G20 CLIMATE RISK ATLAS

Impacts, policy, economics

ARGENTINA

How to read the Atlas: graphs, colours and scenarios.

The maps used in this Atlas are taken from **The World Bank Official Boundaries** - ***https://datacatalog.worldbank.org/search/dataset/0038272*** (accessed on May 28, 2021). For the section Energy, the maps are based on Panoply Data Viewer ***https://www.giss.nasa.gov/tools/panoply/credits.html***

Each sector of this Atlas contains data and information on various climate scenarios.

When reported in graphs, the **colour black** indicates data and information referring to the current state, the past or the baseline.

When the authors refer to **RCP (Representative Concentration Pathways)**, the 3 colours used across the factsheet refer to 3 scenarios, which are 3 different development options with different levels of greenhouse gas emissions, **respectively low emissions (green), medium emissions (orange), and high emissions (red)**. The same colour code is used when RCPs are associated with Shared Socioeconomic Pathways (SSP).

In some cases, the authors refer to global warming scenarios. In these cases, the 3 colours used refer to a temperature rise of **1.5°C (green), 2°C (dark green), and 4°C (red)**.

When the authors refer exclusively to **Shared Socioeconomic Pathways - SSPs** (Population affected by river floods in the section: "Water"), data related to **SSP3** - that encompasses, among other things, slow economic growth, material-intensive consumption, and persisting or worsening inequalities – **are reported in a lighter shade**; **SSP5** – which refers to social and economic development that is coupled with an energy-intensive lifestyle and the abundant exploitation of fossil fuel resources – is shown using a **middle shade of the colour**, whereas data related to **the present** conditions **are represented in a dark shade**.

Further details on scenarios, methodologies, and the full list of references are available at: **www.g20climaterisks.org**

Concept and graphic design by element6.eu

ARGENTINA
CLIMATE

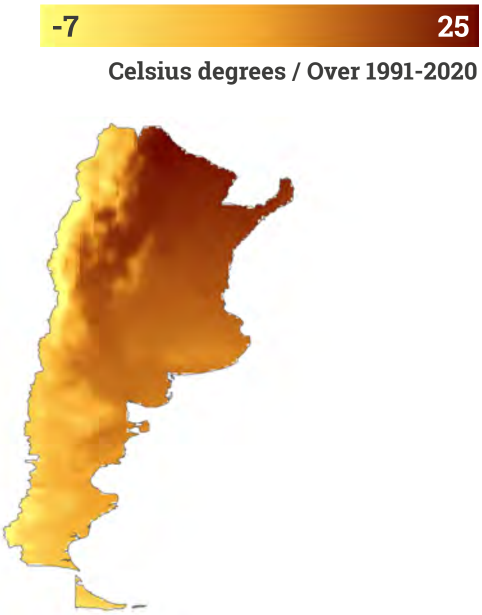
OVERVIEW

Argentina's climate ranges from tropical to polar. This variability is mainly due to the size, heterogeneity and orography of the country, which makes for extreme weather conditions and often leads to natural disasters. The country's climate features and seasonality are influenced by the presence of the Los Andes mountains, which extend along the west of the country, as well as the El Niño-Southern Oscillation and the Indian Dipole.

TEMPERATURE

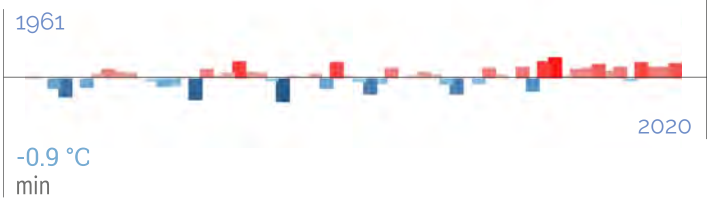
The temperature regime of Argentina is quite heterogeneous with average values increasing from west to east. Lower temperatures are found along the Los Andes mountain range which runs down the west of the country.

MEAN TEMPERATURE



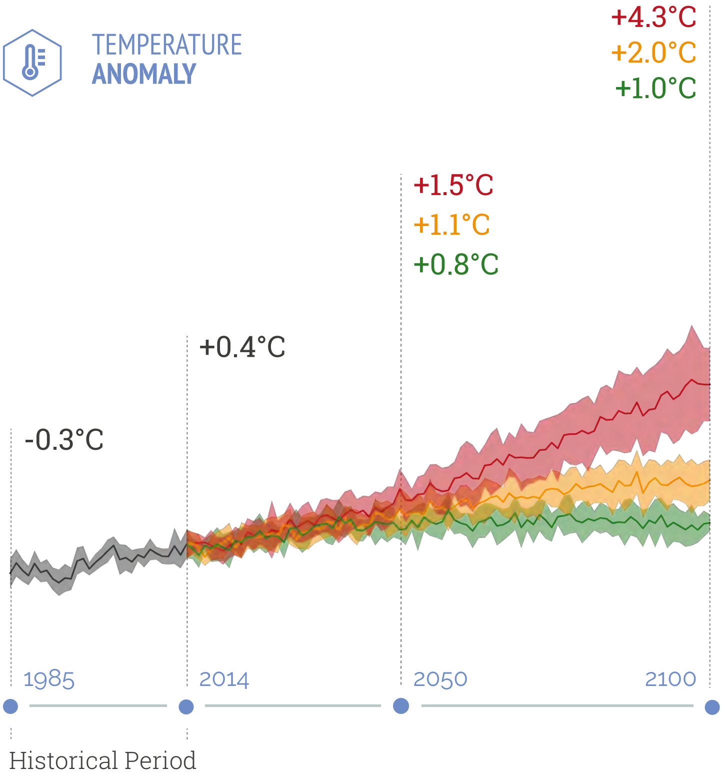
TEMPERATURE TREND

Temperature anomalies over the last 60 years with respect to the annual mean of 15°C in Argentina during the 1961-1990 period



TEMPERATURE PROJECTIONS

Under a low emissions scenario projected temperature variations will remain contained at around +1°C, both by 2050 and 2100.
Under a high emissions scenario, with no reduction in GHG emissions, much greater temperature anomalies are expected by both 2050 and 2100.



EXPECTED VARIATION FOR TEMPERATURE AT 2050

The indicators show variations in selected temperature characteristics for a thirty-year period centred on 2050 (2036-2065) with respect to the reference period 1985-2014.

Annual Mean Temperature
+1.6°C
+1.2°C
+1.0°C

Max Temperature of warmest month
+2.1°C
+1.6°C
+1.2°C

Min Temperature of coldest month
+1.6°C
+1.1°C
+0.9°C

PRECIPITATION

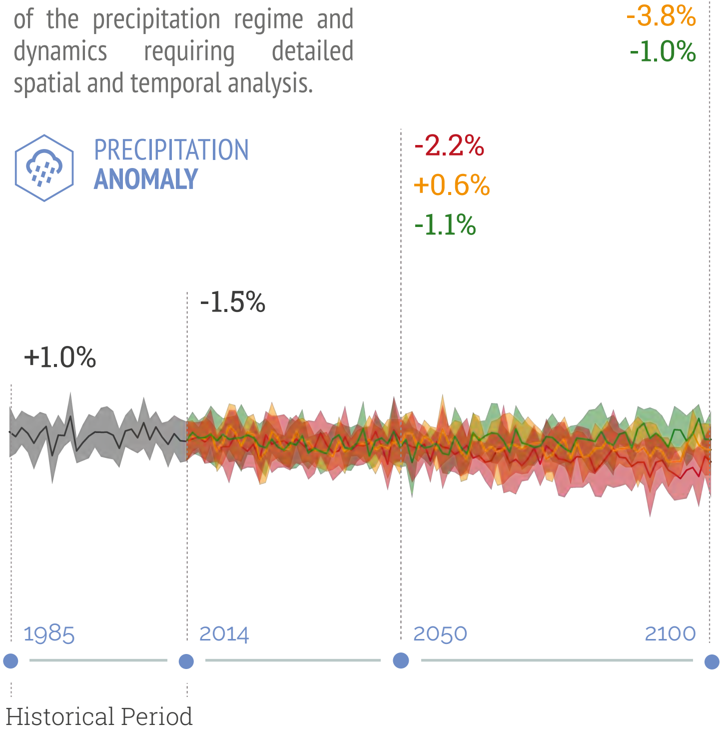
Argentina's precipitation regime is highly variable. It ranges from very humid to arid areas, also showing relevant inter-annual and inter-decadal variations. Precipitation patterns over the Los Andes mountain range are also highly variable due to the effect of factors such as the interaction of mountains with humid air masses coming from the Pacific Ocean. In the south and central areas annual precipitation is generally lower. June to September is the season with least rainfall.

PRECIPITATION PROJECTIONS

Precipitation trends are complex and reveal large variabilities based on the scenario and period considered. For example, the anomalies seen over the historical period can be explained by the complexity of the precipitation regime and dynamics requiring detailed spatial and temporal analysis.

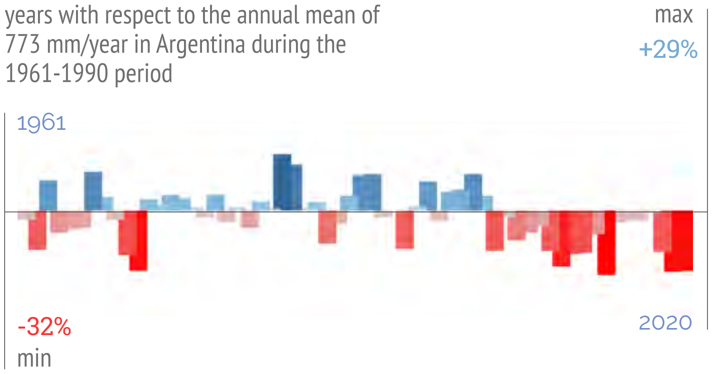
MEAN PRECIPITATION

PRECIPITATION ANOMALY



PRECIPITATION TREND

Precipiation anomalies over the last 60 years with respect to the annual mean of 773 mm/year in Argentina during the 1961-1990 period



EXPECTED VARIATION FOR PRECIPITATION AT 2050

The indicators show variations in selected precipitation characteristics for a thirty-year period centred on 2050 (2036-2065) with respect to the reference period 1985-2014.

Annual total precipitation	-3.2%	-2.4%	-2.1%
Precipitation of wettest month	-0.1%	-0.3%	-0.3%
Precipitation of warmest quarter	-7.6%	-5.7%	-5.4%

VARIATION OF SPECIFIC CLIMATE INDICATORS

Climate indicators variation showing impacts of climate change on sectors such as agriculture, health and water. Analysis considers 3 threshold average temperature increase: **+1.5°C**, **+2°C**, **+4°C**.

Agricultural drought proportion of time	% of time	+30%	+15%	+12%
Hydrological drought proportion of time	% of time	+34%	+20%	+14%
Heatwave duration	% of time	+6,247%	+1,032%	+379%
Runoff increase	% of area	+50%	+36%	+23%
Agricultural drought frequency	% of change	+62%	+33%	+23%
Hydrological drought frequency	% of change	+13%	+12%	+12%
Heatwave frequency	% of change	+92%	+60%	+37%
Runoff decrease	% of area	+12%	+4%	+2%

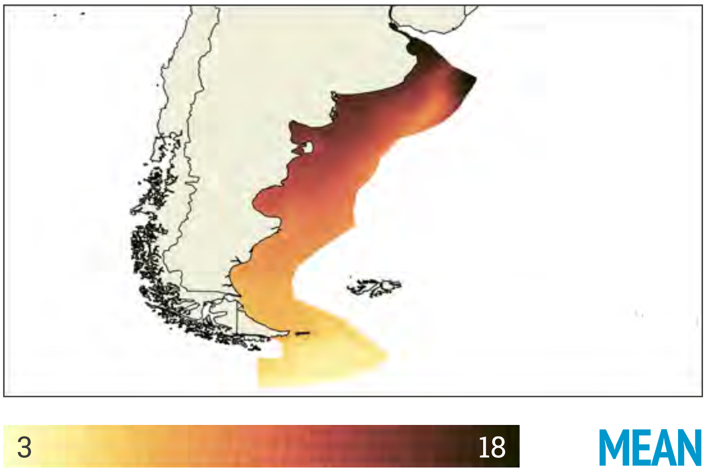
ARGENTINA
OCEAN

OCEAN IN ARGENTINA

Argentina's marine exclusive economic zone (EEZ) includes a wide range of habitats, from the southern polar pelagic ecosystems to the temperate ones hosting nursery grounds for several species. The Atlantic coastal systems can be divided in two parts, namely the northern and southern marine regions.

CURRENT CLIMATE CONDITIONS

Mean sea surface temperatures reflects the different climate regimes, from the cold waters of southern Patagonia to the temperate regime of the northern coasts.

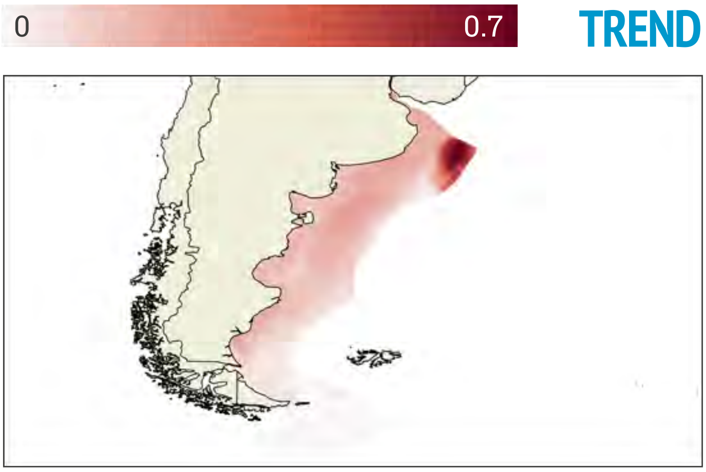


MEAN

SEA SURFACE TEMPERATURE

Celsius degrees / Over 1991-2020

TREND



Surface temperature trends indicate a general warming of 0.2°C per decade in all marine areas, with increased gains in the northernmost regions.

FUTURE PROJECTIONS

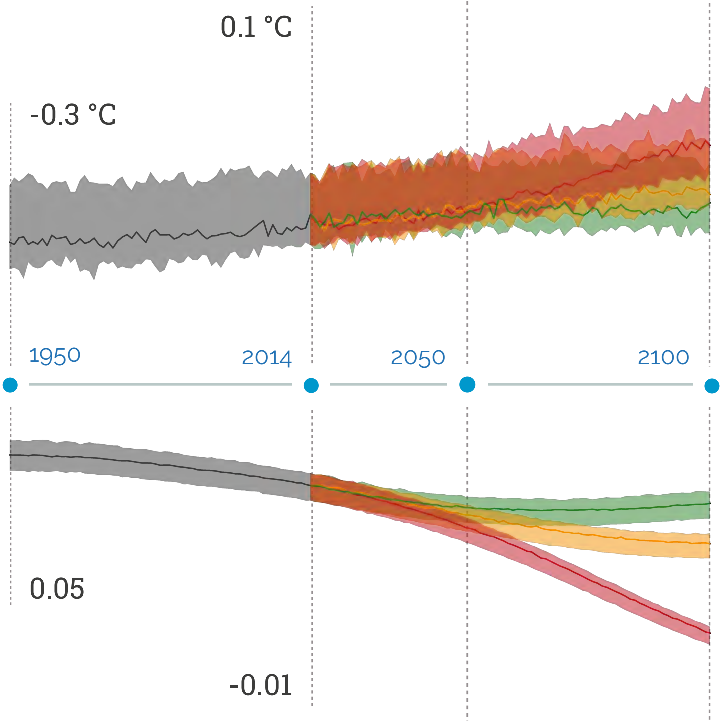
Projected annual changes within the marine EEZ for the two most significant marine indicators of climate change: sea surface water temperatures and pH.

Seawater temperature changes are in line with the definitions of each scenario, with maximum values in 2100 up to +3°C under a high emissions scenario.

+3 °C
+1.5 °C
+0.8 °C

SEA SURFACE TEMPERATURE ANOMALY

+1 °C
+0.9 °C
+0.7 °C



SEA SURFACE pH ANOMALY

-0.09
-0.12
-0.16

Seawater surface pH becomes more acidic in all scenarios, closely reflecting rising atmospheric CO_2 concentrations, and only a low emissions scenario leads to a stable condition by 2100.

-0.08
-0.18
-0.4

ECOSYSTEM INDICATORS AT 2050

Regional changes in key marine ecosystem indicators under projected future scenarios by mid-century (2036-2065) with respect to present climate conditions (1985-2014).

North

South

Temperature regulates the metabolism of marine organisms determining which habitats remain suitable. Excessive warming will likely push ecosystems beyond tolerance thresholds.

North		South	
12.95°C	+0.98 °C	6.40°C	+1.04 °C
	+0.98 °C		+0.78 °C
	+0.67 °C		+0.77 °C

pH represents the acid/base status of marine waters, where a decreasing pH reflects the acidification of the ocean due to increased absorption of atmospheric CO_2.

North		South	
8.09	-0.16	8.08	-0.16
	-0.12		-0.12
	-0.09		-0.09

Oxygen is fundamental to sustain marine life and its reduction can have a large impact on coastal ecosystem services including fisheries and aquaculture.

North		South	
275.35 mmol/m³	-2.55 %	306.27 mmol/m³	-1.72 %
	-2.04 %		-0.84 %
	-1.84 %		-0.58 %

Chlorophyll is an indicator of the biomass available at the base of the marine food web supporting all ecosystem productivity.

North		South	
0.6 mg/m³	+2.52 %	0.63 mg/m³	+3 %
	+14.77 %		+3.79 %
	+1.17 %		+2.37 %

FISH CATCH POTENTIAL

Fish catch potential is an estimate of the maximum fish catch achievable given the marine resources available over a sustained period. It is linked to the concept of maximum sustainable yield, meaning the maximum amount of fish that can be extracted from a system without causing a collapse in fish populations.

It is a characteristic of the natural system, which is substantially different from realized catch, and a direct result of the fishery policy in place.

Fish catch percentage change

2050

-3.3%

-1.3%

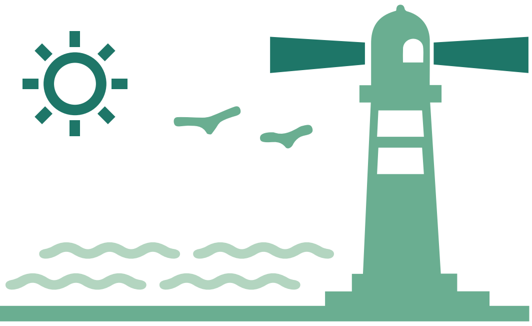
ANALYSIS DETAILS

All datasets were analysed using only data from within the marine EEZ and therefore excluding overseas territories, detached islands and any disputed or joint territories with other nations. In the assessment of current climate conditions, seawater surface tempererature data was obtained using satellite observations distributed in the framework of ESA Climate Change Initiative.

Future projections of marine indicators are represented by the combined analysis of results from 15 different Earth System models participating in the Coupled Model Intercomparison Project Phase 6 (CMIP6). These models include new and better representations of physical and biogeochemical processes, compared to previous IPCC assessment reports.

Fish catch potential data was obtained using the FAO's technical report and refers to the best and worst case climate scenarios from the Fifth IPCC Assessment Report. These mean estimates are subject to substantial uncertainties as discussed in the original work.

ARGENTINA
COASTS



OVERVIEW

Argentina's coastline faces the Southern Atlantic Ocean and extends for 8,397 kilometres. The main coastal cities are Buenos Aires, Mar del Plata and Bahia Blanca. Three main regions can be distinguished running north to south: the fluvial region, with the estuaries of the Paraná and Uruguay rivers; the Plata River region, with the capital Buenos Aires which is the most densely populated, urbanized, and industrialized area; and the southern coastline, including the more pristine Pampean and the Patagonian regions.

Shoreline Length

8,397 km

Sandy Coast Retreat at 2050

-92.7 m

CLIMATE CHANGE HAZARDS

Coastal hazards such as erosion, storm tide inundation and permanent flooding, can have strong adverse impacts on coastal regions, with loss of sandy shores, damage to settlements, infrastructure and ecosystems. Climate change can exacerbate these impacts due to rising sea levels and increasing impacts of waves and storms. The populated shores of Argentina are generally on high ground with cliffs or steep terrain near the shore. For this reason, significant loss of land with high impacts on populated areas is not expected. However, some tidal islands south of the city of Bahia Blanca, in the extreme south of the Province of Buenos Aires, are the exception and may be affected.

SEA LEVEL RISE

Relative sea level rise has been observed over the past century around the coast of Argentina, with a yearly average increase of 1.42 millimetres per year since the 1990s. The latest IPCC projections indicate that, by 2050, global sea levels may rise between 0.18 metres, under a low emissions scenario, and 0.23 metres, under a high emissions scenario.

Observed and projected sea level rise at 2050

1.42 mm/year

0.23 m

0.18 m

EXTREME SEA LEVEL

Extreme sea levels are expected to increase in line with sea level rise, increasing the frequency of damaging high water level conditions. On average, one in 100 year extreme sea level events in Argentina are expected to rise from 3.60 metres at present day to 3.81 metres by 2050, under a medium emissions scenario.

Current and projected extreme sea level at 2050

3.6 m

3.88 m

3.81 m

OBSERVED STORMS

Argentina is mainly influenced by the South Atlantic wave climate, with most waves and wave energy coming from the south and south-east quadrants. Analysis of trends from the last few decades reveal an increment in the frequency, height and duration of the storm surges, in particular in the Río de la Plata region, with increasing erosion. The Río de la Plata estuary is also affected by significant storm surges several times per year.

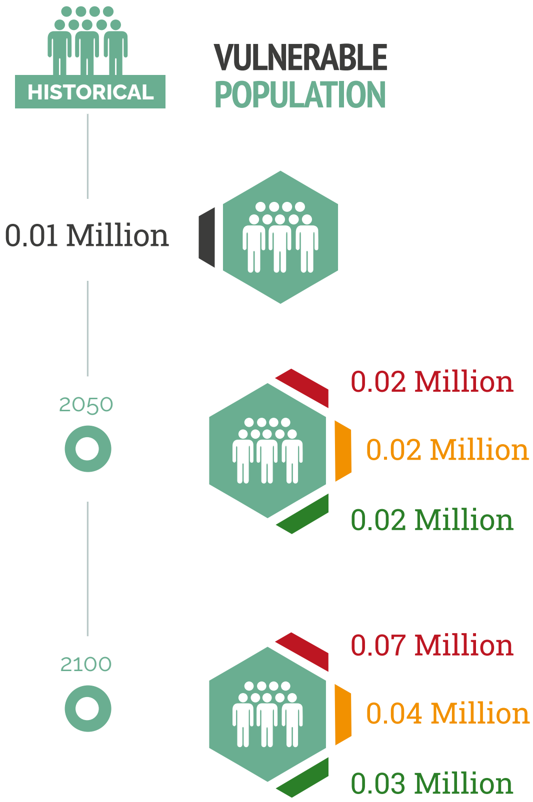
FUTURE STORMS

A southward migration of tropical cyclones from the tropics due to warming water surfaces can be expected, with increasing exposure of Argentina's coast to tropical storms. Rising sea levels will also increase the frequency of extreme sea level events, such as the one in 100 year water level.

VULNERABILITY AND RISK

A significant portion of people living in Argentina reside in coastal zones, with about 3.6 million people living in low elevated lands below 10 metres above sea level, which amounts to approximately 1.9% of the land area of the country. Based on current projections the population of Argentina living in low lying coastal areas could grow to 7.6 million by 2060.

The coast of Argentina is at risk from the impacts of sea level rise and storm surges, in particular the urban areas around the Plata River, including Buenos Aires, and other smaller cities further South, such as Mar De Plata. Most coastal areas further south have relatively minor risk from coastal erosion and floods, given the lack of densely populated areas. More specifically, the population exposed to the annual coastal flood level is expected to increase from 10,000 to 20,0000 people under a medium emission scenario by 2050.



INFLUENCE OF SEA LEVEL RISE ON EXTREME SEA LEVEL

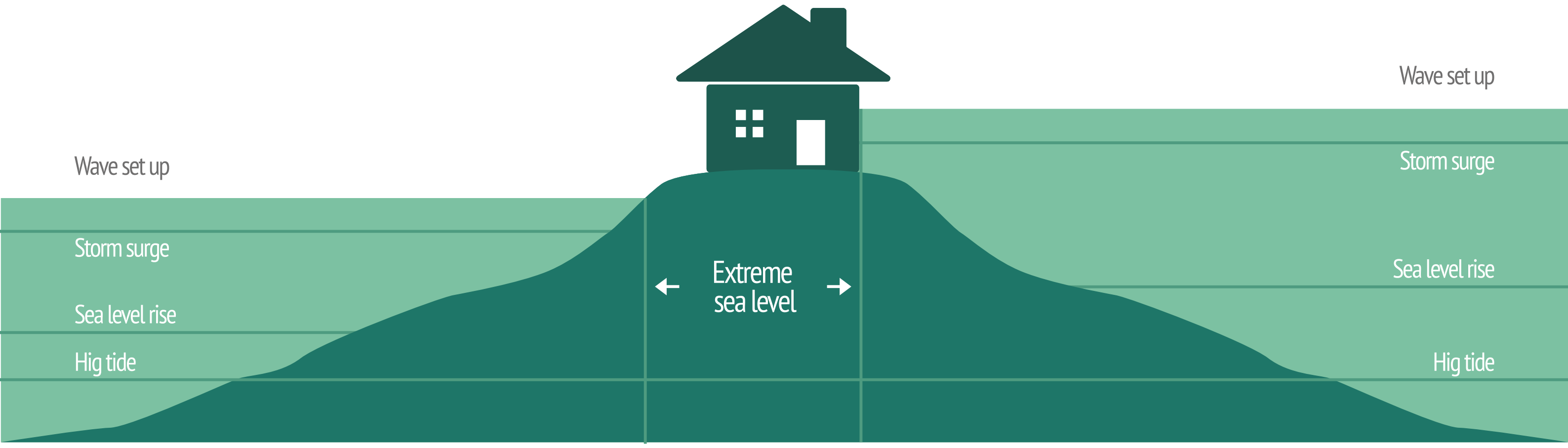
Present and future sea level rise are a consequence of carbon induced global warming causing melting ice and ocean expansion due to heat accumulation.

The extreme sea levels reported here are based on the 100-year storm surge + wave set up + sea level rise + high tide indicators. The first two parameters (storm surge + wave set up) are based on the 100-year value for the event; sea level rise is its projected value at 2050; and high tide is the absolute value of the highest tide calculated for a given locality, which won't be influenced by climate change.

+ **Wave set up** refers to the accumulation of water near the shore due to the presence of breaking waves.

+ **Storm surge** is an occasional increase in sea level driven by shoreward wind-driven water circulation and atmospheric pressure.

+ **High tide** is usually the highest tide reached in a given location based on tide records.



Present sea levels have risen globally by approximately 20 centimetres over the past century.

Future sea level rise is a projection based on different global warming scenarios, at approximately 100 centimetres by the end of 2100, with consequent inundation during extreme sea level events.

ARGENTINA
WATER

OVERVIEW

Argentina can be divided into three climatic and hydrological regions: humid, semi-arid and arid.

Around 76% of the national territory is subject to conditions of aridity or semi-aridity, with average rainfall of less than 800 millimetres per year and 85% of surface water belonging to the La Plata River basin in the urbanized east. Argentina is a water-rich country with an uneven distribution of water resources.

Renewable internal freshwater resources 292 billion m^3

Renewable internal freshwater resources per capita 6,629 m^3

The Rio De La Plata Basin, which concentrates more than 85% of total national water resources, is the largest center for human settlements, urban development, and economic activity in the country.

CLIMATE CHANGE HAZARDS

Climate change can affect water resources due to increasing temperatures, higher rates of evapotranspiration and altered rainfall patterns. This leads to changes in the water cycle, including decrease of snow and ice coverage, alterations in surface runoff and groundwater storage, as well as drought and flood occurrence. In Argentina, precipitation patterns and temperatures are changing, affecting water resources. The highest increases in precipitation (from 1960-2010) occurred in the eastern parts of the country. In the northern regions, the increase in precipitation has led to more variability in precipitation annually, with a higher risk of droughts and consequently affecting agriculture.

KEY POINT RUNOFF

There is very little annual rainfall with less than 1% of available surface runoff in very arid and semiarid provinces, such as San Juan or La Rioja.

The Andes region is particularly at risk in terms of runoff, with most climate models projecting marked surface runoff decreases in the area. Instead, at a country scale, an average increase in surface runoff by approximately 21% and 6% is expected, respectively, under the low emissions and high emissions scenarios for the 2045 to 2055 period, compared to 2015 to 2025.

If temperatures rise by 1.5°C, 2°C or 4°C, 2%, 3.9% or 12% of the country will likely experience an increase in runoff, whereas 23%, 36.1% or 50% of the surface of the country will likely experience a respective decrease in runoff.

2050

Changes in annual runoff
% of change

+5.7%

+20.6%

2050

Runoff increase
% of area

+12.0%

+2.0%

KEY POINT DROUGHTS

The Salta province goes through periodic droughts and contributes to Argentina's desertification at a rate of 2,500 kilometres per year. Wide-scale clearing of forests in the Gran Chaco (covering southern Bolivia, western Paraguay, and northern Argentina) to make way for soybean planting has accelerated the process. The Pampas region is also severely affected by episodic drought events in 2008-2009 and 2017-2018.

These episodes are mainly driven by large-scale atmospheric circulation, such as El Niño, but likely strengthened by climate change. The likelihood of severe droughts in Argentina is expected to increase by 15.9%, 17,9% and 21,9% (2040-2059) under low, medium and high emissions scenarios. Similarly, If temperatures rise by 1.5°C, 2°C or 4°C, hydrological drought frequency is expected to increase by 11%, 12.2% and 13%, respectively.

2050
Severe drought likelihood increase
% of change
+21.9%
+15.9%

2050
Hydrological drought frequency
% of change
+13.0%
+11.0%

2050
Groundwater Recharge
% of change
-17.2%
+10.6%

KEY POINT GROUNDWATER

Argentina's groundwater use has increased significantly over recent decades due to its generalized presence, high reliability during droughts and decent quality in most cases. Current effects of climate change can be seen through the spatial variations of the groundwater availability, also compromised by the more frequent prolonged drought periods. In Argentina, the increase in evapotranspiration may significantly affect those aquifers with a water table close to the ground surface. The water demand is also expected to be higher due to the heat and lower availability of surface water.

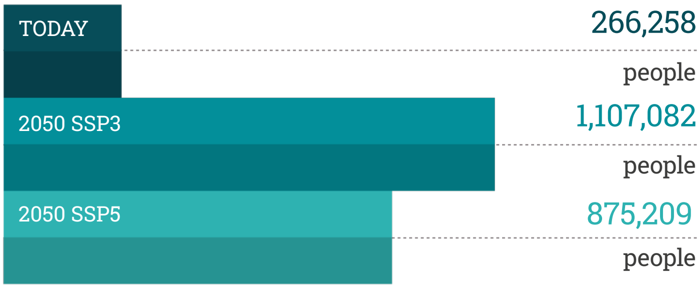
At the country level, a +10.5%, -3%, and -17.2% change of the annual groundwater recharge for 2045-2055 compared to 2015-2025 is expected under low, medium, and high emissions scenarios.

KEY POINT FLOODS

Floods affect some of the population and infrastructure and have a strong impact on agricultural productivity, one of the country's main economic activities. The fluvial systems in Argentina can be classified into three main groups: large tropical rivers, torrential rivers with headwaters in mountain areas, and flat-plain rivers with insufficient drainage efficiency.

In April 2013, the northeastern section of the Buenos Aires province experienced severe flash floods, leading to 101 casualties and extensive damage, with scientists agreeing on the important role of climate change in this disaster. Changes in the population exposed to floods are expected, with an increase from about 266,000 in the present day to 1,100,000 under SSP3 and 875.000 under SSP5 by 2050. As such, potential impacts related to river floods might increase.

POPULATION AFFECTED BY RIVER FLOODS

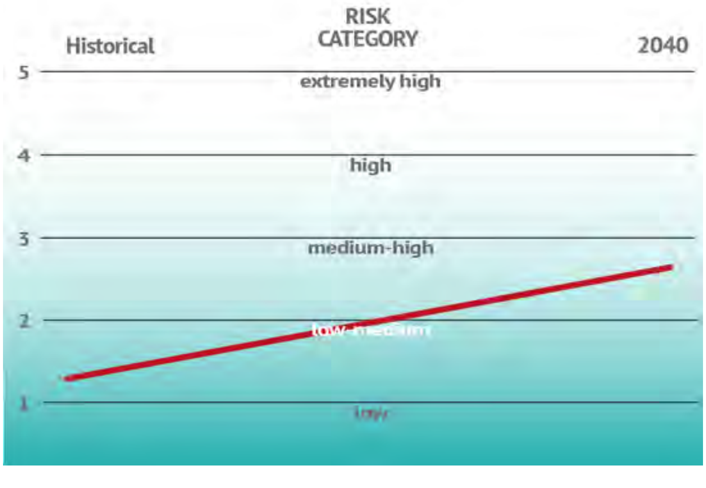


RISK INDICATORS

The water stress index summarises current and future water related vulnerabilities and risks at the global level. Scores are based on the ratio of total water withdrawals, including agriculture, industrial and human consumption, to available renewable surface and groundwater supplies.

WATER STRESS

Argentina's water stress level is considered low-medium for the recent past (1960-2014 average), and it is expected to increase in the near future (2030-2050) based on climate change projections.



ARGENTINA AGRICULTURE

OVERVIEW

Argentina is a leading food producer that relies on abundant and fertile land, together with significant water resources. Recent decades have seen an expansion in the agricultural and irrigated area for the production of key agricultural commodities, mainly focused towards export.

Most grain and oilseed production (wheat, maize, soybean) is concentrated in the Pampas region, whereas the production of higher-value crops such as fruit, vegetables and sugarcane takes place outside of the Pampas.

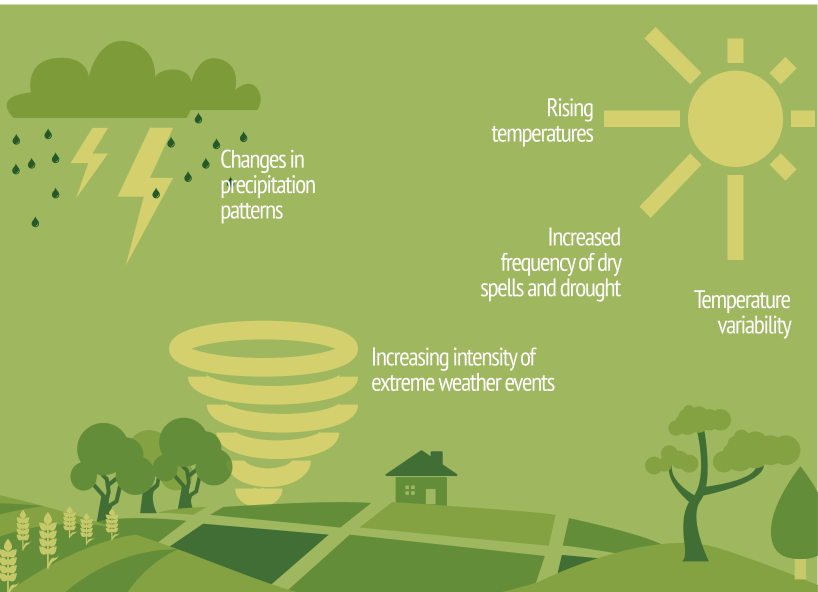
Though water stress in the country is considered to be relatively limited (10.5%), agricultural sector water use to support irrigation is substantial, accounting for 74% of total water withdrawal in 2017.

43.5 Mt	Maize
37.8 Mt	Soybeans
18.5 Mt	Sugarcane
18.5 Mt	Wheat
3.5 Mt	Citrus
2.6 Mt	Grapes

	2000	2018
Added Value of Agriculture, Forestry and Fishing	23,530 USD Million	28,024 USD Million
Share of Agriculture Value added in Total GDP	5.5 %	4.4 %
Agricultural land	28,640 Thousand HA	40,268 Thousand HA
Area Equipped for Irrigation	1,565 Thousand HA	2,360 Thousand HA

EXPEXTED IMPACTS ON AGRICULTURE PRODUCTIVITY

Rising temperatures, reduction in average annual precipitation, and intensification of extreme events such as heat waves and drought, affect production variability with a tendency towards yield reduction for many cultivated species, accompanied by a probable decrease in food quality. Crops respond to increases in temperatures with changes in duration of the growing season, early appearance of phenological phases and potential shifts of cultivation areas toward higher latitudes and altitudes for better growing conditions. However, impacts vary significantly depending on the geographical area and specific crops in question.



CROP PRODUCTIVITY

Crop productivity refers to the harvested yield of a crop per unit of land area. It is strongly influenced by climate and other environmental and management factors.

Climate change is expected to have an impact on the productivity of several major crops, although this may in part be offset by the fertilizing effect of higher CO_2.

Impacts are estimated using a range of model projections based on low to high emission scenarios and reported as percentage changes between the 30-year average around the historical period and the 30-year average around 2050.

7 Maize tons / ha
-1.5 (-2.9)%
-1.8 (-3.0) %

2.8 Soybeans tons / ha
5.2 (-4)%
7.4 (-6.6)%

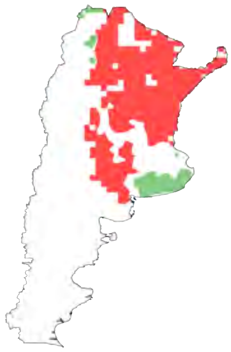
3.2 Wheat tons / ha
0.8 (-5)%
2.9 (-7.3)%

2050

Productivity change with (without) the CO_2 fertilization effect. Estimates assume sufficient water and nutrient supplies, and do not include impacts of pests, disease, or extreme events.

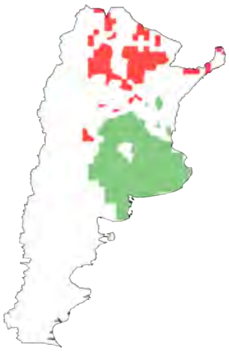
CHANGE IN MAIZE

🟥 − = 🟩 +



CHANGE IN WHEAT

🟥 − = 🟩 +



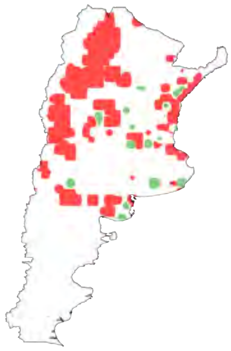
Maize yield is projected to decrease in most areas, excluding some central coastal areas where precipitation patterns during the growing season remain consistent. Soybean cultivation may benefit from climate change, with consistent increases of up to 10% in productivity in the Pampas region where an increase in summer rainfall is expected. Wheat will witness some yield gains in the Pampas, and general decreases outside this region, particularly in the northernmost areas. Projections highlight enhanced prolonged winter droughts and reductions in spring rainfall over central regions, this may pose significant risks to wheat productivity. Yield and quality of grapes may suffer diverse impacts, with colder climate wine-growing regions favoured. This may lead to shifts of wine-growing towards cooler areas (higher latitude or altitude).

ADAPTATION IN AGRICULTURE AND WATER RESOURCES

Climate change may have some positive effects on some of the most widely used crops. However, higher temperatures will generally require an increase in irrigation due to higher plant evapotranspiration and expansion of irrigated areas. This implies increased pressure on water withdrawal from the agricultural sector to maintain production and ensure food security. Currently, irrigation is relatively limited and covers around 5% of Argentina's agricultural lands. Irrigated farming systems (like grapevine cultivation in the West) have allowed for significant intensification of productivity. In the future, further expansion of irrigation in water stressed areas, together with changes in glacial melt and reduced river stream flows, could pose additional stress on freshwater resources prompting use of groundwater for irrigation.

CHANGE IN WATER DEMAND

🟩 − = 🟥 +



Agriculture
Water Demand
% of change

+11.3%
+11.1%

2050

Increase in water demand, associated with the expansion of irrigated areas, will require adaptation practices that favour water-use efficiency and limit the increase of stress on water resources.

ARGENTINA
FORESTS

FORESTS IN ARGENTINA

Given territorial and climatic conditions, Argentine forests (of which 6% are considered primary) are characterized by extreme variety.

In recent decades, deforestation has significantly limited the strategic ability of forests to fight the climate emergency through carbon dioxide absorption.

FORESTED AREA AND CARBON STORAGE

Argentinian forests cover no more than 10% of the country and in recent decades this area has been shrinking. According to the Argentinian Second Biennial Update Report (BUR), deforestation (albeit a decreasing rate) contributes to 14.5% of the country's total emissions.

1990

35 Mln ha
Million hectares
Forested area

154 Tons/ha
Tons of Carbon per hectare
Carbon stock

2020

29 Mln ha
Million hectares
Forested area

163 Tons/ha
Tons of Carbon per hectare
Carbon stock

FOREST PRODUCTIVITY

Forest productivity or Net Primary Production is the net carbon captured by plants. It is the difference between the carbon gained by Gross Primary Production - net photosynthesis measured at the ecosystem scale - and carbon released by plants' respiration. It is expressed per unit land area.

2050

Productivity anomaly
Tons of Carbon per
hectare per year

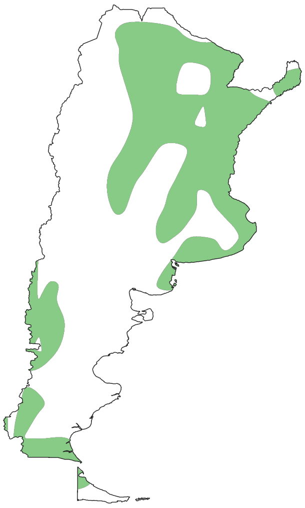
+0.52

+0.30

A generalized increase although weaker in the north. Potentially pronounced increase only in scarcely forested areas such as the Pampas.

Decrease expected in montane cloud forest production in the southernmost area of the Catamarca (24-27°C south).

+ Increase in the duration and severity of drought events which is not sufficiently balanced by the fertilizing effect of CO_2 whereby carbon dioxide stimulates photosynthesis



KEY SPECIES UNDER CLIMATE CHANGE

THERMOPHILIZATION
ANDEAN FORESTS
Pronounced thermophilization of Andean forests, leading towards a higher dominance of warm-adapted species

CONTRACTION
CLOUD FORESTS
Expected contraction of key species ranges

VULNERABILITY
NOTHOFAGUS
Increasing vulnerability of various Nothofagus species to droughts across their entire range of distribution

SHIFT
MONTANE FORESTS
Expected upward shifting of montane forest ecosystems

FIRES IN ARGENTINA

Fire is a structural ecological process that provides several types of ecosystem services and impacts on socio-ecological systems, including human health, carbon budgets, and climate change. Changes in global fire activity are influenced by multiple factors such as land-cover change, policies, and climatic conditions. Fire also releases large quantities of greenhouse gases into the atmosphere, contributing to a vicious cycle.

During the last two decades, the total land area affected by fire was approximately 21.5 million hectares of which 27% involving forests.

BURNING
21.5 MILLION HECTARES

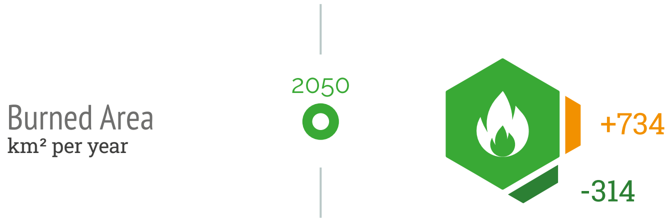
EMITTING
14 TERAGRAMMES OF CARBON PER YEAR

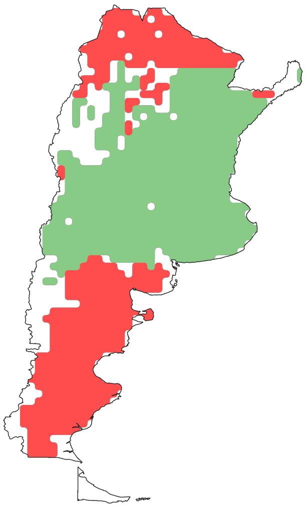
SAVANNA FIRE EMISSIONS CONTRIBUTED TO 53.5% OF TOTAL FIRE RELATED CARBON EMISSIONS

0.57 TERAGRAMMES OF CO_2 EMITTED ANNUALLY BY NATIVE FOREST FIRES IN CENTRAL AND SOUTHERN PATAGONIA

FUTURE BURNED AREA

Under a low emission scenario, the burned area might potentially increase in the northern Montane Grasslands and Shrublands. Also south eastern Temperate Grasslands, Savannas, and Shrublands might experience a slight increase in burned area. Under a medium emission scenario, models project accentuated burned area in northern mountain areas.



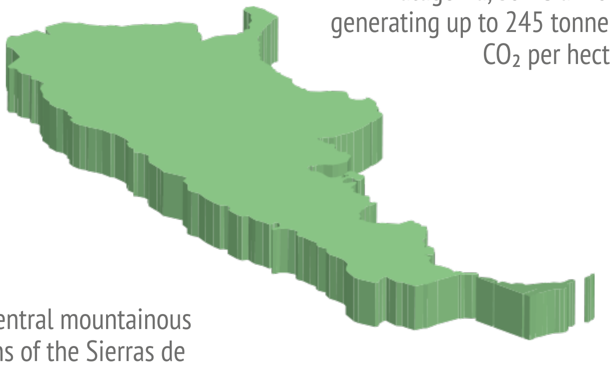


Decrease in burned areas for a low emissions scenario

Increase in burned areas for a low emissions scenario
+ Increased risk of warming and drought in southern Argentina

WHERE DO FIRES OCCUR?

2.5% of the Andean cypress forest, one of the most important tree species of central Patagonia, burns annually generating up to 245 tonnes of CO_2 per hectare.



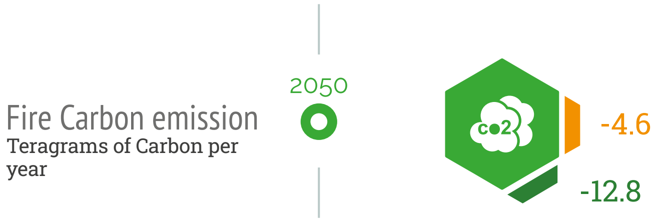
The central mountainous regions of the Sierras de Córdoba and the Andean temperate forests are the most affected in terms of area burned and fire frequency.

WILDLAND URBAN INTERFACE

Wildfires are a major threat to people and property, particularly within the Wildland Urban Interface (WUI) which is the transition zone between houses and wild vegetation areas.
In central Argentina, around 15% of the territory is classified as WUI and a high percentage of buildings are located in the WUI. Furthermore, most of these buildings are found in areas with high burn probability and where historically fires have already occurred.
In this context, forest fires contribute significantly to urban air pollution and particulate matter. For example, during the winter and spring of 2013 there was a strong presence of PM2.5 concentrations as forest fires episodes occurred around Cordoba city in central Argentina.

FUTURE FIRE EMISSIONS

Under a low emission scenario fire emissions might increase in the north and west Temperate Grasslands, Savannas and Shrublands of the Humid Pampas, the Espinal and the Dry Chaco. Under a medium emission scenario, a generalized increase might be more intense throughout mountainous areas in the North.



ARGENTINA
URBAN

OVERVIEW

Over 92% of theA rgentine population lives in urban areas, and an urbanization rate of 95% is expected by 2050.

The urban population is unevenly distributed and highly concentrated. 35% of people live in the Greater Buenos Aires area and a few other large cities, whereas most others other inhabit smaller urban agglomerations around the country.

Built up areas cover 0.32% of the country (8,897.11 square kilometers).

Population in Urban Areas

2020
41,919,857

2050
52,564,488

Graphs refer to data provided by United Nations, Department of Economic and Social Affairs, Population Division (2018).
World Urbanization

Urbanization Rate

2020
92.1%

2050
95.2%

OVERVIEW OF KEY CLIMATE IMPACTS IN URBAN AREAS

Key impacts on urban areas regard flooding from rivers and in urban areas and heat stress from increasing frequency and intensity of heatwaves.

HEATWAVES AND HEAT STRESS

Observations show a general increase in the number of warm nights, alongside an increasing frequency of heatwaves in particular in the most recent period.

This affects major urban centres the most. In Buenos Aires, a particularly intense and long heatwave in 2013, with daytime temperatures up to 40°C, caused an increase in daily deaths by 43%. The elderly were the most affected with mortality among over 84-year-olds rising by 51%.

Energy supply in the metropolitan area of Buenos Aires collapsed due to intense demand for air conditioning. With rising temperatures the frequency and duration of heatwaves is expected to increase. This will impact living conditions in urban areas significantly with higher temperatures due to the urban heat island (UHI) effect.

2050
Cooling Degree Days
% of change
+59.5%
+23.7%
+15.1%

2050
Heatwave frequency
% of change
+91.8%
+60.1%
+37.0%

2050
Heatwave duration
% of time
+6,247%
+1,032%
+379%

INTERACTIONS BETWEEN HEAT AND AIR QUALITY

Heat related health impacts from increasing air temperatures in urban areas are accentuated by air pollution. In Argentina, more than 90% of the urban population is exposed to unsafe levels of pollution such as PM2.5, which regularly exceed the threshold values recommended by the WHO.

In Argentina, more than 90% of the urban population is exposed to unsafe pollution levels, for instance of PM2.5, which exceed the threshold values recommended by the WHO.

2017

Population exposed to air pollution

93.9%

COASTAL FLOODING

Despite decreasing annual precipitations an increase in frequency and intensity of extreme rainfall events will expose most urban areas tomore frequent flooding.

Flooding from sea level rise presents risks for the estuary of the Rio de la Plata and will also affect the capital city of Buenos Aires. If sea levels rise by 50 centimetres these cities woud triple their exposure to the risk of flooding.

Projected sea level rise

2050

0.23 m

0.18 m

2100

0.77 m

0.38 m

EXTREME PRECIPITATION EVENTS

Argentina faces challenges related to changing precipitation patterns, with increasingly frequent extreme precipitation events exposing urban areas to flooding.

Although Argentina has invested in infrastructure to protect from flooding, precipitation events continue to cause damages. In Buenos Aires nearly 200,000 people and at least 32 other cities have recently been affected by floods with over one million people exposed to this risk. Despite decreasing annual precipitations an increase in frequency and intensity of extreme rainfall events will expose most urban areas tomore frequent flooding.

2050

Runoff increase

% of area

+12%

+4%

+2%

SURFACE SEALING AND FLOODS

Heavy precipitation in cities is problematic due to the high level of sealed surfaces. Soil sealing increases run off and reduces the amount of water absorbed by soil. Where there are large amounts of impervious ground cover, short duration extreme rainfall events can lead to increased flooding, even resulting in flash floods.

INEQUALITIES IN FLOOD RISK

Both low and high income households settle in flood prone areas or on steep ground. However, disadvantaged groups have less possibilities to apply flood protection measures to their homes, lobby for protective infrastructures or obtain flood insurance

2010

% of urban population

Population living in slums

14.7%

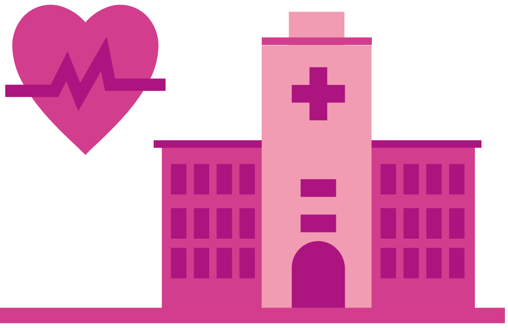
2018

% of total population

Urban population living in areas where elevation is below 5 meters

2.1%

ARGENTINA
HEALTH



OVERVIEW

Argentina's sub-tropical climate is highly appropriate for the transmission of vector-borne diseases such as dengue, malaria, chikungunya, Zika, and leishmaniasis. Rising temperatures will expand the range, seasonality, and distribution of vector-borne illnesses such as malaria and Zika. Projections suggest that the potential spread of these diseases will result in the number of people exposed being tripled by the end of the century.

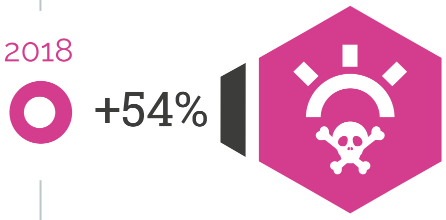
Mean annual temperature was seen to increase by 0.5°C and by 1°C in the Patagonia region over the past 50 years. This projects up to 2°C and 4°C increase in the south and north of the country. This is expected to bring higher levels of hydric stress and increased drought, and desertification. The incidence of waterborne diseases and the distribution of food and vectors may also be affected.

HEAT RELATED MORTALITY

Warming and increased frequency and duration of heatwaves have resulted in an increase in excess mortality and mortality risk in Argentina over the last two decades. In 2018, there was a 54% increase in heat-related deaths from a 2000 to 2004 baseline. 20.5% of heat related mortality in Argentina during 1991 to 2015 can be attributed to human-induced climate change.

Heat-related mortality

% change with respect to 2000-2004

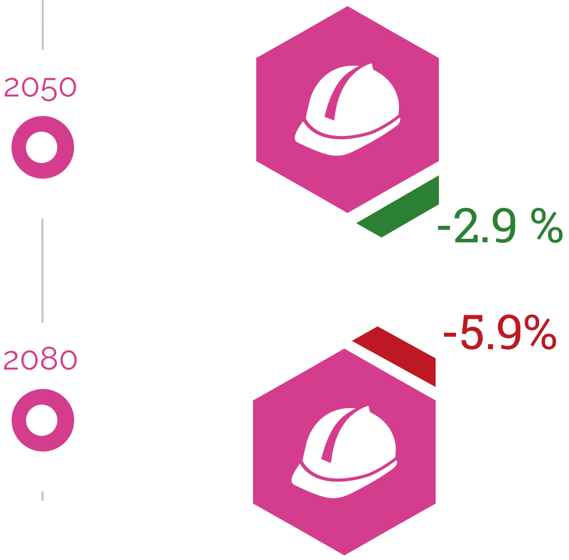


IMPACTS ON LABOUR

Labour is directly affected by changes in environmental conditions. Warming affects both the number of hours worked (labour supply) and on the productivity of workers during their working hours (labour productivity). Both labour supply and productivity are projected to decrease under future climate change in most parts of the world, and particularly in tropical regions. Parts of sub-Saharan Africa, south Asia, and southeast Asia are at highest risk under future warming scenarios. Future climate change will reduce global total labour in the low-exposure sectors by 18 percentage points and by24.8 percentage points in the high-exposure sectors under a 3°C warming scenario

Impact on total labour

% change with respect to 1986-2005 baseline



Warming and heatwaves are projected to affect labour in high-exposure sectors in Argentina. In the agriculture and construction sectors, there was a 49.7% decline in potential hours of labour in 2019 compared to a 1990s baseline. Total labour in Argentina is expected to decline by 2.9% under a low emissions scenario, and by 5.9% under a medium emissions scenario.

CLIMATE CHANGE AND DENGUE

Dengue has spread throughout the tropical world over the past 60 years and now affects over half the world's population. Globally, vectorial capacity for both dengue vectors (A. aegypti and A. albopictus) has been rising steadily since the 1980s, with nine of the ten highest years occurring since 2000.

Climatic stressors are one important driver of the current distribution and incidence of dengue. Climate change is likely to expand the geographical distribution and suitability of several vector-borne human infectious diseases including dengue. The risk of dengue transmission is increased by warming climates, as the growth and development of mosquitoes are significantly influenced by temperature, precipitation, and humidity.

CLIMATE CHANGE AND ZIKA

Zika virus has spread to at least 49 countries and territories since 2013. Climate change impacts on transmission suitability risk have increased over the years and future warming over 1.3 billion additional people could face suitable transmission temperatures for Zika by 2050.

DENGUE AND ZIKA: POPULATION AT RISK

Argentina is already at risk of an increase in climate-induced infectious diseases and these risks will increase due to future climate change. Climate change may extend suitability conditions for vectors and help them spread southwards.

Under a medium emissions scenario, 93.2% of the population will be at risk of transmission-suitable mean temperature for dengue by 2050, whereas 92.5% will be at risk under a high emissions scenario.

In the case of Zika, 54% of the population will be at risk by 2050 under medium emissions, whereas 88.4% will be at risk under high emissions.

CLIMATE CHANGE AND MALARIA

Rising temperatures will expand the range, seasonality, and distribution of vector-borne illnesses such as malaria and Zika. Under a low emissions scenario, 42.2% of the population will be at risk of malaria in 2050. Under a high emissions scenario, this will increase to 44.1% of the population.

Dengue suitability

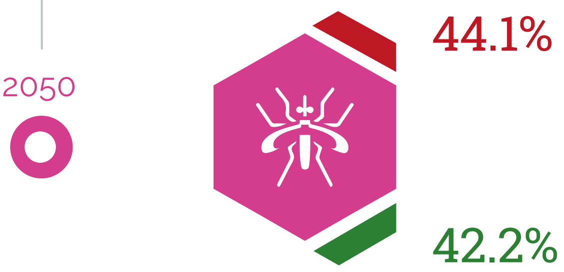
% of population at risk

Zika suitability

% of population at risk

Malaria suitability

% of population at risk



ARGENTINA
ENERGY

ENERGY SYSTEM IN A NUTSHELL

Argentina’s energy mix is dominated by oil (for transportation) and natural gas (for electricity generation). Domestic production of oil is almost entirely absorbed by the internal market.

Over 25% of electricity generation comes from renewable sources. The country's geographic features result in a wide variety of climates and hence of heating and cooling needs.

0.10
ktoe/US$
Energy intensity

5.4%
AC Share in
electricity consumption

9%
Import
dependence ratio

CLIMATE CHANGE TODAY

HEATING

Temperatures have increased on average by 1°C during the last century with uneven patterns across the country, with minimum temperatures increasing more than maximum temperatures, pointing to decreasing heating needs.

HYDROPOWER

Hydropower is already under threat due to water scarcity in the north, north-east and Cuenca de La Plata, and the marked shrinking of Andean glaciers is hinting to an intensification of this pattern in central and southern regions as well.

ENERGY SUPPLY

The current (2019) energy mix of total primary energy supply in Argentina is strongly dominated by fossil fuels (32.8% oil, 54.9% natural gas, 1.74% coal, totalling 89.4% of total primary energy supply), followed by renewable sources (8.3%). There is also some residual nuclear power generation (2.3% of total primary energy supply). Imports are negligible, as the country is largely self-sufficient. Electricity generation relies mostly on natural gas (69% of electricity fuel mix in 2018) and hydropower (12%).

ENERGY DEMAND

In Argentina, energy is used mainly for transport (31.6% of final demand in 2018), industrial uses (29.5% including 6.5% for non-energy uses) and residential (24.7%), followed by commercial use (8.1%), and agriculture (6.1%). Air conditioning’s contribution to residential electricity demand is still moderate (5,4% in 2017).

FUTURE ENERGY DEMAND

Argentina has a variety of climates ranging from the freezing polar tundra of the Tierra del Fuego and alpine in the Andes, to temperate in Buenos Aires, and a subtropical climate in the north.

Hence both effects on heating and cooling needs are expected to be significant. Overall, cooling needs will prevail, leading to an increase of 111 PJ (or 31 million KWh) by 2050 under a medium emissions scenario.

Net change in energy demand due to changes in HDD/CDD
Billion KWh

2050

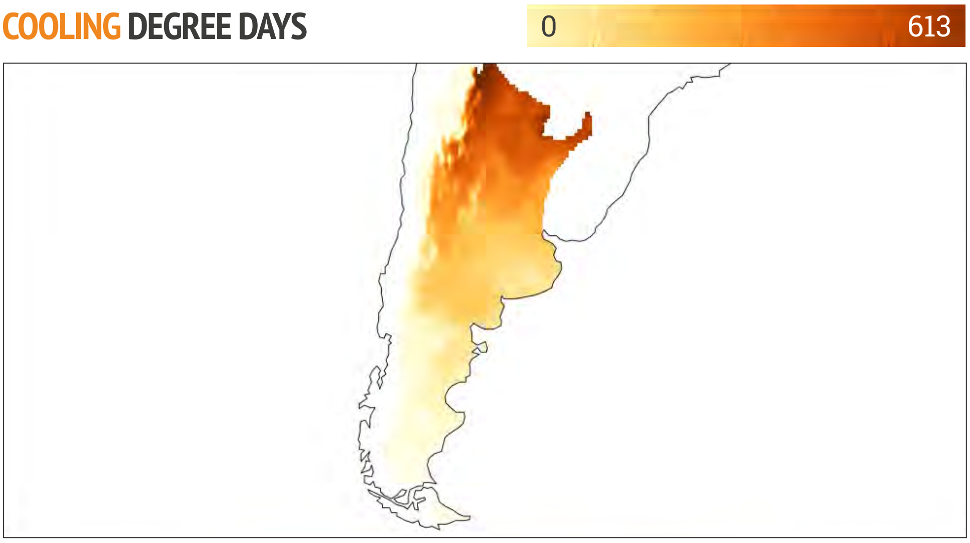
+ 30.84

COOLING NEEDS

Cooling degree days will undergo very marked increases along the northern border, and loose intensity along the north-south axis, although with significant magnitude on the northeast coast (where Buenos Aires lies).

Negligible variations in the sparsely inhabited south and on the mountains.

COOLING DEGREE DAYS

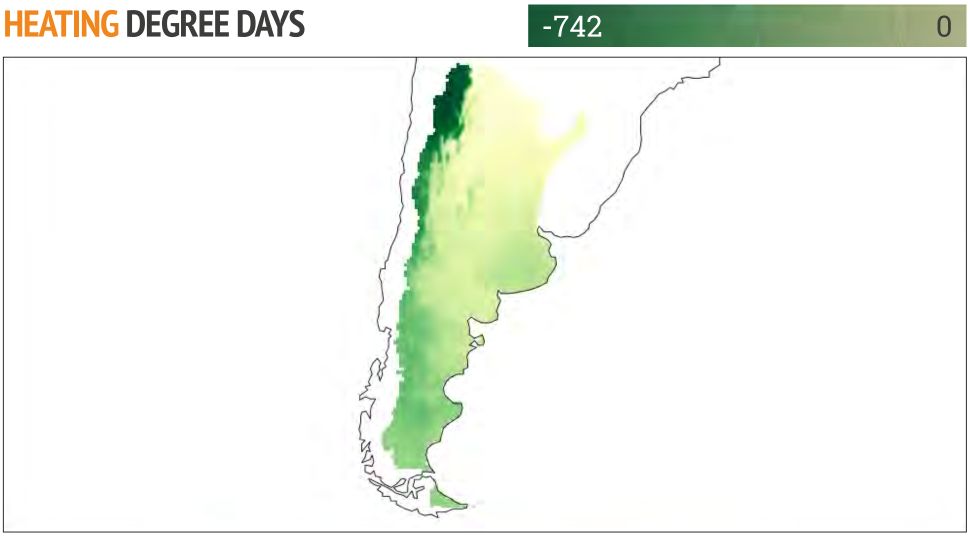


HEATING NEEDS

Highest decrease in heating degree days in the Andean regions in the north of the country, followed by the southern, cold regions of Patagonia and Tierra del Fuego.

Moderate decreases in the central/east coast, including the Buenos Aires area. Negligible changes on the northern border.

HEATING DEGREE DAYS



FUTURE ENERGY SUPPLY

The future configuration of Argentina's energy mix is likely to be determined by the evolution of climate mitigation policies and hence is outside the scope of this report. At the time of writing, there were no confirmed long term decarbonization commitments in place.

Change in Hydropower generation
% of change

2050

-3.69%

-2.99%

EXPECTED IMPACTS OF CLIMATE CHANGE

The main concern regards water availability reduction for hydropower and cooling of thermal power generation plants. However, there is a lack of quantitative estimates of expected impacts.

ARGENTINA ECONOMY

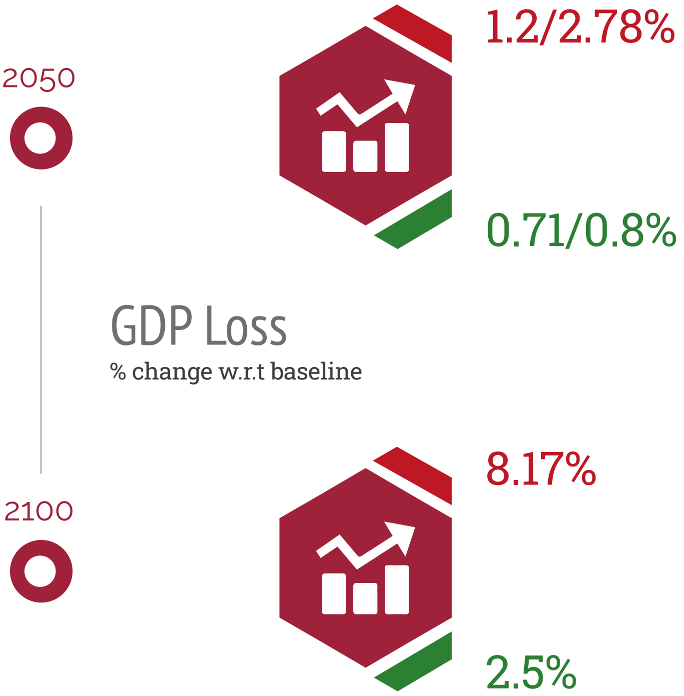
OVERVIEW

Argentina ranks 19th in terms of GDP in the G20 group. Although badly hit by the COVID 19 pandemic, recording a 10% decline in real GDP in 2020, the trend has reversed in 2021, with 5.8% growth in real GDP.

IMPACTS ON GDP

Argentina could experience systemic losses and negative growth impacts due to climate change. GDP losses by mid century could be up to 2.8% of GDP or 8.8 billion EUR under a high emissions scenario.

By the end of the century, GDP is projected to decline by 2.5% or 7.9 billion EUR under a low emissions scenario and by 8.2% of GDP or 25 billion EUR under a high emissions scenario.



2050

1.2/2.78%

0.71/0.8%

GDP Loss

% change w.r.t baseline

2100

8.17%

2.5%

SECTORAL ECONOMIC IMPACTS

IMPACTS ON AGRICULTURE

With 47% of land used for agriculture, and almost 7% of GDP produced by agriculture, forestry and fishing, climate change impacts on agriculture present a significant risk to the overall economy.

It is estimated that a temperature increase consistent with a medium emissions scenarios (between 2°C and 3°C) may decrease agricultural net revenues by 20% to 50%.

However, Argentina is also the world's third largest exporter of soybeans, and the second largest exporter of maize, two crops that, all other factors equal, respond well to rising temperatures. As a matter of fact, yields of both crops are projected to increase under both a medium and high emissions scenario.

Wheat production is more volatile: delines are expected by mid-century, but potential gains could be registered at the end of the century under a high emissions scenario due to the CO_2 fertilization effect.

IMPACTS ON ENERGY

As with all other economic sectors, energy supply and energy networks in Argentina will undergo more intense stress from extreme weather events.

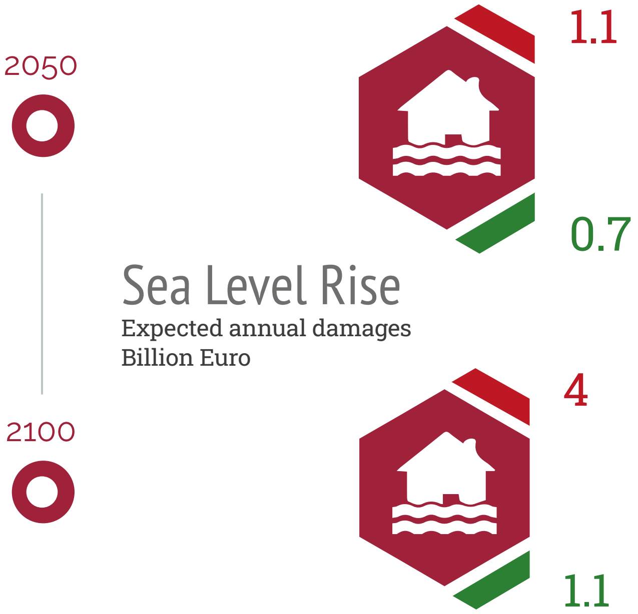
Economic impacts of shifts in household and firm energy demand (see chapter on energy) are difficult to predict and will mostly lead to redistribution effects.

In the case of Argentina, the magnitude of the increase in demand for cooling is expected to slightly exceed the one of decrease in heating demand, leading to a moderate increase in energy bills.

SEA LEVEL RISE DAMAGES

Under current levels of coastal protection, by mid century, sea-level rise and coastal flooding may cost the country 0.7 to 1.1 billion EUR in terms of expected damages to assets in low and high emissions scenarios respectively.

By the end of the century, expected losses can increase to 1.1 billion EUR in the low emissions scenario and to 4 billion EUR under a high emissions scenario.

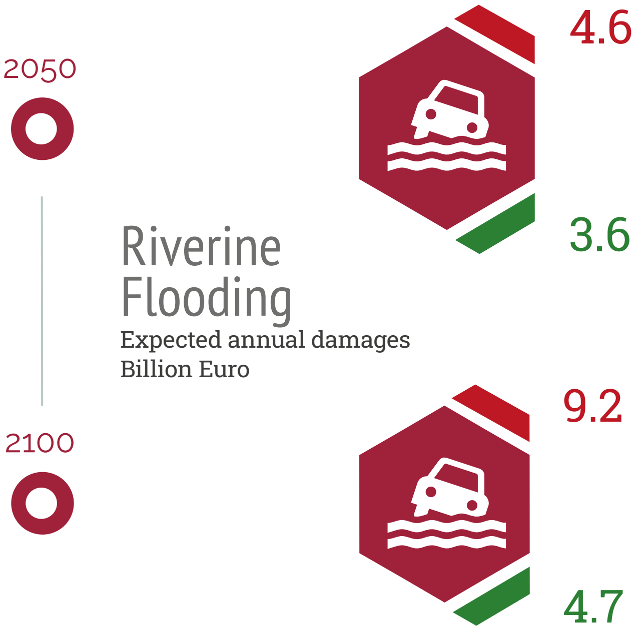


Sea Level Rise
Expected annual damages
Billion Euro

RIVER FLOODING DAMAGES

River flooding may cause damage that has the potential to be even more severe than that arising from sea-level rise.

By mid century total asset losses could reach 3.6 to 4.6 billion EUR, and in the second half of the century 4.7 to 9.2 billion EUR under a low and high emissions scenario, respectively.



Riverine Flooding
Expected annual damages
Billion Euro

IMPACTS ON TOURISM

In recent decades there has been a progressive trend towards prolonged summer climatic conditions during the first part of autumn in most of Argentina.

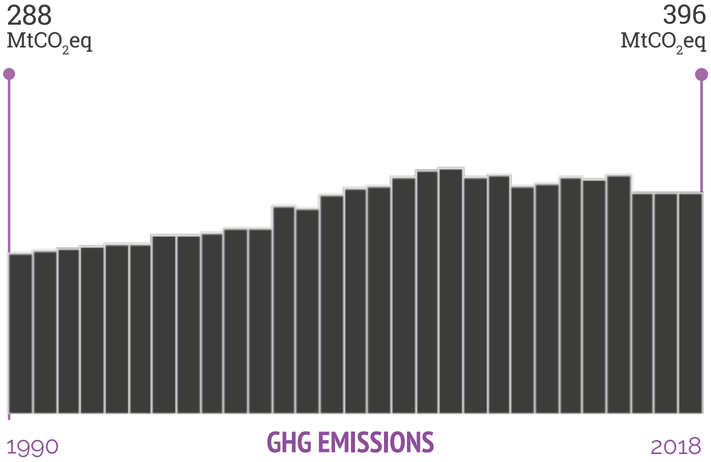
Climate projections show a similar trend for the rest of the century. Both highest summer temperatures and extension of the warm period would favor an increase in domestic tourism to beach areas and the maritime coast.

However Patagonia will probably experience a reduction in the tourism linked with mountains and winter sports, due to the retreat of glaciers and the decreasing trend in precipitation and snow.

ARGENTINA
POLICY

OVERVIEW

Although Argentina is the world's 8th largest country by surface, it has a low population density and accounts for only 0.8% of global emissions. In recent years the emissions trend has been unsteady, but in general emissions are still lower than the peak level registered in 2005.



INTERNATIONAL COMMITMENTS

Argentina ratified the Paris Agreement and submitted its first NDC in 2016, committing to a maximum level of yearly emission of 483 MtCO$_2$eq by 2030. In 2020, Argentina then submitted a second more ambitious NDC, whereby yearly emission cannot exceed 359 MtCO$_2$eq by 2030.

CLIMATE POLICY COMMITMENTS CHRONOLOGY

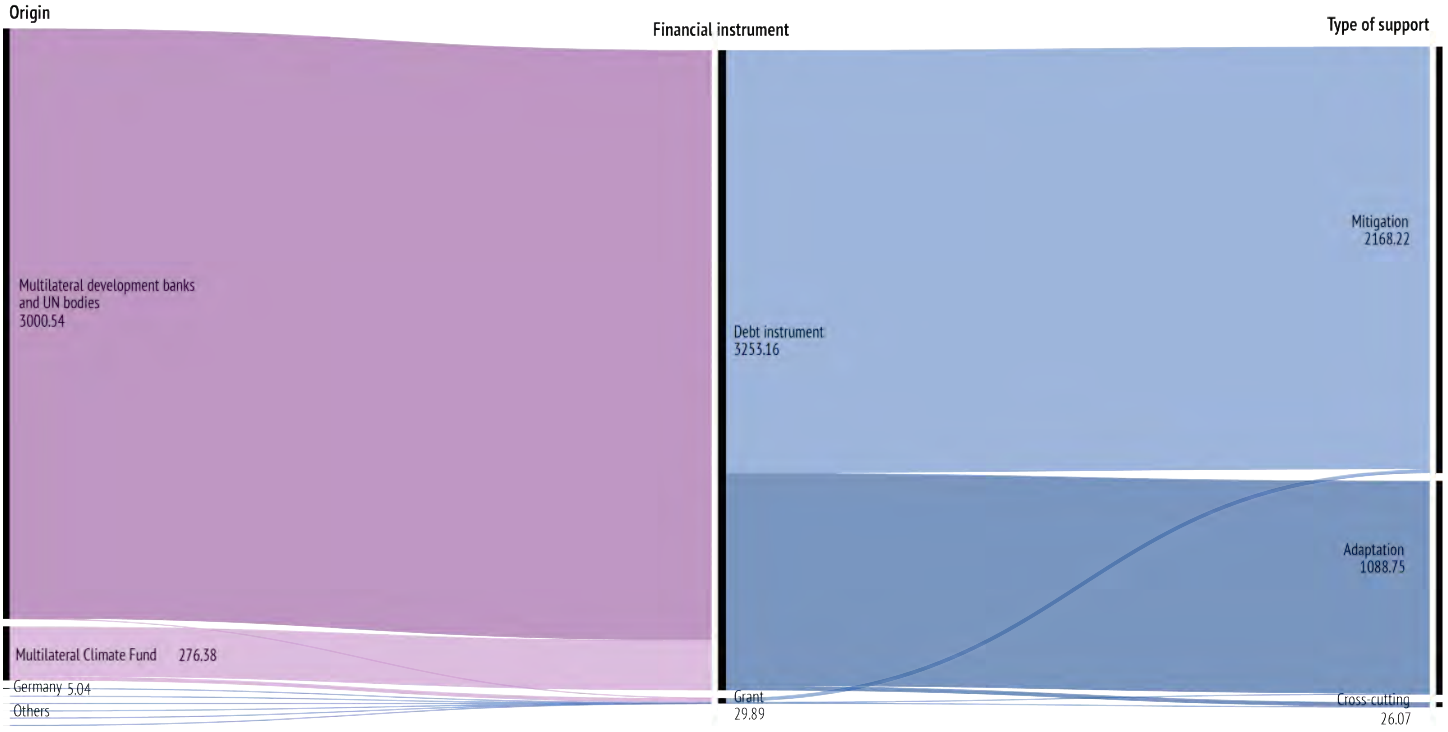
2001 — **Kyoto Protocol - 1st period**
No target

2016 — **Paris Agreement - 1st NDC**
483 MtCO$_2$eq as the maximum level of yearly emissions by 2030

2020 — **Paris Agreement - 2nd NDC**
359 MtCO$_2$eq as the maximum level of yearly emissions by 2030

INTERNATIONAL CLIMATE FINANCE ASSISTANCE

The OECD DAC's climate-related development financial data show that Argentina has received 3.2 billion USD. Almost all of it is provided in the form of debt instruments and comes from multilateral institutions. Mitigation is the main purpose.



SUSTAINABLE RECOVERY POLICY

According to the Global Recovery Observatory, in 2020 Argentina invested 7.34 billion USD in recovery. Post-covid policies were not particularly green, with a negligible amount of sustainable investments.

23.44 billion $	7.34 billion $	0.10 billion $
Total Spending	Recovery Spending	Green Spending

DOMESTIC ADAPTATION POLICY

Argentina has a specific adaptation objective in its NDC. Nevertheless, the country did not adopt an adaptation strategy or plan. There is no legal framework for adaptation planning at a sub-national or sectoral level.

- ○ Domestic Adaptation Policy
  - ● Inclusion of Adaptation in NDCs
  - ○ Integrated Adaptation & Mitigation Policy
  - ○ Dedicated Adaptation Strategy
  - ○ Dedicated Adaptation Plan
- ○ Subordinate Adaptation Policies
  - ○ Sectoral Adaptation Plans
  - ○ Subnational Adaptation Plans

○ Policy not in place ● Active policy

ADAPTATION POLICY HIGHLIGHTS

TRANSNATIONAL INITIATIVES

Regional and local climate risk management in Brazil and Argentina

The objective is to build climate resilience in vulnerable populations in Sao Paulo in Brazil and Cordoba in Argentina, reducing the risk of floods and droughts

Climate change adaptation in vulnerable coastal cities and ecosystems of the Uruguay River

The project aims to build resilience in coastal cities and ecosystems throughout the Uruguay River, both in Argentina and Uruguay by developing shared instruments and tools for planning

NATIONAL INITIATIVES

National Forestry and Climate Change Action Plan

The plan aims to reduce GHG emissions and increase removals in the forestry sector, through a sustainable use of native forests for the reduction of vulnerability

System for Climate Change Risk Maps (SIMARCC)

The SIMARCC is a GIS that allows to visualize the risk maps of the whole Argentinian territory. The platform targets local decision-makers for the development of local adaptation plans

SUBNATIONAL INITIATIVES

Buenos Aires Climate Change Action Plan 2050

The Climate Action Plan 2050 sets out targeted measures to cut greenhouse gas emissions (53% by 2030 and 84% by 2050) and increase resilience

Enhancing the Adaptive Capacity and Increasing Resilience of Small-size Agriculture Producers of the Northeast of Argentina

The project aims to increase the adaptive capacity of smallholders in the face of climate variability impacts, particularly floods and droughts

ENERGY TRANSITION

Argentina shows an overall energy transition indicator a little over the average value with respect to G20 countries. In particular, this position is due to its poor performance in Electrification, 8 points below the average, whereas the Renewables and Fossil Fuels indicators are just above the G20 average.

The transition pathway is well sustained by indicators such as Emissions and Efficiency, where performance is definitely above average. Finally, Argentina shows indicators in line with the G20 average, with a wider margin for improvement.

Energy Transition	58.7	59.9
Fossil Fuels	45.3	46.7
Renewables	19.7	21.2
Efficiency	84.9	87.4
Electrification	70.8	62.8
Emissions	72.9	81.1

G20 AVERAGE

COUNTRY

Only actively pursuing an energy transition based on decarbonization and electrification – from policy and regulation, to health and education – will enable countries to benefit the most from future opportunities and fight climate change whilst ensuring an equitable distribution of wealth.

The Energy Transition indicators were developed by Enel Foundation in cooperation with SACE, and provide a retrospective analysis based on historical data.

G20 CLIMATE RISK ATLAS

Impacts, policy, economics

AUSTRALIA

How to read the Atlas: graphs, colours and scenarios.

The maps used in this Atlas are taken from **The World Bank Official Boundaries** - ***https://datacatalog.worldbank.org/search/dataset/0038272*** (accessed on May 28, 2021). For the section Energy, the maps are based on Panoply Data Viewer ***https://www.giss.nasa.gov/tools/panoply/credits.html***

Each sector of this Atlas contains data and information on various climate scenarios.

When reported in graphs, the **colour black** indicates data and information referring to the current state, the past or the baseline.

When the authors refer to **RCP (Representative Concentration Pathways)**, the 3 colours used across the factsheet refer to 3 scenarios, which are 3 different development options with different levels of greenhouse gas emissions, **respectively low emissions (green), medium emissions (orange), and high emissions (red)**. The same colour code is used when RCPs are associated with Shared Socioeconomic Pathways (SSP).

In some cases, the authors refer to global warming scenarios. In these cases, the 3 colours used refer to a temperature rise of **1.5°C (green), 2°C (dark green), and 4°C (red)**.

When the authors refer exclusively to **Shared Socioeconomic Pathways - SSPs** (Population affected by river floods in the section: "Water"), data related to **SSP3** - that encompasses, among other things, slow economic growth, material-intensive consumption, and persisting or worsening inequalities – **are reported in a lighter shade**; **SSP5** – which refers to social and economic development that is coupled with an energy-intensive lifestyle and the abundant exploitation of fossil fuel resources – is shown using a **middle shade of the colour**, whereas data related to **the present** conditions **are represented in a dark shade**.

Further details on scenarios, methodologies, and the full list of references are available at: **www.g20climaterisks.org**

Concept and graphic design by element6.eu

AUSTRALIA CLIMATE

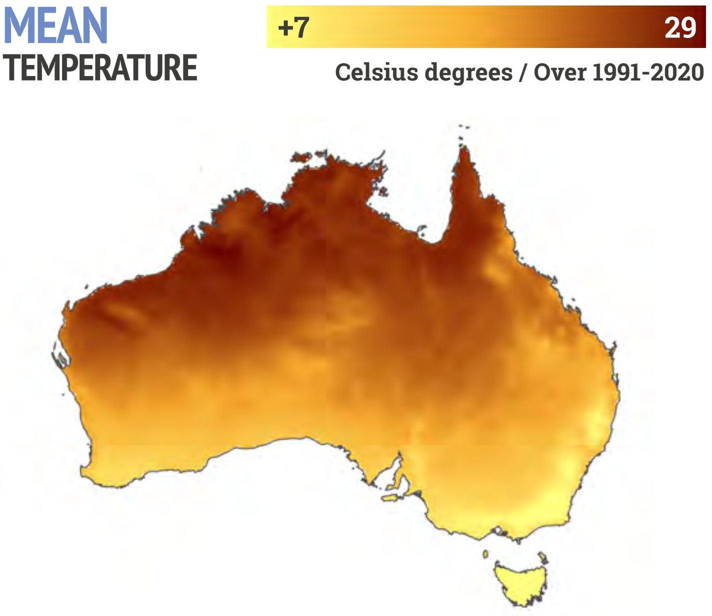
OVERVIEW

Australia is home to tropical, temperate, arid, and alpine climate regimes. Whereas its interior is arid and semiarid, the northern regions are dominated by tropical climate systems with monsoonal rain during the summer and a dry season for the remainder of the year. The southern regions experience winter storm activity originating in the Southern Ocean, and summer high pressure systems pushed southward by the monsoon.

TEMPERATURE

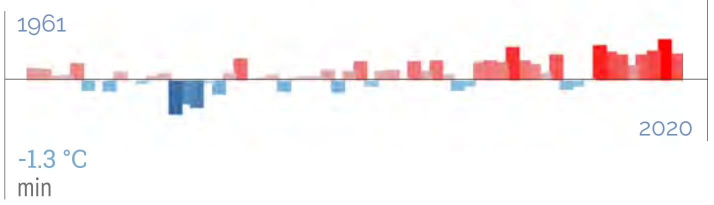
Temperature in Australia varies with latitude. Higher values are typical in the north-west, whereas lower values are reached when approaching the polar zone in the south, especially on the island of Tasmania.

MEAN TEMPERATURE



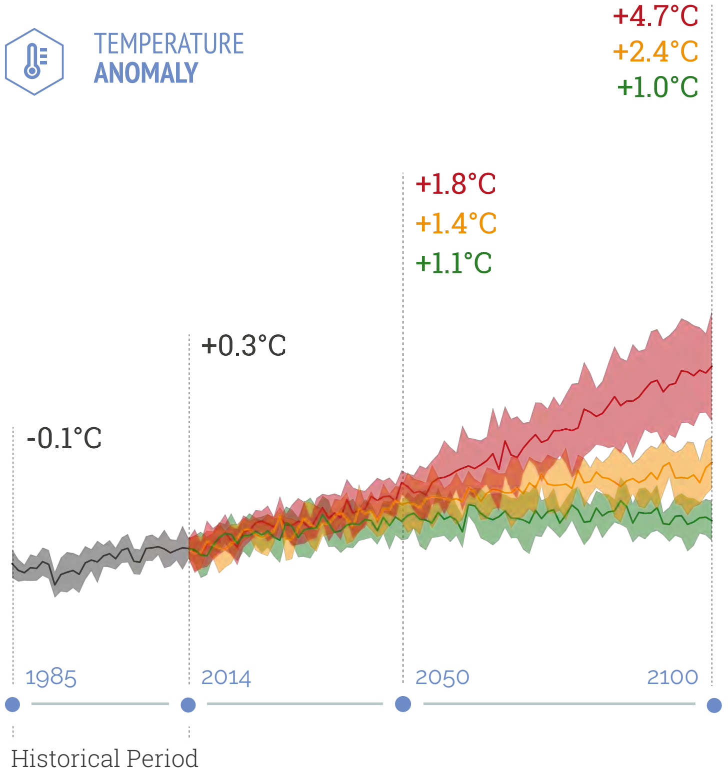
TEMPERATURE TREND

Temperature anomalies over the last 60 years with respect to the annual mean of 22°C in Australia during the 1961-1990 period



TEMPERATURE PROJECTIONS

Under a low emissions scenario projected temperature variations will remain contained at around +1°C, both by 2050 and 2100.
Under a high emissions scenario, with no reduction in GHG emissions, much greater temperature anomalies are expected by both 2050 and 2100.



EXPECTED VARIATION FOR TEMPERATURE AT 2050

The indicators show variations in selected temperature characteristics for a thirty-year period centred on 2050 (2036-2065) with respect to the reference period 1985-2014.

Annual Mean Temperature	Max Temperature of warmest month	Min Temperature of coldest month
+1.8°C	+1.9°C	+1.6°C
+1.4°C	+1.5°C	+1.2°C
+0.9°C	+1.1°C	+0.9°C

PRECIPITATION

Historically observed trends show rising rainfall in many tropical areas and falling rainfall in many temperate areas. Rainfall from tropical cyclones also cause intermittent widespread flooding. The El Niño-Southern Oscillation climate pattern occurs intermittently every 2–7 years affecting inter-annual rainfall patterns in eastern and southern regions. El Niño events are associated with increased likelihood of extreme events such as drought and above average rainfall. Sea surface temperatures also play a role in rainfall variability, particularly in the south of the continent.

MEAN PRECIPITATION

mm/year / Over 1991-2020

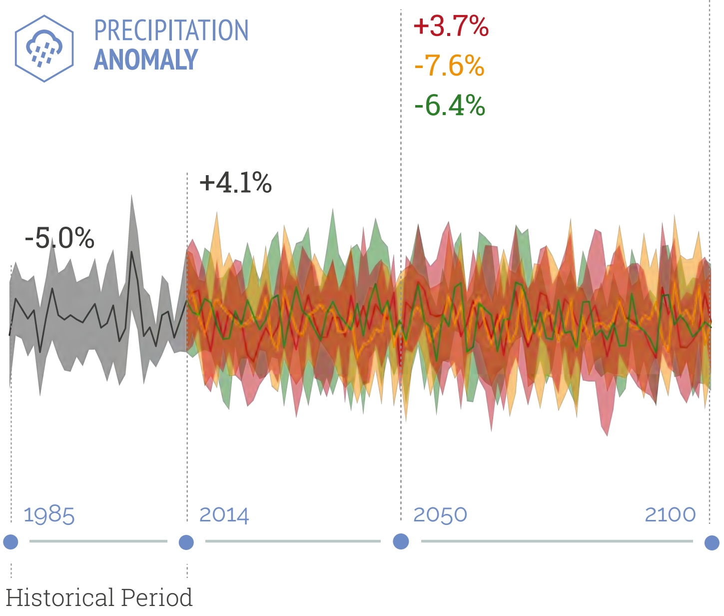
PRECIPITATION TREND

Precipiation anomalies over the last 60 years with respect to the annual mean of 343 mm/year in Australia during the 1961-1990 period

PRECIPITATION PROJECTIONS

Precipitation trends are complex and reveal a large variability following all emissions scenarios, although a slight tendency to reduction is observed under a high emissions scenario. This is due to the complexity of the precipitation regime and dynamics requiring more detailed spatial and temporal analysis.

PRECIPITATION ANOMALY



EXPECTED VARIATION FOR PRECIPITATION AT 2050

The indicators show variations in selected precipitation characteristics for a thirty-year period centred on 2050 (2036-2065) with respect to the reference period 1985-2014.

Annual total precipitation	+0.0%	-2.1%	-0.5%
Precipitation of wettest month	+3.2%	+2.0%	+1.0%
Precipitation of warmest quarter	-3.2%	-3.2%	-0.0%

VARIATION OF SPECIFIC CLIMATE INDICATORS

Climate indicators variation showing impacts of climate change on sectors such as agriculture, health and water. Analysis considers 3 threshold average temperature increase: **+1.5°C**, **+2°C**, **+4°C**.

Agricultural drought proportion of time % of time	+27%	+15%	+12%
Hydrological drought proportion of time % of time	+24%	+13%	+10%
Heatwave duration % of time	+3,980%	+320%	+87%
Runoff increase % of area	+30%	+9%	+5%
Agricultural drought frequency % of change	+76%	+36%	+22%
Hydrological drought frequency % of change	+13%	+10%	+12%
Heatwave frequency % of change	+63%	+24%	+11%
Runoff decrease % of area	+7%	+3%	+2%

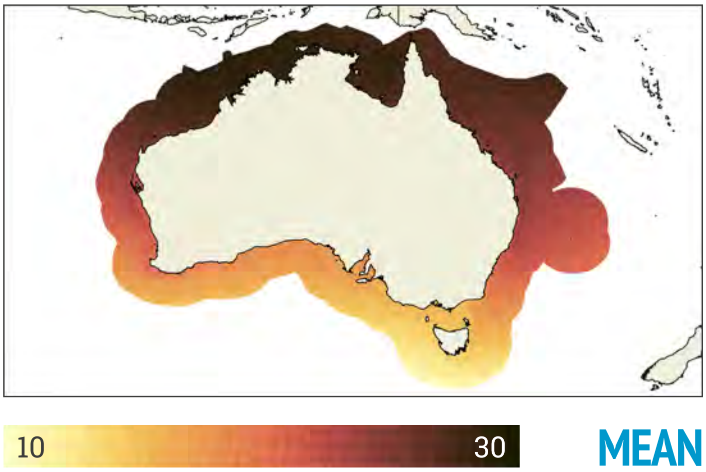
AUSTRALIA OCEAN

OCEAN IN AUSTRALIA

Australia's marine exclusive economic zone comprises a wide range of coastal ecosystems including extensive meadows of seagrasses, tidal salt-marshes, mangroves, and the Great Barrier Reef. In particular, coastal systems can be divided into three main areas: Indian, Pacific and Southern ocean marine regions.

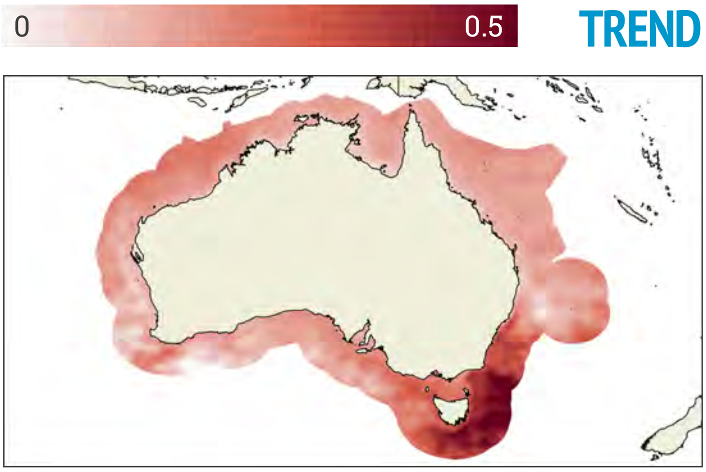
CURRENT CLIMATE CONDITIONS

Mean sea surface temperature reflects the different climate regimes, from the cold waters of Tasmania to the subtropical regime on the northern coasts.



SEA SURFACE TEMPERATURE

Celsius degrees / Over 1991-2020

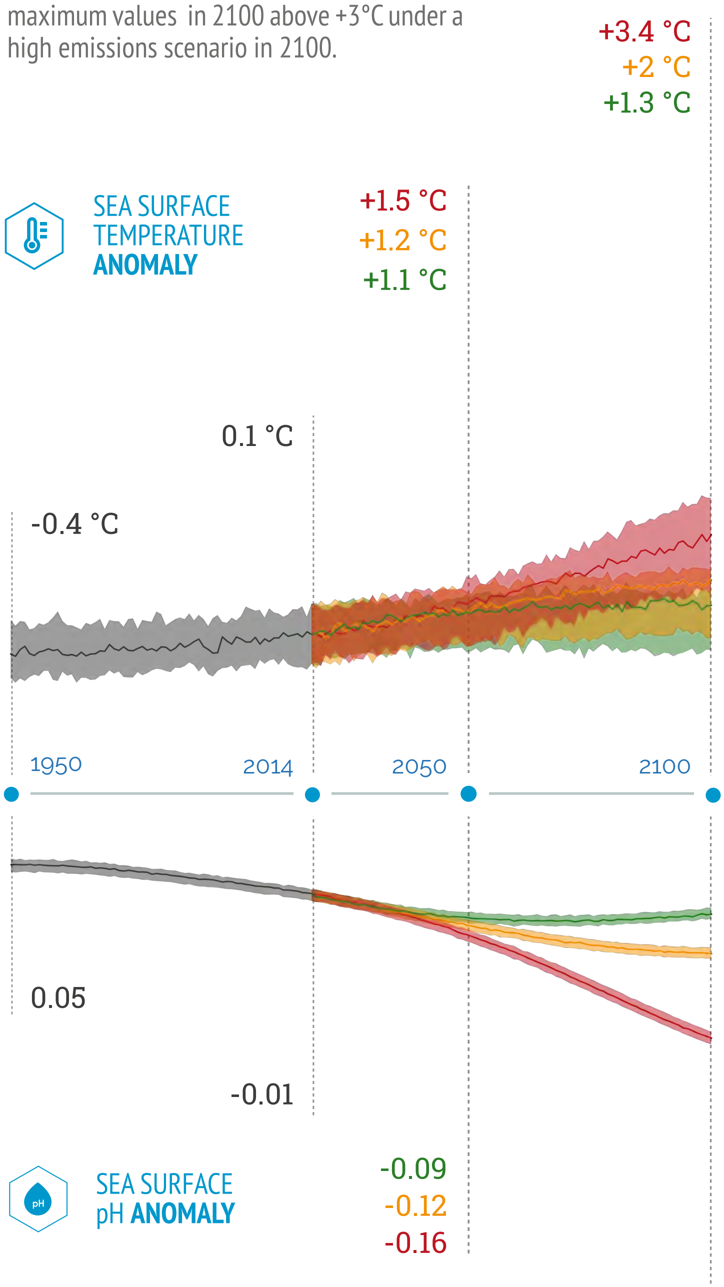


Surface temperature trends indicate a general warming of 0.2°C per decade in all marine areas, with increased gains in the colder regions facing the Southern Ocean.

FUTURE PROJECTIONS

Projected annual changes within the marine EEZ for the two most significant marine indicators of climate change: sea surface water temperatures and pH.

Seawater temperature changes are in line with the definitions of each scenario, with maximum values in 2100 above +3°C under a high emissions scenario in 2100.



Seawater surface pH becomes more acidic in all scenarios, closely reflecting rising atmospheric CO_2 concentrations, and only a low emissions scenario leads to a stable condition by 2100.

ECOSYSTEM INDICATORS AT 2050

Regional changes in key marine ecosystem indicators under projected future scenarios by mid-century (2036-2065) with respect to present climate conditions (1985-2014).

	Indian	Pacific	Southern Ocean
Temperature regulates the metabolism of marine organisms determining which habitats remain suitable. Excessive warming will likely push ecosystems beyond tolerance thresholds.	25.22°C 🟥 +1.26 °C 🟧 +1 °C 🟩 +0.85 °C	22.51°C 🟥 +1.74 °C 🟧 +1.42 °C 🟩 +1.43 °C	15.46°C 🟥 +1.11 °C 🟧 +0.82 °C 🟩 +0.71 °C
pH represents the acid/base status of marine waters, where a decreasing pH reflects the acidification of the ocean due to increased absorption of atmospheric CO_2.	8.09 🟥 -0.16 🟧 -0.12 🟩 -0.09	8.1 🟥 -0.16 🟧 -0.12 🟩 -0.09	8.1 🟥 -0.16 🟧 -0.12 🟩 -0.09
Oxygen is fundamental to sustain marine life and its reduction can have a large impact on coastal ecosystem services including fisheries and aquaculture.	212.9 mmol/m^3 🟥 -2.02 % 🟧 -1.6 % 🟩 -1.35 %	222.6 mmol/m^3 🟥 -2.58 % 🟧 -2.24 % 🟩 -1.89 %	254.59 mmol/m^3 🟥 -1.97 % 🟧 -1.33 % 🟩 -1.21 %
Chlorophyll is an indicator of the biomass available at the base of the marine food web supporting all ecosystem productivity.	0.16 mg/m^3 🟥 -4.29 % 🟧 -11.66 % 🟩 -7.98 %	0.27 mg/m^3 🟥 -6.72 % 🟧 -14.55 % 🟩 +2.24 %	0.34 mg/m^3 🟥 +10.56 % 🟧 +2.35 % 🟩 +4.11 %

FISH CATCH POTENTIAL

Fish catch potential is an estimate of the maximum fish catch achievable given the marine resources available over a sustained period. It is linked to the concept of maximum sustainable yield, meaning the maximum amount of fish that can be extracted from a system without causing a collapse in fish populations.

It is a characteristic of the natural system, which is substantially different from realized catch, and a direct result of the fishery policy in place.

Fish catch percentage change

2050

🟥 -11.4%

🟩 -4.7%

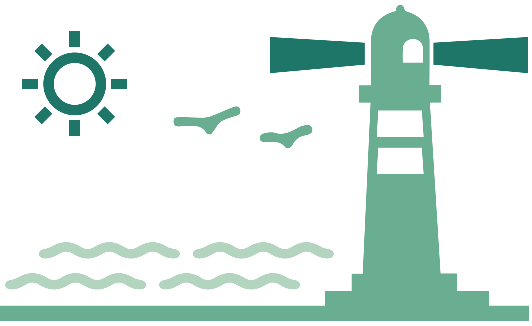
ANALYSIS DETAILS

All datasets were analysed using only data from within the marine EEZ and therefore excluding overseas territories, detached islands and any disputed or joint territories with other nations. In the assessment of current climate conditions, seawater surface tempereture data was obtained using satellite observations distributed in the framework of ESA Climate Change Initiative.

Future projections of marine indicators are represented by the combined analysis of results from 15 different Earth System models participating in the Coupled Model Intercomparison Project Phase 6 (CMIP6). These models include new and better representations of physical and biogeochemical processes, compared to previous IPCC assessment reports.

Fish catch potential data was obtained using the FAO's technical report and refers to the best and worst case climate scenarios from the Fifth IPCC Assessment Report. These mean estimates are subject to substantial uncertainties as discussed in the original work.

AUSTRALIA
COASTS



OVERVIEW

Australia's coastline extends for 66,530 kilometres along the Pacific, Indian and Southern oceans, the Timor Sea and the Gulf of Carpentaria. Tidal waters influence rivers, creeks and waterways for several kilometres inland. Australia has a great variety of coastal ecosystems, including rocky cliffs, sandy beaches and dunes, wetlands and the Great Barrier Reef. Most of the 25 million people living in Australia are concentrated in large coastal cities, with settlements and infrastructure often located in low lying areas and coastal floodplains.

Shoreline Length

66,530 km

Sandy Coast Retreat at 2050

-51.7 m

CLIMATE CHANGE HAZARDS

Coastal hazards such as erosion, storm tide inundation and permanent flooding, can have strong adverse impacts on coastal regions, with loss of sandy shores, damage to settlements, infrastructure and ecosystems. Climate change can exacerbate these impacts due to rising sea levels and increasing impacts of waves and storms. In Australia, tropical cyclones are expected to increase in intensity and possibly impact highly populated coastal areas further south. Changes in rainfall intensity associated with tropical and extratropical storms may exacerbate the impact of storm surges on the coast.

SEA LEVEL RISE

Relative sea level rise has been observed over the past century around the coast of Australia, with a yearly average increase of 1.82 millimetres per year since the 1990s. The latest IPCC projections indicate that, by 2050, global sea levels may rise between 0.18 metres, under a low emissions scenario, and 0.23 metres, under a high emissions scenario.

Observed and projected sea level rise at 2050

1.82 mm/year

0.23 m

0.18 m

EXTREME SEA LEVEL

Extreme sea levels are expected to increase in line with sea level rise, increasing the frequency of damaging high water level conditions. On average, one in 100 year extreme sea level events in Australia are expected to rise from 2.84 metres at present day to 3.03 metres by 2050, under a medium emissions scenario.

Current and projected extreme sea level at 2050

2.84 m

3.12 m

3.03 m

OBSERVED STORMS

The Australian continent features a broad range of wave climate regimes and storm patterns. In general, the northern half of Australia is exposed to large tropical cyclones, whereas other populated areas further south are subject to seasonal ocean storms. With a growing shoreline population, damages to settlements and infrastructure from inundation and erosion have been increasing.

FUTURE STORMS

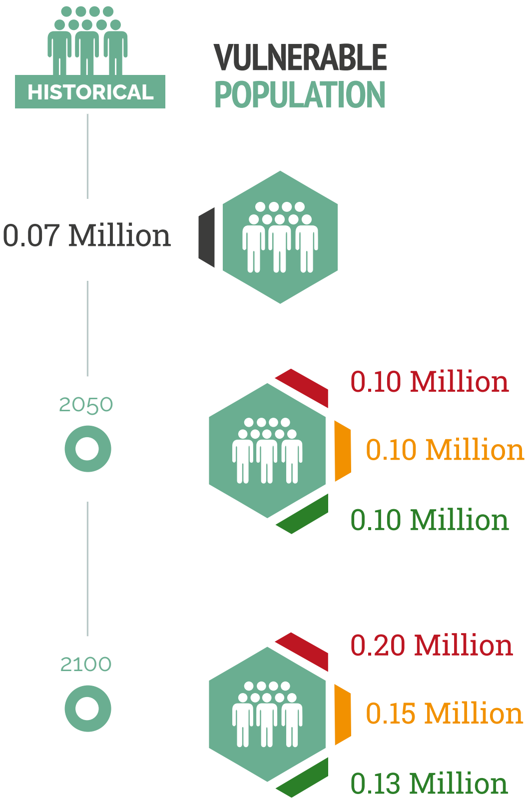
Large storms are expected to increase in intensity as a consequence of the increasing energy stored in ocean waters, exacerbating the impact of the rising waters on buildings, infrastructure, services and ecosystems. Increasing temperatures are likely to affect storm patterns around the Australian continent, with a possible increase in extreme sea levels and a southward migration of tropical storms, affecting areas higher population densities.

VULNERABILITY AND RISK

Population and assets, including buildings and infrastructure, are concentrated on the coast. Coastal areas gradually more at risk of being inundated in the future. Increasing storm energy is likely to exacerbate erosion and inundation issues already present around the Australian coast, which will be compounded by sea level rise.

For example, in the City of Gold Coast, one of the largest coastal cities in Australia, the area vulnerable to climate change is projected to increase by 20% if no action is taken to reduce this impact, including 746 hectares of conservation area. Damage to coastal assets, including buildings and infrastructure are expected from shoreline recession, storm erosion and increasing flood occurrence and intensity.

Key coastal ecosystems can also be impacted by rising seas and increasing storms, with potential damage to mangroves, wetlands, and estuaries. The population exposed to the annual coastal flood level is expected to increase from 70,000 to 100,0000 people under a medium emission scenario by 2050.



INFLUENCE OF SEA LEVEL RISE ON EXTREME SEA LEVEL

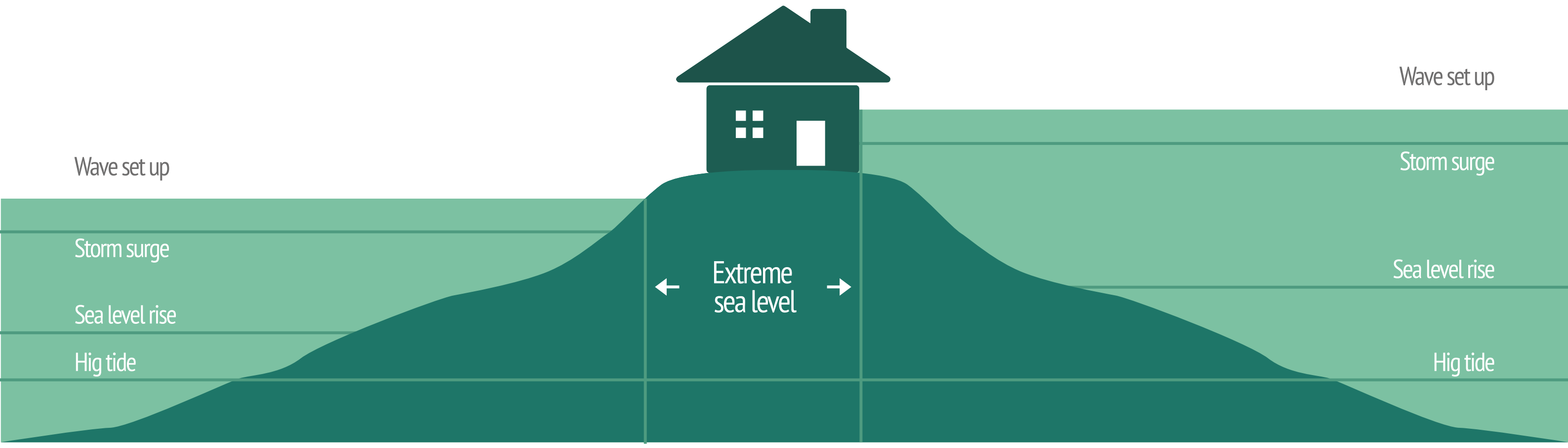
Present and future sea level rise are a consequence of carbon induced global warming causing melting ice and ocean expansion due to heat accumulation.

The extreme sea levels reported here are based on the 100-year storm surge + wave set up + sea level rise + high tide indicators. The first two parameters (storm surge + wave set up) are based on the 100-year value for the event; sea level rise is its projected value at 2050; and high tide is the absolute value of the highest tide calculated for a given locality, which won't be influenced by climate change.

+ **Wave set up** refers to the accumulation of water near the shore due to the presence of breaking waves.

+ **Storm surge** is an occasional increase in sea level driven by shoreward wind-driven water circulation and atmospheric pressure.

+ **High tide** is usually the highest tide reached in a given location based on tide records.



Present sea levels have risen globally by approximately 20 centimetres over the past century.

Future sea level rise is a projection based on different global warming scenarios, at approximately 100 centimetres by the end of 2100, with consequent inundation during extreme sea level events.

AUSTRALIA
WATER

OVERVIEW

Australia has been facing challenges associated with growing urbanization, growing demand for food, and the need for environmental flows, all of which have increased water demand.

The deep vulnerabilities of Australia's water resources have been exposed in recent decades, with extreme floods and droughts also threatening ecosystems. In addition, climate change, mainly in the south, has exposed the region to a further decrease in water availability.

The high variability in precipitation around the country affects runoff, streamflow, groundwater recharge and water availability for human use.

Renewable internal freshwater resources — 492 billion m^3

Renewable internal freshwater resources per capita — 19,998 m^3

40% of Australia sees less than 300 millimetres of rainfall per year. Whereas 72% of water runoff occurs in the north, in coastal Queensland and Tasmania, only 7% is generated in the Murray-Darling Basin, where more than two-thirds of Australia's irrigation water is used. Water harvesting, storage and distribution have therefore become vital to urban and regional development whilst also contributing to the ecological decline of rivers, wetlands and floodplains.

CLIMATE CHANGE HAZARDS

Climate change can affect water resources through increasing temperatures, higher rates of evapotranspiration and altered rainfall patterns. This leads to changes in the water cycle, including decrease of snow and ice coverage, alterations of surface runoff and groundwater storage, as well as drought and flood occurrence. Australia's water security has already been significantly influenced by climate change.

The severity of floods has increased and droughts are becoming more severe due to drier, hotter conditions, leading to declines in soil moisture due to increased water loss from plants and soil. Southeast Australia has experienced a 15% decline in late autumn and early winter rainfall, and a 25% decline in average rainfall in April and May since the mid-1990s.

KEY POINT RUNOFF

Australia is the driest populated continent and, on average, only 9% of precipitation becomes runoff, and approximately 2% percolates through the soil to recharge groundwater: one of the lowest proportions of rainfall conversion in the world.

At a country scale, an average increase in surface runoff by approximately -4% and 4% is expected, respectively, under the low emissions and high emissions scenarios for the 2045-2055 period, compared to 2015-2025.

If temperatures rise by 1.5°C, 2°C or 4°C, 2.0%, 3.3% or 7.0% of the country will likely experience an increase in runoff, whereas 5%, 9.4% or 30% of the surface of the country will likely experience a respective decrease in runoff.

2050

Changes in annual runoff
% of change

+3.6%

-3.8%

2050

Runoff increase
% of area

+7%

+2%

KEY POINT DROUGHTS

Prolonged periods of lower than average rains, mostly driven by the El Niño cycles, can cause droughts and may impact ecosystems, water availability for human uses, including domestic use and agriculture, and create the conditions for catastrophic bushfires. The role of climate change in rainfall reduction over southern Australia and along the Great Dividing Range has been broadly discussed. Many parts of the country - especially in the southeastern regions, but also in the west - have seen sharp declines in cool-season (April to October) rainfall in recent decades.

The likelihood of severe droughts in Australia is expected to increase by 16.8%, 18.1% and 25.6% (2040-2059) under low, medium and high emissions scenarios. Similarly, If temperatures rise by 1.5°C, 2°C or 4°C, there is an expected increase of hydrological drought frequency by 8%, 9.7% and 14%, respectively.

2050
Severe drought likelihood increase
% of change
+25.6%
+16.8%

2050
Hydrological drought frequency
% of change
+13.0%
+9.0%

2050
Groundwater Recharge
% of change
+24.7%
-11.7%

KEY POINT GROUNDWATER

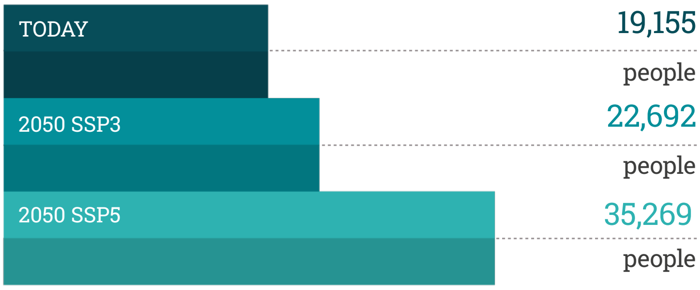
Australia's use of groundwater has increased significantly over recent decades. For example, in the 13 years from 1983 to 1996 the national reliance on groundwater increased by nearly 90%. Current effects of climate change can be seen through the spatial variations of the groundwater availability, also compromised by the more frequent prolonged drought periods.
Many studies agree on a strict positive correlation between future rainfall trends and groundwater recharge in Australia. In addition, coastal groundwater may be susceptible to changes in salinity because of saltwater intrusion, associated with sea level rise. At the country level, a -11.7%, +14.9% and +24.7% change of the annual groundwater recharge for the period 2045-2055 compared to the timeframe 2015-2025 is expected respectively under low medium and high emissions scenario.

KEY POINT FLOODS

The flooding of rivers following heavy rainfall is the most common form of flooding in Australia. Flooding of rivers in inland areas of central and western New South Wales (NSW) and Queensland, as well as parts of Western Australia, can spread for thousands of square kilometres and may last for weeks or even months. For example, the March 2021 floods in NSW, driven by a seasonal La Niña climate, caused widespread damage; at some locations approximately 900 millimetres of rain fell in one week.

Changing rain patterns may affect the frequency and intensity of floods. Changes in the population exposed to river floods are expected, with an increase from about 19,000 in the present day to 23,000 under SSP3 and 35,000 under SSP5 by 2050. As such, potential impacts related to river floods might increase.

POPULATION AFFECTED BY RIVER FLOODS

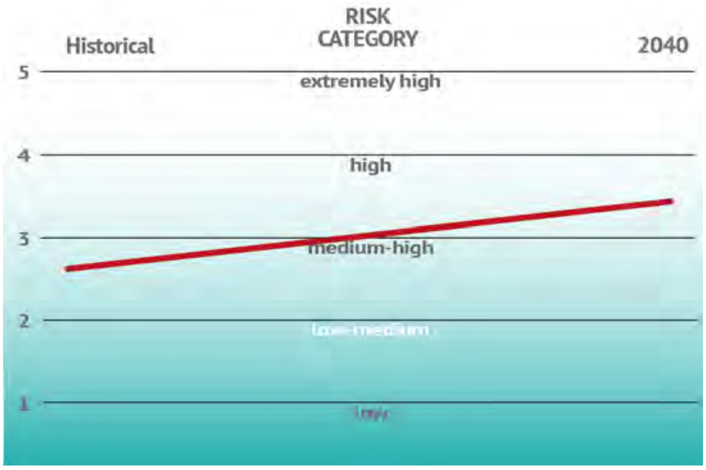


RISK INDICATORS

The water stress index summarises current and future water related vulnerabilities and risks at the global level. Scores are based on the ratio of total water withdrawals, including agriculture, industrial and human consumption, to available renewable surface and groundwater supplies.

WATER STRESS

Australia's water stress level is considered medium-high for the recent past (1960-2014 average), and it is expected to increase in the near future (2030-2050) based on climate change projections.



AUSTRALIA
AGRICULTURE

OVERVIEW

Australia is a major agricultural producer and exporter. In fact, the agricultural sector is still a significant contributor to GDP and employment. Australia is a major agricultural producer and exporter. In fact, the agricultural sector is still a significant contributor to GDP and employment.

Production of cereals, oilseeds and grain legumes, for both human consumption and livestock feed, occurs throughout the more fertile and well-watered areas across New South Wales, Victoria, South Australia, and Western Australia. Sugarcane is also grown throughout tropical areas of Australia such as Queensland, whereas tropical crops and fruits are found right up to the Northern Territory. In the temperate regions of South Australia and New South Wales, there is significant production of fruits (grapes, nuts and citrus) and horticulture. Irrigation in agriculture is extremely important, especially for high value cash crops, adsorbing 64% of total water withdrawal in 2017.

33.5 Mt
Sugarcane

9.3 Mt
Barley

20.9 Mt
Wheat

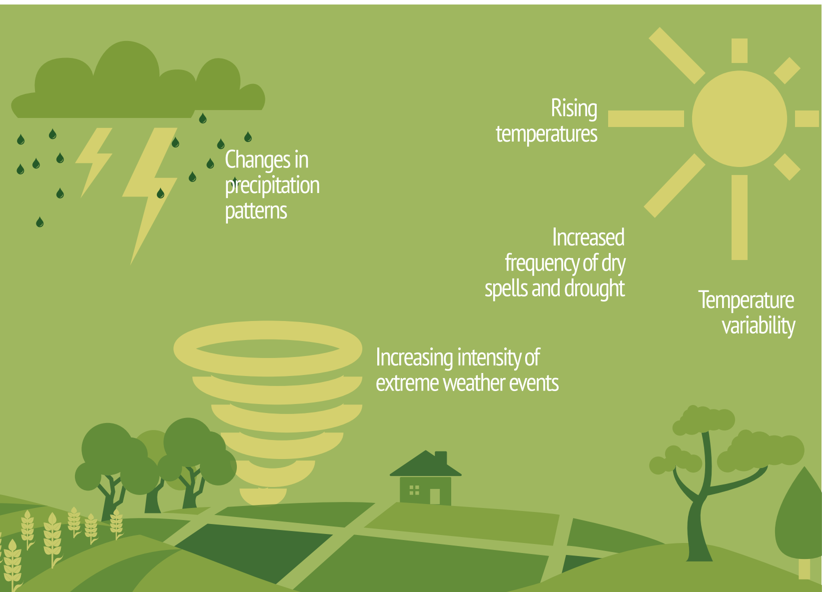
3.9 Mt
Rapeseed

1.7 Mt
Grapes

	Added Value of Agriculture, Forestry and Fishing	Share of Agriculture Value added in Total GDP	Agricultural land	Area Equipped for Irrigation
2000	26,185 USD Million	3.3 %	23,769 Thousand HA	2,384 Thousand HA
2018	30,678 USD Million	2.3 %	31,306 Thousand HA	2,546 Thousand HA

EXPEXTED IMPACTS ON AGRICULTURE PRODUCTIVITY

Rising temperatures, reduction in average annual precipitation, and intensification of extreme events such as heat waves and drought, affect production variability with a tendency towards yield reduction for many cultivated species, accompanied by a probable decrease in food quality. Crops respond to increases in temperatures with changes in duration of the growing season, early appearance of phenological phases and potential shifts of cultivation areas toward higher latitudes and altitudes for better growing conditions. However, impacts vary significantly depending on the geographical area and specific crops in question.



CROP PRODUCTIVITY

Crop productivity refers to the harvested yield of a crop per unit of land area. It is strongly influenced by climate and other environmental and management factors.

Climate change is expected to have an impact on the productivity of several major crops, although this may in part be offset by the fertilizing effect of higher CO_2.

Impacts are estimated using a range of model projections based on low to high emission scenarios and reported as percentage changes between the 30-year average around the historical period and the 30-year average around 2050.

75.2 -6.2 (-6.4)% -8.1 (-8.3)%
Sugarcane
tons / ha

1.8 -0.5 (-5.7)% 4.5 (-3.6)%
Wheat
tons / ha

6.4 -2.6 (-4)% -3.4 (-3.8)%
Maize
tons / ha

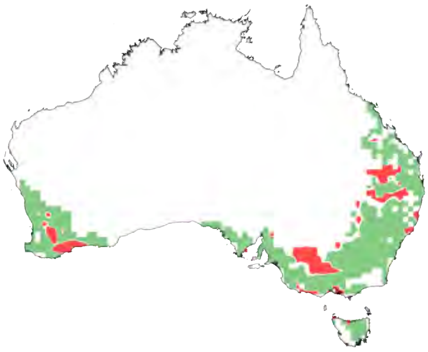
1.2 3.2 (-5.3)% 4.1 (na)%
Rapeseed
tons / ha

2050

Productivity change with (without) the CO_2 fertilization effect. Estimates assume sufficient water and nutrient supplies, and do not include impacts of pests, disease, or extreme events.

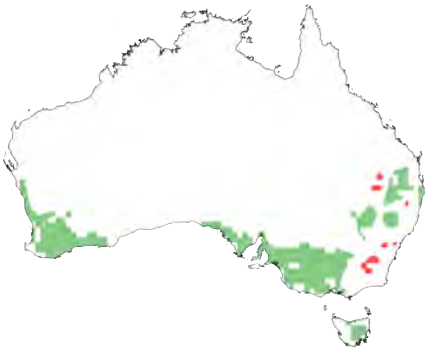
CHANGE IN WHEAT

− = +



CHANGE IN RAPESEED

− = +



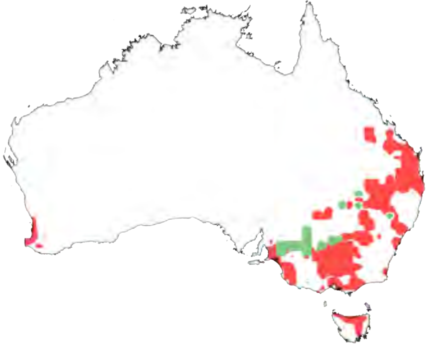
Increasing temperatures and precipitation decline may negatively affect cereal yields, although this may in part be offset by the stimulating effect of higher CO_2. Although projections are characterized by uncertainty in future precipitations, they do reveal an average decrease over the warmer and northern wheat growing areas. Sugarcane, and other C4 crops such as maize, may suffer a strong decline. Sea level rise over coastal areas may also severely effect sugarcane production. Rapeseed cultivation may largely benefit from climate change, with general increases of up to 10% in productivity. Increasing temperatures could severely alter phenology and reduce chill accumulation in the colder periods needed to synchronize flowering and fruiting of tree crops. High temperatures would also have detrimental effects on fruit quality and burn some leafy horticultural crops.

ADAPTATION IN AGRICULTURE AND WATER RESOURCES

Climate change may have some positive effects on some of the most widely used crops. However, higher temperatures will generally require an increase in irrigation due to higher plant evapotranspiration and expansion of irrigated areas. One of the major issues affecting future Australian agriculture could be recurrent droughts and deteriorating water security. Agriculture may become even more reliant on irrigation in the southeast and southwest of Australia, where water resources are already largely overallocated. In contrast, the northern regions are projected to become wetter.

CHANGE IN WATER DEMAND

− = +



Agriculture
Water Demand
% of change

+34.0%
+34.6%

2050

A substantial increase in water demand, from 30 to 35%, to maintain agricultural production, will require adaptation practices and crop varieties that enhance water-use efficiency and limit stress on water resources.

AUSTRALIA FORESTS

FORESTS IN AUSTRALIA

Australian native forests are distributed along the coasts and dominated by eucalypts, playing an important economic, cultural, and environmental role. However the ability of these forests to absorb carbon dioxide and fight global warming is severely undermined by fires. Australia is also home to the third largest mangrove area in the world.

1990

132 Mln ha
Million hectares
Forested area

167 Tons/ha
Tons of Carbon per hectare
Carbon stock

2020

134 Mln ha
Million hectares
Forested area

164 Tons/ha
Tons of Carbon per hectare
Carbon stock

FORESTED AREA AND CARBON STORAGE

Forests cover approximately 17% of Australian lands with a constant trend in recent decades. According to Australian Government plantations, commercial and conservative forests store an estimated 10.5 Gt of carbon (not considering soil). Overall, forests in Australia can be considered as a carbon sink.

FOREST PRODUCTIVITY

Forest productivity or Net Primary Production is the net carbon captured by plants. It is the difference between the carbon gained by Gross Primary Production - net photosynthesis measured at the ecosystem scale - and carbon released by plants' respiration. It is expressed per unit land area.

2050

Productivity anomaly
Tons of Carbon per
hectare per year

+0.14

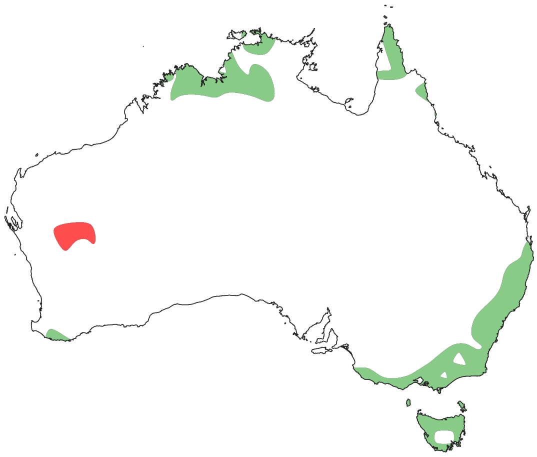
+0.02

Potential increase only in the south east and particularly in Tasmania.

+ Fertilizing effect of increasing atmospheric CO_2, especially for plantations
+ Climate warming is likely to lengthen the growing season

Potential decrease in Western Australia, especially for the native forests of the Mid-West (open woodlands).

+ Extreme heat may limit forest growth in summer



KEY SPECIES UNDER CLIMATE CHANGE

DIEBACKS

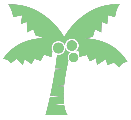
EUCALYPTUS

Large drought-induced diebacks in southwestern Eucalyptus forests

RISK

MEDITERRANEAN WOODLANDS

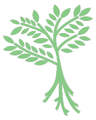
Forests of the Brigalow Belt and the Mediterranean Woodlands are at great risk



VULNERABILITY

SUBTROPICAL FORESTS

Subtropical Moist Forest region shows high vulnerability



VULNERABILITY

MANGROVES

Extreme vulnerability of mangrove ecosystems in the Gulf of Carpentaria and western coast

FIRES IN AUSTRALIA

Fire is a structural ecological process that provides several types of ecosystem services and impacts on socio-ecological systems, including human health, carbon budgets, and climate change. Changes in global fire activity are influenced by multiple factors such as land-cover change, policies, and climatic conditions. Fire also releases large quantities of greenhouse gases into the atmosphere, contributing to a vicious cycle.

During the last two decades the total forest area affected by fire was approximately 144 million hectares.

BURNING
144 MILLION HECTARES OF FOREST

EMITTING
112.5 TERAGRAMMES OF CARBON PER YEAR

SAVANNA FIRE EMISSIONS CONTRIBUTED TO 86.6% OF TOTAL FIRE RELATED CARBON EMISSIONS

COSTING
4.7 BILLION USD IN BUSHFIRE RELATED INJURIES AND FATALITIES BETWEEN 1967 AND 2013

FUTURE BURNED AREA

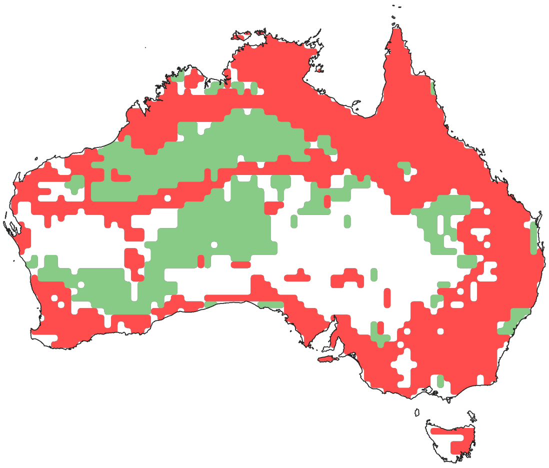
Under a low emissions scenario, Australia might experience a generalized increase in burned area in northern tropical savannas and, to a less extent, in eastern temperate forests. In contrast, northern and southern desert burned area is expected to decrease. Under a medium emissions scenario the distribution of burned area is expected to be similar, except for an increase occurring in northern desert and in mediterranean areas.

Burned Area
km² per year

2050

+12,507

+6,138



Decrease in burned areas for a low emissions scenario

Increase in burned areas for a low emissions scenario

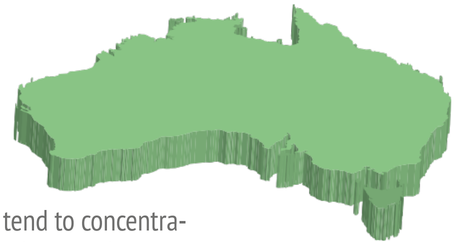
+ Prolonged fire season at the end of the century, particularly in central, northern and western areas.

+ Increasing amount of days with weather conditions considered conducive to fires and number of fires per area.

WHERE DO FIRES OCCUR?

Wildfires in Eucalyptus forests and savannas are the most common, as well as low intensity grass fires in winter and medium intensity shrub fires in spring.

Fire frequency varies by two orders of magnitude among the fire pyroregions. It is highest in the eucalyptus savanna woodlands of the monsoon tropics and lowest in the temperate and tropical rain forests.



Forest fires tend to concentrate in the Northern and Western Australia, North-East Queensland, and South New South Wales and Victoria.

The 2019/2020 fire season registered at least 34 deaths as a direct consequence of bushfires and around 10 million people across three states were exposed to extremely unsafe smoke and ash levels.

VARIATION OF SPECIFIC FIRE INDICATORS

% of change
Average fire danger

2050

+15-40%

+8-15%

days
Average fire season lenght

+20

+10

Billion US$
Losses in timber production

2050

21.1

21.5

FUTURE FIRE EMISSIONS

Under a low emissions scenario, fire emissions are expected to increase in the coastal areas of northern and south-eastern regions, whilst decreasing in central and eastern inland areas. Under a medium emissions scenario, fire emissions are expected to increase over eastern and western inland areas.

Fire Carbon emission
Teragrams of Carbon per year

2050

+10.9

-13.3

AUSTRALIA
URBAN

OVERVIEW

Total population is projected to increase by nearly 30% by 2050, becoming over 90% urbanized.

72% of Australians live in the country's five largest cities with populations ranging between 1 and 5 million people. By 2035, the two largest cities will have over 5 million inhabitants each.

Built up areas cover 0.16% of the country (12,323.78 square kilometers).

Population in Urban Areas

2020
21,903,705

2050
30,186,022

Graphs refer to data provided by United Nations, Department of Economic and Social Affairs, Population Division (2018). World Urbanization

Urbanization Rate

2020
86.2%

2050
91.0%

OVERVIEW OF KEY CLIMATE IMPACTS IN URBAN AREAS

Climate change impacts on cities include heatwaves, extreme rainfall and intense cyclones, harsh fire weather, and severe storm surges associated with sea level rise. Urban built environments, major infrastructure and productivity will increasingly experience the damaging effects of these climate impacts.

HEATWAVES AND HEAT STRESS

Cities are subject to higher temperatures because of the Urban Heat Island (UHI) effect. Built up areas absorb solar radiation during the day and release the heat at night, warming the surrounding air. In Australia, the magnitude of urban overheating is determined by a combination of the UHI effect and dualistic atmospheric circulation systems - cool sea breeze and hot desert winds.

The number of heatwave days is increasing in all capital cities. The length of the longest heatwave is also growing in half of the cities while it remains unchanged in the other half. 5 of the capital cities also observed an increase in heatwave intensity, whereas all experienced an increase in the average intensity of the peak day, ranging from 1°C in Darwin to 4.3°C in Adelaide.

Further, heatwaves have been occuring earlier in all but 1 of the capital cities from 1950-2011. Future scenarios of **+1.5°C**, **+2°C** and **+4°C** mean temperature increase indicate that the frequency and duration of heatwaves will increase for the entire country. This will lead to an increase in the number of cooling degree days.

2050
Cooling Degree Days
% of change
+60.6%
+23.0%
+14.4%

2100
Heatwave frequency
% of change
+63.3%
+24.0%
+11.2%

2050
Heatwave duration
% of time
+3,980%
+320%
+87%

HEAT, HEALTH AND AIR POLLUTION

Heat related health impacts from increasing air temperatures in urban areas are accentuated by air pollution. Wildfire smoke is an important source of PM2.5 and poses risks to human health. Australia is getting warmer, and in many parts drier, thereby providing ideal conditions for wildfires, especially in southern and eastern Australia.

A harsher fire-weather climate is projected for Adelaide, Brisbane, Canberra, Hobart, Melbourne and Sydney, as well as in Perth (in the west). In 2017, nearly 25% of Australians were exposed to levels exceeding WHO guideline values for PM2.5.

2017

Population exposed to air pollution

24.9%

COASTAL FLOODING

Sea level rise will lead to the increased flooding of low-lying coastal areas leading to erosion, loss of beaches, and higher storm surges. As coastlines continue to develop – around 85% of the population live within 50 kilometers of the coast – sea level rise will affect more coastal communities, infrastructure, industry and the environment.

Sea level rise in Australia has been consistent with global increases at an average rate of 2.1 millimetres per year over the past 50 years. Geographical variations show higher observed sea level rise in the north and rates similar to the global average observed in the south and east.

Projected sea level rise

2050

🟥 0.23 m

🟩 0.18 m

2100

🟥 0.77 m

🟩 0.38 m

EXTREME PRECIPITATION EVENTS

Northern Australia is becomming wetter across all seasons. The intensity of short-duration extreme rainfall events has increased by 10% or more in some regions, with larger increases in the north. Conversely, southwest and southeast Australia have experienced drier conditions.

Many regions of the south and east are projected to experience a decrease in cool season rainfall, likely increasing the time spent in drought. However, heavy rainfall is expected to become more intense throughout Australia. Fewer tropical cyclones are projected, but more of those that do occur are projected to be of high intensity, with large yearly variations.

2050

Runoff increase
% of area

🟥 +7%

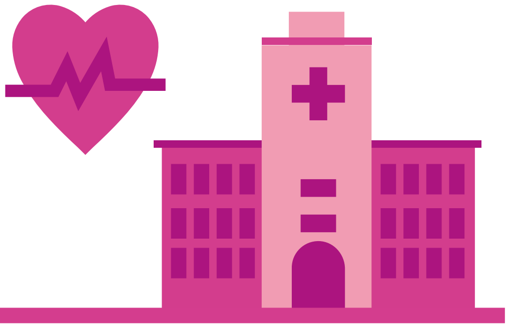
🟩 +3%

🟩 +2%

SURFACE SEALING AND FLOODS

Heavy precipitation in cities is problematic due to the high level of sealed surfaces. Soil sealing increases run off and reduces the amount of water absorbed by soil. Where there are large amounts of impervious ground cover, short duration extreme rainfall events can lead to increased flooding, even resulting in flash floods.

AUSTRALIA
HEALTH



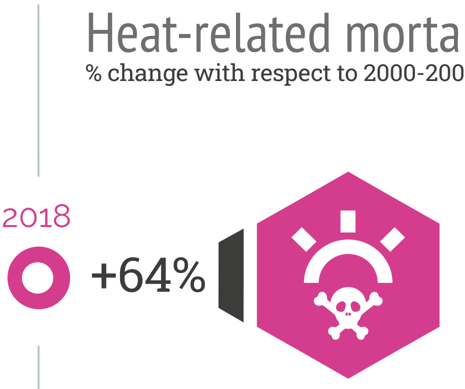
OVERVIEW

Australia is highly vulnerable to climate change due to its unique geoclimatic features. Australia is the driest inhabited continent on earth and has the greatest variability of rainfall of any country. More than 5,332 people died between 1844 and 2010 due to heat exposure, Australia's greatest current climate-related health burden. Winter cold-related deaths arise predominantly through respiratory diseases, often with contributing socio-economic determinants, rather than direct exposure. Further escalation of Australia's hot and erratic climate will lead to more extreme climate-related disasters including heatwaves, droughts, fires, and storms, as well as shifts in disease burdens.

HEAT RELATED MORTALITY

Continuous warming, as well as increased frequency and intensity of bush fires is already harming the health and well-being of Australians and will only get worse. As heatwaves increase in both frequency and intensity, the health impacts among Australians are increasing significantly. These impacts include long-term health, cardiovascular and respiratory diseases.

Estimates show that heatwave-related excess deaths in Australia will increase by 471% under a high emissions scenario by 2080. In 2018, there was a 64% increase in heat-related deaths in Australia from a 2000 to 2004 baseline. 35.7% of Australia's heat-related mortality during 1991 to 2015 can be attributed to human-induced climate change.



Heat-related mortality

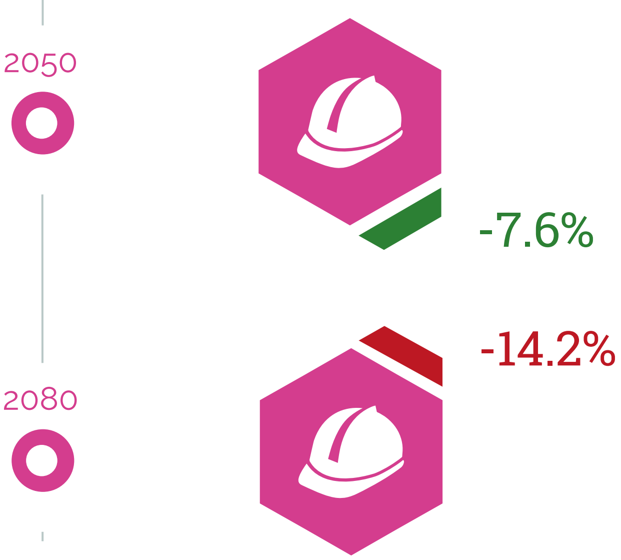
% change with respect to 2000-2004

IMPACTS ON LABOUR

Labour is directly affected by changes in environmental conditions. Warming affects both the number of hours worked (labour supply) and on the productivity of workers during their working hours (labour productivity). Both labour supply and productivity are projected to decrease under future climate change in most parts of the world, and particularly in tropical regions.

Parts of sub-Saharan Africa, south Asia, and southeast Asia are at highest risk under future warming scenarios. Future climate change will reduce global total labour in the low-exposure sectors by 18 percentage points and by24.8 percentage points in the high-exposure sectors under a 3.0°C warming scenario

The changing climate, especially temperature increases, is putting the livelihoods of Australians at risk. For example, in the agriculture and construction sectors, there was a 46.3% decline in potential hours of labour lost in 2019 compared to a 1990-94 baseline. Total labour in Australia is expected to decline by 7.6% under a low emissions scenario, and by 14.2% under a medium emissions scenario.



Impact on total labour

% change with respect to 1986-2005 baseline

CLIMATE CHANGE AND DENGUE

Dengue has spread throughout the tropical world over the past 60 years and now affects over half the world's population. Globally, vectorial capacity for both dengue vectors (A. aegypti and A. albopictus) has been rising steadily since the 1980s, with nine of the ten highest years occurring since 2000.

Climatic stressors are one important driver of the current distribution and incidence of dengue. Climate change is likely to expand the geographical distribution and suitability of several vector-borne human infectious diseases including dengue. The risk of dengue transmission is increased by warming climates, as the growth and development of mosquitoes are significantly influenced by temperature, precipitation, and humidity.

Dengue suitability

% of population at risk

CLIMATE CHANGE AND ZIKA

Zika virus has spread to at least 49 countries and territories since 2013. Climate change impacts on transmission suitability risk have increased over the years and future warming over 1.3 billion additional people could face suitable transmission temperatures for Zika by 2050.

Zika suitability

% of population at risk

DENGUE AND ZIKA: POPULATION AT RISK

Changes to the distribution and abundance of mosquitoes have resulted in more Australians contracting dengue fever in areas where they were not previously at risk.

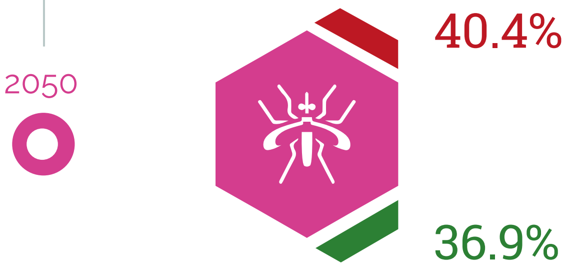
Under a medium emissions scenario, 83.3% of the population will be at risk of transmission-suitable mean temperature for dengue by 2050, whereas 85.9% will be at risk under a high emissions scenario. In the case of Zika, 47.2% of the population will be at risk of transmission-suitable mean temperature for Zika under a medium emissions scenario by 2050, whereas 56% will be at risk under the high emissions scenario.

CLIMATE CHANGE AND MALARIA

Although Malaria transmission has largely been eradicated in Australia since the 1980s, climate change will likely expand the potential range of the major vectors. Since 1950, there has been a 14% increase in the capacity of mosquitos to transmit disease to humans. The risk of malaria is projected to increase in the future. 36.9% of the Australian population will be at risk of malaria under a low emissions scenario in 2050, whereas 40.4% will be at risk under a high emissions scenario.

Malaria suitability

% of population at risk



POLLUTION AND PREMATURE MORTALITY

Australia's air pollution is exacerbated by bushfires, which are projected to increase in frequency and coverage. Pollution from bushfires caused an estimated 2,000 people to be admitted to hospitals with respiratory problems and about 1,300 people to emergency departments with asthma-related conditions.

AUSTRALIA
ENERGY

ENERGY SYSTEM IN A NUTSHELL

Australia is among the top exporters of coal and natural gas. Total energy production is three times (320%) total primary energy supply. However a major transformation of the energy system towards low carbon technologies is under way. The energy intensity of the economy is slightly below world average while carbon intensity of energy production is declining, but remains very high.

0.11
ktoe/US$
Energy intensity

6.8%
AC Share in
electricity consumption

CLIMATE CHANGE TODAY

ENERGY SECURITY

Energy security is threatened by the impacts of climate change. Extremely high temperatures, bushfires and storms all place stress on power stations and energy infrastructure whilst also increasing energy demand as air conditioning use increases.

STORMS

Extreme storms, tornadoes and heat waves have already damaged transmission towers and caused widespread power outages.

HEAT

In 2016, severe weather damaged transmission infrastructure causing a statewide blackout in South Australia; disruptions lasted for up to 2 weeks. The bushfires of 2019-2020 destroyed power lines and poles, transmission lines and cross state interconnectors. Along the east coast tens of thousands of homes lost power. Rural and isolated areas with no backup sources were particularly affected.

ENERGY SUPPLY

Australia is highly dependent on fossil fuels. In 2019, oil accounted for almost 33% of total primary energy supply, followed by coal (31%) and natural gas (29%). In comparison, renewable energy sources accounted for 7%. Coal is a key resource, but mostly exported. Despite being a net exporter of energy, Australia relies on imports for the majority of oil products.

ENERGY DEMAND

Energy is used for transport (41% in 2018, mainly on road), followed by industry (27%), residential (13%), and the tertiary sector (10%). Agriculture and forestry demand is very low. The transport sector is highly reliant on oil products, with very small shares of gas, biofuels, and electricity. Overall energy consumption has increased slightly, while energy demand for transport has increased significantly: by 60% in the last 30 years. Air conditioning accounts for 6.8% of final residential electricity consumption.

FUTURE ENERGY DEMAND

Energy demand is expected to increase due to changing demographics and increasing temperatures. Peak and average demands are influenced by climate. Higher levels of air-conditioner use will increase peak energy demands, exacerbating the risks of power outages.
Overall, total energy demand is projected to increase as increases in summer cooling needs outweigh any decreases in winter heating needs, resulting in an increase in electricity demand of 249 PJ (or 69 million KWh) by 2050 under a medium emissions scenario.

Net change in energy demand due to changes in HDD/CDD
Billion KWh

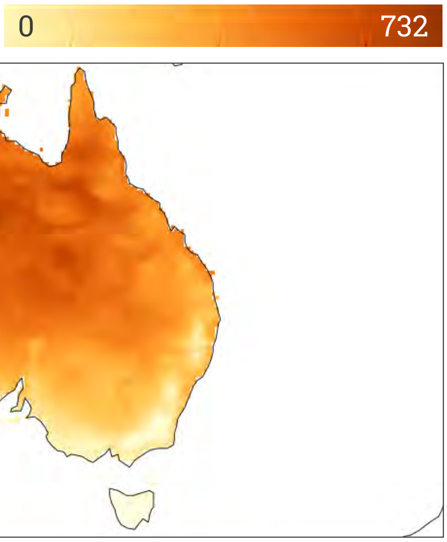
2050

+ 69.13

COOLING NEEDS

Major increases in cooling needs in the cities of central-north states and territories (such as Cairns). Southern coastal cities will face more moderate increases in cooling needs. Under a high emissions scenario, Brisbane and Adelaide will experience the largest increases in energy demand where the increase in summer cooling needs will outweigh the decreases in winter heating needs. In Sydney and Melbourne, average demand will only increase slightly, as their consumption is less sensitive to increasing temperature.

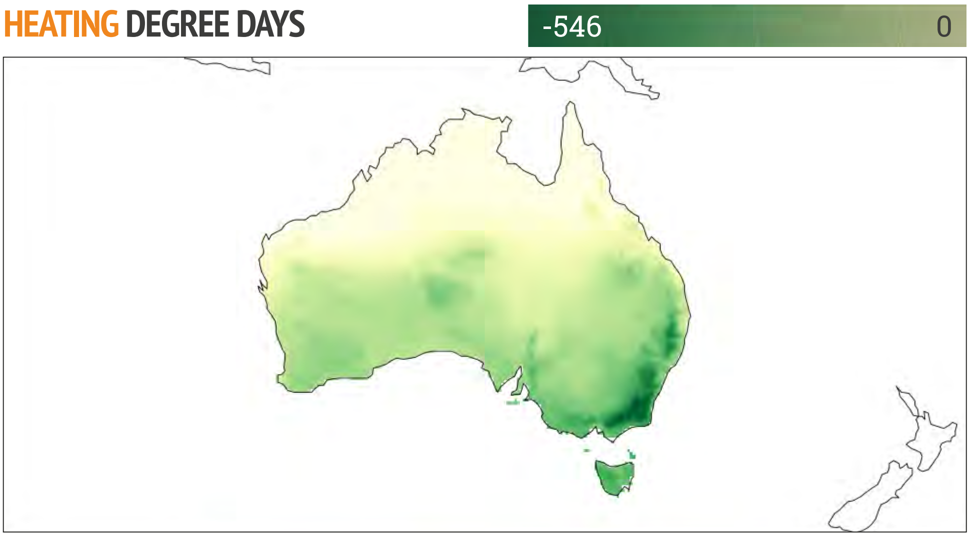
COOLING DEGREE DAYS



HEATING NEEDS

Winter demand is expected to be higher in southern states. Negligible changes are expected in the northern states and territories; some moderate heating degree day decreases in the central elevations, which are however hardly inhabited. Significant decreases in heating needs along the Great Dividing Range and the densely populated coastal areas of Victoria and South Wales, with the major metropolitan areas of Sydney and Melbourne, and in the Australian capital territory with Camberra.

HEATING DEGREE DAYS



FUTURE ENERGY SUPPLY

The future Australian energy mix is likely to be determined by the evolution of energy policies and hence is outside the scope of this report. Australia has not yet set any targets to achieve net zero emissions, but policies do encourage renewable energy growth, particularly for electricity generation. Rising energy security concerns (due to the large share of ageing fossil fuel power stations in the system) were behind new investments in power generation capacity, focused on natural gas as a transition fuel. This is likely to result in a marginal decrease in the relevance and associated vulnerabilities of fossil fuels over the next decade, while carbon-free sources and their vulnerabilities will become slightly more relevant.

Change in Hydropower generation
% of change

2050

-4%

-1.97%

EXPECTED IMPACTS OF CLIMATE CHANGE

As Australia's temperatures rise and the climate becomes drier, there will be increased risks to power stations and energy infrastructure. The risks of bushfires, heat waves and increased peak demands, is expected to increase the risks of energy system failures such as black outs and the risks of damaged infrastructure. A modest reduction in hydropower generation potential is expected.

AUSTRALIA ECONOMY

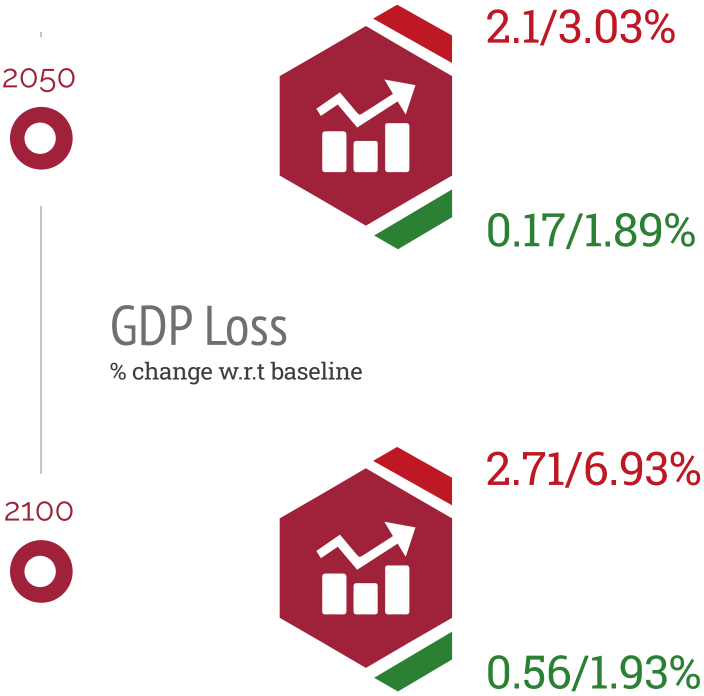
OVERVIEW

Australia ranks 14th in terms of GDP in the G20 group. The COVID 19 crisis affected the economy with a 2.4% real GDP decline in 2020. This trend has reversed in 2021 with a 4.5% growth in real GDP.

IMPACTS ON GDP

The available estimates for economic impact of climate change on the whole Australian economy vary according to the scenarios considered, the time horizon, the direct impacts covered, and the specificities of the estimation method used.

The projected overall macroeconomic impacts range from 0.17% under a low emissions scenario by 2050 to 6.93% under a high emissions scenario by 2100.



2050

2.1/3.03%

0.17/1.89%

GDP Loss

% change w.r.t baseline

2100

2.71/6.93%

0.56/1.93%

SECTORAL ECONOMIC IMPACTS

IMPACTS ON INDUSTRY AND INFRASTRUCTURE

Sea level rise and coastal floods, hurricanes, and forest fires are the major sources of damage to Australian infrastructure. More than half (52%) of Australian coastline is prone to recession under sea level rise.

Rebuilding critical infrastructure after natural disasters between 2015 and 2050 will require 17 billion AUD.

It is also estimated that infrastructure worth over 226 billion AUD in “commercial, industrial, road and rail, and residential assets are exposed to flooding and erosion hazards at a sea-level rise of 1.1metre” a level consistent with a high emissions scenario for 2100.

The increased exposure to extreme events is likely to raise insurance costs for housing and reduce property values. For Australia, this is estimated to result in losses of 571 billion AUD by 2030, 611 billion AUD by 2050 and 770 billion AUD by 2100.

IMPACTS ON AGRICULTURE

Australia is vulnerable to severe droughts, heatwaves, extensive forest fires, hurricanes and floods, which have severely impacted natural areas, agricultural land, agricultural yields and food production. These phenomena are expected to intensify this century.

Major expected effects on crops relate to variations in the land suitable for the production of wheat, rice and grapes. Suitable areas are expected to shift southward and shrink.

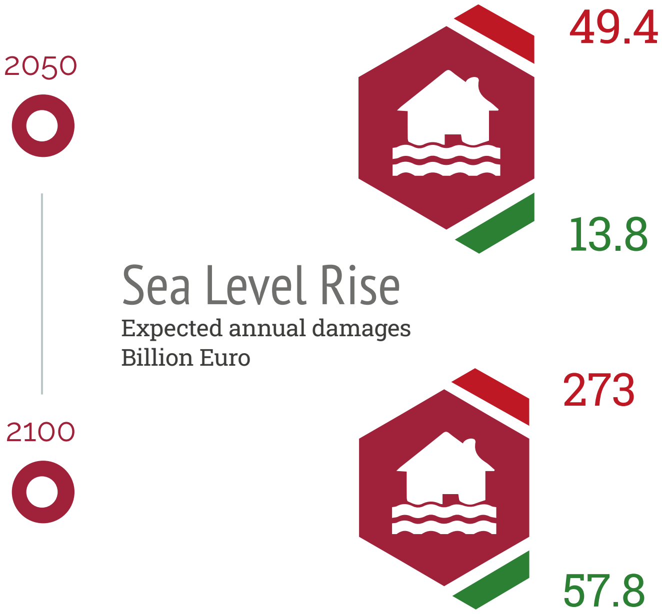
Contractions in the land suitable for cattle grazing is also expected, together with a reduced ability of cattle to withstand increasing temperatures and heatwaves.

Regional projections envisage a loss for the agricultural sector in the state of Victoria of up to 300 million AUD (189 million EUR) by 2050, under “very extreme” heatwave scenarios.

SEA LEVEL RISE DAMAGES

Damage from coastal flooding is projected to be particularly severe. By mid century, expected annual damage to assets from coastal flooding is projected to be 13.8 billion EUR under a low emissions scenario and 49.4 billion EUR under a high emissions scenario.

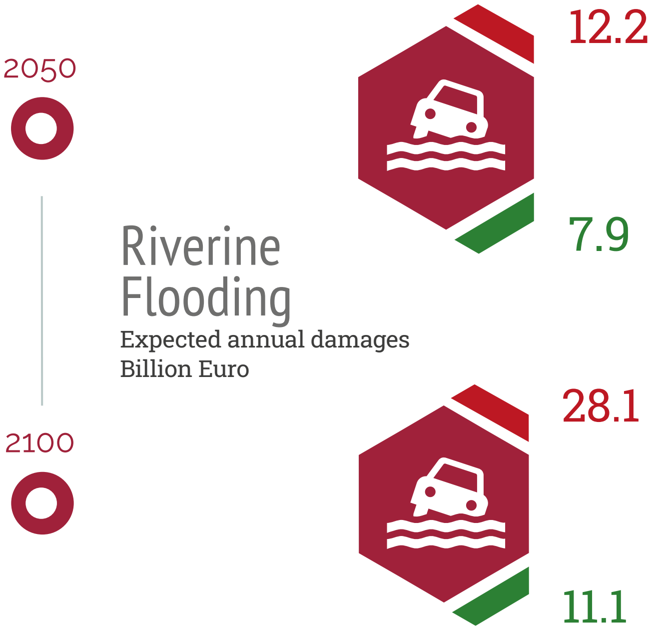
By the end of the century, projected damage related losses may increase to 57.8 billion EUR under a low emissions scenario and 273 billion EUR under a high emissions scenario.



RIVER FLOODING DAMAGES

River flooding is also expected to cause annual damages ranging from 7.9 billion to 12.2 billion EUR by mid century under a low emissions scenario and a high emissions scenario, respectively.

By the end of the century these costs rise to 11.1 billion EUR under a low emissions scenario and 28.1 billion EUR under a high emissions scenario.



IMPACTS ON TOURISM

Tourism is a very important economic sector in Australia. Previously to the COVID 19 crisis, it was the second most valuable export earner (43.3 billion AUD in 2016, just behind iron ore exports with 47.7 billion AUD; these are 27.3 and 30 billion EUR, respectivley) and an important source of jobs (4.9% of the Australian workforce in 2015).

The high vulnerability of this sector stems from its dependence from nature-based destinations, such as the five major attractions identified by international visitors (beaches, wildlife, the Great Barrier Reef, unspoilt wilderness, forests and national parks).

Beach erosion and sea level rise, poisonous jellyfish blooming, coral bleaching, risks of an increase in tropical mosquito-borne diseases, wildfires, storms and floods threaten these attractions.

IMPACTS ON ENERGY

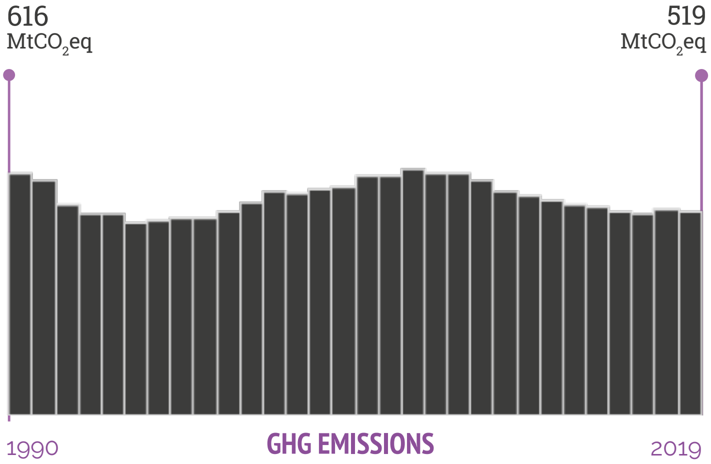
As with all other economic sectors, energy supply and energy networks in Australia will undergo more intense stress from extreme weather events.

Economic impacts of shifts in household and firm energy demand (see chapter on energy) are difficult to predict and will mostly lead to redistribution effects. In the case of Australia, the magnitude of the increase in demand for cooling is expected to far exceed the one of decrease in heating demand, leading to a significant increase in energy bills.

AUSTRALIA
POLICY

OVERVIEW

Australia is the world's 6th largest country, with a population density of 3.2 people per square kilometre. It accounts for 1.3% of global emissions and in 2018 registered one of the highest rates of GHG emissions per capita.



INTERNATIONAL COMMITMENTS

In its 2020 NDC update, Australia reiterated its previous target to reduce greenhouse gas emissions by 26 to 28% below 2005 levels by 2030.

CLIMATE POLICY COMMITMENTS CHRONOLOGY

2007

KYOTO PROTOCOL - 1ST PERIOD

8% of average GHG increase over the four year period 2008-2012

2016

PARIS AGREEMENT - 1ST NDC

Between 26% and 28% of GHG reduction at 2030, with respect to 2005 level

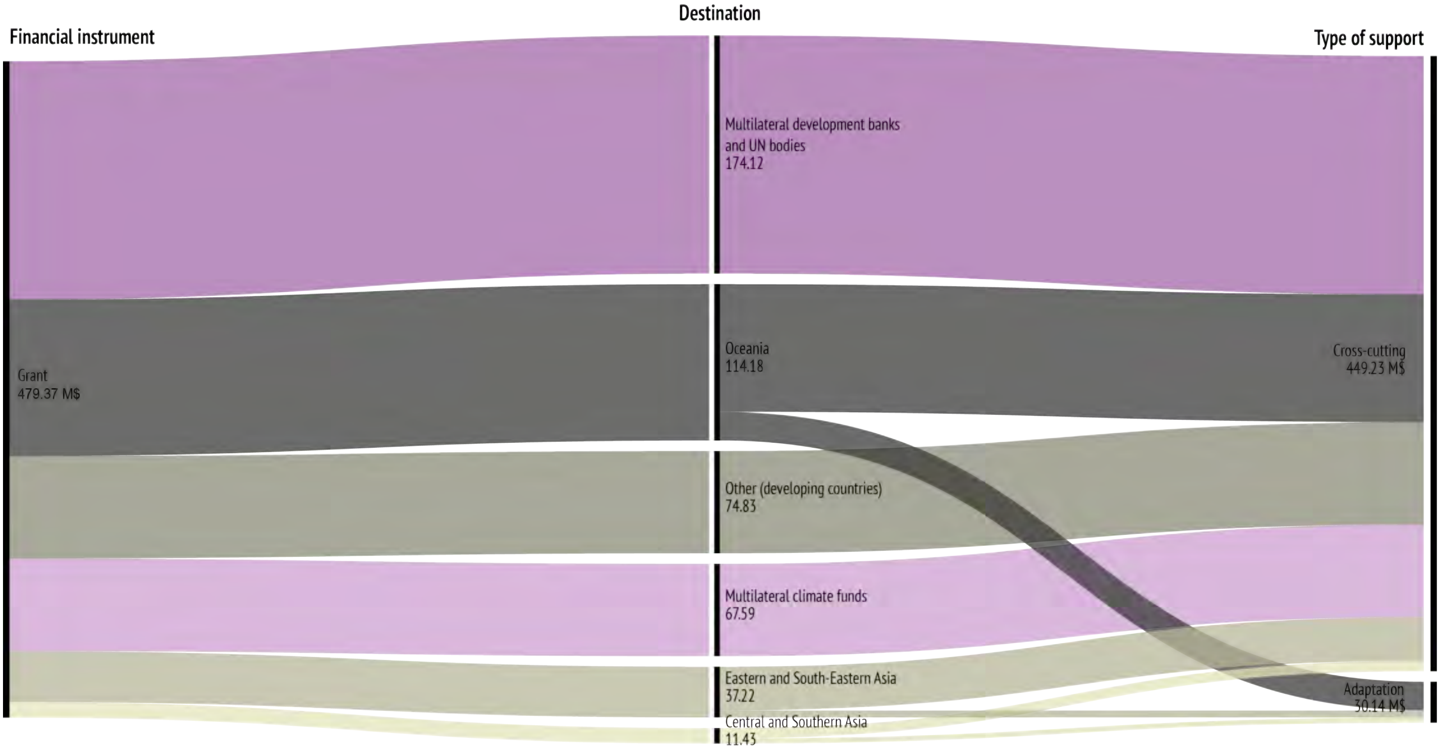
2020

PARIS AGREEMENT - NDC UPDATE

Submitted. Commitments unchanged

INTERNATIONAL CLIMATE FINANCE ASSISTANCE

The 4th Biennial Report data shows that in 2017 and 2018 Australia provided 479.33 million USD to climate action in the form of grants mainly targeting multilateral institutions and Oceanian countries for cross-cutting and adaptation projects.



SUSTAINABLE RECOVERY POLICY

According to the Global Recovery Observatory, in 2020 the proportion of green spending to total recovery spending was 2%.

328.51 billion $	128.92 billion $	2.51 billion $
Total Spending	Recovery Spending	Green Spending

DOMESTIC ADAPTATION POLICY

On 2 December 2015, the Australian Government released a National Climate Resilience and Adaptation Strategy. The department of Agriculture, Water and the Environment announced that it will release a new National Climate Resilience and Adaptation Strategy in late 2021, which will focus on climate adaptation and resilience only.

- ○ Domestic Adaptation Policy
  - ○ Inclusion of Adaptation in NDCs
  - ○ Integrated Adaptation & Mitigation Policy
  - ● Dedicated Adaptation Strategy
  - ○ Dedicated Adaptation Plan
- ● Subordinate Adaptation Policies
  - ● Sectoral Adaptation Plans
  - ● Subnational Adaptation Plans

○ Policy not in place ● Active policy

ADAPTATION POLICY HIGHLIGHTS

TRANSNATIONAL INITIATIVES

Reef Joint Field Management Program

The Program plans and delivers field operations within the Great Barrier Reef World Heritage Area (WHA). This includes Commonwealth and State marine parks and island national parks

Climate and Oceans Support Program in the Pacific

The project aims to help fourteen Pacific national meteorological services make seasonal forecasts and use climate science to make information accessible to their governments and communities and support planning in agriculture, water security and health

NATIONAL INITIATIVES

Electricity Sector Climate Information (ESCI) project

Specific information and data are delivered to the electricity sector to manage risks from extreme weather events and increase the reliability and resilience of electricity systems

CoastAdapt

The National Climate Change Adaptation Research Facility developed an online tool to support local governments and businesses to identify, assess and respond to climate risks in the coastal zone

SUBNATIONAL INITIATIVES

Melbourne Climate Change Adaptation Strategy and Action Plan

The plan addresses the main risks of extreme weather events (heat waves and flash flooding) with the aim to reduce their impacts on the City's current and evolving conditions

Climate Futures for Tasmania

The project delivers locally specific climate information that reflects the highly variable topography of Tasmania and many strong regional variations at a finer scale resolution

ENERGY TRANSITION

The overall Energy Transition indicator for Australia is a little below the G20 average. In particular, this position is driven by a low performance in Renewables (almost 8 points below the average value) due to a low ratio with respect to both energy and electric mix. Also, the Emissions and Fossil Fuels indicators contribute negatively due to a more traditional type of energy mix.

Nevertheless, this situation does not consider recent significant developments and new policy measures implemented by Australia in renewables. On the other hand, Australia has a good performance in infrastructural efficiency and a good electrification of consumption.

Energy Transition	58.7	56.3
Fossil Fuels	45.3	38.2
Renewables	19.7	13.0
Efficiency	84.9	89.9
Electrification	70.8	72.0
Emissions	72.9	68.4

G20 AVERAGE
COUNTRY

Only actively pursuing an energy transition based on decarbonization and electrification – from policy and regulation, to health and education – will enable countries to benefit the most from future opportunities and fight climate change whilst ensuring an equitable distribution of wealth.

The Energy Transition indicators were developed by Enel Foundation in cooperation with SACE, and provide a retrospective analysis based on historical data.

G20 CLIMATE RISK ATLAS

Impacts, policy, economics

BRAZIL

How to read the Atlas: graphs, colours and scenarios.

The maps used in this Atlas are taken from **The World Bank Official Boundaries** - ***https://datacatalog.worldbank.org/search/dataset/0038272*** (accessed on May 28, 2021). For the section Energy, the maps are based on Panoply Data Viewer ***https://www.giss.nasa.gov/tools/panoply/credits.html***

Each sector of this Atlas contains data and information on various climate scenarios.

When reported in graphs, the **colour black** indicates data and information referring to the current state, the past or the baseline.

When the authors refer to **RCP (Representative Concentration Pathways)**, the 3 colours used across the factsheet refer to 3 scenarios, which are 3 different development options with different levels of greenhouse gas emissions, **respectively low emissions (green), medium emissions (orange), and high emissions (red)**. The same colour code is used when RCPs are associated with Shared Socioeconomic Pathways (SSP).

In some cases, the authors refer to global warming scenarios. In these cases, the 3 colours used refer to a temperature rise of **1.5°C (green), 2°C (dark green), and 4°C (red)**.

When the authors refer exclusively to **Shared Socioeconomic Pathways - SSPs** (Population affected by river floods in the section: "Water"), data related to **SSP3** - that encompasses, among other things, slow economic growth, material-intensive consumption, and persisting or worsening inequalities – **are reported in a lighter shade**; **SSP5** – which refers to social and economic development that is coupled with an energy-intensive lifestyle and the abundant exploitation of fossil fuel resources – is shown using a **middle shade of the colour**, whereas data related to **the present** conditions **are represented in a dark shade**.

Further details on scenarios, methodologies, and the full list of references are available at: **www.g20climaterisks.org**

Concept and graphic design by element6.eu

BRAZIL
CLIMATE

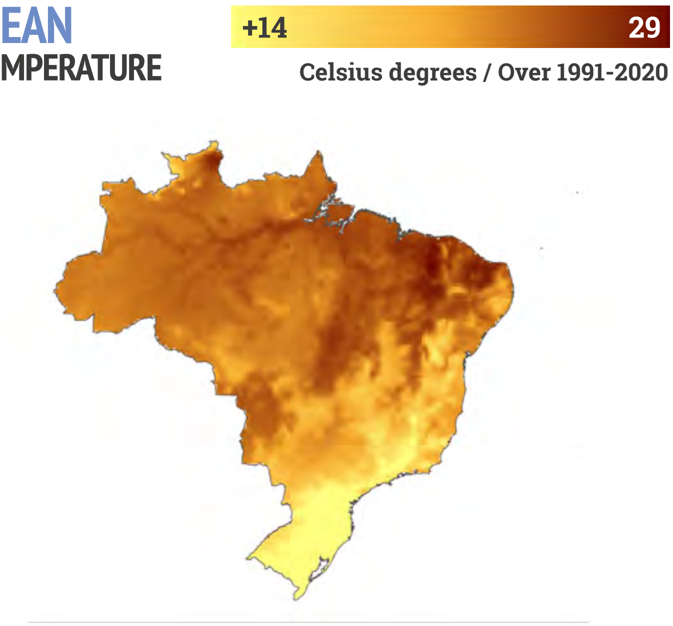
OVERVIEW

Although it extends into the temperate zone, Brazil is a tropical country due to its geographical configuration, coastal length, geomorphology, and territorial air-mass dynamics. The Amazon Basin has a typically hot and tropical climate due to the equatorial air masses; the Brazilian Highlands are subtropical; and the narrow coastal lowland area varies from a tropical climate in the north to temperate in the south. The upland plains of the south also have a temperate climate.

TEMPERATURE

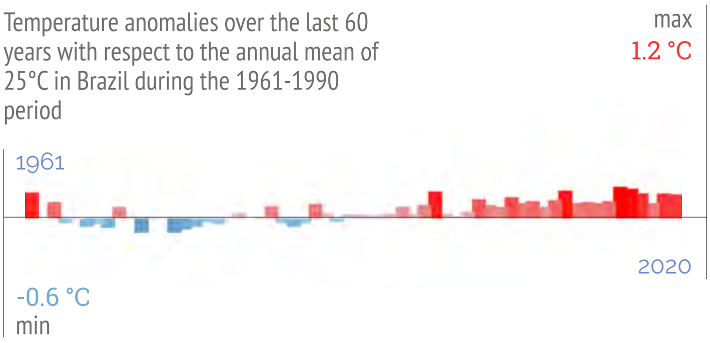
Brazil usually experiences average temperatures around 25°C. The northeast is the hottest part, with temperatures over 35°C often recorded during the dry season. Conversely, temperatures decrease in the mountain areas and southern regions.

MEAN TEMPERATURE



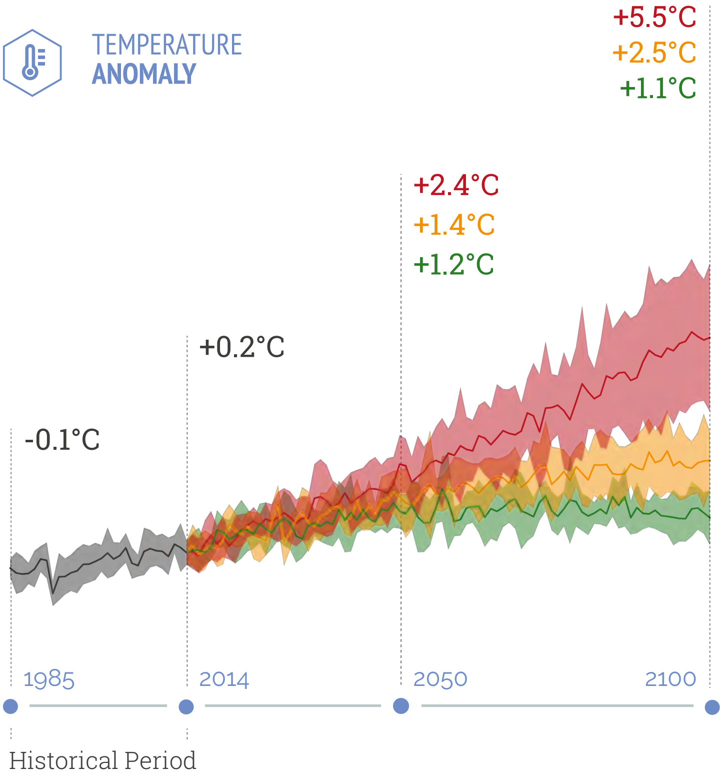
TEMPERATURE TREND

Temperature anomalies over the last 60 years with respect to the annual mean of 25°C in Brazil during the 1961-1990 period



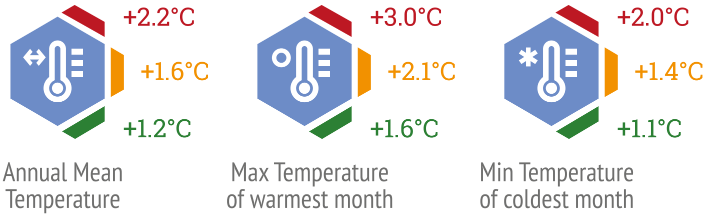
TEMPERATURE PROJECTIONS

Under a low emissions scenario projected temperature variations will remain contained at around +1.1°C, both by 2050 and 2100.
Under a high emissions scenario, with no reduction in GHG emissions, much greater temperature anomalies are expected by both 2050 and 2100.



EXPECTED VARIATION FOR TEMPERATURE AT 2050

The indicators show variations in selected temperature characteristics for a thirty-year period centred on 2050 (2036-2065) with respect to the reference period 1985-2014.



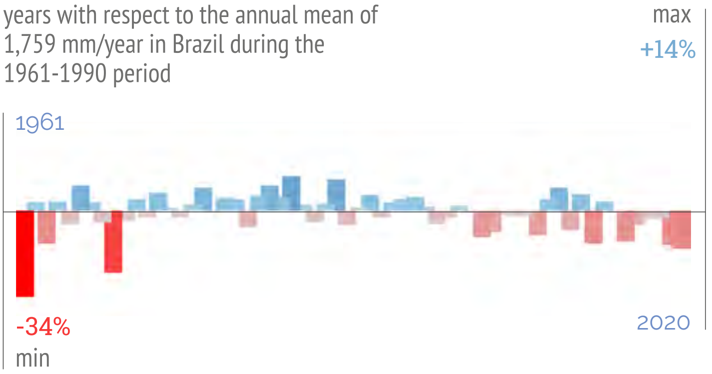
PRECIPITATION

Precipitation patterns over Brazil vary widely, from very humid to arid areas. Most of the country has moderate rainfall falling especially in the summer (between December and April) whereas the Amazon region is notoriously humid, with high annual precipitation. The northeast is the driest part of the country.
During the last decade, annual precipitation anomalies report a significant decrease in precipitation compared to the 1961-1990 period.

MEAN PRECIPITATION

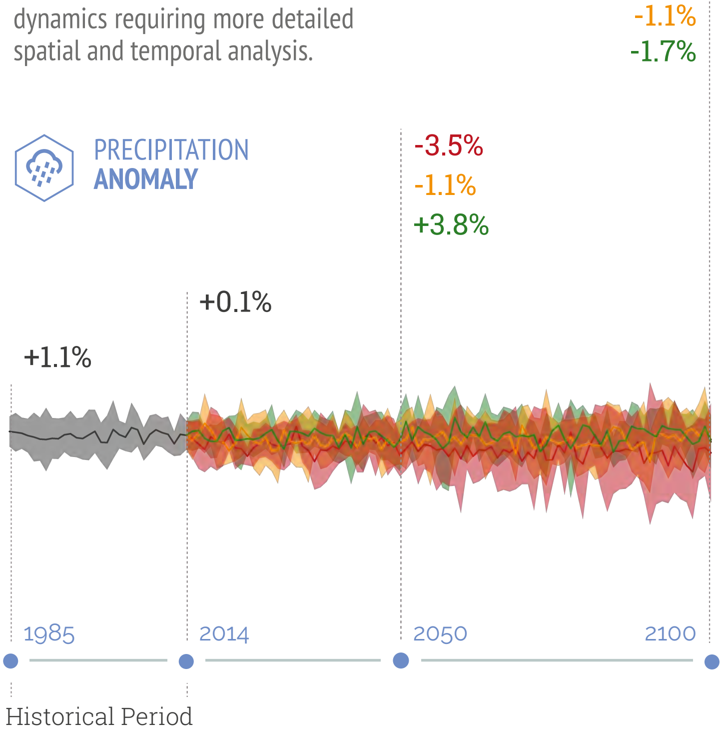
PRECIPITATION TREND

Precipiation anomalies over the last 60 years with respect to the annual mean of 1,759 mm/year in Brazil during the 1961-1990 period



PRECIPITATION PROJECTIONS

Precipitation trends show a clear tendency to reduction under a high emissions scenario with a large variability among the climate models. This is due to the complexity of the precipitation regime and dynamics requiring more detailed spatial and temporal analysis.



EXPECTED VARIATION FOR PRECIPITATION AT 2050

The indicators show variations in selected precipitation characteristics for a thirty-year period centred on 2050 (2036-2065) with respect to the reference period 1985-2014.

Annual total precipitation	-3.2%	-1.1%	-0.0%
Precipitation of wettest month	+2.4%	+2.7%	+2.8%
Precipitation of warmest quarter	-14.5%	-9.3%	-6.5%

VARIATION OF SPECIFIC CLIMATE INDICATORS

Climate indicators variation showing impacts of climate change on sectors such as agriculture, health and water. Analysis considers 3 threshold average temperature increase: **+1.5°C**, **+2°C**, **+4°C**.

Agricultural drought proportion of time	% of time	+27%	+16%	+13%
Hydrological drought proportion of time	% of time	+44%	+24%	+17%
Heatwave duration	% of time	+7,644%	+1,400%	+522%
Runoff increase	% of area	+67%	+50%	+40%
Agricultural drought frequency	% of change	+61%	+34%	+23%
Hydrological drought frequency	% of change	+14%	+14%	+13%
Heatwave frequency	% of change	+99%	+75%	+47%
Runoff decrease	% of area	+8%	+2%	+1%

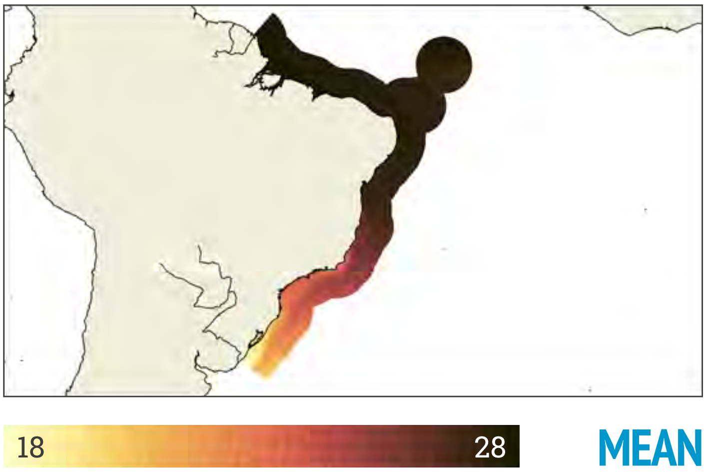
BRAZIL
OCEAN

OCEAN IN BRAZIL

Brazil's marine exclusive economic zone (EEZ) is characterized by temperate to tropical coastal waters, which host a large variety of ecosystems such as mangroves, seagrass meadows, and coral reefs. The Atlantic coastal systems can be divided in two parts, namely the northern and southern marine regions.

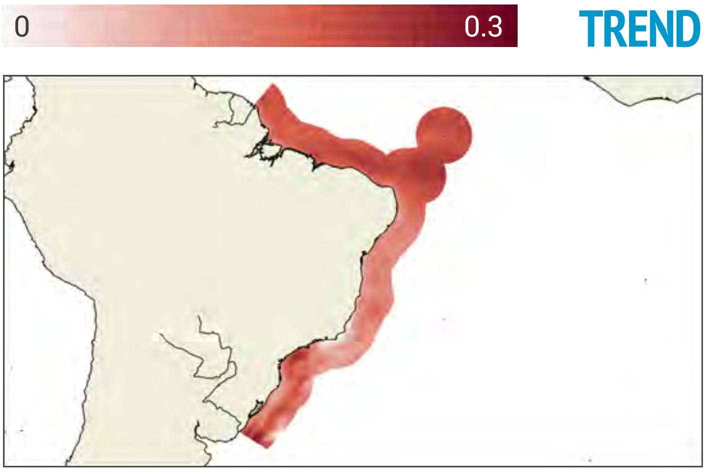
CURRENT CLIMATE CONDITIONS

Mean sea surface temperature reflects the different climate regimes, from the relatively cold waters along southern coasts to the warmer ones on the northern coasts.



SEA SURFACE TEMPERATURE

Celsius degrees / Over 1991-2020

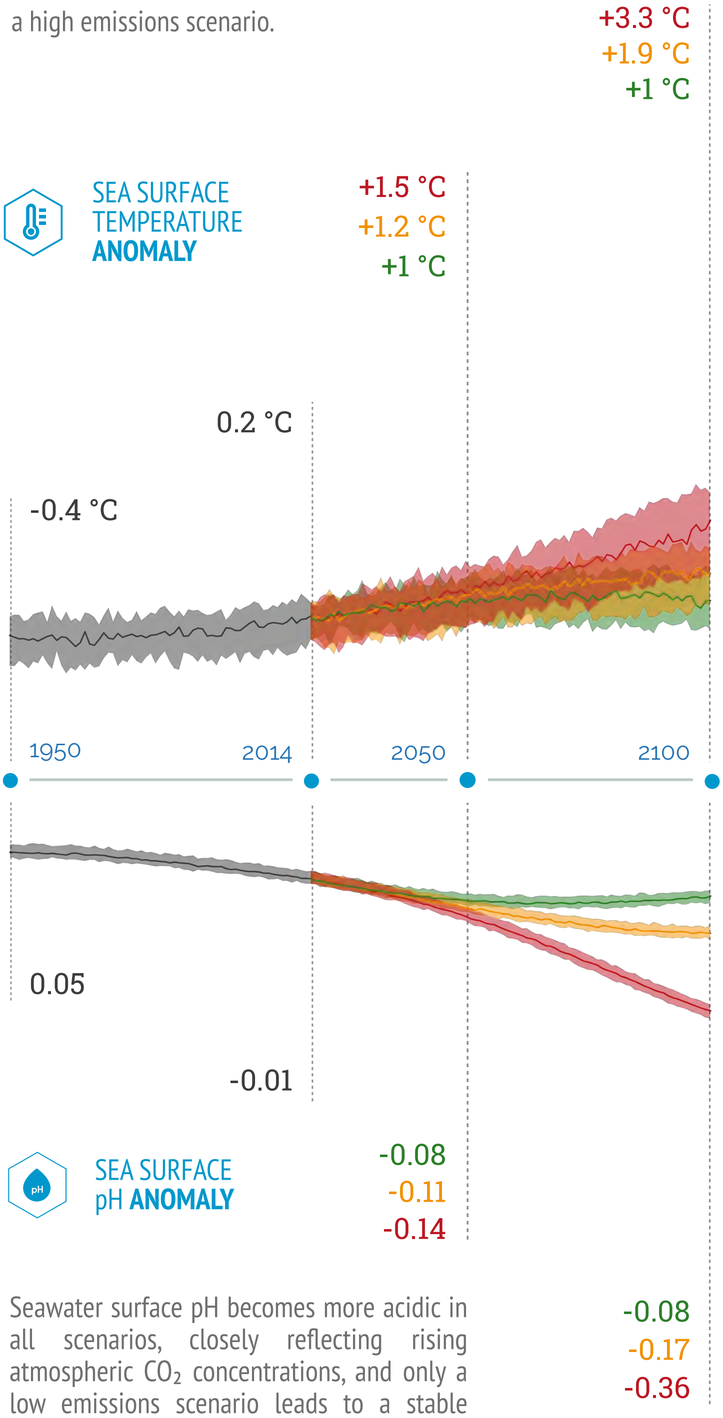


Surface temperature trends indicate a general warming of 0.2°C per decade in all marine areas.

FUTURE PROJECTIONS

Projected annual changes within the marine EEZ for the two most significant marine indicators of climate change: sea surface water temperatures and pH.

Seawater temperature changes are in line with the definitions of each scenario, with maximum values in 2100 close to +4°C under a high emissions scenario.



Seawater surface pH becomes more acidic in all scenarios, closely reflecting rising atmospheric CO_2 concentrations, and only a low emissions scenario leads to a stable condition by 2100.

ECOSYSTEM INDICATORS AT 2050

Regional changes in key marine ecosystem indicators under projected future scenarios by mid-century (2036-2065) with respect to present climate conditions (1985-2014).

Temperature regulates the metabolism of marine organisms determining which habitats remain suitable. Excessive warming will likely push ecosystems beyond tolerance thresholds.

pH represents the acid/base status of marine waters, where a decreasing pH reflects the acidification of the ocean due to increased absorption of atmospheric CO_2.

Oxygen is fundamental to sustain marine life and its reduction can have a large impact on coastal ecosystem services including fisheries and aquaculture.

Chlorophyll is an indicator of the biomass available at the base of the marine food web supporting all ecosystem productivity.

	North	South
Temperature	27.55°C +1.6 °C +1.29 °C +1.05 °C	24.39°C +1.26 °C +1.1 °C +0.85 °C
pH	8.06 -0.14 -0.1 -0.08	8.07 -0.15 -0.11 -0.08
Oxygen	204.61 $mmol/m^3$ -3.23 % -2.3 % -2.2 %	214.06 $mmol/m^3$ -2.39 % -1.94 % -1.65 %
Chlorophyll	0.23 mg/m^3 -5.68 % +14.41 % -0.87 %	0.19 mg/m^3 -4.28 % -3.74 % -2.67 %

FISH CATCH POTENTIAL

Fish catch potential is an estimate of the maximum fish catch achievable given the marine resources available over a sustained period. It is linked to the concept of maximum sustainable yield, meaning the maximum amount of fish that can be extracted from a system without causing a collapse in fish populations.

It is a characteristic of the natural system, which is substantially different from realized catch, and a direct result of the fishery policy in place.

Fish catch percentage change

2050

-8.8%

-4.1%

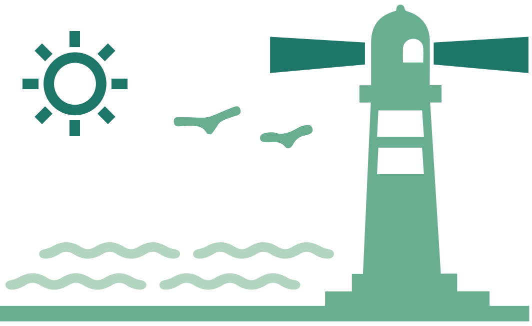
ANALYSIS DETAILS

All datasets were analysed using only data from within the marine EEZ and therefore excluding overseas territories, detached islands and any disputed or joint territories with other nations. In the assessment of current climate conditions, seawater surface tempererature data was obtained using satellite observations distributed in the framework of ESA Climate Change Initiative.

Future projections of marine indicators are represented by the combined analysis of results from 15 different Earth System models participating in the Coupled Model Intercomparison Project Phase 6 (CMIP6). These models include new and better representations of physical and biogeochemical processes, compared to previous IPCC assessment reports.

Fish catch potential data was obtained using the FAO's technical report and refers to the best and worst case climate scenarios from the Fifth IPCC Assessment Report. These mean estimates are subject to substantial uncertainties as discussed in the original work.

BRAZIL
COASTS



OVERVIEW

The Brazilian coastal zone spans approximately 33,000 kilometres along the South Atlantic ocean, across the intertropical and subtropical zones, leading to the presence of very distinct environments of high ecological and touristic relevance, such as: coastal reefs, mangroves, coastal lagoons, sandbanks, wetlands, beaches and dunes. The coastal zone is home to about 50 million people, about a quarter of the country's population, of which most are concentrated in the cities of Rio de Janeiro, Fortaleza, Recife, Belem, and Santa Catarina.

Shoreline Length 33,379 km

Sandy Coast Retreat at 2050 -29.1 m

CLIMATE CHANGE HAZARDS

Coastal hazards such as erosion, storm tide inundation and permanent flooding, can have strong adverse impacts on coastal regions, with loss of sandy shores, damage to settlements, infrastructure and ecosystems. Climate change can exacerbate these impacts due to rising sea levels and increasing impacts of waves and storms. The coastal zone of Brazil includes a variety of coastal forms, including sandy shorelines, cliffs, deltas and estuaries, headlands and low-lying coastal plains. These forms will respond in different ways to sea level rise and possible changes to the wave climate, with the impacts and risks concentrated in the urbanized areas. Some cities are currently experiencing inundation during extreme weather events, combining storm surges with heavy rainfall. This has occurred in the past decades to the cities of Rio de Janeiro, Fortaleza, Recife and Salvador de Bahia. These impacts are expected to worsen with sea level rise.

SEA LEVEL RISE

Relative sea level rise has been observed over the past century around the coast of Brazil, with a yearly average increase of approximately 2.2 millimetres per year since the 1990s. The latest IPCC projections indicate that, by 2050, global sea levels may rise between 0.18 metres, under a low emissions scenario, and 0.23 metres, under a high emissions scenario.

Observed and projected sea level rise at 2050

2.2 mm/year

0.23 m

0.18 m

EXTREME SEA LEVEL

On average, one in 100 extreme sea level events are expected to rise from 1.81 metres at present day to 2.04 metres by 2050 under a medium emissions scenario and up to 82% more by 2100 under a high emissions scenario.

Current and projected extreme sea level at 2050

1.81 m

2.11 m

2.04 m

OBSERVED STORMS

Brazil is mainly influenced by the South Atlantic wave climate, with most waves and wave energy coming from the south and south-east quadrants. The Brazilian coast is also susceptible to storm surges that often lead to coastal flooding and erosive processes, significantly impacting coastal communities. Coastal erosion is common and it has been increasing in the past decades along the coast of Brazil, with impacts on numerous coastal communities and tourist destinations both in northern and southern regions.

FUTURE STORMS

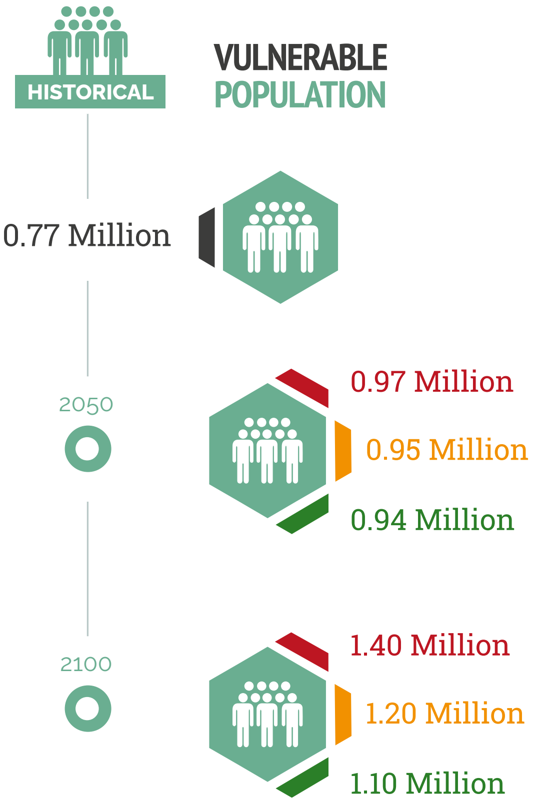
Climate change is expected to result in increases in wave heights due to more intense and frequent storms, which, in conjunction with sea level rise, has the potential to exacerbate the impact of storm surges on coastal communities. A southward migration of tropical cyclones due to warming water surfaces can be expected, increasing the exposure of southern Brazil. Rising sea levels will also increase the frequency of extreme sea level events, such as the one in 100 year water level.

VULNERABILITY AND RISK

Brazil has a high number of people living in the coastal zone, of which approximately 12 million live on low elevated lands below 10 metres above sea level, which amounts to approximately 1.4% of the land area of the country. Based on current projections the population of Brazil living in low lying coastal areas could grow to 19 million by 2060.

Brazil's coastal communities are exposed to climate change driven coastal hazards. Furthermore, the socio-economic divide creates an additional challenge whereby both wealthier and poorer communities live in coastal areas sensitive to sea level rise both in urban and rural settings. In general, risks are associated with the increased exposure of buildings, infrastructure and land to rising sea levels.

The areas at highest risk are the large coastal cities along the seaboard. Under a medium emissions scenario, the population exposed to the annual coastal flood level is expected to increase from 770,000 to 950,000 by 2050.



INFLUENCE OF SEA LEVEL RISE ON EXTREME SEA LEVEL

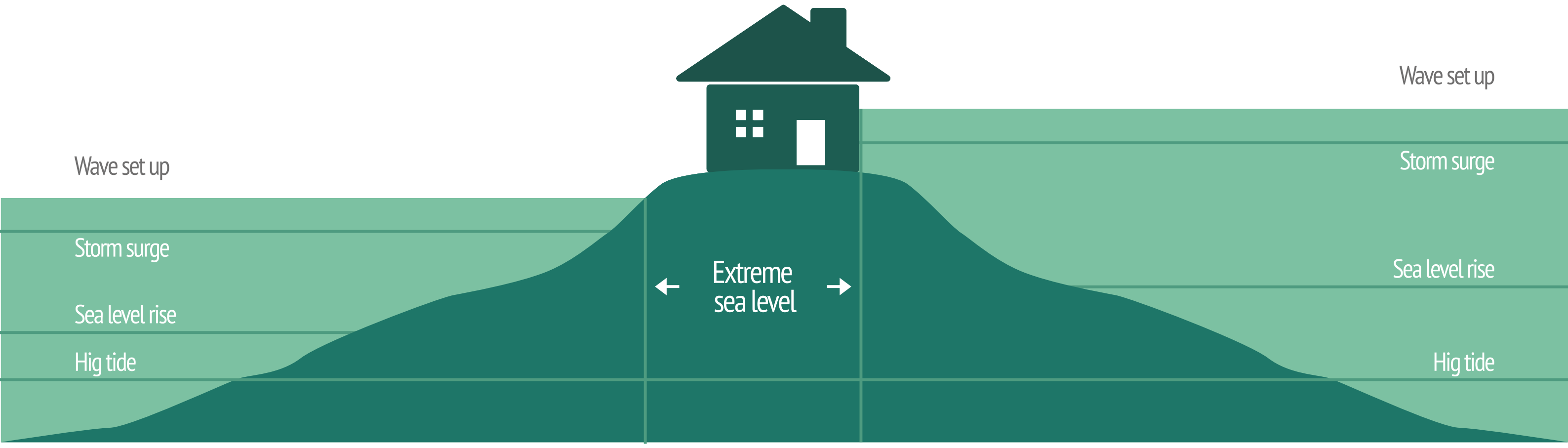
Present and future sea level rise are a consequence of carbon induced global warming causing melting ice and ocean expansion due to heat accumulation.

The extreme sea levels reported here are based on the 100-year storm surge + wave set up + sea level rise + high tide indicators. The first two parameters (storm surge + wave set up) are based on the 100-year value for the event; sea level rise is its projected value at 2050; and high tide is the absolute value of the highest tide calculated for a given locality, which won't be influenced by climate change.

+ Wave set up refers to the accumulation of water near the shore due to the presence of breaking waves.

+ Storm surge is an occasional increase in sea level driven by shoreward wind-driven water circulation and atmospheric pressure.

+ High tide is usually the highest tide reached in a given location based on tide records.



Present sea levels have risen globally by approximately 20 centimetres over the past century.

Future sea level rise is a projection based on different global warming scenarios, at approximately 100 centimetres by the end of 2100, with consequent inundation during extreme sea level events.

BRAZIL
WATER

OVERVIEW

Brazil is unique when it comes to the availability of water resources. The average annual flow of rivers on Brazilian territory is around 180 thousand cubic metres per second. This corresponds to approximately 12% of the planet's 1.5 million cubic metres per second. Furthermore, if waters that originate in foreign territories and flow through Brazil are also considered, the total average flow reaches 267 thousand cubic metres per second, or 18% of world supply.

In contrast regions with relatively low water availability include the eastern north-east Atlantic, eastern Atlantic, Parnaiba and Sao Francisco basins. In the semi-arid portion of these regions, where drought has the most serious repercussions, water scarcity is a critical factor for local populations.

Renewable internal freshwater resources	5,661 billion m^3
Renewable internal freshwater resources per capita	27,238 m^3

Water availability in Brazil depends largely on the climate. The inter-annual climate variability, associated with the El Niño and La Niña phenomenon, or the sea surface temperature variability of the Tropical and South Atlantic, can generate climatic anomalies that produce severe drought and extreme precipitation events. The risks of climate change, whether natural or of anthropogenic origin, have raised great concern in scientific and political circles, the media and the population in general.

CLIMATE CHANGE HAZARDS

Climate change can affect water resources through increasing temperatures, higher rates of evapotranspiration and altered rainfall patterns. This leads to changes in the water cycle, including decrease of snow and ice coverage, alterations of surface runoff and groundwater storage, as well as drought and flood occurrence.
Impacts of climate change on Brazilian water resources are well covered in scientific literature. For instance, discharge of the river Tocantins is projected to decrease by 20% during the 2080-2099 period compared to the 1970-1999 baseline. For the Rio Grande basin, a significant reduction in the runoff, mainly in the baseflow, and an increase in drought severity are also projected for this century.

KEY POINT RUNOFF

Precipitation, evaporation, transpiration and soil moisture are the key factors impacting volume of runoffs and evaporation. Impacts of changes in the surface runoff may include soil erosion, transport of pollutants and increased flood risk. At a country scale, an average increase in surface runoff by approximately 7% and 22% is expected respectively under low and high emissions scenarios for the 2045-2055 period, compared to 2015-2025. If temperatures rise by 1.5°C, 2°C or 4°C, 1%, 2.1% or 8% of the area of the country will likely experience an increase in runoff, whereas 40%, 49.8% and 67% of the surface of the country will likely experience a respective decrease in runoff.

2050

Changes in annual runoff
% of change

+21.8%

+7.1%

2050

Runoff increase
% of area

+8.0%

+1.0%

KEY POINT DROUGHTS

In Brazil, droughts are widespread and recurrent in the northeast region, which has the highest proportion of people living in poverty in the country. Other Brazilian regions have also been affected by droughts in recent years, and the impacts have been reported, especially those that are affecting major agricultural producers, as in west Central Brazil.

Climate model predictions suggest severe drought conditions in the late half of this century over several areas of the world including Brazil. The likelihood of severe droughts in Brazil is expected to increase by 9.3%, 10.9% and 15.1% (2040-2059) under low, medium and high emissions scenarios. Similarly, If temperatures rise by 1.5°C, 2°C or 4°C, there is an expected increase of hydrological drought frequency by 12%, 14% and 14%, respectively.

2050
Severe drought likelihood increase
% of change
+15.1%
+9.3%

2050
Hydrological drought frequency
% of change
+14.0%
+12.0%

2050
Groundwater Recharge
% of change
-2.0%
+6.2%

KEY POINT GROUNDWATER

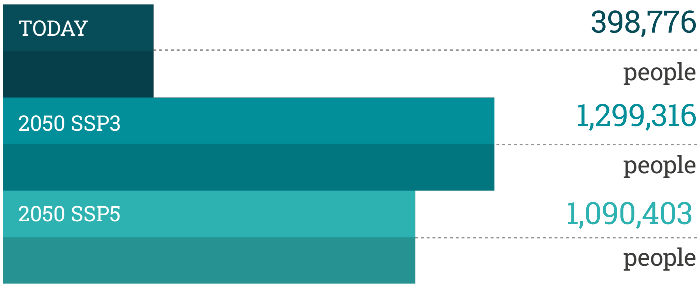
Groundwater has not only a strategic role, it is also of great importance regarding the water supply in Brazilian cities and communities. There are about 416,000 wells in the country, with an annual increase of 10,800 new ones, supplying from 30 to 40% of the population. Water from tubular wells and springs has been used for various purposes, such as human and animal supply, industry, irrigation and leisure. Groundwater serves rural communities in the semi-arid northeast regions, as well as urban populations in various capitals such as Manaus, Belém, Fortaleza, Recife, Natal, Porto Velho, Fortaleza and Maceió. It is also widely exploited for irrigation.

The most vulnerable areas to climate changes are the north and northeast regions, where the aquifer recharge will decrease considerably. In contrast, the climate models show that in general the recharge in the south and southeast regions will increase. Although some punctual differences are observed in these two estimations, the results are still valid for establishing actions to mitigate the problem caused by climate change. At the country level, a +6.2%, +0.5% and -2% change of the annual groundwater recharge for the period 2045-2055 compared to the timeframe 2015-2025 is expected respectively under low, medium and high emissions scenarios.

KEY POINT FLOODS

Flash floods and fluvial floods are among the most important and threatening climate events in Brazil. Cities in the Amazonas state, especially Manaus, suffer from severe river floods, such as in May/June 2021. In fact, every year over 250,000 square kilometres of Amazon floodplain forests are covered by water that overflows from rivers. On the other hand, flash floods are responsible for large issues and damages in a wide range of Brazilian states, because of torrential rains and fast precipitation phenomena that may be amplified by climate change. Changing rain patterns may affect the frequency and intensity of floods and changes in the population exposed to river floods are expected, with a remarkable increase from around 400,000 in the present day to 1,300,000 under SSP3 and 1,100,000 under SSP5 by 2050. As such, potential impacts related to river floods may increase.

POPULATION AFFECTED BY RIVER FLOODS

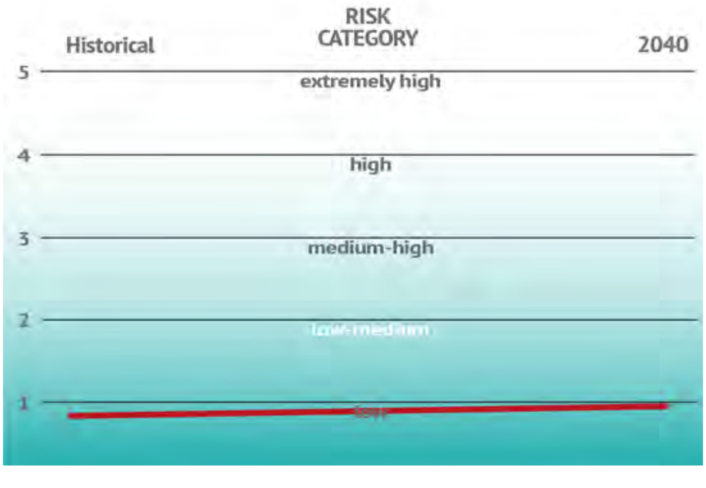


RISK INDICATORS

The water stress index summarises current and future water related vulnerabilities and risks at the global level. Scores are based on the ratio of total water withdrawals, including agriculture, industrial and human consumption, to available renewable surface and groundwater supplies.

WATER STRESS

Brazil's water stress level is considered low (with the best score between the G20 countries) for the recent past (1960-2014 average), but it is expected to increase in the near future (2030-2050) based on climate change projections.



BRAZIL
AGRICULTURE

OVERVIEW

Brazil is a leading agricultural producer that is important globally for both food security and environmental sustainability. It meets most of its domestic agricultural demand, and also plays a major role in international commodity markets with large availability of land, water and agricultural technology.

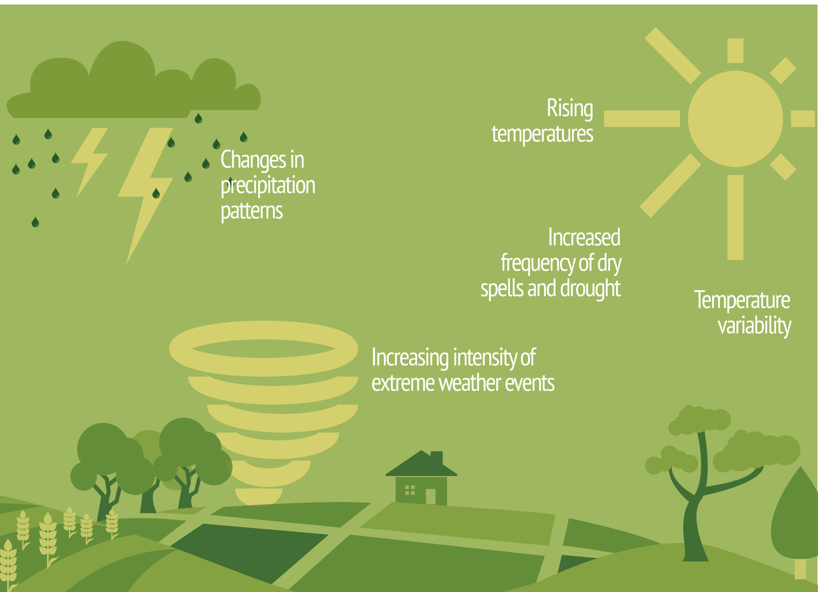
In recent years, Brazil has seen significant increases in harvested areas of soybeans, sugarcane and cereals. Forest products, especially rubber, Brazil nuts, cashews, waxes and fibres, are mostly cultivated on plantations and no longer sourced from wild forest trees. Thanks to its wide climatic range, Brazil produces almost every kind of fruit, from tropical varieties in the north (various nuts and avocados) to citrus and grapes in the temperate southern regions. Irrigation is extremely important for various crops, absorbing 60% of total water withdrawal in 2017.

747.1 Mt	Sugarcane
117.9 Mt	Soybeans
82.4 Mt	Maize
19.4 Mt	Citrus
17.9 Mt	Cassava
3.5 Mt	Coffee

	Added Value of Agriculture, Forestry and Fishing	Share of Agriculture Value added in Total GDP	Agricultural land	Area Equipped for Irrigation
2000	45,626 USD Million	3.8 %	54,870 Thousand HA	3,691 Thousand HA
2018	83,110 USD Million	4.7 %	63,518 Thousand HA	6,955 Thousand HA

EXPEXTED IMPACTS ON AGRICULTURE PRODUCTIVITY

Rising temperatures, reduction in average annual precipitation, and intensification of extreme events such as heat waves and drought, affect production variability with a tendency towards yield reduction for many cultivated species, accompanied by a probable decrease in food quality. Crops respond to increases in temperatures with changes in duration of the growing season, early appearance of phenological phases and potential shifts of cultivation areas toward higher latitudes and altitudes for better growing conditions. However, impacts vary significantly depending on the geographical area and specific crops in question.



CROP PRODUCTIVITY

Crop productivity refers to the harvested yield of a crop per unit of land area. It is strongly influenced by climate and other environmental and management factors.

Climate change is expected to have an impact on the productivity of several major crops, although this may in part be offset by the fertilizing effect of higher CO_2.

Impacts are estimated using a range of model projections based on low to high emission scenarios and reported as percentage changes between the 30-year average around the historical period and the 30-year average around 2050.

74.6
-7.6 (-10.2)%
-6.3 (-8.8)%
Sugarcane
tons / ha

3.3
3.7 (-5.9)%
6.2 (-7)%
Soybeans
tons / ha

5.4
-2.3 (-3.8)%
-2.3 (-3.9)%
Maize
tons / ha

14.7
3.6 (-7.7)%
3.8 (na)%
Cassava
tons / ha

2050

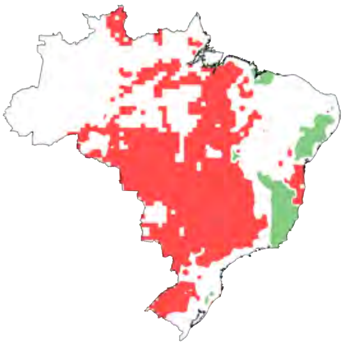
Productivity change with (without) the CO_2 fertilization effect. Estimates assume sufficient water and nutrient supplies, and do not include impacts of pests, disease, or extreme events.

CHANGE IN SOYBEANS

🟥 − = 🟩 +

CHANGE IN MAIZE

🟥 − = 🟩 +



Soybean yields are expected to increase due to rising CO_2 and higher water productivity. However, expected larger rainfall variability will lead to higher yield risks in tropical regions. Sugarcane may suffer a strong decline especially in arid and semi-arid areas where further temperature increases may lead to the highest risks for productivity. Rice cultivation may benefit from higher temperatures, although a decrease in yields is expected for upland rice growing areas in central Brazil due to increased drought stress. Wheat will see an average decrease in productivity, notwithstanding uncertain precipitation estimates. Although higher temperatures may increase photosynthesis and growth, cassava production is projected to remain stable. Enhanced climate extremes will play an important role on productivity and quality of fruits, such as coffee and citrus, and their marketing stability.

ADAPTATION IN AGRICULTURE AND WATER RESOURCES

Climate change may have some positive effects on some of the most widely used crops. However, higher temperatures will generally require an increase in irrigation due to higher plant evapotranspiration and expansion of irrigated areas. The expansion of sugarcane cultivation in the next years will require substantial amounts of water for irrigation. The use of irrigated agriculture will become more significant in the agricultural frontiers of Mato Grosso and the states of Minas Gerais, Bahia, Tocantins, Roraima, and the South of Maranhão and Piauí, depending on road improvements and energy storage in these regions.

CHANGE IN WATER DEMAND

🟩 − = 🟥 +

Agriculture
Water Demand
% of change

+82.8%
+77.2%

2050

Future projections reveal a substantial increase in water demand, from 77% to 83%, to maintain agricultural production in Brazil. This will require adaptation practices and crop varieties that enhance water-use efficiency to limit stress on water resources.

BRAZIL FORESTS

FORESTS IN BRAZIL

Brazil has the second largest forest area in the world after Russia. Over 40% of Brazilian forests are primary, amounting to a unique biodiversity heritage.

Although tropical forests such as the Amazon are obviously widespread, other types such as Caatinga and Cerrado, which are savanna-types, are also very significant. Mangrove forests are present in over 90% of the Brazilian coastline.

FORESTED AREA AND CARBON STORAGE

60% of Brazilian land is currently covered in forests, although this has been decreasing steadily over recent decades. The Brazilian Amazon biome stores approximately 10% of the global forest carbon (>120 k Tg C). Unfortunately, recent studies reveal that as a result of deforestation, fires and the effects of the climate emergency, this carbon sink is rapidly becoming a source.

1990

589 Mln ha
Million hectares
Forested area

149 Tons/ha
Tons of Carbon per hectare
Carbon stock

2020

497 Mln ha
Million hectares
Forested area

154 Tons/ha
Tons of Carbon per hectare
Carbon stock

FOREST PRODUCTIVITY

Forest productivity or Net Primary Production is the net carbon captured by plants. It is the difference between the carbon gained by Gross Primary Production - net photosynthesis measured at the ecosystem scale - and carbon released by plants' respiration. It is expressed per unit land area.

2050

Productivity anomaly
Tons of Carbon per hectare per year

+0.94

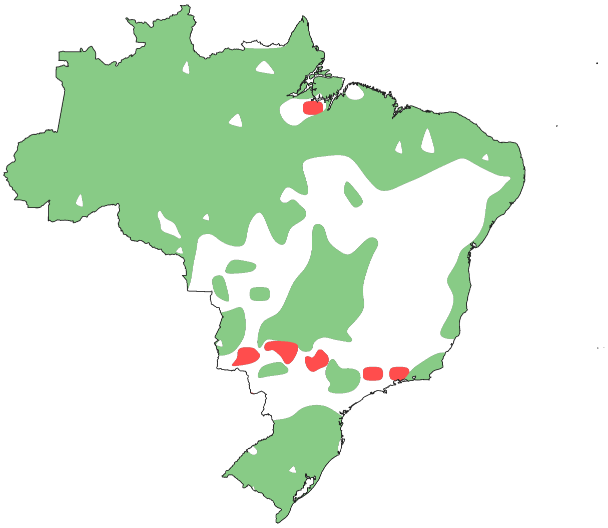
+0.52

Potential increase in net primary productivity for the Amazon river basin excluding some areas of the delta.

+ Fertilizing effect of CO_2 whereby carbon dioxide stimulates photosynthesis

Potential pronounced decrease in the south-east (Atlantic Forest).

+ Increase in the duration and severity of drought events, particularly in the south



KEY SPECIES UNDER CLIMATE CHANGE

VULNERABILITY
ATLANTIC FOREST
High vulnerability of the Atlantic Forest biome

EXPANSION
GENERALIST SPECIES
Expansion of current generalist and disturbance-tolerant species in the Atlantic Forest

COMPOSITION
AMAZON
Undergoing a compositional shift towards a more dry-affiliated Amazon with dry tolerant species

VULNERABILITY
MANGROVES
Rapid sea level rise may threaten coastal mangrove forests particularly in the semiarid north-east

FIRES IN BRAZIL

Fire is a structural ecological process that provides several types of ecosystem services and impacts on socio-ecological systems, including human health, carbon budgets, and climate change. Changes in global fire activity are influenced by multiple factors such as land-cover change, policies, and climatic conditions. Fire also releases large quantities of greenhouse gases into the atmosphere, contributing to a vicious cycle.

During the last two decades, the total land area affected by fire was approximately 792.4 million hectares of which 49% involving forests.

BURNING
792.4 MILLION HECTARES

EMITTING
212 TERAGRAMMES OF CARBON PER YEAR

FOREST FIRE EMISSIONS CONTRIBUTED TO 51% OF TOTAL FIRE RELATED CARBON EMISSIONS

COSTING
BETWEEN 90 MILLION AND 5 BILLION USD IN AVERAGE YEARLY LOSSES IN THE BRAZILIAN AMAZON (1996-1999)

FUTURE BURNED AREA

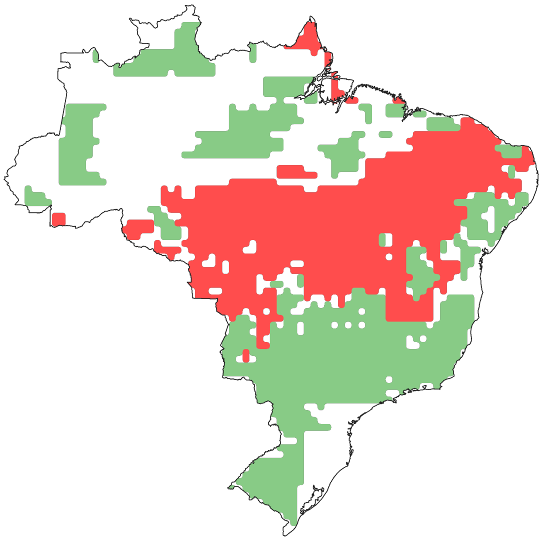
Under low emissions scenario, a generalized increase in burned area is expected in the central areas of Brazil, particularly in the northern areas of Tropical and Subtropical Dry Broadleaf forests of Caatinga and in the north-eastern Grasslands, Savannas and Shrublands of Cerrado. Also, tropical dry forests in the Mato Grosso region, moist forests and Pantanal in Madeira-Tapajos will experience an increase in burned area. In a medium emissions scenario the increase in burned area will seriously affect western Caatinga whilst remaining more contained in the Cerrado.

Burned Area
km² per year

2050

+407

+2,562



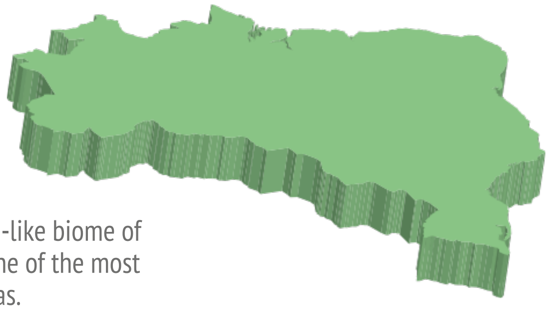
🟩 Decrease in burned areas for a low emissions scenario

🟥 Increase in burned areas for a low emissions scenario

+ Prolonged fire season in the Amazon plain due to rising temperatures

WHERE DO FIRES OCCUR?

Fires affecting Tropical and Subtropical Moist Broadleaf Forests of the Amazon basin are of special interest given their global relevance as a carbon sink.



The savanna-like biome of Cerrado is one of the most affected areas.

VARIATION OF SPECIFIC FIRE INDICATORS

% of change
Expected effort required for fire suppression

2021-2050

+26%

+17%

days per year
Average fire duration in Amazonia

2080-2100

+15

+7

% of change
Areas with fire occurrence probability in Amazonia

2071-2100

+27.7%

+6.9%

FUTURE FIRE EMISSIONS

Under a low emission scenario, fire emissions might slightly increase in northern tropical and subtropical moist broadleaf forests while decreasing in tropical and subtropical savannas and shrubland biomes. Under a medium emission scenario, the greatest changes are projected also across northern and central areas.

Fire Carbon emission
Teragrams of Carbon per year

2050

+8.64

-69.4

BRAZIL
URBAN

OVERVIEW

In Brazil, 87% of the population lives in urban areas, this number is expected to exceed 90% by 2050.

The highest share of the population live in urban areads with less than 300,000 inhabitants, and less than one fifth live in one of the two megacities of more than 10 million inhabitants.

This profile is expected to change only slightly in the future, with slight decreases in the share and number of very small centres due to their growth. In the near future the share of urban population is expected to increase further, to 89.3% in 2030 and to 90.4% in 2050, reaching an overall urban population of 229 million.

Built up areas cover 0.36 % of Brazil (30,665.75 square kilometers), although density is higher along the Atlantic coast.

Population in Urban Areas

2020 186,217,070

2050 215,063,348

Graphs refer to data provided by United Nations, Department of Economic and Social Affairs, Population Division (2018). World Urbanization

Urbanization Rate

2020 87.1%

2050 92.4%

OVERVIEW OF KEY CLIMATE IMPACTS IN URBAN AREAS

The most important impacts for Brazilian urban areas are related mainly related to water, with more intense precipitation events causing land slides and floods, while drought events will impact agriculture, driving migration towards urban areas.

HEATWAVES AND HEAT STRESS

Temperatures across the Amazon Basin have risen by 0.5°C since 1980. Since 1981, major Brazilian cities have shown an upward trend in the frequency of heatwave days per year. In 2019, major Brazilian cities experienced a significant increase in average temperatures, with occurrences of heatwaves in cities such as Rio de Janeiro, where temperatures in summer exceeded 39°C.

High temperatures increase the risk of death from cardio-vascular diseases in major Brazilian cities by 50%, and by 100% for respiratory diseases. Rising urban temperatures are also seen as responsible for the rise of communicable diseases such as dengue in the warmer Brazilian cities. With rising temperatures and increasing frequencies of climate extremes the frequency of heatwaves is also expected to increase.

2050

Cooling Degree Days
% of change

+55.4%
+22.6%
+14.4%

2100

Heatwave frequency
% of change

+98.6%
+75.2%
+46.6%

2050

Heatwave duration
% of time

+7,644%
+1,400%
+522%

INTERACTIONS BETWEEN URBAN HEAT AND PRECIPITATION

Urban heatwaves are also contributing to increases in intensity and frequency of intense urban precipitation. High urban temperatures exacerbate health impacts related to air pollution. In 2017, more than two thirds of the Brazilian population was exposed to levels exceeding WHO guidelines for PM2.5.

2017

Population exposed to air pollution

68.1%

COASTAL FLOODING

With many of the urbanized areas concentrated along the Atlantic coast, cities are highly vulnerable to sea level rise. Areas most vulnerable to sea level rise are concentrated in cities, where flood risk will have the greatest impact on the population.

Projected sea level rise

2050

0.23 m

0.18 m

2100

0.77 m

0.38 m

EXTREME PRECIPITATION EVENTS

In recent years, an increased frequency and intensity of heavy rainfall events has been registered in major urban areas like Sao Paolo and Rio de Janeiro. In recent years, intense precipitation events causing surface water flooding have affected almost all urban areas situated in the most densely populated area along the Atlantic coast.

Between 2009 and 2014, nearly every highly populated municipality in Brazil was affected by floods and about 50,000 low-income homes were destroyed. In the mountain region of Rio de Janeiro, in 2011, there were 916 deaths, more than 35,000 homeless, and economic losses for 1.35% of the federal state's GDP, as a result of extreme rain that caused landslides of large land masses, as well as flash floods and surface water floods across the metropolitan region.

Similar events also occurred in 2018 and 2019 in Rio de Janeiro and in 2020 when the heaviest storm in the city's history caused an accumulated 123.6 millimetres of rain in one hour. In 2020 the city of Sao Paulo also experienced an extreme precipitation event. The intensity of extreme precipitation events is expected to increase in most regions under future climate scenarios.

2050

Runoff increase
% of area

+8%

+2%

+1%

SURFACE SEALING AND FLOODS

Heavy precipitation in cities is problematic due to the high level of sealed surfaces. Soil sealing increases run off and reduces the amount of water absorbed by soil. Where there are large amounts of impervious ground cover, short duration extreme rainfall events can lead to increased flooding, even resulting in flash floods.

UNCONTROLLED URBANIZATION

Risk from increasing run-off is exacerbated by the high rates of uncontrolled developments situated in high risk zones such as low lying, flood prone areas or steep slopes.

The loss of protective vegetative cover enhances vulnerability and heavily contributes to damage and losses in slums. 36.7% of the urban population lived in slums in 1990. However, targeted policies have led to a significant improvement, with 16% living in slums in 2018.

2010

% of urban population
Population living in slums

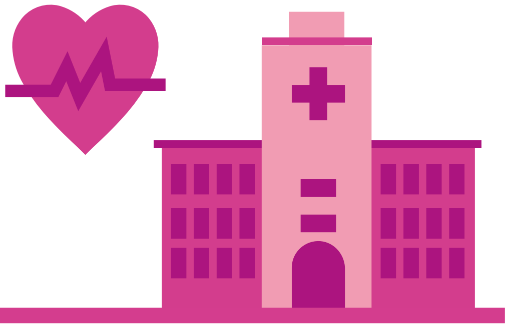
16.3%

2018

% of total population
Urban population living in areas where elevation is below 5 meters

2.0%

BRAZIL
HEALTH



OVERVIEW

Brazil is at risk of both heat-related mortality and climate change-induced vector-borne diseases. Under a high emissions scenario, the mean temperature in Brazil is projected to increase on average by 5.4°C in 2100 compared to 1990. Due to its geographical characteristics, the continental size of its territory, its climatic profile, its large population, and its structural social problems, Brazil may be considered an area vulnerable to the impacts of a changing climate on human health. Also, the persistence of endemic infectious diseases sensitive to climate variability, such as malaria, dengue fever and leptospirosis, and other conditions that determine the overall population health status, contribute to shaping the population's vulnerability.

HEAT RELATED MORTALITY

With a population of 211 million, Brazil is vulnerable to climate change impacts, including reduced water availability, risk of coastal flooding, and health risks associated with heat stress and changing patterns of climate-sensitive vector-borne diseases such as malaria and dengue fever. The highest temperature-related mortality during heat-related events in Brazil is linked to circulatory illnesses. These threats are likely to be particularly damaging due to limited investments in public health and a growing urban population.

Estimates show that heatwave-related excess deaths in Brazil will increase by 854% under a high emissions scenario by 2080, one of the highest in the world. In 2018, a massive 191% increase in heat-related deaths, compared to a 2000 to 2004 baseline, occurred. 67.1% of heat-related mortality during 1991 to 2015 can be attributed to human-induced climate change.

IMPACTS ON LABOUR

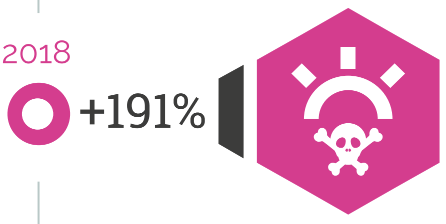
Labour is directly affected by changes in environmental conditions. Warming affects both the number of hours worked (labour supply) and on the productivity of workers during their working hours (labour productivity). Both labour supply and productivity are projected to decrease under future climate change in most parts of the world, and particularly in tropical regions.

Parts of sub-Saharan Africa, south Asia, and southeast Asia are at highest risk under future warming scenarios. Future climate change will reduce global total labour in the low-exposure sectors by 18 percentage points and by24.8 percentage points in the high-exposure sectors under a 3.0°C warming scenario

Labour productivity is projected to decline significantly under a high emissions scenario. In Brazil's agriculture and construction sectors, there was a 37.3% decline in potential hours of labour in 2019 compared to a 1990s baseline. Total labour in Brazil is expected to decline by 12.6% under a low emissions scenario, and by 22.8% under a medium emissions scenario.

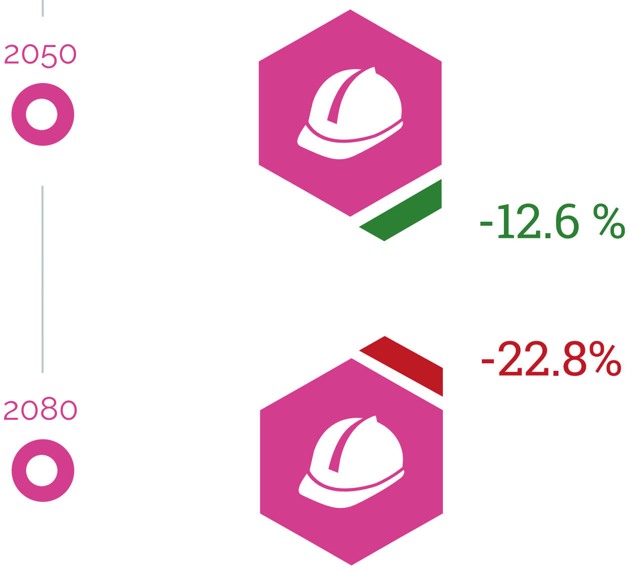
Heat-related mortality

% change with respect to 2000-2004



Impact on total labour

% change with respect to 1986-2005 baseline



CLIMATE CHANGE AND DENGUE

Dengue has spread throughout the tropical world over the past 60 years and now affects over half the world's population. Globally, vectorial capacity for both dengue vectors (A. aegypti and A. albopictus) has been rising steadily since the 1980s, with nine of the ten highest years occurring since 2000.

Climatic stressors are one important driver of the current distribution and incidence of dengue. Climate change is likely to expand the geographical distribution and suitability of several vector-borne human infectious diseases including dengue. The risk of dengue transmission is increased by warming climates, as the growth and development of mosquitoes are significantly influenced by temperature, precipitation, and humidity.

Dengue suitability

% of population at risk

CLIMATE CHANGE AND ZIKA

Zika virus has spread to at least 49 countries and territories since 2013. Climate change impacts on transmission suitability risk have increased over the years and future warming over 1.3 billion additional people could face suitable transmission temperatures for Zika by 2050.

Zika suitability

% of population at risk

DENGUE AND ZIKA: POPULATION AT RISK

Brazil has a high climate and environmental variability. Therefore, regional peculiarities can affect dengue fever transmission differently, with a high level of heterogeneity.

Under a medium emissions scenario, 94.9% of the Brazilian population will be at risk of transmission-suitable mean temperature for dengue by 2050, whereas 93.9% will be at risk under a high emissions scenario. In the case of Zika, 69.8% of the population will be at risk under a medium emissions scenario by 2050, whereas 80.9% will be at risk under a high emissions scenario.

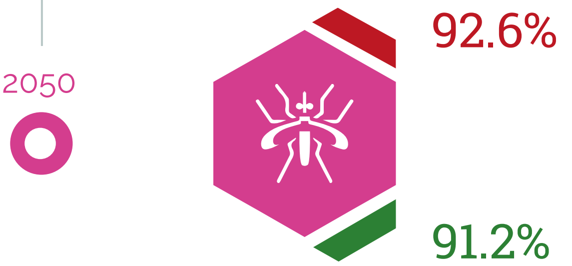
CLIMATE CHANGE AND MALARIA

Brazil is already at risk of climate change-induced malaria transmission and contributes around 40% of all malaria cases reported in Latin America and the Caribbean, a region where major progress towards malaria elimination has been achieved in recent years.

Under a low emissions scenario, 91.2% of the Brazilian population will be at risk of malaria in 2050, whereas 92.6% of the population will be at risk under a high emissions scenario.

Malaria suitability

% of population at risk



POLLUTION AND PREMATURE MORTALITY

Deaths from both outdoor and indoor air pollution represent one in every 26 deaths from all causes in Brazil, making it the ninth-largest mortality risk in the country. Air quality in Brazil is being affected by the cement industry, mining, the petrochemical industry, steel industry, forest and agricultural burning, and vehicle production. In 2019, almost 61,000 deaths were attributable to air pollution exposure in Brazil, an increase of 3.6% compared to 2015.

BRAZIL
ENERGY

ENERGY SYSTEM IN A NUTSHELL

Brazil has one of the lowest carbon intensities in the world (0.14 g/kwh in 2016; the world average is 0.23 g/kWh) due to a high share of renewables (mostly biofuels and hydropower) which meet 45% of primary demand.

This is counterbalanced by a very carbon-intensive use of soil and deforestation, a large production of oil (8th world producer), and the planned further development of new oil fields and coal power plants.

0.10
ktoe/US$
Energy intensity

10.7%
AC Share in electricity consumption

CLIMATE CHANGE TODAY

HYDROPOWER

Hydropower used to meet 70% of electricity demand between the late 90s and 2011; this share, because of lower water availability, dropped to 60% between 2012 and 2014.

FLOODS

The incidence of severe floods is increasing in the country, sometimes with catastrophic tolls in terms of human lives and infrastructures, such as the one that occurred in Rio de Janeiro in 2011.

ENERGY SUPPLY

The current energy mix of total primary energy supply shows a roughly equal split between fossil fuels (52% in 2019) and renewables (46%). Oil alone accounts for 36% of total primary energy supply, but biofuels claim almost one third as well (32.1%). Wind and solar have rapidly increased their contribution from almost zero in 2005 to 2.2% in 2019. There is a residual nuclear capacity, accounting for 1.5%.

ENERGY DEMAND

Energy is used mainly for industry (38,4% of total final demand in 2018, including a 6% share of total demand for non-energy uses), transport (30%), and residential demand (12%), while agriculture and commercial demand both have a 6% share. Air conditioning contributed to residential electricity demand with an 11% share in 2017. Following economic growth, energy demand has risen steadily from 1990 to 2014, when it peaked, and it is now on a declining trend, mainly due to the COVID-19 crisis.

FUTURE ENERGY DEMAND

Increase in cooling needs will dominate, resulting in a net increase of energy demand of about 1,200 PJ (333 billion Kwh) by 2050 under a medium emissions scenario.

Net change in
energy demand due to
changes in DD/CDD
Billion KWh

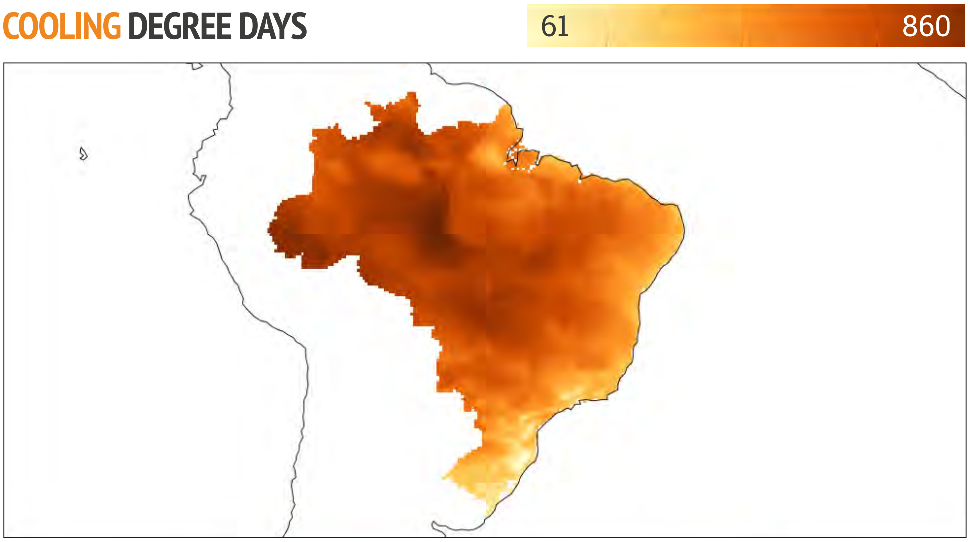
2050

+ 333.47

COOLING NEEDS

Brazil is projected to face an extreme increase in cooling needs all over the country, bar perhaps the extreme south where in any case the increase in cooling degree days will be noticeable. The highest increases will take place in the Amazonas, Acre and Rondonia States.

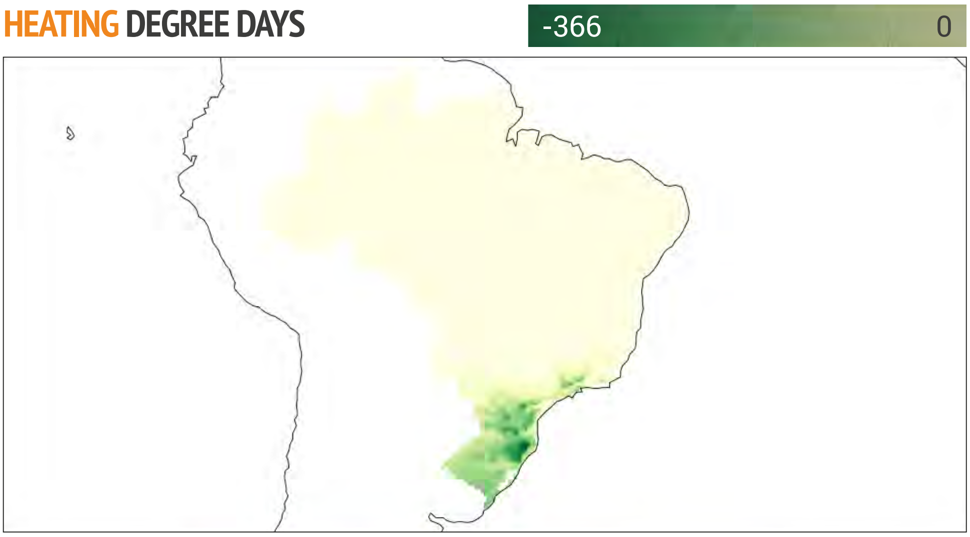
COOLING DEGREE DAYS



HEATING NEEDS

Heating degree days are declining everywhere, albeit they will remain of almost no relevance in most of the country except in the extreme south (Rio Grande do Sul, Santa Catarina), where, in any case, modest decreases will take place.

HEATING DEGREE DAYS



FUTURE ENERGY SUPPLY

The future configuration of the Brazilian energy mix is likely to be determined by the evolution of climate mitigation policies and hence is outside the scope of this report. The current administration is not particularly keen on committing to substantial decarbonization pathways.

Change in
Hydropower generation
% of change

2050

-3.28%

-2.96%

EXPECTED IMPACTS OF CLIMATE CHANGE

Several studies have been conducted on the impacts of climate change on Brazilian hydropower resources. Except for one study, all convene that the expected drop in water availability will result in losses in power generation, but estimates vary considerably according to the scenario, time horizon and river basin considered, and range from 1.6% to 80-90%. The north-east of the country appears to be particularly vulnerable. The overall impact of climate change on biofuels is uncertain, particularly for ethanol extracted from sugarcane, while soybeans production (used for biodiesel) may have to shift from tropical to subtropical regions.

BRAZIL
ECONOMY

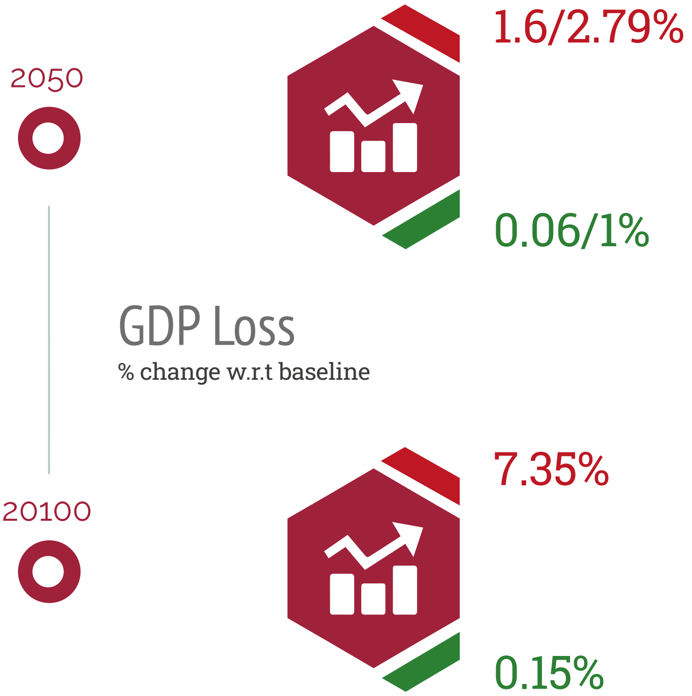
OVERVIEW

Brazil is the largest economy in South America. Although strongly aggected by the COVID 19 pandemic, registering negative real GDP growth of 4.1% in 2020, it is recovering quite fast and in 2021 real GDP growth is currently 3.7%.

IMPACTS ON GDP

In addition to the direct sectoral impacts, climate change will have an effect on the growth rate and overall economic performance of the country. Climate change in Brazil is expected to have a negative impact, and by mid century GDP could fall by 2.8% or 33.4 billion EUR under a high emissions scenario.

By the end of the century costs could more than double, reaching 7.35% of GDP, or 88 billion EUR under the same scenario.



GDP Loss

% change w.r.t baseline

2050

1.6/2.79%

0.06/1%

20100

7.35%

0.15%

SECTORAL ECONOMIC IMPACTS

IMPACTS ON INDUSTRY AND INFRASTRUCTURE

Brazilian coastal areas account for 20% of the population and host the capital cities of most of the 17 coastal states.

Intensification of extreme events due to climate change is an important source of economic losses: average economic damages to water supply, electricity generation, irrigation, federal highways and port infrastructure may amount to 19 billion EUR in 2040 under a medium emissions scenario.

IMPACTS ON AGRICULTURE

The agricultural sector in Brazil accounted for 23% of total GDP in 2017 and 38.5% of total national exports, making the country the world's third largest exporter of agricultural commodities.

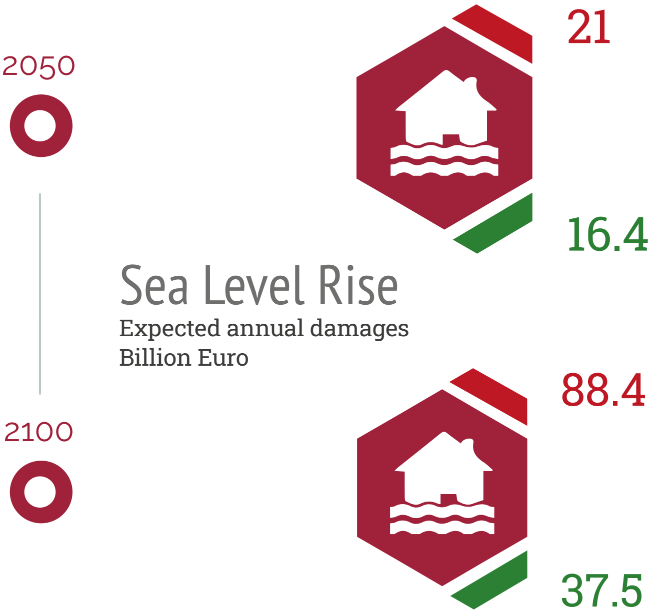
Simulations suggest that climate change will reduce agricultural productivity by 18% in the 2030 to 2049 period, with substantial heterogeneity in different parts of the territory. Estimated annual damages in the agricultural sector in Brazil range from 1% (+1°C) to 39% (+3.5°C) of production value.

Soybeans, Brazil's most important cash crop with total production of 114.6 megatonnes in 2018 and equivalent to 31% of the world's production, would lose about 17% to 38.5% of crop area, resulting in a 6.3% to 36.5% decrease in production and from 1.1% to 34.3% export declines under a high emissions scenario.

SEA LEVEL RISE DAMAGES

Under the current level of coastal protection, by mid century, sea-level rise and coastal flooding may cost the country 16.4 billion to 21 billion EUR in terms of expected damages to assets under low and high emissions scenarios, respectively.

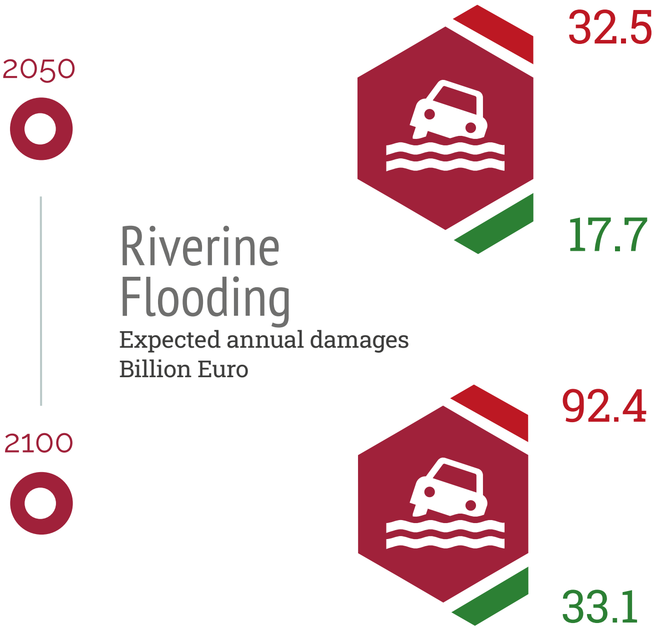
By the end of the century, expected losses can increase to 37.5 billion EUR under a low emissions scenario and 88.4 billion EUR under a high emissions scenario.



RIVER FLOODING DAMAGES

River flooding is also expected to cause significant annual damages, reaching between 17.7 billion to 32.5 billion EUR under a low and high emissions scenarios by 2050, respectively.

By the end of the century, these costs are projected to rise to 33.1 billion EUR under a low emissions scenario and 92.4 billion EUR under a high emissions scenario.



IMPACTS ON ENERGY

Brazil's energy supply mainly depends on hydropower and biofuels. Recent evidence highlights a decreasing trend in water availability for watersheds located in the north and centre of the country and an increasing trend for southern watersheds under both medium and high emissions scenarios.

Economic impacts of shifts in household and firm energy demand (see section on energy) are difficult to predict and will mostly lead to redistribution effects.

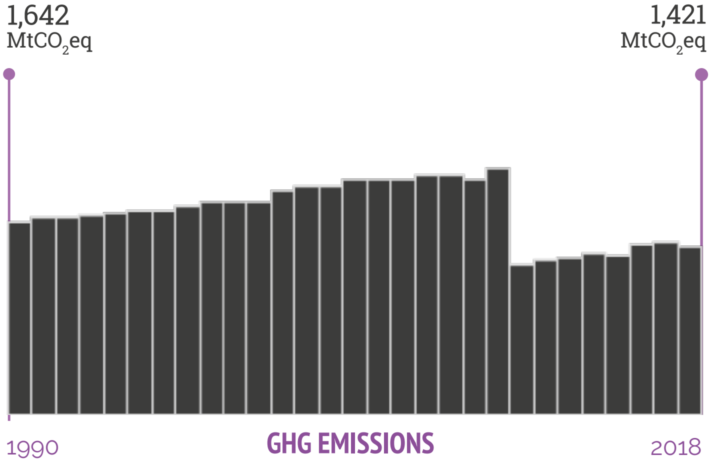
However, in the case of Brazil, there is virtually no savings expected from reduced heating needs, whereas substantial increase in cooling needs is likely to result in steep increases in household expenses for energy bills.

A recent study finds that to compensate for losses in hydropower capacity additional power generation investments will be needed, which range from 65 billion to 232 billion EUR by 2040 under a high emissions scenario, as well as very high operating costs (between a 3.5 and 16.7 fold increase with reference to business as usual).

BRAZIL
POLICY

OVERVIEW

Brazil is one of the largest and most populated countries in the world, accounting for 2,9% of global emissions in 2018. The country ratified the Paris Agreement in 2016 and current emissions are lower than 2005 levels. However, after a significant reduction in 2011, Brazil's emissions have once again increased.



INTERNATIONAL COMMITMENTS

As country not listed in Annex I of the UNFCCC, Brazil did not have any target for the Kyoto Protocol. In its NDC to the Paris Agreement, Brazil committed to reduce its greenhouse gases emissions by 37% in 2025 (with reference to 2005 levels) and by 45% in 2030.

CLIMATE POLICY COMMITMENTS CHRONOLOGY

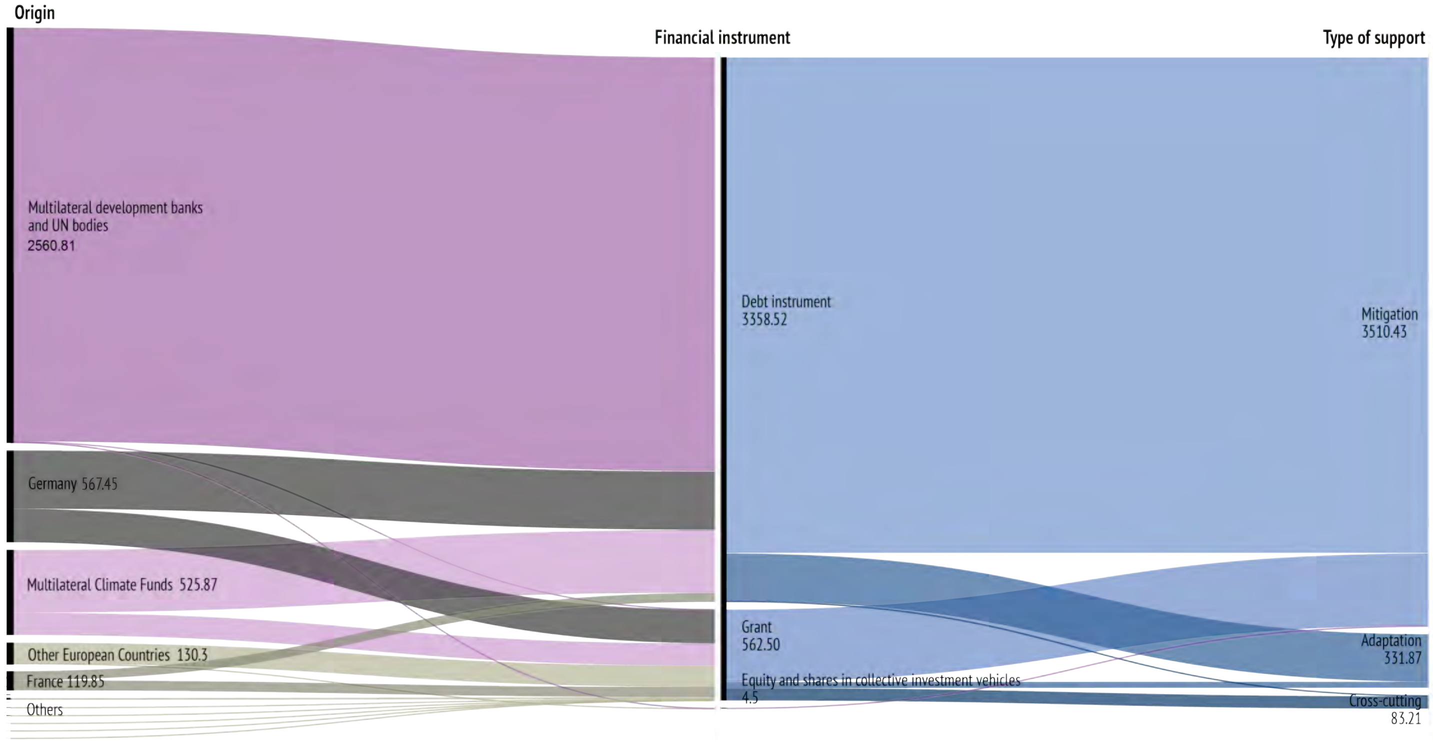
2002 **KYOTO PROTOCOL - 1ST PERIOD**
No target

2016 **PARIS AGREEMENT - 1ST NDC**
37% GHG reduction by 2025, with respect to 2005 levels. Subsequently GHG reduction of 45% by 2030, with respect to 2005 levels

PARIS AGREEMENT - NDC UPDATE
Submitted. Commitments unchanged

INTERNATIONAL CLIMATE FINANCE ASSISTANCE

The diagram shows climate-related development finance received by Brazil in 2017-2018 and reported to OECD DAC. The total amount is 3.9 billion USD. The majority comes from multilateral institutions as debt instruments, whereas the main bilateral donor is Germany.



SUSTAINABLE RECOVERY POLICY

Sustainable recovery is crucial for system transformation. According to the Global Recovery Observatory, Brazil's total public spending in 2020 was 182.56 billion USD. Recovery spending was just a small share of this, but sustainable spending was a significant part of recovery.

182.56
billion $
Total Spending

0.72
billion $
Recovery Spending

0.18
billion $
Green Spending

DOMESTIC ADAPTATION POLICY

Brazil approved a National Adaptation Plan (NAP), that also includes strategic analysis. The NAP foresees that Federal States develop their own adaptation plans and there are no commitments for sector-specific adaptation policies. Brazil does not have particular commitments on adaptation in its NDC.

- ○ Domestic Adaptation Policy
  - ○ Inclusion of Adaptation in NDCs
  - ○ Integrated Adaptation & Mitigation Policy
  - ● Dedicated Adaptation Strategy
  - ● Dedicated Adaptation Plan
- ○ Subordinate Adaptation Policies
  - ○ Sectoral Adaptation Plans
  - ● Subnational Adaptation Plans

○ Policy not in place ● Active policy

ADAPTATION POLICY HIGHLIGHTS

TRANSNATIONAL INITIATIVES

GEF Amazon project

The project contributes to the protection and sustainable use of water and land resources of the Amazon Basin, through an integrated water resources management (IWRM) approach, and a coordinated management of the effects of climate change within Amazonian communities

NATIONAL INITIATIVES

AdaptaClima

AdaptaClima is an online knowledge platform that supports effective adaptation in Brazil by connecting providers and users of knowledge on adaptation and sharing information

Pluviômetros Automáticos

The National Center for Disaster Monitoring and Alert (CEMADEN) installed semi-automatic pluviometers to be managed by local citizens in nearly 800 communities throughout Brazil. Data is collected to create online, open-data national monitoring maps

SUBNATIONAL INITIATIVES

Cabeceiras do Pantanal

The Cabeceiras do Pantanal project aims to protect the springs and preservation areas of the Meseta region of the Upper Paraguay Basin. Together, they are funding the protection of 76,855 hectares of this critical habitat

Rio Operations Center

The Rio Operations Center (ROC) was established in 2010 after torrential rains and flash flooding killed nearly 70 city residents. The ROC integrates the data and monitoring functions of approximately 30 municipal and state agencies and corresponding utilities and is meant to optimize city functioning, manage emergencies as well as day-to-day operations

ENERGY TRANSITION

Brazil has undertaken a significant energy sector transformation process, as demonstrated by its top position among the G20 countries in the overall Energy Transition indicator. In particular, this is due to its outstanding performance in Renewables, mainly onshore wind penetration (which is more than three times the average for G20 countries). The transition path is also well reflected in indicators such as Emissions and Fossil Fuels. In these domains, the country has entered into a virtuous process of transformation, with performances well above the G20 average, which contribute to reduce Brazil's climate change footprint. Looking at the Electrification indicator, there is room for improvement, in spite of the country showing a 99.8% access to electricity: the ongoing digitalization of the grids could spark energy consumption patterns in both residential and transport sectors (e.g. EVs, eMobility, eBikes, Smart Cities). These trends could contribute to limit the impact of climate change on the country's energy sector, improving equitable well-being.

G20 AVERAGE
COUNTRY

Only actively pursuing an energy transition based on decarbonization and electrification – from policy and regulation, to health and education – will enable countries to benefit the most from future opportunities and fight climate change whilst ensuring an equitable distribution of wealth.

The Energy Transition indicators were developed by Enel Foundation in cooperation with SACE, and provide a retrospective analysis based on historical data.

Energy Transition
58.7
72.3

Fossil Fuels
45.3
64.3

Renewables
19.7
60.9

Efficiency
84.9
85.4

Electrification
70.8
64.4

Emissions
72.9
86.6

G20 CLIMATE RISK ATLAS

Impacts, policy, economics

CANADA

How to read the Atlas: graphs, colours and scenarios.

The maps used in this Atlas are taken from **The World Bank Official Boundaries** - ***https://datacatalog.worldbank.org/search/dataset/0038272*** (accessed on May 28, 2021). For the section Energy, the maps are based on Panoply Data Viewer ***https://www.giss.nasa.gov/tools/panoply/credits.html***

Each sector of this Atlas contains data and information on various climate scenarios.

When reported in graphs, the **colour black** indicates data and information referring to the current state, the past or the baseline.

When the authors refer to **RCP (Representative Concentration Pathways)**, the 3 colours used across the factsheet refer to 3 scenarios, which are 3 different development options with different levels of greenhouse gas emissions, **respectively low emissions (green), medium emissions (orange), and high emissions (red)**. The same colour code is used when RCPs are associated with Shared Socioeconomic Pathways (SSP).

In some cases, the authors refer to global warming scenarios. In these cases, the 3 colours used refer to a temperature rise of **1.5°C (green), 2°C (dark green), and 4°C (red)**.

When the authors refer exclusively to **Shared Socioeconomic Pathways - SSPs** (Population affected by river floods in the section: "Water"), data related to **SSP3** - that encompasses, among other things, slow economic growth, material-intensive consumption, and persisting or worsening inequalities – **are reported in a lighter shade**; **SSP5** – which refers to social and economic development that is coupled with an energy-intensive lifestyle and the abundant exploitation of fossil fuel resources – is shown using a **middle shade of the colour**, whereas data related to **the present** conditions **are represented in a dark shade**.

Further details on scenarios, methodologies, and the full list of references are available at: **www.g20climaterisks.org**

Concept and graphic design by element6.eu

CANADA CLIMATE

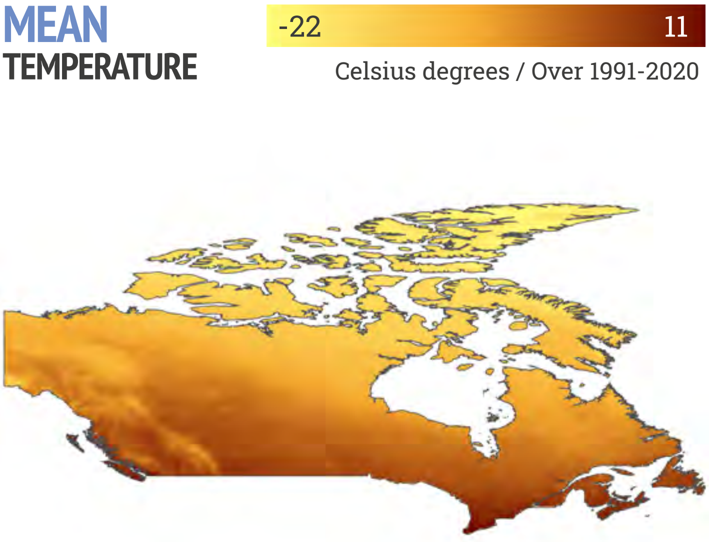
OVERVIEW

Climates and temperatures across Canada vary from region to region due to its great latitudinal distribution. Winters can be harsh in many parts of the country, particularly in the interior provinces, which experience a continental climate. In non-coastal regions, snow can cover the ground for almost six months a year, while in parts of the north snow can persist year-round. Coastal areas have a temperate climate. Much of Northern Canada is covered in ice and permafrost.

TEMPERATURE

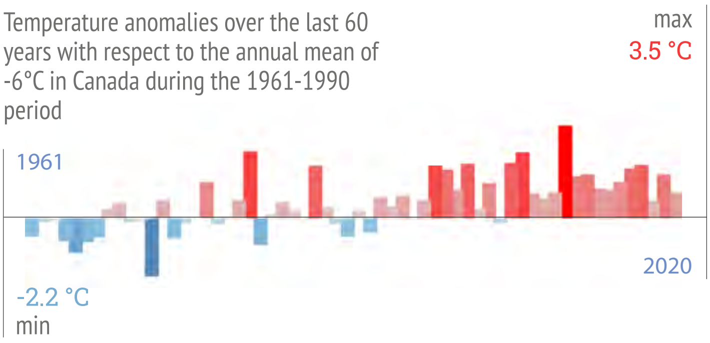
The temperature regime in Canada is highly heterogeneous. Coastal areas are usually cooler than inland areas, where temperatures during the summer have in some cases exceeded 40°C. In contrast, the northern part often experiences temperatures below 0°C.

MEAN TEMPERATURE



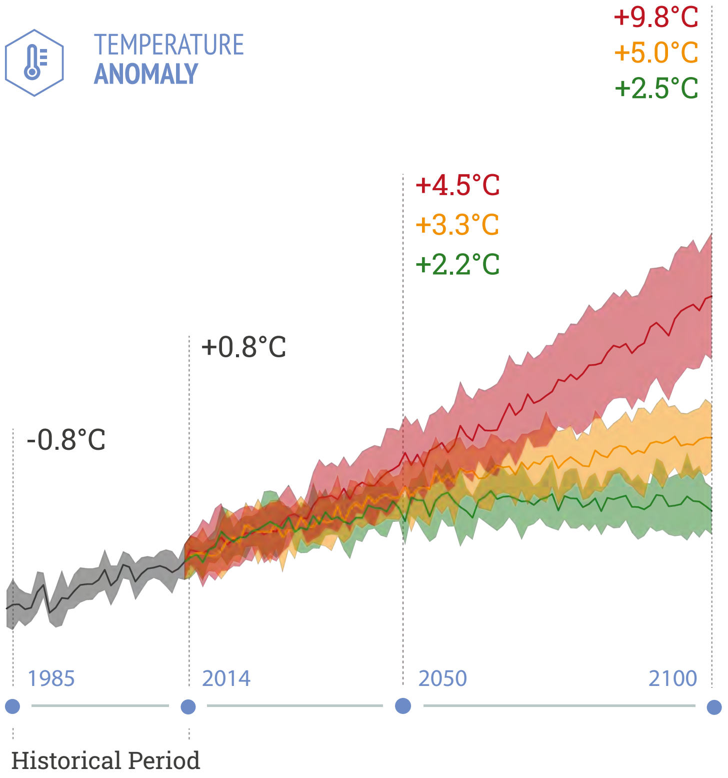
TEMPERATURE TREND

Temperature anomalies over the last 60 years with respect to the annual mean of -6°C in Canada during the 1961-1990 period



TEMPERATURE PROJECTIONS

Under a low emissions scenario projected temperature variations will remain contained under +2.5°C, both by 2050 and 2100.
Under a high emissions scenario, with no reduction in GHG emissions, much greater temperature anomalies are expected by both 2050 and 2100.



EXPECTED VARIATION FOR TEMPERATURE AT 2050

The indicators show variations in selected temperature characteristics for a thirty-year period centred on 2050 (2036-2065) with respect to the reference period 1985-2014.

Annual Mean Temperature	Max Temperature of warmest month	Min Temperature of coldest month
+4.1°C	+2.6°C	+6.1°C
+3.1°C	+1.9°C	+4.4°C
+2.6°C	+1.6°C	+3.6°C

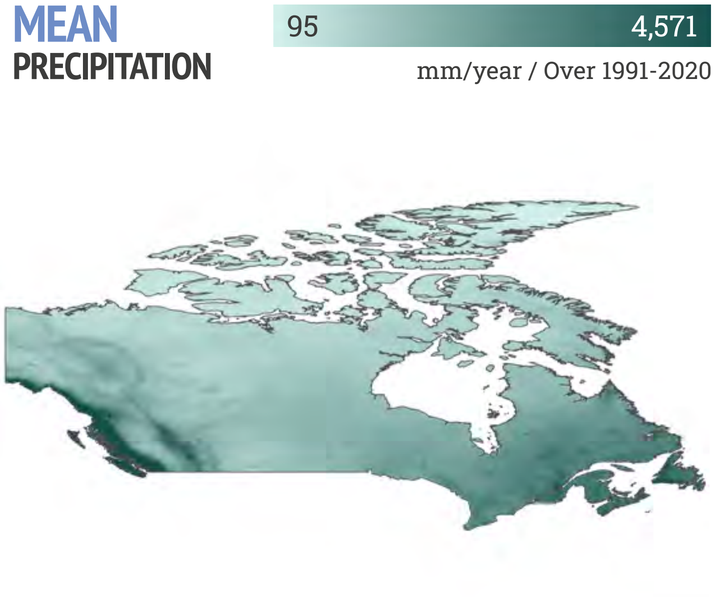
PRECIPITATION

Humid air masses from the Pacific interact with mountains to cause large quantities of rain on the west coast and mountain areas. Several sites along the British Columbia coast receive high annual quantities of precipitation in summer.

On the interior plains and the North there is little precipitation. Spring and summer are wetter than winter. Ontario and Quebec have more rainfall than the interior plains because the air masses pick up water vapour from the Great Lakes. The Atlantic provinces are wetter than the provinces of Central Canada and mostly influenced by cyclones.

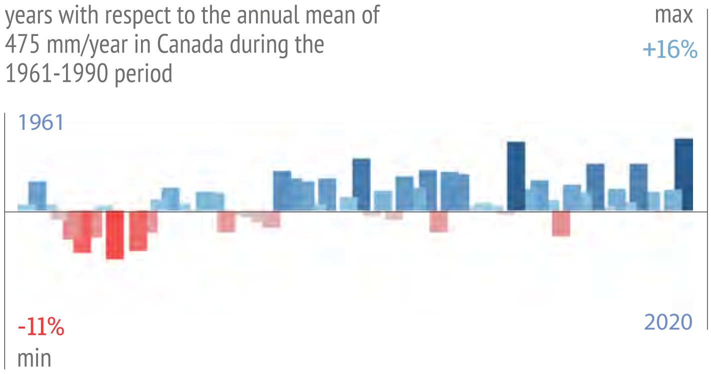
In general, rainfall on Canada's east coast is inferior to that of the west coast because of the prevailing offshore wind.

MEAN PRECIPITATION



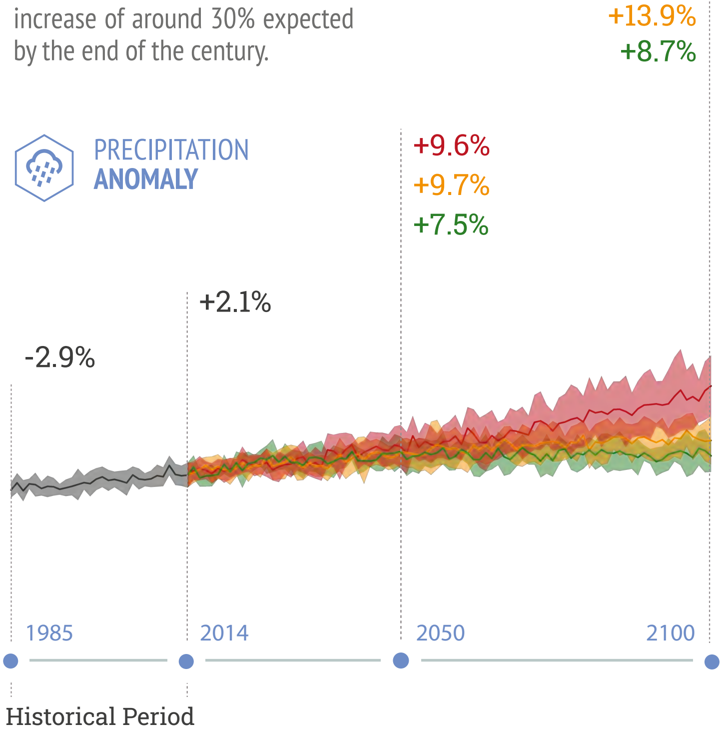
PRECIPITATION TREND

Precipiation anomalies over the last 60 years with respect to the annual mean of 475 mm/year in Canada during the 1961-1990 period



PRECIPITATION PROJECTIONS

Precipitation trends show a clear tendency to increase following all scenarios with a large variability among the involved models. Increases in precipitation are accentuated under a high emissions scenario, with an increase of around 30% expected by the end of the century.



EXPECTED VARIATION FOR PRECIPITATION AT 2050

The indicators show variations in selected precipitation characteristics for a thirty-year period centred on 2050 (2036-2065) with respect to the reference period 1985-2014.

+12.1%
+9.4%
+8.6%
Annual total precipitation

+11.4%
+8.8%
+8.0%
Precipitation of wettest month

+6.5%
+5.6%
+5.6%
Precipitation of warmest quarter

VARIATION OF SPECIFIC CLIMATE INDICATORS

Climate indicators variation showing impacts of climate change on sectors such as agriculture, health and water. Analysis considers 3 threshold average temperature increase: **+1.5°C**, **+2°C**, **+4°C**.

+29%
+13%
+11%
Agricultural drought proportion of time
% of time

+14%
+8%
+7%
Hydrological drought proportion of time
% of time

+1,306%
+181%
+63%
Heatwave duration
% of time

+9%
+1%
+0%
Runoff increase
% of area

+62%
+31%
+23%
Agricultural drought frequency
% of change

+11%
+6%
+11%
Hydrological drought frequency
% of change

+83%
+27%
+14%
Heatwave frequency
% of change

+45%
+27%
+14%
Runoff decrease
% of area

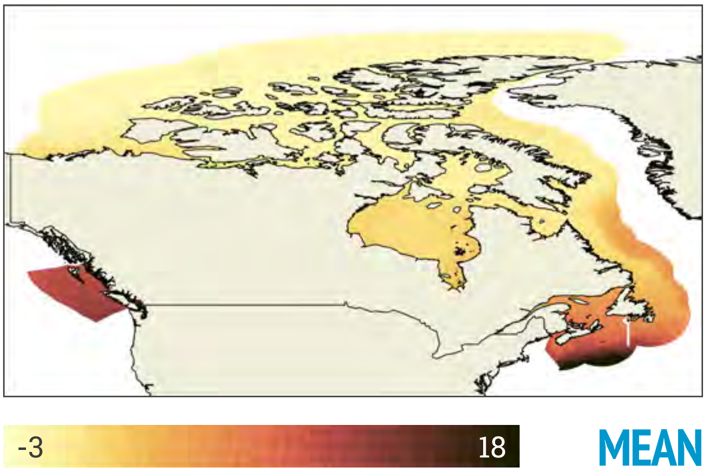
CANADA
OCEAN

OCEAN IN CANADA

Canada's marine exclusive economic zone (EEZ) is characterized by polar to temperate coastal waters, which host a large variety of ecosystems such as coral reefs, eelgrass and kelp beds. In particular, coastal systems can be divided into three main areas, namely Arctic, Atlantic and Pacific marine regions.

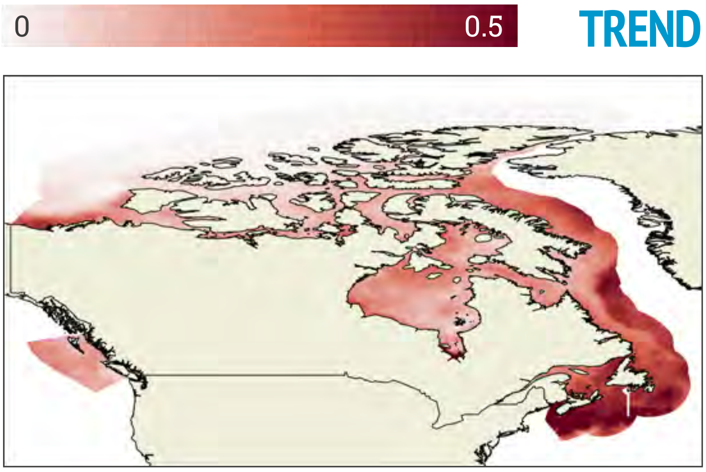
CURRENT CLIMATE CONDITIONS

Mean sea surface temperature reflects the different climate regimes, from the cold waters in the polar northern coasts to the temperate areas in the Atlantic and Pacific.



SEA SURFACE TEMPERATURE

Celsius degrees / Over 1991-2020

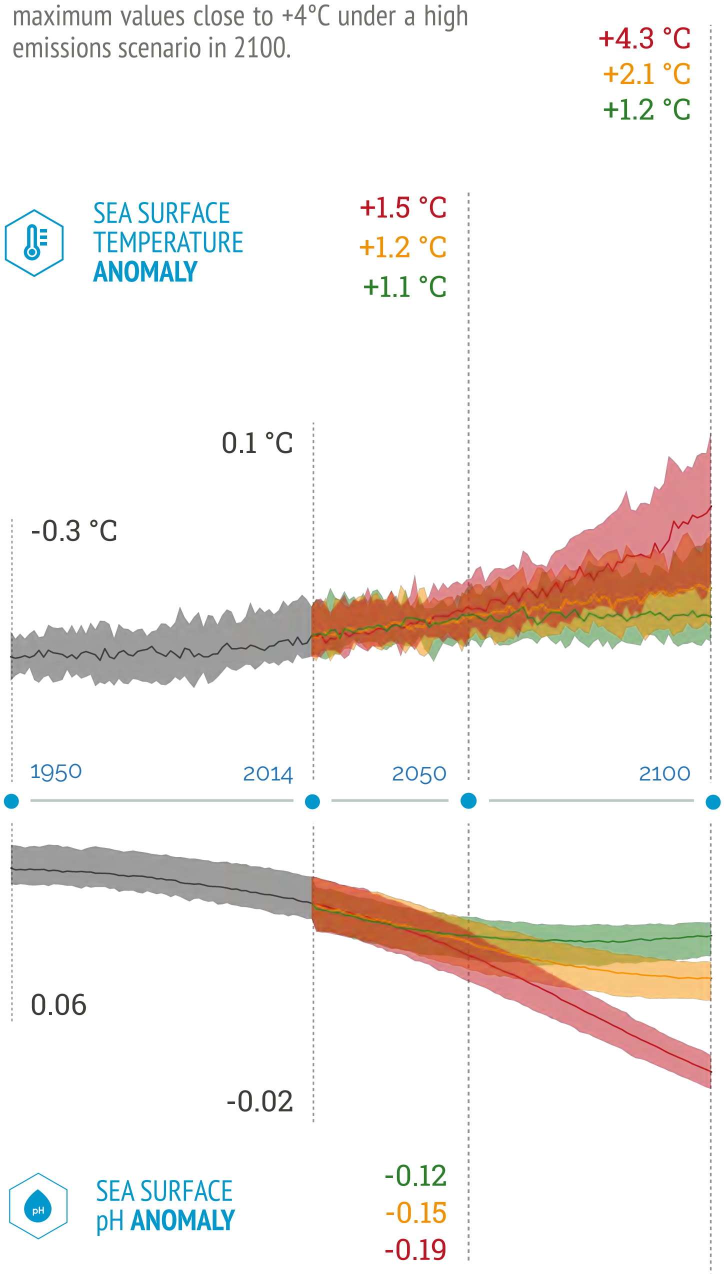


Surface temperature trends indicate a general warming of 0.2°C per decade in all marine areas, with increased gains in the southeastern regions.

FUTURE PROJECTIONS

Projected annual changes within the marine EEZ for the two most significant marine indicators of climate change: sea surface water temperatures and pH.

Seawater temperature changes are in line with the definitions of each scenario, with maximum values close to +4°C under a high emissions scenario in 2100.



Seawater surface pH becomes more acidic in all scenarios, closely reflecting rising atmospheric CO_2 concentrations, and only a low emissions scenario leads to a stable condition by 2100.

ECOSYSTEM INDICATORS AT 2050

Regional changes in key marine ecosystem indicators under projected future scenarios by mid-century (2036-2065) with respect to present climate conditions (1985-2014).


Arctic


Atlantic


Pacific

Temperature regulates the metabolism of marine organisms determining which habitats remain suitable. Excessive warming will likely push ecosystems beyond tolerance thresholds.

pH represents the acid/base status of marine waters, where a decreasing pH reflects the acidification of the ocean due to increased absorption of atmospheric CO_2.

Oxygen is fundamental to sustain marine life and its reduction can have a large impact on coastal ecosystem services including fisheries and aquaculture.

Chlorophyll is an indicator of the biomass available at the base of the marine food web supporting all ecosystem productivity.

	Arctic	Atlantic	Pacific
Temperature	-0.29°C	7.48°C	10.64°C
🟥	+1.22 °C	+1.82 °C	+2.35 °C
🟧	+0.89 °C	+1.75 °C	+1.83 °C
🟩	+0.79 °C	+1.59 °C	+2 °C
pH	8.09	8.1	8.07
🟥	-0.2	-0.18	-0.17
🟧	-0.16	-0.14	-0.13
🟩	-0.13	-0.11	-0.1
Oxygen	368.55 mmol/m^3	309.34 mmol/m^3	287.77 mmol/m^3
🟥	-2.37 %	-3.66 %	-4.53 %
🟧	-1.21 %	-2.87 %	-3.45 %
🟩	-0.83 %	-2.4 %	-3.17 %
Chlorophyll	0.26 mg/m^3	0.48 mg/m^3	0.48 mg/m^3
🟥	-5.7 %	-10.21 %	-6.72 %
🟧	-4.94 %	-3.12 %	-5.25 %
🟩	-14.07 %	-17.29 %	-8.61 %

FISH CATCH POTENTIAL

Fish catch potential is an estimate of the maximum fish catch achievable given the marine resources available over a sustained period. It is linked to the concept of maximum sustainable yield, meaning the maximum amount of fish that can be extracted from a system without causing a collapse in fish populations.

It is a characteristic of the natural system, which is substantially different from realized catch, and a direct result of the fishery policy in place.

Fish catch
percentage
change

2050

🟥 0.0%

🟩 -1.6%

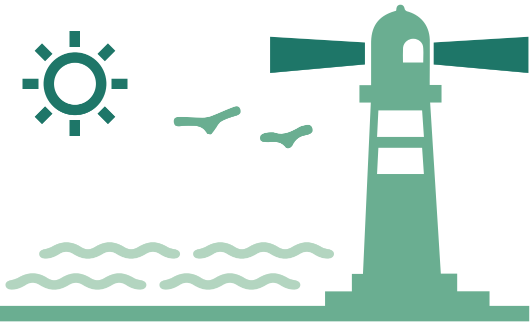
ANALYSIS DETAILS

All datasets were analysed using only data from within the marine EEZ and therefore excluding overseas territories, detached islands and any disputed or joint territories with other nations. In the assessment of current climate conditions, seawater surface tempererature data was obtained using satellite observations distributed in the framework of ESA Climate Change Initiative.

Future projections of marine indicators are represented by the combined analysis of results from 15 different Earth System models participating in the Coupled Model Intercomparison Project Phase 6 (CMIP6). These models include new and better representations of physical and biogeochemical processes, compared to previous IPCC assessment reports.

Fish catch potential data was obtained using the FAO's technical report and refers to the best and worst case climate scenarios from the Fifth IPCC Assessment Report. These mean estimates are subject to substantial uncertainties as discussed in the original work.

CANADA
COASTS



OVERVIEW

With approximately 265,000 kilometres of shoreline, Canada has the longest coastline in the world. It ranges from resistant bedrock to gravel, sand, and mud. Permafrost (perennially frozen ground) is a significant component of much of the northern coastline. The coast is the focus of major economic activity, with most of the coastal population concentrated in the city of Vancouver, on the west coast, and smaller coastal populations on the east coast around Quebec City, Halifax and St Johns.

Shoreline Length

265,523 km

Sandy Coast Retreat at 2050

-25.8 m

CLIMATE CHANGE HAZARDS

Coastal hazards such as erosion, storm tide inundation and permanent flooding, can have strong adverse impacts on coastal regions, with loss of sandy shores, damage to settlements, infrastructure and ecosystems. Climate change can exacerbate these impacts due to rising sea levels and increasing impacts of waves and storms. With a range of shoreline types, Canada's coastal zones have varying sensitivities to projected future climates. Rising sea levels will increasingly erode beaches and flood unprotected low lying areas. Increasing temperatures may also lead to rising land levels due gravitational adjustments in parts of the country covered in permanent or semipermanent ice frost. Some parts of Canada will also experience increasing exposure to extreme weather (on the west coast) or extra-tropical hurricanes (on the Atlantic Coast).

SEA LEVEL RISE

Relative sea level rise has been observed over the past century around the coast of Canada, with a yearly average increase of approximately 1.82 millimetres per year since the 1990s. The latest IPCC projections indicate that, by 2050, global sea levels may rise between 0.18 metres, under a low emissions scenario, and 0.23 metres, under a high emissions scenario.

EXTREME SEA LEVEL

On average, one in 100 extreme sea level events are expected to rise from 2.82 metres at present day to 3.09 metres by 2050 under a medium emissions scenario.

Observed and projected sea level rise at 2050

1.81 mm/year

0.23 m

0.18 m

Current and projected extreme sea level at 2050

2.82 m

3.16 m

3.09 m

OBSERVED STORMS

Canada's coasts are exposed to both the Atlantic and Pacific wave climates. Atlantic hurricanes commonly reach Canada's coasts during the summer season, and large pacific storms, particularly in winter, drive storm surges and shoreline impacts on the Pacific coast, which, on average, experiences larger waves than the Atlantic coast.

FUTURE STORMS

The impacts of climate change on storms and waves are quite uncertain. In general, models suggest that warmer sea temperatures will cause more intense hurricanes on Canada's Atlantic coast, with a poleward shift of the areas affected. Changes in storms affecting Canada's pacific coast are also quite uncertain, with a possible decrease in the size of waves.

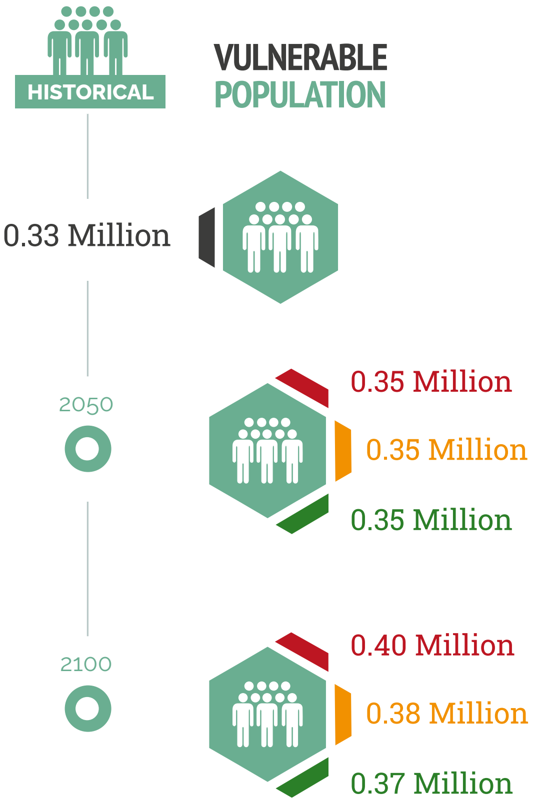
VULNERABILITY AND RISK

Most of the coastal population in Canada is concentrated in Vancouver, on the West Coast, and a few cities on the east coast including Quebec City, Halifax and St Johns. Smaller coastal towns and communities are exposed to the impacts of storms and sea level rise around the country. In Vancouver, parts of the city's low lying areas are already impacted by storm surges, effects which may be exacerbated by future sea level rise.

The risks posed by relative sea-level change vary across Canada and are concentrated in populated areas. Sea level rise and and storm surges could cost Canada in the range 53.7 and 108.7 billion USD, with significant variations in costs and impacts across coastal provinces.

Some provinces, such as Newfoundland and Labrador, may experience marginal impacts, whereas others such as British Columbia could be burdened with the highest costs. Under a medium emissions scenario, the population exposed to the annual coastal flood level is expected to increase from 330,000 to 350,000 people by 2050.

VULNERABLE POPULATION



HISTORICAL

0.33 Million

2050

0.35 Million

0.35 Million

0.35 Million

2100

0.40 Million

0.38 Million

0.37 Million

INFLUENCE OF SEA LEVEL RISE ON EXTREME SEA LEVEL

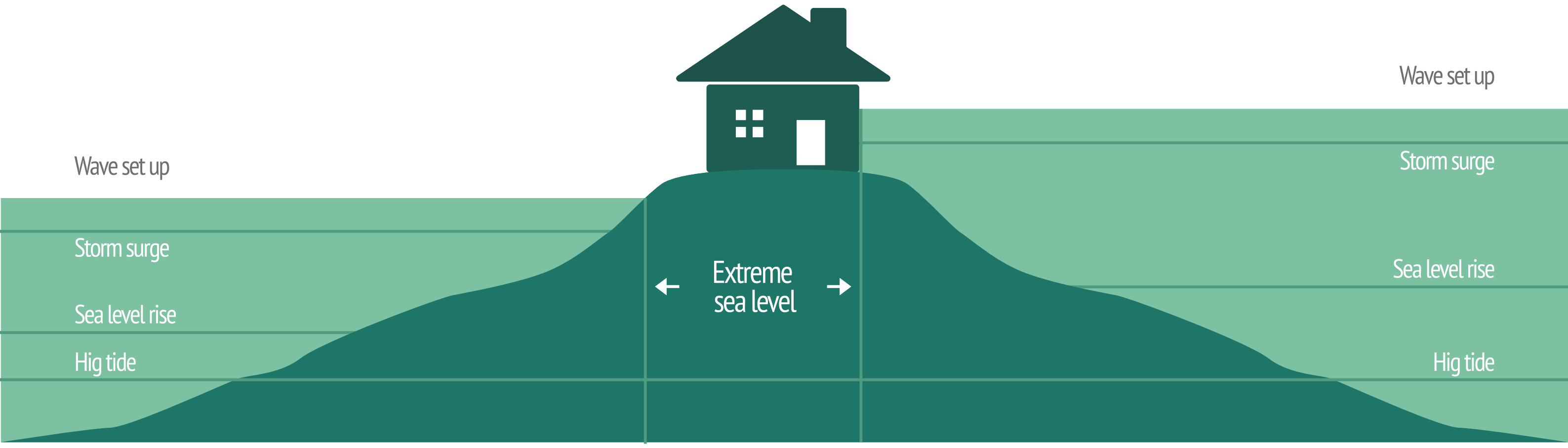
Present and future sea level rise are a consequence of carbon induced global warming causing melting ice and ocean expansion due to heat accumulation.

The extreme sea levels reported here are based on the 100-year storm surge + wave set up + sea level rise + high tide indicators. The first two parameters (storm surge + wave set up) are based on the 100-year value for the event; sea level rise is its projected value at 2050; and high tide is the absolute value of the highest tide calculated for a given locality, which won't be influenced by climate change.

+ Wave set up refers to the accumulation of water near the shore due to the presence of breaking waves.

+ Storm surge is an occasional increase in sea level driven by shoreward wind-driven water circulation and atmospheric pressure.

+ High tide is usually the highest tide reached in a given location based on tide records.



Present sea levels have risen globally by approximately 20 centimetres over the past century.

Future sea level rise is a projection based on different global warming scenarios, at approximately 100 centimetres by the end of 2100, with consequent inundation during extreme sea level events.

CANADA
WATER

OVERVIEW

Canada's fresh water supply is stored in rivers and lakes, which account for almost 12% of the total area of the country, as well as groundwater, ice, and snow.

Although the annual discharge of Canadian rivers amounts to 7% of the world's renewable water supply, aggregate measures show that approximately 60% drains in the north, where less Canadians live.

In fact, 85% of the population live within 300 kilometres of the Canada-USA border and many populated areas have restricted water supplies. Water availability is a major concern when considering water management in Canada.

Renewable internal freshwater resources

2,850
billion m^3

Renewable internal freshwater resources per capita

77,985
m^3

Even in the Great Lakes basin, the world's largest freshwater lake system, some off-lake areas in southern Ontario experience periodic and even chronic water shortage, and groundwater "mining" takes place, whereby more water is taken out of the aquifer than is being recharged.

CLIMATE CHANGE HAZARDS

Climate change can affect water resources through increasing temperatures, higher rates of evapotranspiration and altered rainfall patterns. This leads to changes in the water cycle, including decrease of snow and ice coverage, alterations of surface runoff and groundwater storage, as well as drought and flood occurrence. Climate change impacts on water resources in Canada vary regionally including shortages (droughts), excesses (floods) and associated water quality issues, depending on the season. Since 1948, snowfall has increased in the north, and decreased in southwestern Canada, whereas glacial retreat has been widespread since the late 1800s in Western Canada and since the 1920s in the Arctic, with faster rates of retreat over the past 50 years.

KEY POINT RUNOFF

Runoff is a key indicator for evaluating changes in surface water. At the national level, changes in surface runoff are varied, with significant declines occurring at 11% of localities and significant increases at 4% of localities for the 1967-1996 period, with most decreases concentrated in southern Canada.

In general, an increase in surface runoff is expected across Canada. At a country scale, an average increase in surface runoff by approximately 25% and 7% is expected respectively under a low and high emissions scenarios for the 2045-2055 period, compared to 2015-2025.

If temperatures rise by 1.5°C, 2°C or 4°C, 14%, 26.7% or 45.0% of the area of the country will likely experience an increase in runoff, while 0%, 0.9% and 9% of the surface of the country will likely experience a respective decrease in runoff.

2050

Changes in annual runoff
% of change

+7.3%

+25.2%

2050

Runoff increase
% of area

+45.0%

+14.0%

KEY POINT DROUGHTS

For the Canadian boreal zone as a whole, several regions experienced significant drying between 1951 and 2010, but there were also some areas with significant wetting. The Prairies is the one with the greatest frequency of drought in the country: due to a severe drought that occurred in 2017, crops were affected with poor germination, stunted growth and early maturation. Drought resulted in poor pasture production and unreliable water supplies. In 2021 severe droughts have impacted numerous areas of southwestern Canada.

With expected increases in average temperature across all seasons according to climate models, drought risk is expected to increase in many regions of the country. Current climate models suggest that the southern Canadian Prairies and the interior of British Columbia will be at a higher risk of drought in the future and as temperatures rise, the threat of drought will increase across many regions of Canada.

2050

Severe drought likelihood increase
% of change

+4.6%
+3.7%

2050

Hydrological drought frequency
% of change

+11.0%
+6.0%

KEY POINT GROUNDWATER

The amount and availability of surface water influences groundwater. At the same time, groundwater plays an important role in sustaining base flow for many Canadian rivers. There are marked regional differences in groundwater recharge estimates across the Canadian landmass, with the potential for recharge concentrated on the wast and west coasts, where rainfall is also more prevalent.

Groundwater recharge is directly influenced by the amount of future rainfall, which is expected to decrease mainly in western Canada. Saline intrusion from sea level rise is expected to threaten groundwater reserves near the coast in numerous areas. At the country level, a +2.7%, +12.4% and +14.7% change of the annual groundwater recharge for the period 2045-2055 compared to the timeframe 2015-2025 is expected respectively under low, medium and high emissions scenarios.

2050

Groundwater Recharge
% of change

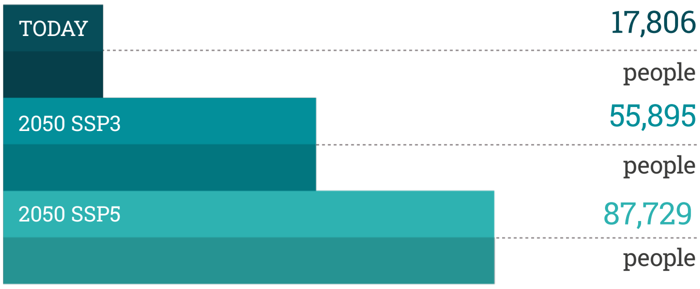
+14.7%
+2.7%

KEY POINT FLOODS

Flash floods can be extremely dangerous and several notable events have occurred in Canada. In the spring of 2013, flooding affected the southern quarter of the state of Alberta, including the city of Calgary. As many as 100,000 people had to be evacuated from the area when the Bow River watershed experienced above-average spring runoff and rainfall, with four people drowning. In Calgary alone, 3,000 buildings were flooded with infrastructure severely damaged.

Severe thunderstorms over the prairies have produced some of the highest rainfall rates and largest local floods in Canada (such as in Calgary, Edmonton and Lethbridge, and Alberta in 2014). Canada may experience an increase in the risk of flooding in many regions in winter due to less ice cover, more precipitation events, and more frequent winter thaw. Changes in the population exposed to floods are expected, with an increase from around 18,000 in the present day to 56,000 under SSP3 and 88,000 under SSP5 by 2050.

POPULATION AFFECTED BY RIVER FLOODS

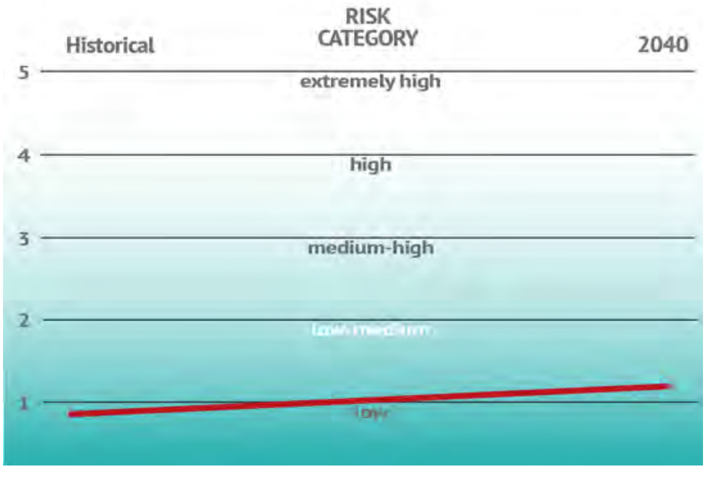


RISK INDICATORS

The water stress index summarises current and future water related vulnerabilities and risks at the global level. Scores are based on the ratio of total water withdrawals, including agriculture, industrial and human consumption, to available renewable surface and groundwater supplies.

WATER STRESS

Canada's water stress level is considered low for the recent past (1960-2014 average), but it is expected to increase in the near future (2030-2050) based on climate change projections.



CANADA
AGRICULTURE

OVERVIEW

Canada is one of the largest agricultural producers and exporters in the world. As with other developed nations, the proportion of the population employed and economic contribution of this sector compared to national GDP fell considerably over the 20th century. However, it still remains an important part of the economy.

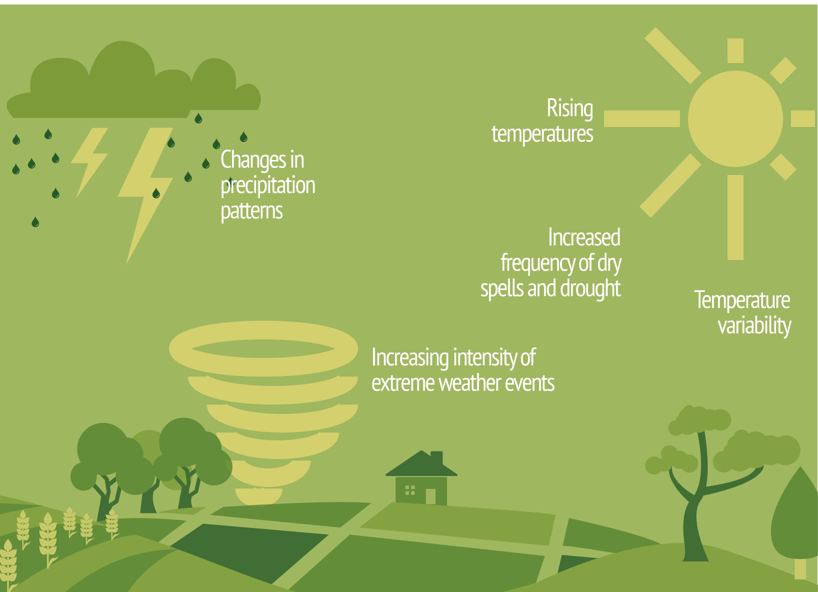
Canada is among the top global producers for canola, oats, milling wheat, flaxseed, dry peas, lentils, and maple syrup, among others. One in eight Canadians works in the agriculture and agri-food sector, which employs over 2 million people between farms, processing plants, boardrooms, laboratories and beyond. A wide range of agricultural practices are used in Canada, from the sprawling wheat fields of the prairies to the summer produce of the Okanagan valley. Only a small fraction (7%) of Canada's land area is suitable for farming; most of which is found in Western Canada.

32.2 Mt	Wheat
13.9 Mt	Maize
20.3 Mt	Rapeseed
7.4 Mt	Soybeans
0.4 Mt	Apples

	Added Value of Agriculture, Forestry and Fishing	Share of Agriculture Value added in Total GDP	Agricultural land	Area Equipped for Irrigation
2000	22,476 USD Million	1.9 %	41,138 Thousand HA	1,145 Thousand HA
2018	31,293 USD Million	1.9 %	38,857 Thousand HA	1,378 Thousand HA

EXPEXTED IMPACTS ON AGRICULTURE PRODUCTIVITY

Rising temperatures, reduction in average annual precipitation, and intensification of extreme events such as heat waves and drought, affect production variability with a tendency towards yield reduction for many cultivated species, accompanied by a probable decrease in food quality. Crops respond to increases in temperatures with changes in duration of the growing season, early appearance of phenological phases and potential shifts of cultivation areas toward higher latitudes and altitudes for better growing conditions. However, impacts vary significantly depending on the geographical area and specific crops in question.



CROP PRODUCTIVITY

Crop productivity refers to the harvested yield of a crop per unit of land area. It is strongly influenced by climate and other environmental and management factors.

Climate change is expected to have an impact on the productivity of several major crops, although this may in part be offset by the fertilizing effect of higher CO_2.

Impacts are estimated using a range of model projections based on low to high emission scenarios and reported as percentage changes between the 30-year average around the historical period and the 30-year average around 2050.

3.3 6.9 (0.2)% 8 (-2.1)%
Wheat
tons / ha

2.2 30.9 (18)% 37.2 (na)%
Rapeseed
tons / ha

9.5 12.9 (9)% 14.6 (6)%
Maize
tons / ha

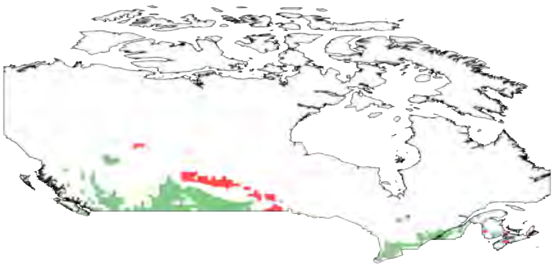
2.8 36.3 (28.2)% 46.7 (25)%
Soybeans
tons / ha

2050

Productivity change with (without) the CO_2 fertilization effect. Estimates assume sufficient water and nutrient supplies, and do not include impacts of pests, disease, or extreme events.

CHANGE IN WHEAT

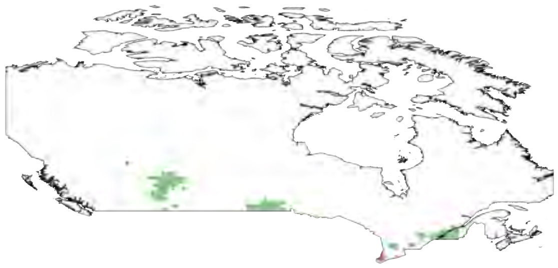
− = +



Longer frost-free seasons, increases in growing degree days, and even increased atmospheric CO_2 can, in theory, lead to better crop yields and productivity. However, an increase in climate variability and the frequency of extreme events would adversely affect the agricultural industry. More pronounced summer droughts may limit a growth in productivity in Canada's prairie provinces.

CHANGE IN MAIZE

− = +



Rapeseed, soybean, maize and even wheat production are expected to undergo increases in productivity under future scenarios. However, these benefits may decline with warming above 2.5 °C. Spring wheat may replace winter wheat throughout most of the prairies and soybean may replace canola in southern areas.

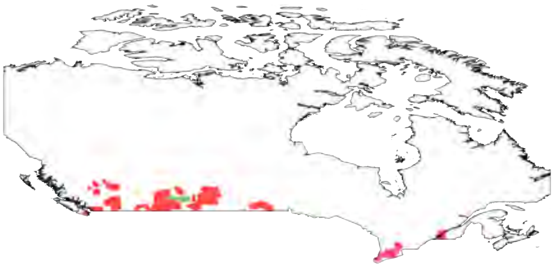
ADAPTATION IN AGRICULTURE AND WATER RESOURCES

Canada's agricultural regions will likely see both drier summers and increased winter and spring precipitation. Projections show that although much of southern Canada will be drier overall in the summer, it could also face an increase in short-lived but very intense rainfall events. Farmers may have to deal with both too much water during the seeding season and too little water during the growing season.

Climate change may induce an increase of 25 to 30% of water requirements for crops. Semi-arid regions may require supplemental irrigation during summers. Although availability of water supplies is extremely consistent and covers agricultural needs, irrigation development can cause increases in relevant energy costs and lead to further emissions by the agricultural sector.

CHANGE IN WATER DEMAND

− = +



Agriculture
Water Demand
% of change

+25.7%
+29.4%

2050

The use of high-efficiency irrigation systems can effectively reduce additional energy demand and costs for pumping and distribution of water in agriculture.

CANADA FORESTS

FORESTS IN CANADA

Canada is one of the most forested countries in the world and Canadian forests contain huge economic, cultural, and environmental value.

Boreal hardwood forests are largely distributed, and over 40% of primary forests are still intact, acting as a very precious source of biodiversity.

1990

348 Mln ha
Million hectares
Forested area

210 Tons/ha
Tons of Carbon per hectare
Carbon stock

FORESTED AREA AND CARBON STORAGE

Nearly 40% of Canada is covered in forests with a stable trend over recent decades. Canadian forests store an enormous amount of carbon in living systems and soil, playing a key role in the country's emissions balance. According to the Canadian Forest Service, although managed forests used to act as a crucial carbon sink, recent natural disturbances have reversed this condition making them a carbon source: releasing more carbon than they accumulate on a yearly basis.

2020

347 Mln ha
Million hectares
Forested area

208 Tons/ha
Tons of Carbon per hectare
Carbon stock

FOREST PRODUCTIVITY

Forest productivity, or Net Primary Production, is the net carbon captu- red by plants. It is the difference between the carbon gained by Gross Primary Production - net photosynthesis measured at the ecosystem scale - and carbon released by plants' respiration. It is expressed per unit land area.

2050

Productivity anomaly
Tons of Carbon per hectare per year

+0.56

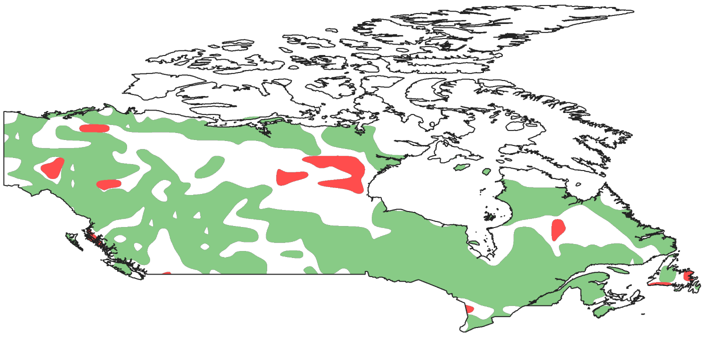
+0.45

Weak increase expected in most of the country. Strong in the northwest.

- \+ Fertilizing effect of increasing atmospheric CO_2
- \+ Melting permafrost
- \+ Lengthening of growing period

Decrease expected on the northern boundary of the distribution ranges (Nunavut), and in large areas of residual boreal primary forest.

- \+ Spread of dangerous insect outbreaks



KEY SPECIES UNDER CLIMATE CHANGE

SHIFTING
BOREAL
Boreal forests are moving northwards too fast

DECREASING PRODUCTION
CONIFERS
Strong decrease in biomass production of dominant boreal species (mid to late successional conifers)

DIEBACK
ASPEN
Increased aspen dieback in the Prairies

INCREASING
COLONIZER SPECIES
Increasing abundance of colonizer temperate species

FIRES IN CANADA

Fire is a structural ecological process that provides several types of ecosystem services and impacts on socio-ecological systems, including human health, carbon budgets, and climate change. Changes in global fire activity are influenced by multiple factors such as land-cover change, policies, and climatic conditions. Fire also releases large quantities of greenhouse gases into the atmosphere, contributing to a vicious cycle.

During the last two decades, the total forest area affected by fire was approximately 41.8 million hectares.

BURNING
41.8 MILLION HECTARES OF FOREST

EMITTING
56.7 TERAGRAMMES OF CARBON PER YEAR

FOREST FIRE EMISSIONS CONTRIBUTED TO 90% OF TOTAL FIRE RELATED CARBON EMISSIONS

COSTING
417 MILLION USD IN ANNUAL SUPPRESSION COSTS (1970-2009)

FUTURE BURNED AREA

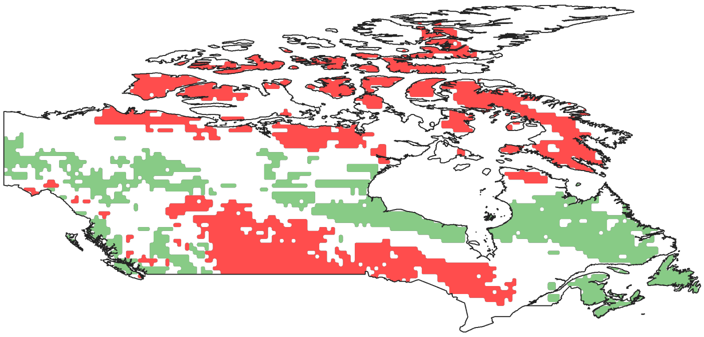
Under a low emissions scenario, models project a generalized increase in burned area over the Artic tundra and mid boreal forests and prairies. This trend is emphasized under a medium emissions scenario, particularly over boreal plains and the western shield. Burned areas may decrease in some taiga forest areas around Hudson bay and in eastern regions.

Burned Area
km^2 per year

2050

+1,238

+943



🟩 Decrease in burned areas for a low emissions scenario

🟥 Increase in burned areas for a low emissions scenario

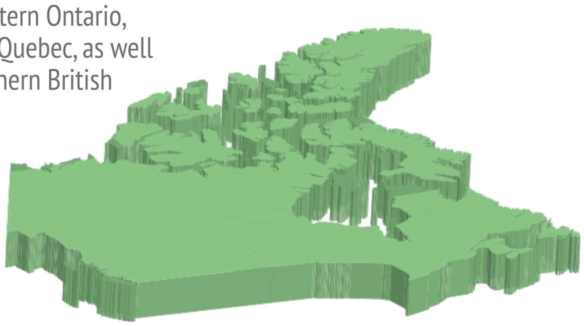
+ Prolonged fire season due to rising temperatures and fuel dryness

+ Increase in the proportion of days with unmanageable fires across northern and eastern boreal forests.

WHERE DO FIRES OCCUR?

Lightning-caused fires are more common in British Columbia, Ontario and Alberta.

Fire occurrence is mainly human-caused in high population density areas such as central and eastern Ontario, south-western Quebec, as well as central-southern British Columbia.



The most affected areas are the Taiga plains and the Taiga Shield down through the Boreal eco-zones.

VARIATION OF SPECIFIC FIRE INDICATORS

% of change
Crown fire days in Eastern Canada
2090
+47%
+9%

% of change
Crown fire days in Western Canada
2090
+45%
+24%

% of change
Average annual fire suppression cost
2041-2070
+58%
+39%

FUTURE FIRE EMISSIONS

Fire emissions follow a similar spatial pattern to burned area with important changes over eastern and western parts of the country under both low and medium emissions scenarios.

Fire Carbon emission
Teragrams of Carbon per year
2050
+44.2
+33.9

CANADA
URBAN

OVERVIEW

A 20% growth in Canada's population is expected by 2050, with the country becoming increasingly more urbanized.

Over half the urban population live in cities with more than 1 million residents, whereas 25% live in cities with fewer than 300,000. The number of big cities and percentage of urban populations residing there are not projected to change much by 2035.

Built up areas cover 0.16% of Canada (15,717.89 square kilometers).

OVERVIEW OF KEY CLIMATE IMPACTS IN URBAN AREAS

With climate change, Canadian cities will face more frequent and intense heat events; increased incidences of poor air quality; short-duration, high-intensity rainfall events; wind storms; wildland-urban interface fires; coastal erosion; storm surge flooding; and decreased water quality.

HEATWAVES AND HEAT STRESS

Cities are subject to higher temperatures because of the Urban Heat Island (UHI) effect. Built up areas absorb solar radiation during the day and release the heat at night, warming the surrounding air. This is a result of several factors including reduced natural landscapes, building material properties, urban geometry and waste heat. Canada is warming at twice the rate of global mean temperature increase. From 1948-2016 the mean annual temperature increased by 1.7°C for all of Canada, and 2.3°C for the northern portion of the country.

Hot days (max temp > 30°C) are uncommon north of 60° latitude, but have increased annually by about 1-3 days at several stations in southern Canada from 1948-2016. Hot nights (min temp > 22°C) have increased at a few stations in southern Ontario and Quebec.

Future scenarios of **+1.5°C**, **+2°C** and **+4°C** mean temperature increse indicate that the frequency and duration of heatwaves will increase for the entire country. This will lead to an increase in the number of cooling degree days.

Population in Urban Areas

2020
30,670,064

2050
39,233,850

Graphs refer to data provided by United Nations, Department of Economic and Social Affairs, Population Division (2018). World Urbanization

Urbanization Rate

2020
81.6%

2050
87.3%

2050

Cooling Degree Days
% of change

+970.7%
+248.1%
+135.4%

2100

Heatwave frequency
% of change

+82.7%
+26.5%
+14.0%

2050

Heatwave duration
% of time

+1,306%
+181%
+63%

HEAT, HEALTH AND AIR POLLUTION

Heat related health impacts from increasing air temperatures in urban areas are furthermore accentuated by air pollution. Wildfires, which are projected to increase in frequency, contribute to lower air quality at the wildland–urban interface. Particulates (especially PM2.5) from wildfire smoke can affect air quality and health across great distances.

2017

Population exposed to air pollution

0%

COASTAL FLOODING

Canada has the most extensive coastline in the world, fronting on the Atlantic, Arctic and Pacific Oceans. Coastal communities in Canada are facing risks including damage to coastal infrastructure, property, and people from inundation, saltwater intrusion and coastal erosion due to sea level rise and storm surges.

The different landscapes and climates of the west coast, north coast and east coast regions influence their relative vulnerability to sea level rise and coastal flooding. Changes in sea-level will vary significantly in the future, and in the areas where sea levels are rising, the frequency and magnitude of storm-surge flooding will increase.

Projected sea level rise

2050

0.23 m

0.18 m

2100

0.77 m

0.38 m

EXTREME PRECIPITATION EVENTS

The amount of precipitation varies widely across Canada, decreasing from south to north. Recent trends show that annual mean precipitation is increasing, on average, with larger percentage increases in northern Canada.

Annual precipitation and winter precipitation are projected to increase accross the country in the 21st century, with larger percentage changes in northern Canada. Summer precipitation is projected to decrease in southern Canada.

2050

Runoff increase
% of area

+45%

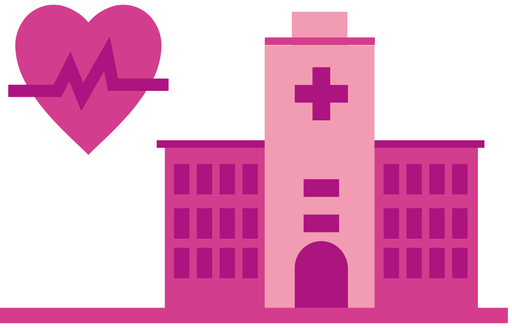
+27%

+14%

SURFACE SEALING AND FLOODS

Heavy precipitation in cities is problematic due to the high level of sealed surfaces. Soil sealing increases run off and reduces the amount of water absorbed by soil. Where there are large amounts of impervious ground cover, short duration extreme rainfall events can lead to increased flooding, even resulting in flash floods.

CANADA
HEALTH



OVERVIEW

Due to its large landmass, the climate-related impacts on the wellbeing of Canadians varies widely from region to region. Future climate change is likely to increase many health risks, including that of infectious diseases. The impacts of climate change on health are increasing rapidly, and at the same time, the health and social systems necessary to mitigate these impacts are often unable to meet the needs of those most vulnerable to climate-related health hazards.

HEAT RELATED MORTALITY

Climate change related health risks in Canada include direct and indirect illnesses and deaths related to poor air quality, water and food borne contamination, changing patterns of diseases spread by animals, ticks and insects. Extreme weather events, including extreme heat events and urban heat islands due to the increase in temperature extremes and the risk of heat-related illness, will increase while exacerbating cardiovascular disease, diabetes, and respiratory diseases. Still, cold exposure in some places will be reduced. Under a high emissions scenario, heatwave-related excess deaths will increase by 455% in Canada.

Under a medium emissions scenario, the increases in heatwave-related excess mortality will be around 293%. In 2018, there was a 58% increase in heat-related deaths in Canada compared to a 2000 to 2004 baseline. 38.5% of heat-related mortality during 1991 to 2015 can be attributed to human-induced climate change.

IMPACTS ON LABOUR

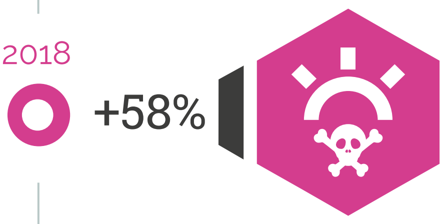
Labour is directly affected by changes in environmental conditions. Warming affects both the number of hours worked (labour supply) and on the productivity of workers during their working hours (labour productivity). Both labour supply and productivity are projected to decrease under future climate change in most parts of the world, and particularly in tropical regions.

Parts of sub-Saharan Africa, south Asia, and southeast Asia are at highest risk under future warming scenarios. Future climate change will reduce global total labour in the low-exposure sectors by 18 percentage points and by24.8 percentage points in the high-exposure sectors under a 3.0°C warming scenario

Canada is one of the few countries projected to experience positive impacts on labour productivity due to climate change. In Canada, there was a 4.4% gain in potential hours of labour in the agriculture and construction sectors in 2019, compared to a 1990s baseline. Total labour in Canada is expected to increase by 0.22% under a low emissions scenario and by 0.36% under a medium emissions scenario.

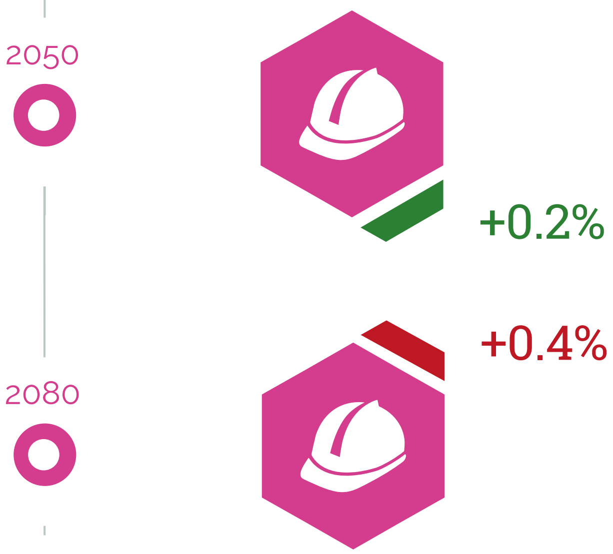
Heat-related mortality

% change with respect to 2000-2004



Impact on total labour

% change with respect to 1986-2005 baseline



CLIMATE CHANGE AND DENGUE

Dengue has spread throughout the tropical world over the past 60 years and now affects over half the world's population. Globally, vectorial capacity for both dengue vectors (A. aegypti and A. albopictus) has been rising steadily since the 1980s, with nine of the ten highest years occurring since 2000.

Climatic stressors are one important driver of the current distribution and incidence of dengue. Climate change is likely to expand the geographical distribution and suitability of several vector-borne human infectious diseases including dengue. The risk of dengue transmission is increased by warming climates, as the growth and development of mosquitoes are significantly influenced by temperature, precipitation, and humidity.

CLIMATE CHANGE AND ZIKA

Zika virus has spread to at least 49 countries and territories since 2013. Climate change impacts on transmission suitability risk have increased over the years and future warming over 1.3 billion additional people could face suitable transmission temperatures for Zika by 2050.

DENGUE AND ZIKA: POPULATION AT RISK

Canada is currently at low risk of dengue and Zika transmissions. Climate change is likely to have both direct and indirect impacts on the burden of West Nile fever, dengue, chickungunya fever, malaria, leishmaniasis, tick-borne encephalitis, Lyme borreliosis, Crimean Congo haemorrhagic fever, spotted fever rickettsioses, yellow fever, Zika, and Rift Valley fever. However, these risks will increase due to future climate change.

Warming temperatures due to climate change are improving the suitability conditions for the spread of ticks that carry Lyme disease in Canada. Under a low-emissions future, additional cases of Lyme disease will increase to around 8,500 annually by mid-century compared to about 600 cases per year.

CLIMATE CHANGE AND MALARIA

Cases of Malaria are rare in Canada; however, climate change will likely increase the occurrence of temperature conditions suitable for malaria transmission. 6.4% of the Canadian population will be at risk of malaria under a low emissions scenario in 2050, whereas 12.5% will be at risk under a high emissions scenario.

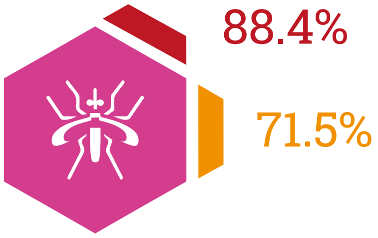
POLLUTION AND PREMATURE MORTALITY

In 2019, 14,600 premature deaths were associated with ambient air pollution exposure in 2015.

Dengue suitability

% of population at risk

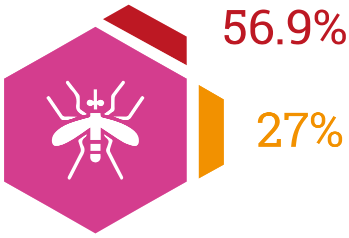
2050



Zika suitability

% of population at risk

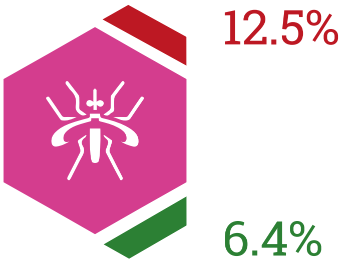
2050



Malaria suitability

% of population at risk

2050



CANADA ENERGY

ENERGY SYSTEM IN A NUTSHELL

With over 75% of electricity generated from non-emitting sources the Canadian electricity system has one of the lowest carbon contents in the world, although fossil fuels dominate the overall energy mix.

In 2019 a carbon tax of was introduced, with plans to increase it gradually. Canada is one of the top world energy producers, with the highest energy supply per capita. Most fossil fuels produced are exported.

0.17
ktoe/US$
Energy intensity

5.2%
AC Share in electricity consumption

CLIMATE CHANGE TODAY

HYDROPOWER

Changes in temperatures and rainfall have impacted surface water levels in Canada, which can have a direct impact on the capacity of hydroelectric power generation.

STORMS

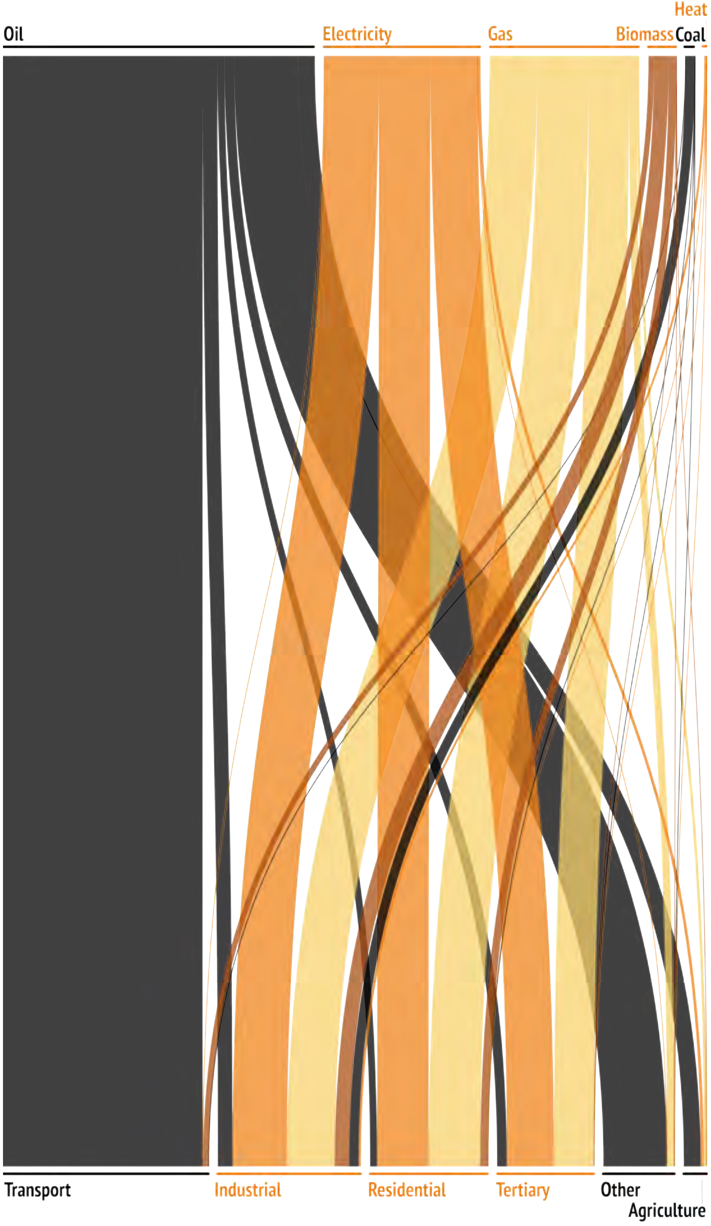
Severe storms, hurricanes and floods have caused major power outages and substantial damage to energy infrastructure, for example Post Tropical Storm Arthur in 2014, the USA Canada ice storm of 2013 and the 2013 flash flood in Toronto.

VULNERABILITY

The energy infrastructure in Canada is ageing and a large proportion will need replacement or updating by 2050. Much of the infrastructure is highly vulnerable to climate risks, as it was designed based on outdated weather-related assumptions.

ENERGY SUPPLY

Canada's total primary energy supply energy mix is dominated by natural gas and oil (both 35% in 2019), followed by hydropower (nearly 11%, and historically a steady and major contributor). Nuclear is also relevant (8% of total primary energy supply in 2019). Coal use is declining, accounting for only 5% in 2019. Renewable sources, including hydro, account for 16% of total energy supply in Canada.



ENERGY DEMAND

Energy demand in Canada is driven mainly by transport (33%), the majority of which for road transport, followed by residential (22%) and tertiary (13%). The agricultural and forestry sector demand is negligible. Industry is also responsible for most of the non-energy use of fuels (9%). Air conditioning accounts for approximately 10% of final residential electricity consumption.

FUTURE ENERGY DEMAND

In Canada, hotter summers will increase peak demand, particularly in large cities due to the urban heat island effect. Increasing energy demand in the USA could also result in an increase in Canadian electricity exports.
Overall, total energy demand is projected to decrease, as the decrease in heating needs more than outweighs the increase in cooling needs, resulting in a net decrease in energy demand slightly in excess of 281 PJ (78 billion KWh) by 2050 under a medium emissions scenario.

Net change in energy demand due to changes in HDD/CDD

Billion KWh

2050

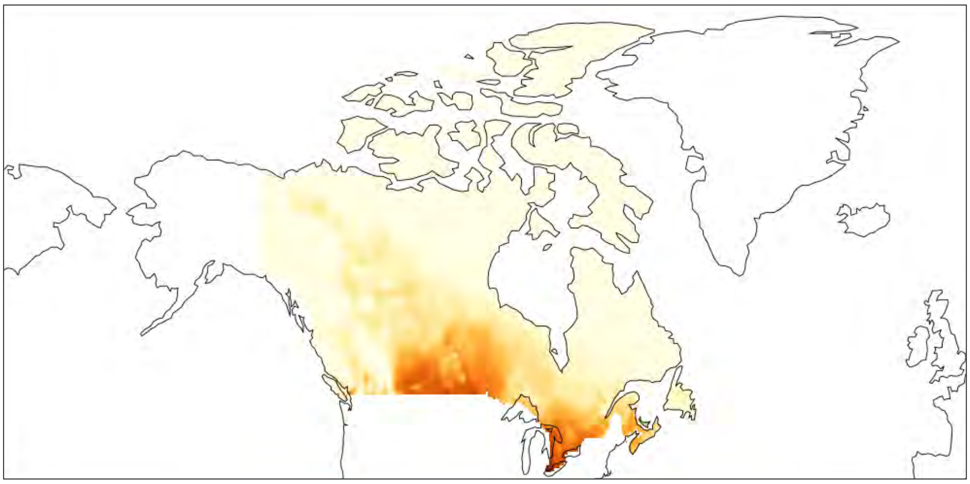
- 78.10

COOLING NEEDS

Cooling needs will increase summer demand in many regions. The effects will be most severe in the south eastern and Prairie regions, while northern regions remain mostly unchanged.

The increase in cooling needs is expected to be less than the decrease in heating needs across the country, resulting in a net decline in energy demand.

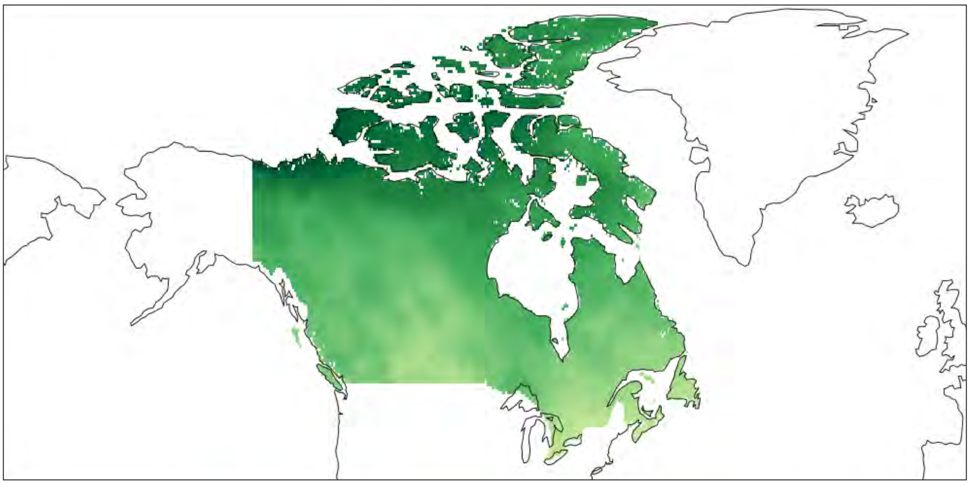
COOLING DEGREE DAYS



HEATING NEEDS

Heating needs are expected to decline drastically all over the country and in particular in the northern regions, outweighing the increases in summer cooling needs expected in the south, along the border with the USA.

HEATING DEGREE DAYS



FUTURE ENERGY SUPPLY

The future configuration of the Canadian energy mix is likely to be determined by the evolution of climate mitigation policies and hence is outside the scope of this report. However, given that Canada has established targets to reduce CO_2 emissions by 30% of 2005 levels and achieve net-zero emissions by 2050, it is likely to result in a reduction in the relevance of fossil fuels and their vulnerabilities, while carbon-free sources and their vulnerabilities will prevail.

Change in Hydropower generation

% of change

2050

-6.41%

-5.79%

EXPECTED IMPACTS OF CLIMATE CHANGE

Studies do not agree about the future of hydropower generation in Canada. They range from average production gains of 7.1% under a low emissions scenario and 4.4% under a high emissions scenario, to decreases by -5.8% and 6.5% under the same two scenarios.

CANADA
ECONOMY

OVERVIEW

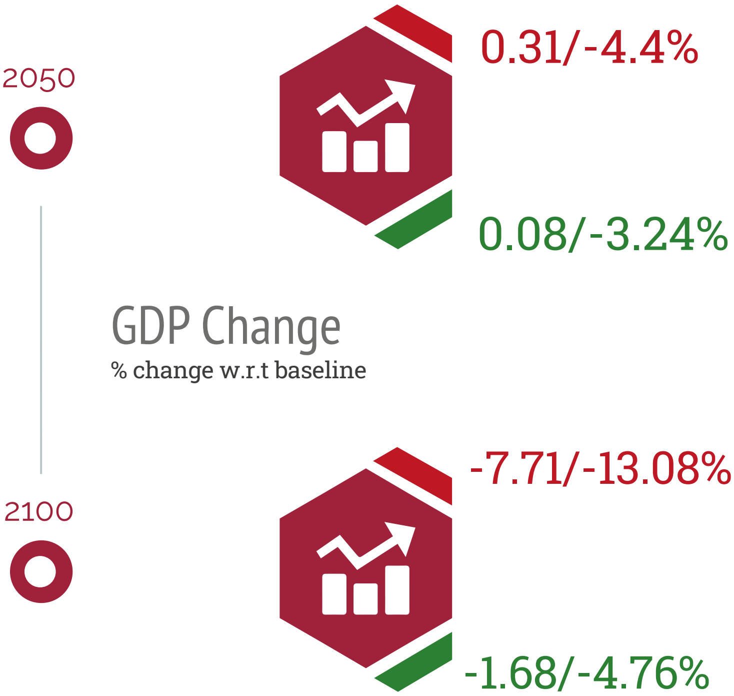
Canada ranks 11th in terms of GDP in the G20 group. The COVID 19 crisis impacted the economy, which registered a 5.4% decline in real GDP in 2020.

IMPACTS ON GDP

Climate change will have an effect on the growth rate and overall systematic economic performance of the country. In the short term and for moderate levels of warming the overall economic impacts of climate change may be slightly positive for Canada.

By mid century, a low emissions scenario is indeed associated with a 33 billion euro loss, but also to possible benefits of 0.8 billion EUR. The high emissions scenario is associated with a loss of 45 billion EUR, but also to potential gains of 3 billion EUR.

By the end of the century, impacts are expected to be unambiguously negative with losses ranging from 18 billion to 49 billion EUR under a low emissions scenario and rising to between 79 billion to 133 billion EUR under a high emissions scenario.



2050

0.31/-4.4%

0.08/-3.24%

GDP Change

% change w.r.t baseline

2100

-7.71/-13.08%

-1.68/-4.76%

SECTORAL ECONOMIC IMPACTS

IMPACTS ON INDUSTRY AND INFRASTRUCTURE

Canada's extensive coastline spreads across three marine coasts and covers 243,000 kilometers. A large majority of the population lives near coastal areas (one in six living within 20 kilometers of a marine coast) leaving them vulnerable to sea level rise and extreme weather events. Climate change is expected to increase the pre-existing risks of flooding and storms.

IMPACTS ON AGRICULTURE

Resource-based industries such as mining, agriculture, forestry, fishing and hunting are a relatively small contributors to Canadian GDP (2.1%). However, they remain an important component of foreign trade and support Canadian wealth. Being a "cold" country, the economic impacts of climate change in the agricultural sector are estimated to be slightly positive for Canada.

Under a medium emissions scenario, Canadian prairie agriculture (where over 80% of Canada's agricultural land is located) could gain between 1.14 billion CAD (0.76 billion EUR) and 1.63 billion CAD (1.08 billion EUR) annually. Relative to the annual value of the Praries' crop and animal production of 11.67 billion CAD (7.7 billion EUR), this is a substantial gain.

Despite these positive predictions, extreme weather events of recent years (2010-2016) in the Canadian Prairies, including flooding, drought and wildfire have been some of the most damaging natural disasters in Canadian history. The 2016 wildfire in Fort McMurray, Alberta cost almost 4 billion CAD (2.65 billion EUR). Climate models predict an increased risk of these events in the future.

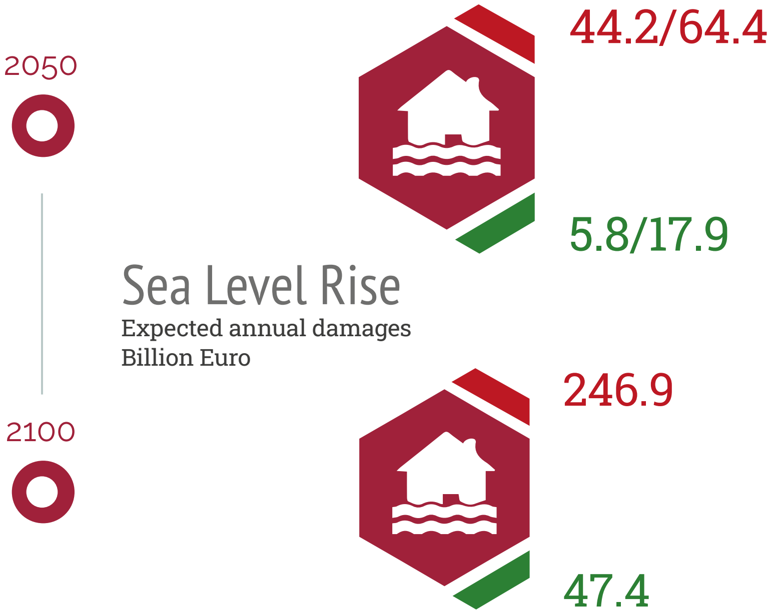
Additionally, drastic economic impacts at a community level can be masked by these aggregate analyses. Certain communities are highly dependent on natural resources for their income and costs will be much larger for these groups, for instance in Aboriginal and Arctic communities, where the subsistence economy makes up between one-quarter and one-half of their total economy.

Overall, climate change will bring both benefits and risks to Canadian agriculture. Achieving the projected benefits will depend on the extent to which farmers adapt and its effectiveness.

SEA LEVEL RISE DAMAGES

Under the current level of coastal protection, by mid century, sea-level rise and coastal flooding may cost the country 5.8 - 17.9 billion EUR and 44.2 billion EUR in terms of expected damage to assets in the low and high emissions scenarios, respectively.

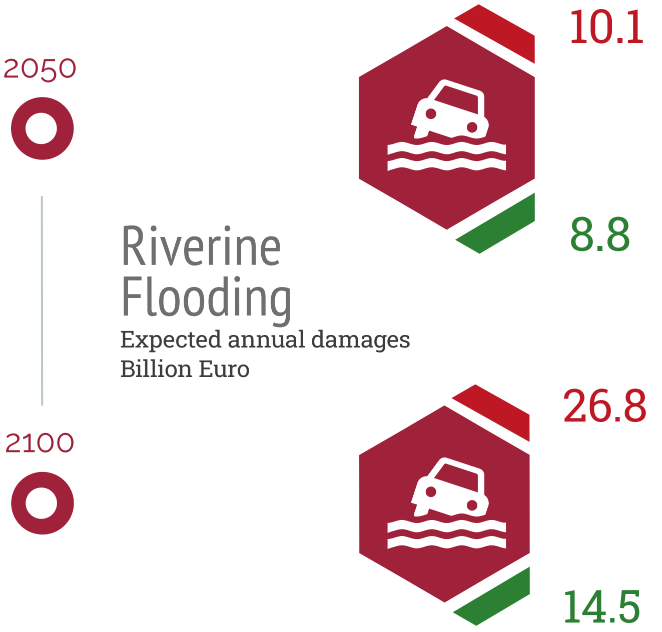
By the end of the century, expected losses can increase to between 47.4 billion and 64.4 billion EUR under a low emissions scenario and to 246.9 billion EUR under a high emissions scenario.



RIVER FLOODING DAMAGES

River flooding is projected to result in significant annual damages. By mid century these are estimated to be 8.8 billion EUR under a low emissions scenario and 10.1 billion EUR under a high emissions scenario.

By the end of the century, damages are projected to be 14.5 billion EUR under a low emissions scenario and 26.8 billion EUR under a high emissions scenario.



IMPACTS ON FORESTRY AND FISHERY

Forestry is another important sector in Canada which makes up 1.7% of national GDP, or 17 billion EUR and where 10% of the world's forest cover resides. Climate change is predicted to increase the risks of wildfires, affecting timber supply and increasing costs of fire management. Climate change could cost Canada between 25 billion CAD (16.6 billion EUR) under a low emissions scenario and 276 billion CAD (183 billion EUR) under a high emissions scenario by 2080 due to reduced timber quantities.

IMPACTS ON ENERGY

Changes in water availability will affect the capacity of hydropower generation in Canada, and could lead to substantial economic losses. Economic impacts of shifts in household and firm energy demand (see chapter on energy) are difficult to predict and will mostly lead to redistribution effects. In the case of Canada, an overall decrease in energy bills is expected due to the heavily reduced heating needs, which is expected to largely exceed any increase in cooling needs. By 2050, under a worst case climate scenario, the potential losses to hydropower generation from extremely low water levels in the Great Lakes and St. Lawrence watershed could reach 1.9 billion EUR. Severe weather such as ice storms and coastal storm surges threaten energy infrastructure in Canada, particularly in Charlottetown, PEI, and parts of Nova Scotia. A large amount of energy infrastructure is outdated and will need replacing by 2050 as it was constructed based on older weather related assumptions.

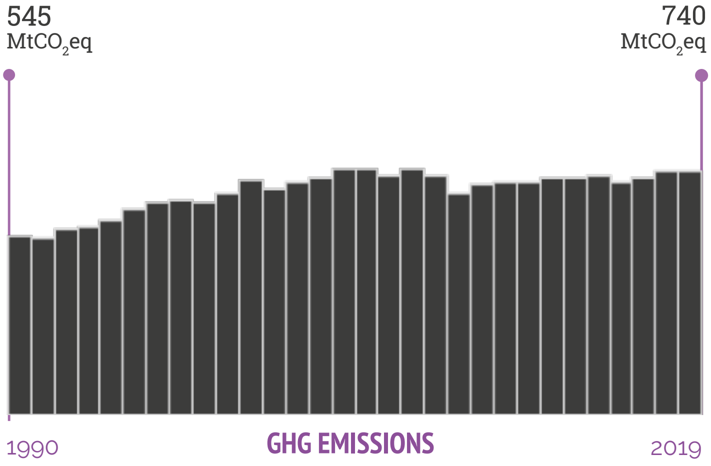
IMPACTS ON TOURISM

No exact figures are available for the economic impact on the Canadian tourism sector as a whole. However, the overall impact is expected to be positive for Canada, where higher temperatures might extend the summer season. However, a high emissions scenario could eliminate over half of the Canadian ski season by the end of the century, resulting in the loss of over 420 million CAD (278.8 million EUR). The 5 billion CAD (3.3 billion EUR) winter tourism industry is also likely to be impacted severely.

CANADA
POLICY

OVERVIEW

Canada is the 2nd largest country in the world, with a population density of 3.9 people per square kilometre. It accounts for 1.6% of global emissions and in 2018 registered one of the highest rates of GHG emissions per capita.



INTERNATIONAL COMMITMENTS

In its 2021 NDC update, Canada strengthened its emissions reduction target from a 30% reduction below 2005 levels by 2030 to at least 40-45%.

CLIMATE POLICY COMMITMENTS CHRONOLOGY

2002

KYOTO PROTOCOL - 1ST PERIOD

6% in yearly average reduction of GHG over the four year period 2008-2012, with respect to 1990 levels

2016

PARIS AGREEMENT - 1ST NDC

30% GHG reduction by 2030, with respect to 2005 levels

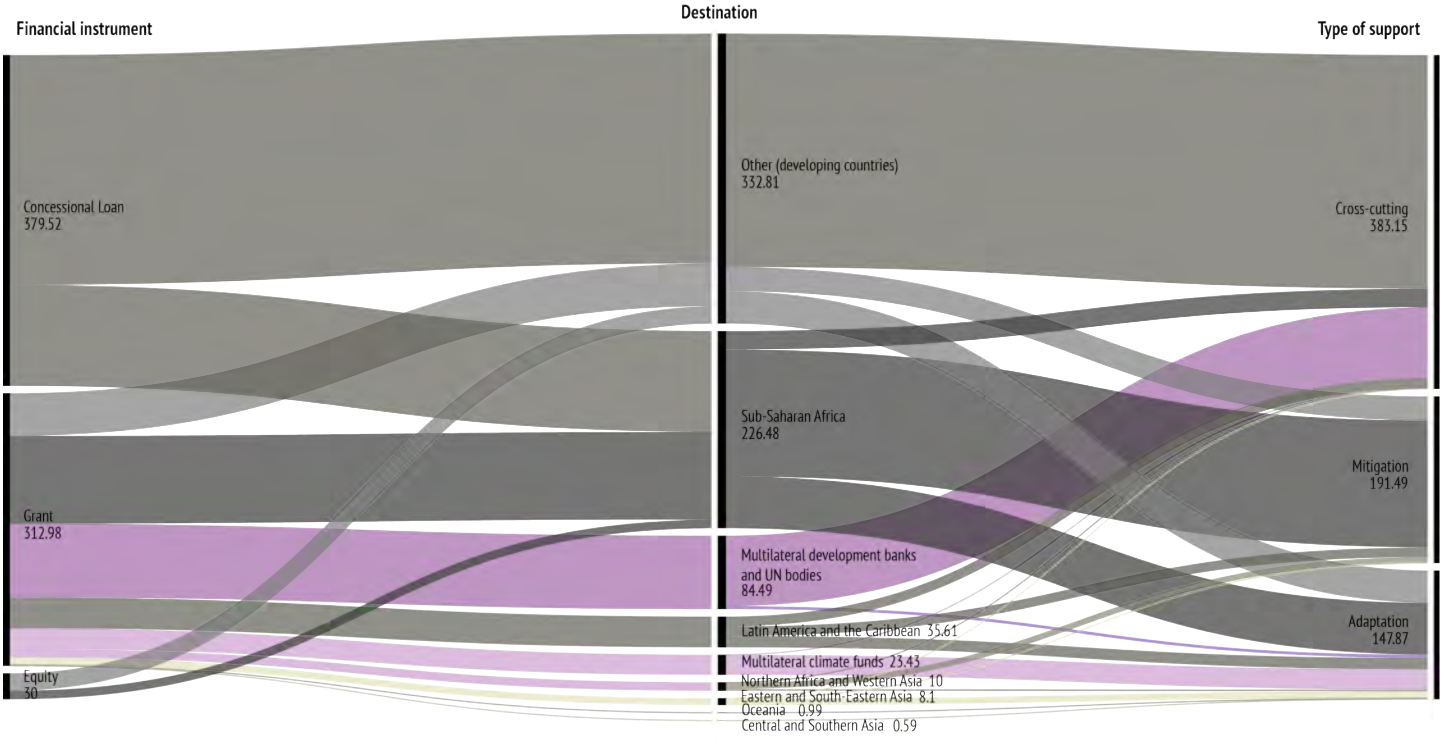
2021

PARIS AGREEMENT - NDC UPDATE

Between 40% and 45% GHG reduction by 2030, with respect to 2005 levels

INTERNATIONAL CLIMATE FINANCE ASSISTANCE

The 4th Biennial Report shows that Canada provided 722.54 million USD in climate-specific development aid in 2017 and 2018, mainly targeting sub-Saharan Africa. More than half of which provided in the form of bilateral concessional loans and equity.



SUSTAINABLE RECOVERY POLICY

According to the Global Recovery Observatory, in 2020 the proportion of green spending out of total recovery spending was 75%, 60% of which was allocated to clean energy infrastructure investments.

249.6 billion $	27.25 billion $	20.31 billion $
Total Spending	Recovery Spending	Green Spending

DOMESTIC ADAPTATION POLICY

The Pan-Canadian Framework on Clean Growth and Climate Change includes actions to advance climate change adaptation and build resilience to climate impacts. In December 2020, Canada's federal government announced its commitment to developing Canada's first-ever national adaptation strategy (NAS).

- ○ Domestic Adaptation Policy
  - ○ Inclusion of Adaptation in NDCs
  - ● Integrated Adaptation & Mitigation Policy
  - ○ Dedicated Adaptation Strategy
  - ○ Dedicated Adaptation Plan
- ○ Subordinate Adaptation Policies
  - ○ Sectoral Adaptation Plans
  - ● Subnational Adaptation Plans

○ Policy not in place ● Active policy

ADAPTATION POLICY HIGHLIGHTS

TRANSNATIONAL INITIATIVES

International Upper Great Lakes Study (IUGLS)

IUGLS was established to improve to outflow regulation of Lake Superior to better address changing needs and the impacts of future climate on water flows, water levels, and associated resources

Canada-US agreement on weather and climate collaboration

The MoU between Canada and US facilitates bilateral cooperation on activities that promote improved meteorological hydrological and environmental forecasts and information

NATIONAL INITIATIVES

CCGP

The Earth Science Sector's Climate Change Geoscience Program (CCGP) develops geoscience information to help land-use planners, industry and regulators to mitigate the climate risks in northern resource development

Climate Lens

The Climate Lens is an assessment framework developed to help decision-makers understand the climate risks with the design, construction and operation of large infrastructure projects in Canada

SUBNATIONAL INITIATIVES

Atlantic Climate Adaptation Solutions (ACASA)

ACASA is a partnership among the provincial governments and regional stakeholders including NGO, tribal governments, and industry to jointly address regional climate change impacts

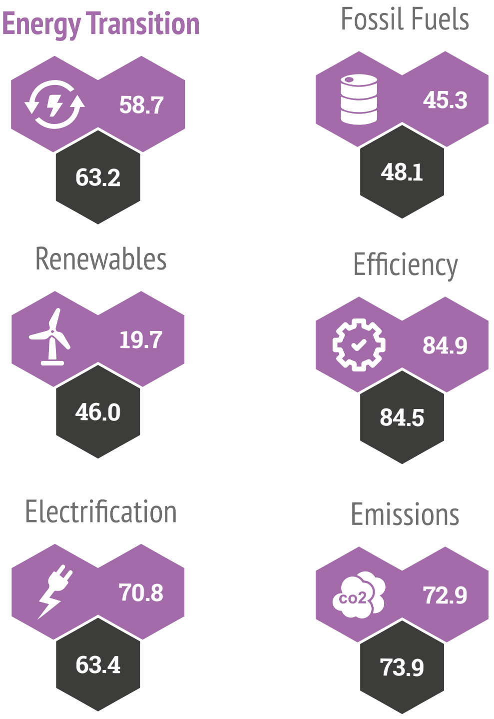
First Nation Adapt Program

The program prioritizes First Nation communities most impacted by climate change (sea level rise, flooding, forest fires, drought, fisheries and winter road failures), by providing funds to assess the impacts on infrastructures and to reduce disaster risk

ENERGY TRANSITION

Canada shows an Energy Transition index about 5 points above the G20 average: this is mainly due to an outstanding performance in Renewables penetration (more than twice the average). Emissions, Efficiency and Fossil Fuels indicators also contribute to the transition, being slightly above or below the average.

On the contrary, looking at the Electrification indicator, there is still room for improvement: the ongoing digitalization of the grids could spark energy consumption patterns in both residential and transport sectors.



Only actively pursuing an energy transition based on decarbonization and electrification – from policy and regulation, to health and education – will enable countries to benefit the most from future opportunities and fight climate change whilst ensuring an equitable distribution of wealth.

The Energy Transition indicators were developed by Enel Foundation in cooperation with SACE, and provide a retrospective analysis based on historical data.

G20 CLIMATE RISK ATLAS

Impacts, policy, economics

CHINA

How to read the Atlas: graphs, colours and scenarios.

The maps used in this Atlas are taken from **The World Bank Official Boundaries** - ***https://datacatalog.worldbank.org/search/dataset/0038272*** (accessed on May 28, 2021). For the section Energy, the maps are based on Panoply Data Viewer ***https://www.giss.nasa.gov/tools/panoply/credits.html***

Each sector of this Atlas contains data and information on various climate scenarios.

When reported in graphs, the **colour black** indicates data and information referring to the current state, the past or the baseline.

When the authors refer to **RCP (Representative Concentration Pathways)**, the 3 colours used across the factsheet refer to 3 scenarios, which are 3 different development options with different levels of greenhouse gas emissions, **respectively low emissions (green), medium emissions (orange), and high emissions (red)**. The same colour code is used when RCPs are associated with Shared Socioeconomic Pathways (SSP).

In some cases, the authors refer to global warming scenarios. In these cases, the 3 colours used refer to a temperature rise of **1.5°C (green), 2°C (dark green), and 4°C (red)**.

When the authors refer exclusively to **Shared Socioeconomic Pathways - SSPs** (Population affected by river floods in the section: "Water"), data related to **SSP3** - that encompasses, among other things, slow economic growth, material-intensive consumption, and persisting or worsening inequalities – **are reported in a lighter shade**; **SSP5** – which refers to social and economic development that is coupled with an energy-intensive lifestyle and the abundant exploitation of fossil fuel resources – is shown using a **middle shade of the colour**, whereas data related to **the present** conditions **are represented in a dark shade**.

Further details on scenarios, methodologies, and the full list of references are available at: **www.g20climaterisks.org**

Concept and graphic design by element6.eu

CHINA CLIMATE

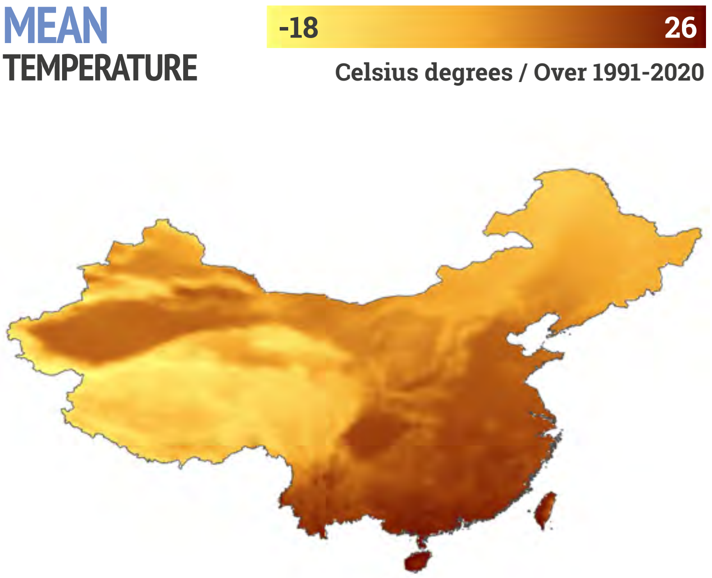
OVERVIEW

China presents a great variety of climates due to its size. The north has a temperate climate whereas the south is subtropical, with very hot summers and mild winters. In the summer, monsoons play an important role in determining weather and climate features throughout the country, blowing huge rain showers in from the east. In winter, dry and cold winds come from the northwest.

TEMPERATURE

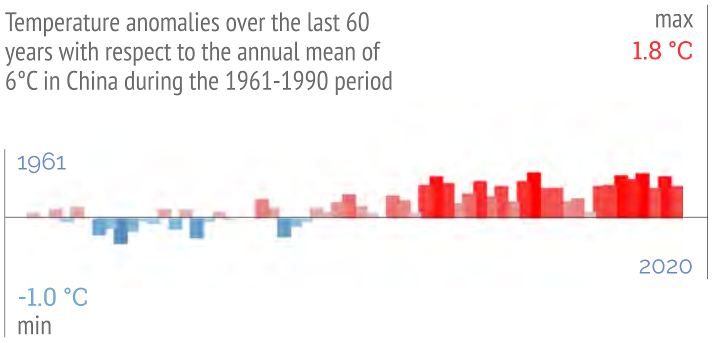
China's temperature regime is quite heterogeneous with higher values along the east coast where the largest cities are located. The lowest temperatures are in the west of the country along the Tibetan plateau.

MEAN TEMPERATURE



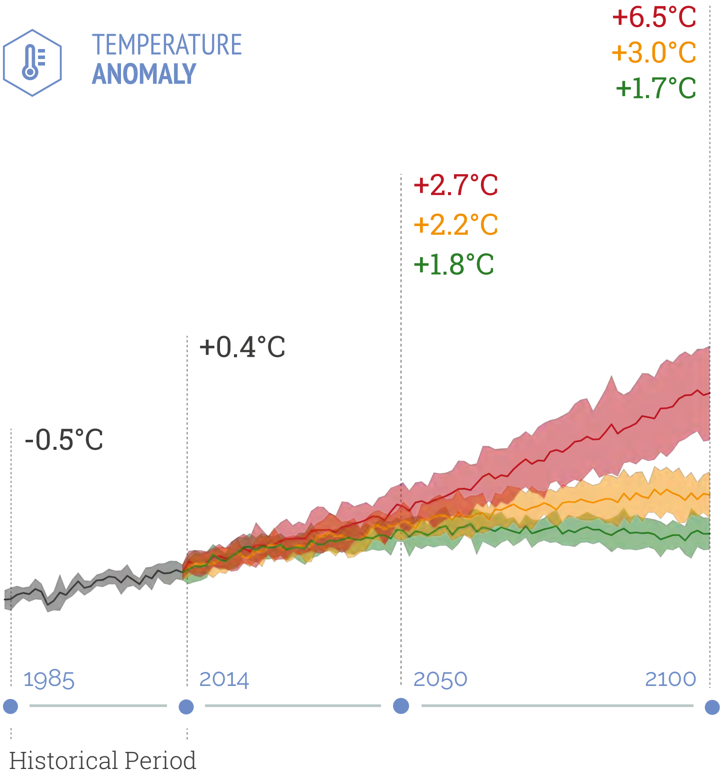
TEMPERATURE TREND

Temperature anomalies over the last 60 years with respect to the annual mean of 6°C in China during the 1961-1990 period



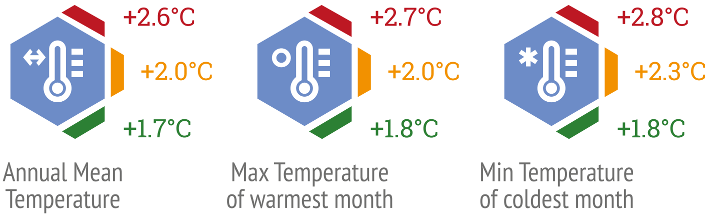
TEMPERATURE PROJECTIONS

Under a low emissions scenario projected temperature variations will remain contained at around +1°C, both by 2050 and 2100.
Under a high emissions scenario, with no reduction in GHG emissions, much greater temperature anomalies are expected by both 2050 and 2100.



EXPECTED VARIATION FOR TEMPERATURE AT 2050

The indicators show variations in selected temperature characteristics for a thirty-year period centred on 2050 (2036-2065) with respect to the reference period 1985-2014.



PRECIPITATION

The precipitation regime in China varies depending on location and time of year, with the East Asian monsoon playing a significant role. The east, south and southwest are generally warm, humid and rainy, whereas the north is usually dry and windy.

During the summer, the rain belt moves gradually from south to north reaching the hot and humid climate in eastern China.

Some years, rainfall causes severe floods, whereas in others there is too little rain to support agriculture.

MEAN PRECIPITATION

13 — 5,710

mm/year / Over 1991-2020

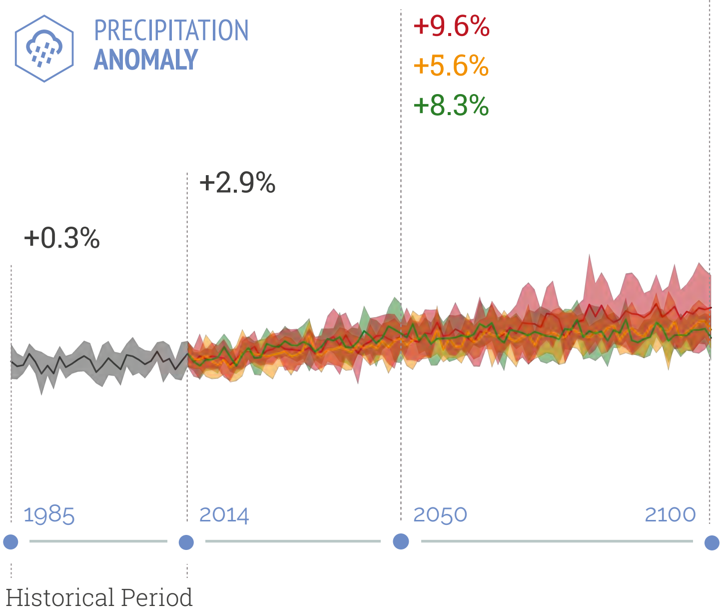
PRECIPITATION TREND

Precipiation anomalies over the last 60 years with respect to the annual mean of 635 mm/year in China during the 1961-1990 period

PRECIPITATION PROJECTIONS

Precipitation trends show a clear tendency to increase, under all emissions scenarios, with a large variability among the involved models and with respect to the reference period. Increase in precipitation is much greater under a high emissions scenario and longer time ranges.

PRECIPITATION ANOMALY



EXPECTED VARIATION FOR PRECIPITATION AT 2050

The indicators show variations in selected precipitation characteristics for a thirty-year period centred on 2050 (2036-2065) with respect to the reference period 1985-2014.

Annual total precipitation	+8.4%	+6.5%	+8.8%
Precipitation of wettest month	+8.7%	+6.9%	+8.5%
Precipitation of warmest quarter	+4.6%	+3.6%	+5.6%

VARIATION OF SPECIFIC CLIMATE INDICATORS

Climate indicators variation showing impacts of climate change on sectors such as agriculture, health and water. Analysis considers 3 threshold average temperature increase: **+1.5°C**, **+2°C**, **+4°C**.

Agricultural drought proportion of time	% of time	+22%	+12%	+10%
Hydrological drought proportion of time	% of time	+13%	+9%	+8%
Heatwave duration	% of time	+1,563%	+232%	+79%
Runoff increase	% of area	+20%	+7%	+2%
Agricultural drought frequency	% of change	+45%	+23%	+18%
Hydrological drought frequency	% of change	+9%	+8%	+10%
Heatwave frequency	% of change	+86%	+32%	+18%
Runoff decrease	% of area	+28%	+10%	+5%

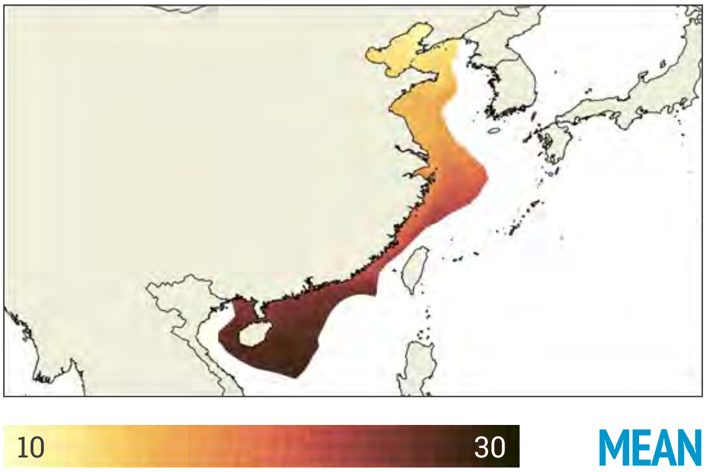
CHINA
OCEAN

OCEAN IN CHINA

China's marine exclusive economic zone (EEZ) is characterized by cold temperate to subtropical coastal waters, which host a large variety of ecosystems such as mangroves, coral reefs, and seagrass beds. In particular, coastal systems can be divided into three main areas: Yellow Sea, East and South China seas.

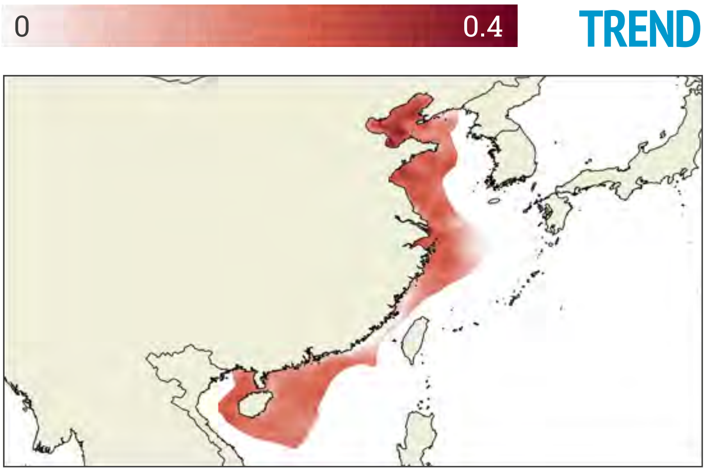
CURRENT CLIMATE CONDITIONS

Mean sea surface temperature reflects the different climate regimes, from the colder waters of the Yellow Sea to the subtropical ones on the southern coasts.



SEA SURFACE TEMPERATURE

Celsius degrees / Over 1991-2020

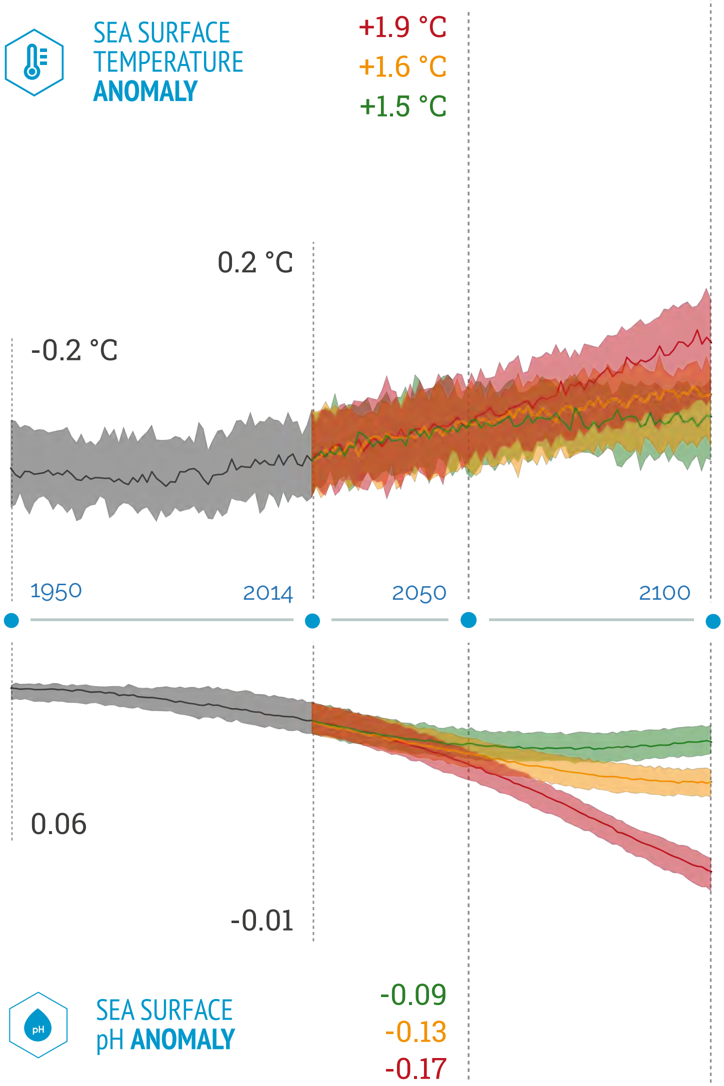


Surface temperature trends indicate a general warming of 0.2°C per decade in all marine areas, with increased gains in northern regions.

FUTURE PROJECTIONS

Projected annual changes within the marine EEZ for the two most significant marine indicators of climate change: sea surface water temperatures and pH.

Seawater temperature changes are in line with the definitions of each scenario, with maximum values close to +4°C under a high emissions scenario in 2100.



Seawater surface pH becomes more acidic in all scenarios, closely reflecting rising atmospheric CO_2 concentrations, and only a low emissions scenario leads to a stable condition by 2100.

ECOSYSTEM INDICATORS AT 2050

Regional changes in key marine ecosystem indicators under projected future scenarios by mid-century (2036-2065) with respect to present climate conditions (1985-2014).

Temperature regulates the metabolism of marine organisms determining which habitats remain suitable. Excessive warming will likely push ecosystems beyond tolerance thresholds.

pH represents the acid/base status of marine waters, where a decreasing pH reflects the acidification of the ocean due to increased absorption of atmospheric CO_2.

Oxygen is fundamental to sustain marine life and its reduction can have a large impact on coastal ecosystem services including fisheries and aquaculture.

Chlorophyll is an indicator of the biomass available at the base of the marine food web supporting all ecosystem productivity.

East China Sea	South China Sea	Yellow Sea
20.14°C +2.05 °C +1.6 °C +1.5 °C	26.36°C +1.58 °C +1.4 °C +1.27 °C	13.87°C +2.56 °C +2.59 °C +2.42 °C
8.12 -0.17 -0.14 -0.1	8.08 -0.16 -0.12 -0.09	8.06 -0.18 -0.14 -0.11
240.44 mmol/m^3 -4.03 % -2.74 % -2.76 %	210.39 mmol/m^3 -2.65 % -2.15 % -1.69 %	278.37 mmol/m^3 -4.84 % -3.2 % -2.92 %
0.39 mg/m^3 -12.31 % -11.79 % -18.46 %	0.25 mg/m^3 -15.32 % -14.52 % -12.5 %	0.29 mg/m^3 -3.75 % -5.8 % -8.53 %

FISH CATCH POTENTIAL

Fish catch potential is an estimate of the maximum fish catch achievable given the marine resources available over a sustained period. It is linked to the concept of maximum sustainable yield, meaning the maximum amount of fish that can be extracted from a system without causing a collapse in fish populations.

It is a characteristic of the natural system, which is substantially different from realized catch, and a direct result of the fishery policy in place.

Fish catch percentage change

2050

-7.9%

-5.3%

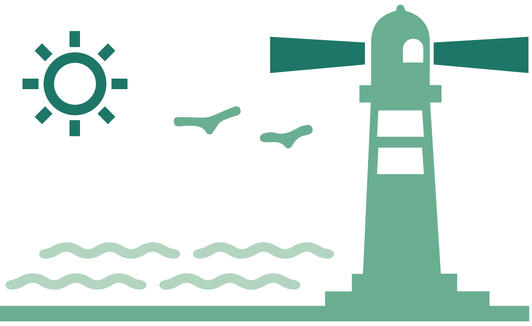
ANALYSIS DETAILS

All datasets were analysed using only data from within the marine EEZ and therefore excluding overseas territories, detached islands and any disputed or joint territories with other nations. In the assessment of current climate conditions, seawater surface tempereture data was obtained using satellite observations distributed in the framework of ESA Climate Change Initiative.

Future projections of marine indicators are represented by the combined analysis of results from 15 different Earth System models participating in the Coupled Model Intercomparison Project Phase 6 (CMIP6). These models include new and better representations of physical and biogeochemical processes, compared to previous IPCC assessment reports.

Fish catch potential data was obtained using the FAO's technical report and refers to the best and worst case climate scenarios from the Fifth IPCC Assessment Report. These mean estimates are subject to substantial uncertainties as discussed in the original work.

CHINA
COASTS



OVERVIEW

The Chinese coastline covers around 30,000 kilometres, stretching across tropical, subtropical and temperate zones. More than 70% of large Chinese cities are located in the coastal areas, and coastal development contributes over 55% to national gross domestic productivity. Vast areas of China's densely populated and highly productive regions are located on the coast, including the Pearl River Delta with the city of Guangzhou and the Yangtze River Delta with the city of Shanghai.

Shoreline Length
30,017 km

Sandy Coast Retreat at 2050
-15.9 m

CLIMATE CHANGE HAZARDS

Coastal hazards such as erosion, storm tide inundation and permanent flooding, can have strong adverse impacts on coastal regions, with loss of sandy shores, damage to settlements, infrastructure and ecosystems. Climate change can exacerbate these impacts due to rising sea levels and increasing impacts of waves and storms. A large proportion of the Chinese shoreline is already experiencing coastal erosion and increasing flood risk, which is expected to be exacerbated in the future by rising sea levels and possible increases in the intensity of large storms and typhoons in the East and South China Sea.

SEA LEVEL RISE

Relative sea level rise has been observed over the past century in China, with an average increase of 2.18 millimetres per year during the past century and approximately 3.4 millimetres per year since 1995. The latest IPCC projections indicate that, by 2050, global sea levels may rise between 0.18 metres, under a low emissions scenario, and 0.23 metres, under a high emissions scenario.

Observed and projected sea level rise at 2050
2.18 mm/year
0.23 m
0.18 m

EXTREME SEA LEVEL

Extreme sea levels are expected to increase in line with sea level rise, increasing the frequency of damaging high water level conditions. Under a medium emissions scenario, one in 100 year extreme sea level events in China are expected to rise from 3.93 metres at present day to 4.11 metres by 2050.

Current and projected extreme sea level at 2050
3.93 m
4.21 m
4.11 m

OBSERVED STORMS

Large parts of China are exposed to storms, with the southern and south-eastern regions experiencing seasonal typhoons. Large storms have been reported in the past, with three extreme tropical cyclone events in 1956, 1969 and 1994 being associated with devastating damage and losses to the Chinese coastal areas.

FUTURE STORMS

Most modelled projections suggest a reduction of tropical cyclone frequency, but an increase in the proportion of very intense tropical cyclones over the western North Pacific in the future. However, some individual studies project an increase in Western Tropical Cyclone frequency. Most studies agree on a projected increase of Western Tropical Cyclone intensity over the 21st century.

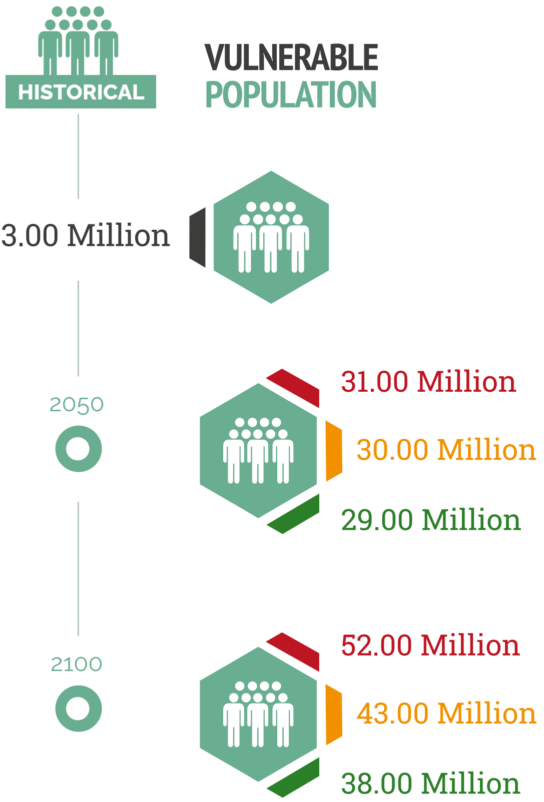
VULNERABILITY AND RISK

China's coasts, in particular its industrialised and heavily populated delta megapolis, are at high risk from sea level rise and storm surges. With urban settlements typically located and developed along shorelines and river estuaries, these are at high risk from flooding, particularly during the wet season.

The Chinese coast is densely populated, and the Pearl River Delta and the Yangtze River Delta are both some the most exposed areas and home to approximately 300 million people and a GDP of 3.4 trillion USD.

In Guangzhou, the biggest city of the Pearl River Delta, 6% of the population currently live within 0.5 metres of sea level. The city is recognised globally as one of the most vulnerable to rising sea levels by the middle of the 21st century, with estimated losses of 254 million USD per year considering a sea level rise of 0.2 metres.

Climate change and sea level rise is increasing the probability of coastal flood occurrence, vulnerability and risk. Under a medium emissions scenario the total population exposed to the annual coastal flood level is expected to increase from 23 million to 30 million by 2050.



INFLUENCE OF SEA LEVEL RISE ON EXTREME SEA LEVEL

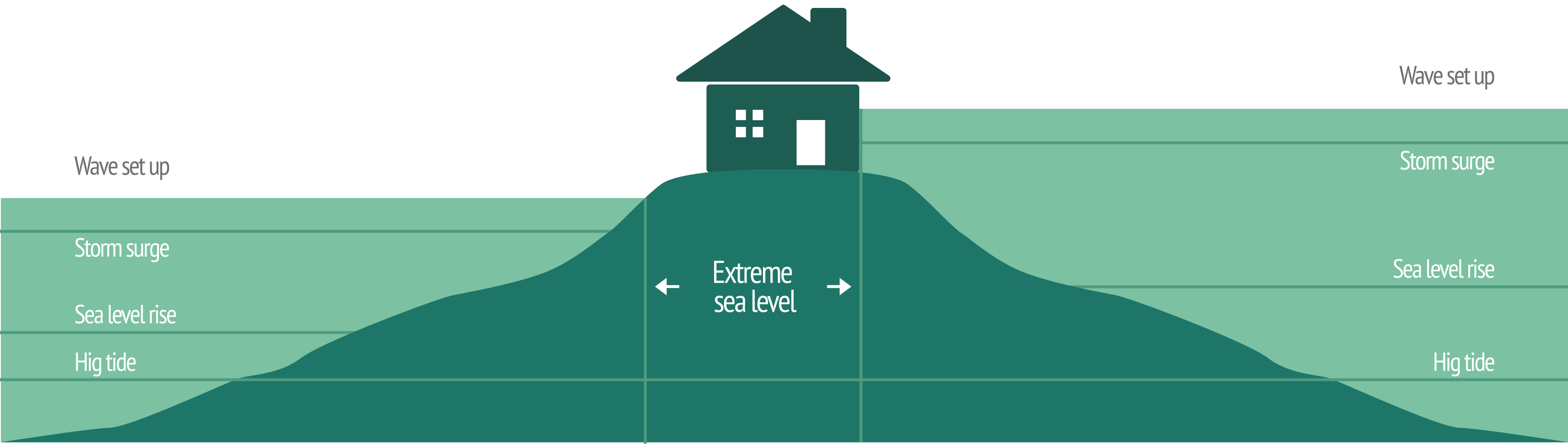
Present and future sea level rise are a consequence of carbon induced global warming causing melting ice and ocean expansion due to heat accumulation.

The extreme sea levels reported here are based on the 100-year storm surge + wave set up + sea level rise + high tide indicators. The first two parameters (storm surge + wave set up) are based on the 100-year value for the event; sea level rise is its projected value at 2050; and high tide is the absolute value of the highest tide calculated for a given locality, which won't be influenced by climate change.

+ **Wave set up** refers to the accumulation of water near the shore due to the presence of breaking waves.

+ **Storm surge** is an occasional increase in sea level driven by shoreward wind-driven water circulation and atmospheric pressure.

+ **High tide** is usually the highest tide reached in a given location based on tide records.



Present sea levels have risen globally by approximately 20 centimetres over the past century.

Future sea level rise is a projection based on different global warming scenarios, at approximately 100 centimetres by the end of 2100, with consequent inundation during extreme sea level events.

CHINA
WATER

OVERVIEW

China has some of the largest water reserves in the world. However, per capita water resources are below 2,100 cubic metres, only 25% of the global average, making China one of the most water scarce countries in the world.

Water resources in China are distributed very unevenly, with substantial intra-annual and inter-annual variations. Whereas southern China has abundant water, the north is very short of water resources.

In fact, areas north of the Yangtze River Basin account for 63.5% of the national territory, yet only have access to 19% of the nations water resources.

Renewable internal freshwater resources
2,813
billion m³

Renewable internal freshwater resources per capita
2,029
m³

In China, about 60% of the 669 largest cities are facing water shortages at a rate of about six billion cubic metres per year, affecting the daily lives of over 40 million urban resident. In the water-scarce North China Plain, the annual water deficit is up to 36 billion cubic metres and may reach 56 billion cubic metres by 2050.

CLIMATE CHANGE HAZARDS

Climate change can affect water resources through increasing temperatures, higher rates of evapotranspiration and altered rainfall patterns. This leads to changes in the water cycle, including decrease of snow and ice coverage, alterations of surface runoff and groundwater storage, as well as drought and flood occurrence. The occurrence of consecutive wet or dry years exposes China to frequent disastrous climatic events. A growing and increasingly wealthy population, coupled with agricultural and industrial development, is bound to increase future water demand. Many northern areas, including the Yellow River, may experience decreasing per capita amounts of available fresh water.

KEY POINT RUNOFF

Compared to the 1960s, the observed mean annual runoff in the 1990s increased by 12.6% and 9.6%, respectively for the Pearl River and the Yangtze river. During the same period, the runoff for the Yellow River and the Songhua river decreased by 30% and 12.6%, respectively.

Hydrological models driven by climate simulations predict an overall increase of river runoff for China between 7.5% and 10%. In the Yellow River basin, annual runoff is expected to increase between 5% and 11%, depending on the emissions scenario considered. At a country scale, instead, an average increase in surface runoff by approximately 17% and 3% is expected respectively under a low and medium emissions scenarios for the 2045-2055 period compared to 2015-2025.

If temperatures rise by 1.5°C, 2°C or 4°C, 5%, 9.6% or 28% of the area of the country will likely experience an increase in runoff, while 2%, 6.9% or 20% of the surface of the country will likely experience a respective decrease in runoff.

2050
Changes in annual runoff
% of change
+3.4%
+17.0%

2050
Runoff increase
% of area
+28.0%
+5.0%

KEY POINT DROUGHTS

Drought is one of the most severe manifestations of climate variability in China. It is a source of concern for agriculture and human life, given that the country is already quite dry (3.32 x 106 square kilometres of drylands). Over the past six decades, very severe droughts hit China in the 1960s, in the late 1970s and early 1980s, and in the late 1990s. Recently, northeastern China has suffered particularly from drought while, surprisingly, arid regions of northwestern China have enjoyed less severe droughts.

Future regional patterns in China are heterogeneous with contiguous areas presenting increases and decreases in water scarcity. In addition, while the growing seasonal mean precipitation may increase, southern China is more likely to experience higher drought intensification rates.

2050 Severe drought likelihood increase
% of change
+21.1%
+12.7%

2050 Hydrological drought frequency
% of change
+9.0%
+7.0%

2050 Groundwater Recharge
% of change
-6.4%
+5.1%

KEY POINT GROUNDWATER

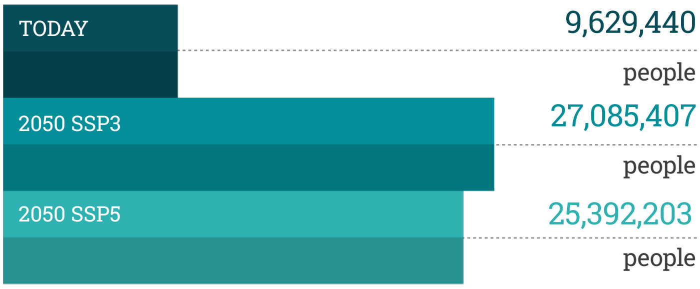
As a reliable source of water supply, groundwater plays an important role in ensuring water security. In China, groundwater provides drinking water for more than 400 cities. In northern China, two thirds of drinking water, half of industrial water, and a third of irrigation water is supplied from groundwater sources. In 2011 there were an estimated 53.8 million groundwater extraction wells in China.

Only 23 years earlier, that number was just 4 million. In addition, groundwater overexploitation has caused severe land subsidence, sea water intrusion and ecological damage in eastern China. Between 1959 and 2013, for example, the eastern city of Tianjin subsided by an estimated 3.44 metres, and hundreds of earth fissures have been observed in the Hebei Plain and Fenwei Basin. Many studies have explored the potential trend of groundwater at a regional scale, showing significant decreases in large areas such as, among others, the Heihe and the Naoli river basin. At the country level, a +5%, +0.3% and -6.5% change of the annual groundwater recharge for the period 2045-2055 compared to the timeframe 2015-2025 is expected respectively under low, medium and high emissions scenarios.

KEY POINT FLOODS

Floods in China cause huge losses to the national economy. Trends in heavy rainfall events causing floods show high spatial heterogeneity. These extreme events seem to become more frequent over northwestern China and the mid-to-lower reaches of the Yangtze River, but less frequent in northeastern China and the northwestern Yangtze River. Changes in the population exposed to river floods are expected, with an increase from around 9,630,000 in the present day to 27,000,000 under SSP3 and 25,400,000 under SSP5 by 2050. As such, potential impacts related to river floods might increase.

POPULATION AFFECTED BY RIVER FLOODS

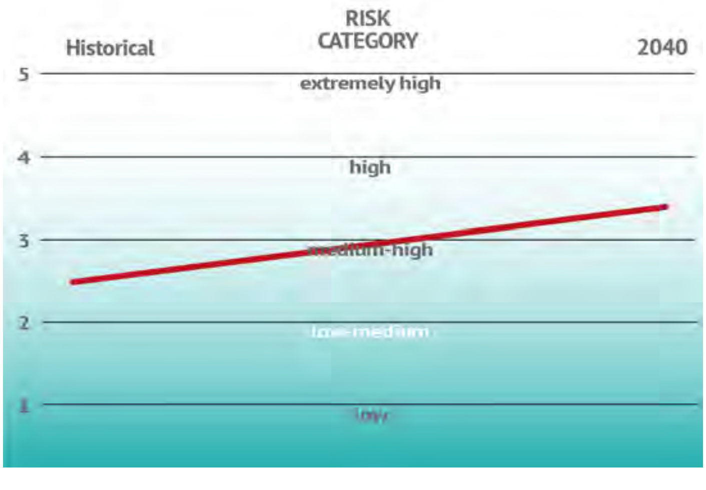


RISK INDICATORS

The water stress index summarises current and future water related vulnerabilities and risks at the global level. Scores are based on the ratio of total water withdrawals, including agriculture, industrial and human consumption, to available renewable surface and groundwater supplies.

WATER STRESS

China's water stress level is considered medium-high for the recent past (1960-2014 average), and it is expected to increase in the near future (2030-2050) based on climate change projections.



CHINA AGRICULTURE

OVERVIEW

China's agricultural sector is a vital economic component and crucial to support a population with increasing food security requirements. China's agricultural sector is a vital economic component and crucial to support a population with increasing food security requirements.

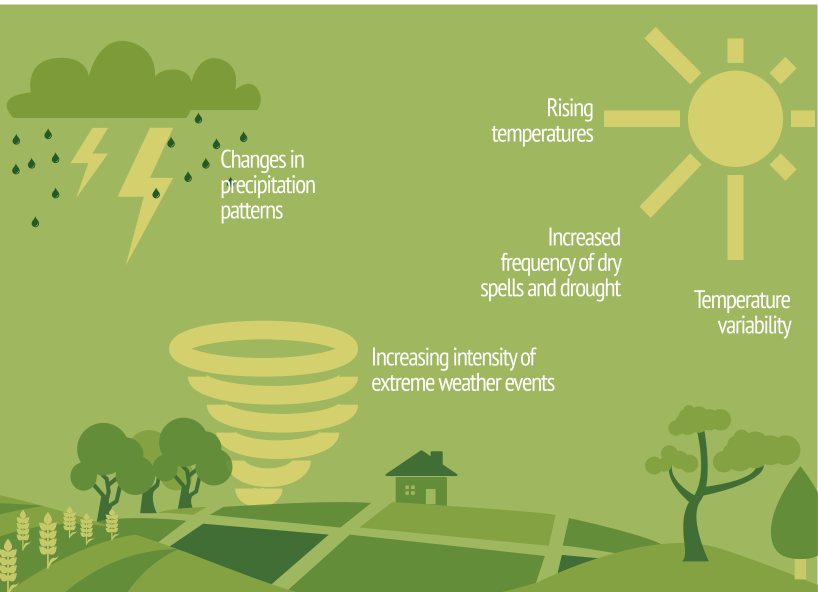
Rice is the dominant crop in the south; wheat is found in most provinces, but particularly in eastern regions; maize cultivations are found from the northeast to the southwest; and sugarcane extends mainly over southern to central regions. Other crops include potatoes, sugarbeets, and various other vegetables and fruits. Major cash crops include mandarins in the south and apples and pears in the north. Food crop production helped keep undernourishment levels below 2.5% of the total population in 2018. However, water withdrawal for agriculture is substantial and accounted for 64.4% of total water withdrawal in 2015, in a country where water stress is estimated to stand at 43%.

257.3 Mt	Maize
131.4 Mt	Wheat
214.1 Mt	Rice
108.7 Mt	Sugarcane
42.5 Mt	Citrus

	Added Value of Agriculture, Forestry and Fishing	Share of Agriculture Value added in Total GDP	Agricultural land	Area Equipped for Irrigation
2000	529,523 USD Million	17.9 %	130,897 Thousand HA	54,201 Thousand HA
2018	1,073,100 USD Million	7.8 %	135,695 Thousand HA	74,160 Thousand HA

EXPEXTED IMPACTS ON AGRICULTURE PRODUCTIVITY

Rising temperatures, reduction in average annual precipitation, and intensification of extreme events such as heat waves and drought, affect production variability with a tendency towards yield reduction for many cultivated species, accompanied by a probable decrease in food quality. Crops respond to increases in temperatures with changes in duration of the growing season, early appearance of phenological phases and potential shifts of cultivation areas toward higher latitudes and altitudes for better growing conditions. However, impacts vary significantly depending on the geographical area and specific crops in question.



CROP PRODUCTIVITY

Crop productivity refers to the harvested yield of a crop per unit of land area. It is strongly influenced by climate and other environmental and management factors.

Climate change is expected to have an impact on the productivity of several major crops, although this may in part be offset by the fertilizing effect of higher CO_2.

Impacts are estimated using a range of model projections based on low to high emission scenarios and reported as percentage changes between the 30-year average around the historical period and the 30-year average around 2050.

6.2
2.5 (0)%
-0.6 (-5.5)%
Maize
tons / ha

7
8.8 (-0.2)%
7.9 (-5.5)%
Rice
tons / ha

5.5
11.3 (4)%
12.3 (-1.8)%
Wheat
tons / ha

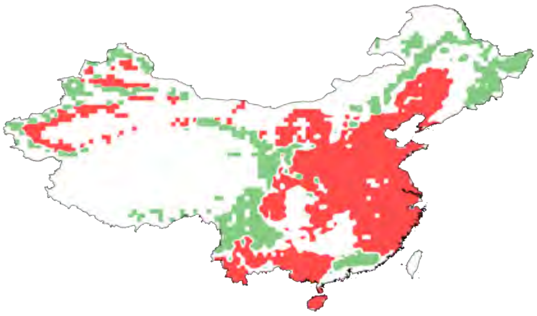
77
3.2 (3.1)%
-3.7 (-3.8)%
Sugarcane
tons / ha

2050

Productivity change with (without) the CO_2 fertilization effect. Estimates assume sufficient water and nutrient supplies, and do not include impacts of pests, disease, or extreme events.

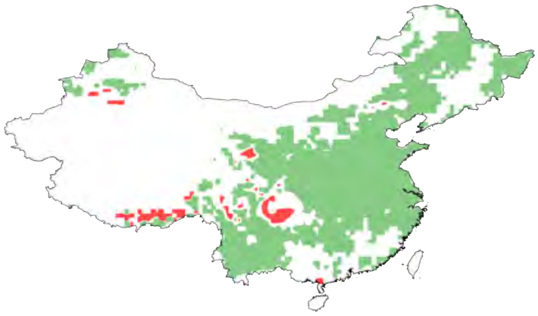
CHANGE IN MAIZE

− = +



CHANGE IN WHEAT

− = +



The magnitude of change in crop productivity for main cereals in China commonly varies between + and - 20%. General increases in wheat productivity are expected throughout China, with the largest gains in the eastern plains. Similar gains in productivity are projected for rice, although these will not be as pronounced as for wheat. Most positive increases in rice productivity are expected in northeastern China, whereas decreases are expected in central China.

A general decline of productivity is projected for maize in East and Central China, and for sugarcane throughout most of its growing region. Increased occurrence of severe droughts would double drought-related yield losses under a high emissions scenario. Widely cultivated fruit and tree crops such as citrus will witness climate related risks to productivity increasing from southeast to northwest, with yield losses mostly associated with seasonal water shortages.

ADAPTATION IN AGRICULTURE AND WATER RESOURCES

Climate change may have some positive benefits to some of the most widely used crops, but higher temperatures will generally require higher agriculture water demand due to higher plant evapotranspiration and expansion of irrigated areas. A 20% to 40% increase in water demand is expected, exerting significant stress on available water resources.

Expansion of irrigated agriculture in China has contributed to the depletion of rivers and groundwater, particularly in the northern regions. Cereal production in 2050 would need to be approximately 70% higher than it was in 2006, which is expected to increase the gap between water supply and demand.

CHANGE IN WATER DEMAND

− = +

Agriculture
Water Demand
% of change

+32.8%
+24.2%

2050

Introducing adaptation practices, such as the use of water efficient crop varieties, changing cropping partners, and investment in irrigation infrastructure, can moderate the negative effects of climate change on grain production and preserve water resources.

CHINA FORESTS

FORESTS IN CHINA

China is home to most forest types, from tropical and evergreen broadleaf forests in the south, to evergreen or deciduous coniferous in the north, as well as temperate ones in the east. In mountainous areas there are also large portions of boreal forests.

This wide variety, including strips of primary forests (5%), make up an invaluable biodiversity heritage.

FORESTED AREA AND CARBON STORAGE

25% of China is covered in forests with a strong increase in recent decades. In forest ecosystems, not considering shrublands, over 40 gigatonnes of carbon are stored, making them a crucial sink for the country. Each year over 163.4 teragrames of carbon are removed from the atmosphere by Chinese forests. Furthermore, data shows that with appropriate management this value could increase.

1990

157 Mln ha
Million hectares
Forested area

37 Tons/ha
Tons of Carbon per hectare
Carbon stock

2020

220 Mln ha
Million hectares
Forested area

45 Tons/ha
Tons of Carbon per hectare
Carbon stock

FOREST PRODUCTIVITY

Forest productivity or Net Primary Production is the net carbon captured by plants. It is the difference between the carbon gained by Gross Primary Production - net photosynthesis measured at the ecosystem scale - and carbon released by plants' respiration. It is expressed per unit land area.

2050

Productivity anomaly
Tons of Carbon per hectare per year

+0.58

+0.44

Slight increase particularly in the most forested areas

+ Fertilizing effect of increasing atmospheric CO_2

No areas with an expected decrease in forest primary production

+ Rising temperature and increasing risk of drought stress

KEY SPECIES UNDER CLIMATE CHANGE

THREATENED
TROPICAL FORESTS
Southern tropical forests may be affected negatively by increasing drought

VULNERABILITY
SUBTROPICAL-BROADLEAF
Higher vulnerability for subtropical mixed broadleaf forests

VULNERABILITY
TEMPERATE-DECIDUOUS
Higher vulnerability for temperate mixed deciduous forests

VULNERABILITY
TEMPERATE-MONTANE
Higher vulnerability for temperate and cold-temperate mountains needleleaf

FIRES IN CHINA

Fire is a structural ecological process that provides several types of ecosystem services and impacts on socio-ecological systems, including human health, carbon budgets, and climate change. Changes in global fire activity are influenced by multiple factors such as land-cover change, policies, and climatic conditions. Fire also releases large quantities of greenhouse gases into the atmosphere, contributing to a vicious cycle.

During the last two decades the total land area affected by fire was approximately 3.75 million hectares of which 41% involved forests.

BURNING
3.75 MILLION HECTARES

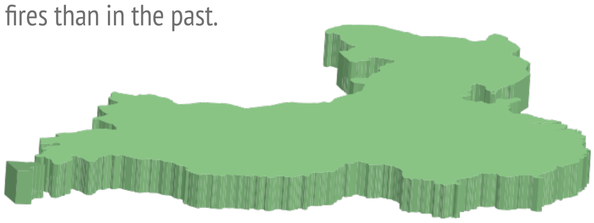
EMITTING
22 TERAGRAMMES OF CARBON PER YEAR

FOREST FIRE EMISSIONS CONTRIBUTED TO 41% OF TOTAL FIRE RELATED CARBON EMISSIONS

WHERE DO FIRES OCCUR?

Natural forests are abundant in the Daxing'an Mountains and the area is currently experiencing less frequent but more severe fires than in the past.

Forest plantations dominate the Fujian and Zhejiang provinces. Forest fire frequency is higher than in Northeast China.



The three main hotspot regions for fire density are: the Daxing'an Mountains in the northeast, the Yunnan and Guizhou provinces in the southwest, and the Fujian and Zhejiang provinces in the southeast.

The Yunnan and Guizhou provinces are characterised by evergreen broadleaf and coniferous forests. Southwest provinces have the highest fire occurrence.

FUTURE BURNED AREA

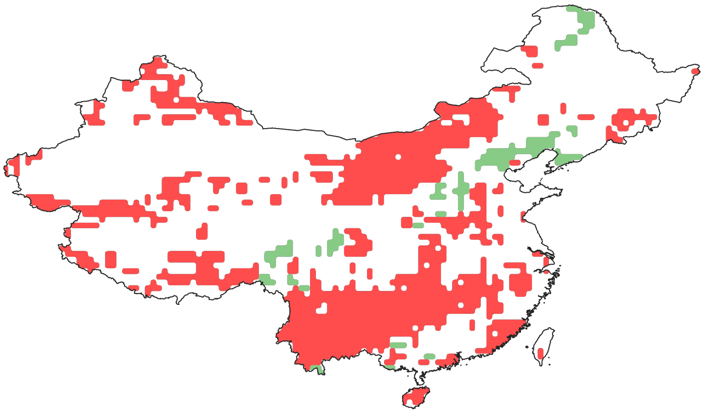
Under a low emissions scenario, models project that by 2050 a generalized increase in burned area might occur across subtropical southern forests and northern shrubland areas. Some western areas might also suffer a large increase in burned area. This trend is accentuated under a medium emissions scenario, particularly in northern areas.

Burned Area
km² per year

2050

+1,774

+1,673



🟩 Decrease in burned areas for a low emissions scenario

🟥 Increase in burned areas for a low emissions scenario
+ Prolonged fire season due to rising temperature
+ Prolonged drought and warming periods.

VARIATION OF SPECIFIC FIRE INDICATORS

max % of change
Fire occurrence probability in Northern Boreal forest

2041-2060

+99.8%

+99.6%

max % of change
Fire occurrence probability in Subtropical Evergreen Broadleaf forest

2041-2060

+89.6%

+84%

FUTURE FIRE EMISSIONS

Fire emissions follow a similar spatial pattern to burned area, with northern and southern areas projected to experience the greatest change under both low and medium emissions scenarios.

Fire Carbon emission
Teragrams of Carbon per year

2050

+26.5

+17.7

CHINA
URBAN

OVERVIEW

China's urbanization rate has seen a sharp rise from 16.2% in 1960 to 61.4% in 2020. Now, growth of urbanization rates and of absolute size of urban population is gradually slowing down, with urbanization rate expected to reach 80% by 2050. Urbanization is fuelled by high rates of migration. Climate change induced migration to cities may ocurr due to those for whom farming becomes an unviable livelihood.

Just over 10% of the population is living in one of the six megacities with more than 10 million inhabitants, and a quarter of the population lives in urban areas between 1 and 5 million inhabitants. While the share of population living in cities with more than 1 million inhabitants is expected to grow further, smaller cities, and in particular those with less than 300,000 inhabitants, will decrease slightly.

Growth rates of urbanization rates and of absolute size of urban population is gradually slowing down, with urbanization rate expected to reach 80% by 2050. Built up areas cover 2.66% of China (248,533.59 square kilometers), although densities along the coastline and in the north-eastern plain are much higher.

Population in Urban Areas

2020: 875,075,919

2050: 1,091,948,003

Graphs refer to data provided by United Nations, Department of Economic and Social Affairs, Population Division (2018). World Urbanization

Urbanization Rate

2020: 61.4%

2050: 80%

OVERVIEW OF KEY CLIMATE IMPACTS IN URBAN AREAS

The vulnerability of China's urban areas to climate impacts is driven by their high level of exposure, in particular to flooding and heat stress. Both types of vulnerabilities are exacerbated by the fast and massive urbanization process of the past century.

HEATWAVES AND HEAT STRESS

Urban areas are particularly vulnerable to heat due to the urban heat island effect. With increasing annual mean temperatures and more frequent heatwaves in China, the urban heat island effect could further increase heat stress and heat related mortality in cities. Increases in excess mortality during heatwaves are found in cities such as Shanghai, where an excess mortality of 0.027% in the central urban area was estimated for a 1998 heatwave, and a peak of 453 additional deaths were registered on a single day during a 2003 heatwave.

Rising temperatures will increase heat stress and heat-related mortality across the country and particularly in large urban areas, with 37,800 excess deaths per year estimated under a high emissions scenario between 2041 and 2060, and 25,800 heat related deaths in urban areas under a low emissions scenario. Cities such as Guangzhou, Shanghai, and Beijing are expected to suffer from significant levels of chronic heat stress.

2050

Cooling Degree Days
% of change

🟥 +120.4%
🟩 +43.4%
🟩 +26.8%

2100

Heatwave frequency
% of change

🟥 +85.5%
🟩 +31.8%
🟩 +18.3%

2050

Heatwave duration
% of time

🟥 +1,563%
🟩 +232%
🟩 +79%

UHI CHANGING REGIONAL CLIMATE

In urban areas, buildings, streets, parking lots etc. accumulate energy from solar radiation due to their material and release this energy during the night. In the Beijing–Tianjin–Hebei metropolitan area, the urban heat island effect has raised regional temperatures by more than 1°C. In Chinese urban agglomerations, high levels of pollution combined with rising air temperatures aggravate health impacts.

2017

Population exposed to air pollution

100.0%

COASTAL FLOODING

Several important urban areas in China are situated in coastal zones vulnerable to sea level rise. Without further protection measures, a 100-year high tide event would affect over 100,000 square kilometers of coastal land and the urban centres.

Projected sea level rise

2050

0.23 m

0.18 m

2100

0.77 m

0.38 m

EXTREME PRECIPITATION EVENTS

Indicators for intense precipitation events show an increasing level in the past decade, and in particular the southern part of China is affected by flooding with waterlogging and typhoons hitting the country regularly. Flash floods occur regularly in Chinese cities. In 2011 flash floods in Beijing caused 79 deaths and approximataly 1.86 billion USD in direct economic losses.

Flash floods in the Beijing, Tianjin and Hebei area left one person dead and 277 million USD in damages in 2017. High end flood risk will increase from between 18 and 34 milion people to 46 and 69 milion affected people in the 2030s and 2040s. Risk from river flooding is expected to increase by at least 20%. Well protected cities like Hubei will also face a 10-fold increase, from between 0.1 and 1 milion people to between 2 and 4 million if protection levels are not increased significantly. The most affected regions are close to Shanghai, although the city itself is well protected.

2050

Runoff increase
% of area

+28%

+10%

+5%

SURFACE SEALING AND FLOODS

Heavy precipitation in cities is problematic due to the high level of sealed surfaces. Soil sealing increases run off and reduces the amount of water absorbed by soil. Where there are large amounts of impervious ground cover, short duration extreme rainfall events can lead to increased flooding, even resulting in flash floods.

URBANIZATION OF FLOOD PLAINS

Urbanization is contributing to rising flood exposure, mainly in the east of the country. Future urbanization is expected to increase the rate of exposure to floods by 54% by 2050.

The trend towards impermeabilization of surfaces has a potentially higher impact on the development of urban flood risks than the projected increases in precipitation due to climate change. 4% of total urban land in China was situated in flood plains in 2015, and future urbanization is expected to increase urbanization of floodplains by 54% by 2050.

2010

% of urban population
Population living in slums

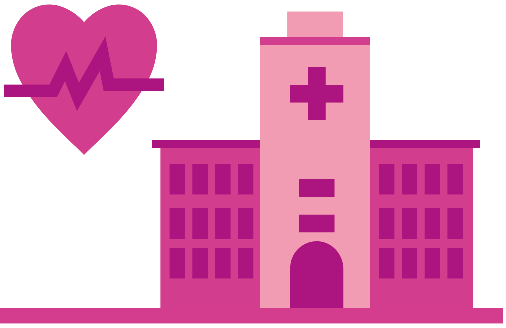
24.6%

2018

% of total population
Urban population living in areas where elevation is below 5 meters

4.2%

CHINA
HEALTH



OVERVIEW

Progress in population health and social development in China are likely to be threatened by the impacts of climate change, including coastal and inland river flooding, increased heat stress, water and food insecurity, and changes in the occurrence of climate-sensitive diseases. Health impacts of climate change in China will be heterogeneous across the regions. Rising temperatures, floods, droughts, and frequent cold spells are the major health threats in the northeast. In north China, the most important health-climate factors are increasing temperatures and droughts, whereas in the northwest, drought is the major climate threat to health. In eastern China, heat waves, intensified precipitation, and frequent floods will increase the risk of water-borne diseases. In central China, increasing frequency and intensity of heat waves, and precipitation shifts are expanding the scope and duration of parasitic infections. In the south, increased precipitation and sea-level rise are likely to increase the spread of dengue and malaria.

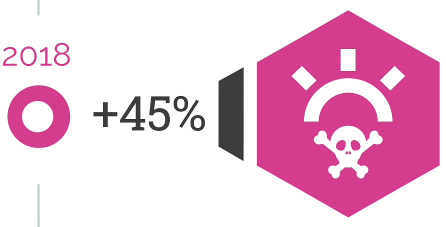
HEAT RELATED MORTALITY

Heatwave-related mortality increased by a factor of four from 1990 to 2019, with 26,800 deaths in 2019. Future high temperatures will cause larger numbers of heat-related deaths among people living in China's southern, eastern, central, and northern areas. Under a high emissions scenario, heatwave-related excess deaths will increase by 92%.

Under a medium emissions scenario, the increases in heatwave-related excess mortality will be around 87%. In 2018, there was a 45% increase in heat-related deaths, compared to the 2000-2004 baseline period. 21.3% of heat-related mortality in China from 2003 to 2008 can be attributed to human-induced climate change.

Heat-related mortality

% change with respect to 2000-2004



IMPACTS ON LABOUR

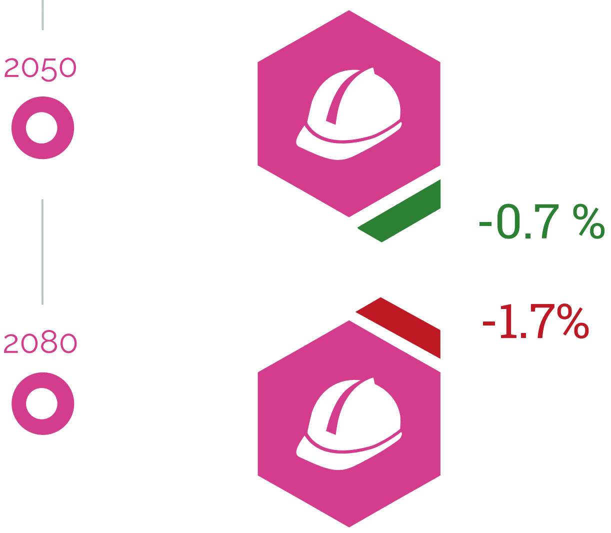
Labour is directly affected by changes in environmental conditions. Warming affects both the number of hours worked (labour supply) and on the productivity of workers during their working hours (labour productivity). Both labour supply and productivity are projected to decrease under future climate change in most parts of the world, and particularly in tropical regions.

Parts of sub-Saharan Africa, south Asia, and southeast Asia are at highest risk under future warming scenarios. Future climate change will reduce global total labour in the low-exposure sectors by 18 percentage points and by24.8 percentage points in the high-exposure sectors under a 3.0°C warming scenario

In 2019, the potential total work hours lost in China were 4.8% higher compared to 2000. Total labour is expected to decline by 0.68% under a low emissions scenario, and by 1.7% under a medium emissions scenario.

Impact on total labour

% change with respect to 1996



CLIMATE CHANGE AND DENGUE

Dengue has spread throughout the tropical world over the past 60 years and now affects over half the world's population. Globally, vectorial capacity for both dengue vectors (A. aegypti and A. albopictus) has been rising steadily since the 1980s, with nine of the ten highest years occurring since 2000.

Climatic stressors are one important driver of the current distribution and incidence of dengue. Climate change is likely to expand the geographical distribution and suitability of several vector-borne human infectious diseases including dengue. The risk of dengue transmission is increased by warming climates, as the growth and development of mosquitoes are significantly influenced by temperature, precipitation, and humidity.

Dengue suitability

% of population at risk

CLIMATE CHANGE AND ZIKA

Zika virus has spread to at least 49 countries and territories since 2013. Climate change impacts on transmission suitability risk have increased over the years and future warming over 1.3 billion additional people could face suitable transmission temperatures for Zika by 2050.

Zika suitability

% of population at risk

DENGUE AND ZIKA: POPULATION AT RISK

Under a medium emissions scenario, 95% of the population will be at risk of transmission-suitable mean temperature for dengue by 2050, whereas 98% will be at risk under a high emissions scenario. In the case of Zika, 90.3% of the population will be at risk of transmission-suitable mean temperatures by 2050, under a medium emissions scenario, whereas 91.7% will be at risk under a high emissions scenario.

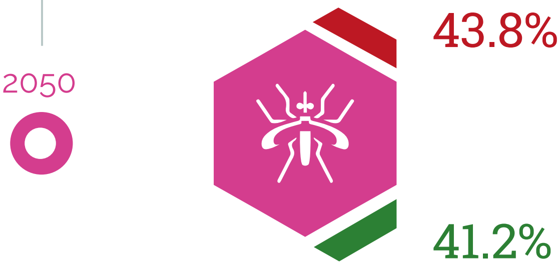
Under a medium emissions scenario, 95% of the population will be at risk of transmission-suitable mean temperature for dengue by 2050, whereas 98% will be at risk under a high emissions scenario. In the case of Zika, 90.3% of the population will be at risk of transmission-suitable mean temperatures by 2050, under a medium emissions scenario, whereas 91.7% will be at risk under a high emissions scenario.

CLIMATE CHANGE AND MALARIA

Despite advancements in vector control and socioeconomic development, climate suitability for malaria is expected to increase in China. 41.2% of the Chinese population will be at risk of malaria under a low emissions scenario in 2050, whereas 43.8% will be at risk under a high emissions scenario.

Malaria suitability

% of population at risk



POLLUTION AND PREMATURE MORTALITY

Air pollution and its adverse effects on public health remain a considerable problem in China, although policies have been implemented to improve the situation. Overall, the age-standardised death rate attributable to air pollution decreased by 60.6% (55.7 to 63.7) between 1990 and 2017. Since China's population is increasing and ageing, the number of PM2.5-related premature deaths is estimated to increase by 84 to 102 by 2020 and by 191 244 by 2030, indicating that the health benefits induced by air quality improvements could be offset by the effect of the population increasing in size and ageing.

CHINA ENERGY

ENERGY SYSTEM IN A NUTSHELL

China is a very energy-intensive economy, due to the sheer size of its population and its manufacturing sector, and the transportation needs within its huge territory and for international trade.

Coal has traditionally been used to meet energy demand, but renewables have undergone a very rapid increase in the last decade.

0.15
ktoe/US$
Energy intensity

9.8%
AC Share in electricity consumption

22%
Import dependence ratio

CLIMATE CHANGE TODAY

BLACKOUT

Prolonged heat in Chinese cities has caused electricity demand to spike, sometimes forcing cuts in power supply, such as in Guangdong in May-June 2021.

WATER

The water-energy nexus has been frequently under strain both due to prolonged periods of drought in Southern China, resulting in water shortages affecting hydropower and thermal power generation, but also due to heavy floods threatening dams and causing overflows.

HEAT

21 out of the 30 most-populated Chinese cities hit 30°C at least three days earlier than average in the last 20 years compared to the 1980 to 2000 period.

ENERGY SUPPLY

Fossil fuels dominate China's total primary energy supply, with coal claiming the lion's share (62% in 2018). 50% of industrial demand is covered by coal and 32% by electricity (which has a 78% share of coal in its mix). Oil (19%) is mainly used for transport, followed by industrial uses. Despite the need for foreign oil, import dependence is low, as most other energy sources are domestic. Electricity grew ten-fold since 1990, with coal and renewables gaining shares. Renewables grew faster - by 50% - since 2000, while coal grew by only 12%.

ENERGY DEMAND

Most energy consumption is claimed by industry (55% in 2018, including 7% of total demand for non energy uses), followed by residential (17%), transport (16%), agriculture (7%), and tertiary uses (4.5%). Air conditioning accounts for 10% of residential electricity demand (2015). Industrial and residential demand doubled in the last decade. The increase in residential demand points to improving household incomes and availability of money for purchasing appliances, including heating and cooling systems.

FUTURE ENERGY DEMAND

A recent study finds that the decrease in heating demand is going to be more than compensated by the increase in cooling needs, resulting, by the end of the century, in a net increase of electricity demand of 16,603 PJ (or 4612 billion KWh) in 2050 under a medium emissions scenario.

Net change in energy demand due to changes in HDD/CDD
Billion KWh

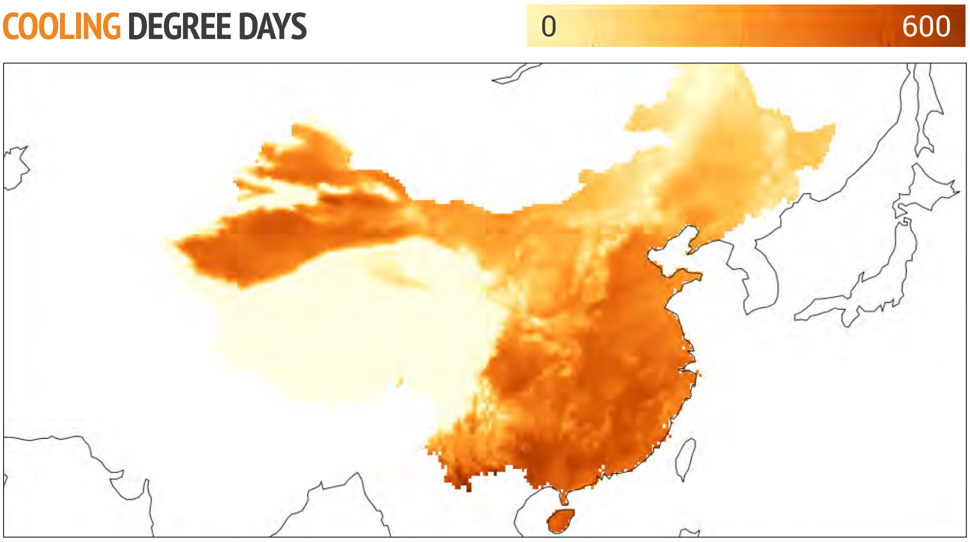
2050

+ 4,612.08

COOLING NEEDS

The highest increases in cooling degree days will occur in the south (Hainan, Hong Kong and the Pearl River delta) and on the coast (Fujian, Zhejiang, Shangai, Jiangsu) but also in desert areas in the west (Xingjiang), where they do not affect a large population.

COOLING DEGREE DAYS

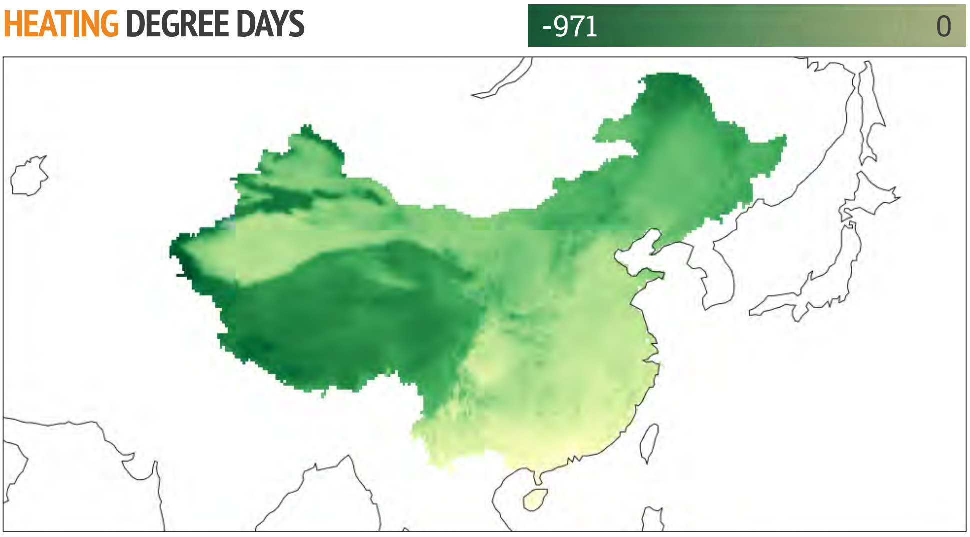


HEATING NEEDS

The pattern is reversed compared to cooling degree days: Substantial drop in heating needs in cold and not very densely populated areas such as Tibet and northern provinces.

Significant decreases in Beijing, moderate ones in densely populated south and east coast, fading to negligible in the extreme south (Hainan, Hong Kong and Pearl River Delta).

HEATING DEGREE DAYS



FUTURE ENERGY SUPPLY

The future configuration of the Chinese energy mix is likely to be determined by the evolution of climate mitigation policies and hence is outside the scope of this report. China has committed to peak its emissions by 2030 and to full decarbonization by 2060. This is likely to result in fossil fuels and their vulnerabilities keeping their relevance for the next decade, while carbon free sources and their vulnerabilities will prevail in the second half of the century.

Change in Hydropower generation
% of change

2050

-4.88%

-3.54%

EXPECTED IMPACTS OF CLIMATE CHANGE

The share of energy infrastructure at risk of being unable to operate due to climate change is estimated at 7.1% under a low emissions scenario, 10.8% under a medium emissions scenario, 11.5% under a high emissions scenario and 14.2% under the highest emissions scenario.

The risks are highest in Xinjiang and Inner Mongolia, and lowest in Tibet and Hainan. A modest reduction in hydropower potential is expected overall. Large hydropower (e.g. the Three Gorges Dam) may face increasing operational complexity, and hence increasing uncertainty for the future of local communities and ecosystems.

CHINA
ECONOMY

OVERVIEW

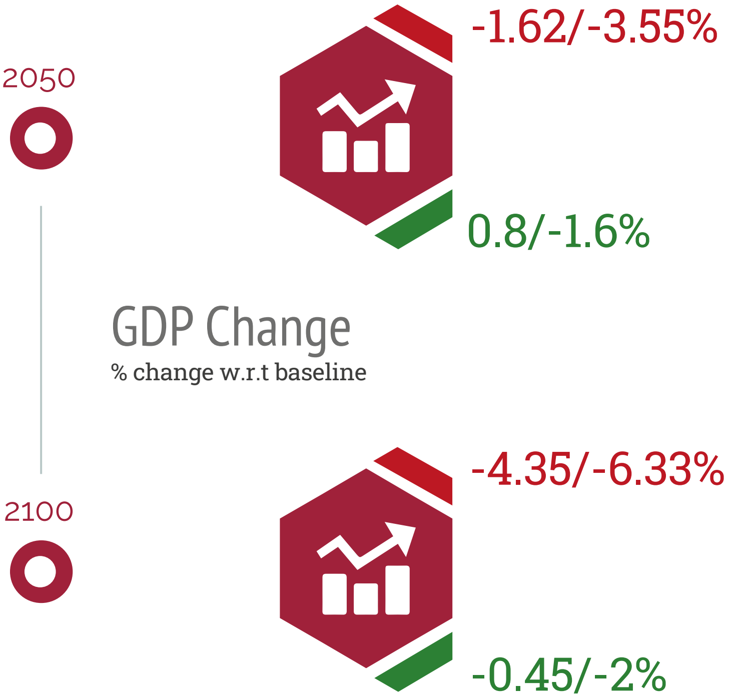
China is the third largest economy of the G20 group and the one showing the highest GDP growth rates.

IMPACTS ON GDP

In a vast area like China, economic impacts from climate change can be extreely different from region to region. Thus the national average clearly provides only a very aggregated view of climate change costs.

This said, under more moderate climate change scenarios like a low emissions scenario, some net gains may occur. Indeed by mid century, economic effects range from a potential gain of 98 billion EUR (0.8% of GDP) to a loss of 195 billion EUR (1.6% of GDP).

However, potential gains vanish with time and, in the second half of the century, China is expected to experience a net loss also under a low emissions scenario. Under a high emissions scenario GDP effects are unambiguously negative and could reach a loss of 772 billion EUR (or more than 6% of GDP).



2050

-1.62/-3.55%

0.8/-1.6%

GDP Change

% change w.r.t baseline

2100

-4.35/-6.33%

-0.45/-2%

SECTORAL ECONOMIC IMPACTS

IMPACTS ON INDUSTRY AND INFRASTRUCTURE

China's extensive manufacturing industry produces 12% of global exports and accounts for 32% of national GDP. By mid-century, climate change is predicted to reduce production in the manufacturing industry by 12% if no adaptation measures are implemented. This translates to a loss of about 33 billion EUR and a 4% decline in annual GDP.

As temperatures increase, and in the absence of any further adaptation measures, more people will be exposed to flooding risks, and the economic costs are projected to increase drastically. China is particularly vulnerable to damages from the flooding of its river basins.

The North China Plain and the Middle-Lower Yangtze Plain will suffer the largest losses, followed by the eastern part of the Loess Plateau, the Guanzhong Plain, and the Sichuan Basin.

IMPACTS ON AGRICULTURE

The agricultural sector accounts for approximately 10% of China's GDP. Economic losses in the agricultural sector caused by droughts are already large in China, estimated at 7 billion USD (5.8 billion EUR).

These costs are projected to increase exponentially as temperatures rise. Under a high emissions scenario, by the middle of the century they are expected to reach 30 billion USD (24.8 billion EUR).

IMPACTS ON ENERGY

As with all other economic sectors, energy supply and energy networks in China will undergo more intense stress from extreme weather events. Economic impacts of shifts in household and firm energy demand (see chapter on energy) are difficult to predict and will mostly lead to redistribution effects. In the case of China, the increase in cooling needs will definitely prevail, bringing about a likely increase in household and firm energy bills.

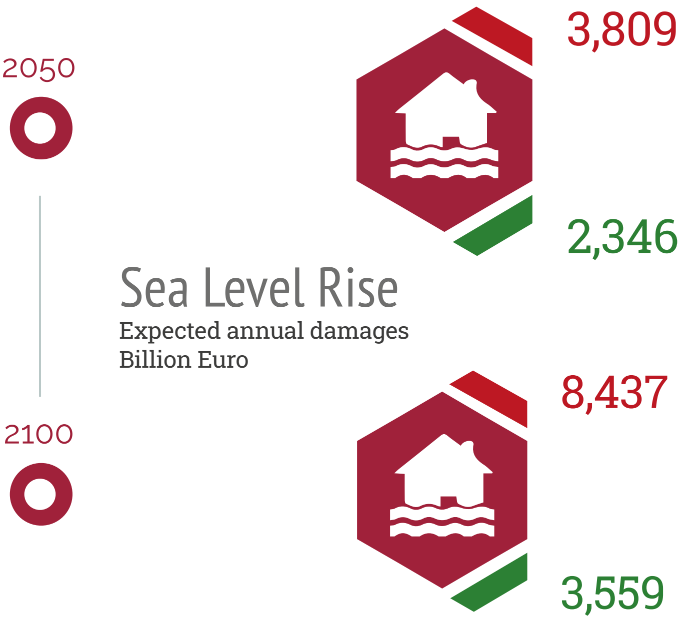
A recent study evaluates (under a high emissions scenario by 2100) the economic value of energy infrastructure assets at risk because of climate change at 1,741 billion yuan, about 258 billion USD.

This amounts to 14.2% of the total electricity assets and 2.1% of the 2017 Chinese GDP. The largest economic value of assets at risk pertain to Xinjiang and Inner Mongolia, whereas Tibet and Hainan are affected the least.

SEA LEVEL RISE DAMAGES

China is expected to face significant costs from coastal flooding. Expected annual damages can range from 2,346 billion EUR under a low emissions scenario to 3,809 billion EUR under a high emissions scenario, by 2050.

By the end of the century losses are projected to be 3,559 billion EUR under a low emissions scenario and reach 8,437 billion EUR under a high emissions scenario.

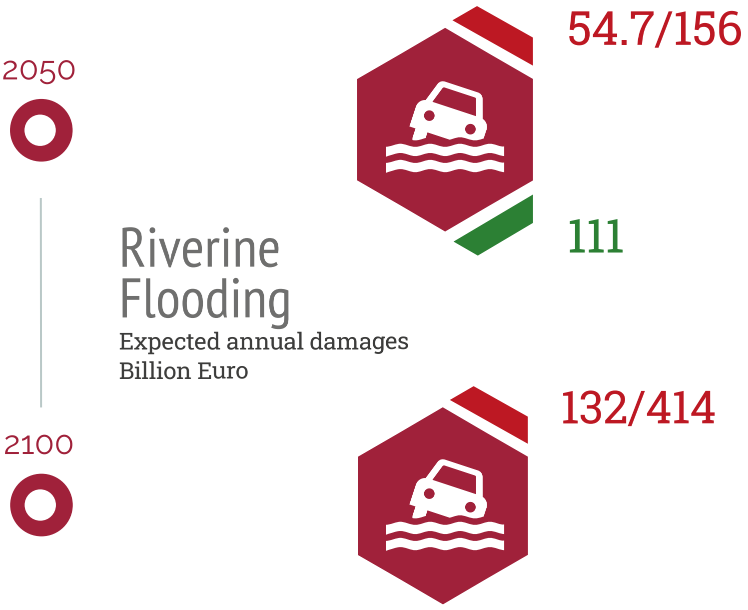


RIVER FLOODING DAMAGES

Current economic losses from river floods are estimated at around 12 billion USD. China is predicted to experience the largest losses globally from fluvial flooding. These will be particularly concentrated in the eastern and coastal regions of Jiangsu Zhejiang, featuring high density of population and economic activity.

By 2050, the expected annual damages from river flooding are projected to 111 billion EUR under a low emissions scenario and in the range of 54.7 billion to 322.5 billion EUR under a high emissions scenario.

By the end of the century, losses are projected to reach 414 billion EUR under a high emissions scenario.



IMPACTS ON TOURISM

Tourism in China has been growing significantly in recent years, contributing 352.4 billion EUR or 3.3% of national GDP in 2017; the same year China's domestic tourism market became the largest in the world, with domestic tourism consumption reaching 697 billion EUR. Comfortable climatic conditions and seasonality are important for the Chinese tourism sector, and could be affected by climate change.

Nonetheless, there are no figures available for the economic impacts of climate change on the tourism sector and only qualitative inferences can be made.

Increasing temperatures will leave some locations less favourable for tourists, and others more attractive. Tourism in the Eastern Qinghai-Tibet Plateau has benefited from warming in recent years, where the number of comfortable days for visitors increased from 5 to 20. In other regions, northern Northeast China and eastern Inner Mongolia Plateau, the comfortable days have decreased, negatively impacting the tourism sector. There is an increasing demand in China for holidays in locations with lower temperatures, in order to escape summer extremes in the majority of regions, and climate change could reduce the availability of these locations, resulting in economic losses. Winter tourism will be negatively impacted.

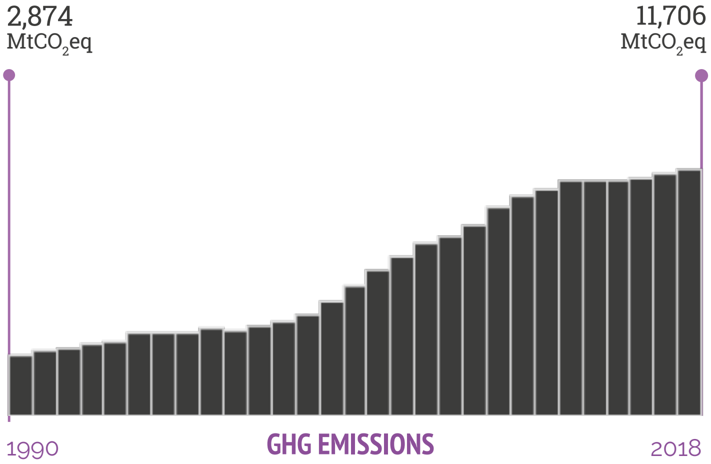
Changing climatic conditions will leave 16% of ski resorts unsuitable for use in the future. Glacier based tourism is the main attraction to visitors in the Qinghai-Tibetan Plateau region (one of China's most popular tourist destinations).

Rising temperatures are causing the glaciers to melt, making them thinner and dirtier, which reduces their aesthetic value and will in turn affect tourism in the area. Income for local communities dependent on glacier tourism will be negatively affected.

CHINA
POLICY

OVERVIEW

China is both the most populated country in the world and the largest single emitter. Emissions are currently growing, even though the rate of increase has slowed in recent years.



INTERNATIONAL COMMITMENTS

The national target for the Paris Agreement is to reach peak emissions by 2030. To do so, China commits to reduce the carbon intensity of each unit of GDP by 60%-65% (with reference to 2005), increase to 20% the share of non-fossil fuel in energy consumption and increase forest stock by 4,5 billion cubic metres.

CLIMATE POLICY COMMITMENTS CHRONOLOGY

2002 **KYOTO PROTOCOL - 1ST PERIOD**

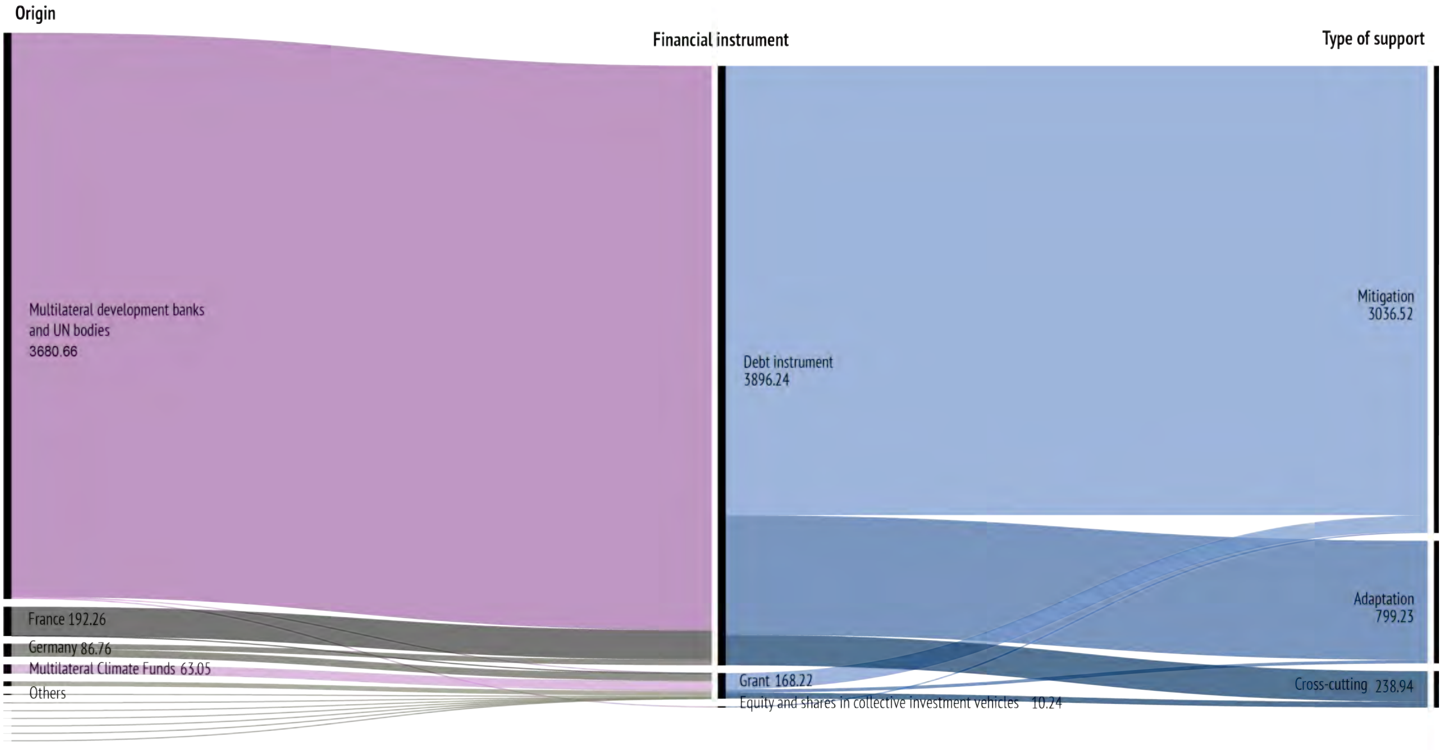
No target

2016 **PARIS AGREEMENT - 1ST NDC**

Peak in GHG emissions by 2030. 60%-65% reduction in GHG emissions per unit of GDP by 2030, with respect to 2005 levels. 20% increase in non-fossil fuel primary energy consumption by 2030. 4.5 billion m^3 increase in volume of forest stock, with respect to 2005 levels

INTERNATIONAL CLIMATE FINANCE ASSISTANCE

According to OECD DAC's climate-related development finance data, in 2017-2018 China received 4.1 billion USD, mainly from multilateral institutions as debt instruments. The main bilateral donor is France. Mitigation is the main expenditure item.



SUSTAINABLE RECOVERY POLICY

According to the Global Recovery Observatory, in 2020 China invested more than 400 billion USD in post-covid recovery, almost 20% of all public expenditure. More than 48 billion USD, 11,9% of recovery expenditure, was dedicated to sustainable investments in the energy sector and green infrastructure.

2,072.34 billion $	406.57 billion $	48.5 billion $
Total Spending	Recovery Spending	Green Spending

DOMESTIC ADAPTATION POLICY

China adopted an adaptation Strategy in 2013. No national Plan is expected, but rather sectoral plans (urban planning, forestry, etc.) and sub-national plans. China has no commitments for adaptation in its NDC.

- ○ Domestic Adaptation Policy
  - ○ Inclusion of Adaptation in NDCs
  - ○ Integrated Adaptation & Mitigation Policy
  - ● Dedicated Adaptation Strategy
  - ○ Dedicated Adaptation Plan
- ● Subordinate Adaptation Policies
  - ● Sectoral Adaptation Plans
  - ● Subnational Adaptation Plans

○ Policy not in place ● Active policy

ADAPTATION POLICY HIGHLIGHTS

TRANSNATIONAL INITIATIVES

Lancang-Mekong Cooperation Mechanism (LMCM)

The LMCM is based on the multilateral mechanism of the Association of South East Asian Nations (ASEAN) and serves to coordinate water sharing among all of the Lancang-Mekong River riparian states: China, Myanmar, Laos, Thailand, Cambodia and Vietnam

NATIONAL INITIATIVES

Sponge City Program (SCP)

SCP was put forward 2014 to relieve the flood inundation and water shortage situation. The SPC program implements not only the concept and practices of low impact development but also comprehensive urban water management strategies. 16 pilot cities received special financial support for the development of SPC

Integrated big data application platform for emergency management

Based on the national data sharing system, the platform aims to make best use of big data, cloud computing and IoT to achieve online monitoring, warning and forecast in advance for major risks

Action Plan for Forestry to Adapt to Climate Change

The Action Plan aims to strengthen the sustainable management of forests, control forest disasters, promote a virtuous cycle of grassland ecology and improve the network of nature reserves

SUBNATIONAL INITIATIVES

Agricultural adaptation in Ningxia

The project sought to understand the impact of climate change on crop yields and the national cereal production, including an assessment of options, implementation, demonstration and monitoring-evaluation

ENERGY TRANSITION

The overall Energy Transition indicator for China is well below the average. This is an expected result in relation to the traditional low performance in Emissions and Fossil Fuels, respectively 13 and 11 points below average. In addition,

Efficiency contributes negatively (more than 13 points below) due to a high energy intensity and a low use of clean cooking. Renewables penetration is increasing and in the future will play a more and more important role.

The Electrification performance, well above the average, is one of the highest in the G20, reflecting the importance of electricity as the main energy vector in the future in all key sectors including transport, industry and buildings.

Energy Transition	58.7	52.9
Fossil Fuels	45.3	34.0
Renewables	19.7	19.8
Efficiency	84.9	71.4
Electrification	70.8	79.5
Emissions	72.9	59.7

G20 AVERAGE

COUNTRY

Only actively pursuing an energy transition based on decarbonization and electrification – from policy and regulation, to health and education – will enable countries to benefit the most from future opportunities and fight climate change whilst ensuring an equitable distribution of wealth.

The Energy Transition indicators were developed by Enel Foundation in cooperation with SACE, and provide a retrospective analysis based on historical data.

G20 CLIMATE RISK ATLAS

Impacts, policy, economics

EUROPEAN UNION

How to read the Atlas: graphs, colours and scenarios.

The maps used in this Atlas are taken from **The World Bank Official Boundaries** - ***https://datacatalog.worldbank.org/search/dataset/0038272*** (accessed on May 28, 2021). For the section Energy, the maps are based on Panoply Data Viewer ***https://www.giss.nasa.gov/tools/panoply/credits.html***

Each sector of this Atlas contains data and information on various climate scenarios.

When reported in graphs, the **colour black** indicates data and information referring to the current state, the past or the baseline.

When the authors refer to **RCP (Representative Concentration Pathways)**, the 3 colours used across the factsheet refer to 3 scenarios, which are 3 different development options with different levels of greenhouse gas emissions, **respectively low emissions (green), medium emissions (orange), and high emissions (red)**. The same colour code is used when RCPs are associated with Shared Socioeconomic Pathways (SSP).

In some cases, the authors refer to global warming scenarios. In these cases, the 3 colours used refer to a temperature rise of **1.5°C (green), 2°C (dark green), and 4°C (red)**.

When the authors refer exclusively to **Shared Socioeconomic Pathways - SSPs** (Population affected by river floods in the section: "Water"), data related to **SSP3** - that encompasses, among other things, slow economic growth, material-intensive consumption, and persisting or worsening inequalities – **are reported in a lighter shade**; **SSP5** – which refers to social and economic development that is coupled with an energy-intensive lifestyle and the abundant exploitation of fossil fuel resources – is shown using a **middle shade of the colour**, whereas data related to **the present** conditions **are represented in a dark shade**.

Further details on scenarios, methodologies, and the full list of references are available at: **www.g20climaterisks.org**

Concept and graphic design by element6.eu

EUROPEAN UNION
CLIMATE

OVERVIEW

Europe is generally characterized by a temperate climate. Most of Western Europe has an oceanic climate, featuring cool to warm summers and cool winters. Southern Europe has a distinctively Mediterranean climate, which features warm to hot, dry summers and cool to mild winters. Central-eastern Europe is classified as having a continental climate, which features warm to hot summers and cold winters.

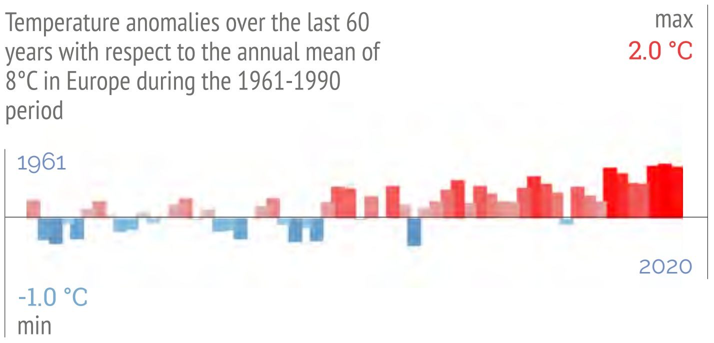
TEMPERATURE

Most of Europe has seasonal temperatures in line with temperate climates around the world, although summers north of the Mediterranean Sea are cooler than in most other areas with temperate climates. Southern countries are the warmest.

MEAN TEMPERATURE

TEMPERATURE TREND

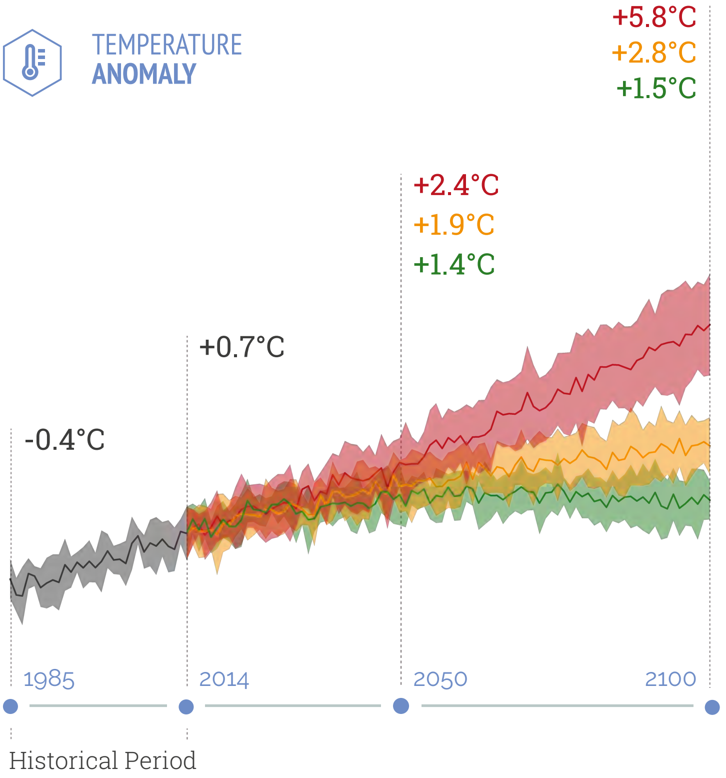
Temperature anomalies over the last 60 years with respect to the annual mean of 8°C in Europe during the 1961-1990 period



TEMPERATURE PROJECTIONS

Under a low emissions scenario projected temperature variations will remain contained at around +1.5°C, both by 2050 and 2100.
Under a high emissions scenario, with no reduction in GHG emissions, much greater temperature anomalies are expected by both 2050 and 2100.

TEMPERATURE
ANOMALY



EXPECTED VARIATION
FOR TEMPERATURE AT 2050

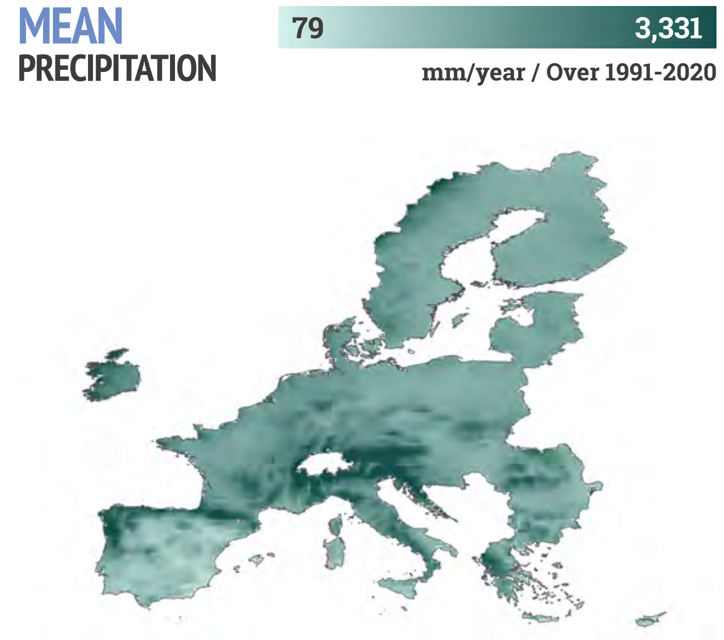
The indicators show variations in selected temperature characteristics for a thirty-year period centred on 2050 (2036-2065) with respect to the reference period 1985-2014.

+2.5°C +1.9°C +1.6°C	+3.0°C +2.3°C +1.9°C	+2.8°C +2.2°C +1.8°C
Annual Mean Temperature	Max Temperature of warmest month	Min Temperature of coldest month

PRECIPITATION

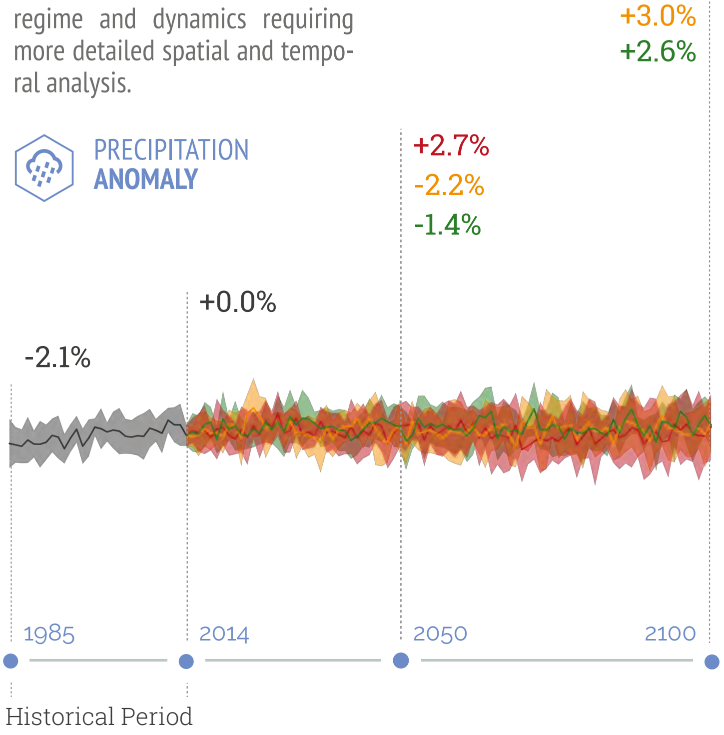
Parts of the Central European plains have a continental climate whereas the coastal lowlands of the Mediterranean area have more of a wet and dry seasonal pattern.
The rainy season extends from October to February, whereas the dry season is mainly in the summer months whereby precipitation can, in some years, be extremely scarce.
Precipitation patterns are highly variable over mountain area such as the Alps and Pyrénées due to factors such us the interaction between mountains and humid air masses coming from coastal areas.

MEAN PRECIPITATION



PRECIPITATION PROJECTIONS

Precipitation trends show a very complex signal, under all emissions scenarios, with a very large variability among climate models. This can be explained considering the complexity of the precipitation regime and dynamics requiring more detailed spatial and temporal analysis.



EXPECTED VARIATION FOR PRECIPITATION AT 2050

The indicators show variations in selected precipitation characteristics for a thirty-year period centred on 2050 (2036-2065) with respect to the reference period 1985-2014.

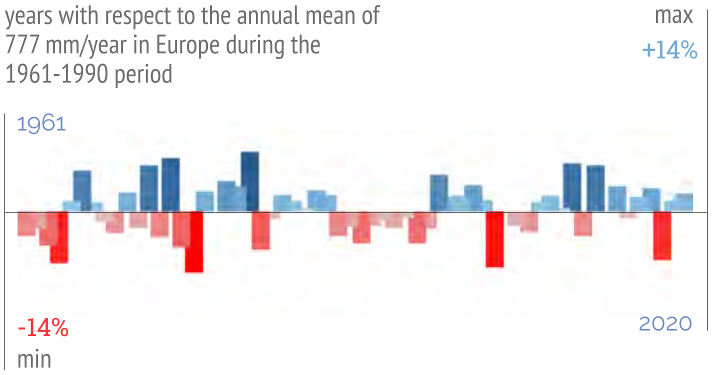
+1.4%
+1.2%
+2.2%
Annual total precipitation

+4.6%
+3.2%
+4.4%
Precipitation of wettest month

-3.8%
-1.2%
-0.6%
Precipitation of warmest quarter

PRECIPITATION TREND

Precipiation anomalies over the last 60 years with respect to the annual mean of 777 mm/year in Europe during the 1961-1990 period



VARIATION OF SPECIFIC CLIMATE INDICATORS

Climate indicators variation showing impacts of climate change on sectors such as agriculture, health and water. Analysis considers 3 threshold average temperature increase: **+1.5°C**, **+2°C**, **+4°C**.

+32%
+17%
+13%
Agricultural drought proportion of time
% of time

+25%
+12%
+10%
Hydrological drought proportion of time
% of time

+1,247%
+184%
+63%
Heatwave duration
% of time

+28%
+12%
+5%
Runoff increase
% of area

+66%
+42%
+30%
Agricultural drought frequency
% of change

+14%
+9%
+13%
Hydrological drought frequency
% of change

+84%
+32%
+19%
Heatwave frequency
% of change

+34%
+20%
+10%
Runoff decrease
% of area

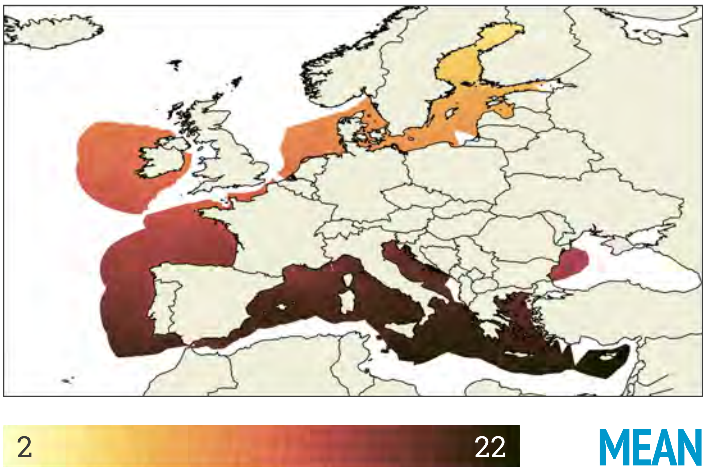
EUROPEAN UNION
OCEAN

OCEAN IN EUROPEAN UNION

The EU's marine exclusive economic zone (EEZ) is characterized by subpolar to temperate coastal waters, which host a large variety of ecosystems with an invaluable biodiversity. The wide enseble of coastal systems can be divided into four main areas: the Atlantic region, the North Sea, the Mediterranean-Black Seas and the Baltic subbasins.

CURRENT CLIMATE CONDITIONS

Mean sea surface temperature reflects the different climate regimes, from the cold subpolar waters in the north to the temperate ones on southern basins.

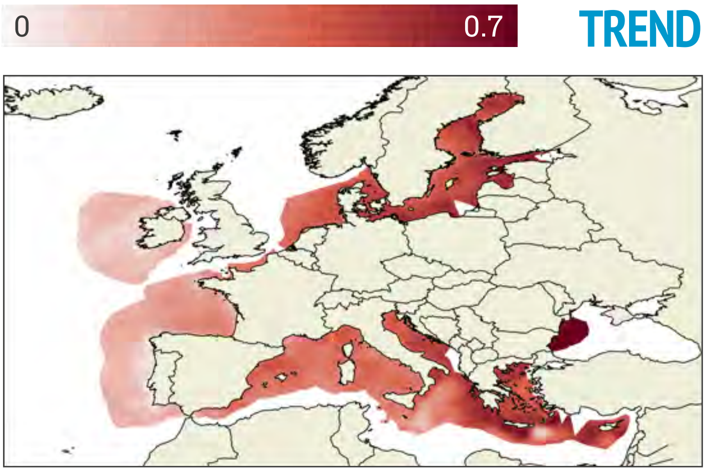


MEAN

SEA SURFACE TEMPERATURE

Celsius degrees / Over 1991-2020

TREND

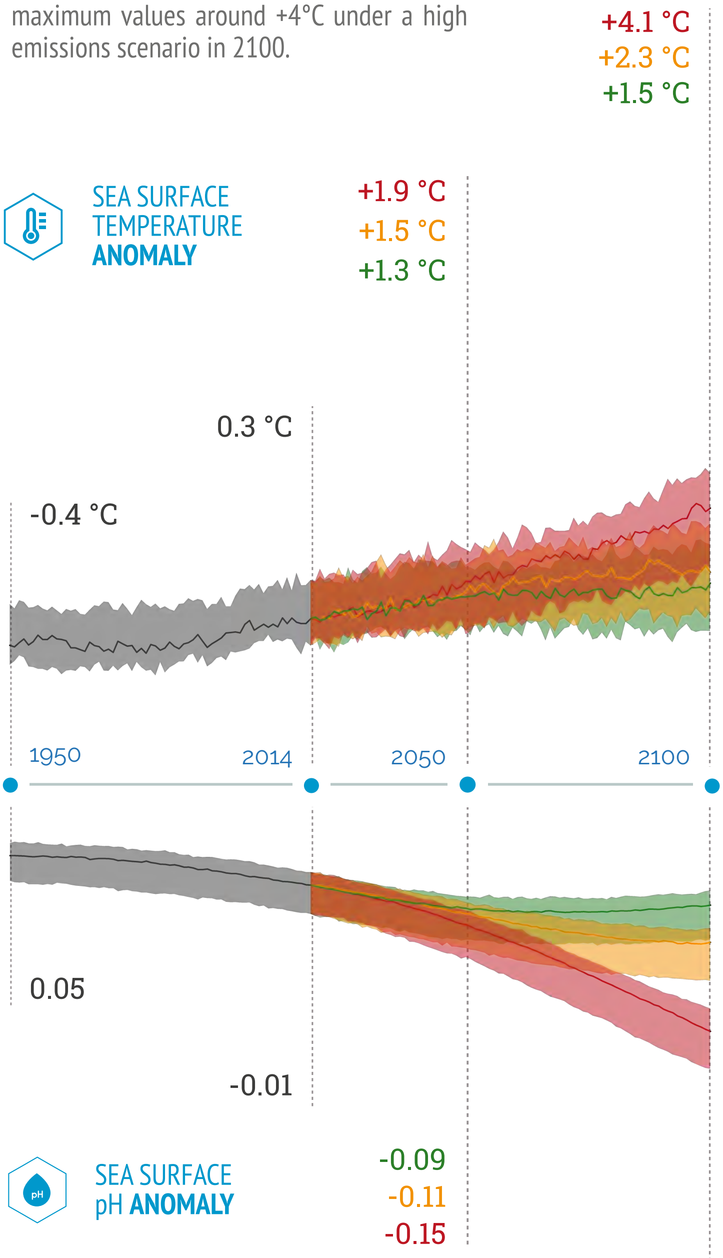


Surface temperature trends indicate a general warming of 0.3°C per decade in all marine areas, with increased gains in the semienclosed basins of the Mediterranean and Baltic Seas.

FUTURE PROJECTIONS

Projected annual changes within the marine EEZ for the two most significant marine indicators of climate change: sea surface water temperatures and pH.

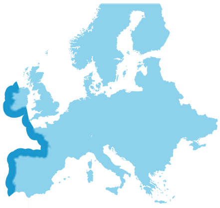
Seawater temperature changes are in line with the definitions of each scenario, with maximum values around +4°C under a high emissions scenario in 2100.



Seawater surface pH becomes more acidic in all scenarios, closely reflecting rising atmospheric CO_2 concentrations, and only a low emissions scenario leads to a stable condition by 2100.

ECOSYSTEM INDICATORS AT 2050

Regional changes in key marine ecosystem indicators under projected future scenarios by mid-century (2036-2065) with respect to present climate conditions (1985-2014).



Atlantic

Mediterranean-Black Seas

North Sea

Baltic

Temperature regulates the metabolism of marine organisms determining which habitats remain suitable. Excessive warming will likely push ecosystems beyond tolerance thresholds.

Atlantic	Mediterranean-Black Seas	North Sea	Baltic
15.10°C	18.90°C	11.22°C	8.06°C
+0.99 °C	+2.58 °C	+1.52 °C	+2.68 °C
+0.83 °C	+1.96 °C	+1.07 °C	+2.06 °C
+0.41 °C	+1.98 °C	+0.83 °C	+1.7 °C

pH represents the acid/base status of marine waters, where a decreasing pH reflects the acidification of the ocean due to increased absorption of atmospheric CO_2.

Atlantic	Mediterranean-Black Seas	North Sea	Baltic
8.11	8.1	8.09	7.76
-0.18	-0.16	-0.18	-0.19
-0.14	-0.13	-0.13	-0.13
-0.11	-0.1	-0.1	-0.11

Oxygen is fundamental to sustain marine life and its reduction can have a large impact on coastal ecosystem services including fisheries and aquaculture.

Atlantic	Mediterranean-Black Seas	North Sea	Baltic
254.97 $mmol/m^3$	236.21 $mmol/m^3$	282.33 $mmol/m^3$	354.62 mmol/m3
-0.71 %	-4.37 %	-3 %	-5.86 %
-0.38 %	-3.27 %	-1.94 %	-4.34 %
+0.04 %	-2.72 %	-1.3 %	-3.53 %

Chlorophyll is an indicator of the biomass available at the base of the marine food web supporting all ecosystem productivity.

Atlantic	Mediterranean-Black Seas	North Sea	Baltic
0.44 mg/m^3	0.15 mg/m^3	0.38 mg/m^3	0.28 mg/m3
-8.9 %	-1.99 %	-15.67 %	-8.57 %
-6.16 %	-10.6 %	-15.67 %	-15.71 %
-15.53 %	-25.17 %	-15.67 %	-24.64 %

FISH CATCH POTENTIAL

Fish catch potential is an estimate of the maximum fish catch achievable given the marine resources available over a sustained period. It is linked to the concept of maximum sustainable yield, meaning the maximum amount of fish that can be extracted from a system without causing a collapse in fish populations.

It is a characteristic of the natural system, which is substantially different from realized catch, and a direct result of the fishery policy in place. The data reported exclude semi-enclosed seas, such as the Baltic, the Mediterranean and the Black Sea.

Fish catch percentage change

2050

-26.5%

-30.6%

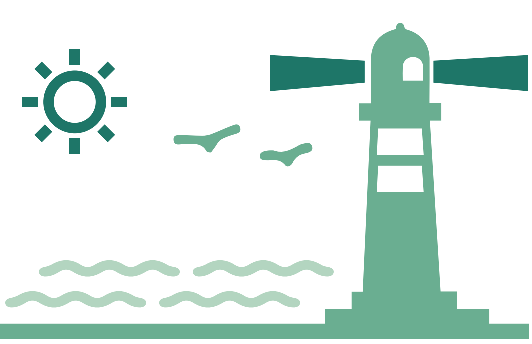
ANALYSIS DETAILS

All datasets were analysed using only data from within the marine EEZ and therefore excluding overseas territories, detached islands and any disputed or joint territories with other nations. In the assessment of current climate conditions, seawater surface tempereratture data was obtained using satellite observations distributed in the framework of ESA Climate Change Initiative.

Future projections of marine indicators are represented by the combined analysis of results from 15 different Earth System models participating in the Coupled Model Intercomparison Project Phase 6 (CMIP6). These models include new and better representations of physical and biogeochemical processes, compared to previous IPCC assessment reports.

Fish catch potential data was obtained using the FAO's technical report and refers to the best and worst case climate scenarios from the Fifth IPCC Assessment Report. These mean estimates are subject to substantial uncertainties as discussed in the original work.

EUROPEAN UNION
COASTS



OVERVIEW

The coastline surrounding the 24 non-landlocked member states of the European Union is long and diverse, bordering the Mediterranean, Baltic and Black Seas, as well as the Atlantic Ocean to the west. Coastal zones make up 13% of the landmass of EEA countries, amounting to 560,000 square kilometres and 68,000 kilometres long. Managing the coastal zones of the EU presents a range of challenges to protect people, ecosystems and socioeconomic systems in exposed coastal areas.

Shoreline Length 68,000 km

Sandy Coast Retreat at 2050 -25.0 m

CLIMATE CHANGE HAZARDS

Coastal hazards such as erosion, storm tide inundation and permanent flooding, can have strong adverse impacts on coastal regions, with loss of sandy shores, damage to settlements, infrastructure and ecosystems. Climate change can exacerbate these impacts due to rising sea levels and increasing impacts of waves and storms. The coastal systems of the EU, and the populations that occupy them, face significant pressures from a variety of forces driven by climate change both on a global scale and regionally. Climate change has led to dangerous increases in sea levels across the European continent that are reshaping the shoreline and damaging coastal habitats, and it has also led to unpredictable hazard events such as storm surges and floods, as well as contributing to shifting patterns in temperature and precipitation on land and sea that could further exacerbate damaging effects in coastal zones. Other potential indicators of climate change include a warming of the sea temperatures, increased acidification, northward species migration, and lowered ecosystem resilience.

SEA LEVEL RISE

Sea level has been rising over the past century, with a further acceleration since 1970, averaging 1.7 millimetres per year around the European coast, and even reaching over 4 millimetres per year on the Mediterranean and North Sea coasts. The latest IPCC projections indicate that, by 2050, global sea levels may rise between 0.18 metres, under a low emissions scenario, and 0.23 metres, under a high emissions scenario.

Observed and projected sea level rise at 2050

1.63 mm/year

0.23 m

0.18 m

EXTREME SEA LEVEL

Under a medium emissions scenario one in 100 year events could occur as often as one in 30 years by 2050. Under a high emissions scenario, extreme sea level events in 2100 may increase by up to 81 centimetres, particularly on the Baltic and North Sea coastlines, with communities across Europe having to face these events annually.

Current and projected extreme sea level at 2050

1.98 m

2.25 m

2.17 m

OBSERVED STORMS

The combination of storms and high waves play an influential role on coastlines with many vulnerable coastal zones threatened by the possibility of storm-driven erosion. Coastal flooding is also a large risk factor particularly when extreme wave heights coincide with spring tides. Patterns in storm surges across Europe have in general not shown any strong trends over recent decades, although high variation makes them difficult to forecast, particularly on a local scale.

FUTURE STORMS

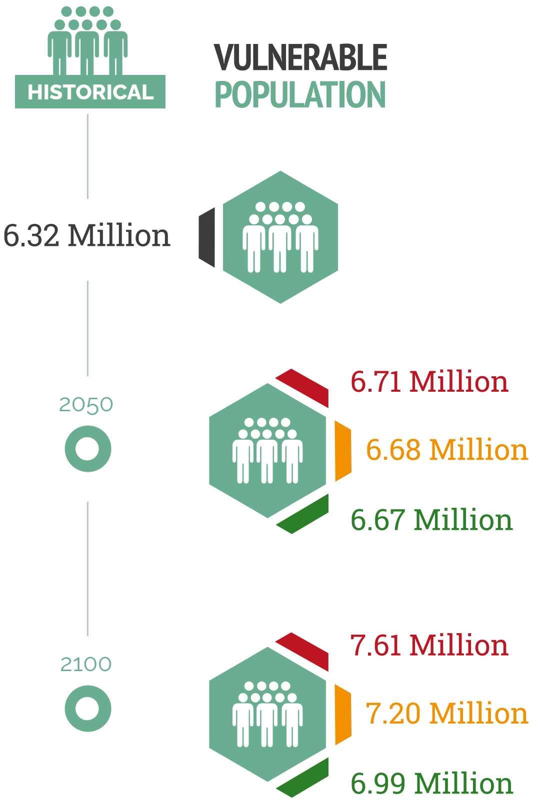
The frequency of high wave and water levels is correlated to rising sea levels, becoming much more likely when considering the effects of future climate change. Under a medium emissions scenario, 1 in 100 year events could occur as often as 1 in 30 years by 2050. With high emissions, extreme sea level events in 2100 may increase by up to 81 centimetres, particularly on the Baltic and North Sea coastlines, with communities across Europe having to face these events annually.

VULNERABILITY AND RISK

The impacts of sea level rise and increased storminess will be felt widely across each of the EU member states, with potentially disastrous consequences. Over 40% of the population of the EU lives within 50 kilometres of the sea, which amounts to at least 200 million people.

The potential impacts that they face will increase year by year, with higher sea levels increasing exposure to flooding events, coastal erosion, and damage to infrastructure. The particularly vulnerable coastal zones of the Mediterranean could face erosion of up to 10 metres per year.

From an economic perspective, assets within a kilometre of the shoreline would be valued at up to 1,000 billion euro for the EU area, with many important cities and ports, as well as economic activities, particularly those concerning tourism, found along the coast. Many natural habitats are also at risk of significant damage, with sand dunes and beaches vulnerable to erosion, and saltwater intrusion from high waters posing a further threat. Under a medium emissions scenario the population exposed to the annual coastal flood level is expected to increase from 6.32 million to 6.68 million by 2050.



INFLUENCE OF SEA LEVEL RISE ON EXTREME SEA LEVEL

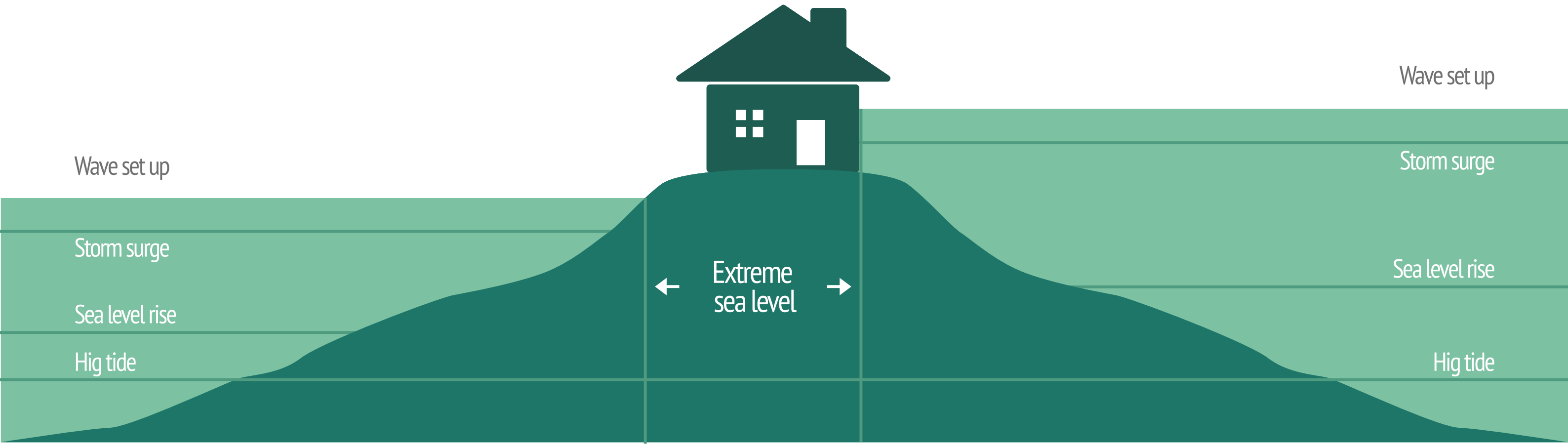
Present and future sea level rise are a consequence of carbon induced global warming causing melting ice and ocean expansion due to heat accumulation.

The extreme sea levels reported here are based on the 100-year storm surge + wave set up + sea level rise + high tide indicators. The first two parameters (storm surge + wave set up) are based on the 100-year value for the event; sea level rise is its projected value at 2050; and high tide is the absolute value of the highest tide calculated for a given locality, which won't be influenced by climate change.

+ **Wave set up** refers to the accumulation of water near the shore due to the presence of breaking waves.

+ **Storm surge** is an occasional increase in sea level driven by shoreward wind-driven water circulation and atmospheric pressure.

+ **High tide** is usually the highest tide reached in a given location based on tide records.



Present sea levels have risen globally by approximately 20 centimetres over the past century.

Future sea level rise is a projection based on different global warming scenarios, at approximately 100 centimetres by the end of 2100, with consequent inundation during extreme sea level events.

EUROPEAN UNION
WATER

OVERVIEW

Water management is a critical issue for numerous regions across the EU, particularly regions with lower rainfall and high population density, and areas with intensive agricultural or industrial activity. In addition to water supply issues, overexploitation of water has led to the drying out of natural areas in western and southern Europe and salt-water intrusion in aquifers, especially along the coast.

The overall extraction and consumption of water resources is mostly balanced in the long term. However, some areas may face water shortages, in particular in southern Europe where much improved efficiency of water use, especially in agriculture, is needed to prevent seasonal water shortages. In addition, climate change may affect water resources and water demand.

With a 2°C increase in global mean temperatures precipitation is expected to increase in most parts of Europe except for the Mediterranean region, with the highest increases over the Alps and Eastern Europe. These increases are likely to be linked to the increase in temperature which triggers more convective storms in the summer months.

CLIMATE CHANGE HAZARDS

In the EU (including the UK), around 51.9 million people and 995 billion euros in economic activity are currently exposed to water scarcity. Furthermore, 75 billion euros in economic activity are exposed to severe water scarcity, a large percentage of which is concentrated in Mediterranean countries. Even with a temperature increase of only 1.5°C, 7.4 million more people and 134 billion more euros in economic activity may become exposed to water scarcity, although the amount of people and economic activity exposed to severe water scarcity will remain constant. Under a high emissions scenario, leading to a temperature increase of over 3°C, an additional 7.7 million people and 99 billion euros in economic activity will be exposed to severe water scarcity.

KEY POINT RUNOFF

A 2°C temperature rise may result in an increase in extreme flooding and droughts, except for the Mediterranean area where a decrease in flow is projected over all four seasons. Surface runoff will increase accordingly and it will be exacerbated by urban expansion. This may cause local water excess problems and sewer overflows. In Northern Europe, numerous urban areas are projected to be more vulnerable to rainfall flooding.

In Southern Europe's arid and semi-arid regions, an increase of 1°C in mean annual temperature and decrease of 5% in mean annual precipitation - a likely scenario by 2030 - may result in an average decrease of 9-25% across its river basins.

2050

Runoff increase

% of area

+34.0%

+10.0%

KEY POINT DROUGHTS

Higher temperatures have significant impacts on human heat stress and related fatalities. An example is the 2003 drought and heatwave that affected large parts of central and northern Europe, with widespread impacts on various economic sectors and the population. Studies have shown how Southern Europe has already been subject to more intense and longer meteorological droughts.

During the 2018 and 2019 summers, severe restrictions on irrigation and reduced power supplies due to severe droughts around Europe raised concerns about a possible increase in the severity and frequency of droughts due to climate change.

KEY POINT GROUNDWATER

About 60% of the drinking water in the EU comes from groundwater, and in some countries in Europe it is the only source of drinking water. In Europe, most groundwater is high quality drinking water that has been naturally filtered by the rock pores through which it passes, although it can be vulnerable to long-lasting contamination by the industrial, agricultural or domestic wastes and leachates. The impacts of climate change on groundwater recharge are driven by water scarcity issues expected in southern European countries and by changes in seasonal regimes of snow-melt, wetter winters, drier summers and prolonged periods of droughts as well as groundwater flooding in other parts of Europe. It also appears that secondary impacts of climate change, caused by human adaptations in energy and water policies, have potentially large impacts on groundwater resources.

KEY POINT FLOODS

Climate change has altered the distribution of river floods in Europe. Specifically, river floods increased in northwestern and parts of central Europe, caused by increasing autumn and winter rainfall; decreased in southern Europe, due to decreasing precipitation and increasing evaporation; and decreased in northeastern Europe, because of decreasing snow cover and snowmelt. While individual catchments can be strongly influenced by changes in land use or other factors, the general homogeneity of the changes in large regions and the fact that they can be explained by observed changes in climate variables indicates that climate change has been the main driver of the changes observed. The distance over which floods affecting different river basins occur has grown from about 80 kilometres in 1960 to 130 kilometres in 2010 in Europe on average. This shows that neighbouring river basins can be flooded at the same time, creating new challenges for flood risk management.

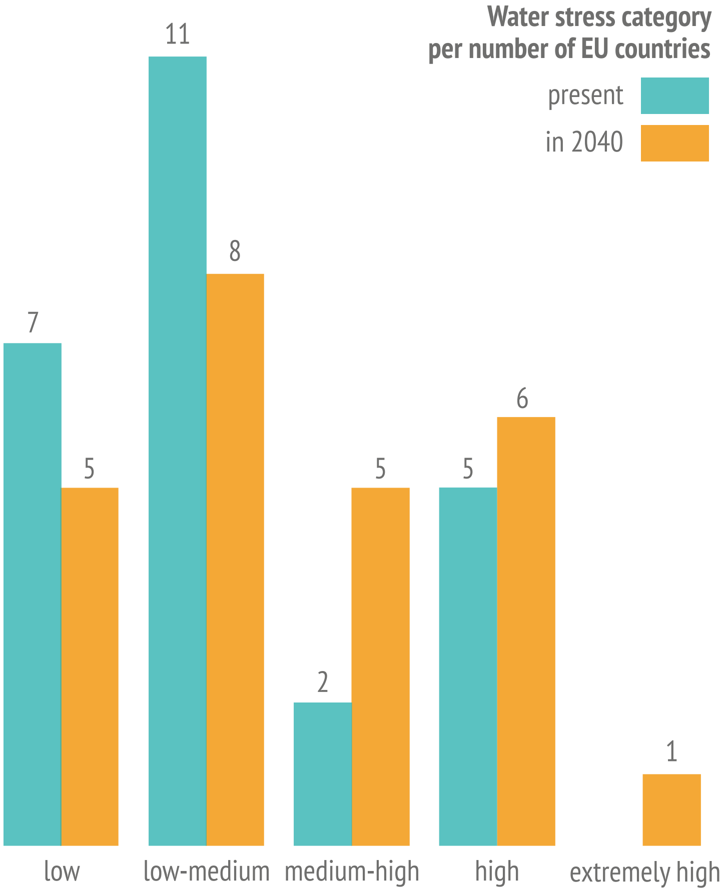
Climate change will increase the population affected and the economic damages from floods in almost all countries in Europe. The strongest increase in flood risk is projected for countries in Western and Central Europe, such as Austria, Hungary, Slovakia and Slovenia. A high emissions scenario could increase the socio-economic impact of floods in Europe more than three-fold by the end of the 21st century.

RISK INDICATORS

Water stress, which is pressure on the quantity and quality of water resources, exists in many places throughout Europe, resulting in serious problems of water shortages, flooding, pollution and ecosystem damage. Although there has been much improvement in water quality since the first European law on bathing water twenty years ago, there has been little progress on the integrated management of water resources, which is the most effective way to address water issues.

WATER STRESS

The intensity of water use, which is the percentage abstraction of water resources available from within the country and from transboundary rivers, varies widely from 0.1% for Iceland to 72% for Belgium, with an average of 15% for Europe. Although some countries rely exclusivley on internal water supplies, others such as The Netherlands, Belgium, Portugal and Hungary, depend on transboundary rivers.



EUROPEAN UNION AGRICULTURE

OVERVIEW

The EU is one of the leading producers and exporters of agricultural products worldwide. The EU produces about 75% of the world's olive oil, as well as 66%, 50% and 13% of the global production of wine, sugar beet, and cereal, respectively.

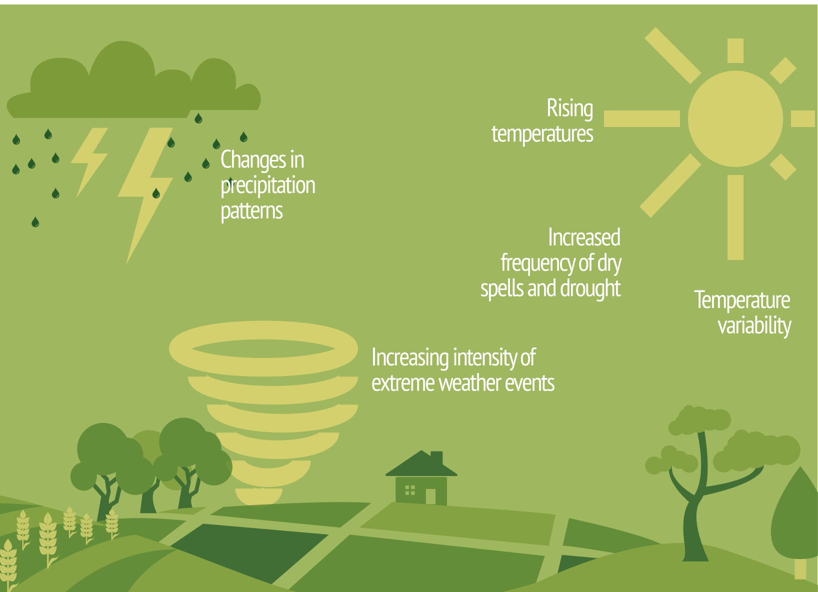
In 2016, about two thirds of the EU-27's utilized agricultural land was based in six Member States: France, Spain, Germany, Poland, Italy and Romania, and about 60% of agricultural produce was from France (18.1 %), Italy (15.3 %), Germany (14.5 %), and Spain (11.3 %). The majority of agricultural land is non irrigated arable land (46%), followed by grassland pastures (18%), and agricultural land with significant areas of natural vegetation (16%). The freshwater use for agriculture accounts for 55% of total water abstraction and is considerably higher in Southern Europe.

124.5 Mt Wheat	111.9 Mt Sugarbeet	69 Mt Maize
50.1 Mt Barley	27.6 Mt Grapes	13.8 Mt Olives

	Added Value of Agriculture, Forestry and Fishing	Share of Agriculture Value added in Total GDP	Agricultural land	Area Equipped for Irrigation
2000	160,016 USD Million	2.3 %	122,753 Thousand HA	18,425 Thousand HA
2018	256,141 USD Million	1.6 %	110,879 Thousand HA	18,631 Thousand HA

EXPEXTED IMPACTS ON AGRICULTURE PRODUCTIVITY

Rising temperatures, reduction in average annual precipitation, and intensification of extreme events such as heat waves and drought, affect production variability with a tendency towards yield reduction for many cultivated species, accompanied by a probable decrease in food quality. Crops respond to increases in temperatures with changes in duration of the growing season, early appearance of phenological phases and potential shifts of cultivation areas toward higher latitudes and altitudes for better growing conditions. However, impacts vary significantly depending on the geographical area and specific crops in question.



CROP PRODUCTIVITY

Crop productivity refers to the harvested yield of a crop per unit of land area. It is strongly influenced by climate and other environmental and management factors.

Climate change is expected to have an impact on the productivity of several major crops, although this may in part be offset by the fertilizing effect of higher CO_2.

Impacts are estimated using a range of model projections based on low to high emission scenarios and reported as percentage changes between the 30-year average around the historical period and the 30-year average around 2050.

5.5 **Wheat** tons / ha
9.3 (2.5)%
11.6 (5.2)%

8.1 **Maize** tons / ha
6.9 (3.3)%
6.6 (-0.2)%

71.4 **Sugarbeet** tons / ha
12.3 (5.4)%
14.2 (na)%

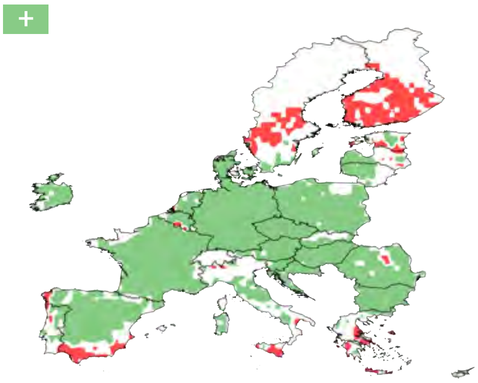
2.9 **Rapeseed** tons / ha
8 (2.7)%
8.5 (na)%

2050

Productivity change with (without) the CO_2 fertilization effect. Estimates assume sufficient water and nutrient supplies, and do not include impacts of pests, disease, or extreme events.

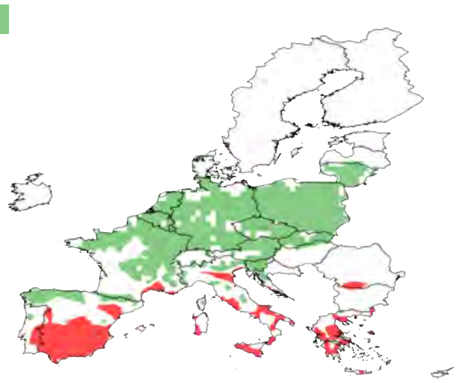
CHANGE IN WHEAT

− = +



CHANGE IN MAIZE

− = +



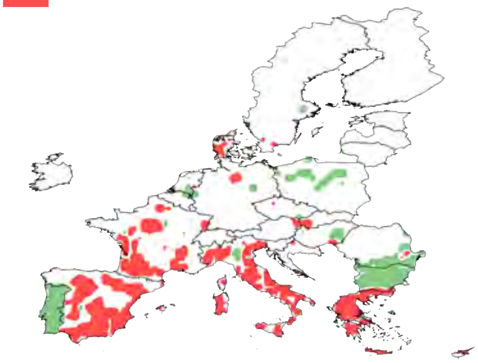
Wheat and maize productivity may benefit from climate change with yield increases projected in northern Europe. Crop losses are instead expected in southern Europe due to higher temperatures that affect the length of the crop growing period and reduce plant biomass accumulation. Extreme climate conditions (like heatwaves, drought and heavy rain) will be more pronounced in the future, triggering heavy yield losses and also affecting regions that are projected to experience average positive agro-climatic changes. Sugarbeet and rapeseed cultivation may also benefit from climate change, with up to 14% and 8% average increases in productivity, respectively. Summer temperature upsurge will harm productivity and reduce quality of perennial species, such as olive trees and grapevines,particularly in the warmest and driest regions. A potential northward and higher altitude shift of tree crop suitable areas is expected.

ADAPTATION IN AGRICULTURE AND WATER RESOURCES

The growing season will become drier in both northern and southern Europe, exposing crops to higher water deficits. However, summer temperatures will increase the most in southern Europe, where water resources may drop up to 40%. Even more intense droughts will occur in areas that are already water scarce. Higher temperatures will generally require more water for agriculture due to higher plant evapotranspiration. This may compromise recharge rates of groundwater levels and risks of saline intrusions into coastal aquifers.

CHANGE IN WATER DEMAND

− = +



Agriculture Water Demand
% of change
19.3
20.6

2050

Major adaptation in agriculture will be needed, particularly in southern Europe, to reduce water resource risks, with potential benefits for climate change mitigation and sustainability goals.

EUROPEAN UNION
FORESTS

FORESTS IN EUROPEAN UNION

The EU27 countries have an extensive and diversified topography hosting a multitude of forest types. In the south there is a predominance of mediterranean vegetation such as scrub and evergreen oak forests. In the north, on the main mountain ranges, the boreal coniferous forest prevails, whereas temperate forests are most common in the innermost territories where broad-leaved trees dominate.

1990

145 Mln ha
Million hectares
Forested area

165 Tons/ha
Tons of Carbon per hectare
Carbon stock

2020

159 Mln ha
Million hectares
Forested area

200 Tons/ha
Tons of Carbon per hectare
Carbon stock

FORESTED AREA AND CARBON STORAGE

With a constant increase in surface area over recent decades, wooded areas now cover almost 40% of the total land surface. This amounts to an overall stock of 30 gigatonnes of carbon including soil. Forests sequester the equivalent of about 400 million tons of carbon dioxide per year: a crucial sink that amounts to approximately 10% of total EU-27 greenhouse gas emissions. However, projections indicate a future decline.

2050

Productivity anomaly
Tons of Carbon per
hectare per year

+0.62

+0.45

FOREST PRODUCTIVITY

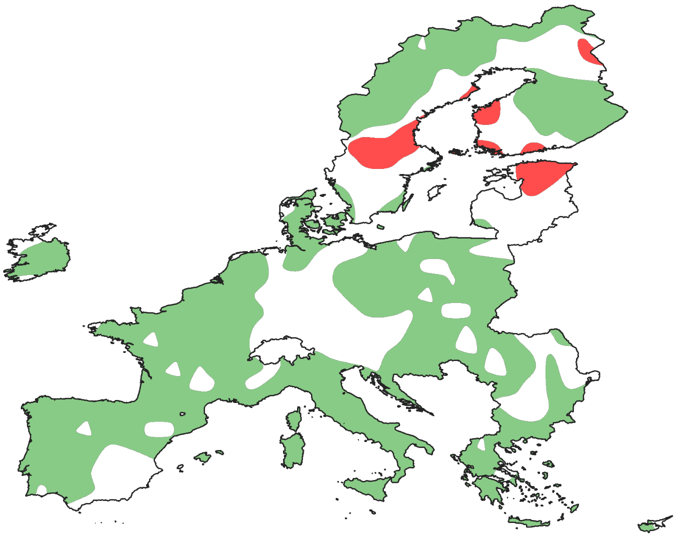
Forest productivity or Net Primary Production is the net carbon captured by plants. It is the difference between the carbon gained by Gross Primary Production - net photosynthesis measured at the ecosystem scale - and carbon released by plants' respiration. It is expressed per unit land area.

Increase expected to be very weak and with high uncertainty between models. Growth areas in the whole continent except for Germany and southern Spain

+ Fertilizing effect of increasing atmospheric CO_2
+ Rising temperatures and nitrogen deposition promotes productivity

Notable decrease of large areas in Baltic countries

+ Lengthening dry season reduces productivity



KEY SPECIES UNDER CLIMATE CHANGE

CHANGE
MEDITERRANEAN
In mediterranean forests in southern Europe intensified drought impacts favour more dry tolerant species

VULNERABILITY
BEECH
Significant impacts on beech forests especially in the central-southern range

THREATENED
SPRUCE
Prolonged droughts are increasing the impacts of bark beetles on Norway spruce forests in Central Europe

GAIN
TEMPERATE
European temperate forests of mesophilic oaks could widen their distribution range to the north compared to boreal forests

FIRES IN EUROPEAN UNION

Fire is a structural ecological process that provides several types of ecosystem services and impacts on socio-ecological systems, including human health, carbon budgets, and climate change. Changes in global fire activity are influenced by multiple factors such as land-cover change, policies, and climatic conditions. Fire also releases large quantities of greenhouse gases into the atmosphere, contributing to a vicious cycle.

During the last two decades, the total area affected by fire was approximately 13.2 million hectares with 1.2 million fires occurring.

BURNING
13.2 MILLION HECTARES

EMITTING
0.22 TERAGRAMMES
OF CARBON PER YEAR

FOREST FIRE EMISSIONS
CONTRIBUTED TO
11% OF TOTAL FIRE RELATED
CARBON EMISSIONS

COSTING
APPROXIMATELY 3.5 BILLION
USD PER YEAR IN ECONOMIC
LOSSES (2000-2017)

FUTURE BURNED AREA

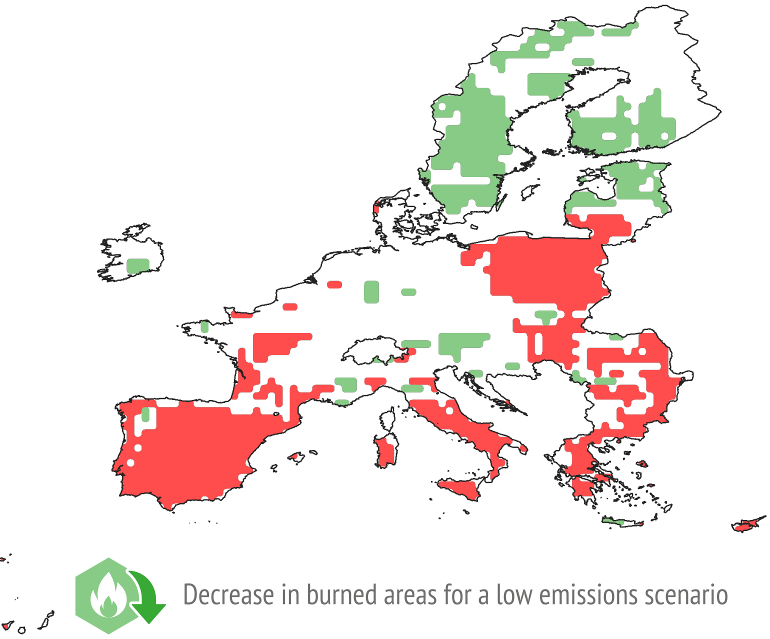
Under a low emissions scenario, a generalized increase in burned area is expected over the Mediterranean, affecting sclerophyllous, conifers and semi-deciduous forests. Some temperate and mixed forests in eastern Europe might also suffer an increase in burned area. However, in some boreal forests of Scandinavia burn area may decrease. Spatial patterns are expected to be similar under a medium emissions scena- rio.

Burned Area
km² per year

2050

+1,659

+1,494



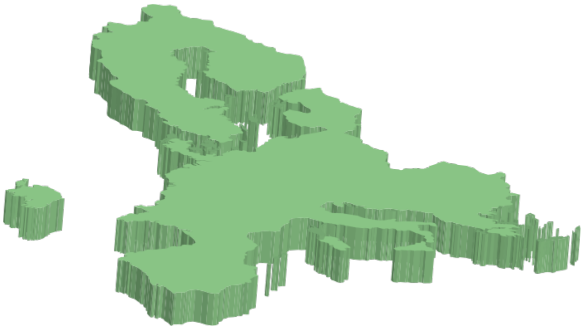
🟩 Decrease in burned areas for a low emissions scenario

🟥 Increase in burned areas for a low emissions scenario
+ Prolonged and more intense fire season
+ Increase in future weather risk due to warming and drought conditions

WHERE DO FIRES OCCUR?

Portugal, Spain, Italy, Greece, and France contributed up to 90% of the total burned area.

611 fatalities occurred between 2000 and 2017.



Fires occur in most European countries, although they affect the Mediterranean region in particular.

Changes in land use, socio-economic factors and climate are the main drivers of fire regime changes in Europe.

VARIATION OF SPECIFIC FIRE INDICATORS

% of change
High-to-extreme fire danger days

+10%

+5%

2041-2071

% of change
Fire season lenght

+10%

2010-2050

% of change
PM2.5 emissions

+18%

+17%

FUTURE FIRE EMISSIONS

Fire emissions might follow a similar spatial pattern to burned area with a pronounced increase in northern boreal forests under a medium emissions scenario.

2050

Fire Carbon emission
Teragrams of Carbon per year

+15.7

+9.8

EUROPEAN UNION
URBAN

OVERVIEW

Urbanization rate in Europe in 2020 was 75%, it is expected to increase to 84% by 2050.

The EU's urban population lives predominantly in smaller urban centres with less than 300,000 inhabitants. There are only two mega-cities with more than 10million inhabitants, although a third one is expected to emerge by 2035.

Bult up areas cover 3.81% of the the European Union (156,895.59 square kilometers).

Population in Urban Areas

2020 556,684,039

2050 598,857,027

Graphs refer to data provided by United Nations, Department of Economic and Social Affairs, Population Division (2018). World Urbanization

Urbanization Rate

2020 74.9%

2050 83.7%

OVERVIEW OF KEY CLIMATE IMPACTS IN URBAN AREAS

The main impacts of climate change on urban areas in the EU relate to increasing heat stress and flood events.

HEATWAVES AND HEAT STRESS

Temperatures in built-up areas are higher than in the surrounding rural areas due to the urban heat island effect. In particular in cities in the northern and western part of the EU, differences in temperatures between city centres and vegetated surroundings can be as high as 9°C. Heat stress during heatwaves accounted for 87% of fatalities from climate and weather related events, mainly due to the heatwave of 2003, which alone caused around 70,000 fatalities across Europe.

Official accounts counted almost 90,000 victims from heatwaves in Europe between 2000 and 2020. The number of hot days and intensity and frequency of heatwaves is expected to rise under all future climate change scenarios. In particular for cities in the Mediterranean area and in Eastern Europe, rising mean temperature increases will increase heat stress in urban areas.

Under such climate conditions, and without any adaptation measures, annual fatalities from extreme heat could rise from 2,700 deaths per year now to approximately 30,000 or 50,000 by 2050, with **1.5°C** or **2°C** global warming, respectively.

2050

Cooling Degree Days
% of change

+305%
+100%
+59%

2100

Heatwave frequency
% of change

+83.7%
+31.8%
+18.9%

2050

Heatwave duration
% of time

+1,247%
+184%
+63%

ENERGY POVERTY

In 2016, more than 20% of households in the European Union faced difficulties in keeping their house cool during heatwaves, due to energy poverty as well as poor quality of housing.

During heatwaves, high levels of air pollution in many European cities worsened health impacts. In 2017, almost 80% of the European population was exposed to levels of air pollution which exceeded WHO thresholds.

COASTAL FLOODING

Europe's population is increasingly concentrated in coastal areas, and many of these are exposed to increasing risks due to sea level rise and more frequent storm surges.

Under a rapid sea level rise scenario, the population exposed to flood risk will increase, for example, from under 5 million to 8.8 million in the Netherlands, and from 1.5 million to 2 million in Germany.

EXTREME PRECIPITATION EVENTS

European cities are vulnerable to flooding from extreme precipitation events, which cause high levels of damage to buildings and infrastructure. While overall precipitation is expected to decrease in most parts of Europe, extreme precipitation events might become more frequent.

Many cities in the European Union have been impacted by intense short-term precipitation events causing surface flooding. In Münster, Germany, 90 millimetres of rain fell in 7 hours, causing 72 million euros in damages in 2014, and in Copenhagen in 2011, 135 millimetres of rain in 2 hours caused losses for more than 800 million euros. Frequency and intensity of brief precipitation events are expected to increase further. Intensifying water cycles and increased seasonality of river flows, will result in more frequent and intense flood events.

2017

Population exposed to air pollution

79.9%

2050

Projected sea level rise

0.23 m

0.18 m

2100

0.77 m

0.38 m

2050

Runoff increase
% of area

+34%

+20%

+10%

SURFACE SEALING AND FLOODS

Heavy precipitation in cities is problematic due to the high level of sealed surfaces. Soil sealing increases run off and reduces the amount of water absorbed by soil. Where there are large amounts of impervious ground cover, short duration extreme rainfall events can lead to increased flooding, even resulting in flash floods.

URBANIZATION OF FLOOD PLAINS

High rates of urbanization and expansion into floodplains have increased levels of exposure to flooding. At the same time, built up and impermeable surfaces increase water run off and make extreme precipitation events more serious. In 2019, built up areas covered 3.8% of the overall surface of the EU.

In cities this rate was around 19.5% in 2015 (19.1% in 2006), and in core city areas (urban morphological zone, UMZ,) this rate was as high as 35.6% (up from 34.9% in 2006).

2010

% of urban population
Population living in slums

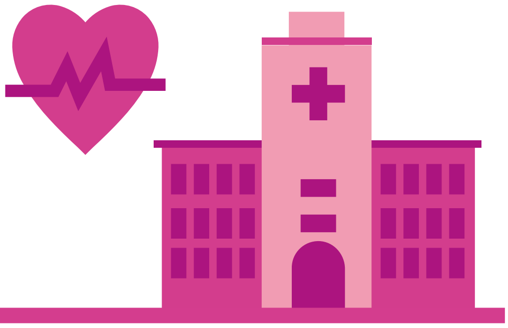
0%

2018

% of total population
Urban population living in areas where elevation is below 5 meters

5.0%

EUROPEAN UNION
HEALTH



OVERVIEW

Climate change affects human health in Europe through warming and increased frequency and intensity of extreme events. Countries in the WHO European Region are experiencing accelerated rates of warming and an unprecedented frequency and intensity of heatwaves. Heat extremes are already leading to increased fatalities and negative health effects, also due to a growing urban population. Along with these direct changes, indirect effects through increases in vector-borne diseases, rodents, or changes in water, food, and air quality are also likely to increase. Climate change also makes some areas in Europe more suitable for infectious diseases, including dengue fever, Vibrio infections and West Nile fever. Environmental factors are estimated to account for almost 20% of all deaths in Europe.

HEAT RELATED MORTALITY

The EU accounted for more than a third of heat-related mortality among the elderly, with 104,000 out of the 296,000 global deaths recorded in 2018. Due to the higher number of people being exposed to heatwaves, heat-related mortality is expected to increase in Europe. Annual mortality from extreme heat is projected to rise from 2,700 deaths currently to around 30,000 under 1.5°C warming, 50,000 under 2°C, and 90,000 under a 3°C warming, by 2100.

In 2018, there was a 33% increase in heat-related deaths in the EU compared to the 2000 to 2004 baseline.

IMPACTS ON LABOUR

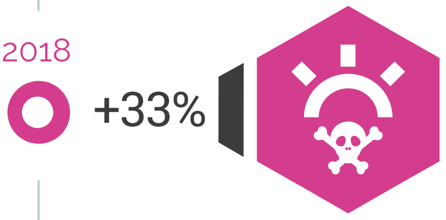
Labour is directly affected by changes in environmental conditions. Warming affects both the number of hours worked (labour supply) and on the productivity of workers during their working hours (labour productivity). Both labour supply and productivity are projected to decrease under future climate change in most parts of the world, and particularly in tropical regions.

Parts of sub-Saharan Africa, south Asia, and southeast Asia are at highest risk under future warming scenarios. Future climate change will reduce global total labour in the low-exposure sectors by 18 percentage points and by24.8 percentage points in the high-exposure sectors under a 3.0°C warming scenario.

Labour is directly affected by changes in environmental conditions and especially heat stress. Total labour in the EU is expected to decline by 0.3% under a low emissions scenario, and by 1.0% under a medium emissions scenario.

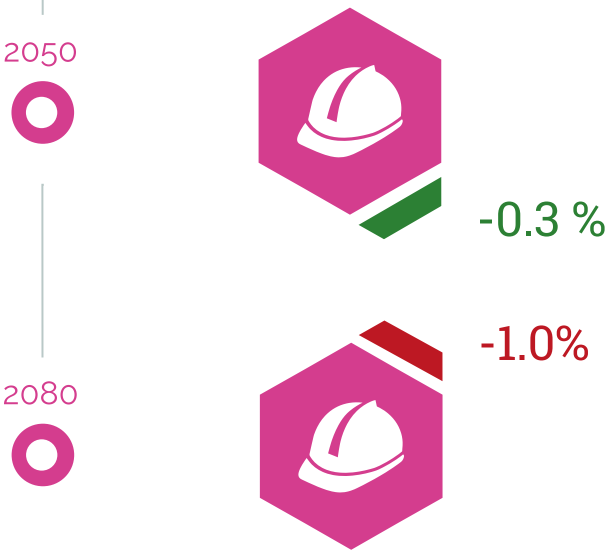
Heat-related mortality

% change with respect to 2000-2004



Impact on total labour

% change with respect to 1986-2005 baseline



CLIMATE CHANGE AND DENGUE

Dengue has spread throughout the tropical world over the past 60 years and now affects over half the world's population. Globally, vectorial capacity for both dengue vectors (A. aegypti and A. albopictus) has been rising steadily since the 1980s, with nine of the ten highest years occurring since 2000.

Climatic stressors are one important driver of the current distribution and incidence of dengue. Climate change is likely to expand the geographical distribution and suitability of several vector-borne human infectious diseases including dengue. The risk of dengue transmission is increased by warming climates, as the growth and development of mosquitoes are significantly influenced by temperature, precipitation, and humidity.

CLIMATE CHANGE AND ZIKA

Zika virus has spread to at least 49 countries and territories since 2013. Climate change impacts on transmission suitability risk have increased over the years and future warming over 1.3 billion additional people could face suitable transmission temperatures for Zika by 2050.

DENGUE AND ZIKA: POPULATION AT RISK

Though dengue cases in Europe are currently non-existent due to the principal vector (mosquito Aedes aegypti) disappearing, another vector (Aedes albopictus) has been introduced into Europe over the last two decades increasing the possibility of dengue transmission. Diseases such as chikungunya, tick-borne diseases, and West Nile virus may also increase.

These risks are likely to increase due to future climate change. Under a medium emissions scenario, 60.2% of the population will be at risk of transmission-suitable mean temperature for dengue by 2050, whereas 71.2% will be at risk under a high emissions scenario.

CLIMATE CHANGE AND MALARIA

The exposure of Europe to malaria transmission will increase as a result of rising temperatures. In 2050, 7% of the EU population will be at risk of malaria under a low emissions scenario, whereas 9.5% will be at risk under a high emissions scenario.

POLLUTION AND PREMATURE MORTALITY

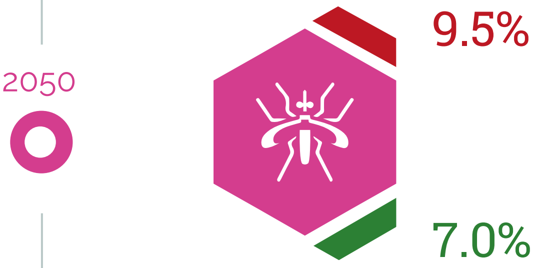
Without adequate adaptation measures, short and long term exposure to air pollution is likely to increase health impacts in the EU. Despite improvements in air quality standards, challenges in terms of health impacts remain. Under a medium emissions scenario, annual premature deaths due to long-term exposure to near-surface ozone and heat will increase from 55,597 (2010) baseline to 86,337 in 2050.

Dengue suitability

% of population at risk

Malaria suitability

% of population at risk



EUROPEAN UNION
ENERGY

ENERGY SYSTEM IN A NUTSHELL

The EU energy system (net of national differences) is still heavily dependent on fossil fuels; however, since 1990 it has experienced a progressive decarbonization and energy efficiency improvement processes. The EU is also a net energy importer. In 2019, it produced domestically around 39% of its own energy, while 61% was imported, showing progressively an increase in energy dependency.

0.07
ktoe/US$
Energy intensity

1.7%
AC Share in
electricity consumption

49.6%
Import
dependence ratio

CLIMATE CHANGE TODAY

TEMPERATURE

Energy demand is affected when changes in parameters like temperature or humidity change the cooling and warming needs of households and firms. Current trends in heating and cooling degree days in the EU already show a consistent shift towards cooling needs as a main driver of energy demand for indoor thermal comfort.

RENEWABLES

Increasing hydropower and wind potential in northern EU, decreasing hydro and biomass in southern EU.

WATER

Water scarcity is reducing efficiency of thermal plants in southern EU. Extreme precipitations, riverine and coastal floods are already disrupting energy infrastructure all over the EU.

ENERGY SUPPLY

The current EU energy mix of total primary energy supply shows a prevalence of oil and gas. The share of renewables ranks third and is increasing. Coal and nuclear follow with similar importance. In 2019, the energy mix in the EU, was mainly made up by five different sources: Petroleum products (including crude oil) 36%, natural gas (22%), renewable energy (15%), nuclear energy and solid fossil fuels (13%).

ENERGY DEMAND

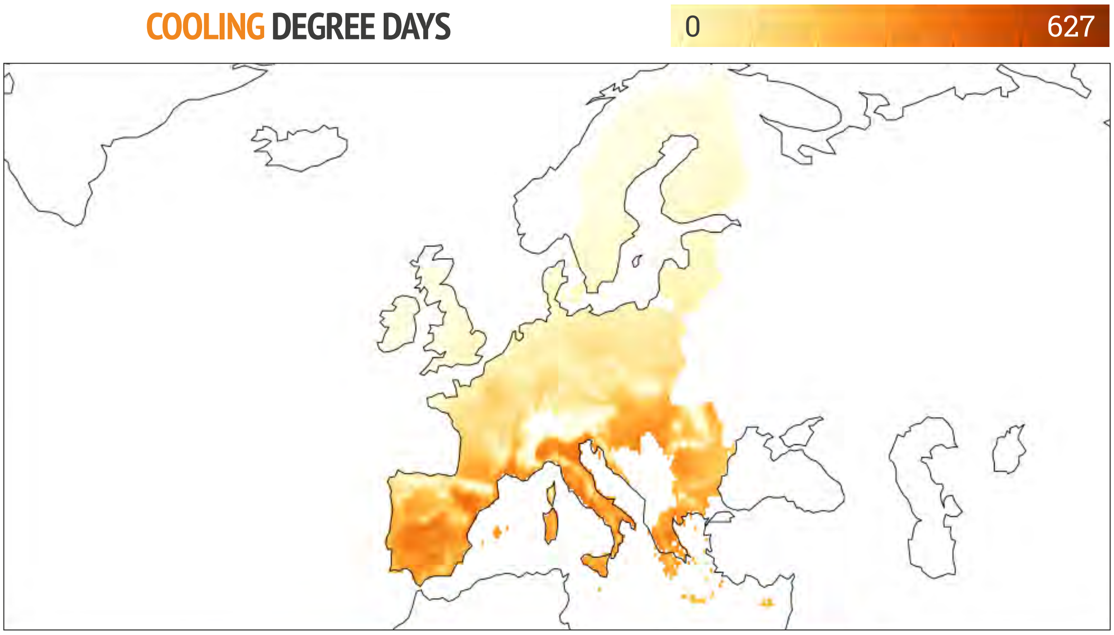
Energy use in Europe is absorbed primarily by industry followed by the transport sector, households, services and agriculture & forestry.
EU energy demand in 2019 as share of final energy consumption: Industry sector 32 %; transport sector 28 %; households 24 %; services 12 %; agriculture & forestry 3 %.

FUTURE ENERGY DEMAND

Residential and commercial demand is mainly driven by heating and cooling needs, determined by temperatures. At the EU level there is evidence that decrease in heating demand will be larger than the increase in cooling needs determining a net reduction in energy demand. Energy demand in the residential sector is projected to shift away significantly from natural gas (-27.5%) and oil products (-41.5%) toward electricity (increasing 3.8%) under a high emissions scenario, by 2070.

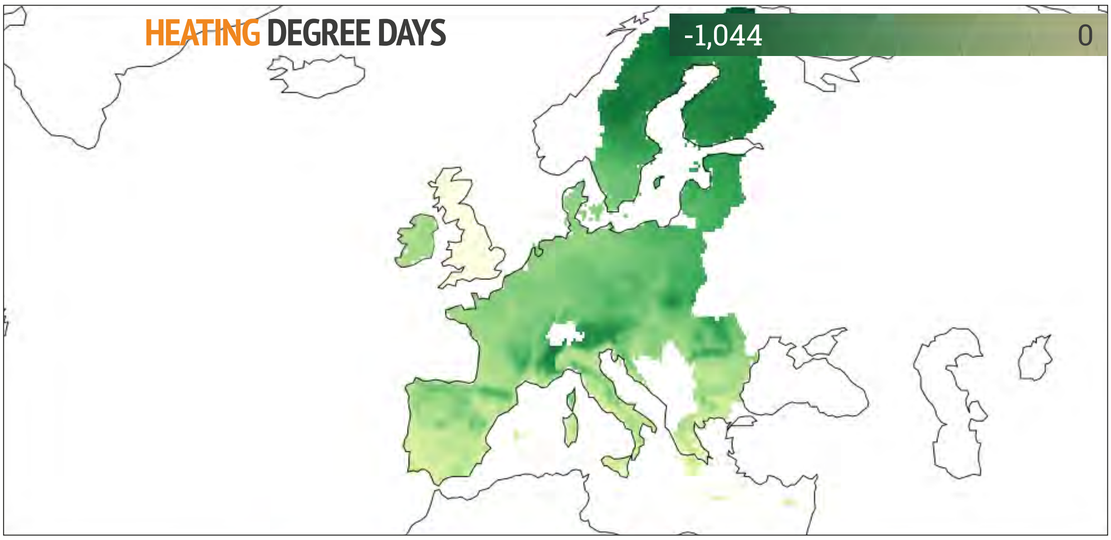
COOLING NEEDS

Marked increases in cooling needs in the Mediterranean Europe, but also in some metropolitan areas of Central Europe.



HEATING NEEDS

Heating needs are expected to decline drastically in Scandinavian coutries and Central/Eastern Europe, and in the the coldest regions of the Mediterannean (Alps, Pyrenees, Spanish mountain ranges).



EXPECTED IMPACTS OF CLIMATE CHANGE

Increasing hydropower supply is projected for northern European regions, while a decline in hydropower and nuclear power is expected in southern Europe due to lower water availability for hydropower generation and for cooling of thermal plants.

Global warming is expected to affect wind and solar production only marginally. Overall EU hydropower production may increase by 2.3% or 3.2%, and nuclear power may decline by 0.7% or 1.8% under 2°C and 3°C warming scenarios respectively.

EUROPEAN UNION
ECONOMY

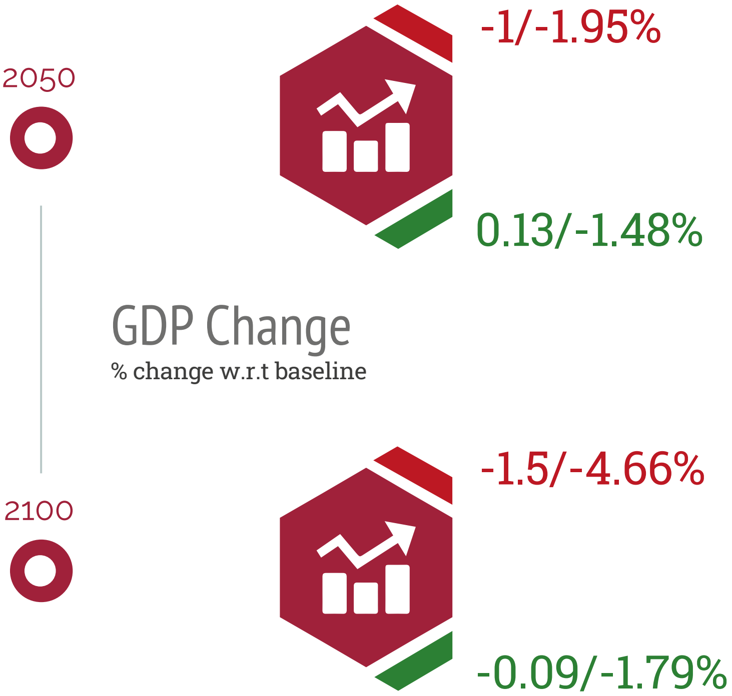
OVERVIEW

In terms of the total value of all goods and services produced, EU GDP in 2019, when the UK was still part of the EU, was 16.4 trillion EUR. Over 64 % of total EU trade is done within the bloc. With just 6.9% of the world's population, EU trade with the rest of the world accounts for 15.6% of global imports and exports. Together with the USA and China, the EU is one of the three largest global players in international trade.

IMPACTS ON GDP

Climate change impacts growth prospects and the overall systemic economic performance of the continent. Studies emerging after the 2014 IPCC AR5, emphasize larger economic losses than previously estimated. There is agreement in the research community that these impacts will hit Southern Europe more than Northern Europe, increasing the North-South divide.

Negative impacts on GDP may be significant. By mid century, under a low emissions scenario, they could reach 1.5% of the EU's GDP; and by the end of century this could rise to 4.7% of GDP, under a high emissions scenario.



2050

-1/-1.95%

0.13/-1.48%

GDP Change

% change w.r.t baseline

2100

-1.5/-4.66%

-0.09/-1.79%

SECTORAL ECONOMIC IMPACTS

IMPACTS ON INDUSTRY AND INFRASTRUCTURE

The EU coastline is 68,000 kilometres long. Almost half of the EU population lives less than 50 kilometres from the sea; the majority is concentrated in urban areas along the coast. Economic assets within 500 metres of the sea have an estimated value of 500 billion to 1,000 billion EUR. Accordingly, climate change induced risk from sea-level rise and intensification of coastal storm surges can generate huge economic impacts.

In the 1960 to 2010 period, river floods increased in northwestern and parts of central Europe, caused by increasing autumn and winter rainfall; decreased in southern Europe, caused by decreasing precipitation and increasing evaporation; and decreased in northeastern Europe, caused by decreasing snow cover and snowmelt.

Flood events have resulted in over 4,300 fatalities and caused direct economic losses of more than 170 billion EUR (based on 2017 values) in EEA member countries over the 1980–2017 period. A possible increase in frequency and intensity due to climate change is particularly concerning.

IMPACTS ON AGRICULTURE

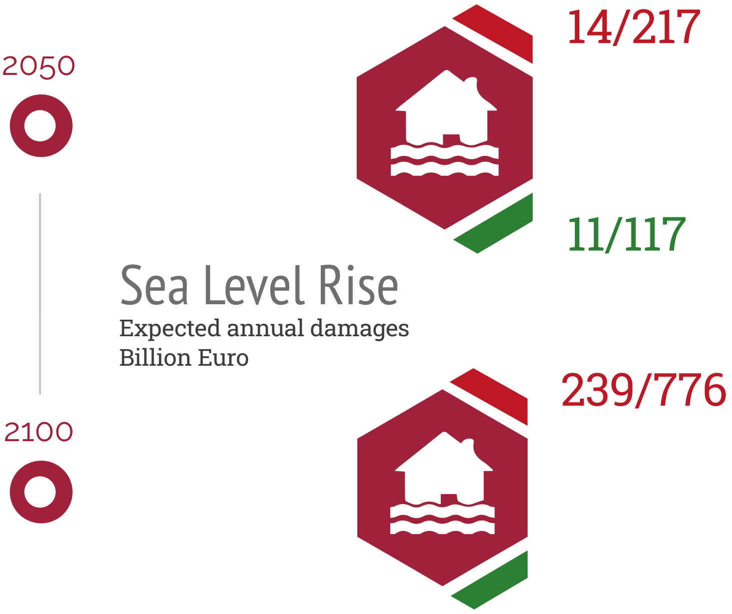
In a large, climatologically, environmentally, and economically differentiated area like the EU, impacts of climate change on agriculture and their economic consequences are highly differentiated depending on crops and regional specificities. Against this background Northern Europe could experience low negative impacts or even moderate yield improvements with associated economic gains due to climate change, whereas Southern Europe may experience substantial production losses, especially with regards to grain, maize and wheat.

The net economic costs for agricultural firms are estimated at 1.7 billion EUR under a medium emissions scenario and 0.83 billion EUR under a high emissions scenario, by 2050. However, by 2070 these could fall to 1 billion EUR and 0.63 billion EUR under a medium and high emissions scenario, respectivley. This is because, losses may be smaller under higher climate signal scenarios given the CO_2 fertilization effect. The interplay between agricultural production changes in the EU and other major producing countries (that may suffer more severe effects), could lead to export increases in wheat, barley, grain maize and soybean, with EU producer prices increasing between 1% and 7%. This could increase EU producer income between 25% and 50% in Northern Europe, and 10% to 30% in Southern Europe.

SEA LEVEL RISE DAMAGES

In the second half of the century, if coastal defenses are not upgraded to contrast increasing climate change risk, expected annual damages to EU coastal infrastructures could reach 776 billion EUR.

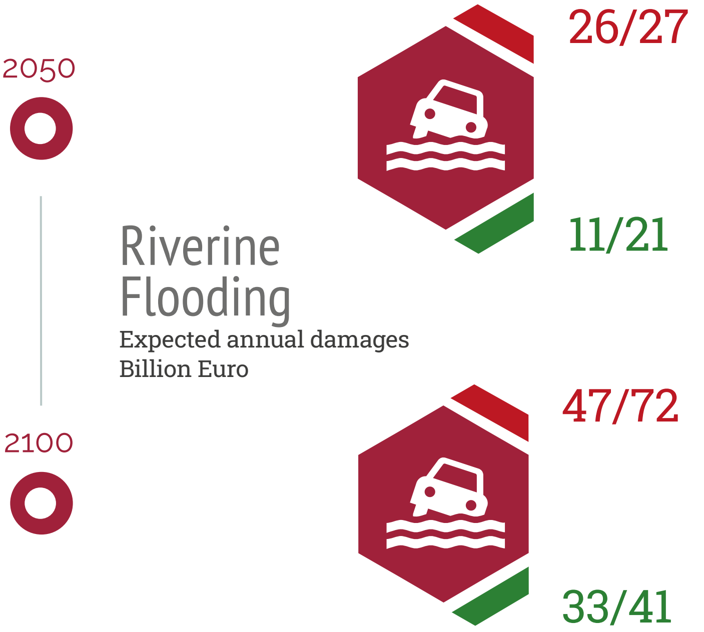
All the available studies also highlight the high benefit to cost ratio of coastal protection measures. Adaptation can reduce expected annual damages by roughly 90% at a cost that is roughly 2% of the avoided damage.



Sea Level Rise
Expected annual damages
Billion Euro

RIVER FLOODING DAMAGES

In a relatively moderate temperature increase scenarios, losses can amount to roughly 21 billion EUR by mid-century and € 30-40 billion end of century. Losses could reach over 70 billion EUR by the end of the century under a high emissions scenario.



Riverine Flooding
Expected annual damages
Billion Euro

IMPACTS ON FORESTRY AND FISHERY

Net production effects are unambiguously negative under a high emissions scenario in the forestry sector, amounting to 11 billion EUR aggregate lost production in 2070, whereas in other climate scenarios net economic gains due to trade effects could be expected even though net forest productivity declines.

The fishing sector can experience losses mostly related to decline in catches. Under a high emissions scenario producer losses can amount 1.3 billion EUR already in 2050.

IMPACTS ON ENERGY

As with all other economic sectors energy supply network in the EU will also be subject to increased stress from extreme weather events (see energy chapter)
The economic consequences in shifts of energy consumption patterns are mostly distributional, with firms and households changing their consumption basket, and increasing energy demand for cooling and decreasing that for warming. This also implies differentiated demand effects across energy vectors, with a lower demand for fossil fuels, oil and natural gas used mostly for warming purposes, and an increase in electricity (see the "Energy" chapter of this Atlas). Increases in electricity demand, induced primarily by cooling needs, represent an increase in production costs for firms. The final impact on GDP is rather moderate: an average decline of 0.2% in 2070 under a high emissions scenario and negligible for a low emissions scenario. However, some Southern European regions may experience macroeconomic losses larger than 1% of GDP not only under a high, but also medium emissions scenario. Under a medium to high emissions scenario, expected annual damage from extreme events on EU energy infrastructure will be 4.2 and 8.2 billion EUR in 2050 and 2080 respectively, roughly 7 and 15 times larger than today.

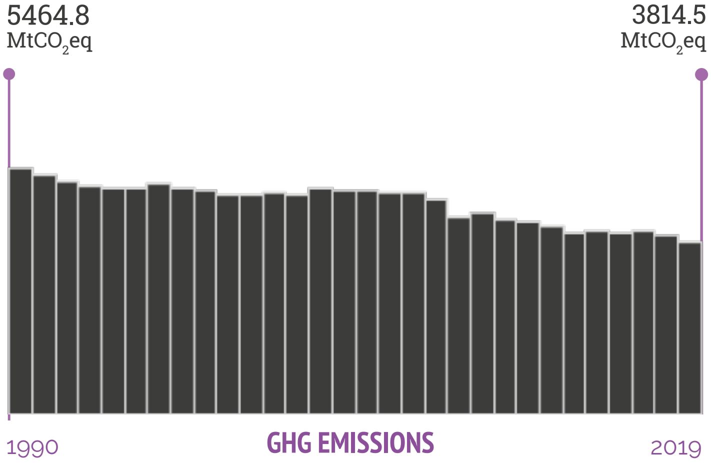
IMPACTS ON TOURISM

Climate change is projected to change the climatic attractiveness of EU countries, increasing the appeal of northern European destinations and decreasing that of southern ones, which will become “too hot”.
It is however difficult to derive a net economic estimate from these trends, as they are also highly dependent on non climatic variables.

EUROPEAN UNION POLICY

OVERVIEW

The EU is responsible for 7.8% of global GHG emissions and has a rate of CO_2 emissions per capita 43% higher than the world average (2018, World Bank). Its emissions have been declining since 1990, and it has a target to reach net zero emissions by 2050.



INTERNATIONAL COMMITMENTS

In its 2020 National Determined Contribution update, the EU strengthened its emissions reduction target from at least 40% reduction below 1990 levels by 2030 to at least 55% reduction.

CLIMATE POLICY COMMITMENTS CHRONOLOGY

2002 **KYOTO PROTOCOL - 1ST PERIOD**

8% yearly average reduction of GHG over the four year period 2008-2012 and applied overall to EU-15 (the 15 States who were EU members in 1997), Bulgaria, Czech Republic, Estonia, Latvia, Liechtenstein, Lithuania, Monaco, Romania, Slovakia, Slovenia, Switzerland

2016 **PARIS AGREEMENT - 1ST NDC**

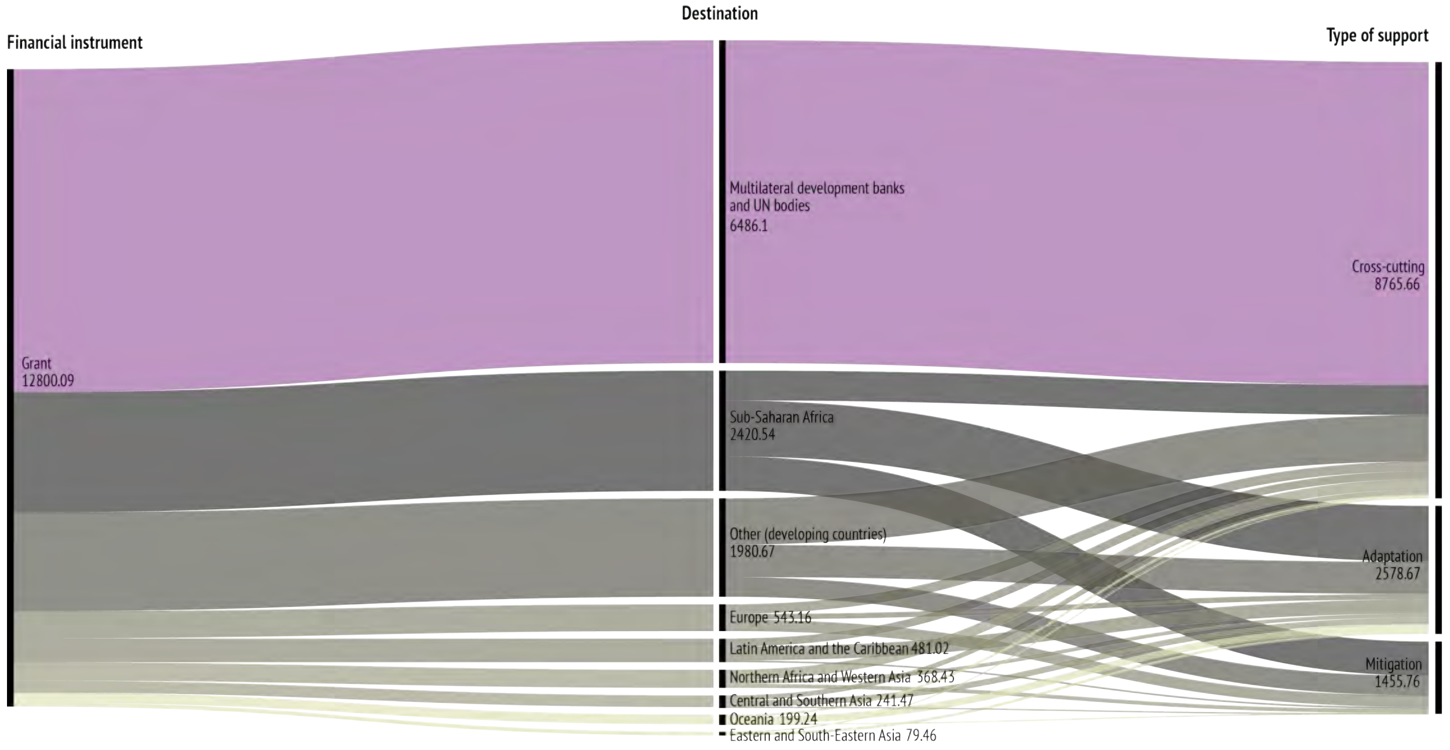
40 % of GHG reduction at 2030, with respect to 1990 level

2020 **PARIS AGREEMENT - NDC UPDATE**

55 % of GHG reduction at 2030, with respect to 1990 level

INTERNATIONAL CLIMATE FINANCE ASSISTANCE

In the 4th Biennial Report, the EU, exercising its own competences as development aid provider, reported $ 12,8 Billion in climate-related development finance in 2017-2018. A half is devoted to bilateral channels and the largest share is directed to sub-Saharan Africa



SUSTAINABLE RECOVERY POLICY

According to the Global Recovery Observatory, in 2020 the proportion of green spending out of the total recovery spending was 10%.

2381.18
billion $
Total Spending

755.33
billion $
Recovery Spending

75.06
billion $
Green Spending

DOMESTIC ADAPTATION POLICY

In 2013 the EU adopted its first strategy on adaptation to climate change which was updated in 2021 to a "Forging a climate-resilient Europe – the new EU Strategy on Adaptation to Climate Change". The new strategy is built around 4 main pillars: smarter adaptation, more systemic adaptation, faster adaptation and international action.

- ○ Domestic Adaptation Policy
  - ○ Inclusion of Adaptation in NDCs
  - ● Integrated Adaptation & Mitigation Policy
  - ● Dedicated Adaptation Strategy
  - ○ Dedicated Adaptation Plan
- ○ Subordinate Adaptation Policies
  - ○ Sectoral Adaptation Plans
  - ○ Subnational Adaptation Plans

○ Policy not in place ● Active policy

ADAPTATION POLICY HIGHLIGHTS

TRANSNATIONAL INITIATIVES

Global Covenant of Mayors for Climate and Energy

An international coalition of cities and local governments with a shared long-term vision of promoting and supporting voluntary action to combat climate change

Global Climate Change Alliance Plus (GCCA+)

GCCA+ is a European Union flagship initiative which is helping the world's most vulnerable countries to address climate change.

EUROPEAN COMMISSION'S INITIATIVES

Climate-ADAPT

European Climate Adaptation Platform Climate-ADAPT supports governmental policy and decision-makers developing/implementing climate change adaptation strategies, policies and actions

The European Topic Centre on Climate Change Impacts, Vulnerability and Adaptation (ETC/CCA)

The ETC/CCA assists the EEA in supporting EU policy by improving data and indicators on climate change and its impacts across sectors and regions, enhancing the assessment of climate change vulnerabilities and natural hazard risks to society and ecosystems and building on current or planned adaptation strategies and actions.

Horizon Europe's Mission "Adaptation to Climate Change"

Horizon Europe is the Commission's programme for R&I. It defined 5 "Missions", to fund research projects that contribute to the political priorities of the European Commission. A specific Mission is dedicated to climate adaptation and specifically to make 150 regions across Europe climate resilience.

THE GREEN DEAL

In December 2019, the European Commission launched the EU Green Deal, a framework for the future European legislation, which promotes on one hand the prosperity of Member States' societies and on the other hand the protection of health and environment. In particular, the Green Deal aims at transforming European economy to achieve carbon neutrality by 2050. Do to so, it tackles the main environmental issues in a systematic way, by starting several parallel legislative processes in the fields of climate (the revision of the Climate Law to strengthen emission targets for 2030 and 2050, but also the new adaptation strategy as well as the package of legislative reforms included in the "Fit for 55" Communication), energy (including a roadmap for the deployment of hydrogen), circular economy (to increase the competitiveness of European manufacture), building sector (for the massive renovation of the building stock), chemistry and pollution prevention (to achieve a toxic-free environment), biodiversity (to restore ecosystems), agri-food (for the transformation of food's supply chains) and mobility (to decarbonize different transportation systems).

G20 CLIMATE RISK ATLAS

Impacts, policy, economics

cmcc

FRANCE

How to read the Atlas: graphs, colours and scenarios.

The maps used in this Atlas are taken from **The World Bank Official Boundaries** - ***https://datacatalog.worldbank.org/search/dataset/0038272*** (accessed on May 28, 2021). For the section Energy, the maps are based on Panoply Data Viewer ***https://www.giss.nasa.gov/tools/panoply/credits.html***

Each sector of this Atlas contains data and information on various climate scenarios.

When reported in graphs, the **colour black** indicates data and information referring to the current state, the past or the baseline.

When the authors refer to **RCP (Representative Concentration Pathways)**, the 3 colours used across the factsheet refer to 3 scenarios, which are 3 different development options with different levels of greenhouse gas emissions, **respectively low emissions (green), medium emissions (orange), and high emissions (red)**. The same colour code is used when RCPs are associated with Shared Socioeconomic Pathways (SSP).

In some cases, the authors refer to global warming scenarios. In these cases, the 3 colours used refer to a temperature rise of **1.5°C (green), 2°C (dark green), and 4°C (red)**.

When the authors refer exclusively to **Shared Socioeconomic Pathways - SSPs** (Population affected by river floods in the section: "Water"), data related to **SSP3** - that encompasses, among other things, slow economic growth, material-intensive consumption, and persisting or worsening inequalities – **are reported in a lighter shade**; **SSP5** – which refers to social and economic development that is coupled with an energy-intensive lifestyle and the abundant exploitation of fossil fuel resources – is shown using a **middle shade of the colour**, whereas data related to **the present** conditions **are represented in a dark shade**.

Further details on scenarios, methodologies, and the full list of references are available at: **www.g20climaterisks.org**

Concept and graphic design by element6.eu

FRANCE CLIMATE

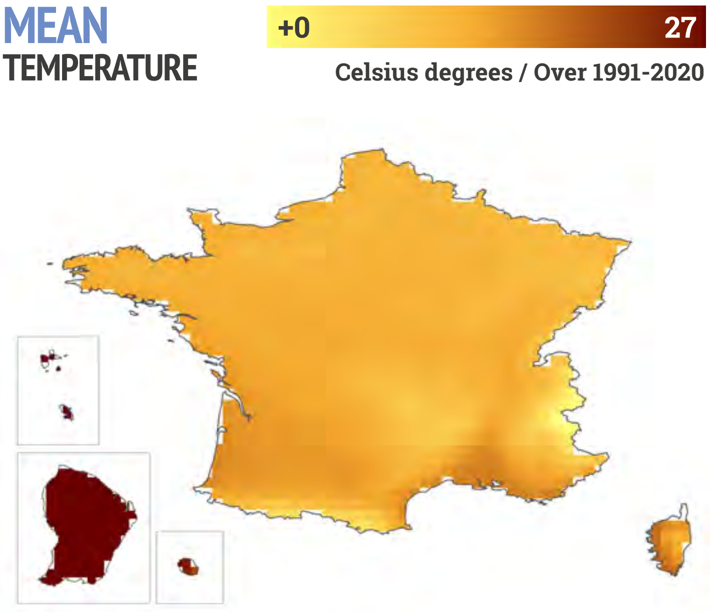
OVERVIEW

France features a temperate climate in the European area and a tropical climate overseas. Looking at the European area, the western part has an oceanic climate with average rainfall spread over many days and modest annual temperature variations. The central-eastern areas have a continental climate which harbours cold winters and hot summers. The south-east has a Mediterranean climate which leads to hot and dry summers.

TEMPERATURE

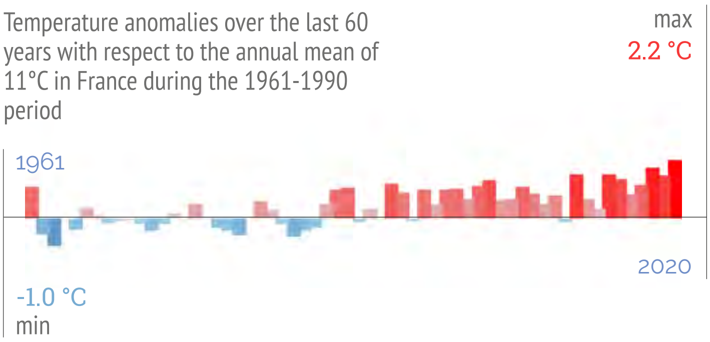
France's European area has a temperature regime in line with most temperate climates. The warmest temperatures are found in the south-east. On the other hand, the overseas departments have higher temperatures which are influenced by their geographical location.

MEAN TEMPERATURE



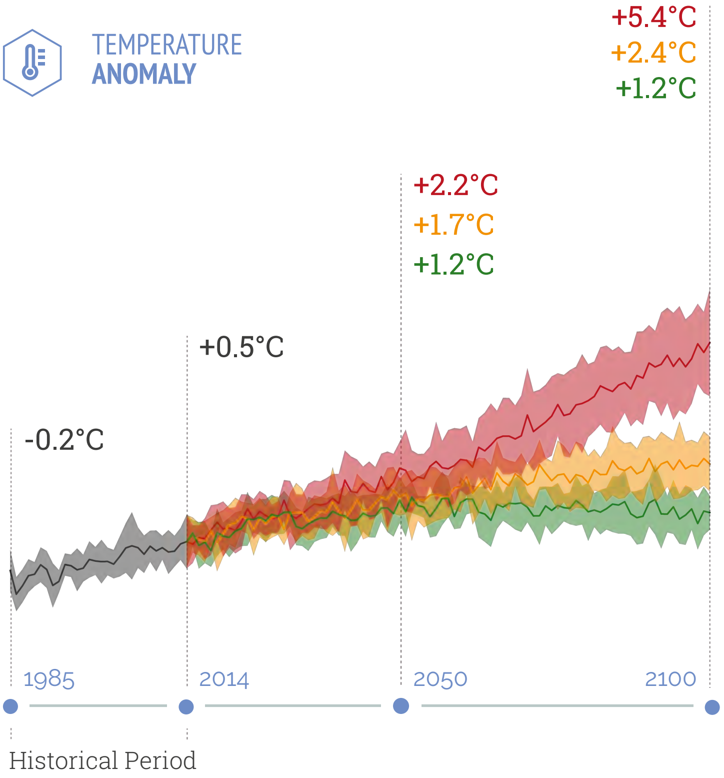
TEMPERATURE TREND

Temperature anomalies over the last 60 years with respect to the annual mean of 11°C in France during the 1961-1990 period



TEMPERATURE PROJECTIONS

Under a low emissions scenario projected temperature variations will remain contained at around +1.2°C, both by 2050 and 2100.
Under a high emissions scenario, with no reduction in GHG emissions, much greater temperature anomalies are expected by both 2050 and 2100.



EXPECTED VARIATION FOR TEMPERATURE AT 2050

The indicators show variations in selected temperature characteristics for a thirty-year period centred on 2050 (2036-2065) with respect to the reference period 1985-2014.

Annual Mean Temperature	Max Temperature of warmest month	Min Temperature of coldest month
+2.1°C	+3.2°C	+1.7°C
+1.6°C	+2.5°C	+1.3°C
+1.3°C	+2.2°C	+1.0°C

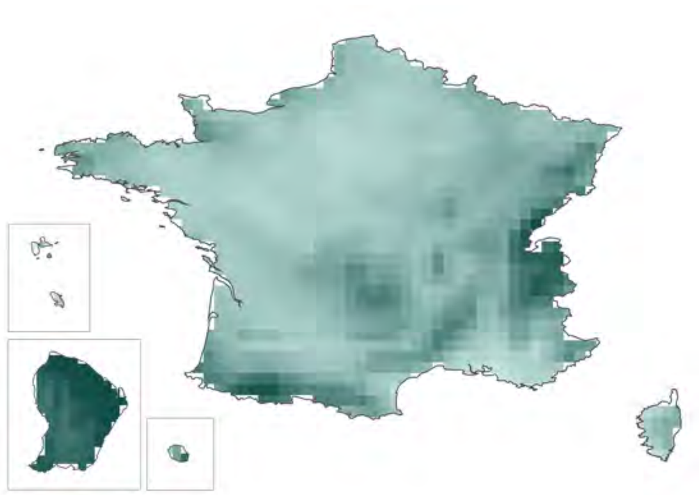
PRECIPITATION

The rainfall regime in France is very complex and influenced by opposite patterns at a local level and inter-annual variations. The overseas departments are generally more or less rainy depending on their geographical location and specific climate conditions.
In the European area, average rainfall in the western and central areas is distributed over many days. In mountainous areas, such as the Alps and Pyrénées, precipitation patterns are highly variable with heavy rainfall and snow three to six months a year.

MEAN PRECIPITATION

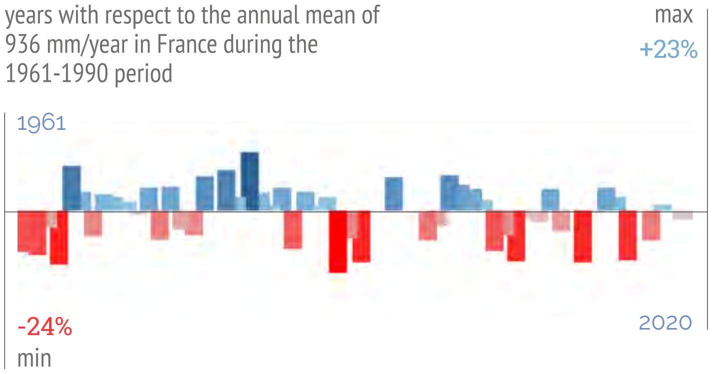
492 2,642

mm/year / Over 1991-2020



PRECIPITATION TREND

Precipiation anomalies over the last 60 years with respect to the annual mean of 936 mm/year in France during the 1961-1990 period



VARIATION OF SPECIFIC CLIMATE INDICATORS

Climate indicators variation showing impacts of climate change on sectors such as agriculture, health and water. Analysis considers 3 threshold average temperature increase: **+1.5°C**, **+2°C**, **+4°C**.

+35%
+19%
+14%
Agricultural drought proportion of time
% of time

+31%
+15%
+12%
Hydrological drought proportion of time
% of time

+1,461%
+261%
+100%
Heatwave duration
% of time

+59%
+29%
+10%
Runoff increase
% of area

+74%
+50%
+35%
Agricultural drought frequency
% of change

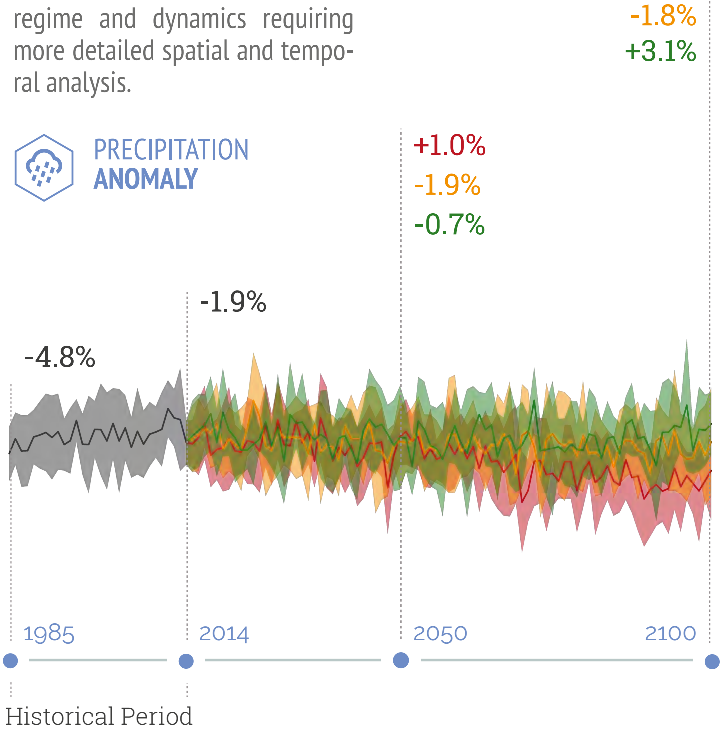
+17%
+12%
+14%
Hydrological drought frequency
% of change

+80%
+35%
+21%
Heatwave frequency
% of change

+10%
+6%
+4%
Runoff decrease
% of area

PRECIPITATION PROJECTIONS

Precipitation trends show a very complex signal, under all emissions scenarios, with a very large variability among climate models. This can be explained considering the complexity of the precipitation regime and dynamics requiring more detailed spatial and temporal analysis.



EXPECTED VARIATION FOR PRECIPITATION AT 2050

The indicators show variations in selected precipitation characteristics for a thirty-year period centred on 2050 (2036-2065) with respect to the reference period 1985-2014.

-4.0%
-2.4%
-0.9%
Annual total precipitation

+3.2%
+2.4%
+3.7%
Precipitation of wettest month

-16.0%
-8.6%
-10.0%
Precipitation of warmest quarter

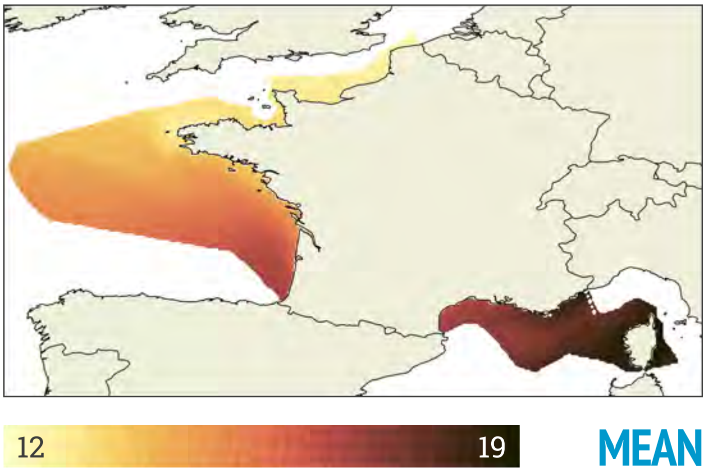
FRANCE
OCEAN

OCEAN IN FRANCE

France's marine exclusive economic zone (EEZ) is mainly characterized by temperate coastal waters, which host a large variety of ecosystems and maritime activities. The wide enseble of coastal systems can be divided into three main areas, namely the Atlantic region, the North and Mediterranean seas.

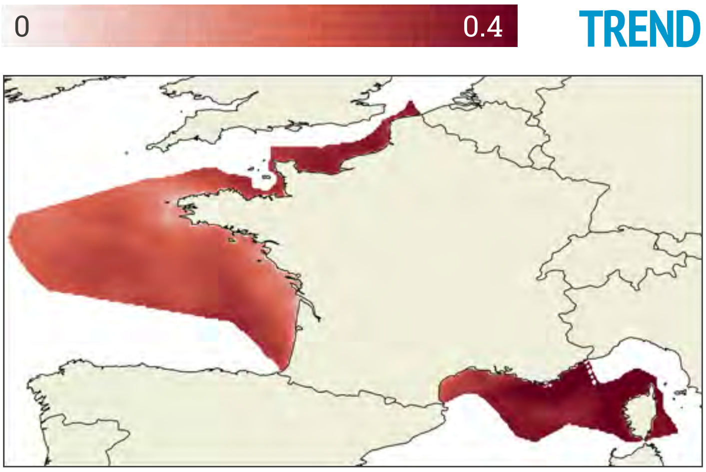
CURRENT CLIMATE CONDITIONS

Mean sea surface temperature reflects the different climate regimes, from the cold Atlantic waters to the warmer ones on southern coasts.



SEA SURFACE TEMPERATURE

Celsius degrees / Over 1991-2020

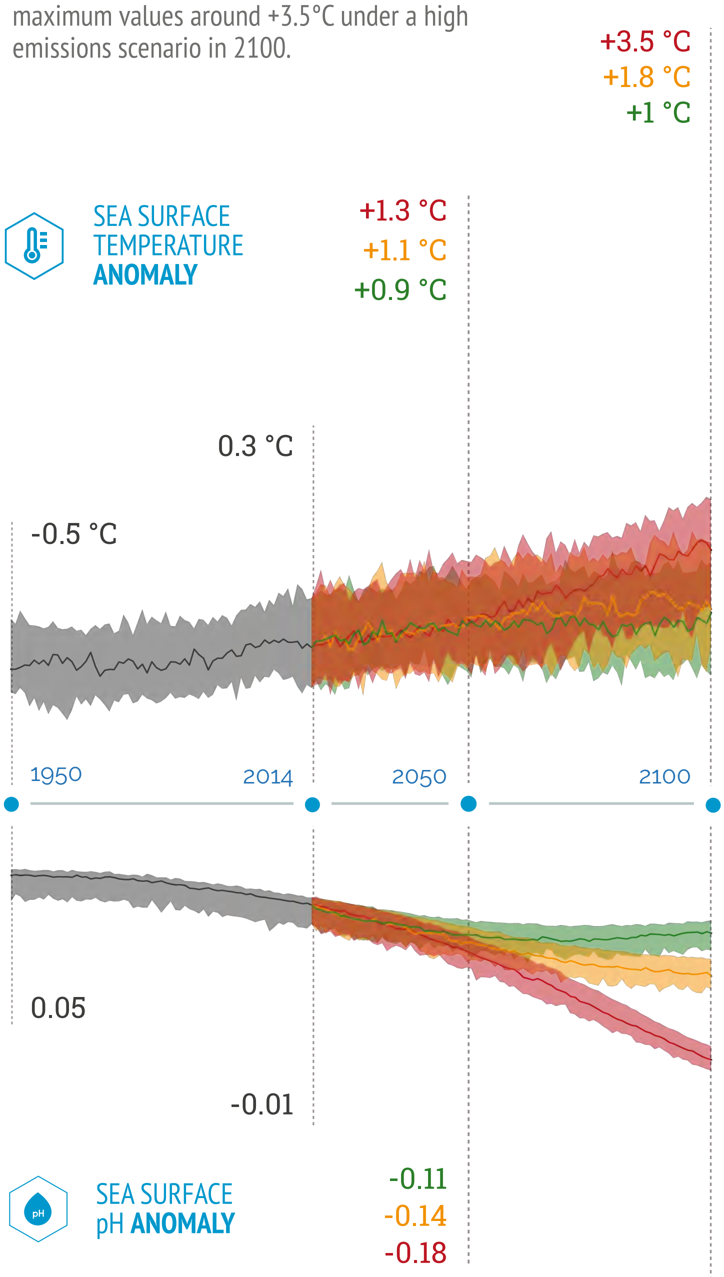


Surface temperature trends indicate a general warming of 0.4°C per decade in all marine areas.

FUTURE PROJECTIONS

Projected annual changes within the marine EEZ for the two most significant marine indicators of climate change: sea surface water temperatures and pH.

Seawater temperature changes are in line with the definitions of each scenario, with maximum values around +3.5°C under a high emissions scenario in 2100.



Seawater surface pH becomes more acidic in all scenarios, closely reflecting rising atmospheric CO_2 concentrations, and only a low emissions scenario leads to a stable condition by 2100.

ECOSYSTEM INDICATORS AT 2050

Regional changes in key marine ecosystem indicators under projected future scenarios by mid-century (2036-2065) with respect to present climate conditions (1985-2014).

Temperature regulates the metabolism of marine organisms determining which habitats remain suitable. Excessive warming will likely push ecosystems beyond tolerance thresholds.

pH represents the acid/base status of marine waters, where a decreasing pH reflects the acidification of the ocean due to increased absorption of atmospheric CO_2.

Oxygen is fundamental to sustain marine life and its reduction can have a large impact on coastal ecosystem services including fisheries and aquaculture.

Chlorophyll is an indicator of the biomass available at the base of the marine food web supporting all ecosystem productivity.

	Atlantic	Mediterranean	North Sea
Temperature	14.93°C +0.96 °C +0.72 °C +0.44 °C	17.78°C +1.53 °C +1.31 °C +1.42 °C	13.54°C +1.47 °C +1.34 °C +0.92 °C
pH	8.11 -0.18 -0.14 -0.11	8.12 -0.16 -0.14 -0.11	8.09 -0.18 -0.14 -0.11
Oxygen	257.08 mmol/m³ -1.18 % -0.9 % -0.27 %	240.06 mmol/m³ -2.58 % -1.92 % -1.29 %	268.76 mmol/m³ -3.18 % -2.72 % -2.28 %
Chlorophyll	0.49 mg/m³ -19.8 % -19.59 % -30.61 %	0.23 mg/m³ -6.84 % -23.93 % -57.69 %	0.41 mg/m³ -24.21 % -23.23 % -27.14 %

FISH CATCH POTENTIAL

Fish catch potential is an estimate of the maximum fish catch achievable given the marine resources available over a sustained period. It is linked to the concept of maximum sustainable yield, meaning the maximum amount of fish that can be extracted from a system without causing a collapse in fish populations.

It is a characteristic of the natural system, which is substantially different from realized catch, and a direct result of the fishery policy in place. The data reported concerns the French part of the Atlantic Ocean and the English Channel only.

Fish catch percentage change

2050

-33.4%

-45.1%

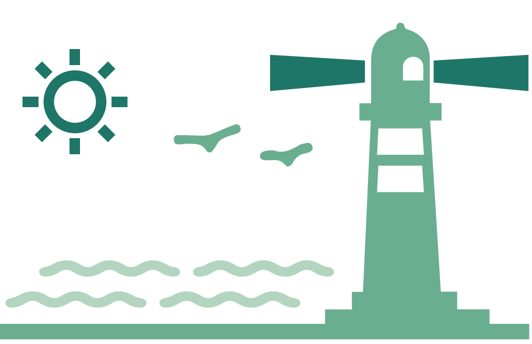
ANALYSIS DETAILS

All datasets were analysed using only data from within the marine EEZ and therefore excluding overseas territories, detached islands and any disputed or joint territories with other nations. In the assessment of current climate conditions, seawater surface tempererature data was obtained using satellite observations distributed in the framework of ESA Climate Change Initiative.

Future projections of marine indicators are represented by the combined analysis of results from 15 different Earth System models participating in the Coupled Model Intercomparison Project Phase 6 (CMIP6). These models include new and better representations of physical and biogeochemical processes, compared to previous IPCC assessment reports.

Fish catch potential data was obtained using the FAO's technical report and refers to the best and worst case climate scenarios from the Fifth IPCC Assessment Report. These mean estimates are subject to substantial uncertainties as discussed in the original work.

FRANCE
COASTS



OVERVIEW

The 7,330 kilometres of French coastline are split into three regions, the largest being on the Atlantic ocean, followed by stretches along the southern North Sea and the Mediterranean Sea, with a further 850 kilometres around the island of Corsica. Just over 40% of the coastline is rocky, with the rest of the coastline a mixture of open beaches, sand flats, and mudflats. 39% of France's 67 million residents live in coastal regions, with notable coastal cities including Marseille, Montpellier, and La Rochelle.

Shoreline Length

7,330 km

Sandy Coast Retreat at 2050

-49.6 m

CLIMATE CHANGE HAZARDS

Coastal hazards such as erosion, storm tide inundation and permanent flooding, can have strong adverse impacts on coastal regions, with loss of sandy shores, damage to settlements, infrastructure and ecosystems. Climate change can exacerbate these impacts due to rising sea levels and increasing impacts of waves and storms. Acute impacts of climate change will be felt on the French coast, with sea level rise and its consequences affecting numerous locations. The combined pressure of these environmental changes can lead to a variety of negative impacts on the population, infrastructure, and natural environment of France's coastal regions.

SEA LEVEL RISE

Relative sea level rise has been observed over the past century around the coast of France, with a yearly average increase of approximately 1.86 millimetres per year since the 1990s. The latest IPCC projections indicate that, by 2050, global sea levels may rise between 0.18 metres, under a low emissions scenario, and 0.23 metres, under a high emissions scenario.

Observed and projected sea level rise at 2050

1.86 mm/year

0.23 m

0.18 m

EXTREME SEA LEVEL

On average, one in 100 extreme sea level events are expected to rise from 3.25 metres at present day to 3.52 metres by 2050 under a medium emissions scenario.

Current and projected extreme sea level at 2050

3.25 m

3.58 m

3.52 m

OBSERVED STORMS

Exposure of the French coastline to unpredictable oceans makes it inherently vulnerable to the impacts of extreme waves and storm surges. Furthermore, these events have been increasingly frequent over recent decades. For example, the devastating 2010 Xynthia windstorm caused billions of euros worth of damage and left 47 people dead when it hit the Atlantic coast. While not all events are so extreme, the continued impacts are being felt through shoreline erosion.

FUTURE STORMS

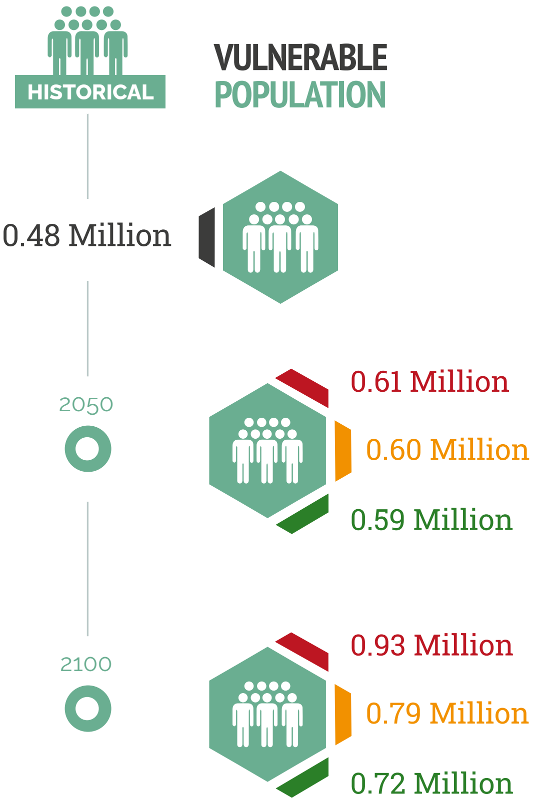
Future storm pattern projections do not give immediate cause for concern, with no significant increase in intensity forecasted for the coming decades. However, the expected rise in sea level will raise the vulnerability of coastal regions, with higher energy waves becoming more frequent. Combined with a growing coastal population and increased precipitation, flood related damages are expected to increase by over 50% by 2100 under a medium emissions scenario.

VULNERABILITY AND RISK

All regions of the French coastline are vulnerable to the risks posed by climate change. With significant populations living in coastal areas, property and infrastructure are threatened by rising sea levels that could cause erosion or even permanent submersion.

This could be the case for up to 140,000 properties in the region of Languedoc-Roussillon alone, leading to massive economic repercussions. Increasing urbanisation along the coastline will also put more people at risk, as seen with the deaths of those living in newer properties following the 2010 Xynthia windstorm.

Valuable environmental zones and habitats could be lost, particularly salt marshes and sand dunes that are more susceptible to the negative impacts of climate change. Much of France's economic productivity is based in the coastal regions. In fact, the blue economy adds 30 billion euros to the country's GDP, largely through tourism and shipping ports, both of which are vulnerable to storm surges and rising sea levels. Under a medium emissions scenario, the population exposed to the annual coastal flood level is expected to increase from 6.32 million to 6.68 million by 2050.



VULNERABLE POPULATION

INFLUENCE OF SEA LEVEL RISE ON EXTREME SEA LEVEL

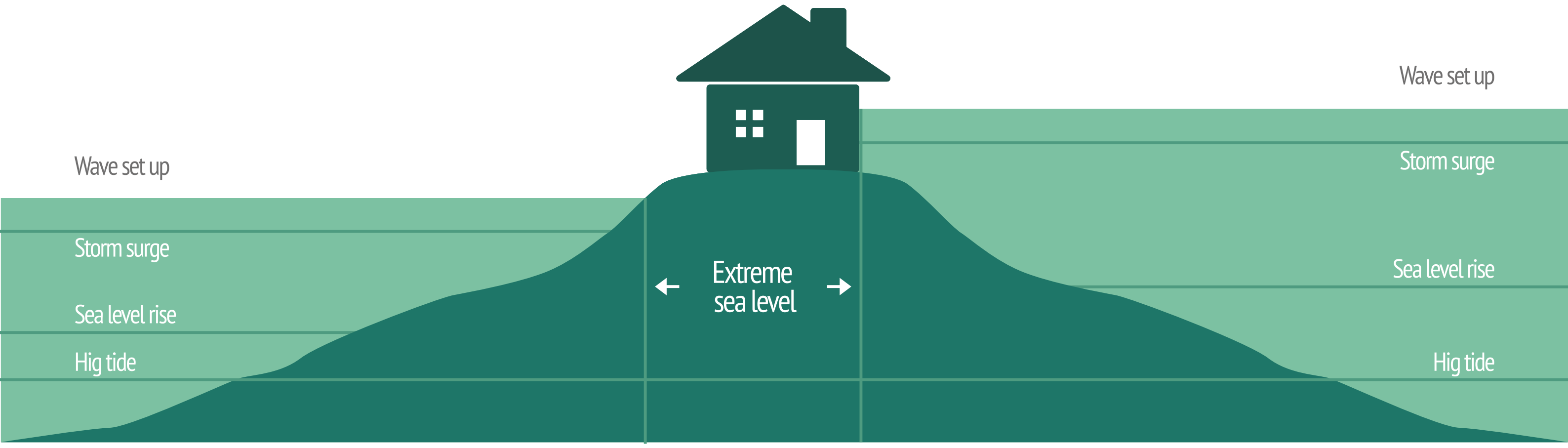
Present and future sea level rise are a consequence of carbon induced global warming causing melting ice and ocean expansion due to heat accumulation.

The extreme sea levels reported here are based on the 100-year storm surge + wave set up + sea level rise + high tide indicators. The first two parameters (storm surge + wave set up) are based on the 100-year value for the event; sea level rise is its projected value at 2050; and high tide is the absolute value of the highest tide calculated for a given locality, which won't be influenced by climate change.

+ **Wave set up** refers to the accumulation of water near the shore due to the presence of breaking waves.

+ **Storm surge** is an occasional increase in sea level driven by shoreward wind-driven water circulation and atmospheric pressure.

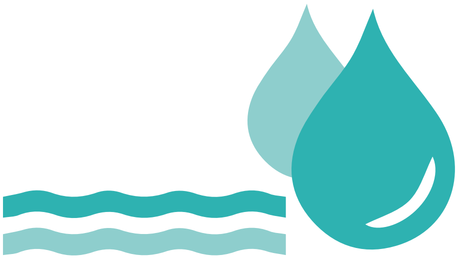
+ **High tide** is usually the highest tide reached in a given location based on tide records.



Present sea levels have risen globally by approximately 20 centimetres over the past century.

Future sea level rise is a projection based on different global warming scenarios, at approximately 100 centimetres by the end of 2100, with consequent inundation during extreme sea level events.

FRANCE
WATER



OVERVIEW

France has an available water stock that is well above the population's needs, providing a buffer against the risk of water stress.

Average annual precipitation ranges from 500 to 2,000 millimetres depending on the geographical location, with lowland areas far from the coast receiving the least amount of rain, whereas mountain areas and the coasts get the most.

The country's water needs stand at 32 billion cubic metres per year. With approximately 270,000 kilometres of permanent waterways and groundwater reserves estimated at 2,000 billion cubic metres, France has a considerable amount of water resources.

Renewable internal freshwater resources: 200 billion m³

Renewable internal freshwater resources per capita: 2,988 m³

The watersheds of the four main French rivers, Garonne, Loire, Rhone and Seine, drain 63% of the territory's water. The rest is provided by numerous coastal basins, the Adour, Somme, Charente, Var, or tributaries of rivers from neighboring countries such as the Rhine and Escaut. On top of the good levels of precipitation and total runoff, France also has very good natural storage capacities, thanks to mountain ranges and large underground aquifers.

CLIMATE CHANGE HAZARDS

Climate change can affect water resources through increasing temperatures, higher rates of evapotranspiration and altered rainfall patterns. This leads to changes in the water cycle, including decrease of snow and ice coverage, alterations of surface runoff and groundwater storage, as well as drought and flood occurrence. The impacts of climate change on France show an increased vulnerability to floods and droughts. Water systems have displayed overall changes throughout the entire country, especially French Alpine glaciers which have shrunk, as well as the glaciers in the Pyrenees. A reduction in the quantity of water resources, coupled with a potential increase in anthropogenic pressure due to demographic growth, could also have significant impacts on water quality.

KEY POINT RUNOFF

In southern France and in major southern river basins, hydrological models have shown that a warming climate induces a decrease in the mean annual runoff, a shift to earlier snow melting in mountainous areas and more severe low-flow conditions.

At a country scale, an average increase in surface runoff by approximately 24% and 1% is expected respectively under low and medium emissions scenarios for the 2045-2055 period compared to 2015-2025.

If temperatures rise by 1.5°C, 2°C or 4°C, 4%, 6.1% or 10% of the country will likely experience an increase in runoff, while 10%, 28.6% or 59% of the surface of the country will likely experience a respective decrease in runoff.

2050

Changes in annual runoff
% of change

+0.8%

+24.0%

2050

Runoff increase
% of area

+10.0%

+4.0%

KEY POINT DROUGHTS

Serious damage to buildings and infrastructure can occur if soil shrinkage is pronounced under drought conditions. For instance, in France, soil subsidence has caused as much damage as floods in recent years. The effects of drought can be aggravated due to aquifer overexploitation.

The southern part of the country (and the whole Mediterranean area) emerged as particularly at risk: temperature increase during the last decades has been accompanied by a local decrease in summer precipitations and an increase in autumn precipitations. Temporal trends in precipitation, temperature and solar radiation have resulted in drier and warmer conditions over the region. Projections indicate that there will be more frequent and severe droughts, surpassing the worst droughts 1981-2010 period.

KEY POINT GROUNDWATER

The climate change impact on surface waters and groundwater resources in several European regions is very problematic. In this context, France has been experiencing large changes in precipitation that affected the groundwater framework in the country. Several works at national scale have projected the impact of climate change on groundwater recharge in France. Confirmed by the diversity of approaches, the emerging trend shows a decrease in recharge primarily caused by increased evapotranspiration.

2050
Severe drought likelihood increase
% of change
+24.9%
+7.8%

2050
Hydrological drought frequency
% of change
+17.0%
+10.0%

2050
Groundwater Recharge
% of change
-2%
-0.4%

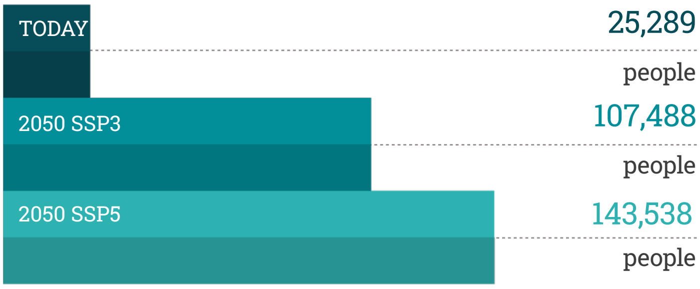
A local example of how climate change may affect the groundwater framework in France is the Rhone-Mediteranee et Corse (RMC) basin: studies show that the RMC basin is moving towards an almost general reduction in groundwater recharge. The trend is around an average decrease in recharge of -10 to -30%. It is most marked in the Aude and the Pyrenees-Orientales where it could reach nearly -50%. At the country level, a -0.4%, -1.3% and +2.7% change of the annual groundwater recharge for the period 2045-2055 compared to the timeframe 2015-2025 is expected under low, medium and high emissions scenarios.

KEY POINT FLOODS

Many studies support the hypothesis of an increase of heavy rainfall events due to global warming, favouring the occurrence of high magnitude torrential flood events in high-altitude catchments. Generalized upward trends in flood magnitude in the northwest of France, downward trends in the southwest and mixed patterns in the center have been found.

Several recent flood events occurred in France, such as in October 2020 and during the summer 2021. This is in line with a detected trend in the intensity of extreme rainfall in many regions of France in the last 50 years of records. Changing rain patterns may affect the frequency and intensity of floods. Changes in the population exposed to river floods are expected, with an increase from about 25,000 in the present day to about 107,000 under SSP3 and 144,000 under SSP5 by 2050. As such, potential impacts related to river floods might increase.

POPULATION AFFECTED BY RIVER FLOODS

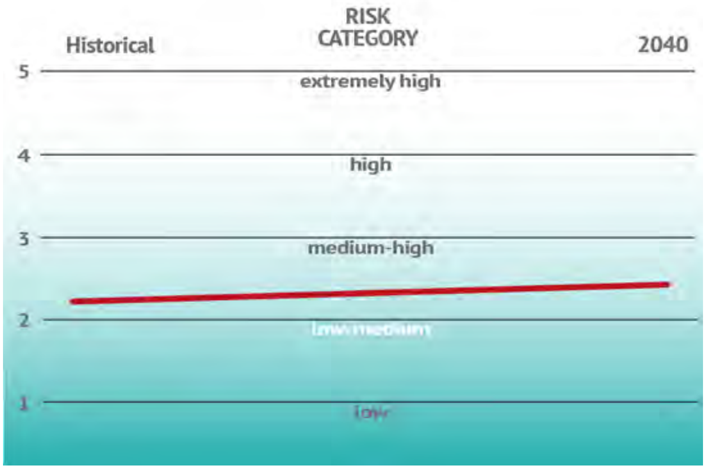


RISK INDICATORS

The water stress index summarises current and future water related vulnerabilities and risks at the global level. Scores are based on the ratio of total water withdrawals, including agriculture, industrial and human consumption, to available renewable surface and groundwater supplies.

WATER STRESS

France's water stress level is considered medium-high for the recent past (1960-2014 average), and it may increase in the near future (2030-2050) based on climate change projections.



FRANCE AGRICULTURE

OVERVIEW

France is the first European country for agricultural production, amounting to 16% of the EU's agricultural land and around 17% of its value. The primary sector counts for around 1.6% of the internal GDP and 2.5% of employment.

The main productions of cereals, oilseeds and industrial crops (mainly sugarbeet) are located in the central-northern plain and in the south-western region, whereas wine production occurs in the southern part of the country, in the Rhone valley and in the Aquitaine region, around the city of Bordeaux.

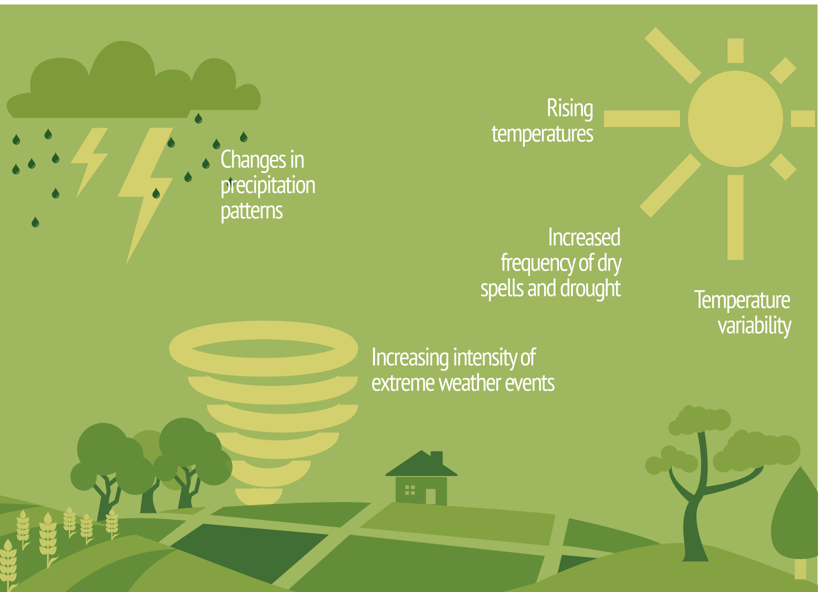
Wine growing is the major crop with the most added value, generating 15% of France's agricultural revenues whilst occupying only 3% of agricultural land. Irrigation concerns around 6% of the agricultural area and it is mainly relevant to the Mediterranean regions.

39.9 Mt	Sugarbeet
12.6 Mt	Maize
35.4 Mt	Wheat
6.3 Mt	Grapes
5 Mt	Rapeseed

	Added Value of Agriculture, Forestry and Fishing	Share of Agriculture Value added in Total GDP	Agricultural land	Area Equipped for Irrigation
2000	34,341 USD Million	1.7 %	19,495 Thousand HA	2,634 Thousand HA
2018	38,706 USD Million	1.5 %	19,132 Thousand HA	2,691 Thousand HA

EXPEXTED IMPACTS ON AGRICULTURE PRODUCTIVITY

Rising temperatures, reduction in average annual precipitation, and intensification of extreme events such as heat waves and drought, affect production variability with a tendency towards yield reduction for many cultivated species, accompanied by a probable decrease in food quality. Crops respond to increases in temperatures with changes in duration of the growing season, early appearance of phenological phases and potential shifts of cultivation areas toward higher latitudes and altitudes for better growing conditions. However, impacts vary significantly depending on the geographical area and specific crops in question.



CROP PRODUCTIVITY

Crop productivity refers to the harvested yield of a crop per unit of land area. It is strongly influenced by climate and other environmental and management factors.

Climate change is expected to have an impact on the productivity of several major crops, although this may in part be offset by the fertilizing effect of higher CO_2.

Impacts are estimated using a range of model projections based on low to high emission scenarios and reported as percentage changes between the 30-year average around the historical period and the 30-year average around 2050.

83.6 **Sugarbeet** tons / ha -8.3 (-18.5)% -6.6 (na)%

7.3 **Wheat** tons / ha 8.4 (2)% 10.4 (4.2)%

8.7 **Maize** tons / ha 6.7 (3.6)% 6.5 (-0.2)%

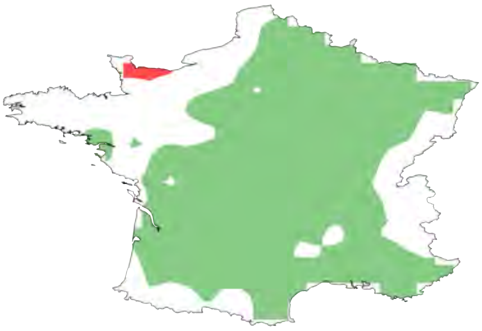
3.1 **Rapeseed** tons / ha 7.2 (1.4)% 8.7 (na)%

2050

Productivity change with (without) the CO_2 fertilization effect. Estimates assume sufficient water and nutrient supplies, and do not include impacts of pests, disease, or extreme events.

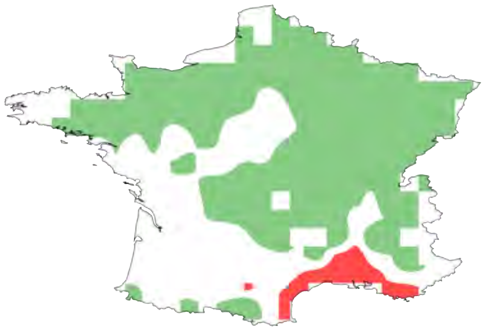
CHANGE IN WHEAT

🟥 − = 🟩 +



CHANGE IN MAIZE

🟥 − = 🟩 +



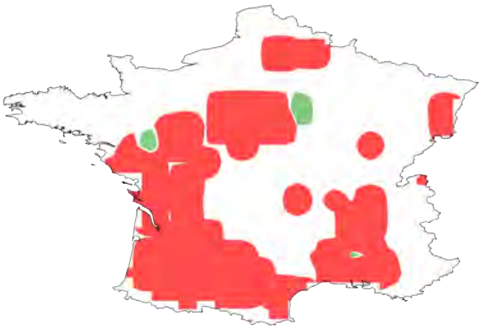
An increase in CO_2 may positively affect the production of C3 plants such as rice, wheat and beet, which are mostly located in the northern regions. Maize productivity shows a small gain in the north, whereas yields may fall in the south, due to the combined effects of extreme temperatures and drought. For grasslands in the central mountainous areas an increase in forage production up to 20% could occur, which would allow for a corresponding increase in animal stocking. In general, field crops and grasslands should be favored, except in the south where there is a risk of accentuated droughts accompanied by high temperatures. For permanent crops such as fruits and vineyards, the generalized advance of phenology may cause risk of frost at the flowering stage, and of reduced fruit quality due to an advance in the sensitive stages.

ADAPTATION IN AGRICULTURE AND WATER RESOURCES

Modern farming systems with abundant surface and groundwater resources have allowed France to become a net exporter of agricultural products. The agricultural sector is the main user of water resources (48% of total consumption in France) and will be particularly affected by summer droughts. Large areas of France have overexploited groundwater resources, which are also likely to decline significantly over the long term and in particular in the Loire basin and the south-west of France. Water scarcity can worsen conflicts between different sectors and reduce flows to natural ecosystems during summer periods.

CHANGE IN WATER DEMAND

🟩 − = 🟥 +



Agriculture
Water Demand
% of change

+57.7%

+60.6%

2050

Further water saving programs in French agriculture should enhance measures for more efficient agriculture, agri-environmental measures, crop diversification and changes in crop practices.

FRANCE FORESTS

FORESTS IN FRANCE

When including French overseas territories all the main types of forests are present in France. From boreal forests in the southern alpine areas, to tropical ones with over 8 million hectares in Guyana alone. The main role, however, is played by deciduous temperate forests. In metropolitan France, wooded areas are almost entirely secondary and shaped by human intervention.

1990

23 Mln ha
Million hectares
Forested area

161 Tons/ha
Tons of Carbon per hectare
Carbon stock

2020

25 Mln ha
Million hectares
Forested area

165 Tons/ha
Tons of Carbon per hectare
Carbon stock

FORESTED AREA AND CARBON STORAGE

French forests account for more than 30% of land showing a constant and significant increasing trend in recent decades. According to the French Ministry of Agriculture and Food, French forests and related ecosystems currently store 88 million tons of CO_2 equivalent every year and high quality wood provides further 33 million tons for substitution effects such as use in buildings.

FOREST PRODUCTIVITY

Forest productivity or Net Primary Production is the net carbon captured by plants. It is the difference between the carbon gained by Gross Primary Production - net photosynthesis measured at the ecosystem scale - and carbon released by plants' respiration. It is expressed per unit land area.

2050

Productivity anomaly
Tons of Carbon per
hectare per year

+0.79

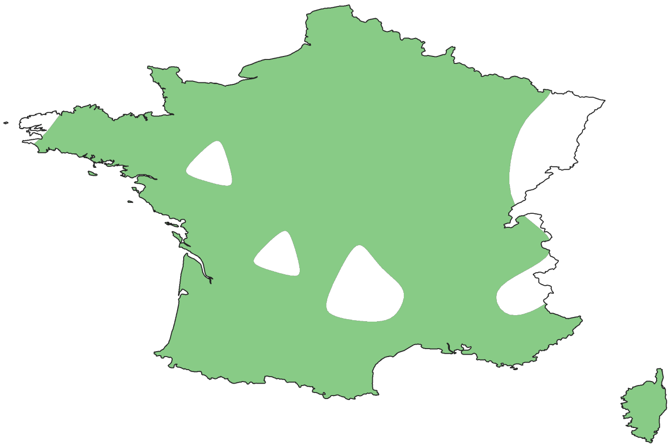
+0.64

Generalized increase in net primary production by 2050. More accentuated under a medium emissions scenario, although with high uncertainty

+ Fertilizing effect of increasing atmospheric CO_2
+ Rising temperatures
+ Lengthening of growing season

No areas with an expected decrease in forest primary production

+ Increasing risk of drought stress



KEY SPECIES UNDER CLIMATE CHANGE

VULNERABILITY
BEECH
Beech forests show very high vulnerability

REDUCTION
SPRUCE
Strong reduction of suitability range for spruce in central France

EXPANSION
MED OAKS
Considerable expansion of mediterranean oaks (holm oak) in the south and temperate oaks in central and northern areas

REPLACEMENT
MARITIME PINE
Maritime pine may play an important replacement role throughout oceanic (western) France

FIRES IN FRANCE

Fire is a structural ecological process that provides several types of ecosystem services and impacts on socio-ecological systems, including human health, carbon budgets, and climate change. Changes in global fire activity are influenced by multiple factors such as land-cover change, policies, and climatic conditions. Fire also releases large quantities of greenhouse gases into the atmosphere, contributing to a vicious cycle.

During the last three decades, the total area affected by fire was approximately 577 thousand hectares with 138 thousand fires occurring.

BURNING

576 THOUSAND HECTARES

EMITTING

0.36 TERAGRAMES OF CARBON PER YEAR

FOREST FIRE EMISSIONS CONTRIBUTED TO 29% OF TOTAL FIRE RELATED CARBON EMISSIONS

COSTING

209 MILLION USD IN 2003 COMPARED TO 97 MILLION USD IN A NORMAL YEAR

FUTURE BURNED AREA

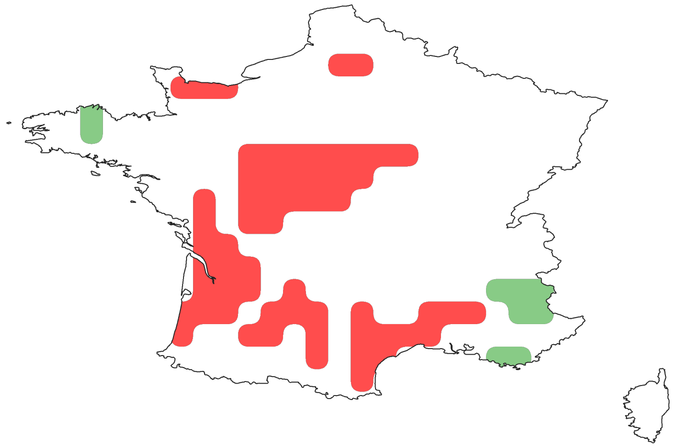
Under a low emissions scenario, burned area is expected to increase in central and southern France affecting temperate broadleaf and mixed forests. Under a medium emissions scenario, burned area is also expected to increase in the Mediterranean forests of southern France.

Burned Area
km² per year

2050

+130

+117



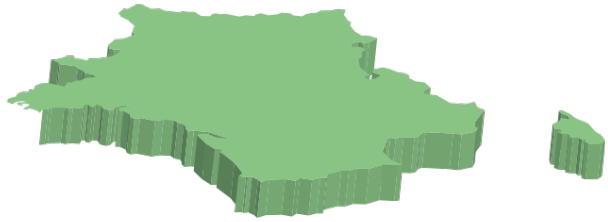
Decrease in burned areas for a low emissions scenario

Increase in burned areas for a low emissions scenario
+ Prolonged and more intense fire season
+ Increase in future weather risk due to warming and drought conditions

WHERE DO FIRES OCCUR?

Between 2000 and 2019 France contributed to 3.7% of the total burned area of the five most fire-affected European Countries.

There is a positive correlation between burned area and high vegetation cover (particularly shrublands), prolonged summer dryness, high unemployment rates, and tourism pressure.



Fires concentrate in south-eastern France and Corsica near the Mediterranean Sea where summer drought and winds facilitate the spread of wildfire.

VARIATION OF SPECIFIC FIRE INDICATORS

% of change
Very high-to-extreme fire danger areas (Corsica and PACA regions)
2036-2045
+217%
+87%

% of change
Fire season lenght
2041-2070
+64%

% of change
PM2.5 emissions
2010-2050
+26%
+15%

FUTURE FIRE EMISSIONS

Scientists predict that fire emissions might increase over the Mediterranean, Cantabrian and northern Atlantic areas especially under a medium emissions scenario.

Fire Carbon emission
Teragrams of Carbon per year

2050

+1.6

+1.1

FRANCE
URBAN

OVERVIEW

In France, 81% of the population lived in urban areas in 2020, this rate is expected to increase only slightly and reach 88% by 2050. The French urban landscape is characterized by a strong role of the central agglomeration of Paris, which is home to 20% of the French population, and an increasing number of growing agglomerations around the country.

The number of relatively small cities is expected to decline slightly, but these cities will remain the most important forms of urban agglomerations, giving home to more than half of the population. The country is still experiencing demographic growth in all types of agglomerations, and demand for dwellings is growing at an even faster pace.

Built up areas cover 4.91% of French territories (26,876.60 square kilometers).

OVERVIEW OF KEY CLIMATE IMPACTS IN URBAN AREAS

French urban areas are expected to be affected by increasing temperatures and more frequent heatwaves as well as by changing precipitation patterns.

HEATWAVES AND HEAT STRESS

In August 2003, a heatwave affected most European countries. In France, the heatwave caused approximately 10 days of median temperatures of 37.5°C during the day and 20°C at night. In Paris, temperature differences between city centers and some rural areas reached 8°C during daytime and 7°C at night. France was the most affected country by the 2003 European heatwave, with an observed excess mortality of 14,800 additional deaths during a period of three weeks in August. 82% of the deaths attributable to the heatwave affected people aged 75 and over. Impacts were particularly heavy in the urban area of Paris and the surrounding departments, with an excess mortality of 150%. Under future warming scenarios, frequency of extreme events like heatwaves will increase, and in particular duration of heatwaves will increase, with major implications for urban areas, increasing, inter alia, the need for cooling facilities of living and working environments. Comparing french urban climate conditions for 2100 with those existing today, reveals that Paris would have a climate comparable to that of current-day Cordoba, whereas the climate of Marseille could become similar to what is actually experienced in Greek cities.

2020

53,217,966

Population in Urban Areas

2050

62,373,862

Graphs refer to data provided by United Nations, Department of Economic and Social Affairs, Population Division (2018). World Urbanization

2020

81.0%

Urbanization Rate

2050

88.3%

2050

Cooling Degree Days
% of change

+236.9%
+78.3%
+47.1%

2050

Heatwave frequency
% of change

+80.1%
+35.1%
+21.4%

2050

Heatwave duration
% of time

+1,461%
+261%
+100%

SOCIO-ECONOMIC FACTORS DRIVING IMPACTS FROM HEATWAVES

During the 2003 heat wave mortality rates in Paris were driven by factors such as age, income, social isolation, illness and quality of insulation in homes. Over 90 victims lived alone and often in small apartments.

More than half the victims lived on the upper floors of buildings and/or in scarcely insulated roof-top dwellings where indoor-temperatures reached 40°C. During the 2003 heat wave, concentrations of pollutants in major French cities were up to 40% higher than the average for the previous years.

2017

Population exposed to air pollution

78.2%

COASTAL FLOODING

The French territory is vulnerable to both coastal flooding and inundations from heavy rainfall inland. Although almost 5% of surfaces are covered by buildings and infrastructure, urbanization over the past decades has involved high risk coastal areas and flood prone areas along rivers. Artificialization of coastal areas is proceeding at high levels, with the concentration of building density three times higher than average French values.

Projected sea level rise

2050

0.23 m

0.18 m

2100

0.77 m

0.38 m

FLOODING

On top of coastal flooding, France is also vulnerable to inundations from heavy rainfall and river flooding inland. Furthermore, high risk areas such as flood prone zones along rivers have experienced new urbanization. In 2010, the winter storm Xynthia hit the French coast, causing 53 deaths and over 4 billion USD in overall damages.

In January 2018, flooding of the rivers Seine and Marne in France, which affected Paris, caused between 190 and 350 million euros in damages despite the flood risk protection measures in place. Under a high emissions scenario, sea level is expected to rise by 1 metre by the end of the century, bringing damage due to erosion, increasingly intense storm surges and extreme flooding to coastal settlements.

2050

Runoff increase

% of area

+10%

+6%

+4%

SURFACE SEALING AND FLOODS

Heavy precipitation in cities is problematic due to the high level of sealed surfaces. Soil sealing increases run off and reduces the amount of water absorbed by soil. Where there are large amounts of impervious ground cover, short duration extreme rainfall events can lead to increased flooding, even resulting in flash floods.

URBANIZATION OF FLOOD PLAINS

Despite overall precipitation decreasing, the impact of extreme and short-term precipitation events on built up urban environments is bound to increase.

2010

% of urban population

Population living in slums

0%

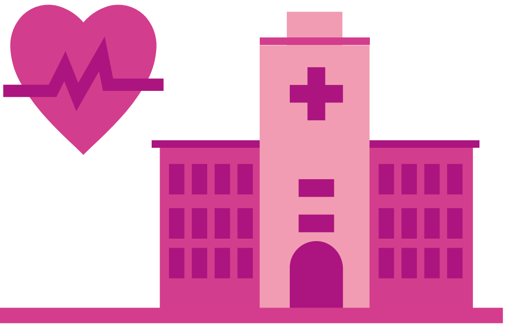
2018

% of total population

Urban population living in areas where elevation is below 5 meters

2.2%

FRANCE
HEALTH



OVERVIEW

The French population is vulnerable due to many climate hazards and extreme weather events, such as heatwaves, floods, and climate suitability for vectors. Changing weather patterns could also impact the emergence, distribution, and prevalence of vector-borne diseases in France, such as chikungunya, dengue, yellow fever, and leishmaniosis. Climate change is expected to increase mean annual temperature and the intensity and frequency of heatwaves, resulting in more people at risk of heat-related medical conditions. France also faces severe impacts from heatwaves.

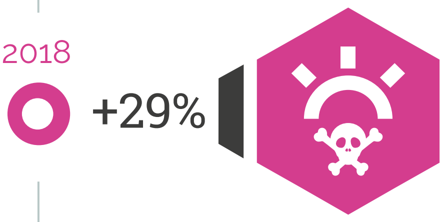
HEAT RELATED MORTALITY

Under a high emissions scenario, heat-related deaths in the elderly (65+ years) is projected to increase to about 61 deaths per 100,000 by 2080, compared to the estimated baseline of about 4 deaths per 100,000 annually between 1961 and 1990. Under a medium emissions scenario, heat-related deaths in the elderly will be 11 per 100,000. In 2018, there was a 29% increase in heat-related deaths in France from a 2000 to 2004 baseline.

Nearly 15,000 people died during the 2003 heatwaves. Up until that year, heatwave events had been underestimated as a threat to French public health. Due to improved public health policies, the number of annual deaths declined to approximately 1,500 people per year during 2018 and 2019. 35.2% of heat-related mortality during 2000 to 2014 can be attributed to human-induced climate change.

Heat-related mortality

% change with respect to 2000-2004



IMPACTS ON LABOUR

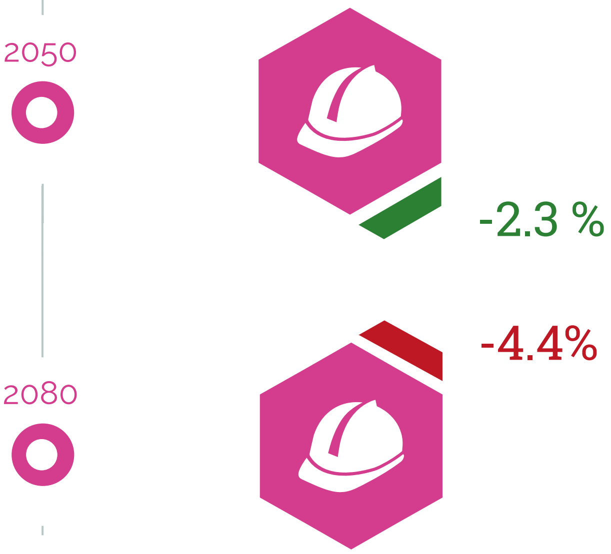
Labour is directly affected by changes in environmental conditions. Warming affects both the number of hours worked (labour supply) and on the productivity of workers during their working hours (labour productivity). Both labour supply and productivity are projected to decrease under future climate change in most parts of the world, and particularly in tropical regions.

Parts of sub-Saharan Africa, south Asia, and southeast Asia are at highest risk under future warming scenarios. Future climate change will reduce global total labour in the low-exposure sectors by 18 percentage points and by24.8 percentage points in the high-exposure sectors under a 3.0°C warming scenario

Total labour in France is expected to decline by 2.3% under a low emissions scenario, and by 4.4% under a medium emissions scenario.

Impact on total labour

% change with respect to 1986-2005 baseline



CLIMATE CHANGE AND DENGUE

Dengue has spread throughout the tropical world over the past 60 years and now affects over half the world's population. Globally, vectorial capacity for both dengue vectors (A. aegypti and A. albopictus) has been rising steadily since the 1980s, with nine of the ten highest years occurring since 2000.

Climatic stressors are one important driver of the current distribution and incidence of dengue. Climate change is likely to expand the geographical distribution and suitability of several vector-borne human infectious diseases including dengue. The risk of dengue transmission is increased by warming climates, as the growth and development of mosquitoes are significantly influenced by temperature, precipitation, and humidity.

Dengue suitability

% of population at risk

CLIMATE CHANGE AND ZIKA

Zika virus has spread to at least 49 countries and territories since 2013. Climate change impacts on transmission suitability risk have increased over the years and future warming over 1.3 billion additional people could face suitable transmission temperatures for Zika by 2050.

DENGUE AND ZIKA: POPULATION AT RISK

Epidemiological risks from dengue and Zika will increase due to climate change in France.

Under a medium emissions scenario, 73% of the population will be at risk of transmission-suitable mean temperatures for dengue by 2050, whereas 90.8% will be at risk under a high emissions scenario. In the case of Zika, 11.6% of the population will be at risk by 2050 under medium emissions, whereas 67.8% will be at risk under high emissions.

Zika suitability

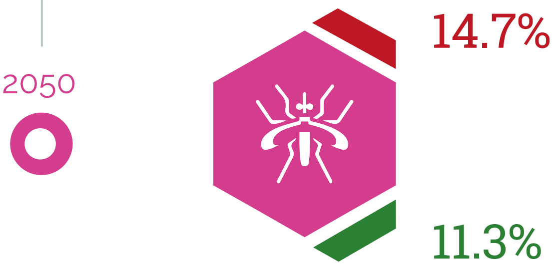
% of population at risk

CLIMATE CHANGE AND MALARIA

In France, the number of imported malaria cases, mainly due to Plasmodium falciparum (85%), was estimated at about 82,000 for the 2000 to 2015 period. 11.3% of the French population will be at risk of malaria under low emissions scenario in 2050, whereas 14.7% will be at risk under a high emissions scenario.

Malaria suitability

% of population at risk



POLLUTION AND PREMATURE MORTALITY

In 2014, some of the most populated cities, with available air pollution data, had annual mean PM2.5 levels above the WHO guideline value of 10 µg/m3. Under a medium emissions scenario, annual premature deaths due to long-term exposure to near-surface ozone and heat will increase from 6,130 in the 2010 baseline period, to 9,439 in 2050.

FRANCE
ENERGY

ENERGY SYSTEM IN A NUTSHELL

The French energy system has a low carbon intensity, owing to the leading role of nuclear energy. France relies on imports for all of its oil and gas consumption.

France has begun an ambitious trajectory towards decarbonisation, with plans to significantly reduce the share of nuclear power and increase renewables in coming decades.

0.08
ktoe/US$
Energy intensity

48%
Import dependence ratio

CLIMATE CHANGE TODAY

NUCLEAR

Heatwaves are a proven issue for France's nuclear power generation, which needs sufficient water for cooling. In 2003, 2006, 2009 and 2018 heatwaves caused temporary shutdowns of nuclear plants in France due to cooling water shortages.

HEATWAVES

Heatwaves caused electricity demand to peak due to cooling needs, putting a strain on the system, already under stress due to cooling water shortages.

SLR

France's extensive coastline means energy infrastructure is affected by rising sea levels due to more frequent flooding.

ENERGY SUPPLY

The current energy mix of total primary energy supply in France shows a strong prevalence of nuclear, which accounts for 42% (2019). The remainder is made up of oil (28%), natural gas (15%) and renewables (11%).The share of renewables has almost doubled since 1990, while coal dropped from 9% to a 3% share only. France imports a relatively large amount of oil and natural gas.

ENERGY DEMAND

Energy in France is used by the transport sector (30%), the majority of which is used for road transport, followed by residential (24%), industrial (18%) and tertiary sectors (15%). Industry is responsible for most of the non-energy use of fuels (9%). The share of agriculture, forestry and fishing is just 2.9%. Energy use has declined since its peak in 2004, due to energy efficiency gains and weak economic growth.

FUTURE ENERGY DEMAND

Overall, in France the decrease in heating demand is going to be more than compensated by the increase in cooling needs resulting in a decrease in electricity demand of 104.4 PJ (or 29 million KWh) by 2050 under a medium emissions scenario. However, peak electricity demand for cooling is predicted to increase throughout Europe, with some of the largest increases in peak electricity demand predicted for France.

Net change in energy demand due to changes in HDD/CDD

Billion KWh

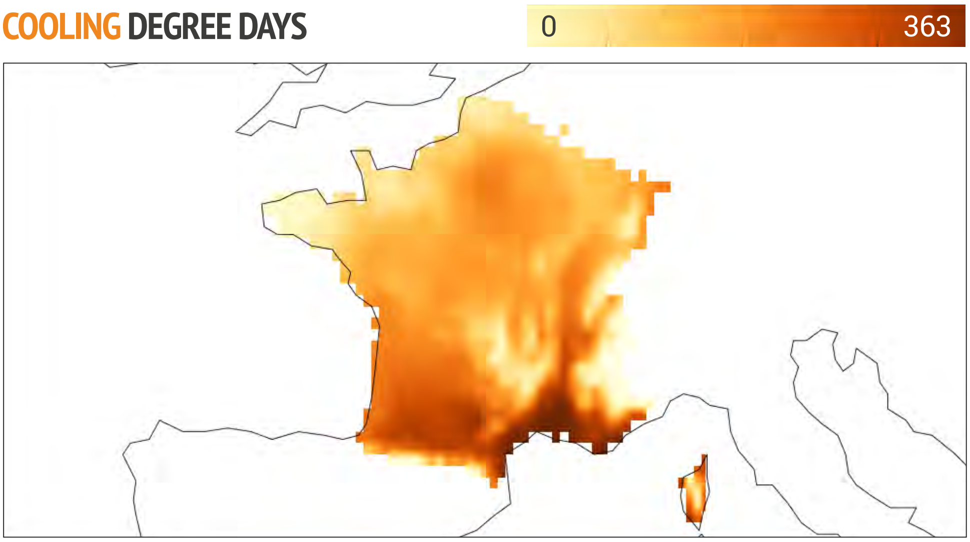
2050

- 29

COOLING NEEDS

Strong increases in cooling needs are expected along the Mediterranean coast, the central-south regions and, to a lower extent, in the Paris area. Milder increases in Bretagne and Normandy and in the mountain areas (Massif Central and Alps).

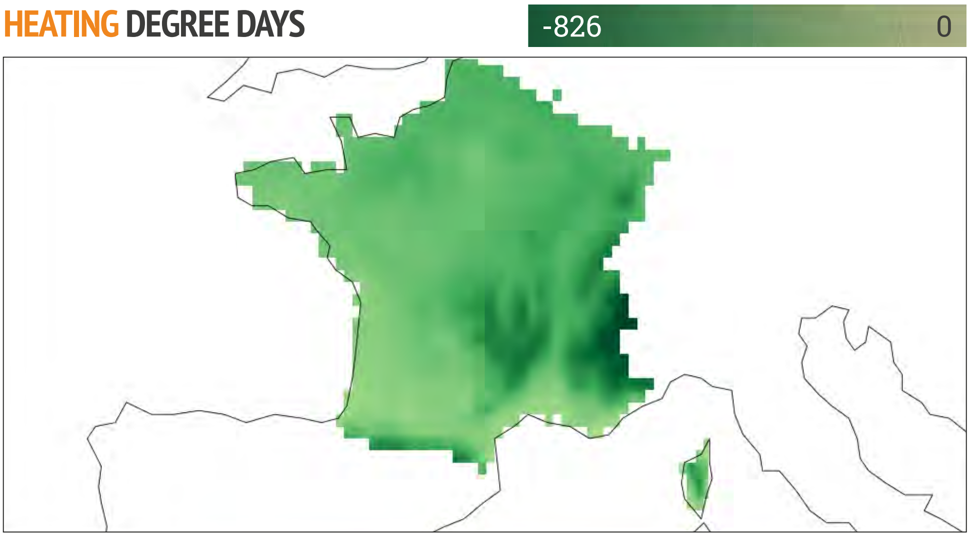
COOLING DEGREE DAYS



HEATING NEEDS

Marked decreases in heating needs are expected all over France, particularly in the mountain regions (Massif Central and Rhône - Alpes)

HEATING DEGREE DAYS



FUTURE ENERGY SUPPLY

The future configuration of the French energy mix is likely to be determined by the evolution of climate mitigation policies and hence is outside the scope of this report. The EU net-zero carbon target by 2050 is likely to result in a marginal relevance of fossil fuels and their vulnerabilities to climate change, while carbon free sources and their vulnerabilities will prevail.

Change in Hydropower generation

% of change

2050

-4.41%

-4.36%

EXPECTED IMPACTS OF CLIMATE CHANGE

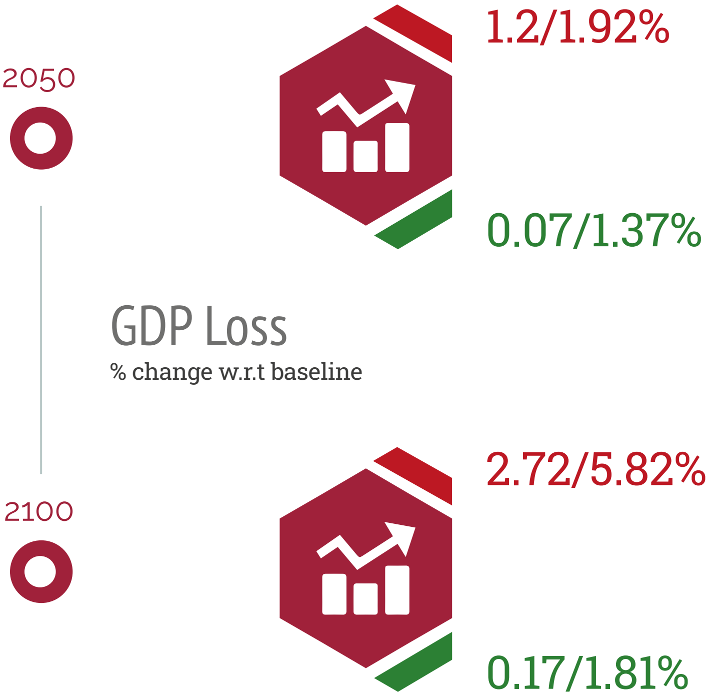
Spiking peak electricity demands during heatwaves and lower water availability during dry periods are the main threats posed to the French energy system. Hydropower may suffer from reduced water availability, particularly in the South.

More frequent extreme events might significantly increase stress on the energy system: besides heatwaves and the ensuing peaks in electricity demand, flash floods may also threaten energy infrastructure.

FRANCE
ECONOMY

OVERVIEW

France is third wealthiest country in the Eurozone and eighth among G20 countries in 2020. France was hit severely by the COVID crisis, registering an 8.2% decline in real GDP growth rate in 2020.



GDP Loss

% change w.r.t baseline

2050

1.2/1.92%

0.07/1.37%

2100

2.72/5.82%

0.17/1.81%

IMPACTS ON GDP

Climate change is expected to have a great impact on the French economy. By 2050 GDP losses may reach about 30 billion EUR (about 1.4% of total GDP) under a low emissions scenario.

In 2100, under a higher emissions scenario climate change could reduce French GDP between 2.7% and5.8%, amounting to roughly 60 to 124 billion EUR.

SECTORAL ECONOMIC IMPACTS

IMPACTS ON INDUSTRY AND INFRASTRUCTURE

Major risks to infrastructure are coming from extreme events such as droughts and floods. In France physical infrastructure was heavily impacted by heatwaves with delays in transportation and power outages.

More than 40% of the 36,500 French communes have been affected by floods (both coastal and river), and flooding is responsible for 80% of the damage attributable to French natural disasters.

A first estimate of the Expected Annual Damage (EAD) to critical infrastructure in France ranges from 0.4 billion euros per year to 2.9 billion euros per year in 2050.

IMPACTS ON AGRICULTURE

Although the agricultural sector accounts only for 2.8% of total GDP, nearly 60% of France's mainland surface area is used for agriculture.

Crop yields are predicted to be negatively affected by climate change: under a high emissions scenario climate models predict a 21.0% decline in winter wheat yield, a 17.3% decline in winter barley yield, and a 33.6% decline in spring barley yield by the end of the century. Increased events such as heatwaves may represent a cost of up to more than 300 million EUR per year in 2100 for a crop such as wheat in the absence of adaptation measures.

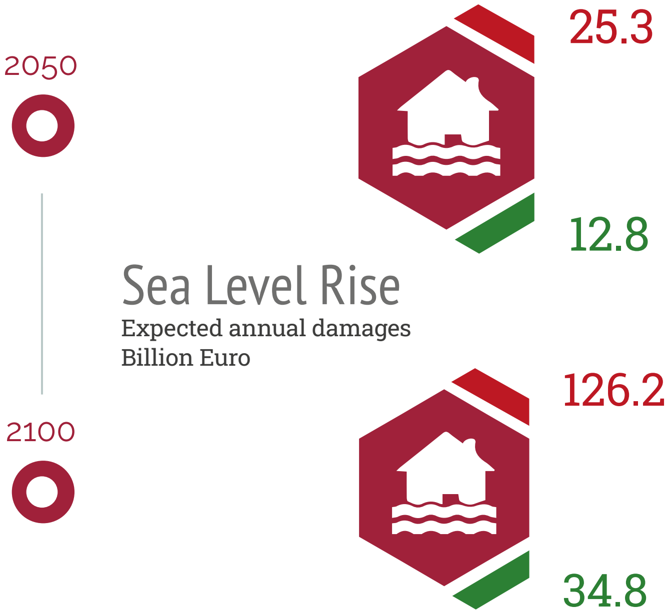
France is a major livestock farming country in the EU. Meadow yields are projected to increase in the northern area, whereas an increased vulnerability is projected in the peri-Mediterranean area with a loss of approximately -70% in the summer period.

The cost of compensating for these drops in yield could reach about 200 million EUR per year in the second half of the 21st century.

SEA LEVEL RISE DAMAGES

Under the current level of coastal protection, by mid century, sea-level rise and coastal flooding could cost the country 12.8 to 25.3 billion EUR in terms of expected damage to assets in low and high emissions scenarios, respectively.

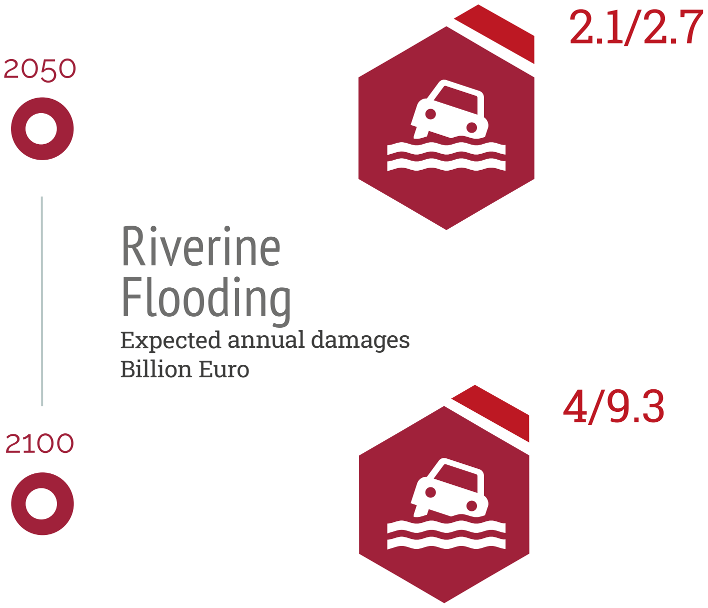
By the end of the century, expected losses can increase to 34.8 billion EUR in a low emissions scenario and to 126.2 billion EUR under a high emissions scenario.



RIVER FLOODING DAMAGES

Fluvial flooding is also expected to cause annual damages amounting to 2.1 billion EUR under a low emissions scenario and 2.7 billion EUR under a high emissions scenario.

By the end of the century the costs are projected to rise to 4 billion EUR under a low emissions scenario and could reach 9.3 billion EUR under a high emissions scenario.



IMPACTS ON ENERGY

As with all other economic sectors, energy supply and energy networks in France will be subject to more intense stress from extreme weather events.

Economic impacts of shifts in household and firm energy demand (see chapter on energy) are difficult to predict and will mostly lead to redistribution effects. In the case of France, the decrease in heating needs will prevail, bringing about a likely decrease in household and firm energy bills.

Expected annual damage to energy infrastructures is projected to show a 24-fold increase compared to present by mid century in a medium to high emissions scenario.

IMPACTS ON TOURISM

Climate change will potentially impact the tourism sector in France. Summer turnover will be negatively affected by a significant reduction in climate attractiveness.

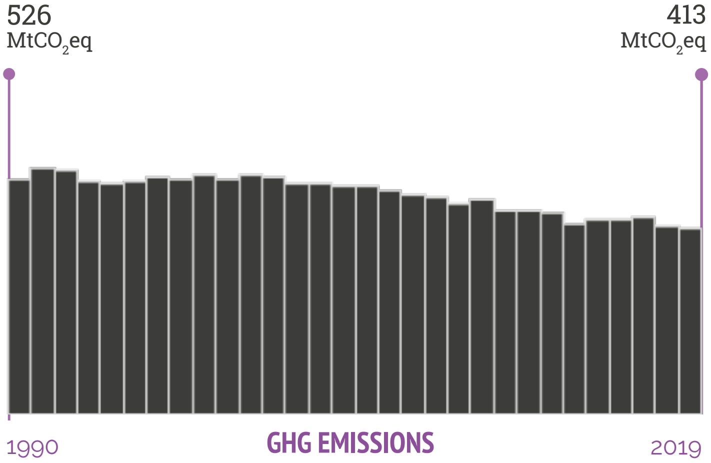
Without adaptation, economic losses associated with the tourism sector range from 15 to 19 billion EUR per year in 2100.

With respect to winter tourism, mountain activities represent 15.5% of total French tourism: a warming of 4°C, and the associated decrease in snow cover, would reduce the number of ski areas from 143 to 55 due to sufficient snow cover.

FRANCE
POLICY

OVERVIEW

France is responsible for 0.92% of global GHG emissions and has a slightly above global average rate of CO_2 emissions per capita. Emissions have been declining since 1991 and a net zero emissions by 2050 target has been set.



GHG EMISSIONS

INTERNATIONAL COMMITMENTS

France has the same target as the EU. In its 2020 NDC update, it strengthened its emissions target to a 55% reduction below 1990 levels by 2030. France has also set itself a carbon neutral by 2050 target.

CLIMATE POLICY COMMITMENTS CHRONOLOGY

2002 **KYOTO PROTOCOL - 1ST PERIOD**

No increase of GHG over the four year period 2008-2012, with respect to 1990 levels

2016 **PARIS AGREEMENT - 1ST NDC**

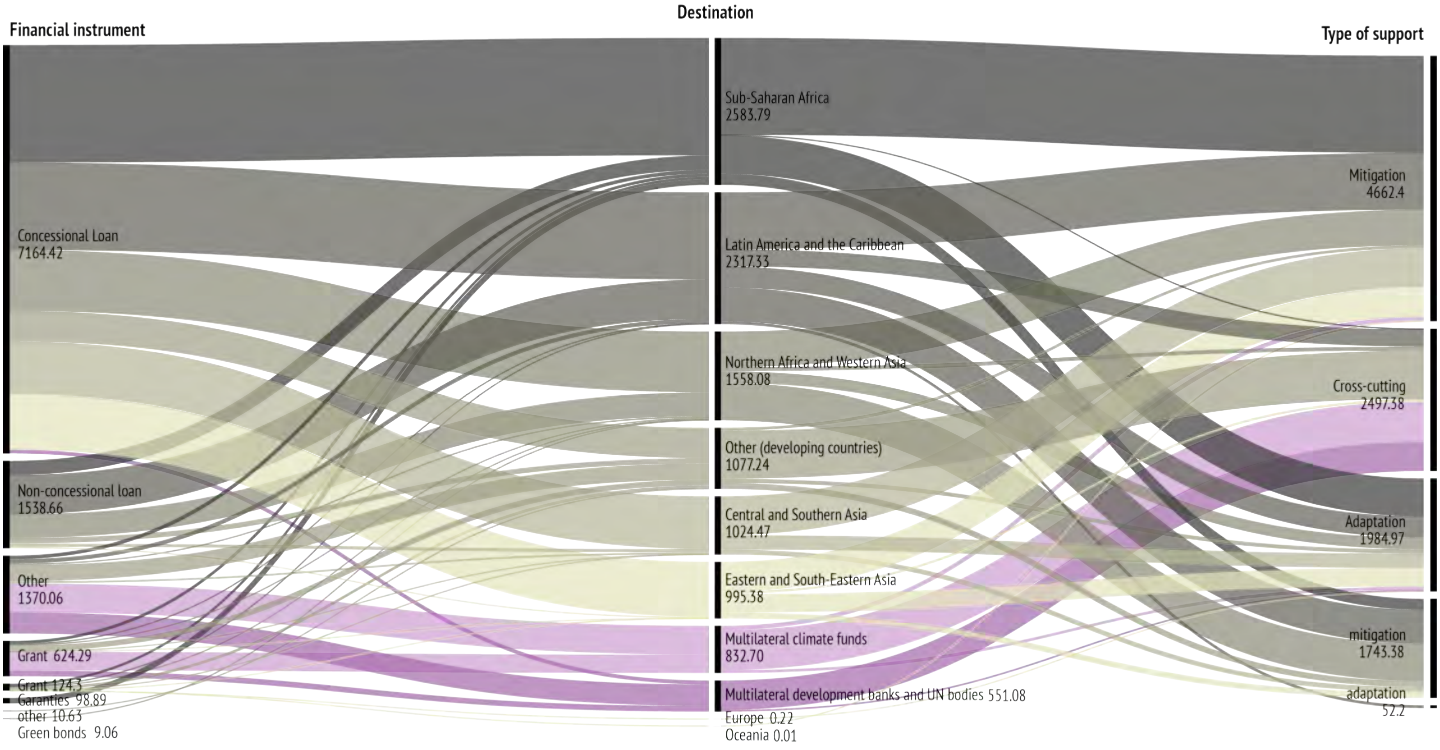
40% GHG reduction by 2030, with respect to 1990 levels

2020 **PARIS AGREEMENT - NDC UPDATE**

55% GHG reduction by 2030, with respect to 1990 levels

INTERNATIONAL CLIMATE FINANCE ASSISTANCE

In the 4th Biennial Report, France reported 10.9 billion USD in development finance for climate in 2017-2018. The majority was mobilised in the form of loans and other financial products to finance mitigation projects particularly in sub-Saharan Africa and Latin America.



SUSTAINABLE RECOVERY POLICY

According to the Global Recovery Observatory, in 2020 the proportion of green spending out of total recovery spending was 38%.

694.17 billion $	104.92 billion $	39.41 billion $
Total Spending	Recovery Spending	Green Spending

DOMESTIC ADAPTATION POLICY

The French National Strategy for Adaptation to Climate Change was adopted in 2006. The first National Adaptation Plan covered the period from 2011to 2015, the second National Adaptation Plan (2018-2022) covers the main sectors of the economy (agriculture, industry and tourism) and territories.

- ○ Domestic Adaptation Policy
  - ○ Inclusion of Adaptation in NDCs
  - ● Integrated Adaptation & Mitigation Policy
  - ● Dedicated Adaptation Strategy
  - ● Dedicated Adaptation Plan
- ● Subordinate Adaptation Policies
  - ● Sectoral Adaptation Plans
  - ● Subnational Adaptation Plans

○ Policy not in place ● Active policy

ADAPTATION POLICY HIGHLIGHTS

TRANSNATIONAL INITIATIVES

Provision of a prediction system allowing for management and optimization of snow in Alpine ski resorts (PROSNOW)

PROSNOW eases the decision-making process and provides more precise snow data to inform snow management strategies and tactics throughout the winter season

ECTAdapt

The aim of ECTAdapt is to develop a common policy on the adaptation to climate change in the Catalan Cross-border Area (Espacio Catalán Transfronterizo - ECT)

NATIONAL INITIATIVES

Climate Change Adaptation Resource Centre

A portal offering documentary resources and suggestions of local initiatives, to raise awareness on the reality of climate change and to facilitate the implementation of adaptation activities

Adapto

Adapto explores solutions to the impacts of climate change on the coast (e.g., sea level rise and more frequent extreme weather events) on 10 pilot sites owned by the Conservatoire du littoral

SUBNATIONAL INITIATIVES

Paris Climate Action Plan

The Climate Action Plan details and specifies the terms for adapting Paris to climate changes and the scarcity of resources in 35 actions that contribute to 30 objectives, while making the city more resilient, more attractive, and a nicer place to live

NATURE 4 CITY LIFE

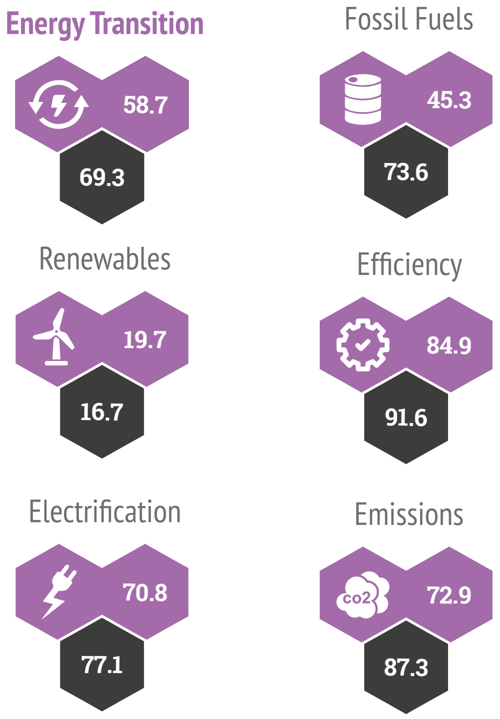
The project aims to strengthen the integration of Green and Blue Infrastructures in urban planning projects to increase urban resilience to climate change in the Region Provence-Alpes-Côte d'Azur

ENERGY TRANSITION

France shows one of the first positions among G20 countries in the overall Energy Transition indicator.

In particular, France has an outstanding performance in Fossil Fuels, almost 30 points above the average, and Emissions, due to nuclear energy capacity. This also impacts on the Efficiency and Electrification domains that have became priorities in France's energy policy a long time ago.

On the other hand, nuclear generation capacity until now, had a negative influence on the poor penetration of renewables (almost 3 points below the average) even if the progressive ageing of the nuclear park will reverse the trend in the coming years.



Only actively pursuing an energy transition based on decarbonization and electrification – from policy and regulation, to health and education – will enable countries to benefit the most from future opportunities and fight climate change whilst ensuring an equitable distribution of wealth.

The Energy Transition indicators were developed by Enel Foundation in cooperation with SACE, and provide a retrospective analysis based on historical data.

G20 CLIMATE RISK ATLAS

Impacts, policy, economics

GERMANY

How to read the Atlas: graphs, colours and scenarios.

The maps used in this Atlas are taken from **The World Bank Official Boundaries** - ***https://datacatalog.worldbank.org/search/dataset/0038272*** (accessed on May 28, 2021). For the section Energy, the maps are based on Panoply Data Viewer ***https://www.giss.nasa.gov/tools/panoply/credits.html***

Each sector of this Atlas contains data and information on various climate scenarios.

When reported in graphs, the **colour black** indicates data and information referring to the current state, the past or the baseline.

When the authors refer to **RCP (Representative Concentration Pathways)**, the 3 colours used across the factsheet refer to 3 scenarios, which are 3 different development options with different levels of greenhouse gas emissions, **respectively low emissions (green), medium emissions (orange), and high emissions (red)**. The same colour code is used when RCPs are associated with Shared Socioeconomic Pathways (SSP).

In some cases, the authors refer to global warming scenarios. In these cases, the 3 colours used refer to a temperature rise of **1.5°C (green), 2°C (dark green), and 4°C (red)**.

When the authors refer exclusively to **Shared Socioeconomic Pathways - SSPs** (Population affected by river floods in the section: "Water"), data related to **SSP3** - that encompasses, among other things, slow economic growth, material-intensive consumption, and persisting or worsening inequalities – **are reported in a lighter shade**; **SSP5** – which refers to social and economic development that is coupled with an energy-intensive lifestyle and the abundant exploitation of fossil fuel resources – is shown using a **middle shade of the colour**, whereas data related to **the present** conditions **are represented in a dark shade**.

Further details on scenarios, methodologies, and the full list of references are available at: **www.g20climaterisks.org**

Concept and graphic design by element6.eu

GERMANY
CLIMATE

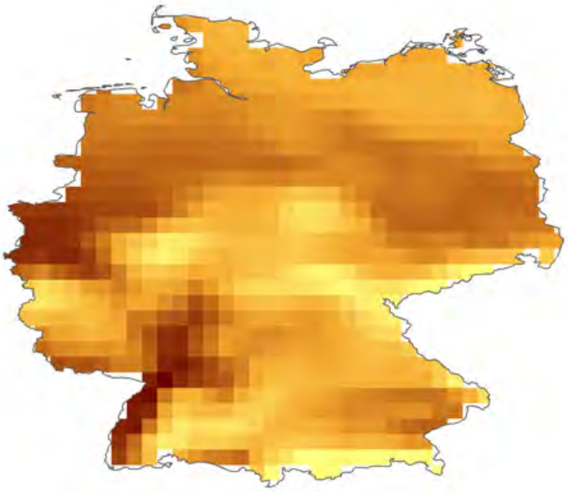
OVERVIEW

Germany has a temperate climate throughout the country with some differences in temperature and precipitation. The northern part is characterised by an oceanic climate with rain all year round. In the eastern part, the climate shows clear continental characteristics, whereas in the central and southern part there is a transitional climate that can be predominantly oceanic or continental and is influenced by the warm föhn wind.

TEMPERATURE

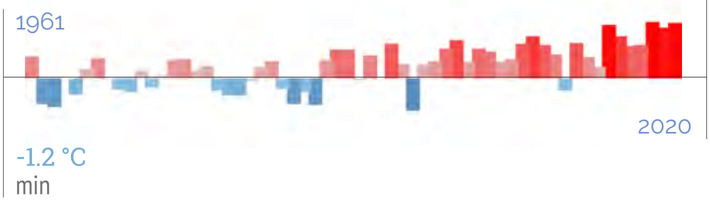
The temperature regime in Germany is homogeneous with slight differences between regions and inter-annual variability. The warmest areas are in the southwest. Extremely high temperatures in the summer and deep, prolonged frost in the winter are rare.

MEAN TEMPERATURE



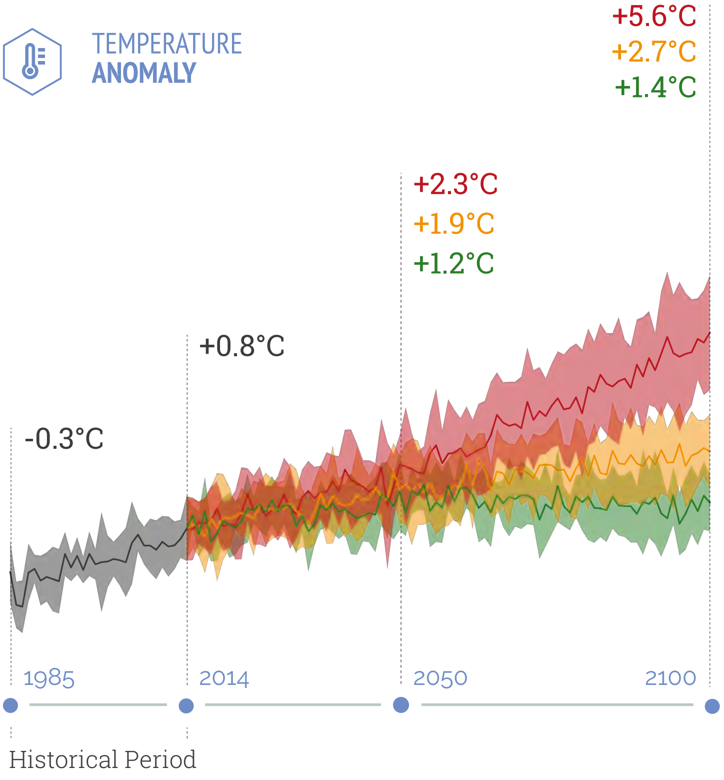
TEMPERATURE TREND

Temperature anomalies over the last 60 years with respect to the annual mean of 9°C in Germany during the 1961-1990 period



TEMPERATURE PROJECTIONS

Under a low emissions scenario projected temperature variations will remain contained under +1.5°C, both by 2050 and 2100.
Under a high emissions scenario, with no reduction in GHG emissions, much greater temperature anomalies are expected by both 2050 and 2100.



EXPECTED VARIATION FOR TEMPERATURE AT 2050

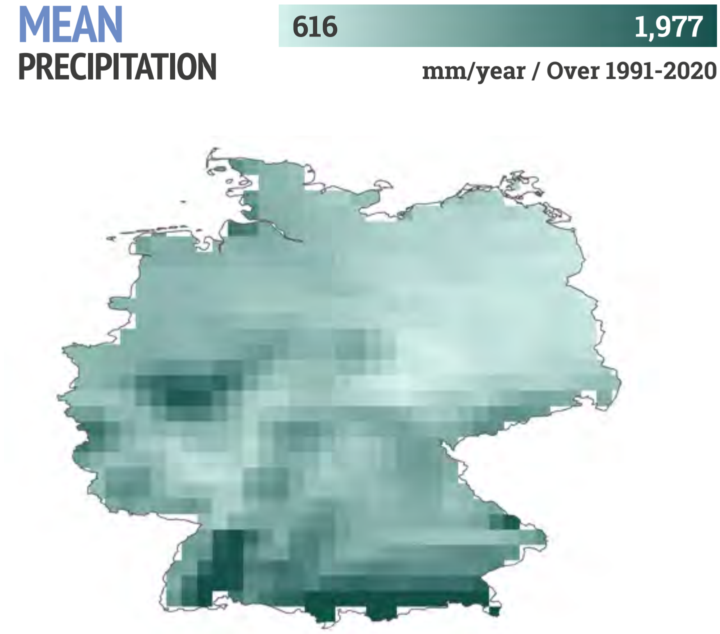
The indicators show variations in selected temperature characteristics for a thirty-year period centred on 2050 (2036-2065) with respect to the reference period 1985-2014.

Annual Mean Temperature	Max Temperature of warmest month	Min Temperature of coldest month
+2.3°C	+3.4°C	+2.4°C
+1.8°C	+2.6°C	+1.9°C
+1.4°C	+2.2°C	+1.7°C

PRECIPITATION

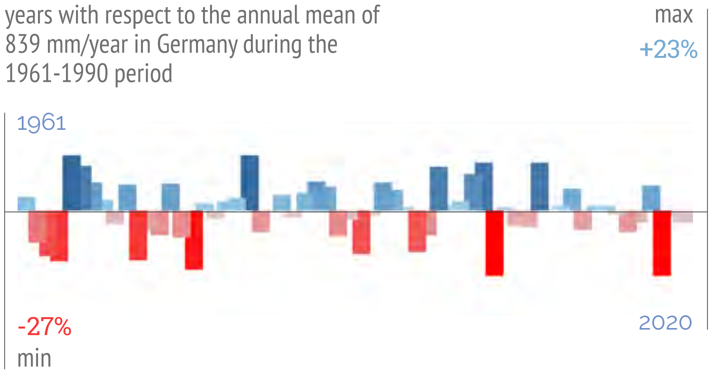
Precipitation in Germany is more-than-abundant, well-distributed and varies between regions. It is lowest in the North German Plain and increases in the Central German Uplands and Alpine regions where annual mean precipitation is up to and exceeding 2,000 mm per year. In general, annual precipitation features a relevant inter-annual variability. This may be related to the complexity of the precipitation regime and to possible compensation between opposite patterns reported at a more local level.

MEAN PRECIPITATION



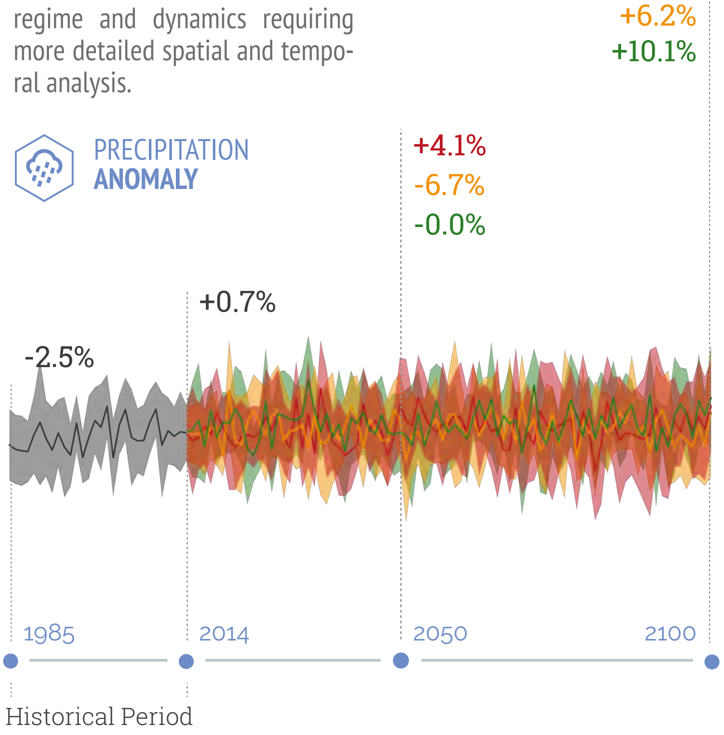
PRECIPITATION TREND

Precipiation anomalies over the last 60 years with respect to the annual mean of 839 mm/year in Germany during the 1961-1990 period



PRECIPITATION PROJECTIONS

Precipitation trends show a very complex signal, under all emissions scenarios, with a very large variability among climate models. This can be explained considering the complexity of the precipitation regime and dynamics requiring more detailed spatial and temporal analysis.



EXPECTED VARIATION FOR PRECIPITATION AT 2050

The indicators show variations in selected precipitation characteristics for a thirty-year period centred on 2050 (2036-2065) with respect to the reference period 1985-2014.

+2.6%
+1.8%
+2.6%
Annual total precipitation

+4.5%
+2.5%
+4.6%
Precipitation of wettest month

-4.2%
-2.4%
-2.2%
Precipitation of warmest quarter

VARIATION OF SPECIFIC CLIMATE INDICATORS

Climate indicators variation showing impacts of climate change on sectors such as agriculture, health and water. Analysis considers 3 threshold average temperature increase: **+1.5°C**, **+2°C**, **+4°C**.

+35%
+19%
+14%
Agricultural drought proportion of time
% of time

+31%
+15%
+12%
Hydrological drought proportion of time
% of time

+1,461%
+261%
+100%
Heatwave duration
% of time

+59%
+29%
+10%
Runoff increase
% of area

+74%
+50%
+35%
Agricultural drought frequency
% of change

+17%
+12%
+14%
Hydrological drought frequency
% of change

+80%
+35%
+21%
Heatwave frequency
% of change

+10%
+6%
+4%
Runoff decrease
% of area

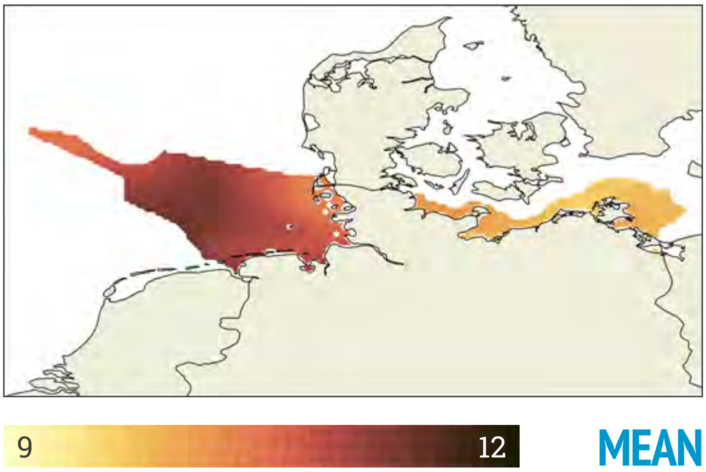
GERMANY
OCEAN

OCEAN IN GERMANY

Germany's marine exclusive economic zone (EEZ) is mainly characterized by cold temperate coastal waters which host highly diverse ecosystems and maritime activities. The wide ensemble of coastal systems can be divided into two main areas: the North Sea and the Baltic Sea.

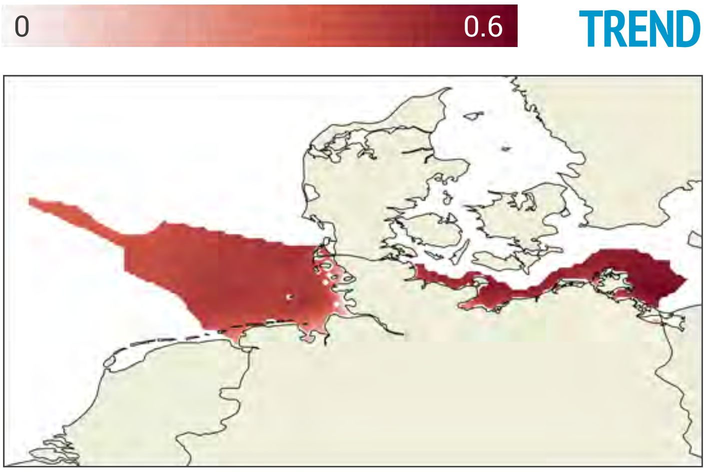
CURRENT CLIMATE CONDITIONS

Mean sea surface temperature reflects the main climate regime, with cold waters characterizing all the national coastal systems.



SEA SURFACE TEMPERATURE

Celsius degrees / Over 1991-2020

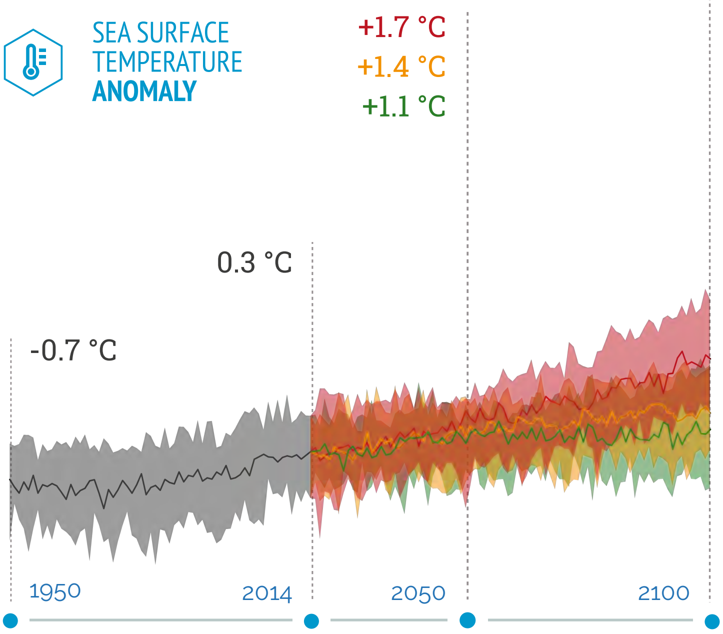


Surface temperature trends indicate a general warming of 0.3°C per decade in all marine areas, with increased gains in the Baltic region.

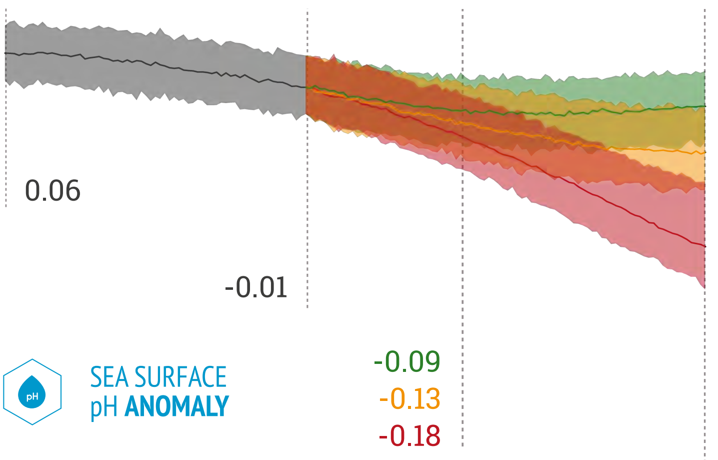
FUTURE PROJECTIONS

Projected annual changes within the marine EEZ for the two most significant marine indicators of climate change: sea surface water temperatures and pH.

Seawater temperature changes are in line with the definitions of each scenario, with maximum values in 2100 close to +4°C under a high emissions scenario.



SEA SURFACE TEMPERATURE **ANOMALY**



SEA SURFACE pH **ANOMALY**

Seawater surface pH becomes more acidic in all scenarios, closely reflecting rising atmospheric CO_2 concentrations, and only a low emissions scenario leads to a stable condition by 2100.

ECOSYSTEM INDICATORS AT 2050

Regional changes in key marine ecosystem indicators under projected future scenarios by mid-century (2036-2065) with respect to present climate conditions (1985-2014).

Baltic

North Sea

Temperature regulates the metabolism of marine organisms determining which habitats remain suitable. Excessive warming will likely push ecosystems beyond tolerance thresholds.

pH represents the acid/base status of marine waters, where a decreasing pH reflects the acidification of the ocean due to increased absorption of atmospheric CO_2.

Oxygen is fundamental to sustain marine life and its reduction can have a large impact on coastal ecosystem services including fisheries and aquaculture.

Chlorophyll is an indicator of the biomass available at the base of the marine food web supporting all ecosystem productivity.

Baltic		North Sea	
10.34°C	+2.05 °C +1.87 °C +1.51 °C	10.72°C	+1.76 °C +1.42 °C +1.17 °C
7.88	-0.17 -0.12 -0.08	8.08	-0.18 -0.13 -0.1
335.96 mmol/m^3	-5.32 % -4 % -3.26 %	285.29 mmol/m^3	-3.34 % -2.48 % -1.7 %
0.39 mg/m^3	-20.31 % -22.62 % -27.51 %	0.36 mg/m^3	-16.2 % -11.73 % -13.97 %

FISH CATCH POTENTIAL

Fish catch potential is an estimate of the maximum fish catch achievable given the marine resources available over a sustained period. It is linked to the concept of maximum sustainable yield, meaning the maximum amount of fish that can be extracted from a system without causing a collapse in fish populations.

It is a characteristic of the natural system, which is substantially different from realized catch, and a direct result of the fishery policy in place. The data reported concerns the German part of the North Sea only.

Fish catch percentage change

2050

-22.1%

-21.9%

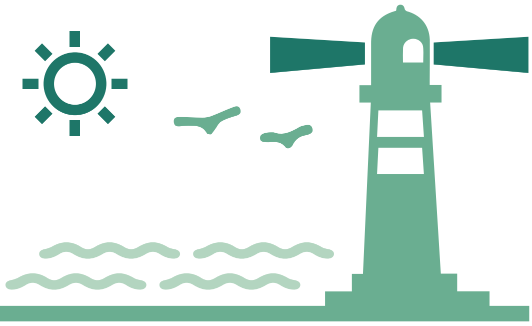
ANALYSIS DETAILS

All datasets were analysed using only data from within the marine EEZ and therefore excluding overseas territories, detached islands and any disputed or joint territories with other nations. In the assessment of current climate conditions, seawater surface tempererature data was obtained using satellite observations distributed in the framework of ESA Climate Change Initiative.

Future projections of marine indicators are represented by the combined analysis of results from 15 different Earth System models participating in the Coupled Model Intercomparison Project Phase 6 (CMIP6). These models include new and better representations of physical and biogeochemical processes, compared to previous IPCC assessment reports.

Fish catch potential data was obtained using the FAO's technical report and refers to the best and worst case climate scenarios from the Fifth IPCC Assessment Report. These mean estimates are subject to substantial uncertainties as discussed in the original work.

GERMANY
COASTS



OVERVIEW

Germany has two stretches of coastline found on either side of the border with Denmark: the North Sea to the west and the Baltic Sea to the east. Although much of the country is landlocked, the coastal area covers land in five of Germany's federal states, including large cities such as Bremen and Hamburg. The German coastline is mostly shallow and made up of wetlands, inlets, small bays and islands.

Shoreline Length 3,624 km

Sandy Coast Retreat at 2050 -65.4 m

CLIMATE CHANGE HAZARDS

Coastal hazards such as erosion, storm tide inundation and permanent flooding, can have strong adverse impacts on coastal regions, with loss of sandy shores, damage to settlements, infrastructure and ecosystems. Climate change can exacerbate these impacts due to rising sea levels and increasing impacts of waves and storms. Climate change will have significant impacts on the environment, infrastructure, and population of the German coast. The coast's natural features will be at an immediate risk from storms and flooding events, which are likely to arrive more frequently and hit with higher intensity, particularly those coming from the North Sea. At the same time, sea levels are rising, and this will compound shoreline effects, leading to an increased impact on the exposed areas. This is all in a complex interplay with changing patterns in temperature and precipitation that make future consequences more severe and difficult to predict.

SEA LEVEL RISE

Relative sea level rise has been observed over the past century around the coast of Germany, with a yearly average increase of approximately 1.45 millimetres per year since the 1990s. The latest IPCC projections indicate that, by 2050, global sea levels may rise between 0.18 metres, under a low emissions scenario, and 0.23 metres, under a high emissions scenario.

Observed and projected sea level rise at 2050

1.45 mm/year

0.23 m

0.18 m

EXTREME SEA LEVEL

On average, one in 100 extreme sea level events are expected to rise from 2.97 metres at present day to 3.28 metres by 2050 under a medium emissions scenario. This could result in one in 100 year extreme events occurring as often as one in every 10 years, considering a sea level rise of 1 metre.

Current and projected extreme sea level at 2050

2.97 m

3.33 m

3.28 m

OBSERVED STORMS

Given the low-lying nature of Germany's coastline, high waves and storms present a significant hazard to the local population and environment. Driven mainly by extreme tides and high wind speeds, there is a long history of dangerous storm surges that have caused coastal erosion, large damage to infrastructure and even numerous casualties. Furthermore, these events have become more frequent and severe throughout the 20th century.

FUTURE STORMS

Climate change is expected to drive more frequent and severe storm surge events, while rising average sea levels will increase the baseline wave height, further exacerbating risks.

VULNERABILITY AND RISK

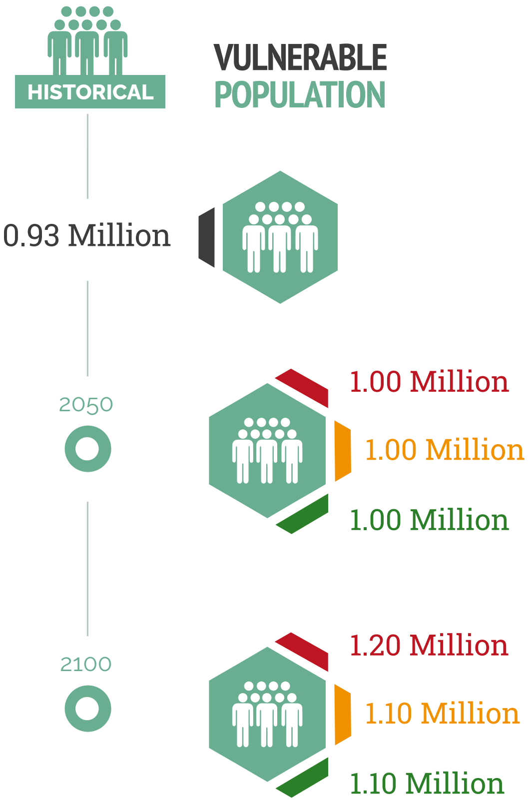
In the future, exposed coastal populations can expect to face a much higher frequency of flooding events, leading to increased economic losses, loss of productivity, and requiring large economic investment for protection and recovery measures.

In terms of commercial activities, the ports of Bremen and Hamburg could face significant impacts from increased flooding due to climate change. The Hamburg harbour in particular is projected to be entirely within the flood risk zone within the coming decades.

Coastal zone ecosystems may face erosion from storms leading to loss of beaches and important habitats, which could potentially end up permanently submerged. Higher water levels could also lead to saltwater intrusion and drainage issues.

The Wadden Sea, considered one of Germany's most important natural area, is at particular risk due to its low-lying position. Under a medium emissions scenario, the population exposed to the annual coastal flood level is expected to increase from 930,000 to 1 million people by 2050.

VULNERABLE POPULATION



INFLUENCE OF SEA LEVEL RISE ON EXTREME SEA LEVEL

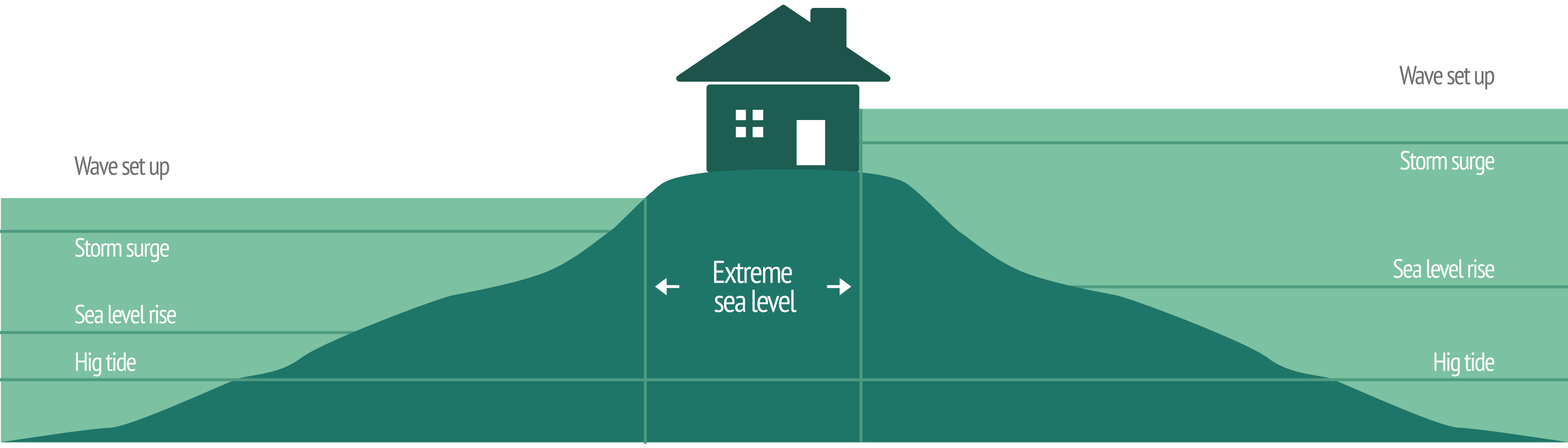
Present and future sea level rise are a consequence of carbon induced global warming causing melting ice and ocean expansion due to heat accumulation.

The extreme sea levels reported here are based on the 100-year storm surge + wave set up + sea level rise + high tide indicators. The first two parameters (storm surge + wave set up) are based on the 100-year value for the event; sea level rise is its projected value at 2050; and high tide is the absolute value of the highest tide calculated for a given locality, which won't be influenced by climate change.

+ Wave set up refers to the accumulation of water near the shore due to the presence of breaking waves.

+ Storm surge is an occasional increase in sea level driven by shoreward wind-driven water circulation and atmospheric pressure.

+ High tide is usually the highest tide reached in a given location based on tide records.



Present sea levels have risen globally by approximately 20 centimetres over the past century.

Future sea level rise is a projection based on different global warming scenarios, at approximately 100 centimetres by the end of 2100, with consequent inundation during extreme sea level events.

GERMANY
WATER

OVERVIEW

Germany has a large reserve of superficial water and groundwater, with 2.2% of the country's surface area covered in water.

Water surfaces include eleven large rivers: Elbe, Danube, Rhine, Weser, Ems, Warnow/Peene, Elder, Schiel/Trave, Oder, Rhone, and Maas.

However, water shortages occur regularly in regions with an unfavorable water balance, particularly Brandenburg which lacks sufficient water to keep river levels constant and to flood leftover pits from strip mining.

Renewable internal freshwater resources
107
billion m^3

Renewable internal freshwater resources per capita
1,294
m^3

Germany has faced an increase in the regional average for mean annual precipitation by about 9%, compared with the beginning of the 20th century, as well as a change in the distribution of rainfall over the summer months, whereby reduced rainfall in July and August is largely offset by heavier rainfall in June. Winter rainfall shows a general increase of around 20%, but the increase of winter rainfall in eastern parts of Germany is compensated by the decreased rainfall in summer.

CLIMATE CHANGE HAZARDS

Climate change can affect water resources through increasing temperatures, higher rates of evapotranspiration and altered rainfall patterns. This leads to changes in the water cycle, including decrease of snow and ice coverage, alterations of surface runoff and groundwater storage, as well as drought and flood occurrence. In Germany, the potential negative impacts of climate change are an increased risk of flooding and a decrease in water supply during summer months. These impacts are the result of an observed shift, which is expected to become more pronounced in future, in precipitation regimes from summer to winter, as well as higher evaporation due to increased temperatures. The probability of extreme rainfall events will continue to increase, particularly in winter.

KEY POINT RUNOFF

Average discharge, as well as the flow regime of German rivers, have been affected since global warming has accelerated dramatically since the middle of the 20th century. The observed changes cover most of the variability in runoff that has been recorded since observations started. They show a high correlation with observed changes in regional climates. Therefore, it can be assumed that a good portion of the effect can be explained by climate change.

In Germany, at a country scale, an average change in surface runoff by approximately -2% and +25% is expected respectively under low and high emissions scenarios for the 2045-2055 period compared to 2015-2025.

If temperatures rise by 1.5°C, 2°C or 4°C, 4%, 6.1% or 10% of the area of the country will likely experience an increase in runoff, while 10%, 28.6% or 59% of the surface of the country will likely experience a decrease in runoff, respectively.

2050

Changes in annual runoff
% of change

+25.3%

-1.8%

2050

Runoff increase
% of area

+10.0%

+4.0%

KEY POINT DROUGHTS

In central and eastern Germany, the territory will suffer from a decreased supply of water during summer. The risk of drought has increased and is accompanied by constraints in agriculture, forestry, energy supply and navigation, and possibly also in drinking water supply. In 2018/19 compound drought and heatwave events in Germany occurred.

This disaster had far-reaching consequences for agriculture and forestry. It affected about 90% of the German territory, placing the country third in the world in terms of disaster impacts in 2018. Moreover, given the high level of dependency on socio-economic systems and critical infrastructures, it led to a series of cascading effects, such as the reduced streamflow of the Rhine river which impaired waterborne transportation, which in turn resulted in increased energy prices.

2050

Severe drought likelihood increase

% of change

+14.2%

+4.4%

2050

Hydrological drought frequency

% of change

+17.0%

+10.0%

2050

Groundwater Recharge

% of change

-6.0%

-3.4%

KEY POINT GROUNDWATER

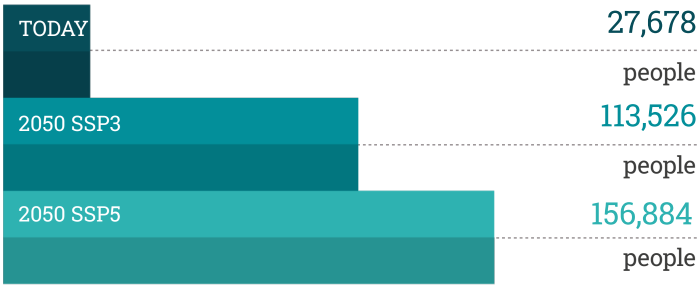
In Germany, groundwater is a vital and essential resource. It is the primary source of water supply for over two-thirds of the population. In addition, groundwater recharge in southern Germany has already decreased over the last decades, mostly because of an increase in evaporation. As such, decreasing groundwater levels and spring discharges, as well as new lowest values, were registered at many measuring points in southern Germany.

A decrease in groundwater recharge is a potential negative impact of climate change. Yet, water supply and distribution are not prepared for water shortages in summer. If no adaptation measures are implemented, the vulnerability of impacted regions, like eastern Germany will be high. At the country level, a -3.37%, -12.19% and -6% decrease of the annual groundwater recharge for the period 2045-2055 compared to the timeframe 2015-2025 is expected under low, medium and high emissions scenarios respectively.

KEY POINT FLOODS

Germany has experienced numerous floods both in the past up to the present day. Recently, the July 2021 floods in the south of North Rhine-Westphalia and north of Rhineland-Palatinate saw average accumulations from 100 to 150 millimetres in 24 hours, equivalent to more than a month's worth of rain. In Reifferscheid, 207 millimetres fell within a nine-hour period while Cologne observed 154 millimetres in 24 hours. Some of the affected regions may not have seen rainfall of this magnitude in the last 1,000 years. The consequences include swelling streams that then washed away houses and cars and triggered massive landslides. With at least 177 deaths, the floods are the deadliest natural disaster in Germany since the North Sea flood of 1962. Changing rain patterns may affect the frequency and intensity of floods. Changes in the population exposed to river floods are expected, with an increase from about 28,000 in the present day to 113,500 under SSP3 and 157,000 under SSP5 by 2050. As such, potential impacts related to river floods might increase remarkably.

POPULATION AFFECTED BY RIVER FLOODS

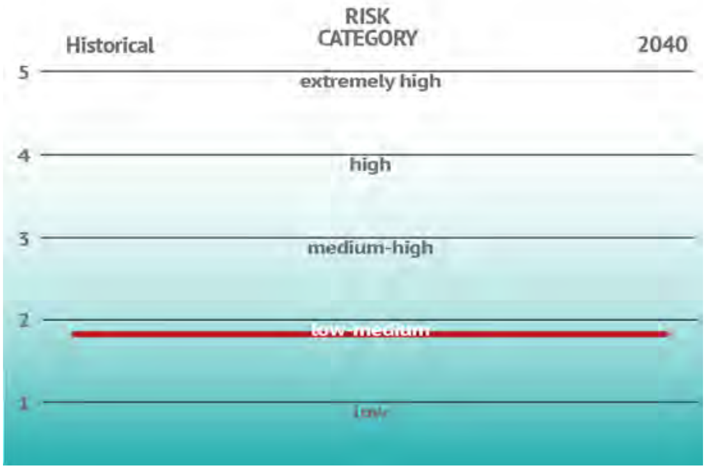


RISK INDICATORS

The water stress index summarises current and future water related vulnerabilities and risks at the global level. Scores are based on the ratio of total water withdrawals, including agriculture, industrial and human consumption, to available renewable surface and groundwater supplies.

WATER STRESS

Germany's water stress level is considered low-medium for the recent past (1960-2014 average), and it is expected to remain stable in the near future (2030-2050) based on climate change projections.



GERMANY AGRICULTURE

OVERVIEW

Agricultural land covers almost half of the German territory, one of the highest shares in the EU. Agricultural labor force represents around 1.8% of the active population and the sector accounts for approximately 0.8% of national GDP.

Germany is the world's third largest exporter of agricultural goods and the largest milk and potatoes producer in the EU. Milk represents the biggest proportion of production value of German agriculture. Cereal, sugarbeet and oilseed production is mainly concentrated in the central regions of Lower Saxony, Saxony Anhalt and Thuringia. Vineyards are found in river valleys in southern and western Germany along the Rhine and the Main.

Around 3% of agricultural land is irrigated, and irrigation is mainly used to contrast short drought periods and to protect crops and plants from frost damage.

26.2 Mt
Sugarbeet

3.7 Mt
Rapeseed

20.3 Mt
Wheat

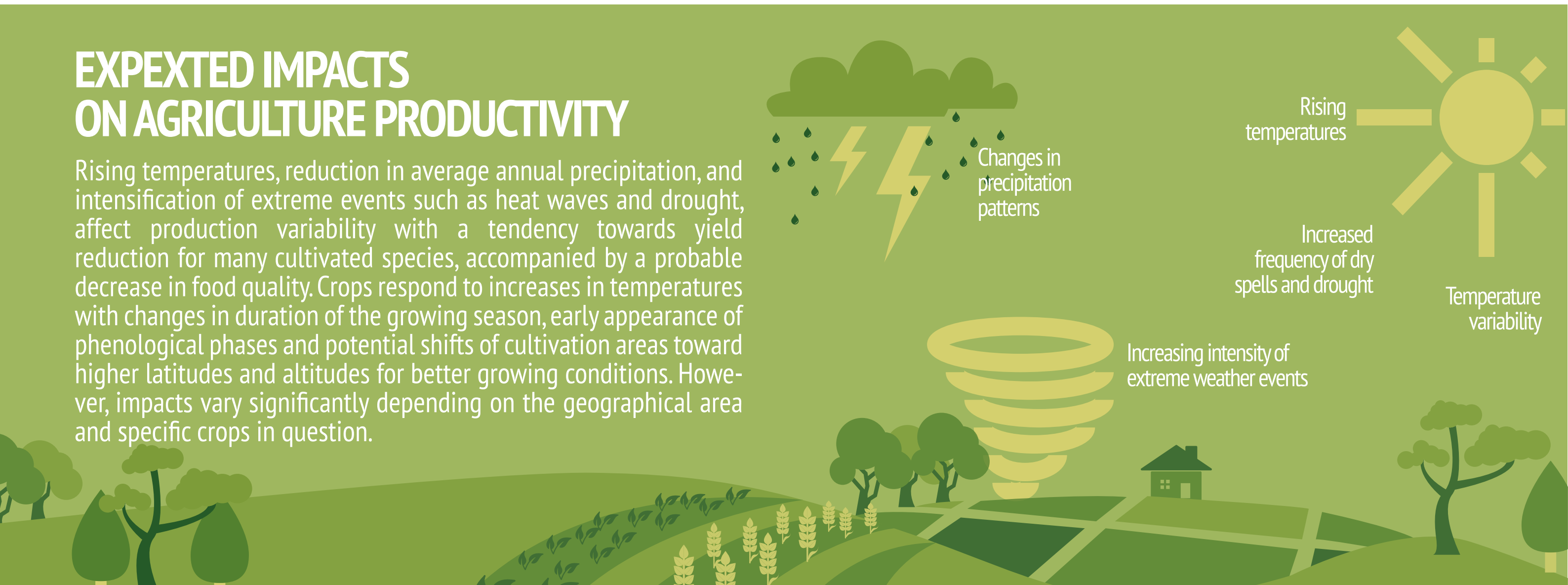
3.3 Mt
Maize

1.4 Mt
Grapes

	Added Value of Agriculture, Forestry and Fishing	Share of Agriculture Value added in Total GDP	Agricultural land	Area Equipped for Irrigation
2000	21,736 USD Million	0.8 %	12,020 Thousand HA	485 Thousand HA
2018	21,690 USD Million	0.6 %	11,930 Thousand HA	676 Thousand HA

EXPEXTED IMPACTS ON AGRICULTURE PRODUCTIVITY

Rising temperatures, reduction in average annual precipitation, and intensification of extreme events such as heat waves and drought, affect production variability with a tendency towards yield reduction for many cultivated species, accompanied by a probable decrease in food quality. Crops respond to increases in temperatures with changes in duration of the growing season, early appearance of phenological phases and potential shifts of cultivation areas toward higher latitudes and altitudes for better growing conditions. However, impacts vary significantly depending on the geographical area and specific crops in question.



CROP PRODUCTIVITY

Crop productivity refers to the harvested yield of a crop per unit of land area. It is strongly influenced by climate and other environmental and management factors.

Climate change is expected to have an impact on the productivity of several major crops, although this may in part be offset by the fertilizing effect of higher CO_2.

Impacts are estimated using a range of model projections based on low to high emission scenarios and reported as percentage changes between the 30-year average around the historical period and the 30-year average around 2050.

68 -3.2 (-11.8)% -1.6 (na)%
Sugarbeet
tons / ha

7 9.7 (2)% 12 (5.8)%
Wheat
tons / ha

3.2 4.9 (-0.8)% 5.9 (na)%
Rapeseed
tons / ha

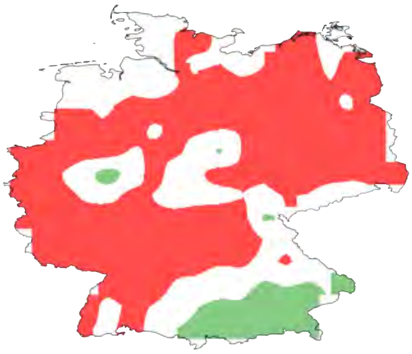
8.5 9.6 (4.7)% 8.9 (-0.2)%
Maize
tons / ha

2050

Productivity change with (without) the CO_2 fertilization effect. Estimates assume sufficient water and nutrient supplies, and do not include impacts of pests, disease, or extreme events.

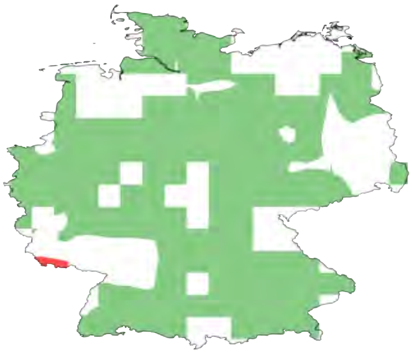
CHANGE IN SUGARBEET

🟥 − = 🟩 +



CHANGE IN MAIZE

🟥 − = 🟩 +



Increasing temperatures and lower levels of precipitation may affect crop yields of cereals and maize. However, higher CO_2 levels can compensate for climate-related crop yield losses. Sugarbeet could be the most affected crop in terms of yield decrease, suffering a strong decline in production due to spring and summer drought and early pest attacks in most regions of the country. Due to climate change and more pronounced droughts, an increase in yield fluctuations is expected for most crops especially under rain-fed conditions. Although an average increase is projected for potato productivity, shortage can also occur as a consequence of larger frequency of summer heat and droughts. A northward expansion of grape growing regions is expected. Traditional grape growing areas will face climate risks due to milder winters with lack of chilling requirements needed for certain varieties and higher frost risks with anticipated bud breaking.

ADAPTATION IN AGRICULTURE AND WATER RESOURCES

Climate change can benefit productivity of several widely used crops. However, higher temperatures will generally require an increase in irrigation demand due to higher plant evapotranspiration. Thus far, irrigation requirements in agriculture have been quite limited. However, irrigation demand is likely to expand in the future especially in areas where precipitation is projected to decline. More frequent and prolonged drought events are expected in the future. The last decade has witnessed several extremely dry years with relatively high impacts on the agricultural sector that highlight the needs for optimal irrigation management.

CHANGE IN WATER DEMAND

🟩 − = 🟥 +

Agriculture
Water Demand
% of change

+9.3%
+8.5%

2050

Water saving technologies in agriculture would help deal with climate risks, including water use efficient irrigation methods, precision farming and the use of water efficient crop varieties.

GERMANY FORESTS

FORESTS IN GERMANY

The history of German forests is strongly linked to human intervention and is still largely shaped by the massive reforestation efforts carried out after the devastation of the Second World War. Almost all German forests are considered secondary forests with a prevalence of conifers, although deciduous temperate species such as beech and oak are constantly increasing.

FORESTED AREA AND CARBON STORAGE

Despite being a very populous country, forests in Germany cover over 30% of the land surface with a very stable trend in recent decades. According to the Third National Forest Inventory, more than 1,100 million tons of carbon are stored in living trees and deadwood removing approximately 52 million tons of CO_2 from the atmosphere every year. Forests are currently considered an important carbon sink for the country.

1990

11 Mln ha
Million hectares
Forested area

153 Tons/ha
Tons of Carbon per hectare
Carbon stock

2020

11 Mln ha
Million hectares
Forested area

196 Tons/ha
Tons of Carbon per hectare
Carbon stock

FOREST PRODUCTIVITY

Forest productivity or Net Primary Production is the net carbon captured by plants. It is the difference between the carbon gained by Gross Primary Production - net photosynthesis measured at the ecosystem scale - and carbon released by plants' respiration. It is expressed per unit land area.

2050

Productivity anomaly
Tons of Carbon per hectare per year

+0.42

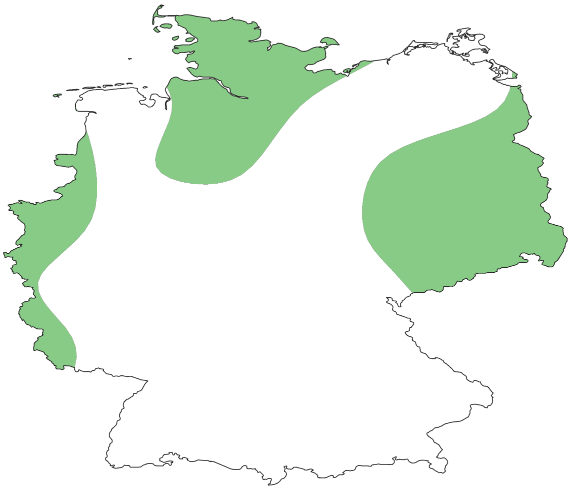
+0.21

Primary productivity will remain relatively stable until 2050, although with a high uncertainty. In contrast, the Saxony and Brandenburg regions of coniferous forests are expected to see an increase

+ CO_2 fertilization and temperature increase promotes productivity

No areas with an expected decrease in forest primary production

+ Sharp increase in drought risk reduces productivity



KEY SPECIES UNDER CLIMATE CHANGE

MORTALITY
SPRUCE
Increased risk of Norway spruce and Scots pine mortality due to decreasing precipitation

SUITABILITY
OAKS
In the driest areas oak shows a much greater future suitability than beech

DEFOLIATION
CONIFERS
South-western Germany emerged as the area with the greatest risk of defoliation due to summer drought stress

INCREASING
MAPLE LIME ELM
In Southern Germany some maple, lime and elm species can play a more prominent role in future climate-resilient mixed forest ecosystems

FIRES IN GERMANY

Fire is a structural ecological process that provides several types of ecosystem services and impacts on socio-ecological systems, including human health, carbon budgets, and climate change. Changes in global fire activity are influenced by multiple factors such as land-cover change, policies, and climatic conditions. Fire also releases large quantities of greenhouse gases into the atmosphere, contributing to a vicious cycle.

During the last three decades, the total area affected by fire was approximately 23.5 thousand hectares with 32.8 thousand fires occurring.

BURNING
23.5 THOUSAND HECTARES

EMITTING
0.22 TERAGRAMMES OF CARBON PER YEAR

FOREST FIRE EMISSIONS CONTRIBUTED TO 30% OF TOTAL FIRE RELATED CARBON EMISSIONS

COSTING
4 MILLION USD PER YEAR IN FOREST FIRE PREVENTION AND CONTROL (2017-2019)

FUTURE BURNED AREA

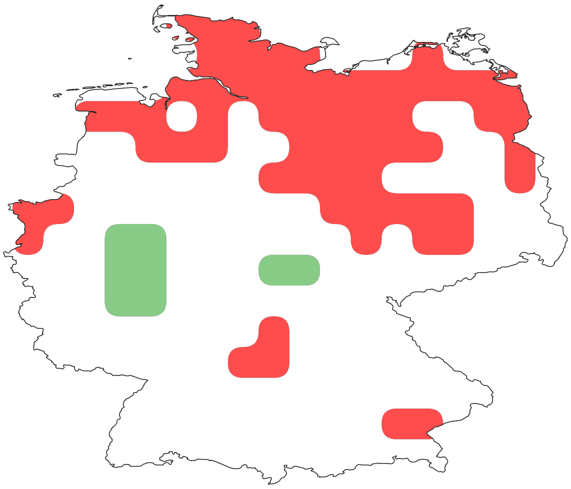
Under low and medium emissions scenarios burned area is expected to increase mainly over the Atlantic and Baltic areas but also over some eastern areas dominated by temperate mixed forests.

Burned Area
km² per year

2050

+23

+23



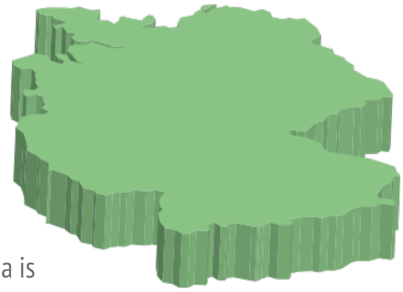
🟩 Decrease in burned areas for a low emissions scenario

🟥 Increase in burned areas for a low emissions scenario
+ Prolonged and more intense fire season
+ Increase in future weather risk due to warming and drought conditions

WHERE DO FIRES OCCUR?

Between 2000 and 2019 Germany contributed to 0.1% of the total burned area in EU.

Extensive pine forests on sites with poor soil and a dry climate are most at risk.



The most affected area is Brandenburg.

VARIATION OF SPECIFIC FIRE INDICATORS

% of change
Average fire danger over fire season
2041-2070
+4%
+0.5%

% of change
High fire danger days per year
2041-2070
+0.2%
+0%

% of change
PM2.5 emissions
2010-2050
PM2.5
+62%
+45%

FUTURE FIRE EMISSIONS

Models project fire emissions to increase particularly in eastern regions dominated by broadleaf and mixed forests. Under a medium emissions scenario, fire emissions might also increase across the entire country.

Fire Carbon emission
Teragrams of Carbon per year
2050
co2
+0.8
+0.6

GERMANY
URBAN

OVERVIEW

With an urbanization rate of 77%, urban areas are home to the majority of the population. By 2050, this rate may increase to almost 85%. Germany has a rather decentralized urban structure with a small number of metropolitan areas with more than 1 million inhabitants, and more than 20 agglomerations counting more than 300.000 residents, whereas the main part of the urban population lives in smaller centers with less than 300,000 people.

Due to migration, recent demographic trends showed a slight increase in population. Despite this short term increase, the long term trends shows that an ageing society, with a consequent increase in the vulnerable population, will not be inverted. Expected growth of urbanized areas will be due to sub-urbanization trends in the wider urban areas. This situation is expected to remain stable in the future. Built up areas cover approximately 8.1% of Germany. Between 2015 and 2019 there was a 320 square kilometer increase in built up areas due to on-going sub-urbanization.

OVERVIEW OF KEY CLIMATE IMPACTS IN URBAN AREAS

The German national vulnerability analysis identifies heat stress as the major future issue in urban areas, followed by flooding due to intense rainfall.

HEATWAVES AND HEAT STRESS

Heat stress, deterioration of the urban climate and air quality are already affecting German cities. Furthermore, increased heat is causing damage to roads, railway infrastructure and runways. In the near future, water shortages may also affect the availability of cooling water for infrastructure and energy production causing interruptions in essential services to urban areas. Impacts from intense heat waves are worse in dense urban areas.

During intense heat waves, mortality increased up to 67% in the central district of Berlin. In the surrounding, less urbanized areas average mortality rates increased between 5% and 32.3%. Within the city, increases in mortality rates were higher in districts with higher rates of soil sealing.

Rising temperatures and duration of heat waves are expected for the whole country. Frequency, intensity and duration of heatwaves will be higher in urban areas compared to the national average, although large scale models have difficulties capturing specific urban geography and representing the urban heat island effect.

Population in Urban Areas

2020 63,930,305

2050 66,825,911

Graphs refer to data provided by United Nations, Department of Economic and Social Affairs, Population Division (2018). World Urbanization

Urbanization Rate

2020 77.5%

2050 84.3%

2050

Cooling Degree Days
% of change

+236.9%
+78.3%
+47.1%

2050

Heatwave frequency
% of change

+80.1%
+35.1%
+21.4%

2050

Heatwave duration
% of time

+1,461%
+261%
+100%

INTERACTIONS BETWEEN HEAT AND AIR QUALITY

Present and future deterioration of the urban climate and air quality related to heatwaves is already an important concern for German cities. Negative health effects in urban areas are caused by an increasing frequency of threshold exceedances of levels of ground ozone concentrations, due to the combined effects of air pollution and heat.

2017

Population exposed to air pollution

89.2%

COASTAL FLOODING

Germany is expecting damage to coastal settlements due to rising sea levels to increase in the distant future, which could also exacerbate impacts of river flooding in coastal areas.

Projected sea level rise

2050

0.23 m

0.18 m

2100

0.77 m

0.38 m

EXTREME PRECIPITATION EVENTS

Damages from river flooding are experienced and expected in cities such as Hamburg, Stuttgart, Munich and the Rhine-Main region and in the districts on the Elbe, Weser, Ems, Danube and the Lower Rhine. After some extreme flood events along major rivers such as the Rhine river (1993, 1995), the Elbe (2002 and 2013), and the Danube (1999, 2002, 2013), in 2021 an unprecedented intense precipitation event caused devastating flooding along a series of tributaries to the major rivers, claiming over 200 lives in Germany, and 43 victims in neighboring areas in Belgium.

2050

Runoff increase
% of area

+10%

+6%

+4%

Damage costs are still being assessed, but insurers expect claims for insured losses between 4 and 5 billion euros. With an insurance coverage of 46%, actual losses will be much higher, and secondary effects, such as interruptions of activities and supply chains are not factored in. Furthermore, material losses could be higher, as only 46% of the calculations do not include non-insured losses. Despite decreasing precipitation trends for the summer season, weather conditions like those leading to the floods of July 2021 are expected to occur more frequently in the future.

SURFACE SEALING AND FLOODS

Heavy precipitation in cities is problematic due to the high level of sealed surfaces. Soil sealing increases run off and reduces the amount of water absorbed by soil. Where there are large amounts of impervious ground cover, short duration extreme rainfall events can lead to increased flooding, even resulting in flash floods.

URBANIZATION AND SOIL SEALING

Under a high emissions scenario, further increases in potential flood damages are expected in the near future, due to the high degree of soil sealing and exposure of assets in densely urbanized areas.

2010

% of urban population

Population living in slums

0%

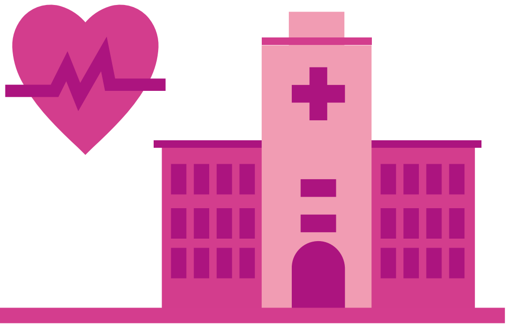
2018

% of total population

Urban population living in areas where elevation is below 5 meters

3.0%

GERMANY
HEALTH



OVERVIEW

Germany has three distinct climatic zones ranging from a mild maritime climate in the north, to a continental climate further inland, and a mountain climate in the south. The country faces significant health impacts attributable to climate change, including a potential increase in the risk of mortality and morbidity from extreme weather, expected changes in the range of vector-borne diseases, and likely increases in the risk of food- and water-borne infections as well as respiratory diseases and allergies. Particularly vulnerable to the impacts of climate change on health are populations with low socioeconomic status or a lack of social networks, the elderly, children and patients with chronic diseases and disabilities. The frequency and duration of heat events in Germany has increased, and the record heatwave in the summer of 2003 led to approximately 7,500 deaths.

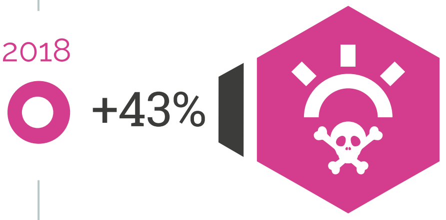
HEAT RELATED MORTALITY

In Germany, climate change has been causing more frequent, more intense, and more extended periods of heat in the summer. Heat-related mortality is projected to increase, and reductions in cold-related mortality are unlikely to compensate for the excess deaths.

Under a high emissions scenario, heat-related deaths in the elderly (65+ years) are projected to increase to about 66 deaths per 100,000 by 2080 (10 deaths per 100,000 under a low emissions scenario), compared to a baseline of under 3 deaths per 100,000. In 2018, there was a 43% increase in heat-related deaths in Germany from a 2000 to 2004 baseline. 28.5% of heat-related mortality in Germany during 1993 to 2015 can be attributed to human-induced climate change.

Heat-related mortality

% change with respect to 2000-2004



IMPACTS ON LABOUR

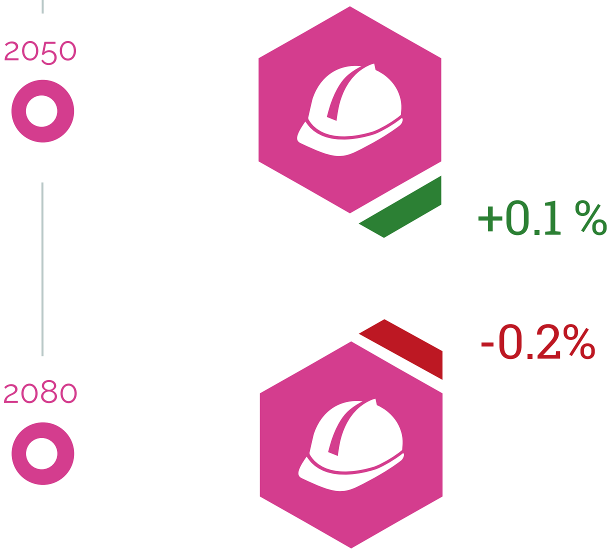
Labour is directly affected by changes in environmental conditions. Warming affects both the number of hours worked (labour supply) and on the productivity of workers during their working hours (labour productivity). Both labour supply and productivity are projected to decrease under future climate change in most parts of the world, and particularly in tropical regions.

Parts of sub-Saharan Africa, south Asia, and southeast Asia are at highest risk under future warming scenarios. Future climate change will reduce global total labour in the low-exposure sectors by 18 percentage points and by24.8 percentage points in the high-exposure sectors under a 3.0°C warming scenario

Germany is expected to experience a 0.14% gain in total labour under a low emissions scenario, whilst suffering a relatively small loss of 0.2% under a medium emissions scenario.

Impact on total labour

% change with respect to 1986-2005 baseline



CLIMATE CHANGE AND DENGUE

Dengue has spread throughout the tropical world over the past 60 years and now affects over half the world's population. Globally, vectorial capacity for both dengue vectors (A. aegypti and A. albopictus) has been rising steadily since the 1980s, with nine of the ten highest years occurring since 2000.

Climatic stressors are one important driver of the current distribution and incidence of dengue. Climate change is likely to expand the geographical distribution and suitability of several vector-borne human infectious diseases including dengue. The risk of dengue transmission is increased by warming climates, as the growth and development of mosquitoes are significantly influenced by temperature, precipitation, and humidity.

CLIMATE CHANGE AND ZIKA

Zika virus has spread to at least 49 countries and territories since 2013. Climate change impacts on transmission suitability risk have increased over the years and future warming over 1.3 billion additional people could face suitable transmission temperatures for Zika by 2050.

DENGUE AND ZIKA: POPULATION AT RISK

Emerging infectious diseases such as dengue fever or chikungunya and leishmaniasis are likely to increase due to climate change.

The risk of vector-borne diseases such as dengue will increase due to future climate change in Germany. Under a medium emissions scenario, 48.1% of the population will be at risk of transmission-suitable mean temperature for dengue by 2050, whereas 97.9% will be at risk under a high emissions scenario. In the case of Zika, 48.4% of the population will be at risk of transmission-suitable mean temperature by 2050 under a high emissions scenario.

CLIMATE CHANGE AND MALARIA

The risk of malaria is relatively low in Germany. In 2050, 2% of the German population will be at risk of malaria under a low emissions scenario, whereas 6.5% will be at risk under a high emissions scenario.

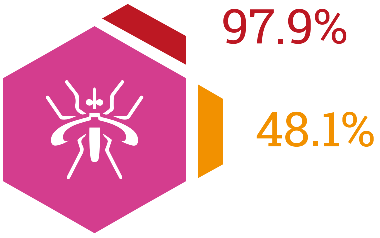
POLLUTION AND PREMATURE MORTALITY

Under a medium emissions scenario, annual premature deaths due to long-term exposure to near-surface ozone and heat will increase from 7,020 in 2010, to 10,321 in 2050.

Dengue suitability

% of population at risk

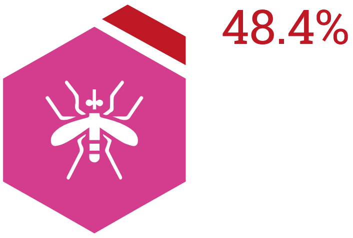
2050



Zika suitability

% of population at risk

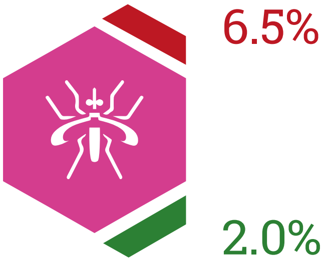
2050



Malaria suitability

% of population at risk

2050



GERMANY
ENERGY

ENERGY SYSTEM IN A NUTSHELL

Germany has a dynamic, diversified economy with one of the lowest energy intensities in the world, despite the major role of manufacturing of energy-intensive and technology-rich goods.

While still heavily dependent from fossil fuels, the Energiewende strategy is pushing for a fast transition to a more efficient, nuclear-free and carbon-neutral energy sector. Wind and biofuels have expanded substantially in the last decades and a complete phase-out of coal is planned by 2038.

0.07
ktoe/US$
Energy
intensity

71%
Import
dependence ratio

CLIMATE CHANGE TODAY

TEMPERATURE

Temperatures have increased by 1.6°C in the period 1880-2010 and a series of consecutive record years for highest mean temperatures have ocurred since 2000, leading to an increase in cooling needs and a decrease in heating needs.

HEATWAVES

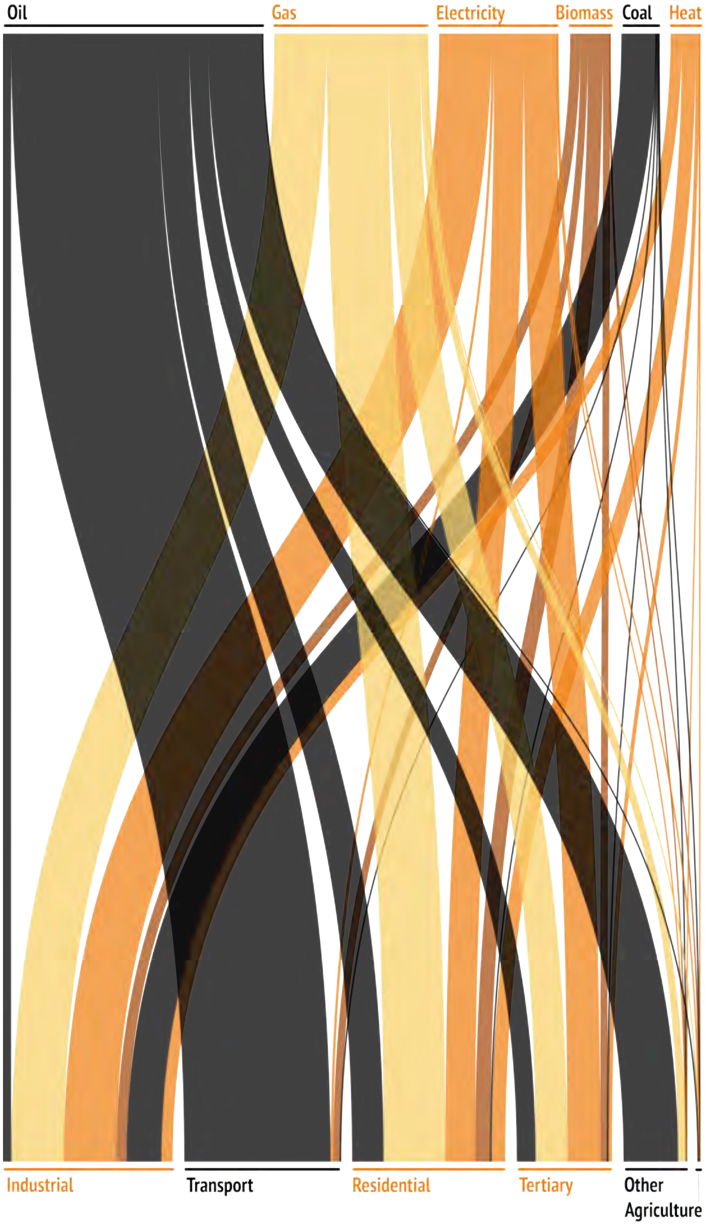
Heatwaves are becoming more and more frequent, with six short- or long-term heat extreme events recorded since 2003, with a record temperature of 42.6°C in 2019.

FLOODS

The devastating floods of the summer of 2021 brought massive devastation to all infrastructure in the areas where it struck, leaving inhabitants without electrical power and natural gas connections.

ENERGY SUPPLY

The current (2019) energy mix is strongly dominated by imported fossil fuels: 33.4% oil, 26.4% natural gas and 17.9% coal. Nuclear (6.3%) has more than halved since 2000. In the last decade, hydropower kept a minimal and roughly constant share (0.6%), whereas biofuels, and wind and solar boomed, with, respectively a 5-fold and 18-fold expansion, and shares that went from 2.3% to 10.1% and from virtually zero to 5.3% between 2000 and 2019.



ENERGY DEMAND

In Germany, energy is used mainly by the industrial sector (35.8% of final demand in 2018, including 9.8% for non-energy use), transport (25.2%) and residential (24.3%), followed by commercial use (13%), while agriculture holds a very minor share (1.6%).

FUTURE ENERGY DEMAND

Germany has a varied climate, but overall, moderately cold conditions prevail. Germans have shown, so far, a clear dislike towards residential air conditioning, even in presence of heatwaves. Overall, this suggests that the decrease in heating needs will prevail, resulting in a decrease in electricity demand of 543.5 PJ (or 151 million KWh) by 2050 under a medium emissions scenario.

Net change in energy demand due to changes in HDD/CDD
Billion KWh

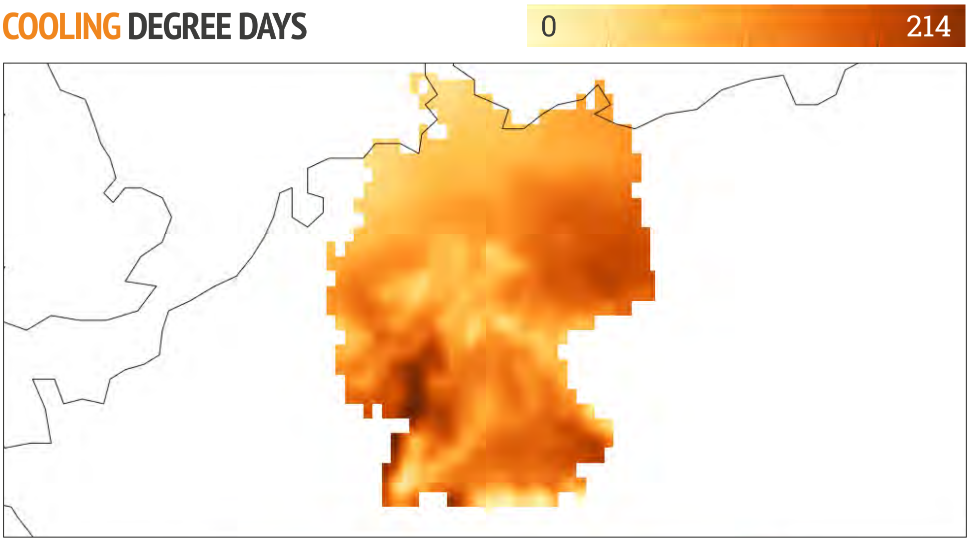
2050

- 150.99

COOLING NEEDS

Cooling needs are projected to increase in the whole country, particularly along the south-western border and around Frankfurt (Hesse). Marked increases are expected also in the east Länder (Saxony and Brandenburg).

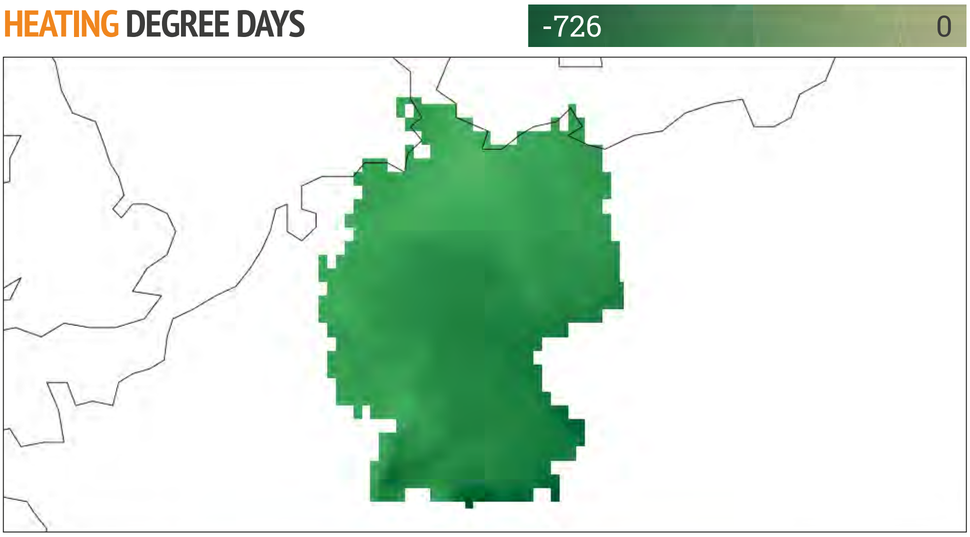
COOLING DEGREE DAYS



HEATING NEEDS

Marked decrease in heating needs are expected all over Germany, stronger in the central Länder and in Bavaria. The maignitude of the heating degree days anomaly largely exceeds that of cooling degree days everywhere in the country.

HEATING DEGREE DAYS



FUTURE ENERGY SUPPLY

The future configuration of the German energy mix is likely to be determined by the evolution of climate mitigation policies and hence is outside the scope of this report. Carbon neutrality is planned by 2050 as for the rest of the EU, and the Energiewende is gaining momentum in moving the country towards a renewables-based energy system, although extra efforts are needed to bring the transport and industrial sectors on schedule. This points to a rapidly increasing relevance of the vulnerabilities of renewable energy sources and a decline of those of traditional sources.

Change in Hydropower generation
% of change

2050

-5.93%

-4.93%

EXPECTED IMPACTS OF CLIMATE CHANGE

Expectations are for modest decreases in hydropower potential; stable conditions for wind and solar; and minor benefits for wood biomass. Droughts may pose a low-level risk for biofuels.

Thermal plants may lose efficiency due to rising temperatures and reduced availability of cooling water; energy infrastructures may be increasingly threatened by floods, flood surges and windstorms.

GERMANY
ECONOMY

OVERVIEW

Germany ranks first the Eurozone and fourth in the G20 group for GDP. The country recovered quite well after the 2008-2009 economic crisis showing, in the 2010-19 period, an average annual real GDP growth rate of roughly 1.9%. It has been hit severely by the COVID crisis, recording a decline of nearly 5% in real GDP growth rate in 2020.

IMPACTS ON GDP

Despite its developed and technology-rich economy, Germany may face no to marginal systemic losses and negative growth impacts from climate change. GDP losses can be significant already by mid century under a low emissions scenario peaking at 1.35% of GDP or 45 billion EUR.

They can more than double reaching 98 billion EUR or nearly 3% of GDP by the end of century under a high emissions scenario.

GDP Change

% change w.r.t baseline

2050

🟥 -0.61/-1.85%

🟩 0.39/-1.35%

2100

🟥 -1.92/-2.95%

🟩 -0.08/-1.85%

SECTORAL ECONOMIC IMPACTS

IMPACTS ON INDUSTRY AND INFRASTRUCTURE

Germany's coastal areas account for 6.8% of the total country surface. The country coastline of roughly 2,400 kilometres is shorter than that of other G20 countries. However, it is rich in infrastructure and commercial hubs. Sea-level rise and storm surges can thus be a source of huge economic losses.

The German territory spans over five large river basins, three medium-scale basins in the coastal areas and small parts of the Oder and Meuse basins.

Over the last five decades flood hazard increased in Germany particularly due to an increase in flood frequency. These trends will be exacerbated by climate change.

IMPACTS ON ENERGY

As with all other economic sectors, energy supply and energy networks in Germany will be subject to more intense stress from extreme weather events.

Economic impacts of shifts in household and firm energy demand (see chapter on energy) are difficult to predict and will mostly lead to redistribution effects. In the case of Germany an overall decrease in energy bills is expected due to the heavily reduced heating needs, whereas cooling needs increase is expected to be minimal.

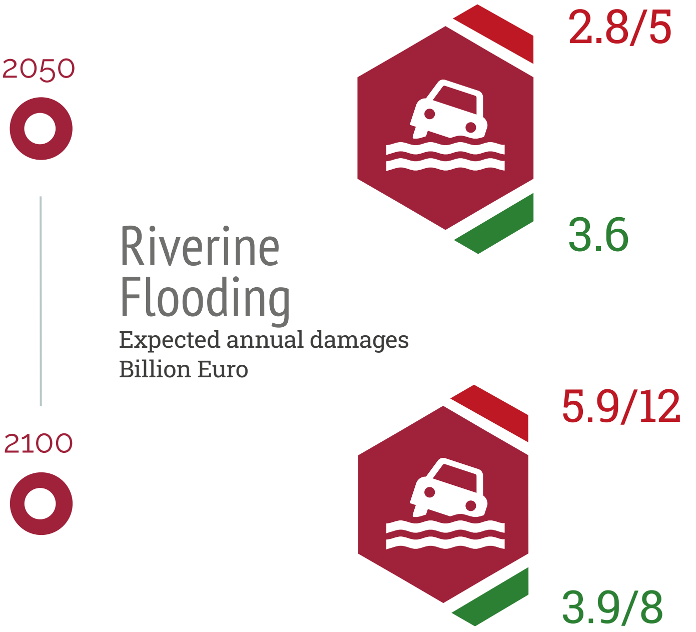
Expected annual damage to energy infrastructure is projected to show a 7-fold increase compared to present by mid century under a medium to high emissions scenario.

SEA LEVEL RISE DAMAGES

In the second half of the century, if coastal defenses are not upgraded to contrast increasing climate change risk, expected annual damages to coastal infrastructure could reach more than 74 billion EUR under a high emissions scenario.

RIVER FLOODING DAMAGES

Increase in frequency and intensity of extreme weather events can generate relevant economic losses associated to riverine floods. 12 billion EUR in expected annual damage to infrastructure assets could be experienced in a high emissions scenario in the second half of this century.



IMPACTS ON AGRICULTURE

As is typical of developed economies, the overall contribution of the German agricultural sector, including forestry and fishing, to national GDP is rather limited: 0.7% in 2019.

Consolidated research emphasizes that climate change, especially when potential CO_2 fertilization effects are considered, could moderately benefit crop production in Central and Northern European countries like Germany with negligible effects on land use changes.

IMPACTS ON TOURISM

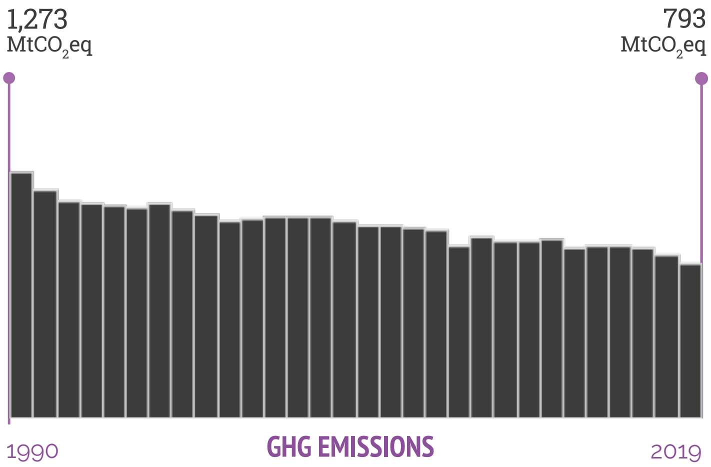
Germany is one of the “cold countries” that in moderate climate change scenarios can increase their climate and environmental attractiveness and experience increases in tourism. Some positive effects are thus expected.

Inbound tourism expenditure may increase by 20% in a low emissions scenario compared to 2018 level.

GERMANY
POLICY

OVERVIEW

Germany is responsible for 1.76% of global GHG emissions and has an almost twice above global average rate of CO_2 emissions per capita. Emissions have been declining since 1991 and a net zero emissions by 2045 target has been set.



GHG EMISSIONS

INTERNATIONAL COMMITMENTS

Compared to the EU emissions reduction target of at least 55% below 1990 levels by 2030, Germany aims to further reduce greenhouse gas emissions by at least 65% by 2030 compared to 1990 levels and be carbon neutral by 2045.

CLIMATE POLICY COMMITMENTS CHRONOLOGY

2002

KYOTO PROTOCOL - 1ST PERIOD

21 % of yearly average reduction in GHG over the four year period 2008-2012, with respect to 1990 levels

2016

PARIS AGREEMENT - 1ST NDC

40% GHG reduction by 2030, with respect to 1990 levels

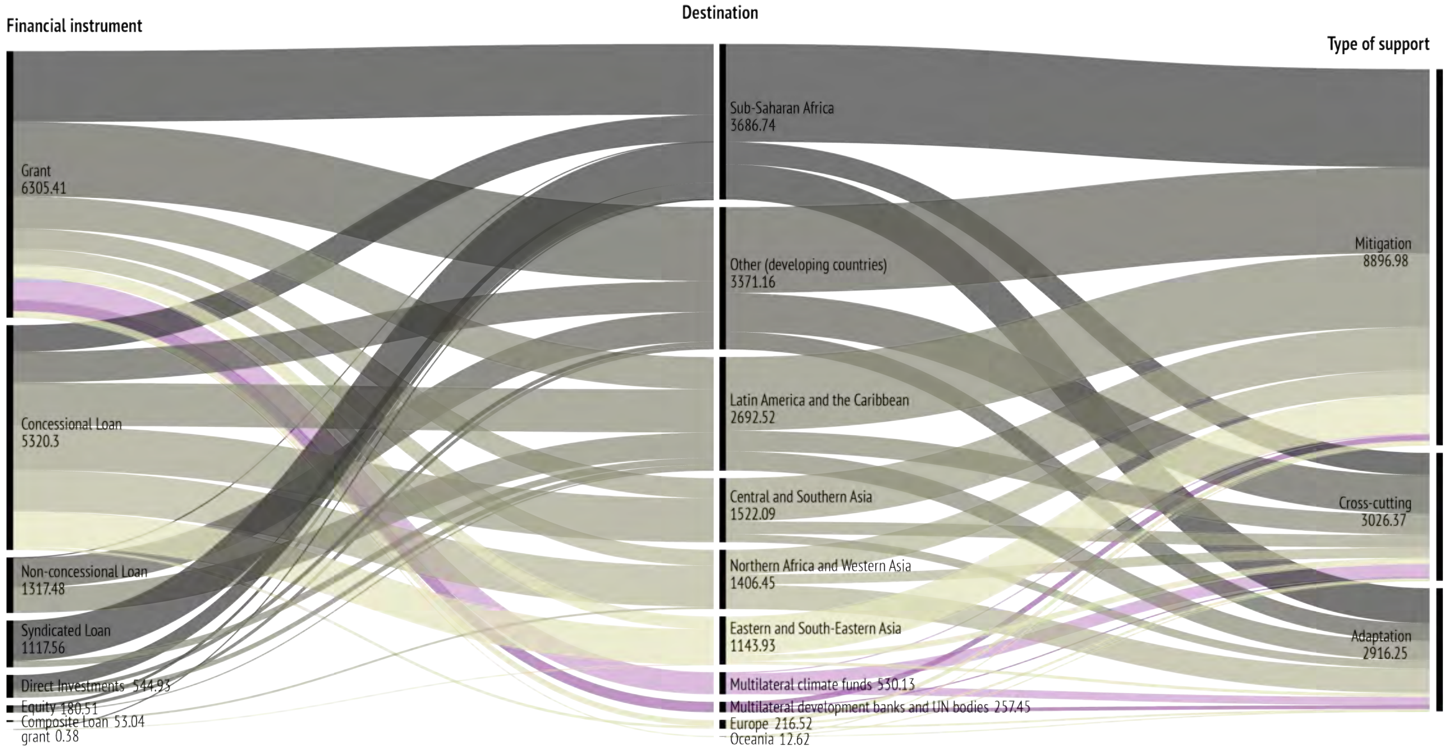
2020

PARIS AGREEMENT - NDC UPDATE

55% GHG reduction by 2030, with respect to 1990 levels

INTERNATIONAL CLIMATE FINANCE ASSISTANCE

The 4th Biennial Report shows that Germany accounted for 14.8 billion USD in climate-related development finance in 2017-2018. More than half was provided in different forms of loan and for mitigation projects. The majority was allocated to sub-Saharan Africa.



SUSTAINABLE RECOVERY POLICY

According to the Global Recovery Observatory, in 2020 the proportion of green spending out of total recovery spending was 47%.

1,357.74 billion $	Total Spending
92.23 billion $	Recovery Spending
43.61 billion $	Green Spending

DOMESTIC ADAPTATION POLICY

The federal government adopted the German Strategy for Adaptation to Climate Change (DAS) in 2008, followed by the Adaptation Action Plan (APA) in 2011. The second Adaptation Action Plan (APA II) clusters the activities in 6 groups: water, infrastructure, land, health, economy, and spatial planning and civil protection.

- ○ Domestic Adaptation Policy
  - ○ Inclusion of Adaptation in NDCs
  - ○ Integrated Adaptation & Mitigation Policy
  - ● Dedicated Adaptation Strategy
  - ● Dedicated Adaptation Plan
- ● Subordinate Adaptation Policies
  - ● Sectoral Adaptation Plans
  - ● Subnational Adaptation Plans

○ Policy not in place ● Active policy

ADAPTATION POLICY HIGHLIGHTS

TRANSNATIONAL INITIATIVES

GLOWA-Danube

The aim of GLOWA-Danube is to investigate with different scenarios the impact of change in climate, population and land use on the water resources of the Upper Danube and to develop and evaluate regional adaptation strategies

LIFE Roll-outClimAdapt

The main goal of the project is to establish innovative approaches to cope with the effects of climate change in North Rhine-Westphalia (Germany) and in West-Overijssel (Netherland) and to create suitable conditions for adaption processes

NATIONAL INITIATIVES

HeatResilientCity

HeatResilientCity (HRC) develops and implements innovative, socially just and user accepted adaptation measures to reduce the summer heat load in buildings and open spaces

KomPass

The portal provides information on observed and projected impacts in sectors agriculture, forest, water, biodiversity, health, transportation and tourism. It includes climate-related datasets and maps, links to projects per geographical units and a database of adaptation projects and measures

SUBNATIONAL INITIATIVES

Adaptation in winter tourism in Spessart

The adaptation strategy of Hesse aims to adapt the local tourism sector by establishing the Spessart region as an all-year touristic site, with mountain biking and hiking as main activities

Hamburg's Green Roof Strategy

The strategy aims at greening at least 70 per cent of both new buildings and suitable flat or gently pitched roofs that are being renovated

ENERGY TRANSITION

Germany is the one of the few countries in G20 that shows above average values for all Energy Transition indicators, even if the aggregated value does not put them in first place. Efficiency performance represents the best practice while Emissions and Electrification are well above the average.

Fossil Fuels show a good performance even if it suffers from the lengthening of the operating period of coal-fired plants after the decision to close the nuclear plants at the end of their cycle. Also, Renewables generation indicator shows a good current performance (more than 2 points above the average).

Energy Transition	58.7	63.8
Fossil Fuels	45.3	50.9
Renewables	19.7	22.1
Efficiency	84.9	93.5
Electrification	70.8	75.7
Emissions	72.9	76.8

G20 AVERAGE

COUNTRY

Only actively pursuing an energy transition based on decarbonization and electrification – from policy and regulation, to health and education – will enable countries to benefit the most from future opportunities and fight climate change whilst ensuring an equitable distribution of wealth.

The Energy Transition indicators were developed by Enel Foundation in cooperation with SACE, and provide a retrospective analysis based on historical data.

G20 CLIMATE RISK ATLAS

Impacts, policy, economics

cmcc

INDIA

How to read the Atlas: graphs, colours and scenarios.

The maps used in this Atlas are taken from **The World Bank Official Boundaries** - ***https://datacatalog.worldbank.org/search/dataset/0038272*** (accessed on May 28, 2021). For the section Energy, the maps are based on Panoply Data Viewer ***https://www.giss.nasa.gov/tools/panoply/credits.html***

Each sector of this Atlas contains data and information on various climate scenarios.

When reported in graphs, the **colour black** indicates data and information referring to the current state, the past or the baseline.

When the authors refer to **RCP (Representative Concentration Pathways)**, the 3 colours used across the factsheet refer to 3 scenarios, which are 3 different development options with different levels of greenhouse gas emissions, **respectively low emissions (green), medium emissions (orange), and high emissions (red)**. The same colour code is used when RCPs are associated with Shared Socioeconomic Pathways (SSP).

In some cases, the authors refer to global warming scenarios. In these cases, the 3 colours used refer to a temperature rise of **1.5°C (green), 2°C (dark green), and 4°C (red)**.

When the authors refer exclusively to **Shared Socioeconomic Pathways - SSPs** (Population affected by river floods in the section: "Water"), data related to **SSP3** - that encompasses, among other things, slow economic growth, material-intensive consumption, and persisting or worsening inequalities – **are reported in a lighter shade**; **SSP5** – which refers to social and economic development that is coupled with an energy-intensive lifestyle and the abundant exploitation of fossil fuel resources – is shown using a **middle shade of the colour**, whereas data related to **the present** conditions **are represented in a dark shade**.

Further details on scenarios, methodologies, and the full list of references are available at: **www.g20climaterisks.org**

Concept and graphic design by element6.eu

INDIA
CLIMATE

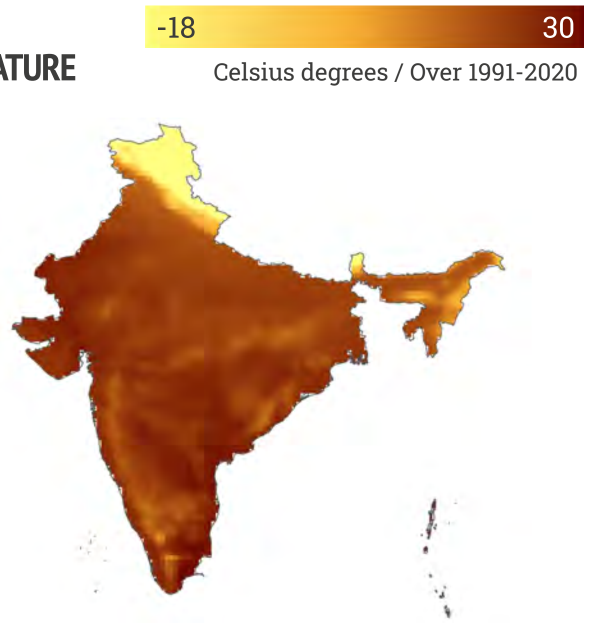
OVERVIEW

The climate in India is generally monsoonal whilst at the same time possessing a wide variety that ranges from tropical in the south to temperate and alpine in the Himalayan north. India's climate is strongly influenced by the Himalayas and the Thar Desert. The Himalayas act as a barrier to cold winds from central Asia, keeping most of the country warmer than other places found at similar latitudes around the world. The Thar Desert attracts the summer monsoon winds from the south-west regulating the rainy season.

TEMPERATURE

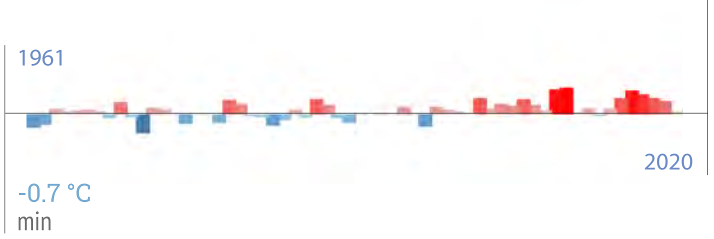
The temperature regime in India is controlled by the distance from water bodies, ocean currents and relief characteristics. In general, annual temperatures are fairly homogeneous and fall in the northern part of the country.

MEAN TEMPERATURE



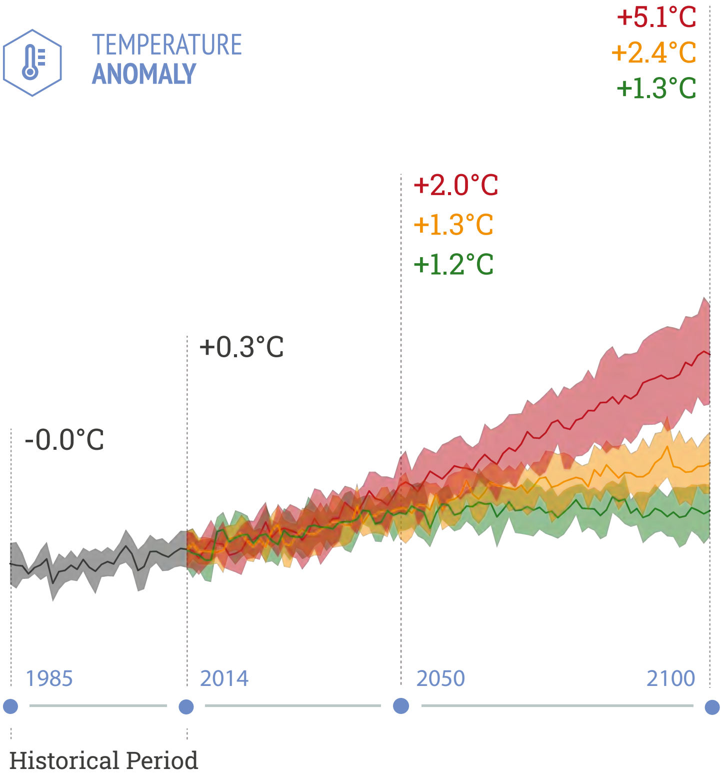
TEMPERATURE TREND

Temperature anomalies over the last 60 years with respect to the annual mean of 25°C in India during the 1961-1990 period



TEMPERATURE PROJECTIONS

Under a low emissions scenario projected temperature variations will remain contained under +1.5°C, both by 2050 and 2100.
Under a high emissions scenario, with no reduction in GHG emissions, much greater temperature anomalies are expected by both 2050 and 2100.



EXPECTED VARIATION FOR TEMPERATURE AT 2050

The indicators show variations in selected temperature characteristics for a thirty-year period centred on 2050 (2036-2065) with respect to the reference period 1985-2014.

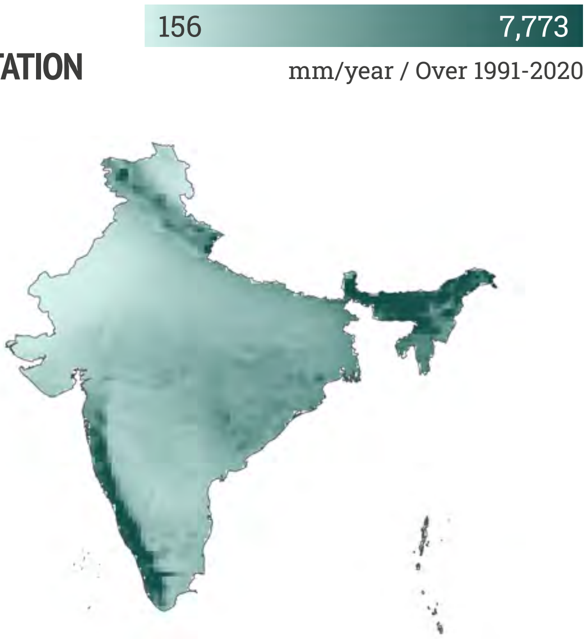
Annual Mean Temperature	Max Temperature of warmest month	Min Temperature of coldest month
+1.8°C	+1.7°C	+2.1°C
+1.3°C	+1.2°C	+1.6°C
+1.2°C	+1.2°C	+1.4°C

PRECIPITATION

The precipitation regime in India is very complex and is mainly governed by monsoon winds from the southwest. The rainy season is between June and September, during which almost 75% of annual precipitation occurs.

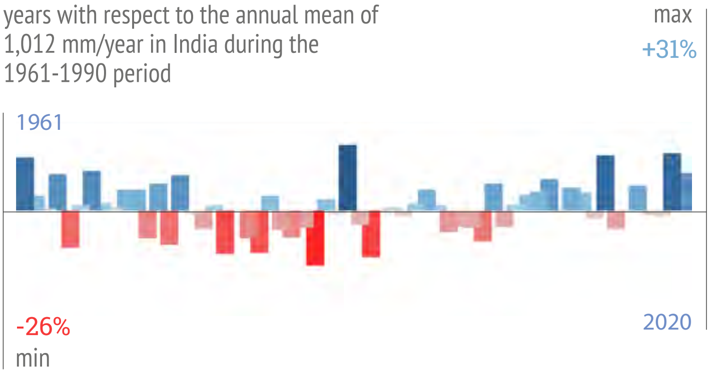
Average precipitation in India is around 1,250 millimetres per year, although a huge spatial variation can be detected. The west coast and north-east India receive more than 4,000 millimetres of precipitation per year. On the other hand, areas such as western Rajasthan and adjacent parts of Gujarat, Haryana, and Punjab see less than 600 millimetres per year. The rest of the country receives moderate precipitation. Due to the nature of monsoons annual precipitation is highly variable.

MEAN PRECIPITATION



PRECIPITATION TREND

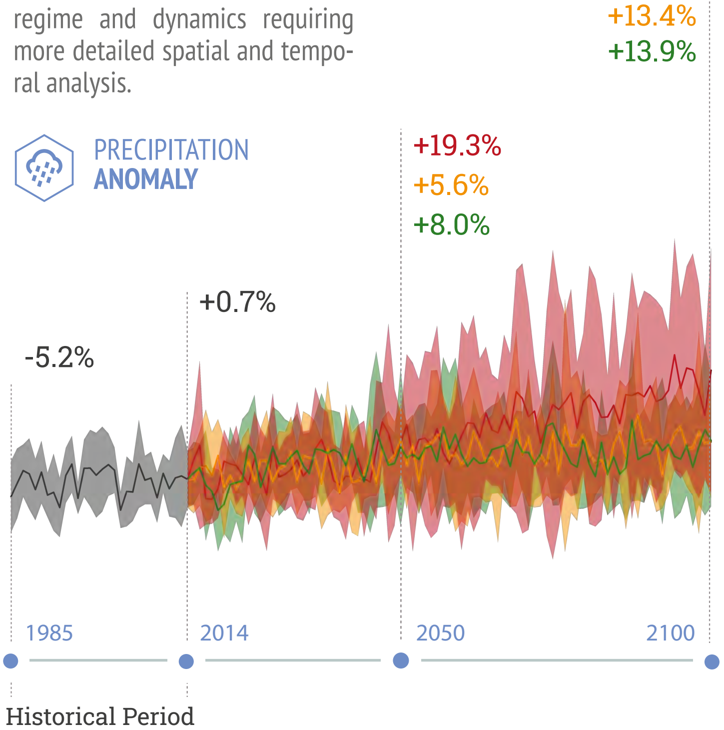
Precipiation anomalies over the last 60 years with respect to the annual mean of 1,012 mm/year in India during the 1961-1990 period



PRECIPITATION PROJECTIONS

Precipitation trends show a very complex signal, under all emissions scenarios, with a very large variability among climate models. This can be explained considering the complexity of the precipitation regime and dynamics requiring more detailed spatial and temporal analysis.

PRECIPITATION ANOMALY



EXPECTED VARIATION FOR PRECIPITATION AT 2050

The indicators show variations in selected precipitation characteristics for a thirty-year period centred on 2050 (2036-2065) with respect to the reference period 1985-2014.

+11.4%
+7.5%
+9.4%
Annual total precipitation

+10.7%
+7.1%
+9.3%
Precipitation of wettest month

+6.6%
+5.8%
+3.2%
Precipitation of warmest quarter

VARIATION OF SPECIFIC CLIMATE INDICATORS

Climate indicators variation showing impacts of climate change on sectors such as agriculture, health and water. Analysis considers 3 threshold average temperature increase: **+1.5°C**, **+2°C**, **+4°C**.

+21%
+13%
+11%
Agricultural drought proportion of time
% of time

+12%
+8%
+7%
Hydrological drought proportion of time
% of time

+2,515%
+525%
+160%
Heatwave duration
% of time

+17%
+6%
+3%
Runoff increase
% of area

+48%
+20%
+13%
Agricultural drought frequency
% of change

+7%
+6%
+11%
Hydrological drought frequency
% of change

+97%
+55%
+32%
Heatwave frequency
% of change

+43%
+33%
+17%
Runoff decrease
% of area

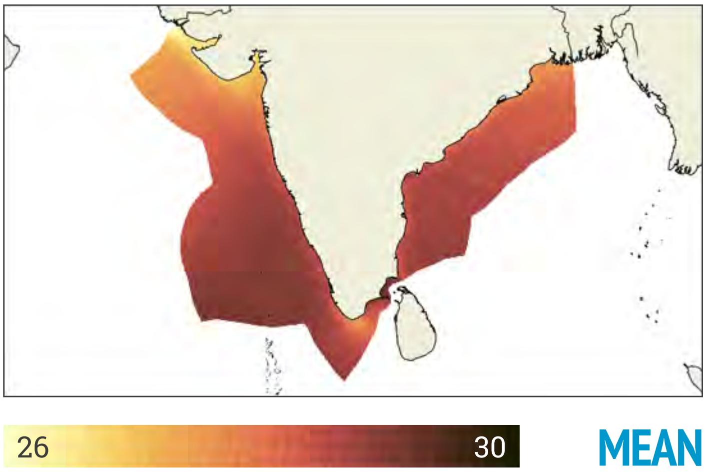
INDIA
OCEAN

OCEAN IN INDIA

India's marine exclusive economic zone (EEZ) has mostly warm coastal waters, which are characterized by a mosaic of ecosystems such as coral reefs, backwaters, mangroves, and seagrasses meadows. Indian coastal systems can be divided in two main areas: the Bay of Bengal and the Laccadives region on the western side.

CURRENT CLIMATE CONDITIONS

Mean sea surface temperature reflects the rather homogeneous climate of the region, with sligthly colder waters in the northern areas.

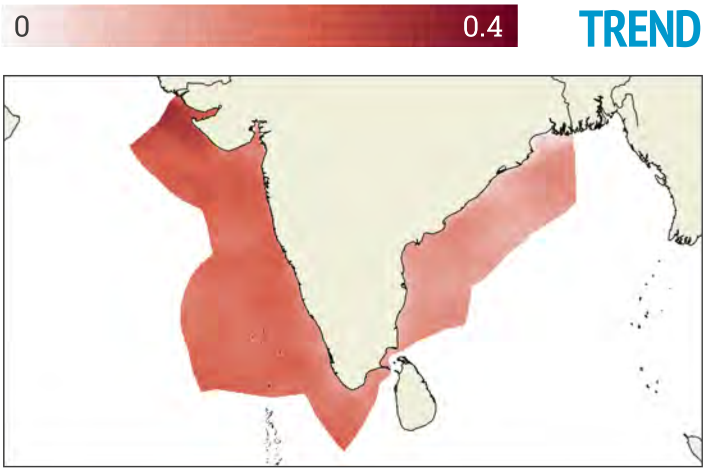


MEAN

SEA SURFACE TEMPERATURE

Celsius degrees / Over 1991-2020

TREND

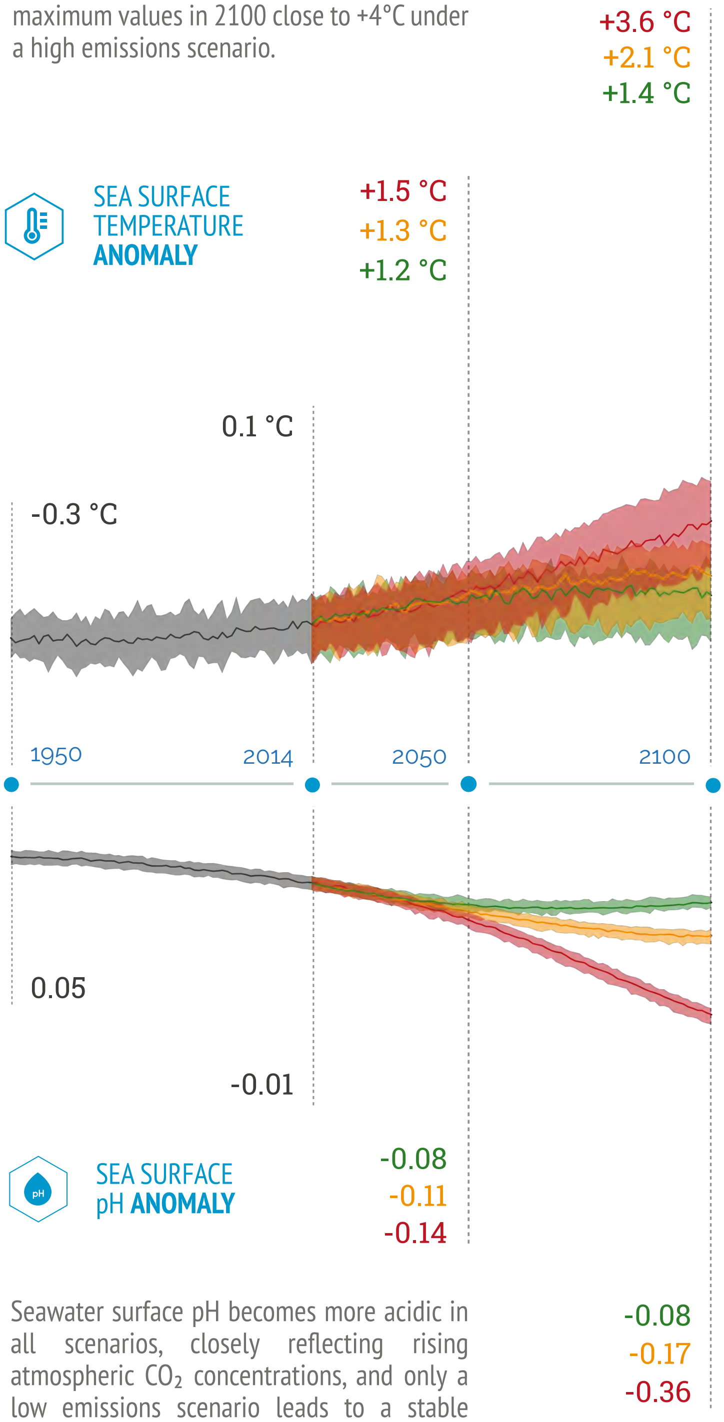


Surface temperature trends indicate a general warming of 0.2°C per decade in all marine areas.

FUTURE PROJECTIONS

Projected annual changes within the marine EEZ for the two most significant marine indicators of climate change: sea surface water temperatures and pH.

Seawater temperature changes are in line with the definitions of each scenario, with maximum values in 2100 close to +4°C under a high emissions scenario.



Seawater surface pH becomes more acidic in all scenarios, closely reflecting rising atmospheric CO_2 concentrations, and only a low emissions scenario leads to a stable condition by 2100.

ECOSYSTEM INDICATORS AT 2050

Regional changes in key marine ecosystem indicators under projected future scenarios by mid-century (2036-2065) with respect to present climate conditions (1985-2014).

Arabian Sea

Bay of Bengal

Temperature regulates the metabolism of marine organisms determining which habitats remain suitable. Excessive warming will likely push ecosystems beyond tolerance thresholds.

pH represents the acid/base status of marine waters, where a decreasing pH reflects the acidification of the ocean due to increased absorption of atmospheric CO_2.

Oxygen is fundamental to sustain marine life and its reduction can have a large impact on coastal ecosystem services including fisheries and aquaculture.

Chlorophyll is an indicator of the biomass available at the base of the marine food web supporting all ecosystem productivity.

	Arabian Sea				Bay of Bengal			
Temperature	28.01°C	+1.6 °C	+1.36 °C	+1.34 °C	28.23°C	+1.34 °C	+1.2 °C	+1.12 °C
pH	8.07	-0.14	-0.11	-0.08	8.07	-0.14	-0.1	-0.08
Oxygen	200.96 $mmol/m^3$	-2.44 %	-2.35 %	-1.52 %	204.91 $mmol/m^3$	-2.08 %	-1.45 %	-1.51 %
Chlorophyll	0.23 mg/m^3	-13.6 %	-19.3 %	-14.47 %	0.46 mg/m^3	-5.66 %	-14.81 %	-7.84 %

FISH CATCH POTENTIAL

Fish catch potential is an estimate of the maximum fish catch achievable given the marine resources available over a sustained period. It is linked to the concept of maximum sustainable yield, meaning the maximum amount of fish that can be extracted from a system without causing a collapse in fish populations.

It is a characteristic of the natural system, which is substantially different from realized catch, and a direct result of the fishery policy in place.

Fish catch percentage change	2050	-17.1% -8.8%

ANALYSIS DETAILS

All datasets were analysed using only data from within the marine EEZ and therefore excluding overseas territories, detached islands and any disputed or joint territories with other nations. In the assessment of current climate conditions, seawater surface tempereerature data was obtained using satellite observations distributed in the framework of ESA Climate Change Initiative.

Future projections of marine indicators are represented by the combined analysis of results from 15 different Earth System models participating in the Coupled Model Intercomparison Project Phase 6 (CMIP6). These models include new and better representations of physical and biogeochemical processes, compared to previous IPCC assessment reports.

Fish catch potential data was obtained using the FAO's technical report and refers to the best and worst case climate scenarios from the Fifth IPCC Assessment Report. These mean estimates are subject to substantial uncertainties as discussed in the original work.

INDIA
COASTS

OVERVIEW

India's 17,000 kilometres of shoreline and coastal zones is densely populated with approximately 14% of the population concentrated in coastal districts, amounting to approximately 200 million people. India's coastal areas are very diverse, with a wide range of geomorphology types and ecosystems, including rocky coasts, sandy beaches, mangroves, tidal flats, estuaries and coastal lagoons. The main coastal cities are Mumbai, on the west coast, Chennai, on the east coast, and Kolkata, on the Ganges Delta.

Shoreline Length 17,181 km

Sandy Coast Retreat at 2050 -116.3 m

CLIMATE CHANGE HAZARDS

Coastal hazards such as erosion, storm tide inundation and permanent flooding, can have strong adverse impacts on coastal regions, with loss of sandy shores, damage to settlements, infrastructure and ecosystems. Climate change may exacerbate these impacts due to rising sea levels and increasing impacts of waves and storms. Climate change impacts on the coastal zone of India are mainly driven by rising sea levels and possible changes in storm intensity and direction, which can exacerbate erosion issues and drive flooding of low lying coastal areas. In addition, changes in rainfall patterns may also exacerbate flooding risk for low lying coastal areas. These impacts are of particular concern in areas where people's livelihoods are based on coastal resources and tourism and in India's coastal mega-cities.

SEA LEVEL RISE

Relative sea level rise has been observed over the past century around the coast of India, with a yearly average increase of approximately 1.56 millimetres per year since the 1990s. The latest IPCC projections indicate that, by 2050, global sea levels may rise between 0.18 metres, under a low emissions scenario, and 0.23 metres, under a high emissions scenario.

Observed and projected sea level rise at 2050

1.56 mm/year

0.23 m

0.18 m

EXTREME SEA LEVEL

On average, one in 100 extreme sea level events are expected to rise from 2.05 metres at present day to 2.23 metres by 2050 under a medium emissions scenario.

Current and projected extreme sea level at 2050

2.05 m

2.31 m

2.23 m

OBSERVED STORMS

The wave climate influencing the Indian coast is very dynamic and driven by seasonally reversing monsoon winds. Annual average significant wave height ranges from 1.5 to 2.5 metres, with the highest waves reaching more than 3 metres. The wave climate is also influenced by the annual and inter-annual variability in monsoon wind and rainfall. In the Indian Ocean north of the equator tropical cyclones can form throughout the year on either side of India.

FUTURE STORMS

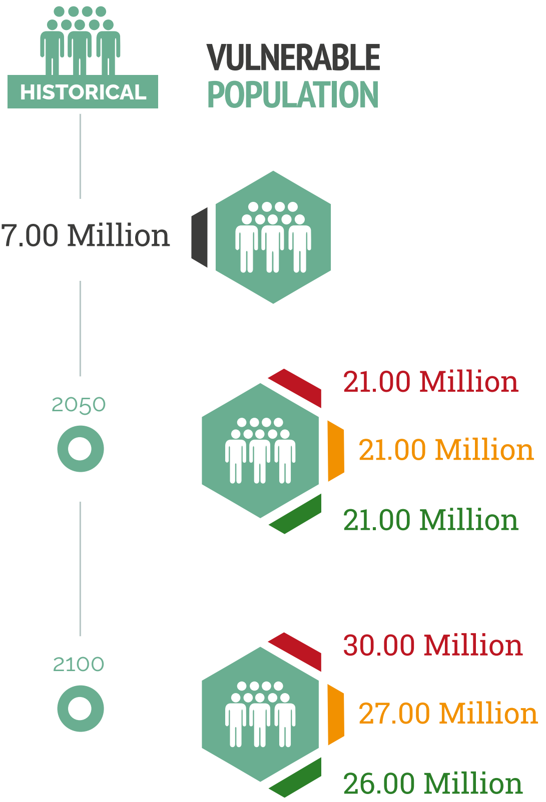
Waves and storms around the Indian coast are expected to change in the future. Recent projections show an increase in wave heights and periods along much of the Indian coast, with maximum wave heights increasing by more than 30% in some locations. At most locations along the east coast, wave periods are expected to increase by almost 20%, whereas along the west coast an increase of around 10% is expected. Similarly, water elevation due to cyclone activity is expected to increase.

VULNERABILITY AND RISK

Approximately 64 million people live in low elevated coastal areas that are less than 10 metres above sea level. These areas are exposed to both coastal erosion and storm surges, with the highest exposure found on the east coast of India. Most of the people in low lying coastal areas are concentrated in the Ganges Delta, one third of which is within the Indian territory, including the city of Kolkata which is home to 4.5 million people.

With a growing coastal economy and an increasing population in coastal areas, India has been managing recent coastal risks with large scale investments aimed at protecting infrastructure, with numerous programs dealing with coastal risk management.

Under a medium emissions scenario, the population exposed to the annual coastal flood level is expected to increase from 17 million to 21 million by 2050.



INFLUENCE OF SEA LEVEL RISE ON EXTREME SEA LEVEL

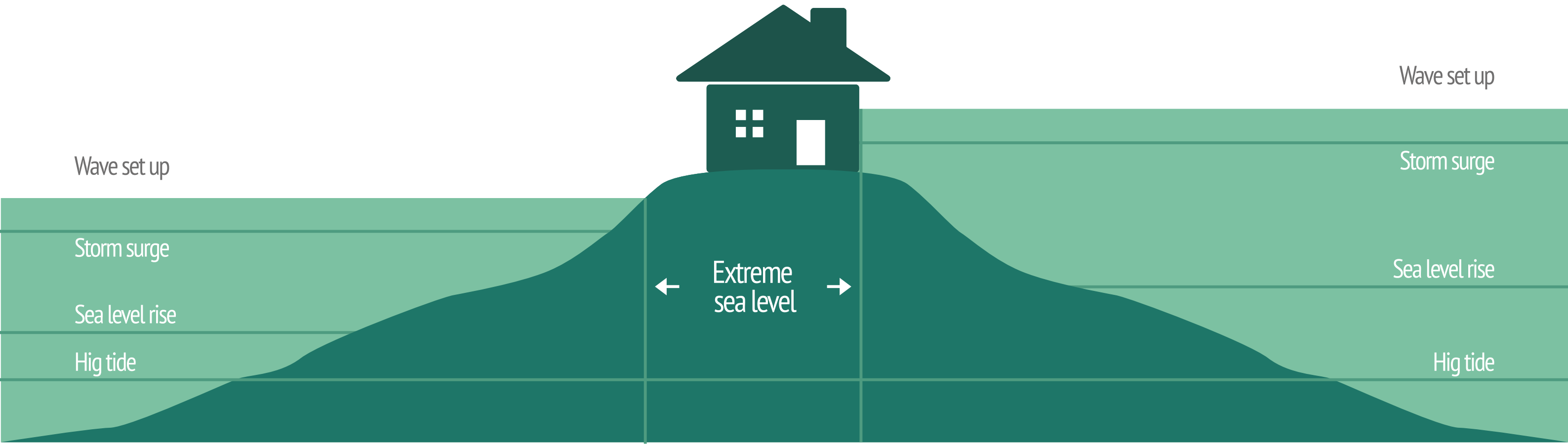
Present and future sea level rise are a consequence of carbon induced global warming causing melting ice and ocean expansion due to heat accumulation.

The extreme sea levels reported here are based on the 100-year storm surge + wave set up + sea level rise + high tide indicators. The first two parameters (storm surge + wave set up) are based on the 100-year value for the event; sea level rise is its projected value at 2050; and high tide is the absolute value of the highest tide calculated for a given locality, which won't be influenced by climate change.

+ **Wave set up** refers to the accumulation of water near the shore due to the presence of breaking waves.

+ **Storm surge** is an occasional increase in sea level driven by shoreward wind-driven water circulation and atmospheric pressure.

+ **High tide** is usually the highest tide reached in a given location based on tide records.



Present sea levels have risen globally by approximately 20 centimetres over the past century.

Future sea level rise is a projection based on different global warming scenarios, at approximately 100 centimetres by the end of 2100, with consequent inundation during extreme sea level events.

INDIA
WATER

OVERVIEW

In India, demand for water resources has been escalating due to a fast growing population over the past century. Total population has already surpassed 1.3 billion and is expected to stabilize only by the year 2050.

Increasing domestic, agricultural, and industrial water requirements are serious challenges for India. Monsoons, the most important source of water for the country, undergo large inter-annual variations associated with global anomalies.

Hence, large disparity in rainfall are reflected in water resources. As a result, vast areas of interior India are arid and semi-arid, with consequent water availability issues.

Renewable internal freshwater resources
1,446
billion m³

Renewable internal freshwater resources per capita
1,080
m³

The Ganges-Brahmaputra-Meghna system is the major contributor to the total water resources potential of the country. Its share amounts to about 60% of total water resource potential of all rivers. About 40% of utilisable surface water resources are presently found in this large system. In the majority of river basins, present utilisation is high and in the range of 50-95% of utilisable surface resources. In rivers such as the Narmada and Mahanadi, however, utilisation percentage is quite low. The corresponding values for these basins are 23% and 34%, respectively.

CLIMATE CHANGE HAZARDS

Climate change can affect water resources through increasing temperatures, higher rates of evapotranspiration and altered rainfall patterns. This leads to changes in the water cycle, including decrease of snow and ice coverage, alterations of surface runoff and groundwater storage, as well as drought and flood occurrence. Per capita availability of freshwater in all major river basins is decreasing rapidly as a result of changes in climate and a growing population. Available resources, in addition, are being depleted and degraded at a fast pace and a large part of river basins will face water scarcity by the year 2050. Even without taking into account the possible impacts of climate change, eight river basins will be critically water scarce by 2050.

KEY POINT RUNOFF

Major and medium river basins contribute over 90% of the total runoff in the country. Locally, surface runoff is expected to decrease drastically in arid and semi-arid India in the future.

At a country scale, an average change in surface runoff by approximately -9% and +2% is expected respectively under low and medium emissions scenarios for the 2045-2055 period compared to 2015-2025.

If temperatures rise by 1.5°C, 2°C or 4°C, 17%, 33.4% or 43% of the country will likely experience an increase in runoff, while 3%, 6.4% or 17% of the surface of the country will likely experience a decrease in runoff, respectively.

2050

Changes in annual runoff
% of change

+2.3%

-8.5%

2050

Runoff increase
% of area

+43.0%

+17.0%

KEY POINT DROUGHTS

Drought causes significant water and food insecurity, leading to economic losses and financial risks in developing countries like India. Droughts pose enormous challenges for drinking and irrigation water supply and also affect the economy of India, where more than 68% of people are dependent upon agriculture. Moreover, about 18% of India's total area is drought-prone, and about 50 million people are annually affected by drought. India faces droughts due to poor summer monsoons caused by natural climate variability or climate change.

In the Deccan Plateau region of India significant drought conditions occur once in 3 years. The Deccan region sees the highest frequency of severe droughts in all of India.

2050
Severe drought likelihood increase
% of change
+9.7%
+5.9%

2050
Hydrological drought frequency
% of change
+7.0%
+6.0%

2050
Groundwater Recharge
% of change
+0.5%
+7.9%

KEY POINT GROUNDWATER

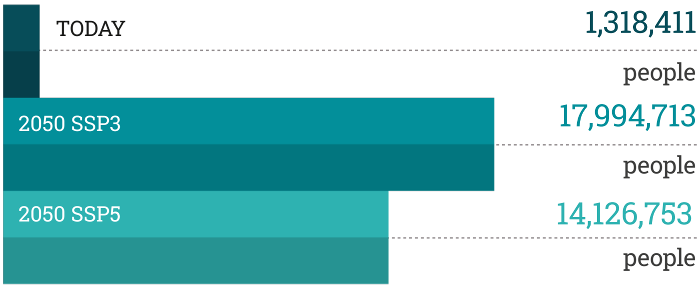
A large part of India is under intensive agriculture and mostly irrigated with this resource. Rapid groundwater depletion remains one of India's most profound sustainability challenges. Extraction of non-renewable groundwater for irrigation in India was used on about 68 cubic kilometres of land per year for the year 2000, which is the highest in the world.

Sustaining groundwater is essential for meeting the needs of food and water in the current and projected future climate, and these necessities appear even more urgent in the northwest regions such as Punjab. There are uncertainties associated with groundwater recharge under climate change, which are linked to precipitation projections under the future climate. Groundwater storage is projected to increase in some Indian areas under the future climate in the absence of groundwater extraction for irrigation primarily due to projected increase in precipitation. Nevertheless, longer droughts and projected increase in irrigation water demands can pose further challenges to already depleted groundwater resources in India.

KEY POINT FLOODS

The increased risk of flash floods as a result of changing rainfall patterns over India has been reported in several recent studies. Extreme precipitation events in India in the past caused flooding, affected the economy, and resulted in the loss of lives. For instance, an extreme precipitation (940 millimetres in 18 hours) event in Mumbai (July 2005) was a disaster that led to flooding that affected 20 million people and caused around 1,200 deaths. Similarly, Mumbai experienced flooding in September 2017 due to extreme precipitation (330 millimetres in 24 hours), which largely affected road transportation. Furthermore, Chennai received 483 millimetres of precipitation in 48 hours in November 2015, which had a devastating impact causing widespread damage. By 2050 slight changes in the number of days with intense precipitation (more than 50 millimetres of rain) is expected, with a small increase of 0.20 days under a low emissions scenario and 0.32 days under a medium emissions scenario.

POPULATION AFFECTED BY RIVER FLOODS

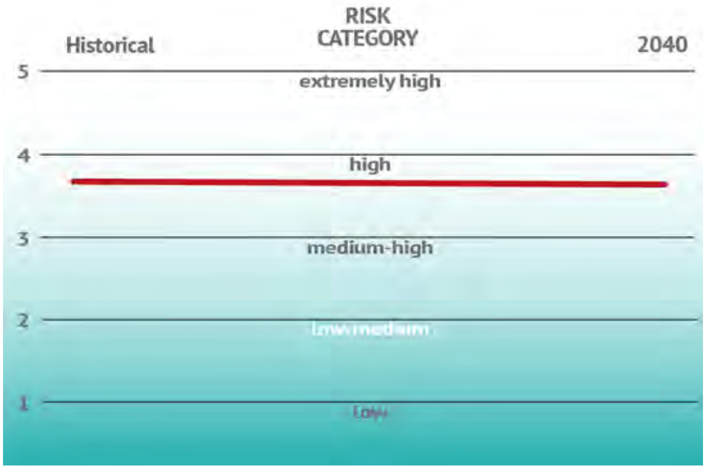


RISK INDICATORS

The water stress index summarises current and future water related vulnerabilities and risks at the global level. Scores are based on the ratio of total water withdrawals, including agriculture, industrial and human consumption, to available renewable surface and groundwater supplies.

WATER STRESS

India's water stress level is considered high for the recent past (1960-2014 average), and it is expected to remain that way in the near future (2030-2050) based on climate change projections.



INDIA AGRICULTURE

OVERVIEW

With a population of 1.37 billion people, India is one of the most populous countries in the world. Given its large spatial distribution and agro-ecosystem diversity, several farming systems exist with a significant cultivation of rice, wheat, sugarcane, vegetables and fruit trees.

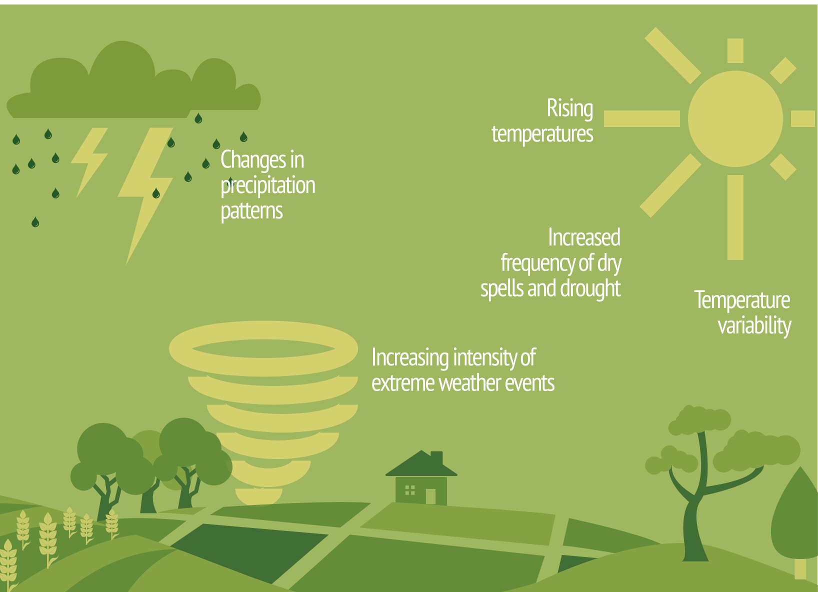
Whereas agricultural contribution to national GDP has declined over the last decades, a large share of the population still depends on agriculture for its subsistence. Irrigation schemes are still expanding to enhance food security. In fact, over 14% of India's population is thought to be undernourished. Agriculture adsorbs over 90% of total water withdrawal in a country with high stress on water resources, raising severe sustainability issues if it is to sustain further irrigation development and cope with climate risks.

379.9 Mt	Sugarcane
174.7 Mt	Rice
99.9 Mt	Wheat
51.3 Mt	Potato
28.7 Mt	Maize
24.9 Mt	Mango

	Added Value of Agriculture, Forestry and Fishing	Share of Agriculture Value added in Total GDP	Agricultural land	Area Equipped for Irrigation
2000	228,143 USD Million	27.9 %	170,130 Thousand HA	60,432 Thousand HA
2018	398,681 USD Million	15 %	169,416 Thousand HA	70,400 Thousand HA

EXPEXTED IMPACTS ON AGRICULTURE PRODUCTIVITY

Rising temperatures, reduction in average annual precipitation, and intensification of extreme events such as heat waves and drought, affect production variability with a tendency towards yield reduction for many cultivated species, accompanied by a probable decrease in food quality. Crops respond to increases in temperatures with changes in duration of the growing season, early appearance of phenological phases and potential shifts of cultivation areas toward higher latitudes and altitudes for better growing conditions. However, impacts vary significantly depending on the geographical area and specific crops in question.



CROP PRODUCTIVITY

Crop productivity refers to the harvested yield of a crop per unit of land area. It is strongly influenced by climate and other environmental and management factors.

Climate change is expected to have an impact on the productivity of several major crops, although this may in part be offset by the fertilizing effect of higher CO_2.

Impacts are estimated using a range of model projections based on low to high emission scenarios and reported as percentage changes between the 30-year average around the historical period and the 30-year average around 2050.

80.1 -9.4 (-9.2)% -10.9 (10.8)%
Sugarcane
tons / ha

4 -0.7 (-8.2)% 0.3 (-11)%
Rice
tons / ha

3.4 -5.6 (-11.4)% -6.1 (-18.3)%
Wheat
tons / ha

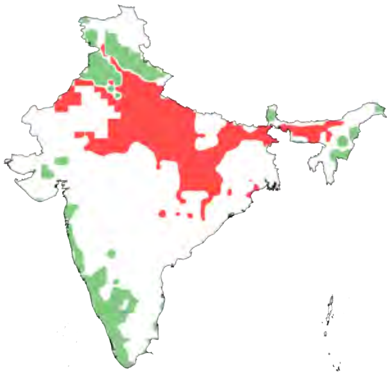
3 -4.9 (-6.4)% -5.8 (-7.6)%
Maize
tons / ha

2050

Productivity change with (without) the CO_2 fertilization effect. Estimates assume sufficient water and nutrient supplies, and do not include impacts of pests, disease, or extreme events.

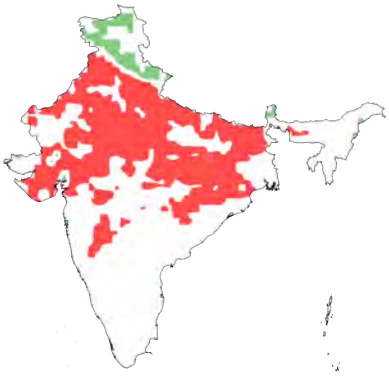
CHANGE IN RICE

🟥 − = 🟩 +



CHANGE IN WHEAT

🟥 − = 🟩 +



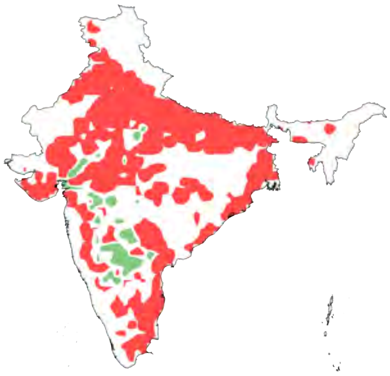
Increasing temperatures will have a strong negative effect on rice yield, especially in the northern and central areas where 15% to 40% of current rainfed rice locations may be at risk. Positive effects on rice yield can be expected in the southern, and to a certain extent eastern, regions. Productivity of wheat is projected to decrease up to 20% in some areas. The strongest decline is expected over central and south-central areas, whereas an increase is foreseen for cooler environments. Sugarcane is a climate sensitive crop and will show a marked decline in crop yields due to higher temperatures overcoming optimum level for photosynthesis. Mango production may be harmed in tropical regions with already prevailing high temperatures. On the other hand, rising minimum temperatures are extending farming into new areas which were previously too cold for mango production.

ADAPTATION IN AGRICULTURE AND WATER RESOURCES

Climate change may have some positive effects on some of the most widely used crops. However, higher temperatures will generally require an increase in irrigation demand due to higher plant evapotranspiration. Utilization of freshwater resources is already significantly high in agriculture, and projected to increase in the future. Climate change will reduce water resources and enhance streamflow seasonal variability. Large parts of India have been dependent on groundwater resources for intensive cereal production. Groundwater may be further depleted and unable to act as a resilient resource under future and more extreme droughts.

CHANGE IN WATER DEMAND

🟩 − = 🟥 +



Agriculture
Water Demand
% of change

+29.1%
+29.1%

2050

To meet agricultural demand for a growing population and cope with climate risks, it will be essential to further promote usage of wastewater and sustainable agriculture through water-efficient adaptation practices.

INDIA FORESTS

FORESTS IN INDIA

India’s vast and varied topography hosts a diverse range of forests: from moist and dry tropical forests to temperate and subtropical montane ones, as well as Himalayan and scrub forests.

Over 20% of India’s forests are primary, making them some of the richest in terms of biodiversity. Indian forests provide water, health, food security and jobs for a country with a growing population of more than 1.3 billion people.

FORESTED AREA AND CARBON STORAGE

Forests cover 25% of India with a steady increase in recent decades. According to recent calculations by the Ministry of Environment Forest and Climate Change, the total carbon stock of Indian forests is over 7 gigatonnes of carbon (of which over 20% in Himalayan forests). Indian forests are a crucial carbon sink.

1990

64 Mln ha
Million hectares
Forested area

95 Tons/ha
Tons of Carbon per hectare
Carbon stock

2020

72 Mln ha
Million hectares
Forested area

100 Tons/ha
Tons of Carbon per hectare
Carbon stock

2050

Productivity anomaly
Tons of Carbon per hectare per year

+0.42

+0.23

FOREST PRODUCTIVITY

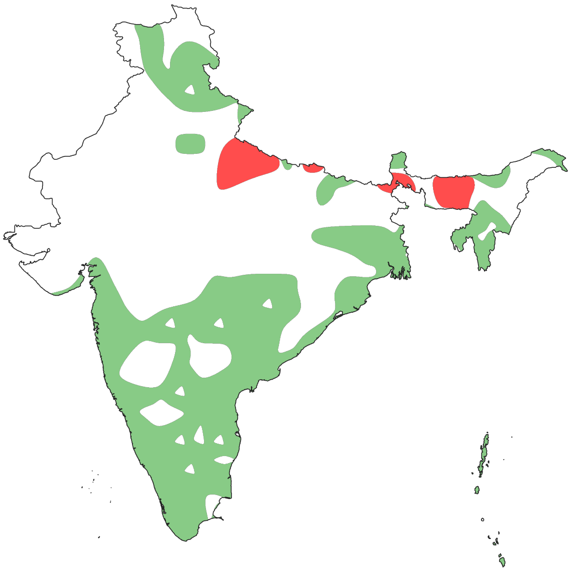
Forest productivity or Net Primary Production is the net carbon captured by plants. It is the difference between the carbon gained by Gross Primary Production - net photosynthesis measured at the ecosystem scale - and carbon released by plants' respiration. It is expressed per unit land area.

A slight increase is possible especially in southern areas.

+ Fertilizing effect of increasing atmospheric CO_2 and rising temperatures promotes productivity

Decrease expected in some sub-Himalayan areas.

+ Increasing risk of drought stress due to modifications in the water regime reduces productivity



KEY SPECIES UNDER CLIMATE CHANGE

XERIFICATION
HIMALAYA
Most forests types, particularly Himalayan forests, are turning xeric

REDUCTION
SAL TREE
Decline of sal tree in central India

REDUCTION
TEAK
Decline of teak from very moist and moist forests

LOW VULNERABILITY
TROPICAL AND MONTANE FORESTS
Less vulnerability shown by tropical rain and montane wet temperate forests

FIRES IN INDIA

Fire is a structural ecological process that provides several types of ecosystem services and impacts on socio-ecological systems, including human health, carbon budgets, and climate change. Changes in global fire activity are influenced by multiple factors such as land-cover change, policies, and climatic conditions. Fire also releases large quantities of greenhouse gases into the atmosphere, contributing to a vicious cycle.

During the last two decades, the total forest area affected by fire was approximately 58.6 million hectares.

BURNING
58.6 MILLION HECTARES

EMITTING
12.5 TERAGRAMMES
OF CARBON PER YEAR

FOREST FIRE EMISSIONS
CONTRIBUTED TO
47.5% OF TOTAL FIRE RELATED
CARBON EMISSIONS

COSTING
164 MILLION USD PER YEAR
IN ANNUAL DAMAGES

WHERE DO FIRES OCCUR?

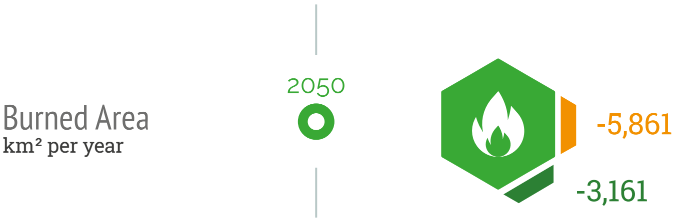
Forest fires affect dry deciduous broadleaved forests in particular due to abundant fuel load and low moisture content in soil.

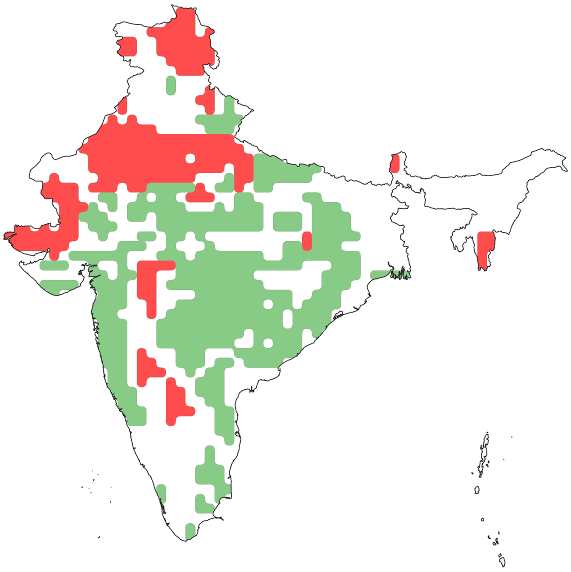
In the north-east, forest fires are mainly associated with traditional practices of shifting cultivation.

Forest fires are now one of the main causes of forest degradation in India, particularly in the regions of Madhya Pradesh, Odisha, and Chhattisgarh.

FUTURE BURNED AREA

By 2050, under both low and medium emission scenarios, a decrease in burned area is expected in tropical and subtropical broadleaf forests over central India. However, a slight increase in burned area is expected over north and north-western areas dominated by xeric shrublands, decidous forests and alpine steppes.





Decrease in burned areas for a low emissions scenario

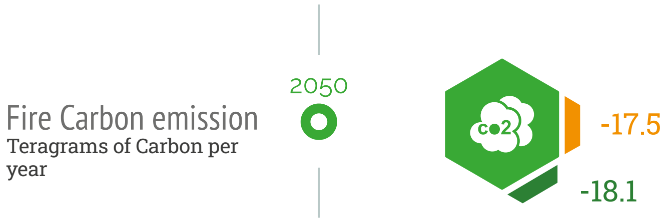
Increase in burned areas for a low emissions scenario
+ Increasing temperatures and decreasing rainfall over largely forested Indian states

CASE STUDY: AIR QUALITY

Due to a prolonged dry spell, 2021 was the worst year out of the last 15 in terms of forest fires in northern India. Uttarakhand's forest fires emitted nearly 0.2 teragrammes of carbon, a record that had gone unchallenged since 2003. On top of forest fires, post-monsoon agricultural fires further affected the already high concentrations of urban air pollution in the Indo-Gangetic Plain. During the period from 2012-2016, their contribution ranged from 7% to 78% of the maximum observed PM2.5 increments in Delhi, suggesting that changes in farming practices that reduce agricultural fires could produce significant health benefits. Another challenge related to forest fires is the threat to protected areas and biodiversity conservation. In eastern India's Similipal Biosphere Reserves, approximately 10-30% of the territory burns each year. In march 2014 a large fire burned in the Sri Venkateshwara National Park, which is home to a wide range of uncommon species.

FUTURE FIRE EMISSIONS

Fire emissions might follow similar spatial patterns to burned areas. A slightly potential increase is expected in eastern subtropical forests and rainforests, particularly under a medium emissions scenario.



INDIA
URBAN

OVERVIEW

India's urbanization rate is expected to grow from 35% in 2020 to more than 50% in 2050. Migration from rural areas due to climate impacts is expected to contribute substantially to this increase in urban population.

Smaller urban areas with less than 300,000 inhabitants have a predominant role in terms of share of the urban population. However, megacities with more than 10 million inhabitants are home to one fifth of the urban population. Urbanization rates are growing rapidly, and urban areas are growing faster than rural areas. India's urban population is expected to grow from 340 million in 2008 to 590 million by 2030, an increasing trend which is expected to continue until 2050 in all types of cities, but in particular in megacities.

Built up areas cover 2.27% of India (67,385.25 square kilometers).

Population in Urban Areas

2020 483,098,640

2050 876,613,025

Graphs refer to data provided by United Nations, Department of Economic and Social Affairs, Population Division (2018). World Urbanization

Urbanization Rate

2020 34.9%

2050 52.8%

OVERVIEW OF KEY CLIMATE IMPACTS IN URBAN AREAS

Indian cities are exposed to multiple climate impacts connected to heat stress and flooding, which amplify the challenges caused by other factors such as poverty and rapid growth combined with scarcely managed urbanization.

HEATWAVES AND HEAT STRESS

Between 1965 and 2010, heat waves increased by an average of 0.23 cases per decade and their duration extended by 0.71 days per decade. Regular heatwave events occur almost every year over most of the country, in particular in the northwest and the south-eastern parts. Average duration of heatwaves over northwest India is between 5 to 7 days per season.

Between 1960 and 2009, mean temperatures in India increased by 0.5% and heat related mortality also rose. In 2010, more than 1,300 people died in the city of Ahmedabad due to heatwaves, with subsequent heatwaves in 2013 and 2015 killing more than 1,500 and 2,500 people across the country. During the intense heatwave of 2016, temperatures reached 52.4°C in the city of Jaisalmer. Heatwaves will become more frequent and prolonged, extending the periods of overheating in urban areas.

2050

Cooling Degree Days

% of change

+54.1%

+20.9%

+13.2%

2050

Heatwave frequency

% of change

+97.4%

+55.4%

+32.1%

2050

Heatwave duration

% of time

+2,515%

+525%

+160%

HEAT, POVERTY AND AIR POLLUTION

Indian cities are among the world's most polluted and put city dwellers at risk throughout the country, exacerbating the impacts of heatwaves in urban areas. The entire urban population of India is constantly exposed to unsafe levels of air pollution which exceed the WHO's threshold values.

Mortality from heat waves is higher in low-income groups with no access to electricity and those that depend on outdoor work.

2017

Population exposed to air pollution

100.0%

COASTAL FLOODING

Three of India's five mega-cities (Kolkata, Mumbai and Chennai) are situated in low-lying coastal areas which are exposed to regular tropical typhoons. Intense rainfall during the monsoon season is also among the key challenges for most other Indian cities, alongside increasing drought events during the dry season.

Projected sea level rise

2050

0.23 m

0.18 m

2100

0.77 m

0.38 m

FLOODING

Intense rainfall during the monsoon season causes regular traffic break downs and hinders urban activities such as going to school, as well as flooding low-lying slums for days. In 2005 an exceptional storm surge with heavy rainfall in Mumbai left killed over 1,000 people, of which most lived in slum areas. The widespread flooding throughout the city, had a strong impact on economic activities and caused the national stock exchange and banking system, including ATMs, to shut down.

Despite reduced rainfall quantities, both rainfall events and storm surges will become more intense. Under a changing climate, a one in 100 years flood event in Kolkata could cost up to 6.8 billion USD due to damage and losses to business interruptions, health care facilities etc. A case similar to the one which occurred in Mumbai in 2005, which corresponds to a one in 100 year event, could increase total losses from 700 to 2,305 million USD.

2050

Runoff increase

% of area

+43%

+33%

+17%

SURFACE SEALING AND FLOODS

Heavy precipitation in cities is problematic due to the high level of sealed surfaces. Soil sealing increases run off and reduces the amount of water absorbed by soil. Where there are large amounts of impervious ground cover, short duration extreme rainfall events can lead to increased flooding, even resulting in flash floods.

UNCONTROLLED URBANIZATION

Risks arising from climate change will add to existing risk drivers in Indian cities, which are commonly due to poverty, ecosystem degradation, and poorly governed, rapid urbanization which resulted in the growth of unplanned settlements and slums, frequently situated in highly exposed areas such as flood plains or steep hills.

35% of urban households live in slums with scarce access to safe drinking water and sanitation, inadequate housing and lack of drainage

2010

% of urban population

Population living in slums

35.2%

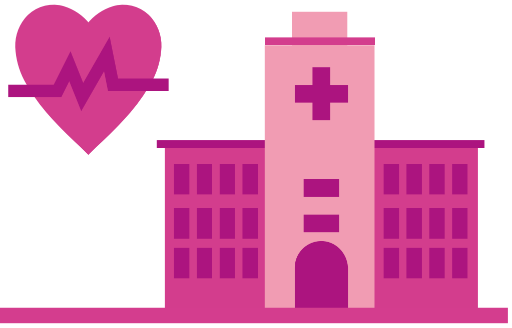
2018

% of total population

Urban population living in areas where elevation is below 5 meters

1.1%

INDIA
HEALTH



OVERVIEW

With a population of 1.4 billion and increased climate change risks due to coastal and inland river flooding, increased heat stress, water and food insecurity, and changes in the occurrence of climate-sensitive diseases, India's decades of advancement in health and social development may be threatened. Extremely hot days (temperatures higher than 35°C) are expected to increase from approximately five per year in 2010, to around 42 per year in 2100. As a result, the death rate due to climate change is projected to increase by 10% - equivalent to 60 deaths per 100,000 people by the end of the century. By 2100, around 1.5 million additional deaths due to climate change are expected in India.

HEAT RELATED MORTALITY

India reported over 31,000 heat-related deaths of people older than 65 in 2018.

Between 1960 and 2009, an increase of 0.5°C in summer mean temperatures increased the probability of mass heat-related mortality by 146%. Under a high emissions scenario, excess mortality will increase by 10% by 2100.

This is equivalent to 1.54 million excess deaths per year due to climate change by 2100 under a high emissions scenario. However, under a medium emissions scenario, this number is projected to decline by 80%. In 2018, there was an 84% increase in heat-related deaths in India compared to the 2000 to 2004 baseline.

IMPACTS ON LABOUR

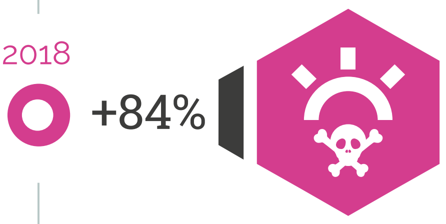
Labour is directly affected by changes in environmental conditions. Warming affects both the number of hours worked (labour supply) and on the productivity of workers during their working hours (labour productivity). Both labour supply and productivity are projected to decrease under future climate change in most parts of the world, and particularly in tropical regions.

Parts of sub-Saharan Africa, south Asia, and southeast Asia are at highest risk under future warming scenarios. Future climate change will reduce global total labour in the low-exposure sectors by 18 percentage points and by24.8 percentage points in the high-exposure sectors under a 3.0°C warming scenario

The effects of climate change on the livelihoods of vulnerable workers engaged in subsistence farming, the informal economy, and the tourism sector has been increasing. 1°C increase in annual temperatures leads to a 2% decline in industrial productivity in India. Total labour is expected to decline by 13.4% under a low emissions scenario, and by 24% under a medium emissions scenario.

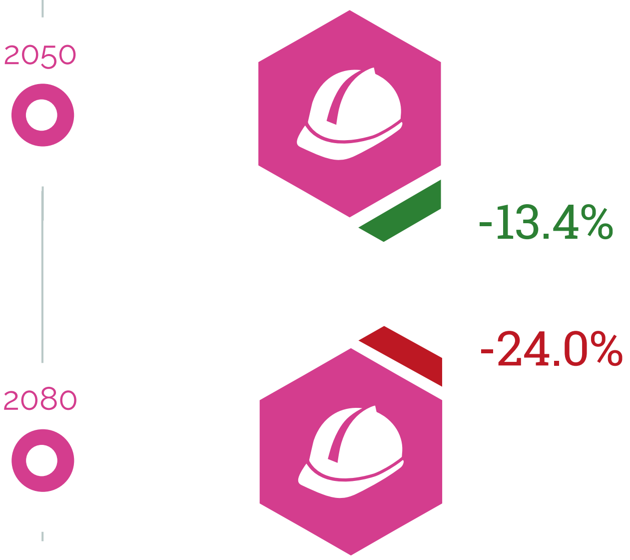
Heat-related mortality

% change with respect to 2000-2004



Impact on total labour

% change with respect to 1986-2005 baseline



CLIMATE CHANGE AND DENGUE

Dengue has spread throughout the tropical world over the past 60 years and now affects over half the world's population. Globally, vectorial capacity for both dengue vectors (A. aegypti and A. albopictus) has been rising steadily since the 1980s, with nine of the ten highest years occurring since 2000.

Climatic stressors are one important driver of the current distribution and incidence of dengue. Climate change is likely to expand the geographical distribution and suitability of several vector-borne human infectious diseases including dengue. The risk of dengue transmission is increased by warming climates, as the growth and development of mosquitoes are significantly influenced by temperature, precipitation, and humidity.

Dengue suitability

% of population at risk

CLIMATE CHANGE AND ZIKA

Zika virus has spread to at least 49 countries and territories since 2013. Climate change impacts on transmission suitability risk have increased over the years and future warming over 1.3 billion additional people could face suitable transmission temperatures for Zika by 2050.

Zika suitability

% of population at risk

DENGUE AND ZIKA: POPULATION AT RISK

Epidemiological risks from dengue and Zika will increase due to future climate change in India.

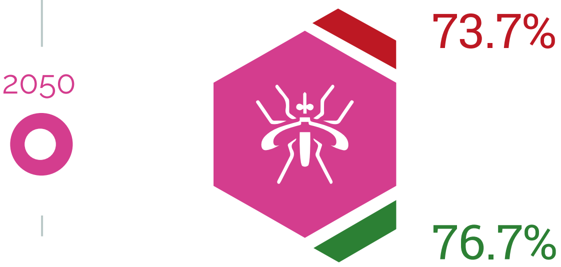
Under a medium emissions scenario, 98.1% of the population will be at risk of transmission-suitable mean temperatures for dengue by 2050, whereas 97% will be at risk under a high emissions scenario. In the case of Zika, 97.2% of the population will be at risk by 2050 under medium emissions.

CLIMATE CHANGE AND MALARIA

Malaria presents a significant public health challenge in India, with more than one million reported annual cases. 76.7% of the Indian population will be at risk of malaria under a low emissions scenario in 2050, whereas 73.7% will be at risk under a high emissions scenario.

Malaria suitability

% of population at risk



POLLUTION AND PREMATURE MORTALITY

1.67 million deaths were attributable to air pollution in 2019, accounting for 17.8% of total deaths in the country. By 2060, 2,039 deaths will be caused by outdoor air pollution per year per million people, compared to 508 in 2010.

INDIA
ENERGY

ENERGY SYSTEM IN A NUTSHELL

India's energy demand has grown fast, tripling over the last 30 years, and increasing by 60% in per capita terms. Energy consumption is the world's third highest (908 million tonnes of oil equivalent). India claims over 10% of the global increase in energy demand since 2000. Per capita energy use and emissions are still less than half the global average.

Within India's energy mix, coal and oil shares grew, while biomass dropped. India is highly dependent on coal, which covers half of energy demand.

0.11
ktoe/US$
Energy intensity

17.8%
AC Share in
electricity consumption

37.8%
Import
dependence ratio

CLIMATE CHANGE TODAY

WATER

In India, 40% of thermal power plants are in areas of high water stress and hence have a capacity factor 21% lower relative to plants with better water availability. In 2013-2016, 14 of the 20 largest utilities faced at least one shutdown due to water shortages. In 2016 alone, 14 terawatt-hours were lost due to insuffcient water availiability.

EXTREME EVENTS

IN 2019, UNSEASONAL PRECIPITATION AND STORMS DAMAGED SEVERAL SOLAR PLANTS. RISING HEAT STRESS AFFECTED HIMALAYAN GLACIERS AND LED TO INCREASED RISKS OF DROUGHTS AND FLOODS. IN 2021, A GLACIAL LAKE OUTBURST CAUSED FLASH FLOODS IN THE HIMALAYAN REGION DESTROYING TWO HYDROELECTRIC DAMS.

ENERGY SUPPLY

The current (2019) energy mix of total primary energy supply in India is dominated by coal (45%), oil (25.6%) and biofuels (20%). Natural gas accounted for 5.7% of total primary energy supply and hydro, solar and wind together accounted for 2.5%. India is dependent on imports for both coal and oil. Despite having rich coal reserves, domestic production cannot keep pace with demand. A lack of domestic oil reserves leaves India highly reliant on crude oil imports.

ENERGY DEMAND

Energy is used by the industrial sector (34% of final demand, mostly in the iron and steel industry), and by the residential (29%) and transport sectors (17%, mostly for road transport). The tertiary sector claims about 4% of final demand. Air conditioning accounts for 17.8% of residential electricity demand (2017). Energy demand largely exceeds domestic supply; hence imports are needed and shortages occasionally occur.

FUTURE ENERGY DEMAND

In India, higher cooling needs are projected to require additional installed power generation capacities of 36 gigawatts by mid century and 136 gigawatts by the end of the century under a high emissions scenario. Energy demand is predicted to increase, as the small drop in heating demand is going to be more than compensated by the vast increase in cooling needs, resulting in a net increase of energy demand of about 1,714 PJ (475 billion Kwh) by 2050 under a medium emissions scenario.

Net change in energy demand due to changes in HDD/CDD
Billion KWh

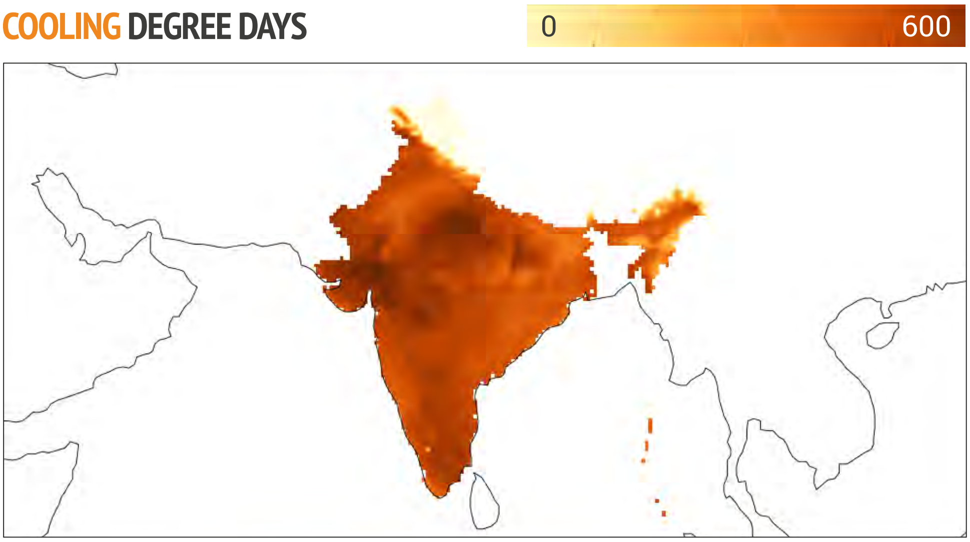
2050

+ 476.07

COOLING NEEDS

It is expected that India will face an increasing number of extreme heat spells. Very strong increase in cooling needs are expected all over the country, particularly in the southern and in the central states, where the capital New Delhi and the largest cities are located. Moderate increases are expected only near the northern border. This may result in increasing pressure on already constrained energy infrastructure assets.

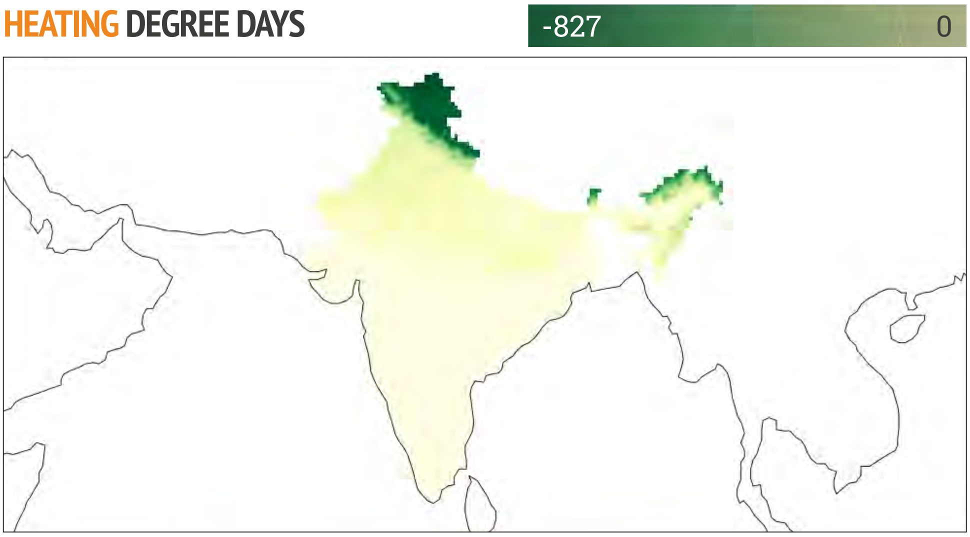
COOLING DEGREE DAYS



HEATING NEEDS

Heating degree days are of almost no relevance in the peninsular part of India. Heating needs are expected to decrease strongly in the states and territories closer to the northern mountain ridges (Ladakh, Jammu and Kashmir, Himachal Pradesh, Uttarakhand and Arunachal Pradesh), which are however not as densely populated as the rest of India.

HEATING DEGREE DAYS



FUTURE ENERGY SUPPLY

The future Indian energy mix is likely to be determined by energy policies and hence is outside the scope of this report. The government set ambitious coal and renewable energy targets, and most energy models expect coal to dominate. India aims to quadruple renewable energy capacity by 2030 and to more than double the share of natural gas. India's NDC include a 40% target for clean-energy installed power-generation capacity and up to a 35% reduction in emissions intensity of GDP by 2030.

Change in Hydropower generation
% of change

2050

-3.60%

-2.62%

EXPECTED IMPACTS OF CLIMATE CHANGE

As water availability is predicted to decrease, most of India's power plants become vulnerable. A large share of fossil fuel infrastructure is located in areas highly vulnerable to climate hazards, such as ports, which will be increasingly threatened by more frequent and severe cyclones and storms.

New projects like Udupi Power Plant (Udupi), Tata Power, Adani Power (Mundra) will be vulnerable. Himalayan glaciers are predicted to shrink fast. This will pose significant threats to hydropower generation.

INDIA ECONOMY

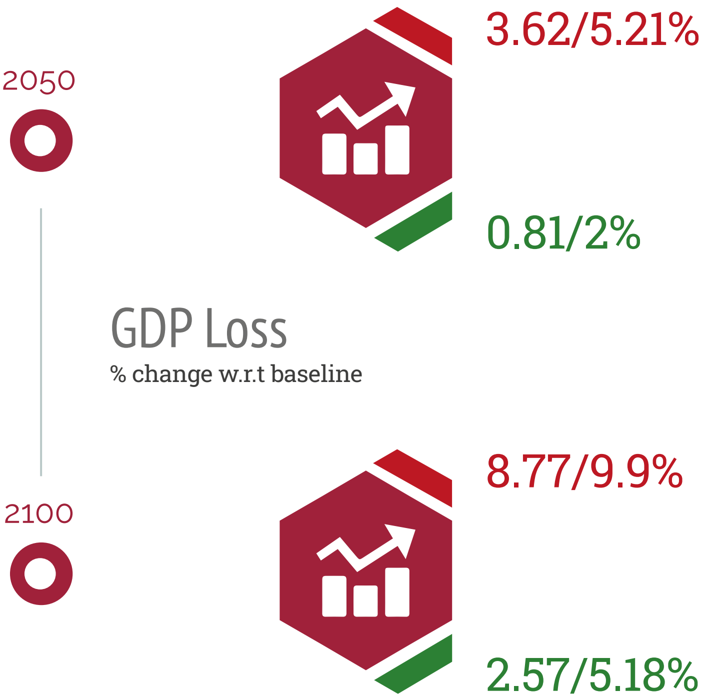
OVERVIEW

India ranks 7th in terms of GDP in the G20 group, with one of the largest growth rates. Due to COVID, for the entire 2020/21 financial year, the overall rate of contraction in India was, in real terms 7.3% .

IMPACTS ON GDP

Without any mitigation, climate change could severely undermine the development gains made in India in recent decades. In a moderate climate change scenario, India is projected to potentially lose between 0.8 and 2% of its GDP by mid century.

By the end of the century costs could double, reaching up to almost 10% of GDP (or 237 billion EUR) under a high emissions scenario.



GDP Loss

% change w.r.t baseline

2050

3.62/5.21%

0.81/2%

2100

8.77/9.9%

2.57/5.18%

SECTORAL ECONOMIC IMPACTS

IMPACTS ON INDUSTRY AND INFRASTRUCTURE

Natural disasters linked to weather extremes pose significant risks to the population and infrastructure in India. Approximately 12% of land is at risk of river flooding and erosion.

The majority of the coastline, densely populated in particular along the eastern part of the country with cities like Calicut, is prone to cyclones and tsunamis, whereas mountainous regions are at risk from landslides and avalanches.

IMPACTS ON AGRICULTURE

Globally, India is the largest producer of milk, pulses and jute, and is the second largest producer of rice, wheat, sugarcane, groundnut, vegetables, fruit and cotton.

At a national level, the agricultural sector is significant, employing more than 60% of the population, and contributing to 16% of GDP in 2019.

The agricultural sector in India is particularly vulnerable to the effects of climate change such as increasing temperatures and variability in rainfall. This will have significant repercussions for the Indian economy and the country's food security that relies mostly on domestic production to meet the needs of a growing population.

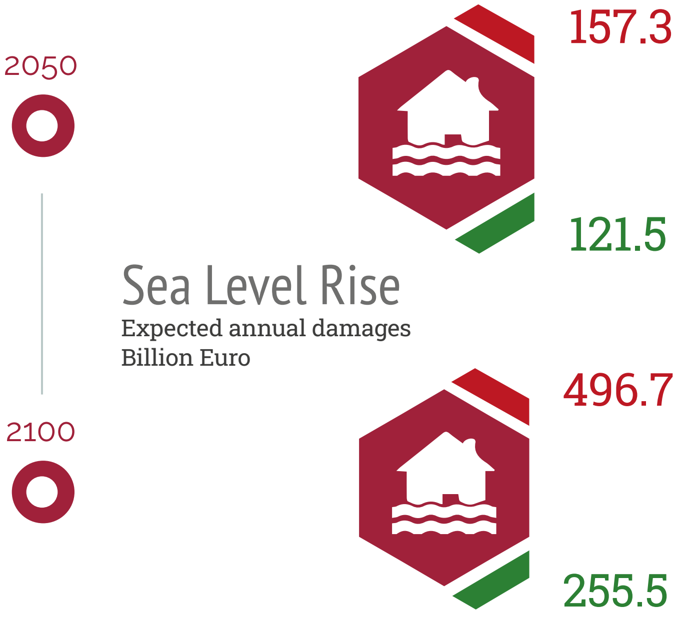
In particular, declines are projected for rice and wheat yields due to climate change, with economic losses by the mid century between 43 and 81 billion EUR(or 1.8-3.4% of GDP).

This is also expected to have substantial effects on Indian farmers' income. It is estimated that in the absence of any adaptation measure, climate change could decrease average farm incomes by 15%, peaking at 25% for unirrigated areas, by the end of the century.

SEA LEVEL RISE DAMAGES

Without any improvement in coastal protection, in a low emissions scenario projected asset losses can amount to 121.5 billion EUR by mid-century and 255.3 billion EUR in the second half of the century.

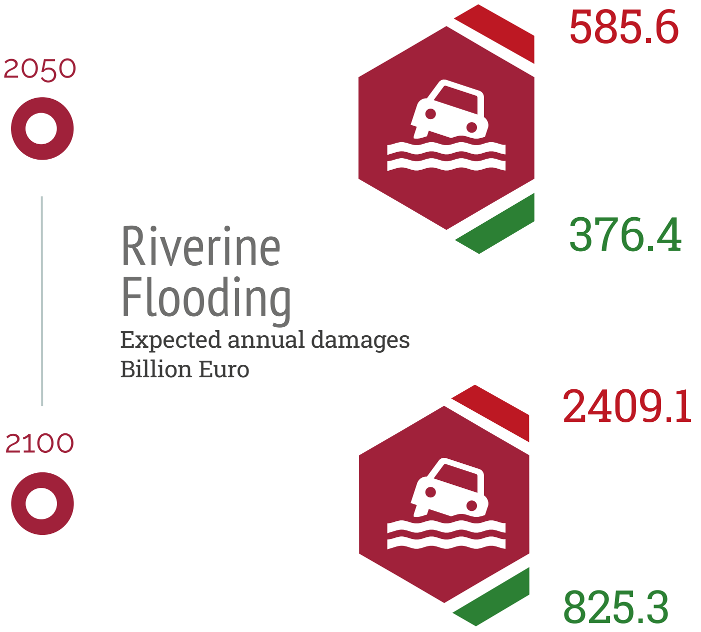
The high emissions scenario features higher losses with potential costs ranging from 157.3 billion EUR in 2050 to 496.7 billion EUR by the end of the century. Sea level rise is also expected to displace many vulnerable coastal communities with an estimated cost from forced migration that, under high emissions, could reach up to 580 million EUR by the end of the century.



RIVER FLOODING DAMAGES

Fluvial flooding is expected to cause substantial losses. The expected annual damages by 2050 are estimated to be 376.4 billion EUR under a low emissions scenario and rise to 585.6 billion EUR under a high emissions scenario.

By the end of the century costs are projected to rise substantially to annual damages of 825.3 billion EUR under a low emissions scenario and may reach 2,409.1 billion EUR under a high emissions scenario.



IMPACTS ON ENERGY

As with all other economic sectors, energy supply and energy networks in India will undergo more intense stress due to droughts and extreme events such as typhoons and floods.

Economic impacts of shifts in household and firm energy demand (see chapter on energy) are difficult to predict and will mostly lead to redistribution effects. In the case of India, there is no demand for heating of any significance in most of the country, and hence the large increase in cooling demand is expected to result in a substantial increase in energy bills.

IMPACTS ON TOURISM

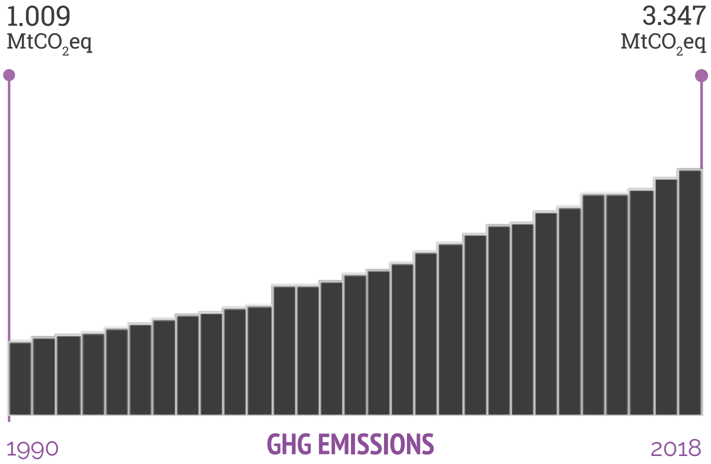
In terms of the tourism sector, to the best of our knowledge no exact costs of climate change have been estimated. However, the occurrence of natural disasters has been linked with a reduction in foreign tourists, but does not seem to affect domestic tourists.

Foreign visitors tend to avoid areas of natural disasters to reduce any risks or disruption, whereas domestic tourists in India mainly travel for religious or social reasons.

INDIA
POLICY

OVERVIEW

Although India is the 2nd most populated country in the world, it has the lowest rate of emissions per capita among G20 countries, accounting for 6.8% of world total GHG emissions in 2018. However, emissions are increasing steadily.



GHG EMISSIONS

INTERNATIONAL COMMITMENTS

India ratified the Paris Agreement in 2016. Its NDC commits to lower the carbon intensity of each unit of GDP by 33%-35% in 2030 (with reference to 2005 levels), to reach 40% of its power capacity supplied by non-fossil fuels by 2030 and to create additional carbon sink up to 3 billion tCO2eq by 2030.

CLIMATE POLICY COMMITMENTS CHRONOLOGY

2002

KYOTO PROTOCOL - 1ST PERIOD

No target

2016

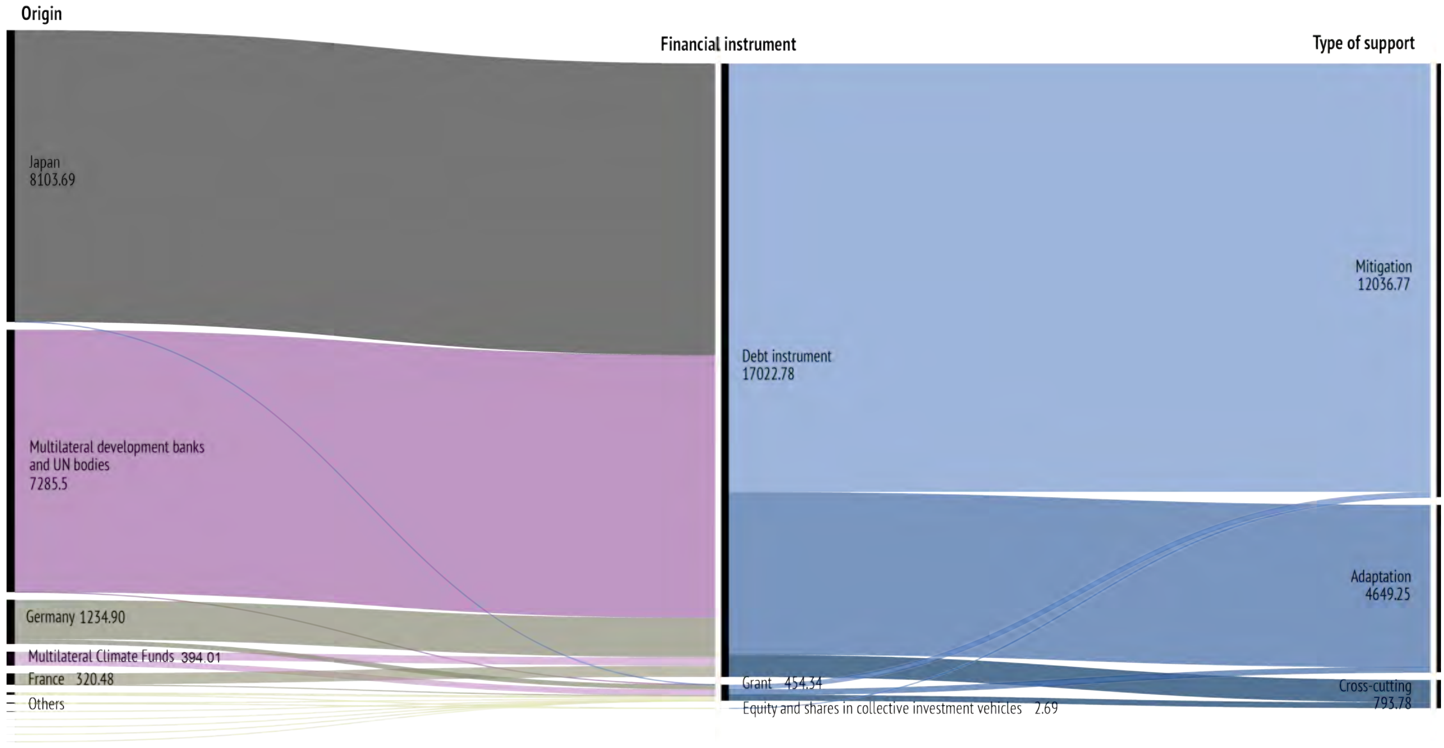
PARIS AGREEMENT - 1ST NDC

33%-35% reduction in GHG emissions per unit of GDP by 2030, with respect to 2005 levels.

40% of power capacity from non-fossil fuel-based resources by 2030. 2.5-3 billion tCO_2eq. of additional carbon sink

INTERNATIONAL CLIMATE FINANCE ASSISTANCE

In 2017-2018, India received 17.5 billion USD in climate-related development finance, according to OECD DAC data. The main sources were bilateral agreements, with Japan as the main donor. Almost all the amount reported is in the form of debt and equity instruments.



SUSTAINABLE RECOVERY POLICY

In 2020, India spent 20.75 billion USD to recover from the sanitary crisis: a fraction of its total expenditure (478,42 billion USD). According to the Global Recovery Observatory, sustainability accounts for 3,6 billion USD.

478.43 billion $	20.75 billion $	3.6 billion $
Total Spending	Recovery Spending	Green Spending

DOMESTIC ADAPTATION POLICY

India has a commitment for adaptation in its NDC. To achieve its targets, India developed an integrated mitigation and adaptation plan. The plan designates sub-national entities and sectoral authorities to provide adaptation plans.

- ○ Domestic Adaptation Policy
  - ● Inclusion of Adaptation in NDCs
  - ● Integrated Adaptation & Mitigation Policy
  - ○ Dedicated Adaptation Strategy
  - ○ Dedicated Adaptation Plan
- ● Subordinate Adaptation Policies
  - ● Sectoral Adaptation Plans
  - ● Subnational Adaptation Plans

○ Policy not in place ● Active policy

ADAPTATION POLICY HIGHLIGHTS

TRANSNATIONAL INITIATIVES

Indian Himalayas Climate Adaptation Programme

The programme aims to enhance the resilience of vulnerable communities in the Indian Himalayas by strengthening Indian institutions in climate science, with a specific focus on glaciology and related areas, as well as planning and policy

NATIONAL INITIATIVES

Modelling of Changing Water Cycle and Climate

Development of hydrological resource assessment and management tools to quantify possible response to climate change and variability

National Water Mission (NWM)

The mission was launched in 2011 to ensure water security and improve access to the resource. It covers the entire water management cycle from water conservation to increasing water use efficiency

SUBNATIONAL INITIATIVES

Climate Change Adaptation in Rainfed Regions of Maharashtra, Madhya Pradesh, and Andhra Pradesh Project (CCA Project)

CCA Project trained local communities to identify and combat climate disasters. It created irrigation models and maps and it maintained springs and canals by clearing lantana and planting bamboo. Where applicable, fish ladders were built to help fish go upstream for breeding

Madurai Action Plan for Blue-Green Infrastructure

The city identified 14 future proofing projects to rehabilitate sewer systems; improve solid waste management; rehabilitate and green infrastructure; manage surface water against floods; balance water supply-demand; plan the future governance system

ENERGY TRANSITION

Among the G20, India is lagging behind in the process of transformation of its energy sector; in particular, the country is at the bottom of the ranking for what regards the Efficiency composite, which takes into account transmission and distribution losses of the electricity grid, the level of energy intensity of the economy and the access to clean cooking services.
India is not progressing much in Emissions, which considers the urban air quality and the level of CO2 emissions. In order to tackle the negative consequences of climate change, there is a lot to do in these two domains. On the contrary, India is quickly moving away from the use of Fossil Fuels and is pushing for their replacement with decarbonized energy sources as also demonstrated by the progress made in the penetration of renewables.
Finally, although the trajectory is encouraging, there is still room for improvement in the Electrification composite, showing the need to improve the quality of electricity supply in terms of readiness, costs, reliability and transparency.

Energy Transition	58.7	52.7
Fossil Fuels	45.3	48.8
Renewables	19.7	25.1
Efficiency	84.9	65.0
Electrification	70.8	67.8
Emissions	72.9	56.7

G20 AVERAGE
COUNTRY

Only actively pursuing an energy transition based on decarbonization and electrification – from policy and regulation, to health and education – will enable countries to benefit the most from future opportunities and fight climate change whilst ensuring an equitable distribution of wealth.

The Energy Transition indicators were developed by Enel Foundation in cooperation with SACE, and provide a retrospective analysis based on historical data.

G20 CLIMATE RISK ATLAS

Impacts, policy, economics

INDONESIA

How to read the Atlas: graphs, colours and scenarios.

The maps used in this Atlas are taken from **The World Bank Official Boundaries** - ***https://datacatalog.worldbank.org/search/dataset/0038272*** (accessed on May 28, 2021). For the section Energy, the maps are based on Panoply Data Viewer ***https://www.giss.nasa.gov/tools/panoply/credits.html***

Each sector of this Atlas contains data and information on various climate scenarios.

When reported in graphs, the **colour black** indicates data and information referring to the current state, the past or the baseline.

When the authors refer to **RCP (Representative Concentration Pathways)**, the 3 colours used across the factsheet refer to 3 scenarios, which are 3 different development options with different levels of greenhouse gas emissions, **respectively low emissions (green), medium emissions (orange), and high emissions (red)**. The same colour code is used when RCPs are associated with Shared Socioeconomic Pathways (SSP).

In some cases, the authors refer to global warming scenarios. In these cases, the 3 colours used refer to a temperature rise of **1.5°C (green), 2°C (dark green), and 4°C (red)**.

When the authors refer exclusively to **Shared Socioeconomic Pathways - SSPs** (Population affected by river floods in the section: "Water"), data related to **SSP3** - that encompasses, among other things, slow economic growth, material-intensive consumption, and persisting or worsening inequalities – **are reported in a lighter shade**; **SSP5** – which refers to social and economic development that is coupled with an energy-intensive lifestyle and the abundant exploitation of fossil fuel resources – is shown using a **middle shade of the colour**, whereas data related to **the present** conditions **are represented in a dark shade**.

Further details on scenarios, methodologies, and the full list of references are available at: **www.g20climaterisks.org**

Concept and graphic design by element6.eu

INDONESIA CLIMATE

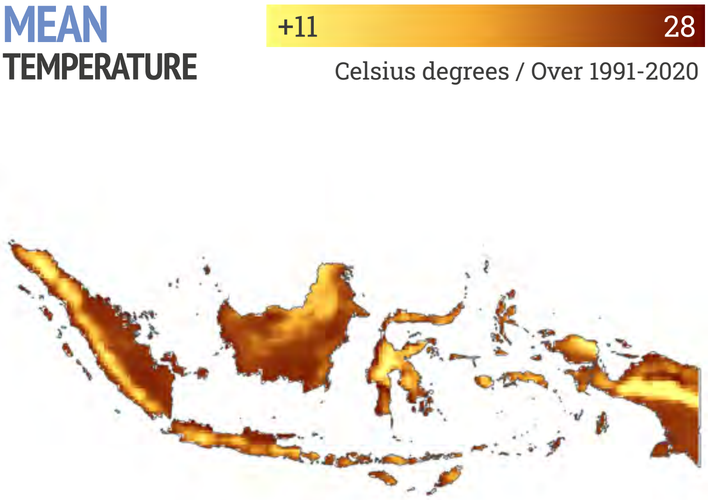
OVERVIEW

Indonesia is almost entirely dominated by a tropical climate which is largely hot and humid, with rainfall occurring mainly in low-lying areas and mountainous regions that experience cooler temperatures. Indonesia sees drier conditions during El Niño events and wetter conditions during La Niña events. The wet season occurs between November and April, leaving May and October typically dry. Relative humidity varies between 70% and 90% and cooler temperatures prevail at higher altitudes.

TEMPERATURE

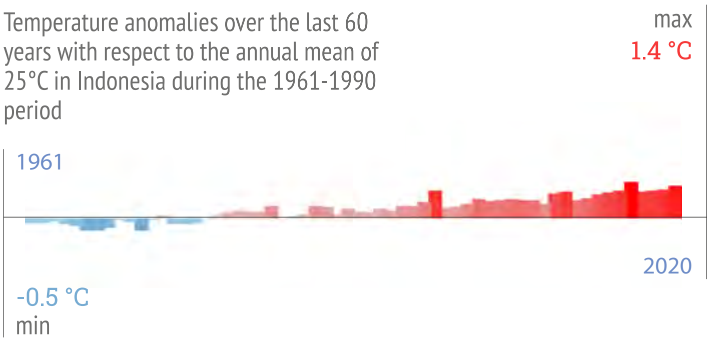
The temperature regime in Indonesia is mainly regulated by the uniformly warm waters surrounding approximately 81% of the country. Higher temperatures are found on the coastal plains and lower ones in the mountainous areas. Seasonal variations in temperature are not so significant.

MEAN TEMPERATURE



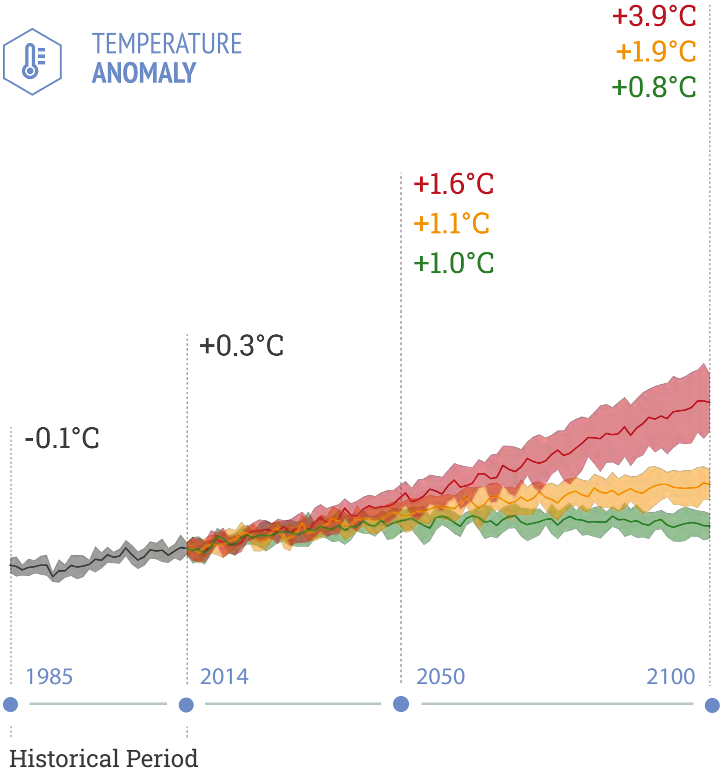
TEMPERATURE TREND

Temperature anomalies over the last 60 years with respect to the annual mean of 25°C in Indonesia during the 1961-1990 period



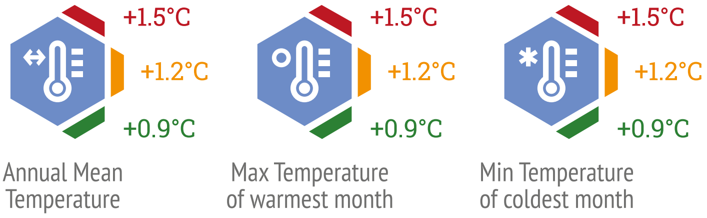
TEMPERATURE PROJECTIONS

Under a low emissions scenario projected temperature variations will remain contained under +1°C, both by 2050 and 2100.
Under a high emissions scenario, with no reduction in GHG emissions, much greater temperature anomalies are expected by both 2050 and 2100.



EXPECTED VARIATION FOR TEMPERATURE AT 2050

The indicators show variations in selected temperature characteristics for a thirty-year period centred on 2050 (2036-2065) with respect to the reference period 1985-2014.



PRECIPITATION

The precipitation regime in Indonesia is variable, especially during the wet and dry seasons. The main variation in average annual precipitation occurs in the southern regions (although this includes increases in wet season precipitation), whereas variations in precipitation in the northern regions is accompanied by a decrease in dry season precipitation.

In general, precipitation in lowland areas averages 1,800-3,200 millimetres per year, increasing with altitude to an average of 6,100 millimetres in some mountainous areas. In the lowlands of Sumatra and Kalimantan, the precipitation range is 3,050-3,700 millimetres. The amount decreases towards the south, in proximity to the desert of north-western Australia.

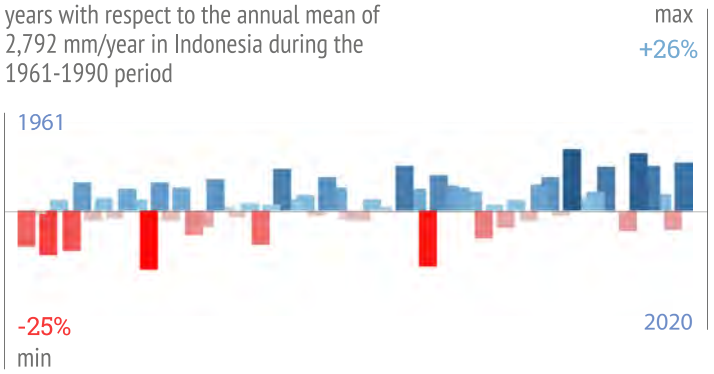
MEAN PRECIPITATION

905 15,200

mm/year / Over 1991-2020

PRECIPITATION TREND

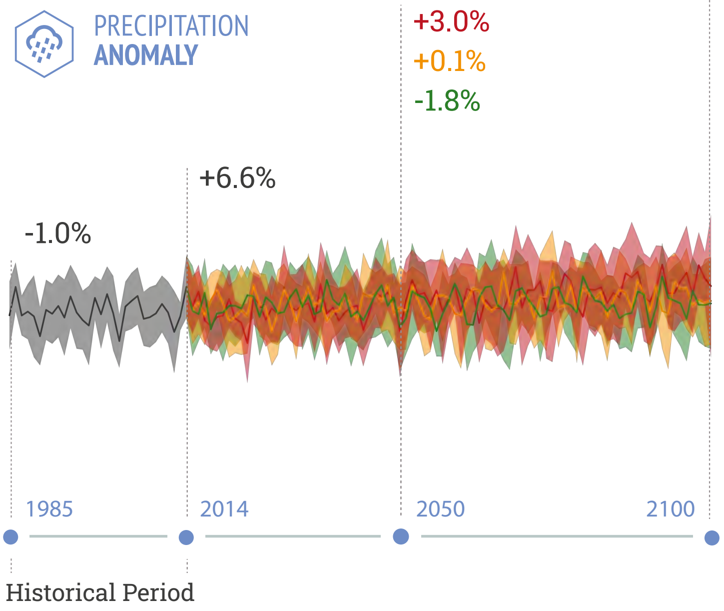
Precipiation anomalies over the last 60 years with respect to the annual mean of 2,792 mm/year in Indonesia during the 1961-1990 period



PRECIPITATION PROJECTIONS

Precipitation trends show a very complex signal, under all emissions scenarios, with a very large variability among climate models. This can be explained considering the complexity of the precipitation regime and dynamics requiring more detailed spatial and temporal analysis.

PRECIPITATION ANOMALY



EXPECTED VARIATION FOR PRECIPITATION AT 2050

The indicators show variations in selected precipitation characteristics for a thirty-year period centred on 2050 (2036-2065) with respect to the reference period 1985-2014.

Annual total precipitation: +2.3% / +2.2% / +2.1%

Precipitation of wettest month: +2.9% / +2.3% / +2.4%

Precipitation of warmest quarter: +0.4% / +1.9% / +0.6%

VARIATION OF SPECIFIC CLIMATE INDICATORS

Climate indicators variation showing impacts of climate change on sectors such as agriculture, health and water. Analysis considers 3 threshold average temperature increase: **+1.5°C**, **+2°C**, **+4°C**.

Agricultural drought proportion of time (% of time): +15% / +10% / +8%

Hydrological drought proportion of time (% of time): +13% / +8% / +8%

Heatwave duration (% of time): +7,933% / +911% / +328%

Runoff increase (% of area): +25% / +11% / +5%

Agricultural drought frequency (% of change): +32% / +17% / +14%

Hydrological drought frequency (% of change): +9% / +8% / +8%

Heatwave frequency (% of change): +98% / +60% / +34%

Runoff decrease (% of area): +35% / +18% / +9%

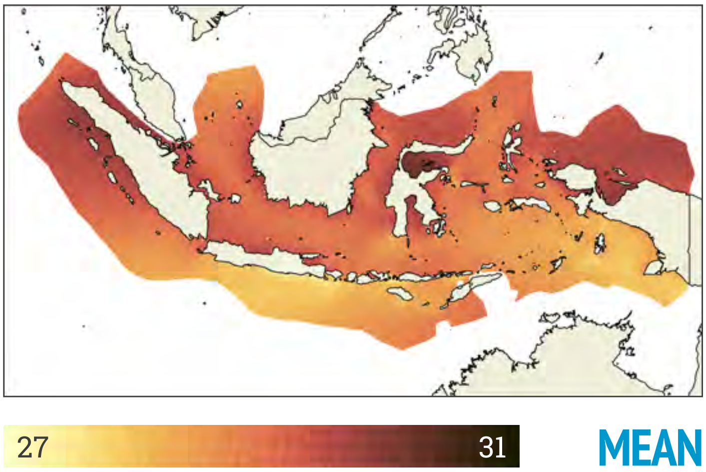
INDONESIA OCEAN

OCEAN IN INDONESIA

Indonesia's marine exclusive economic zone (EEZ) is almost entirely tropical with warm water temperatures and a wide ensemble of ecosystems such as coral reefs, seagrass meadows, algal beds, and mangroves. Indonesian coastal systems can be divided into three main areas: the Java Sea, the Banda Arc and the southern Indian region.

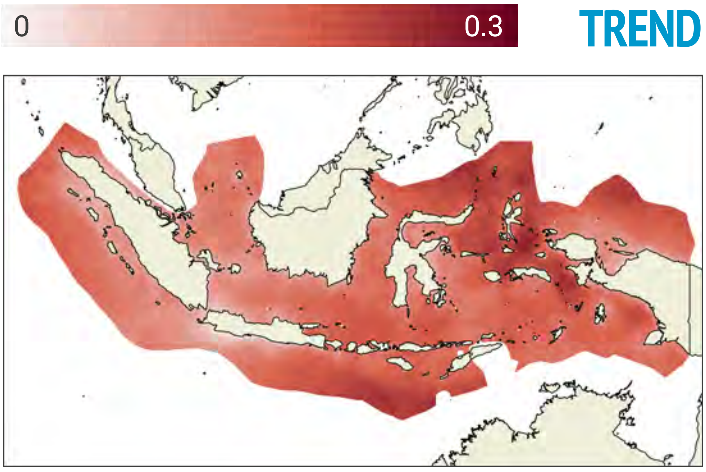
CURRENT CLIMATE CONDITIONS

Mean sea surface temperature reflects the Tropical climate of the region, with values ranging between 27°C and 31°C.



SEA SURFACE TEMPERATURE

Celsius degrees / Over 1991-2020

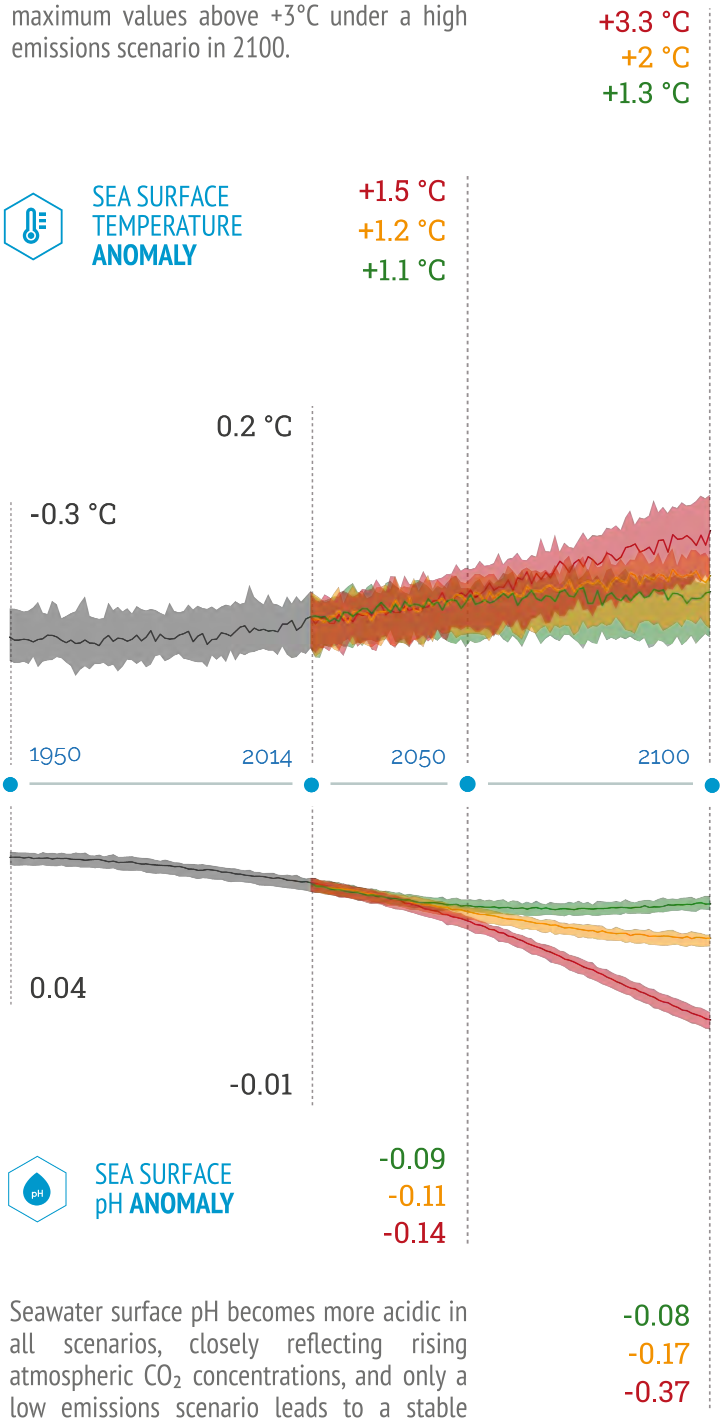


Surface temperature trends indicate a general warming of 0.2°C per decade in all marine areas, with increased gains in the Banda Sea and the Indian oceanic region.

FUTURE PROJECTIONS

Projected annual changes within the marine EEZ for the two most significant marine indicators of climate change: sea surface water temperatures and pH.

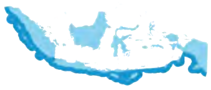
Seawater temperature changes are in line with the definitions of each scenario, with maximum values above +3°C under a high emissions scenario in 2100.



Seawater surface pH becomes more acidic in all scenarios, closely reflecting rising atmospheric CO_2 concentrations, and only a low emissions scenario leads to a stable condition by 2100.

ECOSYSTEM INDICATORS AT 2050

Regional changes in key marine ecosystem indicators under projected future scenarios by mid-century (2036-2065) with respect to present climate conditions (1985-2014).



	Banda Arc	Indian	Java Sea
Temperature regulates the metabolism of marine organisms determining which habitats remain suitable. Excessive warming will likely push ecosystems beyond tolerance thresholds.	29.30°C +1.61 °C +1.35 °C +1.18 °C	29.02°C +1.48 °C +1.22 °C +1.03 °C	29.17°C +1.67 °C +1.44 °C +1.31 °C
pH represents the acid/base status of marine waters, where a decreasing pH reflects the acidification of the ocean due to increased absorption of atmospheric CO_2.	8.06 -0.14 -0.11 -0.09	8.06 -0.14 -0.11 -0.09	8.06 -0.15 -0.11 -0.09
Oxygen is fundamental to sustain marine life and its reduction can have a large impact on coastal ecosystem services including fisheries and aquaculture.	200.72 $mmol/m^3$ -1.78 % -1.37 % -0.99 %	201.75 $mmol/m^3$ -2.2 % -1.71 % -1.18 %	202.03 $mmol/m^3$ -2.05 % -1.62 % -1.16 %
Chlorophyll is an indicator of the biomass available at the base of the marine food web supporting all ecosystem productivity.	0.26 mg/m^3 -14.12 % -17.56 % -9.92 %	0.2 mg/m^3 +2.96 % +2.96 % +0.49 %	0.26 mg/m^3 -0.76 % -5.7 % -11.41 %

FISH CATCH POTENTIAL

Fish catch potential is an estimate of the maximum fish catch achievable given the marine resources available over a sustained period. It is linked to the concept of maximum sustainable yield, meaning the maximum amount of fish that can be extracted from a system without causing a collapse in fish populations.

It is a characteristic of the natural system, which is substantially different from realized catch, and a direct result of the fishery policy in place.

Fish catch percentage change

2050

-20.3%

-5.8%

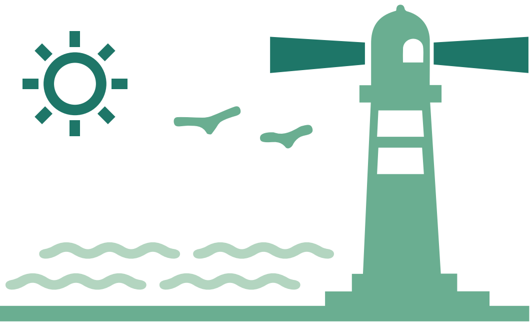
ANALYSIS DETAILS

All datasets were analysed using only data from within the marine EEZ and therefore excluding overseas territories, detached islands and any disputed or joint territories with other nations. In the assessment of current climate conditions, seawater surface tempereature data was obtained using satellite observations distributed in the framework of ESA Climate Change Initiative.

Future projections of marine indicators are represented by the combined analysis of results from 15 different Earth System models participating in the Coupled Model Intercomparison Project Phase 6 (CMIP6). These models include new and better representations of physical and biogeochemical processes, compared to previous IPCC assessment reports.

Fish catch potential data was obtained using the FAO's technical report and refers to the best and worst case climate scenarios from the Fifth IPCC Assessment Report. These mean estimates are subject to substantial uncertainties as discussed in the original work.

INDONESIA
COASTS



OVERVIEW

Indonesia is a densely populated archipelago of more than 17,000 islands and 95,000 kilometres of shorelines. The country's coast hosts important ecosystems and is rich in biodiversity and natural resources which are used for fishing, recreation, waste disposal, power generation, water supply, sands extraction, forestry, farming, residential and industrial purposes. The islands of Java and Sumatra are home to most of the population, including the large coastal cities of Jakarta, Surabaya and Palembang.

Shoreline Length — 95,181 km

Sandy Coast Retreat at 2050 — -39.7 m

CLIMATE CHANGE HAZARDS

Coastal hazards such as erosion, storm tide inundation and permanent flooding, can have strong adverse impacts on coastal regions, with loss of sandy shores, damage to settlements, infrastructure and ecosystems. Climate change can exacerbate these impacts due to rising sea levels and increasing impacts of waves and storms. Climate change impacts on the coastal zones of Indonesia are mainly driven by rising sea levels and possible changes in storm intensity and direction, which can exacerbate erosion issues and drive flooding in low lying areas along the coast. In addition, changes in rainfall patterns can further exacerbate flooding risks for low lying coastal areas. Land subsidence is a major concern for the capital city Jakarta, which is losing land to the sea and is expecting major impacts from future sea level rise.

SEA LEVEL RISE

Relative sea level rise has been observed over the past century with a yearly average increase of approximately 4.97 millimetres per year since the 1990s. This high value reflects land subsidence in some parts of the country. The latest IPCC projections indicate that, by 2050, global sea levels may rise between 0.18 metres, under a low emissions scenario, and 0.23 metres, under a high emissions scenario.

Observed and projected sea level rise at 2050

4.97 mm/year

0.23 m

0.18 m

EXTREME SEA LEVEL

On average, one in 100 extreme sea level events are expected to rise from 1.34 metres at present day to 1.55 metres by 2050 under a medium emissions scenario.

Current and projected extreme sea level at 2050

1.34 m

1.62 m

1.55 m

OBSERVED STORMS

The Indonesian coast is exposed to waves from the Indian Ocean, the Pacific Ocean and internal seas. In general, a general trend of increasing wave height has been observed at different locations.

FUTURE STORMS

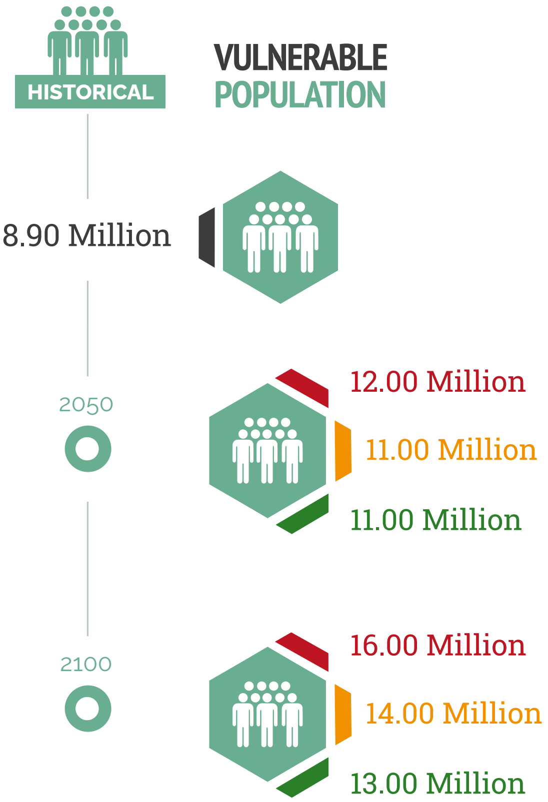
Waves and storms around the Indonesian coast are expected to change in the future. However, trends and patterns are quite unclear and heterogeneous given the size and diversity in wave climate and exposure of the Indonesian archipelago. More intense tropical cyclone activity is expected in response to warming ocean surfaces on both the Indian Ocean and Pacific Ocean side of the vast archipelago. Rising sea levels will also increase the frequency of extreme sea level events, such as the one in 100 year water level.

VULNERABILITY AND RISK

Sea level rise in Indonesia is expected to impact all areas where population is concentrated and in particular the capital city of Jakarta, which is home to more than 10 million people.

In Jakarta, the impact of sea level rise is compounded by one of the highest rates of land subsidence in the world, which is threatening the livelihoods of poorer and marginalised parts of the population in particular. Other areas of Indonesia are expected to suffer from increasing erosion which may impact economic activities.

The shoreline of the island of Bali, the main tourist destination in Indonesia, is subject to severe coastal erosion. In addition, densely populated parts of Java and Sumatra are exposed to sea level rise risk. Under a medium emissions scenario the population exposed to the one in 100 annual coastal flood level is expected to increase from 8.9 million to 11 million by 2050.



VULNERABLE POPULATION

HISTORICAL

8.90 Million

2050

12.00 Million

11.00 Million

11.00 Million

2100

16.00 Million

14.00 Million

13.00 Million

INFLUENCE OF SEA LEVEL RISE ON EXTREME SEA LEVEL

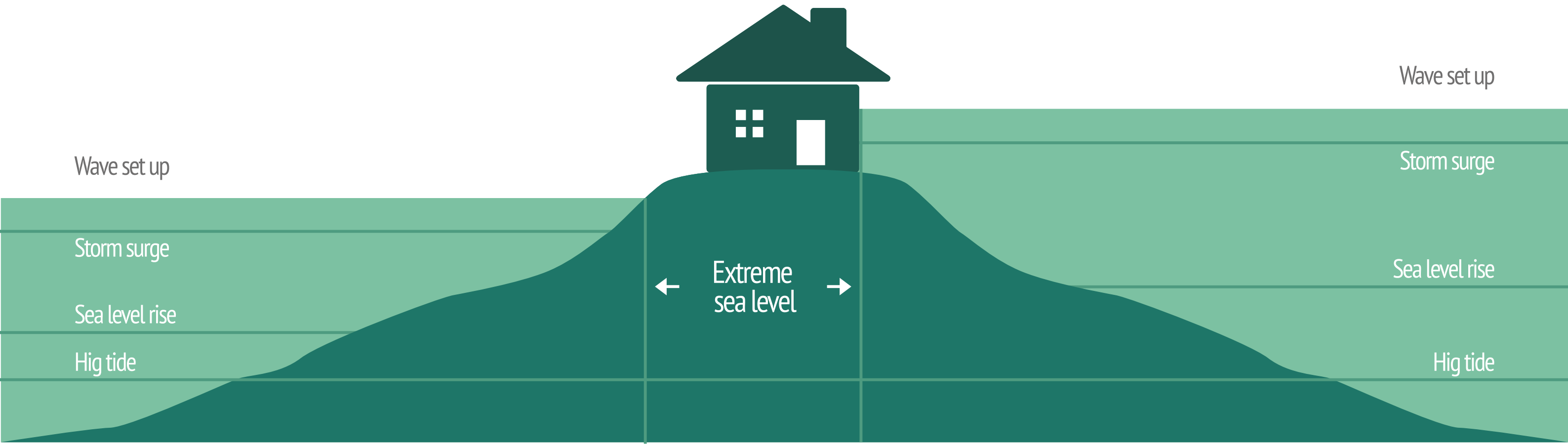
Present and future sea level rise are a consequence of carbon induced global warming causing melting ice and ocean expansion due to heat accumulation.

The extreme sea levels reported here are based on the 100-year storm surge + wave set up + sea level rise + high tide indicators. The first two parameters (storm surge + wave set up) are based on the 100-year value for the event; sea level rise is its projected value at 2050; and high tide is the absolute value of the highest tide calculated for a given locality, which won't be influenced by climate change.

+ **Wave set up** refers to the accumulation of water near the shore due to the presence of breaking waves.

+ **Storm surge** is an occasional increase in sea level driven by shoreward wind-driven water circulation and atmospheric pressure.

+ **High tide** is usually the highest tide reached in a given location based on tide records.



Present sea levels have risen globally by approximately 20 centimetres over the past century.

Future sea level rise is a projection based on different global warming scenarios, at approximately 100 centimetres by the end of 2100, with consequent inundation during extreme sea level events.

INDONESIA
WATER

OVERVIEW

Indonesia has abundant water resources, however they are unevenly distributed throughout the archipelago. Rain measurement data for the country indicates that it has abundant rainfall, though in certain areas occasional water shortages or droughts take place.

When combining groundwater and surface runoff, Indonesia has a potential average water availability of about 2,100 millimetres per year. Significant impacts of land-use changes and environmental degradation are now believed to have changed the natural carbon, nutrient and water cycles.

Renewable internal freshwater resources
2,019
billion m^3

Renewable internal freshwater resources per capita
7,628
m^3

Even though Indonesia is a humid tropical country with high annual average rainfall, the archipelago has to cope with several water-related problems, such as rising water demand, lack of upland/upstream land management, erosion-related degradation, population growth, inefficient irrigation water management, extreme climatic change and over-pumping of groundwater.

CLIMATE CHANGE HAZARDS

Climate change can affect water resources through increasing temperatures, higher rates of evapotranspiration and altered rainfall patterns. This leads to changes in the water cycle, including decrease of snow and ice coverage, alterations of surface runoff and groundwater storage, as well as drought and flood occurrence. In Java, Indonesia's most populated island, rainfall has seen a marked decrease compared to the previous century, particularly during dry seasons which are becoming longer. Furthermore, the current trend in seasonal rainfall changes also implies a proportional reduction in monthly discharge for Java's major rivers. Significant decline in rainfall has threatened Indonesia's water resources due to depletion of forest resources and global climate change.

KEY POINT RUNOFF

Deterioration of watersheds damages the environment and leads to negative consequences downstream, including massive sedimentation of reservoirs, and possibly a change in the runoff pattern, leading to higher peak flows and reduced dry season flows on the archipelago. This effect will possibly be aggravated by the impacts of climate change.

At a country scale, an average change in surface runoff by approximately -11% and +32% is expected respectively under low and medium emissions scenarios for the 2045-2055 period compared to 2015-2025.

If temperatures rise by 1.5°C, 2°C or 4°C, 17%, 33.4% or 43% of the country will likely experience an increase in runoff, while 3%, 6.4% or 17% of the surface of the country will likely experience a decrease in runoff, respectively.

2050
Changes in annual runoff
% of change
+31.6%
-11.3%

2050
Runoff increase
% of area
+35.0%
+9.0%

KEY POINT DROUGHTS

The Indonesian climate is naturally variable from year to year and, at times, drought may occur. Most recorded droughts can be related to "warm" El Niño episodes: in these cases, the normal patterns of tropical precipitation and atmospheric circulation become disrupted and rainfall is reduced over Indonesia, Malaysia, and northern Australia. A similar correlation is found when a strong Indian summer monsoon generates easterly wind that eventually causes drought in Java–Sumatra. The droughts are most notable in the period from August to December, resulting in a late and reduced onset of the rainy season. According to recent studies, Indonesia will experience drier conditions during the boreal summer due to the effect of the global warming. Impacts include the potential for wide-spread forest fires over the archipelago, particularly in Sumatra and Borneo.

2050
Severe drought likelihood increase
% of change
+1.9%
+3.6%

2050
Hydrological drought frequency
% of change
+9.0%
+7.0%

2050
Groundwater Recharge
% of change
+25.4%
-11.9%

KEY POINT GROUNDWATER

The average annual rainfall in Indonesia is of 2,700 millimetres: of which, only an average of 278 millimetres (10%) infiltrates into groundwater. The most relevant groundwater basins can be found in the north of Java and Sumatra, and in the south of Kalimantan and Sulawesi. Deep groundwater is overexploited in most urbanized areas. Low coverage or poor performance of water supply companies, combined with lack of permit enforcement, leads to many industries and housing estates using deep groundwater. The deep aquifers from which groundwater is drawn are usually not replenished and, as a consequence, they are gradually depleted. This causes rapid drawdown of the groundwater table and land subsidence. Serious impacts are felt in north Jakarta, Bandung, and Semarang. Coastal groundwater may be susceptible to changes in salinity because of saltwater intrusion, associated with sea level rise, and overexploitation of groundwater may increment in the next decades, leading to a further depletion of the basins. At the country level, a -12%, +2.5% and +25% change of the annual groundwater recharge for the period 2045-2055 compared to the timeframe 2015-2025 is expected respectively under under low, medium and high emissions scenarios.

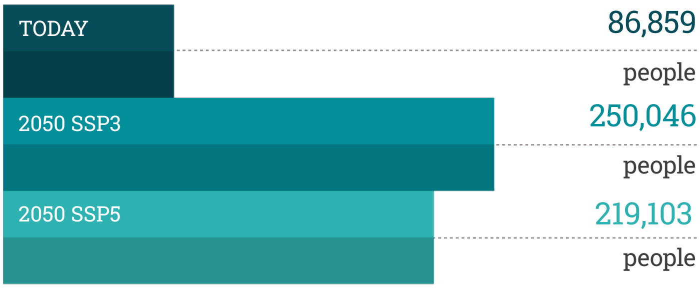
KEY POINT FLOODS

With a climate characterized by high rainfall, frequent intense storms and high runoff, floods are a natural phenomenon in Indonesia. Their impacts are, however, gradually increasing due to settlement and economic development in flood-prone areas.

Flooding has become a major problem in Indonesia, particularly in Java where a large and expanding population combined with past lapses in spatial planning and land management has permitted substantial development in flood-prone areas.

Between 1970 and 2011, 3,980 flood events in Indonesia damaged an estimated 1.1 million hectares of cropland and 65,000 kilometres of roads. By 2050 a slight increase in the number of days with intense precipitation (more than 50 millimetres of rain) is expected, with 0.26 days under a low emissions scenario and 0.41 days under a medium emissions scenario.

POPULATION AFFECTED BY RIVER FLOODS

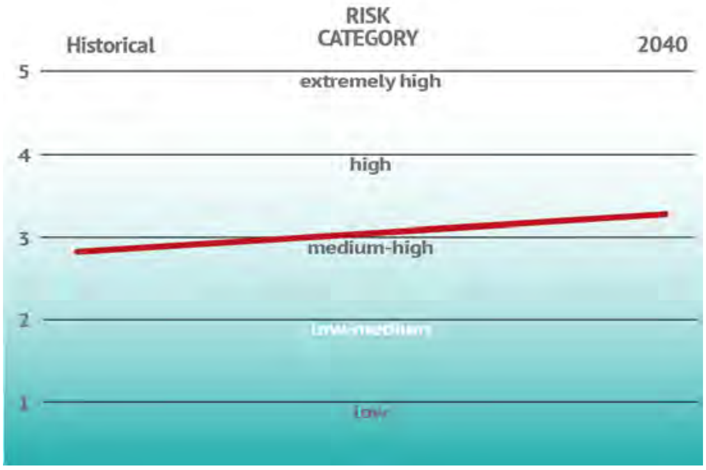


RISK INDICATORS

The water stress index summarises current and future water related vulnerabilities and risks at the global level. Scores are based on the ratio of total water withdrawals, including agriculture, industrial and human consumption, to available renewable surface and groundwater supplies.

WATER STRESS

Indonesia's water stress level is considered medium-high for the recent past (1960-2014 average), and it is expected to increase in the near future (2030-2050) based on climate change projections.



INDONESIA AGRICULTURE

OVERVIEW

Indonesia is one of the world's largest producers and exporters of agricultural products, supplying important commodities such as palm oil, natural rubber, cocoa, coffee, rice, and spices to the rest of the world.

Large plantations dedicated to export cover about 15% of the total agricultural area. However, the majority of farmers are smallholders operating on less than one hectare. The country is a net importer of grains, horticulture and livestock produce. Wetlands play a very important role in food production, including rice and secondary crops (maize, cassava, soybean, sweet potatoes, peanut).

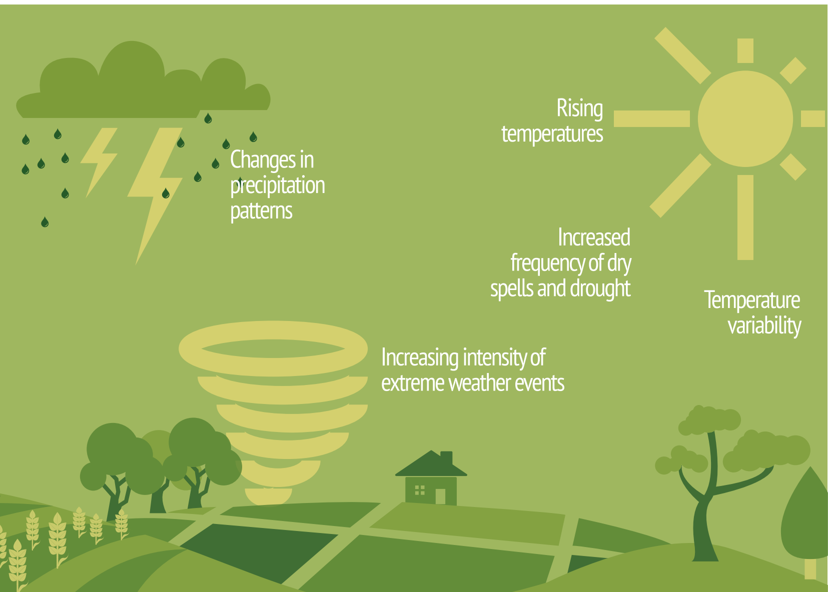
Besides food crops, Indonesia also produces a large number of perennial crops, including rubber, coconut, palm oil, coffee, cocoa, and tea, which are currently exported.

240.9 Mt	Oli Palm
30.3 Mt	Maize
59.2 Mt	Rice
29.5 Mt	Sugarcane
16.1 Mt	Cassava

	Added Value of Agriculture, Forestry and Fishing	Share of Agriculture Value added in Total GDP	Agricultural land	Area Equipped for Irrigation
2000	67,446 USD Million	17.1 %	36,000 Thousand HA	5,500 Thousand HA
2018	129,595 USD Million	13 %	51,300 Thousand HA	6,722 Thousand HA

EXPEXTED IMPACTS ON AGRICULTURE PRODUCTIVITY

Rising temperatures, reduction in average annual precipitation, and intensification of extreme events such as heat waves and drought, affect production variability with a tendency towards yield reduction for many cultivated species, accompanied by a probable decrease in food quality. Crops respond to increases in temperatures with changes in duration of the growing season, early appearance of phenological phases and potential shifts of cultivation areas toward higher latitudes and altitudes for better growing conditions. However, impacts vary significantly depending on the geographical area and specific crops in question.



CROP PRODUCTIVITY

Crop productivity refers to the harvested yield of a crop per unit of land area. It is strongly influenced by climate and other environmental and management factors.

Climate change is expected to have an impact on the productivity of several major crops, although this may in part be offset by the fertilizing effect of higher CO_2.

Impacts are estimated using a range of model projections based on low to high emission scenarios and reported as percentage changes between the 30-year average around the historical period and the 30-year average around 2050.

5.2 2.4 (-4.6)%
3.1 (-6.1)%
Rice
tons / ha

5.4 -6.1 (-8.1)%
-5.7 (-9.3)%
Maize
tons / ha

68.2 -5.3 (-5.5)%
-7.6 (-7.8)%
Sugarcane
tons / ha

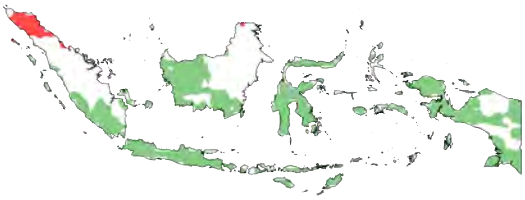
22.9 1.7 (-8.2)%
4.9 (na)%
Cassava
tons / ha

2050

Productivity change with (without) the CO_2 fertilization effect. Estimates assume sufficient water and nutrient supplies, and do not include impacts of pests, disease, or extreme events.

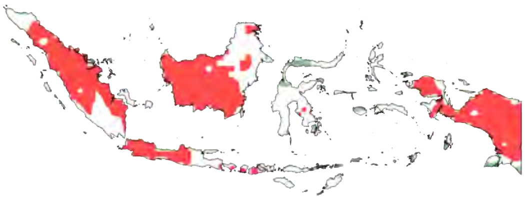
CHANGE IN RICE

− = +



CHANGE IN MAIZE

− = +



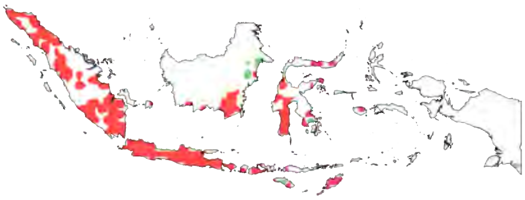
Rice production in the highlands is expected to see higher future yields compared to the lowlands. Furthermore, lowlands along the coasts may also be affected by sea level rise. Sugarcane productivity may suffer from increasing temperatures, as cool winters are needed to facilitate sucrose storage. Sugarcane production is extremely vulnerable to climate change and extreme climate events, such as drought, heat, and flooding. Maize production may also be affected by increasing temperatures, and in particular when water availability is low during El Niño events. Over half of medicinal plant species may lose up to 80% of their growing areas due to climate change. Habitat losses will be aggravated by deforestation and sea level rise. Climate change will affect palm oil production severely, especially after 2050. According to recent studies, palm oil production may decrease from 10% to 41% if temperatures rise from 1 to 4°C.

ADAPTATION IN AGRICULTURE AND WATER RESOURCES

Climate change may have some positive effects on some of the most widely used crops. However, higher temperatures will generally require an increase in irrigation demand due to higher plant evapotranspiration. Total rainfall is expected to increase by an average of 10% from April through June, but decrease by 10 to 25% from July through September. A substantial increase in water demand (45-55%) is foreseen to support irrigation needs. More than 50% of irrigated areas have damaged irrigation infrastructure. Adaptive strategies and appropriate water management will become increasingly necessary to ensure stability and availability of food.

CHANGE IN WATER DEMAND

− = +



Agriculture
Water Demand
% of change

+52.1%
+45.9%

2050

Coping with climate risks will require a substantial improvement in water infrastructure and adaptation practices, such as crop varieties that enhance water-use efficiency, to limit stress on freshwater resources.

INDONESIA
FORESTS

FORESTS IN INDONESIA

Tropical Indonesian rainforests are, by extension, the third largest in the world and nearly half of which are primary forests. Furthermore, the total area of mangrove forest in Indonesia is estimated at about 3.2 million hectares, amounting to 20% of the world's mangrove forest area.

Unfortunately, the rate of primary forest loss due to deforestation is one of the highest in the tropics.

1990

119 Mln ha
Million hectares
Forested area

94 Tons/ha
Tons of Carbon per hectare
Carbon stock

2020

92 Mln ha
Million hectares
Forested area

104 Tons/ha
Tons of Carbon per hectare
Carbon stock

FORESTED AREA AND CARBON STORAGE

Although forests still cover half of Indonesia there has been a sharp decline inrecent decades. Indonesian forests are among the most carbon-dense in the world, mainly due to the presence of mangrove forests. Unfortunately deforestation is reducing this stock and could affect government emission reduction policies.

2050

Productivity anomaly
Tons of Carbon per hectare per year

+1.38

+0.92

FOREST PRODUCTIVITY

Forest productivity or Net Primary Production is the net carbon captured by plants. It is the difference between the carbon gained by Gross Primary Production - net photosynthesis measured at the ecosystem scale - and carbon released by plants' respiration. It is expressed per unit land area.

Marked increase expected throughout the archipelago, particularly under a medium emissions scenario

+ Fertilizing effect of increasing atmospheric CO_2 and nitrogen deposition
+ Rising temperatures promote productivity

No areas with an expected decrease in forest primary production

+ Increasing risk of drought stress due to modifications in the water regime reduces productivity

KEY SPECIES UNDER CLIMATE CHANGE

REDUCTION

STYRAX

Suitable habitats of Styrax sumatrana are likely to be reduced under future climate scenarios

REDUCTION

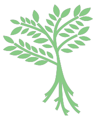
PALAQUIUM

Palaquium species biomass will decrease significantly

REDUCTION

DIPTEROCARP

Dipterocarpus species biomass will decrease significantly



VULNERABILITY

MANGROVES

Rapid sea level rise will threaten coastal Mangrove forests significantly

FIRES IN INDONESIA

Fire is a structural ecological process that provides several types of ecosystem services and impacts on socio-ecological systems, including human health, carbon budgets, and climate change. Changes in global fire activity are influenced by multiple factors such as land-cover change, policies, and climatic conditions. Fire also releases large quantities of greenhouse gases into the atmosphere, contributing to a vicious cycle.

Over the last two decades, the total forest area affected by fires was approximately 3.37 million hectares.

BURNING
3.37 MILLION HECTARES

EMITTING
139 TERAGRAMMES OF CARBON PER YEAR

FOREST FIRE EMISSIONS CONTRIBUTED TO 42% OF TOTAL FIRE RELATED CARBON EMISSIONS

COSTING
16.1 BILLION USD IN DAMAGES AND LOSSES (2015 FIRE SEASON)

FUTURE BURNED AREA

Under a low emission scenario, models project that the total burned area might decrease. Although, in some localized areas in Central and Southern Papua, burned area might increase affecting lowland reainforests and freshwater swamp forests.

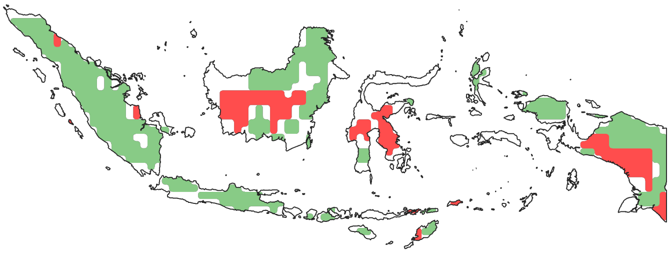
Central areas of Kalimantan and Sulawesi might also experience a slight increase in burned area. Under a medium emissions scenario, burned area projections might project a similar distribution, although Papua will be less affected.

Burned Area
km² per year

2050

-7,080

-5,437

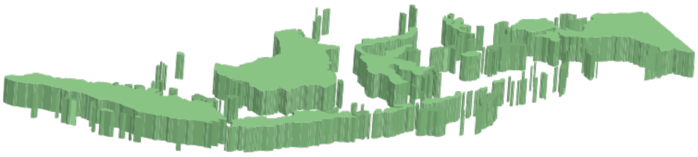


Decrease in burned areas for a low emissions scenario

Increase in burned areas for a low emissions scenario
+ Slight increase in terms of fire season length over Sumatra and Java

WHERE DO FIRES OCCUR?

Peatland fires, which mainly occur on the island of Sumatra, are a cause of major concern due to the large amount of emissions released.



Most affected areas are Central and West Kalimantan, South Sumatra, Riau and Jambi provinces.

VARIATION OF SPECIFIC FIRE INDICATORS

% of change
Extreme fire danger days per year, East Kalimantan

2070-2100

+297%

+209%

% of change
Extreme fire danger days per year, East Sumatra

2070-2100

+275%

+230%

FUTURE FIRE EMISSIONS

Fire emissions follow a similar spatial pattern as burned area. Papua, Kalimantan and Sulawesi show greater projected changes over both low and medium emissions scenarios.

Fire Carbon emission
Teragrams of Carbon per year

2050

-21.03

-13.4

INDONESIA URBAN

OVERVIEW

In 2020, slightly more than half of the population (56.5%) lived in urban areas, which represents a steep increase from 14.5% in 1960. By 2050, this rate is expected to reach 73%.

Urbanization in Indonesia mainly concerns the island of Java, and few other coastal urban areas. Less than 20% of the urban population lives in the capital Jakarta, and another 20% live in the 20 major cities with 1 to 5 milion inhabitants. Therefore the majority of Indonesians lives in minor urban centres with less than 300,000 inhabitants.

Although built up areas cover 1.6% of Indonesia, on the island of Java the figure is 12.8%.

Population in Urban Areas

2020 154,188,546

2050 234 104 967

Graphs refer to data provided by United Nations, Department of Economic and Social Affairs, Population Division (2018). World Urbanization

Urbanization Rate

2020 56.6%

2050 72.8%

OVERVIEW OF KEY CLIMATE IMPACTS IN URBAN AREAS

Climate change impacts on Indonesian cities are connected mainly to sea level rise and rising temperatures.

HEATWAVES AND HEAT STRESS

Observations for the 1960 to 2003 period show an increase in the number of hot days and warm nights. In the city of Bandung, almost 50% of the survey respondents indicated that they had experienced difficulties during their commuting or at work due to hot weather.

Under a high emissions scenario, heat-related mortality for elderly people in the Jakarta metropolitan area will increase by 12 to 15 times in the 2050s.

2050 Cooling Degree Days
% of change

+41.9%
+17.0%
+10.9%

2050 Heatwave frequency
% of change

+97.9%
+59.5%
+33.6%

2050 Heatwave duration
% of time

+7,933%
+911%
+328%

HEAT AND AIR POLLUTION

High levels of air pollution further exacerbate the impacts of heatwaves, in particular in urban areas. According to WHO data, almost the entire population of Indonesia is exposed to high air pollution levels.

2017

Population exposed to air pollution

95.6%

COASTAL FLOODING

75% of Indonesian cities are situated close to the coast. Approximately 175 million people, amounting to almost 70% of the total population, are living in 42 cities and 182 districts found within 50 kilometres of the coast.

Under a future prospective of sea level rise and land subsidence, impacts for the three major coastal cities (Jakarta, Surabaya and Semaran) are expected to rise up to 1 billion, 38.3 million and 0,38 million USD respectively. In Jakarta the number of persons affected would be 318,000, in Surabaya 751,000 and in Semarang 334,000 persons.

Projected sea level rise

2050

0.23 m

0.18 m

2100

0.77 m

0.38 m

FLOODING

Larger urban areas like Jakarta are vulnerable to river flooding, due to reduced drainage and storage capacity of inland watercourses and urban drainage clogged by solid waste and sediments, which adds up to reduced drainage due to sea level rise and land subsidence. Indonesian coastal cities are flooded regularly. In 2007, Jakarta experienced a severe flood that submerged parts of the city under 5 metres of water, killing 46 people.

In 2020, flooding in the city also left 66 people dead and displaced more than 36,000. By 2055 the number of Indonesians exposed to river flooding will increase by 75%, and by 73% for those exposed to coastal hazards. In both cases, the increase is a result of both population growth and climate change bringing more intense precipitation events, rising sea levels and storm surges.

2050

Runoff increase
% of area

+35%

+18%

+9%

SURFACE SEALING AND FLOODS

Heavy precipitation in cities is problematic due to the high level of sealed surfaces. Soil sealing increases run off and reduces the amount of water absorbed by soil. Where there are large amounts of impervious ground cover, short duration extreme rainfall events can lead to increased flooding, even resulting in flash floods.

GROUND WATER ABSTRACTION AND SUBSIDENCE

Land subsidence makes global sea level rise worse by increasing the amount of flood prone areas and salt water intrusion into coastal aquifers. In Jakarta the current rate of subsidence is the fastest in the region compared to other megacities, and estimated to be as high as 11 centimetres per year.

Low income urban dwellers are the most vulnerable, as they are largely concentrated in urban peripheries, with little and low quality infrastructure.

2010

% of urban population

Population living in slums

30.6%

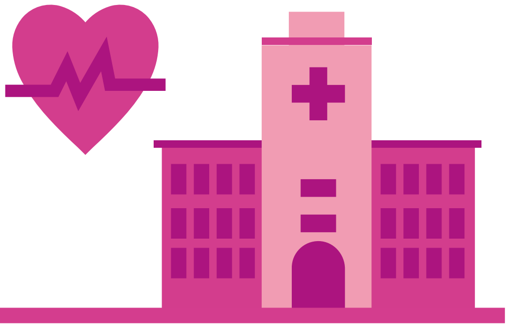
2018

% of total population

Urban population living in areas where elevation is below 5 meters

3.8%

INDONESIA
HEALTH



OVERVIEW

Indonesia has a tropical climate with a monsoonal wet season and a dry season. Topography is extremely varied, ranging from sea and coastal systems to peat swamps and montane forests. More frequent and severe heatwaves, floods, and droughts will increase the incidences of vector-borne diseases such as malaria and dengue (especially during the rainy seasons), water-borne diseases such as diarrhoea, and respiratory diseases. An increase in the incidence of severe respiratory problems due to increase in the frequency and spread of wildfires is also expected.

HEAT RELATED MORTALITY

Rapid industrialisation and a high population density render Indonesia vulnerable to the likely effects of climate change. Climate variability and climate change are already exacerbating many of the disaster risks that the country faces.

Heat-related deaths in the elderly (65+ years) are projected to increase to 53 deaths per 100,000 by 2080 under a high emissions scenario, and 8 deaths per 100,000 under a low emissions scenario - compared to a baseline of less than 1 death per 100,000 annually from 1961 to 1990. In 2018, there was a 180% increase in heat-related deaths in Indonesia compared to the 2000 to 2004 baseline, one of the highest increases in the world.

Heat-related mortality

% change with respect to 2000-2004

2018

+180%

IMPACTS ON LABOUR

Labour is directly affected by changes in environmental conditions. Warming affects both the number of hours worked (labour supply) and on the productivity of workers during their working hours (labour productivity). Both labour supply and productivity are projected to decrease under future climate change in most parts of the world, and particularly in tropical regions.

Parts of sub-Saharan Africa, south Asia, and southeast Asia are at highest risk under future warming scenarios. Future climate change will reduce global total labour in the low-exposure sectors by 18 percentage points and by24.8 percentage points in the high-exposure sectors under a 3.0°C warming scenario

Future warming is projected to significantly affect workers in high-exposure sectors in Indonesia. Total labour in Indonesia is expected to decline by 13.1% under a low emissions scenario, and by 22% under a medium emissions scenario.

Impact on total labour

% change with respect to 1986-2005 baseline

2050

-13.1%

-22.0%

2080

CLIMATE CHANGE AND DENGUE

Dengue has spread throughout the tropical world over the past 60 years and now affects over half the world's population. Globally, vectorial capacity for both dengue vectors (A. aegypti and A. albopictus) has been rising steadily since the 1980s, with nine of the ten highest years occurring since 2000.

Climatic stressors are one important driver of the current distribution and incidence of dengue. Climate change is likely to expand the geographical distribution and suitability of several vector-borne human infectious diseases including dengue. The risk of dengue transmission is increased by warming climates, as the growth and development of mosquitoes are significantly influenced by temperature, precipitation, and humidity.

CLIMATE CHANGE AND ZIKA

Zika virus has spread to at least 49 countries and territories since 2013. Climate change impacts on transmission suitability risk have increased over the years and future warming over 1.3 billion additional people could face suitable transmission temperatures for Zika by 2050.

DENGUE AND ZIKA: POPULATION AT RISK

The mean relative vectorial capacity for dengue fever transmission is projected to increase under both high and low emissions scenarios.

Under a medium emissions scenario, 86.9% of the population will be at risk of transmission-suitable mean temperature for dengue by 2050, whereas 85.6% will be at risk under a high emissions scenario. In the case of Zika, 81.8% of the population will be at risk by 2050 under a medium emissions scenario, whereas 84.3% will be at risk under a high emissions scenario.

CLIMATE CHANGE AND MALARIA

As temperatures rise and water becomes increasingly contaminated, malaria, dengue and cholera are expected to increase. By 2050 more than 98% of the Indonesian population will be at risk of malaria under a low and high emissions scenario – amounting to more than 300 million people.

POLLUTION AND PREMATURE MORTALITY

Air pollution is likely to increase the incidence of respiratory diseases and infections, as well as skin and eye irritations. 29% of deaths from ischemic heart disease, stroke, lung cancer, chronic obstructive pulmonary disease, and acute lower respiratory infections in Indonesia can be attributed to household air pollution.

Dengue suitability

% of population at risk

Zika suitability

% of population at risk

Malaria suitability

% of population at risk

INDONESIA ENERGY

ENERGY SYSTEM IN A NUTSHELL

Indonesia is rich in energy resources. It is the world's fourth-largest coal producer and first exporter (455 million tonnes in 2019), and it also exports natural gas and biofuels (of which Indonesia is the world's largest producer - mainly biodiesel from palm oil). However, internally the use of energy is moderate, and Indonesia manages to keep its energy intensity at very low levels.

0.071
ktoe/US$
Energy intensity

5.8%
AC Share in electricity consumption

CLIMATE CHANGE TODAY

EXTREME EVENTS - FLOODS AND TYPHOONS

Typhoons and the ensuing flooding have affected the operation of power plants by: soaking coal and making it impossible to burn, preventing carriers from delivering fuel, damaging power grids and causing outages.

EXTREME EVENTS -HEAT AND DROUGHTS

Drought and heatwaves affected the cooling potential of power plants and hence their efficiency.

ENERGY SUPPLY

The current (2019) energy mix of total primary energy supply in Indonesia is strongly dominated by fossil fuels (33.5% oil, 17% natural gas, 24% coal, for a total of 74.5% of total primary energy supply). Renewables account for 25.5% with wind and solar claiming over 10% of total total primary energy supply, biofuels 14.5%, while hydropower is negligible. Wind and solar underwent a 13-fold expansion since 1990. The country imports oil, but is otherwise is more than self-sufficient.

ENERGY DEMAND

In Indonesia, energy is mainly used for transport (34.8% of final demand in 2018), industry (37.5%, including 5.4% share of total demand for non-energy use) and residential (22.4%), followed by commercial use (3.9%) and agriculture (1.2%). Air conditioning's contribution to residential electricity demand was 5.8% in 2017.

FUTURE ENERGY DEMAND

Indonesia has a tropical climate; hence only cooling needs are of relevance. This is projected to result in an increase in electricity demand of 1,454 PJ (or 404 million KWh) by 2050 under a medium emissions scenario. Air conditioning units are expected to increase exponentially from 12 million units in 2016 to 236 million units in 2050.

Net change in energy demand due to changes in HDD/CDD
Billion KWh

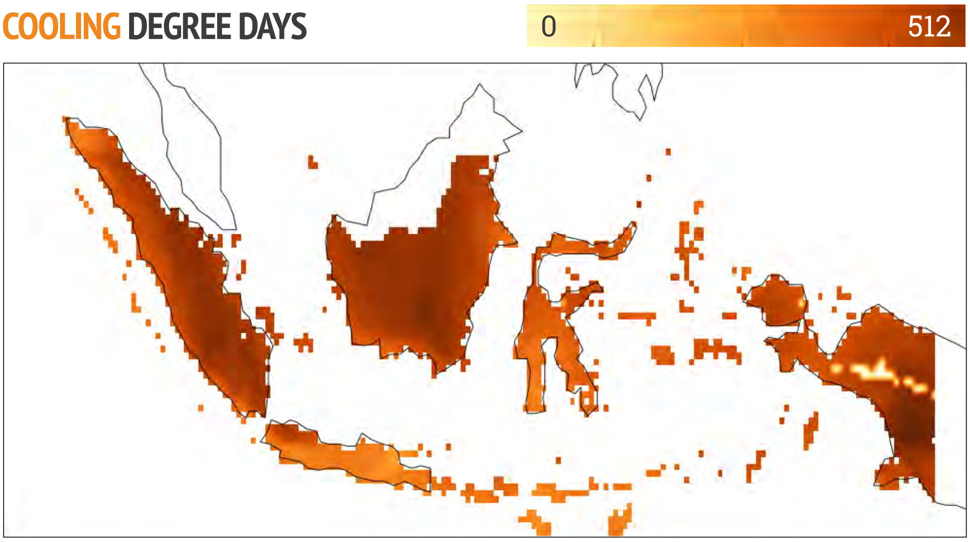
2050

+ 403.97

COOLING NEEDS

Marked increases in cooling degree days are expected all over the country particularly in the interior of the largest islands (Borneo, Sumatra and New Guinea), and in the area of Jakarta.

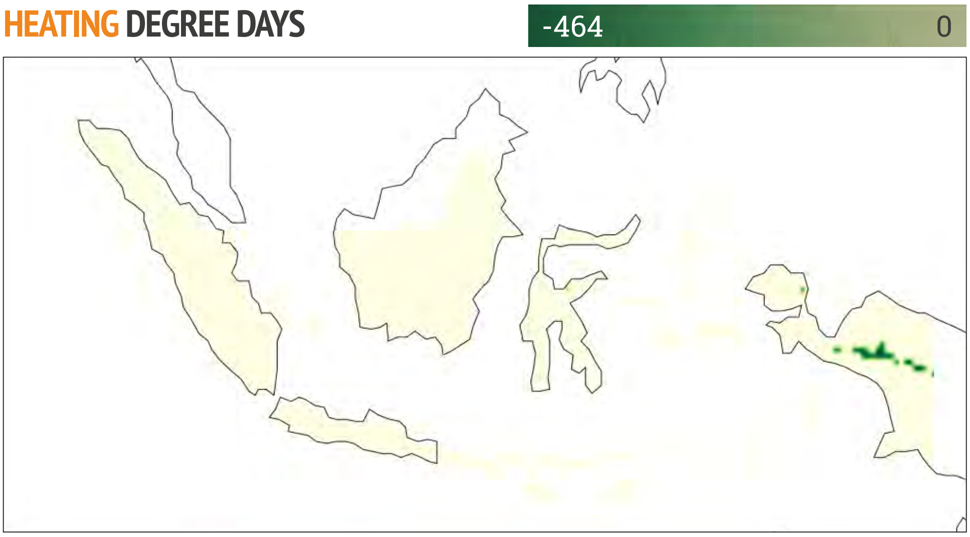
COOLING DEGREE DAYS



HEATING NEEDS

Heating needs anomalies are practically of no relevance. Nominally they affect only the mountain peaks in New Guinea which are hardly inhabited.

HEATING DEGREE DAYS



FUTURE ENERGY SUPPLY

The future configuration of the Indonesian energy mix is likely to be determined by the evolution of energy policies and hence is outside the scope of this report. There appear to be no long-term plans for decarbonization, and the recently planned investments in new coal capacity point to a prevalence, in the coming decades, of vulnerabilities related to fossil fuels.

Change in Hydropower generation
% of change

2050

-2.25%

-1.83%

EXPECTED IMPACTS OF CLIMATE CHANGE

The main concern is for the increased frequency of extreme events, in particular for coastal infrastructure, and the impact of droughts on the thermal efficiency of coal power plants.

In a perspective of increasing cooling demand, severe stress for the electricity system may result, particularly in the more densely populated and economically advanced islands.

INDONESIA
ECONOMY

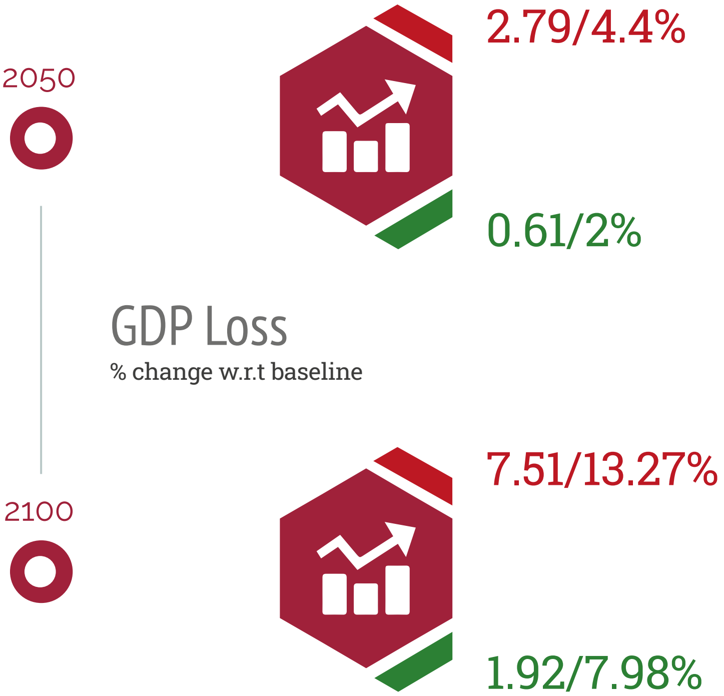
OVERVIEW

Indonesia ranks 17th in terms of GDP among G20 countries. Indonesia was hit less severely by the COVID 19 pandemic compared to other G20 countries, recording a decline in real GDP of 2.1% in 2020 and recovering in 2021 with growth in real GDP of 4.3%.

IMPACTS ON GDP

Climate change will have an effect on the growth rate and overall economic performance of the country. GDP is predicted to decline under both low and high emissions scenarios.

By mid century, costs could reach between 18 and 41 billion EUR (or 2% - 4.4% of GDP) under low and high emissions scenarios, respectively. By the end of the century costs are predicted to become even more severe: Indonesia could stand to lose up to 13.3% of GDP, or 123 billion EUR under a high emissions scenario.



2050

2.79/4.4%

0.61/2%

GDP Loss

% change w.r.t baseline

2100

7.51/13.27%

1.92/7.98%

SECTORAL ECONOMIC IMPACTS

IMPACTS ON INDUSTRY AND INFRASTRUCTURE

Indonesia is an archipelagic state made up of 17,480 islands, accordingly, flooding caused by sea level rise poses serious threats. Many significant infrastructures and economic assets, as well as a large share of the population (50-60%), are located in coastal areas.

IMPACTS ON AGRICULTURE

Agriculture is a key component of the Indonesian economy, contributing 12.8% to GDP (2018 data), and employing almost a third of the labour force. Climate change can exert differentiated impacts on Indonesian crop production.

It is predicted that by the mid century the economic value of corn and rainfed rice may increase, but this will be cancelled out by substantial losses to irrigated rice which makes up a much larger share of overall agricultural output.

Therefore, by mid century climate change is expected to result in a 4 billion EUR reduction under a medium emissions in the overall value of agricultural output. An additional 117 million EUR in damages is expected to occur in the agricultural sector as a result of coastal flooding by mid century.

IMPACTS ON FORESTRY AND FISHERY

Indonesia is the world's largest archipelagic state, and its surrounding waters are among the most fertile fishing areas in the world. The fishing sector is thus an important contributor in terms of food security and employment to the country.

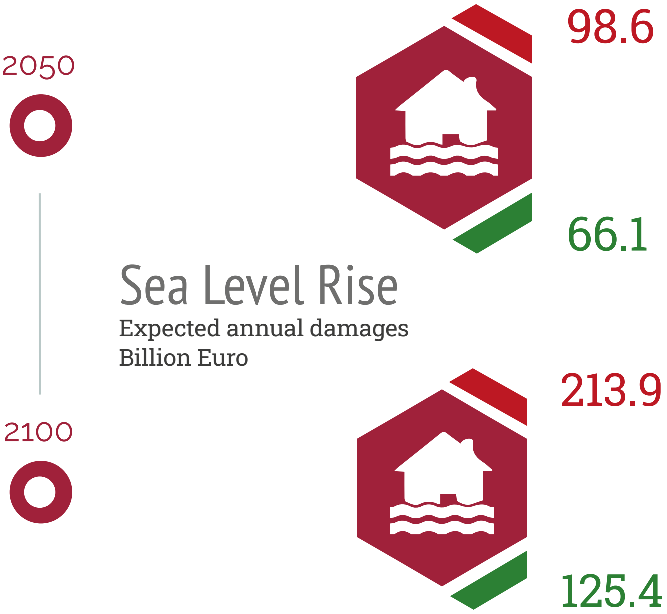
Indonesia is the second largest fish producer in the world, in 2017 fishery related exports totalled approximately 3 billion EUR and fishing activity contributed 2.56% to the country's GDP.

Climate change is projected to adversely affect fish stock and consequently catches. Indonesia is predicted to experience some of the largest reductions in fish stocks around the world with a reduction in maximum catch potential of 23% by mid century.

SEA LEVEL RISE DAMAGES

In the absence of any adaptation measures, sea level rise is predicted to increase the risks of coastal flooding and result in extensive economic losses. By mid century these costs are estimated to be 12 to 66.1 billion EUR and 98.6 billion EUR in terms of expected damages to assets under low and high emissions scenarios, respectively.

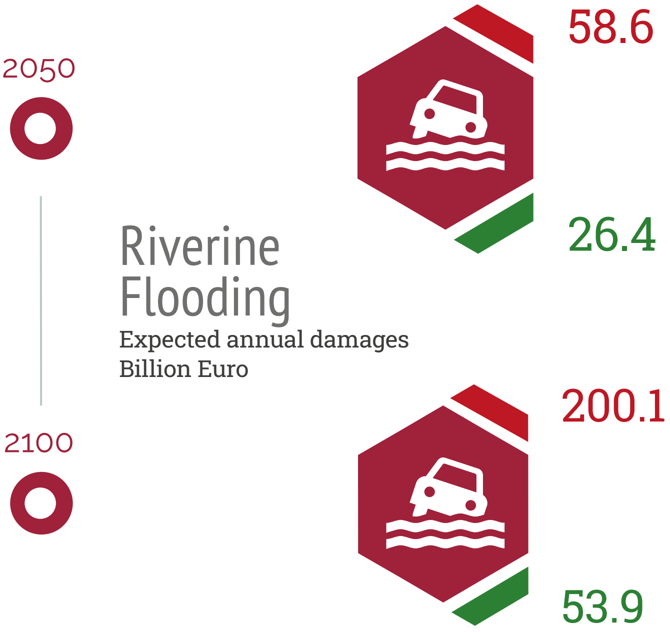
By the end of the century, the losses are projected to be between 125.4 billion and 167 billion EUR under a low emissions scenario and 213.9 billion EUR under a high emissions scenario. Regional analysis shows that the majority of economic losses from sea level rise are likely to occur in Jakarta.



RIVER FLOODING DAMAGES

Fluvial flooding will also cause damage and economic losses. Annual damages are projected to be 26.4 billion EUR under a low emissions scenario and 58.6 billion EUR under a high emissions scenario by 2050.

By the end of the century costs are projected to rise to 53.9 billion EUR under a low emissions scenario and reach 200.1 billion EUR under a high emissions scenario.



IMPACTS ON ENERGY

As with all other economic sectors, energy supply and energy networks in Indonesia will undergo more intense stress from extreme events, such as typhoons, floods and forest fires.

Economic impacts of shifts in household and firm energy demand (see chapter on energy) are difficult to predict and will mostly lead to redistribution effects. In the case of Indonesia, there is no demand for heating of any significance, and hence the large increase in cooling demand is expected to result in a substantial increase in energy bills.

IMPACTS ON TOURISM

Tourism has grown considerably in Indonesia in recent years and accounts for about 4.1% of GDP and employs 10.5% of the labour force. There is a lack of estimates on the economic impacts of climate change on the sector, but some qualitative inferences can be made.

Small island tourism is one of the most popular activities for tourists in Indonesia. Due to reliance on the country's natural resources - clear waters, aesthetic beauty, habitat for biodiversity - one can say with a high degree of certainty that the sector is extremely vulnerable to the effects of climate change and will suffer some economic losses.

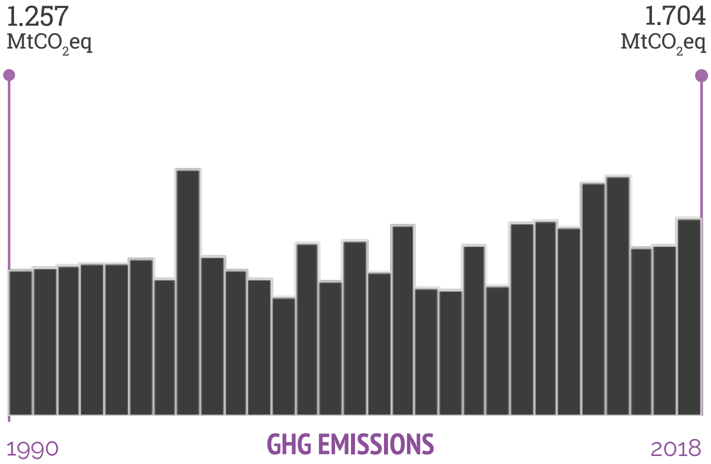
Coral bleaching is expected to increase as sea temperatures rise, reducing the natural beauty and attraction of coral reefs for tourists and locals alike.

Additionally, coastal erosion and the loss of beaches poses serious threats for coastal tourist areas, for instance Bali, where 80% of the population rely on tourism related industries as a source of income. Tourism in low-lying areas will be particularly vulnerable, where built up areas are located very close to the sea with virtually no buffer zone. These areas could become completely inundated by waves during extreme high tides resulting in economic losses.

INDONESIA
POLICY

OVERVIEW

Indonesia is the 4th most populous country in the world, accounting for 3.5% of global emissions. Emissions trends are not steady, as these are highly dependent on land use change and forest wildfire emissions which can vary greatly from year to year.



INTERNATIONAL COMMITMENTS

Indonesia ratified the Paris Agreement in 2016. In its NDC, Indonesia commits to decrease emissions by 26% in 2020 and by 29% in 2030, with reference to a business as usual scenario.

CLIMATE POLICY COMMITMENTS CHRONOLOGY

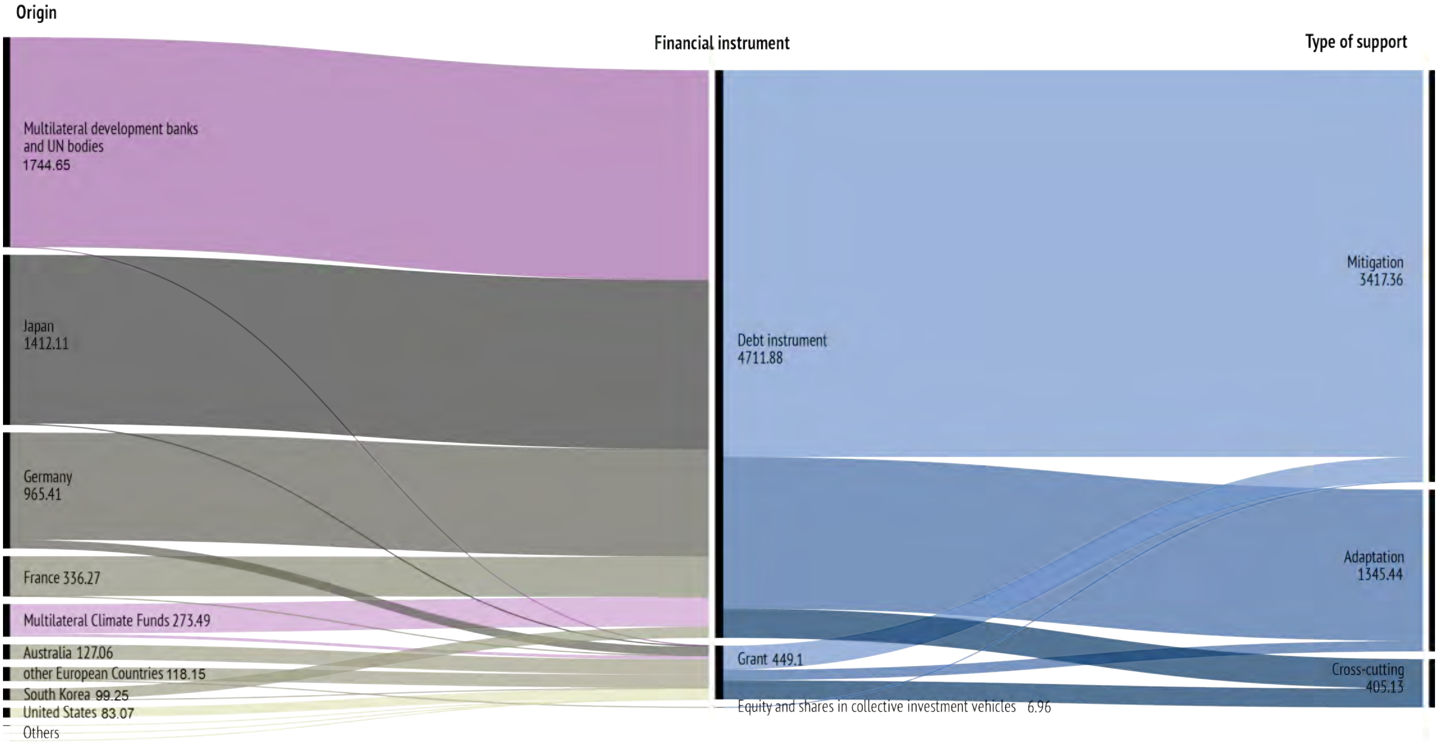
2004 **KYOTO PROTOCOL - 1ST PERIOD**
No target

2016 **PARIS AGREEMENT - 1ST NDC**
26% reduction in GHG by 2020 and 29% reduction by 2030, with reference to a specific business-as-usual scenario

2021 **PARIS AGREEMENT - NDC UPDATE**
Submitted. Commitments unchanged

INTERNATIONAL CLIMATE FINANCE ASSISTANCE

According to OECD DAC data, Indonesia received 5.1 billion USD in climate-related development aid in 2017-2018. Bilateral agreements are the main sources of finance, in particular from Japan and Germany. Debt represents the main instrument. Mitigation accounts for the majority of finance.



SUSTAINABLE RECOVERY POLICY

In 2020, the amount of funds dedicated to post-covid recovery was negligible: 150 million USD. No resources were dedicated to sustainable investments according to the Global Recovery Observatory.

84.35 billion $	0.15 billion $	0 billion $
Total Spending	Recovery Spending	Green Spending

DOMESTIC ADAPTATION POLICY

Indonesia mentions adaptation in its NDC. The country adopted an Adaptation Strategy, but no plan. Sub-national entities are designated to plan adaptation.

○ Domestic Adaptation Policy
- ● Inclusion of Adaptation in NDCs
- ○ Integrated Adaptation & Mitigation Policy
- ● Dedicated Adaptation Strategy
- ○ Dedicated Adaptation Plan

○ Subordinate Adaptation Policies
- ○ Sectoral Adaptation Plans
- ● Subnational Adaptation Plans

○ Policy not in place ● Active policy

ADAPTATION POLICY HIGHLIGHTS

TRANSNATIONAL INITIATIVES

Coral Triangle Initiative (CTI)

CTI was launched to preserve and conserve 75,000 square kilometers of coral reef resources from the impact of climate change and simultaneously strengthen food security for fisheries through an ecosystem approach

South East Asia Network Climate Change (SEAN-CC)

The network aims to strengthen capacities of the South-East Asian governments on the area of climate change to share knowledge and experience of policy formulation and implementation

NATIONAL INITIATIVES

Adaptasi Perubahan Iklim dan Ketangguhan (APIK)

APIK integrated adaptation and disaster risk reduction into national and subnational governance frameworks. It also built the capacity of local communities to address climate change and weather-related hazards

Climate Information System of Indonesia

The national climate change information system of the national Met service in Indonesia is the result of a cooperation between GIZ and the Indonesian Weather, Climate and Geophysics Agency

SUBNATIONAL INITIATIVES

Climate Action Plans (CAP) in Balikpapan and Bogor

The 2 cities of Balikpapan and Bogor developed two CAPs based on an integrated adaptation and mitigation approach, which takes also into account other development agendas for the benefit of the wider community

Jakarta Coastal Defence Strategy

The strategy copes with flooding from the sea, a phenomenon that is increasing in frequency because of sea level rise and soil subsidence in Northern Jakarta

ENERGY TRANSITION

Indonesia has achieved significant results in the process of transformation of its energy sector and is among the top Asian countries in the overall Energy Transition indicator. Notwithstanding many issues, in particular with forestry policy which still persist, the level of CO2 emission per capita and of air pollution has diminished in recent years, with positive effects not only for climate change but also for citizen well-being. The transition pathway is also well reflected in indicators such as Renewables. In these domains, the country has entered into a positive process of transformation. Nevertheless, looking at the Electrification indicator, there is still room for improvement.

	G20 AVERAGE	COUNTRY
Energy Transition	58.7	61.5
Fossil Fuels	45.3	55.9
Renewables	19.7	23.5
Efficiency	84.9	77.3
Electrification	70.8	64.9
Emissions	72.9	86.1

Only actively pursuing an energy transition based on decarbonization and electrification – from policy and regulation, to health and education – will enable countries to benefit the most from future opportunities and fight climate change whilst ensuring an equitable distribution of wealth.

The Energy Transition indicators were developed by Enel Foundation in cooperation with SACE, and provide a retrospective analysis based on historical data.

G20 CLIMATE RISK ATLAS

Impacts, policy, economics

ITALY

How to read the Atlas: graphs, colours and scenarios.

The maps used in this Atlas are taken from **The World Bank Official Boundaries** - ***https://datacatalog.worldbank.org/search/dataset/0038272*** (accessed on May 28, 2021). For the section Energy, the maps are based on Panoply Data Viewer ***https://www.giss.nasa.gov/tools/panoply/credits.html***

Each sector of this Atlas contains data and information on various climate scenarios.

When reported in graphs, the **colour black** indicates data and information referring to the current state, the past or the baseline.

When the authors refer to **RCP (Representative Concentration Pathways)**, the 3 colours used across the factsheet refer to 3 scenarios, which are 3 different development options with different levels of greenhouse gas emissions, **respectively low emissions (green), medium emissions (orange), and high emissions (red)**. The same colour code is used when RCPs are associated with Shared Socioeconomic Pathways (SSP).

In some cases, the authors refer to global warming scenarios. In these cases, the 3 colours used refer to a temperature rise of **1.5°C (green), 2°C (dark green), and 4°C (red)**.

When the authors refer exclusively to **Shared Socioeconomic Pathways - SSPs** (Population affected by river floods in the section: "Water"), data related to **SSP3** - that encompasses, among other things, slow economic growth, material-intensive consumption, and persisting or worsening inequalities – **are reported in a lighter shade**; **SSP5** – which refers to social and economic development that is coupled with an energy-intensive lifestyle and the abundant exploitation of fossil fuel resources – is shown using a **middle shade of the colour**, whereas data related to **the present** conditions **are represented in a dark shade**.

Further details on scenarios, methodologies, and the full list of references are available at: **www.g20climaterisks.org**

Concept and graphic design by element6.eu

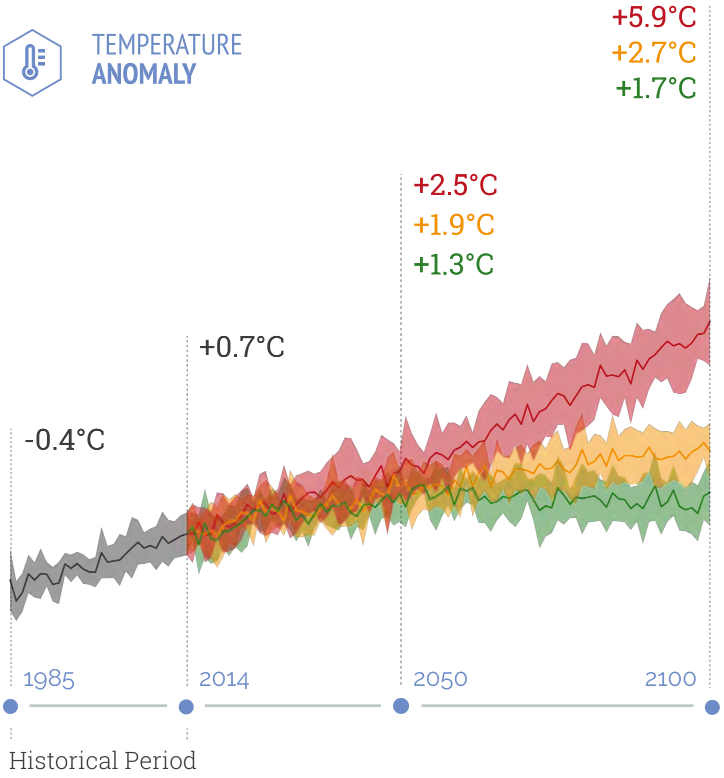
ITALY
CLIMATE

OVERVIEW

Italy is characterized by an extremely variable climate, which is mainly due to the long extension of the country and its geographical position. The northern part exhibits a climate that is similar to the European continent whereas in the South is typically Mediterranean. Finally, the Alps are relativity cold with very peculiar climate features.

TEMPERATURE PROJECTIONS

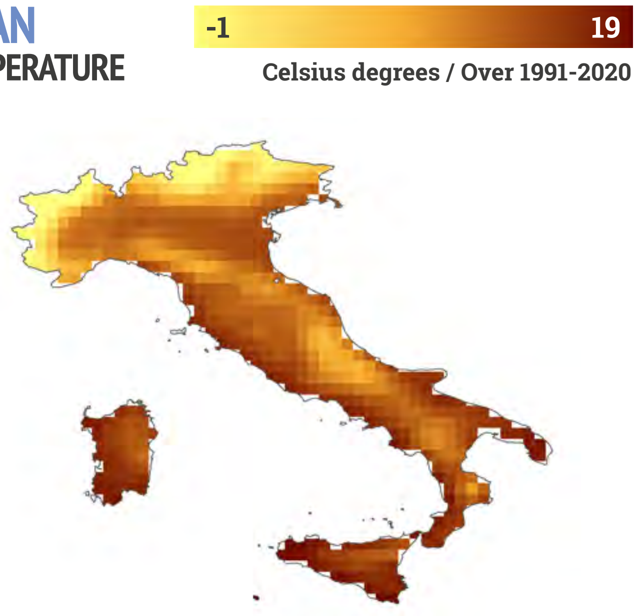
Under a low emissions scenario projected temperature variations will remain contained at around +1.5°C, both by 2050 and 2100.
Under a high emissions scenario, with no reduction in GHG emissions, much greater temperature anomalies are expected by both 2050 and 2100.



TEMPERATURE

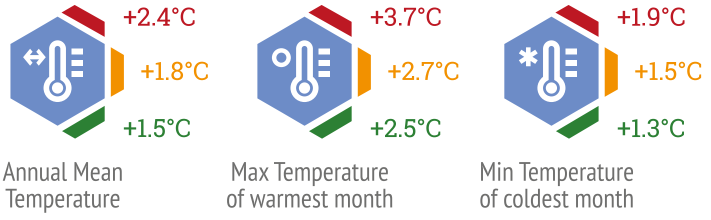
Temperatures in Italy are regulated by the complex orography, ranging from high mountain chains (Alps and Apennines) to a very diverse coastline. Overall, temperatures are lower in Northern Italy and higher in Southern Italy.

MEAN TEMPERATURE



EXPECTED VARIATION FOR TEMPERATURE AT 2050

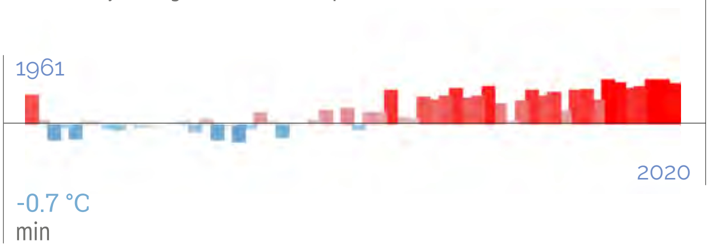
The indicators show variations in selected temperature characteristics for a thirty-year period centred on 2050 (2036-2065) with respect to the reference period 1985-2014.



+2.4°C +1.8°C +1.5°C	+3.7°C +2.7°C +2.5°C	+1.9°C +1.5°C +1.3°C
Annual Mean Temperature	Max Temperature of warmest month	Min Temperature of coldest month

TEMPERATURE TREND

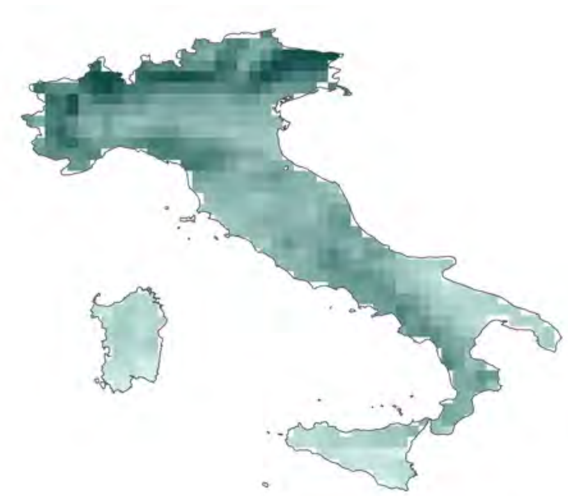
Temperature anomalies over the last 60 years with respect to the annual mean of 13°C in Italy during the 1961-1990 period



PRECIPITATION

The precipitation regime changes a lot due to the complex orography and occurrence of different precipitation dynamics.
The Alps have the highest annual precipitation values, followed by the Apennine mountains, which run down the entire peninsula.
Precipitation patterns show neither pronounced nor constant trends on the Italian territory, due to the complexity of the precipitation regime and to possible compensation between opposite patterns reported at a local level.

MEAN PRECIPITATION



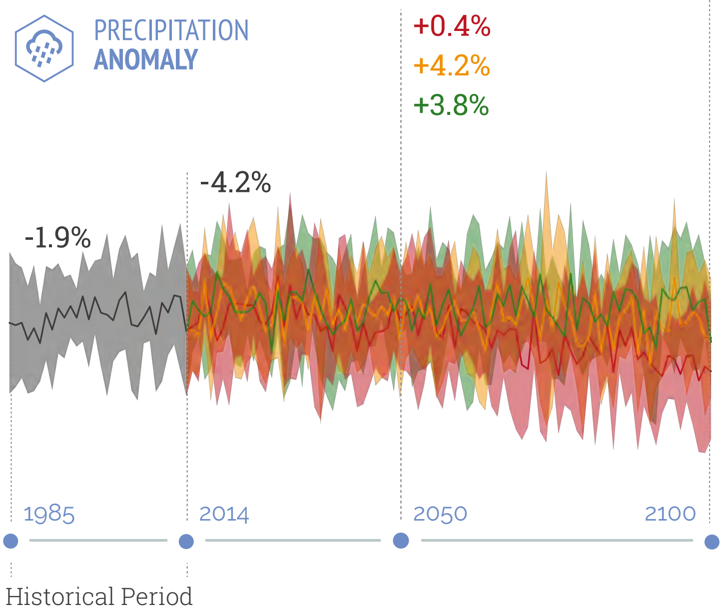
PRECIPITATION TREND

Precipiation anomalies over the last 60 years with respect to the annual mean of 1,025 mm/year in Italy during the 1961-1990 period

PRECIPITATION PROJECTIONS

Precipitation trends show a very complex signal, under all emissions scenarios, with a very large variability among climate models. This can be explained considering the complexity of the precipitation regime and dynamics requiring more detailed spatial and temporal analysis.

PRECIPITATION ANOMALY



EXPECTED VARIATION FOR PRECIPITATION AT 2050

The indicators show variations in selected precipitation characteristics for a thirty-year period centred on 2050 (2036-2065) with respect to the reference period 1985-2014.

-2.1%
+0.4%
+1.5%
Annual total precipitation

+0.8%
+2.4%
+4.8%
Precipitation of wettest month

-7.2%
-4.4%
-5.4%
Precipitation of warmest quarter

VARIATION OF SPECIFIC CLIMATE INDICATORS

Climate indicators variation showing impacts of climate change on sectors such as agriculture, health and water. Analysis considers 3 threshold average temperature increase: **+1.5°C**, **+2°C**, **+4°C**.

+35%
+19%
+14%
Agricultural drought proportion of time
% of time

+31%
+15%
+12%
Hydrological drought proportion of time
% of time

+1,461%
+261%
+100%
Heatwave duration
% of time

+59%
+29%
+10%
Runoff increase
% of area

+74%
+50%
+35%
Agricultural drought frequency
% of change

+17%
+12%
+14%
Hydrological drought frequency
% of change

+80%
+35%
+21%
Heatwave frequency
% of change

+10%
+6%
+4%
Runoff decrease
% of area

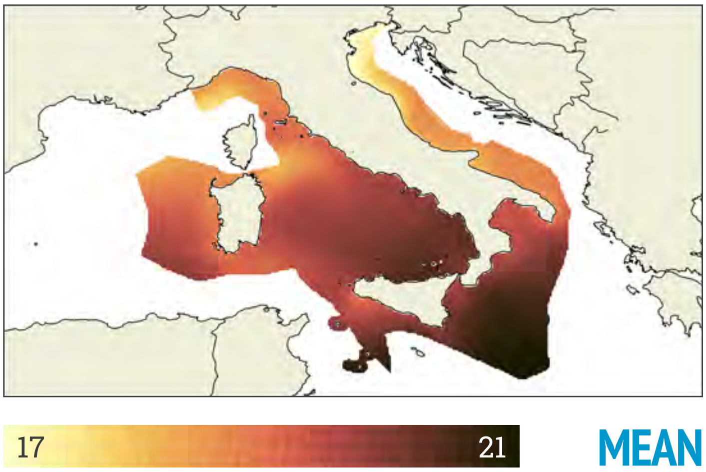
ITALY
OCEAN

OCEAN IN ITALY

Italy's marine exclusive economic zone (EEZ) is mainly characterized by a Mediterranean climate and hosts a large variety of ecosystems such as seagrass meadows, coral reefs, and lagoons. The wide ensemble of coastal systems can be divided into three main subbasins: the Adriatic, Ionian, and Tyrrhenian seas.

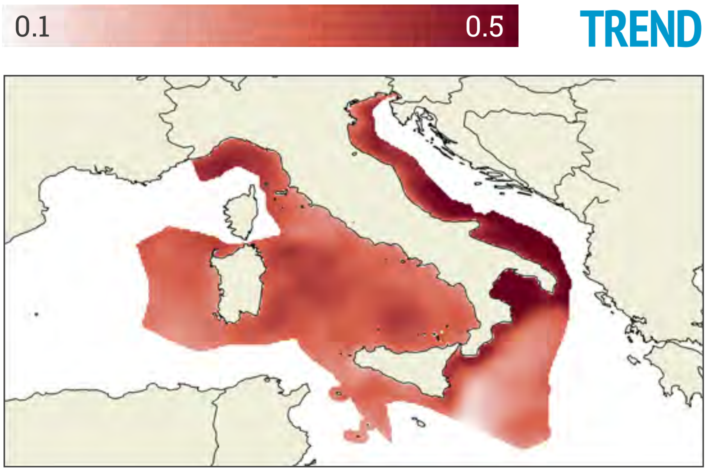
CURRENT CLIMATE CONDITIONS

Mean sea surface temperature reflects the Mediterranean climate regime, with cold waters located in the northern areas and warmer ones along the southern coasts.



SEA SURFACE TEMPERATURE

Celsius degrees / Over 1991-2020

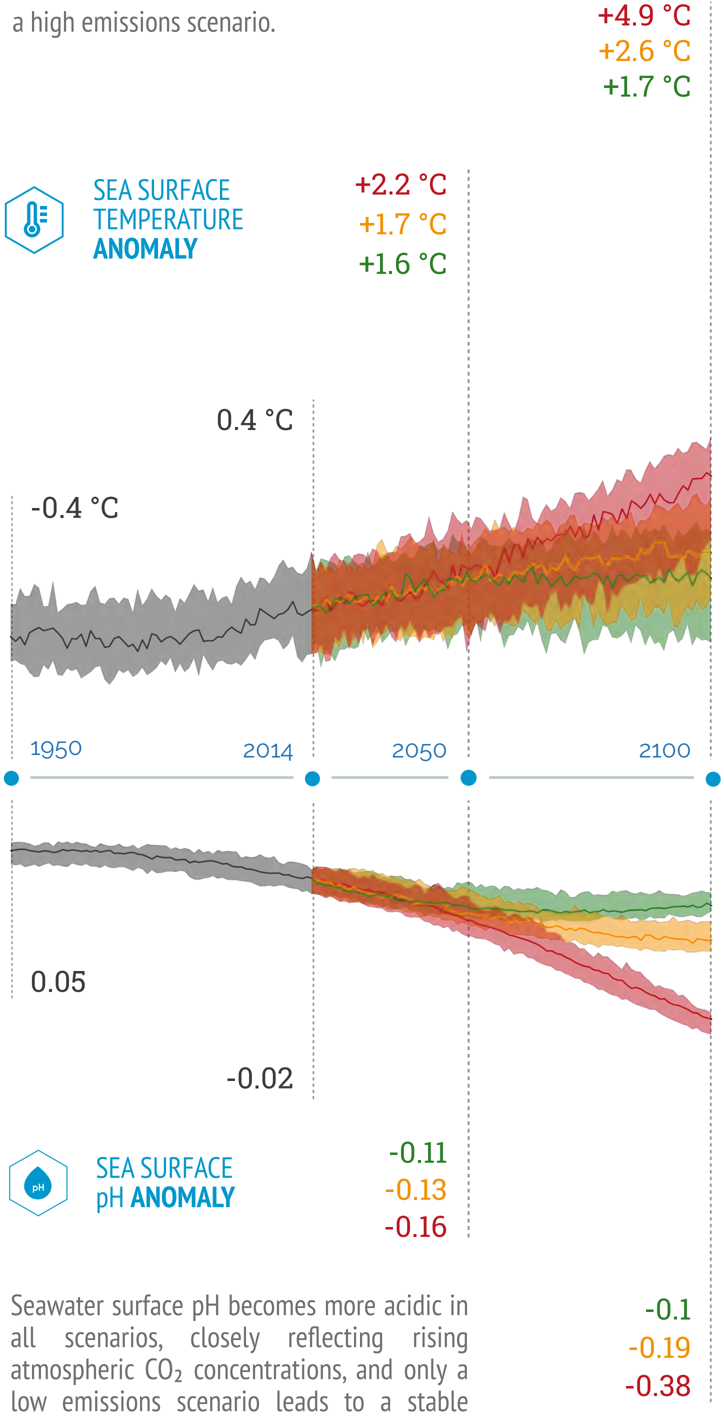


Surface temperature trends indicate a general warming of 0.5°C per decade in all marine areas.

FUTURE PROJECTIONS

Projected annual changes within the marine EEZ for the two most significant marine indicators of climate change: sea surface water temperatures and pH.

Seawater temperature changes are in line with the definitions of each scenario, with maximum values in 2100 close to +5°C under a high emissions scenario.



Seawater surface pH becomes more acidic in all scenarios, closely reflecting rising atmospheric CO_2 concentrations, and only a low emissions scenario leads to a stable condition by 2100.

ECOSYSTEM INDICATORS AT 2050

Regional changes in key marine ecosystem indicators under projected future scenarios by mid-century (2036-2065) with respect to present climate conditions (1985-2014).

	Adriatic	Ionian	Tyrrhenian
Temperature regulates the metabolism of marine organisms determining which habitats remain suitable. Excessive warming will likely push ecosystems beyond tolerance thresholds.	17.94°C 🟥 +2.12 °C 🟧 +1.72 °C 🟩 +1.71 °C	19.44°C 🟥 +2.62 °C 🟧 +1.83 °C 🟩 +1.67 °C	18.78°C 🟥 +2.16 °C 🟧 +1.56 °C 🟩 +1.68 °C
pH represents the acid/base status of marine waters, where a decreasing pH reflects the acidification of the ocean due to increased absorption of atmospheric CO_2.	8.11 🟥 -0.16 🟧 -0.13 🟩 -0.1	8.1 🟥 -0.16 🟧 -0.13 🟩 -0.11	8.11 🟥 -0.16 🟧 -0.13 🟩 -0.11
Oxygen is fundamental to sustain marine life and its reduction can have a large impact on coastal ecosystem services including fisheries and aquaculture.	242.17 mmol/m^3 🟥 -4.96 % 🟧 -3.48 % 🟩 -3.03 %	233.36 mmol/m^3 🟥 -4.46 % 🟧 -3.03 % 🟩 -2.5 %	236.54 mmol/m^3 🟥 -3.04 % 🟧 -2.1 % 🟩 -1.54 %
Chlorophyll is an indicator of the biomass available at the base of the marine food web supporting all ecosystem productivity.	0.17 mg/m^3 🟥 -0.59 % 🟧 +22.35 % 🟩 +4.12 %	0.13 mg/m^3 🟥 0 % 🟧 -27.48 % 🟩 -14.5 %	0.1 mg/m^3 🟥 +13 % 🟧 -7 % 🟩 -4 %

FISH CATCH POTENTIAL

Fish catch potential is an estimate of the maximum fish catch achievable given the marine resources available over a sustained period. It is linked to the concept of maximum sustainable yield, meaning the maximum amount of fish that can be extracted from a system without causing a collapse in fish populations.

It is a characteristic of the natural system, which is substantially different from realized catch, and a direct result of the fishery policy in place.

While no specific data is available for the Italian EEZ, a decrease between 0 and 5% in potential catch for the Mediterranean Sea at mid century has been projected under a high emissions scenario.

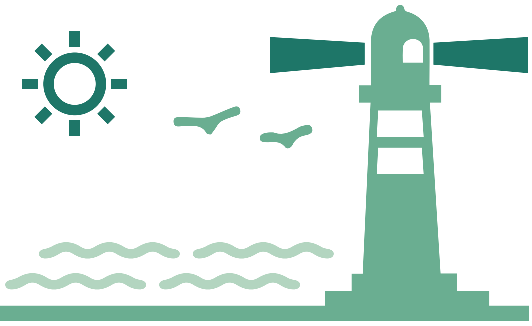
ANALYSIS DETAILS

All datasets were analysed using only data from within the marine EEZ and therefore excluding overseas territories, detached islands and any disputed or joint territories with other nations. In the assessment of current climate conditions, seawater surface tempereperature data was obtained using satellite observations distributed in the framework of ESA Climate Change Initiative.

Future projections of marine indicators are represented by the combined analysis of results from 15 different Earth System models participating in the Coupled Model Intercomparison Project Phase 6 (CMIP6). These models include new and better representations of physical and biogeochemical processes, compared to previous IPCC assessment reports.

Fish catch potential data was obtained using the FAO's technical report and refers to the best and worst case climate scenarios from the Fifth IPCC Assessment Report. These mean estimates are subject to substantial uncertainties as discussed in the original work.

ITALY
COASTS



OVERVIEW

Surrounded by the Mediterranean and Adriatic seas, and with a total length of over 9,000 kilometres, Italy's coastline is exceptionally geographically diverse as well as both historically and economically valuable for the country. Among the coastlines most notable features is the variety of natural features such as rocky and sandy beaches, cliffs, river deltas, wetlands and lagoons. It is also home to a significant proportion of the population.

Shoreline Length

9,226 km

Sandy Coast Retreat at 2050

-17.4 m

CLIMATE CHANGE HAZARDS

Coastal hazards such as erosion, storm tide inundation and permanent flooding, can have strong adverse impacts on coastal regions, with loss of sandy shores, damage to settlements, infrastructure and ecosystems. Climate change can exacerbate these impacts due to rising sea levels and increasing impacts of waves and storms. Coastal erosion and temporary inundation due to storms are quite common along the Italian coast, in particular in areas with low lying beaches. The country has already begun to feel the impacts of sea level rise, with numerous areas being exposed to the impact of inundation and storms, such as the North Adriatic Sea and the Venetian lagoon.

SEA LEVEL RISE

Based on observational data, the average sea level rise for Italy has been estimated at 1.64 millimetres per year since 1903, with the Northern Adriatic area identified as one of the most susceptible to sea level rise. The latest IPCC projections indicate that, by 2050, global sea levels may rise between 0.18 metres, under a low emissions scenario, and 0.23 metres, under a high emissions scenario.

Observed and projected sea level rise at 2050

1.64 mm/year

0.23 m

0.18 m

EXTREME SEA LEVEL

On average, one in 100 extreme sea level events are expected to rise from 1.12 metres at present day to 1.31 metres by 2050 under a medium emissions scenario.

Current and projected extreme sea level at 2050

1.12 m

1.39 m

1.31 m

OBSERVED STORMS

Several regions of the Italian coast, such as the low-lying and subsiding Po Delta, are vulnerable to the effects of storm surges and extreme waves. Although the Mediterranean Sea sees relatively small tides and low energy storms an increasing number of extreme events are being observed, causing alarm due to fears of erosion and other damages, particularly given a rising coastal population.

FUTURE STORMS

A projected increase in the frequency and intensity of extreme waves and storms could worsen the coastal impacts of climate change significantly, especially when considered in combination with sea level rise, which will increase the probability of such events as well as compounding their severity. Although it is possible that storms may not increase in severity in a significant way, expected sea level rise is likely to lead to more severe impacts.

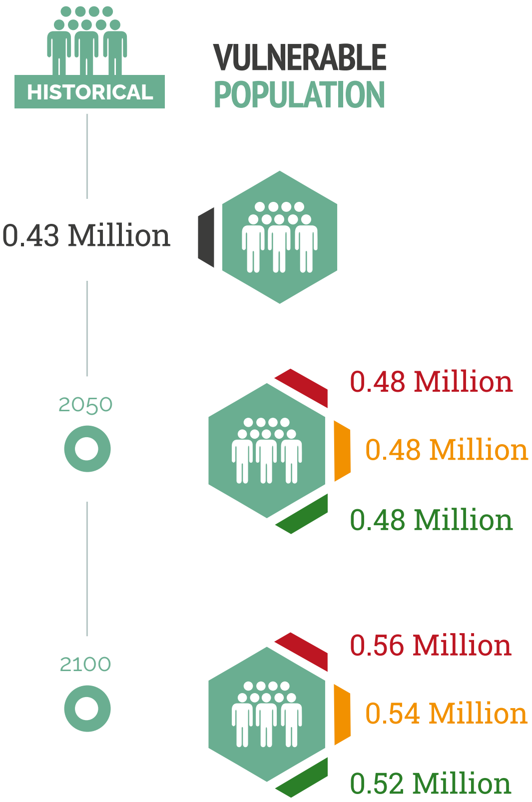
VULNERABILITY AND RISK

Several important sectors are particularly vulnerable to climatic risks, including coastal tourism, which is hugely important to the Italian economy, as well as industrial activities and important infrastructure and assets.

Of particular note is the historic city of Venice, which is already facing significant impacts from sea level rise and storm surges, threatening many points of cultural heritage.

Numerous Italian localities suffer from chronic beach erosion and coastal risks have been increasing in the past few years, going hand in hand with increasing costs of shoreline protection and management.

Furthermore, the fragile ecosystems that can be found in coastal areas, and the wildlife that inhabits them, will be threatened by degradation, saltwater intrusion, and loss of habitat. Under a medium emissions scenario, the population exposed to the annual coastal flood level is expected to increase from 430,000 to 480,0000 people by 2050.



VULNERABLE POPULATION

HISTORICAL

0.43 Million

2050

0.48 Million

0.48 Million

0.48 Million

2100

0.56 Million

0.54 Million

0.52 Million

INFLUENCE OF SEA LEVEL RISE ON EXTREME SEA LEVEL

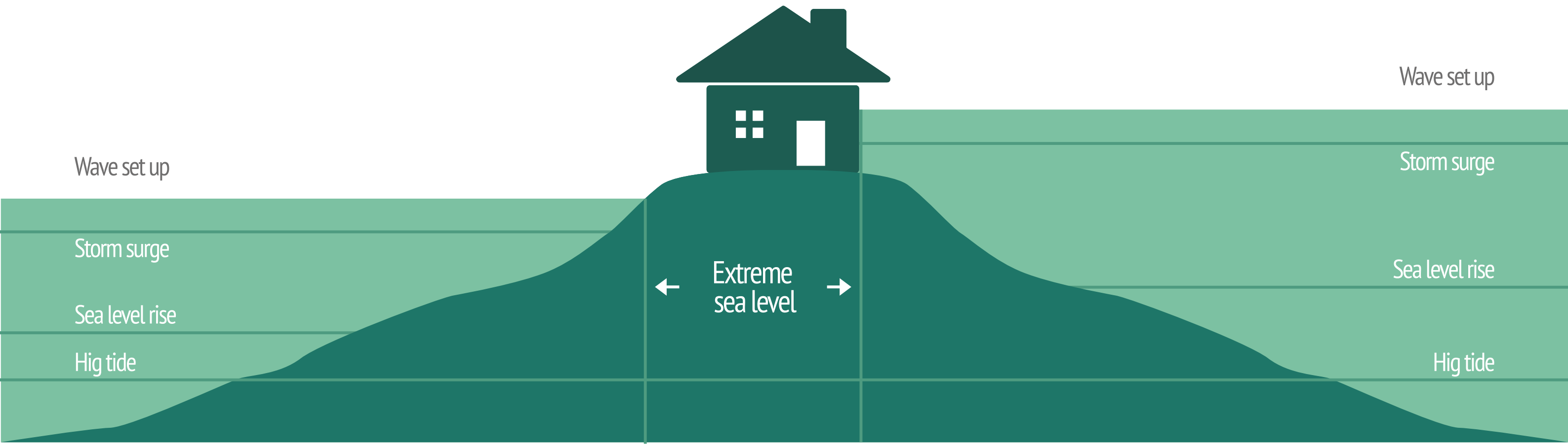
Present and future sea level rise are a consequence of carbon induced global warming causing melting ice and ocean expansion due to heat accumulation.

The extreme sea levels reported here are based on the 100-year storm surge + wave set up + sea level rise + high tide indicators. The first two parameters (storm surge + wave set up) are based on the 100-year value for the event; sea level rise is its projected value at 2050; and high tide is the absolute value of the highest tide calculated for a given locality, which won't be influenced by climate change.

+ **Wave set up** refers to the accumulation of water near the shore due to the presence of breaking waves.

+ **Storm surge** is an occasional increase in sea level driven by shoreward wind-driven water circulation and atmospheric pressure.

+ **High tide** is usually the highest tide reached in a given location based on tide records.



Present sea levels have risen globally by approximately 20 centimetres over the past century.

Future sea level rise is a projection based on different global warming scenarios, at approximately 100 centimetres by the end of 2100, with consequent inundation during extreme sea level events.

ITALY
WATER

OVERVIEW

Italy's water resource distribution is driven by a highly variable annual rainfall, both in volume and spatial distribution. The trend over time and the distribution of cumulative annual rainfall are quite diversified.

This variability affects runoff, streamflow, groundwater recharge and water availability for human activities. Due to its geographical distribution, Italy experiences great meteorological variability from one region to the other, which affects the availability of natural water resources.

The main rivers and the largest lakes are located in the northern and central parts of the country.

Renewable internal freshwater resources — 183 billion m^3

Renewable internal freshwater resources per capita — 3,014 m^3

Italy's water resources are distributed as follows: 60% agriculture, 25% energy and industrial sector, and 15% civil uses. Inefficiencies in distribution networks result in losses of around 40% for both drinking and irrigation waters. The most important rivers in Italy are located in the North of the country, including the Po, Adige and Brenta.

CLIMATE CHANGE HAZARDS

Climate change can affect water resources through increasing temperatures, higher rates of evapotranspiration and altered rainfall patterns. This leads to changes in the water cycle, including decrease of snow and ice coverage, alterations of surface runoff and groundwater storage, as well as drought and flood occurrence. Italy's water security has been deeply affected by climate change: the country is prone to water-related hazards and climate change is expected to increase its vulnerability in coming decades. In the north of Italy, cities that are vulnerable to extreme weather events, such as Venice and its lagoon, are particularly at risk.

KEY POINT RUNOFF

Marked variations in the fluvial seasonal streamflow may be observed due to climate change. In particular, an increase of the flow rate is expected in winter in the Alps and at high altitudes, along with a decrease in the Po river, in the Italian plains and in summer, due to the changes in the snow line and in the water/glacial reservoirs.

At a country scale, an average decrease in surface runoff by approximately -6% and -2% is expected respectively under low and medium emissions scenarios for the 2045-2055 period compared to 2015-2025.

If temperatures rise by 1.5°C, 2°C or 4°C, 4%, 6.1% or 10% of the area of the country will likely experience an increase in runoff, while 10%, 28.6% and 59% of the surface of the country will likely experience a decrease in runoff, respectively.

2050

Changes in annual runoff
% of change

-2.3%

-6.3%

2050

Runoff increase
% of area

+10.0%

+4.0%

KEY POINT DROUGHTS

The central and southern regions of Italy are more likely to experience severe drought events: a common feature of Mediterranean droughts is the persistence of high pressure systems. In the Mediterranean area, drought seems to be connected to La Niña, an anomalously high cooling of the equatorial Pacific Ocean; out of 14 La Niña events, occurring between 1865 and 1990, 13 were associated with droughts in the Mediterranean area. In southern Italy, a widespread decreasing trend of annual rainfall is observed over 97% of the whole area from 1921 to 2001.

The likelihood of severe droughts in Italy is expected to increase by 6%, 19.6% and 23.6% (2040-2059) under low, medium and high emissions scenarios. Similarly, If temperatures rise by 1.5°C, 2°C or 4°C, there is an expected increase of hydrological drought frequency by 11%, 12.2% and 13%, respectively.

2050

Severe drought likelihood increase

% of change

+23.6%

+14.0%

2050

Hydrological drought frequency

% of change

+17.0%

+10.0%

2050

Groundwater Recharge

% of change

-6.8%

+5.9%

KEY POINT GROUNDWATER

Italy is one of the European countries where problems of groundwater overexploitation and subsequent salinization are felt most severely. Groundwater recharge in Italy shows a declining trend, with consequent shrinking of fresh groundwater resources, especially in coastal areas.

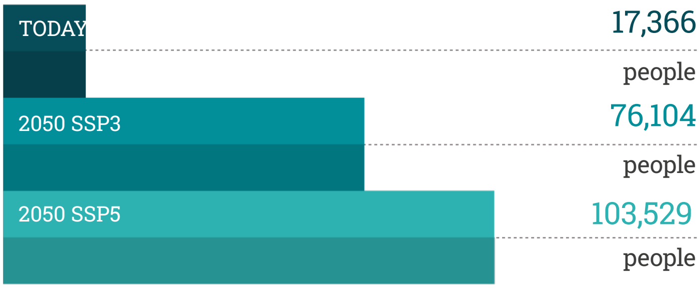
Due to the general decreasing precipitation trend in Italy (especially in the center and south of the peninsula), groundwater recharge is threatened, in particular in the least rainy regions. In addition, coastal groundwater may be susceptible to changes in salinity because of saltwater intrusion, associated with sea level rise. At the country level, a +5.9%, -1.7% and -6.8% change of the annual groundwater recharge for the period 2040-2060 compared to the timeframe 2010-2030 is expected respectively under under low, medium and high emissions scenarios.

KEY POINT FLOODS

Italy is prone to floods, with 28 large events affecting Italy between 1939 and 2004, causing 694 victims, leaving 1.5 million people homeless, 2.85 million people affected and vast economic damage. Many Italian cities have experienced severe flooding events in recent years: for instance, in Rome, between 2010 and 2019, 18 flash flood events occurred; in Milan 23 analogous events, 17 of them related to flooding of the Seveso and Lambro rivers.

Changes in the population exposed to floods are expected, with an increase from about 17,000 in the present day to 76,000 under SSP3 and 103,000 under SSP5 by 2050. As such, potential impacts related to river floods might increase.

POPULATION AFFECTED BY RIVER FLOODS

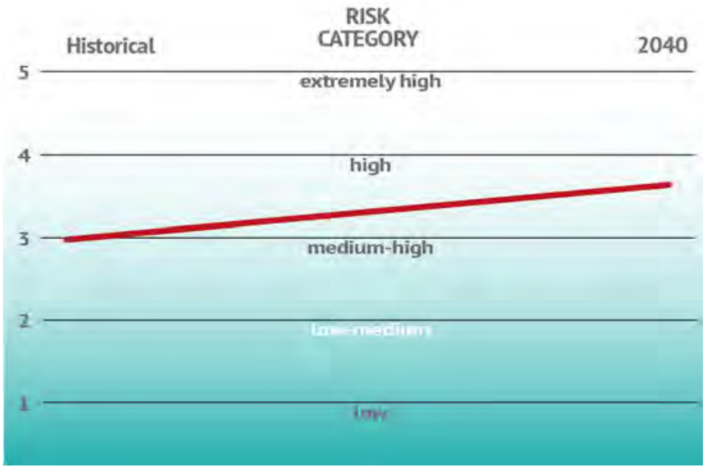


RISK INDICATORS

The water stress index summarises current and future water related vulnerabilities and risks at the global level. Scores are based on the ratio of total water withdrawals, including agriculture, industrial and human consumption, to available renewable surface and groundwater supplies.

WATER STRESS

Italy's water stress level is considered high for the recent past (1960-2014 average), and it is expected to increase in the near future (2030-2050) based on climate change projections.



ITALY
AGRICULTURE

OVERVIEW

Italy is a major agricultural producer and exporter, with agriculture still a relevant sector in terms of GDP and employment.

The Italian landscape and its agriculture are highly diversified, ranging from highly intensive farming in northern Italy to extremely marginal and fragmented farms in mountain zones and southern Italy. More than half of the total agricultural area is cultivated with arable crops (54.5%), whereas the rest features grasslands and pastures (26.7%) and agricultural woody crops (18.5%). Maize and wheat account for about 80% of total cereal production. Among tree crops, the cultivation of olive and grapes stand out.

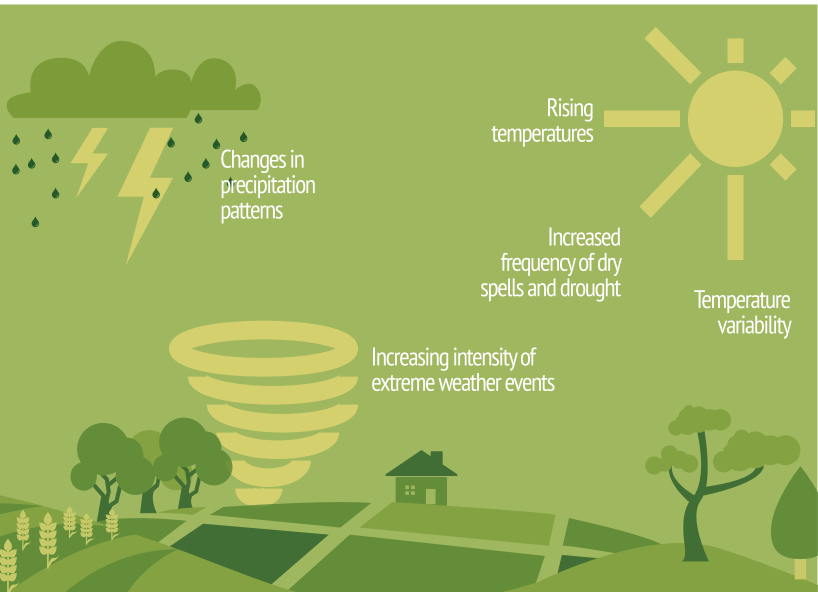
Irrigation adsorbs about 50% of total water withdrawal, and is mostly used for maize, vegetables, fodder crops and several tree crops (olives, grapes, citrus, etc.).

8.5 Mt	Grapes
7.1 Mt	Wheat
6.2 Mt	Maize
5.7 Mt	Tomato
2.5 Mt	Citrus
1.9 Mt	Olives

	Added Value of Agriculture, Forestry and Fishing	Share of Agriculture Value added in Total GDP	Agricultural land	Area Equipped for Irrigation
2000	38,294 USD Million	2.1 %	11,284 Thousand HA	3,856 Thousand HA
2018	36,655 USD Million	1.9 %	9,160 Thousand HA	4,124 Thousand HA

EXPEXTED IMPACTS ON AGRICULTURE PRODUCTIVITY

Rising temperatures, reduction in average annual precipitation, and intensification of extreme events such as heat waves and drought, affect production variability with a tendency towards yield reduction for many cultivated species, accompanied by a probable decrease in food quality. Crops respond to increases in temperatures with changes in duration of the growing season, early appearance of phenological phases and potential shifts of cultivation areas toward higher latitudes and altitudes for better growing conditions. However, impacts vary significantly depending on the geographical area and specific crops in question.



CROP PRODUCTIVITY

Crop productivity refers to the harvested yield of a crop per unit of land area. It is strongly influenced by climate and other environmental and management factors.

Climate change is expected to have an impact on the productivity of several major crops, although this may in part be offset by the fertilizing effect of higher CO_2.

Impacts are estimated using a range of model projections based on low to high emission scenarios and reported as percentage changes between the 30-year average around the historical period and the 30-year average around 2050.

3.9 Wheat tons / ha
9.4 (2.9)%
11.4 (5.7)%

10.2 Maize tons / ha
1.9 (-0.3)%
1.5 (-2.7)%

6.7 Rice tons / ha
11.2 (-1.3)%
13.7 (-0.9)%

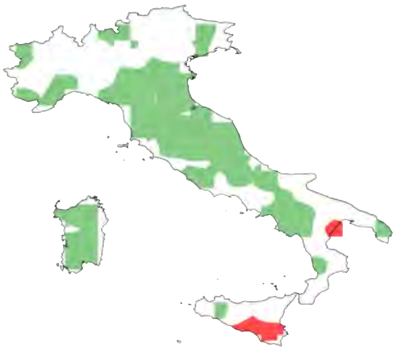
57.9 Sugarbeet tons / ha
7.8 (0.4)%
9.8 (na)%

2050

Productivity change with (without) the CO_2 fertilization effect. Estimates assume sufficient water and nutrient supplies, and do not include impacts of pests, disease, or extreme events.

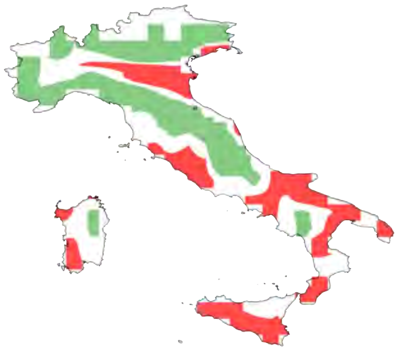
CHANGE IN WHEAT

🟥 − = 🟩 +



CHANGE IN MAIZE

🟥 − = 🟩 +



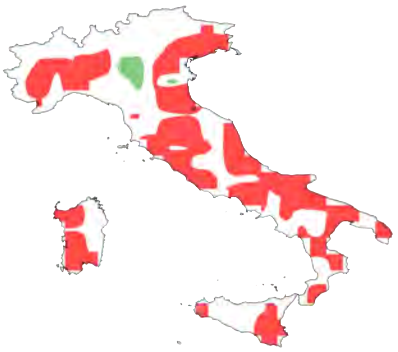
Although wheat productivity is expected to decrease in southern Italy and the major islands, it is expected to see a general increase over central and northern Italy. Maize is the main affected crop with significant losses in yield and some increases at higher elevation. Large yield reductions are also expected for spring-summer crops (sunflower, soy), especially if not irrigated. Rice may see a general yield increase until mid-century, followed by a decrease. However, rice productivity may suffer from extreme temperatures during flowering and ripening. Increasing frequency of extreme weather events during crucial crop development stages (e.g. heat stress during flowering, rainy days during sowing) may reduce yields, particularly of summer crops.
Tree crop productivity is expected to decrease in Mediterranean areas due to drought and high temperatures, which can also deteriorate fruit quality, pushing cultivation of olive and grapes towards colder regions.

ADAPTATION IN AGRICULTURE AND WATER RESOURCES

Climate change may have some positive effects on some of the most widely used crops. However, higher temperatures will generally require an increase in irrigation demand due to higher plant evapotranspiration. Agriculture may therefore become more dependent on more intensive irrigation, especially in the southern regions. Climate change may affect water resources, pointing to a severe reduction in the quantity of renewable water resources, both superficial and underground, in almost all semi-arid areas. Water deficit will worsen in the hot season when resources are scarce and demand for irrigation increases.

CHANGE IN WATER DEMAND

🟩 − = 🟥 +



Agriculture Water Demand
% of change

+17.7%
+18.8%

2050

A consistent increase in water demand (17 to 20% on average) will be required to sustain current levels of agricultural production, and it will require adaptation practices and crop varieties that enhance water-use efficiency and limit stress on water resources.

ITALY FORESTS

FORESTS IN ITALY

Forested areas in Italy, albeit largely fragmented, are considered the most important nature-based solution with which to face the unfolding climate emergency.

Due to its complex topography, Italian forests include a wide variety of types such as deciduous broadleaved woods, mediterranean sclerophyllous and boreal coniferous forests in the Alps.

FORESTED AREA AND CARBON STORAGE

With a constant increase in recent decades, Italian forests have come to cover nearly 40% of the territory. Italian forests remove approximately 46.2 million tons of carbon dioxide from the atmosphere each year, which amounts to 12.6 million tons of accumulated carbon.

1990

8 Mln ha
Million hectares
Forested area

140 Tons/ha
Tons of Carbon per hectare
Carbon stock

2020

10 Mln ha
Million hectares
Forested area

157 Tons/ha
Tons of Carbon per hectare
Carbon stock

FOREST PRODUCTIVITY

Forest productivity or Net Primary Production is the net carbon captured by plants. It is the difference between the carbon gained by Gross Primary Production - net photosynthesis measured at the ecosystem scale - and carbon released by plants' respiration. It is expressed per unit land area.

2050

Productivity anomaly
Tons of Carbon per hectare per year

+1.03

+0.77

Generalized increase expected throughout the country except for the western and eastern mountainous areas. Very marked increase under a medium emissions scenario

+ Fertilizing effect of increasing atmospheric CO_2, nitrogen deposition, rising temperature and increasing length of growing season promotes productivity

No areas with an expected decrease in forest primary production

+ Prolonged periods of drought stress reduce productivity

KEY SPECIES UNDER CLIMATE CHANGE

VULNERABILITY
SPRUCE
Forests dominated by spruce will have a very high vulnerability

SPREAD
THERMOPHILOUS
Progressive natural spread of lower altitude thermophilus species strips both in the Alps and Apennines

EXPANSION
MED OAKS
Considerable expansion of mediterranean oaks such as the holm oak, downy oak and Turkey oak

VULNERABILITY
BEECH
Negative variation in suitability values is expected for European beech, especially in the central and southern Apennines

FIRES IN ITALY

Fire is a structural ecological process that provides several types of ecosystem services and impacts on socio-ecological systems, including human health, carbon budgets, and climate change. Changes in global fire activity are influenced by multiple factors such as land-cover change, policies, and climatic conditions. Fire also releases large quantities of greenhouse gases into the atmosphere, contributing to a vicious cycle.

During the last three decades, the total area affected by fire was approximately 2.6 million hectares with 238 thousand fires occurring.

BURNING
2.6 MILLION HECTARES

EMITTING
0.83 TERAGRAMMES
OF CARBON PER YEAR

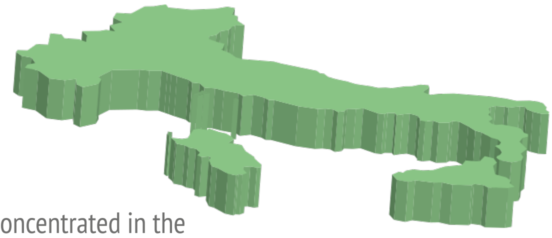
FOREST FIRE EMISSIONS
12% OF TOTAL FIRE RELATED
CARBON EMISSIONS

COSTING
580 MILLION USD IN FIRE
SUPPRESSION AND FIRE
DAMAGES IN 2005 ALONE

WHERE DO FIRES OCCUR?

Between 2000 and 2017, agricultural lands and pastures were most affected contributing to 58% of the total burned area. Heartland and shrubland fires contributed to approximately 17.2% of the total burned area.

Social factors such as unplanned urbanization, land use changes, as well as population dynamics including rural exodus and population ageing, have had a significant effect on fire event frequency, particularly in the south.



Fires are concentrated in the southern regions of Sicily, Sardinia, Calabria, and Campania during the summer months, representing 14% of total burned area in Europe over the last two decades.

The 2017 fire season was one of the worst in recent decades in terms of burned areas, with 160 thousand hectares burned, exceeding the 2008-2016 average by approximately 300%.

FUTURE BURNED AREA

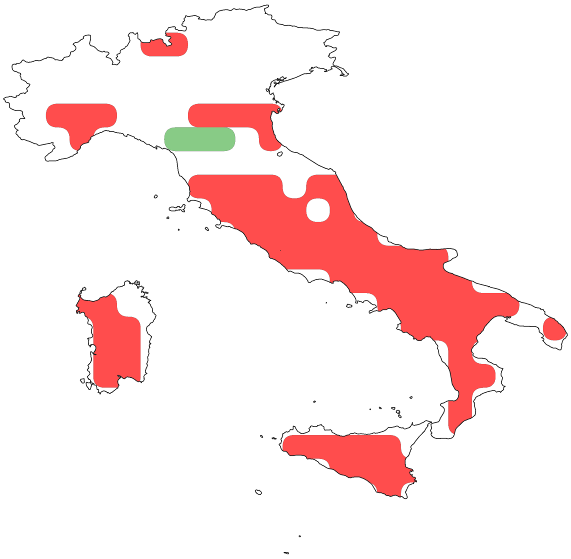
Under a low emissions scenario, models project that the burned area will mainly increase in Sardinia, Sicily, central and southern Italy. This might predominantly affect sclerophyllous and semi-deciduous forests. Burned area under a medium emissions scenario is expected to follow a similar spatial pattern.

Burned Area
km² per year

2050

+131

+120



Decrease in burned areas for a low emissions scenario

Increase in burned areas for a low emissions scenario
+ Prolonged and more intense fire seasons and an increase in future fire weather risk due to warming and drought conditions

VARIATION OF SPECIFIC FIRE INDICATORS

% of change
High fire-risk days
2041-2070
+46%

% of change
Fire season lenght
2041-2070
+11%

% of change
PM2.5 emissions
2010-2050
PM2.5
+46%
+41%

FUTURE FIRE EMISSIONS

Fire emissions might follow the same spatial pattern as burned area with the added variable of a large increase in the alpine areas. Under a medium emissions scenario, this pattern is expected to be more pronounced.

Fire Carbon emission
Teragrams of Carbon per year
2050
CO2
+1.3
+1.0

ITALY
URBAN

OVERVIEW

In 2020, 71% of the population lived in urban areas. This rate is expected to increase slightly by 2050, reaching 82%.

The Italian urban landscape is dominated by small towns, whereby almost half the population live in cities with less than 300,000 inhabitants and more than one third live in the four main Italian cities with more than 1 million inhabitants.

This situation, with a high rate of sub-urbanization, will not change substantially in the near future considering the slightly declining demographic trend.

Built up areas cover 6.77% of Italy (20,387.38 square kilometers).

2020

2050

Population in Urban Areas

42,006,701

44,670,873

Graphs refer to data provided by United Nations, Department of Economic and Social Affairs, Population Division (2018). World Urbanization

2020

2050

Urbanization Rate

71.0%

81.1%

OVERVIEW OF KEY CLIMATE IMPACTS IN URBAN AREAS

Italian cities are most vulnerable to impacts from heatwaves and flooding following intense precipitation events

HEATWAVES AND HEAT STRESS

Heatwaves are increasingly frequent and, in particular night-time temperatures, contribute to health effects. During the 2003 European heatwave, Italy was one of the most affected countries where mortality was up to two times higher than the European average.

During the 2003 heatwave particularly high numbers of heat related deaths were observed in Turin, +23%, and Milan, +23%, a large amount of which among the elderly, as well as people with low incomes and low levels of education.

During a subsequent heatwave in 2008, mortality rates increased by 22 and 30% in Rome and Milan, respectivley. From an analysis of future climate scenarios, increasing mean and summer temperatures and duration of heatwaves are expected for the whole country.

Frequency, intensity and duration of heatwaves will be significantly higher for urban areas.

2050

Cooling Degree Days
% of change

+236.9%
+78.3%
+47.1%

2050

Heatwave frequency
% of change

+80.1%
+35.1%
+21.4%

2050

Heatwave duration
% of time

+1,461%
+261%
+100%

HEAT AND AIR POLLUTION

Heat related health impacts from rising temperatures in urban areas are accentuated by air pollution. While air quality has improved in most EU countries during the past decade, the situation in Italy is improving at a slower pace. Safe levels of air pollution indicators such as PM10 and PM2.5 were often exceeded in more than 30% of major urban areas in Italy in 2017.

The Po plain experiences particularly high concentrations of air pollution due to its geography, which causes frequent situations of air stagnation. Urban population, and in particular the elderly and children, suffer from the combined impacts of air pollution and high temperatures.

2017
Population exposed to air pollution
94.8%

COASTAL FLOODING

In Italy, approximately 4,500 square kilometers of coastal areas are at risk of flooding due to sea level rise over the next 100 years; the areas most at risk are situated in the northern Adriatic Sea, the Po delta and the Venice lagoon, where there are highly urbanized areas, cultural heritage sites and industrial establishments situated below sea level.

Projected sea level rise
2050
0.23 m
0.18 m
2100
0.77 m
0.38 m

FLOODING

Flooding from short but intense precipitation events affects Italian cities frequently, due to an increasing rate of artificial surfaces both in cities and throughout the country. This prevents water from infiltrating into the ground and causes increasing run-off and accumulation of water in the lower parts of cities. Italy is exposed to a high risk of flooding and landslides due to both its geography and rapid urbanization. 91% of Italian municipalities are exposed to medium risks of landslides and inundations and more than 6 million Italians live or work in areas of elevated risk. One of the main drivers is urban and sub-urban expansion into high risk areas despite decreasing demographic trends. Flooding causes important economic damages and frequently leads to loss of human lives. Despite decreasing overall precipitation trends, short and more intense events are expected to occur more frequently in the future, putting in particular urbanized areas with high shares of sealed surfaces under threat.

2050
Runoff increase
% of area
+10%
+6%
+4%

SURFACE SEALING AND FLOODS

Heavy precipitation in cities is problematic due to the high level of sealed surfaces. Soil sealing increases run off and reduces the amount of water absorbed by soil. Where there are large amounts of impervious ground cover, short duration extreme rainfall events can lead to increased flooding, even resulting in flash floods.

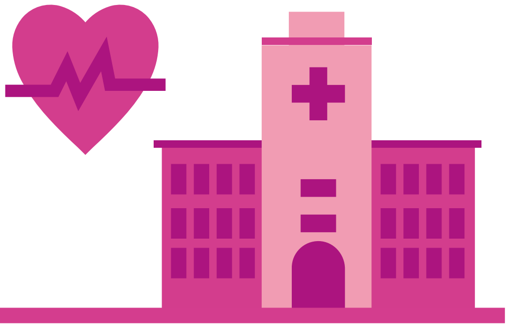
ENERGY POVERTY AND HEAT-WAVES

Energy poverty rates in Italy are higher than the EU average, whereby low income households don't always have the means to keep their homes cool in summer and warm in winter. Under future climate scenarios this problem may be exacerbated.

2010
% of urban population
Population living in slums
0%

2018
% of total population
Urban population living in areas where elevation is below 5 meters
4.2%

ITALY
HEALTH



OVERVIEW

Italy has the highest heat-related effects on daily mortality in the international context (and therefore among the G20), considering both hot temperatures and overall summer temperatures. 30.6% of heat-related mortality in Italy from 1991 to 2015 can be attributed to human-induced climate change. Furthermore, there is a concrete risk of a re-emergence of previously endemic agents (such as tick-borne encephalitis, Lyme disease, Mediterranean spotted fever, and West Nile fever), or the arrival of tropical communicable diseases, such as dengue, chikungunya, Zika, Crimean-Congo fever, or Rift Valley fever and diseases occurring in animals, including, Bluetongue disease and lumpy skin disease.

HEAT RELATED MORTALITY

The Italian population has increasingly been affected by heat waves, especially with over 23% of the Italian population currently over 65. The increase in frequency and intensity of heat waves and population ageing will significantly impact health in the future.

Guo et al. (2018) use historical daily time series of mean temperature and all-cause mortality January 1984 and December 2015 and estimate the change in heatwave-related excess mortality in the period 2031–2080 compared to 1971–2020 (present day).

In 2018, there was a 25% increase in heat-related deaths in Italy from a 2000 to 2004 baseline. 30.6% of heat-related mortality in Italy during 1991 to 2015 can be attributed to human-induced climate change.

IMPACTS ON LABOUR

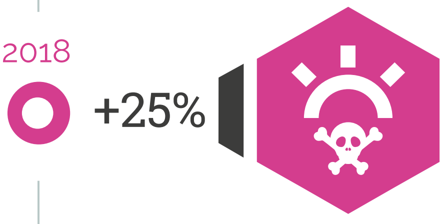
Labour is directly affected by changes in environmental conditions. Warming affects both the number of hours worked (labour supply) and on the productivity of workers during their working hours (labour productivity). Both labour supply and productivity are projected to decrease under future climate change in most parts of the world, and particularly in tropical regions.

Parts of sub-Saharan Africa, south Asia, and southeast Asia are at highest risk under future warming scenarios. Future climate change will reduce global total labour in the low-exposure sectors by 18 percentage points and by24.8 percentage points in the high-exposure sectors under a 3.0°C warming scenario

Labour is directly affected by changes in environmental conditions and especially heat stress. In the agriculture, construction, service, and industrial sectors in Italy, there was a 79.9% decline in potential hours of labour lost in 2019 compared to a 1990-94 baseline. Total labour in Italy is expected to decline by 1.2% under a low emissions scenario, and by 3.1% under a medium emissions scenario.

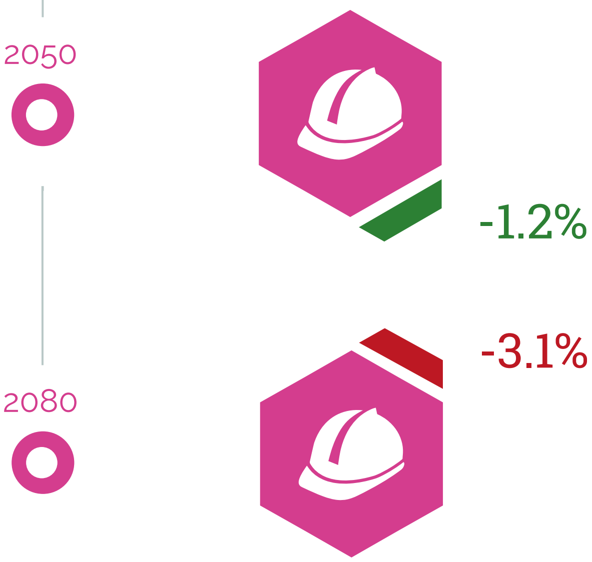
Heat-related mortality

% change with respect to 2000-2004



Impact on total labour

% change with respect to 1986-2005 baseline



CLIMATE CHANGE AND DENGUE

Dengue has spread throughout the tropical world over the past 60 years and now affects over half the world's population. Globally, vectorial capacity for both dengue vectors (A. aegypti and A. albopictus) has been rising steadily since the 1980s, with nine of the ten highest years occurring since 2000.

Climatic stressors are one important driver of the current distribution and incidence of dengue. Climate change is likely to expand the geographical distribution and suitability of several vector-borne human infectious diseases including dengue. The risk of dengue transmission is increased by warming climates, as the growth and development of mosquitoes are significantly influenced by temperature, precipitation, and humidity.

Dengue suitability

% of population at risk

CLIMATE CHANGE AND ZIKA

Zika virus has spread to at least 49 countries and territories since 2013. Climate change impacts on transmission suitability risk have increased over the years and future warming over 1.3 billion additional people could face suitable transmission temperatures for Zika by 2050.

DENGUE AND ZIKA: POPULATION AT RISK

Italy is currently at low risk of dengue and Zika transmissions. However, these risks will increase due to future climate change.

Under a medium emissions scenario, 86.2% of the population will be at risk of transmission suitable mean temperature for dengue by 2050, whereas 87.3% will be at risk under a high emissions scenario.

In the case of Zika, 79.3% of the population will be at risk by 2050 with medium emissions, whereas 86.7% will be at risk under high emissions.

Zika suitability

% of population at risk

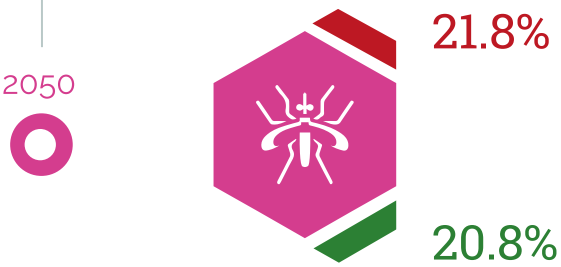
CLIMATE CHANGE AND MALARIA

Although Italy has essentially been free of malaria transmission since the 1970s, malaria transmission stability has been rising due to climatic changes favouring vectors.

More than one-fifth of the Italian population will be at risk of malaria due to future warming. 20.8% of the Italian population will be at risk of malaria in a low emissions scenario in 2050, whereas 21.8% will be at risk under a high emissions scenario.

Malaria suitability

% of population at risk



POLLUTION AND PREMATURE MORTALITY

Short and long term exposure to air pollution can have direct and sometimes severe consequences on health. Although regulations have helped improve outdoor air quality significantly, premature deaths due to exposure to near-surface ozone and heat are likely to increase. Under the medium emissions scenario, annual premature deaths due to long-term exposure to near-surface ozone and heat will increase from 8,349 (2010) baseline to 10,282 in 2050.

ITALY
ENERGY

ENERGY SYSTEM IN A NUTSHELL

Italy has seen a substantial downsizing of its energy-intensive industries over the past 40 years, vis-a-vis an increasing relevance of the service sector.

Italy has a long-standing tradition of energy efficiency policies, which has brought it to have one of the lowest energy intensities of GDP in the world.

0.06
ktoe/US$
Energy intensity

7.9%
AC Share in electricity consumption

85%
Import dependence ratio

CLIMATE CHANGE TODAY

ENERGY

The Italian energy sector has so far shown a high level of resilience to climate related threats due to the international diversification of its supply sources and the reliability of its electricity transmission grid and international interconnectors.

AIR CONDITIONING

In more recent years, increasing summer peak demand for air conditioning has caused stress to the energy system at the local level, resulting in short, localized blackouts.

HYDROPOWER

Spring and summer droughts have already resulted in repeatedly low levels of water in hydropower dams, raising concerns about the ability of the system to satisfy demand. The issue was tackled by increasing imports, but also resulted in higher electricity prices.

ENERGY SUPPLY

Italy's energy mix of total primary energy supply shows a prevalence of oil and gas (respectively, 34% and 42% in 2018), the virtual disappearance of coal (4%), and a still minor, but fast-growing share of renewables (17%, including hydro and biofuels). There is no nuclear energy in the country. Fossil fuels are imported from a diversified portfolio of sources, as national production is negligible.

ENERGY DEMAND

Energy in Italy is mainly used for transport (31% in 2018, mostly on road), residential (27%) and tertiary (14)% sectors. Industry claims a 26.5% share (including 6% of total demand for non-energy uses), while agriculture and fishing combined only amount to a 2.6% share. Air conditioning contributes 7.9% of residential electricity demand.

FUTURE ENERGY DEMAND

Italy has a very varied climate, ranging from cold Alpine valleys to hot southern regions. Overall, the decrease in heating demand is going to be more than compensated by the increase in cooling needs by 60 PJ (16,7 billion Kwh) under a medium emissions scenario.

Net change in energy demand due to changes in DD/CDD
Billion KWh

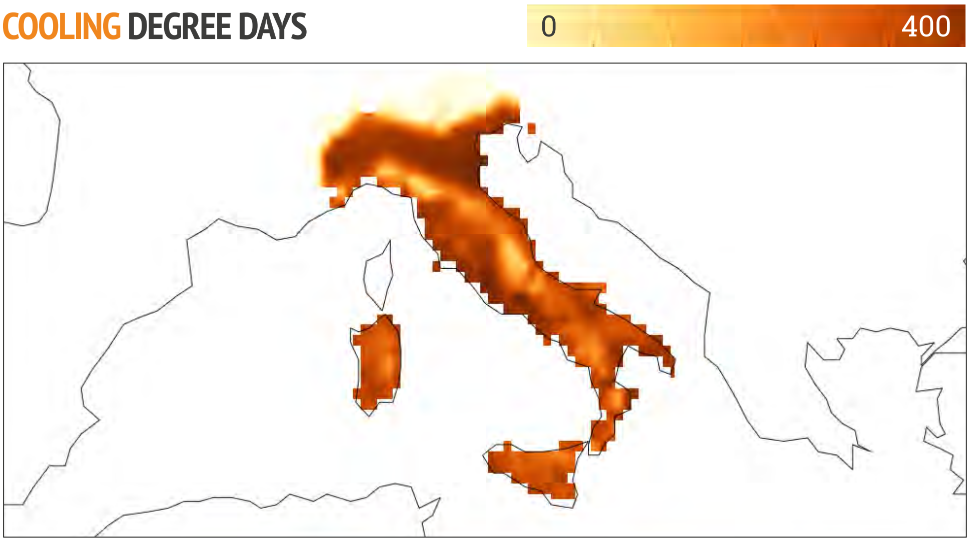
2050

+ 16.69

COOLING NEEDS

Marked increases in cooling degree days all over Italy, bar at the highest elevations in the Alps, whereas the Apennines are less likely to escape from the increase in cooling needs. Stronger increases are expected in the densely populated Po valley, Tuscany, Lazio, Campania (hence in Florence, Rome and Naples) and in general along the coasts.

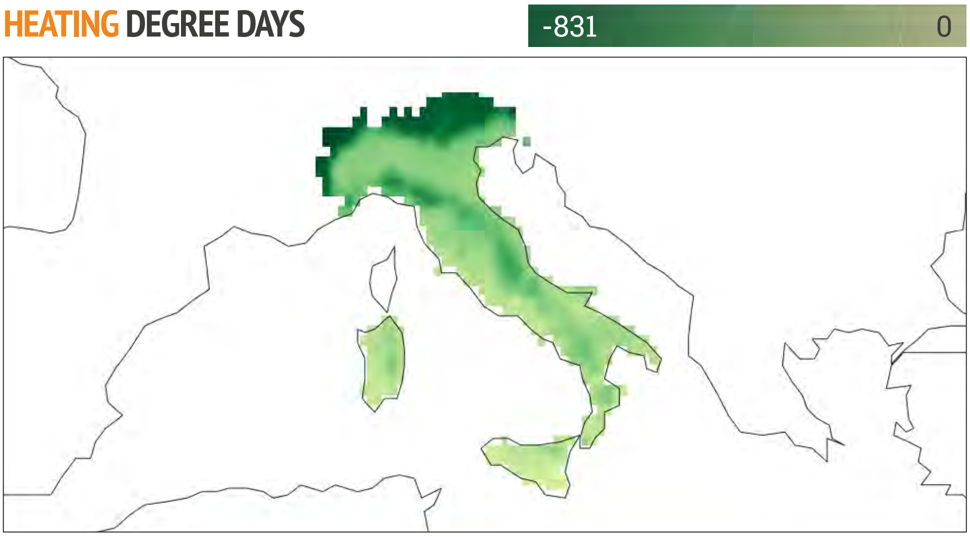
COOLING DEGREE DAYS



HEATING NEEDS

Heating needs are expected to decrease all over Italy, particularly in traditionally colder regions, where the territory is partially mountainous, such as all northern regions and to a lesser extent, central Italy. Moderate decreases expected in southern Italy.

HEATING DEGREE DAYS



FUTURE ENERGY SUPPLY

The future configuration of the Italian energy mix is likely to be determined by the evolution of climate mitigation policies and hence is outside the scope of this report. The EU net-zero carbon target by 2050 is likely to result in a marginal relevance of fossil fuels and their vulnerabilities to climate change, while carbon free sources (renewables and imported electricity) and their vulnerabilities will prevail.

Change in Hydropower generation
% of change

2050

-3.30%

-3.73%

EXPECTED IMPACTS OF CLIMATE CHANGE

The current trend of rising summer temperatures, with rising chances of heatwaves and droughts, is expected to intensify, leading to peak electricity demand coinciding with low water availability for power generation and heat stress on the grid, particularly in central and southern Italy, and in northern cities, due to the heat island effect. Hydropower generation is expected to decrease moderately on average.

ITALY
ECONOMY

OVERVIEW

Italy ranks 8th in GDP among G20 economies. It has been one of the EU economies most severely hit by the COVID crisis, experiencing a decline larger than 9% of GDP in 2020.

IMPACTS ON GDP

Italy, located in the Mediterranean hot spot for temperature, is particularly vulnerable to changing climate conditions. GDP losses related to climate change impacts can be significant already by mid century under a low emissions scenario, peaking at 2.2% of GDP or 36 billion EUR.

Losses could reach 116 billion EUR (more than 8% of GDP) by the end of century in a high emissions scenario.

2050

1.7/3.7%

0.02/2.2%

GDP Loss

% change w.r.t baseline

2100

3.5/8.5%

0.05/3.2%

SECTORAL ECONOMIC IMPACTS

IMPACTS ON INDUSTRY AND INFRASTRUCTURE

Italy features the 5th longest coastline in the EU and the 14th in the world. Damage to coastal area infrastructure from sea-level rise can be particularly severe.

In part due to the country particular oro-geography, today 91% of Italian municipalities are prone to hydro-geological risk; hence the projected increase in frequency and intensity of riverine floods under climate change is particularly worrisome.

IMPACTS ON AGRICULTURE

As is typical of developed economies, the overall contribution of the Italian agricultural sector to national GDP is rather limited: 1.9% in 2019.

Nonetheless the high quality of Italian production offers a fundamental direct and indirect contribution to national exports. For instance, in 2020 the agri-food sector export volume totaled 46,1 billion EUR. Wine product exports alone reached a value of 6,2 billion EUR.

The direct costs of climate change for Italian agriculture may be relevant. Yield losses, affecting among others high value-added cultivars, can determine a production contraction quantifiable in an aggregate cost of 12.5 billion EUR (0.7% of GDP) for a temperature increase of 2°C, to 30 billion EUR (1.9% of GDP) for a temperature increase of 4°C.

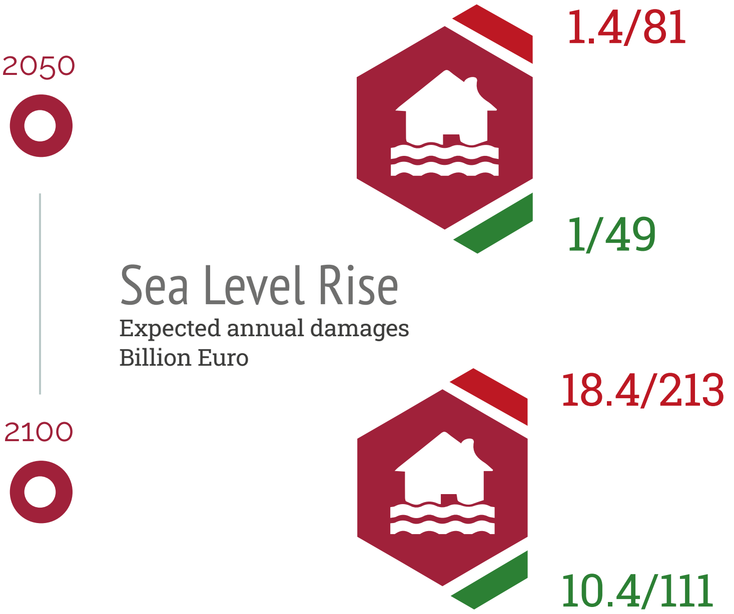
Due to its high-quality cultivars, Italy is also characterized by one of the highest average farmland values in the EU. Climate-change however can reduce the suitability of soils to grow high quality varieties leading to a dramatic decline in farmland values.

Estimates range from a loss of 1–11% of aggregate farmland values under a medium emissions scenario, and a loss of 4-16% under a high emissions scenario by the end of century. Other studies report more pessimistic estimates of a 10% loss in farmland value per degree of temperature increase.

SEA LEVEL RISE DAMAGES

Assuming that no new investments in coastal protection are undertaken, the expected annual damages on assets under a high emissions scenario may peak at 81 billion EUR already in 2050.

By 2100 annual damage can range between 18.4 and 213 billion EUR depending on different assumptions on adaptation.



2050

1.4/81

1/49

Sea Level Rise

Expected annual damages
Billion Euro

2100

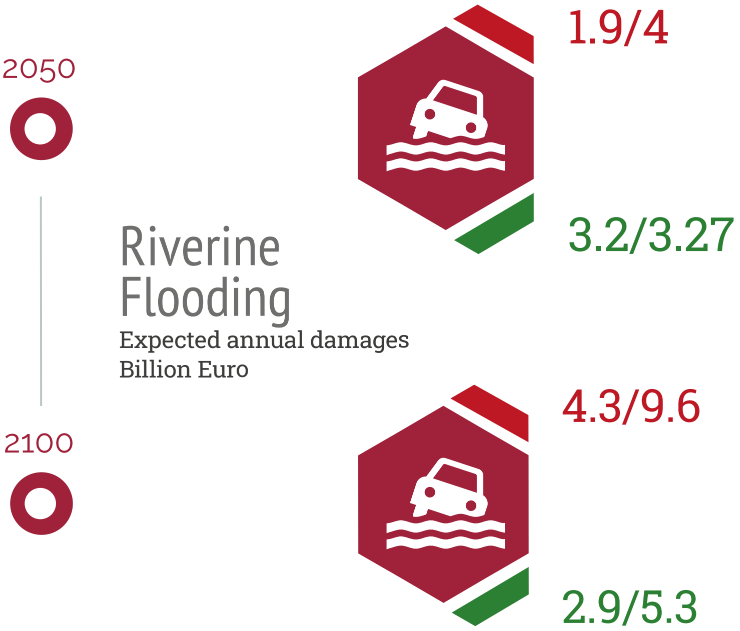
18.4/213

10.4/111

RIVER FLOODING DAMAGES

Increase in frequency and intensity of extreme weather events can generate relevant economic losses associated with riverine floods.

9.6 billion EUR in expected annual damage to infrastructure assets could be experienced under a high emissions scenario in the second half of this century.



2050

1.9/4

3.2/3.27

Riverine Flooding

Expected annual damages
Billion Euro

2100

4.3/9.6

2.9/5.3

IMPACTS ON ENERGY

Economic impacts of shifts in household and firm energy demand (see the "Energy" chapter) are difficult to predict and will mostly lead to redistribution effects.

Being a temperate to warm country, Italy will see a decline in energy consumption for warming and an increase for cooling. Residential electricity demand is for instance expected to increase between 5 and 10% in 2070 under a high emissions scenario. The net effect on household bills is however difficult to estimate.

IMPACTS ON FORESTRY AND FISHERY

The fishing sector may experience a reduction in catches with a direct production loss in 2070 ranging between 191 and 323 million EUR under low emissions and high emissions scenarios, respectively.

IMPACTS ON TOURISM

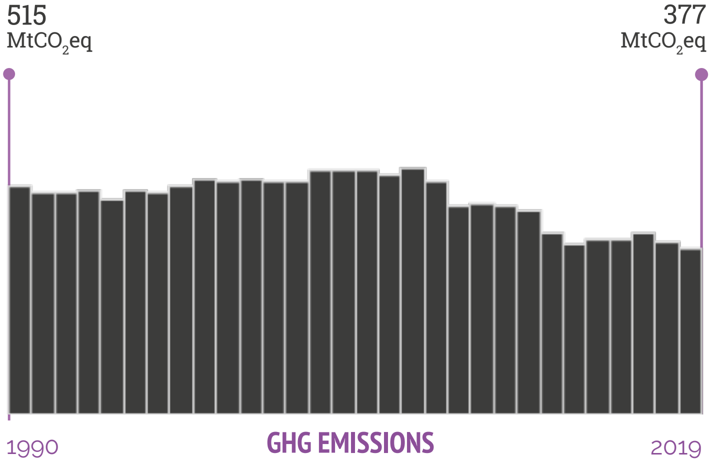
Tourism in Italy is one of the most important tertiary sectors. In 2019, it contributed the 10.4% of national GDP. It can be also one of the sectors most severely impacted by climate change.

The loss of climatic attractiveness and amenity of Italian destinations, becoming too hot, or loosing snow during the winter season, can induce a loss of up to 17 and 52 billion EUR due to touristic demand reduction under a low and high emissions scenario, respectively.

ITALY
POLICY

OVERVIEW

Italy is responsible for 0.87% of global GHG emissions and has a 20% higher than world average rate of CO_2 emissions per capita. Emissions have been declining since 2007, and a net zero emissions by 2050 target has been set.



INTERNATIONAL COMMITMENTS

Italy has the same target as the EU. In its 2020 NDC update, it strengthened its emissions target to a 55% reduction below 1990 levels by 2030.

CLIMATE POLICY COMMITMENTS CHRONOLOGY

2002 **KYOTO PROTOCOL - 1ST PERIOD**

6.5 % yearly average reduction in GHG over the four year period 2008-2012, with respect to 1990 levels

2016 **PARIS AGREEMENT - 1ST NDC**

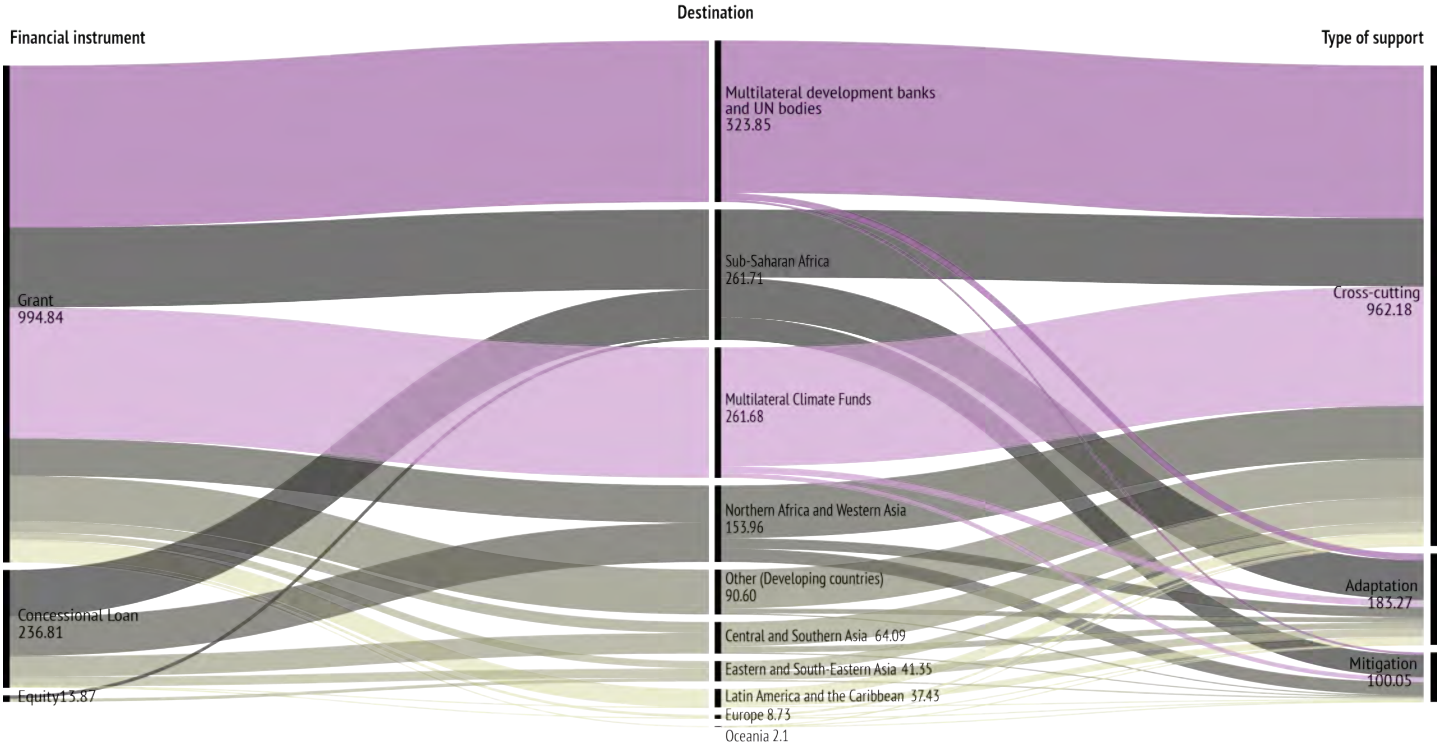
40% in GHG reduction by 2030, with respect to 1990 levels

2020 **PARIS AGREEMENT - NDC UPDATE**

55% GHG reduction by 2030, with respect to 1990 levels

INTERNATIONAL CLIMATE FINANCE ASSISTANCE

Italy's 4th Biennial Report shows a total commitment of 1.2 billion USD for climate action in 2017-2018. This is mainly provided in the form of grants. The majority is directed to multilateral institutions, while bilateral support mainly addresses sub-Saharan Africa.



SUSTAINABLE RECOVERY POLICY

According to the Global Recovery Observatory, in 2020 the proportion of green spending out of total recovery spending was 7%.

693.39 billion $	12.09 billion $	0.81 billion $
Total Spending	Recovery Spending	Green Spending

DOMESTIC ADAPTATION POLICY

In 2015 the Ministry for the Ecological Transition adopted the National Adaptation Strategy to climate change, and in 2016 it started the elaboration of the National Adaptation Plan. Some regions (Emilia Romagna, Lombardy and Sardinia) approved their adaptation strategy. Other regions have started procedures aiming to define planning documents on adaptation.

- ○ Domestic Adaptation Policy
  - ○ Inclusion of Adaptation in NDCs
  - ○ Integrated Adaptation & Mitigation Policy
  - ● Dedicated Adaptation Strategy
  - ○ Dedicated Adaptation Plan
- ○ Subordinate Adaptation Policies
  - ○ Sectoral Adaptation Plans
  - ● Subnational Adaptation Plans

○ Policy not in place ● Active policy

ADAPTATION POLICY HIGHLIGHTS

TRANSNATIONAL INITIATIVES

Regional Climate Change Adaptation Framework for the Mediterranean Marine and Coastal Areas

The aim of the Framework is to set a cross-border approach to increase the resilience of the Mediterranean marine and coastal systems, assisting decision-makers in the implementation of policies

Alpine Climate Action Plan 2.0

The plan is part of the Alpine Climate Target System 2050 strategy that supports progress towards reaching climate-neutral and climate-resilience in the Alps by 2050

NATIONAL INITIATIVES

Creiamo PA

The Ministry of Ecological Transition set up a technical assistance programme to support Italian local administrations in developing their own climate mitigation and adaptation plans

Experimental programme of actions for adaptation to climate change in urban areas

The program aims at increasing the resilience in municipalities with a population of 60,000 inhabitants or more which are subject to climate change risks (heat waves, extreme rainfall and drought)

SUBNATIONAL INITIATIVES

Un filo Naturale

The City of Brescia is developing a "Climate Transition Plan" that will abate greenhouse gases emissions and mitigate the impacts of urban flash floods and urban heat islands

Sardinian Regional Adaptation Strategy

The SRACC aims to assess the climate vulnerability and risk on the island of Sardinia, to identify adaptation options, and to define a governance system for the inclusion of adaption in all regional programs

ENERGY TRANSITION

Italy has undertaken a significant process of transformation of its energy sector and is among the best performers in Efficiency, driven by the low level of energy intensity of the economy and by the advanced digitalization of the electric grid, which had a positive benefit in terms of transmission and distribution losses. During the last decade, many investments have been made in Renewables increasing their fundamental role and also allowing Italy to substitute fossil fuels which are mostly imported. The good performance in terms of the overall Energy Transition indicator is also driven by significant improvements in Emissions. In order to further speed up the transition, Electrification opportunities, especially in buildings and in transport sectors, must be seized.

Energy Transition	58.7	64.6
Fossil Fuels	45.3	52.3
Renewables	19.7	26.2
Efficiency	84.9	93.2
Electrification	70.8	71.3
Emissions	72.9	79.8

G20 AVERAGE

COUNTRY

Only actively pursuing an energy transition based on decarbonization and electrification – from policy and regulation, to health and education – will enable countries to benefit the most from future opportunities and fight climate change whilst ensuring an equitable distribution of wealth.

The Energy Transition indicators were developed by Enel Foundation in cooperation with SACE, and provide a retrospective analysis based on historical data.

G20 CLIMATE RISK ATLAS

Impacts, policy, economics

JAPAN

How to read the Atlas: graphs, colours and scenarios.

The maps used in this Atlas are taken from **The World Bank Official Boundaries** - ***https://datacatalog.worldbank.org/search/dataset/0038272*** (accessed on May 28, 2021). For the section Energy, the maps are based on Panoply Data Viewer ***https://www.giss.nasa.gov/tools/panoply/credits.html***

Each sector of this Atlas contains data and information on various climate scenarios.

When reported in graphs, the **colour black** indicates data and information referring to the current state, the past or the baseline.

When the authors refer to **RCP (Representative Concentration Pathways)**, the 3 colours used across the factsheet refer to 3 scenarios, which are 3 different development options with different levels of greenhouse gas emissions, **respectively low emissions (green), medium emissions (orange), and high emissions (red)**. The same colour code is used when RCPs are associated with Shared Socioeconomic Pathways (SSP).

In some cases, the authors refer to global warming scenarios. In these cases, the 3 colours used refer to a temperature rise of **1.5°C (green), 2°C (dark green), and 4°C (red)**.

When the authors refer exclusively to **Shared Socioeconomic Pathways - SSPs** (Population affected by river floods in the section: "Water"), data related to **SSP3** - that encompasses, among other things, slow economic growth, material-intensive consumption, and persisting or worsening inequalities – **are reported in a lighter shade**; **SSP5** – which refers to social and economic development that is coupled with an energy-intensive lifestyle and the abundant exploitation of fossil fuel resources – is shown using a **middle shade of the colour**, whereas data related to **the present** conditions **are represented in a dark shade**.

Further details on scenarios, methodologies, and the full list of references are available at: **www.g20climaterisks.org**

Concept and graphic design by element6.eu

JAPAN

CLIMATE

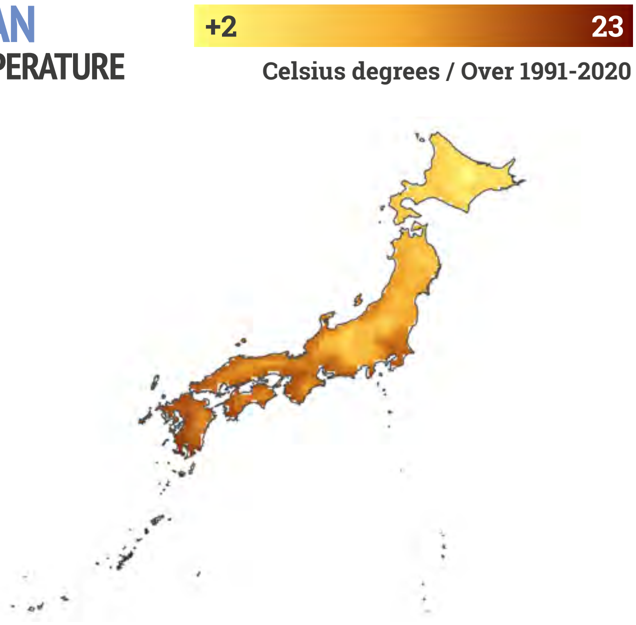
OVERVIEW

Japan features a remarkable variety of climates including a subtropical zone and a sub-polar zone. This is due to its wide latitudinal extent, seasonal winds, and exposure to different types of oceans. The northern part has warm summers but long, cold winters with heavy snowfall; conversely, the central part presents hot, humid summers and moderate to short winters with some areas featuring very heavy snowfall; finally, the southwestern part has long, hot, humid summers and mild winters.

TEMPERATURE

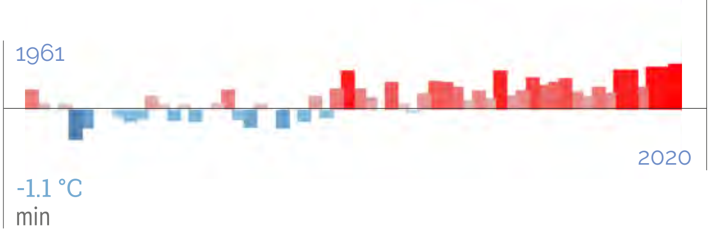
The temperature regime in Japan varies with latitude. More specifically, temperatures are lower in the north, where snow and ice dominate in winter, and rise in the central and southern areas. The south is the warmest area.

MEAN TEMPERATURE



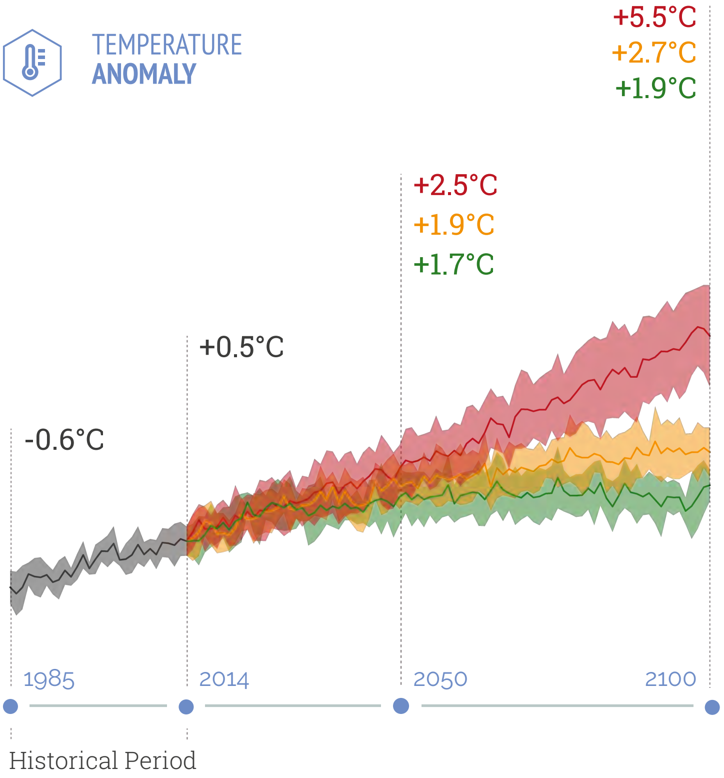
TEMPERATURE TREND

Temperature anomalies over the last 60 years with respect to the annual mean of 1°C in Japan during the 1961-1990 period



TEMPERATURE PROJECTIONS

Under a low emissions scenario projected temperature variations will remain contained under +2°C, both by 2050 and 2100.
Under a high emissions scenario, with no reduction in GHG emissions, greater temperature anomalies are expected, particularly in 2100.



EXPECTED VARIATION FOR TEMPERATURE AT 2050

The indicators show variations in selected temperature characteristics for a thirty-year period centred on 2050 (2036-2065) with respect to the reference period 1985-2014.

+2.4°C	+2.6°C	+2.4°C
+1.9°C	+2.0°C	+1.9°C
+1.5°C	+1.7°C	+1.5°C
Annual Mean Temperature	Max Temperature of warmest month	Min Temperature of coldest month

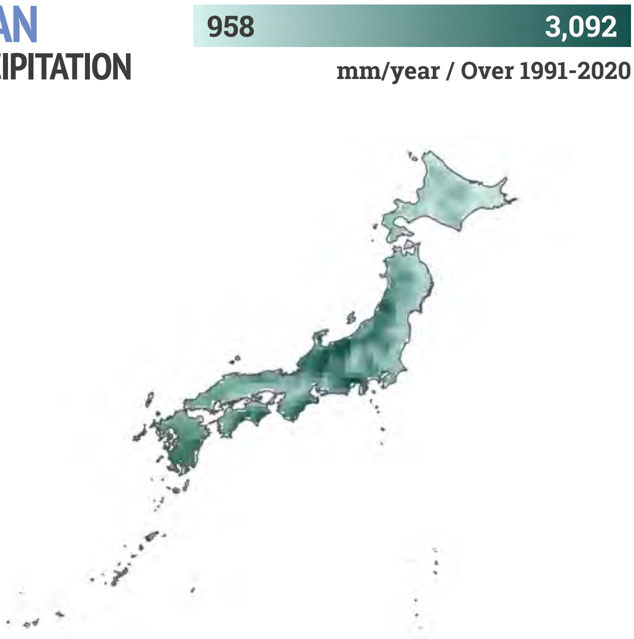
PRECIPITATION

The precipitation regime in Japan features a high spatial variability over the entire archipelago. Annual precipitation averages between 1,000 and 2,500 millimetres.

The hyper-humid Kii Peninsula can receive over 3,000 millimetres per year, making it the world's rainiest subtropical area.

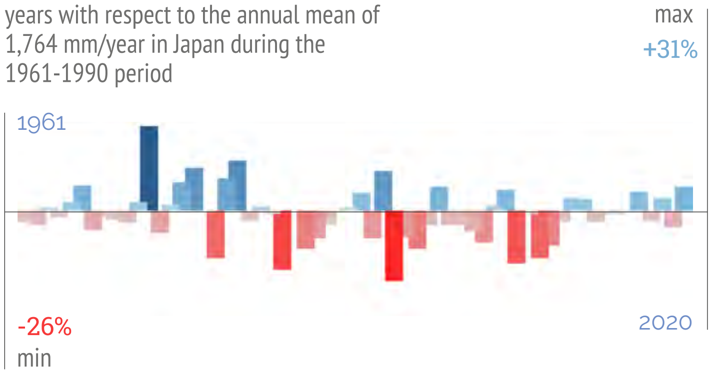
In some years rainfall causes severe floods and landslides, whereas in others there is too little rain to support agriculture.

MEAN PRECIPITATION



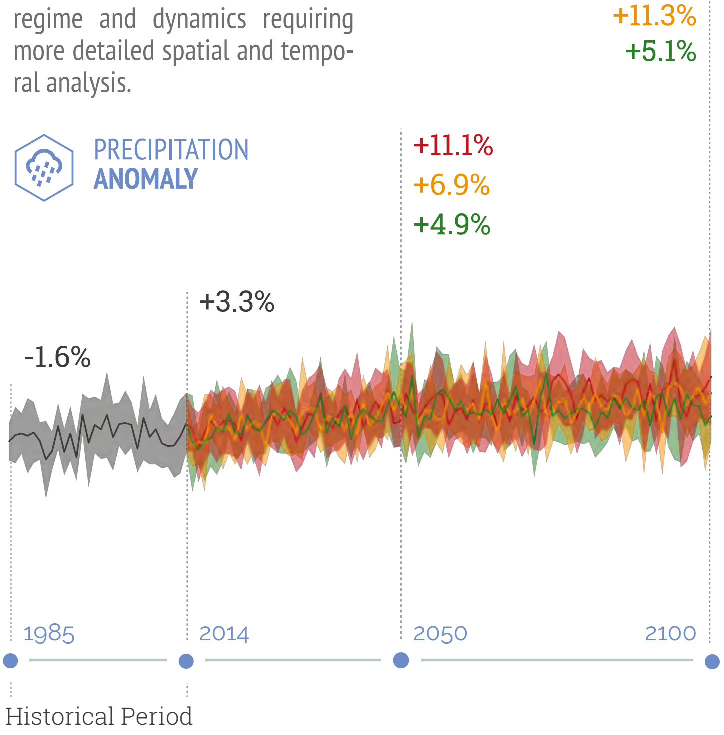
PRECIPITATION TREND

Precipiation anomalies over the last 60 years with respect to the annual mean of 1,764 mm/year in Japan during the 1961-1990 period



PRECIPITATION PROJECTIONS

Precipitation trends show a very complex signal, under all emissions scenarios, with a very large variability among climate models. This can be explained considering the complexity of the precipitation regime and dynamics requiring more detailed spatial and temporal analysis.



EXPECTED VARIATION FOR PRECIPITATION AT 2050

The indicators show variations in selected precipitation characteristics for a thirty-year period centred on 2050 (2036-2065) with respect to the reference period 1985-2014.

Annual total precipitation
+6.7%
+6.1%
+6.5%

Precipitation of wettest month
+7.3%
+7.2%
+6.5%

Precipitation of warmest quarter
+8.1%
+8.5%
+8.0%

VARIATION OF SPECIFIC CLIMATE INDICATORS

Climate indicators variation showing impacts of climate change on sectors such as agriculture, health and water. Analysis considers 3 threshold average temperature increase: **+1.5°C**, **+2°C**, **+4°C**.

Agricultural drought proportion of time
% of time
+22%
+12%
+10%

Hydrological drought proportion of time
% of time
+13%
+9%
+8%

Heatwave duration
% of time
+1,563%
+232%
+79%

Runoff increase
% of area
+20%
+7%
+2%

Agricultural drought frequency
% of change
+45%
+23%
+18%

Hydrological drought frequency
% of change
+9%
+8%
+10%

Heatwave frequency
% of change
+86%
+32%
+18%

Runoff decrease
% of area
+28%
+10%
+5%

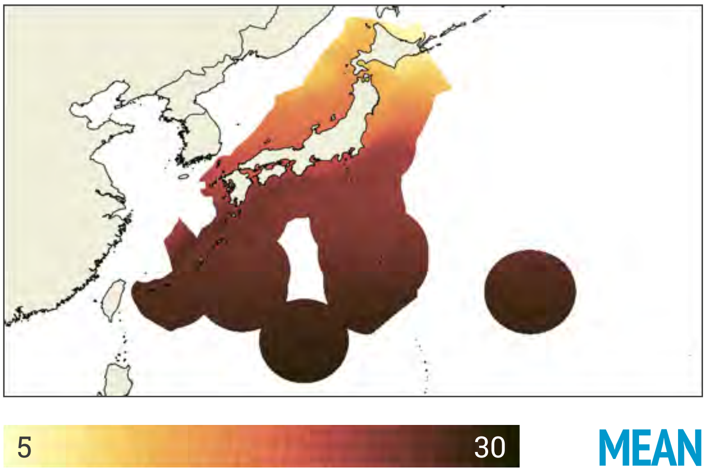
JAPAN
OCEAN

OCEAN IN JAPAN

Japan's marine exclusive economic zone (EEZ) comprises a wide range of environmental conditions, from the cold waters surrounding the island of Hokkaido to the temperate ecosystems of the southern seas. Japanese coastal systems can be divided into three main areas: the Sea of Japan, East China Sea and the Pacific region.

CURRENT CLIMATE CONDITIONS

Mean sea surface temperature reflects the latitudinal variation in climate regimes, with cold waters in the north and warmer ones in the Pacific region.

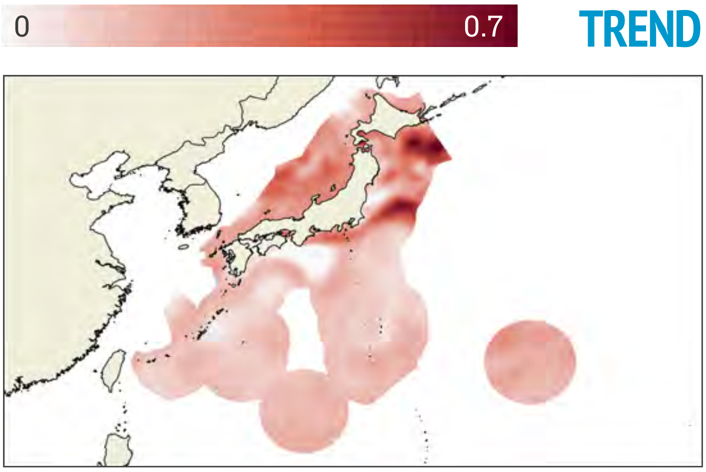


MEAN

SEA SURFACE TEMPERATURE

Celsius degrees / Over 1991-2020

TREND

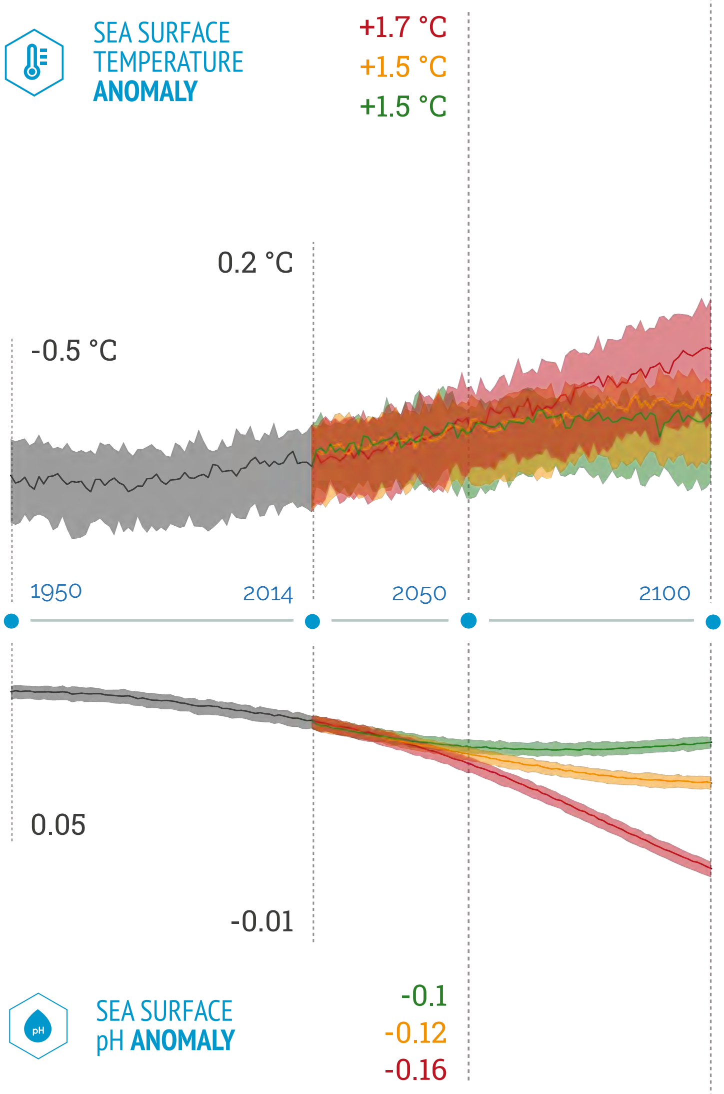


Surface temperature trends indicate a general warming of 0.2°C per decade in all marine areas, with increased gains in the northern areas.

FUTURE PROJECTIONS

Projected annual changes within the marine EEZ for the two most significant marine indicators of climate change: sea surface water temperatures and pH.

Seawater temperature changes are in line with the definitions of each scenario, with maximum values in 2100 close to +4°C under a high emissions scenario.



Seawater surface pH becomes more acidic in all scenarios, closely reflecting rising atmospheric CO_2 concentrations, and only a low emissions scenario leads to a stable condition by 2100.

ECOSYSTEM INDICATORS AT 2050

Regional changes in key marine ecosystem indicators under projected future scenarios by mid-century (2036-2065) with respect to present climate conditions (1985-2014).

East China Sea

Japan Sea

Pacific

Temperature regulates the metabolism of marine organisms determining which habitats remain suitable. Excessive warming will likely push ecosystems beyond tolerance thresholds.

pH represents the acid/base status of marine waters, where a decreasing pH reflects the acidification of the ocean due to increased absorption of atmospheric CO_2.

Oxygen is fundamental to sustain marine life and its reduction can have a large impact on coastal ecosystem services including fisheries and aquaculture.

Chlorophyll is an indicator of the biomass available at the base of the marine food web supporting all ecosystem productivity.

	East China Sea	Japan Sea	Pacific
Temperature	24.94°C +1.78 °C +1.5 °C +1.62 °C	15.21°C +2.43 °C +1.9 °C +2.04 °C	22.35°C +2.08 °C +1.94 °C +2.16 °C
pH	8.09 -0.16 -0.12 -0.1	8.14 -0.18 -0.13 -0.11	8.1 -0.16 -0.13 -0.1
Oxygen	212.78 mmol/m^3 -2.35 % -1.56 % -2 %	257.58 mmol/m^3 -3.59 % -2.94 % -2.89 %	224.18 mmol/m^3 -2.72 % -2 % -2.78 %
Chlorophyll	0.17 mg/m^3 -22.35 % -18.82 % -17.65 %	0.35 mg/m^3 -10.06 % -14.66 % -24.14 %	0.24 mg/m^3 -1.26 % -7.14 % -10.5 %

FISH CATCH POTENTIAL

Fish catch potential is an estimate of the maximum fish catch achievable given the marine resources available over a sustained period. It is linked to the concept of maximum sustainable yield, meaning the maximum amount of fish that can be extracted from a system without causing a collapse in fish populations.

It is a characteristic of the natural system, which is substantially different from realized catch, and a direct result of the fishery policy in place.

Fish catch percentage change

2050

-10.6%

-6.5%

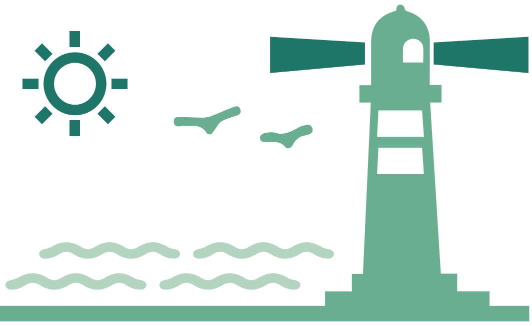
ANALYSIS DETAILS

All datasets were analysed using only data from within the marine EEZ and therefore excluding overseas territories, detached islands and any disputed or joint territories with other nations. In the assessment of current climate conditions, seawater surface tempereture data was obtained using satellite observations distributed in the framework of ESA Climate Change Initiative.

Future projections of marine indicators are represented by the combined analysis of results from 15 different Earth System models participating in the Coupled Model Intercomparison Project Phase 6 (CMIP6). These models include new and better representations of physical and biogeochemical processes, compared to previous IPCC assessment reports.

Fish catch potential data was obtained using the FAO's technical report and refers to the best and worst case climate scenarios from the Fifth IPCC Assessment Report. These mean estimates are subject to substantial uncertainties as discussed in the original work.

JAPAN
COASTS



OVERVIEW

Japan is a densely populated archipelago with 29,000 kilometres of shoreline and around 7,000 islands, 430 of which are inhabited. The two main islands are the Island of Honshu, home to the largest cities, including Tokyo (one of the largest coastal mega-cities in the world), and the Island of Hokkaido. The coastal area of Japan is predominantly made up of rocky shores and sandy beaches, whereas the rest of the coast can be classified as artificial. The coastal zone of Japan sustains a thriving and advanced global economy.

Shoreline Length
29,020 km

Sandy Coast Retreat at 2050
4.7 m

CLIMATE CHANGE HAZARDS

Coastal hazards such as erosion, storm tide inundation and permanent flooding, can have strong adverse impacts on coastal regions, with loss of sandy shores, damage to settlements, infrastructure and ecosystems. Climate change can exacerbate these impacts due to rising sea levels and increasing impacts of waves and storms. Climate change impacts on the coastal zone of Japan are mainly driven by rising sea levels and possible changes in storm intensity and direction, as well as changes in future typhoon frequency, intensity and area of influence.

These changes may exacerbate erosion issues and drive flooding in low lying coastal areas, with potential widespread economic damage. In addition, changes in rainfall patterns may further exacerbate flooding risks. Land subsidence, which in the past was mainly driven by groundwater extraction, is also a concern for many coastal urban areas, resulting in large parts of cities such as Tokyo currently finding themselves below sea level.

SEA LEVEL RISE

Relative sea level rise has been observed over the past century around the coast of Japan, with a yearly average increase of approximately 2.8 millimetres per year since the 1990s. The latest IPCC projections indicate that, by 2050, global sea levels may rise between 0.18 metres, under a low emissions scenario, and 0.23 metres, under a high emissions scenario.

Observed and projected sea level rise at 2050
2.8 mm/year
0.23 m
0.18 m

EXTREME SEA LEVEL

On average, one in 100 extreme sea level events are expected to rise from 2.88 metres at present day to 3.11 metres by 2050 under a medium emissions scenario.

Current and projected extreme sea level at 2050
2.88 m
3.19 m
3.11 m

OBSERVED STORMS

The eastward facing coasts of Japan are exposed to the vast Pacific Ocean swell regime, whereas the western ones are exposed to the swell regime of the Sea of Japan and South China Sea. The swell regime of the Pacific Ocean delivers high energy waves to the east coast of Japan throughout the year, both from the North Pacific during the winter and the South Pacific during the summer. The Japanese coast is also strongly influenced by the typhoon season that runs from May to October.

FUTURE STORMS

Climate change is expected to influence the wave climate of the coast of Japan. Different scenario projections of changes in wave height, period and direction for this century seem to agree on a reduction in wave energy. However, this may be offset by the impact of stronger typhoons fuelled by higher sea surface temperatures. Furthermore, it appears that although there may be a reduction in the number of typhoons, the intensity of these is predicted to increase.

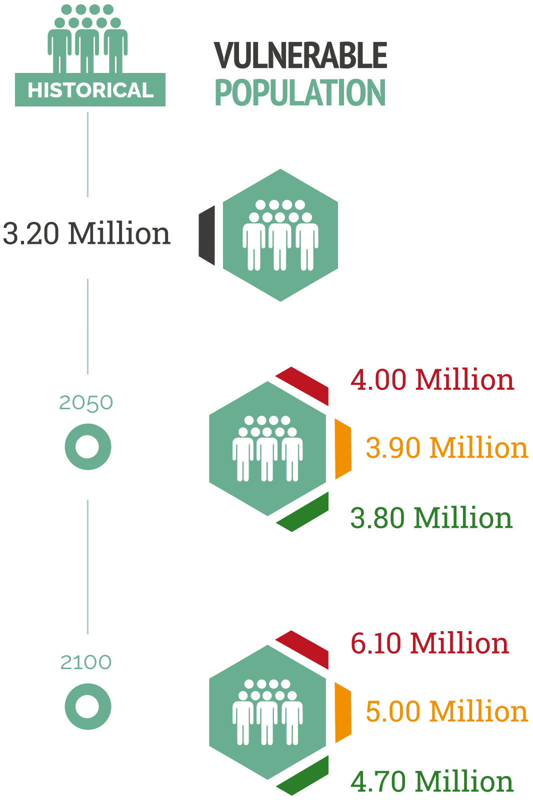
VULNERABILITY AND RISK

Coastal areas of Japan are exposed to the impacts of waves and sea level rise. However, protection measures are in place around most of the country, particularly in areas subject to tsunami inundations, which have a much higher impact on coastal flooding than sea level rise.

Tsunami risk is concentrated in the southern and eastern coasts of Japan, whereas the western coast is less exposed to tsunamis and the impact of storm surges from typhoons.

The most affected areas include Tokyo, Nagoya, Osaka and Okayama. Given the high population density around the south coast of Japan, with more than 100 million people concentrated in coastal urban areas, coastal population exposure can be considered widespread. Under a medium emissions scenario, the population exposed to the annual coastal flood level is expected to increase from 3.2 to 3.9 million people by 2050.

VULNERABLE POPULATION



INFLUENCE OF SEA LEVEL RISE ON EXTREME SEA LEVEL

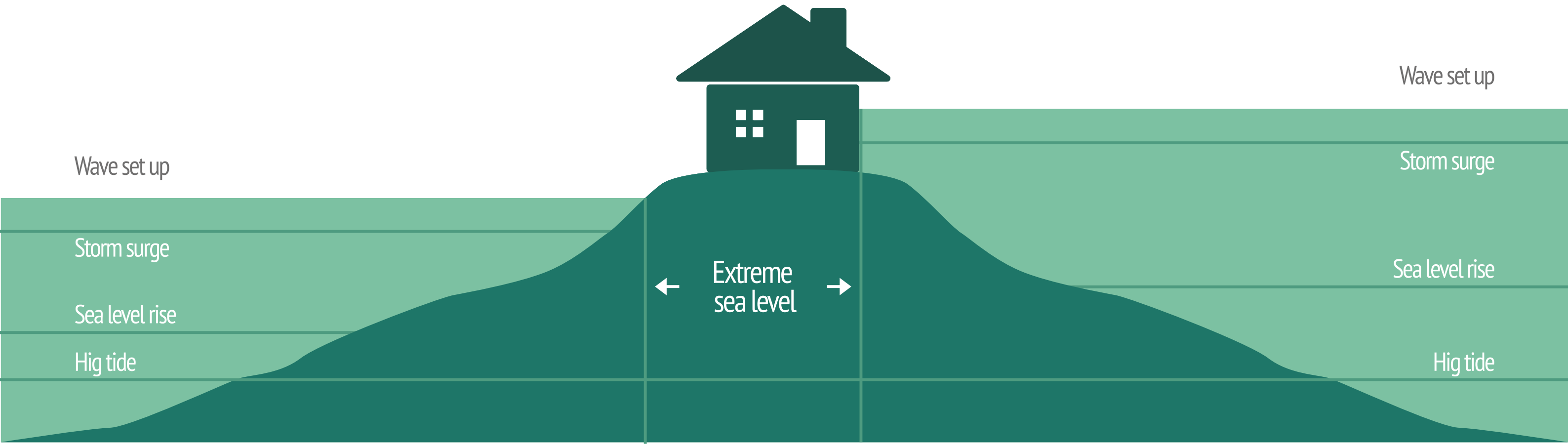
Present and future sea level rise are a consequence of carbon induced global warming causing melting ice and ocean expansion due to heat accumulation.

The extreme sea levels reported here are based on the 100-year storm surge + wave set up + sea level rise + high tide indicators. The first two parameters (storm surge + wave set up) are based on the 100-year value for the event; sea level rise is its projected value at 2050; and high tide is the absolute value of the highest tide calculated for a given locality, which won't be influenced by climate change.

+ **Wave set up** refers to the accumulation of water near the shore due to the presence of breaking waves.

+ **Storm surge** is an occasional increase in sea level driven by shoreward wind-driven water circulation and atmospheric pressure.

+ **High tide** is usually the highest tide reached in a given location based on tide records.



Present sea levels have risen globally by approximately 20 centimetres over the past century.

Future sea level rise is a projection based on different global warming scenarios, at approximately 100 centimetres by the end of 2100, with consequent inundation during extreme sea level events.

JAPAN
WATER

OVERVIEW

Japan's water resources are mostly influenced by rainfall distribution across the main islands. Annual precipitation in Japan is approximately 650 billion cubic metres, of which around 230 billion cubic metres (35%) are lost through evaporation. Therefore, the remaining 420 billion cubic metres are the most left available for human use, which decreases in years of low precipitation, and is reduced to 280 billion cubic metres in years of water shortage, which occur once every 10 years.

The amount of water actually used is approximately 83.5 billion cubic metres, equivalent to roughly 20% of the mean inventory of water resources. In the northern part of Japan, about 50% of the area of the country, snowfall is responsible for a large part of total annual precipitation.

Renewable internal freshwater resources	430 billion m^3
Renewable internal freshwater resources per capita	3,391 m^3

Over the last century the annual mean temperature has increased from 10.3 to 11.5°C. With a further increase in temperature, of 1 to 3°C expected over the rest of the century, snowfall is expected to decrease during the winter, and subsequently, snowmelt supplied to rivers will also decrease in early spring. This may lead to an alteration in the river discharge pattern, which will decrease during spring and early summer and become less gradual.

CLIMATE CHANGE HAZARDS

Climate change can affect water resources through increasing temperatures, higher rates of evapotranspiration and altered rainfall patterns. This leads to changes in the water cycle, including decrease of snow and ice coverage, alterations of surface runoff and groundwater storage, as well as drought and flood occurrence. The impacts of climate change will show pronounced regionality in their magnitude, in the vulnerability to climate change, and in the most significant hydrological processes that will be affected. Common features of climate change impacts include enhanced drought frequency (especially on the Honshu island) and increased flood discharge (especially in Hokkaido and Kanto regions). From June to October these changes may be particularly marked.

KEY POINT RUNOFF

Precipitation, evaporation, transpiration and soil moisture are the key factors impacting volume of runoffs and evaporation. Impacts of changes in the surface runoff may include soil erosion, transport of pollutants and increased flood risk.

At a country scale, an average increase in surface runoff by approximately 12% and 15% is expected respectively under low and medium emissions scenarios for the 2045-2055 period compared to 2015-2025.

If temperatures rise by 1.5°C, 2°C or 4°C, 5%, 9.6% or 28% of the area of the country will likely experience an increase in runoff, while 2%, 6.9% or 20% of the surface of the country will likely experience a decrease in runoff, respectively.

2050

Changes in annual runoff
% of change

+14.7%

+12.1%

2050

Runoff increase
% of area

+28.0%

+5.0%

KEY POINT DROUGHTS

Owing to its topography where rainwater falls in the mountain ranges and flows quickly to the ocean, Japan has experienced repeated drought events in the past. In 1994 for instance, because of the most severe drought episode of the last century, most regions experienced water shortages. During this period, the water quality of major rivers (Lake Sagami, Tsukui, and Tanzawa) deteriorated and the water supply had to be regulated at a very high economic cost. Due to climate change, an increase in the number of days without rain is expected. Except for northern Japan and the central mountainous region, there is a risk that river discharge will decrease, leading to severe drought. In regions where snow melt water is used, maximum river discharge may fall during the snowmelt period and its peak may occur earlier than usual, thereby leading to the possibility of decreased river discharge when water is most in demand.

2050
Severe drought likelihood increase
% of change
+3.4%
+1.9%

2050
Hydrological drought frequency
% of change
+9.0%
+7.0%

2050
Groundwater Recharge
% of change
-16.0%
-1.0%

KEY POINT GROUNDWATER

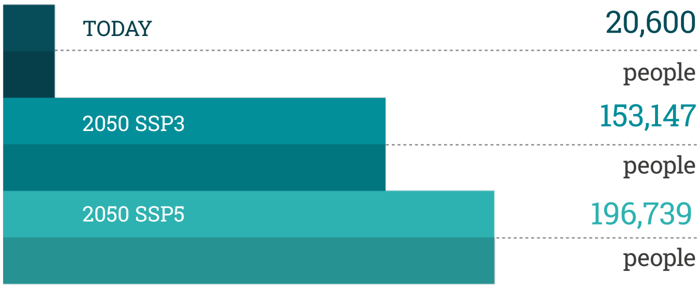
In Japan, groundwater represents approximately 13% (10.4 billion cubic metres) of the total water use (83.5 billion cubic metres), and it has been a traditional source of water supply for a long period of time. After the country entered a rapid phase of industrialization and urbanization, there was an obvious increase in the pressures on the groundwater environment. Uncontrolled abstraction of groundwater soon led to the emergence of problems such as the drawdown of water tables, saline water intrusion near the Tokyo Bay area, and land subsidence. The Tokyo government managed to overcome all of these problems by introducing hard and soft measures. Modern issues such as the impacts of climate change, groundwater seepage to underground infrastructure, and micro-pollutant contamination have recently emerged. In outlying islands, the rise in sea level could lead to further increased salt water intrusion into the groundwater. At the country level, a -1%, -9.2% and -16% decrease of the annual groundwater recharge for the period 2045-2055 compared to the timeframe 2015-2025 is expected respectively under under low, medium and high emissions scenarios.

KEY POINT FLOODS

Japan has been suffering from flood disasters since ancient times and is still exposed to high flood risks, due to the high concentration of people and assets in flood-prone areas. In the archipelago, flood disasters are more likely to happen in small rivers than in large rivers, because small rivers managed by the prefecture have less hazard evaluations than large rivers managed by the country.

In addition, flash floods can be extremely dangerous for the country: for instance, in the early summer 2018 the southwestern part of Japan experienced widespread damages, mudflows and casualties, while forcing millions to evacuate across 15 prefectures, due to severe rainfall events. Changing rain patterns may affect the frequency and intensity of floods. By 2050 a slight increase in the number of days with intense precipitation (more than 50 millimetres of rain) is expected, with 0.34 days under a low emissions scenario and 0.7 days under a high emissions scenario.

POPULATION AFFECTED BY RIVER FLOODS

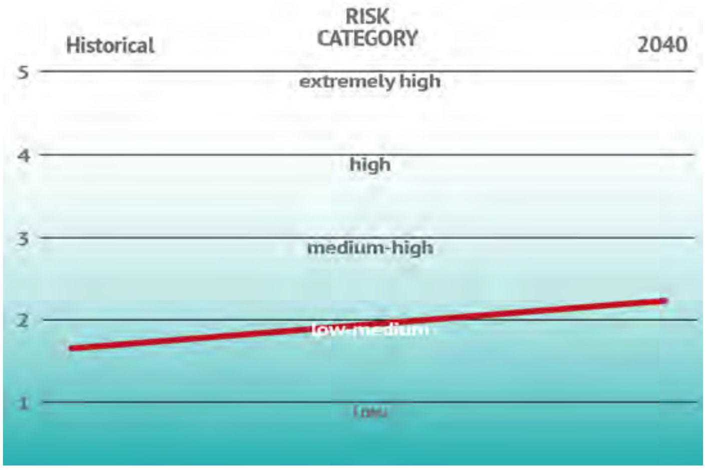


RISK INDICATORS

The water stress index summarises current and future water related vulnerabilities and risks at the global level. Scores are based on the ratio of total water withdrawals, including agriculture, industrial and human consumption, to available renewable surface and groundwater supplies.

WATER STRESS

Japan's water stress level is considered low-medium for the recent past (1960-2014 average), and it is expected to increase in the near future (2030-2050) based on climate change projections.



JAPAN
AGRICULTURE

OVERVIEW

In Japan, cultivated land and the relevance of the agricultural sector have been in steady decline over recent decades, accounting for only 0.9% of the country's GDP in 2018. Farmland is scarce (only 20% of the total area), and high subsidies have been implemented to improve agricultural areas and their productivity, in particular for paddy land.

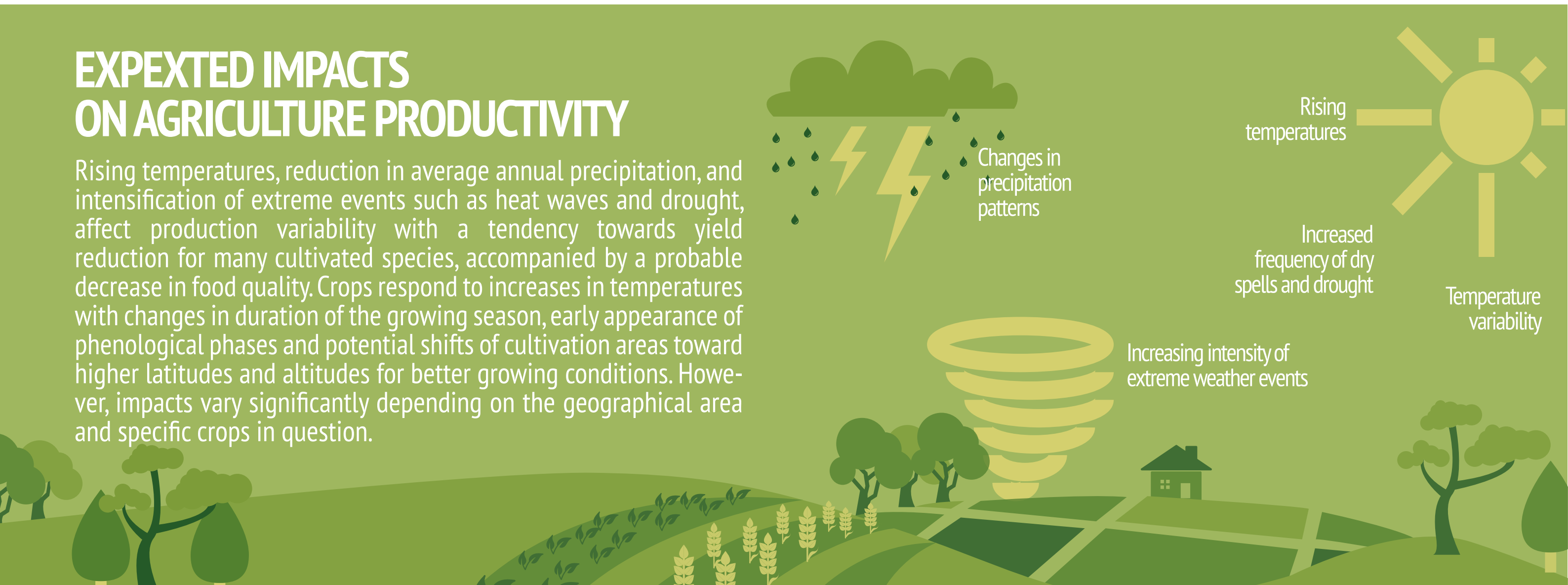
The main staple food is rice, which is grown intensively in most provinces and covers a large portion of domestic consumption. Sugarcane is also grown extensively in Okinawa and Kagoshima prefectures, whereas sugarbeet production is focused in Hokkaido. Farming in Japan is also devoted to high quality crop production, with a focus on several fruit trees (citrus, pome, peaches). In contrast, wheat production is quite limited compared to domestic demand, forcing the country to rely on agricultural imports. Irrigation in agriculture is extremely relevant, especially for rice production, and adsorbed 64% of total water withdrawal in 2017.

10.6 Mt	Rice
1.2 Mt	Sugarcane
3.6 Mt	Sugarbeet
0.8 Mt	Wheat
0.8 Mt	Citrus

	Added Value of Agriculture, Forestry and Fishing	Share of Agriculture Value added in Total GDP	Agricultural land	Area Equipped for Irrigation
2000	67,459 USD Million	1.7 %	4,830 Thousand HA	2,641 Thousand HA
2018	42,908 USD Million	0.9 %	4,420 Thousand HA	2,405 Thousand HA

EXPEXTED IMPACTS ON AGRICULTURE PRODUCTIVITY

Rising temperatures, reduction in average annual precipitation, and intensification of extreme events such as heat waves and drought, affect production variability with a tendency towards yield reduction for many cultivated species, accompanied by a probable decrease in food quality. Crops respond to increases in temperatures with changes in duration of the growing season, early appearance of phenological phases and potential shifts of cultivation areas toward higher latitudes and altitudes for better growing conditions. However, impacts vary significantly depending on the geographical area and specific crops in question.



CROP PRODUCTIVITY

Crop productivity refers to the harvested yield of a crop per unit of land area. It is strongly influenced by climate and other environmental and management factors.

Climate change is expected to have an impact on the productivity of several major crops, although this may in part be offset by the fertilizing effect of higher CO_2.

Impacts are estimated using a range of model projections based on low to high emission scenarios and reported as percentage changes between the 30-year average around the historical period and the 30-year average around 2050.

6.8
13.2 (2.9)%
13.8 (-2.6)%
Rice
tons / ha

66.7
11.9 (5.9)%
12.4 (na)%
Sugarbeet
tons / ha

53.8
-0.1 (0)%
-4.2 (-4)%
Sugarcane
tons / ha

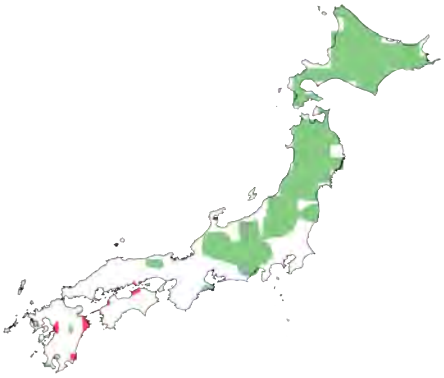
4.3
11.2 (4.5)%
10.7 (3.7)%
Wheat
tons / ha

2050

Productivity change with (without) the CO_2 fertilization effect. Estimates assume sufficient water and nutrient supplies, and do not include impacts of pests, disease, or extreme events.

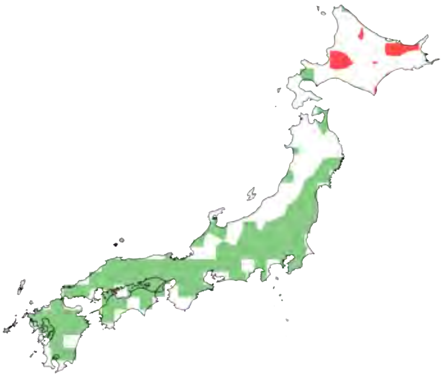
CHANGE IN RICE

🟥 − = 🟩 +



CHANGE IN WHEAT

🟥 − = 🟩 +



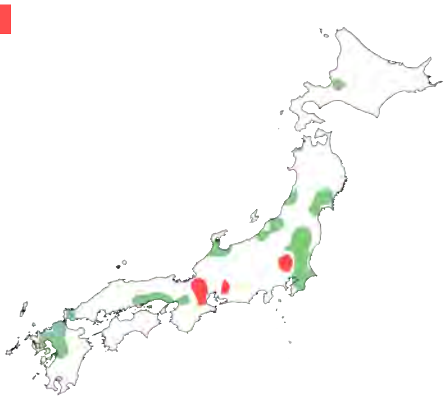
On average, rice productivity may increase, particularly in central and northern areas. However, a decline is expected for extremely warm years due to heat stress. High temperatures could be detrimental to rice yield with increasing levels of immature and cracked grains. Sugarcane may suffer a strong decline, while rapeseed and wheat cultivation may see strong gains in productivity especially in the northern provinces. Warming is projected to lead to an overall increase in the productivity of grass for livestock, with a decrease in temperate grasses and increase in tropical grasses. However, the latter is relatively poor in nutrients. A changing climate may alter suitability and distribution of several high-cash tree crops: Satsuma mandarin gradually expanding northward and inland; Tankan mandarin could replace several coastal areas where Satsuma mandarin is actually cultivated; Grape production in Hokkaido is projected to expand to higher altitudes.

ADAPTATION IN AGRICULTURE AND WATER RESOURCES

Climate change may have some positive effects on some of the most widely used crops. However, higher temperatures may generally require an increase in irrigation demand due to higher plant evapotranspiration and expansion of irrigated areas. Japanese agriculture actually covers 40% of national self-sufficiency in terms of food supply (on a calorie basis). On average, irrigated areas are not expected to increase and in some regions they are even expected to decline, leading to lower water consumption from the agricultural sector. If demand and internal production for grain and other high-cash crop increases, an expansion in irrigated area could pose a threat to water resources in terms of quantity and quality.

CHANGE IN WATER DEMAND

🟩 − = 🟥 +



Agriculture
Water Demand
% of change

-1.2%
-4.9%

2050

Several adaptation practices may help reduce climate risks, such as anticipating crop transplanting to avoid rice earing in the hottest period, developing heat-resistant rice varieties, supporting management and renewal of irrigation facilities.

JAPAN
FORESTS

FORESTS IN JAPAN

Japan's rainy climate and mild temperatures are an ideal environment for forests, making it one of the most forested countries in the world with boreal coniferous forests, temperate deciduous forests and evergreen broadleaf forests.

Over 20% of these are considered primary. Mangrove stands can be found in some places in the southern islands.

FORESTED AREA AND CARBON STORAGE

Nearly 70% of Japan is covered in forests. Japanese forests store almost 3,000 teragrammes of carbon and remove over 1.5 megagrammes of carbon per hectare every year. Forests are undoubtedly a key carbon sink for Japan.

1990

25 Mln ha
Million hectares
Forested area

46 Tons/ha
Tons of Carbon per hectare
Carbon stock

2020

25 Mln ha
Million hectares
Forested area

66 Tons/ha
Tons of Carbon per hectare
Carbon stock

FOREST PRODUCTIVITY

Forest productivity or Net Primary Production is the net carbon captured by plants. It is the difference between the carbon gained by Gross Primary Production - net photosynthesis measured at the ecosystem scale - and carbon released by plants' respiration. It is expressed per unit land area.

2050

Productivity anomaly
Tons of Carbon per hectare per year

+0.59

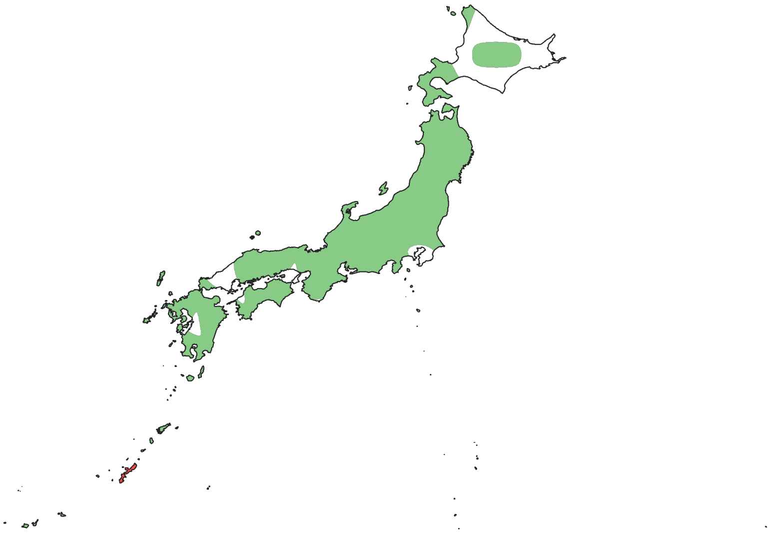
+0.42

Models predict a slight increase in the entire country, but with very high uncertainty

+ Fertilizing effect of increasing atmospheric CO_2 and nitrogen deposition, and rising temperatures promote productivity

Noticeable decrease expected for the island of Okinawa

+ Increasing risk of drought stress reduces productivity



KEY SPECIES UNDER CLIMATE CHANGE

THREATENED
SHIITAKE MUSHROOM
Significant negative impacts on Shiitake mushroom production

VULNERABILITY
BEECH
Beech dominated forests show high vulnerability and could be replaced by Oak dominant types

VULNERABILITY
MANGROVES
Rapid sea level rise will threaten coastal mangrove forests of the islands south of Kyushu

DECREASING
CONIFEROUS
In northern Japan the growth rates of coniferous species will decrease whereas broad-leaved species will increase

FIRES IN JAPAN

Fire is a structural ecological process that provides several types of ecosystem services and impacts on socio-ecological systems, including human health, carbon budgets, and climate change. Changes in global fire activity are influenced by multiple factors such as land-cover change, policies, and climatic conditions. Fire also releases large quantities of greenhouse gases into the atmosphere, contributing to a vicious cycle.

During the last two decades, 36,400 fires occurred.

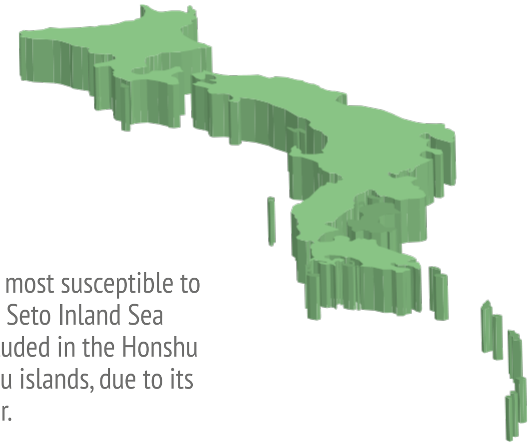
BURNING
19 THOUSAND HECTARES OF FOREST

EMITTING
0.78 TERAGRAMMES OF CARBON PER YEAR

FOREST FIRE EMISSIONS CONTRIBUTED TO 51% OF TOTAL FIRE RELATED CARBON EMISSIONS

WHERE DO FIRES OCCUR?

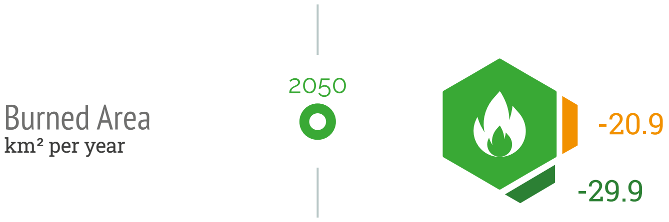
Herbaceous ferns and dead plant matter are the main fuel for forest fires.

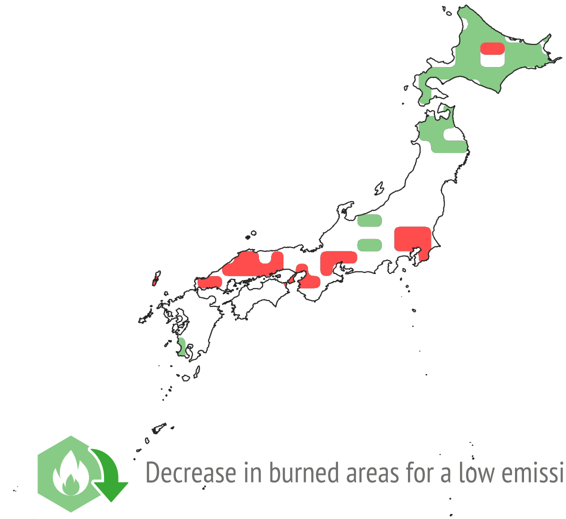


The region most susceptible to fire are the Seto Inland Sea region, included in the Honshu and Shikoku islands, due to its dry weather.

FUTURE BURNED AREA

Under a low emission scenario, models project a generalised decrease in burned areas leading up to 2050, which might concentrate in northern regions dominated by temperate conifer forest. In contrast, in some southern areas dominated by temperate evergreen forests burned area is expected to slightly increase. Under a medium emission scenario, models project temperate conifer forests in the north to experience a slight increase.





Decrease in burned areas for a low emissions scenario

Increase in burned areas for a low emissions scenario
+ Increase in number of days with weather that is considered conducive to fire due to prolonged dry periods
+ Increase in temperature and greater variance in rainfall
+ Prolonged fire season

CASE STUDY: AIR QUALITY

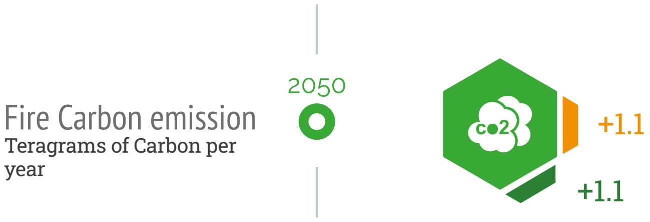
Vegetation fires are a significant source of gases and particulate that can have adverse effects on human health, with impacts at regional and intercontinental scales.

During 2003, 2008 and 2014, anomalous warm and dry conditions over Euro-Asia led to large scale wildfires with smoke reaching the Hokkaido region and affecting air quality in Sapporo.

In the spring of 2003 and 2008, intense Siberian wildfires led to Rishiri Island experiencing high PM2.5 concentrations.

FUTURE FIRE EMISSIONS

Under both low and medium emissions scenarios, fire emissions are expected to increase slightly, following a similar spatial pattern to burned areas with a pronounced increase in north-eastern regions.



JAPAN
URBAN

OVERVIEW

With an urbanization rate of 91.8% in 2020, Japan is one of the most urbanized countries. Population will continue to concentrate in urban areas, with an urbanization rate of almost 95% expected by 2050.

Half of the urban population is concentrated in the two largest urban areas, and 20% in urban areas with less than 300,000 inhabitants. Japan's overall demographic decline will mainly affect medium sized cities, which will lose up to 16% of their population by 2035.

Built up areas cover 10.37% of Japan (38,729.36square kilometers).

Population in Urban Areas

2020 116,099,672

2050 103,038,909

Graphs refer to data provided by United Nations, Department of Economic and Social Affairs, Population Division (2018). World Urbanization

Urbanization Rate

2020 91.8%

2050 94.7%

OVERVIEW OF KEY CLIMATE IMPACTS IN URBAN AREAS

Under a changing climate, Japanese cities and urban agglomerations will be affected by increasing impacts from heatwaves and the consequences of flooding due to heavy rainfall and storm surges.

HEATWAVES AND HEAT STRESS

Japan is experiencing an increasing trend in fatalities due to heat illness, with a peak in 2010, when temperatures were extremely high. Numbers of heat related ilnesses and deaths are increasing. In the period between 1968 and 1994, 2,326 deaths from heat stroke were registered, of which 589 in 1994 when a severe heat wave brought temperatures reaching over 38°C.

During the 2018 summer, a total of 95,137 Japanese residents were taken to hospital with heat stroke symptoms, of which approximately 50% were 65-year-olds and above. Rising average temperatures and increasing numbers of extreme events will lead to more frequent and prolonged heat waves.

As a consequence morbidity and mortality will rise and may even double in eastern and northern Japan.

2050

Cooling Degree Days

% of change

+120.0%
+43.0%
+27.0%

2050

Heatwave frequency

% of change

+85.5%
+31.8%
+18.3%

2050

Heatwave duration

% of time

+1,563%
+232%
+79%

AN AGEING SOCIETY

Japan is a highly urbanized and rapidly ageing society which is problematic as the elderly are particularly vulnerable to heat related impacts, and urban populations are more exposed to high temperatures.

By 2035, approximately 38% of the population will be over 65 years old. High levels of air pollution are increasing the impacts of urban heat. In 2017, almost 77% of the overall population was exposed to levels of air pollution exceeding WHO threshold levels.

2017

Population exposed to air pollution

76.8%

COASTAL FLOODING

Japan is vulnerable to coastal flooding, due to its geography and dense urbanization along the long coastline, in particular on the most populated island of Honshū. Japan is also subject to regular Typhoon landfalls.

2050

2100

Projected sea level rise

0.23 m

0.18 m

0.77 m

0.38 m

FLOODING AND LANDSLIDES

Japan is vulnerable to flooding from extreme precipitation and coastal flooding due to its layout and dense urbanization, in particular on the most populated island of Honshū. High rates of soil sealing also contribute to flooding risks. In 2018, torrential rainfalls resulted in flash floods and mudslides causing more than 200 deaths the evacuation of 2.3 million people and over 7 billion USD in damages.

In the same year a typhoon caused over 12 billion USD in economic damages. Rising sea levels, wave heights and frequency of typhoons are expected to increase damage to human settlements. Future flood risk will increase bringing deeper flood depths, with a 170% increase of flood depth in Tokyo expected by 2050. This will generate damages to real estate and infrastructure by 220% to 240%.

2050

Runoff increase
% of area

+28%

+10%

+5%

SURFACE SEALING AND FLOODS

Heavy precipitation in cities is problematic due to the high level of sealed surfaces. Soil sealing increases run off and reduces the amount of water absorbed by soil. Where there are large amounts of impervious ground cover, short duration extreme rainfall events can lead to increased flooding, even resulting in flash floods.

SOIL SEALING AND FLASH FLOODS

Under a high emissions scenarios, the risk of significant damage to urbanized areas is expected to increase, driven by the combined effect of changing precipitation patterns, rising sea levels and high rates of soil impermeability.

2010

% of urban population

Population living in slums

0%

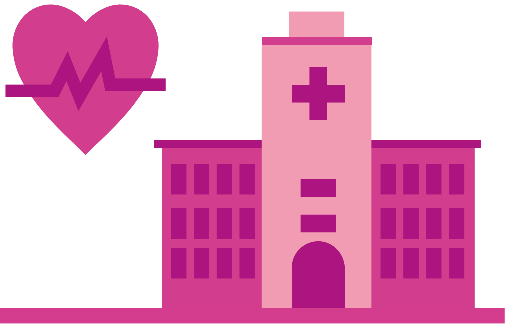
2018

% of total population

Urban population living in areas where elevation is below 5 meters

11.9%

JAPAN
HEALTH



OVERVIEW

Japan’s climate and weather patterns have changed. The increase in mean temperature, combined with the increase in heatwave intensity and heat stress, puts vulnerable populations, such as the elderly, at high risk. It should be noted that Japan has the highest share of the elderly population in the world. Rising temperatures are also expected to facilitate the spread of disease across Japan, including vector-borne diseases such as dengue, which thrives in warmer climates.

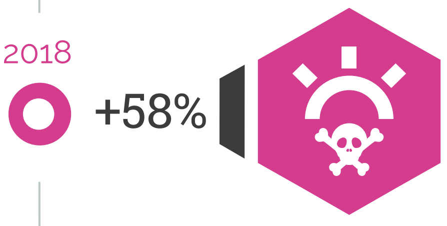
HEAT RELATED MORTALITY

Japan’s ageing population makes it uniquely vulnerable to the changing climate, especially heatwaves. Under a high emissions scenario, heatwave-related excess deaths will increase by 174%, whereas under a moderate warming scenario of medium emissions, the increases in heatwave-related excess mortality will be 104%.

In 2018, there was a 58% increase in heat-related deaths in Japan compared to a 2000 to 2004 baseline. 32.8% of heat-related mortality in Japan from 1991 to 2015 can be attributed to human-induced climate change.

Heat-related mortality

% change with respect to 2000-2004



IMPACTS ON LABOUR

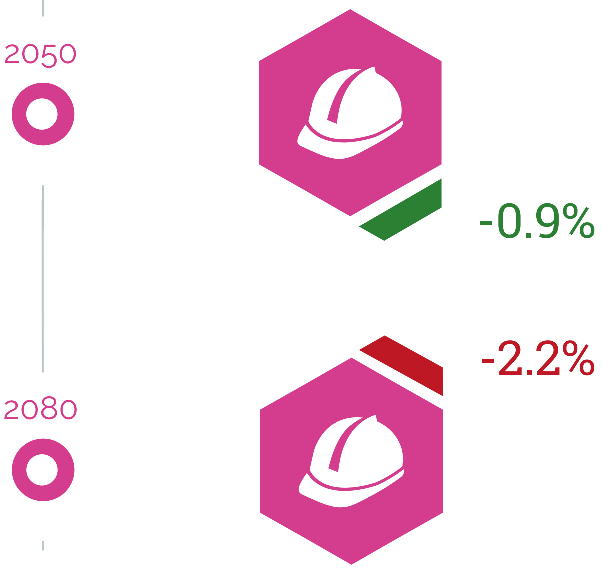
Labour is directly affected by changes in environmental conditions. Warming affects both the number of hours worked (labour supply) and on the productivity of workers during their working hours (labour productivity). Both labour supply and productivity are projected to decrease under future climate change in most parts of the world, and particularly in tropical regions.

Parts of sub-Saharan Africa, south Asia, and southeast Asia are at highest risk under future warming scenarios. Future climate change will reduce global total labour in the low-exposure sectors by 18 percentage points and by24.8 percentage points in the high-exposure sectors under a 3.0°C warming scenario

Total labour in Japan is expected to decline by 0.88% under a low emissions scenario, and by 2.2% under a medium emissions scenario.

Impact on total labour

% change with respect to 1986-2005 baseline



CLIMATE CHANGE AND DENGUE

Dengue has spread throughout the tropical world over the past 60 years and now affects over half the world's population. Globally, vectorial capacity for both dengue vectors (A. aegypti and A. albopictus) has been rising steadily since the 1980s, with nine of the ten highest years occurring since 2000.

Climatic stressors are one important driver of the current distribution and incidence of dengue. Climate change is likely to expand the geographical distribution and suitability of several vector-borne human infectious diseases including dengue. The risk of dengue transmission is increased by warming climates, as the growth and development of mosquitoes are significantly influenced by temperature, precipitation, and humidity.

CLIMATE CHANGE AND ZIKA

Zika virus has spread to at least 49 countries and territories since 2013. Climate change impacts on transmission suitability risk have increased over the years and future warming over 1.3 billion additional people could face suitable transmission temperatures for Zika by 2050.

DENGUE AND ZIKA: POPULATION AT RISK

The 2014 dengue outbreak in Japan may indicate that environmental conditions are becoming favourable.

Under a medium emissions scenario, 84.7% of the population will be at risk of transmission-suitable mean temperature for dengue by 2050, whereas 81.8% will be at risk under a high emissions scenario.

In the case of Zika, 80.7% of the population will be at risk by 2050 under a medium emissions scenario, whereas 82.7% will be at risk under a high emissions scenario.

CLIMATE CHANGE AND MALARIA

Japan is a former malaria-endemic country, where malaria vectors are still present. By 2050, 40.4% and 42.5% of the Japanese population will be at risk of malaria under low and high emissions scenarios, respectively.

POLLUTION AND PREMATURE MORTALITY

An overall 10 µg/m3 increase in daily PM2.5 concentrations was associated with a 1.3% increase in total non-accidental mortality in Japan. By 2060, 779 deaths will be caused by outdoor air pollution per year per million people in Japan compared to 468 in 2010.

Dengue suitability

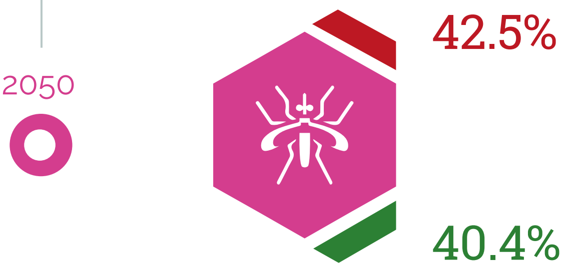
% of population at risk

Zika suitability

% of population at risk

Malaria suitability

% of population at risk



JAPAN
ENERGY

ENERGY SYSTEM IN A NUTSHELL

In recent decades, Japan has made substantial improvements in the overall energy efficiency of its economy.

The 2012 Fukushima disaster, and the ensuing phasing out of nuclear capacity, however, has considerably increased the country's dependence from fossil fuels, which is putting a strong strain on Japan's decarbonization process.

0.08
ktoe/US$
Energy intensity

10.5%
AC Share in
electricity consumption

90.5%
Import
dependence ratio

CLIMATE CHANGE TODAY

EXTREME EVENTS - FLOODS AND TYPHOONS

The Japanese energy system has been hit severely by floods caused by heavy precipitation and typhoons. In September and October 2020, the Faxai and Hagibis typhoons left 10 million homes without electricity. Cooling needs are increasing, following the faster-than-global-average temperature increases, and the increase in heatwave frequency .

HEAT - COOLING NEEDS

Cooling needs are increasing, following the faster-than-global-average increase in temperatures and the increase in heatwave frequency.

HEATWAVES

Heatwave frequency is increasing. Japan has been hit by a particularly strong heatwave in August 2019.

ENERGY SUPPLY

Japan's energy mix shows a strong dependence on (imported) fossil fuels (88% of total primary energy supply in 2019), mostly oil, 38% used mainly for transport, but also coal (27%), and gas (23%), which compensate the drop in nuclear power generation after the Fukushima disaster (4% in 2019 compared to 15% in 2010). Only 8% of total primary energy supply is met by renewable sources (doubling their 1990 share).

ENERGY DEMAND

Energy in Japan is used mainly by the industrial sector (29% of total final consumption in 2018), transport (25%) tertiary sector (17%) and residential demand (15%); whereas agriculture and fishing together have a slim 1.7% share. The share of non-energy use is relevant (12%). Air conditioning contributed 10.5% to residential electricity demand in 2015.

FUTURE ENERGY DEMAND

In Japan, the decrease in heating demand is going to be more than compensated by the increase in cooling needs, resulting in a net increase of energy demand of almost 2,698 PJ (750 billion Kwh) by 2050 under a medium emissions scenario.

Net change in energy demand due to changes in HDD/CDD
Billion KWh

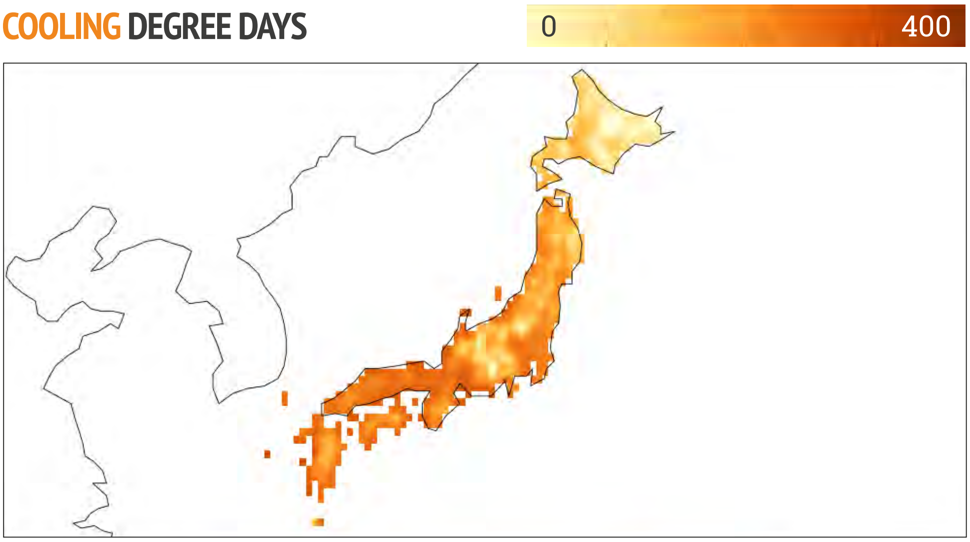
2050

+ 749.68

COOLING NEEDS

Cooling needs increase more substantially in the southern islands of Shikoku and Kyushu, while in Hokkaido and in the elevations of Honshu, only moderate increases will occur.

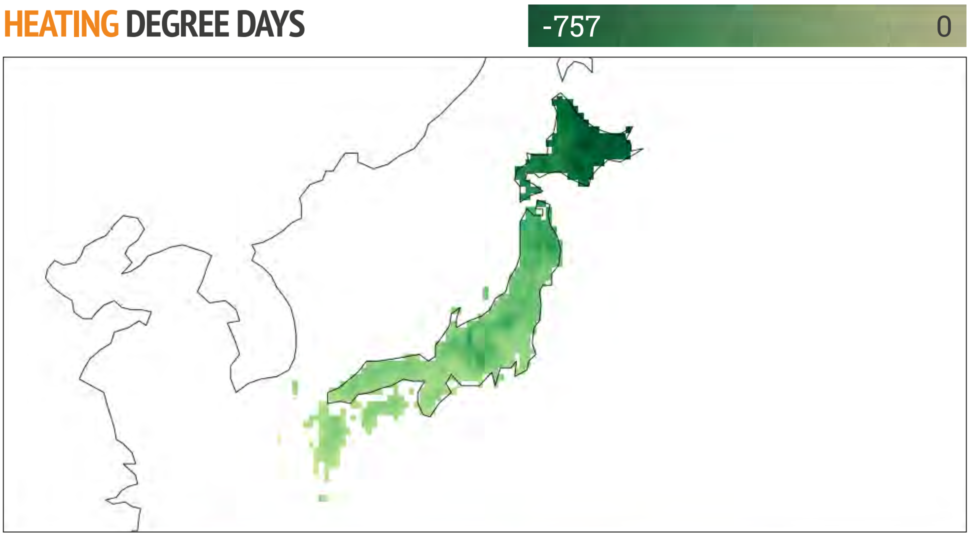
COOLING DEGREE DAYS



HEATING NEEDS

The pattern is somewhat reversed comnpared to cooling needs. Marked decreases in heating needs are expected all over the country, descending in magnitude from Hokkaido where they reach their maximum, to the southern islands where the drop is moderate.

HEATING DEGREE DAYS



FUTURE ENERGY SUPPLY

The future configuration of the Japanese energy mix is likely to be determined by the evolution of climate mitigation policies and hence is outside the scope of this report. In 2020 Japan announced its target for full decarbonization by 2050, but it is still committed to a 26% emission cut by 2030. This is likely to result in fossil fuels (and their vulnerabilities) keeping their relevance for the next few years, while carbon free sources (renewables and the residual nuclear) and their vulnerabilities will prevail in the second half of the century.

Change in Hydropower generation
% of change

2050

-3.56%

-2.63%

EXPECTED IMPACTS OF CLIMATE CHANGE

The 2021 IEA's Japan Policy Review notes that adapting the energy sector to climate change was not perceived as a priority by the Japanese government in the 2015 NDC, and the threats posed were seen as of "not very high significance and low urgency due to the limited number of cases", bar some concern for indirect impacts on imports.

This position does not seem to have changed despite the recent extreme climate events. A modest reduction in hydropower potential is expected.

JAPAN
ECONOMY

OVERVIEW

Japan ranks 4th in terms of GDP among G20 economies. Japan was badly affected by the COVID crisis, recording a decline of 4.8% in real GDP in 2020. In 2021 this trend has reversed and the country has seen 3.3% growth.

IMPACTS ON GDP

There is a noticeable variability across estimates of the overall economic impact of climate change for Japan, although estimates under similar assumptions tend to converge across studies.

The projected overall macroeconomic impacts for Japan range from moderate GDP losses (0.8 %) under a low emissions scenario in 2050, to a loss larger than 10 % under a high emissions scenario by the end of the century.

GDP Loss

% change w.r.t baseline

2050

1.1/3.72%

0.8/1.6%

2100

10.7%

3.47%

SECTORAL ECONOMIC IMPACTS

IMPACTS ON INDUSTRY AND INFRASTRUCTURE

Japan features the 7th longest coastline in the world. Just under half of its population, and about the same proportion of industrial production, is vulnerable to an increase in sea level, due to the increased risk of coastal erosion, storm surges and typhoons.

Within the service macro-sector, the main economic impacts will likely affect trade and transportation. Japan's economy and manufacturing sector are based on highly sophisticated technologies, requiring a wider array of inputs which are usually not produced domestically, but imported. This dependence from imports may also be an important source of climate vulnerability.

For instance, it is estimated that 17% of Japanese imports during the period 2008-2018 originated from countries heavily threatened by climate change. At the same time, Japan could benefit from a possible opening of the transpolar Artic route for freight transport, which would reduce its distance from northern Europe by 37%. However, the actual viability of such a route might be severely limited by safety and environmental factors, and hence the benefits, if any, might be very limited.

IMPACTS ON AGRICULTURE

Agriculture, forestry and fisheries make up a small share of GDP, accounting for just 1% of the country's GDP. Negative impacts of climate change can be expected in terms of reductions in the yield (up to 40%) of high quality rice across Japan, although the overall yield of rice, irrespective of the quality, may in fact increase by up to 30%. Analogously, the quality of fruit and shitake fungi is expected to decrease; the suitable areas for the cultivation of some fruits is expected to shift to higher latitudes and altitudes.

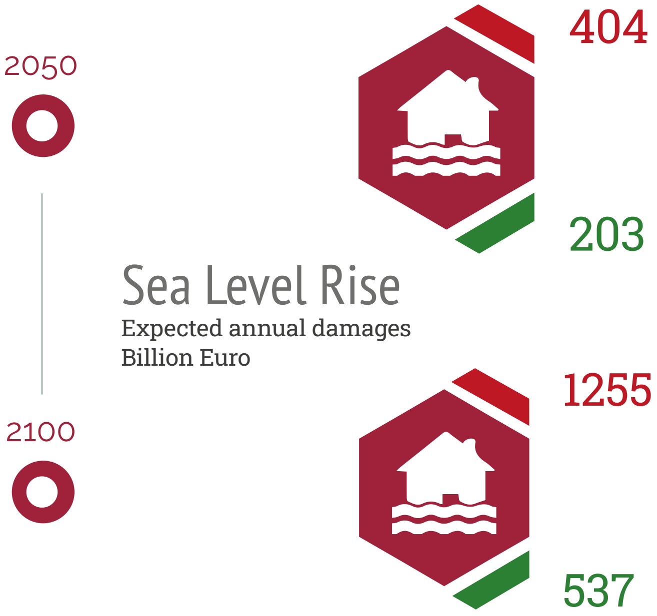
IMPACTS ON FORESTRY AND FISHERY

Increasing sea water temperatures around Japanese shores may result in a drop in fish catches for traditional species (such as Hokkaido wild salmon or abalone in the Tokyo Bay) and/or a transition to tropical species. By mid century losses for the fishing sector could range between 243.6 million EUR under a low emissions scenario to 399.6 million EUR under a high emissions scenario. In the second half of the century, production losses may reach 239 million under a low emissions scenario and 564 million EUR for a high emissions scenario. The areas suitable for the cultivation of edible seaweed are also predicted to decline because of increasing sea water temperatures.

SEA LEVEL RISE DAMAGES

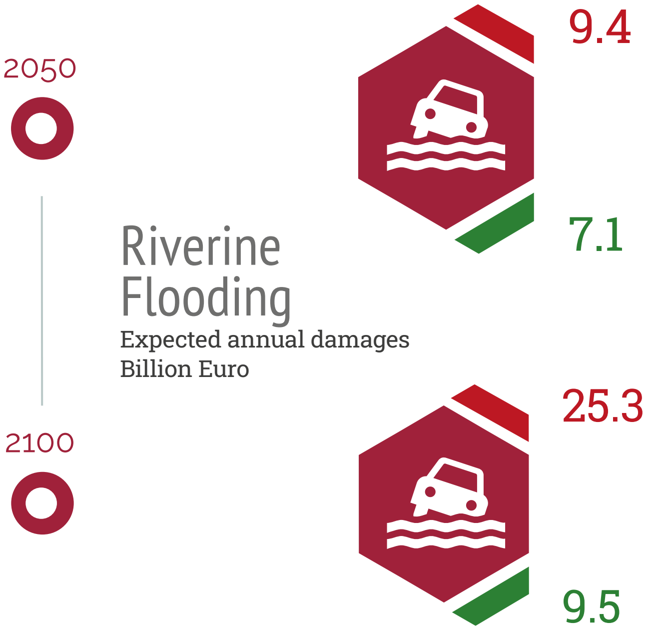
The economic losses induced by projected sea level rise in Japan are massive. Assuming constant levels of coastal protection, in the low emissions scenario asset losses could reach 203 and 537 billion EUR in 2050 and 2070, respectively.

Under a high emissions scenario losses could increase to 404 and 1,255 billion EUR in 2050 and 2070.



RIVER FLOODING DAMAGES

River flooding can also induce substantial damages. By mid century total asset losses could reach 7.1 to 9.4 billion EUR and in the second half of the century 9.5 to 25.3 billion EUR under low and high emissions scenarios, respectively.



IMPACTS ON TOURISM

Japan is an important destination for international tourism, ranking 7th in 2019 in terms of international tourists' receipts. Some of its major attractions are nature-based and hence dependent on climate conditions.

Key tourist hotspots such as autumn foliage season, cherry blossom season and winter drift ice form the Okhotsk Sea in Hokkaido are all expected to undergo a direct negative impact due to increasing temperature. Increasing temperatures will also imply less snow in winter on mountain slopes, and hence negative consequences for skiing activities and mountain winter tourism.

The expected increase of extreme events such as typhoons is also expected to weight negatively on the propension of international tourists to visit this county in the future.

IMPACTS ON ENERGY

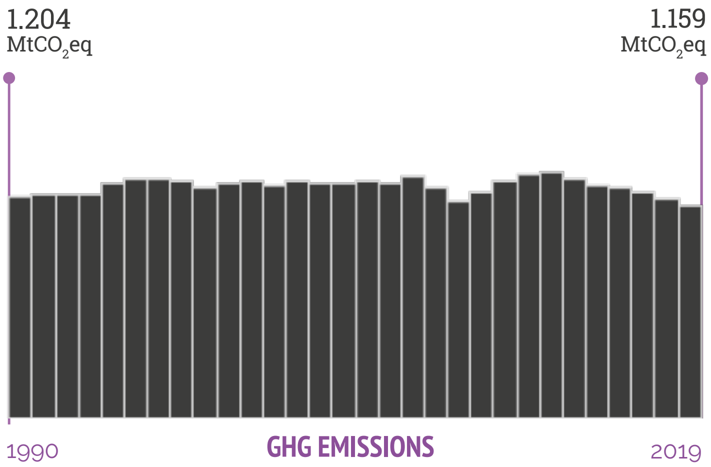
As with all other economic sectors, energy supply and energy networks in Japan will undergo more intense stress from extreme weather events.

Economic impacts of shifts in household and firm energy demand (see chapter on energy) are difficult to predict and will mostly lead to redistribution effects. In the case of Japan, the magnitude of the increase in demand for cooling is expected to exceed by far the (tiny) decrease in heating demand, hence a significant increase in energy bills is expected.

JAPAN
POLICY

OVERVIEW

Japan is responsible for 2.6% of global GHG emissions and has almost twice the world average rate of CO_2 emissions per capita. Emissions have been declining since 2013, and a net zero emissions by 2050 target has been set.



GHG EMISSIONS

INTERNATIONAL COMMITMENTS

In April 2021, Japan proposed an updated NDC target of reducing emissions by 46% below 2013 levels, which was a significant increase from its previous commitment of a 26% reduction.

CLIMATE POLICY COMMITMENTS CHRONOLOGY

2002 **Kyoto Protocol - 1st period**

6% yearly average reduction in GHG over the four year period 2008-2012, with respect to 1990 levels

2016 **Paris Agreement - 1st NDC**

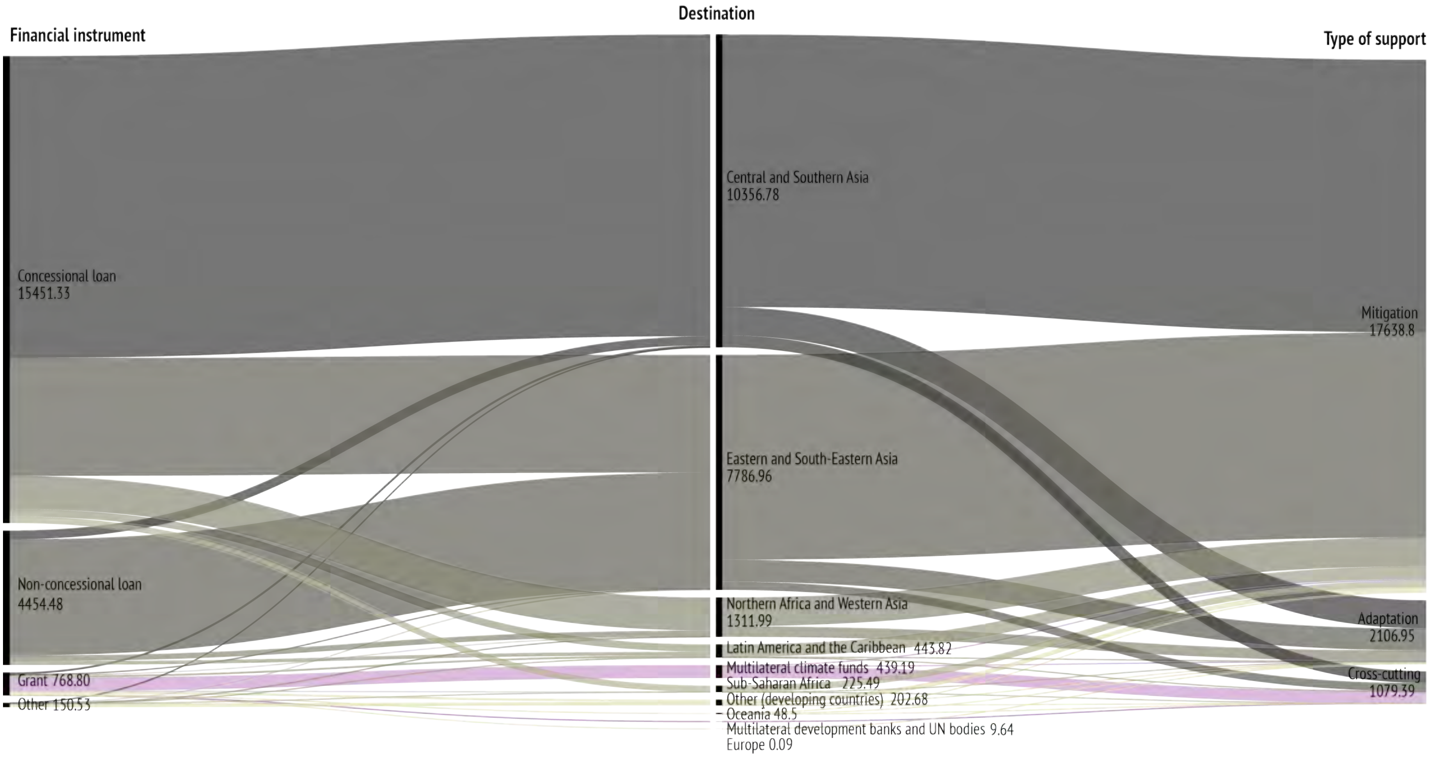
26% of GHG reduction by 2030 with reference to 2013 levels

2021 **Paris Agreement - NDC update**

46% GHG reduction by 2030 with reference to 1990 levels

INTERNATIONAL CLIMATE FINANCE ASSISTANCE

Japan reported a financial commitment of 20.8 billion USD in climate action in 2017-2018 in its 4th Biennial Report, almost all in the form of loans and similar instruments. The majority was directed at Asia. Mitigation was the main type of support.



SUSTAINABLE RECOVERY POLICY

According to the Global Recovery Observatory, in 2020 the proportion of green spending out of total recovery spending was 27%.

1,311.95 billion $	304.48 billion $	80.82 billion $
Total Spending	Recovery Spending	Green Spending

DOMESTIC ADAPTATION POLICY

Japan's National Plan for Adaptation to the Impacts of Climate Change was adopted in 2015 and it includes sectorial measures in Agriculture, Forestry, Fisheries; Water Resources; Natural Ecosystems; Natural Disasters/Coastal Areas; Human Health; Industrial/Economic Activity; and Life of Citizenry and Urban Life.

- ○ Domestic Adaptation Policy
  - ○ Inclusion of Adaptation in NDCs
  - ○ Integrated Adaptation & Mitigation Policy
  - ○ Dedicated Adaptation Strategy
  - ● Dedicated Adaptation Plan
- ● Subordinate Adaptation Policies
  - ● Sectoral Adaptation Plans
  - ● Subnational Adaptation Plans

○ Policy not in place ● Active policy

ADAPTATION POLICY HIGHLIGHTS

TRANSNATIONAL INITIATIVES

Asia-Pacific Climate Change Adaptation Information Platform (AP-PLAT)

The AP-PLAT was established to share climate risk information online with research institutes/universities and to support adaptation measures by providing advanced scientific climate risk information

NATIONAL INITIATIVES

National Plan for Adaptation to the Impacts of Climate Change

In 2015, Japan's government approved the 1st adaptation plan to progress adaptation to climate change impacts systematically and comprehensively across the country

Climate Change Adaptation Information Platform (A-PLAT)

A-PLAT is a portal that provides centralized information related to the impacts of climate change, aiming to support the local governments, businesses, and individuals to consider the adaptation measures to climate change.

SUBNATIONAL INITIATIVES

Tokyo Climate Change Adaptation Policy

The policy focuses on climate change impacts and policies for response to natural disasters, health, agriculture, forestry, and fisheries, water resources and water environment, and natural environment.

Fukuoka City's Climate Change Countermeasures Action Plan

The plan focuses on natural hazards from heavy rainfall and flooding, pressure on water resources, health risks from increased heat, biodiversity loss, and effects on agricultural produce.

ENERGY TRANSITION

Japan is performing along the G20 country average for what regards the overall Energy Transition indicator. In particular, high performance in the Efficiency and Electrification domains are pushing the transformation of the energy sector.

However, much is still to be done in increasing renewables installed capacity and in using less fossil fuels. Progressing along this direction can also lower the level of urban air pollution and of CO2 emissions per capita, further improving the Emissions indicator.

Energy Transition	58.7	60.4
Fossil Fuels	45.3	43.5
Renewables	19.7	11.0
Efficiency	84.9	92.4
Electrification	70.8	80.3
Emissions	72.9	74.9

G20 AVERAGE

COUNTRY

Only actively pursuing an energy transition based on decarbonization and electrification – from policy and regulation, to health and education – will enable countries to benefit the most from future opportunities and fight climate change whilst ensuring an equitable distribution of wealth.

The Energy Transition indicators were developed by Enel Foundation in cooperation with SACE, and provide a retrospective analysis based on historical data.

G20 CLIMATE RISK ATLAS

Impacts, policy, economics

MEXICO

How to read the Atlas: graphs, colours and scenarios.

The maps used in this Atlas are taken from **The World Bank Official Boundaries** - ***https://datacatalog.worldbank.org/search/dataset/0038272*** (accessed on May 28, 2021). For the section Energy, the maps are based on Panoply Data Viewer ***https://www.giss.nasa.gov/tools/panoply/credits.html***

Each sector of this Atlas contains data and information on various climate scenarios.

When reported in graphs, the **colour black** indicates data and information referring to the current state, the past or the baseline.

When the authors refer to **RCP (Representative Concentration Pathways)**, the 3 colours used across the factsheet refer to 3 scenarios, which are 3 different development options with different levels of greenhouse gas emissions, **respectively low emissions (green), medium emissions (orange), and high emissions (red)**. The same colour code is used when RCPs are associated with Shared Socioeconomic Pathways (SSP).

In some cases, the authors refer to global warming scenarios. In these cases, the 3 colours used refer to a temperature rise of **1.5°C (green), 2°C (dark green), and 4°C (red)**.

When the authors refer exclusively to **Shared Socioeconomic Pathways - SSPs** (Population affected by river floods in the section: "Water"), data related to **SSP3** - that encompasses, among other things, slow economic growth, material-intensive consumption, and persisting or worsening inequalities – **are reported in a lighter shade**; **SSP5** – which refers to social and economic development that is coupled with an energy-intensive lifestyle and the abundant exploitation of fossil fuel resources – is shown using a **middle shade of the colour**, whereas data related to **the present** conditions **are represented in a dark shade**.

Further details on scenarios, methodologies, and the full list of references are available at: **www.g20climaterisks.org**

Concept and graphic design by element6.eu

MEXICO
CLIMATE

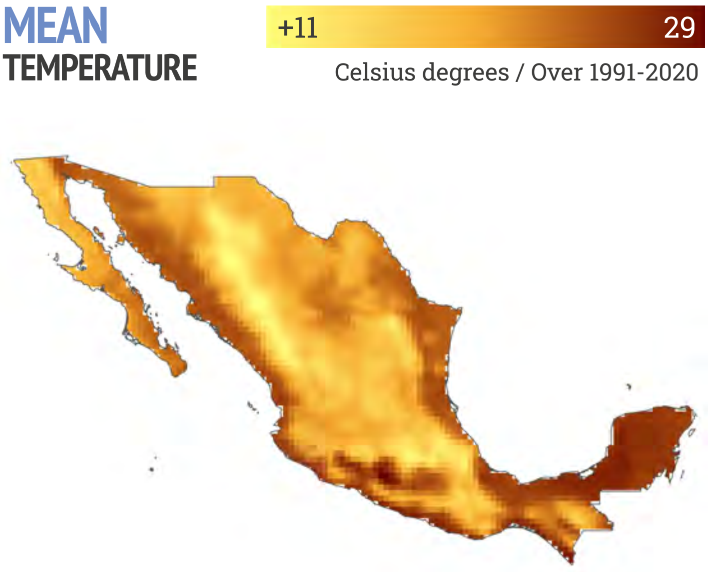
OVERVIEW

Mexico has different climates due to its wide latitudinal extent and the presence of the Northern Atlantic and Northeast Pacific Oceans' subtropical high-pressure systems. Two distinct climate zones may be identified through the Tropic of Cancer: the temperate one, generally arid or moderately rainy with mild to warm summers and cool to cold winters; and the tropical one, which is usually rainy and hot.

TEMPERATURE

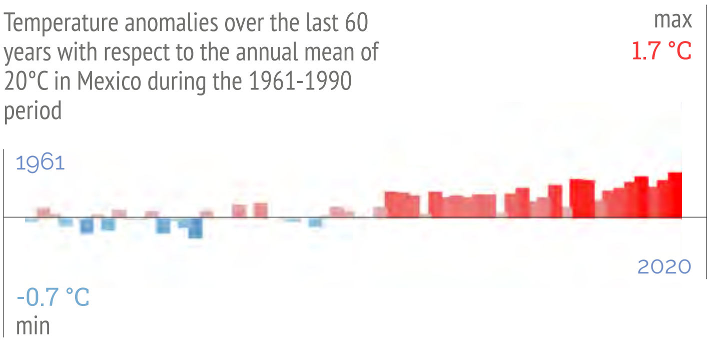
The temperature regime in Mexico varies from north to south. In the northern part, temperatures lower from coastal to inner areas, whereas in the southern part they are generally higher and influenced mainly by elevation.

MEAN TEMPERATURE



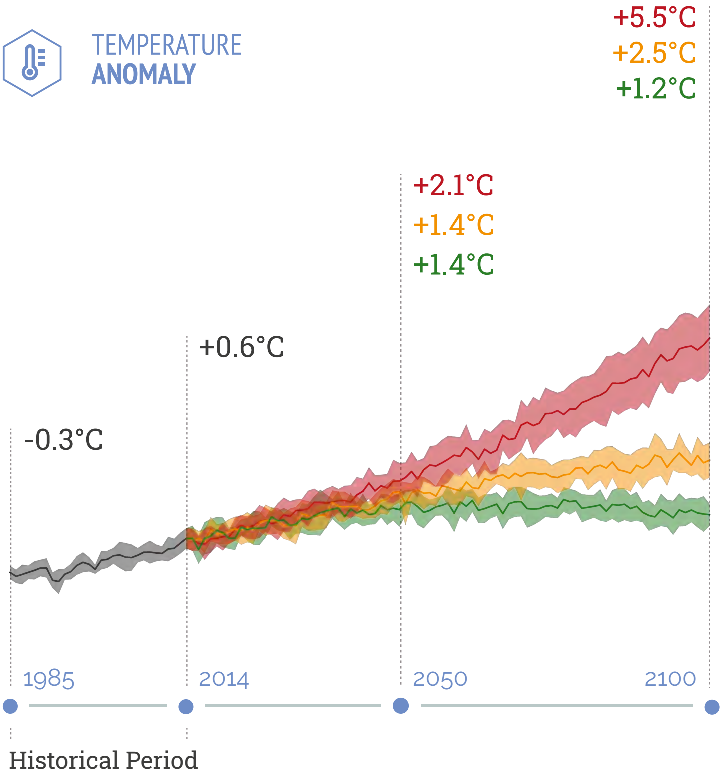
TEMPERATURE TREND

Temperature anomalies over the last 60 years with respect to the annual mean of 20°C in Mexico during the 1961-1990 period



TEMPERATURE PROJECTIONS

Under a low emissions scenario projected temperature variations will remain contained under +1.5°C, both by 2050 and 2100.
Under a high emissions scenario, with no reduction in GHG emissions, much greater temperature anomalies are expected by both 2050 and 2100.



EXPECTED VARIATION FOR TEMPERATURE AT 2050

The indicators show variations in selected temperature characteristics for a thirty-year period centred on 2050 (2036-2065) with respect to the reference period 1985-2014.

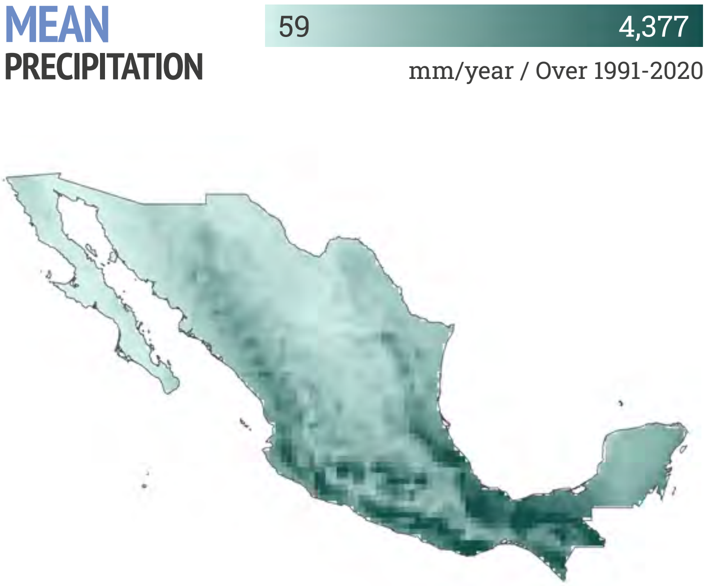
+2.1°C	+2.3°C	+2.0°C
+1.6°C	+1.8°C	+1.5°C
+1.3°C	+1.5°C	+1.2°C
Annual Mean Temperature	Max Temperature of warmest month	Min Temperature of coldest month

PRECIPITATION

The precipitation regime in Mexico changes greatly depending on time of the year and location. Specifically, precipitation processes are mainly determined by rainfall in the rainy season, which spans from June to November. Snowfall is mainly observed in northern states during winter and at the top of mountains and volcanos in central Mexico.

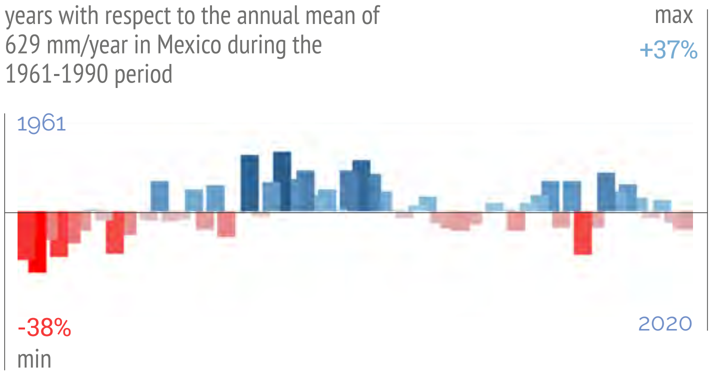
The northern part of the country usually receives scarce precipitation in comparison with the southern part.

MEAN PRECIPITATION



PRECIPITATION TREND

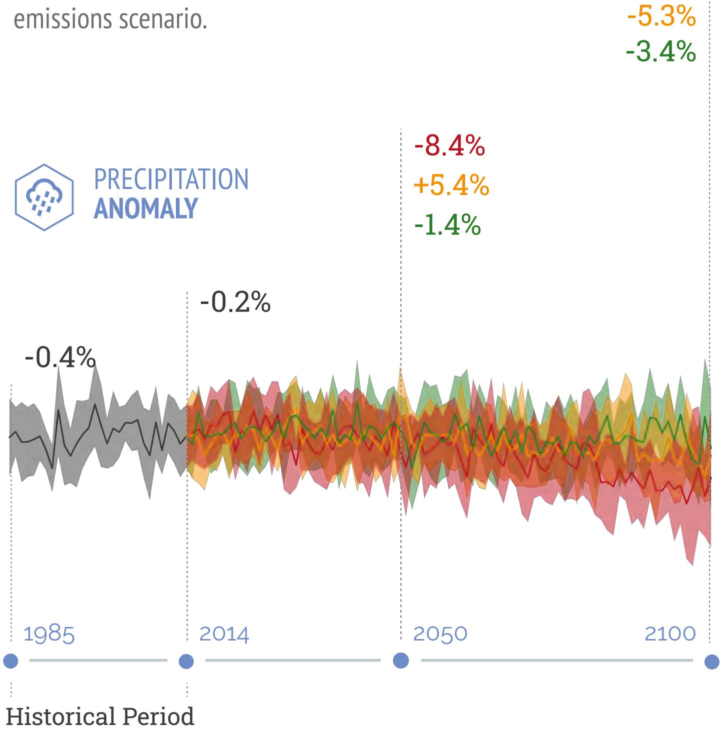
Precipiation anomalies over the last 60 years with respect to the annual mean of 629 mm/year in Mexico during the 1961-1990 period



PRECIPITATION PROJECTIONS

Precipitation trends show a very complex signal, under all emissions scenarios, with a very large variability among climate models. Trends show a however a reduction in precipitation under a high emissions scenario.

PRECIPITATION ANOMALY



EXPECTED VARIATION FOR PRECIPITATION AT 2050

The indicators show variations in selected precipitation characteristics for a thirty-year period centred on 2050 (2036-2065) with respect to the reference period 1985-2014.

-2.2%
-0.9%
+0.6%
Annual total precipitation

+1.5%
+2.8%
+3.3%
Precipitation of wettest month

-5.6%
-4.7%
-0.9%
Precipitation of warmest quarter

VARIATION OF SPECIFIC CLIMATE INDICATORS

Climate indicators variation showing impacts of climate change on sectors such as agriculture, health and water. Analysis considers 3 threshold average temperature increase: **+1.5°C**, **+2°C**, **+4°C**.

+34%
+18%
+13%
Agricultural drought proportion of time
% of time

+29%
+16%
+13%
Hydrological drought proportion of time
% of time

+4,005%
+538%
+195%
Heatwave duration
% of time

+52%
+31%
+22%
Runoff increase
% of area

+72%
+37%
+24%
Agricultural drought frequency
% of change

+15%
+12%
+13%
Hydrological drought frequency
% of change

+98%
+55%
+30%
Heatwave frequency
% of change

+4%
+1%
+0%
Runoff decrease
% of area

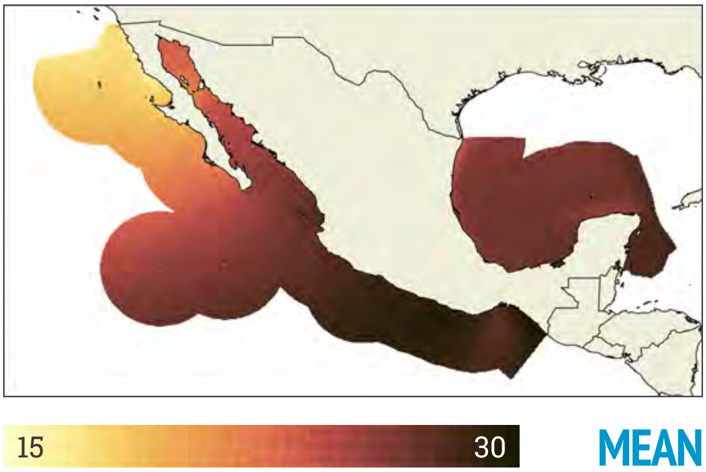
MEXICO
OCEAN

OCEAN IN MEXICO

Mexico's marine exclusive economic zone (EEZ) is mainly characterized by subtropical coastal waters, which host a large variety of ecosystems such as seagrass meadows, coral reefs, and mangroves. The country's coastal systems are naturally diveded into two areas: the Pacific region and the Gulf of Mexico.

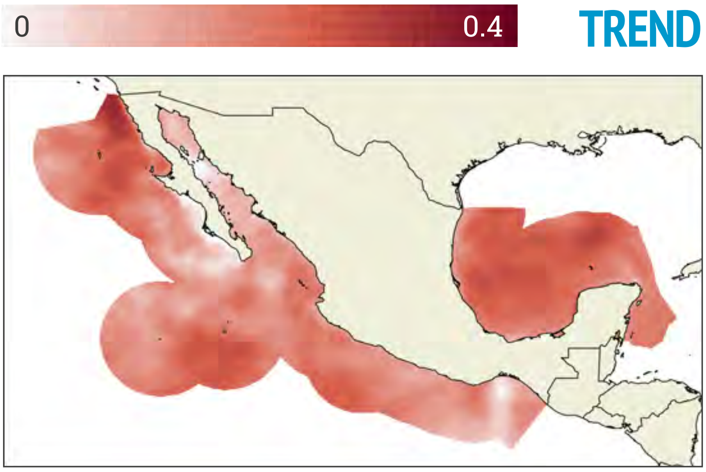
CURRENT CLIMATE CONDITIONS

Mean sea surface temperature reflects the subtropical climate regime, with colder waters located in the northern Pacific area and warmer ones along the coasts in the south.



SEA SURFACE TEMPERATURE

Celsius degrees / Over 1991-2020

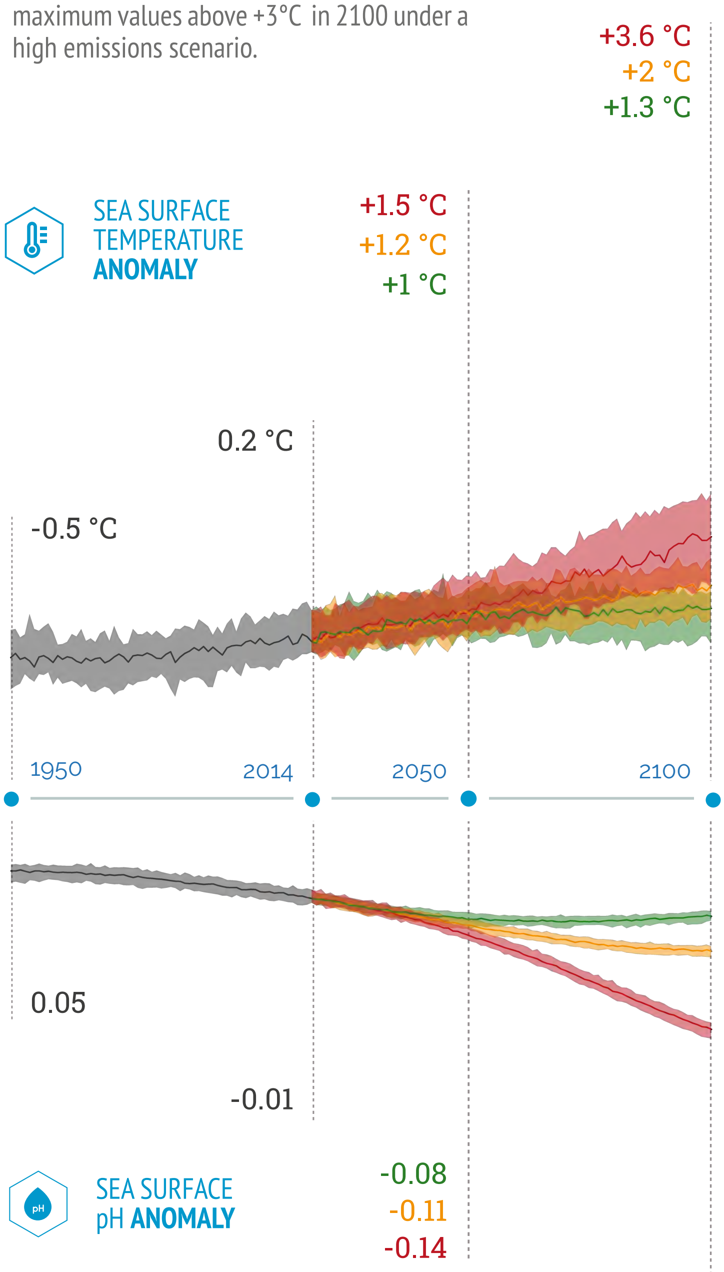


Surface temperature trends indicate a general warming of 0.2°C per decade in all marine areas, with increased gains in the northern Pacific area.

FUTURE PROJECTIONS

Projected annual changes within the marine EEZ for the two most significant marine indicators of climate change: sea surface water temperatures and pH.

Seawater temperature changes are in line with the definitions of each scenario, with maximum values above +3°C in 2100 under a high emissions scenario.



Seawater surface pH becomes more acidic in all scenarios, closely reflecting rising atmospheric CO_2 concentrations, and only a low emissions scenario leads to a stable condition by 2100.

ECOSYSTEM INDICATORS AT 2050

Regional changes in key marine ecosystem indicators under projected future scenarios by mid-century (2036-2065) with respect to present climate conditions (1985-2014).

Temperature regulates the metabolism of marine organisms determining which habitats remain suitable. Excessive warming will likely push ecosystems beyond tolerance thresholds.

pH represents the acid/base status of marine waters, where a decreasing pH reflects the acidification of the ocean due to increased absorption of atmospheric CO_2.

Oxygen is fundamental to sustain marine life and its reduction can have a large impact on coastal ecosystem services including fisheries and aquaculture.

Chlorophyll is an indicator of the biomass available at the base of the marine food web supporting all ecosystem productivity.

	Gulf of Mexico		Pacific	
Temperature	26.89°C	+1.89 °C +1.55 °C +1.22 °C	25.86°C	+1.46 °C +1.08 °C +0.92 °C
pH	8.08	-0.14 -0.1 -0.08	8.04	-0.14 -0.1 -0.08
Oxygen	203.97 mmol/m³	-2.8 % -2.24 % -2.07 %	213.5 mmol/m³	-2.71 % -2.32 % -2.02 %
Chlorophyll	0.13 mg/m³	+0.78 % -2.34 % +2.34 %	0.18 mg/m³	+6.25 % -7.39 % +12.5 %

FISH CATCH POTENTIAL

Fish catch potential is an estimate of the maximum fish catch achievable given the marine resources available over a sustained period. It is linked to the concept of maximum sustainable yield, meaning the maximum amount of fish that can be extracted from a system without causing a collapse in fish populations.

It is a characteristic of the natural system, which is substantially different from realized catch, and a direct result of the fishery policy in place.

Fish catch percentage change

2050

-17.0%

-6.8%

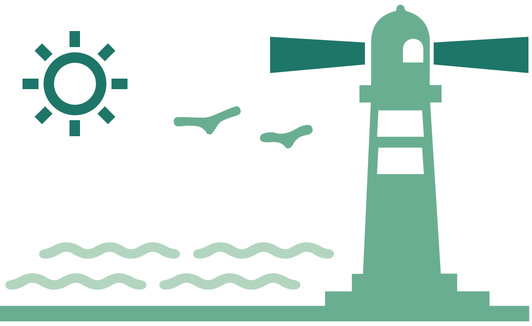
ANALYSIS DETAILS

All datasets were analysed using only data from within the marine EEZ and therefore excluding overseas territories, detached islands and any disputed or joint territories with other nations. In the assessment of current climate conditions, seawater surface tempererature data was obtained using satellite observations distributed in the framework of ESA Climate Change Initiative.

Future projections of marine indicators are represented by the combined analysis of results from 15 different Earth System models participating in the Coupled Model Intercomparison Project Phase 6 (CMIP6). These models include new and better representations of physical and biogeochemical processes, compared to previous IPCC assessment reports.

Fish catch potential data was obtained using the FAO's technical report and refers to the best and worst case climate scenarios from the Fifth IPCC Assessment Report. These mean estimates are subject to substantial uncertainties as discussed in the original work.

MEXICO COASTS



OVERVIEW

Mexico has three distinct coastal regions: the Gulf of Mexico, the Pacific coast and the Gulf of California. Each of these regions is thousands of kilometres long and presents very different environments with unique management challenges.

Whereas the eastern coastline of the Gulf of Mexico is low lying and features numerous sandy beaches and islands, the Pacific coast has many more rocky cliff faces, and the Gulf of California is home to many river basins making it an important area for local biodiversity.

Shoreline Length

23,761 km

Sandy Coast Retreat at 2050

-52.9 m

CLIMATE CHANGE HAZARDS

Coastal hazards such as erosion, storm tide inundation and permanent flooding, can have strong adverse impacts on coastal regions, with loss of sandy shores, damage to settlements, infrastructure and ecosystems. Climate change can exacerbate these impacts due to rising sea levels and increasing impacts of waves and storms. Climate change is affecting the Mexican coastline, particularly in the more vulnerable Gulf of Mexico where sea level rise threatens low lying shoreline areas with erosion and flooding of sandy shores, as well as saltwater intrusion. Also affected by climate change are weather patterns such as precipitation and storms, which will become more irregular and more extreme along the Mexican shoreline.

SEA LEVEL RISE

Relative sea level rise has been at or above the global average for the last 100 years. However, the rate has been accelerated, reaching over 3 millimetres per year since 1990. The latest IPCC projections indicate that, by 2050, global sea levels may rise between 0.18 metres, under a low emissions scenario, and 0.23 metres, under a high emissions scenario.

Observed and projected sea level rise at 2050

3.13 mm/year

0.23 m

0.18 m

EXTREME SEA LEVEL

On average, one in 100 extreme sea level events are expected to rise from 1.85 metres at present day to 2.09 metres by 2050 under a medium emissions scenario.

Current and projected extreme sea level at 2050

1.85 m

2.15 m

2.09 m

OBSERVED STORMS

Both the east and west coasts of Mexico are exposed to the damaging effects of high water levels and extreme tropical storms, particularly in the Gulf of Mexico. In general, hurricanes have the most significant impact on extreme water levels, whereas the mean wave climate is largely controlled by cold winter fronts. Storm surges and waves represent the main cause of damage to coastal infrastructure.

FUTURE STORMS

Sea level rise will increase both the frequency and the severity of extreme wave events, raising the wave climate's baseline level. For example, a strong cold front event in the Isla del Carmen area would see the flooded area increase by 31% when considering a sea level rise of 25 centimetres, and 229% for a 75 centimetre increase. As these events occur annually, they present challenges for the management and adaptation of shoreline erosion and habitat degradation.

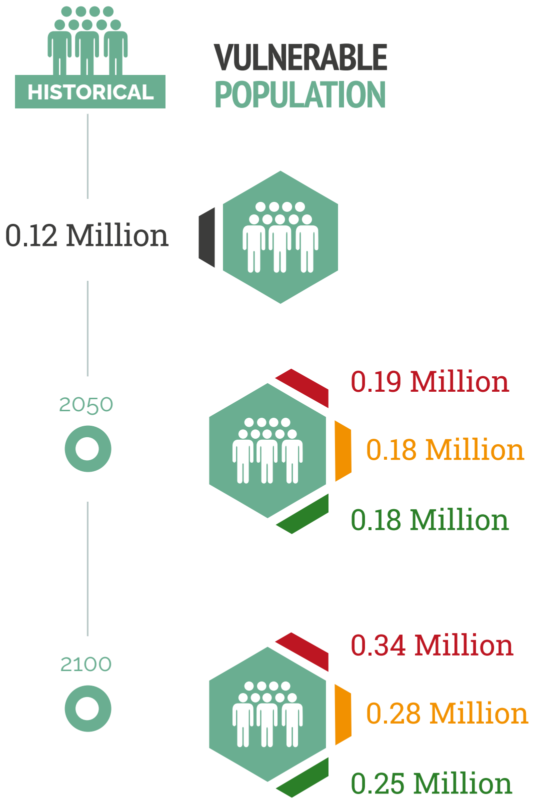
VULNERABILITY AND RISK

Mexico's coastline is home to a significant share of the overall population. By 2015, over half of the country's 102 million people lived in coastal areas, including important cities such as Tijuana and Cancún. Coastal populations are projected to continue to increase throughout the coming decades, putting more people and urbanized areas at risk.

Sea level rise and the development of human infrastructure is leading to a coastal squeeze phenomenon, whereby local habitats are eroded and lose their ability to adapt and survive, particularly those that are susceptible to damage from flooding and salinity. In turn, this leaves these same areas more exposed to extreme storm events.

There is also significant touristic value in the at-risk coastal zones, as well as environmental value in the coastal reefs and dunes that are being degraded by climate change. Under a medium emissions scenario, the population exposed to the annual coastal flood level is expected to increase from 120,000 to 180,000 by 2050.

VULNERABLE POPULATION



INFLUENCE OF SEA LEVEL RISE ON EXTREME SEA LEVEL

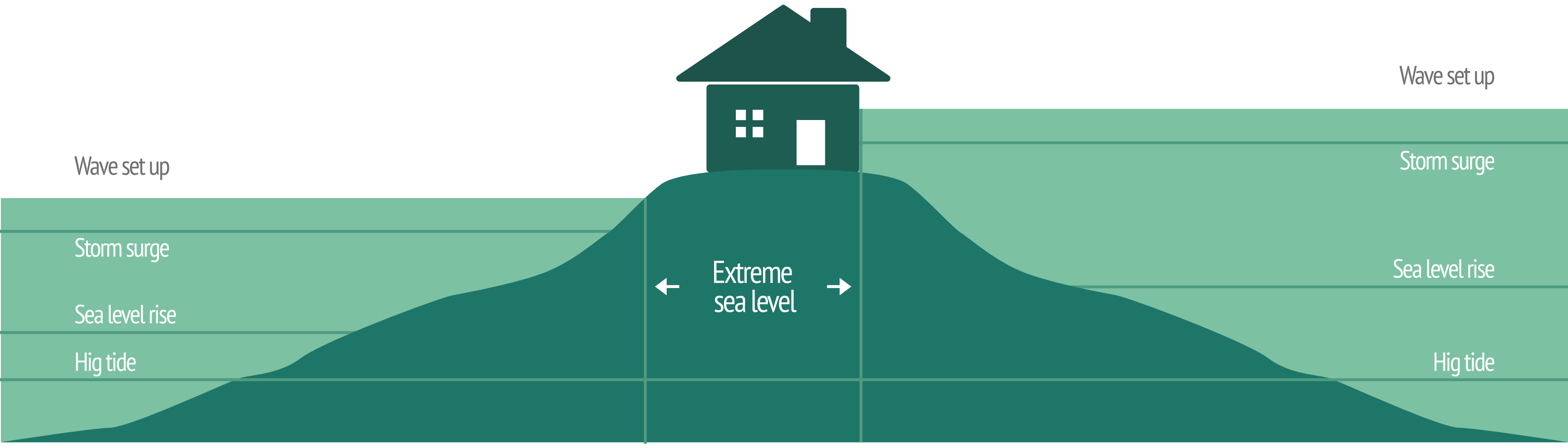
Present and future sea level rise are a consequence of carbon induced global warming causing melting ice and ocean expansion due to heat accumulation.

The extreme sea levels reported here are based on the 100-year storm surge + wave set up + sea level rise + high tide indicators. The first two parameters (storm surge + wave set up) are based on the 100-year value for the event; sea level rise is its projected value at 2050; and high tide is the absolute value of the highest tide calculated for a given locality, which won't be influenced by climate change.

+ **Wave set up** refers to the accumulation of water near the shore due to the presence of breaking waves.

+ **Storm surge** is an occasional increase in sea level driven by shoreward wind-driven water circulation and atmospheric pressure.

+ **High tide** is usually the highest tide reached in a given location based on tide records.



Present sea levels have risen globally by approximately 20 centimetres over the past century.

Future sea level rise is a projection based on different global warming scenarios, at approximately 100 centimetres by the end of 2100, with consequent inundation during extreme sea level events.

MEXICO
WATER

OVERVIEW

Mexico's average annual renewable freshwater is about 0.2% of the world's total volume. Although Mexico receives about 1.4 billion cubic metres of rain per year, 67% of this falls between June and September and precipitation distribution is extremely unequal across the country. It is also estimated that 73% of this rainfall is lost to evapotranspiration.

In Mexico, in 2016, reported water-use distribution was as follows: 76.3% agricultu

Renewable internal freshwater resources
409
billion m^3

Renewable internal freshwater resources per capita
3,277
m^3

Mexico has a diverse climate and high spatial and temporal variability in water resource availability across different geographical regions. 77% of the population lives in the north and central regions where only 33% of the water resources are found, which leads to overexploitation of basins and aquifers.

CLIMATE CHANGE HAZARDS

Climate change can affect water resources through increasing temperatures, higher rates of evapotranspiration and altered rainfall patterns. This leads to changes in the water cycle, including alterations of surface runoff and groundwater storage, as well as drought and flood occurrence. Mexico is likely to be heavily affected by climate change impacts, due to its complex climate and geography. Vast areas in central and northern Mexico already present conditions of very low water availability, especially in the Valley of Mexico. Due to population growth, regional economic development and urbanisation, it is expected that by 2030 several hydrological regions of great importance and extension will have extremely low availability, such as the Rio Grande basin.

KEY POINT RUNOFF

About 22% of the total annual precipitation in Mexico becomes runoff to surface-water bodies. The Lerma-Chapala basin, for instance, is particularly relevant because the largest water body in Mexico is located at its outlet. The long-term rate of change in surface runoff has been estimated considering the variation in future precipitation from climate models, showing a decrease in surface runoff of up to 29% in the northern part of the basin.

In some regions of Mexico, the decrease in surface runoff will be close to 20% by the end of the 21st century. At a country scale, an average change in surface runoff by approximately 13% and -4.4% is expected respectively under low and high emissions scenarios for the 2045-2055 period compared to 2015-2025.

If temperatures rise by 1.5°C, 2°C or 4°C, 0%, 0.8% or 4% of the area of the country will likely experience an increase in runoff, while 22%, 31.4% or 52% of the surface of the country will likely experience a decrease in runoff, respectively.

2050

Changes in annual runoff
% of change

-4.4%

+13.3%

2050

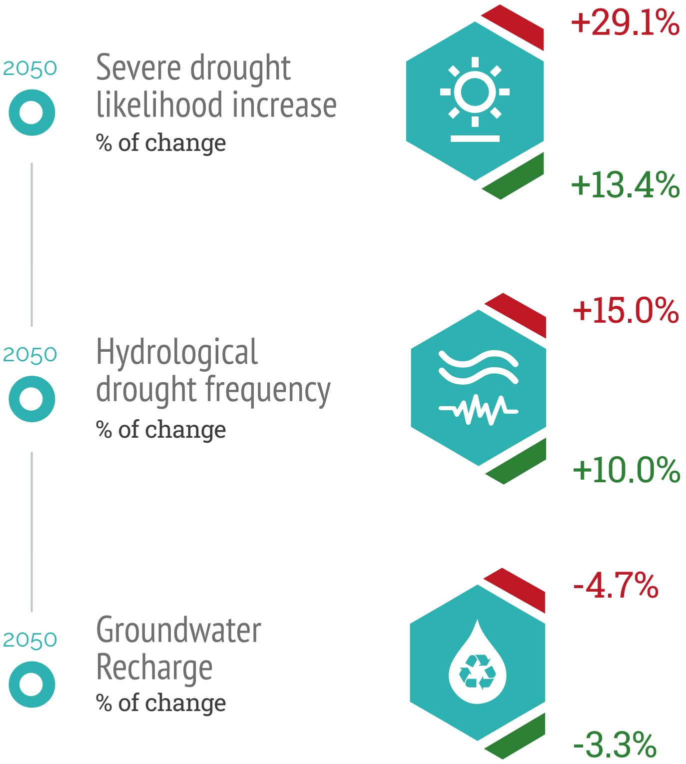
Runoff increase
% of area

+4.0%

0%

KEY POINT DROUGHTS

Drought has been an inevitable natural disaster throughout Mexican history and the northern and northwestern parts of Mexico, where the mean annual precipitation is less than 500 millimetres per year. A recent three-year (2010-2012) drought in Mexico resulted in a huge amount of economic damages, including losses of 450,000 head of cattle, and a reduction in crop yields. The immediate consequence of these damages was the rising price of agricultural products, predominantly affecting the poorest sectors of society. The northern regions suffer a drought on average every 4.1 years with a mean duration of 2.2 years and an intensity of 143 millimetres per year (24.2% below the average). More recurrent and intense droughts are expected as a consequence of climate change and the decrease in precipitation expected in arid and semi-arid areas of the country.



KEY POINT GROUNDWATER

6% of the total annual precipitation in Mexico infiltrates groundwater. Groundwater constitutes an essential reserve for Mexico's socioeconomic development because more than half of its territory is arid or semi-arid, and the water supply depends heavily on groundwater resources, in fact, about one-third of the total consumption comes from aquifers. These are used to irrigate more than two million hectares of land (i.e., one-third of the total irrigated land), to supply about 70% of water requirements for the public-urban sector and to provide water for most of the industrial facilities and almost the entire water demand of the rural population (20 million people).

About 105 regional aquifers are subject to intensive exploitation, which has caused serious environmental impacts during the past four decades and the mining of 11 cubic kilometres per year of the underground water reserve. In response, programs have been initiated for managed aquifer recharge and extraction of brackish groundwater for desalination.

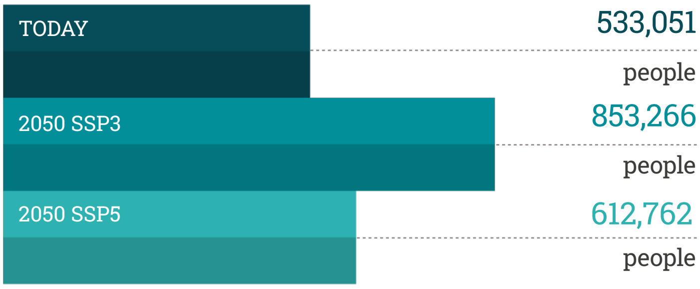
At the country level, a -3.5%, -4% and -4.7% decrease of the annual groundwater recharge for the period 2040-2060 compared to the timeframe 2010-2030 is expected respectively under low, medium and high emissions scenarios.

KEY POINT FLOODS

Local areas in Mexico are flooded basically every year because of tropical hurricanes or other extreme precipitation events. The number of events is already increasing with respect to the first 70-80 years of the last century. Urban developments in flood plains are common in Mexico: the Tabasquena Plain and the lower basin of Bravo River (Tamaulipas), Panuco River (Tamaulipas and Veracruz), Coatzacoalcos River (Veracruz), Papaloapan River (Veracruz), the Coast of Chiapas, the Atoyac, Jamapa, Tecolutla, Nautla and Antigua Rivers (Veracruz) and Tulancingo River (Hidalgo) are clear examples of areas where frequent flooding can be expected.

Heavier rains and increased extreme events are also expected to occur, making some watersheds in Mexico's southeast all the more vulnerable to floods. Changes in the population exposed to floods are expected, with an increase from about 533,000 in the present day to 853,000 under SSP3 and 613,000 under SSP5 by 2050. As such, potential impacts related to river floods might increase.

POPULATION AFFECTED BY RIVER FLOODS

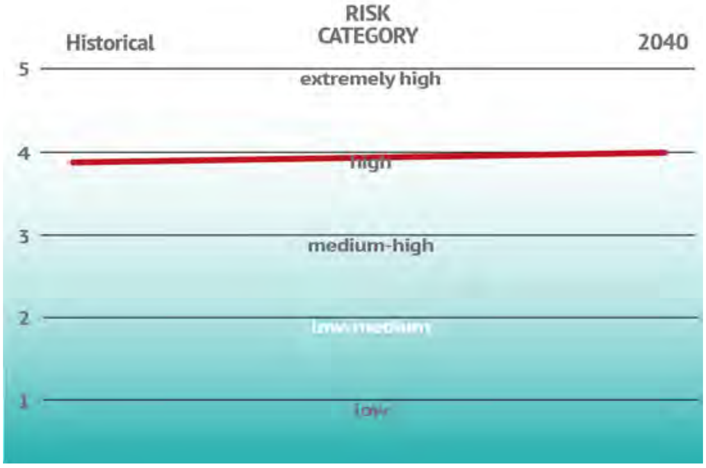


RISK INDICATORS

The water stress index summarises current and future water related vulnerabilities and risks at the global level. Scores are based on the ratio of total water withdrawals, including agriculture, industrial and human consumption, to available renewable surface and groundwater supplies.

WATER STRESS

Mexico's water stress level is considered high for the recent past (1960-2014 average), and it is expected to increase in the near future (2030-2050) based on climate change projections. In fact, the increase might be noticeable enough to place Mexico in the extremely-high risk category.



MEXICO
AGRICULTURE

OVERVIEW

Mexico is the tenth most populated country in the world. Although agriculture only represents 3% of the country's GDP, 13% of the active population is employed the sector. Smallholders represent 85% of agricultural producers, generating over 60% of agricultural employment. Nevertheless, 42% of the population still lives in poverty.

Maize is the most important crop in Mexico, occupying 33% of the total cultivated area, followed by beans, sorghum, sugarcane, wheat, cattle pastures, coffee and fruit trees (oranges, lemons, avocados and mango).

Irrigated areas, though limited to specific regions, contribute significantly to agricultural production. However, they also accounted for up to 76% of total water withdrawal in 2017. Many areas of the country are under significant water stress (32.9%).

56.8 Mt
Sugarcane

8.6 Mt
Citrus

27.2 Mt
Maize

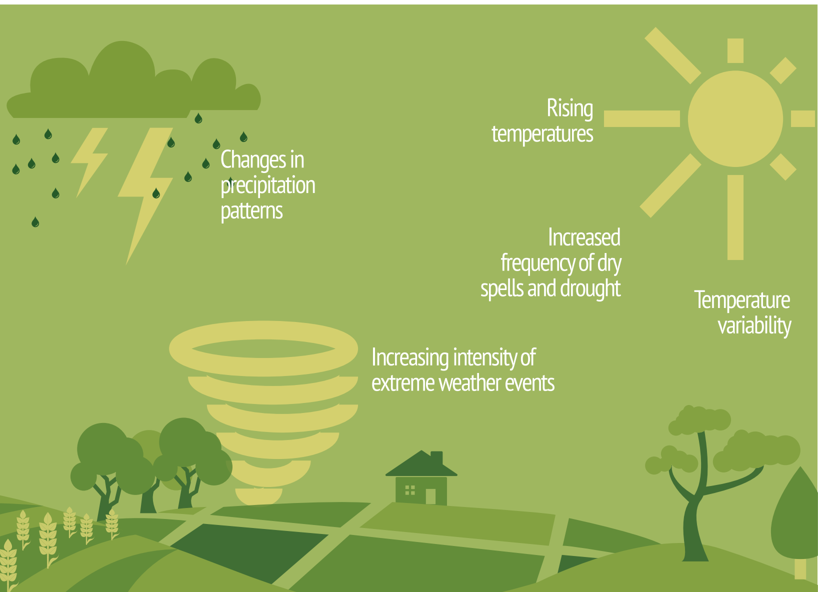
2.9 Mt
Wheat

2.2 Mt
Mango

	Added Value of Agriculture, Forestry and Fishing	Share of Agriculture Value added in Total GDP	Agricultural land	Area Equipped for Irrigation
2000	28,413 USD Million	3.2 %	25,378 Thousand HA	6,300 Thousand HA
2018	40,392 USD Million	3.2 %	26,612 Thousand HA	6,811 Thousand HA

EXPEXTED IMPACTS ON AGRICULTURE PRODUCTIVITY

Rising temperatures, reduction in average annual precipitation, and intensification of extreme events such as heat waves and drought, affect production variability with a tendency towards yield reduction for many cultivated species, accompanied by a probable decrease in food quality. Crops respond to increases in temperatures with changes in duration of the growing season, early appearance of phenological phases and potential shifts of cultivation areas toward higher latitudes and altitudes for better growing conditions. However, impacts vary significantly depending on the geographical area and specific crops in question.



CROP PRODUCTIVITY

Crop productivity refers to the harvested yield of a crop per unit of land area. It is strongly influenced by climate and other environmental and management factors.

Climate change is expected to have an impact on the productivity of several major crops, although this may in part be offset by the fertilizing effect of higher CO_2.

Impacts are estimated using a range of model projections based on low to high emission scenarios and reported as percentage changes between the 30-year average around the historical period and the 30-year average around 2050.

73.4
-6.3 (-6.5)%
-7.6 (-7.8)%
Sugarcane
tons / ha

3.9
-5.3 (-8.8)%
-6.4 (-12.6)%
Maize
tons / ha

5.5
-0.3 (-5.4)%
-0.1 (-9.5)%
Wheat
tons / ha

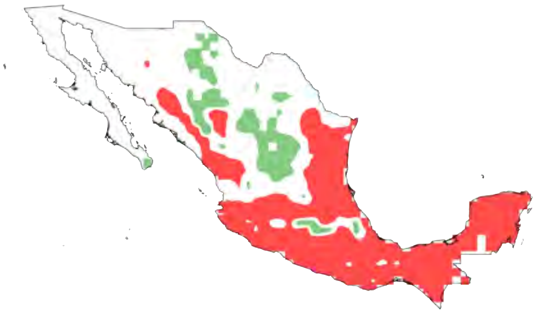
6.3
-0.2 (-7.1)%
1.1 (-7.7)%
Rice
tons / ha

2050

Productivity change with (without) the CO_2 fertilization effect. Estimates assume sufficient water and nutrient supplies, and do not include impacts of pests, disease, or extreme events.

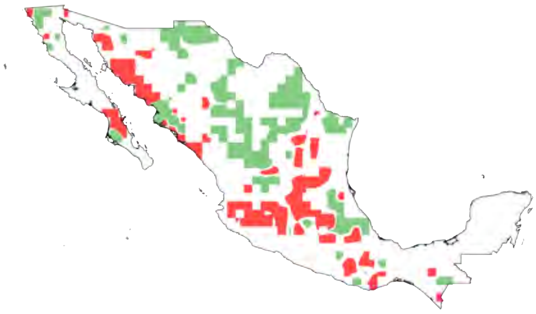
CHANGE IN MAIZE

− = +



CHANGE IN WHEAT

− = +



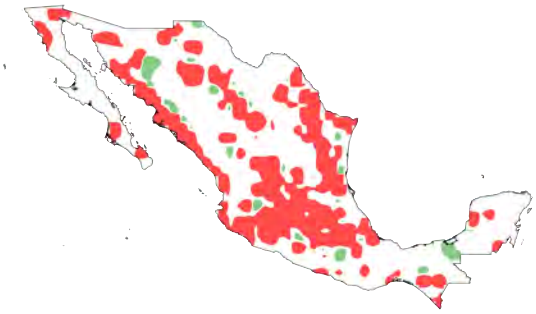
Projected changes in crop productivity predict a significant fall in yields for most cereals. A general and significant decline of productivity is projected for maize and sugarcane throughout most of their growing regions. A higher stability of maize yields is expected for irrigated areas, whereas more significant yield losses are projected for rainfed conditions. Wheat productivity is expected to decline slightly, although positive effects may be observed for irrigated areas in western regions and for rainfed conditions in southernmost regions. Commercial agriculture could see increased vulnerability to pests and diseases, with more than 20% of commercial tomato cultivation becoming less suitable in Mexico. Changes in fruit tree productivity will be critically linked with more frequent climate extremes and water stress.

ADAPTATION IN AGRICULTURE AND WATER RESOURCES

Climate change is enhancing risks and acting as a threat multiplier, particularly with regards to the availability of water. Overall, higher temperatures will lead to more demand for water due to increased plant evapotranspiration. Therefore, to maintain agricultural production and ensure food security additional water resources are needed, increasing potential future water stress. For example, intensive production of high cash tree crops may be hampered in large production areas, such as Michoacán, due to water depletion and more frequent droughts.

CHANGE IN WATER DEMAND

− = +



Agriculture
Water Demand
% of change

+18.9%
+21.6%

2050

Water use efficiency will prove to be a key factor in future agricultural productivity. It will require adaptation strategies ranging from water-saving irrigation, to adoption of new crop varieties, and sustainable water management in general.

MEXICO
FORESTS

FORESTS IN MEXICO

Given its topography and climatic conditions Mexican forests are extremely rich in variety and biodiversity. Half of Mexico's forest areas are primary forests and can be divided into two types: 1/3 tropical and 2/3 temperate forests of conifers and oaks. Mangrove forests grow on almost the entire Atlantic and Pacific coastline.

FORESTED AREA AND CARBON STORAGE

Although deforestation has led to a decreasing trend in recent decades, forested territories amount to almost 35% of the total land surface. Total carbon stored in the aboveground live biomass of forests in Mexico is approximately 1.7 gigatonnes and mangrove forests alone store nearly 240 million tons of organic carbon (blue carbon).

1990

27 Mln ha
Million hectares
Forested area

71 Tons/ha
Tons of Carbon per hectare
Carbon stock

2020

79 Mln ha
Million hectares
Forested area

66 Tons/ha
Tons of Carbon per hectare
Carbon stock

FOREST PRODUCTIVITY

Forest productivity or Net Primary Production is the net carbon captured by plants. It is the difference between the carbon gained by Gross Primary Production - net photosynthesis measured at the ecosystem scale - and carbon released by plants' respiration. It is expressed per unit land area.

2050

Productivity anomaly
Tons of Carbon per hectare per year

+0.27

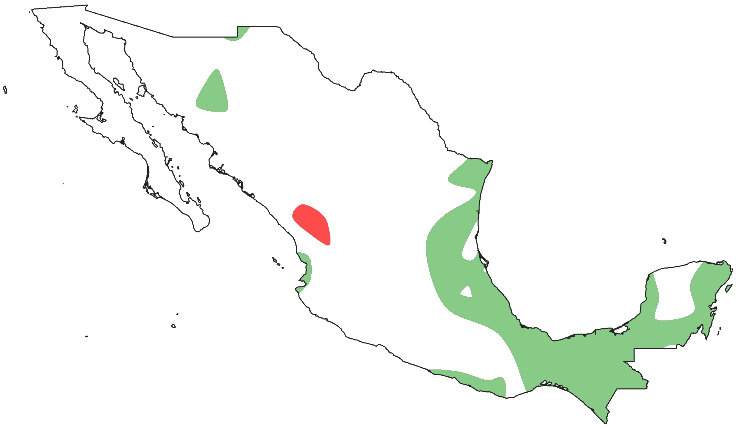
+0.19

Weak increase in southern Mexico and the Yucatan peninsula's tropical forests

+ Fertilizing effect of increasing atmospheric CO_2 and rising temperatures promote productivity

Alarming decrease expected in the central Pacific coast area

+ Increasing length of the dry season reduces productivity



KEY SPECIES UNDER CLIMATE CHANGE

REDUCTION

TROPICAL DRY

Heavy reduction of suitable areas for tropical dry forests in lower mountain ranges

SHIFT

CLOUD FORESTS

Cloud forests and tropical dry forests are expected to move to higher elevations

LOW VULNERABILITY

SHRUBLAND

Lower vulnerability for chaparral shrubland ecosystems

VULNERABILITY

MANGROVES

Rapid sea level rise will pose a significant threat to coastal Mangrove forests in the Gulf of Mexico

FIRES IN MEXICO

Fire is a structural ecological process that provides several types of ecosystem services and impacts on socio-ecological systems, including human health, carbon budgets, and climate change. Changes in global fire activity are influenced by multiple factors such as land-cover change, policies, and climatic conditions. Fire also releases large quantities of greenhouse gases into the atmosphere, contributing to a vicious cycle.

During the last two decades the total land area affected by fires was 5.3 million hectares, of which 2 million hectares were forests.

BURNING
5.3 MILLION HECTARES

EMITTING
22 TERAGRAMMES OF CARBON PER YEAR

FOREST FIRE EMISSIONS CONTRIBUTED TO 40% OF TOTAL FIRE RELATED CARBON EMISSIONS

WHERE DO FIRES OCCUR?

Tropical Humid Forests found in Veracruz, Oaxaca and Tabasco are the most significant contributors to total fire emissions.

In 2006, fire emissions from biomass combustion had a significant impact on air quality in Mexico City contributing to more than half of the aerosol emissions and one third of the overall increase in harmful gas emissions.

Wildfires mostly affect the states of Oaxaca, Tlaxcala, Puebla, Mexico City, Morelos, Coahuila, Hidalgo, Jalisco and Chiapas.

FUTURE BURNED AREA

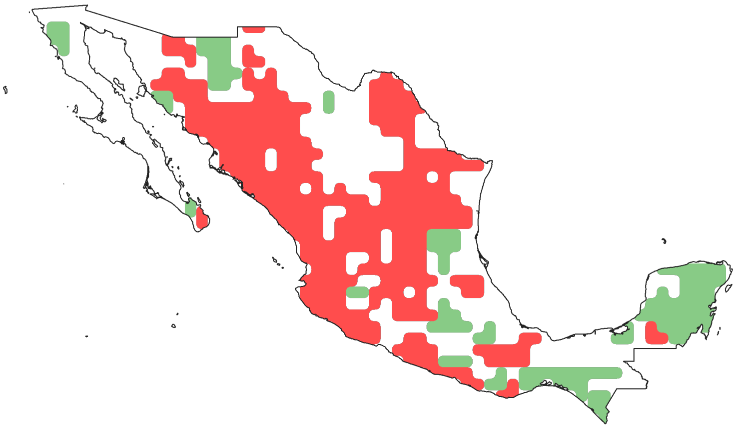
Under a low emissions scenario, burned area might increase significantly in the temperate sierras and tropical dry forests, particularly in the Sonoran and Sinaloan dry forests and in the Sierra Madre Occidental pine-oak forests. Under a medium emissions scenario, the increase might be even more pronounced and widespread, affecting the central part of Mexico and the Oxaca region.

Burned Area
km² per year

2050

+3,353

+1,010



Decrease in burned areas for a low emissions scenario

Increase in burned areas for a low emissions scenario

+ Prolonged and more intense warm and dry periods will impact water availability and induce water stress

+ Generalized increase in fire weather days and a prolonged fire season

+ More frequent El Niño conditions over central Mexico, which may lead to larger and more damaging wildfires

CASE STUDY: AIR QUALITY

In Mexico two main determinants of fire probability were identified: climate anomalies, which are more significant in northern areas and intertwined with climate change impacts; and human activities which are the most important driver in central and southern areas.

In 2019 and 2021, heat and drought conditions created an environment that was highly conducive to fires leading to impacts on air quality and public health, and affecting the homes and communities of those living in the Wildland urban interface (WUI). In 2019, Mexico City declared an environmental emergency as fire smoke contributed to unsafe levels of air pollution.

FUTURE FIRE EMISSIONS

Fire emissions follow a similar spatial pattern to burned area. Central areas and the Yucatan peninsula show greater projected changes under both low and medium emissions scenarios.

Fire Carbon emission
Teragrams of Carbon per year

2050

+10.7

+3.3

MEXICO
URBAN

OVERVIEW

With an urbanization rate of 80%, Mexican cities are the most important living environments in the country and will become even more important in the near future, with 88% of people living in cities by 2050.

This growth will mainly be absorbed by cities with 1 to 5 million inhabitants, which are expected to increase in number and host 25% of the population by 2035, whereas Mexico city is expected to keep its share of approximately 20% of the urban population.

Built up areas cover 1% of Mexico (19,538.95 square kilometers).

Population in Urban Areas

2020 108,074,410

2050 144,909,934

Graphs refer to data provided by United Nations, Department of Economic and Social Affairs, Population Division (2018). World Urbanization

Urbanization Rate

2020 80.7%

2050 88.2%

OVERVIEW OF KEY CLIMATE IMPACTS IN URBAN AREAS

Mexican cities are most vulnerable to heat, heatwaves and flooding.

HEATWAVES AND HEAT STRESS

Many Mexican cities have experienced an increase in heatwave days. In particular, night time temperatures in cities tend to be much higher than in the sourrounding areas.

Urban areas are particularly affected by high temperatures and the urban heat island effect due to high building densities, a high degree of soil sealing, low percentage of green areas, and additional heat from anthropogenic sources such as motor vehicles and air conditioning.

The mortality risk from high temperatures for those that are 65 or older has risen by 3.22%. Heat mortality is also related to air pollution and falls to 1.3% if air pollution is factored in. Rising temperatures will lead to more frequent, prolonged and intense heatwaves.

2050

Cooling Degree Days

% of change

+68.2%

+26.8%

+16.9%

2050

Heatwave frequency

% of change

+4,004.8%

+538.1%

+195.2%

2050

Heatwave duration

% of time

+4,005%

+538%

+195%

INTENSE SOIL SEALING

Urban areas built up environments accumulate high amounts of energy from the sun and release this energy during the night. In contrast vegetation transforms solar radiation energy and cools the surrounding environment. In Mexico City and other cities, this effect is particularly pronounced during night-times when built up environments release heat keeping temperatures high compared to the outskirts, which cool down quickly.

In Mexico City, the most pronounced heat island effects are observed at night during the dry season with city temperatures up to 7.8°C higher than surrounding areas. The difference in temperature between urban and rural areas were positive throughout the year, varying from 5°C at daybreak in the dry season to 1° to 3°C around noon during the wet months. Air pollution in Mexican cities is high, with 99% of urban residents exposed to unsafe levels of air pollution which exceed WHO thresholds.

COASTAL FLOODING

Many tourism centered areas are situated along the coasts and hence exposed to risks associated with climate change. For instance, the city of Cancun is exposed to hurricanes and sea level rise. In these areas wealthy hotel and tourism spots are often provided with appropriate protection, services and resources for recovery, whereas the residential areas lack adequate protection and access to recovery measures.

FLOODING

For Mexico City, annual rainfall quantities and the number of flash flood events have increased in recent decades, the latter of which reached 7 annual events during the first decade of the 21th century with respect to previous values. Research indicates that increasing urban temperatures may also have contributed to a change in precipitation patterns. During the 20th century, annual rainfall in Mexico City increased from 600 millimetres to over 900 millimetres. On 2 August 2006, 50.4 millimetres of rain fell in only 36 minutes, causing severe flooding in the southern and western parts of the city. Despite overall precipitation decreasing throughout the year, the frequency of intense precipitation events in cities such as Mexico City may continue to increase.

2017

Population exposed to air pollution

99.7%

2050

0.23 m

0.18 m

Projected sea level rise

2100

0.77 m

0.38 m

2050

Runoff increase
% of area

+4%

+1%

0%

SURFACE SEALING AND FLOODS

Heavy precipitation in cities is problematic due to the high level of sealed surfaces. Soil sealing increases run off and reduces the amount of water absorbed by soil. Where there are large amounts of impervious ground cover, short duration extreme rainfall events can lead to increased flooding, even resulting in flash floods.

SOIL SEALING AND FLASH FLOODS

In densely built urban areas, intense precipitation events cause flash floods where surfaces are impermeabilized and drainage systems are unable to deal with the high amounts of rainwater. These floods threaten local populations and property.

In Mexico City these risks are exacerbated by subsidence, poorly maintained drainage and sanitation systems that cause contamination. Informal settlements are particularly at risk as they are often built in areas that are exposed to flooding and landslides.

2010

% of urban population
Population living in slums

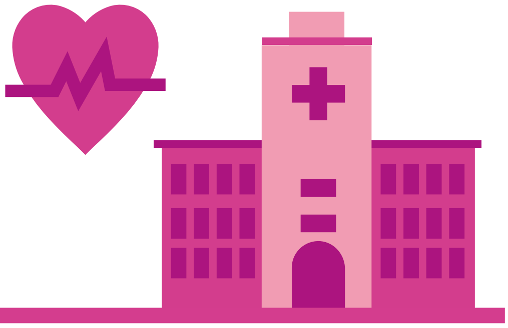
16.0%

2018

% of total population
Urban population living in areas where elevation is below 5 meters

0.8%

MEXICO
HEALTH



OVERVIEW

Increased temperatures, more variable precipitation pattern, and increased frequency and intensity of extreme events such as floods and hurricanes due to climate change may lead to increased heat and vector-borne mortality and morbidity in Mexico. At particular risk are relatively low-income and indigenous communities.

The five most populated cities in Mexico had annual mean PM2.5 levels above the WHO guideline value of 10 µg/m3. 20% of around 4,000 child deaths due to acute lower respiratory infections were attributable to household air pollution.

HEAT RELATED MORTALITY

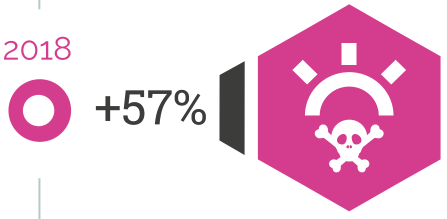
Climate change may lead to increased temperatures and more variable precipitation patterns. Extreme events, such as floods and hurricanes, may lead to increased mortality and morbidity.

Under a high emissions scenario, heat-related deaths in the elderly (65+ years) are projected to increase to 54 deaths per 100,000 by 2080 and 11 deaths per 100,000 under a low emissions scenario; compared to a baseline of less than 3 deaths per 100,000 per year during the 1961 to 1990 period.

In 2018, there was a 57% increase in heat-related deaths in Mexico, compared to the 2000 to 2004 baseline. 44.2% of Mexico's heat-related mortality from 1998 to 2014 can be attributed to human-induced climate change.

Heat-related mortality

% change with respect to 2000-2004



IMPACTS ON LABOUR

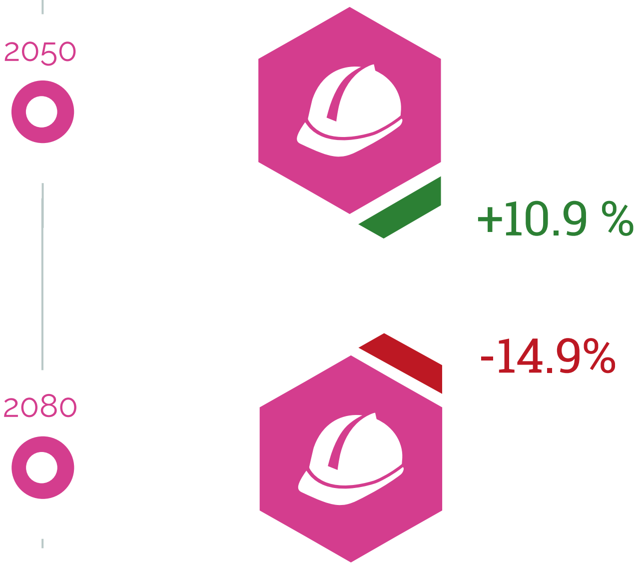
Labour is directly affected by changes in environmental conditions. Warming affects both the number of hours worked (labour supply) and on the productivity of workers during their working hours (labour productivity). Both labour supply and productivity are projected to decrease under future climate change in most parts of the world, and particularly in tropical regions.

Parts of sub-Saharan Africa, south Asia, and southeast Asia are at highest risk under future warming scenarios. Future climate change will reduce global total labour in the low-exposure sectors by 18 percentage points and by24.8 percentage points in the high-exposure sectors under a 3.0°C warming scenario

Total labour in Mexico is expected to decline by 8.2% under a low emissions scenario, and by 14.9% under a medium emissions scenario.

Impact on total labour

% change with respect to 1986-2005 baseline



CLIMATE CHANGE AND DENGUE

Dengue has spread throughout the tropical world over the past 60 years and now affects over half the world's population. Globally, vectorial capacity for both dengue vectors (A. aegypti and A. albopictus) has been rising steadily since the 1980s, with nine of the ten highest years occurring since 2000.

Climatic stressors are one important driver of the current distribution and incidence of dengue. Climate change is likely to expand the geographical distribution and suitability of several vector-borne human infectious diseases including dengue. The risk of dengue transmission is increased by warming climates, as the growth and development of mosquitoes are significantly influenced by temperature, precipitation, and humidity.

Dengue suitability

% of population at risk

CLIMATE CHANGE AND ZIKA

Zika virus has spread to at least 49 countries and territories since 2013. Climate change impacts on transmission suitability risk have increased over the years and future warming over 1.3 billion additional people could face suitable transmission temperatures for Zika by 2050.

DENGUE AND ZIKA: POPULATION AT RISK

Under a medium emissions scenario, 74% of the population will be at risk of transmission-suitable mean temperature for dengue by 2050, whereas 73.3% will be at risk under a high emissions scenario. In the case of Zika, 51.7% of the population will be at risk by 2050 under a medium emissions scenario, whereas 52.5% will be at risk under a high emissions scenario.

Zika suitability

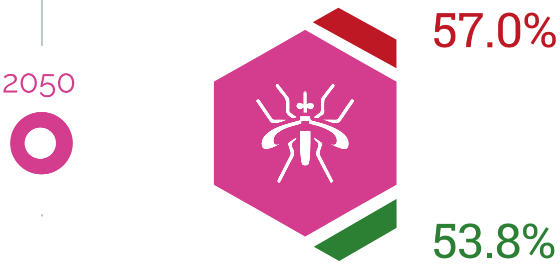
% of population at risk

CLIMATE CHANGE AND MALARIA

53.8% of Mexicans will be at risk of malaria under a low emissions scenario in 2050, whereas 57% will be at risk under a high emissions scenario.

Malaria suitability

% of population at risk



POLLUTION AND PREMATURE MORTALITY

The air pollution disease burden is substantial in Mexico. According to the World Bank, air pollution kills nearly 33,000 Mexicans every year. Nearly 20,000 of these deaths are due to outdoor air pollution, mainly in towns and cities. By 2060, 268 deaths per year per million people will be caused by outdoor air pollution, compared to 122 in 2010.

MEXICO
ENERGY

ENERGY SYSTEM IN A NUTSHELL

Mexico's energy mix is dominated by oil and gas. However, Mexico has one of the lowest energy intensities in the world. Traditionally a net energy exporter, since 2014 Mexico has turned into a net energy importer mainly due to its rising demand for oil products and natural gas. Demographic trends and economic growth are driving energy demand towards a sustained increase.

0.07
ktoe/US$
Energy intensity

16.2%
AC Share in
electricity consumption

22.8%
Import
dependence ratio

CLIMATE CHANGE TODAY

INCREASING TEMPERATURES

Average temperatures have risen by 0.85°C since the 1960s, resulting in electricity demand for cooling needs in 2016 increasing 5-fold (7 to 37 terawatts per hour) compared to 1990 levels.

DECREASING PRECIPITATIONS

The south-east of the country has seen decreasing precipitations, resulting in lower water availiability for hydropower and cooling of thermal plants.

EXTREME EVENTS - HURRICANES

The increasing frequency of extreme events such as hurricanes is posing a serious threat to the Mexican energy infrastructure, in particular oil extraction in the Mexican Gulf.

ENERGY SUPPLY

Mexico's energy mix is strongly dominated by fossil fuels (45.2% oil, 37.8% natural gas, 6.4% coal, for a total of 89.5% of total primary energy supply in 2018). Renewables claim 9% and there is a residual nuclear power generation (1.6% of total primary energy supply). In 2016, Mexico became a net importer; while still exporting oil, it imports oil products due to limited refining capacity, and natural gas, to cope with the fast growth in electricity demand which has doubled since 1997.

ENERGY DEMAND

In Mexico, energy is used mainly by the transport sector (43% of final demand in 2018) and industrial uses (34%, including 4% of total demand for non-energy uses), followed by residential demand (14.5%), whereas agriculture and commercial use claim smaller shares (3.3% and 3.6%). Air conditioning's contribution to residential electricity demand was about 16% in 2017.

FUTURE ENERGY DEMAND

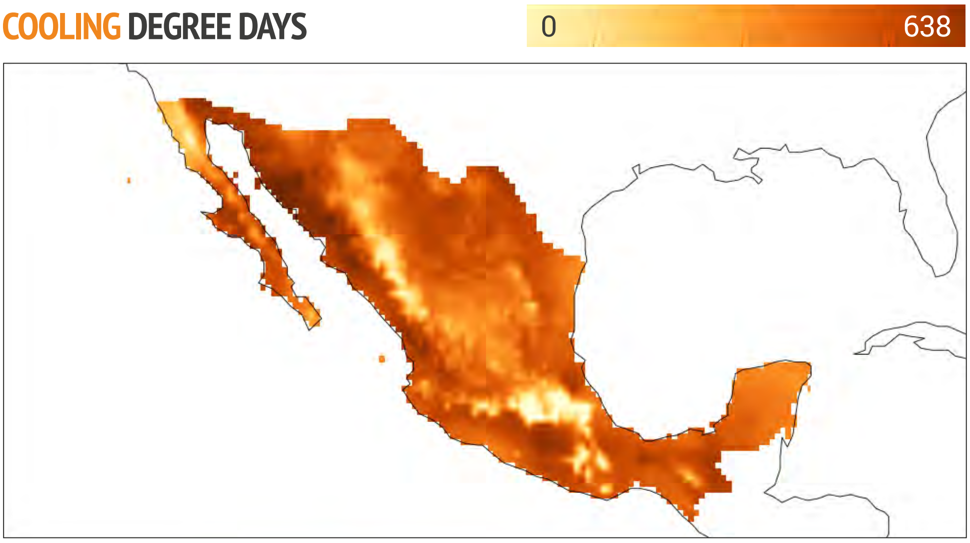
In Mexico, electricity demand for cooling is expected to increase substantially in the coming decades, due to the strong increase in cooling degree days coupled with increasing household incomes.

By 2020, an 8-fold increase in AC units is projected, from 16 million in 2016 to 126 million in 2050.

COOLING NEEDS

Marked increases in cooling needs are expected over most of the country, including mountain areas, excluding the highest elevations. Highest increases esxpected in the northwest.

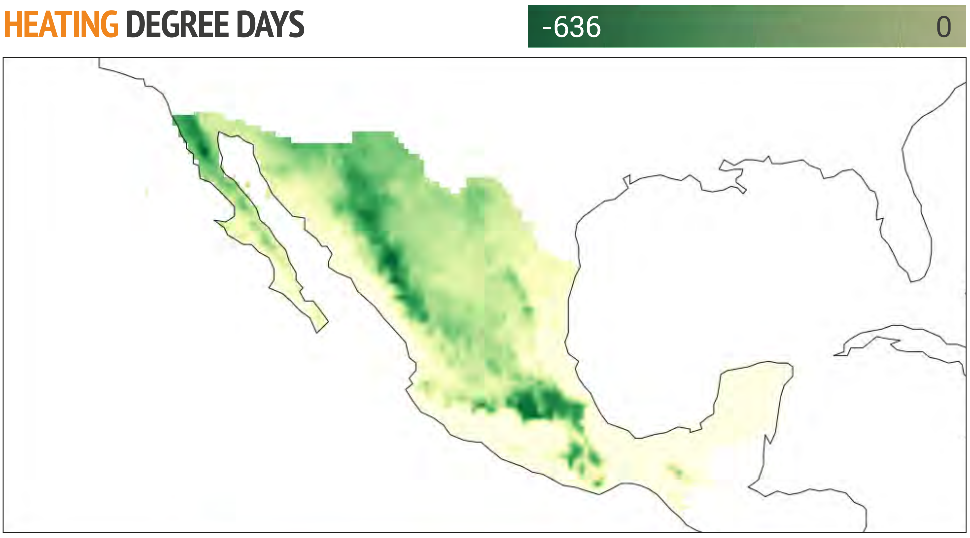
COOLING DEGREE DAYS



HEATING NEEDS

Marked decreases in heating needs are expected only at high elevations. This matters in terms of energy demand for mountain cities, as there are more than 15 cities with over 100,000 inhabitants above 2000 meters, including Mexico City (9 million).

HEATING DEGREE DAYS

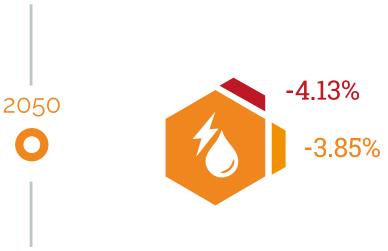


FUTURE ENERGY SUPPLY

The future configuration of the Mexican energy mix is likely to be determined by the evolution of climate mitigation policies and hence is outside the scope of this report. Mexico has a long-term commitment to halving its carbon emissions compared to 2000 levels by 2050.

However, in the wake of the COVID crisis, stimulus programs have given priority to the development of fossil fuel extraction and thermal plants, implying that the vulnerabilities of oil and gas extraction and electricity generation will be prevalent at least until mid-century.

Change in
Hydropower generation
% of change



EXPECTED IMPACTS OF CLIMATE CHANGE

There is a lack of quantitative estimates of impacts on the energy infrastructure; however, both an increase in the threat posed by hurricanes and coastal floods to oil industry infrastructure in the Gulf of Mexico, and a decrease in water availability for hydropower and cooling of thermal plants, is expected.

MEXICO ECONOMY

OVERVIEW

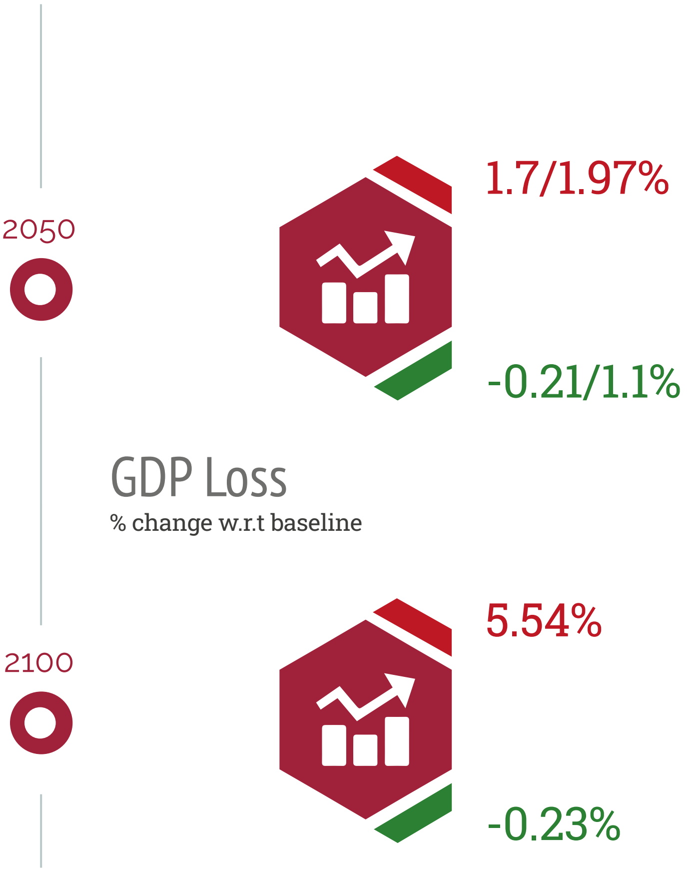
The Mexican economy contracted by 8.3% of GDP in 2020 due to the COVID 19 pandemic. After enduring one of the most severe economic slumps in the G20, it is poised to grow at an estimated high of 5% in 2021, spurred by the growing value of exports.

IMPACTS ON GDP

Climate change will have an effect on the growth rate and overall economic performance of the country. Under less severe climate change scenarios, climate change may have a small positive effect on GDP.

By mid century projections are in the range of a 1.87 billion EUR gain, or 0.21% of GDP, to damages of 17.6 billion EUR or 1.97% of GDP.

By the end of the century estimated aggregate damages could reach 49 billion EUR, or 5.54% of GDP under a high emissions scenario.



GDP Loss

% change w.r.t baseline

SECTORAL ECONOMIC IMPACTS

IMPACTS ON INDUSTRY AND INFRASTRUCTURE

Mexico's extensive coastline spanning two oceans and covering 11,000 kilometres, coupled with its unique topography, make it highly vulnerable to the damages of tropical cyclones and floods. Transport, power and water infrastructure are thus threatened, particularly in coastal areas.

IMPACTS ON AGRICULTURE

Agriculture is a small percentage of overall GDP, accounting for only 3.3%, but it is the third most important economic activity . It remains a key sector of the economy, employing 13.3% of the labour force. Mexico is the leading world producer of avocados, lemons and limes.

The agricultural sector is predicted to be the most badly affected by climate impacts: 80% of weather-related financial losses since 1990 were attributed to agriculture.

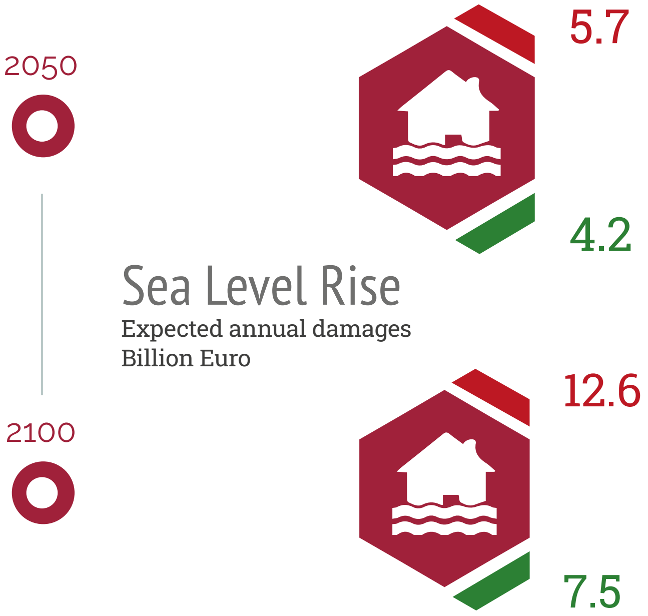
By 2050, depending on the assumptions made, the impacts of climate change on the agricultural sector could be between 8.92 and 24.98 billion EUR (1% to 2.8% of GDP) under a high emissions scenario, and between 1.22 and 1.96 billion EUR (1.37% and 2.2% of GDP) under a medium emissions scenario.

By 2100, the estimated damages under a medium emissions scenario are between 1.2 and 6.727 billion EUR (1.35% and 7.54% of GDP), and under a high emissions scenario between 1.7 and 99 billion EUR (1.91% and 11.15% of GDP).

SEA LEVEL RISE DAMAGES

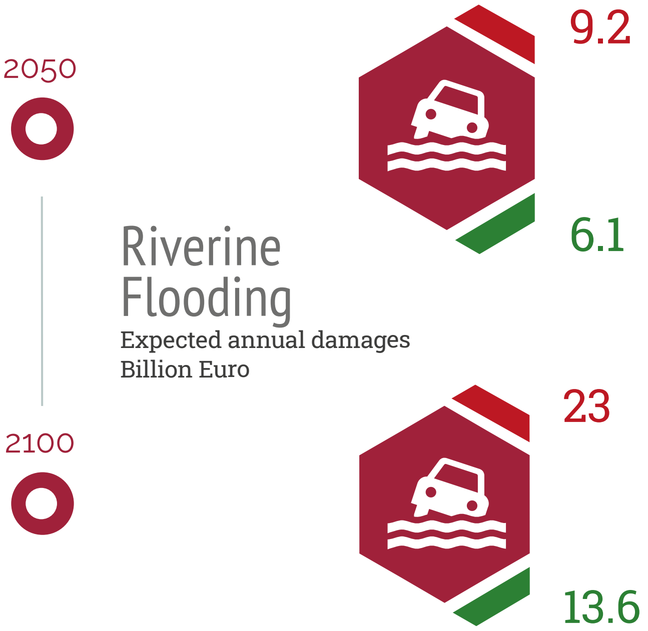
The expected annual damages from sea level rise and riverine flooding as a result of climate change are substantial. By mid century, sea level rise is projected to cause economic losses of 4.2 billion EUR under a low emissions scenario and 5.7 billion EUR under a high emissions scenario in terms of expected damages to assets.

By the end of the century, the costs rise to 7.5 billion EUR under a low emissions scenario and 12.6 billion EUR under a high emissions scenario.



RIVER FLOODING DAMAGES

Riverine floods are also expected to result in economic losses. By mid century, the expected annual damages to assets are between 6.1 billion and 9.2 billion EUR under the low and high emissions scenarios, respectively. By the end of the century, the costs rise to annual damages of 13.6 billion EUR under a low emissions scenario and rise to 23 billion EUR under a high emissions scenario.



IMPACTS ON ENERGY

As with all other economic sectors, energy supply and energy networks in Mexico will undergo more intense stress from extreme weather events.

Economic impacts of shifts in household and firm energy demand (see chapter on energy) are difficult to predict and will mostly imply redistribution effects.

In the case of Mexico, the magnitude of the increase in demand for cooling is expected to exceed by far the (tiny) decrease in heating demand, hence a significant increase in energy bills is expected.

IMPACTS ON TOURISM

Tourism is a key sector of the Mexican economy, contributing 8.7% of GDP in 2018. Coastal areas are a major tourist destination, and are highly vulnerable to climate impacts. The rich marine ecosystems are also at risk of severe weather events and temperature increases.

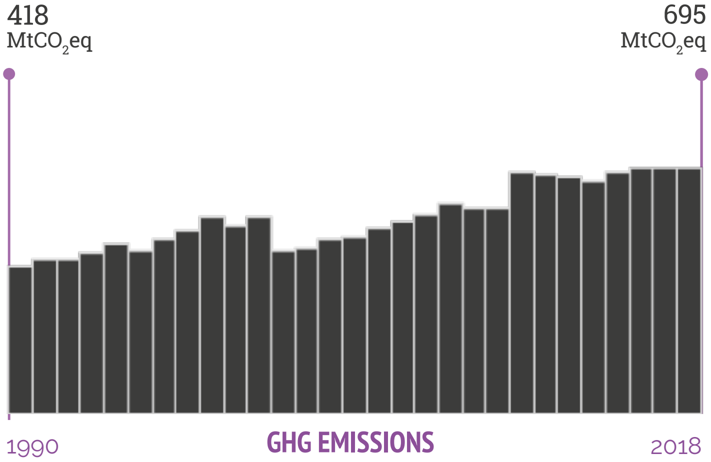
Tourist destinations in Mexico are highly sensitive to climate conditions, so it is expected to be highly impacted by climate change. Hotels located in coastal zones are constantly at risk from the effects of tropical cyclones, and the costs of disaster prevention increase every year.

It is estimated that by 2050, climate impacts on foreign tourism could result in a loss of 89 million EUR or 0.01% of GDP, under both medium and high emissions scenarios.

MEXICO
POLICY

OVERVIEW

Mexico is the world's 11th largest emitter in absolute terms. Nevertheless, it is one of the countries with the lowest per capita emissions of the G20. Although Mexico has committed to the Paris Agreement, emissions continue to grow.



INTERNATIONAL COMMITMENTS

Mexico ratified the Paris Agreement in 2016. In its NDC, Mexico commits to reduce emissions by 22% in 2030, with reference to a business-as-usual scenario. The NDC also includes a commitment for the reduction of black carbon (-51% by 2030 with reference to a business-as-usual scenario).

CLIMATE POLICY COMMITMENTS CHRONOLOGY

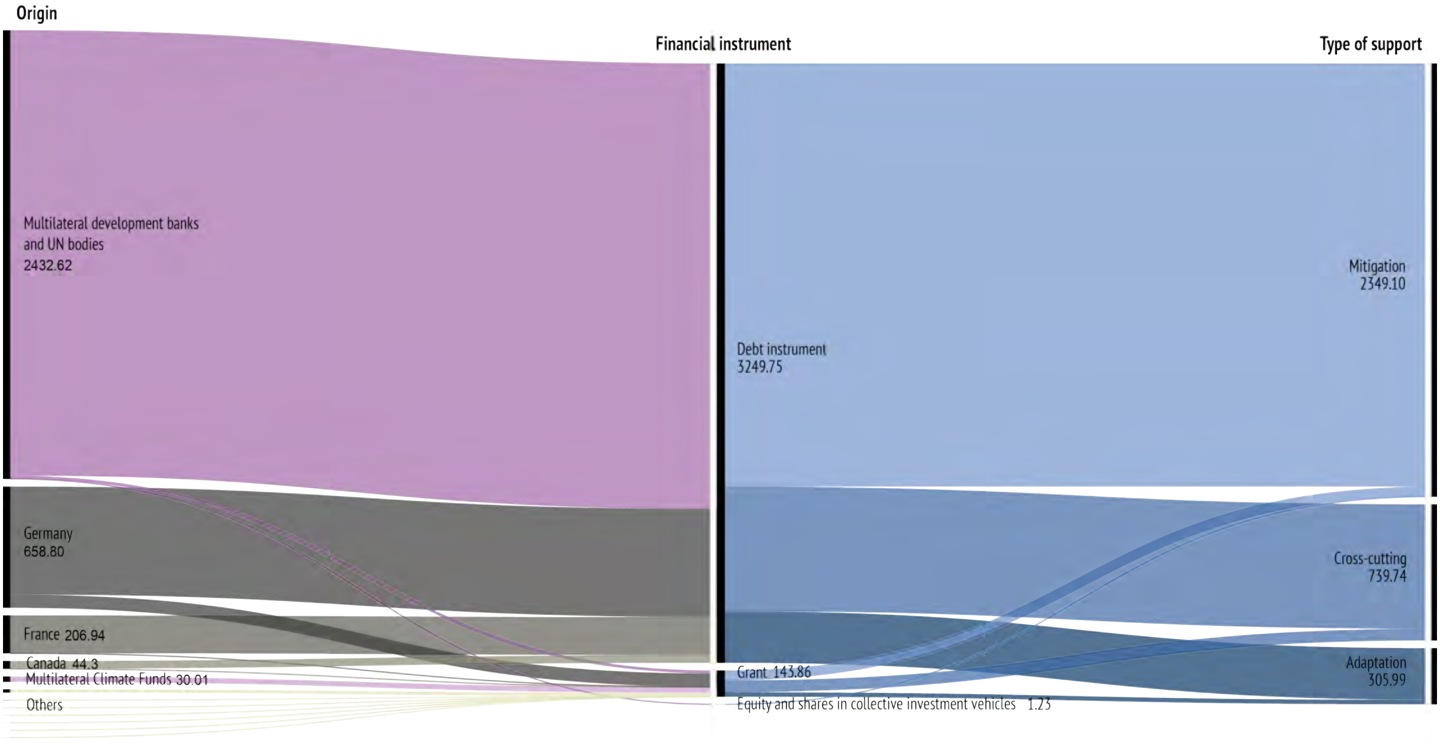
2000 — **KYOTO PROTOCOL - 1ST PERIOD**
No target

2016 — **PARIS AGREEMENT - 1ST NDC**
22% of GHG reduction by 2030, with reference to a specific business-as-usual scenario. 51% reduction in black carbon by 2030, with reference to a specific business-as-usual scenario

2020 — **PARIS AGREEMENT - NDC UPDATE**
Submitted. Commitments unchanged

INTERNATIONAL CLIMATE FINANCE ASSISTANCE

The diagram shows the climate-related development finance received by Mexico in 2017-2018 and reported to the OECD DAC. The total amount is 3,4 billion USD. The majority comes from multilateral institutions in the form of debt instruments.



SUSTAINABLE RECOVERY POLICY

In 2020, Mexico designated 22.3 billion USD to recovery from the healthcare crisis. In the Global Recovery Observatory, no sustainable recovery measures are reported.

34.41 billion $	22.31 billion $	0 billion $
Total Spending	Recovery Spending	Green Spending

DOMESTIC ADAPTATION POLICY

Mexico has included adaptation in its NDC. To achieve its NDCs, Mexico adopted an integrated mitigation and adaptation plan. This policy foresees that sub-national administrations are responsible for the development of adaptation plans.

- ○ Domestic Adaptation Policy
  - ● Inclusion of Adaptation in NDCs
  - ● Integrated Adaptation & Mitigation Policy
  - ○ Dedicated Adaptation Strategy
  - ○ Dedicated Adaptation Plan
- ○ Subordinate Adaptation Policies
  - ○ Sectoral Adaptation Plans
  - ● Subnational Adaptation Plans

○ Policy not in place ● Active policy

ADAPTATION POLICY HIGHLIGHTS

TRANSNATIONAL INITIATIVES

Selva Maya Natural Resources Protection Project

The project aims to maintain the ecosystem functions and cultural values of the Selva Maya that promotes the welfare of its people and provides environmental services of global importance

Canada-Mexico Partnership Environment Working Group

The Canada-Mexico Partnership is a key mechanism for bilateral cooperation between Canada and Mexico on environmental issues, including climate change

NATIONAL INITIATIVES

National Atlas of Vulnerability to Climate Change (ANVCC)

ANVCC provides a structured and systematic set of nationwide maps that show territorial vulnerability to climate change and guide the implementation of adaptation strategies

Climate Change and Biodiversity Explorer (ECCBio)

The tool allows an interactive visualisation of past temperature and precipitation patterns, as well as different future climate change scenarios for the periods 2015-2039, 2045-2069 and 2075-2099

SUBNATIONAL INITIATIVES

Mexico City's Climate Action Program (PACCM)

PACCM targets a wide range of challenges, such as increasing energy efficiency, containing urban sprawl, managing natural resources and preserving biodiversity and increasing research and development

Adaptation to Climate Change Impacts on the Coastal Wetlands in the Gulf of Mexico

The project focused on actions that contribute to local populations' adaptation to floods, lack of clean water, food insecurity and to mangrove conservation

ENERGY TRANSITION

Mexico is performing slightly below the G20 average in the overall Energy Transition indicator and in all domains, with the exception of Emissions where the country is performing much better. In particular, the ongoing digitalization of the electric grid should speed up and increase the level of electrification of energy consumption patterns in the country that will rise over the next few decades thanks to the expected increase in population and wealth: as a consequence, investments in electricity can also improve efficiency. Finally, Mexico should grab much more the opportunities offered by renewable energy sources, as increasing their penetration can also decrease the usage of fossil fuels.

Energy Transition	58.7	56.5
Fossil Fuels	45.3	44.3
Renewables	19.7	13.0
Efficiency	84.9	84.4
Electrification	70.8	63.3
Emissions	72.9	77.6

G20 AVERAGE

COUNTRY

Only actively pursuing an energy transition based on decarbonization and electrification – from policy and regulation, to health and education – will enable countries to benefit the most from future opportunities and fight climate change whilst ensuring an equitable distribution of wealth.

The Energy Transition indicators were developed by Enel Foundation in cooperation with SACE, and provide a retrospective analysis based on historical data.

G20 CLIMATE RISK ATLAS

Impacts, policy, economics

RUSSIA

How to read the Atlas: graphs, colours and scenarios.

The maps used in this Atlas are taken from **The World Bank Official Boundaries** - ***https://datacatalog.worldbank.org/search/dataset/0038272*** (accessed on May 28, 2021). For the section Energy, the maps are based on Panoply Data Viewer ***https://www.giss.nasa.gov/tools/panoply/credits.html***

Each sector of this Atlas contains data and information on various climate scenarios.

When reported in graphs, the **colour black** indicates data and information referring to the current state, the past or the baseline.

When the authors refer to **RCP (Representative Concentration Pathways)**, the 3 colours used across the factsheet refer to 3 scenarios, which are 3 different development options with different levels of greenhouse gas emissions, **respectively low emissions (green), medium emissions (orange), and high emissions (red)**. The same colour code is used when RCPs are associated with Shared Socioeconomic Pathways (SSP).

In some cases, the authors refer to global warming scenarios. In these cases, the 3 colours used refer to a temperature rise of **1.5°C (green), 2°C (dark green), and 4°C (red)**.

When the authors refer exclusively to **Shared Socioeconomic Pathways - SSPs** (Population affected by river floods in the section: "Water"), data related to **SSP3** - that encompasses, among other things, slow economic growth, material-intensive consumption, and persisting or worsening inequalities – **are reported in a lighter shade**; **SSP5** – which refers to social and economic development that is coupled with an energy-intensive lifestyle and the abundant exploitation of fossil fuel resources – is shown using a **middle shade of the colour**, whereas data related to **the present** conditions **are represented in a dark shade**.

Further details on scenarios, methodologies, and the full list of references are available at: **www.g20climaterisks.org**

Concept and graphic design by element6.eu

RUSSIA CLIMATE

OVERVIEW

Russia features almost all world climates, with the exception of tropical, due to its huge landmass which crosses two continents. In general, its predominant climate is a highly continental one, with warm to hot and dry summers and cold winters which prevails in European and Asian Russia, with the exception of the tundra and the extreme southwest. Very strong easterly winds, called Buran, sometimes occur bringing freezing cold temperatures and snowstorms.

TEMPERATURE

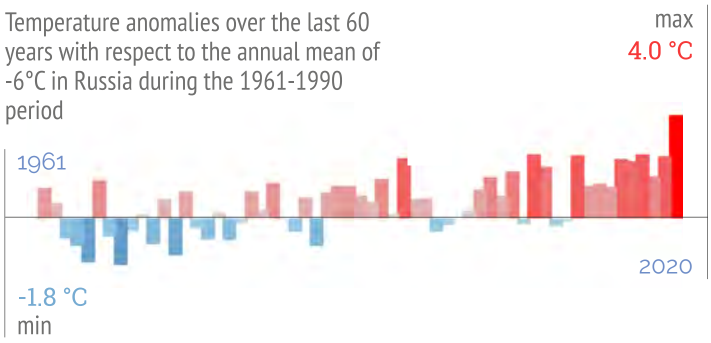
The temperature regime in Russia varies from region to region. In general, two different areas can be detected: Northern and Central European Russia experience a cold climate, and Southern European Russia have higher temperatures, particularly around the Black Sea.

MEAN TEMPERATURE

Celsius degrees / Over 1991-2020

TEMPERATURE TREND

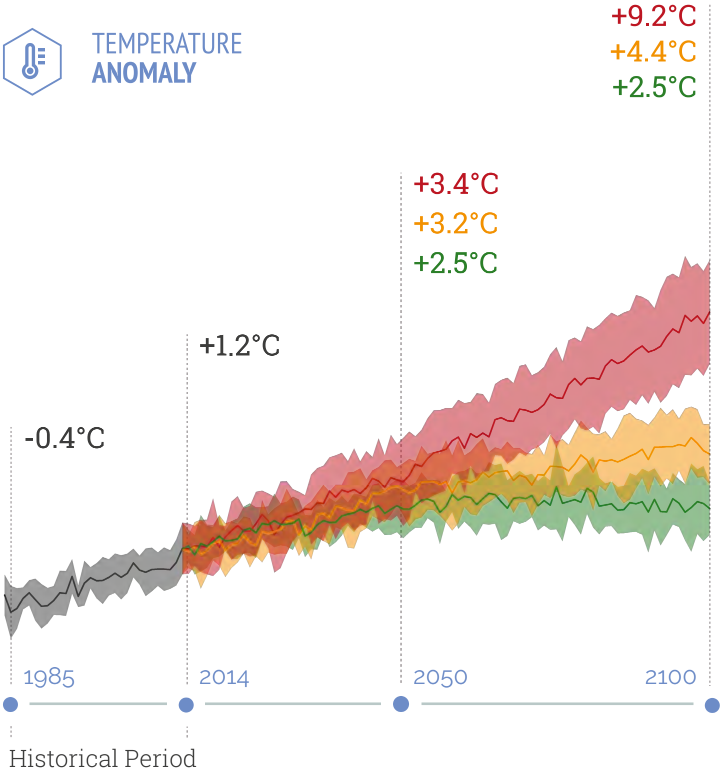
Temperature anomalies over the last 60 years with respect to the annual mean of -6°C in Russia during the 1961-1990 period



TEMPERATURE PROJECTIONS

Under a low emissions scenario projected temperature variations will reach +2.5°C, both by 2050 and 2100.
Under a high emissions scenario, with no reduction in GHG emissions, much greater temperature anomalies are expected by both 2050 and 2100.

TEMPERATURE ANOMALY



EXPECTED VARIATION FOR TEMPERATURE AT 2050

The indicators show variations in selected temperature characteristics for a thirty-year period centred on 2050 (2036-2065) with respect to the reference period 1985-2014.

	Annual Mean Temperature	Max Temperature of warmest month	Min Temperature of coldest month
🟥	+3.9°C	+3.1°C	+5.2°C
🟧	+3.1°C	+2.4°C	+4.2°C
🟩	+2.6°C	+2.0°C	+3.2°C

PRECIPITATION

As with temperatures, the precipitation regime in Russia also varies from region to region due to the size of the country.
The main patterns for annual precipitation reveal that the western part of the country is the rainiest, whereas the central areas are the driest ones. Furthermore, precipitation values are higher in areas around the sea.
An average increase in precipitation in many areas of Russia, as well as rapid snow and glacier melting due to rising temperatures, may lead to an increase in risk of flooding.

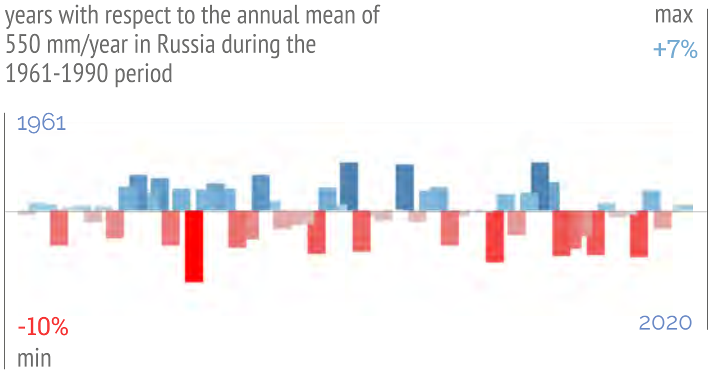
MEAN PRECIPITATION

211 – **2,411**

mm/year / Over 1991-2020

PRECIPITATION TREND

Precipiation anomalies over the last 60 years with respect to the annual mean of 550 mm/year in Russia during the 1961-1990 period



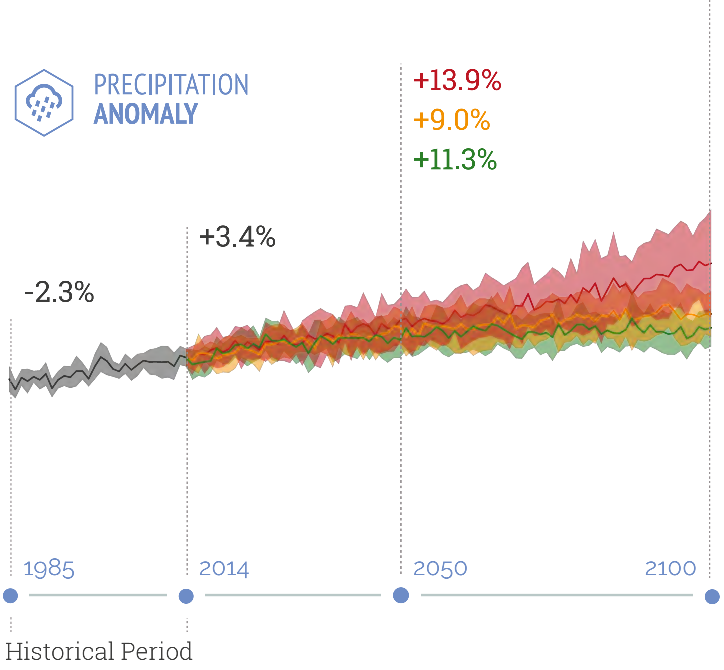
VARIATION OF SPECIFIC CLIMATE INDICATORS

Climate indicators variation showing impacts of climate change on sectors such as agriculture, health and water. Analysis considers 3 threshold average temperature increase: **+1.5°C**, **+2°C**, **+4°C**.

+31% +16% +12%	+20% +9% +8%	+1,026% +137% +42%	+18% +6% +3%
Agricultural drought proportion of time % of time	Hydrological drought proportion of time % of time	Heatwave duration % of time	Runoff increase % of area
+69% +38% +28%	+11% +7% +12%	+81% +28% +17%	+42% +24% +12%
Agricultural drought frequency % of change	Hydrological drought frequency % of change	Heatwave frequency % of change	Runoff decrease % of area

PRECIPITATION PROJECTIONS

Precipitation trends shows an increasing pattern for all the different scenarios. The variability is quite large over all the periods considered. It is more pronounced over the projections period but differences between the scenarios persist.



EXPECTED VARIATION FOR PRECIPITATION AT 2050

The indicators show variations in selected precipitation characteristics for a thirty-year period centred on 2050 (2036-2065) with respect to the reference period 1985-2014.

+12.7% +10.5% +9.5%	+10.8% +9.2% +8.7%	+6.5% +6.1% +6.7%
Annual total precipitation	Precipitation of wettest month	Precipitation of warmest quarter

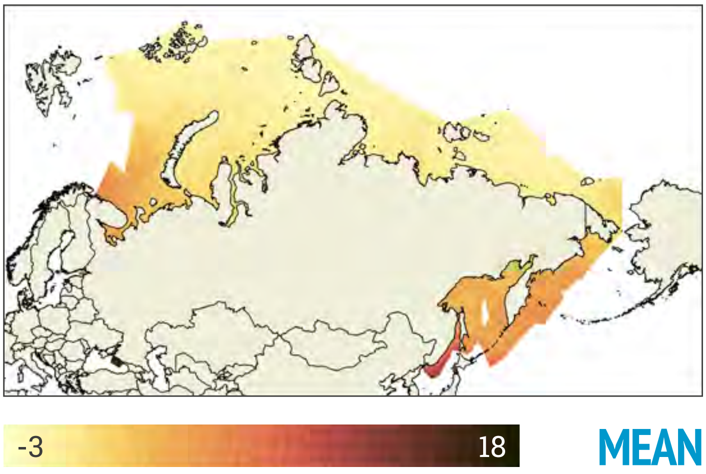
RUSSIA
OCEAN

OCEAN IN RUSSIA

Russia's marine exclusive economic zone (EEZ) is characterized by polar to temperate coastal waters which host a great concentration of wildlife and habitats. Russian coastal systems can be divided into four key areas: Arctic and Pacific marine regions and two small areas within the Baltic and Black Seas.

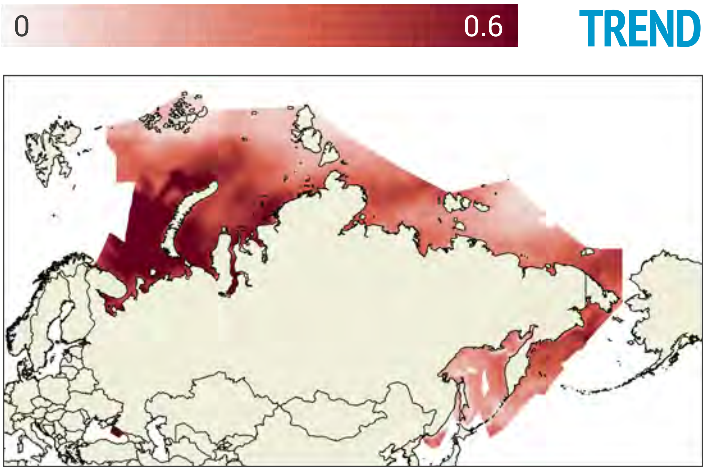
CURRENT CLIMATE CONDITIONS

Mean sea surface temperature reflects the different climate regimes, from the cold Arctic waters to the temperate regime of the southernmost Black Sea.



SEA SURFACE TEMPERATURE

Celsius degrees / Over 1991-2020

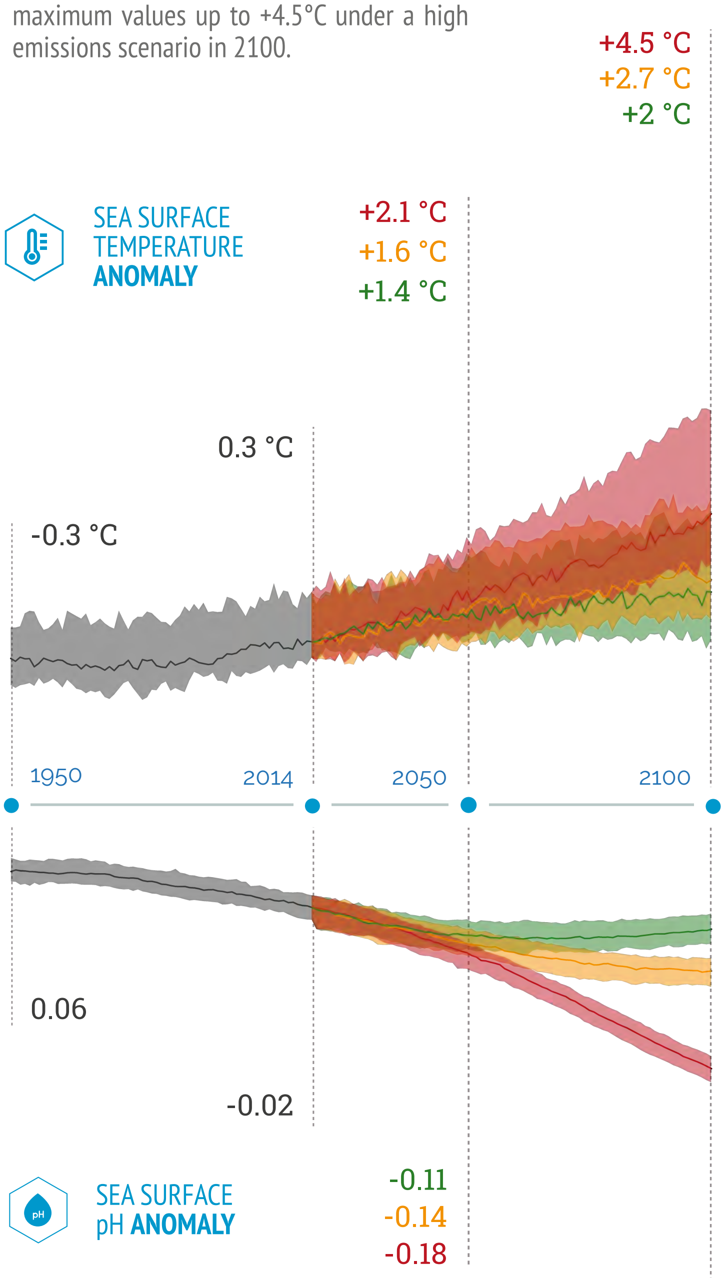


Surface temperature trends indicate a general warming of 0.2°C per decade in all marine areas, with increased gains up to 0.6°C per decade in the Arctic area.

FUTURE PROJECTIONS

Projected annual changes within the marine EEZ for the two most significant marine indicators of climate change: sea surface water temperatures and pH.

Seawater temperature changes are in line with the definitions of each scenario, with maximum values up to +4.5°C under a high emissions scenario in 2100.



Seawater surface pH becomes more acidic in all scenarios, closely reflecting rising atmospheric CO_2 concentrations, and only a low emissions scenario leads to a stable condition by 2100.

-0.1
-0.2
-0.44

ECOSYSTEM INDICATORS AT 2050

Regional changes in key marine ecosystem indicators under projected future scenarios by mid-century (2036-2065) with respect to present climate conditions (1985-2014).

Arctic

Baltic

Black Sea

Pacific

Temperature regulates the metabolism of marine organisms determining which habitats remain suitable. Excessive warming will likely push ecosystems beyond tolerance thresholds.

pH represents the acid/base status of marine waters, where a decreasing pH reflects the acidification of the ocean due to increased absorption of atmospheric CO_2.

Oxygen is fundamental to sustain marine life and its reduction can have a large impact on coastal ecosystem services including fisheries and aquaculture.

Chlorophyll is an indicator of the biomass available at the base of the marine food web supporting all ecosystem productivity.

	Arctic	Baltic	Black Sea	Pacific
Temperature	-0.73°C +1.33 °C +0.9 °C +0.64 °C	9.12°C +2.38 °C +1.99 °C +1.7 °C	15.64°C +2.06 °C +1.44 °C +1.24 °C	4.73°C +2.36 °C +1.92 °C +1.92 °C
pH	8.09 -0.2 -0.16 -0.13	7.83 -0.21 -0.11 -0.12	8.1 -0.19 -0.14 -0.1	8.08 -0.16 -0.12 -0.09
Oxygen	366 mmol/m^3 -3.59 % -2.64 % -1.66 %	354.46 mmol/m^3 -6.51 % -5.33 % -4.95 %	268.97 mmol/m^3 -2.62 % -2.95 % -3.82 %	324.12 mmol/m3 -4.52 % -3.77 % -2.94 %
Chlorophyll	0.33 mg/m^3 -19.76 % -12.16 % -25.84 %	0.29 mg/m^3 -15.59 % -14.24 % -17.63 %	0.23 mg/m^3 -3.88 % +8.19 % -3.02 %	0.66 mg/m3 -10.11 % +4.68 % -7.54 %

FISH CATCH POTENTIAL

Fish catch potential is an estimate of the maximum fish catch achievable given the marine resources available over a sustained period. It is linked to the concept of maximum sustainable yield, meaning the maximum amount of fish that can be extracted from a system without causing a collapse in fish populations.

It is a characteristic of the natural system, which is substantially different from realized catch, and a direct result of the fishery policy in place. The data reported exclude the Russian part of the Black Sea and the Caspian Sea.

Fish catch percentage change

2050

+34.4%

+31.6%

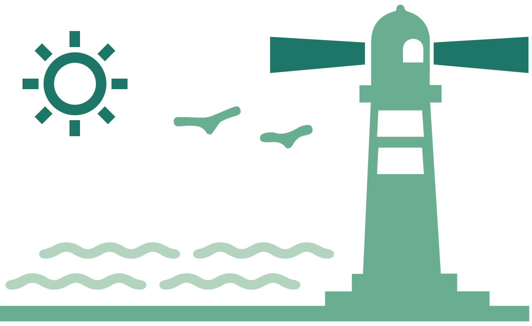
ANALYSIS DETAILS

All datasets were analysed using only data from within the marine EEZ and therefore excluding overseas territories, detached islands and any disputed or joint territories with other nations. In the assessment of current climate conditions, seawater surface tempererature data was obtained using satellite observations distributed in the framework of ESA Climate Change Initiative.

Future projections of marine indicators are represented by the combined analysis of results from 15 different Earth System models participating in the Coupled Model Intercomparison Project Phase 6 (CMIP6). These models include new and better representations of physical and biogeochemical processes, compared to previous IPCC assessment reports.

Fish catch potential data was obtained using the FAO's technical report and refers to the best and worst case climate scenarios from the Fifth IPCC Assessment Report. These mean estimates are subject to substantial uncertainties as discussed in the original work.

RUSSIA
COASTS



OVERVIEW

Russia's shorelines extend more than 110,000 kilometres and border the Baltic, Barents, Kara and East Siberian seas, the Pacific Ocean, the Black Sea and the Sea of Azov. Parts of the vast and diverse shoreline are permanently frosted during winter months. Most of the coastal population is concentrated in the more hospitable parts of the country, including St Petersburg and Kaliningrad on the Baltic Sea, Arkhangelsk on the White Sea and Vladivostok on the Pacific Ocean.

Shoreline Length

110,310 km

Sandy Coast Retreat at 2050

-18.9 m

CLIMATE CHANGE HAZARDS

Coastal hazards such as erosion, storm tide inundation and permanent flooding, can have strong adverse impacts on coastal regions, with loss of sandy shores, damage to settlements, infrastructure and ecosystems. Climate change can exacerbate these impacts due to rising sea levels and increasing impacts of waves and storms. Climate change impacts on Russian coasts are driven by sea level rise, changing storm patterns, and ice and permafrost melting in the northern regions.

Coastal erosion is likely to occur in response to sea level rise along the low lying coastal plains and beaches. Permafrost melting due to rising temperatures also leads to high rates of erosion, which is in turn exacerbated by sea level rise. Coastal flooding may also be accentuated by sea level rise, impacting populated areas, particularly in cities along the Baltic Sea such as Saint Petersburg.

SEA LEVEL RISE

Relative sea level rise in Russia has been observed over the past century with a yearly average increase of approximately 2.47 millimetres. All stations show similar trends for the past century and an acceleration in recent decades.The latest IPCC projections indicate that, by 2050, global sea levels may rise between 0.18 metres, under a low emissions scenario, and 0.23 metres, under a high emissions scenario.

Observed and projected sea level rise at 2050

2.47 mm/year

0.23 m

0.18 m

EXTREME SEA LEVEL

On average, one in 100 extreme sea level events are expected to rise from 2.78 metres at present day to 3.01 metres by 2050 under a medium emissions scenario.

Current and projected extreme sea level at 2050

2.78 m

3.05 m

3.01 m

OBSERVED STORMS

In general, all seas and oceans surrounding Russia are characterized by a wave climate driven by a range of weather systems with associated variability across seasons, years and decades. Whereas more climate variability is observed in the Pacific, driven in particular by the El Niño Southern Oscillation, in the northern and eastern seas surrounding Russia, and in the Black Sea, climate variability has been observed in recent decades and is mostly driven by large scale global oscillations. Storm surges can impact the Baltic Sea and the Gulf of Finland.

FUTURE STORMS

Changes in the wave climate impacting Russian coasts are expected to be in line with the changes projected for the wave climate regions the country is exposed to. For example, future increases in wave energy are expected in the Baltic Sea, and changes in wave energy distribution in the Arctic Sea will also increase due to the melting arctic ice pack. For the Black Sea the impact of climate change is quite uncertain, with both potential decreases or increases in the wave energy distribution. The Russian Pacific is expected to see a decrease in mean wave climate and an increase in extreme conditions. Overall rising sea levels will increase the frequency of extreme sea level events, such as the one in 100 year water level.

VULNERABILITY AND RISK

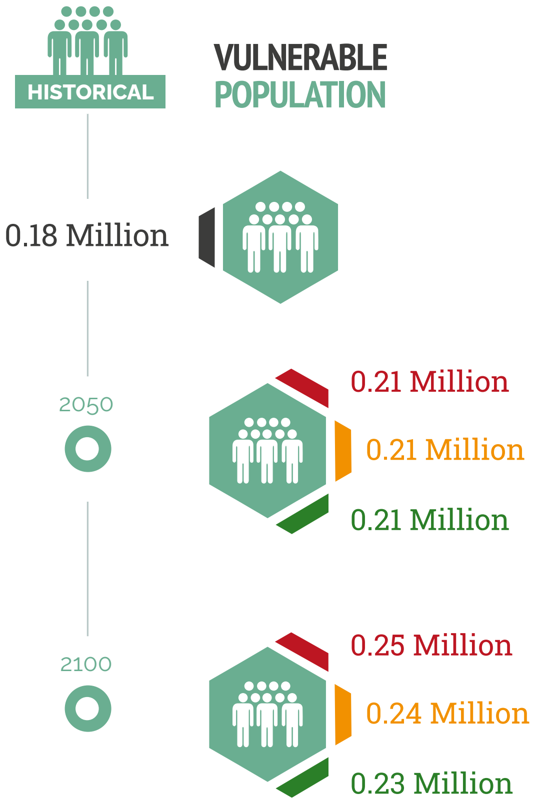
The vast Russian coast is characterised by coastal environments, settlements and urban areas with a range of vulnerabilities and risks associated with sea level rise and storms.

Russia's second largest city, St. Petersburg, is particularly vulnerable to sea level rise, which is already at risk of regular flooding when strong winds blow from the Gulf of Finland. This vulnerability will continue to increase as sea levels rise and storm surges grow more intense.

In the Black Sea, the city of Rostov and the Port of Novorossiysk are particularly exposed to the impacts of sea level rise. 56% of beaches in the Black Sea are projected to retreat by 50% of their maximum width considering a 0.5 metre sea level rise.

Under a medium emissions scenario, the total population exposed to the annual coastal flood level is expected to increase from 180,000 to 210,000 by 2050.

VULNERABLE POPULATION



INFLUENCE OF SEA LEVEL RISE ON EXTREME SEA LEVEL

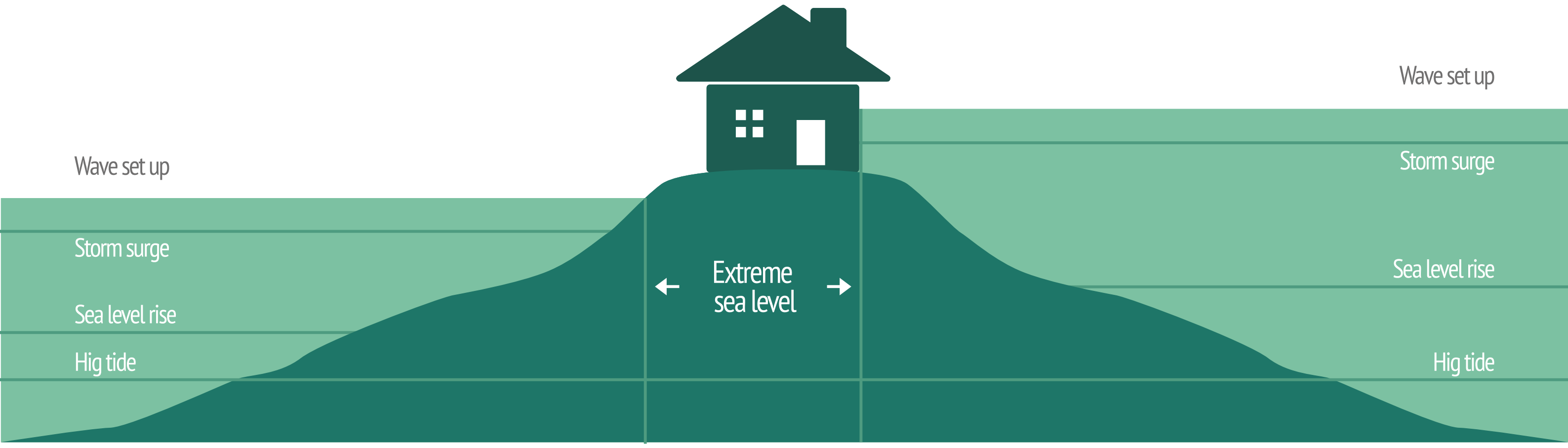
Present and future sea level rise are a consequence of carbon induced global warming causing melting ice and ocean expansion due to heat accumulation.

The extreme sea levels reported here are based on the 100-year storm surge + wave set up + sea level rise + high tide indicators. The first two parameters (storm surge + wave set up) are based on the 100-year value for the event; sea level rise is its projected value at 2050; and high tide is the absolute value of the highest tide calculated for a given locality, which won't be influenced by climate change.

+ **Wave set up** refers to the accumulation of water near the shore due to the presence of breaking waves.

+ **Storm surge** is an occasional increase in sea level driven by shoreward wind-driven water circulation and atmospheric pressure.

+ **High tide** is usually the highest tide reached in a given location based on tide records.



Present sea levels have risen globally by approximately 20 centimetres over the past century.

Future sea level rise is a projection based on different global warming scenarios, at approximately 100 centimetres by the end of 2100, with consequent inundation during extreme sea level events.

RUSSIA
WATER

OVERVIEW

Russia is home to 20% of global freshwater resources. However, water is unevenly distributed within the Russian territory. The central and southern regions of European Russia, where 80% of the country's population and industry is concentrated, have only 10-15% of water resources.

In Russia, approximately 70% of drinking water comes from surface water and 30% from groundwater. Some of the largest freshwater bodies in the world include the Volga, Ob and Dnieper Rivers, as well as Lake Baikal, the world's largest freshwater lake.

Renewable internal freshwater resources	4,312 billion m^3
Renewable internal freshwater resources per capita	29,841 m^3

The overall intake of fresh water from water bodies in Russia is high, amounting to approximately 70 billion cubic metres per year. In 2016, the volume of fresh water used for economic activities amounted to 54.7 billion cubic metres. The main water consumers are manufacturing industries, heat supply and nuclear power companies, utility companies, and agriculture (particularly in the south).

CLIMATE CHANGE HAZARDS

Climate change can affect water resources through increasing temperatures, higher rates of evapotranspiration and altered rainfall patterns. This leads to changes in the water cycle, including decrease of snow and ice coverage, alterations of surface runoff and groundwater storage, as well as drought and flood occurrence. Water availability in Russia is projected to increase by 8 to 10% over the next 30 years. However, the western side of the country is more vulnerable and likely to suffer from water stress. Managing the increased flows will also pose problems, especially when these coincide with extreme weather events. In addition, increasing water shortages are predicted for southern parts of European Russia and many densely populated areas, which already face water supply problems.

KEY POINT RUNOFF

River and surface runoff has been influenced by the general increase in water availability in large parts of Russia over the past decades, due to increasing temperatures and melting ice and snow cover. For example, the annual runoff of the Volga has increased by approximately 9% since the early 1980s and served as the main cause of an almost 2.5 metre rise in the Caspian Sea level.

At a country scale, an average increase in surface runoff by approximately -16% and -4% is expected respectively under low and high emissions scenarios for the 2045-2055 period compared to 2015-2025.

If temperatures rise by 1.5°C, 2°C or 4°C, 2%, 5.4% or 16% of the area of the country will likely experience an increase in runoff, while 4%, 12.3% or 39% of the surface of the country will likely experience a decrease in runoff, respectively.

2050

Changes in annual runoff
% of change

-4.4%

-15.7%

2050

Runoff increase
% of area

+42.0%

+12.0%

KEY POINT DROUGHTS

In Russia, extreme low flow events have been traditionally observed in the southern Asian part, in the basins of Western Siberia and in the Baikal region. However, during the last decade dry periods also started occurring further north: not only in the upstream regions but also in the middle course of the rivers. This may be attributed to an increase in the seasonal climate contrast, which is reflected in the redistribution of rainfall throughout the year. This effect leads to an increase in the duration of dry periods, which now occur not only in the summer but also in spring. Moreover, in the 21st century water scarcity is connected to the appearance of extreme low flow on the rivers of European Russia. These trends are particularly noticeable in the south of the region: in the basin of the Don, Volga and the Ural. For instance, a 8-year long drought event was observed in the Don River basin, which severely affected agriculture, industry and society.

2050
Severe drought likelihood increase
% of change
+5.1%
+5.2%

2050
Hydrological drought frequency
% of change
+11.0%
+7.0%

2050
Groundwater Recharge
% of change
+12.1%
+1.8%

KEY POINT GROUNDWATER

The amount and availability of surface water influences groundwater. Groundwater recharge by precipitation is the main source of groundwater resources, which are suffering from pressure from human uses, in particular in the areas where population density, agriculture and industry is concentrated.

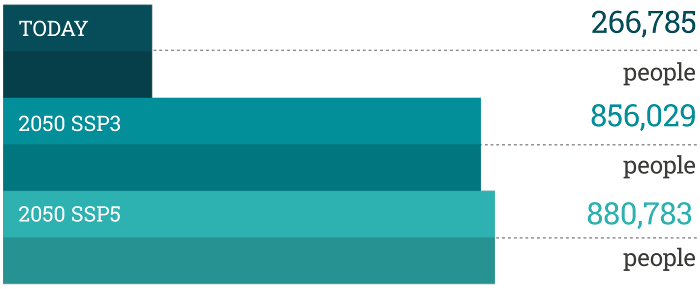
Other parts of Russia have abundant groundwater resources, in particular the remote areas of the northern and central part of the country. Large areas of Russia are expected to increase their groundwater availability, especially in less populated regions and in Siberia and eastern Russia. At the country level, a +1.8%, +5.1% and +12% change of the annual groundwater recharge for the period 2045-2055 compared to the timeframe 2015-2025 is expected respectively under under low, medium and high emissions scenarios.

KEY POINT FLOODS

Many areas of Russia are prone to flash floods and river floods. Extreme events have occurred in the past, with important damages and victims. In Krasnodar Krai, for instance, the equivalent of five months of rainfall fell overnight in summer 2012, leading to 171 casualties and more than 30,000 people affected. Recently, Siberia has also been affected by important floods, with the evacuation of several villages and tens of deaths in southeastern Siberia in 2019.

Furthermore, in 2021 the Sochi region experienced a flash flood and river flood in the same month, leading to extended damage, especially to infrastructure, and the evacuation of the population. Changing rain patterns may affect the frequency and intensity of floods and the population exposed to river floods is expected to increase from about 267,000 in the present day to about 850,000 under SSP3 and 880,000 under SSP5 by 2050, with a potential higher impact of flood events.

POPULATION AFFECTED BY RIVER FLOODS

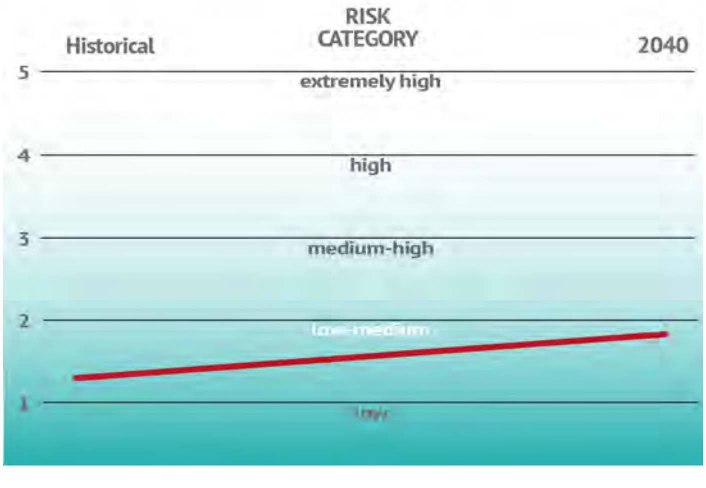


RISK INDICATORS

The water stress index summarises current and future water related vulnerabilities and risks at the global level. Scores are based on the ratio of total water withdrawals, including agriculture, industrial and human consumption, to available renewable surface and groundwater supplies.

WATER STRESS

Russia's water stress level is considered low-medium for the recent past (1960-2014 average), and it is expected to increase in the near future (2030-2050) based on climate change projections.



RUSSIA
AGRICULTURE

OVERVIEW

Agricultural land occupies 13% of the Russian territory and employs 9.7% of the active population, contributing to almost 4% of national GDP. Russia is the world's top wheat exporter, supplying between 20 and 23% of total global demand.

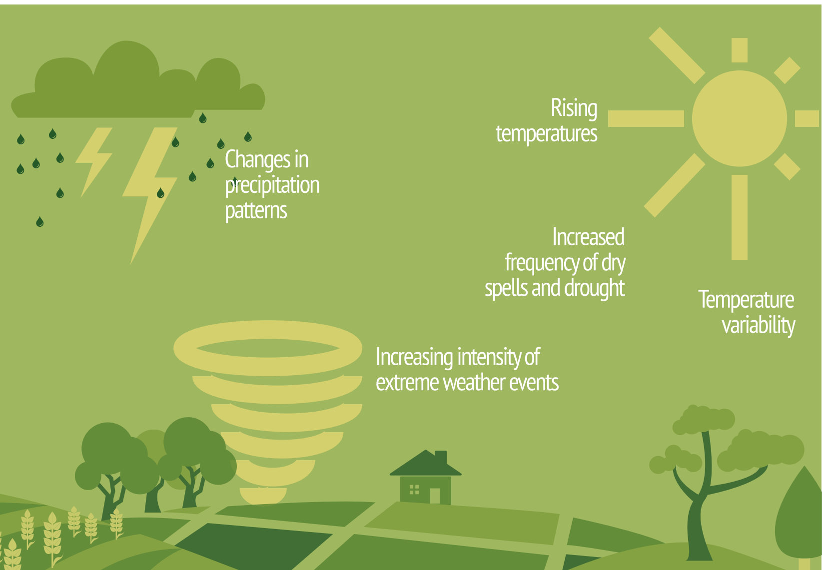
Wheat, sugarbeet, potatoes and other cereals (maize, barley, oats and rye) are the most important crops. Almost 22% of the total arable lands is dedicated to wheat. The main, and most productive, areas for wheat, sunflower and maize are: Southern and North Caucasus, Central and Volga regions, and the south-western part of the country (Central Chernozem Economic Region). Russia is the third largest potato producer in the world, after China and India, with the Republics of Bashkortostan and Tatarstan leading potato production. Irrigated agricultural land corresponds to less than 5% of the total arable land.

72.1 Mt Wheat	42 Mt Sugarbeet	22.4 Mt Potato
17 Mt Barley	12.8 Mt Sunflower	11.4 Mt Maize

	Added Value of Agriculture, Forestry and Fishing	Share of Agriculture Value added in Total GDP	Agricultural land	Area Equipped for Irrigation
2000	37,963 USD Million	4.8 %	126,238 Thousand HA	4,606 Thousand HA
2018	53,639 USD Million	3.8 %	123,442 Thousand HA	4,300 Thousand HA

EXPEXTED IMPACTS ON AGRICULTURE PRODUCTIVITY

Rising temperatures, reduction in average annual precipitation, and intensification of extreme events such as heat waves and drought, affect production variability with a tendency towards yield reduction for many cultivated species, accompanied by a probable decrease in food quality. Crops respond to increases in temperatures with changes in duration of the growing season, early appearance of phenological phases and potential shifts of cultivation areas toward higher latitudes and altitudes for better growing conditions. However, impacts vary significantly depending on the geographical area and specific crops in question.



CROP PRODUCTIVITY

Crop productivity refers to the harvested yield of a crop per unit of land area. It is strongly influenced by climate and other environmental and management factors.

Climate change is expected to have an impact on the productivity of several major crops, although this may in part be offset by the fertilizing effect of higher CO_2.

Impacts are estimated using a range of model projections based on low to high emission scenarios and reported as percentage changes between the 30-year average around the historical period and the 30-year average around 2050.

2.7
9.2 (3.4)%
10.5 (0.2)%
Wheat
tons / ha

43
28.6 (20.3)%
31.6 (na)%
Sugarbeet
tons / ha

1.7
32.9 (22.1)%
38.4 (na)%
Sunflower
tons / ha

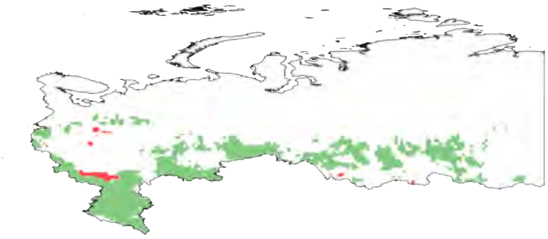
5.2
14.2 (12.2)%
14.7 (-2.6)%
Maize
tons / ha

2050

Productivity change with (without) the CO_2 fertilization effect. Estimates assume sufficient water and nutrient supplies, and do not include impacts of pests, disease, or extreme events.

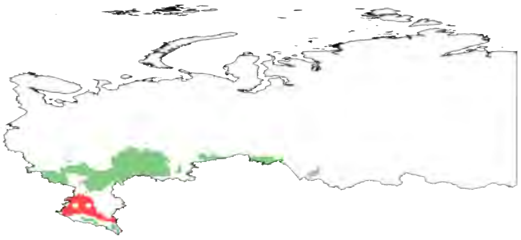
CHANGE IN WHEAT

− = +



CHANGE IN MAIZE

− = +



The impact of global warming is currently assessed as very advantageous, as it reduces the lowest temperatures threatening winter crops, thus allowing for an expansion in favorable agricultural land. In high and middle latitudes, global warming would expand the growing season by an average of 5 to 10 days, although the positive effects could be reduced by abnormal droughts. Climate change will benefit wheat productivity, expanding cultivation areas particularly in Siberia. However, wheat yield productivity will suffer in the Central Chernozem region due to a significant increase in aridity.

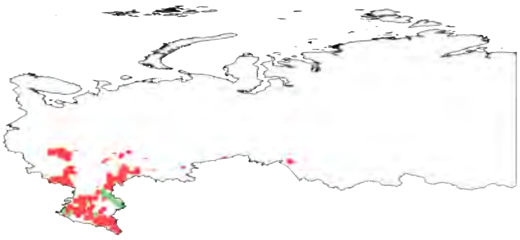
Sugarbeet and sunflowers are expected to be the most favored crops, with their yields increasing by up to 30%. Maize production could suffer in the southern-west regions due to increasing temperature, balancing yield increases for the rest of the country. Thanks to the longer growing season and the possibility of expanding traditional areas of cultivation, potato production can increase in some regions, such as southern Siberia, whereas a decreasing yield is expected in the Central Chernozem Region.

ADAPTATION IN AGRICULTURE AND WATER RESOURCES

Climate change may have positive effects on several widely used crops. However, higher temperatures will generally require an increase in irrigation demand due to increasing evapotranspiration. Although overall water resources are projected to increase in Russia, these are associated with significant increased frequency of high runoff events in central Russia, and more frequent low runoff events in the South. Droughts in 2010 caused severe grain-harvest losses, leading the Russian government to ban wheat exports. Southern regions will become more vulnerable to droughts and other extreme weather, and more reliant on irrigation.

CHANGE IN WATER DEMAND

− = +



Agriculture
Water Demand
% of change
+9.2%
+9.3%

2050

Over half of irrigation systems, mostly concentrated in the South and North Caucasus federal districts, will require work for reconstruction and technical re-equipment in order to cope with climate risks.

RUSSIA FORESTS

FORESTS IN RUSSIA

Russia is home to the largest area of forest in the world and contains around 64% of the world's occupied and intact forests. More than 90% of Russian forests are boreal forests, with a huge diversity and several forest types. Conifers play the dominant role, but there are many deciduous trees (both softwood and hardwood). Floristic diversity of forests increases from north to south.

1990

809 Mln ha
Million hectares
Forested area

158 Tons/ha
Tons of Carbon per hectare
Carbon stock

2020

915 Mln ha
Million hectares
Forested area

164 Tons/ha
Tons of Carbon per hectare
Carbon stock

FORESTED AREA AND CARBON STORAGE

Forests cover about half of the Russian territory, with a slight increasing trend in recent decades. With Canada and Fennoscandia, Russia hosts 90% of the world's boreal forest carbon stock. Half of the estimated terrestrial global carbon sink is located in Russian forests which are a net carbon sink with almost 175 million tons per year, although experiencing a reducing trend. Climate change is expected to increase permafrost melting, which on the one hand favours the establishment of new forests and on the other reduces the overall carbon sink effect.

FOREST PRODUCTIVITY

Forest productivity or Net Primary Production is the net carbon captured by plants. It is the difference between the carbon gained by Gross Primary Production - net photosynthesis measured at the ecosystem scale - and carbon released by plants' respiration. It is expressed per unit land area.

2050

Productivity anomaly
Tons of Carbon per hectare per year

+0.64

+0.50

Increase expected to be widespread and patchy in the whole country

+ Fertilizing effect of increasing atmospheric CO_2, nitrogen deposition, rising temperatures, increasing length of growing period, and permafrost melting promote productivity

Decrease particularly pronounced in the north-east, mainly Yakutia

+ Increasing risk of drought stress due to modifications in the water regime reduces productivity

KEY SPECIES UNDER CLIMATE CHANGE

SHIFTING
SPRUCE
Potential eastward shift of the spatial range of spruce

CHANGES
DOMINANT
Major changes in dominant forests are expected across the southern portion of the Central Siberian Plateau and the southern Far East

THREATENED
BETULA
Betula species should be impacted negativley

EXPANSION
NORTHERN
Pronounced northward shift of forest limit also due to melting permafrost

FIRES IN RUSSIA

Fire is a structural ecological process that provides several types of ecosystem services and impacts on socio-ecological systems, including human health, carbon budgets, and climate change. Changes in global fire activity are influenced by multiple factors such as land-cover change, policies, and climatic conditions. Fire also releases large quantities of greenhouse gases into the atmosphere, contributing to a vicious cycle.

During the last two decades, the total land area affected by fires was approximately 41.8 million hectares of which 77% involved forests.

BURNING
41.8 MILLION HECTARES

EMITTING
140.3 TERAGRAMMES OF CARBON PER YEAR

FOREST FIRE EMISSIONS CONTRIBUTED TO 75% OF TOTAL FIRE RELATED EMISSIONS

COSTING
106 MILLION USD IN FIRE SUPPRESSION COSTS ACROSS SIBERIA AND OTHER REGIONS IN 2019 ALONE

FUTURE BURNED AREA

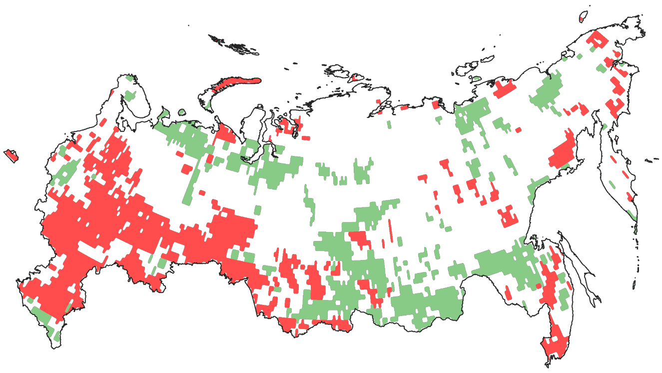
Under a low emissions scenario, models project a general increase in burned area over western areas dominated by temperate broadleaf and boreal forests. This trend might be emphasized under a medium emissions scenario, particularly along the eastern Siberian taiga. A potential decrease in burned area is expected over some southern areas of the Siberian taiga.

Burned Area
km² per year

2050

+969

+580



Decrease in burned areas for a medium low scenario

Increase in burned areas for a low emissions scenario
+ Prolonged fire season, also at the end of the century, especially in central and western regions, as well as increased fire exposure due to weather conditions considered conducive to fires

WHERE DO FIRES OCCUR?

The types of vegetation most affected by fires are the temperate and boreal forests, as well as the southern steppes.

The Asian part of Russia, mainly in its southern half, is the most affected by fires. 2010 was an exception, with catastrophic fires occurring in the central regions of European Russia.

VARIATION OF SPECIFIC FIRE INDICATORS

days
Moderate-to-high fire danger days in western and southern federal districts

2090-2099

+12-17

+6-11

days
Fire-risk days in western Russia and South Siberia

2041-2060

+15-19

Million US$ per year
Cost of forest fire management

2090-2099

+3.4

+2.8

FUTURE FIRE EMISSIONS

Fire emissions follow a similar spatial pattern as burned area. Greater changes are projected over the eastern Siberian taiga under a low emissions scenario and over the European boreal forest under a medium emissions scenario.

Fire Carbon emission
Teragrams of Carbon per year

2050

+75.1

+56.8

RUSSIA
URBAN

OVERVIEW

The rate of Russian urbanisation in 2020 was 74.8%. This is expected to increase to 83% by 2050.

Just two urban areas account for more than 5 million inhabitants: just above 10% of the urban population lives in the Moscow area and a further 5% in the second biggest city, St. Petersburg. The majority of the urban population live in settlements with less than 300,000 inhabitants.

Built up areas cover only 0.32% of Russia (54,082.59 square kilometers).

Population in Urban Areas

2020	107,486,269
2050	110,604,995

Graphs refer to data provided by United Nations, Department of Economic and Social Affairs, Population Division (2018). World Urbanization

Urbanization Rate

2020	74.8%
2050	83.3%

OVERVIEW OF KEY CLIMATE IMPACTS IN URBAN AREAS

The Russian Federation's major cities are vulnerable to heatwaves, and intense rainfall events.

HEATWAVES AND HEAT STRESS

In Russia, extreme temperatures often come with wildfires that impact air quality in urban areas. The 2010 heat wave in the western part of Russia registered daytime temperatures of 40°C and extensive wild fires. The overall death toll was of 55,000 and damages amounted to 400,000 USD.

In Moscow, extremely high temperatures and pollution from the forest fires caused over 10,000 deaths, 40% of which connected to temperatures and the rest caused by the combined effect of air pollution and heat, or air pollution alone. Wildfire smoke exacerbates already high levels of pollution in Russian cities. On average, 91.6% of urban residents are exposed to unsafe air pollution levels above WHO thresholds.

Rising temperatures and increased frequency and intensity of future heatwaves are expected. Summer temperature increases are expected to be higher in southern areas compared to northern ones with an increasing frequency and intensity of heatwaves.

2050 Cooling Degree Days
% of change

+495.0%
+233.0%
+183.0%

2050 Heatwave frequency
% of change

+80.9%
+28.1%
+16.7%

2050 Heatwave duration
% of time

+21%
+5%
+3%

HEAT AND AIR POLLUTION

For Russian cities in the arctic region, impacts on the stability of around 30% to 60% of buildings and infrastructure has ocurred due to changes in permafrost which could reach critical levels by 2040. Under a high emissions scenario, losses from impacts on residential buildings alone are expected to reach 20.7 billion USD by mid century.

During heatwaves, often leading to wildfires, air quality in cities of western Russia is reaching critical values due to smoke. Overall, more than 90% of the Russian population is exposed to pollution levels above WHO thresholds.

2017

Population exposed to air pollution

91.6%

COASTAL FLOODING

In Russia, approximately 1% of the population lives in areas situated below 5 metres from sea level and some cities and urban settlements are exposed to sea level rise and increasing erosion. In 2011 the city of St. Petersburg realized a 25 kilometer system of dams for flood control, which aim to protect the low lying city against frequent catastrophic flooding.

2050

2100

Projected sea level rise

0.23 m

0.18 m

0.77 m

0.38 m

FLOODING

Cities are vulnerable to flooding from intense precipitation events because urban sewage systems are unable to cope with the large amounts of water run-off caused by artificial surfaces. Moscow's urban area is regularly impacted by flooding.

In 2016, after 88 millimetres of rain fell in 24 hours, more than 200 people had to be evacuated. Increasing precipitation and flood events expected over most of the country will impact urban settlements more frequently and with more intensity.

2050

Runoff increase

% of area

+42%

+24%

+12%

SURFACE SEALING AND FLOODS

Heavy precipitation in cities is problematic due to the high level of sealed surfaces. Soil sealing increases run off and reduces the amount of water absorbed by soil. Where there are large amounts of impervious ground cover, short duration extreme rainfall events can lead to increased flooding, even resulting in flash floods.

SOIL SEALING AND FLASH FLOODS

In densely built urban areas, runoff from intense precipitation events will lead to more frequent flash floods due to high rates of soil sealing.

2010

% of urban population

Population living in slums

0%

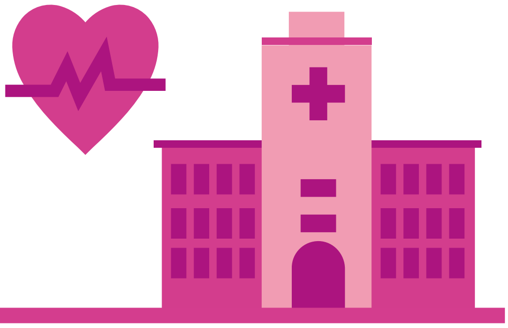
2018

% of total population

Urban population living in areas where elevation is below 5 meters

0.9%

RUSSIA HEALTH



OVERVIEW

Although climate change may bring some warming related benefits to Russia, thermal stress will increase incidences of infectious, respiratory, and cardiovascular diseases in the country. Climate warming and increased numbers of anomalously hot and cold days will affect mortality, especially among the elderly. Climate changes in Russian will also affect the prevalence of infectious diseases and has already increased the incidences of tick-borne diseases. Warming has also improved the habitat conditions for mosquitoes that are carriers of West Nile fever, albeit in small numbers.

HEAT RELATED MORTALITY

Additional mortality from heatwaves in some regions in Russia (e.g., Arkhangelsk) will increase by as much as 80% by 2050 under a high emissions scenario.

In 2018, there was a 15% increase in heat-related deaths compared to the 2000 to 2004 baseline, down from a 31% increase in 2014. Incidences of heatwaves are also increasing in the country, and 11,000 excess deaths from non-accidental causes have been attributed to the 2010 heatwaves.

Heat-related mortality

% change with respect to 2000-2004

IMPACTS ON LABOUR

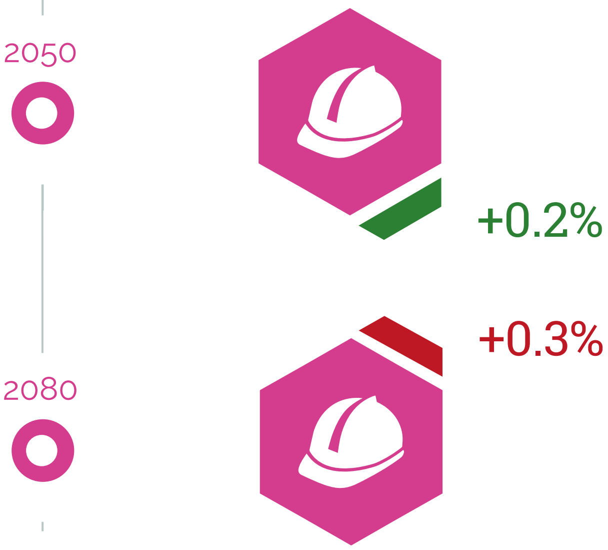
Labour is directly affected by changes in environmental conditions. Warming affects both the number of hours worked (labour supply) and on the productivity of workers during their working hours (labour productivity). Both labour supply and productivity are projected to decrease under future climate change in most parts of the world, and particularly in tropical regions.

Parts of sub-Saharan Africa, south Asia, and southeast Asia are at highest risk under future warming scenarios. Future climate change will reduce global total labour in the low-exposure sectors by 18 percentage points and by24.8 percentage points in the high-exposure sectors under a 3.0°C warming scenario

Russia is one of the few countries projected to make some gains in terms of labour due to future warming. Total labour in Russia is expected to increase slightly due to future climate change: 0.2% under a low emissions scenario and 0.3% under a medium emissions scenario.

Impact on total labour

% change with respect to 1986-2005 baseline



CLIMATE CHANGE AND DENGUE

Dengue has spread throughout the tropical world over the past 60 years and now affects over half the world's population. Globally, vectorial capacity for both dengue vectors (A. aegypti and A. albopictus) has been rising steadily since the 1980s, with nine of the ten highest years occurring since 2000. Climatic stressors are one important driver of the current distribution and incidence of dengue. Climate change is likely to expand the geographical distribution and suitability of several vector-borne human infectious diseases including dengue. The risk of dengue transmission is increased by warming climates, as the growth and development of mosquitoes are significantly influenced by temperature, precipitation, and humidity.

CLIMATE CHANGE AND ZIKA

Zika virus has spread to at least 49 countries and territories since 2013. Climate change impacts on transmission suitability risk have increased over the years and future warming over 1.3 billion additional people could face suitable transmission temperatures for Zika by 2050.

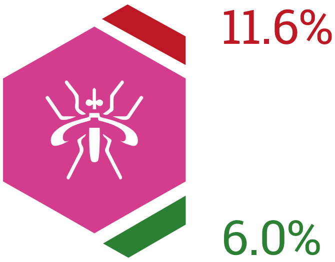
CLIMATE CHANGE AND MALARIA

The distribution and occurrence of malaria is expected to increase due to climate change. This is partially due to both warming and higher parts of the country becoming habitable. 6% of the Russian population will be at risk of malaria under a low emissions scenario in 2050, whereas 11.6% will be at risk under a high emissions scenario.

Malaria suitability

% of population at risk

2050



POLLUTION AND PREMATURE MORTALITY

Under a medium emissions scenario, annual premature deaths due to long-term exposure to near-surface ozone and heat will decrease slightly in Russia from 826 per million in 2010 to 809 per million in 2050.

RUSSIA
ENERGY

ENERGY SYSTEM IN A NUTSHELL

Russia is the largest country in the world, and also home to some of the coldest inhabited places. Russia is very resource-rich (it holds the largest gas reserves). High energy needs for long-distance transport, heating, and industrial use, led to a key role of fossil fuels: oil and gas dominate the energy mix and are Russia's main exports.

The Russian strategy is to maximize the economic value of its fossil fuel endowments, while improving energy efficiency to halve energy intensity by 2030.

0.20
ktoe/US$
Energy intensity

1.5%
AC Share in
electricity consumption

CLIMATE CHANGE TODAY

INCREASING TEMPERATURES

Temperatures have increased by 2°C in 2007-2016 compared to 1990-2000, roughly double the average world increase, resulting in a 15% drop in energy consumption due to lower heating needs. Cooling needs are increasing, particularly in southern regions.

HEATWAVES

Heatwaves hit Russia in 2010 and 2021 resulting in sudden surges in cooling needs. Since 2016, electricity peak demand shifted to summer. About 70% of households in the hottest or most developed regions (Krasnodar Kray, Astrakhan Oblast, and Moscow) installed air conditioning systems.

PERMAFROST THAWING

Permafrost degradation has already threatened infrastructure in 65% of the Russian territory, where 80% of natural gas extraction activities take place.

ENERGY SUPPLY

Russia's energy mix is dominated by fossil fuels (19.5% oil, 54.4% natural gas, 15.7% coal, for a total of 89.6% of total primary energy supply in 2018). Nuclear accounts for 7.1%, and renewables for 3.3%. Electricity generation relies on natural gas (57% of electricity fuel mix in 2018) and coal (19%); renewables and nuclear together hold each an 8% share. Russia is self-sufficient, and a net exporter of energy. In 2020 it ranked as the second largest world producer of natural gas (638 billion cubic metres) and oil (524 million tonnes) after the USA.

ENERGY DEMAND

Energy use is claimed by industry (42.5% of final demand in 2018, including non-energy uses accounting for 15.5% of total demand), residential (29%), transport (19.6%), followed by commercial use (7%) and agriculture and fishing (2%). Air conditioning's contribution to residential electricity demand is negligible (1.5% in 2015), while the one-off heat of 2018 brought it to 34%.

FUTURE ENERGY DEMAND

In Russia, due to the historically rigid climate of most of its territory, climate change may actually result in an improvement in living conditions and in a substantial reduction in energy demand for heating, although the frequency of heatwaves may increase in the future. Overall, heating needs will prevail, leading to an increase of about 1,000 PJ (or 277 million KWh) in 2050 under a medium emissions scenario.

Net change in energy demand due to changes in HDD/CDD
Billion KWh

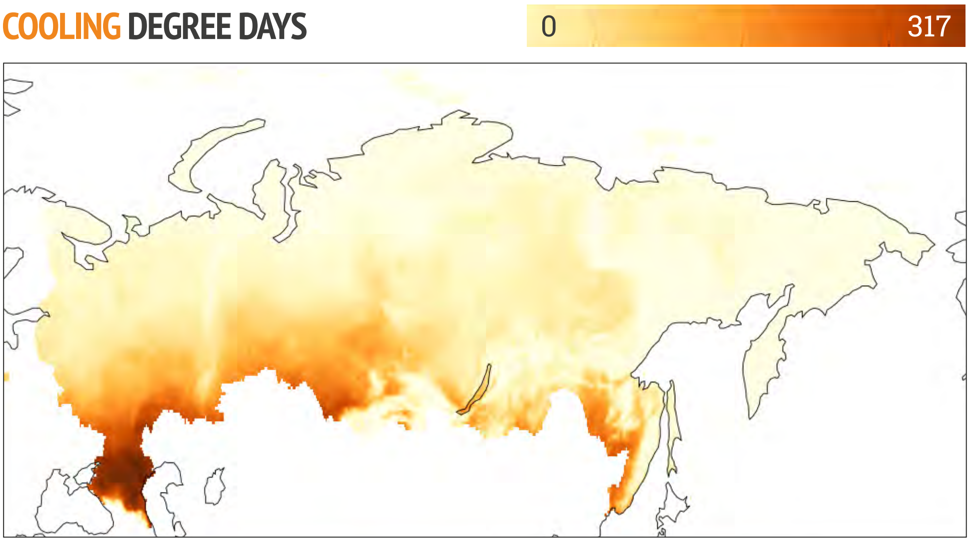
2050

-332.95

COOLING NEEDS

Strong increase in cooling needs in the central–southern areas of the country, particularly between the Black Sea and the Caspian Sea.

COOLING DEGREE DAYS



HEATING NEEDS

Substantial decreases in heating needs are expected all over the country, particularly in the northernmost areas of European Russia and Siberia.

HEATING DEGREE DAYS

FUTURE ENERGY SUPPLY

The future configuration of the Russian energy mix is likely to be determined by the evolution of energy policies and hence is outside the scope of this report. At the time of writing, Russia is focusing on maximizing the economic value of its fossil fuel resources; however it is committing to halving its energy intensity by 2030. Overall, this suggests that there will be no significant change in the nature of the vulnerabilities of the Russian energy sector in the coming decades.

Change in Hydropower generation
% of change

2050

-6.84%

-5.51%

EXPECTED IMPACTS OF CLIMATE CHANGE

Extensive damage to infrastructure from permafrost thawing as well as increasing temperatures and water scarcity may lead to a decrease in the performance of thermal plants resulting in 6 billion KWh of losses by 2050 under a medium emissions scenario. A moderate drop in hydropower potential is also expected. The opening of the Arctic transpolar route may reduce the delivering costs of fossil fuels but the route's economic viability is controversial.

RUSSIA
ECONOMY

OVERVIEW

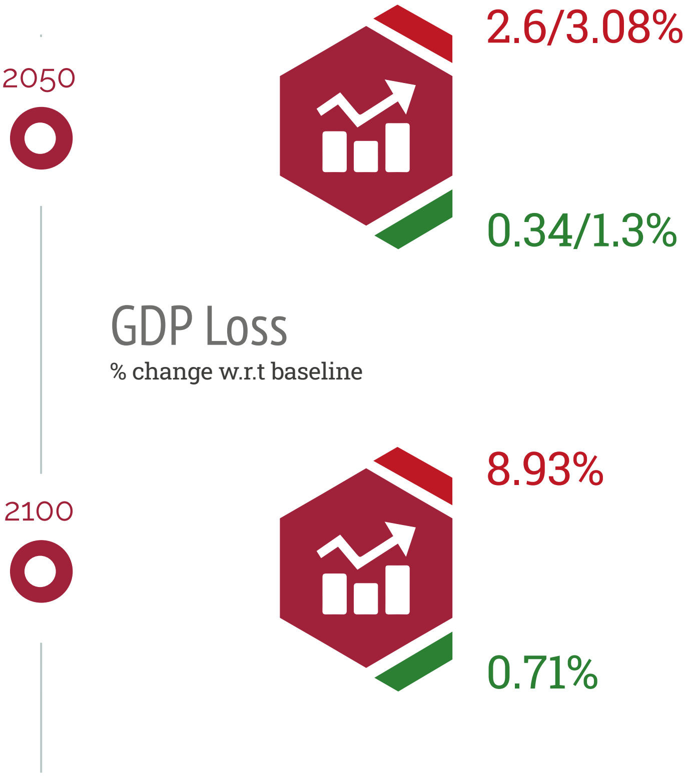
Russia ranks 13th in terms of GDP in the G20 group. The COVID 19 crisis had some impact on the economy where in 2020 real GDP declined by 3.1%. This trend has been reversed, and in 2021 real GDP has grown by 3.8%.

IMPACTS ON GDP

Estimates of the overall economic impact of climate change for Russia vary substantially according to the emissions scenarios considered, the time horizon, the direct impacts covered, and the specificities of the estimation method used.

Some studies foresee noticeable gains from climate change in the next few decades, although all studies agree that gains will turn into losses by the second half of the century.

The projected overall macroeconomic impacts for Russia range from a 6% GDP increase under a low emissions scenario in 2030, to near zero impacts on GDP in 2050, to GDP losses of almost 9% under worst case scenarios such as a high emissions scenario at the end of the century.



GDP Loss

% change w.r.t baseline

SECTORAL ECONOMIC IMPACTS

IMPACTS ON INDUSTRY AND INFRASTRUCTURE

The major cause of concern for Russian infrastructure is the possibility that permafrost, currently present in nearly 65% of the territory of the Russian Federation, will undergo substantial thawing in the coming decades, affecting not only the natural environment, but also any permanent human structures and hence the prospects for human activities in affected areas.

A recent study estimates, under a high emissions scenario in the 2050-2059 period, a decrease in bearing capacity of permafrost of more than 50% over the Russian regions where permafrost is present. This in turn is projected to affect from 6% to 90% of regional infrastructural endowment resulting in economic losses of 87,1 billion EUR, or 1.8% of GDP. 56,1 billion EUR in economic losses are projected by 2050.

Permafrost thawing is likely to threaten the Siberian portion of the Russian railway network, and to damage the Russian road network. It is estimated that in the period 2020-2050 19% of road infrastructure may be at risk with an associated cost ranging from 5 to 10 billion EUR. Extreme weather conditions, in particular strong winds impacting aerial cables, heavy rains, and heatwaves may pose a threat to the whole network. Transport infrastrucutre may also be threatened by sea level rise, in particular in the Sakhalin peninsula and on the Black Sea coasts.

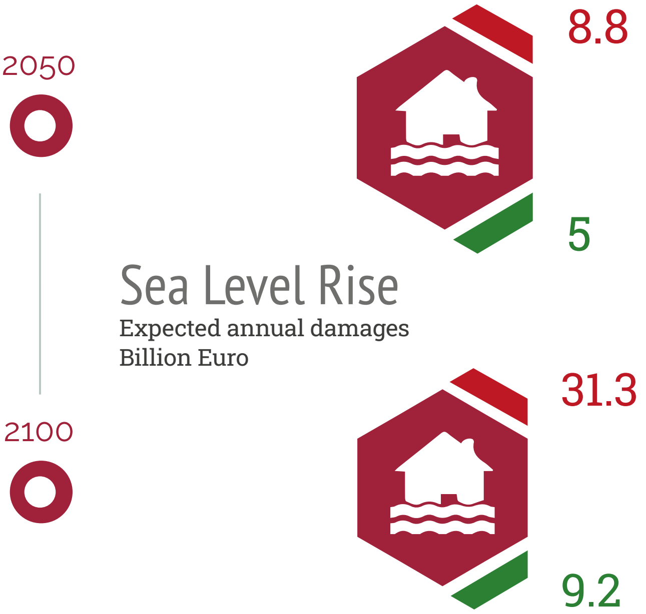
Another major consequence of climate change for transport, could be the opening of naval routes through the Arctic Sea in summer. Despite the inherent uncertainties in modelling ice patterns and dynamics in the Arctic, it appears that all routes, including the transpolar one, may become viable in summer in the second half of the century. However, factors like the riskiness of the route, fuel costs and vessel design seem to suggest that the economic attractiveness of Arctic routes is limited, at least for large container ships, while it could be viable for medium-sized tankers.

IMPACTS ON TOURISM

Before the COVID 19 crisis, Russia ranked 16th as an international destination, with 24.6 million visits in 2018. The direct impact of climate change can increase the attractiveness of Russian destinations, as the traditional harsh cold climate is expected to become milder. Hence, more and more Russian destinations could offer increasingly comfortable climatic conditions for tourist activities for a longer fraction of the year. However, this positive outlook may be dampened or even overturned by the increased incidence of extreme events such as heatwaves and forest fires.

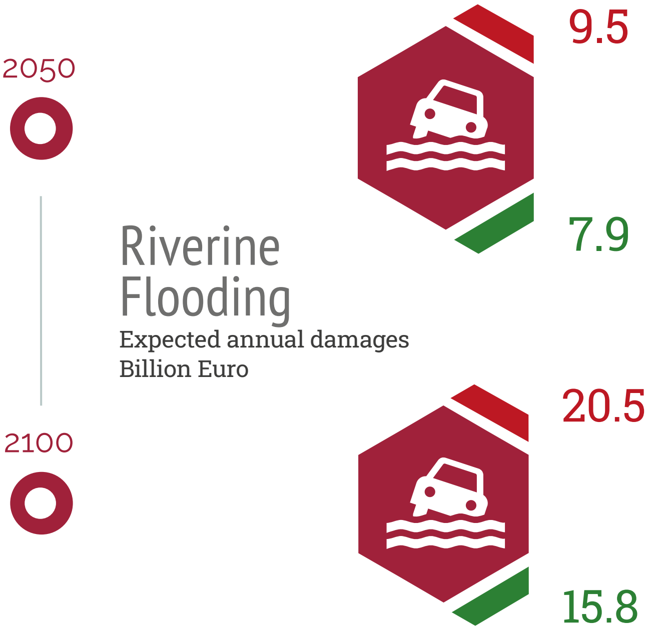
SEA LEVEL RISE DAMAGES

If coastal defenses are not upgraded to contrast increasing climate change risk, expected annual damage to coastal infrastructure is projected to be between 5 and 8.8 billion EUR in 2050 and from 9.2 to 31.3 billion EUR in 2070 under low and high emissions scenarios, respectively.



RIVER FLOODING DAMAGES

Increase in frequency and intensity of extreme weather events can generate relevant economic losses associated to riverine floods. Expected annual damages range from 7.9 to 9.5 billion EUR in 2050 and from 15.8 to 20.5 billion EUR in 2070 under low and high emissions scenarios, respectively.



IMPACTS ON AGRICULTURE

Russia is the largest country in the world with over 17 million square kilometres. It features a great variety of climates, ecosystems, crops and agricultural and silvicultural districts. Consequently, the expected impact of climate change can vary considerably across its territory.

Some studies suggest that the climate of the northern parts of Russia may become more favourable to crop production, particularly in the earlier decades of this century and under moderate climate change scenarios.

Nonetheless, the overall outlook by the end of the century for the whole country entails projected losses overtaking gains, leading to an aggregate decrease in production for higher temperature increases. For instance, wheat yields could increase by 6.7% by 2050 and 2.6% by 2100 under a low emissions scenario; however, under medium and high emissions scenarios, yield is expected to drop by 18%, 8% and 26% by mid century and by 31%, 26% and 55.4% by the end of the century, respectivley.

IMPACTS ON ENERGY

As with all other economic sectors, energy supply and energy networks in Russia will undergo more intense stress from climate-related factors, in particular permafrost thawing, floods and forest fires.

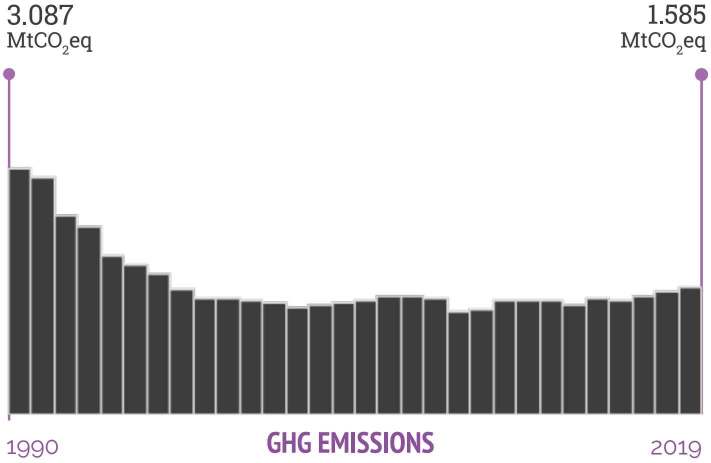
Economic impacts of shifts in household and firm energy demand (see chapter on energy) are difficult to predict and will mostly lead to redistribution effects. In the case of Russia, the magnitude of the increase in demand for cooling is much lower than the decrease in heating demand, hence significant savings on energy bills may result.

There is a lack of specific, comprehensive projections of the economic costs of all relevant climate change impacts on the Russian energy supply infrastructure. However the above-mentioned studies on the economic consequences of permafrost thawing provide an upper bound of damages to energy infrastructure, which are in any case the most relevant ones in the affected areas.

RUSSIA
POLICY

OVERVIEW

Russia is the world's largest country, with a population density of 8.4 people per square kilometre. It accounts for 5.5% of global emissions and has a high rate of GHG emissions per capita.



GHG EMISSIONS

INTERNATIONAL COMMITMENTS

The Russian Federation submitted its 2020 NDC pledging to limit GHG emissions to 70% relative to 1990 levels by 2030, or an emissions reduction target of 30%, taking into account the maximum possible absorptive capacity of forests.

CLIMATE POLICY COMMITMENTS CHRONOLOGY

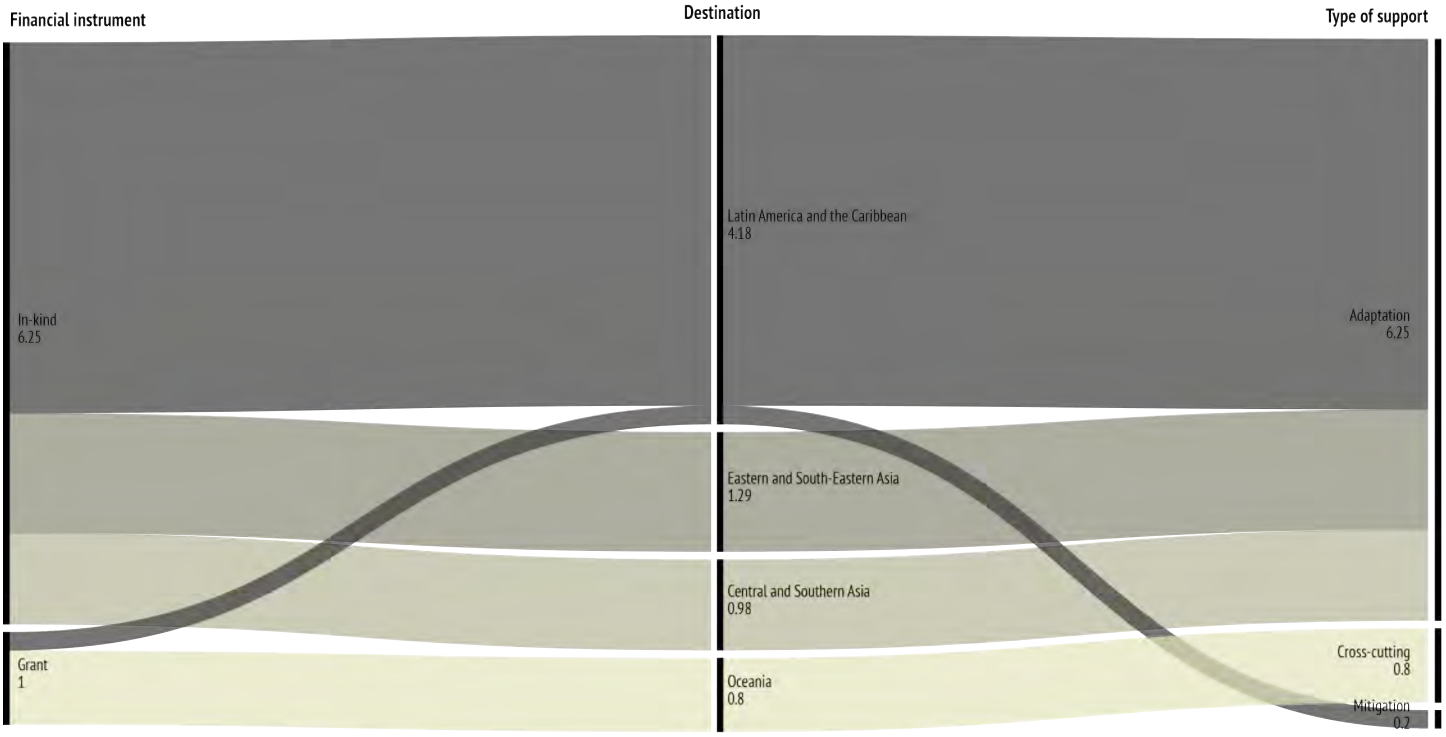
2002 **Kyoto Protocol - 1st period**
No increase in GHG over the four year period 2008-2012, with respect to 1990 levels

2015 **Paris Agreement - 1st NDC**
25%-30% GHG reduction by 2030, with respect to 1990 levels

2020 **Paris Agreement - NDC update**
30% GHG reduction by 2030, with respect to 1990 levels

INTERNATIONAL CLIMATE FINANCE ASSISTANCE

In the 4th Biennial Report, Russia reported 7 million USD for climate action in 2017-2018. The majority of these funds are in-kind contribution for climate-related disaster early response. Latin America and Central/Southern Asia are the main areas of operation.



SUSTAINABLE RECOVERY POLICY

According to the Global Recovery Observatory, there was no green spending out of total recovery spending in 2020.

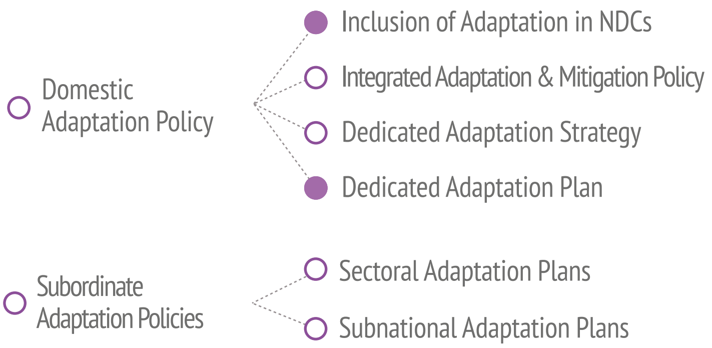
40.76
billion $
Total Spending

0.77
billion $
Recovery Spending

0
billion $
Green Spending

DOMESTIC ADAPTATION POLICY

In 2019 the Russian government approved a National Adaptation Plan for Climate Change which includes a first set of economic and social measures to be implemented by federal and regional authorities.



- ○ Domestic Adaptation Policy
  - ● Inclusion of Adaptation in NDCs
  - ○ Integrated Adaptation & Mitigation Policy
  - ○ Dedicated Adaptation Strategy
  - ● Dedicated Adaptation Plan
- ○ Subordinate Adaptation Policies
  - ○ Sectoral Adaptation Plans
  - ○ Subnational Adaptation Plans

○ Policy not in place ● Active policy

ADAPTATION POLICY HIGHLIGHTS

TRANSNATIONAL INITIATIVES

Climate Box

For five years UNDP has been working with young people in Eastern Europe and Central Asia to educate and empower them to take climate action

Northwest Pacific Region Action Plan (NOWPAP)

NOWPAP's main goal is to protect and sustainably manage the coastal and marine environment in the Northwest Pacific between Russia, China, Japan and South Korea

NATIONAL INITIATIVES

National Action Plan

The plan defines socio-economic measures for sub-national authorities to reduce the vulnerability of the population, the economy and natural sites to the impacts of climate change, and the seizing of the opportunities arising from such changes

National project ECOLOGY

ECOLOGY aims at restoring and protecting natural environments. In particular, the project allocates $ 2.11 billion in 2019-2024 for the preservation and restauration of forests as a way to adapt to climate change adverse effects

SUBNATIONAL INITIATIVES

Integrated Climate Change Strategies for Sustainable Development of the Russian Arctic Regions

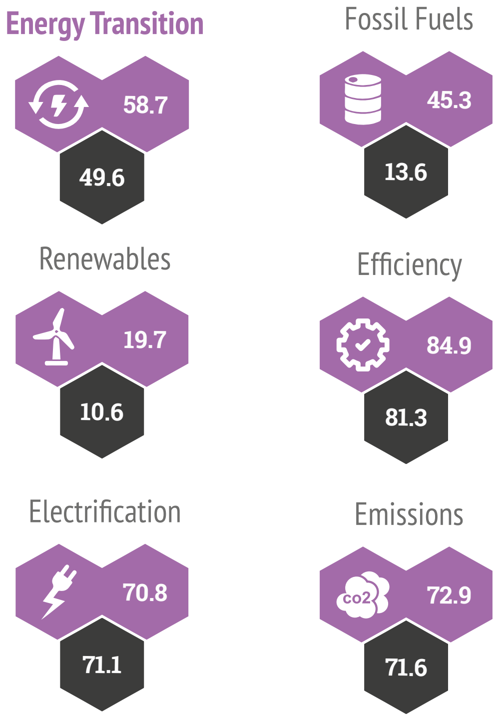
The project assessed climate impacts in Murmansk oblast and provided recommendations to decision-makers, businesses, and the broad public

St. Petersburg's Action Plan for Climate Change Adaptation

The Plan develops a set of adaptation measures and integrates climate risks into the existing risk prevention system to protect St. Petersburg's area against dangerous weather and climate events

ENERGY TRANSITION

Russia's status as a major global oil and gas producer affects the Energy Transition performance of the country, which has not yet undertaken a structured process of transformation of its energy sector, as demonstrated by its position at the bottom of the Energy Transition indicator. In particular, this position is mainly due to poor performance in the Fossil Fuels domain, not only determined by the huge reserves available in the country, but also by the huge value of fossil subsidies in terms of GDP, as well as by their great contribution to the overall energy mix. This fact is confirmed by poor performances in the Renewables domain, a sector in which the country is moving its first steps towards greater penetration of wind power. When it comes to Emissions and Efficiency, Russia appears in the lowest part of the ranking, but it is quite close to the average of the G20 countries, while looking at the Electrification composite. Overall the country occupies a central part in the ranking, slightly above the G20 average.



Only actively pursuing an energy transition based on decarbonization and electrification – from policy and regulation, to health and education – will enable countries to benefit the most from future opportunities and fight climate change whilst ensuring an equitable distribution of wealth.

The Energy Transition indicators were developed by Enel Foundation in cooperation with SACE, and provide a retrospective analysis based on historical data.

G20 CLIMATE RISK ATLAS

Impacts, policy, economics

SAUDI ARABIA

How to read the Atlas: graphs, colours and scenarios.

The maps used in this Atlas are taken from **The World Bank Official Boundaries** - ***https://datacatalog.worldbank.org/search/dataset/0038272*** (accessed on May 28, 2021). For the section Energy, the maps are based on Panoply Data Viewer ***https://www.giss.nasa.gov/tools/panoply/credits.html***

Each sector of this Atlas contains data and information on various climate scenarios.

When reported in graphs, the **colour black** indicates data and information referring to the current state, the past or the baseline.

When the authors refer to **RCP (Representative Concentration Pathways)**, the 3 colours used across the factsheet refer to 3 scenarios, which are 3 different development options with different levels of greenhouse gas emissions, **respectively low emissions (green), medium emissions (orange), and high emissions (red)**. The same colour code is used when RCPs are associated with Shared Socioeconomic Pathways (SSP).

In some cases, the authors refer to global warming scenarios. In these cases, the 3 colours used refer to a temperature rise of **1.5°C (green), 2°C (dark green), and 4°C (red)**.

When the authors refer exclusively to **Shared Socioeconomic Pathways - SSPs** (Population affected by river floods in the section: “Water"), data related to **SSP3** - that encompasses, among other things, slow economic growth, material-intensive consumption, and persisting or worsening inequalities – **are reported in a lighter shade**; **SSP5** – which refers to social and economic development that is coupled with an energy-intensive lifestyle and the abundant exploitation of fossil fuel resources – is shown using a **middle shade of the colour**, whereas data related to **the present** conditions **are represented in a dark shade**.

Further details on scenarios, methodologies, and the full list of references are available at: **www.g20climaterisks.org**

Concept and graphic design by element6.eu

SAUDI ARABIA CLIMATE

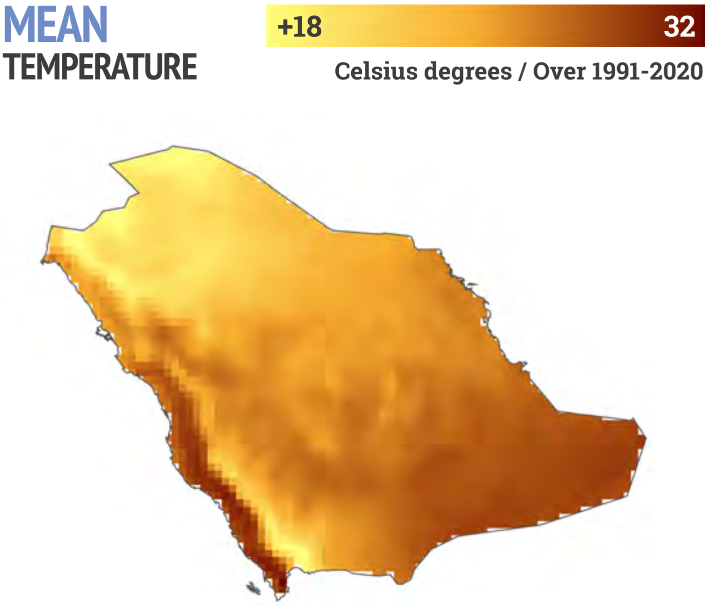
OVERVIEW

Saudi Arabia presents a predominantely desert climate which is extremely hot during the day and then drops in temperature at night. Exceptions include the province of Asir on the western coast, which features a semi-arid climate, and the highlands just north of Yemen, which are characterised by a small area of humid and mild temperature conditions with long summers. These variations are mainly related to the influence of a subtropical high-pressure system.

TEMPERATURE

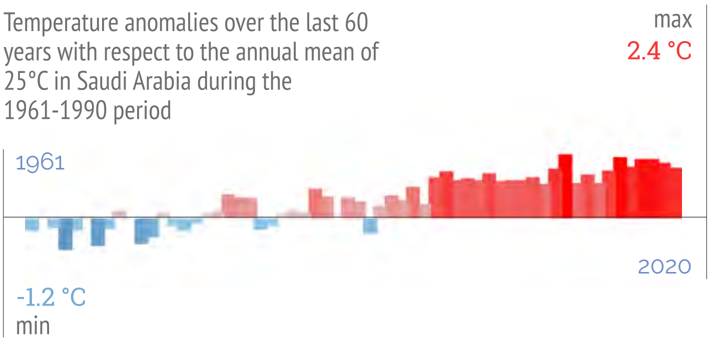
The temperature regime in Saudi Arabia is quite homogeneous with values typical of the desert climate (above 18°C) across the country. The warmest areas are found on the western coast. Summers are very hot throughout the country.

MEAN TEMPERATURE



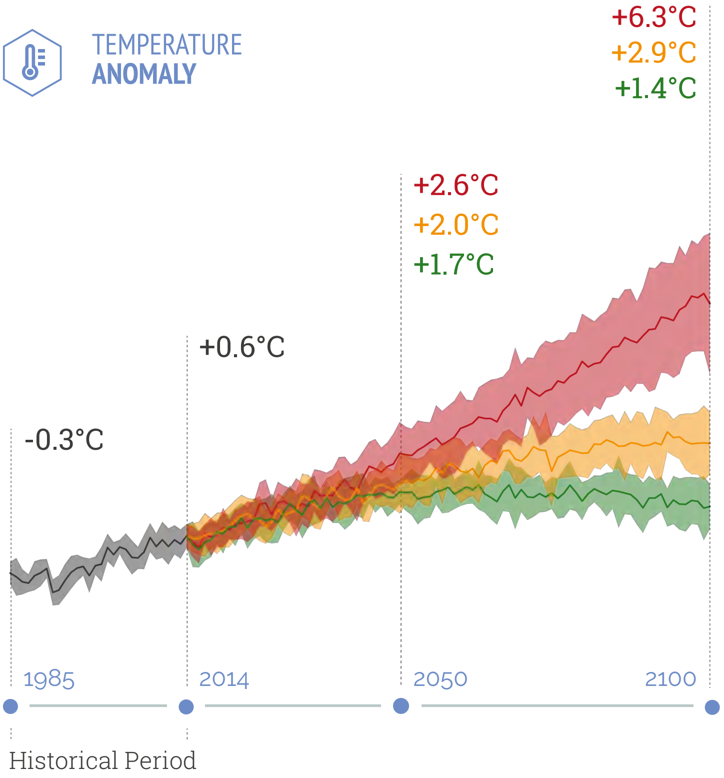
TEMPERATURE TREND

Temperature anomalies over the last 60 years with respect to the annual mean of 25°C in Saudi Arabia during the 1961-1990 period



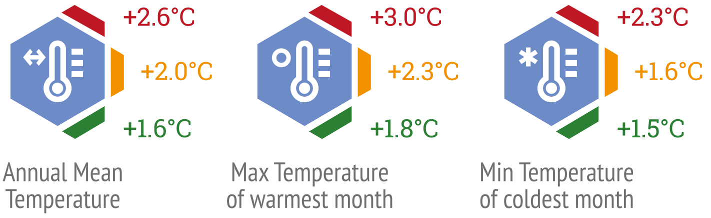
TEMPERATURE PROJECTIONS

Under a low emissions scenario projected temperature variations will remain contained under 2°C, both by 2050 and 2100.
Under a high emissions scenario, with no reduction in GHG emissions, much greater temperature anomalies are expected by both 2050 and 2100.



EXPECTED VARIATION FOR TEMPERATURE AT 2050

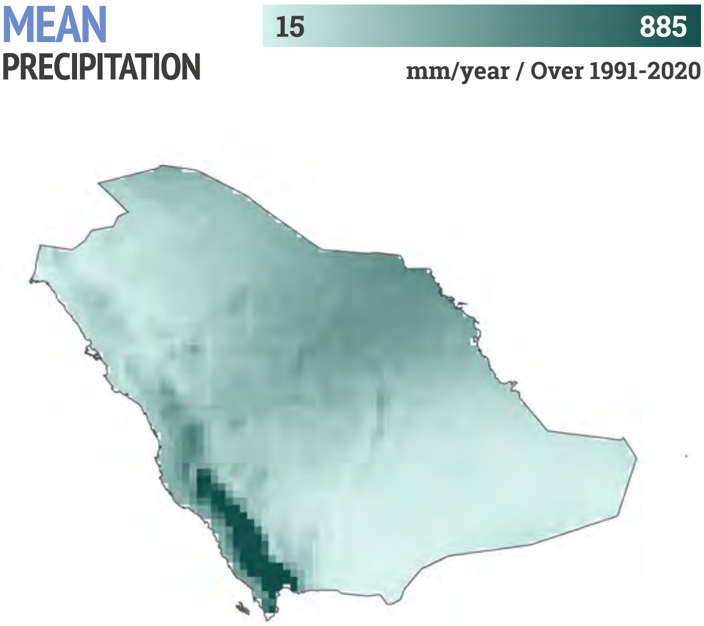
The indicators show variations in selected temperature characteristics for a thirty-year period centred on 2050 (2036-2065) with respect to the reference period 1985-2014.



PRECIPITATION

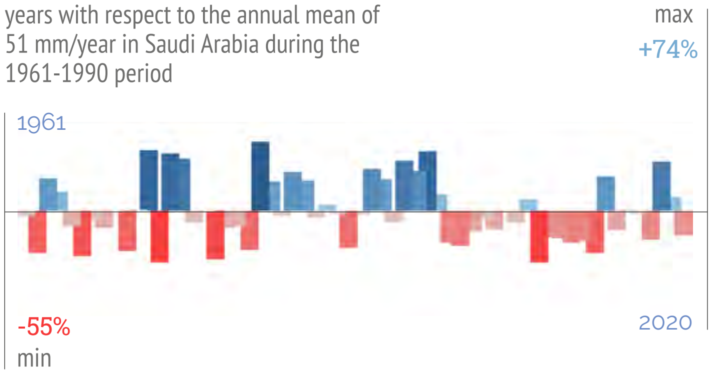
Saudi Arabia sees little rainfall throughout the country.
However, some weather systems move southward along the Red Sea trough and provide winter precipitation as far south as Mecca and even Yemen. In this specific area, precipitation reaches up to 200 to 250 millimetres per year.
Recently, some cities experienced flooding events which were exacerbated by the country's ongoing urbanization.

MEAN PRECIPITATION



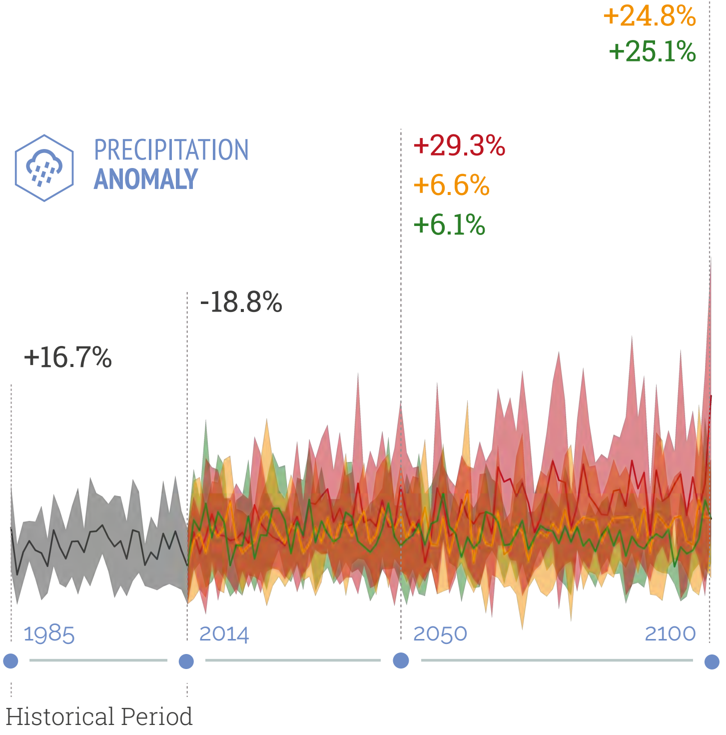
PRECIPITATION TREND

Precipiation anomalies over the last 60 years with respect to the annual mean of 51 mm/year in Saudi Arabia during the 1961-1990 period



PRECIPITATION PROJECTIONS

Precipitation trends show a significant variability also due to the scarce amount of precipitation. The trend is expected to increase and in some cases by more than 70-80% under a high emissions scenario.


PRECIPITATION ANOMALY

EXPECTED VARIATION FOR PRECIPITATION AT 2050

The indicators show variations in selected precipitation characteristics for a thirty-year period centred on 2050 (2036-2065) with respect to the reference period 1985-2014.

+28.3%
+15.9%
+13.6%
Annual total precipitation

+30.0%
+16.1%
+12.5%
Precipitation of wettest month

+43.5%
+16.2%
+29.2%
Precipitation of warmest quarter

VARIATION OF SPECIFIC CLIMATE INDICATORS

Climate indicators variation showing impacts of climate change on sectors such as agriculture, health and water. Analysis considers 3 threshold average temperature increase: **+1.5°C**, **+2°C**, **+4°C**.

+37%
+23%
+18%
Agricultural drought proportion of time
% of time

+20%
+14%
+11%
Hydrological drought proportion of time
% of time

+4,242%
+774%
+284%
Heatwave duration
% of time

+27%
+13%
+5%
Runoff increase
% of area

+88%
+58%
+33%
Agricultural drought frequency
% of change

+11%
+9%
+18%
Hydrological drought frequency
% of change

+100%
+69%
+41%
Heatwave frequency
% of change

+9%
+2%
+1%
Runoff decrease
% of area

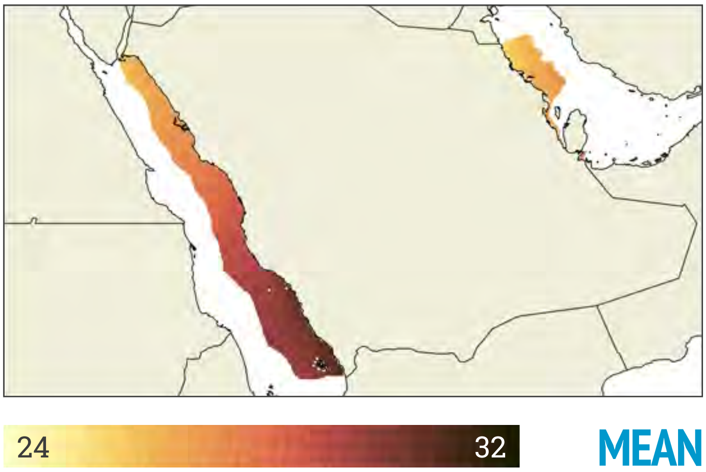
SAUDI ARABIA
OCEAN

OCEAN IN SAUDI ARABIA

Saudi Arabia's marine exclusive economic zone (EEZ) is mainly subtropical with warm water temperatures and a wide ensemble of ecosystems such as mangrove swamps, seagrass beds, and coral reefs. The country's coastal systems are naturally divided into two areas: the Persian Gulf and the Red Sea.

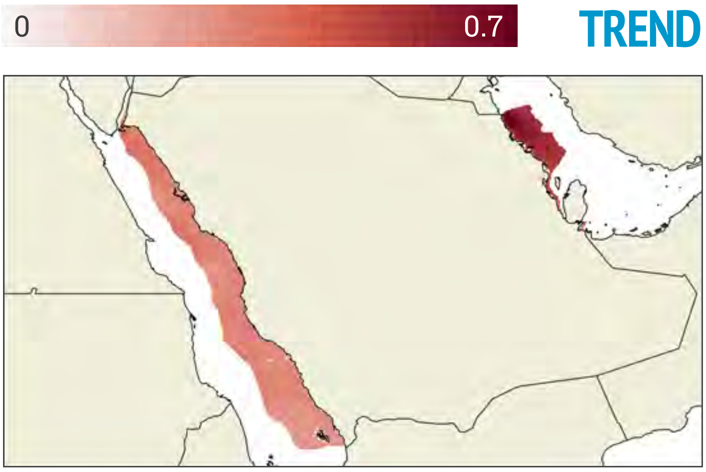
CURRENT CLIMATE CONDITIONS

Mean sea surface temperature reflects the Tropical climate regime, with sigthly colder water in the northern areas.



SEA SURFACE TEMPERATURE

Celsius degrees / Over 1991-2020

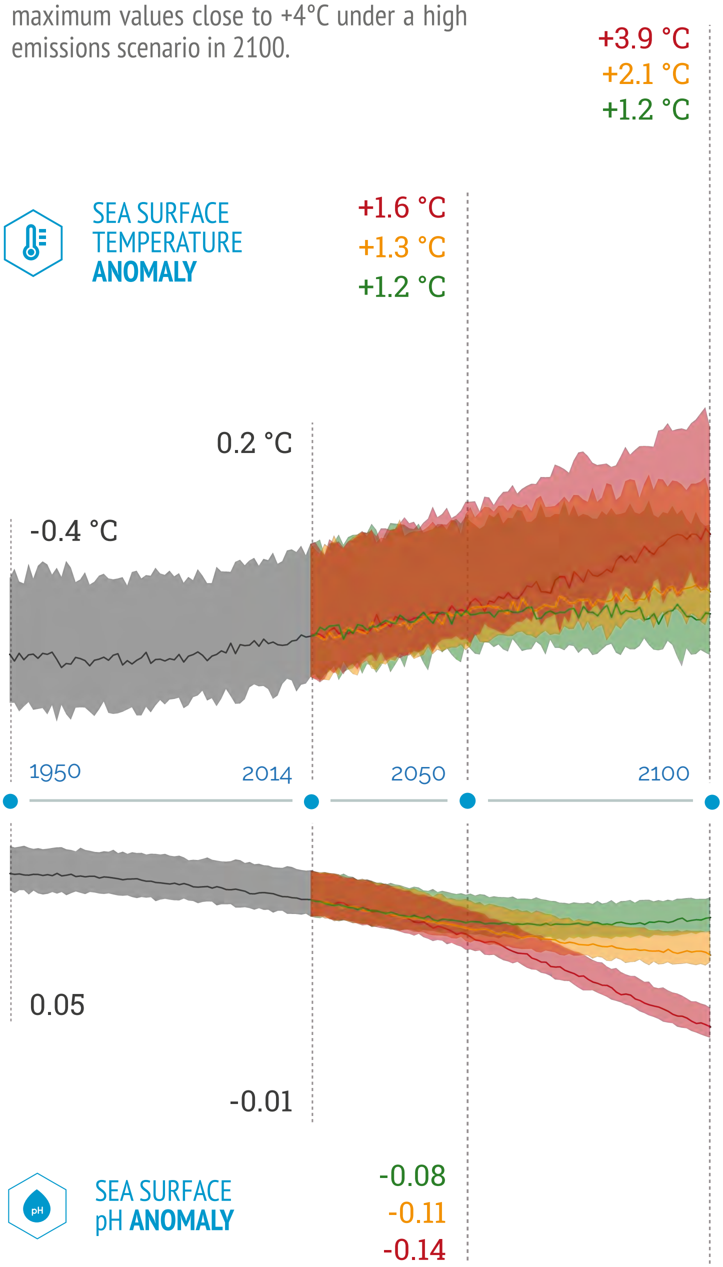


Surface temperature trends indicate a general warming of 0.3°C per decade in the Persian Gulf , with increased gains up to 0.5°C per decade in the Red Sea.

FUTURE PROJECTIONS

Projected annual changes within the marine EEZ for the two most significant marine indicators of climate change: sea surface water temperatures and pH.

Seawater temperature changes are in line with the definitions of each scenario, with maximum values close to +4°C under a high emissions scenario in 2100.



Seawater surface pH becomes more acidic in all scenarios, closely reflecting rising atmospheric CO_2 concentrations, and only a low emissions scenario leads to a stable condition by 2100.

-0.08
-0.17
-0.34

ECOSYSTEM INDICATORS AT 2050

Regional changes in key marine ecosystem indicators under projected future scenarios by mid-century (2036-2065) with respect to present climate conditions (1985-2014).

Temperature regulates the metabolism of marine organisms determining which habitats remain suitable. Excessive warming will likely push ecosystems beyond tolerance thresholds.

pH represents the acid/base status of marine waters, where a decreasing pH reflects the acidification of the ocean due to increased absorption of atmospheric CO_2.

Oxygen is fundamental to sustain marine life and its reduction can have a large impact on coastal ecosystem services including fisheries and aquaculture.

Chlorophyll is an indicator of the biomass available at the base of the marine food web supporting all ecosystem productivity.

	Persian Gulf				Red Sea			
Temperature	24.64°C	+2.15 °C	+1.73 °C	+1.66 °C	27.69°C	+1.48 °C	+1.18 °C	+1.08 °C
pH	8.13	-0.15	-0.11	-0.09	8.07	-0.14	-0.11	-0.08
Oxygen	208.22 mmol/m^3	-3.97 %	-3.08 %	-2.43 %	200.79 mmol/m^3	-2.82 %	-2.23 %	-1.59 %
Chlorophyll	0.13 mg/m^3	-3.1 %	-15.5 %	+59.69 %	0.12 mg/m^3	-0.83 %	-5 %	-7.5 %

FISH CATCH POTENTIAL

Fish catch potential is an estimate of the maximum fish catch achievable given the marine resources available over a sustained period. It is linked to the concept of maximum sustainable yield, meaning the maximum amount of fish that can be extracted from a system without causing a collapse in fish populations.

It is a characteristic of the natural system, which is substantially different from realized catch, and a direct result of the fishery policy in place.

While no specific data is available for the Saudi Arabian EEZ, a decrease in potential catch between 20 and 30% for the Red Sea and between 10 and 20% for the Arabian Sea at mid century have been projected under high emissions scenarios.

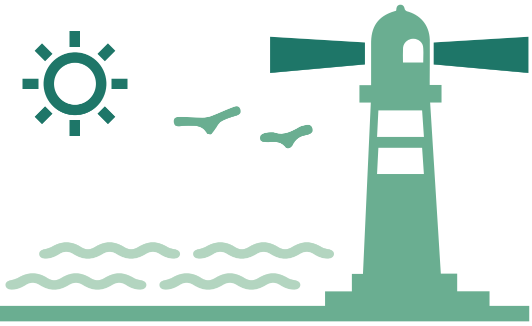
ANALYSIS DETAILS

All datasets were analysed using only data from within the marine EEZ and therefore excluding overseas territories, detached islands and any disputed or joint territories with other nations. In the assessment of current climate conditions, seawater surface tempererature data was obtained using satellite observations distributed in the framework of ESA Climate Change Initiative.

Future projections of marine indicators are represented by the combined analysis of results from 15 different Earth System models participating in the Coupled Model Intercomparison Project Phase 6 (CMIP6). These models include new and better representations of physical and biogeochemical processes, compared to previous IPCC assessment reports.

Fish catch potential data was obtained using the FAO's technical report and refers to the best and worst case climate scenarios from the Fifth IPCC Assessment Report. These mean estimates are subject to substantial uncertainties as discussed in the original work.

SAUDI ARABIA
COASTS



OVERVIEW

Saudi Arabia is the largest country of the Arabian Peninsula, with a shoreline running approximately 1,760 kilometres along the Red Sea and 560 kilometres along the Arabian Gulf, with over 1,000 islands, and more than 7,000 kilometres of shoreline. Most of the shoreline is bordered by the Arabian Desert, or mountains on the southern part of the Red Sea coast and combines sandy beaches and rocky shores, with lower coastal plains prevalent in the coastal region of the Persian Gulf. Large parts of the Red Sea and some parts of the Persian Gulf coast are bordered by coral reefs, and, to a lesser extent, mangroves. Most of the coastal population is concentrated in the cities of Jeddah and the Dammam metropolitan area.

Shoreline Length 7,352 km

Sandy Coast Retreat at 2050 -66.2 m

CLIMATE CHANGE HAZARDS

Coastal hazards such as erosion, storm tide inundation and permanent flooding, can have strong adverse impacts on coastal regions, with loss of sandy shores, damage to settlements, infrastructure and ecosystems. Climate change can exacerbate these impacts due to rising sea levels and increasing impacts of waves and storms. Climate change impacts on the coastal zone of Saudi Arabia are mainly driven by rising sea levels and possible changes in storms intensity and direction affecting the Red Sea and the Persian Gulf. Possible impacts of sea level rise may include salt water intrusion into low lying areas and aquifers, erosion of sandy shorelines and possible inundation of low lying areas, in particular around the Persian Gulf region, characterized by lower coastal sedimentary plains compared to the Red Sea coast. In particular, the urban areas around Damillimetresam are likely to experience the impact of sea level rise.

SEA LEVEL RISE

Relative sea level rise in Saudi Arabia has been observed over the past century with a yearly average increase of 3.74 millimetres per year. More specifically, the Red Sea area has seen a rise of approximately 3.88 millimetres per year, whereas in the Persian Gulf it has been of 3.6 millimetres per year. The latest IPCC projections indicate that, by 2050, global sea levels may rise between 0.18 metres, under a low emissions scenario, and 0.23 metres, under a high emissions scenario.

EXTREME SEA LEVEL

On average, one in 100 extreme sea level events are expected to rise from 0.87 metres at present day to 1.07 metres by 2050 under a medium emissions scenario.

Observed and projected sea level rise at 2050

3.74 mm/year

0.23 m

0.18 m

Current and projected extreme sea level at 2050

0.87 m

1.15 m

1.07 m

OBSERVED STORMS

In the northern part of the Red Sea, wind and waves of the same intensity are present throughout the year, whereas the central and southern zones are characterized by a marked seasonality. In general, a decrease in wave energy has been observed in the southern part of the Red Sea, whereas there is uncertainty regarding changes in the central and northern areas. The Persian Gulf wave climate is mainly driven by winds from the north and north-east quadrant, with relatively low variability in the past decades.

FUTURE STORMS

In both the Red Sea and the Persian Gulf, changes in the weather and wind forces may alter the wave climate. In the Persian Gulf, it appears that under a range of climate change scenarios changes in the wave climate will be of low significance, with a decrease of approximately 9.5% by 2100 under a high emissions scenario. On the other hand, the Red Sea is expected to see an increase in wave height by 2100 under the same scenario. It is also clear that rising sea levels will cause an increase in the frequency of extreme sea level events.

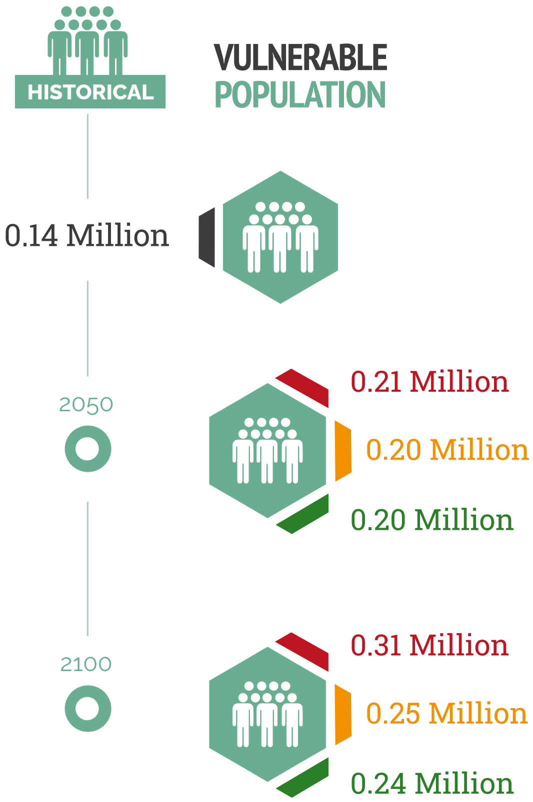
VULNERABILITY AND RISK

Both the Red Sea and Arabian Gulf coast of Saudi Arabia may be impacted by increasing hazards driven by climate change. In the Red Sea, the shoreline is mostly resistant to erosion and inundation by seawater due to its inherent hard nature and the relatively high relief.

However, increasing urbanization may create problems unless new development integrates climate adaptation standards. For example, large parts of Jeddah may suffer from the impacts of sea level rise, including erosion and saltwater intrusion.

The most densely populated area of Saudi Arabia is found along the coast of the Arabian Gulf, with abundant industrial, residential and commercial buildings, and infrastructure situated on lower coastal areas.

Estimates indicate that a 1 metre sea level rise may affect approximately 650 square kilometres of land. Under a medium emissions scenario, the population exposed to the annual coastal flood level is expected to increase from 140,000 to 200,000 by 2050.



VULNERABLE POPULATION

HISTORICAL

0.14 Million

2050

0.21 Million

0.20 Million

0.20 Million

2100

0.31 Million

0.25 Million

0.24 Million

INFLUENCE OF SEA LEVEL RISE ON EXTREME SEA LEVEL

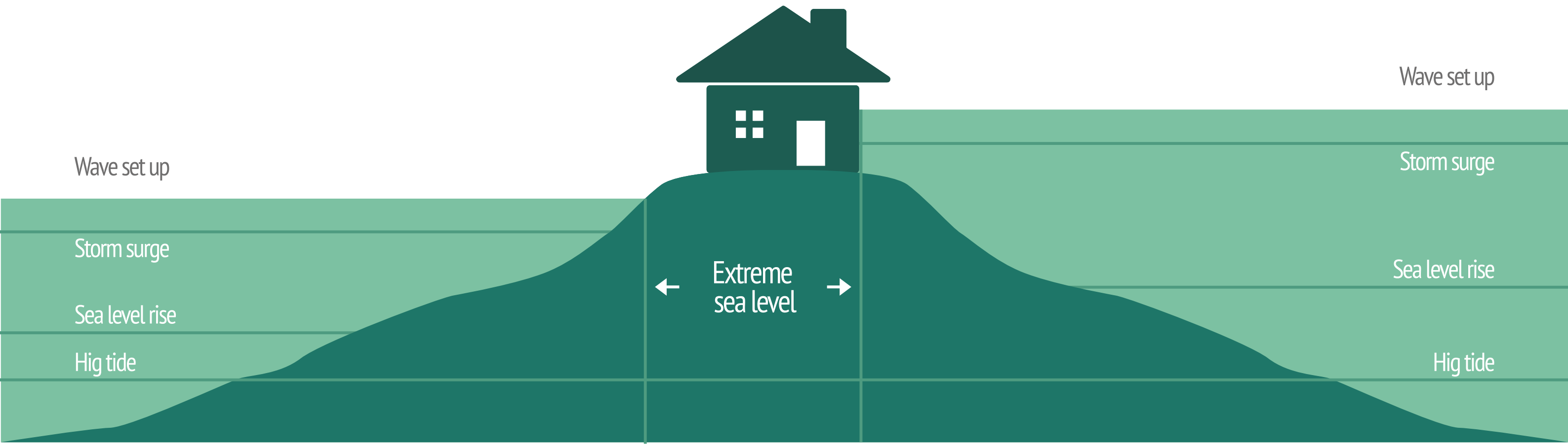
Present and future sea level rise are a consequence of carbon induced global warming causing melting ice and ocean expansion due to heat accumulation.

The extreme sea levels reported here are based on the 100-year storm surge + wave set up + sea level rise + high tide indicators. The first two parameters (storm surge + wave set up) are based on the 100-year value for the event; sea level rise is its projected value at 2050; and high tide is the absolute value of the highest tide calculated for a given locality, which won't be influenced by climate change.

+ Wave set up refers to the accumulation of water near the shore due to the presence of breaking waves.

+ Storm surge is an occasional increase in sea level driven by shoreward wind-driven water circulation and atmospheric pressure.

+ High tide is usually the highest tide reached in a given location based on tide records.



Present sea levels have risen globally by approximately 20 centimetres over the past century.

Future sea level rise is a projection based on different global warming scenarios, at approximately 100 centimetres by the end of 2100, with consequent inundation during extreme sea level events.

SAUDI ARABIA
WATER

OVERVIEW

With limited rainfall throughout the year, water resources in Saudi Arabia are relatively scarce. Water supply is distributed between seawater desalination (50% of drinking water supplies), mining of non-renewable groundwater (40%), and surface water from the mountainous southwest of the country (10%).

Although Saudi Arabia does not have any permanent rivers, it does have numerous wadis (valleys) which are riverbeds that occasionally channel flood waters. Most of the historic aquifers have dried up.

Saudi Arabia stores approximately 150 million cubic metres of water in more than 200 dams found in the Wadi Bisha, Wadi Jizan, Wadi Fatima, and Najran among others.

Renewable internal freshwater resources 2 billion m³

Renewable internal freshwater resources per capita 73 m³

Saudi Arabia's total internal renewable water is estimated to be 2.4 billion cubic metres per year. The water demand in 2009 was 18.51 billion cubic metres, of which 83.5% was used for agriculture. From 2004 to 2009, agricultural water demand decreased by 2.5% per year, and domestic and industrial water demand increased by 2.1% and 2.2% per year. Between 1999 and 2008, domestic water subscribers increased by 22.7%, whereas annual domestic water consumption tripled. Industrial water demands also increased, going from 56 to 713 million cubic metres per year between 1980 and 2009.

CLIMATE CHANGE HAZARDS

Climate change is an important factor for sustainable water resource management in arid and semi-arid countries, and it can affect water resources due to rising temperatures, higher rates of evapotranspiration and altered rainfall patterns. This leads to changes in the water cycle, alterations of surface runoff and groundwater storage, as well as drought and flood occurrence.

The demand for water resources has been increasing in Saudi Arabia in recent decades due to a large population increase, from approximately 5 million in the early 1970s to almost 35 million at present day. This is the main water risk driver, which, coupled with future climate change, can challenge the sustainability of water resources use in the country.

KEY POINT RUNOFF

The source of surface water in Saudi Arabia is seasonal precipitation. The largest quantity of runoff occurs in the western region, which represents approximately 60% of total runoff, although it covers only 10% of the total area of the country. The remaining 40% of runoff occurs in the far south of the western coast covering 2% of the total area. The total runoff in Sudi Arabia is estimated ar 2.2 billion cubic metres per year, most of which infiltrates to recharge the shallow aquifers located along the river valleys and beneath the alluvial fans and plains in various areas.

Changes in runoff may also be influenced by the increasing urbanization and population in the country, with a strong linear correlation between the level of urbanization and both peak discharge and runoff volume. According to modelled projections, an increase in temperature by 1°C and 5°C may reduce surface runoff by 115-184 million cubic metres and 600-960 million cubic metres per year respectively. If temperatures rise by 1.5°C, 2°C or 4°C, 1%, 2.1% or 9% of the area of the country will likely experience an increase in runoff, while 5%, 12.7% or 27% of the surface of the country will likely experience a decrease in runoff, respectively.

2050

Changes in annual runoff
% of change

-42.0%

-6.0%

2050

Runoff increase
% of area

+9.0%

+1.0%

KEY POINT DROUGHTS

Drought events in Saudi Arabia occur mostly due to a deficit of rainfall in the dry season (June to September). The past decades have been influenced by climate change, with annual rainfall below normal for 25 years out of 40, with severe droughts occurring 28% of the years between 1978 and 2017.

Climate change will affect rainfall and consequently droughts in Saudi Arabia. It is estimated that rainfall in the northern part of the country will decrease by an average of 10 millimetres per year, exacerbating the existing drought conditions. In contrast, precipitation in the central and southern regions may increase by 2050. Despite increased rainfall in some areas, evapotranspiration is also expected to increase during this same time, and less than half of the water lost to evapotranspiration will be replenished by rainfall, leaving surface water resources still limited.

2050

Severe drought likelihood increase

% of change

+49.0%

+27.7%

2050

Hydrological drought frequency

% of change

+11.0%

+9.0%

2050

Groundwater Recharge

% of change

-29.3%

+21.4%

KEY POINT GROUNDWATER

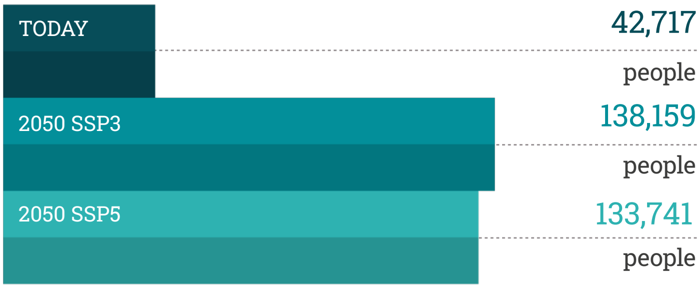
Non-renewable groundwater reserves in Saudi Arabia are estimated to be 259.1-760.6 billion cubic meters with an effective annual recharge of 886 million cubic meters. 80% of water supply demand is met through groundwater. In the past three decades, groundwater exploitation in Saudi Arabia has increased, reaching 17 billion cubic metres per year. The net annual groundwater recharge is very low compared to the rate of withdrawal, with the declining groundwater levels also impacting water quality. Global warming will affect rainfall and temperature, which can have effects on groundwater reserves. In the near future, there will be less groundwater in Saudi Arabia due to the impact of climate change and the increase in annual temperature. For example, by 2050 under a medium emissions scenario there will be a possible reduction in rainfall by about 20% in the northern areas where most of the groundwater reserves are concentrated, with impacts on their potential to recharge. At the country level, a -0.4%, -5.1% and -29.3% change of the annual groundwater recharge for the period 2045-2055 compared to the timeframe 2015-2025 is expected respectively under low, medium and high emissions scenarios.

KEY POINT FLOODS

Floods in Saudi Arabia are rare, however hazardous flash flooding has caused widespread damage and loss of life in the past in numerous urban areas. The desert city of Riyadh, capital of the Kingdom and home to 7.6 million people has been hit by more than ten flash floods in the past thirty years, resulting in more than 160 deaths. Desert urban centres are more at risk in the absence of rivers and drainage outlets to sea, and with rapid population growth, urbanization, and transformation of large areas of sandy desert into concrete, increasing surface runoff speed and volume.

Extreme daily precipitation is expected to change by the middle of this century 2050, with an increase over the western parts of Saudi Arabia in August, particularly along the coast of the Red Sea and surrounding the Asir Mountains, and a reduction over approximately the same area in November. Other areas are expected to experience changes in extreme rainfall, however the trends vary across the country.

POPULATION AFFECTED BY RIVER FLOODS

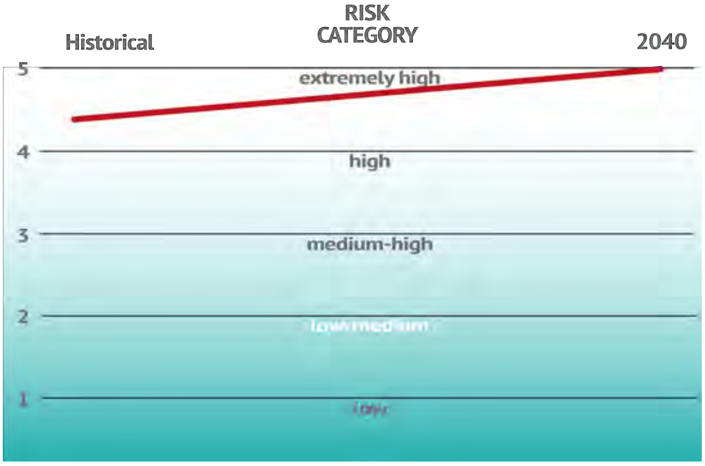


RISK INDICATORS

The water stress index summarises current and future water related vulnerabilities and risks at the global level. Scores are based on the ratio of total water withdrawals, including agriculture, industrial and human consumption, to available renewable surface and groundwater supplies.

WATER STRESS

Saudi Arabia's water stress level is considered extremely high for the recent past (1960-2014 average), and it is expected to further increase in the near future (2030-2050) based on climate change projections.



SAUDI ARABIA
AGRICULTURE

OVERVIEW

The Kingdom of Saudi Arabia is characterized by arid to semi arid climates, due to low rainfall and extremely high temperatures. Agriculture contributes only a small share of national GDP.

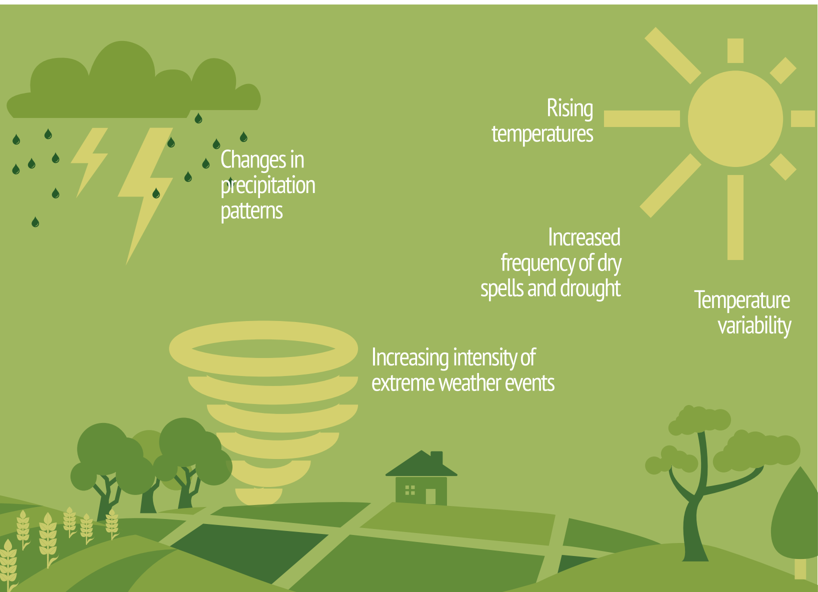
Less than 2% of country's land is arable and used for crops, of which half is rainfed dry farming (mostly in Asir), two-fifths is used for tree crops and the remainder is intensively used for irrigated agriculture in several districts, such as Riyadh, Al-Qa īm, Al Jawf and near Al-Hasa, for instance. Saudi Arabia is a top producer and exporter of dates, second only to Egypt. The main cultivated grain is wheat, with production covering domestic self-sufficiency. Other cultivated crops include barley, sorghum, maize, vegetables and fruits. Agriculture consumes more than 80% of total water withdrawal, mostly from groundwater resources.

1.4 Mt Dates	0.5 Mt Wheat
0.5 Mt Barley	0.7 Mt Fresh Fruits

	Added Value of Agriculture, Forestry and Fishing	Share of Agriculture Value added in Total GDP	Agricultural land	Area Equipped for Irrigation
2000	12,032 USD Million	3.3 %	3,785 Thousand HA	1,616 Thousand HA
2018	17,416 USD Million	2.6 %	3,629 Thousand HA	1,620 Thousand HA

EXPEXTED IMPACTS ON AGRICULTURE PRODUCTIVITY

Rising temperatures, reduction in average annual precipitation, and intensification of extreme events such as heat waves and drought, affect production variability with a tendency towards yield reduction for many cultivated species, accompanied by a probable decrease in food quality. Crops respond to increases in temperatures with changes in duration of the growing season, early appearance of phenological phases and potential shifts of cultivation areas toward higher latitudes and altitudes for better growing conditions. However, impacts vary significantly depending on the geographical area and specific crops in question.



CROP PRODUCTIVITY

Crop productivity refers to the harvested yield of a crop per unit of land area. It is strongly influenced by climate and other environmental and management factors.

Climate change is expected to have an impact on the productivity of several major crops, although this may in part be offset by the fertilizing effect of higher CO_2.

Impacts are estimated using a range of model projections based on low to high emission scenarios and reported as percentage changes between the 30-year average around the historical period and the 30-year average around 2050.

5.7 -1.6 (-7.8)% -0.9 (-13.2)%
Wheat
tons / ha

6.2 -2 (-7)% -1.5 (-10.2)%
Barley
tons / ha

5.9 -5.1 (-8.1)% -5.5 (-9.8)%
Maize
tons / ha

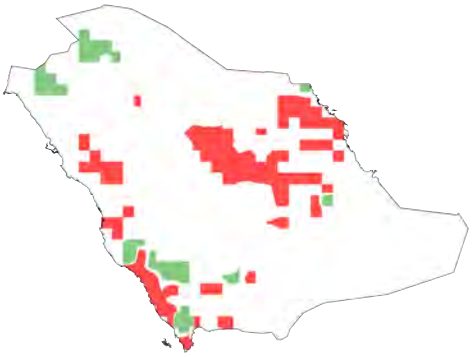
tons / ha

2050

Productivity change with (without) the CO_2 fertilization effect. Estimates assume sufficient water and nutrient supplies, and do not include impacts of pests, disease, or extreme events.

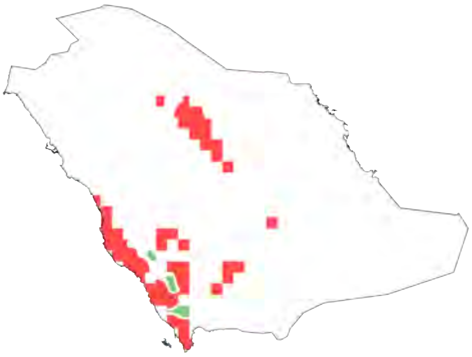
CHANGE IN WHEAT

🟥 − = 🟩 +



CHANGE IN MAIZE

🟥 − = 🟩 +



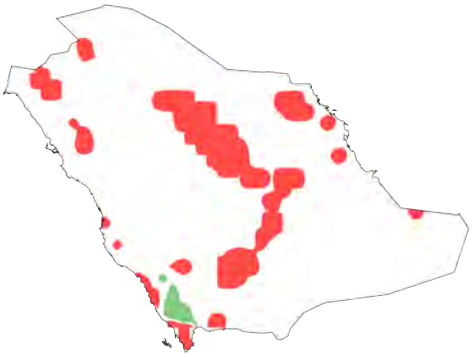
Almost 95% of Saudi Arabia will remain climatically suitable for date palm cultivation in the coming decades. However, a significant reduction in climatic suitability is expected towards the end of the century. Increasing temperatures will severely affect the yield of wheat, barley and sorghum especially in warmer areas and at lower elevation. Crop production is particularly vulnerable to temperature and water availability during the grain maturing stage. Climate risks for wheat productivity and yield stability are more limited for early-maturity varieties of wheat or wheat planted at earlier dates, since these may avoid high-temperature stress (above 30°C) at flowering. Potato cultivation is expected to increase slightly in productivity (5 to 8%).

ADAPTATION IN AGRICULTURE AND WATER RESOURCES

Saudi Arabia has implemented generous subsidies that favor domestic food crop production through irrigation development. Cereal production relies entirely on irrigation and available water resources. Higher future temperatures will, in general, increase water demand for agriculture. Most water withdrawal is from groundwater resources which are difficult to renew in the short term, causing a major depletion of underground water aquifers. There is a growing recognition for the need to promote sustainable water uses that can secure finite water resources over the long term.

CHANGE IN WATER DEMAND

🟩 − = 🟥 +



Agriculture
Water Demand
% of change

+31.8%
+34.2%

2050

It will be essential to promote water use efficiency, crops and cultivars with lower water demand and the use of treated wastewater in the irrigation of permitted crop systems.

SAUDI ARABIA
FORESTS

FORESTS IN SAUDI ARABIA

Forest areas in Saudi Arabia are currently very limited, except for mangroves in coastline areas. These ecosystems are crucial to the carbon cycle ("blue carbon").

FORESTED AREA AND CARBON STORAGE

Mangroves absorb carbon from the atmosphere, which is then stored in the living biomass and the sediments of coastal areas known as "blue carbon". Worldwide, mangrove deforestation contributes to approximately 0.3% of total anthropogenic CO_2 emissions making this phenomenon a climate change accelerator. Mangroves can be considered the most important forest ecosystems of Saudi Arabia. Their distribution is patchy and fragmented and they do not form continuous populations. They are generally restricted to bays, narrow channels, and inland faces of offshore islands. In recent decades the total coverage of Saudi Arabia's Red Sea mangrove forests, which is larger than those of the Persian Gulf, is increasing. These forests grow in the most unfavorable conditions (high salinity values, rivers non-existent, rainfall minimum, hard bottom and very oligotrophic sea), which makes them very vulnerable. Land use changes, in particular the conversion into shrimp farms, rising population, coastal development, industrial waste and effluents and many other factors, contribute to the loss of carbon stock. Furthermore mangroves cannot survive rapid sea level rise.

1990

1 Mln ha
Million hectares
Forested area

51 Tons/ha
Tons of Carbon per hectare
Carbon stock

2020

1 Mln ha
Million hectares
Forested area

51 Tons/ha
Tons of Carbon per hectare
Carbon stock

FIRES IN SAUDI ARABIA

During the last two decades, the total land area affected by fire was approximately 2,880 hectares.

BURNING
2.9 THOUSAND HECTARES

EMITTING
0.015 TERAGRAMMES
OF CARBON PER YEAR

AGRICULTURE FIRE EMISSIONS
CONTRIBUTED TO
50% OF TOTAL FIRE RELATED
CARBON EMISSIONS

FUTURE BURNED AREA

Under a low emissions scenario, models project a generalized decrease in burned area. This trend might be emphasized under a medium emissions scenarios, and is more pronounced in central and western areas.

Burned Area
km^2 per year

2050

-124

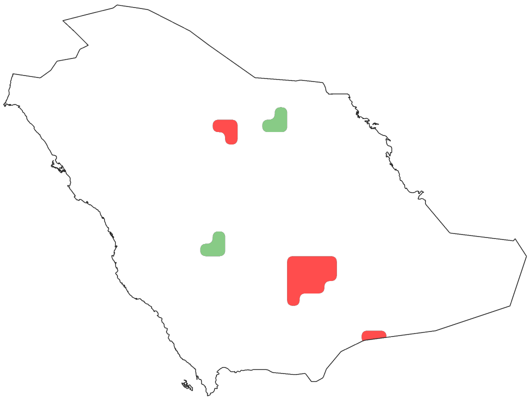
-81

CASE STUDY: WILDFIRES

In October 2020 a wildfire in the Asir region threatened high value juniper woodlands. Wildfire impacts on vegetation differ across tree species, affecting recovery and the services they provide. Analysis carried out in western Saudi Arabia after forest fires revealed that species such as Acacia origena recover much better than junipers and oleas. Therefore, climate change impacts on fire regimes should be kept in mind in order to safeguard services provided by specific forest types such as the cultural and touristic value of juniper forests.

🟩 Decrease in burned areas for a low emissions scenario in 2050

🟥 Increase in burned areas for a low emissions scenario in 2050



SAUDI ARABIA URBAN

OVERVIEW

In Saudi Arabia, 80% of the population lives in urban areas, a number which has increased by 170% since 1960. However, growth rates are slowing down, with an urbanization rate of 90% expected for 2050.

25% of the urban population lives in the only agglomeration with more than 5 milion inhabitants, the capital city, Riyadh. Future growth is expected in cities, with Jeddah reaching the 5 million inhabitants threshold by 2035.

Built up areas cover only 0.32% of Saudi Arabia (6,175.21 square kilometers).

Population in Urban Areas

2020 29,255,576

2050 34,142,975

Graphs refer to data provided by United Nations, Department of Economic and Social Affairs, Population Division (2018). World Urbanization

Urbanization Rate

2020 84.3%

2050 90.4%

OVERVIEW OF KEY CLIMATE IMPACTS IN URBAN AREAS

Saudi Arabian cities are mainly vulnerable to the impacts of heatwaves, flooding following rare events of intense rainfall, and sea level rise.

HEATWAVES AND HEAT STRESS

Temperatures in Saudi cities are increasing, also due to the transformation of urban morphologies. Heat related health impacts from rising temperatures in cities are worsened by high levels of air pollution.

In 2017 all urban areas in Saudi Arabia registered unsafe levels of the air pollution indicator PM 2.5. In 2015, PM 2.5 concentrations (106·2 µg/m3) were the second highest in the world after Qatar. Air pollution shortens average lifespan in the country by 1.5 years.

Increasing mean and summer temperatures, and duration of heatwaves are expected for the whole country. Under a scenario of 4°C warming, duration of heatwaves could increase by more than 4,000%.

Frequency, intensity and duration of heatwaves may be even higher for urban areas due to the difficulties of large scale models in capturing the specific urban geography and representing the urban heat island effect under all scenarios considered.

2050 Cooling Degree Days

% of change

+51.4%

+21.7%

+15.9%

2050 Heatwave frequency

% of change

+99.6%

+68.7%

+40.8%

2050 Heatwave duration

% of time

+4,242%

+774%

+284%

RAPID URBANIZATION

Traditional Saudi Arabian cities with narrow streets provide protection from extreme temperatures during daytime and help cooling down during night time, leading to lower temperatures than the surrounding desert areas. Saudi Arabia's massive urbanization has adopted western urban models with wider and asphalted streets.

As a result, surface temperatures in most urban areas of Riyadh have continued to increase between 1985 and 2015, approaching desert values. High temperatures in urban areas worsen the impact of high levels of air pollution. In 2017, the entire population was exposed to pollution levels above WHO thresholds.

COASTAL FLOODING

Just under 5% of all urban residents live in areas that are less than 5 meters above sea level. Several major cities are situated along the coastlines of the Gulf of Persia and the Red Sea, among these, the country's second largest city, Jeddah. Development along the coastline is growing at a pace of 1% per year, putting further assets at risk from coastal inundation.

FLOODING

Despite low mean precipitation values, Saudi Arabian cities are exposed to flood risks from occasional intense precipitation. A flash flood which hit the city of Jeddah in 2009 caused more than 100 victims and destroyed entire settlements. Victims were situated mainly in the unplanned expansion areas of the city, which coincide with valleys and temporary water courses (Wadis) conveying additional water masses as run-off from the mountains.

Projections for future precipitation patterns show relatively small increases in annual mean, versus significant increases in mean values for the warm season. These mean values cannot seize short term intense precipitation events like the one described for Jeddah, which are expected to become more frequent and can cause major damage, particularly in exposed and unplanned areas around the cities.

2017

Population exposed to air pollution

100.0%

2050

Projected sea level rise

0.23 m

0.18 m

2100

0.77 m

0.38 m

2050

Runoff increase

% of area

+9%

+2%

+1%

SURFACE SEALING AND FLOODS

Heavy precipitation in cities is problematic due to the high level of sealed surfaces. Soil sealing increases run off and reduces the amount of water absorbed by soil. Where there are large amounts of impervious ground cover, short duration extreme rainfall events can lead to increased flooding, even resulting in flash floods.

UNCONTROLLED URBANIZATION

Unplanned expansion of cities and urbanization of flood prone areas such as temporary water courses (Wadis) and low lying coastal areas, increases exposure of urban assets to extreme events.

According to World Bank data, in 2018, 16% of the urban population lived in informal settlements.

2010

% of urban population

Population living in slums

16.2%

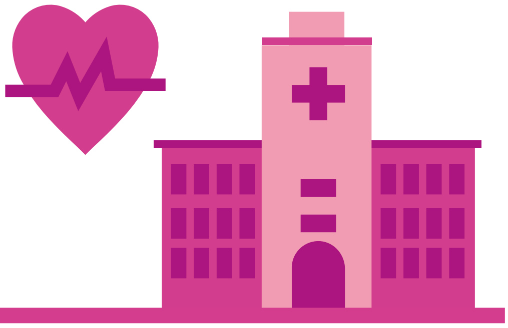
2018

% of total population

Urban population living in areas where elevation is below 5 meters

4.6%

SAUDI ARABIA
HEALTH



OVERVIEW

Saudi Arabia has warmed at a 50% higher rate than the rest of the landmass in the Northern Hemisphere. The most significant health impacts connected to this change will likely occur from heat-related mortality, given the high-temperature increases expected.

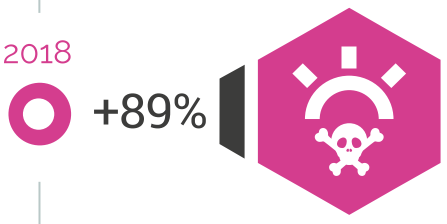
Rising temperatures are likely to increase thermal stresses and extreme weather disasters resulting in increased mortality. Elevated ambient temperatures and humidity are also projected to increase incidences of vector-borne diseases such as malaria.

HEAT RELATED MORTALITY

Thermal discomfort has increased in most parts of Saudi Arabia from 1990 to 2018. In 2018, there was an 89% increase in heat-related deaths in Saudi Arabia compared to the 2000 to 2004 baseline.

Heat-related mortality

% change with respect to 2000-2004



IMPACTS ON LABOUR

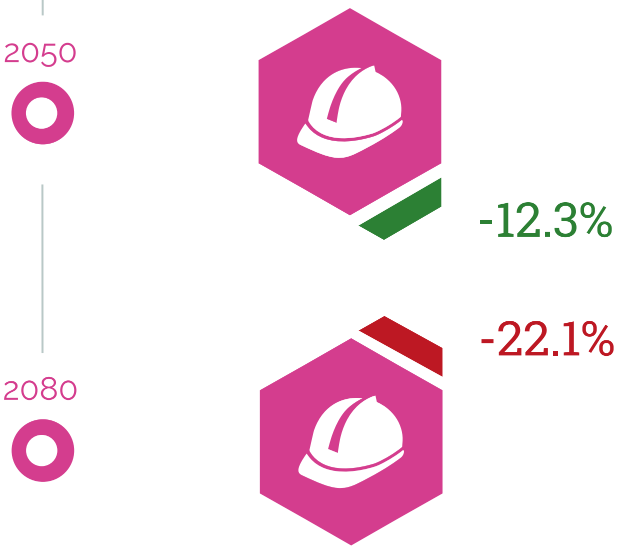
Labour is directly affected by changes in environmental conditions. Warming affects both the number of hours worked (labour supply) and on the productivity of workers during their working hours (labour productivity). Both labour supply and productivity are projected to decrease under future climate change in most parts of the world, and particularly in tropical regions.

Parts of sub-Saharan Africa, south Asia, and southeast Asia are at highest risk under future warming scenarios. Future climate change will reduce global total labour in the low-exposure sectors by 18 percentage points and by24.8 percentage points in the high-exposure sectors under a 3.0°C warming scenario

Total labour is expected to decline by 12.3% under a low emissions scenario, and by 22.1% under a medium emissions scenario.

Impact on total labour

% change with respect to 1986-2005 baseline



CLIMATE CHANGE AND DENGUE

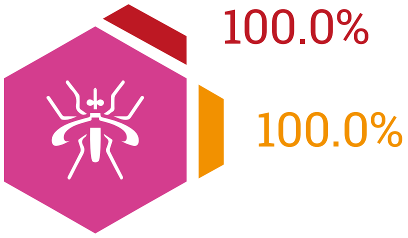
Dengue has spread throughout the tropical world over the past 60 years and now affects over half the world's population. Globally, vectorial capacity for both dengue vectors (A. aegypti and A. albopictus) has been rising steadily since the 1980s, with nine of the ten highest years occurring since 2000.

Climatic stressors are one important driver of the current distribution and incidence of dengue. Climate change is likely to expand the geographical distribution and suitability of several vector-borne human infectious diseases including dengue. The risk of dengue transmission is increased by warming climates, as the growth and development of mosquitoes are significantly influenced by temperature, precipitation, and humidity.

Dengue suitability

% of population at risk

2050



CLIMATE CHANGE AND ZIKA

Zika virus has spread to at least 49 countries and territories since 2013. Climate change impacts on transmission suitability risk have increased over the years and future warming over 1.3 billion additional people could face suitable transmission temperatures for Zika by 2050.

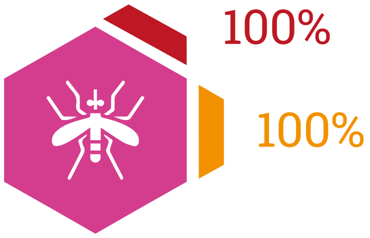
DENGUE AND ZIKA: POPULATION AT RISK

Nearly all of Saudi Arabia's population will be at risk of transmission-suitable mean temperature for dengue and Zika by 2050 under both medium and high emissions scenarios.

Zika suitability

% of population at risk

2050



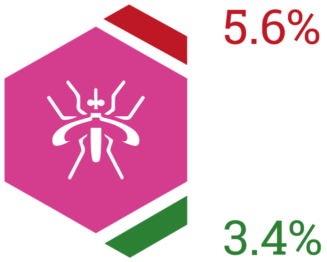
CLIMATE CHANGE AND MALARIA

Though Saudi Arabia has managed to reduce malaria transmission, the changing climate is projected to bring an increase. 3.4% of the Saudi Arabian population will be at risk of malaria under a low emissions scenario in 2050, whereas 5.6% will be at risk under a high emissions scenario.

Malaria suitability

% of population at risk

2050



POLLUTION AND PREMATURE MORTALITY

In 2017, annual deaths attributable to PM2.5 were estimated at 8,536, representing 9% of the total annual deaths in Saudi Arabia. 315,200 disability-adjusted life years were attributable to PM2.5.

SAUDI ARABIA
ENERGY

ENERGY SYSTEM IN A NUTSHELL

Saudi Arabia owns 17.2% of world oil reserves. Oil is the focus of its economy and the main source of wealth, and dominates exports and internal energy use. Energy production in 2018 was 3 times total primary energy supply.

The Saudi government is aware of the need to diversify away from oil in a decarbonizing world: in March 2021, it announced the target of generating 50% of its energy from renewables by 2030, investing massively in solar power generation.

0.14
ktoe/US$
Energy intensity

72.0%
AC Share in electricity consumption

CLIMATE CHANGE TODAY

INCREASING TEMPERATURES

Summer temperatures in Riyadh increased by 2.65 to 3.07°C between 1980 and 2020. This called for extra epower capacity to cope with increasing demand, and in 2015 about 1.2 gigawatts of electricity were added for every 1°C increase.

OIL AND GAS

Thus far, oil and gas infrastructures has shown remarkable resiliance to extreme temperatures.

ENERGY SUPPLY

In Saudi Arabia, 84% of the energy produced is exported. Domestically, oil (62.7% in 2018) and to a lower extent, natural gas (37.2%) account for almost the totality of energy supply, leaving a meagre 0.01% to renewables (mainly solar pilot projects and biofuels). There is no hydropower generation of any significance in the country.

ENERGY DEMAND

In Saudi Arabia, energy is used mainly by industrial sectors (53% of total final consumption in 2018, including non-energy uses accounting for 20% of total demand), transport (31% of final demand), residential demand (9%) and the tertiary sector (7,4%), whereas agriculture has a slim 0.8% share. Air conditioning's contribution to residential electricity demand is extremely high: 72% in 2017.

FUTURE ENERGY DEMAND

Overall projected demand in Saudi Arabia will increase due to increasing cooling needs, reaching about 853 PJ (237 billion Kwh) by 2050 under a medium emissions scenario.

Net change in energy demand due to changes in DD/CDD
Billion KWh

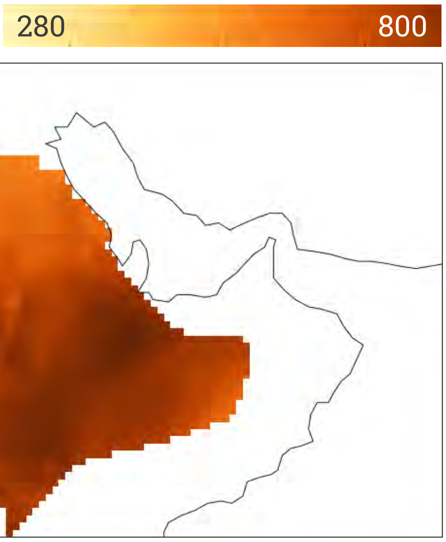
2050

+ 237.09

COOLING NEEDS

Extreme increases in cooling needs are expected all over the country, particularly in the south. The minimum projected anomaly (280 CCD) is 66 CCDs higher than the maximum anomaly for Germany.

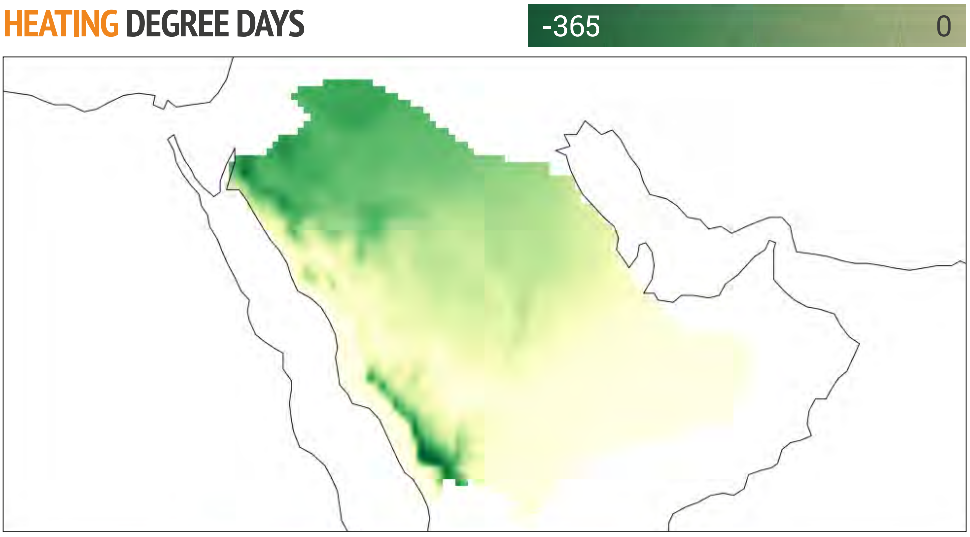
COOLING DEGREE DAYS



HEATING NEEDS

Moderate decrease in heating degree days are expected in the north and on the Red Sea coastal range (Asir region, with the city of Abha, hosting a population slightly over 1 million and a popular destination for domestic tourism).
Negligible changes in the rest of the country.

HEATING DEGREE DAYS



FUTURE ENERGY SUPPLY

The future configuration of the Saudi Arabian energy mix is likely to be determined by the evolution of the country's energy policies and hence is outside the scope of this report.

Saudi Arabia has historically shown a low degree of interest in decarbonization, but the recent target on renewables may imply some significant, albeit still minoritarian, diversification away from fossil fuels for internal energy uses.

This is likely to result in fossil fuels (and their vulnerabilities) keeping their relevance for the next couple of decades, while carbon free sources and their vulnerabilities will probably gain relevance from 2030 in the second half of the century.

EXPECTED IMPACTS OF CLIMATE CHANGE

To the best of our knowledge, there are no country-specific studies on climate change impacts on Saudi energy infrastructure. Increasing frequency of flash floods caused by heavy precipitations, coastal storm surges, and increasing frequency of sandstorms- all phenomena expected for Saudi Arabia under a changing climate - are likely to pose threats to such infrastructure.

SAUDI ARABIA
ECONOMY

OVERVIEW

Saudi Arabia ranks 17th in terms of GDP in the G20 group. The COVID 19 crisis had a severe impact on the economy, whereby in 2020 real GDP declined by 4.1%. This trend has been reversed and in 2021 real GDP has grown by 2.9%.

IMPACTS ON GDP

There is a high degree of variability across macroeconomic estimates of the overall economic impact of climate change for Saudi Arabia.

They range from increase in GDP per capita (0.26%) under a low emissions scenario in 2030 to a loss in GDP potentially larger than 12% in 2050 under a high emissions scenario.

2050

1.05/12.2%

-0.38/4.8%

GDP Loss

% change w.r.t baseline

2100

3.35%

0.78%

SECTORAL ECONOMIC IMPACTS

IMPACTS ON INDUSTRY AND INFRASTRUCTURE

Floods and sea level rise can pose a significant threats to infrastructure located along the coast. This can be particularly problematic for coastal infrastructure that is instrumental to Saudi Arabia's import-export activities, such as harbours, fossil fuel terminals, and refineries.

A key coastal infrastructure for the Saudi Arabian economy and society is water desalination: 50% of the national water demand is met by desalinated water. Saudi Arabia holds 15% of the world's desalination capacity. Desalination plants are usually regarded as an adaptation tool to tackle water shortages caused by climate change. However, if the salted brine resulting from the process is not treated sustainably, it may result in severe pollution of the sea water in which it is discharged, and hence result in maladaptation.

Salt brine has intrinsic economic value as source of salt and metals, however, 80% of salt brine from coastal plants is discharged back into the sea. An interesting feature of desalination plants is that, in areas with high levels of insolation, they can be operated using solar energy instead of fossil fuels. This provides to fossil-fuel-rich, tropical countries such as Saudi Arabia with an interesting opportunity to promote faster decarbonization.

FLOODS DAMAGES

Floods can result also from sudden and intense precipitations all over the country and generate significant damages.

The 2009 flooding of Jeddah, caused by intense precipitation and compounded by the inadequacy of the drainage system, caused 150 deaths and high, but unquantified, economic losses to private properties, transport infrastructure and means of transport.

IMPACTS ON AGRICULTURE

Despite the prevalence of a desertic or very hot and dry climate, agricultural production does take place in Saudi Arabia in suitable areas and accounted for 2.2% of GDP in 2019. There are no projections available about the economic impacts on this sector, only qualitative inferences can be drawn from agronomic studies.

Overall, by the end of the century yields of fruit trees and crops will drop by 5% to more than 25%. Dates are a very relevant crop in Saudi Arabia, both as a key ingredient of the local diet and as an export cash crop: in 2109 Saudi Arabia was the second world producer of dates, with over 1.5 million tons in 2019 and the fourth world exporter with almost 230 million USD in exports.

A recent study finds that, whereas by 2050 most (95%) of the land currently suitable for dates palm tree cultivation will still be able to support this crop, by 2100, the suitable land for the cultivation of dates may shrink substantially, to 25% - 15% of its current extent, and this is likely to turn Saudi Arabia into a net importer of dates – with an almost complete loss of revenues from the exports of this crop.

IMPACTS ON ENERGY

As with all other economic sectors, energy supply and energy networks in Saudi Arabia will undergo more intense stress from extreme weather events, in particular the increasing occurrence of sand storms, and sea level rise for coastal oil and gas terminals and refineries.

Economic impacts of shifts in household and firm energy demand (see chapter on energy) are difficult to predict and will mostly lead to redistribution effects. In the case of Saudi Arabia, the already pervasive cooling needs will further intensify, bringing about a likely significant increase in energy bills.

IMPACTS ON TOURISM

The tourism sector, which accounts for about 7% (1.6% in terms of direct receipts only) of Saudi Arabia's GDP can in principle be affected by climate change.

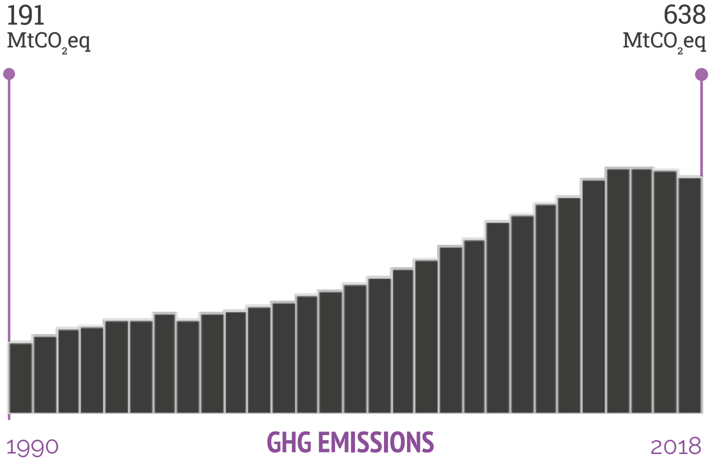
This can happen directly, through the impact of changing climatic features on the thermal comfort of tourists; and indirectly through the impact of increased chances of extreme events or worsened ecosystem conditions, and, consequently, on the attractiveness of the destination. In a hot country like Saudi Arabia outdoor climatic conditions from the human comfort's point of view are already sub-optimal and projected to worsen substantially in the future.

Nonetheless, the vastly predominant motivation to visit Saudi Arabia is religious since the destinations of the hajj, the traditional Muslim pilgrimage, are located in this country. Accordingly, the number of visitors is not expected to vary significantly due to climate change. However, health issues due to increasing temperatures are expected to become more frequent, particularly during the 2040's when the hajj will take place during summer months.

SAUDI ARABIA
POLICY

OVERVIEW

In 2018, Saudi Arabia was the 13th largest emitter among G20 countries. However, it was also 3rd in terms of emissions per capita. Although Saudi Arabia's emissions have grown massively in recent decades, since 2016 they have slowly started to decrease.



INTERNATIONAL COMMITMENTS

Saudi Arabia ratified the Paris Agreement in 2016. According to its NDC, Saudi Arabia is committed to reduce its yearly emission by 130 $MtCO_2eq$ between 2021 and 2030.

CLIMATE POLICY COMMITMENTS CHRONOLOGY

2005 **Kyoto Protocol - 1st period**

No target

2016 **Paris Agreement - 1st NDC**

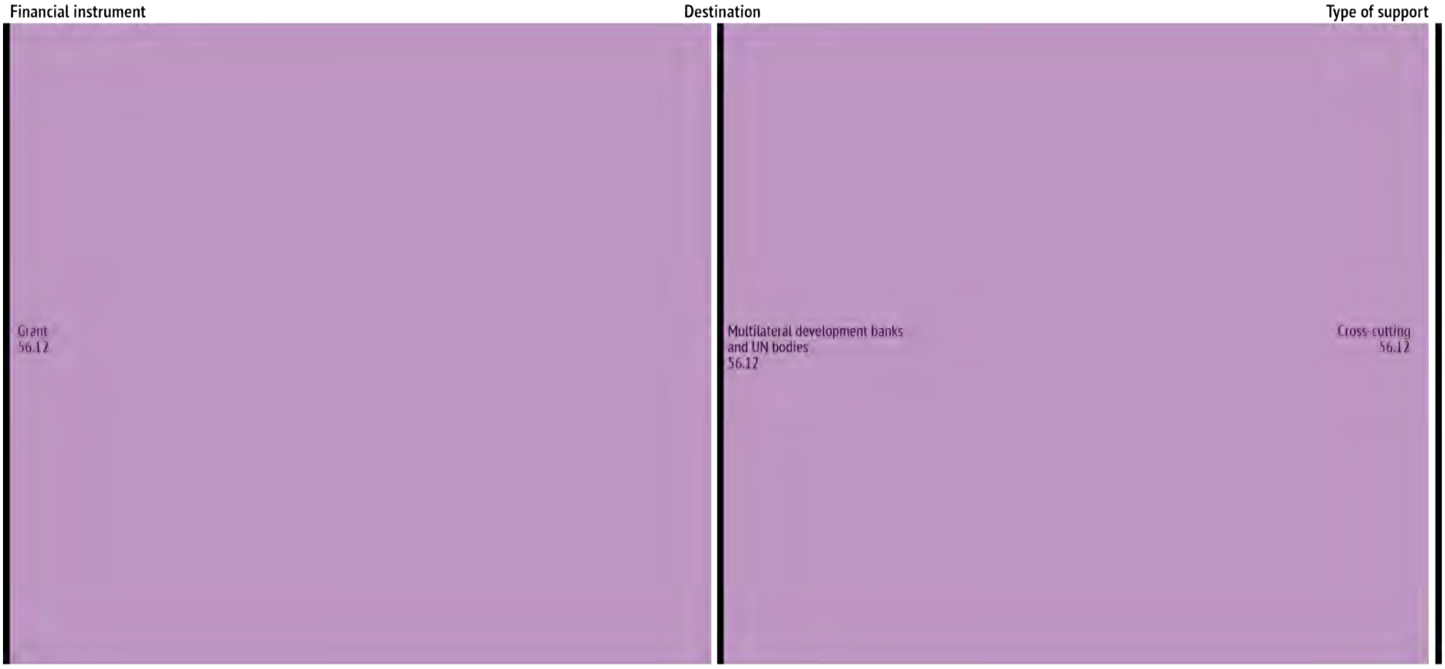
An annual abatement of 130 $MtCO_2eq$ between 2021 and 2030

Paris Agreement - NDC update

No further update

INTERNATIONAL CLIMATE FINANCE ASSISTANCE

OECD DAC data on climate-related development finance shows that Saudi Arabia provided 56 million USD in 2017-2018. This sum is devoted entirely to multilateral institutions and it addresses cross-cutting initiatives.



SUSTAINABLE RECOVERY POLICY

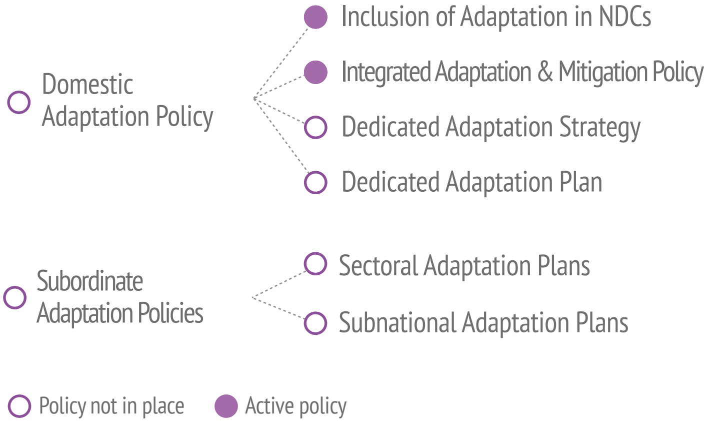
According to the Global Recovery Observatory, Saudi Arabia's total public investments in 2020 account for more than 62 billion USD. 4.21 billion USD are reported as investments for the post-covid recovery. No resources are explicitly dedicated to a sustainable recovery.

62.13
billion $
Total Spending

4.21
billion $
Recovery Spending

DOMESTIC ADAPTATION POLICY

Saudi Arabia included adaptation in its NDC. The country recently adopted an integrated policy for both mitigation and adaptation. This legal framework does not foresee specific sectoral or sub-national adaptation plans.



- ○ Domestic Adaptation Policy
  - ● Inclusion of Adaptation in NDCs
  - ● Integrated Adaptation & Mitigation Policy
  - ○ Dedicated Adaptation Strategy
  - ○ Dedicated Adaptation Plan
- ○ Subordinate Adaptation Policies
  - ○ Sectoral Adaptation Plans
  - ○ Subnational Adaptation Plans

○ Policy not in place ● Active policy

ADAPTATION POLICY HIGHLIGHTS

TRANSNATIONAL INITIATIVES

Middle East Green Initiative

The initiative aims to plant 50 billion trees across the Middle East.

NATIONAL INITIATIVES

Saudi Green Initiative

It is a national initiative that aims to raise vegetation cover, reduce carbon emissions, combat pollution and land degradation, and preserve marine life. Among its goal there is an objective to plant 10 billion trees in Saudi Arabia and to increase protected areas to more than 30% (including marine and coastal ecosystems)

Center of Excellence for Climate Change Research (CECCR)

The CECCR was established in 2010 with a mandate to carry out state-of-the-art research in the field of weather, climate and climate change.

SUBNATIONAL INITIATIVES

Al Baydha Project

It is a land restoration, poverty-alleviation, and heritage preservation program, based on principles of permacultural and hydrological design.

Riyadh Green project

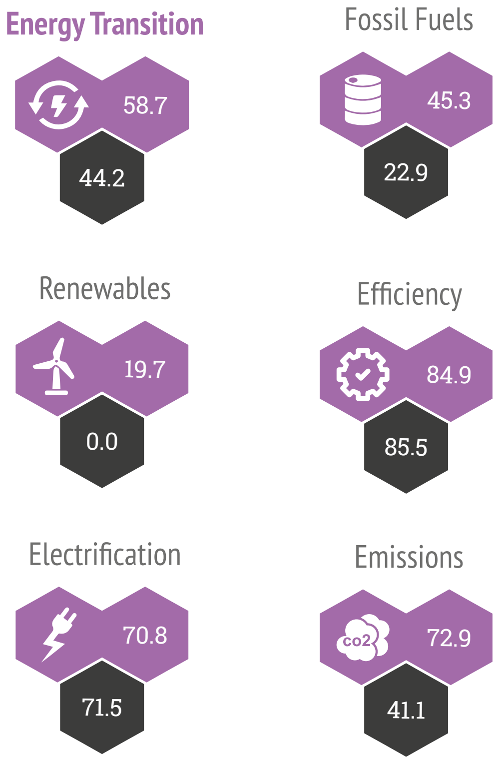
The Green Riyadh project will contribute in increasing the per capita share of green space, and raise total green spaces through planting trees around all city features and facilities as well as in all its provinces. All of the greening will be watered by recycled water from an irrigation network.

ENERGY TRANSITION

Its status of major global oil producer has an impact on the energy transition trajectory of Saudi Arabia. The country has not yet entered into a visible process of transformation of its energy sector, as demonstrated by its position in the bottom part of the ranking. Specifically, Saudi performances are negatively affected by the predominant role of fossil fuels, and in particular of oil.

These performances are reflected in the still very limited contribution of renewables to energy and electricity mixes. Massive extractive activities and reliance on oil products as the main energy input result in negative performance in the Emissions indicator, a domain in which Saudi Arabia performs worse than the G20 average.

On the contrary, the results achieved by the country in the Electrification domain are slightly above the group's average, thanks in particular to the availability of energy/fossil resources used for generation, which ensure universal and stable (though very high pollutant) access to electricity. Similarly, the Saudi's decent performances with respect to the Efficiency indicator, is the result of an economy largely based on the financial rents from the energy sector, rather than an intensive use of energy and economic and industrial input.



Only actively pursuing an energy transition based on decarbonization and electrification – from policy and regulation, to health and education – will enable countries to benefit the most from future opportunities and fight climate change whilst ensuring an equitable distribution of wealth.

The Energy Transition indicators were developed by Enel Foundation in cooperation with SACE, and provide a retrospective analysis based on historical data.

G20 CLIMATE RISK ATLAS

Impacts, policy, economics

cmcc

SOUTH AFRICA

How to read the Atlas: graphs, colours and scenarios.

The maps used in this Atlas are taken from **The World Bank Official Boundaries** - ***https://datacatalog.worldbank.org/search/dataset/0038272*** (accessed on May 28, 2021). For the section Energy, the maps are based on Panoply Data Viewer ***https://www.giss.nasa.gov/tools/panoply/credits.html***

Each sector of this Atlas contains data and information on various climate scenarios.

When reported in graphs, the **colour black** indicates data and information referring to the current state, the past or the baseline.

When the authors refer to **RCP (Representative Concentration Pathways)**, the 3 colours used across the factsheet refer to 3 scenarios, which are 3 different development options with different levels of greenhouse gas emissions, **respectively low emissions (green), medium emissions (orange), and high emissions (red)**. The same colour code is used when RCPs are associated with Shared Socioeconomic Pathways (SSP).

In some cases, the authors refer to global warming scenarios. In these cases, the 3 colours used refer to a temperature rise of **1.5°C (green), 2°C (dark green), and 4°C (red)**.

When the authors refer exclusively to **Shared Socioeconomic Pathways - SSPs** (Population affected by river floods in the section: "Water"), data related to **SSP3** - that encompasses, among other things, slow economic growth, material-intensive consumption, and persisting or worsening inequalities – **are reported in a lighter shade**; **SSP5** – which refers to social and economic development that is coupled with an energy-intensive lifestyle and the abundant exploitation of fossil fuel resources – is shown using a **middle shade of the colour**, whereas data related to **the present** conditions **are represented in a dark shade**.

Further details on scenarios, methodologies, and the full list of references are available at: **www.g20climaterisks.org**

Concept and graphic design by element6.eu

SOUTH AFRICA
CLIMATE

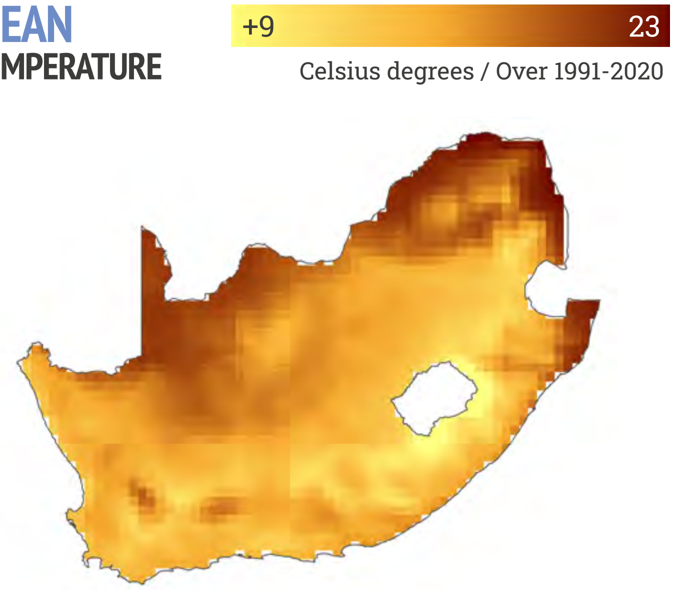
OVERVIEW

The climate in South Africa is more variable than other countries in sub-Saharan Africa due to its subtropical location and the presence of oceans on three sides of the country. In general, it is a warm temperate climate with some differences between west and east coasts, which are related to cold and warm coastal currents and in part influenced by the El Niño–Southern Oscillation. A singularity is the Western Cape which features a Mediterranean climate.

TEMPERATURE

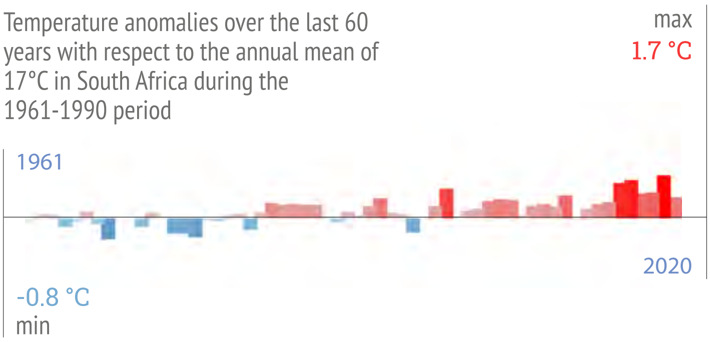
South Africa experiences average annual temperatures of 17°C. The southern and eastern areas are the regions with the lowest temperatures due to their altitude. The warmest areas are the coastal ones and inland areas of the northern Cape.

MEAN TEMPERATURE



TEMPERATURE TREND

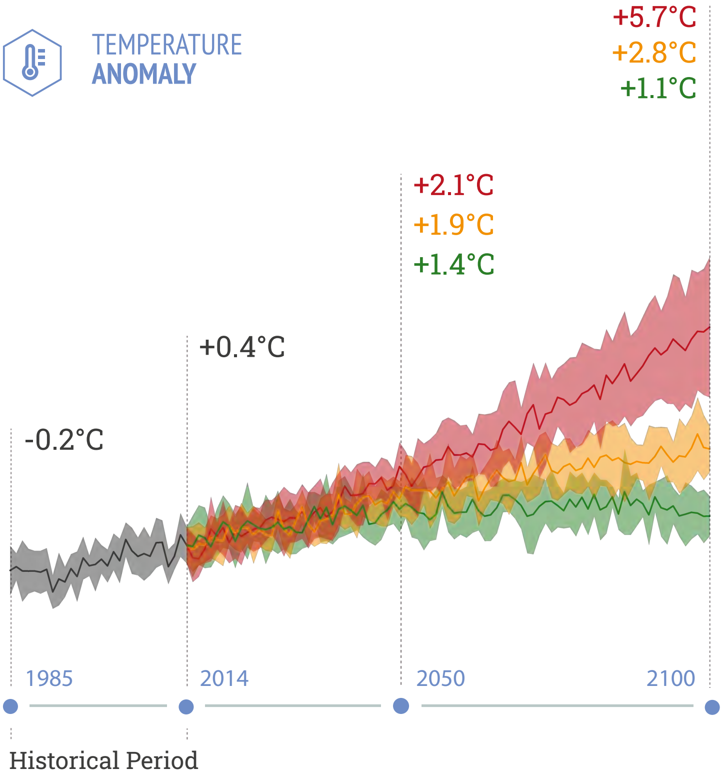
Temperature anomalies over the last 60 years with respect to the annual mean of 17°C in South Africa during the 1961-1990 period



TEMPERATURE PROJECTIONS

Under a low emissions scenario projected temperature variations will remain contained under 1.5°C, both by 2050 and 2100.
Under a high emissions scenario, with no reduction in GHG emissions, much greater temperature anomalies are expected by both 2050 and 2100.

TEMPERATURE ANOMALY



EXPECTED VARIATION FOR TEMPERATURE AT 2050

The indicators show variations in selected temperature characteristics for a thirty-year period centred on 2050 (2036-2065) with respect to the reference period 1985-2014.

Annual Mean Temperature	+2.1°C	+1.6°C	+1.2°C
Max Temperature of warmest month	+2.4°C	+1.8°C	+1.5°C
Min Temperature of coldest month	+1.9°C	+1.5°C	+1.1°C

PRECIPITATION

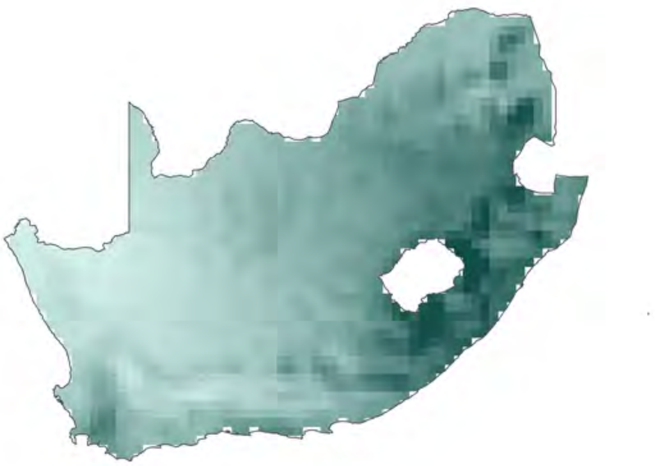
The precipitation regime in South Africa exhibits changes depending on time of the year and location. Generally speaking, South Africa is a relatively dry country: the Western Cape gets most of its rainfall in winter, whereas the rest of the country is generally a summer-rainfall region.

Rainfall concentrations vary across seasons and, at an annual timescale, it is highly irregular in most parts of the country. Changes in South Africa's rainfall seasons could affect farming and water resources. In terms of geographical distribution, there is more precipitation in the coastal areas of the Indian Ocean compared to other parts of the country.

MEAN PRECIPITATION

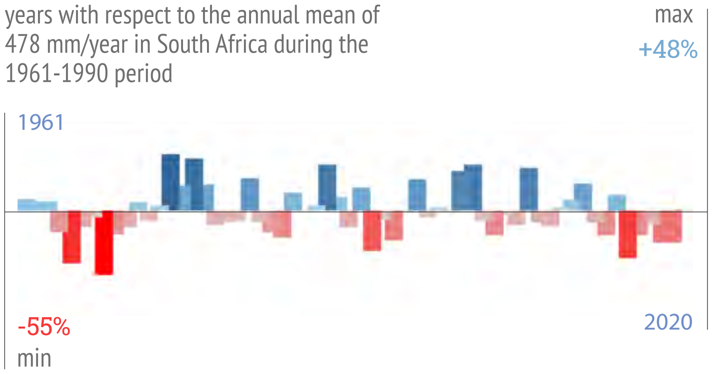
61 2,273

mm/year / Over 1991-2020



PRECIPITATION TREND

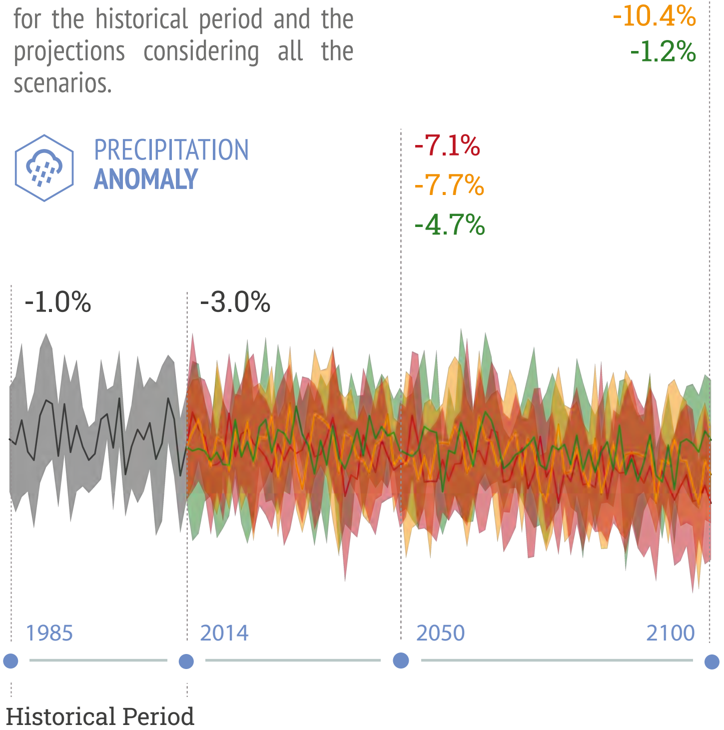
Precipiation anomalies over the last 60 years with respect to the annual mean of 478 mm/year in South Africa during the 1961-1990 period



PRECIPITATION PROJECTIONS

Precipitation trend shows a slight decrease in precipitation during the last part of 21st century: such a decrease in appreciable especially under a high emissions scenario. The variability is quite large both for the historical period and the projections considering all the scenarios.

PRECIPITATION ANOMALY



EXPECTED VARIATION FOR PRECIPITATION AT 2050

The indicators show variations in selected precipitation characteristics for a thirty-year period centred on 2050 (2036-2065) with respect to the reference period 1985-2014.

-5.6%
-3.4%
-1.9%
Annual total precipitation

-1.1%
+0.7%
+0.9%
Precipitation of wettest month

-1.4%
-4.4%
-1.2%
Precipitation of warmest quarter

VARIATION OF SPECIFIC CLIMATE INDICATORS

Climate indicators variation showing impacts of climate change on sectors such as agriculture, health and water. Analysis considers 3 threshold average temperature increase: **+1.5°C**, **+2°C**, **+4°C**.

+39%
+20%
+15%
Agricultural drought proportion of time
% of time

+24%
+13%
+11%
Hydrological drought proportion of time
% of time

+4,825%
+688%
+263%
Heatwave duration
% of time

+42%
+16%
+6%
Runoff increase
% of area

+77%
+42%
+27%
Agricultural drought frequency
% of change

+14%
+11%
+15%
Hydrological drought frequency
% of change

+95%
+58%
+33%
Heatwave frequency
% of change

+8%
+3%
+1%
Runoff decrease
% of area

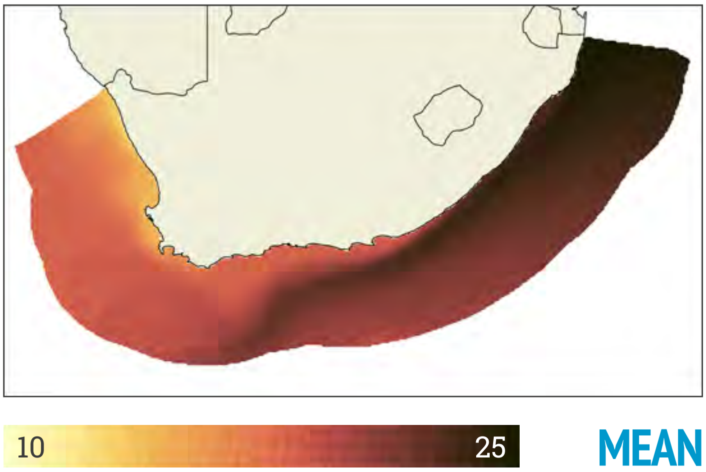
SOUTH AFRICA
OCEAN

OCEAN IN SOUTH AFRICA

South Africa's marine exclusive economic zone (EEZ) varies from colder Atlantic waters to temperate conditions on the Indian Ocean and hosts different coastal ecosystems, such as coral reefs, seagrass meadows and kelp beds. The country's coastal systems are naturally diveded into two areas: the Atlantic and Indian marine regions.

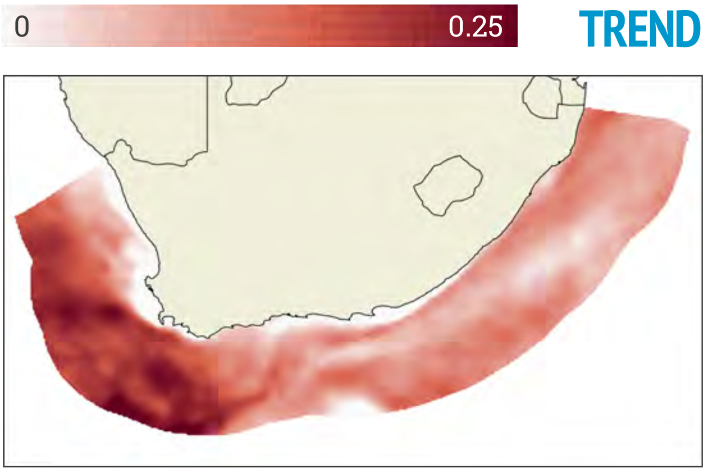
CURRENT CLIMATE CONDITIONS

Mean sea surface temperature reflects the different climate regimes, from the relatively cold waters of the Atlantic region to the warmer ones of the Indian coasts.



SEA SURFACE TEMPERATURE

Celsius degrees / Over 1991-2020

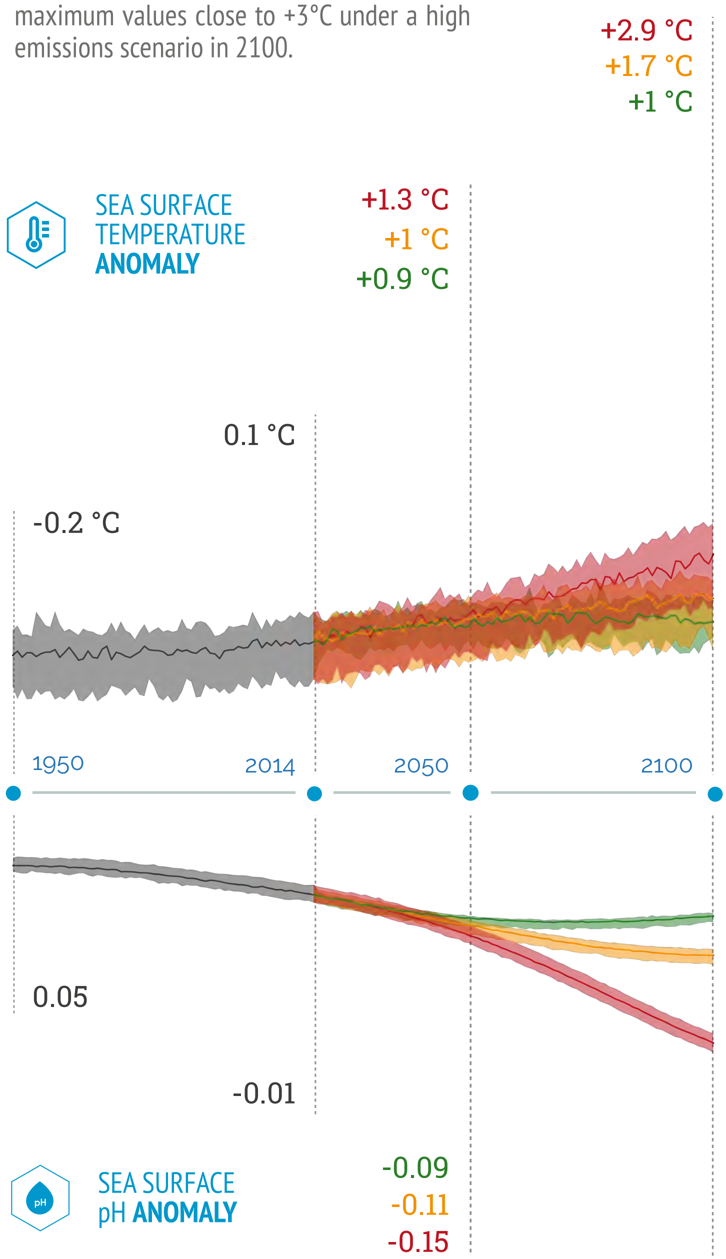


Surface temperature trends indicate a general warming of 0.1°C per decade in all marine areas, with increased gains in the south-western areas.

FUTURE PROJECTIONS

Projected annual changes within the marine EEZ for the two most significant marine indicators of climate change: sea surface water temperatures and pH.

Seawater temperature changes are in line with the definitions of each scenario, with maximum values close to +3°C under a high emissions scenario in 2100.



Seawater surface pH becomes more acidic in all scenarios, closely reflecting rising atmospheric CO_2 concentrations, and only a low emissions scenario leads to a stable condition by 2100.

ECOSYSTEM INDICATORS AT 2050

Regional changes in key marine ecosystem indicators under projected future scenarios by mid-century (2036-2065) with respect to present climate conditions (1985-2014).

Atlantic

Indian

Temperature regulates the metabolism of marine organisms determining which habitats remain suitable. Excessive warming will likely push ecosystems beyond tolerance thresholds.

pH represents the acid/base status of marine waters, where a decreasing pH reflects the acidification of the ocean due to increased absorption of atmospheric CO_2.

Oxygen is fundamental to sustain marine life and its reduction can have a large impact on coastal ecosystem services including fisheries and aquaculture.

Chlorophyll is an indicator of the biomass available at the base of the marine food web supporting all ecosystem productivity.

	Atlantic				Indian			
Temperature	18.89°C	+1.24 °C	+1.04 °C	+0.83 °C	22.56°C	+1.47 °C	+1.13 °C	+1.08 °C
pH	8.11	-0.15	-0.12	-0.09	8.11	-0.15	-0.11	-0.09
O_2	235.24 mmol/m³	-1.52 %	-1.12 %	-1.23 %	221.04 mmol/m³	-2.54 %	-1.89 %	-1.74 %
Chlorophyll	0.69 mg/m³	-2.75 %	-0.14 %	-1.3 %	0.37 mg/m³	-11.41 %	-12.23 %	-10.6 %

FISH CATCH POTENTIAL

Fish catch potential is an estimate of the maximum fish catch achievable given the marine resources available over a sustained period. It is linked to the concept of maximum sustainable yield, meaning the maximum amount of fish that can be extracted from a system without causing a collapse in fish populations.

It is a characteristic of the natural system, which is substantially different from realized catch, and a direct result of the fishery policy in place.

Fish catch percentage change

2050

-11.2%

-6.0%

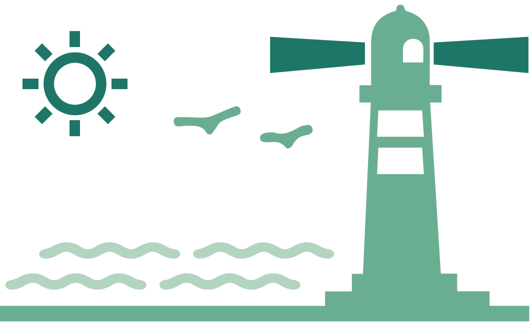
ANALYSIS DETAILS

All datasets were analysed using only data from within the marine EEZ and therefore excluding overseas territories, detached islands and any disputed or joint territories with other nations. In the assessment of current climate conditions, seawater surface tempererature data was obtained using satellite observations distributed in the framework of ESA Climate Change Initiative.

Future projections of marine indicators are represented by the combined analysis of results from 15 different Earth System models participating in the Coupled Model Intercomparison Project Phase 6 (CMIP6). These models include new and better representations of physical and biogeochemical processes, compared to previous IPCC assessment reports.

Fish catch potential data was obtained using the FAO's technical report and refers to the best and worst case climate scenarios from the Fifth IPCC Assessment Report. These mean estimates are subject to substantial uncertainties as discussed in the original work.

SOUTH AFRICA COASTS



OVERVIEW

With 3,751 kilometres of shoreline, the South African coast is very diverse. To the west beaches, cliffs and arid landscapes face the Atlantic Ocean, whereas to the east temperate and grassy environments look out over the Indian Ocean.The largest coastal settlements on are Cape Town and Durban, each with more than 3 million inhabitants, and Port Elizabeth, with around 1 million. The coastal economy has been evolving in recent years, with more economic activity and an increasing population.

Shoreline Length 3,751 km

Sandy Coast Retreat at 2050 -15.3 m

CLIMATE CHANGE HAZARDS

Coastal hazards such as erosion, storm tide inundation and permanent flooding, can have strong adverse impacts on coastal regions, with loss of sandy shores, damage to settlements, infrastructure and ecosystems. Climate change can exacerbate these impacts due to rising sea levels and increasing impacts of waves and storms. Climate change impacts on the coastal zone of South Africa are mainly driven by rising sea levels and possible changes in storm intensity and direction, affecting both the east and west coasts. Some parts of South Africa are also sensitive to the risk of sea level rise and land loss, with the main urban centres on the coast already being actively managed with coastal protection structures. In general, the beaches of South Africa are likely to be impacted by coastal erosion and recession.

SEA LEVEL RISE

Relative sea level rise has been observed over the past century around the coast of South Africa, with a yearly average increase of approximately 1.71 millimetres per year since the 1990s. The latest IPCC projections indicate that, by 2050, global sea levels may rise between 0.18 metres, under a low emissions scenario, and 0.23 metres, under a high emissions scenario.

Observed and projected sea level rise at 2050

1.71 mm/year

0.23 m

0.18 m

EXTREME SEA LEVEL

On average, one in 100 extreme sea level events are expected to rise from 2.29 metres at present day to 2.54 metres by 2050 under a medium emissions scenario.

Current and projected extreme sea level at 2050

2.29 m

2.62 m

2.54 m

OBSERVED STORMS

The wave climate of South Africa is influenced by different types of storms developing both in the South Atlantic and the Indian Ocean. Waves significantly affecting the coastal zone and its infrastructure are generated mainly in the southern Atlantic, or by low pressure systems along the southern to eastern coast and, occasionally, by tropical cyclones moving down the Mozambique channel. The wave climate around the South African coast shows clear seasonality and varies in intensity and directionality.

FUTURE STORMS

Although averages appear to remain constant, there seems to be some variation in individual storm intensities. For example, considering the peaks of individual storms during the more extreme winter period (June to August), an increasing trend of about 0.5 metres over 14 years has been observed. The trend could be indicative of a significant increase in storminess over the coming decades. What is clear is that rising sea levels will also increase the frequency of extreme sea level events.

VULNERABILITY AND RISK

In South Africa the most important drivers of risk to coastal infrastructure from erosion and flooding are waves, tides and future sea level rise.

With most of the coastal population concentrated in a relatively limited number of coastal cities, such as Cape Town and Durban, the population exposure is relatively low given the nature of the shoreline that combine sandy beaches and rocky shores.

Beaches are likely to recede and nearby infrastructure to be damaged in some locations, however, widespread land loss is not expected. Recent estimates show that, under a medium emissions scenario, the total population exposed to the annual coastal flood level is expected to increase from 50,000 to 60,000 people by 2050.

VULNERABLE POPULATION

HISTORICAL

0.05 Million

2050

0.06 Million

0.06 Million

0.06 Million

2100

0.09 Million

0.07 Million

0.06 Million

INFLUENCE OF SEA LEVEL RISE ON EXTREME SEA LEVEL

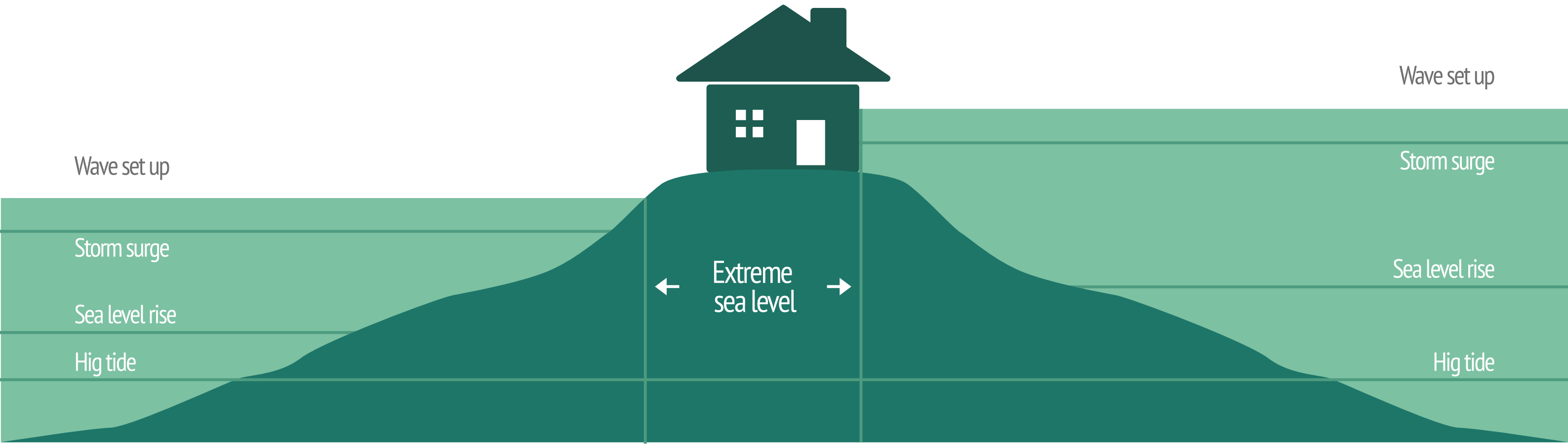
Present and future sea level rise are a consequence of carbon induced global warming causing melting ice and ocean expansion due to heat accumulation.

The extreme sea levels reported here are based on the 100-year storm surge + wave set up + sea level rise + high tide indicators. The first two parameters (storm surge + wave set up) are based on the 100-year value for the event; sea level rise is its projected value at 2050; and high tide is the absolute value of the highest tide calculated for a given locality, which won't be influenced by climate change.

+ **Wave set up** refers to the accumulation of water near the shore due to the presence of breaking waves.

+ **Storm surge** is an occasional increase in sea level driven by shoreward wind-driven water circulation and atmospheric pressure.

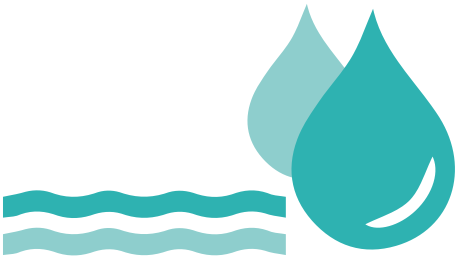
+ **High tide** is usually the highest tide reached in a given location based on tide records.



Present sea levels have risen globally by approximately 20 centimetres over the past century.

Future sea level rise is a projection based on different global warming scenarios, at approximately 100 centimetres by the end of 2100, with consequent inundation during extreme sea level events.

SOUTH AFRICA
WATER



OVERVIEW

South Africa's water resources are, in global terms, scarce and extremely limited. The average rainfall of 450 millimetres per year is well below the world average of 860 millimetres; evaporation is comparatively high; no truly large or navigable rivers exist; and the combined runoff of 49 billion cubic metres per year is less than half of that of the Zambezi River, the closest large river to South Africa.

In addition, South Africa has scarce groundwater resources and the natural availability of water across the country is highly uneven with more than 60% of the river flow arising from only 20% of the land.

Four of South Africa's main rivers are shared with other countries, which together drain about 60% of the country's land area and contribute about 40% of its total river flow.

Renewable internal freshwater resources	45 billion m^3
Renewable internal freshwater resources per capita	786 m^3

With an average precipitation of about 460 millimetres per year, South Africa is a very arid country, especially when compared to the world average precipitation of 860 millimetres per year. Sparse precipitation is aggravated by exceptionally high potential evapotranspiration, that ranges from about 1,800 millimetres per year in the east of the country to more than 3,000 millimetres per year in the north-western part of the country. For the majority of the country, rainfall occurs predominantly as brief afternoon thunderstorms in the summer months. The Western Cape is the exception, which has a typically Mediterranean climate, with frontal rainfall that is concentrated in winter.

CLIMATE CHANGE HAZARDS

Climate change can affect water resources through increasing temperatures, higher rates of evapotranspiration and altered rainfall patterns. This leads to changes in the water cycle, including decrease of snow and ice coverage, alterations of surface runoff and groundwater storage, as well as drought and flood occurrence. Based on rising population, economic growth projections, and current efficiency levels, demand for water by people, industry and agriculture is expected to rise by 17.7 billion cubic metres by 2030, while water supply is projected to amount to 15 billion cubic metres, representing a 17% gap between water supply and demand. Climate extremes are also expected to change in South Africa.

KEY POINT RUNOFF

South Africa's water requirements are mostly provided through surface runoff, captured in rivers and dams. Irrigation accounts for about 62% of the country's water use, while delivering a substantially lower economic yield per unit water than through the other sectors. Lately, the use of groundwater has increased dramatically, primarily due to extraction for irrigation. Nationally, irrigation accounts for over 64% of groundwater use.

At a country scale, an average increase in surface runoff by approximately 5% and 9% is expected respectively under low and high emissions scenarios for the 2045-2055 period compared to 2015-2025. If temperatures rise by 1.5°C, 2°C or 4°C, 1%, 3.2% or 8% of the area of the country will likely experience an increase in runoff, while 6%, 15.5% or 42% of the surface of the country will likely experience a decrease in runoff, respectively.

2050	Changes in annual runoff % of change	+9.0%	+5.0%
2050	Runoff increase % of area	+8.0%	+1.0%

KEY POINT DROUGHTS

South Africa is subject to the occurrence and impacts of droughts, in particular in its western and northern provinces. Frequent droughts in the past have occurred, with detailed records of droughts since the 1950s and very damaging droughts in the 1980s, 1990s and 2010s. Droughts in South Africa are mainly driven by climatic forces and by the influence of climate oscillations such as the El Niño, which is associated with extreme drought conditions.

The latest extreme drought is the 2018-2020 drought caused by the latest El Niño event. Droughts are expected to increase in the future, driven by increasing water use and changing global climatic patterns. More frequent and stronger El Niño events are also possible.

2050

Severe drought likelihood increase

% of change

+38.9%

+21.2%

2050

Hydrological drought frequency

% of change

+14.0%

+10.0%

2050

Groundwater Recharge

% of change

-11.0%

-9.2%

KEY POINT GROUNDWATER

The total renewable groundwater in South Africa is estimated at 10,343 million cubic metres per year (or 7,500 million cubic metres per year under drought conditions), while the current use is between 2,000 and 4,000 million cubic metres per year. In South Africa, groundwater is widely used for rural water supply, particularly in the east of the country, and also for irrigation, particularly in the west.

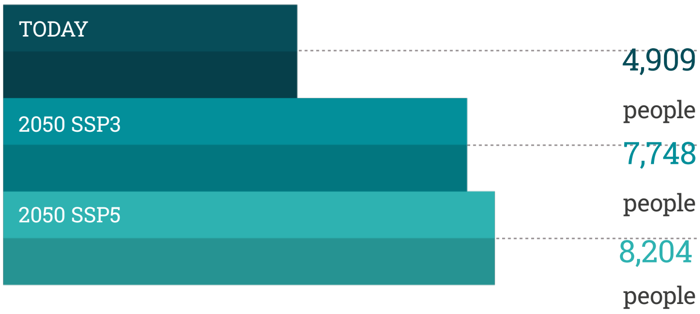
Current estimated groundwater use is between 2,000 and 4,000 million cubic metres per year. Groundwater in South Africa is often overexploited and droughts are causing the depletion of renewable reservoirs. At the country level, a -8.2%, -9.2% and -11% decrease of the annual groundwater recharge for the period 2045-2055 compared to the timeframe 2015-2025 is expected respectively under under low, medium and high emissions scenarios.

KEY POINT FLOODS

Floods are the most frequently recorded disaster in southern Africa. South Africa is no exception and experienced 77 major floods between 1980 and 2010, costing the lives of at least 1,068 people. Many severe floods have occurred since 2010 with losses of life, livelihoods and extensive damage to built infrastructure. Major floods have affected large urban areas such as Johannesburg, Durban and Cape Town.

The highest variability in storm flows can be seen in the western interior, whereas the lowest variability is found in parts of the Eastern Cape, KwaZulu-Natal and the Free State. Changing rain patterns may affect the frequency and intensity of floods and the population exposed to river floods is expected to increase from about 5,000 in the present day to about 7,700 under SSP3 and 8,200 under SSP5 by 2050, with a potential higher impact of river flood events.

POPULATION AFFECTED BY RIVER FLOODS

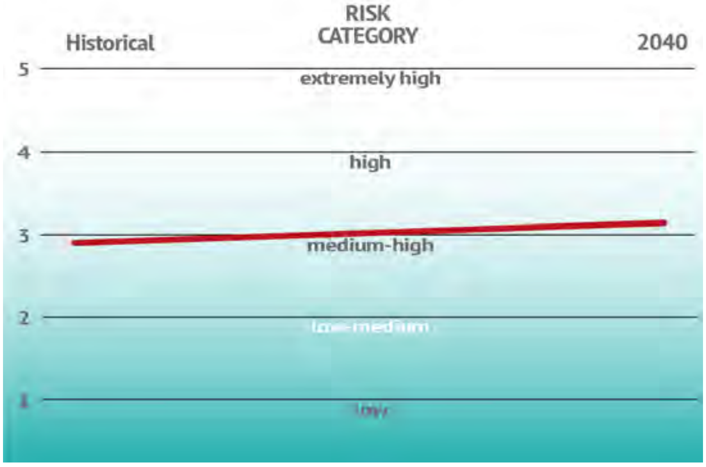


RISK INDICATORS

The water stress index summarises current and future water related vulnerabilities and risks at the global level. Scores are based on the ratio of total water withdrawals, including agriculture, industrial and human consumption, to available renewable surface and groundwater supplies.

WATER STRESS

South Africa's water stress level is considered medium-high for the recent past (1960-2014 average), and it is expected to increase in the near future (2030-2050) based on climate change projections.



SOUTH AFRICA
AGRICULTURE

OVERVIEW

South Africa has a market-oriented agricultural economy that is highly diversified with production of major grains, oilseeds, deciduous and subtropical fruits, sugarcane, citrus, wine and most vegetables. The agriculture to GDP ratio has been decreasing steadily as other sectors have emerged over the years. However, the total value of the sector increased six-fold from 1970 to 2018.

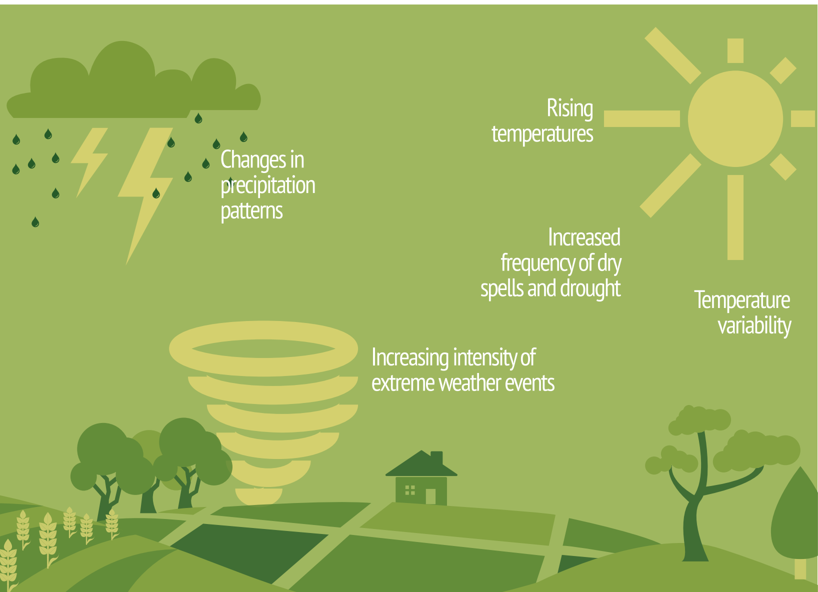
South Africa features a range of agro-ecological zones, including Fynbos, Savanna, Grassland, Nama Karoo, Succulent Karoo, Forest, and Albany Thicket. Each has unique rainfall patterns, and diversified rainfed agricultural conditions. Such diversity allows for the production of different agricultural commodities. Agriculture share was estimated at 60% of total water withdrawal in 2018, with groundwater extensively used in rural and arid areas.

19.3 Mt	Sugarcane
12.5 Mt	Maize
2.9 Mt	Citrus
2.5 Mt	Potato
1.9 Mt	Grapes
1.9 Mt	Wheat

	Added Value of Agriculture, Forestry and Fishing	Share of Agriculture Value added in Total GDP	Agricultural land	Area Equipped for Irrigation
2000	4,971 USD Million	2.5 %	14,197 Thousand HA	1,498 Thousand HA
2018	6,875 USD Million	2.1 %	12,413 Thousand HA	1,670 Thousand HA

EXPEXTED IMPACTS ON AGRICULTURE PRODUCTIVITY

Rising temperatures, reduction in average annual precipitation, and intensification of extreme events such as heat waves and drought, affect production variability with a tendency towards yield reduction for many cultivated species, accompanied by a probable decrease in food quality. Crops respond to increases in temperatures with changes in duration of the growing season, early appearance of phenological phases and potential shifts of cultivation areas toward higher latitudes and altitudes for better growing conditions. However, impacts vary significantly depending on the geographical area and specific crops in question.



CROP PRODUCTIVITY

Crop productivity refers to the harvested yield of a crop per unit of land area. It is strongly influenced by climate and other environmental and management factors.

Climate change is expected to have an impact on the productivity of several major crops, although this may in part be offset by the fertilizing effect of higher CO_2.

Impacts are estimated using a range of model projections based on low to high emission scenarios and reported as percentage changes between the 30-year average around the historical period and the 30-year average around 2050.

67.8 -4 (-3.8)% -6 (-7)%
Sugarcane
tons / ha

5.1 -0.7 (-2.2)% -1.4 (-2.5)%
Maize
tons / ha

3.3 -1.6 (-5.9)% -1.6 (-8.9)%
Wheat
tons / ha

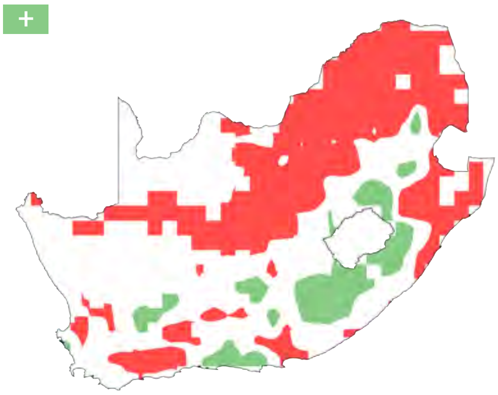
1.4 7.9 (-1.8)% 11.1 (na)%
Sunflower
tons / ha

2050

Productivity change with (without) the CO_2 fertilization effect. Estimates assume sufficient water and nutrient supplies, and do not include impacts of pests, disease, or extreme events.

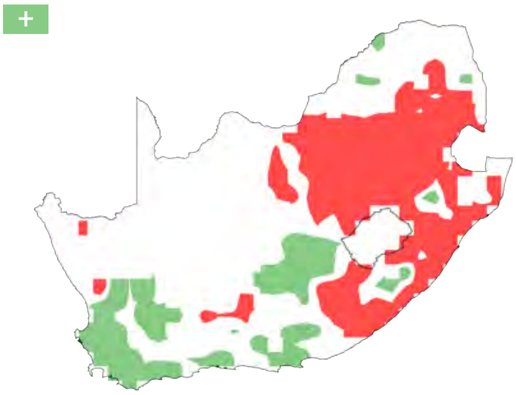
CHANGE IN MAIZE

🟥 − = 🟩 +



CHANGE IN WHEAT

🟥 − = 🟩 +



Key staples such as maize and wheat may suffer a decline in productivity due to extreme heat exposure, with largest yield productivity losses identified in the northern provinces. The impact of climate change will vary among different wheat cultivars. An average marginal decline in wheat productivity at country level, as well as projected yield increases in the Western Cape provinces, are expected. Although sugarcane biomass growth is expected to increase, the sucrose level may decrease due to higher rates of respiration and structural growth.

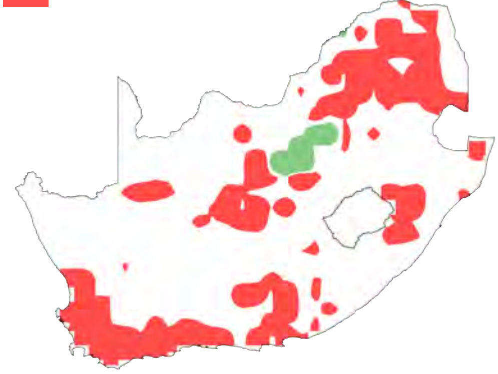
Sunflower seed cultivation may largely benefit from climate change, with general and consistent increases in productivity. Under moderate warming, irrigated vineyards will maintain and increase productivity. For more significant warming, from 2 to 3°C small reductions of 2 to 5% are expected. Larger losses in productivity (10-15%) are expected for non-irrigated vineyards. Fruit Production (apples, pears) in the Western Cape will suffer from lack of winter chilling following warming.

ADAPTATION IN AGRICULTURE AND WATER RESOURCES

One of the major issues affecting future South African agriculture will be linked to more recurrent and pronounced droughts and worsening water security. South Africa has endured ongoing droughts since 2014, most notably in the Western Cape. Over 338 million USD have been lost in the Western Cape agricultural economy due to drought. Irrigation demand in South Africa is highly likely to rise in the future due to increasing temperature and plant evapotranspiration. This increase is likely to result in added pressure on existing water resources, which may in turn lead to less certain water supply for crops and smaller yields from irrigated agriculture.

CHANGE IN WATER DEMAND

🟩 − = 🟥 +



Agriculture
Water Demand
% of change

+21.7% +24.6%

2050

A substantial increase in water demand (20-25%) is expected to maintain agricultural production, which will require adaptation, agronomic practices and crop varieties enhancing water-use efficiency to limit stress on water resources.

SOUTH AFRICA FORESTS

FORESTS IN SOUTH AFRICA

Although highly fragmented, South African forest resources are diverse, rich in biodiversity and widespread, particularly in the central-eastern coastal areas. Their shape is strictly related to the passage of fire.

Afro temperate, coastal, Misbelt, scarp and sand forests are the main types of ecosystems with small strips of mangroves in the estuaries of the east coast which are now critically endangered.

1990

18 Mln ha
Million hectares
Forested area

50 Tons/ha
Tons of Carbon per hectare
Carbon stock

2020

17 Mln ha
Million hectares
Forested area

50 Tons/ha
Tons of Carbon per hectare
Carbon stock

FORESTED AREA AND CARBON STORAGE

South Africa is not a highly forested country. Approximately 15% of the land surface is covered in forests,and the trend has been steadily decreasing in recent decades. Approximately 0,9 gigatonnes of carbon are stored in wooded lands (soil included), with an important portion stored in mangrove ecosystems. South African forests are a net carbon sink.

2050

Productivity anomaly
Tons of Carbon per hectare per year

+0.36

+0.28

FOREST PRODUCTIVITY

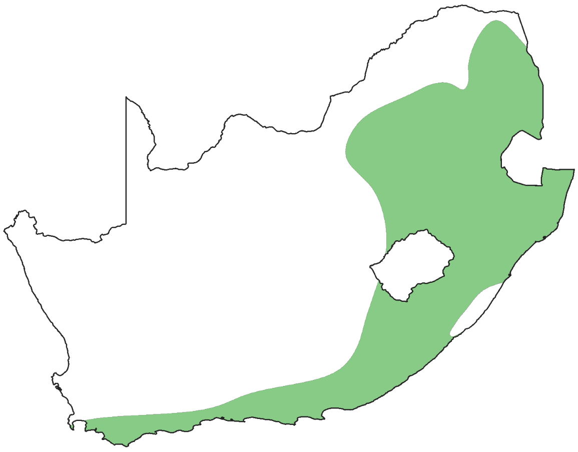
Forest productivity or Net Primary Production is the net carbon captured by plants. It is the difference between the carbon gained by Gross Primary Production - net photosynthesis measured at the ecosystem scale - and carbon released by plants' respiration. It is expressed per unit land area.

Increase particularly in the south and south-east

+ Fertilizing effect of increasing atmospheric CO_2 and nitrogen deposition promote productivity

No areas with an expected decrease in forest primary production

+ Increasing dry season reduces productivity



KEY SPECIES UNDER CLIMATE CHANGE

ENDANGERED
INDIGENOUS
Regenerative capacity of indigenous forest resources are negatively affected by climate extremes

LESS SENSITIVITY
PINUS
Pinus species show less sensitivity to rising temperatures

REDUCTION
REFORESTATION
climate change will probably reduce areas suitable for plantation forests significantly

VULNERABILITY
MANGROVES
Rapid sea level rise will threaten coastal mangrove forests significantly

FIRES IN SOUTH AFRICA

Fire is a structural ecological process that provides several types of ecosystem services and impacts on socio-ecological systems, including human health, carbon budgets, and climate change. Changes in global fire activity are influenced by multiple factors such as land-cover change, policies, and climatic conditions. Fire also releases large quantities of greenhouse gases into the atmosphere, contributing to a vicious cycle.

During the last two decades, the total forest area affected by fire amounts to approximately 0.42 million hectares.

BURNING
0.42 MILLION HECTARES OF FOREST

EMITTING
9.78 TERAGRAMMES OF CARBON PER YEAR

SAVANNA FIRE EMISSIONS CONTRIBUTED TO 84% OF TOTAL FIRE RELATED CARBON EMISSIONS

COSTING
7.8 MILLION USD IN ANNUAL SUPPRESSION COSTS

WHERE DO FIRES OCCUR?

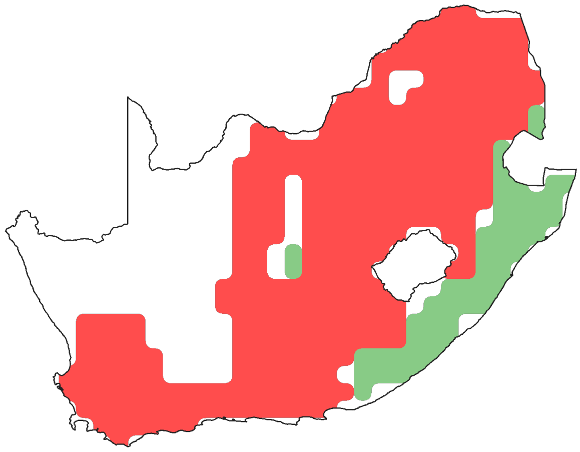
Wilfires mostly affect mountain grasslands and fynbos.

Historically, forest fires are concentrated in the mountainous regions of KwaZulu-Natal and Mpumalanga in the north-east, as well as across the Western Cape.

FUTURE BURNED AREA

Under a low emissions scenario, models project a generalized increase in burned area from Western Cape to the north-eastern regions, encompassing Mediterranean forests, desert shrublands, montane grasslands and subtropical forests. Under a medium emissions scenario, the spatial pattern is expected to be similar. In the future, burned areas might decrease across south-eastern areas.

Burned Area
km² per year



Decrease in burned areas for a low emissions scenario

Increase in burned areas for a low emissions scenario
+ Prolonged fire season length and increased fire exposure in terms of weather conditions considered conducive to fires

CASE STUDY: INVASIVE SPECIES

Invasive alien species not only threaten native vegetation but also affect flammability and fire behaviour.

In 2017, exacerbated by an unprecedented drought, wildfires burned 15,000 hectares in Western Cape destroying more than 800 buildings and killing 7 people. Over half of the biomass consumed belonged to invasive species increasing wildfire severity and difficulty of firefighting.

Large fires might also affect natural touristic attractions impacting on ecosystem services. For instance, in 2018 large fires burned more than 86,000 hectares along the Garden Route in the southern part of the country.

FUTURE FIRE EMISSIONS

Fire emissions follow a similar spatial pattern to burned areas under both low and medium emissions scenarios.

Fire Carbon emission
Teragrams of Carbon per year

SOUTH AFRICA URBAN

OVERVIEW

In South Africa, 67.4% of the population lives in urban areas. This rate is expected to rise both in relative and absolute terms: whereas the urban population currently 39.5 million, it is expected to increase to 58 million, with an urbanization rate of 79.8%, by 2050.

Increases in population are expected, particularly in big agglomerations with more than 5 million inhabitants and in small centres with a population of less than 300,000 people.

While the urban population is increasing, cities need to tackle important challenges related to poverty and inequality as 25% of urban dwellers live in inadequate urban environments lacking basic services.

Built up areas cover only 0.89% of South Africa (10,873.57 square kilometers).

Population in Urban Areas

2020 39,550,889

2050 58,056,843

Graphs refer to data provided by United Nations, Department of Economic and Social Affairs, Population Division (2018). World Urbanization

Urbanization Rate

2020 67.4%

2050 79.8%

OVERVIEW OF KEY CLIMATE IMPACTS IN URBAN AREAS

Climate change impacts are enhancing urban challenges in South Africa. The main climate stressors are increasing heat and water related stress.

HEATWAVES AND HEAT STRESS

Mean temperatures in South Africa are rising and the country is experiencing a significant number of heatwaves. Heatwave impacts in South African cities are actually scarcely monitored due to lack of data.

In Cape Town, a three years drought brought the city's urban water supply down to critical levels of water scarcity in 2018. It was revealed that, already under present day conditions, 28% of South African towns have inadequate water resources and are in need of urgent attention for ensuring equal access to safe drinking water.

With regards to the future climate and the expected rise in both duration and intensity of heatwaves, heatwaves are recognized as an additional challenge for future urban policies. The city of Durban, for instance, expects an increase in mean temperatures by **1.5°C** to **2.5°C** by 2065, as well as an increasing number of heatwaves.

2050 Cooling Degree Days
% of change
+89.0%
+35.0%
+22.0%

2050 Heatwave frequency
% of change
+95.1%
+57.8%
+33.1%

2050 Heatwave duration
% of time
+4,825%
+688%
+263%

UNEQUAL EXPOSURE AND COMPOUNDED IMPACTS

Rising temperatures in urban areas cause health impacts, most of which are felt among those living in poorer neighbourhoods and informal settlements, with limited access to electricity - and thus to air conditioning - and poor housing quality.

For Cape Town, most informal settlements were found to be part of the city's hot spots for urban heat island effects, due to lack of vegetation. Furthermore, the urban heat island effect enhances the impacts of air pollution. The entire urban population of South Africa is constantly exposed to air pollution levels which exceed threshold values recommended by the WHO.

2017

Population exposed to air pollution

100.0%

COASTAL FLOODING

Nearly 20% of the South African coastline has some form of development at less than 100 metres from the shoreline, resulting in a high amount of settlements and infrastructure at risk of storm surges. Due to rising sea levels, such impacts are beginning to affect coastal areas and tourism related infrastructure.

2050

Projected sea level rise

0.23 m

0.18 m

2100

0.77 m

0.38 m

CHANGING PRECIPITATION PATTERNS

Intensity of precipitation events increased, whereas the number of rain days has decreased significantly over the last 50 years. In Cape Town, many of the poorer neighbourhoods found in low-lying areas with high groundwater levels are regularly flooded.

The areas have no stormwater infrastructures and lack systems for waste water disposal. More wealthy neighbourhoods are located on higher ground and are therefore rarely affected by floods. Despite increasing trends in annual precipitation, changing rainfall patterns will bring more intense precipitation events, which increase the risk of flash floods and landslides.

2050

Runoff increase

% of area

+8%

+3%

+1%

SURFACE SEALING AND FLOODS

Heavy precipitation in cities is problematic due to the high level of sealed surfaces. Soil sealing increases run off and reduces the amount of water absorbed by soil. Where there are large amounts of impervious ground cover, short duration extreme rainfall events can lead to increased flooding, even resulting in flash floods.

INFORMAL SETTLEMENTS

Due to high rates of urban growth and a high percentage of households living in slum areas, the exposure of the South African urban population to future floods is critically high. Low income households are particularly affected as these are frequently situated in low lying areas and lack efficient drainage systems.

These urbanization patterns, created during the apartheid period, could lead to the creation of high risk areas and poverty traps where high rates of losses and damages go hand in hand with limited ability to cope and adapt due to marginalization, high poverty, and culturally-imposed gender roles.

2010

% of urban population

Population living in slums

25.6%

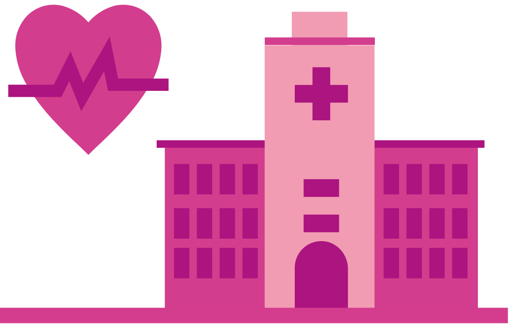
2018

% of total population

Urban population living in areas where elevation is below 5 meters

0.1%

SOUTH AFRICA
HEALTH



OVERVIEW

South Africa already has a high burden of disease linked to environmental stressors, and climate change will exacerbate many of these social and environmental issues. Health risks that climate change may aggravate over the next few decades include: heat stress; vector-borne diseases (such as malaria, dengue fever and yellow fever); extreme weather events; air pollution; and communicable diseases.

HEAT RELATED MORTALITY

Warming and increased frequency and duration of heatwaves has already affected the wellbeing of the South African population.

Under a high emissions scenario, heat-related deaths in the elderly (65+ years) are projected to increase to about 116 deaths per 100,000 by 2050, compared to the baseline estimate of about 2 deaths per 100,000 annually between 1961 and 1990.

Under a low emissions scenario, heat-related deaths in the elderly will increase to 20 deaths per 100,000 in 2050. In 2018, there was a 74% increase in heat-related deaths in South Africa compared to the 2000 to 2004 baseline. 43.8% of heat-related mortality in South Africa, from 1991 to 2015, can be attributed to human-induced climate change.

IMPACTS ON LABOUR

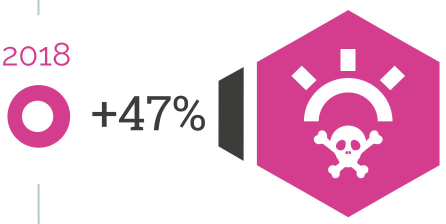
Labour is directly affected by changes in environmental conditions. Warming affects both the number of hours worked (labour supply) and on the productivity of workers during their working hours (labour productivity). Both labour supply and productivity are projected to decrease under future climate change in most parts of the world, and particularly in tropical regions.

Parts of sub-Saharan Africa, south Asia, and southeast Asia are at highest risk under future warming scenarios. Future climate change will reduce global total labour in the low-exposure sectors by 18 percentage points and by24.8 percentage points in the high-exposure sectors under a 3.0°C warming scenario

In South Africa, there was 39.9% loss in potential hours of labour in the agriculture and construction sectors in 2019, compared to the 1990s baseline. Total labour in South Africa is expected to decline by 1.2% under a low emissions scenario, and by 3.1% under a medium emissions scenario.

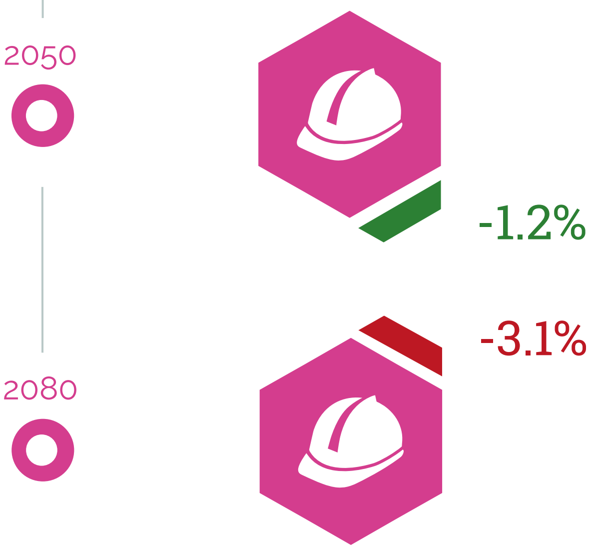
Heat-related mortality

% change with respect to 2000-2004



Impact on total labour

% change with respect to 1986-2005 baseline



CLIMATE CHANGE AND DENGUE

Dengue has spread throughout the tropical world over the past 60 years and now affects over half the world's population. Globally, vectorial capacity for both dengue vectors (A. aegypti and A. albopictus) has been rising steadily since the 1980s, with nine of the ten highest years occurring since 2000.

Climatic stressors are one important driver of the current distribution and incidence of dengue. Climate change is likely to expand the geographical distribution and suitability of several vector-borne human infectious diseases including dengue. The risk of dengue transmission is increased by warming climates, as the growth and development of mosquitoes are significantly influenced by temperature, precipitation, and humidity.

Dengue suitability

% of population at risk

CLIMATE CHANGE AND ZIKA

Zika virus has spread to at least 49 countries and territories since 2013. Climate change impacts on transmission suitability risk have increased over the years and future warming over 1.3 billion additional people could face suitable transmission temperatures for Zika by 2050.

Zika suitability

% of population at risk

DENGUE AND ZIKA: POPULATION AT RISK

As high temperatures and high levels of moisture are favourable conditions for the distribution of dengue vectors, these diseases are likely to increase in the future due to climate change.

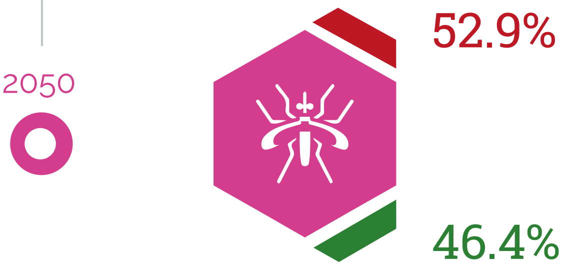
Under a medium emissions scenario, 92% of the population will be at risk of transmission-suitable mean temperature for dengue by 2050, whereas 93.5% will be at risk under a high emissions scenario. In the case of Zika, 38.8% of the population will be at risk by 2050 under medium emissions, whereas 56.3% will be at risk under high emissions.

CLIMATE CHANGE AND MALARIA

As mosquitoes thrive in a warm moist environments, there is enormous concern that projected global warming coupled with ecological factors may make malaria parasites spread over more provinces in South Africa. 46.4% of the South African population will be at risk of malaria under a low emissions scenario in 2050, whereas 52.9% will be at risk under a high emissions scenario.

Malaria suitability

% of population at risk



POLLUTION AND PREMATURE MORTALITY

Air pollutants, including particulate matter (PM), sulphur dioxide, ozone, carbon monoxide, benzene, lead and nitrogen dioxide, are a concern for public health, and their concentration in ambient air is regulated in South Africa. In addition, climate change will influence the concentration of criteria pollutants by affecting weather patterns. Ambient air pollution is estimated to have been responsible for 4% of deaths in South Africa in 2015.

SOUTH AFRICA
ENERGY

ENERGY SYSTEM IN A NUTSHELL

South Africa has one of the highest energy intensities of GDP in the world and relies heavily on domestic coal. Renewables hold a negligible share; the government is pushing to increase diversification of the electricity mix, but currently there is no clear indication about what sources are to be supported.

Due to income inequality, electricity use is skewed towards higher income households, with over half of it accruing to the richest 20% of the population.

0.19
ktoe/US$
Energy
intensity

1.1%
AC Share in
electricity
consumption

CLIMATE CHANGE TODAY

INCREASING TEMPERATURES

In South Africa, mean annual temperatures have increased at least 1.5 times the observed global average increase of 0.65°C during the last 50 years, resulting in increasing cooling needs.

EXTREME EVENTS

A lower water availability and increased exposure to extreme events has been observed. The severe floods of April 2019 severely damaged the electricity grid in the affected areas.

ENERGY SUPPLY

South Africa's energy mix is strongly dominated by coal for industrial use and electricity generation (73% of total primary energy supply in 2018) followed by (imported) oil for transport (15%), which also uses a significant volume of biofuels (6% of total primary energy supply). Natural gas (3%), nuclear (2%) and other renewables (1%) hold very modest to negligible shares. Hydropower is virtually non-existent (0.1%). The country imports oil, oil products and natural gas, but is otherwise more than self-sufficient.

ENERGY DEMAND

In South Africa, energy is used mainly by the industrial sector (41% of final demand in 2018, including non-energy uses accounting for 6.7% of total demand), transport (27%) and residential (19%), followed by commercial use (8.5%) and agriculture and fishing (3.2%). Air conditioning's contribution to residential electricity demand is minimal (1.1% in 2017, 6% of the households) due to the temperate climate, and to the limited affordability of electricity for most of the population.

FUTURE ENERGY DEMAND

South Africa has a dry/temperate climate; hence cooling needs prevails. This is projected to result in an increase in electricity demand of 421 PJ (or 117 million KWh) by 2050 under a medium emissions scenario. Air conditioning units are expected to increase exponentially from 12 million units in 2016 to 236 million units in 2050.

Net change in energy demand due to changes in DD/CDD
Billion KWh

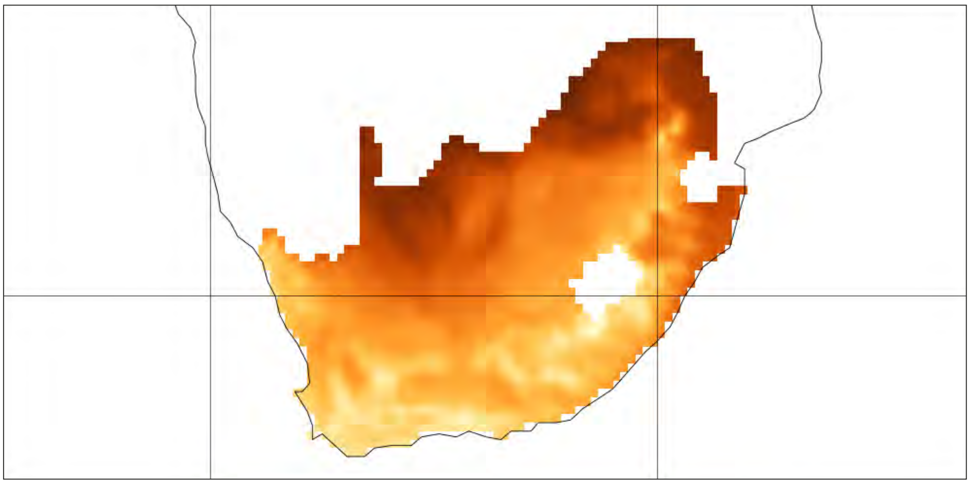
2050

+ 116.98

COOLING NEEDS

Strongest increases in cooling needs along the northern border. Moderate ones around the elevations where heating degree days are expected to drop the most.

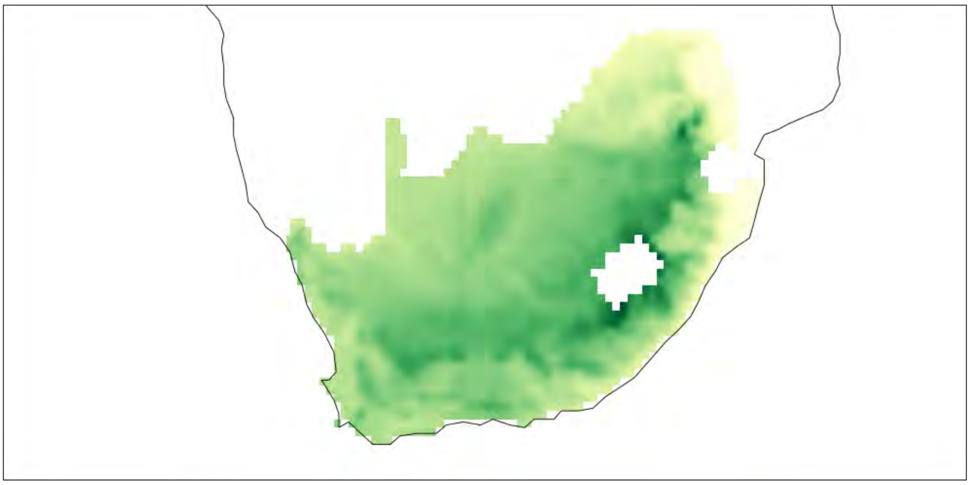
COOLING DEGREE DAYS



HEATING NEEDS

Moderate decreases in heating needs are expected all over the country; larger drops are expected in the southernmost elevations on the plateau above Cape Town, Sutherland, and the areas around Lesotho.

HEATING DEGREE DAYS



FUTURE ENERGY SUPPLY

The future configuration of the South African energy mix is likely to be determined by the evolution of energy policies and hence is outside the scope of this report.

There appear to be no long-term plans for decarbonization, and the push for diversifying away from coal has not yet taken a definite direction; the high relevance of the vulnerabilities of the coal extraction industry and of coal-fueled thermal plants is, however, posed to decrease in the coming decades.

Change in Hydropower generation
% of change

2050

-5.02%

-4.29%

EXPECTED IMPACTS OF CLIMATE CHANGE

There are no quantitative projections of the impacts of climate change on South Africa's energy sector (bar a modest drop in hydropower). Qualitatively, the main concerns are for the impact of increased frequency of extreme events on the energy system, and for the impact of droughts on the thermal efficiency of coal power plants.

SOUTH AFRICA
ECONOMY

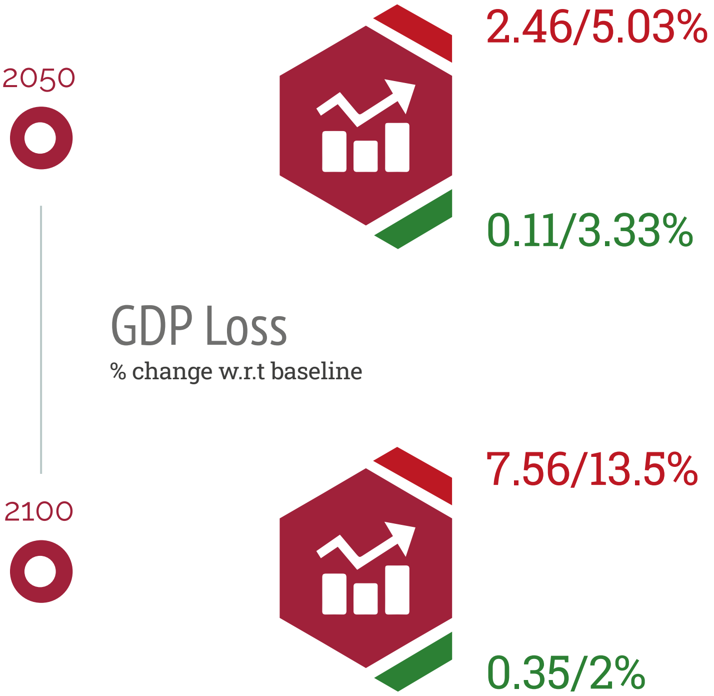
OVERVIEW

South Africa is ranked lowest among the G20 countries in terms of GDP. South Africa was badly hit by the COVID 19 pandemic, recording a decline in real GDP of 7% in 2020. However, the country is recovering with a growth rate of 3.1% in 2021.

IMPACTS ON GDP

Climate change will have an effect on the growth rate and overall economic performance of the country. By mid century, costs could reach between 8 and 12 billion EUR (or 3% to 5% of GDP) under low and high emissions scenarios, respectively.

By the end of the century South Africa could stand to lose up to 13.5% of GDP, or 33 billion EUR under a high emissions scenario.



2050

2.46/5.03%

0.11/3.33%

GDP Loss

% change w.r.t baseline

2100

7.56/13.5%

0.35/2%

SECTORAL ECONOMIC IMPACTS

IMPACTS ON INDUSTRY AND INFRASTRUCTURE

The South African coastline covers more than 3,000 kilometers and links together the east and west coasts of Africa. Infrastructure and economic activities on the coast are exposed to sea-level rise and storm surges.

Road infrastructure alone, assuming that no adaptation measures are taken, could total expected annual damages of 190 million EUR by mid century, rising to 323 million EUR by the end of the century.

IMPACTS ON AGRICULTURE

Climate change induced changes in temperature and precipitation are expected to reduce annual agricultural output.

By mid century, South Africa could lose between 5.7% and 7.1% of the agricultural sector's contribution to value added under medium and high emissions scenarios, respectively. This translates into an economic loss of between 94 million and 122 million EUR.

Predicted declines in agricultural productivity, the resulting increases in domestic prices and negative effects on trade are expected to have serious implications for household incomes that, by mid century, could be reduced by almost 5 billion EUR. All this is also expected to affect GDP growth. Impacts on agriculture alone can determine a drop in GDP by 6% by 2080 relative to a no climate change scenario.

Some slightly positive effects from moderate climate change cannot be excluded in the livestock sector. Under a low emissions scenario by mid century, gains to the ranglands livestock production of between 10.9 to 19.6 million EUR may be experienced due to increase in the productivity of some vegetation types.

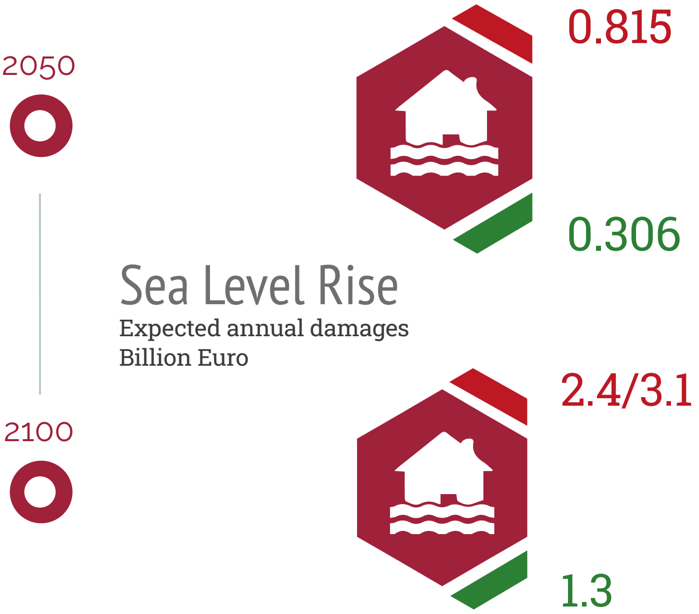
IMPACTS ON FORESTRY AND FISHERY

As a result of declines in the amount of suitable land available for forestry, by mid century also under a low emissions scenario forestry output could be reduced by as much as 43%, for a loss of 41 million EUR.

SEA LEVEL RISE DAMAGES

Under current levels of coastal protection, by mid century, sea-level rise and coastal flooding can cost the country 306 to 815 million EUR in terms of expected damages to assets under low and high emissions scenarios, respectively.

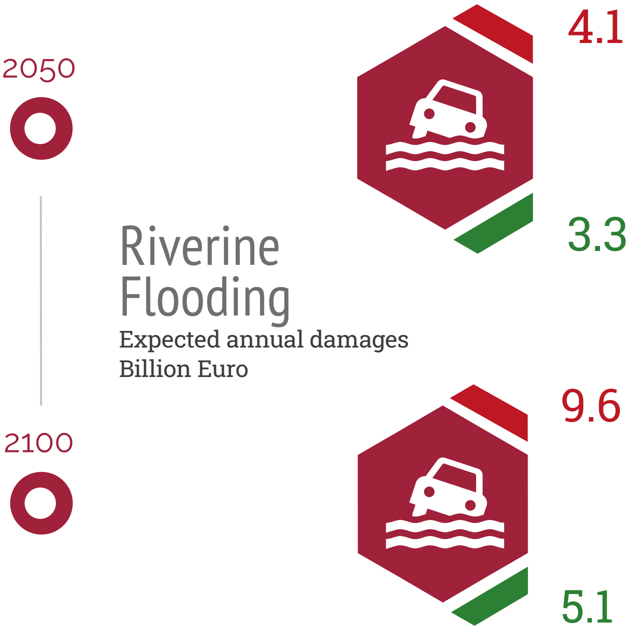
By the end of the century, expected losses may increase to 1.3 billion EUR under a low emissions scenario and 2.4 to 3.3 billion EUR under a high emissions scenario.



RIVER FLOODING DAMAGES

River flooding can also provoke non-marginal damages, in fact, potentially more severe than those from sea-level rise.

By mid century total asset losses could reach 3.3 to 4.1 billion EUR and in the second half of the century 5.1 to 9.6 billion EUR under low and the high emissions scenarios, respectively.



IMPACTS ON ENERGY

As with all other economic sectors, energy supply and energy networks in South Africa will undergo more intense stress from extreme weather events. Economic impacts of shifts in household and firm energy demand (see chapter on energy) are difficult to predict and will mostly lead to redistribution effects.

In the case of South Africa, the magnitude of the increase in demand for cooling is expected to exceed by far the one of the (tiny) decrease in heating demand, hence a significant increase in energy bills is expected.

IMPACTS ON TOURISM

The tourism sector has grown considerably in South Africa over recent decades, and is now a key component of GDP: roughly 11%, or 27.5 billion EUR. The sector is highly reliant on nature-based activities and hence is extremely sensitive to any changes in the climate and any losses to habitats and biodiversity. The country's unique natural resources are the primary attraction for tourists visiting South Africa, where 36% of international visitors were attracted by the wildlife, and 33% by scenic beauty.

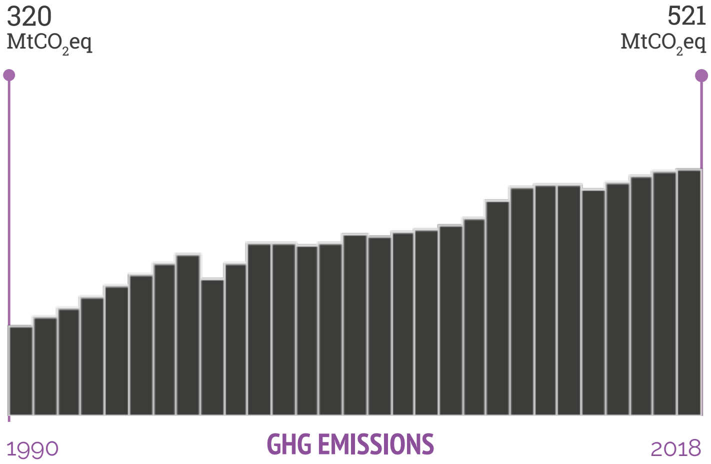
Increasing risk of malaria is expected to reduce the numbers of visitors in South Africa, as they will opt for areas free of the disease. No exact projections have been estimated for the losses to the sector under different climate change scenarios, but clearly the magnitude of losses would be large. Given that 36% of visitors were motivated by wildlife, South Africa stands to lose 3.6% of GDP, or €9 billion if this resource was completely eradicated by climate change. The exact contribution of biodiversity to the sector is difficult to calculate, but it is suggested that biodiversity losses could cost the tourism sector at least 0.23 billion EUR per year.

Additionally, rising temperatures and changing rainfall patterns could alter the length of the tourist season, with knock-on effects for related industries such as transport, restaurants, crafts and other tourist dependent business services such as tour guides.

SOUTH AFRICA POLICY

OVERVIEW

South Africa is the 15th largest emitter among G20 countries, and the 9th in terms emissions per capita. Emissions have increased significantly in recent decades.



GHG EMISSIONS

INTERNATIONAL COMMITMENTS

South Africa ratified the Paris Agreement and submitted its NDC in 2016, with the target of reaching peak carbon emissions by 2030.

CLIMATE POLICY COMMITMENTS CHRONOLOGY

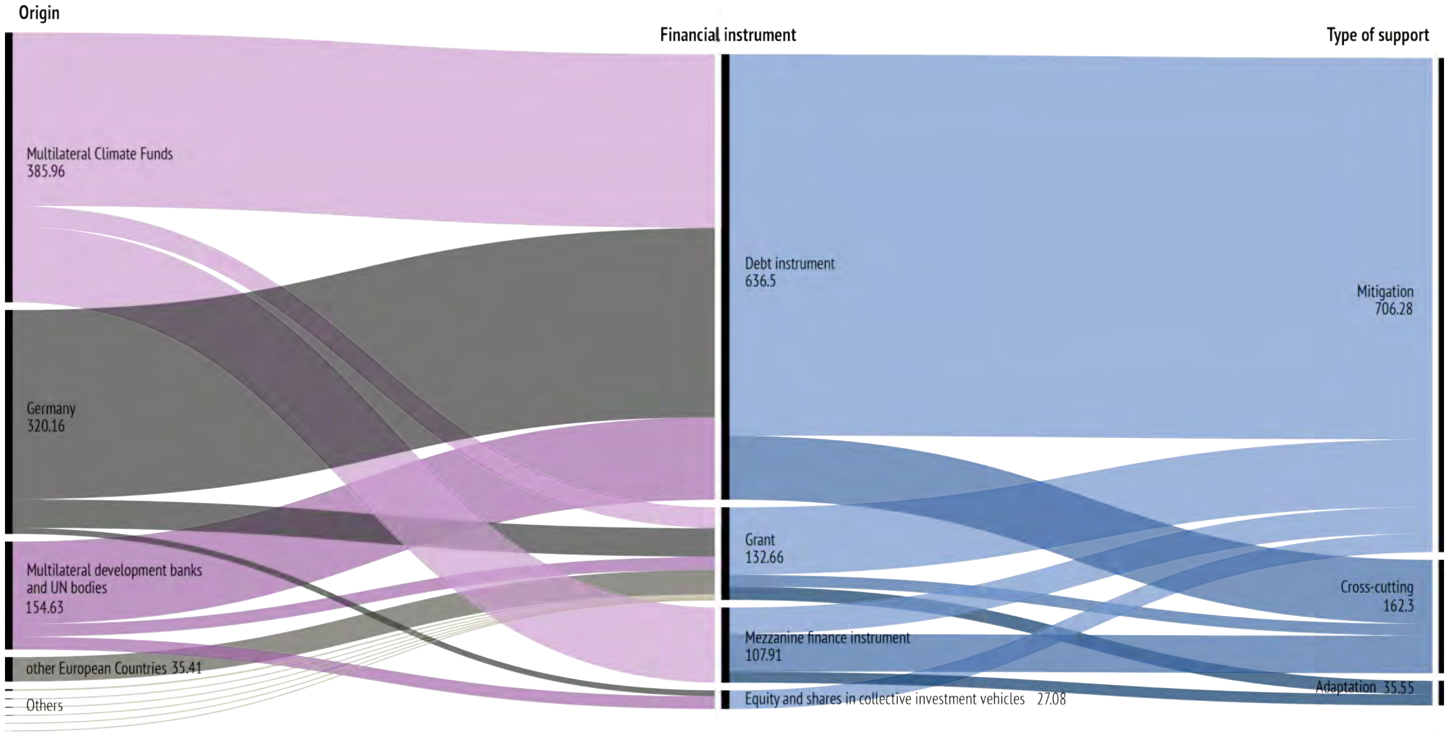
2002 **KYOTO PROTOCOL - 1ST PERIOD**
No target

2016 **PARIS AGREEMENT - 1ST NDC**
Peak GHG emission by 2030

2021 **PARIS AGREEMENT - NDC UPDATE**
Annual emissions in a range of 398-510 MtCO$_2$eq. in 2025 and of 350-420 MtCO$_2$eq. in 2030

INTERNATIONAL CLIMATE FINANCE ASSISTANCE

In 2017-2018 South Africa received 900 million USD in climate-related development finance, according to the OECD DAC's data. More than half comes from multilateral channels, whereas Germany is the main bilateral donor. The majority comes in the form of debt and equity instruments.



SUSTAINABLE RECOVERY POLICY

South Africa allocated 44.14 billion USD to total public spending in 2020. Out of this amount, the Global Recovery Observatory reported 2.45 billion USD in recovery spending. Only a small fraction, amounting to 100 million USD, is labelled as sustainable spending, mainly dedicated to green infrastructure and nature conservation.

44.14 billion $	2.45 billion $	0.1 billion $
Total Spending	Recovery Spending	Green Spending

DOMESTIC ADAPTATION POLICY

South Africa included adaptation in its NDC. The country adopted a dedicated National Adaptation Strategy, while the planning is delegated to sub-national administrations. No sectoral plans are foreseen in this legal framework.

- ○ Domestic Adaptation Policy
  - ● Inclusion of Adaptation in NDCs
  - ○ Integrated Adaptation & Mitigation Policy
  - ● Dedicated Adaptation Strategy
  - ○ Dedicated Adaptation Plan
- ○ Subordinate Adaptation Policies
  - ○ Sectoral Adaptation Plans
  - ● Subnational Adaptation Plans

○ Policy not in place ● Active policy

ADAPTATION POLICY HIGHLIGHTS

TRANSNATIONAL INITIATIVES

Africa Adaptation Initiative

The AAI aims to enhance action on adaptation, with the aim of addressing the adaptation financing gap, and implementing measures to address disaster risk reduction and resilience needs in Africa.

NATIONAL INITIATIVES

The Adaptation Network

The Adaptation Network is a platform for sharing experiences, practical approaches and frameworks relating to climate change adaptation. Membership includes representatives from civil society, government, parastatals, academia and business

Reducing Disaster Risks from Wildfire Hazards Associated with Climate Change in South Africa

The project aims at reducing the country's environmental, social and economic vulnerability to the increased incidence of wildfires, through a biome-scale change in the fire management approach (from reactive fire-fighting to proactive fire management)

SUBNATIONAL INITIATIVES

City of Cape Town Climate Change Strategy

The draft strategy contains 35 goals. For adaptation, they focus on rising temperatures, water scarcity, flood risk and storm damage, coastal erosion, sea level rise, and fire risk.

Building resilience in the greater uMngeni catchment

The project aims to increase resilience of vulnerable communities in the uMgungundlovu District of KwaZulu-Natal, through interventions such as early warning systems, climate-smart agriculture and climate proofing settlements.

ENERGY TRANSITION

South Africa has yet to strengthen its efforts to transform its energy sector, and align itself with the trajectories of the most virtuous G20 countries. This analysis is confirmed by the fact that South Africa ranks below the group's average in all the five indicators considered in the analysis. Reliance on fossil fuels and a still partial process of electrification are two of the main problems affecting South Africa. In the first case the key role of coal in the energy and electricity mixes is not yet sufficiently offset by the penetration of renewables, although it must be noted that South Africa has a limited hydroelectric capacity compared to other G20 members, even though – due to a significant solar and wind potential - interesting efforts are already taking place. Similarly, when it comes to Electrification, the performance of the country has to be contextualized in the African continent, where electrification is extremely low and South Africa represents a positive regional exception. The massive use of coal is also the cause of negative results in terms of Emissions, a sector in which South Africa has the lowest ranking, while poor Efficiency performances are determined by the limited access to modern forms of energy for parts of the South African population and by inefficient energy transportation networks.

G20 AVERAGE
COUNTRY

Only actively pursuing an energy transition based on decarbonization and electrification – from policy and regulation, to health and education – will enable countries to benefit the most from future opportunities and fight climate change whilst ensuring an equitable distribution of wealth.

The Energy Transition indicators were developed by Enel Foundation in cooperation with SACE, and provide a retrospective analysis based on historical data.

Energy Transition	58.7	53.1
Fossil Fuels	45.3	44.5
Renewables	19.7	12.1
Efficiency	84.9	76.1
Electrification	70.8	65.2
Emissions	72.9	67.6

G20 CLIMATE RISK ATLAS

Impacts, policy, economics

SOUTH KOREA

How to read the Atlas: graphs, colours and scenarios.

The maps used in this Atlas are taken from **The World Bank Official Boundaries** - ***https://datacatalog.worldbank.org/search/dataset/0038272*** (accessed on May 28, 2021). For the section Energy, the maps are based on Panoply Data Viewer ***https://www.giss.nasa.gov/tools/panoply/credits.html***

Each sector of this Atlas contains data and information on various climate scenarios.

When reported in graphs, the **colour black** indicates data and information referring to the current state, the past or the baseline.

When the authors refer to **RCP (Representative Concentration Pathways)**, the 3 colours used across the factsheet refer to 3 scenarios, which are 3 different development options with different levels of greenhouse gas emissions, **respectively low emissions (green), medium emissions (orange), and high emissions (red)**. The same colour code is used when RCPs are associated with Shared Socioeconomic Pathways (SSP).

In some cases, the authors refer to global warming scenarios. In these cases, the 3 colours used refer to a temperature rise of **1.5°C (green), 2°C (dark green), and 4°C (red)**.

When the authors refer exclusively to **Shared Socioeconomic Pathways - SSPs** (Population affected by river floods in the section: "Water"), data related to **SSP3** - that encompasses, among other things, slow economic growth, material-intensive consumption, and persisting or worsening inequalities – **are reported in a lighter shade**; **SSP5** – which refers to social and economic development that is coupled with an energy-intensive lifestyle and the abundant exploitation of fossil fuel resources – is shown using a **middle shade of the colour**, whereas data related to **the present** conditions **are represented in a dark shade**.

Further details on scenarios, methodologies, and the full list of references are available at: **www.g20climaterisks.org**

Concept and graphic design by element6.eu

SOUTH KOREA
CLIMATE

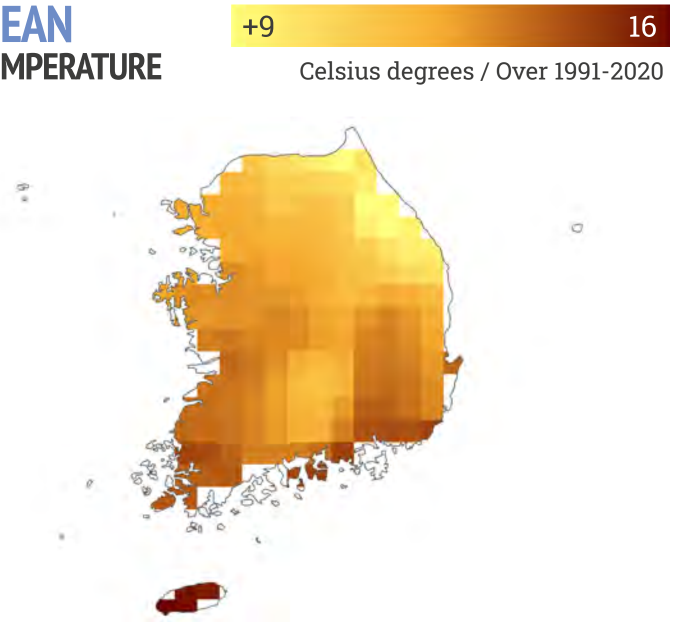
OVERVIEW

The climate in South Korea is temperate with generally long and cold winter seasons and very short, hot, and humid summers. It is mainly regulated by the East Asian Monsoon system. Other factors affecting Korea's climate are the orography, latitude and ocean currents. Due to its southern and seagirt location, Jeju Island has warmer and milder weather than other parts of South Korea.

TEMPERATURE

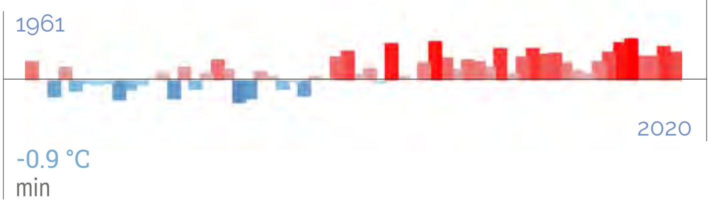
South Korea experiences average annual temperatures of 12°C. The southern part exhibits generally higher temperature especially over the isle of Jeju in the south, whereas the coldest area is in the north-eastern part overlooking the Sea of Japan.

MEAN TEMPERATURE



TEMPERATURE TREND

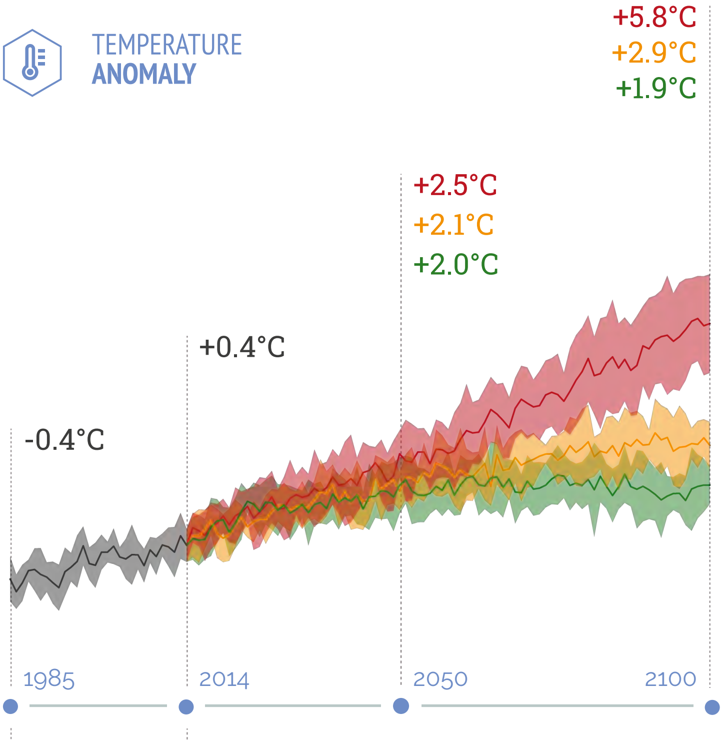
Temperature anomalies over the last 60 years with respect to the annual mean of 12°C in South Korea during the 1961-1990 period



TEMPERATURE PROJECTIONS

Under a low emissions scenario projected temperature variations will remain contained under 2°C, both by 2050 and 2100.
Under a high emissions scenario, with no reduction in GHG emissions, much greater temperature anomalies are expected by both 2050 and 2100.

TEMPERATURE ANOMALY



Historical Period

EXPECTED VARIATION FOR TEMPERATURE AT 2050

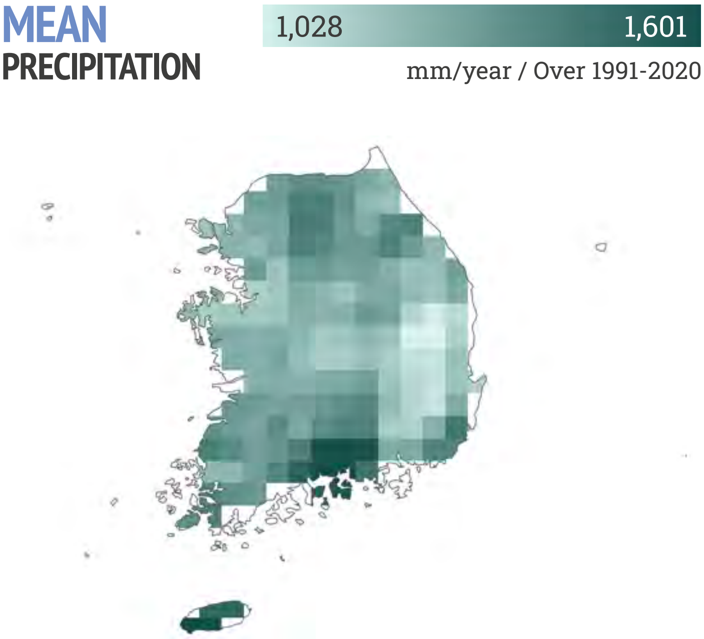
The indicators show variations in selected temperature characteristics for a thirty-year period centred on 2050 (2036-2065) with respect to the reference period 1985-2014.

Annual Mean Temperature	Max Temperature of warmest month	Min Temperature of coldest month
+2.5°C	+2.5°C	+2.9°C
+2.0°C	+1.9°C	+2.4°C
+1.7°C	+1.7°C	+1.9°C

PRECIPITATION

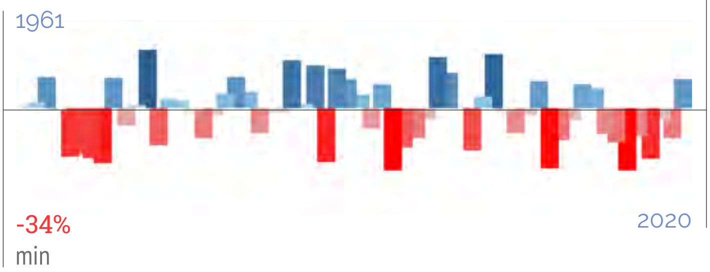
Precipitation over South Korea is affected by the Asian monsoon and characterized by winters with low intensity precipitation and summers with intense precipitations during the monsoon season. During the summer and the first part of the fall season, South Korea also experiences typhoons.
Annual precipitation is higher on the southern coast whereas the northernmost inland regions see the least amount of rain.

MEAN PRECIPITATION



PRECIPITATION TREND

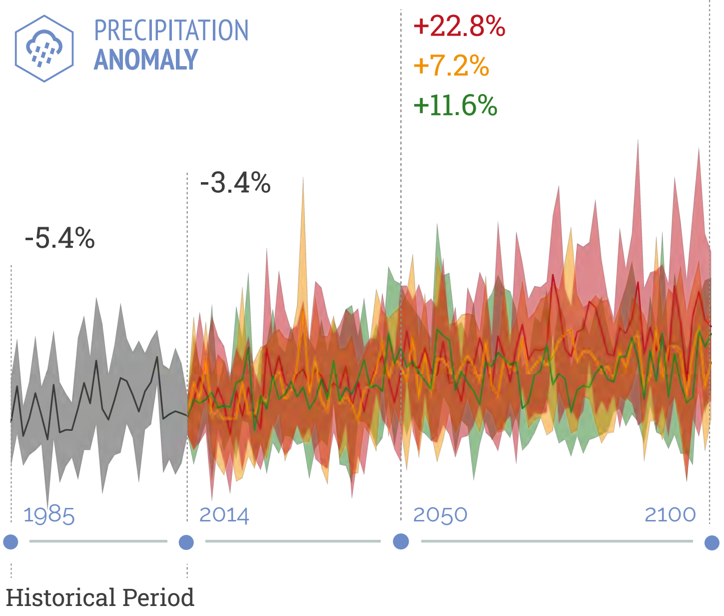
Precipitation anomalies over the last 60 years with respect to the annual mean of 1,280 mm/year in South Korea during the 1961-1990 period



PRECIPITATION PROJECTIONS

Precipitation trends show a general tendency to increase for all the different scenarios considered and are more pronounced under a high emissions scenario. However, the variability reported is quite large, especially over the future periods and for a high emissions scenario over a long time range.

PRECIPITATION ANOMALY



EXPECTED VARIATION FOR PRECIPITATION AT 2050

The indicators show variations in selected precipitation characteristics for a thirty-year period centred on 2050 (2036-2065) with respect to the reference period 1985-2014.

Annual total precipitation
+9.9%
+8.5%
+10.1%

Precipitation of wettest month
+8.8%
+7.7%
+11.8%

Precipitation of warmest quarter
+12.7%
+9.8%
+12.2%

VARIATION OF SPECIFIC CLIMATE INDICATORS

Climate indicators variation showing impacts of climate change on sectors such as agriculture, health and water. Analysis considers 3 threshold average temperature increase: **+1.5°C**, **+2°C**, **+4°C**.

Agricultural drought proportion of time
% of time
+22%
+12%
+10%

Hydrological drought proportion of time
% of time
+13%
+9%
+8%

Heatwave duration
% of time
+1,563%
+232%
+79%

Runoff increase
% of area
+20%
+7%
+2%

Agricultural drought frequency
% of change
+45%
+23%
+18%

Hydrological drought frequency
% of change
+9%
+8%
+10%

Heatwave frequency
% of change
+86%
+32%
+18%

Runoff decrease
% of area
+28%
+10%
+5%

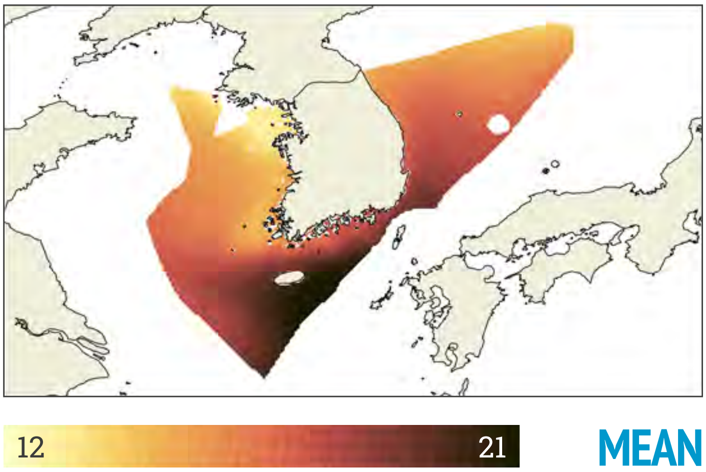
SOUTH KOREA
OCEAN

OCEAN IN SOUTH KOREA

South Korea's marine exclusive economic zone (EEZ) is mainly temperate with warm water temperatures and a wide ensemble of ecosystems such as seagrass beds and coral reefs. The country's coastal systems are naturally divided into two areas: the Yellow Sea and the East Sea.

CURRENT CLIMATE CONDITIONS

Mean sea surface temperature reflects the rather homogeneous temperate climate of the region, with sigthly colder waters in the northern areas.

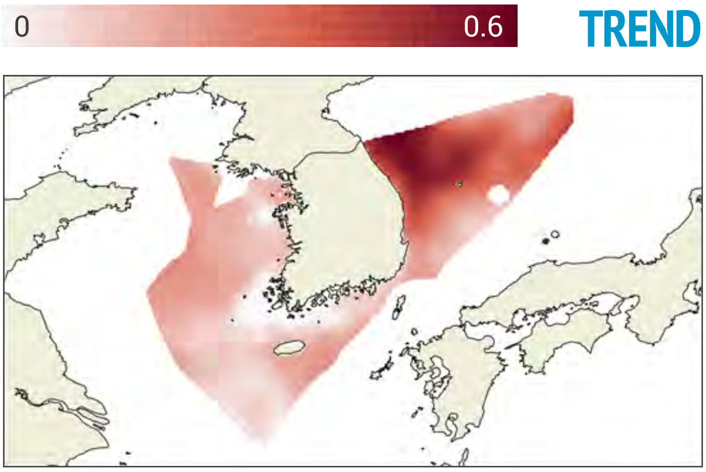


MEAN

SEA SURFACE TEMPERATURE

Celsius degrees / Over 1991-2020

TREND

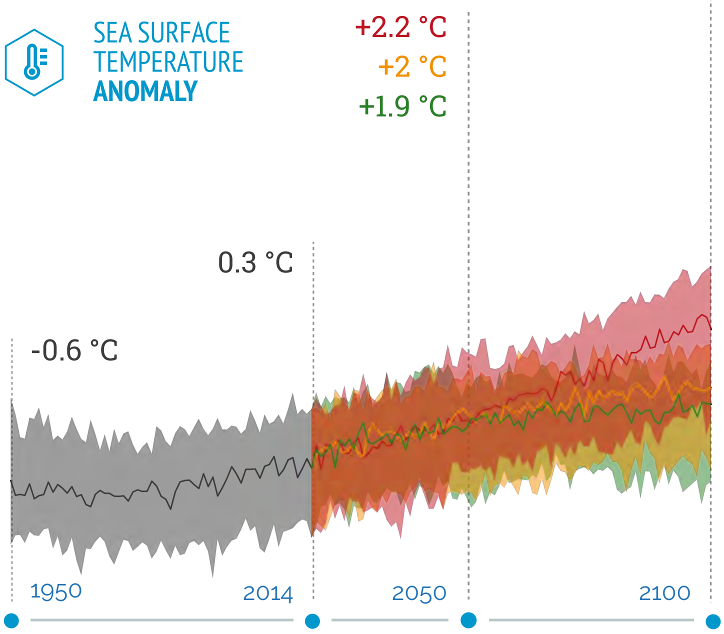


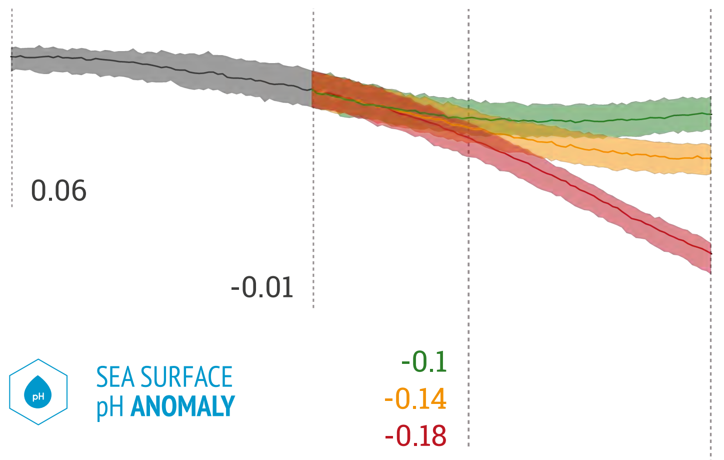
Surface temperature trends indicate a general warming of 0.2°C per decade in all marine areas, with increased gains in the northern part of the East Sea.

FUTURE PROJECTIONS

Projected annual changes within the marine EEZ for the two most significant marine indicators of climate change: sea surface water temperatures and pH.

Seawater temperature changes are in line with the definitions of each scenario, with maximum values around +5°C under a high emissions scenario in 2100.





Seawater surface pH becomes more acidic in all scenarios, closely reflecting rising atmospheric CO_2 concentrations, and only a low emissions scenario leads to a stable condition by 2100.

ECOSYSTEM INDICATORS AT 2050

Regional changes in key marine ecosystem indicators under projected future scenarios by mid-century (2036-2065) with respect to present climate conditions (1985-2014).

East Sea

Yellow Sea

Temperature regulates the metabolism of marine organisms determining which habitats remain suitable. Excessive warming will likely push ecosystems beyond tolerance thresholds.

pH represents the acid/base status of marine waters, where a decreasing pH reflects the acidification of the ocean due to increased absorption of atmospheric CO_2.

Oxygen is fundamental to sustain marine life and its reduction can have a large impact on coastal ecosystem services including fisheries and aquaculture.

Chlorophyll is an indicator of the biomass available at the base of the marine food web supporting all ecosystem productivity.

East Sea	Yellow Sea
17.30°C +2.25 °C +2.01 °C +1.95 °C	16.57°C +2.18 °C +1.85 °C +1.61 °C
8.13 -0.17 -0.13 -0.1	8.1 -0.18 -0.14 -0.11
246.88 mmol/m³ -3.09 % -3.26 % -2.65 %	261.35 mmol/m³ -5.36 % -3.78 % -3.88 %
0.35 mg/m³ -5.76 % -8.65 % -12.1 %	0.29 mg/m³ +1.03 % +1.38 % -1.38 %

FISH CATCH POTENTIAL

Fish catch potential is an estimate of the maximum fish catch achievable given the marine resources available over a sustained period. It is linked to the concept of maximum sustainable yield, meaning the maximum amount of fish that can be extracted from a system without causing a collapse in fish populations.

It is a characteristic of the natural system, which is substantially different from realized catch, and a direct result of the fishery policy in place.

Fish catch percentage change

2050

-2.7%

-0.8%

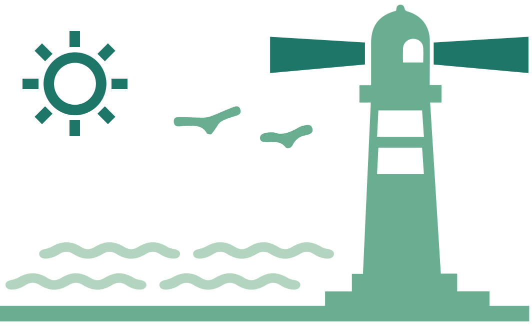
ANALYSIS DETAILS

All datasets were analysed using only data from within the marine EEZ and therefore excluding overseas territories, detached islands and any disputed or joint territories with other nations. In the assessment of current climate conditions, seawater surface tempererature data was obtained using satellite observations distributed in the framework of ESA Climate Change Initiative.

Future projections of marine indicators are represented by the combined analysis of results from 15 different Earth System models participating in the Coupled Model Intercomparison Project Phase 6 (CMIP6). These models include new and better representations of physical and biogeochemical processes, compared to previous IPCC assessment reports.

Fish catch potential data was obtained using the FAO's technical report and refers to the best and worst case climate scenarios from the Fifth IPCC Assessment Report. These mean estimates are subject to substantial uncertainties as discussed in the original work.

SOUTH KOREA
COASTS



OVERVIEW

Korea is a densely populated peninsula with approximately 12,000 kilometres of shoreline and more than 3,000 islands. Long stretches of tidal mud flats are found along the west coast, whereas sandy and rocky beaches are prevalent in the east. The southern coastal waters are characterized by the presence of various semi-enclosed bays and islands. The coastal zone economy includes industrial centres, maritime and air transport, and tourism. The biggest urban conglomerates on the coast include Incheon, Busan and Ulsan.

Shoreline Length
12,478 km

Sandy Coast Retreat at 2050
-43.3 m

CLIMATE CHANGE HAZARDS

Coastal hazards such as erosion, storm tide inundation and permanent flooding, can have strong adverse impacts on coastal regions, with loss of sandy shores, damage to settlements, infrastructure and ecosystems. Climate change can exacerbate these impacts due to rising sea levels and increasing impacts of waves and storms. Climate change impacts on the coastal zone of Korea are mainly driven by rising sea levels and possible changes in storms intensity and direction, and changes in the typhoons frequency, intensity and area of influence in the future. These changes can exacerbate erosion issues and drive flooding of low lying areas on the coast, with potential widespread economic damage. In general, flooding caused by sea level rise and storm surge will have more impact on the low lying and densely populated areas of the west coast.

SEA LEVEL RISE

Relative sea level rise has been observed over the past century around the coast of Korea, with a yearly average increase of approximately 2.4 millimetres per year since the 1990s. The latest IPCC projections indicate that, by 2050, global sea levels may rise between 0.18 metres, under a low emissions scenario, and 0.23 metres, under a high emissions scenario.

Observed and projected sea level rise at 2050
2.4 mm/year
0.23 m
0.18 m

EXTREME SEA LEVEL

On average, one in 100 extreme sea level events are expected to rise from 2.83 metres at present day to 3.08 metres by 2050 under a medium emissions scenario.

Current and projected extreme sea level at 2050
2.83 m
3.12 m
3.08 m

OBSERVED STORMS

The Korean coast is exposed to relatively small swells generated in the Yellow Sea, the South China Sea and the Sea of Japan. Trends in the wave climate have been analysed recently and detect a small increase in wave heights around the Korean peninsula in recent decades. Every year, the Korean coast is influenced by the typhoon season, from May to October, which has historically impacted the southern part of the country with widespread damage from wind and storm surges.

FUTURE STORMS

Climate change is expected to influence the wave climate around the Korean coast. Projections of change in wave height, period and direction for this century under different scenarios seem to agree on a reduction in wave energy. However, this may be offset by the impact of stronger typhoons fuelled by higher sea surface temperatures. Furthermore, it appears that although there may be a reduction in the number of typhoons, the intensity of these is predicted to increase.

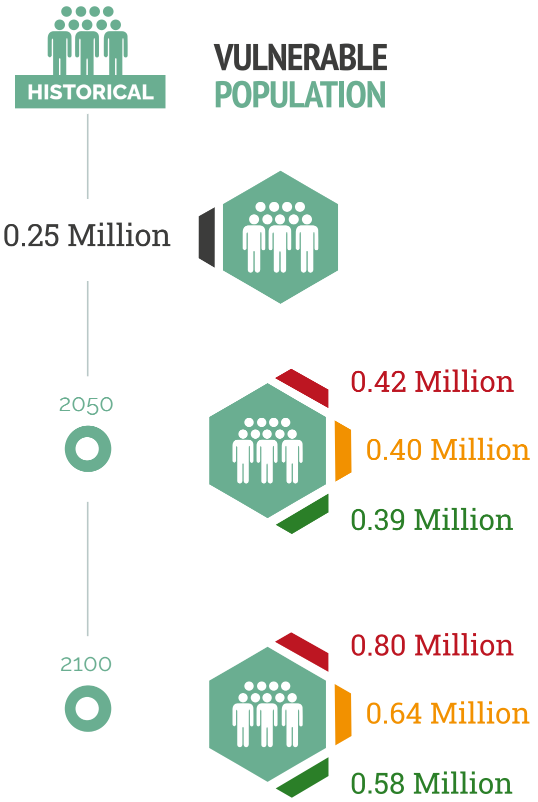
VULNERABILITY AND RISK

Most of the coastal population of South Korea is concentrated in the large urban areas around Incheon, in the north-west, and Busan and Ulsan, in the south east. The low lying areas, however, are concentrated in the western part of the country.

Parts of Incheon and Busan are exposed to the impacts of sea level rise and increasing storm surges, which may lead to significant economic impacts under future sea level rise.

The total damage cost of a 1 metre sea level rise in Korea is estimated at approximately 60 billion USD. Under a medium emissions scenario, the population exposed to the annual coastal flood level is expected to increase from 250,000 to 400,000 people by 2050.

VULNERABLE POPULATION



INFLUENCE OF SEA LEVEL RISE ON EXTREME SEA LEVEL

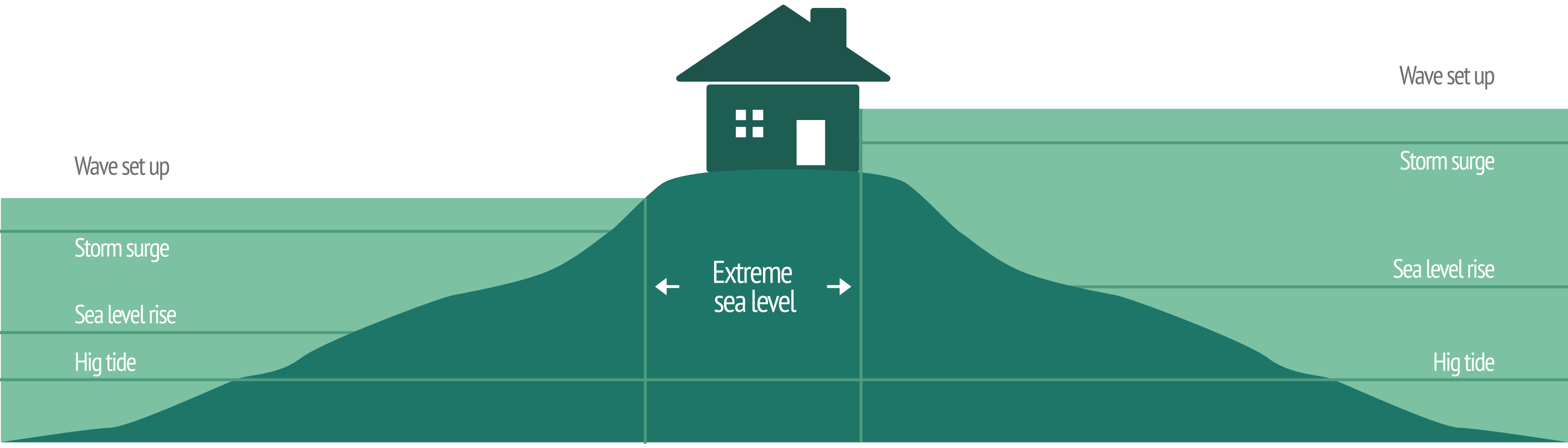
Present and future sea level rise are a consequence of carbon induced global warming causing melting ice and ocean expansion due to heat accumulation.

The extreme sea levels reported here are based on the 100-year storm surge + wave set up + sea level rise + high tide indicators. The first two parameters (storm surge + wave set up) are based on the 100-year value for the event; sea level rise is its projected value at 2050; and high tide is the absolute value of the highest tide calculated for a given locality, which won't be influenced by climate change.

+ **Wave set up** refers to the accumulation of water near the shore due to the presence of breaking waves.

+ **Storm surge** is an occasional increase in sea level driven by shoreward wind-driven water circulation and atmospheric pressure.

+ **High tide** is usually the highest tide reached in a given location based on tide records.



Present sea levels have risen globally by approximately 20 centimetres over the past century.

Future sea level rise is a projection based on different global warming scenarios, at approximately 100 centimetres by the end of 2100, with consequent inundation during extreme sea level events.

SOUTH KOREA
WATER

OVERVIEW

Despite abundant rainfall, South Korea's water resources are relatively scarce. Annual precipitation is 1.6 times higher than the global average, whereas precipitation per capita is only about one sixth. South Korea's population of over 51 million people live in a relatively small country of about 100,363 squared kilometres, of which approximately 65% is mountainous. Most of the rainfall is concentrated in the summer months and more than 60% of the annual precipitation flows into the sea. Therefore, actual available water resources per capita are low.

Water use has increased fivefold: from 5.1 billion cubic metres in 1965 to 25.1 billion cubic metres in 2014; growing faster than the population which has gone from 28.7 million in 1965 to 50.7 million in 2014. However, since 2003 water use has stopped increasing.

Renewable internal freshwater resources
65
billion m^3

Renewable internal freshwater resources per capita
1,262
m^3

The Han River, the Nakdong River, the Geum River and the Yeongsan River are the four major rivers of Korea, with a total area of 67,630 square kilometres and a total length of 1,763 kilometres. As dependence on these four major rivers in Korea increases, so does the potential for water crisis, especially as climate change increases flood and drought impacts.

CLIMATE CHANGE HAZARDS

Climate change can affect water resources through increasing temperatures, higher rates of evapotranspiration and altered rainfall patterns. This leads to changes in the water cycle, including decrease of snow and ice coverage, alterations of surface runoff and groundwater storage, as well as drought and flood occurrence. Records of annual precipitation since 1905 show that the variation range of annual precipitation has been increasing gradually. The value fluctuated rapidly from 754 millimetres in 1939 to 1,756 millimetres in 2003, and the incidence of extreme drought and flood events is increasing. Groundwater and runoff are also linked to these changes in precipitation.

KEY POINT RUNOFF

Monsoon summers between June and September account for approximately 60-70% of the total runoff and precipitation in many areas of South Korea. Future projections show that increasing temperatures will have significant impacts on the intra-annual runoff variation, with the variability of runoff increasing in summer and an increased likelihood of extreme future events. Simulations show that the discharge in July tends to decrease while runoff can increase in August and September. In addition, the mean average low flow may increase while the average wet and normal flow may decrease under climate change.

At a country scale, an average increase in surface runoff by approximately 2% and -17% is expected respectively under low and high emissions scenarios for the 2045-2055 period compared to 2015-2025. If temperatures rise by 1.5°C, 2°C or 4°C, 5%, 9.6% or 28% of the area of the country will likely experience an increase in runoff, while 2%, 6.9% or 20% of the surface of the country will likely experience a decrease in runoff, respectively.

2050

Changes in annual runoff
% of change

-16.7%

+1.8%

2050

Runoff increase
% of area

+28%

+5%

KEY POINT DROUGHTS

Studies have shown that droughts on the Korean Peninsula are more likely when the summer monsoon season is relatively short. Extreme drought occurred in 2015 as precipitation that year was recorded as being the third-lowest since meteorological observations began in 1973. In this case, the Boryeong Dam level was the lowest on record, with an approximately 200 year return period based on the dam design.

Since 1970, South Korea has suffered from drought over a period of five to seven years, and local drought is becoming an increasingly serious concern, with increasing rainfall deviation across multiple regions. In many areas of the peninsula, droughts are estimated to have become more severe especially in spring and winter.

2050
Severe drought likelihood increase
% of change
+5.3%
+6.7%

2050
Hydrological drought frequency
% of change
+9.0%
+7.0%

2050
Groundwater Recharge
% of change
+9.1%
+5.9%

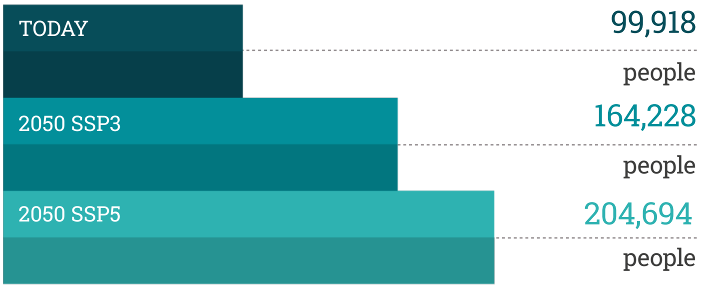
KEY POINT GROUNDWATER

In South Korea, the amount of underground water usage is approximately 4.1 billion cubic metres (2015). Although this usage has been increasing constantly every year, the increase has decelerated since 2013. Due to imprudent groundwater development and inappropriate management, South Korea has confronted some critical groundwater problems, including extensive water level decline and quality deterioration caused by petroleum hydrocarbons and chlorinated solvents. Among 193 national groundwater deep-monitoring wells nationwide, 62% showed decreasing water levels over the period 2004-2008. Based on the groundwater-level data for the last 10 years obtained from the nationwide national groundwater monitoring network, approximately a 0.58 metre decrease in the groundwater level for the next 20 years has been predicted. Excessive groundwater collection and a decrease in the groundwater recharge caused by climate change were qualitatively estimated as the causes. At the country level, a +5%, +5% and -11.4% change of the annual groundwater recharge for the period 2045-2055 compared to the timeframe 2015-2025 is expected respectively under low, medium and high emissions scenarios.

KEY POINT FLOODS

Large-scale flood damage in South Korea, measured in terms of human casualties (dead and missing), has been decreasing since 1959, while property damage has also been gradually decreasing since 2002. Nevertheless, excessive flooding does occur due to changing rainfall patterns that are caused by climate change, such as increased precipitation, decreased days of precipitation and a rise in short-term, localized heavy rain. The frequency of localized heavy rain with 30 millimetres per hour or more, surged by 37%: from 60 instances in the 1980s to 82 times since 2000. Between July 26th and July 28th, 2011, for example, localized heavy rain in the metropolitan area (113 millimetres per hour on the morning of the 27th in Gwanakgu, Seoul; 449.5 millimetres per day in Dongducheon; and 322.5 millimetres per day in Moonsan) inundated the most populated downtown neighborhoods in Seoul. Meanwhile, a large-scale landslide caused by localized heavy rain in the Mt. Woomyeonsan district and Gangwon Chuncheon resulted in numerous casualties, including 57 deaths and 12 missing people.

POPULATION AFFECTED BY RIVER FLOODS

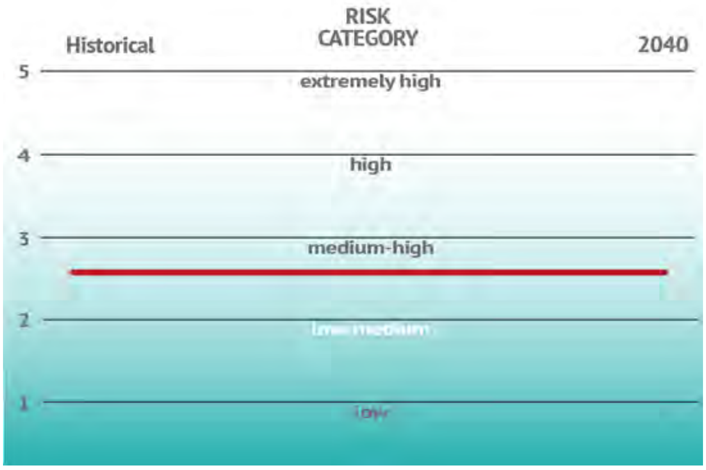


RISK INDICATORS

The water stress index summarises current and future water related vulnerabilities and risks at the global level. Scores are based on the ratio of total water withdrawals, including agriculture, industrial and human consumption, to available renewable surface and groundwater supplies.

WATER STRESS

The water stress level for South Korea is considered medium-high for the recent past (1960-2014 average), and it is expected to remain that way in the near future (2030-2050) based on climate change projections.



SOUTH KOREA

AGRICULTURE

OVERVIEW

Less than 25% of South Korea's area is covered in agricultural land, which is characterized by small family farm structure. Rural population has been decreasing steadily in recent decades, and likewise the share of the national GDP derived from the agricultural sector.

Rice is the most important agricultural crop in South Korea, accounting for about 90% of total cereal production. Other relevant crops produced in the country include barley, wheat, soybean and potatos, yet these only cover a small amount of domestic needs. In addition, a wide variety of fruits and vegetables are cultivated including tangerines, pears, apples, peaches, onions, cabbages and radishes.

Reservoirs are the main source of freshwater for irrigation in agriculture, in particular for paddy fields.

5.2 Mt
Rice

0.6 Mt
Citrus

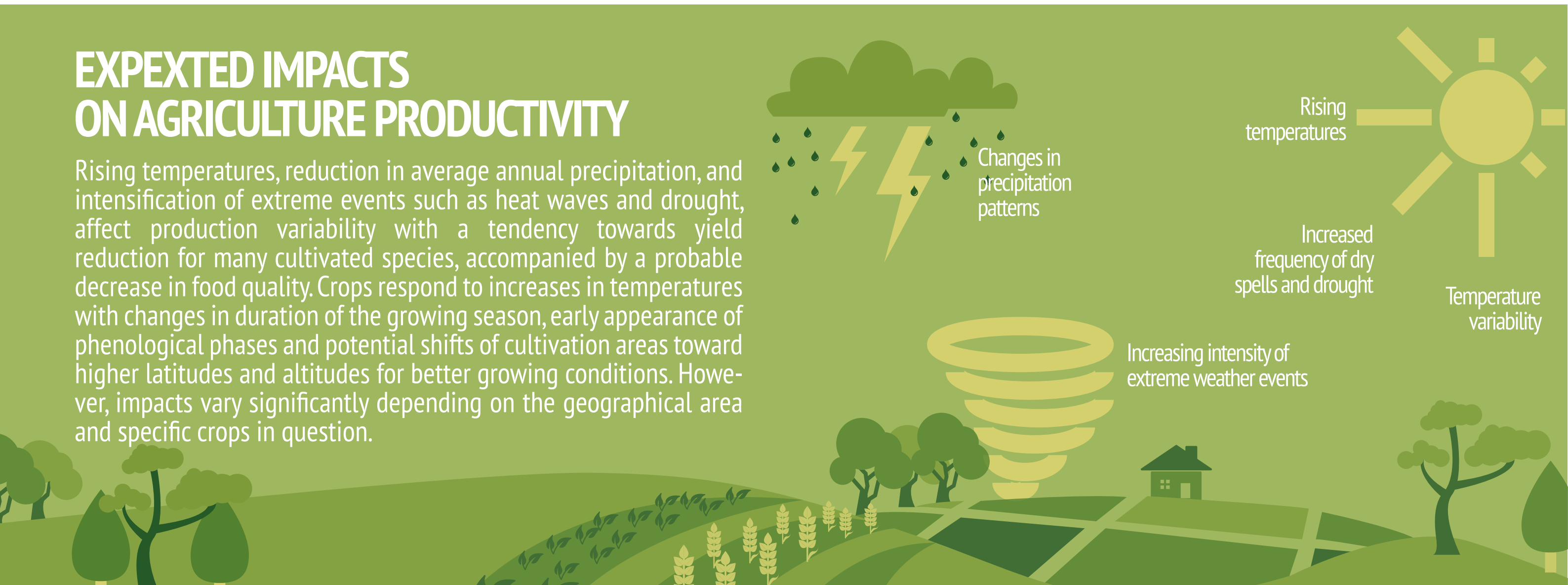
0.2 Mt
Barley

0.6 Mt
Potato

	Added Value of Agriculture, Forestry and Fishing	Share of Agriculture Value added in Total GDP	Agricultural land	Area Equipped for Irrigation
2000	23,931 USD Million	3 %	1,918 Thousand HA	880 Thousand HA
2018	28,767 USD Million	1.8 %	1,596 Thousand HA	707 Thousand HA

EXPEXTED IMPACTS ON AGRICULTURE PRODUCTIVITY

Rising temperatures, reduction in average annual precipitation, and intensification of extreme events such as heat waves and drought, affect production variability with a tendency towards yield reduction for many cultivated species, accompanied by a probable decrease in food quality. Crops respond to increases in temperatures with changes in duration of the growing season, early appearance of phenological phases and potential shifts of cultivation areas toward higher latitudes and altitudes for better growing conditions. However, impacts vary significantly depending on the geographical area and specific crops in question.



CROP PRODUCTIVITY

Crop productivity refers to the harvested yield of a crop per unit of land area. It is strongly influenced by climate and other environmental and management factors.

Climate change is expected to have an impact on the productivity of several major crops, although this may in part be offset by the fertilizing effect of higher CO_2.

Impacts are estimated using a range of model projections based on low to high emission scenarios and reported as percentage changes between the 30-year average around the historical period and the 30-year average around 2050.

7 7.8 (-1)% 5 (-4.4)%
Rice
tons / ha

2.6 3.5 (-4)% 7.9 (2)%
Barley
tons / ha

1.8 11 (3.1)% 10.7 (1.3)%
Soybeans
tons / ha

2050

Productivity change with (without) the CO_2 fertilization effect. Estimates assume sufficient water and nutrient supplies, and do not include impacts of pests, disease, or extreme events.

CHANGE IN RICE

🟥 − = 🟩 +

CHANGE IN SOYBEANS

🟥 − = 🟩 +

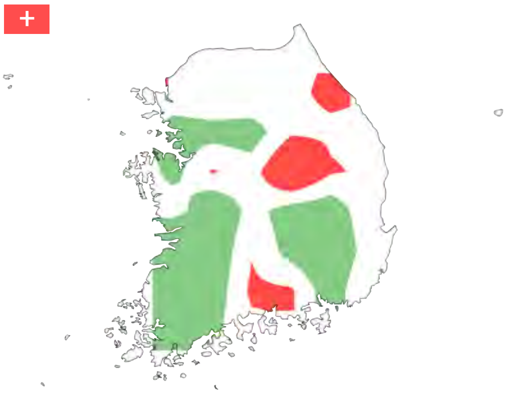
Rice productivity shows an overall tendency to increase, especially for early-maturing varieties, whereas productivity of medium to late-maturing varieties may decrease slightly. Most increases in rice productivity are expected in the northern areas due to warming and more suitable conditions for rice production, whereas a decrease may be expected in southwestern areas. Increasing temperatures may shorten the ripening period, leading to production of poor-quality rice. Extreme events, such as typhoons, may trigger severe drops in rice yields associated with reduction of temperature and sunlight during the ripening period. Due to warmer temperatures, the cultivation regions of apples, pears, peaches and grapes will move northward and/or to inland mountain areas, whereas some areas in the southern regions will become unsuitable for cultivation. Rising temperatures will expand regions suitable for cultivation of several tropical fruits (guava, avocado, atemoya, mango, pitaya, and papaya) in the south-coastal regions.

ADAPTATION IN AGRICULTURE AND WATER RESOURCES

Rural regions may become more vulnerable to water deficits because of seasonal variations in precipitation and droughts. Meanwhile, higher temperatures will generally require a larger agriculture water demand due to higher plant evapotranspiration. Future expansion of under-irrigated agricultural areas may further increase the water demand for irrigation, which is mainly dependent upon reservoirs. An effective operational management of reservoirs is crucial by evaluating the combined sustainability of water demands from multiple sectors and vulnerability of water supplies under climate change.

CHANGE IN WATER DEMAND

🟩 − = 🟥 +



Agriculture
Water Demand
% of change

+3.1%
-6.2%

2050

Resilience of water supplies will benefit from modernization of agricultural infrastructure and development of technology to improve the efficiency of irrigation systems.

SOUTH KOREA
FORESTS

FORESTS IN SOUTH KOREA

South-Korea is characterized by warm-temperate evergreen broadleaf forests in the south, evergreen conifers in the mountains, and deciduous hardwood forests in the rest of the country.

The current situation is strongly influenced by pronounced reduction in adventitious cover in the first half of the 1900s during Japanese colonization and subsequent reforestation policies.

FORESTED AREA AND CARBON STORAGE

South-Korean forests cover almost one third of the country's total land surface. According to recent studies they remove approximately 60 gigagrammes of CO_2 from the atmosphere per year with a constant increasing trend. This will allow Korea to reach a total of 1 gigatonnes of total stock by 2050. Forests are a crucial carbon sink for this country.

1990

7 Mln ha
Million hectares
Forested area

21 Tons/ha
Tons of Carbon per hectare
Carbon stock

2020

6 Mln ha
Million hectares
Forested area

87 Tons/ha
Tons of Carbon per hectare
Carbon stock

2050

Productivity anomaly
Tons of Carbon per
hectare per year

+0.56

+0.52

FOREST PRODUCTIVITY

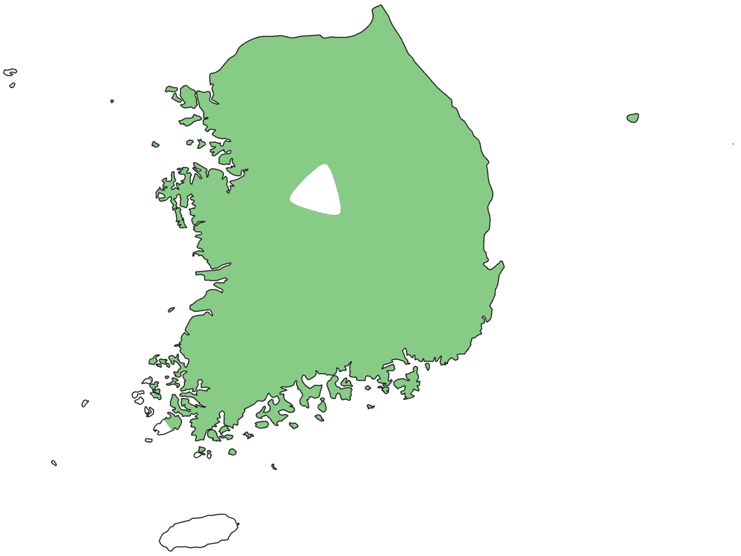
Forest productivity or Net Primary Production is the net carbon captured by plants. It is the difference between the carbon gained by Gross Primary Production - net photosynthesis measured at the ecosystem scale - and carbon released by plants' respiration. It is expressed per unit land area.

Increase in primary production across the entire country

+ Fertilizing effect of increasing atmospheric CO_2, and rising temperatures promote productivity

No areas with an expected decrease in forest primary production

+ Increasing risk of drought stress due to modifications in the water regime reduce productivity



KEY SPECIES UNDER CLIMATE CHANGE

INCREASE
OAKS
Decrease in the distribution of coniferous species in favour of an increase in oak species

SUITABILITY
EVERGREEN FORESTS
Increasing climate suitability for warm temperate evergreen forests

MORTALITY
SUBALPINE CONIFEROUS
Mortality of the subalpine coniferous species was projected to progress rapidly

VULNERABILITY
FIR-THUJA
Very high vulnerability for Korean arborvitae, Khingan and Korean fir

FIRES IN SOUTH KOREA

Fire is a structural ecological process that provides several types of ecosystem services and impacts on socio-ecological systems, including human health, carbon budgets, and climate change. Changes in global fire activity are influenced by multiple factors such as land-cover change, policies, and climatic conditions. Fire also releases large quantities of greenhouse gases into the atmosphere, contributing to a vicious cycle.

During the last two decades, the total land area affected by fire amounts to approximately 42,850 hectares.

BURNING
42.8 THOUSAND HECTARES

EMITTING
0.26 TERAGRAMMES
OF CARBON PER YEAR

FOREST FIRE EMISSIONS
CONTRIBUTED TO
60% OF TOTAL FIRE RELATED
CARBON EMISSIONS

COSTING
34.1 MILLION USD PER YEAR IN
FOREST FIRE PREVENTION

FUTURE BURNED AREA

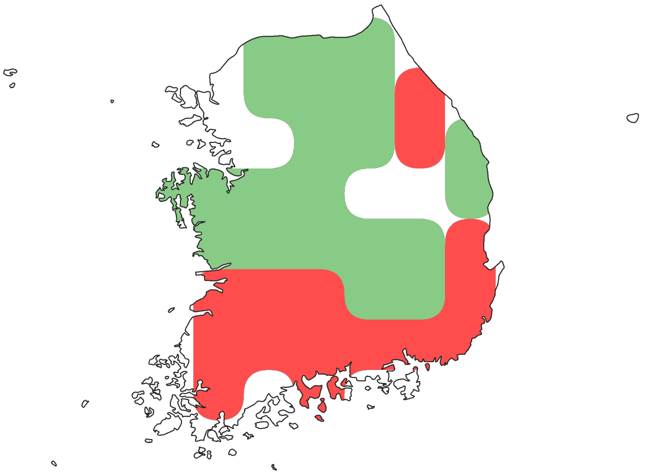
Under a low emission scenario, models project a generalised decrease over northern and central areas while an increase is expected in coastal and central deciduous forests and southern evergreen forests. Under a medium emissions scenario, burned area might decrease across central areas.

2050

Burned Area
km² per year

-17.9

-2.1



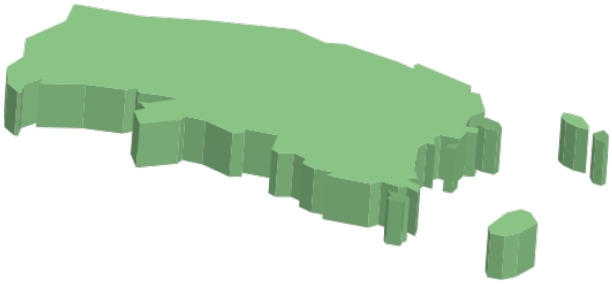
Decrease in burned areas for a low emissions scenario

Increase in burned areas for a low emissions scenario
+ A slight increase in the fire season and the frequency of fires is expected
+ By the end of the century there may be a stronger increase in fire season length.

WHERE DO FIRES OCCUR?

The most affected areas are those dominated by temperate broadleaf and mixed forests in the north Gyeongsang Province.

The north Gyeongsang Province is the country's fire hotspot region.



VARIATION OF SPECIFIC FIRE INDICATORS

% of change
Fire days in spring
2040-2069
+31%

% of change
Fire days in summer
2040-2069
+17%

% of change
Fire days in autumn
2040-2069
+21%

FUTURE FIRE EMISSIONS

Compared to present, under a low emissions scenario scientists project a slight variation in fire emissions. However, under a medium emissions scenario fire emissions might decrease, particularly in north-eastern areas.

2050

Fire Carbon emission
Teragrams of Carbon per year

-0.15

-0.05

SOUTH KOREA
URBAN

OVERVIEW

In 2020, more than 80% of the South Korean population lived in cities. Most cities were built in a short period between 1960 and 1980, and the urbanization rate grew from less than 30% in 1960 to almost 80% in the 1990s. In the near future, the urbanizaiton rate is expected to increase to 86.6% by 2050.

More than 60% of the South Korean urban population lives in urban agglomerations with more than 1 milion inhabitants, while smaller urban centres with less than 300,000 inhabitants account for 7% of the urban population.

Built up areas cover 17.8% of South Korea (7,729.88 square kilometers).

Population in Urban Areas

2020
41,934,110

2050
43,616,033

Graphs refer to data provided by United Nations, Department of Economic and Social Affairs, Population Division (2018). World Urbanization

Urbanization Rate

2020
81.4%

2050
86.4%

OVERVIEW OF KEY CLIMATE IMPACTS IN URBAN AREAS

South Korea's urban areas are mainly vulnerable to heat stress and the effects of storm surges and heavy rainfall resulting from typhoons reaching land.

HEATWAVES AND HEAT STRESS

Frequency, intensity, and persistence of heat waves on the Korean Peninsula have increased since the 1970s. The frequency of tropical nights has also increased, particularly in larger cities and metropolitan areas.

Between 1992 and 2010 approximtely 470,000 heat related deaths in 7 communities were reported. In this period, a total of more than 220 heatwave events of different intensities and lengths were registered, among these there were eight two-day events of very high intensity, six three-day events of medium intensity, and five four-day or longer events. In larger urban areas, these events include more frequent tropical nights, which represent a significant health risk.

In the near future, frequency of heat waves and consequently reliance on air conditioning will increase, in particular under a strong warming scenario. The length of heatwaves could increase by 1,563% and temperatures could rise by the 5.5°C, 2°C and 4°C under high, medium and low emissions scenarios, respectivley.

2050

Cooling Degree Days
% of change

+120.4%
+43.4%
+26.8%

2050

Heatwave frequency
% of change

+85.5%
+31.8%
+18.3%

2050

Heatwave duration
% of time

+1,563%
+232%
+79%

AGEING SOCIETY

The Korean population is ageing rapidly, with 37% of the entire population to be classified as elderly by 2050, and high concentrations living in urban areas. Among the elderly, those living alone are particularly vulnerable due to poverty and difficulties managing their wellbeing.

High temperatures in urban areas worsen impacts of high levels of air pollution. In 2017, the entire Korean population was exposed to levels exceeding WHO guideline values for PM2.5.

2017

Population exposed to air pollution

100.0%

COASTAL FLOODING

Korea's coastline is exposed to regular typhoons. The risk from typhoons is determined by storm and rainfall intensity as well as by rising sea levels. Sea levels around the Korean peninsula have risen by approximately 10 centimetres in the last 40 years, with an annual increase of 2.9 milimetres, observed between 1989 and 2017.

Projected sea level rise

2050

0.23 m

0.18 m

2100

0.77 m

0.38 m

FLOODING

There is an increasing trend in extreme precipitation, with increasing maximum daily precipitation values in some regions, partly due to natural variables. Since the late 1990s, flash floods have emerged as the most frequent natural disaster. Korea experienced severe flood damage caused by typhoons and rainfall in 2006 when flash floods killed 35 people and left 13 others missing.

Damage to property was concentrated in the north eastern province of Gangwon – amounting to approximately 935.5 million USD Annual mean precipitations are expected to increase slightly under all scenarios, whereas summer precipitations are expected to increase at a much higher rate.

2050

Runoff increase
% of area

+28%

+10%

+5%

SURFACE SEALING AND FLOODS

Heavy precipitation in cities is problematic due to the high level of sealed surfaces. Soil sealing increases run off and reduces the amount of water absorbed by soil. Where there are large amounts of impervious ground cover, short duration extreme rainfall events can lead to increased flooding, even resulting in flash floods.

RAPID LAND USE CHANGE AND URBANIZATION

Rapid land use change under intense urban growth is increasing runoff. When combined with more intense precipitation these factors will be responsible for increasing flood damage in larger cities.

2010

% of urban population
Population living in slums

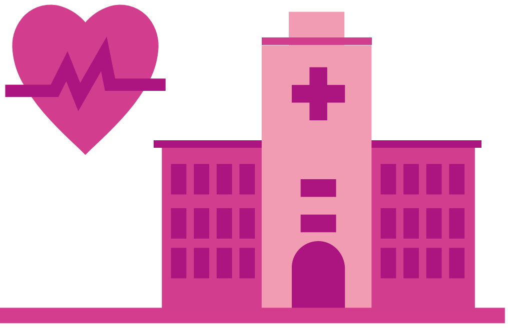
0%

2018

% of total population
Urban population living in areas where elevation is below 5 meters

2.0%

SOUTH KOREA
HEALTH



OVERVIEW

Temperatures in South Korea have increased by 1.5°C in the last century. Warming, heatwaves, and erratic rainfall will increase health risks such as heat-related mortality and vector-borne diseases such as malaria. In South Korea, the risk of death increases by 5% for every 1°C increase in temperature, and the risk of death during a heatwave increases by 8% compared with other periods. In addition, rising temperatures increase the risk of death in the population aged 75 years or older and in chronic disease patients.

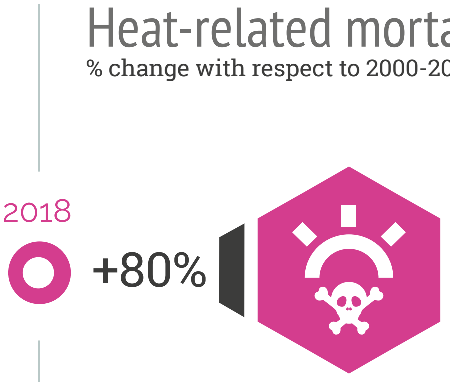
HEAT RELATED MORTALITY

Under a high emissions scenario, heatwave-related excess deaths will increase by 274%, whereas under a medium emissions scenario the increase will be 171%.

In 2018, there was an 80% increase in heat-related deaths from a 2000 to 2004 baseline. 23.9% of heat-related mortality in South Korea during 1997 to 2016 can be attributed to human-induced climate change.

Heat-related mortality

% change with respect to 2000-2004



IMPACTS ON LABOUR

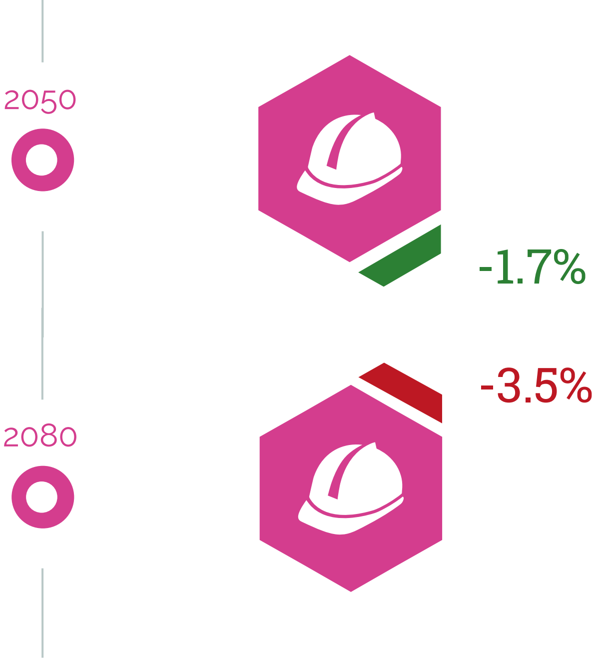
Labour is directly affected by changes in environmental conditions. Warming affects both the number of hours worked (labour supply) and on the productivity of workers during their working hours (labour productivity). Both labour supply and productivity are projected to decrease under future climate change in most parts of the world, and particularly in tropical regions.

Parts of sub-Saharan Africa, south Asia, and southeast Asia are at highest risk under future warming scenarios. Future climate change will reduce global total labour in the low-exposure sectors by 18 percentage points and by24.8 percentage points in the high-exposure sectors under a 3.0°C warming scenario

In South Korea, there was a 49.9% loss in potential hours of labour in the agriculture and construction sectors in 2019, compared to the 1990s baseline. Total labour in South Korea is expected to decline by 1.7% under a low emissions scenario, and by 3.5% under a medium emissions scenario.

Impact on total labour

% change with respect to 1986-2005 baseline



CLIMATE CHANGE AND DENGUE

Dengue has spread throughout the tropical world over the past 60 years and now affects over half the world's population. Globally, vectorial capacity for both dengue vectors (A. aegypti and A. albopictus) has been rising steadily since the 1980s, with nine of the ten highest years occurring since 2000. Climatic stressors are one important driver of the current distribution and incidence of dengue. Climate change is likely to expand the geographical distribution and suitability of several vector-borne human infectious diseases including dengue. The risk of dengue transmission is increased by warming climates, as the growth and development of mosquitoes are significantly influenced by temperature, precipitation, and humidity.

Dengue suitability

% of population at risk

CLIMATE CHANGE AND ZIKA

Zika virus has spread to at least 49 countries and territories since 2013. Climate change impacts on transmission suitability risk have increased over the years and future warming over 1.3 billion additional people could face suitable transmission temperatures for Zika by 2050.

Zika suitability

% of population at risk

DENGUE AND ZIKA: POPULATION AT RISK

The distribution range of insects that are infectious disease vectors is expected to move northward. The domestic settlement of Aedes albopictus, which can spread dengue or Zika viruses, will be possible if the average winter temperature in Korea rises to 10°C or higher in 2050.

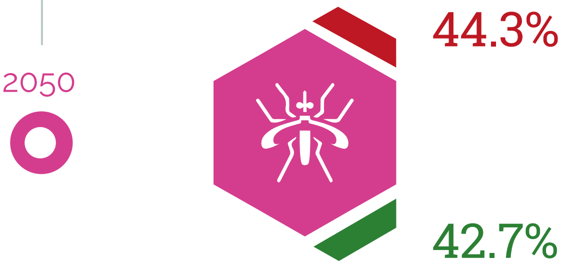
Under a medium emissions scenario, 88.8% of the population will be at risk of transmission-suitable mean temperature for dengue by 2050, whereas 89.6% will be at risk under a high emissions scenario. In the case of Zika, 89.3% of the population will be at risk by 2050 under medium emissions, whereas 81.7% will be at risk under high emissions.

CLIMATE CHANGE AND MALARIA

Although South Korea is no longer a malaria-endemic country, malaria vectors are still present. By 2050, 42.7% and 44.3% of the South Korean population will be at risk of malaria under low and high emissions scenarios, respectively.

Malaria suitability

% of population at risk



POLLUTION AND PREMATURE MORTALITY

By 2060, 1,109 deaths per year per million people will be caused by outdoor air pollution compared to 359 in 2010.

SOUTH KOREA
ENERGY

ENERGY SYSTEM IN A NUTSHELL

South Korea is a highly energy-intensive economy, due to its industrial activity. Fossil fuels dominate the energy mix, but the Korean government has committed to a strong decarbonization pathway over the next two decades.

This entails phasing out coal and nuclear, while increasing energy efficiency in industrial production and boosting renewable sources. In 2015 Korea was one of the first Asian countries to implement an ETS scheme.

0.14
ktoe/US$
Energy intensity

9.2%
AC Share in electricity consumption

87.5%
Import dependence ratio

CLIMATE CHANGE TODAY

INCREASING TEMPERATURES

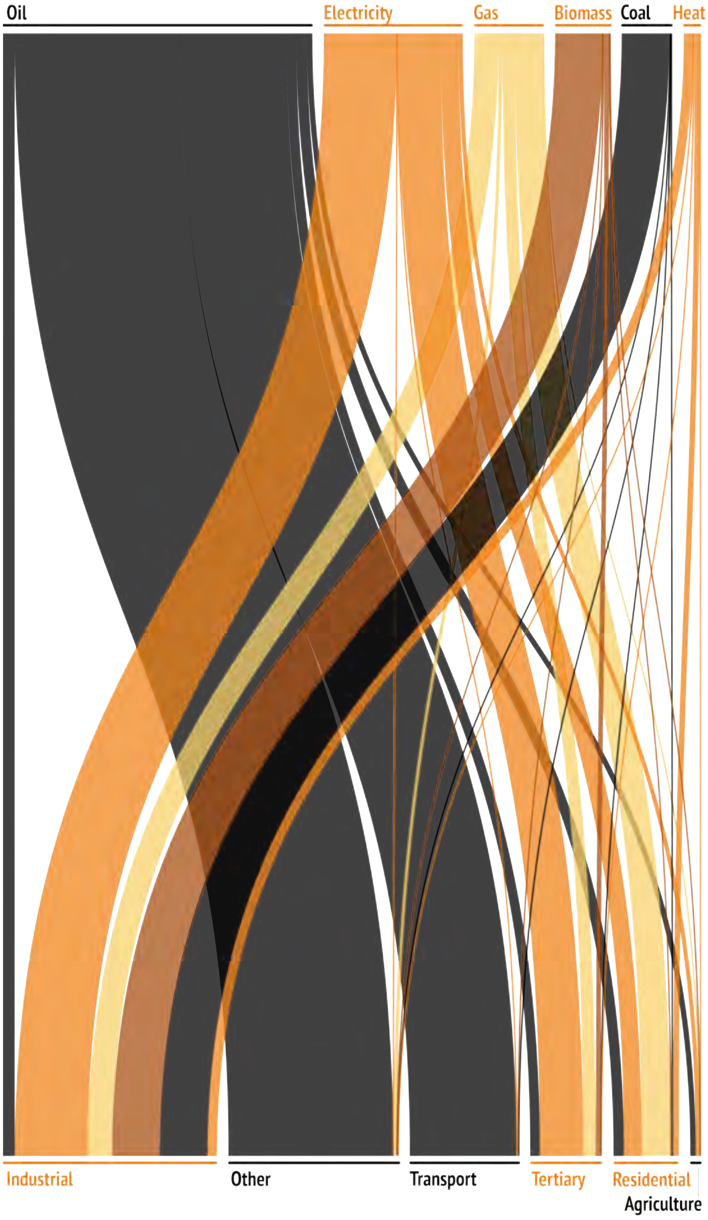
Residential and commercial energy demand has risen due to faster-than-average increasing temperatures (0.18°C every ten years in the last century), heatwaves and cold spells.

HEATWAVES

The 2016 heatwave brought about 32 tropical nights, a peak electricity consumption of 8.37 gigawatts and a rush to purchase cooling appliances: air conditioner sales jumped by 160% , those of dehumidifiers by 245%, and those of electric fans by 92%.

ENERGY SUPPLY

South Korea's total primary energy supply energy mix shows a strong dependence on fossil fuels (83% in 2019), most of which are imported, followed by nuclear (14%), leaving only a marginal share to renewables (4% including hydro, biofuels, and waste).



ENERGY DEMAND

In South Korea, energy is used mainly by industrial sectors (55% of total final consumption in 2018, including non-energy uses accounting for 28% of total demand, and claiming 53% of oil products), transport (19% of final demand), tertiary (12%), and residential demand (12%) while agriculture and fishing together have a slim 1.5% share. Air conditioning's contribution to residential electricity demand was only about 2.5% in 2017.

FUTURE ENERGY DEMAND

Decrease in heating demand in South Korea is going to be more than compensated by the increase in cooling needs, resulting in a net increase in energy demand of about 1,820 PJ (505 billion Kwh) by 2050 under a medium emissions scenario.

Net change in energy demand due to changes in DD/CDD
Billion KWh

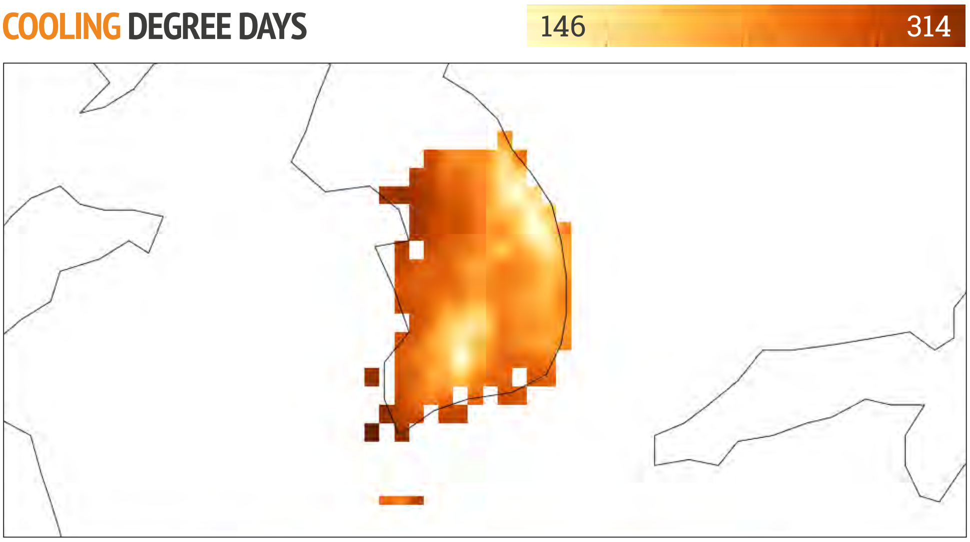
2050

+ 505.58

COOLING NEEDS

Marked, but not extreme, increases in heating days all over the country, more pronounced on the west coast, where the capital city Seoul is, and particularly in the south-west corner of the country.

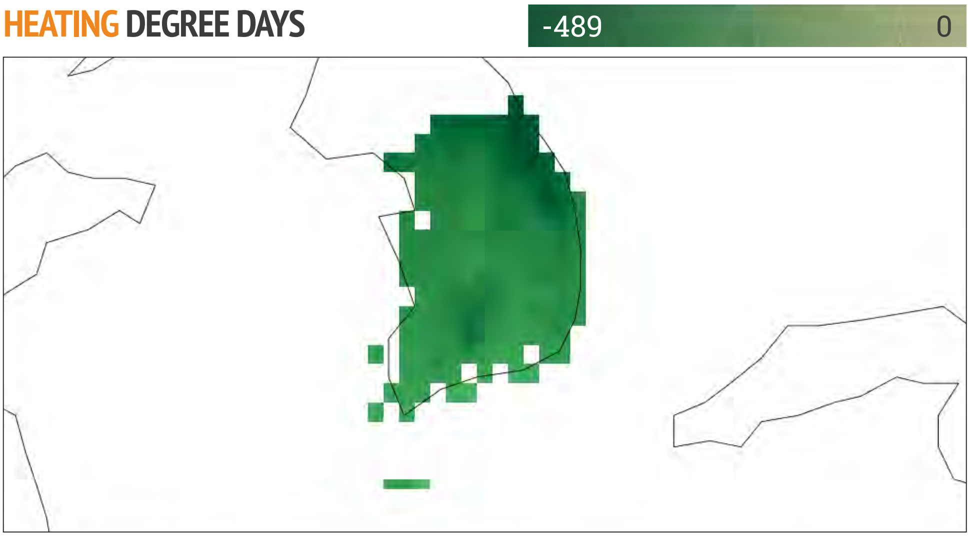
COOLING DEGREE DAYS



HEATING NEEDS

An almost uniform, marked decrease in heating needs is expected all over the country. Slightly more pronounced decreases are expected in the north-east near the border with North Korea.

HEATING DEGREE DAYS



FUTURE ENERGY SUPPLY

The future configuration of the Korean energy mix is likely to be determined by the evolution of climate mitigation policies and hence is outside the scope of this report. Korea is committed to a fast-track decarbonization pathway, which foresees reaching a 20% share of renewable electricity by 2030 and 30-35% by 2040, while phasing-out coal and nuclear and improving energy efficiency. In October 2020 a carbon-neutrality target by 2050 was announced. This is likely to result in fossil fuels (and their vulnerabilities) keeping their relevance for the next couple of decades, while carbon free sources and their vulnerabilities will prevail in the second half of the century.

Change in Hydropower generation
% of change

2050

-4.98%

-2.73%

EXPECTED IMPACTS OF CLIMATE CHANGE

To the best of our knowledge, there are no studies on the impacts on South Korea's energy infrastructure. As for other Asian Pacific countries, floods, heavy precipitation and typhoons will pose increasing threats to such infrastructure. The planned energy transition streamlines adaptation into new infrastructure design, particularly for the electricity grid. A moderate drop in hydropower is expected.

SOUTH KOREA
ECONOMY

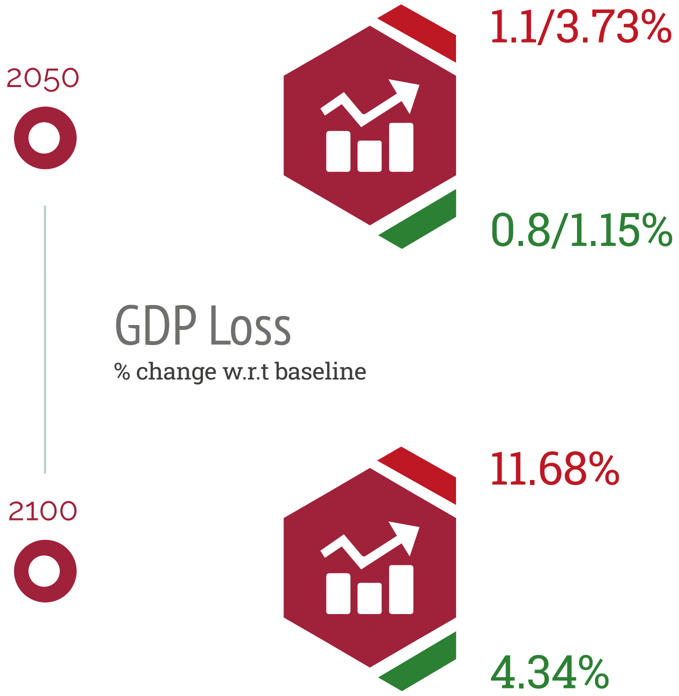
OVERVIEW

South Korea ranks 13th in terms of GDP in the G20 group. As a consequence of the COVID 19 pandemic real GDP declined by 1% in 2020. This trend has been reversed and in 2021 real GDP grew by 3.6%.

IMPACTS ON GDP

The available estimates for economic impact of climate change on the whole of South Korea's economy vary according to the emissions scenarios considered, the time horizon, the direct impacts covered, and the specificities of the estimation method used.

The projected overall macroeconomic impacts for South Korea range from negligible GDP losses (0.3%) under a low emissions scenario in 2030, to 3.7% of GDP losses in 2050 under a high emissions scenario, to greater than 11% GDP losses under worst case scenarios, by the end of the century.



2050

1.1/3.73%

0.8/1.15%

GDP Loss

% change w.r.t baseline

2100

11.68%

4.34%

SECTORAL ECONOMIC IMPACTS

IMPACTS ON INDUSTRY AND INFRASTRUCTURE

Climate-induced risks for transportation facilities and buildings are high in coastal areas of Gangwon-do, Chungnam and Jeolla-do provinces. In the future high-risk areas for both transportation facilities and buildings are expected to expand in the southern part of the Korean Peninsula and inland areas especially under a high emissions scenario.

Over 65% of South Korean fishing ports are already vulnerable to sea-level rise, a percentage that rises under a high emissions scenario to 70% in 2050 and 85% by the end of the century.

IMPACTS ON AGRICULTURE

Climate change will negatively affect future rice productivity and quality of food crops and positively affect the amount of barley, a winter crop. It is also expected that the areas more suitable to growing fruits and vegetables will move northwards, and that the southern islands may become suitable for the cultivation of tropical fruits.

The tropicalization of the sea around South-Korean shores may result in a drop in fish catches and/or a transition to tropical species.

Decreases in rice yields ranging from 4% under a standard medium emissions scenario by mid-century to 14% under a high emissions scenario at the end of the century are expected. Losses for the agricultural sector (rice and barley) may reach 207.5 million EUR by 2050 and 409 million by the end of the century.

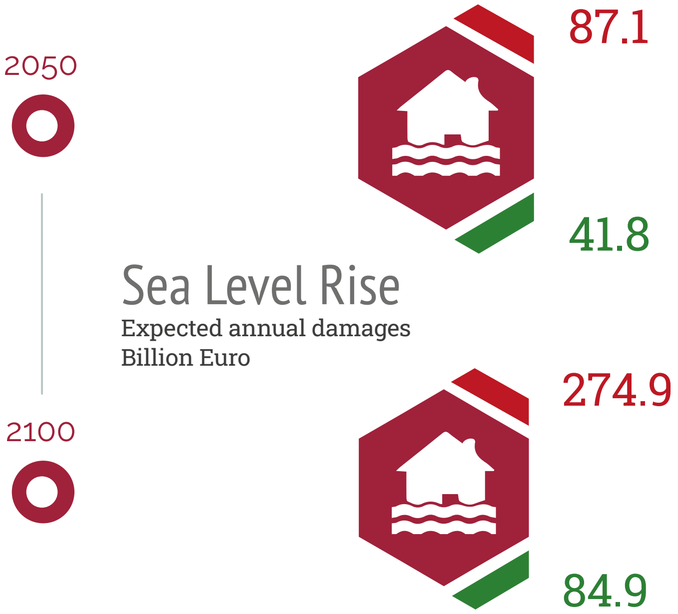
IMPACTS ON FORESTRY AND FISHERY

It is estimated that losses for forestry and ecosystems would amount to, respectively, 117 million and 206 million under a high emissions scenario.

SEA LEVEL RISE DAMAGES

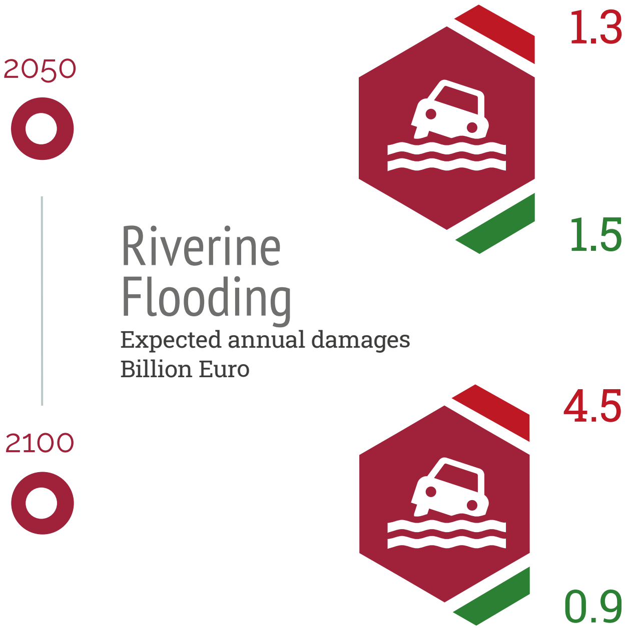
Under the current level of coastal protection, by mid century, sea-level rise and coastal flooding can cost the country 41.8 to 87.1 billion EUR in terms of expected damages to assets in the low and in the high emissions scenarios, respectively.

By the end of the century, expected losses can increase to 84.9 billion and 274.9 billion EUR under low and high emissions scenarios, respectively.



RIVER FLOODING DAMAGES

River flooding can also provoke damages. By mid century total asset losses are projected to be 1.5 to 1.3 billion EUR and in the second half of the century 0.9 to 4.5 billion EUR under low and high emissions scenarios, respectively.



IMPACTS ON ENERGY

As with all other economic sectors, energy supply and energy networks in South Korea will undergo more intense stress from extreme weather events.

Economic impacts of shifts in household and firm energy demand (see chapter on energy) are difficult to predict and will mostly lead to redistribution effects. In the case of South Korea, the magnitude of the increase in demand for cooling is expected to exceed by far the one of the decrease in heating demand, hence a significant increase in energy bills is expected.

IMPACTS ON TOURISM

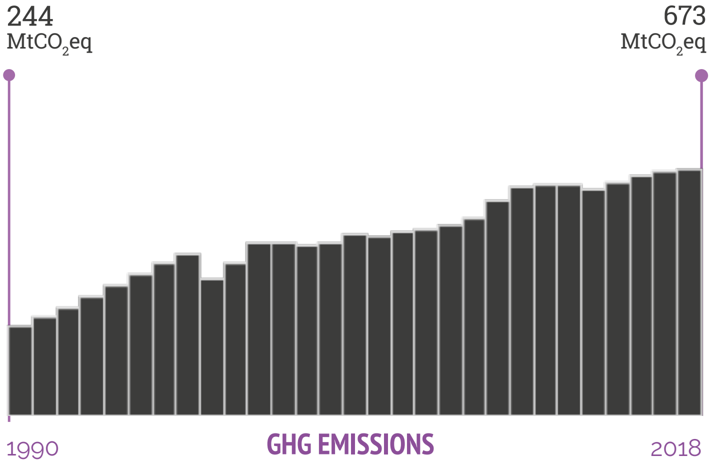
Korea ranked 28th as an international tourist destination in 2017, with 13.36 million arrivals. Tourism is mostly a domestic activity and its dymanics are driven more by international politics or health crises than by climate change.

However, mountain tourism in South Korea is likely to be hit significantly by climate change, with all 17 ski resorts to be gradually driven out of business by the end of the century: three ski resorts will cease operations by the 2030s, 12 by the 2060s and the two remaining ski resorts during the 2090s.

SOUTH KOREA
POLICY

OVERVIEW

Although South Korea is the 12th largest emitter among G20 countries, it is also 6th in terms of emissions per capita. South Korea has more than doubled its emissions in recent decades and the emission trend is still growing steadily.



INTERNATIONAL COMMITMENTS

To achieve the Paris Agreement's target, South Korea submitted an NDC committing to reduce its emissions by 37% in 2030, with reference to a business-as-usual scenario. Recently, South Korea updated its NDC, committing to reduce by 24,4% in 2030 with reference to the emission level of 2017

CLIMATE POLICY COMMITMENTS CHRONOLOGY

2002 **KYOTO PROTOCOL - 1ST PERIOD**

No target

2016 **PARIS AGREEMENT - 1ST NDC**

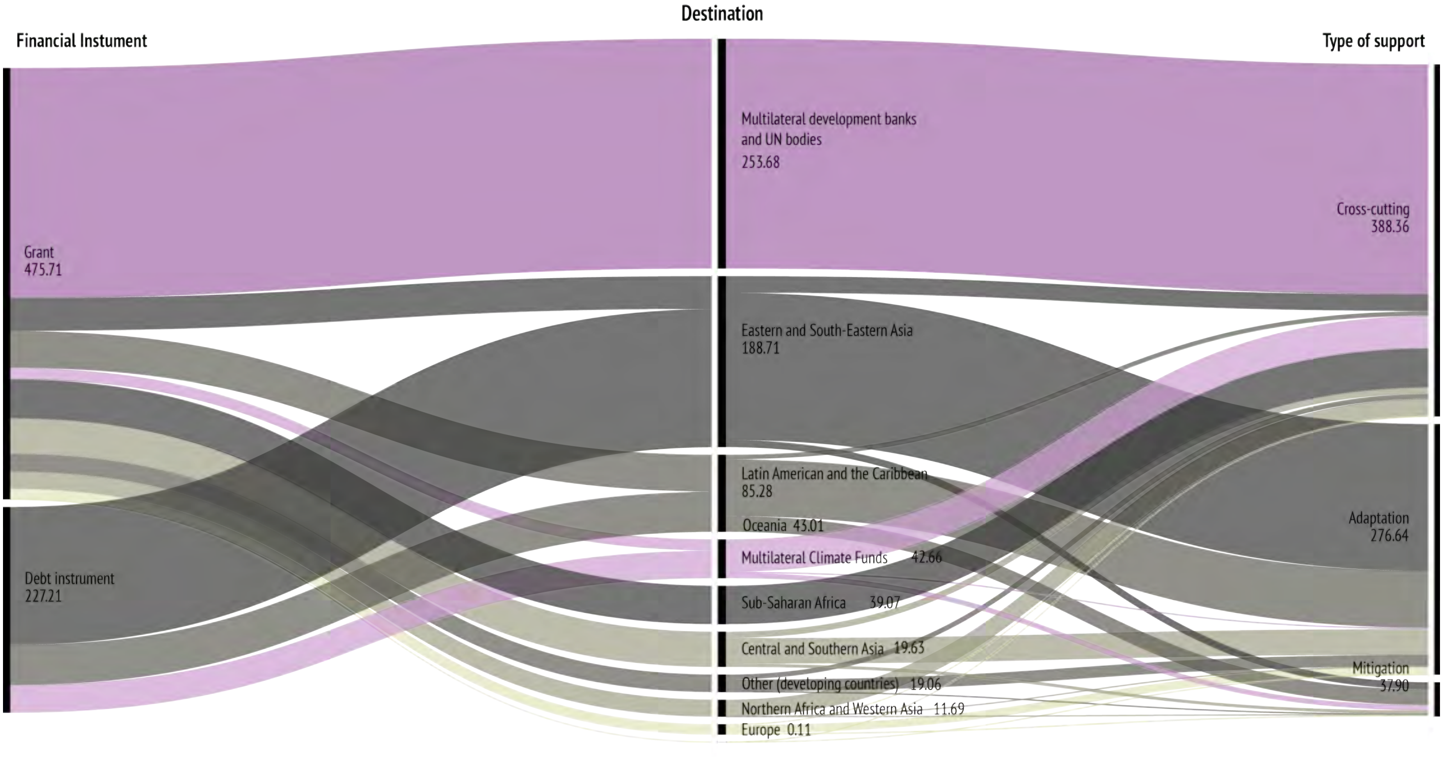
37% GHG reduction by 2030, with reference to a specific business-as-usual scenario

2020 **PARIS AGREEMENT - NDC UPDATE**

24.4% GHG reduction by 2030, with respect to 2017 levels

INTERNATIONAL CLIMATE FINANCE ASSISTANCE

The diagram shows climate-related development finance provided by South Korea in 2017-2018. The total amount is 702 million USD, mainly in the form of grants. The majority is directed to bilateral channels, in particular in Eastern and South-Eastern Asia.



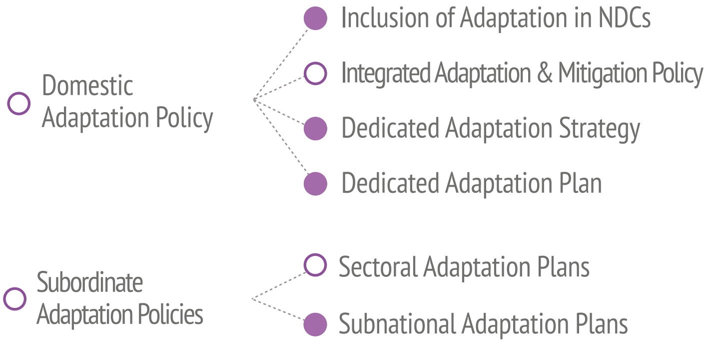
SUSTAINABLE RECOVERY POLICY

The Global Recovery Observatory reports that South Korea spent 685.79 billion USD in 2020. In particular, 186,84 billion USD was devoted to the post-covid recovery. 26,7% of this was dedicated to sustainable recovery, in particular electric mobility, renewable energy, building retrofitting, and nature conservation

685.79 billion $	186.84 billion $	53.97 billion $
Total Spending	Recovery Spending	Green Spending

DOMESTIC ADAPTATION POLICY

South Korea included adaptation in its NDC. The country adopted both a National Adaptation Strategy and a National Adaptation Plan. Sub-national administrations have to develop their own adaptation plan.



- ○ Domestic Adaptation Policy
  - ● Inclusion of Adaptation in NDCs
  - ○ Integrated Adaptation & Mitigation Policy
  - ● Dedicated Adaptation Strategy
  - ● Dedicated Adaptation Plan
- ○ Subordinate Adaptation Policies
  - ○ Sectoral Adaptation Plans
  - ● Subnational Adaptation Plans

○ Policy not in place ● Active policy

ADAPTATION POLICY HIGHLIGHTS

TRANSNATIONAL INITIATIVES

Transboundary Diagnostic Analysis for the Yellow Sea Large Marine Ecosystem

The objective of this regional project is to achieve adaptive ecosystem-based management of the Yellow Sea Large Marine Ecosystem bordered by China, South Korea and North Korea by fostering long-term sustainable institutional, policy and financial arrangements

NATIONAL INITIATIVES

Web-Based Supporting Tool for climate change vulnerability assessment (VESTAP)

The VESTAP is a tool to visualize a full database of impacts and vulnerability assessment. The database includes 455 impacts of future climate data simulated with RCP 4.5 and 8.5, atmospheric environment data and other social statistics

Korea Adaptation Center for Climate Change (KACCC)

KACCC aims to enhance the climate resilience in all the sectors across the country and develop science-based adaption strategies

SUBNATIONAL INITIATIVES

Daegu Climate Change Adaptation Strategies

The “Daegu Climate Change Adaptation Strategies” is an official plan established to seek out vulnerable areas and prepare countermeasures. Daegu has been establishing and implementing these strategies every five years since 2012

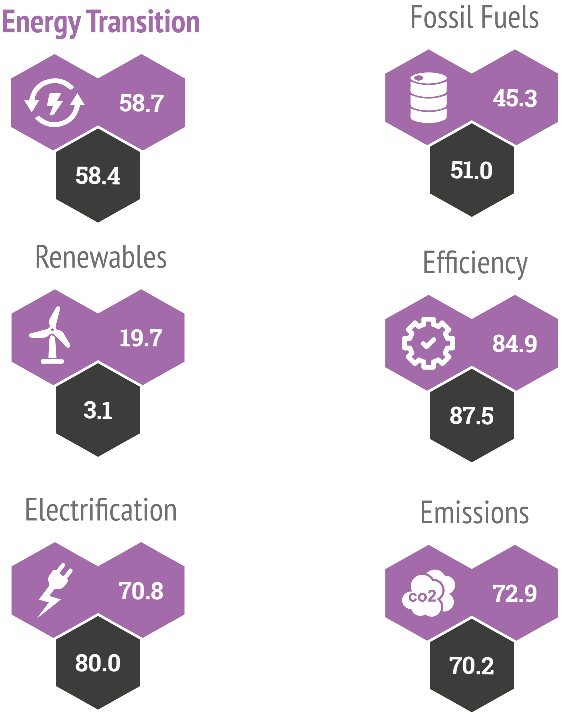
Promise of Seoul

The Promise of Seoul is a comprehensive integrated strategy to both mitigation and adaptation. It covers all areas of climate change, including energy, air quality, transportation, resource recycling, water, ecology, urban agriculture, health, safety and urban planning

ENERGY TRANSITION

South Korea is performing well in the Electrification and in Efficiency domains, revealing how digitalization is one of the main enablers of the energy transition. However, much still needs to be done in terms of increasing electricity generation from renewable energy sources.

Investing in renewables can also help improve urban air quality and reduce CO2 and other emissions, which hinder the fight against climate change. With regards to the Fossil Fuels indicator, performance is above average.



Only actively pursuing an energy transition based on decarbonization and electrification – from policy and regulation, to health and education – will enable countries to benefit the most from future opportunities and fight climate change whilst ensuring an equitable distribution of wealth.

The Energy Transition indicators were developed by Enel Foundation in cooperation with SACE, and provide a retrospective analysis based on historical data.

G20 CLIMATE RISK ATLAS

Impacts, policy, economics

TURKEY

How to read the Atlas: graphs, colours and scenarios.

The maps used in this Atlas are taken from **The World Bank Official Boundaries** - ***https://datacatalog.worldbank.org/search/dataset/0038272*** (accessed on May 28, 2021). For the section Energy, the maps are based on Panoply Data Viewer ***https://www.giss.nasa.gov/tools/panoply/credits.html***

Each sector of this Atlas contains data and information on various climate scenarios.

When reported in graphs, the **colour black** indicates data and information referring to the current state, the past or the baseline.

When the authors refer to **RCP (Representative Concentration Pathways)**, the 3 colours used across the factsheet refer to 3 scenarios, which are 3 different development options with different levels of greenhouse gas emissions, **respectively low emissions (green), medium emissions (orange), and high emissions (red)**. The same colour code is used when RCPs are associated with Shared Socioeconomic Pathways (SSP).

In some cases, the authors refer to global warming scenarios. In these cases, the 3 colours used refer to a temperature rise of **1.5°C (green), 2°C (dark green), and 4°C (red)**.

When the authors refer exclusively to **Shared Socioeconomic Pathways - SSPs** (Population affected by river floods in the section: "Water"), data related to **SSP3** - that encompasses, among other things, slow economic growth, material-intensive consumption, and persisting or worsening inequalities – **are reported in a lighter shade**; **SSP5** – which refers to social and economic development that is coupled with an energy-intensive lifestyle and the abundant exploitation of fossil fuel resources – is shown using a **middle shade of the colour**, whereas data related to **the present** conditions **are represented in a dark shade**.

Further details on scenarios, methodologies, and the full list of references are available at: **www.g20climaterisks.org**

Concept and graphic design by element6.eu

TURKEY
CLIMATE

OVERVIEW

Turkey presents a complex climate: the southern and western coastal areas have a Mediterranean climate whereas the eastern part adjoining Syria and the Middle East are very hot during the summer. Such complexity depends on different factors among which a variable topography, the presence of the Black Sea to the north and, beyond that, the vast Russian plain which in winter acts as a source of very cold air.

TEMPERATURE

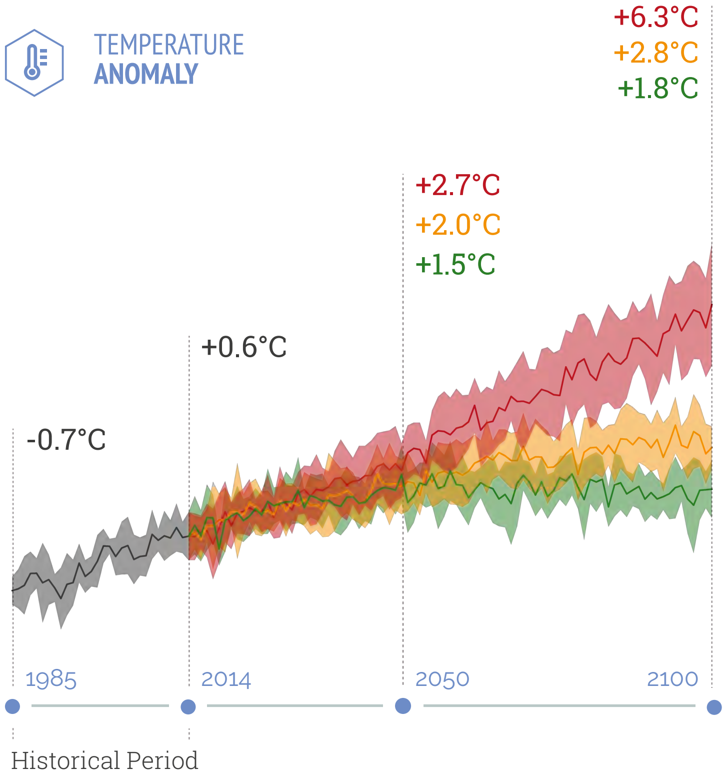
The temperature regime in Tukey varies in space and time according to orography and proximity to the sea. Temperatures are lowest in inland areas, with a marked difference between day and night. The warmest areas are the western and southern coasts.

MEAN TEMPERATURE

Celsius degrees / Over 1991-2020

TEMPERATURE PROJECTIONS

Under a low emissions scenario projected temperature variations will remain contained at around +1.5°C, both by 2050 and 2100.
Under a high emissions scenario, with no reduction in GHG emissions, much greater temperature anomalies are expected by both 2050 and 2100.



EXPECTED VARIATION FOR TEMPERATURE AT 2050

The indicators show variations in selected temperature characteristics for a thirty-year period centred on 2050 (2036-2065) with respect to the reference period 1985-2014.

+2.7°C
+2.0°C
+1.7°C
Annual Mean Temperature

+3.7°C
+2.8°C
+2.3°C
Max Temperature of warmest month

+2.4°C
+1.8°C
+1.7°C
Min Temperature of coldest month

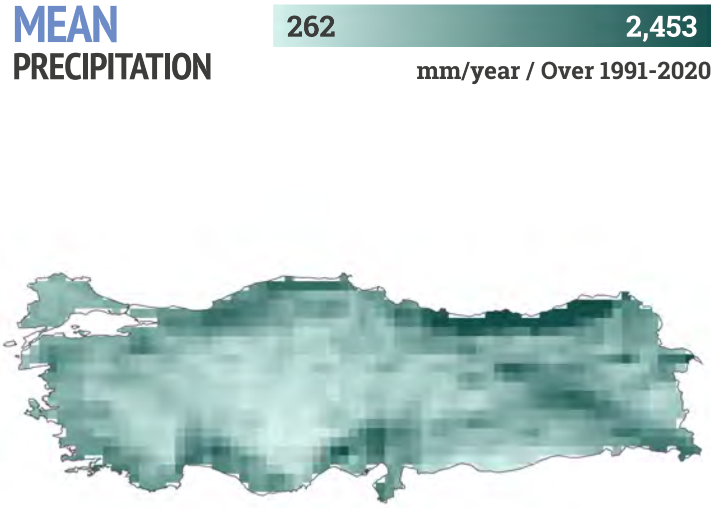
TEMPERATURE TREND

Temperature anomalies over the last 60 years with respect to the annual mean of 11°C in Turkey during the 1961-1990 period

PRECIPITATION

The precipitation regime in Turkey changes depending on the time of year and location. In the inner areas overall precipitation is small, whereas towards the Black Sea it is more significant.
Some years, rainfall causes severe floods and landslides, whereas in others increasing temperatures coupled with decreasing precipitation lead to significant water stress, particularly in the southern and western parts of the country.

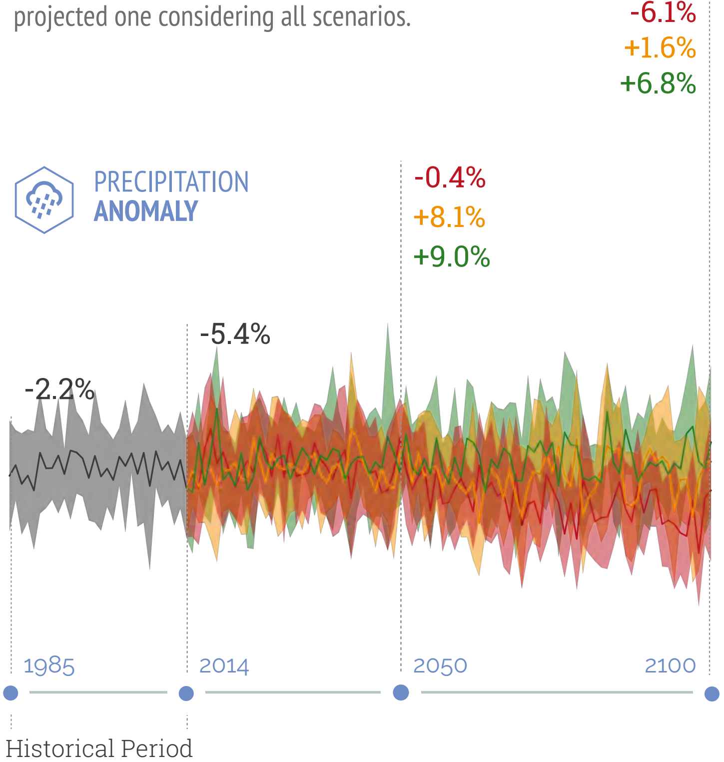
MEAN PRECIPITATION



PRECIPITATION PROJECTIONS

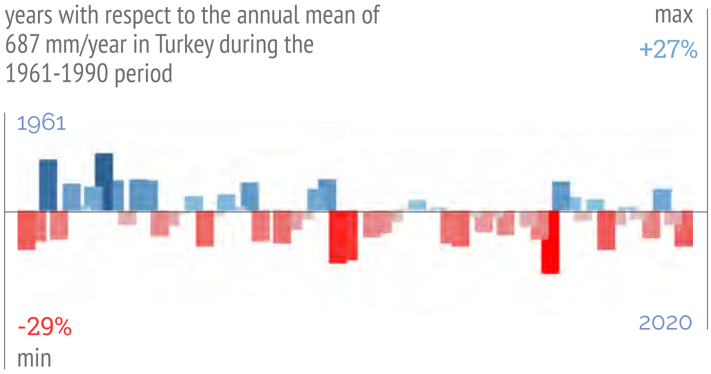
Precipitation is projected to decrease, especially under a high emissions scenario. The variability is quite large both for the historical period and the projected one considering all scenarios.

PRECIPITATION ANOMALY



PRECIPITATION TREND

Precipiation anomalies over the last 60 years with respect to the annual mean of 687 mm/year in Turkey during the 1961-1990 period



EXPECTED VARIATION FOR PRECIPITATION AT 2050

The indicators show variations in selected precipitation characteristics for a thirty-year period centred on 2050 (2036-2065) with respect to the reference period 1985-2014.

Annual total precipitation	-3.0%	-1.5%	+1.7%
Precipitation of wettest month	+1.0%	-1.1%	+2.0%
Precipitation of warmest quarter	-27.6%	-16.9%	-14.0%

VARIATION OF SPECIFIC CLIMATE INDICATORS

Climate indicators variation showing impacts of climate change on sectors such as agriculture, health and water. Analysis considers 3 threshold average temperature increase: **+1.5°C**, **+2°C**, **+4°C**.

Agricultural drought proportion of time % of time	+37%	+23%	+18%
Hydrological drought proportion of time % of time	+20%	+14%	+11%
Heatwave duration % of time	+4,242%	+774%	+284%
Runoff increase % of area	+27%	+13%	+5%
Agricultural drought frequency % of change	+88%	+58%	+33%
Hydrological drought frequency % of change	+11%	+9%	+18%
Heatwave frequency % of change	+100%	+69%	+41%
Runoff decrease % of area	+9%	+2%	+1%

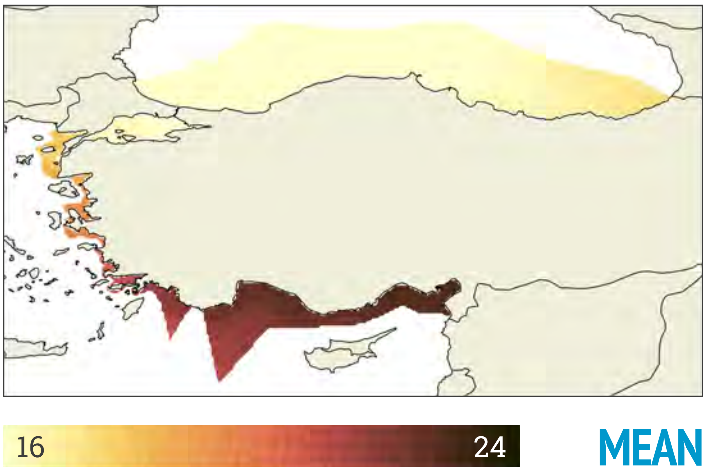
TURKEY
OCEAN

OCEAN IN TURKEY

Turkey's marine exclusive economic zone (EEZ) is mainly temperate with a nearly subtropical regime in the Mediterranean basins, hosting a wide ensemble of ecosystems such as seagrass beds and coral reefs. The country's coastal systems can be divided into three areas: the Aegean Sea, Black Sea, and the levantine part of the Mediterranean Sea.

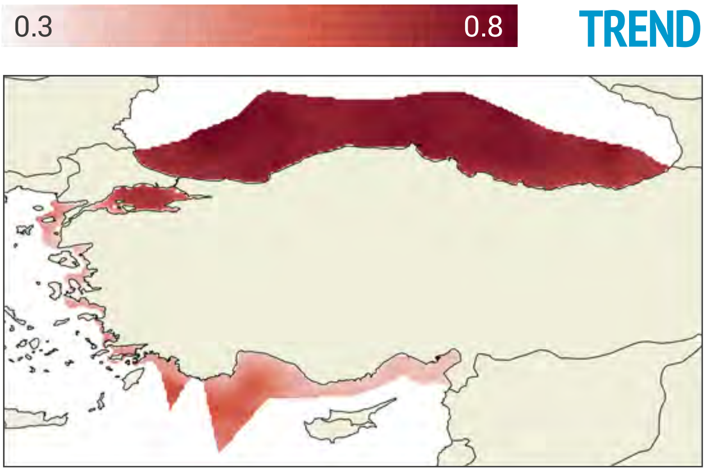
CURRENT CLIMATE CONDITIONS

Mean sea surface temperature reflects the rather homogeneous temperate climate of the region, with colder waters along the Black Sea coasts.



SEA SURFACE TEMPERATURE

Celsius degrees / Over 1991-2020

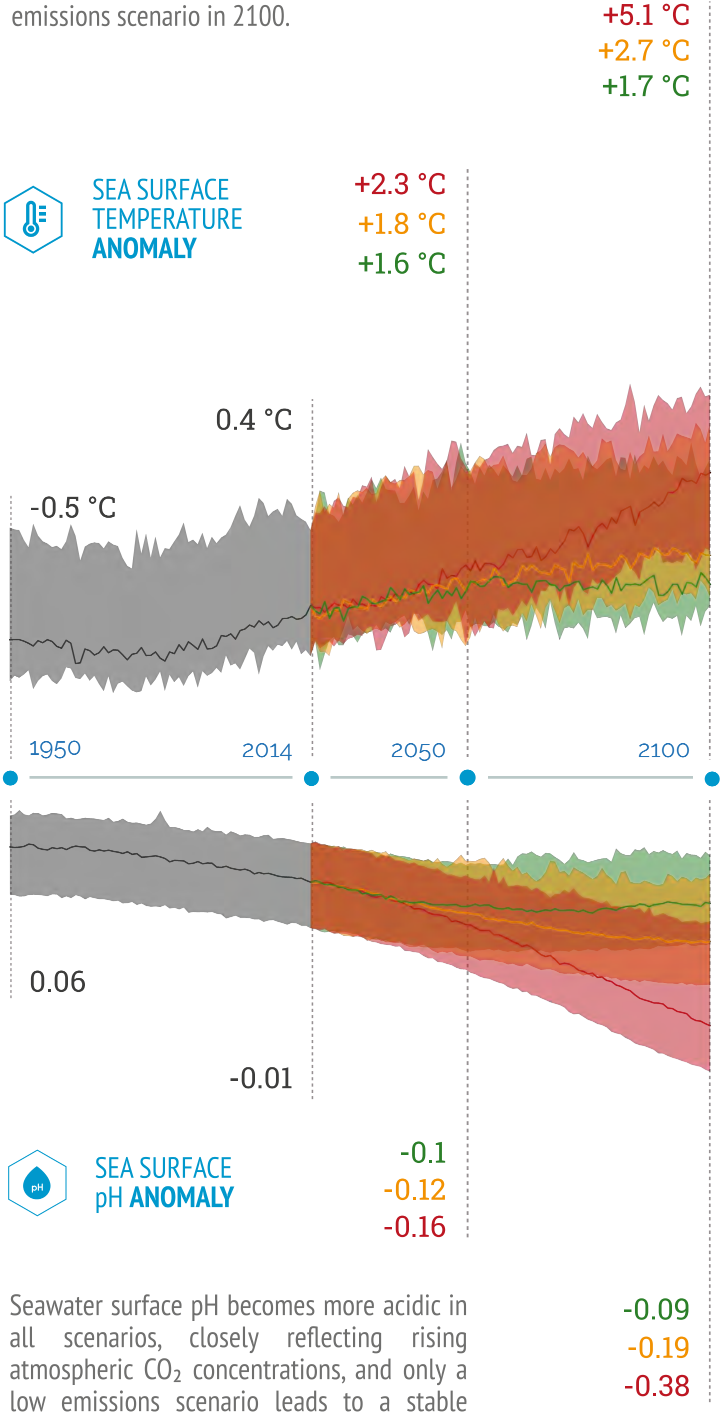


Surface temperature trends indicate a general warming of 0.4°C per decade on the Mediterranean coasts, with increased gains up to 0.7°C per decade along the Black Sea.

FUTURE PROJECTIONS

Projected annual changes within the marine EEZ for the two most significant marine indicators of climate change: sea surface water temperatures and pH.

Seawater temperature changes are in line with the definitions of each scenario, with maximum values close to +5°C under a high emissions scenario in 2100.



Seawater surface pH becomes more acidic in all scenarios, closely reflecting rising atmospheric CO_2 concentrations, and only a low emissions scenario leads to a stable condition by 2100.

ECOSYSTEM INDICATORS AT 2050

Regional changes in key marine ecosystem indicators under projected future scenarios by mid-century (2036-2065) with respect to present climate conditions (1985-2014).



	Aegean Sea	Black Sea	Levantine
Temperature regulates the metabolism of marine organisms determining which habitats remain suitable. Excessive warming will likely push ecosystems beyond tolerance thresholds.	17.43°C 🟥 +2.61 °C 🟧 +2.29 °C 🟩 +2.19 °C	15.84°C 🟥 +2.55 °C 🟧 +2 °C 🟩 +1.81 °C	20.71°C 🟥 +2.06 °C 🟧 +1.57 °C 🟩 +1.34 °C
pH represents the acid/base status of marine waters, where a decreasing pH reflects the acidification of the ocean due to increased absorption of atmospheric CO_2.	8.12 🟥 -0.16 🟧 -0.12 🟩 -0.09	8.12 🟥 -0.17 🟧 -0.13 🟩 -0.11	8.1 🟥 -0.15 🟧 -0.11 🟩 -0.09
Oxygen is fundamental to sustain marine life and its reduction can have a large impact on coastal ecosystem services including fisheries and aquaculture.	243.56 $mmol/m^3$ 🟥 -4.71 % 🟧 -3.79 % 🟩 -3.53 %	266.4 $mmol/m^3$ 🟥 -3.59 % 🟧 -2.94 % 🟩 -3.91 %	227.42 $mmol/m^3$ 🟥 -3.52 % 🟧 -2.93 % 🟩 -2.56 %
Chlorophyll is an indicator of the biomass available at the base of the marine food web supporting all ecosystem productivity.	0.2 mg/m^3 🟥 -4.06 % 🟧 +6.6 % 🟩 -11.68 %	0.18 mg/m^3 🟥 -15.85 % 🟧 -15.85 % 🟩 -20.22 %	0.11 mg/m^3 🟥 +15.45 % 🟧 -2.73 % 🟩 +11.82 %

FISH CATCH POTENTIAL

Fish catch potential is an estimate of the maximum fish catch achievable given the marine resources available over a sustained period. It is linked to the concept of maximum sustainable yield, meaning the maximum amount of fish that can be extracted from a system without causing a collapse in fish populations.

It is a characteristic of the natural system, which is substantially different from realized catch, and a direct result of the fishery policy in place.

While no specific data is available the Turkish EEZ, a decrease in potential catch between 0 and 5% have been projected at mid century under high emissions scenarios for the Mediterranean Sea.

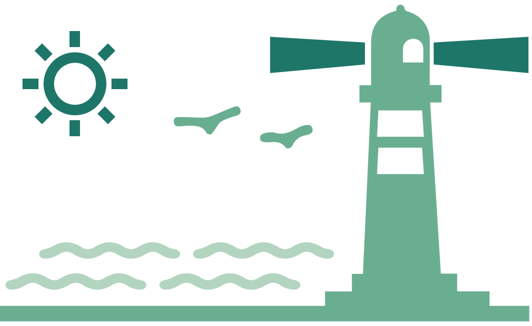
ANALYSIS DETAILS

All datasets were analysed using only data from within the marine EEZ and therefore excluding overseas territories, detached islands and any disputed or joint territories with other nations. In the assessment of current climate conditions, seawater surface tempereraturre data was obtained using satellite observations distributed in the framework of ESA Climate Change Initiative.

Future projections of marine indicators are represented by the combined analysis of results from 15 different Earth System models participating in the Coupled Model Intercomparison Project Phase 6 (CMIP6). These models include new and better representations of physical and biogeochemical processes, compared to previous IPCC assessment reports.

Fish catch potential data was obtained using the FAO's technical report and refers to the best and worst case climate scenarios from the Fifth IPCC Assessment Report. These mean estimates are subject to substantial uncertainties as discussed in the original work.

TURKEY
COASTS



OVERVIEW

Turkish shorelines face the Black Sea to the north, the small Sea of Marmara to the north-west, the Aegean Sea to the west, and the Mediterranean and Black seas to the south, which are connected by the Bosphorus Strait, a natural channel surrounded by the city of Istanbul. With approximately 500 islands and more than 8,000 kilometres of coastline, Turkish coasts combine rocky shores, sandy beaches and a limited number of fertile coastal floodplains. The most important coastal ecosystems are seagrass beds, coastal wetlands and dunes. Most of the coastal population is concentrated in the cities of Istanbul, with over 7 million inhabitants, and the smaller towns of Izmir, Antalya and Mersin on the Mediterranean coast. Numerous coastal settlements are found along the Black Sea and Mediterranean coasts.

Shoreline Length

8,140 km

Sandy Coast Retreat at 2050

-22.7 m

CLIMATE CHANGE HAZARDS

Coastal hazards such as erosion, storm tide inundation and permanent flooding, can have strong adverse impacts on coastal regions, with loss of sandy shores, damage to settlements, infrastructure and ecosystems. Climate change can exacerbate these impacts due to rising sea levels and increasing impacts of waves and storms. Climate change impacts on the coastal zone of Turkey are mainly driven by rising sea levels and possible changes in storms intensity and direction affecting the Eastern Mediterranean and the Black Sea. Possible impacts of sea level rise may include salt water intrusion into low lying areas and aquifers, recession of pocket sandy beaches and adjacent dunes, and shoreline recession in low lying coastal floodplains. These are concentrated on the Southern coast on the Mediterranean, with the delta of the Ceyhan (Pyramus) River being the largest, and less comillimetreson on the Turkish Black coast, where the KiKızılırmak Delta river is the largest.

SEA LEVEL RISE

Relative sea level rise has been observed over the past century, with significant localised increases, mainly driven by eustatic adjustments, of up to 6 millimetres per year, and an average increase of 2 millimetres per year. The latest IPCC projections indicate that, by 2050, global sea levels may rise between 0.18 metres, under a low emissions scenario, and 0.23 metres, under a high emissions scenario.

EXTREME SEA LEVEL

On average, one in 100 extreme sea level events are expected to rise from 0.91 metres at present day to 1.08 metres by 2050 under a medium emissions scenario.

Observed and projected sea level rise at 2050

2 mm/year

0.23 m

0.18 m

Current and projected extreme sea level at 2050

0.91 m

1.17 m

1.08 m

OBSERVED STORMS

The Turkish coast is influenced by storms developing in the Aegean, eastern Mediterranean and Black Sea. Although most parts of the Turkish coast are protected, the most exposed one is the Mediterranean. Trends in the Aegean for the past decades show a possible decrease in wave heights. The Eastern Mediterranean also shows a possible decrease in the wave height. Black Sea trends are uncertain.

FUTURE STORMS

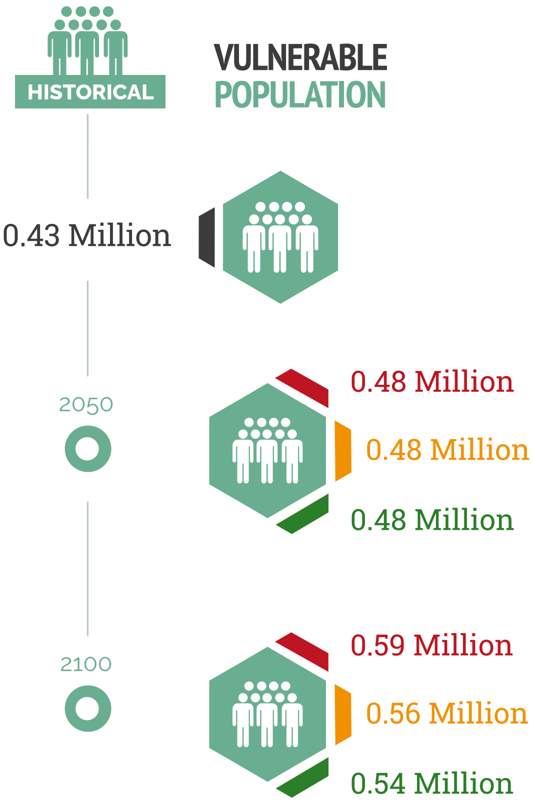
In the Mediterranean and Aegean, mean and maximum wave height under a high emissions scenario appear to be decreasing, with a slight eastward rotation in wave direction. The impact of climate change on the Black Sea region is quite uncertain, with both potential decreases or increases in the wave energy distribution.

VULNERABILITY AND RISK

Parts of the Turkish coast are vulnerable to the impacts of sea level rise, in particular the low lying coastal plains and the beaches along the Black, Aegean and Mediterranean seas. The high level of human activities in coastal areas puts a significant amount of stress on Turkish coastal zones, especially on coastal lowland plains.

The Marmara region around Istanbul has the highest population density of all. Some of the most vulnerable areas include the delta of the Kizilirmak river, mostly attributed to decreasing sediment supply to the coast, and the Ceyhan River delta, at risk from erosion, subsidence and saline intrusion.

Shoreline erosion is impacting numerous coastal tourism destinations on the Turkish coast. Recent analysis shows that approximately 4.8% of the Turkish coast is at high risk from climate change. Under a medium emissions scenario, the total population exposed to the annual coastal flood level is expected to increase from 430,000 to 480,0000 people by 2050.



VULNERABLE POPULATION

HISTORICAL

0.43 Million

2050

0.48 Million

0.48 Million

0.48 Million

2100

0.59 Million

0.56 Million

0.54 Million

INFLUENCE OF SEA LEVEL RISE ON EXTREME SEA LEVEL

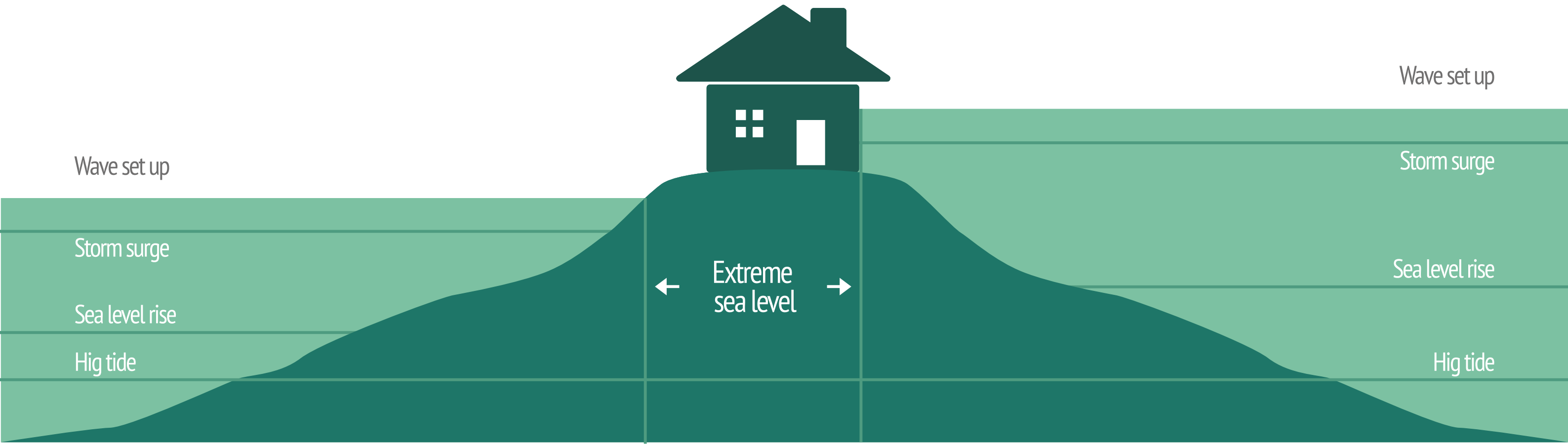
Present and future sea level rise are a consequence of carbon induced global warming causing melting ice and ocean expansion due to heat accumulation.

The extreme sea levels reported here are based on the 100-year storm surge + wave set up + sea level rise + high tide indicators. The first two parameters (storm surge + wave set up) are based on the 100-year value for the event; sea level rise is its projected value at 2050; and high tide is the absolute value of the highest tide calculated for a given locality, which won't be influenced by climate change.

+ Wave set up refers to the accumulation of water near the shore due to the presence of breaking waves.

+ Storm surge is an occasional increase in sea level driven by shoreward wind-driven water circulation and atmospheric pressure.

+ High tide is usually the highest tide reached in a given location based on tide records.



Present sea levels have risen globally by approximately 20 centimetres over the past century.

Future sea level rise is a projection based on different global warming scenarios, at approximately 100 centimetres by the end of 2100, with consequent inundation during extreme sea level events.

TURKEY
WATER

OVERVIEW

Water resources in Turkey are unevenly distributed across 25 hydrological river basins. The rivers often have irregular flows due to changing climate conditions and variations in topography. Rainfall is concentrated in the south and north of the country, with some of the largest rivers being the Kizilirmak River, flowing into the Black Sea, and the Ceyhan River, flowing into the Mediterranean.

Surface and groundwater resources are fairly limited in the highly urbanized and industrialized western part of the country. Annual freshwater consumption is about 44 billion cubic metres, of which 74% is used for agriculture, 15% for domestic uses, and 11% towards industrial uses. Turkey is located in a semi-arid region of the world, and precipitation varies greatly in different seasons and areas.

Renewable internal freshwater resources	227 billion m³
Renewable internal freshwater resources per capita	2,798 m³

Turkey's mean annual precipitation is 643 millimetres, which amounts to 501 billion cubic metres of water. Of this, 274 billion cubic metres evaporate and 69 billion cubic metres leak into aquifers and thus are lost from the water budget. Of the total amount, 158 billion cubic metres are mixed with rivers and lakes as surface water. Whereas 7 billion cubic metres come from neighbouring countries and 41 billion cubic metres are retrieved from groundwater.

CLIMATE CHANGE HAZARDS

Climate change can affect water resources through increasing temperatures, higher rates of evapotranspiration and altered rainfall patterns. This leads to changes in the water cycle, including decrease of snow and ice coverage, alterations of surface runoff and groundwater storage, as well as drought and flood occurrence. Reduced winter precipitation (especially in the western provinces), loss of surface waters, more frequent arid seasons, and degradation of soil are expected in Turkey, all of which are direct threats to water resources. Projections show an increase in the frequency, intensity and duration of extreme weather events such as drought in the south, southeast and west, as well as flooding, particularly in the western Black Sea region.

KEY POINT RUNOFF

With surface water concentrating 80% of the country's water resources, runoff management and variability is a critical challenge for Turkey's water management. Precipitation and runoff exhibit decreasing trends over many regions in Turkey over the past four decades, however, runoff has increased in the mountainous regions in response to higher temperatures and melting snow.

Regional climate change simulations suggest a 10-30% decline in the annual surface runoff of the Aras, Euphrates, and Tigris basins and a slight increase of about 4% in the annual surface runoff of Coruh basin by the end of the present century. At the country level an average increase in surface runoff by approximately 10% and -2% is expected respectively under low and high emissions scenarios for the 2045-2055 period compared to 2015-2025. If temperatures rise by 1.5°C, 2°C or 4°C, 1%, 2.1% or 9% of the area of the country will likely experience an increase in runoff, while 5%, 12.7% or 27% of the surface of the country will likely experience a decrease in runoff, respectively.

2050	Changes in annual runoff % of change	-2.4%	+9.8%
2050	Runoff increase % of area	+9.0%	+1.0%

KEY POINT DROUGHTS

Drought is a major concern in parts of Turkey where rainfall is highly variable and low. The combination of rainfall deficiency with other climatic factors and in particular high temperature creates serious risk of drought in the central and south-eastern parts of the country where agriculture is the main economic sector. Impact of drought in the low and variable rainfall regions of the country can be widespread, affecting water supply for agriculture, industry and the population. Drought risk is distributed unevenly in Turkey, with some areas experiencing higher risk, such as the coastal and central regions. Major droughts in the country have been recorded in 2007-2008 and 2013-2014. Particularly severe drought conditions are expected in the Western Mediterranean and Aegean Regions, although other regions of the country will also face more frequent, intense and long lasting droughts.

2050 Severe drought likelihood increase
% of change
+42.7%
+20.9%

2050 Hydrological drought frequency
% of change
+11.0%
+9.0%

2050 Groundwater Recharge
% of change
-28.4%
-8.5%

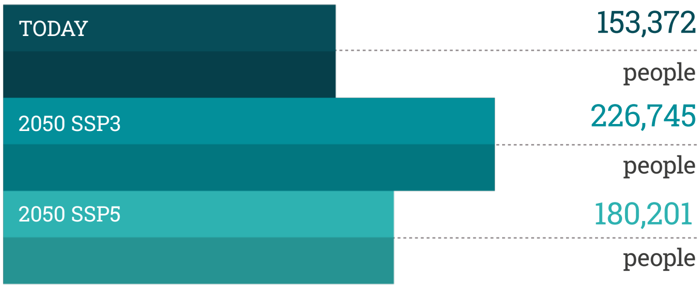
KEY POINT GROUNDWATER

About 18% of the total water resource potential of Turkey is made up of groundwater resources, mainly occurring in alluvial and karstic aquifers: a significant portion of the streamflow of major rivers is supplied by groundwater through springs and baseflow. Large coastal plains and deltas, grabens and pull-apart basins constitute the major alluvial aquifers. Turkey has faced some water mismanagement problems whose consequences are observable in terms of the decline of groundwater levels, reduced spring and streamflows, desiccation of lakes and wetlands, and loss of ecosystems. While a reduction in rainfall in western Turkey and changes in the distribution of rainfall in other parts of the country will affect groundwater availability and recharge, there is uncertainty about the geographical distribution of these changes. At the country level, a -15.9%, -17.6% and -20.3% decrease of the annual groundwater recharge for the period 2045-2055 compared to the timeframe 2015-2025 is expected respectively under low, medium and high emissions scenarios.

KEY POINT FLOODS

Nearly 30% of all the natural disasters in Turkey consist of flood events. Due to the diverse topography and geographic location of Turkey, flood hazards are observed both upstream of catchments as flash floods, and downstream of catchments as over-bank floods. More than 2,000 floods were recorded in the period between 1930 and 2020, causing 1,026 deaths, with about 1.5 million people affected. The number of damaging floods has also increased with the growing population. Floods concentrate in the summer season with a peak in July. Most of the floods and deaths occurred in the Black Sea region. Different regions may be affected differently by climate change. The Black Sea region is expected to experience an increase in flood risk under medium and high emissions scenarios of 100% to 300% by approximately 2050. On the country scale, changes in the amount of people exposed to floods are expected, with an increase from about 153,000 in the present day to 226,000 under SSP3 and 180,000 under SSP5 by 2050.

POPULATION AFFECTED BY RIVER FLOODS

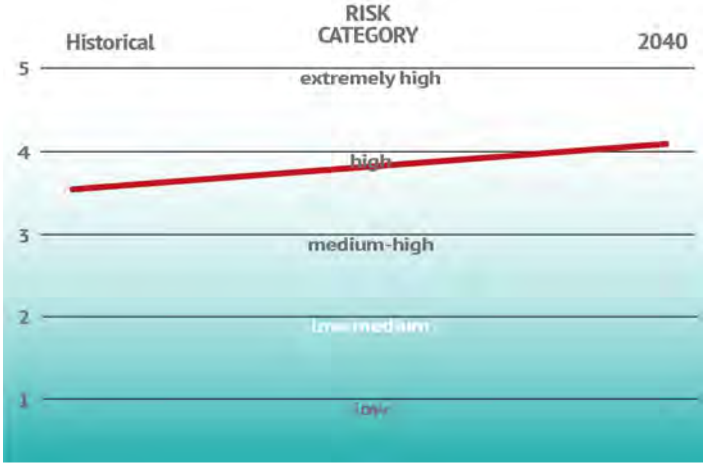


RISK INDICATORS

The water stress index summarises current and future water related vulnerabilities and risks at the global level. Scores are based on the ratio of total water withdrawals, including agriculture, industrial and human consumption, to available renewable surface and groundwater supplies.

WATER STRESS

Turkey's water stress level is considered high for the recent past (1960-2014 average), and it is expected to increase in the near future (2030-2050) based on climate change projections.



TURKEY
AGRICULTURE

OVERVIEW

Turkey's climate varies widely with a combination of maritime and continental patterns shaping several agroclimatic regions: the Black Sea, the southern coastal Mediterranean, and the Aegean and Central Anatolia plateau.

Agricultural fields cover 35% of Turkish land. Wheat is the major staple food crop and is mostly grown in Central Anatolia, but also in Eastern Anatolia and Mediterranean regions. Other relevant cereals include oats and barley in central Anatolia, while maize an d rice are mostly cultivated in the Black Sea and Maramara regions.

Major cultivated industrial crops are sugarbeet, cotton and tobacco. Fruits and vegetables are also important to the Turkish economy with cultivation of grapes, olives, citrus, apricots, figs, hazelnuts, pistachios, melons, potatoes, etc. Agriculture adsorbs 84% of total water withdrawal, and only 20% of agricultural land is irrigated.

20 Mt
Wheat

17.4 Mt
Sugarbeet

7 Mt
Barley

5.7 Mt
Maize

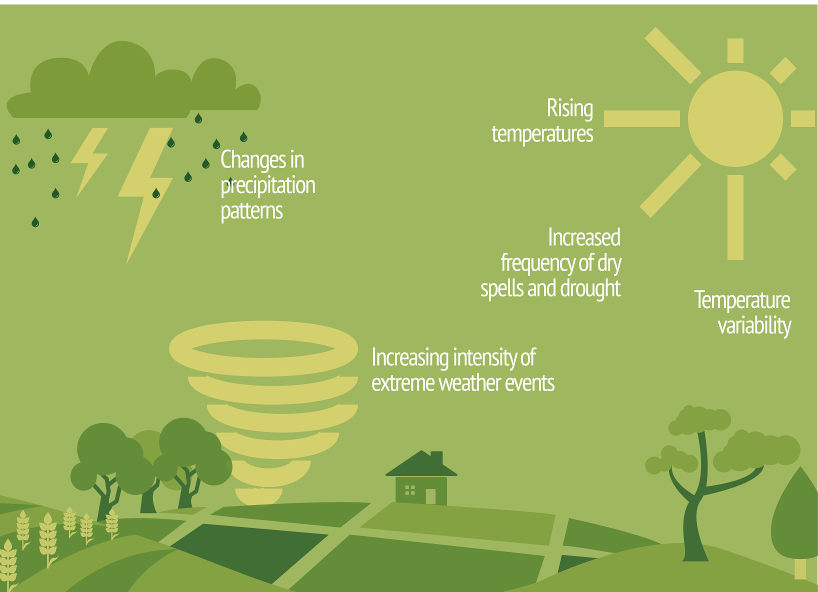
3.9 Mt
Grapes

1.5 Mt
Olives

	Added Value of Agriculture, Forestry and Fishing	Share of Agriculture Value added in Total GDP	Agricultural land	Area Equipped for Irrigation
2000	40,851 USD Million	9.9 %	26,379 Thousand HA	4,745 Thousand HA
2018	61,822 USD Million	6.3 %	23,185 Thousand HA	5,215 Thousand HA

EXPEXTED IMPACTS ON AGRICULTURE PRODUCTIVITY

Rising temperatures, reduction in average annual precipitation, and intensification of extreme events such as heat waves and drought, affect production variability with a tendency towards yield reduction for many cultivated species, accompanied by a probable decrease in food quality. Crops respond to increases in temperatures with changes in duration of the growing season, early appearance of phenological phases and potential shifts of cultivation areas toward higher latitudes and altitudes for better growing conditions. However, impacts vary significantly depending on the geographical area and specific crops in question.



CROP PRODUCTIVITY

Crop productivity refers to the harvested yield of a crop per unit of land area. It is strongly influenced by climate and other environmental and management factors.

Climate change is expected to have an impact on the productivity of several major crops, although this may in part be offset by the fertilizing effect of higher CO_2.

Impacts are estimated using a range of model projections based on low to high emission scenarios and reported as percentage changes between the 30-year average around the historical period and the 30-year average around 2050.

2.7
5.2 (2)%
5.6 (3.9)%
Wheat
tons / ha

59.1
9.9 (-13.1)%
8.1 (na)%
Sugarbeet
tons / ha

9.5
-1.7 (-4.7)%
-2.5 (-7.2)%
Maize
tons / ha

tons / ha

2050

Productivity change with (without) the CO_2 fertilization effect. Estimates assume sufficient water and nutrient supplies, and do not include impacts of pests, disease, or extreme events.

CHANGE IN WHEAT

🟥 − = 🟩 +

CHANGE IN MAIZE

🟥 − = 🟩 +

It is estimated that Turkey will experience overall decreases of up to 25% in maize yield, although a localised increase may be seen in the Black Sea and Maramara regions. Under the combined effect of CO_2 fertilization and increasing temperatures, wheat yields are expected to increase overall, with some losses expected in the Mediterranean southern coastal region. Prolonged drought events may alter the stability of wheat production, particularly in the Central Anatolian provinces. Increasing temperatures will accelerate and shorten cereal phenological stages, reducing time for biomass accumulation and final yield. Hazelnut yield may decrease by up to 13% in the eastern Black Sea sub-region, while some increase can be expected in the Black Sea and Eastern Marmara regions. Hazelnut yield stability will be affected by frost risks associated with earlier blooming of hazelnut flowers.

ADAPTATION IN AGRICULTURE AND WATER RESOURCES

Agriculture is the biggest water user in Turkey and is expected to be severely affected by climate change. Climate change may benefit some widely used crops. However, higher temperatures will generally require an increase in irrigation demand due to higher plant evapotranspiration. Currently, there is a widespread use of inefficient irrigation methods, which may considerably enhance water shortages in the future. Water use efficiency gains of up to 50% are possible by switching from gravity to drip irrigation or sprinkler feed systems.

CHANGE IN WATER DEMAND

🟩 − = 🟥 +

Agriculture
Water Demand
% of change

+44.1%
+46.9%

2050

Adaptation practices should aim to reduce cultivation of water-intensive crops in drought-prone areas, and management should focus on working under climate conditions of water scarcity.

TURKEY
FORESTS

FORESTS IN TURKEY

Turkish forests are generally located in mountainous areas with high biodiversity values. In the north, deciduous forests prevail at moderate elevation, while conifers dominate at higher ones.

Being characterized by a diversified climate, the specific composition of forests varies according to the biogeographical zone, with typical forest formations of different regions.

FORESTED AREA AND CARBON STORAGE

About 30% of Turkey is covered in forests, with a steadily growing trend over the last few decades. Recent estimates confirm that forests remove 90.19 million tons of CO_2 equivalent from the atmosphere, representing a crucial sink for Turkey's emissions reduction policies.

1990

20 Mln ha
Million hectares
Forested area

21 Tons/ha
Tons of Carbon per hectare
Carbon stock

2020

22 Mln ha
Million hectares
Forested area

87 Tons/ha
Tons of Carbon per hectare
Carbon stock

FOREST PRODUCTIVITY

Forest productivity or Net Primary Production is the net carbon captured by plants. It is the difference between the carbon gained by Gross Primary Production - net photosynthesis measured at the ecosystem scale - and carbon released by plants' respiration. It is expressed per unit land area.

2050

Productivity anomaly
Tons of Carbon per
hectare per year

+0.28

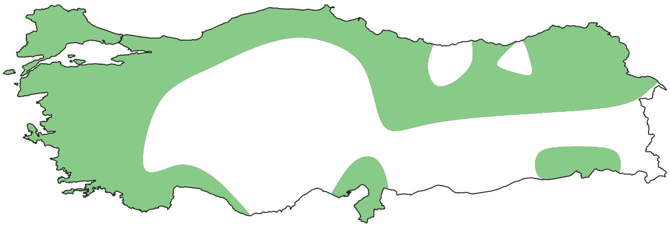
+0.31

Weak increase in western and northern Turkey

+ Fertilizing effect of increasing atmospheric CO_2, rising temperatures, and prolonged growing season promote production

No areas with an expected decrease in forest primary production

+ Increasing risk of drought stress due to modifications in the water regime reduce productivity



KEY SPECIES UNDER CLIMATE CHANGE

REDUCTION
BEECH
Strong reduction of suitability range of Oriental beech (Northern Turkey)

LOW VULNERABILITY
CONIFERS
Southern conifers show less vulnerability

EXPANSION
MEDITERRANEAN
Mediterranean needleleaved evergreen types to expand northwards

VULNERABILITY
PINE
High vulnerability for Turkish pine in drier areas (South)

FIRES IN TURKEY

Fire is a structural ecological process that provides several types of ecosystem services and impacts on socio-ecological systems, including human health, carbon budgets, and climate change. Changes in global fire activity are influenced by multiple factors such as land-cover change, policies, and climatic conditions. Fire also releases large quantities of greenhouse gases into the atmosphere, contributing to a vicious cycle.

During the last three decades, the total forest area affected by fire amounted to approximately 300 thousand hectares with 65.5 thousand fires occurring.

BURNING

300 THOUSAND HECTARES OF FOREST

EMITTING

0.78 TERAGRAMMES OF CARBON PER YEAR

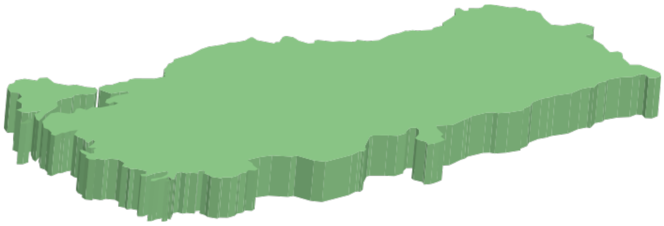
AGRICULTURE RELATED FIRE EMISSIONS CONTRIBUTED TO 73% OF TOTAL FIRE RELATED CARBON EMISSIONS

COSTING

8.6 MILLION USD IN FIRE DAMAGES TO FOREST RESOURCES

WHERE DO FIRES OCCUR?

Wildfires mostly affect mediterranean and temperate broadleaf forests.



Fire prone areas are located across the Mediterranean and Aegean shores.

CASE STUDY: WILDFIRES

In Turkey, the year with most fires was 2013, while the worst fires since 1990 occurred in 1994, 2000, 2008, and 2021. Large wildfires are a challenging threat to the Wildland urban interface (WUI), the transition zone between houses and wild vegetation, as well as for tourism.

In 2008, a large forest fire occurred in Antalya, Turkey's most touristic province, burning for 5 consecutive days and affecting approximately 15,800 hectares of forest.

During the summer of 2021, Turkey had to deal with one of its most pronounced fire seasons. Over the course of a week more than 130 fires were reported mainly across the Mediterranean and Aegean coasts. The number of fires and the burned areas recorded during 2021 were around 104% and 450% greater than the respective averages for 2008 and 2020.

Strong relationships exist between fire activity, drought, high temperatures, low humidity and wind.

FUTURE BURNED AREA

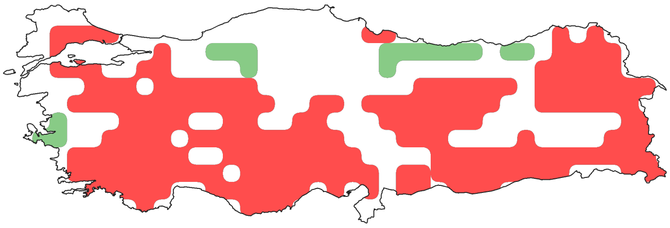
Under a low emissions scenario, the entire country might experience a generalized increase in fires in areas that are dominated by mediterranean shrublands and temperate forests. This trend is further emphasized under a medium emissions scenario.

Burned Area
km² per year

2050

+718

+558



Decrease in burned areas for a low emissions scenario

Increase in burned areas for a low emissions scenario
+ Prolonged fire season across all of Turkey due to rising temperatures

FUTURE FIRE EMISSIONS

Fire emissions follow a similar spatial pattern to burned areas with a marked increase in mediterranean areas under a medium emissions scenario.

Fire Carbon emission
Teragrams of Carbon per year

2050

+4.4

+3.6

TURKEY
URBAN

OVERVIEW

The rate of urbanization in Turkey in 2020 was 76.15% and is expected to reach 86% in 2050.

One quarter of the urban population lives in the agglomeration of Istanbul, and another 33% in urban areas with less than 300,000 inhabitants. Migration from rural areas is on-going and population growth is concentrated in urbanized areas.

Built up areas cover 1.55% of Turkey (12,098.87 square kilometers).

Population in Urban Areas

2020
63,803,445

2050
82,192,061

Graphs refer to data provided by United Nations, Department of Economic and Social Affairs, Population Division (2018). World Urbanization

Urbanization Rate

2020
76.1%

2050
86.0%

OVERVIEW OF KEY CLIMATE IMPACTS IN URBAN AREAS

Major impacts from climate change for Turkish urban areas regard heat stress, flooding and droughts as well as flooding from heavy precipitation events and storm surges.

HEATWAVES AND HEAT STRESS

Mean temperatures in Turkey are increasing, from 13.2°C for the period between 1971 and 2000, to 13.5°C for the period between 1981 and 2010. Heatwave related mortality has increased.

During three heatwaves in Istanbul in 2015, 2016, and 2017, heatwave related mortality increased by 11%, 6%, and 21%, respectively. Frequency and intensity of heatwaves is expected to increase under future climate change, with heatwave frequency to double under a high emissions scenario, by 2050.

2050

Cooling Degree Days
% of change

+51.0%
+22.0%
+16.0%

2050

Heatwave frequency
% of change

+99.6%
+68.7%
+40.8%

2050

Heatwave duration
% of time

+4,242%
+774%
+284%

RAPID URBANIZATION

In Turkey, rapid urbanization is transforming agricultural areas with impervious surfaces and increases population densities at the urban peripheries. The results are decreasing shares of permeable and vegetated surfaces in the urban areas and fringes.

Under heatwaves, differences between urban impermeabilized areas and the surrounding areas are up to 6°C. High temperatures in urban areas worsen impacts from high levels of air pollution. In 2017, the entire Turkish population was exposed to pollution levels exceeding WHO guideline values for PM2.5.

2017

Population exposed to air pollution

100.0%

COASTAL FLOODING

Population densities in Turkish coastal cities are increasing, due to intense migration, thus enhancing the exposure of assets and people in areas vulnerable to increasingly frequent flooding and erosion. Sea level rise will put growing cities on the Mediterranean coast, as well as tourist attractions in Istanbul, at risk.

Projected sea level rise

2050

0.23 m

0.18 m

2100

0.77 m

0.38 m

FLOODING

Changing precipitation patterns are already causing both water scarcity and flash floods in Turkish cities. Due to an increasing rate of soil sealing both in cities and throughout the country, water is prevented from infiltrating into the ground and causes increasing run-off and accumulation of water masses in the lower parts of cities.

Flooding following intense precipitation events lead to loss of life and property in metropolitan cities such as Istanbul, Ankara, Izmir, as well as in smaller cities and rural centres. Precipitation is expected to decrease and become more variable with a potential increase in extreme events both under the form of intense precipitation and drought periods. Consequently, water scarcity will represent a major challenge for urban areas.

2050

Runoff increase

% of area

+9%

+2%

+1%

SURFACE SEALING AND FLOODS

Heavy precipitation in cities is problematic due to the high level of sealed surfaces. Soil sealing increases run off and reduces the amount of water absorbed by soil. Where there are large amounts of impervious ground cover, short duration extreme rainfall events can lead to increased flooding, even resulting in flash floods.

URBAN GROWTH AND LAND USE CHANGE

Urban growth will further increase flood risk, as soil sealing reduces natural drainage capacities of urban soils, accelerating and increasing run off.

Due to future intense urbanization in the urban area of Istanbul, the extent of potentially flooded surfaces may almost double: from 2.4 square kilometers to as much as 4.3 square kilometers for the same event, under intense future urbanization.

2010

% of urban population

Population living in slums

8.6%

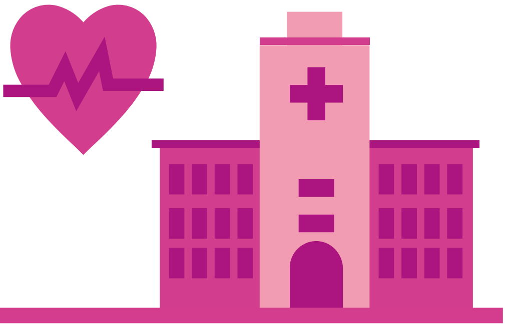
2018

% of total population

Urban population living in areas where elevation is below 5 meters

1.2%

TURKEY
HEALTH



OVERVIEW

Turkey is highly sensitive to the health impacts of climate change, including extreme weather-related deaths, increased morbidity from cardiovascular diseases, and dengue and malaria mortality. It is estimated that the intensity, frequency, duration, and geographical extent of heatwaves will increase due to climate change which will likely increase the frequency and intensity of heatwaves, leading to increased mortality among the elderly and children. Warming, changing rainfall patterns, and increase in frequency and intensity of extreme events, such as heatwaves and floods, will also likely increase the spread of vector-borne diseases, including malaria, Crimean-Congo Haemorrhagic Fever (CCHF), sandfly fever, leishmaniasis, and dengue.

HEAT RELATED MORTALITY

In 2018, there was an 87% increase in heat-related deaths in Turkey, compared to the 2000-2004 baseline.

IMPACTS ON LABOUR

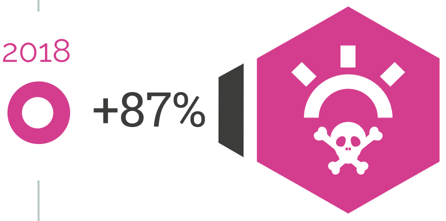
Labour is directly affected by changes in environmental conditions. Warming affects both the number of hours worked (labour supply) and on the productivity of workers during their working hours (labour productivity). Both labour supply and productivity are projected to decrease under future climate change in most parts of the world, and particularly in tropical regions.

Parts of sub-Saharan Africa, south Asia, and southeast Asia are at highest risk under future warming scenarios. Future climate change will reduce global total labour in the low-exposure sectors by 18 percentage points and by24.8 percentage points in the high-exposure sectors under a 3.0°C warming scenario

Total labour in Turkey is expected to decline by 1.4% under a low emissions scenario, and by 2.7% under a medium emissions scenario.

Heat-related mortality

% change with respect to 2000-2004

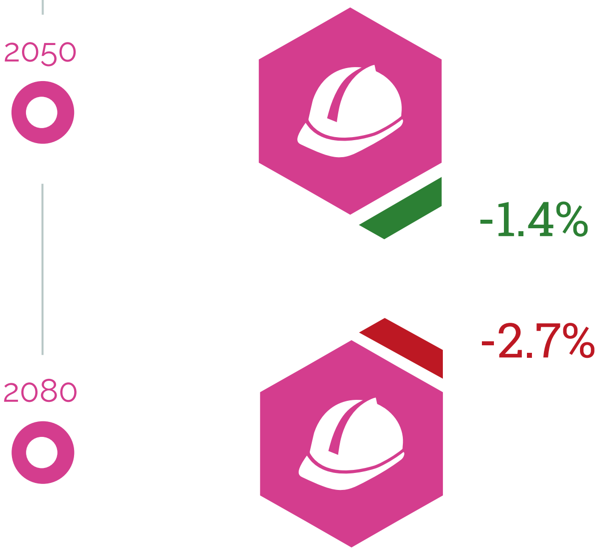


2018

+87%

Impact on total labour

% change with respect to 1986-2005 baseline



2050

-1.4%

2080

-2.7%

CLIMATE CHANGE AND DENGUE

Dengue has spread throughout the tropical world over the past 60 years and now affects over half the world's population. Globally, vectorial capacity for both dengue vectors (A. aegypti and A. albopictus) has been rising steadily since the 1980s, with nine of the ten highest years occurring since 2000.

Climatic stressors are one important driver of the current distribution and incidence of dengue. Climate change is likely to expand the geographical distribution and suitability of several vector-borne human infectious diseases including dengue. The risk of dengue transmission is increased by warming climates, as the growth and development of mosquitoes are significantly influenced by temperature, precipitation, and humidity.

CLIMATE CHANGE AND ZIKA

Zika virus has spread to at least 49 countries and territories since 2013. Climate change impacts on transmission suitability risk have increased over the years and future warming over 1.3 billion additional people could face suitable transmission temperatures for Zika by 2050.

DENGUE AND ZIKA: POPULATION AT RISK

Under a medium emissions scenario, 91.8% of the population will be at risk of transmission-suitable mean temperature for dengue by 2050, whereas 92.9% will be at risk under a high emissions scenario. In the case of Zika, 74.3% of the population will be at risk by 2050 with medium emissions, whereas 82.2% will be at risk with high emissions.

CLIMATE CHANGE AND MALARIA

10.9% of the Turkish population will be at risk of malaria under a low emissions scenario in 2050, whereas 12.6% will be at risk under a high emissions scenario.

Dengue suitability

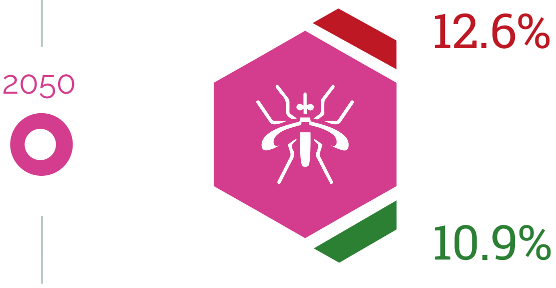
% of population at risk

Zika suitability

% of population at risk

Malaria suitability

% of population at risk



POLLUTION AND PREMATURE MORTALITY

57,779 people died prematurely due to exposure to PM2.5 in Turkey in 2018, compared to 28,924 in 2010.

TURKEY
ENERGY

ENERGY SYSTEM IN A NUTSHELL

Turkey's strong and sustained economic growth over the past decades led to a strong increase in energy demand, resulting in heavy import dependency for oil and gas.

Turkey reacted by diversifying its oil and gas providers, and its overall energy mix. This led to a strong expansion of renewables, the commissioning of its first nuclear plant by 2023, and strong improvements in energy efficiency. Turkey has one of the lowest energy intensities of GDP in the world.

0.06
ktoe/US$
Energy intensity

2.2%
AC Share in electricity consumption

72%
Import dependence ratio

CLIMATE CHANGE TODAY

INCREASING TEMPERATURES

Temperatures in Turkey have been increasing at a yearly rate of 0.0665°C since 1994, which is double the world average, and has resulted in a sharp increase in cooling needs.

EXTREME EVENTS

Extreme weather conditions have already resulted in increased droughts, floods, forest fires and heatwaves, threatening the energy sector's operations and infrastructure.

ENERGY SUPPLY

Fossil fuels dominate the energy mix: 29.3% oil, 28.6% coal, 25.2% natural gas in 2019. There is no nuclear generation yet, but a plant has been commissioned for 2023. While biofuels halved since the 90's, to a 2.2% share, wind and solar underwent a 30-fold expansion, and now cover 9.4% of total primary energy supply, whereas hydropower (5.2%) also saw an almost five-fold increase.

ENERGY DEMAND

In Turkey, energy is used mainly by the industrial sector (about 36% of final demand in 2018, including 4.5% for non-energy use), transport (27%) and residential (20%), followed by commercial use (12%) and agriculture and fishing (4.4%). Air conditioning's contribution to residential electricity demand is still very low (2.2% in 2017).

FUTURE ENERGY DEMAND

Turkey has a variety of climates, ranging from Mediterranean on the west and southern coast, to alpine in the central-east mountains making both heating and cooling needs relevant. Overall, the increase in cooling needs will prevail, resulting in an increase in electricity demand of 477.7 PJ (or 119 million KWh) by 2050 under a medium emissions scenario. Summer demand peak may arise in the presence of heatwaves.

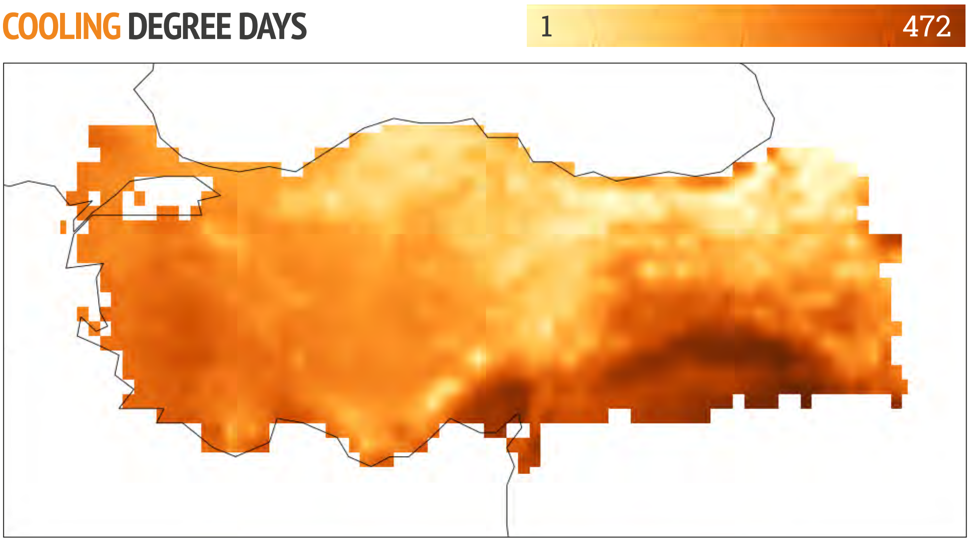
Net change in energy demand due to changes in DD/CDD
Billion KWh

2050

+ 118.8

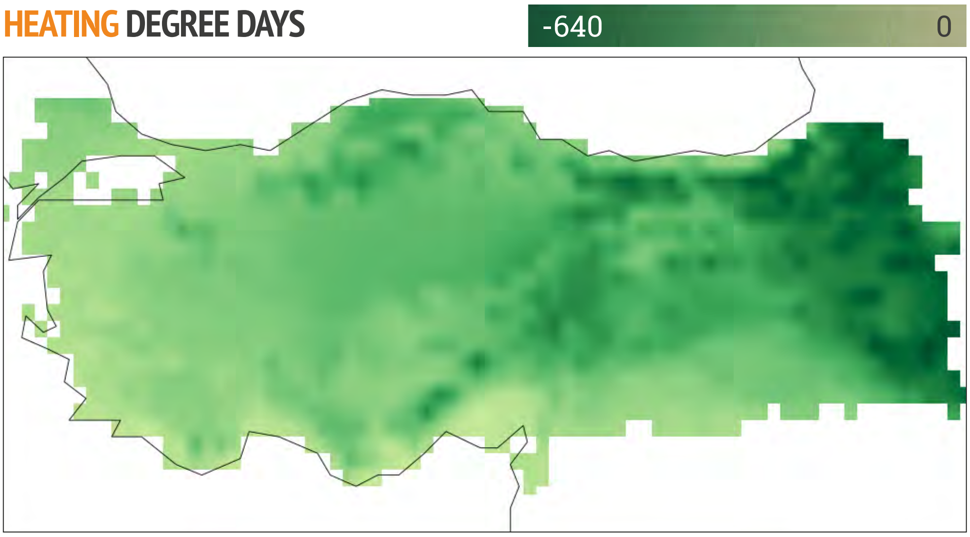
COOLING NEEDS

Highest increase in cooling needs in the southern regions, including the highly touristic Mediterranean coast. Significant increases in the west, with Istanbul showing higher increases than Ankara.


COOLING DEGREE DAYS

HEATING NEEDS

Largest drops in heating needs are expected in the traditionally coldest parts of the country (mountain areas on the eastern border and Black Sea region). Significant decrease in heating degree days are expected all over Turkey.


HEATING DEGREE DAYS

FUTURE ENERGY SUPPLY

The future configuration of the Turkish energy mix is likely to be determined by the evolution of energy policies and hence is outside the scope of this report. Turkey's push to diversify energy sources, beside spurring the current expansion of renewables and opening to nuclear generation, has kept a neutral and pragmatic stance towards all energy sources, and has not yet resulted into a long-term decarbonization commitment; hence there is no evidence to support a substantial shift in the current relative relevance of the various components of the energy mix and their related vulnerabilities.

Change in Hydropower generation
% of change

2050

-4.62%

-3.53%

EXPECTED IMPACTS OF CLIMATE CHANGE

There are no quantitative projections of the impacts of climate change on Turkey's energy sector. Qualitatively, the main concerns are for the decreasing output of hydropower, for the impact of droughts on the thermal efficiency of thermal power plants, for the impacts of heatwaves on the electricity transmission systems, and the impact of increased frequency of extreme events.

TURKEY
ECONOMY

OVERVIEW

Turkey ranks 18th in terms of GDP in the G20 group. The COVID 19 crisis had a small impact when compared to other G20 countries. In 2020 real GDP grew by 1.8%. In 2021 growth continued and real GDP grew by 6%.

IMPACTS ON GDP

The projected macroeconomic impact of climate change on Turkey's economy varies according to the emission scenarios considered, the time horizon, the direct impacts covered, and the specificities of the estimation method used.

It ranges from a virtually unchanged situation (0.07% loss) under a low emissions scenario in 2030, to almost an 8% GDP loss under a high emissions scenario by the end of the century.

GDP Loss

% change w.r.t baseline

2050

0.9/2.26%

0.2/0.6%

2100

7.98%

0.64%

SECTORAL ECONOMIC IMPACTS

IMPACTS ON AGRICULTURE

Until a few decades ago, agriculture was traditionally a major contributor to Turkish GDP. It ha declined steadily from 65% of GDP in 1960 to 6.9% in 2019. An important source of vulnerability for Turkish agriculture is its dependence on precipitation to satisfy its water needs. About three fourths of water consumption in Turkey is used for irrigation (making agriculture the primary water user); however, in 2016, only 31.4% of the cultivated land could be irrigated.

The direct impact of climate change (medium emissions scenario) on agriculture will result in a virtually constant sector's added value (+0.36%) up to 2035, a slight decline between 2035 and 2060 (-1.69%) and a more sustained decline in the last four decades of the century (-5.12%).

The expected decline in precipitations will lower the income of farmers working on rain-fed land by 0.71% by 2060 and by 1.23% by the end of the century, while slightly raising those of the farmers working on irrigated land. The Turkish agri-food industry would undergo similar if smaller impacts, with a virtually constant added value (+0.1%) up to 2035, a slight decline between 2035 and 2060 (-1.14%) and a more sustained decline in the last four decades of the century (-3.32%).

There will be noticeable differences across provinces, with the southern and west-central ones suffering the most in terms of agricultural impacts and the Bosphorus area and north-central provinces taking the hardest hit in terms of agri-food production.

Impacts on livestock have not been assessed yet in economic terms but significant adverse effects are expected from heatwaves as well as from increased occurrence of droughts, floods, and landslides.

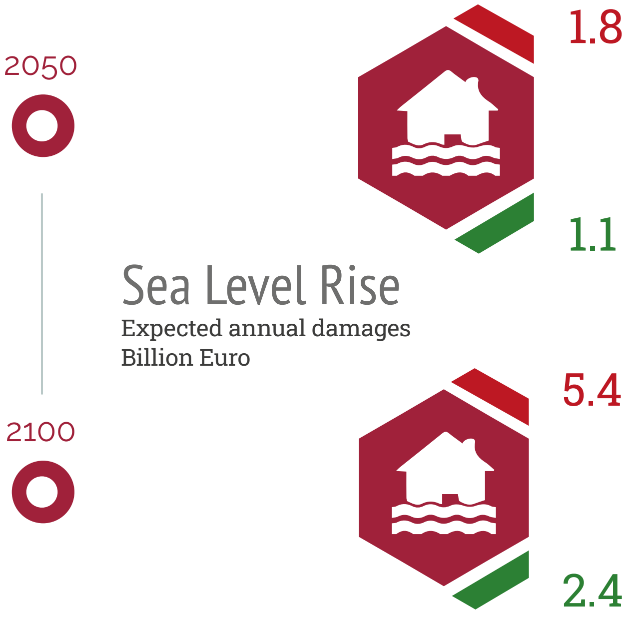
IMPACTS ON ENERGY

As with all other economic sectors, energy supply and energy networks in Turkey will undergo more intense stress from extreme weather events, in particular those related to the water-energy nexus due to floods and droughts.

Economic impacts of shifts in household and firm energy demand (see chapter on energy) are difficult to predict and will mostly lead to redistribution effects. In the case of Turkey, the magnitude of the increase in demand for cooling is expected to exceed by far the one of the decrease in heating demand, hence a significant increase in energy bills is expected.

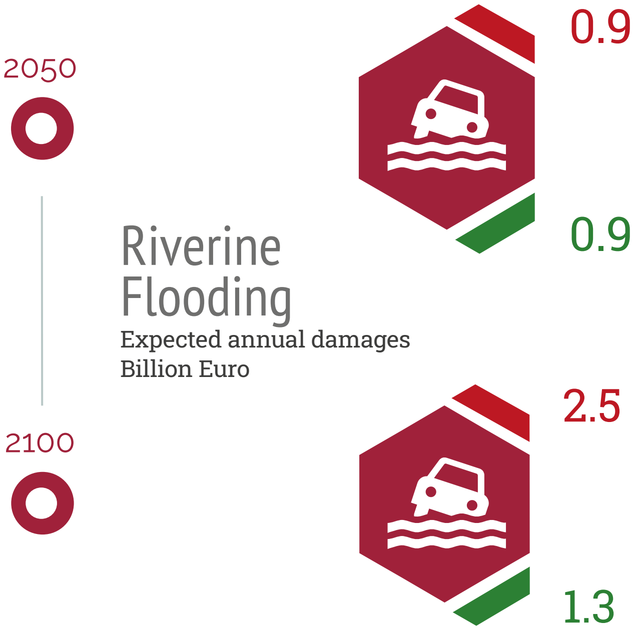
SEA LEVEL RISE DAMAGES

Sea level rise can pose non-marginal threats to Turkish coastal infrastructure. Without improvements in the current level of coastal protection the country may experience physical asset losses amounting to 1.1 and 1.8 billion EUR by mid century and to 2.4 and 5.4 billion EUR by the end of the century in low and high emission scenarios, respectively.



RIVER FLOODING DAMAGES

Riverine floods are only slightly less concerning. Inland infrastructure may be subject to direct annual losses of 0.9 billion EUR by 2050 and ranging between the 1.3 billion EUR for a low emissions scenario and 2.5 billion EUR for a high emissions scenario in the second half of the century.



IMPACTS ON FORESTRY AND FISHERY

Fisheries are expected to suffer negative impacts as well, mainly due to the transition of marine ecosystems along Turkey's coasts towards patterns typical of warmer waters. This transition is already observed and expected to intensify in the future, with tropical species moving into the Mediterranean Sea from the Red Sea and Mediterranean species, in turn, moving into the Black Sea. Such a transition has already resulted in anchovies becoming rare along the Turkish coast on the Black Sea, causing their price to soar by up to 300%.

IMPACTS ON TOURISM

Before the COVID 19 crisis, tourism used to be a very dynamic and fast-growing economic sector in Turkey, accounting for almost 4% of GDP and directly employing 2.2 million people, or 7% of the workforce, in 2018. Almost 52% of total service exports in 2018 came from travel, and 45.8 million international tourists arrived in Turkey in the same year, generating 142.4 TRY (25.6 EUR) billion in revenues.

As with other Mediterranean destinations, Turkey is vulnerable in terms of suitability of climate conditions for tourist activities, particularly for beach-and-sand tourism and urban tourism.

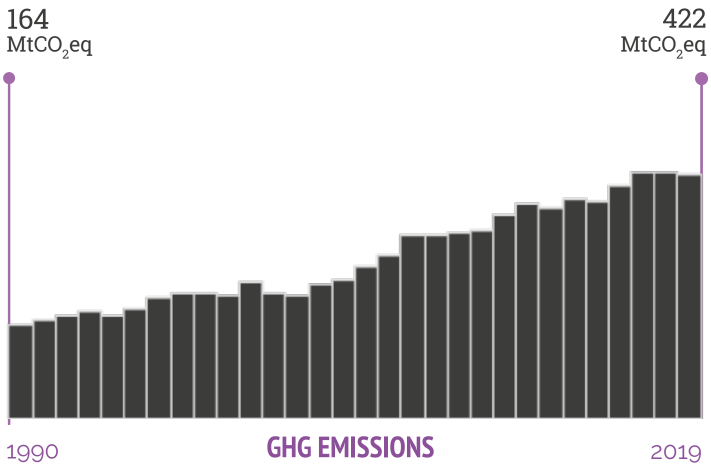
Changing climatic conditions adversely affecting tourism activity might lead, by the end of the century, to overall Turkish GDP losses of 0.89% in case of a 1°C increase in average global temperatures, 2.82% in case of a 2°C increase, and 5.37% in case of a 3°C increase.

Southern beach destinations such as Antalya will be hit the worst, while Istanbul, which can count on a wider range of cultural and historical attractions and whose climatic comfort conditions will not be so severely worsened by climate change, will face only a moderate loss in visitors in percentage terms compared to a no climate change counterfactual scenario.

TURKEY
POLICY

OVERVIEW

Turkey is the world's 20th economy in terms of nominal GDP. It is 16th for GHG emissions among G20 countries. The emissions trend is steadily increasing.



INTERNATIONAL COMMITMENTS

Turkey officially ratified the Paris Agreement in 2021. The Turkish NDC commits to reduce GHG emissions by 21% with reference to a specific business-as-usual scenario by 2030.

CLIMATE POLICY COMMITMENTS CHRONOLOGY

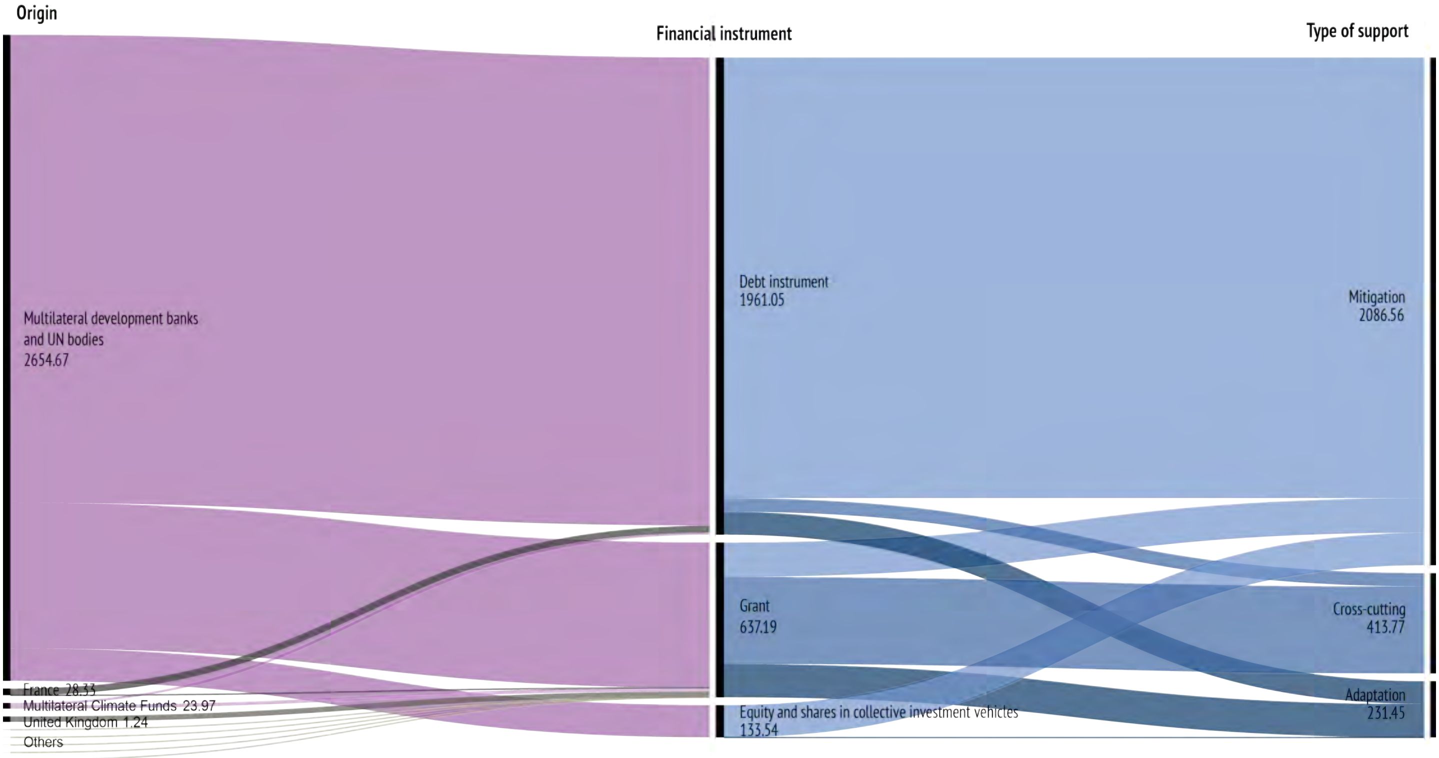
2009 **KYOTO PROTOCOL - 1ST PERIOD**
No target

2021 **PARIS AGREEMENT - 1ST NDC**
21% GHG reduction by 2030, with reference to a specific business-as-usual scenario

PARIS AGREEMENT - NDC UPDATE
No further update

INTERNATIONAL CLIMATE FINANCE ASSISTANCE

The diagram is based on OECD DAC data on climate-related development finance and it shows that Turkey ireceived 2.7 billion USD in 2017-2018, mainly from multilateral financial institutions and in the form of debt instruments.



SUSTAINABLE RECOVERY POLICY

In 2020, Turkey spent 2.63 billion USD to recover from the crisis generated by the Covid-19 pandemic. According to the Global Recovery Observatory, the full amount can be considered sustainable, because it targets clean transports

74.55
billion $
Total Spending

2.63
billion $
Recovery Spending

2.63
billion $
Green Spending

DOMESTIC ADAPTATION POLICY

Turkey developed a framework for adaptation consisting in an Adaptation Strategy with an integrated Adaptation Action Plan (2011). In this framework, sub-national entities are designated to develop their own adaptation plans.

- ○ Domestic Adaptation Policy
  - ○ Inclusion of Adaptation in NDCs
  - ○ Integrated Adaptation & Mitigation Policy
  - ● Dedicated Adaptation Strategy
  - ● Dedicated Adaptation Plan
- ○ Subordinate Adaptation Policies
  - ○ Sectoral Adaptation Plans
  - ● Subnational Adaptation Plans

○ Policy not in place ● Active policy

ADAPTATION POLICY HIGHLIGHTS

TRANSNATIONAL INITIATIVES

Strengthening Multi-Hazard Early Warning Systems and Risk Assessment in the Western Balkans and Turkey

The project aims to reduce the vulnerability of Albania, Bosnia and Herzegovina, Croatia, the Northern Macedonia, Montenegro, Serbia, Kosovo, and Turkey to natural hazards such as drought, flood and forest fires

NATIONAL INITIATIVES

Enhancing Required Joint Efforts on Climate Action Project

Technical assistance is provided on capacity building through an extensive training programme. Effective communication with climate-related stakeholders, and awareness raising activities are conducted and local climate change actions are realised through a grant scheme of 38 projects.

Strategic plan for climate change adaptation of forestry

The Plan aims at enhancing climate adaptation actions to assist the forestry sector to become more resilient by suggesting 9 strategies and 51 respective actions

SUBNATIONAL INITIATIVES

Istanbul Climate Change Action Plan

The plan aims at enhancing resilience of the city's ecosystem, social structure and economy against climate change and reduce greenhouse gas emissions.

Bursa Sustainable Energy and Climate Change Adaptation Plan

The plan outlines the measures to reduce direct urban greenhouse gas emissions and actions to address urban heat island effect, water management, public health, green areas, biodiversity, and corridors.

ENERGY TRANSITION

Turkey ranks in the middle of the ranking for what regards the Energy Transition indicator. Of significance is the positive performance in the Renewables sector, thanks in particular to the role of hydropower and geothermal in the electricity mix, while on the contrary high levels of Emissions are determined by the still relevant role of coal in the electricity mix, by an energy-intensive industrial sector and by high levels of air pollution in the country.

Fossil fuels are still a relevant component of Turkey's energy mix. When it comes to Electrification, Turkey ranks immediately below the group of best performers, thanks in particular to good quality services in this domain.

G20 AVERAGE
COUNTRY

Only actively pursuing an energy transition based on decarbonization and electrification – from policy and regulation, to health and education – will enable countries to benefit the most from future opportunities and fight climate change whilst ensuring an equitable distribution of wealth.

The Energy Transition indicators were developed by Enel Foundation in cooperation with SACE, and provide a retrospective analysis based on historical data.

Energy Transition
58.7
58.7

Fossil Fuels
45.3
45.7

Renewables
19.7
23.4

Efficiency
84.9
85.1

Electrification
70.8
70.7

Emissions
72.9
68.7

G20 CLIMATE RISK ATLAS

Impacts, policy, economics

UNITED KINGDOM

How to read the Atlas: graphs, colours and scenarios.

The maps used in this Atlas are taken from **The World Bank Official Boundaries** - ***https://datacatalog.worldbank.org/search/dataset/0038272*** (accessed on May 28, 2021). For the section Energy, the maps are based on Panoply Data Viewer ***https://www.giss.nasa.gov/tools/panoply/credits.html***

Each sector of this Atlas contains data and information on various climate scenarios.

When reported in graphs, the **colour black** indicates data and information referring to the current state, the past or the baseline.

When the authors refer to **RCP (Representative Concentration Pathways)**, the 3 colours used across the factsheet refer to 3 scenarios, which are 3 different development options with different levels of greenhouse gas emissions, **respectively low emissions (green), medium emissions (orange), and high emissions (red)**. The same colour code is used when RCPs are associated with Shared Socioeconomic Pathways (SSP).

In some cases, the authors refer to global warming scenarios. In these cases, the 3 colours used refer to a temperature rise of **1.5°C (green), 2°C (dark green), and 4°C (red)**.

When the authors refer exclusively to **Shared Socioeconomic Pathways - SSPs** (Population affected by river floods in the section: "Water"), data related to **SSP3** - that encompasses, among other things, slow economic growth, material-intensive consumption, and persisting or worsening inequalities – **are reported in a lighter shade**; **SSP5** – which refers to social and economic development that is coupled with an energy-intensive lifestyle and the abundant exploitation of fossil fuel resources – is shown using a **middle shade of the colour**, whereas data related to **the present** conditions **are represented in a dark shade**.

Further details on scenarios, methodologies, and the full list of references are available at: **www.g20climaterisks.org**

Concept and graphic design by element6.eu

UNITED KINGDOM
CLIMATE

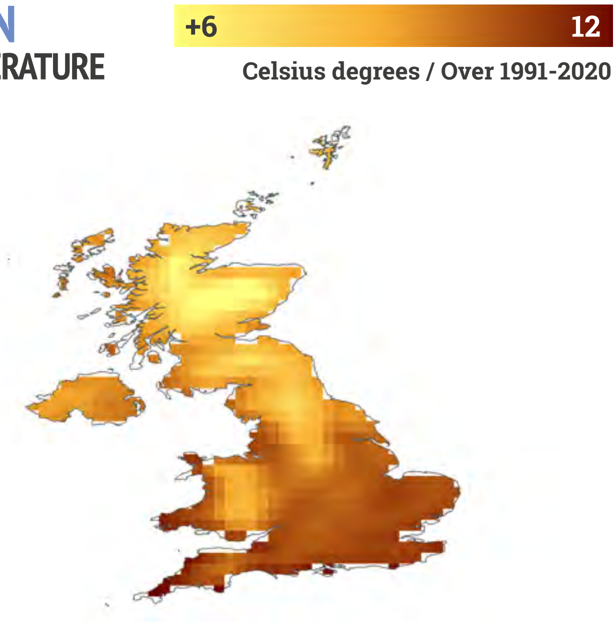
OVERVIEW

The United Kingdom has an oceanic climate, featuring mild summers and cool winters, whereby high temperatures are not very common. It is often cloudy and rainy, whereas thunderstorms are quite rare as hot and cold air masses meet infrequently. The UK's climate is mainly affected by the Atlantic Ocean and latitude, as well as the path of the polar front jet stream which leads to frequent changes in pressure and unsettled weather.

TEMPERATURE

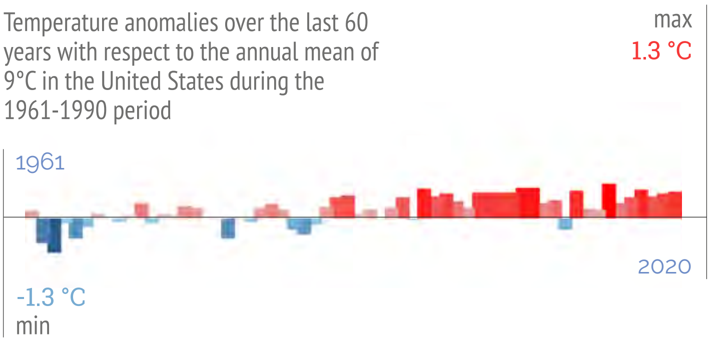
The temperature regime in the UK is affected by the maritime polar air mass coming from the north-west. The southern part of the country, including London, generally presents higher temperatures with respect to the northern part.

MEAN TEMPERATURE



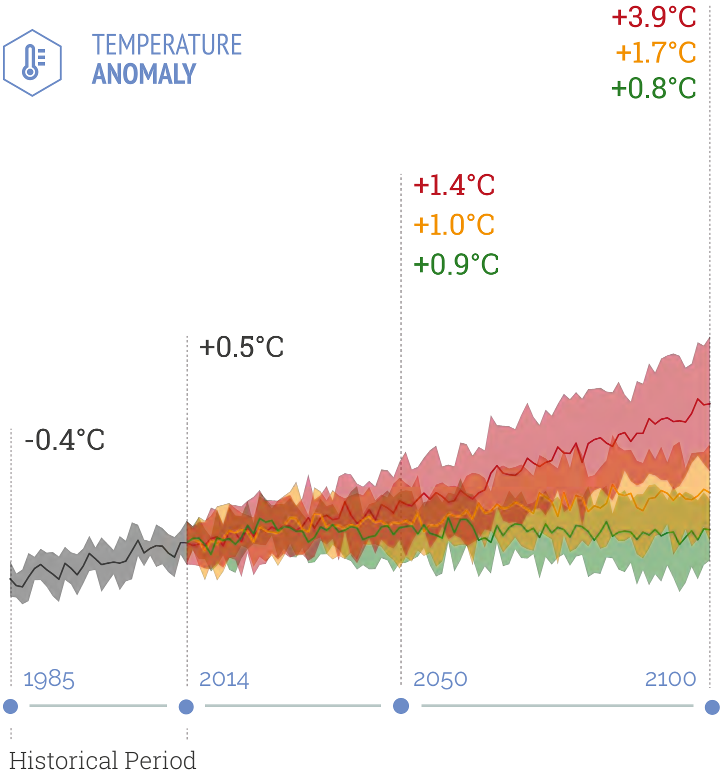
TEMPERATURE TREND

Temperature anomalies over the last 60 years with respect to the annual mean of 9°C in the United States during the 1961-1990 period



TEMPERATURE PROJECTIONS

Under a low emissions scenario projected temperature variations will remain contained under +1°C, both by 2050 and 2100.
Under a high emissions scenario, with no reduction in GHG emissions, much greater temperature anomalies are expected by both 2050 and 2100.



EXPECTED VARIATION FOR TEMPERATURE AT 2050

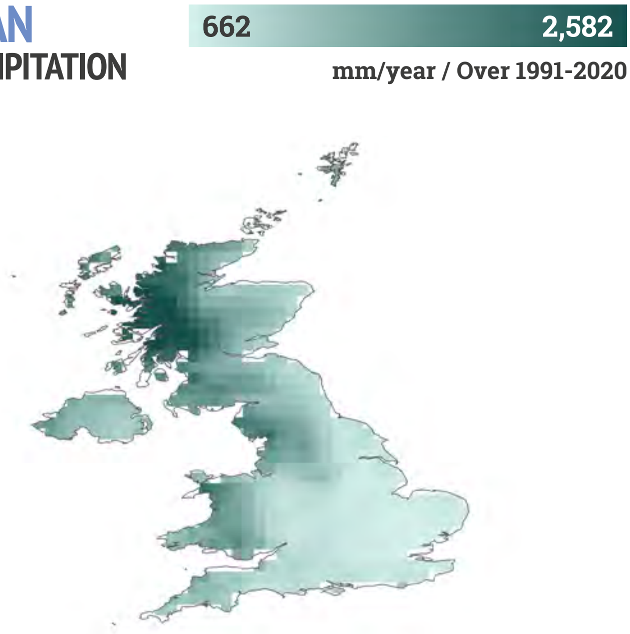
The indicators show variations in selected temperature characteristics for a thirty-year period centred on 2050 (2036-2065) with respect to the reference period 1985-2014.

Annual Mean Temperature	Max Temperature of warmest month	Min Temperature of coldest month
+1.4°C	+2.0°C	+1.2°C
+1.0°C	+1.5°C	+0.9°C
+0.8°C	+1.3°C	+0.6°C

PRECIPITATION

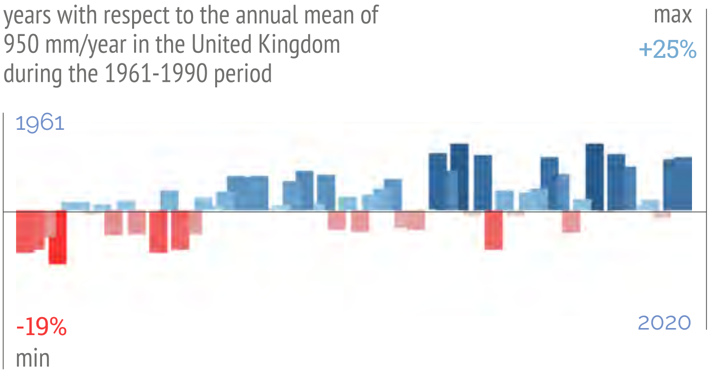
The precipitation regime is mainly characterised by cloudy and rainy weather, with an average annual rainfall of about 950 millimetres per year. Scotland in particular experiences significant rainfall due to the presence of mountains. Autumn and winter are usually the wettest seasons, with the rainfall coming from the clash between warm and cold weather systems. In the summer there is still a moderate amount of rainfall, much of which comes in the form of heavy showers.
The highest frequencies and intensities of extreme rainfall occur during the summer.

MEAN PRECIPITATION



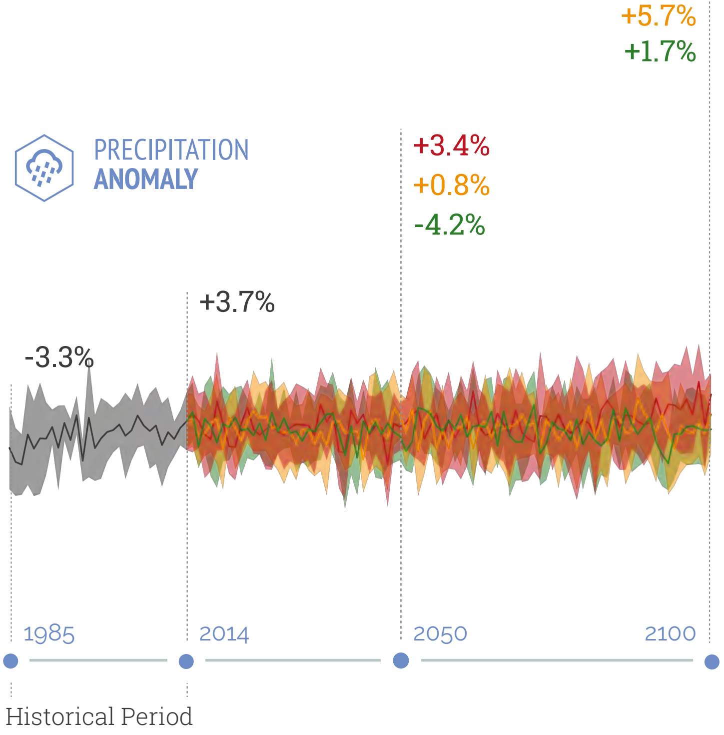
PRECIPITATION TREND

Precipiation anomalies over the last 60 years with respect to the annual mean of 950 mm/year in the United Kingdom during the 1961-1990 period



PRECIPITATION PROJECTIONS

Precipitation is projected to increase slightly in the future. The variability is quite large both for the historical period and the projected one considering all scenarios.



EXPECTED VARIATION FOR PRECIPITATION AT 2050

The indicators show variations in selected precipitation characteristics for a thirty-year period centred on 2050 (2036-2065) with respect to the reference period 1985-2014.

+2.6%
+1.5%
+2.0%
Annual total precipitation

+6.3%
+3.5%
+2.6%
Precipitation of wettest month

-3.2%
-1.9%
-1.0%
Precipitation of warmest quarter

VARIATION OF SPECIFIC CLIMATE INDICATORS

Climate indicators variation showing impacts of climate change on sectors such as agriculture, health and water. Analysis considers 3 threshold average temperature increase: **+1.5°C**, **+2°C**, **+4°C**.

+35%
+19%
+14%
Agricultural drought proportion of time
% of time

+31%
+15%
+12%
Hydrological drought proportion of time
% of time

+1,461%
+261%
+100%
Heatwave duration
% of time

+59%
+29%
+10%
Runoff increase
% of area

+74%
+50%
+35%
Agricultural drought frequency
% of change

+17%
+12%
+14%
Hydrological drought frequency
% of change

+80%
+35%
+21%
Heatwave frequency
% of change

+10%
+6%
+4%
Runoff decrease
% of area

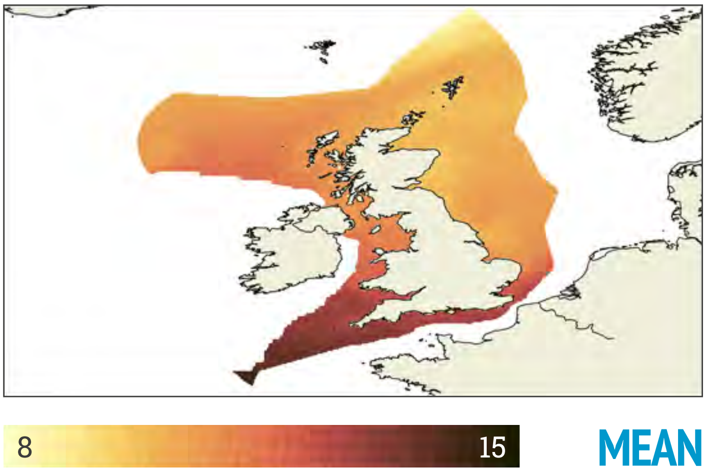
UNITED KINGDOM
OCEAN

OCEAN IN UNITED KINGDOM

The UK's marine exclusive economic zone (EEZ) is mainly temperate, with warm waters in the southern basins, and it hosts a wide diversity of underwater habitats and species. The coastal systems can be divided into two main areas: the Atlantic region and the North Sea.

CURRENT CLIMATE CONDITIONS

Mean sea surface temperatures reflects the climate regime, cold and temperate, with lower values in the northern waters.

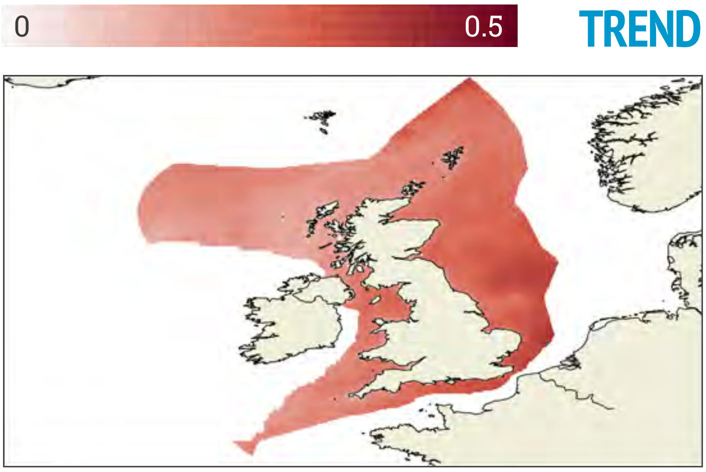


MEAN

SEA SURFACE TEMPERATURE

Celsius degrees / Over 1991-2020

TREND

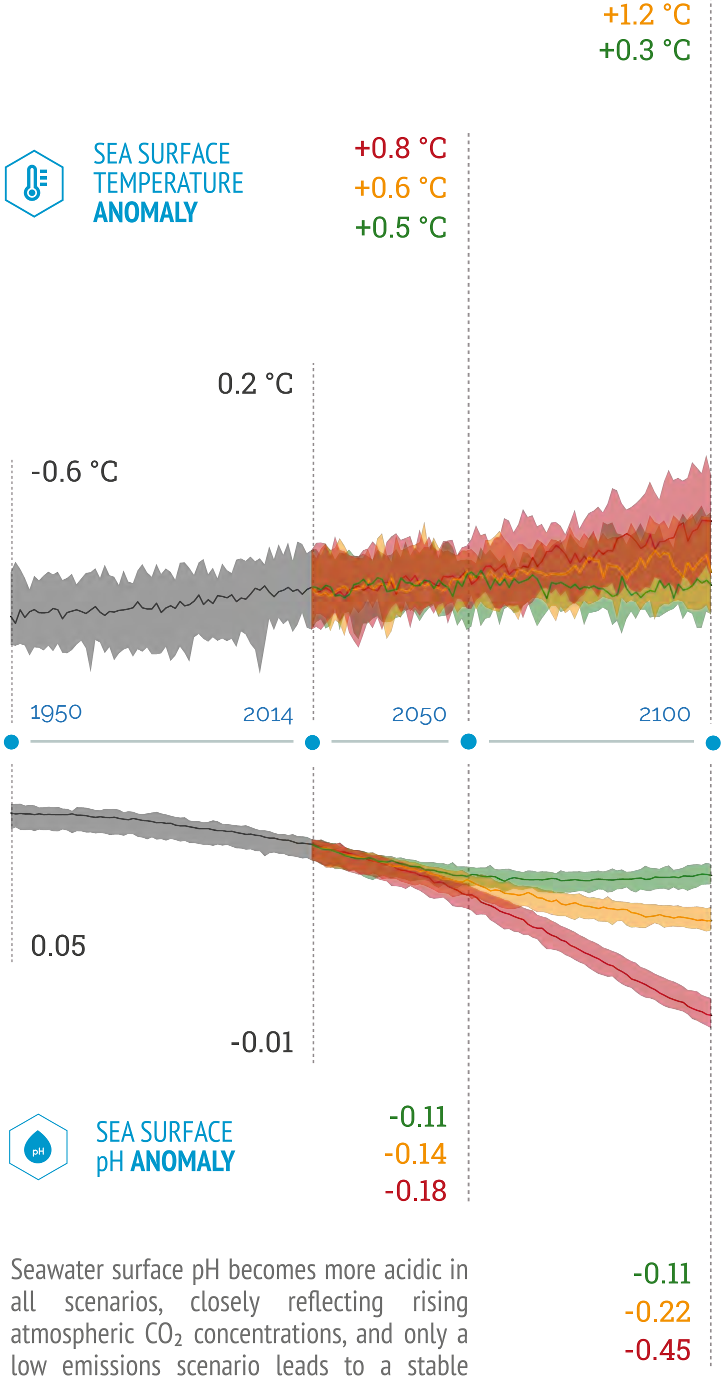


Surface temperature trends indicate a general warming of 0.2°C per decade in all marine areas, with increased gains in the open waters of the North Sea.

FUTURE PROJECTIONS

Projected annual changes within the marine EEZ for the two most significant marine indicators of climate change: sea surface water temperatures and pH.

Seawater temperature changes are in line with the definitions of each scenario, with maximum values close to +2°C under a high emissions scenario in 2100.



Seawater surface pH becomes more acidic in all scenarios, closely reflecting rising atmospheric CO_2 concentrations, and only a low emissions scenario leads to a stable condition by 2100.

ECOSYSTEM INDICATORS AT 2050

Regional changes in key marine ecosystem indicators under projected future scenarios by mid-century (2036-2065) with respect to present climate conditions (1985-2014).

Temperature regulates the metabolism of marine organisms determining which habitats remain suitable. Excessive warming will likely push ecosystems beyond tolerance thresholds.

pH represents the acid/base status of marine waters, where a decreasing pH reflects the acidification of the ocean due to increased absorption of atmospheric CO_2.

Oxygen is fundamental to sustain marine life and its reduction can have a large impact on coastal ecosystem services including fisheries and aquaculture.

Chlorophyll is an indicator of the biomass available at the base of the marine food web supporting all ecosystem productivity.

	Atlantic	North Sea
Temperature	11.74°C +0.54 °C +0.47 °C +0.22 °C	10.48°C +1.38 °C +1.11 °C +0.83 °C
pH	8.12 -0.18 -0.14 -0.11	8.12 -0.19 -0.14 -0.11
O_2	271.82 mmol/m³ -0.49 % -0.28 % +0.17 %	282.85 mmol/m³ -2.61 % -2.05 % -1.7 %
Chlorophyll	0.54 mg/m³ -18.18 % -10.39 % -24.68 %	0.61 mg/m³ -25.49 % -18.75 % -26.32 %

FISH CATCH POTENTIAL

Fish catch potential is an estimate of the maximum fish catch achievable given the marine resources available over a sustained period. It is linked to the concept of maximum sustainable yield, meaning the maximum amount of fish that can be extracted from a system without causing a collapse in fish populations.

It is a characteristic of the natural system, which is substantially different from realized catch, and a direct result of the fishery policy in place.

Fish catch percentage change

2050

-21.8%

-21.3%

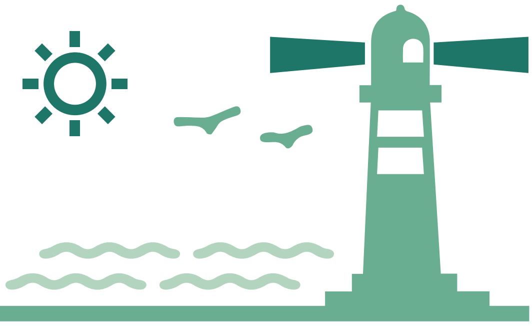
ANALYSIS DETAILS

All datasets were analysed using only data from within the marine EEZ and therefore excluding overseas territories, detached islands and any disputed or joint territories with other nations. In the assessment of current climate conditions, seawater surface tempererature data was obtained using satellite observations distributed in the framework of ESA Climate Change Initiative.

Future projections of marine indicators are represented by the combined analysis of results from 15 different Earth System models participating in the Coupled Model Intercomparison Project Phase 6 (CMIP6). These models include new and better representations of physical and biogeochemical processes, compared to previous IPCC assessment reports.

Fish catch potential data was obtained using the FAO's technical report and refers to the best and worst case climate scenarios from the Fifth IPCC Assessment Report. These mean estimates are subject to substantial uncertainties as discussed in the original work.

UNITED KINGDOM
COASTS



OVERVIEW

The British Isles, situated in the North Sea and exposed to the North Atlantic Ocean, are home to the United Kingdom, a geographically varied country with an equally diverse coastline. With a very long shoreline, characterized by flat sandy dunes, rocky cliffs, the ports and bays of England, lochs and estuaries of Scotland, and coastal mountains and peninsulas of Northern Ireland. This variety means that there are many features to consider for coastal management. Furthermore, relative to the size of the country, the shoreline is much longer than most other nations, a result of the irregular nature of the coastline, as well as the country's numerous islands, that present further natural diversity.

Shoreline Length

19,717 km

Sandy Coast Retreat at 2050

-27.0 m

CLIMATE CHANGE HAZARDS

Coastal hazards such as erosion, storm tide inundation and permanent flooding, can have strong adverse impacts on coastal regions, with loss of sandy shores, damage to settlements, infrastructure and ecosystems. Climate change can exacerbate these impacts due to rising sea levels and increasing impacts of waves and storms. The UK has already begun to see the effects and impacts of climate change on its shorelines, with increasing erosion on numerous beaches around the country and an increasing risk of storm surge inundation in the low lying areas of the east coast of England, including highly populated areas along the Thames Estuary and the City of London, which is currently protected by storm surge barriers.

SEA LEVEL RISE

Sea level rise in the UK, since 1904, has been around 16 centimetres (corrected for land movement). The current rate of sea level rise is approximately 1.7 millimetres per year. The latest IPCC projections indicate that, by 2050, global sea levels may rise between 0.18 metres, under a low emissions scenario, and 0.23 metres, under a high emissions scenario.

Observed and projected sea level rise at 2050

1.7 mm/year

0.23 m

0.18 m

EXTREME SEA LEVEL

On average, one in 100 extreme sea level events are expected to rise from 2.84 metres at present day to 3.03 metres by 2050 under a medium emissions scenario.

Current and projected extreme sea level at 2050

2.84 m

3.12 m

3.03 m

OBSERVED STORMS

The UK is at risk of coastal flooding and overtopping from the combined factors of large waves and high water levels. This was seen notably in the winter of 2013/14 with significant extreme coastal flooding resulting from storms that caused widespread damage. This is also of particular concern for coastal erosion, with the soft cliff faces of the south of England facing issues with weathering, and as many as 100,000 homes at risk from coastal erosion.

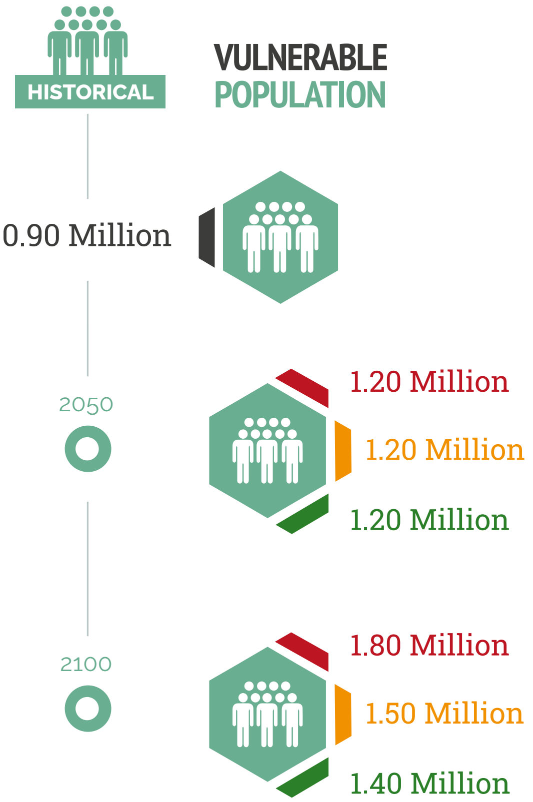
FUTURE STORMS

With rising sea levels, more areas will be at risk from extreme waves and storms in the coming years and will also lead to waves bringing greater energy to the shore, increasing the stress on coastal areas. It is estimated that in some locations in the UK the frequency of extreme sea level events, such as the one in 100 year event, will vastly increase with some areas experiencing increases by up to 100 times compared to current levels.

VULNERABILITY AND RISK

Just as the coastline and the impacts of climate change vary massively, so do the risks faced by the local population, industry, and natural environment. In terms of extreme waves and storm surges, increased wave heights can bring damage to coastal amenities, areas of natural importance and cultural heritage, as well as productive activities, roads and railways. The national supply chain depends on the correct functioning of port operations, and long duration extreme waves can have a strong negative impact on these activities.

London, as an internationally vital financial center, is substantially protected against flooding. Despite this, the city will become increasingly at risk of flooding from storm surge events, with potentially devastating consequences. Other risks come from the unpredictable coastal dynamics caused by climate change, particularly concerning coastal erosion, which is expected to increase significantly, and cause damages of over 100 million GBP per year by the end of the century, with further costs expected to arise from protecting or relocating coastal assets. Under a medium emissions scenario, the total population exposed to the annual coastal flood level is expected to increase from 900,000 to 1.2 million by 2050.



INFLUENCE OF SEA LEVEL RISE ON EXTREME SEA LEVEL

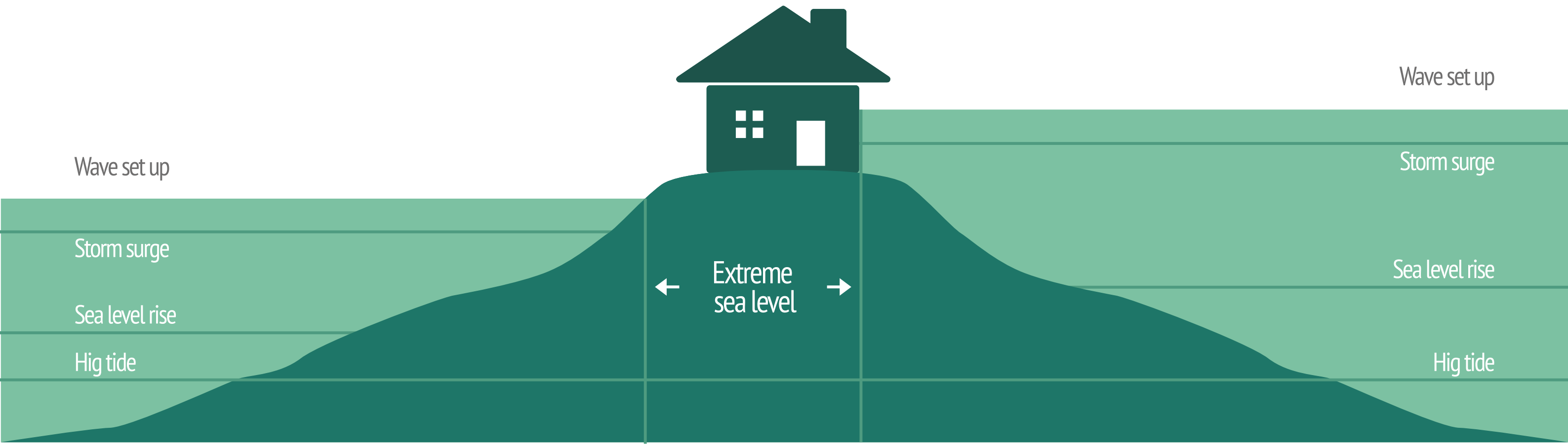
Present and future sea level rise are a consequence of carbon induced global warming causing melting ice and ocean expansion due to heat accumulation.

The extreme sea levels reported here are based on the 100-year storm surge + wave set up + sea level rise + high tide indicators. The first two parameters (storm surge + wave set up) are based on the 100-year value for the event; sea level rise is its projected value at 2050; and high tide is the absolute value of the highest tide calculated for a given locality, which won't be influenced by climate change.

+ **Wave set up** refers to the accumulation of water near the shore due to the presence of breaking waves.

+ **Storm surge** is an occasional increase in sea level driven by shoreward wind-driven water circulation and atmospheric pressure.

+ **High tide** is usually the highest tide reached in a given location based on tide records.



Present sea levels have risen globally by approximately 20 centimetres over the past century.

Future sea level rise is a projection based on different global warming scenarios, at approximately 100 centimetres by the end of 2100, with consequent inundation during extreme sea level events.

UNITED KINGDOM
WATER

OVERVIEW

The healthy functioning of the various water resources of the UK is vital to its population, environment, and economy.

High levels of water abstraction are leading to increased pressures on the country's water systems, and these pressures are being exacerbated by a variety of driving forces resulting from climate change, as well as the prospect of continued population growth and intensification of water usage.

A significant amount of the UK's freshwater sources are being exploited at an unsustainable rate, with much of the withdrawal being used for vital industry and electricity supply.

Renewable internal freshwater resources	145 billion m³
Renewable internal freshwater resources per capita	2,195 m³

Although water supply for average citizens is relatively secure, consumption rates are high and characterized by high levels of waste.

CLIMATE CHANGE HAZARDS

Climate change can affect water resources through increasing temperatures, higher rates of evapotranspiration and altered rainfall patterns. This leads to changes in the water cycle, including decrease of snow and ice coverage, alterations of surface runoff and groundwater storage, as well as drought and flood occurrence. In combination with an expected increase in water demand, the effects of climate change will also influence the UK's ability to provide sufficient clean water. The country is likely to see wetter winters, drier summers, more extreme precipitation events, and warmer average temperatures. These changes will not be seen equally, with spatial variation and unpredictable changes causing further issues for the effective management of water resources.

KEY POINT RUNOFF

It is widely expected that the UK will see increased frequency and severity of extreme rainfalls as a result of anthropogenic climate change. This will increase the pressure on already pressurised drainage systems that may be unable to cope with the effects of surface runoff and in extreme cases its associated flooding events, particularly in the face of increasing urbanisation.

At a country scale, an average increase in surface runoff by approximately 3% is expected under both low and high emissions scenarios for the 2045-2055 period compared to 2015-2025.

If temperatures rise by 1.5°C, 2°C or 4°C, 4%, 6.1% or 10% of the area of the country will likely experience an increase in runoff, while 10%, 28.6% or 59% of the surface of the country will likely experience a decrease in runoff, respectively.

2050

Changes in annual runoff
% of change

+2.5%

+2.9%

2050

Runoff increase
% of area

+10.0%

+4.0%

KEY POINT DROUGHTS

Severe droughts are not experienced commonly in the UK, and are even considered anomalous; however, when they do occur such as in 2018, they can be devastating due to the relative lack of preparation, particularly for vulnerable members of society and for the agricultural sector, which relies on consistent rainfall.

Many parts of the country are likely to see an increase in the occurrence of droughts through longer dry periods and reduced river flow, particularly in the southeast, and the impacts will be made more severe through higher evaporation rates driven by global warming, which could also lead to heatwaves, wildfires, and drying of the land.

2050
Severe drought likelihood increase
% of change
+9.2%
+7.2%

2050
Hydrological drought frequency
% of change
+17.0%
+10.0%

2050
Groundwater Recharge
% of change
-8.7%
+2.6%

KEY POINT GROUNDWATER

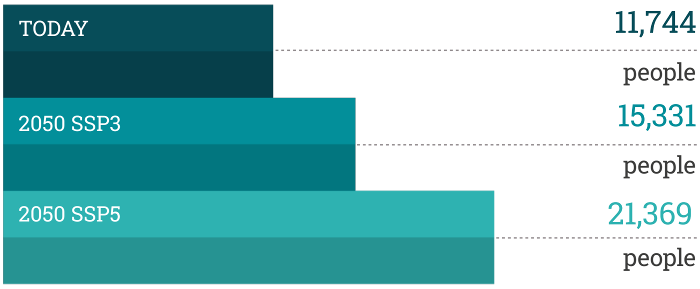
Groundwater plays an important role in the water security of the country, providing nearly a third of the UK's drinking water, and the quality of this water depends largely on the recharge from surface water and minimal runoff. Given the driving factors of groundwater quality and availability, climate change is likely to have significant impacts, both in terms of precipitation and temperature levels, as well as in seasonality.

Excess abstraction from groundwater bodies also poses a significant threat at current unsustainable levels, with 15% of these bodies at risk of future deterioration. At the country level, a +2.6%, -4.4% and -8.7% change of the annual groundwater recharge for the period 2045-2055 compared to the timeframe 2015-2025 is expected respectively under low, medium and high emissions scenarios.

KEY POINT FLOODS

The UK is prone to flooding events, a consequence of precipitation levels in combination with the urbanization and also the physical characteristics of the river catchments. These events are the costliest of all-natural disasters that the UK faces and present high risk to many areas of the country. In 2007, for instance, because of one of the wettest months on record in Britain, severe summer floods caused widespread damage and multiple deaths, and in comparison to many similar events worldwide, were driven largely by surface water flooding. Climate-driven meteorological changes will increase the risk of flooding across the country and in turn exacerbate issues of water security, although these changes will not be evenly distributed, but instead increasing the susceptibility in the northwest of the UK in particular. Changes in the population exposed to floods are expected, with an increase from about 11,000 in the present day to about 15,000 under SSP3 and 21,000 under SSP5 by 2050. As such, potential impacts related to river floods might increase.

POPULATION AFFECTED BY RIVER FLOODS

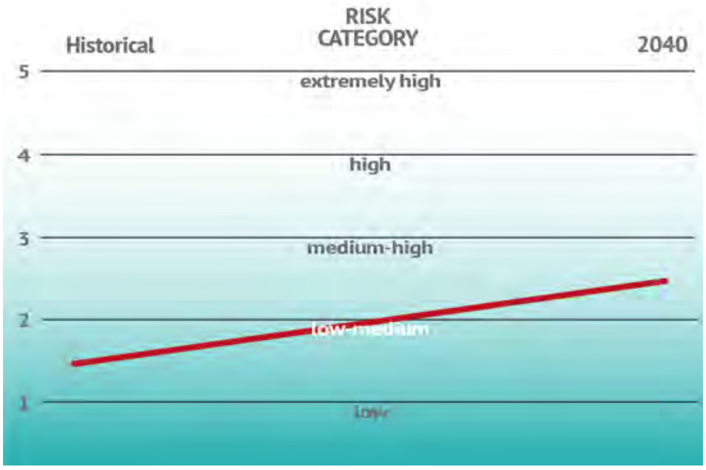


RISK INDICATORS

The water stress index summarises current and future water related vulnerabilities and risks at the global level. Scores are based on the ratio of total water withdrawals, including agriculture, industrial and human consumption, to available renewable surface and groundwater supplies.

WATER STRESS

The UK water stress level is considered low-medium for the recent past (1960-2014 average), and it is expected to increase in the near future (2030-2050) based on climate change projections.



UNITED KINGDOM AGRICULTURE

OVERVIEW

Agricultural area in the United Kingdom accounts for 71% of land use, employing close to half a million people and providing 50% of domestic consumption.

Agriculture in the UK has changed substantially over the last half century, due to technological and socio-economic factors. Cereal crops (mainly wheat and barley) cover 50% of the arable area. Other important productions are oilseed, sugar beet, potatoes, and horticultural crops (fruits and vegetables).

Most of the cultivated areas are located in the lowlands of southeast Great Britain, which have relatively warmer temperatures and lower rainfall. Water abstracted for agriculture in 2017 was less than 1% of the total water abstracted. This value is highly variable from year to year and greatly influenced by rainfall amounts.

13.6 Mt
Wheat

2 Mt
Rapeseed

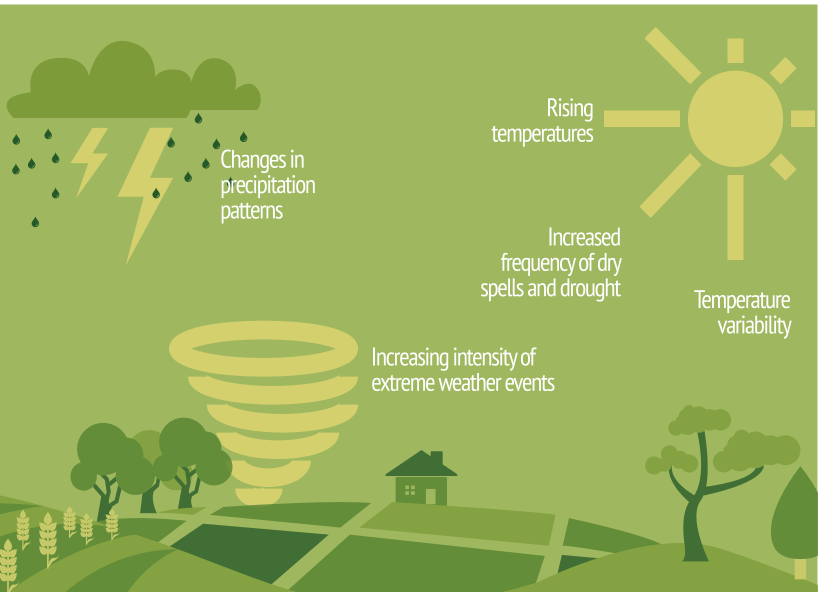
0.5 Mt
Apples

7.6 Mt
Sugarbeet

	Added Value of Agriculture, Forestry and Fishing	Share of Agriculture Value added in Total GDP	Agricultural land	Area Equipped for Irrigation
2000	15,673 USD Million	0.7 %	5,928 Thousand HA	243 Thousand HA
2018	17,413 USD Million	0.6 %	6,084 Thousand HA	208 Thousand HA

EXPEXTED IMPACTS ON AGRICULTURE PRODUCTIVITY

Rising temperatures, reduction in average annual precipitation, and intensification of extreme events such as heat waves and drought, affect production variability with a tendency towards yield reduction for many cultivated species, accompanied by a probable decrease in food quality. Crops respond to increases in temperatures with changes in duration of the growing season, early appearance of phenological phases and potential shifts of cultivation areas toward higher latitudes and altitudes for better growing conditions. However, impacts vary significantly depending on the geographical area and specific crops in question.



CROP PRODUCTIVITY

Crop productivity refers to the harvested yield of a crop per unit of land area. It is strongly influenced by climate and other environmental and management factors.

Climate change is expected to have an impact on the productivity of several major crops, although this may in part be offset by the fertilizing effect of higher CO_2.

Impacts are estimated using a range of model projections based on low to high emission scenarios and reported as percentage changes between the 30-year average around the historical period and the 30-year average around 2050.

8.3 5.3 (-1.8)%
9.2 (2.8)%
Wheat
tons / ha

67.8 -5.1 (-13.2)%
0.8 (na)%
Sugarbeet
tons / ha

3.4 2.4 (-2.8)%
7.2 (na)%
Rapeseed
tons / ha

tons / ha

2050

Productivity change with (without) the CO_2 fertilization effect. Estimates assume sufficient water and nutrient supplies, and do not include impacts of pests, disease, or extreme events.

CHANGE IN WHEAT

− = +

CHANGE IN SUGARBEET

− = +

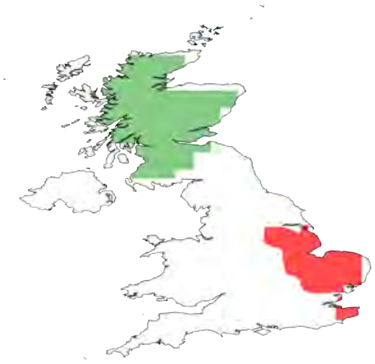
Warmer temperatures will lead to a longer growing season and possible higher yields for some cereal and horticultural crops. Wheat productivity is expected to increase in areas such as the Midlands, and South East England. Projections show an average increase of up to 9% for wheat, and up to 7% for rapeseed. Water scarcity represents one of the main limiting factors for rainfed cereals, oilseed rape and sugar beet in the southern and eastern areas. Sugarbeet productivity is expected to decline by an average of up to 5%, with strongest decline projected for the southern areas, whereas some midland and west areas may benefit from climate change. Potato yields, without restrictions in water or fertilizer, are projected to increase by about 15%, mainly due to increasing temperatures, radiation and CO_2 fertilisation effects. Increases in temperature may lead to a northward shift of suitable areas for many annual and perennial crops (e.g. maize, grapevines, apricots, potatoes).

ADAPTATION IN AGRICULTURE AND WATER RESOURCES

Traditionally, most crops are grown on natural rainfall with limited irrigation requirements. However rainfall may vary significantly across the country and between years. Recent droughts, like the heatwave in 2018, highlight the importance of irrigation in agriculture to cope with significant climate risks. Climate risks will present hotter and drier summers, increasing irrigation demand due to higher plant evapotranspiration and a possible decline in water supplies. Irrigation demand will likely expand in the future especially within catchments where precipitation is projected to decline creating considerable levels of water stress.

CHANGE IN WATER DEMAND

− = +



Agriculture
Water Demand
% of change

+50.7%
+35.5%

2050

Action priorities include integration of technologies to implement precision irrigation, smart sensor networks, irrigation scheduling with weather forecasting, and catchment-based approaches to improve water allocation.

UNITED KINGDOM FORESTS

FORESTS IN UNITED KINGDOM

With a very suitable climate for plant growth, UK forests are characterized by two main types: broadleaved forests, which are largely present throughout the country; and mature conifers which make up 60% of tree types in the north. The majority of woodland cover is made up of planted forests, except for a few hectares in the south. The current distribution is a direct result of the important reforestation policies that took place following the two world wars.

FORESTED AREA AND CARBON STORAGE

In recent decades UK woodland cover has increased to approximately 13%. This increase was more pronounced in Scotland where the cover rate has risen to approximately 17%. According to Forest Research (FR) the forest carbon stock (including soil carbon) is almost 3,8 gigatonnes and forests remove about 20 million tons of carbon dioxide from atmosphere yearly. UK forests are a net carbon sink and vital to the republic's emission reduction policies.

1990

3 Mln ha
Million hectares
Forested area

311 Tons/ha
Tons of Carbon per hectare
Carbon stock

2020

3 Mln ha
Million hectares
Forested area

344 Tons/ha
Tons of Carbon per hectare
Carbon stock

FOREST PRODUCTIVITY

Forest productivity or Net Primary Production is the net carbon captured by plants. It is the difference between the carbon gained by Gross Primary Production - net photosynthesis measured at the ecosystem scale - and carbon released by plants' respiration. It is expressed per unit land area.

2050

Productivity anomaly
Tons of Carbon per hectare per year

+0.84

+0.40

Increase in northern and southern UK and part of Northern Ireland, more pronounced under a medium emissions policy. Very high uncertainty in model projections

+ Fertilizing effect of increasing atmospheric CO_2, nitrogen deposition, rising temperatures, and increasing length of growing period promote productivity

No areas with an expected decrease in forest primary production

KEY SPECIES UNDER CLIMATE CHANGE

INCREASE
CONIFERS
Increases in primary production in upland conifer forests of the north and west of England may result.

VULNERABILITY
OAKS
High vulnerability for native oaks (pedunculate and sessile) in particular in the southern range

PATHOGENS
ALL SPECIES
Increased incidence of pathogens for all species

LOW VULNERABILITY
MIXED
Mixed stands show less vulnerability

FIRES IN UNITED KINGDOM

Fire is a structural ecological process that provides several types of ecosystem services and impacts on socio-ecological systems, including human health, carbon budgets, and climate change. Changes in global fire activity are influenced by multiple factors such as land-cover change, policies, and climatic conditions. Fire also releases large quantities of greenhouse gases into the atmosphere, contributing to a vicious cycle.

During the last two decades, the total land area affected by fire was approximately 89,000 hectares.

BURNING
89 THOUSAND HECTARES

EMITTING
0.06 TERAGRAMMES
OF CARBON PER YEAR

FOREST FIRE EMISSIONS
CONTRIBUTED TO
8.2% OF TOTAL FIRE RELATED
CARBON EMISSIONS

COSTING
UP TO 1.4 MILLION USD IN A
LARGE PEAT MOORLAND FIRE

FUTURE BURNED AREA

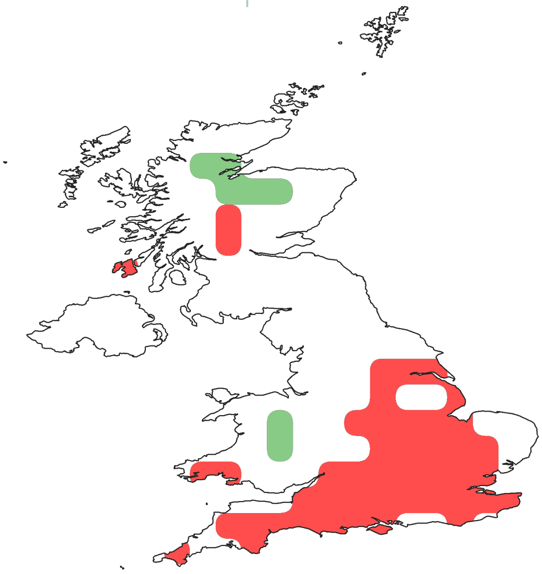
Under low a emissions scenario, burned areas are expected to increase primarily in southern England and predominantly affecting lowland beech forests. This spatial pattern might be less marked under a medium emissions scenario.

Burned Area
km² per year

2050

+9.8

+26.2



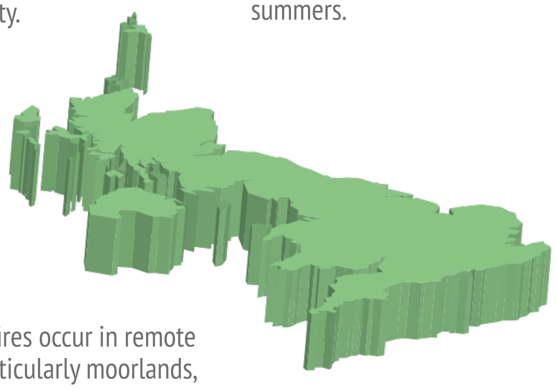
Decrease in burned areas for a low emissions scenario

Increase in burned areas for a low emissions scenario
+ Increase in the number of fires and area affected due to drier summers
+ Increase in vegetation growth due to warmer, wetter winters which will add to the fuel load

WHERE DO FIRES OCCUR?

Most wildfires occur where rural and urban areas meet or on arable land, particularly with regards to fires caused by human activity.

Wildfires occur prevalently in spring because of the availability of dead and dry fine vegetation as fuel, but could also occur during hot and dry summers.



Many large fires occur in remote areas, particularly moorlands, forests and peatland bogs.

VARIATION OF SPECIFIC FIRE INDICATORS

% of change
Average danger over fire season
2041-2070
+0.4%
+0.1%

% of change
High fire danger days per year
2041-2070
+0.2%
0%

% of change
PM2.5 emissions
2010-2050
PM2.5
+22%
+20%

FUTURE FIRE EMISSIONS

Fire emissions follow a similar spatial pattern to burned areas, with projected changes across both low and medium emissions scenarios

Fire Carbon emission
Teragrams of Carbon per year
2050
CO2
+0.31
+0.15

UNITED KINGDOM URBAN

OVERVIEW

The total population is projected to grow by 8% and become more than 90% urbanized by 2050.

Nearly half the urban population lives in cities with fewer than 300,000 residents. London is the largest city, with 16% of the urban population, and is projected to pass 10 million residents by 2035. The remainder of the urban population will live in cities with up to 5 million people, with 45% still living in cities with fewer than 300,000 people.

Built up areas cover 5.78% of the UK (14,060.43 square kilometers).

OVERVIEW OF KEY CLIMATE IMPACTS IN URBAN AREAS

The increasingly apparent impacts of climate change include higher than average temperatures, increased flooding and more extreme weather. There is an increased chance of warmer, wetter winters and hotter, drier summers along with an increase in the frequency and intensity of extremes.

HEATWAVES AND HEAT STRESS

Cities experience higher temperatures than surrounding rural areas because of the Urban Heat Island (UHI) effect, whereby built up areas absorb solar radiation during the day and release heat at night, warming the surrounding air. UHI is caused by factors such as less natural landscapes, the materials used for buildings, urban layouts and waste heat.

The UK's top 10 warmest years on record have all been since 2002 and the average number of hot days per year has been increasing since the 1960s. The average hottest day of the year, in the 10 year period between 2008 and 2017, was on average 0.1°C warmer than the 1981 to 2010 average and 0.8°C warmer than the 1961 to 1990.

Future scenarios of 1.5°C, 2°C and 4°C mean temperature increases indicate that heatwaves will last longer throughout the entire country. This will lead to an increase in the number of cooling degree days.

Population in Urban Areas

2020: 56,495,180

2050: 68,007,652

Graphs refer to data provided by United Nations, Department of Economic and Social Affairs, Population Division (2018). World Urbanization

Urbanization Rate

2020: 83.9%

2050: 90.2%

Cooling Degree Days
% of change

2050
+236.9%
+78.3%
+47.1%

Heatwave frequency
% of change

2050
+80.1%
+35.1%
+21.4%

Heatwave duration
% of time

2050
+1,461%
+261%
+100%

HEAT, HEALTH AND AIR POLLUTION

2,000 people die prematurely every year in the UK from heat-related conditions. Heat related health impacts from increasing air temperatures in urban areas are accentuated by air pollution. PM2.5 is an urban air pollutant that has negative health effects, with emissions in cities primarily coming from power generation, domestic heating and vehicles.

In the UK, PM2.5 levels tend to be highest in urban areas in the southern and eastern parts of the UK, also due to greater exposure to pollution from mainland Europe. In 2017, nearly 66.5% of the UK population was exposed to levels exceeding WHO guideline values for PM2.5.

COASTAL FLOODING

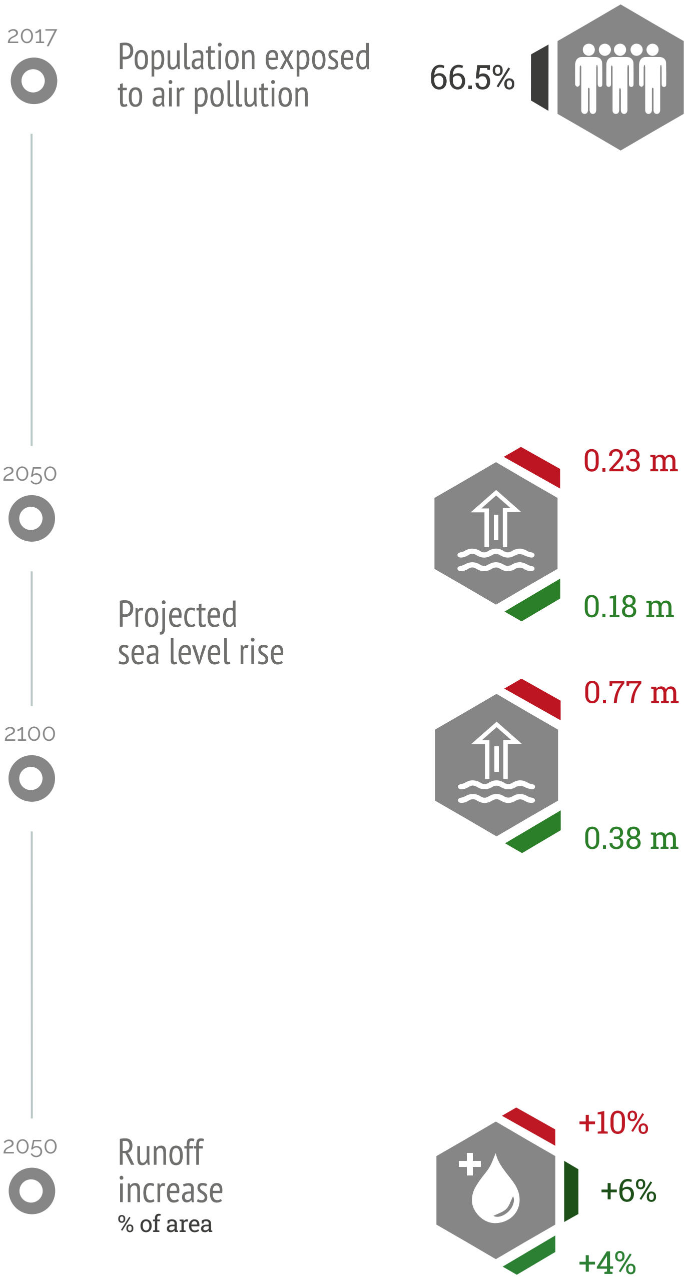
The impacts of flooding and coastal change, which pose risks to communities, businesses and infrastructure in the UK, are already significant and expected to increase as a result of climate change. Average UK sea levels have risen at a rate close to the global average rate of change.

Relative sea level rise is also influenced by vertical movements in the land mass due to isostatic rebound, with a general pattern of sinking in the south and lifting in the north. When corrected for land movement, mean sea level around the UK has risen by about 17 centimetres since the start of the 20th century.

EXTREME PRECIPITATION

There have been upward trends in rainfall across the UK, with more winter rainfall in heavy rainfall events. Total rainfall from extremely wet days (exceeding the 99th percentile of 1961-1990 rainfall) increased by around 17% during 2008-2017.

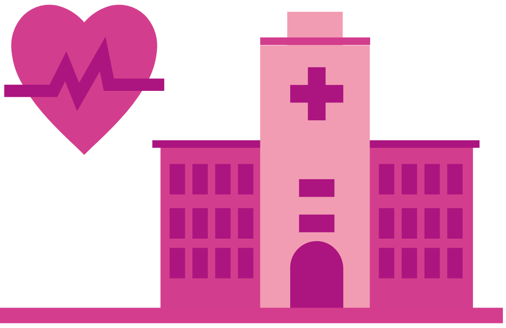
More and heavier rainfall are projected for the UK. Despite overall summer drying trends, increases in the intensity of heavy summer rainfall events are projected. Increases in heavy hourly rainfall intensity, particularly in autumn, are expected due to change in the seasonality of extremes.



SURFACE SEALING AND FLOODS

Heavy precipitation in cities is problematic due to the high level of sealed surfaces. Soil sealing increases run off and reduces the amount of water absorbed by soil. Where there are large amounts of impervious ground cover, short duration extreme rainfall events can lead to increased flooding, even resulting in flash floods.

UNITED KINGDOM
HEALTH



OVERVIEW

Extreme events such as heatwaves and floods have increased significantly in the UK. In addition to increased frequency and severity of such events, climate change will likely have further health impacts: excess mortality and morbidity from heat; respiratory diseases related to ground-level ozone; vector-, water- and food-borne diseases and increases in the prevalence of skin cancer related to UV exposure. The UK experiences a substantial annual heat- and cold-related health burden associated with exposure to current weather patterns. The fraction of deaths attributable to cold weather is currently much larger than that due to hot weather. Future changes in climate are likely to lead to an increase in heat-related deaths in the UK and a proportionally smaller decrease in cold-related impacts. The incidence of existing infectious agents, such as Lyme disease transmitted by ticks, is likely to increase.

HEAT RELATED MORTALITY

Heat-related mortality is projected to increase under future warming scenarios. One positive impact of climate change could be a decrease in winter mortality. However, under a high emissions scenario, heatwave-related excess deaths will increase by 49%.

In 2018, there was a 21% increase in heat-related deaths in the UK compared to the 2000 to 2004 baseline. 35.1% of heat-related mortality in the UK during 1991 to 2016 can be attributed to human-induced climate change.

Heat-related mortality

% change with respect to 2000-2004

2018

+21%

IMPACTS ON LABOUR

Labour is directly affected by changes in environmental conditions. Warming affects both the number of hours worked (labour supply) and on the productivity of workers during their working hours (labour productivity). Both labour supply and productivity are projected to decrease under future climate change in most parts of the world, and particularly in tropical regions.

Parts of sub-Saharan Africa, south Asia, and southeast Asia are at highest risk under future warming scenarios. Future climate change will reduce global total labour in the low-exposure sectors by 18 percentage points and by24.8 percentage points in the high-exposure sectors under a 3.0°C warming scenario

Total labour in the UK is expected to increase by 0.3% under a low emissions scenario and 0.4% under a medium emissions scenario.

Impact on total labour

% change with respect to 1986-2005 baseline

2050

+0.3%

2080

+0.4%

CLIMATE CHANGE AND DENGUE

Dengue has spread throughout the tropical world over the past 60 years and now affects over half the world's population. Globally, vectorial capacity for both dengue vectors (A. aegypti and A. albopictus) has been rising steadily since the 1980s, with nine of the ten highest years occurring since 2000.

Climatic stressors are one important driver of the current distribution and incidence of dengue. Climate change is likely to expand the geographical distribution and suitability of several vector-borne human infectious diseases including dengue. The risk of dengue transmission is increased by warming climates, as the growth and development of mosquitoes are significantly influenced by temperature, precipitation, and humidity.

CLIMATE CHANGE AND ZIKA

Zika virus has spread to at least 49 countries and territories since 2013. Climate change impacts on transmission suitability risk have increased over the years and future warming over 1.3 billion additional people could face suitable transmission temperatures for Zika by 2050.

CLIMATE CHANGE AND MALARIA

Warmer springs associated with climate change and land-use change can lead to rising numbers of ticks. Climate models predict further proliferation this species across Europe, including the UK. Future warming may increase the suitability of the UK's climate for vectors that spread malaria and dengue.

POLLUTION AND PREMATURE MORTALITY

The annual mortality from human-made air pollution in the UK is roughly equivalent to between 28,000 and 36,000 deaths every year. In 2019, the fraction of mortality attributable to long-term exposure to anthropogenic particulate air pollution was estimated at 5.1% in England.

UNITED KINGDOM
ENERGY

ENERGY SYSTEM IN A NUTSHELL

With plans for a “Green Industrial Revolution” and net zero emissions by 2050, the UK is a global leader in decarbonization.

Domestic energy production has declined dramatically by almost 60% since its peak in 1999, leaving the UK increasingly dependent on energy imports. At the same time, renewable energy production has seen significant growth.

0.06
ktoe/US$
Energy intensity

0.0%
AC Share in electricity consumption

37%
Import dependence ratio

CLIMATE CHANGE TODAY

WIND

Strong winds are one of the main causes of damage and disruption to all infrastructure, including energy.

HYDROPOWER

Hydroelectric power generation is dependent on sufficient water availability and power generation was reduced by 7% in 2018 as a result of lower rainfall.

STORMS AND FLOODS

Storms and lightning strikes have caused widespread power outages in Edinburgh (2021), England, Wales (2019) and Northern Ireland (2020). Hundreds of power stations and substations are at significant risk from flooding across the UK.

ENERGY SUPPLY

The UK's energy mix is dominated by fossil fuels, which accounted for 78% of total primary energy supply in 2019. Natural gas and oil accounted for 40% and 35% respectively, whereas use of coal and nuclear are minimal (3% and 9% respectively). The share of fossil fuels in the energy mix has declined over the last 10 years, with coal usage dropping by more than half. The share of renewables has been growing, from just 2% in 2007 to 13.4% in 2019.

ENERGY DEMAND

Energy demand in the UK is dominated by use in transport (32% in 2018, vast majority on road), residential (29%), industry (17%) and tertiary (13%) sectors. In the agriculture, forestry and fishing sectors consumption is minimal. Demand for air conditioning use is almost non-existent.

FUTURE ENERGY DEMAND

In the UK, changes in seasonal demand are expected. Winter heating needs are expected to decrease, while at the same time demand for summer cooling will increase. Overall, energy demand is projected to decrease, as the decrease in heating needs outweighs any increases in summer cooling needs. Energy demand is expected to fall by 984 Pj (274 billion Kwh) by 2050 under a medium emissions scenario.

Net change in energy demand due to changes in HDD/CDD
Billion KWh

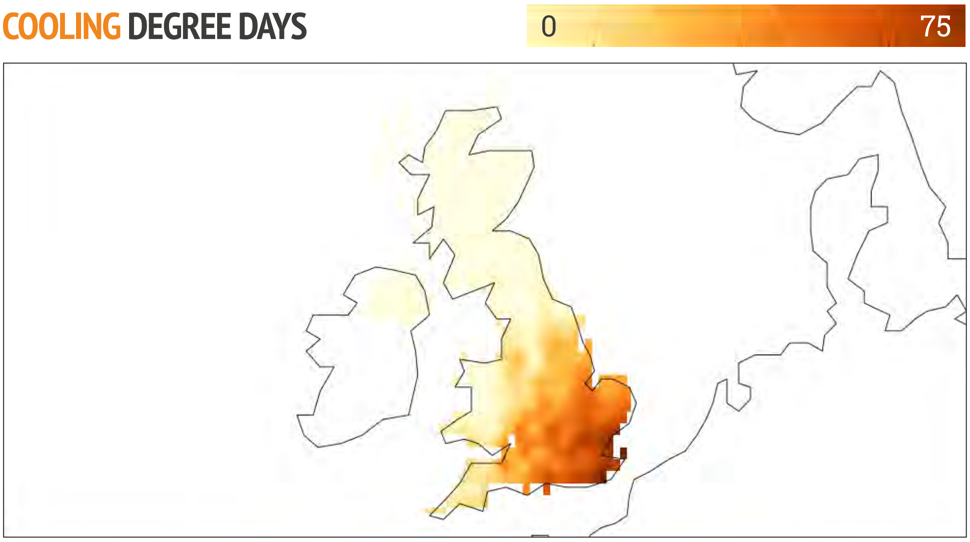
2050

- 273.52

COOLING NEEDS

Negligible increases are expected in Scotland, Northern Ireland, Wales and northern England; some moderate increases in the south, particularly along the British Channel coast. Summer cooling needs could increase energy demand by up to 200% in mid-summer in London.

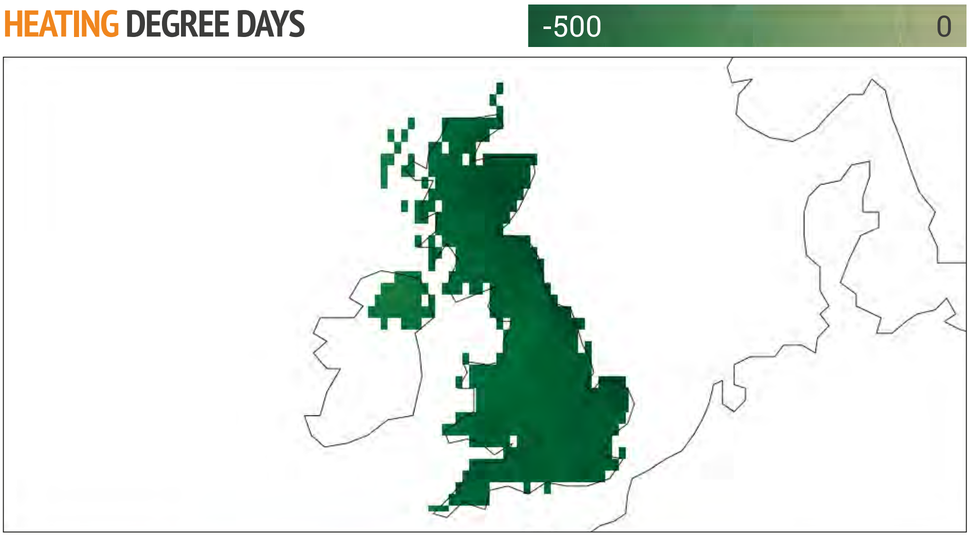
COOLING DEGREE DAYS



HEATING NEEDS

A marked drop in heating needs is expected all over the country, with no major difference between north, south or high and low elevations.

HEATING DEGREE DAYS



FUTURE ENERGY SUPPLY

The future configuration of the UK energy mix is likely to be determined by the evolution of climate mitigation policies and hence is outside the scope of this report. The UK target of net zero emissions by 2050 will likely result in a marginal relevance of fossil fuels and their vulnerabilities to climate change, while carbon free sources and their vulnerabilities will prevail.

Change in Hydropower generation
% of change

2050

-3.21%

-2.86%

EXPECTED IMPACTS OF CLIMATE CHANGE

Strong winds may threat overhead electricity lines as falling trees and branches damage infrastructure. Energy infrastructure located near rivers will be vulnerable to high flows and those near coasts to sea level rise. Increasing frequency and severity of storms may damage energy infrastructure. Hydro power generation is projected to decline.

Fossil fuel power plants may lose efficiency as a result of higher temperatures and reduced water availability needed for cooling. More frequent extreme events and higher temperatures could reduce the capacity of the electricity distribution network.

UNITED KINGDOM
ECONOMY

OVERVIEW

The UK has one of the wealthiest economies among G20 countries. It has been hit severely by the COVID crisis, recording a decline in real GDP growth rate of 9.9% in 2020. However it recovered in 2021with a real GDP growth rate of 5.3%.

IMPACTS ON GDP

Climate change will have an effect on the growth rate and overall economic performance of the country. Although estimates vary, some projections show that in the short run the overall economic impacts of climate change might even be positive.

By mid-century, the effects of climate change could result in gains of between 11.2 and 13.5 billion EUR under a low and high emissions scenario, respectively.

By the end of the century, however, the estimated costs are projected to become severe, peaking at 89.1 billion EUR (or almost 4% of GDP) under a high emissions scenario and 36.6 billion EUR (or 1.6% of GDP) under a low emissions scenario.

2050

0.6/-1.5%

0.5/-1.28%

GDP Change

% change w.r.t baseline

2100

-2.52/-3.97%

0.11/-1.63%

SECTORAL ECONOMIC IMPACTS

IMPACTS ON INDUSTRY AND INFRASTRUCTURE

Sea-level rise represents a major risk in the UK. Without any adaptation, the cost of sea-level rise will lead to a 10% loss of GDP in 2050 under a high emissions scenario. This estimate includes floods, retreat, wetland losses and inundation costs.

SEA LEVEL RISE DAMAGES

Under the current level of coastal protection, the projected costs of coastal flooding are substantial. By the middle of the century, sea-level rise and coastal flooding may cost the country 17.5 to 37 billion EUR in terms of expected damages to assets in low and high emissions scenarios, respectively.

By the end of the century, expected losses may increase to 48.2 billion EUR in a low emissions scenario and could reach 170.8 billion EUR under a high emissions scenario.

2050

37

17.5

Sea Level Rise

Expected annual damages
Billion Euro

2100

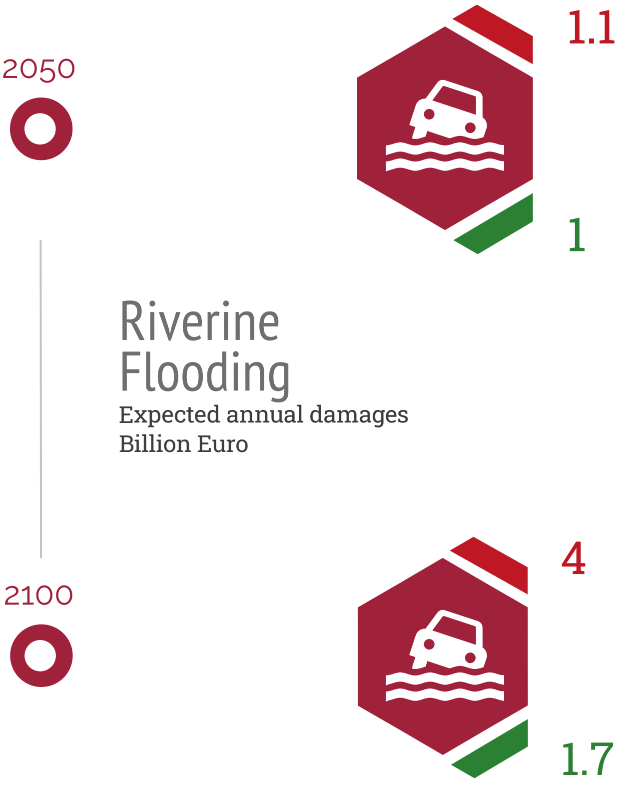
170.8

48.2

RIVER FLOODING DAMAGES

River flooding is also expected to cause damage and economic losses, though less severe than those from sea-level rise. By the mid century total asset losses are projected to be 1 to 1.1 billion EUR under a low and high emissions scenario, respectively.

By the end of the century these costs are projected to rise to 1.7 billion EUR under a low emissions scenario, and could reach 4 billion EUR under a higher emissions scenario.



Riverine Flooding
Expected annual damages
Billion Euro

IMPACTS ON AGRICULTURE

Agriculture uses 71% of UK land and contributes about 0.53% of total GDP. Gross Value Added is estimated to reach £10.4 billion in 2019.

More frequent extreme temperatures and changes to rainfall patterns will lead to overall negative impacts on agricultural production in the UK, even if improved growing conditions for some crops are expected in northern areas where climate will be warmer.

In a medium emissions scenario changes in crop yields are estimated around -5% (range -12% to +3%) in 2050, and -6% by 2080 (range -18% to +2%). Increased flooding, including that caused by sea-level rise, may lead to substantial losses in crop production in low-lying agricultural areas and may contribute to waterlogging and erosion of soil. Estimated productivity loss in 2020 due to soil erosion is 5.314 million EUR, resulting in 2.614 million EUR losses in UK GDP.

IMPACTS ON ENERGY

As with all other economic sectors, energy supply and energy networks in the UK will undergo more intense stress from extreme weather events.

Economic impacts of shifts in household and firm energy demand (see chapter on energy) are difficult to predict and will mostly lead to redistribution effects. In the case of the UK an overall decrease in energy bills is expected due to the heavily reduced heating needs, whereas the increase in cooling need is expected to be negligible.

Expected annual damage to energy infrastructure is projected to show a 13-fold increase compared to present by mid century under a high emissions scenario.

IMPACTS ON TOURISM

Tourism is a key sector in the United Kingdom, expected to expand by 3.8% annually. By 2025 the UK tourism industry will be worth over 257 billion GBP, around 10% of the UK's GDP. Climate change may contribute to an increase in tourism.

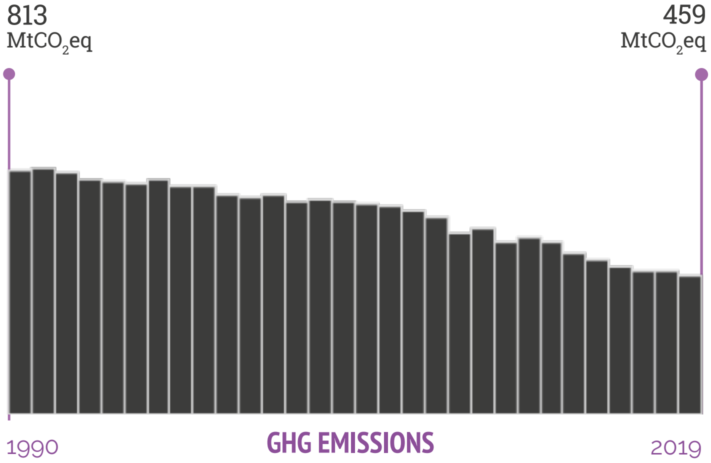
Following the international pattern, tourism shifts north. Especially in the northern regions of the UK the temperate climate may attract European tourists escaping from hot continental summers.

Although economic projections are not available, estimates of the impact of the hot weather of summer 2003 on domestic tourism in the UK found a positive impact on revenues ranging between 17 million and 36 million EUR.

UNITED KINGDOM
POLICY

OVERVIEW

The UK is responsible for 1% of global GHG emissions and has a 20% higher than world average rate of CO_2 emissions per capita. Emissions have been declining since 1991, and a net zero emissions by 2050 target has been set.



INTERNATIONAL COMMITMENTS

The UK adopted a 2050 net zero emissions reduction target, strengthening its previous 2050 goal of at least an 80% GHG emissions reduction below 1990 levels by 2050. The new plan aims for at least a 68% reduction in greenhouse gas emissions by 2030, compared to 1990 levels.

CLIMATE POLICY COMMITMENTS CHRONOLOGY

2002

KYOTO PROTOCOL - 1ST PERIOD

12.5% yearly average reduction in GHG over the four year period 2008-2012, with reference to 1990 levels

2016

PARIS AGREEMENT - 1ST NDC

40% GHG reduction by 2030, with reference to 1990 levels

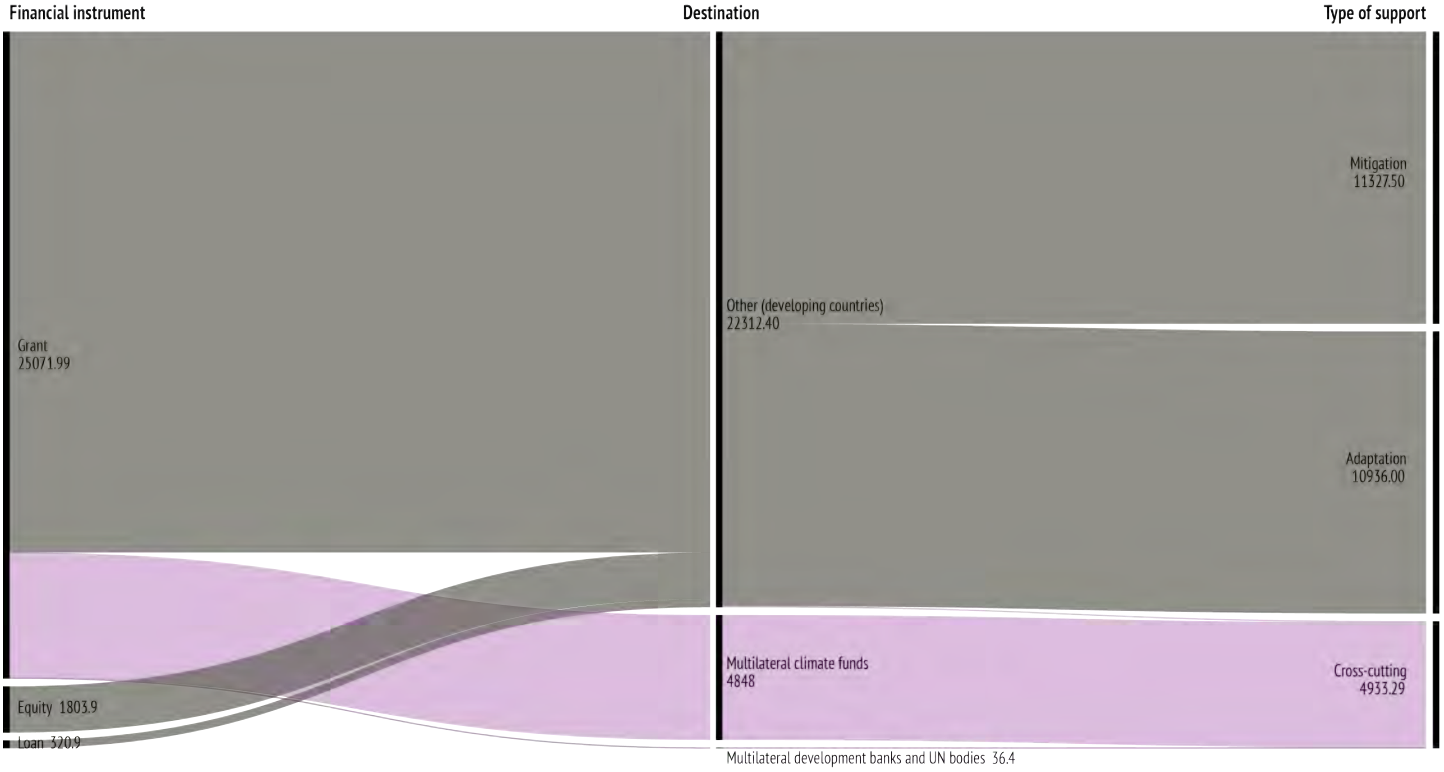
2020

PARIS AGREEMENT - NDC UPDATE

60% GHG reduction by 2030, with reference to 1990 levels

INTERNATIONAL CLIMATE FINANCE ASSISTANCE

The 4th Biennial Report shows that the UK committed 27.1 billion USD for climate-specific development finance in 2017-2018 . The majority was provided through bilateral channels and evenly distributed between adaptation and mitigation projects.



SUSTAINABLE RECOVERY POLICY

According to the Global Recovery Observatory, in 2020 the proportion of green spending out of total recovery spending was 20%, 30% of which was allocated to green market creation.

Total Spending	Recovery Spending	Green Spending
1,296.49 billion $	391.31 billion $	79.22 billion $

DOMESTIC ADAPTATION POLICY

Every 5 years, the National Adaptation Programme (NAP) addresses the risks identified by the UK Climate Change Risk Assessment. The second NAP period runs from 2018 to 2023, and covers the natural environment, infrastructure, people and the built environment, business and industry, and local government sectors.

- ○ Domestic Adaptation Policy
  - ○ Inclusion of Adaptation in NDCs
  - ● Integrated Adaptation & Mitigation Policy
  - ● Dedicated Adaptation Strategy
  - ● Dedicated Adaptation Plan
- ● Subordinate Adaptation Policies
  - ● Sectoral Adaptation Plans
  - ● Subnational Adaptation Plans

○ Policy not in place ● Active policy

ADAPTATION POLICY HIGHLIGHTS

TRANSNATIONAL INITIATIVES

North Sea Region 2020 Strategy

The strategy recognizes climate change risks for the regions, such as sea-level rise, increased coastal flooding, increase of the burden on the marine ecosystem through water warming, acidification and the influx of new species. The strategy calls for a collaborative transnational approach to address climate change across the North Sea

NATIONAL INITIATIVES

Flood and coastal resilience innovation programme

The programme funds 25 areas to provide innovative practical actions that improve resilience to flooding and coastal change, including the ability to adapt to future climate change.

UK Climate Resilience

This programme draws together fragmented climate research and expertise to deliver robust, multi-disciplinary climate risk and solutions research ensuring the UK is resilient to climate variability and change.

SUBNATIONAL INITIATIVES

Manchester Climate Change Framework 2020-25

The high-level strategy sets out how Manchester aims to limit the impacts of climate change and create a healthy, green, socially just city where everyone can thrive.

One City Climate Strategy: A strategy for a carbon neutral, climate resilient Bristol by 2030

The strategy outlines some of the necessary actions to reduce emissions as well as actions to adapt to extreme weather events as a result of climate change, which are expected to increase in the future.

ENERGY TRANSITION

The UK shows an Energy Transition index about 5 points above the G20 average, thanks in particular to outstanding performances in the Efficiency domain, a sector in which the UK is ranked among the top countries of the group. Also in Emissions and Electrification, the UK is positioned in the medium to high part of the ranking, outperforming in both cases the G20 average.
Surprisingly, despite having relevant oil and gas reserves, the UK has a positive performance also in the Fossil Fuels domain, with a score higher that the groups average. However, this positive result on fossil fuels is not accompanied by remarkable performances in Renewables, which is the only indicator where the UK does worse than the G20 average.
In this respect, nuclear generation capacity and reliance on biomass have a negative influence on the poor penetration of renewables even if the progressive ageing of the nuclear park will reverse the trend in the coming years.

	G20 AVERAGE	COUNTRY
Energy Transition	58.7	63.4
Fossil Fuels	45.3	51.8
Renewables	19.7	17.0
Efficiency	84.9	92.6
Electrification	70.8	74.8
Emissions	72.9	80.9

Only actively pursuing an energy transition based on decarbonization and electrification – from policy and regulation, to health and education – will enable countries to benefit the most from future opportunities and fight climate change whilst ensuring an equitable distribution of wealth.

The Energy Transition indicators were developed by Enel Foundation in cooperation with SACE, and provide a retrospective analysis based on historical data.

G20 CLIMATE RISK ATLAS

Impacts, policy, economics

UNITED STATES OF AMERICA

How to read the Atlas: graphs, colours and scenarios.

The maps used in this Atlas are taken from **The World Bank Official Boundaries** - ***https://datacatalog.worldbank.org/search/dataset/0038272*** (accessed on May 28, 2021). For the section Energy, the maps are based on Panoply Data Viewer ***https://www.giss.nasa.gov/tools/panoply/credits.html***

Each sector of this Atlas contains data and information on various climate scenarios.

When reported in graphs, the **colour black** indicates data and information referring to the current state, the past or the baseline.

When the authors refer to **RCP (Representative Concentration Pathways)**, the 3 colours used across the factsheet refer to 3 scenarios, which are 3 different development options with different levels of greenhouse gas emissions, **respectively low emissions (green), medium emissions (orange), and high emissions (red)**. The same colour code is used when RCPs are associated with Shared Socioeconomic Pathways (SSP).

In some cases, the authors refer to global warming scenarios. In these cases, the 3 colours used refer to a temperature rise of **1.5°C (green), 2°C (dark green), and 4°C (red)**.

When the authors refer exclusively to **Shared Socioeconomic Pathways - SSPs** (Population affected by river floods in the section: "Water"), data related to **SSP3** - that encompasses, among other things, slow economic growth, material-intensive consumption, and persisting or worsening inequalities – **are reported in a lighter shade**; **SSP5** – which refers to social and economic development that is coupled with an energy-intensive lifestyle and the abundant exploitation of fossil fuel resources – is shown using a **middle shade of the colour**, whereas data related to **the present** conditions **are represented in a dark shade**.

Further details on scenarios, methodologies, and the full list of references are available at: **www.g20climaterisks.org**

Concept and graphic design by element6.eu

UNITED STATES
CLIMATE

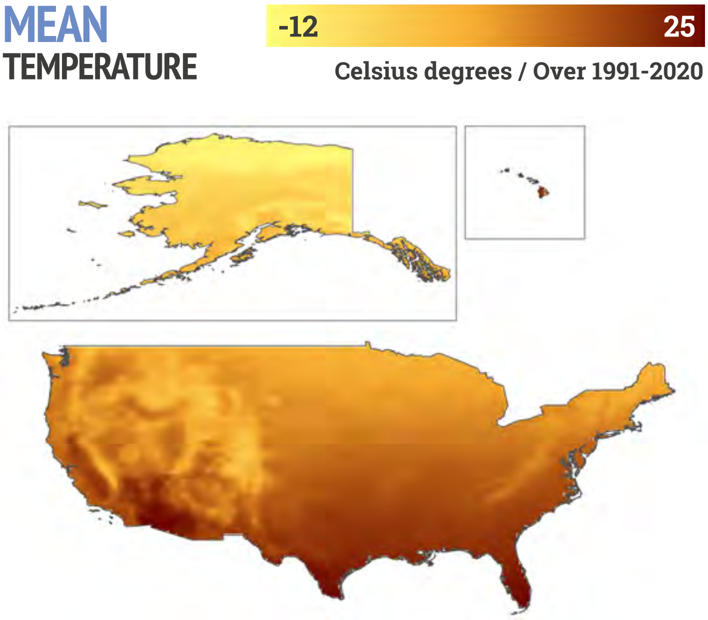
OVERVIEW

The USA has several climates due to its large size and geographical complexity, including mountains and deserts. The predominant climate is continental, with cold winters and hot summers, the duration of which varies according to latitude and distance from the sea. Other climates exist throughout the country, such as alpine in mountainous areas, subarctic in Alaska, tropical in Florida, Mediterranean along the west coast, and desert in the southwest.

TEMPERATURE

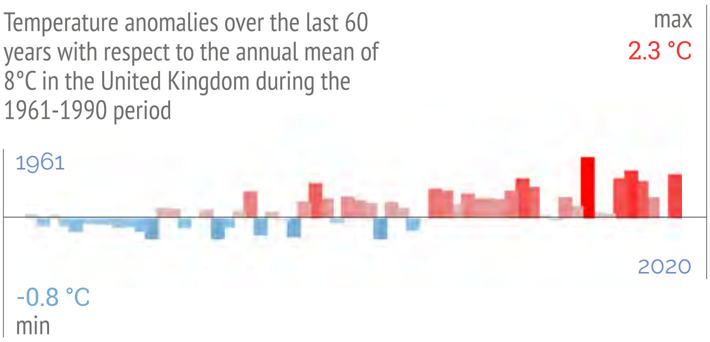
The temperature regime in the USA varies from region to region. In general, temperatures drop from the East Coast to the West Coast depending on latitude and other climatic factors which define climate types.

MEAN TEMPERATURE



TEMPERATURE TREND

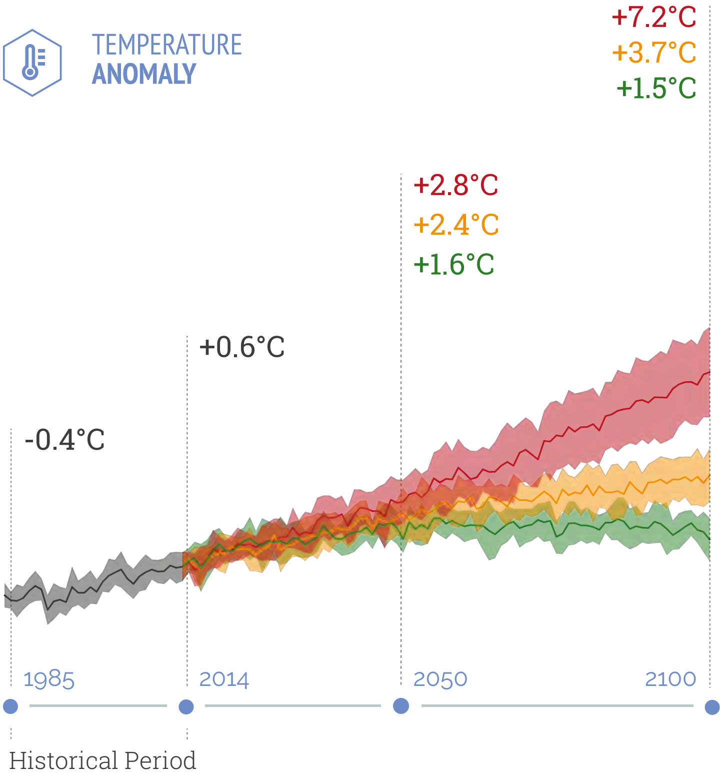
Temperature anomalies over the last 60 years with respect to the annual mean of 8°C in the United Kingdom during the 1961-1990 period



TEMPERATURE PROJECTIONS

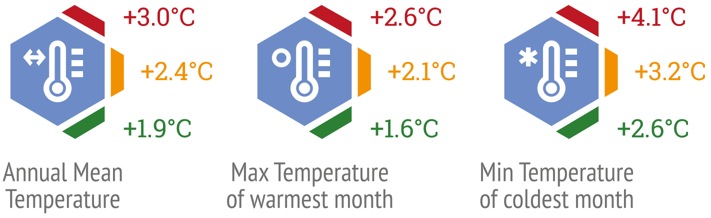
Under a low emissions scenario projected temperature variations will remain contained at around +1.5°C, both by 2050 and 2100.
Under a high emissions scenario, with no reduction in GHG emissions, much greater temperature anomalies are expected by both 2050 and 2100.

TEMPERATURE ANOMALY



EXPECTED VARIATION FOR TEMPERATURE AT 2050

The indicators show variations in selected temperature characteristics for a thirty-year period centred on 2050 (2036-2065) with respect to the reference period 1985-2014.



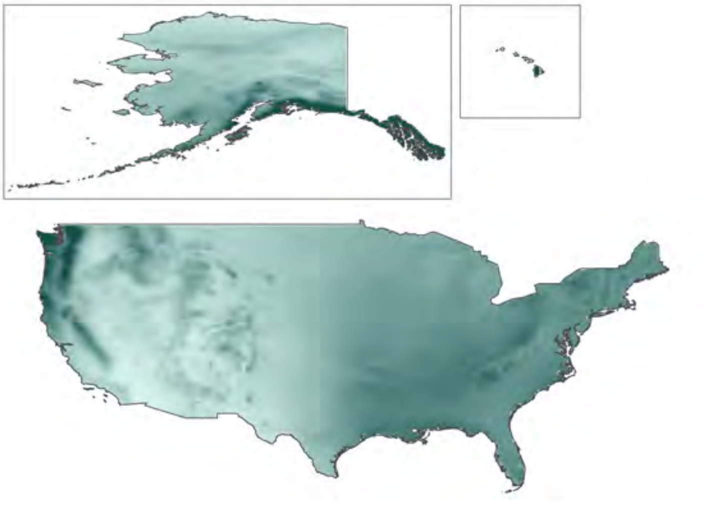
PRECIPITATION

The precipitation regime in the USA varies from region to region due to the country's size and geographical complexity.
The eastern part of the contiguous USA, east of the 98th meridian, the Pacific Northwest Mountains, the Willamette Valley, and the Sierra Nevada are the wettest parts of the country.
The driest areas are the desert Southwest, the Great Basin, the valleys of north-eastern Arizona, eastern Utah and central Wyoming. Increased warming in urban heat islands leads to increased precipitation downwind of cities.

MEAN PRECIPITATION

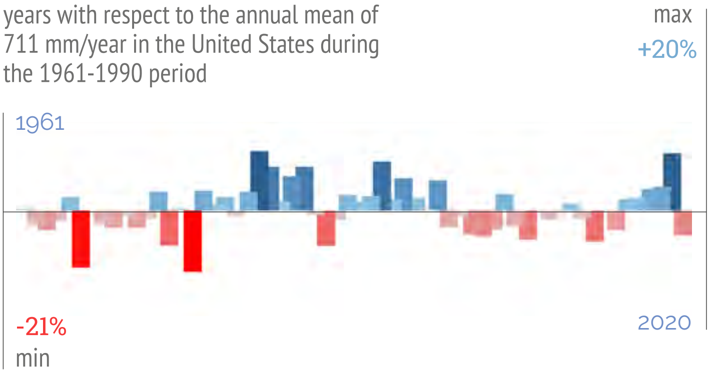
73 – 7,209

mm/year / Over 1991-2020



PRECIPITATION TREND

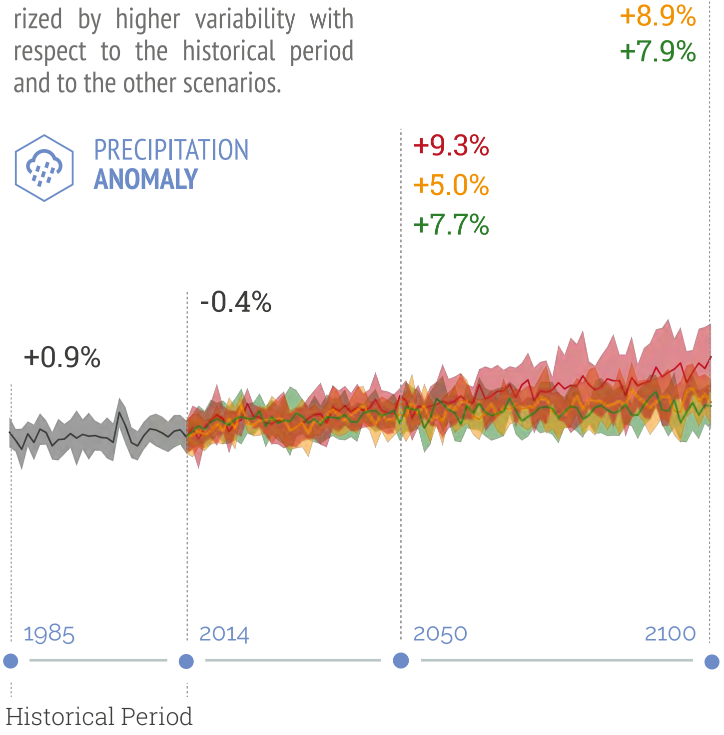
Precipiation anomalies over the last 60 years with respect to the annual mean of 711 mm/year in the United States during the 1961-1990 period



PRECIPITATION PROJECTIONS

Considering the different scenarios, precipitation trends show a general increase in annual precipitation at a country level. Higher increments are reported under a high emissions scenario even if characterized by higher variability with respect to the historical period and to the other scenarios.

PRECIPITATION ANOMALY



EXPECTED VARIATION FOR PRECIPITATION AT 2050

The indicators show variations in selected precipitation characteristics for a thirty-year period centred on 2050 (2036-2065) with respect to the reference period 1985-2014.

+8.2%
+5.9%
+5.8%
Annual total precipitation

+8.7%
+6.9%
+6.3%
Precipitation of wettest month

+6.5%
+4.6%
+6.0%
Precipitation of warmest quarter

VARIATION OF SPECIFIC CLIMATE INDICATORS

Climate indicators variation showing impacts of climate change on sectors such as agriculture, health and water. Analysis considers 3 threshold average temperature increase: **+1.5°C**, **+2°C**, **+4°C**.

+36%
+17%
+13%
Agricultural drought proportion of time
% of time

+21%
+12%
+10%
Hydrological drought proportion of time
% of time

+2,000%
+311%
+117%
Heatwave duration
% of time

+39%
+12%
+4%
Runoff increase
% of area

+67%
+36%
+27%
Agricultural drought frequency
% of change

+14%
+10%
+13%
Hydrological drought frequency
% of change

+91%
+40%
+22%
Heatwave frequency
% of change

+16%
+5%
+2%
Runoff decrease
% of area

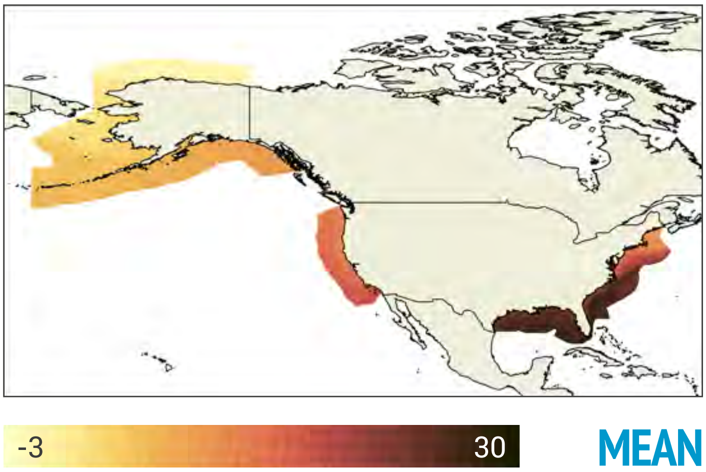
UNITED STATES
OCEAN

OCEAN IN UNITED STATES

The US marine exclusive economic zone (EEZ) comprises a wide range of environmental conditions, from the cold waters surrounding Alaska to the subtropical ecosystem of the southern coasts. Coastal systems can be divided into three main areas: Alaskan, Atlantic and Pacific marine regions.

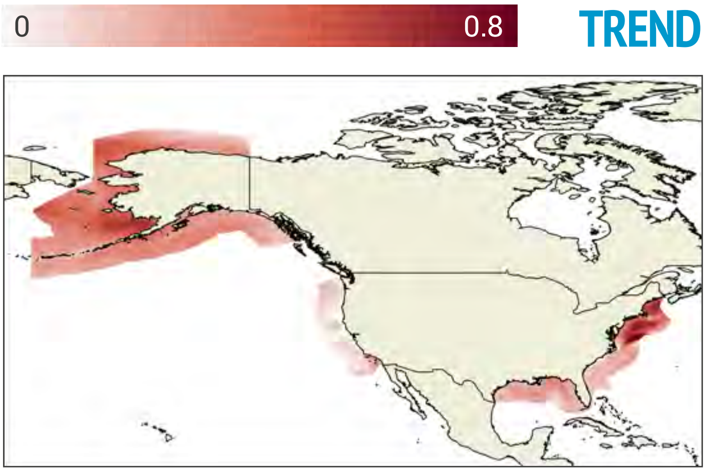
CURRENT CLIMATE CONDITIONS

Mean sea surface temperatures reflects the different climate regimes over the wide EEZ domain.



SEA SURFACE TEMPERATURE

Celsius degrees / Over 1991-2020

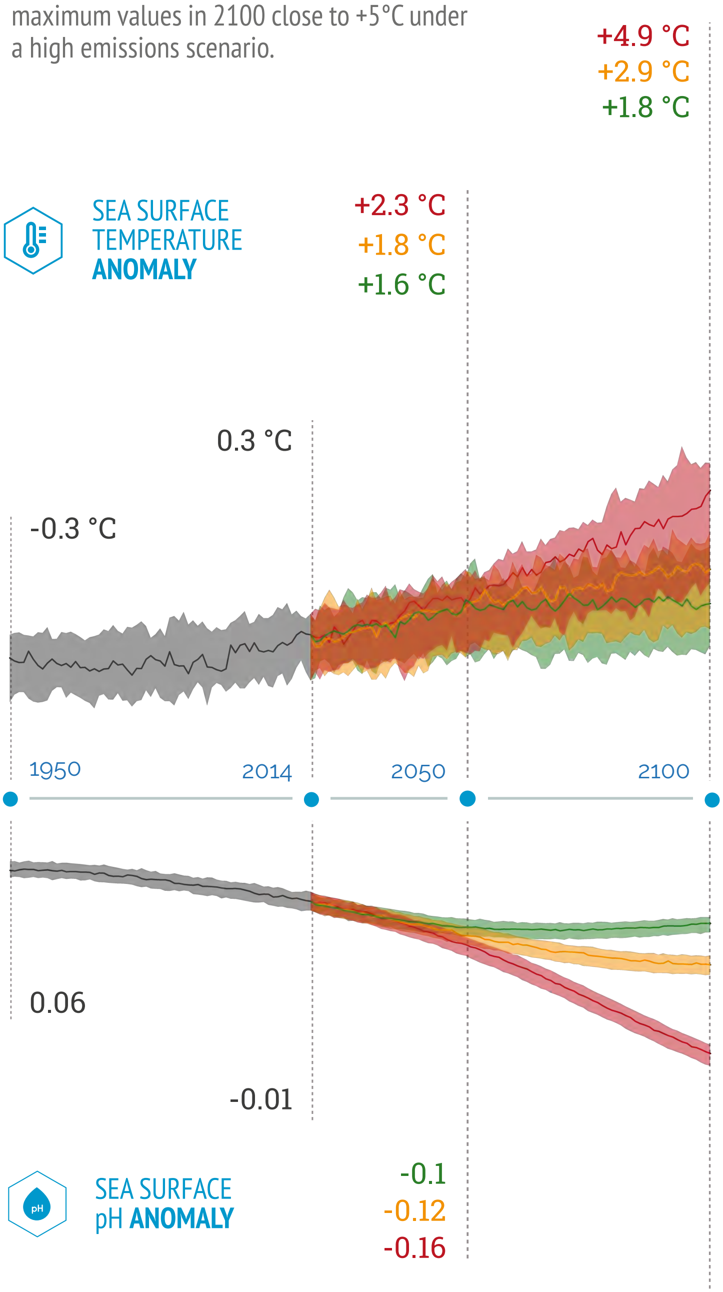


Surface temperature trend indicates high warming rates in the colder marine regions, with values up to 0.8°C/decade

FUTURE PROJECTIONS

Projected annual changes within the marine EEZ for the two most significant marine indicators of climate change: sea surface water temperatures and pH.

Seawater temperature changes are in line with the definitions of each scenario, with maximum values in 2100 close to +5°C under a high emissions scenario.



Seawater surface pH becomes more acidic in all scenarios, closely reflecting rising atmospheric CO_2 concentrations, and only a low emissions scenario leads to a stable condition by 2100.

ECOSYSTEM INDICATORS AT 2050

Regional changes in key marine ecosystem indicators under projected future scenarios by mid-century (2036-2065) with respect to present climate conditions (1985-2014).


Alaska


Atlantic


Pacific

Temperature regulates the metabolism of marine organisms determining which habitats remain suitable. Excessive warming will likely push ecosystems beyond tolerance thresholds.

pH represents the acid/base status of marine waters, where a decreasing pH reflects the acidification of the ocean due to increased absorption of atmospheric CO_2.

Oxygen is fundamental to sustain marine life and its reduction can have a large impact on coastal ecosystem services including fisheries and aquaculture.

Chlorophyll is an indicator of the biomass available at the base of the marine food web supporting all ecosystem productivity.

	Alaska	Atlantic	Pacific
Temperature	4.97°C +2.86 °C +2.24 °C +1.77 °C	23.48°C +1.97 °C +1.62 °C +1.6 °C	15.06°C +2.13 °C +1.74 °C +1.62 °C
pH	8.07 -0.17 -0.13 -0.1	8.1 -0.14 -0.11 -0.08	8.06 -0.16 -0.12 -0.09
Oxygen	322.97 $mmol/m^3$ -4.89 % -4.29 % -3.33 %	219.33 $mmol/m^3$ -4.22 % -3.4 % -3.35 %	260.98 $mmol/m^3$ -3.61 % -3.12 % -2.97 %
Chlorophyll	0.62 mg/m^3 -1.12 % +0.32 % -1.93 %	0.33 mg/m^3 -5.49 % -1.52 % -3.96 %	0.38 mg/m^3 -13.23 % -9.79 % -11.9 %

FISH CATCH POTENTIAL

Fish catch potential is an estimate of the maximum fish catch achievable given the marine resources available over a sustained period. It is linked to the concept of maximum sustainable yield, meaning the maximum amount of fish that can be extracted from a system without causing a collapse in fish populations.

It is a characteristic of the natural system, which is substantially different from realized catch, and a direct result of the fishery policy in place.

Fish catch percentage change

2050

-1.7%

-0.5%

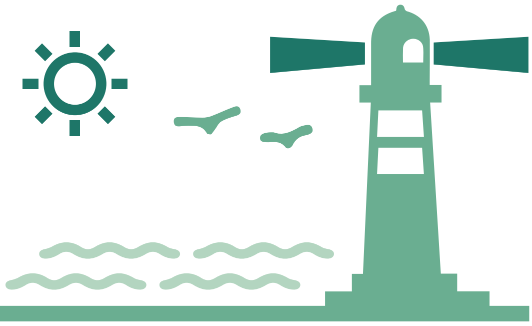
ANALYSIS DETAILS

All datasets were analysed using only data from within the marine EEZ and therefore excluding overseas territories, detached islands and any disputed or joint territories with other nations. In the assessment of current climate conditions, seawater surface tempereature data was obtained using satellite observations distributed in the framework of ESA Climate Change Initiative.

Future projections of marine indicators are represented by the combined analysis of results from 15 different Earth System models participating in the Coupled Model Intercomparison Project Phase 6 (CMIP6). These models include new and better representations of physical and biogeochemical processes, compared to previous IPCC assessment reports.

Fish catch potential data was obtained using the FAO's technical report and refers to the best and worst case climate scenarios from the Fifth IPCC Assessment Report. These mean estimates are subject to substantial uncertainties as discussed in the original work.

UNITED STATES COASTS



OVERVIEW

The extensive coastline of the USA, one of the longest in the world with a total of over 130,000 kilometres, can be broadly split into three regions - the Atlantic, Pacific, and Gulf coasts. The Atlantic coast, home to major metropolitan hubs such as Boston, New York, and Miami, is largely low lying, with sandy beaches and even coral reefs in the Florida Keys. The western Pacific coast is largely rocky, with sandy beaches. The Gulf coast is characterized by large marshlands, deltas and lagoons.

Shoreline Length 133,312 km

Sandy Coast Retreat at 2050 -38.8 m

CLIMATE CHANGE HAZARDS

Coastal hazards such as erosion, storm tide inundation and permanent flooding, can have strong adverse impacts on coastal regions, with loss of sandy shores, damage to settlements, infrastructure and ecosystems. Climate change can exacerbate these impacts due to rising sea levels and increasing impacts of waves and storms. Coastal hazards are becoming more of a concern for USA coastal areas as a result of the increasing impacts of climate change. Changes in the patterns of storm activity and precipitation, as well as warmer temperatures driven by high carbon emissions, are increasing the risk of rising sea levels, storm surges, and coastal inundation. These effects are likely to worsen making destructive events more frequent and leading to further risk of coastal erosion, saltwater intrusion and other negative impacts that have already been observed across the coastline of the USA.

SEA LEVEL RISE

The USA's coastal areas have already seen a noted average sea level rise in the 20th Century, reaching peaks of 1.5-2 millimetres per year, although the extent is dependent on the location. Areas along the east coast have been identified as sea level rise hotspots with an acceleration in the rate of change since the 1980s. The latest IPCC projections indicate that, by 2050, global sea levels may rise between 0.18 metres, under a low emissions scenario, and 0.23 metres, under a high emissions scenario.

Observed and projected sea level rise at 2050

3.24 mm/year

0.23 m

0.18 m

EXTREME SEA LEVEL

Extreme sea levels are expected to rise in line with sea level rise, increasing the frequency of damaging high water level conditions. Under a medium emissions scenario, one in 100 year extreme sea level events in the USA are expected to rise from 3.69 metres at present day to 3.92 metres by 2050.

Current and projected extreme sea level at 2050

3.69 m

3.99 m

3.92 m

OBSERVED STORMS

Waves and storms present a particularly strong threat to the Atlantic coast of the USA, with large hurricanes capable of causing significant damage (such as hurricane Harvey in 2017 and Katrina in 2005). However, the potential for high energy waves to cause continuous erosion and environmental damage exists throughout the coastal regions of the country, particularly in low-lying areas such as in Florida.

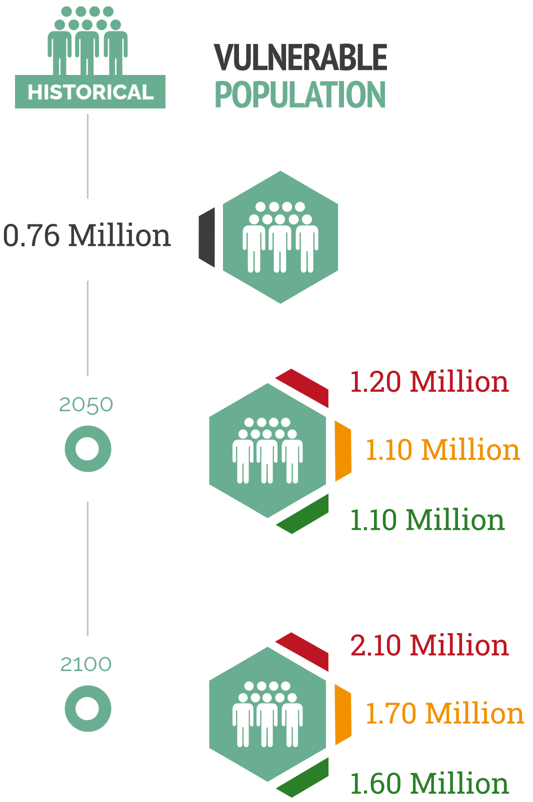
FUTURE STORMS

Global warming will likely exacerbate the issue of storm surges and high waves, both through sea level rise and an intensification in the frequency and severity of tropical storms. The balance of these two factors will depend largely on location. For example, in New York the impact of future sea level rise on the frequency of extreme water level events will have a much larger effect than any changes in the intensity of tropical storms.

VULNERABILITY AND RISK

By 2010, 39% of the USA's population was living in coastal areas, and that number is projected to continue to increase. This represents a large number of people at risk from the coastal impacts of climate change. Over 13 million people live on land that is projected to be flooded by 2100 under a high emissions scenario. Beyond the direct impacts that this would have on urbanized areas and the local population, this could also have knock-on effects by driving migration inland. Coastal biodiversity and species distribution are also prone to the negative impacts of climate change, with sea level-driven habitat loss posing a major threat.

Significant changes would be experience with sea level rise alone, not to mention the more frequent extreme flooding events and their impacts on infrastructure and the natural environment, particularly on the East Coast where the low lying land is more vulnerable to coastal inundation and erosion. The economic impacts could be severe, for example in the Houston-Galveston area which is a major economic and productive centre on the Gulf Coast and which is particularly vulnerable to storm surges and flooding events. Under a medium emissions scenario, the total population exposed to the annual coastal flood level is expected to increase from 760,000 to 1,1 million by 2050.



INFLUENCE OF SEA LEVEL RISE ON EXTREME SEA LEVEL

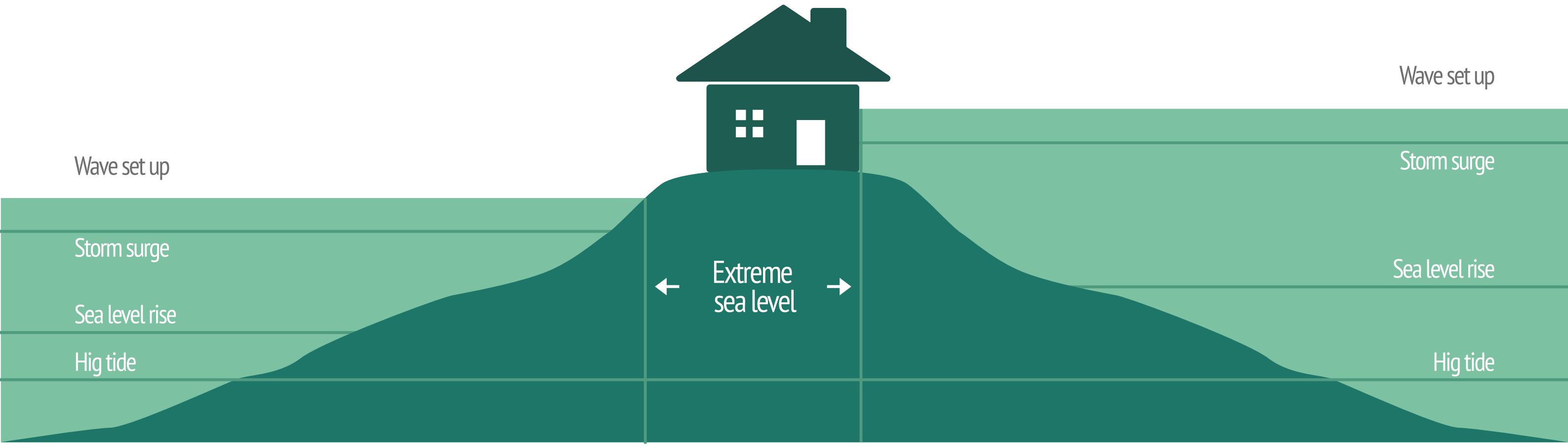
Present and future sea level rise are a consequence of carbon induced global warming causing melting ice and ocean expansion due to heat accumulation.

The extreme sea levels reported here are based on the 100-year storm surge + wave set up + sea level rise + high tide indicators. The first two parameters (storm surge + wave set up) are based on the 100-year value for the event; sea level rise is its projected value at 2050; and high tide is the absolute value of the highest tide calculated for a given locality, which won't be influenced by climate change.

+ Wave set up refers to the accumulation of water near the shore due to the presence of breaking waves.

+ Storm surge is an occasional increase in sea level driven by shoreward wind-driven water circulation and atmospheric pressure.

+ High tide is usually the highest tide reached in a given location based on tide records.



Present sea levels have risen globally by approximately 20 centimetres over the past century.

Future sea level rise is a projection based on different global warming scenarios, at approximately 100 centimetres by the end of 2100, with consequent inundation during extreme sea level events.

UNITED STATES
WATER

OVERVIEW

The USA is a water-rich country in terms of water resources per capita. However, it also faces problems of uneven distribution. The industrial sector uses the largest share of water, with 46% of the total, followed by agriculture with 41%, and domestic use with 13%.

Shifts in rainfall quantities during storms provide evidence that the water cycle is already changing. Over the past 50 years, the amount of rain falling during very heavy precipitation events has increased for most of the USA.

This trend has been most pronounced in the north-east, Midwest, and upper Great Plains, where the amount of rain falling during the most intense 1% of storms has increased by more than 30%.

Renewable internal freshwater resources 2,818 billion m^3

Renewable internal freshwater resources per capita 8,667 m^3

Many areas of the USA, and the western states in particular, face periodical water shortages. The amount of water available in these areas is limited and demand will continue to rise as population grows. Many areas in the west have experienced less rain over the past 50 years, as well as increases in the severity and length of droughts. This is causing particular concern in the south-west of the USA.

CLIMATE CHANGE HAZARDS

Climate change can affect water resources due to increasing temperatures, higher rates of evapotranspiration and altered rainfall patterns. This leads to changes in the water cycle, including decrease of snow and ice coverage, alterations in surface runoff and groundwater storage, as well as drought and flood occurrence. Projected rainfall patterns show a possible decrease in water availability mainly in the west and southwest of the country, including the Colorado River basin, and changes in snowfall and melting patterns which may affect water availability and cycles. The Great Plains and the Mississippi River, may also experience changes in water availability from snow melt and increasing intensities of rainfall events.

KEY POINT RUNOFF

Increasing temperatures, which are likely to impact the entire USA, may result in lower surface runoff as a consequence of increasing evapotranspiration in large areas, possibly counterbalancing the effects of increasing rainfall. This is likely in areas such as parts of the Colorado River basin.

On a country scale, an increase in surface runoff by an average of 7.91% under a low emissions scenario, and 8.21% under a high emissions scenario, is expected for the 2045-2055 period compared to 2015-2025.

If temperatures rise by 1.5°C, 2°C and 4°C, then 2%, 5.4% and 16% of the country will likely experience an increase in runoff, whereas 4%, 12.3% and 39% of the country will likely experience a decrease in runoff for the same temperature changes.

2050

Changes in annual runoff
% of change

+8.3%

+7.9%

2050

Runoff increase
% of area

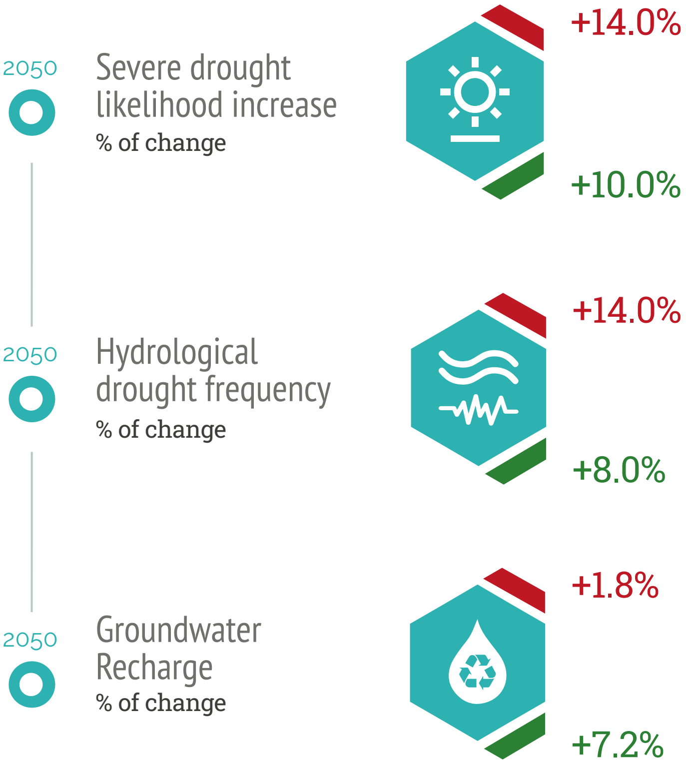
+16.0%

+2.0%

KEY POINT DROUGHTS

Evidence shows that climate change has already led to more intense and longer meteorological droughts in some regions of the world, including the US. For example, the Southwest of the US has been identified as global drought hotspot, with very significant droughts in the 2010s. In part, the severity of these droughts has been attributed to human-induced climate change.

The recent National Climate Assessment shows that seasonal drought is expected to intensify in most US regions, and long-term drought will occur in large areas of the southwest, southern Great Plains, and southeast. This drying trend may pose a substantial threat to US food security as nearly two-thirds of the country's freshwater diversions are used for agricultural irrigation.



KEY POINT GROUNDWATER

Half of the US population relies on groundwater for domestic uses. Water use trend analysis shows that irrigated areas and groundwater withdrawals have increased over the last 30 years in humid and temperate regions, whereas the overall irrigated area has decreased in semi-arid regions. At the same time, the irrigation rate and share of irrigation from groundwater have increased everywhere, suggesting a potential shift in the preferred water source for irrigation.

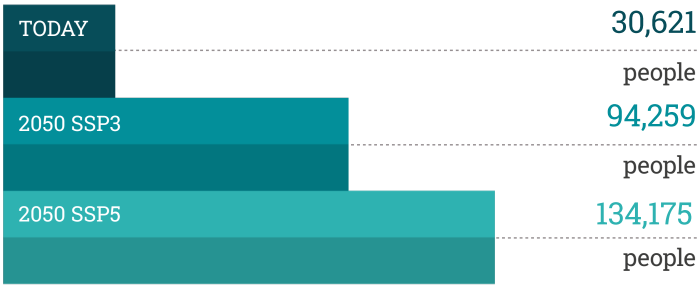
Parts of the south-west are likely to experience declines in groundwater recharge, whereas the north-west may experience slight increases to modest declines. The available estimates indicate average declines of 10-20% in total recharge across the aquifers of the southern states.

On a country level, a +3.5%, +6.4% and -11.4% change in annual groundwater recharge for the period 2045-2055 compared to 2015-2025 is expected under low, medium and high emissions scenarios respectively.

KEY POINT FLOODS

Flooding is the second deadliest climatic hazard in the US, second only to heat. Floods are caused by heavy rain, snowmelt, structural failure of protective structures, or a combination of these factors. In general, flood-related fatalities have increased over the last 25 years compared with the early-to-middle part of the twentieth century. Changing rain patterns may affect the frequency and intensity of floods and the total population exposed to floods is expected to increase from about 30,000 today to about 94,000 under SSP3 and 134.000 under SSP5 by 2050, with higher impact flood events.

POPULATION AFFECTED BY RIVER FLOODS

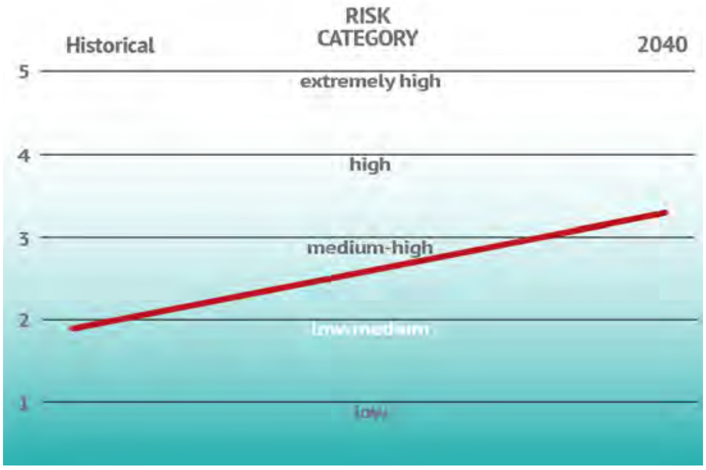


RISK INDICATORS

The water stress index summarises current and future water related vulnerabilities and risks at the global level. Scores are based on the ratio of total water withdrawals, including agriculture, industrial and human consumption, to available renewable surface and groundwater supplies.

WATER STRESS

The USA's water stress level is considered low to medium for the recent past (1960 to 2014 average), although it is expected to increase for the 2030 to 2050 period based on climate change projections.



UNITED STATES
AGRICULTURE

OVERVIEW

Agriculture is a major, and highly mechanized, industry in the USA, which is a net exporter of food and currently the largest producer of maize, second for soy production and fourth for wheat.

Agricultural activity is particularly concentrated in the Great Plains, a vast expanse of flat, arable land in the center of the nation in the region west of the Great Lakes and east of the Rocky Mountains. The eastern, wetter half, is a major corn and soybean producing region known as the Corn Belt, whereas the western, drier half, is known as the Wheat Belt for its high rate of wheat production.

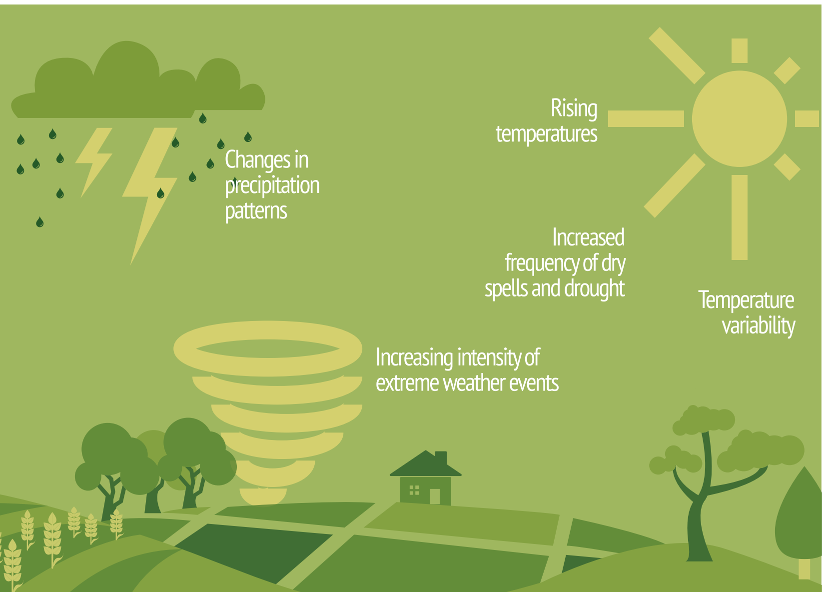
The Central Valley of California produces fruits, vegetables and nuts. The South has historically been a large producer of cotton, tobacco, and rice, although agricultural production has declined over the past century.

364.3 Mt Maize	120.5 Mt Soybeans	51.3 Mt Wheat
31.3 Mt Sugarcane	6.9 Mt Grapes	5.6 Mt Citrus

	Added Value of Agriculture, Forestry and Fishing	Share of Agriculture Value added in Total GDP	Agricultural land	Area Equipped for Irrigation
2000	129,483 USD Million	0.9 %	178,068 Thousand HA	27,000 Thousand HA
2018	183,901 USD Million	0.9 %	160,437 Thousand HA	26,916 Thousand HA

EXPEXTED IMPACTS ON AGRICULTURE PRODUCTIVITY

Rising temperatures, reduction in average annual precipitation, and intensification of extreme events such as heat waves and drought, affect production variability with a tendency towards yield reduction for many cultivated species, accompanied by a probable decrease in food quality. Crops respond to increases in temperatures with changes in duration of the growing season, early appearance of phenological phases and potential shifts of cultivation areas toward higher latitudes and altitudes for better growing conditions. However, impacts vary significantly depending on the geographical area and specific crops in question.



CROP PRODUCTIVITY

Crop productivity refers to the harvested yield of a crop per unit of land area. It is strongly influenced by climate and other environmental and management factors.

Climate change is expected to have an impact on the productivity of several major crops, although this may in part be offset by the fertilizing effect of higher CO_2.

Impacts are estimated using a range of model projections based on low to high emission scenarios and reported as percentage changes between the 30-year average around the historical period and the 30-year average around 2050.

10.8 Maize tons / ha -1.8 (-3.6)% -2.2 (-9.7)%

3.3 Soybeans tons / ha -1.5 (-12.5)% 2.8 (-12)%

3.3 Wheat tons / ha 4 (2)% 4.6 (-0.2)%

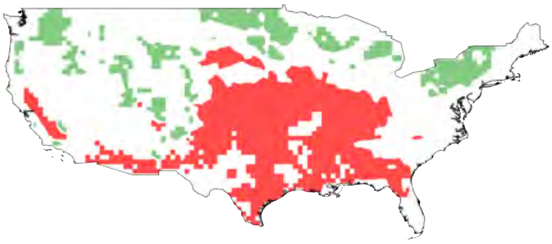
82.2 Sugarcane tons / ha -6.2 (-6.4)% -8.2 (-8.5)%

2050

Productivity change with (without) the CO_2 fertilization effect. Estimates assume sufficient water and nutrient supplies, and do not include impacts of pests, disease, or extreme events.

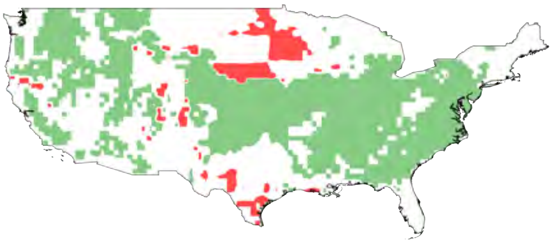
CHANGE IN MAIZE

🟥 − = 🟩 +



CHANGE IN WHEAT

🟥 − = 🟩 +



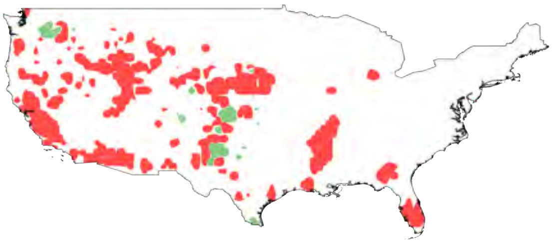
Maize and sugarcane are predicted to suffer a considerable decline in productivity, particularly in semi-arid regions where higher temperatures exceed the optimum temperature for crops. The greatest maize productivity losses are expected in the western and southern regions of United States, where large increases of consecutive dry days and number of hot nights during the grain production period lead to lower productivity and reduced quality. Wheat and soybean may on average increase their productivity. However, productivity changes can have disparities across regions following climate change patterns. Citrus productivity may increase over growing areas in Florida, Arizona, Texas and California, also because of reduced frost risks. Increases in temperatures will shift grape production to cooler climate regions, and actual production areas will require warmer climate varieties and lower quality wines. Nut trees may experience a productivity decline, where milder winters will not be able to fully satisfy chilling requirements, limiting flower emergence and viability.

ADAPTATION IN AGRICULTURE AND WATER RESOURCES

Agriculture in the United States is a major user of both ground and surface water, with much of the irrigated land concentrated in the west and southeast. Water resources are expected to decline in the west and southwest in spring and summer, also due to earlier snowmelt and reduced snowpack. In the last decade, the United States experienced a pronounced drought with more than two-thirds of its counties declared as disaster areas and large declines in aquifer levels. Higher temperatures will generally require an increase in irrigation demand due to higher plant evapotranspiration. Water withdrawals in the Great Plains are expected to exceed renewable freshwater resources by 40%, making them particularly prone to water stress.

CHANGE IN WATER DEMAND

🟩 − = 🟥 +



Agriculture Water Demand
% of change

+9.2%
+10.9%

2050

Climate risks imply substantial increases in water demand (up to 30-35% in some areas) to maintain agriculture production, which will require adaptation practices and crop varieties enhancing water-use efficiency to limit increasing stress on water resources.

UNITED STATES
FORESTS

FORESTS IN UNITED STATES

USA forests play a key role in tackling the climate emergency and can be seen as the country's most important nature-based solution. Given its vastness, the US territory hosts all the main types of existing forests, from boreal to temperate and finally tropical ones.

Of these, nearly 25% are primary forests. In large areas of Florida, a wide distribution of the very important coastal mangrove forest biome is found.

FORESTED AREA AND CARBON STORAGE

Forests cover almost 35% of the country. The United States Forest Service reports that they capture between 15 and 20% of domestic carbon dioxide emissions by storing approximately 800 million metric tons of carbon dioxide per year. The total amount of carbon stored in forest ecosystems to date is almost 58 gigatonnes.

1990

303 Mln ha
Million hectares
Forested area

192 Tons/ha
Tons of Carbon per hectare
Carbon stock

2020

310 Mln ha
Million hectares
Forested area

201 Tons/ha
Tons of Carbon per hectare
Carbon stock

FOREST PRODUCTIVITY

Forest productivity or Net Primary Production is the net carbon captured by plants. It is the difference between the carbon gained by Gross Primary Production - net photosynthesis measured at the ecosystem scale - and carbon released by plants' respiration. It is expressed per unit land area.

Increase particularly pronounced for more forested areas such as on the Eastern and Western coasts

+ Fertilizing effect of CO_2, and increasing length of the growing season due to rising temperatures promote productivity, particularly in the north

Decrease in a few areas, particularly in Midwest and northeastern forests

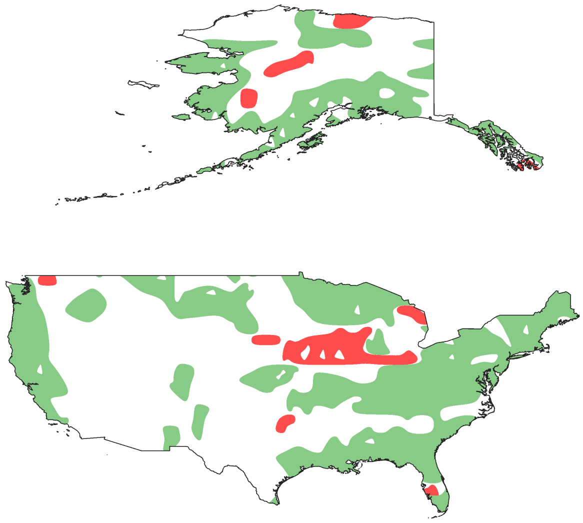
+ Increasing risk of drought stress due to modifications in the water regime reduce productivity

2050

Productivity anomaly
Tons of Carbon per
hectare per year

+0.46

+0.31



KEY SPECIES UNDER CLIMATE CHANGE

LOW VULNERABILITY
OAKS
Systems dominated by oaks show low vulnerability

THREATENED
MANGROVES
Rapid sea level rise will threaten the Florida Everglades coastal mangrove forests

COMPETITIVENESS
HICKORY
Species such as hickory and pine are expected to become more competitive

HIGH VULNERABILITY
BOREAL
Northern and boreal forests will experience high vulnerability and a pronounced decline

FIRES IN UNITED STATES

Fire is a structural ecological process that provides several types of ecosystem services and impacts on socio-ecological systems, including human health, carbon budgets, and climate change. Changes in global fire activity are influenced by multiple factors such as land-cover change, policies, and climatic conditions. Fire also releases large quantities of greenhouse gases into the atmosphere, contributing to a vicious cycle.

During the last two decades, a total of 1,300 million wildland fires occurred.

BURNING
52 MILLION HECTARES

EMITTING
28.8 TERAGRAMMES
OF CARBON PER YEAR

FOREST FIRE EMISSIONS
CONTRIBUTED TO
62% OF TOTAL FIRE RELATED
CARBON EMISSIONS

COSTING
2.9 AND 3.1 BILLION USD IN
SUPPRESSION COSTS BETWEEN
2017 AND 2018

FUTURE BURNED AREA

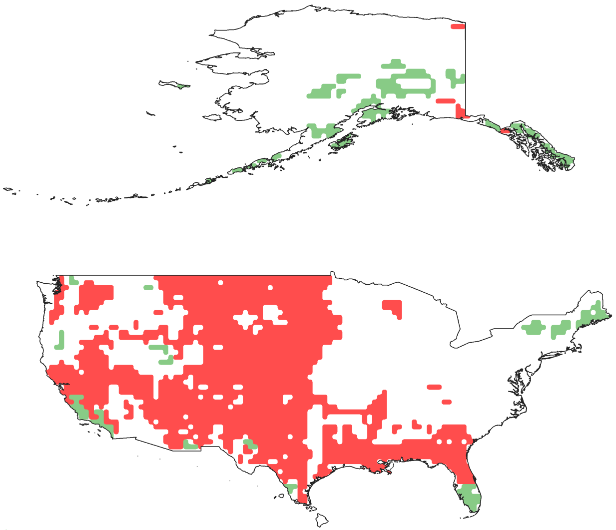
Under a low emissions scenario, models project a generalized increase in burned areas across the south-west basins and plateaus, as well as in northern California and troughout the Great Plains and northern Florida. This trend might be emphasized under a medium emissions scenario, and more pronounced in California and in the Gulf Coastal Plains.

Burned Area
km² per year

2050

+3,517

+2,062



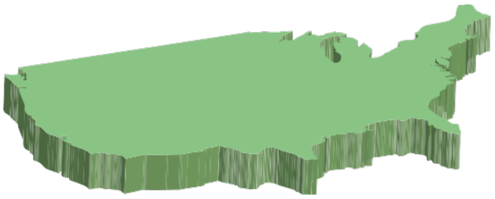
Decrease in burned areas for a low emissions scenario

Increase in burned areas for a low emissions scenario
+ Increasing length of the fire season due to increasing temperatures
+ Increasing length of drought periods and warming

WHERE DO FIRES OCCUR?

In California, shrublands experience high-intensity fires, whereas montane mixed forests are characterized by surface fires.

In western USA forests, 30% of cool and sub-alpine environments are characterized by high severity fires shaping landscape diversity and vegetation regeneration.



Southern and western regions of the US are the most affected by fires.

In low-elevation and mid-montane forests, low severity fires are more frequent.

VARIATION OF SPECIFIC FIRE INDICATORS

% of change
Number of weeks with large wildland fires

2031–2060

+105%

+53%

Billion US$ per year
Health economic damages attributable to wildfires

2050

26

23

cases/year
PM2.5 mortality attributable to wildfires

2050

+1600

+1300

FUTURE FIRE EMISSIONS

Fire emissions follow a similar spatial pattern to burned area. The largest projected changes are expected in the Pacific Northwest (and northern California) and from the Northern Rockies down to the Southwest - with more pronounced changes under a medium emissions scenario.

Fire Carbon emission
Teragrams of Carbon per year

2050

+30

+15

UNITED STATES
URBAN

OVERVIEW

The USA's population is projected to increase by 14% by 2050, becoming increasingly urbanized.

More than 10% of the urban population resides in the 2 largest cities - New York City and Los Angeles, while the majority of urban residents live in cities with 1 to 5 million people.

Built up areas cover 1.54% of the USA (143,238.63 square kilometers).

OVERVIEW OF KEY CLIMATE IMPACTS IN URBAN AREAS

Impacts on cities and their inhabitatns are constantly evolving as climate change increases their exposure and vulnerability to extreme weather events and sea level rise, with significant variations across the country.

Acute and chronic climate stressors and how they interact with local geographic characteristics differ regionally. Most cities are subject to multiple climate impacts that affect multiple urban sectors.

HEATWAVES AND HEAT STRESS

Cities experience higher temperatures than surrounding rural areas because of the Urban Heat Island (UHI) effect, whereby built up areas absorb solar radiation during the day and release heat at night, warming the surrounding air.

UHI is caused by factors such as less natural landscapes, the materials used for buildings, urban layouts and waste heat. Heatwaves are occurring more often than they used to in major cities, increasing from an average of two heatwaves per year during the 1960s, to six per year during the 2010s.

The duration of individual heatwaves and the heatwave season have also been increasing, along with heatwave intensity. Future scenarios of 1.5°C, 2°C and 4°C mean temperature increases indicate that heatwaves will last longer throughout the entire country.

Population in Urban Areas

2020 273,975,139

2050 347,346,215v

Graphs refer to data provided by United Nations, Department of Economic and Social Affairs, Population Division (2018). World Urbanization

Urbanization Rate

2020 82.7%

2050 89.2%

Cooling Degree Days
% of change

2050
+11.6%
+42.3%
+26.2%

Heatwave frequency
% of change

2050
+91.2%
+40.0%
+22.4%

Heatwave duration
% of time

2050
+2,000%
+311%
+117%

HEAT, HEALTH AND AIR POLLUTION

Heat related health impacts from increasing air temperatures in urban areas are furthermore accentuated by air pollution. Wildfires, on the rise in the West, contribute to lower air quality in cities near the wildland–urban interface.

PM2.5 from wildfire smoke is the air pollutant of greatest concern to public health. In 2017, 3.3% of the population was exposed to levels exceeding WHO guideline values for PM2.5.

2017

Population exposed
to air pollution

3.3%

COASTAL FLOODING

The cities most vulnerable to flooding in the USA are low-lying coastal areas, where the built environment is subject to storm surge, high tide flooding, and saltwater intrusion. There has been an increase in coastal flooding since the 1950s, with the rate of increase accelerating at most locations along the East and Gulf coasts; the East Coast endures the most frequent coastal flooding and has experienced the largest increases in the number of flood days.

The ongoing increase in the frequency, depth, and extent of tidal flooding due to sea level rise will cause cascading impacts on the larger economy. The increased probability of heavy precipitation events will further heighten the risk of coastal flooding in the future.

Projected
sea level rise

2050

0.23 m

0.18 m

2100

0.77 m

0.38 m

EXTREME PRECIPITATION

Annual precipitation has decreased in much of the west, southwest, and southeast; and increased in most of the northern and southern plains, Midwest, and Northeast. Across most of the country, heavy precipitation events have increased in both intensity and frequency, however there are important regional differences in trends, with the largest increases occurring in the Northeast.

Seasonal average precipitation projections include a mix of increases, decreases, or little change, depending on location and season. Generally, high-latitude regions are expected to become wetter while the subtropical zone becomes drier. Precipitation extremes will increase in frequency and intensity in the future throughout the contiguous United States.

2050

Runoff
increase
% of area

+16%

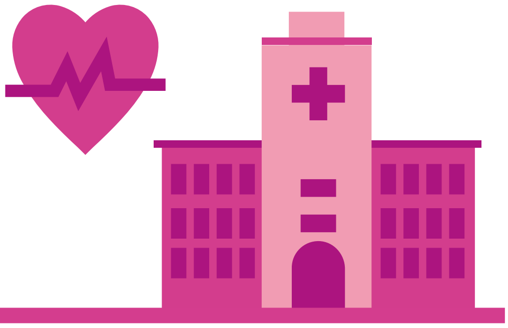
+5%

+2%

SURFACE SEALING AND FLOODS

Heavy precipitation in cities is problematic due to the high level of sealed surfaces. Soil sealing increases run off and reduces the amount of water absorbed by soil. Where there are large amounts of impervious ground cover, short duration extreme rainfall events can lead to increased flooding, even resulting in flash floods.

UNITED STATES HEALTH



OVERVIEW

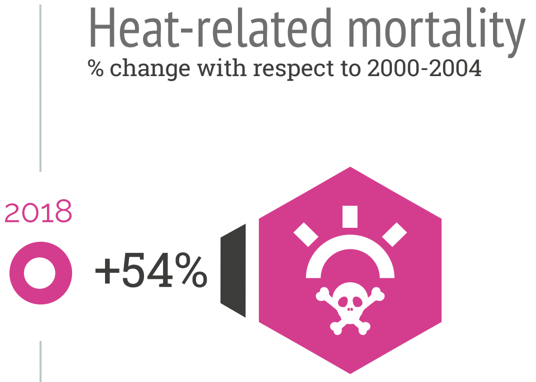
Given the USA's geographical and climatic heterogeneity, climate change poses one of the most significant environmental and human health threats. Rising sea levels, warming oceans, expected increases in the frequency and intensity of extreme weather events and changes in temperature and precipitation patterns pose direct and indirect risks to the health and well-being of the population.

Changing climate patterns will likely cause deterioration of food security, nutrition, and the emergence and reemergence of water-borne, vector-borne, and food-borne diseases. In addition, drivers of climate change, such as air pollution, will increase the risk of cardiovascular diseases, cancers, and respiratory diseases.

HEAT RELATED MORTALITY

Climate change is projected to lead to a significant increase in heat-related deaths. Under a high emissions scenario, heatwave-related excess deaths will increase by 496%, whereas mortality will increase by 309% under a medium emissions scenario.

In 2018, there was a 54% increase in heat-related deaths in the US compared to the 2000 to 2004 baseline. 34.7% of US heat-related mortality from 1991 to 2006 can be attributed to human-induced climate change.

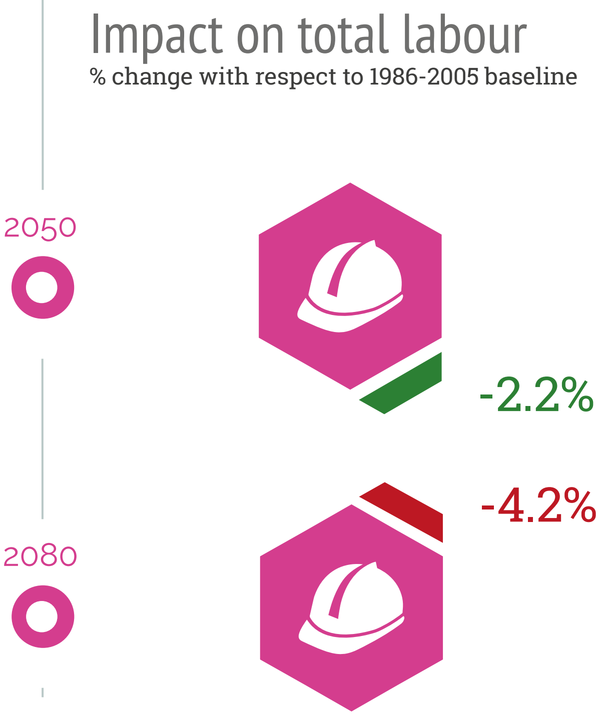


IMPACTS ON LABOUR

Labour is directly affected by changes in environmental conditions. Warming affects both the number of hours worked (labour supply) and on the productivity of workers during their working hours (labour productivity). Both labour supply and productivity are projected to decrease under future climate change in most parts of the world, and particularly in tropical regions.

Parts of sub-Saharan Africa, south Asia, and southeast Asia are at highest risk under future warming scenarios. Future climate change will reduce global total labour in the low-exposure sectors by 18 percentage points and by24.8 percentage points in the high-exposure sectors under a 3.0°C warming scenario

Total labour in the US is expected to decline by 2.2% under a low emissions scenario, and by 4.2% under a medium emissions scenario.



CLIMATE CHANGE AND DENGUE

Dengue has spread throughout the tropical world over the past 60 years and now affects over half the world's population. Globally, vectorial capacity for both dengue vectors (A. aegypti and A. albopictus) has been rising steadily since the 1980s, with nine of the ten highest years occurring since 2000.

Climatic stressors are one important driver of the current distribution and incidence of dengue. Climate change is likely to expand the geographical distribution and suitability of several vector-borne human infectious diseases including dengue. The risk of dengue transmission is increased by warming climates, as the growth and development of mosquitoes are significantly influenced by temperature, precipitation, and humidity.

CLIMATE CHANGE AND ZIKA

Zika virus has spread to at least 49 countries and territories since 2013. Climate change impacts on transmission suitability risk have increased over the years and future warming over 1.3 billion additional people could face suitable transmission temperatures for Zika by 2050.

DENGUE AND ZIKA: POPULATION AT RISK

In the USA, climate change could create suitable conditions for dengue transmission year-round.

Under a medium emissions scenario, 92% of the population will be at risk of transmission-suitable mean temperature for dengue by 2050, whereas 94.6% will be at risk under a high emissions scenario. In the case of Zika, 83.8% of the population will be at risk by 2050 with medium emissions, whereas 88.2% will be at risk under a high emissions scenario.

CLIMATE CHANGE AND MALARIA

Malaria transmission stability will likely increase in the US due to warming. In 2050, 29.5% of the US population will be at risk of malaria under a low emissions scenario, whereas 31.4% will be at risk under a high emissions scenario.

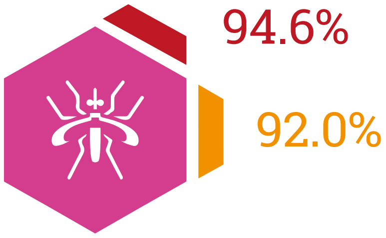
POLLUTION AND PREMATURE MORTALITY

Under a medium emissions scenario, annual premature deaths due to long-term exposure to near-surface ozone and heat will increase from 299 per million (2010) baseline, to 307 per million in 2050.

Dengue suitability

% of population at risk

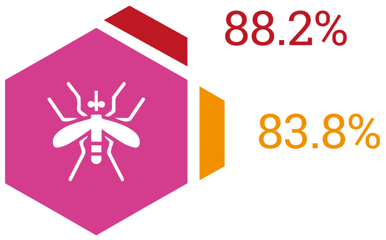
2050



Zika suitability

% of population at risk

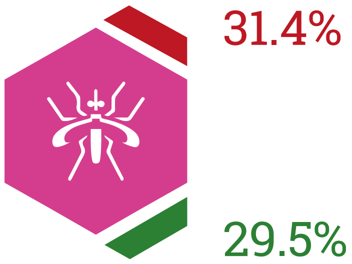
2050



Malaria suitability

% of population at risk

2050



UNITED STATES ENERGY

ENERGY SYSTEM IN A NUTSHELL

Fossil fuels have dominated the USA's energy mix for the last century, although the share of renewables has been growing over the last decade. Oil and gas remain a key feature of the energy landscape, benefitting from cost reductions from drilling and fracking innovations. Energy security is the primary goal of energy policy, and the level of domestic energy production risen steadily over the last two decades.

0.11
ktoe/US$
Energy intensity

26.4%
AC Share in electricity consumption

CLIMATE CHANGE TODAY

EXTREME EVENTS

Extreme weather is the primary cause of power outages across the USA. Higher temperatures, wildfires, flooding, and storms resulted in strong disruptions to transmission lines. In the Gulf Coast, hurricanes cause heavy damage to offshore oil drilling facilities. Hurricanes Katrina and Rita caused damage to over 100 platforms and 558 pipelines.

DROUGHTS

Hydropower generation has been significantly affected by droughts and higher temperatures have forced nuclear plants to reduce generation or shut down.

HEAT

Hotter summers are boosting air conditioning use, resulting in more frequent and longer power outages. The Southwest blackout at the end of the summer of 2011 left 2.7 million people without power for 12 hours.

ENERGY SUPPLY

The USA's total primary energy supply energy mix shows a strong dependence on fossil fuels (83% of total primary energy supply in 2019) of which 36.2% is oil, used mainly for transport, 12.6% coal and 23% gas. Nuclear's contribution has remained steady at 10% since 2010. Only 8% of the total primary energy supply is currently met by renewable sources - doubling their 1990 share, whereas coal has halved.

ENERGY DEMAND

With only 5% of the world's population the USA uses nearly 17% of the world's energy. In 2018, transport claimed 40% of energy demand - mainly to fuel road transport. The industrial sector claims over 17% of energy demand, almost at par with the residential sector. The tertiary sector accounts for 13.6% of final energy demand; energy use in agriculture and forestry is negligible. Air conditioning accounts for a substantial share of final residential electricity, 26.4%.

FUTURE ENERGY DEMAND

In the USA, warmer summers are predicted to increase electricity demand, resulting in higher summer peak loads. Milder winters are expected to decrease energy demands for heating, but by a smaller scale than the increase in summer cooling needs. Overall, net energy demand is predicted to increase. Higher temperatures might affect the energy mix, reducing demand for oil and natural gas used to heat homes, and instead increasing electricity demand for cooling needs.

Net change in energy demand due to changes in DD/CDD
Billion KWh

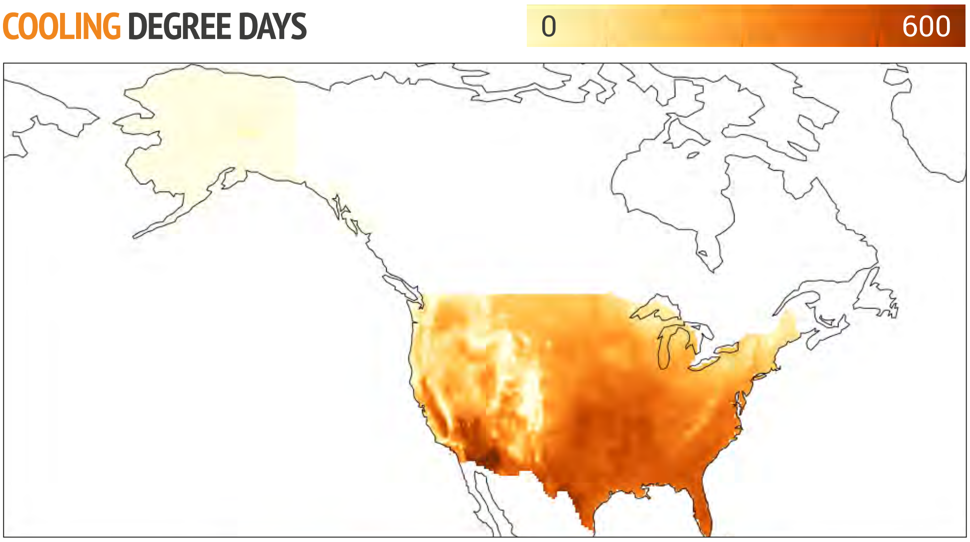
2050

+ 5,338.09

COOLING NEEDS

Warmer and longer summers are expected to increase cooling needs across all regions of the USA. The magnitude of the effects will differ across locations but will be stronger in the southern and central states. Cooling needs are expected to increase for southern regions and exceed any savings from a reduction in heating needs.

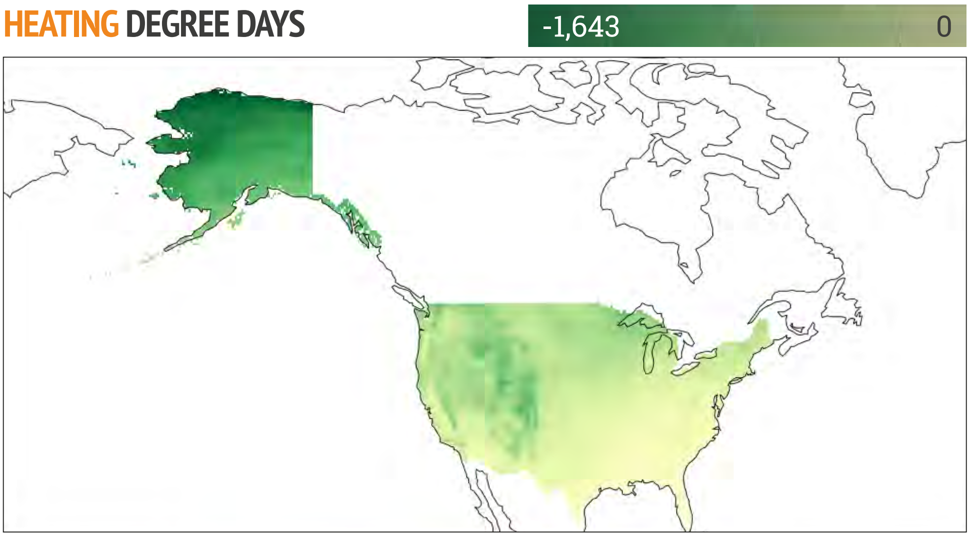
COOLING DEGREE DAYS



HEATING NEEDS

Heating needs are predicted to decrease across the United States as winters become milder. In the northeast, Midwest and northwest where the majority of energy demand is for heating needs, net energy consumption is predicted to decline as the decrease in heating needs exceeds the increase for summer cooling. The extreme decrease in heating degree days in Alaska is expected to be of negligible relevance in terms of energy demands, as the state has a small population.

HEATING DEGREE DAYS



FUTURE ENERGY SUPPLY

The future configuration of the USA's energy mix is likely to be determined by the evolution of climate mitigation policies and hence is outside the scope of this report. The U.S. Climate Crisis Action Plan sets a target of net-zero greenhouse-gas emissions by no later than 2050. Ultimately the policy decisions and the resulting interim targets will shape the future energy supply mix in the USA. These policy targets will likely result in a marginal relevance of fossil fuels and their vulnerabilities to climate change, while carbon free sources and their vulnerabilities will prevail.

Change in Hydropower generation
% of change

2050

-4.64%

-4.84%

EXPECTED IMPACTS OF CLIMATE CHANGE

Increasing wildfire risks will threaten transmission lines across the USA. Energy infrastructure in coastal areas will face increasing risks as extreme tides and storm events increase in frequency and severity. Water shortages will affect thermal power generation. Peak loads during summer droughts might threaten the stability of the energy system.

UNITED STATES ECONOMY

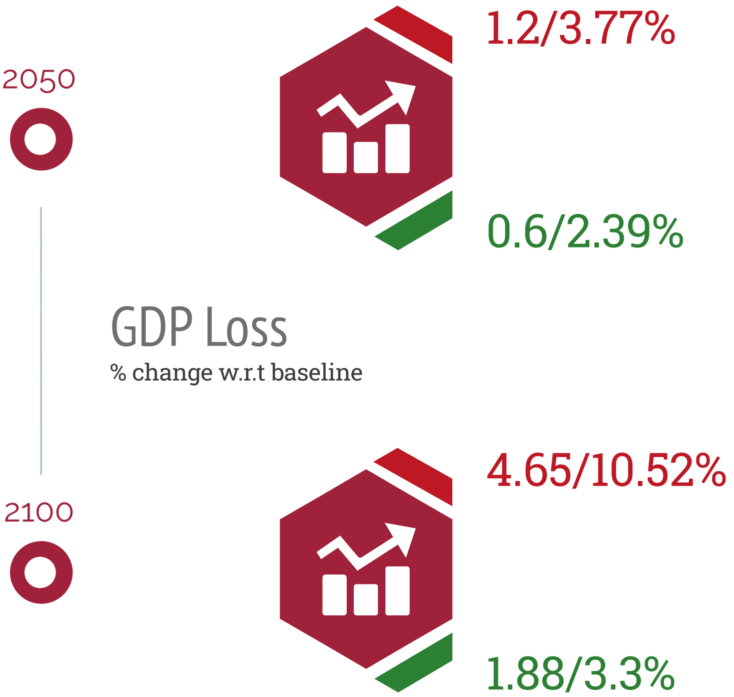
OVERVIEW

The USA has the largest economy in the world in terms of GDP. The COVID 19 pandemic reduced growth rates in 2020, whereby the USA lost 3.5% of real GDP. However, it has recovered quickly with a growth rate of 6.4% in 2021.

IMPACTS ON GDP

Climate change will have an effect on the growth rate and overall systematic economic performance of the country. National losses in GDP may be significant, reaching 2.4% of GDP or 415 billion EUR by mid century under a low emissions scenario, and drastically rising to 10.5% of GDP, or 1.8 trillion EUR, under a high emissions scenario by the end of the century. The costs of climate change are borne unequally across the US, exacerbating pre-existing inequality.

By the end of the century, under a high emissions scenario the poorest counties are likely to experience substantial damages in the range of 2-20% compared to gains exceeding 10% of county income in some regions.



2050

1.2/3.77%

0.6/2.39%

GDP Loss

% change w.r.t baseline

2100

4.65/10.52%

1.88/3.3%

SECTORAL ECONOMIC IMPACTS

IMPACTS ON INDUSTRY AND INFRASTRUCTURE

Sea level rise poses risks to communities, infrastructure and industry along the USA coastline. In particular the coast is crucial for the north-eastern economy, where many major cities and industries are located on the water. Much of this infrastructure is extremely vulnerable to sea level rise.

As a result of climate change, the expected damage from hurricanes is predicted to increase in the future for the USA. Probabilistic estimates of the damages caused by hurricanes and coastal storms show that there could be additional damages amounting to 108 billion USD by the end of the century. Natural disasters are already imposing significant costs on the USA, whereby in 2017 there were 300 billion USD worth of damage to homes, businesses, infrastructure and goods.

IMPACTS ON AGRICULTURE

The agricultural sector in the US is significant, producing almost 330 billion USD in agricultural commodities annually. The forestry sector is an important contributor to wealth production, providing a range of important goods and services from timber products to places of recreation. Wildfires in particular will pose a risk to the majority of the US. It is estimated that mitigation efforts could save the USA's economy between 8.6 and 11 billion USD in wildfire costs relative to a business-as-usual scenario until 2100.

Expected effects on crop yields are highly heterogeneous across crops and regions. This tendency leaves the aggregate damage estimates quite modest relative to the size of the US economy, and potentially some benefits from climate change could be experienced.

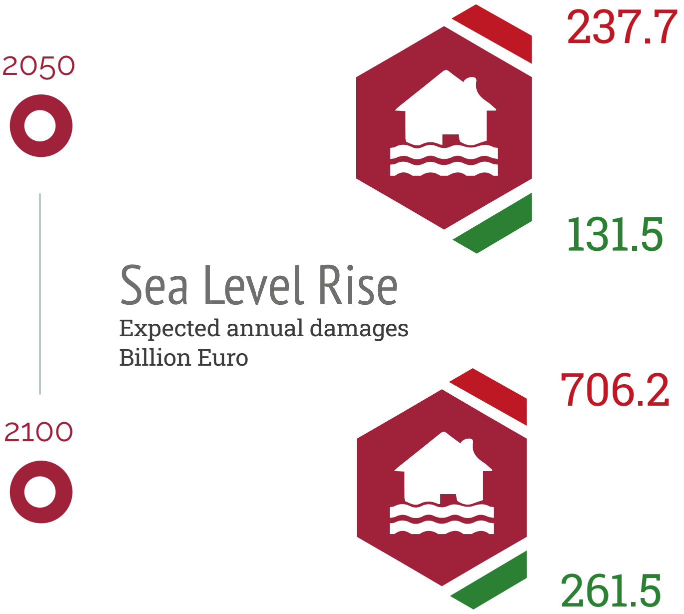
Some estimates place the damage to crop yields under a high emissions scenario in the range of -8.2 to +19 billion USD by mid century and -12 to +53 billion USD by the end of the century. More recent studies emphasize smaller potential gains.

Nevertheless, damage from extreme weather events may be substantial. The EPA estimates that greenhouse gas mitigation measures could avoid damage of up to 6.6 to 11 billion USD in the agricultural sector by 2100 compared to a business-as-usual scenario, and additionally 0.52 billion to 1.5 billion USD in the forestry sector.

SEA LEVEL RISE DAMAGES

Under the current level of coastal protection, by mid century, sea-level rise and coastal flooding could cost the country 131.5 to 237.5 billion EUR in terms of expected damage to assets low and high emissions scenarios, respectively.

By the end of the century, expected losses may increase to 261.5 billion EUR under a low emissions scenario and to 706.2 billion EUR under a high emissions scenario. Damage to coastal properties is unevenly distributed across the country, with the largest losses occurring in the southeast and Atlantic coasts where sea level rise is expected to be higher.



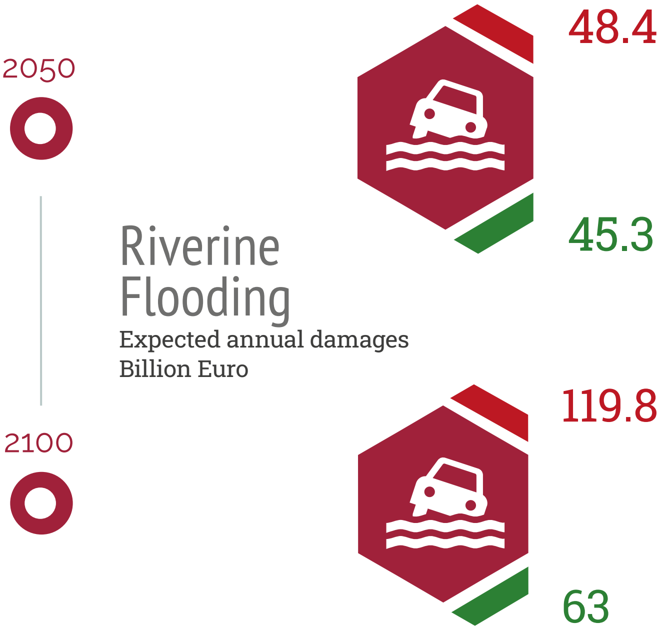
Sea Level Rise

Expected annual damages
Billion Euro

RIVER FLOODING DAMAGES

River flooding can also induce severe damages. By mid century total asset losses are projected to be 45.3 to 48.4 billion EUR under low and high emissions scenarios, respectively.

By the end of the century these costs are projected to rise to 63 and 119.8 billion under low and high emissions scenarios, respectively.



Riverine Flooding

Expected annual damages
Billion Euro

IMPACTS ON FORESTRY AND FISHERY

Under a medium emissions scenario, commercial fishing revenues in the US could experience a total loss of 3.75 billion and 7.5 billion USD under the high emissions scenario by the end of the century.

IMPACTS ON ENERGY

As with all other economic sectors, energy supply and energy networks in the USA will undergo more intense stress from extreme weather events.

Nevertheless, climate change is expected to increase electricity costs and demand. Higher temperatures will increase demand and power generation will become less efficient with the additional costs being passed on to residential and commercial ratepayers. By the end of the century under a high emissions scenario average yearly energy expenditures are projected to increase by between 26.5 and 72.1 billion EUR. There are, however, no overall estimates of the economic impact of climate change on energy infrastructure for the USA.

IMPACTS ON TOURISM

Tourists in the US, both foreign and domestic, are highly climate sensitive and hence the tourist industry depends on the climate itself and the amenities it provides. In particular, winter sports, and destinations popular for coastal and outdoor recreation will be vulnerable to changes in climate.

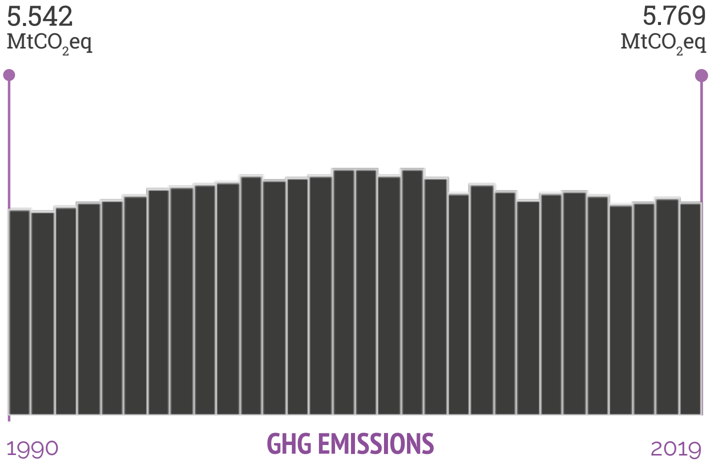
It is estimated that increased coral bleaching will cost the US approximately 18.8 billion USD (15.6 billion EUR) in losses associated with coral reef recreation and 320 million USD (265 million EUR) in recreational freshwater fishing, by the end of the century. Winter sports are a notable contributor to the tourism sector, with over three-quarters of states benefiting economically from these activities.

Winter sporting activities annually contributed 12.2 billion USD (10.1 billion EUR) to the US economy (2009-2010). Changing snowfall patterns are already taking their toll on the economy, resulting in a loss of over 1 billion USD (0.82 billion EUR) over the decade from 1999-2010. Winter temperatures are predicted to rise, exacerbating the losses already experienced by the sector.

UNITED STATES
POLICY

OVERVIEW

The USA is the world's 4th largest country and accounts for 13% of global emissions, with one of the highest rates of GHG emissions per capita. Emissions have been declining since 2004, and a net zero emissions by 2050 target has been set.



INTERNATIONAL COMMITMENTS

In its 2021 NDC update, the USA strengthened their target from a 26-28% emissions reduction below 2005 levels by 2030, to a 50-52% reduction.

CLIMATE POLICY COMMITMENTS CHRONOLOGY

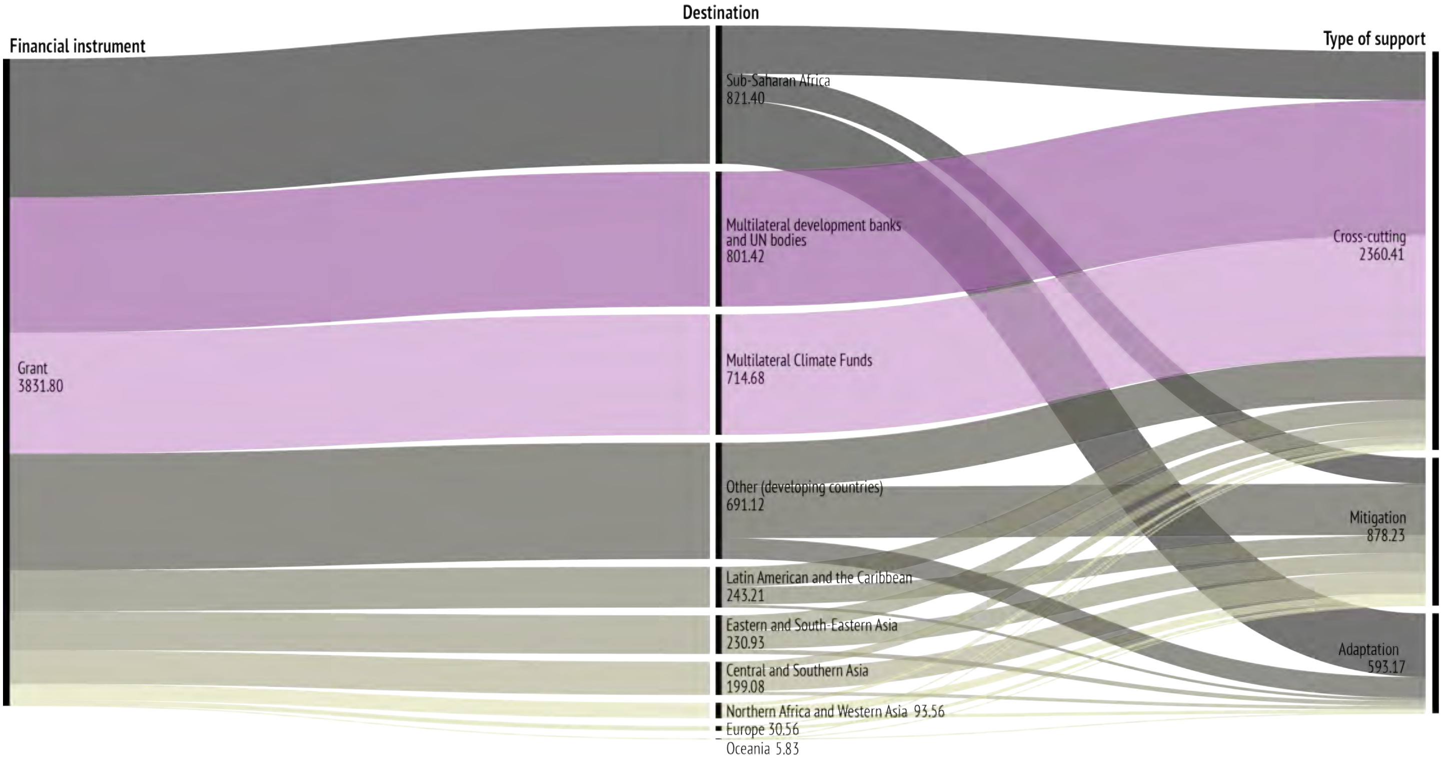
Kyoto Protocol - 1st period
The USA had a 7% GHG reduction target but eventually failed to ratify the Kyoto Protocol

2016 **Paris Agreement - 1st NDC**
Between 26% and 28% GHG reduction by 2025, with reference to 2005 levels

2021 **Paris Agreement - NDC update**
Between 50% and 52% GHG reduction by 2030, with reference to 2005 levels

INTERNATIONAL CLIMATE FINANCE ASSISTANCE

The diagram is based on OECD DAC climate-related development finance data for 2017-2018: the USA are providers of 3.8 billion USD, mainly devoted to cross-cutting projects. The largest share is directed to sub-Saharan Africa.



SUSTAINABLE RECOVERY POLICY

According to the Global Recovery Observatory, in 2020 the proportion of green spending out of total recovery spending was 9%.

4,526.33 billion $	122.76 billion $	10.77 billion $
Total Spending	Recovery Spending	Green Spending

DOMESTIC ADAPTATION POLICY

Through the Executive Order on Tackling the Climate Crisis at Home and Abroad, the United State President, in January 2021, directed federal agencies to develop climate action plans and established a White House Office of Domestic Climate Policy and a National Climate Task Force.

- ○ Domestic Adaptation Policy
  - ○ Inclusion of Adaptation in NDCs
  - ○ Integrated Adaptation & Mitigation Policy
  - ○ Dedicated Adaptation Strategy
  - ○ Dedicated Adaptation Plan
- ● Subordinate Adaptation Policies
  - ● Sectoral Adaptation Plans
  - ● Subnational Adaptation Plans

○ Policy not in place ● Active policy

ADAPTATION POLICY HIGHLIGHTS

TRANSNATIONAL INITIATIVES

International Boundary and Water Commission

International Boundary and Water Commission implements water treaties between the United States and Mexico. It explores an array of adaptive water management strategies to manage climate-related impacts on Colorado River water

NATIONAL INITIATIVES

Climate Change Response Framework (CCRF)

The CCRF is a collaborative, cross-boundary approach among scientists, managers, and landowners to incorporate climate change considerations into natural resource management

U.S. Climate Resilience Toolkit

The Toolkit provides a five-step process that communities can use to identify and assess their climate vulnerabilities. The site also provides other resources from the federal government to help communities put the process into action

SUBNATIONAL INITIATIVES

Southeast Florida Regional Climate Action Plan (RCAP)

RCAP is the Compact's guiding tool for coordinated climate action in Southeast Florida to reduce GHG emissions and build climate resilience. It provides a set of recommendations, guidelines for implementation and best practices for local entities to act in-line with the regional agenda

Climate Ready Boston - Municipal Vulnerability to Climate Change

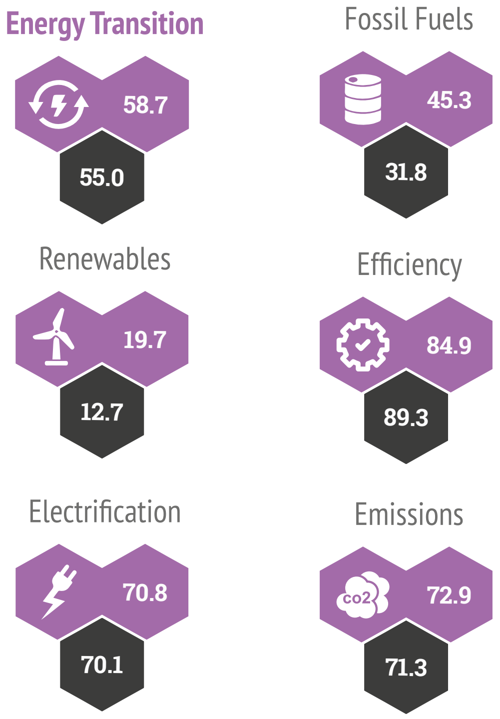
The project forecasts climate change impacts, ranging from sea level rise to extreme weather events. The report used existing research to identify potential municipal infrastructure and other city services that are exposed to climate change

ENERGY TRANSITION

The USA shows an Energy Transition index slightly below the G20 average, positioning itself in the mid-to-low section of the ranking. This is determined in particular by the still heavy contribution of fossil fuels to the USA energy sector, and more in general to its economy and industry.

The USA, is not only the world's largest oil and gas producer, but it is also by far the biggest fossil fuel consumer at a global level. This situation is reflected also on the Renewables indicator, where the country – despite the ongoing process of transformation and massive penetration of wind and solar power – still performs below the group average (though better compared to other big fossil producing countries).

On Emissions and Electrification, the USA scores are slightly below the G20 average, showing the need to continue and strengthen the process of deployment of renewables and power grids in line with its 2050 decarbonization targets. Finally, the country is placed in the mid-to-top part of the ranking when it comes to Efficiency with further improvements expected to happen.



Only actively pursuing an energy transition based on decarbonization and electrification – from policy and regulation, to health and education – will enable countries to benefit the most from future opportunities and fight climate change whilst ensuring an equitable distribution of wealth.

The Energy Transition indicators were developed by Enel Foundation in cooperation with SACE, and provide a retrospective analysis based on historical data.