Intergovernmental Panel on Climate Change - IPCC
Oct 6, 2018

Global Warming of 1.5 ^{o}C

Summary for Policy Makers - spm

translated from Science-talk into English,
by the author of http://RescueTheWorld.net

Authors and acknowledgements - page 1 & 2 / 33

Introduction
The IPCC agreed to create a report about the impacts on climate change, of 1.5 ^{o}C increase of average global temperature (temp), above pre-industrial levels. Contrasts are drawn in the report between this target and 2.0 ^{o}C, or higher. References are provided throughout. (p 3)

Understanding Global Warming of 1.5 ^{o}C
Human activities, also called anthropogenic, are estimated to have caused 1.0 ^{o}C warming above pre-industrial levels. Global warming is likely to reach 1.5 ^{o}C as early as 2030 ...

The period 2006 - 2015 was definitely 0.9 ^{o}C warmer than between 1850 – 1900. Human caused warming is definitely increasing at a rate of 0.2 ^{o}C per decade. Warming is two to three times higher in the Arctic. It is higher over the land than the ocean,

(Upward) trends in intensity and frequency of weather extremes have been detected since 1950 (with even higher trending since 2000).

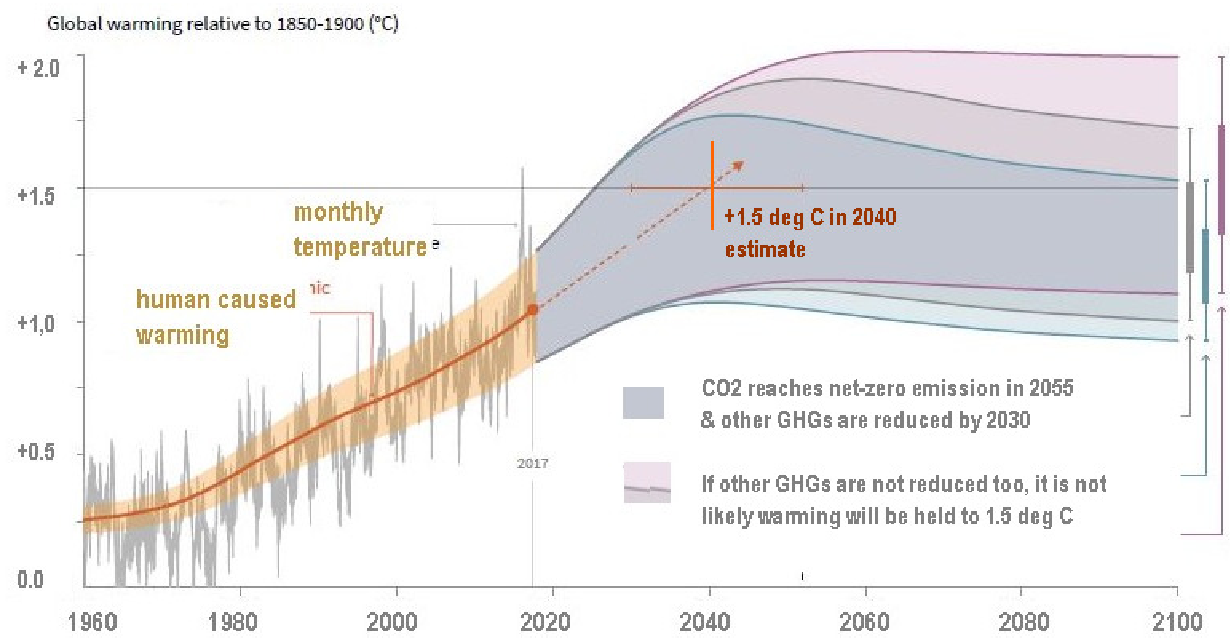
Current levels of Human caused emissions will persist for centuries or more, including sea level rise and impacts from that. IF emission went to zero tomorrow, we might not hit +1.5 ^{o}C. (p4)

Reaching and sustaining net-zero global human caused CO2 emissions would definitely be helpful over future decades. However, we might still require negative “emissions” (CO2 extraction), in order to prevent future climate feedback and sea level rise (p5)

GHGs are Green House Gases. Non-CO2 GHGs include methane, nitrous oxide & ozone.

"Non-CO2 radiative forcing" means ***"warming from GHGs other than CO2".***

Cumulative CO2 (& other GHG) levels affect limiting global warming to +1.5 °C.



(p6)

References and an explanation of the data in **Figure spm.1**

- grey lines:	monthly temp
- orange line:	human caused warming to 2017 and projected to 2040
- net-zero CO2:	assumes a straight line decline in CO2 emission from 2017 levels to zero in 2055 (highly improbable)
- blue area	assumes decline in non-CO2 GHGs also, after 2030 the amount is not specified
- purple area	assumes no decline in non-CO2 GHGs;

limiting warming to +1.5 °C is then unlikely (p7)

There are robust models showing the difference between +1.0 °C, +1.5 °C and +2.0 °C, such as:
- different land and ocean temps
- there will definitely be hot extremes in inhabited areas of the world
- there will most probably be both heavy rainfall and drought in various places

The next paragraph says the same thing as the paragraph above (p8)

With average warming at +1.5 °C, there will definitely be extreme heat up to +3.0 °C (or +5.4 °F) in some regions. With warming at +2.0 °C, there will definitely be extreme heat up to +4.0 °C (or +7.2 °F) in some regions and cold artic nights will have temp changes of up to +6.0 °C (or +10.8°F). Hot days will definitely increase, with the greatest increase occurring in the tropics.

Risks from droughts are projected to be higher at +2.0 °C compared to +1.5°C global warming in some regions and heavy precipitation risk is higher too in northern and eastern continental regions. Heavy rain due to tropical cyclones / hurricanes will be higher, but not in non-tropical regions. As a consequence of heavy precipitation, the fraction of the global land area affected by flood hazards is projected to be larger at +2.0 °C compared to +1.5°C of global warming.

Increase from +1.5 °C to +2.0 °C will add a further sea level rise of 0.1 m or 4 inches. Sea level will definitely continue to rise after 2100, at a rate depending on emissions. Adaptation will be easier on islands, deltas, and low-lying coastal regions if the rate of sea level rise is slowed.

At +1.5 °C, sea level may rise 0.26 to 0.77 m (10 to 30 inches) by 2100. By limiting warming to +1.5 °C versus +2.0 °C, a difference of 4 inches, 10 million fewer people may be affected. (How many persons will be affected by a 30 inch increase in sea level at +1.5 °C? The spm does not say, *but it must be known*, if the massive human impact of an additional 4 inches is known.)

Rising sea levels in coastal areas will definitely cause saltwater intrusion, flooding and damage to infrastructure. Limiting warming to +1.5 °C would allow better adaptation.

Limiting global warming to +1.5°C compared to+ 2°C is definitely projected to lower the impacts on terrestrial, freshwater, and coastal ecosystems and to retain more of their services to humans. (None of these impacts are quantified in the spm, but they must be known.) (p 9)

Percentage change in geographic range for some species, and land / eco-system change

warming	insects	plants	animals	eco-system change
at +1.5 °C	6%	8%	4%	2% - 7%
at +2.0 °C	18%	16%	8%	8% - 20%

High-latitude tundra and boreal forests are particularly at risk of degradation and loss due to climate change. Limiting global warming to +1.5°C rather than +2.0 °C is projected to prevent the thawing over centuries of a permafrost area in the range of 1.5 to 2.5 million km2

Limiting global warming to 1.5°C is projected to reduce risks to marine biodiversity, fisheries, and ecosystems, and their functions and services to humans.

warming	Arctic free of sea-ice	coral reefs	fishing loss	
at +1.5 °C	once per century	70% - 90% loss	1.5 million tons	
at +2.0 °C	once per decade	more than 99% loss	> 3 million tons	

The risk of irreversible loss of many marine and coastal ecosystems increases with global warming, especially at 2°C or more. There are also greater impacts on productivity of fisheries and aquaculture (especially at low latitudes). This also applies to ocean acidification and the ability of shell fish to survive. It applies to species from algae through fish. (p 10)

Climate-related risks to health, livelihoods, food security, water supply, human security, and economic growth are projected to increase with global warming of +1.5 °C and increase further with +20 °C. Poverty and disadvantages are expected to increase in some populations as global warming increases; limiting global warming to +1.5 °C, compared with +2.0 °C, could reduce the number of people both exposed to climate-related risks and susceptible to poverty by *up to several hundred million by 2050.*

Lower risks are projected at +1.5 °C than at +2.0 °C for heat-related morbidity and mortality (very high confidence) and for ozone-related mortality if emissions needed for ozone formation remain high (high confidence). Urban heat islands often amplify the impacts of heatwaves in cities (high confidence). Risks from some vector-borne diseases, such as malaria and dengue fever, are projected to increase with warming from +1.5 °C to +2.0 °C.

warming	cereal crops	food production	livestock	
at +1.5 °C	lower yields and nutrition	lower yields and nutrition	negative impacts	
at +2.0 °C	worse	worse	more negative impacts	

Regions most affected are sub-Saharan Africa, Southeast Asia, and Central and South America. Livestock impacts are lower feed quality, spread of diseases, and water resource availability.

Limiting global warming to +1.5 °C, compared to +2.0 °C, may reduce the numbers of world population exposed water stress by up to 50%. There is considerable variability between regions, with many small island developing states experiencing the most impacts. (p 11)

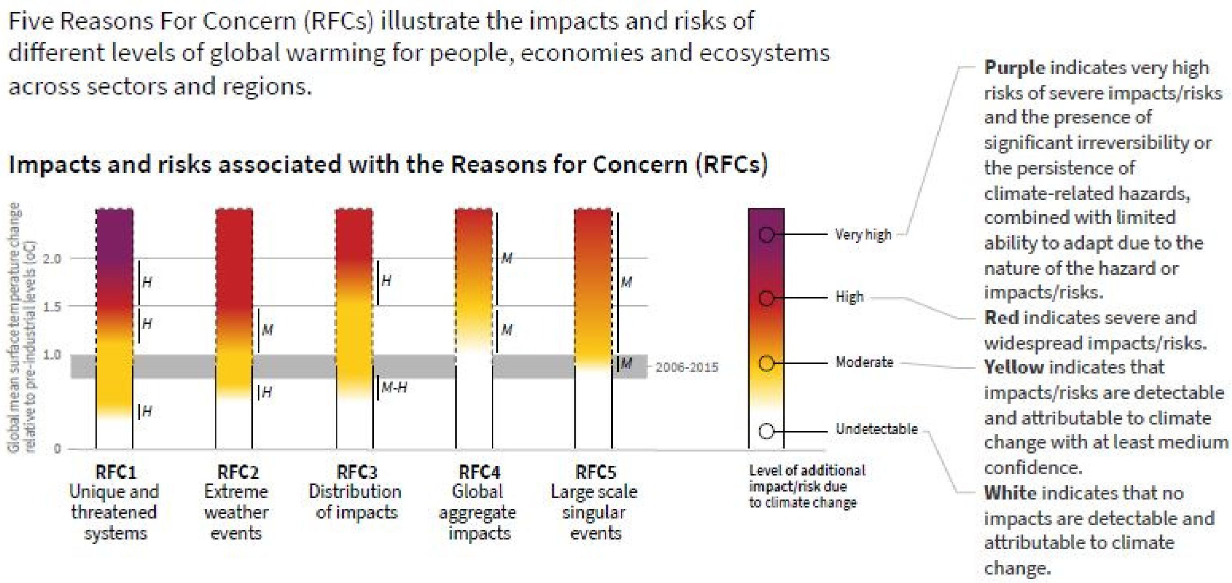
Countries in the tropics and S. Hemisphere subtropics will experience the largest impacts on economic growth due to climate change, should global warming increase from +1.5°C to +2.0 °C

People in Africa and Asia are exposed to more poverty from climate risks, and this increases at +2.0 °C. Risks cross energy, food, and water sectors, creating more hazards.

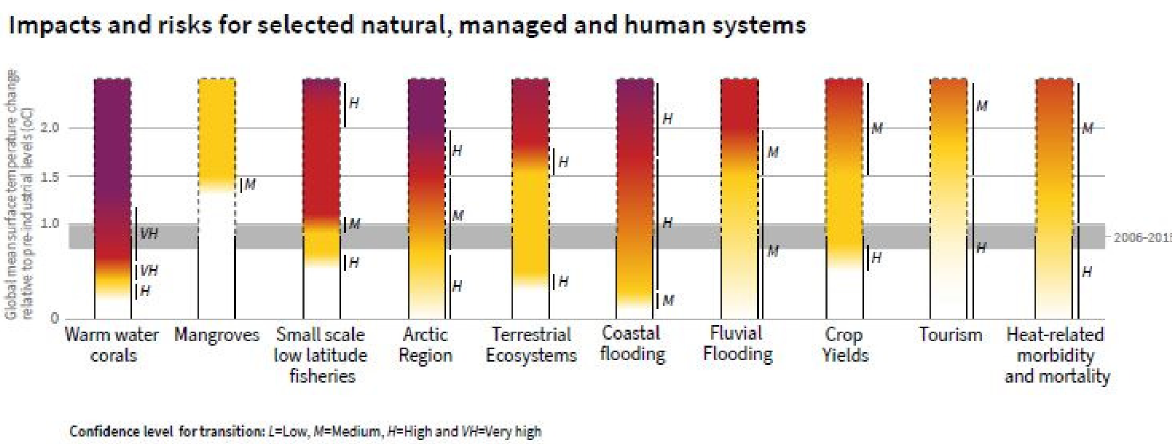
Reasons for concern	**Risk at +1.5°C**	**Risk at +2.0 °C**		
Unique and threatened systems	high	very high		
Extreme weather events	moderate	high		
Distribution of impacts	moderate	high		
Global aggregate impacts	moderate	high		
Large-scale singular events	moderate	high		

(p 12)

How the level of global warming affects impacts and/or risks associated with the Reasons for Concern (RFCs) and selected natural, managed and human systems.



The chart above elaborates on the Concerns in the previous table. Note that the earth is at +1.0 °C today, at the grey horizontal bar, where risks are still low to moderate. Risks progress rapidly to high and very high as warming increases from +1.5 °C to +2.0 °C.



Purple – severe / irreversible impacts Red – severe / wide spread impacts
Yellow – risks due to climate change White – no detectable risks (p 13)

Lliterature was used to make expert judgments to assess the levels of global warming at which levels of impact and/or risk are undetectable, moderate, high or very high. The selection of impacts and risks to natural, managed and human systems in the lower panel is illustrative and is not intended to be fully comprehensive

Definitions of Reasons for Concern:

- RFC1 Unique and threatened systems:
  ecological and human systems that have restricted geographic ranges constrained by climate related conditions and have high endemism or other distinctive properties. Examples include coral reefs, the Arctic and its indigenous people, mountain glaciers, and biodiversity hotspots.
- RFC2 Extreme weather events:
  risks/impacts to human health, livelihoods, assets, and ecosystems from extreme weather events such as heat waves, heavy rain, (extreme winds) , drought and associated wildfires, and coastal flooding.
- RFC3 Distribution of impacts:
  risks/impacts that disproportionately affect particular groups (of people) due to uneven distribution of physical climate change hazards, exposure or vulnerability.
- RFC4 Global aggregate impacts:
  global monetary damage and scale degradation and loss of ecosystems and biodiversity.
- RFC5 Large-scale singular events:
  are large, abrupt and sometimes irreversible changes in systems that are caused by global warming. Examples: disintegration of the Greenland and Antarctic ice sheets.

(p 14)

Most adaptation needs will be lower for global warming of +1.5 °C, compared to +2.0 °C. There are a wide range of adaptation options that can reduce the risks of climate, but here are limits to adaptation and adaptive capacity for some human and natural systems (even) at global warming of +1.5 °C, with associated losses.

Adaptation options

For natural and managed eco-system:
- ecosystem-based adaptation, ecosystem restoration and avoided degradation and deforestation, biodiversity management, sustainable aquaculture, and local knowledge and indigenous knowledge

For the risks of sea level rise
- coastal defence and hardening

For risks to health, livelihoods, food, water, and economic growth, especially in rural lands:
- efficient irrigation, social safety nets, disaster risk management, risk spreading and sharing, community-based adaptation

For risks in urban areas
- green infrastructure, sustainable land use and planning, and sustainable water management

Adaptation is expected to be more challenging for ecosystems, food and health systems at +2.0 °C of global warming than for +1.5 °C. Some vulnerable regions, including small islands and Least Developed Countries, are projected to experience *high multiple interrelated climate risks even at global warming of +1.5 °C.*

Limits to adaptive capacity exist at +1.5 °C of global warming, become more pronounced at higher levels of warming, and vary by sector, with site-specific implications for vulnerable regions, ecosystems, and human health.

Emissions and (Resulting) System Changes at +1.5 °C Global Warming

Global net human caused CO_2 emissions must decline by about 45% from 2010 levels by 2030, in order to limit temp overshoot to +1.5 °C. It assumes reaching net zero CO_2 emissions around 2050. Non-CO_2 emissions (other GHGs) must have similar deep reductions to limit global warming to 1.5°C. *To limit global warming to +2.0 °C, emissions of CO_2 must decline by about 20% by 2030 and reach net zero around 2075*.

CO_2 emissions reductions that limit global warming to 1.5°C with no or limited overshoot can involve different mitigation measures, balancing between lowering energy and resource use intensity, vs rate of de-carbonization, and reliance on carbon dioxide removal (not yet demonstrated in bulk). Different approaches face different implementation challenges, and potential synergies and negative impacts with / on sustainable development. (p 15)

Methods that limit global warming to +1.5 °C with limited overshoot involve deep reductions in emissions of methane and black carbon (35% or more of both by 2050 relative to 2010. (Sources: coal and wood burning)). Non-CO_2 GHG emissions can be reduced by broad mitigation measures in the energy sector. Targeted non-CO_2 mitigation measures can reduce nitrous oxide and methane from agriculture, methane from the waste sector, some sources of black carbon ; coal generated power), and HFCs / refridgerants.

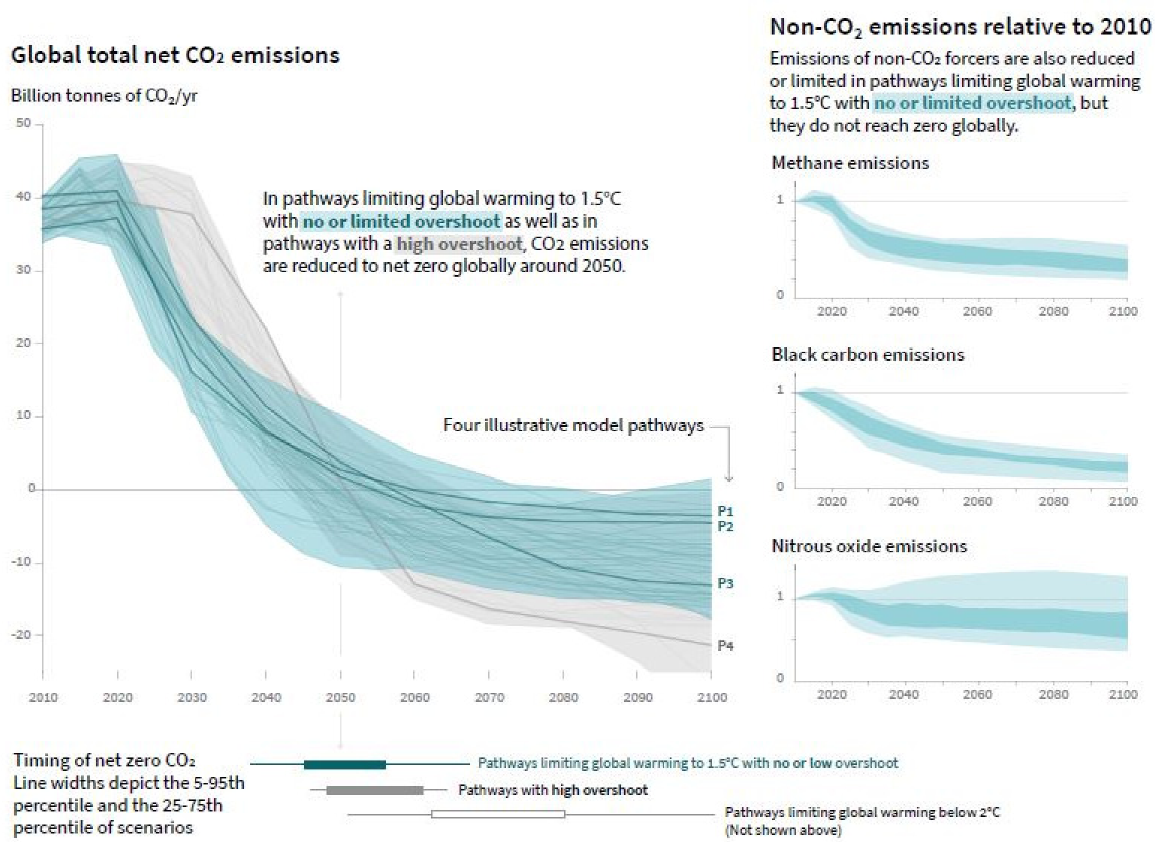
High bioenergy demand (3 billion people burning wood for cooking) can increase emissions of nitrous oxide in some +1.5 °C scenarios. This also highlights the importance improved air quality gained from reductions in black carbon (from burning wood and coal). This can provide direct and immediate population health benefits in all +1.5 °C outcomes.

Limiting global warming requires limiting the total cumulative global human caused emissions of CO_2 since the pre-industrial period, i.e. staying within a total carbon budget. As of 2017, the about 2,200 Gigatons (Gt) of the total CO_2 budget have been used. The remaining budget is being consumed at a rate of 42 Gt per year. Using global mean surface air temperature gives an estimate of the remaining carbon budget of 580 Gt of CO_2 for a 50% probability of limiting warming to +1.5 °C (namely 14 years). There are large uncertainties in the impacts of CO_2 on the rate of global warming, resulting in wide probability ranges for reaching +1.5 °C. Potential additional carbon release from future permafrost thawing and methane release from wetlands would reduce budgets by up to 100 Gt of CO_2 this century and more thereafter.

Artificial reduction of solar radiation reaching the earth is not considered here. It may have substantial risks and is an unknown technology. (p 16 & 17)

Global emissions characteristics

Subject: General characteristics of human caused emissions of CO2, and total emissions of methane, black carbon, and nitrous oxide in amounts that limit global warming to 1.5°C with no or limited overshoot. Net emissions are emissions less removals. Reductions in net emissions can be achieved by different methods, as illustrated in Figure spm3B. A “pathway” is a method. A “model pathway” is the result of the application of different methods.



The shaded area on the right of Figure spm3B shows the full range of CO2 reduction methods analysed in this report. The panels on the right show other GHG emissions ranges for three compounds with large historical impacts on temp and significant emissions coming from sources other than those improved by CO2 mitigation (agriculture, other).

Four different methods are highlighted in the main panel and are labelled P1, P2, P3 and P4 (p 18)

Characteristics of methods P1 through P4, above

P1 (grey area) centers on fossil fuel reductions, and innovations to provide growing energy demands. P2 and other models include absorption of CO2 via agriculture and land use (orange) and use of bio-energy with carbon capture and storage. (Carbon volumes are extremely high and there are no certain methods of storing carbon known today.)

Global indicators	P1
Pathway classification	No or low overshoot
CO_2 emission change in 2030 (% rel to 2010)	-58
↳ in 2050 (% rel to 2010)	-93
Kyoto-GHG emissions in 2030 (% rel to 2010)*	-50
↳ in 2050 (% rel to 2010)	-82
*Final energy demand** in 2030 (% rel to 2010)*	-15
↳ in 2050 (% rel to 2010)	-32
Renewable share in electricity in 2030 (%)	60
↳ in 2050 (%)	77
Primary energy from coal in 2030 (% rel to 2010)	-78
↳ in 2050 (% rel to 2010)	-97
from oil in 2030 (% rel to 2010)	-37
↳ in 2050 (% rel to 2010)	-87
from gas in 2030 (% rel to 2010)	-25
↳ in 2050 (% rel to 2010)	-74
from nuclear in 2030 (% rel to 2010)	59
↳ in 2050 (% rel to 2010)	150
from biomass in 2030 (% rel to 2010)	-11
↳ in 2050 (% rel to 2010)	-16
from non-biomass renewables in 2030 (% rel to 2010)	430
↳ in 2050 (% rel to 2010)	832
Cumulative CCS until 2100 ($GtCO_2$)	0
↳ of which BECCS ($GtCO_2$)	0
Land area of bioenergy crops in 2050 (million hectare)	22
Agricultural CH_4 emissions in 2030 (% rel to 2010)	-24
in 2050 (% rel to 2010)	-33
Agricultural N_2O emissions in 2030 (% rel to 2010)	5
in 2050 (% rel to 2010)	6

There are demanding targets or requirements in **scenario P1**, including.

Renewable energy in electricity by 2030	60%
Reduction in energy from coal by 2030	-78%
Remaining coal energy by 2050	3%
(relative to 2010 levels)	

Oil and gas energy needs to be cut by 37% and 25% respectively by 2030
Oil and gas energy needs to be cut by 87% and 74% respectively by 2050

Growth in nuclear is assumed.
Huge growth in non-biomass renewables is assumed
Agricultural methane requires 25% reduction by 2030
(p 19 & 20)

Changes needed to limit global warming to +1.5 °C (with no or limited overshoot) require rapid and far-reaching transitions in energy, land, urban and infrastructure (including transport and buildings), and industrial systems. These systems transitions are unprecedented in terms of scale, but not necessarily in terms of speed. They imply deep emissions reductions in all sectors and a wide portfolio of mitigation options and a significant increase in investments in mitigation options. (Including carbon capture and storage – CCS)

Approaches that limit global warming to +1.5 °C (with no or limited overshoot) show system changes that are more rapid and pronounced over the next two decades than in 2°C methods. Such rates of system changes have occurred in the past within specific sectors, technologies and spatial contexts, but there is no documented historic precedent for the scale required here.

To stay at +1.5 °C versus +2.0 °C: Energy sector requirements are (a) lower energy use, (b) enhanced energy efficiency and (c) faster electrification, (d) lower emission energy sources. Renewables must supply 70% - 85% of electricity in 2050. Nuclear and fossil fuels with (CCS) energy sources must increase. Use of natural gas with CCS should be limited to 8% of electricity by 2050. Use of coal should be set close to zero by 2050. Despite many challenges, solar energy, wind energy and electricity storage technologies have substantially improved over the past few years and could signal transition in electricity generation.

CO_2 emissions from industry must be about 75% – 90% lower in 2050 relative to 2010, to stay at +1.5°C warming, as compared to 50% - 80% for global warming +2.0 °C. Such reductions can be achieved through new and existing technologies, including electrification, hydrogen, sustainable bio-based feedstocks, product substitution, and carbon capture, utilization and storage (CCUS). These options are technically proven at various scales but their large-scale deployment may be limited by economic, financial, human capacity, institutional constraints, and need for large-scale industrial installations. *Emissions reductions by energy and process efficiency alone are not sufficient to limiting warming to +1.5 °C.*

Urban and infrastructure transition for +1.5 °C implies changes in land and urban planning practices, as well as deeper emissions reductions in transport and buildings, versus global warming below +2.0 °C. (p 21) The transport sector is more influential; the share of low-emission energy would rise from less than 5% in 2020 to about 35–65% in 2050. Economic, institutional and socio-cultural barriers definitely may inhibit these urban and infrastructure transitions, depending on national, regional and local capabilities and the availability of capital.

Transitions in global and regional land use are found in all pathways limiting global warming to +1.5 °C. This requires conversion of pasture, food crop and feed crop land into bio-energy crops (up to 7 million km sq), and an increase of up to 10 million km sq in forests by 2050.

Such large transitions definitely pose profound challenges for sustainable management of the various demands on land for human settlements, food, livestock feed, fibre, bio-energy, carbon storage, bio-diversity and other eco-system services. Required mitigation options include *sustainable intensification of land use (low harm fertilizers, better yields)*, eco-system restoration and *changes towards less resource-intensive diets (plants vs meats).*

Significant (a) bio-energy crops with CCS and (b) agriculture and forest land use improvements are required, to achieve reduction of 5 Gt and 3.6 Gt of CO2, respectively.

Overshoot of +1.5 °C will require CO2 Reduction (CDR) (technology which currently does not exist), to bring temp back to the +1.5 °C level. The higher the overshoot, the more CDR needed. Carbon cycle and climate system understanding is still limited about the effectiveness of net negative emissions to reduce temperatures after they peak.

Most current and potential CO2 removal measures could have significant impacts on land, energy, water, or nutrients if deployed at large scale. Re-forestation and crop bio-energy compete with other land uses and have significant impacts on agricultural and food systems. Effective governance (regulations and enforcement) is needed to limit such trade-offs and ensure permanence of carbon removal in terrestrial, geological and ocean reservoirs. (p 23)

Some agri-forst related CO2 removal measures, such as restoration of natural ecosystems and soil carbon sequestration, could provide co-benefits like improved biodiversity, soil quality, and local food security. (Note that soil carbon sequestration is not a proven technology. Nor is under-ground storage.) Deployed at large scale, they require governance of sustainable land management to protect land carbon stocks and other eco-system functions and services.

Strengthening Global Response,
Considering Sustainable Development and Efforts to Eradicate Poverty

Estimates of the global emissions of current nationally stated mitigation ambitions, submitted under the Paris Agreement, would lead to global greenhouse gas emissions in 2030 of 52–58 Gt of CO2e per year. CO2e measures include other GHGs of equivalent (e) impacts. *Scenarios as a result of these targets would NOT limit global warming to 1.5°C, even if supplemented by very challenging increases in the scale and ambition of emissions reductions after 2030.* Avoiding overshoot, and reliance on (unknown) future large-scale deployment of carbon dioxide removal, can only be achieved if global CO2 emissions start to decline well before 2030.

Scenarios that limit global warming to +1.5 °C show clear emission reductions by 2030. Half of the solutions allow no more than 25–30 Gt of CO2e/year, a 40–50% reduction from 2010 levels. Current nationally stated mitigation ambitions to 2030 are broadly consistent with a global warming of about +3.0 °C by 2100, and with warming continuing afterwards.

Overshoot trajectories result in higher impacts and associated challenges compared to approaches that limit global warming to +1.5 °C. Reversing warming after an overshoot of +0.2 °C or larger during this century would require upscaling and deployment of CO2 reduction at rates and volumes that might not be achievable, given considerable implementation challenges.

The lower the emissions in 2030, the lower the challenge in limiting global warming to +1.5 °C after 2030. The challenges from delayed actions to reduce greenhouse gas emissions include the risk of cost escalation, lock-in of carbon-emitting infrastructure, stranded assets, and reduced flexibility in future response options in the medium to long-term. These may increase uneven distributional impacts between countries at different stages of development.

The ***avoided*** climate change impacts on sustainable development, eradication of poverty and reducing inequalities, would be greater if global warming were limited to +1.5 °C rather than +2.0 °C, if mitigation and adaptation synergies are maximized while trade-offs are minimized. (p 24)

Climate change impacts and responses are closely linked to sustainable development which balances social well-being, economic prosperity and environmental protection. The United Nations Sustainable Development Goals (SDGs), adopted in 2015, provide an established framework for assessing the links between global warming of +1.5 °C or +2.0 °C and development goals that include poverty eradication, reducing inequalities, and climate action. (This is the first paragraph of the spm I could read without editing. Nice)

The consideration of ethics and equity can help address the uneven distribution of adverse impacts associated with +1.5 °C and higher levels of global warming, as well as those from mitigation and adaptation, particularly for poor and disadvantaged populations, in all societies.

Mitigation and adaptation consistent with limiting global warming to +1.5 °C are underpinned by enabling conditions, assessed in SR1.5. These cross the geophysical, environmental-ecological, technological, economic, socio-cultural and institutional dimensions of feasibility. Strengthened (a) multi-level governance, (b) institutional capacity, (c) policy instruments, (d) technological innovation, (e) transfer and mobilization of finance, and (f) changes in human behaviour and lifestyles are all enabling conditions. They enhance the feasibility of mitigation and adaptation options for +1.5 °C compatible systems transitions.

Adaptation options specific to nations, if carefully selected together with enabling conditions, will have benefits for sustainable development and poverty reduction with global warming of +1.5 °C. Negative trade-offs are also possible.

Adaptations that reduce the vulnerability of human and natural systems have many synergies with sustainable development, if well managed. Examples are ensuring food and water security, reducing disaster risks, improving health conditions, maintaining ecosystem services and reducing poverty and inequality. Increasing investment in physical and social infrastructure is a key enabling condition to enhance the resilience and the adaptive capacities of societies. These benefits can occur in most regions with adaptation to +1.5 °C of global warming.

Adaptation to +1.5 °C global warming can also result in trade–offs or mal-adaptations with adverse impacts for sustainable development. For example, if poorly designed or implemented, adaptation projects in a range of sectors can increase greenhouse gas emissions and water use, increase gender and social inequality, undermine health conditions, and encroach on natural eco-systems. These trade-offs can be reduced by adaptations that include attention to poverty and sustainable development.

A mix of adaptation and mitigation options to limit global warming to +1.5 °C, that is implemented in a participatory and integrated manner, can enable rapid, systemic transitions in urban and rural areas. These are most effective when aligned with economic and sustainable development goals, and when local and regional governments and decision makers are supported by national governments. (p 25)

Adaptations that also mitigate emissions can provide synergies and cost savings in most sectors and system transitions. Examples include land management, reduced emissions and disaster risk, or when low carbon buildings are also designed for efficient cooling. Trade-offs between mitigation and adaptation, when limiting global warming to +1.5 °C, such as when bioenergy crops or reforestation encroach on land needed for agricultural adaptation, can undermine food security, livelihoods, eco-system functions and services and other aspects of sustainable development.

Mitigation consistent with +1.5 °C has multiple synergies and trade-offs across the Sustainable Development Goals (SDGs). While the total number of possible synergies exceeds the number of (negative) trade-offs, their net effect will depend on the pace and magnitude of changes, the composition of the mitigation portfolio and the management of the transition.

+1.5 °C scenarios have robust synergies particularly for the SDGs 3 - health, 7 - clean energy, 11 - cities and communities, 12 - responsible consumption and production, and 14 - oceans. Some +1.5 °C scenarios show potential (negative) trade-offs with mitigation for SDGs 1 - poverty), 2 - hunger, 6 - water, and 7 - energy access, if not carefully managed.

+1.5 °C scenarios that include low energy demand, low material consumption, and low GHG-intensive food consumption have the best synergies. They also have the lowest number of (negative) trade-offs, in sustainable development and the SDGs. Such approaches would reduce dependence on (high risk) CO2 reduction. With care taken, sustainable development, eradicating poverty and reducing inequality can support limiting warming to +1.5 °C.

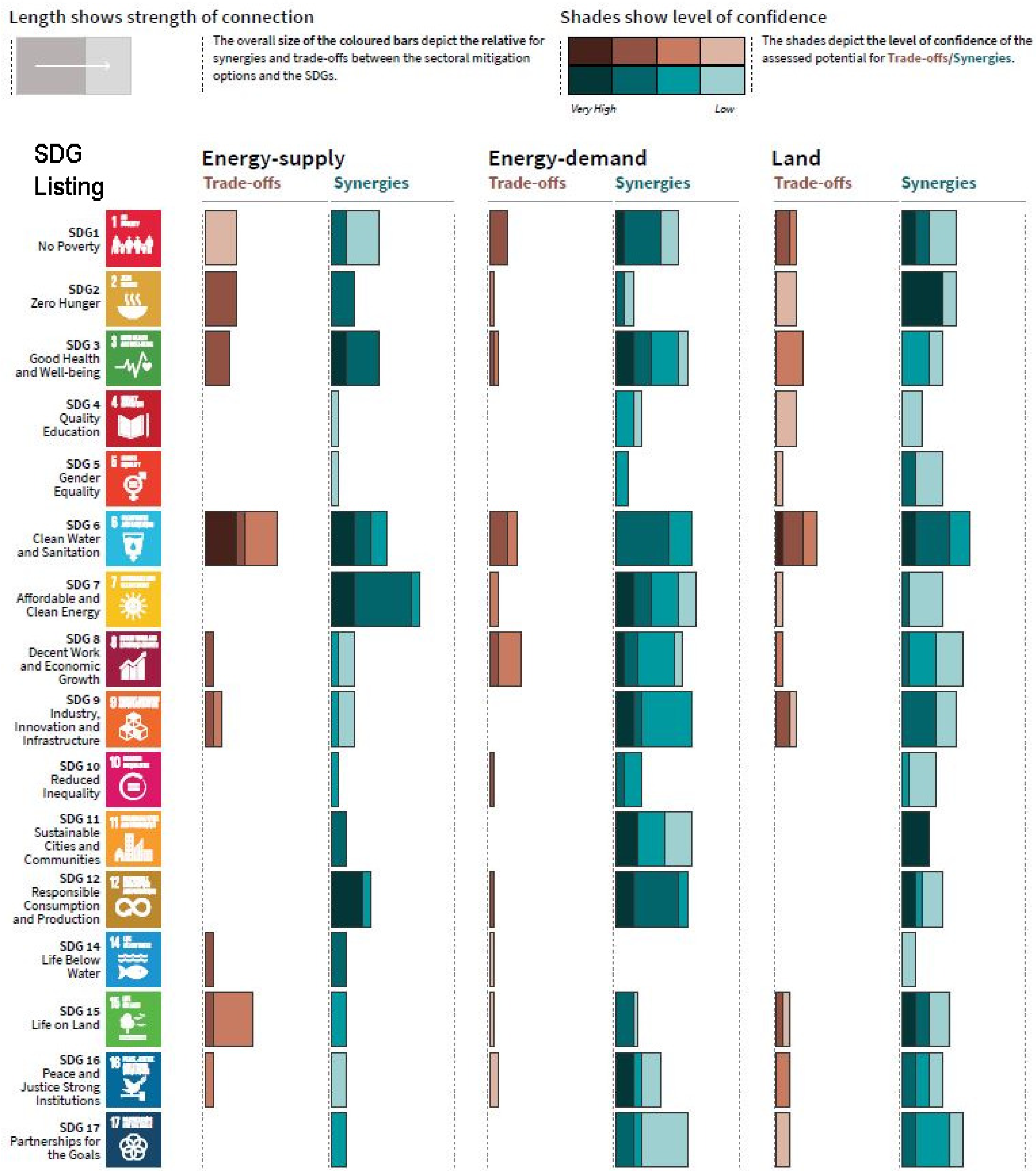
+1.5 °C and +2.0 °C scenarios often rely on the deployment of large-scale land-related measures like re- forestation and crop bio-energy supply, which, if poorly managed, can compete with food production and raise food security concerns. The impacts of carbon dioxide removal (CDR) options on SDGs depend on the type of options and the scale of deployment. If poorly implemented, CDR options such as bio-energy CCS and agri-forest options would lead to (negative) trade-offs. Context-relevant design and implementation requires considering people's needs, bio-diversity, and other sustainable development dimensions.

Mitigation consistent with +1.5 °C outcome creates risks for sustainable development in regions with high dependency on fossil fuels for revenue and employment generation. Policies that promote diversification of the economy and the energy sector (might be able to) address the associated challenges.

Redistributive policies across sectors and populations that shield the poor and vulnerable can resolve trade-offs for a range of SDGs, particularly hunger, poverty and energy access. Investment needs for such complementary policies are only a small fraction of the overall mitigation investments in +1.5 °C outcomes. (p 26)

Linkages between mitigation options and sustainable development using SDGs
(The linkages do not show costs and benefits)

Mitigation options deployed in each sector can be associated with potential positive effects (synergies) or negative effects (trade-offs) with the Sustainable Development Goals (SDGs). The degree to which this potential is realized will depend on the portfolio of mitigation options selected, mitigation policy design, and local circumstances and context. Particularly in the energy-demand sector, the potential for synergies is larger than for trade-offs. The bars on the next chart group individually assessed options, by level of confidence, and take into account the relative strength of the assessed mitigation-SDG connections.



SDGs: 1 – poverty, 2 – zero hunger, 3 – good health & well-being, 4 – quality education, 5 – gender equality, 6 – clean water and sanitation, 7 – affordable and clean energy, 8 – decent work and economic growth, 9 – industry, innovation and infrastructure, 10 – reduced inequality, 11 – sustainable cities and communities, 12 – responsible consumption and production, 14 - life below water, 15 – life on land, 16 – peace and justice; strong institutions, 17 – partnerships for the goals

(p 27)

Limiting the risks from global warming of +1.5 °C in the context of sustainable development and poverty eradication implies system transitions that can be enabled by an increase of adaptation and mitigation investments, policy instruments, the acceleration of technological innovation and behaviour changes.

Directing finance towards investment in infrastructure for mitigation and adaptation could provide additional resources. This could involve the mobilization of private funds by institutional investors, asset managers and development or investment banks, as well as the provision of public funds. Government policies that lower the risk of low-emission and adaptation investments can facilitate the mobilization of private funds and enhance the effectiveness of other public policies. Studies indicate a number of challenges including access to finance and mobilisation of funds.

Adaptation finance consistent with global warming of +1.5 °C is difficult to quantify and compare with +2.0 °C. Knowledge gaps include insufficient data to calculate specific climate resilience-enhancing investments, from the provision of currently under-invested basic infrastructure. Estimates of the costs of adaptation might be lower at global warming of +1.5 °C than for +2.0 °C. Adaptation needs have typically been supported by public sector sources such as national and sub-national government budgets, and in developing countries together with support from development assistance, multi-lateral development banks, and UNFCCC channels. More recently there is a growing understanding of the scale and increase in NGO and private funding in some regions. Barriers include the scale of adaptation financing, limited capacity and access to adaptation finance.

Global efforts limiting global warming to 1.5°C are projected to involve the annual average investment needs in the energy system of around 2.4 trillion USD-2010 between 2016 and 2035 **and represent about 2.5% of the world GDP.**

Policy tools can help mobilise incremental resources, including through shifting global investments and savings and through market and non-market based instruments as well as accompanying measures to secure the equity of the transition, acknowledging the challenges related with implementation including those of energy costs, depreciation of assets and impacts on international competition, and utilizing the opportunities to maximize co-benefits.

The systems transitions consistent with adapting to and limiting global warming to +1.5 °C include the widespread adoption of new and possibly disruptive technologies and practices and enhanced climate-driven innovation. These imply enhanced technological innovation capabilities, including in industry and finance. Both national innovation policies and international cooperation can contribute to the development, commercialization and widespread adoption of mitigation and adaptation technologies. Innovation policies may be more effective when they combine public support for research and development with policy mixes that provide incentives for technology diffusion.

Education, information, and community approaches, including those that are informed by Indigenous knowledge and local knowledge, can accelerate the wide scale behaviour changes consistent with adapting to and limiting global warming to 1.5°C. These approaches are more effective when combined with other policies and tailored to the motivations, capabilities, and resources of specific actors and contexts (high confidence). Public acceptability can enable or inhibit the implementation of policies and measures to limit global warming to 1.5°C and to adapt to the consequences. Public acceptability depends on the individual's evaluation of expected policy consequences, the perceived fairness of the distribution of these consequences, and perceived fairness of decision procedures

Sustainable development supports, and often enables, the fundamental societal and systems transformations that help limit global warming to +1.5 °C. Such changes facilitate the pursuit of climate-resilient development pathways that achieve ambitious mitigation and adaptation in conjunction with poverty eradication and efforts to reduce inequalities.

Social justice and equity are core aspects of climate-resilient development pathways that aim to limit global warming to 1.5°C as they address challenges and inevitable trade-offs, widen opportunities, and ensure that options, visions, and values are deliberated, between and within countries and communities, without making the poor and disadvantaged worse off.

The potential for climate-resilient development pathways differs between and within regions and nations, due to different development contexts and systemic vulnerabilities. Efforts along such pathways to date have been limited and enhanced efforts would involve strengthened and timely action from all countries and non-state actors.

Approaches that are consistent with sustainable development show fewer mitigation and adaptation challenges and are associated with lower mitigation costs. The large majority of modelling studies could not construct approaches characterized by lack of international cooperation, inequality and poverty that were able to limit global warming to +1.5 °C.

Strengthening the capacities for climate action of national and sub-national authorities, civil society, the private sector, indigenous peoples and local communities can support the implementation of ambitious actions implied by limiting global warming to +1.5 °C. International cooperation can provide an enabling environment for this to be achieved in all countries and for all people, in the context of sustainable development. International cooperation is a critical enabler for developing countries and vulnerable regions.

Partnerships involving non-state public and private actors, institutional investors, the banking system, civil society and scientific institutions would facilitate actions and responses consistent with limiting global warming to +1.5 °C. (p 30)

Cooperation on strengthened accountable multilevel governance that includes non-state actors such as industry, civil society and scientific institutions, coordinated sectoral and cross-sectoral policies at various governance levels, gender-sensitive policies, finance including innovative financing and cooperation on technology development and transfer can ensure participation, transparency, capacity building, and learning among different players.

International co-operation is a critical enabler for developing countries and vulnerable regions, to strengthen their action for the implementation of +1.5 °C consistent climate responses, including through enhancing access to finance and technology and enhancing domestic capacities, taking into account national and local circumstances and needs.

Collective efforts at all levels, in ways that reflect different circumstances and capabilities, in the pursuit of limiting global warming to +1.5 °C, taking into account equity as well as effectiveness, can facilitate strengthening the global response to climate change, achieving sustainable development and eradicating poverty. (p 31)

Box SPM 1: Core Concepts Central to this Special Report

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

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

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

Net zero CO_2 emissions: Net-zero carbon dioxide (CO_2) emissions are achieved when anthropogenic CO_2 emissions are balanced globally by anthropogenic CO_2 removals over a specified period.

Carbon dioxide removal (CDR): Anthropogenic activities removing CO_2 from the atmosphere and durably storing it in geological, terrestrial, or ocean reservoirs, or in products. It includes existing and potential anthropogenic enhancement of biological or geochemical sinks and direct air capture and storage, but excludes natural CO_2 uptake not directly caused by human activities.

Total carbon budget: Estimated cumulative net global anthropogenic CO_2 emissions from the preindustrial period to the time that anthropogenic CO_2 emissions reach net zero that would result, at some probability, in limiting global warming to a given level, accounting for the impact of other anthropogenic emissions. {2.2.2}

Remaining carbon budget: Estimated cumulative net global anthropogenic CO_2 emissions from a given start date to the time that anthropogenic CO_2 emissions reach net zero that would result, at some probability, in limiting global warming to a given level, accounting for the impact of other anthropogenic emissions. {2.2.2}

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

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

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

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

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