1. The IPCC Report's summary on Climate Impacts in Germany

Coastal regions such as Hamburg are among the most affected by climate change (IPCC, 2018). Climate change impacts affect "a range of natural and human systems, such as terrestrial, coastal and marine ecosystems and their services; agricultural production; infrastructure; the built environment; human health; and other socio-economic systems" (IPCC, 2018). These trends are largely of anthropogenic nature, as for example for precipitation extremes and flooding in Germany, which are "explained in terms of increasing frequency and persistence of circulation patterns favorable to flooding" (IPCC, 2014). Impacts such as flooding lead to direct losses and fatalities and will increase in the absence of adequate adaptation (IPCC, 2014). More extreme water levels due to rising sea levels are also expected to increase in coastal urban areas such as Hamburg (IPCC, 2018). This can increase flooding and lead to salinization of groundwater and damage to infrastructure from extreme events (IPCC, 2018). "At least 136 megacities (port cities with a population greater than 1 million in 2005) are at risk from flooding due to SLR (with magnitudes of rise possible under 1.5°C or 2°C in the 21st century), unless further adaptation is undertaken" (IPCC, 2018). All these long-term risks (e.g. of coastal flooding) and possible impacts on populations and thus children are projected to increase with higher levels of warming (high confidence) (IPCC, 2018).

2. Demographics

Germany has a population of about 83 million people, 18% of which are under the age of 19. An average 15-year-old German citizen, the petitioner's peer, is expected to live until the age of 90. These demographic estimates can be coupled with the projections of global mean temperature increase. Following the best estimate of the future temperature trajectory based on the Climate Action Tracker increase in the global mean temperature of 1.5°C will be exceeded around the year 2035, 2°C around 2055, and more than 3°C in 2100 (Climate Action Tracker, 2018). Today's German 16-year-old has a probability of 99% to be alive in 2035, 97% in 2055 and 10% in 2100 (World Data Lab, 2019). Nearly all of Germany's children therefore have a very high probability of experiencing a 2°C warmer world and the ensuing impacts, with a portion of them living to possibly experience an even higher warming.

3. Temperature

Each of the past three decades has been successively warmer than all the previous decades in Germany (Weyrich, 2016). The first decade of the 21st century was recorded as being the warmest (Weyrich, 2016). The average near surface temperature has increased by 1.2°C between 1881-2013 (Weyrich, 2016). Moreover, the temperature extremes (number of hot days, tropical nights and heatwaves) are increasing (Weyrich, 2016). At the same time, the number of ice days per year has decreased (Weyrich, 2016).

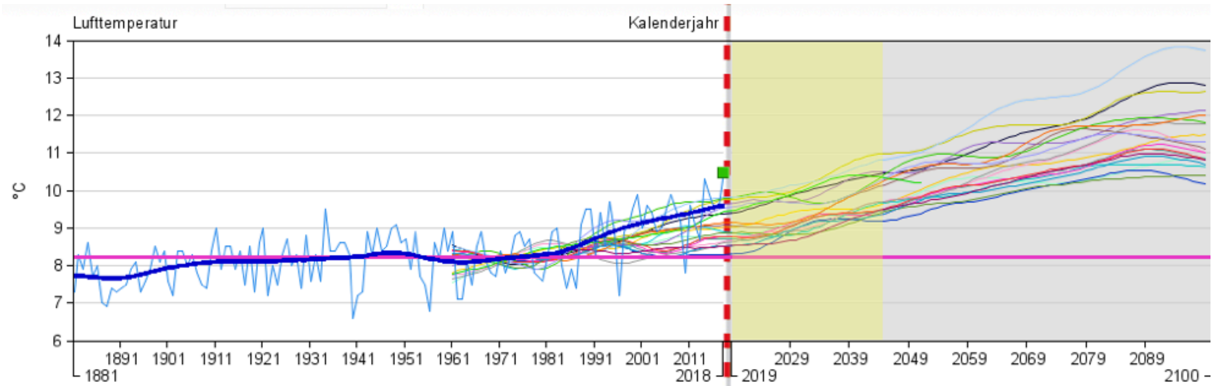

Figure 1: Mean annual temperature for Germany – thick blue line indicates the 30-year mean temperatures from 1881-2018. The future scenario assumes global temperature increases by 2100 at ~2.8°C (RCP6.0) and displays an ensemble of 21 climate models from 2019-2100 (https://www.dwd.de/DE/klimaumwelt/klimaatlas/klimaatlas_node.html)

For the period 2071-2100 the mean annual temperature for Germany is projected to rise by 2.5°C to 4°C (RCP4.5 and RCP8.5) compared to the baseline period (1971-2000) which is within the global average warming levels expected for the respective emissions scenarios (Weyrich, 2016). These effects may be even stronger in urban areas such as Hamburg. The Urban Heat Island (UHI) describes the temperature difference between urban and rural areas (Quante & Colijn, 2016), caused by human activities as well as soil sealing by building and lack of latent heat cooling. In addition, waste heat emissions will add to the rise in temperatures caused by the urban fabric (Quante & Colijn, 2016). Thus, for the urban population heat risks will increase more than for their rural counterparts, which affects energy use, comfort and health (Quante & Colijn, 2016).

4. Precipitation

Average summer precipitation in Germany remained mainly unchanged, whereas winter precipitation has increased by 28%, leading to overall precipitation increases by 10.6% since 1881 (Weyrich, 2016). This precipitation increase is also displayed in figure 2 below. Precipitation intensity and frequency has and will increase during the 20th century (Weyrich, 2016).

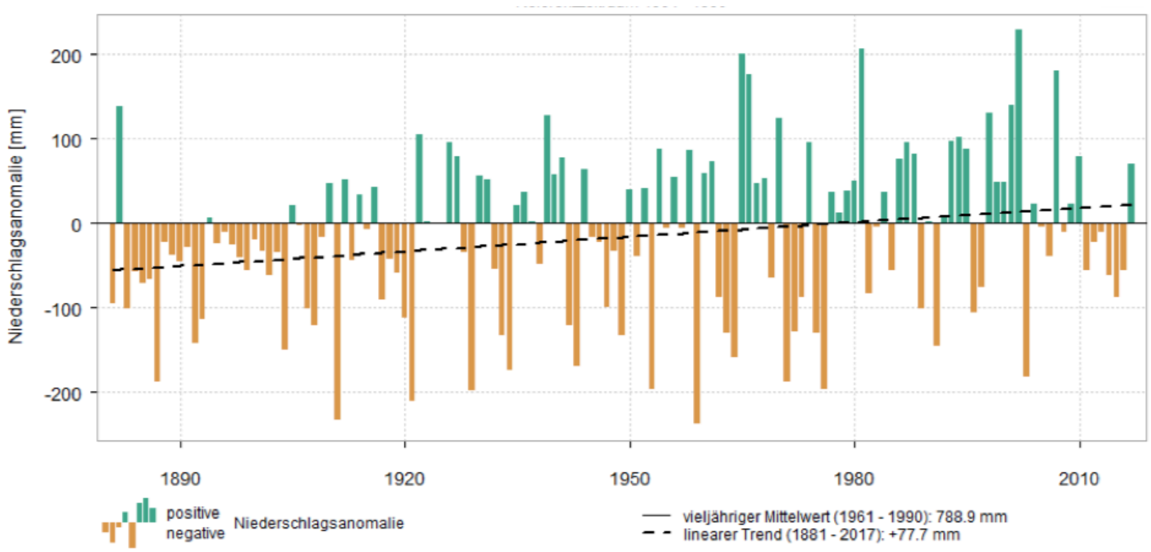

Figure 2: Positive and negative precipitation deviation (mm) of the area average for Germany from 1881-2017 (reference period 1961-1990) (Deutscher Wetterdienst, 2017)

Specifically in the North of Germany, heavy precipitation events have become more frequent and the annual maximum 5-day precipitation has increased from 38 mm to 45 mm (Weyrich, 2016). Precipitation patterns are projected to increase in large parts of Central Europe (and Germany) by 25% (for a projected temperature increase by 4.3°C by 2100 (RCP8.5)) (Weyrich, 2016). Increases in extreme precipitation were found to be largely anthropogenic and will impact direct losses and fatalities in various locations in the absence of adequate adaptation (IPCC, 2014). Extreme precipitation events are projected to increase not only in intensity, but also in length. For central Europe, the probability of a 7 (14) day period of consecutive rain days is projected to increase by about 18% (44%) under 2°C global warming (Pfleiderer et al., 2019). These precipitation increases will challenge urban infrastructure, as it causes streets and houses to flood or even the total breakdown of some urban infrastructure (Quante & Colijn, 2016).

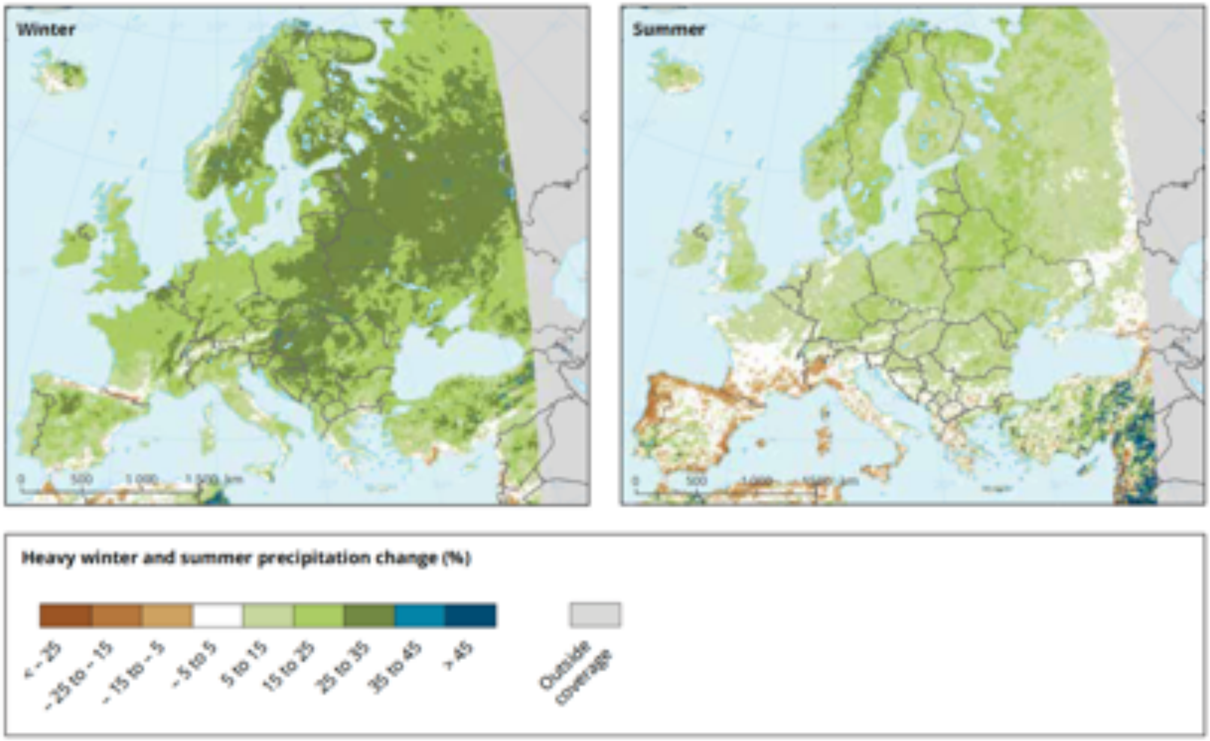

Figure 3: Projected changes in heavy daily precipitation (%) in winter and summer for 2071-2100 with the baseline period 1971-2000 for global temperature increases of 4.3°C by 2100 (RCP8.5) (Jacob et al., 2014)

5. Sea level rise

"Sea level rise is accelerating in response to climate change and will produce significant impacts (high confidence)" (IPCC, 2018). Especially in coastal urban areas or large river deltas, such as Hamburg, more extreme water levels are projected to occur due to rising sea levels, which can lead to flooding and damage of infrastructure (IPCC, 2018). Port cities with a population larger than 1 million in 2005 are "at risk from flooding due to sea level rise (with magnitudes of rise possible under 1.5°C or 2°C in the 21st century), unless further adaptation is undertaken" (IPCC, 2018).

Sea level rise, which is projected to increase with higher levels of warming, will pose long-term risks and impacts on populations, infrastructure and assets (IPCC, 2018). The changes in sea level rise and the resulting coastal flooding have been attributed to anthropogenic climate change since 1970 (IPCC, 2018). Figure 3 shows the local sea level projections for Cuxhaven, the closest tide gauged station to Hamburg (100 km from Hamburg).

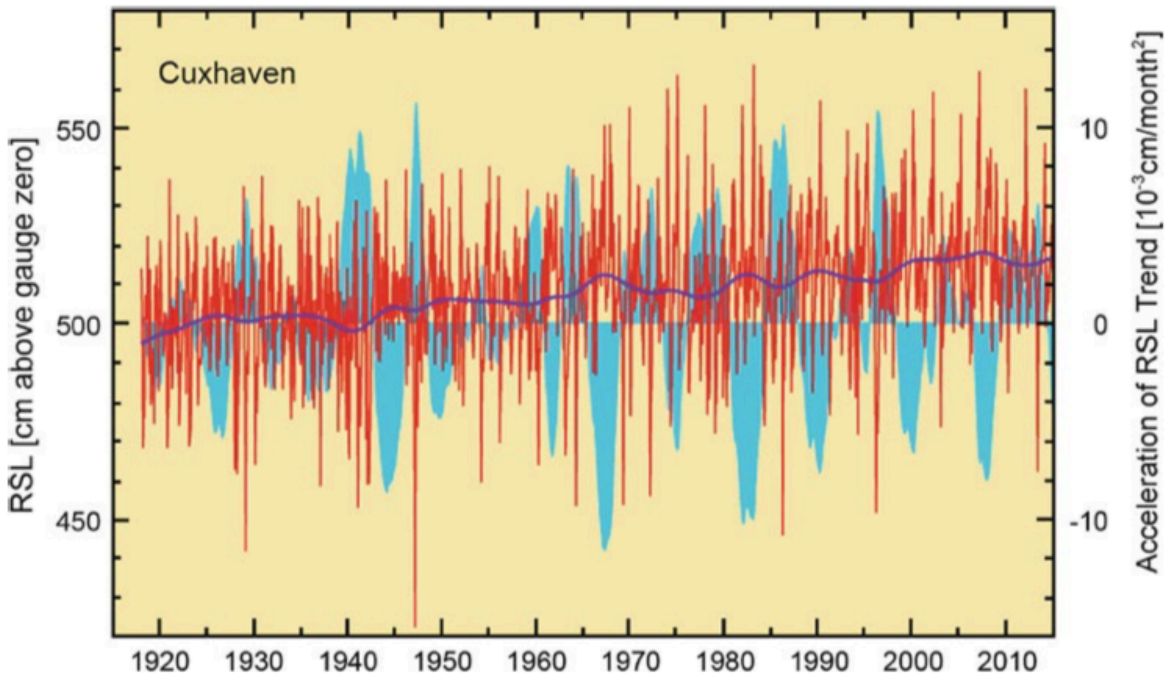

Figure 4: Observed monthly averages (red) of the relative sea level at the gauge station Cuxhaven from 1981-2015 with smoothed curve (dark blue) and acceleration of the rise (right blue) (Meinke and von Storch, 2018)

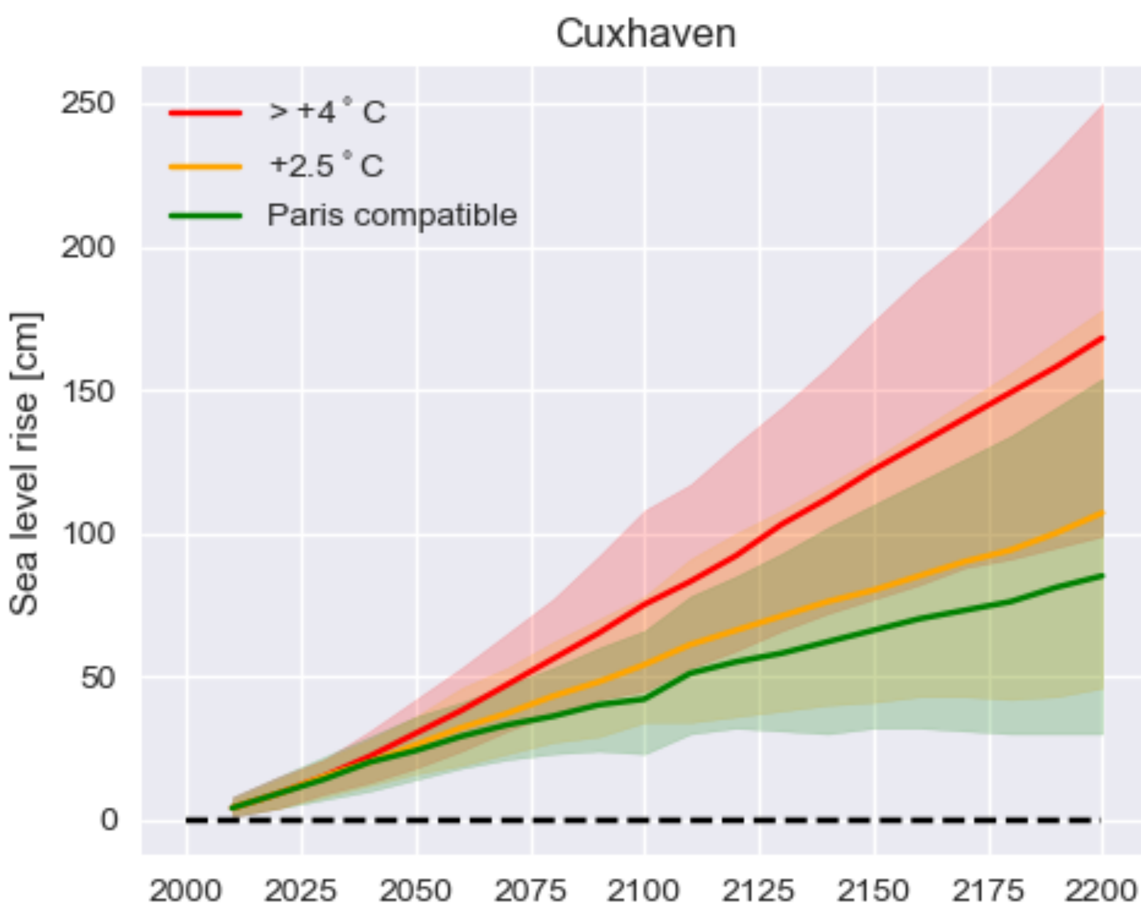

Figure 5: Local sea level projections for Cuxhaven for a scenario compatible with the Paris Agreement (~RCP2.6) (green), a scenario leading to +2.5°C global mean temperature (~RCP4.5) (orange) and a

scenario exceeding +4°C (~RCP8.5) (red) The solid lines represent multi-model medians, the shaded areas include 66% of the models (http://localslr.climateanalytics.org/location/Cuxhaven)

Sea level rise also has implications for groundwater salinization in Germany (Martens, S.; Wichmann, 2011). Sea level rise in coastal areas causes groundwater salinization, which has implications for groundwater resources and public water supply (71% of public water supply depends on groundwater resources) (Martens, S.; Wichmann, 2011). Higher salt contents can only be removed by complex and cost-intensive treatment processes and can thus pose a problem for sustainable water management (Martens, S.; Wichmann, 2011). Figure 5 show how Hamburg and surroundings are currently affected by groundwater salinization. The groundwater salinization levels are expected to increase with increasing sea levels.

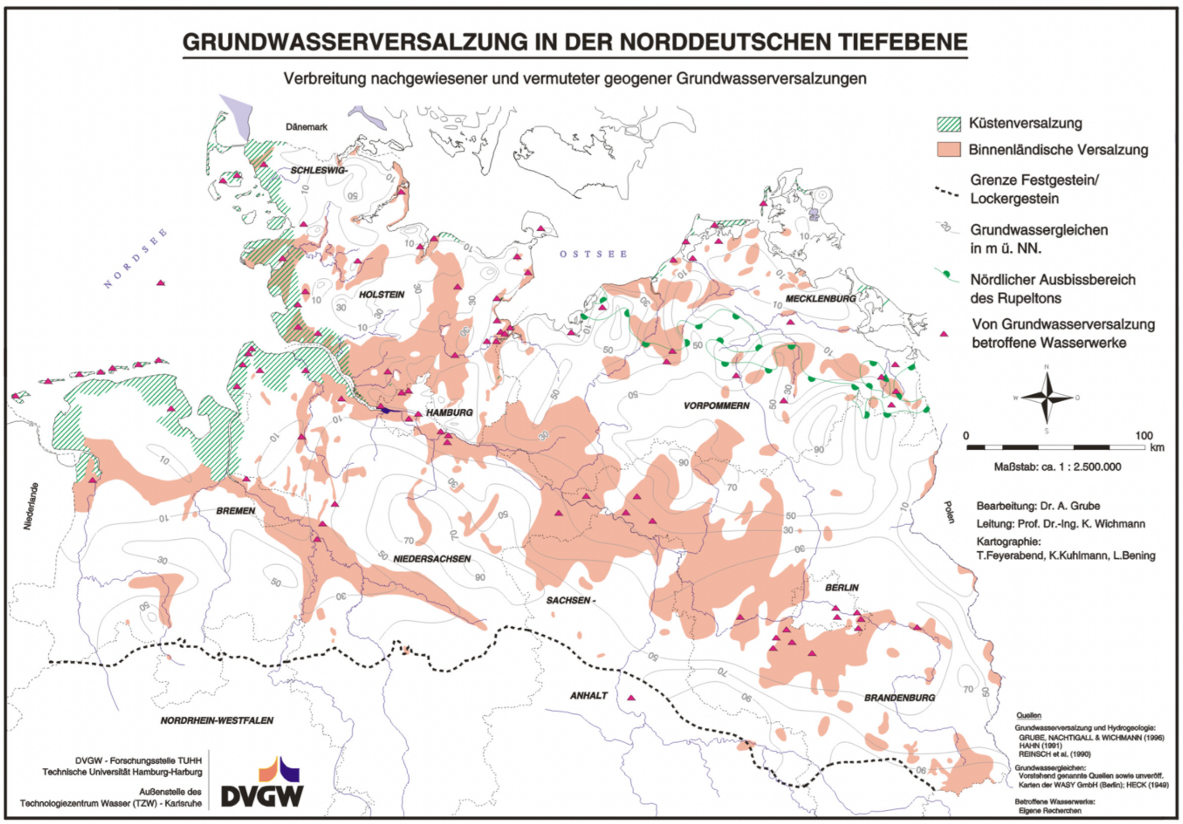

Figure 6: Groundwater salinization in the North German Plain (green areas showing coastal salinization and red areas inland salinization) (Martens, S.; Wichmann, 2011)

6. Extreme weather events

Hamburg has and will be subject to increasing extreme weather events such as heat waves and storms. For example in 1962, the city of Hamburg experienced a catastrophic storm surge, causing 347 deaths, 61 dyke failures and 370 km^2 area flooded. Increasing global temperatures affect the upper layers of the ocean, which drives more intense storms and greater rates of inundation, which together with sea level rise, causes significant impacts (IPCC, 2018).

The IPCC projects that due to increased storm frequency and sea level rise, Europe will be subject to risk of tidal and storm floods with greater erosion in the future (Huang-Lachmann & Lovett, 2016). For example, projected increases in hail (due to more severe thunderstorms) could cause mean annual loss ratios from homeowners' insurance to increase by 15% (2011-2040) and 47% (2041-2070) (IPCC, 2014). The protection level in Hamburg is comparably high, however, there is risk for certain areas (e.g. located close to the Elbe) of being flooded during storm surge.

Heatwaves in Europe are becoming more frequent. June 2019 was the warmest June in Germany since the beginning of observations (Imbery et al., 2019). Figure 7 shows the change in frequency of European climate extremes among different levels of global warming. The probabilities in a given year to reach similar events to the last European extreme values (heatwaves Europe 2003) are displayed for a natural world, the present world, a 1.5°C world and a 2°C world in Figure 8. This indicates, that under global temperature increases of 2°C (~RCP4.5), Europe will experience heat waves as in 2003 in summer as often as six out of ten summers. German children of today will spend more than half of their lives in a 1.5°C or warmer world.

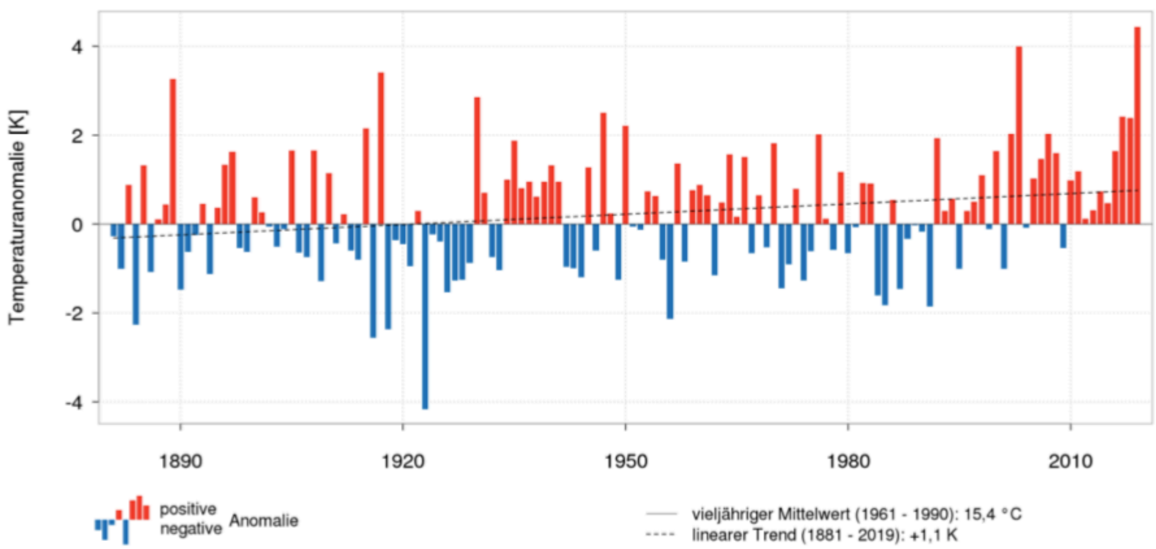

Figure 7: Deviations of June temperatures for Germany (1881-2019) from the long-term average 1961-1990 (Imbery et al., 2019)

			Likelihood of similar event per year			
EVENT	CONTEXT, IMPACT	VARIABLE	NATURAL	CURRENT	1.5°C	2°C
Central Europe JJA 2003	Hottest summer on record, thousands of heat-related deaths	T	1% (1-2%)	25% (17-33%)	42% (32-51%)	59% (50-70%)
		TXx	2% (0-6%)	21% (7-37%)	21% (9-34%)	31% (14-50%)

Figure 8: The change in the frequency of European climate extremes among different levels of warming (King and Karoly, 2017)

7. Floods

Nearly half of the area of Hamburg is declared flood prone (Rose and Wilke, 2015). Moreover, Hamburg is the second largest city in Germany with a population that is exposed to natural flooding threats from the North Sea and the Elbe river, which is also why the city has identified flood as their main climate change challenge (Huang-Lachmann et al., 2016).

Mean annual insured flood loss is projected by the IPCC 5th Assessment Report to increase by 84% in 2011-2040, by 91% in 2041-2070 and by 114% in 2071-2100 (IPCC, 2014). The city of Hamburg faces a total of three different flood risks: storm surges, inland flooding and heavy rainfall (Rose and Wilke, 2015). As there are so many water bodies in Hamburg, there is a specific risk of inland flooding events (Rose and Wilke, 2015). The sensitivity of people varies within the region, however, children (and families with children) are among the most vulnerable, as it takes more time to evacuate in case of emergency (Rose and Wilke, 2015).

8. Sectoral impacts

8.1 Health

Hamburg is one of the cities that has experienced urban climate problems, especially regarding heavy air pollution (Quante & Colijn, 2016). There are higher levels of primary pollutants due to higher emissions from a range of anthropogenic sources, especially in harbor cities like Hamburg and Rotterdam, where emissions from ships add to the air pollution load (Quante & Colijn, 2016). In Hamburg, "poor air quality has serious implications for human health and the related societal costs are considerable" (Quante & Colijn, 2016).

Climate change also has an impact of air pollution levels, for example through changes in temperature, solar radiation or humidity. Heat waves can increase the impacts on air quality, and as they are expected to increase in the coming decades this could have a impact on life expectancy (Quante & Colijn, 2016). At the same time, a sizeable part of air pollution is linked to combustion of fossil fuels, e.g. by vehicle engines or ships, thereby contributing both to global warming as well as local air pollution in particular in the urban context.
In the EU, pollution resulting from human activity is estimated to have reduced life expectancy in 2000 by 8.6 months (Quante & Colijn, 2016). Figure 4 indicates the number of premature deaths due to air pollution in 2000. For example in 2015, 81 people in Germany died prematurely because of pollution (EEA, 2018). It has been argued, that "the effects on air quality of emission changes since preindustrial times are stronger than the effects of climate change" (Quante & Colijn, 2016).

Increasing thermal loads can lead to heat waves (see chapter 6), which particularly affects older people and children (Meinke and von Storch, 2018). There are also changes to the vegetation that can cause a prolongation of the pollen season and thus make the period of symptoms of allergy sufferers longer (Meinke and von Storch, 2018). Moreover, climate change may also favour the spread of pathogens or carriers of infectious diseases (Meinke and von Storch, 2018). Finally, climate warming significantly influences tick populations due to shorter generation times and migration of tick species from warmer regions of Europe to Germany (Meinke and von Storch, 2018). This could be dangerous as ticks (as well as mosquitos) play an increasing role as carriers of pathogens and could thus affect children in Germany and Hamburg.

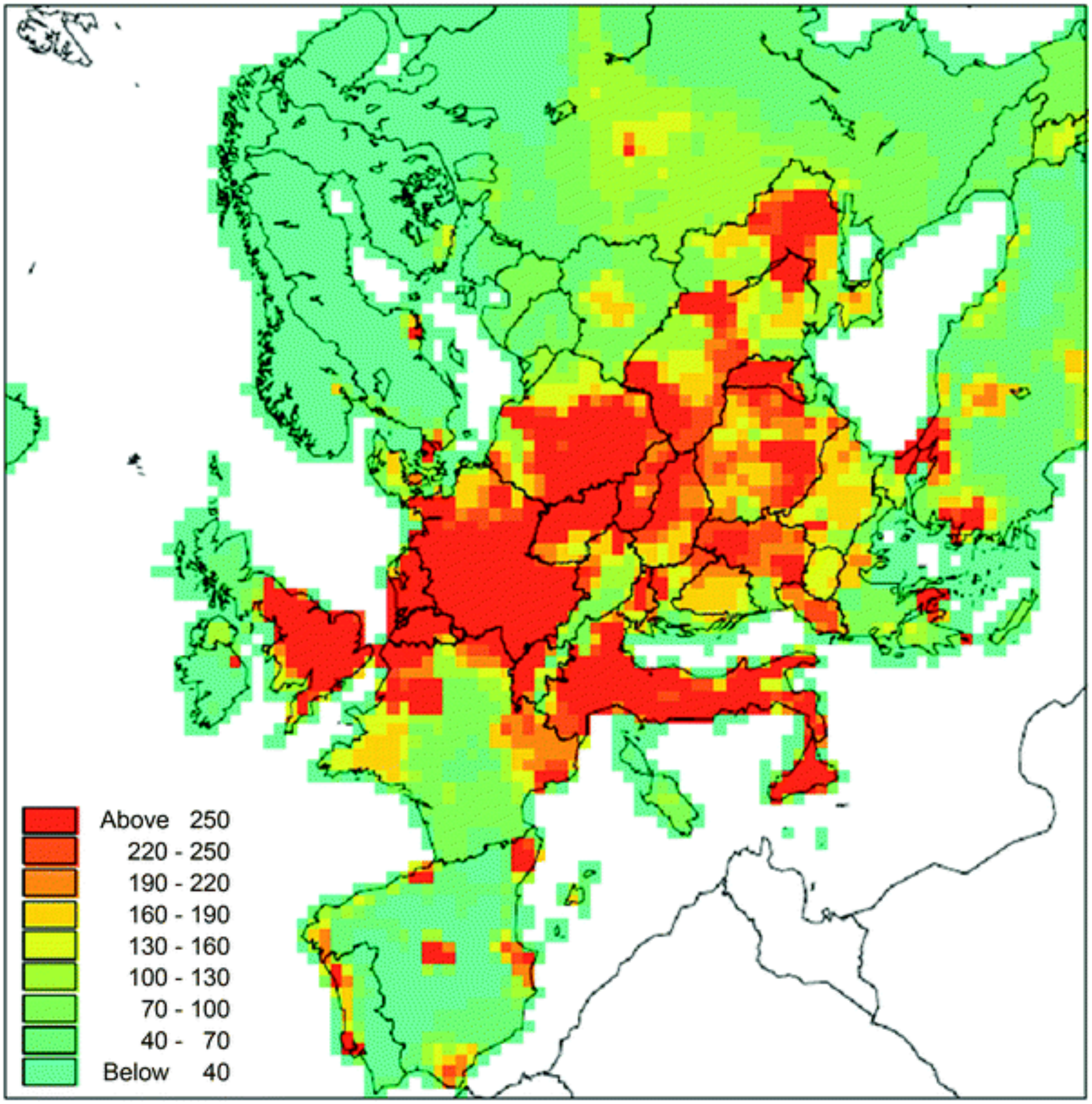

Figure 9: Estimated number of premature deaths due to air pollution per 2500 km2 grid cell in 2000 (Quante & Colijn, 2016)

8.2 Agriculture

Agriculture is an important economic factor for Hamburg as 60% of the metropolitan area of Hamburg are agriculturally used (Herrmann et al., 2016). Climate change may lead to declines in frost occurrence which could lead to longer growing seasons, whereas increasing temperatures can lead to soil moisture stress, impacting crop suitability (IPCC, 2014). The IPCC 5th Assessment Report projected a decrease in wheat, maize and soybean between -8 (4.3°C by 2100 (RCP8.5)) to +4% (2.8°C by 2100 (RCP6.0)) in 2080 (IPCC, 2014). Moreover, an increase in irrigation demand leads to decreasing low flows in rivers (e.g. -25% over the last 25 years in the Ilmenau River) and groundwater abstractions (Herrmann et al., 2016). This could reduce the sustainably recoverable groundwater quantities needed for irrigation and public water supply in the future (Herrmann et al., 2016). As mentioned in chapter 5, sea level rise can lead to salinization of groundwater, which could also substantially affect irrigation water in the future.

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CLIMATE ANALYTICS

2.5. India

Country profile: India - Uttarakhand

Table of Contents

Summary

Together with other South Asian countries, India is among the world's most vulnerable regions, faced with a combination of climate-related hazards and acute vulnerability. The IPCC Fifth Assessment Report (AR5) lists a multitude of challenges that South Asia is currently facing and will continue to experience in the future: temperature increase and more temperature extremes *(high confidence)*, increased rate of sea level rise *(high confidence)*, changing patterns of rainfall and melting snow and ice. At the same time, population will increase, and so will the demand for water and food *(high confidence)*. The region is particularly vulnerable to extreme precipitation, which has often been compounded by deadly floods and landslides. In 2013, Uttarakhand was hit by one of the deadliest recorded floods that left almost 6000 people dead and affected 4500 villages (BBC, 2013). In 2017, major monsoon flooding in the Ganges river basin left more than 1200 people dead and many missing and displaced (Uhe et al., 2019). Additionally, impacts of extreme heat, food and water shortages, can have cascading effects on the livelihoods of the population, particularly its youth that is going to experience further increases in global mean temperature increase and the resulting impacts.

Particularly pertinent to the state of Uttarakhand is climate change-induced retreat and loss of glacial ice, which will threaten the water supply of the local population. Under current emission trajectories, Indian children of today will spend more than half of their lives in a world warmer than 1.5°C above pre-industrial levels and be exposed to health risks from impacts of climate change that will increase in both frequency and intensity in the future. Impacts of floods, heat waves and melting ice can be avoided significantly with mitigation efforts to limit the temperature increase to 1.5°C above the pre-industrial period (Dosio et al., 2018; Lutz et al., 2019; Schleussner et al., 2016; Uhe et al., 2019) .

1. Demographic profile

India's population is currently over 1.3 billion people, making the words second-most populous country (United Nations, 2019). Almost 40% of India's population is under the age of 19 (Wittgenstein Centre for Demography and Global Human Capital, 2018). An average 11-year-old Indian citizen, the petitioner's peer, is expected to live until the age of 81 (World Data Lab, 2019). These demographic estimates can be coupled with the projections of global mean temperature increase for comparisons of climate change timelines and the children's lifespans. Following the best estimate of the future temperature trajectory based on the Climate Action Tracker, increase in the global mean temperature of 1.5°C will be exceeded around the year 2035 (model median), 2°C around 2055, and more than 3°C in 2100 (Climate Action Tracker, 2018). Today's Indian 11-year-old has a probability of 99% to be alive in 2035, 95% in 2055 and 8% in 2100 (World Data Lab, 2019). India's children therefore have a high probability of experiencing a 2°C warmer world and the ensuing impacts, with a portion of them living to possibly experience even higher degrees of warming.

2. The Hindu Kush Himalaya Assessment

The climatic conditions of India and local impacts of climate change are very heterogeneous, and for a more accurate analysis of impacts requires downscaling. The recent assessment of the Hindu Kush Himalaya (HKH) provides comprehensive information on current and future climate-related risks in the region where the Indian petitioner's home – the state of Uttarakhand – is located. The report was produced by the Hindu Kush Himalayan Monitoring and Assessment Programme (HIMAP), as a joint effort of scientists and experts from the region and around the world.

3. Temperature increase

Figure 1 (a) displays temperature and extreme temperature trends for the Hindu Kush Himalaya region from 1901 to 2014. In this period, annual mean surface air temperature increased at a rate of about 0.10 °C per decade. In the past 60 years, the rate of increase has been about 0.20°C per decade. Both temperature trends are congruent with the global mean temperature increases. Figure 1 (b) shows that the occurrences of extreme cold days and nights have decreased, while extreme warm days and nights have increased. For the period 1951-2014, the trend of the average annual minimum temperature was lower than that of the global average, and the trend of the average annual maximum temperature higher than the global average.

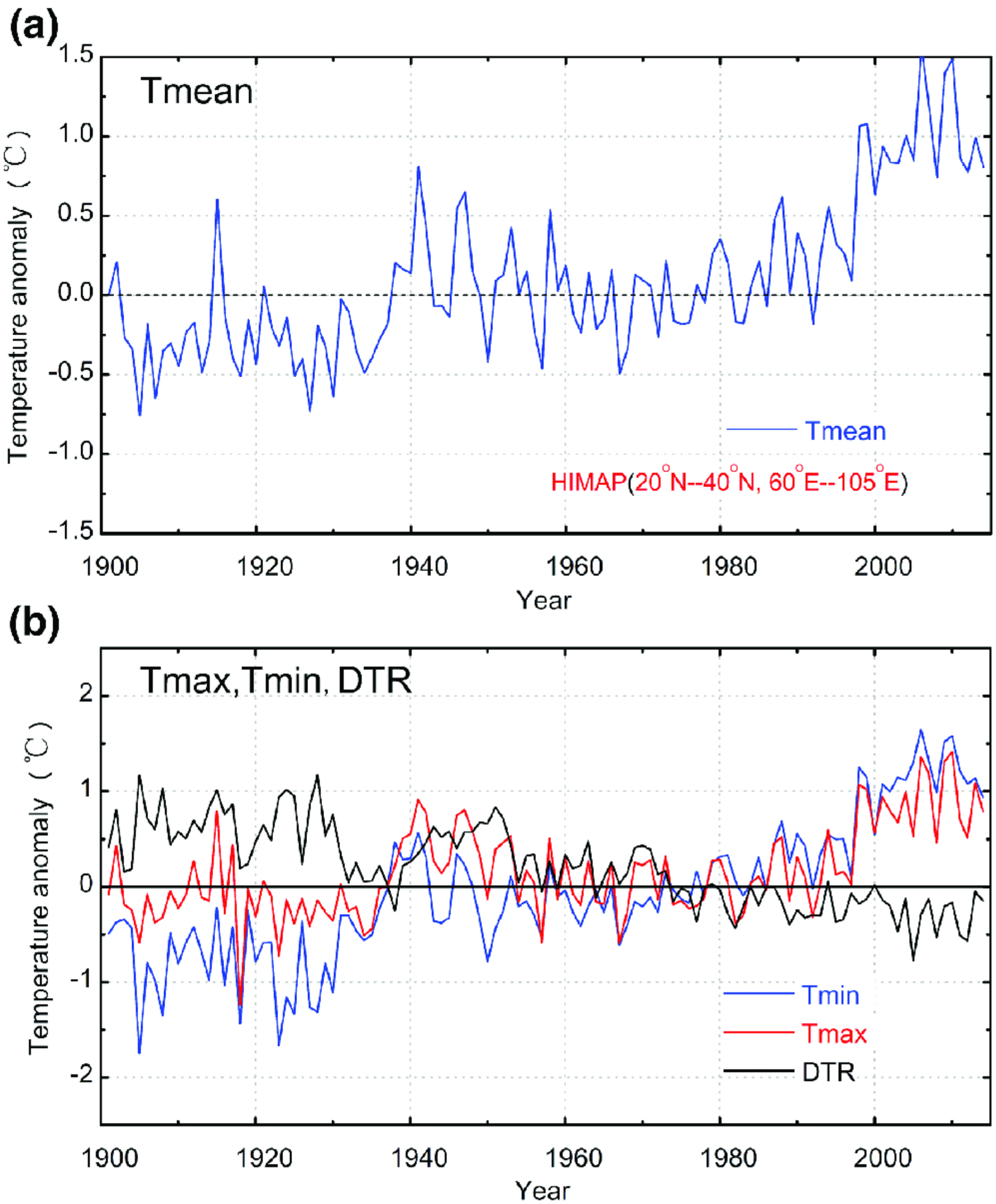


Figure 18: Annual mean temperature anomaly series (C) relative to 1961-1990 mean values for mean temperature (a) and maximum and minimum temperature (b). Source: Krishnan et al. (2019).

Future temperature increase is projected to be higher for the Hindu Kush Himalaya, than the likely ranges reported for global and South Asian regions by the recent IPCC assessment. Figure 2 displays outputs from the Coordinated Regional Downscaling Experiment (CORDEX) models project which show a significant increasing trend in temperature. In the near term (2036–2065), the region is projected to warm by 1.7–2.4 °C for global warming scenarios RCP4.5 (global warming of 1.9°C in the same period) and 2.3–3.2°C for the RCP8.5 (global warming of 2.4°C in the same period). At the end of the century, regional warming is projected to be 2.2–3.3°C for RCP4.5 (global warming of 2.4°C in the same period) and 4.2–6.5 °C for RCP8.5 (global warming of 4.3°C in the same period) (Krishnan et al., 2019). The global warming scenario reaching about 1.6°C by 2100 (RCP 2.6) would for this region imply temperature increases of around 2.0°C for both mid- and end-of-century (Figure 3).

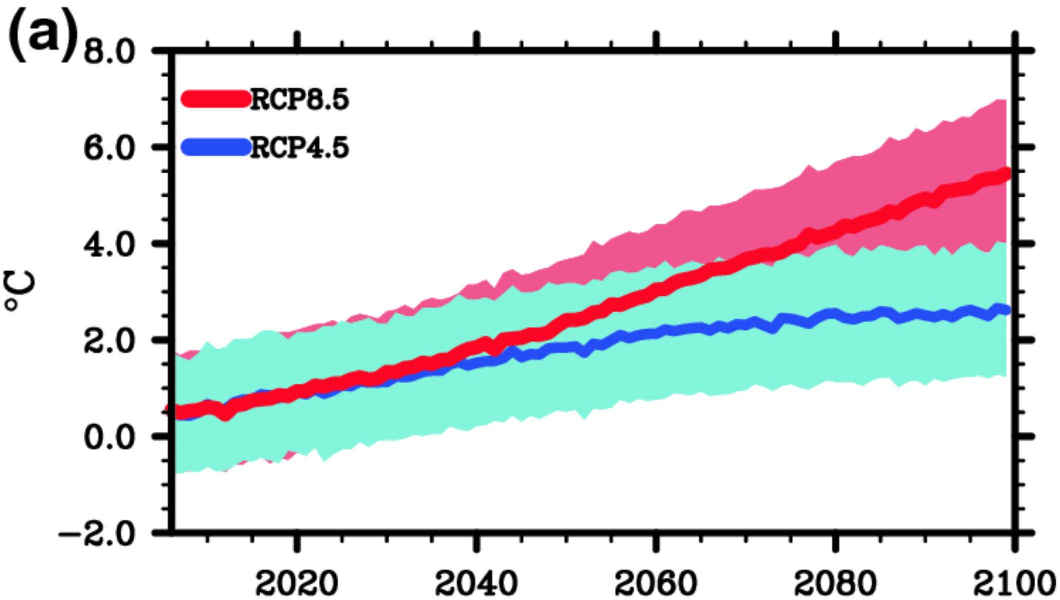


Figure 19: Annual mean surface temperature change from 2006 to 2100 relative to 1976-2005 for the Hindu Kush Himalaya region. Source: Krishnan et al. (2019).

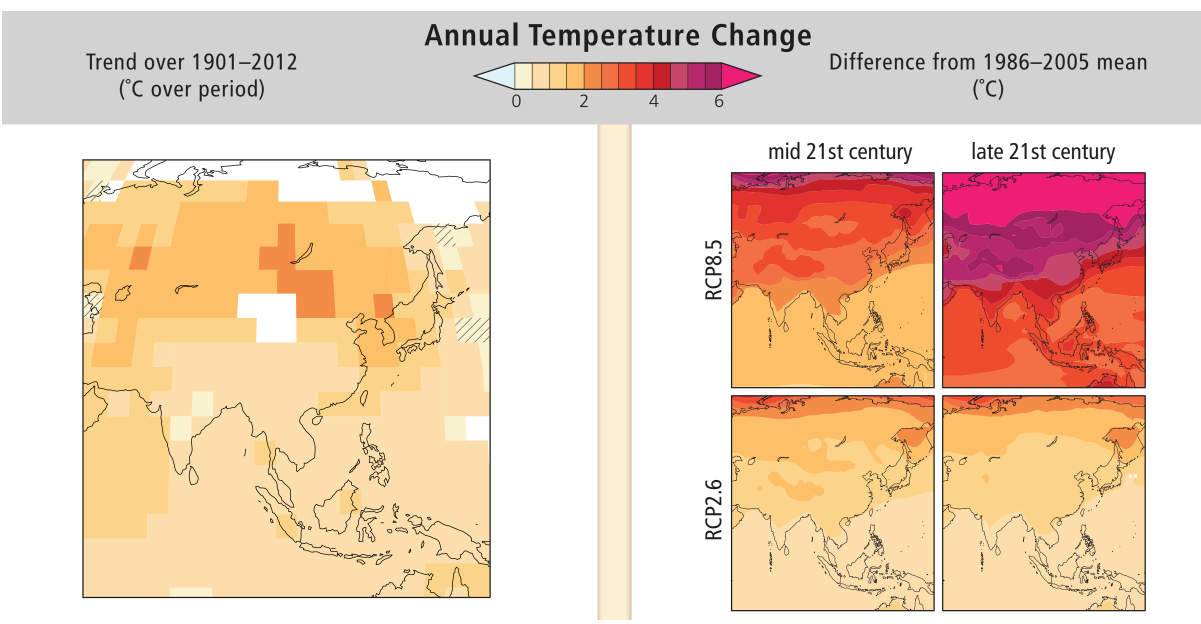


Figure 20: Observed and CMIP5 projected changes in annual temperature in Asia. Source: IPCC (2014).

4. Heat waves

Severe heat waves and warm spells are already occurring and in the future are *likely* to become more frequent and/or longer (IPCC, 2014). For end-of century, maximum population exposed to heatwave days would increase by 18 times the current level under the 1.5°C temperature target, compared to 92 times in a 2°C world (Mishra, Mukherjee, Kumar, & Stone, 2017). Figure 4 shows changes in frequency and duration of heat waves, under the warming scenarios of 1.5°C, 2.0°C and RCP8.5 (4.2°C by 2100). The frequency of severe heat waves in India substantially reduces when limiting the warming to lower degrees, compared to the RCP8.5 scenario during the mid and end of 21st century. The extent to which the impacts are avoided is the highest if the temperature increase is limited to 1.5°C.

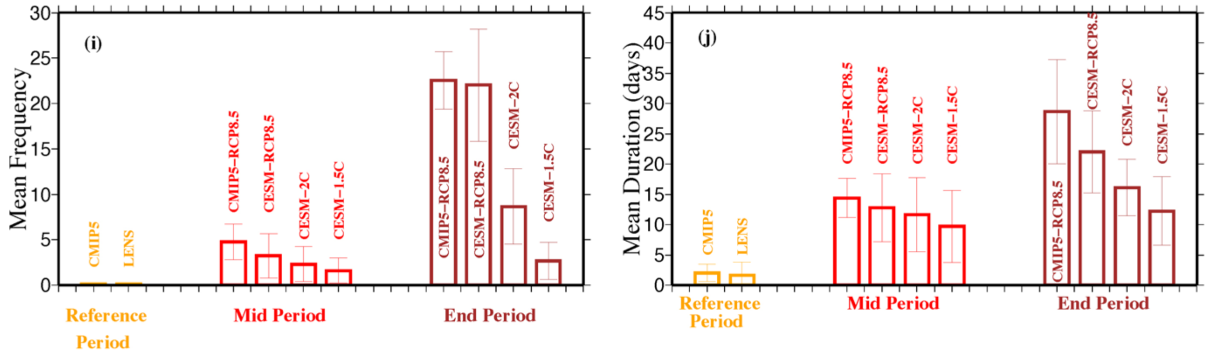


Figure 21: The frequency of heatwaves in India for the reference period (1971-2000), mid-century, end-of-century, for RCP8.5, 1.5°C and 2°C. Source: Mishra et al. (2017).

An additional indicator of heat-related impacts is the wet bulb temperature which combines the air temperature and humidity to indicate the potential for evaporation. Research has shown that a wet-bulb temperature of 35°C can be considered an upper limit on human survivability. Recent estimates project large parts of India to become practically uninhabitable by the end of the century under RCP8.5 scenario (4.2°C in 2100), and with some reduction but nevertheless high wet bulb temperatures under the RCP4.5 scenario (2.4°C in 2100), with Ganges and Indus river basins projected to be affected the most (Im, Pal, & Eltahir, 2017).

5. Precipitation

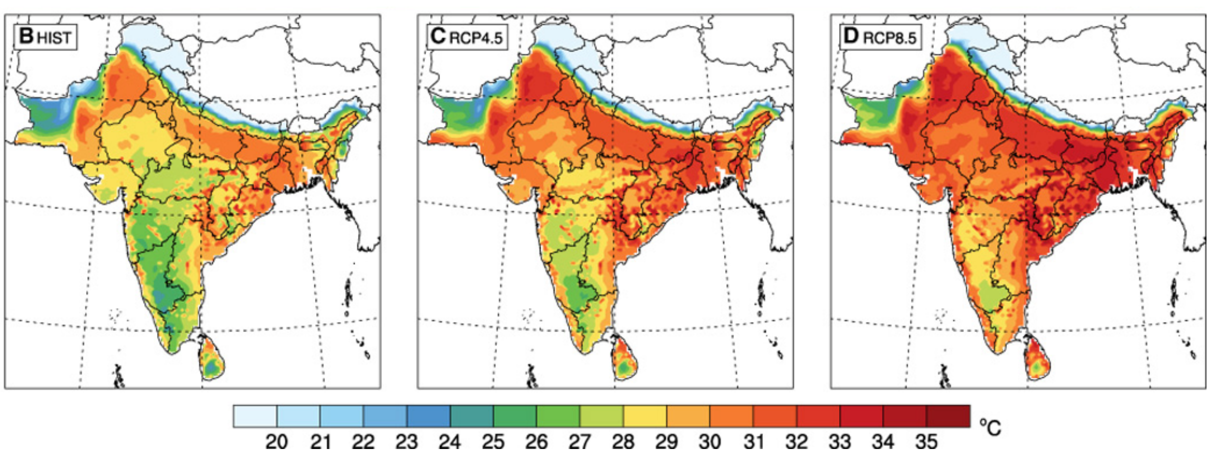


Figure 22: Historical (1975) and projected (2100) wet bulb temperatures in India for RCP4.5 and RCP8.5. Source: Im, Pal & Eltahir (2017).

In the Hindu Kush Himalaya region, the annual precipitation and the annual mean daily precipitation intensity of roughly the last 60 years have increased. Figure 4 shows the regional average annual precipitation percentage anomaly and wet-day anomalies from 1951 to 2013, with a clear upward shift for both indicators since the year 1990.

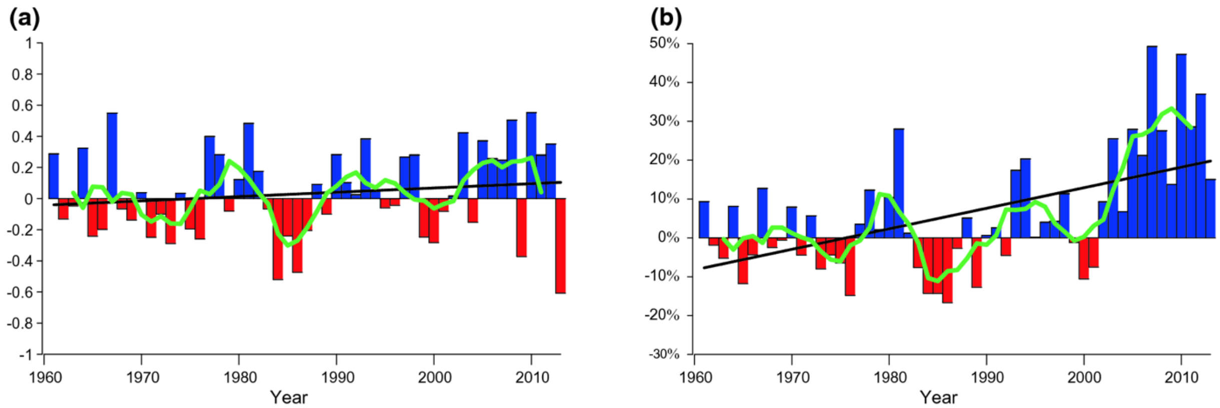


Figure 23: The regional average annual precipitation standardized anomaly (a) and wet day anomaly (b). Green lines are 5-year moving averages, and black lines are linear trends. Source: Krishnan et al. (2019).

Figure 5 shows CMIP5 future projections of annual mean precipitation change in the Hindu Kush Himalayan region. In mid-century, the increase in precipitation is similar for the two scenarios, but at the end-of-century, the increase is higher for the RCP 8.5 scenario (global mean temperature increase of 4.3°C by 2100).

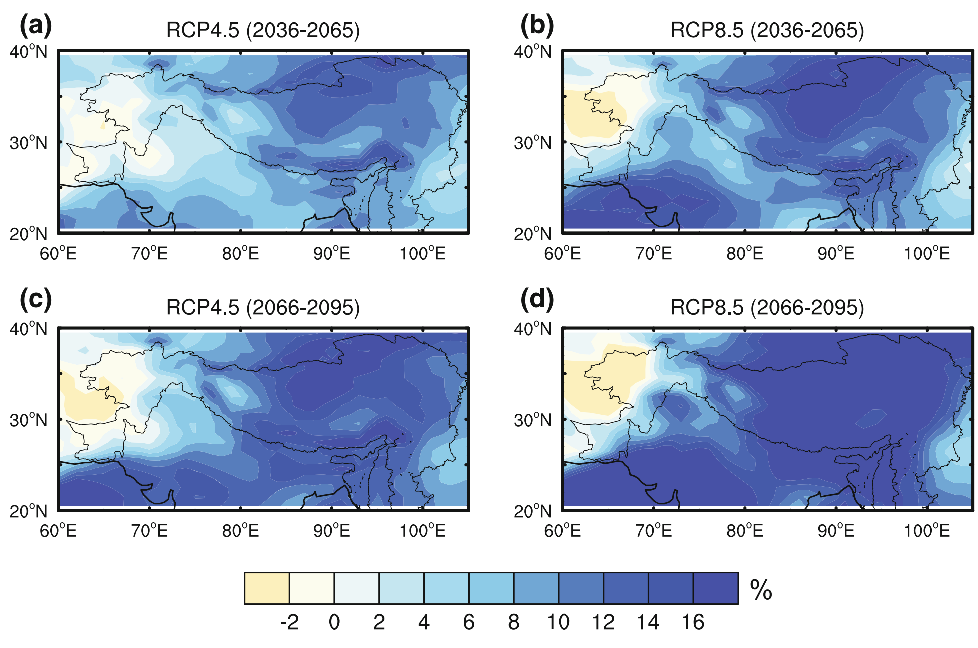


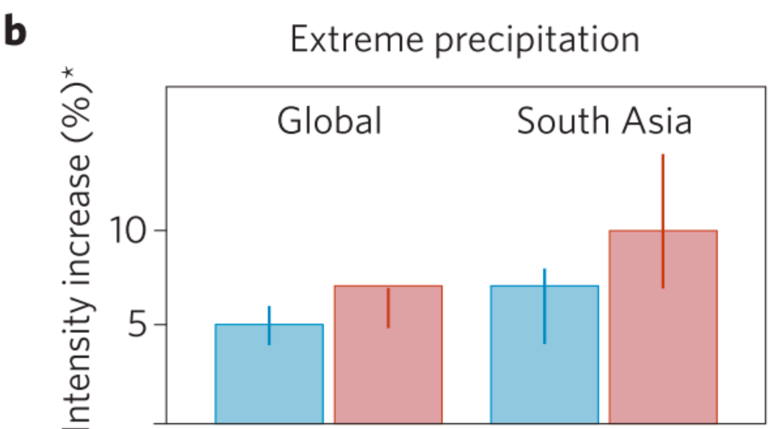
Figure 24: Annual mean precipitation change over the Hindu Kush Himalayan region for mid- and end-of-century for RCP 4.5 and RCP 8.5. Source: Krishnan et al. (2019).

6. Extreme precipitation and floods

India, and in particular its northern states at the slopes of the Himalaya, is very vulnerable to heavy precipitation, flooding and landslides. Floods have caused fatalities almost every year in 2016 more than 70 people died and thousands were displaced in Uttarakhand alone (Davies, 2016). Heavy flooding in 2019 caused dozens of people to be declared dead or missing in the northern states of India (FloodList, 2019). The footprint of climate change in the increase of extreme precipitation is already evident, but will further increase in intensity, particularly in South Asia. Figure 8 shows the higher intensity of extreme precipitation in South Asia compared to a global average, and a substantial difference between a 1.5°C and 2°C warming (Schleussner, Rogelj, et al., 2016). Extreme precipitation is often followed by floods, which are among the costliest natural disasters, both in terms of human casualties and economic losses (Dottori et al., 2018). Climate models project further increase in extreme precipitation and subsequent flooding. Strongest increases are projected for the Ganges basin (Figure 9), even for the 1.5 °C scenario, but with each additional degree, the risk increases further (Lutz et al., 2019; Uhe et al., 2019).

7. Glaciers

Water availability in the Hindu Kush Himalayan region is affected by glacial retreating and melting. The trend has been observed since the 1970s, but has accelerated in the past decades and is expected to continue with climate change. River flows are expected to increase in the short term, but in the long run the trend will reverse because of the eventual shrinkage and disappearance of glaciers and snow cover (Krishnan et al., 2019). Even with limiting the temperature increase to 1.5°C above the pre-industrial period, glaciers will be lost by approximately a third. For higher levels of warming, the loss of glacier ice increases starkly until the end of the century, ranging between 49 ± 7 percent loss for RCP 4.5 (global warming levels of about 2.4°C by 2100), 51 ± 6 percent for RCP 6.0 (global warming levels of about 2.8°C by 2100) and 64 ± 5 per cent loss for RCP 8.5 (global warming levels of about 4.3°C by 2100) until the end of the century. Materialization of either of these scenarios would have serious consequences for the livelihood of the population that relies on this water. Water scarcity will be exacerbated by population growth and higher consumption per capita with higher standards of living (IPCC, 2014).



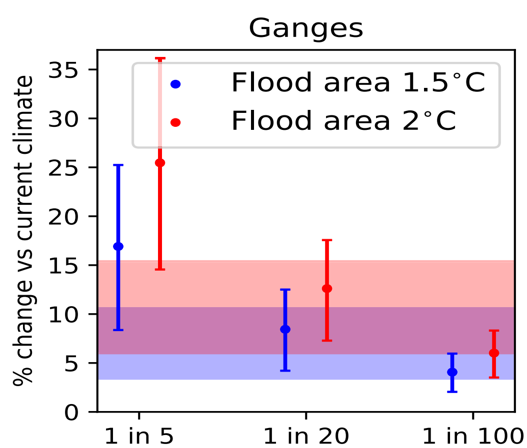


Figure 26: Aggregate changes in flooded area for the Ganges river basin for flood hazards expected once in 5 years, once in 20, and once in 100 years. The medium estimate is shown by the dot (blue for 1.5C of global warming, and red for 2C), and the error bars show the range between high and low estimates. The shaded area shows the range in percentage change in precipitation for the two temperature limits. Source: Uhe et al. (2019)

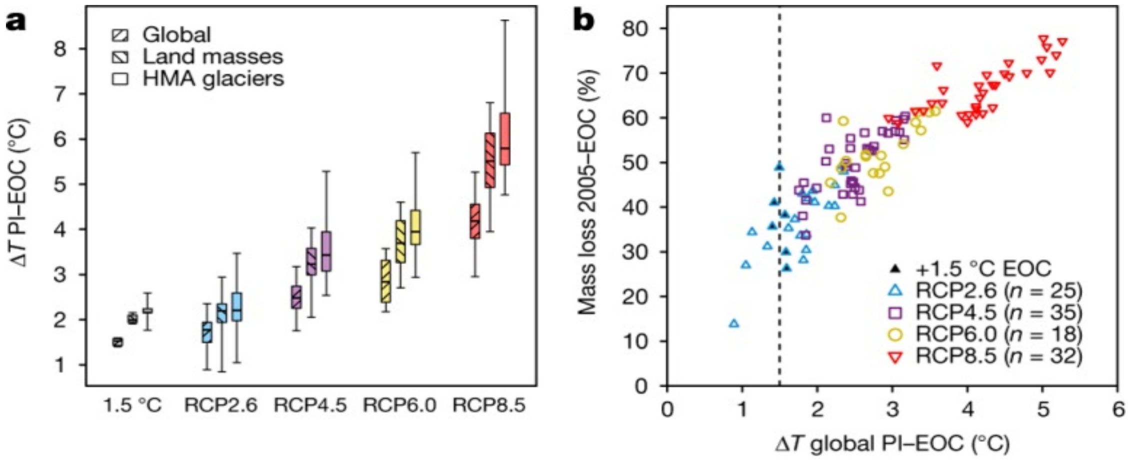


Figure 27: Temperature changes between the pre-industrial period and end-of-century for 1.5C models and four RCP scenarios (a) and the projected loss of ice versus global temperature increase (b). Source: Kraaijenbrink et al.

8. Sectoral impacts

8.1. Agriculture

Over 70% of the population in the Hindu Kush Himalaya relies on agriculture as the main source of income. The region relies on mostly rainfed sources of irrigation, and is therefore vulnerable to the changing patterns of precipitation. Climate change is changing precipitation and heat patterns, which will directly influence agricultural production and subsequently the livelihoods of the populations that depend on it, with children being particularly vulnerable to this risk because of their need to consume more food and water per unit of body than adults (UNICEF, 2015). Additionally, there are indications of climate-induced changes in phenology which pose risks for the production of some of the most important crops in the region (Krishnan et al., 2019). IPCC's 5th Assessment Report points out the effect of heat stress on the expected reduction of the production of wheat in the Indo-Gangetic plains by 50%. This would pose a substantial threat to the people in the region whose food security depends on these crops (IPCC, 2014).

8.2. Health, food and water security

The population's health in India is impacted through different channels: deaths and health hazards from extreme events such as heat and floods; nutritional deficiencies and diseases from food and water contamination and scarcity; mental-health related conditions such as the post-traumatic stress syndrome in disaster-prone areas (IPCC, 2014). 1.1 billion people (17% of the global population) mostly in South and East Asia, North Africa and the Middle East faced serious water shortage and high water stress in the 2000s (Ove Hoegh-Guldberg, Jacob, Taylor, & et al, 2018). Today millions of children mostly in South and East Asia, North Africa and the Middle East are affected by serious water shortage and high water stress, which will increase for a temperature rise of 1.5°C, but will be even higher when temperatures exceed 1.5°C of global warming (Roy et al., 2018).

Due to multiple climate-related stressors, food security is and will remain a major concern in this region. Food production is negatively affected by the changing dynamics of melting and loss of ice. Similarly, increased variability in precipitation and temperature, and the related floods and droughts also directly affect agriculture and thus food security (Rasul et al., 2019).

Research also shows the correlation between rainfall and vector-borne diseases such as malaria and dengue, and parasitic diseases such as diarrhea. In the Himalayan region, there have been outbreaks of vaccine-preventable Japanese encephalitis linked to rainfall. High temperatures are correlated with higher mortality, and heat waves in particular have been shown to have an effect on outdoor workers (IPCC, 2014). Effects of air pollution are pronounced in India, particularly in combination with high temperatures (IPCC, 2014). Air pollution in the Hindu Kush Himalaya region is on the rise and regional air quality has worsened in the past two decades, with the adjacent Indo-Gangetic Plains (IGP) having become one of the most polluted regions in the world.

In the future, climate change will contribute to increased mortality from heat-related stressors an the transmission of the climate-sensitive diseases, with the impacts more evident in regions of lower socio-economic development. More frequent extreme events such as droughts, intense rainfall, and floods will all further exacerbate food insecurity of this region (Rasul et al., 2019). In addition, increasing temperature and higher humidity levels pose additional stress on individuals engaging in physical activity. Safe work activity and worker productivity during the hottest months of the year would be increasingly compromised with additional climate change *(medium confidence)* (Ove Hoegh-Guldberg et al., 2018). Figure 8 shows India as one of the countries most affected by labor loss (hours of labor lost per person, per year), with 80% of the losses linked to the agricultural sector (Watts et al., 2018).

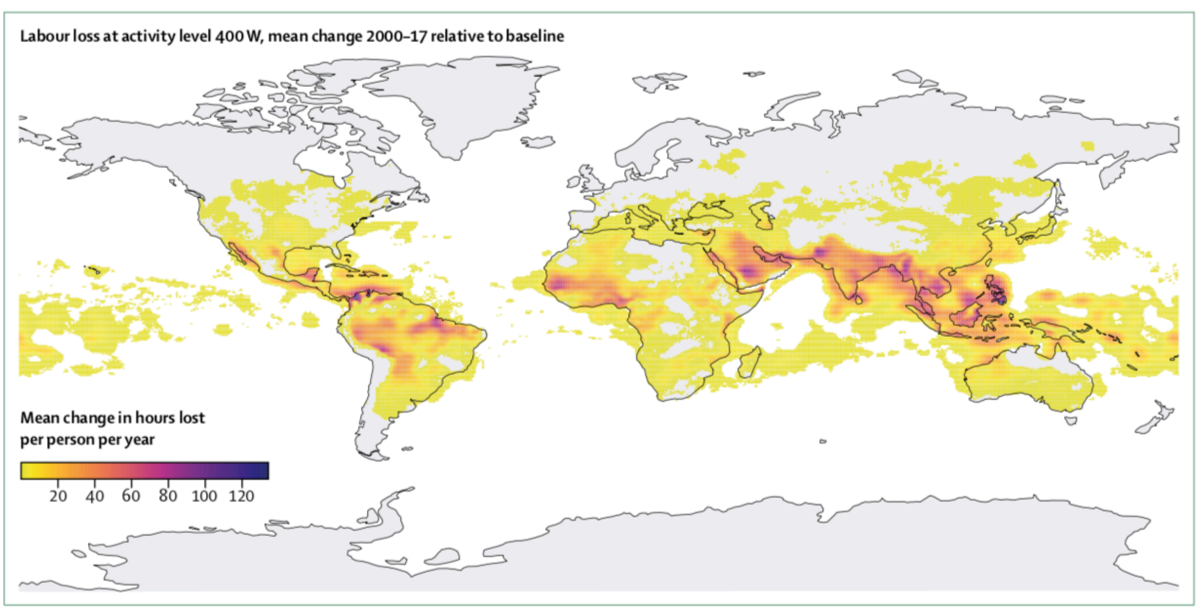


Figure 28: Labor loss at activity level 400W, mean change 2000-2017 relative to 2000. Source: Watts et al. (2018).

8.3. Migration

The annual rate of increase in migration in the countries of the Hindu Kush Himalaya has been high, and the number of internally displaced people also is expected to rise significantly (Krishnan et al., 2019). With further impacts of climate change on livelihoods, internal and international migration will become a necessary coping strategy, leading to profound demographic changes.

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2.6. Marshall Islands

Country profile: Republic of the Marshall Islands

Table of Contents

Summary

The Marshall Islands are located in the Micronesian region of the Pacific Ocean, formed by more than 1200 islands and atolls, 24 of which are inhabited. They are one of the lowest-lying island nation-states in the world, and as such are among the world's most vulnerable to the impacts of climate change. With an average elevation of the islands of about 2 meters above sea level, the Marshall Islands are most acutely vulnerable to the consequences of sea level rise: coastal erosion, flooding, saltwater intrusion into freshwater lenses and loss of marine ecosystems such as coral reefs all of which indirectly endanger livelihoods by threatening food and water security. Warming above 1.5°C would almost certainly lead to the complete loss of coral reef systems around the Marshall Islands also leading to substantial decline in fishing potential. Sea level rise associated with warming scenarios above 1.5°C may lead to the loss of whole islands as early as mid-century.

With the population of about 60,000 people, out which almost half are below the age of 19, the Marshall Islands is a country younger than the world average. For more than half of their lives, children of the Marshall Islands will live in the world with temperatures at least 1.5°C warmer than pre-industrial times. Impacts of climate change will increase in frequency and intensity in the future, and in the case of Marshall Islands well within the lifespans of its children. Without substantial reductions in global emissions, the country could become uninhabitable probably within this century. Limiting warming to 1.5°C will be decisive to ensure a future for the people of the Marshall Islands .

1. The IPCC Report's summary of climate impacts on the Marshall Islands

As most Small Island Developing States (SIDS), the contribution of the Marshall Islands to the global CO_2 emissions is insignificant, yet they are and will remain among the areas most vulnerable to the impacts of climate change and the related health risks. Based on the Fifth Assessment Report (AR5), the key risks for the small islands during the course of the 21st century include "sea level rise (SLR), topical and extratropical cyclones, increasing air and sea surface temperatures, and changing rainfall patterns *(high confidence, robust evidence, high agreement)*", with sea level rise being "the most widely recognized threat *(high confidence; robust evidence, high agreement)"* (Nurse et al., 2014).

2. Demographic profile

The Marshall Islands population is estimated to about 60 000 people, 45% of which are under the age of 19 (UNFPA PSRO, 2014; United Nations Department of Economic and Social Affairs Population Division, 2019). An average 16-year-old Marshallese citizen is expected to live until the age of 80 (World Data Lab, 2019). These demographic estimates can be coupled with the projections of global mean temperature increase for the comparisons of climate change timelines and the children's lifespans. Following the best estimate of the future temperature trajectory, increase in the global mean temperature of 1.5°C will be exceeded around the year 2035 (model median), 2°C around 2055, and more than 3°C in 2100 (Climate Action Tracker, 2018). Today's Marshallese 16-year-old has a probability of 98% to be alive in 2035, 91% in 2055 and 2% in 2100 (World Data Lab, 2019). Nearly all of Marshall Islands' children therefore have a very high probability of experiencing a 2°C warmer world and the ensuing impacts, with a small portion of them living to possibly experience an even higher warming, if no further emission reductions are achieved.

3. Temperature increase

Temperature increases in the Marshall Islands are consistent with the global pattern of global warming. Since 1960s, temperatures on the island of Majuro have increased at the rate of 0.12°C (0.21°F) per decade, and on the island of Kwajalein 0.30°C (0.53°F) per decade (Australian Bureau of Meteorology & CSIRO, 2015). Compared to the period between 1986 and 2005, temperature estimates suggest an increase in mid-century from about 1.0°C in the lowest emissions scenario, to 1.5°C in the RCP 8.5. At the end of the 21st century, the RCP2.6 emissions scenario (which resembles a <2°C scenario) would result in 0.9°C increase, while the highest emissions scenario reaches more than 3°C of warming, compared to the 1985-2005 levels.

	2030		2050		2090	
	°C	°F	°C	°F	°C	°F
RCP 2.6	0.7	1.3	1.0	1.7	0.9	1.6
RCP 4.5	0.7	1.3	1.2	1.9	1.6	2.8
RCP 6.0	0.7	1.2	1.1	1.9	2.0	3.6
RCP 8.5	0.8	1.5	1.5	2.6	3.1	5.7

Table 1: Projected changes in the annual surface temperature for the Marshall Islands relative to the period 1986-2005 (Australian Bureau of Meteorology & CSIRO, 2015).

4. Sea level rise

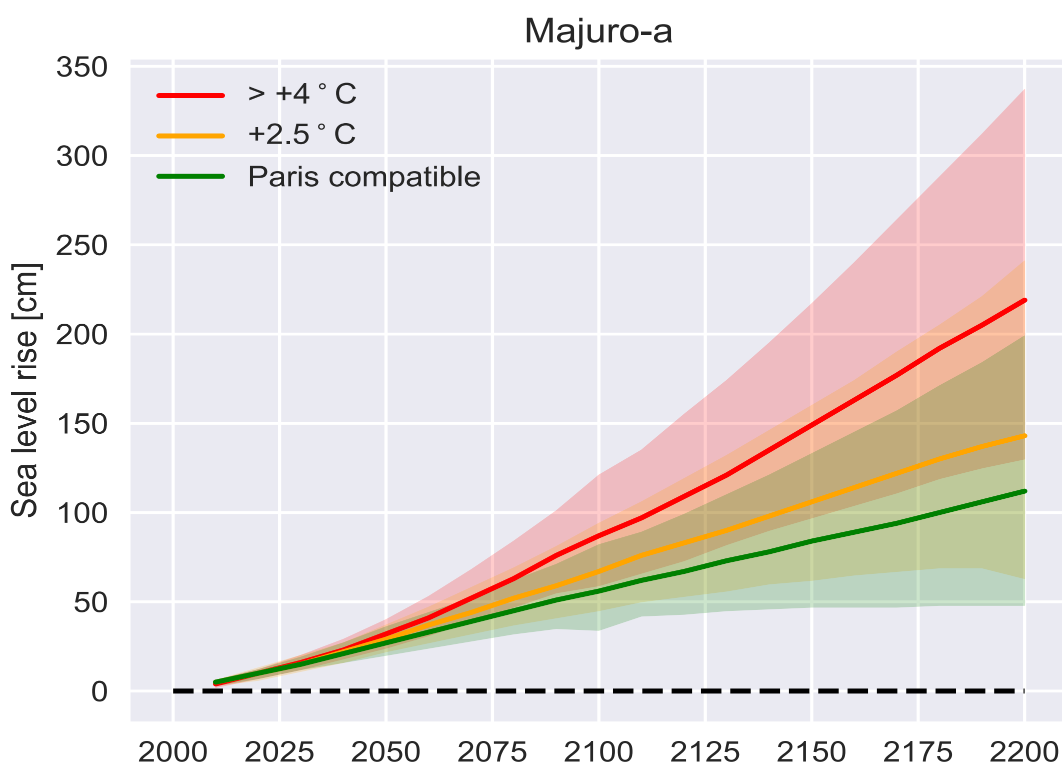

Figure 29: Local sea level projections for the Majuro island, for a scenario compatible with the Paris agreement goal of keeping the temperature increase below 2°C (green), a scenario leading to +2.5°C global mean temperature (orange) and a scenario exceeding +4°C (red). The solid lines represent multi-model medians, the shaded areas include 66% of the models (based on Kopp et al. (2014)).

Sea level increased by about 7 mm per year since 1993, with a higher pace than the global average of 3.2 mm per year. Tropics are expected to experience sea level rise higher than the global average (Slangen et al., 2014), with the projected ranges in different emissions scenarios shown on Figure 1. For mid-century, median estimate is 27 cm increase for the RCP 2.6 scenario, 29 cm for RCP 4.5 and 32 cm for RCP 8.5. In the year 2100, the estimates increase to the median of 56 cm sea level rise for RCP 2.6, 67 cm for RCP 4.5 and 87 cm for RCP 8.5 (Kopp et al., 2014).

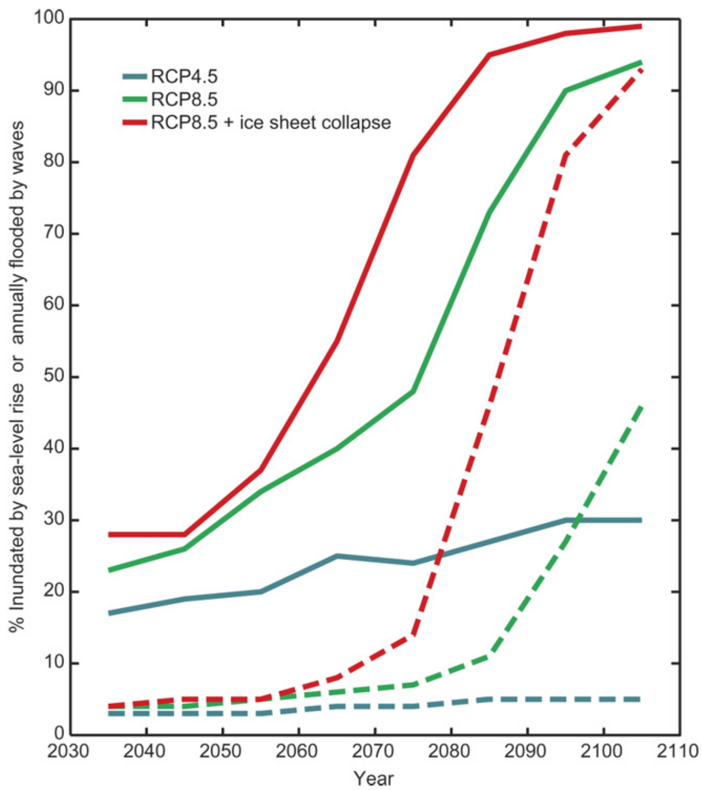

Figure 2: The projected percentage of the Marshall Islands' Roi-Namur Island on Kwajalein Atoll inundated because of sea level rise and annually flooded because of the combined effects of waves and sea level rise. Dashed lines show the percentage of inundated land, and solid lines show the portions of the island annually flooded by waves (Storlazzi et al., 2018).

Local consequences of sea level rise will manifest through the loss of habitable land, and salinization of water resources, both of which have direct impacts on livelihoods. Figure 2 shows how annual flooding could affect up to 30% of the land in mid-century, and up to 100% at the end of the 21st century. However, flooding of 25% of the land is already enough to make water non-potable, and hence threaten water and food security. The contamination of seawater limits freshwater availability for two years after the flooding event, with a 0.4 m of sea level rise (Storlazzi et al., 2018).

As displayed in Figure 1, at the current rates of global warming, the risks of sea level rise continue well beyond the 21st century (see more in Global Impacts, section 3.3). For the generation after today's children, this could mean complete disappearance of the islands. The consequences of present day actions therefore have implications not only for today's children, but also future generations. However, limiting the warming to 1.5°C relative to the pre-industrial times may halt the long term sea level rise below 1 m.

5. Extreme weather events

The climate of the Marshall Islands if affected by the El Niño-Southern Oscillation (ENSO), which manifests in two extreme phases: El Niño, which contributes to warmer wet season and warmer and drier dry seasons; and La Niña, which tends to bring wetter weather conditions than usual. These weather patterns will continue to occur in the future *(very high confidence),* and will cause significant negative socio-economic consequences. The occurrence of El Niño is estimated to double as a consequence of increased global warming, and is expected to cause more devastating weather events (Cai et al., 2014). The occurrences of La Niña are consistent with El Niño, and climate models project a tripling of extreme La Niña events under greenhouse warming (Cai et al., 2015).

Australian Bureau of Meteorology and CSIRO (2015) report the annual mean temperatures and extremely high daily temperatures will continue to rise *(very high confidence)*. Droughts are projected to decline in frequency *(medium confidence).* Average rainfall is projected to increase *(high confidence)*, along with more extreme rain events *(high confidence)*. A substantial increase in the frequency of the most devastating tropical cyclones at 1.5°C of global warming and even more so at 2°C of global warming (Thomas, Pringle, Pfleiderer, & Schleussner, 2017). Compared to the period 1986-2005, the total number of storms in the Central Pacific is projected to increase by 2.7% in the period 2016-2035, and by 33.1% in 2081-2100. The number of category 4 hurricanes is projected to increase by 66.7% in 2016-2035, and 111% in 2081-2100 (Bhatia, Vecchi, Murakami, Underwood, & Kossin, 2018). The intensity of storms also increases with the rise in sea surface temperatures (Bhatia et al., 2019).

6. Coastal ecosystems and livelihoods

Livelihoods of island populations critically depend on coral reefs and their ecosystems, as they are important nutritional sources, as well as generators of employment as fisheries. With increasing ocean acidification and rising ocean temperatures, the survival corals and species that keep the coral ecosystems in balance are under threat. The IPCC AR5 Chapter on small islands states with *"high confidence"* that "sea surface temperature will result in coral bleaching and reef degradation. Given the dependence of island communities on coral reef ecosystems for a range of services including coastal protection, subsistence fisheries, and tourism, there is *high confidence* that coral reef ecosystem degradation will negatively impact island communities and livelihoods" (Nurse et al., 2014). Coral reefs are projected to decline by a further 70–90% at 1.5°C *(high confidence),* and be irreversibly lost at 2°C *(very high confidence)* (IPCC, 2018). The risk of irreversible loss of many marine and coastal ecosystems increases with global warming, especially at 2°C or more (high confidence). Similarly, the negative impact on the catchment potential for fisheries is projected to be three times as large from the warming of 3.5°C as compared to limiting the temperature increase to 1.5°C (Cheung, Reygondeau, & Frölicher, 2016).

7. Health, water and food security

"Until mid-century, projected climate change will impact human health mainly by exacerbating health problems that already exist *(very high confidence).* Throughout the 21st century, climate change is expected to lead to increases in ill-health in many regions and especially in developing countries with low income, as compared to a baseline without climate change *(high confidence)*." (IPCC, 2014)

Climate related health risks with the highest priority in the Marshall Islands (World Health Organization, 2015):

- diarrhoeal disease
- malnutrition
- vector-borne diseases
- ciguatera (fish poisoning)
- mental health

- respiratory disease
- non-communicable diseases
- injuries and deaths from extreme weather events
- other diseases (eye disease, skin disease, radiation-induced illnesses)

The health risks are projected to increase with climate change (Nurse et al., 2014). Direct effects on health stem from extreme weather events which are expected to increase in frequency and intensity. Particularly dengue fever is associated with rainfall, temperature, and unplanned rapid urbanization (UNICEF, 2015). Indirect effects that manifest as a consequence of poor access to water and food insecurity are also expected to further amplify with sea level rise and saltwater intrusion. Scientific models estimate increase in annual flooding that could damage infrastructure and cause unavailability of freshwater, rendering the Marshall Islands uninhabitable by the mid-21st century (Storlazzi et al., 2018), well within the lifespan of its today's children.

Climate change impacts are of particular concern for the agriculture of the Marshall Islands as they have limited space to expand areas of cultivated land. Food security in Micronesia "has worsened in the past half century and climate change is *likely* to further hamper local food production, especially in low-lying atolls". Additionally, deterioration of agricultural land and food production can imply higher dependency on food aid, which can in turn have negative impacts on health outcomes because of poor nutritional quality (Ahlgren, Yamada, & Wong, 2014). Aquatic pathogens that can cause ciguatera fish poisoning (the most common food-borne illness in tropical regions) "are known to be highly-temperature sensitive and may flourish when certain temperature thresholds are reached" (Llewellyn, 2010). Lovell (2011) notes that in the Pacific many of the anticipated health effects of climate change are expected to be indirect, connected to the increased stress and declining well-being that comes with property damage, loss of economic livelihood, and threatened communities.

8. Limits to adaptation

The IPCC Special Report on 1.5°C describes "hard limits" to adaptation in the Small Island Developing States, resulting from the "sea level rise and increased wave run up combined with increased aridity and decreased freshwater availability at 1.5°C warming potentially leaving several atoll islands uninhabitable" (IPCC, 2018). The threat to livelihoods on the Marshall Islands will be exacerbated by the effects of climate change. Migrating, internally or externally, is an adaptation measure, which also results in disruption to society–land relationships and loss of community identity. Relocation can also fail as an adaptation strategy and cause homelessness, unemployment, social marginalization, food insecurity, and increased levels of disease (Keener et al., 2018). Additionally, with the loss of habitable land from the sea level rise, internal migration will not be a viable adaptation strategy, making international migration possibly the only option. Consequently, the entire culture will be at stake as the islanders will find it "increasingly difficult to sustain the region's many unique customs, beliefs and languages" (National Climate Assesssment and Development Advisory Committee (NCADAC), 2013).

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2.7. Nigeria

NIGERIA –Lagos

Table of Contents

Summary

Nigeria is the most populous African country and is heavily dependent on rainfed agriculture. 70% of the Nigerian population is classified as poor of which 35% live in absolute poverty. Poverty and disadvantage have increased with observed warming (about 1°C above pre-industrial levels) and are expected to increase for many populations as average global temperatures increase from 1°C to 1.5°C and higher. Climate change has caused and will cause adverse impacts on livelihoods, life, property and health in Nigeria in particular for children. For example, changing rainfall regimes and patterns with increasing floods devastate farmlands, and increasing temperature and humidity accelerate pests, diseases, and extreme events like storm surges. These climate impacts will cause harm to life and property. Under current emission trajectories, Nigeria's children of today will spend more than half their lives in a world warmer than 1.5°C above pre-industrial levels.

In addition to profound country-wide risks under climate change, Lagos, the capital city of Nigeria, is specifically vulnerable to climate impacts. Lagos' high vulnerability to climate change has been demonstrated by extensive damages to floods and storms, which together with the city's geographic location and inadequate and poorly maintained infrastructure exacerbates the sensitivity. Lagos is expected to rank as the fifth most exposed city to climate change by 2070. For example, projections suggest that by 2070, approximately 550 000 people could be affected by flooding each year due to sea level rise.

If global warming exceeds 1.5°C, the risk of climate related impacts increases, particularly for people exposed to poverty. For example, under a global warming scenario of 4.3°C by 2100 (RCP8.5), the number of days with extreme temperature events increases in the south of Nigeria by about 40 days per year in 2046-2065 and by about 106 per year in 2081-2100.This has severe implications for the health of children in Nigeria. Moreover, with sea level rise being a major threat, limiting global warming to 1.5°C would lower global mean sea level rise and thus enable greater opportunities for adaptation in the human and ecological systems in Nigeria's coastal areas.

Tropical West Africa is found to be at significant risk of declining crop yield for a global temperature increase of 2°C and more, which is seriously endangering food security in the future particularly affecting children under the age of 5. While global hunger has been declining over the past few decades, undernutrition has increased particularly in Sub-Saharan Africa.

1. The IPCC Report's Summery on Climate Impacts in Nigeria

Climate change and its extreme weather events including droughts and floods have significant impacts on economic sectors, natural resources, ecosystems, livelihoods and human health in Africa (IPCC, 2014). The risk of multiple and compound climate-related impacts increase between 1.5°C and 2°C of global warming, with greater proportions of people both so exposed and susceptible to poverty in Africa *(high confidence)* (Hoegh-Guldberg et al., 2018). Particularly in sub-Saharan Africa, reductions in yields of maize, rice, wheat, and potentially other cereal crops will be smaller when limiting warming to 1.5°C compared with 2°C (Hoegh-Guldberg et al., 2018).

Densely populated coastal cities with high poverty and vulnerability to erosion such as Lagos are already impacted, and will be impacted by sea level rise in the future (IPCC, 2014). People living in Lagos, as being disadvantaged, vulnerable and highly dependent on agricultural and coastal livelihoods will be disproportionately higher at risk of adverse consequences with global warming at 1.5°C and beyond (Hoegh-Guldberg et al., 2018).

Coastal flooding, sea level rise and storm surges will affect this lowland area and coastal city and challenge its industries, infrastructure and tourism (IPCC, 2014). Lagos is already affected by floods and is at risk of submersion (IPCC, 2014). Limiting global warming to 1.5°C would lower global mean sea level rise and thus enable greater opportunities for adaptation in the human and ecological systems *(medium confidence)* (Hoegh-Guldberg et al., 2018).

As Figure 1 shows flooding coupled with further effects driven by climate change impact the livelihoods of the poor population in Lagos in particular and increase the vulnerability to climate change driven extreme events such as flooding.

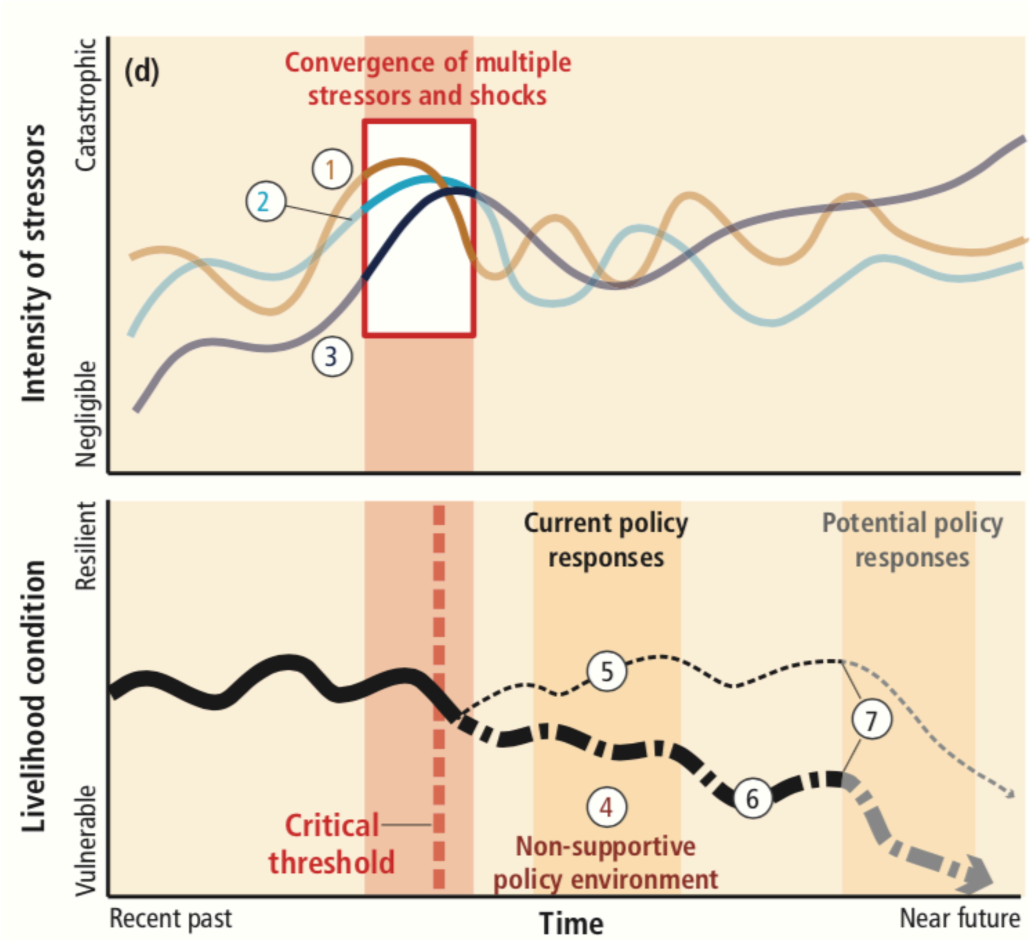

Figure 1: Flooding threatens the livelihoods of people in Lagos, Nigeria, where >70 % live in slums. Increased severity in rainstorms, sea level rise, and storm surges (1) coupled with the destruction of mangroves and wetlands (2), disturb people's jobs as traders, wharf workers, and artisans, while destroying physical and human assets. Urban management, infrastructure for water supply, and storm water drainage have not kept up with urban growth (3). Inadequate policy responses, including uncontrolled land reclamation, make these communities highly vulnerable to flooding (4). Only some residents can afford sand and broken sandcrete blocks (5). Livelihood conditions in these slums are expected to further erode for most households (6). Given policy priorities for the construction of high-income residential areas, current residents fear eviction (7). Source: Olsson et al., 2014

2. Demographics

Nigeria has a population of about 201 million, of which 54% are children under the age of 19 (Wittgenstein Centre for Demography and Global Human Capital, 2018). An average 12-year-old Nigerian citizen, the petitioner's peer, is expected to live until the age of 67 (World Data Lab, 2019). The demographic estimates can be coupled with the projections of global mean temperature increases. Following the best estimate of the future temperature trajectory based on the Climate Action Tracker (Climate Analytics; Ecofys; New Climate Institute, 2019), increase in the global mean temperature is expected to exceed 1.5°C around the year 2035 (model median), 2°C around 2055, and more than 3°C in 2100. Today's Nigerian 12-year-old has a 92% probability of being alive in 2035, 81% in 2055 and 1% in 2100. Nearly all children in Nigeria therefore have a high probability of experiencing a 2°C world and the ensuing impacts, with a portion of them living to possibly experience an even higher warming.

Nigeria counts as one of the most densely populated countries with a population over 200 million people, half of which are considered to be in abject poverty (Idowu, Ayoola, Opele, & Ikenweiwe, 2011). As Table 1 shows, Lagos as a state has seen an extreme population growth, with 763 000 people in 1960 and over 16 million in 2010 (Elias & Omojola, 2015). Lagos is the most populous city in sub-Saharan Africa due to its concentration of economic activities and urban agglomeration (Elias & Omojola, 2015). The population density in Lagos also far exceeds the global average population density of 112 persons per km^2 by inhabiting 20 000 persons per km^2 (Adelekan, 2016). Figure 2 highlights the rapid and extreme growth of Lagos State from 1900 until 2010.

Table 1

Population of Lagos State, 1960–2015 (in millions).

Year	Population
1960	0.07
1970	2.05
1980	4.38
1990	7.74
2000	13.4
2006	17.6
2010	19.8
2015	23.04

Source: Adapted from Lagos State Government [1••].

Table 1: Population of Lagos State from 1960-2015 in millions (Elias and Omojola, 2015)

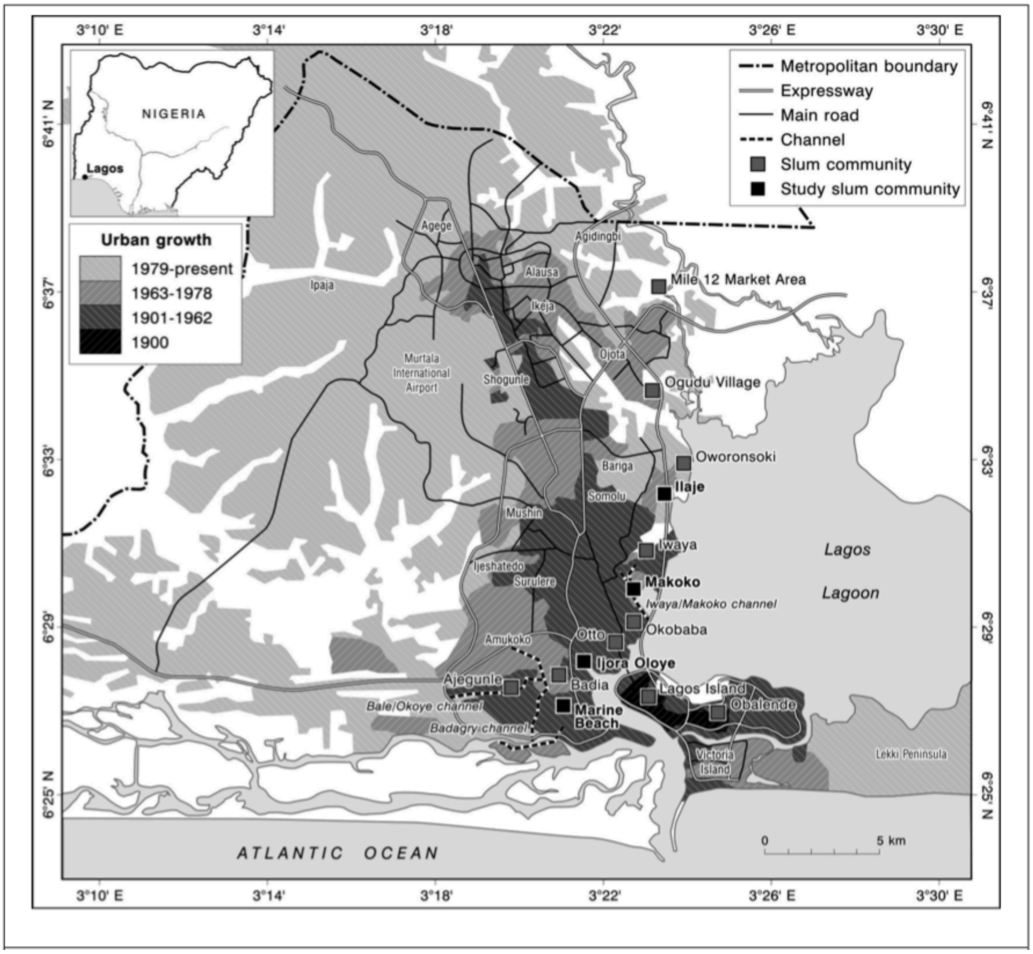

Figure 2: Growth of metropolitan Lagos (1900-present) and location of coastal slum communities (Adelekan, 2010)

3. Temperature Increase

As seen in Figure 3, temperature trends have been increasing in Nigeria since 1901, with a gradual increase until the 1960s and a sharp increase in temperatures from the 1970s onwards until today (Akpodiogaga-a & Odjugo, 2010). Mean air temperature between 1901-2005 was 16.6°C, which shows a temperature increase of 1.1°C over those 105 years. This is higher than the global mean temperature increase in the same time period of 0.74°C recorded since 1860 (Akpodiogaga-a & Odjugo, 2010).

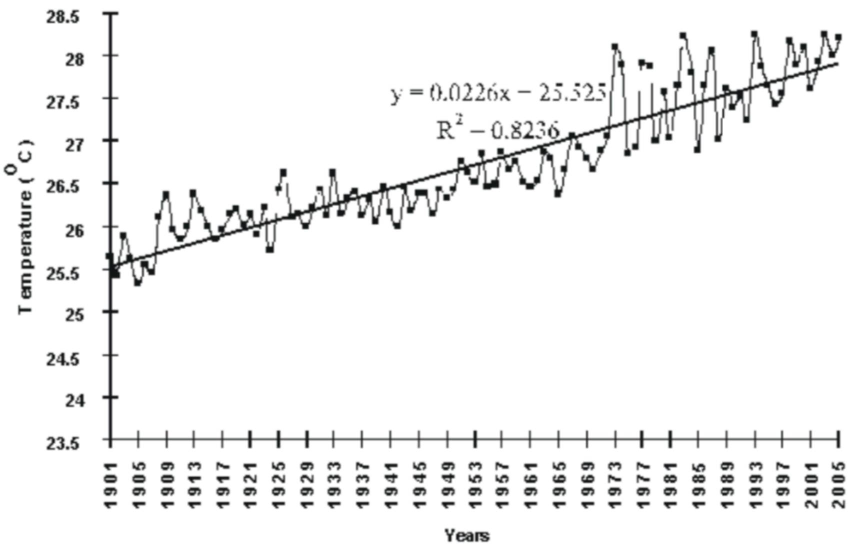

Figure 3: Air temperature distribution in Nigeria between 1901 and 2005 (Akpodiogaga-a & Odjugo, 2010)

Temperatures are further expected to increase for all climate scenarios. Figure 4a indicates the changes in warming over the entire country, with lowest warming over the coastal regions as they receive a cooling effect from the Atlantic Ocean (Abiodun, Lawal, Salami, & Abatan, 2013). Figure 4b also shows the temperature increase from 1960-2100 for a global warming scenario of 2.4°C by 2100 (RCP4.5). Also extreme temperature events are further expected to increase under all emission scenarios.

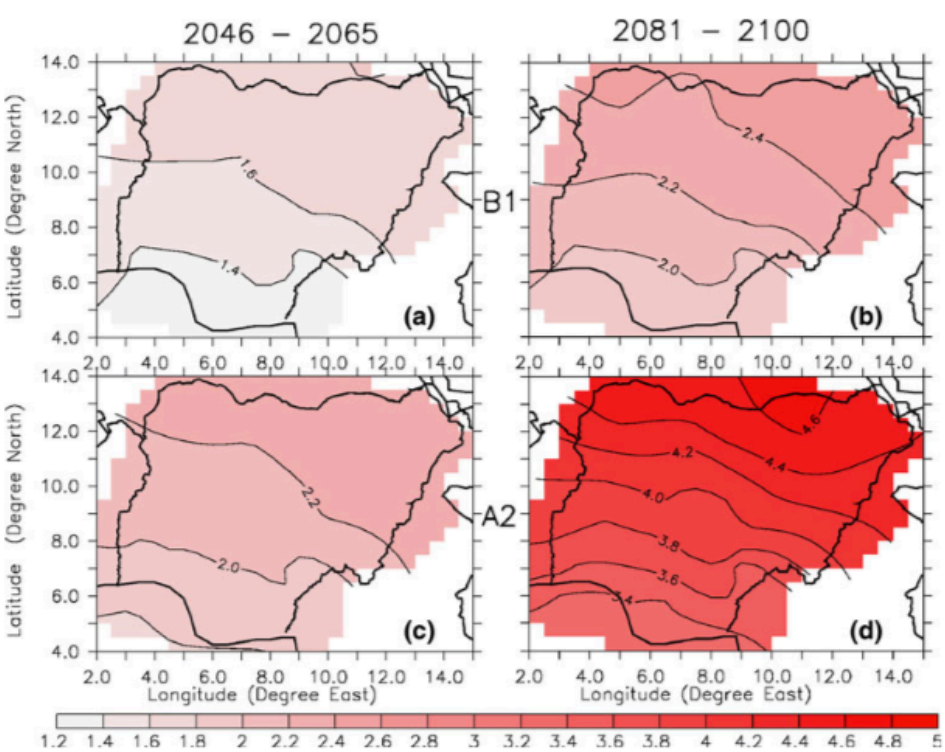

Figure 4a: Spatial distribution of the projected changes in maximum temperature (°C) over Nigeria in the future (2046-2065 and 2081-2100) under B1 (2.4°C global warming by 2100) and A2 (4.5°C global warming by 2100) (Abiodun et al., 2013)

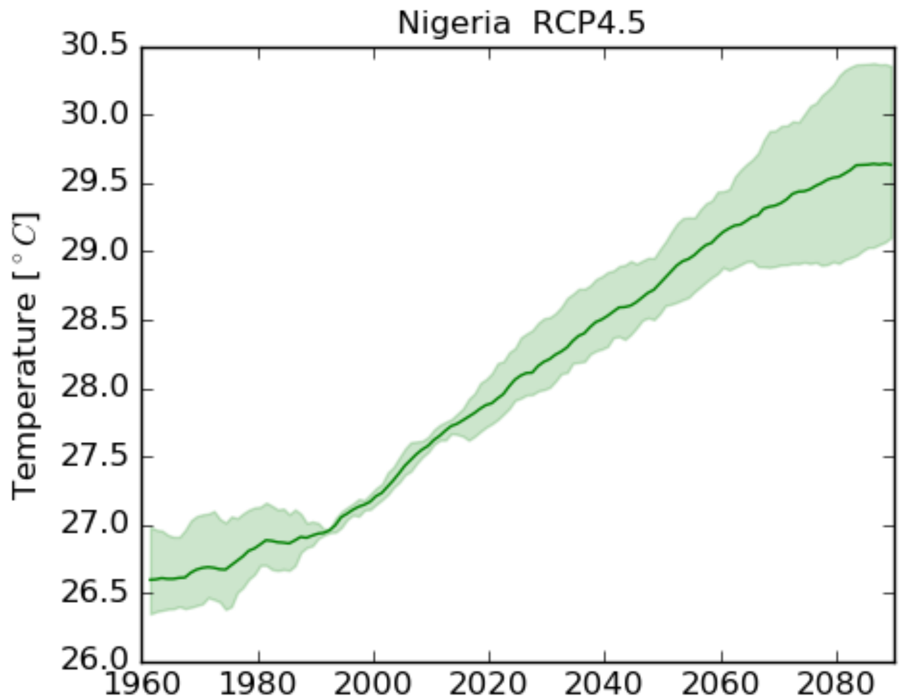

Figure 4b: Regional climate model projections for temperature displayed as a 20 year running mean - the line represents the ensemble mean while the shaded area represent the model spread. The projections are based on a global warming scenario of 2.5°C by 2100 (RCP4.5) (http://regioclim.climateanalytics.org/choices)

For a global warming scenario of 2.4°C by 2100 (RCP4.5), the number of days with extreme temperature event increases in the South of Nigeria by about 24 per year in 2046-2065 and by about 42 per year in 2081-2100 (Abiodun et al., 2013). For a global warming scenario of 4.3°C by 2100 (RCP8.5), the number of days with extreme temperature event increases in the South of Nigeria by about 40 per year in 2046-2065 and by about 106 per year in 2081-2100 (Abiodun et al., 2013).

For a global warming scenario of 2.4°C by 2100 (RCP4.5), the number of days with heat wave events increases in the south of Nigeria by about 3 per year in 2031-2060 and by about 8 per year in 2081-2100 (Abiodun et al., 2013). For a global warming scenario of 4.3°C by 2100 (RCP8.5), the number of days with heat wave events increases in the South of Nigeria by about 7 per year in 2031-2060 and by about 45 per year in 2081-2100 (Abiodun et al., 2013).

Increasing temperatures lead, for example, to river drying up or becoming only seasonally navigable (Akpodiogaga-a & Odjugo, 2010). For example, Lake Chad shrunk by 5.7% from 1963 until the year 2000 (Akpodiogaga-a & Odjugo, 2010). This creates water scarcity and will increase the concentration of users around the remaining limited water resources (Akpodiogaga-a & Odjugo, 2010). Such circumstances also increase the possibility of additional contamination and the transmission of water borne diseases like cholera (Akpodiogaga-a & Odjugo, 2010).

4. Precipitation

In general, Nigeria shows a declining rainfall trend by 81 mm between 1901 and 2005 (Akpodiogaga-a & Odjugo, 2010). The coastal areas however are observed to be experiencing increasing rainfall in recent times (Akpodiogaga-a & Odjugo, 2010). Figure 5 indicates the observed rainfall characteristics between 1971-1995 and 1996-2005.

Rainfall characteristics for Lagos Island

Rainfall characteristics	1971–1995	1996–2005
Mean number of rain days	112	82
Maximum number of rain days	163	105
Minimum number of rain days	76	69
Mean rainfall (mm)	1,697.8	1,647.3

Figure 5: Rainfall characteristics for Lagos Island (Adelekan, 2010)

Rainfall patterns are projected to be wetter over Nigeria (especially over the southern half) in the future (see Figure 6). For global warming of 2.4°C by 2100 (RCP4.5/B1), precipitation is expected to increase by 0.8 mm per day (Abiodun et al., 2013). For global warming of 4.3°C by 2100 (RCP8.5/A2) rainfall is expected to be even stronger (Abiodun et al., 2013). This increase in rainfall is caused by the stronger temperature gradient, as more moisture is transported to produce rainfall over the country, especially over the coastal region (Abiodun et al., 2013).

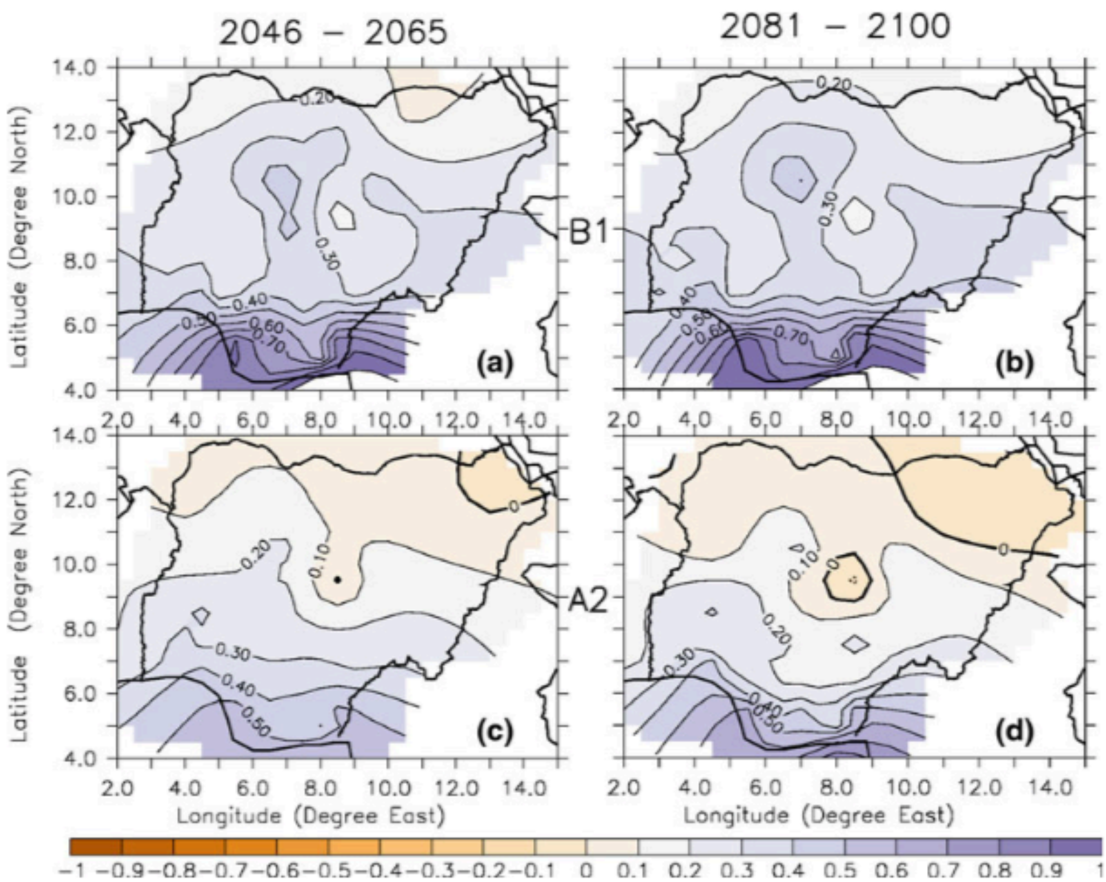

Figure 6a: Spatial distribution of the projected changes in rainfall (mm day-1) over Nigeria in the future (2046-2065 and 2081-2100) under B1 (2.4°C global warming by 2100) and A2 (4.5°C global warming by 2100) (Abiodun et al., 2013)

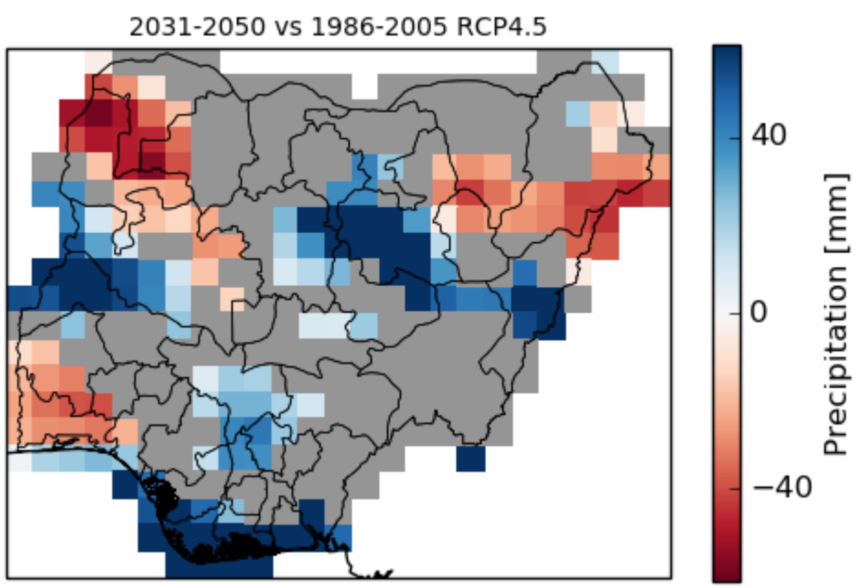

Figure 6b: Projected change in precipitation for 2031-2050 compared to reference period 1986-2005. Here the ensemble mean of regional climate model projections is displayed. Grid cells for which model disagreement is found are colored in gray. The projections are based on a global warming scenario of 2.4°C by 2100 (RCP4.5) (http://regioclim.climateanalytics.org/choices)

5. Sea Level Rise

Sea level rise for Nigeria indicates salt-water intrusion into freshwater, invasion and destruction of mangrove ecosystems, coastal wetlands and coastal beaches (Akpodiogaga-a & Odjugo, 2010). Moreover, sea level rise can indicate population displacement due to coastal inundation, which is already currently a problem in coastal areas of Lagos State (Akpodiogaga-a & Odjugo, 2010). Many of Africa's large coastal cities have a high concentration of poor populations in potentially hazardous regions that are vulnerable to sea level rise. One meter in sea level rise (which is projected to happen under global warming of 4.3°C by 2100 (RCP8.5)) will displace about 14 million people from the coastal areas of Nigeria, which makes it one of the 11 countries with global port cities "with high exposure and vulnerability to sea level rise and storm surges" (Akpodiogaga-a & Odjugo, 2010; Adelekan, 2010).

Lagos as a coastal city has been categorized as one of the 50 cities most exposed to extreme sea level - which is especially concerning regarding the 800% increase in population exposed to sea level rise by the 2070s (Adelekan, 2010). It is projected that sea level rise will affect large parts of the populations towards the end of this century, and the possible cost of adaptation is expected to be between 5-10% of GDP (Fashae & Onafeso, 2011).

Figure 7 shows how a total loss of beach land of 0.75 km^2 occurred in one decade between 1999 and 2009 (Fashae & Onafeso, 2011). As stated by the IPCC, limiting global warming to 1.5°C would lower global mean sea level rise and thus enable greater opportunities for adaptation in the human and ecological systems *(medium confidence)* (Hoegh-Guldberg et al., 2018).

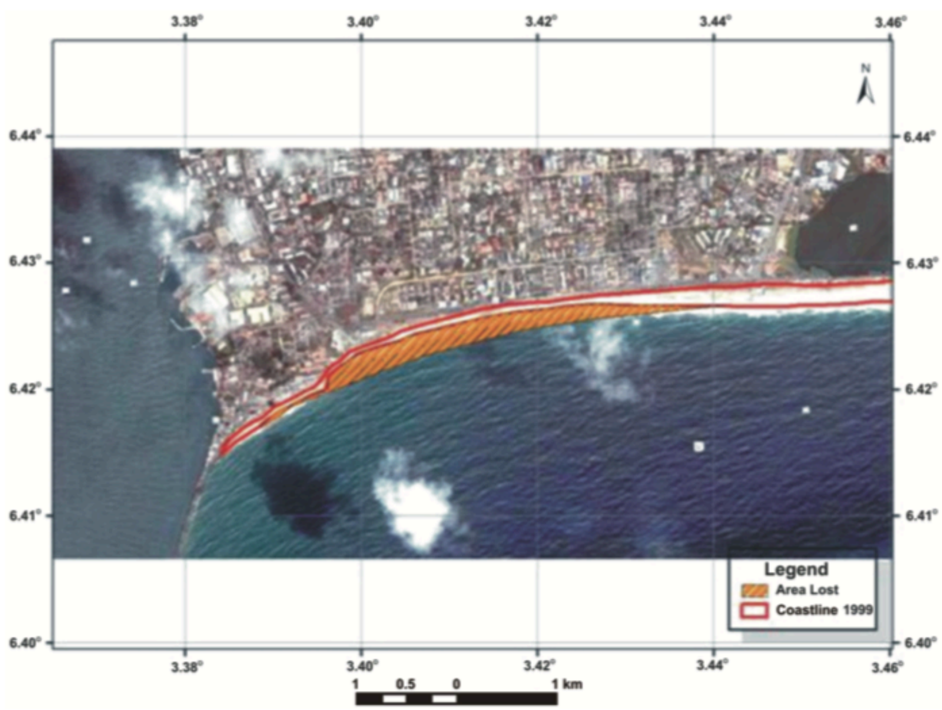

Figure 7: Satellite imagery of Lagos coastline showing the area lost between 1999 and 2009 (Fashae and Onafeso, 2011)

Figure 8 indicates that under global warming of 4°C, sea level rise is expected to increase by 85-125 cm by 2080-2100 (Schellnhuber et al., 2013). For a 2°C warmer world, the rise will be significantly lower yet considerable at between 60-80 cm (Schellnhuber et al., 2013).

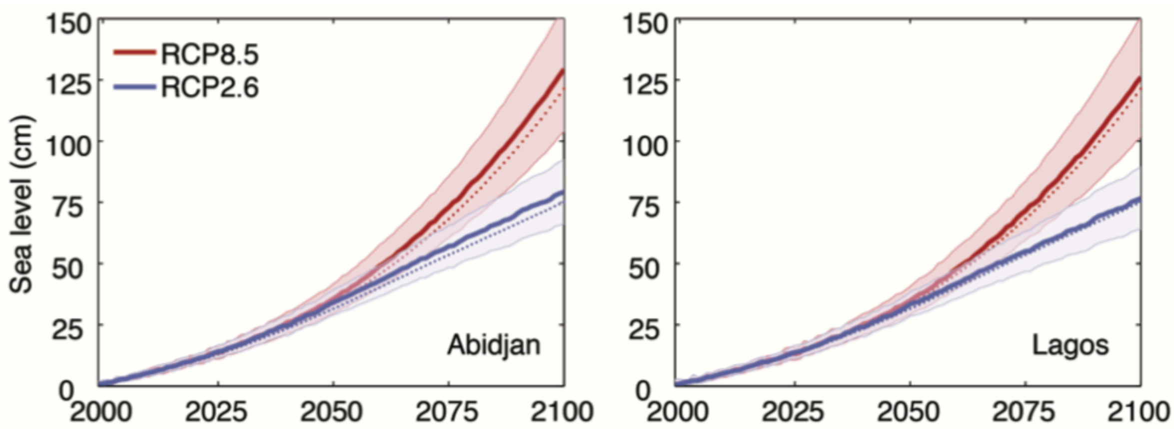

Figure 8: Local sea level rise above 1986-2005 for Abidjan and Lagos until 2100 (in cm) for global temperature increase of 4°C and 2°C (Schellnhuber et al., 2013)

6. Food Security and Droughts

The frequency and intensity of droughts has increased in some regions of the globe, including in West Africa (IPCC, 2019). The IPCC found that in Sub-Saharan Africa, increased land surface air temperature and evapotranspiration and decreasing precipitation leads to desertification and droughts *(medium confidence)* (IPCC, 2019). The frequency and intensity of such droughts is projected to increase particularly in African countries *(medium confidence)* (IPCC, 2019).

"West Africa has a high number of people vulnerable to increased desertification and yield decline" (IPCC, 2019), which is strongly linked with food security in Nigeria. Climate change is already affecting food security in Africa through warming, changing precipitation patterns an increase in some extreme events (IPCC, 2019). While there are some areas in the higher altitudes that might experience an increase in crop yield, tropical West Africa is found to be at significant risk of declining crop yield for a global temperature increase of 2°C and more, which is seriously endangering food security in the future (Hoegh-Guldberg et al., 2018). While global hunger has been declining over the past few decades, undernutrition has increased particularly in Sub-Saharan Africa, which is extremely dangerous for children (IPCC, 2019).

7. Extreme Weather Events

7.1 Extreme Precipitation

Rainstorm intensity has strongly increased over the past years. Mean annual rainfall was similar but the recorded rain days have declined, indicating that rainstorms have been much heavier than those of the earlier periods (Akpodiogaga-a & Odjugo, 2010). Especially in the coastal areas and Lagos, between 1996 and 2005, rainstorms have been heavier despite decreasing numbers of total rain days per annum (Akpodiogaga-a & Odjugo, 2010). Between 1992 and 2007 these extreme rainstorm events destroyed properties in Nigeria and killed 199 people (Akpodiogaga-a & Odjugo, 2010).

In July 2011, for example, there was a heavy rainfall event that lasted 17 hours in which a total of 233.3 mm of rainfall occurred - this amount of rain is equivalent to the precipitation of one whole month (Adelekan, 2016). During this rainfall event, 25 people were killed and over 5000 people had to be displaced from their homes (Adelekan, 2016). One year later 216.3 mm of rainfall was recorded in a single rainfall event, which severely damaged infrastructure, roads, bridges, rail tracks, houses and other properties and claimed seven lives (Adelekan, 2016).

Increases in extreme rainfall over the south of Nigeria are expected. With warming temperatures the atmosphere contains more water at saturation, increasing the possible amount of water during rainfall events (Abiodun et al., 2013). The changes in number of days with extreme rainfall in overall Nigeria are small (less than 1 day per decade) whereas the highest increase (1.2 days per decade) is expected to occur over Lagos under a global warming scenario of 2.4°C in 2100 (RCP4.5) (Abiodun et al., 2013).

7.2 Floods

Due to the combination of sea level rise, extreme precipitation and the low elevation and topography of Lagos, the entire Nigerian coastline is highly susceptible to flooding, especially at high tides and during rainy season (Adelekan, 2010). Flooding can lead to "road tracks inundation, house losses, public health hazards and losses of potable water owing to saltwater intrusion into wells and seaside beels, farmland losses and population displacements and ultimate livestock mortalities" (Idowu et al., 2011). Flooding and associated pollution will also greatly reduce the potable water quantity and water quality in Lagos (Elias & Omojola, 2015). Numerous studies found that highly populated communities within 10 km of the coastline can be inundated or submerged as a result of sea level rise and flooding (Elias & Omojola, 2015). For example, the above described rainfall events of 2011 and 2012 lead to flooding that heavily impacted 1500 households and 10 communities in Lagos (Elias & Omojola, 2015).

In 2005, 136 port cities were assessed for exposed population to flooding with Lagos ranking 30th. Under the current climate scenario Lagos will rank 15th in the future (Adelekan, 2010). A study showed that flooding in different urban communities had worsened between 2002 and 2006, with 71% of the respondents reporting flooding of their streets in 2006, compared with 54% in 2002 (Adelekan, 2010). Figure 9 shows that flooding is a major problem in most parts of metropolitan Lagos (Adelekan, 2010).

Figure 9: Lagos showing communities that were affected by flooding in 2011 (Adelekan, 2016)

8. Sectoral Impacts

8.1 Agriculture

For more than 70% of the population of Nigeria, agriculture is their primary occupation and means of livelihood (Idowu et al., 2011). Agriculture in Nigeria is mainly rainfed and strongly depends on precipitation patterns. Climate change has multiple effects on agriculture, for example, "uncertainties and variations in the pattern of rainfall, floods and devastated farmlands cause pest and diseases migrate in response to climate change while high temperatures smother crops" (Idowu et al., 2011). The future changes in precipitation and temperature will decline harvest of rice, maize, cassava, melon, sorghum and yam by 2.5% per annum (Idowu et al., 2011). Also cacao, oil palm, cotton and others suffer severe setbacks under reduced photoperiods that reduced annual yields by 5.5 metric tons per hectare (Idowu et al., 2011).

Pests and diseases also become uncontrollable under extreme weather events and further decline crop harvest (Idowu et al., 2011). Furthermore, climate change reduces arable land of coastal plains, as can be seen in Figure 7, which reduces agricultural farmland and grazing rangelands for many farmers (Akpodiogaga-a & Odjugo, 2010). Also fish production is affected by climate change as a study of Adeoti et al. (2010) revealed, where the impact of flooding, temperature increase and wind on fish production affected 81% of the fish farmers (Elias &

Omojola, 2015). The livestock sector will also be affected by increases in temperature and humidity. For example, livestock mortalities (stock losses) have increased in poultry, pork and rodent production systems by at least 15% per annum (Idowu et al., 2011). These trends and impacts will further increase with increasing global and local temperatures. In general, reductions in yields of maize, rice, wheat, and potentially other cereal crops will be smaller when limiting warming to 1.5°C compared with 2°C (Hoegh-Guldberg et al., 2018). Figure 10, for example, displays the decrease in maize yields under a global warming scenario of 2.5°C by 2100.

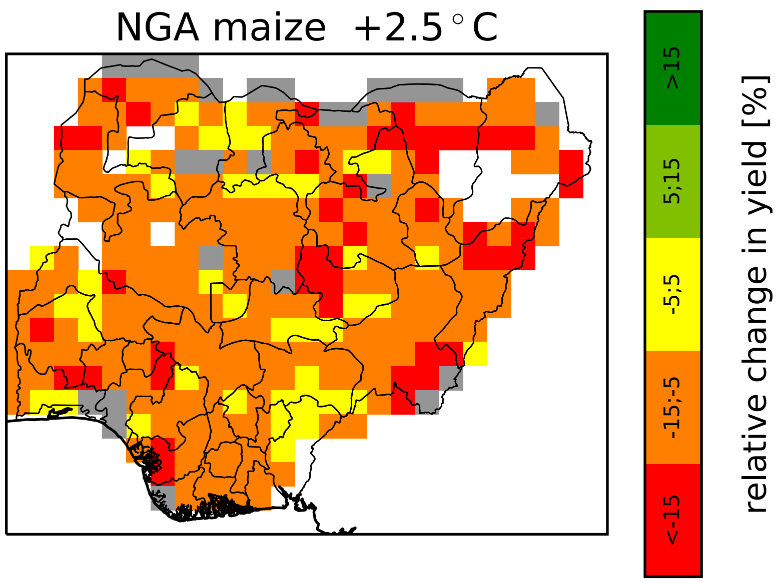

Figure 10: Projected change in maize yield (%) relative to 2000 under global warming scenario of 2.5°C - yellow areas shows small level of impacts, whereas orange areas show a decline between 5-15%, and red areas a decline by more than 15% (http://regiocrop.climateanalytics.org/choices)

8.2 Health

Air pollution, increasing water stress, excessive heat, and suppressed immune system suppression caused by climate change "will result in increasing incidence of excessive death due to heat exhaustion, famine, water related diseases (diarrhea, cholera and skin diseases), inflammatory and respiratory diseases (cough and asthma), depression, skin cancer and cataract" (Akpodiogaga-a & Odjugo, 2010). In 2011 the impact of climate change on the public health of Nigeria's farming communities was reported as 70% of the population being affected by Malaria annually, 45% suffering from skin ailments, 40% noticing a loss of productivity, 4% experiencing heat strokes and 60% witnessing portable water shortages due to floods and/or saltwater intrusion (Idowu et al., 2011).

For example, increasing temperatures will trigger a northward migration of mosquitos, which will extend Malaria fever from the tropical region to the warm temperate regions, increasing the number of people affected (Akpodiogaga-a & Odjugo, 2010). Moreover, the frequency and duration of cholera outbreaks for children in West Africa has been associated with climate change and its changes in precipitation patterns (heavy rainfall) (UNICEF, 2015). The increase in precipitation is also expected to affect the water and sanitation infrastructure and may thus increase the proportion of diarrheal deaths attributable to climate change by 14% by 2050 (U.S. Agency for International Development, 2018).

The Lancet Report estimates that 153 billion labour hours were lost due to climate change and increasing temperatures (Watts et al., 2018). That is an increase of 62 billion compared with the year 2000. 80% of these lost labour hours are linked to the agricultural sector, which explains the strong increase in Nigeria, where 70% depend on agriculture as a source of living (Watts et al., 2018). The IPCC also found that "higher temperature increase will have a negative effect on heat related morbidity and mortality *(very high confidence)*" and that "especially urban populations will be affected by amplified impacts due to urban heat island *(high confidence)*" (Hoegh-Guldberg et al., 2018).

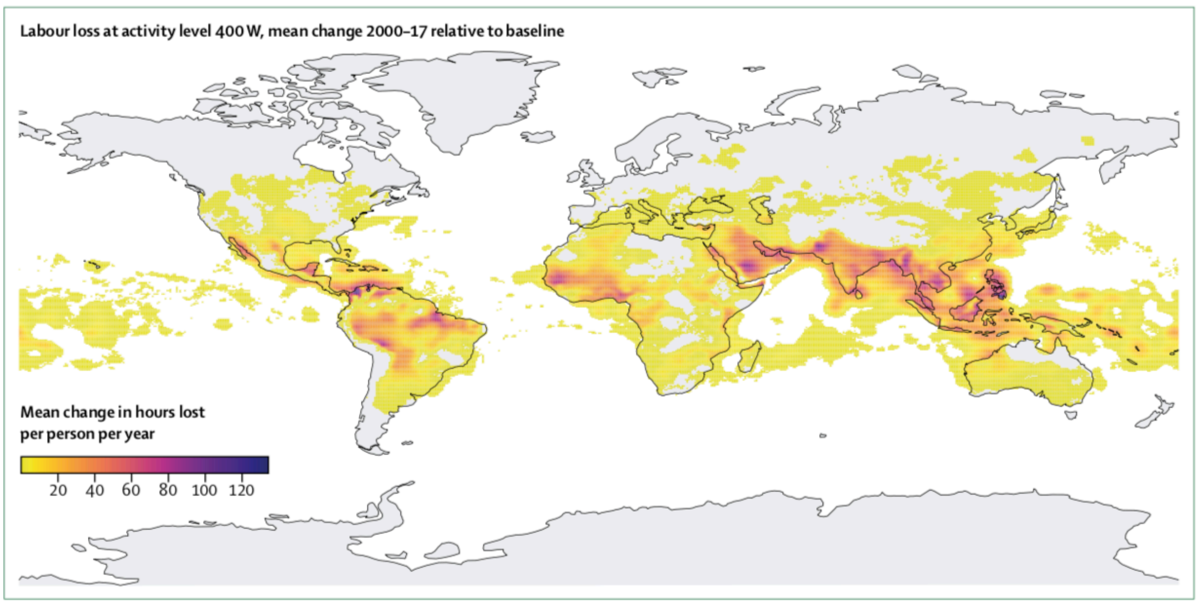

Figure 11: Labour loss at activity level 400 W, mean change in hours lost per person per year 2000-17 relative to baseline (Watts et al., 2018).

8.3 Infrastructure and Displacement

As described above, many climate stressors lead to the loss of roads and road tracks and other parts of infrastructure. This is especially true for farming communities in Nigeria (Idowu et al., 2011). Turbulent floods and inundated road tracks up to 5 months per year also prevents children from attending school; moreover, losses of lives of pupils have been reported (Idowu et al., 2011).

Climate change also leads to population displacement and relocations with immediate abandonment and hence farm occupation decline (Idowu et al., 2011). At least 32 000 farmers are effected annually by displacement in Nigeria's farming communities (Idowu et al., 2011).

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2.8. Sweden - North

Sweden – Karesuando

Summary

Sweden is experiencing an increase in temperature well above global average that manifests itself in a range of impacts for human and ecosystems. The greatest temperature increases have occurred over central and Northern Sweden during winter, with a positive trend in the frequency and intensity of winter warming events. Projections show that warming will continue, at greater rates than the global average in Sweden. Annual precipitation has also increased (between 10 and 40% over Northern Europe) and precipitation changes of additional 20% increases have been projected for a 2°C scenario, with a stronger increase in Northern Sweden during winter. The snow cover is also undergoing large amount of changes: increased precipitation leading to greater accumulation of snow, increased number of freeze-thaw days causing frost damage and increased frequency and areal extent of rain-on-snow events.

These changes hinder foraging conditions for reindeer putting the traditional livelihood of reindeer herding Sami under existential threat. Permafrost thawing accelerates climate change and affects infrastructures and livelihoods. Extreme weather events such as heat waves and wildfires will also intensify and become more frequent. The Sami people, who

closely depend on direct and indirect contributions of ecosystems to their well-being, will be strongly affected by shifts in vegetation zones, damaged grasslands, plant pests and diseases. The reindeer are impacted by decreasing body condition, increasing stress due to the shrinking of grazing lands and variation in fecundity and thus population growth, which has impacts on the Sami people as reindeer are part of their livelihood. The mental and physical health of the Sami is threatened by climate change through increased frequency and distribution of diseases, anxiety linked to environmental changes, and safety issues due to less stable ice and snow routes. The overall livelihood and the rich cultural heritage of the Sami people is therefore at the brink of a socio-ecological tipping point, a critical threshold where it could be irreversibly lost. Under current emission trajectories, the Sami children of today will spend more than half of their lives in a world warmer than 1.5°C above pre-industrial levels.

1. The IPCC report's summary on climate impacts in Northern Sweden

"Increases in temperature throughout Europe and increasing precipitation in Northern Europe" are projected. "Climate projections show a marked increase in high temperature extremes (high confidence), meteorological droughts (medium confidence), and heavy precipitation events (high confidence), with variations across Europe" and "increases in winter wind speed extremes over Central and Northern Europe (medium confidence)". "Observed climate change in Europe has had wide ranging effects throughout the European region including the distribution, phenology, and abundance of animal, fish, and plant species (high confidence)". "Climate change has affected both human health (from increased heat waves) (medium confidence) and animal health (changes in infectious diseases) (high confidence)" (IPCC, 2014, p. 1270).

2. Demographics and intergenerational aspects

Sweden has a population of about 10 million, out of which 22% are children under the age of 19 (Wittgenstein Centre for Demography and Global Human Capital, 2018). An average 8-year-old Swedish citizen is expected to live until the age of 91 (World Data Lab, 2019). The demographic estimates can be coupled with the projections of global mean temperature increases. Following the best estimate of the future temperature trajectory based on the Climate Action Tracker (2019), increase in the global mean temperature is expected to exceed 1.5°C around the year 2035 (model median), 2°C around 2055, and more than 3°C in 2100. Today's Swedish 8-year-old has a 99% probability of being alive in 2035, 99% in 2055 and 38% in 2100. Therefore, these children still have a high probability of experiencing a 2°C world and its respective climate change impacts.

3. Temperature increase

The mean temperature in Sweden over the period 1991-2007 was about 1°C higher than over the period 1961-1990, which is more than twice the global average over this period. The greatest increase (just over 2°C) occurred during winter in central and Northern Sweden (Climate Change Post, 2019). Observational data shows that winters in particular have been warmer in recent decades. Over the past 50 years there has also been a positive trend in both the frequency and intensity of winter warming events (e.g. increased rates for number of melt days) in Northern Scandinavia (Vikhamar-Schuler et al., 2016). This supports findings that climate change warming is amplified in polar regions (Stocker et al. 2013). Projections show that this warming will continue, often at greater rates than the global average.

For Northern Europe, the Fifth Assessment Report (AR5) (IPCC, 2014) states that there will be an increase in high temperature extremes (high confidence). On a European level, North-Eastern Europe and Scandinavia are the regions for which the strongest warming is projected in winter affecting particularly the northern parts of Sweden (*Figure 1*) (Füssel et al., 2017).

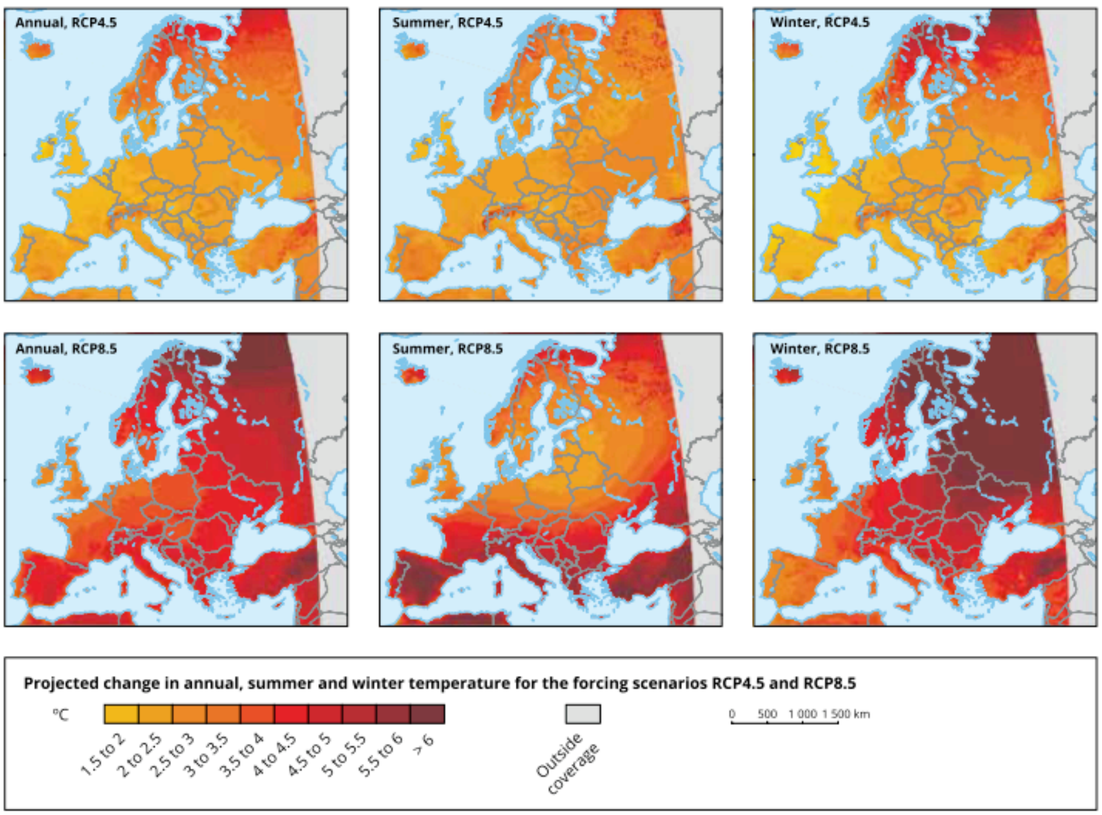
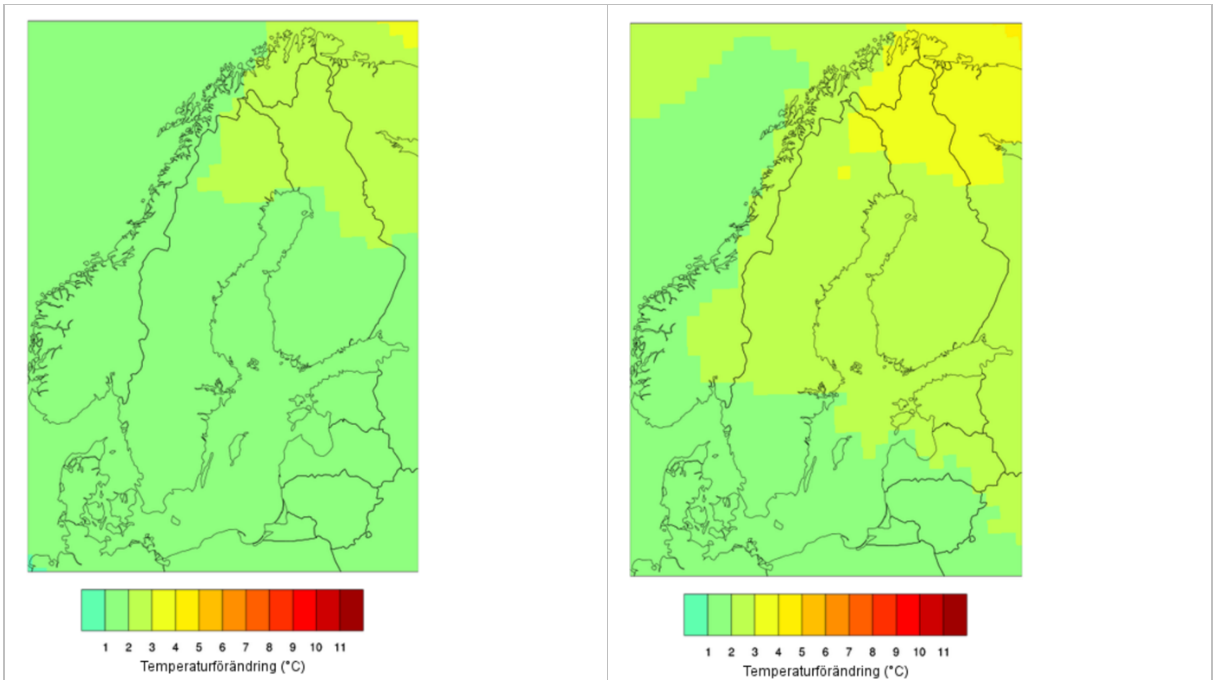


Figure 1: Projected changes in mean annual, summer and winter temperature in the period 2071-2100 for scenarios of 2.4°C expected temperature increase by 2100 (RCP4.5) and 4.3°C expected temperature increase by 2100 (RCP8.5) against the baseline period 1971-2000 (source: Füssel et al., 2017)

Figure 2 shows that with 1.5°C and 2°C of global warming, Northern Sweden will be most affected by an increase in annual mean temperatures (Swedish Meteorological and Hydrological Institute, 2019a). Even greater levels of warming are projected during winter months.



1.5°C global warming	2°C global warming

Figure 2: Calculated change in annual mean temperature (°C) compared to 1971-2000 at the period for 1.5°C and 2°C global warming according to a scenario of 4.4°C expected temperature increase by 2100 (RCP8.5) (Swedish Meteorological and Hydrological Institute, 2019a)

4. Precipitation

Annual precipitation over Northern Europe has increased by between 10 and 40% in the last century, in particular in winter (EEA, 2007; Füssel et al., 2017).

Recent studies summarised in the IPCC Special Report on the Impacts of Global Warming of 1.5°C (SR1.5) have shown that 2°C of global warming was associated with a robust increase in mean precipitation over Northern Europe in winter and in summer (Hoegh-Guldberg et al., 2018). Precipitation changes reaching 20% have been projected for the 2°C scenario (ibid). The latest report from the European Environment Agency (EEA) also states that there will be an increase in river flows, less snow and greater damage by winter storms in this region (Füssel et al., 2017). Precipitation is mostly expected to increase in Northern Sweden and during the winter (Swedish Meteorological and Hydrological Institute, 2019b) (*Figure 2*).

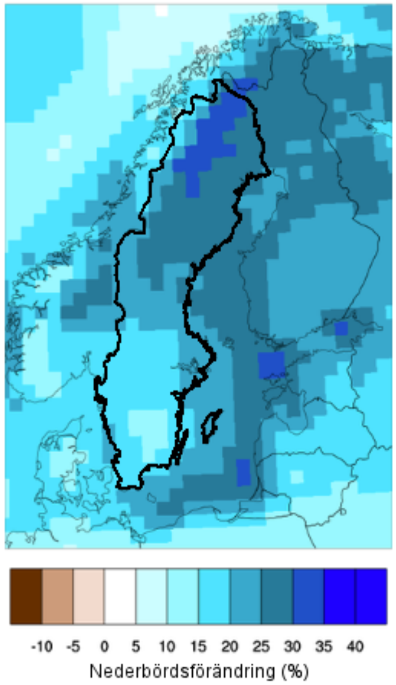


Figure 3: Calculated change in annual precipitation (%) for the period 2071-2100 compared with 1971-2000. The map is based scenarios of 4.3°C expected temperature increase by 2100 (RCP8.5) (Swedish Meteorological and Hydrological Institute, 2019b)

5. Snow cover

Increased precipitation during winter may lead to greater accumulation of snow on pastures, restricting forage access (Tyler et al., 2007). In addition, while most of Europe is expected to experience a decrease in the number of freeze-thaw days under 2°C of warming, Northern Scandinavia will experience a small increase (IMPACT2C, 2019). Melting snow and loss of snow cover, followed by low temperatures of -20°C to -30°C, cause ice encasement and frost damage. Ground-ice formation due to such melting events or winter rain events prevents ungulates (e.g. reindeers) from grazing, leads to vegetation browning, and impacts soil temperatures (Vikhamar-Schuler et al., 2016). Rain-on-Snow events have been implicated in catastrophic die-offs of ungulates in the polar region (Rennert et al., 2009). In addition, the frequency and areal extent of rain-on-snow events is expected to increase in the Arctic (the underlying study focused more on Canada and Alaska) (Rennert et al., 2009). Such an increase would also make it increasingly difficult for reindeer to find suitable foraging conditions, potentially leading to mass starvation or displacement (Mallory and Boyce, 2017). Changes in snow pack structure and quality could also cause problems for reindeer herders when moving their herds (ibid).

6. Permafrost thawing

Permafrost is found in lowland areas at high Northern latitudes in Sweden and is sensitive to climate change (Sannel et al., 2018). Increasing temperatures lead to the thawing of permafrost, threatening to release carbon to the atmosphere (Gisnås et al., 2017). It has a large impact on periglacial environments and results in a substantial positive feedback loops accelerating climate change (Hällberg, 2018). The IPCC has stated that "limiting global warming to 1.5°C rather than 2°C is projected to prevent the thawing over centuries of a permafrost area in the range of 1.5 to 2.5 million km^2 (medium confidence)" (Hoegh-Guldberg et al., 2018). In addition, "climate change exacerbates land degradation, particularly in low-lying coastal areas, river deltas, drylands and in permafrost areas (high confidence)" (IPCC, 2019, p. 3). The thawing of permafrost therefore affects infrastructure and livelihoods (Füssel et al., 2017).

7. Extreme weather events

7.1. Heat waves

The frequency, intensity, duration and spatial extent of heat waves will increase with climate change (Oudin Åström et al., 2013). The heatwaves in 2003, 2007 and 2010 in Europe illustrate the increase in the number of extreme temperature events. The temperatures in 2010 broke 20th and 21st century records, with an 80% probability the record heat would not have occurred without climate change (Oudin Åström et al., 2013). Europe is projected to experience years like 2016 every other year for 1.5° warming and 9 out of 10 years for 2° warming (King and Karoly, 2017). Warm spell durations are projected to increase from 14 days to 24 days for warmings of 1.5°C and 2°C in Northern Europe (Carbon Brief, 2019). The frequency of warm extremes over land will also increase 73% at 1.5°C warming and 179% at 2°C warming in Northern Europe (ibid). *Figure 3* shows the deviation of temperature averages in July 2018, supporting the estimations of increasing heat waves.

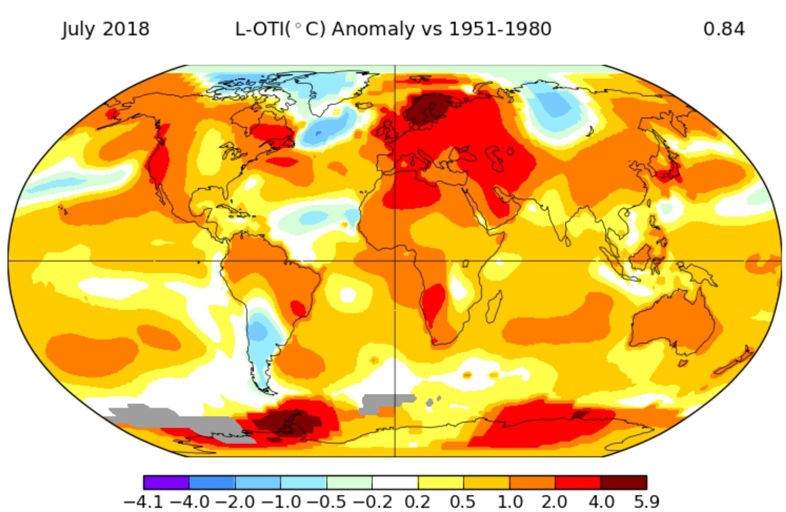


Figure 4: Deviation of temperature averages in July 2018 in comparison of those between 1951-1980. (source: NASA: GISS Surface Temperature Analysis: https://data.giss.nasa.gov/gistemp/maps/)

7.2. Wildfires

Sweden is also exposed to wildfires (3000-4000 fires per year), the large forest areas that are sparsely populated result in large fires with considerable financial impacts (Ministry of the Environment and Energy, 2017), estimated at almost 70 million USD by the Swedish Forestry Agency (The Local, 2018). The fire risk is expected to increase together with the increase in temperature (Ou, 2017), expanding fire-prone areas and fire seasons (Füssel et al., 2017).

During the heatwave of 2018 in Sweden, hot and dry conditions spurred more than 40 fires, resulting in over 10 000 hectares of burned land, 24 times higher than the amount of burned land averaged over 2008-2017 (NASA, 2018). *Figure 5* shows land surface temperature anomalies during that period.

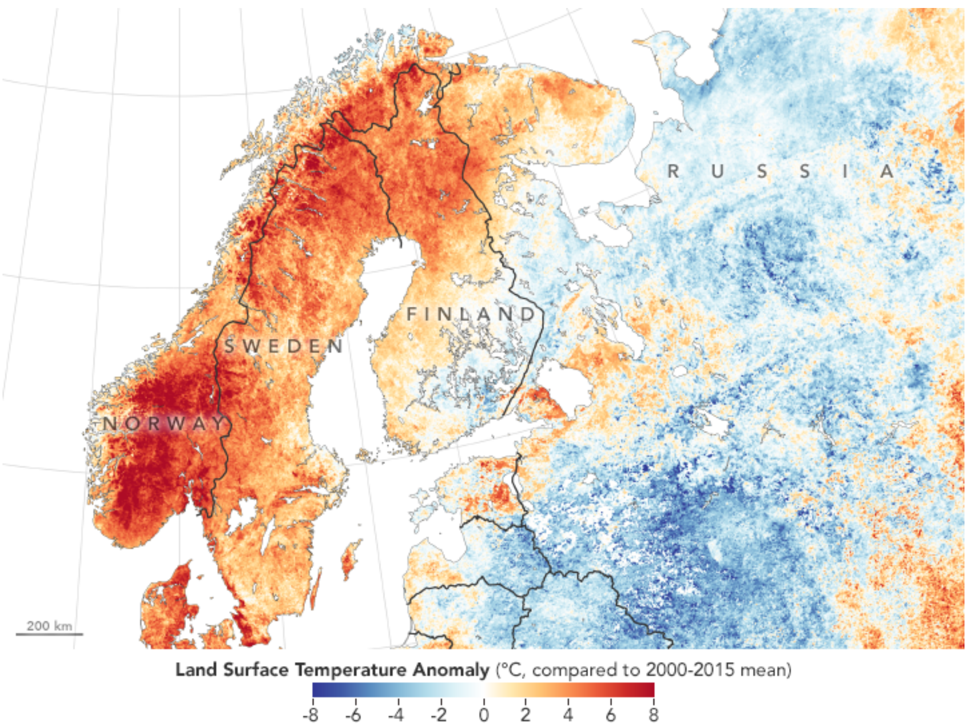


Figure 5: Land surface temperatures from July 1-15, 2018, compared to the 2000–2015 average for the same two-week period (NASA, 2018)

7.3. Floods

Increasing precipitation and thawing permafrost will be reflected in water courses together with the dynamics of freshwater systems, altering lake and wetland patterns and the ecosystems they support (Füssel et al., 2017).

8. Sectoral impacts

8.1. Health

Climate change could particularly impact Sami youth as they become the next generation of reindeer herders which, due to geography, is more likely to be strongly impacted by climate change (Kowalczewski and Klein, 2018). The warming climate is already influencing Sami reindeer culture and mental health and suicide risk partly linked to the changing physical and social environments are major concerns (Jaakkola et al., 2018). Loss of language, culture and urban life can have negative implications for the mental and physical health of the Sami people (Jaakkola et al., 2018; Kowalczewski and Klein, 2018). Increased safety issues also threaten the Sami people due to less stable ice and snow routes (Kowalczewski and Klein, 2018). Rising temperatures and changing precipitation regimes have also been linked to increased frequency and distribution of foodborne, waterborne and vector borne diseases; increased mortality and morbidity from hazardous travel conditions and extreme weather events; and disruptions to nutritional intake from wild foods and an increased reliance on processed foods (Cunsolo Willox et al., 2014). The small population size, their dispersed settlement and urbanization limits the opportunities for cultural adaptation in the changing climate (Jaakkola et al., 2018).

8.2. Ecosystems and agriculture

Ecosystems and human activities in the Arctic will be strongly affected due to the particularly fast increase in air and sea temperatures and the associated melting of land and sea ice (Füssel et al., 2017). “Arctic vegetation zones are likely to shift, causing wide-ranging secondary impacts” (ibid, p. 295). Warm winter temperatures are damaging grasslands, and plant pests and diseases are becoming more abundant.

8.3. Reindeer husbandry

There has been an observed decline in reindeer body condition during warm summers, which has been connected to a lengthening of the period of high insect activity under warmer temperatures (Mallory and Boyce, 2017). Harassment by parasitic insects affects reindeer behavior, movement and body condition during the summer. Reindeer respond to harassment by running, sometimes for long periods, causing increased energy expenditure and decreased time spent foraging (ibid).

The flexibility in herding practices that has allowed reindeer herders to adapt to changing conditions is being eroded by a number of non-climatic factors (e.g. shrinking grazing lands, predation, poor financial conditions), which is enhancing their vulnerability to future climate change. Sami reindeer herders in Sweden already find themselves to be “facing the limit of resilience” as a result of rapidly shifting and unstable weather, changing vegetation, and alterations in the freeze-thaw cycle, and climate change forecasts themselves contribute to stress and anxiety (Furberg et al., 2011).

It is already well documented that large-scale climate variability associated with the North Atlantic and Arctic Oscillations causes variation in growth, body size, survival, fecundity and population growth. This is generally thought to be due to changing grazing conditions (e.g. access to forage beneath snow in winter, or changes in nutritional quality of forage plants in summer) (Tyler et al., 2007).

8.4. Cultural heritage

The Arctic, in comparison to other European regions, has a relatively large proportion of indigenous people (Füssel et al., 2017), in Northern Sweden, the Sami people. The livelihood and culture of the Sami people is threatened by the impacts described above, since they closely depend on ecosystem services for their way of life dominated by hunting, fishing and reindeer herding. Due to these alterations, traditional skills and knowledge are getting lost (Furberg et al., 2011). Reindeer play a major role in the Sami spiritual life, old religions and language also maintain the Sami community and identity, providing structure to the year. However, reindeer-herding Sami are facing the limit of resilience and there is fear among the Sami people that they will be the last generation practicing traditional reindeer herding (Furberg et al., 2011). In addition, as climate change also shifts the distribution and seasonal occurrence of snow, the Sami are also in competition for space, caused by the exploitation of natural resources (Füssel et al., 2017).

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2.9. Sweden South

SWEDEN – Stockholm

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Summary

Sweden is experiencing an increase in temperature well above global average that manifests itself in a range of impacts for human and ecosystems already today.

If global warming exceeds the Paris Agreement limit of 1.5°C, Sweden, including Stockholm, will experience further increase in annual mean temperatures and high extreme temperatures together with an increase in annual precipitation. Ongoing sea level rise also increases flooding risks and coastal erosion. The thawing of permafrost in Northern Sweden threatens to accelerate climate change and leads to land degradation. Extreme weather events such as heat waves and heavy precipitations are expected to increase in frequency and intensity.

These changes lead to agricultural impacts, health impacts due to extreme heat and heat waves, wild-fires and the expansion of insect outbreak zones and high-risk seasons. Under current emission trajectories, Swedish children of today will spend more than half of their lives in a world warmer than 1.5°C above pre-industrial levels.

1. The IPCC Report's summary on Climate Impacts in Sweden

"Projected increases in temperature throughout Europe and increasing precipitation in Northern Europe" are expected, also in Sweden (IPCC, 2014a, p. 1270). This will lead to a wide range of impacts on society and its supporting sectors: "climate change is *likely* to affect human health in Europe" (IPCC, 2014a, p. 1272) and "will increase the likelihood of systemic failures across European countries caused by extreme climate events (medium confidence)"

(IPCC, 2014a, p. 1270). In addition, “sea level rise may damage European cultural heritage, including buildings, local industries, landscapes archaeological sites and iconic places (medium confidence)” (IPCC, 2014a, p. 1272).

2. Demographics and intergenerational aspects

Sweden has a population of about 10 million, out of which 22% are children under the age of 19 (Wittgenstein Centre for Demography and Global Human Capital, 2018). An average 16-year-old Swedish citizen is expected to live until the age of 90 (World Data Lab, 2019). The demographic estimates can be coupled with the projections of global mean temperature increases. Following the best estimate of the future temperature trajectory based on the Climate Action Tracker (2019), increase in the global mean temperature is expected to exceed 1.5°C around the year 2035 (model median), 2°C around 2055, and more than 3°C in 2100. Today’s Swedish 16-year-old has a 99% probability of being alive in 2035, 98% in 2055 and 8% in 2100. These children therefore have a high probability of experiencing a 2°C world and its respective climate change impacts.

3. Temperature increase

Between 1991 and 2018, Sweden's annual average temperature rose by 1.7°C compared to average temperatures in pre-industrial times (1861-1890) (Swedish Meteorological and Hydrological Institute, 2019c). Densely populated areas such as Stockholm, have shifted from a cold-temperate climate to a warm-temperate climate, reducing the frequency of winters with heavy snow (Climate Change Post, 2019).

For Northern Europe, the Fifth Assessment Report (AR5) (IPCC, 2014) states that there will be an increase in high temperature extremes (high confidence). On a European level, North-Eastern Europe and Scandinavia are the regions for which the strongest warming is projected in winter (*Figure 1*) (Füssel *et al.*, 2017).

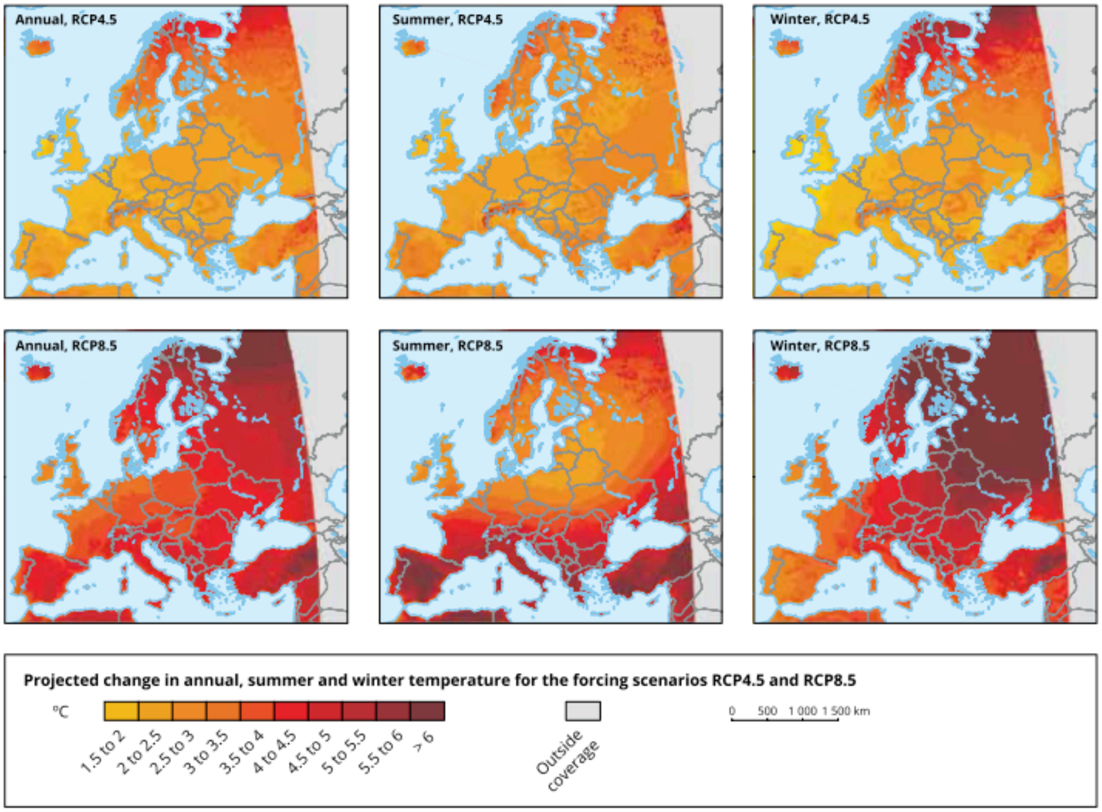


Figure 1: Projected changes in mean annual, summer and winter temperature in the period 2071-2100 for scenarios of 2.4°C expected temperature increase by 2100 (RCP4.5) and 4.3°C expected temperature increase by 2100 (RCP8.5) against the baseline period 1971-2000 (source: Füssel et al., 2017)

Figure 2 shows that with 1.5°C and 2°C of global warming, central and Northern Sweden will be most affected by an increase in annual mean temperatures.

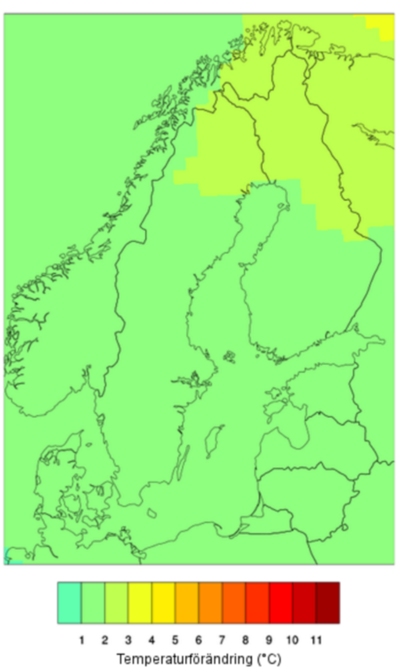
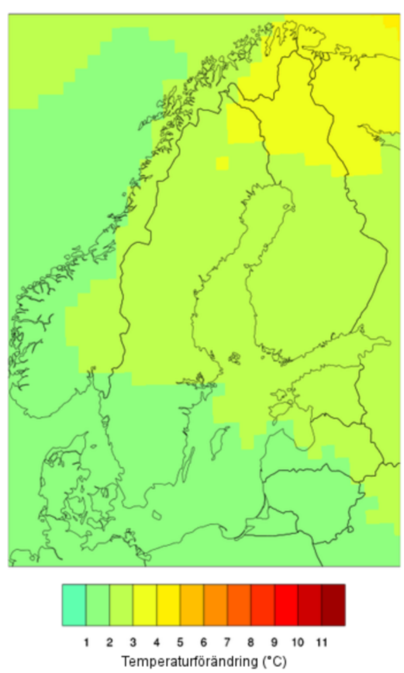
	
1.5°C global warming	2°C global warming

Figure 2: Change in annual mean temperature (°C) compared to 1971-2000 at the period for 1.5°C and 2°C global warming (Swedish Meteorological and Hydrological Institute, 2019b).

4. Precipitation

Annual precipitation over Northern Europe has increased by between 10 and 40% in the last century, in particular in winter (EEA, 2007; Füssel *et al.*, 2017). The calculated change in annual precipitation for Stockholm from 1960 to 2100 represented in *Figure 3*.

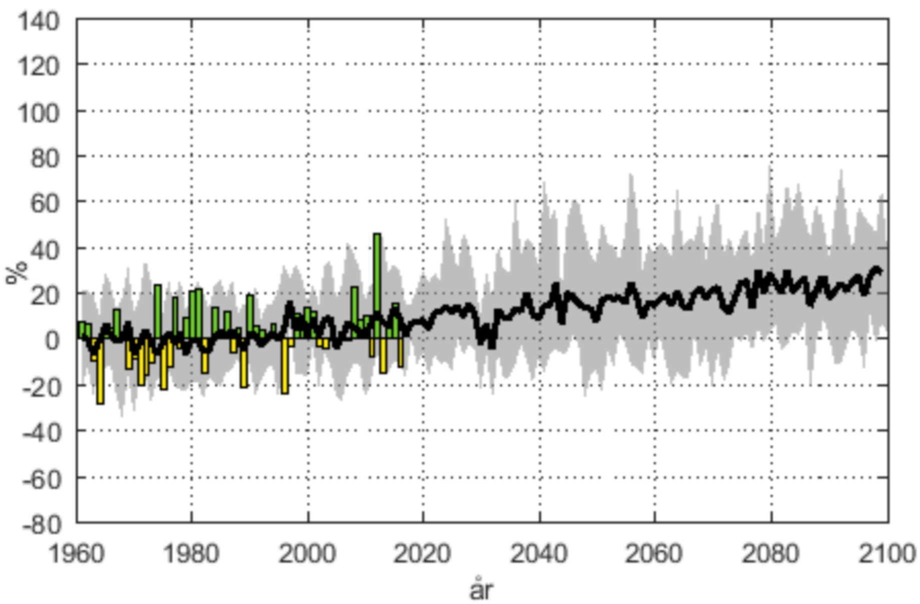


Figure 3: Calculated change in annual precipitation (%) in Stockholm County during the years 1961-2100 compared with normal (mean for 1961-1990). The bars show historic data from observations. The green bars show precipitation above normal and the yellow bars show precipitation below normal. The black line shows the ensemble mean of nine climate scenarios for a scenario of 4.3°C expected temperature increase by 2100 (RCP8.5). The grey field shows the range in variation between the highest and lowest value for the members of the ensemble (source: Swedish Meteorological and Hydrological Institute, 2019a)

Recent studies summarised in the IPCC Special Report on the Impacts of Global Warming of 1.5°C (SR1.5) have shown that 2°C of global warming was associated with a robust increase in mean precipitation over Northern Europe in winter and in summer (*Figure 4*) (Hoegh-Guldberg *et al.*, 2018). Precipitation changes reaching 20% have been projected for the 2°C scenario and are overall more pronounced than with 1.5°C of global warming. Limiting global warming to 1.5°C would limit risks of increases in heavy precipitation events that are projected to occur in Northern Europe (ibid). The latest report from the European Environment Agency (EEA) also states that there will be an increase in river flows, less snow and greater damage by winter storms in this region (Füssel *et al.*, 2017).

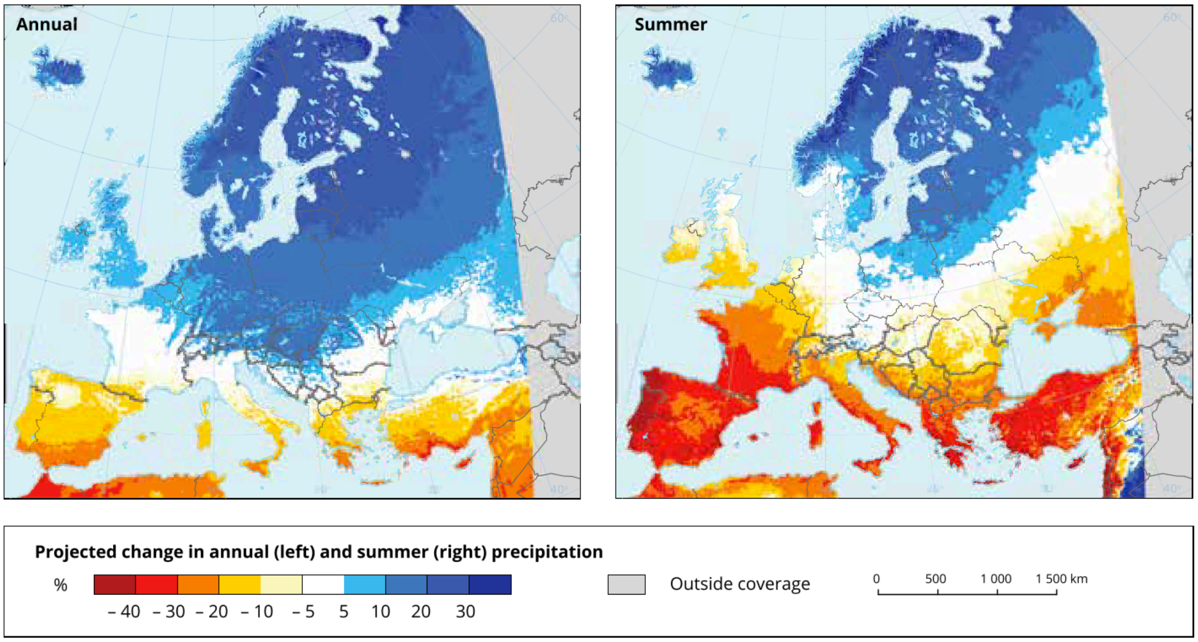


Figure 4: Projected change in annual and summer precipitation during 2071-2100, compared with the baseline period 1971-2000, for a scenario of 4.3°C expected temperature increase in 2100 (RCP8.5), based on many different regional climate model simulations (source: Füssel et al., 2017)

5. Sea level rise

Since 1886, the sea level has risen by just under 20 cm along the Swedish coasts, at an average rate of 1.5 mm per year (Hammarklint, 2009). There has been an increased rate in sea level rise during the last 30 years with an approximate 3mm sea level rise per year between 1980 and 2009. The sea level rise in Stockholm corresponds to the average Baltic sea level rise, due to Stockholm's unique oceanographic position close to the nodal line in the central Baltic Sea (ibid).

In general, coastal zones across Europe are facing an increasing risk of flooding from sea level rise and a possible increase in storm surges (Füssel *et al.*, 2017). According to the AR5 (IPCC, 2014b), global sea levels will continue to rise during the 21st century, very likely exceeding the current global observed rate of 2mm/year during 1971-2010 with the rate of rise of 8 to 16 mm/year from 2081 to 2100 with a scenario of expected 4.3°C global warming by 2100 (RCP8.5) (medium confidence). Sea level rise in the northern Baltic sea including Stockholm is below the global average mainly due to local geostatic processes, but the ongoing rise in sea level is leading to substantial coastal erosion where the land consists of easily eroded soils.

In addition, if the sea level rises, Sweden's third largest lake Mälaren and large freshwater reserve, providing fresh water for 2.5 million Swedes (including the population of Stockholm) is threatened to be contaminated with saltwater from the Baltic Sea. The fresh water in Mälaren and the salt water in the Baltic Sea are on different levels: Mälaren's surface currently averages 0.67 meters above the Baltic sea level (Ekopolitan, 2011). Already today, there is an immediate risk that Lake Mälaren will flood; future scenarios will increase the risk of flooding (The Local, 2004).

6. Permafrost thawing

Permafrost is found in lowland areas at high Northern latitudes in Sweden and is sensitive to climate change (Sannel *et al.*, 2018). Increasing temperatures lead to the thawing of permafrost, threatening to release carbon to the atmosphere (Gisnås *et al.*, 2017). It has a large impact on periglacial environments and results in a substantial positive feedback loops accelerating climate change (Hällberg, 2018). The IPCC has stated that "limiting global warming to 1.5°C rather than 2°C is projected to prevent the thawing over centuries of a permafrost area in the range of 1.5 to 2.5 million km^2 (medium confidence)" (Hoegh-Guldberg *et al.*, 2018). In addition, "climate change exacerbates land degradation, particularly in low-lying coastal areas, river deltas, drylands and in permafrost areas (high confidence)" (IPCC, 2019, p. 3). The thawing of permafrost therefore affects infrastructure and livelihoods.

7. Extreme weather events

Heavy precipitation events are projected to increase, leading to an increased risk of urban floods and associated impacts (Füssel *et al.*, 2017). For the Mälaren lake, for example, the inflow to the lake may be higher than the outflow capacity through the sluices that manage the water levels (WSP, 2015).

The frequency, intensity, duration and spatial extent of heat waves will increase with climate change (Oudin Åström *et al.*, 2013). The heatwaves in 2003, 2007 and 2010 in Europe illustrate the increase in the number of extreme temperature events (*Figure 6*). The temperatures in 2010 broke 20th and 21st century records, with an 80% probability the record heat would not have occurred without climate change (Oudin Åström *et al.*, 2013). Europe is projected to experience summers like 2016 every other year for 1.5°C warming and 9 out of 10 years for 2°C warming (King and Karoly, 2017). The 2018 monthly average temperature graph (*Figure 7*) shows the deviation of the expected average supporting the estimations of increasing heat waves.

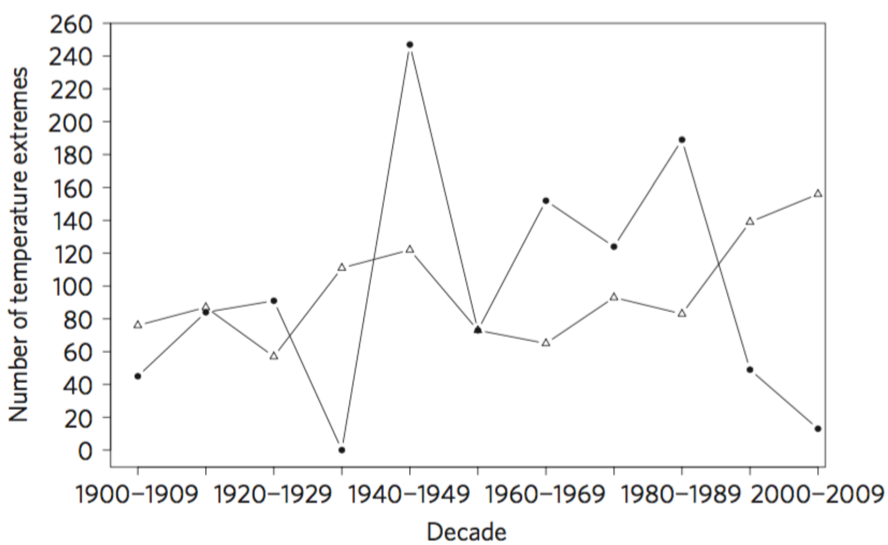


Figure 6: Number of cold/heat extremes per decade 1900-2009 in Stockholm, Sweden (filled circles, number of cold extremes; open triangles, number of heat extremes) (source: Oudin Åström et al., 2013)

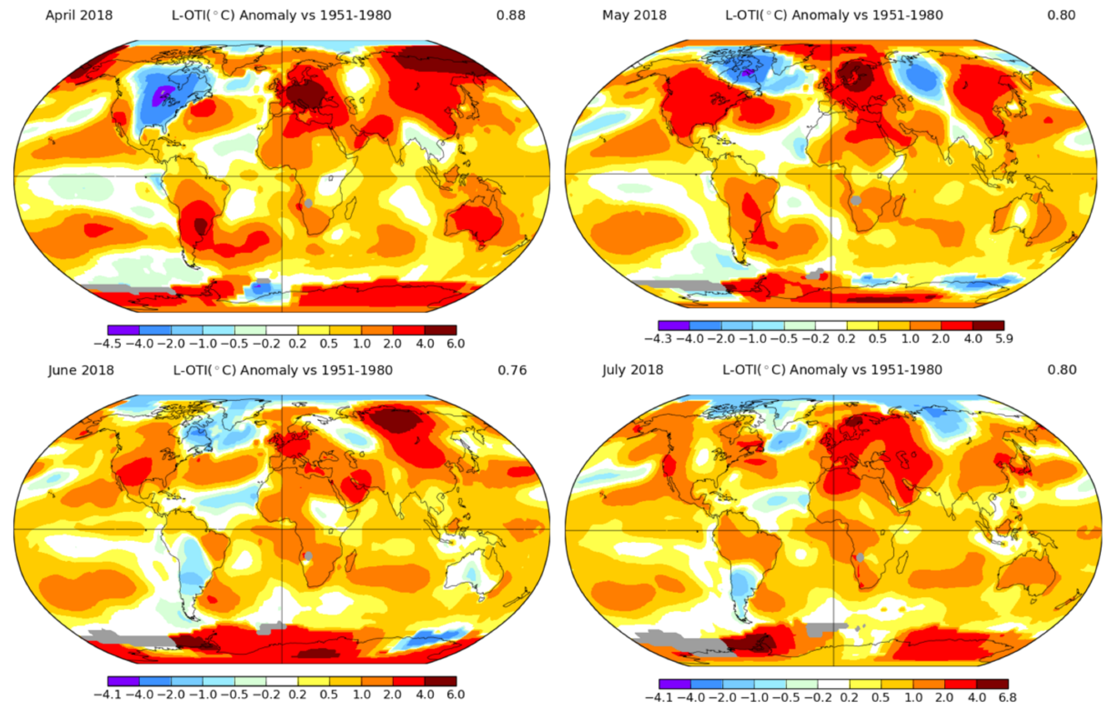


Figure 7: Deviation of monthly temperature averages between April and Juliy2018 in comparison of those between 1951-1980. (source: NASA: GISS Surface Temperature Analysis: https://data.giss.nasa.gov/gistemp/maps/)

Sweden is also exposed to wildfires (3000-4000 fires per year), the large forest areas that are sparsely populated result in large fires with considerable financial impacts (Ministry of the Environment and Energy, 2017). The fire risk is expected to increase together with the increase in temperature (Ou, 2017), expanding fire-prone areas and fire seasons (Füssel *et al.*, 2017).

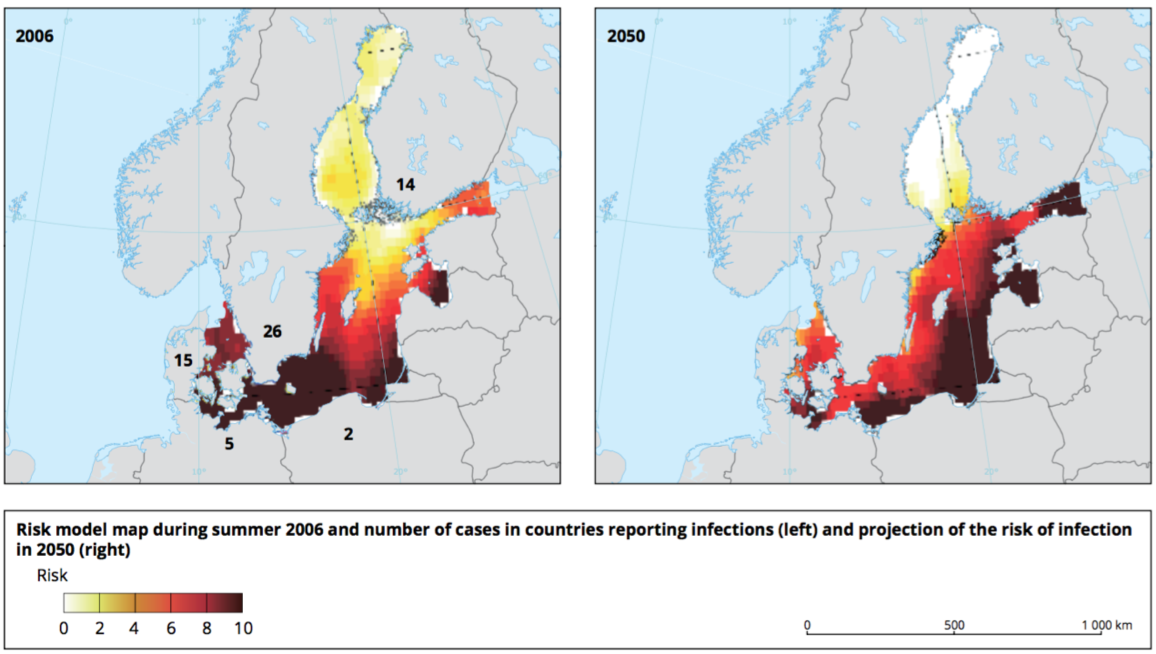
8. Sectoral impacts

8.1 Health

The AR5 (IPCC, 2014a) concluded that there is high to very high confidence that climate change will lead to greater risks of injuries, disease and death, owing to more intense heatwaves and fires, increased risks of undernutrition and consequences of reduced labour productivity in vulnerable populations in Europe.

The negative effects of heat and heat waves on human health cover the spectra from relatively mild symptoms such as heat syncope and fainting to more serious effects such as cramps, heat exhaustion and heat stroke. In Stockholm, mortality from heat extremes between 1980–2009 was double what would have occurred without climate change, due to more frequent events compared to the beginning of the 20th century and an increase in size of the vulnerable population (ageing population and other potentially vulnerable groups). Although temperature shifted towards warmer temperatures in the winter season, cold extremes occurred more frequently, contributing to a small increase of mortality during the winter months (Oudin Åström *et al.*, 2013).

A spread of insect outbreak zones has been observed in boreal forests with the greatest warming (Füssel *et al.*, 2017). Results of the Lancet study (Lindgren and Gustafson, 2001) suggest that milder climate in Sweden has contributed not only to increases in tick-borne encephalitis incidence, but also to increases in the incidence of other diseases transmitted by *Iricinus*, such as Lyme borreliosis and human erlichiosis. Both the SR1.5 (Hoegh-Guldberg *et al.*, 2018) and the EEA report (Füssel *et al.*, 2017) state that climate change negatively affects the emergence of water-borne diseases such as the Vibrio disease in Northern Europe. In fact, the percentage of coastal area suitable for Vibrio infections in the 2010s has increased by 24% compared with the 1980s baseline in the Baltic sea (Watts *et al.*, 2018). Similarly, the number of days suitable per year has almost doubled in the Baltic region, extending the highest risk season by around 5 weeks (ibid). *Figure 7* shows the projection of the risk of infection for 2050.



Note: Left: A risk model map during summer 2006 showing the number of cases in countries reporting infections. Right: A projection of the risk of infection in 2050.

Source: Adapted from Baker-Austin et al., 2012. © 2012 Macmillan Publishers Ltd. Reproduced with permission.

Figure 7: Current and projected risk of Vibrio infections in the Baltic Sea region (source: Füssel et al., 2017)

8.2 Agriculture

Increased frequency of extreme weather events is expected to increase the risk of crop losses and impose risks on livestock production (Füssel *et al.*, 2017). During dry years, water shortages pose serious challenges on a local and national level (including Stockholm). They result in competition between water supply, irrigation or sewage. Therefore, the agricultural sector will be affected by both the increased risk of flooding and drought (Ministry of the Environment and Energy, 2017).

8.3 Cultural heritage

Climate change and its impacts threatens both the livelihood and culture of the Sami, indigenous people of Northern Europe, who have a traditional lifestyle dominated by hunting, fishing and reindeer herding. Therefore, they closely depend on ecosystems for their way of life. However, lately, grazing lands have been shrinking, migration is becoming more difficult and traditional skills and knowledge are disappearing (Furberg, Evengå Rd and Nilsson, 2011).

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CLIMATE ANALYTICS

2.10. USA - Alaska

Country Profile: Akiak, Alaska (USA)

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Summary

Alaska is at the forefront of climate impacts already today: extreme temperatures and more wildfires, melting sea ice and glaciers, rising sea levels, increasing storm surges, increased precipitation and flooding, thawing permafrost, less predictable river conditions and shifting vegetation patterns. Alaska is warming much faster than the global average and these impacts will only intensify with increasing warming.

If global warming exceeds 1.5°C, key risks such as heat waves, glacier loss, sea ice melt, sea level rise, extreme precipitation and permafrost thawing will escalate rapidly. Under current emission trajectories, Alaska's children of today will spend more than half their lives in a world warmer than 1.5°C above pre-industrial levels.

Future impacts of climate change will strongly affect Alaska's Native societies, for which risks are assessed to become very high and exceeding their ability to adapt if warming exceeds 1.5°C. A number of native villages including Akiak are facing imminent flooding and erosion threats. Children in Alaska are vulnerable to psychological and social effects of climate change impacts such as loss of land and relocation including loss of cultural identity. At the same time, health impacts of climate change such as those associated with increases in wildfires in Alaska particularly affect children.

1. The IPCC Report's summary on Climate Impacts in Alaska

The increasing impacts of climate change have and will force indigenous communities in Alaska to relocate (IPCC, 2014). Climate change, for example, leads to increasing permafrost temperatures, which have increased in Alaska up to 3°C since the early 1980s (high confidence) (IPCC, 2014). Permafrost thawing leads to substantial decreases in soil strength, which impacts existing infrastructures such as transport and energy structures and their operation in Alaska (Hoegh-Guldberg et al., 2018). Moreover, Alaska is one of the regions with the largest increases in heavy precipitation events for 1.5°C to 2°C (Hoegh-Guldberg et al., 2018).

A combination of these impacts have already caused an increase in coastal and hillslope erosion, expansion of channel networks and landslides in Alaska since the 1980s (medium confidence), which have been directly attributed to climate change (IPCC, 2014 and IPCC et al., 2018). The seasonal changes and alterations in extreme events that result from climate change could reduce the reliance on indigenous knowledge, such as of the Yup'ik people in Akiak. This would strongly reduce the adaptive capacity of these indigenous communities in Alaska (medium evidence, medium agreement) (Hoegh-Guldberg et al., 2018).

2. Demographics and intergenerational aspects

The United States population is about 330 million, out of which 26% are children under the age of 19 (Wittgenstein Centre for Demography and Global Human Capital, 2018). An average 16-year-old US citizen, the petitioner's peer, is expected to live until the age of 87 (World Data Lab, 2019). The demographic estimates can be coupled with the projections of global mean temperature increases. Following the best estimate of the future temperature trajectory based on the Climate Action Tracker (Climate Analytics; Ecofys; New Climate Institute, 2019), increase in the global mean temperature is expected to exceed 1.5°C around the year 2035 (model median), 2°C around 2055, and more than 3°C in 2100. Today's US 16-year-old has a 99% probability of being alive in 2035, 95% in 2055 and 6% in 2100. Nearly all children in the United States therefore have a high probability of experiencing a 2°C world and the ensuing impacts, with a portion of them living to possibly experience an even higher warming.

Instead of the populations declining through out-migration in Alaska, many of the threatened places in Alaska are growing – raising both the potential costs of relocation and the number of people exposed to risks (Hamilton et al., 2016).

3. Temperature increases

Annual average air temperatures across Alaska have increased over the last 50 years at a rate more than twice the global average (very high confidence) (USGCRP, 2017). Alaska has already warmed by 1.8°C in the last 67 years, which is far above the mean global value of about 0.6°C per century (Wendler et al., 2017).

The average annual temperatures in Alaska are projected to increase by an additional 1.1°C to 2.2°C (2°F to 4°F) by 2050 (Chapin et al., 2014) - which will be experienced by 95% of todays 16-year old children from the US. If global warming is kept below 2°C, Alaska is still projected to warm by 3.3°C to 4.4°C (6°F to 8°F) in the north and 2.2°C to 3.3°C (4°F to 6°F) in the rest of the state by the end of the century. If global warming accelerates beyond 3°C, a temperature rise of 5.5°C to 6.6°C (10°F to 12°F) in the interior and 3.3°C to 4.4°C (6°F to 8°F) in the other parts of the state is expected (Chapin et al, 2014). The Fifth Assessment Report (AR5) also states that there will very likely be a large increase in hot days and a decrease in cool days in Alaska in the future (IPCC, 2014).

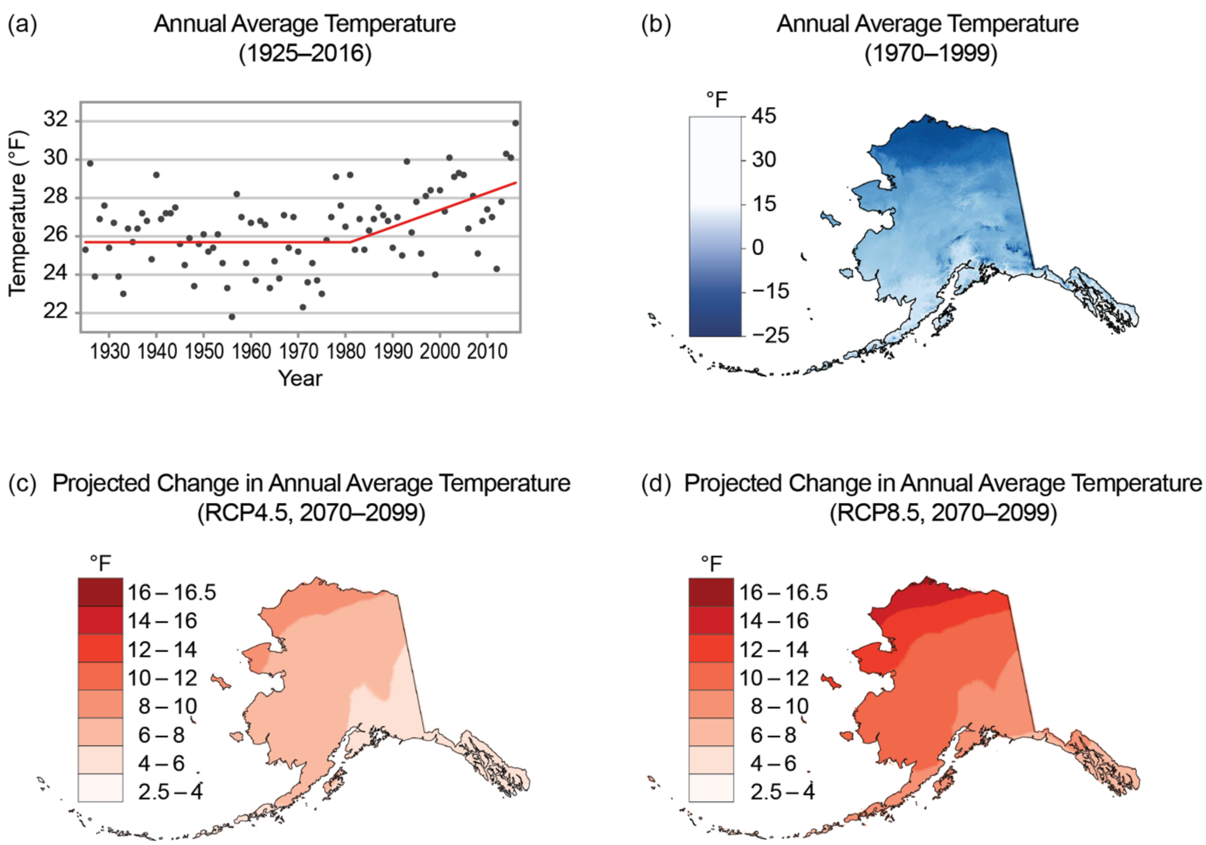

Figure 1: Observed and projected changes in annual average temperature (Fleming et al., 2018)

4. Precipitation

Precipitation increases were observed in all regions of Alaska (Wendler et al., 2017). The average total precipitation in the West, where Akiak is situated, has increased by 16% from 1946 to 2016 (Wendler et al., 2017). Extreme precipitation in summer, following a period of warm weather, has already caused increased glacial melting, which leads to flooding events and often results in additional driftwood movement (Mariana, 2008).

Alaska is one of the regions with the largest increases in heavy precipitation events for 1.5°C to 2°C (Hoegh-Guldberg et al., 2018). Under current emission trajectories, United States and thus

Alaskan children of today will spend more than half their lives in a world warmer than 1.5°C above pre-industrial levels.

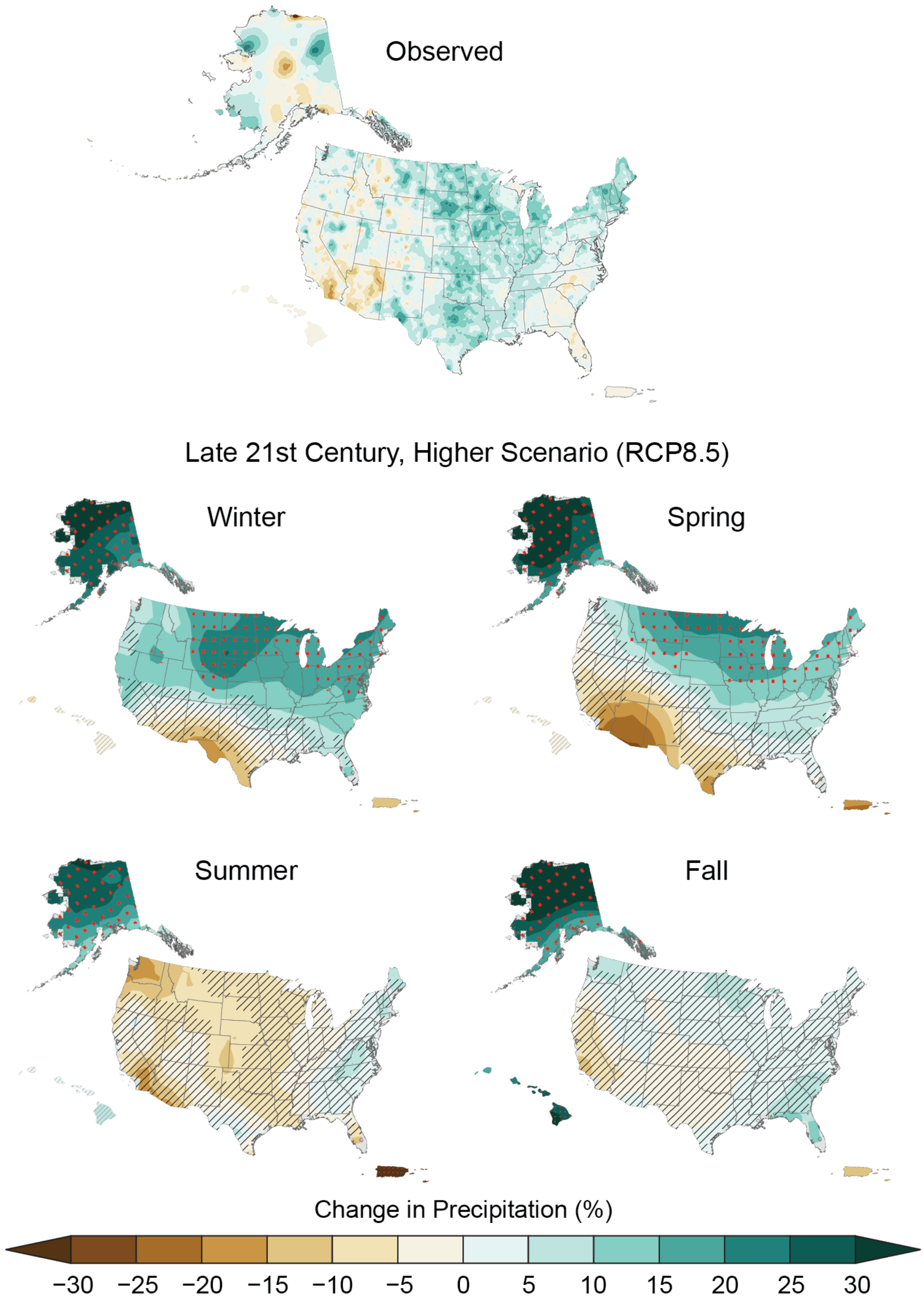

Figure 2: Observed and projected (RCP8.5 – 4.3°C by 2100) change in precipitation for the US (%) (Fleming et al., 2018)

5. Sea ice and glaciers

Annual arctic sea ice extent has decreased between 3.5% and 4.1% per decade since the early 1980s (Fleming et al., 2018). If warming exceeds 1.5°C, an ice-free Arctic in September is to be expected to occur frequently with drastic consequences for the ecosystems and livelihoods depending on sea ice (IPCC, 2018). The winter of 2017/2018 was the lowest winter-maximum areal sea-ice coverage on record (1980-2019) (Stabeno & Bell, 2019). The changes that were observed during the last few years "fall within changes predicted to occur before 2030 – ice retreating earlier and arriving later, resulting in an annual decrease in ice duration of 20-30 days" (Stabeno & Bell, 2019). Moreover, near-bottom ocean temperatures in 2018 were the warmest on record (the data is not yet available for 2019) (Stabeno & Bell, 2019).Sea ice is a relevant surface for numerous marine ecosystems that serve as an important source of carbon for grazers and provide food for people and ecosystems (Fleming et al., 2018). Moreover, organisms such as Arctic cod, polar bears and walruses depend on the sea ice and are directly affected by sea ice loss or thinning (Fleming et al., 2018).

The variability in ice extent has and is predicted to increase in the future, which directly impacts ecosystems "beyond the physics" and the coastal communities of Alaska that depend on sea ice for travels, hunting and to protect coastal infrastructure from winter storm surges (Stabeno & Bell, 2019).

Glaciers also "continue to melt in Alaska, with an estimated loss of 75 ± 11 gigatons (Gt) of ice volume per year from 1994 to 2013, 70% of which is coming from land-terminating glaciers; this rate is nearly double the 1962-2006 rate" (Fleming et al., 2018). With a temperature increase of 4.°C (RCP8.5) by 2100, mean annual runoff is expected to increase by 13% compared to historical conditions (Crumley et al., 2019). This could still be experienced by 6% of todays 16-year olds.

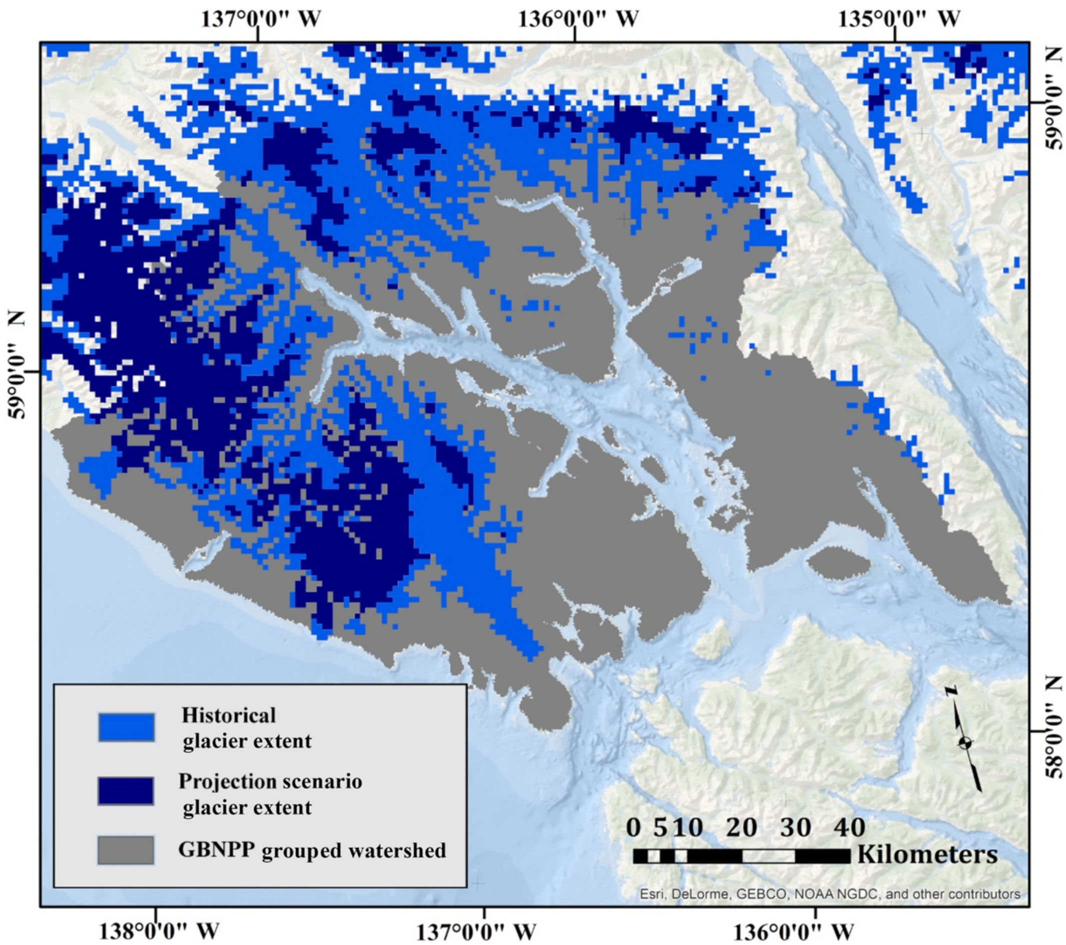

Figure 3: Changes in glacier extent for the historical period (1979-2015) and the projected scenario (2070-2099) using RCP8.5 (4.3°C increase by 2100) (Crumley et al., 2019)

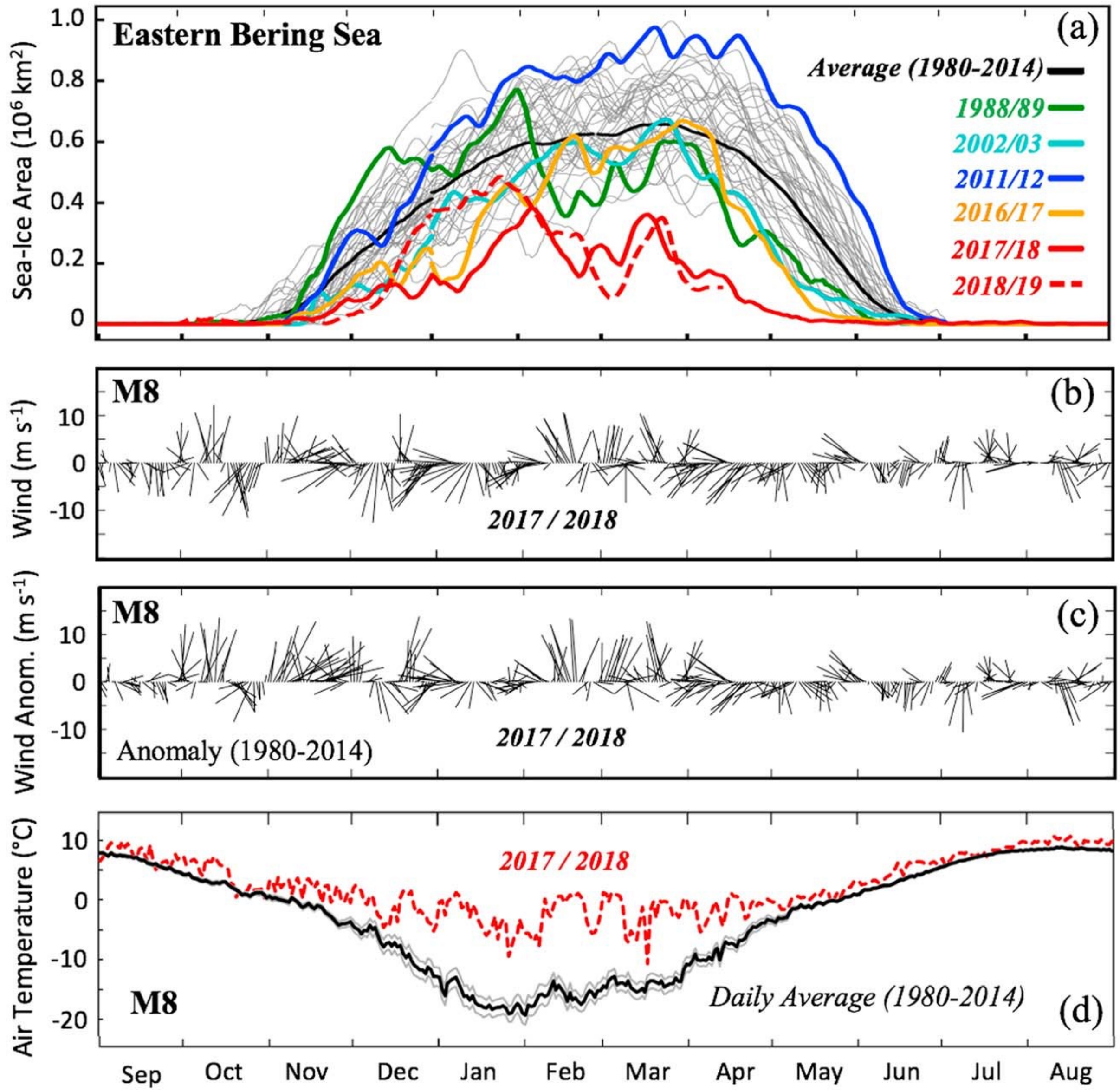

Figure 4: (a) Areal ice cover in the eastern Bering Sa for 1980-2019. (b) Wind and (c) wind anomalies for September 2017 to August 2018. (d) Atmospheric temperature (red) for 2017-2018 and daily mean for 1980-2014 (black) (Stabeno & Bell, 2019)

6. Sea level rise

For intermediate scenarios of climate change (2.4°C by 2100) mean maximum monthly sea levels are projected to increase from 1.8 m to 2.3 m by 2100 and would cause overbank flooding on a monthly basis in the Yukon-Kuskokwim Delta (Terrenzi et al., 2014). This is expected to cause salinization of ponds and meadows, damage vegetation, cause thermokarst and affect village infrastructure (Terenzi et al., 2014).

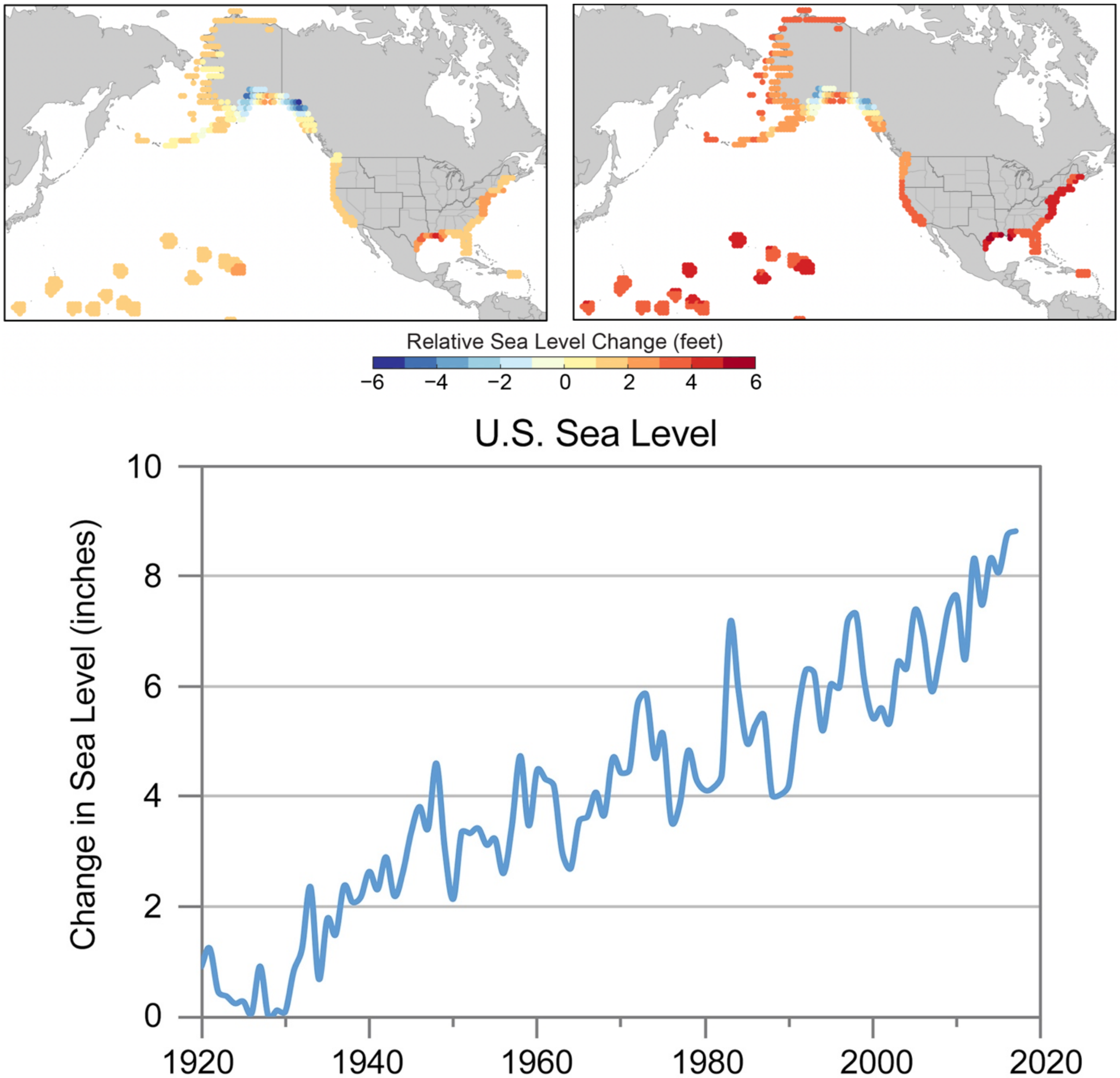

Figure 5: Observed and projected (left RCP4.5 – 2.4°C by 2100; right RCP8.5 – 4.3°C by 2100) changes in US sea level

7. Coastal erosion and coastal flooding

Coastal erosion can be facilitated by sea level rise, thawing permafrost, increasing river flows and reduced sea ice protection of shorelines (Hamilton et al., 2016). There has been an increase in coastal and hillslope erosion, expansion of channel networks and landslides in Alaska since the 1980s (medium confidence), which can be attributed to climate change (IPCC, 2014 and IPCC et al., 2018). These erosions threaten numerous riverine communities such as Akiak and affect their infrastructures (Melvin et al., 2017).

A number of coastal villages were and will be forced to resettle, which can lead to strong resistance in Alaskan native communities and can cost up to 1 million USD per person (Hoegh-

Guldberg et al., 2018). Akiak has been identified as one of the thirty-one Alaskan native villages facing immanent flooding and erosion threats (GAO, 2009).

More than 200 native villages have already been affected by some degree of coastal flooding and erosion, which have caused millions of dollars of property damage and have posed imminent threats to lives, homes and infrastructure (GAO, 2009). A local newspaper reported that in May 2019, there was massive erosion along the riverbank in Akiak (Kim, 2019). Around 30 meter of the river bank was lost within one day, leaving some houses only 3 meter away from the river. There is a growing concern that Akiak might turn into an island as it is surrounded by sloughs that might also be impacted by future erosion (Kim, 2019).

8. Permafrost thawing

Rising temperatures have increased permafrost thawing in most regions of Alaska since the 1980s (GAO, 2009). Permafrost thawing leads to substantial decreases in soil strength, which has impacted existing infrastructures such as transport and energy structures and their operation in Alaska (Hoegh-Guldberg et al., 2018). Other impacts, including an increase of flow speed rock glaciers and debris lobs, have also been related to permafrost changes (IPCC, 2018). Globally, the IPCC has found that "Limiting global warming to 1.5°C rather than 2°C is projected to prevent the thawing over centuries of a permafrost area in the range of 1.5 to 2.5 million km^2 *(medium confidence)*" (IPCC, 2018).

Finally, as large amounts of carbon dioxide and methane are stored in permafrost grounds *(high confidence)*, permafrost thawing has the potential to compromise the ability to limit global temperature increase (USGCRP, 2017). Permafrost thawing will increase with rising temperatures and can be directly attributed to climate change.

9. Wildfires

The thawing of permafrost may cause an increase in wildfires due to drying of land. Large forest fires in Alaska have increased since the early 1980s (high confidence) (USGCRP, 2017). Three out of the four big fire years, which indicates wildfires larger than around 8000 km^2, have occurred after the year 2000 (Fleming et al., 2018). Big forest fires are projected to further increase as the climate warms (medium confidence) (USGCRP, 2017). The area that will be affected by wildfires in 2100 is around 40.000 km^2 (98 million acres) under a scenario that leads to global warming by 2.4°C in 2100 and around 500.000 km^2 (120 million acres) under a scenario that leads to a global warming of 4.3°C by 2100 (Fleming et al., 2018).

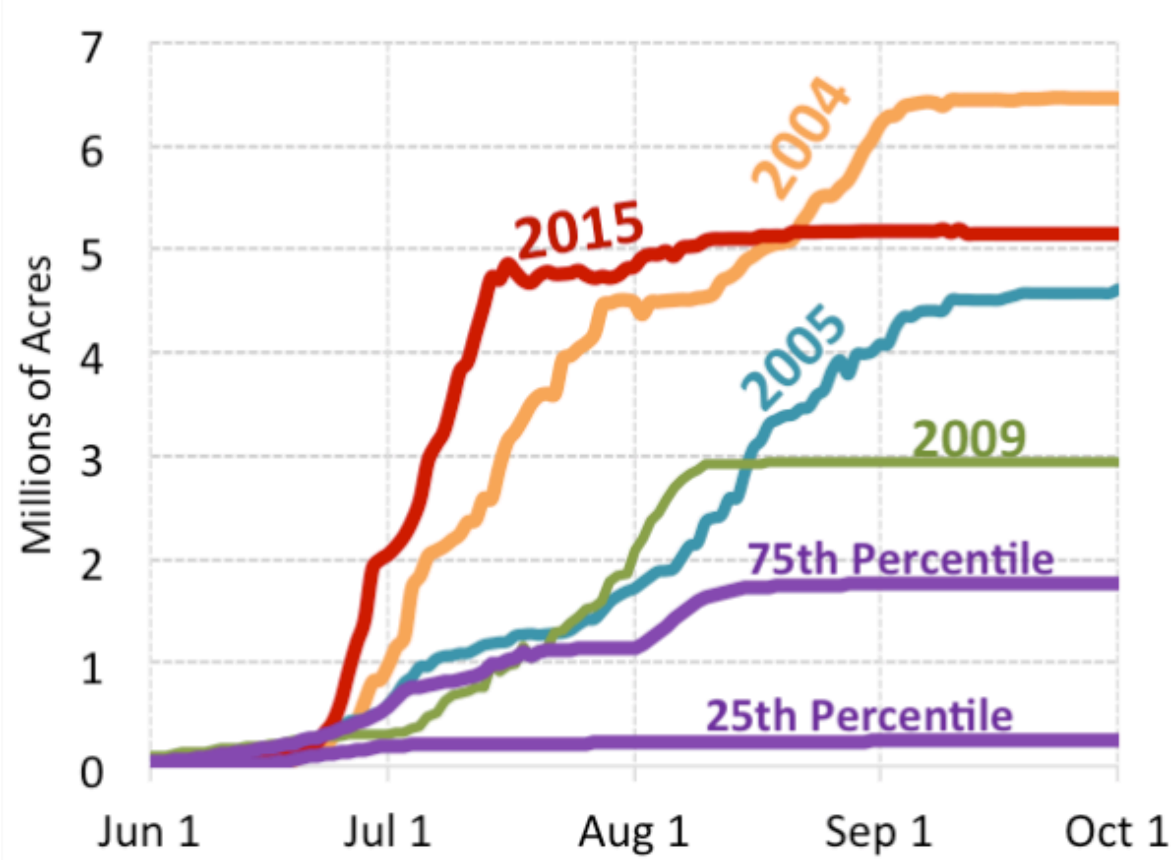

Figure 6: Averaged daily cumulative acres burned for specific recent above-normal fire years in Alaska compared to the climatological 25th and 75th percentile (1994-2015) levels (Partain et al., 2016)

10. Sectoral Impacts

10.1 Health

Climate change impacts such as floods and droughts can hinder water access, which leads to an increased risk of hospitalization from infectious diseases in Alaskan native communities (Cozzetto et al., 2013). Floods and storm damages also increased the "loss of vital food sources, disrupted traditional practices or relocation" (Fleming et al., 2018). Changing climate conditions have also increased hazards associated with subsistence activities among indigenous individuals (Hueffer et al., 2019). There is moreover an increasing risk and emergence of infectious diseases and insect vectors due to climate change, that have not been documented at high latitudes before (Hueffer et al., 2019). Moreover, the contamination of the Arctic and thus Alaskan food web by the industrialized world has endangered the health and wellbeing of indigenous people who depend on marine species (Hueffer et al., 2019).

Children are particularly vulnerable to climate driven increases in air pollution caused by wildfires (Fleming et al., 2018), which are predicted to increase with climate change.

There is also a growing concern of psychological and social effects on children caused by climate change, as community relocation can lead to a loss of cultural connections and adverse childhood experiences (Fleming et al., 2018). The uncertainty associated with these changes has mental health and may lead to substance abuse and self-harm (Fleming et al., 2018). Children are one of the most vulnerable groups to these climate-related changes (Fleming et al., 2018).

10.2 Agriculture and ocean acidification

As many of Alaskan natives, Akiak's Yup'ik children, rely on sea or river waters for hunting, fishing and gathering wild plants for food (GAO, 2009). Increasing temperatures, thinning artic summer sea ice and ocean acidification have strong impacts on ecological systems, such as an alteration in terrestrial and marine ecosystems, which lead to changing animal migration and distribution patterns (Hueffer et al., 2019). These patterns will negatively impact the subsistence practices by indigenous people with increasing climate change (Hueffer et al., 2019).

Ocean acidification, which is accelerated by warming temperatures, negatively affects organisms such as corals and affects the growth, behaviour and survival of relevant species in Alaska (e.g. pink salmon). For increasing global temperatures by 4.3°C in 2100, the Chukchi Sea is expected to cross the ocean acidification threshold (aragonite saturation state) around 2030, whereas the Bering Sea will likely cross the threshold around 2065 (Fleming et al., 2018). This would strongly limit "the ability of many marine species to form shells or skeletons" (Fleming et al., 2018).

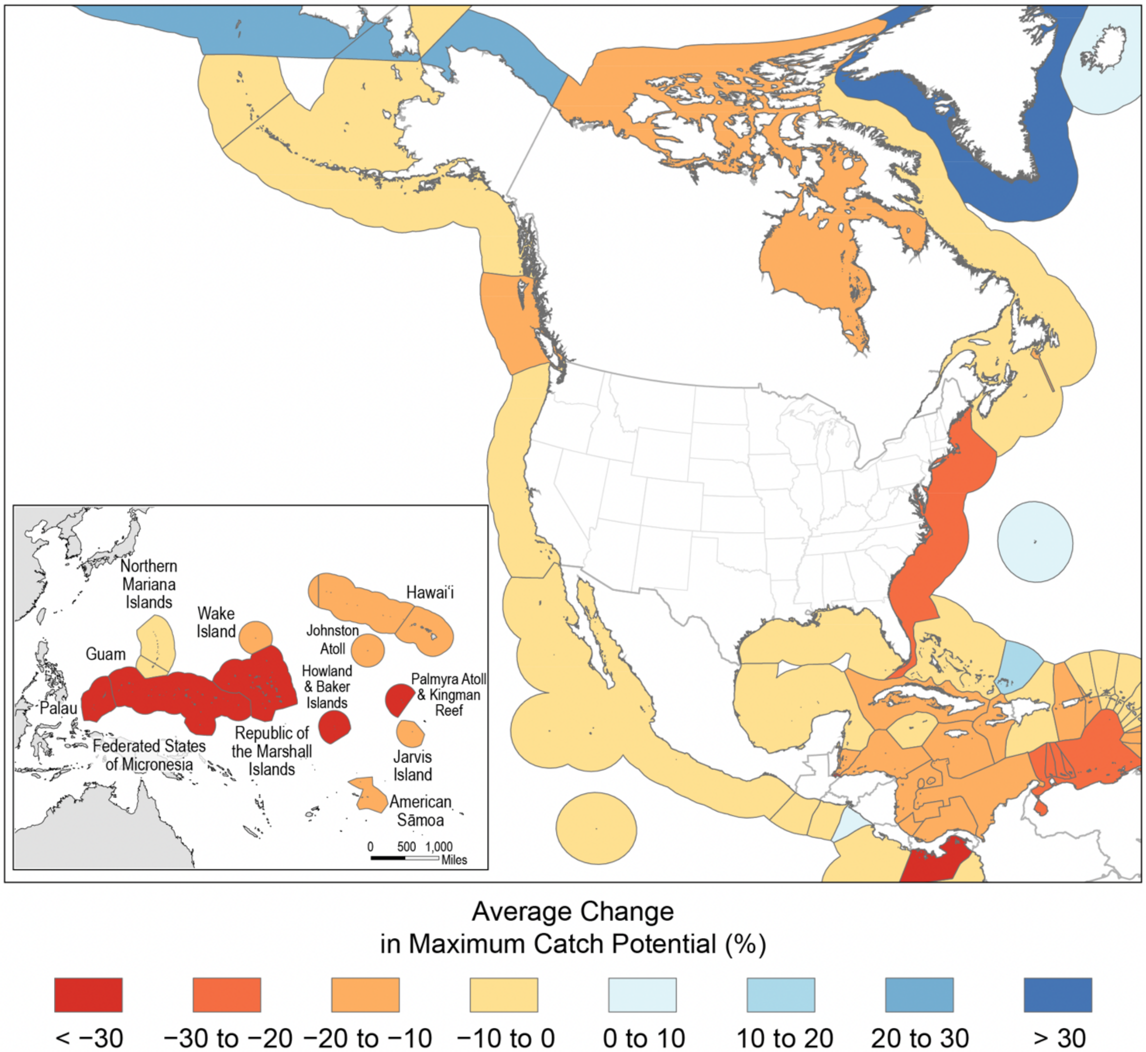

Figure 7: Average change in maximum catch potential in the US (Wendler et al., 2017)

10.3 Infrastructure

Climate change impacts, such as permafrost thawing, threatens homes and infrastructural prerequisites in villages such as Akiak (GAO, 2009). The economic impacts of climate change on infrastructure are projected at 4.2 billion USD to 5.5 billion USD from 2015 to 2099 (Hoegh-Guldberg et al., 2018). Adaptation measures would halve these estimates (Hoegh-Guldberg et al., 2018).

10.4 Cultural heritage and loss of livelihoods

Climate change and its subsequent seasonal changes and changes in extreme events could reduce the reliance on indigenous knowledge, such as of the Yup'ik people in Akiak. This would strongly reduce the adaptive capacity of these indigenous communities in Alaska (medium evidence, medium agreement) (Hoegh-Guldberg et al., 2018). Up until now, the Alaskan Inuit knowledge has ensured the source of food for hunters and reduced various risks (Hoegh-

Guldberg et al., 2018). Climate change will, however, alter subsistence activities and physical settings of Alaskan Native villages such as hunting, fishing and gathering on e.g. shore-fast ice.

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3. Key drivers of global climate change (including discussion of China, US, EU, and India)

CLIMATE ANALYTICS

Key Drivers of Global Climate Change

Table of Contents

Summary

--- Global greenhouse gases (GHG) emitted in 2016, led to the largest annual increase in global concentration of atmospheric CO_2 on record.

---- Nearly three fifths of these total GHG in 2016 were emitted by the top four emitting entities, China, the US, the EU and India.

---- Many countries continue to fall short in their policy ambition and emission reduction targets and this must be addressed in order to keep warming below the imperative 1.5°C

----China: China is the world's largest emitter, and its targets and policies have been rated as highly insufficient, as they are found to be consistent with warming between 3°C and 4°C if all other countries followed a similar approach.

---- United States: The US is one of the top CO_2 emitters in the world on a per capita basis at two and a half times the average of G20 countries in 2015 (Climate Transparency Initiative, 2018), and is currently planning on withdrawing from the Paris Agreement at the end of 2020, the only country with an intention to do so. If this intention is followed through with, it will go completely against significant global progress towards climate change mitigation.

----European Union: The EU's emissions are not consistent with what is required to keep warming to 1.5°C, but rather is consistent with warming between 2°C to 3°C.

----India: Given its growing population and development needs, with almost a fifth of the population still lacking access to electricity, how India chooses to address the growing energy demand has important implications for the global efforts to achieve the Paris Agreement goal.

Global greenhouse gases (GHG) emitted in 2016 totaled 47 $GtCO_2e$, leading to the largest annual increase in global concentration of atmospheric CO_2 on record (Gütschow et al., 2016; World Meteorological Organization, 2017). Nearly three fifths of these total GHG in 2016 (56.5%) were emitted by the top four emitting entities, China, the US, the EU and India (Gütschow et al., 2016). Since then, emissions have continued to rise, with global emissions in 2018 growing at their fastest pace since 2011, and energy emissions reaching a historic high, with China, India and the US accounting for 85% of the net 2018 GHG emissions increase from energy (Climate Action Tracker, 2019a). This increasing emissions trajectory stands in stark contrast to what is needed to keep warming at or below 1.5°C, which is for global emissions to halve by 2030 (Climate Action Tracker, 2019a).

While many countries are on track to meet their Nationally Determined Contributions (NDCs) that outline their current emission reduction commitments to 2030 under the Paris Agreement, overall these commitments amount to a critical deficit in ambition required to limit warming to 1.5°C, with unconditional pledges and targets leading to warming of 3.0°C at the end of the century (Climate Action Tracker, 2018a). Many countries continue to fall short in their policy ambition and emission reduction targets, leading to an even higher deficit as current policies would lead to an expected warming of 3.3°C. The level of ambition and action needs to be stepped up considerably in order to keep warming below the 1.5°C limit as required by the Paris Agreement (Climate Action Tracker, 2019a).

While climate action and ambition needs to increase in virtually all countries in order to close the global emissions gap between current emissions trends and emissions pathway compatible with the Paris Agreement, this briefing will focus on the four biggest emitters: China, the US, the EU and India, who have a critical role to play.

1. China

With its large population, China is the world's largest GHG emitter, contributing 26.3% of global emissions in 2016, almost double the next largest emitter in that year, the US (Gütschow et al., 2016). However, per capita emissions levels are below the global average. While China's annual GHG emissions levelled out between 2013 and 2016, total CO_2 emissions have increased in both subsequent years, rising 2.3% year-on-year (y-o-y) in 2018 (Climate Action Tracker, 2019c; Korsbakken, Andrew, & Peters, 2019). Total emissions (excl. LULUCF) are expected to continue rising to 2020 and beyond to 2030, reaching between 14.4 and 15.8 $GtCO_2e$/yr in 2030. This is an increase in total GHG emissions of 11%-21% above 2017 levels by 2030 (Climate Action Tracker, 2019).

China is currenty on track to meet its NDC requiring a peaking of emissions by 2030 and a reduction in carbon intensity of GDP by 60-65% below 2005 levels by 2030 (Climate Action Tracker, 2019). These targets and policies have been rated as highly insufficient by the Climate Action Tracker (2019), as they are found to be consistent with warming between 3°C and 4°C if all other countries followed a similar approach. These targets are not ambitious enough to limit warming to below 2°C, let alone to 1.5°C as required under the Paris Agreement, unless other countries make much deeper reductions at comparably greater effort. China must therefore substantially increase the ambition of its NDC and climate related policies.

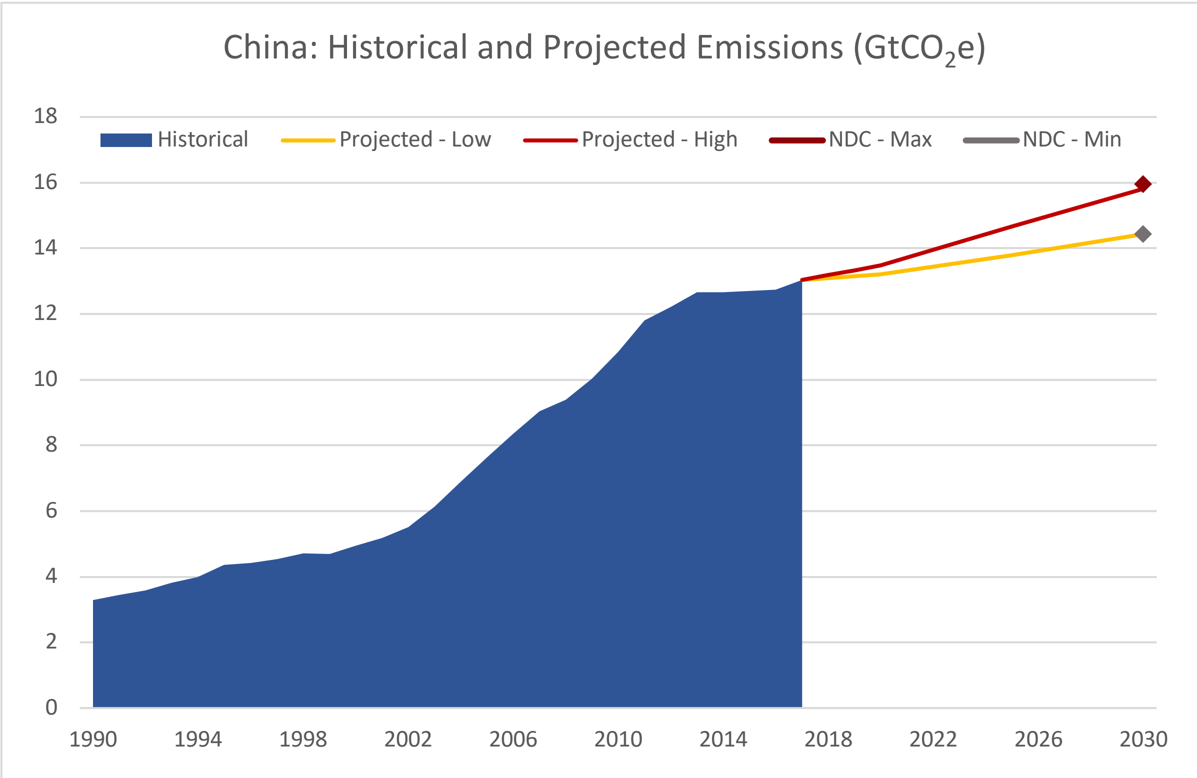

Table 1. Chinese Emissions and Emission Targets
Source: (Climate Action Tracker, 2019a)

Sectoral Emissions and Policy Gaps

Energy:

China's energy sector is heavily dependent on coal power, with the latest data from 2016 showing it constituted 65% of the primary energy supply, down from 2011's peak of 69% (IEA, 2018). This is projected to decrease to 55% by 2030 based on current policies (IEA, 2017). In 2016, China also accounted for 51% of the world's primary coal energy supply (IEA, 2018). Although coal consumption in China peaked in 2013, it has risen in the last two years due to increased electricity demand and heightened heavy industrial output (Feng, 2018).

China's energy related CO_2 emissions are projected to be roughly 70% of China's total GHG in 2020 (IEA, 2017), meaning increasing the ambition of energy policy is imperative. However, the abrupt reduction of subsidies for solar projects and the lifting of a ban on new coal-fired power plants in 2018 are sending Chinese energy policy in the wrong direction. In 2018, China began construction on 28 GW of new coal-fired capacity, bringing total coal capacity under construction to 235 GW. The IPCC Special Report on 1.5°C found that coal needs to exit the power sector by 2050 globally if warming is to be limited to this level (IPCC, 2018), and efforts by China to reduce coal in the next few years will be critical to this. In global cost-optimal, Paris Agreement-consistent pathways, China phases out coal by 2040 (Climate Analytics, 2016).

Industry:

Industry accounted for an estimated 30% of energy-related CO_2 emissions in China in 2017, and increased industrial output was primarily responsible for the overall CO_2 emission increase in 2018 (International Energy Agency, 2018). China has committed to modernising and improving the quality of its industrial sector, implementing an industrial energy saving standard in 2017 which aims to align 80% of China's energy efficiency standards with international standards by 2020. Between 2012 and 2017, 177 compulsory energy consumption and efficiency standards were published, which exist alongside China's Industrial Green Development Plan that promotes green manufacturing and supply chains (Gallagher, Zhang, Orvis, Rissman, & Liu, 2019).

Efforts to monitor and reduce non-CO_2 gases such as hydrofluorocarbons (HFCs) began in 2014, which in 2012 accounted for 1.6% of total Chinese GHG emissions (UNFCCC, 2018), however widespread use of CFC-11, a globally banned ozone depleting substance that is a GHG 4,000 times more potent than CO_2 was reported recently (Environmental Investigation Agency, 2018). Such non-CO_2 GHG emissions are much more potent than CO_2 emissions and are expected to constitute 23-25% of China's total GHG emissions by 2030. While the importance of addressing these emissions is acknowledged in their NDC, greater effort is needed to control projected emission increases.

Transport:

China has seen rapid progress in the uptake of electric vehicles (EVs), with over 1.1 million sold in 2018 (Irle, 2019), constituting a 4.2% market share and meeting the goal of one million vehicles by 2020 two years early. This is largely due to the implementation of subsidies and tax breaks. As part of China's broader industrial policy, a fuel economy standard of 5L/100km is in place for new vehicles from 2020 (Gallagher et al., 2019).

2. US

The US is the world's second largest emitter of GHG, contributing 13.5% of global emissions in 2016 (Gütschow et al., 2016), while also one of the world's top GHG emitters in the world on a per capita basis, at two and a half times the average of all G20 countries in 2015 (Climate Transparency Initiative, 2018). While US GHG emissions peaked in 2007, they subsequently rose in 2010, 2013, and 2014 and preliminary evidence shows them rising in 2018 after three consecutive years of declines (Houser, Pitt, & Hess, 2019). Given the current administration's campaign to rollback US federal climate policy, emissions could potentially increase by up to 400 $MtCO_2e$ over what they were projected to be before President Trump took office (Climate Action Tracker, 2019a). Projected emissions are not expected to fall back below 2017 levels before either 2022 or 2023 under current policies with only minor emission reductions expected to 2030. Emissions are expected to reach between 6.3 and 6.4 $GtCO_2e$ by 2025 and between 6.2 and 6.3 $GtCO_2e$ by 2030 under current policies (Climate Action Tracker, 2019b). This level of emissions is equivalent or slightly below (0-2%) 1990 levels and only 13 to 15% below 2005 levels.

The US is currently planning on withdrawing from the Paris Agreement at the end of 2020, the only country with an intention to do so. If this intention is followed through with, it will go completely against significant progress towards climate change mitigation, as it will not have any official emission reduction targets. The US is in any case not on track to meet its existing NDC of a 26-28% reduction below 2005 levels by 2025. This commitment already falls short of putting the US on an emissions pathway compatible with limiting warming to 1.5°C, being compatible instead with warming between 2°C to 3°C, implying that policies would need to be more robust than even those that are currently being rolled back or planned to be rolled back (Climate Action Tracker, 2019b).

While at the subnational level, some cities, states, businesses, and other organisations are adopting mitigation targets, recent analysis suggests that even if these targets were fully implemented, they would not be enough to meet the NDC targets, resulting in emissions that are 17–24% below 2005 levels in 2025 (incl. LULUCF) (Climate Action Tracker, 2019b).

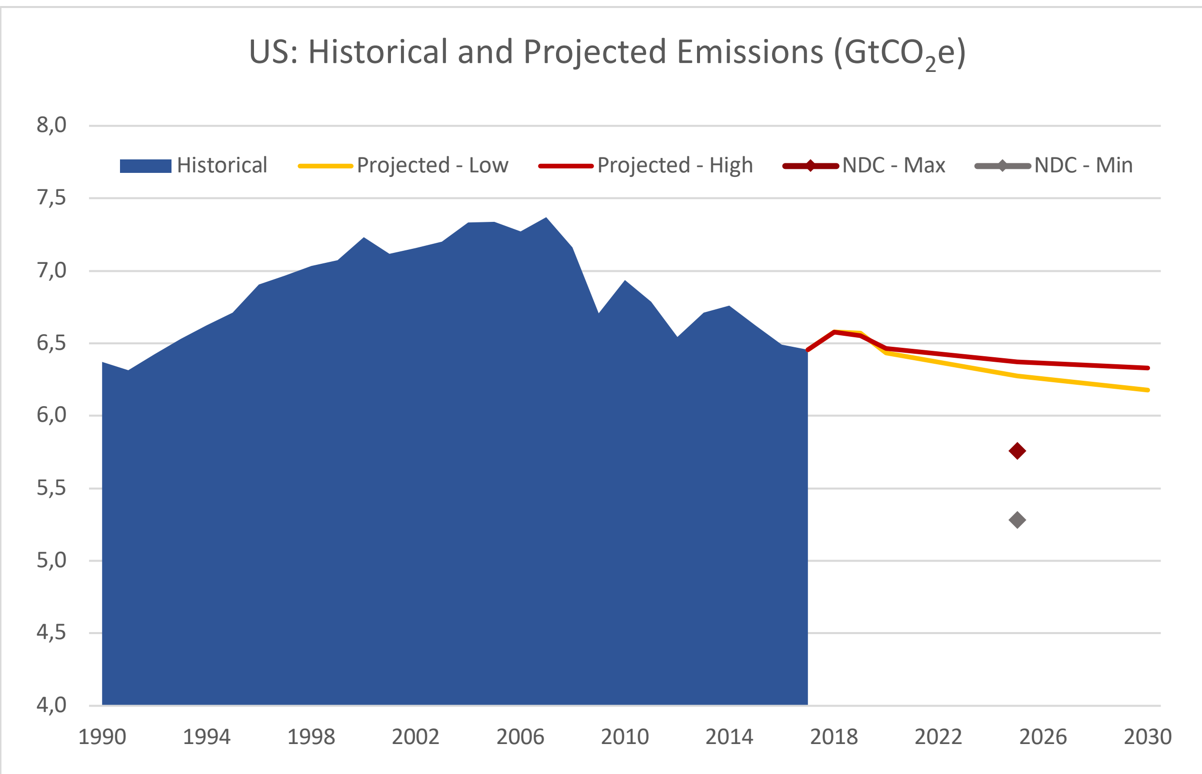

Table 2. US Emissions and Emission Targets
Source: (Climate Action Tracker, 2019a)

Sectoral Emissions and Policy Gaps

Energy:

The emissions intensity of US electricity generation has decreased from its 1997 peak of 639gCO_2/kWh to 427gCO_2/kWh in 2018, thanks in part to an almost doubling of the percentage of renewables from 1990 levels to 21.56% in 2018 (US Department of Energy, 2019a). In 2018 the US became the world's largest producer of crude oil (US.Energy Information Administration, 2018), while LNG exports grew by 53% in 2018 (US Department of Energy, 2019b). Rapidly increasing levels of fracking activity brings with it the threat of higher levels of fugitive methane emissions, with methane gas a much more potent GHG than CO_2 (UNFCCC, 2014). To meet its current NDC, the US would have had to implement the Clean Power Plan (CPP) and the Obama administration`s Climate Action Plan or equivalent measures (Climate Action Tracker, 2019b).

The Trump administration's proposed replacement for the CPP, the Affordable Clean Energy (ACE) rule is a significant departure from the CPP and is likely to result in emissions that are up to 81 $MtCO_2e$ higher in 2025 and 212 $MtCO_2e$ higher in 2030 than if the CPP had been fully implemented (U.S. Energy Information Administration, 2018a). The Trump Administration has also proposed weakening emissions standards for new coal-fired power plants from the 2015 standard of 635 gCO-2/kWh to between 860 and 1000 gCO2/kWh depending on the type of plant (U.S. Energy Information Administration, 2018b).

Industry

The intended prohibition of the use of certain HFCs in industry under the Obama administration's Significant New Alternatives Policy (SNAP) was subsequently blocked by a court ruling (U.S. Environmental Protection Agency, 2018). This means the estimated 78-101 $MtCO_2e$/yr reduction by 2030 that was expected under this policy is unlikely to be achieved (U.S. Environmental Protection Agency, 2015). Meeting the Kigali Amendment of the Montreal Protocol which seeks to eliminate the use of such gases would have required more stringent reductions than those expected under the SNAP programme.

Transport:

While the US has made progress on mandating higher fuel efficiency standards in recent years, these are set to be weakened under a current EPA proposal to freeze them at 2020 levels (U.S. Environmental Protection Agency, Administration, & U.S. National Highway Safety Administration, 2018). This is expected to increase emissions by 22 MtCO2e/yr in 2025 and 76 MtCO2e/yr in 2030 (Climate Action Tracker, 2017). Subsidies to encourage the purchase of EVs have been rolled back over time which will put pressure on the current strong upward trajectory of US EV sales.

3. EU

The EU is the world`s third largest GHG emitter contributing 9.4% of global GHG emissions in 2016 (Gütschow et al., 2016). While EU GHG emissions have been generally trending down since 1990, they were more or less stable between 2014 and 2017, suggesting that the EU needs to increase its efforts to continue its downward emissions trajectory. There have been positive recent policy developments which suggest this is happening. The reform of the EU ETS finalised in 2018 has already led to an increase in the price of allowances. In 2018 the EU adopted new renewable energy and energy efficiency directives with the goals of increasing the share of renewables to 32% and lowering energy demand by 32.5%, both by 2030 (European Parliament and the Council of the European Union, 2018b, 2018c). Currently the EU is also discussing the adoption of the long-term strategy for climate action with the goal of emissions neutrality by 2030 (European Commission, 2018). EU emissions are expected to reach between 2.94 and 3.92 $GtCO_2e$ by 2030 with its NDC falling in the middle of this projection range at 3.39 $GtCO_2e$ by 2030 (Climate Action Tracker, 2019b).

The EU's NDC of at least a 40% GHG emission reduction below 1990 levels by 2030 is not consistent with what is required to keep warming to 1.5°C without requiring other countries to compensate with greater levels of ambition and is instead consistent with warming between 2°C to 3°C. Policies already adopted will result in an emission reduction of around 48% (Climate Action Tracker, 2019a). Thus it is imperative for the EU to go beyond the NDC. Furthermore, to increase planning security and facilitate development of new low carbon solutions, the EU needs to adopt the goal of emissions neutrality by the middle of the century.

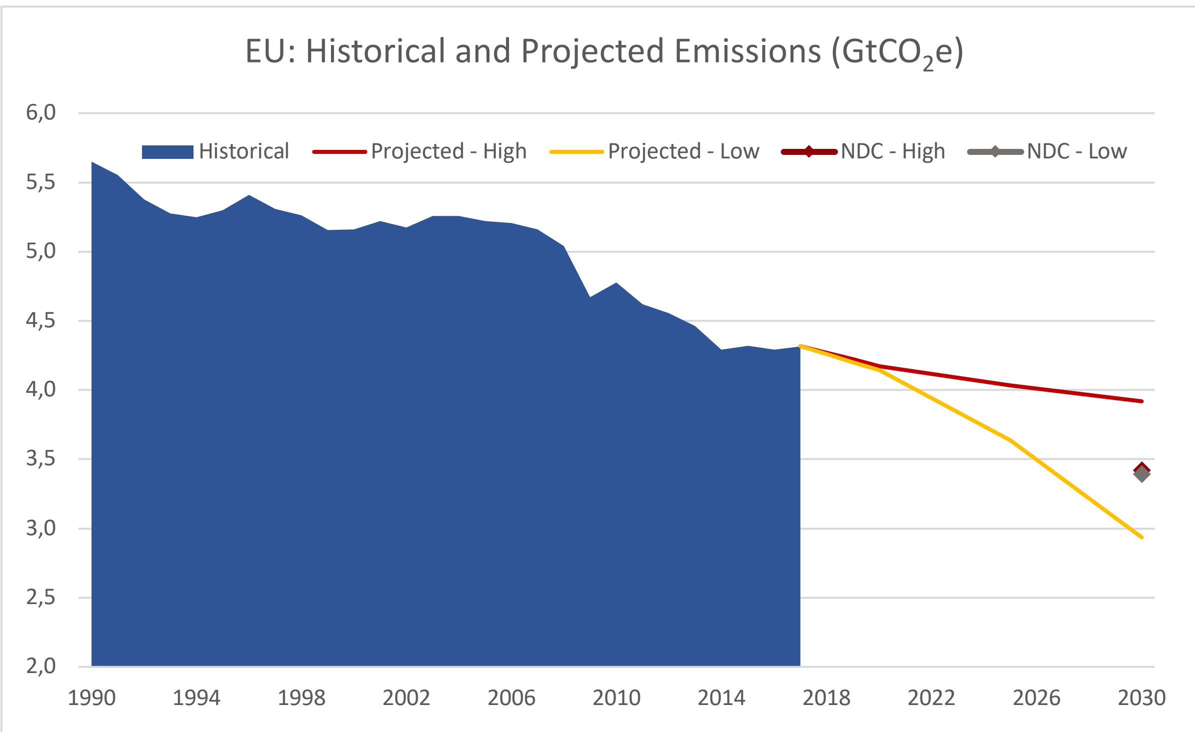

Table 3. EU Emissions and Emission Targets
Source: (Climate Action Tracker, 2019a)

Sectoral Emissions and Policy Gaps

Energy:

The EU has made significant strides recently to increase the ambition of its targets relating to the energy sector. The 2018 adoption of the Renewable Energy Directive sets a binding goal of generating 32% of the EU's gross final energy consumption from renewable sources by 2030, while the Energy Efficiency Directive, adopted at the same time, aims to increase energy efficiency by 32.5% by 2030. Coal phase-out policies are currently being discussed in a number of countries with some already producing target dates. While the renewable energy and energy efficiency goals would result in emissions reduction by 48%, in combination with the coal phase-out plans emissions would fall by at least 50% (Sandbag, 2019).

The National Energy and Climate Plans (NECPs) of EU member states show that more action and ambition is needed in this sector for the EU as a whole, with some member States lagging significantly behind (Flisowska & Moore, 2019). An EU level coal phase-out strategy, however, could facilitate a timely transition away from coal across the continent, and make a large contribution to GHG emission reductions. Furthermore, EU member states are increasing their support for the development of gas infrastructure that will increase EU dependency on energy imports and lock-in the energy sector in a carbon intensive pathway. Abolishing these plans and accelerating the development of renewables and smart solutions to adapt the grid to a 100% share of renewables is essential to meet the emissions neutrality goal.

Industry:

The strengthening of the EU ETS in 2018 will have a significant impact on emission reductions from industry, with many emission intensive sectors covered by the scheme. The 2010 Industrial Emissions Directive works to reduce emissions from those large industrial installations not covered by the ETS, by requiring them to prove they are operating according to the Best Available Techniques (European Parliament and the Council of the European Union, 2010).

Transport:

The transport sector – as well as the building and agriculture sectors – is covered by the Effort Sharing Regulation, which stipulates emissions reduction by 30% by 2030 in comparison to 2005. This goal is divided between EU member states depending on the GDP per capita (European Parliament and the Council of the European Union, 2018d). The transport sector in the EU has seen a large increase in emissions above 1990 levels up until 2017 (28% higher), with the aviation sector in particular doubling in emissions over this time (European Environment Agency, 2018). While aviation is included in the EU ETS, extra-EU flights have been exempted from the obligation to submit emissions allowances and intra-EU flights continue to benefit from Value Added Tax exemptions. Further measures must be taken accordingly to address the rising contribution aviation makes to total emissions. The EU Sustainable Transport Strategy has not been updated since 2009, while the European Investment Bank’s transport policy dates from 2011; both need to be updated to catalyse deepening emission cuts. With multiple policy tools in place to address the transport sector, including emission standards for vehicles and mandates for low carbon vehicles, there is great scope for ratcheting up emission reduction potential from this sector.

Buildings:

The adoption of the Energy Performance Buildings Directive (EPBD) in 2010 committed member countries states to ensuring all new buildings from 2021 are “nearly zero energy buildings”. With many EU member states having low rates of renovation of their existing building stock, the EU also amended the EPBD in 2018 to oblige member states to submit a long-term renovation strategy in order to fully decarbonise their building stock by 2050 (European Parliament and the Council of the European Union, 2018a). Under the Energy Efficiency Directive of 2012, member states are required to ensure that 3% of the total floor area of publicly owned buildings are renovated annually to meet minimum energy requirements (European Parliament and the Council of the European Union, 2012). However, only seven member states complied with this directive, with overall renovation rates sitting between 1-2% annually overall (Climate Action Tracker, 2018b).

4. India

With its large population, India is the world's fourth largest GHG emitter, contributing 7.3% of global GHG emissions in 2016 (Gütschow et al., 2016). However, per capita emissions levels are well below the global average. Given its growing population and development needs, with almost a fifth of the population still lacking access to electricity, how India chooses to address the growing energy demand has important implications for the global efforts to achieve the Paris Agreement goal (Climate Analytics, 2019).

Emissions have been rising steadily since 1990 and are expected to continue rising to 2030, but based on strong recent policy developments, India's projected future GHG emission trajectory is far lower than it would have been otherwise. Emissions are expected to reach between 4.5 and 4.6 $GtCO_2e$ by 2030 (Climate Action Tracker, 2019b).

India is well on track to meet and even overachieve its NDC commitments of reducing the emissions intensity of GDP by 33-35% below 2005 levels by 2030 and the more ambitious conditional target to increase the share of non-fossil-based energy resources to 40% of installed electric power capacity by 2030 (Climate Action Tracker, 2019b). While these targets are not consistent with placing India on a pathway to limit warming to 1.5°C, they are compatible with the ambition level required to limit warming to 2°C if other countries of similar levels of development made similar commitments. Given India is likely to surpass these targets, there is a strong case for India to ratchet up the ambition level of its NDC and reach 1.5°C compatible status.

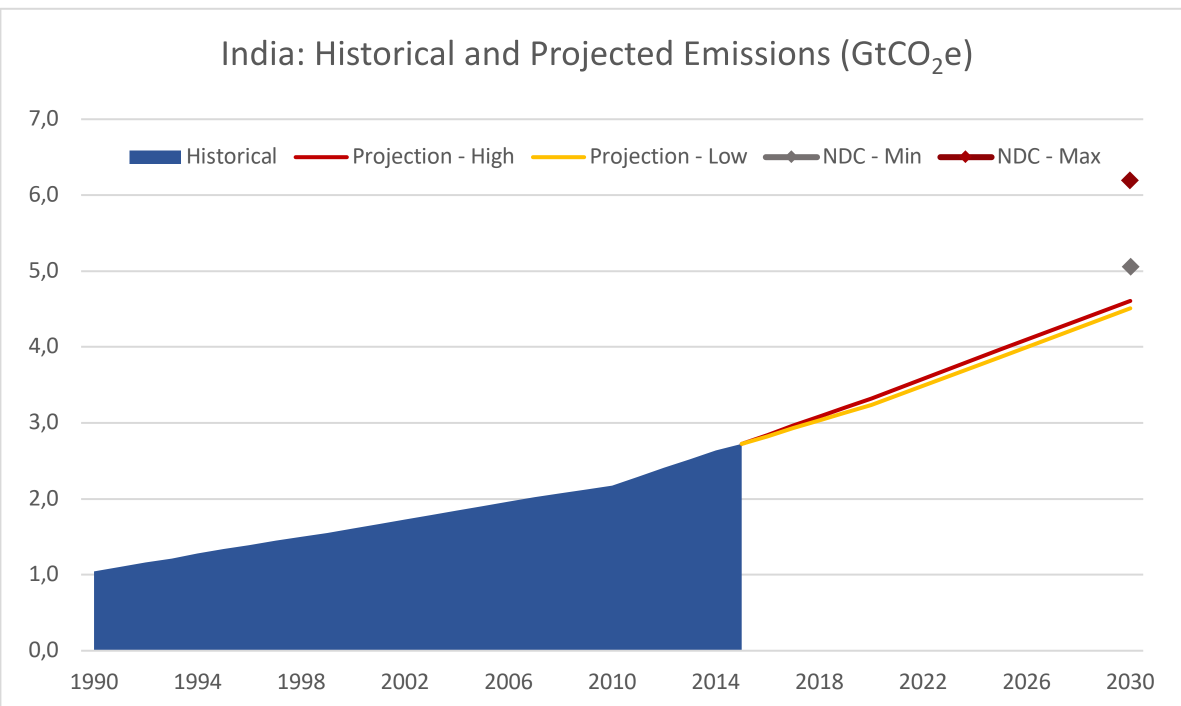

Table 4. Indian Emissions and Emission Targets. **Source:** (Climate Action Tracker, 2019a)

Sectoral Emissions and Policy Gaps

Energy:

The power sector accounted for 32% of India's total emissions (excluding LULUCF) in 2015. India's CO_2 emissions from energy rose by 4.8% in 2018, largely driven by emissions from coal power plants (IEA, 2019). Coal fired power generation accounted for 75% of India's total power generation in 2015 (IEA, 2017), which results in an emissions intensity of power supply (767 gCO_2/kWh) far higher than the global average (475 gCO_2/kWh). While coal capacity is expected to continue growing substantially, with 46GW of additions between 2022 and 2027 (CEA, 2018), the rate of growth in renewable energy capacity is encouraging with current policies expected to lead to non-fossil electricity generation of 40-44% by 2030 which is still not high enough to be consistent with the Paris Agreement (Climate Analytics, 2019).

Significant uncertainty still remains though regarding the trajectory of India's coal power capacity, with subsidies still in place contributing to the expected future capacity (IISD, 2018). However, with strong government support for renewables and falling prices likely to continue the strong uptake in renewables, there is potential that not all future projected coal capacity will eventuate or that future coal plant projects will end up as stranded assets (Dubash, Kale, & Bharvirkar, 2018). The government's Draft National Energy Policy and Three-Year Action Agenda (2017–18 to 2019–20) include recommendations to increase domestic production and distribution of coal, oil and gas, which, if adopted by the government, will prove to be a significant threat to India's climate goals (NITI Aayog, 2017b, 2017a). Addressing concerns over the grid integration of renewables and cancelling the planned coal expansion plans are pivotal steps in the short term for India to meet the goals of the Paris Agreement.

Industry:

India's main tool for increasing industrial energy efficiency is the Perform, Act, Achieve Mechanism, which resembles an emissions trading scheme, although it sets intensity-based energy targets. In addition to this there is an intention to launch a pilot carbon market mechanism for micro, small, and medium enterprises (MSMEs) and the waste sector, which are not covered by existing climate policies and currently rely on outdated technologies, meaning they have a large emissions reduction potential.

Transport:

Recent policy efforts have been put in place to encourage faster uptake of EVs including subsidies and provisions for constructing charging infrastructure (Business Today, 2019), but an announced ambitious sales target of 100% EV sales by 2030 has since not been followed through on. This target would have been consistent with global benchmarks to reach full decarbonisation. India's first light vehicle fuel efficiency standards came into force in 2017, starting at the equivalent of 130 gCO_2/km in 2017 and falling to 113 gCO_2/km in 2022 (Transportpolicy.net, 2017), however there are currently no emission standards for light commercial vehicles.

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4. Drivers of climate change for the following countries

4.1. Argentina

Drivers of Climate Change: the case of Argentina

Table of Contents

Summary

The largest share of Argentina's emissions are from the energy sector, followed by agriculture and Land Use and Land Use Change sector. The electricity sector is the main contributor of Argentina's energy emissions (34%), with fossil fuel-based generation (mostly gas) accounting for 64% of the total generation. In the agriculture sector, livestock farming is the main contributor to emissions (78%), which have been steadily growing historically and are set to continue increasing.

Argentina's climate commitment and projected emissions levels under current policies for 2030 are consistent with global warming between 3°C and 4°C by the end of the century, if all countries were to follow Argentina's approach.

Argentina will need to implement additional policies to meet its 2030 NDC target. While under current policy projections, the energy mix target for biofuels for 2030 will likely be achieved, other targets, in particular the renewable energy share in the electricity sector by 2025 and 2030 and its NDC target by 2030 will be missed by a large margin.

Although Argentina has shown significant positive developments in the transport and electricity sectors by adopting policies increasing the share of biofuels in combustible and pushing the uptake of renewable energies, more climate ambition and action are needed. In the transport sector, mitigation efforts are centered in biofuels use, which prologues dependency on combustion engine vehicles in the medium and long term as demonstrated by

the very low projected penetration rate of electric vehicles in Argentina. Moreover, full decarbonization of the Argentinian power sector is at odds with high government support on natural gas production. Argentina is also lagging behind in agriculture sector emissions mitigation with no particular policies in place to halt emissions growth in this sector.

Paris Agreement compatible emissions pathways require emissions to peak and decline fast afterwards, reaching carbon neutrality by mid-century. In contrast, under current policies, emissions of Argentina are expected to grow by 2030.

Argentina's Emissions Profile

Historical and Projected Emissions

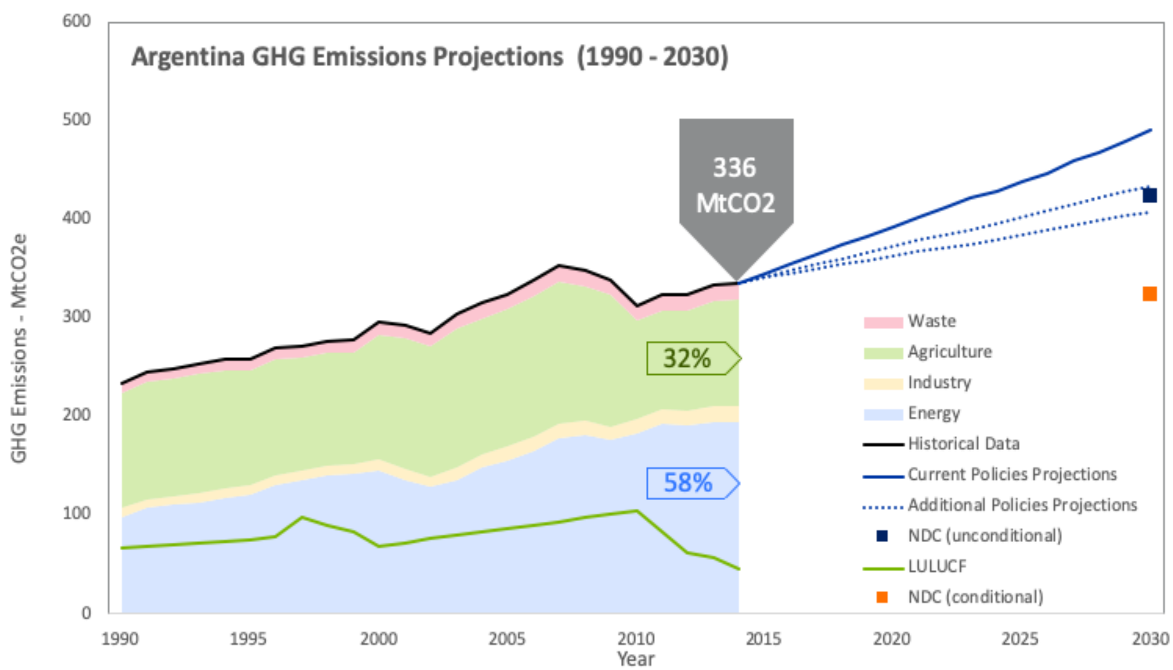

Figure 30: *Historical and projected emissions of Argentina from 1990 to 2030 based on the most recent update from Climate Action Tracker* (Climate Action Tracker, 2019)*. Sector breakdown is made available from the National Inventory Report from 2017 submitted by the Government of Argentina* (Ministerio de Ambiente y Desarrollo Sustentable, 2017)*. Shares of Agriculture and Energy sectors (respectively 32% and 58%) are here indicated excluding LULUCF emissions.*

As shown in figure 1, historical emissions in Argentina decreased significantly between 2007 and 2010 reaching 313 $MtCO_2$ in 2010 excluding Land Use and Land Use Change (LULUCF). Since then, Argentina's emissions have been steadily growing to reach 336 $MtCO_2$ in 2014 (excl. LULUCF), upon most recent historical data provided by official sources (Secretaria de Ambiente y Desarrollo Sustentable, 2017). Third party sources estimated the country emissions for 2015 and 2016, reaching a share of 0,8% of emissions worldwide in 2016 (Gütschow, Jeffery, & Gieseke, 2019).

According to Climate Action Tracker most recent assessment (Climate Action Tracker, 2019), under current policies, annual emissions from all sectors (excluding LULUCF) are still projected to grow significantly, by about 56% above 2010 levels by 2030, reaching approximately 490 $MtCO_2$ in 2030. This is equal to doubling 1990 emissions levels.

The current policies emissions projections shown in figure 1 is based on the mitigation scenarios underlying the third National Communication of Argentina to the UNFCCC (Secretariat of Environment and Sustainable Development, 2015). Additional policy scenarios, assuming a full implementation of the renewable targets and additional energy efficiency measures, shown in figure 1 are based on the Energy Scenarios from the Ministry of Energy (Ministry of Energy and Mining Argentina, 2018).

Key sectors drivers of Emissions

The largest share of Argentina's emissions is from the energy sector, accounting for 58% of the total (excl. LULUCF) in 2017 (Figure 30), followed by agriculture emissions accounting for 32% of the total (excl. LULUCF). Instead of being an emissions sink, the LULUCFs sector is the third largest single contributor to Argentinian total emissions, accounting for 46 Mt in 2014, which is equivalent to 12% of total emissions (including LULUCF).

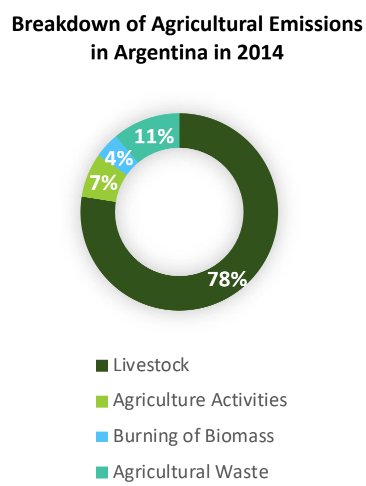

Figure 31: *Shares of agricultural activities in agricultural emissions in 2017.*
Source: National Inventory Report from 2014, Argentina (Ministry of Environment Argentina, 2017)

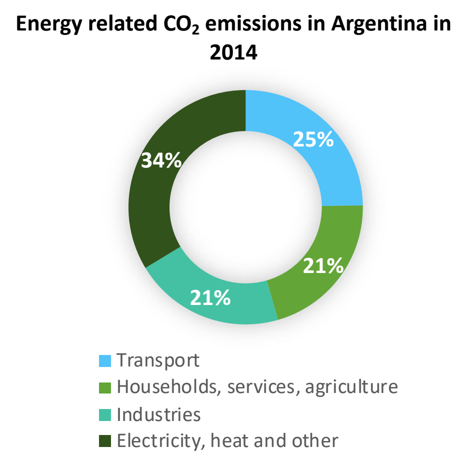

Figure 32: *Shares in energy related co_2 emissions.*
Source: G20 Brown to Green report 2018 (Climate Transparency, 2018).

- **Drivers of Energy emissions:**

The electricity sector is the main contributor of Argentina's energy emissions, accounting for 34% of energy related emissions in 2014, representing approximately 34% of the energy related emissions in 2014 (Climate Transparency, 2018). Fossil fuel-based generation dominates electricity supply in Argentina accounting for 64% of the total generation in 2017, of which 90% is generated by natural gas, 8% by liquid fuels (diesel and fuel oil), and a marginal 2% by coal (CAMMESA, 2019). Electricity generation from hydro resources represented 29% of the generation mix in the same year, followed by 5% from nuclear and less than 2% from non-conventional renewable sources (i.e., biomass, wind and solar).

The transport sector is the second largest contributor to Argentina's energy emissions and accounted for about 25% of Argentina's energy related emissions in 2014 (Climate Transparency, 2018). Road transport, with 90% of all transport related emissions in 2014, constitutes by far the most important source of transport-related emissions (Ministry of Environment and Sustainable Development, 2017), with the emissions being distributed equally between passenger vehicles and trucks.

- **Drivers of Agriculture emissions:**

Agriculture emissions from Argentina are driven by livestock farming representing approximately 78% of the agriculture emissions in 2014, of which 71% is due to Enteric Fermentation and which has been steadily growing (Ministry of Environment and Sustainable Development, 2017). The agriculture sector, with a strong exports-oriented nature, has a huge importance for the Argentinian economy. Although its value added to GDP has been decreasing over the last decade, it accounts currently for 5% (Agriculture and Forestry sectors included), above world average which is of 3.5% (World Bank, 2018). The land area used for agriculture on the other hand has increased to above 54% in Argentina (World Bank, 2018) which has an impact on forestry. LULUCF emissions have been reported so far by the Argentinian government together with agriculture emissions, representing together 40 % of total emissions (see figure 1).

Country specific targets and compliance

Country specific targets

Sector	Target 2020	NDC Target 2030	Other national targets
Economy wide, incl. LULUCF	List of Nationally Appropriate Mitigation Actions (NAMAs)	1) Unconditional target: 483 $MtCO_2$ by 2030 incl. LULUCF 422 $MtCO_2$ by 2030 excl. LULUCF 2) Conditional target: 369 $MtCO_2$ by 2030 excl. LULUCF 322 $MtCO_2$ by 2030 excl. LULUCF	
Energy			1) To achieve 20% and 25% of renewables shares (excl. hydro) by 2025 and 2030 respectively. 2) 20% blending of biodiesel in liquid fuels for trucks and the incorporation of flex-fuel technologies for gasoline-gasoline based cars by 2030

Agriculture	No mitigation targets.
LULUCF	Restoration of 20,000 ha annually until 2030

Table 1. *Sector specific emission targets.*

Sources: Most recent Argentina Climate Action Tracker update (Climate Action Tracker, 2019)*, National Plan for the restauration of the Native Forest* (Ministry of Environment and Sustainable Development, 2018)*, National Energy Action Plan (Ministry of Energy of Argentina, 2017).*

How well is the country complying with its targets?

- **Compliance with Targets:**

According to the Climate Action Tracker most recent assessment, Argentina will need to implement additional policies to meet its NDC 2030 target, see **Figure 30**, with a gap of 68 $MtCO_2$ in 2030 (Climate Action Tracker, 2019). Additional policy scenarios, assuming a full implementation of the renewable targets and additional energy efficiency measures, based on the Energy Scenarios from the Ministry of Energy could close this gap, and even lead to an overachievement of the unconditional NDC target.

With regards to sector specific targets, by the implementation of some short-term measures such as Biofuels Law 26.093 amended in 2016 through the Resolution 37/2016 aiming at the uptake of biofuels in the transport sector, the target to reach 20% blending of biodiesel seems to be reasonable (Climate Action Tracker, forthcoming). This stands in strong contrast with current policy projections in the electric sector, which would only lead to a 7% renewable share by 2025 (excl. hydro) missing by far the electricity share target for non-conventional renewables in 2025 (Climate Action Tracker, forthcoming). Although emissions from forestry sector have been significantly reduced since the implementation of the Native Forests Law in 2010, the law has only been partially implemented, where for example between 2010 and 2015, only 8.5% of the total targeted budget for the conservation of native forests was spent (Climate Action Tracker, 2019).

- **Global Warming Pathway regarding NDC and current policies projections:**

  Based on the Climate Action Tracker methodology, Argentina's climate commitment and projected emissions levels under current policies for 2030 are not consistent with holding warming to below 2°C, let alone limiting it to 1.5°C as required under the Paris Agreement, and are instead consistent with warming between 3°C and 4°C, if all countries were to follow Argentina's approach (Climate Action Tracker, 2019).

  Paris Agreement compatible emissions pathways require emissions to peak and decline fast afterwards, reaching carbon neutrality by mid-century. In contrast, under current policies, emissions of Argentina are expected to grow by 2030 (Climate Action Tracker, 2019).

Country's climate policies and practices:

How are the key and most emitting sectors under current policies contributing to limit global warming to 1.5°?

The following table shows an overview of positive and negative policy developments in four key emitting sectors in Argentina compared with sector-specific short-term benchmarks for limiting global warming to 1.5°C as identified by (Kuramochi et al., 2017).

Sector	1.5 °C-consistent benchmark	Assessment and opportunities for improvement
Electricity and heat sector	Sustain the global average growth of renewables and other zero and low carbon power until 2025 to reach 100% by 2050	+ Increasing political will to support an accelerated increase of renewables + Policy instrument in place to initiate uptake of renewables in line with renewable targets (envisioned growth of non-conventional renewables from 2.5% of total electricity consumption in 2018 to 12% in 2019). + Uptake of renewable generation encouraged at different scales: from large-scale renewable projects to decentralized electricity generation at residential level + Grid expansion initiatives planned from 2019 onwards are expected to remove barriers that support a further deployment of renewables - Renewable projects are facing major delays due to financial difficulties and grid-related limitations. Large-scale renewable auctions suspended until grid limitations are resolved. - Government shows strong support for natural gas in electricity generation through subsidies and tax benefits, which put higher shares of renewables and the full decarbonization of the power sector by mid-century or shortly thereafter at doubt. - Additional actions are needed to achieve the share of renewables (excl. hydro) electricity supply set in the targets.
	No new coal plants commissioned, reduce emissions from coal power by at least 30% by 2025	+ Government's support of renewables and natural gas might lead to completely phase out of coal from the electricity mix + Share of coal in total power generation is currently low (<2%), making a coal phase-out relatively easy to manage - No policy exists to formally phase out coal fired plants and one plant currently under construction - The only operating coal-fired plant has gone through several refurbishments that has postponed its decommissioning
Transport sector	Last fossil fuel car sold before 2035	+ Several minor demand-side efficiency policies are in place that aim to reduce emissions in transport sector +/- Substantial growth of biofuels driven by higher blending mandates in fuels. However, there are sustainability concerns regarding the impact of biofuel production on LULUCF. +/- Moderate overall impact is expected from proposed mitigation actions in National Mitigation Plan: aiming to reach an annual emission reduction of up to 7,6% in 2030 if all measures would be implemented. - No overarching 1.5°C compatible vision for transport sector - Incipient uptake of EV with low coverage in transport sector policies to incentivize their uptake

		- Tax exemptions for CNG and LPG encourage the continuation and use of these fossil-powered vehicles
Agriculture	Keep emissions in 2020 at or below current levels, establish and disseminate regional best practice, ramp up research	+ There are activities around climate smart agriculture and crop rotation, however no comprehensive policy framework +/- Emissions intensity of agricultural production has decreased over the last two decades, due to improved farming methods but also economies of scale. This is driven by the need to most efficient production practices to remain competitive on the global market. - No overarching 1.5°C compatible vision for agriculture sector
LULUCF	Reduce emissions from forestry and other land use to 95% below 2010 by 2030, stop net deforestation by 2025	- Deforestation remains an issue, also due to pressure from agriculture and livestock farming expansion + Commercial forest plantations growing and certain policy developments to promote reforestation such as Law 27.487 to support investments in forests (previously law 25.080)

Table 2: *Positive and negative policy developments in key sectors.*

Source: Scaling Up Climate Action in Argentina (Climate Action Tracker, forthcoming).

Lacking policies and practices or negatively contributing to global warming in key and most emitting sectors

- **No full decarbonization of power sector envisioned:** Despite a substantial growth of renewables in the short and medium-term, Argentina has no specific sectoral plan or target to reach the required 100% share of low-carbon electricity generation by 2050 to be in line with the Paris Agreement temperature target. In fact, latest energy sector plans from the Secretariat of Energy (Secretaría de Energía Argentina, 2018) and the support to natural gas indicate that the government aims to further develop the natural gas industry and make this fuel the main energy source in the country. Under these conditions, it seems unlikely to reach full decarbonization of the power system by mid-century if Argentina will not decrease its gas consumption soon and avoids building up significant additional infrastructure (Climate Action Tracker, forthcoming).

- **No action on cattle-related (livestock) agricultural activities and impact on forestry:** the livestock farming sector is the main contributor of the agriculture sector (78% in 2014 from Agricultural emissions from Argentina), and so far, no policy instruments in place or planned to mitigate emissions have been announced. In addition to the large methane emissions produced by this activity, the area needed for grazing and production of animal feed puts stress on forests and is reason for other environmental and social concerns. Exports of agricultural products play an important role in this context, with the growth of beef-demand expected worldwide (Climate Action Tracker, forthcoming).

- **Limited decarbonization of the transport sector:** Implemented policies such as blending cuts for biofuels are expected to have a limited impact on moving Argentina towards a 1.5° compatible vision for the sector, even though Argentina is considerably above global average in terms of share of biofuels in transport, fossil fuels consumption in the sector is still growing and further increases are projected with Incipient uptake of EVs insufficient policies to incentivize their uptake. Additionally, these biofuels policies must be assessed from a sustainability point of view considering trade-offs and impacts of large-scale biofuels production on food security, forestry protection and emissions from land use (Climate Action Tracker, forthcoming).

- **Public finance in power sector subsiding coal, oil and gas sectors**: In 2018, it is estimated that 93% of total public finance to power went to coal, oil and gas projects in contrast with close to no financing towards renewables projects and no financing streams were identified for "grey sector" (such as nuclear, biomass, large-scale hydropower etc.) (Climate Transparency, 2018).

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4.2. Brazil

Drivers of Climate Change: the case of Brazil

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Summary

Emissions excluding land use, land use change and forestry, (LULUCF) in Brazil rose steadily from 1990 to 2014, declined from 2014 to 2016, but resumed growth after 2016. Brazil's remarkable progress in forestry emissions mitigation observed since 2005 has stopped, and deforestation and resulting emissions increases have picked up speed again in recent years after the reversal of key environmental policies in Brazil, driving LULUCF emissions up.

Brazil's climate commitments and projected emissions through 2030 under current policies are consistent with global warming between 2°C and 3°C by the end of the century, if all countries were to follow Brazil's approach.

Brazil will need to strengthen its current policies or implement additional policies to meet its NDC targets (2025 and 2030). Under current policy projections, the indicative NDC energy mix targets for renewable energy and biofuels for 2030 will likely be achieved, other targets, in particular in the LULUCFs sector, will be missed by a large margin.

In the transport sector, mitigation efforts are centered in biofuels use, which prolongs dependency on combustion engine vehicles in the medium and long term as demonstrated by the low current and projected penetration rate of electric vehicles in Brazil.

Moreover, despite its large share of renewable power generation, full decarbonization of the Brazilian power sector is at odds with high government support fossil fuels. Brazil is also lagging behind in agriculture sector emissions mitigation with no particular policies in place to halt emissions growth in this sector, particularly from cattle.

Paris Agreement compatible emissions pathways require emissions to peak and decline fast afterwards, reaching carbon neutrality by mid-century. In contrast, under current policies, emissions of Brazil—both including and excluding LULUCF — are expected to increase steadily through 2030.

Brazil's Emissions Profile

Historical and Projected Emissions

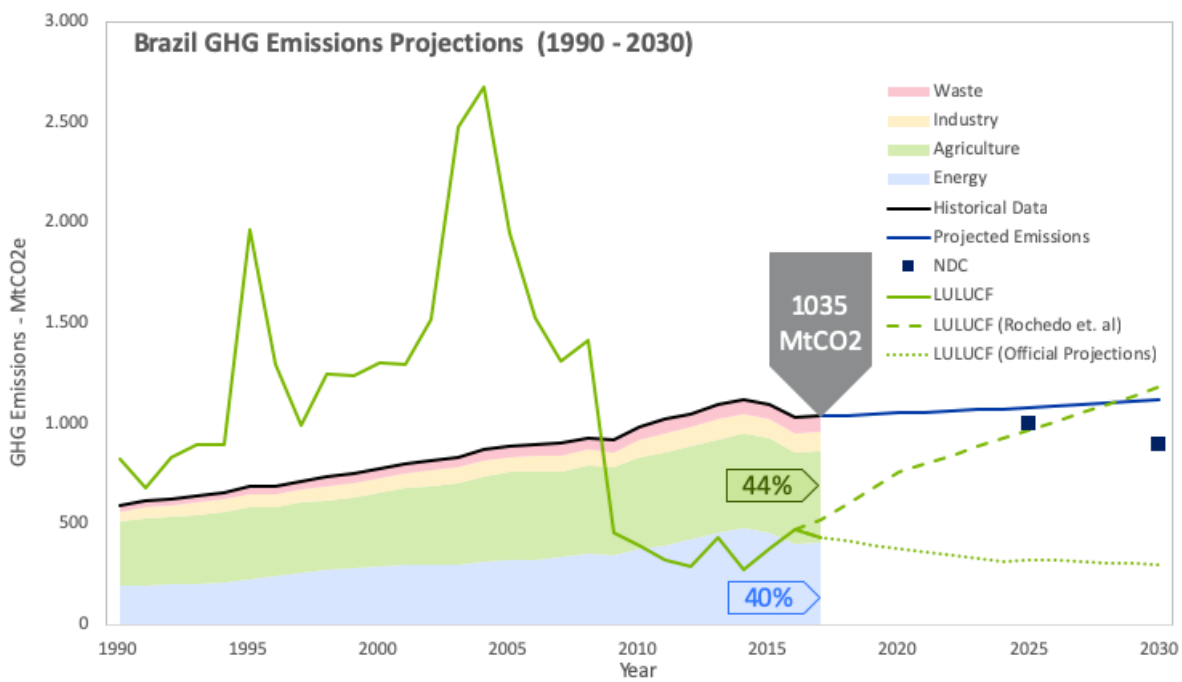

Figure 33: *Historical and projected emissions of Brazil from 1990 to 2030 based on the most recent update from Climate Action Tracker* (Climate Action Tracker, 2019). *Historical emissions are taken from official communication until 2015* (Ministry of Science Technology and Innovations and Communications, 2019) *and complemented with third party sources until 2017* (Observatório do Clima, 2019).

As shown in Figure 1, emissions excluding land use, land use change and forestry, (LULUCF) in Brazil rose steading from 1990 to 2014, declined from 2014 to 2016, and has risen to 1035 $MtCO_2$ in 2017, Third party sources estimated the country account for roughly 2.3% of global emission excluding LULUCF (Gütschow, Jeffery, & Gieseke, 2019). It is of especial concern that Brazil's remarkable progress in reducing LULUCF emissions from 2005 to 2014 has stopped, with LULUCF emissions increasing since 2014 due to the reversal of key environmental policies (Observatório do Clima, 2019) (Climate Action Tracker, 2019).

With current policies, Brazil will reach emissions levels (excluding LULUCF) of 1079 MtCO2e in 2025 and 1121 MtCO2e by 2030 (respectively, 27% and 32% above 2005 levels and 92% and 99% above 1990 levels) (Climate Action Tracker, 2019). Official projections for the LULUCF sector show decreasing emissions until 2030 (Ministério da Ciência Tecnologia Inovações e Comunicações Brasil, 2017) but alternative projections by Brazilian modeling groups show emissions from this sector going in the opposite direction (Rochedo et al., 2018).

Key sector drivers of Emissions

The largest share of Brazil's emissions excluding LULUCF correspond to non-energy related emissions, with Agriculture emissions accounting for 44% of the total in 2017 (Figure 30) Energy related emissions accounted for 40% of the emissions in 2017.

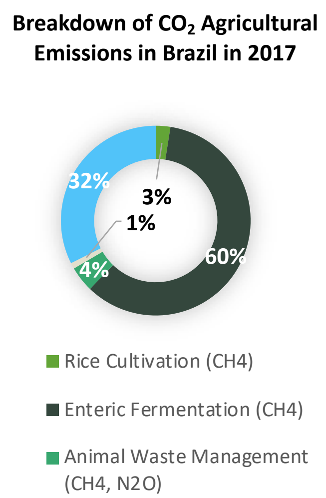

***Figure 2**: Shares of agricultural activities in agricultural emissions in 2017.*
Source: Observatóro do Clima, 2019.

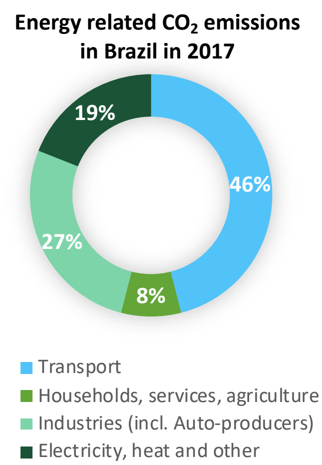

***Figure 3**: Shares in energy-related CO_2 emissions. Source: G20 Brown to Green report 2018* (Climate Transparency, 2018).

- **Drivers of LULUCF emissions:**

Since the early 1990's, the land use and forestry sector was usually the largest source of GHG emissions in Brazil. This picture changed significantly between 2005 and 2014, when effective anti-deforestation policies, including the National Forest Code, the Action Plan for Deforestation Prevention and Control in the Legal Amazon (PPCDAm) and the Cerrado (PPCerrado), were implemented and resulted in a reduction on LULUCF emissions of about 86% between 2005 and 2012. Brazil's remarkable progress in forestry emissions mitigation observed since 2005 has stopped, with deforestation and resulting emissions increases picking up speed again in recent years after the reversal of key environmental policies in Brazil (Observatório do Clima, 2019). In 2018, Brazil recorded the highest loss of tropical primary rainforest in the world of 1.3 million hectares, mostly due to deforestation in the Amazon, with major impacts in indigenous territories (Climate Action Tracker, 2019).

- **Drivers of Agriculture emissions:**

Agriculture is an important industry in Brazil, due to the immense land resource available. The most significant products are coffee, soybeans, wheat, rice, corn, sugarcane, cocoa, citrus and beef. Main drivers of agriculture emissions are the activities related to Agricultural Soils and Enteric Fermentation contributing respectively to 32% and 60% to the sector emissions (Observatório do Clima, 2019). If the indirect emissions of the agriculture sector (mostly related to deforestation resulting from the expansion of the agricultural frontier) were accounted for, the agricultural sector would be by far the single largest emissions source in Brazil (Climate Action Tracker, 2019). Together, the Agriculture and Land Use and Land Use Changes sector accounted for almost 70% of the country's emissions in 2017 (FABLE Consortium, 2019).

- **Drivers of Energy emissions:**

With around 80% of the electricity production coming from renewable energy sources (mainly hydro), emissions from fuel-combustion are mainly driven by transport. As shown in Figure 3, the transport sector emits 46% of Brazil's CO_2 from fossil fuel combustion, followed by industry (27%) and electricity (19%) in 2017 (Climate Transparency, 2018). Transport emissions have more than doubled since 1990 (Climate Transparency, 2018) mainly due to increased vehicle ownership. Road transport accounted for 92% of transport emissions in 2017 (Observatório do Clima, 2019).

Country specific targets and compliance

Country specific targets

Sector	Target 2020	NDC Target 2025	NDC Target 2030	Other national targets
Economy wide, incl. LULUCF	36.1% - 38.9% under BAU	1.3GtCO_2 (37% below 2005 emissions levels incl LULUCF)	1.2 GtCO_2 (43% below 2005 emissions levels incl LULUCF)	
LULUCFs			1) Zero illegal deforestation in the Brazilian Amazonia 2) Restore and reforest12 million ha of forests 3) Enhance sustainable native forest management	
Agriculture			1) Restore 15 million hectares of degraded pasturelands 2) Enhance 5 million hectares of integrated cropland-livestock-forestry systems	

Energy	1) Achieve 45% of renewables in the energy mix 2) Increase the share of sustainable biofuels in the energy mix to approximately 18% 3) Achieve 23% of renewables (other than hydro) in the power supply	1) 47% share of renewable energy in the energy mix by 2027 2) 21% share of biofuels in the energy mix by 2027 3) 22% of renewables (other than hydro) in power supply by 2027 4) Reduce carbon intensity of transportation fuels by 10.1% by 2028 from base year 2017

Table 1. *Sector specific emission targets*

Sources: Most recent Brazil (Climate Action Tracker, 2019), Brazil's NDC (Government of Brazil, 2015), National Biofuel Policy, Renovabio (Conselho nacional de política energética, 2018b), Brazil's Ten-Year Plan for Energy Expansion (Ministerio de Minas e Energia, 2018).

How well is the country complying with its targets?

- **Compliance with Targets:**

According to the Climate Action Tracker most recent assessment, Brazil will need to implement additional policies to meet its NDC targets (2025 and 2030), see **Figure 30**, with a gap of 86-88 MtCO2 in 2025 and of 228-231 MtCO2 in 2030 (Climate Action Tracker, 2019).

With regards to sector specific targets, under current policy projections, the indicative NDC target of a 45% share of renewables in the total energy mix by 2030 will be achieved, with renewable energy expected to represent 47% of the energy mix in 2027 (Ministerio de Minas e Energia, 2018). The biofuels indicative target (18% by 2030) will also be achieved with the most recent energy plan targeting 21% share of biofuels by 2027. Policies in place to achieve this target include the Renovarbio program and a new resolution on increasing the share of biodiesel (Conselho nacional de política energética, 2018a). In contrast, Brazil is going in the opposite direction with regards to its targets in LULUCFs sector, as recent legislative proposals are going against successful environmental policies and a relaxation of the forest code in 2012 (Rochedo et al., 2018). Impacts were observed in 2016, when deforestation in the Amazon increased 30% compared to 2015 (IPAM, 2017). Brazil is also lagging being in agriculture sector emissions mitigation, with no particular policies in place to halt emissions growth in this sector, which accounts for 44% of its non-LULUCF emissions in 2017.

- **Global Warming Pathway regarding NDC and current policies projections:**

Brazil's climate commitment and projected emissions levels under current policies for 2030 are not consistent with holding warming to below 2°C, let alone limiting it to 1.5°C as required under the Paris Agreement. They are instead consistent with warming between 2°C and 3°C, if all countries were to follow Brazil's approach (Climate Action Tracker, 2019).

Paris Agreement-compatible emissions pathways require emissions to peak and decline fast afterwards, reaching carbon neutrality by mid-century. In contrast, under current policies, emissions of Brazil are expected to grow by 2030 (Climate Action Tracker, 2019).

Country’s climate policies and practices

How are the key and most emitting sectors under current policies contributing to limit global warming to 1.5°?

The following table shows an overview of positive and negative policy developments in four key emitting sectors in Brazil compared with sector-specific short-term benchmarks for limiting global warming to 1.5°C as identified by (Kuramochi et al., 2017).

Sector	Necessary step	Assessment and opportunities for improvement
Power	Sustain the growth of renewables and other zero and low carbon power until 2025 to reach 100% by 2050	+ Historically high share of renewable generation. + NDC target to increase the share of renewables (other than hydropower) in power generation to at least 23% by 2030. + 6 large-scale renewable energy auctions planned up to the end of 2021 - Huge untapped potential for renewable power. - **Plan to increase share of investments in fossil energy sources to 76.1% of total energy investments in the period 2018-2027** **- Long-term energy scenarios released by the Energy Ministry show a 2050 energy mix projection that has very similar shares of fossil fuels compared to current levels.**
	No new coal plants, reduce emissions from coal power by at least 30% by 2025	+ Low historical importance of coal in the electricity mix. - New coal capacity still planned to come online threatens achievement of NDC goal. Four power plants are currently in pre-construction phase (CoalSwarm, 2019). - Coal generation allowed to participate in national energy auctions
Transport	Last fossil fuel car sold before 2035	+ Brazil has one of the highest shares of biofuels in road transport of the world. + National Target to reduce the carbon intensity of transportation fuels by 10,1% by 2028 from base year 2017 + August 2019 Resolution that sets increasing percentage of biodiesel blending from 11% in 2019 to 15% in 2023. -Focus on biofuels prologues dependency on combustion engine vehicles in the medium and long term. - Insignificant share of Electric Vehicles sales and no policies in place to promote the use of EVs, which would be needed to achieve decarbonization without putting additional pressure on forests.
LULUCF	Reduce emissions from forestry and other land use to 95% below 2010 by 2030, stop net deforestation by the 2020s	+ Anti-deforestation policies reduced LULUCF emissions by 85% between 2005 and 2012. + NDC pledge to maintain and strengthen current policies in the sector. - Increased biofuel production could lead to increased land use emissions. - Deforestation in the Amazon region increasing again since 2016. - Legislative acts and decrees in 2017 have lowered environmental licensing requirements, suspended the ratification of indigenous lands, reduced the size of protected areas in the Amazon, and facilitated land grabbers to obtain the deeds of illegally deforested areas as large as 2,500ha per farm in the Amazon rainforest (Rochedo et al., 2018).

Agriculture	Keep emissions at or below current levels, establish and disseminate regional best practice, ramp up research	+ NDC pledge to restore degraded pasturelands and enhance integrated cropland-livestock-forestry systems by 2030. + Policy instrument to promote low-carbon agriculture (ABC Program) already in place. - Implementation lag in policy instruments. - No policy instruments in place or planned to mitigate emissions from cattle-raising sector, which is expected to grow fast and is the main contributor of the Agriculture sector.

Table 2: *Positive and negative policy developments in key sectors.*

Source: Evaluations of Climate Analytics.

Lacking policies and practices or negatively contributing to global warming in key and most emitting sectors

- **Reversal of action on deforestation:** while Brazil's NDC target aims at zero illegal deforestation, recent legislative proposals (see section 3.1) have had a direct impact on increasing deforestation observed already since 2016 (see section 2.2), and thus increasing GHG emissions from the LULUCFs sector, which together with the agriculture sector are the top contributors to the country's emissions. The previous administration had already begun reverting key environmental policies in Brazil (budget cuts to the environmental authorities, and reversal of LULUCF policies already in place). Bolsonaro's administration, supported by "ruralist" legislators who have traditionally opposed land preservation efforts and other anti-deforestation policies, has continued with the reversal of key environmental policies and weakening of environmental institutions (Climate Action Tracker, 2019). The changes include eliminating 95% of the Ministry of Environment's budget for climate change-related activities; transferring the body responsible for certifying Indigenous territory from National Indian Foundation to the Ministry of Agriculture; easing the rules for converting environmental fines into alternative compensations; changes in the Forest Code to extend deadlines for enforcement measures; and the abolition of most committees and commissions for civil participation and social control in the Federal Government (Climate Action Tracker, 2019).

- **No action on cattle-related activities:** the cattle sector has historically been the main contributor of the agriculture sector (64% in 2107, (Observatório do Clima, 2019)), and so far no policy instruments are in place or planned to mitigate emissions.

- **Limited decarbonization of transport:** even if Brazil is on track to reduce emissions from its transport sector through the increase of the use of biofuels, the full decarbonization will be only possible by a shift within the transport sector to zero emissions technologies such as electric vehicles (EVs), which currently have an insignificant penetration rate and no clear strategy for substantial increase. The Ministry of Energy projects an insignificant share of EVs in the market until at least 2035, reaching 11% penetration rate in 2050 (Climate Action Tracker, 2019). Moreover, the increase in the production of biofuels will require an increase of land-use for this purpose, putting additional pressure on the land-use sector, which is experiencing growing deforestation.

- **Increasing the share of fossil fuels:** full decarbonization of the Brazilian power sector is at odds with recent policy developments which show the government is planning to increase investments in fossil fuels to meet Brazil's increasing energy demand. In fact, the share of fossil fuels in the Brazilian energy matrix is increasing while the share of renewable energy sources in the energy supply has been declining— from around 50% in the 1990s to only 39% in 2014 and has only started to rise again in the last three years, reaching 47% in 2017 (Climate Action Tracker, 2019)

- **High subsidies in fossil-fuels and in power sector**: In 2016, Brazil's fossil fuel subsidies were US$16.2bn, doubling since 2007. Between 2007 and 2016, subsidies were greater than the G20 average per unit of GDP. The largest subsidy is the PIS/CONFINS[1] measure to maintain fixed prices for the import and retail sale of gasoline, diesel, aviation kerosene and natural gas. With regards to the power sector, in 2016, 66% of total public finance to power went to coal, oil and gas projects in contrast with 21% to renewables projects and 14% others (such as nuclear, biomass, large-scale hydropower etc.) (Climate Transparency, 2018).

[1] The PIS (Program of Social Integration) and COFINS (Contribution for the Financing of Social Security) are federal taxes based on the turnover of companies.

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4.3. France

Drivers of Climate Change: France

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Summary

France's total greenhouse gas emissions have been increasing since 2014. The main drivers of emissions in France is the transport sector followed by agriculture and building sectors, which account for 71% of total emissions in 2016 excluding LULUCF.

France has failed to meet its 2015-2018 domestic emissions target and under current policy the renewable energy share in the electricity sector by 2030 and its EU NDC target by 2030 will be missed by a large margin.

Although France has historically low CO_2 emissions from its energy sector due to its high nuclear share, transport and buildings sectors emissions have been stagnant for the past decade. In transport sector mitigation efforts are centered in the introduction of low-carbon technology vehicles but no policy is targeted to limit road transport demand and low investment levels are directed to modal shift from road transport. Reductions in support schemes for renovation (such as tax credit) have been put in place to reduce emissions from the building sector, but related administrative procedures remain too complex, resulting in a limited improvement in buildings' energy efficiency. France is also lagging behind in its 2030 renewable energy share and has postponed its nuclear share target of 50% from 2025 to 2035.

France's domestic 2030 mitigation target and current policy projections are consistent with warming of between 3°C and 4°C, if all countries made comparable efforts. Similarly, the EU's NDC target of a 40% reduction below 1990 levels by 2030 is compatible with warming of

between 2°C and 3°C if all countries made comparable commitments. It is therefore imperative that France adopts more ambitious targets and policies.

1. France's Emission Profile

1.1. Historical and Projected Emissions

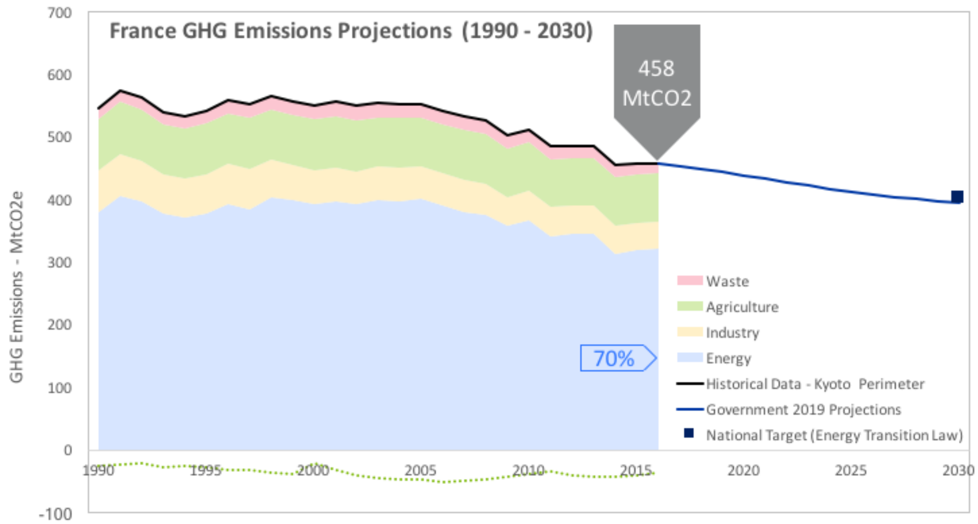

Figure 34 : Historical and projected emissions of France from 1990 to 2030 based the National Inventory Report 2018 (European Environmental Agency, 2018)*, and the National Integrated Climate and Energy Plan published in January 2019, scenario based on "existing measures"* (Ministère de la Transition écologique et solidaire, 2019)*. Emissions provided here cover the Kyoto Perimeter, which includes metropolitan France and overseas territories included in the EU.*

Following a "pick and decline" trajectory between 1990 and 1994, France's total greenhouse gas (GHG) emissions have grown until 1998 to decline until its lowest recorded emissions level in 2014 reaching 454,2 $MtCO_2e$ (excluding LULUCF). France's emissions have however been growing since 2014 to reach 458 $MtCO_2e$ (excluding LULUCF) in 2016, roughly 16% lower than 1990 levels. France's 2016 constituted approximately 1.0% of global emissions for that year.

Based on current policies, France's emissions are expected to be 394 $MtCO_2$ by 2030, roughly 28% below 1990 excluding LULUCF (Ministère de la Transition écologique et solidaire, 2019).

France's LULUCF accounting approach within its target remains unclear: no precision has been given whether LULUCF emissions are planned to be accounted in the 40% emissions reduction domestic target. If LULUCF emissions are excluded in the base year and included in the target year, as France's communications seem to indicate, this approach is called "gross-net" and the use of this approach raises many questions in terms of the environmental integrity of the target (Rocha et al., 2015).

1.2. Key emission contributions

The largest share of France's emissions corresponds to the energy sector, accounting for 70% of the total (excl. LULUCF) in 2016 (Figure 1), followed by Agriculture emissions accounting for 17% of the total (excl. LULUCF).

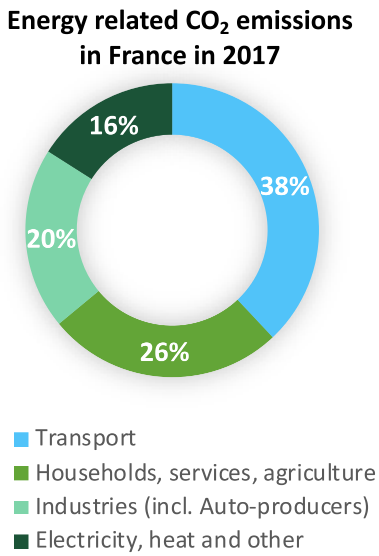

Figure 35: Emissions Breakdown from Energy Sector in France in 2016. Source: Brown to Green Report 2018 (Climate Transparency., 2018)

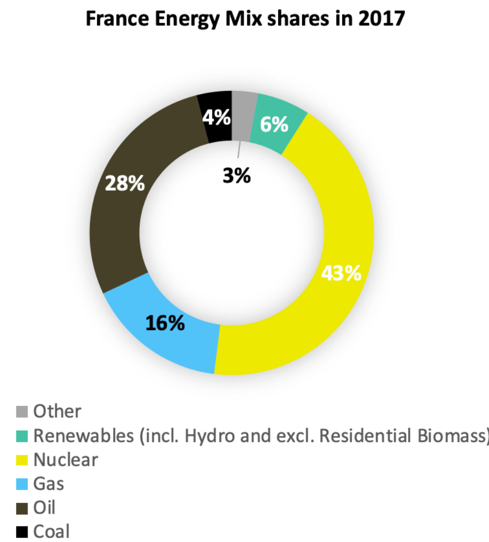

Figure 3: Shares of energy sources in France's energy mix of 2017. Source : Brown to Green Report 2018, France (Climate Transparency., 2018)

- **Drivers of Energy Emissions:**

The transport sector is the main contributor of France's energy emissions, accounting for 38% of energy related emissions in 2016, of which 96,1% was generated by road transport in 2016 (Agora Verkehrswende, 2018) which is steadily growing since 2014 (Observatoire Climat Energie, 2018). Road transport emissions are dominated by private passenger transport, representing 53,7% of emissions in France in 2015 (Ministère de la Transition écologique et Solidaire, 2017). This increase is partly due to the decrease of diesel-based cars sales to the profit of gasoline-based cars and intensive fuel-consuming cars such as SUVs together with an increase of road transport-demand three times higher than expected in the period 2015-2018 (Haut Conseil pour le Climat, 2019).

Emissions from buildings sector (private as well as tertiary) is the second largest contributor to energy emissions, reaching 19% of total GHG emissions in 2018, mostly due to domestic fuel for thermal usage as well as the use of fluorinated gazes (such as for air conditioning). Building sector emissions have been very insignificantly decreasing since 1990 (4% per year). Although CO_2 emissions have been decreasing due to a better energy efficiency of buildings and the use of non-fossil fuel energy, this has been balanced by an increase of surfaces to be heated as well as in the use of fluorinated gazes (HFC and PFC) such as for air conditioning (Haut Conseil pour le Climat, 2019).

- **Drivers of Agriculture Emissions:**

Following the energy sector, the agriculture sector is the second largest emitting sector in France accounting for 17% of total GHG emissions in 2016. In 2018, 45% of these emissions are provided by methane (CH_4) emissions due to enteric fermentation followed by N_2O emissions coming from cultivated soils (Haut Conseil pour le Climat, 2019).

2. Country specific targets and compliance

2.1. Sector specific emission targets

Table 2: Sector specific emission reduction targets. Low-Carbon National Strategy, Draft December 2018 (Ministère de la Transition écologique et Solidaire, 2018).

Sector	**Target 2020**	**Target 2030**	**Other national targets**
Economy wide	20% below 1990 level	40% below 1990 level	Carbon-Neutrality by 2050
Energy Production		60% below 1990 level	Renewable energy (share of gross final energy consumption): • 23% by 2020 • 32% by 2030 Share of Nuclear Energy in power production reduced to 50% by 2035 Virtually decarbonize energy sector: 97% below 1990 levels by 2050
Transport		28% below 1990 level	Final energy consumption: 16% below 2016 level by 2028 Virtually decarbonize transport sector: 97% below 1990 levels by 2050 Last fossil-fuel based vehicle sold in 2040
Buildings		53% below 1990 level	Final energy consumption: 14% below 2012 level by 2028 Virtually decarbonize building sector: 94% below 1990 level by 2050
Industry		63% below 1990 level	89% below 1990 levels by 2050
Agriculture		22% below 1990 level	50% below 1990 levels by 2050

2.2. How well is the country complying with its targets?

Target Compliance

France's newly appointed independent climate advisory council, the Haut Conseil pour le Climat (HCC) indicated in its recent report published in June 2019 that France is not on track to meet its carbon neutrality target for 2050 and thus its 40% emissions reductions target for 2030, having emitted 4% more than what was needed to meet these targets for the period

2015-2018 (Haut Conseil pour le Climat, 2019). Upon French government projections, under existing measures, emissions are projected to be reduced up to 28% below 1990 level excluding LULUCF emissions. It is unclear yet if France plans to include its LULUCFs sinks in the target, if included, this would mean a reduction of 39% below 1990, which would virtually meet the targets. However, the sectoral emission targets require a strong deviation in current emission reduction trajectories for most sectors. Government projections for emission reductions under current policies for other sectors are shown in Table 2.

Table 3 : Government emission projections with existing measures for 2030. Source: Targets are based from the Low-Carbon Draft Strategy published in December 2018 (Ministère de la Transition écologique et Solidaire, 2018) *and the projections are based on the National integrated Climate-Energy Plan published in January 2019* (Ministère de la Transition écologique et solidaire, 2019).

Sector	Target 2030	Projection to 2030 with existing measures
Economy wide	40% below 1990 level	28% below 1990 level excl. LULUCF 39% below 1990 incl. LULUCF
Energy production	60% below 1990 level	30% below 1990 level
Agriculture	22% below 1990 level	14% below 1990 level
Industry	63% below 1990 level	50% below 1990 level
Transport	28% below 1990 level	1% above 1990 level

The EU's nationally determined contribution (NDC) under the Paris Agreement is for a 40% reduction in emissions below the 1990 level by 2030. Under the EU's Effort Sharing Regulation, EU Member States have binding targets to reduce their GHG emissions from those sectors not covered by the EU Emissions Trading Scheme (ETS) that were agreed on largely according to their relative economic strength. The overall EU 2030 target for these sectors, which includes transport, buildings, agriculture and waste, is a 30% reduction below the 2005 level, which translate for France to a reduction of 37% below 2005 levels.

Upon Governmental projections, France is not on track to meet its 2030 EU Target of 37% emissions reduction below 2005 for non-ETS sectors. In fact, non-ETS emissions projections under existing measures are expected to be 18% higher than the target in 2030. France will need to make higher efforts to reach its EU NDC target as well as to reach its domestic target of 40% reduction below 1990 levels by 2030.

Global Warming Pathway Related to EU and National Targets

Based on the methodology of the Climate Action Tracker, the EU's NDC and projected emissions under current policies for 2030 are not consistent with holding warming to below 2°C, let alone limiting it to 1.5°C as required under the Paris Agreement. EU projected 2030 emission levels are instead consistent with warming of between 2°C and 3°C, if all countries made comparable commitments (Climate Action Tracker, 2019). Downscaling the Climate

Action Tracker fair share range for the European Union to France[2], it can be concluded that France's domestic mitigation target and current policy projections are consistent with warming of between 3°C and 4°C, if all countries made comparable efforts.

3. Country's climate policies and practices

3.1. How are the key and most emitting sectors under current policies contributing to limit global warming to 1.5°?

The following table shows an overview of positive and negative policy developments in four key emitting sectors in France compared with sector-specific short-term benchmarks for limiting global warming to 1.5°C as identified by (Kuramochi et al., 2017).

Sector	Necessary step	Assessment and opportunities for improvement
Transport	Last fossil fuel car sold before 2035	+National programmes to sup-port shift to public transport: Development of High Speed Railway Lines (HSL) and dedicated-lane public transport (757 km of additional new high-speed lines put into service between 2015 and 2020) +Financial support scheme for „combined transport" where the main link of the transport chain is rail, waterway or maritime +/- National target on end date for sales of fossil fuel cars in 2040 existing but still not compliant with PA benchmark of 2035. -Missing the emissions trajectory cap for 2015-2018 by 9% above the target -Fuel-tax abandoned in December 2018 -No specific policies to moderate the increase of private road transport demand -Slow electrification of the transport sector -Support scheme to the purchase of Electric Bicycles restricted in January 2018
Buildings		+ construction of low-consumption buildings to become standard by 2012 + construction of energy-plus houses to become standard by 2020. -missing the emissions trajectory cap for 2015-2018 by 16% above the target -slow renovation rate due to complex administrative procedures and non-stable regulations -lack of monitoring framework does not allow precise assessment of the sector
Agriculture	Keep emissions in 2020 at or below current levels, establish and disseminate regional best practice, ramp up research	+/- Slow reduction of emissions observed (8% between 1990 and 2018) -No comprehensive policy to close the gap and accelerate the decarbonization of the sector

[2] France fair share range is calculated by applying a proportional percent reduction below 2005 emissions levels from the EU fair share range, adjusted considering the higher proportional reduction obligation of France according to the EU's Effort Sharing Regulation.

Industry	All new installations in emissions-intensive sectors are low-carbon after 2020, maximise material efficiency	-no target for new installations in emission-intensive sectors to be low-carbon
Energy	Sustain the growth of renewables and other zero and low carbon power until 2025 to reach 100% by 2050	- Share of Nuclear Energy in power production target of 50% postponed from 2025 to 2035. - France will not meet its 2020 and 2030 renewable energy targets of 23% and 32% respectively in final energy consumption. Renewable Energy Shares in is expected to reach between 16,6% - 20,4% under current policies in 2020 (Navigant, 2019). - 2050 decarbonization strategy relies on sinks and the development of CCS technology yet unclear
	No new coal plants, reduce emissions from coal power globally by at least 30% by 2025, coal phase out by 2030 in EU and OECD countries.	+ coal phase-out planned for 2021

3.2. Policy deficiencies and policies or practices negatively contributing to global warming in key sectors

- **Transportation Policies needs to be reinforced:** the transport sector and more specifically the private passenger road transport is the main contributor to France National GHG emissions. While France targets to close to 30% by 2030 compared to 1990, transport emissions have remained stagnant for the past decade. A slow electrification combined with a slow modal shift and an increase in demand may explain this increase in emissions. (Haut Conseil pour le Climat, 2019). While the French Mobility law was adopted in June 2019, the concrete financing plan of its implementation is so far unclear and thus threaten the feasibility of its implementation (Autorité Environnementale Conseil général de l'environnement et du développement durable, 2019; I4CE - Institute For Climate Economics, 2019) and an attempt of the government to introduce a fuel-tax bill on private transport generated massive social protest in 2018 which led to the government's abandonment of the bill. While limiting the road transport demand and supporting the transition from road to other transport modals will need stronger measures, the support to the purchase of electric bicycles which had proven its benefit in 2017 was restricted in 2018 (Autorité Environnementale Conseil général de l'environnement et du développement durable, 2019; Rüdinger et al., 2018).

- **Lagging behind in renewable energy and energy efficiency targets:** France will not meet its 2020 and 2030 renewable energy targets having postponed from 2025 to 2035 the target of a 50% share of nuclear in energy production. 2020 renewable share in final energy consumption is expected to reach between 16,6% - 20,4% under current policies (Navigant, 2019). A lack of investment in the renewable energy sector together with a lack of clarity and planification on the phase-down from the nuclear sector contribute to this trend (Climate Action Network Europe (CAN), 2018; Rüdinger et al., 2018). In the buildings sector, France to meets its emissions reduction 2017 target (+22% compared to the 2017 target in building sector) and is unlikely to meet its 2030 target (see previous section). An unclear support scheme for renovations with heavy administrative implementation and constantly changing scope are slowing the rate of renovations (Haut Conseil pour le Climat, 2019; Rüdinger et al., 2018). It is estimated that to reverse this trend France should spend between 15 to 30 billion euro per year over 30 years which is much higher than what is currently planned (13,5 billion euros) (Autorité Environnementale Conseil général de l'environnement et du développement durable, 2019).

- **High level of "Brown" climate investments:** in 2017, investments in non-climate friendly investments reached 27 billion euros which support the use of fossil fuels energy. 98% of them were dedicated to fossil-fuel vehicles sector. "Green" investments were 1,5 times lower than expected to meet emissions cap settled for the period 2015-2018 (Haut Conseil pour le Climat, 2019).

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4.4. Germany

Drivers of Climate Change: Germany

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Summary

Germany's total greenhouse gas emissions steadily declined between 1990 and 2010, but have largely been stagnant since. The main drivers of emissions in Germany are the energy, transport and industry sectors, which account for 75% of total emissions.

Germany has made significant strides in its approach to climate change policy, with its Energiewende project leading to strong renewable energy uptake over many years and with its advocacy for robust EU action on the issue and on ambitious climate policy in the past. However, in recent years Germany's progress in decarbonizing its economy has stalled and so has its former leadership role within the EU. Germany will now definitely miss its own 2020 emission reduction target and also the binding EU 2020 target for sectors outside the European Emissions Trading Scheme (ETS). This raises questions as to whether Germany will step up its climate policy to embrace transformational change towards becoming largely greenhouse gas neutral by 2050, as agreed by the Government in its long-term strategy adopted in 2016.

Emissions in the key sectors of transportation and industry have been rising over recent years until 2017, with current policies in these sectors found to be lacking in transformational ambition. Germany will need to implement additional policies if it is to meet its 2030 target of a 55% emission reduction below 1990 levels, while meeting even its 38% target under the EU ESR is likely to be challenging without increasing its policy ambition.

Germany's domestic 2030 mitigation target consistent with warming of between 2°C and 3°C, if all countries made comparable commitments, while current policy projections would be in line with between 3°C and 4°C global warming. Similarly, the EU's NDC target of a 40% reduction below 1990 levels by 2030 is compatible with warming of between 2°C and 3°C if all countries made comparable commitments. It is therefore imperative that Germany adopts more ambitious targets and policies.

4. Germany's Emission Profile

4.1. Historical and Projected Emissions

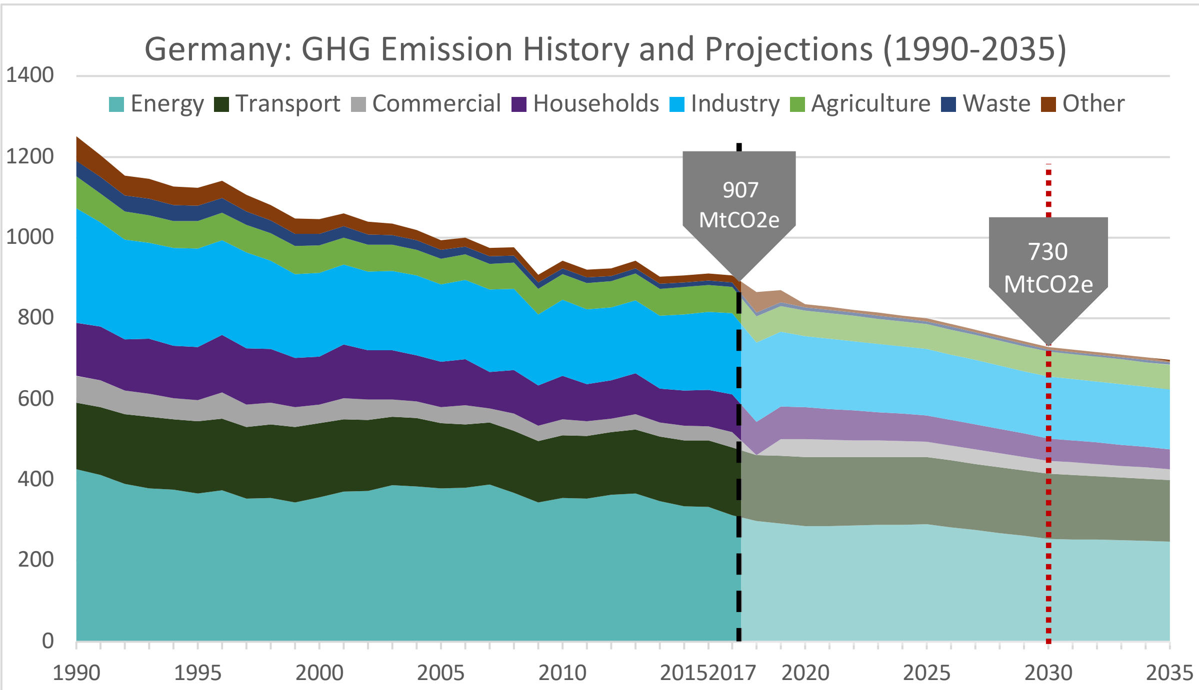


Figure 1: *Historical and projected emissions of Germany from 1990 to 2035.*

Source: German Ministry of Environment, 2017a, 2019c

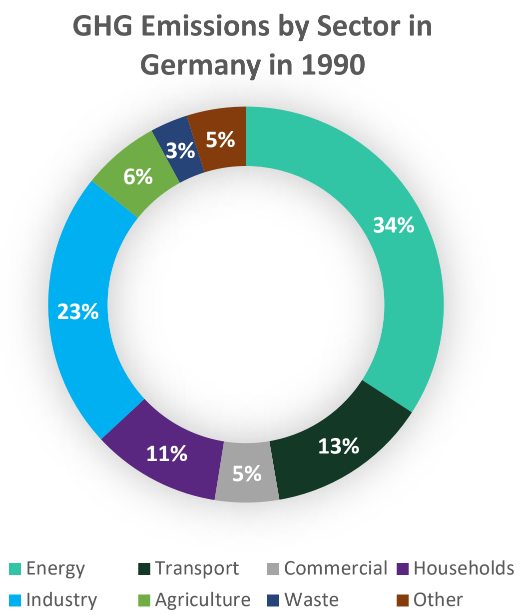
Germany's total greenhouse gas (GHG) emissions steadily declined between 1990 and 2010, but have been largely stagnant since. Emissions data from 2017 puts Germany's overall emissions at 907 $MtCO_2e$ (excluding LULUCF), roughly 28% lower than 1990 levels. Germany's 2016 level of GHG emissions (911 $MtCO_2e$) constituted approximately 1.9% of global emissions for that year (Gütschow, Jeffery, & Gieseke, 2019).

Based on current policies[3], Germany's emissions are expected to be 730 $MtCO_2$ by 2030 (German Ministry of Environment, 2019d).

[3] Emissions projections include policies implemented as of 2017, as reported in the latest projection report provided to the European Commission in 2019. These projections do not yet include the effect of new policies and market trends in the last two years, nor policies currently under discussion such as the coal phase-out regulation, which is expected to become a national law by the end of 2019.

4.2. Key emission contributions

Germany's energy, transport and industry sectors contributed a combined 75% of emissions in 2017, up from 70% in 1990. This is primarily due to a lack of emission reductions from the transport sector, with transport increasing its emission share from 13.1% in 1990 to 18.5% in 2017 (German Ministry of Environment, 2019b).



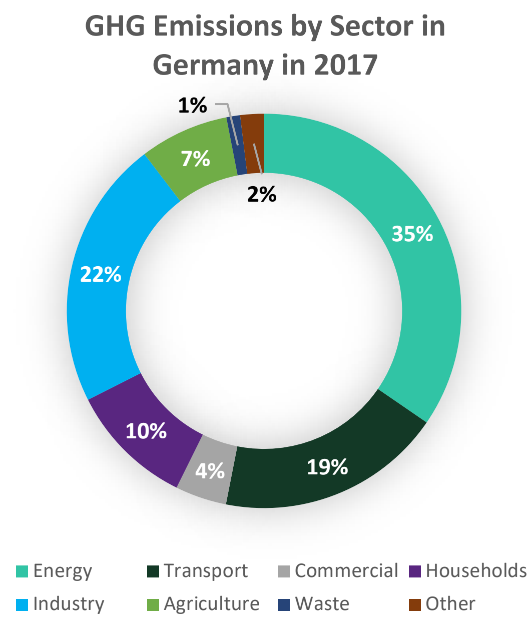


Figure 2: *GHG emissions contributions by sector in 1990 (left) and 2017 (right).*
Source: German Ministry of Environment, 2019c

- **Drivers of Energy Emissions:**

Due to a fall in the price of coal and of CO_2 emission allowances from 2010 and increasing natural gas prices, coal fired power began replacing that from gas plants, pushing them out of the market. This led to a paradoxical situation whereby GHG emissions were rising despite an increasing share of renewable energy in Germany's energy supply (Graichen, Redl, & Kleiner, 2014).

Strong investment in renewable energy, led higher by the introduction of feed-in tariff legislation in 2000 has led to a more than doubling of output from renewable sources between 2010 and 2018. Continued strong growth in renewable energy capacity will be required to offset the looming reductions in coal power capacity related to the likely 2038 coal phase-out, while also replacing nuclear energy capacity that is scheduled to be phased out by 2022 (German Ministry of Environment, 2019e). Energy sector emissions resumed their downward trajectory from 2014, although the latest government projections show energy sector emission reductions stagnating between 2020 and 2025 (German Ministry of Environment, 2019d).

- **Drivers of Transport Emissions:**

Despite Germany´s transport sector achieving a steady reduction in emissions from their peak in 1999 to the recession year of 2009, emissions have been rising since, peaking in 2017 above 1990 levels (German Ministry of Environment, 2019c). While Germany´s automotive manufacturers have invested substantially in researching lower emission vehicles (VDA, 2017), the average weight of German cars has increased substantially since 2000, with the average mass of the German new car fleet 170kg heavier than the European average in 2016 (Campestrini & Mock, 2011; International Council on Clean Transportation, 2017). In addition, German car manufacturers have considerable political clout and were behind the successful push by Germany to water down EU level emissions standards for vehicles in 2013. Meanwhile demand for electric vehicles has failed to materialise, with battery and plug-in hybrid sales accounting for less than 2% of total passenger vehicle sales in 2018 (German Federal Motor Transport Authority, 2019).

5. Country specific targets and compliance

5.1. Sector specific emission targets

Sector	Target 2020	Target 2030	Other national targets
Economy wide excl. LULUCF	40% below 1990 level	55% below 1990 level	Extensive greenhouse gas neutrality by 2050
Energy		61-62% below 1990 level	Renewable energy (share of gross final energy consumption): • 18% by 2020 • 30% by 2030 Primary energy consumption: 50% below 2008 level by 2050 Almost complete decarbonisation of the energy supply by 2050
Transport		40-42% below 1990 level	Final energy consumption: 40% below 2005 level by 2050 Virtually decarbonised transport system by 2050
Industry		49-51% below 1990 level	Greenhouse gas neutrality by 2050
Buildings		66-67% below 1990 level	Primary energy demand for buildings: 80% below 2008 level by 2050 Virtually carbon neutral building stock by 2050
Agriculture		31-34% below 1990 level	Further reductions beyond the 2030 target by 2050

Table 1. *Sector specific emission targets.*

Source: German Ministry of Environment, 2016, 2019b

5.2. How well is the country complying with its targets?

- **Compliance with Targets:**

According to the German federal government, Germany will miss its own goal of a 40% reduction in GHG emissions below 1990 levels by 2020 by a large margin, with the current projection showing a reduction of 33% by 2020 (German Ministry of Environment, 2019d). This makes the achievement of its 2030 target of a 55% reduction below 1990 levels much more difficult, and will require substantial additional policies to be put in place. Germany edging closer, however to meeting its 2020 goal of 18% of gross final energy consumption sourced from renewable energy, reaching 16,6% in 2018 (German Ministry of Environment, 2019a).

The sectoral emission targets require a strong deviation in current emission reduction trajectories for most sectors. Government projections for emission reductions under current policies for other sectors are shown in Table 2.

Sector	Target 2030	Projection to 2030 with Current Policies
Economy wide excl. LULUCF	55% below 1990 level	42% below 1990 level
Energy	61-62% below 1990 level	40% below 1990 level
Agriculture	31-34% below 1990 level	23% below 1990 level
Industry	49-51% below 1990 level	46% below 1990 level
Transport	40-42% below 1990 level	3% below 1990 level

Table 2. *Targeted vs. Projected Sectoral Emission Reductions*

Source: German Ministry of Environment, 2019d, 2019b

Under the EU's Effort Sharing Regulation, EU Member States have binding targets to reduce their GHG emissions from those sectors not covered by the EU Emissions Trading Scheme (ETS) that were agreed on largely according to their relative economic strength. The overall EU 2030 target for these sectors, which includes transport, buildings, agriculture and waste, is a 30% reduction below the 2005 level, with Germany's target set at 38% below the 2005 level (German Ministry of Environment, 2019b). Under current projections, Germany's emissions from these sectors is set to be 26.5% below the 2005 level in 2030 (German Ministry of Environment, 2019d).

- **Global Warming Pathway Related to EU and National Targets:**

The EU's nationally determined contribution (NDC) under the Paris Agreement is for a 40% reduction in emissions below the 1990 level by 2030. While Germany is on track, with current policies, for a 41% reduction in emissions below 1990 levels by 2030, this in effect requires other EU countries, many of which are less wealthy than Germany, to make comparatively higher emissions reduction efforts in order to meet the EU NDC. Germany is not on track to achieve its domestic target of 55% reduction below 1990 levels by 2030.

Based on the methodology of the Climate Action Tracker, the EU's NDC and projected emissions under current policies for 2030 are not consistent with holding warming to below 2°C, let alone limiting it to 1.5°C as required under the Paris Agreement. EU projected 2030 emission levels are instead consistent with warming of between 2°C and 3°C, if all countries made comparable commitments (Climate Action Tracker, 2019). Downscaling the Climate Action Tracker fair share range for the European Union to Germany[4], it can be concluded that Germany's domestic mitigation target is also consistent with warming of between 2°C and 3°C, if all countries made comparable commitments, while current policy projections would be in line with between 3°C and 4°C global warming.

6. Country's climate policies and practices

6.1. How are the key and most emitting sectors under current policies contributing to limit global warming to 1.5°?

Table 3 shows an overview of positive and negative policy developments in four key emitting sectors in Germany compared with sector-specific short-term benchmarks for limiting global warming to 1.5°C as identified by (Kuramochi et al., 2017).

Sector	Necessary step	Assessment and opportunities for improvement
Power	Sustain the growth of renewables and other zero and low carbon power until 2025 to reach 100% by 2050	+ More than doubling in renewable energy share of electricity production since 2010, to 35.2% in 2018 + Recently improved renewable energy target of 65% of electricity production by 2030 - Significant slowdown in investment in onshore wind power - Subsidies for solar, wind and biomass facilities will begin expiring in 2020
	No new coal plants, reduce emissions from coal power globally by at least 30% by 2025, coal phase out by 2030 in EU and OECD countries.	+ Legislation passed in 2016 to transition 2.7GW of lignite coal plants to "security standby" before being shut down after four years + No new coal plants are planned, and phase-out has been agreed to by 2038, with a review scheduled in 2032 for a potential phase out date of 2035 + Emissions from coal to be reduced by 30% by 2022 - Multiple coal plants have been commissioned in recent years, making it costlier and more difficult to abide by the 2038 phase-out date - 2038 date is not consistent with the Paris Agreement benchmark for coal phase-out in OECD countries, which would require a full phase-out by 2030
Transport	Last fossil fuel car sold before 2035	+ Up to €4,000 grants for electric vehicle purchases + €300 committed for construction of charging infrastructure + €5 billion invested to encourage electric mobility since 2009 - Germany pushed for weaker EU vehicle emission standards both in 2013 and 2018, leading to less ambitious legislation

[4] See table X. The Germany fair share range is calculated by applying a proportional percent reduction below 2005 emissions levels from the EU fair share range, adjusted considering the higher proportional reduction obligation of Germany according to the EU's Effort Sharing Regulation (8% more than EU average).

		- Subsidies still exist for diesel fuel and for car travel under the commuters' tax allowance - Low EV uptake compared to European neighbours and target of 1 million EVs on German roads by 2020 has been pushed back to 2022
Industry	All new installations in emissions-intensive sectors are low-carbon after 2020, maximise material efficiency	+ Commitment to double Germany's resource efficiency from 1994 levels by 2020 + A range of Energy efficiency policies have been implemented including incentives for energy management systems + Only sector projected to come close to meeting its 2030 target under current policies - A large proportion of industrial emission reductions since 1990 were due to East German factory closures, not process improvements, emissions have stagnated instead of decreasing between 2009 and 2017.

Table 3. *Positive and Negative Policy Developments in Key Sectors*

Source: Climate Analytics own evaluation, Climate Analytics, 2016, 2018

6.2. Policy deficiencies and policies or practices negatively contributing to global warming in key sectors

- **Climate Action Law has not been legislated:** While many German states have implemented their own climate action legislation, of yet there is, no federal German climate law, even though there is a political commitment to do so (CDU, CSU, & SPD, 2018). Such climate action legislation ensures a country's national climate targets are legally binding, creating enforceable consequences if they are not met. Such enforceable consequences already exist at the EU level, however, Germany's EU emission reduction responsibilities are less stringent than its national targets (German Ministry of Environment, 2019b). A first draft of the climate action legislation was sent to the chancellery in early 2019 by the Environment ministry (Appunn & Wettengel, 2019), but was met with fierce criticism by many in Chancellor Angela Merkel's conservative party. Under the proposed law, the current 2030 sector targets would not only become legally binding, but they would be broken down into annual emission budgets (Appunn & Wettengel, 2019). This is similar to the already existing EU Effort Sharing Regulation (ESR), which stipulates countries not meeting their annual targets must purchase emission reductions from other EU countries that have overachieved their targets (European Commission, 2016). Under the proposed legislation, shortfalls under the ESR would be allocated at a sector level and paid by the corresponding ministry budget.

- **Energy policies must be strengthened:** Though Germany has seen a strong uptake in renewable energy in the last decade, coal still constituted 35% of German electricity production in 2018 (AG-Energiebilanzen, 2019). The recommendation in 2019 to a coal phase out date is a promising development, but the date of 2038 is not consistent with the Paris Agreement. An analysis on least cost pathways for a global coal phase out found that OECD countries should phase out coal by no later than 2030 (Climate Analytics, 2018). With renewable energy feed-in tariffs being replaced by auctioning from 2020 onwards and investment in wind energy flagging (Eckert, 2019; German Ministry of Environment, 2017b), there is a risk that Germany's strong recent progress on renewable energy uptake will falter without further government support.

- **Industry emissions have been rising:** Germany made strong progress on industrial decarbonization throughout the 1990s as inefficient East German plants were shut down and efficiency policies were implemented. However, emissions from industry stabilised around the turn of the century and actually rose between 2013 and 2017 to reach above 2001 levels in 2017 (German Ministry of Environment, 2019c). While Germany has targets and policies for energy efficiency (German Ministry of Environment, 2019b), no significant policy to focus Germany's emission reduction efforts from industry towards decarbonisation has yet been implemented, however, with the Climate Action Plan, the Government has decided to develop a strategy toward decarbonisation together with Industry (German Ministry of Environment, 2016).

- **Transportation policies are proving insufficient:** Transport emissions in Germany peaked in 1999, but have not yet fallen below 1990 levels after sitting flat between 2007 and 2012 and rising thereafter until 2017 (German Ministry of Environment, 2019c). Electrification of the German vehicle stock is an important strategy, particularly as the proportion of renewable energy stock rises, but so far German policy on this front is not strong enough. Subsidies are in place to encourage the purchase of electric vehicles (EVs) (German Ministry of Economy and Energy, 2019), but there is no target set for phasing out fossil fuel LDV sales, and the target of 1 million EVs on German roads by 2020 has been pushed back to 2022 (Heller, 2018). With Germany lagging in its EV uptake, it makes the existence of the commuter's tax allowance for vehicle costs particularly damaging with regards to emissions, while subsidies available for diesel fuel work against EV uptake.

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CLIMATE ANALYTICS

4.5. Turkey

Drivers of Climate Change: the case of Turkey

Table of Contents

Summary

Emissions in Turkey have been steadily growing since 1990, with most of the growth coming from energy related emissions. Energy emissions (excluding LULUCF) are (72%), followed by Industry (13%) and Agriculture (12%).

Turkey's climate commitment and projected emissions levels under current policies for 2030 are consistent with global warming above 4°C by the end of the century, if all countries were to follow Turkey's approach. In addition, Turkey remains one of the few countries in the world that have not ratified the Paris Agreement.

In the energy sector, besides the planned increase of renewable shares in the power sector and some energy efficiency measures, Turkey continues with its plan to meet increasing energy demand by building new coal-fired power plants and promote the use of domestic coal, which is against a decarbonization of the power sector. Due to its strategic location and the increasing demand on Liquified Natural Gas (LNG) worldwide, Turkey is also promoting the use of natural gas abroad and developing its storage and regasification capacities

Although Turkey has settled a partly successfully renewable auctions program (YEKA), if the delays and cancellation for renewables experienced so far were to continue, it is unlikely that the targeted timeline of renewable shares increase will be met. Tukey is also lagging behind

on transport sector, dependent on fossil-fuel and with insufficient incentives for low-carbon alternatives.

Turkey will need to review the ambition of its INDC and sectorial targets to meet the 1.5°C compatible benchmarks and scale up climate action substantially to halt emissions growth. Paris Agreement compatible emissions pathways require emissions to peak and decline fast afterwards, reaching carbon neutrality by mid-century. In contrast, under current policies, emissions of Turkey are expected to grow by 2030.

Turkey's Emissions Profile

Historical and Projected Emissions

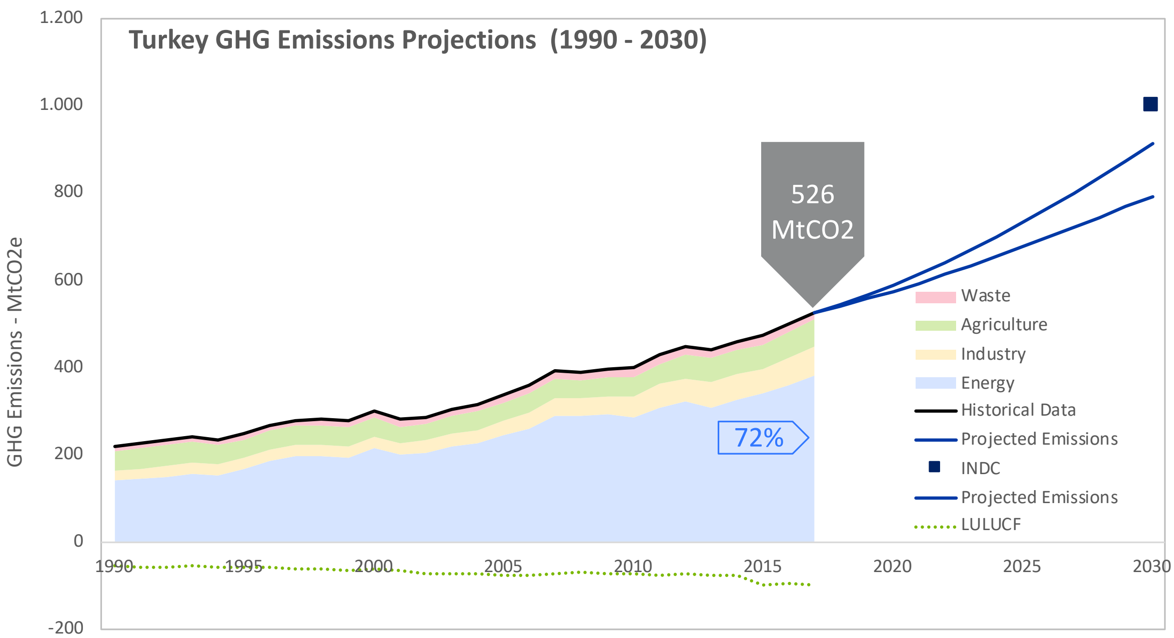

Figure 36: *Historical and projected emissions of Turkey from 1990 to 2030 based on the most recent update from Climate Action Tracker* (Climate Action Tracker, 2019)*. Share of the Energy sector (72%) is here indicated excluding LULUCF emissions.*

As shown in figure 1, historical emissions in Turkey have been steadily growing since 1990 to reach 526 $MtCO_2$ emissions in 2017 (excluding LULUCF), which is more than doubling 1990 levels of emissions, with most of the growth coming from energy related emissions. Third party sources estimated the country emissions for 2015 and 2016, reaching a share of 1,1% of emissions worldwide in 2016 (Gütschow, Jeffery, & Gieseke, 2019).

According to Climate Action Tracker most recent assessment (Climate Action Tracker, 2019), under current policies, annual emissions from all sectors (excluding LULUCF) are still projected to grow significantly, namely by between 199% to 229% above 2010 levels by 2030, reaching about 792-914 $MtCO_2$ in 2030, which is equal to doubling emissions from 2010 levels.

The projection of current policies shown in figure 1 (Climate Action Tracker, 2019) is based on the mitigation scenarios underlying the seven National Communication of Turkey to the UNFCCC (Republic of Turkey Ministry of Environment and Urbanization, 2018), including Turkey's nuclear power plant planned to be launched in 2023 (Republic of Turkey Ministry of Environment and Urbanization, 2018) and expected to be fully operational by 2025. The upper-bound projections for the current policies scenario are based on the "with measures" scenario from the National Communication, including a nuclear target for 2025 The lower-bound of the current policy projection is based on historical trends of GDP elasticity of energy and industry GHG emissions between 1990 and 2017 with adjusted GDP on more recent growth estimates (IMF, 2018; PWC, 2017), due to unrealistic high assumptions made within official projections.

Key sectors drivers of Emissions

The largest share of Turkey current emissions (excluding LULUCF) correspond to energy emissions, accounting for 72% of the total in 2017 (Figure 30), followed by Industry (13%) and Agriculture (12%).

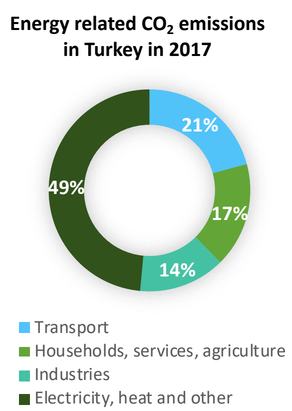

Figure 37: *Shares in energy related co₂ emissions. Source: G20 Brown to Green report 2018* (Climate Transparency, 2018)

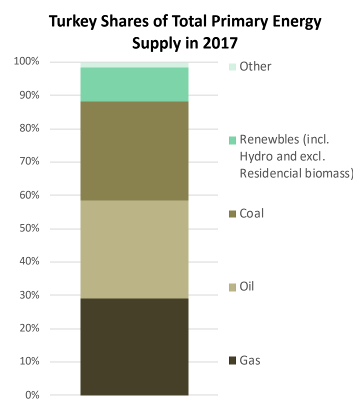

Figure 38: *Share of total primary Energy Supply in Turkey in 2017. Source: G20 Brown to Green report 2018* (Climate Transparency, 2018)

- **Drivers of Energy emissions:**

Electricity and heat sector is the main contributor of Turkey's energy emissions, accounting for 49% of energy related emissions in 2017, representing approximately 28% of the total national GHG emissions in 2017 (excl. LULUCF) (Turkish Statistical Institute, 2019). Fossil fuel-based generation dominates primary energy supply in Turkey accounting for over 70% of the electricity mix in 2017, with 37% of electricity generation coming from natural gas, followed by coal (32%). Renewable generation is dominated by hydro (20%). Liquid fuel, waste, wind and geothermal contribute the remaining 11% (IEA, 2019). Turkey's electricity sector heavily relies on natural gas, mostly imported from Russia. To reduce dependency and meet the increasing power demand (expected to be 4% to 6% annually (Erdin & Ozkaya, 2019)), the

Turkish Government aims to increase the share of electricity generation based on coal and renewables (Republic of Turkey Ministry of Environment and Urbanization, 2016) (Climate Action Tracker, forthcoming 2019). 2018 saw Turkey breaking its record in domestic coal production, which reached 101.5 million tonnes (Anadolu Agency, 2019) and the government is continuing to press for a large expansion in coal power with close to 37 GW of planned power plants (announced, pre-permitted and permitted) (Coalswarm, 2019). This stands in strong contrast to the global need to reduce the use of coal in electricity by two-thirds over 2020-2030 and to zero by 2050 (IPCC, 2018). Turkey is also embarking on nuclear power plant production. Having no nuclear power at the moment, the Energy and Natural Resources Minister announced that between 2023 and 2030 Turkey will put three nuclear power plants into operation, expected to meet 10% of the country-wide electricity consumption (Republic of Turkey Ministry of Environment and Urbanization, 2018).

- **Drivers of Transport Emissions:**

Transport emissions account for around 18% of Turkey's GHG emissions (excl. LULUCF) (Republic of Turkey Ministry of Environment and Urbanization, 2018). Transport sector emissions are dominated by the road transport accounting for 93% of transport sector GHG emissions in 2017. Turkish inventory data shows that between 1990 and 2017, road transport-related emissions more than tripled (Turkish Statistical Institute, 2019). The majority of transport is road-based, with diesel playing a major role and LPG having an notably high share in sector fuel use (71,5% for Gas and Diesel in 2016 and 13,6% for LPG in 2016) (Agora Verkehrswende, 2018).

Country specific targets and compliance

Country specific targets

Sector	Target 2020	INDC[5] Target 2030	Other national targets
Economy wide, incl. LULUCF	None	Unconditional target: 21% below BAU by 2030 [356% above 1990 by 2030 excl. LULUCF] [150% above 2010 by 2030 excl. LULUCF]	
Energy		Increasing capacity of production of electricity from solar power to 10 GW and from wind power to 16 GW until 2030	1) Increase the share of renewables in the electricity generation mix to 38,8% by 2023 2) 20% reduction in energy intensity by 2023 compared to 2008
Transport			Increase the share of railway transport above 15% (which was 5% in 2009), thereby reducing the road transport share to below 60% in 2023 (which was 81% in 2009).

[5] As of August 15th 2019, Turkey has not ratified the Paris Agreement, making its 2030 emissions target only an "Intended Nationally Determined Contribution" (INDC). Source for ratification status: https://treaties.un.org/Pages/ViewDetails.aspx?src=TREATY&mtdsg_no=XXVII-7-d&chapter=27&lang=_en&clang=_en

Table 1: *Sector specific emission targets.*

Sources: Most recent Turkey Climate Action Tracker update (Climate Action Tracker, 2019), National Renewable Energy Action Plan (Ministry of Energy and Natural Resources, 2014), National Energy Efficiency Strategy Paper (Republic of Turkey Ministry of Energy and Natural Resources, 2012), National Climate Change Action Plan (Republic of Turkey Ministry of Environment and Urbanisation, 2011), 11th Development Plan (Presidency of the Republic of Tukey, 2019)

How well is the country complying with its targets?

- **Compliance with Targets:**

According to the Climate Action Tracker most recent assessment, Tukey is on track to overachieve its INDC 2030 target although rated as "critically insufficient" by Climate Action Tracker (Climate Action Tracker, 2019). Turkey remains one of the only two G20 countries that have not ratified the Paris Agreement. Its Intended National Determined Contribution (INDC) target submitted in 2015 is equivalent to a 90% increase from 2017 levels, excluding LULUCF.

With regards to sector specific targets, based on the high share of hydropower in electricity generation (25% in 2016), Tukey has already achieved its National Renewable Energy Action Plan target of 30% power generation from renewable sources for 2023 (IEA, 2018) and unveiled a new target in its 11th Development Plan published in July 2019 of 38,8% share of renewable energy in electricity generation in 2023 (Presidency of the Republic of Tukey, 2019). However, it is still lagging behind from its INDC targets of solar and wind energy installed capacity, where even though the Ministry of Energy and Natural Resources has new plans for an additional 10 GW of solar PV and 10 GW of wind capacity to be installed in the coming decade, ongoing delays for renewables auctioning and installation are threatening the achievement of the target (Climate Action Tracker, 2019).To meet its renewable energy share target, the government has introduced in 2016 the Renewable Energy Resource Areas (YEKA) strategy, a tender process to procure the production of renewable energy on 'Renewable Energy Designated Areas' (REDAs) which are deemed most suitable for energy generation and the first auctions were awarded for a Solar PV plant in March 2017 and for a Wind onshore plant in August 2017 (Sarı, Saygın, & Lucas, 2019). A third wind onshore auction (1 GW) has recently (May 2019) been awarded to the German-Turkish consortia (Enercon-Enerjisa) (Daily Sabah, 2019). However, while the 2017 auctioning process was successful, the 1.2 GW off-shore wind auction initially announced for June 2018 has been postponed to 2019 at the earliest. This was followed by the cancellation of the second solar PV YEKA auction, originally planned for January 2019.

- **Global Warming Pathway regarding INDC and current policies projections:**

Based on the Climate Action Tracker methodology, Turkey's climate commitment and projected emissions levels under current policies for 2030 are not consistent with holding warming to below 2°C, let alone limiting it to 1.5°C as required under the Paris Agreement, and are instead consistent with warming above 4°C, if all countries were to follow Turkey's approach (Climate Action Tracker, 2019).

Paris Agreement compatible emissions pathways require emissions to peak and decline fast afterwards, reaching carbon neutrality by mid-century. In contrast, under current policies, emissions of Turkey are expected to grow by 2030 (Climate Action Tracker, 2019).

Country's climate policies and practices:

How are the key and most emitting sectors under current policies contributing to limit global warming to 1.5°?

The following table shows an overview of positive and negative policy developments in two key emitting sectors in Turkey compared with sector-specific short-term benchmarks for limiting global warming to 1.5°C as identified by (Kuramochi et al., 2017).

Sector	1.5 °C-consistent benchmark	Assessment and opportunities for improvement
Electricity and heat sector	Sustain the global average growth of renewables and other zero and low carbon power until 2025 to reach 100% by 2050	+ The renewable energy share grew significantly in recent years (from 27% in 2012 to 33% in 2016) with big additions of wind and solar capacity and clear national targets and policies to increase share further in the future. + National Energy Efficiency Action Plan can attenuate energy demand growth facilitate integration of higher shares of renewable energy - Current target (38,8% by 2023) will not be sufficient to meet the 1.5°C compatible benchmark of 59%-81% by 2030 (world average) - Delays in both RE projects construction and auctions, put at risk the achievement of the RE installation targets - Significant untapped potential for renewable power, especially solar power
	No new coal plants commissioned, reduce emissions from coal power by at least 30% by 2025	- The use of "clean coal technologies" and measures to increase energy efficiency is mentioned in the National Climate Change Action Plan - 1.2 GW of additional capacity is under construction, with completion expected by the end of 2019 and significant new coal capacity in the pipeline (37 GW of planned power plants (announced, pre-permitted and permitted) (Coalswarm, 2019) - Increasing domestic coal production and domestic push for further increase with announced tenders for coal mines acquisition (Ahval, 2019).
Transport	Last fossil fuel car sold before 2035	+ Policies in place focused on the development of legal arrangements, capacity building and promotion of alternative fuels and clean vehicles - No overarching 1.5°C/2°C compatible vision for transport sector in Turkey - Insignificant share of EVs (less than 1% since 2011) and no policy to ramp up EVs uptake

Table 2: *Positive and negative policy developments in key sectors of Turkey.*

Source: Scaling Up Climate Action in Turkey (Climate Action Tracker, forthcoming 2019).

Lacking policies and practices or negatively contributing to global warming in key and most emitting sectors

- **Increasing coal share in power sector:** besides renewable energy sources, coal is considered the most important source of substitution to reduce the dependency on imported natural gas. To meet its increased energy demand, Turkey plans to build new coal-fired power plants (Istanbul Policy Center, 2016) and, as the Ministry of Energy and Natural Resources announced in May 2019, is holding tenders for coal mines promoting domestic coal. 1.2 GW of additional capacity is under construction, with completion expected by the end of 2019 and *s*ignificant new coal capacity in the pipeline (37 GW of planned power plants (announced, pre-permitted and permitted) (Coalswarm, 2019). Apart from the impact on emissions, this would add severe stress to already drought-prone regions, increasing the threat to water demand, by adding competition with other water users (Climate Action Tracker, 2019).

- **Incentivation to increase natural gas share in energy mix:** Due to its strategic location and the increasing demand on Liquified Natural Gas (LNG) worldwide, Turkey is aiming to become a gas trading hub by developing its storage and regasification capacities : two new floating storage and regasification units (FSRU) planned by 2023 when the second FSRU was commissioned in January 2018 (DAILY SABAH, 2019).

- **No incentives to shift to low-carbon vehicles:** current National action plans (namely NCCAP[6] and NEEAP)[7] stay qualitative (i.e. development of legal arrangements, capacity building and promotion of alternative fuels and clean vehicles) and it is unclear whether the intended development and promotion of alternative fuels and clean vehicle technologies can be realized in the near to medium-term. Tax incentives for smaller and low-carbon fueled cars are insufficient to cause a clear shift of the market to low-carbon vehicles (Climate Action Tracker, forthcoming 2019).

- **Public finance in power sector subsiding coal, oil and gas sectors**: In 2017, it is estimated that 83% of total public finance to power went to coal, oil and gas projects in contrast with close to no financing towards renewables projects while 17% financing streams were identified for "grey sector" (such as nuclear, biomass, large-scale hydropower etc.) (Climate Transparency, 2018).

- **No ratification of the Paris Agreement:** Turkey remains one of the only two G20 countries that have not ratified the Paris Agreement and submitted its INDC in 2015.

[6] National Climate Change Action Plan (Republic of Turkey Ministry of Environment and Urbanisation, 2011)
[7] National Renewable Energy Action Plan (Ministry of Energy and Natural Resources, 2014)

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APPENDIX D

APPENDIX D.1
Climate Impacts in Palau

Additional Country Reports
Climate Impacts in Palau

Report by: Earthjustice

September 2019

D.1

Climate Impacts in Palau

Palau is a cluster of 586 volcanic, limestone and coral islands in the western Pacific Ocean, just north of the Equator, twelve of which are permanently inhabited.[1] Twenty five percent of the land area is below 10 meters above sea level.[2] Palau's higher ground is not well suited for habitation and economic activity due to steep slopes and thick vegetation, so most Palauans live and work in the country's coastal lowlands.[3] The economy relies on tourism, fishing, and subsistence agriculture.[4] The main island of Babeldaob, comprising 75 percent of Palau's land area, is unsuited for large-scale agriculture due to severely leached and acidic soils.[5] With a population of 21,000, Palau's per capita GDP was just $14,700 in 2017.[6] Palau has the most diverse coral of Micronesia, with a high density of tropical marine habitats including mangroves, seagrass beds, deep algal beds, mud basins, lagoons, and tidal channels.[7]

Palau is already experiencing disruptive changes due to climate change, including extensive coastal erosion, coral bleaching, ocean acidification, persistent alteration of regional weather patterns, decreased productivity in fisheries and agriculture, saltwater intrusion into taro and yam cultivation areas during extreme high tides, severe water shortages, and more widespread and frequent occurrence of mosquito-borne diseases.[8] According to the Government of Palau:

> Palau is particularly vulnerable to the impacts of climate change, principally from sea level rise and the increase in extreme events (drought, flooding, Category 4 and 5 typhoons). Sea-level rise threatens vital infrastructure, settlements, and facilities that support the livelihood of island communities. Moreover, under most climate change scenarios, water resources in small islands are likely to be seriously compromised. Subsistence and commercial agriculture will be adversely affected by climate change, and ocean warming and acidification will heavily impact coral reefs, fisheries, and other marine-based resources crucial to our livelihoods, economy and culture.[9]

In its Fifth Assessment Report of 2014, the Intergovernmental Panel on Climate Change (IPCC) projects that anthropogenic climate change will have significant adverse effects not only on the natural environment, but also on the human populations that inhabit that environment and rely on its processes and services.[10] Climate change impacts in the tropical Pacific are projected to increase significantly by the end of the century.[11] In Palau's region, the IPCC Fifth Assessment projects median **surface air temperature increase** in the range 0.5°C to 0.9°C by 2100 compared to 1986–2005.[12] **Precipitation events** are also projected to become more extreme by the end of the century.[13] **Sea level rise**, along with extreme sea level events including swell waves, storm surges, and ENSO events, poses risks of sea flood and erosion for low-lying coastal areas and atolls.[14] **Overwash** of sea water will degrade fresh groundwater resources.[15] **Sea temperature rise** will result in increased coral bleaching and reef degradation.[16]

Subsistence agriculture in Palau consists primarily of taro, cassava, coconuts, and sweet potatoes.[17] Taro is culturally and religiously important crop traditionally cultivated in coastal lowlands by women.[18] It is particularly threatened by saltwater intrusion and wave overtopping.[19] During El Niño-Southern Oscillation (ENSO) events, major damage to taro crops has occurred, with poor recovery.[20] Fires are also a major hazard during ENSO events.[21] Steep grasslands are severely impacted by these fires, and the subsequent erosion harms downstream mangrove forests, lagoons, and coral reefs.[22]

Fisheries in the Pacific are predicted to be harmed by climate change impacts, including sea temperature rise, increasing acidity and salinity, changing currents, and typhoon damage.[23] Palauans rely on fresh fish a food source.[24] Nearly every household participates in coastal fishing,[25] and annual per capita fish consumption is over 67 kilograms per year.[26] Fish protein comprises 52 percent of animal protein in the average diet.[27] As fish become harder to catch, Palauans will have to reduce the amount of fish (and thus protein essential for good nutrition) in their diets, or turn to substitutes that are more expensive.[28] Decline of coral communities will reduce the richness of fish species and will result in local extinctions and loss of species within key functional groups of fish.[29] Rising ocean temperatures also increase the risk of ciguatera fish poisoning.[30]

Coral bleaching threatens coastal marine ecosystems and the tourism industry. Rising sea surface temperatures trigger to corals eject their symbiotic algae in response to stress, resulting in coral bleaching, mass mortality of reefs, and loss of storm protection to coastlines and mangroves.[31] Palau's corals were in excellent condition prior to the 1997-8 ENSO, but one-third died at that time, with nearly 100% mortality of some coral species in some locations.[32] Tourism is a major foreign exchange earner and employment provider, responsible for 47% of the GDP.[33] Business and tourist arrivals in 2015 reached nearly 168,000 visitors, roughly eight times the national population.[34] As snorkeling and scuba diving are the major tourist attractions, the loss of coral reefs is a major threat to Palau's tourism sector.[35] The 1997-8 ENSO caused more than USD100 million in damage to Palau's corals, equivalent to 88 percent of that year's GDP.[36] According to a UNESCO 2017 report, Palau's World Heritage-listed coral reef, Rock Islands Southern Lagoon, will face ecosystem collapse caused by bleaching occurring more than twice per decade as early as 2028 under a business as usual CO_2 emissions scenario. [37] Only if CO2 emissions reductions are implemented to keep temperature rise to within 1.5°C above preindustrial levels will the twice per decade bleaching risk be eliminated during this century, giving Palau's coral reefs a much greater chance of survival.[38]

Palau suffers from **severe water shortages** during ENSO events.[39] In 2016, extreme drought prompted the President to declare a state of emergency. The capital city received its lowest recorded rainfall in 65 years and a major reservoir dried up.[40] By the end of this century, the IPCC (2014) projects that intensity and/or duration of drought in the western Pacific is likely to increase.[41]

Trends in **extreme temperature** across the South Pacific from 1961 to 2003 show increases in the annual number of hot days and warm nights, particularly following ENSO events.[42] Increased heat events around the world are linked to increased cardiovascular mortality, respiratory illnesses, malnutrition from crop failures, and altered transmission of infectious diseases.[43] Palauans are already suffering from increases in dengue fever and other diseases.[44]

High surface water temperatures intensify the destructive force of **tropical storms**.[45] These storms threaten the lives of Palauans during the rainy season from June to December each year.[46] Rising sea levels raise the baseline for storm surges, increasing the risk of catastrophic loss of life and infrastructure onshore.

Rising sea levels also pose a serious threat to the majority of Palauans.[47] The IPCC predicts that sea levels will rise an additional 0.23 to 0.47 meters before the end of the century if global fossil fuel use is not significantly reduced.[48] This will exacerbate inundation, storm surges, erosion and other coastal hazards, threatening vital infrastructure and facilities that support island communities.[49] Entire atolls, including the state of Kayangel, will disappear if sea levels rise to one meter.[50] Loss of lands due to sea level rise could force thousands of Palauan citizens to become climate migrants and to move to other countries.[51] According to Palau's Permanent Representative to the United Nations, displacement to another country "might be the only option if climate change continues at the current or increased rate without significant and urgent mitigation by the international community."[52] Such involuntary relocation would result in the loss of Palau's traditional cultural practices developed over thousands of years, including the indigenous language of Palau and matrilineal land inheritance.[53]

Human health in Palau may suffer from lack of access to adequate safe water, adequate nutrition, as well as increased stress and declining well-being that comes from property damage, loss of economic livelihood, threatened communities.[54] Freshwater scarcity, more intense droughts and storms could lead to a deterioration in standards of hygiene, increasing exposure to communicable diseases and other health risks. [55]

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APPENDIX D.2
Climate Impacts in South Africa

Additional Country Reports Climate Impacts in South Africa

Report by: Earthjustice

September 2019

Climate Impacts in South Africa

Sub-Saharan Africa will experience some of the greatest negative effects of climate change of any region globally.[1] The South African government recognises that the country is extremely vulnerable to the impacts of climate change,[2] and that a global average temperature increase of 2°C translates to up to 4°C for South Africa by the end of the century.[3]

Already, temperature extremes have increased significantly in frequency annually across the country, and rainfall has shown high inter-annual variability.[4] In the last five years, South Africa has experienced record temperature highs, droughts and fires.[5] This has been impacting on food prices and exacerbating the already high poverty levels in South Africa.[6] These costs are predicted to escalate, as climate-related disasters, such as droughts and fires, get larger in extent and magnitude. In 2017/2018, the fires in the Garden Route (Knysna/George area of South Africa), resulted in up to R6 billion (300 million US Dollars) in losses, and the losses resulting from the Western Cape drought on the Agriculture sector alone, were R14 billion (916 million US Dollars) (more than double the damage costs from extreme climate events in the preceding decade),[7] with 30 000 jobs lost.[8] The likelihood of an event like the 2015-2017 Western Cape drought recurring has increased threefold as a result of existing global warming, and will increase an additional three times with 2°C global warming.[9]

Significant socio-implications from climate change are expected, particularly for vulnerable groups and communities, in South Africa under the South African government's own predicted climate futures. These implications will largely be felt through: significant warming (as high as 5–8°C, over the South African interior by the end of this century);[10] impacts on water resources, such as changes in water availability; and a higher frequency of natural disasters (flooding and drought), with cross-sectoral effects on human settlements, health, disaster risk management and food security.[11] Climate change poses a high risk for the water quality and flow of the Olifants,[12] Limpopo and Crocodile Rivers.[13]

If temperature increases are not limited to 1.5 degrees, Southern Africa will be exposed to increased food shortages and poverty.[14] The cooler coastal regions of the country are likely to see significant in-migration from the interior of the country (as well as from further north on the continent).[15]

In addition, South Africa's unique biodiversity is at great risk – as climate change poses a threat to indigenous flora such as the Cape Floristic Kingdom, fauna and ecosystems, which are deeply ingrained in the cultural identity of the people of South Africa. This will have knock-on effects for livelihoods dependent on these ecosystems.[16]

D.2

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APPENDIX D.3

Climate Impacts in Tunisia

Additional Country Reports
Climate Impacts in Tunisia

Report by: Earthjustice

September 2019

D.3

Climate Impacts in Tunisia

Tunisia is one of the most climate vulnerable countries of the Mediterranean.[1]

1. Temperature

Based on historical climate conditions and recent trends over the past few decades, Tunisia’s temperatures range from an average monthly high of 30.5°C in mid-summer to an average monthly low of 10°C in mid-winter.[2] Tunisia's mean annual temperatures rose by about 1.4°C in the 20th century, with the fastest warming taking place in the summer (1.8°C) and the least in the spring (1.4°C).[3] Most of the warming has occurred since the 1970s, though summer mean maximums have risen since the 1960s.[4] The number of warm days per year has also increased.[5] A global analysis shows a statistically significant increase in heat waves and warm nights in North Africa.[6]

According to the World Bank Group (2019):

- Annual maximum temperature is likely to increase by 1.5°C to 2.5°C by 2030 and 1.9°C to 3.8°C by 2050.[7]
- Annual minimum temperature is likely to rise from 0.9°C to 1.5°C by 2030 and from 1.2°C to 2.3°C by 2050.[8]
- The number of hot days is projected to increase by about 1.3 days per year between 2020 and 2039.[9]
- The duration of heatwaves is likely to increase by 4 to 9 days by 2030 and by 6 to 18 days by 2050.[10]
- The duration of cold spells is likely to decrease by 1 to 3 days by 2030 and by 2 to 4 days by 2050. [11]

2. Precipitation and Flooding

In Tunisia, there are notable differences between mean annual rainfall from the south (less than 100 mm on the margins of the Sahara) to north (more than 700 mm on the Mediterranean coast) [12] Over the last few decades, Northern Africa, including Tunisia, has experienced a significant decrease in the amount of precipitation received in winter and early spring. [13] The record indicates over 330 dry days with less than 1 mm day rainfall per year over a 1997–2008-time period. Annual rainfall has decreased 5% per decade in northern Tunisia since 1950, while heavy rainfall events have become more frequent.[14] Western Tunisia has experienced stable or declining rainfall, while eastern Tunisia has experienced increasing winter totals since the 1950s.[15] Spring rainfall has decreased in most areas, but particularly in the eastern half of the country. [16] Autumn rainfall has declined mostly in the southern region.[17] There is an association between El Niño and reductions in rainfall for parts of Tunisia.[18]

A reduction in rainfall over northern Africa is very likely by the end of this century.[19] The annual and seasonal drying and warming signal over the northern African region (including Tunisia) is a consistent feature in the global and regional climate change projections. [20] The greatest uncertainty is in summer rainfall over southern Tunisia.[21]

All models project a likely decrease in overall precipitation in Tunisia by 2050, with most projecting a minimum decrease of around 4% and maximum decrease varying from 7% to as much as 22%.[22]

The duration of dry spells is likely to increase by 1 to 21 days by 2030 and by 1 to 30 days by 2050. [23]

3. Drought

The decrease in precipitation is accompanied by an anticipated increase in the frequency and intensity and droughts and flooding.[24]

Nearly two-thirds of Tunisia is semiarid to arid, with frequent drought.[25] Droughts have been traced back to the sixth century; between 1907 and 1997, Tunisia experienced 23 dry years.[26] Most recently, Tunisia experienced drought in 1982, 1987 to 1989, 1993 to 1995, with its worst drought in over 50 years from 1999 to 2002. [27]

The combination of higher temperatures and declining rainfall is projected to reduce water resources in Tunisia.[28] Projections also suggest a drying trend in the region, particularly along the Mediterranean coast, driven by large decreases expected in summertime precipitation.[29] North Africa would be particularly affected by droughts that would be more frequent, more intense and longer-lasting. [30] Drought would be more frequent in summer than in winter.[31]

4. Sea Level Rise and Storm Surge

Sea levels have risen across the Mediterranean by an average of more than 3.1 mm each year since 1992, although records from further back indicate considerable local variability.[32] Since 1990, Mediterranean Sea levels have risen 5–10% faster than the 20th century mean rate.[33]

By 2030, the total, Mediterranean basin averaged sea level rise will be between 6.86 and 17.92 cm.[34] By 2040–2050, the total Mediterranean basin averaged sea level rise will be 9.8 and 25.6 cm.[35] Sea levels are projected to rise between 3 and 61 cm this century, depending upon local heat and salinity levels of the Mediterranean.[36] Between 1% and 3% of land in Tunisia will be affected by a 1-meter sea level rise.[37]

5. Winds and Storms

Recent cyclone trends in Tunisia are not readily available, so estimates are highly uncertain.[38] Uncertainties in projections of cyclone frequency and tracks make it difficult to project how these changes will impact particular regions.[39] There is only low confidence in region-specific projections,[40] but global and regional climate scenarios show fewer cyclones over the Mediterranean.[41]

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