Chapter 21

Future Developments Without Targeted Policies

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Executive summary

Together with other tools, model-based scenario analysis provides a useful method to explore whether environment related targets of the Sustainable Development Goals (SDGs) and related Multilateral Environmental Agreements (MEAs) are going to be achieved *(well established)*. Assessing whether current trends are leading to fulfilment of the selected targets outlined in Chapter 20 is complex: it requires insights into the interactions of different trends and systems, inertia and cross-scale relationships. A combination of qualitative storylines and quantitative scenario tools can help to explore possible futures trends, while taking the many complexities into account. While scenarios can never be forecasts, because surprises may occur, they can inform decision makers of the likely implications of current trends. {21.2}

An assessment of the scenario literature concludes that a continuation of current trends will probably not lead to fulfilment of selected environment related targets of the SDGs and related MEAs *(well established)*. **While some improvement is projected for indicators related to human development – albeit not fast enough to meet the targets – those related to the natural resource base are projected to move further in the wrong direction** *(established, but incomplete)*. Projected ongoing population growth, and economic development imply that the demand for food, water and energy will strongly increase towards 2050. At the same time, business-as-usual scenarios show a clear improvement over time in reducing hunger, increasing access to safe drinking water and adequate sanitation, and increasing access to modern energy services, but not fast enough to meet the related SDG targets by 2030. Furthermore, although projected improvements in resource efficiencies across the board (agricultural yields, nutrient use efficiency, water use efficiency and energy efficiency) will somewhat limit the impacts of resource use on the environment, these improvements are not enough to reduce the pressure on already stressed environmental systems. As a result, trends in environmental degradation are projected to continue at a rapid rate. Related targets are not achieved. {21.4}

Under current trends, environmental pressures related to the agricultural and food system will further increase *(well established)***.** As the global population and per capita incomes are projected to grow, both per capita and total food consumption expected to rise. At the same time, the number of undernourished people is projected to decline to 300-650 million in 2030, a figure that still significantly exceeds the target for ending global hunger. Furthermore, food production and land use are directly related to many environmental problems. Global agricultural demand is projected to increase by 50-60 per cent. Over the last decades, around four-fifth of the increase in food demand was met by agricultural intensification, and one-fifth by an increase in agricultural area. This trend is expected to more or less continue. Together, food production systems will continue to contribute to land expansion, increasing water demand and nutrient runoff, biodiversity loss and land degradation. Related targets are not achieved. {21.3.2}

Without new policies, the objectives of the Paris Agreement are not achieved *(well established)***.** Primary energy supply is projected to grow by 50-70 per cent between 2010 and 2050**.** Moreover, fossil fuels are expected to remain prominent in the world energy system. As a result, energy use is expected to continue to be the main cause of greenhouse gas (GHG) emissions. In addition, the agricultural systems and land use will continue to contribute to GHG emissions. Current and planned climate policies, as formulated by different countries under the Paris Agreement of the United Nations Framework Convention on Climate Change, are expected to lead, at best, to a sstabilization of emissions. This is considerably less than would be needed to achieve the objectives of the Paris Agreement, i.e. to keep the temperature well below 2°C, and if possible below 1.5°C. Achieving these objectives would require an almost complete decarbonization of the energy system. {21.3.3}

Ambient air pollution is expected to continue to contribute to millions of premature deaths in the coming decades *(established but incomplete)***.** There are different forms of urban and regional air pollution. Exposure to ambient fine particulate matter ($PM_{2.5}$) is estimated to have caused approximately 4 million premature deaths in 2016 and can be used as an indicator of adverse health effects of ambient air pollution. Without stringent policies to control air pollution, ambient $PM_{2.5}$ concentrations are expected to increase. Most trend scenarios assume that past trends of stricter air pollution policies coupled with increasing incomes continue in the future, i.e. that more stringent air pollution policies are applied in developing countries as their incomes increase, thereby projecting a slow decrease in emissions of $PM_{2.5}$ and its precursors in most global regions. However, this trend would still not be sufficient to reduce $PM_{2.5}$ concentrations below the least stringent air quality target of the World Health Organization (WHO) in large parts of Asia, the Middle East and Africa, resulting in 4.5 to 7 million premature deaths globally by mid-century {21.3.3}

Global water scarcity and the population affected by it are expected to increase *(established, but incomplete)*. Global human water demand is projected to increase by around 25 to 40 per cent this century. The rise is primarily driven by rapid population growth and increased industrial activities (higher electricity and energy use) in developing countries. An increase in irrigated area and irrigation intensity is also projected, but its effect will probably be compensated by improvements in irrigation efficiency in regions with strong economic development. Changing rainfall patterns will exert additional pressure on regional water availability. By 2050, the Asian population living in areas exposed to severe water stress is projected to increase by around 50 per cent compared with 2010 levels, putting severe pressure on non-renewable groundwater reserves. {21.3.4}

Oceans are expected to continue to be polluted and overexploited *(established, but incomplete).* Nutrient (nitrogen and phosphorus) flows from freshwater into world oceans exceed sustainable levels and as a result the risks of dead zones and toxic algae blooms in coastal areas are projected to increase. This is largely related to increased fertilizer use in agricultural production and developments in wastewater treatment that are lagging behind improvements in access to sanitation. As a result of an increasing concentration of carbon dioxide (CO_2), oceans are expected to further acidify, negatively affecting marine organisms' ability to create shells and skeletons or even resulting in their dissolution. Acidification is expected to increase most rapidly in polar regions. Finally, under current fishing strategies, the projected increase in demand for fish is expected to reduce the proportion of fish stocks that remain at biologically sustainable levels. {21.3.5}

Preventable environmental health risks are projected to remain prominent in 2030, with related negative impacts on child mortality *(established, but incomplete).* Nearly one-quarter of all deaths globally in 2012 can be attributed to environmental factors, with a greater portion occurring in vulnerable populations (children and the elderly) and in developing countries. Prominent environmental risk factors – i.e. exposure to ambient air pollution, and not having access to clean water, adequate sanitation or modern energy services – together with global hunger are expected to improve towards 2030, but not fast enough to achieve related targets in all countries. Related global child mortality is projected to decline, but not enough to achieve the SDG targets in many developing countries. Especially in sub-Saharan Africa, child mortality rates remain high, with a continued, although smaller, share related to preventable environmental risk factors. {21.3.6}

21.1 Introduction

Chapter 20 provided an overview of environment related targets that the international community committed to support, based on the Sustainable Development Goals (SDGs) and a range of Multilateral Environmental Agreements (MEAs). This chapter examines the international scenario literature to assess to what extent current and long-term trends are in line with achieving these targets, and to understand and highlight potential implementation gaps.

21.2 Global environmental scenarios

Environmental and sustainable development targets are usually formulated for a time period somewhere in the future. In an effort to inform decision makers concerned with global environmental and sustainability challenges, Global Environmental Assessments (GEA) explore possible futures, with a special focus on investigating the consequences of current trends and assessing whether the committed goals and targets are going to be met (Clark, Mitchell and Cash 2006; van Vuuren *et al.* 2012). This is not straightforward: clearly, no one knows which path the world will take in the next 40 years, and world views influence our expectations of this path. Assessments deal with the outlook component and the uncertainty involved in different ways. Some use a reference scenario that captures a likely future state. Others use multiple scenarios reflecting different storylines. In all cases, the scenarios are "plausible descriptions of how the future developments might evolve, based on a coherent and internally consistent set of assumptions ("scenario logic") about the key relationships and driving forces (i.e. the technology, economy, environment interplay)" (Nakicenovic *et al.* 2000). Often a storyline is quantified within a model. While model-based quantification can help to take account of the many relationships that exist across scales, between regions, in time and across various sectors and environmental problems, the storyline elements help to ensure consistency for other elements that are more difficult to quantify. The main purpose of this scenario methodology is to be as scientifically rigorous as possible, while providing policy relevant information (van Vuuren *et al.* 2012).

Over the past few years, a large number of environmental assessment reports has been published. Many of these focus on specific environmental issues, such as climate change (Intergovernmental Panel on Climate Change [IPCC] 2014a), biodiversity loss (Secretariat of the Convention on Biological Diversity [SCBD] 2014) and the management and restoration of land resources (United Nations Convention to Combat Desertification [UNCCD] 2017). These can ensure the input of scientific information into decision-making processes for the three Rio conventions, i.e. UNFCCC, CBD and UNCCD, respectively. Other environmental assessments have a less clear focus on specific decision-making processes. More sectoral environmental assessments address key drivers of environmental change, for example, the global energy system (Global Energy Assessment [GEA] 2012; International Energy Agency [IEA] 2017a) and the global agricultural system (Organisation for Economic Co-operation and Development [OECD] and the Food and Agriculture Organization of the United Nations [FAO] 2017). Finally, some environmental assessments look more closely at the interrelations between environmental issues and how they relate to human development. Examples include the Millennium Ecosystem Assessment (Millennium Ecosystem Assessment [MEA] 2005) and the United Nations Environment Programme's (UNEP) Global Environment Outlook reports (e.g. UNEP 2012).

Interestingly, a limited number of key archetypical scenarios, or scenario families, reappear in many of these assessments (van Vuuren *et al.* 2012). The term 'scenario family' denotes a set of scenarios in the literature that share a similar storyline or logic, resulting in a similar kind of quantification. Based on these key elements, van Vuuren *et al.* (2012) identified six scenario families:

i. economic-technological optimism/conventional markets scenarios;
ii. reformed market scenarios;
iii. global sustainability scenarios;
iv. regional competition/regional markets scenarios;
v. regional sustainable development scenarios; and
vi. business-as-usual or trend scenarios.

None of these scenarios is a prediction or forecast of the future. They are only meant to explore plausible future development pathways.

This chapter focuses on business-as-usual or trend scenarios. This type of scenario assumes that basic socioeconomic mechanisms continue to operate as they did in the past, and that no explicit new policies are introduced to meet specific policy targets. We assess the scenarios literature to analyse to what extent current and long-term trends are in line with achieving the environment-related targets of the SDGs and related MEAs (see selection of targets in Chapter 20), and to understand and highlight potential implementation gaps. The scenario assessment is used as a benchmark against which possible alternative future development pathways, that aim to achieve the selected targets simultaneously, are evaluated (see Chapter 22).

Box 21.1: Waste as an important cause of environmental degradation

Part A of the sixth Global Environment Outlook (GEO-6) identified a number of consistent waste management issues of global concern, especially food waste and marine litter. It also pointed to a growing disparity across regions. Developed regions generate some 56 per cent of food waste, compared with 44 per cent in developing regions. Also, while developed regions increasingly invest in circular economy measures, about 3 billion people lack access to controlled waste disposal facilities, generating both health risks and environmental impacts. Plastic waste is of particular concern. However, there is a general lack of future waste flow studies, and such scenarios are mostly missing from the literature. Chapters 21 and 22 therefore do not discuss waste as a separate issue. Nevertheless, the problem of waste management is central to achieving several SDGs, and policies to address the growing waste problem will need to carefully consider both demand reduction and supply side restructuring.

Box 21.2: The Shared Socioeconomic Pathways

The Shared Socioeconomic Pathways (SSPs) are five distinct global pathways describing the future evolution of key aspects of society that together imply a range of challenges for mitigating and adapting to climate change (O'Neill *et al.* 2017; Riahi *et al.* 2017). They have been developed into storylines and quantitative measures for a broad range of issues, including energy and land-use developments and related GHG emissions, based on scenarios and various other methods. As they are formulated relatively broadly and cover a wide range of possible futures, they are also used extensively for other fields of environmental research and assessment. The five SSPs are:

i. sustainable development (SSP1);
ii. the middle road (SSP2);
iii. a fragmented world (SSP3);
iv. inequality (SSP4); and
v. fossil fuel-based development (SSP5).

The SSPs are not policy-free; they include all kinds of assumptions on policies. However, since they were formulated specifically to support climate change research and assessment, the reference scenario versions of the SSPs are free of climate policy beyond the base year. The SSPs are certainly not free of environmental and sustainable development policies. In fact, key elements in SSP1, for instance, are low population growth, economic convergence, rapid technology development of environmentally friendly technologies and the introduction of environmental policies. By contrast, in SSP3 the fragmented world leads to high population growth, slow economic development and a focus on security issues; and thus, little priority for environmental issues.

Box 21.3: The need for coordination among environmental assessments

There are currently several assessments that include an outlook component and focus on specific SDGs. These include the Global Biodiversity Outlook, the Global Land Outlook, the Intergovernmental Science-Policy Platform on Biodiversity and Ecosystem Services, and the Global Environment Outlook. As highlighted in the 2030 Agenda for Sustainable Development, it is clear that the SDGs cannot be achieved without taking into account important synergies and trade-offs across these goals (see also Section 22.4.2). For this reason, it will become increasingly important to coordinate the work across the various assessments, and check whether the key findings address the SDG agenda as a whole.

Not all relevant issues are addressed equally in the scenario literature. For instance, there are many scenarios published on climate change, while only a few scenario studies focus on water pollution. Other issues of global concern, such as chemicals and waste, are hardly addressed in the scenario literature **(see Box 21.1)**. The available literature thus limits the scope of the analysis. As a result, not all relevant issues that are discussed in Part A of GEO-6, such as chemicals and waste, are covered in the analysis in Chapters 21 and 22.

A widely used set of scenarios are the Shared Socioeconomic Pathways (SSPs; see **Box 21.2**). The SSPs were developed principally to support climate research (van Vuuren *et al.* 2014; Riahi *et al.* 2017) but are also used extensively for other fields of environmental research and assessment. They explore a wide set of possible futures. Within the set, SSP2 is a scenario that represents medium developments for key drivers such as population, economic growth and technology development. Our assessment focuses on business-as-usual or trend scenarios, using the middle-of-the-road SSP2 scenario as a common thread across the different issues discussed. Other trend scenarios are used where relevant. Furthermore, SSP3 scenario results are shown where possible to indicate the risk of higher population growth.

21.3 The achievement of SDGs and related MEAs in trend scenarios

Business-as-usual or trend scenarios, as discussed in Section 21.2, are used to assess to what extent current and long-term trends are in line with achieving selected SDG targets **(see Tables 20.1 and 20.2)**. Achievement of the selected targets is assessed in five distinct clusters of closely related environmental issues **(see Figure 21.1)**. While interlinkages across these clusters exist, presenting them in these five clusters allows a more focused discussion. Four of the five clusters are closely related to the five environmental themes discussed in Part A (air, biodiversity, oceans, land and freshwater). Biodiversity and land are clustered together, as they are both strongly linked to developments in agriculture. In addition, human health is discussed as an individual cluster.

21.3.1 Drivers

There are several key drivers of global environmental change. Here, we focus on population, urbanization and economic development. While climate change is discussed as a driver in Chapter 2, given that it cannot be influenced in the short term, it is assessed here as a global environmental challenge, as part of the energy, climate and air cluster. The role of technology is also discussed within the different clusters, primarily in the context of efficiency of resource use. It should be noted that (un)sustainable consumption and production practices also play a key role (see Section 2.5).

Population

The United Nations' World Population Prospects (United Nations 2017) and the population scenarios underlying the SSPs (Samir and Lutz 2017) are among those mainly used in the literature (see Section 2.2). The scenarios share important characteristics: they project population growth to continue and to reach a level of around 8.5 billion by 2030 and around 9-10 billion by 2050 **(see Figure 21.2)**. The high population growth scenarios, such as SSP3, are typically associated with slow improvements in human development. Low population projections result from a relative rapid drop in fertility rates. More than half the anticipated growth is expected to occur in Africa and around 30 per cent in Asia (mainly South Asia). After 2050, Africa is projected to be the only region experiencing substantial population growth.

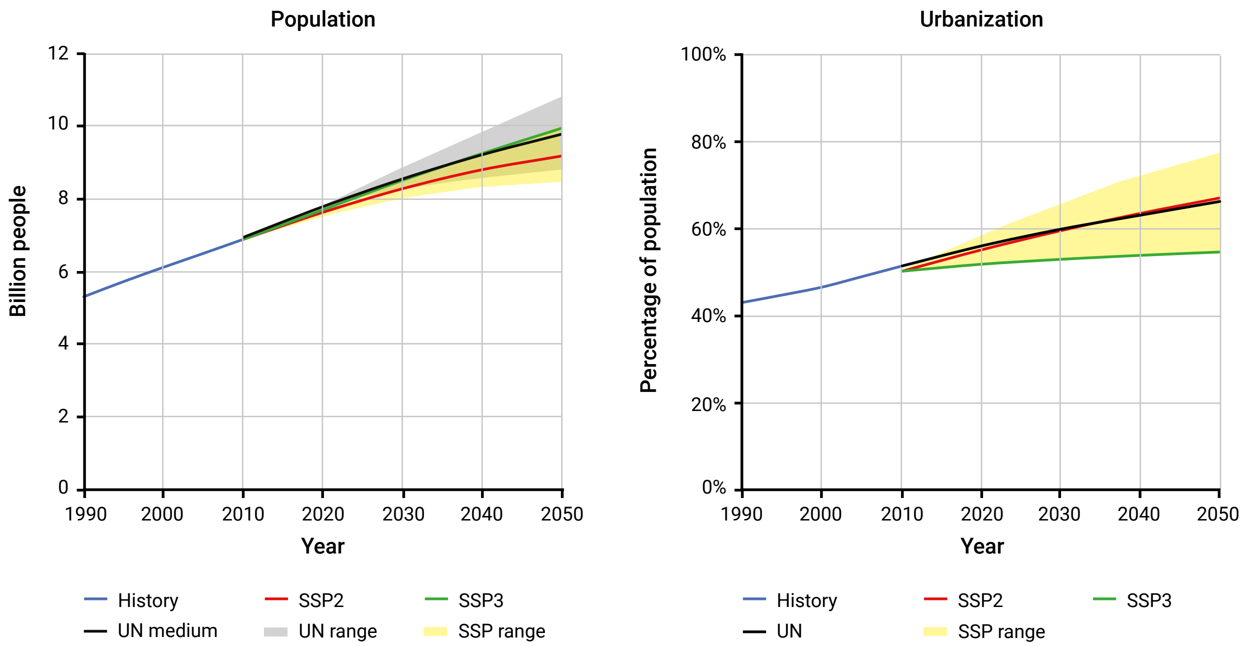
Urbanization

On a global scale, more people currently live in urban compared to rural areas (see Section 2.3). Urbanization levels differ significantly across world regions, with more than 80 per cent of the population living in urban areas in Latin America and the Caribbean, and only around 40 per cent in Africa. Urbanization is projected to increase in all regions, with average global urbanization levels growing to around 60 per cent in 2030 and 67 per cent in 2050 under the United Nations' World Urbanization prospects and SSP2 (United Nations 2014; Jiang and O'Neill 2017) **(see Figure 21.2)**. Together with an increasing overall population, the global urban population is projected to grow by more than two-thirds between now and

Figure 21.1: Selected targets and their related clusters as examined in this chapter

	Agriculture, food, land and biodiversity	Energy, air and climate	Fresh water	Oceans	Human health
Human well-being	• End hunger	• Achieve universal access to modern energy services	• Achieve universal access to safe drinking water and adequate sanitation	• End hunger	• End preventable deaths of children under 5
Sustainable consumption and production	• Increase agricultural productivity • Increase nutrient use efficiency	• Increase energy efficiency • Increase the share of renewable energy	• Increase water-use efficiency	• Increase agricultural productivity • Increase nutrient use efficiency	
Natural resource base	• Achieve land degradation neutrality • Halt biodiversity loss	• Limit global warming • Improve air quality in cities	• Reduce water scarcity • Improve water quality	• Sustainably manage ocean resources • Minimize ocean acidification • Reduce marine nutrient pollution	

Figure 21.2: Future projections of the global population (left) and urbanization (right)



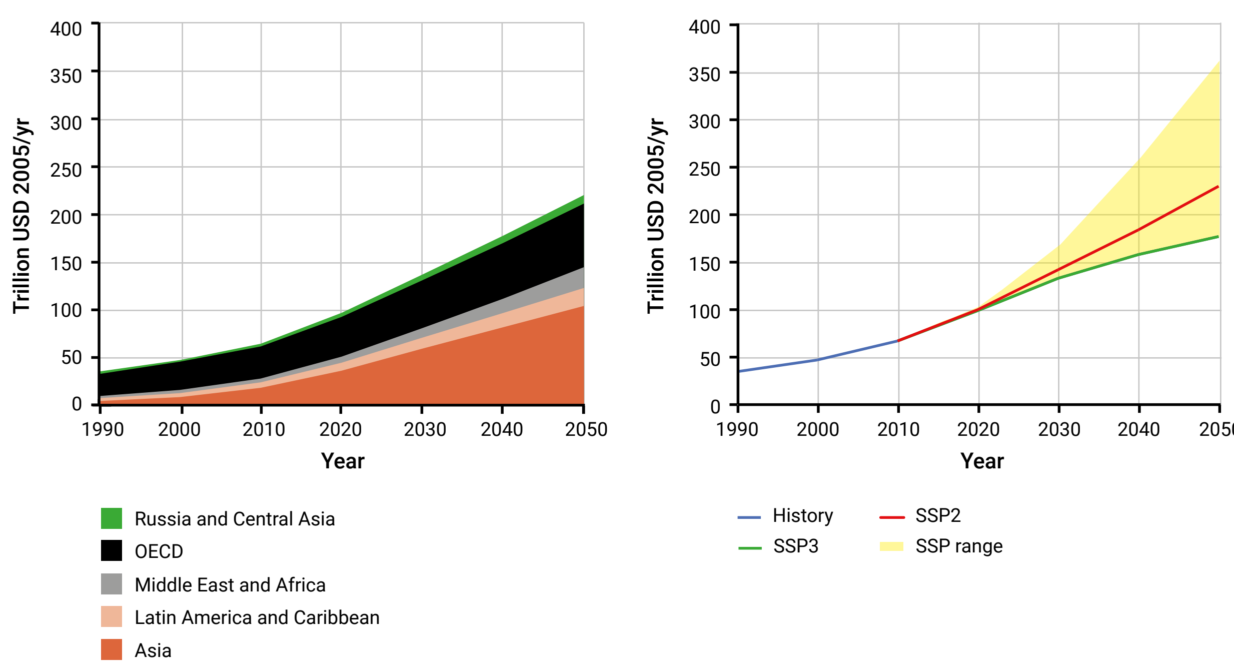
Source: SSP projections (Jiang and O'Neill 2017; Samir and Lutz 2017); UN projections (United Nations 2014; United Nations 2017).

2050, with an increase of nearly 90 per cent in Africa and Asia (United Nations 2014). Under SSP3, assumptions on slow economic development coincide with a slower urbanization rate. Still, as total population growth is much higher, the urban population is projected to increase significantly.

Economic development

In the past 30 years, the world economy grew on average by 3.5 per cent per year, a rate buoyed by strong economic growth in emerging economies in Asia (see Section 2.4). Most economic institutes only publish projections for the coming decade or shorter. In fact, most long-term economic projections are developed as part of environmental

Figure 21.3: Future projections of total GDP per region under SSP2 (left) and global GDP under SSP2 and SSP3 (right)



Source: Dellink *et al.* (2017).

assessments. The SSPs project the historic growth to continue, with around 3.1 per cent per year under SSP2 and 2.5 per cent under SSP3 (Dellink *et al.* 2017). For OECD countries, the projected economic growth is somewhat lower than the historical rate (1.7 per cent under SSP2), with annual growth declining over time due to ageing of the population. By contrast, low-income countries are projected to grow by around 3-5 per cent per year. Due to currently scarce capital inflows and high returns on capital investments, the potential for growth in labour and capital productivity is strong. For Asian countries, the projected growth rates are slightly lower than the rapid historical rates, further diminishing over time as a result of the maturing of their economies, with productivity levels approaching those of OECD countries. By contrast, growth rates are higher in Latin America and the Caribbean as well as Middle East and North Africa. While this implies that in relative terms there is some convergence between different parts of the world, the gaps remain significant. In terms of relative shares, these projections imply a strong shift. For instance, the OECD countries' current share of the global economy under SSP2 is projected to fall to less than one-third (compared with around one-half at present), while Asia's share is projected to grow to almost 50 per cent.

The economic projections also have implications for poverty. Historically, absolute poverty, as indicated by the number of people living on less than US$1.90 a day, fell from 1.85 billion in 1990 to fewer than 800 million in 2013 (World Bank 2016a). Projections for 2030 range from 100 million to more than 1 billion, with most studies suggesting a level of 400 to 600 million people (Chandy, Ledlie and Penciakova 2013; Burt, Hughes and Milante 2014). The variation in the scenarios is due to the large differences in assumptions about growth in household consumption and changes in income distribution.

21.3.2 Agriculture, food, land and biodiversity

Food production and land use are directly related to a range of environmental problems (see Chapter 8). As population and incomes are projected to rise, food consumption, both per capita and total, is also expected to rise (Bijl *et al.* 2017; Popp *et al.* 2017). In 2050, estimated total crop production (food, feed and biofuels) ranges from 5,800 million tons per year to 8,300 million tons per year, an increase of 50 to 130 per cent from 2010 levels (Tilman *et al.* 2011; Popp *et al.* 2017), though most projections suggest an increase of 50 to 60 per cent.

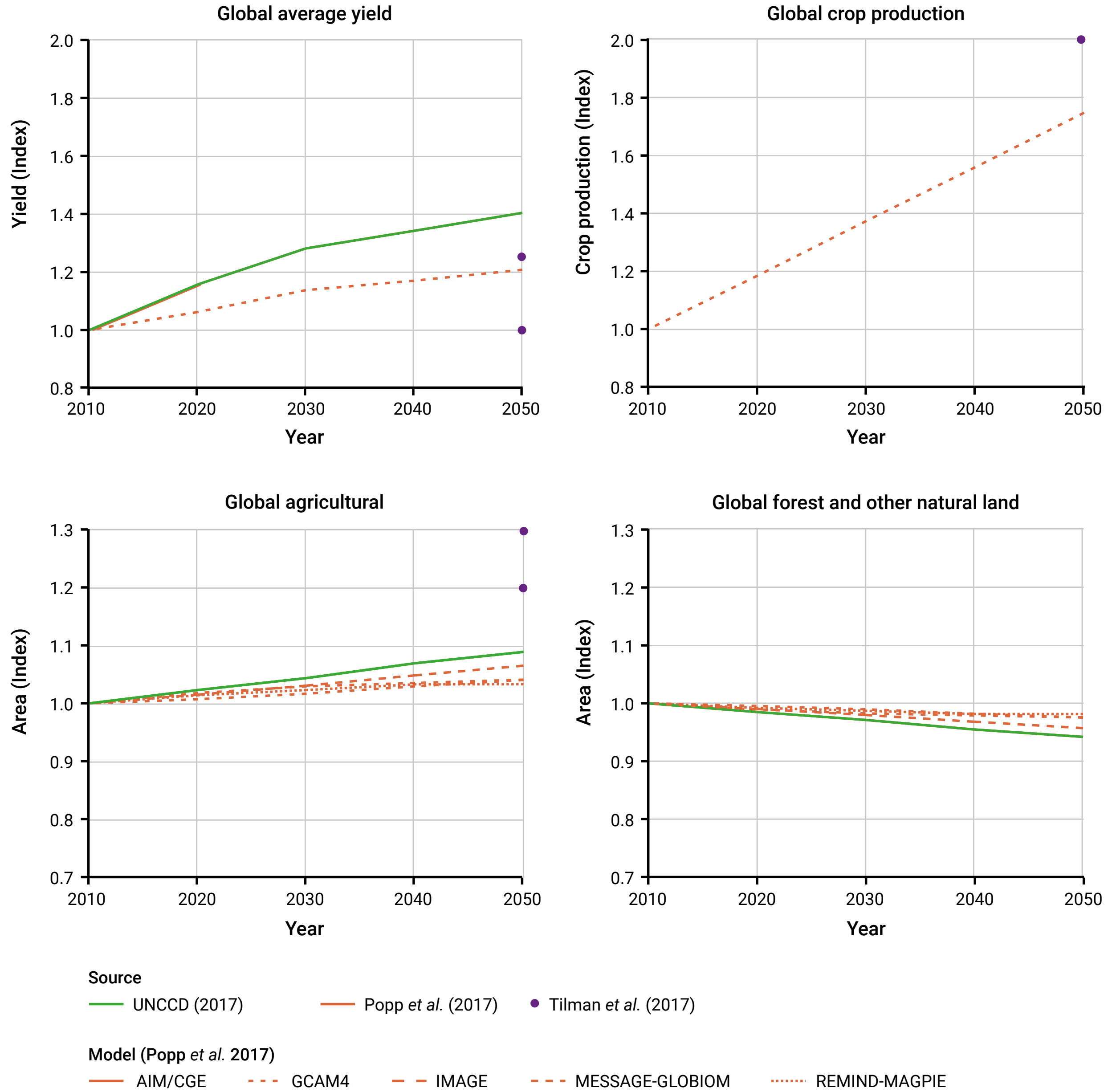
Over the last decades, globally, about 80 per cent of the increase in food demand was met by agricultural intensification (increase in crop yields and move towards more intensified animal husbandry systems) and 20 per cent by an increase in agricultural area (Smith *et al.* 2010). These shares are projected to more or less continue into the future. The net result is an increase in total agricultural area (cropland and pasture) in 2050 of 3-9 per cent (Popp *et al.* 2017). Given that, in a number of regions the most productive lands have already been put to use, land expansion takes place on less productive land, requiring more area per ton of production (van der Esch *et al.* 2017). Overall, expansion comes at the expense of forests and savannahs, which are home to important biodiversity hotspots, carbon sinks and other ecosystem services (CBD 2014).

Overall, cereal yields are projected to increase by 0.4 to 0.9 per cent per year between 2010 and 2050 (Alexandratos and Bruinsma 2012; Popp *et al.* 2017), down from 1.9 per cent per year between 1961 and 2007 (Alexandratos and Bruinsma 2012). These future yield increases will be achieved through a combination of changes in fertilizer application, irrigation use and other means (e.g. mechanization, breeding), potentially increasing environmental pressures.

Box 21.4: Climate change impacts on agriculture

In the business-as-usual scenarios, global mean temperature is expected to increase to more than 2°C in 2050 and 2.5-6°C in 2100 (IPCC 2014b). For agriculture, such climate change is expected to pose significant risks by changing seasonal rainfall patterns, increasing peak temperatures, increasing the frequency and severity of droughts, increasing the risk of catastrophic events (storms) and disrupting ecosystem services to agriculture. This could clearly have a negative impact on the ability of the agricultural system to achieve the SDGs with respect to hunger, sustainable agriculture and protection of biodiversity. Projected impacts vary across crops and regions, and for different adaptation scenarios. In general, tropical regions are expected to experience more severe negative impacts than temperate regions – and they do so at lower levels of warming (in the historical period, stronger impacts in temperate regions have been reported according to IPCC). If adaptation to climate change is implemented, yields may increase, particularly in temperate regions, via the combined effect of climate change and CO_2 fertilization. According to the IPCC assessment, after 2050 there is a greater risk of more severe impacts. The combination of the growing demand for food and a temperature rise in the high end of the projections, implies substantial risks to food security at global and regional levels.

Figure 21.4: Future projections of global average crop yield (top left), crop production (top right), agricultural area (bottom left), and forest and other natural land area (bottom right)

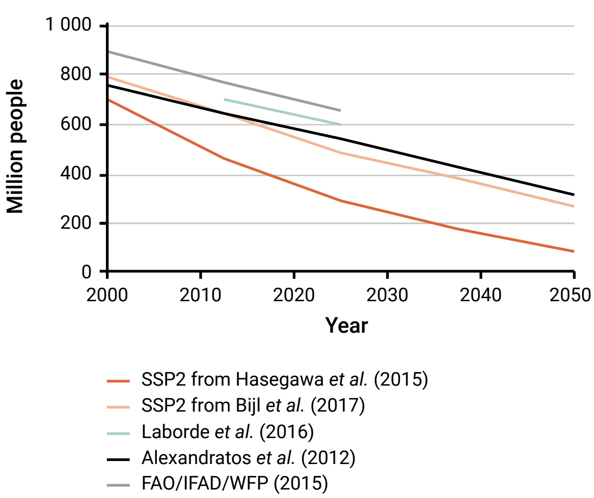


Source: Tilman *et al.* 2011; Popp *et al.* 2017; UNCCD 2017. For Popp *et al.* (2017), only results from the SSP2 scenario are shown. For Tilman *et al.* (2011), only the 'current tech' scenario with fertilizer use greater than or equal to today's values are shown.

Trends in hunger

A key challenge in this cluster is ending hunger by 2030 (SDG target 2.1). Between 2005 and 2014, global hunger has decreased, both in absolute and relative terms. However, since 2014 hunger has been on the rise, with an estimated 815 million people being undernourished in 2016 (FAO *et al.* 2017). Global models project a decrease in the undernourished population towards 2030, driven mostly by an expected income increase in current low-income regions (Alexandratos and Bruinsma 2012; Hasegawa *et al.* 2015; Laborde *et al.* 2016; Bijl *et al.* 2017; FAO *et al.* 2017). These projections are generally based on data from before 2014, and therefore do not include the recent rise in levels of hunger. Differences in historic hunger levels generally relate to the year that the model switches from historic data to model projections (here mostly 2005 or 2010). The number of undernourished people across the different studies is projected to be 300- 650 million people in 2030 and around 100 to 300 million in 2050 **(Figure 21.5)**. While this represents an improvement compared with today's figures, these levels significantly exceed the target of ending hunger by 2030.

Figure 21.5: Future projections of global undernourished population



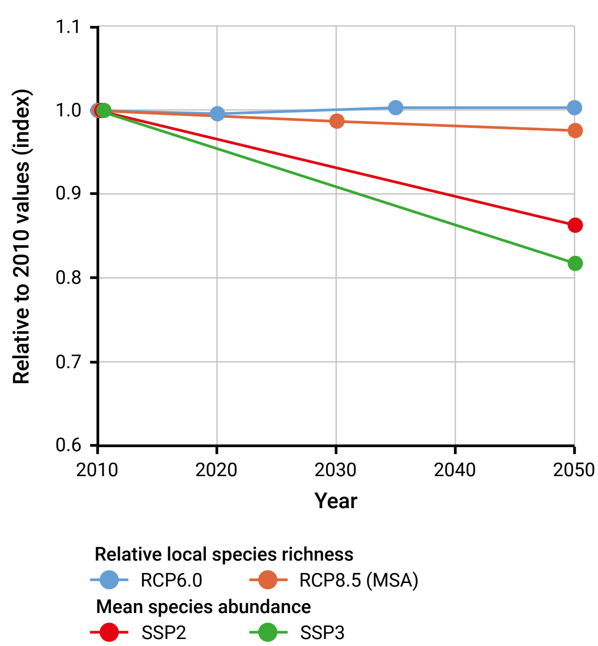
Source: Alexandratos and Bruinsma 2012; FAO, International Fund for Agricultural Development and World Food Programme 2015; Hasegawa *et. al* 2015; Laborde *et al.* 2016; Bijl *et al.* 2017.

Trends in biodiversity loss

As discussed in Chapter 6, biodiversity loss has a number of causes (SDG target 15.5). Most scenario studies have ascertained that natural habitat loss has been, and still is, the single most important factor causing biodiversity loss (Millennium Ecosystem Assessment 2005; Newbold *et al.* 2015). However, trends in water scarcity, climate change, pollution and disturbance all drive a further decline in biodiversity, while business-as-usual scenarios show that many of these factors are likely to worsen in the future (SCBD 2014; Kok *et al.* 2018). Climate change is projected to become a major cause of biodiversity loss, with species impacted by a range of factors including: temperature increase, altered precipitation patterns and rising sea levels. Climate change is also projected to alter the distribution of biomes over the coming century, with one-tenth to one-half of global land being highly vulnerable to biome shifts under climate change (Gonzalez *et al.* 2010). Boreal forests may be particularly vulnerable (Gonzalez *et al.* 2010; Gauthier *et al.* 2015), but projections also show that 5-6 per cent of land area in Latin America could undergo biome shifts as a result of climate change by the end of the century (Boit *et al.* 2016). The combination of anthropogenic drivers could push some regional social-ecological systems beyond tipping points and transition them to states with severely reduced biodiversity and ecosystem services (Leadley *et al.* 2014).

Studies published after Global Biodiversity Outlook-4 provide further consensus that biodiversity will continue to decline under business-as-usual scenarios. Model projections suggest changes in a number of different dimensions of biodiversity. The Global Land Outlook provides projections of Mean Species Abundance (MSA), a measure of the intactness of ecosystems, projecting a further increase of MSA loss: from 34 per cent in 2010 to 43 and 46 per cent in 2050, under SSP2 and SSP3, respectively (van der Esch *et al.* 2017; **Figure 21.6**). Using scenarios of land-use change consistent with the IPCC's Representative Concentration Pathway (RCP) 8.5, Newbold *et al.* (2015) projected a fall of local species richness by 3.4 per cent by 2100 **(see Figure 21.6)**. The combination of climate and land use change for the same RCP scenario is projected to lead to a cumulative loss of 38 per cent of species from vertebrate communities (Newbold 2018). Many of the effects are concentrated in biodiverse but economically disadvantaged countries (Newbold *et al.* 2015) and in tropical grasslands and savannahs (Newbold 2018). Furthermore, an extrapolation of the Living Planet Index (LPI), a measure of changes in

Figure 21.6: Future projections of relative local species richness for a range of climate stabilisation scenarios and Mean Species Abundance (MSA) for SSP2 and SSP3 land-use



Source: Relative species richness from Newbold *et al.* 2015; Mean species abundance from van der Esch *et al.* 2017 terrestrial, marine and freshwater vertebrate populations, suggests that by 2020 populations will have declined by 67 per cent, on average, compared to their 1970 population size (World Wide Fund for Nature [WWF] 2016). Population sizes of mammalian carnivores and ungulates are also projected to decline under future land use and climate change (Visconti *et al.* 2016). Declines of 18-35 per cent by 2050 were projected in a LPI-like index, base on species dispersal ability. These abundance declines are associated with an 8-23 per cent increase in the risk of extinction (Visconti *et al.* 2016).

Trends in land degradation

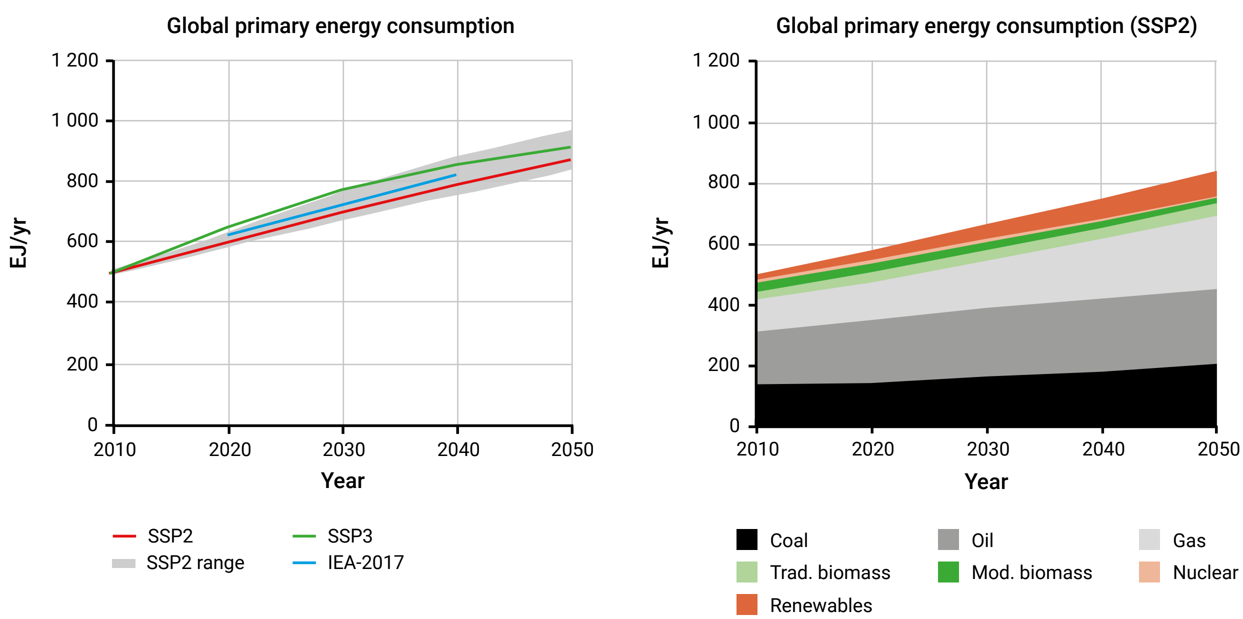
Land degradation (SDG target 15.3) is a major problem worldwide, and is linked to food insecurity, vulnerability to climate change and poverty, as well as to mitigation of GHG emissions (UNCCD 2017; van der Esch *et al.* 2017). Estimates of the number of people affected by land degradation vary between a low range of 1.3-1.5 billion (Bai *et al.* 2008; Barbier and Hochard 2016; see Chapter 8) and much higher estimates of 3.2 billion (Intergovernmental Science-Policy Platform on Biodiversity and Ecosystem Services [IPBES] 2018). Although a significant proportion of those affected are poor rural inhabitants living on marginal lands, land degradation also occurs in prime agricultural lands due to mismanagement and/or overgrazing. For example, in Brazil, more than half of all pastures are in an advanced state of degradation, causing significant loss of productivity (Strassburg *et al.* 2014; Assad *et al.* 2015). In fact, expansion and unsustainable practices in agriculture and livestock production are the most important direct drivers of land degradation (IPBES 2018).

Globally, between 1982 and 2010, when correcting for climate effects, a declining trend in net primary productivity (NPP) is observed in about 12 per cent of agricultural land and in about 5 per cent of natural land (Schut *et al.* 2015; van der Esch *et al.* 2017). Regionally, the Russian Federation/Central Asia and sub-Saharan Africa have about double the share of agricultural land with a declining NPP (Schut *et al.* 2015; van der Esch *et al.* 2017). Compared to an undisturbed state, current NPP is estimated to be significantly lower on 28 million km^2, or 23 per cent, of the global terrestrial area, corresponding to about a 5 per cent loss in global NPP (Smith *et al.* 2016; van der Esch *et al.* 2017). Soil degradation involves, among other things, soil erosion and loss of soil organic carbon. Historically, around 176Gt of soil organic carbon (8 per cent) has already been lost as a result of land-use changes, including the conversion of natural land to agriculture, and overgrazing in grasslands (Stoorvogel *et al.* 2017a; Stoorvogel *et al.* 2017b). As a consequence of continued land conversion and unsustainable land management, an additional 27Gt of soil organic carbon is projected to be lost between 2010 and 2050, affecting agricultural yields through reduced water-holding capacity and loss of nutrients (van der Esch *et al.* 2017). Furthermore, losses in soil organic carbon will have wider effects on biodiversity, hydrology and carbon emissions. Further land degradation is expected to occur based on trends in land use **(see Figure 21.4)**, climate change and increasing pressure on land and water resources. Land degradation is especially of concern in drylands, where, by 2050, human populations are projected to increase by 40 to 50 per cent under the SSP2 scenario, which is far greater than the 25 per cent increase projected for non-drylands (van der Esch *et al.* 2017). Overall, these trends show that without targeted policies, a land degradation neutral world will not be achieved.

21.3.3 Energy, air and climate

The energy system plays a crucial role in achieving sustainable development. The use of energy is a prerequisite for human welfare. At the same time, current energy consumption and production patterns contribute strongly to climate change and air pollution. In the next few decades, energy demand

Figure 21.7: Future projections of global primary energy consumption (left panel) and per energy carrier in the SSP2 marker scenario (right panel)



Source: SSP Public Database 2016; IEA 2017a ; Riahi *et al.* 2017.

is expected to increase further, driven by population growth and related human activities. Overall, most scenarios project a 50-70 per cent increase in primary energy demand over the 2015-2050 period. This is despite a projected decrease in energy intensity of around 1-2.5 per cent per year, similar to that achieved historically (e.g. van Vuuren *et al.* 2016; Riahi *et al.* 2017). Although renewables are by far the fastest growing form of energy, fossil fuels continue to contribute the lion's share of total energy supply in scenarios without new policies. In most business-as-usual scenarios, the renewable energy share increases from 15 per cent in 2015 to around 20-30 per cent in 2050 (full range 10-30 per cent) (van Vuuren *et al.* 2016). Renewables started from a small share in 2015 and are mostly successful in replacing fossil fuels in the power sector, which constitutes an important but limited part of total energy consumption. Scenario studies specifically examining the impact of policies formulated by countries as part of their pledges under the Paris Agreement often have a somewhat lower energy demand and faster growth of non-fossil energy, but at best these result in a stabilization of fossil fuel demand.

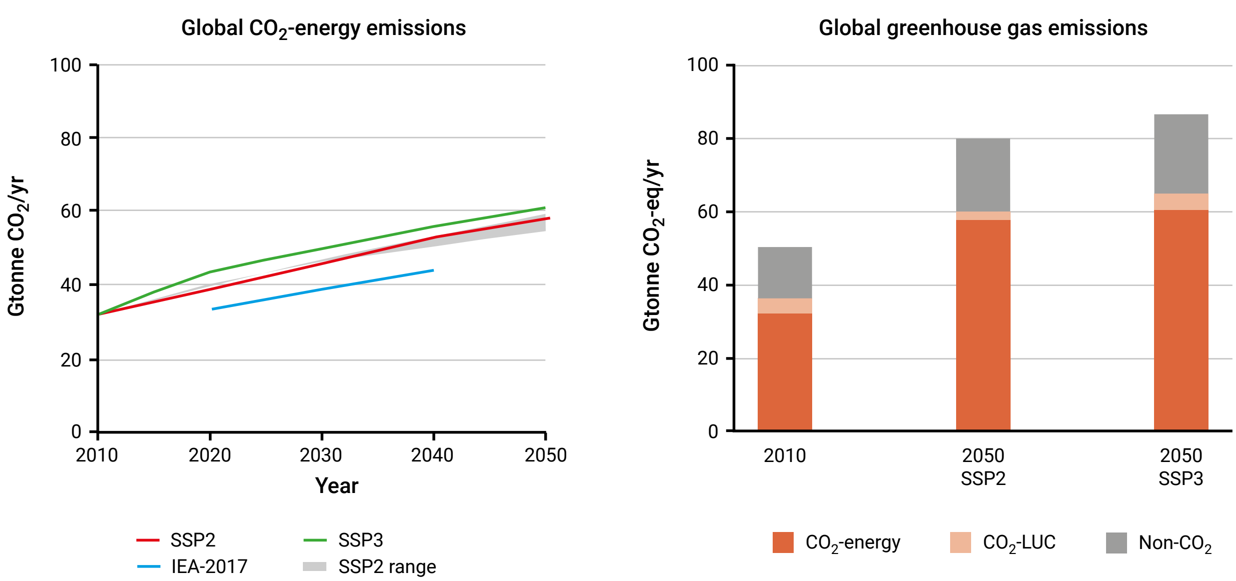
Trends in access to modern energy services

Access to modern energy services (SDG target 7.1) is an important prerequisite for human development (IEA 2017b). Currently, around 2.8 billion people worldwide rely on traditional biomass, kerosene and coal – fuels not considered to be clean – while 1.1 billion people do not have access to electricity (IEA 2017b). Exposure to household air pollution, caused by the use of traditional biomass in open fires or traditional stoves, can lead to child and adult mortality and morbidity. Overall, in 2015, household air pollution was responsible for almost 3 million deaths worldwide, including 250,000 child deaths (GBD 2016 SDG Collaborators 2017). Since 2000, progress has been made in all regions, especially in Asia, while in sub-Saharan Africa population growth largely outpaced the progress made. These trends are projected to continue towards 2030 (Lucas *et al.* 2015; Dagnachew *et al.* 2017; IEA 2017b; Lucas, Dagnachew and Hof 2017). Overall, the population without access to clean cooking fuels is projected to decrease to around 2.3 billion people by 2030, with larger improvements in urban areas than in rural areas (IEA 2017b). Under SSP2 assumptions, by 2030 around 140,000 children under five per year are projected to die as a result of household air pollution (Lucas *et al.* 2018). Model projections also show a decline in the population without access to electricity to around 700 million in 2030, with most regions, except sub-Saharan Africa, reaching near universal access (IEA 2017b). Although between 2010 and 2030, more than 550 million additional people are projected to gain access to electricity in sub-Saharan Africa, 500 million people would still not have access in 2030, many of them living in rural areas (Dagnachew *et al.* 2017).

Trends in climate change

Increasing fossil fuel use implies increasing greenhouse gas emissions and related global mean temperature (SDG 13). For the 2010-2050 period, GHG emissions are projected to increase by 30-70 per cent (*Riahi et al.* 2017; IEA 2017a; **Figure 21.8**). Most of this increase is projected for low-income countries. Nevertheless, per capita emissions remain highest in OECD countries. Emissions of greenhouse gases are not only expected to increase due to these energy-related trends; other activities are also expected to contribute. These include CO_2 emissions from land-use change (LUC) (slowly decreasing over time) and non-CO_2 emissions related to energy and agriculture. The sum of non-CO_2 emissions is expected to increase further over time, driven mostly by trends in agriculture.

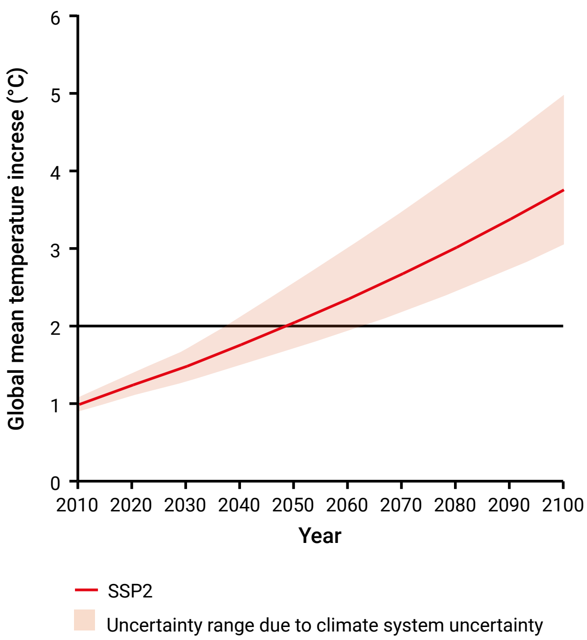
Figure 21.8: Projected increase in global CO_2 emissions (left) and total GHG emissions (right)



Source: Results are shown for SSP2 (average across the different models elaborating this scenario and the lowest and highest in the range, Riahi *et al.* 2017) and SSP3 (model average; Riahi *et al.* 2017), as well as the IEA scenario (IEA 2017a, reference case).

As a result of this global emission increase, global temperature is expected to rise from around 1°C above pre-industrial levels in 2016 (Visser *et al.* 2018) to around 4°C by 2100 in SSP2, most likely passing the 2°C target of the Paris Agreement before 2050 (IPCC 2014b; see **Figure 21.9**). There are substantial differences in temperature increase across different areas of the world. Typically, temperature increase is greater at higher latitudes, such as the temperate zone and in polar regions. In addition to changes in temperature, considerable changes in precipitation are projected to occur , with some regions becoming drier and others becoming wetter. However, such detailed patterns in climate change variables are still very uncertain. In many places, the projected warming would exceed the global mean temperature increase (which is defined as the increase in temperature above land and oceans). Using projected changes in temperature, the IPCC has assessed the impacts associated with climate change (IPCC 2014b). For a warming as high as in the business-as-usual scenarios projected here the impacts are assessed to be severe, for all categories. This includes sea level rise, negative impacts on agriculture globally (**see Box 21.4**), negative impacts on biodiversity, and the risk of irreversible changes in the complete climate system.

Figure 21.9: Global mean temperature increase



Source: SSP2 database, range taken from baseline scenarios in IPCC (2014b).

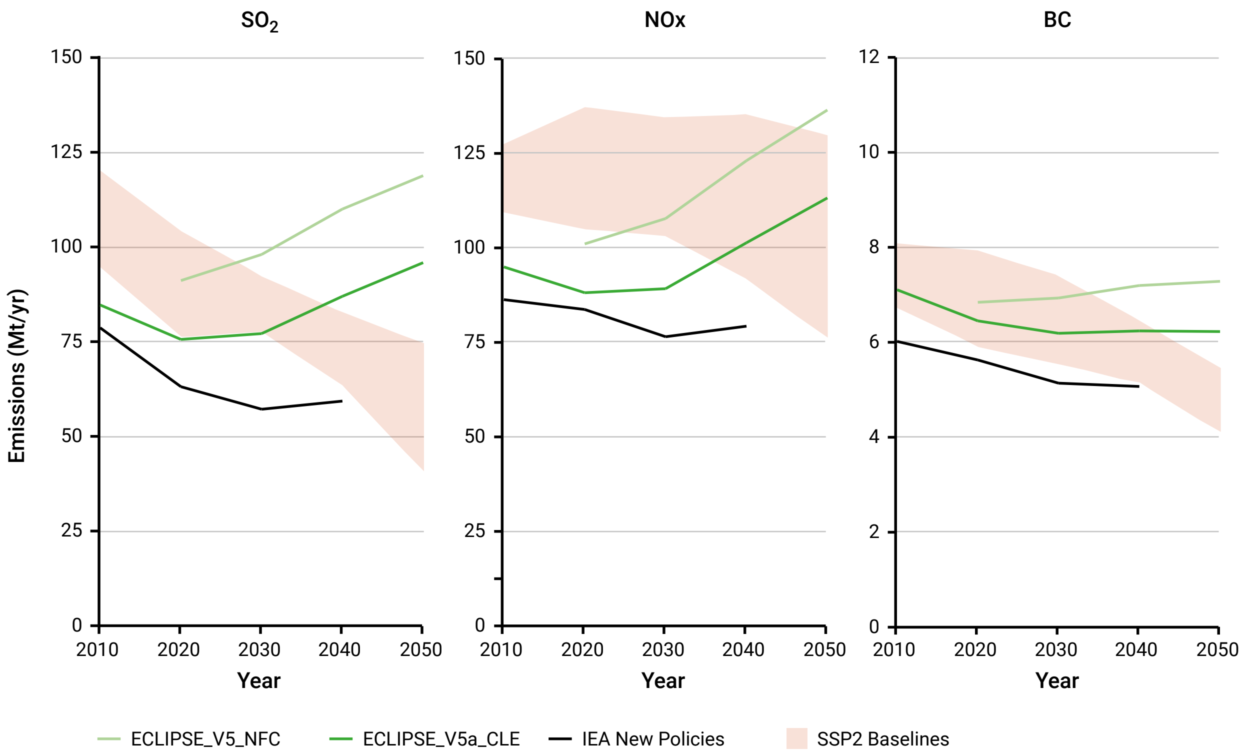
Trends in air pollution

From the public health perspective, airborne particles and ground level ozone are the most important air pollutants (SDG target 11.6), with exposure to $PM_{2.5}$ contributing the most to premature deaths (see Chapter 5). The Global Burden of Disease study estimated that exposure to ambient $PM_{2.5}$ was the fifth-ranking mortality risk factor in 2015, contributing to approximately 4 million deaths and 103 million years of healthy life lost (Cohen *et al.* 2017).

Several projections of future air pollution have been made over the past few years (Stohl *et al.* 2015; IEA 2016; OECD 2016; Klimont *et al.* 2017; Rao *et al.* 2017; UNEP 2017). Many projections have been built using emission factors from successive versions of the Greenhouse Gas and Air Pollution Interactions and Synergies (GAINS) model (Amann *et al.* 2011; Klimont *et al.* 2017). In addition to the evolution of these underlying emission factors, future projections differ in their assumptions about energy supply and demand, and the extent to which air pollution control policies will be implemented in the future.

The most pessimistic scenarios examine a situation in which no additional air pollution control policies are implemented. An example is the OECD (2016) study, that projects a significant increase in air pollution emissions by 2060 due to increasing economic activity and energy demand. More realistic scenarios look into expected improvement in air pollution legislation. For instance, the IEA-New Policies Scenario (IEA 2016) projects a more optimistic future in which recently announced policies, including Nationally Determined Contributions (NDCs), under the Paris Agreement, are implemented, leading to the use of emission control technologies and facilitating a shift to cleaner energy sources. These new policies will lead to a slow decline in global air pollutant emissions by 2040, although rapidly developing regions are likely to continue to experience increases in air pollution emissions (IEA 2016; UNEP 2017). In high-income countries, emission decreases are expected as a result of increasingly stringent air pollutant emission standards on power plants and vehicles, shifts to low-carbon sources for electricity generation, and increased energy efficiency. In developing regions, the growth in economic activity and energy demand is still expected to outpace efforts on pollution control until income level reaches a certain point. However, $PM_{2.5}$ emissions (primarily organic carbon (OC) and black carbon (BC)) and exposures may decline due to increased access to clean energy sources for cooking, heating and lighting (IEA 2016). The ECLIPSE project (Stohl *et al.* 2015; Klimont *et al.* 2017), which has been used more broadly by the atmospheric research community, e.g. the 2017 Emissions Gap Report (UNEP 2017), includes a current legislation (CLE) scenario that falls between the OECD and IEA pathways. Air pollution emissions scenarios were developed for each of the SSPs based on sets of assumptions about the stringency and implementation of future air pollution emissions controls consistent with the overall scenario storylines (Rao *et al.* 2017). These scenarios also used the emission factors of the GAINS model. To 2040, the range of the SSP air pollutant emission scenarios captures the more pessimistic scenarios of continued growth without additional policies (OECD 2016) and the more optimistic scenarios of new policies (IEA 2016).

Figure 21.10: Future projections of emissions for air pollutants SO_2, NO_x and BC



Source: ECLIPSE_V5_NFC and ECLIPSE_V5a_CLE represent ECLIPSE's 'no further control' and 'current legislation' scenarios (Stohl *et al.* 2015; Klimont *et al.* 2017). IEA New Policies represent IEA's new policy scenario that includes NDCs of the Paris Agreement (IEA 2016). For the SSP2 scenario, the shading represents the range for all models (Rao *et al.* 2017).

Overall, scenarios without new policies show a small decrease or increase in air pollutant emissions. Based on data from the Global Burden of Disease (GBD 2016 Risk Factors Collaborators 2017), in 2016 approximately 95 per cent and 58 per cent of the world's population lived in areas where annual mean $PM_{2.5}$ concentrations exceeded the 10µg/m^3 guideline and the least stringent interim target of 35µg/m^3, respectively, contributing to approximately 4 million premature deaths (Health Effects Institute 2018). Using emissions data as input, the TM5-FASST source-receptor model (van Dingenen *et al.* 2018) can be used to estimate annual $PM_{2.5}$ concentrations, which can be mapped onto future population projections to estimate those exposed to specific $PM_{2.5}$ levels and the number of premature deaths. By 2050, the projected values for populations exposed to $PM_{2.5}$ concentrations above 10µg/m^3 and 35µg/m^3 are 63 and 9 per cent, respectively, for the SSP2 marker scenario (Rao *et al.* 2017), and 81 and 40 per cent, respectively, for the ECLIPSE V5a 'current legislation' scenario (Stohl *et al.* 2015; Klimont *et al.* 2017). This implies that air pollution will continue to contribute to millions of premature deaths annually, with the IEA New Policies scenario estimate of 4.5 million premature deaths for 2040 (IEA 2016), and the ECLIPSE V5a scenario estimate of 7 million premature deaths for 2050 (Stohl *et al.* 2015; Klimont *et al.* 2017) spanning the range in the literature. Global economic losses due to decreased labour productivity, increased health care costs and decreased crop yields could amount to 1 per cent of global gross domestic product (GDP) by 2060 (OECD 2016). There are large differences across regions, with some experiencing as much as 3 per cent loss in GDP (OECD 2016).

21.3.4 Freshwater

Freshwater - related environmental problems are closely linked to developments in the agriculture, food, land and biodiversity cluster (see Section 21.3.2) and the energy, air and climate cluster (see Section 21.3.3), both as a natural resource and as a sink for pollution. Freshwater is essential for human health (drinking water and sanitation), as well as for agriculture and energy production, while an imbalance of freshwater supply and demand can cause severe water scarcity. Furthermore, excess nutrient losses (nitrogen and phosphorus) to aquatic ecosystems through run-off and erosion can cause the eutrophication of lakes and rivers.

Trends in drinking water and sanitation

In 2015, nearly 2.1 billion people lacked access to safely managed drinking water services (SDG target 6.1), while 0.8 billion of these even lacked an improved source (World Health Organization [WHO] and United Nations Children's Fund [UNICEF] 2017). Furthermore, 4.5 billion people lacked access to safely managed sanitation services (SDG target 6.2), while 2.3 billion of these even lacked an improved source (WHO and UNICEF 2017). Overall, unsafe drinking water, sanitation and hand washing (WASH) were responsible for around 1.5 million deaths, including 410,000 child deaths, mainly due to diarrheal diseases (GBD 2016 SDG Collaborators 2017). Lucas *et al.* (2018) project that, by 2030, more than 30 million children will still live without access to improved drinking water services, and about 150 million will lack access to improved sanitation, under SSP2 assumptions. This translates into 400 million people that live without access to improved drinking water services and about 2 billion without access to improved sanitation. Especially the sanitation challenge is a pressing one. Between 2015 and 2030, around 5.6 billion people will require safely managed sanitation and around 1.3 billion people will need to switch from open to fixed point defecation (Mara and Evans 2018). Improved access to safely managed WASH would lead to a significant reduction in the number of children suffering from related ill health. However, under SSP2 assumptions, by 2030 around 220,000 children under five are projected to die as the result of inadequate drinking water and sanitation facilities (Lucas *et al.* 2018).

Trends in water quality

Freshwater pollution includes different types of chemicals, but also excessive nutrient loading (nitrogen and phosphorus) of aquatic ecosystems through run-off and erosion and declining silica concentrations. Since scenario studies related to chemicals are largely missing from the scientific literature **(see Box 21.3)**, the analysis of trends for this target focuses on nutrient pollution.

Nitrogen (N) and phosphorus (P) fertilizers have played a major role in food production, but they have also found their way into nearly every water body across the globe, causing eutrophication of rivers, lakes and reservoirs (SDG target 6.3). The most important anthropogenic source of nitrogen in freshwater ecosystems is agriculture-related N-fixation (nitrogen fertilizer use and biological crop fixation). For phosphorus, the main anthropogenic sources are phosphorus fertilizer use and wastewater. Current agricultural N-fixation is estimated at 116-127TgN/yr (Bouwman *et al.* 2017). Alexandratos and Bruinsma (2012) project an increase of synthetic N use to 138TgN/yr in 2050, while Mogollón *et al.* (2018a) project an increase to 185 and 260TgN/yr in 2050 under an SSP2 and SSP3 scenario, respectively, illustrating the uncertainty in future projections. Global phosphorus inputs to cropland are projected to increase from 14.5TgP/yr in 2010 (Bouwman *et al.* 2017) to 26 and 27TgP/yr in 2050 under an SSP2 and SSP3 scenario, respectively (Mogollón *et al.* 2018b).

Future projections of N fertilizer use depend strongly on developments in N use efficiency (NUE), which declined from 0.42 in 1970 to 0.35 in the 1980s and then increased again to 0.42 in 2010 (Bouwman *et al.* 2017). The decreasing trend in the 1980s was due to increasing fertilizer use in low-input countries, which initially led to an apparent decline in efficiency, while the later increase was largely the result of improvement in agricultural practices and environmental legislation in developed regions (Bouwman *et al.* 2017; Rao *et al.* 2017). These trends are projected to continue in the future, with projected NUE for SSP2 increasing to 0.55 in 2050 (Mogollón *et al.* 2018a). The P use efficiency (PUE) declined from 0.51 in 1970 to somewhat lower values in the 1980s, and then to 0.6 in 2010 (Mogollón *et al.* 2018b). Future PUE values depend strongly on phosphorus accumulation (low PUE) in residual soil pools or their depletion (high PUE), which can be regarded as a contribution to future production.

It is clear that current and projected nitrogen and phosphorus use in agriculture significantly exceeds the target levels of 62TgN/yr and 6.2TgP/yr. At the same time, construction of dams and the development of reservoirs for water storage and hydropower generation leads to trapping of silica (Si) (e.g. Mavaara, Dürr and van Cappellen2014; Ran *et al.* 2018). The distortion of the nutrient stoichiometry (increasing N:P, increasing N:Si) may lead to the proliferation of harmful algae. The global problem of harmful algae is now on a pathway of more and more frequent blooms, in more places with an increasing extent, and with more toxins (Glibert 2017).

Wastewater is another important source of nutrients in freshwater systems. Improved sanitation is focused on health aspects, and sanitation systems are designed to hygienically separate excreta from human contact. However, without wastewater treatment, sewage systems create direct emissions of nutrients and organic waste to surface water (van Puijenbroek *et al.* 2015). Although access to sanitation is projected to increase, expansion of wastewater treatment will be outpaced by population growth and urbanization trends in developing countries (van Puijenbroek, Beusen and Bouwman 2019). As a result, global nutrient emissions from untreated sewage are projected to increase from 10TgN/yr in 2010 to 17TgN/yr in 2050, and from 1.5TgP to 2.4TgP under SSP2 assumptions (van Puijenbroek, Beusen and Bouwman 2019).

Trends in water scarcity

At present, more than 2 billion people across the globe live in river basins with excess water stress (SDG target 6.4), i.e. the proportion of total freshwater withdrawal to total renewable freshwater above a threshold of 40 per cent (Oki and Kanae 2006; Veldkamp *et al.* 2015; Liu *et al.* 2017). In some countries in Africa and Asia, the proportion extends beyond 70 per cent (Economic and Social Council 2017).

Global human water demand, i.e. water withdrawal, is projected to increase under all trend scenarios. Some scenarios show quite large increases, i.e. from around 4,000km^3 yr^{-1} now to 5,500km^3 yr^{-1} by 2050 (38 per cent) under SSP2 (Wada *et al.* 2016; Satoh *et al.* 2017). Others show a smaller increase, based on expected efficiency improvements. For instance, Bijl *et al.* (2018) project a 26 per cent increase in total water demand by 2050 under an SSP2 scenario. For the high demand scenario, consumptive water use is projected to increase from 2,000km^3 yr^{-1} now to 2,500km^3 yr^{-1} by 2050 (25 per cent) under SSP2 (Wada and Bierkens 2014). An additional 10 per cent increase of water use is expected under SSP3 (Wada *et al.* 2016).

Improvement in water-use efficiency is expected to vary for different sectors (agriculture, industry and households), and ranges between 0.3 and 1.0 per cent per year under the SSP scenario, which mostly follows historical development (Flörke *et al.* 2013; Wada *et al.* 2016). Furthermore, the efficiency improvement is expected to vary substantially across different regions, depending on available infrastructure and economic investments. The greatest increases in total water demand are expected in Africa, many parts of Asia, the western United States of America, Mexico, and Latin America (Hanasaki *et al.* 2013a; Hanasaki *et al.* 2013b; Wada *et al.* 2016) and will largely be the result of rapidly growing population and increasing industrial activities (higher electricity and energy use) in currently developing countries (Hanasaki *et al.* 2013a; Hanasaki *et al.* 2013b; Bijl *et al.* 2016; Wada *et al.* 2016; Satoh *et al.* 2017).

Increases in future agricultural water demand are primarily driven by the expansion of irrigated areas and projected climate change, which enhances evaporative demand for irrigated crops (Hanasaki *et al.* 2013a; Hanasaki *et al.* 2013b; Wada and

Bierkens 2014; Mouratiadou *et al.* 2016). Compared with the domestic and industrial sector, the projected irrigation water demand shows a much lower increase of 20 to 30 per cent by the end of this century (Elliot *et al.* 2014), although some project a doubling of irrigation water withdrawals between 2010 and 2050 (Chaturvedi *et al.* 2015). Although modest changes in global average irrigation efficiency are projected (Hanasaki *et al.* 2013a; Hanasaki *et al.* 2013b), this will probably compensate for the increase in irrigated areas and irrigation intensity (Wada *et al.* 2013), with significant differences in efficiencies across regions (Chaturvedi *et al.* 2015). It should be noted that increasing atmospheric CO_2 concentrations can improve crop growth and reduce crop transpiration, while simultaneously, increased biomass use could potentially offset the gains in crop transpiration (Wada *et al.* 2013).

The trends under both medium and high water demand scenarios (SSP2 and SSP3) imply that water scarcity is expected to increase. For instance, studies project a large increase in water scarcity over 74 to 86 per cent of the total area of Asia under different SSP scenarios, and that at least 20 per cent of the area will probably be subject to severe water stress by the 2050s in Asia (Wada and Bierkens 2014; Satoh *et al.* 2017). It is important to note that a severe reduction in water resources is expected in many parts of arid and semi-arid regions due to climate change (Schewe *et al.* 2014). At present, more than 1 billion people in Asia live in regions with severe water stress, totalling almost one-third of the Asian population (Liu *et al.* 2017). By 2050, the Asian population exposed to severe water stress conditions is expected to increase by 42 to 75 per cent, depending on which scenario is considered (SSP1-3), potentially extending to 2 billion people under the SSP3 high water demand scenario (Satoh *et al.* 2017). Globally, the number of people living in a severe water stress areas show a similar trend, increasing from 2 billion people now to between 2.8 and 3.4 billion people by 2030, under the SSP2 and SSP3 scenarios, respectively (Hanasaki *et al.* 2013a; Hanasaki *et al.* 2013b). Increased water stress can damage renewable freshwater resources to the point where they are unable to sustain human activities and fulfil their ecological functions (Satoh *et al.* 2017; Greve *et al.* 2018). The consequences of water stress also affect agriculture, health and income. Studies show that water stress could lead to a 7-10 per cent reduction in GDP in Central and East Asia by 2050 (World Bank 2016b; Satoh *et al.* 2017).

At the same time, the amount of non-renewable groundwater abstraction is projected to double for almost all major groundwater users under the SSP2 and SSP3 scenarios. The share of non-renewable to total groundwater abstraction is expected to increase from 30 to 40 per cent, indicating a growing reliance of human water use on non-renewable groundwater resources (Elliot *et al.* 2014; Wada and Bierkens 2014). In some areas, the groundwater table may drop too deep, or the aquifer or river may run out of water, increasing concern for food security, energy, cities and ecosystems (Vanham *et al.* 2018).

21.3.5 Oceans

Ocean - related environmental problems are closely linked to developments in the agriculture, food, land and biodiversity cluster (see Section 21.3.2) and the energy, air and climate cluster (see Section 21.3.3), both as a natural resource and as a sink for pollution. Oceans are an important source of food and nutrition for billions of people, and although not discussed in the current section, they are also important for renewable energy, including offshore wind farms and tidal energy. With respect to pollution, excess nitrogen and phosphorus loadings associated with anthropogenic activities, including agriculture and sewage, can cause dead zones and toxic algae blooms in inland and coastal waters, while increasing CO_2 emissions, mostly generated by the energy system, exacerbate ocean acidification.

Trends in marine nutrient pollution

Major threats from nutrient enrichment and changing nutrient ratios are the development of dead zones and toxic algae blooms in inland and coastal waters. The Si:N and Si:P ratios in rivers have declined steadily during the past century (Billen, Lancelot and Meybeck 1991). This is due to elevated N and P loadings associated with anthropogenic activities (Beusen *et al.* 2016), while dissolved Si supply to rivers (primarily from rock weathering) is decreasing due to enhanced Si retention in reservoirs (Conley 2002). As a result community structures change, since siliceous algae (diatoms) require Si in balance with N and P (Si:N $\approx$ 1; Si:P $\approx$ 16). Threats from marine nutrient pollution (SDG target 14.1) occur when N and P are present in excess relative to Si, and phytoplankton communities are dominated by non-diatoms and often toxic algae and cyanobacteria proliferate (Anderson, Glibert and Burkholder 2002).

Global river N export estimates range from 37Tg N/yr (Beusen *et al.* 2016) to 43Tg N/yr (Seitzinger *et al.* 2010) for the year 2000. For global river P export estimates range from 4TgN/yr (Beusen *et al.* 2016) to 9Tg N/yr (Seitzinger *et al.* 2010). Increasing inputs from agriculture and wastewater are projected to result in an increase of the global river nitrogen export from 40Tg N/yr in 2006 to 47Tg N/yr in 2050, while P exports are projected to increase from 4Tg P/yr in 2006 (based on Beusen *et al.* 2016) to 5Tg P/yr in 2050, according to the SSP2 scenario (Ligtvoet *et al.* 2018). Although there are considerable uncertainties in historic estimates of phosphorus flow from freshwater systems into the ocean, future trends are moving in the wrong direction.

Trends in ocean acidification

Increases in CO_2 concentrations result in increased ocean acidity (SDG target 14.3) and decreased ocean productivity. Under a high emissions scenario (RCP 8.5) the global average ocean acidity level (pH) is projected to decline by approximately 0.2 in 2060 (Palter *et al.* 2018) and by 0.33 in 2090 (Bopp *et al.* 2013), compared with the 1990s. Lower pH levels (higher acidity) reduce the concentration of carbonate ions, which are required by marine organisms to create shells and skeletons. Higher acidity means that the global average calcium carbonate ($CaCO_3$) saturation state of seawater with respect to aragonite (a type of $CaCO_3$ produced by marine organisms, the saturation state of which is denoted: Ωarg) in the upper water column would decline to levels that are significantly below the selected target level of 2.75Ωarg – from 2.94Ωarg in 2010 to around 1.8Ωarg in 2100 (Zheng and Cao

2014). Declines in carbonate saturation state make it more difficult for marine organisms to form shells and skeletons, can lead to their dissolution, and may increase natural mortality or decrease somatic growth and egg viability (Cattano *et al.* 2018). Regionally, acidification is expected to increase most rapidly in polar areas, with carbonate ion concentrations projected to fall below aragonite saturation levels in the Arctic Ocean beginning in 2048, and in the Southern Ocean in around 2067 (Bopp *et al.* 2013; Ciais *et al.* 2013). It should be noted that nitrogen and phosphorus run-off into the ocean from agriculture and industrial sources can lead to locally enhanced ocean acidification (Billé *et al.* 2013).

Trends in ocean resources

Protecting ocean resources (SDG target 14.4) is critical, as oceans are sources of food and nutrition for billions of people, especially in income-poor coastal zones where significant shares of nutrition and income derive from fisheries. In addition to being a direct source of human food, fish also contribute indirectly to human nutrition when used as fishmeal in aquaculture and livestock feed. Historically, fish demand per capita has risen significantly from 6kg/yr in 1950 to 20.3kg/yr in 2016 (FAO 2018), with other estimates spanning the range 18.8-21.4kg/yr in 2011 (Troell *et al.* 2014; Béné *et al.* 2015). At the same time, there has been a trend towards farmed fish. Since 2014, humans have consumed more farmed fish than wild fish (FAO 2016). Projections from FAO suggest that demand for fish will continue to grow in the future (FAO 2018). However, studies indicate that a sustainable increase in wild fish catch will be difficult under current fishing strategies (Garcia, Rice and Charles 2016; FAO 2018). One important concern is that projections of marine primary productivity, which supports all marine fisheries, and ultimately all marine life, suggest a decline to 2100 under an RCP 8.5 scenario (Bopp *et al.* 2013; Fu, Randerson and Moore 2016), although considerable uncertainties remain (Laufkötter *et al.* 2015). No projections of the 'proportion of fish stocks within biologically sustainable levels' – the official SDG indicator – are available in the literature. As a proxy, projections of global fisheries under an unchanged climate and current management scenario, suggest that, the proportion of fish stocks at or below a target biomass that can undergo recovery would increase from 53 per cent today to 88 per cent in 2050 (Costello *et al.* 2016). However, a wide range of improved management measures already in place. In most countries that are funding science and management adequately (Melnychuk *et al.* 2017), significantly improve the prospects for sustainability (Costello *et al.* 2016). Catch potential is projected to decline by an average of 7.7 per cent by 2050, while revenue might decline by 10.4 per cent over the same period (Lam *et al.* 2016).

21.3.6 Human health

In 2012, 23 per cent of deaths globally were due to modifiable environmental factors– "those reasonably amenable to management or change given current knowledge and technology, resources, and social acceptability," (Prüss-Üstün *et al.* 2016) – with a greater portion occurring in vulnerable populations (children and the elderly) and developing countries (Prüss-Üstün *et al.* 2016). The environment affects human health within households (e.g. through unsafe water, sanitation and hygiene, and indoor air pollution), in communities (e.g. outdoor air pollution), and on a global scale (e.g. climate change) (Smith and Ezzati 2005; Hughes *et al.* 2011).

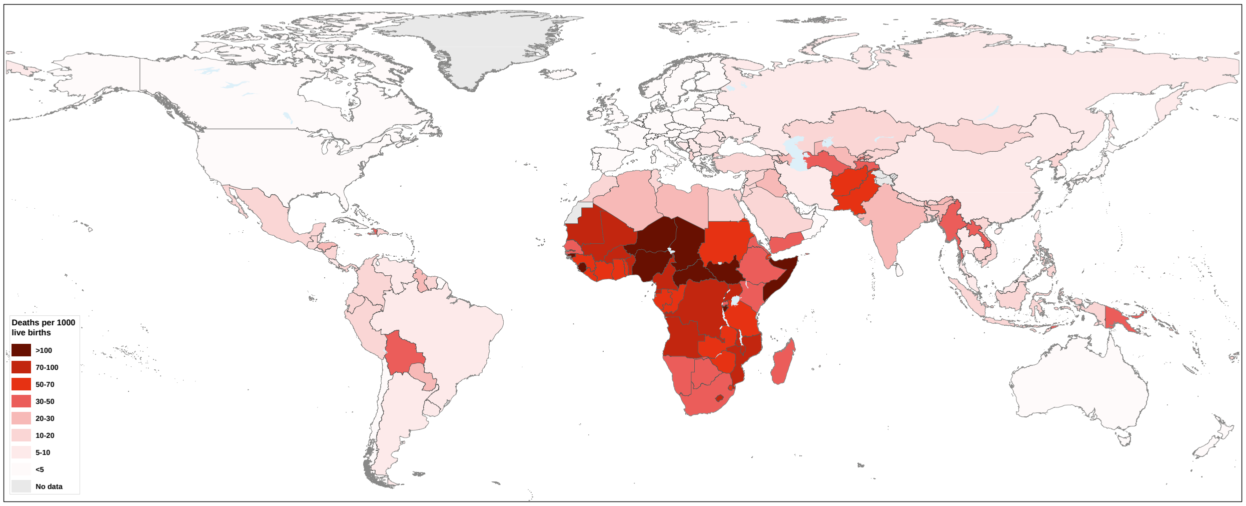
The proportion of the population with access to safe water, sanitation, and hygiene facilities, as well as clean cooking facilities has been increasing significantly reducing health impacts related to communicable diseases. These trends are projected to continue to 2050 (see Sections 21.3.3 and 21.3.4). For example, global Disability Adjusted Life Years (DALYs), the number of years lost to poor health or early death related to household air pollution due to use of solid fuels, decreased from 9.2 per cent of total DALYs in 1990 to 6.8 per cent in 2016 (Institute for Health Metrics and Evaluation 2016), and is projected to further decline to under 3 per cent by 2024 (Kuhn *et al.* 2016). Hughes *et al.* (2011) also project significant decreases in mortality from communicable diseases, largely related to strong economic development. However, many people are projected to live without proper access to improved drinking water and sanitation and clean cooking facilities by 2030, and the levels of improvement across these risk factors vary widely by region. Furthermore, health risks associated with outdoor air pollution and climate change have been increasing (WHO 2014; Forouzanfar *et al.* 2015; Cohen *et al.* 2017). The impact from ambient particulate matter pollution will continue to contribute to millions of premature deaths annually in the coming decades (see Section 21.3.3). Likewise, climate change is projected to have substantial negative health impacts in the coming decades, among them heat exposure, coastal flooding, diarrhoea, malaria and undernutrition (Hughes *et al.* 2011; WHO 2014).

Environmental risk factors at household level have been declining since 1990, while risk factors at community and global level have been increasing. Global health risks have been shifting away from environmental risks and towards behavioural risks (e.g. smoking, childhood undernutrition, and alcohol use) and metabolic risks (e.g. high blood pressure, and high body mass index) (WHO 2009; Forouzanfar *et al.* 2015). This shift in risk factors is part of a larger epidemiological transition, which has occurred globally over the past two centuries – mortality rates have been decreasing and shifting towards risks that affect people later in life (Murray *et al.* 2015).

Trends in child mortality

Under-five mortality is generally seen as a good indicator of quality of life (see Section 20.4.1). Global child mortality (SDG target 3.2) declined dramatically from 91 deaths per thousand live births in 1990 to 43 per thousand live births in 2015, one of the most successful achievements of the Millennium Development Goal period (You *et al.* 2015). Yet more than 5 million children died in 2016 before reaching their fifth birthday, and 26 per cent of these deaths were due to environmental factors within our control (Prüss-Üstün *et al.* 2016). The five leading environmental risk factors (in order of health impact) are: household air pollution, unsafe drinking water, ambient particulate matter, unsafe sanitation, and insufficient handwashing (WHO 2009; Forouzanfar *et al.* 2015). Furthermore, malnutrition, including fetal growth restriction, child stunting and wasting, micronutrient deficiencies and suboptimal breastfeeding are important health risk factors, related to about 45 per cent of child deaths in 2011 (Black *et al.* 2013). In 1990, these five leading environmental factors accounted for nearly 2.8 million deaths in children under five (30 per cent of total under-five deaths), which decreased to just over 800,000 deaths in 2016 (24 per cent of total under-5 deaths). Currently, 79 countries have under-five mortality rates higher than the SDG target of 25 per 1,000 live births –

Figure 21.11: Projected under-five mortality rate in 2030



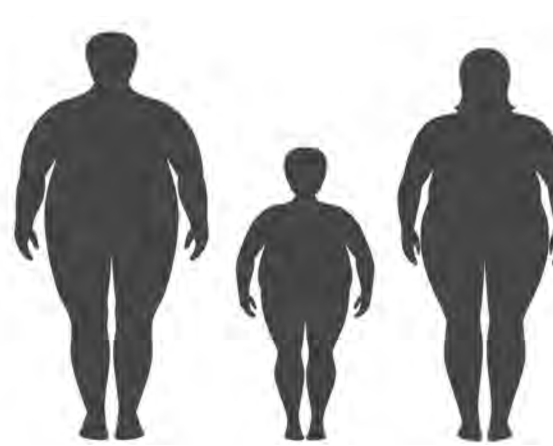
Source: Moyer and Hedden (2018).

partly due to persistent and sometimes even increasing environmental risk factors in low- and middle-income countries (GBD 2015 SDG Collaborators 2016).

Global child mortality is projected to decrease further to around 23 to 39 deaths per thousand live births by 2030, which is not enough to achieve the SDG target (Hughes *et al.* 2011; Liu *et al.* 2015; You *et al.* 2015; GBD 2016 SDG Collaborators 2017). This means that an estimated 47 countries are not on track to achieve the target by 2030, mostly in sub-Saharan Africa (You *et al.* 2015). As a result of decreasing child mortality, global average life expectancy at birth is projected to increase to over 77 by 2050, compared with 71 in 2015 (Samir and Lutz 2017; United Nations 2017). It should be noted that average figures such as these conceal huge differences in life expectancy, especially related to differences in poverty within and across countries.

Child mortality, especially from diarrhoea and pneumonia, is expected to decrease significantly, due to projected improvements in hunger levels (see Sections 21.3.2), access to modern sources of energy (see Section 21.3.3), and access to clean drinking water and sanitation (see Section 21.3.4), as well as to improved overall development levels (Lucas *et al.* 2018). However, by 2030, the five leading environmental risk factors, together with child underweight and malaria, are nevertheless projected to contribute to around 15 per cent of total child deaths, with a greater portion in sub-Saharan Africa (Lucas *et al.* 2018). These health impacts are largely preventable, but require interventions aimed at ensuring cleaner and sustainable access to food, water and energy services. Furthermore, climate change can exacerbate child mortality risks, for example, through impacts on food security and consequent levels of child underweight. Including climate change impacts on child underweight in their base case scenario projection, Hughes *et al.* (2011) project 70,000 additional child deaths in 2050, mostly in southern Asia and sub-Saharan Africa.

It should be noted that household, community and global environmental factors affect many human development indicators beyond child mortality and, in turn, that child mortality is affected by many factors other than modifiable environmental factors. As indicated above, the epidemiological transition implies a change in the balance of risks attributable to the environment, e.g. from water - related communicable diseases, to non-communicable diseases related to, for example, ambient air pollution. Success in dealing with the first of these will show far greater benefits for under-five mortality than success in dealing with the second. Furthermore, other environmental health risk factors affecting health in the under-fives – undernourishment for some, obesity for others – may show as increased risks to health and mortality in later life, rather than (or in addition to) mortality in the under-fives.



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Box 21.5: Country level achievement of selected SDG targets

The 2030 Agenda is a global agenda, to be implemented at national level. This chapter explicitly evaluates future developments of selected environment-related SDG targets at a global level. The analysis concludes that without enhanced policies, the targets are unlikely to be met. However, the level of success differs largely across countries. Moyer and Hedden (2018) explored future country level progress under a SSP2 scenario, for eight SDG targets and nine related indicators. These targets link to selected SDG targets for the human well-being cluster, supplemented by SDG targets addressing poverty eradication and education. The nine indicators, though not comprehensive, represent multiple dimensions of human development.

In line with conclusions in this chapter **(see Table 21.2)**, the study concludes that between 2015 and 2030, the world will make only marginal progress towards achieving the nine SDG indicators. On all country indicator combinations explored (nine indicators for 186 countries = 1,674 indicator values in each year), 43 per cent had already achieved target values in 2015, which is projected to increase to 53 per cent in 2030. Only 17 per cent of the countries are projected to achieve all SDG targets analysed by 2030, while 15 per cent of the countries do not achieve any of the selected SDG targets. Most of these latter countries are in sub-Saharan Africa. The analysis highlights difficulty in achieving target values for access to sanitation, universal lower secondary education and reducing the prevalence of underweight children, representing persistent development issues. The child mortality SDG target is projected to be achieved by 67 per cent of countries in 2030, while only 8 per cent achieve this target in sub-Saharan Africa.

Table 21.1: Percentage of countries by region projected to achieve selected SDG targets in 2030

	Europe and Russian Federation	Latin America and Caribbean	Middle East and North Africa	Non-OECD Asia Pacific	North America	OECD Asia Pacific	South Asia	Sub-Saharan Africa	World
Extreme poverty	100	68	85	70	100	100	79	21	67
Hunger	95	32	70	26	100	100	43	10	48
Underweight children	82	48	30	26	100	100	14	0	37
Child mortality	98	90	90	74	100	50	71	6	67
Primary school completion	100	94	85	78	100	100	86	33	77
Lower secondary school	89	35	40	48	100	100	50	4	45
Access to safe water	98	94	95	70	100	100	93	17	72
Improved sanitation	80	29	65	43	100	100	43	4	44
Access to electricity	100	68	90	48	100	100	71	2	60

Source: Moyer and Hedden (2018).

21.4 Are we achieving the targets?

The results of the scenario assessment are summarized in **Table 21.2** with reference to the selected SDG targets and indicators (see Chapter 20). None of these targets is assessed to be achieved in the business-as-usual scenarios examined, but clear differences exist.

For the targets grouped under human well-being, the projected trends show improvements over time, but not sufficient to achieve them by 2030. However, several targets are projected to be achieved in the longer term, or at least come relatively close to being achieved; for instance, the prevalence of undernourishment is projected to be reduced by two-thirds or more in 2050. While progress is sufficiently rapid to compensate for the growing world population, many people will nevertheless be left without proper access to food, modern energy services or adequate drinking water and sanitation. Linked to this, environmentally related human health impacts are decreasing significantly, but far from enough to achieve the SDG target on under-five mortality. Environmental health risk factors remain especially prominent in sub-Saharan Africa.

Table 21.2: Past and future trends related to selected targets (see Section 20.4)

Cluster	Selected target for GEO-6	Indicator	2010 Level	Target value	Projected value[1]	Trend
Human well-being	End hunger	Prevalence of undernourishment	800-900 million people	0 in 2030	300-500 million people in 2030	↘
	Universal access to modern energy services	People without access to electricity and people without access to clean cooking fuels	2.8 billion and 1.1 billion	0 in 2030	2.3 billion and 700 million in 2030	↘
	Universal access to safe drinking water and adequate sanitation	People who lack access to improved drinking water and people who lack access to improved sanitation	0.8 billion and 2.3 billion	0 in 2030	0.4 billion and 2 billion in 2030	↘
	End preventable deaths of children under 5	Under-five mortality rate	52 deaths per 1,000 live births	<25 deaths per 1,000 live births in 2030	23-39 deaths per 1,000 live births in 2030	↘
Natural resource base	Improve water quality	Nitrogen fertilizer use and biological nitrogen fixation	120TgN/yr	< 62TgN/yr	185TgN/yr in 2050	↗
		Fertilizer use with phosphorus	14.5TgP/yr	< 6.2TgP/yr	26TgP/yr in 2050	↗
	Reduce water scarcity	Population living in water scare areas	2 billion	-	2.8 billion in 2030	↗
	Improve air quality in cities	Percentage population exposed to $PM_{2.5}$ above 35μg/m^3	58 per cent	0 per cent in 2050	9-40 per cent in 2050	↘
	Limit global warming	Global mean temperature increase	1°C in 2016	< 2.0 / 1.5°C by 2100	4°C by 2100	↗
	Reduce marine nutrient pollution	P flow from freshwater systems into the ocean	4TgP/yr in 2006	-	5TgP/yr in 2050	↗
	Minimize ocean acidification	Average global surface aragonite saturation level	2.94Ωarg	> 2.75Ωarg	1.8Ωarg in 2100	↗
	Sustainable management of ocean resources	Proportion of fish stocks at or below target biomass that can undergo recovery	53 per cent	-	88 per cent in 2050	↗
	Achieve land degradation neutrality	Loss in soil organic carbon	176Gt historically	-	27GtC between 2010 and 2050	↗
	Halt biodiversity loss	Loss in Mean Species Abundance (MSA)	34 per cent	< 36 per cent from 2030 onwards	43 per cent in 2050	↗

↗ Target projected not to be achieved; trend in opposite direction or no significant improvement;
↘ Target projected not to be achieved; trend in right direction;
↓ Target projected to be achieved (none).

Source: All values are based on Section 21.3. [1] Projected values are mostly for SSP2 scenarios, except for energy access, under five mortality rate, ocean acidification and fish stocks above target biomass. For air pollution, results of the ECLIPSE scenario are also included due to the large uncertainty range.

For the targets grouped under natural resource base, the gap remains relatively large, and for most targets they even become wider. Although resource use efficiency (in terms of yield and nutrient use, water and energy efficiency) is projected to improve, mostly in line with historical trends **(see Table 21.3)**, trends in climate change, biodiversity loss, water scarcity, nutrient pollution and land degradation are projected to continue to move in the wrong direction. Only the proportion of the population exposed to $PM_{2.5}$ concentrations above 35µg/m^3 is projected to decrease. Still, under a SSP2 scenario, 63 per cent of the population is projected to be exposed to $PM_{2.5}$ above 10µg/m^3 by 2050, concluding that air pollution will continue to contribute to millions of premature deaths in the coming decades.

Overall, the scenario analysis shows that the world is not on track to achieve selected environment - related targets of the SDGs and related MEAs. A significant increase in the rate of improvement with respect to reducing child mortality, air pollution control, hunger eradication and achieving access to clean water, sanitation and modern sources of energy is required. Furthermore, achieving the targets that address the natural resource base, including on climate change, biodiversity loss, land degradation, water scarcity and pollution of freshwater and oceans, requires a clear break with current trends, with absolute decoupling of human development from environmental degradation.

Table 21.3: Historic and business-as-usual trends in resource use efficiency sustainable consumption and production

Selected target for GEO-6	Indicator	Historic development	Trend in business-as-usual scenarios
Increase agricultural productivity (Section 21.3.2)	Yield improvement over time (cereals)	1.9 per cent/yr (1970-2010)	0.4-0.9 per cent/yr (2010-2050)
Increase nutrient-use efficiency (Section 21.3.2)	Total N inputs to the crop N yields	0.42 in 2010	0.55 in 2050
Increase water-use efficiency (Section 21.3.4)	Change in water-use efficiency over time	0.2-1 per cent/yr (1970-2010)	0.3-1 per cent/yr (2010-2050)
Increase the share of renewable energy (Section 21.3.3)	Renewable energy share in total final energy consumption	15 per cent in 2010	20-30 per cent in 2050
Increase energy efficiency (Section 21.3.3)	Reduction in energy intensity over time (measured in terms of primary energy and GDP)	1-2 per cent/yr (1970-2010)	1-2.5 per cent/yr (2010-2050)

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