WWF CLIMATE & ENERGY POSITION PAPER SEPTEMBER 2018

OVERSHOOTING TEMPERATURE LIMITS

Position Summary

1. WWF urges countries to raise their ambition so as to keep global warming below 1.5°C without overshoot:
    a. We should avoid overshooting 1.5°C to limit risks of irreversible climate change impacts on species, biodiversity and people;
    b. To do this we should focus on rapid and deep greenhouse gas emissions cuts across the whole economy;
    c. Carbon dioxide removal will also be needed but should not delay or replace efforts to cut emissions; and
    d. Adaptation will be needed at 1.5°C and we will need to prepare for higher temperatures.

Position Statement

1. WWF urges countries to limit the rise in global average temperature to below 1.5°C for the whole century. We should avoid overshooting 1.5°C as even a temporary breach of this limit leads to unacceptable increases in the risk of irreversible and potentially catastrophic climate change impacts on species, terrestrial and ocean ecosystems, and people.
2. Our focus should be on early and stringent reductions in emissions by all means possible – exiting fossil fuels (coal, oil, gas); scaling up renewable energy; reducing energy demand through energy efficiency; rapidly electrifying energy demand in transport and heat; stopping deforestation and reducing emissions of non-CO_2 greenhouse gases. At the same time significant long-term changes in consumption patterns are needed by avoiding loss and waste in food and other resources and changing consumption patterns (e.g. eating more plant- and less animal-based products on a global scale in line with dietary guidelines; moderating demand for aviation by promoting lower-carbon alternatives). We also need to increase the rate of carbon dioxide removal through sinks, for example via reforestation and other forms of ecosystem restoration. All of this demands increasing ambition in the country pledges (nationally determined contributions – NDCs) by 2020 and the political will to make structural changes in the economy; it also demands better compliance with targets.

3. Staying below 1.5°C (overshoot or not) implies that some carbon dioxide removal will be needed, however this should neither delay or replace reductions in emissions and will need to be implemented, at a minimum, in a way that does not cause greater damage to ecosystems than climate change itself.

4. Even at 1.5°C we will face climate impacts, losses and damages to species, ecosystems, and people, and significant adaptation will be needed. On a precautionary principle we need to improve climate resilience and prepare for a world above 1.5°C.

Annexure I: Background

1. A 1.5°C "overshoot" scenario is one in where the global temperature rise exceeds the 1.5°C limit for a number of years before returning to below 1.5°C by the end of the century. Non-overshoot scenarios always remain below the temperature limit – as seen in Figure 1 below.

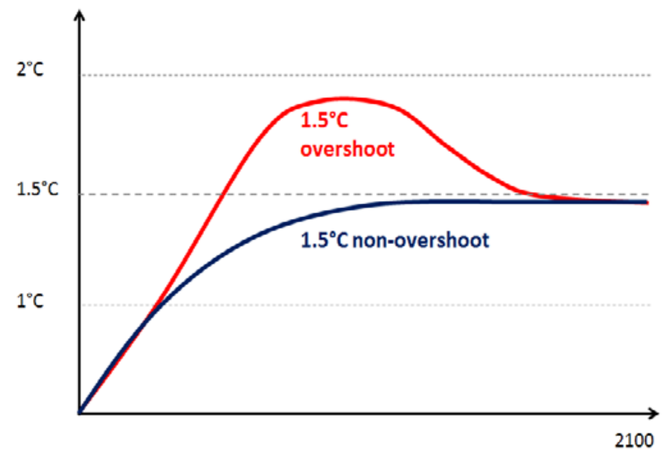

Figure 1: Overshoot and non-overshoot temperature rise pathways

2. Since the Paris Agreement, researchers have developed several scenarios consistent with 1.5°C by the end of the century – most of these overshoot and return to 1.5°C with only a small number providing a probability of 66%[1] of limiting temperature rise to below 1.5°C for the whole century.

3. All 1.5°C-consistent scenarios (both overshoot and non-overshoot) have these characteristics:

   a. A near-term global emissions peak;

   b. A rapid and deep decline in global emissions; and

   c. Reaching net-negative emissions around mid-century.

4. This implies that all 1.5°C-consistent scenarios require:

   a. Rapid and deep emissions cuts across the whole global economy – this is at unprecedented rates of decarbonisation in most sectors; and

   b. Large-scale carbon dioxide removal – scaling up from now[2].

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[1] In IPCC reports, 66% is used to define a 'likely' probability of an outcome

[2] Carbon dioxide removal will be required to cancel out any residual emissions which cannot be mitigated and /or to reduce atmospheric carbon dioxide concentrations for overshoot scenarios. Related papers on carbon dioxide removal and natural climate solutions as carbon dioxide removal will also be developed.

5. Non-overshoot pathways are more challenging because, in general, they require earlier peaking, faster reductions, earlier large-scale carbon dioxide removal and reaching net-negative emissions earlier. This implies earlier and deeper mitigation action (even more rapid and large scale structural changes in the energy system) and earlier scaling-up of carbon dioxide removal options.
6. On the other hand, overshooting 1.5°C would lead to higher, and in some cases irreversible, climate impacts on societies and ecosystems. It increases the risk of passing climate thresholds or 'tipping points'. and require more, and more expensive, adaptation.

Annexure II: Summary of Evidence

Nearly all 1.5°C scenarios result in an overshoot

1. Scenarios that restrict climate forcing to 1.9 Watts per square metre (Wm^{-2}), with a likely probability that warming will be below 1.5°C in 2100, reach a maximum median temperature during the period to 2100. This maximum median temperature ranges from 1.5 - 1.8°C[3]. An important factor in determining the size of the peak is how quickly emissions are reduced to 2030. If emissions in 2030 are at the upper end of the range, the probability of limiting peak warming to below 1.5°C is approximately halved. Figure 2 below shows the temperature outcomes of the scenarios limiting climate forcing to 1.9 Wm^{-2}.
2. The overshoots in the scenarios result from the limited carbon budget remaining to keep below 1.5°C and the constraints in the models. Given the limited carbon budget remaining (see text box), any delay in emission reductions increases the risk associated with a temperature overshoot and would require faster subsequent emissions reductions and/or more carbon dioxide removal.

Box 1: Carbon budgets

The carbon budget is a measure of the total greenhouse gas emissions linked to a particular temperature rise. The relationship between total greenhouse gas emissions and that temperature rise is complex and there is more than one way to determine the 'allowable' budget for 1.5°C. For a 66% chance of remaining below 1.5°C, the estimated budgets range from -257 to 818 $GtCO_2$[4]. The negative figure indicates that we have already used up the allowable carbon budget. The size of the budget determines what role carbon dioxide removal would play in limiting warming. If the remaining budget is below 650 $GtCO_2$, even at the highest rates of transformation of the energy system currently deemed feasible in the models then carbon
dioxide removal will be needed to limit temperature to below 1.5°C[5].

[3] Rogelj et al Scenarios towards limiting global mean temperature increase below 1.5 °C Nature Climate Change 2018 https://doi.org/10.1038/s41558-018-0091-3
[4] https://www.carbonbrief.org/analysis-how-much-carbon-budget-is-left-to-limit-global-warming-to-1-5c (accessed 10/4/18)
[5] Elmar Kriegler, Gunnar Luderer, Nico Bauer, Lavinia Baumstark, Shinichiro Fujimori, Alexander Popp, Joeri Rogelj, Jessica Strefler, Detlef P. van Vuuren. Pathways limiting warming to 1.5°C: a tale of turning around in no time? Philosophical Transactions of the Royal Society. Published 2 April 2018.DOI: 10.1098/rsta.2016.0457

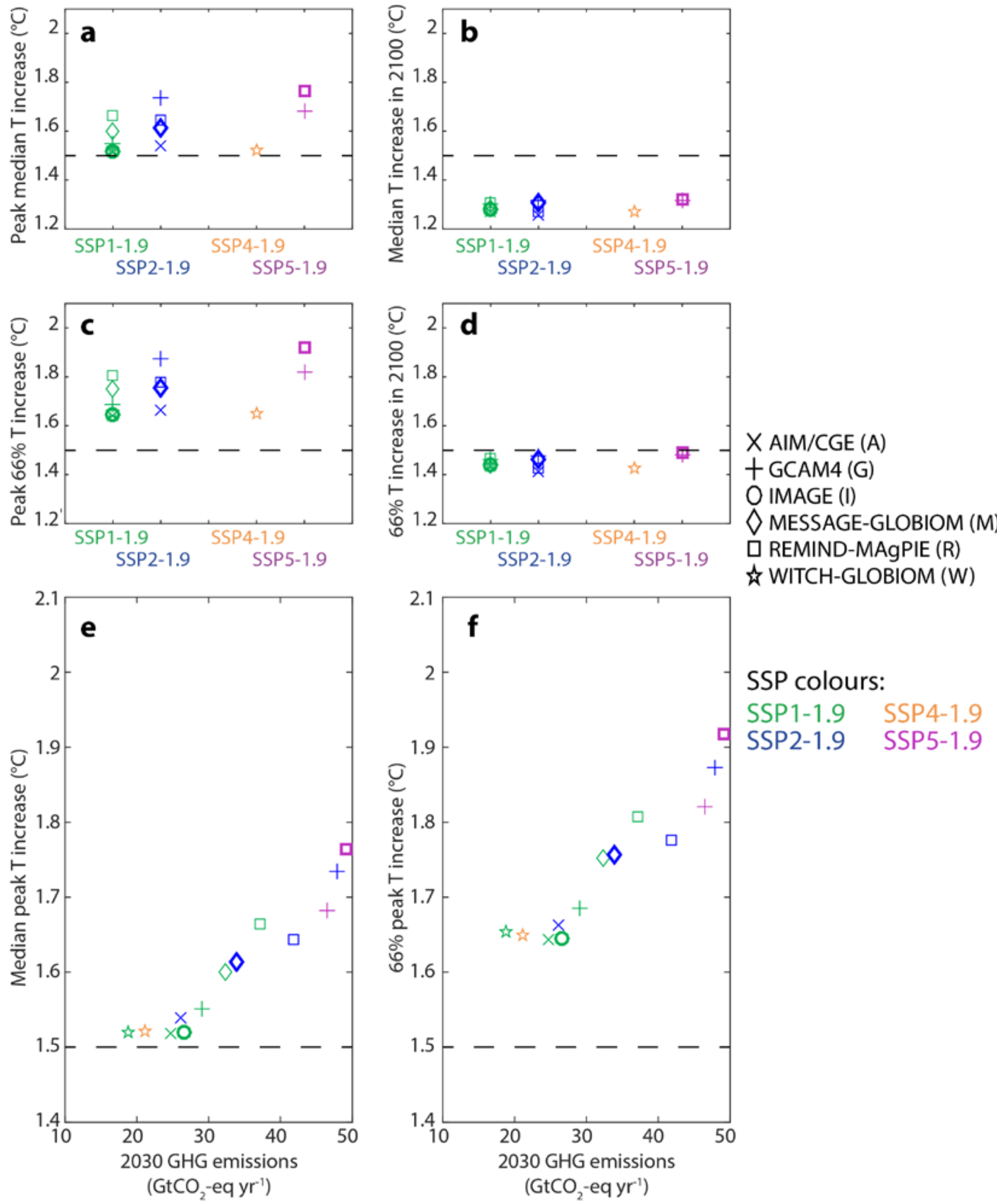

Figure 2: Temperature outcomes of 1.9 Wm^{-2} scenarios. Distribution of median peak (panel **a**) and year-2100 (panel **b**) global mean temperature increase relative to preindustrial levels computed with the reduced complexity carbon-cycle and climate model MAGICC in a probabilistic setup; **c**,**d**, as panels **a** and **b** but for 66th percentile warming; **e**,**f**, correlation between 2030 global GHG emissions levels and peak temperature increase. Bold symbols show the marker implementation of each SSP. Source Rogelj et al., 2018.

3. The constraints in the models include assumptions regarding how fast the large investments and structural changes in the economy can be implemented and how soon carbon dioxide removal can begin. The assumptions are informed by political and economic considerations. For example, the models may be constrained to reflect the emission reductions in line with the NDCs to 2030 and only replace infrastructure when economically optimal. The intention behind those assumptions is to give a realistic representation of what might be possible, although there is much discussion whether this is actually achieved. For example, the cost of renewables has decreased more rapidly than is included in many models thus making them more economic, while conversely the development of carbon capture and storage has been much slower than included.

Even short term rise above 1.5°C leads to increased risk of irreversible and potentially catastrophic climate change impacts

4. There is substantial scientific research into the impact of a 2°C or higher global temperature rise which generally shows increasing impacts with increasing temperature. The body of research on the incremental difference in impacts between 1.5°C and 2°C is smaller but growing.

5. The research shows that the projected climate impacts at 1.5°C are less than at 2°C, although in most cases there is impact even at 1.5°C[6]. With 2°C warming, there will be more pronounced weather and extreme events that can cause a global and widespread impact on humans and ecosystems. For example

   a. "nearly 700 million people (9.0% of world population) will be exposed to extreme heat waves at least once every 20 years in a 1.5°C world, but more than 2 billion people (28.2%) in a 2°C world"[7].

   b. The differential impact on biodiversity are similarly significant. A review of literature shows that a significantly reduced number of species would face a potential loss of 50% of their climatic range in 1.5°C compared to 2°C[8]. The difference in impact on coral reefs is also significant with almost all reefs at risk of long-term degradation at 2°C (see Figure 3). In addition, some impacts of higher temperatures are irreversible, such as mortality of species and ecosystems, so that even brief periods of overshoot can have long-lasting impacts on natural systems, especially if the peak in global mean temperature is high. These impacts include habitats which include geological barriers such as mountain tops which can limit the ability of species to move out of unsuitable habitats and survival of those species[9].

6. Other specific differences are summarised in Figure 3 below. Two geographical regions in particular will likely be exposed to higher risk even at 1.5°C: the tropics, due to the limited capacity of species to adapt to moderate global warming, as many species are already near their upper thermal limits, and high northern latitudes, where temperature increases are projected to be much larger than average[10].

[6] Schleussner et al, Differential climate impacts for policy-relevant limits to global warming: the case of 1.5-° C and 2-° C. Earth System Dynamics, 7(2), 327, 2016.
[7] Alessandro Dosio et al. Extreme heat waves under 1.5°C and 2°C global warming. Environ. Res. Lett in press 2018 http://iopscience.iop.org/article/10.1088/1748-9326/aab827/pdf
[8] Smith P, Price J, Molotoks A, Warren R, Malhi Y. 2018 Impacts on terrestrial biodiversity of moving from a 2°C to a 1.5°C target. *Phil. Trans. R. Soc. A* **376**: 20160456. http://dx.doi.org/10.1098/rsta.2016.0456
[9] O'Neill et al, IPCC reasons for concern regarding climate change risks, Nature Climate Change volume 7, pages 28–37 (2017)
[10] IPCC. Climate Change 2014: Impacts, Adaptation, and Vulnerability. Part A: Global and Sectoral Aspects. Contribution of Working Group II to the Fifth Assessment Report of the Intergovernmental Panel on Climate Change, 2014.

	1.5°C	2°C	
Heat wave (warm spell) duration [month]			
Global	**1.1** [1;1.3]	**1.6** [1.4;1.8]	Tropical regions up to 2 months at 1.5°C or up to 3 months at 2°C
Reduction in annual water availability [%]			
Mediterranean	**9** [5;16]	**17** [8;28]	Other dry subtropical regions like Central America and South Africa also at risk
Increase in heavy precipitation intensity [%]			
Global	**5** [4;6]	**7** [5;7]	Global increase in intensity due to warming; high latitudes (>45°N) and monsoon regions affected most.
South Asia	**7** [4;8]	**10** [7;14]	
Global sea-level rise			
in 2100 [cm]	**40** [30;55]	**50** [35;65]	1.5°C end-of-century rate about 30% lower than for 2°C reducing long-term SLR commitment.
2081-2100 rate [mm/yr]	**4** [3;5.5]	**5.5** [4;8]	
Fraction of coral reef cells at risk of long-term degradation [Constant case, %]			
2050	**90** [50;99]	**98** [86;100]	Only limiting warming to 1.5°C may leave window open for some ecosystem adaptation.
2100	**70** [14;98]	**99** [85;100]	
Changes in local crop yields over global and tropical present day agricultural areas including the effects of CO_2-fertilization [%]			
Wheat Global	**2** [-6;17]	**0** [-8;21]	Projected yield reductions are largest for tropical regions, while high-latitude regions may see an increase. Projections not including highly uncertain positive effects of CO_2-fertilization project reductions for all crop types of about 10% globally already at 1.5°C and further reductions at 2°C.
Wheat Tropics	**-9** [-25;12]	**-16** [-42;14]	
Maize Global	**-1** [-26;8]	**-6** [-38;2]	
Maize Tropics	**-3** [-16;2]	**-6** [-19;2]	
Soy Global	**7** [-3;28]	**1** [-12;34]	
Soy Tropics	**6** [-3;23]	**7** [-5;27]	
Rice Global	**7** [-17;24]	**7** [-14;27]	
Rice Tropics	**6** [0;20]	**6** [0;24]	

Figure 1: Main results. Median projections are given in bold. The 66% uncertainty range is given in square brackets.

Figure 3: Main results on differential impacts between 1.5°C and 2°C from C.-F. Schleussner et al 2016[11].

[11] C F Schleussner et al, Differential climate impacts for policy-relevant limits to global warming: the case of 1.5 ◦C and 2 ◦C Earth Syst. Dynam., 7, 327–351, 2016 www.earth-syst-dynam.net/7/327/2016/ doi:10.5194/esd-7-327-2016

7. There are also several thresholds in the climate system which could lead to irreversible changes as a result of changing climate. Some of these thresholds lead to rapid changes (often called 'tipping points') and others to slower positive feedbacks. An example of the latter is the melting of Siberian Permafrost where large-scale melting could release large amounts of methane which would add to global warming. Research suggests that the area melted under 1.5°C would be 30% (200 million hectares) lower than at 2°C[12]. Other examples include Amazon rainforest dieback, the loss of Arctic and Antarctic sea-ice and Greenland and Antarctic ice-sheets. Science cannot say exactly at which level of warming a threshold is passed and so identify a temperature range instead, but risks associated with crossing multiple thresholds increases with rising temperature[13]. Figure 4 shows the number of abrupt climate change events (tipping points) in different temperature ranges. A large number of tipping points have ranges in between 1.5 to 2°C warming and so accepting overshooting 1.5°C implies accepting these tipping point risks.

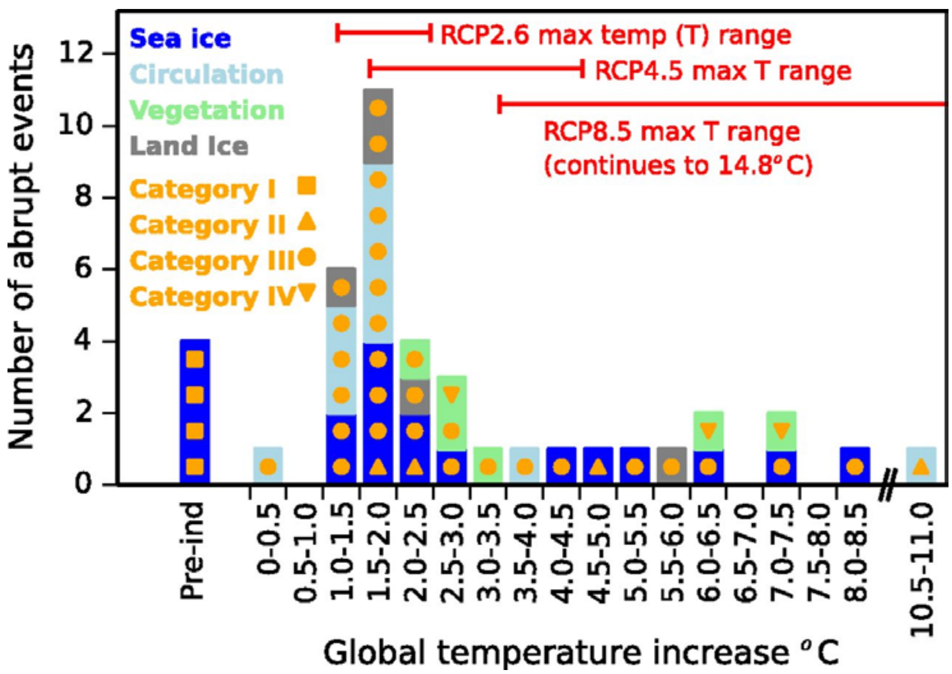

Figure 4: Abrupt shifts as a function of global temperature increase. Shown are the number of abrupt climate changes occurring in the CMIP5 database for different intervals of warming relative to the preindustrial climate. Drijfhout et al. 2015[14]

[12] Chadburn et al, An observation-based constraint on permafrost loss as a function of global warming. Nature Climate Change NCLIMATE3262. 10 April 2017

[13] Lenton, T. M., & Ciscar, J.-C. Integrating tipping points into climate impact assessments. Climatic Change, 117(3), 585-597, 2013

[14] Drijfhout et al., Catalogue of abrupt shifts in Intergovernmental Panel on Climate Change climate models, 2015

1.5°C is more economically favourable than 2°C but relative costs of overshoot or not is undetermined

8. A smaller global temperature rise implies more early mitigation effort and so higher upfront costs to reduce greenhouse gas emissions; but lower costs of adapting to climate impacts and lower risk of changes to which humanity could not adapt.

   A recent study found that limiting warming to 1.5°C would result in "improved economic outlook of at least 10% higher levels of global GDP by 2050"[15]. This is due to, for example, reduced length of heatwaves, a lower risk of flooding for low-lying countries and a lower risk of reduced crop yields. No equivalent studies have been identified that examine the difference between overshoot or no overshoot scenarios.

9. The overall economic impact results from the investments needed to reduce emissions sufficiently to limit temperature rise to 1.5°C balanced by the cost savings from the avoided impacts and from the lower running-costs for low-carbon energy technologies.

   In terms of investments, the aggregated cost between 2010 and 2100 of a 1.5°C scenario is estimated to be 1.5 to 2 times that for 2°C. The differences in short-term costs are more pronounced, as 1.5°C requires much faster decarbonisation of energy systems than 2°C – with aggregated costs between 2010 and 2030 estimated to be 2 to 3 times higher than for 2°C. These costs though would have only a limited impact on economic growth of a few tenths of percent per year[16].

[15] Pursuing the 1.5°C limit: Benefits & opportunities, Climate Vulnerable Forum and UNDP report, 2016
[16] Rogelj et al., Energy system transformations for limiting end-of-century warming to below 1.5°C, Nature Climate Change June 2015 p519-526

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To stop the degradation of the planet's natural environment and to build a future in which humans live in harmony with nature.

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