7 Climate Change

Editorial note:

The current draft will be revised after Eionet review to reflect review comments, strengthen coherence across chapters and improve interlinkages

7.1 Thematic summary assessment

1. Climate change is already happening. Several climate variables, including global and European temperatures and sea level, have repeatedly broken long-term records in recent years. Some changes in the climate system, such as sea level rise, are accelerating. Climate change has also increased the occurrence of several climate and weather extremes, including heat waves, heavy precipitation, floods and droughts, in many regions of Europe.
2. Climate change is creating risks, and limited opportunities, to the environment, the economy and people. These risks are expected to further increase in the future as the climate continues to change, depending on mitigation policies. Europe is also affected by the impacts of climate change outside Europe, which can affect Europe through different pathways, such as trade and migration.
3. In order to limit the adverse effects of climate change, strong mitigation and adaptation efforts are needed. 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 average temperature to well below 2 °C compared with pre-industrial levels and to aim at limiting the increase to 1.5 °C, as stated in the Paris Agreement.
4. EU GHG emissions decreased by about 22 % in the past 25 years due to the combined result of policies and measures and economic factors. As a result, the carbon and energy intensity of the EU economy is lower now than it was in 1990. The transport sector remains a key challenge to decarbonise the economy.
5. The EU remains on track to achieve its GHG emission reduction target of 20% compared to 1990 but is not on track to achieve the EU's target of a 40 % reduction by 2030. Much faster rates of emission reductions would be needed to achieve the EU's objective of an 80-95% reduction by 2050.
6. According to a recent REFIT evaluation, the EU adaptation strategy adopted in 2013 has delivered on most of its objectives. Climate change adaptation is increasingly mainstreamed in EU policies, programmes and strategies, the EU has 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 Climate-ADAPT facilitates the exchange of knowledge relevant for adaptation across Europe. However, the evaluation also identified areas where further action is needed.
7. The EU is broadly on track towards the target of spending at least 20 % of its budget for 2014–2020 on climate-related actions, but further efforts are needed. This target seems to have triggered a shift in climate-related spending in some policy areas, but not in others.

Theme	Past trends (10-15 years)	Outlooks 2030	Prospects to meet policy objectives /targets		
Greenhouse gas emissions and mitigation efforts			2020☑	2030☒	2050☒
Climate change and impacts on ecosystems			2020 ☒		
Climate change risks to society			2020		
Climate change adaptation efforts			2020		

Explanation of the summary assessment table

Past EU trends in GHG emissions are positive and the 2020 targets are within reach. However, the 2030 and 2050 targets are more ambitious, and, although emissions are projected to decrease, the current pace of emission reductions will not be sufficient to meet these targets. Stronger efforts are needed, also globally. Adverse impacts from climate change on ecosystems and society have been and are projected to be dominant in most European regions. Continuing climate change also makes it more difficult to achieve other environmental policy targets (e.g. on biodiversity protection and water quality). Whereas implementation of climate-change adaptation is in its early stages in many countries, future action is expected to occur at the EU, transnational, national and city levels.

GHG historic data are based on GHG inventories, which are reported according to UNFCCC and IPCC Guidelines, and are subject to an international review process. The uncertainty in GHG projections is higher. The assessment of past climate change and its impacts is based primarily on direct observations, complemented by other data sources. The aggregated assessment is considered robust, despite considerable uncertainties about climate change and its impacts on specific systems and sectors at the regional level. Regarding adaptation, information about national plans is based on country reporting to the EEA and on an assessment by the European Commission.

7.2 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 as well as human health and well-being are sensitive 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 policies 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. 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 (see Section 7.3 for further details). 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 in order to minimize 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).

7.3 Policy context

Mitigation and adaptation are both necessary to limit the risks from 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. The central aim of the Paris Agreement is to keep the global temperature rise well below 2 °C above pre-industrial levels and to pursue 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 humanity can emit without exceeding a given level of warming. The EU has implemented many legislative acts aimed at reducing the emissions of the most important greenhouse gases and at enhancing their sinks (see Table 7.1). One feature of EU’s domestic climate legislation is that it has the key objective of delivering on the agreed international commitments 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.

In contrast, adaptation to climate change is difficult to measure quantitatively, and there is no single metric for doing so. In fact, the effectiveness of adaptation measures often can only be assessed after an extreme weather event has happened. As a result, the policy targets for adaptation at the global and European level are less quantifiable, and monitoring focusses so far 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’ 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 Fisheries Policy, the Floods Directive and the Water Framework Directive, and policies related to biodiversity protection.

Mitigation as well as adaptation are facilitated by a suitable policy framework, adequate financial resources, and targeted information and knowledge. There are quantified targets for climate change finance at the global and the European level (see Table 7.1). Interestingly, neither of these targets distinguishes between mitigation and adaptation. Further support for adaptation actions in Europe is provided, among others, by the Copernicus Climate Change Service and dedicated research projects (e.g. under Horizon 2020 and JPI Climate).

Table 7.1 Selected policies and targets related to climate change

Policy Objectives & Targets	Sources	Target Year	Agreement
Climate change mitigation			
Limit human-induced global temperature rise to well below 2 °C (and to pursue efforts to limit the temperature increase to 1.5 °C) above pre-industrial levels	Paris Agreement (UN)	Permanent	Binding International treaty
•20% cut in greenhouse gas emissions (from 1990 levels) •20% of EU energy from renewables •20% improvement in energy efficiency To achieve the 20% target:	EU 2020 climate and energy package	2020	Binding GHG target

•EU emissions trading system (ETS) sectors would have to cut emissions by 21% (compared to 2005) **•non-ETS sectors would need to cut emissions by 10% (compared to 2005) – this is translated into individual binding targets for Member States.**			
•At least 40% cuts in greenhouse gas emissions (from 1990 levels) **•At least 32% share for renewable energy** **•At least 32.5% improvement in energy efficiency** **To achieve the at least 40% target:** **•EU emissions trading system (ETS) sectors would have to cut emissions by 43% (compared to 2005) – to this end, the ETS is to be reformed and strengthened** **•non-ETS sectors would need to cut emissions by 30% (compared to 2005) – this needs to be translated into individual binding targets for Member States.**	**EU 2030 climate and energy framework**	**2030**	**Binding GHG target**
•By 2050, the EU should cut greenhouse gas emissions to 80% below 1990 levels •Milestones: 40% emissions cuts by 2030 and 60% by 2040	EU 2050 low-carbon roadmap	2050	Non-binding commitment
Net-zero GHG emissions	EU strategy for long-term EU greenhouse gas emission reductions	2050	Non-binding commitment
Overarching objectives: secure, competitive and sustainable energy; Specific objectives: expand security of energy supply; connected EU energy market; reducing energy demand and improving energy efficiency; decarbonising the energy mix; and to 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)	2020	Non-binding commitment
Strengthen resilience and adaptive capacity to climate-related hazards and natural disasters in all countries	SDG Target 13.1 (UN) ; Paris Agreement (UN)	2030	Non-binding commitment
Integrate climate change measures into national policies, strategies and planning	SDG Target 13.2 (UN) ; Paris Agreement (UN)	2030	Non-binding commitment
All Member States are encouraged to adopt comprehensive adaptation strategies	EU Strategy on adaptation to climate change (Commission Communication and Council Conclusions)	2017	Non-binding commitment
Climate-proofing EU action: mainstream adaptation measures into EU policies and programmes		N.A.	Non-binding commitment
Climate change finance			
Developed countries shall mobilize jointly U$ 100 billion annually to address the mitigation and adaptation needs of developing countries	Cancun Pledge (UN), Paris Agreement (UN), SDG Target 13.4 (UN)	2020	International treaty
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)	2014-2020	Non-binding commitment

7.4 Key trends in Europe and in European countries, including outlooks

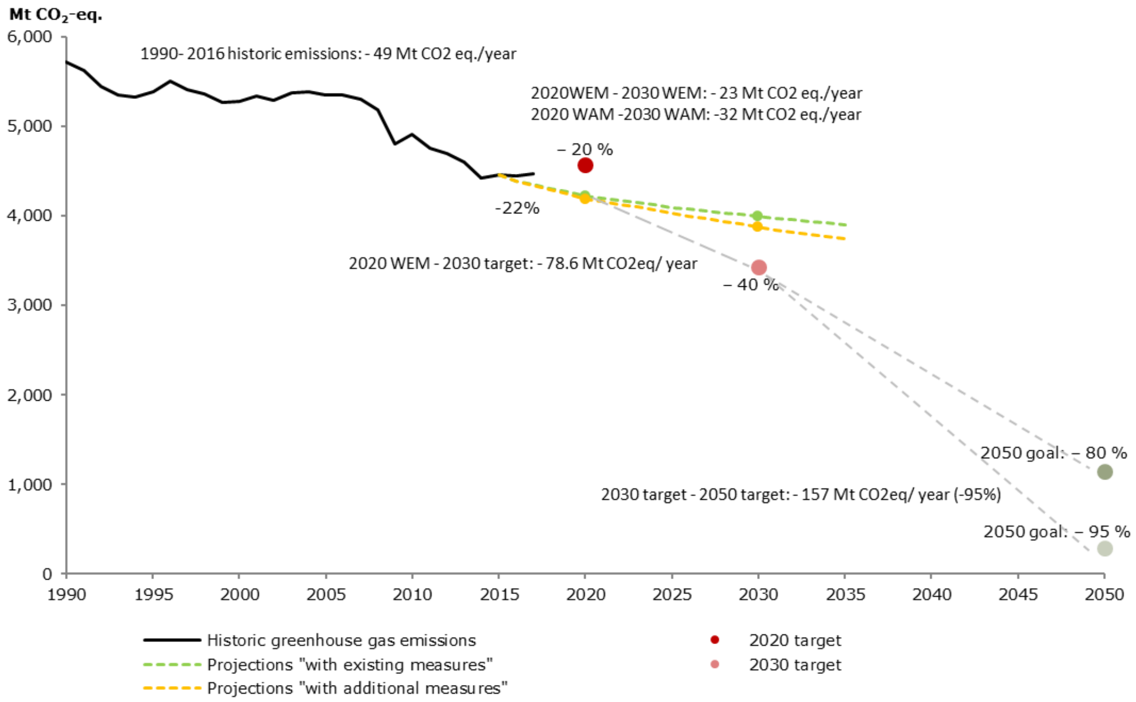
7.4.1 Emissions of greenhouse gases and climate change mitigation efforts

[Editorial note: The climate change mitigation sections will be updated, before publication, to include the 2019 GHG inventory submissions and the 2019 MS projections under the EU MMR]

Snapshot of EU's GHG emission trends and projections

Figure 7.1 shows that the total GHG emissions excluding LULUCF and including international aviation have been reduced by 1.3 billion tonnes of CO_2eq between 1990 and 2016. This represents a reduction of 22% in the past 26 years. Although there is a clear trend towards lower GHG emissions in the EU (EEA, 2018b), early GHG estimates for 2017 suggest the EU increased emissions by 0.6% compared to 2016 (EEA, 2018c).

Figure 7.1 GHG emissions 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 WEM scenario reflects existing policies and measures, whereas the WAM scenario considers the additional effects of planned measures reported by Member States.

Source: (EEA, 2018j).

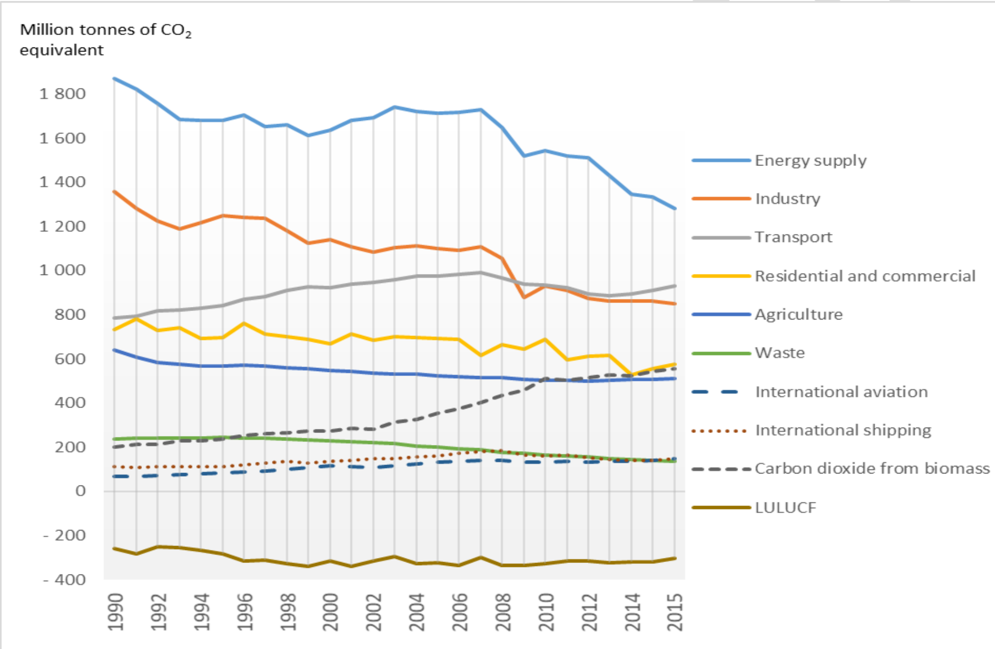
The reduction in total GHG emissions since 1990 means that the EU remains on track to meet its 2020 target. However, according to the latest projections reported by Member States (EEA, 2018d), only the 2020 target is within reach. Substantial efforts will therefore be needed to reach the 2030 target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

The EU is the sum of its Member States and almost all of them have reduced emissions since 1990. Almost 50% of the EU net-decrease was accounted for by Germany and the UK (Table 7.3). The overall mitigation efforts by most Member States were partly offset by higher GHG emissions in a few MS, notably in Spain.

On an aggregate level, Figure 7.2 shows that GHG emissions decreased in the majority of sectors between 1990 and 2016, 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 CO_2 emissions from biomass combustion. 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 replacing fossil fuel sources in the EU. The pressures from these sectors are not only relevant to climate change but also to other environmental variables *[editorial note: add cross-reference to chapter 13]*.

On a more detailed level, Table 7.2 shows that the largest emission reductions took place in manufacturing industries and construction, electricity and heat production, and residential combustion. The largest decrease in emissions in relative terms occurred in waste management, through reduced and better controlled landfilling. Emissions from HFCs and road transportation increased substantially over the 1990-2016 period.

Figure 7.2 GHG emissions by main sector in the EU-28, 1990-2015



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); LULUCF: CRF 4 (LULUCF).

International aviation, international shipping and CO_2 biomass are Memorandum items not included in national GHG totals.

Source: EEA

This represents a challenge for Member States and the achievement of the 2030 targets under the EU Effort Sharing Regulation since transport accounts for about one third of emissions covered by the sectors where national mitigation targets apply.

Table 7.2 Overview of EU-28 plus Iceland source categories whose emissions increased or decreased by more than 20 million tonnes CO_2 equivalent in the period 1990–2016

Source category	Million tonnes (CO_2 equivalents)
Road Transportation (CO_2 from 1.A.3.b)	163
Refrigeration and Air conditioning (HFCs from 2.F.1)	97
Aluminium Production (PFCs from 2.C.3)	-21
Agricultural Soils: Direct N_2O Emissions From Managed Soils (N_2O from 3.D.1)	-26
Fugitive emisisons from Natural Gas (CH_4 from 1.B.2.b)	-26
Cement Production (CO_2 from 2.A.1)	-28
Fluorochemical Production (HFCs from 2.B.9)	-29
Commercial/Institutional (CO_2 from 1.A.4.a)	-40
Enteric Fermentation: Cattle (CH_4 from 3.A.1)	-44
Nitric Acid Production (N_2O from 2.B.2)	-46
Adipic Acid Production (N_2O from 2.B.3)	-57
Manufacture of Solid Fuels and Other Energy Industries (CO_2 from 1.A.1.c)	-61
Coal Mining and Handling (CH_4 from 1.B.1.a)	-69
Managed Waste Disposal Sites (CH_4 from 5.A.1)	-73
Residential: Fuels (CO_2 from 1.A.4.b)	-109
Iron and steel production (CO_2 from 1.A.2.a +2.C.1)	-120
Manufacturing industries (excl. Iron and steel) (Energy-related CO_2 from 1.A.2 excl. 1.A.2.a)	-278
Public Electricity and Heat Production (CO_2 from 1.A.1.a)	-420
Total	**-1356**

Source: EEA

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

Between 2005 and 2016, emissions covered under the EU ETS have 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 larger consumption of hard coal and lignite for power generation. Since then, however, ETS emissions have decreased by a faster rate than non-ETS. To the improvements observed in the 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 are allocacted to the end-user sectors, EEA figures show that the largest emission reductions in the period following the economic recession were by and large accounted for by industry as a whole (EEA, 2012).

Of the net EU reduction in total GHG emissions between 2005 and 2016, two thirds was accounted for 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 Effort Sharing Regulation) currently represent about 60 % of total greenhouse gas emissions in the EU, and 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 bulidings, non-ETS industry and waste management. Emission reductions in agriculture and transport have been modest since 2005; and, for transport, emissions have actually increased consecutively in the last few years, both for freight and passenger cars.

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:

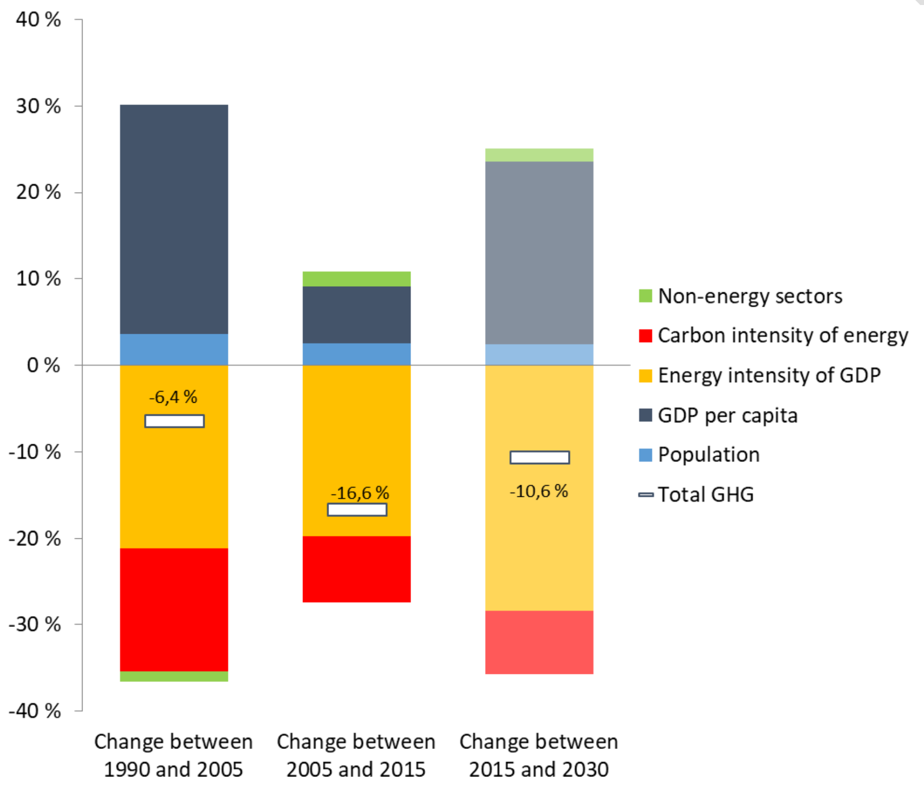
1. Higher GDP would usually lead to higher GHG emissions, other factors equal, because economic growth is intrinsically linked to an energy system that remains heavily dependent of fossil fuels in most European countries (EEA, 2014b). Yet, the figure shows that emissions decreased and are expected to decrease further as GDP increases, confirming that that attempts to mitigate climate change do not necessarily conflict with a growing economy. In addition, GHG intensities of Member States have both decreased since 1990 and converge. One reason for this convergence is the strong growth in the use of renewable 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.
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 the last years. This positive trends has been due both to the higher contribution from renewable energy sources in the fuel mix and to the switch from the more carbon-intensive coal to the less carbon intensive gas. The lower carbon intensity of energy (i.e. fewer emissions to produce and use 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 more gas, less coal and a lower consumption of oil, are expected to drive emission reductions in the future.
3. The decrease in primary energy intensity was the largest contributing factor to lower CO_2 emissions from fossil fuel combustion in the past. The lower energy intensity of GDP can be explained by improvements in energy efficiency (transformation and end-use) and the strong uptake of renewables, as well as by changes in the structure of the economy and a higher share of the services sector compared to the more energy intensive industrial sector[1]. The decrease in the primary energy intensity of energy, is

[1] There are various reasons for the lower share of industry in Europe. 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 the analysis of emission trends. Yet, the assessment of progress

expected to remain a key factor in the transition to a low carbon economy. This means continued improvements in energy efficiency, both in transformation and end-use.

4. The largest emission reductions occurred in the energy combustion sector. Although the effects shown in the decomposition analysis have been modest (as energy-related emissions have decreased faster than non-energy emissions), the actual emission reductions observed in industrial processes, agriculture and waste management have been substantial since 1990. The largest emission reductions will continue to occur in the energy sector, although all sectors of the economy are expected to contribute to meeting climate mitigation objectives.

Figure 7.3 Drivers of GHG emission reductions in the EU-28, 1990-2016



Note: 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 respective 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' variables.

Source: EEA

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 provisional overall estimates for GHG emission reductions by 2030 (with existing policies and measures), as reported by Member States, are consistent with a 30 % reduction compared with 1990 (excluding LULUCF, including international aviation). Whereas the EU is on track to achieve its 20 % GHG reduction target by 2020, more efforts to reduce GHG emissions will be needed to

towards GHG mitigation targets used here is consistent with how the targets have been defined (production-based approach). Also, while Europe may be indirectly generating some of the emissions elsewhere for final consumption in Europe — exported EU emissions — a share of Europe's own emissions can also be traced to final consumption of European goods outside Europe — imported EU emissions.

achieve its reduction target of at least 40 % by 2030 (EEA, 2018j). 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. In this regard, transport emissions would have to decrease substantially for the EU and MS to meet their targets.

It is worth highlighting that warmer winters is another factor of lower GHG emissions in Europe. There has been lower fuel use due to the lower demand for space heating due to better insulation standards and retrofitting in buildings. Also, and notwithstanding the different trends by country and region, Europe has been experiencing milder winters since 1990. There is also a clear positive correlation between heating degree days (HDDs) and fuel use and emissions from the residential sector. According to Eurostat data (Eurostat, 2019), the current demand for heating in Europe is below its long-term average (defined as 1980-2004). An EEA analysis on heating and cooling (EEA, 2016b), showed that HDDs 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 (CDDs) increased on average by almost 2 % per year during the same period, particularly in southern Europe. Because temperatures in Europe are projected to increase, the trends of lower HDDs and higher CDDs are also expected to continue, if not accelerate.

In sum, 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. These include, among others:
- the growing use of energy from renewable sources;
- the use of less carbon-intensive fossil fuels (e.g. switch from coal to gas);
- improvements in energy efficiency;
- structural changes in the economy, with a higher share of services and a lower share of more energy-intensive industry in total GDP;
- the effects of economic recession;
- the milder winters experienced in Europe on average since 1990, which has reduced the demand for energy to heat households.

Finally, in spite of good progress in reducing GHG emissions intensity and decarbonising the EU economy, fossil fuels are still the largest source of energy and emissions in the EU. There cannot be a complete decoupling of emissions from economic growth in a fossil-fuel economy. This is because energy demand, which 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.

[Editorial note: The table below will be updated with 2017 GHG inventory data and the projections reported in 2019.]

Table 7.3 Country comparison – Climate mitigation variables and indicators by country: trends and projections

	Change in total GHG emissions excluding LULUCF 1990-2016 (%)	GHG emissions per GDP in 2016 (PPS, EU-28=100)	GHG emissions per capita in 2016, (tCO2 eq. per person)	Change in the carbon intensity of energy 1990-2016	Change in the total energy intensity of the economy 1990-2016	Projected change in total GHG emissions 2015-2030 (%)
Austria	3.1	84	9.4	-22.1	-16.2	-11.1
Belgium	-18.5	106	10.8	-28.6	-24.3	-2.9
Bulgaria	-43.0	199	8.4	-11.6	-58.2	-6.1
Croatia	-23.8	114	5.9	-13.2	-19.5	3.5
Cyprus	52.9	156	11.3	3.8	-24.7	-7.0
Czech Republic	-34.4	164	12.4	-25.1	-48.3	-12.7
Denmark	-26.1	85	9.3	-25.8	-35.8	5.5
Estonia	-51.4	224	15.0	-24.5	-59.9	-5.4
Finland	-16.0	117	11.1	-29.7	-20.6	-12.0
France	-14.4	79	7.1	-20.0	-25.8	-12.0
Germany	-25.9	106	11.4	-14.5	-39.5	-16.8
Greece	-10.3	148	8.8	-18.5	-12.6	-9.7
Hungary	-34.2	108	6.3	-26.1	-37.5	-3.1
Ireland	13.4	87	13.5	-12.9	-63.8	11.0
Italy	-16.2	86	7.2	-17.5	-15.3	-9.5
Latvia	-56.2	106	6.0	-29.8	-54.1	7.4
Lithuania	-58.0	108	7.1	-21.3	-67.8	10.1
Luxembourg	-12.5	88	19.8	-21.2	-52.3	-4.3
Malta	-0.6	61	5.0	-32.4	-54.3	-11.3
Netherlands	-8.4	109	12.2	-7.1	-31.7	-12.8
Poland	-15.0	175	10.5	-11.2	-61.7	-8.8
Portugal	15.8	102	6.9	-7.9	-9.1	-20.0
Romania	-54.2	114	5.8	-22.3	-65.3	8.3
Slovakia	-44.4	114	7.6	-35.7	-64.8	-0.8
Slovenia	-4.8	121	8.6	-18.2	-27.3	-2.3
Spain	16.4	92	7.3	-12.3	-19.1	-0.6
Sweden	-23.9	53	5.6	-28.5	-40.5	-13.5
United Kingdom	-36.4	84	7.9	-25.0	-46.4	-18.1
EU-28	-22.4	100	8.7	-19.5	-35.9	-10.5
Iceland	45.1	147	16.7	-43.0	12.7	-
Norway	4.6	81	10.5	1.0	-29.8	-
Liechtenstein	-17.7	-	5.0	-	-	-
Switzerland	-5.6	46	6.4	-	-	-
Turkey	139.9	116	6.4	0.5	-11.1	-

Notes: GHG aggregates include international aviation and exclude the LULUCF sector. For the West-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 their Biennial Update Reports to UNFCCC and from European Commission projects such as the ECRAN.

Source: EEA

Summary assessment

Table 7.4 Summary assessment related to greenhouse gas emissions and mitigation efforts

Greenhouse gas emissions and mitigation efforts		
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 heat demand from milder winter conditions also played a role.
Outlooks 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) but insufficient to meet the 2030 decarbonisation target.
Prospects to meet policy objectives/targets	2020 ☑	The EU remains on track to achieve its 20% 2020 target compared to 1990. Further mitigation efforts are required to meet the 40 % reduction target by 2030 compared to 1990. Even faster rates of emission reductions are required to meet the 2050 objective of reduction GHG emissions of 80% to 95%.
	2030 ☒	
	2050 ☒	
Robustness	GHG historic data are based on GHG inventories reported to the UNFCCC, and to the EU under the EU Monitoring Mechanism. Although there is uncertainty in emission estimates, GHG inventories undergo a thorough QA/QC and review process on an annual basis. Outlooks are based on GHG projections data from Member States as reported under the EU MMR. The uncertainty in the projections is higher but the estimates for 2020 and 2030 at EU level are fully consistent with what Member States report to the EU.	

7.4.2 Link between climate change mitigation, adaptation and other policy areas

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 efforts 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 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.

Climate change mitigation and adaptation objectives can be mutually reinforcing, but also in conflict with each other. One strategy that often brings about mitigation as well as adaptation benefits is ecosystem-based adaptation (EbA), which uses ecosystem services as a 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). This strategy overlaps with concepts like nature-based solutions and includes natural water retention measures ([2]) and green infrastructure (EC, 2013b). When designed, implemented and monitored appropriately, EbA often has a higher benefit-cost ratio than traditional infrastructure works due to the multiple environmental, social, economic and cultural co-benefits it generates, especially when non-monetary aspects are included as well. EbA can also contribute to climate change mitigation by reducing emissions caused by ecosystem degradation and/or by enhancing carbon stocks.

[Editorial note: A number of co-benefits from climate change mitigation will be discussed in an upcoming EEA report (expected in Q2 of 2019) on the key trends and drivers underpinning the GHG inventory submission to UNFCCC]

7.4.3 Climate change and its impacts on ecosystems

[Editorial note: This section will be updated with information from the Copernicus Climate Change Service (C3S) State of the Climate Report 2018, to be published in spring 2019.]

All ecosystems, many economic activities as well as 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 the futures, and of selected impacts on ecosystems. More detailed information on this topic is available in a recent EEA report (EEA, 2017b).

Average temperature

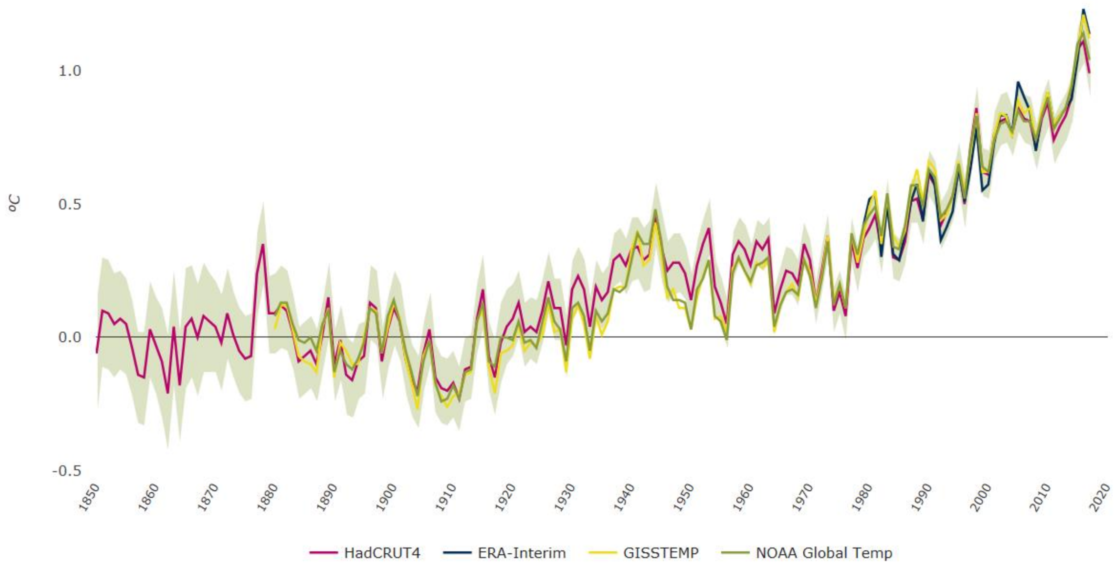
[Editorial note: To be updated based on latest assessment of CSI 012 (planned for early 2019)]

Global average annual near-surface (land and ocean) temperature in the last decade (2008–2017) was about 0.9 °C warmer than the pre-industrial average (1850–1899) (Figure 7.4); the European land area has warmed by 1.6-1.7 °C over the same period. Of the 17 warmest years on the record globally, 16 have occurred since 2000 (EEA indicator 'Global and European temperature' (CSI 012)).

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 realized. For the three highest of the four representative concentration pathways (emissions scenarios) considered by the 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 rapid global emissions reductions are necessary to keep the chance of limiting global mean temperature increase to 1.5 °C (IPCC, 2018).

([2]) http://nwrm.eu

Figure 7.4 Global average near surface temperature since the pre-industrial period



Source: [EEA indicator 'Global and European temperature' (CSI 012)]

Heat extremes

[Editorial note: To be updated based on latest assessment of CSI 012 (planned for early 2019)]

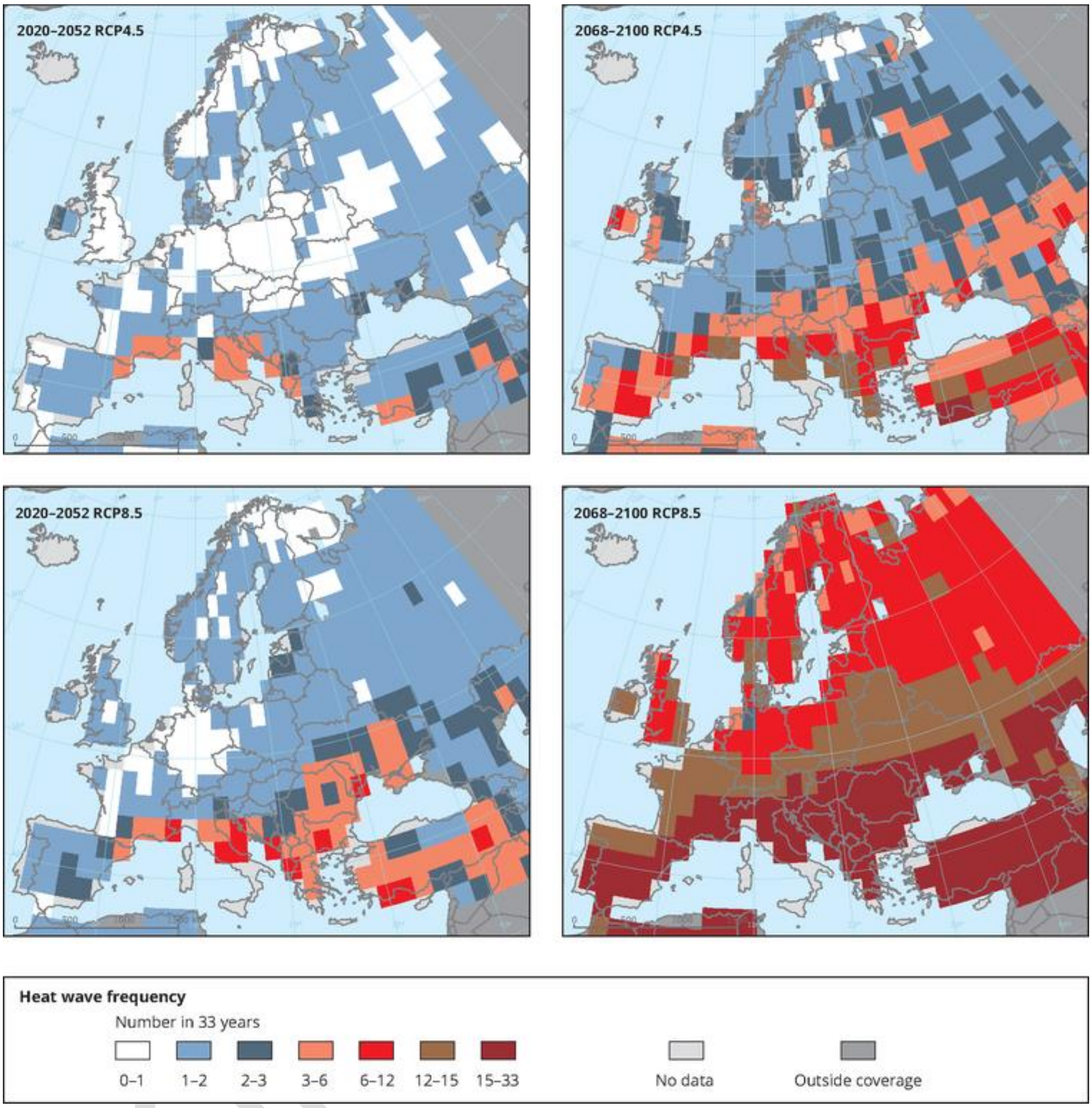
Annually averaged land temperatures in Europe have increased considerably faster than global temperatures (see above), and daily maximum temperatures in Europe have increased much faster than annually averaged temperatures. This means that a given increase in global mean temperature is associated with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

Heat extremes and heat waves in Europe have increased considerably since the 1950s, with notable impacts on ecosystems, economic activities and human health. 500-year-old temperature records were broken over 65 % of Europe in the period 2003–2010 alone. Afterwards, the years 2014, 2015, 2016 and 2018 broke further temperature records in Europe. Human-induced climate change made those unprecedented recent heat waves in Europe much more likely than they would have been otherwise (EEA indicator 'Global and European temperature' (CSI 012)).

Heat waves are projected to become even more frequent and longer lasting in Europe. Under a high emissions scenario, very extreme heat waves (much stronger 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 two years in the second half of the 21st century (Figure 7.5). 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. The effects of heat waves are exacerbated in cities due to the urban heat island effect.

Figure 7.5 Extreme heat waves in the future under two different forcing scenarios



Note: RCP4.5 corresponds to a medium emissions scenario whereas RCP8.5 refers to a high emissions scenario. Neither of these scenarios is compatible with the stabilization target of the Paris Agreement.

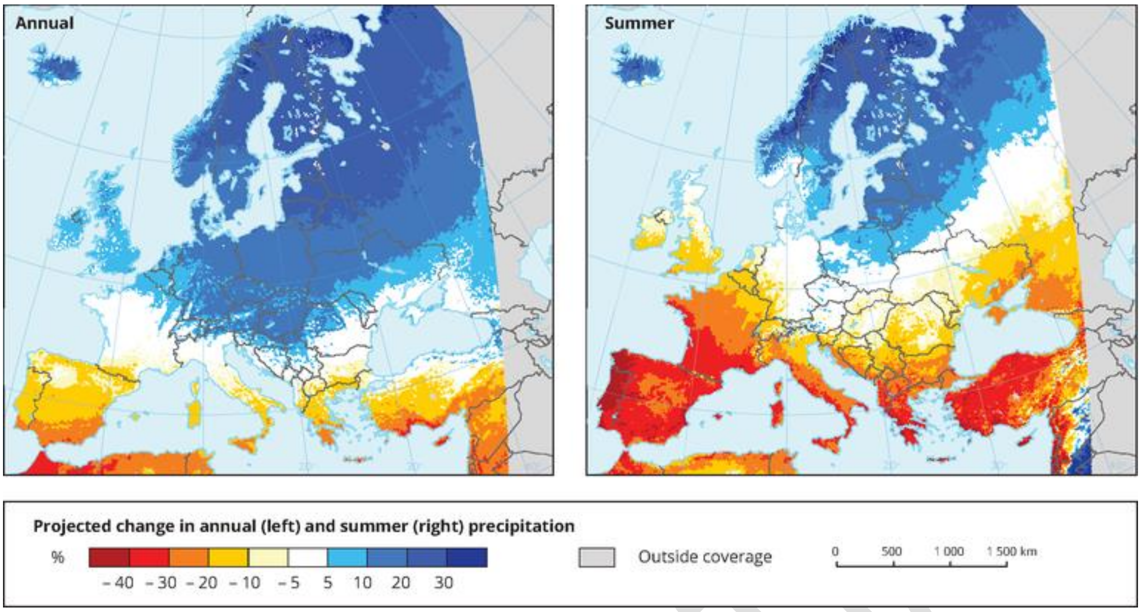
Source: EEA indicator 'Global and European temperature' (CSI 012), adapted from (Russo et al., 2014).

Total precipitation

Source: Latest assessment of CLIM002 (from early 2017)

Observed and projected changes in precipitation vary substantially 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, the projected decrease in southern Europe is strongest in the summer (Figure 7.6) (EEA indicator 'Mean precipitation' (CLIM 002)).

Figure 7.6 Projected changes in annual and summer precipitation



Note: Projected changes in annual (left) and summer (right) precipitation (%) in the period 2071-2100 compared to the baseline period 1971-2000 for the forcing scenario RCP 8.5. Model simulations are based on the multi-model ensemble average of RCM simulations from the EURO-CORDEX initiative.

Source: [EEA indicator 'Mean precipitation' (CLIM 002)], based on EURO-CORDEX data.

Heavy precipitation and inland floods

[Editorial note: To be updated based on Latest assessment of CLIM004 (planned for early 2019)]

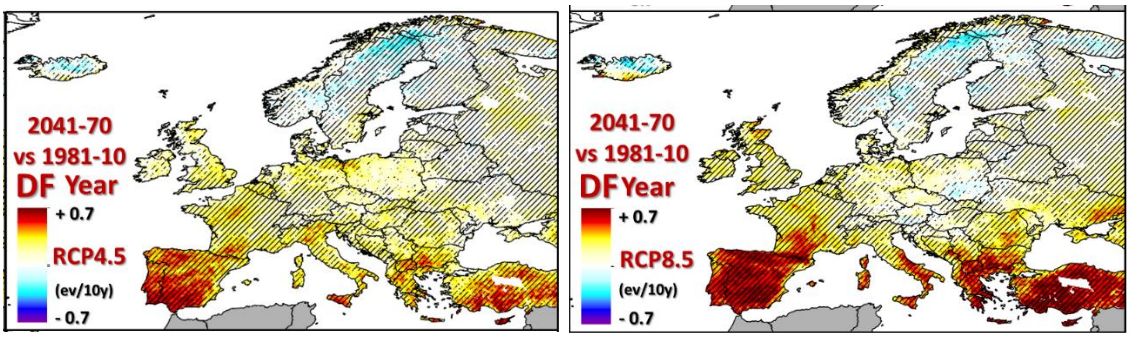
The intensity of heavy precipitation events, which can cause floods, has increased in summer and winter in most parts of northern Europe. The largest increase has been observed for particularly strong precipitation events. Different indices show diverging trends for southern Europe. Heavy precipitation events are likely to become more frequent in most parts of Europe (EEA indicator 'Heavy precipitation' (CLIM 004)).

The number of very severe flood events in Europe has increased in recent decades, but with large inter-annual variability. Various European-wide studies project river floods to become more frequent in north-western and central-western parts of Europe; available studies come to divergent results 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 indicator 'River floods' (CLIM 017)).

Droughts

Drought conditions have generally increased in southern Europe and decreased in northern Europe, with 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 (Figure 7.7). 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 (EEA indicator 'Meteorological and hydrological droughts' (CLIM018)). For further information on freshwater systems affected by climate change, see Chapter 4.

Figure 7.7 Projected changes in the frequency of meteorological droughts



Note: The maps show projected changes in the number of months with drought conditions by mid-century (2041-2070 relative to 1981-2010) for two different emissions scenario: RCP4.5 (left) and RCP8.5 (right). For an explanation of these scenarios, see Figure **7.5**.

Source: JRC (Spinoni et al., 2018).

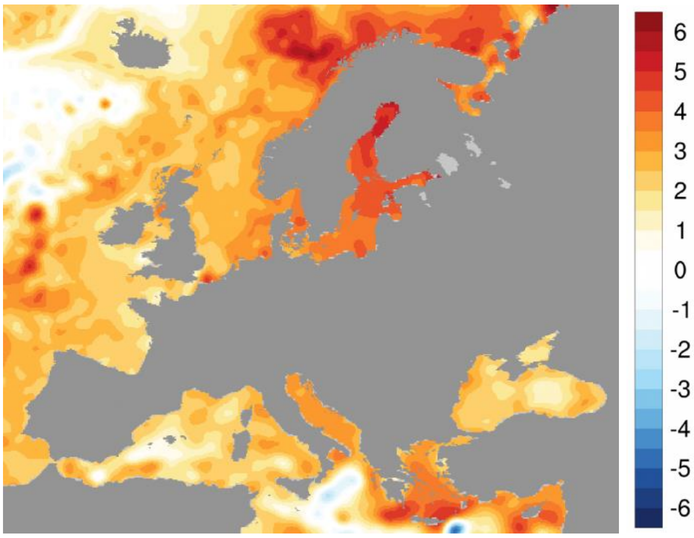
Global and European sea level

[Editorial note: To be updated based on Latest assessment of CSI047 (planned for January 2019)]

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 AR5 projected a rise in global sea level over the 21st century that is likely in the range of 28–98 cm (depending on the emissions scenario), but substantially higher values of sea level rise were not ruled out. Several 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 are projected for the following centuries if the stabilization goal of the Paris Agreement is not met (EEA indicator 'Global and European sea level' (CSI 047).

All coastal regions in Europe have experienced an increase in absolute sea level, but with significant regional variation (Figure 7.8). 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 lives (see also Chapter 6). All available studies project that the economic damages from coastal floods in Europe would increase many-fold in the absence of adaptation.

Figure 7.8 Trend in absolute mean sea level across Europe



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

Source: C3S Sea level indicator (C3S, 2018)

Further changes in the climate system

Climate change is also evident through melting glaciers, decreasing sea ice and warming oceans. Furthermore, the CO_2 emissions driving global climate change are turning the oceans more acidic (sour), which inhibits the growth of calcifying organisms (see also 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 northward and, for land-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 indicator 'Distribution shifts of plant and animal species' (CLIM 022); EEA indicator 'Distribution shifts of marine species' (CLIM 015)). Climate change is also leading to changes in the seasonality of biological events, such as flowering of plants or hatching of birds. 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 (see also 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 indicator 'Forest composition and distribution' (CLIM 034)). More severe 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 indicator 'Forest fires' (CLIM 035)). 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, 2017b, section 4.4.7). These combined impacts considerably affect forest structure, the functioning of forest ecosystems and their services (see also Chapter 5).

Summary assessment

Table 7.5 Summary assessment for sub-theme 'climate change and its impacts on ecosystems'

Climate change and its impacts on ecosystems		
Past trends (10-15 years)		Anthropogenic climate change is ongoing and has led to increasing impacts on ecosystems. In some cases, such as sea level rise, changes have been accelerating.
Outlooks 2030		Climate change will continue in the coming decades, with increasingly severe impacts on species and ecosystems projected.
Prospects to meet policy objectives/targets	2020	While there are no specific targets related to climate change and its impacts on ecosystems in Europe, the 7th EAP 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, even though considerable uncertainties exist for climate change and its impacts on specific ecosystems at the regional level.	

7.4.4 Climate change risks to society

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

Health impacts of climate change

Heat waves are the most deadly climate extremes in Europe; they have caused tens of thousands of premature deaths in Europe since 2000. The projected substantial increase in the frequency and magnitude of heat waves will lead to a large increase in mortality over the next 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 combination of higher temperatures as a result of the urban heat island affect, frequent combination of heat with air pollution, and high population density (EEA indicator 'Extreme temperatures and health' (CLIM 036)).

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-borne, water-borne and food-borne diseases, pollen allergens and air pollution incidents. For example, extremely warm water temperatures in the Baltic Sea and the North Sea during recent heat waves were associated with unprecedented peaks in *Vibrio* infections in humans (EEA, 2017b, section 5.2).

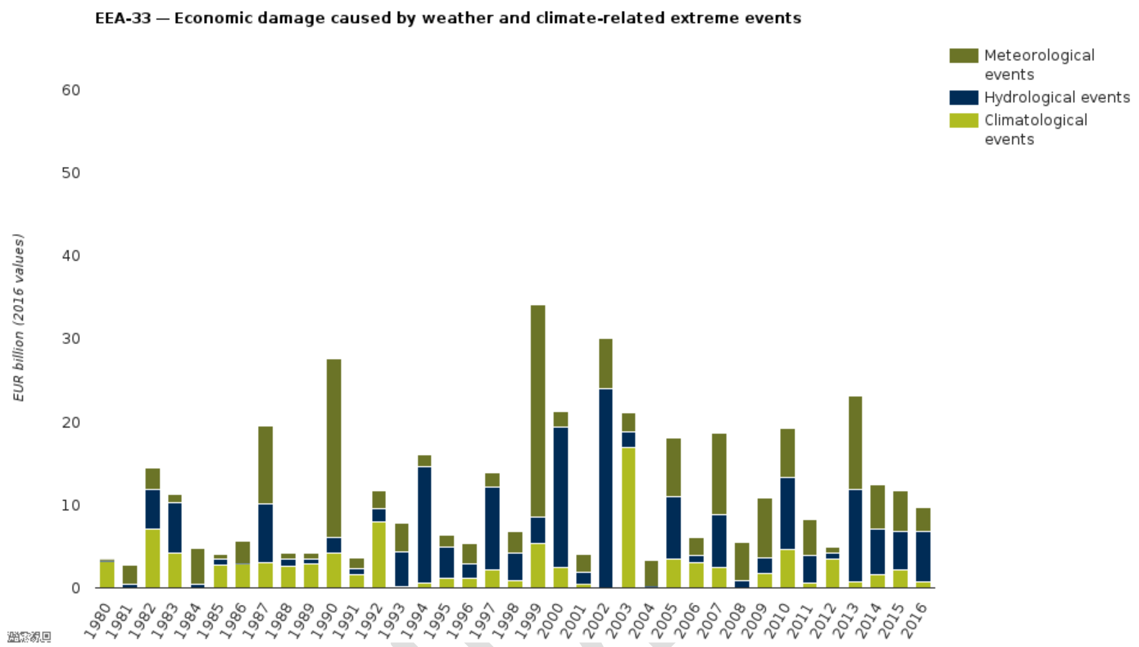
Economic losses from climate-related extremes

[Editorial note: This text will be updated based on the Latest assessment of CSI042 (planned for early 2019]

The direct economic losses caused by weather and climate-related extremes in the EEA member countries amounted to approximately EUR 436 billion (in 2016 Euro values) over the period

1980-2016 (Figure 7.9). Most of the losses were caused by a small number of very strong events, which makes the detection of trends difficult ([EEA indicator 'Economic losses from climate-related extremes' (CSI 042)](#)). Model simulations performed by the JRC project large increases in most climate hazards in Europe, with considerable economic damages. For example, impacts on critical infrastructure could rise ten-fold during the 21st century due to climate change along in the absence of effective adaptation (Forzieri et al., 2016, 2018).

Figure 7.9 Economic damage caused by climate-related extreme events



Source: [EEA indicator 'Economic losses from climate-related extremes' (CSI 042)](#)

Other economic impacts of climate change

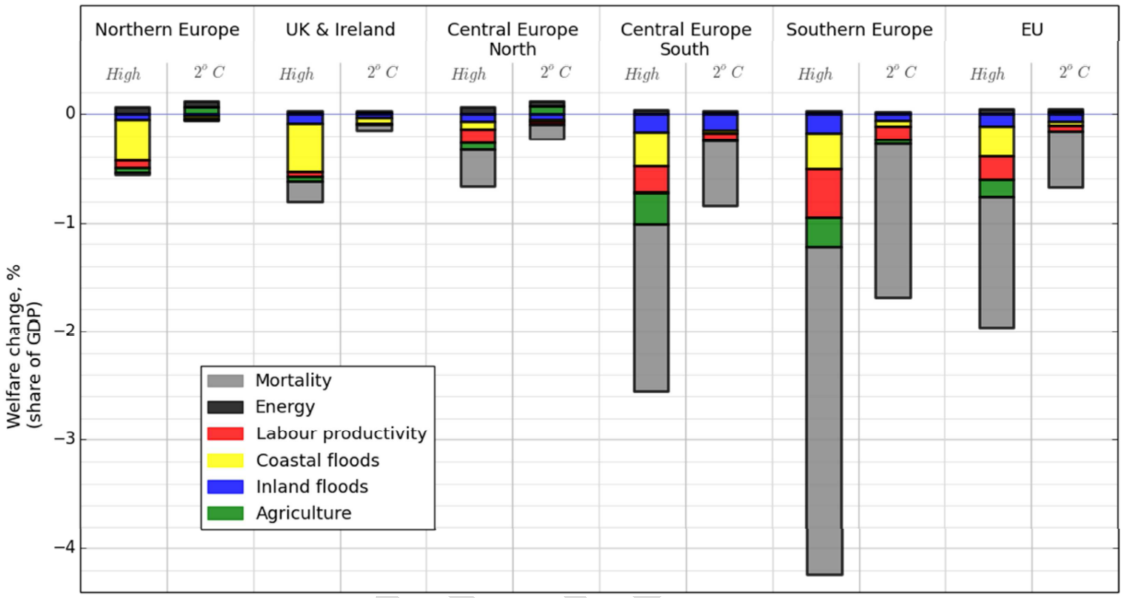
A changing climate is affecting a wide range of economic sectors and human activities, including agriculture, forestry, fisheries, water management, coastal and flood protection energy, transport, tourism, construction and human health. Various research projects have assessed the multi-sectoral social 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 future versus current impacts (EEA, 2017b, section 6.3).

The PESETA III study by the JRC estimates the net welfare loss from climate change in the EU at 1.9 % of GDP under a high warming scenario (RCP8.5) and 0.7 % under a 2 °C scenario (see Figure 7.10). Southern and central-southern Europe are projected to suffer by far the highest costs 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 welfare impacts is the energy sector, due to reduced heating needs 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 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, 2017b, section 6.3; EC, 2018b, Annex XIII).

European societies are also affected by the impacts of climate change occurring outside Europe, which can affect Europe through different pathways, such as international trade and migration (EEA, 2017b, section 6.4; Ciscar et al., 2018).

Figure 7.10 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: Sweden, Finland, Estonia, Lithuania, Latvia and Denmark. UK & Ireland: United Kingdom and Ireland. Central Europe North: Belgium, Netherlands, Germany and Poland. Central Europe South: France, Austria, Czech Republic, Slovakia, Hungary, Slovenia and Romania. Southern Europe: Portugal, Spain, Italy, Greece and Bulgaria.

Source: JRC (Ciscar et al., 2018)

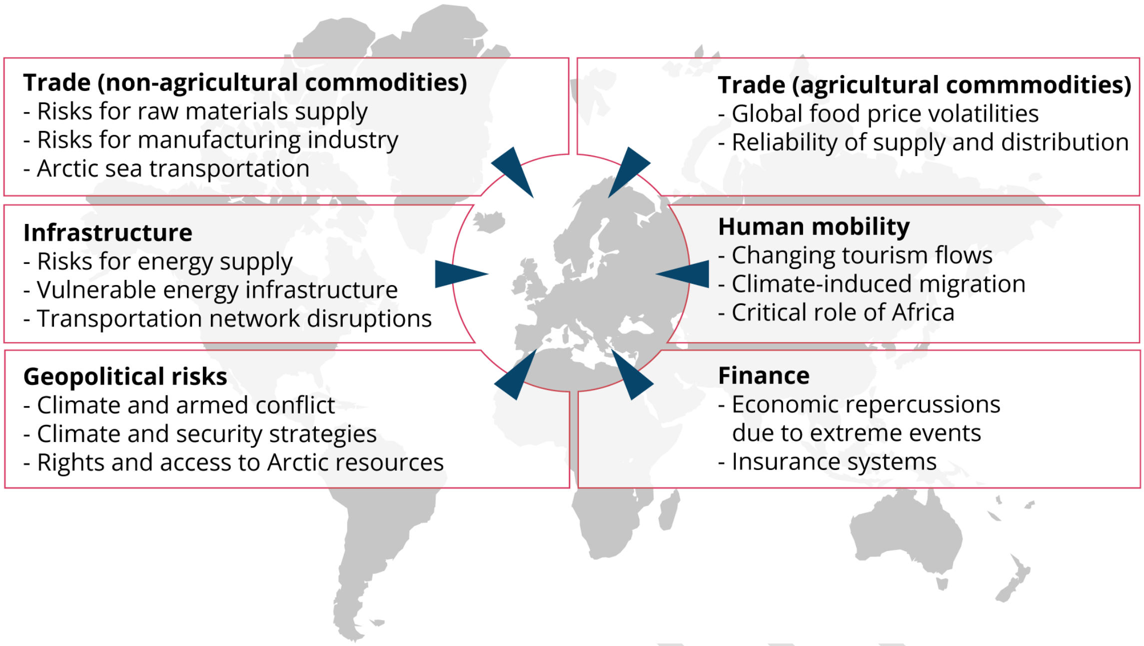
Europe's vulnerability to climate change impacts occurring outside Europe

European societies are also affected by the impacts of climate change outside Europe, which can affect Europe through different pathways, such as international trade and migration, as illustrated in Figure 7.11 . These "cross-border effects" may significantly influence the overall risk of climate change to regions, sectors and people. Cross-border effects of climate change may be caused by a single extreme weather event (for examples, a temporary disruption of global supply chains due to damaged production or transport infrastructure following a flood), by prolonged periods of extreme weather (for example, an extreme drought that increases world market prices of agricultural droughts) or by gradual climate change (for example, flooding of densely populated coastal areas that triggers internal and international migration) (EEA, 2017b, section 6.4).

The strongest evidence for Europe's sensitivity to cross-border impacts are the economic effects caused by climate‑induced global price volatilities; disruptions to transportation networks such as ports; and changes in the Arctic environment.

According to several studies, European vulnerability to cross-border effects of climate change is expected to increase in the coming decades, but quantitative projections are not yet available.

Figure 7.11 Overview of major pathways of indirect climate change impacts for Europe



Summary assessment

Table 7.6 Summary assessment for sub-theme 'climate change risks to society'

Climate change risks to society		
Past trends (10-15 years)	(red)	Premature deaths due to heatwaves 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.
Outlooks 2030	(red)	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 with substantial variation across regions and economic activities.
Prospects to meet policy objectives/targets	2020 (yellow)	There are no specific targets for climate-related health risks although the 7th EAP requires decisive progress is 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 lower health impacts due to adaptation.
Robustness	Data on past climate-sensitive health impacts originates 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 is derived from insurance data, including estimates of nun-insured losses. Attribution of trends is difficult because of the sparsity of the most costly events as well as concurrent developments in hazard, exposure and vulnerability.	

7.5 Responses and prospects for meeting agreed targets and objectives

7.5.1 Climate change mitigation

A number of policies have played an important role in GHG emission reductions in the past 26 years (EEA, 2018g) (EEA, 2018f). 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 Agriculture Policy (CAP) and the Landfill Directive have had a positive impact on reducing greenhouse gas emissions from methane and nitrous oxides. The Montreal Protocol on ozone-depleting substances (ODS) has been one of the most successful multilateral environmental (and indirectly climatic) agreements to date, contributing to substantial GHG emissions reductions 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 cut the production and consumption of HFCs by over 80 % over the next 30 years.

Considerable co-benefits exist for air pollution and climate policies (although some trade-offs exist as well, see Chapter 8)

. For example, 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). Indeed, the EU has been able to reduce GHG emissions and air pollution, improve energy efficiency and achieve higher shares of renewable energies, and at the same time increase economic growth. Although much remains to be done, policy makers should consider the co-benefits and trade-offs between climate policies and other policies, including environmental policies, in the design of new legislation in order to 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-run relationship between GHG emissions, economic growth and fossil-energy use, 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 MS, this long-run 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. The analysis concluded that there is a need to further improve energy efficiency and carbon intensity to meet the EU's 2030 and 2050 objectives, and completely decouple GHG emissions from energy use and economic growth.

Indeed, although there have been strategies and various policies aimed at reducing GHG in the EU since 2005, the effect of such policies, globally, has been relatively modest. This is because the EU represents 8% of global GHG emissions. The 2020 EU climate and energy framework was partly designed to help the EU achieve its international 20% reduction target by 2020 under the UNFCCC as well as its 20% emission reduction under its 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, 2015a). The modalities, procedures and guidelines of the enhanced transparency framework under the Paris Agreement, or Paris rulebook, were decided at COP24 (UNFCCC, 2018).

In 2018, the European Council adopted the '2030 climate and energy framework' (EU, 2018a). The headline target of a 40 % reduction in greenhouse gas emissions by 2030 is consistent with the EU's National Determined Contribution under the Paris Agreement and with the EU's longer-term EU objective of the '2050 low-carbon economy roadmap' of reducing its GHG emissions by 80 % by 2050 compared to 1990, with milestones of 40 % by 2030 and 60 % by 2040. The climate-change mitigation objectives are also part of the Energy Union Framework Strategy, which includes the strategic objectives to reduce energy demand, improve energy efficiency and decarbonise the energy mix. Finally, the European Commission proposed in November 2018 an EU strategy for long-term EU greenhouse gas emission reductions, which proposes options for reducing GHG emissions between 80 % and up to net zero emissions by 2050.

Although EU domestic legislation is in place in order to meet the Paris Agreement objectives, it is yet unclear whether the current NDCs by all signatories to the Paris Agreement are consistent with the overall UNFCCC objective of avoiding dangerous anthropogenic interference with the climate system (UNFCCC, 1992). The Paris Agreement requires each Party to prepare, communicate and maintain successive nationally determined contributions (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, 2015b). 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 degree and 1.5 degree targets.

The Paris agreement also recognises the role of local and regional actors 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, 2019). In Europe, over 7000 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 occur at any levels of government.

The challenge is big. Three out of four representative concentration pathways (the global emissions scenarios used in the latest IPCC report) exceed 2 °C of global warming during the 21st century, and most likely in the 2040s (IPCC, 2013; Vautard et al., 2014). Very rapid global emissions reductions are necessary to keep the chance of limiting global mean temperature increase to 1.5 °C (IPCC, 2018).

7.5.2 Climate change adaptation

A number of multilateral frameworks under the United Nations (UN) with relevance for climate change adaptation have been adopted since 2015. Besides the Paris Agreement on Climate Change (UNFCCC, 2015c), 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 (GGA) 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, 2015c, Art. 7) and thus, linking adaptation and sustainable development. SFDRR and SDGs also consider adaptation as crucial, therefore possible synergies could arise on 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.

Adaptation efforts of the EU

The EU strategy on adaptation to climate change (EC, 2013a) 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 EC published an evaluation of the EU Adaptation Strategy (EC, 2018c, 2018b, 2018a). While there is no specific monitoring and evaluation framework for the strategy, the eight different actions defined in the strategy are evaluated in their own right.

The evaluation of the EU Adaptation Strategy, based on the REFIT criteria (EC, 2012a), shows progress for each of the actions between 2013 and 2018, and added value to national and sub-national efforts. For example, climate change adaptation is increasingly mainstreamed in 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 Climate-ADAPT facilitates the exchange of knowledge relevant for adaptation across Europe. While the adaptation strategy promoted adaptation action plans, it was less effective as regards implementation, monitoring and evaluation of those plans. Reflecting on lessons learned, the evaluation emphasizes the needs for: applying available knowledge for decision-making under uncertainty, for example through science-policy dialogues; improved 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 of national adaptation strategies and plans; encouraging the establishment of local adaptation strategies in all Member States; and improved 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 in 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, 2018c).

Climate-proofing of EU action mainly includes mainstreaming adaptation in key vulnerable sectors. The adaptation strategy explicitly refers to the Common Agricultural Policy, the Cohesion Policy and the Common Fisheries Policy, but progress has been made as well in mainstreaming into disaster risk reduction, water, urban and development cooperation policies. A full list of EU policy initiatives where adaptation is mainstreamed, or is being mainstreamed, is available in Annex XI of the Staff Working Document (EC, 2018b). Adaptation is also mainstreamed in the Regulation on the Governance of the Energy Union and Climate Action, 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).

[Editorial note: The following paragraph will be updated in April 2019, following the launch of the revised Climate-ADAPT website.]

Better informed decision making, with a central role for Climate-ADAPT([3]) is also an objective of the EU Adaptation Strategy. Climate-ADAPT aims to provide a common European knowledge base to support a better informed decision making on adaptation; in April 2019 it contained xxx database items, xxx case studies and had xxx subscribers to its newsletter across Europe. With a growing number of countries implementing adaptation action plans, the information provided by Climate-ADAPT shifts to knowledge on the implementation and monitoring of adaptation and

([3]) https://climate-adapt.eea.europa.eu/

the development of appropriate indicator sets, e.g. by improving the Adaptation Support Tool(4), and a branding as a first-stop shop for adaptation information in Europe, complementary to the national adaptation portals (EEA, 2018i).

The Copernicus Climate Change Service (C3S)(5) provides an increasing amount of data on past and projected climate change freely 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

[Editorial comment: The final report will include a more comprehensive reporting of findings from the 'horizontal' assessment included in the evaluation of the EU Adaptation Strategy.]

Adaptation to climate change involves increasing societies' resilience to extreme climate-related events as well as to gradual changes in climate. The effectiveness and efficiency of many national adaptation policies can only be assessed in the long term, and even then an exact assessment is impossible due to the lack of a counterfactual. Consequently, there are no legally binding quantitative objectives and targets regarding adaptation at European level. Besides the requirements for the national communications to the UNFCCC, the only mandatory reporting for EU Member States on Adaptation comes from the Regulation on a mechanism for monitoring and reporting greenhouse gas emissions (MMR Regulation, EU, 2013, Art. 15). From 2021 onwards, mainstreamed in the Regulation on the Governance of the Energy Union and Climate Action, integrated reporting on adaptation actions will be submitted every two years instead of every four years, in accordance with the requirements agreed upon under the UNFCCC and the Paris Agreement, including the Rulebook adopted in December 2018 (UNFCCC, 2015c, 2018; EU, 2018b). *[Editorial note: References to these legal documents will be updated once the final versions have been published.]*

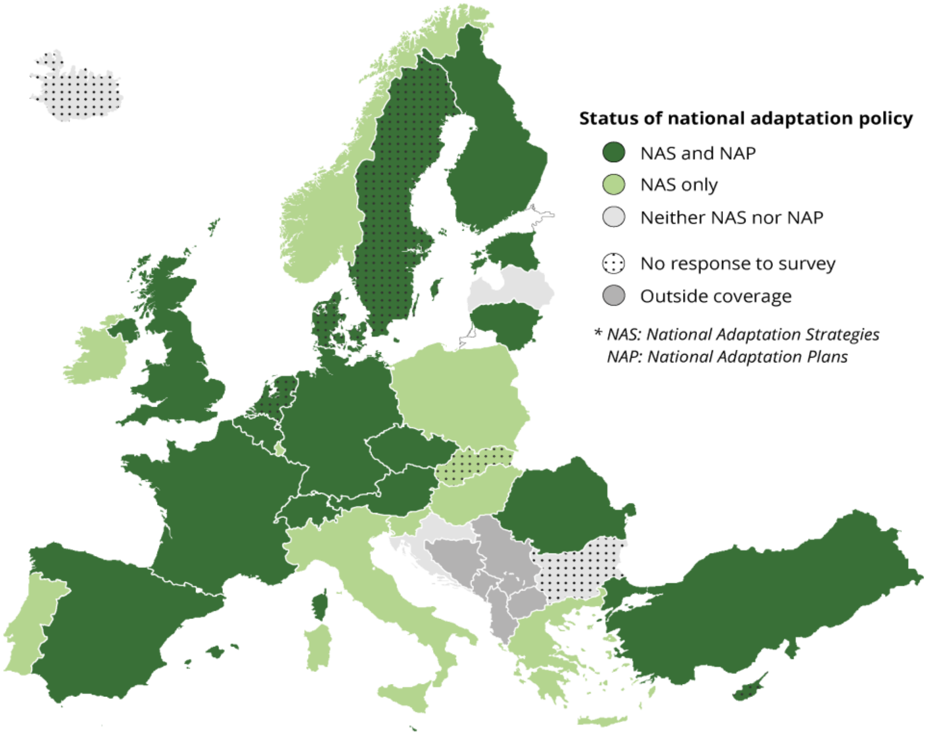
To date, 25 EU Member States and four other EEA member countries have adopted a national adaptation strategy (NAS) (EEA, 2018h), underpinned by climate change vulnerability and risk assessments (EEA, 2018e). In addition, 15 EU Member States and two other EEA member countries have developed a national action plan (NAP) (see Figure 7.12). Since 2013, there has been a steady increase in the number of NASs and NAPs being adopted by countries. Over the same period, several countries adopted a revised NAS (EEA, 2018h).

Progress is expected to continue as the EU Member States without a NAS today (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 now starts a plan (UNDP, 2018), and 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 the Former Yugoslav Republic of Macedonia (Zdraveva et al., 2014).

(4) https://climate-adapt.eea.europa.eu/knowledge/tools/adaptation-support-tool
(5) https://climate.copernicus.eu/

Figure 7.12 Overview of national adaptation policies



Note: NAS: National Adaptation Strategy; NAP: National Adaptation Plan.

Source: Adapted from (EEA, 2018h; EC, 2018b).

[Editorial note: This map will be updated to achieve consistency with the EEA Annual Indicator Report 2018 (EEA, 2018h) *and the 'horizontal assessment' included in the evaluation of the EU Adaptation Strategy (EC, 2018b, Table IX-1). Foreseen changes: IE: NAS and NAP; MT, SE and LI: NAS. Dots for AT, FI, IE, NL, PT, RO and legend label "NAS updated"]*

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 lacking behind. Almost all EU Member States include transboundary cooperation on adaptation issues in the water sector due to the requirements of the Water Framework Directive (EU, 2000) and the Floods Directive (EU, 2007), and the attention given to the topic 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).

A limited number of countries have started to monitor and report on adaptation policies and actions at national level (EEA, 2014a). So far, even fewer countries are evaluating adaptation policies at national level. The countries that monitor these use mainly 'process-based' methods, and very few countries use 'outcome-based' approaches to assess if and how vulnerability has decreased and/or resilience has increased, because such approaches use complex methodologies and are resource intensive (Mäkinen et al., 2018; EC, 2018b, Annex IX). It will therefore not be possible to determine with any certainty whether or not decisive progress in increased resilience can be 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, 2017b, 2018a). The EU Strategy on Adaptation to Climate Change has encouraged all EU Member States to adopt comprehensive adaptation strategies, including cross-border issues. With respect to climate change adaptation, this is reflected in the strategic objectives and actions in all four existing EU macro-regional strategies: for the Baltic Sea, the Danube, the Adriatic and Ionian, and the Alpine regions (EC, 2010, 2012c, 2014, 2015).

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 with different levels of implementation. (Ramieri et al., 2018; EEA, 2018a).

Adaptation efforts in cities

[Editorial comment: The number of actual action plans submitted and those at the monitoring stage will be updated in May 2019.]

Whilst the European and national levels provide the political, legislative and financial framework for adaptation, it is important to acknowledge the importance of local adaptation actions addressing the specific situation of particular locations. In 2018, 147 local adaptation strategies were identified across 28 EU countries and Norway (Aguiar et al., 2018). However, many more European cities are engaged in initiatives related to climate change adaptation at European and global level. By April 2019, over xxx local authorities in the European region have committed themselves to adaptation within the Covenant of Mayors for Climate and Energy, while xxx action plans are submitted and xxx local authorities have a monitoring programme (Covenant of Mayors, 2018). Other initiatives directly relevant to adaptation are: C40 cities, Making Cities Resilient (UNISDR) and 100 Resilient Cities (Rockefeller Foundation) (EEA, 2017c)([6]).

Involvement of cities in one or more of 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, 2017c; Covenant of Mayors, 2018).

Many cities are already putting adaptation measures in practice. Frontrunner cities, such as Copenhagen or Rotterdam, are examples how urban areas can be transformed to meet the adaptation challenge (see also Chapter 17). Others, such as Helsinki, are exploring how adaptation can be monitored (EEA, 2016c). In the absence of national strategies, cities can take the lead on adaptation within countries by adopting and implementing adaptation strategies and plans, such 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 for example in the case of the 44MPA project in Poland (Ministry of the Environment, 2018).

([6]) The cities participating in these initiatives are mapped in the Urban Vulnerability Map Book within Climate-ADAPT (https://climate-adapt.eea.europa.eu/knowledge/tools/urban-adaptation)

Summary assessment

Table 7.7 Summary assessment for sub-theme 'climate change adaptation efforts'

Climate change adaptation efforts		
Past trends (10-15 years)		The consideration of climate change 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.
Outlooks 2030		Further action on climate change adaptation is ongoing or planned at European, national and subnational levels.
Prospects to meet 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, due to 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 country 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.	

7.5.3 Climate change finance

Source: Information on DG CLIMA website and underlying studies.

Most measures for mitigating or adapting to climate change require financing, either initially or permanently. Addressing climate change is to a large extent an investment challenge. Some measures also involve running costs. Investments in adaptation generally brings local or regional benefits whereas mitigation investments brings benefits to everyone, because it reduces global climate change. This section briefly reviews two financial targets related to EU domestic spending and EU international spending.

EU budget targets

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 acknowledged that ambitious work was underway, and that the target has led to more, and better focussed, climate action in the European Regional Development Fund and the Cohesion Fund. At the same time, the report stressed a serious risk that the 20% target will not be met, and that no significant shift towards climate action has occurred in the areas of agriculture, rural development and fisheries. The report also emphasized methodological weaknesses of the current tracking method, including the failure of tracking mitigation and adaptation spending separately (European Court of Auditors, 2016). Broadly similar conclusions, and various suggestions for improved climate mainstreaming in the next EU Multiannual Framework (2021-2027), have been reached in a recent study for DG CLIMA (Forster et al., 2017).

International climate change finance

In the Copenhagen Accord under the UNFCCC, developed countries have made the collective commitment to mobilize jointly U$ 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, 2015c). However, neither of these agreements includes details on individual contributions between different (groups of) countries, on the shares of public and private finance, and on the ratios of different finance instruments. As a result, reviews regarding the progress towards this target are difficult to conduct, and the results are contentious.

A study by the OECD suggested that climate funding for developing countries from public sources had reached US$44 billion in 2014, up from US$38 billion in 2013. It projected that public funding would reach US$67 billion in 2020, including US$37 of bilateral public finance and US$30 of multilateral public finance. The study found that current estimated levels of private finance mobilization would not be sufficient to reach the US$100 billion target in 2020, but it stressed that the private finance mobilization may change over time (OECD, 2016). A submission by developed countries and the EU to the UNFCCC, which was largely based on the OECD study, projected that aggregated funding levels for climate action in developing countries would reach more than US$100 billion in 2020 (UNFCCC, 2016). Further information on the need for and the availability of funds for adaptation in developing countries is available from UNEP (UNEP, 2016).

A study by academic and humanitarian organisations has raised criticism regarding these estimates and the underlying methodology, stressing ambiguity in definitions and lack of transparency in reporting (AdaptationWatch, 2016).

7.6 References

AdaptationWatch, 2016, *Towards Transparency. 2016 Adaptation Finance Transparency Gap Report*, AdaptationWatch (http://www.adaptationwatch.org/s/Adaptation-Watch-Report-2016-Digital-FIN.pdf).

Aguiar, F. C., et al., 2018, ‘Adaptation to climate change at local level in Europe: An overview’, *Environmental Science & Policy* 86, pp. 38-63 (DOI: 10.1016/j.envsci.2018.04.010).

C3S, 2018, ‘Indicators 2017 - Sea level’, Copernicus Climate Change Service (https://climate.copernicus.eu/node/339) accessed 19 December 2018.

Ciscar, J. ., et al., 2018, *Climate impacts in Europe: final report of the JRC PESETA III project*, JRC Science for Policy Report No EUR 29427 EN, Publications Office of the European Union (http://doi.org/10.2760/93257) accessed 29 November 2018.

Covenant of Mayors, 2018, ‘Covenant of Mayors’ (https://www.covenantofmayors.eu/) accessed 30 August 2018.

Covenant of Mayors, 2019, ‘European Union & Western Europe - Global Covenant of Mayors’ (https://www.globalcovenantofmayors.org/region/europe/) accessed 4 January 2019.

EC, 2010, Communication from the Commission to the European Parliament, the Council, the European Economic and Social Committee and the Committee of the Regions — European Union strategy for Danube region (COM (2010) 715 final of 8 December 2010).

EC, 2011, Communication from the Commission to the European Parliament, the Council, the European Economic and Social Committee and the Committee of the Regions — A budget for Europe 2020. Part II: policy fiches (COM(2011) 500 final 29 June 2011).

EC, 2012a, Communication from the Commission to the European Parliament, the Council, the European Economic and Social Committee and the Committee of the Regions — EU Regulatory Fitness (COM(2012) 746 final 12 December 2012).

EC, 2012b, Communication from the Commission to the European Parliament, the Council, the European Economic and Social Committee and the Committee of the Regions: Blueprint to Safeguard Europe's Water Resources (COM (2012) 673 final, Brussels, 14.11.2012).

EC, 2012c, Communication from the Commission to the European Parliament, the Council, the European Economic and Social Committee and the Committee of the Regions concerning the European Union Strategy for the Baltic Sea Region (COM(2012) 128 final).

EC, 2013a, Communication from the Commission to the European Parliament, the Council, the European Economic and Social Committee and the Committee of the Regions - An EU Strategy on adaptation to climate change (COM(2013) 216 final, Brussels, 16.04.2013).

EC, 2013b, Communication from the Commission to the European Parliament, the Council, the European Economic and Social Committee and the Committee of the Regions: Green Infrastructure (GI) — Enhancing Europe's natural capital (COM(2013) 249 final).

EC, 2014, Communication from The Commission to the European Parliament, the Council, the European Economic and Social Committee and the Committee of the Regions concerning the European Union Strategy for the Adriatic and Ionian Region (COM/2014/0357 final).

EC, 2015, Communication from The Commission to the European Parliament, the Council, the European Economic and Social Committee and the Committee of the Regions concerning a European Union Strategy for the Alpine Region (COM/2015/0366 final).

EC, 2016, Commission Staff Working Document Accompanying the document Communication from the Commission to the European Parliament and the Council Mid-term review/revision of the multiannual financial framework 2014-2020 An EU budget focused on results (SWD(2016) 299 final).

EC, 2018a, Commission Staff Working Document. Adaptation preparedness scoreboard. Country fiches Accompanying the document from the Commission to the European Parliament and the Council on the implementation of the EU Strategy on adaptation to climate change (SWD/2018/460 final).

EC, 2018b, Commission Staff Working Document. Evaluation of the EU Strategy on adaptation to climate change. Accompanying the document Report from the Commission to the European Parliament and the Council on the implementation of the EU Strategy on adaptation to climate change. (SWD(2018) 461 final).

EC, 2018c, Report from the Commission to the European Parliament and the Council on the implementation of the EU Strategy on adaptation to climate change. (COM(2018) 738 final).

EC, 2019a, 'Effort sharing: Member States' emission targets | Climate Action' (https://ec.europa.eu/clima/policies/effort_en) accessed 4 January 2019.

EC, 2019b, 'EU Emissions Trading System (EU ETS) | Climate Action' (https://ec.europa.eu/clima/policies/ets_en) accessed 4 January 2019.

ECA, 2018, *Floods Directive: progress in assessing risks, while planning and implementation need to improve*, Special report No 25/2018, European Court of Auditors, Luxembourg (https://www.eca.europa.eu/en/Pages/DocItem.aspx?did=47211).

EEA, 2011, 'Greenhouse gas emissions in Europe: a retrospective trend analysis for the period 1990 - 2008 — European Environment Agency' (https://www.eea.europa.eu/publications/ghg-retrospective-trend-analysis-1990-2008) accessed 4 January 2019.

EEA, 2012, 'End-user GHG emissions from energy: Reallocation of emissions from energy industries to end users 2005...-2010 — European Environment Agency' (https://www.eea.europa.eu/publications/end-user-ghg-emissions-energy) accessed 4 January 2019.

EEA, 2014a, *National adaptation policy processes in European countries - 2014*, Publication No 4/2014, European Environment Agency (http://www.eea.europa.eu/publications/national-adaptation-policy-processes) accessed 11 June 2015.

EEA, 2014b, 'Why did GHG emissions decrease in the EU between 1990 and 2012? — European Environment Agency' (https://www.eea.europa.eu/publications/why-are-greenhouse-gases-decreasing) accessed 4 January 2019.

EEA, 2016a, 'Analysis of key trends and drivers in greenhouse gas emissions in the EU between 1990 and 2014 — European Environment Agency' (https://www.eea.europa.eu/publications/analysis-of-key-trends-ghg) accessed 4 January 2019.

EEA, 2016b, 'Heating and cooling degree days — European Environment Agency' (https://www.eea.europa.eu/data-and-maps/indicators/heating-degree-days/assessment) accessed 4 January 2019.

EEA, 2016c, *Urban adaptation to climate change in Europe 2016 — Transforming cities in a changing climate*, EEA Report No 12/2016, European Environment Agency (http://www.gppq.fct.pt/h2020/_docs/brochuras/env/urban-adaptation-report-2016.pdf).

EEA, 2017a, 'Analysis of key trends and drivers in greenhouse gas emissions in the EU between 1990 and 2015 — European Environment Agency' (https://www.eea.europa.eu/publications/analysis-of-key-trends-and) accessed 4 January 2019.

EEA, 2017b, *Climate Change, impacts and vulnerability in Europe 2016 — An indicator-based report*, EEA Report No 1/2017, European Environment Agency (https://www.eea.europa.eu/publications/climate-change-impacts-and-vulnerability-2016).

EEA, 2017c, 'Urban Vulnerability Map Book — Climate-ADAPT' (https://climate-adapt.eea.europa.eu/knowledge/tools/urban-adaptation) accessed 30 August 2018.

EEA, 2018a, *Addressing climate change adaptation in transnational regions in Europe*, EEA Briefing, European Environment Agency (https://www.eea.europa.eu/themes/climate-change-adaptation/adaptation-policies/adaptation-policies-in-transnational-regions).

EEA, 2018b, *Annual European Union greenhouse gas inventory 1990-2016 and inventory report 2018*, EEA Report No 5/2018, European Environment Agency (https://www.eea.europa.eu//publications/european-union-greenhouse-gas-inventory-2018) accessed 11 September 2018.

EEA, 2018c, 'Approximated EU GHG inventory: proxy GHG estimates for 2017 — European Environment Agency' (https://www.eea.europa.eu/publications/approximated-eu-ghg-inventory-proxy) accessed 4 January 2019.

EEA, 2018d, 'Member States' greenhouse gas (GHG) emission projections — European Environment Agency' (https://www.eea.europa.eu/data-and-maps/data/greenhouse-gas-emission-projections-for-4) accessed 4 January 2019.

EEA, 2018e, *National climate change vulnerability and risk assessments in Europe, 2018*, EEA Report No 1/2018, European Environment Agency (https://www.eea.europa.eu/publications/national-climate-change-vulnerability-2018).

EEA, 2018f, 'National policies and measures on climate change mitigation in Europe — European Environment Agency' (https://www.eea.europa.eu/themes/climate/national-policies-and-measures/national-policies-and-measures-on) accessed 4 January 2019.

EEA, 2018g, 'National policies and measures on climate change mitigation in Europe in 2017 — European Environment Agency' (https://www.eea.europa.eu/publications/national-policies-and-measures-on-climate-change-mitigation) accessed 4 January 2019.

EEA, 2018h, 'Number of countries that have adopted a climate change adaptation strategy/plan' (https://www.eea.europa.eu/airs/2018/environment-and-health/climate-change-adaptation-strategies) accessed 18 December 2018.

EEA, 2018i, *Sharing adaptation information across Europe*, EEA Report No 3/2018, European Environment Agency (https://www.eea.europa.eu/publications/sharing-adaptation-information-across-europe) accessed 17 August 2018.

EEA, 2018j, 'Trends and projections in Europe 2018 - Tracking progress towards Europe's climate and energy targets — European Environment Agency' (https://www.eea.europa.eu/publications/trends-and-projections-in-europe-2018-climate-and-energy) accessed 4 January 2019.

EU, 2000, Directive 2000/60/EC of the European Parliament and of the Council of 23 October 2000, establishing a framework for community action in the field of water policy (EC 2000/60/EC).

EU, 2007, Directive 2007/60/EC of the European Parliament and of the Council of 23 October 2007 on the assessment and management of flood risks (OJ L288, 06.11.2007, p.27-34).

EU, 2013, Regulation (EU) No 525/2013 of the European Parliament and of the Council of 21 May 2013 on a mechanism for monitoring and reporting greenhouse gas emissions and for reporting other information at national and Union level relevant to climate change and repealing Decision No 280/2004/EC (OJ L 165, 18.6.2013, p. 13–40).

EU, 2018a, 'Effort sharing regulation: Council adopts emission reduction targets - Consilium' (https://www.consilium.europa.eu/en/press/press-releases/2018/05/14/effort-sharing-regulation-council-adopts-emission-reduction-targets/#) accessed 4 January 2019.

EU, 2018b, REGULATION (EU) 2018/… OF THE EUROPEAN PARLIAMENT AND OF THE COUNCIL of ... on the Governance of the Energy Union and Climate Action, (ENER 264, CLIMA 127, CODEC 1222).

European Council, 2013, Conclusions of the European Council (Multiannual Financial Framework) (EUCO 37/13).

European Court of Auditors, 2016, *Spending at least one euro in every five from the EU budget on climate action: ambitious work underway, but at serious risk of falling short*, Special report No 31/2016, European Court of Auditors, Luxembourg (https://www.eca.europa.eu/en/Pages/DocItem.aspx?did=39853).

Eurostat, 2019, 'Database - Eurostat' (https://ec.europa.eu/eurostat/data/database) accessed 4 January 2019.

Forster, D., et al., 2017, *Climate mainstreaming in the EU budget. Preparing for the next MFF: final report*, Publications Office of the European Union, Luxembourg.

Forzieri, G., et al., 2016, 'Multi-hazard assessment in Europe under climate change', *Climatic Change* 137(1-2), pp. 105-119 (DOI: 10.1007/s10584-016-1661-x).

Forzieri, G., et al., 2018, 'Escalating impacts of climate extremes on critical infrastructures in Europe', *Global Environmental Change* 48, pp. 97-107 (DOI: 10.1016/j.gloenvcha.2017.11.007).

IPCC, 2013, 'Summary for policymakers', in: Stocker, T. F. et al. (eds), *Climate change 2013: the physical science basis. Contribution of Working Group I to the fifth assessment report of the Intergovernmental Panel on Climate Change*, Cambridge University Press, Cambridge, pp. 1-29.

IPCC, 2018, *Global Warming of 1.5 °C: An IPCC special report on the impacts of global warming of 1.5 °C above pre-industrial levels and related global greenhouse gas emission pathways, in the context of strengthening the global response to the threat of climate change, sustainable development, and efforts to eradicate poverty*, Intergovernmental Panel on Climate Change, Geneva, Switzerland (http://report.ipcc.ch/sr15/pdf/sr15_spm_final.pdf) accessed 10 November 2018.

Kundzewicz, Z. W., et al., 2016, 'Differences in flood hazard projections in Europe – their causes and consequences for decision making', *Hydrological Sciences Journal* (DOI: 10.1080/02626667.2016.1241398).

Kundzewicz, Z. W., et al., 2018, 'Changes in river flood hazard in Europe: a review', *Hydrology Research* 49(2), pp. 294-302 (DOI: 10.2166/nh.2017.016).

Mäkinen, K., et al., 2018, *Indicators for adaptation to climate change at national level - Lessons from emerging practice in Europe*, ETC/CCA Technical Paper No 2018/3 (https://cca.eionet.europa.eu/reports/TP_3-2018).

Ministry of Environmental Protection, 2017, *Second National Communication of the Republic of Serbia under the United Nations Framework Convention on Climate Change*, Ministry of Environmental Protection, Belgrade (https://unfccc.int/sites/default/files/resource/SNC%20Eng_Serbia.pdf) accessed 17 August 2018.

Ministry of the Environment, 2018, ‘Development of Urban Adaptation Plans for cities with more than 100,000 inhabitants in Poland’ (http://44mpa.pl/?lang=en) accessed 30 August 2018.

OECD, 2016, *2020 projections of Climate Finance towards the USD 100 billion goal*, Technical Note, OECD Publishing (https://www.oecd.org/environment/cc/Projecting%20Climate%20Change%202020%20WEB.pdf).

Radusin, S., et al., 2017, *Third national communication and second biennial update report on greenhouse gas emissions of Bosnia and Herzegovina - under the United Nations Framework Convention On Climate Change, July 2016*, UNDP in Bosnia and Herzegovina, Sarajevo (https://unfccc.int/sites/default/files/resource/TNC%20AND%20SBUR%20ENG.pdf) accessed 17 August 2018.

Rafaelsen, B., et al., 2017, *Study on macro-regional strategies and their links with cohesion policy. Final Report*, European Commission, Brussels (http://ec.europa.eu/regional_policy/sources/cooperate/alpine/eusalp_links_cohesion_policy.pdf).

Ramieri, E., et al., 2018, *Adaptation policies and knowledge base in transnational regions in Europe*, ETC/CCA Technical Paper No 2018/4 (https://cca.eionet.europa.eu/reports/TP_4-2018).

Russo, S., et al., 2014, ‘Magnitude of extreme heat waves in present climate and their projection in a warming world’, *Journal of Geophysical Research: Atmospheres* 119(22), pp. 12500-12512 (DOI: 10.1002/2014JD022098).

Secretariat of the Convention on Biological Diversity, 2009, *Connecting Biodiversity and Climate Change Mitigation and Adaptation: Report of the Second Ad Hoc Technical Expert Group on Biodiversity and Climate Change*, Technical Series No 41, UNEP, Montreal (https://www.cbd.int/doc/publications/cbd-ts-41-en.pdf) accessed 7 September 2018.

Spinoni, J., et al., 2018, ‘Will drought events become more frequent and severe in Europe?’, *International Journal of Climatology* 38(4), pp. 1718-1736 (DOI: 10.1002/joc.5291).

UN, 2017, ‘United Nations sustainable development agenda’, United Nations Sustainable Development (http://www.un.org/sustainabledevelopment/development-agenda/) accessed 22 November 2017.

UNDP, 2018, ‘National Adaptation Plans in Bosnia and Herzegovina | UNDP’s Climate Change Adaptation Portal’ (http://adaptation-undp.org/projects/national-adaptation-plans-bosnia-and-herzegovina) accessed 30 August 2018.

UNEP, 2016, *The Adaptation Finance Gap Report 2016*, United Nations Environment Programme (UNEP), Nairobi.

UNFCCC, 1992, ‘Status of Ratification of the Convention | UNFCCC’ (https://unfccc.int/process/the-convention/what-is-the-convention/status-of-ratification-of-the-convention) accessed 7 January 2019.

UNFCCC, 2010, *Report of the Conference of the Parties on its fifteenth session, held in Copenhagen from 7 to 19 December 2009. Addendum. Part two: action taken by the Conference of the Parties at its fifteenth session*, Conference Report No FCCC/CP/2009/11/Add.1, United

Nations Framework Convention on Climate Change, Geneva, Switzerland (http://unfccc.int/documentation/documents/advanced_search/items/6911.php?priref=600005735#beg) accessed 5 August 2015.

UNFCCC, 2015a, *Adoption of the Paris Agreement*, No Decision 1/CP.21, United Nations Framework Convention on Climate Change, Bonn, Germany (https://unfccc.int/resource/docs/2015/cop21/eng/l09r01.pdf).

UNFCCC, 2015b, 'EU Submits its Climate Action Plan | UNFCCC' (https://unfccc.int/news/eu-submits-its-climate-action-plan) accessed 4 January 2019.

UNFCCC, 2015c, *Paris Agreement*, No FCCC/CP/2015/L.9/ rev 1, United Nations Framework Convention on Climate Change (https://unfccc.int/sites/default/files/english_paris_agreement.pdf).

UNFCCC, 2016, 'Roadmap to US$100 Billion. Submission as requested by Paris decision para 114 of 1.CP/21' (http://www4.unfccc.int/Submissions/Lists/OSPSubmissionUpload/261_295_131233554162587561-Roadmap%20to%20the%20US$100bn%20(UNFCCC).pdf).

UNFCCC, 2018, Paris Rulebook. Proposal by the President. Informal compilation of L-documents (Draft decisions 1/CP.24, 1/CMP.14 and 3/CMA.1).

UNISDR, 2015, *Sendai Framework for Disaster Risk Reduction 2015 - 2030*, The United Nations Office for Disaster Risk Reduction (UNISDR), Geneva, Switzerland (http://www.unisdr.org/we/inform/publications/43291) accessed 23 November 2017.

Vautard, R., et al., 2014, 'The European climate under a 2 °C global warming', *Environmental Research Letters* 9(3), p. 034006 (DOI: 10.1088/1748-9326/9/3/034006).

Velders, G. J. M., et al., 2007, 'The importance of the Montreal Protocol in protecting climate', *Proceedings of the National Academy of Sciences* 104(12), pp. 4814-4819 (DOI: 10.1073/pnas.0610328104).

Zdraveva, P., et al., 2014, *Third national communication on climate change*, Ministry of environment and physical planning, Skopje.