SUMMARY: IPCC SPECIAL REPORT ON 1.5°C
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The purpose of this report is to provide an alternative perspective to the IPCC Special Report on 1.5°C. The aim is to provide a digestible report that uses language and content more familiar to the general public. In addition, this report provides a more critical lense on some of the assumptions and inputs used by the IPCC. Supporting information and additional resources can be found at the IPCC website. This document has been summarized in the same format as the original report, with section numbers corresponding to chapter numbers.

1. INTRODUCTION, CONTEXT AND KEY FINDINGS

1.1. INTRODUCTION & CONTEXT

This summary presents key findings from the IPCC Special Report on the impacts of global warming of 1.5°C above pre-industrial levels, related global greenhouse gas emission pathways, and projected scenarios. The findings are in the context of strengthening the global response to the threat of climate change and linking it to sustainable development, as well as efforts to eradicate poverty. It also relates the findings to the goals and articles of the Paris Agreement and the pathways to achieving the emissions reductions goals within it.

The Special Report is prepared in the context of unequivocal and sustained global warming and sea level rise and continued emissions of greenhouse gases. It assesses and compiles research on global and regional climate change, vulnerabilities, impacts and risks at 1.5°C warming above pre-industrial levels for natural and human systems. The findings provide new insights on impacts that may be avoided with 1.5°C global warming compared to 2°C and assesses the pace and scale of transformations consistent with limiting global warming to 1.5°C compared to 2°C, considering adaptation and mitigation options.

1.2. KEY FINDINGS

LIMITING warming to 1.5°C cannot be considered a 'safe' option. Global warming of only 1.5°C involves a substantial risk to natural and human systems when compared with 1°C, which is approximately our current level of warming on a global average over the most recent time period.

WHEN trying to understand what a 1.5°C warmer world would imply for society it is important to keep in mind that we are already at least two thirds of the way there as of 2018.

AT 1.5°C of warming or above, we are likely to trigger climatic, environmental, and ecological tipping points and thresholds from which we won't be able to reverse or recover.

TO AVOID temperatures exceeding 1.5°C, the rate of human-induced warming would need to be reduced, starting immediately, by 50% by the 2040s and subsequently reduced to zero on a similar timescale thereafter.

IMPLEMENTATION of the current level of Nationally Determined Contributions (NDCs) to reduce greenhouse gases, as specified in the Paris Agreement by 2023 or 2030, will not by themselves be sufficient to meet this goal and to limit warming to 1.5°C.

FUNDAMENTAL connections between human rights and equity are associated with the conditions that contribute to a 1.5°C warmer world. Three key points of connection between climate change and equity include:

- **ASYMMETRY** in the contributions to the problem;
- **ASYMMETRY** in impacts and vulnerability, such that the worst impacts may fall on those that are least responsible for the problem, including future generations; and
- **ASYMMETRY** in the power to decide and implement solutions and response strategies.

MITIGATION and adaptation options for the future also have potentially profound implications for equity, especially if framed without considerations of the complex local national to regional linkages and feedbacks in socio-ecological and socio-economic systems.

LIMITING warming to 1.5°C versus 2°C will ensure higher levels of human food water and ecosystem security through reduction of heat stress, more moderate impacts on agriculture and water, lower risks from extreme events, and reduced stress on unique and threatened systems, thus aligning with the goals of The UN 2030 Agenda for Sustainable Development Goals (SDGs).

SIGNIFICANT numbers of positive synergies exist between implementing the 17 SDGs and reasonable potential pathways for adaptation and mitigation that limits warming to 1.5°C. However, without strengthened and rapid contributions to complete decarbonization of energy supplies, and a firm commitment from all countries, institutions, and communities to equity and fairness, pathways to 1.5°C will not allow the international community to simultaneously reach The UN 2030 Agenda stated goals.

2. HUMAN INDUCED CLIMATE CHANGE IS HAPPENING

Human induced warming reached approximately 1°C above pre-industrial levels in 2017.

GREATER warming has already been experienced in many regions and seasons.

OVER a quarter of the global population already lives in regions that have already experienced more than 1.5°C of warming in at least one season.

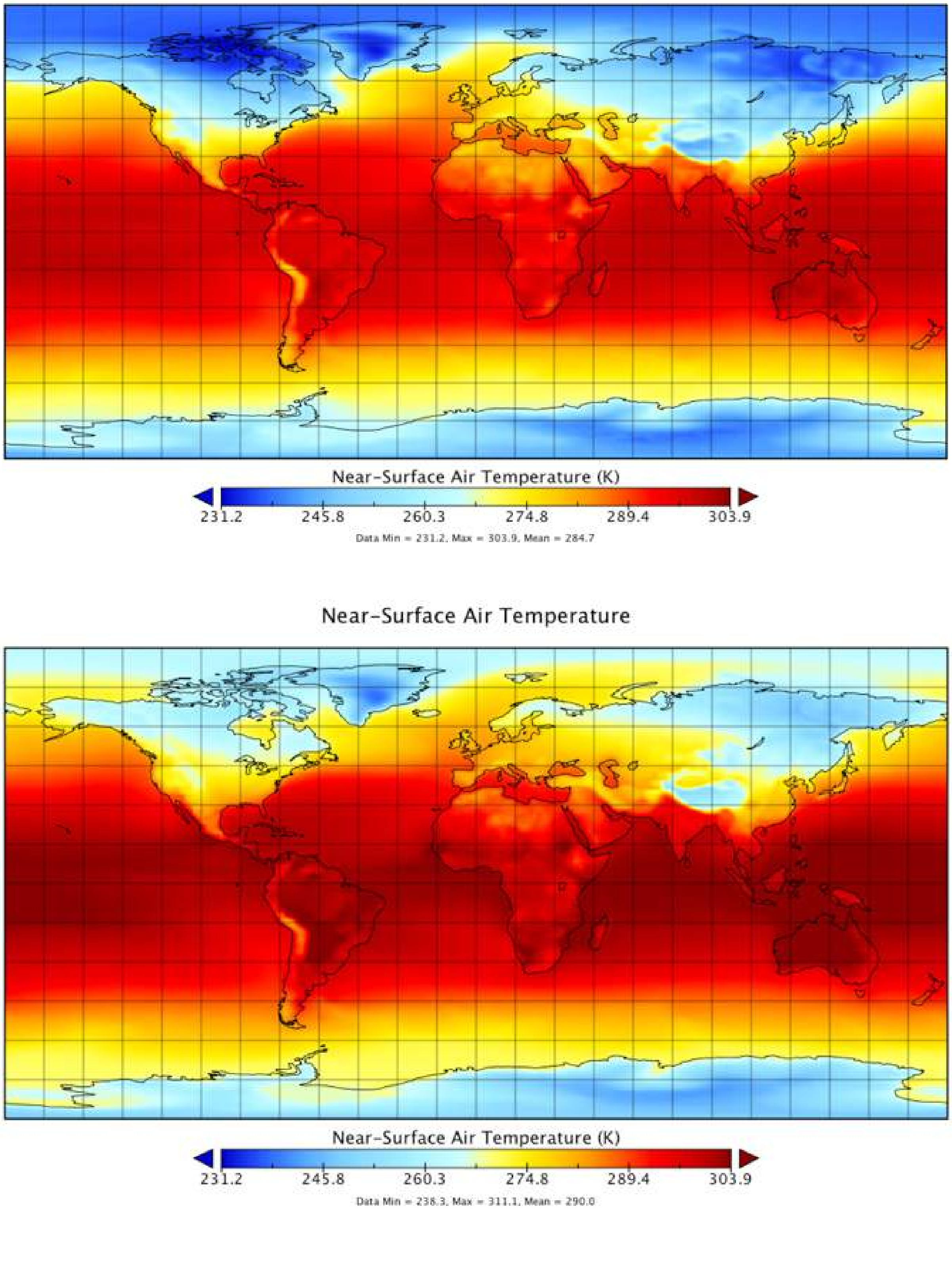

FIGURE 1 GLOBAL TEMPERATURES FROM THE START OF 1950 VS. PROJECTED GLOBAL TEMPERATURE IN 2100. DATA FROM UCAR'S COMMUNITY CLIMATE SYSTEM MODEL 4.0

AT PRESENT rate of human-induced warming, global temperatures would reach 1.5°C in the 2040s, or earlier, with different regions experiencing different levels of warming and different impacts.

Many impacts of warming passing through 1.5°C would be very different from the impacts if stabilized at 1.5°C, or returned to 1.5°C following an overshoot.

SOME ecosystems may not recover after a temperature overshoot.

BEYOND just warming, impacts are also driven by GHG concentrations, these impacts will be worse at higher concentrations and unable to be reversed.

IMPACTS can also result from ambitious efforts to constrain GHG concentrations – such as the displacement of land by Bioenergy with Carbon Capture and Storage.

A 1.5°C warmer world will exacerbate other global scale risks such as:

The degradation of ecosystems

Extreme events such as heat waves

Reduced food security

Increased disease outbreaks

Reduced access to fresh water.

An increase in global mean temperature also implies substantial increases in the occurrence and/or intensity of some extreme weather events. The severity of impacts also depends on the vulnerabilities of different communities and their exposure to climate threats.

The probability of extreme weather and climate events and irreversible changes increases rapidly at higher warming levels. Extreme weather and climate risks that result in resource depletion, conflict and forced migration are impacting economic development worldwide. Increased exposure to these hazards and severe inequity in resource distribution, chronic poverty and marginality in many global regions amplifies vulnerability to climate change. Many existing risks specific to rural areas and medium to large size urban areas and cities will be magnified.

3. REMAINING CARBON BUDGET

The "carbon budget" refers to the amount of carbon dioxide (or equivalent greenhouse gas) which we can emit into the atmosphere until we reach a certain warming threshold. This special report explores two types of remaining carbon budgets for each of the two temperature targets on which it focuses, 1.5°C and 2.0°C.

THRESHOLD PEAK BUDGET (TPB), defined as cumulative CO_2 emissions from 1 January 2016 until the global mean temperature peaks in each of the two temperature target scenarios.

THRESHOLD RETURN BUDGET (TRB), defined as cumulative CO_2 emissions allowed until global mean temperature returns to either 1.5 or 2°C after a temporary temperature overshoot occurs.

The values beginning on the updated start date of January 1, 2019 are:

1 | For limiting average global warming to 1.5°C, the TPB is about 460 Gigatonnes, and the TRB is about 470 Gigatonnes, thus very similar, and well within the associated uncertainty range for these budgets.

2 | For limiting average global warming to 2.0°C, the TPB is about 1330 Gigatonnes, and the TRB is about 790 Gigatonnes.

If these projected budgets are correct, and we continue to emit CO_2 at present rates, without reducing annual emissions, **the carbon budget for a 1.5 degree C scenario would be exceeded in about 12 years, around 2030. If aiming for a 2.0 degree target, without an overshoot scenario, at present rates of emissions, the carbon budget would be reached by 2040.**

4. A COMPARISON OF GENERIC MITIGATION PATHWAYS FOR 1.5 AND 2.0 DEGREE TARGETS — KEY POLICY CHOICES AND METHODOLOGIES

4.1 MITIGATION PATHWAYS

There is a near certainty that the Earth will warm substantially more than 1.5°C above pre-industrial levels, perhaps as much as 3.0°C or more.

IN CONTRAST, limiting warming to 1.5°C would require a rapid phase out of net global carbon dioxide (CO_2) emissions so that zero carbon emissions can be achieved by 2040, and deep reductions in non-CO_2 drivers of climate change such as methane.

SUCH ambitious mitigation pathways may be put more at risk by high population growth, low economic development, and the existing very limited efforts to reduce energy demand.

Stabilizing the average level of warming to only 1.5°C is feasible if strong policy, legal, and regulatory action is implemented in the very short term.

IN COMPARISON to a 2°C limit, required transformations to keep the temperature increase under 1.5°C are qualitatively very similar

The global average temperature can stay below 1.5°C in two fundamentally different ways: non-overshoot pathways that keep global temperatures below 1.5°C at all times in the future, and pathways that overshoot 1.5°C, peaking at temperatures above 1.5°C and then returning to 1.5C later in the century (e.g. by 2100).

UNFORTUNATELY, the probabilities of these different risks are unknowable, but the direction of the relative impacts are quite well-known.

This assessment evaluates the temperature impacts of emissions associated with the global energy system, land use, and other sectors of the economy which emit greenhouse gases.

WHILE integrated assessment models yield results that might provide some insight into the consequences of a few limited policy options, the model result typically reported in the peer-reviewed literature are significantly constrained by multiple underlying assumptions.

THESE assumption are not consistent with real world impacts of climate change and with the economic trade-offs involved in mitigating climate change.

FOR these reasons, their results must not be taken as convincing evidence for what appropriate mitigation scenarios and pathways should comprise, and these results must be complemented in this assessment with other types of studies and evidence.

4.2 INTEGRATED ASSESSMENT MODELS (IAMS)

Most of the literature that is based on runs of the well-known integrated assessment models relies upon incomplete cost-benefit analyses in which most of the benefits of mitigating climate change and many mitigation costs are not included at all.

FURTHER research is needed to determine reasonably accurate benefits and costs of mitigating climate change from this time forward.

ONE important consequence of these major model inadequacies is that most published research based on those models has a strong bias towards producing overshoot scenarios as a purported requirement of mitigating climate change.

THIS apparent conclusion must therefore be reviewed with some skepticism.

The IAMs that are described throughout the official report result in 1,180 scenarios.

THESE scenarios run on various models and evaluate differing scenarios, incomplete economic costs and benefits, and rely on different sets of input assumptions.

IN PARTICULAR, the models emphasize the costs of mitigating climate change, particularly from a macroeconomic perspective, but fail to highlight the huge economic and other benefits from avoided disasters which result from climate changes.

IN GENERAL, however, because the models are not used in a public and transparent way in which their key input assumptions are available for scientific review, the results cannot be trusted.

WE RECOMMEND making all input assumptions publicly available and transparent.

If IAMs are going to be used in the future to assist in making climate policy, we must conduct extensive sensitivity analyses using these models on different values of the discount rate.

THE current discount rate used throughout the IAMs reported in the official report currently is at or about 5% per year in real dollars, and represents a private investor discount rate, not a social discount rate (Davidson 2006).

YET, this is a very highly controversial choice and all relevant issues involved in how and why to choose an appropriate discount rate on which to base climate change mitigation policies must be discussed at length.

IN CONTRAST with the existing IAM-based literature, an appropriate social discount rate for long-term planning purposes should be in the range of 1%-2% and must be explored in multi-model sensitivity studies (Davidson 2006).

THIS is because the discount rate provides the mathematical means by which inter-generational equity is modeled, and, thus, its value is a critical input.

4.3 NATIONALLY DETERMINED CONTRIBUTIONS

Assuming the implementation of current emissions reductions in line with countries' pledges under the Paris Agreement, known as the NDCs, it is not possible to stay below 1.5 C of warming.

EVEN if economic, policy, and technological development considerations are taken in to account then most if not all of the TPB would be exhausted by 2030.

THIS means there is very high risk that warming will exceed 1.5°C during the 21st century and remain above it beyond 2100 if emissions are reduced only to the level of current commitments, or remain above them.

NDCS, therefore, must be reconsidered and stronger action needs to be taken.

Delayed action or weak near-term policies will guarantee the likelihood of exceeding 1.5°C , leading to even greater long-term mitigation challenges.

HISTORICAL emissions levels and the very limited existing mitigation policies already mean that pathways that can hold global warming below 1.5°C will be a major challenge for the entire world.

THIS may imply a higher requirement for carbon dioxide removal (CDR) and a higher and longer exceedance of the 1.5°C temperature limit, if 1.5°C can ever be reached again.

Adopting a 1.5°C rather than 2°C temperature target implies feasible yet faster socio-technical transitions and deployment of mitigation measures.

THE shift from 2°C to a 1.5°C target also implies more

Climate action	Type of action	Examples
Mitigation	Adoption of renewable energy sources	Solar PV Solar water heaters
	Implementing resource efficiency in building	Insulation Low-carbon building materials
	Adoption of low-emission innovations	Electric vehicles Heat pumps
	Adoption of energy efficient appliances	Energy-efficient heating or cooling Energy-efficient appliances

	Energy saving behaviour	Walk or cycle rather than drive short distances Use mass transit rather than fly Lower room temperature Line drying of laundry
	Use low energy products and materials with a low energy content (i.e. requiring little energy to be produced and transported)	Reduce meat and dairy consumption Buy local, seasonal food Reduce use of aluminium products
	Organisational behaviour	Design of low-emission products and procedures Replace business travel by videoconferencing
Adaptation	Growing different crops and raising different animal varieties	Use crops with higher tolerance for higher temperatures or CO_2 elevation
	Flood protective behaviour	Elevating barriers between rooms Building elevated storage spaces Building drainage channels outside the home
	Heat protective behaviour	Staying hydrated Travelling to cool places Installing green roofs
	Drought and lack of freshwater supply	Rationing water Constructing wells or rainwater tanks
Mitigation & adaptation	Citizenship behaviour	Contributing to environmental organisations Petitioning on climate action

FIGURE 2 IPCC WORKING GROUP II TOP LEVEL FINDINGS INDICATE THE POTENTIAL OF INCREASED RISK RELATIVE TO TEMPERATURE INCREASES COMPARED TO PRE-INDUSTRIAL LEVELS (IPCC 2014).

ambitious international cooperation and transformative policy environments in the short term that target both supply and demand.

TO KEEP the target of limiting warming to 1.5°C within reach, the stringency and effectiveness of the policy portfolios is critical.

PATHWAYS that assume stringent demand-side policies, and thus lower energy intensity and energy demand, reduce the likelihood of exceeding 1.5°C.

4.4 CARBON PRICING

Strong carbon pricing mechanisms are necessary in 1.5°C scenarios to achieve the most cost-effective emissions reductions.

THIS will only work in conjunction with other laws and regulatory policies, which provide investment incentives and implementation requirements for each major mitigation technology.

CARBON prices for limiting warming to 1.5°C would probably have to be set significantly higher sooner compared to those required to achieve a 2°C target.

CARBON pricing must be complemented by other policy instruments since most consumers and businesses do not react as strongly to price signals as is often assumed in economic models.

Limiting climate change to 1.5°C requires a marked shift in investment patterns, implying the need for a reformed financial system aligned with the increased mitigation challenges.

STUDIES reveal a very large gap between current investment levels and patterns and those compatible with 1.5°C (or 2°C) scenarios.

WHEREAS uncertainties exist regarding the extent of required investments (at least several trillion USD annually on both the supply side and demand side for the indefinite future), studies demonstrate the need for strong policies that redirect existing financial resources into mitigation investments and that reduce transaction costs for bankable zero-carbon energy technology projects.

4.5 CARBON DIOXIDE REMOVAL

Non-overshoot 1.5°C scenarios require deep reductions in CO_2 in each year until carbon neutrality is achieved.

CARBON neutrality is probably required by about 2040 if substantial linear decreases begin immediately.

COMPARED to 2°C pathways, 1.5°C pathways obviously must rely more on additional emissions reductions than on additional CDR.

RELYING on any significant amount of CO_2 reductions due to CDR technologies would be a very high risk strategy for the world, and based on the precautionary principle, should be strongly avoided.

In particular, it is important to balance any proposed use of biomass-based CDR (BECCS) with the understanding that high uncertainties and risks exist for the possible deployment, development, and use of BECCS and other CDR technologies.

ANY proposed reliance on these technologies for use in projected overshoot scenarios must be extremely cautious and should be avoided if at all possible.

RECENT research indicates that deployment and use of BECCS would also be extremely costly in order to be effective.

CDR measures, and their deployment, have fundamentally different consequences for achieving sustainable development objectives.

BIOENERGY demand would be very substantial in overshoot 1.5°C pathways due to its multiple energy uses and CDR potential.

BOTH BECCS and afforestation require very large amounts of land to produce sufficient amounts of sustainable biomass and to store enough CO_2 through the growth of trees.

IN 1.5°C overshoot pathways, bioenergy often need to supply nearly as much energy as wind and solar combined, and nearly half as much as total fossil fuel energy today.

THE possible scale of bioenergy and BECCS deployment depends on its future cost as well as on related policy choices, such as land and water use restrictions or reductions.

MORE BECCS is obviously required in 1.5°C scenarios when fossil fuels are phased-out more slowly, thus the phase-out of all fossil fuels must occur very rapidly.

4.6 POLICY CONSIDERATIONS

In general, limiting warming to 1.5°C can be achieved synergistically with poverty alleviation, improved energy security, and public health.

SOME trade-offs exist, such as increased biomass production and its use for biofuels has the potential to increase pressure on land and water resources, food production, and biodiversity.

In 1.5°C scenarios, mitigation options must be deployed more rapidly, at greater scale, and with a greater portfolio of options from the very beginning than in 2°C scenarios.

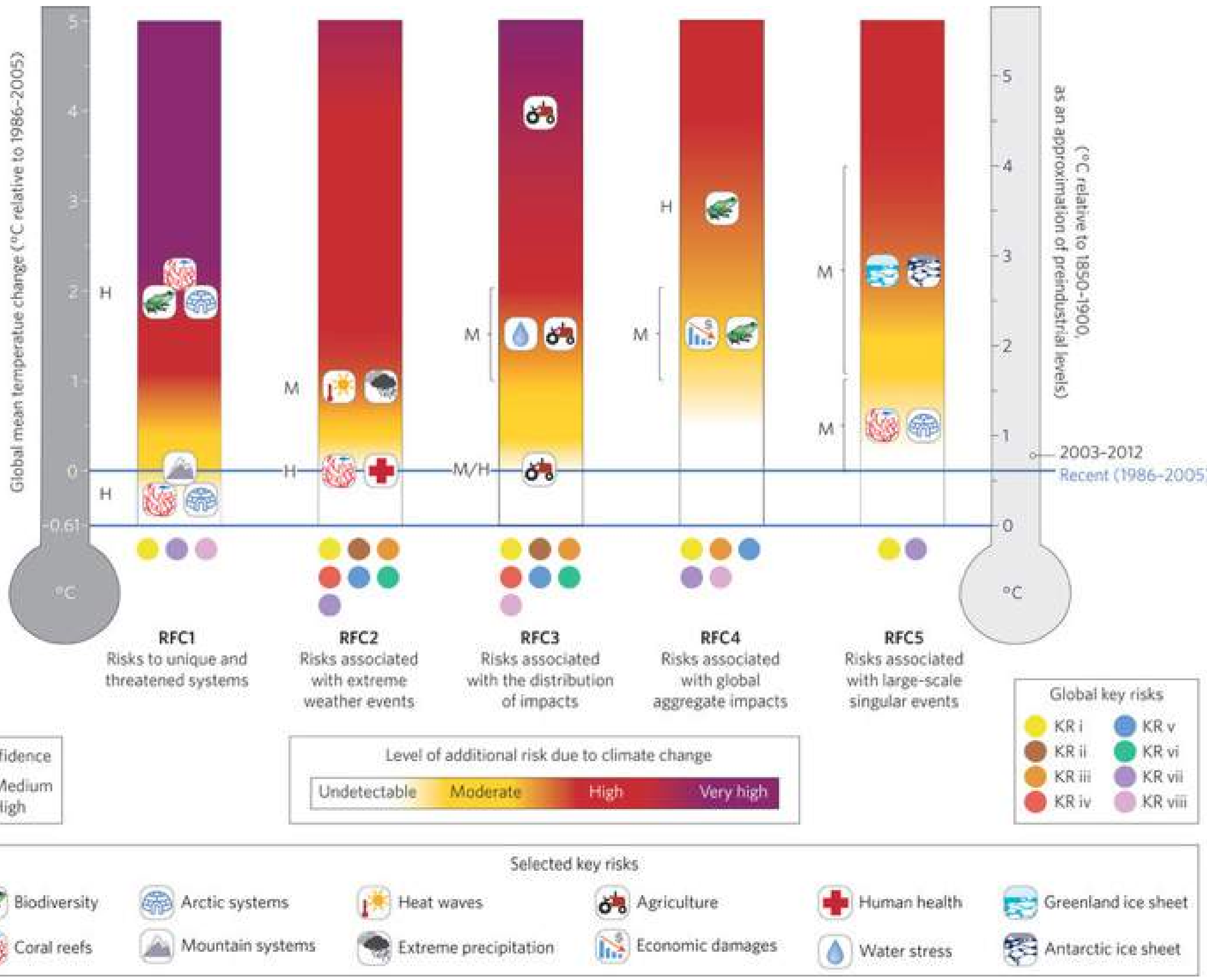

FIGURE 3 THE IPCC RISK FRAMEWORK GENERICALLY OUTLINES THE WAYS IN WHICH RISK OCCURS AS WELL AS WAYS IN WHICH NEXT STEPS CAN BE TAKEN.

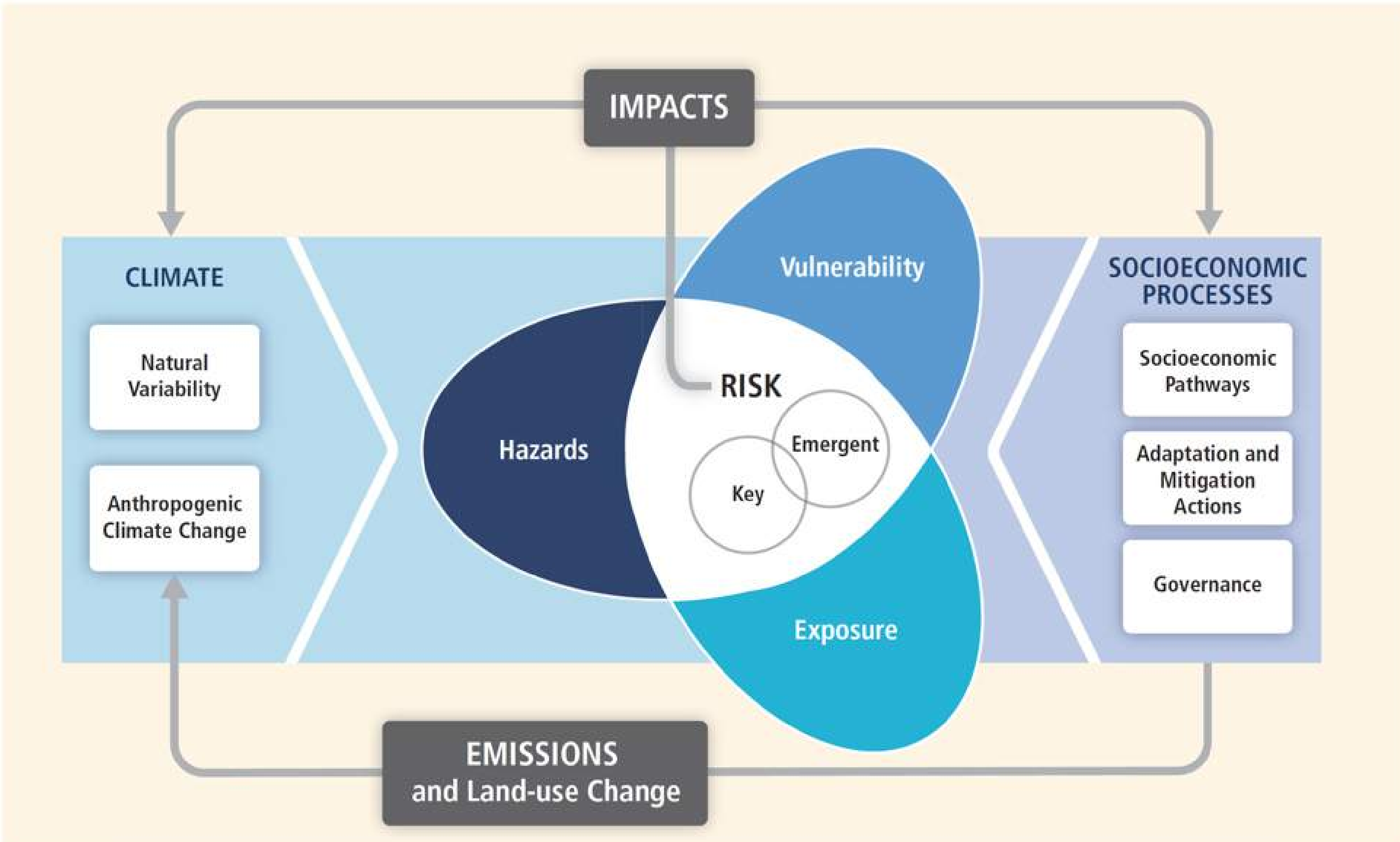

FIGURE 4 THE SUSTAINABLE DEVELOPMENT GOALS INCLUDE A SERIES OF ACTIONS TO IMPROVE PROSPERITY ACROSS THE GLOBE. (UNDP 2016).

KEY technical and behavioural options are sector specific but generally include energy efficiency improvements to all buildings and appliances, reduction in demand, and switching to zero-carbon sources of energy (renewable electricity supplies).

A large number of demand-side measures and behavioral changes are critical elements of both 1.5°C and 2.0 degree scenarios.

THESE include: significant reductions of per capita energy demand in areas of the world with high consumption; substantial decreases in livestock per capita as a consequence of lower meat diets; less private vehicle transportation demand per capita due to enhanced public transportation and more use of electrically driven freight rail; reductions in food waste; the elimination of deforestation; improvements in end-use efficiency in commercial and industrial facilities (e.g. appliances, industrial processes, insulation, and heavy commercial vehicles).

BY 2030, all end-use sectors (including building, transport, and industry) must show significant demand reductions.

5. HOW WILL 1.5 °C WARMING IMPACT OUR PLANET?

We expect an increase in almost all risks associated with changes in air temperature, precipitation patterns, extreme events, storms and sea level rise with any rise in the global mean surface temperature. Therefore it is imperative that we minimize warming to the lowest degree possible.

NOT all regions will be impacted in the same way over the same time scales. The magnitude and timing of these impacts will vary by latitude, geographic region, and degree of urbanization.

5.1 PHYSICAL CHANGES: 1.5°C VS. 2°C

Most regions around the world would experience significant differences for both mean and extreme temperatures between 1.5°C and 2°C scenarios.

CHANGES in the number of and severity of extreme temperatures are likely to have the most impact, especially on land regions.

MAINTAINING 1.5°C will reduce the rate of increase for extreme temperatures in comparison to 2.0°C. This is critical considering that the increase in extreme temperatures is projected to be more three times greater than the corresponding change in global mean surface temperature, for some regions.

ADDITIONALLY, maintaining 1.5°C vs 2.0°C would reduce the risk from hot days (10% warmest) that disproportionately affect the tropics and lead to less frequent and less intense hot spells in most land regions and urban "heat islands."

Extreme weather events are expected to increase in frequency even under very little additional warming. If we can remain in a 1.5 °C world we are significantly reducing the risks associated with increased precipitation, floods, water scarcity and drought.

CHANGES to precipitation patterns are significantly different (though highly variable) at 1.5°C than 2.0°C, with an overall trend toward more intense precipitation events. These changes in precipitation will disproportionately impact high-latitude and high-altitude regions, as well as Eastern Asia and Eastern North America.

CHANGES to large storm systems are expected even under relatively small amounts of further warming. The most intense (category 4 and 5) cyclones are projected to occur more frequently, with higher peak wind speeds and lower central pressures under 2°C vs 1.5°C of global warming.

Oceans are experiencing unprecedented changes with critical thresholds being reached at 1.5°C and above. Risks related to sea level rise, loss of sea ice and changes to ocean chemistry will be lower in a 1.5°C world versus 2°C, but we will still see sea level rise through the end of the century even under 1.5°C scenarios.

SEA level rise will be lower for 1.5°C vs 2°C but available research shows that sea level will continue to rise for several decades and even past the end of the century.

LIMITS to our ability to adapt to sea level rise will be reached sooner at 2°C than 1.5°C.

SEA ice will likely persist at 1.5°C scenarios but will not be maintained at 2°C.

AS ATMOSPHERIC CO_2 concentrations increase, ocean chemistry is changing in fundamental ways which may take many millennia to recover from.

OCEAN acidification is driving large-scale changes and is amplifying the effects of temperature on essential ecosystem service providers (e.g. coral and oysters) and vital food production species.

OCEAN acidification that is equivalent to levels at 1.5°C will be much less damaging than that at 2°C or higher.

5.2 GOING BEYOND 1.5°C WARMING WOULD EXACERBATE OTHER ENVIRONMENTAL RISKS

Climate change impacts all ecosystems (and the services they provide) on all continents and across all oceans. The risk of future extensive damage to terrestrial, wetland and freshwater, coastal and marine ecosystems increases significantly between today and a 1.5°C world, and even more so between 1.5°C and 2°C. Past 1.5°C we are likely to set off ecological tipping points and thresholds we will not be able to recover from.

LOCAL species extinction risks are much less in a 1.5°C versus a 2°C world. More intact ecosystems will allow for increased function of ecosystem services and will be accompanied by reduced risks of other biodiversity related factors such as forest fires, storm damage and the geographic spread of invasive species, pests and diseases.

MARINE food sources provide 20% of the nutrition of 3 billion people globally. Fisheries and aquaculture are already experiencing pressure from ocean warming and acidification, and these impacts are projected to get progressively worse under 1.5°C, 2.0°C and higher global temperatures.

SOIL respiration is increased which reduces soil carbon storage, a vital ecosystem service, as temperatures increase.

NATURAL coastal ecosystems can act as cost effective solutions for rising sea levels and intensifying storms by protecting coastal regions, however these ecosystem services are likely diminished under 1.5°C and greater warming. Although coastal ecosystems can serve as a buffer for storm surge and protect against sea-level rise, these natural defenses may deteriorate under additional climatic stressors

5.3 HOW COULD MITIGATION PATHWAYS IMPACT OUR PLANET?

FEEDBACK between land-use changes required by various mitigation strategies need to be considered due to their potential impact on ecosystem services, the carbon cycle, and local weather patterns. Large- and local-scale changes in what we plant or build to combat climate change can create biophysical feedbacks that alter temperature and precipitation through changes in land surface characteristics.

6. HOW MIGHT CLIMATE CHANGE AFFECT OUR HUMAN SOCIETIES AND SYSTEMS

6.1 IMPACTS OF WARMING ON ECONOMICS AND SOCIETY

Globally, the projected impacts on economic growth of 1.5°C of global warming are very similar to current impacts under about 1°C of global warming. Under 2°C of global warming, however, lower economic growth is projected for many countries, with low-income countries projected to experience the greatest losses.

INCREASING temperatures will directly impact climate-dependent tourism markets. Sectors affected include sun and beach and snow sports tourism, with lesser impact on other tourism markets that are less climate sensitive.

Average global temperatures that extend beyond 1.5°C are likely to increase poverty and disadvantage in many populations globally.

CHANGES in weather patterns and more frequent and extreme weather events will push marginalized people into poverty as they lack the means to recover from shocks

BY THE mid to late of 21st century, climate change is projected to be poverty multiplier that makes poor people poorer and increases poverty headcount.

IN MOST cases, warming of 2°C poses greater risks to population centers (urban areas) than warming of 1.5°C, often varying by vulnerability of location (coastal and non-coastal), infrastructure sectors (energy, water, transport), and by levels of poverty.

Warming will significantly erode people's mitigation capacity and undermine their livelihoods in terms of economic assets, housing, infrastructure and social networks

THE risks for hundreds of millions of people in coastal communities from eroding livelihoods, loss of cultural identity, and reduced coastal protection are lower with global warming of 1.5 °C compared to 2.0°C

There are deep implications for equity: impacts and vulnerability, future generations

KEEPING global temperature to 1.5°C will still prove challenging for small island developing states (SIDS) which are already facing significant threat from climate change and other stressors at 1°C of warming, and cause strains on national systems - due to increased weather events/shocks

6.2 IMPACTS OF WARMING ON GLOBAL CONFLICT AND HUMAN HEALTH

Keeping average global warming to 1.5°C is likely to reduce the factors that can contribute to human conflict such as extreme events and eroding food and water supplies.

CONSTRAINING global warming to 1.5°C compared to 2.0°C reduces stress on global water resources by an estimated 50%.

RISK to crop production is also reduced in a 1.5°C world compared with 2.0°C

Warming of 2°C poses greater risks to human health than warming of 1.5°C, often with complex regional patterns, with a few exceptions.

WARMER temperatures are likely to affect the transmission of infectious diseases, with increases and decreases projected depending on disease, region, and degree of temperature change. The magnitude and pattern of future impacts will very likely depend on the extent and effectiveness of additional adaptation and vulnerability reduction, and on mitigation for risks past mid-century.

6.3 CLIMATE CHANGE AND EQUITY

Pursuing the UN 2030 Agenda Sustainable Development Goals may have resounding effects and synergies on limiting warming to 1.5°C and on adaptive capacities, particularly for the most vulnerable populations.

THE UN 2030 Agenda for Sustainable Development established a set of 17 Sustainable Development Goals (SDGs). SDG13 focuses on urgent action to combat climate change impacts, and the impact of possible adaptation and mitigation responses, as well as how these responses interact with efforts to achieve sustainable development goals.

Limiting global warming to 1.5°C is expected to make it easier to pursue sustainable development, with higher potential to eradicate poverty, reduce inequality, and foster equity than 2°C.

LIMITING warming will reduce the risks for livelihoods and for human food water and ecosystem security through reduction of heat stress, more moderate impacts on agriculture and water, lower risks from extreme events, and reduced stress on unique and threatened environmental systems.

1.5°C of global warming will still have broad impacts and will disproportionately affect currently disadvantaged and vulnerable populations.

MORE severe impacts expected in the case of temperature overshoot, thus directly impeding any potential sustainable development actions taken in pursuance of the SDGs.

Exact scope of the effect of warming on SDGs are constrained to broad assumptions, given that most literature speaks in terms of general trends instead of site specific vulnerabilities at the age, gender, class, race, disability, and other questionable social groups. However, general outcomes can be extrapolated:

IT IS heavily assumed that limiting warming to 1.5°C vs 2°C will reduce exposure to poverty in Africa and Asia, and will increase chances of meeting SDGs by 2030.

NEGATIVE outcomes can potentially occur either in the form of maladaptation, poor mitigation techniques, or adverse consequences of particular adaptation strategy. Adaptation can increase poverty and debt, agricultural adaptation can compete with protecting biodiversity, or overlooks either poor or female individuals.

ADAPTATION needs will be lower in a 1.5°C warmer world. Limits to adaptation and resulting losses to lives, livelihoods, and infrastructure exist at every level of warming, with place-specific implications, for example for Small Island Developing States.

Co-benefits and synergies with implementing SDGs would be substantial. Adaptation and mitigation options that show higher synergies with SDGs are those that emerge from cross-sectoral efforts at city scale.

THESE include new sectoral organizations based on the circular economy such as decarbonization and dematerialization, and multi-policy interventions that follow systemic approaches.

A NUMBER of mitigation intervention in the Agriculture, Forestry, and Other Land Use (AFOLU) sector could help to deliver the SDGs, such as sustainable and climate-smart land/agricultural management, the shift toward sustainable healthy diets, and reduction of food waste.

THE RAPID pace and magnitude of required changes lead also to increased risks for trade-offs for a number of other sustainable development dimensions particularly risk of hunger, poverty, and basic needs such as energy access. Reducing these risks requires smart policy designs and mechanisms that shield the poor and redistribute the burden to minimize exposure of the most vulnerable populations.

6.4 LINKING SUSTAINABLE DEVELOPMENT PATHWAYS TO EQUITY

All sustainable development pathways, including climate-resilient development pathways, entail low-emissions trajectories that simultaneously promote fair and equitable climate resilience and effort sharing.

THESE pathways take into account the following key aspects: the urgency for the 1.5°C target, the need to achieve global net zero emissions, the achievement of goals for sustainable development, the need to enhance the capacity to adapt, the scale of societal transformation required, and the ethics, equity, and well-being implications of embarking on such a substantial transformation.

PARTICIPATORY governance and social learning can situate key aspects to enable transformative social change in a 1.5°C compatible development pathway. Dominant pathways and entrenched power differentials continue to undermine the rights, values, and priorities of disadvantaged populations in decision making.

Sustainable development pathways that focus on the creation of renewable energy systems provide a unique opportunity to enable equity across race, gender, and economic lines and move away from known dominant pathways that undermine progress.

THE involvement of stakeholders through participatory mechanisms is necessary for addressing these challenges to support sustainable climate policy integration. Community member participation in the partnership, planning, implementation, and long-term monitoring of climate-development projects will allow for increased local empowerment, in addition to improving the longevity of the project.

POPULATIONS historically left out of the fossil fuel industry's energy development now have an opportunity to rebuild their own energy systems. Inclusive energy policies and strategies allow for community stakeholder control of policy and implementation actions.

While integrated approaches between mitigation, adaptation, and sustainable development are possible, they will not always be necessary, suitable, or efficient for all situations.

THE efficiency of these integrated approaches to deliver triple-wins depends on the satisfaction of several conditions. In practice, adaptation, mitigation, and SD dimensions are closely interlinked such that concrete decision making requires integrated vision.

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GLOSSARY

Adaptation: Preemptive actions taken in order to decrease the likelihood of extreme events due to human-caused climate change.

Aquaculture: The practice of farming or raising aquatic life for a specified (typically profitable) purpose.

BECCS: Bio-energy with carbon capture and storage (BECCS) is a proposed methodology for removing carbon from the atmosphere.

Biodiversity: The variety of all life on earth including all micro-organisms, plants, animals, and ecosystems. Ecosystems with high levels are diversity are often considered to be more resilient and resistant to disturbance.

Carbon storage (vegetation and soil): Through photosynthesis plants can store carbon in their tissues (both shoot and root). Carbon stored in soil comes from the growth and death of plant tissue and the transfer of carbon from plants to associated microbes and fungi (Ontl and Schulte 2012).

CDR: Carbon dioxide removal (CDR) is an umbrella term used to describe any technology that aims to take existing carbon out of our atmosphere.

Circular Economy: An alternative to our current economic system where resources are used for as long as possible with the least impact and are then recovered and reused to create new products.

Climate: Weather conditions and patterns averaged or observed over an extended period of time. A weather event is what happens on any given day whereas the climate is what typically happens based on historical data.

Discount rate: The rate at which we choose to price things for the future based on current value. For example, a dollar today may be worth more or less in your pocket now than it would be in the future.

Ecosystem: A community of organisms that interact with each other and their environment in a given area.

Ecosystem services: Quantifiable benefits to humans that occur through natural processes. Ecosystem services include shoreline protection, erosion prevention, carbon storage, food resources as well as countless other benefits.

Extinction: The death of a species either locally or globally.

Extreme events: Events that occur significantly less than or significantly greater than average.

Feasibility: The systems-level capacity to achieve a specific goal or target. A complete vision requires integration of natural system considerations into human system scenarios, the placement of technical transformations into their political, social, and institutional context.

Global average temperature: The average of land surface air and sea surface temperatures over a 30-year period, corrected for the impact of any short-term natural climate drivers, such as volcanoes, in that 30-year period.

Global mean sea level: This is the total depth of the sea averaged for every available point across the globe.

Global mean surface temperature: This is the temperature measured at land surface and averaged for every available point across the globe.

Heat Island: A heat island is a term used to describe an area in which the temperature is greater than surrounding areas as a product of the environment. Typically heat islands are found in urbanized areas in which dense populations, concentration of emissions, and relatively few green spaces are found.

Hot days: The number of days in a year that are classified as days that exceed a temperature threshold. Temperature thresholds are calculated relative to the average and a hot day must be, at the very least, in exceedance of the average.

Integrated Assessment Models (IAMs): Integrated assessment models are theoretical models on climate that use economic and policy assumptions to provide suggestions for decision makers.

Impact/Projected impact: refers to observed consequences or outcomes (positive or negative) of climate change on human and natural systems. Projected impact refers to the projected consequences of climate change for physical (e.g. air, water, energy) and biogeochemical (e.g. carbon cycle, ecosystems, chemistry) systems where there is high confidence in the change and that other drivers would not alter the projection.

Mitigation: Actions taken that are intended to lessen the impact of the natural environment.

NDC: Nationally determined contributions (NDCs) are what various countries have promised in the way of reducing their climate impact.

Non-overshoot: A scenario that allows the world to remain at or below a certain temperature goal such as not exceeding 1.5°C over industrial temperature levels.

Ocean acidification: The process by which the ocean becomes more acidic (lower pH) as a result of carbon uptake.

Overshoot: A scenario that allows the world to exceed a certain temperature goal, such as exceeding the goal of 1.5°C over industrial temperature levels. This is typically, but not always, coupled with proposals to get back down to the original goal once it has been exceeded.

Participatory Governance: Collaborative governance efforts where all potentially affected stakeholders are a part of the administrative process.

Pathway: The specific evolution over time of particular climate variables, such as emissions or temperatures, while scenario will be used to refer to the underlying assumptions. Used interchangeably with 'scenario'.

Respiration (vegetation and soil): The breathing mechanism used in flora in which oxygen is consumed and carbon dioxide released.

Risk/Projected risk: Refers to the projected consequence(s) of climate change for human–influenced systems where drivers of vulnerability and exposure (e.g., demographic change, urbanization pathways, changes in income, progress in research and development) can influence the magnitude and pattern of the projection.

Sea Ice: Ice that is found in the ocean whether is be in terms of a glacier or otherwise.

Small Island Developing States (SIDS): Maritime countries that generally share similar sustainable development challenges including limited resources, remoteness, small populations, and susceptibility to natural disasters.

Sustainable development: '... development that meets the needs of the present without compromising the ability of future generations to meet their own needs' (WCED, 1987).

Sustainable Development Goals (SDG): A set of goals created by the United Nations that serves as a universal call to action to end poverty, protect the planet, and ensure a more prosperous world for all.

TPB: Threshold Peak Budget (TPB) is defined as cumulative CO_2 emissions from 1 January 2016 until the global mean temperature peaks in each of the two temperature target scenarios.

TRB: Threshold Remaining Budget (TRB) is defined as cumulative CO_2 emissions allowed until global mean temperature returns to either 1.5 or 2°C after a temporary temperature overshoot occurs.

Weather: The observed temperature, precipitation, humidity, and other outside behavior on any given day without historical context.

Wetlands: Marsh or swamp areas that are considered habitat to many insects and amphibious creatures.

REFERENCES

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