Executive Summary

This chapter frames the context, knowledge-base and assessment approaches used to understand the impacts of 1.5°C global warming above pre-industrial levels and related global greenhouse gas emission pathways, building on the IPCC Fifth Assessment Report (AR5), in the context of strengthening the global response to the threat of climate change, sustainable development and efforts to eradicate poverty.

Human-induced warming reached approximately 1°C (±0.2°C *likely* range) above pre-industrial levels in 2017, increasing at 0.2°C (±0.1°C) per decade (*high confidence*). Global warming is defined in this report as an increase in combined surface air and sea surface temperatures averaged over the globe and a 30-year period. Unless otherwise specified, warming is expressed relative to the period 1850-1900, used as an approximation of pre-industrial temperatures in AR5. For periods shorter than 30 years, warming refers to the estimated average temperature over the 30 years centered on that shorter period, accounting for the impact of any temperature fluctuations or trend within those 30 years. Accordingly, warming up to the decade 2006-2015 is assessed at 0.87°C (±0.12°C *likely* range). Since 2000, the estimated level of human-induced warming has been equal to the level of observed warming with a *likely* range of ±20% accounting for uncertainty due to contributions from solar and volcanic activity over the historical period (*high confidence*). {1.2.1}

Warming greater than the global average has already been experienced in many regions and seasons, with average warming over land higher than over the ocean (*high confidence*). Most land regions are experiencing greater warming than the global average, while most ocean regions are warming at a slower rate. Depending on the temperature dataset considered, 20-40% of the global human population live in regions that, by the decade 2006-2015, had already experienced warming of more than 1.5°C above pre-industrial in at least one season (*medium confidence*). {1.2.1 & 1.2.2}

Past emissions alone are *unlikely* to raise global-mean temperature to 1.5°C above pre-industrial levels but past emissions do commit to other changes, such as further sea level rise (*high confidence*)**.** If all anthropogenic emissions (including aerosol-related) were reduced to zero immediately, any further warming beyond the 1°C already experienced would *likely* be less than 0.5°C over the next two to three decades (*high confidence*), and *likely* less than 0.5°C on a century timescale (*medium confidence*), due to the opposing effects of different climate processes and drivers. A warming greater than 1.5°C is therefore not geophysically unavoidable: whether it will occur depends on future rates of emission reductions. {1.2.3, 1.2.4}

1.5°C-consistent emission pathways are defined as those that, given current knowledge of the climate response, provide a one-in-two to two-in-three chance of warming either remaining below 1.5°C, or returning to 1.5°C by around 2100 following an overshoot. Overshoot pathways are characterized by the peak magnitude of the overshoot, which may have implications for impacts. All 1.5°C-consistent pathways involve limiting cumulative emissions of long-lived greenhouse gases, including carbon dioxide and nitrous oxide, and substantial reductions in other climate forcers (*high confidence*). Limiting cumulative emissions requires either reducing net global emissions of long-lived greenhouse gases to zero before the cumulative limit is reached, or net negative global emissions (anthropogenic removals) after the limit is exceeded. {1.2.3, 1.2.4, Cross-Chapter Boxes 1 and 2}

This report assesses projected impacts at a global average warming of 1.5°C and higher levels of warming. Global warming of 1.5°C is associated with global average surface temperatures fluctuating naturally on either side of 1.5°C, together with warming substantially greater than 1.5°C in many regions and seasons (*high confidence*), all of which must be taken into account in the assessment of impacts. Impacts at 1.5°C of warming also depend on the emission pathway to 1.5°C. Very different impacts result from pathways that remain below 1.5°C versus pathways that return to

1.5°C after a substantial overshoot, and when temperatures stabilize at 1.5°C versus a transient warming past 1.5°C. (*medium confidence*) {1.2.3, 1.3}

Ethical considerations, and the principle of equity in particular, are central to this report, recognising that many of the impacts of warming up to and beyond 1.5°C, and some potential impacts of mitigation actions required to limit warming to 1.5°C, fall disproportionately on the poor and vulnerable (*high confidence*). Equity has procedural and distributive dimensions and requires fairness in burden sharing, between generations, and between and within nations. In framing the objective of holding the increase in the global average temperature rise to well below 2°C above pre-industrial levels, and to pursue efforts to limit warming to 1.5°C, the Paris Agreement associates the principle of equity with the broader goals of poverty eradication and sustainable development, recognising that effective responses to climate change require a global collective effort that may be guided by the 2015 United Nations Sustainable Development Goals. {1.1.1}

Climate adaptation refers to the actions taken to manage impacts of climate change by reducing vulnerability and exposure to its harmful effects and exploiting any potential benefits. Adaptation takes place at international, national and local levels. Subnational jurisdictions and entities, including urban and rural municipalities, are key to developing and reinforcing measures for reducing weather- and climate-related risks. Adaptation implementation faces several barriers including unavailability of up-to-date and locally-relevant information, lack of finance and technology, social values and attitudes, and institutional constraints (*high confidence*). Adaptation is more likely to contribute to sustainable development when polices align with mitigation and poverty eradication goals (*medium confidence*) {1.1, 1.4}

Ambitious mitigation actions are indispensable to limit warming to 1.5°C while achieving sustainable development and poverty eradication (*high confidence*). Ill-designed responses, however, could pose challenges especially—but not exclusively—for countries and regions contending with poverty and those requiring significant transformation of their energy systems. This report focuses on 'climate-resilient development pathways' , which aim to meet the goals of sustainable development, including climate adaptation and mitigation, poverty eradication and reducing inequalities. But any feasible pathway that remains within 1.5°C involves synergies and trade-offs (*high confidence*). Significant uncertainty remains as to which pathways are more consistent with the principle of equity. {1.1.1, 1.4}

Multiple forms of knowledge, including scientific evidence, narrative scenarios and prospective pathways, inform the understanding of 1.5°C. This report is informed by traditional evidence of the physical climate system and associated impacts and vulnerabilities of climate change, together with knowledge drawn from the perceptions of risk and the experiences of climate impacts and governance systems. Scenarios and pathways are used to explore conditions enabling goal-oriented futures while recognizing the significance of ethical considerations, the principle of equity, and the societal transformation needed. {1.2.3, 1.5.2}

There is no single answer to the question of whether it is feasible to limit warming to 1.5°C and adapt to the consequences. Feasibility is considered in this report as the capacity of a system as a whole to achieve a specific outcome. The global transformation that would be needed to limit warming to 1.5°C requires enabling conditions that reflect the links, synergies and trade-offs between mitigation, adaptation and sustainable development. These enabling conditions have many systemic dimensions—geophysical, environmental-ecological, technological, economic, socio-cultural and institutional—that may be considered through the unifying lens of the Anthropocene, acknowledging profound, differential but increasingly geologically significant human influences on the Earth system as a whole. This framing also emphasises the global interconnectivity of past, present and future

human–environment relations, highlighing the need and opportunities for integrated responses to achieve the goals of the Paris Agreement. {1.1, Cross-Chapter Box 1}

changes in climate at 1.5°C warming, especially in cases where no climate model simulations or analyses are available.

Impacts of 1.5°C global warming can be assessed in part from regional and global climate changes that have already been detected and attributed to human influence (e.g., Schleussner et al., 2017) and are components of the climate system that are most responsive to current and projected future forcing. For this reason, when specific projections are missing for 1.5°C global warming, some of the assessments of climate change provided in Chapter 3 (Section 3.3) build upon joint assessments of a) changes that were observed and attributed to human influence up to the present, i.e. for 1°C global warming and b) projections for higher levels of warming (e.g., 2°C, 3°C or 4°C) to assess the changes at 1.5°C. Such assessments are for transient changes only (see Chapter 3, Section 3.3).

Besides quantitative detection and attribution methods, assessments can also be based on indigenous and local knowledge (see Chapter 4, Box 4.3). While climate observations may not be available to assess impacts from a scientific perspective, local community knowledge can also indicate actual impacts (Brinkman et al., 2016; Kabir et al., 2016). The challenge is that a community's perception of loss due to the impacts of climate change is an area that requires further research (Tschakert et al., 2017).

Costs and benefits analysis

Cost-benefit analyses are common tools used for decision-making, whereby the costs of impacts are compared to the benefits from different response actions (IPCC, 2014d, e). However, for the case of climate change, recognising the complex inter-linkages of the Anthropocene, cost-benefit analyses tools can be difficult to use because of disparate impacts versus costs and complex interconnectivity within the global social-ecological system (see Box 1.1 and Cross-Chapter Box 5 in Chapter 2). Some costs are relatively easily quantifiable in monetary terms but not all. Climate change impacts humans' lives and livelihoods, culture and values and whole ecosystem. It has unpredictable feedback loops and impacts on other regions, (IPCC, 2014e) giving rise to indirect, secondary, tertiary and opportunity costs that are typically extremely difficult to quantify. Monetary quantification is further complicated by the fact that costs and benefits can occur in different regions at very different times, possibly spanning centuries, while it is extremely difficult if not impossible to meaningfully estimate discount rates for future costs and benefits. Thus standard cost–benefit analyses become difficult to justify (IPCC, 2014e; Dietz et al., 2016) and are not used as an assessment tool in this report.

1.6 Confidence, uncertainty and risk

This report relies on the IPCC's uncertainty guidance provided in Mastrandrea et al. (2011), and sources given therein. Two metrics for qualifying key findings are used:

Confidence: Five qualifiers are used to express levels of confidence in key findings, ranging from *very low*, through *low*, *medium*, *high*, to *very high*. The assessment of confidence involves at least two dimensions, one being the type, quality, amount or internal consistency of individual lines of evidence, and the second being the level of agreement between different lines of evidence. Very high confidence findings must either be supported by a high level of agreement across multiple lines of mutually independent and individually robust lines of evidence or, if only a single line of evidence is available, by a very high level of understanding underlying that evidence. Findings of low or very low confidence are presented only if they address a topic of major concern.

Likelihood: A calibrated language scale is used to communicate assessed probabilities of outcomes, ranging from *exceptionally unlikely* (<1%), *extremely unlikely* (<5%), *very unlikely* (<10%), *unlikely* (<33%), *about as likely as not* (33–66%), *likely* (>66%), *very likely* (>90%), *extremely likely* (>95%)

to *virtually certain* (>99%). These terms are normally only applied to findings associated with high or very high confidence. Frequency of occurrence within a model ensemble does not correspond to actual assessed probability of outcome unless the ensemble is judged to capture and represent the full range of relevant uncertainties.

Three specific challenges arise in the treatment of uncertainty and risk in this report. First, the current state of the scientific literature on 1.5°C means that findings based on multiple lines of robust evidence for which quantitative probabilistic results can be expressed may be few, and not the most policy-relevant. Hence many key findings are expressed using confidence qualifiers alone.

Second, many of the most important findings of this report are conditional because they refer to ambitious mitigation scenarios. Conditional probabilities often depend strongly on how conditions are specified, such as whether temperature goals are met through early emission reductions, reliance on negative emissions, or through a low climate response. Whether a certain risk is deemed likely at 1.5°C may therefore depend strongly on how 1.5°C is specified, whereas a statement that a certain risk may be substantially higher at 2°C relative to 1.5°C may be much more robust.

Third, achieving ambitious mitigation goals will require active, goal-directed efforts aiming explicitly for specific outcomes and incorporating new information as it becomes available (Otto et al., 2015). This shifts the focus of uncertainty from the climate outcome itself to the level of mitigation effort that may be required to achieve it. Probabilistic statements about human decisions are always problematic, but in the context of robust decision-making, many near-term policies that are needed to keep open the option of achieving 1.5°C may be the same, regardless of the actual probability that the goal will be met (Knutti et al., 2015).

1.7 Storyline of the report

The storyline of this report (Figure 1.6) includes a set of interconnected components. The report consists of five chapters, a Technical Summary and a Summary for Policymakers. It also includes a set of boxes to elucidate specific or cross-cutting themes, as well as Frequently Asked Questions for each chapter and a Glossary.

At a time of unequivocal and rapid global warming, this report emerges from the long-term temperature goal of the Paris Agreement; strengthening the global response to the threat of climate change by pursuing efforts to limit warming to 1.5°C through reducing emissions to achieve a balance between anthropogenic emissions by sources and removals by sinks of greenhouse gases. The assessment focuses first, in Chapter 1, on how 1.5°C is defined and understood, what is the current level of warming to date, and the present trajectory of change. The framing presented in Chapter 1 provides the basis through which to understand the enabling conditions of a 1.5°C warmer world and connections to the SDGs, poverty eradication, and equity and ethics.

In Chapter 2, scenarios of a 1.5°C warmer world and the associated pathways are assessed. The pathways assessment builds upon the AR5 with a greater emphasis on sustainable development in mitigation pathways. All pathways begin now, and involve rapid and unprecedented societal transformation. An important framing device for this report is the recognition that choices that determine emissions pathways, whether ambitious mitigation or ‘no policy’ scenarios, do not occur independently of these other changes and are, in fact, highly interdependent.

Projected impacts that emerge in a 1.5°C warmer world and beyond are dominant narrative threads of the report and are assessed in Chapter 3. The chapter focuses on observed and attributable global and regional climate changes and impacts and vulnerabilities. The projected impacts have diverse and uneven spatial, temporal, and human, economic, and ecological system-level manifestations. Central