Summary for Policy Makers

Introduction

This Synthesis Report (SYR) brings forward the main findings of the 5thAssessment Report (AR5) of the Intergovernmental Panel on Climate Change (IPCC). The SYR, the final document in the AR5 cycle, is based on the three underlying Working Group contributions as well as two Special Reports.

Human interference with the climate system is occurring, and climate change poses risks for human and natural systems. This report assesses all aspects of climate change and provides information to support decision making in this field.

Climate change will alter human and natural systems, and responding to it involves issues of equity, justice, fairness, and value. It is a collective action problem at the global scale.

The challenges presented by climate change involve many uncertainties. Because there is a wide range of possible outcomes, responding to climate change involves managing risks. Despite the challenges, there are many opportunities for reducing the risks related to climate change and for building on synergies with other social, economic, and development objectives.

1. Observed Changes

Anthropogenic emissions of greenhouse gases have continued to rise since 1970 with larger absolute increases over the last decade. Human influence on the climate system is clear, and is estimated to have been the dominant cause of the warming observed since 1950. Changing climate has been linked to impacts on natural and human systems on all continents and across the oceans.

Warming of the climate system is unequivocal, and since the 1950s, many of the observed changes are unprecedented over decades to millennia. The atmosphere and ocean have warmed, the amounts of snow and ice have diminished and sea level has risen (Figure SPM.1*).*
The globally averaged combined land and ocean surface temperature data as calculated by a linear trend, show a warming of 0.85 [0.65 to 1.06]°C over the period 1880 to 2012, when multiple independently produced datasets exist. The total increase between the average of the 1850–1900 period and the 2003–2012 period is 0.78 [0.72 to 0.85] °C[1], based on the single longest dataset available . Each of the last three decades has been successively warmer at the Earth's surface than any preceding decade since 1850. In the Northern Hemisphere, 1983–2012 was *likely* the warmest 30-year period of the last 1400 years (*medium confidence*). *{1.2}*

[1] Ranges in square brackets indicate a 90% uncertainty interval unless otherwise stated.

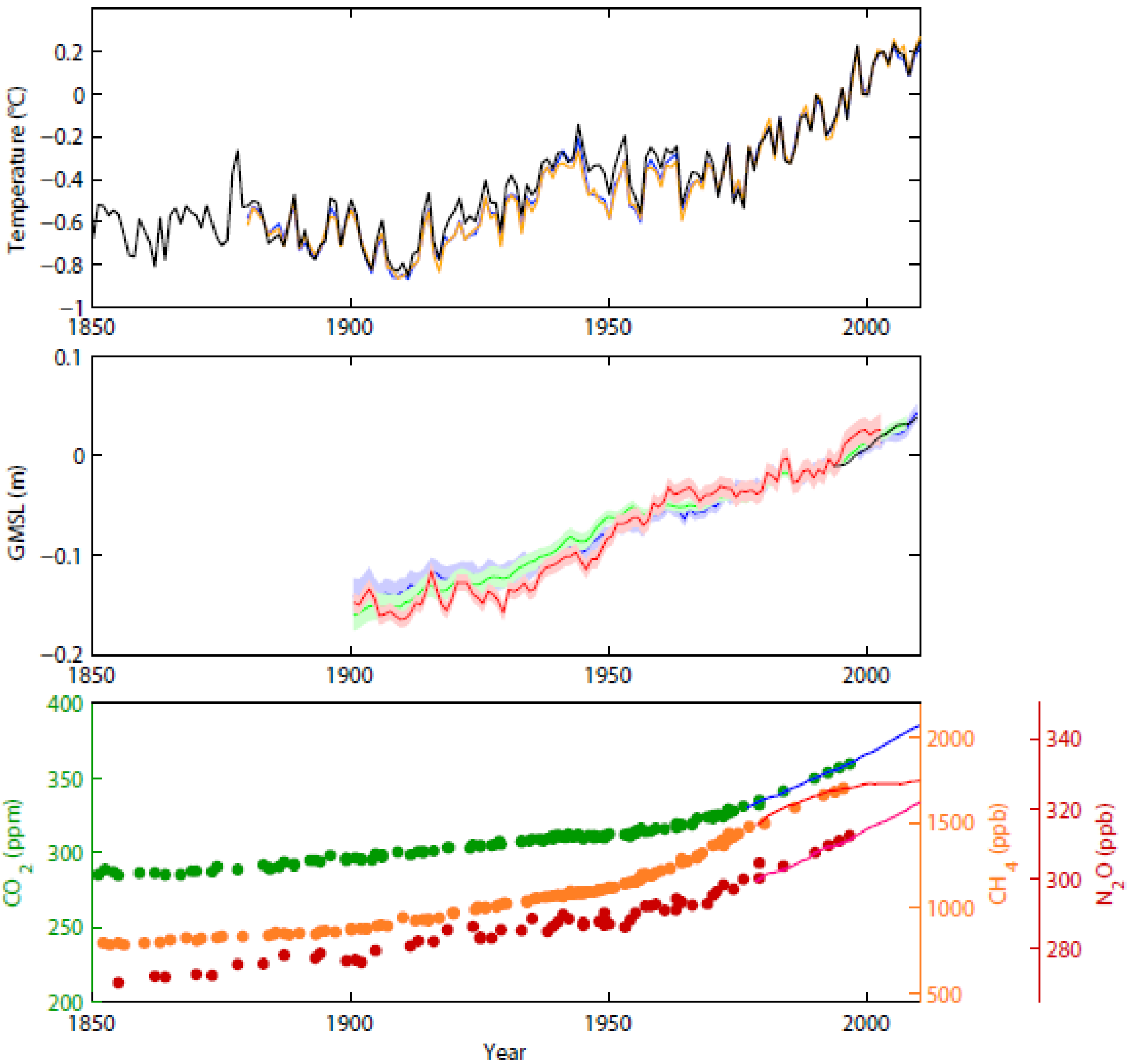

Figure SPM.1: observed indicators of a changing global climate. Top) Observed annually and globally averaged combined land and ocean surface temperature anomalies, middle) global mean sea level change; bottom: Atmospheric concentrations of greenhouse gases carbon dioxide (CO_2) determined from ice core data (green) and from direct atmospheric measurements (blue); methane and Nitrous Oxide (Figure 1.1).

Ocean warming dominates the increase in energy stored in the climate system, accounting for more than 90% of the energy accumulated between 1971 and 2010 (*high confidence*). It is *virtually certain* that the upper ocean (0−700 m) warmed from 1971 to 2010, and it *likely* warmed between the 1870s and 1971. Oceanic uptake of anthropogenic CO_2 results in gradual acidification of the ocean. The pH of ocean surface water has decreased by 0.1 since the beginning of the industrial era (*high confidence*). It is *very likely* that regions of high salinity, where evaporation dominates, have become more saline, while regions of low salinity where precipitation dominates have become fresher since the 1950s, providing indirect evidence for changes in evaporation and precipitation over ocean. *{1.2}*

Over the last two decades, the Greenland and Antarctic ice sheets have been losing mass, glaciers have continued to shrink almost worldwide, and Arctic sea ice and Northern Hemisphere spring snow cover have continued to decrease in extent (*high confidence*) (see Figure 1.1). There is *high confidence* that permafrost temperatures have increased in most regions of the Northern Hemisphere since the early 1980s in response to increased air temperature and changing snow cover. *{1.2; 1.4.2}*

The rate of sea level rise since the mid-19th century has been larger than the mean rate during the previous two millennia (*high confidence*). Over the period 1901–2010, global mean sea level rose by 0.19 [0.17 to 0.21]m. *{Figure 1.1, 1.2}*

In recent decades, changes in climate have caused impacts on natural and human systems on all continents and across the oceans. *{1.4}*
Evidence of climate-change impacts is strongest and most comprehensive for natural systems. Some impacts on human systems have also been attributed to climate change, with a major or minor contribution of climate change distinguishable from other influences (Figure SPM.2). In many regions, changing precipitation or melting snow and ice are altering hydrological systems, affecting water resources in terms of quantity and quality (*medium confidence*). Many terrestrial, freshwater, and marine species have shifted their geographic ranges, seasonal activities, migration patterns, abundances, and species interactions in response to ongoing climate change (*high confidence*). Based on many studies covering a wide range of regions and crops, negative impacts of climate change on crop yields have been more common than positive impacts (*high confidence*).

Changes in many extreme weather and climate events have been observed since about 1950, including decrease in cold temperature extremes, increase in hot temperature extremes, and increase in high sea level events, and some of these changes have been linked to human influences . Impacts from recent climate-related extremes, such as heat waves, droughts, floods, cyclones, and wildfires, reveal significant vulnerability and exposure of some ecosystems and many human systems to current climate variability**.** There has been increased heat-related mortality and decreased cold-related mortality in some regions as a result of warming (*medium confidence).{1.5}*

The character and severity of impacts from climate extremes depends not only on the extremes themselves but also on exposure and vulnerability and consequently so do their associated risks. Differences in vulnerability and exposure arise from non-climatic factors and from multidimensional inequalities often produced by uneven development processes (*very high confidence*). These differences shape differential risks from climate change. *{1.5}*

Adaptation experience is accumulating across regions in the public and private sector and within communities; and adaptation is becoming embedded in some planning processes, with more limited implementation of responses. *{1.6}*

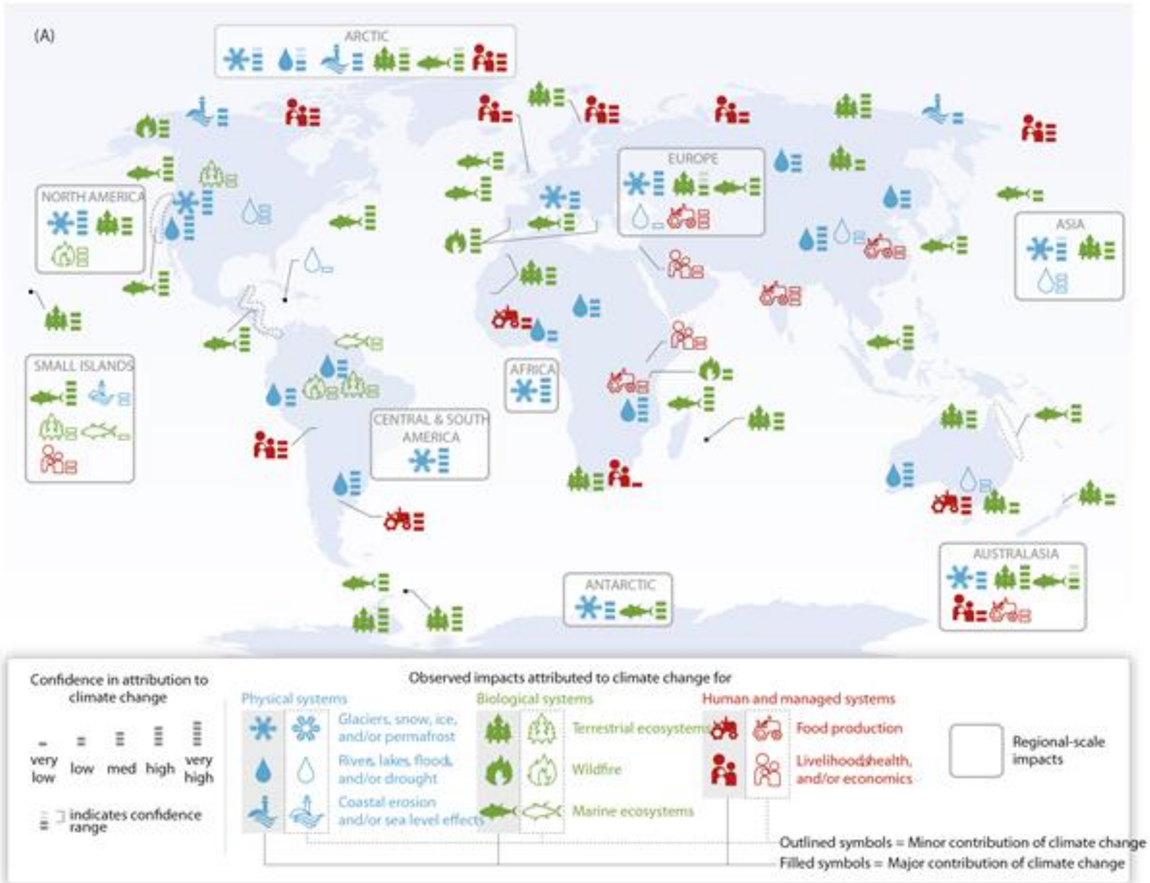

Figure SPM.2: Global patterns of observed climate change impacts in recent decades attributed to climate change, based on studies since the AR4. For categories of attributed impacts, symbols indicate affected systems and sectors, the relative contribution of climate change (major or minor) to the observed change, and confidence in attribution. (Figure 1.8)

Atmospheric concentrations of the well mixed greenhouse gases CO_2, CH_4 and N_2O have all shown large increases since the preindustrial era (Figure SPM.1). Despite multinational institutions and national policies aimed at mitigating emissions, anthropogenic greenhouse gas emissions have risen more rapidly between 2000-2010 than in the preceding decades, driven mainly by economic and population growth (Figure SPM.3). The largest single driver of current climate change is the cumulative increase of anthropogenic CO_2 emissions. The largest share of anthropogenic CO_2 emissions is emitted by a small number of countries. *{1.3}*

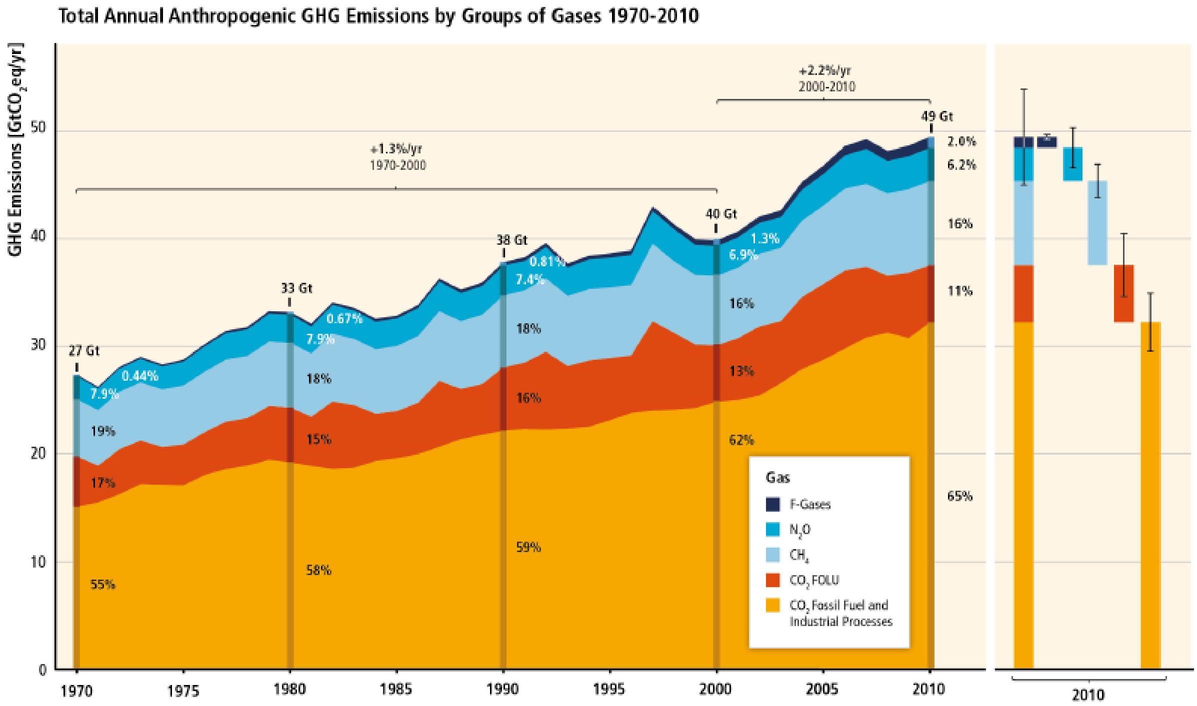

Figure SPM.3: Total annual anthropogenic GHG emissions ($GtCO_2eq/yr$) by groups of gases 1970-2010: CO_2 from fossil fuel combustion and industrial processes; CO_2 from Forestry and Other Land Use (FOLU); methane (CH4); nitrous oxide (N2O); fluorinated gases8 covered under the Kyoto Protocol (F-gases). At the right side of the figure GHG emissions in 2010 are shown again broken down into these components with the associated uncertainties (90% confidence interval) indicated by the error bars. Emissions of non-CO_2 gases are converted into CO_2-equivalent emissions based on GWP_{100} from the IPCC Second Assessment Report. (Figure 1.4)

About half of cumulative anthropogenic CO_2 emissions between 1750 and 2010 have occurred in the last 40 years *(high confidence)*. Anthropogenic CO_2 emissions were 2000 ± 310 $GtCO_2$ to the atmosphere between 1750 and 2011.About half of these anthropogenic CO_2 emissions have remained in the atmosphere (880 ± 35 $GtCO_2$) since 1750. The rest was removed from the atmosphere by sinks, and stored in the natural carbon cycle reservoirs. Total anthropogenic GHG emissions have continued to increase over 1970 to 2010 with larger absolute decadal increases toward the end of this period (*high confidence*). CO_2 emissions from fossil fuel combustion and industrial processes contributed about 78% of the total GHG emission increase from1970 to 2010, with a similar percentage contribution for the period 2000–2010 (*high confidence).*

Human influence has been detected in warming of the atmosphere and the ocean, in changes in the global water cycle, in reductions in snow and ice, and in global mean sea level rise, and in changes in some climate extremes. It is *extremely likely* that human influence has been the dominant cause of the observed warming since the mid-20th century.*{1.4}*

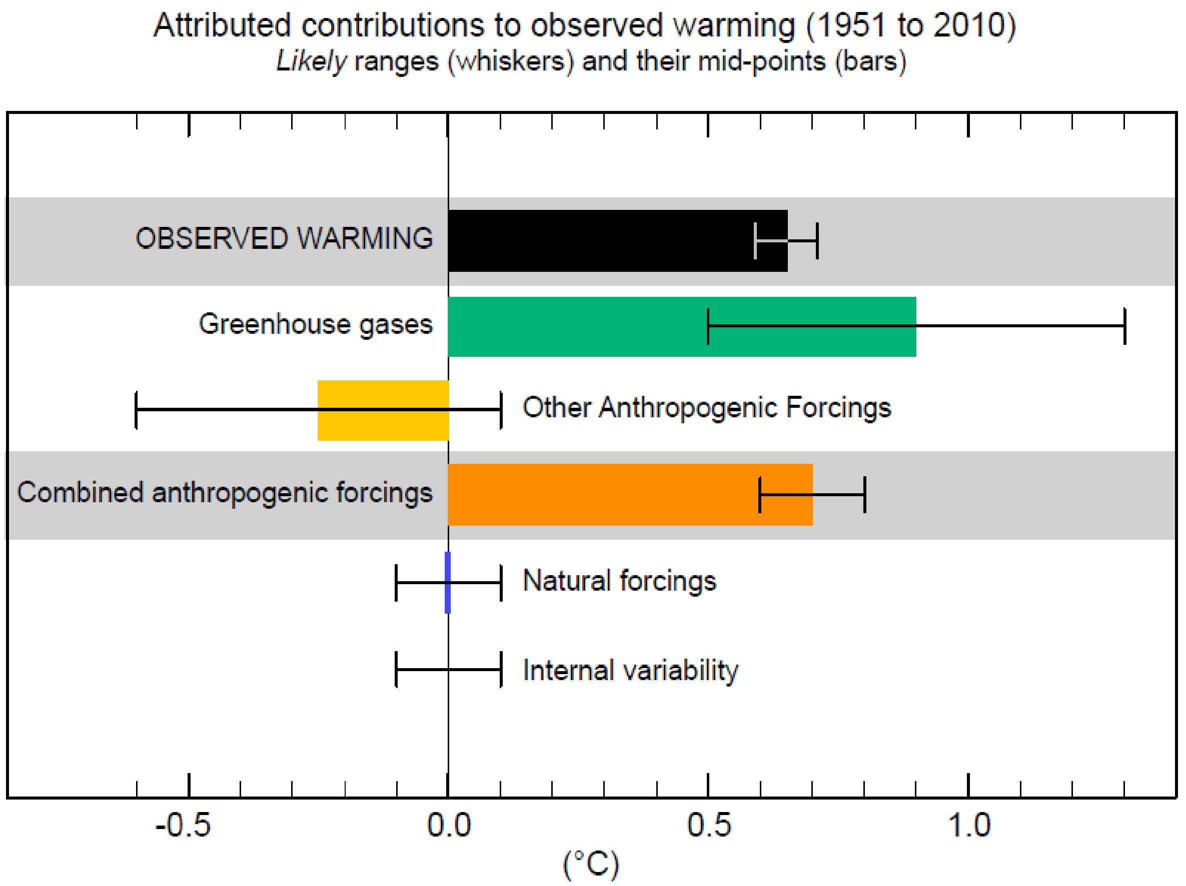

Figure SPM.4: Assessed *likely* ranges (whiskers) and their mid-points (bars) for attributable warming trends over the 1951–2010 period due to well-mixed greenhouse gases, other anthropogenic forcings, combined anthropogenic forcings, natural forcings, and internal climate variability. Observations are shown in black with the 5–95% uncertainty range due to observational uncertainty in this record. These attributed ranges (colours) are based on estimating the contribution to observed warming by fingerprints for external forcing derived from climate model simulations. (Figure SYR 1.2)

It is *extremely likely* that more than half of the observed increase in global average surface temperature from 1951 to 2010 was caused by the anthropogenic increase in greenhouse gas concentrations and other anthropogenic forcings together (Figure SPM.4). Over every continental region except Antarctica, anthropogenic forcings have *likely* made a substantial contribution to surface temperature increases since the mid-20th century. It is *likely* that anthropogenic influences have affected the global water cycle since 1960 and contributed to the retreat of glaciers since the 1960s, and to the increased surface mass loss of the Greenland ice sheet since 1993. It is *very likely* that human influences have contributed to Arctic sea ice loss since 1979 and that they have made a substantial contribution to increases in global upper ocean heat content (0–700 m) observed since the 1970s. *{1.4}*

2. Future climate changes, risks and impacts

Continued emissions of greenhouse gases will cause further warming and long-lasting changes in all components of the climate system. Limiting climate change and associated risks to people and ecosystems will require substantial and sustained reductions of greenhouse gases emissions. *{2}*.

Anthropogenic greenhouse gas emissions are mainly determined by population size, economic activity, energy use, land-use patterns, technology change and climate policy *{2.1}*. Livelihoods, lifestyles and behaviors also have significant influences on GHG emissions trajectories. *{4.2}*

The "Representative Concentration Pathways", or RCPs, describe the 21st century evolution of atmospheric greenhouse gas concentrations, land-use changes and emissions of air pollutants under four very different futures *{2.1}*. RCP8.5 represents a high emission scenario with no climate mitigation policies; RCP6.0

represents many middle-of-the-road scenarios with very modest or no climate policies; RCP4.5 represents a medium mitigation scenario; while RCP2.6 represents more aggressive mitigation scenarios which aim to keep global warming below 2°C above pre-industrial temperatures (Figure SPM.5).

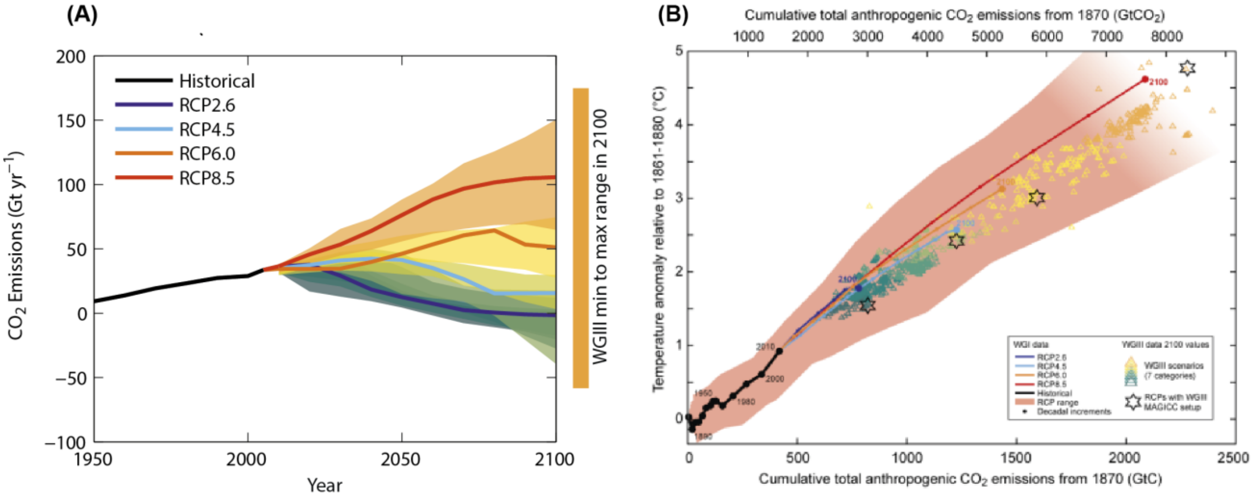

Figure SPM. 5 (a): CO_2 emission and the resulting radiative forcing levels included in the RCPs (lines) and the associated scenarios categories used in WGIII (colored areas) **(b)** Global mean surface temperature increase as a function of cumulative total global CO_2 emissions from various lines of evidence. Multi-model results from a hierarchy of climate-carbon cycle models for each RCP until 2100 are shown (colored lines). Model results over the historical period (1860 to 2010) are indicated in black. The colored plume illustrates the multi-model spread over the four RCP scenarios and fades with the decreasing number of available models in RCP8.5. Decadal averages are labelled using dots with the label referring to the year ending the decade. Triangles correspond to estimates for the year 2100 under 962 scenarios evaluated by WGIII, divided into the 7 categories described in Section 3.2. The four large star symbols are estimates for the 4 RCPs by the MAGICC6 simple model, with the set up used for the WGIII scenarios estimates. Temperature values are always given relative to the 1861-1880 period, and emissions are cumulative since 1870. (Figure 2.1, Figure 2.4)

Cumulative emissions of CO_2 are the dominant factor determining the global mean surface warming by the late 21st century *{2.4.5}*. There is a strong and consistent relationship between projected cumulative CO_2 emissions and projected 21st century temperature change in both the RCPs and the wider set of mitigation scenarios analysed in WGIII (figure 2.4). Limiting the warming to less than 2°C above pre-industrial with a probability of 50% or >66% require cumulative CO_2 emissions since 1870 to stay below about 3000 and about 2900 $GtCO_2$, respectively, when accounting for non-CO_2 forcings . An amount of 1890 $GtCO_2$ (1630-2150) was emitted by 2011. Meeting the 2°C goal with a >66% probability will require GHG emissions reductions of roughly 40% to 70% in 2050 relative to 2010 through fundamental changes in energy systems and potentially land use and agriculture, and emission levels near zero $GtCO_2$eq or below in 2100 *{Box Art. 2}.*

Over the 21st century projected warming will affect the atmosphere, ocean and the cryosphere. The global mean surface air temperature change for the period 2016-2035 will *likely* be in the range 0.3˚C-0.7˚C (*medium confidence*). By mid-21st century, the rate of global warming begins to be more strongly dependent on the emissions scenario. *{2.4.1}*

Global-mean surface air temperature change for 2081–2100 will *likely* be 0.3°C–1.7°C under RCP2.6 to 2.6°C–4.8°C under RCP8.5 (Table 2.1).Global surface air temperature change for the end of the 21st century is *likely* to exceed 1.5°C relative to 1850-1900 for all RCP scenarios except RCP2.6. It is *likely* to exceed 2°C for RCP6.0 and RCP8.5, *more likely than not* to exceed 2°C for RCP4.5, but *unlikely* to exceed 2°C for RCP2.6 (*medium confidence*). *{2.4.1}*

It is *virtually certain* that there will be more frequent hot and fewer cold temperature extremes over most land areas on daily and seasonal time-scales, as the global mean temperature increases. It is *very likely* that heat waves will tend to occur more often and last longer. Occasional cold winter extremes will continue to occur*{2.4.1}.*

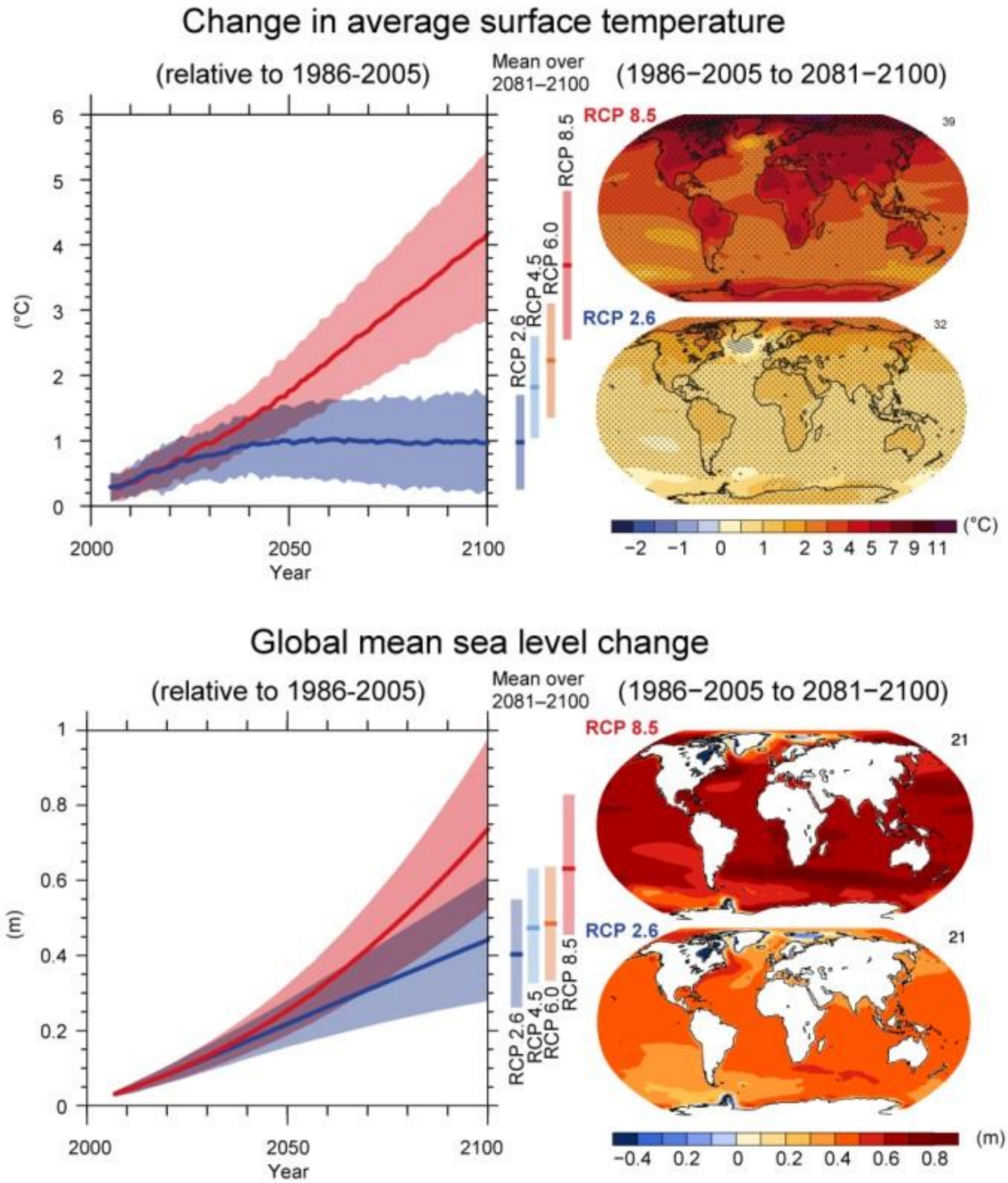

Figure SPM.6: CMIP5 multi-model simulated time series from 2005 to 2100 for change in global annual mean surface temperature (top left) and global mean sea level rise (bottom left). Time series of projections and a measure of uncertainty (shading) are shown for scenarios RCP2.6 (blue) and RCP8.5 (red). The mean and associated uncertainties averaged over 2081-2100 are given for all RCP scenarios as colored vertical bars at the right end side of each panel. CMIP5 multi-model mean projections 2081– 2100 under the RCP2.6 (top map) and RCP8.5 (bottom map) scenarios for annual mean surface temperature change (top right panel) and annual mean average sea level (bottom right panel). The number of CMIP5 models used to calculate the multi-model mean is indicated in the upper right corner of each panel. Hatching shows regions where the multi-model mean is small compared to internal variability (i.e., less than one standard deviation of internal variability in 20-year means). Stippling shows regions where the multi-model mean is large compared to internal variability (i.e., greater than two standard deviations of internal variability in 20-year means) and where 90% of models agree on the sign of change see WGI, Box 12.1). All changes are relative to 1986–2005. (Figure 2.2, Figure 2.3)

Year-round reductions in Arctic sea ice are projected for all RCP scenarios. Based on an assessment of the subset of models that most closely reproduce the observations, a nearly ice-free Arctic Ocean[2] in September before mid-century is likely for RCP8.5 (*medium confidence*). In the Antarctic, a decrease in sea ice extent and volume is projected with low confidence. *{2.4.3}*

It is virtually certain that near-surface permafrost extent at high northern latitudes will be reduced as global mean surface temperature increases. *{2.4.3}*

The global glacier volume, excluding glaciers on the periphery of Antarctica, is projected to decrease by 15 to 55% for RCP2.6, and by 35 to 85% for RCP8.5 (*medium confidence*). *{2.4.3}*

Global mean sea level will continue to rise during the 21st century and beyond. Global mean sea level rise will likely be in the ranges of 0.26 to 0.55 m for RCP2.6 to 0.45 to 0.82 m for RCP8.5. Sea level rise will not be uniform. By the end of the 21st century, it is very likely that sea level will rise in more than about 95% of the ocean area. About 70% of the coastlines worldwide are projected to experience sea level change within 20% of the global mean sea level change .Coastal and low-lying areas will increasingly experience submergence, flooding and erosion throughout the 21st century and beyond, due to sea-level rise (*very high confidence*). *{2.4.3, 2.5.1}*

Climate change will create new and amplify existing risks for natural and human systems {2.5}. There is high risk of substantive impacts on terrestrial and aquatic ecosystems as result of climate change, causing mostly negative consequences for biodiversity and ecosystem services (*high confidence*) . Throughout the 21st century, climate change will further challenge food, livelihood and human security and wellbeing, not only in developing countries. To a lesser extent, climate change will reduce some risks and generate benefits. *{2.5, 2.5.1}*

Increasing magnitudes of warming increase the likelihood of severe, pervasive, and irreversible impacts. Some risks of climate change are considerable at 1 or 2°C above preindustrial levels. Global climate change risks are high to very high with global mean temperature increase of 4°C or more above preindustrial levels in all reasons for concern, and include severe and widespread impacts on unique and threatened systems, substantial species extinction, large risks to global and regional food security, and the combination of high temperature and humidity compromising normal human activities, including growing food or working outdoors in some areas for parts of the year (high confidence). The precise levels of climate change sufficient to trigger tipping points (thresholds for abrupt and irreversible change) remain uncertain, but the risk associated with crossing multiple tipping points in the earth system or in interlinked human and natural systems increases with rising temperature (*medium confidence*). *{2.5}*

Climate change over the 21st century is projected to reduce renewable surface water and groundwater resources significantly in most dry subtropical regions (*robust evidence*, *high agreement*), intensifying competition for water among sectors (*limited evidence, medium agreement*). *{2.5.2}*

For the major crops (wheat, rice, and maize) in tropical and temperature regions, climate change without adaptation is projected to negatively impact production for local temperature increases of 2°C or more above late-20th-century levels, although individual locations may benefit (*medium confidence*) (Figure SPM.7). *{2.5.2}*

Heat stress, extreme precipitation, sea level rise, inland and coastal flooding, drought, landslides, air pollution, and water scarcity pose risks in urban areas for people, economies, and ecosystems, with risks amplified for those lacking essential infrastructure and services or living in exposed areas (*very high confidence*). *{2.5.2}*

Rural areas will experience major impacts on water availability and supply, food security, infrastructure, and agricultural incomes, including shifts in the production areas of food and non-food crops around the world (*high confidence*). *{2.5.2}*

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[2] when sea ice extent is less than 10^6 km^2 for at least five consecutive years

For most economic sectors, the impacts of changes in population, age structure, income, technology, relative prices, lifestyle, regulation, and governance are projected to be large relative to the impacts of climate change (*medium evidence, high agreement*). *{2.5.2}*

Climate change is expected to lead to increases in ill-health in many regions, especially in developing countries with low income (*high confidence*). Up to mid-century, the impact will mainly be through exacerbating health problems that already exist (*very high confidence*). *{2.5.2}*

Climate change is projected to increase displacement of people (*medium evidence, high agreement*). Many populations that lack the resources for mobility and migration experience higher exposure to extreme weather events, particularly in developing countries with low income. *{2.5.2}*

Climate change can indirectly increase risks of violent conflicts in the form of civil war and intergroup violence by amplifying well-documented drivers of these conflicts such as poverty and economic shocks (*medium confidence*). *{2.5.2}*

Climate change impacts are projected to slow down economic growth, make poverty reduction more difficult, further erode food security, and prolong existing and create new poverty traps, the latter particularly in urban areas and emerging hotspots of hunger (*medium confidence*). *{2.5.2}*

Risks caused by a changing climate depend on the change in climate, but also on the exposure, vulnerability, and ability to adapt of the affected system. Adaptation has the potential to reduce climate change impacts significantly, but its potential differs between sectors and there are constraints and limits to adaptation (Figure SPM.7). ***{2.5, 3.3}***

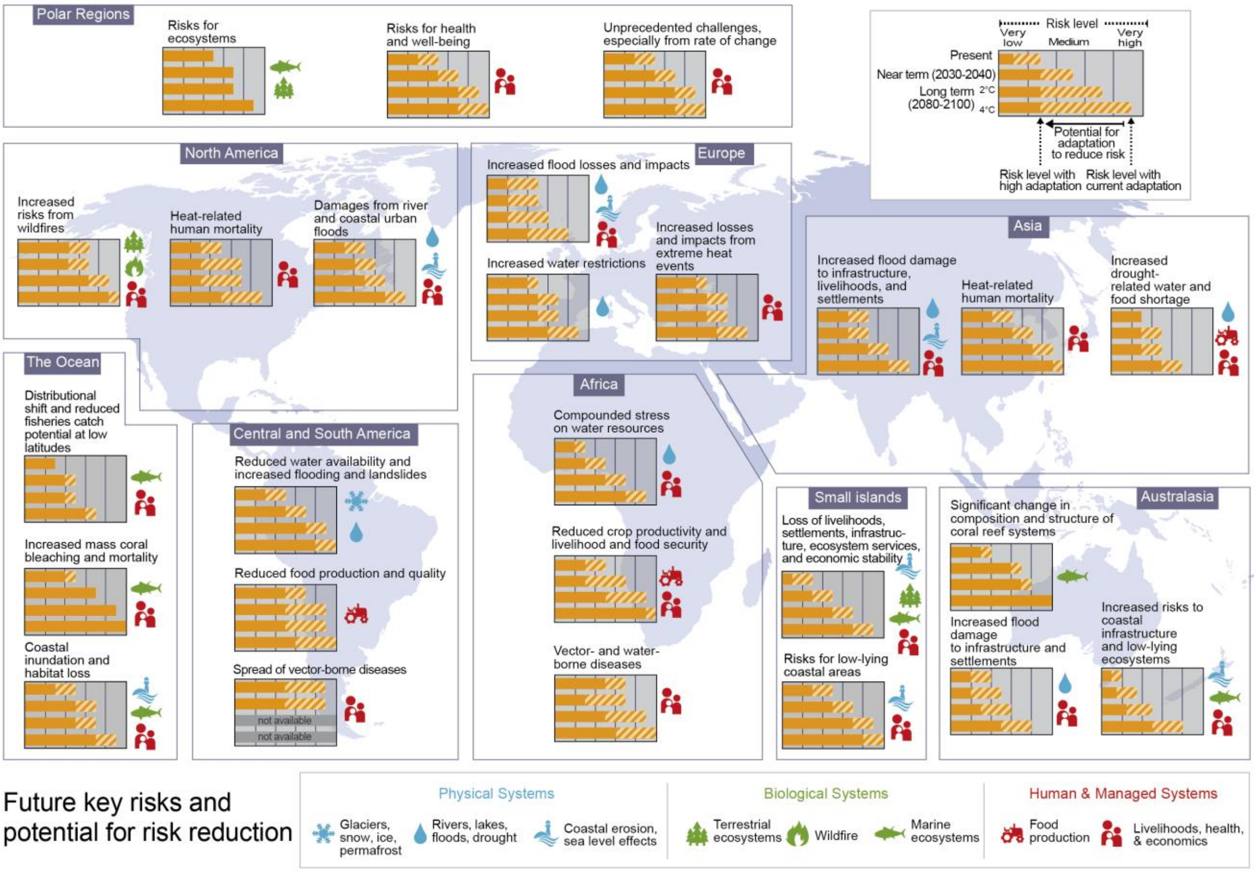

Figure SPM.7: Example of regional key risks for physical, biological, and human and managed systems, and potential for risk reduction through adaptation. Key risks are identified based on assessment of the literature and expert judgment. Each risk is characterized as very low, low, medium, high, or very high. Risk levels are presented at three time frames: present, near-term (2030-2040), and long-term (2080-2100). Near-term indicates that projected levels of global mean temperature do not diverge substantially across emission scenarios. Long-term differentiates between a global mean temperature increase above 2°C and 4°C above pre-industrial levels. For each timeframe, risk levels are estimated for a continuation of current adaptation and for a high adaptation state". *{WGII TS Table 4}*

Many aspects of climate change and its impacts will continue for centuries even if anthropogenic emissions of greenhouse gases cease. The risk of abrupt and irreversible change increases with larger warming and with direct effects of accumulating CO_2 causing ocean acidification . The effects of CO_2 emissions persist for centuries; depending on the scenario, 15-40% of emitted CO_2 will remain in the atmosphere longer than 1,000 years {2.1}. This represents a substantial multi-century climate change commitment created by past, present and future emissions of CO_2. *{2.6}*

Some processes such as shifting biomes, re-equilibrating soil carbon, melting ice sheets, warming of the deep ocean and associated sea level rise have intrinsic long timescales which will result in changes detectable hundreds to thousands of years after global surface temperature is stabilized. *{2.6}*

Within this century, magnitudes and rates of climate change associated with medium- to high-emission scenarios (RCP4.5, 6.0, and 8.5) pose high risk of abrupt and irreversible regional-scale change in the composition, structure, and function of terrestrial and freshwater ecosystems, including wetlands (*medium confidence*). Examples that could lead to substantial impact on climate are the boreal-tundra Arctic system (*medium confidence*) and the Amazon forest (*low confidence*). Ocean acidification will affect marine ecosystems for centuries if CO_2 emissions continue (*high confidence*). *{2.6}*

There is little evidence in global climate models of a threshold in the transition from a perennially ice-covered to a seasonally ice-free Arctic Ocean beyond which further sea ice loss is unstoppable and irreversible. Sustained mass loss by ice sheets would cause larger sea level rise, and some part of the mass loss might be irreversible. Global mean sea level rise will continue for many centuries beyond 2100 *(virtually certain)*. *{2.6}*

An effectively irreversible reduction in permafrost extent is *virtually certain* with continued rising global temperatures. Carbon accumulated over hundreds to thousands of years in frozen soils could be emitted through decomposition within decades as a result of permafrost thaw. Current permafrost areas are projected to become net emitters of carbon during the 21st century under future warming scenarios. *{2.6}*

3. Transformations and changes in systems

3.1 Mitigation pathways

In the absence of additional mitigation efforts, GHG emissions will continue to grow, and cause a median increase in global mean surface temperature of more than three to almost five degrees Celsius relative to pre-industrial levels by 2100. Deep cuts in GHG emissions to limit warming to 2°C relative to pre-industrial levels remain possible, yet will entail substantial technological, economic, institutional, and behavioural challenges. Similar challenges would have to be faced for less ambitious mitigation, but over a longer period of time.

Baseline scenarios, those without additional mitigation, result in global mean surface temperature increases in 2100 from 3.7 to 4.8°C compared to pre-industrial levels (median values; the range is 2.5°C to 7.8°C when including climate uncertainty) *(high confidence)*. Baseline scenarios (scenarios without explicit additional efforts to constrain emissions) exceed 450 parts per million (ppm) CO_2eq by 2030 and reach CO_2eq concentration levels between 750 and more than 1300 ppm CO_2eq by 2100. This is similar to the range in atmospheric concentration levels between the RCP 6.0 and RCP 8.5 pathways in 2100. *{3.2}*

There are multiple scenarios with a range of technological and behavioral options, with different characteristics and implications for sustainable development, that are consistent with different levels of mitigation. Mitigation scenarios span atmospheric concentration levels in 2100 from 430 ppm CO_2eq to above 720 ppm CO_2eq, which is comparable to the 2100 forcing levels between RCP 2.6 and RCP 6.0. Mitigation scenarios in which it is likely that the temperature change caused by anthropogenic GHG emissions can be kept to less than 2°C relative to pre-industrial levels are characterized by atmospheric concentrations in 2100 of about 450 ppm CO_2eq (*high confidence*). Scenarios that reach about 650 ppm CO_2eq by 2100 are unlikely to limit temperature change to below 2°C relative to pre-industrial levels. Only a limited number of studies have explored scenarios that are *more likely than not* to bring temperature change back to below 1.5 °C by 2100 relative to pre-industrial levels; these scenarios bring atmospheric concentrations to below 430 ppm CO_2eq by 2100. *{3.2}*

Scenarios reaching atmospheric concentration levels of about 450 ppm CO_2eq by 2100 include substantial cuts in anthropogenic GHG emissions by mid-century through large-scale changes in energy systems and potentially land use. (high confidence). Scenarios reaching these concentrations by 2100 include 40% to 70% reductions in GHG emissions by 2050 relative to 2010, and those with more modest reductions are characterized by higher overshoot (>0.4 Wm2) and substantial reliance on CDR technologies. Scenarios reaching these concentrations are also characterized a tripling to nearly a quadrupling of the share of zero- and low-carbon energy supply from renewables, nuclear energy and fossil energy with carbon dioxide capture and storage (CCS), or bioenergy with CCS (BECCS) by the year 2050.They describe a wide range of changes in land use, reflecting different assumptions about the scale of bioenergy production, afforestation, and reduced deforestation. Scenarios reaching higher concentrations include similar changes, but on a slower timescale. On the other hand, scenarios reaching lower concentrations require these changes on a shorter timescale. *{3.2}*

Delaying mitigation efforts beyond those in place today through 2030 is estimated to substantially increase the difficulty of the transition to low longer-term emissions levels and narrow the range of options consistent with maintaining temperature change below 2 C relative to pre-industrial levels (*high confidence*). Cost-effective mitigation scenarios that make it at least as likely as not that temperature change will remain below 2°C relative to pre-industrial levels (2100 concentrations between about 450 and 500 ppm CO_2eq) are typically characterized by annual GHG emissions in 2030 of roughly between 30 GtCO_2eq and 50 GtCO_2eq (Figure SPM.8, left panel). Scenarios with annual GHG emissions above 55 GtCO_2eq in 2030 are characterized by substantially higher rates of emissions reductions from 2030 to 2050 (Figure SPM.8, middle panel); much more rapid scale-up of low-carbon energy over this period (Figure SPM.8, right panel); a larger reliance on CDR technologies in the long term and higher transitional and long term economic impacts (Table SPM.1). *{3.2}*

The Cancun Pledges are not consistent with emission pathways that are characterized by annual GHG emissions in 2030 below 50 GtCO_2eq and are therefore subject to increased mitigation challenges, if temperature increase is maintained below 2°C relative to pre-industrial levels.. Due to these increased mitigation challenges, many models with annual 2030 GHG emissions higher than 55 GtCO_2eq could not produce scenarios reaching atmospheric concentration levels that make it as likely as not that temperature change will remain below 2°C relative to pre-industrial levels. *{3.2}*

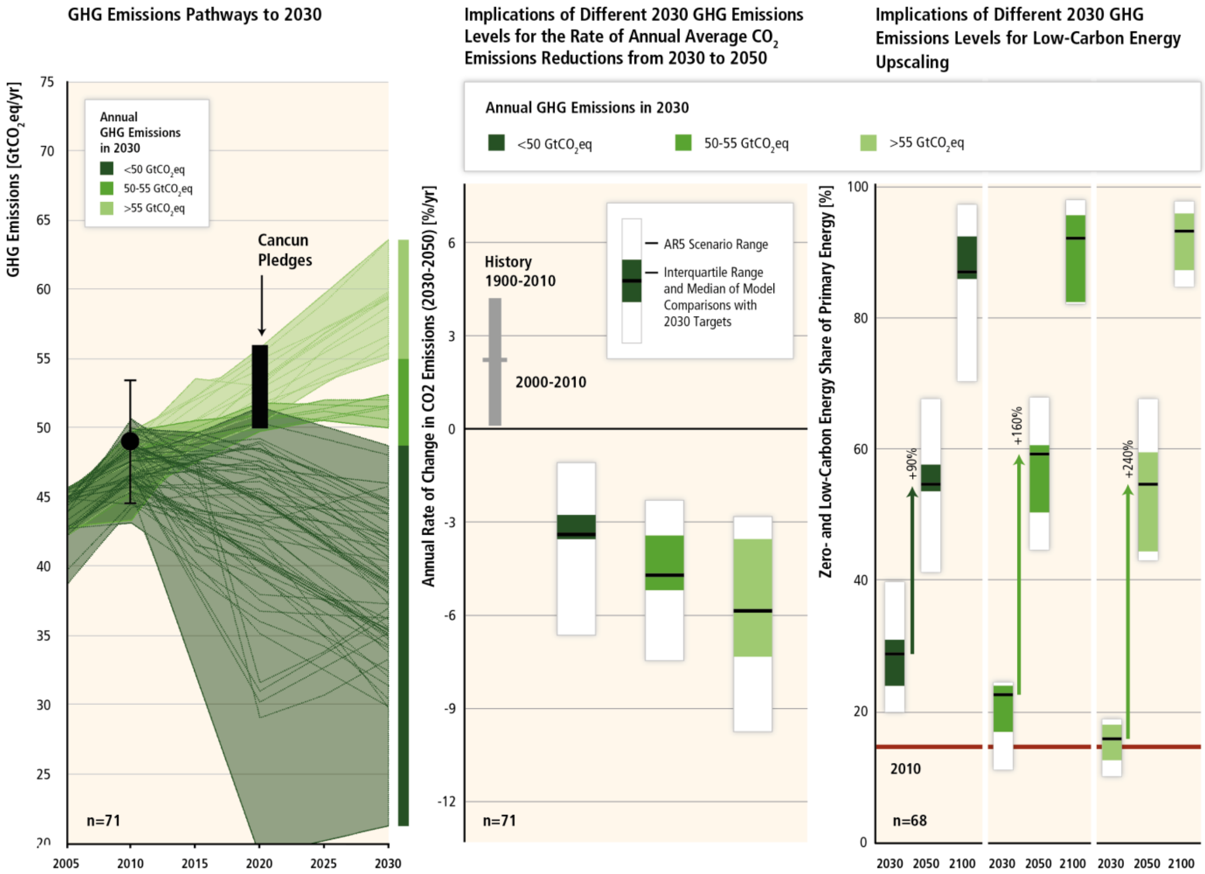

Figure SPM.8: The implications of different 2030 GHG emissions levels for the rate of CO_2 emissions reductions and low-carbon energy upscaling from 2030 to 2050 in mitigation scenarios reaching about 450 to 500 (430–530) ppm CO_2eq concentrations by 2100. The scenarios are grouped according to different emissions levels by 2030 (colored in different shades of green). The left panel shows the pathways of GHG emissions ($GtCO_2$eq/yr) leading to these 2030 levels. The black bar shows the estimated uncertainty range of GHG emissions implied by the Cancún Pledges. The middle panel denotes the average annual CO_2 emissions reduction rates for the period 2030–2050. It compares the median and interquartile range across scenarios from recent intermodel comparisons with explicit 2030 interim goals to the range of scenarios in the Scenario Database for WGIII AR5. Annual rates of historical emissions change (sustained over a period of 20 years) are shown in grey. The arrows in the right panel show the magnitude of zero and low-carbon energy supply up-scaling from 2030 to 2050 subject to different 2030 GHG emissions levels. Zero- and low-carbon energy supply includes renewables, nuclear energy, and fossil energy with carbon dioxide capture and storage (CCS), or bioenergy with CCS (BECCS). Note: Only scenarios that apply the full, unconstrained mitigation technology portfolio of the underlying models (default technology assumption) are shown. Scenarios with large net negative global emissions (>20 $GtCO_2$eq/yr), scenarios with exogenous carbon price assumptions, and scenarios with 2010 emissions significantly outside the historical range are excluded (Figure 3.3).

Estimates of the aggregate economic costs of mitigation vary widely and are highly sensitive to model design and assumptions as well as the specification of scenarios, including the characterization of technologies and the timing of mitigation *(high confidence)*. Based on their specific assumptions, mitigation scenarios that reach atmospheric concentrations of about 450ppm CO_2eq by 2100 entail losses in global consumption—not including benefits of reduced climate change as well as co-benefits and adverse side-effects of mitigation[3]—of 1% to 4% (median: 1.7%) in 2030, 2% to 6% (median: 3.4%) in 2050, and 3% to 11% (median: 4.8%) in 2100 relative to consumption in baseline scenarios that grows anywhere from 300% to more than 900% over the century. These numbers correspond to an annualized reduction of consumption growth by 0.04 to 0.14 (median: 0.06) percentage points over the century relative to annualized

[3] The total economic effects at different temperature levels would include mitigation costs, co-benefits of mitigation, adverse side-effects of mitigation, adaptation costs and climate damages. Mitigation cost and climate damage estimates at any given temperature level cannot be compared to evaluate the costs and benefits of mitigation. Rather, the consideration of economic costs and benefits of mitigation should include the reduction of climate damages relative to the case of unabated climate change.

consumption growth in the baseline that is between 1.6% and 3% per year. Under the absence or limited availability of technologies, mitigation costs can increase substantially depending on the technology considered (Table SPM.1, orange segment). Delaying additional mitigation further increases mitigation costs in the medium to long term (Table SPM.1, blue segment). Mitigation scenarios reaching about 450 or 500 ppm CO_2eq by 2100 show reduced costs for achieving air quality and energy security objectives, with significant co-benefits for human health, ecosystem impacts, and sufficiency of resources and resilience of the energy system; these scenarios did not quantify other co-benefits or adverse side-effects. *{3.2}*

Table SPM.1: Global mitigation costs in cost-effective scenarios and estimated cost increases due to assumed limited availability of specific technologies and delayed additional mitigation. Cost estimates shown in this table do not consider the benefits of reduced climate change as well as co-benefits and adverse side-effects of mitigation. The green columns show consumption losses in the years 2030, 2050, and 2100 (green) and annualized consumption growth reductions (bright green) over the century in cost-effective scenarios relative to a baseline development without climate policy.[1] The orange columns show the percentage increase in discounted costs[2] over the century, relative to cost-effective scenarios, in scenarios in which technology is constrained relative to default technology assumptions.[3] The blue columns show the increase in mitigation costs over the periods 2030–2050 and 2050–2100, relative to scenarios with immediate mitigation, due to delayed additional mitigation through 2020 or 2030.[4] These scenarios with delayed additional mitigation are grouped by emission levels of less or more than 55 $GtCO_2eq$ in 2030, and two concentration ranges in 2100 (430–530 ppm CO_2eq and 530–650 CO_2eq). In all figures, the median of the scenario set is shown without parentheses, the range between the 16th and 84th percentile of the scenario set is shown in the parentheses, and the number of scenarios in the set is shown in square brackets.[5] (Table 3.2)

	Consumption losses in cost-effective implementation scenarios				**Increase in total discounted mitigation costs in scenarios with limited availability of technologies**				**Increase in mid- and long term mitigation costs due delayed additional mitigation up to 2030**			
	[% reduction in consumption relative to baseline]			**[percentage point reduction in annualized consumption growth rate]**	**[% increase in total discounted mitigation costs (2015–2100) relative to default technology assumptions]**				**[% increase in mitigation costs relative to immediate mitigation]**			
2100 Concentration (ppm CO_2eq)	**2030**	**2050**	**2100**	**2010-2100**	**No CCS**	**Nuclear phase out**	**Limited Solar / Wind**	**Limited Bio-energy**	**≤55 $GtCO_2eq$**		**>55 $GtCO_2eq$**	
									2030–2050	**2050–2100**	**2030–2050**	**2050–2100**
450 (430–480)	**1.7 (1.0–3.7) [N: 14]**	**3.4 (2.1–6.2)**	**4.8 (2.9–11.4)**	**0.06 (0.04–0.14)**	**138 (29–297) [N: 4]**	**7 (4–18) [N: 8]**	**6 (2–29) [N: 8]**	**64 (44–78) [N: 8]**	**28 (14–50) [N: 34]**	**15 (5–59)**	**44 (2–78) [N: 29]**	**37 (16–82)**
500 (480–530)	**1.7 (0.6–2.1) [N: 32]**	**2.7 (1.5–4.2)**	**4.7 (2.4–10.6)**	**0.06 (0.03–0.13)**								
550 (530–580)	**0.6 (0.2–1.3) [N: 46]**	**1.7 (1.2–3.3)**	**3.8 (1.2–7.3)**	**0.04 (0.01–0.09)**	**39 (18–78) [N: 11]**	**13 (2–23) [N: 10]**	**8 (5–15) [N: 10]**	**18 (4–66) [N: 12]**	**3 (-5–16) [N: 14]**	**4 (-4–11)**	**15 (3–32) [N: 10]**	**16 (5–24)**
580–650	**0.3 (0–0.9) [N: 16]**	**1.3 (0.5–2.0)**	**2.3 (1.2–4.4)**	**0.03 (0.01–0.05)**								

Notes:

[1] Cost-effective scenarios assume immediate mitigation in all countries and a single global carbon price, and impose no additional limitations on technology relative to the models' default technology assumptions.

[2] Percentage increase of net present value of consumption losses in percent of baseline consumption (for scenarios from general equilibrium models) and abatement costs in percent of baseline GDP (for scenarios from partial equilibrium models) for the period 2015–2100, discounted at 5% per year.

[3] No CCS: CCS is not included in these scenarios. Nuclear phase out: No addition of nuclear power plants beyond those under construction, and operation of existing plants until the end of their lifetime. Limited Solar/Wind: a maximum of 20% global electricity generation from solar and wind power in any year of these scenarios. Limited Bioenergy: a maximum of 100 EJ/yr modern bioenergy supply globally (modern bioenergy used for heat, power, combinations, and industry was around 18 EJ/yr in 2008 [11.13.5]).

[4] Percentage increase of total undiscounted mitigation costs for the periods 2030–2050 and 2050–2100.

[5] The range is determined by the central scenarios encompassing the 16th and 84th percentile of the scenario set. Only scenarios with a time horizon until 2100 are included. Some models that are included in the cost ranges for concentration levels above 530 ppm CO_2eq in 2100 could not produce associated scenarios for concentration levels below 530 ppm CO_2eq in 2100 with assumptions about limited availability of technologies or delayed additional mitigation.

3.2 Adaptation pathways

Adaptation is essential for reducing damages associated with climate change. Adaptation options and their potential benefits are context-specific, differ between sectors and regions and depend on the rate and amount of climate change experienced. Recognizing diverse interests, circumstances, social-cultural contexts, and expectations, as well as building adaptive capacity at all levels, underpins effective selection and implementation of adaptation options and the pursuit of climate-resilient pathways. *{3.3}*

Adaptation can contribute to the wellbeing of current and future populations, the security of assets and the maintenance of ecosystem services now and in the future as the climate changes. Adaptation planning and implementation at all levels of governance are contingent on societal values, objectives, and risk perceptions (*high confidence*). Recognition of diverse interests, circumstances, social-cultural contexts, risk perceptions and expectations can benefit decision-making processes. Desired adaptation outcomes and pathways to these usually require effective engagement with the range of affected stakeholders, operating in a decision environment with policy support to overcome constraints at various levels. *{3.3}*

Effective adaptation strategies can link with sustainable development to reduce vulnerability but such strategies are challenging to implement and they are related fundamentally to what the world accomplishes with climate-change mitigation (*high confidence*). They are increasingly supported by targeted decision-support processes and tools that help address the many uncertainties, and by institutions that broker knowledge among different actors. *{3.3}*

Large magnitudes of warming increase the likelihood of severe, pervasive and irreversible impacts that make adaptation challenging. A temperature rise above 4°C would risk damaging agricultural production and ecosystems worldwide, and increase the rate of extinction of species (*high confidence*). It would also risk crossing tipping-points that could lead to disproportionately large responses in the earth system (*low confidence*). Precisely how much climate change would trigger tipping-points remains uncertain, but the likelihood of crossing them increases with increasing greenhouse gas emissions (*medium confidence*). *{3.3}*

There are limits to adaptation; greater rates and magnitude of climate change increase the likelihood of exceeding adaptation limits(*high confidence*). Poor planning, overemphasising short-term outcomes, or failing to sufficiently anticipate consequences can result in maladaptation (*medium evidence, high agreement*), including path-dependent development patterns that increase the vulnerability of some groups to future climate change**.** *{3.3}*

Restricting adaptation responses to incremental changes in existing systems and structures, without considering transformational change, may increase costs and losses, and miss out on opportunities. Transformational adaptation includes introduction of new technologies or practices, formation of new structures or systems of governance, adaptation at greater scale or magnitude and shifts in the location of activities.

3.3 Interactions between mitigation and adaptation

Climate change, mitigation, and adaptation create a large array of risks that differ in nature, magnitude, and their potential to cause irreversible consequences. Adaptation and mitigation can reduce climate change risks, but they do so over different timescales, face limits linked to resource, institutional and capacity constraints, and involves uncertainties and risks related to economic, environmental, and societal outcomes. {*3.4*}

Decisions about mitigation and adaptation involve a broad range of risks and tradeoffs connected with other policy objectives and ethical considerations; it is thus impossible to define a single best mitigation target or balance between mitigation and adaptation. Nevertheless, information on various emissions pathways is useful input into decision-making in the context of climate change. *{3.4}*

***Adaptation and mitigation reduce climate change risks, but* they face limits linked to resource, institutional and capacity constraints, and involve uncertainties and risks related to economic, environmental, and societal outcomes.** Adaptation will have relatively more substantial influence on climate risks in the near future. In the second half of the 21st century and beyond, the risks of climate change will increasingly be affected by cumulative impact of previous mitigation and adaptation actions and by their interaction with development pathways. Key vulnerabilities and risks related to ecosystems, food and water, development and other socioeconomic factors can be integrated into five Reasons for Concern (RfC). Figure SPM.9 uses the RfC to provide an illustration of how climate change risks are reduced by mitigation, for various mitigation scenarios. As illustrated in Figure SPM 9, however, not all risks can be directly linked to temperature change, and other metrics matter such as the rate of change, ocean acidification, and sea level rise also matter. The Box on Article 2 of UNFCCC applies this framework to the context of Article 2 of the UNFCCC and "dangerous" climate change. *{3.4, Box Art.2}*

Mitigation also involves risks and uncertainties. These risks are particularly high for the most ambitious mitigation pathways and include those associated with large-scale deployment of technology options for producing low-carbon energy – including bioenergy, nuclear power, carbon capture with storage, and even wind power – the potential for high aggregate economic costs, large impacts on vulnerable countries and industries. They affect human health, food security, energy security, poverty reduction, biodiversity conservation, water availability, income distribution, efficiency of taxation systems, labour supply and employment, urban sprawl, and the growth of developing countries. *{3.4}*

Risks from mitigation and from climate change are different in nature, magnitude, and in their potential to cause irreversible consequences. In an iterative risk management framework, the level of desirable efforts over the short-term is increased by the inertia in the climate system and the possibility of irreversible and catastrophic impacts from climate change**.** *{3.4}*

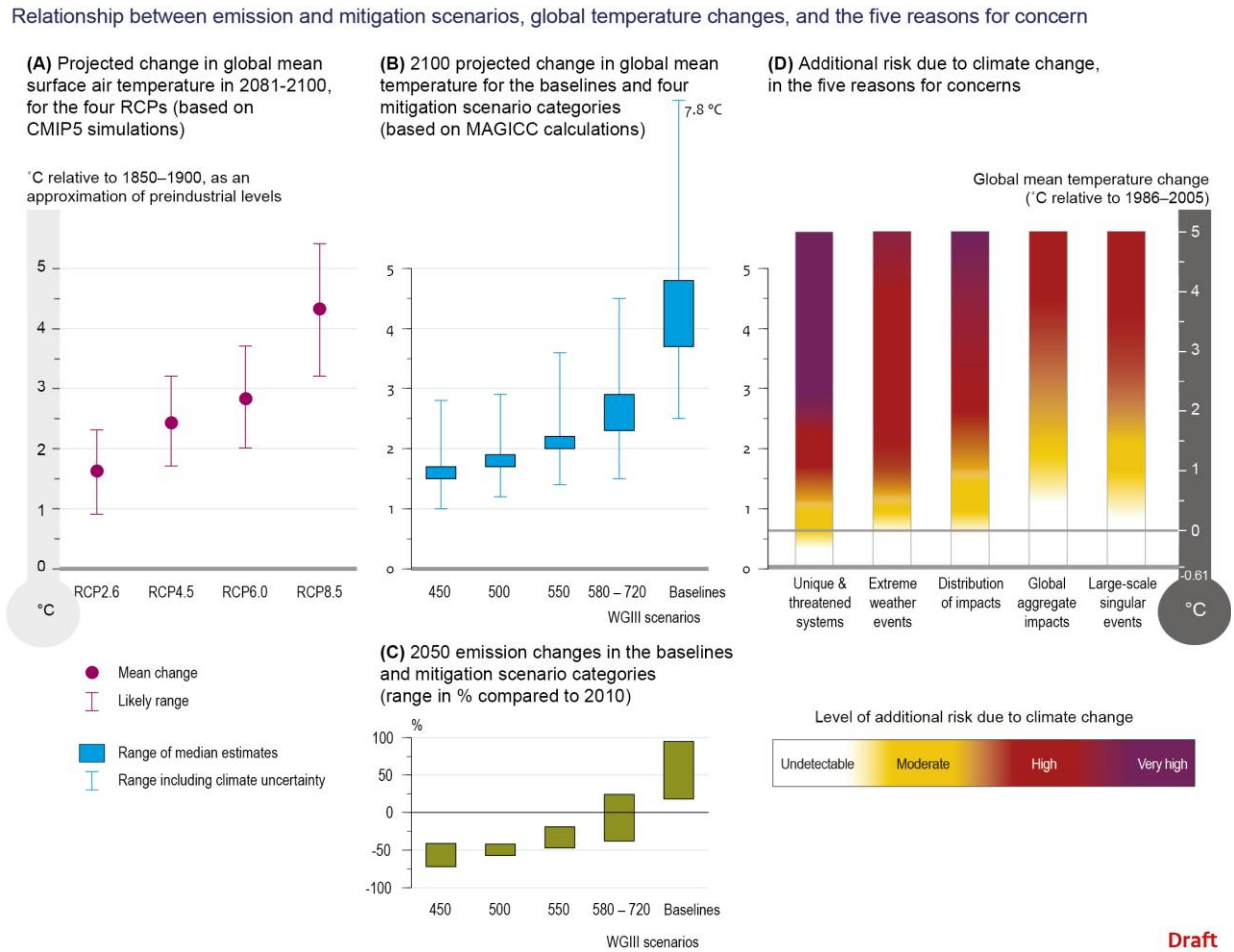

Figure SPM.9: Relationship between emission and mitigation scenarios, global temperature changes, and the five Reasons for Concerns (RfC). Temperature changes shown compared with pre-industrial levels. For reference, the extreme right temperature axis shows temperature changes with respect to the 1986-2005 period. **Panel a** shows projected change in global temperature in 2081-2100 for the four RCPs, based on CMIP5 simulations (see Table 2.1). **Panel b** shows the projected temperature increase in 2100, calculated using the MAGICC climate model for the baselines and four mitigation scenario categories defined in Chapter WGIII.6, indicating the uncertainty range resulting both from the range of emission scenario projections within each category and the uncertainty in the climate system (data from WGIII.6). **Panel c** shows the 2050 changes in emissions in the corresponding baselines and mitigation scenario categories (positive changes refer to cases where emissions in 2050 are larger than 2010). For instance, the mitigation scenarios in the 450 category – i.e. with CO2e concentration in 2100 between 430 and 480ppm – have emissions in 2050 that are between 41 and 72% percent lower than emissions in 2010 (Table WGIII.SPM.1). **Panel d** reproduces the five reasons for concerns from WGII Assessment Box SPM.1 Figure 1, using the same temperature axis than Panel a. Risks associated with reasons for concern (from left to right, denoted as RFC1-5 in Article 2 Box) are shown for increasing levels of climate change. The color shading indicates the additional risk due to climate change when a temperature level is reached and then sustained or exceeded. Examples of risks represented by RFC1 include those to coral reefs and the Arctic system; RFC2, includes risks associated with extreme heat; RFC3, regionally differentiated risks to food and water; RFC4, aggregate economic damages and biodiversity loss; RFC5, risk associated with a large sea level rise due to loss of mass from polar ice sheets. Undetectable risk (white) indicates no associated impacts are detectable and attributable to climate change. Moderate risk (yellow) indicates that associated impacts are both detectable and attributable to climate change with at least medium confidence, also accounting for the other specific criteria for key risks. High risk (red) indicates severe and widespread impacts, also accounting for the other specific criteria for key risks. Purple, introduced in this assessment, shows that very high risk is indicated by all specific criteria for key risks.*{Ch.19.2}* Note the different temperature baselines used in WGII Assessment Box SPM.1 Figure 1. Beyond 2100, temperature, and therefore risk, decreases in most of the lowest three scenarios and increases further in most of the others.

4. Adaptation and Mitigation Measures

4.1 Mitigation measures

Stabilizing GHG concentrations in the atmosphere at low levels requires mitigation throughout the economy. Efforts in one sector determine the needs in others. Low stabilization scenarios are dependent upon a full decarbonisation of energy supply. Reductions in energy demand can limit the mitigation requirements and provide flexibility in the up-scaling of energy-supply technologies, avoid lock-in into carbon-intensive infrastructure and increase the cost-effectiveness of mitigation scenarios. *{4.3}*

Decarbonizing (i.e. reducing the carbon intensity of) electricity generation is a key component of cost-effective mitigation strategies in achieving low-stabilization levels *(medium evidence, high agreement){4.3}.*Energy supply is the largest and fastest growing contributor to global GHG emissions and offers opportunity for decarbonisation through renewable energy (RE), nuclear power, and carbon dioxide capture and storage (CCS). The wide range of options for decarbonizing energy supply provides flexibility in technology choice. The available technologies differ in their costs, risks and co-benefits. In most ambitious long-term mitigation scenarios, the economy is fully decarbonized at the end of the 21st century Accelerated electrification of energy end use, coupled with decarbonization of the majority of electricity generation by 2050 and an associated phase out of freely emitting coal generation, is a common feature of scenarios reaching roughly 550 ppm $C0_2$eq or less by 2100.*{4.3}*

Demand reductions in the energy end-use sectors are a key mitigation strategy and affect the scale of the mitigation challenge for the energy supply side (*high confidence) {4.3}.* Limiting energy demand: 1) increases policy choices by maintaining flexibility in the technology portfolio; 2) reduces the required pace for up-scaling low-carbon energy supply technologies and hedges against related supply side risks (Figure SPM…); 3) avoids lock-in to new, or potentially premature retirement of, carbon-intensive infrastructures; 4) maximizes co-benefits for other policy objectives, since the number of co-benefits for energy end-use measures outweighs the adverse side-effects which is not the case for all supply-side measures and 5) increases the cost effectiveness of the transformation (as compared to mitigation strategies with higher levels of energy demand) (*medium confidence*). However, energy service demand reductions are unlikely in developing countries or for poorer population segments whose energy service levels are low or partially unmet.*{4.3}*

The AFOLU sector plays a key role in low stabilization scenarios because it provides options to remove carbon dioxide from the atmosphere (high confidence AFOLU plays a central role for food security and sustainable development. The most cost-effective mitigation options in forestry are afforestation, sustainable forest management and reducing deforestation, with large differences in their relative importance across regions. In agriculture, the most cost-effective mitigation options are cropland management, grazing land management, and restoration of organic soils .*{4.3}*

Systemic cross-sectoral approaches to mitigation are expected to be more cost-efficient and more effective in cutting emissions than a focus on individual technologies and sectors. In this regard, human settlements play a key role in climate change mitigation. Since most of the world's urban areas in 2030 have not yet been built, spatial planning in these new areas can help avoid locking in carbon intensive patterns of infrastructure and urban form. In established cities, the potential lies in retrofitting existing urban forms and infrastructure. Mitigation in urban areas is most effective when planning strategies and cross-sectoral policy instruments are aligned to increase accessibility, promote land-use mix, and reduce urban sprawl.*{4.3}*

4.2 Mitigation policies

Policies to reduce GHG emissions or to support low-GHG technologies have increased since the AR4.
In many countries these policies have helped to reduce emission intensity. Ambitious mitigation will require policies sufficiently effective to induce fundamental shifts in investment flows. There is an increasing focus on policy design to integrate climate change mitigation with other economic, environmental and social objectives. *{4.5}*

As a global commons problem[4], effective climate change mitigation requires international cooperation.

The United Nations Framework Convention on Climate Change (UNFCCC) is the main multilateral forum focused on addressing climate change, with nearly universal participation. Other institutions organized at different levels of governance have resulted in diversifying international climate change cooperation. Policy linkages among regional, national, and sub-national climate policies offer potential climate change mitigation and adaptation benefits (medium evidence, medium agreement). Linkages can be established between national policies, various instruments, and through regional cooperation.
The number of national and sub-national plans and strategies for mitigating climate change has increased since AR4, but there is inadequate evidence to assess their impacts on emissions and without coordination, policy instruments may not work as expected. *{4.5.1.2}*

Technology development, deployment and diffusion can be important components of mitigation and adaptation efforts. However, they face challenges with scaling up, and with integration in existing systems and in local contexts. Technology policy includes technology-push (e.g. publicly-funded R&D) and demand-pull (e.g. governmental procurement programs), but for adaptation also includes a strong focus on technology transfer, as adaptation technologies are often familiar and already applied elsewhere but need to be adapted to local circumstances. *{4.5.3}*

Behaviour, lifestyle and culture have considerable influence on energy use and associated GHG emissions (*high agreement, medium evidence*), with high mitigation potential in some sectors, in particular when complementing technological and structural change (*medium evidence, medium agreement*). Shifts toward more emission-intensive lifestyles might contribute to higher energy and resource consumption and therefore higher mitigation costs, but emissions can be substantially lowered through changes in consumption patterns, dietary change and reduction in food wastes. The social acceptability and/or effectiveness of climate policies may be dependent upon the extent to which they incentivise, or are contingent upon, changes in lifestyles or behaviours. *{4.2}*

Effective mitigation and adaptation efforts can require both changes in patterns of investment in all countries and increases in financial support for developing countries. Substantial reductions in emissions would require large changes in investment patterns (high agreement, robust evidence). Within appropriate enabling environments, the private sector, along with the public sector, can play an important role in financing mitigation and adaptation. Limited evidence indicates a gap between global adaptation needs and the funds available for adaptation (*medium confidence*). Appropriate governance arrangements and institutions are essential conditions for efficient, effective, and sustainable financing of mitigation and adaptation measures. *{4.5.4}*

The distribution of mitigation costs across countries can differ from the distribution of the actions themselves (*high confidence*)**.** In globally cost-effective scenarios, the majority of mitigation efforts takes place in countries with the highest future emissions in baseline scenarios. Some studies exploring particular effort-sharing frameworks, under the assumption of a global carbon market, have estimated substantial global financial flows associated with mitigation for scenarios leading to 2100 atmospheric concentrations of about 450 to 550 ppm CO_2eq. *{ 3.2}*

4.3 Adaptation measures

A first step for adaptation is often to reduce current climate-related risks (*high confidence*).
Adaptation options can have multiple and overlapping entry points. Significant co-benefits, synergies, and tradeoffs exist among individual adaptation options. For many natural ecosystems, the adaptation options are limited and focus mostly on reducing other pressures. For many human systems, a wider portfolio of options exists, including transformational responses, but their implementation faces a range of constraints. *{4.4}*

[4] As this expression is used in the social sciences, it has no specific implications for legal arrangements or for particular criteria regarding effort sharing.

A first step for adaptation is often to reduce current climate-related risks (*high confidence*). Integration of appropriate adaptation strategies and actions into development planning and decision-making can proactively prepare for a range of future climates while helping to improve human health and livelihoods, social and economic well-being, and environmental quality now. However, some near-term responses to increasing risks related to climate change may also limit future choices. For example, enhanced protection of exposed assets can lock in dependence on further protection measures. *{4.4}*

Adaptation options can have multiple and overlapping entry points. Significant co-benefits, synergies, and tradeoffs exist among individual adaptation options. Appropriate entry points depend on co-benefits and opportunities within wider development plans and strategic goals, and existing other climate and non-climate pressures. The effectiveness of specific adaptation options is influenced by culture, institutions, risk perception, resources and resource entitlement. Individual adaptation measures can complement each other, but some approaches entail significant trade-offs with and reduce the effectiveness of other actions (*very high confidence*). *{4.4}*

The potential for individual adaptation measures to reduce risk differs between sectors and regions, and changes over time. For many natural ecosystems, the adaptation options are limited and focus mostly on reducing other pressures. For many human systems, a wider portfolio of options exists, including transformational responses, but their implementation faces a range of constraints. *{4.4}*

- *Freshwater resources*: Adaptive water management techniques, including scenario planning, learning-based approaches, and flexible and low-regret solutions, can help create resilience to uncertain hydrological changes and impacts due to climate change (*limited evidence, high agreement*).
- *Terrestrial and freshwater ecosystems*: Management actions, such as maintenance of genetic diversity, assisted species migration and dispersal, manipulation of disturbance regimes (e.g., fires, floods), and reduction of other stressors, can reduce, but not eliminate, risks of impacts to terrestrial and freshwater ecosystems due to climate change, as well as increase the inherent capacity of ecosystems and their species to adapt to a changing climate (*high confidence*).
- *Coastal systems and low-lying areas:* Adaptation can reduce some of the projected damages from flooding in river basins and coasts, driven by increasing urbanization and by increasing sea levels and peak river discharges (*high confidence*), but the relative costs of coastal adaptation vary strongly among and within regions and countries for the 21st century.
- *Marine systems and oceans:* Marine forecasting and early warning systems as well as reducing non-climatic stressors can help reduce risks for some fisheries and aquaculture industries, but options for unique ecosystems such as coral reefs are limited (*high confidence*).
- *Food production system/Rural areas*: Adaptation options for agriculture include technological responses (e.g., stress-tolerant crop varieties, irrigation), enhancing smallholder access to credit and other critical production resources, and strengthening institutions at local to regional levels to support gender-oriented measures (*high confidence*).
- *Urban areas, key economic sectors and services:* Urban adaptation benefits from effective multi-level urban risk governance, alignment of policies and incentives, strengthened local government and community adaptation capacity, synergies with the private sector, and appropriate financing and institutional development (*medium confidence*).
- *Human health, security and livelihoods*: Adaptation options that focus on strengthening existing delivery systems and institutions as well as insurance and social protection strategies offer the best examples for securing health, security and livelihoods in the near term (*high confidence*).

4.4 Interactions among mitigation, adaptation and sustainable development

Achieving sustainable development and addressing climate change are closely related concerns, and involve trade-offs and synergies between multiple objectives, attention to interactions between different types of policies, and the likely need for transformational change in systems. *{3.5}*

Climate change poses an increasing threat to equitable and sustainable development. Some climate-related impacts on development are already being observed. Climate change is a threat multiplier, exacerbating other threats to social and natural systems in ways that place additional burdens on the poor and constrain possible development paths for all. Development along current pathways can contribute to climate risk and vulnerability, further eroding the basis for sustainable development. *{3.5}*

Casting climate policy in the context of sustainable development includes attention to achieving climate resilience through both adaptation and mitigation. **In the framework of sustainable development the design of climate policy involves the recognition of trade-offs and synergies across multiple objectives**. Most climate policies intersect with other goals, either positively or negatively, creating the possibility of "co-benefits" or "adverse side effects". A multi-objective perspective helps to identify those policies that advance multiple goals and those that involve trade-offs among objectives. Strategies and actions can be pursued now that will move towards climate-resilient pathways for sustainable development, while at the same time helping to improve livelihoods, social and economic well-being, and responsible environmental management. *{Box 3.1, 3.5}*