G20 CLIMATE RISK ATLAS

Impacts, policy, economics

GERMANY

With the scientific contribution of Enel Foundation

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

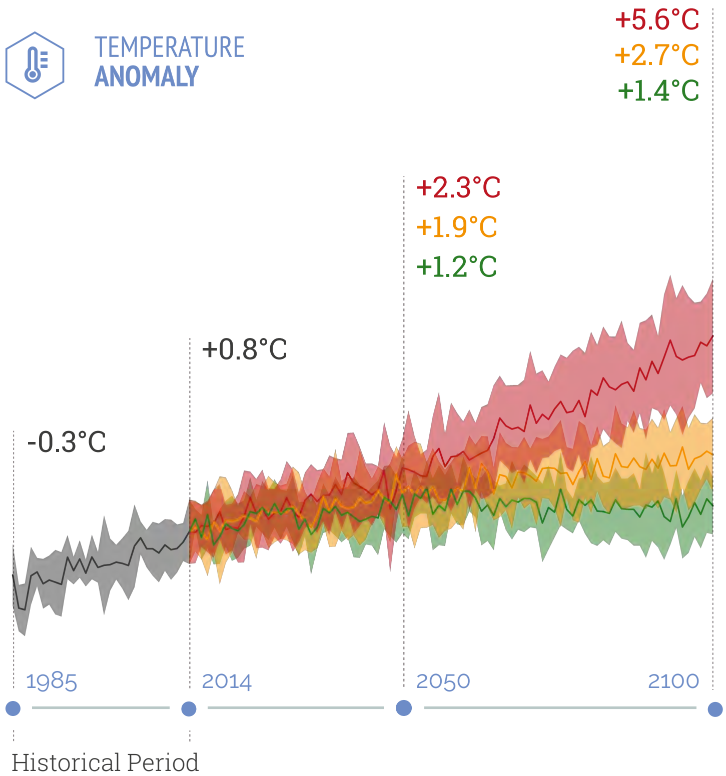
GERMANY CLIMATE

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 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.

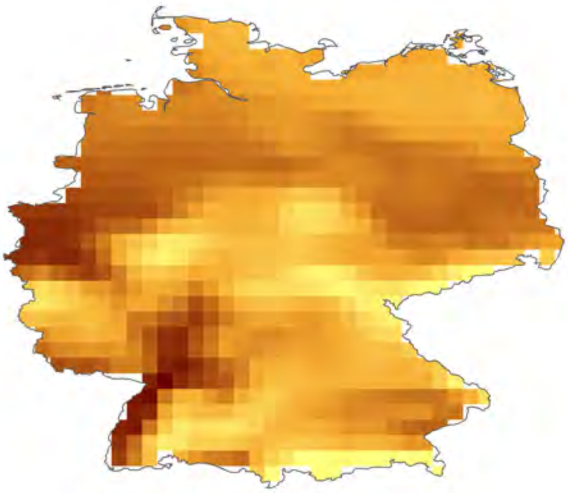


TEMPERATURE

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.

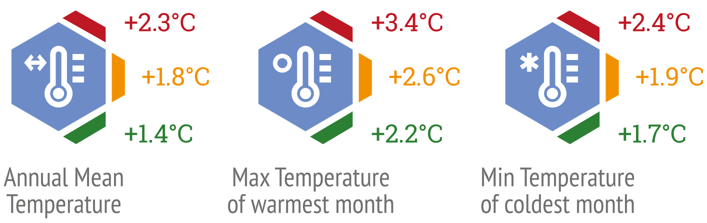
MEAN TEMPERATURE

+5 — 11
Celsius degrees / Over 1991-2020



EXPECTED VARIATION FOR TEMPERATURE AT 2050

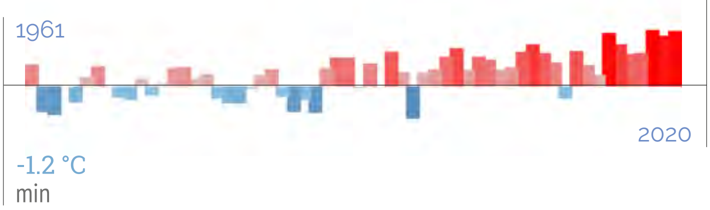
The indicators show variations in selected temperature characteristics for a thirty-year period centred on 2050 (2036-2065) with respect to the reference period 1985-2014.



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

max
2.1 °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.

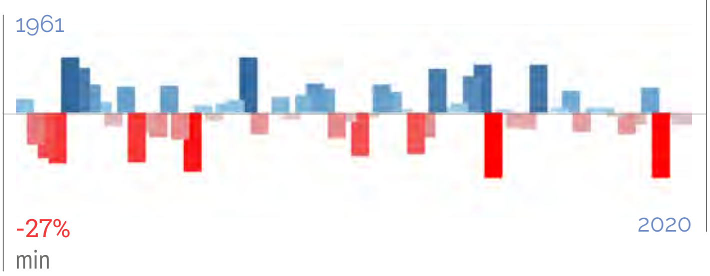
MEAN PRECIPITATION

616 — 1,977

mm/year / Over 1991-2020

PRECIPITATION TREND

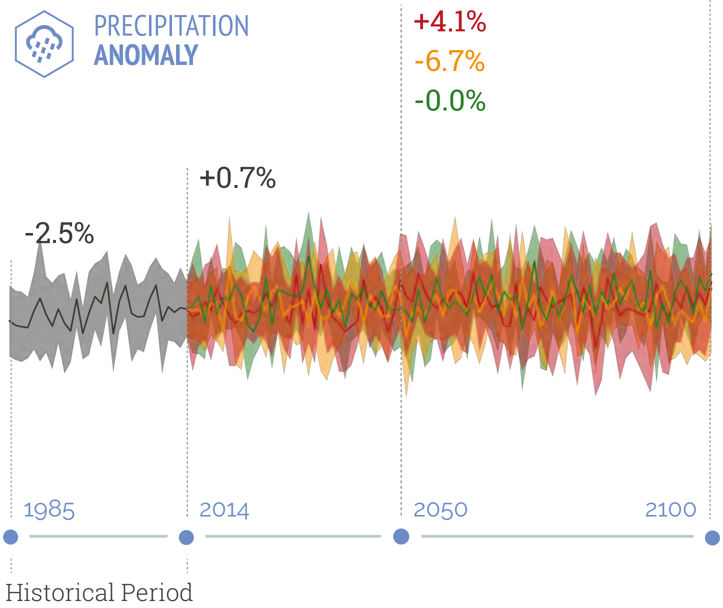
Precipiation anomalies over the last 60 years with respect to the annual mean of 839 mm/year in Germany during the 1961-1990 period



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.

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.

Indicator	+4°C	+2°C	+1.5°C
Annual total precipitation	+2.6%	+1.8%	+2.6%
Precipitation of wettest month	+4.5%	+2.5%	+4.6%
Precipitation of warmest quarter	-4.2%	-2.4%	-2.2%

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**.

Indicator	Unit	+4°C	+2°C	+1.5°C
Agricultural drought proportion of time	% of time	+35%	+19%	+14%
Hydrological drought proportion of time	% of time	+31%	+15%	+12%
Heatwave duration	% of time	+1,461%	+261%	+100%
Runoff increase	% of area	+59%	+29%	+10%
Agricultural drought frequency	% of change	+74%	+50%	+35%
Hydrological drought frequency	% of change	+17%	+12%	+14%
Heatwave frequency	% of change	+80%	+35%	+21%
Runoff decrease	% of area	+10%	+6%	+4%

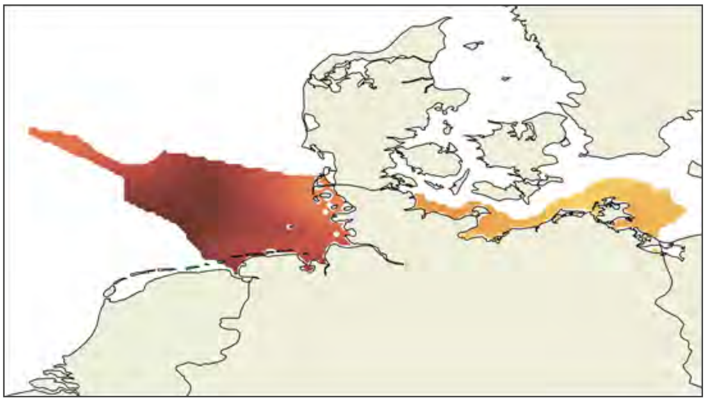
GERMANY OCEAN

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.

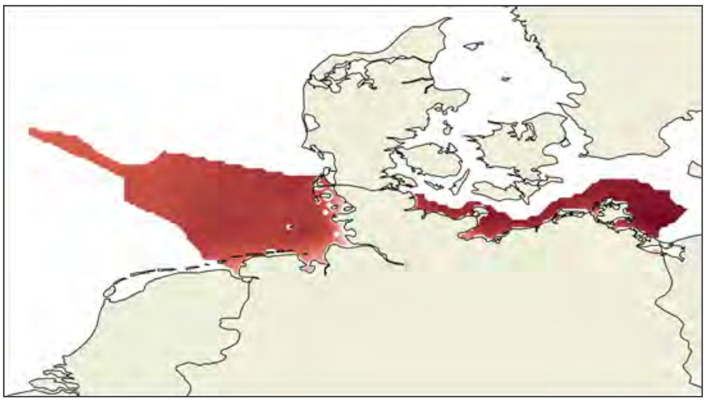


MEAN

SEA SURFACE TEMPERATURE

Celsius degrees / Over 1991-2020

TREND

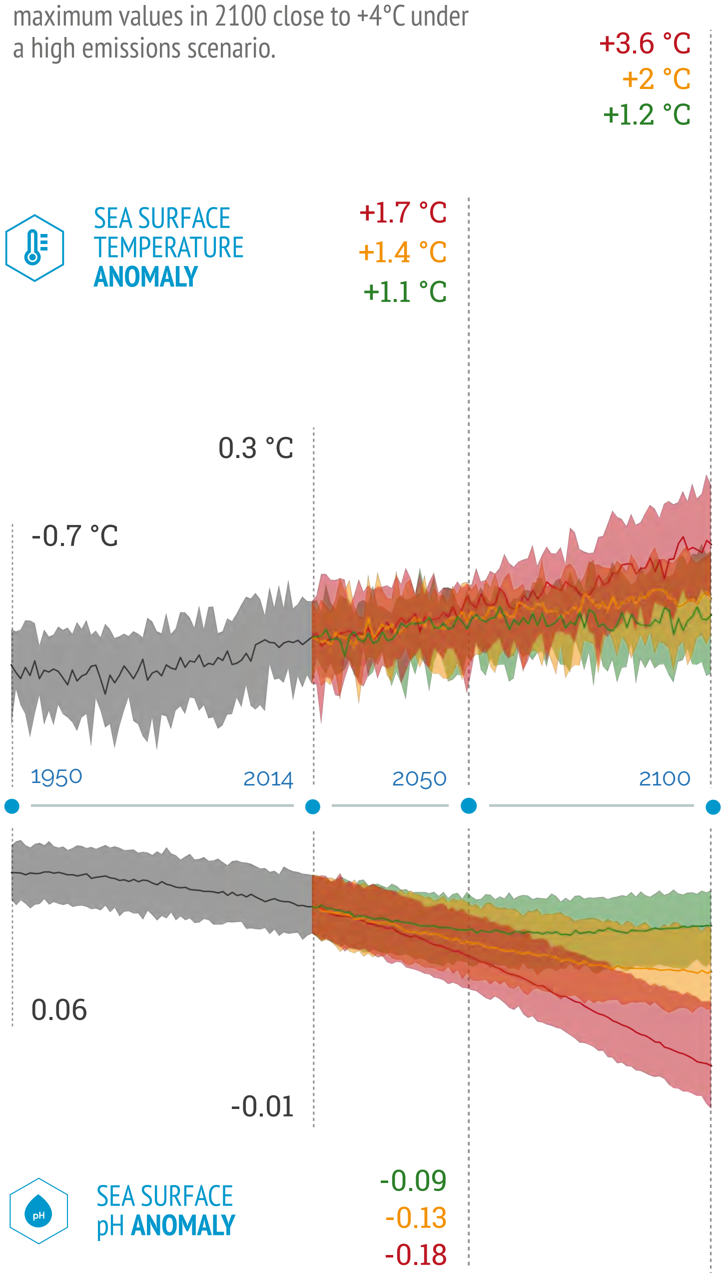


Surface temperature trends indicate a general warming of 0.3°C per decade in all marine areas, with increased gains in the Baltic region.

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.



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
-0.2
-0.43

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).

Indicator	Baltic	Baltic change	North Sea	North Sea change
Temperature regulates the metabolism of marine organisms determining which habitats remain suitable. Excessive warming will likely push ecosystems beyond tolerance thresholds.	10.34°C	+2.05 °C / +1.87 °C / +1.51 °C	10.72°C	+1.76 °C / +1.42 °C / +1.17 °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.	7.88	-0.17 / -0.12 / -0.08	8.08	-0.18 / -0.13 / -0.1
Oxygen is fundamental to sustain marine life and its reduction can have a large impact on coastal ecosystem services including fisheries and aquaculture.	335.96 mmol/m³	-5.32 % / -4 % / -3.26 %	285.29 mmol/m³	-3.34 % / -2.48 % / -1.7 %
Chlorophyll is an indicator of the biomass available at the base of the marine food web supporting all ecosystem productivity.	0.39 mg/m³	-20.31 % / -22.62 % / -27.51 %	0.36 mg/m³	-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%

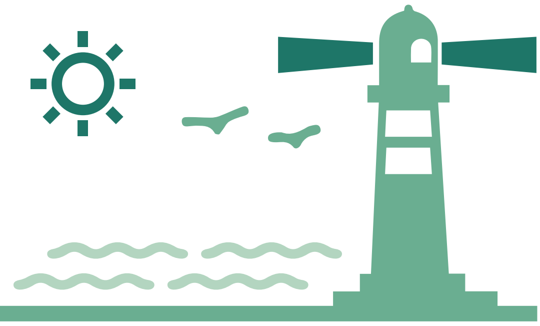
ANALYSIS DETAILS

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.

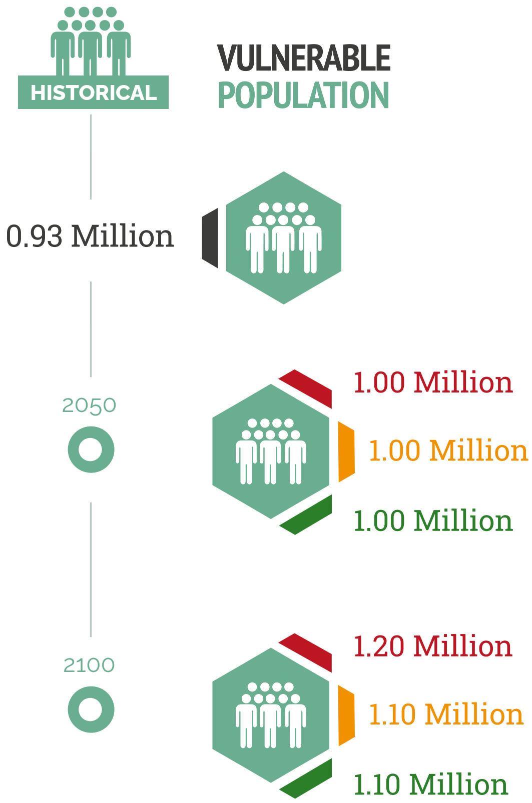
VULNERABILITY AND RISK

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.



INFLUENCE OF SEA LEVEL RISE ON EXTREME SEA LEVEL

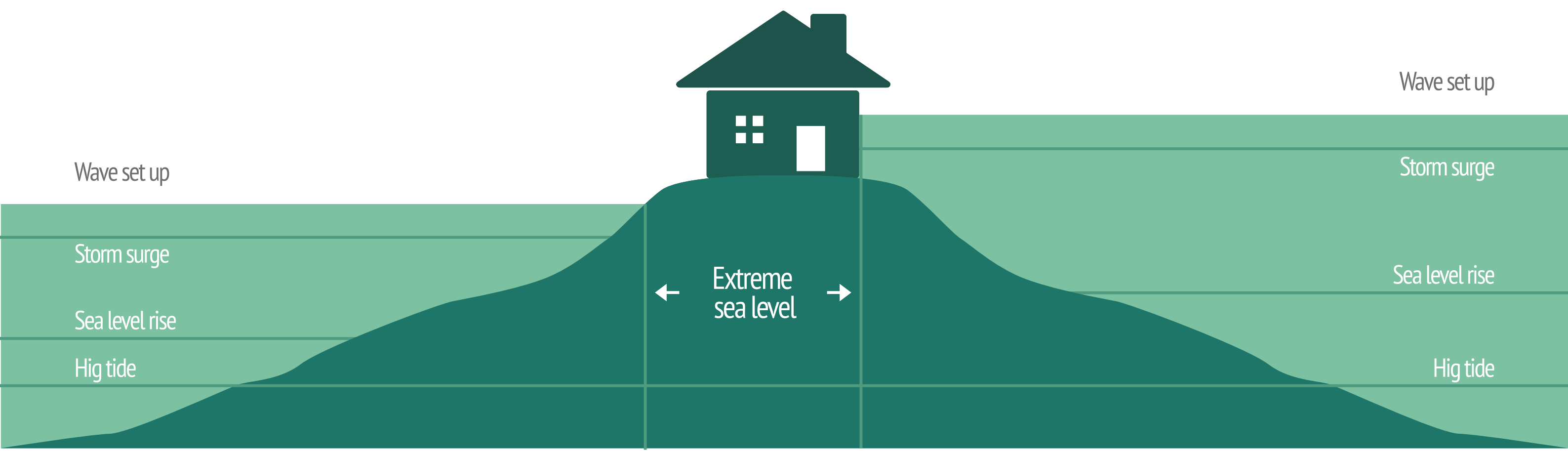
Present and future sea level rise are a consequence of carbon induced global warming causing melting ice and ocean expansion due to heat accumulation.

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.

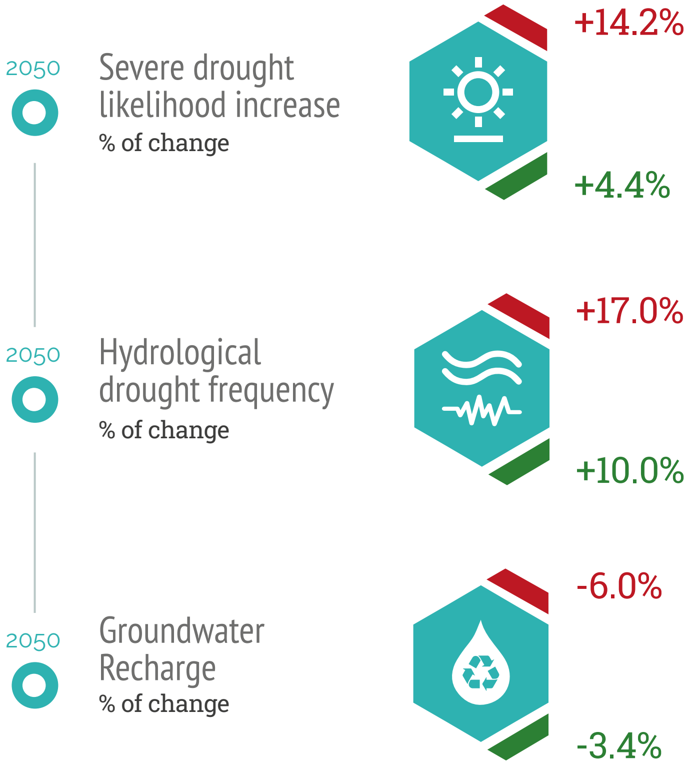
2050 — Changes in annual runoff (% of change): +25.3% / -1.8%

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.



KEY POINT GROUNDWATER

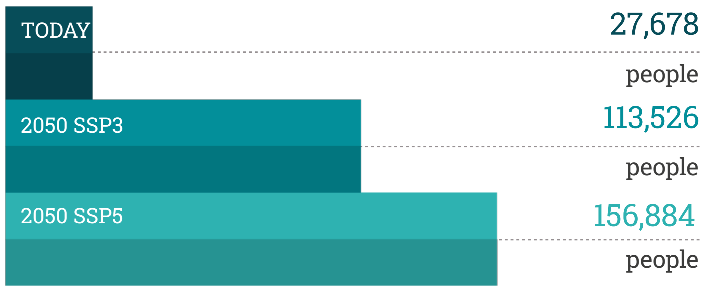
In Germany, groundwater is a vital and essential resource. It is the primary source of water supply for over two-thirds of the population. In addition, groundwater recharge in southern Germany has already decreased over the last decades, mostly because of an increase in evaporation. As such, decreasing 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

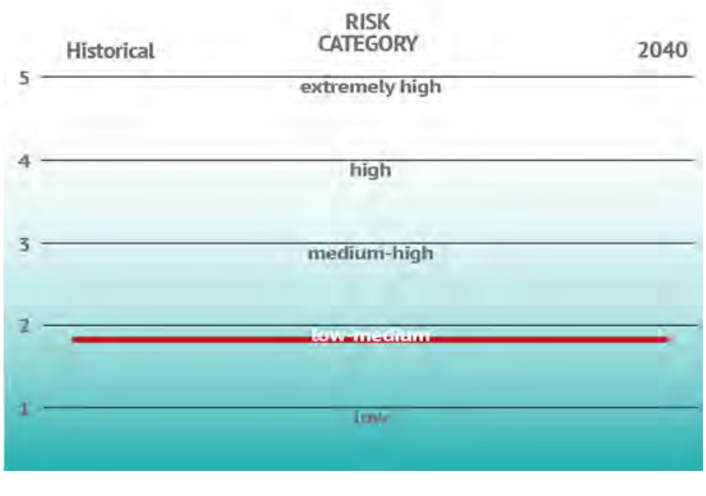


RISK INDICATORS

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

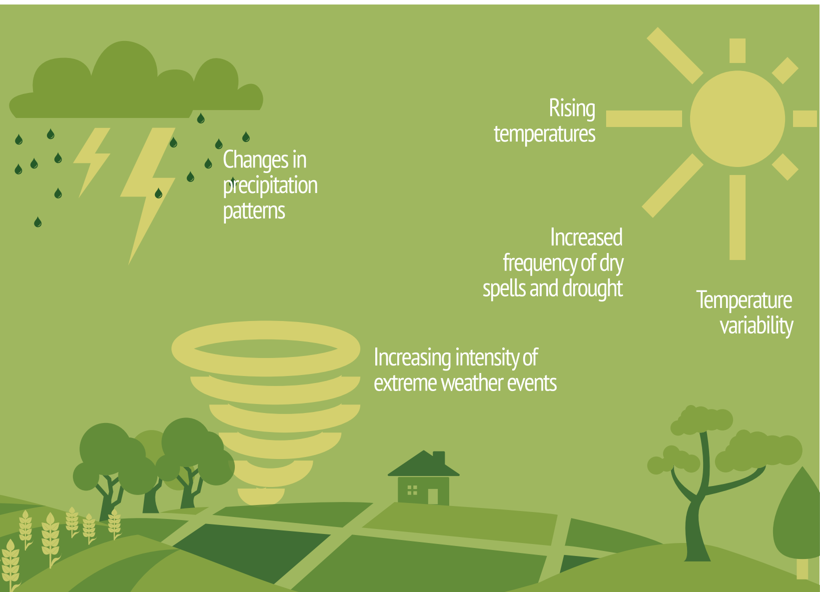
3.3 Mt Maize

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

EXPECTED 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.

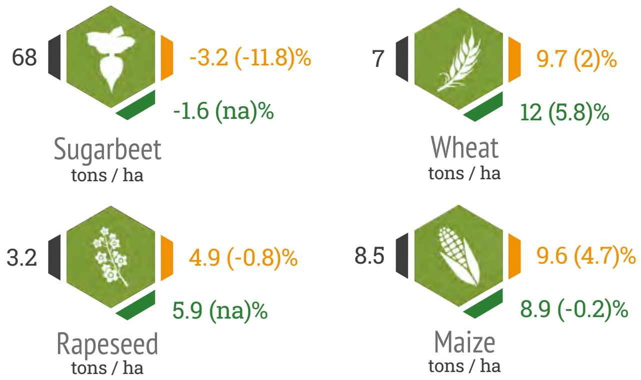


CROP PRODUCTIVITY

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.

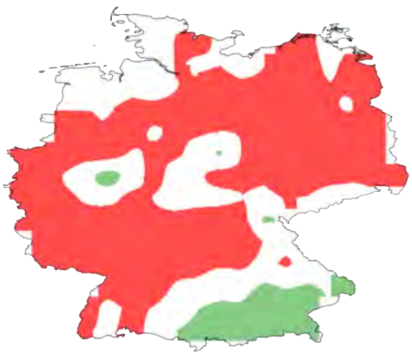


2050

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

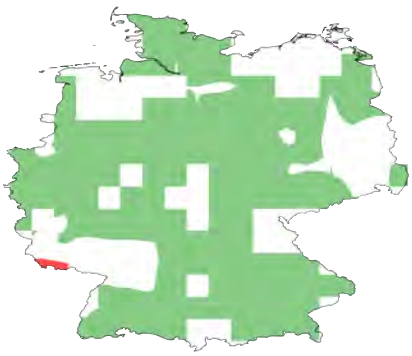
CHANGE IN SUGARBEET

− = +



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.

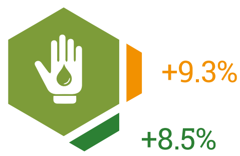
ADAPTATION IN AGRICULTURE AND WATER RESOURCES

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



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.

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

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.

2050

Productivity anomaly
Tons of Carbon per hectare per year

+0.42

+0.21

FOREST PRODUCTIVITY

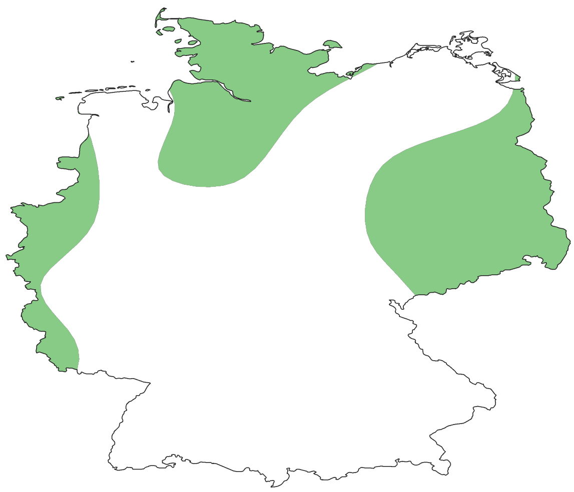
Forest productivity or Net Primary Production is the net carbon captured by plants. It is the difference between the carbon gained by Gross Primary Production - net photosynthesis measured at the ecosystem scale - and carbon released by plants' respiration. It is expressed per unit land area.

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

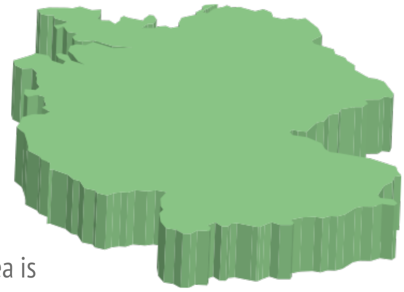
FOREST FIRE EMISSIONS CONTRIBUTED TO 30% OF TOTAL FIRE RELATED CARBON EMISSIONS

COSTING
4 MILLION USD PER YEAR IN FOREST FIRE PREVENTION AND CONTROL (2017-2019)

WHERE DO FIRES OCCUR?

Extensive pine forests on sites with poor soil and a dry climate are most at risk.

Between 2000 and 2019 Germany contributed to 0.1% of the total burned area in EU.



The most affected area is Brandenburg.

FUTURE BURNED AREA

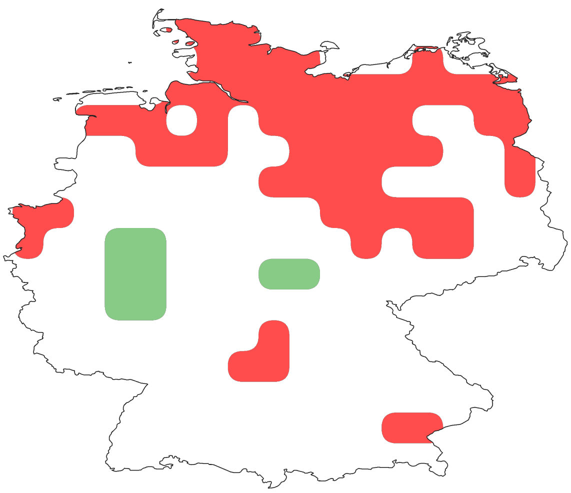
Under low and medium emissions scenarios burned area is expected to increase mainly over the Atlantic and Baltic areas but also over some eastern areas dominated by temperate mixed forests.

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

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
CO_2
+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.

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%

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.

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.

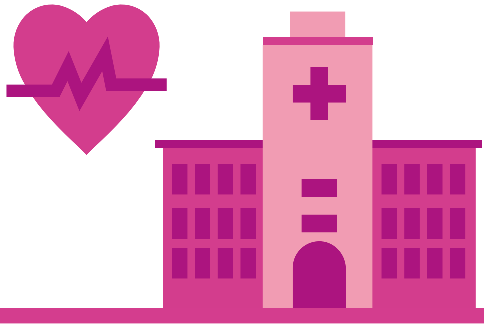
2010

% 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



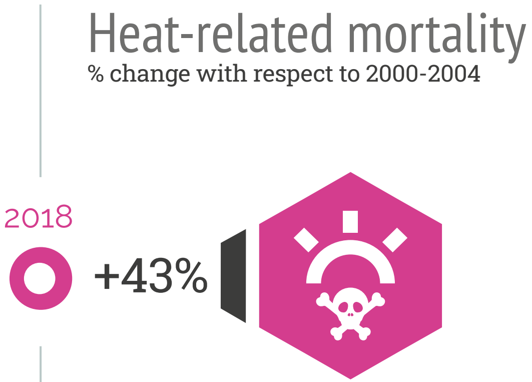
OVERVIEW

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.

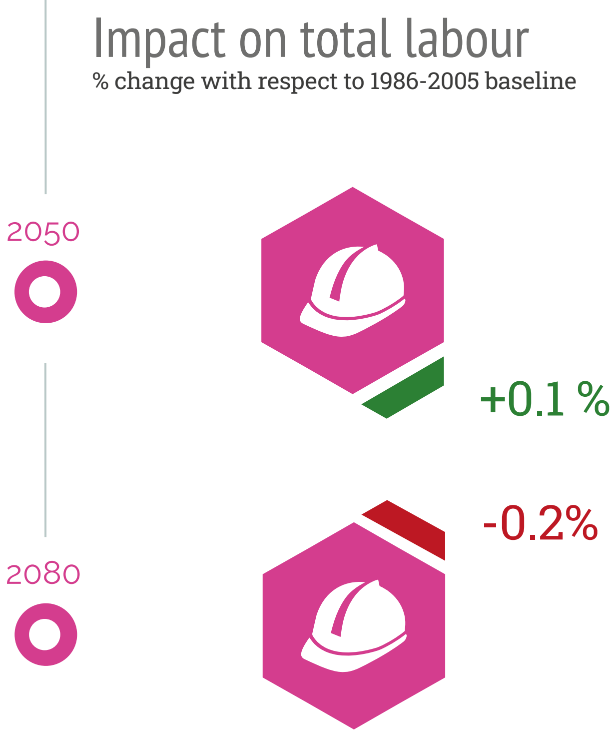


IMPACTS ON LABOUR

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.



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

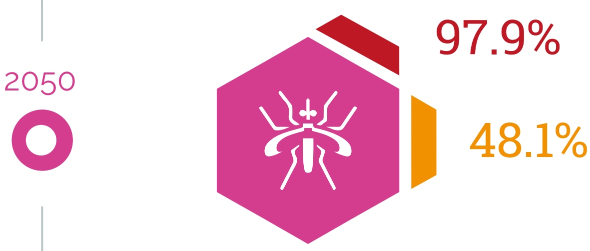
The risk of malaria is relatively low in Germany. In 2050, 2% of the German population will be at risk of malaria under a low emissions scenario, whereas 6.5% will be at risk under a high emissions scenario.

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

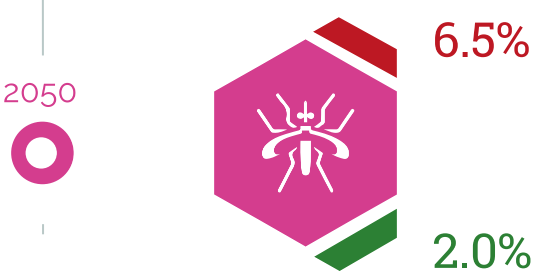


Zika suitability

% of population at risk

Malaria suitability

% of population at risk



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

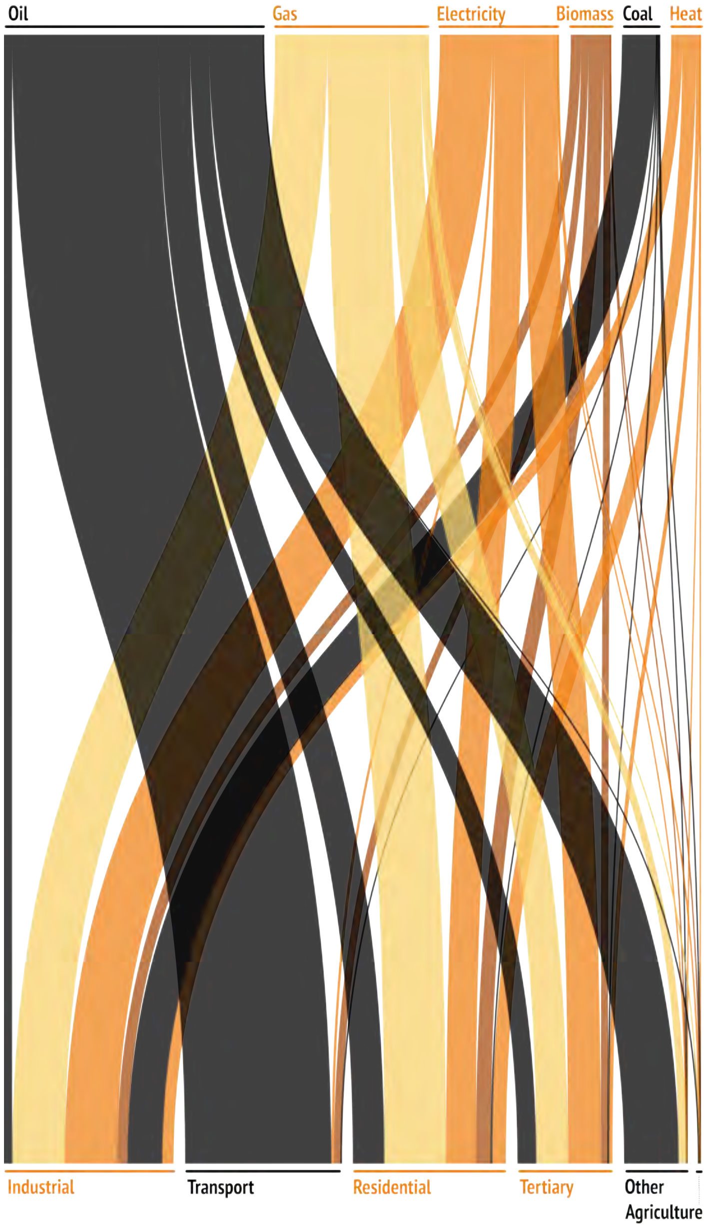
Heatwaves are becoming more and more frequent, with six short- or long-term heat extreme events recorded since 2003, with a record temperature of 42.6°C in 2019.

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

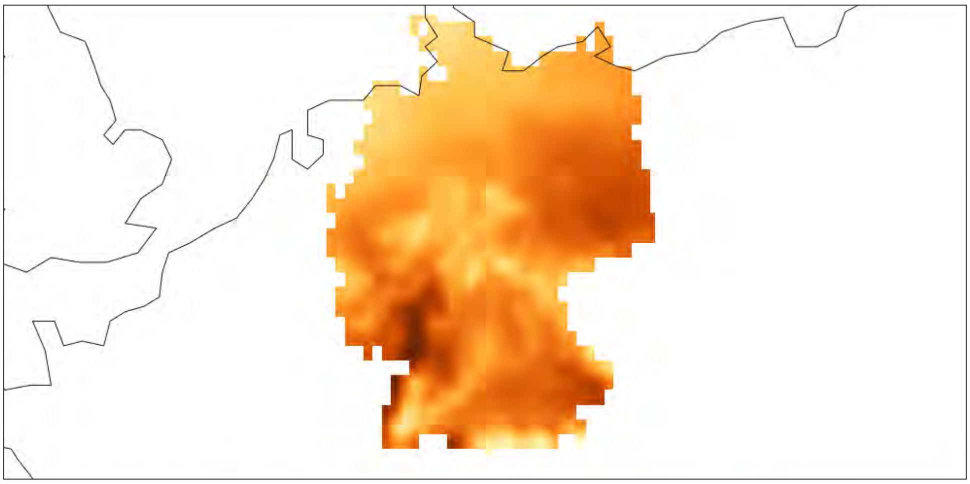
- 150.99

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

0 — 214

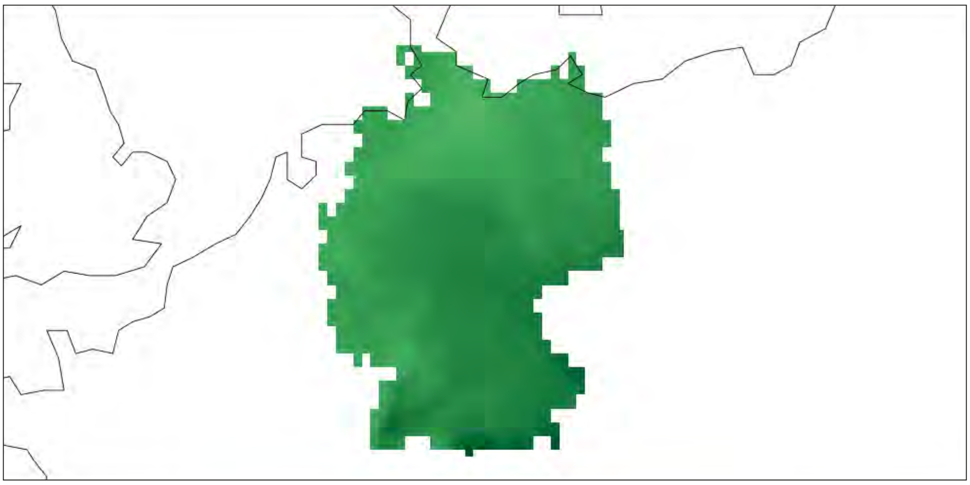


HEATING NEEDS

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

-726 — 0



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

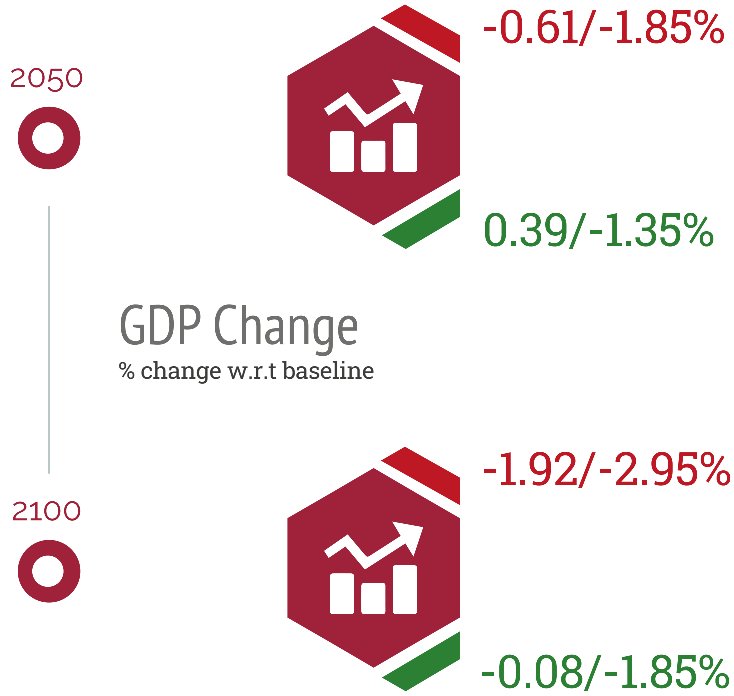
OVERVIEW

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.



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.

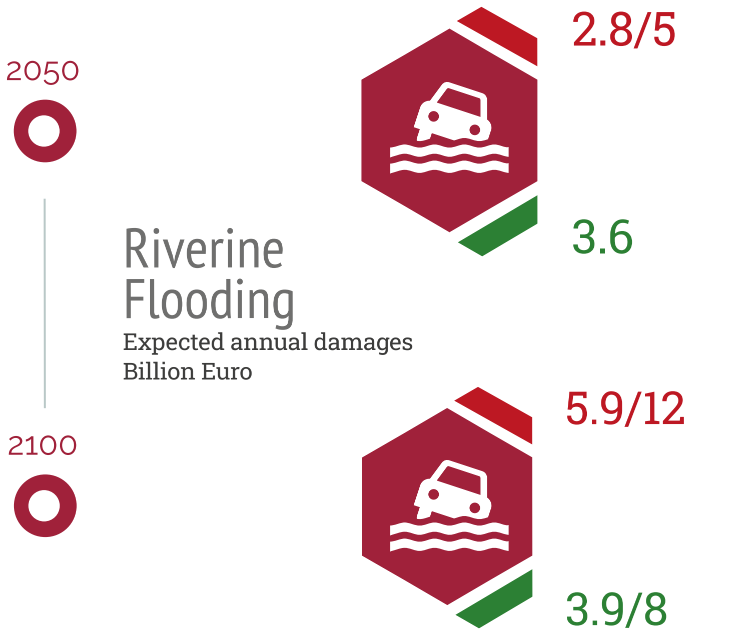
Expected annual damage to energy infrastructure is projected to show a 7-fold increase compared to present by mid century under a medium to high emissions scenario.

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

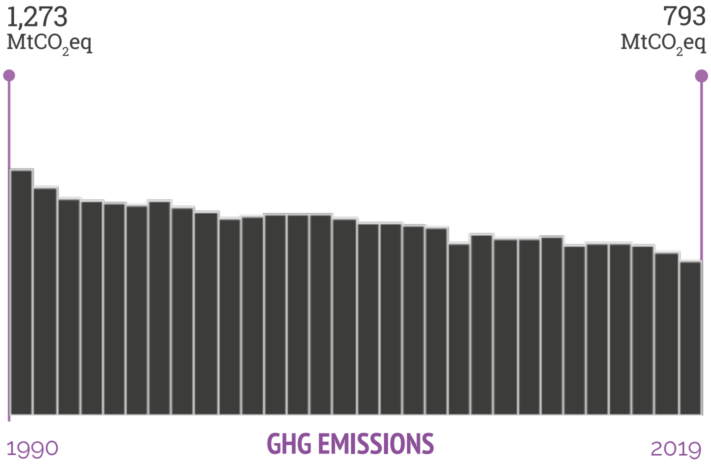
Germany is one of the "cold countries" that in moderate climate change scenarios can increase their climate and environmental attractiveness and experience increases in tourism. Some positive effects are thus expected.

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.



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**

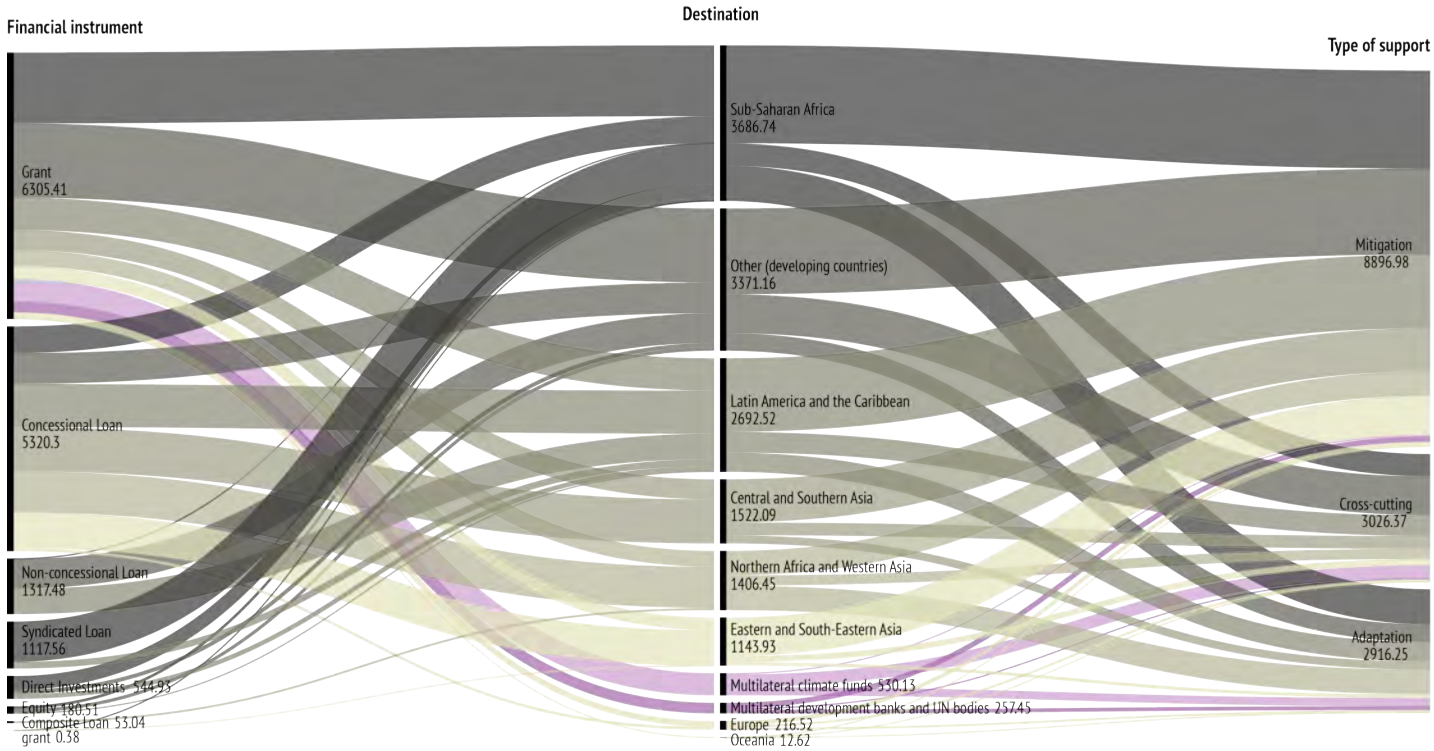
40% GHG reduction by 2030, with respect to 1990 levels

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%.

Total Spending	Recovery Spending	Green Spending
1,357.74 billion $	92.23 billion $	43.61 billion $

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).

Indicator	G20 Average	Country
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.