014 source-oriented regulations for emission controls for medium combustion plants, non-road mobile machinery and domestic solid fuel combustion, as well as the implementation of the 2016 NEC Directive (EU, 2016).

The resulting emission projections from this scenario indicate whether the EU Member States are on track to meet the 2030 reduction commitments set within the NEC Directive or not and to which extent additional measures will be needed to reach the reduction commitments.

The Clean Air Outlook analyses do not consider measures to comply with air quality limit (and target) values set in

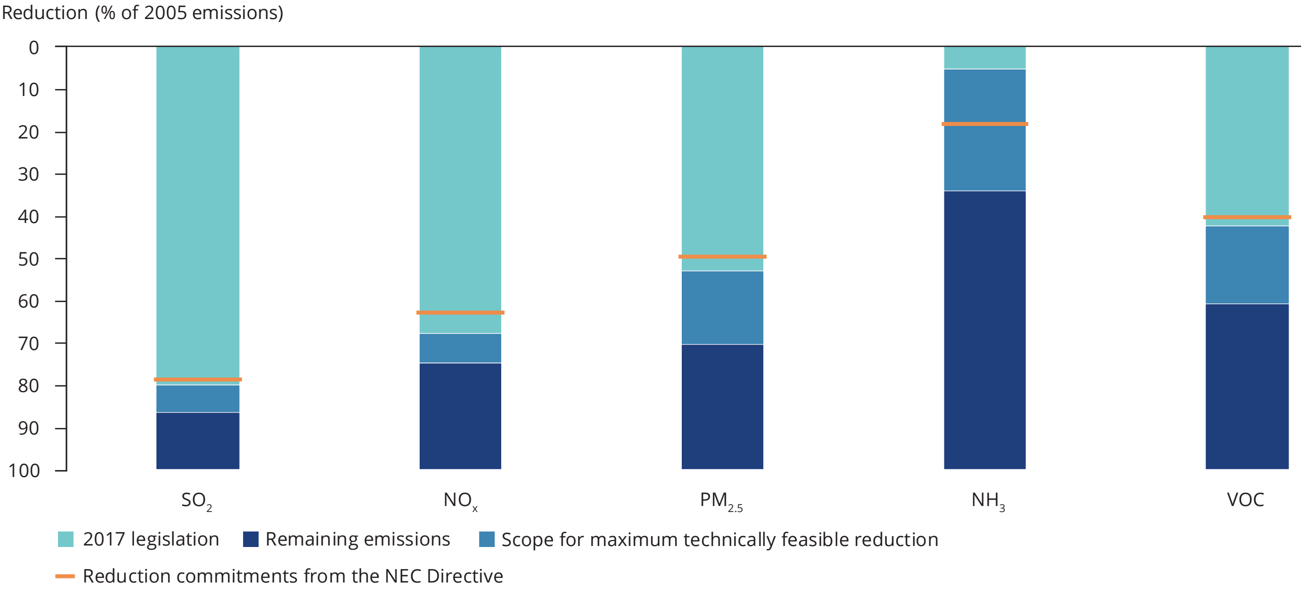
BOX 8.1
Regions, areas and periods with high air pollutant emissions

In parts of Europe (particularly eastern Europe and northern Italy) burning of wood, coal and other solid fuels in domestic stoves, especially during winter time, leads to locally or regionally high fine particulate matter ($PM_{2.5}$) emissions. The International Institute for Applied Systems Analysis estimated that solid fuel combustion in households contributes only about 2.7 % to total energy consumption in the EU-28, whereas it is responsible for more than 45 % of the total emissions of primary $PM_{2.5}$, i.e. three times more than road transport (Amann et al., 2018a).

Moreover, in street canyons with a high density of buildings and high levels of road traffic, nitrogen oxide emissions can be very high locally, leading to exceedances of air quality standards for nitrogen dioxide.

Furthermore, intensively managed agricultural areas, particularly when animal manure is spread on fields with no or little vegetation cover, can have very high ammonia emissions temporarily. This contributes to the formation of high levels of PM in the air, again contributing to exceedances of air quality standards for protecting human health (Section 8.3.2). ■

FIGURE 8.3 EU-28 emission reductions in 2030 relative to 2005



Notes: Specific developments in each country and sector might emerge differently, particularly due to the flexibility mechanisms built into the climate and energy package.
The maximum technically feasible reduction reflects full implementation of the technical emission control measures, going beyond what is required by current legislation.

Source: Amann et al. (2018b).

TABLE 8.2 Summary assessment — emissions of air pollutants

Past trends and outlook		
Past trends (10-15 years)		There were steep declines in emissions of the main air pollutants from 2000 to 2017, although improvements slowed down after 2010. The exception is ammonia, for which emissions have increased since 2013.
Outlook to 2030		Continued progress is expected as implementation of current policies to mitigate air pollutant emissions continues. However, ammonia emissions are projected to decrease only slightly. Full implementation of policies is required to deliver improvements, which will also be supported by climate change, energy and transport legislation.
Prospects of meeting policy objectives/targets		
2020	☑	The EU as a whole is on track to meet the 2020 targets for the main air pollutants, although there are still issues regarding ammonia in some countries. However, according to reported emission projections, most Member States are not expected to meet their reduction commitments in 2030. This is largely due to projected developments in ammonia emissions and local/regional issues with small-scale combustion of solid fuels. Additional measures on top of current legislation are required.
2030	☐	
Robustness		Information on air pollutant emissions is robust. It is based on officially reported inventory data under the National Emission Ceilings (NEC) Directive (in place since 2001). The European Commission and the Convention on Long-range Transboundary Air Pollution review emissions inventories regularly (including NEC Directive projections in 2019). Reported emission projections, particularly those for 2030, are more uncertain, and reporting under the 2016 revised NEC Directive only started in 2017. The emission scenarios were calculated with the GAINS model, which uses authoritative, sound input data and is regularly used by the European Commission for impact assessments and projections, and the underlying assumptions are documented.

the Air Quality Directives. An example is local air pollution abatement plans in cities, such as traffic restrictions that aim to reduce NO_x and PM emissions (Section 8.4).

Figure 8.3 shows the results of the Clean Air Outlook analyses for emissions of the five main air pollutants (Amann et al., 2018b). With legislation fully implemented, including the 2016 NEC Directive, the EU would not only meet the emission reduction commitments for SO_2 and NO_x but also attain the 2030 commitments for primary $PM_{2.5}$ and volatile organic compounds (VOCs). For NH_3, abatement measures are driven by the NEC Directive alone, which lacks ambition concerning this pollutant. However, if technically feasible reduction measures were applied, the NH_3 emission reduction commitments for the EU could be achieved (Figure 8.3). The situation in single Member States can be different, i.e. according to the scenario analyses it is envisaged that some will surpass their commitments. It is expected that other Member States will not reach their national emission reduction commitments for one or several pollutants (e.g. France, Germany, Poland and Spain for NH_3 and also several countries for $PM_{2.5}$) (Amann et al., 2018b). A number of countries will have to take additional measures, as full implementation of the legislation is not sufficient. Overachievement in some Member States reflects the synergies between different policies (air pollution, climate and energy).

8.3.2 Concentrations of air pollutants

►See Table 8.3

In recent years, the air quality standards of some pollutants have only rarely been exceeded, i.e. for SO_2, carbon monoxide (CO), benzene (C_6H_6) or the toxic metals (EEA, 2019b). Nevertheless, full attainment of respective limit and target values has not yet been achieved.

The EU is on track to meet the 2020 emission reduction targets for all air pollutants except for ammonia emissions in some countries.

Trend analyses published by the EEA (EEA, 2016) showed a significant downward trend in annual mean concentrations of PM_{10} at 75 % of the 839 monitoring stations considered. Less than 1 % of the stations registered a significant increasing trend. On average, the decreases were larger for urban traffic stations than for those measuring urban background levels. This pattern was also consistent for $PM_{2.5}$ (period 2006-2014). For O_3, trends depend on the metrics used. For those metrics reflecting the highest concentrations, the trends were decreasing. For the annual mean, the trend at rural sites was also decreasing, but it was small and frequently not significant. In contrast, at traffic stations, the annual mean showed an upward trend. Finally, the annual mean concentrations of NO_2 also showed on average downward trends at all types of the 1 261 stations considered, but the trends were stronger in absolute terms at traffic stations.

Even if these trends indicate a reduction in concentrations at most of the stations, there remain persistent exceedances of the regulated standards especially for PM, NO_2, O_3 and benzo[*a*]pyrene (BaP). Taking NO_2 as an example, Map 8.1 shows concentrations above the annual limit value in 2017 all over Europe (in 17 EU-28 Member States and four other EEA-39 countries), especially at traffic stations (EEA, 2019h). This is mainly because the anticipated reductions in emissions of NO_x have not been met in real-world driving conditions, and diesel engine emissions in particular have been bigger than expected.

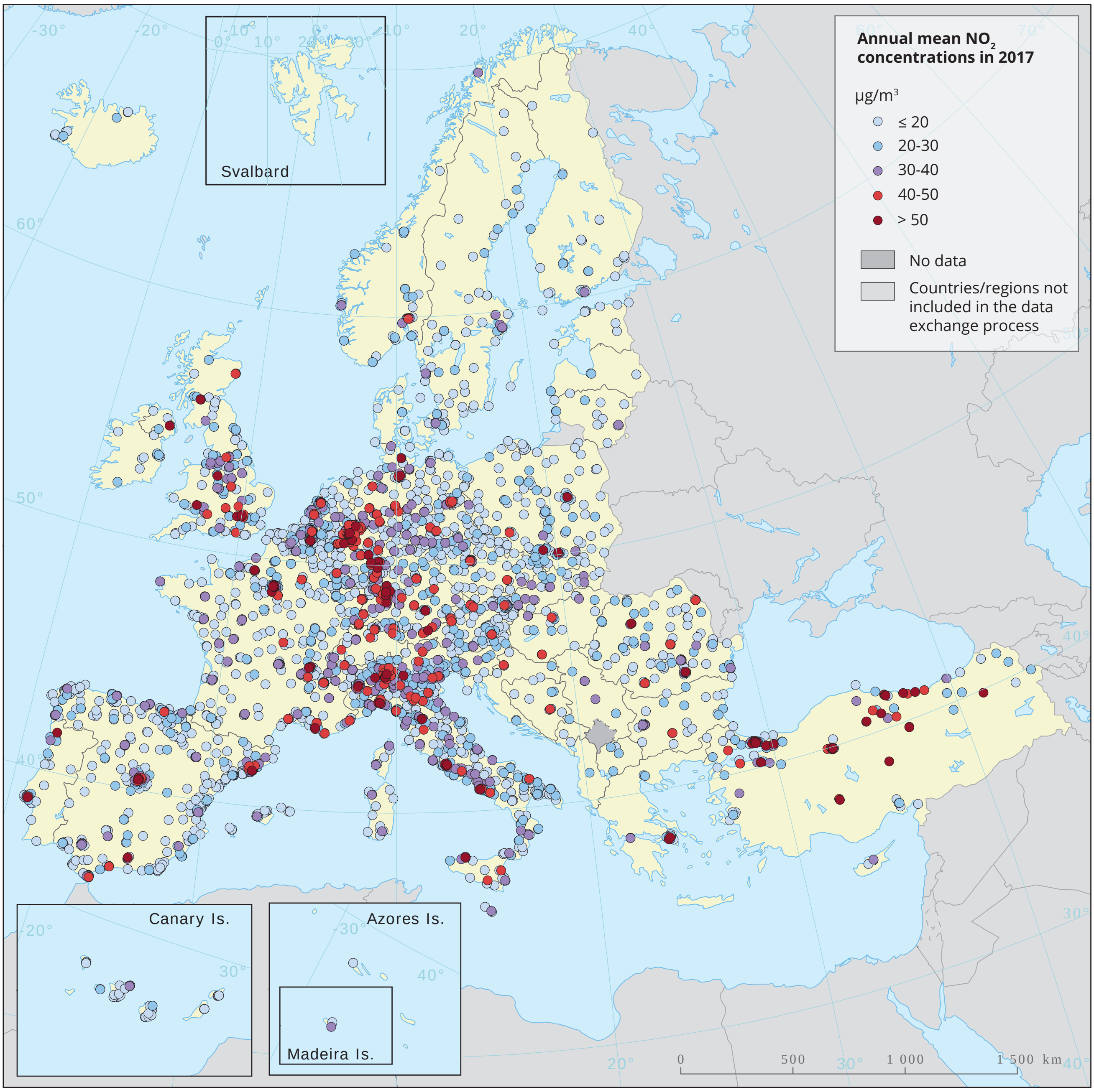
Exceedances of EU air quality standards for particulate matter, nitrogen dioxide, ground-level ozone and benzo[*a*]pyrene remain.

High pollutant concentrations are especially serious in urban areas, where most of the European population lives (Eurostat, 2018). Poor air quality in cities can be mainly attributed to the high levels of emissions from road traffic (as the case of NO_2 shows) and residential combustion in urban areas (namely for $PM_{2.5}$ and BaP). In some cases the situation is made worse by conditions unfavourable for the dispersion of emissions because of topography and meteorological conditions (Box 8.1).

If, instead of considering the EU standards, concentrations of pollutants are compared with the WHO air quality guidelines (WHO, 2006), the picture is even more negative. Figure 8.4 shows, per country, a summary of the $PM_{2.5}$ concentrations registered at all the stations in that country. While seven Member States and three other EEA-39 countries reported concentrations above the annual limit value for $PM_{2.5}$ in 2017 (plus another one in 2016), in only three countries were all the concentrations reported below the World Health Organization (WHO) air quality guidelines.

A recurrent issue in recent years is the occurrence of episodes of high PM concentrations. These episodes last for several days and can affect large parts of Europe. Residential heating, agriculture, road transport and, to a lesser extent, industry have been identified as the main sources (Tarrasón et al., 2016;

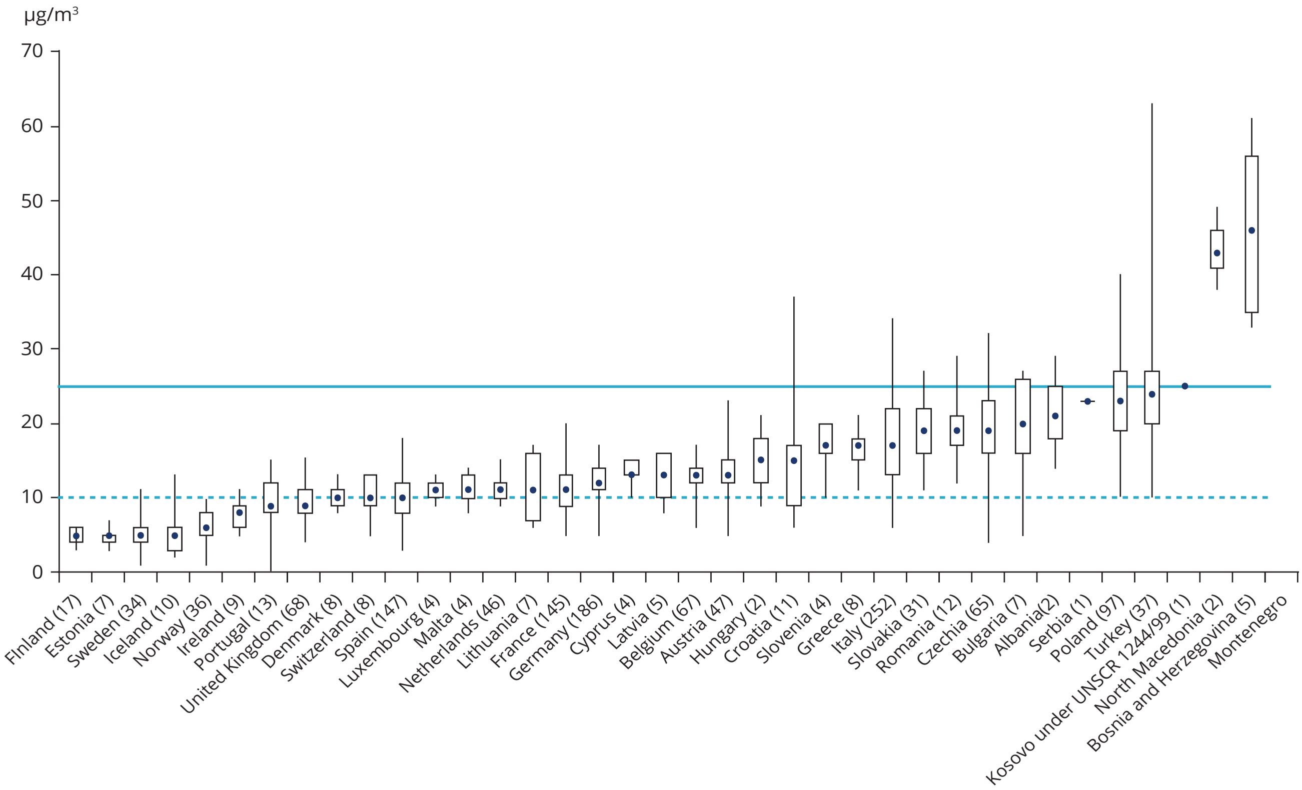
MAP 8.1 Annual mean NO_2 concentrations in 2017



Note: Observed concentrations of NO_2 in 2017. Dots in the last two colour categories correspond to values above the EU annual limit value and the equal WHO air quality guidelines (40 μg/m³). Only stations with > 75 % of valid data have been included in the map. The French overseas territories' stations are not shown in the map but can be found at EEA (2019j).

Source: EEA (2019a).

FIGURE 8.4 **Country comparison — $PM_{2.5}$ concentrations in 2017**



Notes: The graph is based on annual mean concentration values at the station level. For each country, the number of stations considered (in brackets), the lowest, highest and average (blue dots) concentrations and the 25th (bottom side of the box) and 75th (top side of the box) percentiles are shown. At 25 % of the stations, levels are below the 25th percentile; at 25 % of the stations, concentrations are above the 75th percentile. The limit value set by EU legislation is marked by the upper horizontal line. The WHO air quality guideline is marked by the lower dashed horizontal line. The country's situation depends on the number of operational stations. Concentrations correspond to values measured at stations, without taking into account that, for checking compliance with the Air Quality Directive (EU, 2008), there is the possibility of subtracting contributions from natural sources and winter road sanding/salting.

Data from Albania, Kosovo (under United Nations Security Council Resolution 1244/99) and Serbia are for 2016.

Source: EEA (2019a).

Hamer et al., 2017). The formation of secondary PM also plays an important role. For example, several episodes in spring time are mostly due to NH_3 coming from the use of fertilisers applied to agricultural fields and to NO_x emissions from urban traffic. In some cases, dust from the Sahara also contributes to the increase in PM concentrations.

The ambition to achieve the EU legal standards by 2020 as specified in the Clean Air Programme for Europe (EC, 2013a) appears pessimistic. According to the above-mentioned analysis (EEA, 2016), if the averaged trend over the period 2000-2014 is extrapolated to 2020, 1.6 % of the stations are expected to still have concentrations above the annual limit value for PM_{10} (and 3 % of stations for $PM_{2.5}$). Similarly, 7 % of stations measuring O_3 are expected to have concentrations above the European target value and 7 % of stations measuring NO_2 to have concentrations above the annual limit value.

This outlook has also been confirmed by the information reported by European countries as part of their plans to improve air quality. Some countries have indicated that they anticipate achieving compliance with PM, NO_2 and BaP legal standards beyond 2020 and in some cases as late as 2026 (EEA, 2019c).

TABLE 8.3 Summary assessment — concentrations of air pollutants

Past trends and outlook		
Past trends (10-15 years)		Since 2000 there has been a decrease in concentrations of the main air pollutants.
Outlook to 2030		Continued progress is expected and full implementation of current policies would deliver reductions in fine particulate matter ($PM_{2.5}$) concentrations to levels below the WHO air quality guidelines in almost all of the EU-28. For nitrogen dioxide, around 3 % of stations are still likely to exceed the limit value (same as the WHO guideline). For the rest of the European countries where the National Emissions Ceiling Directive is not applied, the outlook is more uncertain without efforts to implement the Gothenburg Protocol.
Prospects of meeting policy objectives/targets		
2020	☒	Europe is not on track to meet policy objectives by 2020, as there will still be exceedances for most air quality standards. If current policies are fully implemented, the objective of meeting the WHO air quality guidelines is expected to be achieved in most areas by 2030.
2030	☑	
Robustness		Information on air pollutant concentrations is robust enough, as the Ambient Air Quality Directives have been in place for more than two decades and have ensured a common and comparable monitoring methodology. The prospects to 2020 are based on trend analysis and projections of the measured air concentrations and also on the projections reported by the Member States on their implementation of air quality plans and measures. Finally, the outlook to 2030 is based on the calculations of the GAINS model, used for many years for impact assessments and projections by the European Commission, and the underlying assumptions are documented.

Looking further ahead (Section 8.3.1), modelled scenarios suggest that the significant decreases in precursor emissions are expected to reduce $PM_{2.5}$ concentrations in almost every country below the WHO guideline by 2030 (Amann et al., 2018b). The only exceptions are expected to be in northern Italy and southern Poland. Regarding NO_2, the analysis predicts that only 3 % of the almost 2 000 analysed monitoring stations are expected to be above the annual limit value and the equivalent WHO guideline by 2030.

8.3.3 Impacts on human health and well-being

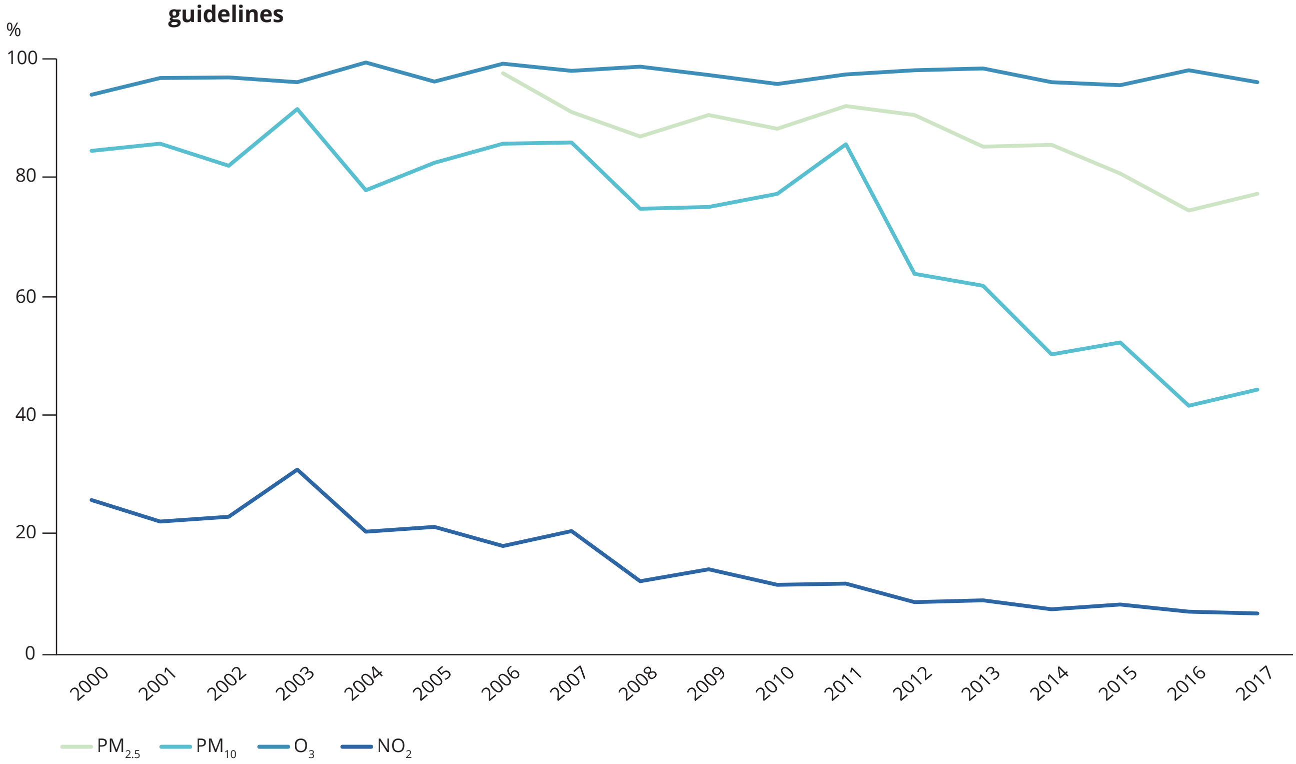
► See Table 8.4

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 PM as a separate component of air pollution mixtures, have been classified as carcinogenic (IARC, 2013).

95 % of the EU urban population remain exposed to pollutant concentrations above WHO air quality guidelines.

The fact that in many cases air pollutant concentrations remain above the legal standards implies that the population's exposure to those pollutants is also high. Focusing on people living in urban areas, where higher population densities and high air pollution coincide, Figure 8.5 shows that a considerable percentage of the EU-28 population is still living in areas with concentrations of pollutants above the WHO air quality guidelines. Since 2000, the trend has been decreasing for all pollutants, with the exception of O_3. That is particularly evident for PM in the latest 6 years shown in the figure. Nevertheless, as the starting point was high, the ambition of having none of the population living in areas where the WHO guidelines are exceeded seems unachievable by 2020. This is especially true for O_3, for which exposure above the WHO guidelines has been stable at around 95 % of the

FIGURE 8.5 **EU urban population exposed to air pollutant concentrations above selected WHO air quality guidelines**



Source: EEA (2019g).

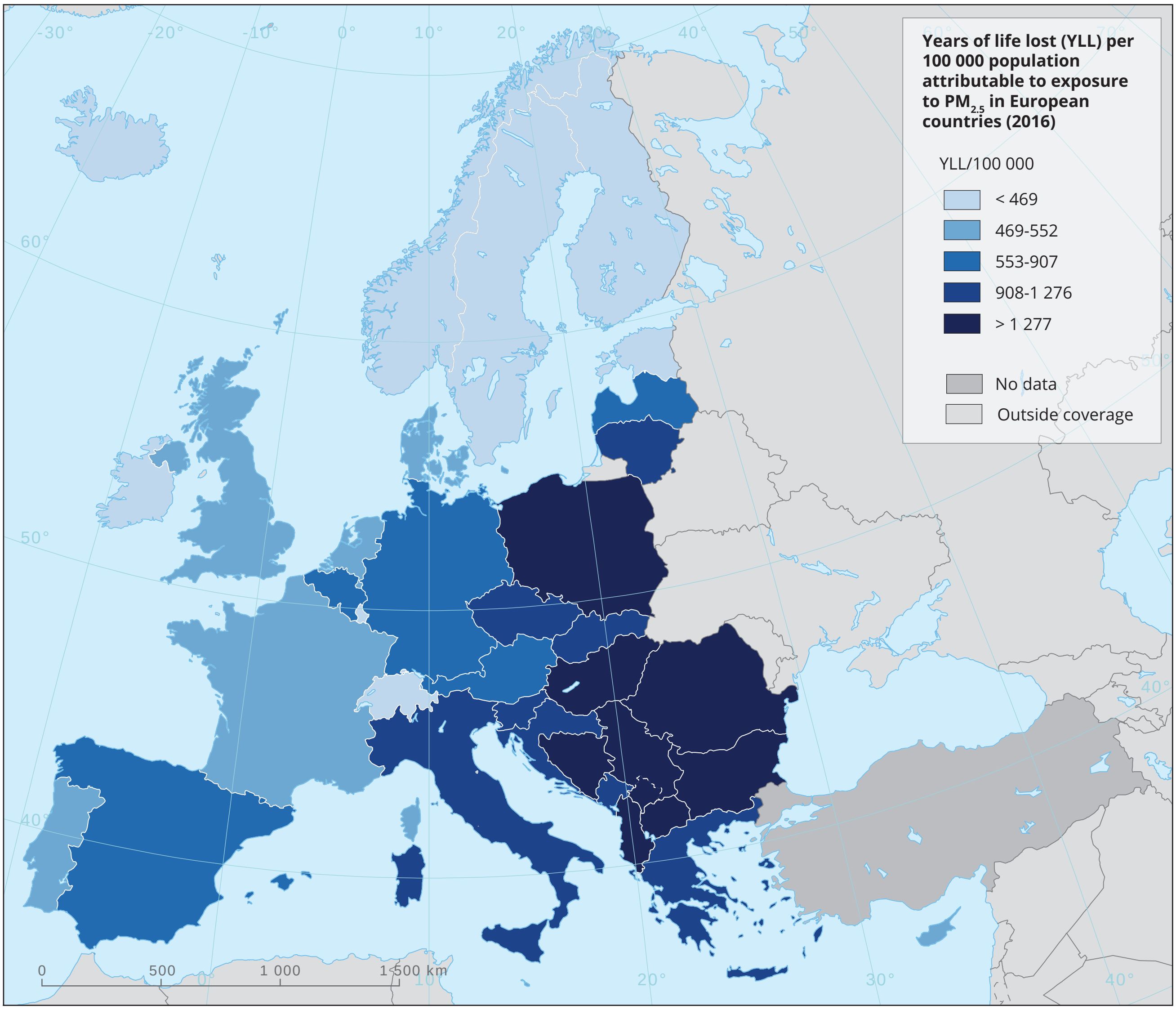
EU-28 urban population. Considering the EU legal standards, up to almost 20 % of the EU-28 urban population still lives in areas where at least one of the standards is exceeded (EEA, 2019g).

It is anticipated that the commitments to reduce air pollutant emissions by 2030 under the revised NEC Directive (Figure 8.2) will result in a reduction in the population exposed to $PM_{2.5}$ concentrations above the WHO guideline to around 13 % by 2030, and in most of those locations the exceedances will be small enough to be addressed by local measures (Amann et al., 2018b). The latest estimations indicate that exposure to $PM_{2.5}$ is responsible for around 400 000 premature deaths in Europe every year (EEA, 2019b). Exposure to NO_2 and O_3 were responsible for around 70 000 and 15 000 premature deaths in 2017, respectively. These calculations are made for individual pollutants without taking into account that pollution is a mix of all of them and concentrations are in some cases correlated. Therefore, the impacts cannot simply be aggregated, as this may result in double counting of the effects (EEA, 2019b). The impacts of air pollution may also be expressed in terms of years of life lost ([1]).

Map 8.2 shows years of life lost per 100 000 inhabitants (as a way of normalising the numbers and making countries easily comparable independently of their size and population) in 2016 for $PM_{2.5}$. The largest relative impacts are observed in the central and eastern European countries where the highest concentrations are also observed, i.e. ordered by relative impacts, Kosovo (under UNSCR 1244/99), Serbia, Bulgaria, Albania and North Macedonia. The detailed data for each country, together with the impacts of NO_2 and O_3, can be found in the EEA's report on air quality in Europe (EEA, 2019b).

([1]) Years of life lost (YLL) are defined as the years of potential life lost due to premature death. YLL is an estimate of the number of years that people in a population would have lived had there been no premature deaths. The YLL measure takes into account the age at which deaths occur and therefore the contribution to the total is greater for a death occurring at a young age than that for a death occurring at an older age (EEA, 2018a).

MAP 8.2 **Estimated years of life lost per 100 000 population attributable to exposure to $PM_{2.5}$ in European countries in 2016**



Note: YLL, years of life lost. The classification of values in map legends is quantiles, so one fifth of countries fall in each class. The calculations are made for all of Europe and they may differ for specific studies at country level.

Source: Based on EEA (2019b).

400 000

premature deaths per year in Europe are attributable to exposure to $PM_{2.5}$.

A recent study (ETC/ACM et al., 2018) assessed the long-term trends in the exposure of the European population to $PM_{2.5}$ concentrations from 1990 to 2015 and the associated premature deaths. The study points to a median decrease in premature mortality attributed to exposure to $PM_{2.5}$ of about 60 % in Europe between 1990 and 2015.

Existing scientific evidence (EEA, 2018c) shows that in Europe some groups are more affected by air pollution than others because they are also more exposed or vulnerable to

TABLE 8.4 Summary assessment — air pollution impacts on human health and well-being

Past trends and outlook		
Past trends (10-15 years)		Europe's air quality is improving and although fine particulate matter ($PM_{2.5}$) still causes serious impacts on health, there has been an estimated 60 % reduction in premature mortality attributed to exposure to $PM_{2.5}$ since 1990.
Outlook to 2030		Full implementation of current policies is expected to deliver projected reductions in premature deaths attributable to $PM_{2.5}$ of 54 % by 2030. However, 194 000 premature deaths are estimated to occur, which indicates that there is still a need to substantially reduce the number of premature deaths and illnesses from air pollution.
Prospects of meeting policy objectives/targets		
2030	☑	The 54 % reduction in premature deaths attributable to $PM_{2.5}$ anticipated by 2030 goes beyond the 52 % objective set by the 2013 Clean Air Programme for Europe.
Robustness		Analysis of past trends has used different data sets but a common methodology to estimate the number of premature deaths. Although the different data sets show a wide range of final results, the median values have been considered. The main uncertainty in the health risk assessments is the concentration-response functions used. The functions recommended by WHO have been used in all calculations. Finally, for prospects, the GAINS model has again been used and the underlying assumptions are documented.

environmental hazards. Older people, children and those with pre-existing health conditions are more vulnerable, while lower socio-economic groups tend to be more exposed (Chapter 14). For a 'business as usual' (i.e. baseline) emissions scenario, models project that the impacts of air pollution are expected to continue decreasing. Beyond 2020, and without further measures, reductions in the impacts on health are expected to continue but at a considerably slower rate (Maas and Grennfelt, 2016). According to the EEA (EEA, 2015), around 144 000 premature deaths could be avoided in the EU in 2012, compared with the real situation, if the WHO air quality guidelines had been attained. According to Amman et al. (2018b), taking into account the overachievements in reducing emissions that might result from fully implementing EU legislation, premature deaths attributable to $PM_{2.5}$ are expected to decline by 54 % from 2005 to 2030 (from 418 000 cases to 194 000), assuming a constant population between 2005 and 2030.

54 %

of premature deaths from $PM_{2.5}$ in Europe could be avoided by 2030 if current policies are implemented fully.

8.3.4
Impacts on ecosystems
► See Table 8.5

Air pollution may directly affect vegetation and fauna and the quality of water and soils as well as the ecosystem services that they support. The atmospheric deposition of nitrogen as nitrate and ammonium compounds can disrupt terrestrial and aquatic ecosystems by introducing excessive amounts of nutrient nitrogen, which can lead to changes in species diversity and to invasions of new species. When this happens, the so-called critical load for eutrophication by nitrogen is exceeded (Box 8.2). NH_3 and NO_x, together with SO₂, also contribute to the acidification of soil, lakes and rivers, causing biodiversity loss.

The cooperative programme for monitoring and evaluation of the long-range transmission of air pollutants in Europe (EMEP) shows that in 2016 critical loads for eutrophication were exceeded in virtually all European countries, in about 62 % of the ecosystem area (EMEP, 2018). This confirms that, although the magnitude of critical load exceedances decreased in most areas, deposition of atmospheric nitrogen remains a threat to ecosystem health. In 2016, the highest exceedances occurred in the Po valley (Italy), on the Dutch-German-Danish border and in north-eastern Spain. Steps taken to mitigate emissions of nitrogen compounds have to date been insufficient to provide conditions in which ecosystems can begin to recover

TABLE 8.5 Summary assessment — air pollution and impacts on ecosystems

Past trends and outlook		
Past trends (10-15 years)		Lower emissions of air pollutants have contributed to fewer exceedances of acidification and eutrophication limits. However, in 2016, the critical loads for eutrophication were still exceeded in over 62 % of the European ecosystem area.
Outlook to 2030		Further progress is expected regarding acidification of forest soils and freshwaters due to reductions in atmospheric sulphur and nitrogen deposition. A few acidification hot spots are expected to remain in 2030 due to regional ammonia emissions. Furthermore, there is a time lag between reducing emissions and the recovery of ecosystems. The total area where critical loads for eutrophication are exceeded is projected to be 49 % of European ecosystems, although the magnitude of exceedance is expected to be significantly less than in 2005 in most areas.
Prospects of meeting policy objectives/targets		
2020	☐	Europe is on track to meet policy targets to reduce the acidification of sensitive ecosystems. However, Europe is not on track to meet policy targets to reduce eutrophication, which aim to reduce the ecosystem area exceeding eutrophication limits to 35 % by 2030. Current projections suggest that 49 % of the area is expected to still be in exceedance of critical loads.
2030	☐	
Robustness		Critical loads exceedance modelling requires input from many different sources, and hence it is subject to uncertainty. Critical loads are based on information provided by the scientific community in the Working Group on Effects under the Convention on Long-range Transboundary Air Pollution. The critical loads concept has been applied and developed for around four decades.

from eutrophication. Thus, further reductions are necessary (Maas and Grennfelt, 2016), particularly of NH_3 emissions.

The Clean Air Outlook analysis suggests that achieving compliance with the commitments to reduce emissions (Section 8.3.1) will not achieve the improvements suggested in the 2013 European Commission proposal for the NEC Directive by 2030 (Amann et al., 2018b). In 2005, 67 % of European ecosystems were exposed to nitrogen deposition exceeding the critical loads (78 % of the protected Natura 2000 areas). According to the scenario that assumes that Member States meet the commitments to reduce emissions, this area would be 49 % in 2030, although the magnitude of exceedance is expected to be significantly less than in 2005 in most areas. The Clean Air for Europe Programme calls for the area in exceedance to be reduced to 35 % (Table 8.1). The outlook suggests that biodiversity in 58 % of all Natura 2000 areas is expected to still be at risk in 2030 due to excessive atmospheric nitrogen deposition (Amann et al., 2018b).

The percentage of agricultural areas in the EEA-33 exposed to O_3 levels above the EU legal concentration standards has fluctuated between 15 and 69 % over the period 2000-2017, with some interannual variations due to meteorological conditions (EEA, 2019i). How this exposure affects crops is uncertain. According to current scientific knowledge, the so-called O_3 flux-approach is a better indicator of O_3 damage to vegetation. This methodology estimates the amount of O_3 that actually enters the plant via small pores (stomata) on the leaf surface. The amount depends on the opening and closing of the stomata under, for example, different conditions of temperature, humidity and light intensity (Mills et al., 2017).

8.4 Responses and prospects of meeting agreed targets and objectives

Europe is moving towards the air pollutant emissions and concentration objectives and targets framed in the EU legislation. Effects-based abatement measures under the 1979 CLRTAP and its protocols, mirrored in EU legislation, have led to a sharp decline in emissions, especially of SO_2. Economic growth and trends in air pollution have been progressively decoupled.

Maas and Grennfelt (2016) estimated that, if economic growth and air pollution trends were not decoupled, exceedance of critical loads for acidification in Europe would be 30 times higher than currently and three times higher for eutrophication caused by airborne nitrogen. Average $PM_{2.5}$ levels would be similar to levels in current European hot spots, with health impacts three times higher, and around 600 000 more European citizens would have died prematurely. Health impacts from O_3 would be 70 % higher and O_3 damage to crops 30 % higher. Overall, average life expectancy is 12 months more than in the hypothetical unabated world.

Efficient implementation of EU air quality standards includes effective action at various governance levels, i.e. at national, regional and local levels, and across administrative boundaries between public authorities as well as across different sectors (EC, 2018c). However, achieving policy coherence across administrative and governance levels is challenging, as are efforts to generate political and public support for improving air quality beyond the minimum EU standards (EEA, 2019f). A coherent planning approach to reducing air pollution includes local air quality plans and urban planning in general, national air pollution control programmes for reducing sectoral emissions and national energy and climate plans. The European Commission will continue to support countries to achieve clean air goals, for example through clean air dialogue with EU Member States, the EU urban agenda and the European Structural and Investment Funds or by facilitating domestic funding schemes that allow investment in low- and zero-emission mobility (EC, 2018b).

However, for most of the main air pollutants, EU Member States and EEA member countries still fail to achieve some national emission ceilings, some of the EU air quality standards and, especially, the WHO air quality guidelines. This makes it difficult to reach the long-term objectives of achieving levels of air quality that do not give rise to significant negative impacts on, and risks to, human health and the environment.

Economic growth and trends in air pollution have been progressively decoupled.

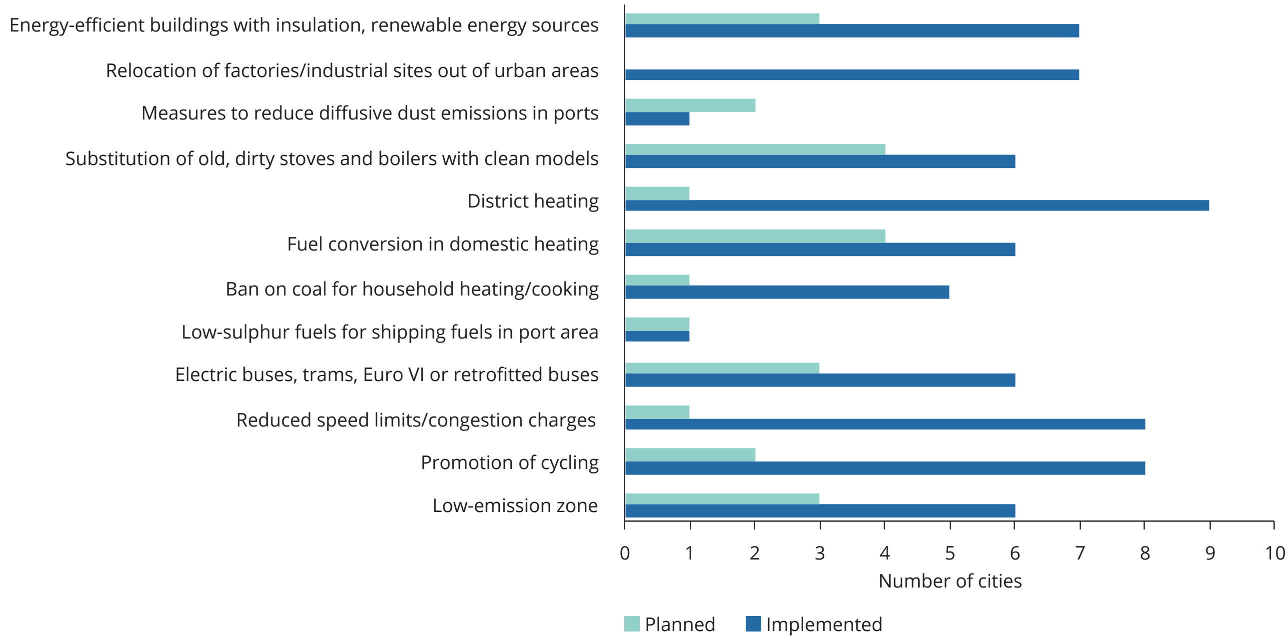
The reasons are, first, that not all sectors reduced their emissions at the same pace (e.g. agriculture). Second, integration of air policy with other policies such as those on climate has also resulted in trade-offs. The European Court of Auditors recommends that the Commission takes action to better align policies that contain elements that can be detrimental to clean air (e.g. climate and energy, transport, industry and agriculture policies) with the air quality objectives (ECA, 2018). Third, the various levels of implementation of measures require coordination of the international, national, regional and local governance levels (see, for example, the implementation of the Ambient Air Quality Directives). Finally, there are some sectors or mechanisms that may be underestimated in emissions inventories. Examples are resuspension of PM, the condensable fraction of primary PM or international shipping and aviation. As the relationship between emitted pollutants and measured concentrations is not linear, the use of models, which include processes assessing chemistry, dispersion and (changes in) meteorology, is essential to help understand the relation between emission sources and concentrations in ambient air.

BOX 8.2
The critical loads concept

A critical load is a 'quantitative estimate of an exposure to one or more pollutants below which significant harmful effects on specified sensitive elements of the environment do not occur according to present knowledge' (UNECE, 2018b). It represents the upper limit of one or more pollutants deposited on the Earth's surface that an ecosystem, such as a lake or a forest, can tolerate without its function (e.g. the nutrient nitrogen cycle) or its structure (e.g. with respect to plant species' richness) being damaged.

A positive difference between the deposition loads of acidifying and/or eutrophying airborne pollutants and the critical loads is termed an 'exceedance'. Areas and magnitude of exceedance are visualised in a map in the EEA indicator 'Exposure of ecosystems to acidification, eutrophication and ozone (EEA, 2019i). ■

FIGURE 8.6 **Examples of the main air pollution mitigation measures in place and planned in the pilot cities**



Source: EEA (2019f).

8.4.1 Synergies and trade-offs between air pollution and climate policies

Greenhouse gases (GHG) and air pollutants have mostly common emission sources. The 2020 climate and energy package (Chapter 7) implies reduced use of fuel and energy, reduced GHG and air pollutant emissions and thus co-benefits in the form of improved air quality. The European Commission has proposed a strategy for achieving a climate-neutral economy by 2050. The EU has implemented many legislative acts aimed at reducing the emissions of the most important GHGs, and several of those also result in reductions in emissions of air pollutants (Chapter 7). One example is the goal to decarbonise European transport by 2050 through mobility and energy transitions (Chapter 13). Tackling climate change requires global mitigation efforts.

> Reducing greenhouse gas emissions, as well as fuel and energy use, not only benefits energy efficiency and climate change but also improves air quality.

Achieving a net-zero GHG emissions economy on top of existing air pollution measures is expected to reduce premature deaths caused by $PM_{2.5}$ by more than 40 % and reduce the cost of damage to health by around EUR 200 billion per year (EC, 2018a). A recent study suggests that worldwide air quality benefits on morbidity, mortality and agriculture could globally offset the costs of implementing climate policies (Vandyck et al., 2018).

Nevertheless, some trade-offs between policies are obvious, for instance in transport, promoting the uptake of diesel vehicles because of their lower CO_2 emissions entailed higher real-world emissions of NO_2, worsening the air quality situation in cities (see below). Promoting biomass as a carbon-neutral fuel for domestic heating contributes to a local increase in $PM_{2.5}$, BaP and black carbon concentrations (EEA, 2016).

8.4.2 Air quality management in cities

In 2018, the EEA undertook a follow-up of the 2013 air implementation pilot organised by the EEA in cooperation with the European Commission (EEA, 2013). The follow-up project re-assessed the challenges of implementing EU air quality legislation in 10 European cities. All urban authorities stated that the air quality in their cities had improved since

2013, mainly due to implementing EU policies (EEA, 2019f).

Although most abatement measures address emissions from road traffic, mainly of NO_x and PM (EEA, 2019f), other pollutant sources are now being tackled, for example fuel combustion in residential stoves, inland shipping or construction and demolition activities, including emissions from non-road mobile machinery (Figure 8.6).

Cities express the need for a more comprehensive approach across Europe to allow an improved and more regular exchange of knowledge and experience of, for example, good practice and capacity building. They stress that implementing air quality legislation on the local scale would be beneficial if initiatives at the national and/or EU level were implemented and took effect. Examples are the enforcement of type approval procedures for vehicles (e.g. mandatory compliance testing of vehicles during use), national-/EU-level labelling schemes based on real-world driving emissions or product-specific regulations (ecodesign, energy labelling).

Local transport authorities need to decide on the implementation of low-emission zones, urban road tolling systems, charging schemes to reduce congestion in the city centres or a general reduction in congestion by fostering the development of alternative modes of transport and the use of cleaner, more energy-efficient vehicles. With improved EU guidance, urban vehicle access regulation schemes can be a basis for such planning (Ricci et al., 2017).

Under the NEC Directive (EU, 2016), Member States are required to draw up national air pollution control programmes, which should contribute to the successful implementation of air quality plans established under the EU's Ambient Air Quality Directives. The European Court of Auditors recommends making air quality plans results oriented and reporting to the European Commission on a yearly basis on their implementation (ECA, 2018). Overall, achieving coherence between control programmes and air quality plans, addressing air pollutants as well as GHG emissions, is essential for improving the air pollution situation in Europe.

Due to the transboundary nature of air pollution, action and cooperation at global, national and local levels are required.

8.4.3 Timely information and involving citizens

The Ambient Air Quality Directives have proved to be very efficient in establishing a strong European Monitoring Network ([2]) with around 4 000 monitoring stations managed by countries' competent authorities and reporting data annually to the EEA. These stations measure air pollutant concentrations following common rules, methodologies and agreed quality controls. Countries officially report concentrations of air pollutants to the EEA to comply with the requirements of the Directives. First, these measurements are validated values, reported on a yearly basis and used by the European Commission to check compliance with standards and enforce implementation of measures to improve air quality. The European Court of Auditors has recommended advancing the deadline for reporting these data from 30 September of the following year to at least 30 June (ECA, 2018). Countries also report up-to-date data on an hourly basis to keep citizens informed about the air quality situation in 'near-real time'. This allows the EEA to inform citizens about the air quality situation in the whole of Europe via its up-to-date viewer ([3]). Based on these timely data, the EEA in cooperation with the European Commission has developed a tool to provide more easily understood information for European citizens: the European air quality index ([4]). This index fulfils the Court of Auditors' recommendation to seek agreement on harmonising air quality indices (ECA, 2018).

Assessment of air quality depends not only on measurements taken at monitoring points but also on results obtained from air quality models. Several countries report modelling results, mainly as a supplementary assessment method. The European Commission aims to streamline environmental reporting, and one suggestion is to make 'better use of data generated through the Copernicus programme' (EC, 2017). The Copernicus Atmosphere Monitoring Service (CAMS, 2018) uses an ensemble of leading European chemical dispersion models, considering changes in meteorology, to forecast air pollution and to analyse past pollution episodes (e.g. Tarrasón et al., 2018). The CAMS approach includes the use of up-to-date and validated measurement data reported to the EEA under the Ambient Air Quality Directives.

A key new element of the Copernicus space component is based on the

([2]) https://www.eea.europa.eu/data-and-maps/dashboards/air-quality-statistics
([3]) https://www.eea.europa.eu/data-and-maps/explore-interactive-maps/up-to-date-air-quality-data
([4]) https://www.eea.europa.eu/themes/air/air-quality-index/index

'Sentinel missions'. The latest constitutes a sentinel (5P) with the tropospheric monitoring instrument (Tropomi) on board, a state-of-the-art instrument that can map pollutants such as NO_2, methane (CH_4), CO, SO_2 and PM (ESA, 2019). Currently, the main use of such satellite data is mapping, monitoring and detecting trends. The potential use of such data for improving emission inventories or information on air quality, for example within CAMS, still needs evaluation.

Another suggestion from the European Commission (EC, 2017) is to 'promote the wider use of citizen science to complement environmental reporting'. More and more European citizens wish to measure air quality in their surroundings themselves using simple diffusion tubes or so-called low-cost sensors. This raises peoples' awareness regarding air quality problems and can contribute to changes in behaviour. Cooperation with city, regional or national authorities is an opportunity to re-establish trust in the work of these institutions and their official measurements. A recent example of a well-planned and coordinated citizen science initiative is the 'curious noses' project in Flanders, Belgium, in which 20 000 people measured the air quality (NO_2) near their own houses and near schools during May 2018. The results are also being used to improve a regional air quality model (CurieuzeNeuzen Vlaanderen, 2018).

8.4.4
Europe's transport sectors have great potential for positive change

The increasing demand for domestic and international road transport, aviation and shipping services, key components of Europe's mobility system, also leads to increased pressures on human health, the environment and climate (EEA, 2017). These sectors are important sources of NO_x, primary and secondary PM, and SO_x (the latter in particular for shipping).

Citizens are better informed about air pollution through real time air quality information.

They contribute significantly not only to local and regional, but also global air (and climate) pollution. Each sector has great potential for change, not only through technical innovations for effectiveness such as design or changes in practices, but also with respect to the potential introduction of new or different fiscal measures to promote the uptake of cleaner transport technologies and/or changes in societal behaviour. At present for example, many different types of subsidies are extended to existing manufacturers, infrastructure providers and operators, all of which can inhibit shifting to a more sustainable mobility system. Across the different modes, unequal forms of fuel taxation can similarly potentially prevent investment and shifting to more environmentally friendly types of passenger and freight transport.

With regard to passenger road transport, and especially in cities, electric vehicles are expected to be a key future component of Europe's mobility

To further improve air quality, additional efforts focused on the food, mobility and energy systems are needed to reduce emissions.

system, helping to reduce impacts on climate change and air quality. By 2030, battery electric vehicles (BEVs) could be between 3.9 % and 13.0 % of new car registrations, depending on the EU-wide fleet average CO_2 target levels set for passenger cars in the future (EEA, 2018b). As the new Regulation on CO_2 emission performance standards (EU, 2019) requires a reduction of 37.5 % by 2030 compared with 2021, it seems likely that the share will be at the higher end of this range. However, the environmental impacts of BEVs, and their advantages or disadvantages relative to vehicles with an internal combustion engine, are influenced by a range of key variables associated with vehicle design, vehicle choice and use patterns, reuse and recycling and the electricity generation mix. There is, therefore, an increasing need to understand BEVs from a systems perspective. This involves an in-depth consideration of the environmental impact of the product using life cycle assessment approaches (EEA, 2018b).

International rather than local factors are largely responsible for the significant demand for transport from the aviation and shipping sectors, driven, for example, by the globalisation of trade and often led by consumers through tourism and the global supply chains of certain types of food and manufactured goods. This requires implementing international abatement measures, which is challenging because agreements are only slowly reached (EEA, 2017; Engleryd and Grennfelt, 2018). Examples of measures in place are global ship fuel sulphur limits or sulphur and NO_x emission control areas, so far only established in Europe in the Baltic and North Seas. Airports have a similar infrastructure to that of cities: emissions from the numerous ground support services, such as vehicles operating at or around runways, airport heating, and transport to and from airports by passengers and freight services all significantly contribute to the emissions of air pollutants. Changing local mobility systems is challenging, but it offers many opportunities to improve local air quality (Section 8.4.2).

8.4.5 Technical and non-technical abatement measures can reduce nitrogen emissions

Agriculture is the economic sector in which air pollutant emissions have been reduced the least. NH_3 emissions are still high and have even increased in recent years, favouring the formation of secondary PM in the air, which contributes to episodes of high PM concentrations and exceedances of air quality standards (Section 8.3.2).

High NH_3 emissions are the main reason why atmospheric nitrogen deposition is still, and is expected to remain, a major threat to sensitive ecosystems such as nutrient-poor grasslands (Chapter 3). NH_3 is also the main reason why a few hot spots in Europe still exceed the critical loads for ecosystem acidification. According to Amman et al. (2018b) several EU Member States will need to introduce additional measures to reach the NEC Directive commitments to reduce $PM_{2.5}$ and especially NH_3. Regarding primary $PM_{2.5}$ emissions from agriculture, one low-cost measure is to ban the open-air burning of agricultural waste.

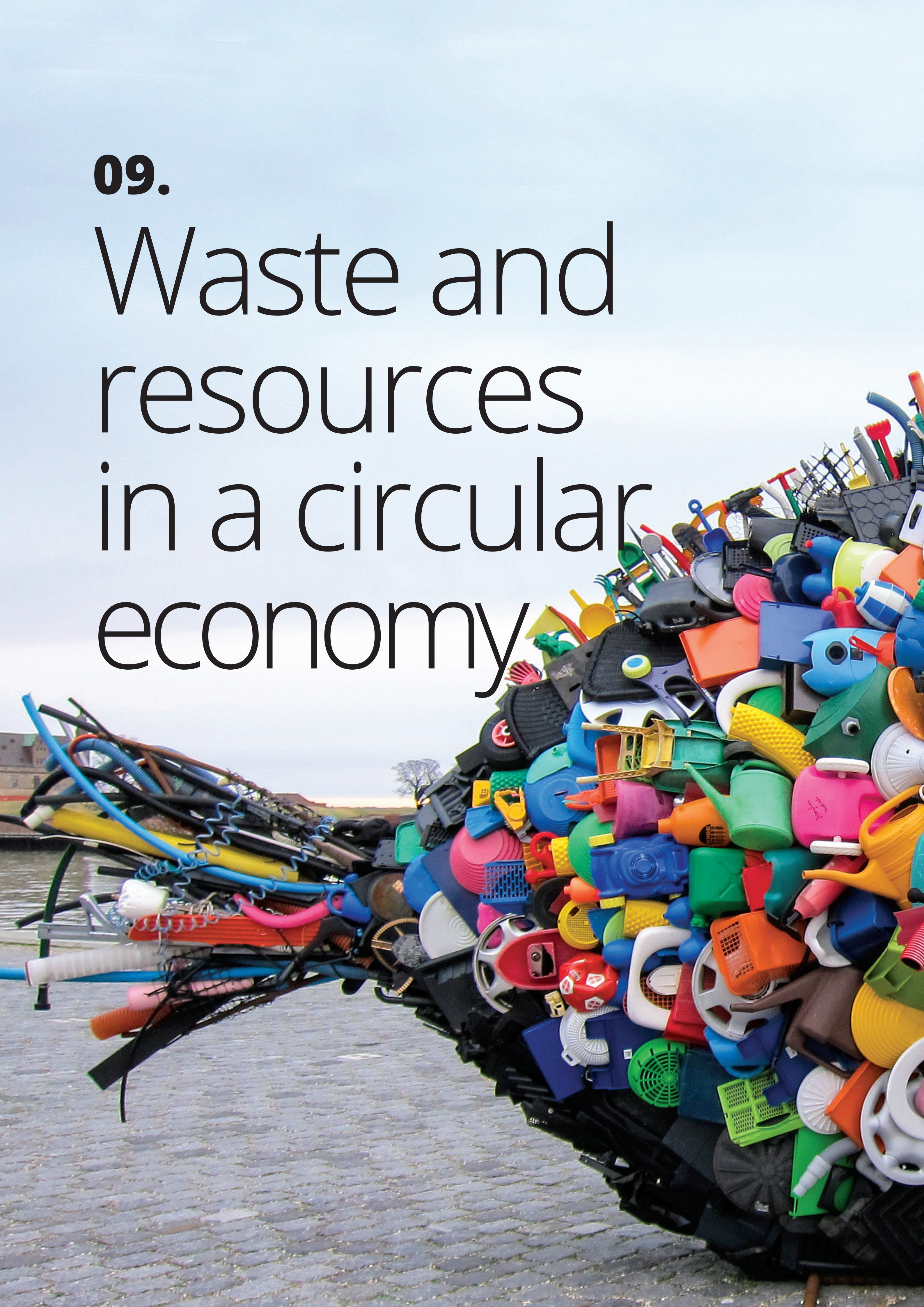
Technical solutions for sustainable reductions in NH_3 emissions in the agriculture sector are available. They include low-emission techniques for spreading manures and mineral fertilisers, the measure with the greatest potential to reduce NH_3 emissions, and animal feeding strategies (EC, 2019a). According to a study by the International Institute for Applied Systems Analysis (IIASA), based on Eurostat data, disposing of manure from livestock farming causes about 78 % of all NH_3 emissions in the EU-28. A total of 80 % of manures originate from 4 % of farms housing more than 50 livestock units (LSU). The largest farms (with more than 500 LSU), represent about 0.3 % of all farms, and IIASA estimates that they produce manure that releases about 22 % of all NH_3 emissions. Variations across the Member States are large, reflecting the different structures of the agricultural systems in the EU (Amann et al., 2017).

There are no farm size thresholds in place, and the current tendency is increasingly to establish big industrial-scale farms, particularly in some countries. While the Industrial Emissions Directive (EU, 2010) covers big pig and poultry farms, cattle farms are not regulated.

Indirectly, reducing food waste or increasing overall efficiency in the food chain will also reduce air pollutant emissions from agriculture. In a Nordic Council of Ministers report, Engleryd and Grennfelt (2018) raise the possibility of linking agricultural subsidies to obligations to reduce emissions as well as producing healthy food. Furthermore, the editors of the report suggest including the environment in national and international dietary guidance. Such measures, which particularly aim to reduce the consumption of (red) meat would also reduce CO_2 emissions from agriculture. In conclusion, Engleryd and Grennfelt recommend joining up approaches across the nitrogen cycle and state that an overarching EU nitrogen policy, which aims to improve nitrogen resource efficiency and reduce nitrogen waste, would have considerable co-benefits for air, climate, water and the economy (Chapter 14).

09.

Waste and resources in a circular economy



Key messages

- Increasing resource efficiency, preventing waste generation and using waste as a resource are at the core of the circular economy, and have considerable potential to reduce environmental pressures both within Europe and outside Europe's borders. These strategies may also contribute to alleviating the growing concern over Europe's dependency on imported resources and over securing access to critical raw materials, some of which play a fundamental role in deploying low-carbon, renewable energy technologies.

- Resource use in the economy of the 28 EU Member States declined over the last decade, while resource productivity improved. This was largely due to trends in overall economic growth and certain structural changes in the economy, rather than a result of direct policy intervention. Resource efficiency is expected to further improve in Europe, albeit with increasing levels of material resource use.

- At the other end of the materials chain, Europe continues to generate a large amount of waste but is increasingly moving towards more recycling. However, progress is slow and several countries are at risk of not meeting agreed targets. Waste-related targets and requirements will help Europe to increase recycling, although the prospects for reducing waste generation are less certain.

- Overall, the large amounts of resources used and waste generated and the rather low contribution of recycled materials to the material demands of the economy indicate that Europe is still far away from the goal of becoming a circular economy.

- Recently, policies have started to improve the framework conditions for a circular economy, albeit with the main focus on waste. In order to fully realise the potential benefits, it will be crucial to design materials and products in a way that enables durability, reuse, repair and upgrading, refurbishment, remanufacturing and recycling, and that prevents contamination of material cycles.

Thematic summary assessment

Theme	Past trends and outlook		Prospects of meeting policy objectives/targets	
	Past trends (10-15 years)	Outlook to 2030	2020	2030
Circular use of materials	Improving trends dominate	Developments show a mixed picture		☐ Partly on track
Material resource efficiency	Improving trends dominate	Developments show a mixed picture	☑ Largely on track	
Waste generation	Trends show a mixed picture	Developments show a mixed picture	☐ Partly on track	
Waste management	Improving trends dominate	Improving developments dominate	☐ Partly on track	

Note: For the methodology of the summary assessment table, see the introduction to Part 2. The justification for the colour coding is explained in Section 9.3, Key trends and outlooks (Tables 9.2, 9.3, 9.4 and 9.5).

09.
Waste and resources in a circular economy

9.1 Scope of the theme

Increasing resource efficiency, preventing waste generation and using waste as a resource are important strategies on the road to the circular economy (Figure 9.1). They have considerable potential to reduce the environmental pressures associated with Europe's economic activities (both within Europe and outside), as well as bringing benefits to the economy. Therefore, they are important environmental goals in Europe.

Resource efficiency, waste prevention and using waste as a resource are at the core of the circular economy.

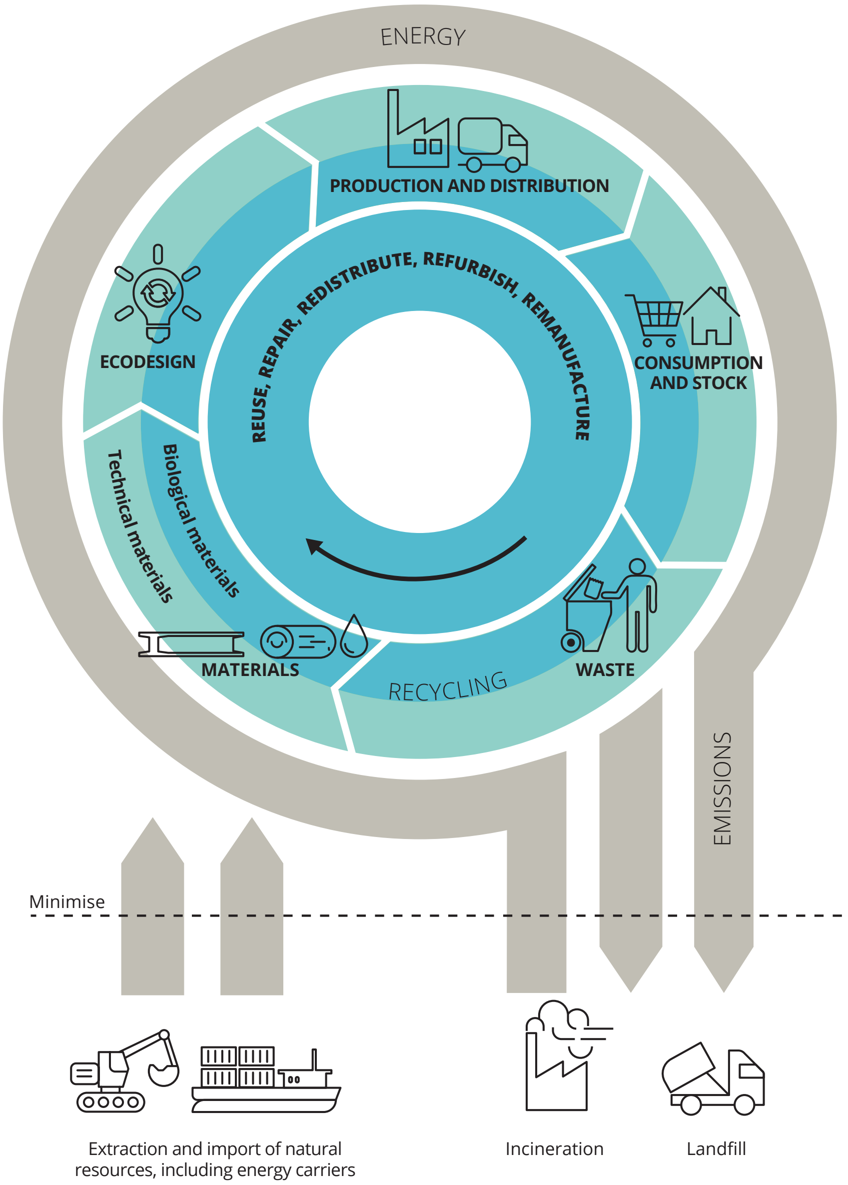
The scope of this chapter covers material resources (including the use of material resources, resource efficiency, and security of supply and access to critical raw materials) and waste (including waste prevention, and waste generation and management). Total waste, excluding major mineral wastes, has been selected as a broad waste type for the assessment, together with some subcategories for which specific targets apply (municipal waste, packaging waste, waste electrical and electronic equipment, end-of-life vehicles, batteries). While food waste, hazardous waste, construction and demolition waste, and mining waste are important waste streams, they have not been assessed in this chapter.

9.2 Policy landscape

The overall objectives of EU and European countries' policies related to waste and resources are to improve resource efficiency, reduce waste generation and improve waste management, thereby moving towards a circular, low-carbon economy and carbon neutrality. The EU's circular economy action plan (EC, 2015) provides a framework of measures towards achieving these objectives (Chapter 2) across the life cycle of materials and products. While the revised Waste Framework Directive (EU, 2008, 2018b) and other revised waste directives introduce a large range of new provisions aiming to move waste up the waste hierarchy, other measures aim to align other policy areas, such as chemicals, ecodesign and water use, with circular economy goals.

The EU has not set quantitative targets for the use of resources or for improvements in resource productivity, although a few Member States have adopted national targets. In recent years, policies on ensuring security of supply of raw materials, and in particular access to critical raw materials, increasingly address resource use (EC, 2008, 2011b). For industrial facilities, the Industrial Emissions Directive (EU, 2010) requires improving material efficiency and reducing waste generation; however,

FIGURE 9.1 **Circular economy system diagram**



Source: EEA (2016a).

the related best available techniques conclusions currently contain no binding provisions in this area (Chapter 12).

The waste hierarchy is the overarching principle of EU waste policies in which waste prevention has the highest priority, followed by preparing for reuse, recycling and other recovery and finally disposal as the least desirable option (EU, 2008, 2018b). In line with the waste hierarchy, EU waste legislation includes more than 30 binding targets for the management of waste for the period 2015-2035 but none for waste prevention. However, EU Member States are obliged to take measures on waste prevention including food waste and plastic bags and to report on reuse. Most recently, the Single-use Plastics Directive introduces, inter alia, a ban on certain plastics items, targets for separate collection and recycled content for plastic bottles and producer responsibility schemes for cigarette butts and fishing gear (EU, 2019b).

In addition, several of the United Nations 2030 Sustainable Development Goals (SDGs) address waste and resources, notably SDG 12 on sustainable consumption.

Table 9.1 presents a selected set of relevant policy objectives and targets addressed in this report.

9.3 Key trends and outlooks

9.3.1 Circular use of materials

► *See Table 9.2*

The circular economy aims to keep materials and products in use for as long as possible, extracting the maximum value from them while in use and recycling them at the end of their life cycle. From a circular and low-carbon economy perspective, achieving a more circular use of materials is key to improving resource efficiency and helps to reduce the demand for virgin materials (EEA, 2016a). The European Commission's circular economy monitoring framework (EC, 2018c) aims to measure progress towards the circular economy. It focuses on macroeconomic indicators and waste, reflecting a lack of data on new business models, longevity of products, reuse, repair and remanufacturing.

The road towards a more circular use of materials and products starts at the very beginning of the life cycle. One of the most important factors is

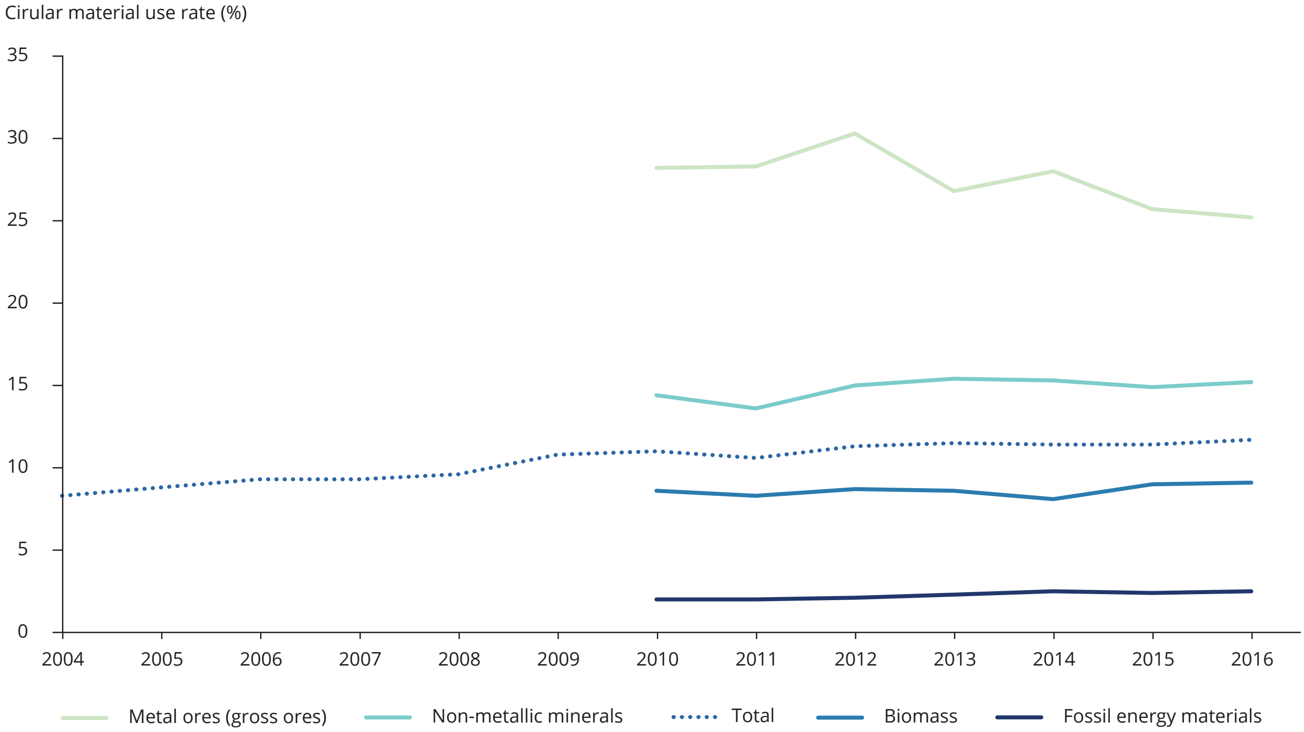
TABLE 9.1 Overview of selected policy objectives and targets

Policy objectives and targets	Sources	Target year	Agreement
Resource use and efficiency			
Improve resource efficiency	7th EAP (EU, 2013); Roadmap to a resource efficient Europe (EC, 2011a)	2020	Non-binding commitments
Strive towards an absolute decoupling of economic growth and environmental degradation	7th EAP (EU, 2013)	2020	Non-binding commitments
Create more with less, delivering greater value with less input, using resources in a sustainable way and minimising their impacts on the environment	7th EAP (EU, 2013)	2050	Non-binding commitments
Achieve the sustainable management and efficient use of natural resources	SDG 12.2 (global, national) (UN, 2015); 7th EAP (EU, 2013)	2030	Non-binding commitments
Waste generation and management			
50 %/55 %/60 %/65 % of municipal waste is prepared for reuse or recycled (differing calculation method for the 50 % target)	Waste Framework Directive (EU, 2008, 2018b)	2020/2025/2030/2035	Legally binding
Reduce landfill of biodegradable municipal waste to 75 %/50 %/35 % of the same waste generated in 1995	Landfill Directive (EU, 1999)	2006/2009/2013	Legally binding
Reduce landfill to a maximum of 10 % of municipal waste generated	Landfill Directive (EU, 1999, 2018a)	2035	Legally binding
Specific targets for collection, recycling and/or recovery of packaging waste, construction and demolition waste, WEEE, end-of-life vehicles, batteries, single-use plastics (incl. market restrictions and requirements for recycled content)	Waste Framework Directive (EU, 2008, 2018b), Packaging Waste Directive (EU, 1994, 2018c), WEEE Directive, ELV Directive (EU, 2000), Batteries Directive (EU, 2006); Single-use Plastics Directive (EU, 2019b))	2008-2035	Legally binding
All plastics packaging should be recyclable	EU plastics strategy (EC, 2018a)	2030	Non-binding commitments
Waste generation to decline absolutely and per capita, and reduction and sound management of hazardous waste	7th EAP (EU, 2013)	2020	Non-binding commitments
Energy recovery to be limited to non-recyclable waste	7th EAP (EU, 2013)	2020	Non-binding commitments
Halve per capita global food waste at the retail and consumer levels and reduce food losses along production and supply chains, including post-harvest losses	SDG 12.3 (UN, 2015)	2030	Non-binding commitments

Note: 7th EAP, Seventh Environment Action Programme; ELV Directive, End-of-life Vehicles Directive; WEEE Directive, Waste Electrical and Electronic Equipment Directive.

the design of materials and products. Better design can make products last longer and repairable, easier to be disassembled at the end of their life and recycled, and hence can help recyclers to recover valuable materials and components for reuse. Avoiding the use of substances of concern reduces both environmental and health hazards as well as waste management costs and enables clean material cycles. Moreover, through better design, products can contain significant quantities of recycled materials, and reused components can be integrated into new products. The design of products and materials heavily influences the costs of subsequent steps towards using waste as a resource and

FIGURE 9.2 Trends in the circular material use rate, EU-28



Source: Eurostat (2019a).

thus the competitiveness of secondary materials compared with virgin materials.

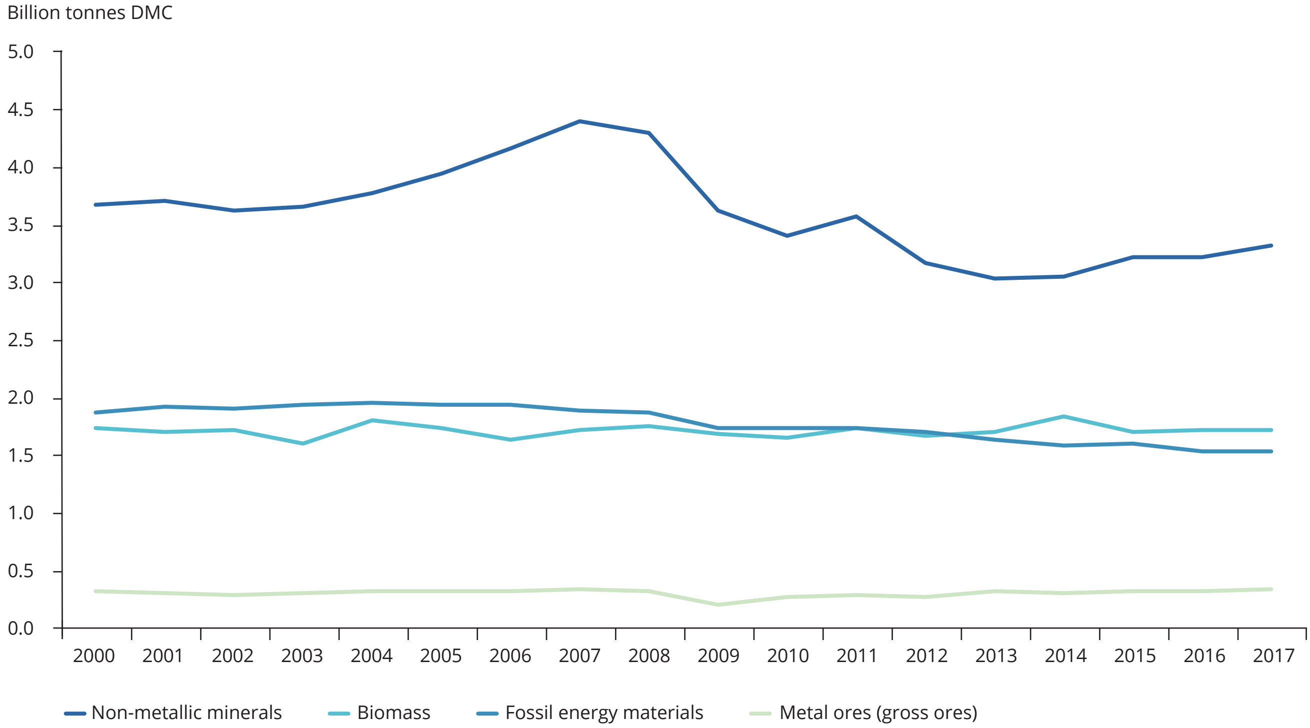
The 'circular material use' (CMU) rate (EC, 2018c) — one of the indicators in the circular economy monitoring framework — measures the contribution of recycled materials to the overall demand for materials. The higher this rate, the lower the need for extracting primary raw materials. In the period 2004-2016, the CMU rate in the 28 EU Member States (EU-28) slowly, but steadily, increased from about 8 % to around 12 %. The CMU rate is highest for metals and metal ores, followed by non-metallic minerals (Figure 9.2).

Recycling is also key for improving environmental sustainability, due to the generally lower impacts of recycling processes compared with extracting raw materials and primary production (EC, 2018h; OECD, 2019). As the availability and concentrations of ores are generally decreasing, the role of recycling becomes even more crucial to guarantee the security of the supply of raw materials, especially for those that are considered critical to the functioning and competitiveness of the EU economy (British Geological Survey et al., 2017).

> A more circular use of materials is key to improving resource efficiency and to reducing the demand for virgin materials.

While the CMU rate gives a general picture at an aggregated level, the contribution of secondary materials to material use varies significantly among different materials. The highest contributions are found for lead (75 %) and silver (55 %). Among the critical raw materials, the highest shares are found for vanadium (44 %), tungsten (42 %) and cobalt (35 %). This is partly a result of materials being used in easily collected appliances. It is also driven by waste legislation that requires recycling of materials and the extraction and recovery of specific components from products at the end of life (EC, 2018h). However, for most low-volume metals and rare Earth elements, recycling contributes

FIGURE 9.3 Trends in materials use by type of material, EU-28



Note: 2017 data are Eurostat estimates.

Source: Eurostat (2019g).

only marginally to meeting the demand for materials. This is because primary extraction is often cheaper than recycling or recovery, as these materials are integrated into products in small quantities, making their recycling costly. It is worth noting that demand for these materials in modern technologies such as renewable energy systems and communication, are expected to increase rapidly (EC, 2018h) (Box 9.1).

Many factors currently limit recycling's potential to meet materials demand, including (EC, 2018f):

- dissipative material losses during the use phase of a product;
- loss of material through improper collection;
- material quality becoming degraded during collection and processing (downcycling),
- build-up of stocks;
- product designs that impede recycling;
- lack of suitable recycling infrastructure;
- contamination with hazardous substances; and
- economic factors resulting, for example, from the need for decontamination and price competition with virgin materials.

Materials containing substances that were previously widely used but are now identified as substances of concern pose risks to health (such as phthalates) (Pivnenko et al., 2016) and create a large burden for society, and such legacy materials will have to be managed for many years to come (Chapter 10). Turning waste into a resource requires addressing these limiting factors, and several initiatives are under way. For example, the new recycling targets and related requirements in the revised waste directives require stepping up recycling efforts. The European strategy for plastics in a circular economy (EC, 2018a) envisages measures to improve the economics and quality of plastics recycling, and the European Chemicals Agency is developing a database of hazardous materials in products (EU, 2008, 2018b). The Single-use Plastics Directive for the first time sets a target for recycled content,

TABLE 9.2 Summary assessment — circular use of materials

Past trends and outlook		
Past trends (10-15 years)		The limited available data show a slowly improving trend from a very low baseline.
Outlook to 2030		The implementation of policies focused on the circular economy, ensuring security of supply and the low-carbon economy and carbon neutrality agenda is expected to foster the circular use of materials. However, the uncertain outlook for resource use might hamper improvements, and multiple barriers to exploiting the full potential of reuse, refurbishment, remanufacturing and recycling need addressing.
Prospects of meeting policy objectives/targets		
2030	☐	Europe is partially on track regarding meeting the circular economy objective to keep resources in use for as long as possible by extracting the maximum value from them while in use, and recycling and regenerating products and materials at the end of their life cycles. Existing targets are likely to drive the economy towards more circularity but the pace of development is currently highly uncertain.
Robustness		The methodology to calculate the circular material use rate is reliable, but it is dominated by minerals and fossil fuels and does not capture qualitative aspects of circular material use and related environmental impacts. Outlook information is lacking, so the assessment relies primarily on expert judgement.

BOX 9.1
Renewable energy and critical raw materials

Wind and photovoltaic energy technologies rely on a variety of materials. Six of these materials, namely neodymium, praseodymium, dysprosium, indium, gallium and silicon metal, are identified as critical materials and thus their supply is at a high risk (EC, 2017b).

Europe's demand for these and other critical materials is expected to increase in the future, depending on the deployment rates of wind and photovoltaic technologies as well as developments in the technologies. If supply of these materials is expected to be low, wind and photovoltaic power may not grow as fast as expected. Nonetheless, the consequences of a demand/supply imbalance can be mitigated by incentivising actions that support resource efficiency, recycling and substitution of these critical materials with other, non-critical, materials. For instance, rare Earth elements are no longer used in some new generation wind turbines (EC, 2018h). ■

related to plastic bottles. At the same time, technological developments have made recycling more effective and can be expected to continue doing so.

In the future, the extent to which demand for materials can be met with recycled materials depends both on developments in materials demand and on the generation and management of waste. The high degree of uncertainty in these two aspects means an even higher uncertainty regarding future trends in circular material use. Nonetheless, the increased policy and research focus on the circular economy is likely to foster a more circular use of materials in the future.

9.3.2 Material resource efficiency

► *See Table 9.3*

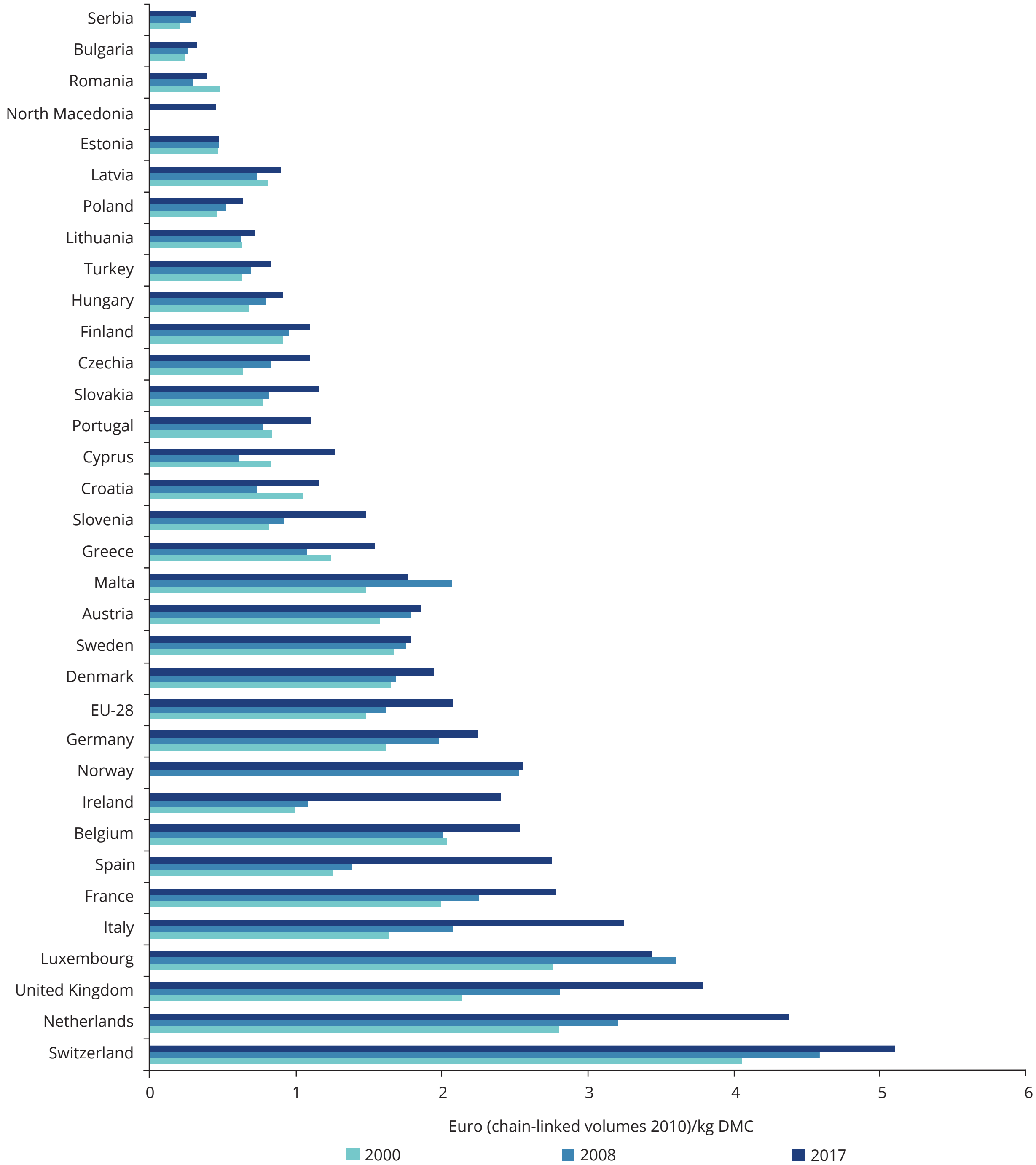
Europe continues to use a large amount of material resources, as measured by domestic material consumption (DMC). Total resource use in the EU-28 decreased by 9 % between 2000 and 2017, from 7.6 billion tonnes DMC to 6.8 billion tonnes (and from 15.5 tonnes/capita in 2000 to 13.4 t/capita in 2017). However, much of this decline was caused by the financial crisis of 2008 and the resulting drop in construction activities, accompanied by a shift in the economy towards a higher share of services (Eurostat, 2019f). Prior to the crisis (the period between 2000 and 2007), material consumption in the EU-28 actually increased steadily (Figure 9.3), only to drop by 17 % between 2007 and 2017 for total DMC, and by 28 % for non-metallic minerals. Provisional data for 2018 indicate again an increase for total DMC (Eurostat, 2019g).

An increasing share of the resource input to the EU-28 economy comes from abroad (23 % in 2017). Reliance on imports is particularly high for metals and fossil fuels; for the latter category,

23 %

of the EU's resource inputs in 2017 came from abroad.

FIGURE 9.4 **Country comparison — resource productivity in Europe**



Note: For Turkey, 2016 substituted for 2017 data. For Serbia, 2001 substituted for 2000 data. 2017 data include estimates and provisional data.

Source: Eurostat (2019m).

TABLE 9.3 Summary assessment — material resource efficiency

Past trends and outlook		
Past trends (10-15 years)		Material consumption in the EU-28 declined during the last decade, and resource efficiency improved. The economic recession contributed to this trend, along with decreasing use of fossil fuels and the changing structure of the economy.
Outlook to 2030		Most projections and/or scenarios envisage the use of materials increasing globally, and to a lesser extent in the EU, while resource efficiency is projected to increase. Recent policies on the circular economy as well as on climate change mitigation can be expected to contribute to improve resource efficiency.
Prospects of meeting policy objectives/targets		
2020	☑	Europe is on track to meet the Seventh Environment Action Programme objective of improving resource efficiency by 2020. However, policy objectives are non-binding and without measurable targets or a clear threshold to indicate when objectives have been achieved.
Robustness		Eurostat has compiled a long, reliable time series of data on material flows and resource productivity for more than 30 European countries. However, material flow-based indicators do not capture important issues such as impacts of resource use, or environmental burdens related to extraction of imported resources, which can be significant. Trends shown by material flow-based indicators are also heavily influenced by the high share of largely inert construction materials. Outlook information for Europe is sparse, thus the outlook assessment relies partly on expert judgement.

the share of imports is increasing continuously (Eurostat, 2019g). This results in some shifting of the environmental burden to countries outside the EU, whereby pressures related to the extraction of resources occur in the producing country and not where those resources are actually used (Chapters 1 and 16).

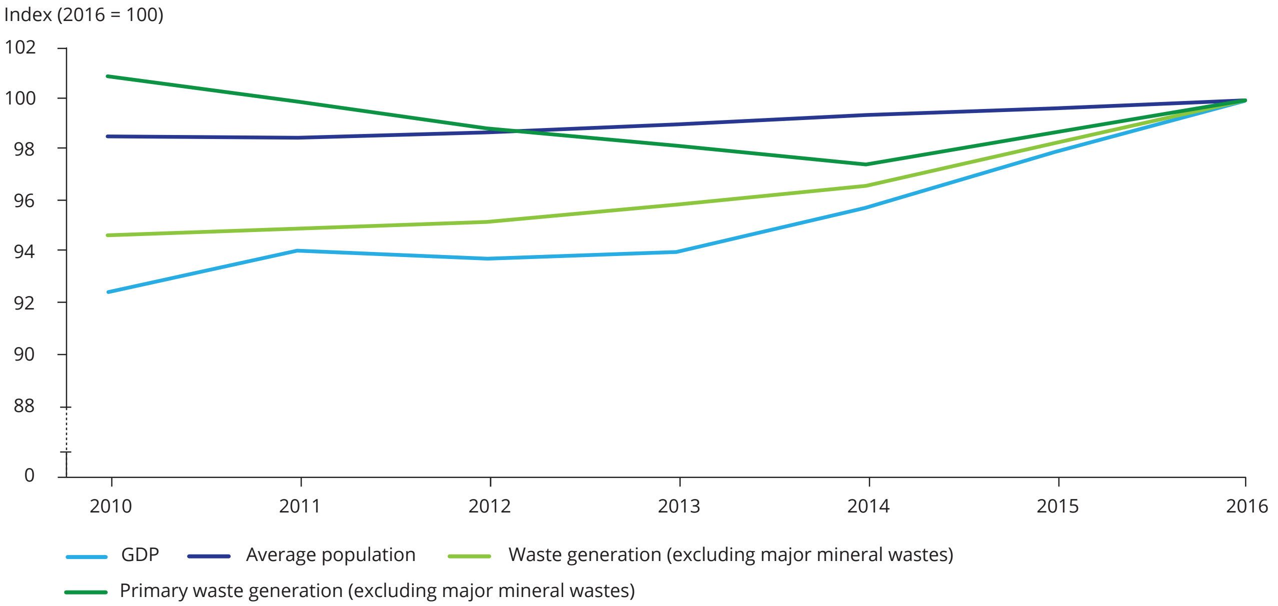
Resource efficiency in the EU is expected to improve, albeit with an increase in material use.

Resource productivity — the ratio between gross domestic product (GDP) and DMC — in the EU as a whole increased by 40 % between 2000 and 2017. However, as shown in Figure 9.4, there are large differences between individual countries, both in absolute terms and in trends over time. For example, within the EU, resource productivity varies by a factor of 14 between the Netherlands and Bulgaria. The change in resource productivity in the period between 2000 and 2017 varied from an increase of 143 % in Ireland and 119 % in Spain to a decline of 18 % in Romania.

Notably, the same countries (Switzerland, Netherlands, United Kingdom, Luxembourg and Italy) have remained at the top of the resource productivity rankings in Europe, with another group of countries consistently remaining at the bottom (Bulgaria, Romania, Estonia, Poland and Lithuania). These differences are strongly influenced by countries' differing economic structures, including the highly relevant mining sector in Bulgaria, Romania, Estonia and Poland (Eurostat, 2019i). Within the latter group, the improvement in resource efficiency has been limited, which means that the gap between these countries and the most resource-efficient countries is increasing (Eurostat, 2019m).

Some of the countries with the highest resource efficiency also have a high share of imports in their material input. Replacing domestically extracted resources with imports may result in an 'artificial' increase in importing countries' resource productivity. To highlight this, Eurostat has developed the raw material consumption indicator, available for the EU-28 as a bloc. In 2016, the EU's raw material consumption per capita was about 14.2 tonnes, compared with 13.4 tonnes of DMC (and largely followed

FIGURE 9.5 **Trends in waste generation (excluding major mineral wastes), economic development and population, EEA-33**



Note: Country coverage: EU-28, Iceland, Norway. Waste data for 2011, 2013 and 2015 are interpolated.

Source: EEA, based on data from Eurostat (Eurostat, 2019e, 2019d, 2019l).

the same trend as DMC) (Eurostat, 2019g, 2019h).

On a positive note, there has been a clear, long-term decrease in the use of fossil fuels (down by 19 % between 2000 and 2017), mainly due to an increasing shift to energy from renewable sources and overall improvements in energy efficiency. This positive outlook is expected to continue in the light of policy focus on energy efficiency and decarbonisation (Chapter 7). Meanwhile, the demand for biomass for energy use is expected to increase in most decarbonisation scenarios (EC, 2018e) and might increase as well as a substitute for non-renewable materials in the framework of Europe's move towards a bioeconomy (EC, 2018b).

The outlook for the other two categories (i.e. non-metallic minerals and metals) is difficult to assess, as it is largely driven by macroeconomic conditions and the investment climate.

Waste (excluding major mineral wastes) generation increased slightly to 1.8 tonnes per person in 2016.

Globally, most projections indicate continued growth in the extraction and use of resources — a key driver of global environmental change (Chapter 1), with the highest growth expected in developing countries. Material use is still expected to grow in EU Member States as well, while resource efficiency is projected to increase (IRP, 2019; OECD, 2019). Closing material loops and increasing recovery and recycling of materials are necessary steps to decrease our reliance on imports and to reduce environmental pressures. However, there are concerns that continuously growing demand will increasingly lead to resource extraction in new areas with potentially high environmental risks, such as the Arctic or the deep sea.

9.3.3 Waste generation

► *See Table 9.4*

The amount of total waste (excluding major mineral wastes) has increased in the 33 EEA member countries (EEA-33) since 2010 alongside GDP (Figure 9.5). This comprises both primary and secondary waste such as residues from

TABLE 9.4 Summary assessment — waste generation

Past trends and outlook		
Past trends (10-15 years)		Generation of waste (primary waste excluding major mineral wastes) has stayed rather stable, and it is partially decoupled from economic development and population growth.
Outlook to 2030		While outlook information is sparse, generation of some waste types is projected to increase slightly. The renewed policy focus on waste prevention measures can be expected to counter growth in waste generation, but a lack of clear targets as well as many other factors influencing waste generation makes their effects uncertain.
Prospects of meeting policy objectives/targets		
2020	☐	Prospects for meeting the Seventh Environment Action Programme objective to reduce waste generation are mixed. Recent data show an increase, along with growth in GDP. While waste prevention programmes are expected to reduce the amount of waste generated, many measures are rather weak and their overall effectiveness has not been evaluated so far on a European level.
Robustness		Total waste excluding major mineral wastes was selected to show trends in waste generation, because the uncertainty for mineral waste is rather high and because it covers a broad range of waste types. The time series is rather short, as earlier data (2004-2008) are excluded as they are influenced by data consolidation. Outlook information is very limited and is only available for some smaller waste streams; therefore, outlook and prospects of meeting the policy objectives are only assessed qualitatively and mainly rely on expert judgement.

Europe is increasingly moving towards more recycling but progress is slow.

waste sorting and incineration (about 17 % of total waste). The observed increase is mainly driven by secondary waste resulting from an increase in waste incineration and waste sorting operations. Meanwhile, developments in primary waste have been more stable. Waste (excluding major mineral wastes) generated per inhabitant increased slightly to 1.8 tonnes per person in 2016. This average masks large country differences, ranging from less than 1 to more than 3 tonnes per person (Eurostat, 2019e), partly reflecting the different structures of countries' economies. The generation of municipal waste, representing about 10 % of total waste, decreased between 2007 and 2013 in the EU-28 but has been increasing again since 2013 (Eurostat, 2019j). Many factors influence waste generation, including economic development, incomes and prices, structural changes in the economy, consumption and fashion trends and technological developments, as well as policies on waste prevention and resource efficiency. These factors vary strongly by waste type.

Outlook information for waste generation is very sparse and limited to a few waste types. For example, the generation of municipal waste in the EU-28 is projected to increase by about 2 % over the period 2015-2035 (ETC/WMGE, 2018). End-of-life vehicles are expected to increase slightly until 2020 (Peck et al., 2017). Waste electric and electronic equipment (WEEE) and waste batteries have been increasing continuously since 1995 and 2006, respectively, and that is expected to continue until 2020 (Huisman et al., 2016). WEEE generation in the Western Balkans is estimated to grow by one third by 2030 (Hogg et al., 2017). Waste incineration residues and sorting residues are likely to increase along with expected changes in waste management.

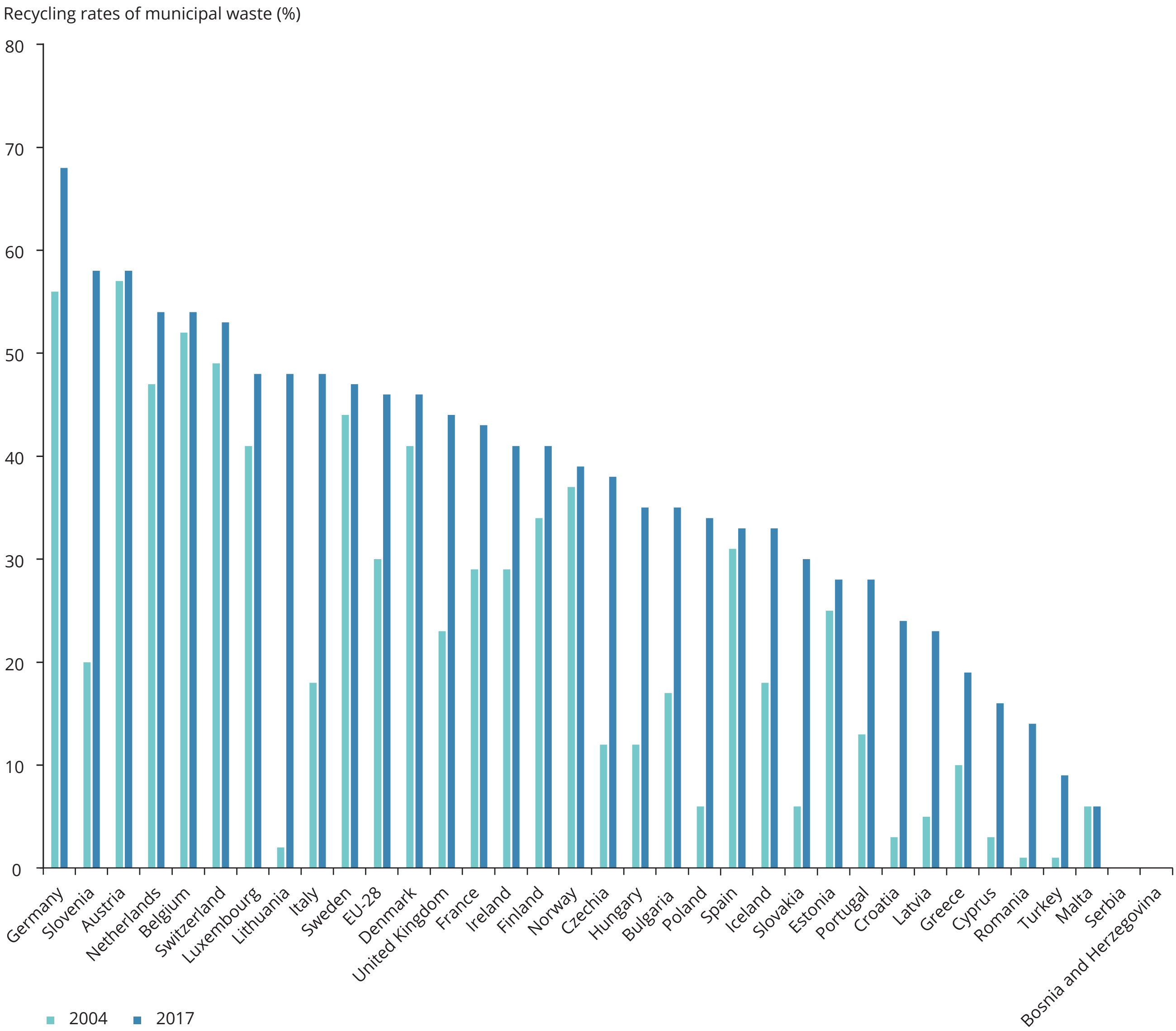
9.3.4 Waste management

► *See Table 9.5*

Waste management in the EU-28 is improving but rather slowly. In 2016, 53.7 % of total waste, excluding major mineral wastes, was recycled, 23.5 % disposed in landfill and 20.5 % incinerated; backfilling and other disposal accounted for the remainder. Although the waste hierarchy gives priority to recycling over incineration, shares of both recycling and incineration have increased by 2 percentage points each since 2010, and landfilling has dropped by 4 percentage points (Eurostat, 2019o). These trends are likely to be influenced by the many waste targets and requirements, including mandatory separate collection (Section 9.2).

Nearly all countries have increased their shares of municipal waste recycled since

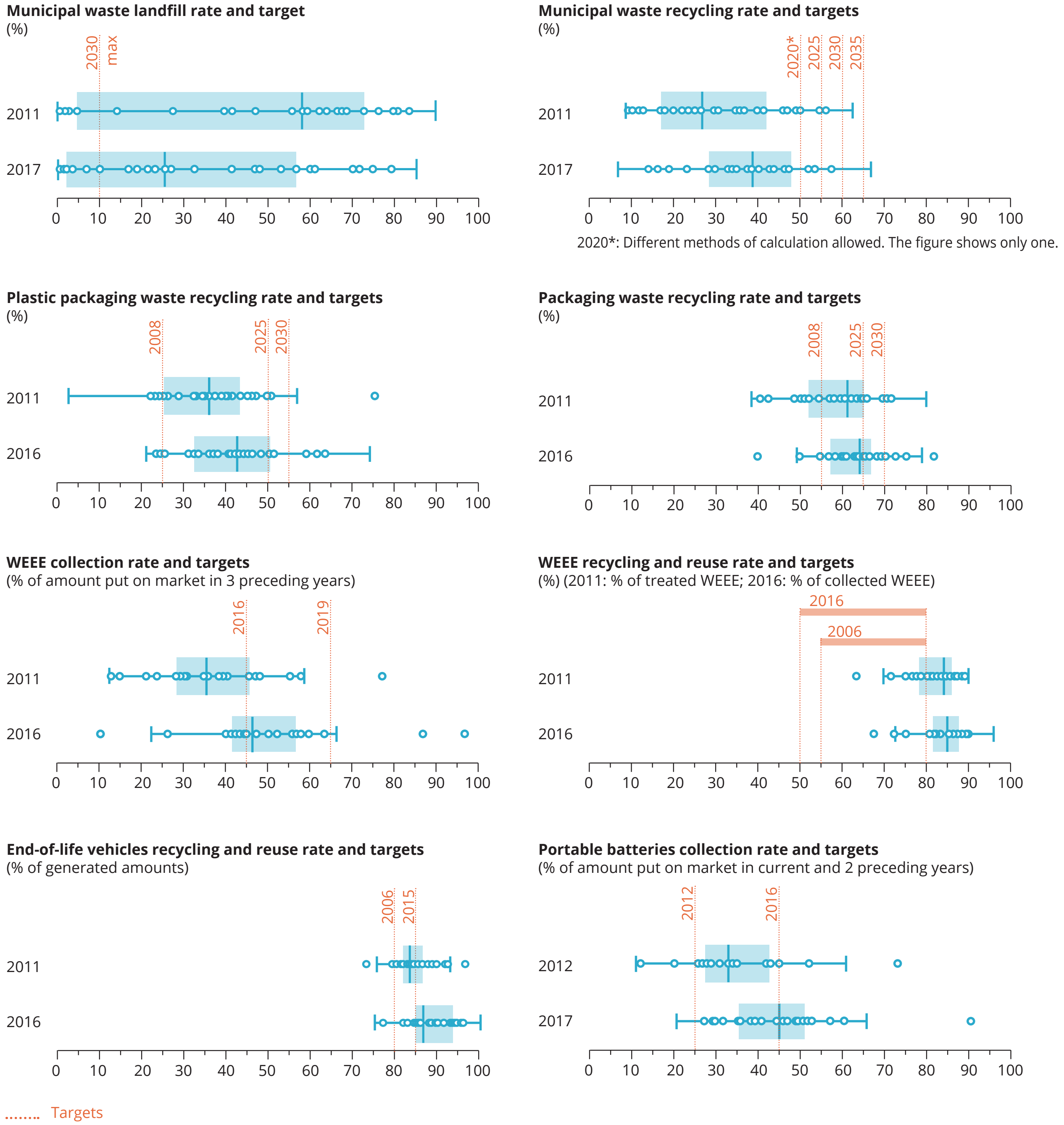
FIGURE 9.6 **Country comparison — recycling rates of municipal waste, EEA-33, Bosnia and Herzegovina, and Serbia**



Notes: The recycling rate is calculated as the percentage of municipal waste generated that is recycled, composted and anaerobically digested, and it might also include preparing for reuse. Changes in reporting methodology mean that 2017 data are not fully comparable with 2004 data for Austria, Belgium, Croatia, Cyprus, Estonia, Lithuania, Italy, Norway, Malta, Poland, Romania, Slovakia, Slovenia and Spain. 2005 data were used instead of 2004 data for Poland because of changes in methodology. On account of data availability, instead of 2004 data, 2003 data were used for Iceland, 2007 data for Croatia, 2008 data for Bosnia and Herzegovina and 2006 data for Serbia; and instead of 2017 data, 2016 data were used for Iceland and Ireland. 2017 data for Cyprus, Germany, France, Luxembourg, Poland, Slovenia, Switzerland, Spain and Turkey include estimates. The EU-28 data for 2004 are calculated with 2007 data for Croatia.

Sources: EEA, based on Eurostat (2019j) and data from the Czech Ministry of the Environment for Czechia.

FIGURE 9.7 Progress towards selected waste management targets, EEA-33



Notes: The boxes show the upper and lower quartiles for all countries, the line in the box shows the median and the dots show countries. For municipal waste, the calculation methods for compliance with the targets differ from the data shown in the figure. Derogation periods apply for several countries for some of the targets. Municipal waste and packaging waste: recycling rates calculated as shares of generated waste. In some cases, WEEE collection rates and packaging recycling rates are overestimated because the amounts put on the market are underreported (Eurostat, 2017). Gap-filling of data was applied in some cases to increase the comparability of the trends across data years. Country coverage: EEA-33 (excluding Switzerland and Turkey) for packaging waste, batteries, WEEE and end-of-life vehicles, and EEA-33 for municipal waste.

Sources: EEA based on Eurostat (2019c, 2019j, 2019k, 2019n, 2019p). Targets: relevant EU waste directives (EU, 1994, 2000, 2002, 2006, 2012, 2018b, 2018a, 2018c).

TABLE 9.5 Summary assessment — waste management

Past trends and outlook		
Past trends (10-15 years)		Management of total waste (excluding major mineral wastes) as well as of several specific waste streams moves slowly towards recycling and away from landfill, but large differences between countries persist. Substandard and illegal practices are still of concern.
Outlook to 2030		Waste management is expected to improve further, driven by existing and new waste management targets and new requirements introduced in the recently revised waste legislation. However, strong implementation efforts are required. The quality aspects of recycled materials, including substances of concern, need more attention.
Prospects of meeting policy objectives/targets		
2020	☐	On average, EU Member States are progressing towards the binding waste management targets, but several countries are at risk of missing the targets unless efforts are considerably intensified.
Robustness		Information on waste management is rather robust, but earlier data are still influenced by data consolidation issues, and shortcomings in reporting are documented for some countries. Information on illegal waste activities is extremely limited. Outlook information exists only for a few selected waste streams; therefore, the assessment of outlooks and prospects of meeting policy targets/objectives is largely based on expert judgement.

2004, but differences among countries are still high (Figure 9.6).

Across European countries, key measures that aim to increase recycling have included bans or restrictions on landfilling, mandatory separate collection; landfill and incineration taxes, and waste collection fees designed to incentivise separate collection (such as pay-as-you-throw schemes) (EEA, 2016b). In particular, the targets to reduce landfilling of biodegradable municipal waste have triggered investments in incineration and pre-treatment of mixed waste such as mechanical-biological treatment. While these technologies have lower environmental pressures than landfill, high treatment capacities might discourage separate collection and waste prevention and can create lock-ins to less favourable waste management options. Latvia, Lithuania, Poland and Spain have mechanical-biological treatment capacities to treat more than 50 % of their municipal waste (ETC/WMGE, 2019), while Belgium, Denmark, Estonia, Finland, the Netherlands, Norway, Sweden and Switzerland have dedicated incineration capacities to incinerate more than 50 % of their municipal waste (ETC/WMGE, 2017).

Policies adopted before 2018 are expected to deliver an increase of only 6 percentage points in municipal waste recycling. Full implementation of the targets under the new EU waste legislation adopted in 2018 is expected to result in a 26 percentage point increase by 2035 (ETC/WMGE, 2019). Outlook information for the management of most other waste types is not available. Key influencing factors include prices for virgin materials and energy (competing with recycled materials and energy from waste), developments in sorting and recycling technologies and the composition and recyclability of new products and novel materials, as well as prices and capacities for different types of waste treatment, and waste and broader circular economy policies.

On average, countries are moving closer to the EU's specific waste management targets (Figure 9.7). However, several countries are still lagging behind targets (EC, 2018g), and in some countries improper waste management still exists (Box 9.2).

> While on average, countries are progressing towards EU waste management targets, several countries are at risk of not meeting them.

BOX 9.2
Substandard and illegal waste activities pose risks to human health and the environment

Improper waste management, such as inefficient collection services, dumping of waste in dumpsites, illegal waste disposal activities and littering, still exist in Europe, posing risks to human health and the environment, including soil pollution. In the period 2015-2018, the European Commission has referred Bulgaria, Greece, Italy, Romania, Slovakia, Slovenia and Spain to the European Court of Justice for breaching the requirements of the EU Landfill Directive (EC, 2019b). Many municipalities in the Western Balkan countries and Turkey use substandard dumps to dispose of waste (ETC/WMGE, 2016; Hogg et al., 2017), and Serbia operates one of the world's 50 biggest still active dumpsites (D-Waste Environmental Consultants Ltd., 2014). The region also lacks treatment capacity for hazardous waste, and stockpiled hazardous wastes are often not stored appropriately (Hogg et al., 2017).

According to a report by EnviCrimeNet and Europol (2015), the waste industry is one of the biggest businesses targeted by criminal groups, as it offers potentially higher profits than those from illegal drugs but much lower sanctions and risks of detection. The report warns that this situation 'enables organised crime groups to further infiltrate the legal economy. Environmental crimes undermine the rule of law and damage the reputation of the EU and its [Member States].' In particular, the illegal disposal of asbestos and the illegal export of WEEE and end-of-life vehicles offer high profits. The Countering WEEE Illegal Trade project (Huisman et al., 2015) found that, in 2012, 4.65 million tonnes of electronic waste were not properly managed or illegally traded within the EU, and that only 35 % of all such waste reached the official collection and treatment system. This leads to potential hazards for human health and the environment but also represents a loss of valuable materials.

Littering and dumping of waste on both land and sea, as well as improper waste management systems are important sources of marine litter, affecting marine ecosystems (Chapter 6). The recently adopted EU Directives on single-use plastics (EU, 2019b) and port reception facilities (EU, 2019a) aim to prevent waste becoming marine litter. ■

9.4
Responses and prospects of meeting agreed targets and objectives

Both resource use and waste generation are closely linked to Europe's patterns of production and consumption (Chapter 16). In the 2015 circular economy action plan (EC, 2015), the European Commission identified a wide variety of initiatives to be implemented across the value chain. A larger number of steps have already been taken to implement these initiatives (EC, 2019c). Strategic objectives of the 7th EAP include creating 'a resource efficient, competitive, green low-carbon economy', reducing the generation of waste both in absolute terms and per capita and improving waste management. However, there are no concrete targets for resource use, resource efficiency and waste prevention in the EU legislation, and only a handful of countries have adopted national targets for resource efficiency or waste prevention. Meanwhile, many specific waste management targets specify the waste hierarchy for a range of products/materials (Section 9.2).

EU waste policies drive recycling but the outlook for limiting waste generation is uncertain.

9.4.1
Relevance, effectiveness and coherence of current policies

The circular economy policy objectives are still rather new and it is therefore premature to assess their effects. However, one notable trend is that several countries and regions/devolved administrations have already adopted strategies, action plans or roadmaps for developing the circular economy (Box 9.3). As of spring 2019, these include Belgium (and in addition Flanders and Brussels Capital Region), Denmark, Finland, France, Italy, the Netherlands, Portugal, Slovenia, and Scotland in the United Kingdom. Poland

BOX 9.3
National experience of circular economy policies

A recent EEA review of experience and lessons learned from developing circular economy policies (EEA, forthcoming) shows some common threads in the frontrunner countries. The development of circular economy policies needs to involve a broad range of stakeholders. In several countries, the government increasingly plays the role of a facilitator and moderator in this process, not just a regulator and enforcer. A number of actions rely on voluntary approaches, underpinned by a clear business case. Several governments estimated and promoted the benefits for their country's economy arising from implementing the circular economy. Finally, some apply a broad definition of 'resources' to be used in closed cycles: raw materials, water, space, food and excavated soil (e.g. Flanders in Belgium).■

and Spain are on the verge of adopting such strategies or action plans, whereas several countries are developing them. Others embed the circular economy in climate policy or combinations of waste and resource policies, e.g. England in the United Kingdom and Wallonia in Belgium (EEA, forthcoming). The European Commission's Environmental Implementation Review (EC, 2019a) notes that several EU Member States 'should better implement circular economy principles' and 'further incentivise resource efficiency measures'.

Significant increases in resource efficiency that have occurred since 2007/2008 have been in part due to the way the economic crisis affected most economies and the resulting structural change (e.g. the sharp decline in construction). Furthermore, the picture is also affected by the nature of available indicators, which use a very aggregated measure of resource consumption.

It is not possible to conclusively evaluate the effect of policies for material use and resource efficiency, partly because policy objectives are formulated rather vaguely and in part due to the variety of driving factors at play (e.g. geography, climate, structure of the economy, energy mix, consumption patterns). Trends vary strongly across individual countries, driven by a complicated mix of underlying drivers. The main driver determining trends in resource use in recent years seems to be macroeconomic changes. Furthermore, given such a wide variety of factors at play it is difficult to demonstrate the causality of policy interventions.

However, the wave of policy measures stipulated in the 2015 circular economy action plan and follow-up measures (Section 9.2) can be expected to improve resource efficiency in the future. Moreover, policies on ensuring security of supply of raw materials, and in particular critical raw materials, started to increase the attention given to secondary raw materials. There is also growing emphasis on creating synergies with the low-carbon economy.

At the other end of the material resource use chain, generation of waste has stabilised at a high level (Section 9.3.3). While no binding EU targets exist, EU Member States had to adopt waste prevention programmes according to the Waste Framework Directive by 2013, and all EU Member States, as well as Iceland, Norway and Turkey, have such programmes (EEA, 2019). Recently, the revised Waste Framework Directive strengthened the requirements on waste prevention and obliges Member States to evaluate waste prevention measures. In addition, it introduces a reporting obligation for reuse and for food waste for the first time and mandates the European Commission to review the data reported with a view to setting waste prevention targets. Nevertheless, waste prevention remains a challenge in all EU Member States (EC, 2017a, 2019a).

Meanwhile, most waste prevention programmes started operating around 2013 or later, so the available data may not yet reflect the full effects of implementation. Knowledge on the effects of specific waste prevention measures is still limited and requires disentangling policy effects from economic and other factors. Such analysis is not available on a European level so far. The majority of policy instruments in the programmes concern information and awareness raising, which are generally considered weak policy instruments.

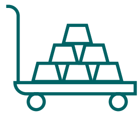
However, the overall economic policy goal of continued economic growth may conflict with the objective of waste prevention unless strong measures are taken, for example moving towards less waste-intensive business models and extending the lifetime of products. This illustrates that waste generation is unlikely to be strongly reduced through waste policies alone. It needs to be addressed in a systemic way along the value chain, by fundamentally changing patterns of production and consumption. For example, preventing food waste needs to address the drivers of food waste in the whole food system (ECA, 2016; Ciccarese and Vulcano, 2017) (Chapter 16).

Waste management trends, as shown in Section 9.3.4, indicate that European waste management is moving towards more recycling, albeit very slowly. This development is certainly driven by EU waste policies, especially the binding targets. However, waste management targets relate to the weight of wastes, whereas it is their quality that determines their value as secondary raw materials in the circular economy.

The prospects of meeting specific waste management targets are mixed across Europe. Fourteen EU Member States are at risk of missing the 2020 50 % recycling target for certain waste fractions from households, set in the 2008 Waste Framework Directive (EC, 2018g; ETC/WMGE, 2018). Meeting the new targets on recycling and landfilling of municipal waste in combination with more stringent calculation methods for compliance, as well as the collection targets for batteries and WEEE, will require considerable additional efforts by most countries (Figure 9.7).

9.4.2
Benefits of moving towards a circular economy

Improving waste management contributed to mitigating the EU's greenhouse gas emissions (Chapters 7 and 12), mainly due to the Landfill Directive's technical requirements and the diversion of waste from landfill. However, replacing virgin materials with recycled ones in most cases leads to environmental benefits beyond the waste sector itself (OECD, 2019). For example, taking a life cycle approach, municipal waste management has already avoided more greenhouse gas emissions than it generated directly, and it is estimated that these avoided emissions (i.e. net environmental benefits) will increase steadily in the period 2015-2035 if the new targets are achieved (ETC/WMGE, 2019).



Waste and resource management provided about 3 million jobs in the EU in 2016.

Avoiding generating waste and decreasing the demand for virgin materials usually delivers higher environmental benefits than other options. It reduces both the need to treat the resulting waste and the pressures from extracting virgin resources and producing the products in the first place. For example, the production step is responsible for about 73-96 % of greenhouse gas emissions, acidification and eutrophication related to food waste in Europe, while food processing, distribution, consumption and food waste disposal, including composting, together account for the rest (Scherhaufer et al., 2018).

The waste management and resource management sectors provided about 3 million jobs in the EU in 2016 and employment has increased by 79 % since the year 2000. However, growth in employment in the sector slowed considerably after 2011 (Eurostat, 2019b).

Reaping the full potential benefits of enhancing resource efficiency and the use of waste as resources will require more attention to overcome a number of barriers, as illustrated in Section 9.3.1. More focus is needed on the longevity of products, the recyclability and uptake of recycled materials, preventing contamination with substances of concern, and improved waste collection and treatment efficiencies. Such barriers are often of a systemic nature and need action across policy domains. For example, internalising environmental impacts in the prices of materials, energy and products would create fairer markets for these circular solutions. Plastics are a good example to illustrate these aspects (EC, 2018a). Some shortcomings in EU waste policies are addressed in the revised waste directives adopted in 2018, but more coherence is needed especially between legislation on waste, products and chemicals (EC, 2018d).

There is still a long way to go to turn Europe into a truly 'circular economy where the value of products, materials and resources is maintained in the economy for as long as possible' (EC, 2015). The circular economy action plan of 2015 and its related initiatives, and several national circular economy strategies are positive steps in this direction. In order to reap the highest benefits most efficiently, focusing on areas of high resource use, high resource value and high environmental impact seems most appropriate. Nonetheless, 'making the circular economy a reality will however require long-term involvement at all levels, from Member States, regions and cities, to businesses and citizens' (EC, 2017c).

10. Chemical pollution

Key messages

- European chemical policies have contributed to improved air and surface water quality and reduced related harm to the environment and people's health. Nevertheless, on-going exposure to chemical pollution continues to negatively affect human health and the environment. Latent and irreversible damage to human health is of particular concern.

- The projected increase in chemical production and continued emissions of persistent and hazardous chemicals suggests that the total chemical burden on health and the environment is unlikely to decrease.

- The large variety of chemicals used in Europe makes it impossible to carry out robust risk assessments for each individual chemical and monitor their presence in environmental media and in people. Significant knowledge gaps remain regarding the impacts of chemicals on health and the environment.

- Current policies mainly address single chemicals and often in separate policy domains. A shift to a more integrated approach for chemicals governance that better fosters innovation within Europe is needed. The current single substance approach is not fit for assessing and managing the risks of the large number of chemicals on the European market in the immediate future. A shift towards tackling chemical groups rather than single substances offers opportunities to accelerate risk management.

- A transition to chemicals and products that are safe by design, as well as using less hazardous chemicals along the entire life cycle of products, offers significant opportunities to reduce chemical pollution and improve circularity and innovation in Europe's economy.

Thematic summary assessment

Theme	Past trends and outlook		Prospects of meeting policy objectives/targets
	Past trends (10-15 years)	Outlook to 2030	2020
Emissions of chemicals	Trends show a mixed picture	Deteriorating developments dominate	Largely not on track
Chemical pollution and impacts on ecosystems	Trends show a mixed picture	Deteriorating developments dominate	Largely not on track
Chemical pollution and risks to human health and well-being	Trends show a mixed picture	Deteriorating developments dominate	Largely not on track

Note: For the methodology of the summary assessment table, see the introduction to Part 2. The justification for the colour coding is explained in Section 10.3, Key trends and outlooks (Tables 10.2, 10.3 and 10.4).

10.
Chemical pollution

10.1 Scope of the theme

Society benefits from using chemicals while aiming to minimise risks to the environment and human health. Chemicals are widely used in everyday life and many economic sectors are dependent on chemicals, such as agriculture, manufacturing of consumer products, infrastructure and technology, and energy. Given this widespread and diverse use (Bernhardt et al., 2017; Landrigan et al., 2017; Gross and Birnbaum, 2017), this chapter focuses mainly on synthetic chemicals, such as industrial chemicals, pesticides, biocides and chemicals in products, and particularly on the most hazardous substances or those that accumulate in humans and the environment. It excludes fertilisers and air pollutants from combustion processes, which are addressed in other chapters in this report.

An overview of the 'chemical universe' and emissions is presented, along with an assessment of how chemicals impact on human health and the environment and the responses that have been put in place to deal with key challenges. Given the cross-cutting nature of chemicals, this chapter complements the assessment of pollutants from the perspective of specific media (Chapters 4, 5, 6 and 8) and from the perspective of sources of pollution (Chapters 12 and 13).

> Exposure to chemical pollution negatively impacts human health and the environment.

Emissions of chemical pollutants occur across various stages of the chemical or product's life cycle and exposure to chemicals may occur through many routes, including point and diffuse sources (Figure 10.1). Chemicals produced or used in one place may also spread regionally and globally. While chemical accidents at manufacturing facilities can lead to loss of life and severe pollution locally, they are outside the scope of this report. However, data are available in the eMARS database (JRC, 2018).

Risk assessment is a tool used to inform decision-making. It is based on data on the chemical's hazard and level of exposure, which combine to provide a measure of the risk of causing effects (Risk = Hazard × Exposure). Hazards vary by type and the timescale in which they manifest. An example of an acute hazard is pesticide poisoning, whereas chronic hazards may develop over time and result in diseases such as cancer. The toxicity of hazardous substances depends on both the chemical and the vulnerability of humans or ecosystems when exposed. For example, if an organism is exposed during fetal development, or exposed to multiple stresses, this can increase vulnerability, meaning that the chemical is hazardous even at low doses.

FIGURE 10.1 Point and diffuse sources of emissions and the exposure routes for humans and the environment

Source: EEA.

BOX 10.1 Definitions of key terms

Persistent chemicals have high intrinsic molecular stability and do not easily degrade in the environment or in living organisms or during technical processing. Persistent organic pollutants (POPs) is a specific subcategory, with polychlorinated biphenyls (PCBs), per- and polyfluorinated alkyl substances (PFAS) and organomercury being examples.

Mobile chemicals are either very water soluble or very volatile making them difficult to remove with abatement and remediation technologies.

Accumulation occurs in the environment or in humans if the rate of input exceeds the rate of removal.

Bioaccumulation occurs when chemicals accumulate in living organisms, typically due to a long-term intake of food or water contaminated with chemicals that are not efficiently removed from the organism. Accumulation of fat-soluble chemicals occurs in fatty tissues (e.g. PCBs and dioxins), but chemicals may also accumulate in the blood and organs (e.g. PFAS).

Endocrine-disrupting chemicals (EDCs) interfere with the development or the functioning of the hormonal system such as the female sex hormones (oestrogens), male sex hormones (testosterone) or thyroid hormones. Examples include bisphenol A (BPA) and phthalates (e.g. di-(2-ethylexyl) phthalate, DEHP).

Developmentally toxic chemicals damage the development and future functioning of the endocrine (hormonal) system, the immune system or the neurological system (affecting brain development). Critical windows of exposure are associated with different stages of the development of an organism. Organotins (e.g. tributyltin, TBT) and perfluorooctane sulfonate (PFOS) are examples of immunotoxic substances, whereas lead, organomercury and organophosphate pesticides are examples of neurotoxic chemicals.

Substances of very high concern (SVHC) is a term used in the EU chemicals regulation REACH (registration, evaluation, authorisation and restriction of chemicals), for single or groups of chemicals that are subject to authorisation. EU legislation requires that SVHCs should be substituted with less harmful alternatives and the REACH Regulation provides for risk management processes to achieve this aim. The SVHC criteria target substances that have one or more of the following properties: carcinogenic; mutagenic; toxic for reproduction; persistent, bioaccumulative and toxic (PBT); very persistent and very bioaccumulative (vPvB) or giving rise to equivalent levels of concern. Examples of the substances causing equivalent concern include neurotoxic and endocrine-disrupting chemicals. ■

Overall risks result from the combined exposure to single chemicals released from various sources but also from mixtures of chemicals. High exposure typically happens as a result of repeated exposures and when chemicals accumulate in the environment or in people. Accumulation occurs when the input of chemicals is greater than the rate at which they are degraded or excreted from living organisms. This may occur with chemicals produced at high volume that are continuously released into the environment at a rate that exceeds the removal rate, as well as with lower volumes of persistent chemicals (see Box 10.1 for definitions).

10.2 Policy landscape

The Seventh Environment Action Programme (7th EAP) states that Europe aims to achieve, by 2020, the objective that chemicals are produced and used in ways that lead to the minimisation of significant adverse effects on human health and the environment (EU, 2013). Policies to deliver this objective include more than 40 pieces of legislation including horizontal legislation, and legislation covering specific chemical products, consumer products, wastes, emissions to the environment and environmental quality standards.

Risk assessments are not possible for every chemical used in Europe due to the large variety of chemicals that exist.

Table 10.1 presents an overview of selected relevant policy targets and objectives. The 7th EAP also established a mandate for the European Commission (Directorate-General for Environment) to develop 'by 2018 a Union strategy for a non-toxic environment that is conducive to innovation and the development of sustainable substitutes including non-chemical solutions' (EU, 2013).

REACH is the Regulation on registration, evaluation, authorisation and restriction of chemicals (EU, 2006b) and is the key piece of horizontal legislation that aims to protect human health and the environment. The REACH Regulation obliges companies to provide information on the properties and hazards of chemicals they manufacture and market in the EU and to manage the associated risks. The regulation also calls for the progressive substitution of the most hazardous chemicals when economically and functional alternatives have been identified. This is done by restrictions on their uses, or by authorising the chemical uses for defined purposes. The Classification, Labelling and Packaging (CLP) Regulation (EU, 2008b) aims to protect human health and the environment by putting in place the rules for the classification, labelling and packaging of chemicals. In combination with the REACH Regulation, this ensures that information about the hazards of chemicals and mixtures of chemicals are communicated down the supply chain, alerting workers to the presence of a hazard and the need for risk management (EU, 2009b). The CLP legislation also protects the aquatic environment through classification of some types of chemical hazards in line with international standards (Amec Foster Wheeler et al., 2017).

Regarding chemical products, the EU has directives and regulations in place (with amendments) to restrict various uses, occurrences and emissions of chemicals. Some examples include detergents (EU, 2004a), biocides (EU, 2012), plant protection products, including pesticides (EU, 2009d), and pharmaceuticals (EU, 2001b). Furthermore, policies limit some use and presence of hazardous chemicals in consumer products to ensure consumer safety and protect the environment from diffuse emissions, including personal care products, cosmetics, textiles, electronic equipment and toys (Amec Foster Wheeler et al., 2017), as well as food contact plastics (EU, 2011a), food (EU, 2002) and drinking water (EU, 2001a, 2006a).

European chemical policies have contributed to improved air and surface water quality.

Efforts to close material cycles under the action plan for the circular economy have implications for the chemical life cycle, with the potential for recycled material flows to contain and even magnify legacy chemicals as well as other hazardous chemicals that are not restricted or authorised (EC, 2015). The circular economy, and its benefits of reducing pressures on resources, nature and the climate, could therefore be supported if clean and non-toxic material cycles were ensured. A 2018 Commission communication sets out options for addressing the interface between chemical, product and waste legislation (EC, 2018c).

European policies also control emissions of chemicals to the environment and set maximum thresholds for the presence of certain chemicals in air and in water bodies. Legislation addresses point source emissions from industrial installations and from urban waste water treatment plants (Chapter 12). Legislation also addresses emissions of chemicals that are hazardous and of global concern due to the transboundary nature of their transport and impacts, such as persistent organic pollutants (POPs). Typically, policies regulate use, emissions or occurrences of single substances. Increasingly authorities seek to manage the risks of substances as groups when those substances share similarities in their chemical characteristics (ECHA, 2018d).

In addition to policies at European level, several of the Sustainable Development Goals (SDGs) (UN, 2015) address the risks from chemicals. SDG 12 on sustainable consumption and production patterns calls for the environmentally sound management of chemicals and waste throughout their life cycle. SDG 3 on ensuring healthy lives and promoting well-being for all at all ages sets the goal of substantially reducing the number of deaths and illnesses from hazardous chemicals. Finally, SDG 6 identifies the need to minimise releases of hazardous chemicals to water to achieve sustainable management of water and sanitation for all. The SDGs' objectives on chemicals are supported at the global level by implementation of the *Strategic approach to international chemicals management*, a policy framework to promote chemical safety (UNEP, 2006).

10.3 Key trends and outlooks

10.3.1 The chemical universe

The chemical universe captures the wide range of chemical products in use today: chemicals that are deliberately or unintentionally emitted from agriculture, industrial processes and urban areas, and legacy chemicals that persist in the environment from previous emissions. Two aspects of this universe create concern: the sheer volume of chemicals in use and the potential combined toxicity of these diverse chemicals.

TABLE 10.1 Overview of selected policy objectives and targets

Policy objectives and targets	Sources	Target year	Agreement
Chemical pollution			
Improve the protection of human health and the environment through registration, evaluation, authorisation and restriction of chemicals	REACH Regulation (EU, 2006b)	N/A	Binding
Develop a strategy for a non-toxic environment	7th EAP (EU, 2013)	2018	Non-binding commitment
Risks for the environment and health associated with the use of hazardous substances, including chemicals in products, are assessed and minimised	7th EAP (EU, 2013)	2020	Non-binding commitment
Policy response in place for endocrine disrupters, and for combination effects of mixtures of chemicals	7th EAP (EU, 2013), EC (2012)	2015	Non-binding commitment
To prevent or, where that is not practicable, to reduce emissions to air, water and land and to prevent the generation of waste in order to achieve a high level of protection of the environment taken as a whole	IED (EU, 2010)	N/A	Non-binding commitment
Develop a strategy on pharmaceuticals in water	2000/60/EC and 2008/105/EC	2015/2017	Binding
The use of plant protection products does not have any harmful effects on human health or unacceptable influence on the environment, and such products are used sustainably	7th EAP (EU, 2013)	2020	Non-binding commitment
Minimise the use/emissions of listed POPs, following addition of a POP to the list	EC 850/2004, EC 96/59, CLRTAP (UNECE, 1979)	New facilities: 2 years, existing facilities: 8 years after entry into force	Binding
Priority hazardous substances under Directive 2008/105/EC are eliminated from surface waters in accordance with the WFD	WFD (2000/60/EU)	N/A	Binding
Contaminants are not at a level giving rise to pollution effects	MSFD (2008/56/EC)	2020	Binding
All relevant substances of very high concern, including substances with endocrine-disrupting properties, are placed on the REACH candidate list	7th EAP (EU, 2013)	2020	Non-binding commitment
Reduce cancers/deaths from workplace exposures to chemicals	EU Roadmap on carcinogens (EU-OSHA, 2017a), 2009/104/EC	N/A	Non-binding commitment
Reduce mercury levels in the environment and human exposure and protect human health and the environment from anthropogenic emissions and releases of mercury and mercury compounds	EU Mercury strategy (EC, 2005), Minamata Convention on Mercury (Council of the European Union, 2013)	N/A	Non-binding commitment
Restriction of the use of certain hazardous substances in electrical and electronic equipment	RoHS Directive (EU, 2011b)	2019	Binding

Note: 7th EAP, Seventh Environment Action Programme; CLRTAP, Convention on Long-range Transboundary Air Pollution; IED, Industrial Emissions Directive; MSFD, Marine Strategy Framework Directive; POP, persistent organic pollutant; RoHS Directive, Directive on restriction of hazardous substances; WFD, Water Framework Directive; N/A, non-applicable.

Between 2000 and 2017, the production capacity of the global chemical industry increased from 1.2 to 2.3 billion tonnes (UNEP, 2019). In terms of diversity, 22 600 chemical registrations were registered under the REACH legislation in August 2019. This number omits chemicals on the market at volumes of below 1 tonne, as well as polymers, and those already regulated under existing regulation such as pesticides and pharmaceuticals. The total number of synthetic chemicals on the market has been estimated at 100 000 substances (Milieu Ltd et al., 2017) and 600 000 substances can be searched in toxicological databases (DTU, 2019). There are also an unknown number of transformation products from chemicals during their life cycles (Ng et al., 2011). At the same time, the volume and diversity of chemicals continues to increase (CEFIC, 2018).

Two aspects of the chemical universe create concern: the sheer volume of chemicals in use and the potential combined toxicity of these diverse chemicals.

Thoroughly assessing how the chemical universe constitutes a risk to human health and the environment requires information on the toxic (hazardous) effects of each substance, its potency and the extent to which the environment and people are exposed to each chemical, whether as a single substance or in mixtures. This in turn requires an understanding of how chemicals are used and altered throughout their life cycles, how they end up in various environmental media and how they combine in the environment. The main challenge in assessing the overall risk, is that the majority of substances in the chemical universe lack either a full hazard characterization and/or exposure estimates across ecosystems and in humans.

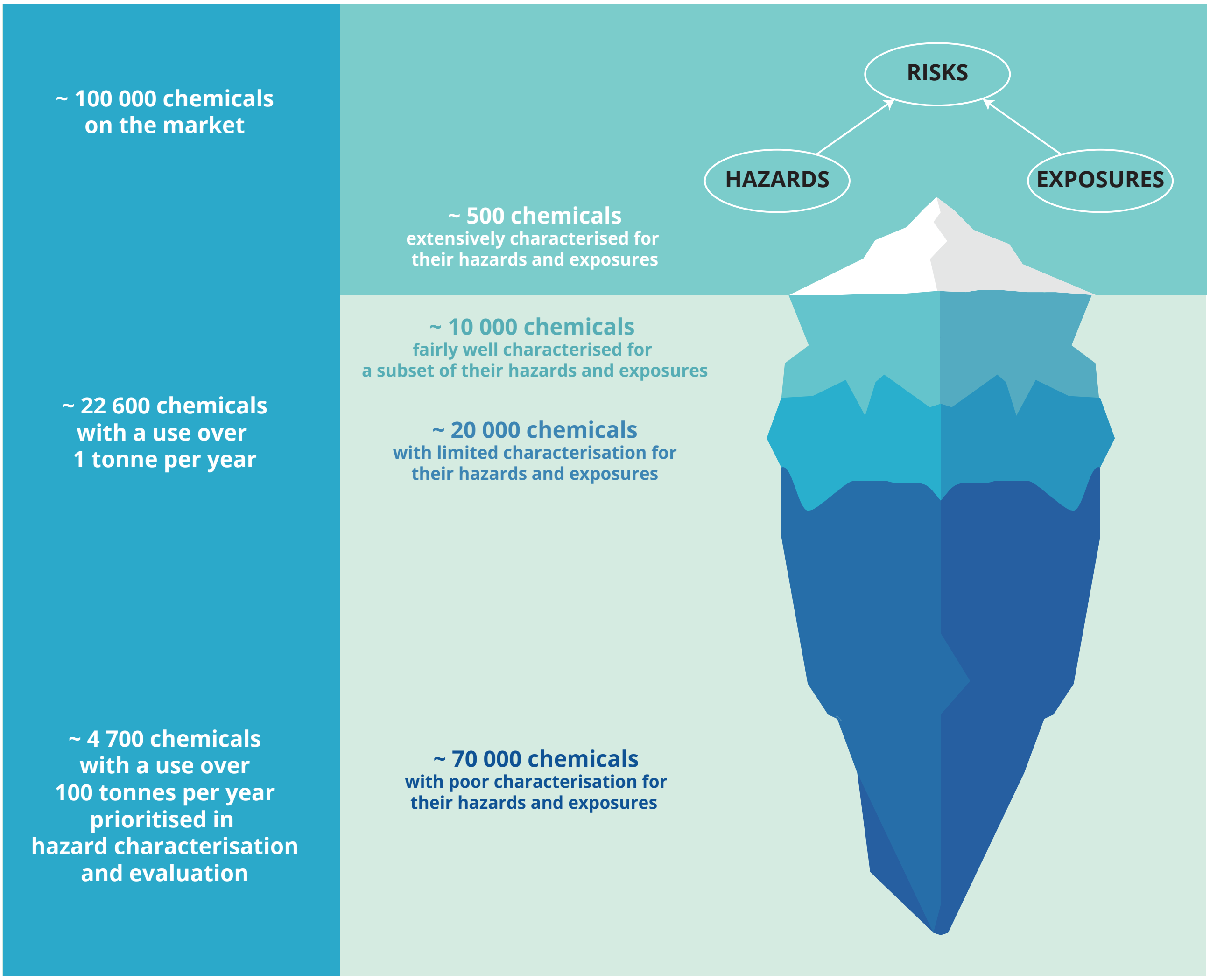
Different approaches to registering, assessing and monitoring chemicals create challenges in estimating how well chemical risks are assessed. As shown in Figure 10.2, it is estimated that robust information exists for about 500 chemicals and by April 2019, ECHA considered 450 substances as being sufficiently regulated (ECHA, 2019b). Another 10 000 substances are considered to have their risks fairly well characterised, while limited risk information is available for around 20 000 substances. The majority, around 70 000 substances have hardly any information on their hazards or exposures. While these may be present in small volumes, they contribute to the overall chemical risk and a fuller characterisation of hazards may be warranted. Given the diversity of substances, it is however unrealistic in terms of time and resources to comprehensively test all chemicals to identify their hazardous properties and to monitor for their presence in environmental media, in biota and in humans. This suggests that in addition to the existing tools, additional regulatory and other means are required, to enable effective management of the risks posed by chemicals, regardless of their source. In addition, improved information on volumes of specific chemicals could also enable modelling of exposures.

To get a rough estimate of how chemical risks are evolving in Europe, trends in the production and consumption of chemicals and changes in the proportion of chemicals on the market that are classified as hazardous to the environment and/or human health can be evaluated. In the EU, 282 million tonnes of industrial chemicals were produced in 2017. Of these, 28 %, or 75 million tonnes, were hazardous to the environment and 75 %, or 209 million tonnes, were hazardous to health. The proportions of chemicals hazardous to the environment and/or hazardous to health remained stable from 2008 to 2017 (Eurostat, 2019).

The consumption of industrial chemicals in the EU in 2017 was 304 million tonnes. Of these, 22 % were hazardous to the environment and 71 % were hazardous to health, similar proportions to those for chemical production. The proportion of consumed chemicals hazardous to the environment declined by 5 % from 2008 to 2017, with a decline of 6 % for chemicals hazardous to health, suggesting a downward trend in the overall hazard posed (Eurostat, 2019). However, the information available on chemical hazards is incomplete and the classification criteria under the CLP Regulation do not effectively capture certain health impacts, in particular long-term developmental toxicities associated with endocrine disruption, neurotoxicity and immunotoxicity, as well as certain categories of chemicals hazardous to the environment, such as persistent, bioaccumulative and toxic (PBT) and very persistent, very bioaccumulative (vPvB) substances. The approach is based on the hazard profile of individual substances and does not account for the combined effects of chemical mixtures. These issues imply that the associated risk to human health and the environment from chemical production and consumption is likely to be understated.

Production and consumption data provide a weak proxy for exposure to chemicals for several reasons. Actual exposure is determined by emissions during the chemical's life cycle, including use and waste phases and possible reuse, and not by the tonnage produced or consumed. Certain very hazardous chemicals are used in closed systems, reducing opportunities for exposure. Data for industrial chemicals also exclude important chemical sectors, such as pharmaceuticals and pesticides,

FIGURE 10.2 The unknown territory of chemical risks



Note: The numbers in the figure do not include impurities, transformation products or structural variants (isomers) of chemicals placed on the market. ~ 500 chemicals: Chemicals which are considered sufficiently regulated (ECHA, 2019b), typically legacy and well-known chemicals characterised for most known hazards, which have limit values and are regularly are monitored by quantitative methods in most media. ~ 10 000 chemicals: Chemicals on EU or national legislation lists which are characterised for some but not for all known hazards, which have specific limit values, and are monitored quantitatively, but irregularly across time, media or space. ~ 20 000 chemicals: Chemicals with hazards characterised mainly by modelling, or where exposure data are based on qualitative screenings done occasionally and in few media. ~ 70 000 chemicals: typically low volume chemicals for which usually no or very few hazards characteristics are available and information on uses and exposure is scarce, not characterised or measured in very few media.

Sources: EEA based on Danish EPA (2019); EC (2009); ECHA (2019a, 2019b, 2019c); EFSA (2012); EU (2009a, 2009c, 2011a, 2015); Geiser (2015); JRC (2016); Ng et al. (2011); OECD (2018); Sobek et al. (2016); UNEP (2018).

in which there are significant emissions to the environment. In addition, trends in the production and consumption of chemicals in Europe have been affected by the shift in manufacturing of goods requiring chemical inputs, such as textiles and electronics, to outside the EU (CEFIC, 2018). Chemicals used in manufacturing outside Europe are imported in finished products and emissions along the product's life cycle occur in Europe. Emissions outside Europe may also be transported long distances, adding to the total burden of chemicals in the European environment. Finally, any assessment of the chemical burden on the environment must also account for legacy chemicals already present in the environment, held in old products still in circulation or present in recycled materials.

Looking ahead, society's reliance on chemicals is projected to grow. In Europe, the consumption of pharmaceuticals is projected to increase as a result of the ageing population (Moritz et al., 2017). Global chemical production is projected to triple between 2010 and 2050, mainly outside Europe (OECD, 2012). European chemical production is also projected to increase up to 2030 (CEFIC, 2018). The projected increase in the production and consumption of chemicals and the complexity of the chemical universe creates significant challenges for efforts to reduce the risk to human health and the environment from chemical pollution.

10.3.2 Emissions of chemical pollutants to the environment

►See Table 10.2

Emissions of chemicals into the environment are governed by legislation addressing specific sources (e.g. the Industrial Emissions Directive, 2010/75/EU, and Urban Waste Water Treatment Directive, 91/271/EEC),

Persistent emissions and expected growth in chemical production make a reduction in the chemical burden on health and the environment unlikely.

receiving media (e.g. the Convention on Long-range Transboundary Air Pollutants, CLRTAP, and Water Framework Directive, 2000/60/EC) and specific types of chemicals (e.g. the POP Regulation, 850/2004/EC, which is currently being revised).

Emission trends

Very few chemicals are regularly monitored in flows of emissions to the environment in Europe. The number of substances monitored and reported at EU level in various emission sources are set out below.

- Emissions of 91 single or groups of substances to water, air and soil from about 30 000 industrial facilities, including waste water treatment plants, are reported in the European Pollutant Release and Transfer Register (E-PRTR) (Chapter 12; EEA, 2019b).

- Emissions to water of 45 priority substances reported under the Water Framework Directive's inventory of emissions, discharges and losses, covering both diffuse and point emissions. Data on industrial emissions are drawn from E-PRTR reporting, while diffuse emissions are estimated.

- Emissions to water of several groups of hazardous substances, including pesticides, metals and metalloids, organic substances and other determinants, voluntarily reported to the EEA by member countries under the Water Information System for Europe (WISE) SoE emissions dataflow (Chapter 4). The substances reported vary for each country.

- Emissions of 26 single and groups of substances to air reported under the CLRTAP (EEA, 2018c) covering estimated volumes from several sources (Chapter 8).

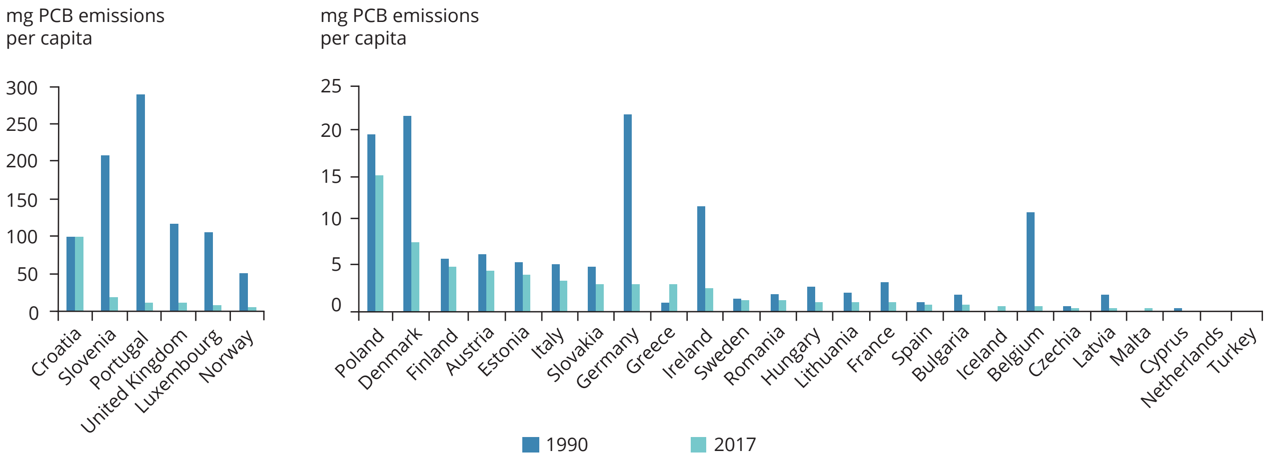
Chemical emissions to air There have been reductions in emissions to air of polychlorinated biphenyls (PCBs) and hexachlorobenzene (HCB) — two groups of POPs — as well as mercury, with declines of 83 %, 96 % and 72 %, respectively, in the period 1990-2017 and little improvement over the last decade (EEA, 2019a). Emissions of 23 chemicals from industrial installations reported to the E-PRTR with sufficient data coverage (not including heavy metals and pollutants formed during combustion) decreased by between 37 % and 93 % in the period 2007-2016, with the highest decreases in the first half of this period. Many of them are SVHCs that should be subject to substitution where there are suitable alternatives. Emissions of toluene and hydrogen cyanide increased by 13-22 % (EEA, 2019c), while emissions of seven heavy metals decreased by more than 17 % (Chapter 12). Emissions of ozone-depleting substances have been reduced as a result of partial substitution with hydrochlorofluorocarbons, which are potent greenhouse gases — an example of a regrettable substitution.

Chemical emissions to water Emissions of chlorinated substances from industrial installations and waste water treatment plants showed mixed trends, while emissions of heavy metals and other organic substances

BOX 10.2 Emissions of persistent organic pollutants

Persistent organic pollutants (POPs) are persistent, bioaccumulative and toxic. Certain POPs are targeted by a range of policies. Polychlorinated biphenyls (PCBs) are a group of POPs whose use has been prohibited since 2004 (EU, 2004b). However, stocks of PCBs in existing buildings and industrial facilities continue to result in emissions. In 2017, Croatia, Slovenia and Poland emitted the highest amounts of PCB per capita, associated with the legacy use of these substances, and there has been little progress in reducing emissions in Croatia and Poland since 1990 (Figure 10.3). However, in Croatia, leaks from electrical transformers and capacitors are the main sources of emissions, and these are estimated using highly uncertain emission factors (MoEE, 2019). Portugal, Slovenia, the United Kingdom and Luxembourg have been very successful in decreasing emissions. Removal of sources such as electrical (capacity) insulators has been one of the more efficient ways to cut emissions (EEA, 2019a), but more focus is needed on PCBs in the existing stock of buildings. There is some uncertainty in the data. For example, emissions from buildings — which can be significant — are not routinely included in emission inventories, and emissions are calculated using emission factors that most probably underestimate the actual emissions (BiPro et al., 2017; Glüge et al., 2017). ■

FIGURE 10.3 Country comparison — reductions in PCB emissions to air per capita in EEA member countries



Note: The figures are at different scales. No data available for Liechtenstein and Switzerland. Emissions reported by Cyprus, Malta and the Netherlands are close to zero. Turkey did not report data. Main emission sources are the industry, energy and waste sectors as well as the commercial, institutional and households sector.

Source: EEA (2019a).

decreased in the period 2008-2016 (EEA, 2019b). However, comparable data are limited to only a few substances, and emissions reported under different reporting mechanisms are partly inconsistent, while data on emissions from diffuse sources to water are largely lacking. Few countries report pesticide emissions to water, and for only a few selected pesticides, so no picture is available for European trends in pesticide emissions (EEA, 2018b). Emissions of SVHCs and POPs, which have been restricted in their use, are likely to have decreased, although these are not directly monitored (EEA, 2017b).

Current EU policies mainly address single chemicals and often in separate policy domains.

Chemical emissions to soil Some information on contamination of soils

TABLE 10.2 Summary assessment — emissions of chemicals

Past trends and outlook		
Past trends (10-15 years)		There are mixed trends, as emissions to air of a few well-known, regulated, persistent and hazardous chemicals (e.g. many substances of very high concern, polychlorinated biphenyls (PCBs), hexachlorobenzene, mercury) have decreased whereas emissions to water of selected chlorinated and organic chemicals from industrial installations and waste water treatment plants remained rather stable. However, the large majority of chemicals that are emitted are not monitored, including more than 2 500 persistent and mobile chemicals.
Outlook to 2030		Continuous progress is expected regarding emissions of the few chemicals that have been banned or restricted in use, e.g. PCBs and some pesticides. However, even reduced emissions will still contribute to further accumulation of persistent chemicals in the environment, presenting challenges regarding environmentally sound management of chemicals throughout their life cycles. Policies governing emissions of chemicals lag behind the challenge of addressing the large amount of chemicals of unknown fate and properties.
Prospects of meeting policy objectives/targets		
2020	☒	Europe is making progress towards the objective to minimise the use and emissions of listed persistent organic pollutants. However, Europe is not on track to meet the objective to minimise the release of hazardous chemicals to air, water and land, given the lack of information about emissions of thousands of persistent chemicals.
Robustness		Emissions data to air, water and soil cover very few chemicals out of the thousands released to the environment. Monitoring methods and reference chemical substances are lacking for the majority of chemicals in use. Data on emissions to water from different reporting mechanisms are in many cases inconsistent, and little information is available on diffuse emissions. Outlook information on emissions of chemicals is largely absent. The assessment of past trends, outlooks and prospects for meeting policy objectives relies primarily on expert judgement.

by chemicals is available through the Land Use and Coverage Area Frame Survey (LUCAS) soil programme — mainly heavy metals and in the future also pesticide residues (Chapter 5). However, data on emissions to soils are not available at European level because of a lack of a common policy regarding the monitoring and managing of such emissions. At country and regional levels, monitoring of emissions may take place. Mapping and targeted monitoring of sites contaminated with past or present industrial activities using hazardous chemicals can help to identify potential risks, such as contamination of drinking water (EEA, 2019b).

Looking ahead, available outlook information on emissions of chemicals is largely absent. Restrictions on use should result in a decrease in emissions. However, because of accumulated stocks in products and the environment, decreasing emissions will not necessarily result in similar decreasing trends in the concentrations in the environment. Accumulated persistent chemicals may continue to be released from products and buildings, and stocks in soil, sediment and ice may be re-mobilised due to storms, ice melting or flooding of contaminated soils (Wöhrnschimmel et al., 2016; Newkirk II, 2017). With the increasing frequency and magnitude of such events due to climate change, the risk of re-mobilising hazardous chemicals will increase (Moritz et al., 2017). Therefore, humans and the environment are exposed to emissions from both current activities and historical emissions accumulated in the environment (Gabbert and Hilber, 2016; Brack et al., 2017).

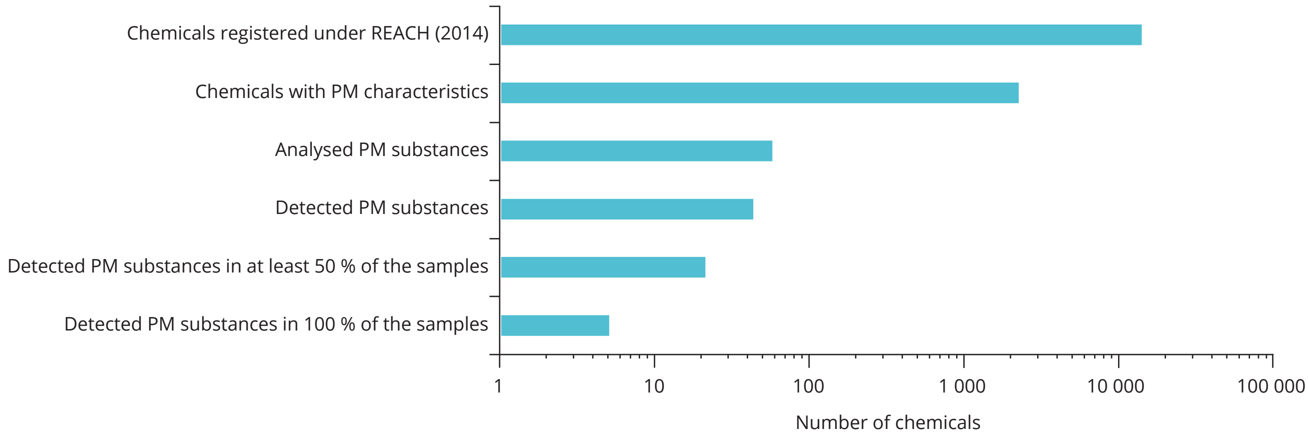
Emerging concerns

Out of the thousands of industrial chemicals produced and released to the environment, emissions are monitored and reported for only a few. Very limited emissions data are available at the European level for diffuse emissions from pesticides, biocides, pharmaceuticals, detergents, products and materials present in consumer goods and buildings (Bolinius et al., 2018). A group of persistent, highly water soluble and mobile chemicals are generating increasing concern and have been

BOX 10.3 Persistent and mobile chemicals in European surface water

The European research project on chemicals in water — PROMOTE (Helmholtz Centre for Environmental Research, 2018) — found that of the 14 076 chemicals registered under REACH legislation in 2014, 2 520 were (very) persistent and (very) mobile. Only 57 of them could be measured, because methods were lacking for the rest. 75 % (43) of the measured chemicals were found at least once in the 14 water samples from three European countries. Half of the water samples contained 21 of the substances measured. All of the water samples contained five of these substances (melamine, 2-acrylamino-2-methylpropane sulfonate, p-toluenesulfonic acid, 1,3-diphenylguanidine, 1,3-di-o-tolylguanidine). Concentrations ranged from nanograms per litre to micrograms per litre, raising concerns, as several of these substances resist even advanced drinking water treatment processes (Brendel et al., 2018; Arp et al., 2017). However, emissions and occurrences of the 43 substances are not monitored under current EU regulations. ■

FIGURE 10.4 Fraction of REACH chemicals that are persistent and mobile and found in water



Note: The scale is logarithmic, PM substances classified as persistent and mobile.

Sources: Schulze et al. (2018, 2019), Brendel at al. (2018); Arp et al. (2017); Arp and Hale (forthcoming).

found in European freshwaters (Box 10.3). In response, Germany has recently proposed that such chemicals be treated under the REACH Regulation as chemicals of equivalent concern to substances classified as (very) persistent, (very) bioaccumulative and toxic (Neumann and Schliebner, 2017; Arp, 2018). More generally it has been proposed that persistency itself may be the property to avoid (Cousins et al., 2019) for chemicals that are safe by design (Kümmerer, 2018).

A large majority of emitted chemicals remain unmonitored in the environment.

10.3.3 Impacts of chemical pollution on the environment

► See Table 10.3

There is a lack of knowledge of the impacts of many individual chemicals and chemical mixtures on the environment. Not all chemicals or their transformation products have been assessed, and ecotoxicity assessments focus on very few species and ecosystems. This means that knowledge about the presence of chemicals is not enough to explain observed effects, while ecological impact information alone is similarly not sufficient to identify the chemicals causing that impact. Instead, multiple lines of evidence are needed as well as precautionary approaches (EEA, 2018a). Assessments of environmental impacts based on monitoring data for the commonly known legacy pollutants are likely to underestimate the risks (Sobek et al., 2016).

The EU aims to achieve the objective that the use of plant protection products does not have any harmful effects on human health or unacceptable influence on the environment and that such products are used sustainably. Recently, the risks posed by pesticides, in particular neonicotinoids and their effects on pollinators, have been widely demonstrated. Decades of pesticide use is also a factor in the substantial decline in insects populations in Europe and in the related decline in insect-feeding birds (Hallmann et al., 2017, 2014) (Chapter 3).

The European Food Safety Authority (EFSA) has recently increased its efforts to include environmental risks in its risk assessments, for example to understand how using pesticides affects pollinators and sensitive ecosystems. A recent EFSA study developed a procedure for identifying potential emerging chemical risks to health via the food chain due to REACH-registered substances. Of the approximately 15 000 substances registered under the REACH Regulation at the time of the study, 2 336 unique substances were selected for assessment. In terms of emerging risks to health via the food chain, 212 chemicals were identified as being released to the environment and/or poorly biodegraded, bioaccumulating in food/feed and representing a chronic human health hazard. Carcinogenic/mutagenic substances and surfactants dominated the top 10 list of substances (Oltmanns et al., 2019).

With the increasing frequency and magnitude of storms, flooding and ice-melting due to climate change, the risk of re-mobilising hazardous chemicals will increase.

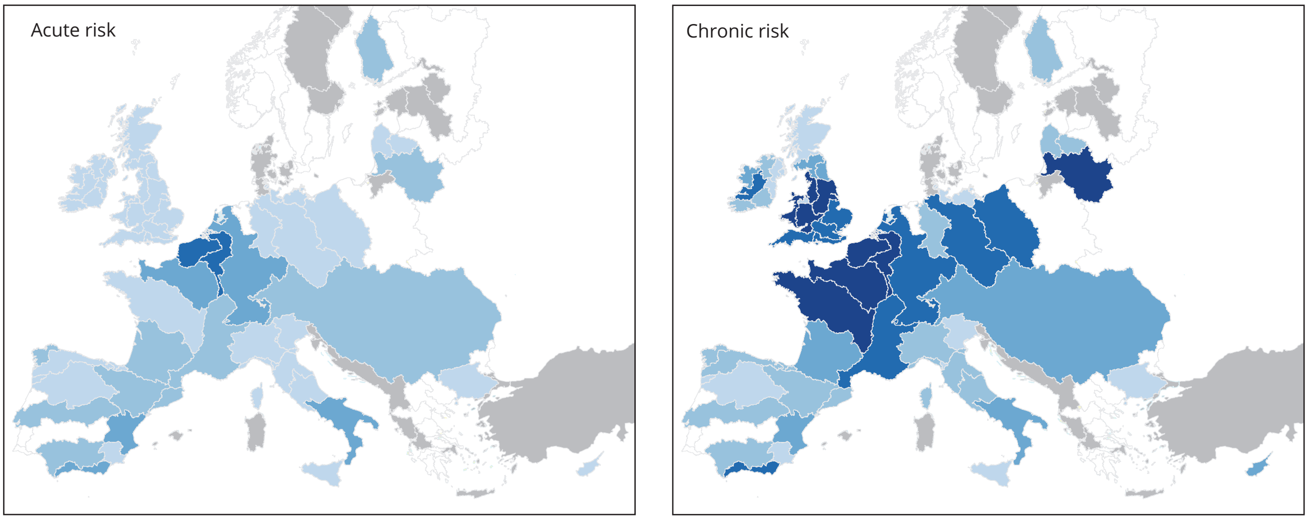
The use of chemicals can also have an impact on ecosystem services, for example clean soils for food production. Chemical pollutants may build up in soil through the application of pesticides, inorganic fertilisers containing metals, and sludge, and manure and waste water for irrigation containing pharmaceuticals, biocides, detergents and microplastics. In 2018, it was estimated that potentially 2.8 million locally contaminated sites exists in the EU-28 Member States, mainly from waste disposal and treatment, and that this is a significant environmental hazard for terrestrial and aquatic ecosystems (Payá Pérez and Rodriguez Eugenio (2018). Legacy pesticides threaten drinking water in Denmark and Spain. Soil pollutants affect both invertebrates and microbes and decrease their capacity to break down plant matter to nutrients, affecting the productivity of soils (Chapter 5).

The Water Framework Directive sets maximum thresholds for a range of chemicals in surface and groundwater bodies. In the second river basin management plans, 38 % of Europe's surface water bodies achieved good chemical status (EEA, 2018d). A relatively small number of substances are responsible for the failure to achieve good chemical status, with mercury responsible for causing failure in a large number of water bodies (Chapter 4). Brominated flame retardants (the polybrominated diphenyl ethers, pBDEs), tributyltin, polycyclic aromatic hydrocarbons and heavy metals were the most frequently found in freshwater in Europe (EEA, 2018d).

Significant knowledge gaps remain regarding the impacts of the total burden of chemicals on human health and the environment.

A pioneering study analysing risk from chemicals used monitoring data on chemical concentrations, reported in the WISE SoE database (Malaj et al., 2014). A total of 223 substances monitored in European freshwater systems were evaluated, and the study found that single chemicals were likely to exert acute lethal and chronic long-term effects on sensitive fish, invertebrate or algae species. They reported an acute risk at 14 % and a chronic risk at 42 % of the sites investigated using an individual chemical risk assessment approach (Map 10.1). Increasing chemical risk was associated with deterioration in the quality status of fish and invertebrate communities. Pesticides, tributyltin, polycyclic aromatic hydrocarbons and brominated flame retardants were the major contributors to the chemical risk and were related to agricultural and urban areas in the upstream catchments (EEA, 2018d). The study also found that the expected risk increases with the availability of chemical monitoring data, confirming that current monitoring underestimates risks. The sources of these chemicals are a mixture of point source emissions from waste water treatment plants, industrial facilities, contaminated sites and diffuse emissions from agrochemicals and sludge (Huber et al., 2016; Kümmerer, 2018).

MAP 10.1 Acute and chronic chemical risk estimates in European river basins



Chemical risk estimates for European river basins (%)

< 10 | 10-25 | 25-50 | 50-75 | 75-100 | < 6 sites | No data

Note: The map displays the fraction of sites where the maximum chemical concentration exceeds the *acute risk* threshold, and the mean chemical concentration exceeds the *chronic risk* threshold for any organism group. The calculations are based on reported chemical monitoring data and calculated using risk estimates for individual compounds. The colours indicate low chemical risk (light blue) to high chemical risk (dark blue). Direct comparisons between river systems are potentially biased by the ecotoxicologically relevant compounds analysed and the limit of quantification of the compounds. See Malaj et al. (2014) for further discussion of potential bias in the data (maps have been adapted).

Source: Malaj et al. (2014).

However, there are no cases in which only a single substance occurs in the environment. More recently, systematic efforts have demonstrated that mixtures of chemicals affect ecosystem integrity in aquatic ecosystems to the extent that simultaneous exposure to pesticides, along with other forms of stress, can render aquatic organisms up to 100 times more vulnerable to pesticides (Liess et al., 2016; Posthuma et al., 2016). The EU projects SOLUTIONS and MARS found that on average 20 % of aquatic species are lost due to exposure to chemical mixtures, with increasing exposure reducing the integrity of aquatic ecosystems (Posthuma et al., 2019).

In the marine environment, the Marine Strategy Framework Directive's objective of achieving good environmental status for contaminants will not be achieved by 2020, as contaminants continue to give rise to pollution (Chapter 6).

The Marine Strategy Framework Directive objective regarding contaminants will not be achieved by 2020.

However, success has been achieved in reducing the levels and effects of specific chemicals that are banned such as tributyltin, which has been used in antifouling paint (AMAP, 2018). While there has been a reduction in PCB emissions, air levels remain high (Wöhrnschimmel et al., 2016), as do PCB levels in fish and other marine organisms in the North-East Atlantic and the Baltic and Black Seas. Meanwhile, PCB levels have decreased in northern seas but increased in the Mediterranean (EEA, 2015). Long-lived organisms high up the food chain are particularly vulnerable because of their high accumulation of POPs. Killer whales

TABLE 10.3 Summary assessment — chemical pollution and impacts on ecosystems

Past trends and outlook	
Past trends (10-15 years)	There are mixed trends, as the occurrence of some individual substances and their related impacts on ecosystems have decreased. However, the effects of most chemicals in the environment have not been assessed, and many of them are likely to have substantial impacts on biodiversity and ecosystems.
Outlook to 2030	The accumulation of persistent chemicals and continued emissions of hazardous and persistent chemicals into the environment mean that it is likely that impacts of chemical pollution on ecosystems will not decrease. Legacy and emerging pollutants in soil are a particular concern considering the lack of a European policy on soil. Overall, current policies lag behind in addressing a large number of chemicals, and procedures do not keep up with the pace of developments, such as increasing production, new chemicals entering the market, chemicals in imported articles, and gaps in the evidence base.
Prospects of meeting policy objectives/targets	
2020 ☒	Europe is not on track to minimise the significant adverse effects of chemicals on the environment by 2020. Only 38 % of Europe's water bodies are in good chemical status, and the Marine Strategy Framework Directive objective regarding contaminants will not be achieved.
Robustness	The availability of monitoring data on chemicals in the environment influences the assessment of risk, and the risks appear higher where information is available than where it is lacking. The risks are likely greatly underestimated, as only a fraction of chemicals are monitored and assessed, and mixture effects and multiple stressors are not included in risk assessments. Knowledge of the impacts of chemical pollution on ecosystems is very scattered, and outlook information is absent; therefore, the assessment of these impacts relies primarily on expert judgement.

now risk extinction because PCBs are impairing their reproduction and health (Desforges et al., 2018).

Emerging concerns

Continuous and high-volume releases of bioactive biocides, fungicides, plant protection products, surfactants and pharmaceuticals into the environment affect ecosystems and pose risks for the development of wider antibiotic and fungal resistance. In 2017, the European Commission issued an action plan on antimicrobial resistance (EC, 2017), which will complement existing laws such as the Biocidal Product Regulation (EU, 2012). A strategy for pharmaceuticals in the environment was adopted in March 2019 (EC, 2019a), as called for in the Water Framework Directive and reiterated by a European Council decision in December 2016 (Council of the European Union, 2016). The rapid development and use, and emissions of nanomaterials into the environment, which may pose different and less well-understood risks, is another area of concern (EEA, 2013; EU, 2013; Hansen, 2018).

10.3.4 Human exposure to chemical pollution and impacts on human health

► *See Table 10.4*

The overarching policy goal regarding the impacts of chemicals on health is to minimise significant adverse effects from the production and use of chemicals. There is evidence that human exposure to a complex mixture of hazardous chemicals via environmental pollution generates a range of negative health outcomes (WHO, 2016; Landrigan et al., 2017; Bopp et al., 2018;). The range of chronic diseases associated with exposure to hazardous chemicals includes allergies, asthma, reproductive disorders, neurological disorders such as Parkinson's disease and autism, immune system and cardiovascular disorders, diabetes and cancer. These health impacts may shorten life expectancy (mortality) and/or may lead to increased illness (morbidity) over the course of a lifetime or in later generations (WHO, 2016).

People are exposed to mixtures of chemicals via their diet, the environment and contact with a wide range of consumer products. Some groups of people in society are more vulnerable, either because they are exposed to higher concentrations of hazardous chemicals or to mixtures of chemicals or because their bodies are more sensitive to the impacts of hazardous chemicals. Workers handling chemicals are typically exposed to the highest levels (EU-OSHA, 2017a). Young children and pregnant women are particularly sensitive, as exposure to chemicals that cause developmental toxicity to the endocrine, neurological and immune systems during fetal development and early childhood can result in chronic diseases later in life or in later generations (Grandjean and Bellanger, 2017).

There is a lack of robust data on the actual exposure of the European population to hazardous chemicals to feed into an understanding of the risks to human health. In order to better understand exposure to chemicals, human biomonitoring can be used to measure the concentrations of chemicals in blood, breast milk, urine or hair. The European human biomonitoring initiative, HBM4EU, is currently gathering human exposure data for 17 groups of chemicals, as well as mixtures and emerging substances, and exploring links to health impacts. The aim of the initiative is to produce coherent, comparable exposure data for the European population in order to evaluate existing measures and support the development of targeted policy measures to deliver chemical safety.

In terms of exposure to pesticide residues in food, in 2015 more than 97 % of food samples collected across the EU contained pesticides within the legal limits, with just over 53 % free of quantifiable residues (EFSA, 2017). Concerns remain regarding human exposure to neurotoxic pesticides (Grandjean and Landrigan, 2014; Mie et al., 2018) and mixtures of pesticides (Hass et al., 2017). Regulation 396/2005/EC on the maximum residue levels of pesticides in or on food and feed of plant and animal origin highlights the importance of further work to develop a methodology to take into account cumulative and mixture effects. EFSA is undertaking a number of activities to deliver on this mandate.

Current evidence suggests that POPs and certain metals are responsible for a substantial proportion of the chemical burden on health, both as individual substances and in mixtures (Evans et al., 2016). Under the global monitoring plan conducted by the World Health Organization and UN Environment in support of the Stockholm Convention on Persistent Organic Pollutants, hundreds of POPs have been identified in human breast milk, including PCBs and brominated flame retardants (Fång et al., 2015), as well as per- and polyfluorinated alkyl substances, or PFAS (Nyberg et al., 2018; EFSA, 2018). Due to their bioaccumulation properties, POPs that have been phased out continue to be a significant source of exposure (Evans et al., 2016).

Minimising the signficant adverse impacts of chemicals including pesticides in Europe by 2020 is unlikely.

Methylmercury is an example of a developmental neurotoxicant that affects the brain development of fetuses and young children. The most significant route of human exposure to mercury is diet, with the highest blood mercury concentrations found in communities that consume lot of predatory fish (e.g. species such as marlin, swordfish and tuna). It is estimated that a minority of European fish consumers reach mercury levels considered hazardous by the World Health Organization (WHO) (Castaño et al., 2015). However, children are more vulnerable, and it has been estimated that every year throughout Europe, nearly 1.8 million babies, approximately one third of all births, are born with methylmercury levels above a safe limit (Bellanger et al., 2013). Countries with higher levels of large predatory fish consumption were estimated to have proportionately more babies born with mercury levels above the limit. The potential impact on children's brain development is lifelong and can result in significant cognitive impairment with related economic costs (Grandjean and Bellanger, 2017). Pregnant women can continue to follow official dietary guidelines and consume fish while avoiding large predatory species to lower mercury intake.

People are exposed to mixtures of chemicals via their diet, the environment and contact with a wide range of consumer products.

Concerns have been growing in Europe for many years regarding the risks to health from endocrine-disrupting chemicals, for example bisphenols, phthalates, benzophenones and some pesticides (Kortenkamp et al., 2012; EC, 2018b). Endocrine disruptors interfere with natural hormone systems, can have affects at very low doses and can result in health effects long after the exposure has stopped. Exposure to endocrine disruptors in the womb may disturb the development of the child causing irreversible health effects, and it can even have consequences for the next generation. Endocrine disruption is also associated with health outcomes including lower fertility, obesity and diabetes. The increased incidence of testicular cancer over a short time scale has been linked to exposure to endocrine disruptors (Skakkebaek et al., 2015). A recent study estimated the cost of health impacts from exposure to endocrine disruptors in the EU to be EUR 157 billion annually as a result

TABLE 10.4 Summary assessment — chemical pollution and risks to human health and well-being

Past trends and outlook		
Past trends (10-15 years)		Despite reduced emissions of some known hazardous substances, concerns remain regarding daily human exposure to chemicals and their health effects, including allergies and premature death of workers. Exposure to legacy pollutants remains a health concern despite emission reductions, as does exposure to developmentally toxic substances, such as endocrine-disrupting, neuro- and immunotoxic chemicals.
Outlook to 2030		The impact of accumulated chemicals, and continued emissions of hazardous and persistent chemicals, suggests that human exposure to complex mixtures of chemicals will continue to increase. Increased imports of articles and recycling of materials may increase exposure to chemicals of concern. Current policies lag behind in assessing and regulating the risks of exposure to the large majority of chemicals in use. It is therefore unlikely that the negative effects of chemicals on human health will decrease.
Prospects of meeting policy objectives/targets		
2020	☒	Europe is not on track to meet the objective of minimising risks to health from hazardous chemicals by 2020. However, progress has been made, and the REACH Regulation has been successful in identifying a number of substances of very high concern and putting risk management measures in place.
Robustness		There is a lack of data on exposure and toxicity for a large number of chemicals, as well as knowledge gaps regarding several types of toxicities and mixture toxicity. There are no coherent time trends in exposure data at European level with which to assess trends, and there are data gaps regarding emerging substances. The assessment of past trends, outlooks and prospects of meeting policy objectives relies primarily on expert judgement.

of disease and dysfunction across the human life course (Trasande et al., 2016). A number of substances in the chemical group phthalates, the most widely used plasticisers, have been found to have endocrine-disrupting properties (DEHP, BBP, DBP and DiBP). These along with bisphenol A are subject to risk management measures under the REACH Regulation (EU, 2016, 2018b).

> Exposures to hazardous chemicals and their corresponding health risks are likely to increase in the future.

Emerging concerns

There are growing concerns regarding a large number of emerging substances that are not included in routine monitoring at the European level and for which impacts on environment and health are poorly understood. An example is the group of PFAS which includes more than 4 700 chemicals that are or degrade to very persistent compounds (OECD, 2018). They are widely used as surfactants, stain and water repellents, emulsifiers and lubricants in consumer products, pharmaceuticals, pesticides and industrial processes (Scheringer et al., 2014; Ritscher et al., 2018). As a consequence, PFAS have been found everywhere, even in the most remote parts of the world. Those PFAS that bioaccumulate have been found in high levels in biota and in the blood, organs and breast milk of humans (Nyberg et al., 2018). This generates concern, as several PFAS have been associated with decreased immune system function, increased cholesterol levels, and kidney and testicular cancer (Rappazzo et al., 2017), and some are suspected of being endocrine disrupters (Kar et al., 2017; EFSA, 2018).

In terms of regulatory control, some PFAS are listed as POPs under the Stockholm Convention and are subject to phasing out. Perfluorooctanoic acid (PFOA) is restricted under the REACH legislation, and other PFAS are classified as SVHCs under REACH. Based on new evidence on the harmful effects of PFAS on humans, EFSA has recently provisionally lowered the tolerable intake for PFOA and perfluorosulfonic acid (PFOS) in food and water and estimated that a significant proportion of Europeans are exposed above the health-based limits (EFSA, 2018). A recent study estimated the annual health-related costs due to exposure to PFAS at 2.8-4.6 billion EUR for the five Nordic countries and 52-84 billion EUR for all EEA countries. The costs related to environmental remediation were estimated to be 46 million-11 billion EUR over the next

20 years for the five Nordic countries (Nordic Council of Ministers, 2019).

Antimicrobial resistance is a worldwide, increasing threat to human health (UNEP, 2017). Health and food sectors are heavily involved in action to mitigate the risk (WHO, 2017) but understanding of the significance of the environment as an exposure pathway lags behind (EEA, 2016, 2018b). Major potential areas for transmission are in discharges from industry and urban waste water treatment plants and in the use of biocides and antibiotics in agriculture for veterinary use.

While a range of evidence is presented here for substances known to be hazardous, there are considerable uncertainties regarding the total burden of disease related to chemical exposure and it is likely to be underestimated (Landrigan et al., 2017; Gross and Birnbaum, 2017; Grandjean and Bellanger, 2017). Looking ahead, the projected growth in consumption of chemicals, the rather stable proportion of those known to be hazardous and the accumulation of persistent chemicals together suggest that human exposure to hazardous chemicals is likely to increase, with corresponding impacts on health.

10.4 Responses and prospects of meeting agreed targets and objectives

10.4.1 Relevance, effectiveness and coherence of current policies

Chemicals legislation encompasses different policy domains. The REACH Regulation addresses industrial chemicals, while pesticides, pharmaceuticals, food contact materials and others are addressed separately. This complexity of chemicals legislation creates some challenges in terms of coherence and effectiveness, and its relevance is challenged by the frequency with which new chemicals are introduced, the regulation and monitoring of relatively few and mainly single substances and the expansion of our knowledge of the risks of chemicals (EEA, 2013).

up to 70 %

of REACH registration dossiers were found to be noncompliant.

The main drivers for the introduction of the REACH legislation (EU, 2006b) were to address the information gap regarding chemicals and to accelerate risk assessment and the implementation of risk management for existing chemicals to protect human health and the environment (EC, 2019c). Some 10 years after its entry into force, the REACH Regulation is fully operational, although progress towards the objectives is lagging behind initial expectations. The second REACH review (EC, 2018a) identified shortcomings in its implementation that hamper the achievement of its objectives, including up to 70 % of registration dossiers not being compliant (ECHA, 2018b; BFR, 2018) and the need to simplify the authorisation process, ensure a level playing field for non-EU countries and ensure policy coherence between REACH and other legislation. In addition, the time required for substances of potential concern to human health to be evaluated under the REACH legislation has been estimated at 7-9 years, during which time exposure continues. Only after evaluation is complete are risk management measures put in place through processes that also take considerable time. In a context in which over 22 600 chemical substances are registered under REACH, many with unknown properties and impacts, the current substance-by-substance approach involving an extended period until risk management measures are put in place is not fit for purpose. Despite these shortcomings, the REACH Regulation has positioned the EU as a frontrunner in this area and influenced legislation in other countries.

Alongside REACH, the CLP Regulation, the POPs Regulation and the Directive on restriction of hazardous substances (RoHS) have contributed significantly to managing the risks and reducing exposure to hazardous chemicals, such as SVHCs (EC, 2019c). Legislation has, however, not effectively prevented occupational diseases (EC, 2016; EU-OSHA, 2017b), but a roadmap to reduce occupational cancers in Europe has been developed (EU-OSHA, 2017a).

Risk assessments used within chemicals legislation were reviewed as part of the European Commission's fitness check of the most relevant chemicals legislation (EC, 2019c). Risk assessment processes require significant amounts of data as input, but when there are gaps in the evidence base it may lead to a trade-off between decision-making in the context of uncertainty or delaying decision-making to generate more data. When data do not permit a complete evaluation of the risk but the potential risks could be severe, the Treaty on the Functioning of the European Union, Article 191 (EU, 2008a), allows for the application of the precautionary principle. The principle enables a rapid response through preventive decision-taking to protect human, animal or plant health (EC, 2000). However, the precautionary principle is not used to its full potential, as is highlighted in the REACH review (EC, 2018a).

10.4.2 Cross-cutting challenges

Although humans and the environment are generally exposed to mixtures of chemicals, the current approach to risk assessment in chemicals legislation is generally based on single substances. Understanding of the risks of exposure to mixtures is growing, and efforts have been made to review available methodologies for risk assessment of mixtures (Bopp et al., 2015, 2016). EFSA has prepared guidance on harmonised methodologies for human and animal health and ecological risk assessment of combined exposure to multiple chemicals (EFSA Scientific Committee et al., 2019). The HBM4EU project will gather and produce data on actual human exposure to mixtures of chemicals as a basis for risk assessment.

Regulating groups of chemicals rather than single substances is being considered by the European Commission and the European Chemicals Agency (ECHA) as a means of speeding up risk assessment, hazard assessment and risk management (ECHA, 2018a, 2018b). Recent examples include the restriction of four phthalates (EU, 2018a) and the proposal to have a PFAS group limit in EU drinking water (European Parliament, 2018). Another argument for regulating groups of substances is avoiding regrettable substitutions, whereby a banned hazardous chemical is replaced by a similar chemical subsequently found to be harmful. In implementing the REACH legislation, ECHA now pays increasing attention to the structural similarity between substances and has also started to consider substances in groups to avoid regrettable substitutions (ECHA, 2018d).

Legacy chemicals that are now strictly regulated but that persist and accumulate in the environment, such as PCBs and heavy metals, remain an issue for both ecosystems and human health.

> Designing safer chemicals and products for circular use would support the transition to a circular economy and a non-toxic environment.

Looking ahead, this raises concerns regarding substances currently in use or produced that are persistent, accumulating or mobile. As knowledge on hazards increases, some of these substances are likely to be found to be toxic after they have already been released into the environment. As cleaning up is often not feasible or too costly, this calls for a preventive regulatory focus on such substances.

The 7th EAP calls for safety concerns related to endocrine disruptors to be effectively addressed in EU legislation by 2020 (EU, 2013). In response, the EU published scientific criteria for the identification of active substances in pesticides (EC, 2018b) and biocides (EU, 2017) that have endocrine-disrupting properties. The EU is investing in research on endocrine disruptors to produce evidence and develop methods to support decision-making. The Commission will also launch a comprehensive screening of the legislation applicable to endocrine disruptors, which will include a public consultation (EC, 2018b).

In the 7th EAP, it was anticipated that a non-toxic environment strategy would be developed by 2018, which was intended to address some of these cross-cutting challenges. A future initiative on sound management of chemicals and waste would need to link to the broader international policy agenda, including the strategic approach to international chemicals management and the SDGs.

10.4.3 Looking ahead to a non-toxic, circular economy

The transition to a non-toxic environment will require different approaches to managing hazardous chemicals in products and in the environment. The systematic application of the precautionary principle, a stronger focus on preventing emissions, reducing the use of hazardous chemicals in products and regulating groups of substances could all effectively reduce exposure while keeping up with the rapid introduction of new chemicals (EEA, 2018a; EC, 2019c). Establishing inventories of chemicals of concern in products may enable more frequent enforcement and lead to increased levels of compliance (ECHA, 2018c). Early warning systems to detect mixtures of emerging contaminants in air, water and sensitive biota close to emission points could support faster action. An important future task is devising better controls to prevent banned substances from entering Europe as chemicals or in manufactured products (EC, 2019b)

At the same time, Europe aims to develop into a circular economy that maximises the value and use of products and materials through reuse, repair, refurbishment and recycling (Chapter 9). Moving towards a circular economy will therefore require a high level of traceability and a risk management approach that deals with legacy substances and long-term risks (Pivnenko and Fruergaard, 2016; EEB, 2017). Risk assessment needs to consider not only the first life of a product but also all potential future lives and hence different exposure scenarios from those considered in a linear economy. One of the key areas for action will be to ensure the safe disposal of toxic substances at the end of the product's life cycle. Efforts to clean up material flows can enhance the long-term potential for circularity.

Ensuring greater future use of chemicals and products that are safe and circular by design would support the transitions to both a circular economy and a non-toxic environment. Their development requires education of chemists and material designers in how to design and develop safer chemicals and products (Warner and Ludwig, 2016; Kümmerer, 2018), as well as targeted and interdisciplinary innovation support, as highlighted in ECHA's recent strategy (ECHA, 2018d). Moreover, Best Available Techniques conclusions under the Industrial Emissions Directive (Chapter 12) can promote safe-by-design chemicals. A reduction in material and chemical complexity and a focus on ecodesign and on the function delivered by a product will help facilitate the transition to clean material cycles, with good performance and competitive prices compared with using virgin materials (EEA, 2017a). Their uptake can be speeded up through the use of clean procurement (Box 10.4), and considering essential versus non-essential uses. While a transition to a non-toxic and circular economy based on safer chemicals may not be simple to achieve, it could nevertheless provide systemic solutions, which would support environmental sustainability and progress towards the SDGs and boost innovation in Europe.

BOX 10.4
The NonHazCity project: regional knowledge building and public procurement to reduce emissions of hazardous chemicals into the Baltic Sea

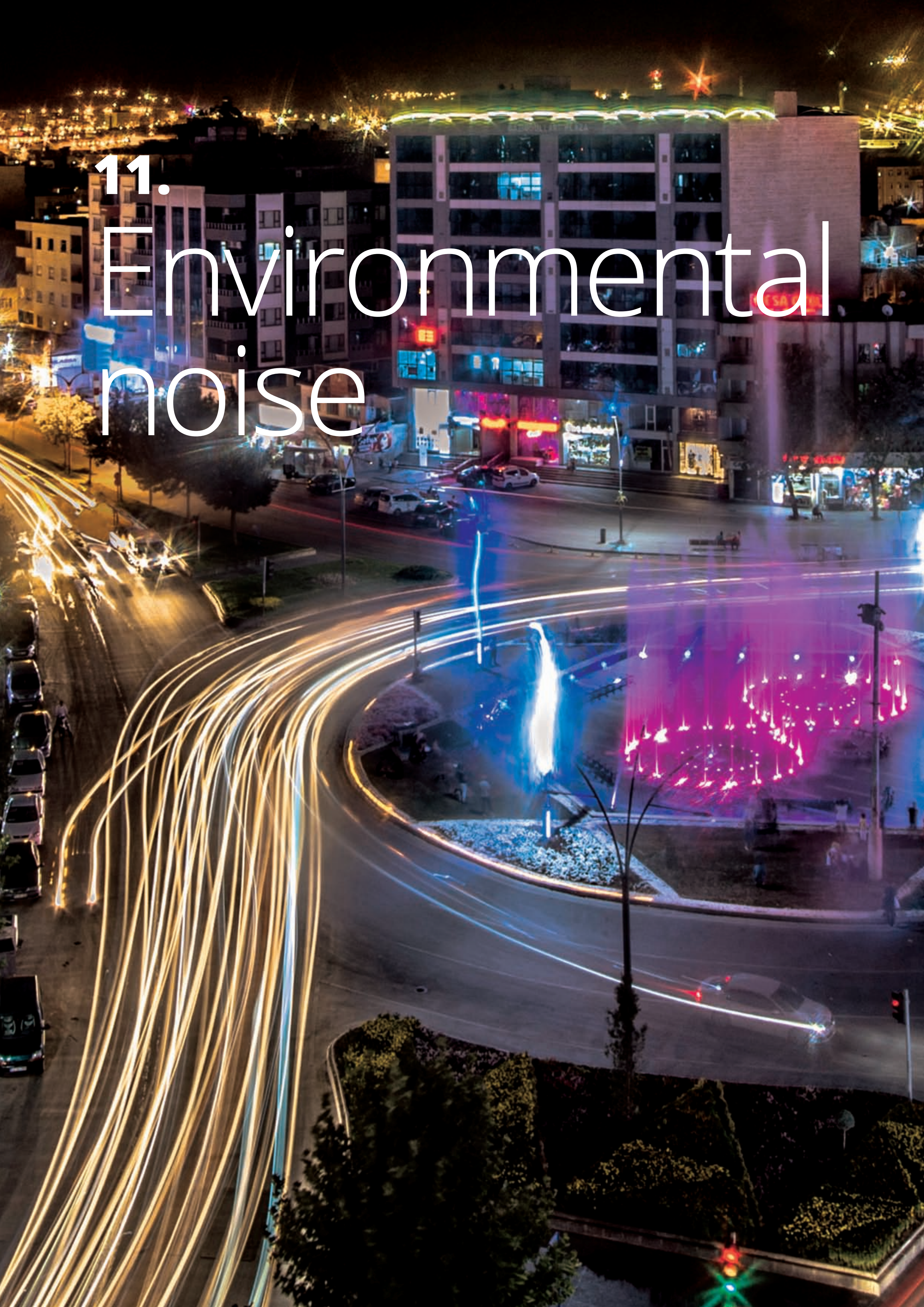
Eleven cities in eight countries (Belarus, Estonia, Finland, Germany, Latvia, Lithuania, Poland and Sweden) joined efforts to reduce emissions of hazardous chemicals into the Baltic Sea. The project addresses small-scale emitters, including municipalities, small and medium-sized enterprises, and households and aims to reduce the use and emissions of hazardous chemicals. Substances selected from the list of priority substances under the Water Framework Directive and substances of very high concern under the REACH Regulation were screened in urban waste water and storm water, in waste water treatment plant influents and effluents and in sewage sludge. Potential upstream sources were identified using maps and data on chemicals in everyday old and new products.

Hazardous chemicals were widely detected. Waste water treatment plants cannot completely remove all chemicals, implying that emissions must be tackled at source. In terms of sources, diffuse sources related to product emissions, such as indoor dust and laundry waste water, are more important than industrial point sources for some chemicals. Old products frequently contain higher levels of hazardous chemicals than new products.

The project recommended public awareness campaigns and dialogue with small and medium-sized enterprises to guide purchasing choices and behaviour. Municipalities can develop and implement clean chemicals strategies and reduce their use of hazardous chemicals through public procurement. Procurement criteria should include hazardous substances and address compliance with relevant legislation. ■

Source: Gercken et al. (2018).

11. Environmental noise



Key messages

- Environmental noise remains a major environmental health problem in Europe with at least 20 % of the EU's population living in areas where noise levels are considered harmful to health.

- Road traffic noise is the most dominant source of environmental noise, with an estimated 113 million people affected by long-term daily average noise levels of at least 55 dB(A) and 79 million people affected by night-time noise levels of at least 50 dB(A).

- Exposure to noise pollution harms health. Long-term exposure is estimated to contribute to 48 000 new cases of heart disease per year in Europe and to 12 000 premature deaths. In addition to this, it is estimated that 22 million people suffer severe annoyance, 6.5 million people suffer severe sleep disturbance and 12 500 school children may suffer learning impairment due to aircraft noise.

- The number of people exposed to high levels of noise since 2012 has broadly remained stable. The objective of the Seventh Environment Action Programme — to significantly reduce noise pollution in the EU and move closer to World Health Organization recommended levels by 2020 — will not be achieved.

- An increase in the numbers exposed to environmental noise is projected as a result of future urban growth and increased mobility demands. Therefore reducing noise pollution will require further efforts.

- The implementation of the Environmental Noise Directive, introduced in 2002, has not yet achieved its full potential. It would be achieved if Member States implemented it fully, particularly with respect to completeness, comparability and timeliness of reporting, as well as implementing action plans that include the protection of quiet areas.

Thematic summary assessment

Theme	Past trends and outlook		Prospects of meeting policy objectives/targets
	Past trends (10-15 years)	Outlook to 2030	2020
Population exposure to environmental noise and impacts on human health	Trends show a mixed picture	Deteriorating developments dominate	☒ Largely not on track
Preservation of quiet areas	Trends show a mixed picture	Developments show a mixed picture	☒ Largely not on track

Note: For the methodology of the summary assessment table, see the introduction to Part 2. The justification for the colour coding is explained in Section 11.3, Key trends and outlooks (Tables 11.3 and 11.4).

11. Environmental noise

11.1 Scope of the theme

Environmental noise is a pervasive pollutant that adversely affects the health and well-being of Europe's citizens as well as wildlife. Although noise is a product of many human activities, the most widespread source of environmental noise is transport. To this effect, noise caused by transport is considered to be the second most significant environmental cause of ill health in western Europe, after fine particulate matter pollution (Hänninen et al., 2014; WHO and JRC, 2011). According to the World Health Organization (WHO), prolonged exposure to environmental noise is associated with an increased risk of negative physiological and psychological health outcomes (WHO, 2018). These include cardiovascular and metabolic effects, reduced cognitive performance in children, and severe annoyance and sleep disturbance. As a result of projections of rapid urban growth and increased demand for transport, a simultaneous increase in exposure to noise and the associated adverse effects can be anticipated (Jarosińska et al., 2018). Furthermore, there is also increasing evidence regarding the harmful effects of transport noise on wildlife (Shannon et al., 2016). The effects of noise vary depending on the species, although, in general, noise interferes with animals' feeding, hunting and breeding behaviour.

> Noise remains a major cause of environment-related health problems in Europe.

The state of the knowledge presented in this chapter is based on data reported by the EEA 33 member countries excluding Turkey (EEA-33) in accordance with the Environmental Noise Directive (END) on a 5-year cycle (EU, 2002) and submitted up to 1 January 2019. The data cover noise sources such as roads, railways and airports, inside and outside urban areas as well as industry inside urban areas. The results presented in this chapter show the number of people exposed to noise levels of 55 dB or higher during the day-evening-night period, as well as to night-time noise levels of 50 dB or higher for the three rounds of noise mapping in 2007, 2012 and 2017 (see Box 11.1). Throughout the chapter, and according to the Seventh Environment Action Programme (7th EAP), those are referred to as 'high noise levels'. However, even levels below these thresholds have been found to have negative health effects (WHO, 2009, 2018). The impact of noise on health is assessed in terms of annoyance, sleep disturbance, cardiovascular effects, cognitive impairment in children, and annual premature deaths caused by heart disease.

Identifying and protecting areas undisturbed by environmental noise is also a requirement under the END. Therefore, a spatial assessment of noise exposure data combined with land use cover data for areas potentially unaffected by noise pollution in European

TABLE 11.1 Overview of selected policy objectives and targets

Policy objectives and targets	Sources	Target year	Agreement
Noise reduction			
Significantly reducing noise pollution in the EU moving closer to WHO recommended levels.	7th EAP (EU)	2020	Non-binding commitment
Implementing measures to reduce noise at source and including improvements in city design	7th EAP (EU)	2020	Non-binding commitment
Decreasing noise levels below the values specified in the WHO noise guidelines is strongly recommended	WHO (2018)	N/A	Non-binding commitment
Member States must prepare noise maps every 5 years to determine exposure to environmental noise from transport and industry sources. These noise maps serve as the basis for adopting action plans designed to prevent and reduce harmful exposure in areas affected by noise from roads, railways, airports and industry. The plans should also aim to protect quiet areas against an increase in noise	Directive 2002/49/EC	N/A	Legally-binding
Impacts on human health and well-being			
By 2030, reduce by one third premature mortality from non-communicable diseases through prevention and treatment and promote mental health and well-being	SDG 3	2030	Non-binding commitment

Note: SDG, Sustainable Development Goal; N/A, non-applicable.

cities is presented for 2012 and 2017. Quiet areas are not only beneficial for human health but are also consistent with the need to protect species vulnerable to noise and areas of valuable habitat.

11.2 Policy landscape

The EU 7th EAP (EU, 2013) recognises that a large number of people living in major urban areas are exposed to high levels of noise at which adverse health effects frequently occur. To address this environmental impact, it sets out the objective that by 2020 noise pollution in the EU needs to be significantly decreased, moving closer to WHO recommended levels. To meet this objective, the 7th EAP identified the need to implement an updated EU noise policy aligned with the latest scientific evidence as well as measures to reduce noise at source, including by improving urban design.

In the EU, the END is the primary legislative tool for achieving noise reduction. The Directive offers a common approach to avoiding and preventing exposure to environmental noise through the reporting of noise mapping and action planning, thereby reducing its harmful effects as well as preserving quiet areas (EU, 2002). Accompanying the END, there are a number of other legislative measures that aim to address or control noise at source, such as by imposing noise limits on certain vehicles or equipment or their components or by restricting their operation (EEA, 2014).

> Quiet areas are beneficial for human health and wildlife.

Table 11.1 presents an overview of selected policy targets and objectives on environmental noise addressed in this chapter.

Although, as shown in Box 11.2, health and well-being can be affected at levels below the END reporting thresholds, there is a significant lack of data on the number of people exposed to noise

BOX 11.1
EU noise indicators

The Environmental Noise Directive (END) defines two important noise indicators to be used for noise mapping and action planning:

L_{den}: Long-term average indicator designed to assess annoyance and defined by the END. It refers to an A-weighted average sound pressure level over all days, evenings and nights in a year with an evening weighting of 5 dB and a night weighting of 10 dB.

L_{night}: Long-term average indicator defined by the END and designed to assess sleep disturbance. It refers to an A-weighted annual average night period of exposure.

High noise levels are defined in the 7th EAP as noise levels above 55 dB L_{den} and 50 dB L_{night}. ■

BOX 11.2
The 2018 Environmental noise guidelines for the European region (WHO, 2018)

In 1999 and 2009 the World Health Organization (WHO) published guidelines to protect human health from exposure to community noise and night noise. Since then there has been a substantial increase in the number and quality of studies on environmental noise exposure and health outcomes. Following the Parma Declaration on Environment and Health, adopted at the Fifth Ministerial Conference (2010), the Ministers and representatives of Member States in the WHO European Region requested WHO to develop updated guidelines on environmental noise. To this end, WHO commissioned systematic reviews to assess the relationship between environmental noise and health outcomes such as cardiovascular and metabolic effects, annoyance, effects on sleep, cognitive impairment, hearing impairment and tinnitus, adverse birth outcomes, and quality of life, mental health and well-being. These reviews are the basis for the development of the recommended noise levels above which negative effects on health begin according to our best knowledge. ■

Reducing noise below these levels is recommended (WHO, 2018).

	Road	Rail	Aircraft
L_{den}	53 dB	54 dB	45 dB
L_{night}	45 dB	44 dB	40 dB

levels below 55 dB L_{den} and 50 dB L_{night}, as reporting at such levels is voluntary.

11.3
Key trends and outlooks

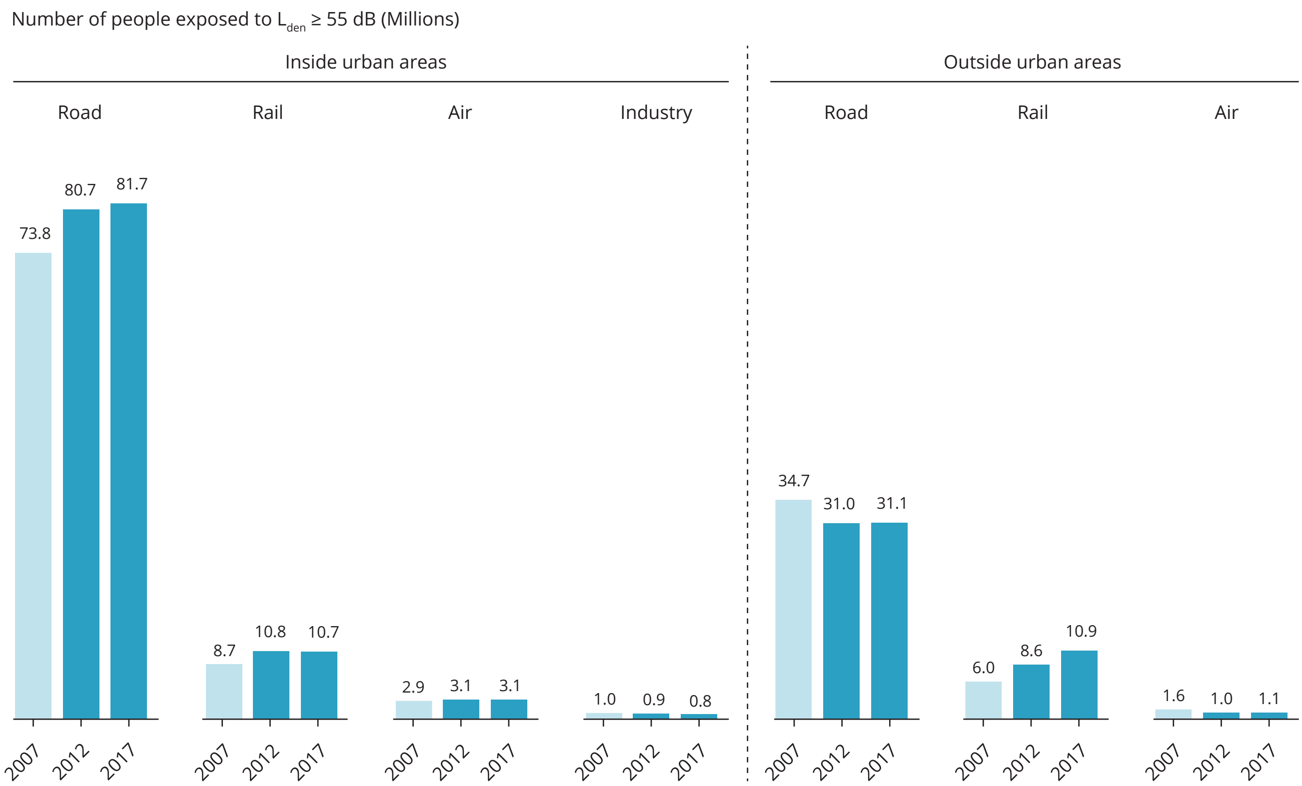
11.3.1
Population exposure to environmental noise and impacts on human health

► See Table 11.3

To support the implementation of the END (EU, 2002), the EEA gathers population exposure data from its 33 member countries (EEA-33). The current state of knowledge on noise sources and population exposure in Europe is largely based on this database. According to the latest data, the overall number of people exposed to day-evening-night average sound levels of 55 dB or higher is estimated to be 113 million for road traffic noise, 22 million for railway noise, 4 million for aircraft noise and less than 1 million for noise caused by industry. Similarly, road traffic is by far the biggest source of environmental noise during night-time, followed by railway, air and industrial noise, respectively. These results indicate that at least 20 % of Europeans are exposed to long-term average day-evening-night noise levels of 55 dB or more and more than 15 % to night-time noise levels of 50 dB or more — levels at which adverse health effects can occur (Figures 11.1, 11.2, 11.3).

Trends between 2012 and 2017 suggest that the number of people exposed to levels considered harmful to human health has generally remained stable across most of the noise sources, with the exception of railway noise outside urban areas for which there was a significant increase of 27 %. Efforts to reduce exposure to noise from individual sources may be being offset by continuing migration to urban areas, which implies a growth in population, activity and traffic. Increased demand for passenger and goods transport across cities, regions and countries can also negatively influence efforts to reduce the number of people exposed to high noise levels. There are regulations related to noise action plans that have come into force recently but that have not yet clearly reduced the reported number of people exposed to noise. This is the case, for example, for Regulation 598/2014 on noise

FIGURE 11.1 **Number of people exposed to L_{den} ≥ 55 dB in Europe, based on areas covered by strategic noise maps, EEA-33 (Turkey not included)**



Note: There are comparability issues between 2007 and the other reporting years because of different reporting requirements. There may be comparability issues between 2012 and 2017 because of a lack of common assessment methods or incomplete reporting of exposure assessments. Due to gaps in the reported data, a gap-filling procedure was used to estimate the number of people exposed to high noise levels in 2012 and 2017, introducing a degree of uncertainty into the assessment.

Source: EEA (2019a).

20 %

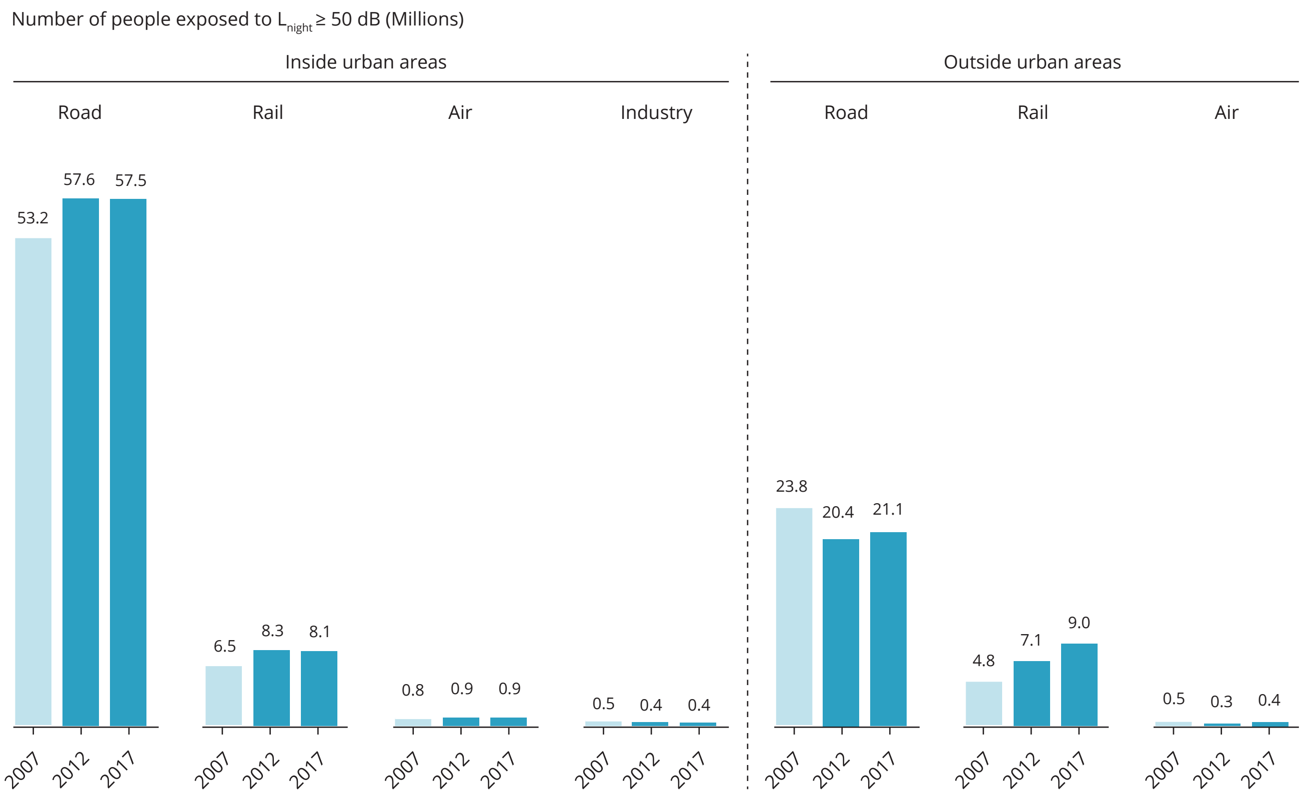
of the EU's population lives in areas where noise levels are considered harmful to human health and well-being.

management at airports, which calls for cutting noise levels by deploying modern aircraft, careful land use planning, quieter ground control operations and restrictions on night-time flying (EU, 2014).

This assessment (2012-2017) takes into account gap-filled data from urban areas with more than 100 000 inhabitants as well as major roads with more than 3 million vehicles per year, railways with more than 30 000 trains per year and airports with more than 50 000 movements per year. The data shown for 2007 have to be treated with caution, as the reporting requirements for urban areas, major roads and railways in 2007 were different from those in 2012 and 2017. The 2007 data refer to noise in urban areas with more than 250 000 inhabitants, major roads with more than 6 million vehicles a year and railways with more than 60 000 trains a year. Therefore, the results from 2007 are not fully comparable to those from 2012 and 2017.

As shown in Figure 11.3, there is a considerable variability in the percentage of the population

FIGURE 11.2 Number of people exposed to L_{night} ≥ 50 dB in Europe, based on areas covered by strategic noise maps, EEA-33 (Turkey not included)



Note: There are comparability issues between 2007 and the other reporting years because of different reporting requirements. There may be comparability issues between 2012 and 2017 because of a lack of common assessment methods or incomplete reporting of exposure assessments. Due to gaps in the reported data, a gap-filling procedure was used to estimate the number of people exposed to high noise levels in 2012 and 2017, introducing a degree of uncertainty into the assessment.

Source: EEA (2019a).

exposed to high noise levels within individual countries — from 9 % of the population exposed to road traffic noise in Slovakia to 54 % in Cyprus. The variability between countries may be due to several factors. One of them is the way in which countries define agglomerations. The END states that data need to be reported for all agglomerations with a population in excess of 100 000 and a population density such that the Member State considers them urbanised areas. Therefore, it depends how countries define density and how they delimit agglomerations in their territories. For instance, Switzerland may have a high percentage of people exposed to road noise inside urban areas, as it reports 13 agglomerations according to its own agglomeration criteria. Conversely, countries with a similar population such as Portugal or Norway report six and five agglomerations, respectively. Another reason may be the density of transport networks in the country. For instance, in the central part of Europe (e.g. Austria, Belgium, France, Germany, Luxembourg and Switzerland), where the railway network is denser and well

Road traffic is the main source of noise with about 113 million people affected by daily average noise levels of 55dB or higher.

FIGURE 11.3 **Country comparison — percentage of the total country population exposed to L_{den} ≥ 55 dB in 2017, EEA-33 (Turkey not included)**

					Outside urban areas		
	Road	Rail	Air	Industry	Road	Rail	Air
Austria	24.2	6.6	0.1	0.1	8.2	5.7	0.1
Belgium	14.0*	1.0*	0.6*	0.2*	8.6	2.2	0.6*
Bulgaria	28.8*	0.6*	0.1*	0.0*	1.5		
Croatia	7.7	0.6	0.0	0.0	2.8	0.0	
Cyprus	49.2*	3.2*	0.9*	1.0*	4.7*		
Czechia	16.7	0.7	0.1	0.0	6.9	1.8	0.1
Denmark	18.5	0.5*	0.1*	0.0*	5.0	1.5	0.0*
Estonia	22.7	0.5	0.2	0.5	0.5		
Finland	8.8	1.6	0.1*	0.0*	2.1	0.6	0.4
France	23.5*	3.6*	0.7*	0.2*	9.8	3.9	0.0*
Germany	6.9*	3.7	0.7	0.1*	3.3	4.0	0.4
Greece	7.9*	1.3*	0.4*	0.1*	0.2*	0.0*	0.0*
Hungary	16.4	1.3	0.0	0.0	1.8	0.9	0.3
Iceland	16.6		0.5*	0.2			0.5
Ireland	14.4	0.6	0.6		4.8	0.3	0.0
Italy	13.7*	0.9*	0.7*	0.1*	12.0*	3.3	0.3*
Latvia	27.0	2.0	0.0	0.7	1.2	0.1	0.1
Liechtenstein					11.4*		
Lithuania	26.3	0.4	0.4	0.3	0.8	0.0	
Luxembourg	24.5	1.5	10.1	0.0	11.2	3.3	1.1
Malta	22.4		1.9	0.0	3.7		
Netherlands	19.3	1.3	0.4	0.3	1.0	0.5	0.0
Norway	15.2*	2.2*	0.2*	0.0*	2.6*	0.2	0.1*
Poland	11.6	0.6*	0.1	0.1*	5.7	0.5	0.0
Portugal	5.2	0.4	0.9	0.0	8.6*	1.0	1.3
Romania	13.3*	1.5*	0.2*	1.2*	1.6*	0.1*	0.0*
Slovakia	6.7*	2.4*	0.0*	0.0*	2.9*	2.0*	
Slovenia	9.8	1.2		0.0	5.5	1.1	
Spain	24.8*	1.1*	0.2*	0.2*	4.2*	0.7*	0.3
Sweden	12.3	2.9	0.2*	0.0	3.3	2.7	0.2
Switzerland	30.6	3.4	1.1	0.2*	5.1	2.4	0.0
United Kingdom	14.5	1.9	1.5	0.2	6.5	0.7	0.2*

* Data totally or partially estimated

0 Percentage of the population exposed to high noise levels (L_{den}) 50

Note: Based on areas covered by the END.

Sources: EEA (2019b); ETC/ATNI (2019b).

TABLE 11.2 Estimated number of people suffering from various health outcomes due to environmental noise in 2017, EEA-33 (Turkey not included)

	High annoyance	High sleep disturbance	Ischemic heart disease	Premature mortality	Cognitive impairment in children
Inside urban areas					
Road	12 525 000	3 242 400	29 500	7 600	
Rail	1 694 700	795 500	3 100	800	
Air	848 300	168 500	700	200	9 500
Industry	87 200	23 400	200	50	
Outside urban areas					
Road	4 625 500	1 201 000	10 900	2 500	
Rail	1 802 400	962 900	3 400	900	
Air	285 400	82 900	200	50	2 900

Note: Premature mortality calculated as premature mortality due to ischaemic heart disease.

Source: EEA (2019a).

developed, a higher percentage of people are exposed to railway noise outside urban areas than in other countries.

Exposure to environmental noise is associated with an increased risk of negative physiological and psychological health outcomes. Widespread exposure to noise from transport (road traffic, railway and aircraft) is of major concern, affecting the health and well-being of millions of people in Europe. In particular, long-term exposure to environmental noise can lead to a number of adverse health outcomes such as annoyance, sleep disturbance, negative effects on the cardiovascular and metabolic systems, and cognitive impairment in children. Sleep disturbance and annoyance, mostly related to road traffic noise, are the most prevalent effects (Jarosińska et al., 2018).

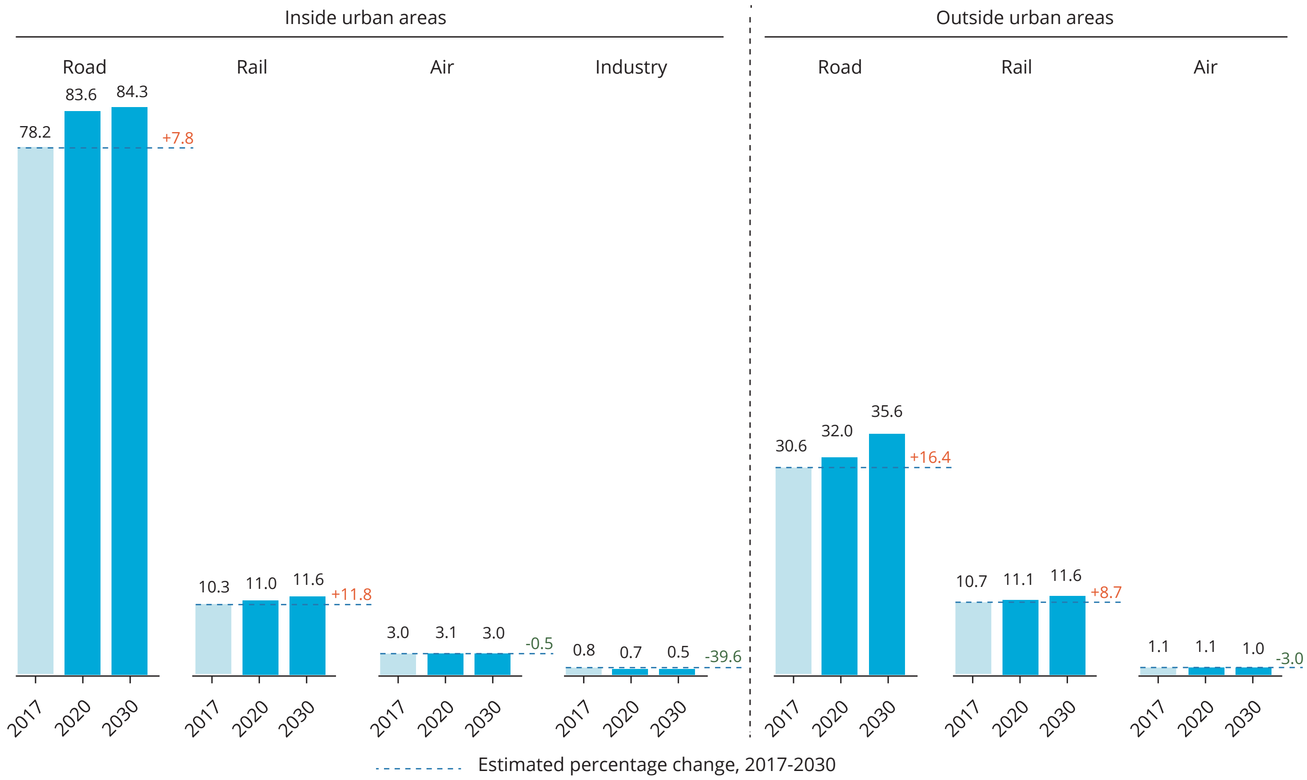
Based on the latest health impact assessment of the 2017 round of noise mapping (EEA, 2019a), around 22 million adults living in agglomerations or near major sources with noise levels of 55 dB L_{den} or more are estimated to be highly annoyed by noise from road traffic, railways, aircraft and industry. Moreover, it is estimated that 6.5 million adults suffer high sleep disturbance due to night-time noise levels of 50 dB L_{night} or more. Exposure to environmental noise from road traffic, railways, aircraft and industry contributes every year to about 48 000 new cases of ischaemic heart disease, and 12 000 premature deaths (Table 11.2). Aircraft noise has also been associated with a decrease in children's cognitive performance in schools that are affected by flight paths. As a result, it is estimated that around 12 500 children in Europe aged 7-17 years old have a reading impairment as a result of exposure to aircraft noise.

48 000 new cases of heart disease and 12 000 premature deaths are estimated to occur annually due to long-term exposure to noise pollution.

In terms of the individual noise sources, road traffic noise, as the most prevalent source of environmental noise, not surprisingly has the largest contribution to the burden of disease due to noise (75 %) followed by railways (20 %), aircraft (4 %) and industry (0.5 %). The major part of the burden of disease, including annoyance, sleep disturbance, heart disease and cognitive impairment due to noise, occurs inside urban areas of more than 100 000 inhabitants (EEA, 2019a).

FIGURE 11.4 Outlook for 2020 and 2030, EU-28

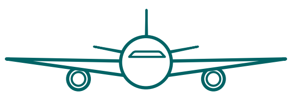
Number of people exposed to L_{den} ≥ 55 dB (millions) and estimated percentage change, 2017-2030



Source: ETC/ATNI (2019a).

Instead of just assessing the number of premature deaths, the WHO (2011) developed methods to quantify the burden of disease from environmental noise using disability-adjusted life-years (DALYs), which combine years of life lost due to premature mortality and years of life lost due to time lived in any state of less than full health. The DALYs lost due to noise-induced health outcomes were estimated to be equivalent to 437 000 years for sleep disturbance, 453 000 years for annoyance, 156 000 years for cardiovascular heart disease and 75 years for cognitive impairment in children (EEA, 2019a).

However, the effects presented here may be underestimated, as new scientific evidence (see Box 11.1) shows that health and well-being can be affected at lower noise levels than those specified under the END (WHO, 2018). Currently, there is a lack of data on the number of people exposed below 55 dB L_{den} and 50 dB L_{night}, meaning that the health impact of noise is likely to be greater than that presented in this assessment. Moreover, END data do not cover the full territory within countries, and therefore there are people affected by noise that are not accounted for in the estimations presented. Although not recently quantified, the associated loss to the population's health due to noise has an economic impact in Europe. Monetary costs can also be related to reduced house prices, loss of working days and reduced potential to develop land for certain uses (EC, 2000).



12 500 school children may suffer learning impairment due to aircraft noise.

Noise outlooks for 2020 and 2030 have been projected using current information on transport and urban trends (ETC/ATNI, 2019a) and have considerable uncertainty, as they are based primarily on forecast increases in traffic and on various policy objectives.

The outlook shows that it is unlikely that noise pollution will decrease significantly

TABLE 11.3 Summary assessment — population exposure to environmental noise and impacts on human health

Past trends and outlook		
Past trends (10-15 years)		The overall number of people exposed to high levels of noise remained rather stable between 2012 and 2017, with the exception of railway noise outside urban areas for which a significant increase occurred. More than one fifth of the population is exposed to high levels of noise likely to have adverse effects on health. Noise remains a major environmental health problem in Europe, causing around 12 000 premature deaths each year.
Outlook to 2030		By 2030, projected estimates show an increase in the number of people affected by noise from the most prevalent sources (e.g. road and rail). Exposure to air traffic noise is projected to remain relatively stable.
Prospects of meeting policy objectives/targets		
2020	☒	Europe is not on track to meet the Seventh Environment Action Programme objective of significantly reducing noise pollution by 2020. Efforts to reduce noise are being offset by an increase in the numbers of people living in urban areas and increases in traffic. Effective action plans to manage and reduce noise are needed.
Robustness		The assessment is based on reported and gap-filled noise data from the 33 EEA member countries. The data in this report are based on a data set for 2012 that is approximately 92 % complete and a data set for 2017 that is 66 % complete. A gap-filling exercise was carried out to complete the noise data that were not reported. This introduces some uncertainties into the assessment. There are also some comparability issues between the first and the subsequent rounds of noise mapping due to the use of different assessment methods. The health impacts are calculated using the World Health Organization 2018 Environmental noise guidelines for the European region. The outlook depends on predictions of traffic growth and future policy objectives, and therefore there are considerable uncertainties.

by 2020, given that road and rail and air transport traffic is forecast to increase, as is the number of inhabitants living in urban areas. As a result, it is likely that the health impacts of environmental noise will be more widespread by 2020 (Figure 11.4).

In the longer term, even if targets for switching to electric vehicles in cities are met, as outlined in the White Paper, *Roadmap to a single European transport area: towards a competitive and resource efficient transport system* (EC, 2011), the number of people exposed to road traffic noise inside urban areas is still set to increase by approximately 8 % in the period 2017-2030. If the objective of halving conventionally fuelled cars in urban areas by 2030 is not achieved, a higher increase can be expected.

Noise outside urban areas will increase by 2030, in particular for road and rail traffic, due to an anticipated increase in the number of passenger and freight road and rail vehicles. Although railway noise inside and outside urban areas presents a considerable increase in terms of number of people exposed (i.e. 12 % and 9 %, respectively), this scenario already takes into account measures to be taken on silent brake retrofitting of freight trains (ERA, 2018).

Europe is not on track to meet the 7th EAP objective of significantly reducing noise pollution by 2020.

Aviation noise will stabilise only if all the anticipated technology improvements stated in the *European aviation environmental report* are met by 2030. Even if the number of flight movements is expected to increase, improvements in aircraft design could stabilise but not significantly reduce overall noise exposure by 2030 (EASA et al., 2016). The noise contribution from industry inside urban areas is projected to decrease. However, the number of people estimated to be exposed to industrial noise is already very small, and overall the number of people impacted by this reduction is very low.

BOX 11.3
Effects of noise on wildlife

Although the focus of the Environmental Noise Directive is on reducing the harmful effects of noise on human health, noise also affects wildlife. Whether in the terrestrial or the marine environment, many species rely on acoustic communication for important aspects of life, such as finding food or locating a mate. Anthropogenic noise can potentially interfere with these functions and thus adversely affect diversity of species, population size and population distribution.

One of the most studied effects of anthropogenic noise on wildlife is its impact on the singing behaviour of birds (Gil and Brumm, 2013). A study in the forest near Tegel airport in the city of Berlin found that some songbird species started their dawn song earlier than the same species singing in a nearby forest that was less affected by aircraft noise (Dominoni et al., 2016). The authors of the study concluded that the birds in the vicinity of the airport started singing earlier in the morning to gain more time for uninterrupted singing before the aircraft noise set in. In addition, it was found that during the day, chaffinches avoided singing during aircraft take-off when the noise exceeded a certain threshold, 78 dB(A), further suggesting that airport noise can impair acoustic communication in birds. ■

11.3.2
Preservation of quiet areas

► See Table 11.4

Noise pollution comes from a variety of sources and is widely present not only in the busiest urban environments but also in natural environments. The END recognises the need to preserve areas of good acoustic environmental quality, referred as 'quiet areas', to protect the European soundscape. Quiet areas offer reduced sound levels from traffic and provide a respite from environmental stress and opportunities for rest and relaxation. Apart from the physical and mental health benefits for humans, quiet areas are also important for animals (Box 11.3).

Although the data reported as part of the END currently contain little information on how the countries, regions and cities define and protect quiet areas in their territories, there are indications showing an improvement in the definition and designation of quiet areas in recent years (EC, 2017; Peris et al., 2019). Most countries have criteria in place to define quiet areas, mainly in urban areas. Quiet areas in cities vary in their characteristics, such as noise levels, size of the area and land cover type. However, to date not all of the countries that have a definition of quiet areas in place have designated such areas. Currently, there are at least 15 countries that have designated some quiet areas in their territories (ETC/ATNI, 2019c).

There are currently no data on whether quiet areas in Europe have increased or decreased. However, considering their beneficial health effects, it is important to identify potential quiet areas in places with high population density (Shepherd et al., 2013). A combined spatial assessment of noise exposure, land use and land cover data for areas potentially unaffected by noise pollution in selected cities from the EEA-33 shows a mixed picture (ETC/ATNI, 2019c). While some cities, such as Aalborg, Aarhus,

Quiet areas protect wildlife and human health but their designation and protection are still under development in Europe.

Cork, Dublin, Hamburg, Lausanne, Munich and Zurich experienced a significant increase in areas considered to be potentially 'quiet', others, such as Vilnius, Valletta, Prague, Copenhagen, Cologne or Dusseldorf, experienced a loss of quiet areas (Figure 11.5). The increase in quiet areas was mainly in residential areas while the loss was due to a decrease in green and 'blue' space. Although the reason for these results is not known, local noise action plans, nature conservation plans and measures related to urban planning can have an effect on gains or losses of quiet areas in urban settings. However, a change in the modelling methodologies used for traffic could also lead to changes that are not strictly related to an increase or decrease in noise.

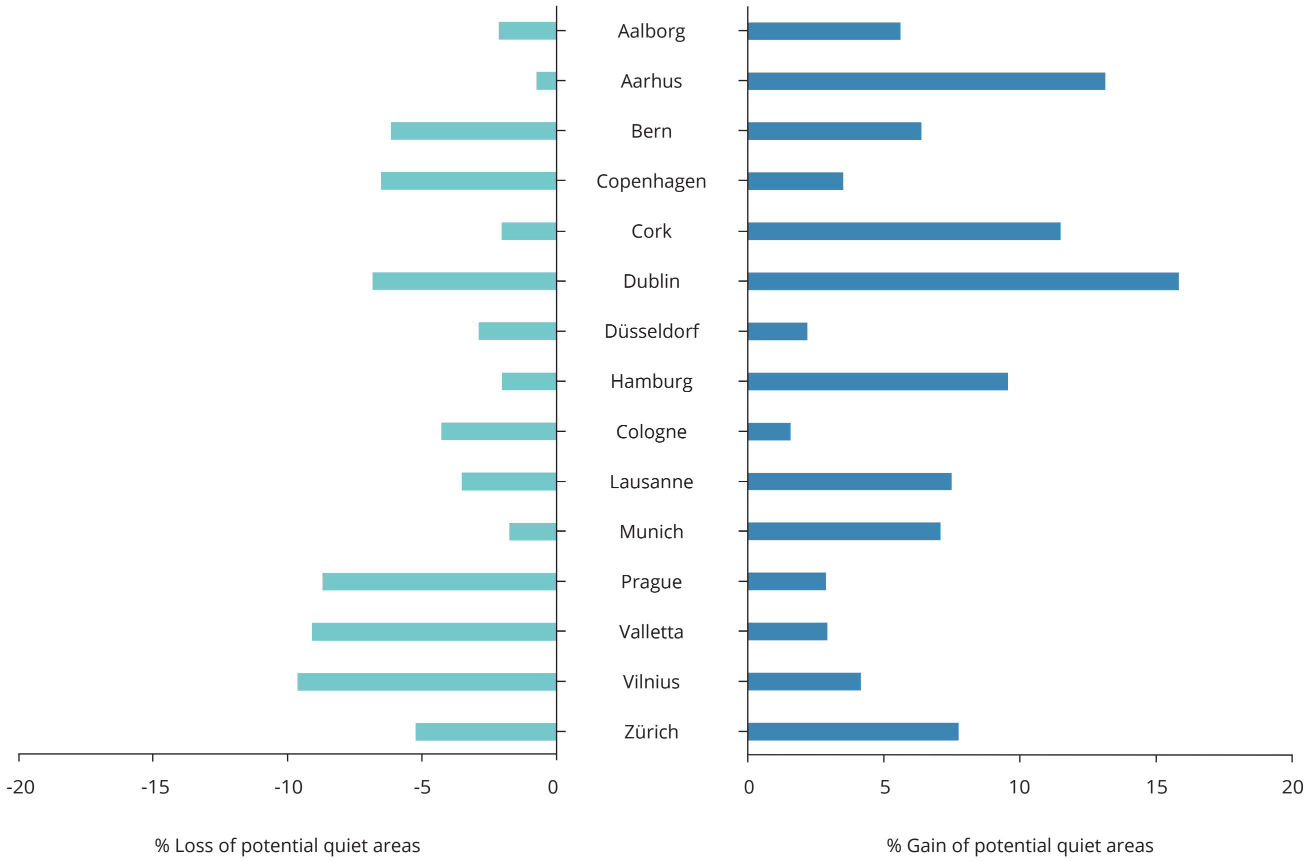
11.4
Responses and prospects of meeting agreed targets and objectives

11.4.1
Assessment of policies, and prospects for reaching policy targets and objectives

Population exposure to environmental noise and impact on human health

Despite the substantial progress since the END introduced data mapping and development of noise action plans, the Directive remains not fully implemented. For example, noise exposure data from the 2012 and 2017 rounds of noise

FIGURE 11.5 Change in quiet areas between 2012 and 2017 in selected cities



Note: The city selection was based on the availability of noise data for 2012 and 2017 for all sources. There may be comparability issues between cities due to a lack of a common assessment method.

Source: ETC/ATNI (2019c).

TABLE 11.4 Summary assessment — preservation of quiet areas

Past trends and outlook		
Past trends (10-15 years)	(yellow)	Progress has been made in developing definitions of quiet areas as well as in defining selection criteria for designating them. However, the designation and protection of quiet areas is underdeveloped. There is variability between cities in terms of gains and losses of potentially quiet areas.
Outlook to 2030	(yellow)	Further progress is expected as current legislation, which obliges countries to protect areas of good acoustic quality, is likely to increase the number of action plans designated to protect quiet areas.
Prospects of meeting policy objectives/targets		
2020	☒	The designation and protection of quiet areas in Europe is still under development. There is not a complete designation of quiet areas in countries, and areas identified as quiet are not always protected through action plans.
Robustness		This assessment is based on both data reported by EEA member countries, using a questionnaire on the status of the definition, designation and protection of quiet areas, and on an analysis of land cover data and noise data in urban areas in selected cities for which data are available.

mapping are still incomplete, with only approximately 92 % and 66 %, respectively, of the expected data having been reported. In the 2007, 2012 and 2017 rounds of noise mapping, there was no common method for mapping in place. Therefore, countries may have used different assessment methods across the years. These inconsistencies in the quality and quantity of reported data make the noise situation across Europe difficult to assess. However, there are prospects for improvement. The EU has developed a common method for noise mapping (EC, 2019). As a result, it is expected that noise mapping assessments will be harmonised, making it easier to compare data across countries.

A considerable number of people are still exposed to high noise levels. Despite the efforts to achieve a significant reduction in noise pollution, through the implementation of the END and other EU noise-related regulations, the overall number of people exposed to high levels of noise remained rather stable between 2012 and 2017. Therefore, the objective of the 7th EAP — to significantly reduce noise pollution in the EU and move closer to WHO recommended levels by 2020 — will not be achieved. What is more, in the light of projections of urban growth in Europe and an increased demand for transport, an increase in the population exposed to environmental noise is anticipated by 2020. Similarly, the longer term outlook is not encouraging. For example, even if the objectives outlined in the 2011 White Paper, *Roadmap to a single European transport area: towards a competitive and resource efficient transport system*, of halving conventionally fuelled cars in urban areas by 2030 are achieved, the number of people exposed to road noise, the most prevalent source, is set to increase. Likewise, it is likely that noise outside urban areas will increase by 2030, in particular for road and rail traffic, due to an increase in the number of passenger and freight road and rail vehicles. Aviation noise will be stabilised only if the anticipated technology improvements stated in the *European aviation environmental report* (EASA et al., 2016) are met by 2030.

Achieving the 7th EAP objectives of reducing the impacts of noise on people would have required more effective development and implementation of noise action plans in areas of concern. Although action plans in accordance with the END should have been drawn up for the major transport sources and the largest urban areas, there is a large proportion of countries for which such plans are missing (EC, 2019). The 7th EAP states that noise reduction should be achieved by implementing measures to reduce noise at the source, including improvements in urban design (Box 11.4). Data on action plans submitted by countries under the END show that noise reduction at the source (e.g. improving road and rail surfaces, air traffic management, reducing speed limits, retrofitting, managing traffic flows) is an extensively reported mitigation measure for all sources of noise inside and outside urban areas (EEA, 2017). Land use and urban planning, which are linked to city design (e.g. protecting sensitive receivers using street design and providing quiet zones) are also reported for all noise sources but represent a small percentage of the mitigation measures generally chosen to address noise problems. Other less cost-effective mitigation measures employed to manage noise are those related to the path of the noise, such as introducing noise barriers, or those related to the receiver, such as providing home insulation.

The implementation of such action plans by countries has proven to be cost-effective. The fitness check on the implementation of the END concluded that the Directive has not yet achieved its full potential, although estimations show a favourable cost-benefit ratio of 1:29 (EC, 2017). In other words, in cases in which action plans including measures for noise management have been adopted, the benefits have outweighed the costs. However, in the 2017 evaluation of the END, the completeness of action plans was low, with less than 50 % of required action plans completed for the second round of noise mapping in 2012 (EC, 2017).

It is yet to be seen how national and local authorities will respond to the recent introduction of the *Environmental noise guidelines for the European region* (WHO, 2018), which show that levels below 55 dB L_{den} and 50 dB L_{night} are likely to cause health problems. At the moment, noise reporting and delivering action plans to combat noise levels below the aforementioned END thresholds remains voluntary for countries. National and local noise action plans targeted at levels lower than those outlined in the END could potentially lead to reduced environmental noise levels and subsequent benefits for health.

Preservation of quiet areas

There is a need to preserve areas of good acoustic quality, namely quiet or tranquil areas. Noise policy objectives specified in the 7th EAP can only be achieved if measures are taken to reduce exposure to high noise levels, which also implies preserving areas that are currently undisturbed by noise. If areas of good sound quality are neglected or ignored, more people may become exposed to noise. Likewise, the number of potentially restorative spaces, including parks or quiet urban quarters, could also decrease, resulting in a negative impact on well-being.

Regarding the END, action plans that aim to identify and protect quiet areas within the strategic noise mapping process enable competent authorities to control the sound quality within them. However, the END does not provide a clear definition of quiet areas, leaving countries ample opportunity for interpretation. Therefore, practical

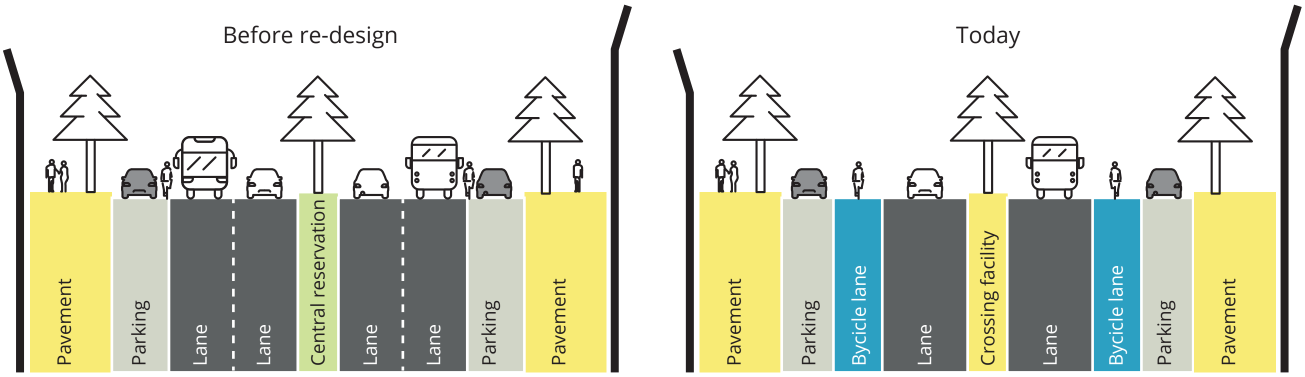
BOX 11.4 Implementation of noise action plans in Berlin: a success story

The use of the noise maps in accordance with the Environmental Noise Directive (END) helped many cities in Europe detect high noise zones. Berlin, like many other urban areas, is affected by noise pollution, in particular from road traffic.

During the first round of noise mapping in 2007, Berlin found that a considerable number of people were exposed to night-time noise levels considered harmful to health. As a result of these data, and in line with the END, noise action plans were implemented. The mitigation measures consisted of reducing or narrowing the roadway to decrease the traffic levels and concentrate traffic in the middle of the roadway, moving it away from buildings. The traffic area released by this measure provided space for bicycle lanes and pedestrian islands (Figure 11.6). Pilot projects were implemented in four main road sections used by approximately 20 000 motor vehicles per day.

Implementing noise reduction measures by redesigning roadways helped to significantly reduce the number of people exposed to night-time noise levels of 50 dB or higher (Table 11.5). ■

FIGURE 11.6 Redesign of roadways in Berlin to reduce traffic noise: before and after



Source: Senate Department of Berlin/LK Argus GmbH.

TABLE 11.5 Night-time noise levels in Berlin, 2007 and 2012

Number of people	L_{night} dB(A)				
	>50-55	>55-60	>60-65	>65-70	>70
2007	183 000	146 000	135 300	56 300	1 400
2012	168 200	150 100	121 600	24 300	300

guidance in this area needs to be further developed (EC, 2017) to allow countries to fully integrate the protection of quiet areas into their action plans. Countries have indicated that this is an area under development, and so an increase in measures to protect quiet areas may be expected in the future (ETC/ATNI, 2019c). Areas of good acoustic quality can be preserved by implementing measures similar to those used to reduce noise. Moreover, given that a quiet area can also be one with a pleasant soundscape, in cities quiet areas could also be protected by enhancing positive sounds such as those from natural features (Matsinos et al., 2017) (Chapter 17).

12.

Industrial pollution

Key messages

- Industry contributes significantly to the emissions of many pollutants and greenhouse gases into the European environment. Releases of pollutants by European industry have generally decreased during the last decade and are expected to continue to do so.

- Environmental policy has been the main driver of reductions in industrial emissions in the past decade, especially for emissions to air for which the reductions are larger than those for emissions to water.

- However only emissions of historically important pollutants are reported by industry, and information on emerging pollutants is lacking. A lack of robust data does not allow assessment of progress towards overall clean production processes.

- The impacts and costs of pollution from industry to the environment and human health remain high. Existing policy instruments are expected to lead to further reductions in industrial emissions but current policies do not address the full scope of the industrial pollution load to the environment.

- Decarbonisation of industry stimulated by climate change mitigation policies is expected to be the main driver of reductions in industrial air pollutant and greenhouse gas emissions in the medium and long term. However there is clear scope for further integration of environmental objectives into the EU's industrial policy.

Thematic summary assessment

Theme	Past trends and outlook		Prospects of meeting policy objectives/targets
	Past trends (10-15 years)	Outlook to 2030	2020
Pollutant emissions from industry	Improving trends dominate	Developments show a mixed picture	☐ Partly on track
Clean industrial technologies and processes	Improving trends dominate	Developments show a mixed picture	☐ Partly on track

Note: For the methodology of the summary assessment table, see the introduction to Part 2. The justification for the colour coding is explained in Section 12.3, Key trends and outlooks (Tables 12.2 and 12.4).

12. Industrial pollution

12.1 Scope of the theme

Industry is a key component of Europe's economy and plays a significant role in society's economic well-being. It accounts for 17.6 % of gross domestic product (GDP) (Eurostat, 2018b) and directly employs 36 million people (Eurostat, 2018a) in the 28 EU Member States (EU-28). At the same time, industrial activities are a source of pressure on the environment in the form of emissions to the atmosphere and water ecosystems, generating waste and consuming resources. This chapter assesses the trends in and outlooks for these pressures as well as the progress towards implementing clean industrial technologies and processes.

This assessment addresses the energy supply, extractive and manufacturing industry sectors as well as waste and waste water management. Please refer to the EEA's recent work on mapping emission inventories for more details (EEA, 2018b). Here, the extractive and manufacturing sectors are grouped into heavy industry (ferrous and non-ferrous metal processing, extractive industry) and light industry (food and drink, pulp, paper and wood, other manufacturing).

Industry contributes significantly to pollutant emissions into Europe's environment.

The European Pollutant Release and Transfer Register (E-PRTR) (EEA, 2019h) is the main data source for this chapter. It is supplemented by the Large Combustion Plant (LCP) inventory (EEA, 2018c), the data reported under the Convention on Long-Range Transboundary Air Pollution (CLRTAP) (EEA, 2019f), and the Greenhouse Gas (GHG) inventory (EEA, 2019g), reported under the European Monitoring Mechanism Regulation (MMR; EU/ 525/2013).

The assessment covers a range of key industrial air pollutants and GHGs, namely those reported to the E-PRTR between 2007 and 2011 by at least 5 % of all the facilities in each industrial sector (see Section 12.3.1 and Figure 12.3). Emissions of GHGs contribute to climate change (Chapter 7), while air pollutants have various health and environmental impacts (Chapter 8).

All reported substances released to water are taken into account rather than choosing specific key pollutants (see Section 12.3.1 and Figure 12.5). The various pollutants in the overarching pollutant groups can have a variety of impacts (Chapters 4 and 6). Persistent and mobile substances that cannot be removed by waste water treatment plants are covered in more detail in Chapter 10.

More details on sources as well as the potential health and environmental

TABLE 12.1 Selected policy objectives and targets

Policy objectives and targets	Sources	Target year	Agreement
Industrial Pollution			
'…to prevent or, where that is not practicable, to reduce emissions into air, water and land and to prevent the generation of waste, in order to achieve a high level of protection of the environment taken as a whole'	IED (EU, 2010)	Permanent	Binding legislation
'By 2020, […] significantly reduce [the release of chemicals] to air, water and soil in order to minimize their adverse impacts on human health and the environment'	SDG 12.4 (UN, 2015)	2020	Non-binding commitment
'By 2030, upgrade infrastructure and retrofit industries to make them sustainable, with increased resource-use efficiency and greater adoption of clean and environmentally sound technologies and industrial processes…'	SDG 9.4 (UN, 2015)	2030	Non-binding commitment
'…uptake by industry of best available techniques and emerging innovations…'	7th EAP (EC, 2013)	2020	Non-binding commitment
Increase resource efficiency of industry	IED (EU, 2010)	N/A	Non-binding commitment

Note: 7th EAP, Seventh Environment Action Programme; N/A, non-applicable.

impacts of the pollutants covered are also available on the E-PRTR website ([1]).

Not all pollutants released into the environment by industry are monitored or reported, which limits the scope of this chapter. For example, more than 22 600 chemical substances are registered for use under the Regulation on registration, evaluation, authorisation and restriction of chemicals (REACH Regulation; (EC) No 1907/2006; ECHA, 2019), while the European industrial policy requires regular emission reporting of only 91 specific pollutants. REACH and other legislation governing the use and placing on the market of chemicals are addressed elsewhere (Chapter 10). Likewise, the resource efficiency of industry is assessed in detail in Chapter 9. In addition, the EEA indicator 'Industrial waste in Europe' provides additional information (EEA, 2019d). Industrial pollutant releases to land (see Chapter 5) and the resulting soil contamination, industrial waste (see Chapter 9) and industrial accidents are not covered in this chapter either.

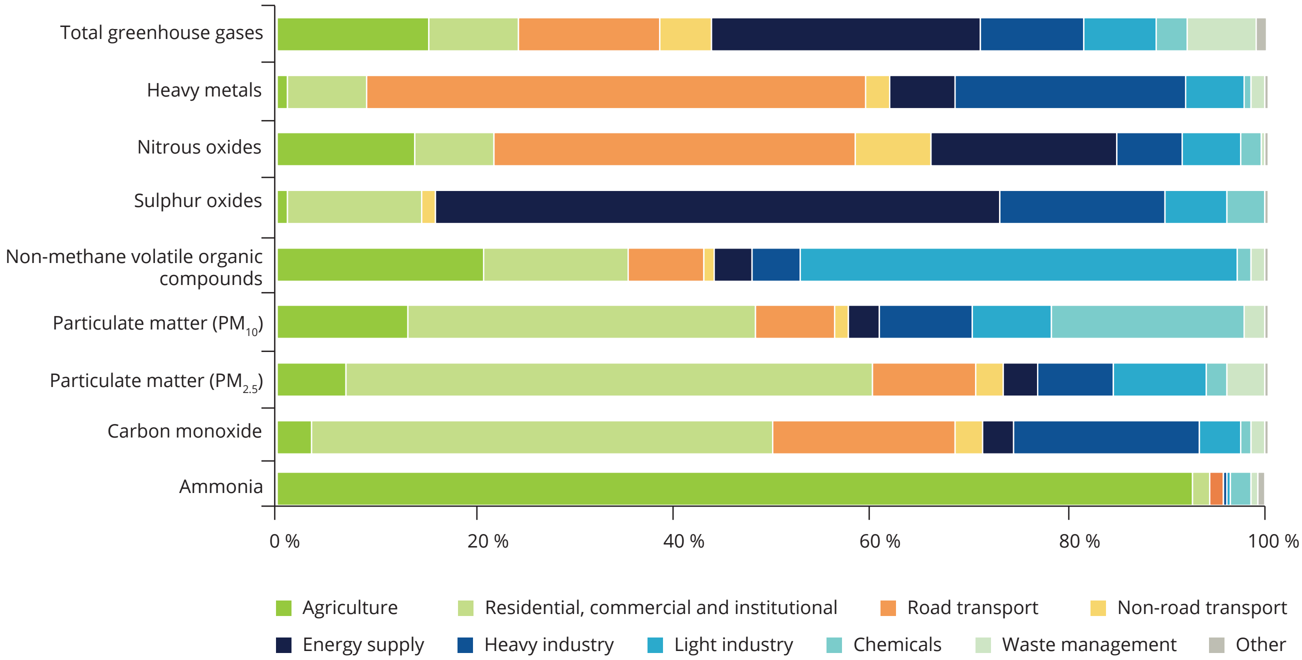
12.2 Policy landscape

Regulation of industrial pollution in the EU started in the 1970s, addressing especially transboundary air pollution and aiming to ensure a level playing field in the EU internal market (Hey, 2005). Even at that time, European industrial pollution policy was in many ways designed to support objectives established in other policy themes. Today, examples of this include:

- national pollutant emission ceilings established by the National Emission Ceiling (NEC) Directive (2016/2284/EU; Chapter 8);
- the binding commitment to achieve good ecological and chemical status of all water bodies in Europe in accordance with the Water Framework Directive (WFD, 2000/60/EC) as well as the requirement to treat urban waste water under the Urban Waste Water Treatment Directive (UWWTD; 91/271/EEC; Chapter 4);
- climate change mitigation policy objectives and targets, for example in the EU 2020 climate and energy package (EC, 2009), the EU 2030 climate

([1]) https://prtr.eea.europa.eu/#/home

FIGURE 12.1 **Air pollutant and greenhouse gas emissions as a percentage of total EEA-33 pollutant emissions in 2017, by sector**



Notes: Heavy metals include arsenic, cadmium, chromium, copper, lead, mercury and zinc and are aggregated by mass. Only those air pollutants covered by the CLRTAP are included.

Sources: EEA (2019g) for total GHGs and EEA (2019f) for air pollutants.

and energy framework (EC, 2014) or the European Commission long-term strategy for a climate neutral economy (EC, 2018) (Chapter 7);

- the policy framework provided by the EU circular economy action plan (EC, 2015), which also relies on sectoral policies to achieve widespread implementation (Chapter 9).

The Industrial Emissions Directive (IED; 2010/75/EU) contributes towards achieving many of these and other policy objectives and forms the centrepiece of industrial pollution policy. The IED is designed to take the entire environmental performance of industrial installations into account and introduces a mechanism that identifies the most cost-effective means of achieving emission reductions for a host of different industrial activities (so-called best available techniques; see also Section 12.3.2). In order to monitor progress regarding industrial pollutant emissions and to give the public access to these environmental data, the EU established the E-PRTR via the E-PRTR Regulation (EC) No 166/2006). The IED to-date does not cover all industrial activities such as mining and quarrying (which is covered by the E-PRTR).

Table 12.1 summarises the most important policy objectives and targets that relate specifically to industrial pollution. The EU's overarching industry policy, which covers everything from access to markets, competitiveness and cybersecurity to circularity and the low-carbon economy is also of relevance (EC, 2017). The United Nations Sustainable Development Goals (SDGs; UN, 2015) also address industrial pollution, for example via SDG target 9.4 and 12.4.

Greenhouse gas emissions from industry on the other hand are addressed separately by the EU emissions trading system (EU ETS; Directive 2003/87/EC) (see Chapter 7).

12.3 Key trends and outlooks

12.3.1 Pollutant emissions from industry

► See Table 12.2

Contribution of industry to air emissions

Industry was responsible for more than one quarter of nitrogen oxide (NO_x), particulate matter (here as particles ≤ 10 µm, PM_{10}) and carbon monoxide (CO) emissions and more than half of total GHG, sulphur oxide (SO_x) and non-methane volatile organic compound (NMVOC) emissions in 2017 (Figure 12.1). The relative importance

BOX 12.1 Success in reducing sulphur dioxide emissions across the EU-28

The acidifying characteristics of sulphur dioxide (SO_2) (as well as other pollutants such as NO_x) led to the well-known environmental problem of 'acid rain', which resulted in acidification of soils and freshwaters, losses of fish stocks and harm to forests across many parts of Europe. This problem was first addressed through policy during the 1970s and 80s by the United Nations Economic Commission for Europe Convention on Long-range transboundary Air Pollution, CLRTAP (UNECE, 1979) and the first and second sulphur protocols. The 1999 Gothenburg Protocol under CLRTAP and the corresponding EU National Emission Ceilings Directive later introduced binding emission ceilings for four key pollutants including SO_2. The Large Combustion Plant (LCP) Directive (2001/80/EC) on the other hand aimed to address SO_2 emissions from the activity contributing the most to total emissions in the EU: coal burning in power plants.

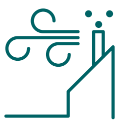
Figure 12.2 shows SO_2 emissions per unit of solid fuel (mostly coal) burned (a so-called 'implied emission factor') for those EU Member States that have such power plants. The requirements of the LCP Directive came into force in 2008 and their effect on SO_2 emissions is clearly visible in the decrease in the emission factor between 2005 and 2010. Countries with high emission factors in 2005, namely Bulgaria, Romania, Spain, Greece and Portugal, all experienced a sharp decline during that time (between -92 % in Portugal and -36 % in Romania).

Countries with medium-high emission factors for SO_2 — such as Poland, Belgium, Ireland and Italy — also achieved significant reductions by 2010. In addition, even the best performers, such as Finland, Slovenia, Germany, Denmark, the Netherlands and Austria, managed to reduce their already low emission factors further.

Further significant reductions in emission factors between 2010 and 2015 in Bulgaria, Romania, Estonia, Greece, France and Italy are likely to be linked to new stipulations coming into force under the Industrial Emissions Directive (IED; 2010/75/EU) in 2016.

New, binding and more ambitious emission limits were adopted in 2017 under the IED and will need to be reflected in permits by 2021 at the latest. This is more closely examined in Section 12.4.1 and in an EEA briefing (EEA, 2019a). The environmental performance of power plants can be tracked via the EEA indicator on emissions from large combustion plants (EEA, 2017a). ■

Sources: UNECE (1979); EEA (2017a, 2018c, 2019c).



In 2017, over half of CO_2 emissions came from industry.

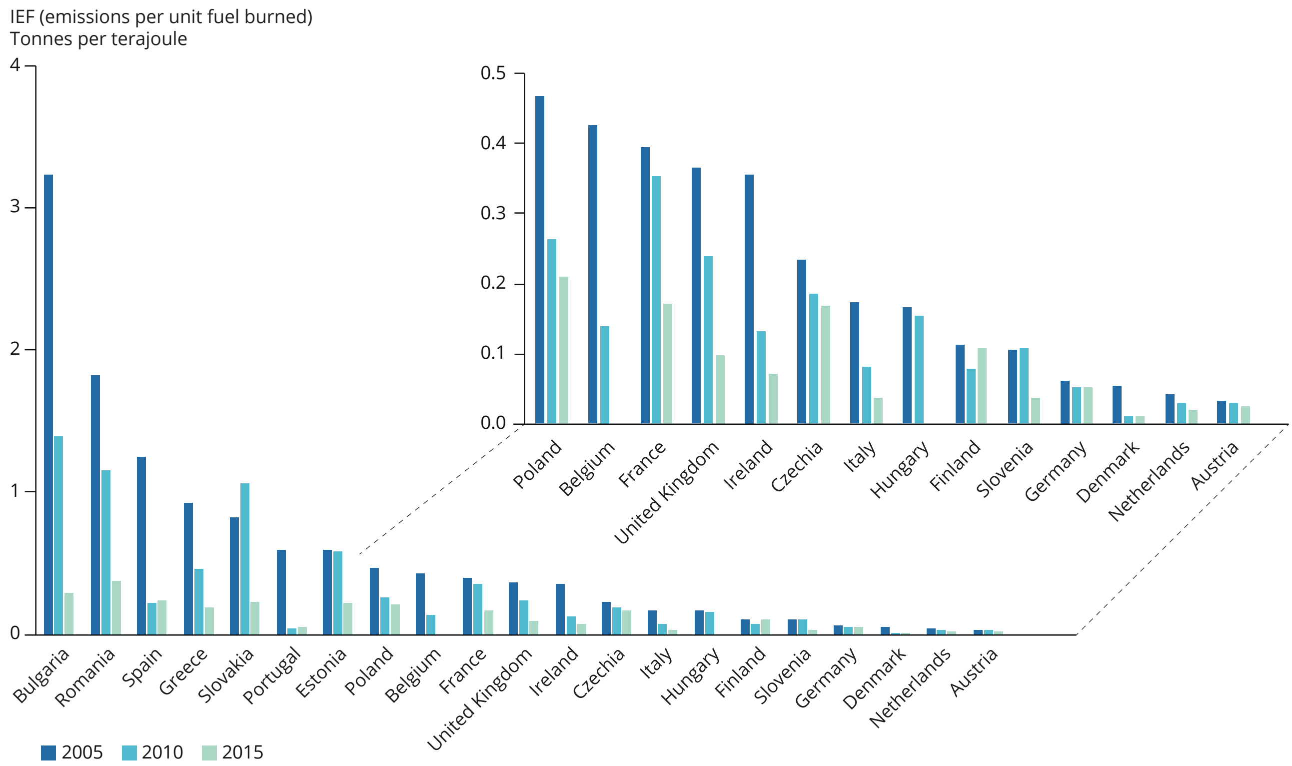
of each subsector in the context of pollutant emissions has not changed significantly since 2007 (EEA, 2019f, 2019g).

Emissions to air are often associated with the combustion of fossil fuels, which may, for example, result in emissions of SO_x, NO_x, PM_{10}, heavy metals including mercury and GHGs such as carbon dioxide (CO_2) and nitrous oxide (N_2O). This obviously applies to power plants but also to many other industrial activities that may have their own electricity or heat production on site, such as iron and steel manufacturing or cement production. Activities during which dust is generated also contribute to air emissions of, for example, particulate matter. Solvent use (e.g. during metal processing or chemical production) may lead to emissions of NMVOCs among others.

Industrial air emission trends

Reported air emissions from industry decreased for all key air pollutants and GHGs in the respective industrial sectors over the decade leading up

FIGURE 12.2 **Implied emission factors (IEFs) for SO_2 emissions from power plants burning predominantly solid fuel in 2005, 2010 and 2015, EU-28**



Note: Countries listed according to their 2005 rank. Includes only power plants for which solid fuel constitutes more than 95 % of fuel input. Countries that do not feature have no such power plants. No 2005 and 2010 data available for Sweden and Croatia. United Kingdom value for 2005 replaced by first reported value from 2007. Slovakia value for 2015 replaced by 2016 value to account for maintenance work at largest Slovakian coal power plant.

Source: EEA, 2017a

to 2017. Overall SO_x emissions have declined by 54 % since 2007, NO_x by more than one third and emissions of GHGs from industry by 12 % (Figure 12.3).

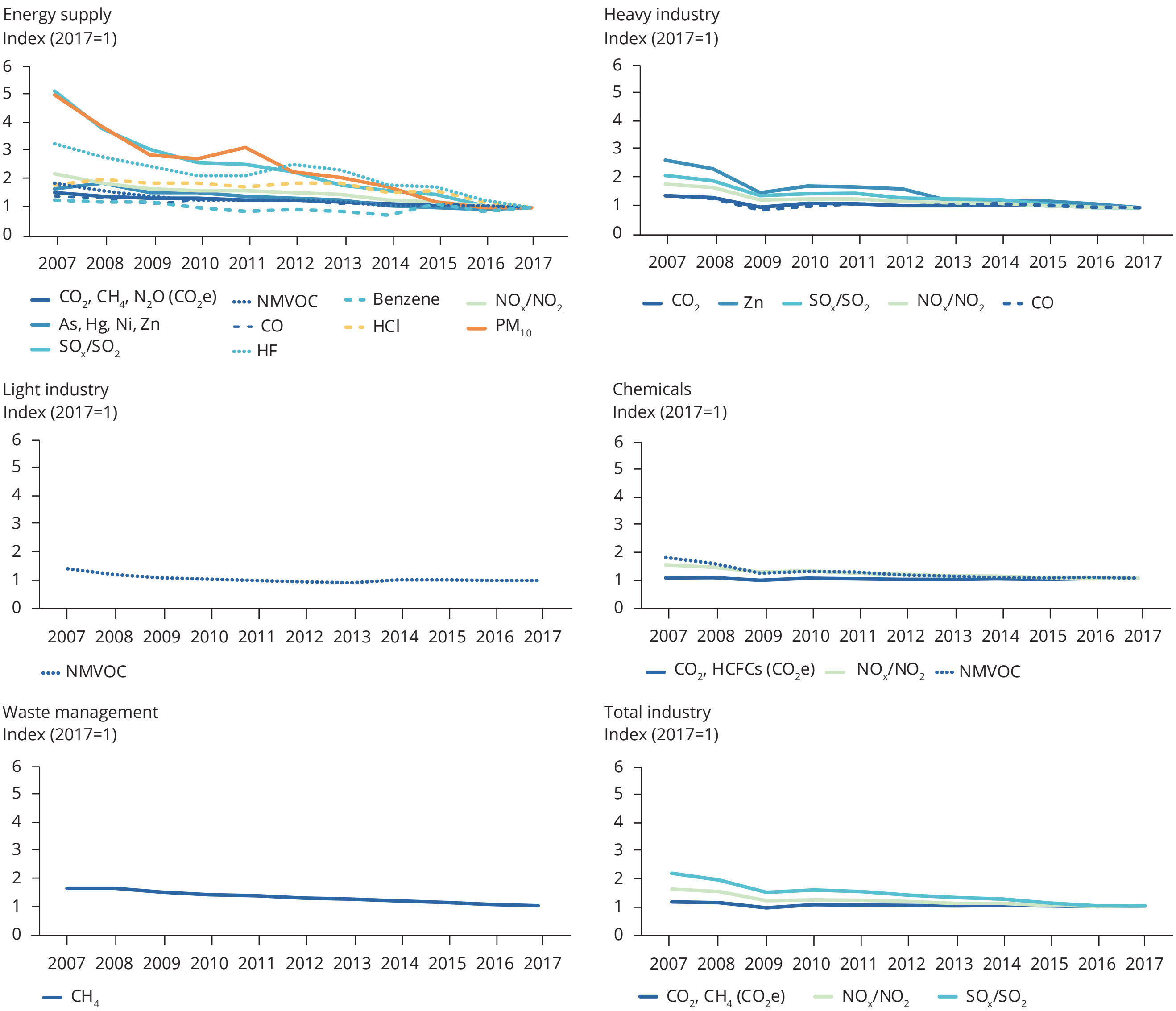
Each of the industry sectors has seen reductions in emissions of its main pollutants. Emissions of pollutants from power plants in the energy supply sector have all decreased since 2007, especially for SO_x, PM_{10} (by 80 % each) and NO_x (by about half). Other emissions were also reduced including fluorine (as hydrogen fluoride) and chlorine (as hydrogen chloride), both by-products of coal burning, heavy metals (arsenic, mercury, nickel and zinc) and to a lesser extent GHGs and CO. NMVOC and benzene emissions largely associated with refineries in the energy supply sector have also been reduced, albeit less significantly.

Key pollutants in heavy industry also tend to relate to fossil fuel combustion and were all reduced including zinc (by almost two thirds), and SO_x and NO_x (by around half). In the chemical sector, both NMVOC (associated with solvent use) and NO_x emissions dropped significantly but CO_2 emissions less so.

The reduction in methane emissions from the waste management sector reflects the decrease in the number of landfill sites in operation (Eurostat, 2018c) and waste being landfilled (Chapter 9) as well as the improvements in recovering methane from these sites (EEA, 2019a).

Air pollution and its effects on the environment and humans are addressed in detail in Chapter 8 and industry's role in climate change mitigation in Chapter 7. It should be noted that releases of many emerging air pollutants are currently not monitored. Chapter 10 explores this issue in more depth.

FIGURE 12.3 Emissions of key industrial air pollutants and GHGs for the EEA-33, 2007-2017, by industry sector



Notes: The E-PRTR does not contain data for Turkey. As, arsenic; CH_4, methane; CO, carbon monoxide; CO_2e, carbon dioxide equivalent; HF, hydrogen fluoride; Hg, mercury; Ni, nickel; NMVOC, non-methane volatile organic compounds; NO_2, nitrogen dioxide; N_2O, nitrous oxide; NO_x, nitrogen oxides; PM_{10}, particulate matter; SO_2, sulphur dioxide; SO_x, sulphur oxides; Zn, zinc.

Source: EEA (2019h).

Information is lacking on emerging pollutants, as industry only reports on emissions of pollutants of historic importance.

Contribution of industry to water emissions

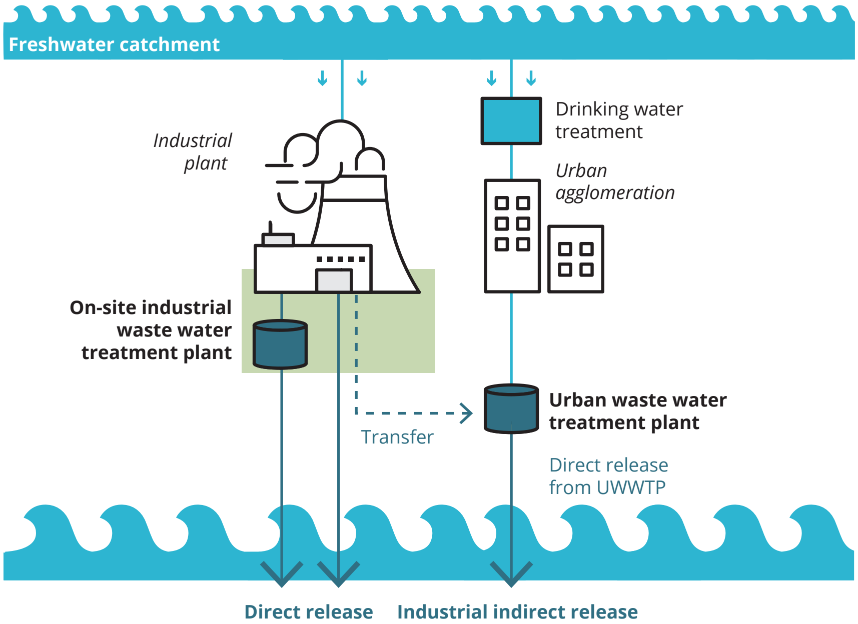
There are a host of industrial activities that use water, for example for the generation of steam in power plants, in scrubbers to remove pollutants from combustion gases or during manufacturing to clean equipment between batches. In many cases this results in waste water that is later returned to the environment, often after undergoing treatment.

Recent national assessments suggest that 18 % of surface water bodies

BOX 12.2 Understanding industrial releases of waste water

Direct releases to water by industry often require on-site treatment (Figure 12.4) but may also be possible without any treatment if the waste water is benign to the receiving water body (e.g. waste water from process cooling). In many cases, industry transfers waste water to urban waste water treatment plants (UWWTPs). These are in turn not the original source of pollution and simply end up releasing part of the pollutant load post-treatment (here referred to as indirect releases to the environment). It is also important to note that UWWTPs receive waste water that may contain pollutants from other non-industrial sources, including commercial activities and households. ■

FIGURE 12.4 Direct releases by industry versus transfers to waste water treatment plants



Source: EEA (2019e).

in the EU-28 countries are affected by chemical pollution from point sources (EEA, 2018a). More specifically, chemical releases from urban waste water treatment plants (UWWTPs) are reported as a pressure for 12 % and releases from industry for 5 % of these water bodies. Industry therefore contributes to the poor ecological status of European waters but to a lesser degree than other diffuse sources (Chapter 4). Box 12.2 explains industrial releases of waste water. The implementation of waste water treatment can be tracked via the EEA indicator on urban waste water treatment (EEA, 2017b).

Data in the E-PRTR (EEA, 2019h) allow an assessment of the relative contribution to these pressures by industry sectors (see next section below).

18 %

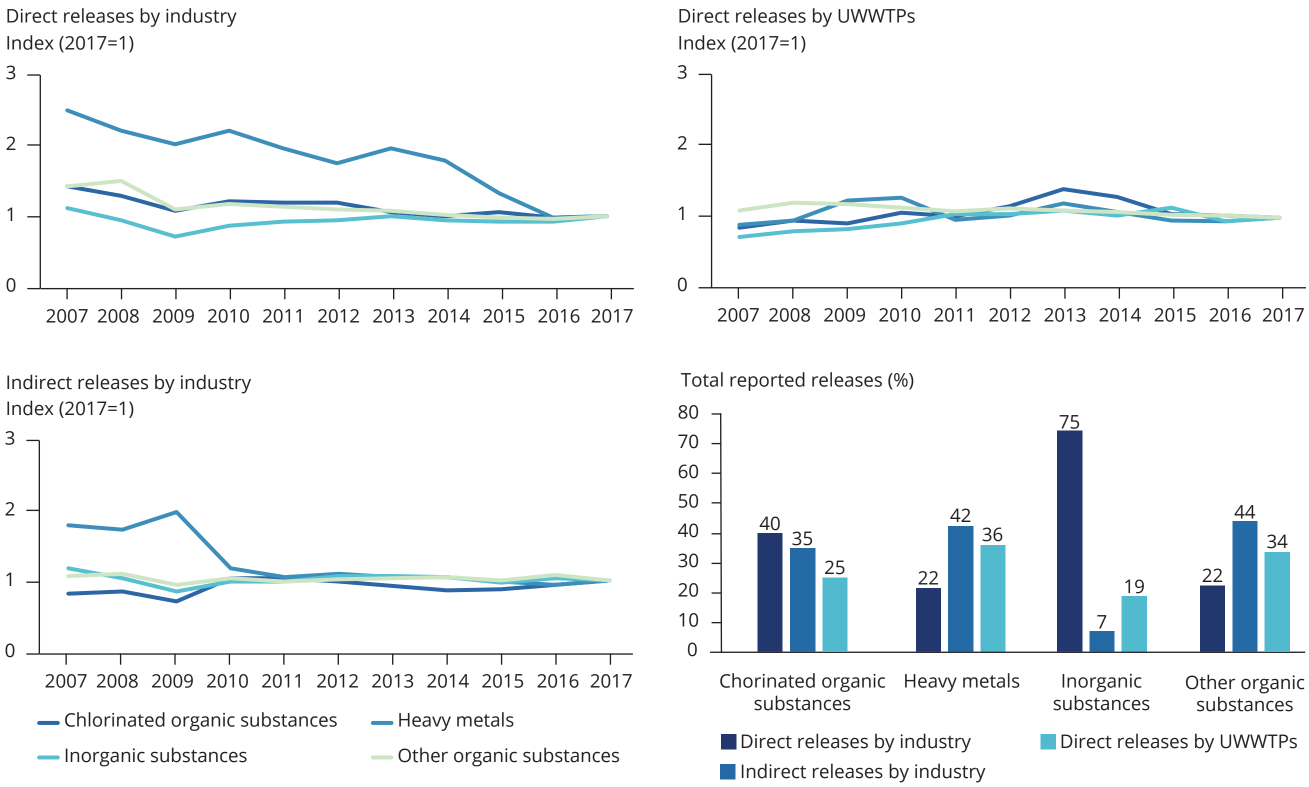
of surface water bodies in the EU are affected by chemical pollution from point sources.

Failure to achieve good chemical status (Chapter 4), however, is linked to legacy pollution with mercury, polybrominated diphenyl ethers and polycyclic aromatic hydrocarbons. Regarding surface waters, these substances are largely linked to past industrial activity (e.g. atmospheric deposition of mercury), and for ground water they are linked to past mining activity and seepage from contaminated industrial sites (see also EEA, 2018a).

Industrial water emission trends

Reported direct releases of pollutants by industry in the EEA-33 have decreased (slightly or more significantly) since 2007 for most pollutant groups, while indirect releases (i.e. transfers from industry to UWWTPs) have marginally

FIGURE 12.5 Total pollutant emissions to water and transfers to UWWTPs by industry for the EEA-33, 2007-2017, by pollutant group



Notes: The E-PRTR does not contain data for Turkey. Trends are in some cases strongly influenced by releases reported by individual facilities.

Source: EEA (2019h).

increased (EEA, 2019h). Findings from a recent report on industrial waste water (EEA, 2019e) are briefly summarised below and in Figure 12.5:

- Inorganic substances (and in particular nitrogen and phosphorus) account for the large majority of total direct and indirect releases of pollutants overall to surface waters (about 98 % of the total by mass). Chemical production is responsible for more than half of direct inorganic chemical releases in recent years, followed by UWWTPs and extractive industries (around 20 % each). Both chemicals and extractive industries also dominate indirect releases of inorganic substances. Releases (direct or indirect) of these substances do not necessarily represent the largest environmental pressure. Chlorides, for example, may exist at higher levels naturally and large releases (1) may merely be a result of that rather than industrial processes and (2) may not have a negative impact on the ecosystem as a result.

There has been more progress in reducing industrial emissions to air than to water.

- Chlorinated organic substances are directly released largely by light industry (pulp, paper and wood in particular) followed by UWWTPs. They account for less than 1 % of total direct releases by mass. Chemical production on the other hand is responsible for the majority of indirect releases of these substances.

BOX 12.3 The concept and development of best available techniques

The concept of best available techniques (BATs) dates back to the Integrated Pollution Prevention and Control Directive (IPPCD, 96/61/EC, replaced by the Industrial Emissions Directive, IED, in 2010). It stipulated that industrial installations must be issued with integrated permits that take into account emissions to air, water and soil, use of raw materials, energy efficiency, site restoration, noise and prevention of accidents.

To support authorities in Member States in charge of issuing permits, the European Commission created the European Integrated Pollution Prevention and Control Bureau with the task of steering information exchange on BAT. This information-sharing system remains in place today. The bureau publishes comprehensive reference documents (known as best available technique reference documents or BREFs) for specific industrial activities. They contain information on the techniques and processes used in a specific industrial sector in the EU, current emission and consumption (e.g. water, energy, materials) trends, and techniques to consider for determining BATs, as well as emerging techniques (see also Evrard et al., 2016, for an analysis of the whole process). During the time that the IPPCD was in force, Member State authorities were able to set emission limit values and other permit conditions that deviated from what was recommended in these documents. This flexibility resulted in notable differences in the emission limits for comparable industrial processes across the EU-28 (Entec, 2011).

To guarantee a level playing field and harmonise the emission limits across European industry, the more recent IED has since required the bureau to draw up conclusions for each of these reference documents (the BAT conclusions). These conclusions contain various elements that Member States need to implement, such as limits on emissions and other stipulations. This constitutes one of the major improvements introduced through the IED with a view to increasing the uptake of clean and environmentally sound technologies and processes. BAT conclusions, however, also include benchmarks of expected environmental performance, for example ratios between process inputs and outputs or levels of expected waste generation for specific processes. An up-to-date list of the documents containing the emission limit values and other reference values for a host of different industrial activities can be found on the website of the Joint Research Centre (JRC, 2018).

Some EEA-33 countries go further and develop country-specific BATs. This is the case in Estonia, where a BAT for the oil shale industry was developed to address one of the country's main emitting sectors. ■

Sources: Entec (2011); Evrard et al. (2016); JRC (2018).

- Other organic substances account for the second largest total of direct releases (2 %) (2). They are directly released predominantly by UWWTPs and light industry (especially pulp, paper and wood). Light industry and chemical production also indirectly release them. Toxic substances that feature more prominently include phenols, nonylphenols and nonylphenol ethoxylates (NP/NPEs, used, for example, in detergents), di(2-ethylhexyl)phthalate (DEHP, used, for example as softeners in plastic) and fluoranthene (a biomass combustion residue).

- Direct releases of heavy metals can largely be attributed to UWWTPs. E-PRTR data show that this is at least in part the case because an amount of heavy metals of the same order of magnitude as total direct releases is transferred to UWWTPs by industry. Some of the prominent heavy metal

In many cases, industry transfers waste water to urban waste water treatment plants.

(2) Such releases include total organic compounds, which are in fact not pollutants per se but a measure of how much organic matter is being released.

TABLE 12.2 Summary assessment — pollutant emissions from industry

Past trends and outlook		
Past trends (10-15 years)		Improving trends dominate, as industrial emissions to air and water have decreased in the past decade. There has been particular progress in reducing emissions to air related to energy supply and emissions to water related to the metal production and processing sector. However, some industrial emissions have increased, such as emissions to water of other organic substances by extractive industries. Overall, progress has been more pronounced for air than for water.
Outlook to 2030		Continued progress is expected as implementation of current policies to mitigate industrial emissions continues. Full implementation of policies is required to deliver improvements. Importantly, climate change legislation will play an important role in driving further greenhouse gas (GHG) and air pollutant releases from industry. However, many emerging pollutants are often not adequately monitored but require increased attention to address environmental and health risks.
Prospects of meeting policy objectives/targets		
2020	☐	Europe is making progress towards the policy objective of significantly reducing emissions of pollutants. Although current policies and measures are delivering pollution control, the release of hazardous chemicals to air and water remains problematic. Even though current policy addresses major pollutants and GHGs and many industrial activities, the industrial pollution load to the environment is not covered entirely.
Robustness		Information on industrial emissions comes from data reported by countries. These are only available for a subset of industrial activities and for a limited number of pollutants. Emissions are often estimated or calculated by industrial facility operators. Outlooks are based on a number of separate assessments in the energy supply sector, which estimate future emissions and determine the impact of existing (and, therefore, future) policy measures. The outlooks for water are qualitative in nature with greater uncertainties. The assessment of outlooks and prospects of meeting policy objectives also rely on expert judgement.

emission trends are driven largely by individual facilities. This is the case for releases from metal production and processing. The fact that a large aluminium production site in France installed abatement technology after 2014 is clearly reflected in the overall downward trend in releases of heavy metals. The trend for heavy metals in extractive industries is further dominated by a Polish mine. Similarly, a large chemical works producing basic organic chemicals in Austria dominated European transfers of heavy metals to UWWTPs during the period 2007-2009. Non-industrial sources of heavy metals in water that may be sent to UWWTPs for treatment include run-off from roads as well as domestic waste water.

An unknown number of emerging water pollutants is currently not reported to the E-PRTR. This includes some of the pollutants currently treated as priority hazardous substances under the Water Framework Directive daughter Directive 2013/39/EU, such as dicofol (a pesticide related to DDT), quinoxyfen (a fungicide) and hexabromocyclododecane (HBCDD, a brominated flame retardant). These substances may be released to European waters by UWWTPs. Please refer also to Chapters 4 and 10 for further information.

12.3.2 Clean industrial technologies and processes

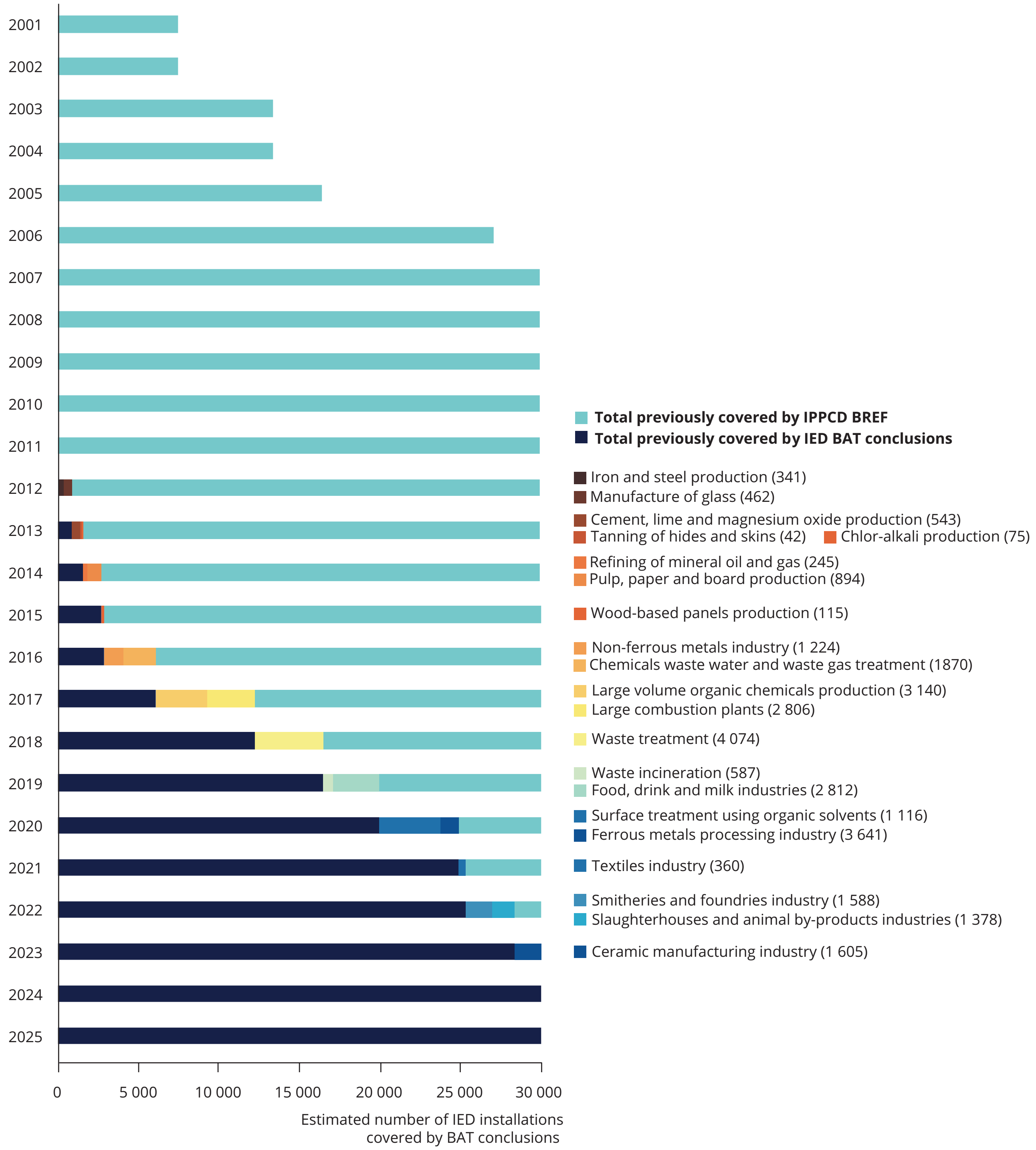
► See Table 12.4

The adoption of clean and environmentally sound technologies and processes features as an objective in both SDG 9 and the EU Seventh Environment Action Programme (7th EAP). This section assesses progress with respect to this objective.

Decarbonisation of industry is expected to be a major driver of air pollutant emission reductions.

The number of industrial installations covered by best available technique (BAT) reference documents (known as BREFs) and their conclusions (Box 12.3) serves as a proxy to assess trends in establishing clean technologies and processes in industrial activities across Europe. Figure 12.6 shows that BREFs were developed for the most polluting industrial activities between 2001 and 2007 (under the precursor to the IED, namely the Integrated Pollution Prevention and Control Directive, IPPCD, 96/61/EC). These reference documents

FIGURE 12.6 Estimated number of installations covered by the IED and by BAT conclusions



Notes: This overview is based on data from an IPPCD implementation report and thus excludes installations in Croatia. Intensive rearing of pigs and poultry is also excluded because of how industry is defined in Section 12.1. The number of installations for 'Production of chlor-alkali' and 'Wood-based panels production' are based on the respective BREFs rather than the implementation report referenced in the figure source line. Discrepancies arise because IPPCD and IED activities cannot be mapped entirely and various BAT conclusions do not cover entire IED activities. There is also overlap in IED activities between different BAT conclusions. As of 2019, new reporting requirements under the EU Registry on Industrial Sites will provide more accurate data in the near future. Estimates for dates in the future are based on expert judgement.

Source: AMEC Foster Wheeler (2016b).

TABLE 12.3 **Examples of references to environmental performance other than emissions in BAT documents developed under the IED**

Area	Activities	Example measures
Energy efficiency	Large combustion plants, cement production and production of milk	Relevant BAT conclusions specify associated energy efficiency levels (BAT-AEELs)
	All IED activities	Energy efficiency BREF: any industrial activity should include a minimum standard of energy efficiency management, continuous environmental improvement and a map of energy efficiency aspects in any given installation as well as potential for improvement
Material use	Sinter production (iron and steel manufacturing), non-ferrous metal alloy production and recovery, and paper-making	Relevant BAT conclusions establish raw material versus product output ratios
	Production of chlor-alkali	BREF bans mercury from the production process
	Polymer production	Polymer BREF establishes associated environmental performance levels (BAT-AEPLs) for monomer consumption
	Processing of crushed seeds or beans	Food, drink and milk BAT conclusion establishes BAT-AEPLs for hexane consumption
Waste generation	Sinter production (iron and steel manufacturing) and non-ferrous metal alloy production	Relevant BAT conclusions provide amounts of waste typically produced per unit of production
	Polymer production	Polymer BREF establishes BAT-AEPLs for the amounts of waste produced
	Chlorine production	Chlor-alkali BAT conclusion establishes BAT-AEPLs for sulphuric acid residue per unit of chlorine produced
	Refineries, tanning of hides and skins, and cement production	Relevant BAT conclusions provide recommended content of hazardous chemicals in final products and/or waste

Source: EEA, based on JRC (2018) and Ricardo Energy & Environment and VITO (2019).

will remain in place until they are revised under the IED, when binding conclusions are also added (Box 12.3). Most BREFs will have been revised by 2020 while a few are only likely to be developed by 2025.

Figure 12.6 clearly shows that there is continued progress with respect to establishing a regulatory push to improve the uptake of BATs by issuing permits to installations, at least within the scope of industrial activities covered by the IED. The examples of large combustion plants, and iron and steel manufacturing installations presented in Section 12.4.1 further show that such regulation has improved the environmental performance of industry regarding pollutant emissions in the past. However, decisions on investment with respect to pollutant abatement are not only driven by environmental regulation but are often tied to scheduled maintenance and technological upgrades that may have occurred regardless of whether regulation is introduced or not (Ricardo Energy & Environment, 2018).

Environmental policy has led to reductions in industrial emissions in the past decade.

The environmental performance benchmarks contained in various BAT conclusions provide an important link to resource efficiency (see also Ricardo Energy & Environment and VITO (2019)). The circular economy package (EC, 2015; Chapter 9) stipulates the incorporation of guidance on energy and resource use into the BREFs and their conclusions. Table 12.3 presents selected examples. Such benchmarks are, however, currently

TABLE 12.4 Summary assessment — clean industrial technologies and processes

Past trends and outlook		
Past trends (10-15 years)		An increasing number of industrial facilities are covered by emission limits and other environmental requirements. There is evidence that this has led to reductions in emissions of pollutants, but it is less clear whether this has resulted in improvements in general environmental management in industry.
Outlook to 2030		Further progress is expected regarding the environmental performance of industry. By 2025 more stringent best available technique (BAT) conclusions are expected to cover all industrial activities currently regulated by the Industrial Emissions Directive. Industry's transition to a low-carbon economy is predicted to contribute further to emission reductions. However, uncertainties remain over whether general environmental performance beyond air and water pollution abatement will be fully implemented and thus whether the objective of implementing clean industrial technologies and processes can be achieved. Therefore, industrial pollution is likely to continue to adversely impact human health and the environment.
Prospects of meeting policy objectives/targets		
2020	☐	Europe is making good progress towards the policy objective of securing industry's adoption of clean and environmentally sound technologies and industrial processes. Although these are delivering pollution control, release of pollutants remains problematic.
Robustness		The scope of the Industrial Emissions Directive is not all-inclusive and a number of industrial processes are not covered. The number of installations covered by each BAT reference document and BAT conclusion is an estimate based on reported data, which may be incomplete. The overarching objective of implementing clean industrial technologies and processes is generic and does not provide a clear target. Therefore, the assessment of past trends, outlooks and prospects of meeting policy objectives also relies on expert judgement.

not applied systematically or in a harmonised way across the EU, indicating considerable potential for improvement and also for contributing to the circular economy and energy efficiency goals. A comprehensive assessment of the integration of environmental performance beyond emissions to air and water will be possible only once permits become accessible through the forthcoming implementation of the EU Registry on Industrial Sites. This registry incorporates reporting obligations under the IED and the E-PRTR and will be operational from late 2019 onwards.

A number of BAT conclusions also attempt to guide operators to think about establishing synergistic relationships with other industrial stakeholders, for example by capturing waste materials or surplus energy resulting from processes that may be of value to others. This concept of industrial symbiosis (e.g. Bilsen et al., 2015) is enshrined in BAT for tanneries with respect to chromium, for solid residues from steel production and for sludge or filter dust from non-ferrous metal production.

> Industrial pollution is likely to continue to adversely impact human health and the environment.

Other drivers towards more clean and environmentally sound technologies include environmental policies and regulations that aim to reduce GHG emissions and thus affect, for example, the energy mix in the power sector (Chapter 7). The EU Emissions Trading System (ETS) and the Renewable Energy Directive (2009/28/EC) are examples of this. There may also be additional incentives for reducing the environmental impact of industrial installations such as cutting energy use and thereby operating cost, displaying better corporate social responsibility via voluntary green initiatives or taking advantage of associated governmental funding initiatives (e.g. as reported for emerging technologies by 12 Member States in the context of IED implementation reporting; AMEC Foster Wheeler, 2016a).

The European Commission reviews legislation to ensure that it continues to be fit for purpose and provides benefits to society. The IED is currently being assessed as part of that review process and a conclusion is expected in early 2020. Both its integration with other EU policies and progress on implementing environmental performance benchmarks contained in BAT conclusions may be touched upon during this review.

12.4 Responses and prospects of meeting agreed targets and objectives

12.4.1 Policy responses to tackle industrial pollution

Industrial pollution has been addressed at the national and regional levels across Europe for decades, and it is beyond the scope of this chapter to summarise all of these policy responses. Instead, the IED serves as a recent example of increasingly integrated regulation of industrial pollution at the European level.

Policy coherence and relevance

The IED has been explained in detail throughout this chapter (see, for example, Box 12.3). The Directive is very much a technical piece of legislation that regulates industrial point source emissions and aims to increase environmental performance cost-effectively through BREFs. The IED already represents an integration of multiple pieces of legislation that previously existed side by side. Section 12.2 further highlights that, by regulating the industrial sector, the IED contributes to objectives set by a host of other policies on air pollution, water quality and the circular economy, to name a few. These connections to other policy arenas are currently not evident in the IED itself due to its age. There is therefore potential to further improve this integration through the ongoing review of the IED (Section 12.3.2).

Another important aspect of the IED is that GHG emissions from industry are not included in its scope. They are instead addressed by the EU ETS (for a critique of this separation see, for example, Peeters and Oosterhuis, 2014) (see also Section 12.2 and Chapter 7). There is nonetheless a clear link between policies and legislation that aim to establish a low-carbon economy in Europe and industrial pollution (and industrial air emissions in particular; see, for example, EC, 2018).

A 2019 EEA report on industrial waste water (EEA, 2019e) concluded that a revision of the activity and pollutant lists and reporting thresholds of the E-PRTR Regulation could help to better monitor progress towards controlling pollution from installations covered by the IED. In this context, emerging pollutants should also be considered. These pollutants are touched upon in more detail in Chapters 4 and 10. Industry releases thousands of different chemicals into the European environment and only a small fraction of them are currently monitored. Such a revision could also help to better align reporting on waste water treatment plants under the UWWTD and the E-PRTR. The presence of reporting thresholds in general hampers the interpretation of the data reported and therefore complicates sound policymaking. Activity lists and pollutants subject to reporting under national and regional pollutant release and transfer registers (PRTRs, e.g. the E-PRTR) as well as associated reporting thresholds are currently also being reviewed (see, for example, UNECE, 2018).

The contribution of the Industrial Emissions Directive to circular and low-carbon economy could be improved.

It should further be noted that our understanding of the impact of substances on the environment and human health is developing over time. This in turn can determine whether or not these impacts are addressed by specific policy instruments and, for example, monitored. It is therefore currently possible to assess progress towards reducing industrial pollutant emissions for only the harmful substances for which emissions are reported. An assessment of whether or not policy is relevant (or effective) therefore changes over time along with our understanding of the substances released by industry. Certain aspects of industrial pollution policy are therefore reactive by definition (Chapter 10).

The 2017 European Commission industrial policy strategy (EC, 2017) identifies a number of sector policy priorities, such as competitiveness, cybersecurity and skills, but fails to mention the IED or in fact the topic of pollution at all. The environmental aspects highlighted are limited to decarbonisation and resource efficiency. This underlines that industrial pollution considerations need to be further integrated across different policy areas (see also Sanden, 2012) and should be considered during the ongoing development of a new industrial policy strategy for the EU.

Another good example of this is the contribution that the IED is intended to deliver with respect to the Commission's circular economy package. The analysis above (Section 12.3.2) shows that, although some BAT conclusions mention best practices for increasing energy efficiency, improving material use and reducing waste generation, incorporating these environmental performance benchmarks into operating permits varies across Member States and a fully-fledged assessment of their effectiveness is currently hampered by a lack of data. It is very likely that the potential contribution of the IED to the circular and low-carbon economy could be improved (Ricardo Energy & Environment and VITO, 2019). This is of particular relevance because a transition from a linear to a circular model of production is required to help minimise future emissions and material throughput. This is evident in the European Commission's recent long-term strategy for a climate neutral economy (EC, 2018), in which industry plays a central role in the transition to a low-carbon and circular economy. Incrementally stricter emission limits on their own will not achieve this feat in the long term (Ghisellini et al., 2016). Instead, this transition can take place only when resource scarcity implications and economic benefits are as much a focus as environmental benefits (see also EEA, 2016; Lieder and Rashid, 2016). In addition, the transition to a circular and low-emission industrial sector in

Europe will require additional regulatory approaches that address new industrial processes and material cycles.

The IPPCD had been criticised for being a soft regulation that relies on industrial as well as regulatory capacities in Member States to set permit conditions that improve the environmental performance of installations rather than setting top-down emission limits that apply across Europe (Koutalakis et al., 2010). Although some of these perceived shortcomings have been addressed via the IED, some argue that these changes did not go far enough to ensure completely effective control of industrial emissions (Lange, 2011; Conti et al., 2015; Lee, 2014). Permit conditions may therefore still differ between similar installations in similar settings as long as either their emissions are within the range outlined in the BAT conclusion or they are covered by a derogation.

A recent report by the European Topic Centre for Air Pollution, Transport, Noise and Industrial Pollution (ETC/ATNI, 2019) further shows that, while the level of production in heavy industry has remained stable in Europe, emissions of pollutants to air from that production have decreased as a result of pollution abatement. Additional European demand over the past few decades has, however, been met by production outside Europe, resulting in a potential outsourcing of associated pollutant emissions.

Effectiveness of existing policy

The effectiveness of policy can only be assessed properly if its goals and objectives are clearly defined, measurable and reliable, as well as if relevant data are available for this purpose. These conditions are to a certain extent met with respect to pollutant emissions from specific industrial sectors that will serve as examples in this section. For many other industrial sectors, the data available are not sufficient to properly evaluate the effectiveness of policy.

There is clear scope for further integration of environmental objectives into the EU's industrial policy.

An *ex post* assessment of the Large Combustion Plants Directive (LCPD) (EEA, 2019b) is one example of a policy effectiveness assessment. It identified some of the drivers behind past emission releases to air from combustion units in the energy supply sector (i.e. power plants), heavy industry (most prominently in iron and steel and metal processing), light industry (e.g. pulp, paper and wood) and waste management (co-incineration of waste). The assessment found that past improvements in the relative emissions from these units was the dominant factor in reducing the emissions of SO_2 (such improvements alone led to a 71 % reduction between 2004 and 2015), NO_x (38 %) and dust (75 %, which includes PM_{10}). These improvements in turn are the result of a stricter compliance regime coming into effect in 2008 for existing power plants under the LCPD. In particular, countries with previously very high emission factors for these three air pollutants saw significant reductions around that time.

Other factors identified by the assessment as having an impact on emissions from power plants included a reduction in the energy intensity of economic sectors (contributing to a 7-9 % reduction for the three pollutants between 2004 and 2015), a rise in economic activity (5-6 % increase) and shifts in the energy mix (12-15 % decrease) (compare with Figure 12.2 and Figure 12.3). Another contributing factor was the switch from fossil fuels to biomass, which was in part driven by the EU ETS as well as by the implementation of renewable energy targets in the Renewable Energy Directive. Stricter emission limit values and new BAT conclusions in the IED had probably already had an effect on emission reductions up until 2015 (see also Box 12.1).

A second recent assessment for the European Commission (Ricardo Energy & Environment, 2018) analysing the iron and steel sector also found a strong link between BATs published for the sector in 2012 under the IED and reductions in air pollutants achieved on the ground. According to the study, air pollutant emissions reported to the E-PRTR by iron and steel manufacturers decreased compared with what they would have been based on 2016 steel production data and emission factors from 2012 (per unit of steel produced). The authors of the study found that emissions of SO_x had been reduced by 29 %, of NO_x by 14 %, of PM_{10} by 25 % and of mercury by 26 %.

The relatively small contribution of large industrial point sources to overall environmental pressure on European surface waters is noted in Section 12.3.2. These point sources are almost all regulated by the IED. However, underlying data also suggest that small point sources not regulated by the IED appear to exert greater pressure on the quality of surface waters (EEA, 2019e).

In the waste management sector, the EU Landfill Directive (1999/31/EC) (with its provisions on technical requirements on landfill sites and for diverting waste from landfill), as well as EU waste policies (aiming to move waste towards reuse and recycling), worked hand in hand with emission control policies, leading to reductions in methane emissions (Figure 12.3 and Chapter 9).

Such examples as those outlined above show that broadly effective industrial pollution policy is in place for many large industrial sectors. The example of the power plants in particular highlights that the introduction of strict, ambitious emission limits can be an effective driving force to reduce pollutant emissions. More data are needed to assess the effectiveness of current policies to regulate emissions from other industrial activities (and for other pollutants), including those not yet covered by the IED.

However, the lack of a comprehensive EU industry policy that addresses environmental performance as an integrated aspect of the sector, as well as the limited scope of existing data on pollutant releases from all industrial activities, indicates potential for further policy integration. The importance of this is underlined by the ongoing costs that pollution from the sector imposes on Europe's society. An earlier study examining the costs of air pollution from industry in Europe (EEA, 2014) found that the then levels of emissions caused damage in the order of at least EUR 59 billion (or EUR 115 per capita) in 2012.

12.4.2 Prospects for meeting agreed targets and objectives

Incorporating more efficient, clean technologies and processes within Europe's industrial sectors will be important to ensure continued reductions in emissions of pollutants and improved environmental and climate performance.

Historical industrial pollutant emissions have been decreasing, especially with respect to emissions to air. Decreases have been most dramatic with respect to SO_2, NO_x and dust (or PM_{10}) emissions associated with combustion processes. A recent assessment for the EEA (ETC/ACM and Dauwe, 2018) shows that emissions of SO_2 and NO_x from power plants could be reduced by at least two thirds by 2030 and dust emissions by more than half over the same period as a result of new emission limits for the sector. According to the assessment, future emission trends in the power sector will in particular be driven by EU climate and energy policy (Section 12.4.1). It should be noted that, although the power sector can arguably meet these strict new pollutant emission limits by retrofitting a number of existing plants while replacing others with new, more efficient ones, it will also be necessary to decommission some of these plants to meet EU targets for decarbonisation (Chapter 7) (see EEA, 019c).

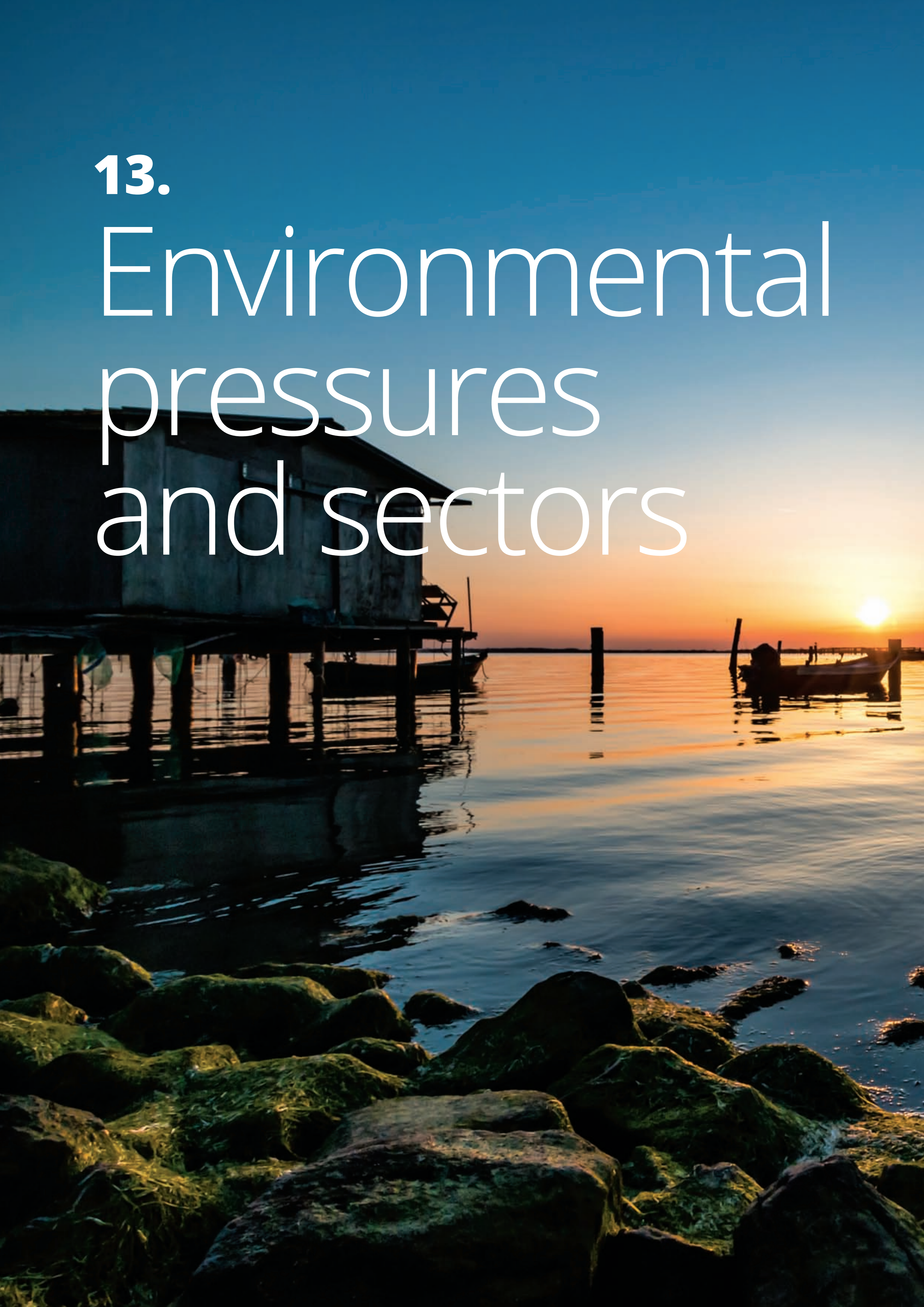
Existing and incoming EU policy instruments are expected to further reduce industrial emissions.

While more waste water is now receiving some form of treatment before being released into the environment, decreases in pollutant emissions to water have been more modest. Although overall reported releases of waste water by industry and UWWTPs have decreased slightly since 2007, real progress has been achieved only with respect to heavy metal loads. The current trend to further control indirect emissions of pollutants by industry under the IED (i.e. waste water that is treated at UWWTPs before being released to the environment) may lead to reduced pollution of European surface waters in the future, but whether or not this materialises remains to be seen (EEA, 2019e).

Further reductions in industrial pollution — at least regarding the currently reported pollutants — are nonetheless likely to be due to the regulation mentioned throughout this chapter. Under the IED regime, a host of new BAT conclusions have been or will be published, with each coming into effect within a 4-year window. This effectively means that mandatory emission limits for industrial activities ranging from pulp, paper and wood to refineries, non-ferrous metals, waste treatment and chemicals, as well as power plants, will be lowered further overall between now and 2030 (see also Ricardo Energy & Environment, 2017). This applies to emissions to both air and water. Transfers of pollutants to UWWTPs will also be increasingly regulated under the IED, which in turn may lead to a reduction in the pollutant load entering the environment from UWWTPs. The ongoing European Commission fitness checks of the UWWTD and WFD are also expected to further address the regulatory gap with respect to emissions to water.

These findings are reassuring, but there are a number of important caveats. In the E-PRTR only releases of specific pollutants above an accompanying threshold have to be reported. Monitoring of concentrations of pollutants in surface waters is also limited to a specific list of pollutants (Chapter 4). Chapter 10 therefore points to the fact that a multitude of emerging pollutants is still being released into Europe's environment without being subject to monitoring. Such releases may have significant, but as yet unknown, impacts on the environment and human health.

13.
Environmental pressures and sectors



Summary

- The EU Seventh Environment Action Programme (7th EAP) aims to ensure that by 2020 the overall environmental impact of all major sectors of the economy is significantly reduced and that sectoral policies are developed and implemented in a way that supports environment and climate targets and objectives.

- Current developments are not in line with policy ambitions. Overall, environment and climate related concerns are not sufficiently integrated into sectoral policies and implementation requires improvement. It is unlikely that the objective of significantly reducing the overall environmental impact of all major sectors of the economy by 2020 will be met.

- Strengthening environmental integration into policy areas, such as agriculture, transport, industry and energy, and EU spending programmes is essential, but the overall approach of environmental integration has not been successful when it comes to reducing environmental pressures from economic sectors.

- Environmental policies create economic opportunities and contribute to broader social and economic objectives. However, the loss of momentum in the development of eco-industries indicates that further efforts are needed to realise the 7th EAP's ambitions of a resource-efficient, green and competitive low-carbon economy.

- There are benefits from complementing a sectoral focus and environmental integration approach with a broader systems perspective. This improves understanding of interactions and enables more coherent and effective policy interventions to reduce environmental pressures along whole value chains.

13. Environmental pressures and sectors

13.1 Introduction

As part of efforts to turn Europe into a resource-efficient, green and competitive low-carbon economy, the EU Seventh Environment Action Programme (7th EAP) aims to ensure that by 2020 the overall environmental impact of all major sectors of the economy is significantly reduced and that sectoral policies are developed and implemented in a way that supports relevant environment and climate related targets and objectives. It also calls for an increase in the market share of green technologies and enhancing the competitiveness of European eco-industries (EC, 2013c). This dual focus reflects the fact that well-designed and implemented environmental policies also create wealth, trade and job opportunities, contributing to broader social and economic objectives.

To date, there has been over two decades of efforts to mainstream environmental and climate considerations into other policy areas. Environmental integration has been pursued in primary sectors such as agriculture, through the common agricultural policy (CAP), and fisheries, through the common fisheries policy, and in the cohesion policy. More recently, the EU's integrated maritime policy aims to take a more coherent approach to maritime issues. It focuses on issues that do not fall under a single sector and seeks to improve coordination rather than replace sector-specific policies. The EU has also committed to spending 20 % of the EU's 2014-2020 multiannual financial framework on climate-related action, a decision aiming to mainstream climate action within all policy areas.

The EU aims to significantly reduce the environmental impacts of all major sectors of the economy by 2020.

The preceding chapters have highlighted the role of a range of sectors in driving environmental degradation as well as presenting the contribution of different sectors to emissions of pollutants. This chapter focuses on a smaller number of selected sectors, namely agriculture, marine fisheries and aquaculture, forestry and transport, given their important role generating pressures and impacts on natural capital. What follows is not a comprehensive assessment of the environmental impacts of these sectors, rather it focuses on selected key pressures and how well environmental considerations have been integrated into relevant sectoral policies. The extent to which industry is making progress towards reducing pollutant emissions and implementing clean and environmentally sound industrial technologies and processes is assessed in Chapter 12. This chapter also looks at recent developments and trends with regard to the economic sector known as the environmental goods and services sector, also known as eco-industries and the market for environmental technologies. In doing so, the chapter provides insights into the role of European environment and climate policies in addressing the environmental pressures from economic activities and the wider secondary socio-economic benefits that these measures can deliver for society.

> Providing food is the primary function of agriculture, but it also provides other essential functions such as contributing to rural development and managing landscapes.

13.2 Agriculture

13.2.1 Socio-economic relevance of the sector and policy landscape

Providing food is the primary function of European agriculture, but it also provides other essential functions such as contributing to rural development and managing landscapes. The relative importance of agriculture in the EU economy has been in decline over the last 50 years. In 2017, the sector contributed 1.2 % of EU gross domestic product (GDP) and, while its relative economic importance compared with other economic sectors is low, it contributed EUR 188.5 billion gross value added (GVA) to the economy, with EUR 57.2 billion invested in agricultural capital (Eurostat, 2018a). In 2016, about 9.7 million people worked in agriculture corresponding to a small and decreasing share (4.2 %) of the EU's total workforce, with farming remaining a predominantly family activity (Eurostat, 2018a). Agriculture remains important in rural areas as indicated by its higher share in rural employment (13.5 % in 2014) ([1]). In addition, as agriculture produces raw materials as well as food, it also supports employment and GVA creation in other sectors.

While contributing to the economy, the sector is also a large recipient of subsidies. The agricultural sector has received substantial support under the main sectoral policy framework, the CAP. The CAP was allocated around 38 % of the overall EU budget for 2014-2020 and currently has an annual budget of around EUR 59 billion (EC, 2013d). The extent of public support is indicated by the average share of EU subsidies in agricultural factor income of more than 35 % during the period 2010-2014 (European Parliament Research Service, 2017). However, this is not distributed equally across the sector. In 2017, 6.5 million out of 10.5 million farms received direct payments, and 0.5 % of all beneficiaries obtained 16.4 % of total direct payments (DG Agriculture, 2018b, 2018a; Eurostat, 2019c).

The CAP has strongly framed the development of the agricultural sector and has had a prevailing socio-economic focus. There has been a shift from a primarily sector-oriented policy to a more integrated rural development policy with structural and agri-environmental measures. The CAP 2014-2020 has the general objectives of contributing to the sustainable management of natural resources and climate action, balanced territorial development and viable food production. It comprises two main pillars: Pillar 1 provides direct payments to farmers and market interventions; and Pillar 2 supports rural development programmes. An important feature of the current CAP is the recognition that farmers should be rewarded for the provision of public goods even if they do not have a market value: however, this process has much further to go (Buckwell et al., 2017). While the CAP cannot be regarded as providing a framework for a comprehensive food policy, it includes food and food production-related objectives and measures, focusing on food security and safety and on consumer prices.

Agricultural activities and the resulting environmental outcomes are also important factors in achieving policy objectives across a range of areas. These include the objectives of the EU nature legislation and the 2020 biodiversity strategy (in particular target 3A), objectives related to air pollution (National Emission Ceilings Directive), greenhouse gas (GHG) emissions (Effort Sharing Regulation and the LULUCF Regulation — on land use, land use change and forestry) and water quality (Water Framework Directive and Nitrates Directive). Agriculture also has a key role to play in achieving the Sustainable Development Goals (SDGs), particularly SDG 2 — zero hunger — and, for Europe, SDG 12 — responsible production and consumption. The 7th EAP also contains two objectives directly relevant to agriculture, namely, to ensure by 2020 (1) that the nutrient cycle is managed in a more sustainable way, and (2) that the use of plant protection products does not harm human health or the environment and such products are used sustainably.

([1]) This refers to the EU-28 and the primary sector as a whole, including agriculture, forestry and fisheries (DG Agriculture, 2017a).

13.2.2 Selected sectoral trends in Europe, including outlooks

The development of the agricultural sector, farming patterns and the environment

Agriculture across Europe is highly diverse, reflecting different biogeographic, economic, territorial and social conditions. The main share of land in Europe is used by agriculture, and the sector depends on the sustainable use of natural resources and ecosystem services such as pollination. Farming structures vary significantly across Europe and within countries.

The main share of land in Europe is used by agriculture and the sector depends on the sustainable use of natural resources and ecosystem services.

Agricultural production has increased since the 1950s as a result of a mix of European and national policy measures, production-related subsidies, technological innovations and market incentives (EEA, 2017c). The EU is broadly self-sufficient in most agricultural primary commodities, although this has decreased with increasing specialisation, and it is the single largest exporter of agri-food products globally (EC, 2016c). At the same time, the sector is strongly dependent on imports (notably unprocessed raw materials), such as soybeans used for livestock feed. Over the last decade energy and climate policies have driven an increase in energy crop production as a way of reducing reliance on fossil fuels (OECD/FAO, 2017).

In 2016, two thirds of the EU's farms were smaller than 5 ha and operating 6 % of the utilised agricultural area (UAA). However the general pattern of development in the agricultural sector has been towards a greater concentration of agriculture within the hands of relatively few large, often corporately owned, farms (Eurostat, 2016a), and in 2016, 3.3 % of farms were larger than 100 ha and operated 53 % of the UAA (Eurostat, 2019c).

While agricultural production has increased, the number of farms (and farmers) has been in decline (from 14.5 million farms in 2005 to 10.5 million in 2016) and is projected to decrease further with ageing farmers not being replaced (Eurostat, 2018a). Among the reasons for these developments are structural and technological changes, meaning that production takes place on fewer, larger and more capital-intensive farms (EC, 2016c). From 2007 to 2016 there has also been an increase in landless (zero-hectare) farms (Eurostat, 2018c). In the case of livestock, this type of production is less dependent on the availability of land and the environmental impacts are not always local.

There have also been changes in the extent and management of agricultural land. Grass- and cropland together make up 39 % of land cover in the EU. The proportion of total land accounted for by agricultural land is shrinking. The area of cropland, generally good quality arable land, is decreasing as a consequence of retiring farmers selling land and urbanisation but also because of afforestation and re-conversion of cropland to permanent grassland (OECD/FAO, 2017; Chapter 5). Efforts to increase production efficiency have driven increases in arable land parcel sizes across Europe, although trends vary regionally. This is frequently accompanied by a loss of landscape features (ETC ULS, 2019; Chapter 5). At the same time, agricultural land is falling fallow, because farming in marginal areas is being given up (IEEP, 2010; Terres et al., 2015).

Although the dominant trend remains towards intensification, around 9 % of agricultural land is part of Natura 2000 sites (DG Agriculture, 2017b) and around 30 % is classified as high nature value farmland (Chapter 5). The share of organic production in total agricultural production has also increased significantly in the EU and is projected to increase further. The area under organic farming increased by 18.7 % from 2012 to 2016 and now comprises 6.7 % of UAA (Eurostat, 2018d).

Agricultural production both contributes to climate change and is affected by climate change (Chapter 7; EEA, 2019a). In recent years, the sector has been increasingly affected by extreme weather events, leading to reduced yields (EEA, 2017b). Regionally, production in Europe might benefit from a longer vegetation period, leading to increasing yields of some crops. Adapting production can buffer climate-driven shocks, while affecting land use and land cover, and the traditional cultural landscape. In addition to ozone, other air pollutants also affect agricultural production.

Looking ahead, some short-term prospects for the sector can be outlined

based on current trends (based on EC, 2018a; OECD/FAO, 2017, 2018). Although there are regional and crop-related differences, productivity is projected to increase further. Steadily growing global demand for fresh dairy products and affordable feed prices should favour the livestock sector. Maize production is also expected to increase, while there will be a shift from rapeseed production to soybeans. This reflects the current trend towards an agricultural sector less oriented to producing biofuels and more to extending protein crop production.

Agriculture and environmental pressures

Agricultural activities in Europe have multiple impacts on the environment, climate and human health. Unsustainable farming practices lead to pollution of soil, water, air and food, overexploitation of natural resources and biodiversity loss and ecosystem degradation. Agricultural policy has been particularly influential in shaping European landscapes and the nature they contain. The pressures and threats for all terrestrial species, habitats and ecosystems most frequently reported by Member States are associated with agriculture (EEA, 2015). Europe is experiencing a decline in biodiversity primarily due to the loss, fragmentation and degradation of natural and semi-natural ecosystems and agricultural intensification is one of the main causes (Chapter 3).

Figure 13.1 presents selected agricultural activities and their related environmental pressures and impacts including nutrient emissions, ammonia (NH_3) and GHG emissions, pesticide and antibiotic use, soil compaction and water use. Past trends and outlooks are shown at EU level, which does not account for variation across Europe and between different types of farming practices.

> Agricultural intensification is one of the main causes of biodiversity loss and ecosystem degradation in Europe.

For some environmental pressures from agriculture no clear improving trends in absolute figures can be observed, whereas other pressures such as GHG and NH_3 emissions have increased in recent years (Figure 13.1). For instance, pesticide sales have remained relatively stable since 2011. While there are limitations to linking trends in sales with risks to human health and the environment, the use of pesticides has far-reaching impacts on food chains, soil health and biodiversity (Chapters 3, 4, 5 and 10). The share of GHG emissions from agriculture is currently around 10 % and while overall emissions have declined from 1990, in the last few years they have increased from both livestock and soils (Chapter 7).

Agriculture is the economic sector in which air pollutant emissions have been reduced the least and it is the main source of NH_3 emissions. While NH_3 emissions decreased in the EU in the period 1990-2010, they are still high and have increased since 2013, driven primarily by livestock production. This impacts aquatic and terrestrial ecosystems and also favours the formation of secondary particulate matter in the air, contributing to exceedances of air quality standards and impacting human health. In spring time these exceedances are mostly due to NH_3 coming from the use of fertilisers and nitrogen oxide (NO_x) emissions from urban traffic (Chapter 8).

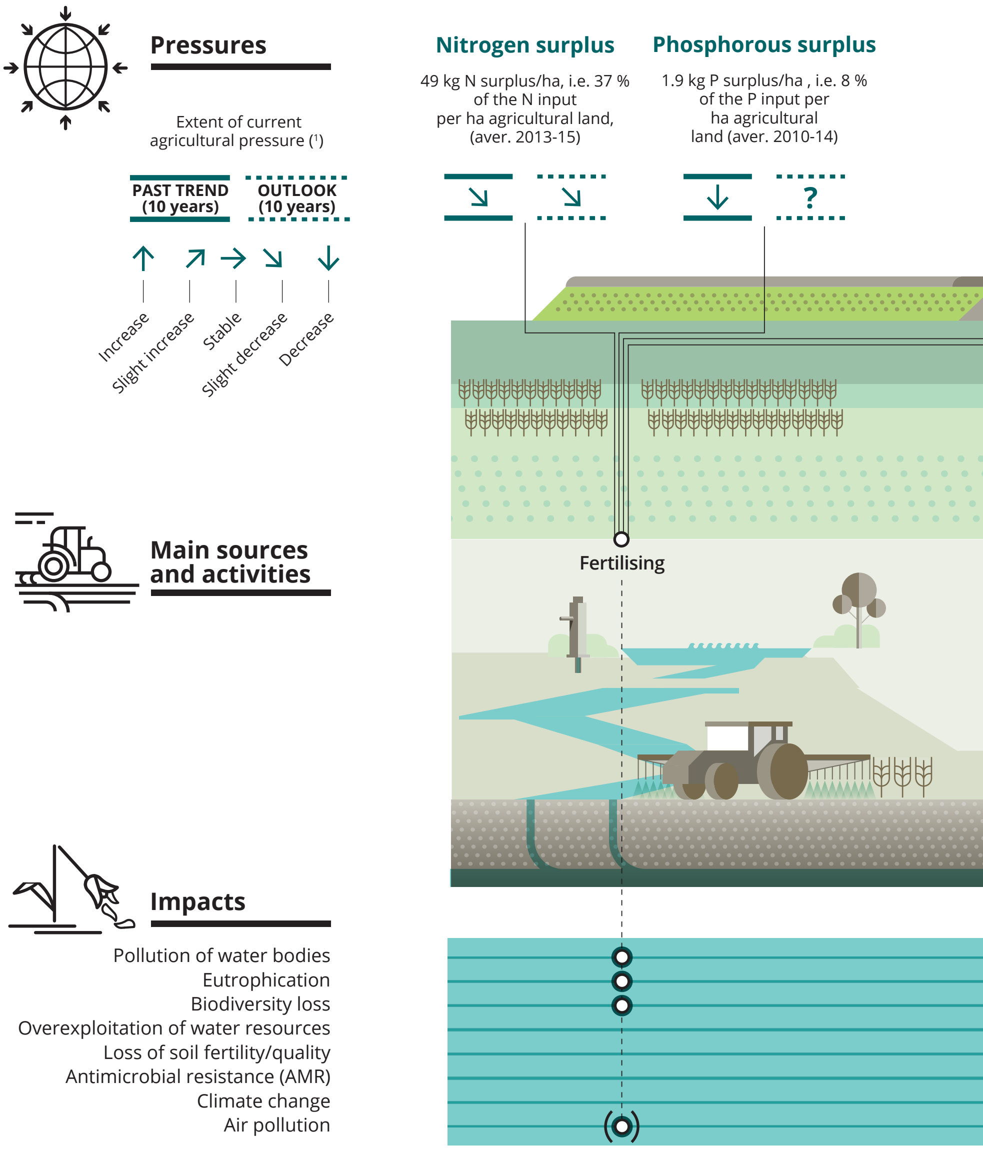
The use of nitrogen-based fertilisers in agriculture is a primary cause of diffuse pollution, one of the main environmental pressures from agriculture. Excess nitrogen discharges to the environment (soil, air and water) results in systemic environmental problems such as eutrophication. Run-off and leaching from agricultural land has been identified as the main source of nitrogen in surface and ground water bodies (Chapter 4). Nitrogen losses are captured in the nitrogen balance ([2]), which is used to assess performance regarding nutrient emissions by estimating the nitrogen surplus to the environment. Important determinants of nitrogen surplus are the amount of overall fertiliser applied to fields and the uptake by grass and harvested plants, which are influenced by farm management decisions.

The nitrogen surplus has decreased over the years from very high levels in the 1990s. From 2000 to 2015, the gross nitrogen balance improved, although this trend has levelled out since 2010 (Figure 13.2). Over the period 2000-2015, the efficiency of nitrogen use (total nitrogen outputs divided by total nitrogen inputs) also increased, contributing to the improving trend in the nitrogen balance (Figure 13.2) (Eurostat, 2018b). However, this efficiency increase did not result in significant decreases in nutrient losses. The EU as a whole and some regions in particular still have an unacceptable surplus of nitrogen

([2]) For information on the ‘Agricultural land: nitrogen balance’ indicator, references, and country-level information, see www.eea.europa.eu/airs/2018/natural-capital/agricultural-land-nitrogen-balance.

FIGURE 13.1 Pressures and impacts from agriculture on the environment — past trends and outlooks, EU-28

Agriculture has multiple impacts on the environment, climate and human health. This figure presents selected agricultural activities and their related environmental pressures and impacts. Unsustainable farming practices lead to pollution of soil, water, air and food and over-exploitation of natural resources. Past trends and outlooks show a mixed picture regarding the environmental sustainability of the agriculture sector.



Nitrogen surplus
Agriculture is the main user of nitrogen (N) globally. Over-use of N fertilisers causes eutrophication of aquatic and terrestrial ecosystems (Chapter 4, 6 and 14).

Phosphorous surplus
If more phosphorus (P) fertiliser is applied than taken up by plants, it may result in pollution of e.g. ground and freshwater and cause eutrophication (Chapter 4).

Notes:

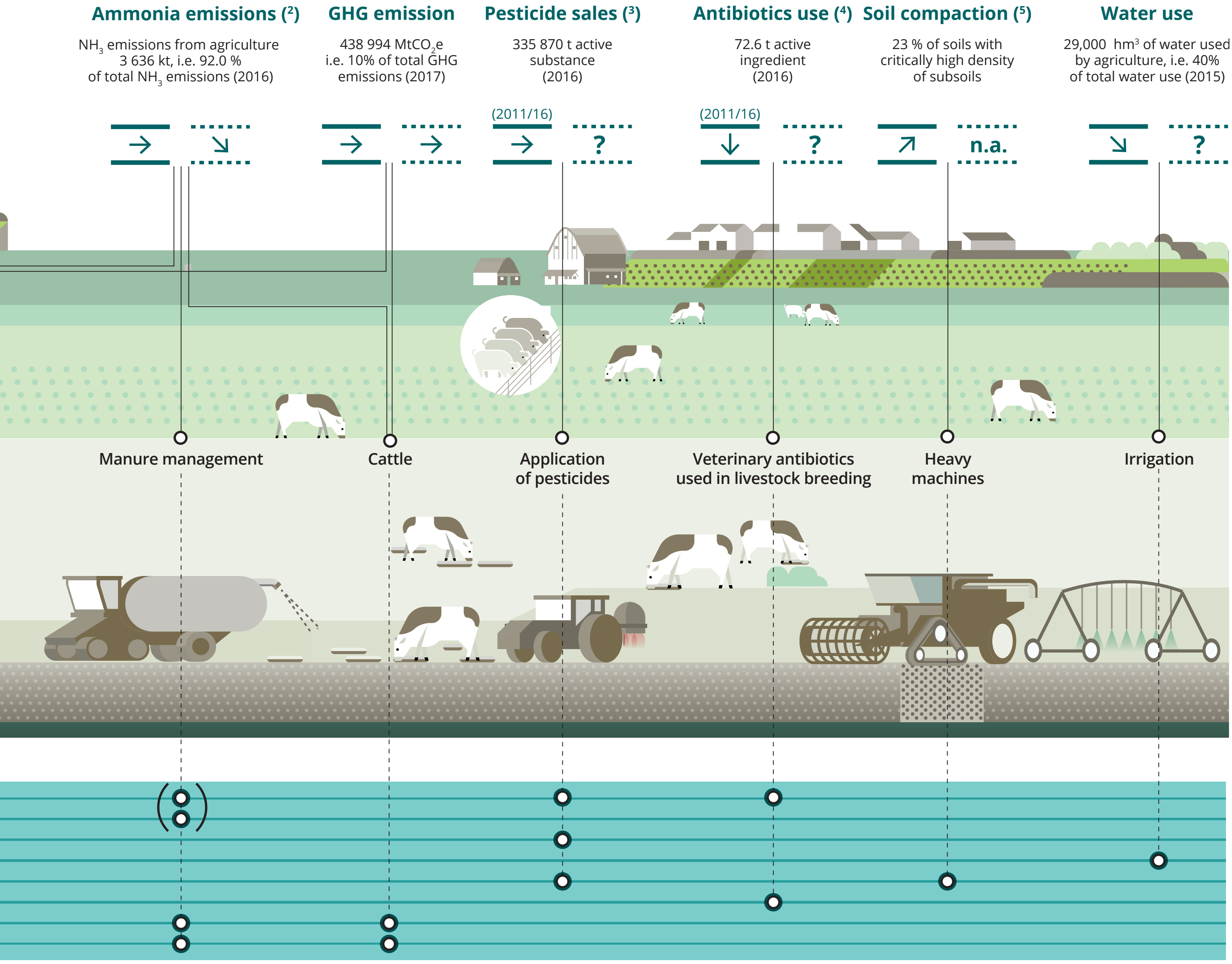
(1) If not stated otherwise, the assessment period for past trends is around 10 years, and the outlooks are provided for the year 2030. Trends are classified as 'stable' if changes are not larger than +- 1 %, as 'slightly increasing/decreasing', if changes are smaller than +/-/= 5 %, as 'increasing/ decreasing' if changes are larger than 5 %. For the outlooks projections are referring to scenarios with existing policy measures.

(2) Data for 2017 for 27 MS.

(3) Data for 16 Member States.

(4) Data for 25 Member States (past trend), data for 27 Member States (outlook).

(5) Based on expert assessment.



Ammonia emissions
Ammonia (NH_3) emissions from e.g. manure management result in air pollution and can bring harm to sensitive ecosystems (Chapter 8).

GHG emission
GHG emissions from e.g. livestock farming, agricultural land, fertilizer use and enteric fermentation contribute to climate change (Chapter 7).

Pesticide sales
Agriculture is the main user of pesticides in most countries. Pesticides have been linked to impacts on biodiversity and human health (Chapter 10).

Antibiotics use
Sold veterinary antibiotics are mainly used in animal breeding. Over use and untailored use (Chapter 10) may cause Antimicrobial resistance (AMR).

Soil compaction
Soil compaction may cause loss of soil fertility and reduce the capacity of soils to retain water and store carbon (Chapter 5).

Water use
Agriculture is a main user of freshwater resources. Overexploitation may lead to decreasing groundwater levels, salt water intrusion and loss of wetlands (Chapter 4).

FIGURE 13.2 Development of the gross nitrogen balance, nitrogen use efficiency and gross value added, EU-27

Notes: GNB, gross nitrogen balance; NUE, nitrogen use efficiency; GVA (agri), agricultural gross value added (agricultural industry). GNB and NUE are based on Eurostat data (aei_pr_gnb), Eurostat estimates for Estonia (2015), Romania and Croatia (2004-2014) Belgium, Bulgaria, Denmark, Greece, Italy, Cyprus, Latvia, Lithuania, Luxembourg, Malta (2004-2015). GVA of the agricultural industry (values at current prices) based on Eurostat data (tag00056), economic accounts for agriculture — values at current prices.

Source: EEA calculations based on Eurostat data. 2005 = 1.

from agricultural land, and nutrient levels still exceed nutrient critical loads in most of the EU. Looking ahead, a decrease of 2.6 % in comparison to 2008 is projected for the average nitrogen surplus in the EU by 2030. The largest fall in the surplus is projected in regions where a reduction in livestock herd size is expected (EC, 2017b).

Many factors can influence the development of the nitrogen balance and trends vary regionally. These factors include ambitions to reduce production costs, policy measures, the availability and prices of different types of nitrogen fertilisers and livestock numbers (EC, 2011b; Eurostat, 2018b). Efficiency gains observed in Europe may have been achieved by adapting nitrogen management, such as changes in fertiliser application techniques or by more targeted selection of varieties (Balafoutis et al., 2017; Schrijver, 2016; Zarco-Tejada et al., 2014).

Technological developments have the potential to enable more targeted use of inputs. However, such synergies between environmental and economic interests do not occur when it comes to the structure and diversity of agricultural landscapes, and soil quality and health. Efforts to increase production efficiency and income have resulted in increasing land parcel sizes, a reduction in landscape features and drainage of land. This consolidation, increasing homogeneity and change in the use of agricultural landscapes has been linked to negative impacts on biodiversity and soil (ETC/ULS, 2019; Chapters 3 and 5).

In addition, various pressures from agriculture can have combined impacts on ecosystems and have cumulative effects. For example, in relation to soil, pesticide use can reduce soil biodiversity, irrigation can lead to salinisation, soil compaction resulting from heavy machinery use can reduce growth and resilience of crops as well as carbon formation and water retention capacity, and the risk of soil erosion is also increased through compaction as well as through increased land parcel size (Chapter 5).

Reducing the environmental impact of agriculture would improve progress across a range of environment and climate policy objectives.

13.2.3
Responses and prospects of meeting agreed targets and objectives

Reducing the environmental impact of agricultural activities would contribute to improved progress towards a wide range of environment and climate policy objectives. Available indicators show limited progress regarding the likelihood of achieving the sector-related objectives in the 7th EAP, namely that the nutrient cycle is managed in a more sustainable way and that the use of plant protection products does not harm human health or the environment and such products are used sustainably. The Environmental Implementation Review highlighted NH_3 emissions and water pollution from nitrates caused by intensive agricultural activities as areas where efforts need to be increased (EC, 2019).

Emission-related impacts from agriculture to the environment can be reduced to a certain extent through more efficient and targeted use of inputs to agricultural production and innovation and new technologies. However, efficiency gains do not necessarily contribute to the reduction in all types of pressures, especially those related to landscapes, biodiversity and soils. The use of more environmentally sustainable farming practices such as organic agriculture and agroecology offers the potential to reduce a broader range of environmental pressures.

One of the main mechanisms to address environmental pressures from agriculture has been mainstreaming of environment and climate objectives into the CAP. There are three main mechanisms used: (1) cross-compliance; (2) greening measures; and (3) a set of voluntary measures including agri-environmental measures.

Cross-compliance was first introduced in 2003 and is a prerequisite for receiving several types of CAP funds. It currently comprises (1) statutory management requirements selected from existing directives and regulations on environment, food safety, plant and animal health, which apply to all farmers; and (2) additional standards for good agricultural and environmental conditions (GAEC), which apply only to CAP beneficiaries and deal with the protection of water, soil and carbon stocks and the maintenance of land and landscape features. Non-compliance may result in sanctions (based on EC, 2011b, 2013d; Alliance Environnement, 2007; ECA, 2017).

Greening measures were introduced in the period 2014-2020 and target the majority of farmers receiving direct payments. They comprise establishing ecological focus areas, crop diversification schemes and maintaining permanent grassland. The aim of greening measures is to make more farmers deliver environment and climate benefits, going beyond cross-compliance and acknowledging the provision of public goods (EC, 2011b).

A range of voluntary measures drives the mainstreaming of environmental and climate concerns into the CAP. Under Pillar 2, Member States have to spend at least 30 % of their budgets on measures related to environment and climate mitigation. Flexibility is given in selecting measures offered under national or regional rural development programmes. These include area-based agri-environmental-climate schemes, support for organic farming, farming in areas with natural constraints, investments in sustainable production and providing farm advisory systems covering several environment- and climate-related subjects.

The share of UAA subject to the different regimes provides an indication of their outreach and their theoretical potential but not of their effectiveness. In 2016, 83 % of UAA was subject to cross-compliance; 77 % was subject to at least one greening obligation and 10 % was under GAEC (DG Agriculture, 2019).

While environment, climate and public concerns are considered within the CAP, assessing its environmental and climate performance is challenging for several reasons. Firstly, there is a lack of target setting at the level of environmental impacts. Assessing policy performance on the basis of the extent of area under certain management regimes, or budget allocated, assumes that the measures implemented are effective and there is compliance with standards. Secondly, while the CAP is a common EU policy, implementation patterns vary among Member States and the degree of Member States' flexibility has increased. Thirdly, the environmental performance of the sector does not equal that of the CAP, as farmers' decisions are not only influenced by policies. Finally, responsibilities for mainstreaming and/or achieving environment and climate objectives related to agriculture vary. For instance, the EU 2020 biodiversity strategy explicitly requires concrete action in the field of the CAP initiated at European and national level. In contrast, the CAP contributes to climate mitigation and adaptation more generally by offering instruments to enable Member States to achieve their national targets, and Member States are responsible for achieving such targets and deciding on the means of doing so.

Nevertheless, some conclusions on the CAP's effectiveness in relation to the environment can be made. Cross-compliance has led to some reduction in pressures on the environment, for example nutrient emissions. Yet, there is still non-compliance by farmers, cases of infringement and potential for improving implementation at all levels (farmer, national, EU) (ECA, 2016). Greening is commonly considered an inefficient policy instrument that has not led to significant changes in farming practices, and the degree of flexibility decreases its potential (Alliance Environnement, 2017; ECA, 2017; Brown et al., 2019). For CAP Pillar 2, the share of 30 % of spending on measures related to the environment and climate will be achieved. However, Member States' political wills and ambitions are key determinants of the effective use of Pillar 2.

Overall, the integration of environmental objectives into the CAP does appear to have resulted in some reductions in environmental pressures such as nutrient emissions. The market reform of the CAP has also been identified as contributing to a reduction in GHG emissions from methane and nitrous oxide (Chapter 7). However, the portfolio of CAP instruments can be used and implemented more effectively for the benefit of the environment and climate mitigation (Brown et al., 2019; ENRD, 2017; Terluin et al., 2017; Zezza, 2017).

> Farmers share the aim of a sustainable and resilient food system.

In general, and in line with developments in other sectors, quantitative and enforceable targets that go beyond the assessment of budget spend could stimulate more effective and impact-oriented implementation of the CAP. Although there are some challenges in defining such targets, they could include environmental pressures directly linked to agriculture and captured in agri-environment indicators, for example NH_3 emissions, water quality, soil quality, gross nitrogen balance and impacts on biodiversity as indicated by trends in populations of farmland birds.

Looking ahead to the future of the CAP post 2020, current legislative proposals aim to make the CAP more responsive to current and future challenges. The nine objectives are economic (ensure a fair income to farmers; increase competitiveness; rebalance the power in the food chain); environmental (climate change action; environmental care; preserve landscapes and biodiversity); and social (support generational renewal; vibrant rural areas; protect food and health quality). The outcomes will largely depend on how Member States use the tools provided at European level to tailor ambitious action towards those objectives, as the level of national flexibility will further increase. Therefore, flexibility has risks around reduced levels of ambition and compliance as well as opportunities to take an integrated approach that addresses trade-offs between objectives.

Simultaneously addressing multiple ecosystem services was identified as one factor for increasing the effectiveness, efficiency and equity of the CAP (IPBES, 2018). As flexibility may also lead to lower environmental ambitions, a common set of mandatory minimum conditions and production standards is required, such as maintaining landscape features, minimum soil cover and crop diversification and rotation. Lessons learnt suggest that supplementing these with measures that are based on scientific evidence of their effectiveness and tailored to regional needs and site-specific conditions will be needed to achieve noteworthy nature conservation progress (Brown et al., 2019; Pe'er et al., 2017; EC, 2015b, 2016b; Sutherland et al., 2017).

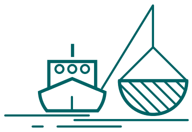
Currently, European farmers face many pressures and often run their businesses sandwiched between the immense upstream market power of input suppliers and downstream food processers and retailers (Buckwell et al., 2017). Yet, the objectives of the 7th EAP and the SDGs and the long-term interests of farmers are the same — a sustainable and resilient food system. This highlights the need to think beyond the CAP and take a food systems approach. Doing so expands the focus of attention from producers to other actors and identifies effective interventions that go beyond a sectoral approach (Chapter 16).

13.3 Marine fisheries and aquaculture

13.3.1 Socio-economic relevance of the sector and policy landscape

Fisheries and aquaculture products are an important source of protein and a crucial component of a healthy diet. They deliver important ecosystem services to society. In the EU, commercial fisheries provided about 152 720 jobs in 2017 (STECF, 2017) and aquaculture accounted for about 75 300 jobs in 2016 (STECF, 2018a). Although relatively small, the fishing sector plays an important societal role by providing economic activity and employment in many coastal communities.

The EU fishing fleet is very diverse, with the vast majority of boats less than 12 metres long, a smaller number of vessels exceeding 40 metres in length and a still poorly understood number of recreational fishery vessels ([3]). From an economic perspective, overall the EU fleet is profitable (STECF, 2018b). Fisheries depend on healthy seas more than any other industry, as healthy, well-managed oceans are a prerequisite for long-term investments and job creation in fisheries and the broader blue economy. Well-managed fisheries result in a cascade of positive outcomes, including increased income to fishers and reduced impacts on the wider environment.



Fisheries is an important sector providing economic activity and employment in many coastal communities.

In Europe, fish stocks and fishing fleets are managed by the common fisheries policy (CFP) ([4]). The CFP also includes rules on aquaculture, which are reinforced by the blue growth agenda component. The CFP applies to all vessels fishing in European waters and also to European vessels fishing in non-European waters. The scope of the CFP includes the conservation of marine biological resources and the sustainable management of fisheries targeting them. To that end, the CFP is adapting exploitation rates to ensure that, within a reasonable time frame, the exploitation of marine biological resources is restored and populations of harvested stocks are maintained above levels that can produce the maximum sustainable yield (MSY ([5])). In parallel, safeguarding healthy commercial fish and shellfish populations is one of the 11 descriptors (descriptor 3 ([6])) of the Marine Strategy Framework Directive (MSFD) for achieving good environmental status (GES). This objective is closely related to the objectives of the CFP, in particular the objective of ensuring MSY for all stocks by 2015 where possible, and at the latest by 2020. In addition, the MSFD also addresses sea floor integrity in descriptor 6 ([7]). Sea floor integrity is a key compartment for marine life, and some fishing practices such as trawling and dredging jeopardise it. Also closely related to the objectives of the CFP are commitments in the EU 2020 biodiversity strategy, in particular target 4, which requires that, by 2015, fishing is sustainable and that, by 2020, fish stocks are healthy. Fishing must have no significant adverse impacts on species and ecosystems, so that all European oceans and seas can be ecologically diverse and dynamic, as well as clean, healthy and productive by 2020.

In the context of the EU integrated maritime policy, the combination of these two key policy instruments (CFP and MSFD), along with biodiversity conservation measures under the Birds and Habitats Directives and the EU Directive on Maritime Spatial Planning (2014/89/EU) constitute the basis for the EU to deliver on its commitments to achieving healthy and productive seas as well as ensuring appropriate conservation and sustainable use of the European regional seas. Furthermore, these policy measures contribute to the overall EU vision defined in the 7th EAP of 'living well, within the limits of the planet' and more recently within the global framework on SDGs, in particular the fishing-related targets within SDG 14 on life below water.

([3]) Based on data submitted by Member States under the data collection framework, there were 63 976 active vessels and 20 444 inactive vessels in 2015. Of the active vessels, 74 % were classed as small-scale coastal vessels, 25 % as large-scale vessels and the remaining 1 % as distant-water vessels (STECF, 2017).

([4]) The CFP was first introduced in the 1970s and went through successive updates, the most recent of which took effect on 1 January 2014.

([5]) MSY is the maximum catch (in numbers or mass) that, on average, can be removed from a population (or stock) over an indefinite period. Exploiting fish stocks at or below MSY allows them to be maintained or recovered to healthy levels, providing food for consumers while contributing to important ecosystem and marine food web functions.

([6]) Descriptor 3: populations of all commercially exploited fish and shellfish are within safe biological limits, exhibiting a population age and size distribution that is indicative of a healthy stock. Three criteria for good environmental status have been identified for the commercial fish and shellfish: (1) level of exploitation; (2) reproductive capacity; and (3) healthy age and size distribution.

([7]) Descriptor 6: sea floor integrity is at a level that ensures that the structure and functions of the ecosystems are safeguarded and that benthic ecosystems, in particular, are not adversely affected.

The overall use of fish and shellfish stocks in Europe is beyond the limits for long-term sustainability.

13.3.2 Selected sectoral trends in Europe, including outlooks

Production of fish and aquaculture

In the EU, 80 % of production comes from fisheries and 20 % from aquaculture. In Europe there has been a steady decline in production since 2000 in both aquaculture (by 16 %) and capture fisheries (by 17 %; Eurostat, 2017). In 2015, total production of fishery products in Europe was an estimated 6.4 million tonnes (live weight equivalent). The EU is the fourth largest seafood producer worldwide, accounting for about 3 % of global fisheries and aquaculture production in 2015, compared with China, which produced 39 % (EUMOFA, 2018). There is a difference between the EEA member countries and cooperating countries (EEA-39), where pisces marine aquaculture (~60 %) dominates total aquaculture production, and the EU Member States (EU-28), where mollusca marine aquaculture (~50 %, comprising mussels, oysters and clams) accounts for around half of total production. The countries that contribute the most to European production (EEA-39) are Norway (approximately 46 %), followed by Spain, Turkey, the United Kingdom, France, Italy and Greece. Together these seven countries account for 90 % of all aquaculture production in Europe. Norway's production is nearly all farming of Atlantic salmon. Turkish production consists mainly of trout (inland), sea bream and sea bass (marine) (EEA, 2018c).

Overall impacts

Fish stocks are a renewable resource if exploited in an appropriate manner. Overfishing has been historically present in all EU regional seas (Jackson et al., 2001). This causes changes to marine food webs affecting species composition and abundance, and incidental catches of non-target species increase the magnitude of such change. Other impacts, for example damage to the seabed, are related to fishing methods and the type of fishing gear used.

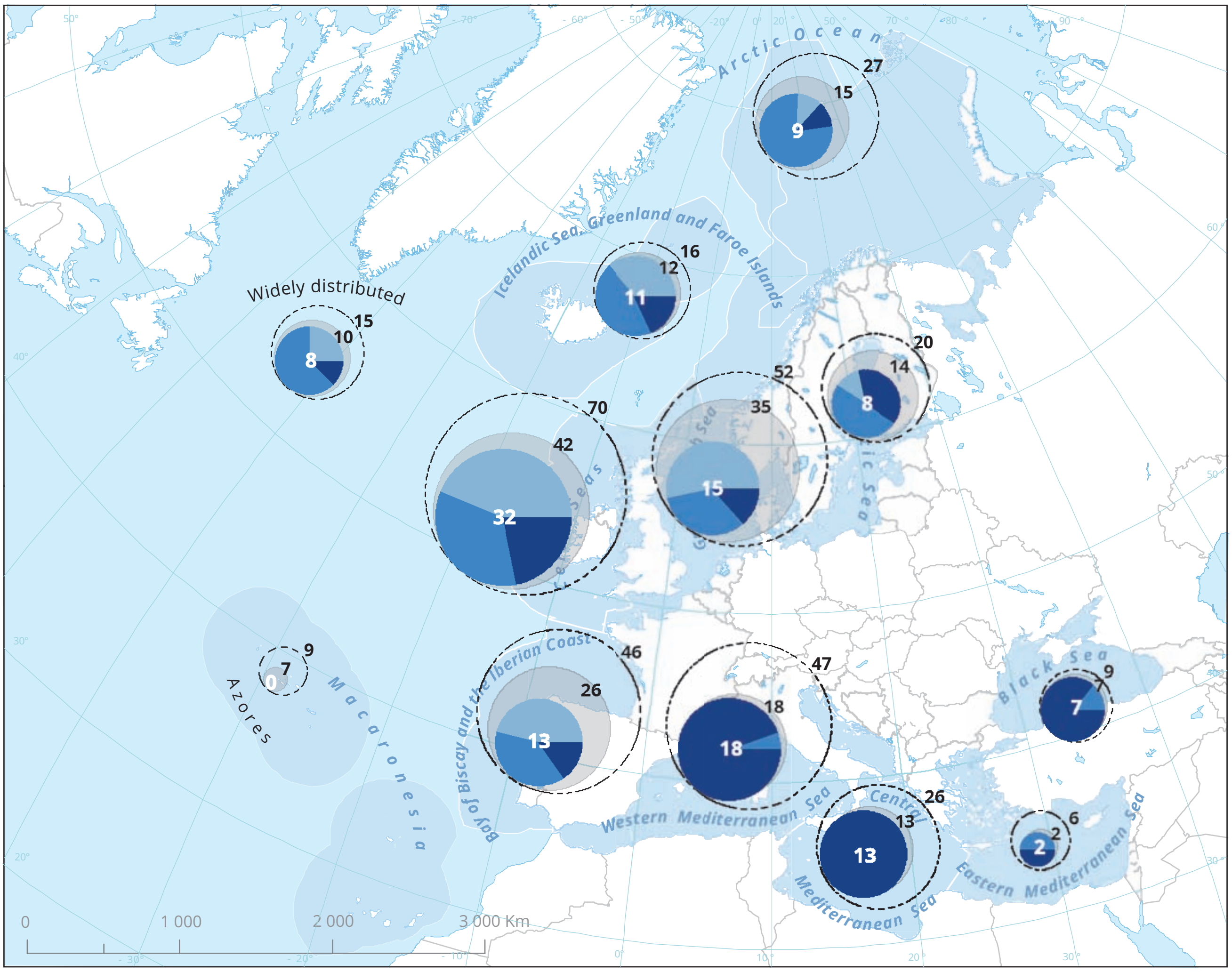
Aquaculture can include the culture of fish, shellfish and algae. Farming is carried out in land-based systems, such as recirculating systems, ponds or tanks (e.g. trout) or water-based systems in coastal (e.g. clams), onshore or offshore waters, using structures such as pens (e.g. salmon) and ropes (e.g. algae, mussels). Bivalves and algae extract food from the water column and do not require feeding in culture. Bivalves remove particulate organic matter and algae remove dissolved inorganic matter, which provides ecosystem services such as carbon sequestration and nutrient removal and has a lower environmental impact than the culture of fed species. Algae are also farmed in closed recirculating systems with almost complete water-recycling rates.

Finfish are cultured in closed systems, with minimal impact, and in open systems in the natural environment. Finfish at higher trophic levels require feeding, leading to impacts on the benthic ecosystem and surrounding environment due to the accumulation of faecal matter and uneaten feed. Integrated multi-trophic aquaculture addresses this issue by integrating the culture of species at different trophic levels (e.g. finfish, mussels, algae), with one species removing the nutrients produced by the other, in a circular loop, minimising losses to the environment. Concerns over the use of antibiotics have decreased considerably in recent years because of a drastic reduction in their use for the top cultured finfish species (e.g. salmon), but this still remains to be addressed at a wider level. A further environmental concern regarding the culture of fed species comes from fishing for feed, as fisheries are the main source of fishmeal and fish oil. Escapees of any cultured species, both native and exotic, can compete with wild stocks for habitat and food. Fisheries, fish and shellfish farming are all also a source of marine litter, and lost gear can cause additional damage to ecosystems by 'ghost fishing' and degrading to create microplastics.

Status of stocks

The overall use of fish and shellfish stocks in Europe currently remains beyond the limit for long-term environmental sustainability (Map 13.1). The latest available information shows that around 55% of the assessed fish and shellfish stocks in Europe's seas for which sufficient information is available, are in good status when assessing against the level of fishing mortality, their reproductive capacity, or both criteria. Of the assessed stocks, 27 % are in good status according to both fishing pressure and reproductive capacity (i.e. spawning stock biomass), and 28.5 % are in good status according to one of the two criteria (Map 13.1). 45 % of assessed stocks are not in good status. These percentages vary considerably between EU marine regions — from at least 62-87.5 % of the stocks meeting at least one of the GES criteria in the regions in the NE Atlantic and the Baltic Sea to only two out of 33 (6 %) and one out of 7 (14.3 %) in the

MAP 13.1 **Status of the assessed European commercial fish and shellfish stocks in relation to good environmental status per EU marine region, 2015-2017**



Status of the assessed European fish and shellfish stocks in relation to Good Environmental Status (GES) per EU Marine Region in 2015-2017

Number of assessed stocks for which adequate information is available to determine GES (X)

- Stocks in good status based on both fishing mortality and reproductive capacity
- Stocks in good status based on only one of fishing mortality or reproductive capacity
- Stocks not in good status based on both fishing mortality and reproductive capacity

Total number of assessed stocks (Y)

Total number of stocks (Z)

Note: This figure shows the status of the assessed European commercially exploited fish and shellfish stocks in relation to 'good environmental status' (GES) per EU marine region in 2017 (2016 data for the Mediterranean and Black seas). Stocks for which adequate information is available to determine GES for fishing mortality (F) and/or reproductive capacity (spawning stock biomass (SSB)) are included (where Z, total number of stocks; Y, total number of assessed stocks; and X, number of stocks for which adequate information is available to determine GES on the basis of these two criteria). A distinction is made between stocks in (1) good status based on both F and SSB; (2) in good status based on only one criteria, F or SSB (either because one of the two criteria are not in good status or there is only one available criteria and it is in good status); and (3) not in good status (based on both F and SSB or there is only one criteria available and it is not in good status). See EEA (2019b) methodology section for further information on how good status is determined. As assessments are carried out in a multiannual cycle within the Mediterranean Sea, the number of stocks included for this region depends on the period covered.

Mediterranean Sea and the Black Sea respectively (EEA, 2019b).

In addition, the EU faces the dual challenge of the need to assess more stocks and the need for better information on all stocks to inform MSY-based stock assessments. Despite recent improvements in the North-East Atlantic, a major step change is required to reduce both the proportion of total allowable catches (TACs) [8] set above scientific recommendations and the number of TACs set without scientific recommendations, as this curtails opportunities for earlier recovery of stocks. Strong management decisions and transparent decision-making processes are required if TACs are to be brought into line with scientific advice by 2020 (Nimmo and Cappell, 2017).

13.3.3 Responses and prospects of meeting agreed targets and objectives

Environmental ambitions and objectives are strong policy drivers for fisheries management in Europe. Mainstreaming of environmental considerations is in place, and high-level objectives, such as the MSFD's and CFP's objectives related to achieving GES for the marine environment, have provided a basis for policy alignment. Evidence demonstrates that targeted policy actions and committed management efforts can protect and/or restore species and habitats and can help to preserve ecosystem integrity. Fisheries management efforts are clear examples of positive action and illustrate the effect of policies on trends in some long-term pressures in the North-East Atlantic Ocean and Baltic Sea (Chapter 6, Figure 6.5). Since the early 2000s, better management of fish and shellfish stocks has contributed to a clear decrease in fishing pressure in these two regional seas. Signs of recovery in the reproductive capacity of several fish and shellfish stocks have started to appear. If these efforts continue, meeting the 2020 objective for healthy fish and shellfish stocks in the North-East Atlantic Ocean and Baltic Sea could be possible, based on two of the three MSFD criteria (i.e. fishing mortality and reproductive capacity) (EEA, 2019b).

Healthy fish populations depend on healthy marine ecosystems.

In contrast, there is no sign of improvement in the Mediterranean and Black Seas, where about 92 % of the stocks assessed are fished at biologically unsustainable levels (EEA, 2019b). These levels require urgent action, and success will depend on the availability and quality of marine information, the political will to implement scientific recommendations, and adequate uptake of management measures. In addition to improved scientific information, greater accessibility to already available information would enable more effective monitoring of progress towards CFP objectives.

European policy is also having a wider impact globally. The EU is by far the largest single market for seafood (EUMOFA, 2018; FAO, 2018) and has used this important leverage to drive a reduction in illegal, unreported and unregulated (IUU) fishing through its IUU Regulation, introduced in 2010. The EU's market leverage in combination with the IUU Regulation can drive improvement in the social and environmental performance of EU source fisheries worldwide. Although a balance would have to be achieved between fair market access and social and environmental performance, consolidation and application of international standards offers a route for the EU to facilitate improvement of source fisheries to performance levels consistent with the CFP. The upside of improving fisheries management worldwide has been quantified at up to USD 83 billion, 15 % of which would be gains resulting from applying the CFP in EU fisheries (World Bank, 2017).

Ensuring healthy fish and shellfish populations does not depend solely on fishing at environmentally sustainable levels. Healthy fish populations depend on healthy marine ecosystems. Attempts to manage Europe's seas must account for the global context, multiple interactions between society and the environment, and possible unexpected changes. This will improve system understanding and help identify novel interlinkages and drivers of change, providing insights into potential future problems. Europe's marine ecosystems continue to display symptoms of degradation and loss of resilience, which will be exacerbated by the effects of climate change (Chapter 6). Without an integrated approach to the management and protection of Europe's seas, the outlook beyond 2020 for productive seas and healthy fish and shellfish populations will continue to give cause for concern.

[8] Total allowable catches, or fishing opportunities, are catch limits (expressed in tonnes or numbers) that are set for most commercial fish stocks. The Commission prepares the proposals, based on scientific advice on the stock status from advisory bodies such as the International Council for the Exploration of the Sea and the Scientific, Technical and Economic Committee for Fisheries.

13.4 Forestry

13.4.1 Socio-economic relevance of the sector and policy landscape

According to pan-European statistics, forests cover more than 40 % of the EEA-39 region. In addition to wood supply, European forest ecosystems provide multiple functions. They host a major part of Europe's biodiversity, deliver inputs to other economic sectors, and provide forest products and ecosystem services for society and human well-being (EEA, 2016b).

Economically, Europe is one of the world's biggest roundwood producers (Forest Europe, 2015a). In 2015, about 420 000 enterprises were active in wood-based industries across the EU-28; representing 20 % of manufacturing enterprises (Eurostat, 2017). The forest-based sector contributes around 7-8 % of the EU's manufacturing GDP and employs over 3.4 million people (Eurostat, 2018a). Socially, forests have excellent recreational value and are an important part of landscape amenities and cultural heritage, and deliver improved human health and well-being, as well as employment in rural regions of Europe.

Although there is no common European forest policy in terms of a legal framework, forests are addressed across a range of environment and climate policies. The ecosystem dimension of forests is addressed in the 7th EAP, the Birds and Habitats Directives and the EU biodiversity strategy. The productive role of forests is relevant to the Renewable Energy Directive. The current EU forest strategy (EC, 2013a) embraces forest-related elements of various strategies and policies and its implementation relates to the bioeconomy strategy (EC, 2018a), circular economy package (EC, 2015a) and, following the Paris Agreement, the LULUCF Regulation. These objectives are also supported by global initiatives, such as the SDGs (15.2), the Convention on Biological Diversity and the United Nations Framework Convention on Climate Change, where the prevention of deforestation receives primary attention through reducing emissions from deforestation and degradation. The role of forests in mitigating the risks of natural disasters is stressed in the Sendai Framework for Disaster Risk Reduction (UN, 2015).

> Forests comprise 48 % of the Natura 2000 network and their use for wood production is restricted.

European forestry has a long tradition of developing and applying sustainable forest management (SFM), which has been monitored since 1998 based on an agreed set of six criteria and 52 indicators, capturing the multiple productive, social and environmental functions and services of forests (Forest Europe, 2015a). SFM aims to ensure a range of forest ecosystem services such as the protection and maintenance of biodiversity, as forests contain the greatest variety of species found in any terrestrial ecosystem, as well as protection against landslides, and water and air purification (EEA, 2016b; Thorsen et al., 2014).

13.4.2 Selected sectoral trends in Europe, including outlooks

How forest natural capital is managed is decisive for the condition of forest biodiversity and ecosystems and for the provision of products and ecosystem services. According to Corine Land Cover analyses, the forest area is overall stable in Europe (EEA, 2018d; Chapter 5). Close to 90 % of European forests are available for wood supply, and they are mostly managed in accordance with the principles of SFM. Less than 5 % of European forest areas are considered undisturbed, or natural) (Forest Europe, 2015b), while less than 1 % can be considered primary or virgin forests (Sabatini et al., 2018). Thirty million hectares of forests are protected as Natura 2000 areas, equalling 48 % of all Natura 2000 protected areas, and their use for wood production is restricted.

Supply of forest products and services

The dominant product provided by forests is wood. Reported roundwood production in the EU-28 reached 458 million m^3 in 2016 (Eurostat, 2018a). Of this, 21.6 % was used as fuelwood and the rest was industrial roundwood used for sawn wood and veneers, pulp and paper production. While EU industrial roundwood production has remained on average 45 million m^3 lower than in 2007, the production and trade of wood for fuel has grown substantially since 2010, and increasing demand has been driven by policy objectives to increase the use of energy from renewable sources.

Wood products such as pellets and briquettes account for 45 % of the EU-28's gross inland energy consumption of renewables, reaching more than 70 % in some countries. Imports of wood pellets from outside Europe have doubled reaching 6 billion tonnes in 2015 (Eurostat, 2018a). Timber production is projected to double over the next two decades (Bais-Moleman et al., 2018), which may result in challenges for the forest-based sector's ability to mobilise wood. Less than two thirds of Europe's forest growing stock was mobilised in

the period from 1990 to 2016 (Forest Europe, 2015a). This is likely to be due to the fragmented ownership of forests, which creates difficulty in accessing and mobilising wood resources. About 60 % of the European forests are privately owned, of which more than 60 % have an area of less than 1 ha; the average size of holdings is below 5 ha (Schmithüsen and Hirsch, 2010). However, recent studies indicate that reported removals might be underestimated (Camia et al., 2018; Schelhaas et al., 2018; Chapter 5).

The forest-based sector also supplies non-wood products, such as cork, mushrooms, berries, game, many of which are not marketed, although their value has been estimated at EUR 723 million, indicating their economic importance (Forest Europe, 2015a). Furthermore, in line with the new bioeconomy strategy, the forest sector is increasingly exploring novel products, such as bioplastics, biocomposites, wood-based textiles for clothing, and the use of forests for climate-smart construction materials. These new products are expected to require low volumes of forest biomass while providing high value (de Jong et al., 2012).

The increased awareness of the multifunctionality of forests and the many benefits of forest ecosystem services for society has promoted developments in the forest sector that respond to these broader environmental and societal needs. The benefits provided by forest ecosystem services comprise the above-mentioned provisioning services (e.g. wood and fibres) and important regulating services (e.g. clean air and water, flood and erosion control, forest water regulation and resource management). Forests are also important in climate change mitigation and adaptation as they sequester and store carbon in the forest ecosystem and in harvested wood products. Cultural services include accessible and attractive forest areas, rich in biodiversity, that support education and nature-based sustainable tourism, and recreational and health related activities. However, realising these ecosystem benefits for society requires careful integration of biodiversity considerations into the forestry sector. There are little available data on the economic value of marketed forest ecosystem services, although the income from forest ecosystem services exceeds that from timber production in many European countries (Forest Europe, 2015a; Marchetti et al., 2018).

Environmental pressures

Only one third of the forest habitats listed under the EU Habitats Directive are in favourable conservation status (Chapter 3). For bird populations, nearly two thirds of the assessments of woodland and forest species are secured (i.e. they show no foreseeable risk of extinction and have not declined or depleted). This is better than for other ecosystem types such as agricultural areas (EEA, 2015). Regarding common birds, forest birds show less decline than farmland birds (EEA, 2018a).

Natural (storms, pests) and human-induced disturbances (forest fires, infrastructure and tourism) are threats to Europe's forests (Chapter 7). Climate change is expected to trigger increased frequencies and intensities of natural disturbances (Seidl et al., 2017). Storm damage is projected to increase by 15 % by 2100, potentially resulting in a 5 % annual reduction in carbon sequestration by forests (Gardiner et al., 2013). Boreal regions experiencing increased air temperatures have reported large-scale insect outbreaks (Pureswaran et al., 2018). Some species of fungi and pests benefit from milder winters in temperate forests, facilitating their spread, such as ash dieback. Despite many uncertainties, it is generally accepted that there has been an increase in the incidence of pests and diseases in European forests (FAO, 2006; Desprez-Loustau et al., 2007) and a shift in the spatial and temporal ranges of insects, as a result of climate change.

Only a third of forest habitats protected under the EU Habitats Directive show a favourable conservation status.

Fires cause damage by altering the ecosystem structure, composition and condition. Severe wildfires may remove soil organic matter and result in erosion and the loss of nutrients and biodiversity (Certini, 2005; Santín and Doerr, 2016). This may turn forest soils into carbon sources (Ludwig et al., 2018). Several studies suggest that climate change would lead to a marked increase in the potential for forest fires in south-eastern, south-western and, in relative terms, western-central Europe (Khabarov et al., 2016; Bedia et al., 2014). The burnt area in southern Europe could more than double during the 21st century for a reference climate scenario and increase by nearly 50 % for a 2 °C scenario (Ciscar et al., 2014). Additional adaptation measures would substantially reduce the risk of forest fires, such as prescribed burning, firebreaks and behavioural changes (Khabarov et al., 2016; Chapter 7).

Forest ecosystems also have to cope with multiple pressures generated from human-related activities (EEA, 2016b). These include activities that directly affect ecosystems and habitats such as certain forest management practices. In particular, intensively managed even-aged forests and biomass production plantations may have a severe impact on whole habitats through clear-cutting and deadwood removal. Long-term loss of biodiversity in temperate and boreal forests has been observed under management systems that favour

60 %

of forests in the EU-28 are certified compared with 12 % globally.

even-aged forests and plantations (Sing et al., 2018). Nevertheless, only 10 % of Europe's forests have been classified as intensively managed (EEA, 2016b). Forest fragmentation is another factor contributing to biodiversity loss, illustrating the interlinkages between forestry and other sectors such as transport (Chapter 5).

Other human-induced pressures have an indirect impact on the forest ecosystem, for example air pollution, climate change and invasive alien species. Deposition of sulphate (SO_4^{2-}) causes the acidification of forest soils and is reported to be high in central and southern Europe. Likewise, nitrate (NO_3^-) deposition causes eutrophication and acidification in western Europe (Sardans et al., 2016; Petrash et al., 2019). Although Europe's forests show no tendency towards defoliation or forest decline, several studies show signs of nutrient imbalances in European forests, such as increasing limitation of phosphorus in trees and forest stands (Michel and Seidling, 2017; Goswami et al., 2017). Invasive alien species are also negatively impacting forest ecosystem processes leading to reduced forest condition, biodiversity and productivity. For example, the non-native black cherry (*Prunus serotina*) is widespread, challenging foresters to regenerate their forests with native forest trees (EEA, 2016b). Further global change is likely to increase the presence and spread of invasive alien species and the damage they cause to forest resources.

13.4.3 Responses and prospects of meeting agreed targets and objectives

The implementation of EU biodiversity policy still remains a major challenge, and there has been little improvement in the conservation status of forest habitats and species since 2013 despite the implementation of the EU forest strategy (EC, 2018d). Although there are no concrete targets for the sustainable management of European forests, a common management objective is the need to balance production and biodiversity and minimise the impacts described above. SFM provides criteria and indicators that foster governance, institutional frameworks and indicators to measure success in balancing the production function with ecological concerns, for example the amounts of deadwood and biological and genetic diversity. Although SFM does not give specific recommendations for management regimes, increasing evidence shows that the ecological aspects of SFM would need to embrace management approaches that promote more uneven-aged forests with, for example, long-term irregular or small-scale shelter wood systems or even single-tree selective systems, as in 'close-to-nature silviculture', as far as this is economically feasible and suitable for the forest type (Banaś et al., 2018; Hessenmöller et al., 2018). Systems that ensure structural diversity and small-scale variability in ecosystems and habitats have less impact on biodiversity (Chaudhary et al., 2016; Puettmann et al., 2015).

Under the LULUCF Regulation, forest management practices are expected to try to optimise forest functions as carbon sinks and as a natural asset for the bioeconomy. The different objectives of climate policies and bioeconomy and biodiversity policies can result in trade-offs if high-disturbance management systems, such as intensively managed plantations and short-rotation forests for biofuels, are promoted, as these are not in line with long-term biodiversity considerations. Recent scenario analysis (Kändler and Riemer, 2017) shows that a 'nature conservation preference scenario' gives the best results for both climate change and biodiversity conservation, in line with other nature-based solutions (Chapter 17).

Certification is a tool to enhance SFM. The two most widely applied schemes are the Forest Stewardship Council (FSC) and the Programme for the Endorsement of Forest Certification (PEFC). More than 60 % of forests in the EU-28 are certified, mostly under the FSC or PEFC or both, compared with 12 % globally. The area under certification has been increasing in recent years, which could reflect an increase in the area for which evidence of SFM is available. To date, this is probably the best way to evaluate the sustainability of forest management (EEA, 2016b).

Good governance, science-informed content and holistic policies are crucial to provide the right incentives for sustainable forest management to build a synergistic relationship between biodiversity and bioeconomy-related goals. Although some progress has been made, the Environmental Implementation Review states explicitly that some Member States should improve their protection of forests through incentives for foresters following the EU forest strategy and SFM principles (EC, 2019).

13.5 Transport

13.5.1 Socio-economic relevance of the sector and policy landscape

Economic competitiveness and social welfare depend on an efficient and accessible transport system. Roughly 11.5 million people, corresponding to 5.2 % of the EU's total workforce, were employed in the transport sector in

2016, contributing EUR 652 billion in GVA to the economy (Eurostat, 2019f, 2019g). The sector is a source of government revenue through vehicle and fuel taxes, and infrastructure charges, but it is also a large recipient of subsidies. Transport is a key source of environmental pressures in Europe, especially of GHGs, air pollutants and noise. It also takes up large swathes of land and contributes to urban sprawl, the fragmentation of habitats and the sealing of surfaces.

The sector and its environmental impacts are subject to regulatory, planning and investment decisions at various levels. National, regional and local governments typically play an important role in transport planning and infrastructure development. The European level provides the regulatory framework for many aspects of transport, establishes common objectives and is also an important source of infrastructure funding for many Member States. Because of the cross-border nature of many transport activities, there are also numerous international agreements and treaties, in particular in the frameworks of the United Nations Economic Commission for Europe (UNECE), the International Civil Aviation Organization (ICAO) and the International Maritime Organization (IMO).

Although the transport sector is crucial for achieving the EU's decarbonisation ambition, there is no specific and binding target for reducing GHGs in EU legislation or international commitments for the sector as a whole. There is, however, a close link between transport GHG emissions and the EU's pledge under the Paris Agreement to reduce its total GHG emissions by at least 40 % by 2030 compared with 1990 levels. The EU is planning to deliver on this pledge by reducing emissions under the EU Emissions Trading System (ETS) by 43 % and emissions in the sectors not covered by the ETS by 30 % below 2005 levels by 2030. Transport is a key sector outside the ETS, but

Transport is one of the main sectors responsible for climate change, air pollution and noise in the EU.

the electricity consumed by transport (e.g. by electric rail transport or electric cars) is included in the ETS, along with domestic aviation (within the European Economic Area). International aviation is currently excluded, as the Carbon Offsetting and Reduction Scheme for International Aviation (CORSIA), developed within the ICAO framework, will be introduced in 2021. Under CORSIA, the process of monitoring, reporting and verification of GHG emissions from international aviation started in 2019. International shipping is mainly covered by the IMO. A European process for monitoring, reporting and verification of carbon dioxide (CO_2) emissions from international shipping started in 2018.

To implement the required reduction in the non-ETS sectors, the newly adopted Effort Sharing Regulation established individual national 2030 targets. Each Member State is, in principle, free to decide where and how to make reductions, but transport is the dominant source and needs to be tackled in order to reach the overall target.

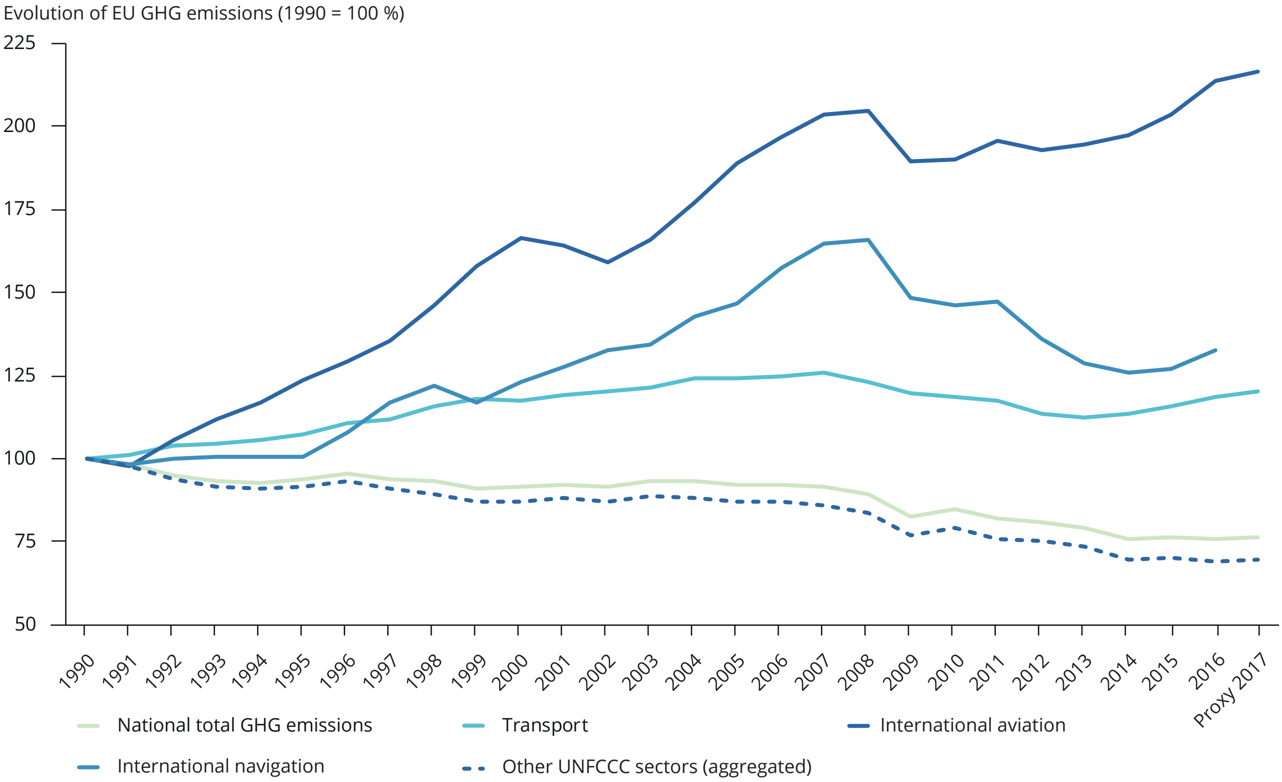
To this end, increasingly stringent requirements to reduce CO_2 emissions from cars and vans have been introduced and recently extended until 2030 (see the EU Regulation on post-2020 CO_2 emission targets for cars and vans (EU, 2019). In early 2019, agreement was also reached on similar requirements for lorries. In addition, the Clean Vehicles Directive has been reviewed and now includes binding minimum targets for clean and zero-emission vehicles in public procurement. The revised Renewable Energy Directive (EU, 2018) requires a minimum of 14 % renewable energy in final transport sector energy consumption by 2030.

European legislation also sets progressively stricter emission limits for air pollutants from cars and vans and for lorries, buses and coaches. Known as 'Euro standards', these apply to important air pollutants including NO_x and particulate matter (PM) from the tailpipe and also to evaporative emissions from the fuelling system. However, the exploitation of weaknesses in the laboratory-based tests has resulted in widespread exceedance of the NO_x limits for diesel cars and vans in real-world driving conditions. This is one of the reasons why European air quality requirements are breached in many urban areas. To address this situation, a new on-road test now complements laboratory-based testing. This new test is mandatory for all new cars and vans as from September 2019. Shipping and aviation also have a significant impact on air quality (EEA, 2017a).

13.5.2 Selected sectoral trends in Europe, including outlooks

Transport activity in Europe is still strongly correlated with environmental pressures. Although efficiency improvements have had a mitigating effect, the growing demand for transport still translates into increasing environmental pressures. GHG emissions increased by roughly one quarter between 1990 and 2016 (including international aviation but excluding international shipping) (Figure 13.3). Transport's share of the EU's total GHG emissions increased

FIGURE 13.3 **EU GHG emissions in the transport sector, 1990-2017**



Notes: Preliminary data for 2017 (EEA, 2018e). Preliminary data for 2017 are not available for international navigation.

UNFCCC, United Nations Framework Convention on Climate Change.

Source: EEA.

from 15 % to 24 % during the same period. This is mainly a result of the continued reliance of the EU transport system on fossil fuels and of growing transport demand. Important new EU legislation has recently been agreed on to reverse this trend, but it remains to be seen to what extent this can offset the expected increase in transport demand.

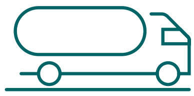
The road sector is key within the transport sector, and in 2016 it accounted for 72 % of all GHG emissions from transport (including international aviation and international shipping). Passenger cars and vans account for 72.5 % of road transport emissions, followed by trucks and buses at 26.3 %.

A 24 % increase in total EU GHG emissions was noted from the transport sector in 2016, compared to 1990.

Shipping and aviation are the second and third biggest sources of transport GHG emissions after road transport, and international aviation has seen rapid growth in GHG emissions over the last two decades.

Regarding air pollutant emissions from transport (e.g. NO_x, PM, SO_2, sulphur dioxide), there has been a strong decline in the overall volume since 1990, but important problems with local air quality due to transport emissions persist. Road transport alone was responsible for 39 % of the EU's total NO_x emissions in 2016 and non-road transport (aviation, railways, inland waterways etc.) for another 9 %. In the same year, transport in its entirety also accounted for 13 % of $PM_{2.5}$ (particulate matter ≤ 2.5 μm diameter) and 12 % of PM_{10} (particulate matter ≤ 10 μm diameter) emissions (EEA, 2018b). Non-exhaust emissions (e.g. particles from brake and tyre wear) have increased in importance over time. It is estimated that they can account for more than half of the total PM_{10} emissions from road transport (EEA, 2016a). The sources and effects of air pollution are described in greater detail in Chapter 8.

Transport is also the dominant source of environmental noise in the EU, with over 113 million people exposed to high levels of road traffic noise. Road traffic noise makes the largest contribution to the burden of disease due to noise (80 %) (Chapter 11). Transport infrastructures such as roads and railway tracks are also a main cause of landscape fragmentation and they alter ecological conditions by cutting through natural habitats (Chapters 3, 4 and 5). Looking ahead, there are a number of promising technological developments and also some signs of changes in behaviour that could put the transport sector on a more sustainable trajectory (Chapter 16). However, so far these have not resulted in reduced environmental pressures.



Strengthening environmental integration into transport policy is vital.

13.5.3 Responses and prospects of meeting agreed targets and objectives

The focus of EU transport policy is on increasing the efficiency of the transport system and also on internalising the economic costs of environmental and health impacts where feasible. It is not a policy objective to curb mobility. Transport impacts are not just determined by economic activity and technology, however. They are also linked to land use planning, culture and lifestyles, which makes a very broad set of policies relevant to transport impacts.

There is no EU-level transport strategy setting out specific transport policy measures to achieve the 40 % reduction in GHG emissions by 2030 that the EU is committed to. The 2011 White Paper on transport, *Roadmap to a single European transport area — towards a competitive and resource efficient transport system*, is the only EU policy document that contains a numerical target for the transport sector (EC, 2011c) beyond 2030. It sets out the ambition to reduce GHG emissions from transport by at least 60 % by 2050 compared with 1990 levels. The EU strategy for low-emission mobility reiterates this target and identifies priority areas for action (EC, 2016a). However, the analysis behind the long-term strategy (EC, 2018c) shows that a reduction of more than 60 % will be required to achieve the goals of the Paris Agreement. A transport-related target also exists in the Renewable Energy Directive which requires that at least 10 % of transport fuels must come from renewable sources by 2020. In addition, the Fuel Quality Directive mandates a reduction in the GHG intensity of transport fuels by a minimum of 6 % by 2020. The proportion of renewable energy used in transport stood at 7.6 % in 2017 and the EU trend in the share of renewables in transport remains well below the target path required to reach the 2020 goal (Eurostat, 2019i).

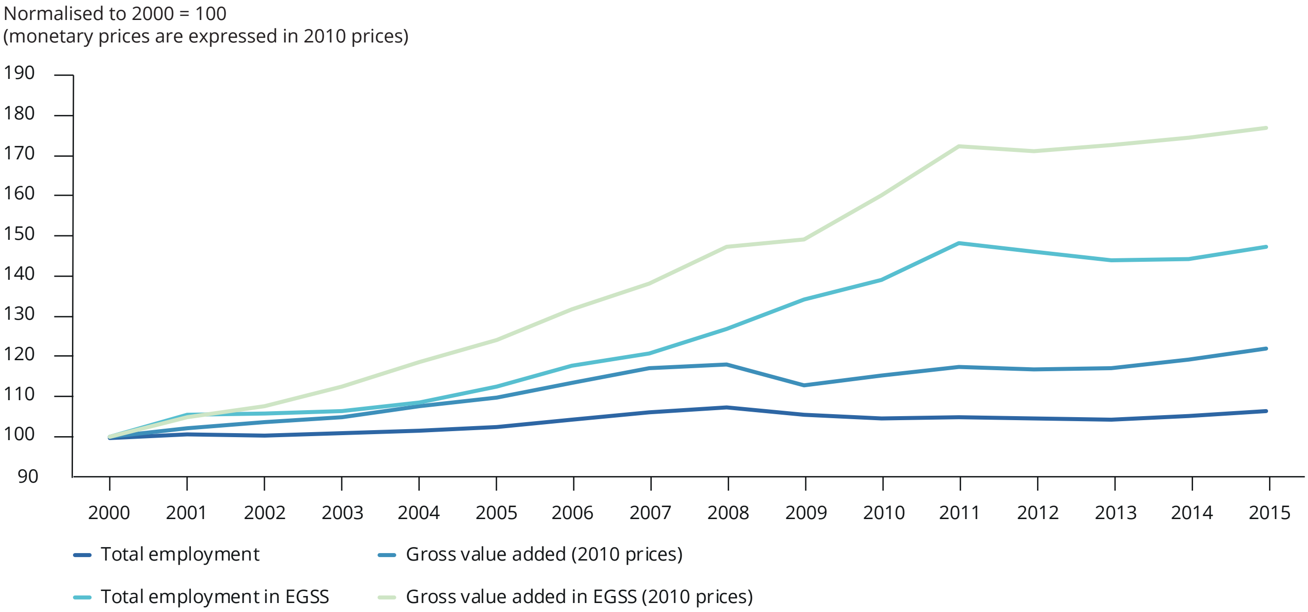
European air quality targets are not transport specific, but transport plays a central role as a source of emissions under the Ambient Air Quality and National Emissions Ceilings Directives. It is the main source of NO_x and an important source of particulate matter (PM_{10} and $PM_{2.5}$). In particular, the annual nitrogen dioxide (NO_2) limit values are exceeded in many European cities, which is directly linked to road transport and diesel cars in particular. As to landscape fragmentation, target 2 of the EU biodiversity strategy (EC, 2011a) includes the objective to restore at least 15 % of degraded ecosystems by 2020, inter alia, by establishing green infrastructure. The green infrastructure strategy (EC, 2013b) describes practical ways of reducing fragmentation. Regarding transport noise, the Environmental Noise Directive requires noise maps and action plans for major roads, railways and airports but does not include targets. The 7th EAP sets out the broad objective of reducing the overall environmental impact of production and consumption in the mobility sector by 2020.

The available data on GHG emissions from transport and local air pollution do not indicate that the transport sector is already on a trajectory that is compatible with long-term targets and improved air quality. However, European Commission projections that take into account the expected future effect of agreed policy measures conclude that the target to reduce GHG emissions will be achieved. An assessment against noise and landscape fragmentation objectives is more difficult because of the absence of EU-wide targets.

Overall, achieving environmental targets is complicated by the fact that transport policy is subject to conflicting objectives, including those for economic development, territorial cohesion and environmental sustainability. Furthermore, the governance of the transport sector is complex, located at multiple levels, and policy integration is challenging. International negotiations are required to effectively address the environmental effects of the aviation and maritime shipping sectors, which are responsible for a growing share of NO_x and GHG emissions (EEA, 2017a).

Although environmental objectives inform most transport policy decisions, this does not always translate into optimal outcomes from an environmental perspective (especially in the domains of

FIGURE 13.4 Value added and employment in the EU-28: total economy versus the EGSS



Source: EEA, based on Eurostat (2019a, 2019e, 2019h, 2019b, 2019d).

taxation and infrastructure development). There appears to be consensus on the importance of integrating environmental objectives into all European policies relevant to transport. This means anticipating the impacts on transport of policies in other sectors of the economy, in particular of decisions on urban planning, land management and taxation. However, there is limited evidence that this is happening in a consistent and effective manner.

13.6 Developments in eco-industries

The wider societal benefits of well-designed and implemented environmental policies are substantial in Europe. Environmental regulations often create incentives for new economic activities that develop less polluting goods and services. The 7th EAP aims to boost the competitiveness of eco-industries and strengthen the market share of green technologies by 2020. This may contribute to reducing environmental pressures as well as delivering important socio-economic benefits in terms of wealth, job creation and trade. The environmental goods and services sector (EGSS) ([9]), also called eco-industries or environmental industries, produces products and services aimed at protecting the environment and managing natural resources.

13.6.1 Environmental goods and services sector

Since 2000, the EGSS has outperformed the total economy of the EU-28 in terms of creating economic prosperity and employment. From 2000 until 2011, there was a steep increase in GVA, but since then the EGSS has displayed similar growth rates to the total economy (Figure 13.4). Employment in the EGSS increased by about 47 % during the period between 2000 and 2015 compared with 6 % in the total economy of the EU-28.

While the EGSS represents a small share of total economic performance in terms

([9]) The EGSS follows a globally agreed statistical standard covering environmental protection and resource management activities (for more information, see Eurostat (2016b)).

of GVA, its economic significance grew from 2000 to 2015, with an increased share of both GVA (from 1.6 % to 2.3 %) and employment (from 1.3 % to 1.8 %). Labour productivity in the EGSS is higher than in the overall economy, and the EGSS is on average 25 % more productive than the overall economy. One reason for this may relate to the fact that industries belonging to the EGSS are more technologically and capital intensive.

13.6.2
Market share of green technologies

Since 2012, the growth of the market for environmental technologies in Europe has lost some momentum, as illustrated by the trends in the development of the EGSS (Figure 13.4). However environmental policies, in particular those encompassing mandatory targets, can also stimulate international trade by creating demand for environmental and energy technologies. International trade in green technologies can bring economic benefits for Europe while also providing global benefits through the circulation and transfer of green technological knowledge across borders (EEA, 2014). The global market for environmental technologies and resource efficiency is considered to have high growth potential, with a projected average annual growth rate of 6.9 % up to 2025 (BMU, 2018).

From 2000 to 2015, industries producing environmental protection goods performed better, in terms of the export growth rate of the companies producing them, than total manufactured goods (Gehrke and Schasse, 2017). During the period between 2002 and 2015, the share of global exports of environmental protection goods of the four largest EU economies (Germany, France, United Kingdom and Italy) decreased from 33 % to 25 %, a situation comparable to that of the United States and Japan.

The EU environmental economy grew faster than the overall economy in terms of employment and value added since 2000.

The combined share of the eastern European countries (Poland, Czechia, Slovakia, Slovenia, Hungary, Latvia and Estonia) increased from 3.2 % to 5.9 %. At the same time China increased its export share from 4.6 % to 16.2 %.

Europe is improving its role as a provider of wind technologies to the world market, with total exports growing rapidly from very low levels at the beginning of the current decade up to about EUR 6.5 billion in 2016. This decreased in 2017, which can be partly attributed to a slowdown in the creation of new capacity globally. Of the top 10 producers of wind technologies, five are located in Europe (Germany, Denmark and Spain), and together they accounted for about 49 % of the world market in 2017 (REN21, 2018). Chinese producers (4 out of the top 10) have an increasing role in the world market, and trade data indicate a decline in EU exports to China; however, trade volumes with China are still small.

Developments in green technologies are not limited to eco-industries, as companies belonging to traditional industries have also diversified into green technology and now account for 43 % of the world market for environmental technology and resource efficiency. Mechanical engineering has the highest share of 18 %, followed by electrical engineering (13 %), the chemical industry (9 %) and automotive engineering (3 %) (BMU, 2018). Therefore, traditional industries are playing a crucial role in progressing towards a resource-efficient, green and competitive low-carbon economy. At the same time, it is essential that these industries adopt environmentally sustainable, resource-efficient and low carbon production technologies. This involves aiming for more widespread application of innovation with environmental benefits by enterprises in all sectors of the economy. The EU undertakes community innovation surveys assessing the uptake of these innovations in the EU. The results of the last such survey from 2014 reveal that reducing energy use and CO_2 emissions, recycling waste or water for own use or sale, and reducing pollution and material or water use are the main purposes of investments in environmentally sound innovation. The main driver of uptake is benefits for the company's reputation and the fact that the benefits of these investments apply within the company and do not negatively affect end-users (Alquézar and Kwiatkowski, 2019).

The importance of traditional industries is illustrated by recent research on how economies can be transformed so that long-term climate protection objectives are met while reducing consumption of natural resources (UBA, 2017). Steel production is of great importance when considering the trade-offs between climate and natural resource policies and also illustrates well the potential trade-offs between different SGDs (Chapter 15). The iron and steel sector is one of the largest energy-consuming sectors and is responsible for 7 % of total global CO_2 emissions from fossil fuels (IEA, 2018). Fossil fuel combustion in this and other industrial sectors also contributes significantly to air pollution in Europe (Chapter 12). At the same time, the steel intensity of electricity-generating technologies differ widely, with some renewable electricity-generating technologies

Strengthening environmental integration into sectoral policies is essential to improve policy implementation.

having the highest steel requirements. Therefore, the iron and steel sector, a traditional industrial sector, is crucial to any economic transformation, as it could be technically feasible that GHG emissions from this sector can be almost completely avoided (UBA, 2017). In addition, increasing the circular use of materials could lead to steel production being based on scrap steel with a corresponding decrease in resource extraction.

There is considerable technical potential for decarbonising energy- and material-heavy economic sectors, such as aluminium, plastics, cement and steel, by managing demand through material efficiency and circularity. It is projected that the CO_2 emissions of these sectors could be reduced by up to 56 % in European economies by 2050, primarily by increasing material efficiency and enhancing circularity through improved product design and new business models (Energy Transition Commission, 2018).

Decarbonisation and reduced consumption of natural resources can be achieved in parallel, and the global costs of decarbonising four industrial sectors — cement, steel, ethylene and NH_3 — have been estimated to be about USD 21 trillion between now and 2050. However, the costs could be considerably lower, in the range of about USD 11 trillion if zero-carbon electricity prices fall further compared with fossil fuel electricity prices (McKinsey & Company, 2018).

Traditional industries are the producers and suppliers of intermediate inputs for the production of green technologies. Therefore, the projected growth in markets for green technologies is heavily dependent on the economic output of and jobs in traditional industries (BMU, 2014). This illustrates the need to assess the whole value chain of environmental technologies and consider the role of traditional industries, as well as those defined as eco-industries, in progressing towards a resource-efficient, green and competitive low-carbon economy.

Advancements in technology and an increase in the deployment of eco-innovations is crucial for the transition towards a low-carbon, resource-efficient and circular economy, but at the same time rebound effects may limit the reduction in environmental pollution. The efficiency gains of technological improvements may be partially offset by a reduction in costs, which leads to an increase in demand (EEA, 2013; Sorrell, 2007; Greening et al., 2000). Assessing rebound effects is also critical for the sharing economy, as savings from sharing initiatives can result in increased use of other goods and services (Skjelvik et al., 2017). The setting of absolute and quantifiable reduction targets at sectoral or economy-wide level can reduce such rebound effects.

13.7 Conclusions

The sectors assessed here are major contributors to significant environmental pressures including climate change, biodiversity loss, air pollution and water pollution. There is a mixed picture in terms of past trends and an outlook in which current developments are not in line with policy ambitions. Agriculture in particular has been identified as a key source of environmental pressures, demonstrating the need for greater ambitions in terms of reducing impacts of agricultural activities on biodiversity, freshwater, marine pollution, GHG and NH_3 emissions and soils.

The pace of change also differs across sectors. For example, while there have been reductions in GHG emissions from industry, GHG emissions from transport and NH_3 emissions from agriculture continue to increase. The current status of many fish stocks requires urgent action. For both fisheries and forestry, increased political will is needed to implement scientific recommendations. It is unlikely that the objective of significantly reducing the overall environmental impact of all major sectors of the economy by 2020 will be met.

The importance of policy coherence and environmental integration has been highlighted in the preceding chapters, for example the need for improved coherence between the CAP, CFP and biodiversity objectives (Chapter 3) and between rural development plans under the CAP and the Water Framework Directive (Chapter 4). Analysis of the relationships at the nexus between agriculture and water shows that a more integrated approach is possible (EC, 2019). Environmental objectives have clearly been integrated into a range of sectoral policies. However, there are some challenges in assessing how successful this has been in reducing environmental pressures because of the limited availability of evidence and the fact that environmental outcomes are influenced by factors other than policy.

The integration of environmental objectives into the CAP does appear to have resulted in a reduction in some environmental pressures such as nutrient emissions. The market reform of the CAP has also been identified as contributing to a reduction in GHGs from methane and nitrous oxide (Chapter 7). However, structural changes in the economy have also contributed to a reduction in environmental pressures linked to economic activities.

Looking ahead, it is clear that the policy approach of environmental integration has not been successful when it comes to reducing environmental pressures from sectors. In many cases, sectoral policies encompass a range of objectives, governance is complex and policy integration is challenging, and the environment is a lower priority than other objectives. For example, the EU industrial policy strategy brings together a wide range of policies relating to industry (EC, 2017a). However environmental aspects do not feature prominently, with the exception of references to achieving a low-carbon and circular economy, while industrial pollution is not mentioned. This highlights the scope for further environmental integration across industrial policy, especially in the context of the policy objective of industry having a share of 20 % of GDP by 2020. Strengthening environmental integration into key policy areas such as agriculture, industry and transport, at both the framing and execution stages, is essential to improve policy implementation (EC, 2019).

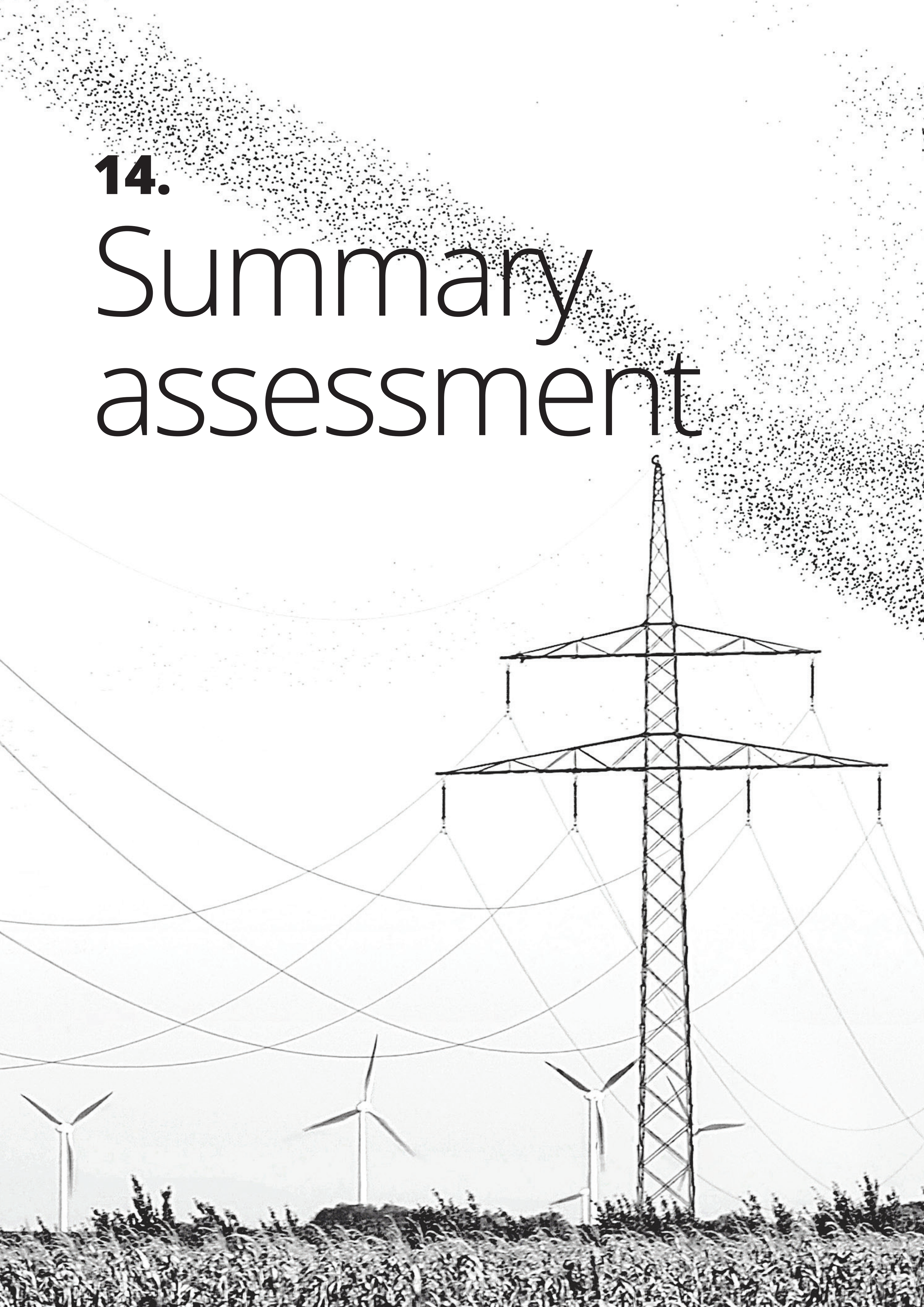
Environmental policies create economic opportunities and contribute to broader social and economic objectives. Ambitious and fully implemented policies create conditions that stimulate the development of environmental technologies, creating new job opportunities as well as offsetting potential job losses in other sectors of the economy. However, the loss of momentum in the development of the environmental goods and services sector indicates that further efforts are needed to realise the 7th EAP ambitions of a resource-efficient, green and competitive low-carbon economy.

In addition, the sectors featured here have to deliver multiple societal functions, supporting livelihoods as well as having a vital role in stewardship of the environmental resources they ultimately depend on. This means that policy interventions need to consider environmental, economic, social and governance dimensions and their inherent synergies and trade-offs. There are benefits from complementing a sectoral focus and environmental integration approach with a broader systems perspective (Chapter 15). This places sectoral activities within wider production and consumption systems, improving our understanding of interactions and enabling more coherent and effective policy interventions to reduce environmental pressures along whole value chains, thereby realising potential co-benefits for human health and well-being.

Policy needs to consider environmental, economic, social and governance dimensions and their synergies and trade-offs.

14.

Summary assessment



14. Summary assessment

14.1 Introduction

The Seventh Environment Action Programme (7th EAP) plays a central role in the current European environment and climate policy landscape, providing strategic direction and a framework for EU environmental policies. Since its publication, it has underpinned initiatives such as the circular and low-carbon economy. Over the same period, there have been globally driven complementary policy developments in the form of the Paris Agreement on climate change and the 2030 agenda for sustainable development (Chapter 2).

The 7th EAP thematic priority objectives build on existing environment and climate legislation and policy initiatives and promote their implementation. Effective implementation of the environmental acquis provides the foundation for securing these broader, more strategic objectives as well as contributing to the 2050 sustainability vision of the 7th EAP. The preceding chapters provide an overview of past trends, outlooks and prospects towards policy objectives and targets. These are brought together here to provide an overview from the perspectives of the 7th EAP's priority objectives. The summary assessments of past trends and prospects are broader than those found in a series of reports published by the EEA, which used a stable set of indicators to monitor the progress of the 7th EAP at action level (EEA, 2016, 2017, 2018). The summary assessment also goes beyond those reports by providing a longer term outlook to 2030.

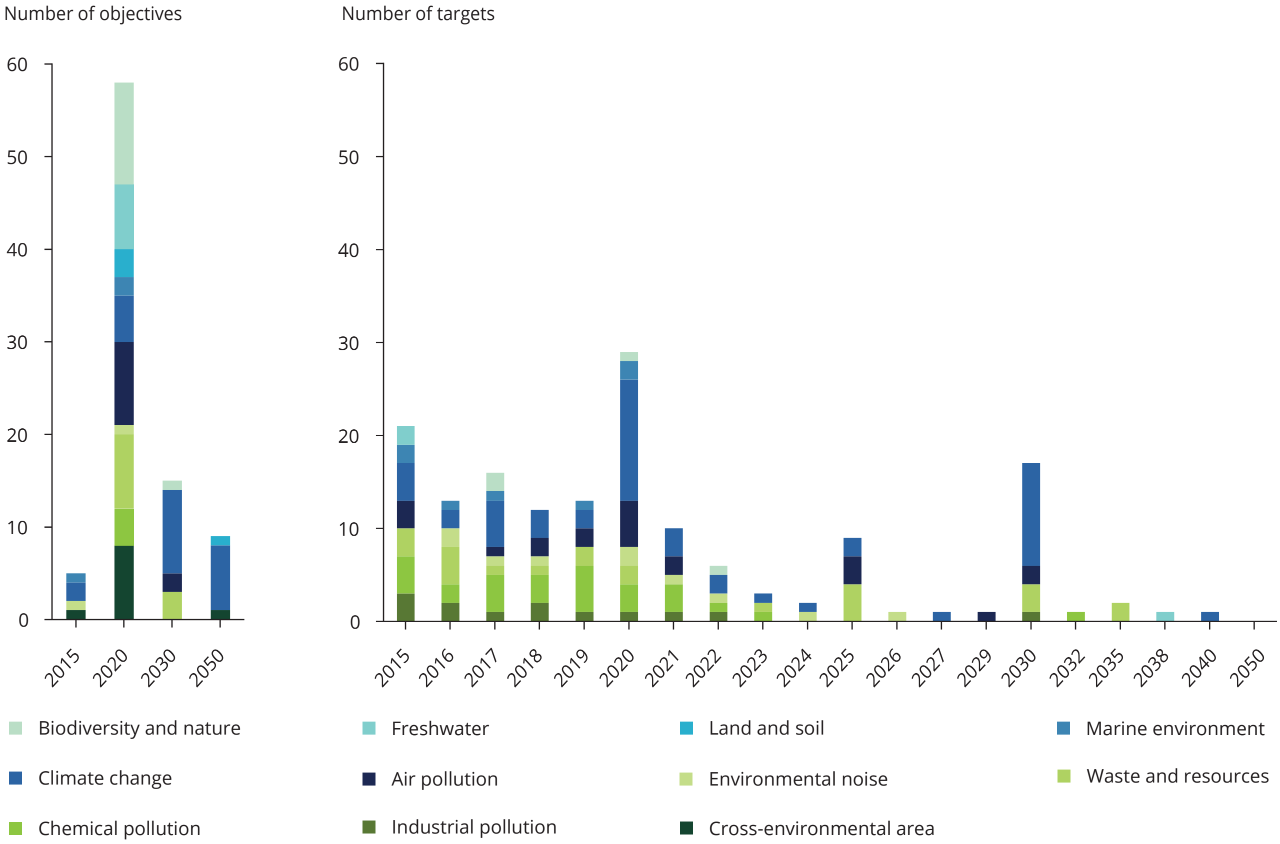
> Effective implementation of the environmental acquis provides the foundation for achieving longer term policy objectives.

While environmental objectives are evenly spread across different themes, there are considerably more binding targets for climate change, air pollution, waste and chemicals than for biodiversity, freshwater and the marine environment and none for land and soil (Figure 14.1). Across the 10 environmental themes addressed in T*he European environment — state and outlook 2020* (SOER 2020), the substantial majority of binding targets and non-binding objectives are set for 2020 with a smaller number set for 2030. The summary assessment reflects this, primarily focusing on the 2020 and 2030 time horizons. It also looks ahead to consider prospects in the context of the Sustainable Development Goals (SDGs), as this comprehensive set of sustainability goals and targets can be expected to be increasingly integrated throughout future EU policy frameworks.

14.2 Summary assessment of past trends, outlooks and prospects

The overall summary assessment table presented below has been compiled from the summary assessments in Chapters 3-12. It is structured

FIGURE 14.1 Overview of non-binding objectives and binding targets of EU environmental policy, 2015-2050



Source: Paleari (2019).

While there has been progress in many areas, the EU falls short of achieving a number of environmental objectives and targets for 2020.

by the 7th EAP priority thematic objectives to provide an overview at a European level from the following cross-cutting perspectives: protecting, conserving and enhancing natural capital; resource-efficient, circular and low-carbon economy; and safeguarding from environmental risks to health and well-being.

The assessments summarised in Table 14.1 indicate that, although there have been improvements in many areas, substantial challenges remain and Europe is not on track to meet policy objectives and targets in many areas. The following sections assess progress and prospects in relation to the three thematic priority objectives and selected cross-cutting issues.

14.3 Protecting, conserving and enhancing natural capital

Priority objective 1 of the 7th EAP is 'to protect, conserve and enhance the Union's natural capital' (EU, 2013). The objective recognises the fundamental role of natural capital in determining economic prosperity and social well-being. The scope of the objective encompasses seven main areas:

TABLE 14.1 Summary of past trends, outlooks and prospects of meeting policy objectives/targets

Theme	Past trends and outlook		Prospects of meeting policy objectives/targets		
	Past trends (10-15 years)	Outlook to 2030	2020	2030	2050
Protecting, conserving and enhancing natural capital					
Terrestrial protected areas	Green	Yellow	☑		
Marine protected areas	Green	Yellow	☑		
EU protected species and habitats	Yellow	Yellow	☒		
Common species (birds and butterflies)	Red	Red	☒		
Ecosystem condition and services	Red	Yellow	☒		
Water ecosystems and wetlands	Yellow	Yellow	☒		
Hydromorphological pressures	Red	Yellow	☒		
State of marine ecosystems and biodiversity	Yellow	Red	☒		
Pressures and impacts on marine ecosystems	Yellow	Red	☒		
Urbanisation and land use by agriculture and forestry	Red	Red			☒
Soil condition	Red	Red	☒		
Air pollution and impacts on ecosystems	Yellow	Yellow	☐	☐	
Chemical pollution and impacts on ecosystems	Yellow	Red	☒		
Climate change and impacts on ecosystems	Red	Red	☒		
Resource-efficient, circular and low-carbon economy					
Material resource efficiency	Green	Yellow	☑		
Circular use of materials	Green	Yellow		☐	
Waste generation	Yellow	Yellow	☐		
Waste management	Green	Green	☐		
Greenhouse gas emissions and mitigation efforts	Green	Yellow	☑	☒	☒
Energy efficiency	Green	Yellow	☐	☒	☒
Renewable energy sources	Green	Yellow	☑	☒	☒
Emissions of air pollutants	Yellow	Yellow	☑	☐	
Pollutant emissions from industry	Green	Yellow	☐		
Clean industrial technologies and processes	Green	Yellow	☐		
Emissions of chemicals	Yellow	Red	☒		
Water abstraction and its pressures on surface and groundwater	Green	Yellow	☒		
Sustainable use of the seas	Yellow	Yellow	☐		
Safeguarding from environmental risks to health and well-being					
Concentrations of air pollutants	Green	Yellow	☒	☑	
Air pollution impacts on human health and well-being	Green	Yellow		☑	
Population exposure to environmental noise and impacts on human health	Yellow	Red	☒		
Preservation of quiet areas	Yellow	Yellow	☒		
Pollution pressures on water and links to human health	Yellow	Yellow	☒		
Chemical pollution and risks to human health and well-being	Yellow	Red	☒		
Climate change risks to society	Red	Red	☐		
Climate change adaptation strategies and plans	Green	Green	☐		

(1) biodiversity and ecosystem services; (2) transitional and coastal waters and freshwaters; (3) marine waters; (4) land; (5) the impact of air pollution on ecosystems and biodiversity; (6) the nutrient cycle; and (7) forests.

14.3.1
Progress and prospects to 2030 (2050)

The EU's natural capital is not yet being protected, conserved and enhanced in line with the ambitions of the 7th EAP. A low proportion of the assessed protected species (23 %) and habitats (16 %) are considered to be in favourable conservation status, and Europe is not on track to meet its overall target of halting biodiversity loss by 2020. Significant progress has been made in areas such as designation of protected areas, some species have recovered and action has been taken to address specific threats, for example the EU initiative on pollinators. Policy responses, although successful in some areas, have been insufficient to halt biodiversity loss and the degradation of ecosystem services. The prospects to 2030 would be more positive with more effective implementation of existing policies, effective management of sites and improved policy coherence, especially for sectoral policies, particularly agriculture (Chapter 3).

Reduced pollution has improved the quality of Europe's water, particularly following the implementation of urban waste water treatment. However, the objective of achieving good ecological status for all of Europe's water bodies by 2020 will not be met, as currently only 40 % of surface waters have achieved good ecological status and 38 % have achieved good chemical status. The situation is more positive regarding groundwater bodies, with 74 % achieving good chemical status and 89 % achieving good quantitative status. The main pressures on Europe's surface and groundwater bodies continue to arise from nutrient and other chemical pollution, changes in hydromorphology and water abstraction. While some pressures such as point source pollution and water abstraction have declined, others have not. Looking ahead, although Europe is on the way to achieving good status of its water bodies, river basin management will need to evolve to address the management of water quality and quantity in the context of a changing climate and potentially increasing pressures on aquatic ecosystems and wetlands. Doing so would also support the achievement of biodiversity and marine policy objectives (Chapter 4).

13 %

of urban land consumed, has been recycled despite urban land recycling being key to achieving the EU target of no net land take by 2050.

Turning to the marine environment, European countries have, through joint efforts, managed to reduce selected pressures and positive effects are starting to be seen. These include recovery of some fish stocks and species, and an increasing number of stocks are now being fished at maximum sustainable yield. The target for designation of marine protected areas has been met, but trends in widespread or common species are mixed. The target of achieving good environmental status of European marine waters by 2020 is unlikely to be achieved in relation to key pressures such as contaminants, eutrophication, invasive alien species and marine litter. Looking ahead, the marine environment is under pressure from the developing blue economy, which includes traditional and emerging maritime activities such as extraction of living and non-living resources, transport, energy production and tourism. In the face of this unprecedented amount of human activities competing to use the marine environment, the outlook for achieving the policy vision of healthy, clean and productive European seas is challenging (Chapter 6).

Further efforts are needed to protect, conserve and enhance the EU's natural capital in line with the ambitions of the 7th EAP.

Land and soil function together to provide a range of ecosystem services including food production, nutrient cycling and climate change mitigation and adaptation. The proportions of Europe's main land cover types are relatively stable. Annual net land take has decreased from 922 km^2 in the period 2000-2006 to 440 km^2 in the period 2012-2018, and there has been a decline in the annual rate of loss of land to artificial surfaces. The current rate of land recycling is low (13 % of urban land development), yet this could be key to achieving the EU target of no net land take by 2050. Landscape fragmentation continues to increase, especially in some rural and less populated areas, although the increase was lower in and around Natura 2000 sites than in unprotected areas. Soil degradation remains an issue of concern across many parts of Europe, and the loss of soil functions impedes sustainable land management and therefore the 7th EAP objective of achieving this by 2020. Looking ahead, a review of the challenges facing Europe and developing a coherent policy framework would greatly assist

BOX 14.1 Challenges, synergies and opportunities — integrated management of nitrogen

The need for integrated and adaptive management approaches for natural capital is clear. Current responses to complex problems can be characterised by fragmented approaches, as illustrated by the case of nitrogen. The 7th EAP aims to ensure that by 2020 'the nutrient cycle (nitrogen and phosphorus) is managed in a more sustainable and resource-efficient way.'

Diffuse pollution from nutrients, from agriculture in particular, affects the status of terrestrial, freshwater, coastal and marine ecosystems and biodiversity (Chapters 3, 4, 5 and 6). There have been improvements in the agricultural nitrogen balance (Chapter 13) and concentrations of nitrates in rivers and groundwater are declining (Chapter 4). The Nitrates Directive is a key instrument for reducing water pollution from nitrates from agricultural sources. A recent review concluded that, despite some positive progress, nutrient overload from agriculture continues to be one of the biggest pressures on the aquatic environment and that further efforts are needed (EC, 2018b).

There are still unacceptable losses of nitrogen to the environment and substantial improvements are needed to manage the nitrogen cycle sustainably. The *European nitrogen assessment* identified a package of seven key actions for better management of the European nitrogen cycle (Sutton et al., 2011). These related to agriculture, transport and industry, waste water treatment and societal consumption patterns and aimed to provide an integrated package for the development and application of policy actions. Six years later, the authors concluded that the *European nitrogen assessment* resulted in a better understanding of the nitrogen cycle and increased awareness of the issues, stimulating further assessments and policy development at global and national levels (Sutton et al., 2017). They also highlight the important role that food choices play in influencing nitrogen emissions (Westhoek et al., 2015) and the potential co-benefits of making a closer link between food choices and the environment, health and well-being (Chapter 16). ■

in achieving the SDG target of land degradation neutrality and the longer term 7th EAP ambition of no net land take by 2050, along with slowing trends in the expansion of urban areas and transport infrastructure (Chapter 5).

Air pollution continues to impact biodiversity and ecosystems through the deposition of excessive nitrogen resulting in eutrophication. In many areas nitrogen inputs from the atmosphere exceed levels that ecosystems can tolerate without being damaged and, in 2016, around 62 % of the area of European ecosystems was exposed to excessive levels. Looking ahead, exceedances should decline, but medium-term projections suggest that biodiversity in 58 % of all Natura 2000 areas will remain at risk from excessive atmospheric nitrogen deposition in 2030 (Chapter 8).

Concentrations in the environment of some individual chemicals targeted by policy instruments have decreased and can be expected to decline further. However, the effects of most chemicals on ecosystems have not been assessed. Accumulation of chemicals and the continued emission of persistent and hazardous chemicals suggest that the impacts of chemical pollution on ecosystems will not decrease and that Europe is not on track to minimise the significant adverse effects of chemicals on the environment by 2020 (Chapter 10).

62 %

of the area of European ecosystems was exposed to levels of nitrogen beyond that which they can safely tolerate.

Climate change is already impacting biodiversity and ecosystems. Looking ahead, climate change impacts are expected to intensify and the underlying drivers of biodiversity loss are expected to persist (Chapter 7). This means that the outlook for protecting, conserving and enhancing natural capital is not positive. Natural capital will continue to be degraded and depleted from habitat loss, fragmentation and degradation, as well as climate change, natural resource extraction, pollution and invasive alien species. Socio-economic activities such as agriculture, fisheries, transport, industry and energy production will continue to exert pressures and demands on Europe's ecosystems. For the forestry and the

BOX 14.2 Challenges, synergies and opportunities — harnessing the co-benefits of mitigation actions

Pursuing the objective of turning Europe into a resource-efficient, green and competitive low-carbon economy provides opportunities to harness synergies across policy areas. At the same time, it also poses challenges in terms of recognising and addressing trade-offs.

Climate change mitigation is a useful example to illustrate these co-benefits and trade-offs. First of all, recent decreases in greenhouse gas (GHG) emissions in times of economic growth in Europe show that climate change mitigation and economic progress are not mutually exclusive. Indeed, since 2000 eco-industries have outperformed the total economy of the EU-28 in terms of creating economic prosperity and employment. Between 2000 and 2015, employment in eco-industries grew by about 47 % compared with 6 % for the overall economy (Chapter 13).

Climate change mitigation also has strong co-benefits for air pollution. Shifts in the energy sector as a result of EU climate mitigation policy (e.g. the EU Emissions Trading System and renewable energy targets) have contributed to reductions in air pollutants. In addition, policies such as the Nitrates Directive, the market reform of the common agricultural policy and the Landfill Directive have had positive effects on reducing non-carbon dioxide gases, such as methane and nitrous oxide (Chapter 7). In turn, trade-offs between climate change mitigation and air pollution policies need to be carefully considered. For example, promoting diesel vehicles because of their lower carbon dioxide emissions and promoting biomass as a carbon-neutral fuel for domestic heating has led to a decline in air quality, especially in urban areas (Chapter 8). The Montreal Protocol and the banning of chlorofluorocarbons (CFCs), which subsequently caused an increase in the use of substituted hydrofluorocarbons (HFCs), regulated by the Kyoto Protocol, illustrates the need for policy coherence and integrated approaches.

There are also substantial co-benefits between measures to promote renewable energy, energy efficiency and climate mitigation. The additional consumption of renewable energy since 2005 has allowed the EU to cut its demand for fossil fuels and related GHG emissions by about one tenth (EEA, 2017). Reducing GHG emissions, increasing energy efficiency and increasing the share of renewable energy in final energy consumption are complementary and are part of the 2030 climate and energy framework and the recent EU strategy for a climate-neutral economy by 2050 (EC, 2018a). In addition, actions to protect and restore ecosystems can contribute to mitigation and adaptation efforts by reducing emissions caused by ecosystem degradation and by enhancing carbon stocks. ■

fisheries sectors, projected increases in demand for biomass/wood and seafood will require the use of integrated ecosystem management approaches and sustainable forest management to ensure sustainable use of natural capital.

In conclusion, Europe risks destroying its natural capital without a full appreciation of what is being lost. For example, the overall economic benefits of the Natura 2000 network have been estimated at EUR 200-300 billion per year (Brink et al., 2013) and the cost of not reaching the headline targets of the EU biodiversity strategy to 2020 has been estimated at EUR 13 billion per year (COWI and Eunomia, 2019). The mapping and assessment of ecosystems and their services (MAES) process and the EU knowledge innovation project on natural capital accounting (KIP INCA) will strengthen the knowledge base for future actions at European and national levels, including the incorporation of natural capital into accounting systems in order to integrate natural capital concerns adequately into economic systems and decision-making.

Europe risks destroying its natural capital without a full appreciation of what is being lost.

Particularly in relation to biodiversity, when policy objectives and targets are not met, there is a tendency to reiterate them while extending the time frame. Retaining ambition is essential but current approaches do not address the root cause of most of the pressures on Europe's natural capital, which are linked to societal systems of production and consumption. In addition to further implementation of existing policies, including sectoral policies and increased use of nature-based solutions, structural changes in these societal systems are needed to sufficiently reduce pressures on natural capital and put Europe on track to meeting the ambitions set out in the 7th EAP and the EU biodiversity strategy. These aspects are assessed in Part 3.

14.4
A resource-efficient, circular and low-carbon economy

Priority objective 2 of the 7th EAP is 'to turn the Union into a resource-efficient, green and competitive low-carbon economy' (EU, 2013). Therefore, it is based on the recognition that the prevailing economic paradigm, based on continuously growing natural resource use and harmful emissions, cannot be sustained in the long term (EEA, 2015). The scope of the objective encompasses five main areas: (1) resource efficiency; (2) waste; (3) climate and energy; (4) sustainable consumption and production; and (5) water efficiency.

14.4.1
Progress and prospects to 2030 (2050)

Concerning resource efficiency and the circular economy, trends since 2000 in Europe's territory are encouraging. Material consumption in the EU Member States (EU-28) declined during the last decade, and resource efficiency improved as gross domestic product increased. The circular use of materials has also slightly improved since 2004. Together, this has led to an increase in resource productivity of almost 39 % since 2000, albeit with large differences between countries. This indicates progress in dematerialising economic output, although these trends do not take into account materials used and discarded during the production of imported goods. Looking ahead, prospects to 2030 are highly uncertain, partly due to the absence of measurable and binding policy targets, while global demand for resources is expected to rise strongly (Chapter 9).

Past trends for resource efficiency, the circular economy, and climate and energy are encouraging; the outlook is less positive.

When it comes to waste, past trends show an increase in the amount of total waste generated in Europe, although there are large differences among countries and there has been some decoupling of waste from economic development and population growth. The outlook to 2030 is less optimistic, as certain types of waste are expected to increase and many waste prevention programmes are rather weak and their effectiveness at the European level is unknown. More encouragingly, waste management is improving, with increasing recycling rates and less reliance on landfilling. These positive waste management trends are expected to continue; however, several countries are expected to miss their binding waste management targets and the quality aspects of recycled materials requires increased attention (Chapter 9).

The climate and energy targets for the short (2020), medium (2030) and long term (2050) are a fundamental pillar for achieving a resource-efficient and low-carbon economy. Past trends show that the EU has made substantial progress in decoupling carbon emissions from economic growth. Total greenhouse gas (GHG) emissions declined by 22 % between 1990 and 2017 as a result of the combined effect of policies and measures, and economic factors, including shares of energy from renewable sources increasing steadily to 17.5 % in 2017. Energy efficiency has improved as well, and final energy consumption decreased to levels similar to those in 1990. However, since 2014 an increase in final energy demand has been observed, driven in particular by increased demand from the transport sector. If this trend continues, the EU's 2020 target for energy efficiency might not be met without additional efforts (Chapter 7).

The medium and long-term outlook for climate and energy is less positive. With existing policies and measures, the estimates reported by Member States suggest reductions in GHG emissions of 29 % by 2030 compared with 1990 levels, whereas the EU target is at least 40 %. Even faster rates of emission reductions and stronger mitigation efforts will be required to meet the 2050 objective of reducing GHG emissions by at least 80 %. Likewise, for the EU to reach its 2030 energy targets of 32 % renewables and 32.5 % energy efficiency, continuing at the current rate of progress will not be sufficient. EU legislation was adopted in 2018 in all three areas to ensure stronger climate action to reduce GHG emissions, increase the use of renewables and deliver on energy efficiency targets (Chapter 7). The transformation into a low-carbon energy system requires substantial investments across all sectors and increased efforts regarding the implementation of energy efficiency measures and the further deployment of renewable energy sources, including their uptake in the transport sector.

Transforming Europe into a green and competitive economy requires adopting sustainable patterns of production and consumption. This involves reducing the overall environmental pollution load and the environmental impact of major economic sectors. Past trends show a mixed picture in this regard.

Encouragingly, there have been strong decreases in overall emissions of the main air pollutants, although since 2000 the rates of reduction have levelled off (Chapter 8). Industrial emissions to air and water have decreased substantially, emissions to air of some chemicals have decreased, and clean industrial technologies and processes are gaining ground (Chapter 12). Likewise, more sustainable practices have emerged in the forestry and maritime sectors. Other past trends are less positive. Despite improved efficiencies overall, environmental pressures from transport have increased due to growing demand. Emissions of ammonia from agriculture have recently increased, and the production and consumption of chemicals hazardous to health and the environment has remained stable.

Looking ahead, the prospects for moving towards sustainable production and consumption in key sectors are mostly mixed or even negative. Air, soil and water pollution from agriculture is expected to remain high, despite some regional improvements in relation to the nitrogen balance. GHG emissions, and air and water pollutant emissions from industry are expected to further decline. In the transport sector, GHG emissions might stabilise, but their high level means that transport sector emissions will be a key barrier to the EU's reaching its GHG reduction targets. Regarding chemical production, increases are projected, and hazardous substances in products coming from outside Europe are of particular concern.

Lastly, water efficiency has improved, with decreases in water abstraction of 19 % from 1990 to 2015 for the EU as a whole, but water abstraction still exceeds 20 % of the renewable freshwater resource in 19 % of Europe's areas (Chapter 4). Looking ahead, climate change is expected to increasingly determine water availability, and thus increased focus will be needed on measures to further reduce water use by households and agriculture.

Reaching the EU's long-term policy goals requires sustainable production and consumption patterns.

In conclusion, Europe has been able to reduce GHG emissions and air pollution, improve resource efficiency and energy efficiency, and achieve higher shares of renewable energy while increasing economic growth. However, much remains to be done to improve the environmental sustainability of Europe's production and consumption patterns and to reach long-term policy targets and objectives. This would require consideration of the co-benefits and trade-offs between policy areas, including climate, resource efficiency and environmental policies, in the design of new legislation. In addition, the assessment of progress does not take into account the full environmental impacts of production and consumption in Europe exerted outside Europe. These aspects are assessed in Part 3.

14.5 Safeguarding people from environmental risks to health and well-being

Priority objective 3 of the 7th EAP is 'to safeguard the Union's citizens from environment-related pressures and risks to health and well-bring' (EU, 2013). Therefore, it is based on the recognition that human health and well-being are intimately linked to the state of the environment. The scope of the objective encompasses seven main areas: (1) air quality; (2) environmental noise; (3) drinking and bathing water quality; (4) hazardous chemicals; (5) pesticides; (6) nanomaterials; and (7) climate change adaptation.

14.5.1 Progress and prospects to 2030 (2050)

Environmental pressures continue to contribute significantly to the overall burden of disease in Europe, in particular non-infectious diseases. While emissions of air pollutants have declined, almost 20 % of the EU-28 urban population lives in areas with air pollutant concentrations above at least one EU air quality standard and up to 95 % lives in areas exceeding World Health Organization (WHO) air quality guidelines for ozone. The latest estimates indicate that exposure to fine particulate matter (≤ 2.5 μm, $PM_{2.5}$) is responsible for around 400 000 premature deaths in Europe every year with the largest relative impacts observed in central and eastern European countries. Looking ahead, it is envisaged that the commitments to reduce air pollutant emissions by 2030 will result in a decrease in the population exposed to $PM_{2.5}$ concentrations above WHO guidelines. The estimated number of premature deaths attributable to $PM_{2.5}$ should halve, although at 194 000 there is still a need to substantially reduce the number. Developments in the transport sector are also not compatible with objectives for local air quality (Chapter 8).

Environmental noise continues to constitute a major environmental health problem, with at least 20 % of the EU's population living in areas where noise levels are considered to be harmful to health. It is estimated that long-term exposure to environmental noise contributes to at least 48 000 new cases of heart disease each year. Although

BOX 14.3 Challenges, synergies and opportunities — addressing inequalities

Safeguarding human health is an important driver for environmental policy, but environmental risks to health do not affect everyone in the same way. The unequal distribution of environmental and socio-economic conditions combined with pervasive inequalities affects vulnerability to multiple environmental pressures, including those related to environment and climate.

There are pronounced regional differences in social vulnerability and exposure to environmental health hazards across Europe (EEA, 2019).

Groups such as children, the elderly and those in poor health are more vulnerable and tend to be more adversely affected than the general population. The impacts of noise, air pollution and extreme temperatures on health closely reflects socio-economic differences within society. Groups of lower socio-economic status, for example the unemployed and those on low incomes, tend to be more negatively affected. This is as a result both of greater exposure from living in inadequate housing or areas with intense road traffic and of higher vulnerability linked to the ability to avoid or cope with environmental health hazards.

These inequalities are only partially addressed by current policy and practice and are likely to continue in the future. To address this, policies will need to respond to an ageing and increasingly vulnerable population concentrated in urban areas and to the unequal distribution of costs and benefits across society. Enhancing coherence between social and environmental policies regarding health, climate change, air pollution and urban design will help tackle inequalities in environmental risks and impacts on health and well-being. ■

Human health and well-being remain affected by exposure to air pollution, noise, hazardous chemicals and climate change.

a considerable number of people are exposed to noise and 6.5 million people suffer sleep disturbance, this has remained stable since 2012 despite efforts to achieve a significant reduction. Looking ahead, the Environmental Noise Directive has not yet achieved its full potential. Further implementation and progress in developing quiet areas will contribute to reducing the health impact of noise and also benefit biodiversity (Chapter 11).

There have been improvements in drinking and bathing water quality and both are generally of high quality throughout Europe, reflecting decades of effort and investment. However, some persistent and mobile chemicals resist even advanced drinking water treatment. There is a lack of robust data on the actual exposure of the European population to hazardous chemicals, as well as on their toxicity, to inform an understanding of the risks to human health. Concerns have been increasing over endocrine diseases and disorders, which have grown in line with more widespread use of chemicals. Concerns are also growing in relation to exposure to neuro- and immunotoxic chemicals, which impair childhood development and can result in chronic disease outcomes later in life or in successive generations. Looking ahead, while there is uncertainty around future developments, the accumulation of persistent chemicals and continued emissions of hazardous chemicals suggest that human exposure to complex mixtures of chemicals over a lifetime will not decrease and that Europe is not on track to meet the objective of minimising risks to health from hazardous chemicals by 2020 (Chapter 10).

Climate change presents both direct and indirect risks to health and well-being, especially for more vulnerable groups through impacts from heat waves, forest fires, flooding and changing patterns in the prevalence of infectious diseases. Looking ahead, accelerating climate change is likely to further increase negative health effects, particularly mortality from heat waves (Chapter 7). Responses such as ecosystem-based adaptation have potential to reduce the vulnerability of communities to climate change and when designed, implemented and monitored appropriately can deliver multiple benefits, including improved health and well-being.

Looking ahead, the outlook for reducing environmental risks to health and well-being is uncertain. The complexity of systemic risks to health, coupled with important gaps and uncertainties in the knowledge base, warrant a precautionary approach. Early identification of emerging issues can help ensure a higher level of public safety and environmental protection. A recent review of emerging health and environment issues highlighted a range of risks, including chemicals in recycled materials, pharmaceuticals and illicit drugs in waste water and surface waters, and persistent and mobile chemicals (EC, 2018c).

In conclusion, European policies have successfully reduced some risks to health and well-being, especially those from air pollution. However, human health and well-being are still affected by exposure to air pollution, noise, hazardous chemicals and increasing risks from climate change. Fully implementing and strengthening the policies Europe has put in place is expected to reduce these impacts. Developing a stronger framework integrating environment and health is an opportunity to take a more holistic approach in which risks to health are managed by considering hazard, exposure and vulnerability and supported by a stronger knowledge base.

14.6 Understanding state, trends and prospects

Looking across the three priority areas of the 7th EAP presented in Table 14.1, Europe has made progress in reducing some key environmental pressures. There are differences in the scope and number of themes included in the summary table in the SOER 2015 (EEA, 2015) and in Table 14.1 that need to be taken into account in any comparison. Overall the summary table shows a similar picture to that presented in SOER 2015 in that policies have had a clearer impact in reducing environmental pressures than in protecting ecosystems and biodiversity, and human health and well-being.

95 %

of Europeans live in areas with ozone pollution that is above WHO guidelines.

Reductions in environmental pressures have not yet translated into a sufficient reduction in environmental impacts, resulting in an outlook towards 2030 that is less positive than past trends in many areas, particularly in relation to natural capital. The outlook for most themes reflects a mixed picture regarding developments across the wide range of factors that determine environmental outcomes.

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 included in the assessment. In relation to energy and climate change, the prospects differ when considering different time horizons and prospects are better in the short term than in the longer term.

SOER 2020 shows that Europe is either not on track or only partially on track for the majority of goals and targets.

A variety of factors contribute to this picture, for example:

- While some pressures from agriculture, GHG and air pollutant emissions and levels of resource use have decreased, they remain substantial.

- The complexity of environmental systems can cause a considerable time lag between reducing pressures and improvements in the state of and prospects for natural capital and human health and well-being. In addition, legacies from the past, such as hydromorphological changes in rivers, accumulated pollutants and soil sealing, continue to negatively impact on natural capital and ecosystem services.

- The pace of progress has slowed in relation to, for example GHG emissions, industrial emissions, waste generation, the nitrogen balance, energy efficiency, the share of renewable energy and employment in the environmental goods and services sector. This indicates the need to go beyond incremental improvements and address the systemic drivers behind environmental pressures, such as resource-intensive production and consumption patterns, increasing demand for transport and continuing urbanisation, to achieve the scale of change needed.

- Environmental outcomes are often determined by a complex mixture of factors, as clearly illustrated by the wide range of factors that contribute to biodiversity loss. This can limit the effectiveness of policy measures if the impacts of external pressures counteract the effects of policy measures and local management efforts.

- The situation in Europe is also influenced by global developments, as illustrated by climate change. Europe contributes to global warming — currently 8 % of global GHG emissions — while at the same time it is affected by changes in the global climate system. This includes direct effects, such as increased risks of flooding, heat waves and droughts, and also possible indirect effects triggered by climate change impacts outside Europe, such as global food price volatility or the economic repercussions of extreme weather events.

The cost of not implementing EU environmental policy is at least EUR 55 billion annually.

14.7 Supporting action — the Seventh Environment Action Programme enabling framework

The 7th EAP enabling framework aims to support effective action to achieve the three priority objectives (POs). It contains a range of horizontal measures that also aim to benefit environmental policy beyond the scope and time frame of the 7th EAP (EU, 2013). The focus here is on three of the key pillars of the enabling framework, with the others, namely securing investment for environment and climate policy (PO 6), enhancing the sustainability of cities (PO 8) and increasing the effectiveness of addressing international environment and climate-related challenges (PO 9), as addressed in Parts 3 and 4.

14.7.1 Improving implementation

Priority objective 4 of the 7th EAP is 'to maximise the benefits of Union environment legislation by improving implementation' (EU, 2013). A recent study estimated that the total costs to society of current gaps in the implementation of environmental policy is at least EUR 55 billion annually (COWI and Eunomia, 2019). The European Commission launched the Environmental Implementation Review in 2016 with the aim of improving implementation by identifying causes of gaps in implementation and addressing systemic obstacles to environmental integration across policy sectors. The main challenges and good practices are mapped across countries. A review undertaken by the European Parliament on the implementation of the 7th EAP identified a range of issues that need to be addressed (European Parliament, 2017). These are coherent with the assessments in the preceding chapters, which identify a range of successes and challenges regarding implementation.

Looking across the three thematic priority areas, significant gaps in implementation, enforcement, financing and policy integration are affecting efforts to protect European ecosystems (EC, 2019a). While Europe has reached its target regarding designation of protected areas, designation is not a guarantee of effective management and conservation (Chapters 3 and 6). However, the situation regarding a resource-efficient, circular and low-carbon economy is more positive. There is a good level of implementation of climate legislation and the 2020 targets will be met. However, waste management and waste prevention have been identified as problematic issues (EC, 2019a; European Parliament, 2017). Regarding environmental risks to health and well-being, key areas to address include the failure to implement air quality legislation in urban areas, the need to accelerate reduction of emissions by further reducing emissions from transport and agriculture, and developing action plans to tackle environmental noise.

In addition, important policy gaps remain. For example, a coherent policy to protect Europe's soils from erosion, compaction, sealing and contamination is missing, and policies to curb land take and land fragmentation lack clear targets, measures and incentives. Current policy frameworks contain few long-term binding objectives and targets (Figure 14.1), which, combined with shorter and medium-term targets, can enable progress towards longer term, more strategic objectives such as the 7th EAP's vision for 2050.

14.7.2 Environmental integration and policy coherence

Priority objective 7 of the 7th EAP is 'to improve environmental integration and policy coherence' (EU, 2013). This reflects the fact that achieving environment and climate policy objectives depends not only on effective implementation but also on integration of the environment into other policy areas. Although some progress has been made (Chapter 13), overall, environment and climate-related concerns are not sufficiently integrated into other policy areas, with the common agricultural policy (CAP) regularly identified as lacking coherence with the 7th EAP (European Parliament, 2017). The preceding chapters have also highlighted the need for improved coherence between the common fisheries policy, the CAP and biodiversity objectives (Chapter 3) and between rural development plans under the CAP and the Water Framework Directive (Chapter 4) and chemical and waste management policies (Chapter 9). Strengthening environmental integration into policy areas such as agriculture, transport, industry and energy, and EU spending programmes is essential, but the overall approach of environmental integration has not been successful when it comes to addressing environmental pressures from economic sectors.

14.7.3 The knowledge base for environmental policy

Priority objective 5 of the 7th EAP is 'to improve the knowledge and evidence base for Union environmental policy' (EU, 2013). The summary assessment tables in Chapters 3-12 provide information on the robustness of the knowledge base underpinning the assessments in terms of the quality of the evidence, uncertainty and knowledge gaps across the range of environmental themes. Regarding natural capital, important developments such as the MAES process and the EU knowledge innovation project on natural capital accounting (KIP INCA) will strengthen the knowledge base for policy and decision-making. The knowledge base is improving regarding the impacts of climate change and species loss on ecosystem services (European Parliament, 2017). Regarding environmental risks to health, important gaps remain in relation to chemicals, particularly the effects of exposure to mixtures (Chapter 10) and the interaction between systemic risks and other health determinants (European Parliament, 2017).

Looking across the three priority areas, there are also differences regarding the availability of forward-looking information. Outlook information is very limited or lacking for many areas related to natural capital or environmental risks to health and well-being. There is much better availability of outlook information, particularly quantitative projections and modelling of scenarios in relation to climate, energy, air pollutants and transport.

System transitions are needed to achieve the EU's 2050 vision of a sustainable, climate-neutral economy.

14.8 Looking ahead: the Seventh Environment Action Plan vision, the Paris Agreement and the Sustainable Development Goals

The recent evaluation of the 7th EAP highlights its value in providing a framework that has enabled stakeholders to come together to set priorities and one that has contributed to greater coherence in and commitment to EU and national policies and actions. The consensus built around the 7th EAP has also helped European countries speak with one voice in the global context in relation to the SDGs and the Paris Agreement (EC, 2019b).

Efforts over recent decades on policy implementation and integration mean that Europe's environment is in better shape than it would have been otherwise, providing a solid foundation for future developments. However, the value of this can be expected to decline over time as impacts on the climate, ecosystems and human health are expected to persist or increase. This points to the need for further efforts regarding policy implementation and integration, as well as systemic and integrated approaches that address natural capital, climate change, resource use and environment and health challenges in a broader sustainability context.

While the interrelated nature of the priority objectives of the 7th EAP provide an opportunity to harness synergies across policy areas and scales, this also presents challenges in terms of addressing issues in an integrated way. Gaps remain between ambitions, for example that 'structural changes in production, technology and innovation as well as consumption patterns and lifestyles have reduced the overall impact of production and consumption in the food, housing and mobility sectors' and the largely thematic and sectoral focus of current actions. Indeed, the evaluation of the 7th EAP highlights that the ecological impacts of the mobility sector and food system remain too high (EC, 2019b).

A major opportunity exists in relation to the climate-neutral, circular and bioeconomy strategies in the EU. These frameworks rely on the same natural resource base; therefore, more integrated management of natural resources, including consideration of potential synergies and trade-offs, would enable more effective reduction of environmental pressures along the value chain. This would improve consistency between producer and consumer-oriented policy interventions and bring a spatial perspective that respects ecosystem functions, prioritises conservation measures and accounts for the dynamics of the wider countryside.

Looking ahead, achieving the 2050 vision of the 7th EAP, as well as Europe's related vision for a sustainable economy, will require system transitions supported by new types of knowledge, policy design and governance arrangements. These aspects are assessed more fully in Parts 3 and 4.

PART 3

Sustainability prospects

15.
Sustainability through a system lens

Summary

- The EU has committed to ambitious, long-term environmental and climate goals with the aim of 'living well, within the limits of our planet', but current measures are insufficient to achieve these goals.

- Many global megatrends continue to intensify persistent environmental problems, while emerging trends are increasingly influential in shaping environmental outcomes. They embed both risks and opportunities for Europe and its environment, as illustrated by recent social and technological innovations.

- Overall, Europe can act on these drivers of change to shape a sustainable future.

- Persistent environmental and climate problems resist traditional policy responses. They cannot be fully resolved without addressing broader sustainability issues that address environmental, social, economic and governance dimensions at the European and global scales.

- The Sustainable Development Goals (SDGs) framework exemplifies the systemic nature of sustainability issues. Achieving the SDGs and other long-term sustainability goals requires considering their interactions, including trade-offs, co-benefits and transboundary effects between Europe and the rest of the world. Designing policy frameworks that pursue these goals requires systems thinking.

- While many systems perspectives exist, *The European environment — state and outlook 2020* (SOER 2020) focuses on three key systems — those meeting European demand for food, energy and mobility — while providing relevant insights on other societal systems.

15. Sustainability through a system lens

15.1 From environment to sustainability

15.1.1 The EU has committed to ambitious environmental and climate goals

In recent decades, Europe has increasingly recognised the significance of many environmental and climate challenges at both European and planetary scales. In particular, it has become aware of the increased risks — environmental, social, economic and geopolitical — for Europe and the world in relation to transgressing global ecological limits related to climate, resource use, pollution, biodiversity loss and ecosystem degradation (EU, 2013; EC, 2019). For example, it has acknowledged that, without strong measures to curb greenhouse gas (GHG) emissions, continued global warming will substantially increase the likelihood of severe, pervasive and irreversible consequences such as the collapse of natural ecosystems (Arctic, coral reefs, Amazon forest), erosion of global food security or displacement of people at unprecedented scales. Likewise, it has recognised that accelerated depletion and degradation of ecosystems continuously erodes nature's capacity to deliver the services that underpin almost every aspect of human well-being and thereby jeopardises sustainable development (Chapter 1).

'Living well, within the limits of our planet' is the EU's sustainability vision for 2050.

Against this backdrop, the EU has set itself an ambitious vision for 2050 with the aim of 'living well, within the limits of our planet' and a focus on three key objectives: (1) protecting natural capital; (2) achieving resource efficiency and decarbonisation; and (3) safeguarding against environmental pressures and risks to health and well-being (EU, 2013). In line with this vision, the EU and its Member States have adopted ambitious environmental and climate targets and objectives. These include the legally binding objective to cut GHG emissions to at least 40 % below 1990 levels by 2030 (European Council, 2014), and the ambition to cut GHG emissions by 80-95 % by 2050 (EC, 2011a). In 2018, the European Commission published its strategic long-term vision for a prosperous, modern, competitive and climate-neutral European economy by 2050, which shows how Europe can lead the way to climate neutrality while ensuring a socially fair and just transition (EC, 2018a).

Other long-term objectives include achieving no net land take by 2050, halting the loss of biodiversity and the degradation of ecosystem services, and producing and using chemicals in ways that minimise significant adverse effects on human health and the environment. Recognising that 'many environmental challenges are global and can only be fully addressed through a comprehensive global approach' (EU, 2013), it has also promoted, shaped and endorsed two major, highly significant, long-term global, agreements. The United Nations (UN) 2030 agenda for sustainable development includes long-term goals and targets covering all critical environmental and climate issues, while the Paris Agreement establishes the international goal of limiting global warming to well below 2 °C above pre-industrial levels and pursuing efforts to limit the temperature increase to 1.5 °C above pre-industrial levels (Chapter 2).

15.1.2
Despite progress, the EU is not on track to reach many environmental goals

Viewed together, the thematic and sectoral assessments in this report (Chapters 3-13) present a worrying outlook for Europe's environment in the coming decades. They lead to the conclusion that many long-term EU environment and climate targets will not be met with existing policy interventions if current trends continue (Chapter 14). This applies, for example, to the EU's ambitious objectives to reduce GHG emissions. Although these targets are in line with the global goal set by the Paris Agreement, the projected pace of reducing GHG emissions after 2020 is clearly insufficient to achieve them (Chapter 7).

More short-term objectives and targets will not be met for a range of environmental issues related to natural capital and environmental impacts on health and well-being. For example, Europe will not achieve good environmental status for all of its water bodies and regional seas by 2020, nor will it achieve sustainable soil management. It is not on track to minimise significant adverse effects of chemicals on the environment by 2020. The health and well-being of European citizens still suffers substantially from exposure to air pollution, noise, hazardous chemicals and, increasingly, risks resulting from climate change (Chapter 14).

> Many long-term EU environment and climate targets will not be met with existing policy interventions.

In fact, some objectives and targets have been renewed over the years, without signs of significant progress. For instance, the EU first set the target of halting biodiversity loss in the EU by 2010. When this was not achieved, it set the same target for 2020 (EC, 2006, 2011b). Despite many local conservation successes, for instance through the extension of the Natura 2000 network of protected areas, the mid-term review of the EU biodiversity strategy to 2020 reported 'no significant progress' towards the headline target (EC, 2015), an assessment further supported by the analysis in Chapter 3.

15.1.3
Persistent environmental problems resist traditional policy responses

While some explanation for these shortfalls can be found in implementation deficits or time lags between implementation and measurable ecological changes (Chapter 14), this diagnosis triggers more fundamental questions. Have we truly recognised the scale of change required to achieve Europe's environmental goals? Have we fully understood the reasons for the persistence of environmental and climate problems?

As emphasised in Chapter 1, the very same human activities that have delivered major improvements in living standards and well-being since the 1950s have been the source of unprecedented environmental degradation in Europe and worldwide and of anthropogenic changes to the climate system. If environmental problems, such as biodiversity loss and climate change, have been resistant to policy interventions over several decades, it is mainly because their underlying causes have been insufficiently or ineffectively tackled.

Ultimately, the environmental pressures related to energy use, extraction of natural resources, chemical use, land use, waste generation, and so on, originate from the same production and consumption processes that provide societal needs such as food, mobility, heating and shelter (EEA, 2015). As research and policy increasingly acknowledge, resolving persistent environmental problems will require more ambitious, upstream and comprehensive responses than those provided by past environmental policy interventions (Chapter 2). The scale and complexity of the challenge for governance is augmented by the impacts of global megatrends on Europe and its environment.

15.1.4
Many global megatrends continue to intensify environmental problems

There is widespread consensus that many global megatrends — large-scale, high-impact and long-term trends — are likely to affect Europe and its environment strongly in the coming decades (EEA (forthcoming), 2020b). A growing global population and the emergence of an affluent middle class across the world, is accelerating global demand for materials, land, water and energy, with cascading effects on ecosystems and climate change (Chapter 1). With European industrial regions already facing a number of challenges regarding access to both primary and secondary raw materials (EC, 2017a), these trends put Europe at further risk of supply shortages. This could result in increased pressures on natural resources in Europe (EEA (forthcoming), 2020b).

Turning to a technological perspective, the widespread digitalisation of economies and societies worldwide is expected to continue shaping European production and consumption profoundly (Chapter 1). While digitalisation creates a wide range of opportunities for society, the overall implications for the European environment are uncertain. Digitalisation can foster product traceability (e.g. blockchain — see Box 15.1) and efficiency gains in production processes. However, the exponential increase in personal connected devices and sensors (e.g. related to the Internet of Things) requires increased infrastructure deployment and energy consumption, leading to additional environmental pressures (EEA (forthcoming), 2020b). Moreover, the increasingly short lifespan of such devices contributes to a rapid increase in waste electrical and electronic equipment (WEEE) and associated problems of recycling and disposal.

From a geopolitical perspective, increased volatility and tensions in the global multilateral system (EPSC, 2018; MSC, 2019) may jeopardise the implementation of existing global agreements, such as the Paris Agreement, and compromise further concerted international action on other environmental issues (EEA (forthcoming), 2020b). With key countries tempted to turn their backs on multilateral agreements, 'Europe will have to deploy environmental diplomacy in a hitherto unseen way' (ESPAS, 2019).

15.1.5
Drivers of change embed both risks and opportunities

Many global megatrends have worrying implications for Europe's

Global megatrends are likely to have major impacts on Europe and its environment.

environment. But other drivers of change, such as more Europe-specific trends and emerging trends, suggest a more open and nuanced outlook. For instance, in contrast to many world regions, stagnating population trends in Europe potentially offer a more favourable context for decreasing the environmental pressures resulting from European consumption (Chapter 16). On the other hand, ageing population trends in Europe could lead to higher domestic energy demand, for example due to increased heating and cooking linked to a higher proportion of smaller households (Bardazzi and Pazienza, 2017). They may also bring substantial challenges for fiscal and financial sustainability (EEA (forthcoming), 2020a). Ultimately, much depends on how much individual consumption levels and patterns can change in Europe.

To assess this, it is essential to pay more attention to emerging trends that carry the seeds of change. For instance, promising social innovations originating from citizens, cities and communities, such as collaborative consumption, have recently emerged as new ways of consuming (EEA, 2015). While these more sustainable behaviours remain niche for the time being, their mainstreaming into everyday practice could decrease environmental pressures from consumption, particularly if accompanied by changes in product design (EEA, 2017) and lower standards of material consumption in European lifestyles (e.g. through sufficiency). Similarly, many emerging trends related to technological innovation, such as blockchain technology, synthetic biology, artificial meat or drones, bring new opportunities for Europe and its environment, as well as new risks (Box 15.1). Amid this uncertainty, one conclusion emerges: the future is open and it can be shaped. Europe can either be carried along by ongoing trends or it can seek to bend them towards a more sustainable trajectory. As agents of change who can shape or adapt to drivers of change, the EU and European citizens are not powerless in their efforts to live well, within the limits of our planet.

15.1.6
Environmental issues are inseparable from broader sustainability issues

The scale of environmental challenges and the implications of global megatrends together imply the need for fundamental and urgent changes in our societies and economies, with significant consequences for lifestyles, jobs, habits, and so on. Resolving environmental problems inevitably implies the need to address broader sustainability issues. It raises questions about 'how our system of prosperity [can] be maintained' within local and global ecological limits (Hajer, 2011). This presents a fundamentally different challenge from those of the 1970s or 1980s, when specific environmental problems could be tackled with targeted instruments. The complex and systemic character of today's sustainability challenges requires a different policy response.

First, policy interventions must be designed to consider the environmental, social, economic and governance dimensions of human activities, which are interconnected in many ways. Significant changes in any one dimension (e.g. environmental) will affect the others (e.g. socio-economic) in ways that are sometimes beneficial,

BOX 15.1 Emerging trends: four examples related to technological innovation

Assessing prospects for the environment in a fast-changing world requires considering not only environmental trends and global megatrends but also emerging trends. Although fewer data are available to characterise these societal, technological, economic and geopolitical developments, it is crucial to anticipate their potential implications as early as possible. In the field of technological innovation, for instance, there are some rapidly emerging trends that are likely to have significant impacts on the environment, as well as on society and the economy (EEA and FLIS, 2019). Examples include:

Blockchain, which consists of an open, distributed and public computer-based ledger for transactions, illustrates the new opportunities offered by digitalisation. Its applications, such as cryptocurrencies (e.g. bitcoin) and decentralised autonomous organisations, could radically transform existing governance arrangements, electoral procedures and financial transactions. Environmental protection could benefit, for example, from increased traceability and accountability in supply chain management (Kouhizadeh and Sarkis, 2018). However, mainstreaming of blockchain also raises concerns in relation to climate change mitigation, as the current processes for transaction verification, or 'mining', are highly energy intensive.

Synthetic biology, which involves the assembly of entirely new sequences of DNA and entire genomes, is already being applied in the pharmaceutical, chemical, agricultural and energy sectors. Promising uses for environmental protection include bioremediation of polluted industrial sites, pollution detection, protection of species at risk, and bio-based products (Science for Environment Policy, 2016). Nevertheless, its application to control disease vectors, for example by genetically engineering mosquitoes to prevent the spread of malaria, could disrupt ecosystems in unexpected ways and lead to biodiversity loss (CBD, 2015).

Artificial meat, which refers to meat cultivated *in vitro* from stem cells of living animals, may offer an alternative and novel solution to the rising global demand for meat consumption (especially in Asia). Its mainstreaming could help to decrease greenhouse gas (GHG) emissions from livestock, which account for a significant proportion of all anthropogenic emissions, i.e. 14.5 % according to the United Nations Food and Agriculture Organization's global life cycle approach (Gerber et al., 2013). Even if the production costs of artificial meat decrease in the coming years, its mainstreaming will remain largely dependent on its societal acceptance (e.g. cultural and psychological barriers) as well as on reliable food safety protocols.

Drones are increasingly used for delivery by e-commerce and the logistics industry, potentially providing a significant contribution to reducing GHG emissions from the transport sector. Indeed, recent research shows that delivery drones can outperform conventional delivery trucks (Goodchild and Toy, 2018), diesel vans (Figliozzi, 2017) and motorcycles (Park et al., 2018) in terms of GHG emissions. However, an assessment of the whole life cycle of drones (including extra warehousing, battery use, etc.) has yet to be performed. The mainstreaming of delivery drones would also bring new threats to wildlife, especially birds, and create additional noise and visual impacts in urban environments. ■

The complex nature of the sustainability challenge requires a new policy response.

sometimes detrimental, and often uncertain (Chapter 16).

Second, the roots of environmental degradation and climate change are so intrinsically linked to the structure and functioning of our societies and economies — in Europe but also in most advanced economies throughout the world — that our long-term environment and climate goals will not be achieved without fundamental transformations in the ways we consume and produce. This provokes questions about how policy can trigger systemic change that engages society as a whole (Chapter 17).

Third, patterns and mechanisms of consumption and production co-evolve with each other not only at the European scale but also internationally through trade, communication, policy and knowledge transfers (see Section 15.2). This means that the response to sustainability issues affecting Europe is generally not just a European response but one that requires strong coordination among the international community. For instance, achieving climate neutrality in Europe by 2050 will have only a limited effect on climate change mitigation (and its impacts) if other countries do not take similar action. The Paris Agreement and the 2030 agenda for sustainable development are encouraging signs of this international alignment.

15.2 The systemic nature of sustainability issues

15.2.1 The Sustainable Development Goals cannot be pursued successfully in isolation

The SDGs framework offers the most comprehensive and widely shared view of our common sustainability challenges worldwide (see Figure 2.1 in Chapter 2 for a description of the SDGs). The 2030 agenda for sustainable development calls on governments and other stakeholders to achieve 17 SDGs and 169 associated targets, bringing together economic, social and environmental considerations in ways that mutually reinforce each other. The UN has stressed that the agenda should be viewed as an indivisible whole in which all targets are equally important. As the goals are closely interlinked, however, pursuing them concurrently implies the need to consider their interactions. This brings both challenges and opportunities for policies and implementation.

Achieving the SDGs implies a need to consider their interactions, trade-offs and co-benefits.

Some of these interactions are now well known and have been acknowledged (sometimes after a delay) by policymakers. For example, the case of first-generation biofuels has made it clear that the goal of increasing bioenergy production (SDGs 7 and 13) can easily enter into conflict with the goal of fostering food security (SDG 2), as both require the use of agricultural land, which is an increasingly scarce resource (Chapter 16). However, there is growing recognition of the multiple co-benefits that protecting, conserving, enhancing and restoring natural capital (SDGs 14 and 15) provide for health and well-being objectives (SDG 3). For instance, ecosystem-based approaches, such as green infrastructure and nature-based solutions, can fulfil several functions on the same piece of land such as helping to reduce air pollution, mitigating heat stress, reducing noise in urban environments and providing opportunities for increased physical activity and improved mental health (Chapters 3, 6 and 17).

Studying the interactions between different societal goals is not something new. It is at the core of research on sustainability. Indeed, policy integration and coherence has been on the agendas of international organisations (e.g. Organisation for Economic Co-operation and Development, UN Environment) and European and national institutions for some time (Chapter 2). At the EU level, all proposed legislation goes through an impact assessment, which needs to include a description of potential environmental, social and economic impacts. Although such assessments are valuable, they are insufficient to address sustainability issues, which require an awareness of the systemic interactions between the societal outcomes pursued by various policies. Indeed, pursuing any single SDG target does not affect other targets in a binary way but rather systemically, potentially triggering cascading effects. Box 15.2 outlines a systemic approach that aims to unpack these interactions in a manner that supports more robust implementation strategies (EEA and SEI, 2019).

15.2.2 The SDGs highlight European-global interactions

In addition to the interactions between different SDGs in Europe, the global character of the SDGs implies the need to acknowledge interactions with efforts to achieve them in other world regions. In line with the EU's commitment to 'foster the sustainable economic, social and environmental development of developing countries' (EU, 2007), progress towards the SDGs in the EU should not compromise progress in other regions but rather support it. This focus is at the core of policy coherence for sustainable development, which has been endorsed by the EU and applied in some areas. In particular, the EU has been a frontrunner in ensuring coherence between its trade and development policies, especially for the least developed countries (EC, 2018b). It is increasingly recognised that achieving the SDGs will now require the mainstreaming of this approach (OECD, 2018; EC, 2019).

This endeavour should start with a better understanding of the transboundary effects of EU measures to achieve the SDGs. Transmission channels are numerous and include financial flows, imports and exports of goods and services (especially through global value chains), diffusion of waste and pollution (e.g. to the EU's neighbourhood), migration (e.g. the 'brain drain') or knowledge transfers (OECD, 2017). As regards environment protection and climate action, the pursuit of SDG targets in Europe can potentially lead to the externalisation of the same environmental problems

BOX 15.2 SDG interactions

In 2016, a framework for mapping and categorising Sustainable Development Goals (SDGs) interactions was proposed, using a seven-point scale to describe the nature of interactions. (Nilsson et al., 2016; Griggs et al., 2017). The methodology was further developed by the Stockholm Environment Institute (SEI) to assess SDG interactions in different contexts. By adding cross-impact analysis (Figure 15.1) and using network analysis techniques, it provides a systemic and contextual perspective on the SDGs (Griggs et al., 2017; Weitz et al., 2018). The results show, for example, which targets are most and least influential for making progress on the SDGs, where there are critical trade-offs and synergies, and where stakeholders have shared or conflicting interests. This is useful to guide priority-setting and cross-sector collaboration for implementing the SDGs.

When applying the analysis at the EU scale (EEA and SEI, 2019), the SDG framework reveals many synergies. However, the relationship between SDGs 12-15, crucial for environmental protection and climate action, and other SDGs (such as SDGs 1 and 7-11) potentially involve trade-offs. The main reason is that increased income (SDG 1), better access to energy (SDG 7), more economic growth (SDG 8), and industrial and infrastructure investments (SDG 9) tend to increase overall consumption and natural resource extraction. They therefore make it harder to achieve targets on efficient use of natural resources (target 12.2), better management of chemicals and waste (target 12.4), climate mitigation (target 13.2) and protection of terrestrial ecosystems and biodiversity (targets 15.1 and 15.5). Acknowledging these tensions more explicitly reinforces the call for alternative pathways for sustainable development.

The example of steel can illustrate how important the choice of interventions will be when trying to achieve societal goals that are potentially conflicting. Steel is a central component of an industrial society and thus for progress on SDG 9. The global demand for steel is expected to increase with increasing economic development, and steel production already accounts for about 7 % of global carbon dioxide emissions, which makes it the single largest sector in terms of industrial emissions (Pérez-Fortes et al., 2014). Thus, there is a clear tension with climate change mitigation (SDG 13). To meet the SDGs, the Paris Agreement and EU targets for reducing emissions from steel production to near zero by 2050, while promoting a thriving steel industry within the EU, a systemic change all the way from production to recycling is needed (Åhman et al., 2018). In Sweden, three companies focusing on iron ore mining, steel manufacturing and power utility have joined forces to develop a novel process for fossil fuel-free steel production (Åhman et al., 2018). Such an initiative moves beyond capture and storage of carbon dioxide as the approach for limiting climate impacts from heavy industry to avoiding emissions being generated in the first place. It tries to address fully the trade-off between SDGs 9 and 13 through better internalisation of negative effects from industrialisation and infrastructure development in the long term. ■

or the creation of other kinds of challenges in other countries, reducing their chances of achieving those SDGs. This 'burden shifting' could negatively affect the global achievement of the SDGs and could also feed back negatively on Europe in areas relating to the global commons (e.g. climate change mitigation, healthy oceans). Key externalities to be considered in the field of environment and climate action include (Lucas et al., 2016; OECD, 2017, 2018):

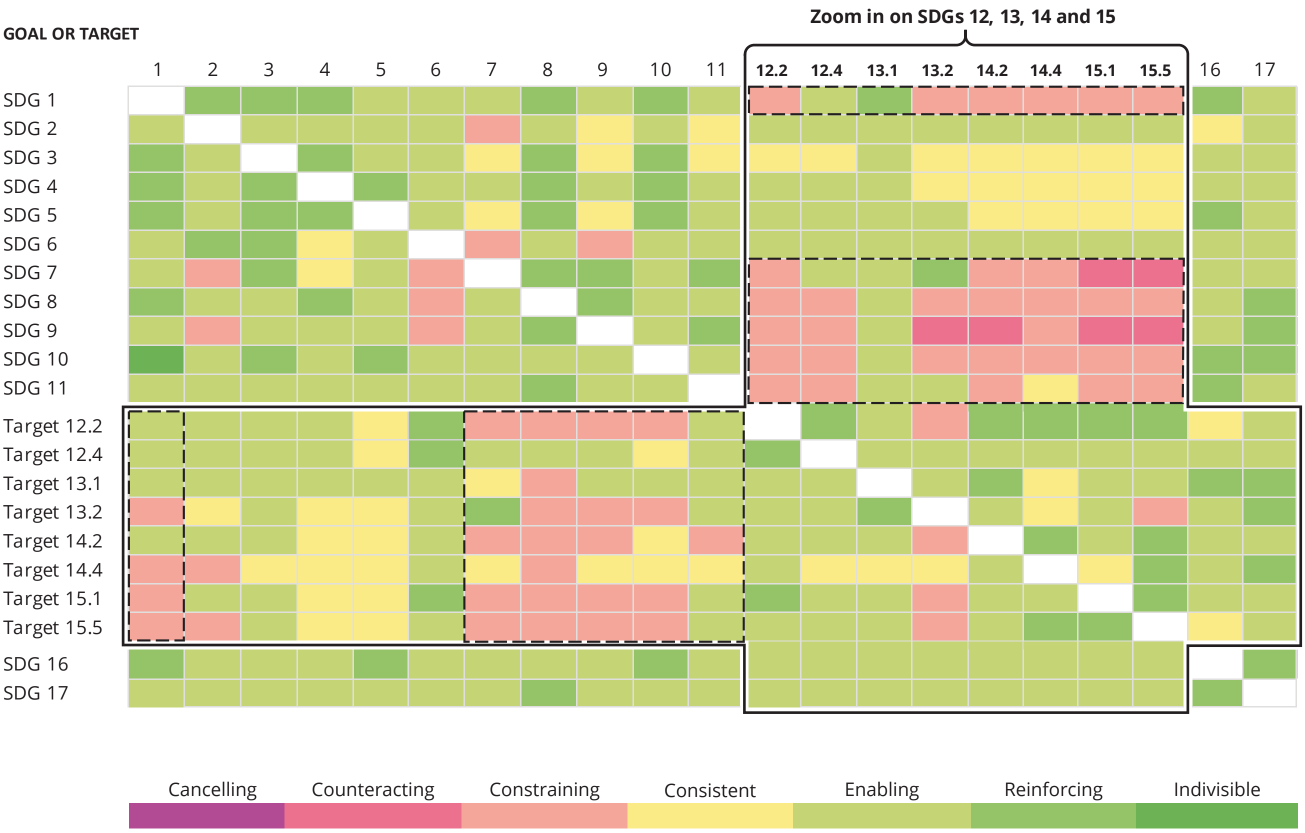
- environmental pressures (e.g. SDGs 6, 7, 12, 14, 15) on resources or conditions in other countries that are attributable to EU consumption (SDGs 8 and 12) (see Chapters 2 and 16 on footprint indicators), for example deforestation in producing countries resulting from EU imports (e.g. palm oil, soybean, exotic woods);

- adverse impacts of EU reliance on energy-intensive imports (SDG 7) on the decarbonisation efforts of other countries (SDG 13);

- unintended consequences of biofuel subsidies (SDG 7) on food prices through competition for land, possibly impacting the food security of the most vulnerable households in developing countries (SDG 2);

- shifting production abroad as a result of stringent EU policies on biodiversity conservation, reduced use of agricultural inputs or climate mitigation (SDGs 2 and 13-15), leading to a potential increase in unsustainable agricultural practices and polluting

FIGURE 15.1 Visualising SDG interactions



Source: EEA and SEI (2019).

industries in those countries (SDGs 2, 3, 14, 15);

- cross-border impacts of air and water pollution (SDGs 6 and 12).

There are obviously many positive externalities, especially those linked to trade, investments, official development assistance, diffusion of innovation and exchange of environmental information and knowledge. The EEA's cooperation with the EU's southern and eastern neighbourhood countries is a good example of the latter (EEA, 2018a, 2019).

15.2.3
The 2030 agenda aims for systemic transformation

In addition to recognising systemic challenges, the 2030 agenda for sustainable development embraces the notion of transformation, as expressed in its main title *Transforming our world*

The 2030 agenda for sustainable development embraces the notion of transformation.

(UN, 2015). World leaders have declared that they are 'determined to take the bold and transformative steps which are urgently needed to shift the world onto a sustainable and resilient path' (UN, 2015). In recent years, this has been echoed and expanded on by a large number of international organisations and initiatives, which share the ambition of bringing 'transformative change', 'transitions' or 'system transitions' into the heart of their assessments. Such assessments include *The World in 2050* (TWI2050, 2018); the IPCC Special Report *Global warming of 1.5* °C (IPCC, 2018); Future Earth's work on *Transformations* (Future Earth, 2019); the *Global assessment report on biodiversity and ecosystem services* (IPBES, 2019); and *The Sixth Global Environmental Outlook* (UN Environment, 2019). For instance, *The World in 2050* highlights the need for 'bold and appropriate changes in values and deployment of policy instruments' to foster six key transformations related to human capacity and demography; consumption and production; decarbonisation and energy; food, biosphere and water; smart cities; and the digital revolution.

At the European level, the proposed long-term climate-neutral strategy stresses that the options it proposes 'will radically transform our energy system, land and agriculture sector, modernise our industrial fabric and our transport systems and cities, further affecting all activities of our society' (EC, 2018a). Similarly, the European Commission's reflection paper, *Towards a sustainable Europe by 2030*, acknowledges the need for 'a transition to a low-carbon, climate-neutral, resource-efficient and biodiverse economy in full compliance with the United Nations 2030 Agenda and the 17 SDGs' (EC, 2019). Both documents emphasise that the various dimensions of sustainability are inextricably intertwined. They acknowledge that transitions will have difficult implications for a number of sectors and regions, particularly those 'whose economies depend on activities that either are expected to decline or will have to transform in the future.' (EC, 2018a). They therefore stress the need for transitions that are socially fair, 'for the benefit of all, leaving no one behind, ensuring equality and inclusiveness' (EC, 2019).

SOER 2020 focuses on three critical societal systems: energy, food and mobility.

15.3 Understanding and responding to sustainability challenges

15.3.1 Achieving sustainability goals will require systems thinking

As shown in previous sections and exemplified by the SDGs, sustainability challenges are systemic in nature and require systemic responses. Policies and decisions that take a systemic view of sustainability issues based on science-informed analysis have a better chance of long-term success. As stressed by the European Commission, 'isolated, piecemeal approaches have proven to be ineffective. We need to formulate strategies that are comprehensive and integrated.' In the EU, this implies, for example, a thorough consideration of the systemic interactions between the climate-neutral economy, the circular economy and the bioeconomy frameworks (Chapters 16 and 17).

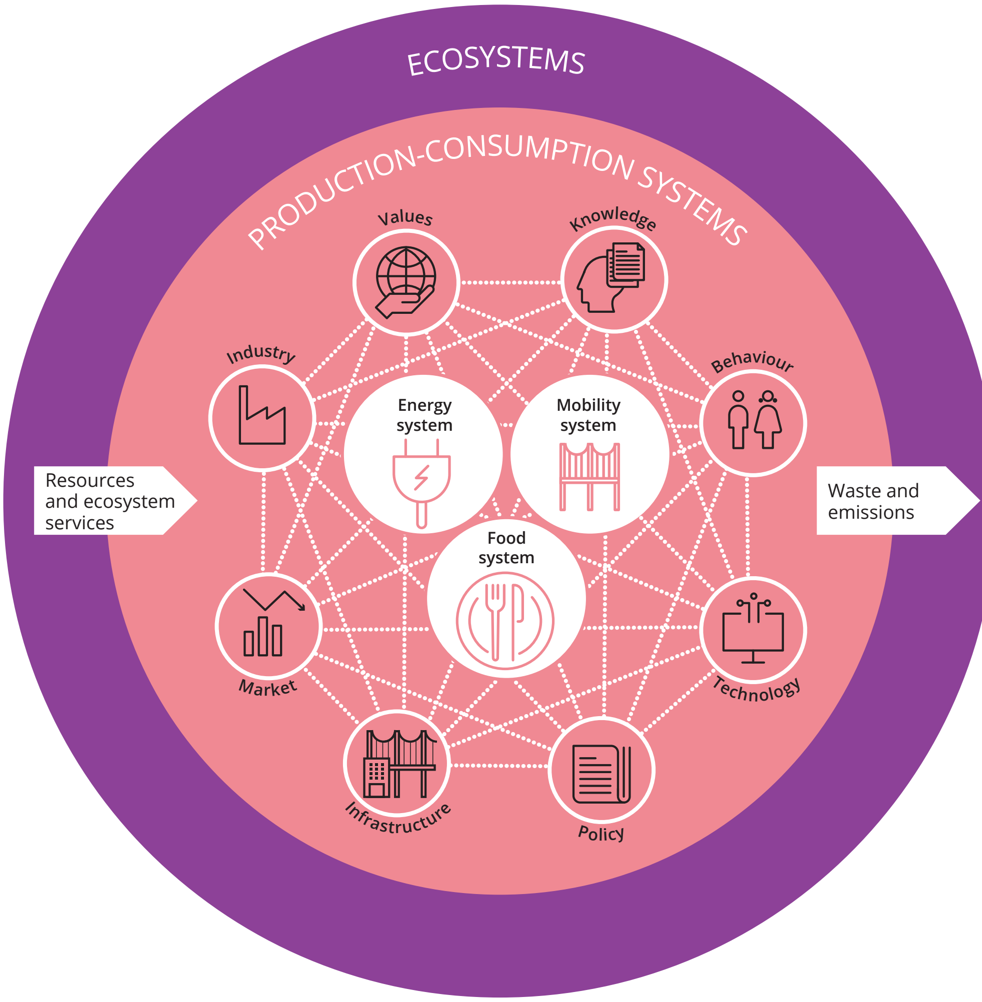
From a knowledge perspective, adopting a systemic view, also referred to as 'systems thinking', helps in approaching and reflecting on the complex or 'wicked' problems facing Europe. For example, 'recognising the food system as a complex adaptive system, which comprises multiple actors with diverse interests and values, provides a richer understanding of the system and the associated sustainability challenges' (EEA, 2016). It does so by mobilising systems lenses that allow the observation of natural and social phenomena at the right scale, by zooming in and out, and looking for underlying structures and patterns (Chapter 16). It also complements traditional modes of problem-solving with more solutions-oriented approaches (Chapter 17).

As systems are ultimately mental constructs, a variety of systems lenses can — and should — be used to shed light on sustainability issues, in order to draw on contrasting but complementary knowledge. Decades of research in academic fields such as complexity science, ecology, sustainability science, evolutionary economics or innovation studies have produced a variety of relevant systems approaches, providing insights into the environment, climate and sustainability challenges and possible responses. Among them, the socio-ecological, socio-technical and socio-economic approaches offer complementary perspectives on different kinds of interactions, as well as on different temporal and geographical scales (EEA, 2018b).

15.3.2 This report focuses on three key systems for transformation

While the need for societal transformation is increasingly recognised in sustainability science and policy, the question of which systems need to be addressed is less settled. Following the conclusions of SOER 2015, *The European environment — state and outlook 2015*, the two following chapters focus in particular on three key systems: those meeting Europe's demand for energy, food and mobility. These are selected for attention because of their key role

FIGURE 15.2 **Ecosystems and production-consumption systems**



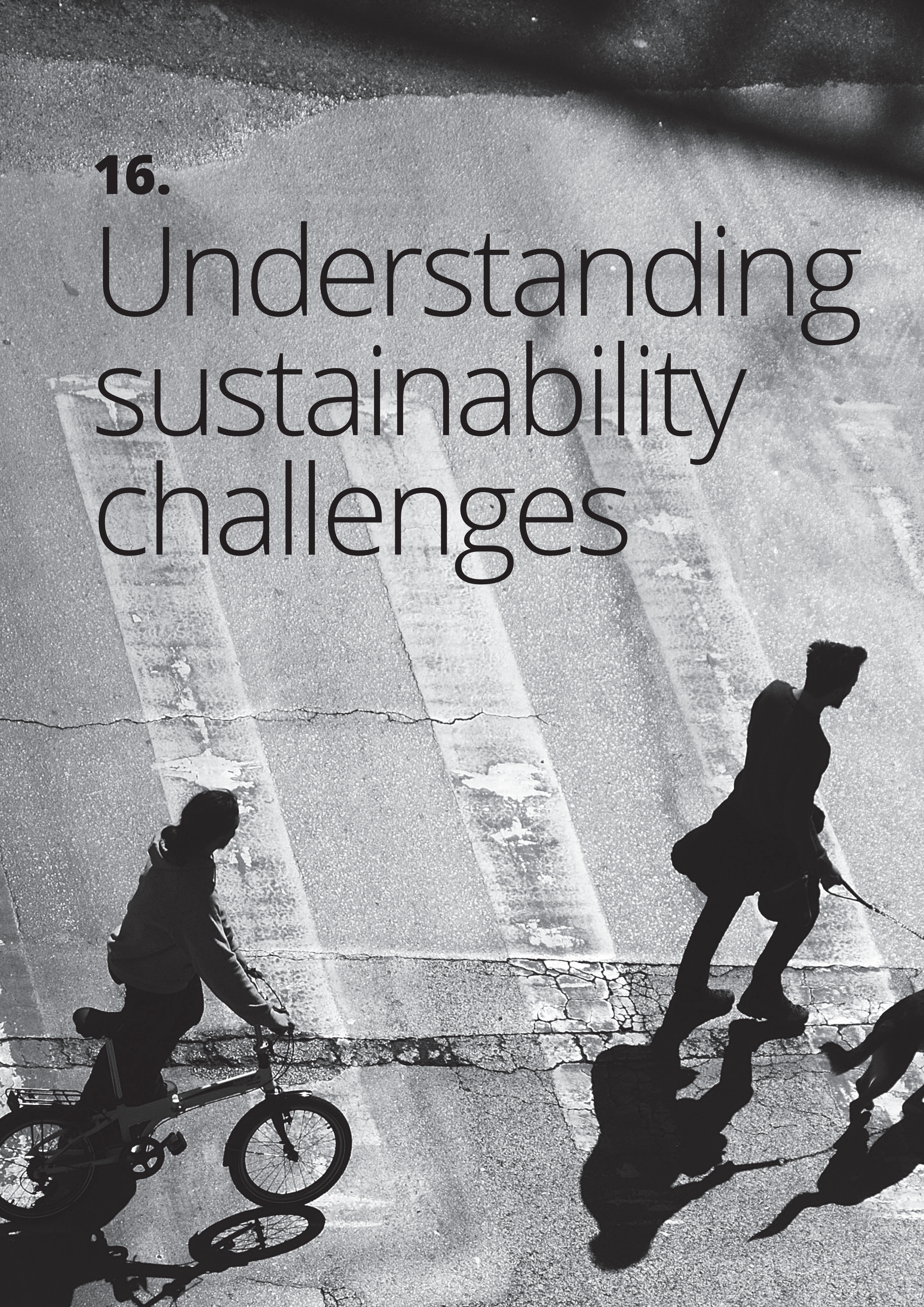
Source: EEA.

in supporting European societies, their substantial environmental impacts and their prominence in EU policy frameworks. The three systems also differ in character, illustrating contrasting challenges and varying degrees of progress in achieving transitions (Chapter 16). Collectively, they offer valuable insights for understanding other important production-consumption systems, such as those relating to housing, clothing or consumer goods. These production-consumption systems are considered within a broader frame, in which they are understood in relation to the ecosystems that they depend on — both as a source of natural resources and ecosystem services and as a sink for waste and emissions (Figure 15.2).

On this basis, the next two chapters provide more detailed assessments of the systemic challenges facing Europe and how the EU can respond. Chapter 16 illustrates how current configurations of key production-consumption systems (food, energy and mobility) and Europe's overall consumption patterns and levels relate to sustainability challenges. It emphasises the cross-cutting nature of those sustainability challenges, encompassing environmental, social and economic dimensions, and it reflects on knowledge needs, societal perspectives and policy approaches. Drawing on a growing body of research and practice increasingly recognised by international organisations (OECD, 2016; IPCC, 2018), Chapter 17 explores how European governments and societies can more broadly address systemic barriers to change and achieve fundamental transitions to sustainability.

16.

Understanding sustainability challenges



Summary

- European consumption is tied to economic growth and living standards but also drives environmental impacts across the world. Europe's environmental footprint is much higher than the global average.

- The food, energy, and mobility systems account for much of Europe's pressures on the environment and health, and are linked to many dimensions of human well-being. These systems must be transformed to achieve Europe's sustainability objectives.

- In production-consumption systems, the co-evolution of system elements — technologies, regulations, infrastructures, behaviours, etc. — creates lock-ins and other barriers to change.

- Links between production-consumption systems create additional challenges. Addressing problems in one system may shift the burden or produce other trade-offs or unexpected outcomes — partly because the systems rely on a shared natural capital base.

- The resource nexus approach can help understand the combined pressures from production-consumption systems, manage system interactions within environmental limits and promote policy coherence.

- Production-consumption systems vary greatly across Europe, implying that actions must be tailored to local realities. Technology-focused measures should be complemented with approaches addressing consumption levels and behaviours.

- Drivers of change at different scales present challenges and also opportunities for transitions. Production-consumption systems will undergo transformations in coming decades. Europe can either be carried along by these events or it can actively shape them.

16.
Understanding sustainability challenges

16.1
The need to transform European consumption and production

The EU has achieved unprecedented levels of prosperity and well-being during recent decades, and its social, health and environmental standards rank among the highest in the world. These achievements are considerable. Yet, as outlined in Chapter 15, Europe today needs to achieve urgent and fundamental changes in its core systems of production and consumption if it is to sustain and enhance its progress to achieving sustainability goals. Building on that assessment, this chapter provides a more detailed analysis of the need for sustainability transitions and the challenges that this entails.

16.1.1
Europe's economy and its environmental implications

Europe has gone through a series of major industrial transformations during the past two and a half centuries. In recent decades, the structure of the European economy has progressively shifted from an industry-intensive structure towards a service economy. This shift has been more rapid since the 1990s, although there is significant variability between European countries (OECD, 2019; Eurostat, 2018g). The service sector now accounts for some three quarters of EU gross value added (GVA), with agriculture, industry and construction accounting for the remainder (Eurostat, 2018g). A similar distribution can be observed for employment (Eurostat, 2018c).

Europe needs to achieve fundamental changes in core systems of production and consumption.

Agriculture accounts for only 2 % of GVA and employment but contributes significantly to environmental pressures (Chapter 13).

Trade has always been fundamentally important for the European economy, reflecting its open character and high dependence on natural resources from around the world (Section 1.5). Internationally, the 28 EU Member States (EU-28) represent the second largest exporter and importer of goods, accounting for 16 % of global exports and 15 % of global imports (extra-EU) by value in 2018 (Eurostat, 2019b). In physical terms, the EU imports mainly raw products (more than 60 % of total imports), such as biomass, metals, non-metallic minerals and fuels, as inputs to production. It exports primarily finished goods for final and industrial consumption (more than 50 % of all physical exports) (Eurostat, 2018j).

The EU is highly dependent on metal ores and fossil fuel resources from the rest of the world. Reliable access to critical raw materials has become a growing concern, as many are used in high-tech products and emerging innovations such as information and communications technology (ICT)-related and renewable energy technologies (EC, 2018e; Chapter 9). For fossil fuels, the heaviest reliance is on oil, hard coal and natural gas, making Europe vulnerable to supply and energy price shocks. At the same time, fossil fuel combustion is the major source of greenhouse gas (GHG) emissions and air pollution, and it contributes significantly to ecosystem degradation.

Imported raw and intermediate products such as iron and steel, rubber and plastics result in emissions of toxic substances, as well as a significant use of energy over their production cycle (Nuss and Eckelman, 2014). Overall, they represent the largest contributors to impacts on human and ecosystem health associated with European imports (Sala et al., 2019). Imports of solid biomass, biofuels and bioliquids contribute directly to deforestation and forest degradation (Olesen et al., 2016) and indirectly through conversion of non-agricultural land such as forests, wetlands and peatlands (EC, 2019d). This mechanism, known as indirect land use change, could also negate some or all of the GHG emission savings of individual biofuels (EC, 2012).

European citizens today enjoy high material standards of living compared with other world regions. Household adjusted disposable income is among the highest in the world (Eurostat, 2018l). Although significant differences still occur across countries and regions, the EU-28 also recorded the highest expenditure on social protection, and the lowest poverty and inequality rates across G20 regions (Eurostat, 2018l).

Despite the 2007-2009 economic crisis, EU household consumption expenditure increased by 38 % between 1996 and 2016 (Eurostat, 2018f). In 2017, almost half of EU-28 household consumption expenditure related to food, transport and housing (including water, electricity, gas and other fuels) (Eurostat, 2019a). In recent years, Europeans have spent relatively less on basic needs such as food, clothing and furnishings, and more on ICT (a four-fold increase in spending), recreation and culture, and health.

Europe's rising levels of affluence drive existing environmental pressures and create new ones.

An average European citizen in the EU-28 spends 3.4 times more on goods and services than the world average (World Bank, 2018), while energy consumption per capita is almost twice the global average (OECD/IEA, 2014). In the EU-28, there are more than 500 passenger cars for every 1 000 inhabitants, which is almost four times the world average (Eurostat, 2018m).

As in other regions, Europe's demand for goods and services is growing in proportion to rising levels of affluence (Sala et al., 2019). These trends are driving existing environmental pressures and creating new ones. The goods and services purchased in Europe are characterised by very different resource inputs and emissions. Increasingly globalised and complex supply chains mean that consumers have limited awareness of the full social, economic and environmental implications of their purchasing decisions (EEA, 2015). According to recent estimates, food products, in particular meat and dairy products, are among the largest contributors to environmental impacts associated with consumption, in terms of acidification, eutrophication, climate change, and land and water use (Beylot et al., 2019a). Manufactured products and raw materials contribute most to human and ecological toxicity (Beylot et al., 2019b).

Purchases of services (e.g. health, education, restaurant meals and hotels) account for 25 % of EU expenditure (Eurostat, 2018h) and for a significant share of impacts associated with EU-28 final consumption. Such services rely on large inputs of products from other sectors, such as food, machinery or electricity. This means that their overall environmental footprint (i.e. the direct and indirect environmental pressures generated by the consumption of goods and services) is often higher or much higher than that associated with manufacturing (EEA, 2014b).

16.1.2 Environmental footprints, trends and decoupling

Taken together, European consumption patterns are associated with substantial environmental footprints. Carbon, water, land and material footprints per capita are between 1.5 and 2.4 times higher in the EU than at the global level (Tukker et al., 2016; Wood et al., 2018).

For the period 1995-2011, Europe's environmental footprint showed mixed trends. Pressures such as acidification and eutrophication decreased significantly, while others such as land, energy use and GHGs were either stable or grew. The water use footprint grew steadily over the period, while material use increased overall, despite a significant reduction around the time of the 2008 economic crisis. Early estimates for 2012-2015 indicate that overall environmental footprints have further stabilised or slightly decreased (NTNU, 2018).

The decoupling of economic growth from resource use and environmental impacts remains a priority objective for EU policy. Overall, the economy of EEA member countries has grown faster than all environmental footprints since the 1990s (Stadler et al., 2018). Acidification and eutrophication have decoupled in absolute terms, meaning that, although GDP has increased, emissions of pollutants contributing to acidification and eutrophication have decreased. GHG emissions, energy, water and material consumption decoupled from gross domestic product (GDP) only in relative terms during the same time frame, meaning that they grew more slowly than GDP.

These reductions in emission intensity were primarily the result of regulation-driven technological improvements in Europe during the period 1995-2007 (EEA, 2013a, 2014a). Subsequently, the economic crisis and consequent structural changes have been the main driver of reduced consumption and related environmental footprints (EEA, 2015). More recently, factors such as macroeconomic changes, shifts in consumption and trade patterns, and eco-efficiency in the production of goods and services have combined to stabilise some environmental footprints.

Structural change in the European economy, such as the shift towards services and the reduction in some industrial activities, has been shown to increase reliance on imports of industrial goods, especially energy-intensive ones, and consequent outsourcing of harmful emissions (Velasco-Fernández et al., 2018; Baumert et al., 2019; Jiborn et al., 2018). In recent years, material efficiency trends observed for Organisation for Economic Co-operation and Development (OECD) countries have been mainly driven by technological improvements occurring in non-OECD countries (Ekins et al., 2017; Wood et al., 2018). Within Europe, the decline of the construction sector after the financial crisis also had an influence (Chapter 9).

16.1.3 Food, energy and mobility systems

The need to transform Europe's consumption and production is well recognised and is increasingly crystallising into a focus on particular systems. As indicated in Chapter 15, the analysis in the coming sections focuses on three systems in particular — those meeting European demand for food, energy and mobility. This selection partly reflects the key functions that these systems perform and their related prominence in EU policy. In part, it reflects the findings of scientific studies, which identify consumption categories such as food, mobility and housing as key drivers of environmental pressures (Tukker et al., 2006, 2010; Ivanova et al., 2016; EEA, 2013a, 2014a). Environmental pressures associated with energy use are assigned to the different end use categories, with mobility and housing accounting for a large proportion.

16.2 The food system

16.2.1 The food system at a glance

Food systems have evolved greatly in recent centuries from predominantly local systems of exchange into complex global networks of production, consumption and trade (EEA, 2017b; UNEP, 2016). They are shaped by many factors: economic, environmental, political, technological and social, including cultural norms and lifestyles. A food system can be defined as all the elements (environment, people, inputs, processes, infrastructures, institutions, etc.) and activities that relate to the production, processing, distribution, preparation and consumption of food and to the outputs of those activities, including socio-economic and environmental outcomes (HLPE, 2014b). Food system actors include those directly involved in food chain activities, as well as governments and civil society, which set the wider policy and societal contexts (EEA, 2017b). The main purpose and function of the food system is to provide food and nutrition security but, depending on its characteristics, it can either enhance or degrade ecosystem health.

The food system is characterised by considerable diversity in Europe, because of variations in climate and morphology and diversity of soils, landscapes and seascapes, socio-economic conditions, technical skills and levels of investment. For example, the structure of farms varies substantially across countries in terms of physical and economic size. The proportion of the national population dwelling in rural areas in the EU-28 ranges from less than 1 % to up to 20 % (EC, 2018j). Producing and processing fish as food in the EU is still largely dependent on small and medium-sized businesses, and this sector plays an important role in many coastal communities (EEA, 2017b). While the agriculture and fisheries sectors have declined in relative importance economically over the last 50 years, the wider food and drink industry is one of the largest manufacturing sectors in the EU in terms of employment, turnover and value added.

In addition to meeting various societal needs, the food system is responsible for a vast array of impacts on the environment through emissions of pollutants, depletion of resources, loss of biodiversity and degradation of ecosystems in Europe and beyond (IPES Food, 2019). Agricultural production, processing and logistics are the phases contributing most to environmental impacts arising from the food system (Crenna et al., 2019). Moreover, a significant share of food is wasted in Europe because of inefficiencies across the value chain. This leads to significant burdens on the environment (Corrado and Sala, 2018; Scherhaufer et al., 2018), as well as ethical concerns.

The European food system is characterised by wide use of technologies, high external inputs (e.g. fossil fuels, fertilisers and pesticides), low labour inputs, and long and often complex supply chains (EEA, 2017b). It is also diverse, with many small-scale family-based producers operating alongside large, globalised food companies and suppliers. The global dimension increasingly influences the food system in Europe, as international markets, technological developments and transport systems have made it possible to connect food production and consumption globally (EEA, 2017b). This offers larger market opportunities for EU production and consumption but exposes EU primary production to the high price volatility of global agricultural commodities and strong competition. Global financial markets are increasingly influencing land transactions, agricultural production decisions, rural credit provision, risk insurance, commodity pricing, and food distribution and retail (HLPE, 2014a).

Europe is a net exporter of meat, dairy products, cereals and wine. It is a net importer of tropical fruits, coffee, tea, cocoa, soybean products, palm oil, and seafood and fish products. Imports of fish and aquaculture products meet 55 % of European demand (EUMOFA, 2015). In 2015, Europe had a negative trade balance in physical terms (kilograms) (Eurostat, 2016a); the difference between trends in volume and in value reflects the relatively low monetary value of some imports, e.g. soybeans and palm oil, compared with the higher value of exports such as processed foods, chocolate and wine. Nevertheless, the majority of food consumed in the EU is still produced within the EU and most EU trade in food and drink products takes place between EU countries (EEA, 2017b).

How the food system is structured and organised has implications for consumption patterns and levels, including diets. Food consumption patterns also vary substantially across European countries. For example, meat consumption ranges between 100 and 160 g/day, fish and seafood between 10 and 60 g/day and milk and dairy product consumption between 170 and 520 g/day (EFSA, 2008). The share of household expenditure attributed to food and non-alcoholic beverages in the EU-28 varies between 8 % and 28 % (Eurostat, 2018i).

In the EU today, five of the seven biggest risk factors for premature death — high blood pressure, cholesterol and body mass index, inadequate fruit and vegetable intake, and alcohol abuse — relate to how we eat and drink (EC, 2014; EEA, 2017b; IPES Food, 2019). Up to 7 % of EU health budgets is spent each year directly on diseases linked to obesity, with additional indirect costs resulting from productivity losses (EC, 2014). The average European per capita consumption of animal protein is now 50 % higher than in the early 1960s and double the global average (PBL, 2011). The amount of food consumed outside the home has increased, while the amount of time devoted to cooking and eating food at home has fallen (Trichopoulou, 2009). There has also been a shift towards the consumption of energy-dense but low-nutrient processed foods (IPES Food, 2016).

88 million

tonnes of food is lost along the supply chain or wasted at the household level.

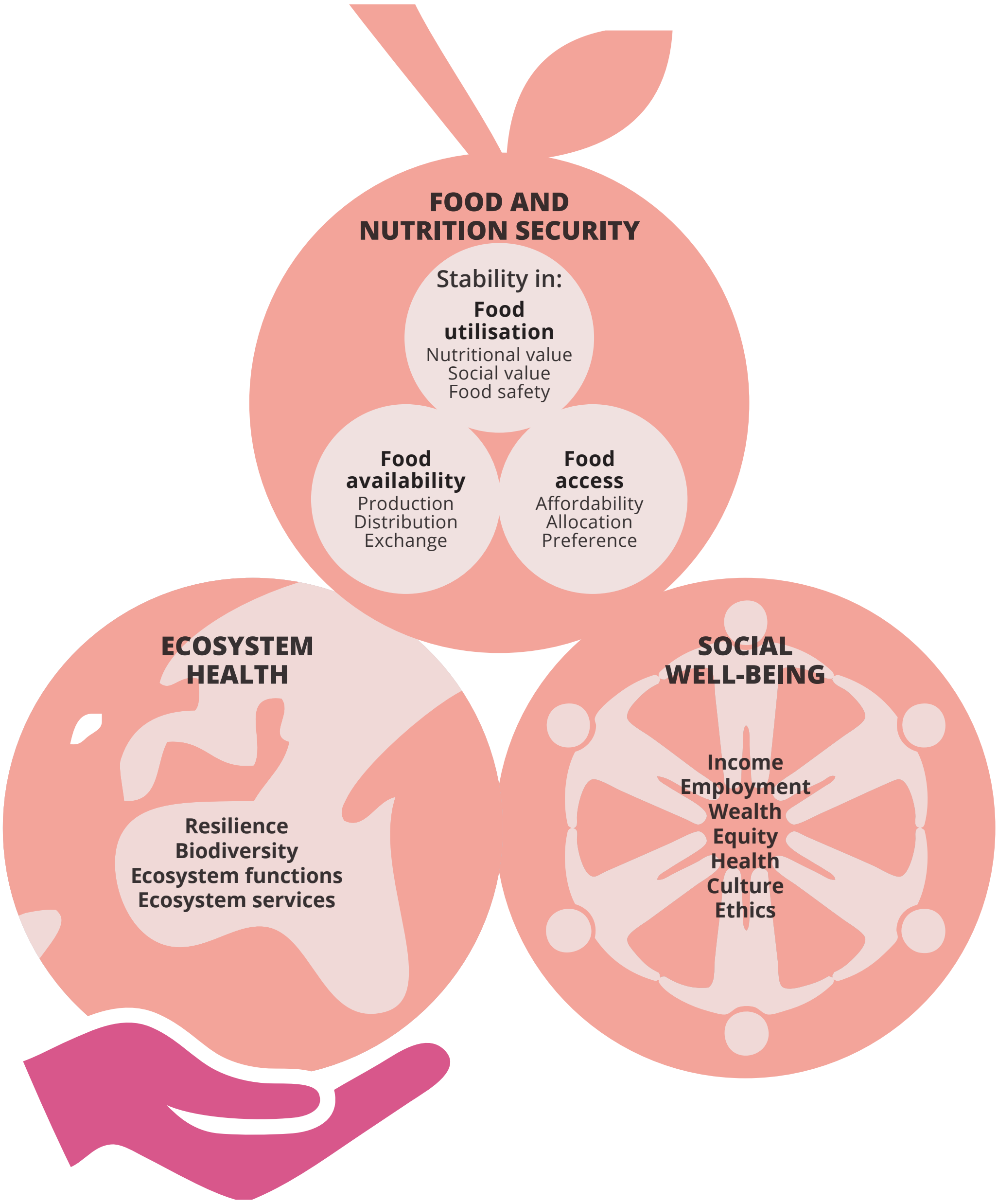
Moreover, increased consumption of food and drink products 'on the go' is expected to contribute further to littering and leakage of plastic waste — a growing environmental concern (EC, 2018c).

Overall, food production and consumption in Europe has environmental, social and economic impacts beyond European borders, including concerns regarding access to food worldwide. European production has particular impacts through imports of feed used in both livestock and aquaculture production. In 2013, Europe imported (net) some 27 million tonnes of soybeans and soybean products, largely from South America, the vast majority of which were genetically modified and not permitted to be cultivated in Europe (EEA, 2017b). This type of trade has been responsible for losses of habitat and biodiversity as well as land use conflicts (EEA, 2014a).

16.2.2 Trends and prospects

Overall, progress towards sustainable outcomes (Figure 16.1) is still limited in the food system. Unhealthy diets contribute to increasing levels of obesity, and more than half of the EU's population in 2014 was estimated to be overweight (Chapter 1). On average across the EU-28, 16 % of adults were obese in 2014 (OECD and EU, 2018). Agriculture still has high impacts on the European environment, while several fish stocks remain depleted in some European seas as well as worldwide (Chapter 13). Food consumption in Europe is generating increasing environmental pressures abroad (Chapter 1). Food waste is also excessive. Annually in the EU around 88 million tonnes of food is lost along the supply chain, or simply wasted at the household level, with corresponding estimates as high as EUR 143 billion (FUSIONS, 2016).

FIGURE 16.1 Food system desired outcomes



Source: EEA (2017b).

As illustrated in thematic and sectoral analyses in Part 2 of this report, current prospects indicate that, without fundamental changes in the food system, the outcomes will not be in line with achieving sustainability goals. The food system depends on healthy ecosystems and their services in Europe and worldwide. Key policy frameworks such as the EU common agricultural policy and the common fisheries policy have limitations in their effectiveness regarding environmental outcomes, such as protecting natural capital (Chapter 13). The food system in Europe is increasingly threatened by such losses as well as by climate change impacts, as it relies on relatively stable climatic and ecological patterns to perform its functions (Chapter 7).

There have been warnings of a potential global collapse of entomofauna (Hallmann et al., 2017; Sánchez-Bayo and

Wyckhuys, 2019). Moreover, an expanding bio-based economy in Europe is expected to increase demand for feedstock and shift agricultural production from food to non-food crops as industrial sectors seek substitutes for chemicals based on fossil resources. Similarly, the demand for bioenergy, including new energy crops, is expected to increase as a result of decarbonisation efforts (EC, 2018g). This could lead, in turn, to further competition for land use, increased use of biomass and risks of higher exploitation of natural capital in Europe, including the use of forests and other semi-natural areas in Europe, further challenging conservation and protection efforts envisaged by the EU biodiversity strategy.

In response to global developments, such as a growing global middle class and increased demand for land, food and bioenergy (Chapter 1), the European food system could develop in different ways — each involving synergies and trade-offs. If long-term trends continue regarding economic growth, technology, employment and trade in the agri-food sector, and without additional policy interventions, it is likely that the food system would be shaped by increased competitiveness and export orientation, rather than meeting health, environmental and economic goals together. Increased competitiveness in the agri-food sector would be likely to increase the trend towards fewer, larger and more capital-intensive farms (Chapter 13; IPES Food, 2019), lead to more nutrient pollution due to surpluses of livestock biowaste and increased use of fertilisers.

A move towards increasing export orientation could further consolidate the current 'high volume and low margin' model, based on high-tech and intensive agriculture. The increased reliance on digital technologies and appliances (e.g. drones, sensors, satellite images) also envisaged by the common agricultural policy and EU research programmes (EC, 2018h; IPES Food, 2019) could possibly reduce direct demand for fertilisers, pesticides, water, etc., per unit of land or product, but it is also likely to increase the need for machinery and appliances and energy infrastructure, potentially generating new environmental burdens. At the same time, the current innovation paradigm in EU policies locks the food system into a vicious cycle of 'techno-fixes' and short-termism that reinforces 'trends towards intensive, large-scale monoculture-based production', despite their demonstrable harm and trade-offs across environmental and socio-economic issues, (IPES Food, 2019). For example, the 2017 renewal of the license for glyphosate, was characterised by controversies concerning negative effects on soils and water and led to public reactions against the decision, as precautionary principle and protection of human health were perceived to be side-lined against economic interests (see IPES Food, 2019).

An expanding bio-based economy in Europe is likely to increase competition for land use.

Alternatively, a combination of low-input agriculture in Europe and increased import dependency could ensure the supply of raw materials to the food industry and subsequent export of processed food. In this case, environmental pressures could be reduced in Europe, but they are likely to be externalised to other countries through trade. Another pathway would see food production systems turn towards low-input models, with short supply chains and reduced imports, in conjunction with lower consumption levels in the EU. The implications of such developments on jobs in the agri-food sector are not clear.

The barriers to a more sustainable configuration of the European food system are numerous. They are largely due to the interdependence between the food system and many other economic sectors (e.g. processing, retail), the concentration of power in large, globally networked and vertically integrated companies, and the consequent shift in influence from primary producers to actors downstream in supply chains (EEA, 2017b; UNEP, 2016). Sunk costs associated with large-scale processing plants, as well as with investments in research and development (R&D) and advertising — a prominent feature of the European food and drink industry (Galizzi and Venturini, 2012) — may create further barriers to change.

16.2.3 Towards system change

There is a wide range of potential actions to transform the food system to deliver more sustainable outcomes, including changes in production practices, dietary changes, improvements in technologies and management, and reductions in food loss and waste (for the livestock sector, see Buckwell and Nadeu, 2018; Springmann et al., 2018).

Changes in production practices may create opportunities to reduce environmental pressures. However, emphasis on increasing yields, productivity and efficiency has led to negative consequences for the environment (IAASTD, 2009). Instead, shifting towards practices such as precision farming, agroecology, or low-input and organic agriculture is often indicated as a potential way of reducing pressures on the environment and human health through reduced inputs and improved management practices.

Efficiency gains could, however, lead to lower costs and, in turn, to increased demand for food products, thereby offsetting environmental benefits. Innovative technologies and processes often raise concerns regarding their ethical and social implications and may create new, unexpected and unintended environmental challenges (EEA, 2013c). Therefore, changes in production practices would be more effective if combined with reduced consumption levels and changes in patterns of demand.

In contrast, it has been demonstrated that following the principles of agroecology and fully recognising agricultural multifunctionality, e.g. by maintaining and enhancing biodiversity within agricultural systems, may reduce the trade-offs between food production and ecosystem health, as well as creating a more resilient food system (FAO, 2014; Liere et al., 2017). Production processes that require lower inputs may be associated with reduced yields, however, thus requiring more land to be converted to production to fulfil overall demand, unless other measures are also implemented, such as reduced food wastage and use of animal products (Muller et al., 2017).

Changing habits and behaviour are also fundamental levers for transforming the food system. Diets 'inextricably link human health and environmental sustainability' (Willett et al., 2019) and can act as levers for change. Sustainable diets have lower environmental impacts and contribute to food and nutrition security as well as to healthy lives for present and future generations. Achieving a sustainable food system for everyone, according to the EAT-Lancet Commission on Food, Planet, Health, would require major improvements in food production practices, reduced food waste and substantial shifts towards healthy dietary patterns (Willett et al., 2019). The latter would entail an 'appropriate caloric intake, based on a diversity of plant-based foods, low amounts of animal source foods, unsaturated rather than saturated fats, and small amounts of refined grains, highly processed foods, and added sugars' (Willett et al., 2019). It has been demonstrated that reducing animal-based food, especially beef, can significantly decrease environmental pressures (Conijn et al., 2018; Sala et al., 2019). However, savings associated with reduced consumption of meat and dairy products may lead to a shift in expenditure to other goods and services (e.g. transport) or increased resilience on imports with higher production impacts, thus offsetting the environmental benefits associated with dietary change. Apart from health considerations, a wider set of ethical concerns expressed by citizens and consumers on aspects such as animal health and welfare or support for the local economy, could also contribute to shaping the food system.

> Changing habits and behaviour are fundamental levers for transforming the food system.

There is no overarching policy addressing the food system in Europe; rather, there are multiple policies across many different domains. Current European policies establish a common framework for governance and action, define incentives and direct research and innovation (EC, 2016a; EEA, 2017b; IPES Food, 2019). Several actions included in the circular economy action plan (EC, 2015), including commitments to reduce food wastage (Chapter 9), the expected ban on 'single-use' plastics (EC, 2019a), the revised waste legislative framework and the proposed fertiliser products regulation (EC, 2016d), are expected to improve the performance of the food system in the years to come by reducing waste and increasing reuse and recycling (EC, 2019c).

However, the broad range of policies relevant for food has to respond to many competing forces and vested interests, often leading to conflicting goals. For example, commitments to align policies with climate and development goals run in parallel with initiatives encouraging meat and dairy producers to seek new export markets (IPES Food, 2018, 2019). The main targets of key policy measures are generally farmers, fishers and consumers. While these food system actors are the largest in numbers (EEA, 2017b), they do not necessarily have the most power or influence to bring about change. Other food system actors such as suppliers, retailers and service providers actively shape the 'food environment' — the physical, social and economic surroundings that influence what people eat. For example, the 10 biggest retail companies in the EU have a combined market share of over 50 % (Heinrich Böll Stiftung et al., 2017), exerting a large influence over both producers and consumers. Influencing the food environment could be an important lever for change with regard to dietary composition, reducing food waste and supporting more sustainable production (EEA, 2017b).

European policies and initiatives could make better use of leverage points in the food system to bring about fundamental changes in the system as a whole (Meadows, 1999, 2008). For example, targeting more actions to the food industry, including suppliers, retailers and the distribution sector, could help accelerate progress towards sustainable pathways (EEA, 2017b). Moreover, incentives, such as direct payments to farmers, could be redesigned to better reflect the principles of agroecology and reward provision of public goods (IPES Food, 2019).

The development of a common policy framework for the food system could turn into a fundamental enabler of system change and promote transitions to sustainability by realigning sectoral policies across production, processing, distribution and consumption (IPES Food, 2019). Developing a systemic policy framework for food — connecting across the Sustainable Development Goals and EU policies — can also mobilise and guide contributions from many policy areas and provide a basis for a broad range of stakeholders to explore pathways for the system's transition.

16.3 The energy system

16.3.1 The energy system at a glance

The energy system is shaped by a multitude of forces related to the production, conversion, delivery, and use of energy, including economic and political forces as well as broader societal ones, such as cultural norms and lifestyles (Allwood et al., 2014). The energy system spans all resources, infrastructures, activities and actors directly and indirectly involved in meeting European demand for energy, as well as in the final consumption of energy. It includes the energy sector (i.e. the sector of the economy responsible for extraction, production and distribution of energy carriers), as well as major resource users such as buildings and construction, industry and households.

The energy system is characterised by significant diversity across Europe and its regions, particularly concerning aspects such as the energy mix, market liberalisation, the age of the energy infrastructure, carbon intensity and consumption levels. The choice of fuel type varies significantly across Europe; some countries meet their energy needs by relying on a broad range of primary sources, including renewables and nuclear energy, while others rely almost exclusively on fossil fuels (EEA, 2017d). This influences the carbon intensity of electricity production, with countries registering values from as high as 800 g CO_2/kWh to as low as 15 g CO_2/kWh (EEA, 2018e). The structure of the electricity market shows significant variations too. A handful of EU Member States are still characterised by a complete monopoly, and in five EU countries the largest generator accounts for at least 70 % of the market. In the majority of cases, however, the share of the largest incumbent ranges between 14 % and 50 % (Eurostat, 2018b). Regional diversity can also be seen in the age of energy infrastructure (installed capacity) (EEA, 2016d).

Energy use in the household sector differs for of a number of reasons: climatic, structural (e.g. state and age of the building stocks), socio-economic and behavioural (e.g. household appliances, heating/cooling and cooking habits, uptake of energy-efficient technologies). In 2016, per capita energy consumption in the household sector of the EU-28 ranged from 0.2 tonnes of oil equivalent (toe) per capita in Malta to 1 toe/capita in Finland (EEA, 2018c).

> The use of fossil fuels for energy purposes is the principal cause of environmental impacts from the energy system.

Access to clean, secure and affordable energy is a vital service in Europe as well as globally. In Europe, rising awareness of the energy system's impacts on the planet have led to sustainability becoming the third key pillar of EU energy policies during the 1990s. In 2013, the Seventh Environment Action Programme set the direction for the European energy system of the future, with climate change being a particularly relevant driver of system change.

The production and consumption of energy creates a wide range of pressures on the environment and on public health. As half of EU energy consumption is satisfied through imports (Eurostat, 2018d), pressures arise at both the local level and globally. The use of fossil fuels for energy purposes remains the principal cause of environmental impacts across the energy system, causing adverse human health effects and harming crops, forests, water ecosystems, buildings and infrastructures (Chapter 7, 8 and 12). Nuclear energy also entails risks to health and ecosystems, especially nuclear waste management and potential accidents. Renewable energy technologies are also contributing to environmental pressures on land, ecosystems and human health, and depletion of resources across their full life cycle, especially if local and regional environmental conditions are insufficiently addressed during the project design and implementation phases.

Overall, the EU and its Member States are all net importers of energy carriers. In absolute terms, the EU is the largest energy importer in the world, with imports meeting 54 % of its energy needs in 2016. More specifically, 87 % of all oil products, 70 % of all natural gas and 40 % of all coal consumed in the EU were imported (Eurostat, 2018d). The import of solid biomass, biofuels and bioliquids to meet the needs for Europe's demand for energy carriers, is associated with significant impacts on biodiversity (Section 16.2 and

Chapter 1). The EU's dependence on imports has increased since 1990 as domestic fossil fuel production continues to decline due to depletion of resources and economic factors. Despite this, the increase in energy dependence stabilised around 2005, against the backdrop of increased production from sources of renewable energy. Although imported energy is essential for the EU's economy to function, significant amounts of money leave the EU economy in exchange for energy resources.

The call to phase out inefficient fuel subsidies and environmentally harmful subsidies is put forward by organisations, such as the World Bank, the International Monetary Fund and the OECD, and by the leaders of the G7 and G20 economies as well as by the European Commission (EC, 2011a; EU, 2013). Their elimination 'could raise government revenue by USD 2.9 trillion (3.6 percent of global GDP), cut global CO_2 emissions by more than 20 percent, and cut pre-mature air pollution deaths by more than half' (Coady et al., 2015).

Overall, energy consumption ([1]) fell on average after the economic crisis and has been on the rise since 2014. In 2016, gross inland energy consumption in the EU-28 (1 640 million tonnes of oil equivalent, Mtoe) was 2 % less than in 1990, and about 10 % less than it was during the peaks in consumption of 2005 and 2006. Oil, natural gas, and coal together supplied 71 % of the EU's gross energy needs. Equal shares of nuclear energy and renewables met the remaining consumption. The final energy consumed by end-users was only 2 % higher in 2016 than in 1990. A similar pattern is observed when the energy footprint of final consumption in Europe is analysed, a metric that combines both direct and indirect use of energy to satisfy final demand (e.g. energy embedded in products consumed in Europe), although the data are for a shorter time series and of lower quality. The transport sector demanded most energy, equalling one third of the total, followed by households and industry, accounting for one quarter each (Eurostat, 2018e). Non-energy uses of energy resources (fuels used as raw materials in various sectors) represented only 9 % of the final energy use in 2016 in the EU (Eurostat, 2018e; Figure 16.2).

The EU is the largest energy importer in the world, with imports meeting 54 % of its energy needs in 2016.

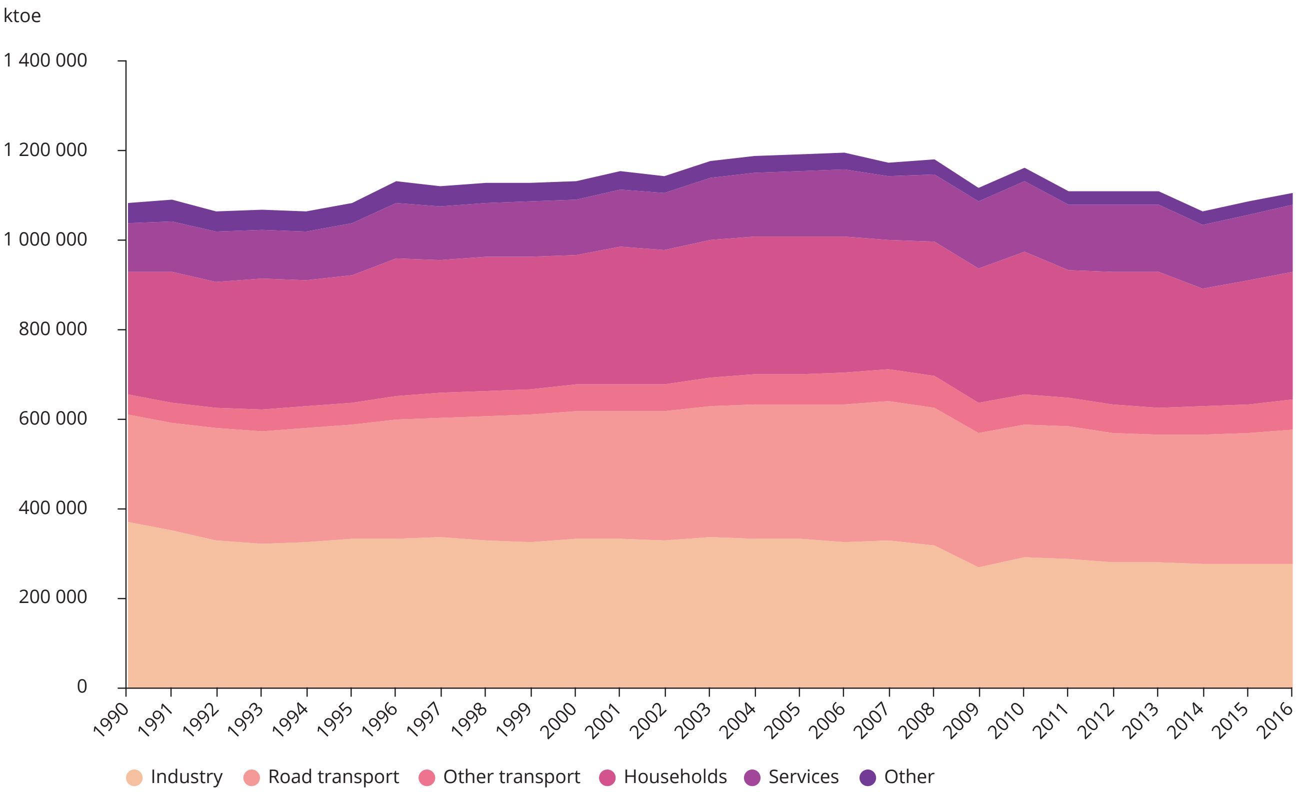
Combustion-based installations generating power and producing heat are still dominant, but shares of renewables are growing, driven by economies of scale, incentives and technological progress. Much of the EU's coal-based power capacity is more than 40 years old and is being operated at or near the end of its planned lifetime. In contrast, gas-fired power plants across Europe are younger (EEA, 2016d). Nuclear energy still plays an important role in half of the EU Member States, but its overall share in electricity generation across Europe is declining. The development of low-carbon and low-pollution energy technologies has been a major R&D and policy endeavour for several decades. A few technologies, in particular wind turbines and solar photovoltaic (PV) panels have seen substantial reductions in cost and are expected to become cost-competitive within a few years in the current EU energy market system. Renewable energy sources are used most widely in the heating and cooling energy market sector, in which the use of biomass (in district heating plants and in small-scale residential boilers and stoves) dominates all other renewables. In 2016, renewables accounted for the overwhelming majority (86 %) of new EU electricity-generating capacity for the ninth consecutive year (EEA, 2017c).

16.3.2
Trends and prospects

Trends concerning the energy system indicate that progress has been made towards reducing energy demand and increasing renewable energy shares. The EU energy system is changing rapidly, but it is still highly dependent on imports of fossil fuels, heightening the risks to supply and adverse impacts on climate, biodiversity and health. The electricity sector is currently driving the change, and other sectors such as heat and cooling, and transport show limited improvements. Europeans also consume less energy than they did 10 years ago. Efficiency gains, structural shifts in the economy towards less energy-intensive sectors such as services (EEA, 2018b), policy interventions (e.g. targets on energy efficiency — see Chapter 7), and the recession of 2008 have all contributed to reducing the demand for energy. In contrast, the demand for energy from road and air transport has continued to increase since 2009 (EEA, 2018b).

([1]) It is important to distinguish between 'final energy consumption' and 'gross inland energy consumption', as they have different meanings and implications for policy. Final energy consumption covers all energy supplied to the final consumer's door for all energy uses. In contrast, gross inland energy consumption is the total energy demand of a country or region and represents the quantity of energy necessary to satisfy the inland consumption of the country or region under consideration.

FIGURE 16.2 **Final energy consumption by sector**



Source: Eurostat (2018e).

Demographic and lifestyle changes may increase demand for energy, land and infrastructure.

The future of the European energy system will also depend on global and regional drivers of change. Trends in demography and lifestyle changes in Europe are likely to entail shifts towards smaller households requiring a higher floor area per individual, as well as increased demand for land and infrastructure (EEA, 2014a), larger stocks of household appliances and consumer goods (EEA, 2012), and personal electronic devices associated with the digitalisation of all aspects of life. All these trends potentially increase the demand for electricity. Projected impacts of climate change could have negative effects on the security of energy supply (EEA, 2019).

The energy system in Europe is likely to be increasingly exposed to the effects of price volatility, associated with the risk of disruption in supply due to potential conflicts and instability in exporting countries, trade and protectionism (EPSC, 2018), increased global demand and competition (OECD/DASTI, 2016), and a lower return on energy investments in newly discovered oil fields and oil tar sands (Murphy, 2014). In the short term, this trend may encourage the extraction of unconventional fuels in Europe (e.g. Neville et al., 2017). To counter the effects of energy price volatility and meet EU and global climate ambitions, the EU and its Member States aim to accelerate the transition to an efficient, renewables-based energy system. EU governing bodies are expected to introduce stronger policies on energy efficiency, including policies for energy demand management and to incentivise the substitution of carbon-intensive fossil fuels technology with renewable energy technologies.

The rise of 'prosumers' — private citizens who both consume and produce electricity, often by installing household solar PV panels — is recognised as a rapidly growing phenomenon (Sajn, 2016). This trend could significantly change the electricity system towards increased decentralisation as cities and neighbourhoods become more important in making collective decisions about energy production, supply and consumption, which has implications for the governance structure of energy networks. There are still many technological barriers and unknowns associated with such shifts. Some renewable energy technologies, such as solar PV and wind, are characterised by intermittent production patterns, which, if considered on a small scale and alone, will not meet the continuous demand for electricity from industry and households given the current infrastructure. For this reason, renewable electricity supply is currently backed up by non-renewable energy technologies such as coal and nuclear power plants or natural gas (Smil, 2016). The future development of energy storage technologies will be central to the transformation of the energy system (Verzijlbergh et al., 2017).

Integrating electricity grids would help the EU to achieve a well-functioning, secure and climate-compatible electricity market with a high share of variable renewable electricity production. Seventeen Member States are on track to reach their 10 % grid connectivity target by 2020 ([2]) (EC, 2017b). In the light of the further rapid growth expected in renewable electricity, continued progress in grid and market integration is needed (EEA, 2016d; EC, 2016c; Grossi et al., 2018). Enabling intermittent energy sources such as renewables to meet the continuous demand for energy will require additional storage capacity (i.e. batteries). These investments are not negligible in terms of demand for energy and materials and GHG emissions when considered over their life cycles (see Di Felice et al., 2018).

However, the recently negotiated recasts of the Electricity Directive and Electricity Regulation are expected to enable consumers to participate actively in the move towards a less centralised energy system (EC, 2019b), to facilitate 'cross-border trade', to allow for more flexibility to accommodate an increasing share of renewable energy in the grid and to 'drive the investments necessary to provide security of supply' (EC, 2019b).

The future of the European economy and its structure will also play a fundamental role in the energy system. Along with economic development and prosperity in Europe, a shift has taken place, away from energy and labour intensive domestic activities and towards high end production, complex and globalised supply chains (e.g. the car industry) and delocalisation of heavy industry (e.g. steel production in China) alongside other manufacturing sectors (e.g. clothing and textiles, ICT).

The continuing of this trend in Europe may facilitate the uptake of electricity, hydrogen or e-fuels in industry and manufacturing and may progressively phase out energy and labour intensive industrial processes for which substitute low-carbon technologies are not readily available to scale, in this way keeping both opportunities and challenges within certain social and economic domains. Yet, there are several technological and economic barriers associated with deploying such technologies to scale, not least their dependence on large quantities of renewable energy. Moreover, environmental impacts associated with their life cycles need to be better understood across both production and consumption phases.

From a climate perspective, it would be a missed opportunity if globalisation merely shifted emissions across geographical boundaries, resulting in increasing externalisation of emissions associated with Europe's demand for goods and services (Chapter 1) without reducing GHG emissions at the planetary scale.

16.3.3 Towards system change

The pace of the EU's progress towards climate and energy targets is not fast enough to meet its commitments to the Paris Agreement (Chapter 7). Increased efforts are needed to meet the EU's climate and energy targets for 2030, and the scale of change required to reach its 2050 objectives is even greater (EEA, 2018i, 2018h) — all the more so to reach the goal of climate neutrality set out by the European Commission in its long-term strategy (EC, 2018f). Continuing with the current structure of and trends in the energy system would not allow the EU to reach either 80-95 % decarbonisation or climate neutrality by 2050.

Several options have been proposed in the literature, enabling countries to develop specific strategies that take into account national circumstances (IPCC and Edenhofer, 2012; IPCC et al., 2014; IPCC, 2018; EC, 2018g). These include mitigation options such as combinations of low-carbon technologies (e.g. wind power, solar PV systems, bioenergy for heat and power, and biofuels), infrastructure development (e.g. electricity transmission lines, cross-border interconnections and storage), increased efficiency and savings (e.g. from energy-intensive industries and final consumption), carbon capture and storage, land restoration, changes

([2]) In 2014, the European Council called on Member States to aim to achieve interconnection of a minimum 10 % of their installed electricity generation capacity by 2020.

in consumption and lifestyles, and governance approaches.

The European Commission's proposed 'long-term vision for a prosperous, modern, competitive and climate neutral economy' (EC, 2018f) indicates that an economy with net-zero GHG emissions could be achieved by combining strategic building blocks such as maximising energy efficiency, including zero-emission buildings; deploying renewables and electricity to fully decarbonise Europe's energy supply; embracing clean, safe and connected mobility systems; developing competitive industry and the circular economy; developing a smart network infrastructure and interconnections; developing the bioeconomy and creating and enhancing essential carbon sinks; and tackling remaining CO_2 emissions with carbon capture and storage. It also suggests an enabling framework for the long-term transition (Chapter 17).

The transition towards a low-carbon energy sector can itself create new risks and dependencies that need to be anticipated. These include new raw material dependencies for high-tech renewable energy technologies and cybersecurity risks as a result of increasing ICT applications (Chapter 9). Moreover, fundamental changes in how energy is produced are likely to reshape the prevailing set of societal and geopolitical interactions and impacts (WEF, 2018b), potential disruption of the labour market (WEF, 2018a), as well as through new opportunities for employment in growing clean technology sectors.

Such changes will also lead to trade-offs with conservation of natural capital and likely effects on food and water security. Tackling climate change by upscaling the deployment of bioenergy without sufficiently strong safeguards has attracted criticism of its overall sustainability and effects in mitigating climate change (European Parliament, 2015; ECA, 2016). In short, bioenergy — depending on source and type — can result in a range of trade-offs with other environmental issues, such as land use, biodiversity and ecosystem functioning, water, and nutrient and carbon cycles, and can even result in additional GHG emissions (EEA, 2013b). To minimise some of these environmental impacts, the Renewable Energy Directive (EU, 2009) sets sustainability and GHG emission-saving criteria for biofuels and bioliquids, which have subsequently been complemented by the 2015 Indirect Land Use Change Directive (EU, 2015). For the period 2021-2030, the recast Renewable Energy Directive (EU, 2018) strengthens the existing criteria and expands the application of sustainability criteria to all uses of biomass for energy, i.e. also for heating and power.

The transition towards a low-carbon energy sector can itself create new risks and dependencies that need to be anticipated.

All the scenarios considered by the long-term vision rely on a substantial use of biomass for energy and point towards trade-offs with land use and protection of natural capital in Europe and beyond. Overall, substituting fossil fuels with renewable energy requires an increase in land use for PV panels, wind farms and biofuel production, the extent of which depends on the envisaged energy mix. If the demand for biomass is met through production in Europe, it might entail competition for land and trigger energy use by the agricultural sector. Although importing the feedstock from outside Europe might ease domestic competition for land, it would generate direct and indirect land use change in other parts of the world, which has potential implications for global loss of biodiversity.

Removing CO_2 from the atmosphere by enhancing natural carbon sinks or engineering technologies is also advocated as an option for the long-term reduction of GHG emissions (EC, 2018f). The land use, land use change and forestry (LULUCF) sector in Europe is today a net sink, as forest land alone compensates for net emissions arising from all other land covers; however, its future contribution to reducing GHG emissions is expected to decrease, mainly because of forest ageing and increased use of forest biomass (EC, 2018f). As recently indicated by IPBES (2018), land restoration and avoided degradation of forests, wetlands, grasslands and croplands could contribute significantly to the climate mitigation efforts needed at the global scale and in a cost-effective manner (Seddon et al., 2019).

Contrary to high-disturbance management systems (e.g. monocultures, fast-rotation forests), nature-based solutions are expected to contribute to multiple goals (Sections 13.4.3 and 17.3.1). In addition to carbon sequestration and consequent climate regulation, protecting natural capital would also lead to other important co-benefits for society, such as improved health and well-being (ten Brink et al., 2016). In contrast, carbon capture and storage (CCS) technologies have so far failed to develop at the expected rate, even with supportive EU regulation and co-funding opportunities (EC, 2018a). No large-scale commercial CCS plant is currently operating in Europe. This technology would need to overcome several economic and social challenges, including public acceptance, if it is to be deployed at the continental scale. Among other technical challenges, CCS-equipped power plants are estimated to require approximately 15-25 % more energy, thus needing 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, 2011a).

Overall, the energy system has the most developed and comprehensive EU policy framework, which covers aspects ranging from energy security to the internal market and to climate and environmental considerations. It concerns aspects of both production and final consumption. However, options for achieving net-zero carbon emissions, such as those envisaged by the long-term climate-neutral strategy (EC, 2018f), largely focus on technology options and expected efficiency gains across all sectors of the economy. There is much less focus on other levers such as behaviour and lifestyles (e.g. less carbon-intensive diets and modes of transport, limited demand for air transport, reduced demand for heating and cooling). Research on climate change tends to focus on mitigation and supply-side technological solutions, while a better understanding of behaviours and norms that determine households consumption is often overlooked (Creutzig et al., 2018).

Achieving change requires engaging several actors within the energy system, as well as taking advantage of multiple leverage points. The EU institutions and Member States define policies, regulate the functioning of the energy market, ensure security of supply and have the final choice over the national energy mix (EU, 2012). They are also responsible for creating enabling conditions for new entrants to the energy market, limiting market dominance and the power of incumbent system operators and strengthening the rights of individual consumers. Although they promote energy efficiency and new and renewable forms of energy production, and also influence energy policy indirectly by mitigating climate and environmental impacts across the energy system, they are just one among the many actors influencing citizens' choices and lifestyles.

> Policies for achieving net-zero carbon emissions often focus on technology and efficiency gains rather than behaviours and lifestyles.

A broader set of actors, such as non-governmental organisations, energy service companies, grassroots platforms, think tanks, academia, innovation centres, sponsors and the media, will potentially enable the conditions for creating policy and converting regulation into practice (Backhaus, 2010). Most importantly, they are well suited to promoting changes in norms, habits and practices in ways that can reduce consumption of direct and embedded energy. Changes in these aspects should be deployed, together with stronger policy instruments, such as taxing unsustainable energy carriers and their emissions, and removing fossil fuel subsidies. Such measures would promote cross-sectoral and demand-side changes towards a more sustainable configuration of the energy system.

16.4
The mobility system

16.4.1
The mobility systems at a glance

The mobility system spans all resources, structures and activities involved in moving physical objects, including both people and goods. It is a complex system shaped by a multitude of forces — including economic and broader societal ones, such as cultural norms and lifestyles — evolving over long time scales. The transport sector addressed in Chapter 13 is just one of these components, albeit a fundamental one.

The transport sector is generally defined as an economic activity (see Eurostat, 2018o) and described in terms of GVA, employment, number of enterprises, etc. In contrast, the mobility system includes aspects that go beyond economic activity, such as personal mobility and individual behaviour, infrastructures, urban and regional planning, investments, policy and regulatory measures, as well as a multitude of actors such as producers, users, policymakers and civil society.

For the purpose of this assessment, the boundaries of the system are defined by the geographical focus on Europe and its global transport links. The specific properties of different modes of transport (road, rail, aviation and maritime, walking, cycling), such as capacity, speed and infrastructural requirements, define the supply side of transport and have a strong effect on mobility choices. In addition, mobility-related industries account for a significant share of the EU's economy and employment. For example, the production of motor vehicles alone accounted for 2.4 million jobs in 2015 (Eurostat, 2018a).

The mobility system shows marked diversity across Europe, concerning aspects such as network infrastructure and connectivity, modes of transport, share of renewable fuels, car ownership and overall demand (EEA, 2018j; EC, 2018l; Eurostat, 2018n), as well as socio-economic and geographical variations. For example, an increase in levels of car ownership, resulting in bigger car fleets, has been observed, particularly in countries joining the EU since 2004, alongside an expansion in the demand for transport in tandem with a stagnating or declining share of the more environmentally friendly modes of transport, such as rail transport (EEA, 2018f). This has been indicated as a key reason for increases in the transport sector's GHG emissions (EEA, 2018g).

Mobility is a means of satisfying fundamental needs, be it for personal purposes or as part of the economy. Most EU citizens make mobility choices every day, for example to reach their workplace, go shopping and access the social infrastructure such as schools, libraries and hospitals. Lifestyle choices and behavioural aspects play an important role in determining the shape and environmental impact of the mobility system, as established patterns are hard to change, even if better, more environmentally friendly mobility options become available. It has been shown that the shape of the mobility system partly determines the form of the built environment, and vice versa (Zijlstra and Avelino, 2012). Shopping centres outside or on the fringes of urban areas, suburbanisation and the need for long commutes when working and living areas are separated can all result in dependence on cars (Guerra and Cervero, 2011).

Alongside personal mobility, the system also plays a central role in production and trade. Europe is a transport hot spot with a high concentration of infrastructure by international comparison. It connects different world regions through major airports and sea ports, and plays a central role in global transport of passengers and goods. Complex logistics chains are the hallmarks of economic globalisation, as they now connect different production stages within countries, across world regions and even globally. This is especially relevant for complex products such as electronic equipment and the car industry. Raw materials (e.g. iron ore, crude oil and coal) and agricultural products (e.g. wheat, rice and soybeans) are among the most transport-intensive goods.

Europe has had limited success in reducing transport emissions and shifting towards more sustainable transport modes.

The mobility system generates important negative impacts on ecosystems and health. Rising car ownership rates and the growing road network have led to dramatic gains in personal mobility, but they have also resulted in important economic, societal and environmental problems (Geels et al., 2012). The spectrum is broad and ranges from well-documented, direct impacts on the climate and air quality, noise pollution, loss of biodiversity and fragmentation of landscape and habitats to more indirect impacts such as urban sprawl and invasive alien species entering in the ballast water of ships (Chapters 3-13). Transport also creates indirect impacts by stimulating demand in a range of other economic sectors, including extraction of raw materials, production of infrastructure and vehicles, electricity generation, petroleum refining, and recycling and disposal of materials.

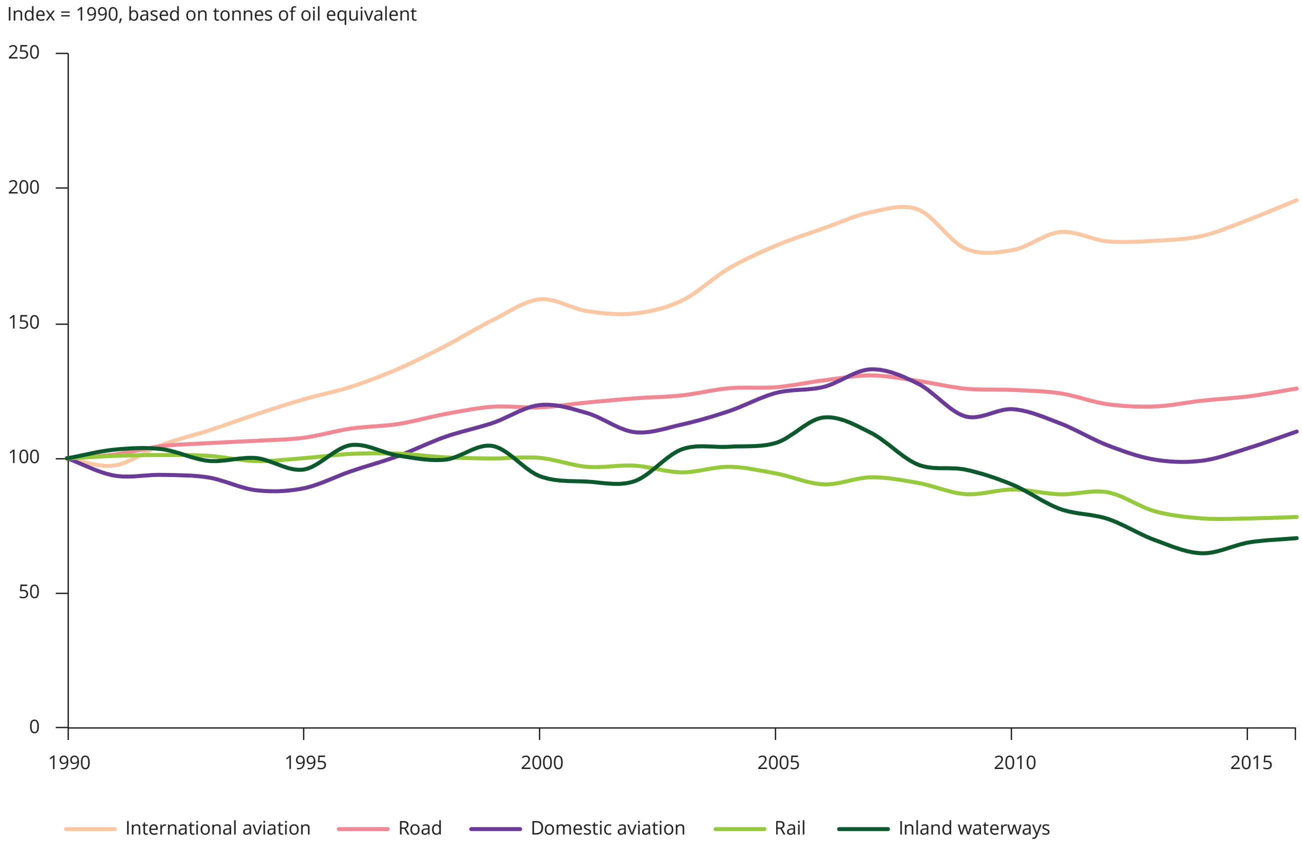
The EU mobility system is heavily dependent on imported oil; thus, it is intrinsically interconnected to the energy system. Transport accounted for 33 % of the EU's final energy consumption in 2016 (EC, 2018k) and only 7 % of the final energy used in transport came from renewable sources (Eurostat, 2018k). The remainder was largely made up of oil and petroleum products, of which 87 % were imported in 2016 (Eurostat, 2018k). Liquid fuels from fossil fuel sources have a high energy density, are relatively cheap, relatively easy to transport and handle, and are supported by a mature infrastructure. This creates a lock-in that keeps the petrol- and diesel-powered internal combustion engine the principal source of power for cars.

16.4.2 Trends and prospects

The mobility system has had limited success in reducing emissions and shifting towards more sustainable transport modes. While other sectors have already seen a certain reduction in emissions, GHG emissions from transport have increased by 26 % since 1990 (including international aviation but excluding international shipping). Following a peak in 2007, emissions decreased for 6 consecutive years. This largely coincides with a period of economic contraction, which had a dampening effect on transport demand. However, since 2013 emissions have risen again year on year. This puts the EU's mobility system in the spotlight. In future, it will need to run on much less carbon to avoid thwarting the EU's ambitions for mitigating climate change. Within the mobility system, road transport accounts for the biggest share (73 % in 2016), but aviation emissions have seen the strongest growth (Figure 16.3).

The political goal of shifting transport from more polluting modes towards less polluting modes has not had an obvious impact on demand or infrastructure development in the EU. Demand for passenger transport in the EU was at a record level of 6.8 trillion passenger-kilometres (pkm) in 2016. At 3.7 trillion tonne-kilometres (tkm), demand for freight transport was also close to its all-time high (EC, 2018k). The length of the EU's motorway network, for example, has seen uninterrupted growth over the last 25 years (EC, 2018k). Simultaneously, car ownership rates have kept going up — from 342 cars per 1 000 inhabitants in 1990 to 507 in 2016 (EC, 2018k). At the same time, the overall length of the rail

FIGURE 16.3 Energy consumption by transport mode



Source: Eurostat (2018e).

network has been shrinking, although more than half of it is now electrified (54 % in 2016).

Current prospects indicate increased demand for transport and mobility services in Europe and globally. According to the European Commission, passenger and freight transport are expected to have grown by about 42 % and 60 %, respectively, by 2050 compared with 2010 levels (EC, 2017a). Given similar trends in most other high-income countries and rapid growth in demand in low- and middle-income countries, it is likely that more people and goods will move around in the world in future than ever before. The shift in economic power towards developing regions and a fast-growing global middle class is also expected to increase trade with emerging economies, potentially requiring additional infrastructure at EU ports. In Europe, although some cities are experiencing a decline in their populations due to ageing and internal EU migration (UNDESA, 2018), others are expected to grow further (Eurostat, 2016b) and demand more mobility services, which may also occur as a result of the large number of infrastructure projects planned for the future (EEA, 2016c).

Demand for transport and mobility services is projected to grow in Europe and globally.

Another important development is the rapidly growing role of ICT across the mobility system. Real-time travel data, partly automated driving and the push towards autonomous driving can make the system more efficient and enable multi-modal, seamless transport services. The 'mobility as a service' approach seeks to detach mobility from vehicle ownership by bringing together all relevant means of transport to enable individual trips. It has the potential to reduce car ownership rates and improve capacity use across transport modes. Yet, the overall effect of ICT on the environmental pressures from the mobility system remains unclear, apart from having important social implications including personal data protection and privacy. The available research findings on automated and connected driving indicate that the technology can make vehicles more efficient and cut their emissions, but at the societal level it could also lead to additional demand for transport, longer commutes and rebound effects as a result of improved efficiency and lower costs (Taiebat et al., 2018).

Rapid progress in battery, fuel cell, bio- and electrofuel technology is starting to affect road transport, although uptake is limited. Regulatory pressure for more efficient cars and vans has already resulted in a small but rapidly growing share of battery electric vehicles (BEVs) and plug-in hybrids (PHEVs). However, with a combined share of 1.5 %, they represented only a small fraction of the new car market in 2017, which is still dominated by petrol and diesel cars (97 %). 2017 was also the first year that hydrogen cars became commercially available in Europe with 175 registrations (EEA, 2018a).

Alternative technologies and fuels are also starting to play a role in sea and air transport (e.g. 'advanced' biofuels and synthetic fuels ([3])), but market-ready technologies are not yet widely available and tend to suffer from poor cost-competitiveness, as well as low levels of energy efficiency. This is also due to weaker regulatory pressure as a result of the difficulty of agreeing binding rules at the international level. Batteries are also not universally suited to all transport modes. For international shipping, and especially for commercial aviation, their low energy density compared with liquid fuels is still an important disadvantage.

Achieving EU policy objectives will require urgent and large-scale change in the mobility system.

16.4.3 *Towards system change*

The scale of change in the mobility system required to meet EU objectives is large and the timeline is short. Changes are required not only to mitigate climate change but also to improve air quality, reduce exposure to traffic noise and address a broad range of other impacts. Measures concerning technological options, infrastructure, digital innovation, optimisation and societal and consumer choices are often advocated as ways of transforming the mobility system (see also EC, 2018g).

While efficiency gains and new technologies offer a range of opportunities, their viability and overall environmental and social effects at the system level are often less clear. The drive towards more efficiency appears to be driven by both markets and policies, for example the CO_2 emission regulations for cars and vans (EU, 2014). However, it mainly takes the form of incremental improvements in technology that are insufficient to put the mobility system on a trajectory towards achieving the EU's sustainability objectives. Incremental efficiency improvements are often offset by growth in demand or negated by countervailing market trends. For example, heavier and less aerodynamic cars, especially the trend towards so-called sport utility vehicles (SUVs), are partly offsetting progress in engine technology (EEA, 2018d). Moreover, the positive impacts of regulatory measures — even those already implemented — are often apparent only in the medium to long term because of the turnover in the vehicle fleet.

The results of research on the life cycle impacts of a typical battery electric vehicle in Europe show lower GHG emissions compared with conventional equivalents (EEA, 2018a). This is even with the EU's current electricity mix, which still contains electricity from coal (EEA, 2018a). Although the results are characterised by uncertainties and overall effects at the system scale, the benefits are expected to increase over time if the carbon intensity of the EU's electricity mix decreases. However, producing an electric vehicle is currently more harmful to the environment and human health than producing a conventional one owing to the extraction and processing of raw materials such as copper and nickel. Potentially strong synergies exist between mitigating CO_2 emissions in Europe and reducing other local environmental impacts, such as air pollution and exposure to noise. Electric vehicles offer benefits for local air

([3]) Synthetic fuels (also known as e-fuels) are produced by transforming electricity into synthetic gases (hydrogen, methane or other gases) and liquids. They can be stored and used in multiple applications, across different economic sectors (EC, 2018g). The technologies underpinning these processes are also known as 'power-to-X' technologies.

quality due to zero tailpipe pollution and less noise.

The technology-infrastructure-behaviour link is of central importance for driving change in the mobility system. The electrification of road transport is one example. Although it has gained momentum because of various incentive schemes and increasingly stringent CO_2 limits for the new car fleet, so far the uptake of this technology is still limited. The reasons for this are barriers and lock-ins that keep the system on its current path, including high prices, lack of a charging infrastructure, limited driving ranges and consumer attitudes (EEA, 2016e). The fact that the bulk of the traffic and refuelling infrastructure is already in place and will remain largely unchanged for decades because of its long life span, high investment costs and the overall duration of the infrastructure planning cycle impedes systemic change. Moreover, infrastructure development is often subject to conflicting demands, and environmental concerns do not always prevail. This aspect makes the mobility system subject to considerable inertia, and the effects of decisions taken today to reduce its impacts on the environment and health will usually take years and sometimes decades to materialise.

There is currently too much focus on technology and governance, and behavioural aspects tend to be neglected. The built environment, residential areas and the location of services are significant conditioning factors for how people make everyday mobility choices as well as for what options might become available (Wegener, 2004). Therefore, the transition of the mobility system is dependent on transitions in the built environment (EEA, 2016e). Spatial planning is a key issue in breaking the infrastructure lock-in. Investing more in infrastructure that facilitates walking, cycling and public transport is already driving change towards more sustainable urban mobility.

Tackling regulations that drive urban sprawl (e.g. a building permit system that requires creating parking space) and changing taxation arrangements that make long commutes financially feasible could be suitable starting points. However, positive outcomes ultimately depend on accessible and attractive alternatives to individual motorised transport, as well as incentives to substitute physical transport with ICT, where possible, and to shift demand for transport to the most efficient modes.

Lifestyle choices and behavioural aspects play an important role in determining the shape of the mobility system, its impacts and its potential for reconfiguration. Decisions with profound environmental impacts, including car ownership, choice of vehicle and more generally mode of travel are linked to lifestyle. This insight can, for example, be used in public service campaigns encouraging sustainable transport (Thøgersen, 2018) as a leveraging point to change mobility behaviour, especially in urban areas. Taxation is an effective instrument to stimulate behavioural change, especially when well designed to take account of unintended regressive effects. Some European countries have announced their intention of reducing the tax differential between petrol and diesel, as a lower tax on diesel is not justified from an environmental perspective (Harding, 2014; see also Box 16.1). However, applying the principle in practice is often blocked by entrenched interests or by public concern about equity.

At the same time, the public discourse on mobility and its environmental effects is changing, as air quality problems linked to emissions from combustion engines, and diesel engines in particular, have become a major concern. A number of national governments have recently announced plans to phase out internal combustion engine cars. While implementing a phase-out in Europe would probably require a coordinated

BOX 16.1
Tax differentials, petrol versus diesel — examples of Belgium and France

Diesel is taxed at a lower rate than petrol in EEA Member States with the exceptions of the United Kingdom, where the two energy products have been taxed at the same rate since 2000 (EEA, 2016b), and Switzerland, where the diesel tax rate is higher than that on petrol. One of the reasons for the tax differential was to reduce fuel costs for hauliers, as diesel was mainly used as a fuel by commercial vehicles such as trucks and buses. However, the share of diesel-powered passenger vehicles has increased over the last two decades in Europe. The share of registration of new diesel-powered passenger cars increased from 23.1 % in 1995 to 56.1 % in 2011 in the 15 Member States that joined the EU before 1 May 2014. Since 2011, the share has dropped to 44.8 % in 2017 (ACEA, 2018).

Countries such as Belgium and France are in the forefront of reducing this tax differential. France set its tax on diesel at 71 % of the tax rate levied on petrol in 2010 and that increased to 88 % in 2018 (EC, 2019e). In Belgium, the diesel tax rate was set at 59 % of the petrol rate in 2010 but increased by 66 % in the period up to July 2018. In contrast, the petrol tax rate was reduced by 2.2 % during the same period, so that the tax rates on petrol and diesel are now equal. All changes are calculated based on nominal prices. ■

approach at the level of the single market and a long time horizon, clearly stating the political ambition can give direction to industry and consumers and be a leveraging point for achieving change.

To date there is no overarching strategy linking the mobility system in its entirety to all of the priority objectives set out in the Seventh Environment Action Programme. Nevertheless, with its three 'Europe on the move' packages, the European Commission 'has developed a comprehensive, integrated, and forward-looking approach to achieving clean, connected and competitive mobility for EU citizens' (EC, 2018e). Although the need to adopt a systems perspective to address challenges concerning GHG and air pollutant emissions is clearly acknowledged in several EU policies (EC, 2011b, 2018e) and policy proposals (EC, 2017c, 2018i), the emphasis is generally on technology pathways, efficiency gains and optimisation (e.g. digitalisation, automation, batteries), as well as related enabling factors (e.g. research and innovation, industrial leadership, multi-modal transport networks).

Europe is at the forefront of efforts to tackle the environmental impacts of the mobility system. Policies seek to maximise benefits for citizens by increasingly addressing decarbonisation and promoting the circular economy, safety, innovation, jobs and competitiveness (EC, 2018e). Nevertheless, impacts on natural capital, including habitats and biodiversity, and land and soil, are currently less prominently addressed. A broader understanding of the mobility system and its interactions, and increasing policy integration, is therefore crucial to achieve environmental objectives in Europe.

> Progress towards sustainability transitions is hindered by a variety of systemic challenges.

16.5 Insights across the three systems

The assessment of Europe's food, energy and mobility systems in Sections 16.2-16.4 highlights some of the key challenges that Europe faces in achieving its long-term environmental and sustainability goals. Although there are signals of progress in food, energy and mobility, trends in environmental outcomes are not in line with meeting Europe's long-term environmental and sustainability goals. Moreover, a wide range of megatrends and emerging trends are likely to create additional challenges (Chapter 1 and Section 15.1).

Looking across the three systems, it is apparent that progress towards sustainability transitions in production and consumption systems is hindered by a variety of systemic challenges. The mechanisms that make the systems resistant to change are varied in nature, relating to the technological, economic and biophysical elements in the systems, as well as feedback mechanisms and cross-system interactions. Several of these challenges emerge as recurring features, although their characteristics differ across the food, energy and mobility systems.

First, the three systems are characterised by lock-ins and path dependency. In part, this reflects the fact that the system elements — technologies, regulations, infrastructures, user patterns, and so on — have co-evolved over decades to form relatively stable configurations. They are also multi-functional, implying that changes will result in a complex mixture of trade-offs.

Second, Europe's production and consumption systems are very often dominated by a small number of established actors. Moreover, there are marked differences in the roles and powers of actors along the value chain, for example between incumbents and new entrants. Such vested interests contribute to system inertia.

Third, achieving sustainability objectives is fundamentally dependent on individual and societal consumption choices — encompassing consumption levels, patterns and lifestyles. Local initiatives are emerging, offering new models of consuming and producing. Yet, the choices made by individuals and governments are still largely influenced by the dominant socio-economic paradigm, which generally promotes globalisation, consumerism, individualism and short-termism.

Fourth, it is also important to acknowledge the local heterogeneity of the food, energy and mobility systems. Each differs markedly across Europe and its regions, in terms of economic and infrastructural development and related consumption patterns, behaviours and lifestyles. Countries and regions also vary greatly in terms of their natural endowments and related biophysical limits (e.g. availability of natural resources, productivity, yields, but also technical efficiencies). This implies that responses must be tailored to local realities; there are no 'one-size-fits-all' solutions that apply across Europe.

Fifth, the three systems are highly interconnected with each other, giving rise to pressures and impacts across varied ecological systems and natural resources. They are also shaped by changes in the fiscal and financial systems. This interconnectedness across systems means that system reconfiguration is likely to lead to trade-offs among sustainability outcomes.

Sixth, policies can create enabling conditions to facilitate systemic change towards achieving sustainability objectives. Looking across the three systems, it is evident that thematic and sectoral policies increasingly reflect a systemic understanding of sustainability challenges. Several thematic policies cover aspects ranging from production to demand, often addressing impacts across the full supply chain, e.g. through life cycle thinking. Yet, the systems differ in terms of the ambition and coverage of the main policy frameworks. In contrast to the energy and mobility systems, there is currently no overarching policy on the food system in Europe. Moreover, even in the energy and mobility areas, the new frameworks are not comprehensive. Although issues such as security of supply, air pollution and climate are recognised in full across energy and mobility, other environmental aspects such as protecting natural capital are not sufficiently covered. Governance responses are likewise oriented towards a limited set of approaches, emphasising technologies and market-based instruments.

16.5.1 Societal lock-ins and barriers

The complexity and inertia that characterise Europe's systems of production and consumption arise in large part from the co-evolution of diverse elements over long periods. For example, the emergence of the car as the dominant form of land-based transport during the 20th century was accompanied by major private investments in the skills, knowledge and infrastructure for producing cars; public investments in the road infrastructure; the emergence of industries to manufacture and deliver fuel, tyres and other accessories; adaptation of urban design to suit the car; and changes in behaviour, expectations and cultural values linked to car ownership (Unruh, 2000).

The key idea is that the many interlinkages within and between complex systems mean that there are often strong economic, social and psychological incentives that lock society into particular ways of meeting its needs. Radically altering these systems is likely to disrupt established investments, jobs, consumption patterns and behaviours, knowledge and values, inevitably provoking resistance from affected industries, regions or consumers. The interactions between these diverse elements also mean that efforts to change complex societal systems can often produce unintended outcomes or surprises.

Looking across the three systems, a number of important lock-ins stand out, although their relative importance varies between systems:

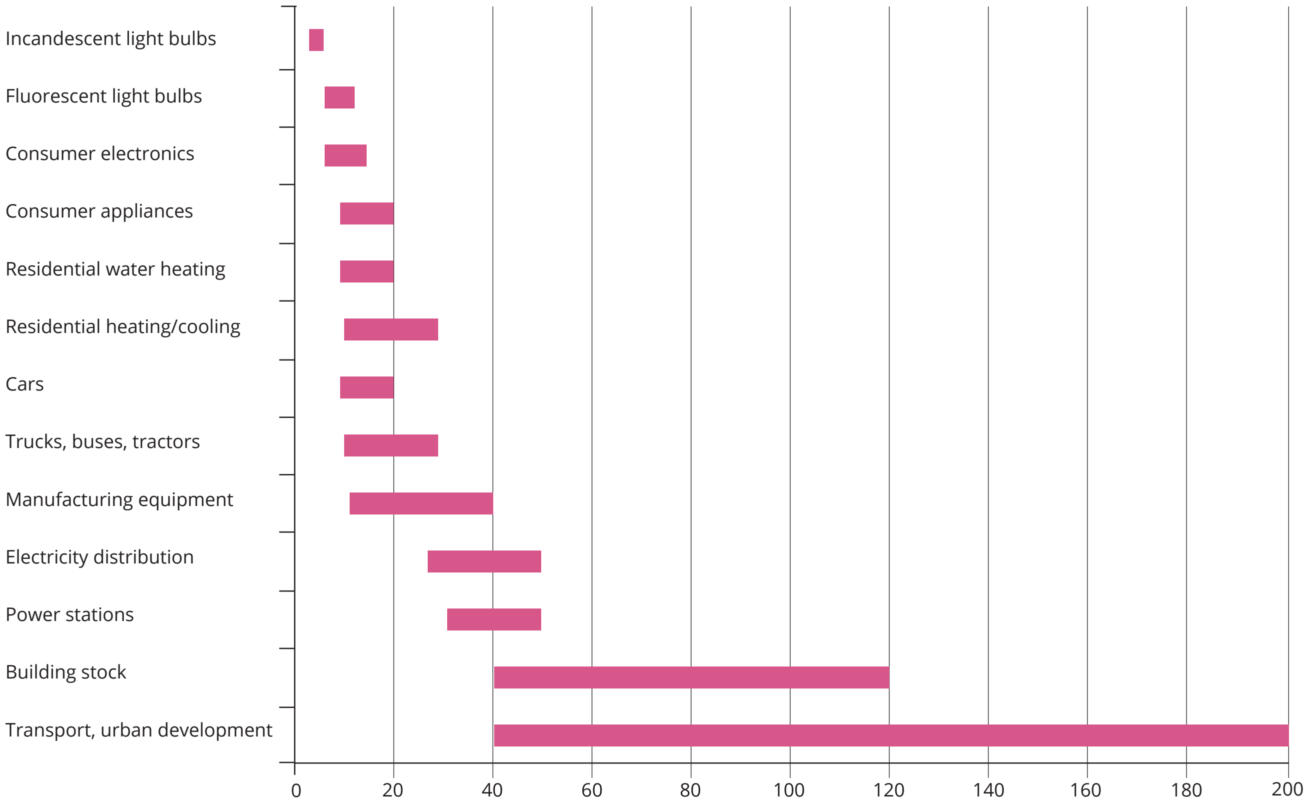
- Emergence of a dominant design: Production costs for new technologies often drop significantly as output grows due to economies of scale and learning-by-doing, as well as network effects (Arthur, 1994). As a result, a technology (e.g. the internal combustion engine) can establish itself as the 'dominant design', enjoying significant price/performance advantages over subsequent innovations. A dominant design becomes further entrenched when supply chains and industry networks emerge to supply inputs, complementary technologies or infrastructure. This greatly increases the jobs, earnings and investments tied to the dominant design.

- Sunk costs: Public and private investments in infrastructure — particularly transport links and urban development — are often very substantial and long lasting (Figure 16.4). Businesses and employees likewise make major investments in manufacturing plants, knowledge and skills, which are geared towards particular modes of production. In the energy sector, for example, investments in upstream extraction (oil and gas rigs, coal mines), conversion (power plants, oil and gas refineries) and infrastructure (oil and gas pipelines, electricity grids, gas grids) are huge, constituting deep sunk costs that incumbent industries are likely to protect. The lifetimes of these assets and infrastructures are in the order of decades, further locking in existing systems.

- Jobs and earnings: Disruptive innovations threaten established businesses and can lead to structural economic change, resulting in job losses and even impacting whole regional economies. These effects are likely to create major resistance from industry groups and trade unions. For example, Europe's energy sector employs close to 2.2 million people, spread over 90 000 enterprises and representing 2 % of total added value (EC, 2016b). Some regions are strongly dependent on particular forms of energy production. For instance, many of the 180 000 European jobs in coal mining and 60 000 jobs in coal-fired power plants are concentrated in eastern Europe, which creates resistance to transitions in those areas. These realities are a key driver behind calls for a 'just transition' (ILO, 2015; UNFCCC, 2015).

- User practices and lifestyles tend to co-evolve with technologies and related infrastructures. Mobility, for example, is a 'derived demand', which supports other social practices such as leisure, visiting friends, shopping, commuting to work, business travel and taking children to school. For many of these activities, cars are often the most practical form of transport (in terms of travel time, carrying capacity, comfort), which is why many people choose this transport mode over others. Car use is also stabilised by long-standing positive cultural discourses, which associate cars with values such as freedom, individuality, power and success (Sheller, 2004). Cognitive biases such as

FIGURE 16.4 **Average lifespans for selected energy-related capital stock**



Source: Based on Philibert and Pershing (2002).

loss aversion, status quo bias and the endowment effect — whereby people overvalue something simply because they own it — can further deter lifestyle changes.

- Technological readiness and infrastructural development play fundamental roles too. For example, the 'carbon lock-in' in the energy system (EEA, 2016d) stems from a combination of the mechanisms described above. The shift towards a more distributed energy system increasingly reliant on renewable energy is likely to entail both stranded assets (e.g. fossil fuel power facilities), and expensive investments in new infrastructures to ensure a reliable supply of electricity. This looks

> Market prices often misrepresent the social and environmental costs of different modes of producing and consuming.

set to include investments to increase the back-up capacity and extend grids to allow more trade in electricity (van Vuuren and Hof, 2018). Lack of technological readiness (e.g. carbon capture and storage, large-scale back-up batteries, power-to-X) is a fundamental barrier to decarbonisation.

- Biophysical lock-ins are created by constraining factors, such as water availability, soil quality and the status of pollinators. These can affect opportunities for transformation, particularly in the food system (Oliver et al., 2018). For example, it may be hard to shift away from intensive farming practices if heavy reliance on specific crops and livestock leads to a loss of genetic diversity in other varieties, or if resulting soil degradation makes it hard to reduce chemical inputs.

16.5.2 Political and economic barriers

The effects of these lock-ins are often compounded by additional barriers linked to economic and political processes. The structure and organisation of modern production-consumption systems has been influenced to a large extent by market incentives. Because market prices often misrepresent the social and environmental costs of different modes of producing and consuming, this has contributed to systems that are harmful and unsustainable.

Unfortunately, governments are often constrained in their abilities to impose regulations and pricing instruments that are consistent with long-term sustainability goals. Groups with vested interests sometimes use corporate political strategies to shape policies in their favour (Hillman and Hitt, 1999; Levy and Egan, 2003). For example, powerful mobility-related industries (particularly the car industry) have been quite effective in lobbying against stricter environmental regulations and 'gaming' emission tests (Fontaras et al., 2017).

Policy interventions that remove environmentally harmful subsidies or put in place taxes to address externalities will create winners and losers. For example, taxing food, energy and mobility can have regressive distributional impacts — hitting poor people hardest because they spend a greater proportion of their income on such necessities (EEA, 2011b). It is also likely to have varying effects on urban and rural populations, young people and the elderly.

Electoral incentives can further discourage politicians from introducing measures that are likely to be unpopular in the short term but deliver long-term benefits for society. At the broadest scale, governments may be locked in to the economic growth paradigm that is known to be socially and environmentally harmful, partly because of the need to maintain employment levels and finance the welfare state (Kemp et al., 2018).

Altering sectoral policies (e.g. relating to standards for products or processes) can be difficult because producers and consumers make choices and investments based on them. The common agricultural policy (CAP), for example, is a cornerstone of EU policy that has helped to ensure stable access to affordable food for Europeans, supporting livelihoods in farming, and modernising European agriculture. But it is also criticised for its associated environmental outcomes (ECA, 2018). Attempts to reform it radically have proven difficult; the structural stability of the CAP policy framework encourages gradual adjustment of agricultural practices (Chapter 13).

The globalisation of production-consumption systems creates additional challenges. Consumers and producers (at different stages) are unaware of the socio-economic and environmental impacts of their choices and have limited influence over them. These same characteristics significantly constrain the efficiency of territorially based policy instruments, particularly as efforts to prevent an environmental or socio-economic problem in one location may result in substitution effects or relocation of production overseas (known as 'burden shifting').

Electoral incentives can deter governments from acting sustainably.

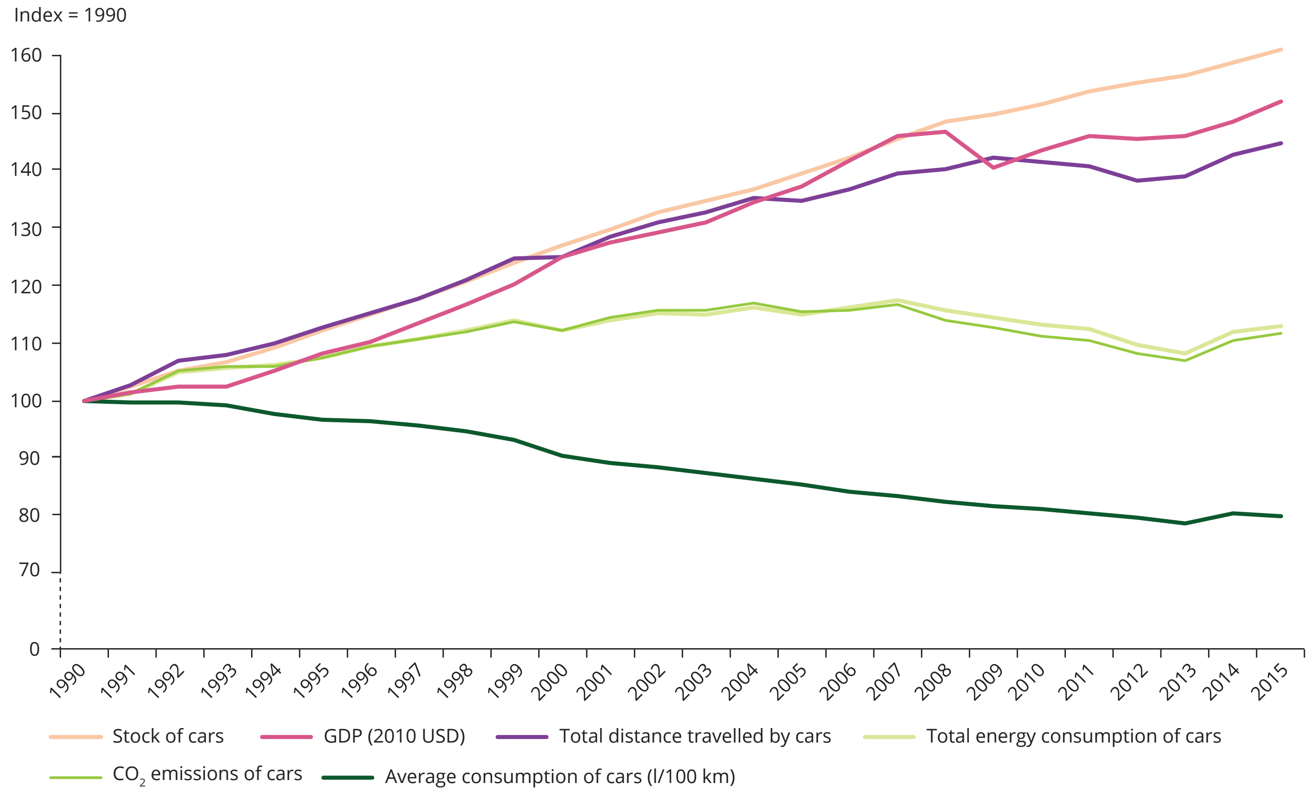
16.5.3 Rebound effects

The effectiveness of policy interventions can also be offset by feedback within systems. For example, technology-driven gains 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 is often referred to 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 to 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 macroeconomic scale by the resulting savings being spent elsewhere in the economy (Font Vivanco et al., 2018).

Improvements in fuel efficiency in cars have not led to a reduction in fuel consumption or GHG emissions because of increased car ownership and the distances driven (Figure 16.5). 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

FIGURE 16.5 Fuel efficiency and fuel consumption in private cars, 1990-2015



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

of focusing on transforming whole systems, rather than seeking to alter aspects of production or consumption.

16.5.4 System interactions and the resource nexus

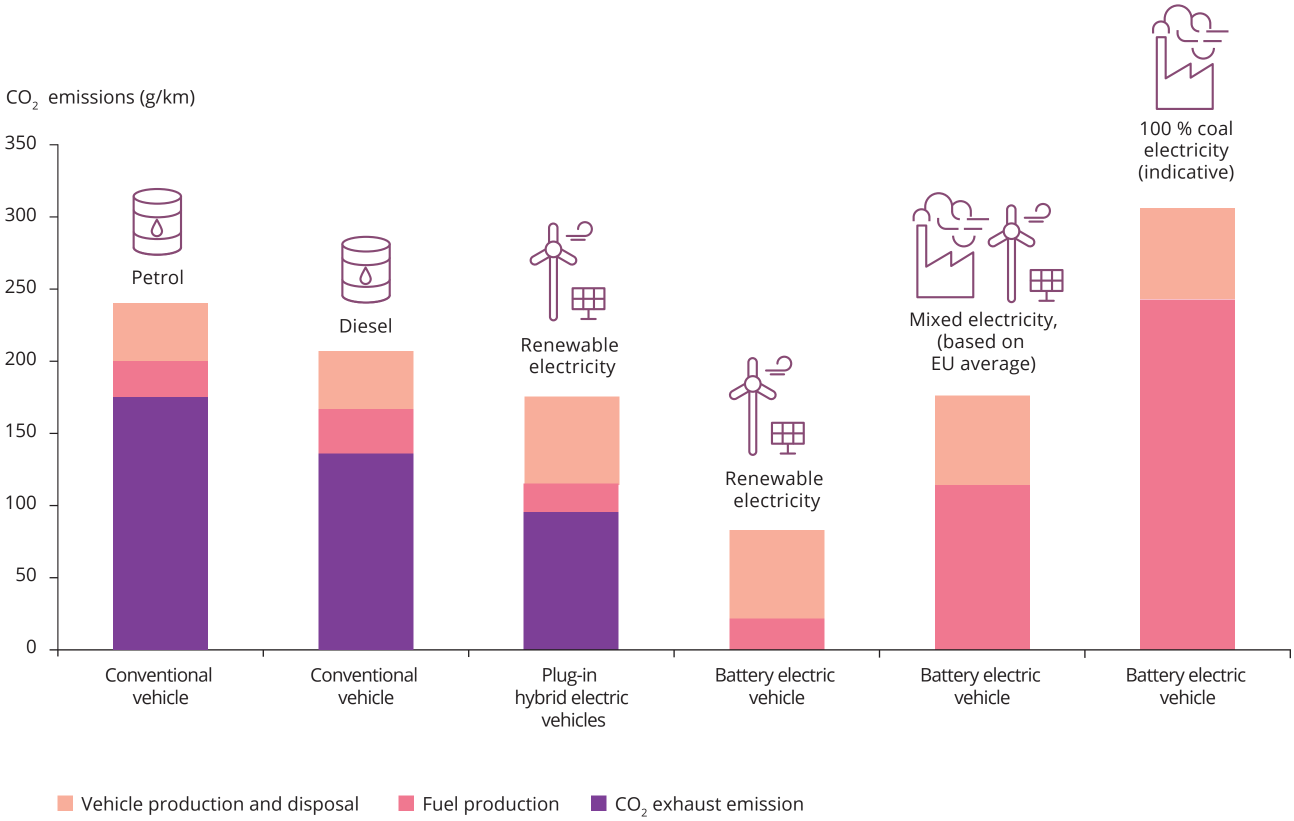
Analysing production-consumption systems in terms of their interlinked social, economic and environmental dimensions provides vital insights into the barriers to transforming them. Yet, focusing on individual systems understates the governance challenge. In reality, these systems (and others) are linked in complex ways, creating further lock-ins, trade-offs and uncertainties.

The food, energy and mobility systems are linked both directly and indirectly. Relatively simple interactions occur because the systems overlap in significant respects, implying that changes in one system have implications in others. For example, the shift to electric vehicles is likely to play an important role in reducing transport-related GHG emissions in coming years, but the benefits will depend heavily on the source of electricity used to charge vehicles (Figure 16.6). Investment choices in the electricity sector can therefore constrain or enable the transition towards electrical mobility.

The resource nexus

Less direct but very important links between the food, energy and mobility systems arise because of their shared reliance on natural systems, both as a source of resources and as a sink for wastes and emissions. As a result,

FIGURE 16.6 **Life cycle CO_2 emissions for different vehicles and fuel types**



Sources: EEA (2016a), drawing on TNO (2015).

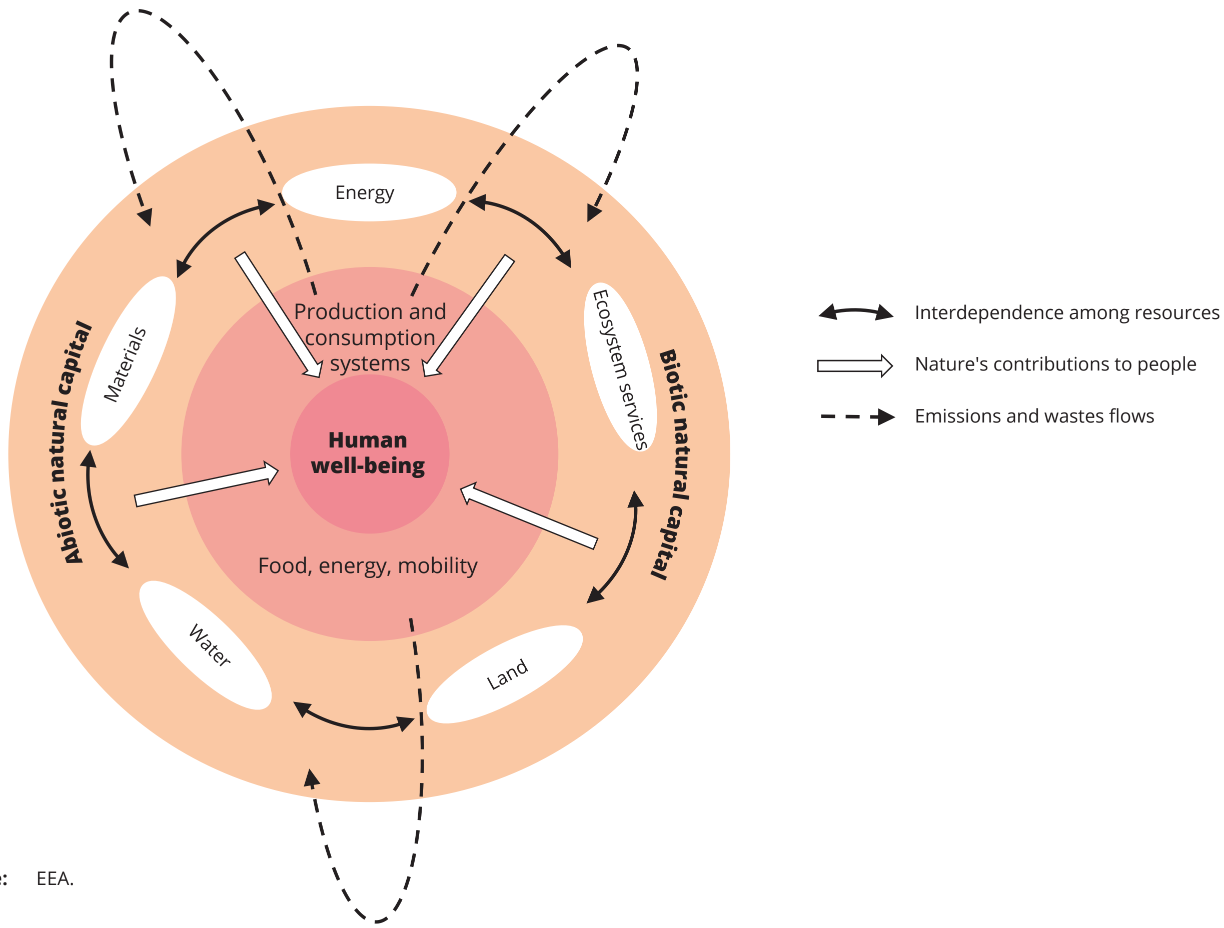
The concept of the 'resource nexus' recognises that food, energy, water, land, materials and ecosystems are interconnected.

addressing problems in one area may simply shift the burden to other systems.

Choices regarding land use affect both the current outcomes of the food, energy and mobility systems and the potential for sustainability transitions. Such choices focus in particular on how land is used to produce food, fuel and biomass, to sequester carbon and to provide other ecosystem services. Agriculture, forestry and land use are recognised as important factors in meeting long-term climate goals because of the need to achieve negative emissions through carbon sequestration. Achieving this will require that the interlinkages across systems are considered and the trade-offs and co-benefits identified.

The concept of the 'resource nexus' essentially recognises that food, energy, water, land, materials and ecosystems (Figure 16.7) are interconnected across space and time (Hoff, 2011). It supports sustainability governance by helping to identify how best to balance socio-economic and environmental concerns. As the World Economic Forum (WEF, 2011) notes, 'any strategy that focuses on one part of the water-food-energy nexus without considering its interconnections risks

FIGURE 16.7 **The five-node resource nexus — water, land, energy, materials and ecosystem services — embedded in natural capital**



Source: EEA.

serious unintended consequences', such as externalisation of environmental pressures, burden shifting or distributional effects.

For example, analysis of 50 existing EU policies confirms that policy is normally framed within distinct sectoral mandates, e.g. for water, agriculture or energy (Venghaus and Hake, 2018). Interactions between these three domains have only recently become a focus for attention, primarily through informal statements of intent. The policy areas in which cross-sectoral thinking is most advanced are the agricultural and water sectors, because of agriculture's key role as a source of pressures on aquatic environments. Nexus thinking does not emerge prominently in policies regulating the energy sector, except in relation to the impact of biofuels and bioliquids on biodiversity, water resources, water quality and soil quality (Venghaus and Hake, 2018).

The low-carbon, circular, bioeconomy nexus

The emergence of broader and more systemic EU policy frameworks addressing the low-carbon economy, circular economy and bioeconomy offers the potential for more integrated management of natural resources. Yet these frameworks also rely on the same resource base, creating potential synergies and trade-offs, as well as raising questions about whether their cumulative impacts are compatible with protecting natural capital in Europe and globally. Considering current and future trends, there is a need to develop more knowledge of synergies and trade-offs and of how to reconcile economic activities, social needs and sustainable management of ecosystems (EC, 2018d).

The finite capacity of ecosystems to supply goods and services can also create biophysical lock-ins, potentially limiting opportunities for sustainability transitions. For example, potential tensions can be expected between the CAP, the low-carbon economy, the circular economy and the bioeconomy, linked to goals of increasing competitiveness and protecting local ecosystems. The EU's low-carbon economy, circular economy and bioeconomy policies all target increased use of biomass to replace fossil fuels, both to generate energy and as inputs to the chemicals and pharmaceuticals sectors. Yet, resource nexus analysis suggests that ecosystems cannot supply biomass and assimilate waste and emissions at the rate needed to meet these policy objectives.

Similarly, the need for new infrastructures and materials to support the transition to a low-carbon economy may be inconsistent with the goal of creating a more circular economy. A study by the International Resource Panel calculated that low-carbon technologies will require over 600 million tonnes of metal resources by 2050 to cover additional infrastructure and wiring requirements. Battery electric vehicles, for example, increase metal consumption by around 50 % compared with petrol vehicles (Ekins et al., 2017). If this demand is not dealt with in a circular manner, this will lead to higher GHG emissions.

At the same time, there are also important synergies between the frameworks. For example, recycling critical raw materials can help secure the resources, such as rare Earth metals, needed for renewable energy technologies. More broadly, circular strategies (e.g. reuse, recycling, product-service systems, sharing) reduce GHG emissions, either directly (e.g. avoiding transport) or because the strategy requires fewer materials and/or products to meet the same needs. This then avoids GHG emissions in the extraction, production, transport and waste processing phases of these (avoided) products. The implications are significant. In a review of four countries, the OECD found that materials management (production of goods and fuel, transport of goods, food production and storage, waste processing) accounted for 50-65 % of national GHG emissions (OECD, 2012). Another study estimated that implementing simple, already feasible, design options to extend the lifetimes of laptops, printers and washing machines in the EU could lead to savings in GHG emissions of over 1 million tonnes per year. This is equivalent to taking 477 000 cars off the road for a year (EEB, 2015).

> In complex systems, policy interventions can result in 'risk migration', with successes in one area offset by the emergence of new risks elsewhere.

Finally, in a systemic context, policy interventions can also result in 'risk migration', in which successes in one area are offset by the emergence of new risks elsewhere. For instance, the circular economy package aims to minimise extraction of raw materials and energy use by keeping products for longer within the economy and by recycling. However, the limited ability to track chemicals in a circular economy could lead to the accumulation of hazardous substances in recycled materials and increase exposure to chemicals (EEA, 2017a; Chapters 9 and 10).

16.6 Challenges for governance

The need to transform how we produce and consume is now widely acknowledged in research and policy. Yet the analysis in this chapter highlights the extent of the challenge ahead. In seeking to transform societal systems, policymakers and other actors across society face diverse barriers and lock-ins, as well as substantial trade-offs and the likelihood of unintended outcomes.

The analysis of the food, energy and mobility systems illustrates that technology-oriented efficiency improvements alone will not be sufficient to achieve the very substantial and urgent reductions in environmental pressures that are required. Instead, there is a need to complement incremental improvements to established systems with other measures addressing the scale or patterns of consumption.

The 'avoid-shift-improve' logic provides a useful framework for guiding policies and actions towards reducing environmental pressures and addressing systemic challenges, as indicated by Creutzig et al. (2018). As illustrated in Table 16.1 for the mobility, energy and food systems, 'avoid' refers to the avoidance of unnecessary demand and overconsumption, 'shift' refers to moving consumption towards the mode/device/service with the least impact, and 'improve' refers to increasing the environmental performance of the process/product/service (e.g. production, use, end-of-life phases).

The resource nexus approach exposes another key governance challenge, highlighting the interdependence of production and consumption systems and their cumulative impacts on ecosystems. Transforming production-consumption systems inevitably produces trade-offs, as well as far-reaching and uncertain impacts. Yet established governance and knowledge systems are seldom

TABLE 16.1 **The 'avoid-shift-improve' framework applied to the food, energy and mobility systems**

System	Avoid	Shift	Improve
Mobility	Compact cities, integrated transport and land use planning, teleworking, sharing	Shift from car to cycling, walking or public transport	Eco-driving, smaller, lightweight vehicles
Energy	Passive houses or retrofitted, long-lasting devices, sharing machinery and appliances	Heat pumps, district heating and cooling, combined heat and power, recycled materials	Condensing boilers, insulation options, energy-efficient appliances
Food	Intake of calories and nutrients according to daily needs, reducing food waste	Shift to protein sources other than meat where appropriate	Fresh instead of processed food, product ecolabels

Source: Modified, based on Creutzig et al. (2018).

designed to handle this kind of complexity. Policies and actions at different levels of governance — from communities to international organisations — are often developed in silos addressing specific sectors or issues (Stirling, 2014; Wallis, 2015; Venghaus and Hake, 2018). Research is often similarly compartmentalised within disciplinary boundaries, while indicators and knowledge infrastructures are seldom developed and organised in ways that support a systemic understanding of challenges and responses. Collectively, these factors make it hard to achieve adaptive governance processes that can respond rapidly to new information about the barriers, opportunities, trade-offs and co-benefits associated with systemic change.

To achieve sustainable system outcomes, there is a need for policies that embrace the inherent interconnectedness of system components, interactions across systems, and links between economic, social and environmental goals. To anticipate potential implications and unintended consequences such interventions should be assessed against multiple criteria. These include feasibility against ecological and biophysical constraints, their viability for economy and society (e.g. effects on jobs, structure of the economy, import dependency), and their ability to meet multiple sustainability goals simultaneously, both inside and outside Europe (Giampietro et al., 2009; MAGIC-NEXUS Project, 2018; Ripa et al., 2018).

> To achieve sustainable outcomes, there is a need for policies to embrace systems' interconnectedness and links between economic, social and environmental goals.

Looking ahead, the pressures on existing systems are set to increase. In addition to global demographic, economic and environmental trends, the emergence of a cluster of related technologies — including artificial intelligence, robotics, 3D printing, the Internet of Things, nanotechnology and biotechnology — threatens to disrupt economic and social systems in profound ways. According to Klaus Schwab, founder of the World Economic Forum, 'We stand on the brink of a technological revolution that will fundamentally alter the way we live, work, and relate to one another. In its scale, scope, and complexity, the transformation will be unlike anything humankind has experienced before.' (Schwab, 2015).

The coming transformations are likely to be disruptive for industries, investments and labour markets, creating major challenges for societies. Yet, they also present opportunities to reshape societal systems in ways that are urgently needed. Chapter 17 explores these themes in more detail, examining how Europe's governments and societies can respond to sustainability challenges by finding ways to change production and consumption patterns in ways that can create a resilient and sustainable future.

17. Responding to sustainability challenges

Summary

- Responding to the persistent and emerging challenges facing Europe will require transitions in the production-consumption systems driving impacts on the environment and health.

- Sustainability transitions are highly complex and uncertain processes. Governments cannot simply plan and implement them. Yet, public policies and institutions are essential to catalyse and orient systemic changes in cooperation with businesses and civil society.

- Transitions involve the emergence and upscaling of diverse innovations. There is a need for more emphasis on social innovation, behavioural change and nature-based solutions.

- Public policies and institutions can promote system innovation, including by supporting experimentation, correcting market failures, facilitating the spread of new ideas and approaches, and helping ensure a just transition.

- Governments can accelerate systemic change by helping cities to innovate and network, by reorienting financial flows towards sustainable investments and by developing relevant knowledge systems and skills.

- Achieving sustainability transitions requires public engagement in defining visions and pathways, coherence across policy domains and scales, and use of foresight and adaptive approaches to navigate risks. Ecosystem-based approaches can help manage cross-system interactions within environmental boundaries.

17.

Responding to sustainability challenges

17.1
From challenges to responses

During the last two decades, the concepts of 'sustainability transitions' and 'transformations' have become increasingly prominent in the academic literature (Köhler et al., 2019). Since 2015, this trend has been matched by a growing uptake of the language and logic of sustainability transitions in European policy frameworks. As noted in Chapter 15, the EU's long-term strategy for a climate-neutral Europe and the European Commission's reflection paper on the 2030 agenda for sustainable development (EC, 2018b, 2019d) adopt the language of transitions systematically. Similarly, EU strategies such as the circular economy action plan, the Energy Union strategy and the 'Europe on the move' agenda embrace a systemic rather than a sectoral focus, emphasising economic transformation towards long-term targets (EC, 2015a, 2015b, 2017a). They are characterised by multidimensional goals, addressing themes such as jobs, competitiveness, fair access to resources and sustainability; a focus on diverse societal actors and creating stakeholder platforms; and increasing adoption of system transitions approaches, including particular emphasis on innovation.

Systemic change is necessary for the EU to achieve its sustainability objectives.

As discussed in Chapter 16, the many interlinkages in societal systems create a profoundly complex challenge for governance. Lock-ins, barriers and feedbacks mean that interventions may encounter resistance or produce unexpected outcomes, such as shifting problems to other locations, rather than tackling them. These interdependencies also mean that pursuing environmental goals is likely to produce synergies or trade-offs with other sustainability objectives.

Europe is not alone in needing to achieve systemic change. Indeed, Europe cannot achieve its sustainability objectives in isolation. The interconnection of the world's environmental, social and economic systems implies the need for concerted international efforts. These are global problems, requiring global responses.

In responding to these challenges, the EU's economic scale, diplomatic and trade links, and leadership in environmental governance confer significant influence. Beyond intergovernmental processes, the globalisation of supply chains mean that European product standards and business practices can have effects well beyond Europe's borders. Similarly, the consumption choices of Europeans also have implications for environmental and social outcomes across the world.

Nevertheless, there are clear constraints on Europe's ability to shape environmental outcomes in other

By embracing transitions, demonstrating solutions and seizing related opportunities Europe can lead the global effort for change.

regions. Decision-making processes at the global level are frequently slow and produce disappointing outcomes, and enforcement mechanisms are often lacking (EEA, 2015b). With this in mind, Europe's greatest potential influence may come from global leadership in embracing the need for transformation — demonstrating that there are solutions to the problems facing countries and regions across the world and seizing associated social and economic opportunities.

The EU's emerging strategic policy frameworks provide an essential foundation but in practice they are just a start. Major questions remain to be answered. How, for example, can the EU and its Members States translate their long-term ambitions into coherent and relevant actions? How can society-wide systemic change be catalysed and steered towards long-term goals? And what role do public policies and institutions at different levels have in such processes? This chapter begins to respond to those questions.

17.2 Understanding sustainability transitions

17.2.1 The multi-level perspective on transitions

The growing body of research into sustainability transitions and transformations has its roots in diverse research fields. Disciplines such as ecology, evolutionary economics, innovation theory and political economy each focus on different kinds of change processes and scales of activity. Yet, this diversity is increasingly coalescing into a broadly shared understanding of sustainability challenges, which emphasises the barriers to transforming complex systems and the role of drivers of change at the macro and micro levels in enabling the emergence of new ways of living, working and thinking (EEA, 2018).

The 'multi-level perspective' on transitions (Figure 17.1) is a useful model for understanding how these interactions shape the dynamics of change in production-consumption systems (Smith et al., 2010; Markard et al., 2012; Geels et al., 2017). It describes transition processes as arising from the interplay of developments at three levels: regime, niche and landscape.

The regime comprises the diverse factors that structure existing modes of producing and consuming. As discussed in Section 16.5, these include technologies, regulations, infrastructures, behaviours and cultural norms, which have co-evolved in ways that hinder the emergence of alternative technologies, business models and social practices. In terms of price and performance, for example, novel innovations are likely to struggle against established approaches that have benefited from decades of incremental improvements and investments.

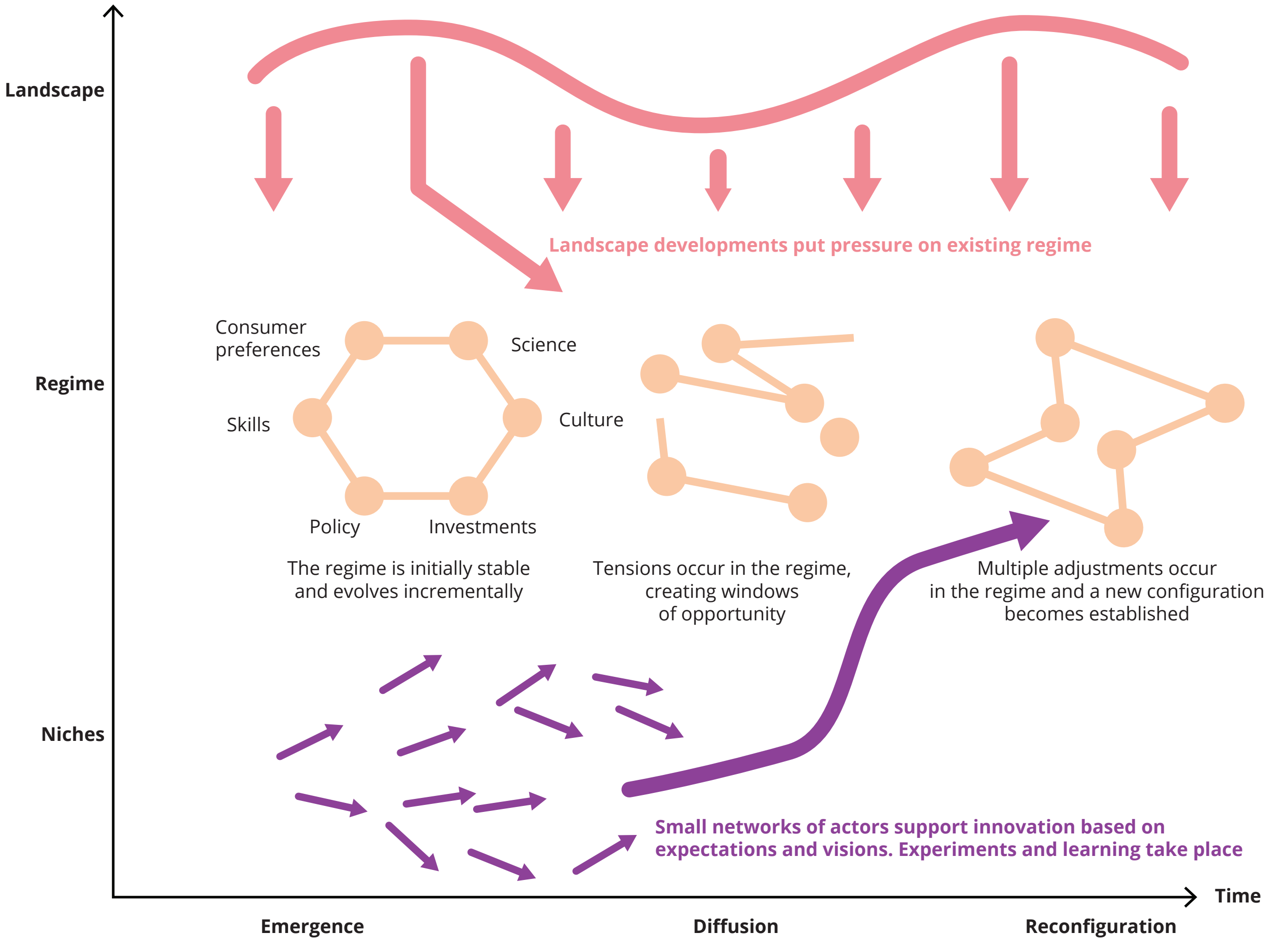
For innovations to alter the dominant system, three things are needed: niches, landscape developments, and cracks in existing regimes (Kemp et al., 1998). Niches are protected spaces, such as R&D (research and development) labs or demonstration projects, where entrepreneurs can experiment and develop radical innovations without direct exposure to market forces, consumer preferences, and so on (Smith and Raven, 2012). Landscape developments include long-term megatrends (e.g. social, economic, environmental) as described in Chapter 1, or more sudden shocks (e.g. a nuclear accident), which disrupt the regime. Cracks in existing regimes may arise from internal problems, external landscape pressures or bottom-up pressure from niche innovations (Turnheim and Geels, 2012). Collectively, this implies that transitions occur through dynamic, multi-level interactions between diverse actors, including businesses, users, researchers, policymakers, social movements and interest groups.

Figure 17.1 distinguishes three phases within transitions processes: the emergence of novel practices or technologies; their diffusion and uptake across society; and the disruption and reconfiguration of established systems. At each phase, innovations face major barriers, including inadequate funding, uncertainty about technical viability and consumer responses, incompatibility with established regulations or cultural norms, and active resistance from incumbent businesses.

Transitions are thus fundamentally uncertain processes, typified by setbacks and accelerations, surprises and unintended consequences. This makes it impossible to know in advance precisely what innovations will emerge, whether or how they will be integrated into lifestyles, and how they will affect sustainable outcomes.

Figure 17.2 presents an application of the multi-level perspective to the food system, including illustrative examples of landscape trends and important technological, social and organisational innovations. The multi-level perspective also provides a framework for integrating ideas from a range of transitions perspectives (e.g. Smith, 2012; Göpel, 2016). These include insights into how social practices change; the role of

FIGURE 17.1 The multilevel perspective on sustainability transitions



Source: Based on Geels (2002).

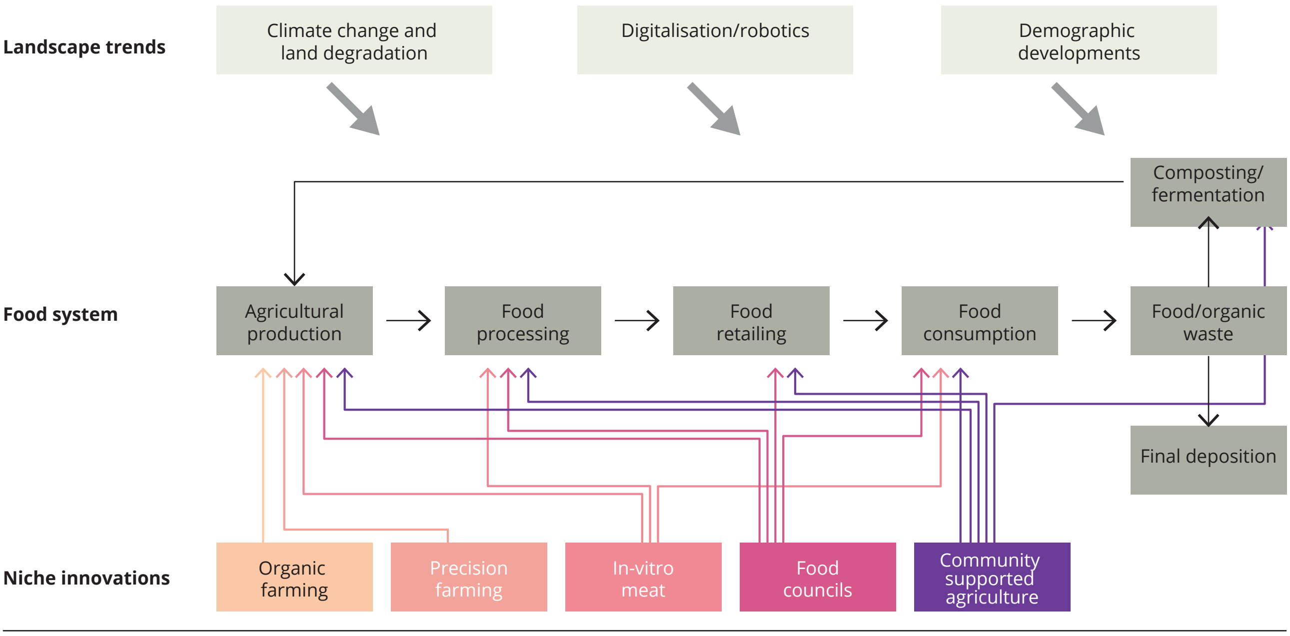
Sustainability transitions are non-linear, society-wide processes built on innovation and knowledge creation.

communities and cities in enabling more polycentric forms of governance, founded on bottom-up action by communities and other groups; the potential impacts of systemic change on society and the environment; and the importance of practices, values, worldviews and paradigms (EEA, 2018).

17.2.2 Implications for governance

The dynamics and interactions set out in the multi-level perspective point to the need for new governance approaches to support sustainability transitions. Historically, societies have relied on governments to manage the risks and harms associated with economic growth — primarily employing regulations and pricing instruments to correct market failures and using intergovernmental agreements to address transboundary issues and global collective action problems such as climate change. While these tools remain essential, they also face important constraints. For example, governments often face significant political barriers when seeking to introduce regulations and pricing instruments consistent with long-term sustainability goals. Equally, the deficiencies of global governance processes often mean that negotiated targets lack the necessary ambition and enforcement mechanisms.

FIGURE 17.2 Applying the multi-level perspective to the food system



Such realities imply that a purely hierarchical, top-down approach to achieving Europe's sustainability objectives will not achieve systemic change at the scale and pace needed. As Hajer at al. (2015) argue:

The SDGs [Sustainable Development Goals] … risk falling short of expectations because of what we call 'cockpit-ism': the illusion that top-down steering by governments and intergovernmental organisations alone can address global problems. In view of the limited effectiveness of intergovernmental efforts and questions about the capacity of national governments to affect change, the SDGs need to additionally mobilise new agents of change such as businesses, cities and civil society.

These observations have been associated with a shift in focus from government towards the broader concept of governance, which emphasises the complementary role of governments, markets and networks in organising society (Rhodes, 1997; van Heffen et al., 2000; EEA, 2015b). Such reasoning acknowledges the limitations of government power but also recognises that public authorities have unique capacities, resources and powers to identify and agree society-wide goals; to correct the operation of markets; and to stimulate and enable polycentric forms of governance, based on social interaction and information sharing.

For example, stringent environmental regulations and pricing instruments remain important, but promoting system innovation also requires a policy mix that supports the emergence and diffusion of new technologies and practices, helps phase out established systems and ensures a fair sharing of costs and benefits. Urban authorities and city networks have a key role. Public bodies are also vital in stimulating needed investment, developing necessary knowledge, providing directionality and coherence to activities across society, and creating mechanisms to anticipate and adapt to new risks and emerging issues. These issues are explored in detail in the remainder of this chapter.

17.3 Catalysing innovation and system change

Sustainability transitions are long-term processes, often extending over 25-50 years or more (Grin et al., 2010) and involving the emergence and upscaling of multiple innovations over shorter time scales. No single innovation

TABLE 17.1 Examples of sustainability innovations in the mobility, food and energy domains

	Mobility	Food	Energy
Incremental technical innovation	Fuel-efficient petrol or diesel cars	Precision farming, food waste valorisation, integrated pest management	Insulation, energy-efficient appliances, efficient gas or coal-fired power plants
Radical technical innovation	Battery electric vehicles, electric bikes, alternative fuels, autonomous vehicles	Permaculture, no-tillage farming, plant-based meat and dairy products, genetic modification	Renewable electricity, heat pumps, passive houses, whole-house retrofitting, smart meters
Social or behavioural innovation	Car sharing, modal shift, teleconferencing, teleworking, internet retail	Alternative food networks, organic food, dietary change, urban farming, food councils	Decentralised energy production ('prosumers'), community energy, energy cafes
Business model innovation	Mobility services, car sharing, remanufacturing vehicles, bike sharing	Alternative food networks, organic food	Energy service companies, back-up capacity, vehicle-to-grid electricity provision
Infrastructural innovation	Intermodal transport systems, compact cities, integrated transport and land use planning	Reforms to distribution systems, storage provision and better food waste management	District heating systems, smart grids, bio-methane in reconfigured gas grid

will hold the key to systemic change. Equally, the diversity of local contexts and challenges means that there are no single solutions applicable everywhere.

The electric motor, for example, will surely have a role in transforming the European mobility system, but it would still imply substantial resource demands, pollution and congestion (Section 16.4). The fundamental issue is not how to create a more sustainable car but rather how to meet society's need for point-to-point mobility and, perhaps more fundamentally, for social interaction and access to goods and services. As such, the transition to sustainable mobility will require numerous changes, ranging from car-sharing schemes, driverless cars and a shift to alternative modes of transport (e.g. walking, cycling) to improved spatial planning and novel communication technologies that can reduce the need for mobility. Such innovations will bring changes in social norms, values and lifestyles.

While transitions involve changes across society, governments have a key role in stimulating and orienting the direction of change and in reducing the many barriers to transitions. This section explores how public policies and institutions can provide support at each of the three phases identified in Figure 17.1 — emergence of innovations, their diffusion and subsequent reconfiguration of established systems.

17.3.1 Promoting sustainability innovation and experimentation

Novel social practices, technologies and business models are the core innovations that can drive systemic change. A diversity of ideas and approaches is important, because the viability and sustainability impacts of individual innovations are very hard to anticipate in advance and will often vary in different contexts. In the energy, food and mobility domains, multiple innovations are emerging that deviate in one or more dimensions from current modes of consuming and producing (Table 17.1). Sometimes these involve reviving or adapting older practices, for example initiatives that facilitate the reuse or repair of products. In addition, different forms of innovation often interact. Car sharing and bike sharing are not just about behavioural change, but they also represent new business models and new technologies (e.g. electronic booking systems, GPS — or global positioning systems, smart cars).

TABLE 17.2 Changing innovation policy framings

Overarching framing	Key features	Era	Policy rationale	Policy approaches (examples)
Innovation for growth	Science and technology for growth, promoting production and consumption	Since the 1950s	Responding to market failure: public good character of innovation necessitates state action	State financing of basic R&D, incentives for business R&D (e.g. tax breaks, subsidies)
National system of innovation	Importance of knowledge systems in development and uptake of innovations	Since the 1980s	Responding to system failure: maintaining competitiveness, coordinating system stakeholders	Promoting science hubs; incentivising coordination; SMEs; education and training
Transformative change	Alignment of social and environmental challenges with innovation objectives	Since the 2010s	Promoting transformation: pathways, coordination domains, experimentation, learning	Social challenges (H2020), SDGs, mission-oriented approaches to innovation (FP9)

Note: FP9, Framework Programme 9; H2020, Horizon 2020; SMEs, small and medium-sized enterprises.

Source: Based on Schot and Steinmueller (2018).

The character, rationale and extent of government interventions to support innovation has developed over time (Table 17.2). From the mid-20th century, policy interventions focused on addressing market failures, using state investments in R&D to compensate for inadequate private investment. Since the 1980s, governments have extended this focus to include promoting learning and knowledge circulation within innovation systems, comprising diverse actors including universities, businesses and government agencies. Both of these framings for innovation policy remain valid and important today. Europe could certainly do more to increase investments in basic research (Section 17.4.2) and to use education, science, business and tax policies to create an environment that enables and promotes innovation across society. But recent transitions research also points to the emergence of a third generation of innovation policy that focuses on enabling and promoting transformation towards long-term sustainability objectives, as exemplified by the SDGs (Schot and Steinmueller, 2018).

This emphasis on the directionality of innovation reflects a growing awareness that economic development approaches that promote all innovation and then seek to tackle harmful consequences through regulation and economic instruments are unsustainable. In practice, it implies the need not only to stimulate particular types of innovation (e.g. green technologies) but also for greater emphasis on real-world experimentation and learning, using pilots, demonstration projects and urban labs. These provide a means of exploring sustainability outcomes, identifying barriers, facilitating social acceptance and building coalitions of actors. Accepting and learning from failures is essential (Temmes et al., 2014).

Making innovations work in the real world requires inputs from diverse actors.

Making innovations work in the real world often requires input from a diverse range of actors with different kinds of resources, including researchers, businesses, investors, regulators and users. This point is integral to the EU's concept of Responsible Research and Innovation (EC, 2014b). Its importance is also expressed clearly in the EU's 'Lamy report' on maximising the impact of EU research and innovation programmes (EC, 2017d):

Fully mobilising and involving stakeholders, end-users and citizens in the post-2020 EU R&I programme, for instance in defining its missions, will not only increase the degree of co-creation, it will also maximise its impact and stimulate a stronger demand *for innovative products and services as well as a better grasp of social changes. This will bring open science and open innovation to the next level and turn Europe into a continental living innovation lab.*

In recent years, European innovation policy has broadened its focus to RD&D (research, development and demonstration). It could continue further towards promoting real-world demonstrations and experiments, for example by providing additional financial support for social and grassroots innovations. In the EU context, the establishment of an Innovation Fund, to distribute financial resources collected under the EU Emissions Trading System, is a useful step. The new fund will support, on a competitive basis, the demonstration of innovative technologies and breakthrough innovations in areas such as renewables, carbon capture and utilisation (CCU) and energy storage (EC, 2018j).

Public authorities can also assist local projects by facilitating networking and knowledge exchange through workshops, innovation or implementation agencies, or by establishing (digital) platforms. Another option is to provide exemptions from regulations that hinder particular innovations or entrepreneurship. For example, emulating a government programme in the Netherlands, the EU's circular economy action plan applied the concept of 'innovation deals', which identify and address potential regulatory obstacles for innovators (EC, 2018h). Such measures would align with the EU's ambition to 'stimulate a culture of experimentation and risk taking' (EC, 2018d), while respecting environmental standards and the precautionary principle.

Engaging and mobilising society

Citizens, communities and civil society groups represent important sources of creativity and innovation. Indeed, as Stirling (2015) notes, 'It is remarkable how many current major global industries are building around once-marginal technologies like wind turbines, ecological farming, super energy-efficient buildings, or green chemistry. All of these owe key elements in their pioneering origins to early development by grassroots social movements.' As such, transitions policy should build on the groundswell of bottom-up sustainability initiatives and further mobilise the 'energetic society' of engaged citizens, professional non-governmental organisations (NGOs) and motivated communities (Hajer, 2011).

Social innovations and grassroots innovations tend to be more radical than business-driven greening efforts, for example in questioning conventional consumerism and advocating change in user practices and lifestyles. They are often more oriented towards social justice or alternative economic rationales (e.g. community ownership, self-sufficiency). They are also highly contextual and often developed in response to real local problems (Seyfang and Smith, 2007).

In recent years, many European countries have experienced a surge of bottom-up social and grassroots innovations. Several of the promising innovations highlighted in Table 17.1 started as grassroots initiatives. For example, alternative food networks (AFNs) are food provisioning practices based on shorter supply chains and direct producer-consumer interactions (e.g. farmers markets, direct farm sale, weekly box schemes). In addition to reducing transport-related pollution, AFNs entail more direct interactions with food producers, potentially fostering a better understanding of environmental and social impacts of food choices and influencing consumer expectations and food system norms (Forssell, 2017).

> Social innovations and grassroots innovations are often more radical than business-driven 'greening' efforts.

There are now thousands of community energy initiatives across Europe (Hossain, 2018), some benefiting directly from EU support. Such initiatives are decentralised, small-scale forms of energy production (often solar photovoltaic (PV) or wind turbines) that are locally owned and operated, often engaging civil society groups, such as social enterprises, schools, businesses, faith groups, local government or utility companies (Seyfang et al., 2014). In Germany, more than 700 community energy initiatives (mostly citizens in cooperatives) account for about 40 % of renewable energy capacity (DECC, 2014; de Vries et al., 2016).

Similarly, there are several hundred 'transition town' initiatives in Europe. Transition towns are community projects that aim to increase self-sufficiency to reduce the potential effects of climate change and economic instability. They do this by stimulating renewable energy production, lifestyle change, community housing, alternative local currencies, repair cafes and community cafes using food that would otherwise go to waste. There are many similar networking initiatives at international and national levels, for example Global Action Plan and Switzerland's 'Les artisans de la transition' (ADLT, 2019; GAP, 2019).

National and European monitoring of social and grassroots innovations is difficult and underdeveloped, but the total number of initiatives across

BOX 17.1
Climathon: transformative approaches to flood risk adaptation

To support transformative adaptation, the city of Vejle, Denmark, co-organised with Climate-KIC a 24-hour Climathon event, to develop innovative ways to adapt to river and coastal flooding in Vejle. The event was open to those with a desire to create new solutions, including engineers, designers, business people, software developers, social scientists and legal or financial experts. The attendees pitched their solution to a panel of experts, including city representatives. The winning idea addressed surface flooding by replacing a standard pavement with a partly glass-covered underground concrete stream: a 'transparent urban waterway'. The winning team established the company Climate Change Consulting DK, meaning that the event produced both innovative solutions and entrepreneurial activity. ■

Source: ETC/CCA et al. (2018).

In addition to generating financial returns, nature-based solutions can deliver substantial non-market benefits.

Europe is likely to number in the tens of thousands. Cumulatively they represent a substantial amount of societal energy that policymakers could engage with more strategically (e.g. Box 17.1). Although social and grassroots innovations sometimes receive some short-term seed money, they are rarely the focus of dedicated policy attention and sustained support.

Governments could offer more support for civil society innovations, for example by funding citizens' groups and projects; providing privileged access to public infrastructure (e.g. vacant land or offices); facilitating the circulation of knowledge about grassroots projects; stimulating experimental partnerships with public services (e.g. schools, hospitals); and more publicly displaying support for citizen-led sustainability projects and their positive contribution to public life locally. This may require some institutional change to overcome the potential mismatch between informal grassroots innovations and formal procedures for policy support (e.g. proposal writing, organisational structures, accountability, budgetary reporting). Intermediary organisations that connect and support multiple initiatives (Section 17.3.2) also play a valuable role in this area.

Nature-based solutions

The EU's Seventh Environment Action Programme, the biodiversity strategy to 2020 and the EU's Horizon 2020 research and innovation programme each promote the use of 'green infrastructure' and 'nature-based solutions' as responses to sustainability problems and as an alternative to 'grey infrastructure' (i.e. human-engineered solutions, often employing concrete and steel). Green infrastructure and nature-based solutions make use of the capacity of ecosystems to deliver highly valuable regulating services — such as capturing carbon, regulating water flows or moderating extreme events — while also providing cultural benefits (Raymond et al., 2017).

Compared with grey infrastructure, nature-based solutions can perform well in financial terms, as well as providing substantial non-market co-benefits (Box 17.2). For example, restoring or creating wetlands on the banks of rivers upstream can function as watersheds that can concurrently mitigate flooding downstream, filter contaminated water, increase biodiversity and enhance recreation opportunities. Landscape conservation and restoration measures can function as natural water filtration plants, replacing conventional water treatment technologies. Forests can reduce or even prevent pollutants from entering streams that supply fresh water to downstream urban areas. Man-made features such as green walls, green roofs and sustainable urban drainage systems can mitigate the impacts of storm water by slowing the rate of run-off through retention, as well as decreasing urban heat effects, improving insulation and providing habitat for a variety of species.

Green infrastructure can be implemented either standalone or in integrated solutions that combine both green and grey infrastructure. Integrating green infrastructure into spatial planning can capitalise on the strengths of both grey and green infrastructure to foster resilient results (Browder et al., 2019). Green infrastructure can also be applied on different scales — from green walls and roofs on buildings, to green belts through industrial complexes, to large-scale watershed restoration and reforestation, in urban, peri-urban, rural and marine areas. The co-benefits are diverse. For example, evidence from 18 'urban labs' across Europe shows that high-quality, biodiversity-rich areas of urban green infrastructure can help address air pollution, noise, climate change impacts, heat waves, floods and public health problems (Maes et al., 2017). Investments can also provide more direct economic benefits, such as increasing property values. In designing initiatives and policy interventions, it is important to ensure that such benefits are distributed fairly, including across localities, regions and income groups.

The relative novelty of nature-based solutions can mean that they are sometimes expensive in financial terms when compared with grey infrastructure alternatives, which have benefited from decades of investments and efficiency improvements. As with other innovations, however, wider use of nature-based solutions is likely to produce economies of scale and learning, leading to cost reductions. For example, the cost of green roofs has fallen substantially in several countries during recent years (Nurmi et al., 2013).

17.3.2 Supporting diffusion of promising innovations

For many innovations, moving beyond experimentation towards wider adoption occurs via market diffusion, as learning and expanding production enable a new product or business model to become more competitive. In other cases, such as local initiatives and social innovations, the diffusion process may occur through replication or adaptation of an idea in a new location. In either case, innovations often face major barriers to upscaling, ranging from upfront costs of switching to a new technology and consumer uncertainties to the absence of necessary infrastructure or mechanisms for sharing knowledge. Perhaps most fundamentally, incumbents often enjoy a competitive advantage because the social and environmental costs of production are not fully represented in market prices.

'Levelling the playing field' by fixing market failures

Governments have a variety of tools available to help innovations to become mainstream. Economists often favour the use of economy-wide instruments, such as environmental taxes or cap-and-trade policies, which internalise the social and environmental costs of production in market prices. Models suggest that 'technology-neutral' instruments of this sort are cost-effective because they enable market forces to direct investments towards the most efficient technologies, and avoid errors when public authorities seek to pick winners.

In addition to shaping the selection environment for new technologies and supporting their diffusion, broadly focused instruments such as taxes and regulations can also stimulate innovation. Although it runs counter to common perceptions, there is much evidence to support the 'Porter hypothesis' that strict environmental policy can stimulate innovation and job creation, rather than hindering them (Rayment et al., 2009; OECD, 2010; EEA, 2014, 2016c). The European countries with the most stringent environmental policies are generally characterised by high levels of eco-innovation and economic competitiveness (Figure 17.3; EEA, 2016b).

Economic instruments also have some important limitations. First, efforts to tax activities in one location may not have the desired effect if they cause production to shift to other countries or incentivise businesses to use substitute resources (ETC/SCP et al., 2015). Second, introducing general economic instruments (e.g. a carbon tax) faces major political obstacles because the benefits are diffuse, hard to measure, and lie in the future, whereas the costs are concentrated and immediate (Hughes and Urpelainen, 2015). Powerful industries (oil, cars, utilities, retail) tend to resist their introduction and consumers may also raise opposition, particularly because the costs of environmental taxes may fall disproportionately on lower income

BOX 17.2
Non-market benefits of Lisbon's street trees

A cost-benefit analysis of street trees in Lisbon (Soares et al., 2011) showed that for every EUR 1 invested annually by the municipality in tree management, residents receive benefits valued at EUR 3.11. Each of Lisbon's trees is estimated to provide annual benefits of EUR 4.27 in energy savings, EUR 0.23 in reduced CO_2 emissions, EUR 3.75 in reduced air pollutant deposition, EUR 33.18 in reduced storm water run-off and as much as EUR 100.40 in increased real estate values. In total, Lisbon's 41 247 street trees are calculated to provide services valued at EUR 5.8 million annually, while EUR 1.3 million is spent maintaining them.

Further city case studies can be found at the Oppla platform: https://oppla.eu/nbs/case-studies. ■

Environmental policy can often drive innovation and job creation, rather than hindering them.

FIGURE 17.3 Demanding environmental policy is associated with greater competitiveness and more eco-innovation

Notes: The figure includes all EEA member countries for which data are available on stringency of environmental policy. OECD, Organisation for Economic Co-operation and Development.

Source: EEA (2016b).

Environmental tax reforms need to ensure a socially fair distribution of costs and benefits.

groups (Chapter 16). This often leads to defeat or watering down of the instrument. It is notable, for example, that, despite years of advocacy for a shift towards increasing taxation of environmental harms, as well as their administrative cost-effectiveness, environmental tax revenues in the 28 EU Member States (EU-28) decreased from 2.6 % to 2.4 % of gross domestic product (GDP) between 1995 and 2017. Nevertheless, revenues from environmental taxes amounted to some EUR 370 billion in 2017 — funds that could be more clearly directed in support of sustainability transitions.

These challenges also point to the benefits of coordinating environmental taxation across countries to limit burden shifting. They also highlight the need to design and communicate environmental taxes as part of broader packages of environmental fiscal reform that ensure a socially fair distribution of costs and benefits. This can include offsetting new taxes with reduced taxation of other activities (e.g. labour or sustainable consumption), as well as direct support for the groups or regions affected.

A third concern with general economic instruments is that empirical studies suggest that purportedly neutral policy tools inevitably involve an element of selection, as they steer resources to technologies that are currently cheapest but not necessarily those that are most promising or potentially disruptive. For this reason, technology-specific instruments may also be needed to drive the development and deployment of radically new technologies (Bergek and Berggren, 2014).

Promoting specific innovations

Diffusion of innovations often requires targeted measures that reduce the costs and uncertainties of switching to new technologies and practices. For example, financial instruments such as purchase subsidies, low-interest loans or feed-in-tariffs can help offset price differentials with established products. Non-financial incentives (including removing legal barriers, e.g. for food donations) can further increase the appeal of initiatives. Public procurement can create a market for sustainable goods and services (e.g. Copenhagen's public sector canteens and food services served 88 % organic food in 2015 (KK, 2016)). Investments in necessary infrastructure are often essential for diffusion of technologies (e.g. distributed energy production). And safety regulations and standardisation can generate trust and confidence in novel technologies.

Standards can also influence the diffusion of innovations, including beyond Europe's borders. Standards, certification schemes and labels often emerge through an interaction of different stakeholders, with civil society organisations proposing new benchmarks, and companies promoting their harmonisation and enforcement in different regions as a means of reducing production costs or achieving a level playing field with competitors.

Diffusion also involves changing user practices, norms and business processes. In part, this is about developing positive narratives. Uptake of renewable technologies in Germany, for example, was initially underpinned by positive stories about renewable energy and green growth and jobs related to German manufacturers of wind turbines and solar panels (Geels et al., 2016). This narrative was promoted by a green advocacy coalition, which included not just environmental groups, solar PV and wind associations but also metal and machine workers, farmer groups and church groups. Governments and other actors can shape narratives by disseminating information (e.g. via labelling or media campaigns) and framing it in ways that positively affect attitudes, beliefs and norms (e.g. social marketing or 'nudging'). Insights from behavioural sciences are increasingly applied to policy initiatives across Europe (EC, 2016a).

In view of the recent proliferation of initiatives and labels related to environmental and sustainability information, it is essential to develop standards to increase consumer trust. In 2013, the European Commission published a recommendation on the use of the product and organisation environmental footprint (PEF and OEF) methods (EC, 2013a). This was followed by collaboration with industry to develop and apply methods and develop approaches to verification and communication aimed at building a single market for green products.

Integration of innovations into the business environment often represents a challenge, as incumbent businesses are often geared towards established technologies and practices — in terms of investments, skills, knowledge, organisational structures and revenue flows. In some instances, the emergence of innovations may lead to the collapse of incumbents; in others, established firms may hinder the diffusion of an innovation or shift their business model towards embracing it. Policies influence this process of integration in the business environment both by stimulating consumer demand and by facilitating or mandating changes in production. Box 17.3 illustrates the broad range of measures that are contributing to diffusion of electric vehicles.

Upscaling local projects and grassroots innovations

The upscaling of sustainability innovations also depends critically on sharing knowledge and insights gained from experimentation and demonstration projects. In practice, lessons and insights are seldom shared widely, which often leads local innovators to 'reinvent the wheel'. The impact of Europe's many bottom-up initiatives will be less as long as they remain fragmented and short lived (Turnheim et al., 2018).

Knowledge sharing is particularly important for grassroots initiatives and social innovations, which rely less on market forces to drive diffusion. In these cases, scaling can take the form of 'scaling out' — replicating a social innovation in a different location; 'scaling up' — influencing laws and policies at higher levels; or 'scaling deep' — developing narratives that resonate with cultural values (Moore et al., 2015). All types of scaling rely on knowledge transmission.

Governments can stimulate the circulation of knowledge and lessons learned between social innovation projects and pilots, for example by standardising information and

Knowledge sharing is particularly important to enable the diffusion of grassroots initiatives and social innovations.

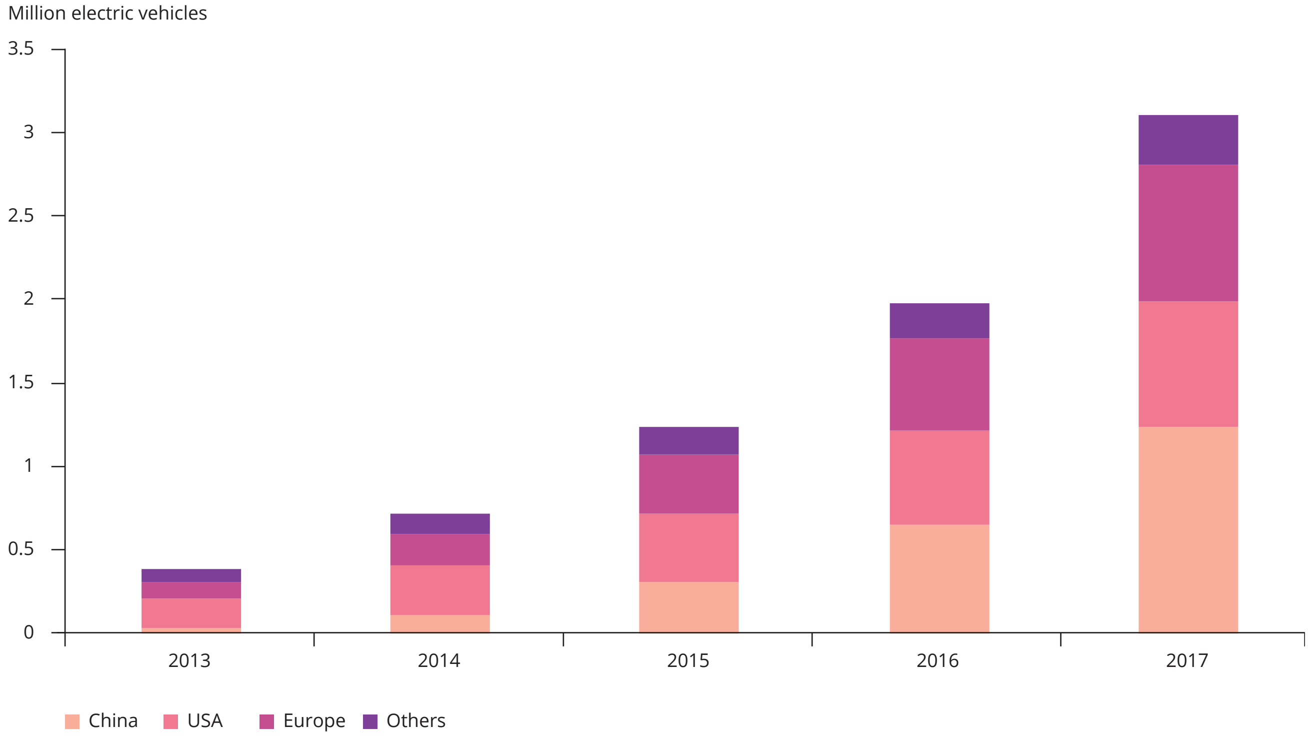
BOX 17.3 Electric vehicle diffusion

Electric vehicles have started diffusing, and the total global stock passed 3 million in 2017 (Figure 17.4). Annual sales in 2017 were 54 % higher than in 2016, surpassing 1 million units, with more than half of those global sales in China (IEA, 2018b). Only a few countries have fairly high market shares: Norway (39.2 %), Iceland (12 %) and Sweden (6.3 %). The remainder have shares under 3 %. In 2017, members of the International Energy Agency's Electric Vehicles Initiative (EVI) set the aspirational goal of achieving a 30 % market share for electric vehicles in each country by 2030. The EVI members comprise Canada, China, Finland, France, Germany, India, Japan, Mexico, the Netherlands, Norway, Sweden, the United Kingdom and the United States.

In all of the countries that are pioneering the diffusion of electric vehicles, public policies at national and local levels are playing a major role. The most prominent are direct consumer incentives such as vehicle purchase subsidies or tax exemptions. There is a clear correlation between the strength of financial incentives and the speed of diffusion (Wesseling, 2016). Even with grants, however, the up-front costs of electric vehicles remain higher than those of other cars. Early adopters are often middle-aged, well-educated, affluent, urban men, who are motivated by pro-environmental attitudes, a desire to save on fuel costs and an active interest in new technology (Nilsson and Nykvist, 2016). These factors point to the importance of complementary measures that can shift public perceptions and drive changes in business practice, as well as the value of policy support for electrifying public transport.

Measures used across Europe include financial support to the electric vehicle industry; public investments in charging infrastructure or subsidies for home chargers; public procurement of electric vehicles (e.g. for municipal vehicle fleets); state aid for electric public transport; indirect consumer incentives such as preferential access to bus lanes, free or preferential parking, access to low-emission zones, free charging at public stations and road toll exemptions; consumer outreach and education policies; and regulatory incentives such as sales targets for electric vehicle manufacturers or bans on sales of internal combustion engine vehicles (EEA, 2016a; CCC, 2018; EC, 2018i). ■

FIGURE 17.4 Cumulative global fleet of electric vehicles



Source: IEA (2018a).

BOX 17.4 Austrian biomass district heating systems

Biomass district heating (BMDH) systems (which use pellets and waste wood from Austria's forests) emerged in the late 1970s in rural villages. They were pioneered by new entrants to the market, such as sawmill owners, carpenters and monasteries, who sold heating services to nearby houses. From the mid-1980s, these small- to medium-scale village heat-only systems started to diffuse more widely. At this time, farmers, who in Austria often own forests, started building more local BMDH plants to develop the market for wood products.

Recognising opportunities for rural revitalisation, public authorities began to provide support. Dedicated intermediary organisations, such as the Austrian Biomass Association, were created to compare experiences, formulate lessons and share insights. Pioneering provinces launched energy agencies that provided training, technical advice and financial support for BMDH developers. These activities substantially improved technical and economic performance in the 1980s and early 1990s. Collectively, these changes resulted in a 10-fold increase in the total number of BMDH systems in Austria between the mid-1980s and the end of the 1990s.

At the national level, the federal Environmental Promotion Fund streamlined the complex policy environment by harmonising the eligibility, application and payment procedures for capital grants for BMDH systems in 1995. In 2000, technical performance guidelines were introduced and disseminated through seminars and training courses. Stable rules enabled more reliable calculation of cost-benefits, which in the early 2000s stimulated the involvement of energy utilities and the National Forestry Agency, which constructed large-scale BMDH systems to co-generate heat and power. This produced exponential growth in the period 2000-2010. By 2010, Austria had approximately 3 100 BMDH systems, of which about 2 500 were village heating systems. ■

Source: Based on Geels and Johnson (2018).

organising workshops. Implementation agencies (e.g. energy agencies or innovation agencies) can play a valuable role as intermediaries, because they engage with multiple projects, enabling them to compare them and extract and codify general lessons, so that these can provide insights for new projects or policymaking (Geels and Deuten, 2006; Kivimaa, 2014). Box 17.4 illustrates the role of intermediaries in knowledge circulation and aggregation in the diffusion of biomass district heating systems in Austria.

Social and grassroots initiatives are often diverse in character and context specific, which can make it difficult to extract lessons and disseminate good practice. Nevertheless, intermediary organisations or social networks can play a useful role (EEA, 2018). The Transition Network, for instance, encompasses more than a thousand local transition initiatives in 43 countries and has developed a guide that articulates core values and operational principles for setting new initiatives (TN, 2018). Similarly, Community Power, a network established by Friends of the Earth Europe to support community energy, engages in knowledge sharing and political lobbying for legislative change (EEA, 2018).

Grassroots innovations can take several decades to reach scale (e.g. Box 17.5). They can be nurtured through dedicated efforts such as providing local finance (e.g. public banks), community building, political lobbying, professionalisation, engaging with incumbent actors and providing policy support. Mainstreaming may also involve a degree of co-option (e.g. by big businesses) and divergence from their initial grassroots visions and values (Berkhout, 2006; von Oelreich and Milestad, 2017).

> Public institutions and social networks have key roles in sharing knowledge and lessons learned.

17.3.3 Managing phase-out, disruption and structural change

Deliberate phase-out actions that target the decline of existing technologies and practices are necessary to accelerate sustainability transitions. Such actions are still quite rare, but they are gaining political salience and include bans

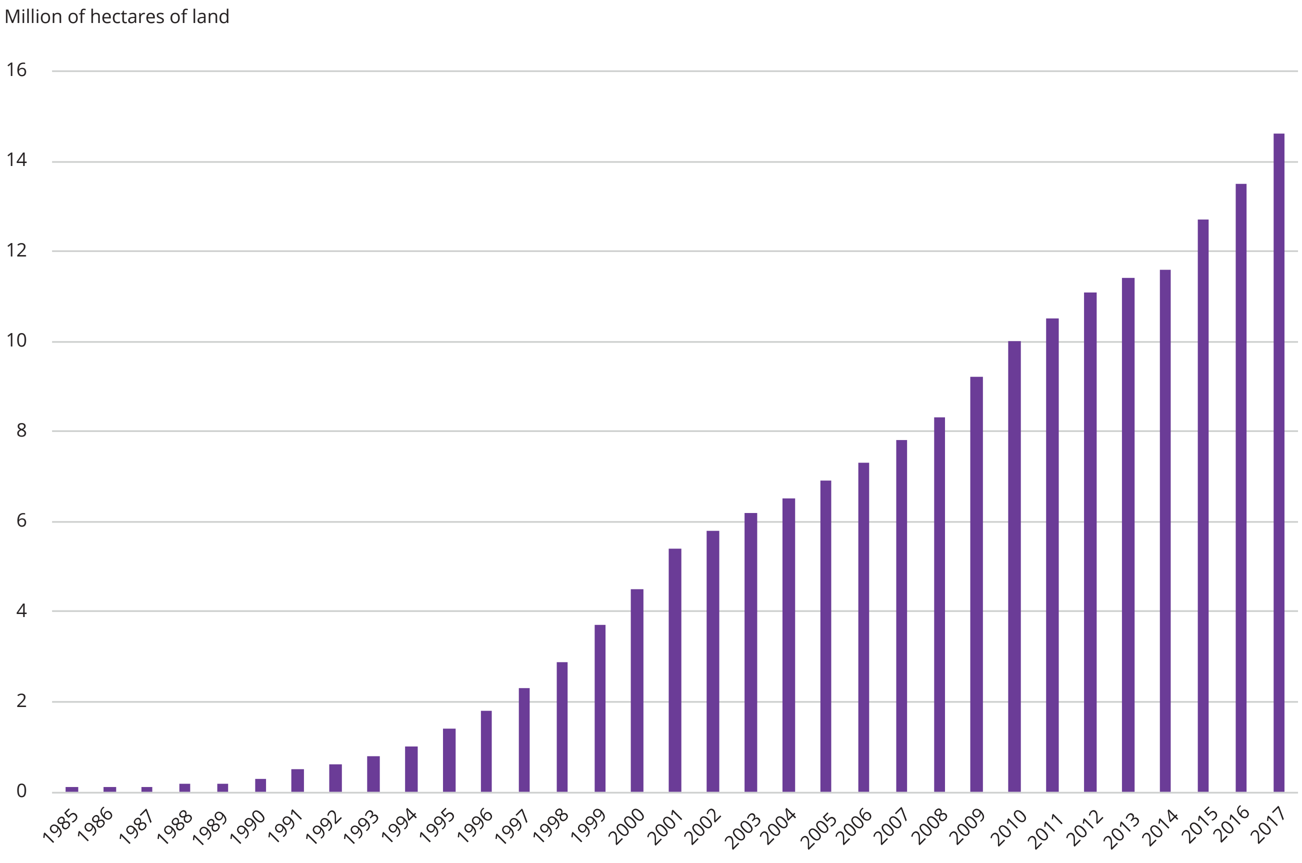
BOX 17.5 **Mainstreaming organic food**

Organic food was pioneered in the 1930s by activist farmers and scientists as a means of recycling nutrients and organic matter and improving human and animal health. Between 1970 and 1990, a more organised organic food movement emerged, advocating small-scale production and localism. Gradually, associations were created that developed organic standards to build consumer trust and engaged in political advocacy to gain policy support (Smith, 2006; von Oelreich and Milestad, 2017).

In the 1990s and early 2000s, market demand for organic food grew (Figure 17.5), partly in response to food scandals. Supermarkets became interested, encouraging farmers to convert to organic production, and policymakers introduced organic farming policies and supported research and technical training.

As big farming businesses entered the market, greater pressure to standardise production and provide predictable outputs drove small farmers out of business. Organic farming moved from niche to mainstream and, in the process, diverged from some of its initial grassroots values such as local production and broader sustainability values (Smith, 2006). Although organic food has become a profitable and fast-growing market, it remains more expensive than mainstream food, which means that wider diffusion beyond affluent consumers or those simply willing to pay extra may require continued policy support (Aschemann-Witzel and Zielke, 2017). ■

FIGURE 17.5 Organic agricultural land coverage in Europe, 1985-2015



Sources: FIBL and IFOAM (2016); FIBL (2019).

TABLE 17.3 Policy approaches for addressing the negative socio-economic consequences of transitions for workers, regions and firms

	Compensation (defensive, reactive)	Structural reorientation (active)
Workers	Compensation for losses, e.g. redundancy payments, early retirement benefits	Skill upgrading and retraining programmes, financial assistance to relocate, wage subsidies, assistance in finding new jobs
Regions, communities	Compensation for losses (e.g. increased transfer of resources to local policymakers or regions), relocating public agencies to particular regions	Regional assistance for economic diversification, e.g. direct investments in public goods (e.g. infrastructure), regional innovation policies, subsidies or tax incentives to new businesses in growth sectors, technical assistance
Firms	Compensation for lost asset values or 'grandfathering' of existing assets, state subsidy of company liabilities (e.g. pension or site remediation liabilities)	Grants or in-kind assistance to (1) upgrade existing technologies or practices, (2) stimulate reorientation towards new technologies and markets

Source: Adapted from Spencer et al. (2018).

or regulations, removal of implicit or explicit subsidies, and targeted financial incentives, which make a technology less attractive (Kivimaa and Kern, 2016). For example, the European Commission's 2009 phase-out of incandescent light-bulbs accelerated the transition towards compact fluorescent lights (CFLs) and light emitting diodes (LEDs). In 2015, Finland, the Netherlands and the United Kingdom decided to phase out coal use and in 2017 joined 16 other countries in creating the Powering Past Coal Alliance. Bans on sales of internal combustion engine vehicles have been announced for 2025 (Norway), for 2030 (Ireland, the Netherlands, Austria), and for 2040 (France, United Kingdom) (CCC, 2018). And the EU's Energy Union calls for the removal of all environmentally harmful subsidies (EC, 2015b).

Governments have an essential role in supporting the 'losers' from transition processes and addressing inequities. While the 'creative destruction' associated with structural economic change always creates hardship for those in declining sectors, the impacts can be particularly acute in regions where particular sectors dominate the local economy and are closely tied to the local culture and identity. The historical decline of the old industrial regions, dependent on coal, steel or bulk chemicals (e.g. Lorraine in France, Limburg in Belgium and the Midlands in the United Kingdom), disrupted entire communities, creating unemployment and other social problems (Baeten et al., 1999; Campbell and Coenen, 2017). Coal and lignite extraction and support services still account for more than 5 % of employment in the Polish part of Silesia (EC, 2018g). Rural economies may likewise be strongly intertwined with established systems of agricultural production (Chapter 13).

Such concerns are increasingly reflected in policymaking. For example, the Paris Agreement includes a call for a 'just transition of the workforce and the creation of decent work and quality jobs'. The renewed EU industrial policy strategy (EC, 2017c) likewise emphasises that 'The benefits of industrial transformation need to be widely spread and those who lose out must be able to find opportunities and support to adapt. Lifelong learning, equal opportunities and fair access to education, training and technological skills are at the heart of building such resilience.' The most recent update of the EU Emissions Trading System specifies that revenues from auctioning allowances and from a new Modernisation Fund should be used to support a just transition, for example through retraining and supporting new employment opportunities.

Governments can alleviate negative consequences through compensation measures or actions aimed at reorientation, innovation and developing skills, as outlined in Table 17.3. The relatively successful reorientation of the German Ruhr region in the 1980s and 1990s involved both kinds of policies (Box 17.6).

EU cohesion policy has already moved from a focus on social welfare (transferring funds to less developed regions) to more active, restructuring approaches. For example, the EU's flagship regional innovation approach 'smart specialisation' is increasingly supporting regions in industrial transition, which can face particular challenges in accessing regional support mechanisms (EC, 2017b).

BOX 17.6
Restructuring the German Ruhr coal region

Coal, steel and related industries in the Ruhr region, which employed more than half a million people, faced economic decline in the 1970s and 1980s because of cheaper imports. Initial efforts aimed to improve competitiveness (e.g. subsidies, mergers) but, when this proved insufficient, controlled mine and plant closures provided compensation payments, early retirement packages and wage subsidies. By the mid-1980s, the region was also engaged in a proactive industrial policy, aiming to stimulate 'sunrise technologies' such as environmental technologies (e.g. energy efficiency, renewable energy, recycling and waste combustion), which could build on the region's existing engineering capabilities. Regional diversification succeeded in making the Ruhr a key centre for environmental industry, technology and research. It also focused on its 'industrial culture', turning former mines and steel factories into tourist destinations.

In contrast to the traditional top-down industrial policy, the reorientation strategy was implemented in partnership with municipalities, universities and private actors. Although policymakers were important for providing strategic direction, quality control and funding, their role was also to facilitate 'dialogue and collaboration between stakeholders that led to the inception of 'regional development coalitions', i.e. bottom-up co-operation between different actors in a local or regional setting based on a socially broad mobilisation and participation' (Campbell and Coenen, 2017). ■

The European Commission has established a smart specialisation pilot to help regions in acute crisis or falling into decline to transform and diversify into new, sustainable economic sectors. It also supports coal regions in transition, and it has established thematic platforms on industrial modernisation, energy and agri-food, enabling policymakers, researchers, business and civil society to pool experience.

17.4 Key enablers of change: cities, finance and knowledge

Three cross-cutting themes stand out as having particular importance in enabling change:

- Cities are crucial for transitions. They are hubs of creativity, innovation and learning, with the capacity to effect systemic change at local scales and to share ideas through city networks. Urban areas also face particular vulnerabilities that necessitate transformative adaptation.

- Finance has a key role in either impeding or enabling sustainability transitions. Today it tends to do more of the former. As the United Nations Environment Programme (UNEP, 2018) notes, 'Clearly, some capital is flowing to the new economy that we need. But far more is continuing to support the old economy.'

- Knowledge is essential for understanding challenges and designing responses. The EU has developed an unrivalled knowledge system to support the design and implementation of established environmental policies, but the emergence of systemic and transformative policy frameworks creates the need for new knowledge and competencies.

17.4.1 Leveraging the potential of cities and city networks

Almost three quarters of the EU's population live in cities, meaning that much of the production-consumption dynamics in European society also resides there. The density of urban populations also creates opportunities for resource-efficient ways of living and means that sustainability initiatives can have considerable impact. The United Nations affirms the role of cities with its New Urban Agenda and through SDG 11 — 'Make cities inclusive, safe, resilient and sustainable'.

In Europe, the EU's 2016 Pact of Amsterdam (establishing the EU urban agenda) arguably marked the start of 'a new role-redefining phase for cities: one in which cities are no longer only the object of EU policymaking, but now also become part of policymaking itself. Since then, cities got a 'seat at the table' of EU governance.' (Potjer and Hajer, 2017).

Transformative adaptation is particularly urgent in cities. This is due to both their physical characteristics (e.g. the heightened impacts of heat waves and flooding) and their concentration of population and economic/cultural assets, which often intensifies economic losses and vulnerabilities, especially for those residents with low incomes or poor health. The dependence of cities on their hinterlands and wider areas for food, water, energy and other essential supplies means that they are vulnerable to climate-related impacts both within the city borders and beyond.

Supporting urban innovation

Cities also provide good settings for engaging citizens, businesses and local governments in innovating and co-creating knowledge and in enabling experimentation and learning. For example, local authorities can trial solutions on a relatively small scale before rolling them out more widely, or they can experiment with different options in various districts (Heiskanen and Matchoss, 2018). Cities can support social innovation and grassroots initiatives by providing institutional support and resources (e.g. facilitation, access to unused urban space). Stakeholder engagement is often easy to achieve because of the proximity of public authorities, businesses and users. For instance, deploying modern tramways in French cities involved stakeholder consultations and learning processes, leading to ways of handling grievances about disruptions during construction (e.g. through compensation, dialogue, re-routing) (Turnheim and Geels, 2019).

European and national authorities can reinforce urban experimentation by providing additional resources, increasing local powers, and developing criteria and standards for urban sustainability. Maximising the impact of individual initiatives requires sequences of urban projects to build on each other's experience. This can involve intra-city learning — sharing knowledge among initiatives within a city or region, for example through workshops or working groups. It can also take the form of inter-city learning, with flows of knowledge between cities mediated by national, regional or global networks (e.g. Box 17.7). For example, the C40 Climate Leadership Group is a network of global megacities that increasingly sees itself as a key global actor on climate change rather than just a collection of pilot projects. The International Council for Local Environmental Initiatives (ICLEI) increasingly engages with systemic local sustainability transformations (ICLEI, 2015). And the Global Covenant of Mayors for Energy and Climate Change facilitates monitoring and sharing of best practices among more than 7 000 cities worldwide (primarily European) that commit to reducing CO_2 emissions by at least 40 % by 2030 and increasing resilience to climate change.

Public policies are essential to offset inequities and facilitate structural change.

Transitions at city scale

Cities themselves also represent distinct systems that can be transformed. Urban authorities have strategic agency, dedicated budgets and responsibilities for providing local services such as water and sanitation, mobility, energy and waste disposal, particularly in countries benefitting from political decentralisation (e.g. Sweden) or federalism with municipal autonomy (e.g. Germany) (Ehnert et al., 2018). These characteristics create opportunities to stimulate transitions in close interaction with citizens and other actors.

Cities such as Birmingham, Castellón, Frankfurt, Valencia and Wrocław have begun to implement comprehensive urban transition programmes that promote 'stakeholder partnerships to maximise the learning and economies of scale that arise from a focused, concentrated approach' (Climate KIC, 2015). Some large cities are actively reconfiguring local transport systems (tram, bus, cycling, car sharing), district heating or housing, or developing experimental neighbourhoods and urban living labs. Pioneering cities are also setting new targets that sometimes exceed national targets. Table 17.4 shows European city targets for renewable energy. Similar urban targets have been set for heat supply (e.g. renewable heat, district heating or solar thermal heating) and transport (e.g. bans on petrol and diesel cars in Athens, Madrid or Paris) (IRENA, 2018).

75 %

of Europeans live in cities — meaning that much of the production-consumption dynamics in European society also reside there.

At the same time, other cities, towns and regions are trailing behind for a variety of reasons. Larger cities tend to benefit from scale and special institutional and regulatory powers compared with smaller cities. Some may be reluctant to promote transitions because of the economic importance of local (polluting) industries, while others may face challenges in accessing city networks (e.g. because of language barriers). Perhaps most fundamentally, urban authorities may lack the competency, resources or responsibility to pursue transformational approaches. European and national policymakers can help address these disparities by offering financial, technical and administrative support, for example through the EU's URBACT programme.

17.4.2
Financing innovation and investment

Ensuring that public and private investments support sustainability goals is arguably the single most important challenge. Barriers exist at each stage of innovation — from invention through to broad diffusion of technologies, practices and business models. In the earliest stages, the public good characteristics of basic research and uncertainty about

BOX 17.7 HINKU: towards carbon-neutral municipalities

In Finland, municipalities are collaborating to curb their greenhouse gas emissions beyond the requirements of EU targets and schedules. The project 'HINKU: towards carbon-neutral municipalities' brings together local authorities, businesses, experts and citizens to find cost-effective ways of reducing emissions, especially in the transport, housing and food sectors. By 2030, the participants hope to have reduced emissions by 80 % compared with 2007 levels.

HINKU started in 2008 as a network of five small municipalities with 36 000 inhabitants. By 2018, it had expanded to 42 municipalities totalling more than 750 000. The results are positive. HINKU municipalities have already reduced greenhouse gas emissions by 30 %, while creating jobs and improving energy self-sufficiency. Finland's climate and energy legislation, based on international and EU laws, has provided a key driver for the HINKU process. The programme also enjoys support from across the political spectrum and at different levels of government. At the national level, the Finnish Environment Institute (SYKE) coordinates and facilitates the HINKU process, for example by calculating annual greenhouse gas emission inventories for each HINKU municipality, supporting public relations and helping municipalities to access external research funding.

Communication and sharing information and ideas through a common platform are central to the HINKU process. A network for frontrunners — the HINKU forum — helps create innovative solutions and distribute data, experiences and good practices to other localities and stakeholders. Experimentation in municipalities is helping to identify ways of engaging residents and overcoming barriers to the uptake of new technologies. For example, joint procurement of solar panels enables municipalities and households to combine their purchasing power and secure lower costs. First carried out in 2014, joint procurement is now expanding in Finland. ■

Sources: FIBL and IFOAM (2016); FIBL (2019).

TABLE 17.4 Selected European city-wide renewable energy targets

Target	Year	City (country)
100 % renewable energy in total energy mix	2029	Sønderborg (DK)
	2030	Frederikshavn (DK), Malmö (SE), Växjö (SE)
	2040	The Hague (NL)
	2050	Copenhagen (DK), Frankfurt (DE), Hamburg (DE)
100 % renewable energy in electricity mix	2020	Skellefteå (SE)
	2025	Munich (DE)
	2030	Osnabrück (DE)
	2035	Groningen (NL)

Source: IRENA (2018).

returns can deter private firms from investing in R&D, implying an important role for public spending. As innovations move towards commercialisation they may struggle to cross the 'valley of death' — the funding gap that arises as public grants decline, the need for private finance increases, and commercial returns remain low. Finally, the sheer scale of financial resources needed to effect broad diffusion of innovations — in particular, the costs of necessary investments in infrastructure (e.g. housing retrofits, electricity grids, transport systems) — are especially daunting. At each stage, market failures (e.g. environmental externalities) and policy failures (e.g. erratic shifts in incentive structures) deter investment in sustainability innovations and perpetuate the flow of financial resources towards unsustainable modes of production and consumption.

Like other regions, Europe faces problems in each of these areas. In the research domain, in its Europe 2020 strategy (EC, 2010) the EU committed to raise R&D spending to 3 % of GDP by 2020. Despite improving from 1.76 % since 2008, total R&D investment stood well below the target at 2.03 % in 2016. This was substantially below investment in the United States (2.79 %), Japan (3.29 %) and South Korea (4.23 %). In 2015, China also surpassed the EU's investment in R&D (Eurostat, 2018).

R&D investments in sustainability-related domains have fluctuated. Energy R&D more than doubled between 2001 and 2010 (Figure 17.6), benefiting significantly from the stimulus package expenditure in 2009, which aimed to prevent economic collapse after the financial crisis (Grubb et al., 2014). Spending has also diversified significantly, shifting from a heavy (and arguably wasteful) focus on nuclear energy in the 1980s towards a much broader portfolio of low-carbon technologies. Overall, however, spending has not recovered to its peak in the 1980s, and since 2010 it has declined.

Achieving sustainability transitions will require much more ambitious public investment in innovation.

Similar trends are apparent in other important sustainability-related domains. Government spending on R&D in the agriculture, environment and transport areas has increased significantly since the early 2000s in EU countries, with transport in particular receiving a boost after the financial crisis. However, investment has declined in all three areas during recent years (Eurostat, 2019; OECD, 2019), potentially weakening European competitiveness and opportunities for a broad transition.

At the same time, there appears to be growing recognition of the need for much greater public investment in sustainability-oriented R&D. For example, the EU and 24 countries (including some EU Member States), which together account for 80 % of global investment in clean energy R&D, have pledged to double that spending to approximately USD 30 billion annually by 2021 as part of the Mission Innovation initiative. This increase is intended to accelerate significantly the availability of affordable clean energy (Mission Innovation, 2018). There is a strong case for extending this level of ambition beyond a narrow focus on clean energy technologies towards supporting diverse forms of innovation in other domains such as sustainable food and mobility and non-toxic chemicals.

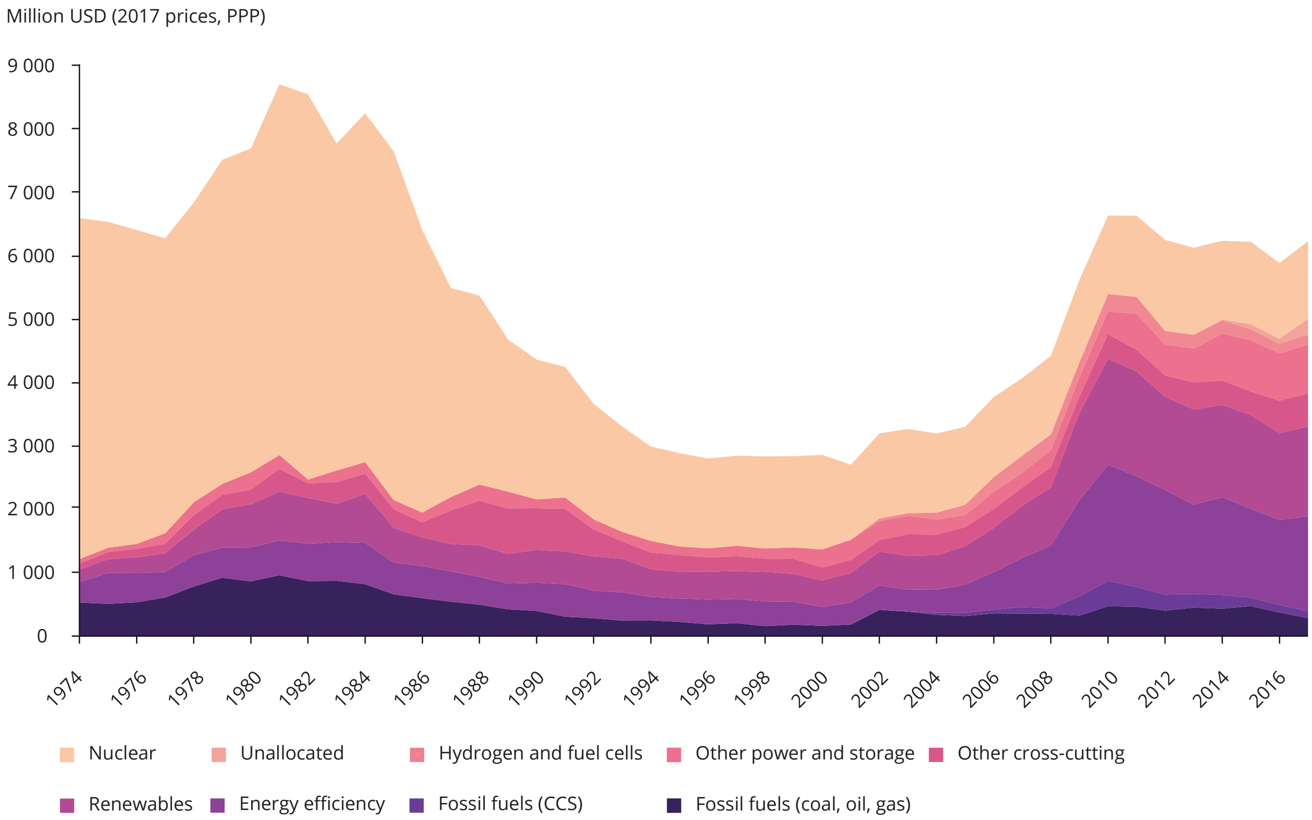
Beyond research, there are concerns about the availability of finance in Europe to support progress towards commercialisation and bridge the 'valley of death'. A variety of private sources of finance can support the commercialisation of innovations, including venture capital, business angels (wealthy entrepreneurs or philanthropists), crowdfunding and blockchain funding. Yet, it is doubtful that these sources alone will ensure the large-scale, long-term and targeted investments needed to address the urgent sustainability challenges facing Europe today (EEA, 2019). This implies a key role for governments in stimulating, orienting and complementing private investments (Saha and Muro, 2017; Sopher, 2017).

Such a role is not without controversy, as it runs counter to prevailing reasoning, which promotes markets as the primary engine of innovation and recommends that public policy focus on correcting market failures. Yet, ambitious public investments played foundational roles in many of the most transformative innovations during the 20th century (Auerswald and Branscomb, 2003; Mazzucato, 2015). Achieving sustainability transitions is likely to require even greater levels of ambition, engagement and risk-taking from the state, accompanied by a willingness to accept failures alongside successes (Mazzucato and Perez, 2015).

Financing diffusion and fixed capital formation

Broader diffusion of innovations and development of related infrastructure will require huge investments. For example, the United Nations Conference on Trade and Development (UNCTAD, 2014) estimates that achieving the SDGs will require global investments of USD 5-7 trillion annually. Simply meeting Europe's 2030 climate change targets will require additional funding

FIGURE 17.6 **Trends in energy R&D spending in Europe by technology (based on IEA estimates)**



Note: CCS, carbon capture and storage; PPP, purchasing power parity.

Source: IEA (2018c).

Diffusion of clean technologies and the transformation of whole production-consumption systems will require huge investments.

of EUR 180 billion annually (EC, 2018e). These vast sums appear broadly attainable when seen in the context of total investment (gross capital formation) in the global economy (USD 20.0 trillion in 2017) and in Europe (USD 3.5 trillion) (World Bank, 2018). But they will evidently entail a significant reorientation of public and private spending across society.

Financing socio-technical transitions will necessarily draw on a diverse array of interacting funding sources, including institutional investors. As noted in the European Commission's sustainable finance action plan, 'Banks, insurance companies and pension funds are the main source of external finance for the European economy and … could provide the critical mass of investments needed to close the gap for the transition to a more sustainable economy' (EC, 2018f). At present, however, financial resources primarily consolidate established modes of production and consumption. For example, pension funds and insurance companies allocate just 1-2 % of their assets to 'green sectors' compared with the 5-10 % distributed to 'brown' sectors, such as oil, gas and coal, and the 20-25 % put into other high-carbon sectors, such as metals, chemicals, transport and automobiles (Rademaekers et al., 2017).

Public authorities, households and end-users (e.g. vehicle owners) also have a central role in financing transitions, reflecting the investments needed in demand-side sectors, notably buildings and transport. Rademaekers et al. (2017) estimate, for example, that achieving the EU's 2030 climate and energy targets will require more than EUR 1 trillion of investments in transport and buildings in the period 2021-2030 compared with less than EUR 80 billion for power generation and the electricity grid.

Collectively, these different public and private actors arguably have the resources to finance transitions, yet a variety of barriers and market failures deter such investments. For example, many sustainability innovations have unattractive risk/return profiles. Concerns about stranded assets may encourage investors to lobby against policies promoting systemic change. Public investments are constrained by weak economic growth and a continued focus on fiscal consolidation. Many end-users are prevented from investing in cost-saving efficiency improvements by often daunting upfront costs.

Public policy tools can help create markets for sustainability innovations by clearly signalling the intended development pathways, thereby reducing risks and stimulating investment. For example, the EU is broadly on track to achieve its target of allocating 20 % of its budget to climate action under the Multiannual Financial Framework 2014-2020. The European Commission proposes to increase this to 25 % in the 2021-2027 time frame (EC, 2018c). Furthermore, public procurement of goods and services amounts to 16 % of GDP in the EU (EC, 2017e), implying that it can also provide a major stimulus for innovation and diffusion. Other tools include taxes and subsidies, feed-in tariffs, tradable permits and obligations to use energy from renewable sources. For such interventions to be effective, however, it is essential that the policy signals are robust and stable. Sudden shifts in policy represent an important source of risk that can significantly undermine investor confidence.

Combining investment sources through 'blended finance' mechanisms can also increase financial flows (OECD, 2018b). For example, investments by development banks or government agencies that cover the high-risk tranches of investments can stimulate private investment. This is the logic behind the EU's European Fund for Strategic Investments, which aims to catalyse investment of at least EUR 0.5 trillion, with 40 % targeting innovation and infrastructure projects that contribute to climate action.

Another important barrier to investment by banks and institutional investors is a reported shortage of high-quality and sizeable projects that promise stable investment returns (Rademaekers et al., 2017). Energy efficiency investments, for example, are often small and distributed across numerous households and businesses, implying high transaction costs. Responding to this challenge is likely to involve developing technical and knowledge capacity — for example at city level — to help ensure a steady flow of good-quality projects (OECD, 2018a). Another useful approach involves aggregating small projects into a larger pool to attract investment, for example by securitising green mortgages used to finance residential retrofits. As households will need to provide a substantial proportion of the investment to achieve Europe's climate targets, it will be particularly important to find ways to help them meet these costs (e.g. Box 17.8). Elaborating government guidelines on green securitisation could support the development of this market (Aldersgate Group, 2018).

Green bonds provide another mechanism to increase large-scale institutional investments. The green bond market has expanded very rapidly, rising from a global issuance of USD 3.4 billion in 2012 to USD 161 billion in 2017, in part because of the availability of secondary markets for investments. However, optimism about the rapid growth of green bonds needs to be tempered. First, increased transparency is needed to ensure that they are not used for 'greenwashing' (Aldersgate Group, 2018). Second, despite rapid growth, green bonds account for less than 1 % of the global bond market. The flow of investment into fossil fuel exploitation continues to dwarf global investments in renewables (OECD, 2018a).

Additional measures could seek to reformulate institutional rules and formal expectations of financial actors. For instance, pursuant to its action plan on financing sustainable growth, the European Commission plans to develop a unified classification system (to better define what counts as sustainable finance); develop standards and labels for sustainable financial products (including green bonds); better integrate sustainability in ratings and research by credit-rating agencies; change the fiduciary duties of institutional investors and asset managers, so that they more systematically consider sustainability factors and risks in investment processes; strengthen disclosure responsibilities and accounting rules, so that companies are required to inform investors about sustainability performance and risks; and assess the possible negative impact of the Basel III regulatory framework on European bank lending, investment and other activities, which are critical for sustainable finance.

By signalling intended development pathways, public policies can reduce risks and stimulate investment.

BOX 17.8 Energiesprong

Shifting to energy-efficient buildings is a huge challenge. The EU requires all new houses to be 'zero energy' by 2021, meaning that they produce as much energy as they use on heating, lighting, and so on. However, new houses represent only a tiny proportion of the continent's total housing stock. As about 40 % of Europe's CO_2 emissions come from heating and lighting in buildings, retrofitting existing buildings is crucial for climate change mitigation. Unfortunately, this requires a substantial investment from homeowners.

Launched in 2010, the Dutch initiative Energiesprong — later expanded to France, the United Kingdom, Germany and North America — tackles this financial obstacle with a clever shift in perspective. Dutch households spend about EUR 13 billion on energy each year. If, instead, they were to use the same money to repay a long-term loan, then it would effectively free up about EUR 225 million today to invest in the housing stock, which is equivalent to between EUR 30 000 and EUR 40 000 per household.

Energiesprong succeeds by coordinating relevant sectors and identifying 'win-win' solutions. Banks were persuaded to finance energy refurbishments because Energiesprong secured a 30-year energy performance warranty on refurbished homes and brokered a deal to refurbish 111 000 housing association properties. The building sector and the economy as a whole also stand to gain from these big investments, and households benefit from better insulated homes, higher property values and more spending power once loans are repaid.

Experimentation and learning have played an important role in upscaling the programme. A focus on reducing costs in the initial phase resulted in a 30 % improvement in the price-performance ratio, greatly improving the initiative's financial viability. Reducing the renovation time to 1 week per dwelling likewise made the process more appealing to homeowners. As the programme extends into other countries, economies of scale and continued innovation should drive further improvements in performance.■

Sources: FIBL and IFOAM (2016); FIBL (2019).

Investing in natural capital

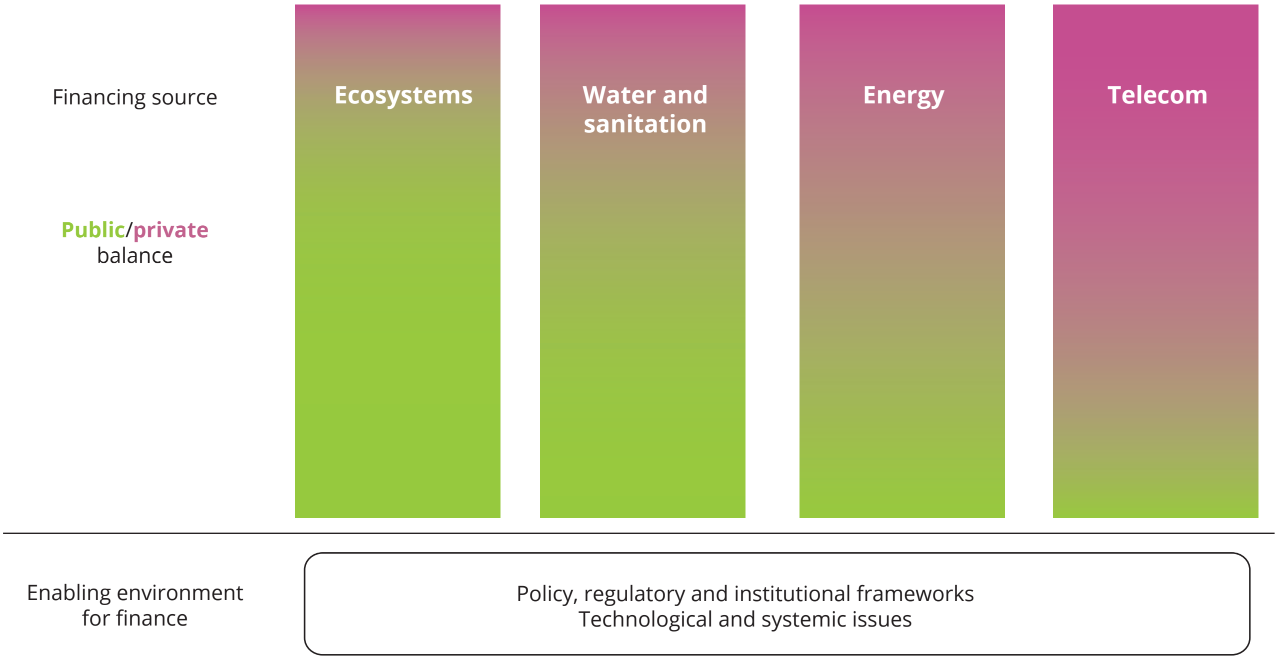
Investments in green infrastructure and nature-based solutions enhance ecological resilience and society's capacity to transform and adapt, often delivering benefits that far exceed their costs. In its landmark study on land degradation, the Intergovernmental Science-Policy Platform on Biodiversity and Ecosystem Services (IPBES, 2018) found that timely action to avoid, reduce and reverse land degradation is essential for achieving the majority of the SDGs and would deliver co-benefits for nearly all of them. In addition to enhancing biodiversity and ecosystem services, the benefits of restoration include increased employment, increased business spending, improved gender equity, increased local investment in education and improved livelihoods. Moreover, the value of these benefits is, on average, 10 times the cost.

Nevertheless such investments often face major barriers. These include a lack of awareness about potential benefits, limited design and implementation capacities, and strong vested interests in developing grey infrastructure. Whereas grey infrastructure investments often deliver immediate returns, benefits from green solutions can take 10-15 years to realise. Perhaps most importantly, the benefits of investments in nature often have public good characteristics, meaning that they accrue to society generally rather than to private actors.

As private actors often have weak incentives to invest, there is often a significant role for the public sector (UN, 2018; Figure 17.7), either as the sole source of finance or in motivating private spending (e.g. through co-financing or planning requirements). The European Investment Bank's Natural Capital Financing Facility exemplifies this approach, providing funding to projects that promote conservation, restoration, management and enhancement of natural capital, including ecosystem-based solutions (EIB, 2019).

Bottom-up innovations in finance provide another potential source of funding for green infrastructure and nature-based solutions (Toxopeus

FIGURE 17.7 The continuum of public and private finance in achieving the SDGs

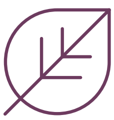


Source: UN (2018).

and Polzin, 2017). For example, crowdfunding provides a mechanism for spreading the costs of investments across a large group of people, which corresponds well with the dispersed benefits arising from environmental public goods (see also Box 17.9).

17.4.3 Knowledge and skills to support transformative policy

The knowledge systems that developed to support environmental governance during the 20th century were well adapted to the challenges and thinking of that time. Confidence in the capacities of governments to plan and steer societal development using regulations and economic instruments underpinned the widespread use of rational analytical approaches, such as modelling, grounded in assumptions of mainstream economics about how people respond to incentives, individually and collectively. These analytical approaches remain essential, but it is increasingly clear that they are not sufficient.



Investing in natural capital often delivers benefits that far exceed costs.

Integrated assessment modelling, for example, provides many valuable insights — helping to set agendas and long-term targets; identify lowest cost pathways and optimal configurations of technologies; communicate urgency and costs of delay; and map out trade-offs and distributional impacts associated with systemic change (van Vuuren and Hof, 2018). Like all analytical perspectives, however, it has important limitations and blind spots, which can lead to it providing misleading guidance if used in isolation. In particular, it neglects many of the fundamental characteristics of transitions, such as the role of shocks, non-linearities, resistance, radical

BOX 17.9
Crowdfunding bottom-up initiatives in Ghent

To moderate climate change impacts, Ghent is seeking to create more green areas in the city. In keeping with the city's reputation for being social and creative, local authorities are seeking to actively engage citizens in developing bottom-up initiatives. Since many of these small-scale projects face difficulties securing finance, Ghent has developed a crowdfunding platform that allows citizens to propose and finance their ideas for the city. Two projects addressing climate adaptation have been successfully realised with the support of the crowdfunding. gent platform. Both promote creating green spaces and food production in the city, one by creating mini-gardens on balconies in social housing and the other by transforming stone facades into vertical gardens. In addition to providing food, these initiatives support biodiversity, mitigate extreme temperatures and reduce greenhouse gas emissions. The projects are small compared with global climate change challenges. However, the crowdfunding platform has proved to be an excellent instrument for realising small drops of climate mitigation and adaptation measures that have the opportunity to generate larger ripple effects. ■

innovation, actors and institutions, social practices and behavioural shifts.

The inherently uncertain, exploratory and open-ended character of transitions creates the need for a much broader range of knowledge to support governance. This includes a need for much better understanding about complex societal systems, including the interactions, lock-ins and feedbacks that influence sustainability outcomes, social acceptance and political feasibility. Identifying the opportunities and risks associated with systemic change also requires better information about the impacts of drivers of change and cross-system interactions.

Ecosystem-based management requires accounting systems that monitor and assess the cumulative impacts of environmental pressures from multiple sectors. This can support assessment of the economic and social risks and costs that arise from continued degradation of ecosystems. The globalised character of modern production-consumption systems implies a need for a better understanding of Europe's environmental and social footprint to help inform the governance of transitions.

The importance of innovation for transitions necessitates a knowledge system that enables society to learn from successes and failures, replicate and upscale promising initiatives, identify unexpected consequences, and avoid lock-ins to unsustainable innovation pathways. Identifying goals and pathways requires information about the interests and preferences of different groups and their visions for the future. And the viability and credibility of polycentric governance hinges on the presence of robust monitoring and reporting systems that meet user needs.

To the extent that it is currently available, knowledge about these themes resides in multiple disciplines

Enabling sustainability transitions will require a transformation of the knowledge system supporting governance.

and with diverse actors across society, making only a limited contribution to policy and governance. As stated in the Amsterdam Declaration on global change (IGBP et al., 2001), 'A new system of global environmental science is required. ... It will draw strongly on the existing and expanding disciplinary base of global change science; integrate across disciplines, environment and development issues and the natural and social sciences; collaborate across national boundaries on the basis of shared and secure infrastructure.'

Supporting sustainability transitions will therefore require actions such as pluralising evaluations — combining multiple analytical approaches and engaging with different research communities; engaging with societal concerns — recognising different viewpoints and preferences through interactions with diverse social actors and stakeholders; attending to real-world complexities — tracking developments in existing systems and abstracting lessons from (local) initiatives; and co-creating knowledge — ensuring that the knowledge is relevant, actionable and understandable by engaging decision-makers and other stakeholders in knowledge co-production. The last point especially is much easier said than done.

Developing and using new forms of knowledge often requires that policymakers and other actors have access to relevant concepts, competencies and institutional mechanisms. These include, for example, the need to develop an understanding of system and transitions concepts; the need to develop skills in participatory foresight techniques that enable different actors to explore possible futures; the need for stakeholder engagement skills and platforms that enable policymakers to engage with business, NGOs, citizens, researchers and others; and the need for a governance culture that promotes experimentation and acknowledges the need to accept and learn from failures.

More broadly, there is a need to create networks that can tap into, organise and communicate the knowledge dispersed across society. Intermediary organisations that bridge between science, policy and society will have an important role. Similarly, the emergence of 'platforms of action' (e.g. under the Paris Agreement and the EU's circular economy action plan) provide a novel means of collating and sharing practice-based evidence among non-state and public actors. Making the most of their potential will require developing new methods to categorise and use this kind of knowledge (Steward, 2018).

17.5 Governance of innovation, innovations in governance

In combining state actions across multiple policy domains with bottom-up innovation and experimentation, sustainability transitions involve difficult governance challenges. How, for example, can such complex, dispersed and emergent processes be steered towards multiple, long-term sustainability goals? How can societies achieve coherence across policy domains and levels of governance? How can the inevitable risks and uncertainties associated with systemic change be managed? This section explores these questions. It concludes with reflections on how regions can combine different approaches to governance to manage nature-society interactions within environmental limits.

Developing shared visions for long-term development can inspire and guide action at different scales of governance.

17.5.1 Setting the direction for transitions

Unlike most past transformations of production-consumption systems, sustainability transitions are purposeful and directional. Although the future of society cannot be known in advance, the desired outcomes are reasonably clearly defined — most prominently in the SDGs but also in the growing body of long-term visions and targets in instruments such as the Paris Agreement and the EU's long-term framework policies addressing themes such as climate, energy, mobility and biodiversity.

Developing ambitious macro-level visions and goals is an important first step in guiding transitions in desirable directions. Visions can help in identifying possible alternative ways to meet social needs, tackle the problems that need to be solved and define the roles of different actors. Perhaps most importantly, they provide a shared narrative for actors across society, extending beyond electoral cycles and short-term objectives. This can help in coordinating activities and steering innovation, learning processes and investments (Smith et al., 2005; Hekkert et al., 2007).

In an increasingly complex and fragmented governance context, such visions and associated narratives can have a powerful influence on both state and non-state actors. For example, many EU Member States have responded to the EU circular economy strategy by voluntarily preparing national circular economy plans (see Chapter 9). At the sub-national level, regional governments and cities are committing to reductions in greenhouse gas emissions that often exceed national targets (Averchenkova et al., 2017; see also Chapter 7). In the United States, withdrawal from the Paris Agreement has prompted more than 2 000 American businesses, 280 cities and counties, and 340 colleges and universities to announce that they are still in the Agreement and determined to achieve the United States' commitment on emissions (Watts, 2017).

Visions and associated pathways are inherently normative, as they involve choices, trade-offs and prioritisation of certain goals and values over others. Societal actors are likely to have very different perspectives on how to move forwards, even if they agree on the overarching sustainability goals. This underlines the need to develop visions through collaborative processes that involve state, business and civil society actors. Achieving this is often difficult because stakeholders vary greatly in their priorities, resources, values and discourses.

Visioning and other foresight approaches can help actors to explore alternative futures systematically and collectively. As noted in the EU's better regulation toolbox (EC, 2018a), 'Foresight and other forward-looking tools complement quantitative modelling with a system thinking and long-term approach. … They facilitate thinking out-of-the-box. The objective is to engage with different possible futures (e.g. providing alternative futures) and challenge present assumptions thereby broadening the policy horizon.' Such approaches are not only about cognitive outcomes (based on expert judgements), but also about using creative and participatory processes to foster communication, learning, agreement and commitment.

Visions count for little if they are not translated into actions. It is therefore important to involve political actors (or those with political influence) in developing them. There is also a need to translate visions and goals into concrete policies and projects, backed up by specific targets, implementing agencies and monitoring frameworks. Backcasting is often used to translate future goals into a range of transition pathways, which can then be used to develop policy strategies and programmes (Figure 17.8).

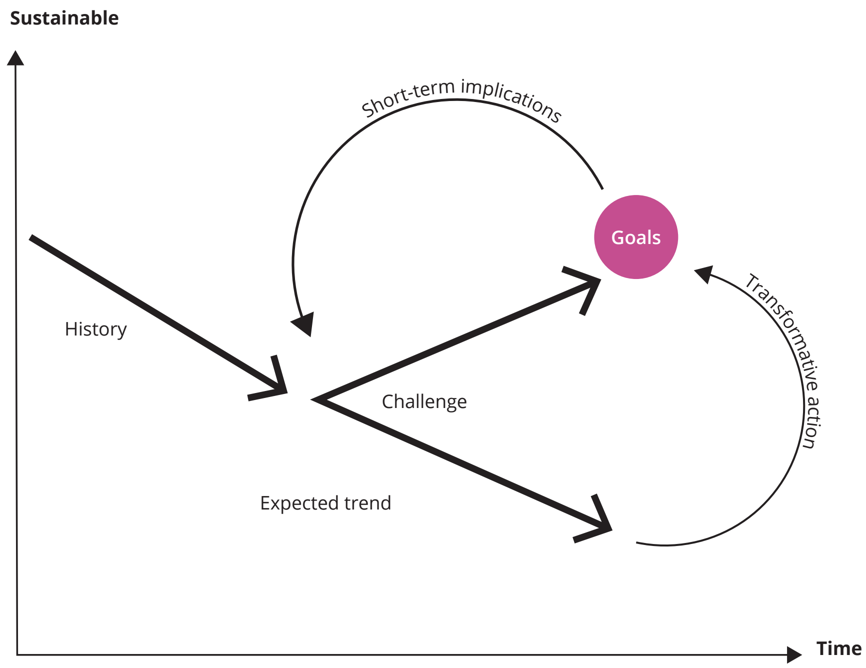
Within Europe, the process of translating visions into targets is well advanced in some policy areas. For example, the EU's 2011 *Roadmap for moving to a competitive low carbon economy in 2050* (EC, 2011) used modelling and scenario analysis to map out milestones and sectoral reductions needed to achieve the EU's 2050 target of reducing greenhouse gas emissions by 80-95 %. Subsequent frameworks have elaborated much more detailed targets and measures to achieve the long-term goal.

Similarly, the EU's circular economy action plan (EC, 2015a) articulates a vision and breaks it down into more concrete sub-goals and focus areas addressing topics such as plastics, waste and critical raw materials. In contrast, the food domain lacks an overarching sustainability vision and long-term goals, making it hard to develop policies and targets to support food system transitions. The SDGs and existing EU strategies can provide a foundation for engaging stakeholders and developing a shared vision for the food system.

Another mechanism for translating broad visions into concrete actions comes in the form of missions that convey a sense of urgency and common purpose, thereby stimulating innovation and investments. As outlined by Mazzucato (2018), targeted missions provide a means of bridging between macro-level goals or challenges and micro-level projects and experimentation (Figure 17.9).

Like broader visions, missions are intended to be motivational and foster bottom-up activity, as well as creating a frame for target setting and monitoring. However, by shifting the focus from broad challenges to more specific and ambitious but achievable problems (e.g. achieving 100 carbon-neutral cities in Europe by 2030) they provide a more specific focus for research, investment and economic growth. In this way, they aim to promote collaboration between all actors in the innovation ecosystem, including corporations and disruptive start-ups, public institutions and users (RISE, 2018).

FIGURE 17.8 Backcasting analysis

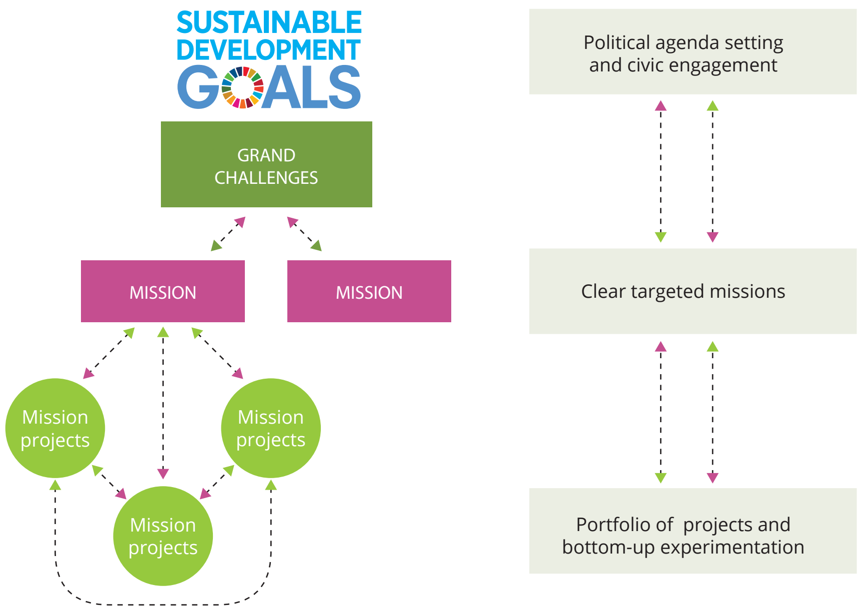


Source: van Vuuren and Hof (2018).

17.5.2 Coherence across policy domains and levels of governance

Systemic changes necessarily link to a broad range of policy domains, extending well beyond environment and sectoral policies, such as energy and agriculture, to embrace cross-cutting areas such as innovation, competition, tax, industry, education and welfare (Figure 17.10). Actions in each of these areas contribute to stimulating, orienting and facilitating systemic change. In practice, however, the fact that policies — at all levels of governance — are often developed in departmental silos with contrasting objectives and expertise means that misalignments and conflicts are inevitable (Section 16.6). This incoherence can slow down transition processes, creating contradictory signals about the direction of travel and deterring investments (OECD, 2015).

FIGURE 17.9 From challenges to missions



Source: Mazzucato (2018).

Actions to improve coherence are therefore important.

At the EU level, measures to enhance coordination include the better regulation agenda and the European Semester process (EC, 2019a, 2019c). Both contribute to improved environmental governance, for example through fitness checks of environmental legislation and the greening of the European Semester (EC, 2019b).

While EU policies can provide an important impetus for sustainability transitions across Europe, transitions are reliant to a very large degree on policy decisions and activities at Member State, regional or local levels. These different governance levels vary not only in their capacities but also in the barriers that they face, implying that they each contribute in different ways to transition processes. It is therefore important to achieve effective multi-level and multi-actor governance, with policy actions at each level reinforcing each other, exploiting opportunities and overcoming barriers.

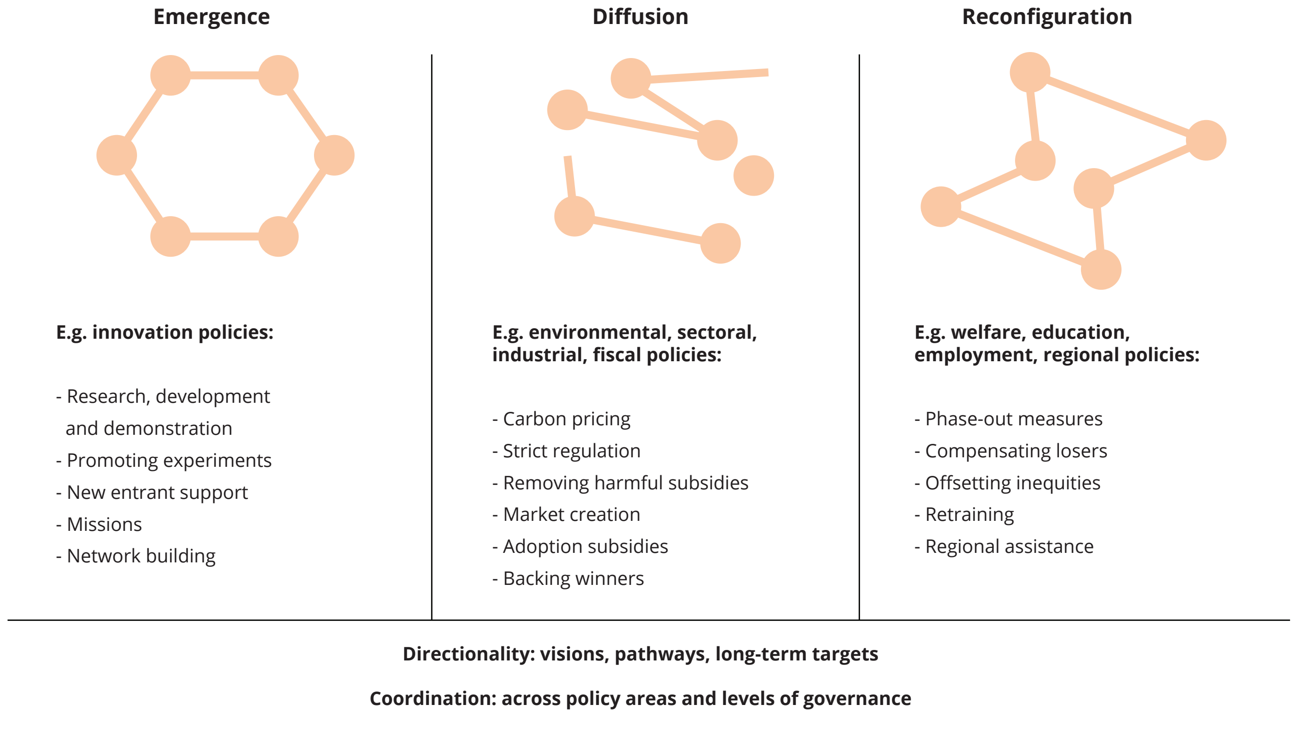
Misalignments can take a variety of forms. At the broadest level, policymakers may be pursuing inherently inconsistent policy goals (Rogge and Reichardt, 2016; Kern et al., 2017). For example, policies that subsidise renewables to make them more competitive may coexist with subsidies to fossil fuel-based industries that aim to support employment. In other instances, incoherent instruments can create barriers to change. In Finland, for example, operators of some new transport services found it extremely difficult to get the necessary permits to operate, as they could not be classified as taxis or goods transport (Temmes et al., 2014).

At the EU level, the European Commission has identified a variety of barriers that hinder the emergence and diffusion of innovation, including product market regulation, competition rules, market fragmentation, risk aversion and access to seed and start-up capital (EC, 2016b, 2017d, 2018d). As a result, 'Disruptive and breakthrough innovations are still too rare in Europe' (EC, 2018d). More generally, existing policies and rules are often geared towards established ways of meeting needs and may actively support them through subsidies or public procurement. As such, mapping and reducing barriers — temporarily or permanently — is an important step in creating niches for innovation.

Coordination can be further enhanced by organisational innovations, such as super-ministries that combine policy domains, political advisers with cross-departmental remits, inter-ministerial committees or independent units (OECD, 2015), such as a transitions unit in the prime minister's office. Many examples of such innovations exist in relation to climate and energy policy, and new initiatives are also emerging in some areas, for example Spain's Circular Economy Inter-ministerial Committee. There would be benefits in developing such mechanisms to address sustainability transitions, building on the experience of national sustainable development committees and ministries.

City networks represent another useful institutional mechanism to coordinate actions across levels of governance. For example, the Eurocities network specifically aims to reinforce the role of local governments in multi-level governance by helping enable cities to deliver on the EU's strategic priorities. As well as connecting cities directly to EU-level policymaking, it provides a platform for knowledge sharing among the local governments of more

FIGURE 17.10 Policy mixes for sustainability transitions



Source: Adapted from Geels (2006).

Systemic changes link to a broad range of policies including energy, agriculture, innovation, competition, tax, industry, education and welfare.

than 140 of Europe's largest cities, accounting for 130 million citizens.

The EU's strategic policies relating to the circular economy, the low-carbon economy and the bioeconomy represent key frameworks for coordinating the diverse actions needed to achieve economic transformation (EC, 2011, 2015a, 2018b). As the European Commission has noted in its reflection paper on the 2030 sustainability agenda (EC, 2019d), 'If we are to succeed, we must pull in the same direction at all levels. It is therefore of the utmost importance that all actors in the EU prioritise the sustainability transition. They must further develop the cross-cutting policy agendas that have been adopted at the EU level in recent years.'

While developing more cross-cutting frameworks would certainly be valuable, it is important to stress that such frameworks are likely to be misaligned. As emphasised in Section 16.6, this underlines the need for careful assessment of synergies and trade-offs, including those resulting from shared reliance on a limited natural resource base.

17.5.3 Avoiding potential harms in transition processes

From a risk management perspective, it is essential that societies promote innovations that contribute to sustainability goals and constrain those that are harmful. In practice, however, the impacts of new technologies and ideas are very hard to anticipate because they depend to a large degree on how innovations are used and integrated into ways of living and how they interact with other complex systems and drivers of change.

Novel chemicals, for example, can present direct threats to human and environmental health, and the accumulation and interaction of such substances in the environment or within organisms can amplify uncertainties. Similarly, the interplay of innovations and social responses may produce counter-productive outcomes, for example if car-sharing schemes cause people to cycle or walk less (Rademaekers et al., 2018). Interdependencies between systems can produce unexpected harms, such as the deforestation and food price increases that accompanied expanded biofuel production in the early 2000s. Structural economic change is sure to create winners and losers, potentially affecting whole regions.

These realities create difficult dilemmas. In many cases, the social and environmental consequences of innovations cannot be anticipated; by the time they do become apparent, widespread diffusion and associated lock-ins may make the innovation very difficult to remove (Collingridge, 1980). Yet, Europe cannot afford not to innovate. Inaction greatly increases environmental risks and has severe human and financial consequences.

Research and practice point to a variety of strategies for responding to these dilemmas. First, governments and other actors can certainly do better at exploring and identifying potential risks *ex ante*, building on existing impact assessment approaches and employing a variety of tools and analytical approaches. Such approaches must go well beyond simple forecasting exercises, based on historical data. Instead, the International Risk Governance Council (IRGC, 2018) recommends combining foresight approaches (which employ participatory approaches to map out possible futures, risks and opportunities) with 'broadsight' approaches that explore outcomes in horizontally interconnected systems.

The 'resource nexus' perspective employed to explore cross-system interactions in Chapter 16 exemplifies the latter approach. Other valuable techniques include horizon scanning to identify and interpret weak signals of potentially important developments (Box 17.10); developing scenarios for possible future changes in systems as a means of identifying potential risks or windows or opportunity; modelling of pathways to explore impacts and trade-offs, or using agent-based or system dynamics models to explore potential changes in systems (EEA, 2018).

Promoting diversity in innovation is vital to increase creativity, mitigate lock-ins, hedge against surprises and enable learning.

Although potential hazards must be identified as early and accurately as possible, the non-linear and open-ended nature of systemic change (as well as the pace and scale of technological innovation) mean that assessing and mitigating all risks in advance is impossible. Societies do not know what innovations will emerge, how they will influence and co-evolve with social practices, and what environmental and social impacts will emerge. These are 'unknown unknowns' — issues of fundamental uncertainty, rather than risks that can be assessed and balanced. In such situations, the precautionary principle provides a useful tool to support decision-making.

The precautionary principle stipulates that, where there are threats of serious or irreversible damage, lack of full scientific certainty shall not be used as a reason for postponing cost-effective measures to prevent environmental degradation. Although this is sometimes interpreted as a barrier to technological progress, a more nuanced understanding casts the precautionary principle as a source of guidance in situations in which risk assessment tools are inadequate. Rather than automatically requiring bans on potentially harmful innovation, it opens up a range of response strategies centred on acknowledging ignorance and uncertainty. These include the need to need to 'consider alternatives, explore uncertainties, maximise learning and promote adaptability in careful, reversible, step-by-step implementation' (Stirling, 2015).

Promoting diversity in innovation is essential because it nurtures creativity, mitigates lock-ins, hedges against surprises, enables learning and increases tolerance of failure of individual innovations. It provides the foundation for shifting to alternative innovation pathways in the event of surprises or unexpected consequences. But achieving this goal requires that diversity be complemented with real-world pilots and trialling, monitoring and evaluation, learning and communication.

These themes come together in adaptive governance approaches such as 'transitions management', which addresses change in socio-technical systems such as energy and mobility, and 'adaptive management', which focuses on nature-society interactions. Both acknowledge the risks and uncertainties inherent in transforming complex systems and seek to navigate these processes through iterative cycles of vision setting, experimentation, monitoring and evaluation. They put particular emphasis on the importance of social learning and stakeholder participation, reflecting the uncertain and pluralistic nature of knowledge (Foxon et al., 2008).

Applying a precautionary approach ultimately raises questions about the purpose and direction of innovation — questions that fall outside the focus of narrow forms of risk assessment and are often brushed

BOX 17.10 Identifying emerging risks and opportunities for Europe's environment and policies

Even when successful in its original intended use, innovation can result in unexpected and harmful consequences for the environment and human health. As numerous historical examples illustrate, mitigating harmful impacts requires identifying potential hazards as early and accurately as possible (EEA, 2001, 2013). In addition to enabling interventions to limit impacts, early warning can help stimulate the development of substitutes, hence contributing to sustainable innovation.

The increasing rate and complexity of technological and societal change (Chapters 1 and 15) means that early warning systems need to anticipate risks and opportunities that are not yet observable (Science for Environment Policy, 2016). Emerging risks can result from the introduction of radically new products or technologies (e.g. synthetic biology, artificial meat), the changing context in which they operate (e.g. climate change) or systemic effects related to radical transformations (e.g. energy systems). Another kind of challenge is associated with the public's risk perception, as some technological innovations can be met with more societal protest or controversy than expected (e.g. first-generation biofuels, wind turbines, nanotechnologies, genetically modified organisms), especially in times of decreasing trust in institutions and experts.

Against this backdrop, the Seventh Environment Action Programme calls for improvements in 'the understanding of, and the ability to evaluate and manage, emerging environmental and climate risks' (EC, 2013b). In 2017, the Environment Knowledge Community (EKC) ([1]) established the EU foresight system for the systematic identification of emerging environmental issues (FORENV) 'to identify, characterise and assess emerging issues that may represent risks or opportunities to Europe's environment'. FORENV adopts a systematic and participatory approach to risk management, building on methodologies such as horizon scanning, text mining or media monitoring (EC, 2017f) and on relevant expertise. In particular, it links with the Scientific Committee on Health, Environmental and Emerging Risks (SCHEER) and the Eionet Forward-Looking Information and Services (FLIS) representatives from EEA member countries. The first 2018-2019 annual cycle is focusing on identifying key emerging issues at the environment-social interface and communicating them to policymakers and the public at large, encouraging appropriate and timely action. ■

aside by popular discourses about the value of innovation. For example, Genus and Stirling (2018) argue that 'Taken as a whole, EU initiatives and policies tend to characterise innovation in an undifferentiated way — as a self-evidently generally 'good thing' irrespective of the specific kind of innovation involved or the alternatives that might thereby be foreclosed.' A more precautionary approach — including open, participatory approaches to define directionality — is in tune with the EU's concept of Responsible Research and Innovation (EC, 2014a), and very much at the heart of the shift to mission-oriented and transformative innovation policy.

17.5.4 Managing system interactions within environmental limits

As discussed in Section 16.5, production-consumption systems interact in many ways — both with each other and with ecosystems, for example through the resource nexus. Achieving Europe's long-term sustainability goals will therefore depend on governance approaches that reflect these interactions and help ensure that systems operate together within environmental limits.

Ecosystem-based management has emerged as a key governance approach for addressing the many interactions within and between society and nature. Ecosystem-based management aims to coordinate the interactions between multiple actors and sustainability outcomes in ways that preserve ecosystem services and ensure that society operates within environmental limits.

([1]) The Environment Knowledge Community is an informal platform of five Commission Directorates-General (for Environment, Climate Action and Research and Innovation, the Joint Research Centre, Eurostat) and the EEA that was set up in 2015 with the objective of improving the generation and sharing of environmental knowledge for EU policies.

In practice, ecosystem-based management brings together many of the features of innovative governance already highlighted in this section. In addition to being a distinctively 'place-based' governance approach, ecosystem-based management involves (McLeod and Leslie, 2009; NOAA, 2018):

- Engaging multiple actors: Rather than addressing individual sectors, ecosystem-based management highlights the importance of interactions between stakeholders in a socio-ecological system and their cumulative impacts on the environment. This includes engaging actors at different levels — from local to global — in coordinating actions and sharing data.

- Actions towards shared targets: Engaging sectors, public authorities and other actors is achieved by defining shared targets linked to ecosystem functioning. For example, the Water Framework Directive requires that water bodies achieve good ecological status across a variety of biological, hydromorphological and physico-chemical characteristics.

- Focusing on diverse sustainability outcomes: Ecosystem-based management captures the full range of benefits associated with maintaining ecosystem service flows, as well as the trade-offs inherent in reconciling the activities of multiple sectors and other actors at a particular spatial scale.

- Monitoring and adaptive governance: Recognising that complex systems are constantly changing in ways that cannot be predicted or controlled, ecosystem-based management embraces an adaptive governance style, grounded in flexible and innovative institutions that are highly responsive to new information and experiences.

Ecosystem-based approaches help in understanding environmental trends and coordinating collective action to preserve natural capital.

- Multidisciplinarity: Understanding the interactions of multiple societal and ecological systems requires broad knowledge, including 'synthesizing and applying knowledge from across social and natural sciences, as well as the humanities' (Leslie and McLeod, 2007).

Within EU governance, ecosystem-based management underpins some of the key environmental policies that together contribute to implementing the EU biodiversity strategy, notably the Water Framework Directive and the Marine Strategy Framework Directive. Since their introduction, these tools have enabled a shift in governance, bringing together sectors and Member States to consider and balance their collective interests and assess the cumulative pressures that they are placing on particular regions (EEA, 2015a).

The shift to a systems approach in EU environmental governance is not simple, because it challenges established knowledge, skills, decision making processes and structures (Voulvoulis et al., 2017). Perhaps, partly for these reasons, Europe still has a long way to go to achieve good status in its freshwater and marine ecosystems (as discussed in Part 2 of this report). Nevertheless, adopting ecosystem-based approaches provides an essential starting point for understanding the links between ecological status and the diverse pressures imposed by society and for coordinating collective action in ways that preserve Europe's natural capital. As such, there could be significant value in strengthening the implementation of ecosystem-based management and extending its use in EU environmental policy.

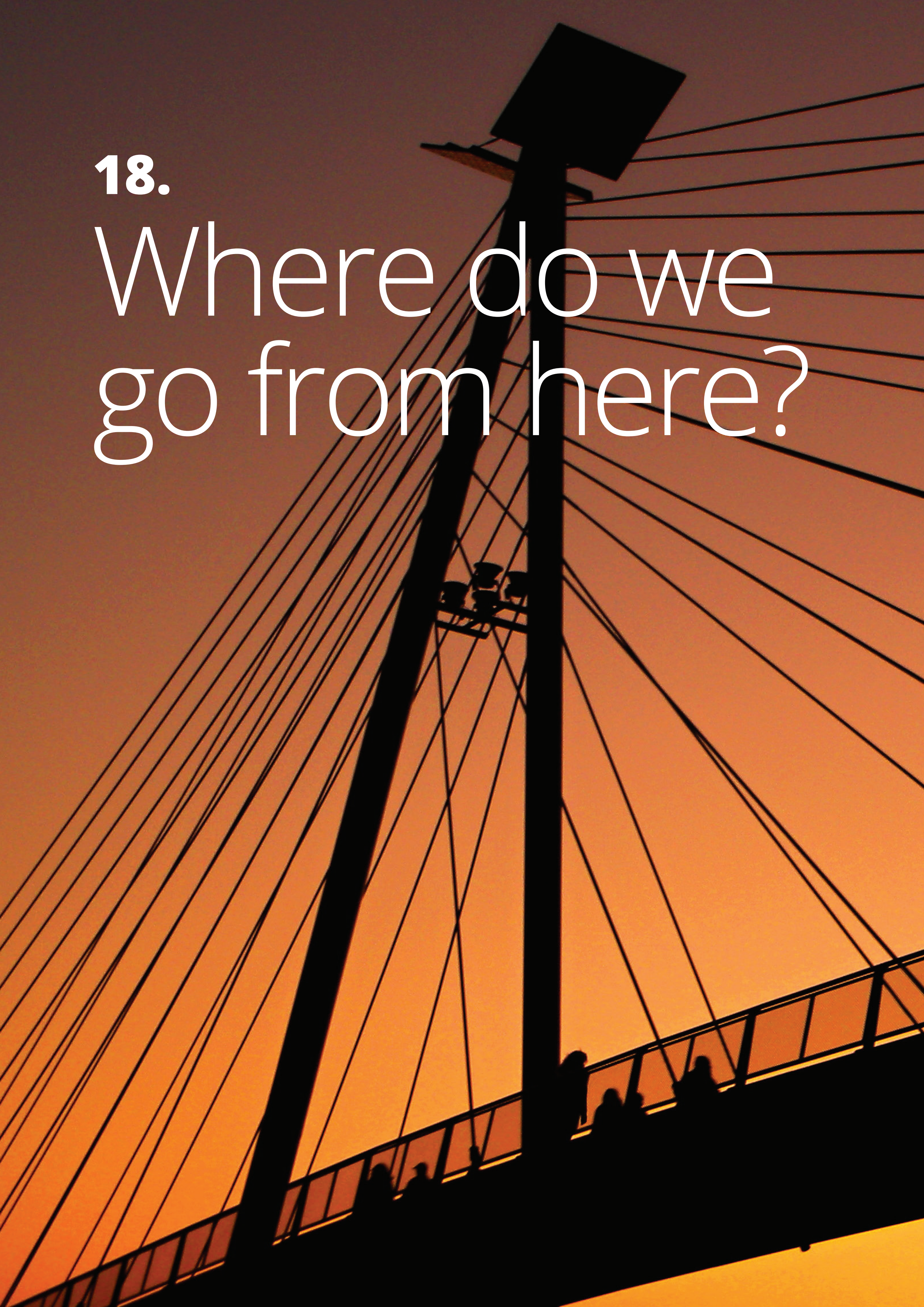
Overall, ecosystem-based management provides a natural complement to the transitions frameworks described in this chapter. Whereas the multi-level perspective is much stronger than ecosystem-based management in explaining the dynamics of change in production-consumption systems, it gives limited consideration to cross-system interactions and environmental impacts and thresholds. In contrast, ecosystem-based management addresses precisely these kinds of interlinkages and effects, using ecological criteria, and exploring them at the spatial scales most appropriate for managing nature-society interactions, such as a river catchment area or a regional sea spanning multiple administrative boundaries. Considering the multi-level perspective and ecosystem-based management together in future policy design could help accelerate sustainability transitions in line with the 2050 vision of the Seventh Environment Action Programme.

PART 4

Conclusions

18.

Where do we go from here?



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Summary

- Europe faces persistent environmental challenges of unprecedented scale and urgency. Where there has been progress on reducing emissions and impacts on human health, the improvements are insufficient to meet the long-term objectives to 2050. Such persistent challenges are resistant to traditional policy responses and could be more fully resolved if they were addressed as broader sustainability issues that cross environmental, social, economic and governance dimensions and at European and global levels. Addressing them will require policies, investments and knowledge to be brought together to transform the systems driving unsustainability while maximising the environmental, social and economic co-benefits.

- Awareness about the environmental and climate crisis is increasing across society. Citizens, businesses and communities are experimenting with new ways of living and working. Governments should harness the energy in these initiatives and encourage upscaling by supporting social and technological innovation, enabling new ways of networking and engaging stakeholders in participative governance, and ensuring socially fair transitions.

- Achieving sustainability transitions will depend on coherent contributions across all policy domains. Beyond full implementation of existing policies, this means embracing the Sustainable Development Goals as an overarching framework for policymaking and action. The EU's new body of systemic, transformative policy frameworks will also be vital in mobilising and guiding actions at different levels. However, important gaps remain, particularly for the food system.

- There are opportunities to reorient the financial flows that structure Europe's consumption and production. Governments have an essential role in investing in public goods, financing innovation and experimentation, and shaping private investment and financial markets. Key tools include fiscal reform and actions to promote sustainable finance, alongside adopting metrics to measure progress that go 'beyond gross domestic product (GDP)'.

- Sustainability transitions will require a detailed understanding of the systems driving environmental challenges and potential pathways to sustainability and their implications across society. New and more inclusive modes of knowledge production are needed, building on big data and foresight. Developing knowledge and skills will require investment in research, education and life-long learning.

- During the forthcoming EU policy cycle, Europe's leaders have the opportunity to shape future developments that will not be available to their successors. Achieving Europe's long-term sustainability goals is still possible — but it requires an immediate and fundamental shift in Europe's responses, including more concerted international action.

18. Where do we go from here?

18.1 Critical choices in 2020

The EU and its nearest neighbours stand at a critical juncture. Despite progress in reducing some environmental pressures in recent decades, Europe faces environmental and sustainability challenges of unprecedented scale and urgency, which it cannot successfully address alone. Calls for global action are being made across science, policy and society. The Intergovernmental Panel on Climate Change (IPCC) has concluded that global CO_2 emissions need to be roughly halved during the coming decade to keep global warming to a maximum of 1.5 °C (IPCC, 2018). Global use of resources is projected to double by 2060 compared with current levels (IRP, 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). Approximately 19 million premature deaths are estimated to occur annually as a result of pollution of the air, soil, water and food globally (UNEP, 2017).

2020

The decade from 2020 to 2030 will be of vital importance in determining Europe's opportunities in the 21st century.

Overcoming these challenges is possible, but it will require a significant shift in the character and scale of Europe's responses and coordinated actions across society and internationally. Despite decades of efforts on sustainable development, humanity's impact on the environment and climate is greater than ever before. The decade from 2020 to 2030 will be of vital importance in determining Europe's opportunities in the 21st century.

In response to these challenges, Europe will need to achieve a rapid and fundamental 'transition to a low-carbon, climate-neutral, resource-efficient and biodiverse economy' (EC, 2019, p. 14). That means transforming the key societal systems driving pressures on the environment and climate and impacts on health — notably energy, food and mobility. It also means addressing the use of resources and chemicals across society and protecting biodiversity and ecosystems and their services. This means rethinking not just technologies and production processes but also governance approaches, consumption patterns and lifestyles.

The food, energy and mobility systems are crucial sources of greenhouse gas (GHG) emissions and therefore drivers of climate change. They also contribute to diverse forms of pollution, as well as land use change and landscape fragmentation. The food system has particularly far-reaching impacts on natural systems and people's health and well-being, for example through diffuse nutrient pollution. Chemical use across society also results in widespread environmental harm, and there are few safe-by-design alternatives available yet.

There are considerable barriers to achieving systemic change at the pace and scale required. People have become acclimatised to negative messages on the state of the environment, leading to inadequate or delayed responses. For many European citizens and politicians, the costs of this inaction can feel distant and intangible. Moreover, systemic change inevitably challenges established investments, jobs, policies, behaviours and norms. This can provoke resistance from businesses, employees and society more broadly. Vested interests are one of the biggest obstacles to necessary change. The drive to maintain a competitive advantage can deter individual countries and businesses from pursuing ambitious environmental goals.

Yet there are also reasons for optimism. Some European citizens are becoming increasingly vocal in expressing their frustration at the shortfalls in environment and climate governance. Non-governmental organisations (NGOs) have taken legal action against national governments for not taking sufficient measures to fight climate change. Young people are becoming increasingly engaged and calling on policymakers to act more decisively (e.g. the school strike for climate campaign). In parallel, innovations have emerged rapidly in recent years, for example in the form of clean energy technologies and social innovations such as community energy, mobility and food initiatives. Some cities and regions are leading the way in terms of ambition. Knowledge of systemic challenges and responses is growing and is increasingly reflected in key European policy frameworks.

All of these developments are important because they create space for governments to act and bring a new scale of ambition to policy, investments and actions. They also help raise awareness, encouraging European citizens to rethink their behaviours and lifestyles. Fundamentally, the choice in 2020 is straightforward: to continue on a trajectory that puts the environment, future economic development, well-being and social cohesion at risk, or to change trajectory, setting Europe on a strong and credible development pathway to achieve a sustainable future.

The current rate of progress will not be sufficient to meet 2030 and 2050 climate and energy targets.

18.2 Challenges and opportunities

18.2.1 The main findings of SOER 2020

As demonstrated in Part 2 of this report, nature underpins and sustains human health, well-being and livelihoods. However, this foundation is deteriorating fast. Europe's success in addressing the degradation of natural systems has been limited. The majority of EU 2020 targets related to protecting, maintaining and enhancing natural capital will not be achieved. The overall objective of the EU biodiversity strategy to halt the loss of biodiversity and ecosystem services by 2020 will not be met. The outlook for 2030 is not encouraging, and achieving the Sustainable Development Goals (SDGs) dedicated to protecting terrestrial and marine ecosystems (SDGs 14, 15) and other related targets (SDGs 2, 6) is very unlikely.

In contrast, Europe has made progress in reducing pressures. GHG emissions and air pollution have been reduced while economic growth has been sustained. However, the pace of progress has slowed in relation to GHG emissions, industrial emissions, energy efficiency and the share of energy from renewable sources. This indicates the need to go beyond incremental improvements and to ensure that technology-driven efficiency gains are not offset by increasing demand. The outlook to 2030 suggests that the current rate of progress will not be sufficient to meet 2030 and 2050 climate and energy targets. In addition, addressing environmental pressures from economic sectors through environmental integration has not been successful, as illustrated by agriculture's impacts on biodiversity and pollution of the air, water and soil.

The global burden of disease and premature death related to environmental pollution is three times greater than that arising from AIDS (acquired immune deficiency syndrome), tuberculosis and malaria combined (Landrigan et al., 2017). In Europe, human health and well-being are still affected by exposure to air pollution, noise, hazardous chemicals and increasing risks from climate change. Environmental risks to health do not affect everyone in the same way and there are pronounced local and regional differences across Europe in terms of social vulnerability and exposure to environmental health hazards. Groups of lower socio-economic status tend to be more negatively affected. The outlook to 2030 for reducing environmental risks to health and well-being is uncertain. Current trends, coupled with important gaps and uncertainties in the knowledge base, give rise to concerns.

The interrelated nature of Europe's objectives in relation to natural capital, transforming the economy and reducing environmental risks to health and well-being mean that outcomes are determined by a complex mix of factors. Persistent environmental problems, such as loss of biodiversity, ecosystem degradation and climate change, are intertwined with economic activities and lifestyles. For example, the way food is produced and consumed influences progress across a range of policy areas such as biodiversity and nature protection, climate change mitigation and adaptation, water quality and quantity, soil protection, the circular economy and the bioeconomy. The systemic and transboundary nature of challenges can limit the effectiveness of policy measures that do not address the root causes of environmental damage, such as unclean production, overconsumption and ecologically wasteful trade.

Although signs of progress have been observed across the food, energy and mobility systems, environmental impacts remain high and current trends are not in line with long-term environmental and sustainability goals. Achieving such goals involves addressing environmental, economic, social and governance dimensions together, bringing in the perspectives of a broad range of stakeholders, and taking coherent actions across society.

The conclusions of SOER 2020 are clear. Policies have been more effective in reducing environmental pressures than in protecting biodiversity and ecosystems and human health and well-being. Despite the achievements of European environmental governance, the outlook for Europe's environment in the coming decades is discouraging. Even in areas in which progress has been made, such as climate change mitigation, the scale of improvement needs to increase in the coming decades. Meanwhile, global megatrends, such as the continued growth in the population, economic output and the demand for resources, rising atmospheric GHG levels and worsening impacts from climate change, are intensifying environmental problems. New concerns are also emerging from technological developments and geopolitical changes, with implications for the European environment that are not clear.

Full implementation of existing policy would take the EU a long way towards achieving its environmental goals up to 2030.

In essence, Europe, along with the rest of the world, is running out of time to avoid catastrophic impacts on the economy and society from climate change, ecosystem degradation and overconsumption of natural resources. We are running out of time and space to adapt to such impacts. There is an urgent need to mitigate pressures more rapidly and restore ecosystems to support sustainability objectives.

This has implications for the development and implementation of policy and governance, investments and knowledge. But it also brings opportunities to identify more effective interventions. Embracing a wider systems perspective enables the identification of key synergies, trade-offs, lock-ins and systemic responses. For example, land use influences environmental outcomes across the food, energy and mobility systems as well as the built environment. Therefore, land use choices can play a critical role in transformation, but the interlinkages need to be considered to ensure that problems are not simply shifted elsewhere.

18.2.2 Strengthening policy implementation, integration and coherence

Since the 1970s, Europe has constructed a comprehensive set of environmental standards, founded on an unparalleled international system of monitoring, assessment and knowledge development. A growing understanding of Europe's environmental challenges increasingly highlights the need for new kinds of governance responses. Yet established environmental policy instruments, such as environmental quality standards, emissions limits and legally binding targets, remain indispensable tools for changing the trajectory towards sustainability.

As demonstrated in Part 2, Europe's environmental policy framework — the environmental acquis — has reduced some environmental pressures during recent decades while enhancing prosperity and well-being. Yet persistent weaknesses in policy implementation mean that Europe is not realising the full benefits of existing legislation. It is estimated that 420 existing gaps in the implementation of environmental legislation cost society EUR 30-80 billion annually (COWI and Eunomia, 2019).

Full implementation of existing policy would take the EU a long way towards achieving its environmental goals up to 2030. Improving implementation will depend on increased funding and capacity building, inclusive governance approaches that involve businesses and citizens, and better coordination of local, regional and national authorities. It will also require actions to strengthen the knowledge base supporting thematic and sectoral policies. SOER 2020 has identified knowledge gaps in diverse areas, ranging from marine ecosystems and environmental tipping points to drivers of resource consumption and the effects of exposure to chemicals.

Beyond implementation, there is a need to address gaps and strengthen some existing policy frameworks. Key gaps relate to land and soil and an integrated framework for environment and health, including chemicals. Binding, European-wide quantitative targets are lacking for resource efficiency, resource use, waste prevention and biodiversity. Other policy frameworks lack clearly defined steps towards long-term goals.

Better integration of environmental goals into sectoral policy is also essential. Integrating climate goals into energy policy has delivered important progress, although further integration of environmental objectives is needed, as decarbonisation can create significant pressures on ecosystems. In other areas, progress has been weaker. In the agricultural sector, environmental integration into key policies such as the common agricultural policy (CAP) has not prevented continued loss of biodiversity and environmental degradation. This points to the need for much more ambitious and far-reaching efforts. More broadly, environmental objectives could be more fully integrated into economic decision-making, through, for example, the EU's annual 'European semester' policy coordination process and improved use of Europe's system of integrated environmental and economic accounting and measures of society-wide progress that go beyond GDP.

Improving policy coherence can also enable more progress towards objectives. For instance, large subsidies for fossil fuel-based energy persist, despite ambitious climate change and clean energy objectives. Tackling diffuse nutrient (nitrogen, phosphorus) pollution will likewise require more coherent policies for agriculture, transport, industry and waste water treatment. It also requires an integrated approach across the land-sea continuum. Embracing a wider food system perspective — beyond thematic and sectoral policies — would be particularly beneficial, because diffuse nutrient pollution is also influenced by society's consumption patterns, such as in food choices.

18.2.3 Developing systemic policy frameworks

Recognising the need for coherent action across policy areas and levels of government, the EU has started

The coverage of long-term EU policy frameworks needs to be extended to other important systems and issues, such as food, chemicals and land use.

to develop a series of systemic, long-term policy frameworks that address multidimensional sustainability outcomes. Some focus on particular areas, for example the Energy Union and the 'Europe on the move' agenda. Others are more cross-cutting, addressing decarbonisation and dematerialisation of the economy as a whole. Such instruments include the EU strategies for a low-carbon, circular and bio-based economy, as well as the proposed strategy for a climate-neutral Europe (EC, 2011, 2015, 2018a, 2018b). They complement established frameworks such as the environment action programmes, which enable stakeholders to come together to set priorities, contribute to stronger commitments and enhance the coherence of EU and national policies and actions.

The new frameworks are essential. They signal a new understanding of sustainability challenges and responses, enhancing political commitment and coherence across policy areas and levels of government. Yet they are only a start. The coverage of long-term EU frameworks needs to be extended to other important systems and issues, such as food, chemicals and land use. There are already growing calls for the EU to develop a 'common food policy' (EESC, 2017; IPES Food, 2018).

It will also be important to develop comparable cross-cutting strategies at other levels of governance — including national, regional and city (EC, 2019) — and to translate strategic long-term visions and goals into ambitious and binding targets and policies. Developing concrete missions, as planned under Horizon Europe, provides a valuable means of mobilising and coordinating public and private investments and of engaging coalitions of actors in ways that can support transformative change.

18.2.4 Leading the global response towards sustainability

Europe cannot achieve its sustainability goals in isolation. Global environmental and sustainability problems require global responses. The IPCC and UNFCCC (United Nations Framework Convention on Climate Change) processes that resulted in the Paris Agreement exemplify the kinds of concerted international efforts that are needed in other environmental fields. The EU can use all its influence to ensure that current Intergovernmental Science-Policy Platform on Biodiversity and Ecosystem Services (IPBES) and Convention on Biological Diversity (CBD) work on biodiversity results in an ambitious global agreement in 2020. The EU could also push for global frameworks on resource use, building on the work of the International Resource Panel and the EU's own circular economy approach. And it could make full use of Europe's diplomatic and economic influence to promote the adoption of environmental standards at the global level and their incorporation into international trade rules.

The EU has an essential role in keeping sustainability at the top of the global agenda. Being a world leader in terms of its level of sustainability will benefit the European economy, as well as helping preserve peace and security in Europe, its neighbourhood and beyond. If action is not taken, climate change and global environmental degradation will undoubtedly lead to conflicts and forced migration, jeopardising geopolitical stability and the international rules-based system.

The United Nations' 2030 agenda for sustainable development and the SDGs provide an essential framework for steering and coordinating these international efforts. Full implementation of the 2030 agenda in Europe and active support for implementation in other regions (e.g. through the EU's external action, development aid and trade policies) will be essential if Europe is to provide global leadership in achieving sustainability transitions. Outsourcing of unsustainable practices to other regions must be avoided, as this would undermine the other regions' efforts to achieve the SDGs. Instead, the EU should foster a level playing field for sustainability innovation worldwide and export the sustainable solutions it develops.

Global responses should also extend beyond intergovernmental approaches to embrace transnational networks of civil society organisations, subnational governments and companies. The EU could also find more ways to connect more strongly with such networks, not only from a funding perspective but also to build on their experience and know-how when setting up new international initiatives.

18.3 Enabling sustainability transitions

18.3.1 Fostering innovation throughout society

Changing trajectory will depend critically on the emergence and spread of new social practices, technologies, business models and nature-based solutions throughout society. Innovations in these diverse areas hold the potential to trigger behavioural changes and new ways of thinking and living. The seeds of this shift already exist. More and more businesses, entrepreneurs, researchers, city administrations and local communities are experimenting with new ways of producing and consuming. This diversity is essential, as it is not possible to foresee the viability and appeal of novel ideas or to anticipate their impacts and implications when taken up and used widely.

> There are often major barriers and lock-ins that hinder the emergence and upscaling of innovations.

In practice, there are often major barriers and lock-ins that hinder the emergence and upscaling of innovations. Novelties may struggle to compete with established approaches that have benefited from decades of efficiency improvements. Existing technologies are often tightly linked to behaviours, cultural norms and values. Policies and market failures may further protect incumbents from competition. And systemic changes, such as the shift to renewable energy technologies or to plant-based diets, can disrupt whole sectors, leading to stranded assets and job losses. This is likely to provoke strong resistance from some businesses and consumers.

These realities point to an essential role for diverse public policies and institutions in stimulating the emergence of bottom-up solutions and facilitating system innovation. Policies can provide resources and incentives to enable experimentation and real-world piloting of new practices. They can stimulate the diffusion of promising innovations by correcting market failures, promoting the diffusion of knowledge or offering diverse incentives for their adoption. They can create an enabling framework for social innovations by creating networks, facilitating interactions and providing financial support. And they can promote the phasing out of unsustainable activities.

Environmental policies are important, for example in stimulating innovation and shaping the incentives that guide investment. But system innovation requires coherent contributions from diverse policy areas, including innovation and research, industry and sectors, education, welfare, trade and employment. Systemic policy frameworks can enable sustainability transitions by guiding and aligning actions across policy areas and scales.

The challenges of and needs for regional development are highly diverse across Europe. Local settings provide vital opportunities for experimenting with novel policy approaches and learning about what works and what does not. Innovation therefore depends heavily on the enabling environment created by local and regional governments in both urban and rural areas. Cities and municipalities have a particularly important role as hubs of innovation, often with distinct powers and capacities to network and share ideas. They are often well ahead of national governments and EU policy in terms of ambition and creativity.

18.3.2 Scaling up investments and reorienting finance

Following the economic and financial crisis of 2008, governments have focused on rebuilding public finances and returning the economy to growth. Although these are understandable goals, the potential costs of failing to tackle environmental and climate challenges continue to grow. Although achieving sustainability transitions will require major investment, Europeans stand to gain hugely — as a result of both avoided harm to nature and

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society and the economic and social opportunities that such transitions create. This implies an urgent need to prioritise and upscale investments in sustainability transitions, even if that means redirecting public funds from debt reduction in the short term.

Estimates of the investment required to achieve a climate-neutral Europe illustrate both challenges and opportunities (EC, 2018b). Modernising and decarbonising the EU economy is estimated to require additional investment in the energy system and related infrastructure of EUR 175-290 billion each year. But it would bring major health benefits, for example reducing health problems related to fine particulate matter by around EUR 200 billion per year. Cumulative savings from reduced imports of fossil fuels are projected to total EUR 2-3 trillion in the period 2031-2050. The shift to energy from renewable sources will also open up new opportunities for European countries in global clean energy markets, which are already worth EUR 1.3 trillion.

Mitigating climate change is only one part of the investment challenge. Globally, achieving the SDGs may cost USD 5-7 trillion annually (UNCTAD, 2014). Such investment looks feasible compared with total global investment of approximately USD 20 trillion (World Bank, 2019). But it will require a fundamental reorientation of public and private spending. At present, much of Europe's investment perpetuates unsustainable modes of producing and consuming, guided by market prices that do not reflect environmental and social harms.

Public investment is essential for financing sustainability transitions, particularly in areas in which market incentives for private investment are weak. This is often the case when returns on expenditure are highly uncertain (e.g. investments in innovation) or accrue to society generally (e.g. investments in public infrastructure or natural capital). Governments need to be more active in these areas by creating incentives to stimulate and direct business investment. They can also do more to facilitate household investment (e.g. in retrofitting of housing), which accounts for a substantial proportion of the spending needed to achieve climate goals. In these areas, public policies and institutions can help in overcoming the high upfront costs for households and high transaction costs for banks that are currently a barrier to the necessary investment.

Cumulative savings from reduced imports of fossil fuels are projected to total EUR 2-3 trillion in the period 2031-2050.

Environmental fiscal reform, aimed at both increasing environmental taxes and removing harmful subsidies, will be essential to correct market failures and achieve cost-effective investment. Modelling indicates that achieving long-term climate targets using pricing measures (e.g. environmental taxes, tradable permits) will require very steep increases in carbon prices in the coming years (IEA and IRENA, 2017), implying considerable political barriers. This underlines the need to design environmental fiscal reforms in ways that offset regressive impacts. It also implies a need for joined-up approaches that combine environmental taxes with tools such as feed-in-tariffs, portfolio standards, minimum performance standards, public procurement and co-financing mechanisms, such as the EU's European Fund for Strategic Investments.

Engaging the financial sector in sustainable investment is likely to require additional measures, for example developing robust and shared definitions of sustainable investment, increasing transparency and enhancing reporting requirements on environmental and sustainability risks. Accelerated implementation of the EU's sustainable finance action plan will be essential.

Much more can be done to achieve existing commitments. The EU has made little progress towards its goal of increasing R&D (research and development) spending to 3 % of GDP by 2020. The public sector also needs to ensure that investments promote challenge-led research, targeting environment- and climate-friendly innovations and nature-based solutions. Governments need to become much more active in stimulating, orienting and complementing private investments at later stages of innovation. This will necessitate greater levels of ambition, engagement and risk-taking and a willingness to accept failures alongside successes.

18.3.3
Managing risks and ensuring a socially fair transition

Transition processes are unpredictable and often produce unintended consequences and surprises. Innovations such as novel chemicals and materials can present direct threats to human and environmental health including the risk of causing irreversible harm. The interplay of innovations and social responses may produce counter-productive outcomes, as in the case of car-sharing schemes causing people to cycle or walk less. Interdependencies between systems can produce unexpected harm, such as the deforestation and increases in food prices that accompanied expanded biofuel production in the early 2000s.

Equally, however, sustainability transitions will create diverse new jobs and opportunities — often in ways that are hard to anticipate in advance.

Successful governance of sustainability transitions will require societies to acknowledge the potential risks, opportunities and trade-offs and devise ways to navigate them. The need to ensure that both benefits and costs are shared fairly across society is reflected in growing calls for just and socially fair transitions.

Policies have an essential role here, for example in supporting companies and workers in industries facing phasing out. Measures such as retraining, subsidies, technical assistance or investment can help negatively affected regions and ensure that they secure benefits from systemic change. The growing use of EU regional and innovation policy to help badly affected regions to transition towards sustainable economic sectors is a welcome development. But there is a need for more ambitious and far-reaching action.

Democratising information, enabling local action and empowering communities are key prerequisites for a just transition. There are many legitimate perspectives on desirable futures and choices on how to reach them. Effective governance requires participatory processes that enable diverse stakeholders to identify shared visions and goals and credible pathways to reach them.

Foresight approaches can help stakeholders across society to share diverse opinions and ideas, collectively visualise alternative futures, potential pathways to reach them and options for policy and action. Early identification of emerging risks and opportunities related to technological and societal developments is crucial, as are approaches that help expose trade-offs and negative cumulative impacts. In practice, however, assessing and mitigating all risks in advance is impossible. Governance of sustainability transitions must therefore apply precautionary approaches that avoid lock-ins to dangerous pathways by acting on early warnings from science and society and by promoting experimentation, monitoring and adaptive learning.

Transitions processes can be supported by ensuring knowledge is used to empower action across society.

18.3.4 *Linking knowledge with action*

To support existing environmental policy objectives, there is a clear need to invest in better *in situ* monitoring to address existing knowledge gaps, for example in the areas of biodiversity and soil. Europe should seize the major opportunities that digitalisation offers for knowledge production and communication. It is now possible to collect, store and process ever larger amounts of data, for example those generated by Earth observation services (e.g. Copernicus), automated sensors in the environment, and crowd-sourced contributions from citizens. Although 'big data' are currently difficult to interpret, new data analytics and artificial intelligence (AI) offer new means of doing so, providing insights into what is happening and why.

The emergence of new sustainability challenges and systemic and transformative policy responses, coupled with the desire to promote and navigate transition processes across society, creates new opportunities and demands for knowledge. These include detailed evidence about the structure, drivers and dynamics of production-consumption systems at different scales and evidence that enables societies to learn from successes and failures, to upscale promising initiatives and to identify barriers to change and unexpected consequences. Furthermore, ICT (information and communications technology) and AI should be harnessed to support decision support tools that help societal stakeholders select transition pathways and adapt them as circumstances and knowledge change.

Transitions processes also call for more systems-oriented, anticipatory and transdisciplinary approaches to knowledge and action. For example, the social sciences can provide vital insights into how to scale up social and grassroots innovations for sustainability (e.g. through practice-based knowledge), how to overcome lock-ins, conflicts and vested interests, and how to trigger individual and societal changes towards sustainable lifestyles (e.g. the link between providing information and behavioural change).

Effective science-society interfaces at all levels of governance can ensure that knowledge is understood and used to empower action across society. This requires public institutions to collaborate and combine their knowledge and skills, as well as developing new capacities and competencies, for example in relation to systems thinking, foresight and engaging stakeholders. It also means empowering citizens, for example by ensuring that lifelong education increases environmental literacy and enables active public participation in environmental protection and transitions processes.

More than ever, ensuring that relevant and credible knowledge is actually used by decision-makers is a key challenge. In the broader societal context of increased distrust of public institutions and experts and of greater use of more decentralised, less regulated channels of information (e.g. social networks, blogs), knowledge organisations such as the EEA and Eionet (the European Environment Information and Observation Network) need to reflect on their approaches to gathering, labelling and communicating their knowledge.

18.4 The next 10 years — from ambition to action

Europe has only 30 years to achieve its long-term vision of 'living well, within the limits of our planet'. Thirty years may seem like a long time, but it is now almost five decades since the Stockholm Declaration on the Human Environment (UN, 1972). In that period, many of Europe's sustainability challenges have grown. Achieving the 2050 vision will therefore require an immediate and fundamental shift in the character and scale of Europe's response.

In 2020, Europe's leaders have the opportunity to shape future developments that will not be available to their successors. The 2030 agenda for sustainable development and the Paris Agreement provide clear international acknowledgement of the need for urgent and far-reaching action. Europe has a unique window of opportunity to lead the global response to sustainability challenges. But it faces critical choices. What should Europe do differently in 2020 and the decade that follows?

SOER 2020 points to six key areas in which bold action is needed:

- **Enable transformative change across Europe** — by harnessing the ambition, creativity and power of citizens, businesses and communities to shift towards sustainable production and consumption patterns and lifestyles. Ensure that diverse policy areas work together to enable transitions. Promote the emergence and spread of diverse ideas and innovations by helping bottom-up initiatives to learn and network. Engage stakeholders in inclusive governance processes to open up a broader range of societal responses. And ensure that transitions are socially fair, particularly for the most vulnerable in society.

- **Embrace the SDGs as an overarching framework for policymaking and implementation** — at all scales, and complement them with additional measures if the goals could be more ambitious, for example on air pollution and impacts on health. Actively support implementation of the SDGs in other regions, in particular Europe's neighbourhood. Use Europe's diplomatic and economic influence to promote the adoption of global environmental standards, including in international trade rules. And avoid outsourcing unsustainable practices that undermine other countries' efforts to achieve the SDGs.

- **Realise the unfulfilled potential of existing environmental policies** — by achieving full implementation across Europe through increased funding, capacity building, stakeholder engagement and better coordination of local, regional and national authorities. Increase public awareness of the co benefits for prosperity, security and well-being. Address gaps in policy and monitoring in areas such as land, soil and chemicals. And ensure that integrating environmental goals into sectoral policies produces significant and measurable outcomes.

- **Develop systemic policy frameworks with binding targets** — to mobilise and guide actions across society (starting with the food system and an integrated framework for environment and health). Engage stakeholders in developing transformative visions and pathways that reflect the diverse realities across Europe and maximise environmental, social and economic co-benefits. Use resource nexus and ecosystem-based management approaches to avoid burden shifting, respect environmental limits and achieve integrated management of natural resources.

- **Reorient public budgets, private investments and financial markets towards promoting sustainability transitions** — by making full use of public resources to invest in innovations and nature-based solutions, procure sustainably and support affected sectors and regions. Develop and adopt metrics for measuring society's progress towards sustainability that go beyond GDP. Mobilise and direct private spending by shaping investment and consumption choices, including through environmental fiscal reform and removing harmful subsidies. Engage the financial sector in sustainable investment by implementing and building on the EU's sustainable finance action plan.

- **Develop knowledge and skills fit for the 21st century** — focusing on understanding the key systems driving sustainability challenges and opportunities for change. Build capacity to navigate a rapidly changing world by investing in education, life-long learning and R&D programmes focused on sustainability. Harness the potential of new digital technologies to generate and share relevant knowledge that support all decision-makers to make choices consistent with pathways to sustainability.

The extent of the environmental and climate crisis is clear. Calls for action have been made across society and SOER 2020 confirms the urgent need for transformative change. Now is the time to act.

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CHAPTER 17 — RESPONDING TO SUSTAINABILITY CHALLENGES

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