G20 CLIMATE RISK ATLAS

Impacts, policy, economics

cmcc

JAPAN

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

JAPAN
CLIMATE

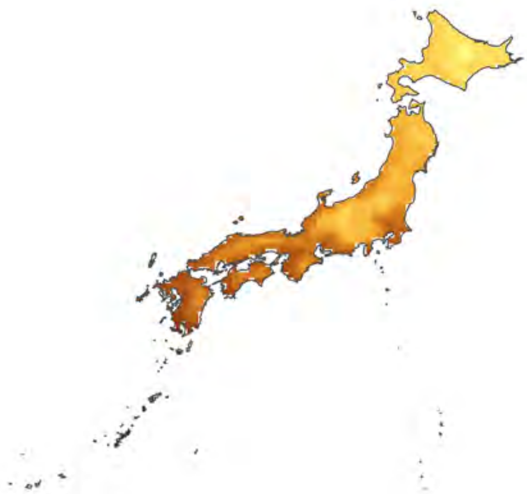
OVERVIEW

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

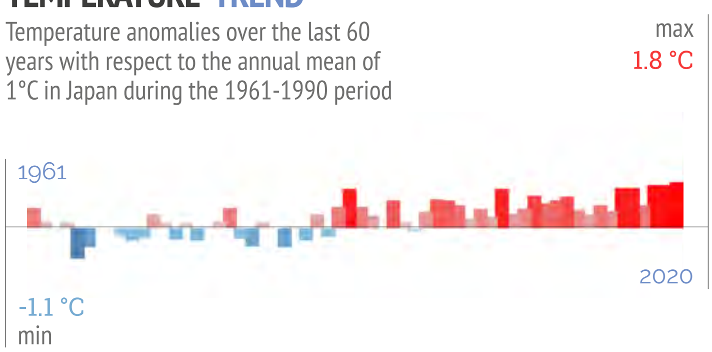
The temperature regime in Japan varies with latitude. More specifically, temperatures are lower in the north, where snow and ice dominate in winter, and rise in the central and southern areas. The south is the warmest area.

MEAN TEMPERATURE



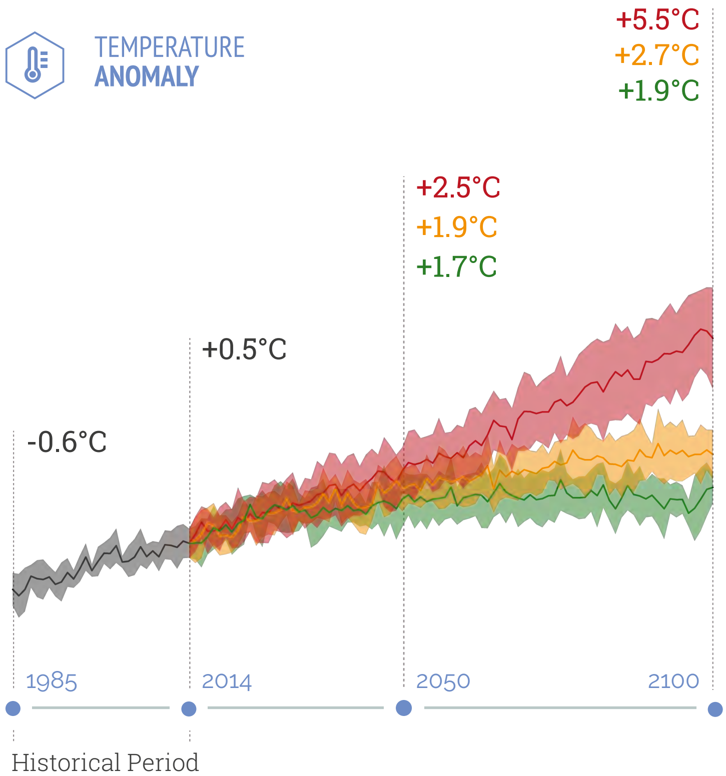
TEMPERATURE TREND

Temperature anomalies over the last 60 years with respect to the annual mean of 1°C in Japan during the 1961-1990 period



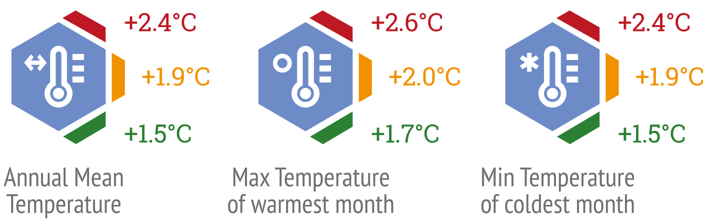
TEMPERATURE PROJECTIONS

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.



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.

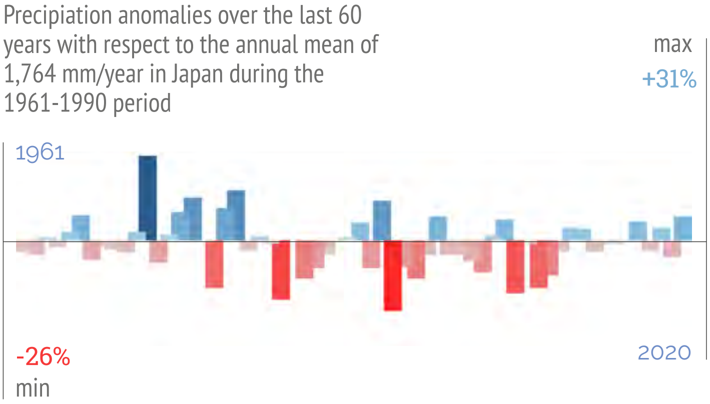
MEAN PRECIPITATION

958 — 3,092

mm/year / Over 1991-2020

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



VARIATION OF SPECIFIC CLIMATE INDICATORS

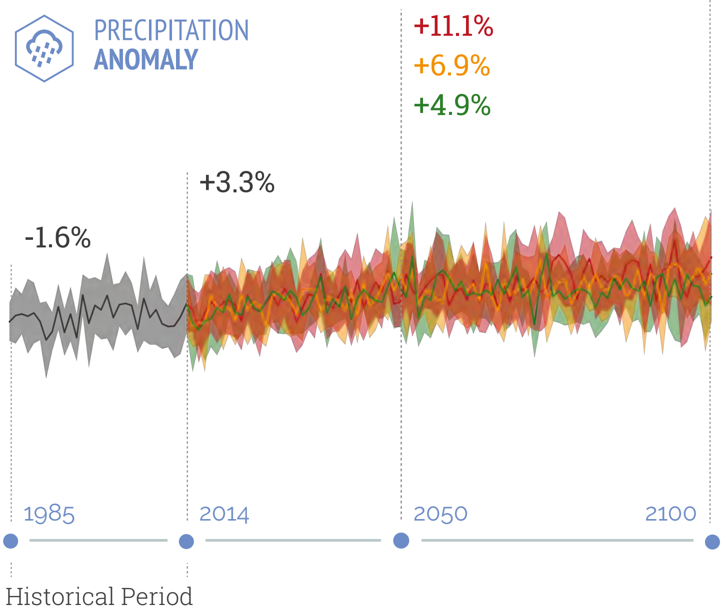
Climate indicators variation showing impacts of climate change on sectors such as agriculture, health and water. Analysis considers 3 threshold average temperature increase: **+1.5°C**, **+2°C**, **+4°C**.

Indicator	+4°C	+2°C	+1.5°C	Unit
Agricultural drought proportion of time	+22%	+12%	+10%	% of time
Hydrological drought proportion of time	+13%	+9%	+8%	% of time
Heatwave duration	+1,563%	+232%	+79%	% of time
Runoff increase	+20%	+7%	+2%	% of area
Agricultural drought frequency	+45%	+23%	+18%	% of change
Hydrological drought frequency	+9%	+8%	+10%	% of change
Heatwave frequency	+86%	+32%	+18%	% of change
Runoff decrease	+28%	+10%	+5%	% 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.

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	+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%

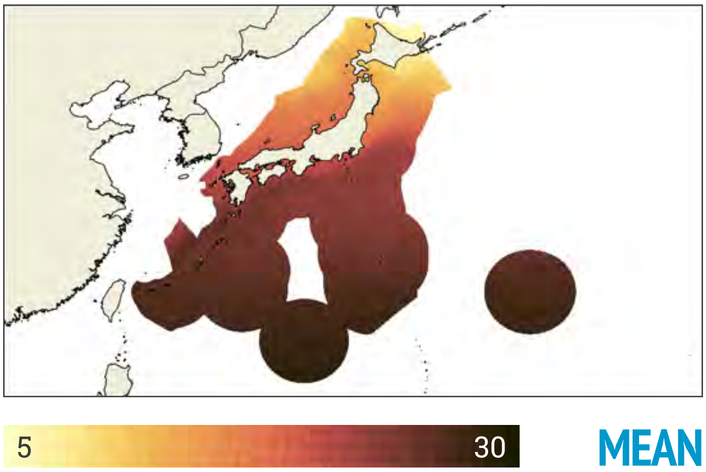
JAPAN OCEAN

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.

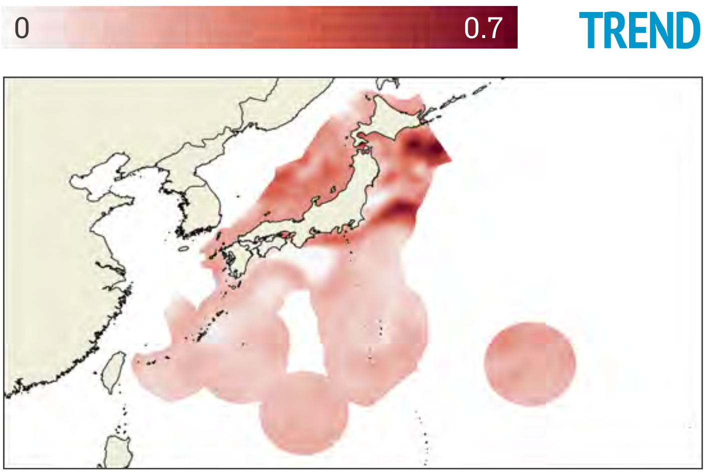


MEAN

SEA SURFACE TEMPERATURE

Celsius degrees / Over 1991-2020

TREND

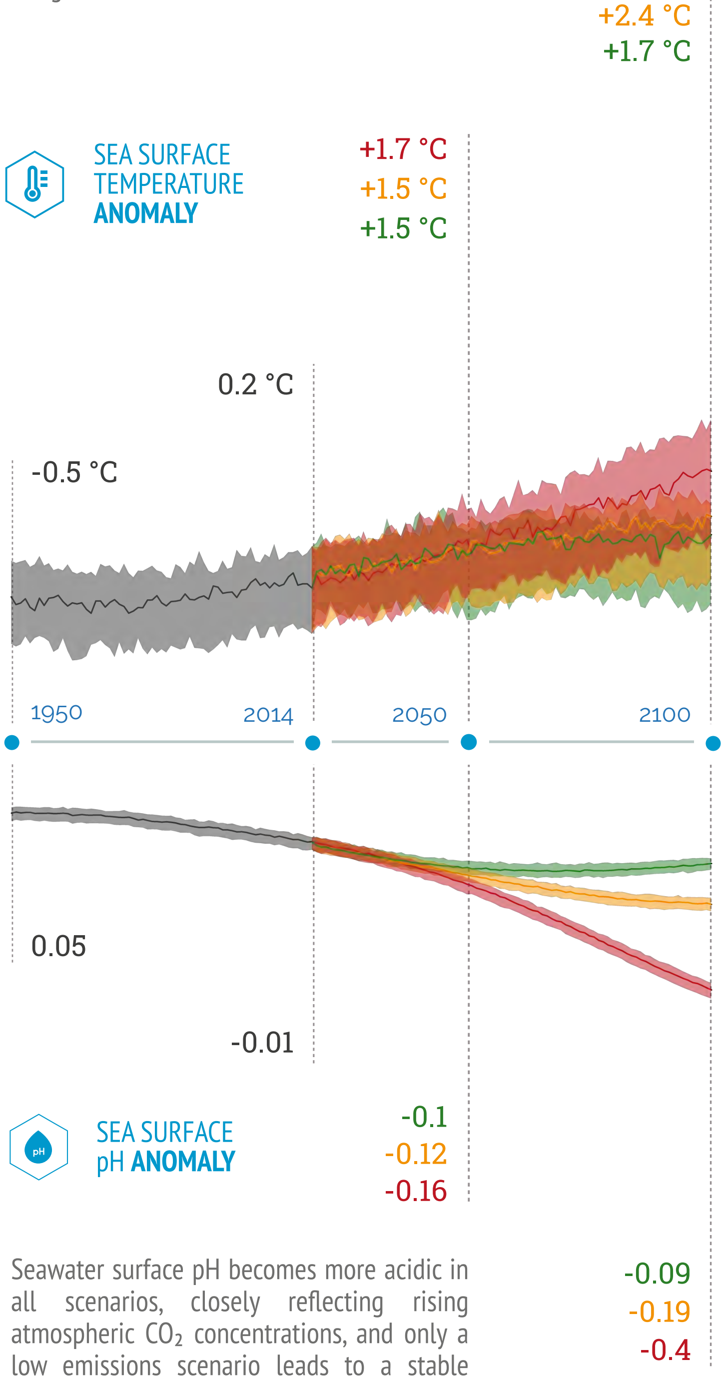


Surface temperature trends indicate a general warming of 0.2°C per decade in all marine areas, with increased gains in the northern areas.

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.	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 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 -0.1	8.14 -0.18 -0.13 -0.11	8.1 -0.16 -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.	212.78 mmol/m³ -2.35 % -1.56 % -2 %	257.58 mmol/m³ -3.59 % -2.94 % -2.89 %	224.18 mmol/m³ -2.72 % -2 % -2.78 %
Chlorophyll is an indicator of the biomass available at the base of the marine food web supporting all ecosystem productivity.	0.17 mg/m³ -22.35 % -18.82 % -17.65 %	0.35 mg/m³ -10.06 % -14.66 % -24.14 %	0.24 mg/m³ -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

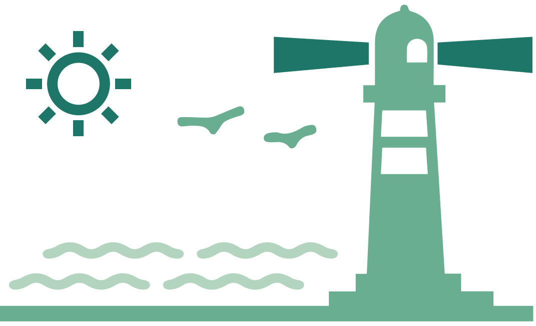
All datasets were analysed using only data from within the marine EEZ and therefore excluding overseas territories, detached islands and any disputed or joint territories with other nations. In the assessment of current climate conditions, seawater surface tempereture data was obtained using satellite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

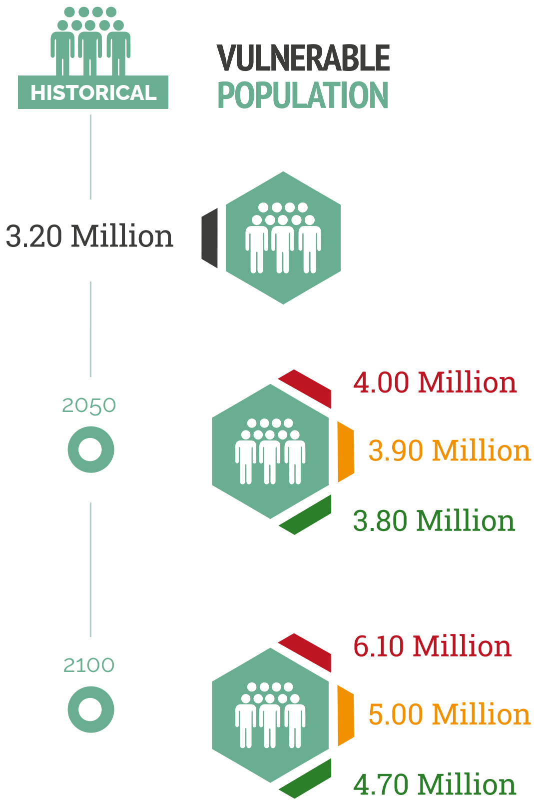
Climate change is expected to influence the wave climate of the coast of Japan. Different scenario projections of changes in wave height, period and direction for this century seem to agree on a reduction in wave energy. However, this may be offset by the impact of stronger typhoons fuelled by higher 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.



INFLUENCE OF SEA LEVEL RISE ON EXTREME SEA LEVEL

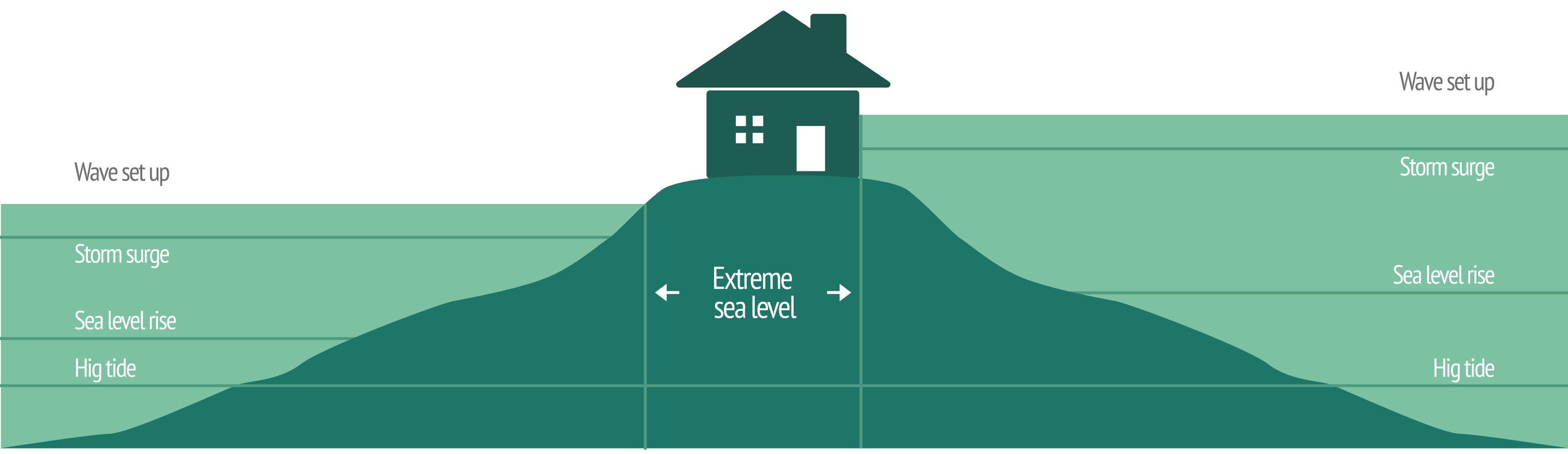
Present and future sea level rise are a consequence of carbon induced global warming causing melting ice and ocean expansion due to heat accumulation.

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

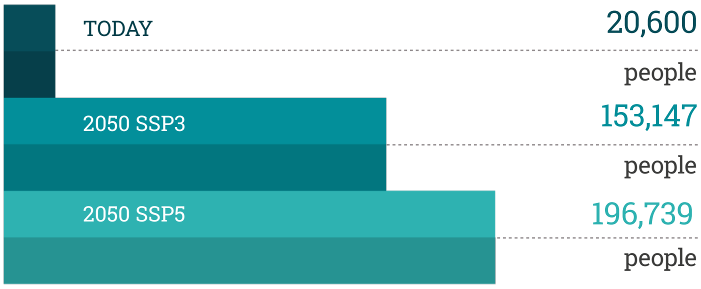
In Japan, groundwater represents approximately 13% (10.4 billion cubic metres) of the total water use (83.5 billion cubic metres), and it has been a traditional source of water supply for a long period of time. After the country entered a rapid phase of industrialization and urbanization, there was an 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

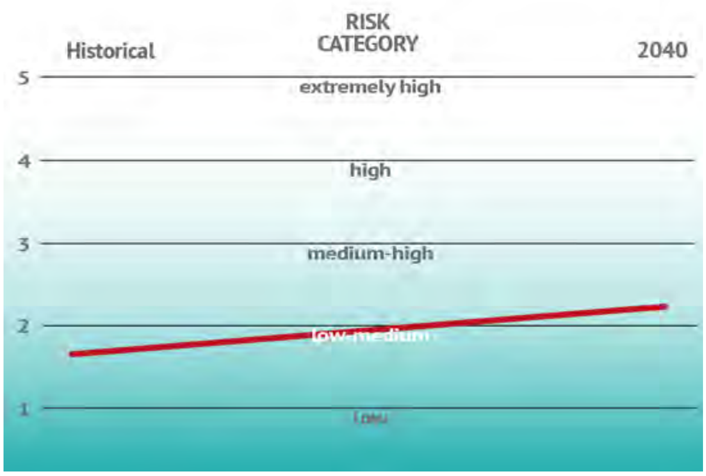


RISK INDICATORS

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

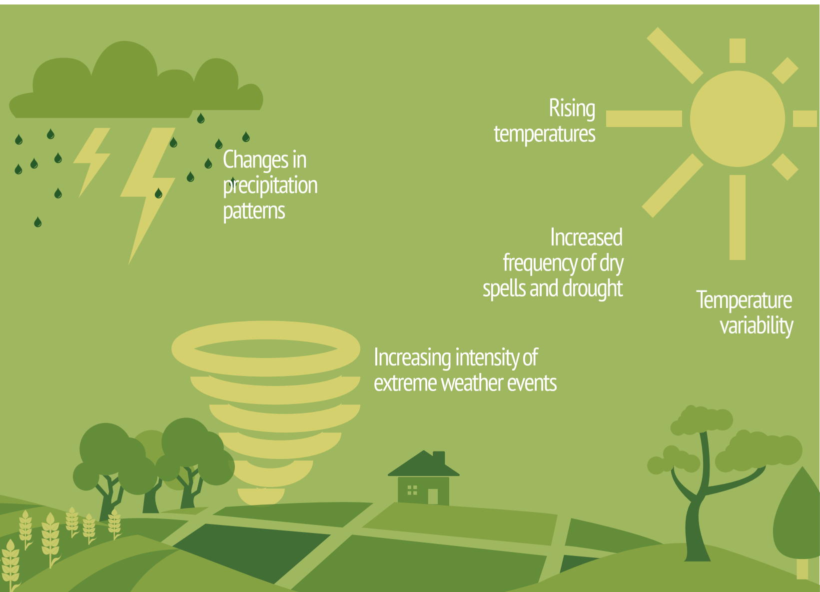
0.8 Mt
Wheat

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

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.

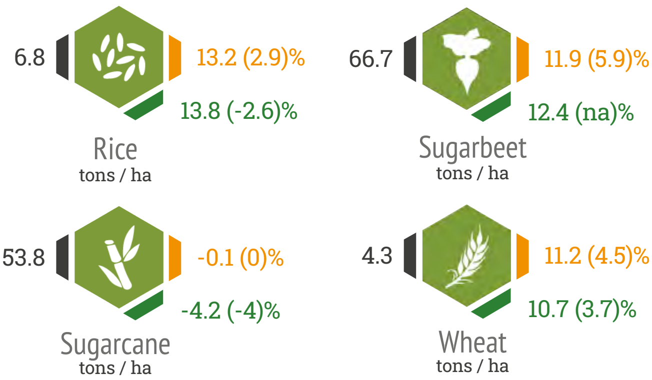


CROP PRODUCTIVITY

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.

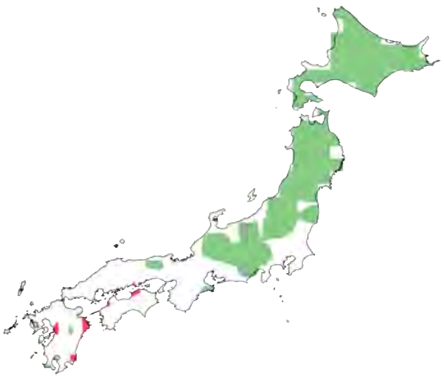


2050

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.

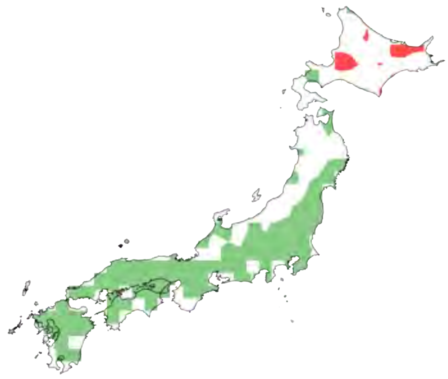
CHANGE IN RICE

− = +



CHANGE IN WHEAT

− = +



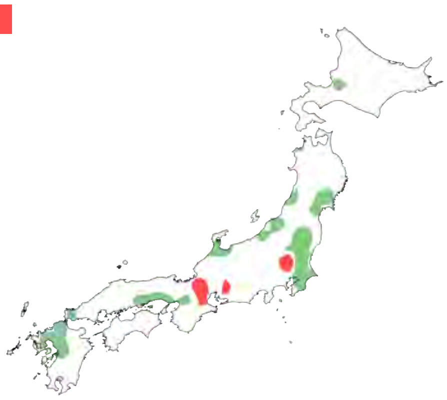
On average, rice productivity may increase, particularly in central and northern areas. However, a decline is expected for extremely warm years due to heat stress. High temperatures could be detrimental to rice yield with increasing levels of immature and cracked grains. Sugarcane may suffer a strong 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

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

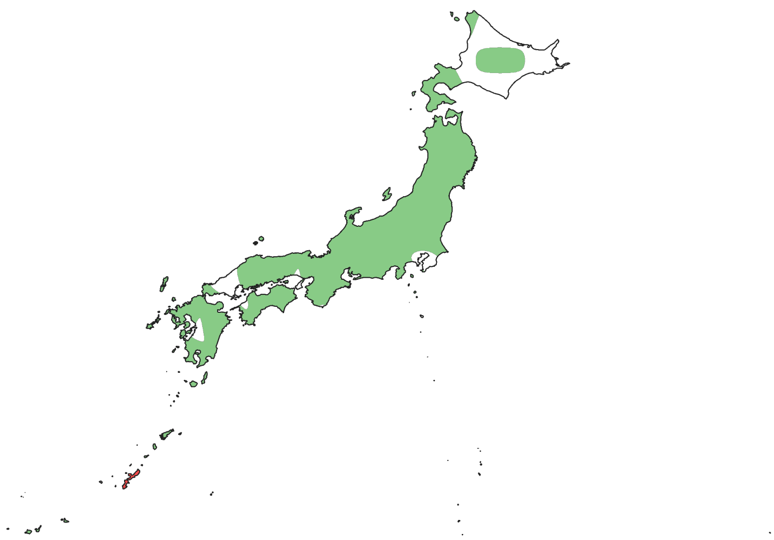
+0.42

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.

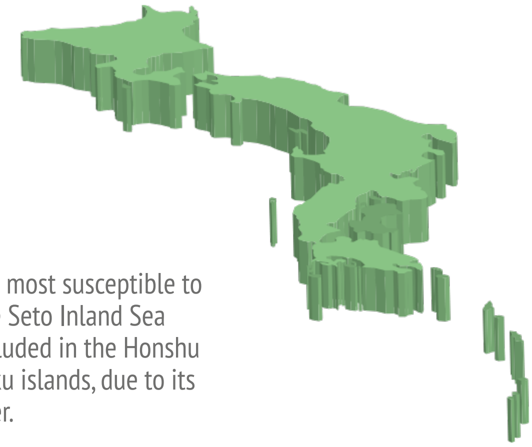
BURNING
19 THOUSAND HECTARES OF FOREST

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.

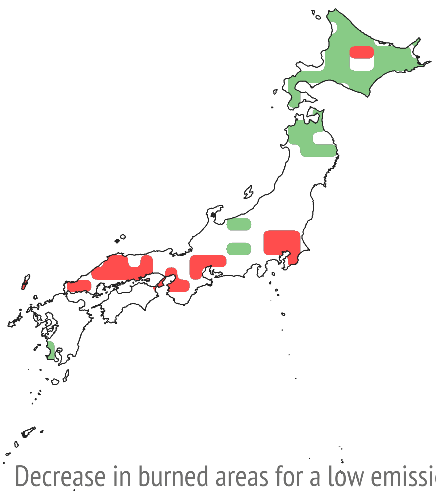


The region most susceptible to fire are the Seto Inland Sea region, included in the Honshu and Shikoku islands, due to its dry weather.

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.

Burned Area
km² per year




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.

Fire Carbon emission
Teragrams of Carbon per year

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.

Projected sea level rise

2050

0.23 m

0.18 m

2100

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

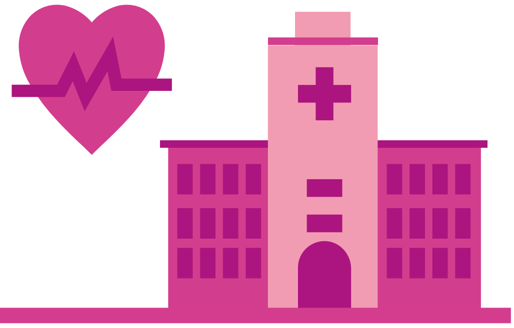
% of total population

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.

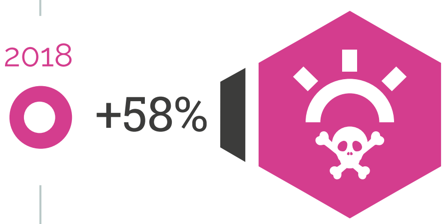
HEAT RELATED MORTALITY

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

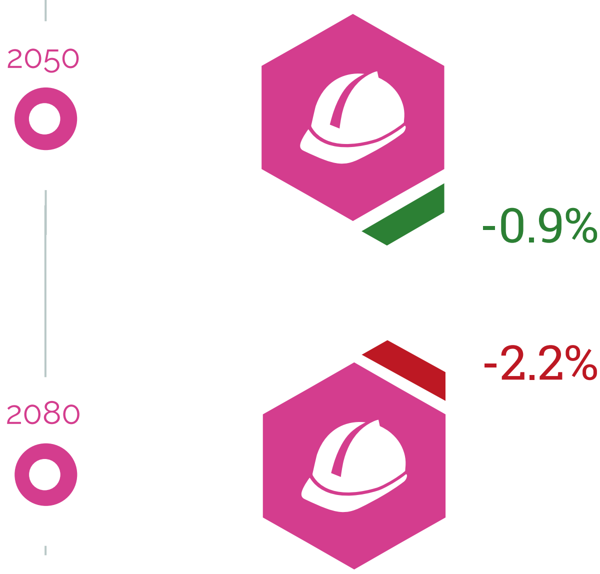
Labour is directly affected by changes in environmental conditions. Warming affects both the number of hours worked (labour supply) and on the productivity of workers during their working hours (labour productivity). Both labour supply and productivity are projected to decrease under future climate change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

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

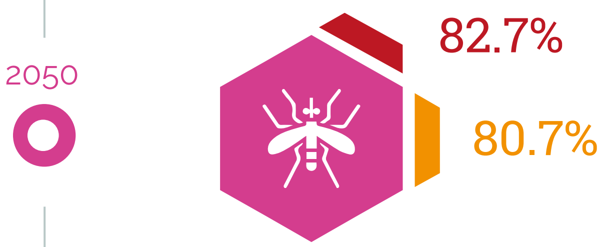
The 2014 dengue outbreak in Japan may indicate that environmental conditions are becoming favourable.

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.

Zika suitability

% of population at risk

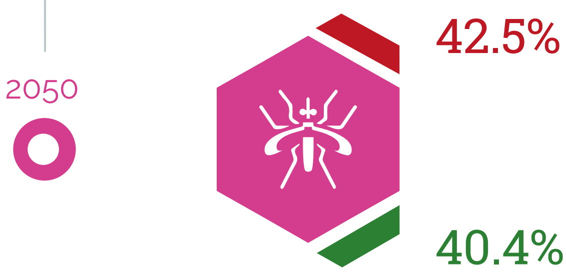


CLIMATE CHANGE AND MALARIA

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.

Malaria suitability

% of population at risk



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.

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

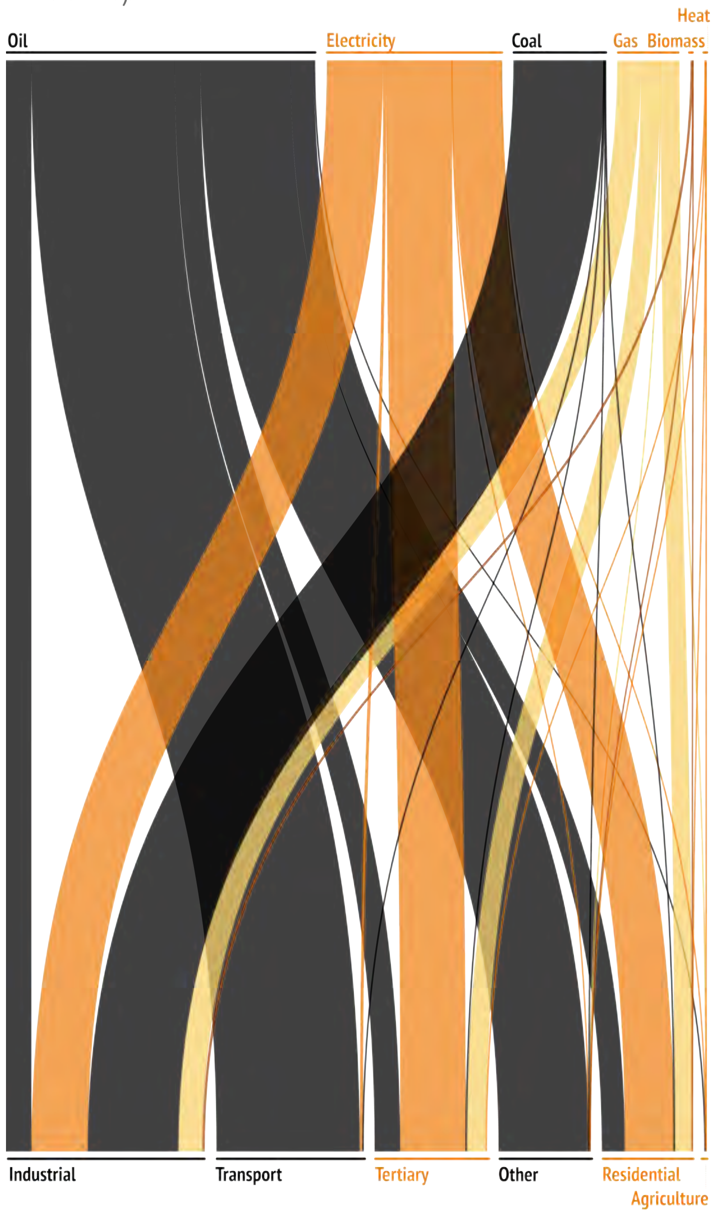
Cooling needs are increasing, following the faster-than-global-average increase in temperatures and the increase in heatwave frequency.

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

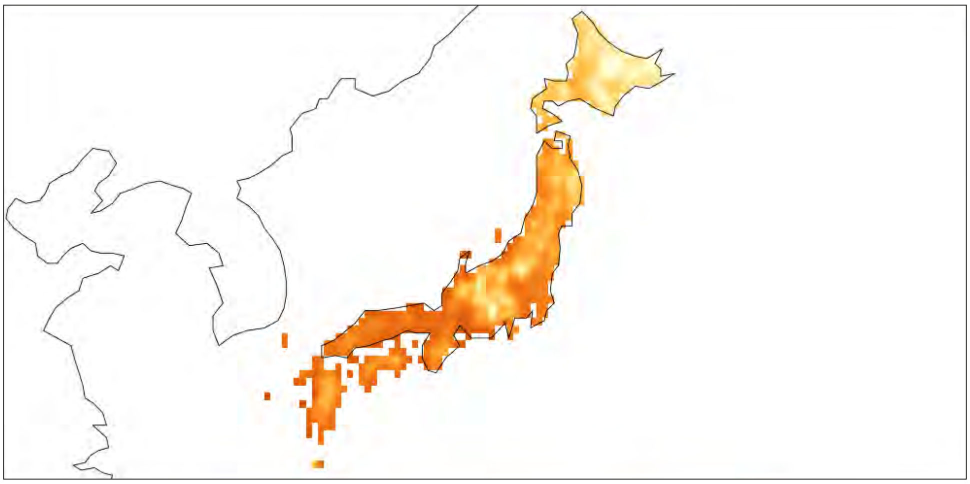
+ 749.68

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

0 400

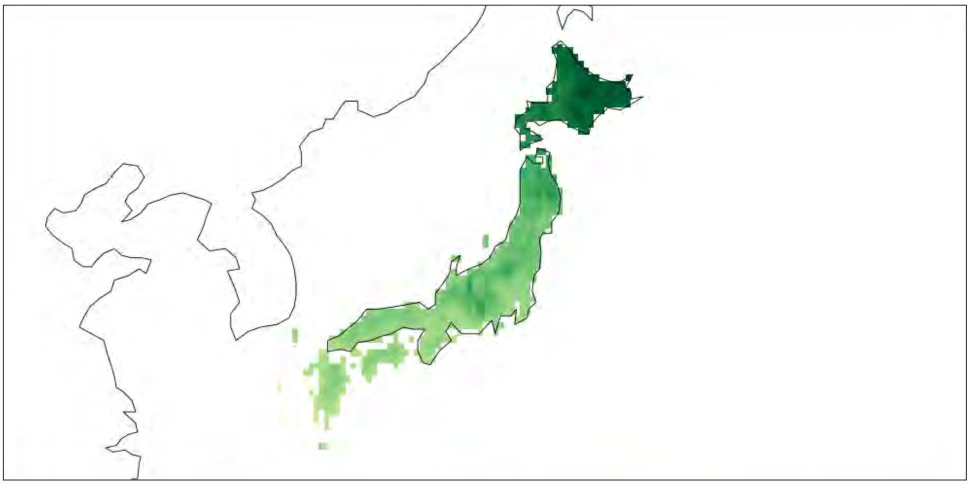


HEATING NEEDS

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

-757 0



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.

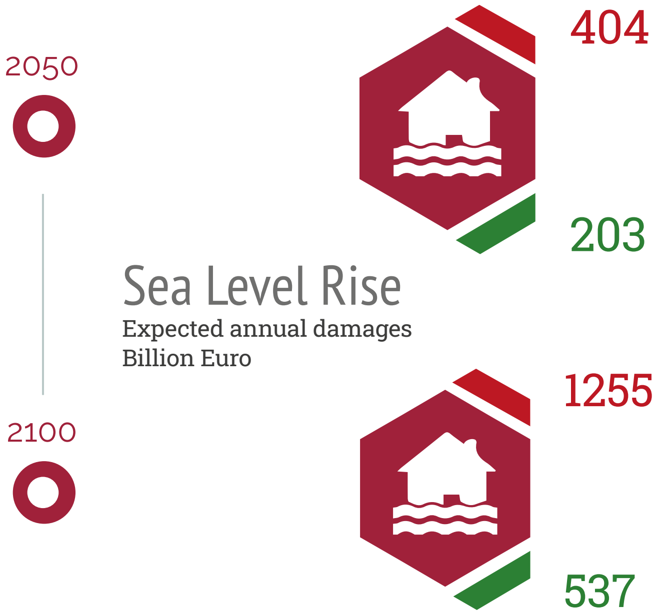
IMPACTS ON FORESTRY AND FISHERY

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

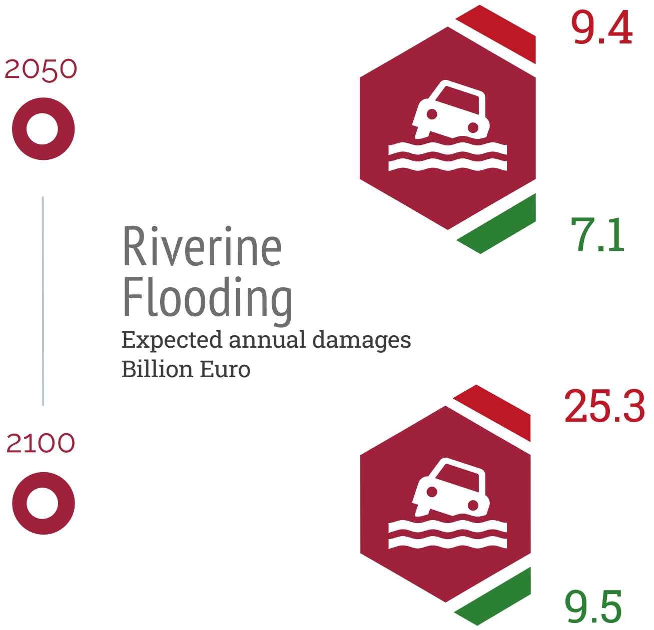
The economic losses induced by projected sea level rise in Japan are massive. Assuming constant levels of coastal protection, in the low emissions scenario asset losses could reach 203 and 537 billion EUR in 2050 and 2070, respectively.

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

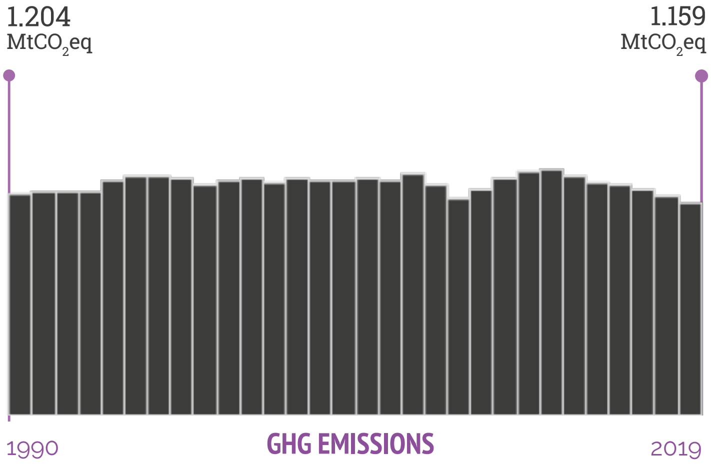
As with all other economic sectors, energy supply and energy networks in Japan will undergo more intense stress from extreme weather events.

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.



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

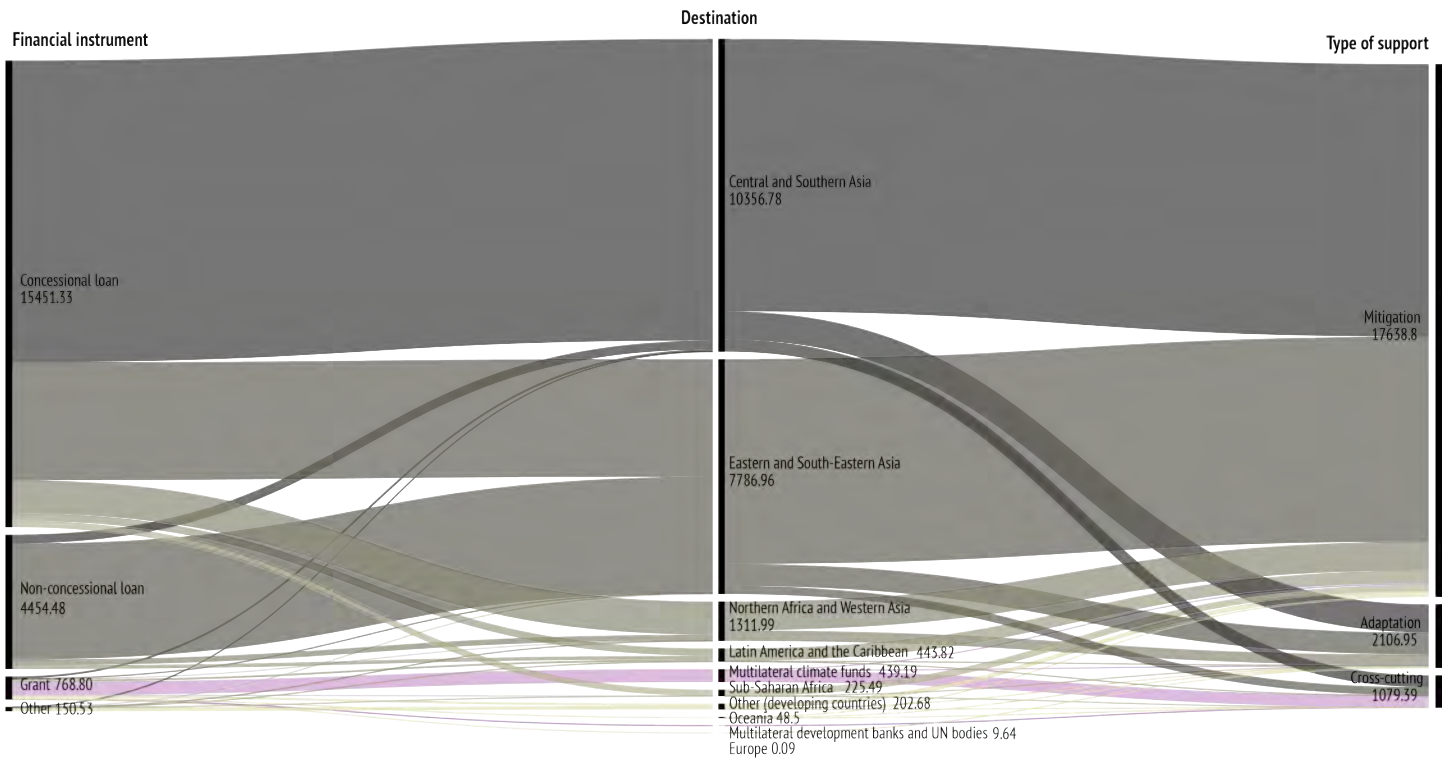
2002 — **Kyoto Protocol - 1st period**
6% yearly average reduction in GHG over the four year period 2008-2012, with respect to 1990 levels

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%.

Total Spending	Recovery Spending	Green Spending
1,311.95 billion $	304.48 billion $	80.82 billion $

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.

Indicator	G20 Average	Country
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.