Summary for Policy Makers

Drafting Authors:
Myles Allen (UK), Heleen De Coninck (The Netherlands), Opha Pauline Dube (Botswana), Marion Ferrat (UK/France), Ove Hoegh-Guldberg (Australia), Daniela Jacob (Germany), Kejun Jiang (China), Valérie Masson-Delmotte (France), Wilfran Moufouma-Okia (France/Congo), Rosalind Pidcock (UK), Anna Pirani (Italy), Elvira Poloczanska (Germany), Hans-Otto Pörtner (Germany), Aromar Revi (India), Debra C. Roberts (South Africa), Joeri Rogelj (Austria/Belgium), Joyashree Roy (India), Priyadarshi R. Shukla (India), James Skea (UK), Raphael Slade (UK), Drew Shindell (USA), William Solecki (USA), Michael Taylor (Jamaica), Petra Tschakert (Australia), Henri Waisman (France), Panmao Zhai (China)

Date of Draft: 08 January 2018

Notes: First Order Draft of SR1.5 SPM for Expert and Government review.

SPM 1 Introduction

SPM 1.1 Context

This summary presents key findings from the 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. The narrative of the summary is supported with a series of highlighted headline statements.

The certainty in key assessment findings[1] in this Special Report is communicated as in the IPCC AR5[2] Working Group Reports and Special Reports. The constraints on the timeline and literature available for the preparation of this report means that many policy-relevant statements are presented with a confidence qualifier, not a likelihood and this does not detract from their importance. {1.6}

The Special Report is prepared in the context of unequivocal and sustained global warming and sea level rise, and continued emissions of greenhouse gases. The Special Report assesses knowledge on global climate change, regional climate changes, vulnerabilities, impacts and risks at 1.5°C global warming above pre-industrial levels for natural and human systems, taking into account adaptive capacities and their limits. It provides new insights on impacts that may be avoided with 1.5°C global warming compared to 2°C. It explores global greenhouse gas emission pathways consistent with limiting global warming to 1.5°C above pre-industrial levels, including those which temporarily exceed 1.5°C global warming before returning to 1.5°C by the end of this century. The Special Report assesses the pace and scale of transformations consistent with limiting global warming to 1.5°C compared to 2°C global warming, in the context of sustainable development, poverty eradication and equity, considering adaptation and mitigation options.

This report includes information relevant to the Paris Agreement including: Article 2 on strengthening the global response to the threat of climate change, in the context of sustainable development and efforts to eradicate poverty; Article 4 on achieving a balance between anthropogenic emissions by sources and removals by sinks of greenhouse gases in the second half of this century, on the basis of equity; Article 7 on enhancing adaptive capacity, strengthening resilience and reducing vulnerability to climate change, with a view to contributing to sustainable development; Article 8 on averting, minimizing and addressing loss and damage associated with the adverse effects of climate change; Article 9 on providing financial resources to assist developing country Parties; Article 10 on sharing a long-term vision on the importance of fully realizing technology development and transfer; Article 11 on enhancing the capacity and ability of developing country Parties, in particular countries with the least capacity; Article 12 on enhancing climate change education, training, public awareness, public participation and public access to information; and Article 14 on the Global Stocktake.

---

[1] Each finding is grounded in an evaluation of underlying evidence and agreement. In many cases, a synthesis of evidence and agreement supports an assignment of confidence. The summary terms for evidence are: limited, medium or robust. For agreement, they are low, medium or high. A level of confidence is expressed using five qualifiers: very low, low, medium, high and very high, and typeset in italics, e.g., *medium confidence*. The following terms have been used to indicate the assessed likelihood of an outcome or a result: virtually certain 99–100% probability, very likely 90–100%, likely 66–100%, about as likely as not 33–66%, unlikely 0–33%, very unlikely 0–10%, exceptionally unlikely 0–1%. Additional terms (extremely likely 95–100%, more likely than not >50–100%, more unlikely than likely 0–<50%, extremely unlikely 0–5%) may also be used when appropriate. Assessed likelihood is typeset in italics, e.g., *very likely*. See for more details: Mastrandrea, M.D., C.B. Field, T.F. Stocker, O. Edenhofer, K.L. Ebi, D.J. Frame, H. Held, E. Kriegler, K.J. Mach, P.R. Matschoss, G.-K. Plattner, G.W. Yohe and F.W. Zwiers, 2010: Guidance Note for Lead Authors of the IPCC Fifth Assessment Report on Consistent Treatment of Uncertainties, Intergovernmental Panel on Climate Change (IPCC), Geneva, Switzerland, 4 pp

[2] AR5: Fifth Assessment Report of the IPCC.

Box SPM 1: Definition of global mean surface temperature change and 1.5°C global warming

This report adopts a working definition of global mean surface temperature change at any given time relative to the climatology of pre-industrial levels as combined land surface air temperature and sea surface temperature, averaged for a 30-year period centred on that time. The climatology of pre-industrial global mean is based on the 51-year period 1850-1900. (Figure SPM1) {1.2, Figure 1.2}

In this report, '1.5°C global mean temperature' or '1.5°C warmer world' refers to a 1.5°C human-induced globally-averaged surface temperature change above the pre-industrial climatology.

SPM 1.2 High level statements from this report

- There is very high risk that under current emission trajectories and current national pledges global warming will exceed 1.5°C above preindustrial levels. Limiting global warming to 1.5°C would require a rapid phase out of net global carbon dioxide (CO_2) emissions and deep reductions in non-CO_2 drivers of climate change such as methane, with more pronounced and rapid reductions required than for limiting global warming to 2°C.

- Even if global warming is limited to 1.5°C above pre-industrial temperatures, climatic trends and changing extreme events in oceans and over land imply risks for ecosystems and human societies larger than today, especially where vulnerabilities are highest. Projected impacts are larger at 2°C, with the potential to affect more strongly economic development, increase costs of adaptation, damage, and loss, and cause increasing risks by exceeding the adaptive capacity of vulnerable systems. Sea level rise will continue for centuries at both 1.5°C and 2°C global warming.

- In a 1.5°C warmer world, climate change and climate change responses will affect people in countries at all levels of development, but those most at risk will be individuals and communities experiencing multidimensional poverty, persistent vulnerabilities, and various forms of deprivation and disadvantage. This is unless adaptation and mitigation actions are guided by concerns for equity and fairness and enhanced support for eradicating poverty and reducing inequalities.

- Holding global warming to below 1.5°C implies transformational adaptation and mitigation, behaviour change, supportive institutional arrangements and multi-level governance.

- Emissions reductions in all sectors would be needed in order to meet the long-term temperature goal of the Paris Agreement. All available 1.5°C pathways include three broad approaches, to varying extent. The first is lowering energy demand in buildings, industry and transport, and demand for agricultural products. The second is lowering emissions from energy supply, land use and agriculture through, for example, the deployment of low carbon energy technologies. The third is through removing carbon dioxide from the atmosphere.

- Different portfolios of emission reduction measures have different implications for sustainable development, including regional climate change, food security, biodiversity, the provision of ecosystem services, and the vulnerability of the poor. While demand side measures have many synergies with sustainable development, portfolios that mainly consider supply side measures and affect patterns of land use carry a greater risk of trade-offs.

- Delayed action or weak near-term policies increase mitigation challenges in the long-term and increase the risks associated with exceeding 1.5°C global warming temporarily (referred to as 'overshoot') or of warming remaining above 1.5°C by the end of the century. Delayed action or weak near-term policies increase the severity of projected impacts and adaptation needs. Modelling suggests that having a 66% likelihood of holding warming below 1.5°C throughout the 21st century without overshoot is already out of reach.

SPM 1.3 Background

1.1 Greenhouse gas emissions from human activities are the dominant cause of global warming, which has been occurring at an average rate of 0.17°C (±0.07°C) per decade since 1950. The global mean temperature in 2017/18 is estimated to be 1°C higher relative to pre-industrial levels. At current rates of warming, global mean temperature would reach 1.5°C by the 2040s. {1.1, 1.2.2, 1.2.3}

- The global mean temperature reached approximately 1°C above pre-industrial levels around 2017/2018[3]. Over one quarter of the global population lives in regions that already experience greater warming than the global average, with annual mean temperatures exceeding 1.5°C in at least one season. Such regions are found particularly in northern mid- and high-latitudes *(high confidence)*. (Figure SPM1) {1.1, 1.2.2, 1.2.3, Figure 1.3}

- At the present rate of greenhouse gas emissions and global warming of 0.17°C (±0.07°C) per decade, as assessed in the AR5, global mean temperatures would reach 1.5°C in the 2040s *(high confidence)*. (Figure SPM1) {1.2.2, 1.2.3}

1.2 Future global warming will depend primarily on future cumulative CO_2 emissions. As cumulative CO_2 emissions are reduced under ambitious mitigation scenarios, the mitigation of emissions of other climate warming agents becomes progressively more important. {1.2.6, 2.2, 2.3}

- Avoiding substantial global mean warming (more than 0.2°C) beyond what is already experienced is geophysically possible, but depends on rates of reductions in emissions of climate forcers. There would be a regional adjustment following a cessation of emissions, such that some regions would warm even if the global mean temperature does not *(high confidence)*. (Figure SPM1) {1.2.6, 2.2, 2.3}

- Limiting global mean warming to 1.5°C would require rapid and deep reductions in greenhouse gas emissions, even with a temporary overshoot and later return to 1.5°C warming. The Nationally Determined Contributions (NDCs) submitted under the Paris Agreement will result, in aggregate, in global greenhouse gas emissions in 2030 that are higher than those in scenarios compatible with limiting global warming to 1.5°C by 2100. {1.2.2, 2.3.1, 2.3.4, 2.2.5, 4.3.8; Cross-Chapter Box 4.1}

---

[3] This is using the definition of SPM Box 1 and includes an extrapolation or near term predictions of future warming so that the level of anthropogenic warming is reported for a 30 year period centered on today.

1.3 At 1.5°C global warming, the risks to natural, managed and human systems depend on development pathways, levels of vulnerability, on the choices of adaptation and mitigation options, on the occurrence of overshoot above 1.5°C, and their different implications at regional scales. Adaptation and mitigation measures also have consequences for sustainable development. {1.3, Cross-Chapter Box 3.2, 5.6}

- Impacts at 1.5°C in this report refers to the projected impacts when global mean temperature is 1.5°C above pre-industrial levels. {1.3}

- Many impacts are different in a world where global warming is limited to 1.5°C compared to a world in which global mean temperature temporarily overshoots 1.5°C. As some impacts are irreversible, such as mortality of species and ecosystems, even brief periods of overshoot can have long-lasting impacts on natural systems, especially if the peak in global mean temperature is high *(high confidence)*. {Cross-Chapter Box 3.2}

- Impacts will depend on the level of vulnerability of human and natural systems, their capacity to adapt to changing conditions, and the stage of differential national development trajectories. (Figure SPM3) {5.6}

- Climate-resilient development pathways have the potential to meet the goals of sustainable development, including poverty eradication and reducing inequalities, while emphasising equity and fairness with respect to the deep societal transformation needed to limit global warming to 1.5°C and to achieve desirable futures and well-being for all. {5.6, Figure 5.5}

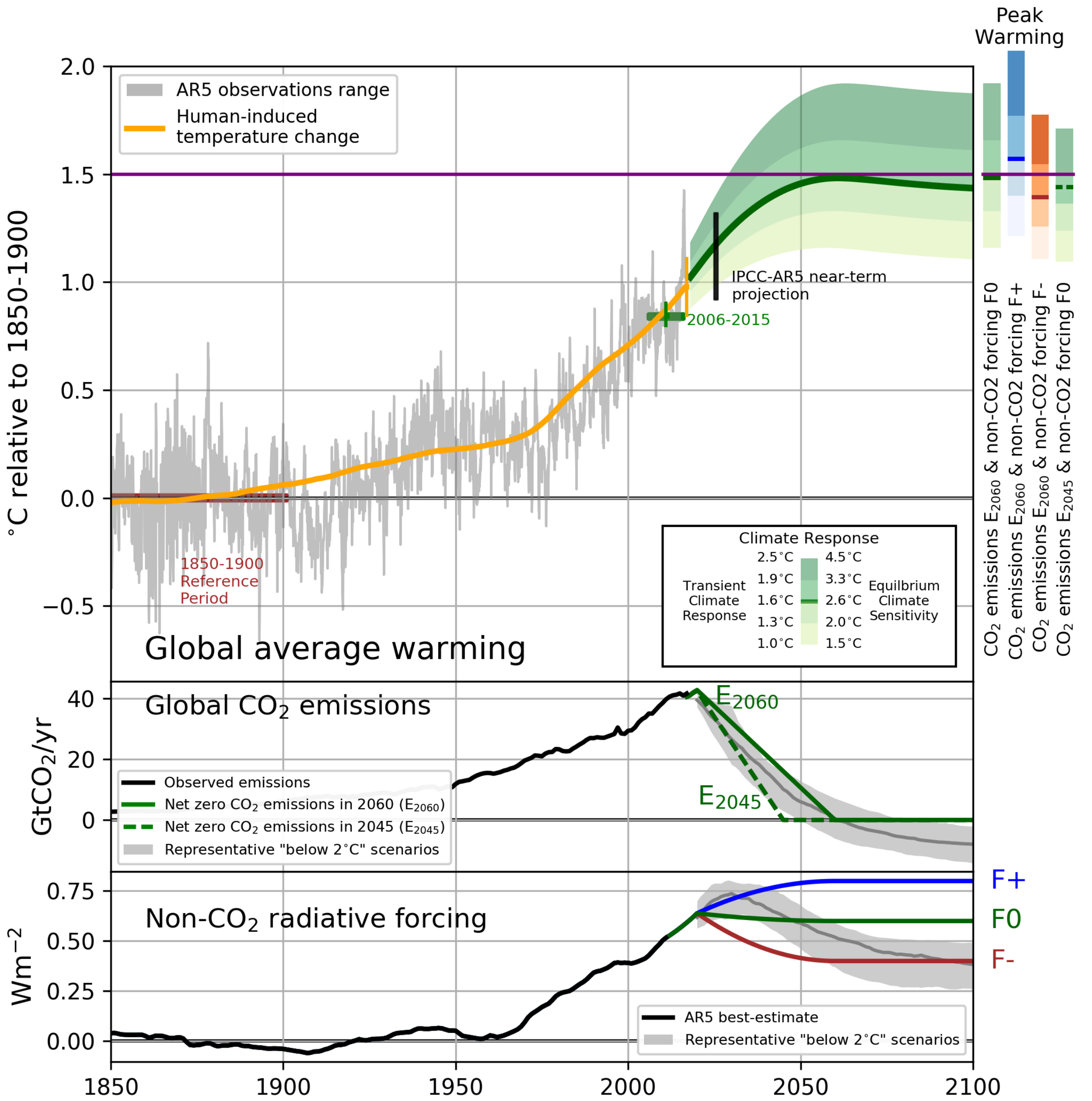

Figure SPM 1: Observed global warming, and estimation of human-induced temperature change for a range of possible climate response magnitudes. Illustration of future warming response to two stylized scenarios of reductions in CO2 emissions, with different hypothetical non-CO2 forcing stabilization.

Change in global mean temperature using updated AR5 observational datasets (grey shaded band) updated until end of 2016, relative to the reference period 1850-1900. The average warming levels corresponding to the SR1.5 near-term reference period (2006-2015) is shown with uncertainties (vertical green bar). One estimate of historical human-induced temperature change is shown {Figure 1.1}, with the yellow vertical bar indicating the estimated uncertainties in the human-induced warming for the final data point (2016) calculated using the relative uncertainty in near-term warming trend from AR5. The AR5 assessment of near-term projections are marked with a black bar. Possible global temperature responses to a stylized linear decline of CO_2 emissions from 2020 to net zero in 2060 (E_{2060}, middle panel) is shown (upper panel, green shading) for a set of possible climate system properties taken from across the AR5 assessed ranges, and assuming a future non-CO_2 radiative forcing that stabilises at present-day levels (F0 – bottom panel). Bars to the right of the upper panel illustrate the possible peak warming under different stabilised levels of future non-CO_2 radiative forcing levels above or below current levels (blue and brown bars), and under a more rapid stylized decline in CO_2 emissions to reach net-zero in 2040 (E_{2045}, right-most bar). The 17-83 percentiles of the scenarios ensemble described in {Chapter 2} are shown in the bottom two panels for reference.

SPM 2 Impacts of 1.5°C global warming and associated risks

[Missing confidence statements to be complemented after revision of Chapter 3 Executive Summary]

2.1 Every increase of 0.5°C of global mean surface temperature increases the risks of climate change impacts. The increase in global land surface temperatures is larger than the global average. Risks associated with changes in precipitation patterns and some extreme events, storms, and sea level rise increase *(high confidence)*. The rise in extreme temperatures in some regions can be more than three times larger than the change in global mean surface temperature. {3.3.1, 3.3.2, 3.3.7, Cross-Chapter Box 3.2, Cross-Chapter Box 4.3}

- Changes in temperature and preciptation extreme indices are detectable in observations for the 1991-2010 period compared with 1960-1979, during which time an approximate 0.5°C global warming occurred. {3.3.1}

- In some regions, the rise in extreme temperatures is projected to be more than three times larger than the change in global mean surface temperature. {3.3.1, 3.3.2, Cross-Chapter Box 3.2}

- The risks from land-based heatwaves and temperature extremes increase with global mean temperature rise. There is a faster rate of increase of temperature extremes in most land regions at 2°C compared to 1.5°C, in particular in Central and Eastern North America, Central and Southern Europe, the Mediterranean, Western and Central Asia, and Southern Africa. {3.3.1, 3.3.2, Cross-Chapter Box 3.2}

- An increased risk from hot days (10% of warmest days) occurs with the additional 0.5°C from 1.5°C to 2°C global warming. The increase in risk is most pronounced in the tropics. (Figure SPM3) {3.3.1, 3.3.2, Cross-Chapter Box 3.2}

- Projected risks from water scarcity, flood and drought are greater at 2°C global warming compared to 1.5°C. The largest increase of risks associated with floods at 2°C, compared to 1.5°C, are projected in Asia, North America and Europe. The greatest increase in water stress is projected for the Mediterranean region. (Figure SPM3) {Cross-Chapter Box 4.3}

- There is greater risk from the most intense tropical cyclones with 2°C of global warming compared to 1.5°C. The most intense (category 4 and 5) tropical cyclones are projected to occur more frequently, with higher peak wind speeds and lower central pressures at 2°C compared to 1.5°C of global warming. {3.3.7}

2.2 Climate change impacts all ecosystems and their services on all continents and in the oceans, including terrestrial, wetland and freshwater, marine and coastal ecosystems. Risks increase between today and global warming of 1.5°C, as well as between 1.5°C and 2°C global warming. {3.3.1, 3.3.2, 3.3.3., 3.3.4, 3.4.9, 3.5.6, Box 3.5}

- Impacts on natural systems are *likely* to be less at 1.5°C than at 2°C based on knowledge of past impacts. {3.3.1, 3.3.2}

- There is greater risk in the Arctic region with increasing level of global warming, for example, for ecosystems, permafrost and human systems. Such regions experience warming rates faster than the global average *(high confidence)*. (Figure SPM2) {3.3.3., 3.3.4, 3.4.9, 3.5.6, Box 3.5}

2.3 In the oceans, higher levels of temperature, acidification and hypoxia increase the risk to ecosystems and biodiversity. The loss of Arctic sea ice and the degradation of sub-tropical and tropical coral reefs are significantly larger at 2°C than at 1.5°C. {3.4, 3.4.4.1.4, 3.4.4.1.5, 3.4.4.1.6, 3.4.4.2, 3.4.4.2.1, 3.4.6.4, 3.5.2.4, Box 3.6, 3.7}

- Increased warming increases the risk of the Arctic Ocean being nearly ice free in September, with it being possible at 1.5°C global warming. {3.4.4.1.6}

- Global warming of 1.5°C leads to fundamental changes in ocean chemistry from which it may take many millennia to recover. At global warming of 1.5°C, ocean acidification is driving large-scale changes and amplifying the risks of temperature rise for ocean biological systems. Oceans are experiencing unprecedented changes with critical thresholds being reached at global warming of 1.5°C and above, for example driving some species to relocate and novel ecosystems to appear. Ecosystems that are relatively less able to move are projected to experience high rates of mortality and loss. {3.4.4.1.4, 3.4.4.1.5}

- Observed shifts in ocean biodiversity have major implications for food webs, ecosystem structure and services, fisheries, and human livelihoods. The risk of elevated local extinction rates in tropical regions is higher with 2°C of global warming compared to 1.5°C. (Figure SPM2) {3.4}

- Warm water coral reef ecosystems are losing live coral cover at present. They are at high risk that at 1.5°C and at 2°C they will no longer be dominated by corals. (Figure SPM2) {3.4.4.2.1}

- Marine ecosystem services, fisheries and aquaculture are already at risk today from ocean warming and acidification, and these impacts are projected to get progressively worse with global warming of 1.5°C, 2°C and higher. (Figure SPM2) {3.4.4.2, 3.4.6.4, 3.5.2.4, Box 3.6, 3.7}

2.4 On land, risks of local and regional species extinction, range loss and shifts in biodiversity distribution are lower at 1.5°C than at 2°C. {3.3.2.2, 3.4.3.1, 3.4.3.5, 3.5.2.4.2, 3.5.5.10}

- Risks for natural and managed ecosystems are amplified on drylands compared to humid lands. {3.3.2.2, 3.4.3.5, 3.5.5.10}

- Shifts in elevation and latitude of biomes in boreal, temperate, and tropical ecosystems have occurred with 1°C of warming (*high confidence*) and are attributable to anthropogenic climate change. Approximately 25% more biome shifts are projected to occur in the Arctic, Tibet, Himalayas, South Africa and Australia with 2°C global warming compared to 1.5°C. (Figure SPM3) {3.4.3.1}

- Local species extinction (extirpation) risks are higher in a 2°C warmer world, compared to 1.5°C. Climate-induced range losses in plants, vertebrates and insects increase by approximately 50% with 2°C global warming compared to 1.5°C (*medium confidence*). (Figure SPM2) {3.5.2.4.2}

2.5 Sea level will continue to rise for centuries. Sea level rise will be greater with 2°C global warming compared to 1.5°C, increasing risks to coastal ecosystems, infrastructure, and freshwater supplies. High risk levels and adaptation limits are expected to be reached earlier at 2°C compared to 1.5°C in many locations. {1.2.6, 3.3.12, 3.3.12.3, 3.4, 3.4.4.2.3}

- Past emissions do not commit to substantial future surface warming, but do commit to future sea level rise. It is *virtually certain* that sea level will continue to rise in both 1.5°C and 2°C worlds well beyond the end of the current century. {1.2.6, 3.3.12}

- Available studies suggest that global mean sea level rise by 2100 will be ~0.1m greater in a 2ºC world compared to 1.5ºC. Thresholds for irreversible, multi-millennial loss of the Greenland and West Antarctic ice sheets may occur at 1.5°C or 2°C global warming. The projected risk associated with long-term commitment to multi-metre-scale sea level rise is greater for a 2°C warmer world compared to 1.5°C. {3.3.12.3}

- The risks for hundreds of millions of people in coastal communities from eroding livelihoods, loss of cultural identity, ill health, and reduced coastal/mangrove protection are lower with global warming of 1.5°C compared to 2°C. (Figure SPM2) {3.4}

- Impacts associated with sea level rise and salinity changes to groundwater or estuaries are critically important in sensitive environments such as small islands. Preserving or restoring natural coastal ecosystems can be a more cost-effective protection of coastal regions from rising sea levels and intensifying storms compared to artificial interventions, such as building sea walls and coastal hardening. {3.4.4.2.3}

2.6 The risks to human societies through impacts on health, livelihood, food, and water security, human security, and infrastructure are higher with 1.5°C global warming compared to today, and higher still with 2°C global warming compared to 1.5°C. These risks are greatest for people facing multiple forms of poverty, inequality, and marginalisation; people in coastal communities and those dependent on agriculture; poor urban residents; and communities displaced from their homes. {3.4.6.2, 3.4.6.5, 3.4.7.2, 3.4.7.3, 3.4.4.2.3, 3.4.9.25.2.13.4.10.1, 3.4.10.2, 3.5.5.4, 3.5.5.5, Box 3.2, Box 3.3, Box 3.7, 5.2.2, 5.2.3, 5.6.3}

- Impacts of 1.5°C global warming will disproportionately affect already disadvantaged and vulnerable populations, particularly indigenous people and systems in the Arctic, agriculture- and coastal-dependent livelihoods, and small-island developing states. More severe impacts are expected where global temperature exceeds 1.5°C (*medium evidence*, *high agreement*). Limits to adaptation and associated losses exist at every level of temperature increase *(medium confidence)*, with place-specific implications, for example for Pacific Small Island Developing States (Figure SPM3) {5.2.1, 5.2.2, 5.2.3, 5.6.3}

- Globally, the poorest people are projected to experience the impacts of 1.5°C global warming predominantly through increased food prices, food insecurity and hunger, income losses, lost livelihood opportunities, adverse health impacts and population displacements. Such impacts can occur, for instance, from increased heat stress and other extreme events, such as coastal flooding, with over 100 million people projected to go into poverty through impacts on agriculture and food prices (*limited evidence, medium agreement*) {3.4.10.1, 5.2.2}

- Warming of 2°C poses greater risks to human health than warming of 1.5°C, often with complex regional patterns, with a few exceptions. Warmer temperatures are *likely* to affect the transmission of infectious diseases with increases and decreases projected depending on the disease (e.g., malaria, dengue, West Nile virus, and Lyme disease), region, degree of temperature change, and also *very likely* depending on the extent and effectiveness of additional adaptation and vulnerability reduction. (Figure SPM2, SPM3) {3.4.7.2}

- Constraining global warming to 1.5°C compared to 2°C reduces stress on global water resources by an estimated 50% (relative to 1980-2009), with reduced stress particularly in the Mediterranean region {3.4.10.2, 3.5.5.5, Box 3.2}.

- Risk to crop production in the Middle-East, Sub-Saharan Africa, South East Asia, and Central and South America, is reduced when global warming is limited to 1.5°C compared to 2°C. The risk for food production and extreme poverty is significant in these regions with 1.5°C global warming. {3.4.6.2, 3.5.5.4, 3.4.6.5, 3.4.7.3}

- Increasing temperatures will directly impact climate dependent tourism markets, including sun and beach and snow sports tourism (*high confidence*). {Box 3.3, Box 3.7, 3.4.4.2.3, 3.4.9.2}

2.7 Global warming of 1.5°C implies higher risks than today for the displacement of people, conflict, and surpassing limits to adaptation, though the level of risk is lower than at 2°C global warming. {3.4.6.2, 3.4.7.1, 3.4.10, 3.4.10.1, 3.4.10.2, 5.2, 5.2.1, 5.2.2}

- Limiting global warming to 1.5°C compared to 2°C or higher levels of warming will lower the risk of extreme events and threats to food and water security and hence lessen the potential for political struggles over scarce resources, which contributes to lessening human conflict. {3.4.10}

- Global warming above 1.5°C will worsen existing inequalities and increase poverty through ill health, increased food prices and hunger, mal- and under-nutrition, the erosion of livelihoods, displacement, and potential loss of what is meaningful for people's dignity and lives. {3.4.6.2, 3.4.7.1, 3.4.10.1, 5.2.1, 5.2.2}

- Disaster-related displacement is projected to increase over the 21st century with over 90% of disaster-related displacement between 2001 to 2015 related to climate and weather events *(medium confidence)*. {3.4.10.2}

- [Place holder: adaptation and limits to adaptation, and residual risks. {CH3, CH4, 5.2}]

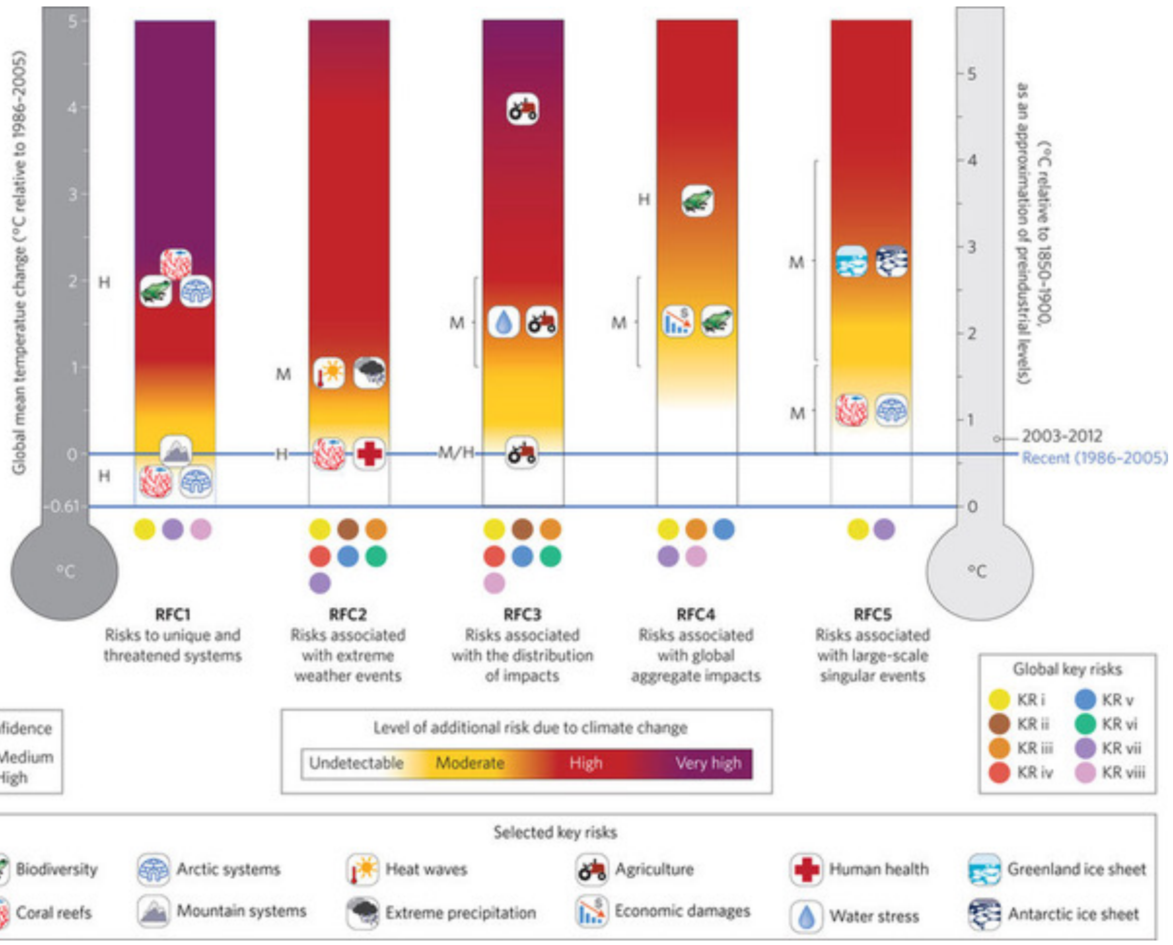

Figure SPM 2: [Placeholder] Levels of risk associated with 5 different reasons for concern are illustrated for increasing levels of global mean temperature and are the same as those presented in the IPCC AR5 Working Group II report. Icons indicate selected risks that played an important role in locating transitions between levels of risks. Coloured dots indicate overarching key risk categories that were considered in the assessment for each reason for concern (RFC)[4]. Confidence in the judgments of risk transitions is indicated as medium (M) or high (H) and the range over which transitions take place is indicated with brackets. For example, for RFC1 there is *high confidence* in the location of the transition from Undetectable to Moderate risk, which is informed by impacts to coral reef, Arctic and mountain systems; and there is *high confidence* in the location of the transition from High to Very High risk, which is informed by impacts to coral reef and Arctic systems as well as to species associated with unique and threatened systems. This assessment takes autonomous adaptation into account, as well as limits to adaptation (RFC 1, 3, 5) independently of development pathway. [To be updated and developed to highlight more clearly the recent literature on the differences between risks for 1.5°C/2°C warming].

[4] Key risk categories (O'Neill et al., 2017): (i) Risk of death, injury, ill-health, or disrupted livelihoods in low-lying coastal zones and small island developing states and other small islands due to storm surges, coastal flooding, and sea-level rise. (ii) Risk of severe ill-health and disrupted livelihoods for large urban populations due to inland flooding in some regions. (iii) Systemic risks due to extreme weather events leading to breakdown of infrastructure networks and critical services such as electricity, water supply, and health and emergency services. (iv) Risk of mortality and morbidity during periods of extreme heat, particularly for vulnerable urban populations and those working outdoors in urban or rural areas. (v) Risk of food insecurity and the breakdown of food systems linked to warming, drought, flooding, and precipitation variability and extremes, particularly for poorer populations in urban and rural settings. (vi) Risk of loss of rural livelihoods and income due to insufficient access to drinking and irrigation water and reduced agricultural productivity, particularly for farmers and pastoralists with minimal capital in semi-arid regions. (vii) Risk of loss of marine and coastal ecosystems, biodiversity, and the ecosystem goods, functions, and services they provide for coastal livelihoods, especially for fishing communities in the tropics and the Arctic. (viii) Risk of loss of terrestrial and inland water ecosystems, biodiversity, and the ecosystem goods, functions, and services they provide for livelihoods.

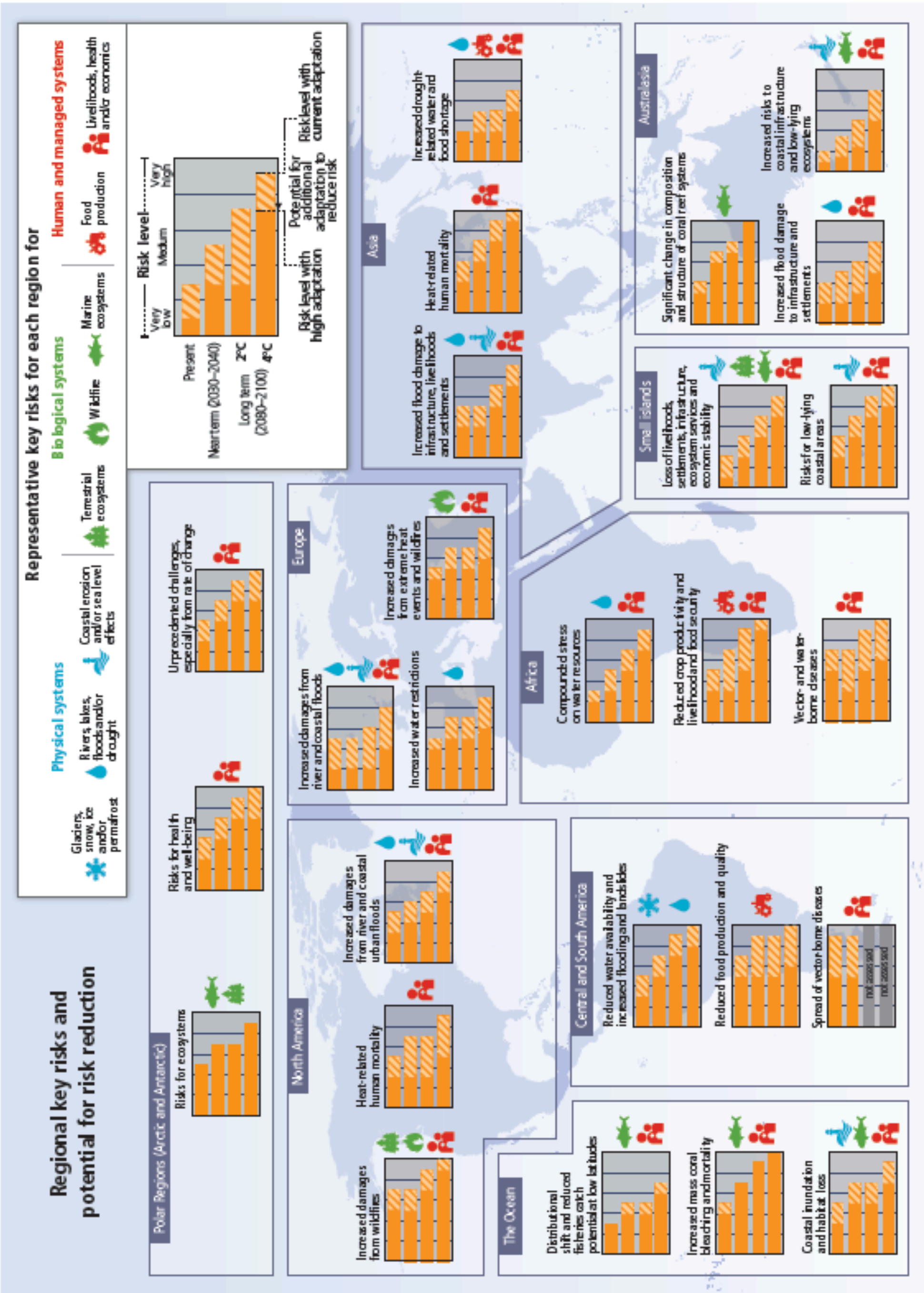

Figure SPM 3: [Place holder – AR5 SYR Figure SPM.8 and caption] Representative key risks for each region, including the potential for risk reduction through adaptation and mitigation, as well as limits to adaptation. Each key risk is assessed as very low, low, medium, high or very high. Risk levels are presented for three time frames: present, near term (here, for 2030–2040) and long term (here, for 2080–2100). In the near term, projected levels of global mean temperature increase do not diverge substantially across different emission scenarios. For the long term, risk levels are presented for 2°C global temperature increase above pre-industrial levels. For each timeframe, risk levels are indicated for a continuation of current adaptation and assuming high levels of current or future adaptation. Risk levels are not necessarily comparable, especially across regions. Identification of key risks was based on expert judgment using the following specific criteria: large magnitude, high probability or irreversibility of impacts; timing of impacts; persistent vulnerability or exposure contributing to risks; or limited potential to reduce risks through adaptation or mitigation. [To be adapted according to Chapter 3 outcomes. Risk assessment for +4°C to be dropped.]

SPM 3 Emission pathways and policy responses compatible with 1.5°C global warming

3.1 The assessed literature identifies potential emission pathways consistent with limiting global warming to 1.5°C. Some pathways hold warming below 1.5°C throughout the 21st century while in others global warming overshoots 1.5°C before returning to 1.5°C by 2100. {1.2.2, 2.1.3, 2.2.2, 2.3.2, 2.3.4, 2.2.5, 2.5.1, 2.5.2, 2.6.2, 4.3.8, Cross-Chapter Box 4.1}

- Limiting global mean warming to 1.5°C would require rapid and deep reductions in greenhouse gas emissions, even with a temporary overshoot and later return to 1.5°C. The Nationally Determined Contributions (NDCs) submitted under the Paris Agreement will result, in aggregate, in global greenhouse emissions in 2030 which are higher than those in scenarios compatible with global warming of 1.5°C by 2100 *(high confidence)*.

- Because of the cumulative impact of CO_2 emissions, any delay in emission reductions (including the delay implied by the post-2020 start date of the NDCs) significantly increases the risk associated with a temperature overshoot and would require faster subsequent emissions reductions and/or more CO_2 removal. CO_2 removal can accelerate the decline of CO_2 emissions to help avoid a temperature overshoot, and in scenarios where a temperature overshoot occurs, active net CO_2 removal is required to achieve a global mean temperature of 1.5°C by the end of the 21st century *(high confidence)*. {1.2.2, 2.3.1, 2.3.4, 2.2.5, 4.3.8, Cross-Chapter Box 4.1}

- Based on integrated assessment models, historical emissions, current policies and patterns of investment have already placed scenarios limiting warming below 1.5°C without overshoot with at least 66% likelihood out of reach. *(medium confidence)*. {2.1.3, 2.3.2, 2.5.1, 2.5.2}

- Uncertainties remain in radiative forcings and Earth system feedbacks. For a given emission scenario, these uncertainties increase the risk of global warming exceeding 1.5°C *(medium confidence)*. {2.2.2, 2.6.2}

3.2 Cumulative future CO_2 emissions compatible with avoiding a given level of global warming are often referred to as carbon budgets. Carbon budgets depend on the likelihood of avoiding a given level of global warming. They also account for changes in non-CO_2 climate forcers, such as methane and aerosols. Carbon budgets may refer to cumulative emissions from 2016 until peak warming or until warming returns to 1.5°C after a temporary overshoot. {2.1.3, 2.2.1, 2.2.2, 2.3.1, 2.4.2, 2.5.1, 2.6.1, 2.6.2}

- Two types of carbon budgets are used in this assessment. The threshold peak budget is defined as the cumulative CO_2 emissions from 1 January 2016 until the time that the global mean temperature peaks at (or below) 1.5°C or 2°C. The threshold return budget is defined as the cumulative CO_2 emissions from 1 January 2016 until the time that global mean temperature returns to 1.5°C or 2°C after a temperature overshoot. Both types of carbon budget account for non-CO_2 climate drivers (Table SPM1, Figure SPM4). {2.1.3, 2.2.1, 2.6.1, 2.6.2}

- The threshold peak budget compatible with a 50% likelihood of limiting warming to 1.5°C without overshoot is estimated to be 580 (490-640) $GtCO_2$ (Table SPM1). This budget would be exhausted in 12-16 years if emissions were to continue at 2015 levels, and thus it would be impossible, at that point, to limit global warming to 1.5°C without overshoot. {2.2.2}

- The expected magnitude of future warming from non-CO_2 drivers depends on the emission pathway. In the 5% of emission pathways that experience the greatest warming due to non-CO2 drivers, there is a 3% chance that the 1.5°C threshold peak budget is already exhausted and a 25% chance that the threshold return budget is already exhausted. The likelihood that the threshold return budget is exhausted is reduced to less than 1% in scenarios with the most ambitious mitigation pathways for non-CO_2 warming agents *(medium confidence)*. (Figure SPM3, SPM4) {2.2.2, 2.3.1, 2.4.2, 2.5.1}

- If emissions of non-CO_2 climate drivers are not significantly reduced, there is a higher than 66% likelihood that global temperature will exceed 1.5°C, even with the most stringent CO_2 mitigation considered in 1.5°C scenarios *(medium confidence)*. {2.2.2, 2.3.1, 2.4.2, 2.5.1}

	Likelihood of limiting warming	**Threshold Return Budgets $GtCO_2$**	**Threshold Peak Budgets $GtCO_2$**
Limiting warming to 1.5°C	50% likelihood	590 (420–880)	580 (490–640)
	66% likelihood	390 (200–730)	*Not Available*
Limiting warming to 2°C	50% likelihood	960 (570–1460)	1450 (1330–1550)
	66% likelihood	910 (570–1210)	1180 (1050–1380)

Table SPM 1: Two types of remaining carbon budgets based on available scenarios and compatible with different likelihoods of limiting warming to 1.5°C or 2°C. Median and likely range due to geophysical uncertainty (around median non-CO_2 contribution) of Threshold Peak Budget (*medium confidence*) and Threshold Return Budget (*medium confidence*) in $GtCO_2$ compatible with 1.5°C or 2°C for the 1st January 2016 onwards[5]. {Table 2.4}.

[5] Budgets are computed assuming that warming is limited to 1.5°C with either 50% likelihood or 66% likelihood and accounting for non-CO_2 drivers. Budget ranges are based on available scenarios and span physical uncertainty arund the median achievement of non-CO_2 emission reductions.

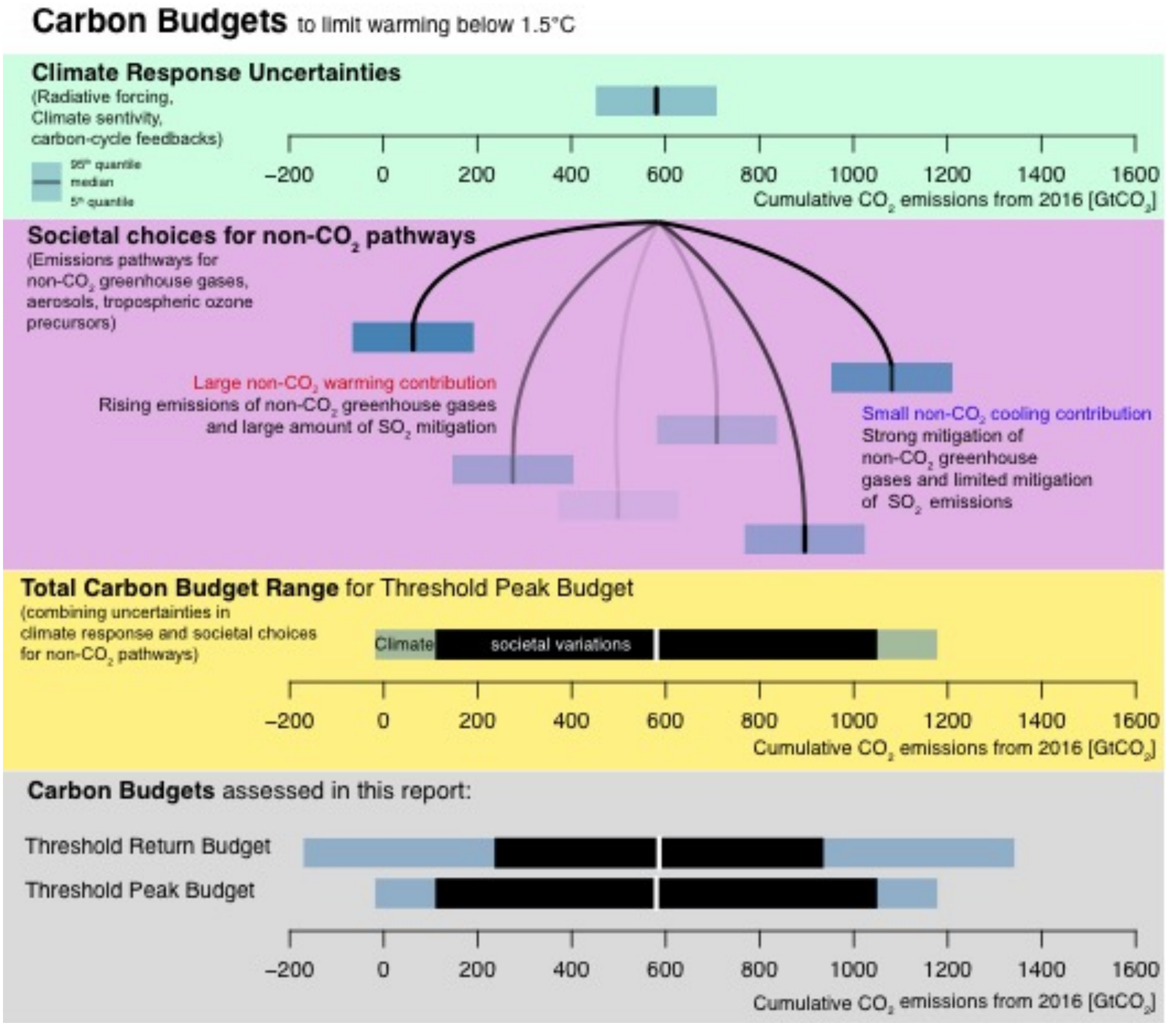

Figure SPM 4: Summary of the various uncertainties affecting carbon budget size for holding warming below 1.5°C relative to preindustrial levels from the 1st January 2016 onwards. For threshold peak budget best estimate of 580 $GtCO_2$ as given in Table SPM 1, the climate response uncertainties associated to this budget are represented by the 5%-95% confidence interval inferred from outcomes due to variation of geophysical parameters in the simple climate model setup used for this assessment. Uncertainties in climate response include those associated to radiative forcing, climate sensitivity, and carbon-cycle feedbacks. Societal choices influencing the carbon budget size are related to societal variations for non-CO_2 forcing which are illustrated by the full range of forcing futures found in the integrated pathways available in the SR1.5 scenarios database. A "large non-CO_2 warming contribution" represents 0.85 W m^{-2} of non-CO_2 radiative forcing at the time of deriving the carbon budget, a "small non- CO_2 cooling contribution" represents -0.02 W m^{-2} of non-CO_2 radiative forcing. The median non- CO_2 radiative forcing estimate across all available pathways is 0.45 W m^{-2} of non-CO_2 radiative forcing. The total carbon budget range provides an overview of the combined uncertainties in threshold peak budget due to the aforementioned factors. Median threshold peak budgets and threshold return budgets as given in Table SPM 1 are indicated by the vertical bold white line in the bottom panel.

3.3 All emission pathways compatible with a 50% or higher likelihood of limiting global warming to 1.5°C by 2100 imply rapid reductions in global CO_2 emissions, reaching net zero around or shortly after the middle of the 21st century. Such pathways also imply stringent reductions in non-CO_2 climate forcers, primarily methane, black carbon and hydrofluorocarbons. {1.3, 1.2, 2.2.2, 2.4.1, 2.3.1, 2.3.4. 2.5.3}

- 1.5°C scenarios involve deep reductions in global CO_2 emissions and must reach net zero before global warming reaches 1.5°C. They also involve deep reductions in non-CO2 drivers. *(high confidence)*. {1.3, 1.2, 2.2.2, Table 2.7, 2.4.1, 2.3.1, 2.3.4. 2.5.3}

- Because of the cumulative impact of global CO_2 emissions, any initial delay in emission reductions requires faster subsequent reductions to meet the same temperature ambition, or subsequent active net CO_2 removal to reduce temperatures following a temperature overshoot. {1.2}

3.4 All 1.5°C emission pathways involve rapid and extensive transitions in energy systems, urban systems, and patterns of land use. More extensive and rapid transitions in these systems would lower the requirement for CO_2 removal in the second half of the 21st century. {2.1.3, 2.3.1, 2.3.2, 2.3.4, 2.4.1, 2.4.2, 2.4.3, 2.5.1, 2.5.2, 4.2, 4.2.2, 2.3.4, 4.4}

- Modelled pathways for remaining below 1.5°C require rapid rates of change in emissions. Historically, rapid rates of change have been observed temporarily and in some sectors, for example, electricity supply. There is, however, no documented precedent for the geographical and economic scale of the energy, land, urban and industrial transitions implicit in pathways consistent with a 1.5°C warmer world has no documented historic precedents. Such transitions require more planning, coordination and disruptive innovation across actors and scales of governance than the spontaneous or coincidental changes observed in the past (*medium agreement, medium evidence*). {4.2, 4.2.2, 4.4}

- In 1.5°C scenarios, mitigation options are deployed more rapidly, at greater scale, and with a more complete portfolio of possible mitigation options deployed than in 2°C scenarios. {2.3.4, 2.4.1, 2.4.2, 2.4.3}

- Delayed action or weak near-term policies increase the likelihood of exceeding the 1.5°C target and the amount of stranded investment in fossil-based capacity, leading to higher long-term mitigation challenges *(high confidence)*. {2.1.3, 2.3.2, 2.5.1, 2.5.2}.

- In 1.5°C pathways rapid and extensive mitigation as well as CO_2 removal occur simultaneously. Such pathways generally rely more heavily on additional mitigation measures than they do CO_2 removal. Compared to 2°C pathways, additional mitigation measures account for around two thirds of the ~600 $GtCO_2$ of CO_2 reductions by the end of the century, and CO_2 removal for the remaining third (~180 $GtCO_2$ for the median). {2.3.1, 2.3.4}

3.5 All mitigation pathways compatible with limiting global warming to 1.5°C by 2100 involve removal of CO_2 from the atmosphere. Scenarios with high overshoots, where global warming may reach up to 1.9°C before returning to 1.5°C by 2100, involve more CO_2 removal than scenarios that keep overshoot as low as possible. There is a high chance that the levels of CO_2 removal implied in the scenarios might not be feasible due the required scale and speed of deployment required and trade-offs with sustainable development objectives. {2.2.2, 2.4.1, 2.3.1, 2.3.3, 2.3.4. 2.4.2, 2.4.4, 2.5.3, 2.6.4, 4.3.8}

- All the 1.5°C pathways analysed use CO_2 removal in some form to compensate for emissions from sectors for which no mitigation measures have been identified. {2.2.2, Table 2.7, 2.4.1, 2.3.1, 2.3.4. 2.5.3}

- The total amount of CO_2 removal projected in 1.5°C pathways in the literature is of the order of 380-1130 $GtCO_2$ over the 21st century. 25-85% of this CO_2 removal is used to compensate for emissions for which no mitigation measures have been identified, while the remainder is used after carbon neutrality has been achieved to compensate for exceeding the carbon budget prior to that point *(medium confidence)*. {2.3.1, 2.6.4}

- The required scale of CO_2 removal depends on emissions reductions in the coming decades and the degree by which they exceed the 1.5°C carbon budget. {2.3.1}

- Biomass demand is substantial in all 1.5°C pathways due to its multiple energy uses and CO_2 removal potential. The future availability of, and demand for, biomass is closely linked to land use transitions and transitions in other sectors.

- All 1.5°C pathways include the option of CO_2 removal measures such as afforestation and/or biomass energy with carbon capture and storage (BECCS). Other options, such as direct air capture and storage, are in early stages of development or need significant upgrading to be effective mitigation options and are not typically included in current scenarios. BECCS is deployed as early as 2020 in some scenarios but is not deployed at all in others. Both BECCS and afforestation have implications for how land is used to produce biomass through the growth of trees and energy crops or to store CO_2 in vegetation and soil *(high confidence)*. {2.3.3, 2.4.2, 2.4.4, 2.5.3, 4.3.8}

- Measures that lead to a net removal of CO_2 from the atmosphere are affected by multiple feasibility constraints. For example, increased biomass production and use has the potential to increase pressure on land and water resources, food production, biodiversity, and to affect air-quality. Therefore, the scale and speed of implementation assumed in some 1.5°C pathways may be challenging (*high agreement*). {2.3.3, 2.4.2, 2.4.4, 2.5.3, 4.3.8}

3.6 Some patterns of development, for example those that involve high population growth, slow economic development, and limited capacity to transform energy, urban and land use systems, increase the chance that holding global warming to 1.5°C by 2100 is beyond reach, causing associated risks. The extent and speed of required mitigation efforts are related to the underlying pace and nature of development, political will, behaviour and lifestyle. {2.3.1, 2.3.4, 2.4.1, 2.4.2, 2.4.3, 2.3.5, 2.5, 2.5.1, 2.5.2, 4.4.1, 4.4.4.3, 4.4.5, 5.4, 5.6}

- The transformations necessary to limit warming to 1.5°C are qualitatively similar to those for a 2°C limit, but more pronounced and rapid over the next decades *(high confidence)*. Limiting global warming to 1.5°C rather than 2°C implies a more complete portfolio of mitigation measures, faster socio-technical transitions, and more ambitious international policies in the short term that target both supply and demand *(very high confidence)*. Such transformations would involve rapid and large scale behaviour and lifestyle change *(very high confidence)*. {2.3.1, 2.3.4, 2.4.1, 2.4.2, 2.4.3, 2.3.5, 2.5, 2.5.1, 2.5.2, 4.4.1, 4.4.4.3, 4.4.5}

- Sustainable development, the Sustainable Development Goals and well-being for all will be difficult to achieve without sufficient consideration of the equity and ethics of such rapid and deep transformations, as well as their social and political feasibility. {5.4, 5.6}.

3.7 Issues related to governance and ethics, public acceptability and impacts on sustainable development could render solar radiation management economically, socially and institutionally infeasible. {4.3.9, 4.4.1, 4.4.4, 4.4.5, Cross-Chapter Box 4.2}

- While none of the pathways assessed in the Special Report include solar radiation management, solar radiation management has been considered in the context of reducing temperature-related impacts of global warming, while other impacts, such as those related to ocean acidification, would largely remain unaffected. Even in the uncertain case that some of the adverse side effects of solar radiation management could be avoided, multi-level governance issues, ethical implications, public resistance and impacts on sustainable development could render solar radiation management economically, socially and institutionally infeasible. {4.4.1, 4.4.4, 4.4.5}

- Uncertainties related to solar radiation management include technological maturity, physical understanding, efficiency to limit global warming, and the ability to scale, govern and legitimise their potential implementation. (*low agreement, medium evidence*). {4.3.9, Cross-Chapter Box 4.2}

SPM 4 Strengthening the global response in the context of sustainable development and efforts to eradicate poverty

4.1 There is very high likelihood that under current emission trajectories and current national pledges the Earth will warm globally more than 1.5°C above preindustrial levels, causing associated risks. The nationally determined contributions submitted under the Paris Agreement will result, in aggregate, in global greenhouse emissions in 2030 which are higher than those in scenarios compatible with limiting global warming to 1.5°C by 2100. More ambitious pledges would imply higher mitigation costs in the short-term, albeit offset by a variety of co-benefits, but would lower both mitigation and adaptation costs in the long-term. {2.3.1, 2.3.1.1, 2.3.5, 2.5.1, 2.5.2, 4.2.1, 4.4, 4.4.1, 4.4.2, 4.4.6, Cross-Chapter Box 4.1, 5.4.2}

- Following current nationally determined contribution pledges, no scenario can be produced that allows for the interactions between the energy, economic, and land-use systems that would be required to limit global warming to below 1.5°C. {2.3.1.1, 2.3.5, Table 2.7, Cross-Chapter Box 4.1}

- There is very high likelihood that under current emission trajectories and current national pledges until 2030, global warming will reach 1.5°C above preindustrial levels by mid-century and remain above that level even in 2100, causing associated risks *(high confidence)*. {1.2.6, 2.3.1, 2.3.5, 2.5.1}

- The transition and adaptation to a world in which global warming is limited to 1.5°C can only be realized by upscaling and accelerating the implementation of rapid, far-reaching, multi-level and cross-sectoral climate mitigation and adaptation actions, integrated with sustainable development initiatives (*high agreement, medium evidence*) (Box SPM 2). {Cross-Chapter Box 4.1, 4.2.1, 4.4}

- Delaying actions to reduce greenhouse gas emissions increases the risk of cost escalation, stranded assets, job losses, and reduced flexibility in future response options in the medium to long-term. These may increase uneven distributional impacts between countries at different stages of development (*medium evidence, high agreement*). {5.4.2}

- To strengthen implementation of the global response, all countries would need to significantly raise their level of ambition, shift financial flows and investment patterns, improve coherence in governance, address equity across and between generations and regions, and strengthen capacities, including traditional knowledge. (*medium agreement, high evidence*). {2.5.2, 4.4.1; 4.4.2, 4.4.6}

4.2 Energy transitions in pathways compatible with limiting global warming to 1.5°C by 2100 involve end-use efficiency improvements, reductions in energy demand, a rapidly growing share of renewable energy and other low carbon energy supplies, and electrification of end-use. These changes also occur in 2°C scenarios, but each element of the energy transition occurs more rapidly and at a greater scale in 1.5°C scenarios. **{2.3.3, 2.3.4, 2.4, 2.5.1, 2.5.2, 4.3.2, 4.3.5, 4.3.2, 2.4.3, 4.4.3, 4.4.5, 5.4.1, 5.4.3, 5.4.2}**

- Energy transitions are currently taking place in many sectors and regions around the world, but at a slower pace in energy-intensive industry and international transport (*high agreement, medium evidence*). {4.3.2, 4.3.5, 4.3.2}

- Final energy demand in 2100 is generally 20-60% higher relative to 2014 levels across available 1.5°C scenarios. However, energy demand lower than present day, together with strong growth in economic output until the end of the century, is found in scenarios with shifts to more sustainable energy, material and food consumption patterns. {2.4.3, 4.4.5, 4.4.3}

- Large reductions of per capita energy demand in areas with high consumption are critical elements of 1.5°C scenarios. These are accompanied by increased efficiency in end uses (e.g. appliances, industrial processes, insulation, lighter vehicles, etc.) and often by substantial decreases in per capita livestock demand, demand for private vehicle transportation, food waste and deforestation. *(medium confidence)*. {2.3.4, 2.4}

- 1.5°C scenarios include rapid electrification of energy end use (about two thirds of final energy by 2100), and rapid decreases in the carbon intensity of electricity and of remaining fossil fuel use *(high confidence)*. The electricity sector is fully decarbonized by mid-century in both 1.5°C and 2°C pathways. Additional emissions reductions compared to 2°C pathways come predominantly from energy end use sectors (transport, buildings, industry). {2.3.3}

- The share of primary energy from renewables increases rapidly in most 1.5°C pathways, with renewables becoming the dominant source by 2050. Low-carbon energy, which includes renewable energy, sustainable biomass and nuclear, supplies on average about one third (15-87% full scenario range) of primary energy in 2030 and on average about two thirds (36-97% range) in 2050.

- Coal use would be phased out rapidly in most 1.5°C pathways with annual reduction rates of 4-5%. In pathways where coal use is not entirely phased out by 2050, it is combined with carbon capture and storage and there is virtually no unabated coal use. Most 1.5°C pathways indicate slowly declining use of oil, and a wide range of natural gas use with varying levels of carbon capture and storage.

- A broad portfolio of different mitigation policy options, including carbon pricing mechanisms and regulation, would be necessary in 1.5°C pathways to achieve the most cost-effective emissions reductions *(high confidence)*. Reduction in energy demand can also be achieved through behaviour change. Discounted carbon prices for limiting warming to 1.5°C are three to seven times higher compared to 2°C, depending on models and socioeconomic assumptions *(medium confidence)*. {2.5.1, 2.5.2, 4.4.5, 4.4.3}

- The choice of the portfolio of mitigation options and the policy instruments that are used for implementation will largely determine the overall synergies and trade-offs of 1.5°C mitigation pathways for sustainable development *(very high confidence)* (Figure SPM5) {5.4.1,5.4.3, Figure 5.4.1, 5.4.2}.

Sector	**Changes by 2050 compared to 2010 in Chapter 2**	**Decreased energy use compared to the reference scenario**	**Decreased energy use compared to a 2ºC pathway**
Transport	[22%] increase in final energy use [36%] share of low-emission energy (electricity, hydrogen, biofuels)	[39%]	[17%]
Buildings	[20%] reduction in final direct energy use [60% electrification	[22%]	[8%]
Industry	[16%] increase in final energy use [86%] reduction coal use [36%] electrification 0.8-1.8 $GtCO_2$ avoided yr^{-1} by CCS (median: 1.5)	[28%]	[20%]
Electricity	Almost zero-emission by 2050 (some coal/gas with CCS still allowed)	Not Available	Not Available

Note: Sectoral changes are based on the median across the range of assessed pathways

Table SPM 2: [Place holder] Sectoral changes by 2050 consistent with 1.5ºC pathways based on section 2.4. Increasing energy use in end-use sectors is due to higher activity levels. The columns "Decreased energy used compared to REF" and "Decreased energy use compared to a 2ºC pathway" indicate that considerable cuts in energy use would be made compared to the reference scenario and to a 2ºC scenario. {Table 4.1}

4.3 Pathways compatible with limiting global warming to 1.5°C by 2100 involve land transitions that imply increasing use of land for sustainable bioenergy production and carbon storage. There is also a need for large volumes of sub-surface carbon storage. Land use mitigation and adaptation options are interlinked with regional climate, food systems, dietary patterns, forest management, regional climate, biodiversity, ecosystems service provision and the Sustainable Development Goals. {Chapter 3, 3.7.2.1, 4.3.3, 4.3.6, 4.3.8, 4.4.3, 4.4.5, 4.5.3, 5.4.1.2, 5.4.1.5}

- Global and regional land-use and ecosystem transitions in 1.5°C pathways lead to impacts on agricultural and natural resource-dependent livelihoods *(medium agreement, medium evidence)*. If not managed carefully, significant changes in agriculture and forest systems risk weakening ecosystem health, leading to food, water and livelihood security challenges, reducing social and environmental feasibility of land-use related mitigation options. {Chapter 3, 4.3.3, 4.3.8, 4.5.3}

- Land use is an important driver of regional climate. Biophysical climate feedbacks of land use change are not considered in the development of the socio-economic pathways. {3.7.2.1}

- Agriculture, forestry and other land use mitigation options that take into account local people´s needs, biodiversity and other sustainable development concerns provide large synergies with Sustainable Development Goals particularly within rural areas of developing countries (*high confidence*). {5.4.1.2, 5.4.1.5}

- Changing agricultural practices using principles of conservation agriculture, efficient irrigation, and mixed crop-livestock systems are effective adaptation strategies. Behavioural change around diets would reduce emissions and pressure on land. {4.3.3, 4.4.3, 4.4.5, 4.5.3}

- Several overarching adaptation options that are closely linked to sustainable development can be implemented across rural landscapes, such as investing in health, social safety nets, and insurance for risk management, or disaster risk management and education-based adaptation options. {4.3.6, 4.5.3}

4.4 Limiting global warming of 1.5°C implies the need for transformational adaptation and mitigation, behaviour change, and multi-level governance. The implementation of far reaching measures is limited by institutional and innovation capabilities. {1.4, 2.3.4, 2.4, 2.5.1, 2.5.2, 4.4.1, 4.4.2, 4.4.3, 4.4.4, 4.4.5, 4.5.4, 5.4.1, 5.4.1.3, 5.6.4}

- The feasibility of limiting warming to 1.5°C in this report is addressed by considering the capacity to achieve a specific goal or target, requiring the integration of natural system considerations into the human system scenarios, the placement of technical transformations into their political, social, and institutional context. {4.5.4}

- Public and formal institutional and innovation capabilities are a limiting factor almost everywhere around the world, particularly in Least Developed Countries and and among populations facing multidimensional poverty, persistent inequalities, and high vulnerabilities. This results in a scarcity of the critical mass of actors needed for the implementation of far reaching measures (*high agreement, medium evidence*). {4.4.1, 4.4.2, 4.4.4, case studies in 4.4, 5.6.4}

- Economies dependent upon fossil fuel-based energy generation and/or export revenue will be affected by the reduced use of fossil fuels necessary to meet ambitious climate goals, despite multiple other sustainable development benefits. There is a need for supplementary policies, including retraining, to ease job losses and the effects of higher energy prices, when they occur, particularly in developing countries where the workforce is largely semi- or unskilled (*very high confidence*) {5.4.1.3}.

- A broad portfolio of different mitigation policy options, including carbon pricing mechanisms and regulation, information provision and technological and infrastructural changes are necessary in 1.5°C pathways to achieve the most cost-effective emissions reductions *(high confidence)*. {2.5.1, 2.5.2, 4.4.1, 4.4.3, 4.4.5}

- Packages of policy instruments targeting key factors enabling and promoting change, working across governance levels and promoting innovation, are needed to implement a rapid and far-reaching response *(medium agreement, medium evidence)*. Policy instruments, both price and non-price, are needed to accelerate the deployment of carbon-neutral technologies. Evidence and theory suggests that some form of carbon pricing can be necessary but insufficient in isolation *(medium agreement)*. {2.5.1, 2.5.2, 4.4.3, 4.4.4, 4.4.5}

- Transitioning from climate change mitigation and adaptation planning to practical implementation is a major challenge in constraining global temperature to 1.5°C. Barriers include finance, information, technology, public attitudes, special interests, political will, social values and practices and human resource constraints plus institutional capacity to strategically deploy available knowledge and resources. {1.4, 4.4.1, 4.4.3}

- Policy and finance actors may find their actions to limit warming to below 1.5°C more cost-effective and acceptable if multiple factors affecting behaviour are considered (*high agreement, medium evidence*). Behaviour- and lifestyle-related measures have led to limited emission reductions and have promoted effective adaptation behaviour around the world *(high confidence)*. {2.3.4, 2.4, 4.4.1, 4.4.3, Figure 4.4}

- Mitigation actions in the energy demand sectors and behavioural response options with appropriate management of rebound effects can advance multiple Sustainable Development Goals simultaneously, more so than energy supply side mitigation actions *(very high confidence)*. (Figure SPM5) {5.4.1, Table 5.1 a-c, Figure 5.4.1}

- Multi-level governance in a 1.5°C warmer world can create an enabling environment for mitigation and adaptation options, behavioural change, policy instruments and innovation, and be aligned with the political economy of both adaptation and mitigation (*medium agreement, medium evidence*). However, power asymmetries undermine the rights, values, and priorities of disadvantaged populations in decision making *(high confidence)*. {4.4, 4.4.1, 5.5, 5.6}

4.5 Pathways that are consistent with limiting global warming to 1.5°C target energy efficiency and demand provide strong synergies between sustainable development and mitigation actions. These actions can bring high synergies for water and air quality, public health, and terrestrial and marine ecosystems. The risks for poverty, hunger and energy access of mitigation measures can be alleviated by redistributive measures. {2.3, 2.5, 4.3.7, Boxes 4.1, 4.2 and 4.3, 5.4.1, 5.4.1.3, 5.4.1.4, 5.4.1.5, 5.4.2, 5.4.2.2, 5.4.3}

- Mitigation options that emerge from cross-sectoral efforts at city scale show enhanced synergies with Sustainable Development Goal, as well as those emerging from new sectoral organisations based on the circular economy concept such as zero waste, decarbonisation and dematerialisation, and multi-policy interventions following systemic approaches *(medium evidence, high agreement)*. {Boxes 4.1, 4.2 and 4.3, 5.4.1.4}.

- Pathways limiting global warming to 1.5°C with options to reduce short-lived climate forcers, such as methane, black carbon and short-lived hydrofluorocarbons, have co-benefits for sustainable development in terms of health through the prevention of air pollution. However, reducing sulphates and other cooling air pollutants comes with trade-offs for reducing warming. (Figure SPM4, SPM6) {2.3, 2.5, 4.3.7, 5.4.1.5}

- Pathways limiting global warming to 1.5°C that feature very low energy demand show pronounced positive effects across multiple Sustainable Development Goals (*very high confidence*), though increased risk of sustainable development trade-offs, notably those that affect poor and indigenous populations. They assume radical socio-cultural and organizational innovation, which can create challenges for social acceptability. (Figure SPM5, Figure SPM6, Box SPM 2) {5.4.1.3, 5.4.2.2, Table 5.1}

- Policy designs and measures can reduce trade-offs between mitigation options compatible with 1.5°C warming and achieving sustainable development and the Sustainable Development Goals (*high confidence*). {5.4.1, 5.4.3, Figure 5.4.1, 5.4.2}

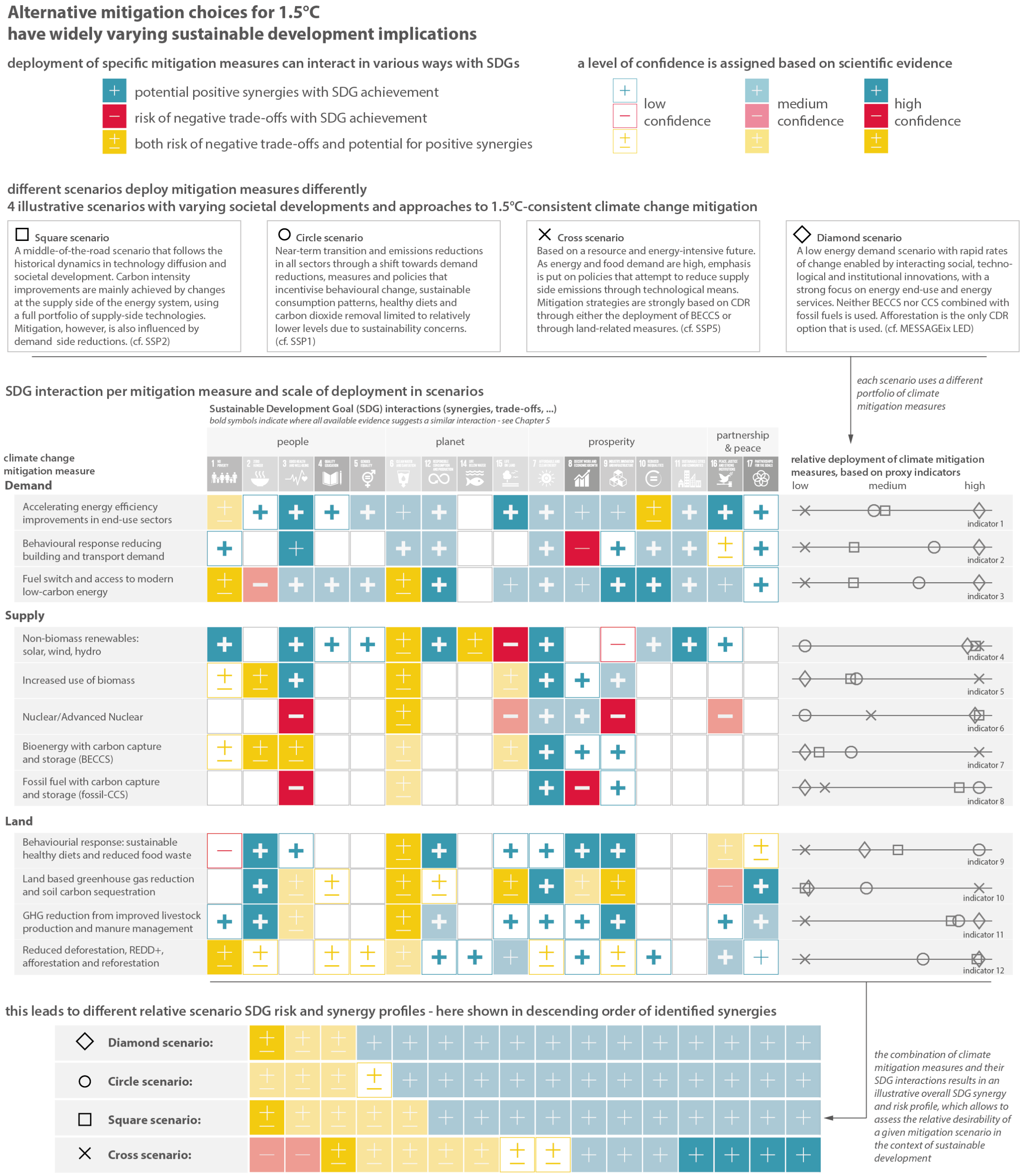

Figure SPM 5: Interactions of individual mitigation measures and alternative mitigation portfolios for 1.5°C with Sustainable Development Goals (SDGs). The assessment of interactions between mitigation measures and individual SDGs {5.4}.[6]

[6] Proxy indicators are: 1) Compound annual growth rate of primary energy (PE) to final energy (FE) conversion from 2020 to 2050; 2) % change in FE between 2010 and 2050; 3) Year-2050 carbon intensity of FE; 4) Year-2050 PE that is non-bio RE; 5) Year-2050 PE from biomass; 6) Year-2050 PE from nuclear; 7) Year-2050 $GtCO_2$ BECCS; 8) Year-2050 $GtCO_2$ Fossil-CCS; 9) Year-2050 share of non-livestock in food energy supply; 10) Cumulative CO_2 AFOLU over 2020-2100 period; 11) CH_4 and N_2O AFOLU emissions per unit of total food energy supply; 12) Change in global forest area between 2020 and 2050. Values of Indicators 2, 3, and 11 are inverse related with the deployment of the respective measures. The scenario values are displayed on a relative scale from zero to one where the lowest scenario is set to the origin and the values of the other indicators scaled so that the maximum is one.

4.6 Reducing climate vulnerability through adaptation is mostly synergistic with sustainable development, especially those associated with agriculture, health and ecosystems. Adaptation needs will be lower in a 1.5°C as compared to a 2°C warmer world, but adaptation limits are expected to be exceeded in multiple systems and regions in a 1.5°C warmer world {Chapter 3; 4.4.1, 4.4.3, 4.4.6, 4.5.1, 5.2.3, 5.3.2, 5.6.3}

- Adaptation needs will be lower in a 1.5°C as compared to a 2°C warmer world. Limits to adaptation and resulting losses to lives, livelihoods and infrastructure exist at every level of warming (*medium confidence*), with place-specific implications, for example for Small Islands Developing States. While transformational adaptation is necessary under current (~1°C) warming conditions, adaptation limits are expected to be exceeded in multiple systems and regions in a 1.5°C warmer world, putting large numbers of poor and vulnerable people, systems and regions at risk (*medium evidence)* {Chapter 3; 4.4.1, 4.4.3, 4.4.6, 4.5.1, 5.2.3, 5.6.3}

- Reducing climate vulnerability through adaptation is mostly synergistic with sustainable development in general, and the Sustainable Development Goals specifically *(high confidence)*. Some adaptation strategies result in trade-offs and make it more difficult to meet some Sustainable Development Goals *(high confidence)*. Transformative adaptation required to achieve sustainable development in a 1.5°C warmer world needs to address the root socio-economic and cultural causes of vulnerability (*high confidence*). {5.3.2}

4.7 There is a risk from adaptation to global warming of 1.5°C being unattainable without increased finance and the active involvement of the financial sector. Adaptation measures will require more investment than today, but less than for global warming of 2°C. Financial and technological support is needed to build capacity for effective responses and climate multi-level governance in many countries. {Chapter 3, 4.4.6, 4.5.1}

- While adaptation finance has increased, weakness in distribution and monitoring mechanisms undermine their potential impact. {Chapter 3, 4.4.6, 4.5.1}

- Adaptation to global warming of 1.5°C would be unattainable without the active involvement of the financial sector, including central and multilateral banks, as front-loading of investments compared to current actions is unavoidable. This requires significant institutional capacity building at multiple levels to handle both climate and transition risks in the mainstream financial sector in all countries. (*medium agreement, medium evidence*). {4.4.6}

4.8 Adaptation and mitigation measures relating to the design and implementation of sustainable climate smart agriculture, shifts to sustainable and healthy diets, reduced food waste, and sustainable and climate smart forest management are cost-effective. In rural areas, there are large potential synergies with the Sustainable Development Goals. {4.3.3, 4.4.1, 4.4.5, 4.5.2, 4.5.3, 5.4.1.2, 5.4.1.5, 5.4.3}

- Combining adaptation and mitigation options can increase cost effectiveness, but the potential to scale up remains a challenge, for example, for agroforestry, ecosystem-based adaptation, efficient food production, afforestation and reforestation *(medium agreement)* (Box SPM 2). {4.3.3, 4.4.1, 4.5.2, 4.5.3}

- Sustainable and climate-smart land/agricultural management, the shift toward sustainable and healthy diets and reduction of food waste and climate-smart sustainable forest management provide cost-effective measures and in many cases, CO_2 removal. Their design and implementation that take into account local people´s needs, biodiversity and other sustainable development concerns provide large synergies with Sustainable Development Goals particularly within rural areas of developing countries. However, climate-smart agriculture can be biased towards technological solutions and ignore (gender) inequalities (Figure SPM7) *(high confidence)*. {5.4.1.2, 5.4.1.5}

- There are policies that can shield the poor or redistribute the burden of mitigation trade-offs related to land use e.g. cash transfers, food subsidies and improvements in yields *(high confidence)*. (Figure SPM7) {4.4.5, 5.4.3, Figure 5.4.2}

4.9 Climate-resilient development pathways aim to simultaneously meet the Sustainable Development Goals, strive for low-carbon societies, and limit global warming to 1.5°C, within the frame of equity and well-being for all. The potential for successfully pursuing such pathways depends on a country's development status and on the capacities of communities, institutions, and organisations to adapt and to mitigate, and hence differs substantially between richer and poorer nations. {1.4.1, 2.4.3, 2.5.2, 2.5.3, 4.4.1, 4.4.5, 4.5.1, 4.4.6, Box 4.6, 5.3.1, 5.4.1, 5.5.1, 5.5.2, 5.5.3, 5.5.4, 5.6.2, 5.6.3, 5.6.4}

- Scenarios show that with policies that focus on sustainable development with shifts to more sustainable energy, material and food consumption patterns, and lower energy demand could be achieved together with strong growth in economic output until the end of the century *(medium to high confidence).* (Figure SPM7) {2.4.3, 2.5.2, 2.5.3}

- The efficiency of integrated approaches between mitigation, adaptation and sustainable development approaches to deliver triple-wins depends on several enabling conditions *(medium evidence, high agreement)*. {4.4.1, 5.3.1, 5.4.1, 5.5.1, 5.5.2, 5.5.3, 5.5.4}

- Mitigation and adaptation policies each have the potential for profound implications on equity, especially if framed without considerations of the complex local-national to regional linkages and feedbacks in social-ecological systems. {1.4.1, 4.4.5}

- The impacts on equity of climate change depend upon the conditions under which limiting global warming to 1.5°C and adapting to 1.5°C can be achieved. There are three key inequalities related to equity impacts: in the contributions to the problem; in impacts and vulnerability, such that the worst impacts may fall on those that are least responsible for the problem, including future generations; and in the power to implement solutions and response strategies. {1.4.1}

- The potential for climate-resilient development pathways differs between richer and poorer nations and regions (*very high confidence*), given different levels of development as well as differential responsibilities and capacities to cut emissions, eradicate poverty, and reduce inequalities and vulnerabilities. {5.6.2, 5.6.3}

- Community-led and bottom-up approaches offer potentials for climate-resilient development pathways at scale. At level of individuals, communities, and groups, emphasis on well-being, social inclusion, equity, and human rights helps to overcome limitations in capacity *(medium evidence; high agreement)*. {Box 4.6, 4.4.1, 5.6.2; 5.6.3}

- Participatory multi-level governance and iterative social learning constitute key aspects to enable transformative social change in a 1.5°C compatible development pathway. Yet, dominant pathways and entrenched power differentials continue to undermine the rights, values, and priorities of disadvantaged populations in decision making *(high confidence)*. {4.4.1, 5.6.4}

- Very limited indicators and monitoring and evaluation systems currently exist that track multi-level progress toward equitable, fair, and socially desirable low-carbon futures (*high confidence*). {4.5.1, 5.6.4}

- Examples from around the world illustrate that 1.5°C-compatible, inclusive, prosperous and healthy societies are possible. At the same time, very few cities, regions, countries, businesses or communities are truly in line with 1.5°C. Increased ambition, connecting emission reduction options via interconnected value chains and multi-level governance, and enhanced capabilities are necessary (*medium agreement, medium evidence)*. {Case studies in 4.4, 4.4.1, 4.4.2, 4.4.6}

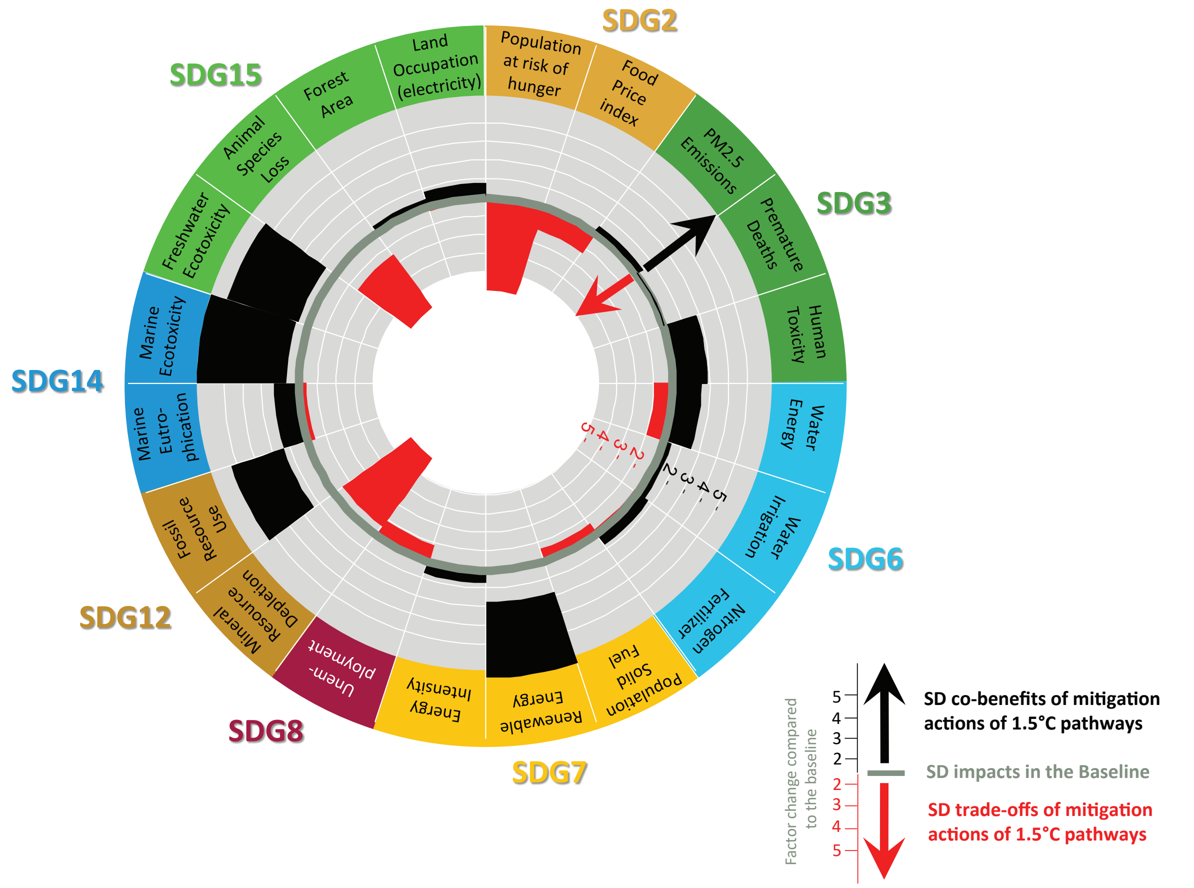

Figure SPM 6: Co-benefits (black) and risks for trade-offs (red) of mitigation consistent with limiting mean temperature to 1.5°C by 2100 assuming middle-of-the-road future socio-economic development. Co-benefits and trade-offs are measured in 2050 relative to middle-of-the-road baseline pathways without new mitigation policies (bold grey circle), and cover 21 sustainable development dimensions across seven Sustainable Development Goals (SDGs) (and selected sub-targets). Range denotes estimates across six different integrated assessment models, which were coupled to disciplinary models for the assessment of hunger, health, energy access, toxicity, and mineral resource implications of the pathways. Note that the realization of the side-effects will critically depend on local circumstances and implementation practice. Trade-offs across many SD dimensions can be eradicated through complementary/redistributional measures. Figure is not comprehensive and focuses on SD dimensions for which quantifications across models are available.

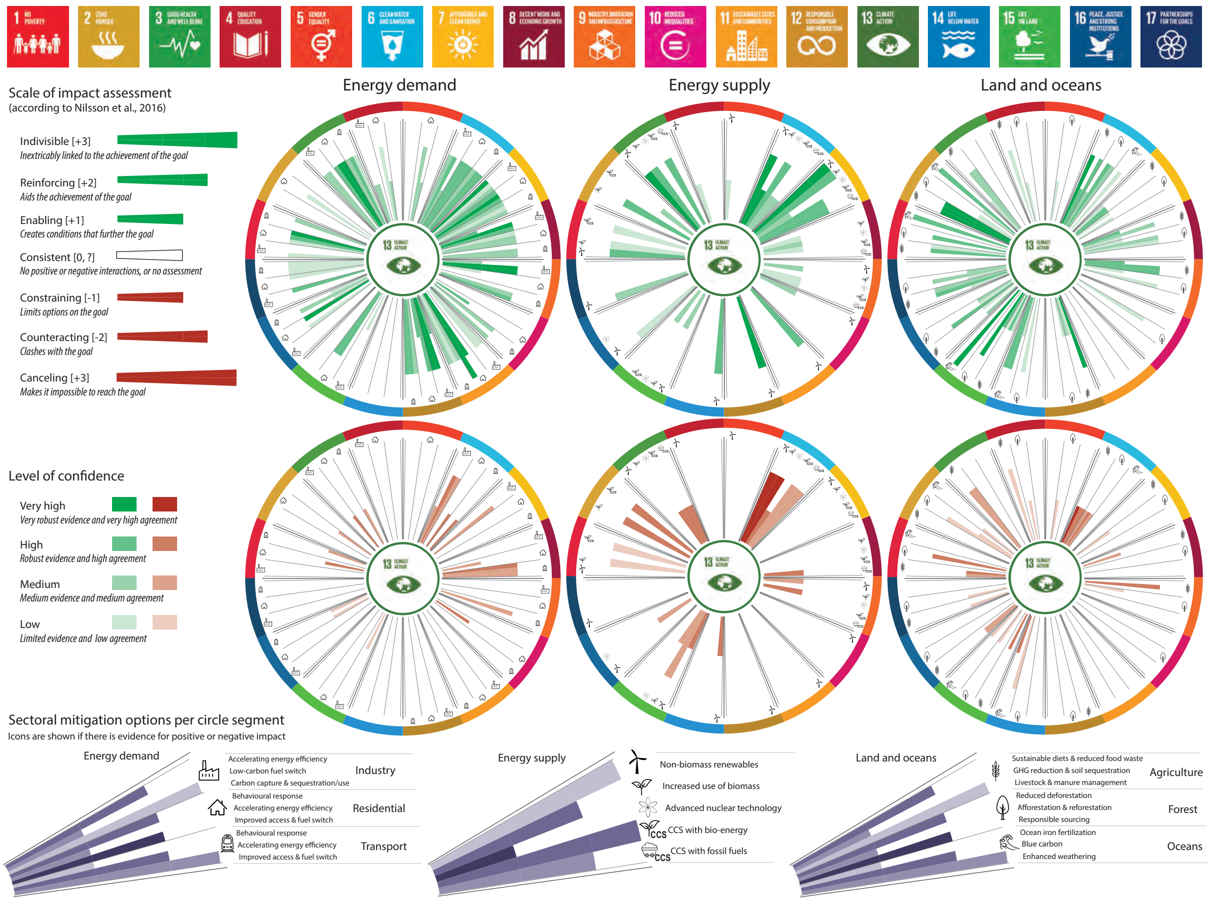

Figure SPM 7: Synergies and trade-offs between mitigation options and sustainable development goals. Top three wheels are representing synergies and bottom three wheels show trade-offs. Colours on the border of the wheels correspond to the Sustainable Development Goals (SDGs) listed above. Here SDG 13 climate action is at the centre because the figure shows if mitigation actions (climate action) in various sectors are taken then what do they interact with the 16 SDGs. Vertically, starting from the first left side, pairs of wheels correspond to synergies (Top) and trade-offs (Bottom) of three mitigation actions undertaken in each of the energy demand sectors (Industry, Residential and Transport sectors). Middle pair of wheels vertically shows the synergies (Top) and tradeoffs (Bottom) with SDGs of the five mitigation actions taken in the energy supply sector. Right most pair, shows synergies (top) and tradeoffs (bottom) with SDGs of three types of mitigation actions in each of the sectors Agriculure, Forestry and Oceans. Length of the coloured bars show the strength of the synergies or tradeoffs. Longer the bar higher is the strength. Shade of the color represent level of confidence based on evidence and agreement in the literature. Darker the shade higher is the confidence and lighter the shade confidence level is lower. White within wheels show no interaction between the corresponding mitigation action sand the SDG, grey within the wheels show knowledge gap. Bottom panel shows various mitigation actions in each sector and corresponding symbols.

Box SPM 2: Cities and global warming of 1.5°C

Box SPM 2.1 Rapid, systemic transitions in urban areas will be a critical element of an accelerated transition to a 1.5°C world. {1.1, 1.41, 4.3, 4.3.7, 5.4.1.4, Box 5.1}

- Such deep, structural changes can be enabled by a rapidly implemented, integrated mix of mitigation and adaptation measures, facilitated by local and regional governments, supported by national governments, and aligned with sustainable development. Both technological and social innovations in enabling technologies can contribute to 1.5°C pathways, including smart grids, energy storage technologies and general-purpose technologies, such as information and communication technologies and artificial intelligence. {4.3.7}

- Limiting global warming to 1.5°C is associated with an opportunity for innovative global, national and subnational governance, enhancing adaptation and mitigation within the framework of sustainable development, and linked with global scale trends including increased urbanization and decoupling of economic growth from greenhouse gas emissions. {1.1,1.4.1}

- The circular economy concept such as zero waste, decarbonisation and dematerialisation shows high synergies with sustainable development goals {Box 5.1, 5.4.1.4, 4.3}

Box SPM 2.2 Each additional level of global warming increases risks to urban areas, and future impacts will depend on vulnerabilities (location, infrastructure and levels of poverty) and adaptation capacities {3.2.1, 3.3, 3.3.2, 3.3.12, 3.4.8, Cross-Chapter Box 3.2, 4.3, 5.4.1.3, Box 5.1}

- An additional 0.5°C of warming increases risks to urban areas. For example, under a mid-range population growth scenario, more than 350 million more people would be exposed to heat stress by 2050 in mega-cities with 1.5°C of global warming. {3.2.1, 3.3, Cross-Chapter Box 3.2}

- Warming of 2°C poses greater risks to urban areas than warming of 1.5°C in most cases, often varying by vulnerability of location (coastal and non-coastal), infrastructure sectors (energy, water, transport), and by levels of poverty. {3.3.2, 3.3.12, 3.4.8}

- In 1.5°C pathways, all end-use sectors, such as the food (livestock), building, transport, and industry sector, require significant demand reductions by 2030, beyond those projected for 2°C pathways. {Box 5.1, 5.4.1.3, 4.3}

Box SPM 2.3 Combining adaptation and mitigation options can increase cost effectiveness, but the potential to scale up remains a challenge. {4.3.3; 4.3.4; 4.4.1; 4.5.2; 4.5.3}

- Examples include land-use planning, urban planning and urban design *(medium agreement)*; implementing building codes and standards to reduce energy use and manage risk *(high agreement)*. Sustainable water management (*high evidence, medium agreement*) and investing in green infrastructure (*medium evidence, high agreement*) to deliver sustainable water and environmental services and support urban agriculture are less cost effective but identified as important elements for fostering urban climate resilience. However, it is often challenging to combine governance, finance and social and policy support including alignment of the multiple objectives and timings, even if multiple benefits are achieved {4.3.3; 4.3.4; 4.4.1; 4.5.2; 4.5.3}