Input to the Talanoa Dialogue from Climate Analytics

April 2018

This input summarises scientific findings relevant to the Talanoa Dialogue and the 1.5°C temperature limit in the Paris Agreement. The structure follows the guiding questions the Dialogue. Climate Analytics provides a pool of information on science, impacts and risks of 1.5°C, the feasibility of holding warming below 1.5°C, necessary steps to limit warming to 1.5°C, and emissions reduction targets and 1.5°C pathways here: http://climateanalytics.org/briefings/1-5c-key-facts.html

A. Key messages

Additional information, sources and publication references on the key messages are provided in section B below.

Where are we?

- Long-term average global mean temperature (GMT) has reached ~1°C above pre-industrial levels.
- Observed warming of 0.5°C (e.g. since the 1960s) has led to significant attributable impacts including in extreme weather events occurrence.
- Observed warming and its associated impacts are already undermining the ability of developing countries to meet their sustainable development priorities and there is clear evidence for climate related Loss and Damage.
- Record-setting heat extremes, heavy precipitation events and droughts are being experienced all over the world, many of which can be attributed at least in part to human induced climate change.
- Climate change is already affecting the health of hundreds of millions of people through heat waves, reduced crop yields, spread of infectious disease, air pollution and extreme events, among others. Vulnerable populations and those living in low- and middle-income countries are the most affected.
- Ocean systems are particularly vulnerable to the impacts of climate change and impacts on ocean systems are already widespread. There is already clear evidence of loss and damage inflicted by climate change on oceans.
- A renewable energy revolution is fundamentally reshaping the global energy landscape. Renewable energy and storage systems are the cheapest source of new energy supply in many parts of the world now.

Where do we want to go?

Limiting warming to below 1.5°C will greatly reduce dangerous impacts of climate change, especially in the most vulnerable regions.

- Only limiting warming to below 1.5ºC will keep projected sea level rise under 1m in the long run. For every five years delay of the peak in global CO_2 emissions, sea levels will rise by about 20cm in 2300.
- There is a very slim chance of survival for tropical coral reefs if warming exceeds 1.5°C. Limiting warming to 1.5°C will leave some chance for ecosystems to adapt, but losses in coral cover, already occurring today, will still be extensive.
- Limiting warming to 1.5°C reduces the risk of passing critical tipping points, in particular in ocean, sea ice and ice sheet systems. Reaching such tipping points could lead to unstoppable multi-metre sea-level rise over the coming centuries and millennia.
- Risks posed by extreme heat increase steeply with warming in particular in tropical regions. Limiting warming to 1.5°C will significantly reduce risks by extreme temperature and heat waves, when compared to 2°C.
- Limiting warming to 1.5°C also has substantial benefits for food and water resources.
    - Marine fisheries would avoid significant damages, especially in tropical regions.
    - Dry regions such as the Mediterranean would experience a substantially lower drop in water available and low flows at 1.5°C warming, when compared to 2°C. At the same time, extreme flooding risks would be lower for flood prone regions in South Asia. A significant portion of the water stored in Asian mountain glaciers would be saved.
    - Tropical agriculture is highly vulnerable to climate change, with much greater yield reductions projected for 2°C warming than 1.5°C.
- Keeping temperature rise by 2100 to below 1.5°C is feasible, but requires early and rapid action to reduce emissions in all sectors. New socio-economic modeling confirms earlier findings that the 1.5°C limit can be achieved by peaking total greenhouse-house gases by 2020, reducing total global CO_2 emissions to zero by md century and reducing total global greenhouse-gas emissions to zero by 2065.

How do we get there?

- Aggregated together the collective effect of current nationally determined emission reduction targets until 2030 are grossly insufficient to achieve the goals of the Paris Agreement.

- A pathway consistent with limiting temperature rise to below 1.5°C by 2100 will require
    - A rapid shift away from traditional fossil-fuel use towards large-scale low-carbon energy supplies, reduced energy use, and carbon-dioxide removal
    - A global phase-out of unabated coal and complete decarbonisation of the power sector by mid century
    - Implementing additional mitigation efforts in the industry, buildings, and transport sectors to achieve significantly lower emissions over the coming decades and by mid-century
- Rapid observed technological change in renewable energies and storage technologies allows for much more stringent near-term emissions reductions.

B. Additional information

Where are we?

> *Average global mean temperature (GMT) has reached ~1°C above pre-industrial levels, and many parts of the world have already experienced record-setting hot extremes, heavy precipitation events and droughts. Severe impacts are already being experienced in key sectors (water, agriculture, fisheries, health) and will worsen as GMT increases.*

Global mean temperature increase

As defined by the UNFCCC, climate change is “attributed directly or indirectly to human activity” and comes “in addition to natural climate variability”. Therefore, to assess where we are with regards to achieving the long-term temperature goal of the Paris Agreement, one needs to consider the average global mean temperature (GMT) over long-term periods of at least 20 years in order to cancel out the effects of short-term natural variations (Rogelj et al., 2017).

The long-term average GMT is already ~1°C above pre-industrial levels, and this is largely attributable to human induced climate change. This means that we are 0.5°C from exceeding the below 1.5°C goal in the Paris Agreement. However, the need to use long-term averages to assess warming levels means that a breach of 1.5°C GMT in any individual year does not mean the long-term temperature goal has been exceeded, as long as the long-term average remains below 1.5°C (see our briefing for more information). Because of natural variability, stabilising the GMT increase below 1.5ºC above pre-industrial time would imply that, on average, every other year would be warmer than this level (Rogelj et al., 2017).

The temperature levels mentioned in the Paris Agreement long-term temperature goal[1] can only be understood as global average temperature increases above the global average pre-industrial climate of the earth. The averaging period for the temperature increases are a few to several decades, in other words relevant to estimating climate changes (e.g. 20-30 years) as has been standard in successive IPCC reports and as is embedded in the UNFCCC. All IPCC assessments have in general defined the pre-industrial climate as that prevailing in the mid to late 19th century. Consistent with this, the IPCC AR5 estimates the global mean surface air temperature rise above pre-industrial relative to an 1850-1900 pre-industrial reference period based on the HadCRUT4 observational dataset. In the IPCC AR5 projected future warming from climate models was related to the 1986-2005 period, which was established at 0.61°C warmer than the 1850-1900 preindustrial reference period based on the HadCRUT4 observational dataset. Climate projections for say 2030-2050 as being 1°C warmer than the 1986-2005 period, are then 1.61°C warmer than the defined pre-industrial period. Any measure of temperature rise that uses a different definition of GMT (for example, using a different reference period from observational data) could have implications for the carbon budget and climate change impacts compared to the equivalent temperature rise using definitions similar to the AR5 definitions. Therefore, given that the Paris Agreement was negotiated on the

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[1] Article 2.1(a): “Holding the increase in the global average temperature to well below 2 °C above pre-industrial levels and pursuing efforts to limit the temperature increase to 1.5 °C above pre-industrial levels, recognizing that this would significantly reduce the risks and impacts of climate change.”

basis of IPCC AR5 science, it is vital that progress towards the Paris Agreement temperature goal is based on global mean climatological averages (20-30 years) referenced to the 1850-1900 pre-industrial climate used in the IPCC AR5. To do otherwise risks 'changing the goal posts' with important implications for policy, including carbon budgets and emission pathways.

Observed impacts

Current warming levels are already leading to severe impacts all across the world. Observations show that these impacts are already undermining the ability of developing countries to meet their sustainable development priorities. Some of these impacts are described below.

1) Extreme weather events

Anthropogenic global warming has already increased the probability of record-setting hot extremes, heavy precipitation events and droughts over 50 to 90% of North America, Europe and East Asia (Diffenbaugh, 2018). Evidence from the observational record has shown that half a degree of warming has previously caused substantial changes in hot and cold extremes as well as extreme precipitation events (Schleussner et al, 2017).

Looking at specific extreme weather events that have already occurred, greenhouse gas emissions have significantly altered the odds of their occurrence. The probability of strong heatwave events has increased in many parts of the world (e.g. Europe in 2003, in Egypt in 2015 and in Argentina in December 2013; Stott et al, 2004, Mitchell et al., 2016, Hannart et al., 2015), whilst the probability of strong cold spells is decreasing (Christidis et al. 2014, Trenary et al. 2016). Human-driven global warming also contributed to intensify many drought events globally, such as those from 2015 in Ethiopia and southern Africa and from 2014 in the Southern Levant region (Funk et al. 2016, Bergaoui et al. 2015), as well as the Australian Millennium Drought (Cai et al., 2014). It also reinforced specific heavy precipitation events, such as, among others, those which occurred in northern India in June 2013, in Colorado in September 2013 or in Southern England in 2014 (Singh et al., 2014, Eden et al., 2016, Schaller et al. 2016).

2) Tropical cyclones

Tropical cyclones represent an existential threat to tropical island and coastal communities, causing significant loss and damage for island states and coastal communities. Attribution of tropical cyclones to climate change remains difficult. However, the physical factors that drive tropical cyclone formation – such as warm sea surface temperatures – are connected to climate change, and recent decades have seen an increasing trend in tropical cyclone activity and intensity in the North Atlantic (Bindoff et al., 2013). As sea surface temperatures warm further, probability of the stronger cyclones rises, and under 2.5ºC of global warming, the most devastating storms are projected to occur up to twice as often as today (Bacmeister et al., 2016).

It is important to also consider the attribution to climate change of the climate hazards posed by tropical cyclones. These climate hazards – such as the risk of coastal and freshwater flooding - are intensified by the heavier rainfall and sea level rise that climate change induces. For example, climate change made precipitation from Hurricane Harvey in August 2017 15% more intense (van Oldenborgh et al. 2017), while at the same time increasing the risk of coastal flooding due to sea-level rise.

For more information see our tropical cyclones briefing

3) Ocean impacts

Unprecedented marine heatwaves critically affecting coastal and ocean ecosystems are already being observed today, and a steep rise in their intensity and frequency is projected with increasing warming. For example, a heatwave in early 2016 in Australia and the South Pacific led to widespread coral bleaching in the Coral Sea and extensive die-back of mangroves in northern Australia. Under 2°C warming, such heat waves would be the new normal, occurring in 9 out of 10 years.

4) Health impacts

In the past 50 years significant efforts have been made to improve public health, which are currently undermined by climate change. Between 2000 and 2016, the medium temperature increase worldwide has been about 0.4°C, while the areas where most people live increased by 0.9°C, impacting human health already today. During the same timeframe increasing temperatures have caused the labour capacity to decrease by 5.3%, and an estimated 125 million additional vulnerable adults were exposed to heatwaves (Watts et al. 2017).

Increasing temperatures have a negative impact on crop yields particularly in the tropics. For each 1°C temperature increase the global wheat production decreases by 6%. For rice every increase of 1°C in night temperatures during the growing season causes a 10% reduction of the rice grain yield. With decreasing crop productivity, the vulnerability to undernutrition increases. Between 1990 and 2016 the number of people suffering from undernutrition has increased from 398 to 422 million affecting people in the 30 most vulnerable countries (Watts et al. 2017).

A coal phase-out is not only relevant to reduce CO2 emissions, but also offers health co-benefits like improved air quality. According to the WHO air pollution increases the chance of dying of lung cancer, a stroke, chronic respiratory disease or heart disease (WHO 2018). The population being exposed to air pollution has increased by 11.2% since 1990 and affects particularly urban population (Watts et al. 2017).

For more information see our ocean impacts briefing

Rapid developments of renewable energies

According to IRENA, Solar PV module prices have fallen by around 80% since the end of 2009, while wind turbine prices have fallen by 30–40% (IRENA, 2018). Prices have fallen much faster than even in the most stringent carbon pricing scenarios applied in the IPCC AR5 (Creutzig et al., 2017). Renewable energies are the cheapest source of energy in many parts of the world already today (IRENA, 2018). This fundamentally alters the starting point for ambitious action on climate.

Where do we want to go?

> *In order to reduce the risk of passing critical tipping points in the climate system, and to minimize the dangerous impacts of climate change, the world should move towards and stay on a pathway consistent with limiting warming to 1.5°C. Limiting warming to below 1.5°C is feasible, but requires early and rapid action in all sectors.*

The differences in climate impacts between 1.5°C and higher levels of warming are significant. Therefore, to minimize the impacts of climate change and prevent the most dangerous impacts from occurring, we must keep warming below 1.5°C. The difference between 1.5°C and 2°C is particularly significant in regions with limited adaptive capacity and high exposure. For example, heatwaves in tropical regions are projected to last about 2 months at 1.5°C and up to about 3 months at 2°C (Schleussner et al., 2016a). Extreme precipitation increases by 7% under 1.5°C and 10% under 2°C in South Asia, which would likely be connected to changes in monsoon precipitation. More information is provided in this briefing note.

Figure 1 shows the difference between 1.5°C and 2°C for a number of different impacts. Some key impacts elaborated on below.

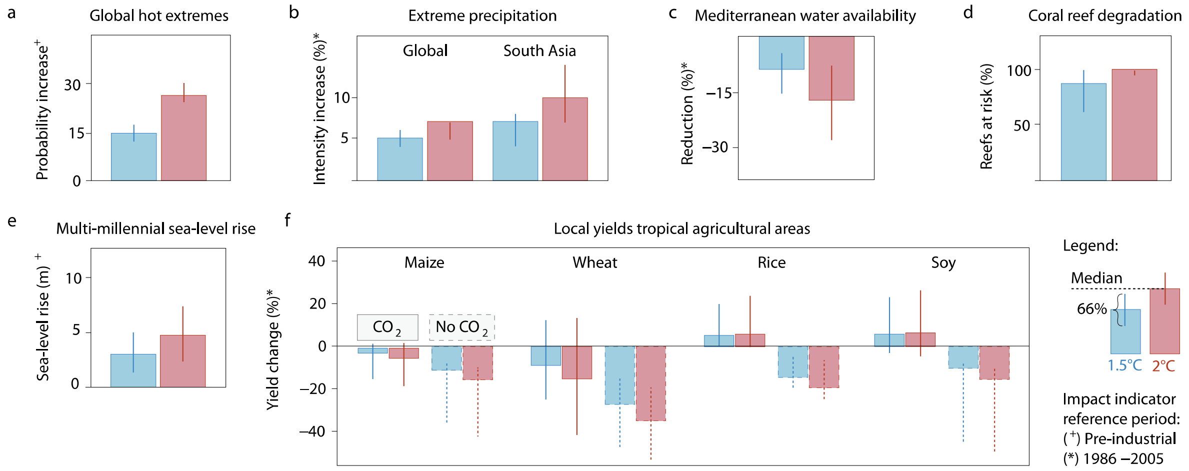

Figure 1: Difference between 1.5°C and 2°C warming, from Schleussner et al. (2016b).

Sea Level Rise

Sea level rise as a result of anthropogenic climate change is a key impact affecting ocean and coastal systems. Under warming of 2°C, we could be looking at sea-level rise of 5m and more over the coming centuries (Nauels et al., 2017). Only limiting warming to below 1.5°C will keep sea-level rise under 1m (Mengel et al., 2018).

A rise in sea levels will lead to a steep increase in coastal flooding risks. Drastic increases in coastal flooding risks demonstrate the loss and damage inflicted by climate change even when warming is limited to 1.5°C. Under a warming scenario of 2°C by 2100, we can expect sea level rise of 50cm, and present “one in fifty years" coastal floods will be occurring every year (Vitousek et al., 2017). By 2150, relative to the 2°C scenario and based on median sea level projections, GMST stabilization of 1.5°C spares the inundation of lands currently home to about 5 million people, including 60 000 individuals currently residing in Small Island Developing States (Rasmussen et al., 2018).

Coastal and ocean ecosystems – tropical coral reefs and mangroves

Most tropical coral reefs would not survive a warming of 2°C. Limiting warming to 1.5°C will leave some chance for ecosystems to adapt, but losses in coral cover, already occurring today, will still be extensive.

Rising sea levels could be detrimental for mangrove ecosystems in some low-lying regions, for example in the Solomon Islands and Sumatra. Mangroves may be completely submerged before the end of the century in areas where sediment input is not sufficient for mangroves to grow in pace with sea level rise, and the important ecosystem services they provide – including coastal protection – will be lost.

Marine fisheries

Under a warming pathway implied by policies currently in place, Indo-Pacific maximum catch potential would be almost halved. In the Indo-Pacific, reduction in maximum catch potential doubles between a warming of 1.5°C and 2°C. As a consequence, there are large benefits in terms of avoided damages to marine fisheries of meeting the 1.5ºC global warming target (Cheung et al., 2016). Benefits are largest for tropical regions.

Water resources

Substantial increases in annual run-off at 1.5°C are projected for the high northern latitudes and the Asian monsoon regions, while water availability at the same time is substantially reduced in subtropical regions. These changes intensify under 2°C (Doell et al., 2018). Annual run-off for the Mediterranean region is projected to reduce by about 9% under 1.5°C compared to 17% in a 2°C world (Schleussner et al., 2016a).

Limiting warming to 1.5°C may prevent melting of almost two thirds of presently stored ice-mass in high mountain glaciers in Asia, which decreases to only about 50% if warming exceeds 2°C (Kraaijenbrink et al., 2017).

Agriculture

Without considering CO_2 fertilization or adaptation, each degree-Celsius increase in global mean temperature has been found reduce global yields of wheat by 6.0%, rice by 3.2%, maize by 7.4%, and soybean by 3.1% (Zhao et al. 2017). An additional warming of 0.5°C will therefore have consistently negative effects on global production (Schleussner et al., 2018). For wheat and maize, projected median yield reductions of local crop yields over the tropical regions double between 1.5°C and 2°C (Schleussner et al., 2016b).

Tipping Points

A tipping point is reached when a small amount of warming leads to an abrupt, at times irreversible shift within on component of the earth system (Lenton et al., 2008). While quantifying the exact tipping point of one tipping element is challenging, an overall agreement exists that the likelihood of passing a specific tipping point increases with global temperature.

Warming beyond 1.5°C strongly increases the risks of reaching critical tipping points for ocean systems and for the Greenland and Antarctic ice sheets. Reaching such tipping points could lead to unstoppable multi-meter sea-level rise over centuries and millennia to come. For example, the Greenland ice sheets may become unstable beyond a global mean temperature increase of 1.6°C irreversibly leading to an additional amount of up to 7 m global mean sea level rise over the course coming millennia. (Robinson et al., 2012).

Recent findings from West Antarctica suggesting that an irreversible marine ice-sheet instability has already been triggered there for several basins (Favier et al., 2014), although a direct attribution of this tipping to an anthropogenic origin cannot be made with sufficient confidence.

Tipping points also occur in sea ice and atmospheric systems. For example, the abrupt loss of sea ice and reduced snow cover has been suggested to affect the mid-latitudinal atmospheric circulation leading to more persistent and extreme weather in those regions (Cohen et al., 2014 , Wu et al, 2016).

Half of all tipping points identified in AR5 models would be tipped already under a 2°C warming, compare to about 20% under 1.5°C (Drijfhout et al., 2015).

Limiting warming to 1.5°C by 2100 is feasible

- The scientific findings based on low-emission scenarios (also assessed by the IPCC in its latest (Fifth) assessment report) show that it is both physically and economically feasible to limit warming to below 1.5°C by 2100. Recently, more scenarios have become available that further support the feasibility of limiting warming to 1.5°C by 2100 and allow a more comprehensive assessment of the technological and economical requirements (Rogelj et al. 2018). These confirm earlier findings that a pathway consistent with limiting temperature rise to below 1.5°C by 2100 will require peaking total greenhouse-house gases by 2020, reducing total global CO_2 emissions to zero by 2055 and reducing total global greenhouse-gas emissions to zero by 2065

  Limiting warming to below 1.5°C by 2100 requires similar transformations in the energy system as holding warming to below 2°C during the 21st century, but the decarbonisation of the energy system needs to be faster and more pronounced.

See our briefings *for more information, here, here and* here

How do we get there?

Characteristics of 1.5°C pathways are assessed in great detail in our briefing on 1.5°C feasibility. Key findings include:

- **Reaching the 1.5°C limit requires the same technologies as 2°C, deployed faster.** A critical technology for both well below 2°C and 1.5°C pathways is negative CO_2 emissions technology. This is necessary to compensate for the insufficient global greenhouse gas emissions reductions realised to date.
- **Energy efficiency is key.** Energy efficiency plays a critical role in low stabilisation scenarios in general. The related reductions in energy demand need to be greater, particularly from 2030, to hold warming below 1.5°C rather than 2°C.

The most recent 1.5°C scenarios mentioned above (Rogelj et al. 2018) confirm these earlier findings and emphasize that a pathway consistent with limiting temperature rise to below 1.5°C by 2100 will require a rapid shift away from traditional fossil-fuel use towards large-scale low-carbon energy supplies, reduced energy use, and carbon-dioxide removal. A global phase-out of unabated coal is needed, as well as a complete decarbonisation of the power sector by mid century. Implementing additional mitigation efforts in the industry, buildings, and transport sectors to achieve significantly lower emissions over the coming decades and by mid-century

A rapid coal phase-out is essential: CO_2 emissions from operating coal power plants in all regions in the world largely surpass the global emissions budget in line with limiting warming to below 1.5°C. To be in line with the Paris Agreement, the OECD and EU countries need to phase out coal the fastest – by 2030. China would need to phase out coal around 2040, and the rest of the world by 2050.

The steeply declining costs of renewables will enable their rapid deployment

Costs of renewable energy have declined dramatically over the last years and much faster than previously expected (IRENA, 2018). This fundamentally alters the deployment trajectories of such technologies in stringent mitigation pathways. Creutzig et al. (2017) have for example found an increase in deployment of photovoltaic (PV) by more than a 100% in an integrated energy-economic model, compared to simulations included in the IPCC AR5. At the same time, near term estimates for battery storage show a similar potential for cost reductions observed for PV in the last decade. Total installed costs could fall by 50-60% by 2030 (IRENA, 2017). This changing cost landscape allows for much more stringent near term emission reductions enabling 1.5°C.

Well below 2°C – implications for mitigation pathways

The scientific community interpreted the Cancun temperature goal of holding warming 'below 2°C' as scenarios that hold warming below 2^{o}C with likelihood of 66% including in the IPCC AR5. These scenarios have a median peak twenty-first century warming of, at most, around 1.8 °C. In the Paris Agreement, the long term temperature goal was strengthened to 'Holding the increase in the global average temperature to well below 2 °C above pre-industrial levels and pursuing efforts to limit the temperature increase to 1.5 °C above pre-industrial levels', signalling a lower peak warming level than in the former "hold below 2^{o}C" goal. In addition, in scientific terms this mean a significant increase in the likelihood that warming would be held below the 2^{o}Clevel. The Paris Agreement does not indicate a probability, but it is clear that a simple ‘relabelling’ of scenario and policy pathways with a 66% likelihood to stay below 2°C that were formerly used to define the Cancun temperature goal to be “Paris Agreement compatible pathways” is not appropriate. Pathways limiting warming to 1.5°C by 2100 simultaneously also keep warming below 2°C with likelihood of >80% over the full 21st century (Schleussner et al., 2016b). Any assessments of emission reduction targets and inputs into the Talanoa Dialogue need to account for this important difference.

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