

SPM

Summary for Policymakers

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Introduction

This Report responds to the invitation for IPCC '... to provide a Special Report in 2018 on the impacts of global warming of 1.5°C above pre-industrial levels and related global greenhouse gas emission pathways' contained in the Decision of the 21st Conference of Parties of the United Nations Framework Convention on Climate Change to adopt the Paris Agreement.¹

The IPCC accepted the invitation in April 2016, deciding to prepare this 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.

This Summary for Policymakers (SPM) presents the key findings of the Special Report, based on the assessment of the available scientific, technical and socio-economic literature² relevant to global warming of 1.5°C and for the comparison between global warming of 1.5°C and 2°C above pre-industrial levels. The level of confidence associated with each key finding is reported using the IPCC calibrated language.³ The underlying scientific basis of each key finding is indicated by references provided to chapter elements. In the SPM, knowledge gaps are identified associated with the underlying chapters of the Report.

A. Understanding Global Warming of 1.5°C⁴

A.1 Human activities are estimated to have caused approximately 1.0°C of global warming⁵ above pre-industrial levels, with a *likely* range of 0.8°C to 1.2°C. Global warming is *likely* to reach 1.5°C between 2030 and 2052 if it continues to increase at the current rate. (*high confidence*) (Figure SPM.1) {1.2}

A.1.1 Reflecting the long-term warming trend since pre-industrial times, observed global mean surface temperature (GMST) for the decade 2006–2015 was 0.87°C (*likely* between 0.75°C and 0.99°C)⁶ higher than the average over the 1850–1900 period (*very high confidence*). Estimated anthropogenic global warming matches the level of observed warming to within ±20% (*likely range*). Estimated anthropogenic global warming is currently increasing at 0.2°C (*likely* between 0.1°C and 0.3°C) per decade due to past and ongoing emissions (*high confidence*). {1.2.1, Table 1.1, 1.2.4}

A.1.2 Warming greater than the global annual average is being experienced in many land regions and seasons, including two to three times higher in the Arctic. Warming is generally higher over land than over the ocean. (*high confidence*) {1.2.1, 1.2.2, Figure 1.1, Figure 1.3, 3.3.1, 3.3.2}

A.1.3 Trends in intensity and frequency of some climate and weather extremes have been detected over time spans during which about 0.5°C of global warming occurred (*medium confidence*). This assessment is based on several lines of evidence, including attribution studies for changes in extremes since 1950. {3.3.1, 3.3.2, 3.3.3}

¹ Decision 1/CP.21, paragraph 21.

² The assessment covers literature accepted for publication by 15 May 2018.

³ Each finding is grounded in an evaluation of underlying evidence and agreement. A level of confidence is expressed using five qualifiers: very low, low, medium, high and very high, and typeset in italics, for example, *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, for example, *very likely*. This is consistent with AR5.

⁴ See also Box SPM.1: Core Concepts Central to this Special Report.

⁵ Present level of global warming is defined as the average of a 30-year period centred on 2017 assuming the recent rate of warming continues.

⁶ This range spans the four available peer-reviewed estimates of the observed GMST change and also accounts for additional uncertainty due to possible short-term natural variability. {1.2.1, Table 1.1}

B. Projected Climate Change, Potential Impacts and Associated Risks

B.1 Climate models project robust⁷ differences in regional climate characteristics between present-day and global warming of 1.5°C,⁸ and between 1.5°C and 2°C.⁸ These differences include increases in: mean temperature in most land and ocean regions (*high confidence*), hot extremes in most inhabited regions (*high confidence*), heavy precipitation in several regions (*medium confidence*), and the probability of drought and precipitation deficits in some regions (*medium confidence*). {3.3}

B.1.1 Evidence from attributed changes in some climate and weather extremes for a global warming of about 0.5°C supports the assessment that an additional 0.5°C of warming compared to present is associated with further detectable changes in these extremes (*medium confidence*). Several regional changes in climate are assessed to occur with global warming up to 1.5°C compared to pre-industrial levels, including warming of extreme temperatures in many regions (*high confidence*), increases in frequency, intensity, and/or amount of heavy precipitation in several regions (*high confidence*), and an increase in intensity or frequency of droughts in some regions (*medium confidence*). {3.2, 3.3.1, 3.3.2, 3.3.3, 3.3.4, Table 3.2}

B.1.2 Temperature extremes on land are projected to warm more than GMST (*high confidence*): extreme hot days in mid-latitudes warm by up to about 3°C at global warming of 1.5°C and about 4°C at 2°C, and extreme cold nights in high latitudes warm by up to about 4.5°C at 1.5°C and about 6°C at 2°C (*high confidence*). The number of hot days is projected to increase in most land regions, with highest increases in the tropics (*high confidence*). {3.3.1, 3.3.2, Cross-Chapter Box 8 in Chapter 3}

B.1.3 Risks from droughts and precipitation deficits are projected to be higher at 2°C compared to 1.5°C of global warming in some regions (*medium confidence*). Risks from heavy precipitation events are projected to be higher at 2°C compared to 1.5°C of global warming in several northern hemisphere high-latitude and/or high-elevation regions, eastern Asia and eastern North America (*medium confidence*). Heavy precipitation associated with tropical cyclones is projected to be higher at 2°C compared to 1.5°C global warming (*medium confidence*). There is generally *low confidence* in projected changes in heavy precipitation at 2°C compared to 1.5°C in other regions. Heavy precipitation when aggregated at global scale is projected to be higher at 2°C than at 1.5°C of global warming (*medium confidence*). As a consequence of heavy precipitation, the fraction of the global land area affected by flood hazards is projected to be larger at 2°C compared to 1.5°C of global warming (*medium confidence*). {3.3.1, 3.3.3, 3.3.4, 3.3.5, 3.3.6}

B.2 By 2100, global mean sea level rise is projected to be around 0.1 metre lower with global warming of 1.5°C compared to 2°C (*medium confidence*). Sea level will continue to rise well beyond 2100 (*high confidence*), and the magnitude and rate of this rise depend on future emission pathways. A slower rate of sea level rise enables greater opportunities for adaptation in the human and ecological systems of small islands, low-lying coastal areas and deltas (*medium confidence*). {3.3, 3.4, 3.6}

B.2.1 Model-based projections of global mean sea level rise (relative to 1986–2005) suggest an indicative range of 0.26 to 0.77 m by 2100 for 1.5°C of global warming, 0.1 m (0.04–0.16 m) less than for a global warming of 2°C (*medium confidence*). A reduction of 0.1 m in global sea level rise implies that up to 10 million fewer people would be exposed to related risks, based on population in the year 2010 and assuming no adaptation (*medium confidence*). {3.4.4, 3.4.5, 4.3.2}

B.2.2 Sea level rise will continue beyond 2100 even if global warming is limited to 1.5°C in the 21st century (*high confidence*). Marine ice sheet instability in Antarctica and/or irreversible loss of the Greenland ice sheet could result in multi-metre rise in sea level over hundreds to thousands of years. These instabilities could be triggered at around 1.5°C to 2°C of global warming (*medium confidence*). (Figure SPM.2) {3.3.9, 3.4.5, 3.5.2, 3.6.3, Box 3.3}

⁷ Robust is here used to mean that at least two thirds of climate models show the same sign of changes at the grid point scale, and that differences in large regions are statistically significant.

⁸ Projected changes in impacts between different levels of global warming are determined with respect to changes in global mean surface air temperature.

C. Emission Pathways and System Transitions Consistent with 1.5°C Global Warming

C.1 In model pathways with no or limited overshoot of 1.5°C, global net anthropogenic CO₂ emissions decline by about 45% from 2010 levels by 2030 (40–60% interquartile range), reaching net zero around 2050 (2045–2055 interquartile range). For limiting global warming to below 2°C¹¹ CO₂ emissions are projected to decline by about 25% by 2030 in most pathways (10–30% interquartile range) and reach net zero around 2070 (2065–2080 interquartile range). Non-CO₂ emissions in pathways that limit global warming to 1.5°C show deep reductions that are similar to those in pathways limiting warming to 2°C. (*high confidence*) (Figure SPM.3a) {2.1, 2.3, Table 2.4}

C.1.1 CO₂ emissions reductions that limit global warming to 1.5°C with no or limited overshoot can involve different portfolios of mitigation measures, striking different balances between lowering energy and resource intensity, rate of decarbonization, and the reliance on carbon dioxide removal. Different portfolios face different implementation challenges and potential synergies and trade-offs with sustainable development. (*high confidence*) (Figure SPM.3b) {2.3.2, 2.3.4, 2.4, 2.5.3}

C.1.2 Modelled pathways that limit global warming to 1.5°C with no or limited overshoot involve deep reductions in emissions of methane and black carbon (35% or more of both by 2050 relative to 2010). These pathways also reduce most of the cooling aerosols, which partially offsets mitigation effects for two to three decades. Non-CO₂ emissions¹² can be reduced as a result of broad mitigation measures in the energy sector. In addition, targeted non-CO₂ mitigation measures can reduce nitrous oxide and methane from agriculture, methane from the waste sector, some sources of black carbon, and hydrofluorocarbons. High bioenergy demand can increase emissions of nitrous oxide in some 1.5°C pathways, highlighting the importance of appropriate management approaches. Improved air quality resulting from projected reductions in many non-CO₂ emissions provide direct and immediate population health benefits in all 1.5°C model pathways. (*high confidence*) (Figure SPM.3a) {2.2.1, 2.3.3, 2.4.4, 2.5.3, 4.3.6, 5.4.2}

C.1.3 Limiting global warming requires limiting the total cumulative global anthropogenic emissions of CO₂ since the pre-industrial period, that is, staying within a total carbon budget (*high confidence*).¹³ By the end of 2017, anthropogenic CO₂ emissions since the pre-industrial period are estimated to have reduced the total carbon budget for 1.5°C by approximately 2200 ± 320 GtCO₂ (*medium confidence*). The associated remaining budget is being depleted by current emissions of 42 ± 3 GtCO₂ per year (*high confidence*). The choice of the measure of global temperature affects the estimated remaining carbon budget. Using global mean surface air temperature, as in AR5, gives an estimate of the remaining carbon budget of 580 GtCO₂ for a 50% probability of limiting warming to 1.5°C, and 420 GtCO₂ for a 66% probability (*medium confidence*).¹⁴ Alternatively, using GMST gives estimates of 770 and 570 GtCO₂, for 50% and 66% probabilities,¹⁵ respectively (*medium confidence*). Uncertainties in the size of these estimated remaining carbon budgets are substantial and depend on several factors. Uncertainties in the climate response to CO₂ and non-CO₂ emissions contribute ±400 GtCO₂ and the level of historic warming contributes ±250 GtCO₂ (*medium confidence*). Potential additional carbon release from future permafrost thawing and methane release from wetlands would reduce budgets by up to 100 GtCO₂ over the course of this century and more thereafter (*medium confidence*). In addition, the level of non-CO₂ mitigation in the future could alter the remaining carbon budget by 250 GtCO₂ in either direction (*medium confidence*). {1.2.4, 2.2.2, 2.6.1, Table 2.2, Chapter 2 Supplementary Material}

C.1.4 Solar radiation modification (SRM) measures are not included in any of the available assessed pathways. Although some SRM measures may be theoretically effective in reducing an overshoot, they face large uncertainties and knowledge gaps

11 References to pathways limiting global warming to 2°C are based on a 66% probability of staying below 2°C.

12 Non-CO₂ emissions included in this Report are all anthropogenic emissions other than CO₂ that result in radiative forcing. These include short-lived climate forcers, such as methane, some fluorinated gases, ozone precursors, aerosols or aerosol precursors, such as black carbon and sulphur dioxide, respectively, as well as long-lived greenhouse gases, such as nitrous oxide or some fluorinated gases. The radiative forcing associated with non-CO₂ emissions and changes in surface albedo is referred to as non-CO₂ radiative forcing. {2.2.1}

13 There is a clear scientific basis for a total carbon budget consistent with limiting global warming to 1.5°C. However, neither this total carbon budget nor the fraction of this budget taken up by past emissions were assessed in this Report.

14 Irrespective of the measure of global temperature used, updated understanding and further advances in methods have led to an increase in the estimated remaining carbon budget of about 300 GtCO₂ compared to AR5. (*medium confidence*) {2.2.2}

15 These estimates use observed GMST to 2006–2015 and estimate future temperature changes using near surface air temperatures.

Box SPM.1: Core Concepts Central to this Special Report

Global mean surface temperature (GMST): Estimated global average of near-surface air temperatures over land and sea ice, and sea surface temperatures over ice-free ocean regions, with changes normally expressed as departures from a value over a specified reference period. When estimating changes in GMST, near-surface air temperature over both land and oceans are also used.¹⁹ {1.2.1.1}

Pre-industrial: The multi-century period prior to the onset of large-scale industrial activity around 1750. The reference period 1850–1900 is used to approximate pre-industrial GMST. {1.2.1.2}

Global warming: The estimated increase in GMST averaged over a 30-year period, or the 30-year period centred on a particular year or decade, expressed relative to pre-industrial levels unless otherwise specified. For 30-year periods that span past and future years, the current multi-decadal warming trend is assumed to continue. {1.2.1}

Net zero CO₂ emissions: Net zero carbon dioxide (CO₂) emissions are achieved when anthropogenic CO₂ emissions are balanced globally by anthropogenic CO₂ removals over a specified period.

Carbon dioxide removal (CDR): Anthropogenic activities removing CO₂ from the atmosphere and durably storing it in geological, terrestrial, or ocean reservoirs, or in products. It includes existing and potential anthropogenic enhancement of biological or geochemical sinks and direct air capture and storage, but excludes natural CO₂ uptake not directly caused by human activities.

Total carbon budget: Estimated cumulative net global anthropogenic CO₂ emissions from the pre-industrial period to the time that anthropogenic CO₂ emissions reach net zero that would result, at some probability, in limiting global warming to a given level, accounting for the impact of other anthropogenic emissions. {2.2.2}

Remaining carbon budget: Estimated cumulative net global anthropogenic CO₂ emissions from a given start date to the time that anthropogenic CO₂ emissions reach net zero that would result, at some probability, in limiting global warming to a given level, accounting for the impact of other anthropogenic emissions. {2.2.2}

Temperature overshoot: The temporary exceedance of a specified level of global warming.

Emission pathways: In this Summary for Policymakers, the modelled trajectories of global anthropogenic emissions over the 21st century are termed emission pathways. Emission pathways are classified by their temperature trajectory over the 21st century: pathways giving at least 50% probability based on current knowledge of limiting global warming to below 1.5°C are classified as ‘no overshoot’; those limiting warming to below 1.6°C and returning to 1.5°C by 2100 are classified as ‘1.5°C limited-overshoot’; while those exceeding 1.6°C but still returning to 1.5°C by 2100 are classified as ‘higher-overshoot’.

Impacts: Effects of climate change on human and natural systems. Impacts can have beneficial or adverse outcomes for livelihoods, health and well-being, ecosystems and species, services, infrastructure, and economic, social and cultural assets.

Risk: The potential for adverse consequences from a climate-related hazard for human and natural systems, resulting from the interactions between the hazard and the vulnerability and exposure of the affected system. Risk integrates the likelihood of exposure to a hazard and the magnitude of its impact. Risk also can describe the potential for adverse consequences of adaptation or mitigation responses to climate change.

Climate-resilient development pathways (CRDPs): Trajectories that strengthen sustainable development at multiple scales and efforts to eradicate poverty through equitable societal and systems transitions and transformations while reducing the threat of climate change through ambitious mitigation, adaptation and climate resilience.

¹⁹ Past IPCC reports, reflecting the literature, have used a variety of approximately equivalent metrics of GMST change.

2

Mitigation Pathways Compatible with 1.5°C in the Context of Sustainable Development

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830 billion USD2010 (range of 150 billion to 1700 billion USD2010 across six models). Total energy-related investments increase by about 12% (range of 3% to 24%) in 1.5°C pathways relative to 2°C pathways. Average annual investment in low-carbon energy technologies and energy efficiency are upscaled by roughly a factor of six (range of factor of 4 to 10) by 2050 compared to 2015, overtaking fossil investments globally by around 2025 (*medium confidence*). Uncertainties and strategic mitigation portfolio choices affect the magnitude and focus of required investments. {2.5.2}

Future Emissions in 1.5°C Pathways

Mitigation requirements can be quantified using carbon budget approaches that relate cumulative CO₂ emissions to global mean temperature increase. Robust physical understanding underpins this relationship, but uncertainties become increasingly relevant as a specific temperature limit is approached. These uncertainties relate to the transient climate response to cumulative carbon emissions (TCRE), non-CO₂ emissions, radiative forcing and response, potential additional Earth system feedbacks (such as permafrost thawing), and historical emissions and temperature. {2.2.2, 2.6.1}

Cumulative CO₂ emissions are kept within a budget by reducing global annual CO₂ emissions to net zero. This assessment suggests a remaining budget of about 420 GtCO₂ for a two-thirds chance of limiting warming to 1.5°C, and of about 580 GtCO₂ for an even chance (*medium confidence*). The remaining carbon budget is defined here as cumulative CO₂ emissions from the start of 2018 until the time of net zero global emissions for global warming defined as a change in global near-surface air temperatures. Remaining budgets applicable to 2100 would be approximately 100 GtCO₂ lower than this to account for permafrost thawing and potential methane release from wetlands in the future, and more thereafter. These estimates come with an additional geophysical uncertainty of at least ±400 GtCO₂, related to non-CO₂ response and TCRE distribution. Uncertainties in the level of historic warming contribute ±250 GtCO₂. In addition, these estimates can vary by ±250 GtCO₂ depending on non-CO₂ mitigation strategies as found in available pathways. {2.2.2, 2.6.1}

Staying within a remaining carbon budget of 580 GtCO₂ implies that CO₂ emissions reach carbon neutrality in about 30 years, reduced to 20 years for a 420 GtCO₂ remaining carbon budget (*high confidence*). The ±400 GtCO₂ geophysical uncertainty range surrounding a carbon budget translates into a variation of this timing of carbon neutrality of roughly ±15–20 years. If emissions do not start declining in the next decade, the point of carbon neutrality would need to be reached at least two decades earlier to remain within the same carbon budget. {2.2.2, 2.3.5}

Non-CO₂ emissions contribute to peak warming and thus affect the remaining carbon budget. The evolution of methane and sulphur dioxide emissions strongly influences the chances of limiting warming to 1.5°C. In the near-term, a weakening of aerosol cooling would add to future warming, but can be tempered by reductions in methane emissions (*high confidence*). Uncertainty in radiative forcing estimates (particularly

aerosol) affects carbon budgets and the certainty of pathway categorizations. Some non-CO₂ forcers are emitted alongside CO₂, particularly in the energy and transport sectors, and can be largely addressed through CO₂ mitigation. Others require specific measures, for example, to target agricultural nitrous oxide (N₂O) and methane (CH₄), some sources of black carbon, or hydrofluorocarbons (*high confidence*). In many cases, non-CO₂ emissions reductions are similar in 2°C pathways, indicating reductions near their assumed maximum potential by integrated assessment models. Emissions of N₂O and NH₃ increase in some pathways with strongly increased bioenergy demand. {2.2.2, 2.3.1, 2.4.2, 2.5.3}

The Role of Carbon Dioxide Removal (CDR)

All analysed pathways limiting warming to 1.5°C with no or limited overshoot use CDR to some extent to neutralize emissions from sources for which no mitigation measures have been identified and, in most cases, also to achieve net negative emissions to return global warming to 1.5°C following a peak (*high confidence*). The longer the delay in reducing CO₂ emissions towards zero, the larger the likelihood of exceeding 1.5°C, and the heavier the implied reliance on net negative emissions after mid-century to return warming to 1.5°C (*high confidence*). The faster reduction of net CO₂ emissions in 1.5°C compared to 2°C pathways is predominantly achieved by measures that result in less CO₂ being produced and emitted, and only to a smaller degree through additional CDR. Limitations on the speed, scale and societal acceptability of CDR deployment also limit the conceivable extent of temperature overshoot. Limits to our understanding of how the carbon cycle responds to net negative emissions increase the uncertainty about the effectiveness of CDR to decline temperatures after a peak. {2.2, 2.3, 2.6, 4.3.7}

CDR deployed at scale is unproven, and reliance on such technology is a major risk in the ability to limit warming to 1.5°C. CDR is needed less in pathways with particularly strong emphasis on energy efficiency and low demand. The scale and type of CDR deployment varies widely across 1.5°C pathways, with different consequences for achieving sustainable development objectives (*high confidence*). Some pathways rely more on bioenergy with carbon capture and storage (BECCS), while others rely more on afforestation, which are the two CDR methods most often included in integrated pathways. Trade-offs with other sustainability objectives occur predominantly through increased land, energy, water and investment demand. Bioenergy use is substantial in 1.5°C pathways with or without BECCS due to its multiple roles in decarbonizing energy use. {2.3.1, 2.5.3, 2.6.3, 4.3.7}

Properties of Energy and Land Transitions in 1.5°C Pathways

The share of primary energy from renewables increases while coal usage decreases across pathways limiting warming to 1.5°C with no or limited overshoot (*high confidence*). By 2050, renewables (including bioenergy, hydro, wind, and solar, with direct-equivalence method) supply a share of 52–67% (interquartile range) of primary energy in 1.5°C pathways with no or limited overshoot; while the share from coal decreases to 1–7% (interquartile range),

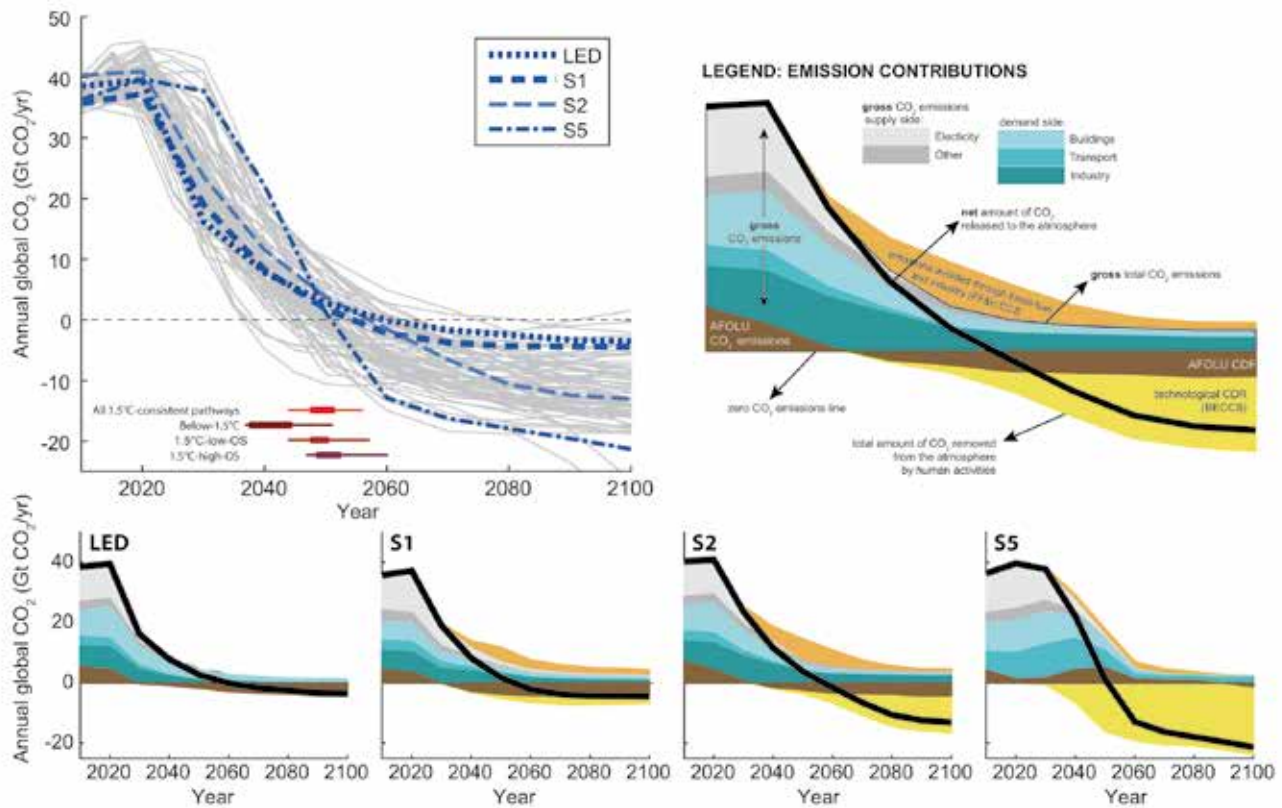


Figure 2.5 | Evolution and break down of global anthropogenic CO₂ emissions until 2100. The top-left panel shows global net CO₂ emissions in Below-1.5°C, 1.5°C-low-overshoot (OS), and 1.5°C-high-OS pathways, with the four illustrative 1.5°C-consistent pathway archetypes of this chapter highlighted. Ranges at the bottom of the top-left panel show the 10th–90th percentile range (thin line) and interquartile range (thick line) of the time that global CO₂ emissions reach net zero per pathway class, and for all pathways classes combined. The top-right panel provides a schematic legend explaining all CO₂ emissions contributions to global CO₂ emissions. The bottom row shows how various CO₂ contributions are deployed and used in the four illustrative pathway archetypes (LED, S1, S2, S5, referred to as P1, P2, P3, and P4 in the Summary for Policymakers) used in this chapter (see Section 2.3.1.1). Note that the S5 scenario reports the building and industry sector emissions jointly. Green-blue areas hence show emissions from the transport sector and the joint building and industry demand sector, respectively.

like BECCS (S2 and S5 pathways in Figure 2.5) (Luderer et al., 2018; Rogelj et al., 2018). Major drivers of these differences are assumptions about energy and food demand and the stringency of near-term climate policy (see the difference between early action in the scenarios S1, LED and more moderate action until 2030 in the scenarios S2, S5). Furthermore, the carbon budget in each of these pathways depends also on the non-CO₂ mitigation measures implemented in each of them, particularly for agricultural emissions (Sections 2.2.2, 2.3.3) (Gernaat et al., 2015). Those pathways differ not only in terms of their deployment of mitigation and CDR measures (Sections 2.3.4 and 2.4), but also in terms of the resulting temperature overshoot (Figure 2.1). Furthermore, they have very different implications for the achievement of sustainable development objectives, as further discussed in Section 2.5.3.

2.3.2.2 Pathways keeping warming below 1.5°C or temporarily overshooting it

This subsection explores the conditions that would need to be fulfilled to stay below 1.5°C warming without overshoot. As discussed in Section 2.2.2, to keep warming below 1.5°C with a two-in-three (one-in-two) chance, the cumulative amount of CO₂ emissions from 2018 onwards need to remain below a carbon budget of 420 (580) GtCO₂; accounting for the effects of additional Earth system feedbacks until 2100 reduces this estimate by 100 GtCO₂. Based on the current state of knowledge,

exceeding this remaining carbon budget at some point in time would give a one-in-three (one-in-two) chance that the 1.5°C limit is overshoot (Table 2.2). For comparison, around 290 ± 20 (1 standard deviation range) GtCO₂ have been emitted in the years 2011–2017, with annual CO₂ emissions in 2017 around 42 ± 3 GtCO₂ yr⁻¹ (Jackson et al., 2017; Le Quéré et al., 2018). Committed fossil-fuel emissions from existing fossil-fuel infrastructure as of 2010 have been estimated at around 500 ± 200 GtCO₂ (with about 200 GtCO₂ already emitted through 2017) (Davis and Caldeira, 2010). Coal-fired power plants contribute the largest part. Committed emissions from existing coal-fired power plants built through the end of 2016 are estimated to add up to roughly 200 GtCO₂, and a further 100–150 GtCO₂ from coal-fired power plants under construction or planned (González-Eguino et al., 2017; Edenhofer et al., 2018). However, there has been a marked slowdown of planned coal-power projects in recent years, and some estimates indicate that the committed emissions from coal plants that are under construction or planned have halved since 2015 (Shearer et al., 2018). Despite these uncertainties, the committed fossil-fuel emissions are assessed to already amount to more than two thirds (half) of the remaining carbon budget.

An important question is to what extent the nationally determined contributions (NDCs) under the Paris Agreement are aligned with the remaining carbon budget. It was estimated that the NDCs, if successfully