# Chapter 5: Sustainable Development, Poverty Eradication and Reducing Inequalities

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Where reference is made to Table 5.3, this is available as a supplementary pdf (file Chapter 5 – Table 5.3)

## Executive Summary

This chapter takes sustainable development as the starting point and focus for analysis. It considers the broad and multifaceted bi-directional interplay between sustainable development, including its focus on eradicating poverty and reducing inequality in their multidimensional aspects, and climate actions in a 1.5°C warmer world. These fundamental connections are embedded in the Sustainable Development Goals (SDGs). The chapter also examines synergies and trade-offs of adaptation and mitigation options with sustainable development and the SDGs and offers insights into possible pathways, especially climate-resilient development pathways toward a 1.5°C warmer world.

### Sustainable Development, Poverty, and Inequality in a 1.5°C Warmer World

**Limiting global warming to 1.5°C rather than 2°C would make it markedly easier to achieve many aspects of sustainable development, with greater potential to eradicate poverty and reduce inequalities (*medium evidence, high agreement*)**. Impacts avoided with the lower temperature limit could reduce the number of people exposed to climate risks and vulnerable to poverty by 62 to 457 million, and lessen the risks of poor people to experience food and water insecurity, adverse health impacts, and economic losses, particularly in regions that already face development challenges (*medium evidence, medium agreement*) {5.2.2, 5.2.3}. Avoided impacts between 1.5°C and 2°C warming would also make it easier to achieve certain SDGs, such as those that relate to poverty, hunger, health, water and sanitation, cities, and ecosystems (SDGs 1, 2, 3, 6, 12, 14, and 15) (*medium evidence, high agreement*) {5.2.3, Table 5.3 available as a supplementary pdf }.

**Compared to current conditions, 1.5°C of global warming would nonetheless pose heightened risks to eradicating poverty, reducing inequalities and ensuring human and ecosystem well-being (*medium evidence, high agreement*).** Warming of 1.5°C is not considered 'safe' for most nations, communities, ecosystems and sectors and poses significant risks to natural and human systems as compared to current warming of 1°C (*high confidence*) {Cross-Chapter Box 12 in Chapter 5}. The impacts of 1.5°C would disproportionately affect disadvantaged and vulnerable populations through food insecurity, higher food prices, income losses, lost livelihood opportunities, adverse health impacts, and population displacements (*medium evidence, high agreement*) {5.2.1}. Some of the worst impacts on sustainable development are expected to be felt among agricultural and coastal dependent livelihoods, indigenous people, children and the elderly, poor labourers, poor urban dwellers in African cities, and people and ecosystems in the Arctic and Small Island Developing States (SIDS) (*medium evidence, high agreement*) {5.2.1 Box 5.3, Chapter 3 Box 3.5, Cross-Chapter Box 9 in Chapter 4}.

### Climate Adaptation and Sustainable Development

**Prioritisation of sustainable development and meeting the SDGs is consistent with efforts to adapt to climate change (*high confidence*).** Many strategies for sustainable development enable transformational adaptation for a 1.5°C warmer world, provided attention is paid to reducing poverty in all its forms and to promoting equity and participation in decision-making (*medium evidence, high agreement*). As such, sustainable development has the potential to significantly reduce systemic vulnerability, enhance adaptive capacity, and promote livelihood security for poor and disadvantaged populations (*high confidence*) {5.3.1}.

**Synergies between adaptation strategies and the SDGs are expected to hold true in a 1.5°C warmer world, across sectors and contexts (*medium evidence, medium agreement*).** Synergies between adaptation and sustainable development are significant for agriculture and health, advancing SDGs 1 (extreme poverty), 2 (hunger), 3 (healthy lives and well-being), and 6 (clean water) (*robust evidence, medium agreement*) {5.3.2}. Ecosystem- and community-based adaptation, along with the incorporation of indigenous and local knowledge, advances synergies with SDGs 5 (gender equality), 10 (reducing inequalities), and 16 (inclusive societies), as exemplified in drylands and the Arctic (*high evidence, medium agreement*) {5.3.2, Box 5.1, Cross-Chapter Box 10 in Chapter 4}.

**Adaptation strategies can result in trade-offs with and among the SDGs (*medium evidence, high agreement*).** Strategies that advance one SDG may create negative consequences for other SDGs, for instance SDGs 3 versus 7 (health and energy consumption) and agricultural adaptation and SDG 2 (food security) versus SDGs 3, 5, 6, 10, 14, and 15 (*medium evidence, medium agreement*) {5.3.2}.

**Pursuing place-specific adaptation pathways toward a 1.5°C warmer world has the potential for significant positive outcomes for well-being, in countries at all levels of development (*medium evidence, high agreement*).** Positive outcomes emerge when adaptation pathways (i) ensure a diversity of adaptation options based on people's values and trade-offs they consider acceptable, (ii) maximise synergies with sustainable development through inclusive, participatory, and deliberative processes, and (iii) facilitate equitable transformation. Yet, such pathways would be difficult to achieve without redistributive measures to overcome path dependencies, uneven power structures, and entrenched social inequalities (*medium evidence, high agreement*) {5.3.3}.

**Mitigation and Sustainable Development**

**The deployment of mitigation options consistent with 1.5°C pathways leads to multiple synergies across a range of sustainable development dimensions. At the same time, the rapid pace and magnitude of change that would be required to limit warming to 1.5°C, if not carefully managed, would lead to trade-offs with some sustainable development dimensions (*high confidence*).** The number of synergies between mitigation response options and sustainable development exceeds the number of trade-offs in energy demand and supply sectors, Agriculture, Forestry and Other Land Use (AFOLU) and for oceans (*very high confidence*) {Figure 5.3, Table 5.3 available as a supplementary pdf }. 1.5°C pathways indicate robust synergies particularly for the SDGs 3 (health), 7 (energy), 12 (responsible consumption and production), and 14 (oceans) (*very high confidence*) {5.4.2, Figure 5.4}. For SDGs 1 (poverty), 2 (hunger), 6 (water), and 7 (energy), there is a risk of trade-offs or negative side-effects from stringent mitigation actions compatible with 1.5°C (*medium evidence, high agreement*) {5.4.2}.

**Appropriately designed mitigation actions to reduce energy demand can advance multiple SDGs simultaneously. Pathways compatible with 1.5°C that feature low energy demand show the most pronounced synergies and the lowest number of trade-offs with respect to sustainable development and the SDGs (*very high confidence*).** Accelerating energy efficiency in all sectors has synergies with SDG 7, 9,11, 12, 16, 17 {5.4.1, Figure 5.3, Table 5.2} (*robust evidence, high agreement*). Low demand pathways, which would reduce or completely avoid the reliance on Bioenergy with Carbon Capture and Storage (BECCS) in 1.5°C pathways, would result in significantly reduced pressure on food security, lower food prices, and fewer people at risk of hunger (*medium evidence, high agreement*) {5.4.2, Figure 5.4}.

**The impacts of Carbon Dioxide Removal (CDR) options on SDGs depend on the type of options and the scale of deployment (*high confidence*).** If poorly implemented, CDR options such as bioenergy, BECCS and AFOLU would lead to trade-offs. Appropriate design and implementation requires considering local people´s needs, biodiversity, and other sustainable development dimensions (*very high confidence*) {5.4.1.3, Cross-Chapter Box 7 in Chapter 3}.

**The design of the mitigation portfolios and policy instruments to limit warming to 1.5°C will largely determine the overall synergies and trade-offs between mitigation and sustainable development (*very high confidence*). Redistributive policies that shield the poor and vulnerable can resolve trade-offs for a range of SDGs (*medium evidence, high agreement*).** Individual mitigation options are associated with both positive and negative interactions with the SDGs (*very high confidence*) {5.4.1}. However, appropriate choices across the mitigation portfolio can help to maximize positive side-effects while minimizing negative side-effects (*high confidence*) {5.4.2, 5.5.2}. Investment needs for complementary policies resolving trade-offs with a range of SDGs are only a small fraction of the overall mitigation investments in 1.5°C pathways (*medium evidence, high agreement*) {5.4.2, Figure 5.5}. Integration of mitigation with adaptation and sustainable development compatible with 1.5°C requires a systems perspective (*high confidence*) {5.4.2, 5.5.2}.

**Mitigation measures consistent with 1.5°C create high risks for sustainable development in countries with high dependency on fossil fuels for revenue and employment generation (*high confidence*).** These risks are caused by the reduction of global demand affecting mining activity and export revenues and challenges to rapidly decrease high carbon intensity of the domestic economy (*robust evidence, high agreement*) {5.4.1.2, Box 5.2}. Targeted policies that promote diversification of the economy and the energy sector could ease this transition (*medium evidence, high agreement*) {5.4.1.2, Box 5.2}.

**Sustainable Development Pathways to 1.5°C**

**Sustainable development broadly supports and often enables the fundamental societal and systems transformations that would be required for limiting warming to 1.5°C (*high confidence*).** Simulated pathways that feature the most sustainable worlds (e.g., Shared Socioeconomic Pathways (SSP)1) are associated with relatively lower mitigation and adaptation challenges and limit warming to 1.5°C at comparatively lower mitigation costs. In contrast, development pathways with high fragmentation, inequality and poverty (e.g., SSP3) are associated with comparatively higher mitigation and adaptation challenges. In such pathways, it is not possible to limit warming to 1.5°C for the vast majority of the integrated assessment models (*medium evidence, high agreement*) {5.5.2}. In all SSPs, mitigation costs substantially increase in 1.5°C pathways compared to 2°C pathways. No pathway in the literature integrates or achieves all 17 SDGs (*high confidence*) {5.5.2}. Real-world experiences at the project level show that the actual integration between adaptation, mitigation, and sustainable development is challenging as it requires reconciling trade-offs across sectors and spatial scales (*very high confidence*) {5.5.1}.

**Without societal transformation and rapid implementation of ambitious greenhouse gas reduction measures, pathways to limiting warming to 1.5°C and achieving sustainable development will be exceedingly difficult, if not impossible, to achieve (*high confidence*).** The potential for pursuing such pathways differs between and within nations and regions, due to different development trajectories, opportunities, and challenges (*very high confidence*) {5.5.3.2, Figure 5.1}. Limiting warming to 1.5°C would require all countries and non-state actors to strengthen their contributions without delay. This could be achieved through sharing of efforts based on bolder and more committed cooperation, with support for those with the least capacity to adapt, mitigate, and transform (*medium evidence, high agreement*) {5.5.3.1, 5.5.3.2}. Current efforts toward reconciling low-carbon trajectories and reducing inequalities, including those that avoid difficult trade-offs associated with transformation, are partially successful yet demonstrate notable obstacles (*medium evidence, medium agreement*) {5.5.3.3 Box 5.3, Cross-Chapter Box 13 in this Chapter}.

**Social justice and equity are core aspects of climate-resilient development pathways for transformational social change. Addressing challenges and widening opportunities between and within countries and communities would be necessary to achieve sustainable development and limit warming to 1.5°C, without making the poor and disadvantaged worse off (*high confidence*).** Identifying and navigating inclusive and socially acceptable pathways toward low-carbon, climate-resilient futures is a challenging yet important endeavour, fraught with moral, practical, and political difficulties and inevitable trade-offs (*very high confidence*) {5.5.2, 5.5.3.3 Box 5.3}. It entails deliberation and problem-solving processes to negotiate societal values, well-being, risks, and resilience and determine what is desirable and fair, and to whom (*medium evidence, high agreement*). Pathways that encompass joint, iterative planning and transformative visions, for instance in Pacific SIDS like Vanuatu and in urban contexts, show potential for liveable and sustainable futures (*high confidence*) {5.5.3.1, 5.5.3.3, Figure 5.6, Box 5.3, Cross-Chapter Box 13 in this Chapter}.

**The fundamental societal and systemic changes to achieve sustainable development, eradicate poverty and reduce inequalities while limiting warming to 1.5°C would require a set of institutional, social, cultural, economic and technological conditions to be met (*high confidence*).** The coordination and monitoring of policy actions across sectors and spatial scales is essential to support sustainable development in 1.5°C warmer conditions (*very high confidence*) {5.6.2, Box 5.3}. External funding and technology transfer better support these efforts when they consider recipients' context-specific needs (*medium evidence, high agreement*) {5.6.1}. Inclusive processes can facilitate transformations by ensuring participation, transparency, capacity building, and iterative social learning (*high confidence*) {5.5.3.3, Cross-Chapter Box 13, 5.6.3}. Attention to power asymmetries and unequal opportunities for development, among and within countries is key to adopting 1.5°C-compatible development pathways that benefit all populations (*high confidence*) {5.5.3, 5.6.4, Box 5.3}. Re-examining individual and collective values could help spur urgent, ambitious, and cooperative change (*medium evidence, high agreement*) {5.5.3, 5.6.5}.

## 5.1 Scope and Delineations

This chapter takes sustainable development as the starting point and focus for analysis, considering the broader bi-directional interplay and multifaceted interactions between development patterns and climate actions in a 1.5°C warmer world and in the context of eradicating poverty and reducing inequality. It assesses the impacts of keeping temperatures at or below 1.5°C global warming above pre-industrial levels on sustainable development and compares the avoided impacts to 2°C (Section 5.2). It then examines the interactions, synergies and trade-offs of adaptation (Section 5.3) and mitigation (Section 5.4) measures with sustainable development and the Sustainable Development Goals (SDGs). The chapter offers insights into possible pathways toward a 1.5°C warmer world, especially through climate-resilient development pathways providing a comprehensive vision across different contexts (Section 5.5). We also identify the conditions that would be needed to simultaneously achieve sustainable development, poverty eradication, the reduction of inequalities, and the 1.5°C climate objective (Section 5.6).

### *5.1.1 Sustainable Development, SDGs, Poverty Eradication and Reducing Inequalities*

Chapter 1 (see Cross-Chapter Box 4 in Chapter 1) defines sustainable development as 'development that meets the needs of the present and future generations' through balancing economic, social and environmental considerations, and then introduces the United Nations (UN) 2030 Agenda for Sustainable Development which sets out 17 ambitious goals for sustainable development for all countries by 2030. These Sustainable Development Goals (SDGs) are: no poverty (SDG 1), zero hunger (SDG 2), good health and well-being (SDG 3), quality education (SDG 4), gender equality (SDG 5), clean water and sanitation (SDG 6), affordable and clean energy (SDG 7), decent work and economic growth (SDG 8), industry, innovation and infrastructure (SDG 9), reduced inequalities (SDG 10), sustainable cities and communities (SDG 11), responsible consumption and production (SDG 12), climate action (SDG 13), life below water (SDG 14), life on land (SDG 15), peace, justice and strong institutions (SDG 16), and partnerships for the goals (SDG 17).

The IPCC Fifth Assessment Report (AR5) included extensive discussion of links between climate and sustainable development, especially in Chapter 13 (Olsson et al., 2014) and Chapter 20 (Denton et al., 2014) in WGII and Chapter 4 (Fleurbaey et al., 2014) in WGIII. However, the AR5 preceded the 2015 adoption of the SDGs and the literature that argues for their fundamental links to climate (Wright et al., 2015; Salleh, 2016; von Stechow et al., 2016; Hammill and Price-Kelly, 2017; ICSU, 2017; Maupin, 2017; Gomez-Echeverri, 2018).

The SDGs build on efforts under the UN Millennium Development Goals to reduce poverty, hunger and other deprivations. According to the UN, the Millennium Development Goals were successful in reducing poverty and hunger and improving water security (UN, 2015a). However, critics argued that they failed to address within-country disparities, human rights, and key environmental concerns, focused only on developing countries, and had numerous measurement and attribution problems (Langford et al., 2013; Fukuda-Parr et al., 2014). While improvements in water security, slums, and health may have reduced some aspects of climate vulnerability, increases in incomes were linked to rising greenhouse gas (GHG) emissions and thus to a trade-off between development and climate change (Janetos et al., 2012; UN, 2015a; Hubacek et al., 2017).

While the SDGs capture many important aspects of sustainable development, including the explicit goals of poverty eradication and reducing inequality, there are direct connections from climate to other measures of sustainable development including multidimensional poverty, equity, ethics, human security, well-being, and climate-resilient development (Bebbington and Larrinaga, 2014; Robertson, 2014; Redclift and Springett, 2015; Barrington-Leigh, 2016; Helliwell et al., 2018; Kirby and O'Mahony, 2018) (see Glossary). The UN proposes sustainable development as 'eradicating poverty in all its forms and dimensions, combating inequality within and among countries, preserving the planet, creating sustained, inclusive and sustainable economic growth and fostering social inclusion' (UN, 2015b). There is *robust evidence* of the links between climate change and poverty (see Chapter 1, Cross-Chapter Box 4). The AR5 concluded with *high confidence* that disruptive levels of climate change would preclude reducing poverty (Denton et al., 2014; Fleurbaey et al., 2014). International organisations have since stated that climate changes 'undermine the ability of all countries to achieve sustainable development' (UN, 2015b) and can reverse or erase improvements in living conditions and decades of development (Hallegatte et al., 2016).

Climate warming has unequal impacts on different people and places as a result of differences in regional climate changes, vulnerabilities and impacts, and these differences then result in unequal impacts on sustainable development and poverty (Section 5.2). Responses to climate change also interact in complex ways with goals of poverty reduction. The benefits of adaptation and mitigation projects and funding may accrue to some and not others, responses may be costly and unaffordable to some people and countries, and projects may disadvantage some individuals, groups and development initiatives (Sections 5.3 and 5.4; Cross-Chapter Box 11 in Chapter 4).

### *5.1.2 Pathways to 1.5°C*

Pathways to 1.5°C (see Chapter 1, Cross-Chapter Box 1 in Chapter 1, Glossary) include ambitious reductions in emissions and strategies for adaptation that are transformational, as well as complex interactions with sustainable development, poverty eradication, and reducing inequalities. The AR5 WGII introduced the concept of climate-resilient development pathways (CRDPs) (see Glossary) which combine adaptation and mitigation to reduce climate change and its impacts, and emphasise the importance of addressing structural, intersecting inequalities, marginalisation, and multidimensional poverty to 'transform […] the development pathways themselves toward greater social and environmental sustainability, equity, resilience, and justice' (Olsson et al., 2014). This chapter assesses literature on CRDPs relevant to 1.5°C global warming (Section 5.5.3), to understand better the possible societal and systems transformations (see Glossary) that reduce inequality and increase well-being (Figure 5.1). It also summarises the knowledge on conditions to achieve such transformations, including changes in technologies, culture, values, financing, and institutions that support low-carbon and resilient pathways and sustainable development (Section 5.6).

[INSERT FIGURE 5.1 HERE]

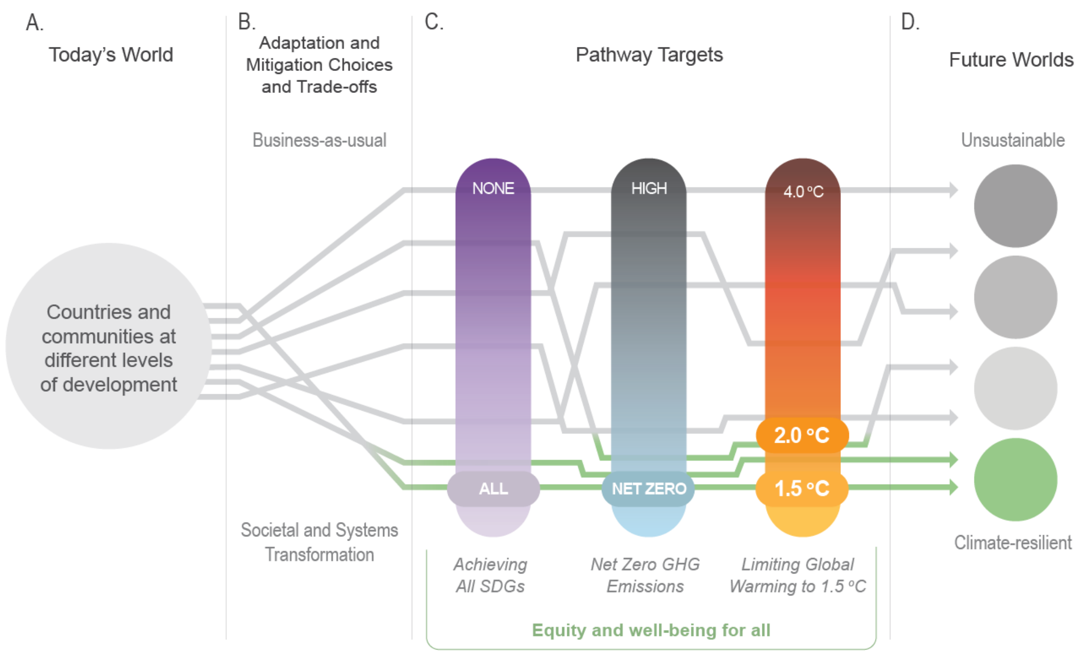


**Figure 5.1:** Climate-resilient development pathways (CRDPs) (green arrows) between a current world in which countries and commuities exist at different levels of development (A) and future worlds that range from

climate-resilient (bottom) to unsustainable (top) (D). CRDPs involve societal transformation rather than business-as-usual approaches, and all pathways involve adaptation and mitigation choices and trade-offs (B). Pathways that achieve the Sustainable Development Goals by 2030 and beyond, strive for net zero emissions around mid-21st century, and stay within the global 1.5°C warming target by the end of the 21st century, while ensuring equity and well-being for all, are best positioned to achieve climate-resilient futures (C). Overshooting on the path to 1.5°C will make achieving CRDPs and other sustainable trajectories more difficult; yet, the limited literature does not allow meaningful estimates.

### *5.1.3 Types of evidence*

We use a variety of sources of evidence to assess the interactions of sustainable development and the SDGs with the causes, impacts, and responses to climate change of 1.5°C warming. We build on Chapter 3 to assess the sustainable development implications of impacts at 1.5°C and 2°C, and Chapter 4 to examine the implications of response measures. We assess scientific and grey literature, with a post-AR5 focus, and data that evaluate, measure, and model sustainable development-climate links from various perspectives, quantitatively and qualitatively, across scales, and through well documented case studies.

Literature that explicitly links 1.5°C global warming to sustainable development across scales remains scarce; yet, we find relevant insights in many recent publications on climate and development that assess impacts across warming levels, the effects of adaptation and mitigation response measures, and interactions with the SDGs. Relevant evidence also stems from emerging literature on possible pathways, overshoot, and enabling conditions (see Glossary) for integrating sustainable development, poverty eradication, and reducing inequalities in the context of 1.5°C.

## 5.2 Poverty, Equality, and Equity Implications of a 1.5°C Warmer World

Climate change could lead to significant impacts on extreme poverty by 2030 (Hallegatte et al., 2016; Hallegatte and Rozenberg, 2017). The AR5 concluded, with *very high confidence*, that climate change and climate variability worsen existing poverty and exacerbate inequalities, especially for those disadvantaged by gender, age, race, class, caste, indigeneity and (dis)ability (Olsson et al., 2014). New literature on these links is substantial, showing that the poor will continue to experience climate change severely, and climate change will exacerbate poverty (Fankhauser and Stern, 2016; Hallegatte et al., 2016; O’Neill et al., 2017a; Winsemius et al., 2018) (*very high confidence*). The understanding of regional impacts and risks of 1.5°C global warming and interactions with patterns of societal vulnerability and poverty remains limited. Yet, identifying and addressing poverty and inequality is at the core of staying within a safe and just space for humanity (Raworth, 2017; Bathiany et al., 2018). Building on relevant findings from Chapter 3 (see Section 3.4), this section examines anticipated impacts and risks of 1.5°C and higher warming on sustainable development, poverty, inequality, and equity (see Glossary).

### *5.2.1 Impacts and Risks of a 1.5°C Warmer World: Implications for Poverty and Livelihoods*

Global warming of 1.5°C will have consequences for sustainable development, poverty and inequalities. This includes residual risks, limits to adaptation, and losses and damages (Cross-Chapter Box 12 in this Chapter; see Glossary). Some regions have already experienced a 1.5°C warming with impacts on food and water security, health, and other components of sustainable development (*medium evidence, medium agreement*) (see Chapter 3, Section 3.4). Climate change is also already affecting poorer subsistence communities through decreases in crop production and quality, increases in crop pests and diseases, and disruption to culture (Savo et al., 2016). It disproportionally affects children and the elderly and can increase gender inequality (Kaijser and Kronsell, 2014; Vinyeta et al., 2015; Carter et al., 2016; Hanna and Oliva, 2016; Li et al., 2016).

At 1.5°C warming, compared to current conditions, further negative consequences are expected for poor people, and inequality and vulnerability (*medium evidence, high agreement*). Hallegatte and Rozenberg (2017) report that, by 2030 (roughly approximating a 1.5°C warming), 122 million additional people could experience extreme poverty, based on a 'poverty scenario' of limited socio-economic progress, comparable to the Shared Socioeconomic Pathway (SSP)4 (inequality), mainly due to higher food prices and declining health, with substantial income losses for the poorest 20% across 92 countries. Pretis et al. (2018) estimate negative impacts on economic growth in lower-income countries at 1.5°C warming, despite uncertainties. Impacts are likely to occur simultaneously across livelihood, food, human, water, and ecosystem security (Byers et al., 2018) (*limited evidence, high agreement*), but the literature on interacting and cascading effects remains scarce (Hallegatte et al., 2014; O'Neill et al., 2017b; Reyer et al., 2017a, b).

Chapter 3 outlines future impacts and risks for ecosystems and human systems, many of which could also undermine sustainable development and efforts to eradicate poverty and hunger, and protect health and ecosystems. Chapter 3 findings (see Section 3.5.2.1) suggest increasing Reasons for Concern from moderate to high at a warming of 1.1 to 1.6°C, including for indigenous people, their livelihoods, and ecosystems in the Arctic (O'Neill et al., 2017b). In 2050, based on the Hadley Centre Climate Prediction Model 3 (HadCM3) and the Special Report on Emission Scenarios (SRES) A1b scenario (roughly comparable to 1.5°C warming), 450 million more flood-prone people would be exposed to doubling in flood frequency, and global flood risk would increase substantially (Arnell and Gosling, 2016). For droughts, poor people are expected to be more exposed (85% in population terms) in a warming scenario greater >1.5°C for several countries in Asia and Southern and Western Africa (Winsemius et al., 2018). In urban Africa, a 1.5°C warming could expose many households to water poverty and increased flooding (Pelling et al., 2018). At 1.5ºC warming, fisheries-dependent and coastal livelihoods, of often disadvantaged populations, would suffer from the loss of coral reefs (see Chapter 3, Box 3.4).

Global heat stress is projected to increase in a 1.5°C warmer world and by 2030, compared to 1961-1990, climate change could be responsible for additional annual deaths of 38,000 people from heat stress, particularly among the elderly, and 48,000 from diarrhoea, 60,000 from malaria, and 95,000 from childhood undernutrition (WHO, 2014). Each 1°C increase could reduce work productivity by 1 to 3% for people working outdoors or without air conditioning, typically the poorer segments of the workforce (Park et al., 2015).

The regional variation in the 'warming experience at 1.5°C' (see Chapter 1, Section 1.3.1) is large (see Chapter 3, Section 3.3.2). Declines in crop yields are widely reported for Africa (60% of observations), with serious consequences for subsistence and rain-fed agriculture and food security (Savo et al., 2016). In Bangladesh, by 2050, damages and losses are expected for poor households dependent on freshwater fish stocks due to lack of mobility, limited access to land, and strong reliance on local ecosystems (Dasgupta et al., 2017). Small Island Developing States (SIDS) are expected to experience challenging conditions at 1.5°C warming due to increased risk of internal migration and displacement and limits to adaptation (see Chapter 3, Box 3.5, Cross-Chapter Box 12 in this Chapter). An anticipated decline of marine fisheries of 3 million metric tonnes per degree warming would have serious regional impacts for the Indo-Pacific region and the Arctic (Cheung et al., 2016).

### *5.2.2 Avoided Impacts of 1.5°C versus 2°C Warming for Poverty and Inequality*

Avoided impacts between 1.5°C and 2°C warming are expected to have significant positive implications for sustainable development, and reducing poverty and inequality. Using the SSPs (see Chapter 1, Cross-Chapter Box 1 in Chapter 1; Section 5.5.2), Byers et al. (2018) model the number of people exposed to multi-sector climate risks and vulnerable to poverty (income < $10/day), comparing 2°C and 1.5°C; the respective declines are from 86 million to 24 million for SSP1 (sustainability), from 498 million to 286 million for SSP2 (middle of the road), and from 1220 million to 763 million for SSP3 (regional rivalry), which suggests overall 62-457 million less people exposed and vulnerable at 1.5°C warming. Across the SSPs, the largest populations exposed and vulnerable are in South Asia (Byers et al., 2018). The avoided impacts on poverty at 1.5°C relative to 2°C are projected to depend at least as much or more on development scenarios than on warming (Wiebe et al., 2015; Hallegatte and Rozenberg, 2017).

Limiting warming to 1.5°C is expected to reduce the people exposed to hunger, water stress, and disease in Africa (Clements, 2009). It is also expected to limit the number of poor people exposed to floods and droughts at higher degrees of warming, especially in African and Asian countries (Winsemius et al., 2018). Challenges for poor populations relating to food and water security, clean energy access, and environmental well-being are projected to be less at 1.5°C, particularly for vulnerable people in Africa and Asia (Byers et al., 2018). The overall projected socio-economic losses compared to present day are less at 1.5°C (8% loss of gross domestic product per capita) compared to 2°C (13%), with lower-income countries projected to experience greater losses, which may increase economic inequality between countries (Pretis et al., 2018).

### *5.2.3 Risks from 1.5°C versus 2°C Global Warming and the Sustainable Development Goals*

The risks that can be avoided by limiting global warming to 1.5ºC rather than 2°C have many complex implications for sustainable development (ICSU, 2017; Gomez-Echeverri, 2018). There is *high confidence* that constraining warming to 1.5°C rather than 2°C would reduce risks for unique and threatened ecosystems, safeguarding the services they provide for livelihoods and sustainable development, and making adaptation much easier (O'Neill et al., 2017b), particularly in Central America, the Amazon, South Africa, and Australia (Schleussner et al., 2016; O'Neill et al., 2017b; Reyer et al., 2017b; Bathiany et al., 2018).

In places that already bear disproportionate economic and social challenges to their sustainable development, people will face lower risks at 1.5°C compared to 2°C. These include North Africa and the Levant (less water scarcity), West Africa (less crop loss), South America and South-East Asia (less intense heat), and many other coastal nations and island states (lower sea-level rise, less coral reef loss) (Schleussner et al., 2016; Betts et al., 2018). The risks for food, water, and ecosystems, particularly in subtropical regions such as Central America, and countries such as South Africa and Australia, are expected to be lower at 1.5°C than at 2°C warming (Schleussner et al., 2016). Less people would be exposed to droughts and heat waves and the associated health impacts in countries such as Australia and India (King et al., 2017; Mishra et al., 2017).

Limiting warming to 1.5°C will make it markedly easier to achieve the SDGs for poverty eradication, water access, safe cities, food security, healthy lives, and inclusive economic growth, and will help to protect terrestrial ecosystems and biodiversity (*medium evidence, high agreement)* (Table 5.3 (see available as a supplementary pdf)). For example, limiting species loss and expanding climate refugia will make it easier to achieve SDG 15 (see Chapter 3, Section 3.4.3). One indication of how lower temperatures benefit the SDGs is to compare the impacts of Representative Concentration Pathway (RCP)4.5 (lower emissions) and RCP8.5 (higher emissions) on the SDGs (Ansuategi et al., 2015). A low emissions pathway allows for greater success in achieving SDGs for reducing poverty and hunger, providing access to clean energy, reducing inequality, ensuring education for all, and making cities more sustainable. Even at lower emissions, a medium risk of failure exists to meet goals for water and sanitation, and marine and terrestrial ecosystems.

Action on climate change (SDG 13), including slowing the rate of warming, would help reach the goals for water, energy, food, and land (SDGs 6, 7, 2, and 15) (Obersteiner et al., 2016; ICSU, 2017) and contribute to poverty eradication (SDG 1) (Byers et al., 2018). Although the literature that connects 1.5°C to the SDGs is limited, stabilising warming at 1.5°C by the end of the century is expected to increase the chances of achieving the SDGs by 2030, with greater potentials to eradicate poverty, reduce inequality, and foster equity (*limited evidence*, *medium agreement*). There are no studies on overshoot and dimensions of sustainable development, although literature on 4°C suggests the impacts would be severe (Reyer et al., 2017b).

**Table 5.1:** Sustainable development implications of avoided impacts between 1.5°C and 2°C global warming

| Impacts | Chapter 3 section | 1.5°C | 2°C | Sustainable development goals (SDGs) more easily achieved when limiting warming to 1.5°C |
|---|---|---|---|---|
| **Water scarcity** | 3.4.2.1 | 4% more people exposed to water stress | 8% more people exposed to water stress with 184-270 million people more exposed | SDG 6 water availability for all |
| | Table 3.4 | 496 (range 103-1159) million people exposed and vulnerable to water stress | 586 (range 115-1347) million people exposed and vulnerable to water stress | |
| **Ecosystems** | 3.4.3 Table 3.4 | Around 7% of land area experiences biome shifts | Around 13% (range 8-20%) of land area experiences biome shifts | SDG 15 to protect terrestrial ecosystems and halt biodiversity loss |
| | Box 3.5 | 70-90% of coral reefs at risk from bleaching | 99% of coral reefs at risk from bleaching | |
| **Coastal cities** | 3.4.5.2 | Less cities and coasts exposed to sea level rise and extreme events | More people and cities exposed to flooding | SDG 11 to make cities and human settlements safe and resilient |
| | 3.4.5.1 | 31-69 million people exposed to coastal flooding | 32-79 million exposed to coastal flooding | |
| **Food systems** | 3.4.6 and Box 3.1 | Significant declines in crop yields avoided, some yields may increase | Average crop yields decline | SDG 2 to end hunger and achieve food security |
| | Table 3.4 | 32-36 million people exposed to lower yields | 330-396 million people exposed to lower yields | |
| **Health** | 3.4.7 | Lower risk of temperature related morbidity and smaller mosquito range | Higher risks of temperature related morbidity and mortality and larger range of mosquitoes | SDG 3 to ensure healthy lives for all |
| | Table 3.4 | 3546-4508 million people exposed to heatwaves | 5417-6710 million people exposed to heatwaves | |

[INSERT CROSS-CHAPTER BOX 12 HERE]

**Cross-Chapter Box 12:** Residual risks, limits to adaptation and loss and damage

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**Introduction**

Residual climate-related risks, limits to adaptation, and loss and damage (see Glossary) are increasingly assessed in the scientific literature (van der Geest and Warner, 2015; Boyd et al., 2017; Mechler et al., 2018). The AR5 (IPCC, 2013; Oppenheimer et al., 2014) documented impacts that have been detected and attributed to climate change, projected increasing climate-related risks with continued global warming, and recognised barriers and limits to adaptation. It recognised that adaptation is constrained by biophysical, institutional, financial, social, and cultural factors, and that the interaction of these factors with climate change can lead to soft adaptation limits (adaptive actions currently not available) and hard adaptation limits (adaptive actions appear infeasible leading to unavoidable impacts) (Klein et al., 2014).

**Loss and damage - concepts and perspectives**

"Loss and Damage" (L&D) has been discussed in international climate negotiations for three decades (INC, 1991; Calliari, 2016; Vanhala and Hestbaek, 2016). A work programme on L&D was established as part of the Cancun Adaptation Framework in 2010 supporting developing countries particularly vulnerable to climate change impacts (UNFCCC, 2010). Conference of the Parties (COP) 19 in 2013 established the Warsaw International Mechanism for Loss and Damage (WIM) as a formal part of the United Nations Framework Convention on Climate Change (UNFCCC) architecture (UNFCCC, 2013). It acknowledges that L&D "includes, and in some cases involves more than, that which can be reduced by adaptation" (UNFCCC, 2013). The Paris Agreement recognised "the importance of averting, minimising and addressing loss and damage associated with the adverse effects of climate change" through Article 8 (UNFCCC, 2015).

There is no one definition of L&D in climate policy, and analysis of policy documents and stakeholder views has demonstrated ambiguity (Vanhala and Hestbaek, 2016; Boyd et al., 2017). UNFCCC documents suggest that L&D is associated with adverse impacts of climate change on human and natural systems, including impacts from extreme events and slow-onset processes (UNFCCC, 2011, 2013, 2015). Some documents focus on impacts in developing or particularly vulnerable countries (UNFCCC, 2011, 2013). They refer to economic (loss of assets and crops) and non-economic (biodiversity, culture, health) impacts, the latter also being an action area under the WIM workplan, and irreversible and permanent loss and damage. Lack of clarity of what the term addresses (avoidance through adaptation and mitigation, unavoidable losses, climate risk management, existential risk) was expressed among stakeholders, with further disagreement ensuing about what constitutes anthropogenic climate change *versus* natural climate variability (Boyd et al., 2017).

**Limits to adaptation and residual risks**

The AR5 described adaptation limits as points beyond which actors' objectives are compromised by intolerable risks threatening key objectives such as good health or broad levels of well-being, thus requiring transformative adaptation for overcoming soft limits (Dow et al., 2013; Klein et al., 2014) (see Chapter 4, Sections 4.2.2.3 and 4.5.3; Cross-Chapter Box 9 in Chapter 4; Section 5.3.1). The AR5 WGII risk tables, based on expert judgment, depicted the potential for, and the limits of, additional adaptation to reduce risk. Near-term (2030-2040) risks can be used as a proxy for 1.5°C warming by the end of the century, and compared to longer-term (2080-2100) risks associated with an approximate 2°C warming. Building on the AR5 risk approach, Figure 5.2 provides a stylised application example to poverty and inequality.

**[INSERT CROSS-CHAPTER BOX 12, FIGURE 5.2 HERE]**


**Figure 5.2:** Stylised reduced risk levels due to avoided impacts between 2°C and 1.5°C warming (in solid red-orange), additional avoided impacts with adaptation under 2°C (striped orange) and under 1.5°C (striped yellow), and unavoidable impacts (losses) with no or very limited potential for adaptation (grey), extracted from the AR5 WGII risk tables (Field et al., 2014), and underlying chapters by Adger et al. (2014) and Olsson et al. (2014). For some systems and sectors (A), achieving 1.5°C could reduce risks to low (with adaptation) from very high (without adaptation) and high (with adaptation) under 2°C. For other areas (C), no or very limited adaptation potential is anticipated, suggesting limits, with the same risks for 1.5°C and 2°C. Other risks are projected to be medium under 2°C with further potential for reduction, especially with adaptation, to very low levels (B).

**Limits to adaptation, residual risks, and losses in a 1.5°C warmer world**
The literature on risks at 1.5°C (versus 2°C and more) and potentials for adaptation remains limited, particularly for specific regions, sectors, and vulnerable and disadvantaged populations. Adaptation potential at 1.5°C and 2°C is rarely assessed explicitly, making an assessment of residual risk challenging. Substantial progress has been made since the AR5 to assess which climate change impacts on natural and human systems can be attributed to anthropogenic emissions (Hansen and Stone, 2016) and to examine the influence of anthropogenic emissions on extreme weather events (NASEM, 2016), and on consequent impacts on human life (Mitchell et al., 2016), but less so on monetary losses and risks (Schaller et al., 2016). There has also been some limited research to examine local-level limits to adaptation (Warner and Geest, 2013; Filho and Nalau, 2018). What constitutes losses and damages is context-dependent and often requires place-based research into what people value and consider worth protecting (Barnett et al., 2016; Tschakert et al., 2017). Yet, assessments of non-material and intangible losses are particularly challenging, such as loss of sense of place, belonging, identity, and damages to emotional and mental wellbeing (Serdeczny et al., 2017; Wewerinke-Singh, 2018a). Warming of 1.5°C is not considered 'safe' for most nations, communities, ecosystems, and sectors and poses significant risks to natural and human systems as compared to current warming of 1°C (*high confidence*) (see Chapter 3, Section 3.4, Box 3.4, Box 3.5, Cross-Chapter Box 6 in Chapter 3). Table 5.2, drawing on findings from Chapters 3, 4 and 5, presents examples of soft and hard limits in natural and human systems in the context of 1.5°C and 2°C of warming.

**Table 5.2:** Soft and hard adaptation limits in the context of 1.5°C and 2°C of global warming

| System/Region | Example | Soft Limit | Hard Limit |
|---|---|---|---|
| Coral reefs | Loss of 70-90% of tropical coral reefs by mid-century under 1.5°C scenario (total loss under 2°C scenario) (se Chapter 3, Sections 3.4.4 and 3.5.2.1, Box 3.4) | | ✓ |
| Biodiversity | 6% of insects, 8% of plants and 4% of vertebrates lose over 50% of the climatically determined geographic range at 1.5°C (18% of insects, 16% of plants, 8% of vertebrates at 2°C) (see Chapter 3, Section 3.4.3.3) | | ✓ |
| Poverty | 24-357 million people exposed to multi-sector climate risks and vulnerable to poverty at 1.5°C (86-1,220 million at 2°C) (see Section 5.2.2) | ✓ | |
| Human health | Twice as many megacities exposed to heat stress at 1.5°C compared to present, potentially exposing 350 million additional people to deadly heat wave conditions by 2050 (see Chapter 3, Section 3.4.8) | ✓ | ✓ |
| Coastal livelihoods | Large-scale changes in oceanic systems (temperature, acidification) inflict damage and losses to livelihoods, income, cultural identity and health for coastal-dependent communities at 1.5°C (potential higher losses at 2°C) (see Chapter 3, Sections 3.4.4, 3.4.5, 3.4.6.3, Box 3.4, Box 3.5, Cross-Chapter Box 6; Chapter 4, Section 4.3.5; Section 5.2.3) | ✓ | ✓ |
| Small Island Developing States | Sea level rise and increased wave run up combined with increased aridity and decreased freshwater availability at 1.5°C warming potentially leaving several atoll islands uninhabitable (see Chapter 3, Sections 3.4.3, 3.4.5, Box 3.5; Chapter 4, Cross-Chapter Box 9) | | ✓ |

**Approaches and policy options to address residual risk and loss and damage**
Conceptual and applied work since the AR5 has highlighted the synergies and differences with adaptation and disaster risk reduction policies (van der Geest and Warner, 2015; Thomas and Benjamin, 2017), suggesting more integration of existing mechanisms, yet careful consideration is advised for slow-onset and potentially irreversible impacts and risk (Mechler and Schinko, 2016). Scholarship on justice and equity has

provided insight on compensatory, distributive, and procedural equity considerations for policy and practice to address loss and damage (Roser et al., 2015; Wallimann-Helmer, 2015; Huggel et al., 2016). A growing body of legal literature considers the role of litigation in preventing and addressing loss and damage and finds that litigation risks for governments and business are bound to increase with improved understanding of impacts and risks as climate science evolves (*high confidence*) (Mayer, 2016; Banda and Fulton, 2017; Marjanac and Patton, 2018; Wewerinke-Singh, 2018b). Policy proposals include international support for experienced losses and damages (Crosland et al., 2016; Page and Heyward, 2017), addressing climate displacement, donor-supported implementation of regional public insurance systems (Surminski et al., 2016) and new global governance systems under the UNFCCC (Biermann and Boas, 2017).

[END CROSS-CHAPTER BOX 12]

## 5.3 Climate Adaptation and Sustainable Development

Adaptation will be extremely important in a 1.5°C warmer world since substantial impacts will be felt in every region (*high confidence*) (Chapter 3, Section 3.3), even if adaptation needs will be lower than in a 2°C warmer world (see Chapter 4, Sections 4.3.1 to 4.3.5, 4.5.3, Cross-Chapter Box 10 in Chapter 4). Climate adaptation options comprise structural, physical, institutional, and social responses, with their effectiveness depending largely on governance (see Glossary), political will, adaptive capacities, and availability of finance (Betzold and Weiler, 2017; Sonwa et al., 2017; Sovacool et al., 2017) (see Chapter 4, Sections 4.4.1 to 4.4.5). Even though the literature is scarce on the expected impacts of future adaptation measures on sustainable development specific to warming experiences of 1.5°C, this section assesses available literature on how (i) prioritising sustainable development enhances or impedes climate adaptation efforts (Section 5.3.1); (ii) climate adaptation measures impact sustainable development and the Sustainable Development Goals (SDGs) in positive (synergies) or negative (trade-offs) ways (Section 5.3.2); and (iii) adaptation pathways towards a 1.5°C warmer world affect sustainable development, poverty, and inequalities (Section 5.3.3). The section builds on Chapter 4 (see Section 4.3.5) regarding available adaptation options to reduce climate vulnerability and build resilience (see Glossary) in the context of 1.5°C-compatible trajectories, here with emphasis on sustainable development implications.

### *5.3.1 Sustainable Development in Support of Climate Adaptation*

Making sustainable development a priority, and meeting the SDGs, is consistent with efforts to adapt to climate change (*very high confidence*). Sustainable development is effective in building adaptive capacity if it addresses poverty and inequalities, social and economic exclusion, and inadequate institutional capacities (Noble et al., 2014; Abel et al., 2016; Colloff et al., 2017). Four ways in which sustainable development leads to effective adaptation are described below.

Firstly, sustainable development enables transformational adaptation (see Chapter 4, Section 4.2.2.2) when an integrated approach is adopted, with inclusive, transparent decision making, rather than addressing current vulnerabilities as stand-alone climate problems (Mathur et al., 2014; Arthurson and Baum, 2015; Shackleton et al., 2015; Lemos et al., 2016; Antwi-Agyei et al., 2017b). Ending poverty in its multiple dimensions (SDG 1) is often a highly effective form of climate adaptation (Fankhauser and McDermott, 2014; Leichenko and Silva, 2014; Hallegatte and Rozenberg, 2017). However, ending poverty is not sufficient, and the positive outcome as an adaptation strategy depends on whether increased household wealth is actually directed towards risk reduction and management strategies (Nelson et al., 2016), as shown in urban municipalities (Colenbrander et al., 2017; Rasch, 2017) and agrarian communities (Hashemi et al., 2017), and whether finance for adaptation is made available (Section 5.6.1).

Secondly, local participation is effective when wider socio-economic barriers are addressed via multi-scale planning (McCubbin et al., 2015; Nyantakyi-Frimpong and Bezner-Kerr, 2015; Toole et al., 2016). This is the case, for instance, when national education efforts (SDG 4) (Muttarak and Lutz, 2014; Striessnig and

Loichinger, 2015) and indigenous knowledge (Nkomwa et al., 2014; Pandey and Kumar, 2018) enhance information sharing, which also builds resilience (Santos et al., 2016; Martinez-Baron et al., 2018) and reduces risks for maladaptation (Antwi-Agyei et al., 2018; Gajjar et al., 2018).

Thirdly, development promotes transformational adaptation when addressing social inequalities (Section 5.5.3, 5.6.4), as in SDGs 4, 5, 16, and 17 (O'Brien et al., 2015; K. O'Brien, 2016). For example, SDG 5 supports measures that reduce women's vulnerabilities and allow women to benefit from adaptation (Antwi-Agyei et al., 2015; Van Aelst and Holvoet, 2016; Cohen, 2017). Mobilisation of climate finance, carbon taxation, and environmentally-motivated subsidies can reduce inequalities (SDG 10), advance climate mitigation and adaptation (Chancel and Picketty, 2015), and be conducive to strengthening and enabling environments for resilience building (Nhamo, 2016; Halonen et al., 2017).

Fourthly, when sustainable development promotes livelihood security, it enhances the adaptive capacities of vulnerable communities and households. Examples include SDG 11 supporting adaptation in cities to reduce harm from disasters (Kelman, 2017; Parnell, 2017); access to water and sanitation (SDG 6) with strong institutions (SDG 16) (Rasul and Sharma, 2016); SDG 2 and its targets that promote adaptation in agricultural and food systems (Lipper et al., 2014); and targets for SDG 3 such as reducing infectious diseases and providing health cover are consistent with health-related adaptation (ICSU, 2017; Gomez-Echeverri, 2018).

Sustainable development has the potential to significantly reduce systemic vulnerability, enhance adaptive capacity, and promote livelihood security for poor and disadvantaged populations (*high confidence*). Transformational adaptation (see Chapter 4, Sections 4.2.2.2 and 4.5.3) would require development that takes into consideration multidimensional poverty and entrenched inequalities, local cultural specificities, and local knowledge in decision-making, thereby making it easier to achieve the SDGs in a 1.5°C warmer world (*medium evidence, high agreement*).

### *5.3.2 Synergies and Trade-offs between Adaptation Options and Sustainable Development*

There are short-, medium-, and long-term positive impacts (synergies) and negative impacts (trade-offs) between the dual goal of keeping temperatures below 1.5°C global warming and achieving sustainable development. The extent of synergies between development and adaptation goals will vary by the development process adopted for a particular SDG and underlying vulnerability contexts (*medium evidence, high agreement*). Overall, the impacts of adaptation on sustainable development, poverty eradication, and reducing inequalities in general, and the SDGs specifically, are expected to be largely positive, given that the inherent purpose of adaptation is to lower risks. Building on Chapter 4 (see Section 4.3.5), this section examines synergies and trade-offs between adaptation and sustainable development for some key sectors and approaches, also.

*Agricultural adaptation*: The most direct synergy is between SDG 2 (zero hunger) and adaptation in cropping, livestock, and food systems, designed to maintain or increase production (Lipper et al., 2014; Rockström et al., 2017). Farmers with effective adaptation strategies tend to enjoy higher food security and experience lower levels of poverty (FAO, 2015; Douxchamps et al., 2016; Ali and Erenstein, 2017). Vermeulen et al. (2016) report strong positive returns on investment across the world from agricultural adaptation with side benefits for environment and economic well-being. Well-adapted agricultural systems contribute to safe drinking water, health, biodiversity, and equity goals (DeClerck et al., 2016; Myers et al., 2017). Climate-smart agriculture has synergies with food security, though it can be biased towards technological solutions, may not be gender sensitive, and can create specific challenges for institutional and distributional aspects (Lipper et al., 2014; Arakelyan et al., 2017; Taylor, 2017).

At the same time, adaptation options increase risk for human health, oceans, and access to water if fertiliser and pesticides are used without regulation or when irrigation reduces water availability for other purposes (Shackleton et al., 2015; Campbell et al., 2016). When agricultural insurance and climate services overlook the poor, inequality may rise (Dinku et al., 2014; Carr and Owusu-Daaku, 2015; Carr and Onzere, 2017; Georgeson et al., 2017a). Agricultural adaptation measures may increase workloads, especially for women, while changes in crop mix can result in loss of income or culturally inappropriate food (Carr and Thompson, 2014; Thompson-Hall et al., 2016; Bryan et al., 2017), and they may benefit farmers with more land to the detriment of land-poor farmers, as seen in the Mekong River Basin (see Chapter 3, Cross-Chapter Box 6 in Chapter 3).

*Adaptation to protect human health*: Adaptation options in the health sector are expected to reduce morbidity and mortality (Arbuthnott et al., 2016; Ebi and Del Barrio, 2017). Heat-early-warning systems help lower injuries, illnesses, and deaths (Hess and Ebi, 2016), with positive impacts for SDG 3. Institutions better equipped to share information, indicators for detecting climate-sensitive diseases, improved provision of basic health care services, and coordination with other sectors also improve risk management, thus reducing adverse health outcomes (Dasgupta et al., 2016; Dovie et al., 2017). Effective adaptation creates synergies via basic public health measures (K.R. Smith et al., 2014; Dasgupta, 2016) and health infrastructure protected from extreme weather events (Watts et al., 2015). Yet, trade-offs can occur when adaptation in one sector leads to negative impacts in another sector. Examples include the creation of urban wetlands through flood control measures which can breed mosquitoes, and migration eroding physical and mental well-being, hence adversely affecting SDG 3 (K.R. Smith et al., 2014; Watts et al., 2015). Similarly, increased use of air conditioning enhances resilience to heat stress (Petkova et al., 2017); yet it can result in higher energy consumption, undermining SDG 13.

*Coastal adaptation*: Adaptation to sea-level rise remains essential in coastal areas even under a climate stabilisation scenario of 1.5°C (Nicholls et al., 2018). Coastal adaptation to restore ecosystems (for instance by planting mangrove forests) support SDGs for enhancing life and livelihoods on land and oceans (see Chapter 4, Sections 4.3.2.3). Synergistic outcomes between development and relocation of coastal communities are enhanced by participatory decision-making and settlement designs that promote equity and sustainability (Voorn et al., 2017). Limits to coastal adaptation may rise, for instance in low-lying islands in the Pacific, Caribbean, and Indian Ocean, with attendant implications for loss and damage (see Chapter 3 Box 3.5, Chapter 4, Cross-Chapter Box 9 in Chapter 4, Cross-Chapter 12 in Chapter 5, Box 5.3).

*Migration as adaptation*: Migration has been used in various contexts to protect livelihoods from challenges related to climate change (Marsh, 2015; Jha et al., 2017), including through remittances (Betzold and Weiler, 2017). Synergies between migration and the achievement of sustainable development depend on adaptive measures and conditions in both sending and receiving regions (Fatima et al., 2014; McNamara, 2015; Entzinger and Scholten, 2016; Ober and Sakdapolrak, 2017; Schwan and Yu, 2017). Adverse developmental impacts arise when vulnerable women or the elderly are left behind or if migration is culturally disruptive (Wilkinson et al., 2016; Albert et al., 2017; Islam and Shamsuddoha, 2017).

*Ecosystem-based adaptation (EBA)*: EBA can offer synergies with sustainable development (Morita and Matsumoto, 2015; Ojea, 2015; Szabo et al., 2015; Brink et al., 2016; Butt et al., 2016; Conservation International, 2016; Huq et al., 2017), although assessments remain difficult (Doswald et al., 2014) (see Chapter 4, Section 4.3.2.2). Examples include mangrove restoration reducing coastal vulnerability, protecting marine and terrestrial ecosystems, and increasing local food security; as well as watershed management reducing flood risks and improving water quality (Chong, 2014). In drylands, EBA practices, combined with community-based adaptation, have shown how to link adaptation with mitigation to improve livelihood conditions of poor farmers (Box 5.1). Synergistic developmental outcomes arise where EBA is cost effective, inclusive of indigenous and local knowledge, and easily accessible by the poor (Ojea, 2015; Daigneault et al., 2016; Estrella et al., 2016). Payment for ecosystem services can provide incentives to land owners and natural resource managers to preserve environmental services with synergies with SDGs 1 and 13 (Arriagada et al., 2015), when implementation challenges are overcome (Calvet-Mir et al., 2015; Wegner, 2016; Chan et al., 2017). Trade-offs include loss of other economic land use types, tension between biodiversity and adaptation priorities, and conflicts over governance (Wamsler et al., 2014; Ojea, 2015).

*Community-based adaptation (CBA)*: CBA (see Chapter 4, Sections 4.3.3.2) enhances resilience and sustainability of adaptation plans (Ford et al., 2016; Fernandes-Jesus et al., 2017; Grantham and Rudd, 2017; Gustafson et al., 2017). Yet, negative impacts occur if it fails to fairly represent vulnerable populations and to foster long-term social resilience (Ensor, 2016; Taylor Aiken et al., 2017). Mainstreaming CBA into planning and decision-making enables the attainment of SDG 5, 10, and 16 (Archer et al., 2014; Reid and Huq, 2014; Vardakoulias and Nicholles, 2014; Cutter, 2016; Kim et al., 2017). Incorporating multiple forms of indigenous and local knowledge (ILK) is an important element of CBA, as shown for instance in the Arctic region (Apgar et al., 2015; Armitage, 2015; Pearce et al., 2015; Chief et al., 2016; Cobbinah and Anane, 2016; Ford et al., 2016) (see Chapter 4, Cross-Chapter Box 9, Box 4.3, Section 4.3.5.5). ILK can be synergistic with achieving SDGs 2, 6, and 10 (Ayers et al., 2014; Lasage et al., 2015; Regmi and Star, 2015; Berner et al., 2016; Chief et al., 2016; Murtinho, 2016; Reid, 2016).

There are clear synergies between adaptation options and several SDGs, such as poverty eradication, elimination of hunger, clean water, and health (*robust evidence, high agreement*) as well-integrated adaptation supports sustainable development (Eakin et al., 2014; Weisser et al., 2014; Adam, 2015; Smucker et al., 2015). Substantial synergies are observed in the agricultural and health sectors, and in ecosystem-based adaptations. However, particular adaptation strategies can lead to adverse consequences for developmental outcomes (*medium evidence, high agreement*). Adaptation strategies that advance one SDG can result in trade-offs with other SDGs, for instance, agricultural adaptation to enhance food security (SDG 2) causing negative impacts for health, equality, and healthy ecosystems (SDGs 3, 5, 6, 10, 14 and 15), and resilience to heat stress increasing energy consumption (SDGs 3 and 7), and high-cost adaptation in resource-constrained contexts (*medium evidence, medium agreement*).

### *5.3.3 Adaptation Pathways toward a 1.5°C Warmer World and Implications for Inequalities*

In a 1.5°C warmer world, adaptation measures and options would need to be intensified, accelerated, and scaled up. This entails not only the right 'mix' of options (asking 'right for whom and for what?') but also a forward-looking understanding of dynamic trajectories, that is adaptation pathways (see Chapter 1, Cross-Chapter Box 1 in Chapter 1), best understood as decision-making processes over sets of potential action sequenced over time (Câmpeanu and Fazey, 2014; Wise et al., 2014). Given the scarcity of literature on adaptation pathways that navigate place-specific warming experiences at 1.5°C, this section presents insights into current local decision making for adaptation futures. This grounded evidence shows that choices between possible pathways, at different scales and for different groups of people, are shaped by uneven power structures and historical legacies that create their own, often unforeseen change (Fazey et al., 2016; Bosomworth et al., 2017; Lin et al., 2017; Murphy et al., 2017; Pelling et al., 2018).

Pursuing a place-specific adaptation pathway approach toward a 1.5°C warmer world harbours the potential for significant positive outcomes, with synergies for well-being possibilities to 'leap-frog the SDGs' (J.R.A. Butler et al., 2016), in countries at all levels of development (*medium evidence, high agreement*). It allows for identifying local, socially-salient tipping points before they are crossed, based on what people value and trade-offs that are acceptable to them (Barnett et al., 2014, 2016; Gorddard et al., 2016; Tschakert et al., 2017). Yet, evidence also reveals adverse impacts that reinforce rather than reduce existing social inequalities and hence may lead to poverty traps (Nagoda, 2015; Warner et al., 2015; Barnett et al., 2016; J.R.A. Butler et al., 2016; Godfrey-Wood and Naess, 2016; Pelling et al., 2016; Albert et al., 2017; Murphy et al., 2017) (*medium evidence, high agreement*).

Past development trajectories as well as transformational adaptation plans can constrain adaptation futures by reinforcing dominant political-economic structures and processes, and narrowing option spaces; this leads to maladaptive pathways that preclude alternative, locally-relevant, and sustainable development initiatives and increase vulnerabilities (Warner and Kuzdas, 2017; Gajjar et al., 2018). Such dominant pathways tend to validate the practices, visions, and values of existing governance regimes and powerful members of a community while devaluing those of less privileged stakeholders. Examples from Romania, the Solomon Islands, and Australia illustrate such pathway dynamics in which individual economic gains and prosperity matter more than community cohesion and solidarity; this discourages innovation, exacerbates inequalities, and further erodes adaptive capacities of the most vulnerable (Davies et al., 2014; Fazey et al., 2016; Bosomworth et al., 2017). In the city of London, United Kingdom, the dominant adaptation and disaster risk management pathway promotes resilience that emphasises self-reliance; yet, it intensifies the burden on low-income citizens, the elderly, migrants, and others unable to afford flood insurance or protect themselves against heat waves (Pelling et al., 2016). Adaptation pathways in the Bolivian Altiplano have transformed subsistence farmers into world-leading quinoa producers, but loss of social cohesion and traditional values, dispossession, and loss of ecosystem services now constitute undesirable trade-offs (Chelleri et al., 2016).

A narrow view of adaptation decision making, for example focused on technical solutions, tends to crowd out more participatory processes (Lawrence and Haasnoot, 2017; Lin et al., 2017), obscures contested values, and reinforces power asymmetries (Bosomworth et al., 2017; Singh, 2018). A situated and context-specific understanding of adaptation pathways that galvanises diverse knowledge, values, and joint initiatives, helps to overcome dominant path dependencies, avoid trade-offs that intensify inequities, and challenge policies detached from place (Fincher et al., 2014; Wyborn et al., 2015; Murphy et al., 2017; Gajjar et al., 2018). These insights suggest that adaptation pathway approaches to prepare for 1.5°C warmer futures would be difficult to achieve without considerations for inclusiveness, place-specific trade-off deliberations, redistributive measures, and procedural justice mechanisms to facilitate equitable transformation (*medium evidence, high agreement*).

[INSERT BOX 5.1 HERE]

**Box 5.1:** Ecosystem- and Community-based Practices in Drylands

Drylands face severe challenges in building climate resilience (Fuller and Lain, 2017), yet, small-scale farmers can play a crucial role as agents of change through ecosystem- and community-based practices that combine adaptation, mitigation, and sustainable development.

Farmer Managed Natural Regeneration (FMNR) of trees in cropland is practised in 18 countries across Sub-Saharan Africa, Southeast Asia, Timor-Leste, India, and Haiti and has, for example, permitted the restoration of over five million hectares of land in the Sahel (Niang et al., 2014; Bado et al., 2016). In Ethiopia, the Managing Environmental Resources to Enable Transitions (MERET) programme, which entails community-based watershed rehabilitation in rural landscapes, supported around 648,000 people, resulting in the rehabilitation of 25,400,000 hectares of land in 72 severely food-insecure districts across Ethiopia during 2012–2015 (Gebrehaweria et al., 2016). In India, local farmers have benefitted from watershed programmes across different agro-ecological regions (Singh et al., 2014; Datta, 2015).

These low-cost, flexible community-based practices represent low-regrets adaptation and mitigation strategies. These strategies often contribute to strengthened ecosystem resilience and biodiversity, increased agricultural productivity and food security, reduced household poverty and drudgery for women, and enhanced agency and social capital (Niang et al., 2014; Francis et al., 2015; Kassie et al., 2015; Mbow et al., 2015; Reij and Winterbottom, 2015; Weston et al., 2015; Bado et al., 2016; Dumont et al., 2017). Small check dams in dryland areas and conservation agriculture can significantly increase agricultural output (Kumar et al., 2014; Agoramoorthy and Hsu, 2016; Pradhan et al., 2018). Mitigation benefits have also been quantified (Weston et al., 2015); for example, FMNR over five million hectares in Niger has sequestered 25–30 Mtonnes of carbon over 30 years (Stevens et al., 2014).

However, several constraints hinder scaling-up efforts: inadequate attention to the socio-technical processes of innovation (Grist et al., 2017; Scoones et al., 2017), difficulties in measuring the benefits of an innovation (Coe et al., 2017), farmers' inability to deal with long-term climate risk (Singh et al., 2017), and difficulties for matching practices with agro-ecological conditions and complementary modern inputs (Kassie et al., 2015). Key conditions to overcome these challenges include: developing agroforestry value chains and markets (Reij and Winterbottom, 2015) and adaptive planning and management (Gray et al., 2016). Others include inclusive processes giving greater voice to women and marginalised groups (MRFCJ, 2015a; UN Women and MRFCJ, 2016; Dumont et al., 2017), strengthening of community land and forest rights

(Stevens et al., 2014; Vermeulen et al., 2016) and co-learning among communities of practice at different scales (Coe et al., 2014; Reij and Winterbottom, 2015; Sinclair, 2016; Binam et al., 2017; Dumont et al., 2017; Epule et al., 2017).

[END BOX 5.1]

## 5.4 Mitigation and Sustainable Development

The AR5 WGIII examined the potential of various mitigation options for specific sectors (energy supply, industry, buildings, transport, and Agriculture, Forestry, and Other Land Use (AFOLU); it provided a narrative of dimensions of sustainable development and equity as a framing for evaluating climate responses and policies, respectively, in Chapters 4, 7, 8, 9, 10, and 11 (IPCC, 2014a). This section builds on analysis of Chapters 2 and 4 of this report to re-assess mitigation and sustainable development in the context of 1.5°C global warming as well as the Sustainable Development Goals (SDGs).

### *5.4.1 Synergies and Trade-offs between Mitigation Options and Sustainable Development*

Adopting stringent climate mitigation options can generate multiple positive non-climate benefits that have the potential to reduce the costs of achieving sustainable development (IPCC, 2014b; Ürge-Vorsatz et al., 2014, 2016; Schaeffer et al., 2015; von Stechow et al., 2015). Understanding the positive impacts (synergies) but also the negative impacts (trade-offs) is key for selecting mitigation options and policy choices that maximise the synergies between mitigation and developmental actions (Hildingsson and Johansson, 2015; Nilsson et al., 2016; Delponte et al., 2017; van Vuuren et al., 2017b; McCollum et al., 2018).
Aligning mitigation response options to sustainable development objectives can ensure public acceptance (IPCC, 2014a), encourage faster action (Lechtenboehmer and Knoop, 2017), and support the design of equitable mitigation (Holz et al., 2017; Winkler et al., 2018) that protect human rights (MRFCJ, 2015b) (Section 5.5.3).

This sub-section assesses available literature on the interactions of individual mitigation options (see Chapter 2, Sections 2.3.1.2, Chapter 4, Sections 4.2 and 4.3) with sustainable development and the SDGs and underlying targets. Table 5.3 (available as a supplementary pdf) presents an assessment of these synergies and trade-offs and the strength of the interaction using an SDG-interaction score (see Glossary) (McCollum et al., 2018), with evidence and agreements levels. Figure 5.3 presents the information of Table 5.3 (available as a supplementary pdf), showing gross (not net) interactions with the SDGs. This detailed assessment of synergies and trade-offs of individual mitigation options with the SDGs (Table 5.3 a–d (available as a supplementary pdf), Figure 5.3) reveals that the number of synergies exceeds that of trade-offs. Mitigation response options in the energy demand sector, AFOLU, and oceans have more positive interactions with a larger number of SDGs compared to those on the energy supply side (*robust evidence, high agreement*).

#### *5.4.1.1 Energy Demand: Mitigation Options to Accelerate Reduction in Energy Use and Fuel Switch*

For mitigation options in the energy demand sectors, the number of synergies with all sixteen SDGs exceeds the number of trade-off (Figure 5.3, also Table 5.3 (available as a supplementary pdf)) (*robust evidence, high agreement*). Most of the interactions are of reinforcing nature, hence facilitating the achievement of the goals.

Accelerating energy efficiency in all sectors, which is a necessary condition for a 1.5°C warmer world (see Chapters 2 and 4), has synergies with a large number of SDGs (Figure 5.3, Table 5.3 (available as a supplementary pdf)) (*robust evidence, high agreement*). The diffusion of efficient equipment and appliances across end use sectors has synergies with international partnership (SDG 17) and participatory and transparent institutions (SDG 16) because innovations and deployment of new technologies require trans-national capacity building and knowledge sharing. Resource and energy savings support sustainable production and consumption (SDG 12), energy access (SDG 7), innovation and infrastructure development (SDG 9), and sustainable city development (SDG 11). Energy efficiency supports the creation of decent jobs by new service companies providing services for energy efficiency, but the net employment effect of efficiency improvement remains uncertain due to macro-economic feedback (SDG 8) (McCollum et al., 2018).

In the buildings sector, accelerating energy efficiency by way of, for example, enhancing the use of efficient appliances, refrigerant transition, insulation, retrofitting, and low- or zero-energy buildings generates benefits across multiple SDG targets. For example, improved cook stoves make fuel endowments last longer and hence reduce deforestation (SDG 15), support equal opportunity by reducing school absences due to asthma among children (SDGs 3 and 4), and empower rural and indigenous women by reducing drudgery (SDG 5) (Derbez et al., 2014; Lucon et al., 2014; Maidment et al., 2014; Scott et al., 2014; Cameron et al., 2015; Fay et al., 2015; Liddell and Guiney, 2015; Shah et al., 2015; Sharpe et al., 2015; Wells et al., 2015; Willand et al., 2015; Hallegatte et al., 2016; Kusumaningtyas and Aldrian, 2016; Berrueta et al., 2017; McCollum et al., 2017) (*robust evidence, high agreement*).

In energy-intensive processing industries, 1.5ºC-compatible trajectories require radical technology innovation through maximum electrification, shift to other low-emission energy carriers such as hydrogen or biomass, integration of Carbon Capture and Storage (CCS) and innovations for Carbon Capture and Utilisation (CCU) (see Chapter 4, Section 4.3.4.5). These transformations have strong synergies with innovation and sustainable industrialisation (SDG 9), supranational partnerships (SDGs 16 and 17) and sustainable production (SDG 12). However, possible trade-offs due to risks of CCS-based carbon leakage, increased electricity demands, and associated price impacts affecting energy access and poverty (SDGs 7 and 1) would need careful regulatory attention (Wesseling et al., 2017). In the mining industry, energy efficiency can be synergetic or face trade-offs with sustainable management (SDG 6), depending on the option retained for water management (Nguyen et al., 2014). Substitution and recycling are also an important driver of 1.5ºC-compatible trajectories in industrial systems (see Chapter 4, Section 4.3.4.2). Structural changes and reorganisation of economic activities in industrial park/clusters following the principles of industrial symbiosis (circular economy) improves the overall sustainability by reducing energy and waste (Fan et al., 2017; Preston and Lehne, 2017) and reinforce responsible production and consumption (SDG 12) through recycling, water use efficiency (SDG 6), energy access (SDG 7), and ecosystem service value enhancement (SDG 15) (Karner et al., 2015; Zeng et al., 2017).

In the transport sector, deep electrification may trigger increases of electricity prices and adversely affect poor populations (SDG 1), unless pro-poor redistributive policies are in place (Klausbruckner et al., 2016). In cities, governments can lay the foundations for compact, connected low-carbon cities, which are an important component of 1.5ºC-compatible transformations (see Chapter 4, Section 4.3.3) and show synergies with sustainable cities (SDG 11) (Colenbrander et al., 2016).

Behavioural responses are important determinants of the ultimate outcome of energy efficiency on emission reductions and energy access (SDG 7) and their management requires a detailed understanding of the drivers of consumption and the potential for and barriers to absolute reductions (Fuchs et al., 2016). Notably, the rebound effect tends to offset the benefits of efficiency for emission reductions through growing demand for energy services (Sorrell, 2015; Suffolk and Poortinga, 2016). However, high rebound can help in providing faster access to affordable energy (SDG 7.1) where the goal is to reduce energy poverty and unmet energy demand (Chakravarty et al., 2013)(see Chapter 2, Section 2.4.3). Comprehensive policy design, including rebound supressing policies such as carbon price and policies that encourage awareness building and promotional material design, are needed to tap the full potential of energy savings, as applicable to 1.5°C warming context (Chakravarty and Tavoni, 2013; IPCC, 2014b; Karner et al., 2015; Zhang et al., 2015; Altieri et al., 2016; Santarius et al., 2016) and to address policy-related trade-offs and welfare-enhancing benefits (Chakravarty et al., 2013; Chakravarty and Roy, 2016; Gillingham et al., 2016) (*robust evidence,* *high agreement*).

Other behavioural responses will affect the interplay between energy efficiency and sustainable development. Building occupants reluctant to change their habits may miss out on welfare-enhancing energy efficiency opportunities (Zhao et al., 2017). Preferences for new products and premature obsolescence for appliances is expected to affect sustainable consumption and production adversely (SDG 12) with ramifications for resource use efficiency (Echegaray, 2016). User behaviour change towards increased physical activity, less reliance on motorised travel over short distances, and the use of public transport would help to decarbonise the transport sector in a synergetic manner with SDGs 3, 11, and 12 (Shaw et al., 2014; Ajanovic, 2015; Chakrabarti and Shin, 2017) while reducing inequality in access to basic facilities (SDG 10) (Lucas and Pangbourne, 2014; Kagawa et al., 2015). However, infrastructure design and regulations would need to ensure road safety and address risks of road accidents for pedestrians (Hwang et al., 2017; Khreis et al., 2017) to ensure sustainable infrastructure growth in human settlements (SDGs 9 and 11) (Lin et al., 2015; SLoCaT, 2017).

#### *5.4.1.2 Energy Supply: Accelerated Decarbonisation*

Decreasing the share of coal in energy supply in line with 1.5ºC-compatible scenarios (see Chapter 2, Section 2.4.2) reduces adverse impacts of upstream supply-chain activities, in particular air and water pollution, and coal mining accidents, and enhances health by reducing air pollution, notably in cities, showing synergies with SDGs 3, 11 and 12 (Yang et al., 2016; UNEP, 2017).

Fast deployment of renewables like solar and wind, hydro, modern biomass, together with the decrease of fossil fuels in energy supply (see Chapter 2, Section 2.4.2.1), is aligned with the doubling of renewables in the global energy mix (SDG 7.2). Renewables could also support progress on SDGs 1, 10, 11, and 12 and supplement new technology (Chaturvedi and Shukla, 2014; Rose et al., 2014; Smith and Sagar, 2014; Riahi et al., 2015; IEA, 2016; McCollum et al., 2017; van Vuuren et al., 2017a) (*robust evidence, high agreement*). However, some trade-offs with the SDGs can emerge from offshore installations, particularly SDG 14 in local contexts (McCollum et al., 2017). Moreover, trade-offs between renewable energy production and affordability (SDG 7) (Labordena et al., 2017) and other environmental objectives would need to be scrutinised for potential negative social outcomes. Policy interventions through regional cooperation building (SDG 17) and institutional capacity (SDG 16) can enhance affordability (SDG 7) (Labordena et al., 2017).The deployment of small-scale renewables, or off-grid solutions for people in remote areas (Sánchez and Izzo, 2017), has strong potential for synergies with access to energy (SDG 7), but the actualisation of these potentials requires measures to overcome technology and reliability risks associated with large-scale deployment of renewables (Giwa et al., 2017; Heard et al., 2017). Bundling energy-efficient appliances and lighting with off-grid renewables can lead to substantial cost reduction while increasing reliability (IEA, 2017). Low-income populations in industrialised countries are often left out of renewable energy generation schemes, either because of high start-up costs or lack of home ownership (UNRISD, 2016).

Nuclear energy, the share of which increases in most of the 1.5ºC-compatible pathways (see Chapter 2, Section 2.4.2.1), can increase the risks of proliferation (SDG 16), have negative environmental effects (e.g., for water use, SDG 6), and have mixed effects for human health when replacing fossil fuels (SDGs 7 and 3) (see Table 5.2). The use of fossil CCS, which plays an important role in deep mitigation pathways (see Chapter 2, Section 2.4.2.3), implies continued adverse impacts of upstream supply-chain activities in the coal sector, and because of lower efficiency of CCS coal power plants (SDG 12), upstream impacts and local air pollution are likely to be exacerbated (SDG 3). Furthermore, there is a non-negligible risk of carbon dioxide leakage from geological storage and the carbon dioxide transport infrastructure (SDG 3) (Table 5.3 (available as a supplementary pdf)).

Economies dependent upon fossil fuel-based energy generation and/or export revenue are expected to be disproportionally affected by future restrictions on the use of fossil fuels, under stringent climate goals and higher carbon prices; this includes impacts on employment, stranded assets, resources left underground, lower capacity use, and early phasing out of large infrastructure already under construction (Johnson et al., 2015; McGlade and Ekins, 2015; UNEP, 2017; Spencer et al., 2018) (Box 5.2) (*robust evidence, high agreement*). Investment in coal continues to be attractive in many countries as it is a mature technology, provides cheap energy supply, large-scale employment, and energy security (Jakob and Steckel, 2016; Vogt-Schilb and Hallegatte, 2017; Spencer et al., 2018). Hence, accompanying policies and measures would be required to ease job losses and correct for relatively higher prices of alternative energy (Oosterhuis and Ten Brink, 2014; Oei and Mendelevitch, 2016; Garg et al., 2017; HLCCP, 2017; Jordaan et al., 2017; OECD, 2017; UNEP, 2017; Blondeel and van de Graaf, 2018; Green, 2018). Research on historical transitions shows that managing the impacts on workers through retraining programs is essential in order to align the phase down of mining industries with meeting ambitious climate targets, and the objectives of a 'just transition' (Galgóczi, 2014; Caldecott et al., 2017; Healy and Barry, 2017). This aspect is even more important in developing countries where the mining workforce is largely semi- or un-skilled (Altieri et al., 2016; Tung, 2016). Ambitious emission reduction targets can unlock very strong decoupling potentials in industrialised fossil exporting economies (Hatfield-Dodds et al., 2015).

[START BOX 5.2 HERE]

**Box 5.2:** Challenges and Opportunities of Low-Carbon Pathways in Gulf Cooperative Council (GCC) Countries

The Gulf Cooperative Council (GCC) region (Bahrain, Kuwait, Oman, Qatar, Saudi Arabia, and United Arab Emirates) is characterised by high dependency on hydrocarbon resources (natural oil and gas), with high risks of socio-economic impacts of policies and response measures to address climate change. The region is also vulnerable to the decrease of the global demand and price of hydrocarbons as a result of climate change response measures. The projected declining use of oil and gas under low emissions pathways creates risks of significant economic losses for the GCC region (e.g., Waisman et al., 2013; Van de Graaf and Verbruggen, 2015; Al-Maamary et al., 2016; Bauer et al., 2016), given that natural gas and oil revenues contributed to ~70% of government budgets and > 35% of the gross domestic product in 2010 (Callen et al., 2014).

The current high energy intensity of the domestic economies (Al-Maamary et al., 2017), triggered mainly by low domestic energy prices (Alshehry and Belloumi, 2015), suggests specific challenges for aligning mitigation towards 1.5°C-consistent trajectories, which would require strong energy efficiency and economic development for the region.

Economies of the region are highly reliant on fossil fuel for their domestic activities. Yet, the renewables deployment potentials are large, deployment is already happening (Cugurullo, 2013; IRENA, 2016), and positive economic benefits can be envisaged (Sgouridis et al., 2016). Nonetheless, the use of renewables is currently limited by economics and structural challenges (Lilliestam and Patt, 2015; Griffiths, 2017a). Carbon Capture and Storage (CCS) is also envisaged with concrete steps towards implementation (Alsheyab, 2017; Ustadi et al., 2017); yet, the real potential of this technology in terms of scale and economic dimensions is still uncertain.

Beyond the above mitigation-related challenges, human societies and fragile ecosystems of the region are highly vulnerable to the impacts of climate change, such as water stress (Evans et al., 2004; Shaffrey et al., 2009), desertification (Bayram and Öztürk, 2014), sea level rise affecting vast low costal lands, and high temperature and humidity with future levels potentially beyond adaptive capacities (Pal and Eltahir, 2016). A low-carbon pathway that manages climate-related risks within the context of sustainable development requires an approach that jointly addresses both types of vulnerabilities (Al Ansari, 2013; Lilliestam and Patt, 2015; Babiker, 2016; Griffiths, 2017b).

The Nationally Determined Contributions (NDCs) for GCC countries identified energy efficiency, deployment of renewables, and technology transfer to enhance agriculture, food security, protection of marine, and management of water and costal zones (Babiker, 2016). Strategic vision documents, such as Saudi Arabia's "Vision 2030", identify emergent opportunities for energy price reforms, energy efficiency, turning emissions in valuable products, and deployment of renewables and other clean technologies, if accompanied with appropriate policies to manage the transition and in the context of economic diversification (Luomi, 2014; Atalay et al., 2016; Griffiths, 2017b; Howarth et al., 2017).

[END BOX 5.2 HERE]

#### *5.4.1.3 Land-based Agriculture, Forestry and Ocean: Mitigation Response Options and Carbon Dioxide Removal*

In the AFOLU sector, dietary change towards global healthy diets, that is, a shift from over-consumption of animal-related to plant-related diets, and food waste reduction (see Chapter 4, Section 4.3.2.1) are in synergy with SDGs 2 and 6, and SDG 3 through lower consumption of animal products and reduced losses and waste throughout the food system, contributing to achieving SDGs 12 and 15 (Bajželj et al., 2014; Bustamante et al., 2014; Tilman and Clark, 2014; Hiç et al., 2016).

Power dynamics plays an important role in achieving behavioural change and sustainable consumption (Fuchs et al., 2016). In forest management (see Chapter 4, Section 4.3.2.2), encouraging responsible sourcing of forest products and securing indigenous land tenure has the potential to increase economic benefits by creating decent jobs (SDG 8), maintaining biodiversity (SDG 15), facilitating innovation and upgrading technology (SDG 9), and responsible and just decision making (SDG 16) (Ding et al., 2016; WWF, 2017) (*medium evidence, high agreement*).

Emerging evidence indicates that future mitigation efforts that would be required to reach stringent climate targets, particularly those associated with Carbon Dioxide Removal (CDR) (e.g., Bioenergy with Carbon Capture and Storage (BECCS) and afforestation and reforestation), may also impose significant constraints upon poor and vulnerable communities (SDG 1) via increased food prices and competition for arable land, land appropriation, and dispossession (Cavanagh and Benjaminsen, 2014; Hunsberger et al., 2014; Work, 2015; Muratori et al., 2016; Smith et al., 2016; Burns and Nicholson, 2017; Corbera et al., 2017) with disproportionate negative impacts upon rural poor and indigenous populations (SDG 1) (Grubert et al., 2014; Grill et al., 2015; Zhang and Chen, 2015; Fricko et al., 2016; Johansson et al., 2016; Aha and Ayitey, 2017; De Stefano et al., 2017; Shi et al., 2017) (Section 5.4.2.2, Table 5.3 (available as a supplementary pdf), Figure 5.3) (*robust evidence, high agreement*). Crops for bioenergy may increase irrigation needs and exacerbate water stress with negative associated impacts on SDGs 6 and 10 (Boysen et al., 2017).

Ocean Iron Fertilisation (OIF) and enhanced weathering have two-way interactions with life under water and on land and food security (SDGs 2, 14, and 15) (Table 5.3 (available as a supplementary pdf)). Development of blue carbon resources through coastal (mangrove) and marine (seaweed) vegetative ecosystems encourages integrated water resource management (SDG 6) (Vierros, 2017), promotes life on land (SDG 15) (Potouroglou et al., 2017); poverty reduction (SDG 1) (Schirmer and Bull, 2014; Lamb et al., 2016) and food security (SDG 2) (Ahmed et al., 2017a, b; Duarte et al., 2017; Sondak et al., 2017; Vierros, 2017; Zhang et al., 2017).

[INSERT FIGURE 5.3 HERE]

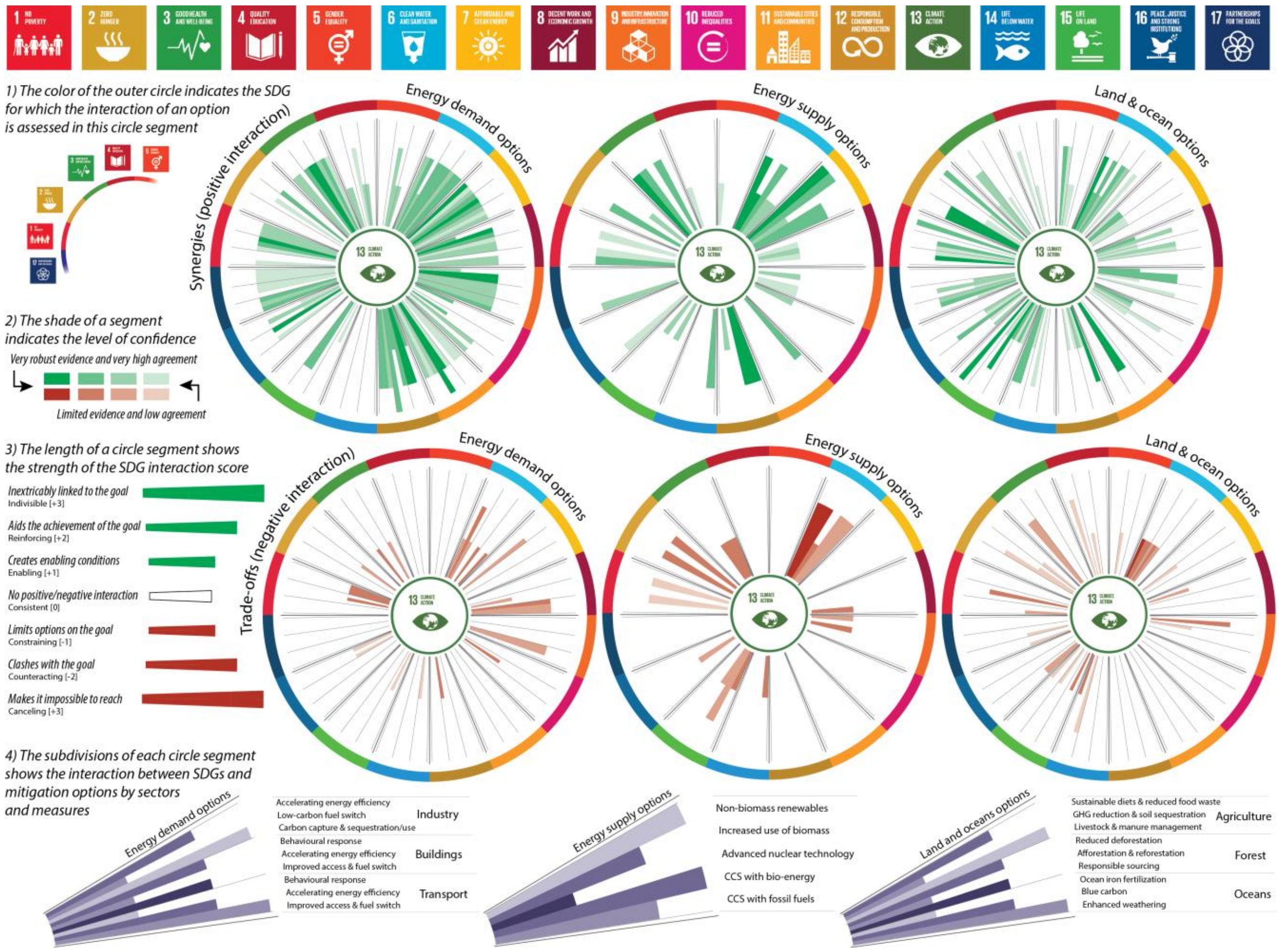


**Figure 5.3: Synergies and trade-offs and gross Sustainable Development Goal (SDG)-interaction with individual mitigation options.** The top three wheels represent synergies and the bottom three wheels show trade-offs. The colours on the border of the wheels correspond to the SDGs listed above, starting at the 9 o'clock position, with reading guidance in the top-left corner with the quarter circle (Note 1). Mitigation (climate action, SDG 13) is at the centre of the circle. The coloured segments inside the circles can be counted to arrive at the number of synergies (green) and trade-offs (red). The length of the coloured segments shows the strength of the synergies or trade-offs (Note 3) and the shading indicates confidence (Note 2). Various mitigation options within the energy demand sector, energy supply sector, and land and ocean sector, and how to read them within a segment are shown in grey (Note 4). See also Table 5.3 (available as a supplementary pdf).

### *5.4.2 Sustainable Development Implications of 1.5°C and 2°C Mitigation Pathways*

While previous sections have focused on individual mitigation options and their interaction with sustainable development and the SDGs, this section takes a systems perspective. Emphasis is on quantitative pathways depicting path-dependent evolutions of human and natural systems over time. Specifically, the focus is on fundamental transformations and thus stringent mitigation policies consistent with 1.5°C or 2°C, and the differential synergies and trade-offs with respect to the various sustainable development dimensions.

Both 1.5°C and 2°C pathways would require deep cuts in greenhouse gas (GHG) emissions and large-scale changes of energy supply and demand, as well as in agriculture and forestry systems (see Chapter 2, Section 2.4). For the assessment of the sustainable development implications of these pathways, we draw upon studies that show the aggregated impact of mitigation for multiple sustainable development dimensions (Grubler et al., 2018; McCollum et al., 2018; Rogelj et al., 2018) and across multiple Integrated Assessment

Modelling (IAM) frameworks. Often these tools are linked to disciplinary models covering specific SDGs in more detail (Cameron et al., 2016; Rao et al., 2017; Grubler et al., 2018; McCollum et al., 2018). Using multiple IAMs and disciplinary models is important for a robust assessment of the sustainable development implications of different pathways. Emphasis is on multi-regional studies, which can be aggregated to the global scale. The recent literature on 1.5°C mitigation pathways has begun to provide quantifications for a range of sustainable development dimensions, including air pollution and health, food security and hunger, energy access, water security, and multidimensional poverty and equity.

#### *5.4.2.1 Air Pollution and Health*

Greenhouse gases and air pollutants are typically emitted by the same sources. Hence, mitigation strategies that reduce GHGs or the use of fossil fuels typically also reduce emissions of pollutants, such as particulate matter (e.g., PM2.5 and PM10), black carbon (BC), sulphur dioxide ($SO_2$), nitrogen oxides ($NO_x$), and other harmful species (Clarke et al., 2014) (Figure 5.4), causing adverse health and ecosystem effects at various scales (Kusumaningtyas and Aldrian, 2016).

Mitigation pathways typically show that there are significant synergies for air pollution, and that the synergies increase with the stringency of the mitigation policies (Amann et al., 2011; Rao et al., 2016; Klimont et al., 2017; Shindell et al., 2017; Markandya et al., 2018). Recent multi-model comparisons indicate that mitigation pathways consistent with 1.5°C would result in higher synergies with air pollution compared to pathways that are consistent with 2°C (Figures 5.4 and 5.5). Shindell et al. (2018) indicate that health benefits worldwide over the century of 1.5°C pathways could be in the range of 110 to 190 million fewer premature deaths compared to 2°C pathways. The synergies for air pollution are highest in the developing world, particularly in Asia. In addition to significant health benefits, there are also economic benefits from mitigation, reducing the investment needs in air pollution control technologies by about 35% globally (or about 100 billion US$2015 per year to 2030 in 1.5°C pathways) (McCollum et al., 2018) (Figure 5.5).

#### *5.4.2.2 Food Security and Hunger*

Stringent climate mitigation pathways in line with ‘well below 2°C’ or ‘1.5°C’ goals often rely on the deployment of large-scale land-related measures, like afforestation and/or bioenergy supply (Popp et al., 2014; Rose et al., 2014; Creutzig et al., 2015). These land-related measures can compete with food production and hence raise food security concerns (Section 5.4.1.3) (P. Smith et al., 2014). Mitigation studies indicate that so-called ‘single-minded’ climate policy, aiming solely at limiting warming to 1.5°C or 2°C without concurrent measures in the food sector, can have negative impacts for global food security (Hasegawa et al., 2015; McCollum et al., 2018). Impacts of 1.5°C mitigation pathways can be significantly higher than those of 2°C pathways (Figures 5.4 and 5.5). An important driver of the food security impacts in these scenarios is the increase of food prices and the effect of mitigation on disposable income and wealth due to GHG pricing. A recent study indicates that, on aggregate, the price and income effects on food may be bigger than the effect due to competition over land between food and bioenergy (Hasegawa et al., 2015).

In order to address the issue of trade-offs with food security, mitigation policies would need to be designed in a way that shields the population at risk of hunger, including through the adoption of different complementary measures, such as food price support. The investment needs of complementary food price policies are found to be globally relatively much smaller than the associated mitigation investments of 1.5°C pathways (Figure 5.4) (McCollum et al., 2018). Besides food support price, other measures include improving productivity and efficiency of agricultural production systems (FAO and NZAGRC, 2017a, b; Frank et al., 2017) and programs focusing on forest land-use change (Havlík et al., 2014). All these lead to additional benefits of mitigation, improving resilience and livelihoods.

van Vuuren et al. (2018) and Grubler et al. (2018) show that 1.5°C pathways without reliance on BECCS can be achieved through a fundamental transformation of the service sectors which would significantly reduce energy and food demand (see Chapter 2, Sections 2.1.1, 2.3.1, and 2.4.3). Such low energy demand (LED) pathways would result in significantly reduced pressure on food security, lower food prices, and put fewer people at risk of hunger. Importantly, the trade-offs with food security would be reduced by the avoided impacts in the agricultural sector due to the reduced warming associated with the 1.5°C pathways (see Chapter 3, Section 3.5). However, such feedbacks are not comprehensively captured in the studies on mitigation.

#### *5.4.2.3 Lack of Energy Access/Energy Poverty*

A lack of access to clean and affordable energy (especially for cooking) is a major policy concern in many countries, especially in those in South Asia and Africa where major parts of the population still rely primarily on solid fuels for cooking (IEA and World Bank, 2017). Scenario studies which quantify the interactions between climate mitigation and energy access indicate that stringent climate policy which would affect energy prices could significantly slow down the transition to clean cooking fuels, such as liquefied petroleum gas (LPG) or electricity (Cameron et al., 2016).

Estimates across six different IAMs (McCollum et al., 2018) indicate that, in the absence of compensatory measures, the number of people without access to clean cooking fuels may increase. Re-distributional measures, such as subsidies on cleaner fuels and stoves, could compensate for the negative effects of mitigation on energy access. Investment costs of the re-distributional measures in 1.5°C pathways (on average around 120 billion per year to 2030; Figure 5.5) are much smaller than the mitigation investments of 1.5°C pathways (McCollum et al., 2018). The recycling of revenues from climate policy might act as a means to help finance the costs of providing energy access to the poor (Cameron et al., 2016).

#### *5.4.2.4 Water Security*

Transformations towards low-emissions energy and agricultural systems can have major implications for freshwater demand as well as water pollution. The scaling up of renewables and energy efficiency as depicted by low emissions pathways would, in most instances, lower water demands for thermal energy supply facilities (‘water-for-energy’) compared to fossil energy technologies, and thus reinforce targets related to water access and scarcity (see Chapter 4, Section 4.2.1). However, some low-carbon options such as bioenergy, centralised solar power, nuclear, and hydropower technologies could, if not managed properly, have counteracting effects that compound existing water-related problems in a given locale (Byers et al., 2014; Fricko et al., 2016; IEA, 2016; Fujimori et al., 2017a; McCollum et al., 2017; Wang, 2017).

Under stringent mitigation efforts, the demand for bioenergy can result in a substantial increase of water demand for irrigation, thereby potentially contributing to water scarcity in water-stressed regions (Berger et al., 2015; Bonsch et al., 2016; Jägermeyr et al., 2017). However, this risk can be reduced by prioritising rain-fed production of bioenergy (Hayashi et al., 2015, 2018; Bonsch et al., 2016), but might have adverse effects for food security (Boysen et al., 2017).

Reducing food and energy demand without compromising the needs of the poor emerges as a robust strategy for both water conservation and GHG emissions reductions (von Stechow et al., 2015; IEA, 2016; Parkinson et al., 2016; Grubler et al., 2018). The results underscore the importance of an integrated approach when developing water, energy, and climate policy (IEA, 2016).

Estimates across different models for the impacts of stringent mitigation pathways on energy-related water uses seem ambiguous. Some pathways show synergies (Mouratiadou et al., 2018) while others indicate trade-offs and thus increases of water use due to mitigation (Fricko et al., 2016). The signal depends on the adopted policy implementation or mitigation strategies and technology portfolio. A number of adaptation options exist (e.g., dry cooling), which can effectively reduce electricity-related water trade-offs (Fricko et al., 2016; IEA, 2016). Similarly, irrigation water use will depend on the regions where crops are produced, the sources of bioenergy (e.g., agriculture vs. forestry) and dietary change induced by climate policy. Overall, and also considering other water-related SDGs, including access to safe drinking water and sanitation as well as waste-water treatment, investments into the water sector seem to be only modestly affected by stringent climate policy compatible with 1.5°C (Figure 5.5) (McCollum et al., 2018).

**[INSERT FIGURE 5.4 HERE]**

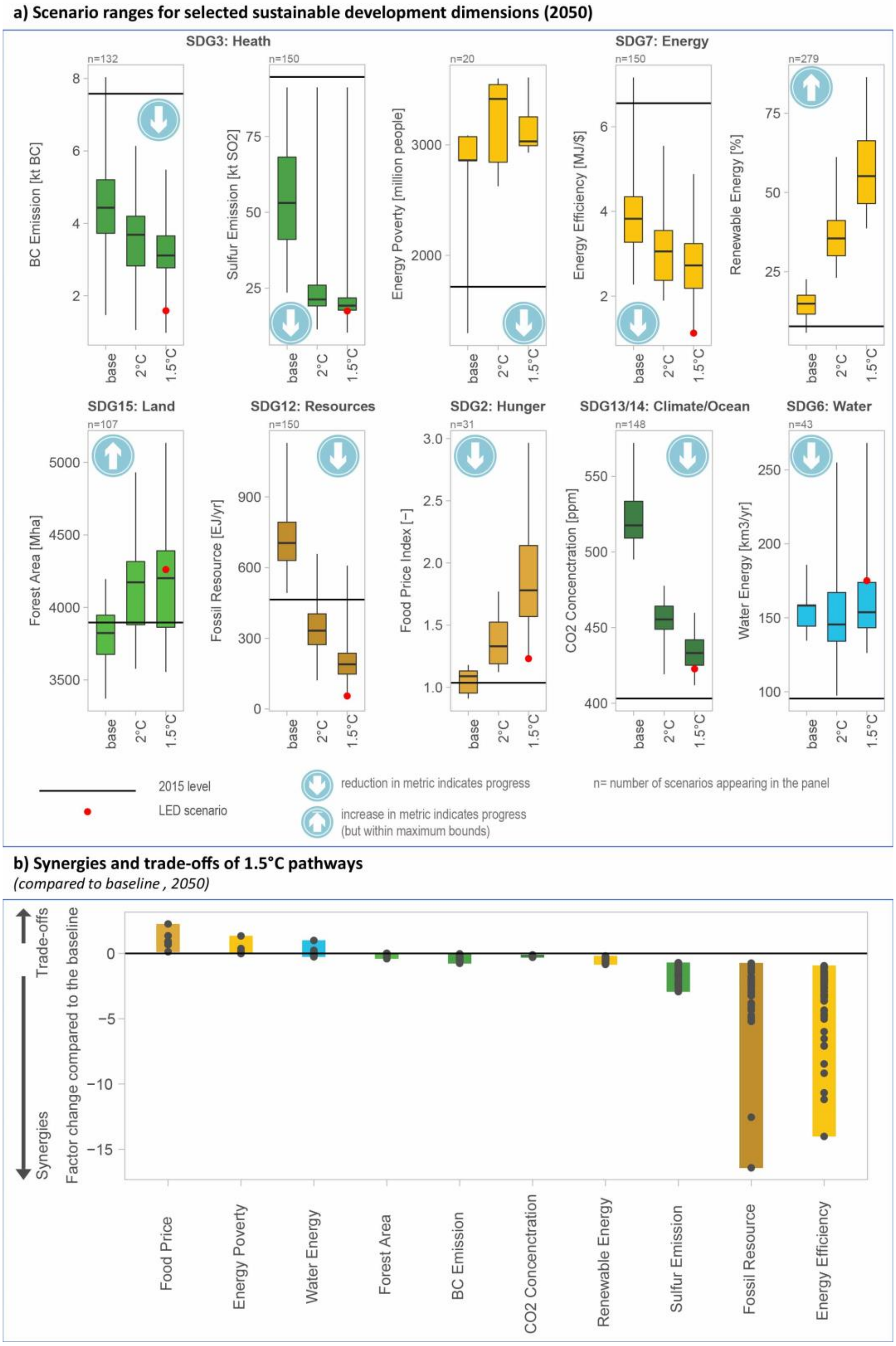

**Figure 5.4: Sustainable development implications of mitigation actions in 1.5°C pathways**. **Panel (a)** shows ranges for 1.5°C pathways for selected sustainable development dimensions compared to the ranges of 2°C pathways and baseline pathways. The panel (a) depicts interquartile and the full range across the scenarios for Sustainable Development Goal (SDG) 2 (hunger), SDG 3 (health), SDG 6 (water), SDG 7 (energy), SDG 13 (climate), and SDG 15 (land). Progress towards achieving the SDGs is denoted by arrow symbols (increase or decrease of indicator). Black horizontal lines show 2015 values for comparison. Note that sustainable development effects are estimated for the effect of mitigation and do not include benefits from avoided impacts (see Chapter 3, Section 3.5). Low energy demand (LED) denotes estimates from a pathway with extremely low energy demand reaching 1.5°C without Bioenergy with Carbon Capture and Storage (BECCS). **Panel (b)** presents the resulting full range for synergies and trade-offs of 1.5°C pathways compared to the corresponding baseline scenarios. The y-axis in panel (b) indicates the factor change in the 1.5°C pathway compared to the baseline. Note that the figure shows gross impacts of mitigation and does not include feedbacks due to avoided impacts. The realisation of the side-effects will critically depend on local circumstances and implementation practice. Trade-offs across many sustainable development dimensions can be reduced through complementary/re-distributional measures. The figure is not comprehensive and focuses on those sustainable development dimensions for which quantifications across models are available. Sources: 1.5°C pathways database of Chapter 2 (Grubler et al., 2018; McCollum et al., 2018).

**[INSERT FIGURE 5.5 HERE]**

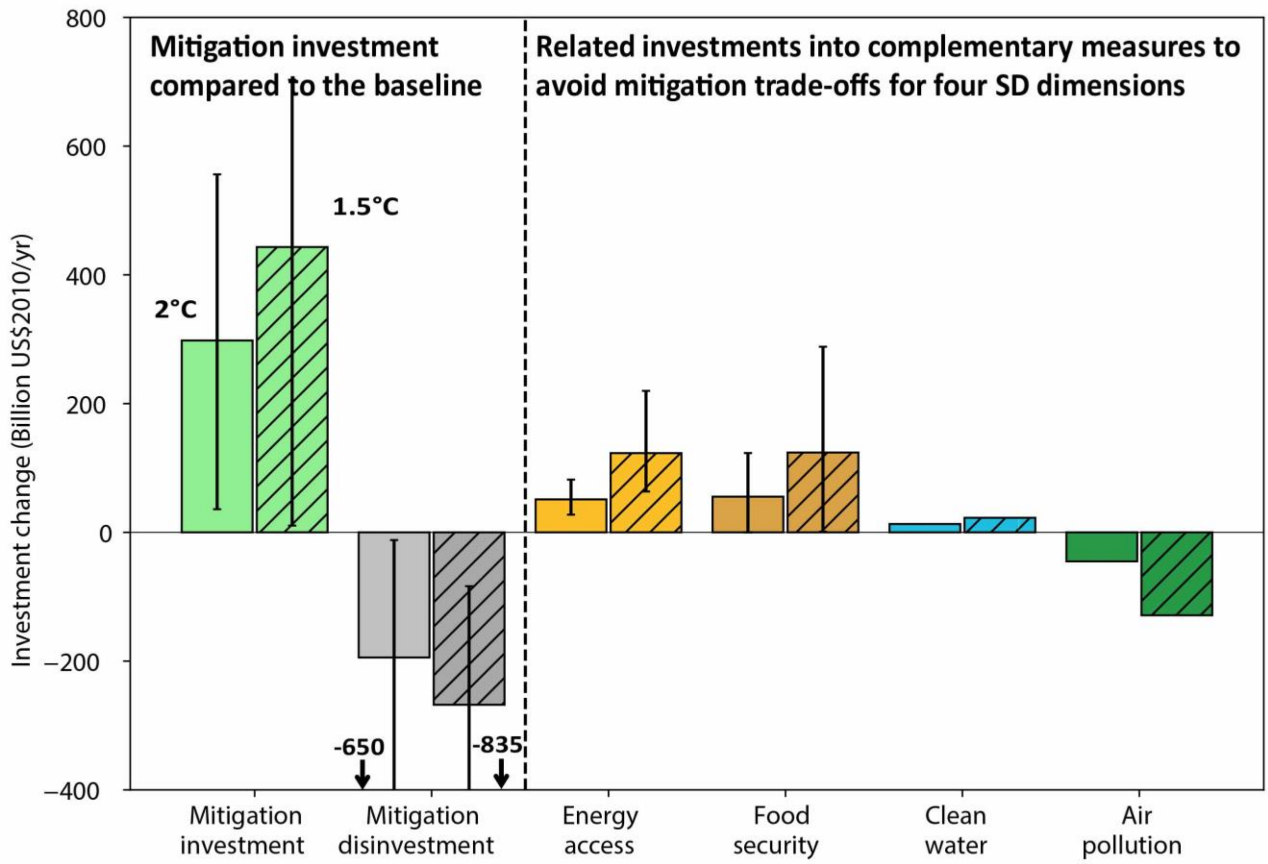


**Figure 5.5: Investment into mitigation up until 2030 and implications for investments for four sustainable development dimensions**. Cross-hatched bars show the median investment in 1.5°C pathways across results from different models, and solid bars for 2°C pathways, respectively. Whiskers on bars represent minima and maxima across estimates from six models. Clean water and air pollution investments are available only from one model. Mitigation investments show the change in investments across mitigation options compared to the baseline. Negative mitigation investments (grey bars) denote disinvestment (reduced investment needs) into fossil fuel sectors compared to the baseline. Investments for different

sustainable development dimensions denote the investment needs for complementary measures in order to avoid trade-offs (negative impacts) of mitigation. Negative sustainable development investments for air pollution indicate cost savings, and thus synergies of mitigation for air pollution control costs. The values compare to about US$(2010) 2 trillion (range of 1.4 to 3 trillion) of total energy-related investments in the 1.5°C pathways. Source: estimates from CD-LINKS scenarios summarised by McCollum et al. (2018).

In summary, the assessment of mitigation pathways shows that, to meet the 1.5°C target, a wide range of mitigation options would need to be deployed (see Chapter 2, Sections 2.3 and 2.4). While pathways aiming at 1.5° C are associated with high synergies for some sustainable development dimensions (such as human health and air pollution, forest preservation), the rapid pace and magnitude of the required changes would also lead to increased risks for trade-offs for other sustainable development dimensions (particularly food security) (Figures 5.4 and 5.5). Synergies and trade-offs are expected to be unevenly distributed between regions and nations (Box 5.2), though little literature has formally examined such distributions under 1.5°C consistent mitigation scenarios. Reducing these risks requires smart policy designs and mechanisms that shield the poor and redistribute the burden so that the most vulnerable are not affected. Recent scenario analyses show that associated investments for reducing the trade-offs for, for example, food, water and energy access to be significantly lower than the required mitigation investments (McCollum et al., 2018). Fundamental transformation of demand, including efficiency and behavioural changes, can help to significantly reduce the reliance on risky technologies, such as BECCS, and thus reduce the risk of potential trade-offs between mitigation and other sustainable development dimensions (von Stechow et al., 2015; Grubler et al., 2018; van Vuuren et al., 2018). Reliance on demand-side measures only, however, would not be sufficient for meeting stringent targets, such as 1.5°C and 2°C (Clarke et al., 2014).

## 5.5 Sustainable Development Pathways to 1.5°C

This section assesses what is known in the literature on development pathways that are sustainable and climate-resilient and relevant to a 1.5°C warmer world. Pathways, transitions from today's world to achieving a set of future goals (see Chapter 1, Section 1.2.3, Cross-Chapter Box 1), follow broadly two main traditions: first, as integrated pathways describing the required societal and systems transformations, combining quantitative modelling and qualitative narratives at multiple spatial scales (global to sub-national); and second, as country- and community-level, solution-oriented trajectories and decision-making processes about context- and place-specific opportunities, challenges, and trade-offs. These two notions of pathways offer different, though complementary, insights into the nature of 1.5°C-relevant trajectories and the short-term actions that enable long-term goals. Both highlight to varying degrees the urgency, ethics, and equity dimensions of possible trajectories and society- and system-wide transformations, yet at different scales, building on Chapter 2 (see Section 2.4) and Chapter 4 (see Section 4.5).

### *5.5.1 Integration of Adaptation, Mitigation, and Sustainable Development*

Insights into climate-compatible development (see Glossary) illustrate how integration between adaptation, mitigation, and sustainable development works in context-specific projects, how synergies are achieved, and what challenges are encountered during implementation (Stringer et al., 2014; Suckall et al., 2014; Antwi-Agyei et al., 2017a; Bickersteth et al., 2017; Kalafatis, 2017; Nunan, 2017). The operationalisation of climate-compatible development, including climate-smart agriculture and carbon-forestry projects (Lipper et al., 2014; Campbell et al., 2016; Quan et al., 2017), shows multi-level and multi-sector trade-offs involving 'winners' and 'losers' across governance levels (Kongsager and Corbera, 2015; Naess et al., 2015; Ficklin et al., 2017; Karlsson et al., 2017; Tanner et al., 2017; Taylor, 2017; Wood, 2017) (*high confidence*). Issues of power, participation, values, equity, inequality, and justice transcend case study examples of attempted integrated approaches (Nunan, 2017; Phillips et al., 2017; Stringer et al., 2017; Wood, 2017), also reflected in policy frameworks for integrated outcomes (Stringer et al., 2014; Di Gregorio et al., 2017; Few et al., 2017; Tanner et al., 2017).

Ultimately, reconciling trade-offs between development needs and emission reductions towards a 1.5°C warmer world requires a dynamic view of the interlinkages between adaptation, mitigation, and sustainable development (Nunan, 2017). This entails recognition of the ways in which development contexts shape the choice and effectiveness of interventions, limit the range of responses afforded to communities and governments, and potentially impose injustices upon vulnerable groups (UNRISD, 2016; Thornton and Comberti, 2017). A variety of approaches, both quantitative and qualitative, exist to examine possible sustainable development pathways under which climate and sustainable development goals can be achieved, and synergies and trade-offs for transformation identified (Sections 5.3 and 5.4).

### *5.5.2 Pathways for Adaptation, Mitigation, and Sustainable Development*

This section focuses on the growing body of pathways literature describing the dynamic and systemic integration of mitigation and adaptation with sustainable development in the context of a 1.5°C warmer world. These studies are critically important for the identification of 'enabling' conditions under which climate and the SDGs can be achieved, and thus help the design of transformation strategies that maximise synergies and avoid potential trade-offs (Sections 5.3 and 5.4). Full integration of sustainable development dimensions is, however, challenging, given their diversity and the need for high temporal, spatial, and social resolution to address local effects, including heterogeneity related to poverty and equity (von Stechow et al., 2015). Research on long-term climate change mitigation and adaptation pathways has covered individual SDGs to different degrees. Interactions between climate and other SDGs have been explored for SDGs 2, 3, 4, 6, 7, 8, 12, 14, and 15 (Clarke et al., 2014; Abel et al., 2016; von Stechow et al., 2016; Rao et al., 2017) while interactions with SDGs 1, 5, 11, and 16 remain largely underexplored in integrated long-term scenarios (Zimm et al., 2018).

Quantitative pathways studies now better represent 'nexus' approaches to assess sustainable development dimensions. In such approaches (see Chapter 4, Section 4.3.3.8), a sub-set of sustainable development dimensions are investigated together because of their close relationships (Welsch et al., 2014; Conway et al., 2015; Keairns et al., 2016; Parkinson et al., 2016; Rasul and Sharma, 2016; Howarth and Monasterolo, 2017). Compared to single objective climate-SDG assessments (Section 5.4.2), nexus solutions attempt to integrate complex interdependencies across diverse sectors in a systems approach for consistent analysis. Recent pathways studies show how water, energy, and climate (SDGs 6, 7 and 13) interact (Parkinson et al., 2016; McCollum et al., 2018), calling for integrated water-energy investment decisions to manage systemic risks. For instance, the provision of bioenergy, important in many 1.5°C-consistent pathways, can help resolve 'nexus challenges' by alleviating energy security concerns, but can also have adverse 'nexus impacts' on food security, water use, and biodiversity (Lotze-Campen et al., 2014; Bonsch et al., 2016). Policies that improve the resource use efficiency across sectors can maximise synergies for sustainable development (Bartos and Chester, 2014; McCollum et al., 2018; van Vuuren et al., 2018). Mitigation compatible with 1.5°C can significantly reduce impacts and adaptation needs in the nexus sectors compared to 2°C (Byers et al., 2018), In order to avoid trade-offs due to high carbon pricing of 1.5°C pathways, regulation in specific areas may complement price-based instruments. Such combined policies generally lead also to more early action maximizing synergies and avoiding some of the adverse climate effects for sustainable development (Bertram et al., 2018).

The comprehensive analysis of climate change in the context of sustainable development requires suitable reference scenarios that lend themselves to broader sustainable development analyses. The Shared Socioeconomic Pathways (SSPs) (O'Neill et al., 2017a; Riahi et al., 2017) (Chapter 1, Cross-Chapter Box 1 in Chapter 1) constitute an important first step in providing a framework for the integrated assessment of adaptation and mitigation and their climate-development linkages (Ebi et al., 2014). The five underlying SSP narratives (O'Neill et al., 2017a) map well into some of the key SDG dimensions, with one of the pathways (SSP1) explicitly depicting sustainability as the main theme (van Vuuren et al., 2017b).

To date, no pathway in the literature proves to achieve all 17 SDGs because several targets are not met or not sufficiently covered in the analysis, hence resulting in a sustainability gap (Zimm et al., 2018). The SSPs facilitate the systematic exploration of different sustainable dimensions under ambitious climate objectives. SSP1 proves to be in line with eight SDGs (3, 7, 8, 9, 10, 11, 13, and 15) and several of their targets in a 2°C warmer world (van Vuuren et al., 2017b; Zimm et al., 2018). But, important targets for SDGs 1, 2, and 4 (i.e., people living in extreme poverty, people living at the risk of hunger, and gender gap in years of schooling) are not met in this scenario.

The SSPs show that sustainable socio-economic conditions will play a key role in reaching stringent climate targets (Riahi et al., 2017; Rogelj et al., 2018). Recent modelling work has examined 1.5°C-consistent, stringent mitigation scenarios for 2100 applied to the SSPs, using six different Integrated Assessment Models (IAMs). Despite limitations of these models which are coarse approximations of reality, robust trends can be identified (Rogelj et al., 2018). SSP1 - which depicts broader "sustainability" as well as enhancing equity and poverty reductions - is the only pathway where all models could reach 1.5°C and is associated with the lowest mitigation costs across all SSPs. A decreasing number of models was successful for SSP2, SSP4, and SSP5, respectively, indicating distinctly higher risks of failure due to high growth and energy intensity as well as geographical and social inequalities and uneven regional development. And reaching 1.5°C has even been found infeasible in the less sustainable SSP3 - "regional rivalry" (Fujimori et al., 2017b; Riahi et al., 2017). All these conclusions hold true if a 2°C objective is considered (Calvin et al., 2017; Fujimori et al., 2017b; Popp et al., 2017; Riahi et al., 2017). Rogelj et al. (2018) also show that fewer scenarios are, however, feasible across different SSPs in case of 1.5°C, and mitigation costs substantially increase in 1.5°C pathways compared to 2°C pathways.

There is a wide range of SSP-based studies focusing on the connections between adaptation/impacts and different sustainable development dimensions (Hasegawa et al., 2014; Ishida et al., 2014; Arnell et al., 2015; Bowyer et al., 2015; Burke et al., 2015; Lemoine and Kapnick, 2016; Rozenberg and Hallegatte, 2016; Blanco et al., 2017; Hallegatte and Rozenberg, 2017; O'Neill et al., 2017a; Rutledge et al., 2017; Byers et al., 2018).
New methods for projecting inequality and poverty (downscaled to sub-national rural and urban levels as well as spatially-explicit levels) have enabled advanced SSP-based assessments of locally sustainable development implications of avoided impacts and related adaptation needs. For instance, Byers et al. (2018) find that, in a 1.5°C warmer world, a focus on sustainable development can reduce the climate risk exposure of populations vulnerable to poverty by more than an order of magnitude (Section 5.2.2). Moreover, aggressive reductions in between-country inequality may decrease the emissions intensity of global economic growth (Rao and Min, 2018). This is due to the higher potential for decoupling of energy from income growth in lower-income countries, due to high potential for technological advancements that reduce the energy intensity of growth of poor countries - critical also for reaching 1.5°C in a socially and economically equitable way. Participatory downscaling of SSPs in several European Union countries and in Central Asia shows numerous possible pathways of solutions to the 2-1.5°C goal, depending on differential visions (Tàbara et al., 2018). Other participatory applications of the SSPs, for example in West Africa (Palazzo et al., 2017) and the south-eastern United States (Absar and Preston, 2015), illustrate the potentially large differences in adaptive capacity within regions and between sectors.

Harnessing the full potential of the SSP framework to inform sustainable development requires (1) further elaboration and extension of the current SSPs to cover sustainable development objectives explicitly; (2) the development of new or variants of current narratives that would facilitate more SDG-focused analyses with climate as one objective (among other SDGs) (Riahi et al., 2017); (3) scenarios with high regional resolution (Fujimori et al., 2017b); (4) a more explicit representation of institutional and governance change associated with the SSPs (Zimm et al., 2018); and (5) a scale-up of localised and spatially-explicit vulnerability, poverty and inequality estimates, which have emerged in recent publications based on the SSPs (Byers et al., 2018) and are essential to investigate equity dimensions (Klinsky and Winkler, 2018).

### *5.5.3 Climate-Resilient Development Pathways*

This section assesses the literature on pathways as solution-oriented trajectories and decision-making processes for attaining transformative visions for a 1.5°C warmer world. It builds on climate-resilient development pathways (CRDPs) introduced in the AR5 (Olsson et al., 2014) (Section 5.1.2) as well as growing, literature (e.g., Eriksen et al., 2017; Johnson, 2017; Orindi et al., 2017; Kirby and O'Mahony, 2018; Solecki et al., 2018) that uses CRDPs as a conceptual and aspirational idea for steering societies towards low-carbon, prosperous, and ecologically safe futures. Such a notion of pathways foregrounds decision-making processes at local to national levels to situate transformation, resilience, equity, and well-being in the complex reality of specific places, nations, and communities (Harris et al., 2017; Ziervogel et al., 2017; Fazey et al., 2018; Gajjar et al., 2018; Klinsky and Winkler, 2018; Patterson et al., 2018; Tàbara et al., 2018).

Pathways compatible with 1.5°C warming are not merely scenarios to envision possible futures but processes of deliberation and implementation that address societal values, local priorities, and inevitable trade-offs. This includes attention to politics and power that perpetuate business-as-usual trajectories (K. O'Brien, 2016; Harris et al., 2017), the politics that shape sustainability and capabilities of everyday life (Agyeman et al., 2016; Schlosberg et al., 2017), and ingredients for community resilience and transformative change (Fazey et al., 2018). Chartering CRDPs encourages locally-situated and problem-solving processes to negotiate and operationalise resilience 'on the ground' (Beilin and Wilkinson, 2015; Harris et al., 2017; Ziervogel et al., 2017). This entails contestation, inclusive governance, and iterative engagement of diverse populations with varied needs, aspirations, agency, and rights claims, including those most affected, to deliberate trade-offs in a multiplicity of possible pathways (see Figure 5.6) (Stirling, 2014; Vale, 2014; Walsh-Dilley and Wolford, 2015; Biermann et al., 2016; J.R.A. Butler et al., 2016; K.L. O'Brien, 2016; Harris et al., 2017; Jones and Tanner, 2017; Mapfumo et al., 2017; Rosenbloom, 2017; Gajjar et al., 2018; Klinsky and Winkler, 2018; Lyon, 2018; O'Brien, 2018; Tàbara et al., 2018) (*high confidence*).

[INSERT FIGURE 5.6 HERE]

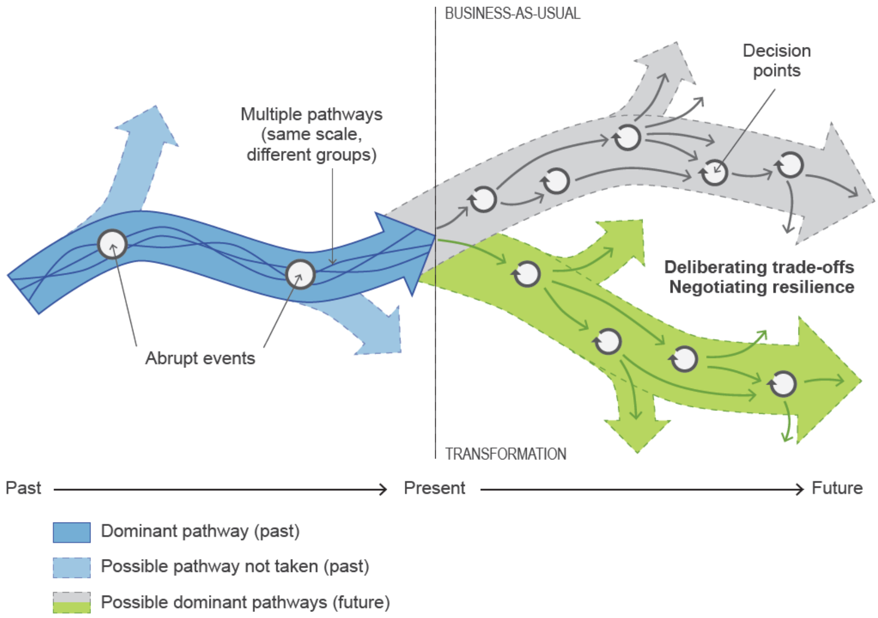


**Figure 5.6:** Pathways into the future, with path dependencies and iterative problem-solving and decision-making (after Fazey et al. (2016).

### *5.5.3.1 Transformations, Equity, and Well-being*

Most literature related to CRDPs invokes the concept of transformation, underscoring the need for urgent and far-reaching changes in practices, institutions, and social relations in society. Transformations toward a 1.5°C warmer world would need to address considerations for equity and well-being, including in trade-off decisions (see Figure 5.1).

To attain the anticipated *transformations*, all countries as well as non-state actors would need to strengthen their contributions, through bolder and more committed cooperation and equitable effort-sharing (Rao, 2014; Frumhoff et al., 2015; Ekwurzel et al., 2017; Holz et al., 2017; Millar et al., 2017; Shue, 2017; Robinson and Shine, 2018) (*medium evidence, high agreement*). Sustaining decarbonisation rates at a 1.5°C-compatible level would be unprecedented and not possible without rapid transformations to a net-zero-emissions global economy by mid-century or the later half of the century (see Chapters 2 and 4). Such efforts would entail overcoming technical, infrastructural, institutional, and behavioural barriers across all sectors and levels of society (Pfeiffer et al., 2016; Seto et al., 2016) and defeating path dependencies, including poverty traps (Boonstra et al., 2016; Enqvist et al., 2016; Haider et al., 2017; Lade et al., 2017). Transformation also entails ensuring that 1.5°C-compatible pathways are inclusive and desirable, build solidarity and alliances, and protect vulnerable groups, including against disruptions of transformation (Patterson et al., 2018).

There is growing emphasis on the role of *equity, fairness*, and *justice* (see Glossary) regarding context-specific transformations and pathways to a 1.5°C warmer world (Shue, 2014; Thorp, 2014; Dennig et al., 2015; Moellendorf, 2015; Klinsky et al., 2017b; Roser and Seidel, 2017; Sealey-Huggins, 2017; Klinsky and Winkler, 2018; Robinson and Shine, 2018) (*medium evidence, high agreement*). Consideration for what is equitable and fair suggests the need for stringent decarbonisation and up-scaled adaptation that do not exacerbate social injustices, locally and at national levels (Okereke and Coventry, 2016), uphold human rights (Robinson and Shine, 2018), are socially desirable and acceptable (von Stechow et al., 2016; Rosenbloom, 2017), address values and beliefs (O'Brien, 2018), and overcome vested interests (Normann, 2015; Patterson et al., 2016). Attention is often drawn to huge disparities in the cost, benefits, opportunities, and challenges involved in transformation within and between countries, and the fact that the suffering of already poor, vulnerable, and disadvantaged populations may be worsened, if care to protect them is not taken (Holden et al., 2017; Klinsky and Winkler, 2018; Patterson et al., 2018).

*Well-being for all* (Dearing et al., 2014; Raworth, 2017) is at the core of an ecologically safe and socially just space for humanity, including health and housing to peace and justice, social equity, gender equality, and political voices (Raworth, 2017). It is in alignment with transformative social development (UNRISD, 2016) and the 2030 Agenda of 'leaving no one behind'. The social conditions to enable well-being for all are to reduce entrenched inequalities within and between countries (Klinsky and Winkler, 2018), rethink prevailing values, ethics and behaviours (Holden et al., 2017), allow people to live a life in dignity while avoiding actions that undermine capabilities (Klinsky and Golub, 2016), transform economies (Popescu and Ciurlau, 2016; Tàbara et al., 2018), overcome uneven consumption and production patterns (Dearing et al., 2014; Häyhä et al., 2016; Raworth, 2017) and conceptualise development as well-being rather than mere economic growth (Gupta and Pouw, 2017) (*medium evidence, high agreement*).

#### *5.5.3.2 Development Trajectories, Sharing of Efforts, and Cooperation*

The potential for pursuing sustainable and climate-resilient development pathways toward a 1.5°C warmer world differs between and within nations, due to differential development achievements and trajectories, and opportunities and challenges (Figure 5.1) (*very high confidence*). There are clear differences between high-income countries where social achievements are high, albeit often with negative effects on the environment, and most developing nations where vulnerabilities to climate change are high and social support and life satisfaction are low, especially in the Least Developed Countries (Sachs et al., 2017; O'Neill et al., 2018). Differential starting points for CRDPs between and within countries, including path dependencies (Figure 5.6), call for sensitivity to context (Klinsky and Winkler, 2018). For the developing world, limiting warming to 1.5°C also means potentially severely curtailed development prospects (Okereke and Coventry, 2016) and risks to human rights from both climate action and inaction to achieve this goal (Robinson and Shine, 2018) (Section 5.2). Within-country development differences remain, despite efforts to ensure inclusive societies (Gupta and Arts, 2017; Gupta and Pouw, 2017). Cole et al. (2017), for instance, show how differences between provinces in South Africa constitute barriers to sustainable development trajectories and for operationalising nation-level SDGs, across various dimensions of social deprivation and environmental stress, reflecting historic disadvantages.

Moreover, various equity and effort- or burden-sharing approaches to climate stabilisation in the literature allow to sketch national potentials for a 1.5°C warmer world (e.g., CSO Review, 2015; Meinshausen et al., 2015; Okereke and Coventry, 2016; Anand, 2017; Bexell and Jönsson, 2017; Holz et al., 2017; Otto et al., 2017; Pan et al., 2017; Robiou du Pont et al., 2017; Kartha et al., 2018; Winkler et al., 2018). Many approaches build on the AR5 'responsibility-capacity-need' assessment (Clarke et al., 2014), complement other proposed national-level metrics for capabilities, equity, and fairness (Heyward and Roser, 2016; Klinsky et al., 2017a), or fall under the wider umbrella of fair share debates on responsibility, capability, and right to development in climate policy (Fuglestvedt and Kallbekken, 2016). Importantly, different principles and methodologies generate different calculated contributions, responsibilities, and capacities (Skeie et al., 2017).

The notion of nation-level fair shares is now also discussed in the context of limiting global warming to 1.5°C, and the Nationally Determined Contributions (NDCs) (see Chapter 4, Cross-Chapter Box 11 in Chapter 4) (CSO Review, 2015; Mace, 2016; Holz et al., 2017; Pan et al., 2017; Robiou du Pont et al., 2017; Kartha et al., 2018; Winkler et al., 2018). A study by Pan et al. (2017) concluded that all countries would need to contribute to ambitious emission reduction and that current pledges for 2030 by seven out of eight high-emitting countries would be insufficient to meet 1.5°C. Emerging literature on justice-centred pathways to 1.5°C points toward ambitious emission reductions domestically and committed cooperation internationally whereby wealthier countries support poorer ones, technologically, financially, and otherwise to enhance capacities (Okereke and Coventry, 2016; Holz et al., 2017; Robinson and Shine, 2018; Shue, 2018). These findings suggest that equitable and 1.5°C-compatible pathways would require fast action across all countries at all levels of development rather than late accession of developing countries (as assumed under SSP3, see Chapter 2), with external support for prompt mitigation and resilience-building efforts in the latter (*medium evidence, medium agreement*).

Scientific advances since the AR5 now also allow to determine contributions to climate change for non-state actors (see Chapter 4, Section 4.4.1) and their potential to contribute to CRDPs (*medium evidence, medium agreement*). This includes cities (Bulkeley et al., 2013, 2014; Byrne et al., 2016), businesses (Heede, 2014; Frumhoff et al., 2015; Shue, 2017), transnational initiatives (Castro, 2016; Andonova et al., 2017), and industries. Recent work demonstrates the contributions of 90 industrial carbon producers to global temperature and sea level rise, and their responsibilities to contribute to investments in and support for mitigation and adaptation (Heede, 2014; Ekwurzel et al., 2017; Shue, 2017) (Sections 5.6.1 and 5.6.2).

At the level of groups and individuals, equity in pursuing climate resilience for a 1.5°C warmer world means addressing disadvantage, inequities, and empowerment that shape transformative processes and pathways (Fazey et al., 2018), and deliberate efforts to strengthen the capabilities, capacities, and well-being of poor, marginalised, and vulnerable people (Byrnes, 2014; Tokar, 2014; Harris et al., 2017; Klinsky et al., 2017a; Klinsky and Winkler, 2018). Community-driven CRDPs can flag potential negative impacts of national trajectories on disadvantaged groups, such as low-income families and communities of colour (Rao, 2014). They emphasise social equity, participatory governance, social inclusion, and human rights, as well as innovation, experimentation, and social learning (see Glossary) (*medium evidence, high agreement*) (Sections 5.5.3.3 and 5.6).

#### *5.5.3.3 Country and Community Strategies and Experiences*

There are many possible pathways toward climate-resilient futures (O'Brien, 2018; Tàbara et al., 2018). Literature depicting different sustainable development trajectories in line with CRDPs is growing with some specific to 1.5°C global warming. Most experiences to date are at local and sub-national levels (Cross-Chapter Box 13 in this Chapter) while state-level efforts align largely with green economy trajectories or planning for climate resilience (Box 5.3). Due to the fact that these strategies are context-specific, the literature is scarce on comparisons, efforts to scale up, and systematic monitoring.

States can play an enabling or hindering role in transitions to 1.5°C warmer worlds (Patterson et al., 2018). The literature on strategies to reconcile low-carbon trajectories with sustainable development and ecological sustainability through green growth, inclusive growth, de-growth, post-growth, and development as well-being shows *low agreement* (see Chapter 4, Section 4.5). Efforts that align best with CRDPs are described as 'transformational' and 'strong' (Ferguson, 2015). Some view 'thick green' perspectives as enabling equity, democracy, and agency building (Lorek and Spangenberg, 2014; Stirling, 2014; Ehresman and Okereke, 2015; Buch-Hansen, 2018), others show how green economy and sustainable development pathways can align (Brown et al., 2014; Georgeson et al., 2017b), and how a green economy can help link the SDGs with NDCs, for instance in Mongolia, Kenya, and Sweden (Shine, 2017). Others still critique the continuous reliance on market mechanisms (Wanner, 2014; Brockington and Ponte, 2015), and disregard for equity and distributional and procedural justice (Stirling, 2014; Bell, 2015).

Country-level pathways and achievements vary significantly (*robust evidence, medium agreement*). For instance, the Scandinavian countries rank top in the Global Green Economy Index (Dual Citizen LLC, 2016), although they also tend to show high spill-over effects (Holz et al., 2017) and transgress their biophysical boundaries (O'Neill et al., 2018). State-driven efforts in non-member countries of the Organisation for Economic Co-operation and Development include Ethiopia's 'Climate-resilient Green Economy Strategy', Mozambique's 'Green Economy Action Plan', and Costa Rica's ecosystem- and conservation-driven green transition paths. China and India have adopted technology and renewables pathways (Brown et al., 2014; Death, 2014, 2015, 2016; Khanna et al., 2014; Chen et al., 2015; Kim and Thurbon, 2015; Wang et al., 2015; Weng et al., 2015). Brazil promotes low per-capita GHG emissions, clean energy sources, green jobs, renewables, and sustainable transportation while slowing rates of deforestation (Brown et al., 2014; La Rovere, 2017) (see Chapter 4, Box 4.7). Yet, concerns remain regarding persistent inequalities, ecosystem monetisation, lack of participation in green-style projects (Brown et al., 2014), and labour conditions and risk of displacement in the sugarcane ethanol sector (McKay et al., 2016). Experiences with low-carbon development pathways in Least Developed Countries (LDCs) highlight the crucial role of identifying synergies across scale, removing institutional barriers, and ensuring equity and fairness in distributing benefits as part of the right to development (Rai and Fisher, 2017).

In small islands states, for many of which climate change hazards and impacts at 1.5°C pose significant risks to sustainable development (see Chapter 3 Box 3.5, Chapter 4 Box 4.3, Box 5.3), examples of CRDPs have emerged since the AR5. This includes the SAMOA Pathway: SIDS Accelerated Modalities of Action (see Chapter 4, Box 4.3) (UN, 2014a; Government of Kiribati, 2016; Steering Committee on Partnerships for SIDS and UNDESA, 2016; Lefale et al., 2017) and the Framework for Resilient Development in the Pacific, a leading example of integrated regional climate change adaptation planning for mitigation and sustainable development, disaster risk management and low carbon economies (FRDP, 2016). Small islands of the Pacific vary significantly in their capacity and resources to support effective integrated planning (McCubbin et al., 2015; Barnett and Walters, 2016; Cvitanovic et al., 2016; Hemstock, 2017; Robinson and Dornan, 2017). Vanuatu (Box 5.3) has developed a significant coordinated national adaptation plan to advance the 2030 Agenda for Sustainable Development, respond to the Paris Agreement, and reduce the risk of disasters in line with the Sendai targets (UNDP, 2016; Republic of Vanuatu, 2017).

[START BOX 5.3 HERE]

**Box 5.3:** Republic of Vanuatu – National Planning for Development and Climate Resilience

The Republic of Vanuatu is leading Pacific Small Island Developing States (SIDS)to develop a nationally coordinated plan for climate-resilient development in the context of high exposure to hazard risk (MCCA, 2016; UNU-EHS, 2016). The majority of the population depends on subsistence, rain-fed agriculture and coastal fisheries for food security (Sovacool et al., 2017). Sea level rise, increased prolonged drought, water shortages, intense storms, cyclone events, and degraded coral reef environments threaten human security in a 1.5°C warmer world (see Chapter 3, Box 3.5) (SPC, 2015; Aipira et al., 2017). Given Vanuatu's long history of disasters, local adaptive capacity is relatively high, despite barriers to the use of local knowledge and technology, and low rates of literacy and women's participation (McNamara and Prasad, 2014; Aipira et al., 2017; Granderson, 2017). However, the adaptive capacity of Vanuatu and other SIDS is increasingly constrained due to more frequent severe weather events (see Chapter 3 Box 3.5, Chapter 4, Cross-Chapter Box 9 in Chapter 4) (Gero et al., 2013; Kuruppu and Willie, 2015; SPC, 2015; Sovacool et al., 2017).

Vanuatu has developed a national sustainable development plan for 2016-2030: the People's Plan (Republic of Vanuatu, 2016). This coordinated, inclusive plan of action on economy, environment, and society aims to strengthen adaptive capacity and resilience to climate change and disasters. It emphasises rights of all Ni-Vanuatu, including women, youth, the elderly, and vulnerable groups (Nalau et al., 2016). Vanuatu has also developed a Coastal Adaptation Plan (Republic of Vanuatu, 2016), an integrated Climate Change and Disaster Risk Reduction Policy (2016–2030) (SPC, 2015), and the first South Pacific National Advisory Board on Climate Change & Disaster Risk Reduction (SPC, 2015; UNDP, 2016).

Vanuatu aims to integrate planning at multiple scales, and increase climate resilience by supporting local coping capacities and iterative processes of planning for sustainable development and integrated risk assessment (Aipira et al., 2017; Eriksson et al., 2017; Granderson, 2017). Climate-resilient development is also supported by non-state partnerships, for example, the 'Yumi stap redi long climate change'– or the Vanuatu non-governmental organisation Climate Change Adaptation Program (Maclellan, 2015). This programme focuses on equitable governance, with particular attention to supporting women's voices in decision making through allied programs addressing domestic violence, and rights-based education to reduce social marginalisation; alongside institutional reforms for greater transparency, accountability, and community participation in decision-making (Davies, 2015; Maclellan, 2015; Sterrett, 2015; Ensor, 2016; UN Women, 2016).

Power imbalances embedded in the political economy of development (Nunn et al., 2014), gender discrimination (Aipira et al., 2017), and the priorities of climate finance (Cabezon et al., 2016) may marginalise the priorities of local communities and influence how local risks are understood, prioritised, and managed (Kuruppu and Willie, 2015; Baldacchino, 2017; Sovacool et al., 2017). However, the experience of the low death toll after Cyclone Pam suggests effective use of local knowledge in planning and early warning may support resilience at least in the absence of storm surge flooding (Handmer and Iveson, 2017; Nalau et al., 2017). Nevertheless, the very severe infrastructure damage of Cyclone Pam 2015 highlights the limits of individual Pacific SIDS efforts and the need for global and regional responses to a 1.5°C warmer world (Dilling et al., 2015; Ensor, 2016; Shultz et al., 2016; Rey et al., 2017) (see Chapter 3 Box 3.5, Chapter 4 Box 4.3).

[END BOX 5.3 HERE]

Communities, towns, and cities also contribute to low-carbon pathways, sustainable development and fair and equitable climate resilience, often focused on processes of power, learning, and contestation as entry points to more localised CRDPs (*medium evidence, high agreement*) (Cross-Chapter Box 13 in this Chapter, Box 5.2). In the Scottish Borders Climate Resilient Communities Project (United Kingdom), local flood management is linked with national policies to foster cross-scalar and inclusive governance, with attention to systemic disadvantages, shocks and stressors, capacity building, learning for change, and climate narratives to inspire hope and action, all of which are essential for community resilience in a 1.5°C warmer world (Fazey et al., 2018). Narratives and storytelling are vital for realising place-based 1.5°C futures as they create space for agency, deliberation, co-constructing meaning, imagination, and desirable and dignified pathways (Veland et al., 2018). Engagement with possible futures, identity, and self-reliance is also documented for Alaska where 1.5°C warming has already been exceeded and indigenous communities invest in renewable energy, greenhouses for food security, and new fishing practices to overcome loss of sea ice, flooding, and erosion (Chapin et al., 2016; Fazey et al., 2018). The Asian Cities Climate Change Resilience Network (ACCRN) facilitates shared learning dialogues, risk-to-resilience workshops, and iterative, consultative planning in flood-prone cities in India; vulnerable communities, municipal governmental agents, entrepreneurs, and technical experts negotiate different visions, trade-offs, and local politics to identify desirable pathways (Harris et al., 2017).

Transforming our societies and systems to limit global warming to 1.5°C and ensuring equity and well-being for human populations and ecosystems in a 1.5°C warmer world would require ambitious and well-integrated adaptation-mitigation-development pathways that deviate fundamentally from high-carbon, business-as-usual futures (Okereke and Coventry, 2016; Arts, 2017; Gupta and Arts, 2017; Sealey-Huggins, 2017). Identifying and negotiating socially acceptable, inclusive, and equitable pathways toward climate-resilient futures is a challenging, yet important, endeavour, fraught with complex moral, practical, and political difficulties and inevitable trade-offs (*very high confidence*). The ultimate questions are: what futures do we want (Bai et al., 2016; Tàbara et al., 2017; Klinsky and Winkler, 2018; O'Brien, 2018; Veland et al., 2018), whose resilience matters, for what, where, when and why (Meerow and Newell, 2016), and 'whose vision … is being pursued and along which pathways' (Gillard et al., 2016).

[START CROSS-CHAPTER BOX 13 HERE]

**Cross-Chapter Box 13:** Cities and Urban Transformation

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**Global Urbanisation in a 1.5°C Warmer World**

The concentration of economic activity, dense social networks, human resource capacity, investment in infrastructure and buildings, relatively nimble local governments, close connection to surrounding rural and natural environments, and a tradition of innovation provide urban areas with transformational potential (Castán Broto, 2017) (see Chapter 4, Section 4.3.3). In this sense, the urbanisation mega-trend that will take place over the next three decades, and add approximately 2 billion people to the global urban population (UN, 2014b), offers opportunities for efforts to limit warming to 1.5°C.

Cities can also, however, concentrate the risks of flooding, landslides, fire, and infectious and parasitic disease that are expected to heighten in a 1.5°C warmer world (Chapter 3). In African and Asian countries where urbanisation rates are highest, these risks could expose and amplify pre-existing stresses related to poverty, exclusion, and governance (Gore, 2015; Dodman et al., 2017; Jiang and O'Neill, 2017; Pelling et al., 2018; Solecki et al., 2018). Through its impact on economic development and investment, urbanisation often leads to increased consumption and environmental degradation and enhanced vulnerability, risk, and impacts (Rosenzweig et al., 2018). In the absence of innovation, the combination of urbanisation and urban economic development could contribute 226 $GtCO_2$ in emissions by 2050 (Bai et al., 2018). At the same time, some new urban developments are demonstrating combined carbon and Sustainable Development Goals (SDG) benefits (Wiktorowicz et al., 2018), and it is in towns and cities that building renovation rates can be most easily accelerated to support the transition to 1.5°C pathways (Kuramochi et al., 2018), including through voluntary programs (Van der Heijden, 2018).

**Urban Transformations and Emerging Climate-Resilient Development Pathways**

1.5°C pathways require action in all cities and urban contexts. Recent literature emphasises the need to deliberate and negotiate how resilience and climate-resilient pathways can be fostered in the context of people's daily lives, including the failings of everyday development such as unemployment, inadequate housing, and growing informality, in order to acknowledge local priorities and foster transformative learning (Vale, 2014; Shi et al., 2016; Harris et al., 2017; Ziervogel et al., 2017; Fazey et al., 2018; Macintyre et al., 2018). Enhancing deliberate transformative capacities in urban contexts also entails new and relational forms of envisioning agency, equity, resilience, social cohesion, and well-being (Gillard et al., 2016; Ziervogel et al., 2016) (Section 5.5.3). Two examples of urban transformation are explored here.

The built environment, spatial planning, infrastructure, energy services, mobility, and urban-rural linkages necessary in **rapidly growing cities in South Asia and Africa** in the next three decades present mitigation, adaptation and development opportunities that are crucial for a 1.5°C world (Newman et al., 2017; Lwasa et al., 2018; Teferi and Newman, 2018). Realising these opportunities would require the structural challenges of poverty, weak and contested local governance, and low levels of local government investment to be addressed on an unprecedented scale (Wachsmuth et al., 2016; Chu et al., 2017; van Noorloos and Kloosterboer, 2017; Pelling et al., 2018).

Urban governance is critical to ensuring that the necessary urban transitions deliver economic growth and equity (Hughes et al., 2018). The proximity of local governments to citizens and their needs can make them powerful agents of climate action (Melica et al., 2018), but urban governance is enhanced when it involves multiple actors (Ziervogel et al., 2016; Pelling et al., 2018), supportive national governments (Tait and Euston-Brown, 2017) and sub-national climate networks (see Chapter 4, Section 4.4.1). Governance is complicated for the urban population currently living in what is termed 'informality'. This population is expected to triple, to three billion, by 2050 (Satterthwaite et al., 2018), placing a significant portion of the world's population beyond the direct reach of formal climate mitigation and adaptation policies (Revi et al., 2014). How to address the co-evolved and structural conditions that lead to urban informality and associated vulnerability to 1.5°C of warming is a central question for this report. Brown and McGranahan (2016) cite evidence that the informal urban "green economy" that has emerged out of necessity in the absence of formal service provisions is frequently low-carbon and resource-efficient.

Realising the potential for low carbon transitions in informal urban settlements would require an express recognition of the unpaid-for contributions of women in the informal economy, and new partnerships between the state and communities (Ziervogel et al., 2017; Pelling et al., 2018; Satterthwaite et al., 2018). There is no guarantee that these partnerships will evolve or cohere into the type of service delivery and climate governance system that could steer the change on a scale required to limit to warming to 1.5°C (Jaglin, 2014). However, transnational networks such as Shack/Slum Dwellers International, C40, the Global Covenant of Mayors, and International Council for Local Environmental Initiatives (ICLEI), as well as efforts to combine in-country planning for Nationally Determined Contributions (NDCs) (Andonova et al., 2017; Fuhr et al., 2018) with those taking place to support the New Urban Agenda and National Urban Policies, represent one step towards realising the potential (Tait and Euston-Brown, 2017). So too do "old urban agendas" such as slum upgrading and universal water and sanitation provision (McGranahan et al., 2016; Satterthwaite, 2016; Satterthwaite et al., 2018).

**Transition Towns (TTs)** is a type of urban transformation mainly in high-income countries. The grassroots TT movement (origin in the United Kingdom) combines adaptation, mitigation, and just transitions, mainly at the level of communities and small towns. It now has >1,300 registered local initiatives in >40 countries (Grossmann and Creamer, 2017), many of them in the United Kingdom, the United States, and other high-income countries. TTs are described as 'progressive localism' (Cretney et al., 2016), aiming to foster a 'communitarian ecological citizenship' that goes beyond changes in consumption and lifestyle (Kenis, 2016). They aspire to promote equitable communities resilient to the impacts of climate change, peak oil, and unstable global markets; re-localisation of production and consumption; and transition pathways to a post-carbon future (Feola and Nunes, 2014; Evans and Phelan, 2016; Grossmann and Creamer, 2017).

TT initiatives typically pursue lifestyle-related low-carbon living and economies, food self-sufficiency, energy efficiency through renewables, construction with locally-sourced material, and cottage industries (Barnes, 2015; Staggenborg and Ogrodnik, 2015; Taylor Aiken, 2016). Social and iterative learning through the collective involves dialogue, deliberation, capacity building, citizen science engagements, technical re-skilling to increase self-reliance, for example canning and preserving food and permaculture, future visioning, and emotional training to share difficulties and loss (Feola and Nunes, 2014; Barnes, 2015; Boke, 2015; Taylor Aiken, 2015; Kenis, 2016; Mehmood, 2016; Grossmann and Creamer, 2017).

Important conditions for successful transition groups include flexibility, participatory democracy, care ethics, inclusiveness, and consensus-building, assuming bridging or brokering roles, and community alliances and partnerships (Feola and Nunes, 2014; Mehmood, 2016; Taylor Aiken, 2016; Grossmann and Creamer, 2017). Smaller scale rural initiatives allow for more experimentation (Cretney et al., 2016) while those in urban centres benefit from stronger networks and proximity to power structures (North and Longhurst, 2013; Nicolosi and Feola, 2016). Increasingly, TTs recognise the need to participate in policy making (Kenis and Mathijs, 2014; Barnes, 2015).

Despite high self-ratings of success, some TT initiatives are too inwardly focused and geographically isolated (Feola and Nunes, 2014) while others have difficulties in engaging marginalised, non-white, non-middle-class community members (Evans and Phelan, 2016; Nicolosi and Feola, 2016; Grossmann and Creamer, 2017). In the United Kingdom, expectations of innovations growing in scale (Taylor Aiken, 2015) and carbon accounting methods required by funding bodies (Taylor Aiken, 2016) undermine local resilience building. Tension between explicit engagements with climate change action and efforts to appeal to more people have resulted in difficult trade-offs and strained member relations (Grossmann and Creamer, 2017) though the contribution to changing an urban culture that prioritises climate change can be underestimated (Wiktorowicz et al., 2018).

Urban actions that can highlight the 1.5°C agenda include individual actions within homes (Werfel, 2017; Buntaine and Prather, 2018), demonstration zero carbon developments (Wiktorowicz et al., 2018), new partnerships between communities, government and business to build mass transit and electrify transport (Glazebrook and Newman, 2018), city plans to include climate outcomes (Millard-Ball, 2013), and support for transformative change across political, professional, and sectoral divides (Bai et al., 2018).

[END CROSS-CHAPTER BOX 13 HERE]

## 5.6 Conditions for Achieving Sustainable Development, Eradicating Poverty and Reducing Inequalities in 1.5°C Warmer Worlds

This chapter has described the fundamental, urgent, and systemic transformations that would be needed to achieve sustainable development, eradicate poverty, and reduce inequalities in a 1.5°C warmer world, in various contexts and across scales. In particular, it has highlighted the societal dimensions, putting at the centre people's needs and aspirations in their specific contexts. Here, we synthesise some of the most pertinent enabling conditions (see Glossary) to support these profound transformations. These conditions are closely interlinked and connected by the overarching concept of governance, which broadly includes institutional, socioeconomic, cultural, and technological elements (see Chapter 1, Cross-Chapter Box 4 in Chapter 1).

### *5.6.1 Finance and Technology Aligned with Local Needs*

Significant gaps in green investment constrain transitions to a low-carbon economy aligned with development objectives (Volz et al., 2015; Campiglio, 2016). Hence, unlocking new forms of public, private, and public-private financing is essential to support environmental sustainability of the economic system (Croce et al., 2011; Blyth et al., 2015; Falcone et al., 2018) (see Chapter 4, Section 4.4.5). To avoid risks of undesirable trade-offs with the SDGs caused by national budget constraints, improved access to international climate finance is essential for supporting adaptation, mitigation, and sustainable development, especially for Least Developed Countries (LDCs) and Small Island Developing States (SIDS) (Shine and Campillo, 2016; Wood, 2017) (*medium evidence, high agreement*). Care needs to be taken when international donors or partnership arrangements influence project financing structures (Kongsager and Corbera, 2015; Purdon, 2015; Ficklin et al., 2017; Phillips et al., 2017). Conventional climate funding schemes, especially the Clean Development Mechanism (CDM), have shown positive effects on sustainable development but also adverse consequences, for example on adaptive capacities of rural households and uneven distribution of costs and benefits, often exacerbating inequalities (Aggarwal, 2014; Brohé, 2014; He et al., 2014; Schade and Obergassel, 2014; Smits and Middleton, 2014; Wood et al., 2016a; Horstmann and Hein, 2017; Kreibich et al., 2017) (*robust evidence, high agreement*). Close consideration of recipients' context-specific needs when designing financial support helps to overcome these limitations as it better aligns community needs, national policy objectives, and donors' priorities, puts the emphasis on the increase of transparency and predictability of support, and fosters local capacity building (Barrett, 2013; Boyle et al., 2013; Shine and Campillo, 2016; Ley, 2017; Sánchez and Izzo, 2017) (*medium evidence, high agreement*).

The development and transfer of technologies is another enabler for developing countries to contribute to the requirements of the 1.5°C objective while achieving climate resilience and their socioeconomic development goals (see Chapter 4, Section 4.4.4). International-level governance would be needed to boost domestic innovation and the deployment of new technologies such as Negative Emission Technologies toward the 1.5°C objective (see Chapter 4, Section 4.3.7), but the alignment with local needs depends on close consideration of the specificities of the domestic context in countries at all levels of development (de Coninck and Sagar, 2015; IEA, 2015; Parikh et al., 2018). Technology transfer supporting development in developing countries would require an understanding of local and national actors and institutions (de Coninck and Puig, 2015; de Coninck and Sagar, 2017; Michaelowa et al., 2018), careful attention to the capacities in the entire innovation chain (Khosla et al., 2017; Olawuyi, 2017), and transfer of not only equipment but also knowledge (Murphy et al., 2015) (*medium evidence, high agreement*).

### *5.6.2 Integration of Institutions*

Multi-level governance in climate change has emerged as a key enabler for systemic transformation and effective governance (see Chapter 4, Section 4.4.1). On the one hand, low-carbon and climate-resilient development actions are often well aligned at the lowest scale possible (Suckall et al., 2015; Sánchez and Izzo, 2017), and informal, local institutions are critical in enhancing the adaptive capacity of countries and marginalised communities (Yaro et al., 2015). On the other hand, international and national institutions can provide incentives for projects to harness synergies and avoid trade-offs (Kongsager et al., 2016).

Governance approaches that coordinate and monitor multi-scale policy actions and trade-offs across sectoral, local, national, regional, and international levels are therefore best suited to implement goals toward 1.5°C warmer conditions and sustainable development (Ayers et al., 2014; Stringer et al., 2014; von Stechow et al., 2016; Gwimbi, 2017; Hayward, 2017; Maor et al., 2017; Roger et al., 2017; Michaelowa et al., 2018). Vertical and horizontal policy integration and coordination is essential to take into account the interplay and trade-offs between sectors and spatial scales (Duguma et al., 2014; Naess et al., 2015; von Stechow et al., 2015; Antwi-Agyei et al., 2017a; Di Gregorio et al., 2017; Runhaar et al., 2018), enable the dialogue between local communities and institutional bodies (Colenbrander et al., 2016), and involve non-state actors such as business, local governments, and civil society operating across different scales (Hajer et al., 2015; Labriet et al., 2015; Hale, 2016; Pelling et al., 2016; Kalafatis, 2017; Lyon, 2018) (*robust evidence, high agreement*).

### *5.6.3 Inclusive Processes*

Inclusive governance processes are critical for preparing for a 1.5°C warmer world (Fazey et al., 2018; O'Brien, 2018; Patterson et al., 2018). These processes have been shown to serve the interests of diverse groups of people and enhance empowerment of often excluded stakeholders, notably women and youth, (MRFCJ, 2015a; Dumont et al., 2017). They also enhance social and co-learning which, in turn, facilitates accelerated and adaptive management and the scaling up of capacities for resilience building (Ensor and Harvey, 2015; Reij and Winterbottom, 2015; Tschakert et al., 2016; Binam et al., 2017; Dumont et al., 2017; Fazey et al., 2018; Lyon, 2018; O'Brien, 2018), and provides opportunities to blend indigenous, local, and scientific knowledge (Antwi-Agyei et al., 2017a; Coe et al., 2017; Thornton and Comberti, 2017) (see Chapter 4, Section 4.3.5.5, Box 4.3; Section 5.3) (*robust evidence, high agreement*). Such co-learning has been effective in improving deliberative decision-making processes that incorporate different values and world views (Cundill et al., 2014; C. Butler et al., 2016; Ensor, 2016; Fazey et al., 2016; Gorddard et al., 2016; Aipira et al., 2017; Fook, 2017; Maor et al., 2017), and create space for negotiating diverse interests and preferences (O'Brien et al., 2015; Gillard et al., 2016; DeCaro et al., 2017; Harris et al., 2017; Lahn, 2017) (*robust evidence, high agreement*).

### *5.6.4 Attention to Issues of Power and Inequality*

Societal transformations to limit global warming to 1.5°C and strive for equity and well-being for all are not power neutral (Section 5.5.3). Development preferences are often shaped by powerful interests that determine the direction and pace of change, anticipated benefits and beneficiaries, and acceptable and unacceptable trade-offs (Newell et al., 2014; Fazey et al., 2016; Tschakert et al., 2016; Winkler and Dubash, 2016; Wood et al., 2016b; Karlsson et al., 2017; Quan et al., 2017; Tanner et al., 2017). Each development pathway, including legacies and path dependencies, creates its own set of opportunities and challenges and winners and losers, both within and across countries (Figure 5.6) (Mathur et al., 2014; Ficklin et al., 2017; Phillips et al., 2017; Stringer et al., 2017; Wood, 2017; Gajjar et al., 2018) (*robust evidence, high agreement*).

Addressing the uneven distribution of power is critical to ensure that societal transformation toward a 1.5°C warmer world does not exacerbate poverty and vulnerability or create new injustices but rather encourages equitable transformational change (Patterson et al., 2018). Equitable outcomes are enhanced when they pay attention to just outcomes for those negatively affected by change (Newell et al., 2014; Dilling et al., 2015; Naess et al., 2015; Sovacool et al., 2015; Cervigni and Morris, 2016; Keohane and Victor, 2016) and promote human rights, increase equality, and reduce power asymmetries within societies (UNRISD, 2016; Robinson and Shine, 2018) (*robust evidence, high agreement*).

### *5.6.5 Reconsidering Values*

The profound transformations that would be needed to integrate sustainable development and 1.5°C-compatible pathways call for examining the values, ethics, attitudes, and behaviours that underpin societies (Hartzell-Nichols, 2017; O'Brien, 2018; Patterson et al., 2018). Infusing values that promote sustainable development (Holden et al., 2017), overcome individual economic interests and go beyond economic growth (Hackmann, 2016), encourage desirable and transformative visions (Tàbara et al., 2018), and care for the less fortunate (Howell and Allen, 2017) is part and parcel of climate-resilient and sustainable development pathways. This entails helping societies and individuals to strive for sufficiency in resource consumption within planetary boundaries alongside sustainable and equitable well-being (O'Neill et al., 2018). Navigating 1.5°C societal transformations, characterised by action from local to global, stresses the core commitment to social justice, solidarity, and cooperation, particularly regarding the distribution of responsibilities, rights, and mutual obligations between nations (Patterson et al., 2018; Robinson and Shine, 2018) (*medium evidence, high agreement*).

## 5.7 Synthesis and Research Gaps

The assessment in Chapter 5 illustrates that limiting global warming to 1.5°C is fundamentally connected with achieving sustainable development, poverty eradication, and reducing inequalities. It shows that avoided impacts between 1.5°C and 2°C temperature stabilisation would make it easier to achieve many aspects of sustainable development, although important risks would remain at 1.5°C (Section 5.2). Synergies between adaptation and mitigation response measures with sustainable development and the Sustainable Development Goals (SDGs) can often be enhanced when attention is paid to well-being and equity while, when unaddressed, poverty and inequalities may be exacerbated (Section 5.3 and 5.4). Climate-resilient development pathways (CRDPs) open up routes toward socially desirable futures that are sustainable and liveable, but concrete evidence reveals complex trade-offs along a continuum of different pathways, highlighting the role of societal values, internal contestations, and political dynamics (Section 5.5). The transformations towards sustainable development in a 1.5°C warmer world, in all contexts, involve fundamental societal and systemic changes over time and across scale, and a set of enabling conditions without which the dual goal is difficult if not impossible to achieve (Sections 5.5 and 5.6).

This assessment is supported by growing knowledge on the linkages between a 1.5°C warmer world and different dimensions of sustainable development. However, several gaps in the literature remain:

Limited evidence exists that explicitly examines the real-world implications of a 1.5°C warmer world (and overshoots) as well as avoided impacts between 1.5°C versus 2°C for the SDGs and sustainable development more broadly. Few projections are available for households, livelihoods, and communities. And literature on differential localised impacts and their cross-sector interacting and cascading effects with multidimensional patterns of societal vulnerability, poverty, and inequalities remains scarce. Hence, caution is needed when global-level conclusions about adaptation and mitigation measures in a 1.5°C warmer world are applied to sustainable development in local, national, and regional settings.

Limited literature has systematically evaluated context-specific synergies and trade-offs between and across adaptation and mitigation response measures in 1.5°C-compatible pathways and the SDGs. This hampers the ability to inform decision-making and fair and robust policy packages adapted to different local, regional, or national circumstances. More research is required to understand how trade-offs and synergies will intensify or decrease, differentially across geographic regions and time, in a 1.5ºC warmer world and as compared to higher temperatures.

Limited availability of interdisciplinary studies also poses a challenge for connecting the socio-economic transformations and the governance aspects of low-emission, climate-resilient transformations. For example, it remains unclear how governance structures enable or hinder different groups of people and countries to negotiate pathway options, values, and priorities.

The literature does not demonstrate the existence of 1.5°C-compatible pathways achieving the "universal and indivisible" agenda of the 17 SDGs, and hence does not show whether and how the nature and pace of changes that would be required to meet 1.5°C climate stabilisation could be fully synergetic with all the SDGs.

The literature on low-emission and climate-resilient development pathways in local, regional, and national contexts is growing. Yet, the lack of standard indicators to monitor such pathways makes it difficult to compare evidence grounded in specific contexts with differential circumstances and therefore to derive generic lessons on the outcome of decisions on specific indicators. This knowledge gap poses a challenge for connecting local-level visions with global-level trajectories to better understand key conditions for societal and systems transformations that reconcile urgent climate action with well-being for all.

## Frequently Asked Questions

**FAQ 5.1:** What are the connections between sustainable development and limiting global warming to 1.5°C?

***Summary:*** *Sustainable development seeks to meet the needs of people living today without compromising the needs of future generations, while balancing social, economic and environmental considerations. The 17 UN Sustainable Development Goals (SDGs) include targets for eradicating poverty; ensuring health, energy and food security; reducing inequality; protecting ecosystems; pursuing sustainable cities and economies; and a goal for climate action (SDG13). Climate change affects the ability to achieve sustainable development goals and limiting warming to 1.5°C will help meet some sustainable development targets. Pursuing sustainable development will influence emissions, impacts and vulnerabilities. Responses to climate change in the form of adaptation and mitigation will also interact with sustainable development with positive effects, known as synergies, or negative effects, known as trade-offs. Responses to climate change can be planned to maximize synergies and limit trade-offs with sustainable development.*

For more than 25 years, the United Nations (UN) and other international organizations have embraced the concept of sustainable development to promote wellbeing and meet the needs of today's population without compromising the needs of future generations. This concept spans economic, social and environmental objectives including poverty and hunger alleviation, equitable economic growth, access to resources, and the protection of water, air and ecosystems. Between 1990 and 2015, the UN monitored a set of eight Millennium Development Goals (MDGs). They reported progress in reducing poverty, easing hunger and child mortality, and improving access to clean water and sanitation. But with millions remaining in poor health, living in poverty, and facing serious problems associated with climate change, pollution and land use change, the UN decided that more needed to be done. In 2015, the UN *Sustainable Development Goals* (SDGs) were endorsed as part of the 2030 Agenda for Sustainable Development. The 17 SDGs (Figure FAQ 5.1) apply to all countries and have a timeline for success by 2030. The SDGs seek to eliminate extreme poverty and hunger; ensure health, education, peace, safe water, and clean energy for all; promote inclusive and sustainable consumption, cities, infrastructure and economic growth; reduce inequality including gender inequality; combat climate change and protect oceans and terrestrial ecosystems.

Climate change and sustainable development are fundamentally connected. Previous IPCC reports found that climate change can undermine sustainable development, and that well-designed mitigation and adaptation responses can support poverty alleviation, food security, healthy ecosystems, equality and other dimensions of sustainable development. Limiting global warming to 1.5°C would require mitigation actions and adaptation measures to be taken at all levels. These adaptation and mitigation actions would include reducing emissions and increasing resilience through technology and infrastructure choices, as well as changing behaviour and policy. These actions can interact with sustainable development objectives in positive ways that strengthen sustainable development, known as *synergies*. Or negative ways, where sustainable development is hindered or reversed, known as *trade-offs*.

An example of a synergy is sustainable forest management, which can prevent emissions from deforestation and take up carbon to reduce warming at reasonable cost. It can work synergistically with other dimensions of sustainable development by providing food (SDG 2), cleaning water (SDG 6) and protecting ecosystems (SDG 15). Other examples of synergies are when climate adaptation measures, such as coastal or agricultural projects, empower women and benefit local incomes, health and ecosystems.

An example of a trade-off can occur if ambitious climate change mitigation compatible with 1.5°C changes land use in ways that have negative impacts on sustainable development. An example could be turning natural forests, agricultural areas, or land under indigenous or local ownership to plantations for bioenergy production. If not managed carefully, such changes could undermine dimensions of sustainable development by threatening food and water security, creating conflict over land rights, and causing biodiversity loss. Another trade-off could occur for some countries, assets, workers, and infrastructure already in place if a switch is made from fossil fuels to other energy sources without adequate planning for such a transition. Trade-offs can be minimised if effectively managed as when care is taken to improve bioenergy crop yields to reduce harmful land-use change or where workers are retrained for employment in lower carbon sectors.

Limiting temperatures to 1.5°C can make it much easier to achieve the SDGs, but it is also possible that pursuing the SDGs could result in trade-offs with efforts to limit climate change. There are trade-offs when people escaping from poverty and hunger consume more energy or land and thus increase emissions, or if goals for economic growth and industrialization increase fossil fuel consumption and greenhouse gas emissions. Conversely, efforts to reduce poverty and gender inequalities, and to enhance food, health and water security can reduce vulnerability to climate change. Other synergies can occur when coastal and ocean ecosystem protection reduces the impacts of climate change on these systems. The sustainable development goal of affordable and clean energy (SDG 7) specifically targets access to renewable energy and energy efficiency, important to ambitious mitigation and limiting warming to 1.5°C.

The link between sustainable development and limiting global warming to 1.5°C is recognized by the Sustainable Development Goal for climate action (SDG 13) which seeks to combat climate change and its impacts while acknowledging that the UNFCCC is the primary international, intergovernmental forum for negotiating the global response to climate change.

The challenge is to put in place sustainable development policies and actions that reduce deprivation, alleviate poverty and ease ecosystem degradation while also lowering emissions, reducing climate change impacts and facilitating adaptation. It is important to strengthen synergies and minimize trade-offs when planning climate change adaptation and mitigation actions. Unfortunately, not all trade-offs can be avoided or minimised, but careful planning and implementation can build the enabling conditions for long-term sustainable development.


**FAQ 5.1, Figure 1:** Climate change action is one of the United Nations Sustainable Development Goals (SDGs) and is connected to sustainable development more broadly. Actions to reduce climate risk can interact with other sustainable development objectives in positive ways (synergies) and negative ways (trade-offs).

**FAQ 5.2:** What are the pathways to achieving poverty reduction and reducing inequalities while reaching the 1.5°C world?

***Summary:*** *There are ways to limit global warming to 1.5°C above pre-industrial levels. Of the pathways that exist, some simultaneously achieve sustainable development. They entail a mix of measures that lower emissions and reduce the impacts of climate change, while contributing to poverty eradication and reducing inequalities. Which pathways are possible and desirable will differ between and within regions and nations. This is due to the fact that development progress to date has been uneven and climate-related risks are unevenly distributed. Flexible governance would be needed to ensure that such pathways are inclusive, fair, and equitable to avoid poor and disadvantaged populations becoming worse off. 'Climate-Resilient Development Pathways' (CRDPs) offer possibilities to achieve both equitable and low-carbon futures.*

Issues of equity and fairness have long been central to climate change and sustainable development. Equity, like equality, aims to promote justness and fairness for all. This is not necessarily the same as treating everyone equally, since not everyone comes from the same starting point. Often used interchangeably with fairness and justice, equity implies implementing different actions in different places, all with a view to creating an equal world that is fair for all and where no one is left behind.

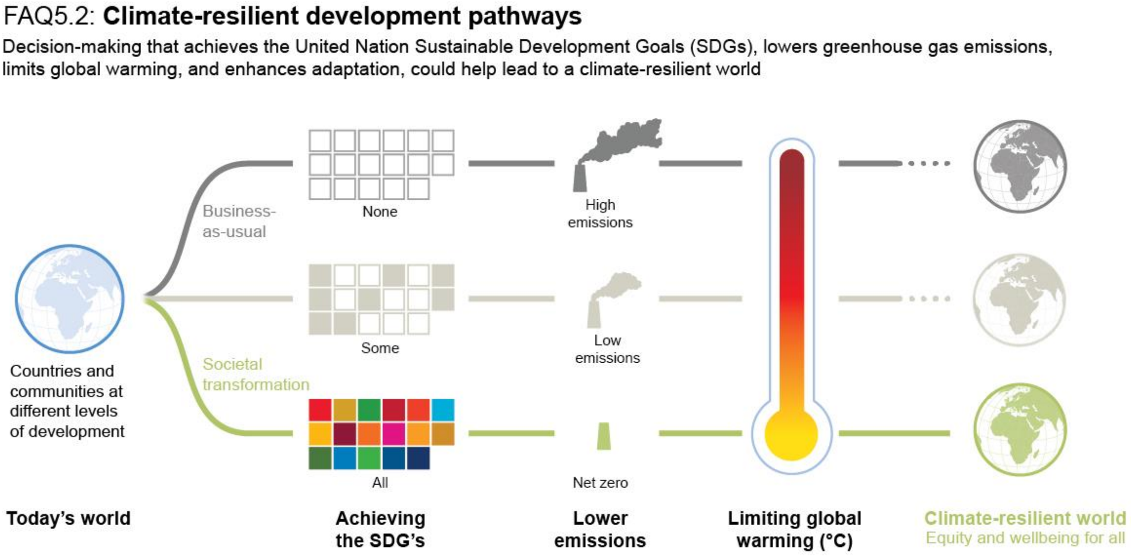
The Paris Agreement states that it "will be implemented to reflect equity… in the light of different national circumstances" and calls for "rapid reductions" of greenhouse gases to be achieved "on the basis of equity, and in the context of sustainable development and efforts to eradicate poverty". Similarly, the United Nations Sustainable Development Goals (SDGs) include targets to reduce poverty and inequalities, and to ensure equitable and affordable access to health, water, and energy for all.

The principles of equity and fairness are important for considering pathways that limit warming to 1.5°C in a way that is liveable for every person and species. They recognise the uneven development status between richer and poorer nations, the uneven distribution of climate impacts (including on future generations), and the uneven capacity of different nations and people to respond to climate risks. This is particularly true for those who are highly vulnerable to climate change such as indigenous communities in the Arctic, people whose livelihoods depend on agriculture or coastal and marine ecosystems, and inhabitants of small-island developing states. The poorest people will continue to experience climate change through the loss of income and livelihood opportunities, hunger, adverse health effects, and displacement.

Well-planned adaptation and mitigation measures are essential to avoid exacerbating inequalities or creating new injustices. Pathways that are compatible with limiting warming to 1.5°C and aligned with the SDGs consider mitigation and adaptation options that reduce inequalities in terms of who benefits, who pays the costs, and who is affected by possible negative consequences. Attention to equity ensures that disadvantaged people can secure their livelihoods and live in dignity, and that those who experience mitigation or adaptation costs have financial and technical support to enable fair transitions.

Climate-resilient development pathways (CRDPs) describe trajectories that pursue the dual goal of limiting warming to 1.5°C while strengthening sustainable development. This includes eradicating poverty as well as reducing vulnerabilities and inequalities for regions, countries, communities, businesses, and cities. These trajectories entail a mix of adaptation and mitigation measures consistent with profound societal and systems transformations. The goals are to meet the short-term SDGs, achieve longer-term sustainable development, reduce emissions toward net zero around the middle of the century, build resilience and enhance human capacities to adapt, all while paying close attention to equity and well-being for all.

The characteristics of CRDPs will differ across communities and nations, and will be based on deliberations with a diverse range of people, including those most affected by climate change and by possible routes toward transformation. For this reason, there are no standard methods for designing CRDPs or for monitoring their progress toward climate-resilient futures. However, examples from around the world demonstrate that flexible and inclusive governance structures and broad participation often help support iterative decision-making, continuous learning, and experimentation. Such inclusive processes can also help to overcome weak institutional arrangements and power structures that may further exacerbate inequalities.




**FAQ 5.2, Figure 1:** Climate-resilient development pathways (CRDPs) describe trajectories that pursue the dual goal of limiting warming to 1.5°C while strengthening sustainable development. Decision-making that achieves the SDGs, lowers greenhouse gas emissions and limits global warming could help lead to a climate-resilient world, within the context of enhancing adaptation.

Ambitious actions already underway around the world can offer insight into CRDPs for limiting warming to 1.5°C. For example, some countries have adopted clean energy and sustainable transport while creating environmentally friendly jobs and supporting social welfare programs to reduce domestic poverty. Other examples teach us about different ways to promote development through practices inspired by community values. For instance, *Buen Vivir*, a Latin American concept based on indigenous ideas of communities living in harmony with nature, is aligned with peace, diversity, solidarity, rights to education, health, and safe food, water, and energy, and well-being and justice for all. The Transition Movement, with origins in Europe, promotes equitable and resilient communities through low-carbon living, food self-sufficiency, and citizen science. Such examples indicate that pathways that reduce poverty and inequalities while limiting warming to 1.5°C are possible and that they can provide guidance on pathways towards socially desirable, equitable, and low-carbon futures.

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