G20 CLIMATE RISK ATLAS

Impacts, policy, economics

cmcc

SOUTH KOREA

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

SOUTH KOREA CLIMATE

OVERVIEW

The climate in South Korea is temperate with generally long and cold winter seasons and very short, hot, and humid summers. It is mainly regulated by the East Asian Monsoon system. Other factors affecting Korea's climate are the orography, latitude and ocean currents. Due to its southern and seagirt location, Jeju Island has warmer and milder weather than other parts of South Korea.

TEMPERATURE

South Korea experiences average annual temperatures of 12°C. The southern part exhibits generally higher temperature especially over the isle of Jeju in the south, whereas the coldest area is in the north-eastern part overlooking the Sea of Japan.

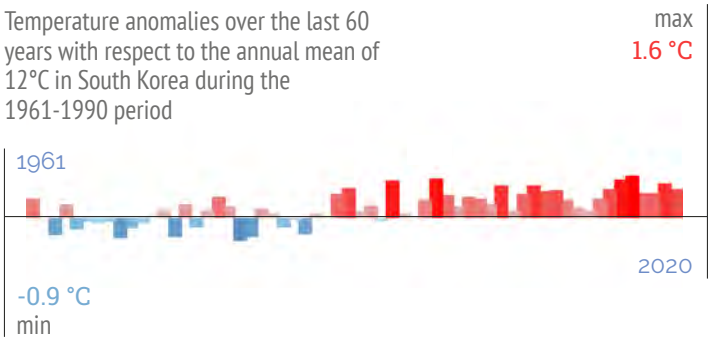
MEAN TEMPERATURE

+9 — 16

Celsius degrees / Over 1991-2020

TEMPERATURE TREND

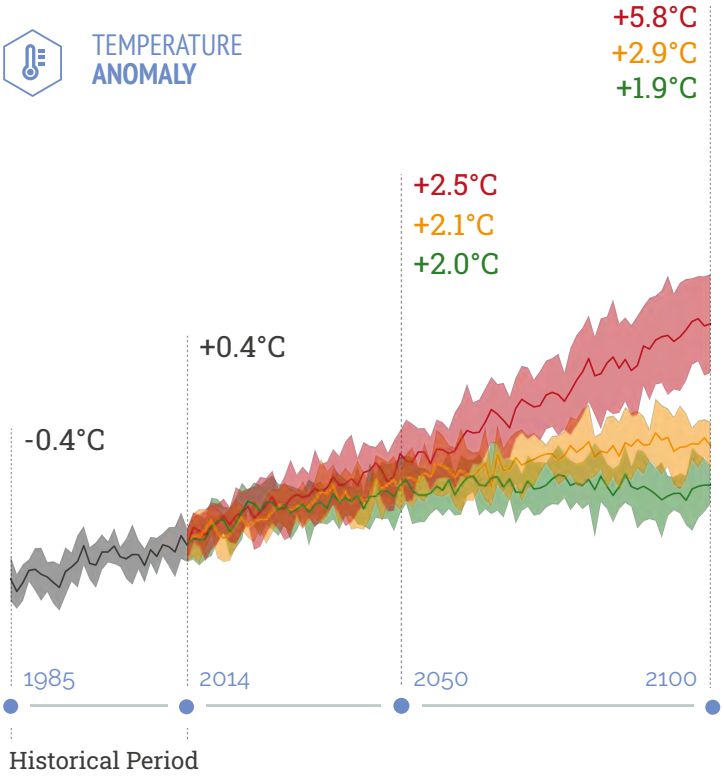
Temperature anomalies over the last 60 years with respect to the annual mean of 12°C in South Korea during the 1961-1990 period



TEMPERATURE PROJECTIONS

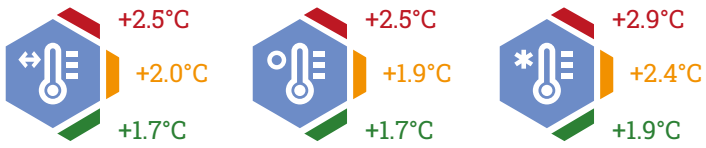
Under a low emissions scenario projected temperature variations will remain contained under 2°C, both by 2050 and 2100.
Under a high emissions scenario, with no reduction in GHG emissions, much greater temperature anomalies are expected by both 2050 and 2100.

TEMPERATURE ANOMALY



EXPECTED VARIATION FOR TEMPERATURE AT 2050

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



PRECIPITATION

Precipitation over South Korea is affected by the Asian monsoon and characterized by winters with low intensity precipitation and summers with intense precipitations during the monsoon season. During the summer and the first part of the fall season, South Korea also experiences typhoons.
Annual precipitation is higher on the southern coast whereas the northernmost inland regions see the least amount of rain.

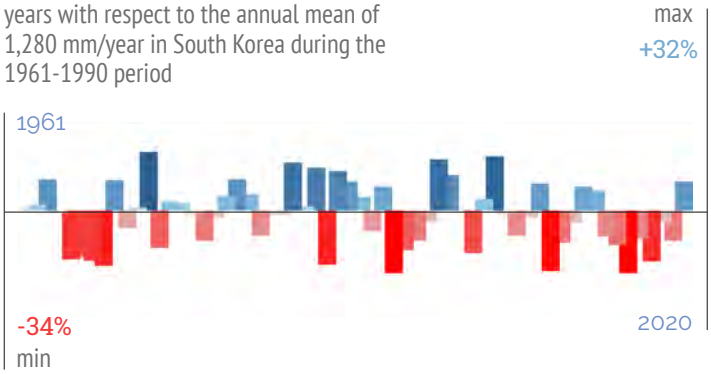
MEAN PRECIPITATION

1,028 — 1,601

mm/year / Over 1991-2020

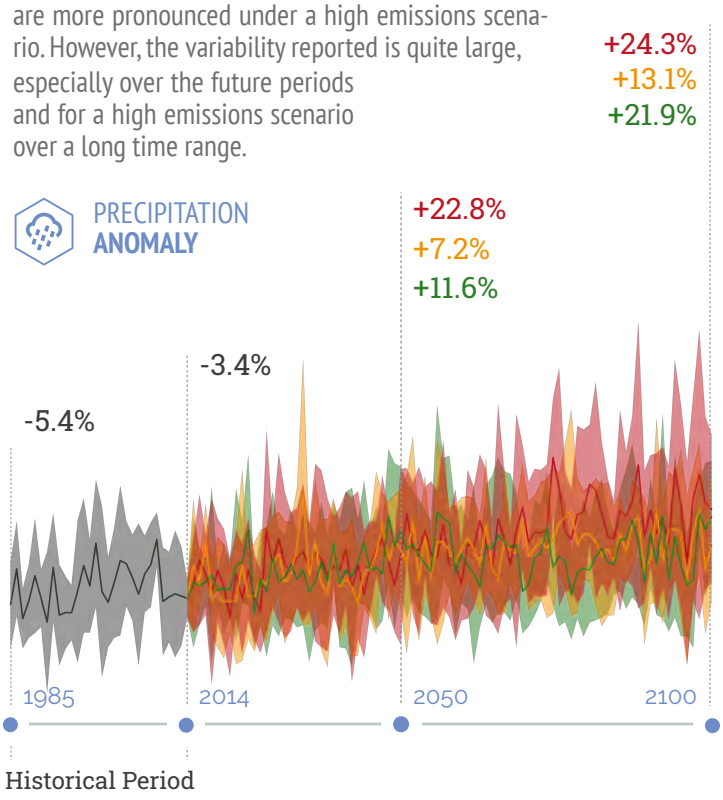
PRECIPITATION TREND

Precipiation anomalies over the last 60 years with respect to the annual mean of 1,280 mm/year in South Korea during the 1961-1990 period



PRECIPITATION PROJECTIONS

Precipitation trends show a general tendency to increase for all the different scenarios considered and are more pronounced under a high emissions scenario. However, the variability reported is quite large, especially over the future periods and for a high emissions scenario over a long time range.



EXPECTED VARIATION FOR PRECIPITATION AT 2050

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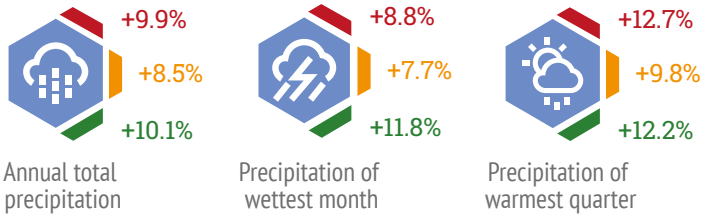
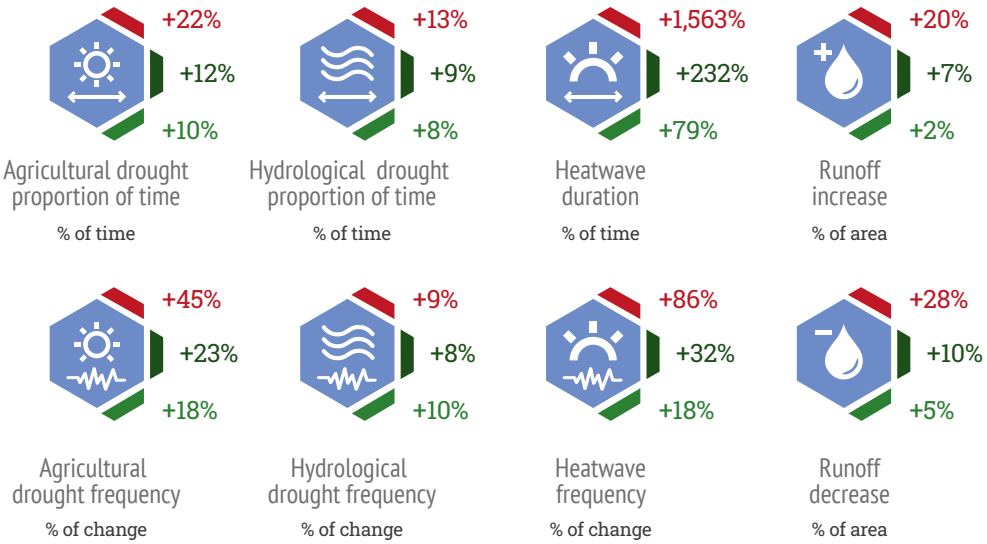


VARIATION OF SPECIFIC CLIMATE INDICATORS

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**.



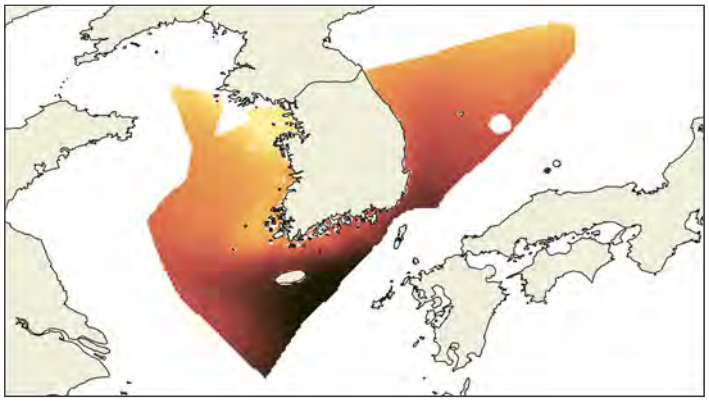
SOUTH KOREA OCEAN

OCEAN IN SOUTH KOREA

South Korea's marine exclusive economic zone (EEZ) is mainly temperate with warm water temperatures and a wide ensemble of ecosystems such as seagrass beds and coral reefs. The country's coastal systems are naturally divided into two areas: the Yellow Sea and the East Sea.

CURRENT CLIMATE CONDITIONS

Mean sea surface temperature reflects the rather homogeneous temperate climate of the region, with sigthly colder waters in the northern areas.

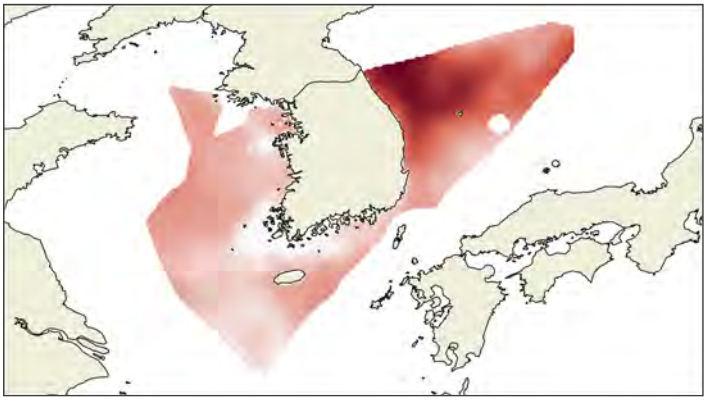


12 — 21 **MEAN**

SEA SURFACE TEMPERATURE

Celsius degrees / Over 1991-2020

0 — 0.6 **TREND**



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

FUTURE PROJECTIONS

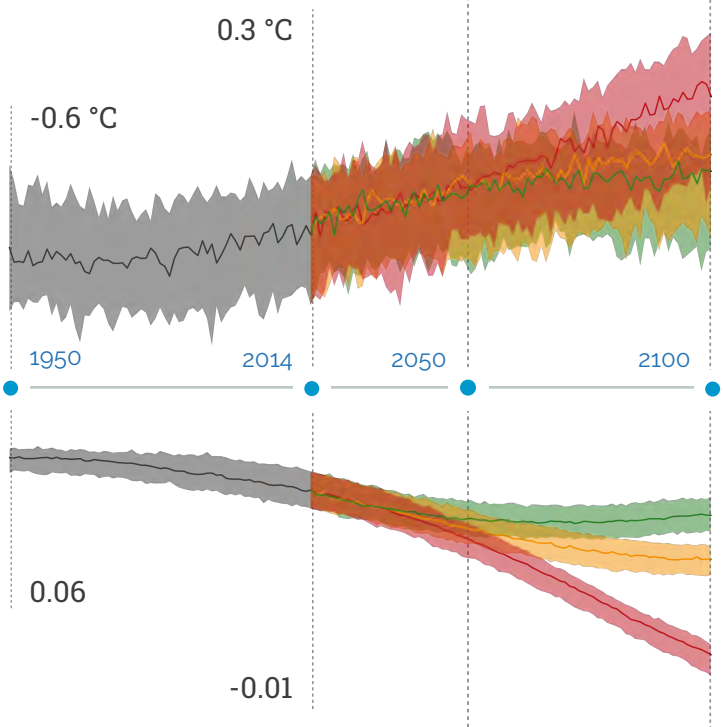
Projected annual changes within the marine EEZ for the two most significant marine indicators of climate change: sea surface water temperatures and pH.

Seawater temperature changes are in line with the definitions of each scenario, with maximum values around +5°C under a high emissions scenario in 2100.

+5 °C
+3 °C
+2.3 °C

SEA SURFACE TEMPERATURE **ANOMALY**

+2.2 °C
+2 °C
+1.9 °C



SEA SURFACE pH **ANOMALY**

-0.1
-0.14
-0.18

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

-0.1
-0.21
-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).

East Sea

Yellow Sea

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

East Sea	Yellow Sea
17.30°C	16.57°C
+2.25 °C	+2.18 °C
+2.01 °C	+1.85 °C
+1.95 °C	+1.61 °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.

East Sea	Yellow Sea
8.13	8.1
-0.17	-0.18
-0.13	-0.14
-0.1	-0.11

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

East Sea	Yellow Sea
246.88 mmol/m³	261.35 mmol/m³
-3.09 %	-5.36 %
-3.26 %	-3.78 %
-2.65 %	-3.88 %

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

East Sea	Yellow Sea
0.35 mg/m³	0.29 mg/m³
-5.76 %	+1.03 %
-8.65 %	+1.38 %
-12.1 %	-1.38 %

FISH CATCH POTENTIAL

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

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

Fish catch percentage change

2050

-2.7%

-0.8%

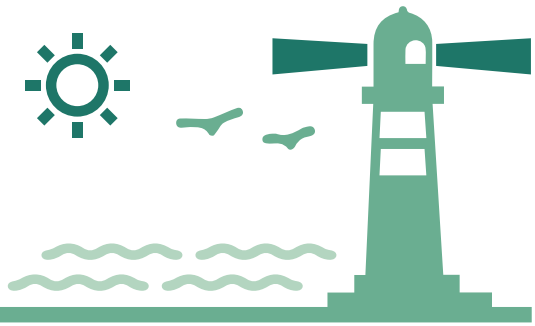
ANALYSIS DETAILS

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

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

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

SOUTH KOREA COASTS



OVERVIEW

Korea is a densely populated peninsula with approximately 12,000 kilometres of shoreline and more than 3,000 islands. Long stretches of tidal mud flats are found along the west coast, whereas sandy and rocky beaches are prevalent in the east. The southern coastal waters are characterized by the presence of various semi-enclosed bays and islands. The coastal zone economy includes industrial centres, maritime and air transport, and tourism. The biggest urban conglomerates on the coast include Incheon, Busan and Ulsan.

Shoreline Length

12,478 km

Sandy Coast Retreat at 2050

-43.3 m

CLIMATE CHANGE HAZARDS

Coastal hazards such as erosion, storm tide inundation and permanent flooding, can have strong adverse impacts on coastal regions, with loss of sandy shores, damage to settlements, infrastructure and ecosystems. Climate change can exacerbate these impacts due to rising sea levels and increasing impacts of waves and storms. Climate change impacts on the coastal zone of Korea are mainly driven by rising sea levels and possible changes in storms intensity and direction, and changes in the typhoons frequency, intensity and area of influence in the future. These changes can exacerbate erosion issues and drive flooding of low lying areas on the coast, with potential widespread economic damage. In general, flooding caused by sea level rise and storm surge will have more impact on the low lying and densely populated areas of the west coast.

SEA LEVEL RISE

Relative sea level rise has been observed over the past century around the coast of Korea, with a yearly average increase of approximately 2.4 millimetres per year since the 1990s. The latest IPCC projections indicate that, by 2050, global sea levels may rise between 0.18 metres, under a low emissions scenario, and 0.23 metres, under a high emissions scenario.

Observed and projected sea level rise at 2050

2.4 mm/year

0.23 m

0.18 m

EXTREME SEA LEVEL

On average, one in 100 extreme sea level events are expected to rise from 2.83 metres at present day to 3.08 metres by 2050 under a medium emissions scenario.

Current and projected extreme sea level at 2050

2.83 m

3.12 m

3.08 m

OBSERVED STORMS

The Korean coast is exposed to relatively small swells generated in the Yellow Sea, the South China Sea and the Sea of Japan. Trends in the wave climate have been analysed recently and detect a small increase in wave heights around the Korean peninsula in recent decades. Every year, the Korean coast is influenced by the typhoon season, from May to October, which has historically impacted the southern part of the country with widespread damage from wind and storm surges.

FUTURE STORMS

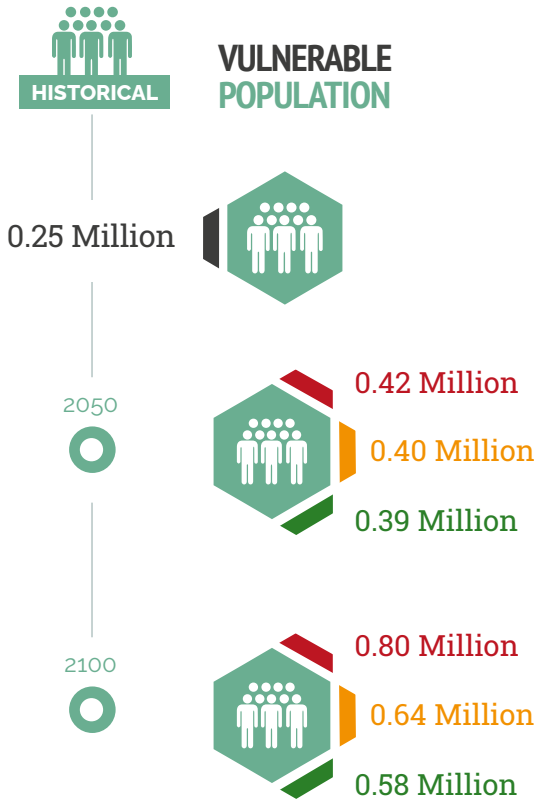
Climate change is expected to influence the wave climate around the Korean coast. Projections of change in wave height, period and direction for this century under different scenarios seem to agree on a reduction in wave energy. However, this may be offset by the impact of stronger typhoons fuelled by higher sea surface temperatures. Furthermore, it appears that although there may be a reduction in the number of typhoons, the intensity of these is predicted to increase.

VULNERABILITY AND RISK

Most of the coastal population of South Korea is concentrated in the large urban areas around Incheon, in the north-west, and Busan and Ulsan, in the south east. The low lying areas, however, are concentrated in the western part of the country.

Parts of Incheon and Busan are exposed to the impacts of sea level rise and increasing storm surges, which may lead to significant economic impacts under future sea level rise.

The total damage cost of a 1 metre sea level rise in Korea is estimated at approximately 60 billion USD. Under a medium emissions scenario, the population exposed to the annual coastal flood level is expected to increase from 250,000 to 400,000 people by 2050.



INFLUENCE OF SEA LEVEL RISE ON EXTREME SEA LEVEL

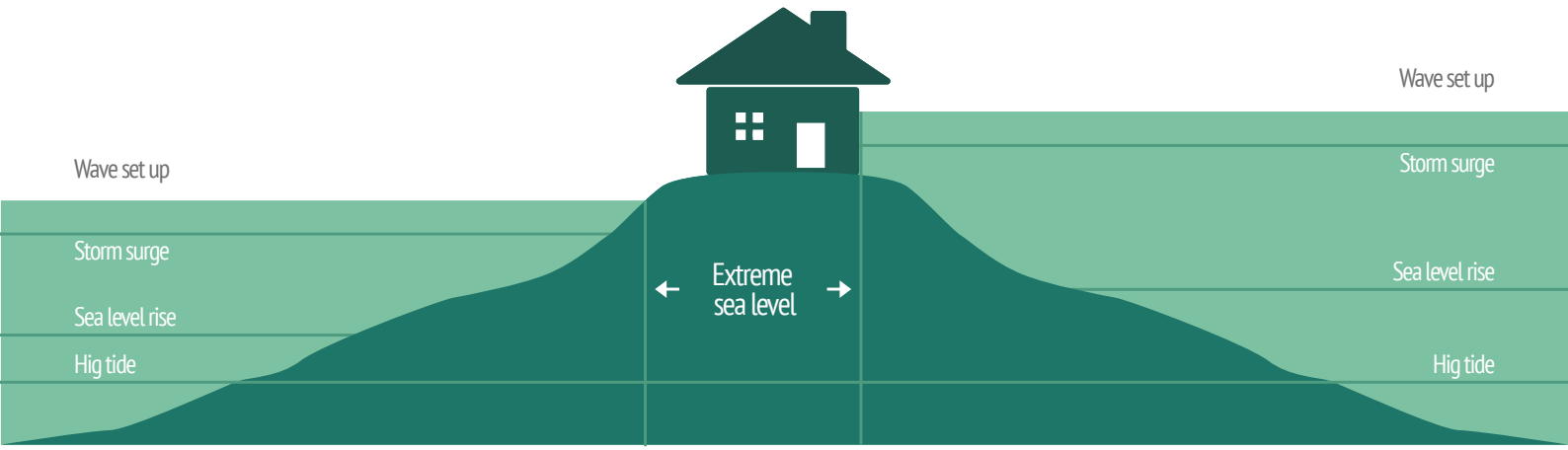
Present and future sea level rise are a consequence of carbon induced global warming causing melting ice and ocean expansion due to heat accumulation.

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

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

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

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



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

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

SOUTH KOREA WATER

OVERVIEW

Despite abundant rainfall, South Korea's water resources are relatively scarce. Annual precipitation is 1.6 times higher than the global average, whereas precipitation per capita is only about one sixth. South Korea's population of over 51 million people live in a relatively small country of about 100,363 squared kilometres, of which approximately 65% is mountainous. Most of the rainfall is concentrated in the summer months and more than 60% of the annual precipitation flows into the sea. Therefore, actual available water resources per capita are low.

Renewable internal freshwater resources: 65 billion m^3

Renewable internal freshwater resources per capita: 1,262 m^3

Water use has increased fivefold: from 5.1 billion cubic metres in 1965 to 25.1 billion cubic metres in 2014; growing faster than the population which has gone from 28.7 million in 1965 to 50.7 million in 2014. However, since 2003 water use has stopped increasing.

The Han River, the Nakdong River, the Geum River and the Yeongsan River are the four major rivers of Korea, with a total area of 67,630 square kilometres and a total length of 1,763 kilometres. As dependence on these four major rivers in Korea increases, so does the potential for water crisis, especially as climate change increases flood and drought impacts.

CLIMATE CHANGE HAZARDS

Climate change can affect water resources through increasing temperatures, higher rates of evapotranspiration and altered rainfall patterns. This leads to changes in the water cycle, including decrease of snow and ice coverage, alterations of surface runoff and groundwater storage, as well as drought and flood occurrence. Records of annual precipitation since 1905 show that the variation range of annual precipitation has been increasing gradually. The value fluctuated rapidly from 754 millimetres in 1939 to 1,756 millimetres in 2003, and the incidence of extreme drought and flood events is increasing. Groundwater and runoff are also linked to these changes in precipitation.

KEY POINT RUNOFF

Monsoon summers between June and September account for approximately 60-70% of the total runoff and precipitation in many areas of South Korea. Future projections show that increasing temperatures will have significant impacts on the intra-annual runoff variation, with the variability of runoff increasing in summer and an increased likelihood of extreme future events. Simulations show that the discharge in July tends to decrease while runoff can increase in August and September. In addition, the mean average low flow may increase while the average wet and normal flow may decrease under climate change.

At a country scale, an average increase in surface runoff by approximately 2% and -17% is expected respectively under low and high emissions scenarios for the 2045-2055 period compared to 2015-2025. If temperatures rise by 1.5°C, 2°C or 4°C, 5%, 9.6% or 28% of the area of the country will likely experience an increase in runoff, while 2%, 6.9% or 20% of the surface of the country will likely experience a decrease in runoff, respectively.

2050

Changes in annual runoff
% of change

-16.7%

+1.8%

2050

Runoff increase
% of area

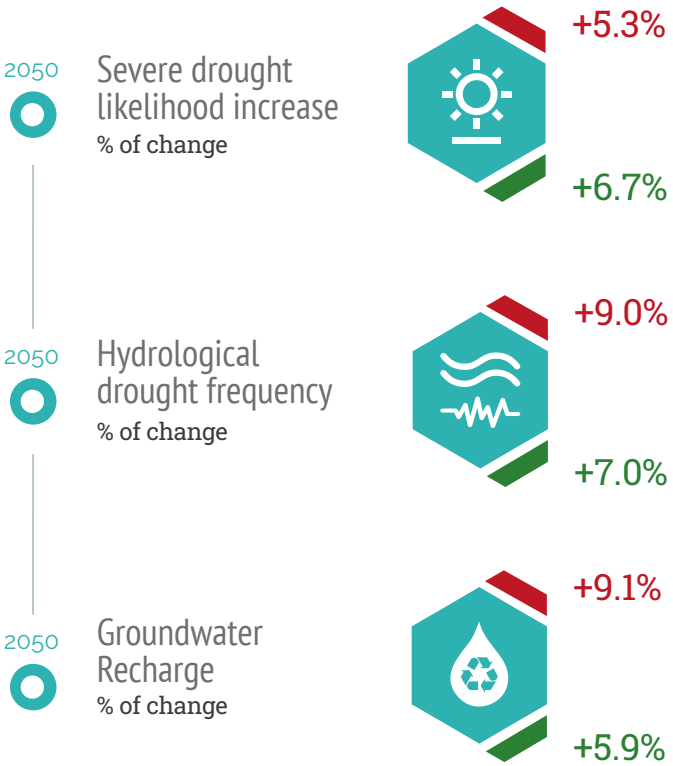
+28%

+5%

KEY POINT DROUGHTS

Studies have shown that droughts on the Korean Peninsula are more likely when the summer monsoon season is relatively short. Extreme drought occurred in 2015 as precipitation that year was recorded as being the third-lowest since meteorological observations began in 1973. In this case, the Boryeong Dam level was the lowest on record, with an approximately 200 year return period based on the dam design.

Since 1970, South Korea has suffered from drought over a period of five to seven years, and local drought is becoming an increasingly serious concern, with increasing rainfall deviation across multiple regions. In many areas of the peninsula, droughts are estimated to have become more severe especially in spring and winter.



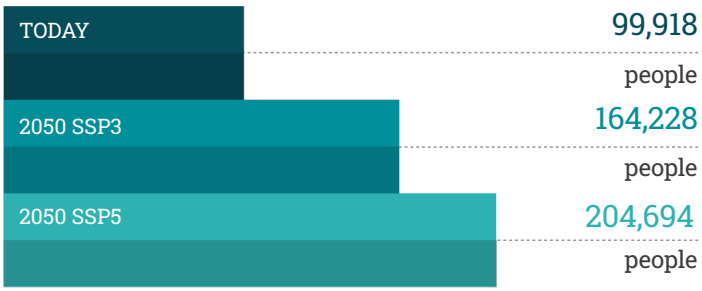
KEY POINT GROUNDWATER

In South Korea, the amount of underground water usage is approximately 4.1 billion cubic metres (2015). Although this usage has been increasing constantly every year, the increase has decelerated since 2013. Due to imprudent groundwater development and inappropriate management, South Korea has confronted some critical groundwater problems, including extensive water level decline and quality deterioration caused by petroleum hydrocarbons and chlorinated solvents. Among 193 national groundwater deep-monitoring wells nationwide, 62% showed decreasing water levels over the period 2004-2008. Based on the groundwater-level data for the last 10 years obtained from the nationwide national groundwater monitoring network, approximately a 0.58 metre decrease in the groundwater level for the next 20 years has been predicted. Excessive groundwater collection and a decrease in the groundwater recharge caused by climate change were qualitatively estimated as the causes. At the country level, a +5%, +5% and -11.4% change of the annual groundwater recharge for the period 2045-2055 compared to the timeframe 2015-2025 is expected respectively under low, medium and high emissions scenarios.

KEY POINT FLOODS

Large-scale flood damage in South Korea, measured in terms of human casualties (dead and missing), has been decreasing since 1959, while property damage has also been gradually decreasing since 2002. Nevertheless, excessive flooding does occur due to changing rainfall patterns that are caused by climate change, such as increased precipitation, decreased days of precipitation and a rise in short-term, localized heavy rain. The frequency of localized heavy rain with 30 millimetres per hour or more, surged by 37%: from 60 instances in the 1980s to 82 times since 2000. Between July 26th and July 28th, 2011, for example, localized heavy rain in the metropolitan area (113 millimetres per hour on the morning of the 27th in Gwanakgu, Seoul; 449.5 millimetres per day in Dongducheon; and 322.5 millimetres per day in Moonsan) inundated the most populated downtown neighborhoods in Seoul. Meanwhile, a large-scale landslide caused by localized heavy rain in the Mt. Woomyeonsan district and Gangwon Chuncheon resulted in numerous casualties, including 57 deaths and 12 missing people.

POPULATION AFFECTED BY RIVER FLOODS

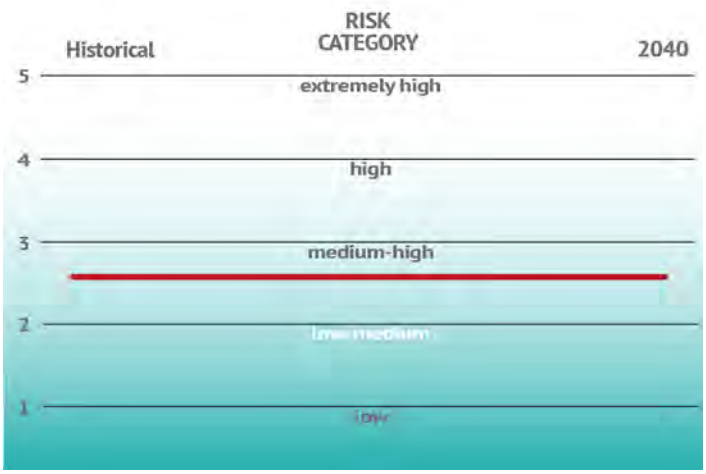


RISK INDICATORS

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

WATER STRESS

The water stress level for South Korea is considered medium-high for the recent past (1960-2014 average), and it is expected to remain that way in the near future (2030-2050) based on climate change projections.



SOUTH KOREA AGRICULTURE

OVERVIEW

Less than 25% of South Korea's area is covered in agricultural land, which is characterized by small family farm structure. Rural population has been decreasing steadily in recent decades, and likewise the share of the national GDP derived from the agricultural sector.

Rice is the most important agricultural crop in South Korea, accounting for about 90% of total cereal production. Other relevant crops produced in the country include barley, wheat, soybean and potatos, yet these only cover a small amount of domestic needs. In addition, a wide variety of fruits and vegetables are cultivated including tangerines, pears, apples, peaches, onions, cabbages and radishes.

Reservoirs are the main source of freshwater for irrigation in agriculture, in particular for paddy fields.

5.2 Mt
Rice

0.6 Mt
Citrus

0.2 Mt
Barley

0.6 Mt
Potato

Added Value of Agriculture, Forestry and Fishing

2000: 23,931 USD Million

2018: 28,767 USD Million

Share of Agriculture Value added in Total GDP

2000: 3 %

2018: 1.8 %

Agricultural land

2000: 1,918 Thousand HA

2018: 1,596 Thousand HA

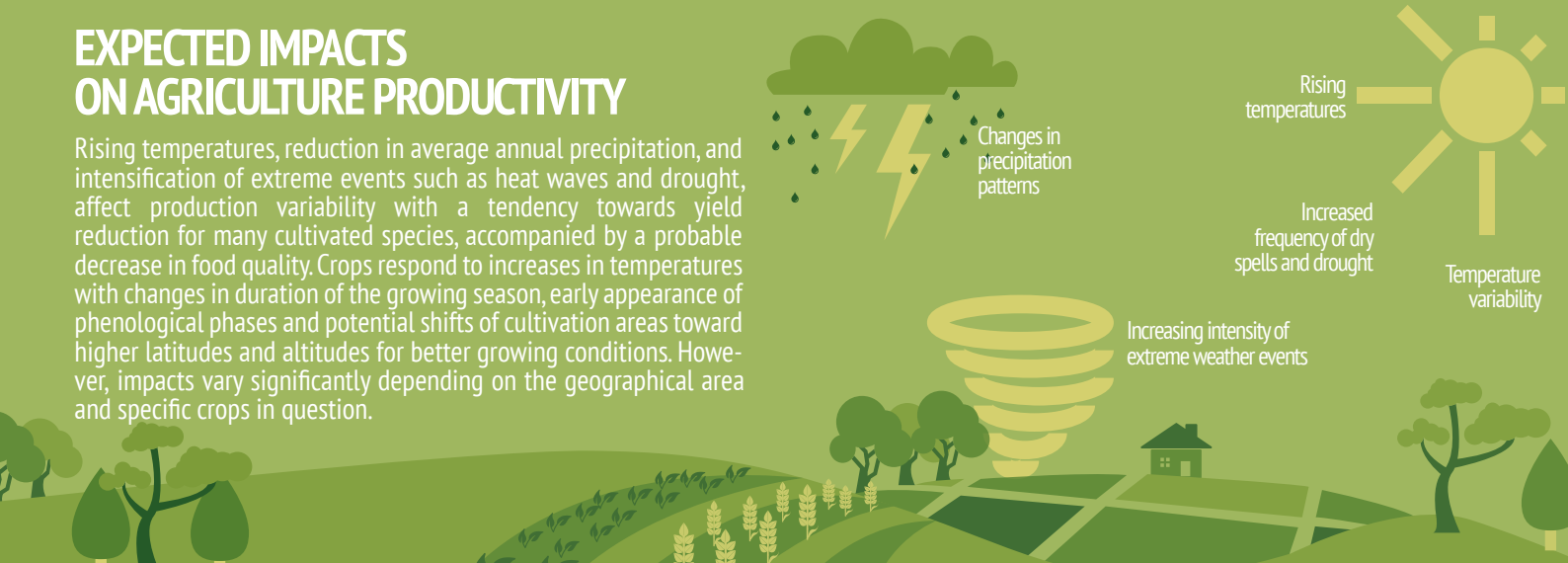
Area Equipped for Irrigation

2000: 880 Thousand HA

2018: 707 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.

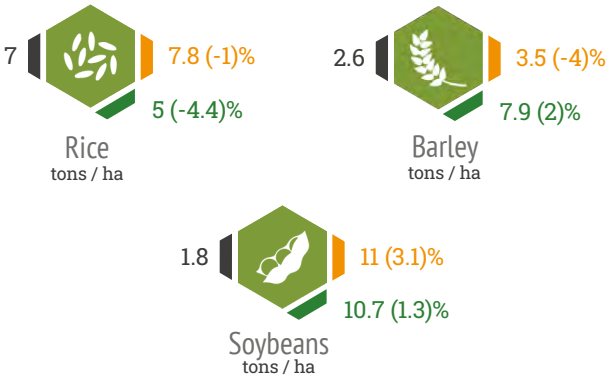


CROP PRODUCTIVITY

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.

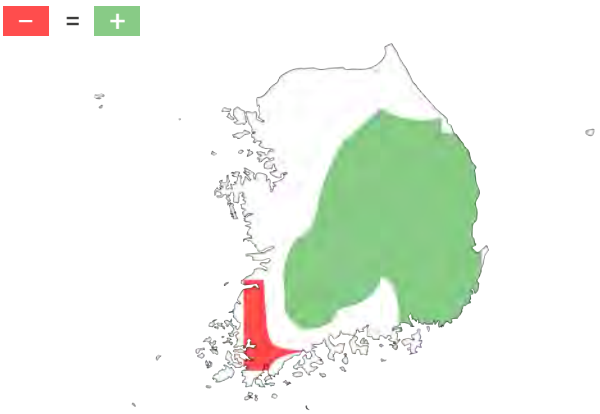
Impacts are estimated using a range of model projections based on low to high emission scenarios and reported as percentage changes between the 30-year average around the historical period and the 30-year average around 2050.



2050

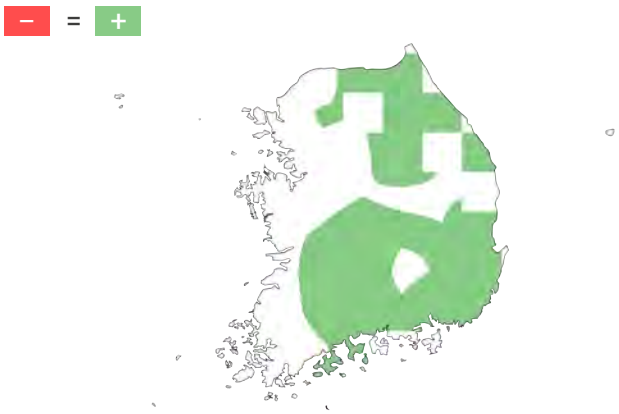
Productivity change with (without) the CO_2 fertilization effect. Estimates assume sufficient water and nutrient supplies, and do not include impacts of pests, diseases, or extreme events.

CHANGE IN RICE



Rice productivity shows an overall tendency to increase, especially for early-maturing varieties, whereas productivity of medium to late-maturing varieties may decrease slightly. Most increases in rice productivity are expected in the northern areas due to warming and more suitable conditions for rice production, whereas a decrease may be expected in southwestern areas. Increasing temperatures may shorten the ripening period, leading to production of poor-quality rice. Extreme events, such as typhoons, may trigger severe drops in rice yields

CHANGE IN SOYBEANS

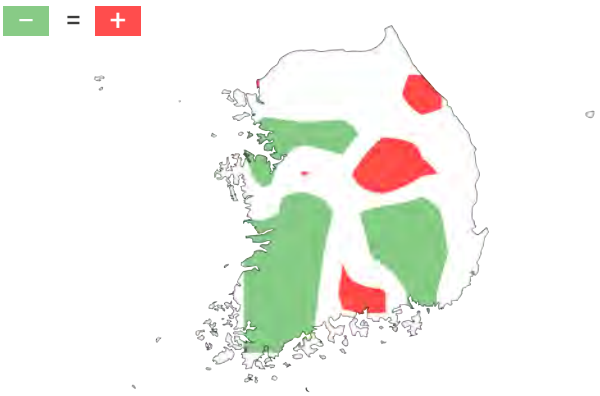


associated with reduction of temperature and sunlight during the ripening period. Due to warmer temperatures, the cultivation regions of apples, pears, peaches and grapes will move northward and/or to inland mountain areas, whereas some areas in the southern regions will become unsuitable for cultivation. Rising temperatures will expand regions suitable for cultivation of several tropical fruits (guava, avocado, atemoya, mango, pitaya, and papaya) in the south-coastal regions.

ADAPTATION IN AGRICULTURE AND WATER RESOURCES

Rural regions may become more vulnerable to water deficits because of seasonal variations in precipitation and droughts. Meanwhile, higher temperatures will generally require a larger agriculture water demand due to higher plant evapotranspiration. Future expansion of under-irrigated agricultural areas may further increase the water demand for irrigation, which is mainly dependent upon reservoirs. An effective operational management of reservoirs is crucial by evaluating the combined sustainability of water demands from multiple sectors and vulnerability of water supplies under climate change.

CHANGE IN WATER DEMAND



2050

Agriculture
Water Demand
% of change

Resilience of water supplies will benefit from modernization of agricultural infrastructure and development of technology to improve the efficiency of irrigation systems.

SOUTH KOREA FORESTS

FORESTS IN SOUTH KOREA

South-Korea is characterized by warm-temperate evergreen broadleaf forests in the south, evergreen conifers in the mountains, and deciduous hardwood forests in the rest of the country.

The current situation is strongly influenced by pronounced reduction in adventitious cover in the first half of the 1900s during Japanese colonization and subsequent reforestation policies.

FORESTED AREA AND CARBON STORAGE

South-Korean forests cover almost one third of the country's total land surface. According to recent studies they remove approximately 60 gigagrammes of CO_2 from the atmosphere per year with a constant increasing trend. This will allow Korea to reach a total of 1 gigatonnes of total stock by 2050. Forests are a crucial carbon sink for this country.

1990

7 Mln ha
Million hectares
Forested area

21 Tons/ha
Tons of Carbon per hectare
Carbon stock

2020

6 Mln ha
Million hectares
Forested area

87 Tons/ha
Tons of Carbon per hectare
Carbon stock

2050

Productivity anomaly
Tons of Carbon per hectare per year

+0.56

+0.52

FOREST PRODUCTIVITY

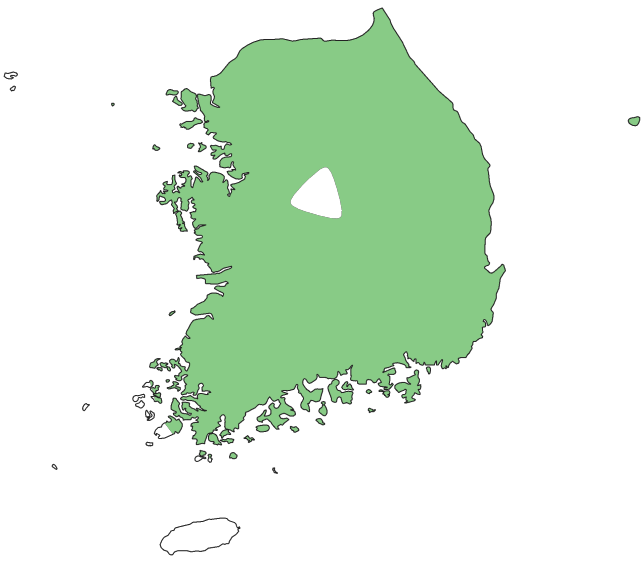
Forest productivity or Net Primary Production is the net carbon captured by plants. It is the difference between the carbon gained by Gross Primary Production - net photosynthesis measured at the ecosystem scale - and carbon released by plants' respiration. It is expressed per unit land area.

Increase in primary production across the entire country

+ Fertilizing effect of increasing atmospheric CO_2, and rising temperatures promote productivity

No areas with an expected decrease in forest primary production

+ Increasing risk of drought stress due to modifications in the water regime reduce productivity



KEY SPECIES UNDER CLIMATE CHANGE

INCREASE
OAKS
Decrease in the distribution of coniferous species in favour of an increase in oak species

SUITABILITY
EVERGREEN FORESTS
Increasing climate suitability for warm temperate evergreen forests

MORTALITY
SUBALPINE CONIFEROUS
Mortality of the subalpine coniferous species was projected to progress rapidly

VULNERABILITY
FIR-THUJA
Very high vulnerability for Korean arborvitae, Khingan and Korean fir

FIRES IN SOUTH KOREA

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

During the last two decades, the total land area affected by fire amounts to approximately 42,850 hectares.

BURNING
42.8 THOUSAND HECTARES

EMITTING
0.26 TERAGRAMMES OF CARBON PER YEAR

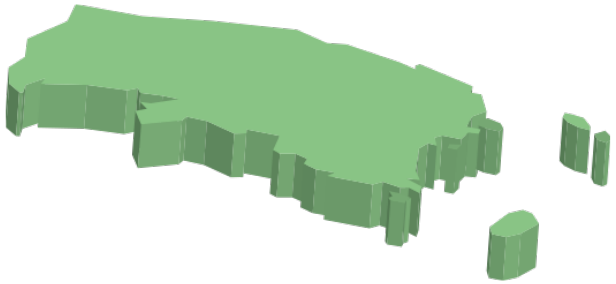
FOREST FIRE EMISSIONS CONTRIBUTED TO 60% OF TOTAL FIRE RELATED CARBON EMISSIONS

COSTING
34.1 MILLION USD PER YEAR IN FOREST FIRE PREVENTION

WHERE DO FIRES OCCUR?

The most affected areas are those dominated by temperate broadleaf and mixed forests in the north Gyeongsang Province.

The north Gyeongsang Province is the country's fire hotspot region.



FUTURE BURNED AREA

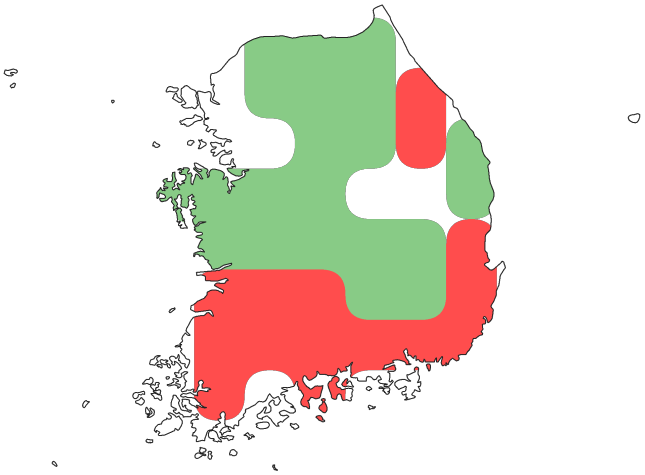
Under a low emission scenario, models project a generalised decrease over northern and central areas while an increase is expected in coastal and central deciduous forests and southern evergreen forests. Under a medium emissions scenario, burned area might decrease across central areas.

Burned Area
km² per year

2050

-17.9

-2.1



Decrease in burned areas for a low emissions scenario

Increase in burned areas for a low emissions scenario

+ A slight increase in the fire season and the frequency of fires is expected

+ By the end of the century there may be a stronger increase in fire season length.

VARIATION OF SPECIFIC FIRE INDICATORS

% of change
Fire days in spring
2040-2069
+31%

% of change
Fire days in summer
2040-2069
+17%

% of change
Fire days in autumn
2040-2069
+21%

FUTURE FIRE EMISSIONS

Compared to present, under a low emissions scenario scientists project a slight variation in fire emissions. However, under a medium emissions scenario fire emissions might decrease, particularly in north-eastern areas.

Fire Carbon emission
Teragrams of Carbon per year

2050

-0.15

-0.05

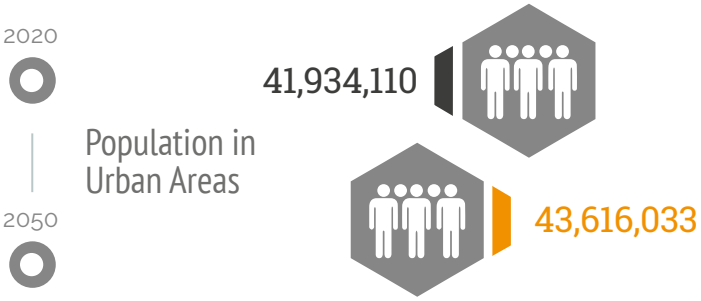
SOUTH KOREA URBAN

OVERVIEW

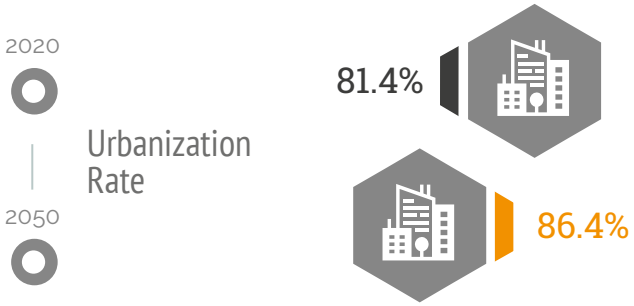
In 2020, more than 80% of the South Korean population lived in cities. Most cities were built in a short period between 1960 and 1980, and the urbanization rate grew from less than 30% in 1960 to almost 80% in the 1990s. In the near future, the urbanizaiton rate is expected to increase to 86.6% by 2050.

More than 60% of the South Korean urban population lives in urban agglomerations with more than 1 milion inhabitants, while smaller urban centres with less than 300,000 inhabitants account for 7% of the urban population.

Built up areas cover 17.8% of South Korea (7,729.88 square kilometers).



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



OVERVIEW OF KEY CLIMATE IMPACTS IN URBAN AREAS

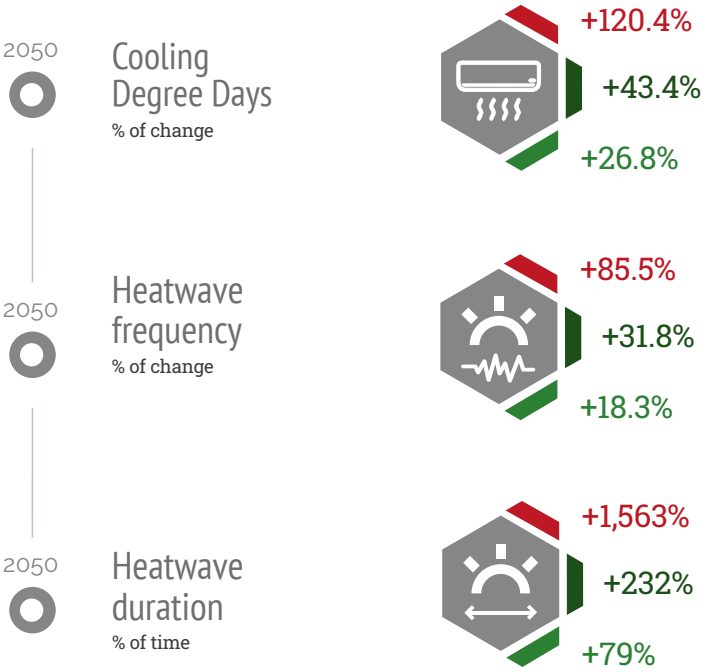
South Korea's urban areas are mainly vulnerable to heat stress and the effects of storm surges and heavy rainfall resulting from typhoons reaching land.

HEATWAVES AND HEAT STRESS

Frequency, intensity, and persistence of heat waves on the Korean Peninsula have increased since the 1970s. The frequency of tropical nights has also increased, particularly in larger cities and metropolitan areas.

Between 1992 and 2010 approximtely 470,000 heat related deaths in 7 communities were reported. In this period, a total of more than 220 heatwave events of different intensities and lengths were registered, among these there were eight two-day events of very high intensity, six three-day events of medium intensity, and five four-day or longer events. In larger urban areas, these events include more frequent tropical nights, which represent a significant health risk.

In the near future, frequency of heat waves and consequently reliance on air conditioning will increase, in particular under a strong warming scenario. The length of heatwaves could increase by 1,563% and temperatures could rise by the 5.5°C, 2°C and 4°C under high, medium and low emissions scenarios, respectivley.



AGEING SOCIETY

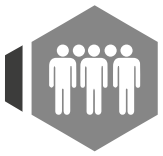
The Korean population is ageing rapidly, with 37% of the entire population to be classified as elderly by 2050, and high concentrations living in urban areas. Among the elderly, those living alone are particularly vulnerable due to poverty and difficulties managing their wellbeing.

High temperatures in urban areas worsen impacts of high levels of air pollution. In 2017, the entire Korean population was exposed to levels exceeding WHO guideline values for PM2.5.

2017

Population exposed to air pollution

100.0%



COASTAL FLOODING

Korea's coastline is exposed to regular typhoons. The risk from typhoons is determined by storm and rainfall intensity as well as by rising sea levels. Sea levels around the Korean peninsula have risen by approximately 10 centimetres in the last 40 years, with an annual increase of 2.9 milimetres, observed between 1989 and 2017.

2050

Projected sea level rise

0.23 m

0.18 m

2100

0.77 m

0.38 m

FLOODING

There is an increasing trend in extreme precipitation, with increasing maximum daily precipitation values in some regions, partly due to natural variables. Since the late 1990s, flash floods have emerged as the most frequent natural disaster. Korea experienced severe flood damage caused by typhoons and rainfall in 2006 when flash floods killed 35 people and left 13 others missing.

Damage to property was concentrated in the north eastern province of Gangwon – amounting to approximately 935.5 million USD Annual mean precipitations are expected to increase slightly under all scenarios, whereas summer precipitations are expected to increase at a much higher rate.

2050

Runoff increase

% of area

+28%

+10%

+5%

SURFACE SEALING AND FLOODS

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

RAPID LAND USE CHANGE AND URBANIZATION

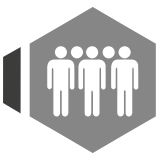
Rapid land use change under intense urban growth is increasing runoff. When combined with more intense precipitation these factors will be responsible for increasing flood damage in larger cities.

2010

% of urban population

Population living in slums

0%

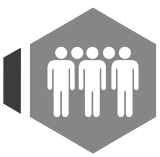


2018

% of total population

Urban population living in areas where elevation is below 5 meters

2.0%



SOUTH KOREA
HEALTH

OVERVIEW

Temperatures in South Korea have increased by 1.5°C in the last century. Warming, heatwaves, and erratic rainfall will increase health risks such as heat-related mortality and vector-borne diseases such as malaria. In South Korea, the risk of death increases by 5% for every 1°C increase in temperature, and the risk of death during a heatwave increases by 8% compared with other periods. In addition, rising temperatures increase the risk of death in the population aged 75 years or older and in chronic disease patients.

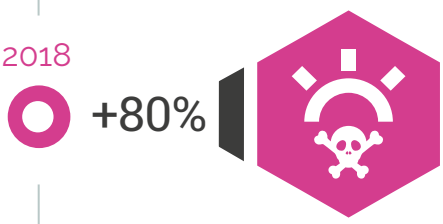
HEAT RELATED MORTALITY

Under a high emissions scenario, heatwave-related excess deaths will increase by 274%, whereas under a medium emissions scenario the increase will be 171%.

In 2018, there was an 80% increase in heat-related deaths from a 2000 to 2004 baseline. 23.9% of heat-related mortality in South Korea during 1997 to 2016 can be attributed to human-induced climate change.

Heat-related mortality

% change with respect to 2000-2004



IMPACTS ON LABOUR

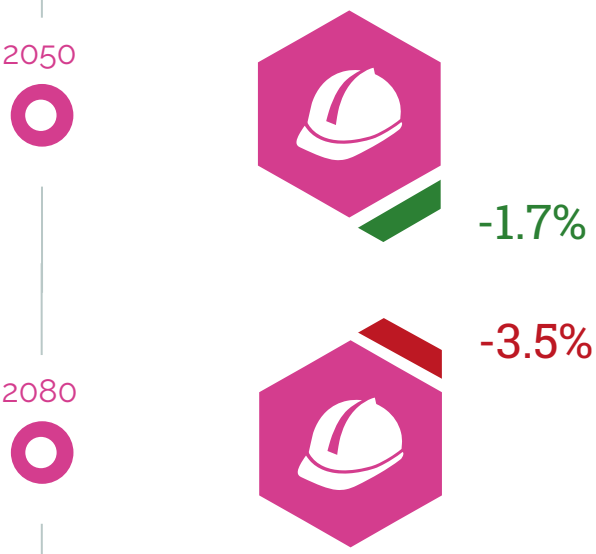
Labour is directly affected by changes in environmental conditions. Warming affects both the number of hours worked (labour supply) and on the productivity of workers during their working hours (labour productivity). Both labour supply and productivity are projected to decrease under future climate change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

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

In South Korea, there was a 49.9% loss in potential hours of labour in the agriculture and construction sectors in 2019, compared to the 1990s baseline. Total labour in South Korea is expected to decline by 1.7% under a low emissions scenario, and by 3.5% under a medium emissions scenario.

Impact on total labour

% change with respect to 1986-2005 baseline



CLIMATE CHANGE AND DENGUE

Dengue has spread throughout the tropical world over the past 60 years and now affects over half the world's population. Globally, vectorial capacity for both dengue vectors (A. aegypti and A. albopictus) has been rising steadily since the 1980s, with nine of the ten highest years occurring since 2000. Climatic stressors are one important driver of the current distribution and incidence of dengue. Climate change is likely to expand the geographical distribution and suitability of several vector-borne human infectious diseases including dengue. The risk of dengue transmission is increased by warming climates, as the growth and development of mosquitoes are significantly influenced by temperature, precipitation, and humidity.

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 distribution range of insects that are infectious disease vectors is expected to move northward. The domestic settlement of Aedes albopictus, which can spread dengue or Zika viruses, will be possible if the average winter temperature in Korea rises to 10°C or higher in 2050.

Under a medium emissions scenario, 88.8% of the population will be at risk of transmission-suitable mean temperature for dengue by 2050, whereas 89.6% will be at risk under a high emissions scenario. In the case of Zika, 89.3% of the population will be at risk by 2050 under medium emissions, whereas 81.7% will be at risk under high emissions.

CLIMATE CHANGE AND MALARIA

Although South Korea is no longer a malaria-endemic country, malaria vectors are still present. By 2050, 42.7% and 44.3% of the South Korean population will be at risk of malaria under low and high emissions scenarios, respectively.

POLLUTION AND PREMATURE MORTALITY

By 2060, 1,109 deaths per year per million people will be caused by outdoor air pollution compared to 359 in 2010.

Dengue suitability

% of population at risk

2050

89.6%

88.8%

Zika suitability

% of population at risk

2050

89.3%

81.7%

Malaria suitability

% of population at risk

2050

44.3%

42.7%

SOUTH KOREA ENERGY

ENERGY SYSTEM IN A NUTSHELL

South Korea is a highly energy-intensive economy, due to its industrial activity. Fossil fuels dominate the energy mix, but the Korean government has committed to a strong decarbonization pathway over the next two decades.

This entails phasing out coal and nuclear, while increasing energy efficiency in industrial production and boosting renewable sources. In 2015 Korea was one of the first Asian countries to implement an ETS scheme.

0.14
ktoe/US$
Energy intensity

9.2%
AC Share in electricity consumption

87.5%
Import dependence ratio

CLIMATE CHANGE TODAY

INCREASING TEMPERATURES

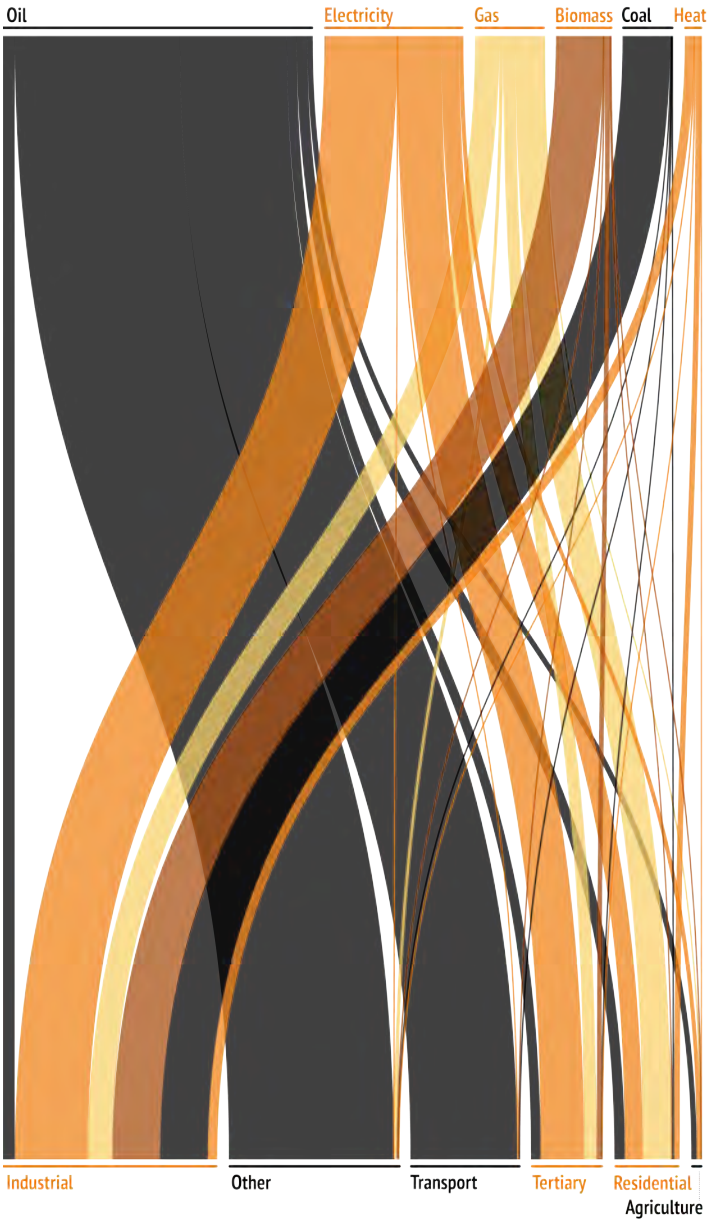
Residential and commercial energy demand has risen due to faster-than-average increasing temperatures (0.18°C every ten years in the last century), heatwaves and cold spells.

HEATWAVES

The 2016 heatwave brought about 32 tropical nights, a peak electricity consumption of 8.37 gigawatts and a rush to purchase cooling appliances: air conditioner sales jumped by 160% , those of dehumidifiers by 245%, and those of electric fans by 92%.

ENERGY SUPPLY

South Korea's total primary energy supply energy mix shows a strong dependence on fossil fuels (83% in 2019), most of which are imported, followed by nuclear (14%), leaving only a marginal share to renewables (4% including hydro, biofuels, and waste).



ENERGY DEMAND

In South Korea, energy is used mainly by industrial sectors (55% of total final consumption in 2018, including non-energy uses accounting for 28% of total demand, and claiming 53% of oil products), transport (19% of final demand), tertiary (12%), and residential demand (12%) while agriculture and fishing together have a slim 1.5% share. Air conditioning's contribution to residential electricity demand was only about 2.5% in 2017.

FUTURE ENERGY DEMAND

Decrease in heating demand in South Korea is going to be more than compensated by the increase in cooling needs, resulting in a net increase in energy demand of about 1,820 PJ (505 billion Kwh) by 2050 under a medium emissions scenario.

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

Billion KWh

2050

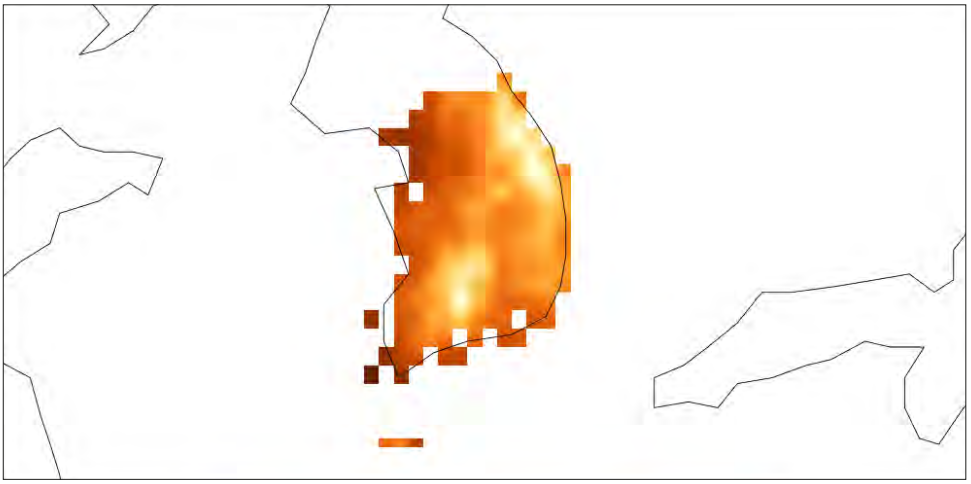
+ 505.58

COOLING NEEDS

Marked, but not extreme, increases in heating days all over the country, more pronounced on the west coast, where the capital city Seoul is, and particularly in the south-west corner of the country.

COOLING DEGREE DAYS

146 — 314

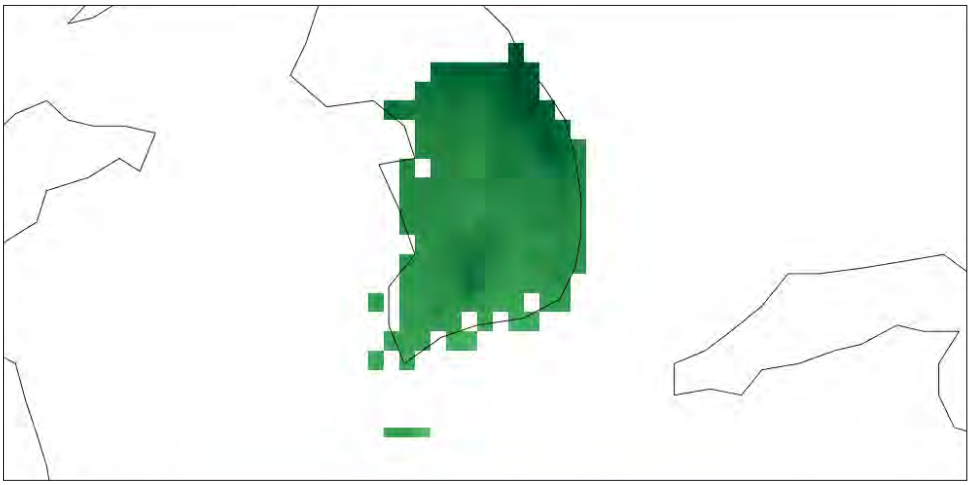


HEATING NEEDS

An almost uniform, marked decrease in heating needs is expected all over the country. Slightly more pronounced decreases are expected in the north-east near the border with North Korea.

HEATING DEGREE DAYS

-489 — 0



FUTURE ENERGY SUPPLY

The future configuration of the Korean energy mix is likely to be determined by the evolution of climate mitigation policies and hence is outside the scope of this report. Korea is committed to a fast-track decarbonization pathway, which foresees reaching a 20% share of renewable electricity by 2030 and 30-35% by 2040, while phasing-out coal and nuclear and improving energy efficiency. In October 2020 a carbon-neutrality target by 2050 was announced. This is likely to result in fossil fuels (and their vulnerabilities) keeping their relevance for the next couple of decades, while carbon free sources and their vulnerabilities will prevail in the second half of the century.

Change in Hydropower generation

% of change

2050

-4.98%

-2.73%

EXPECTED IMPACTS OF CLIMATE CHANGE

To the best of our knowledge, there are no studies on the impacts on South Korea's energy infrastructure. As for other Asian Pacific countries, floods, heavy precipitation and typhoons will pose increasing threats to such infrastructure. The planned energy transition streamlines adaptation into new infrastructure design, particularly for the electricity grid. A moderate drop in hydropower is expected.

SOUTH KOREA ECONOMY

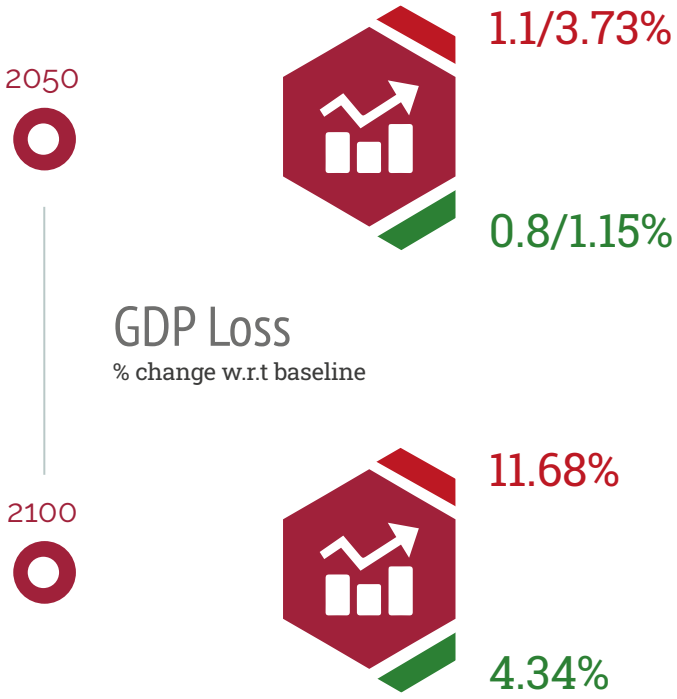
OVERVIEW

South Korea ranks 13th in terms of GDP in the G20 group. As a consequence of the COVID 19 pandemic real GDP declined by 1% in 2020. This trend has been reversed and in 2021 real GDP grew by 3.6%.

IMPACTS ON GDP

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

The projected overall macroeconomic impacts for South Korea range from negligible GDP losses (0.3%) under a low emissions scenario in 2030, to 3.7% of GDP losses in 2050 under a high emissions scenario, to greater than 11% GDP losses under worst case scenarios, by the end of the century.



SECTORAL ECONOMIC IMPACTS

IMPACTS ON INDUSTRY AND INFRASTRUCTURE

Climate-induced risks for transportation facilities and buildings are high in coastal areas of Gangwon-do, Chungnam and Jeolla-do provinces. In the future high-risk areas for both transportation facilities and buildings are expected to expand in the southern part of the Korean Peninsula and inland areas especially under a high emissions scenario.

Over 65% of South Korean fishing ports are already vulnerable to sea-level rise, a percentage that rises under a high emissions scenario to 70% in 2050 and 85% by the end of the century.

IMPACTS ON AGRICULTURE

Climate change will negatively affect future rice productivity and quality of food crops and positively affect the amount of barley, a winter crop. It is also expected that the areas more suitable to growing fruits and vegetables will move northwards, and that the southern islands may become suitable for the cultivation of tropical fruits.

The tropicalization of the sea around South-Korean shores may result in a drop in fish catches and/or a transition to tropical species.

Decreases in rice yields ranging from 4% under a standard medium emissions scenario by mid-century to 14% under a high emissions scenario at the end of the century are expected. Losses for the agricultural sector (rice and barley) may reach 207.5 million EUR by 2050 and 409 million by the end of the century.

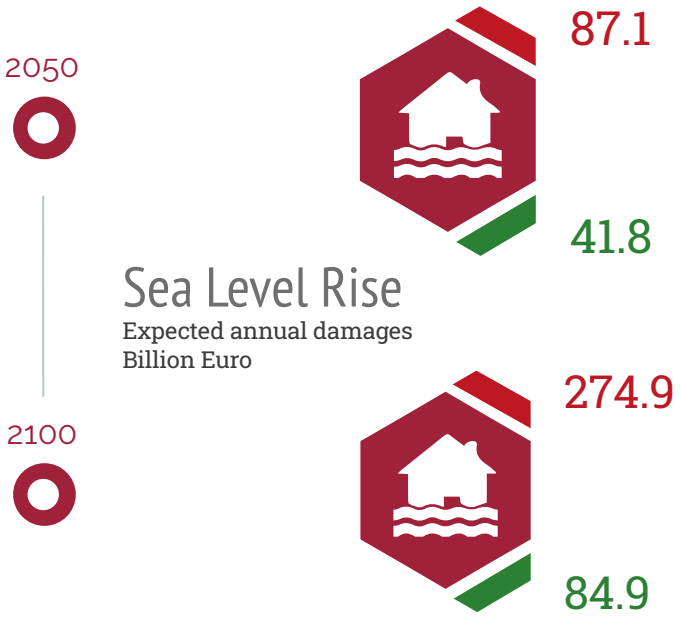
IMPACTS ON FORESTRY AND FISHERY

It is estimated that losses for forestry and ecosystems would amount to, respectively, 117 million and 206 million under a high emissions scenario.

SEA LEVEL RISE DAMAGES

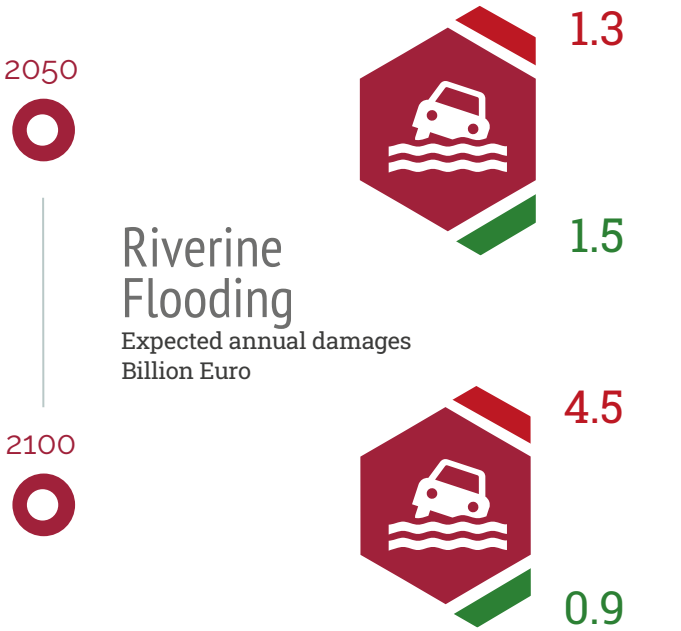
Under the current level of coastal protection, by mid century, sea-level rise and coastal flooding can cost the country 41.8 to 87.1 billion EUR in terms of expected damages to assets in the low and in the high emissions scenarios, respectively.

By the end of the century, expected losses can increase to 84.9 billion and 274.9 billion EUR under low and high emissions scenarios, respectively.



RIVER FLOODING DAMAGES

River flooding can also provoke damages. By mid century total asset losses are projected to be 1.5 to 1.3 billion EUR and in the second half of the century 0.9 to 4.5 billion EUR under low and high emissions scenarios, respectively.



IMPACTS ON ENERGY

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

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

IMPACTS ON TOURISM

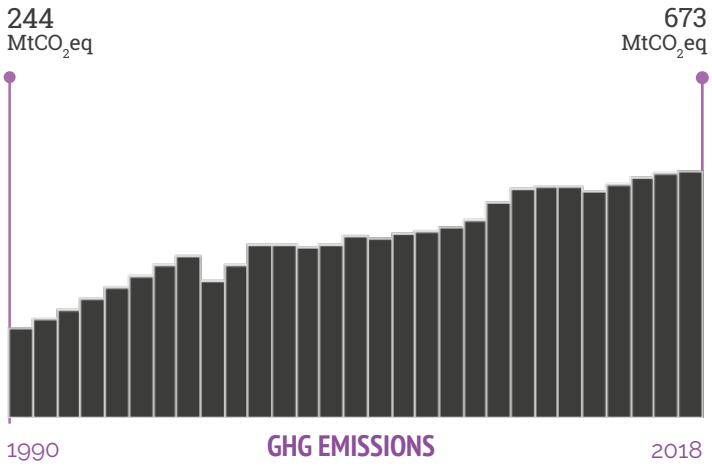
Korea ranked 28th as an international tourist destination in 2017, with 13.36 million arrivals. Tourism is mostly a domestic activity and its dymanics are driven more by international politics or health crises than by climate change.

However, mountain tourism in South Korea is likely to be hit significantly by climate change, with all 17 ski resorts to be gradually driven out of business by the end of the century: three ski resorts will cease operations by the 2030s, 12 by the 2060s and the two remaining ski resorts during the 2090s.

SOUTH KOREA POLICY

OVERVIEW

Although South Korea is the 12th largest emitter among G20 countries, it is also 6th in terms of emissions per capita. South Korea has more than doubled its emissions in recent decades and the emission trend is still growing steadily.



INTERNATIONAL COMMITMENTS

To achieve the Paris Agreement's target, South Korea submitted an NDC committing to reduce its emissions by 37% in 2030, with reference to a business-as-usual scenario. Recently, South Korea updated its NDC, committing to reduce by 24,4% in 2030 with reference to the emission level of 2017

CLIMATE POLICY COMMITMENTS CHRONOLOGY

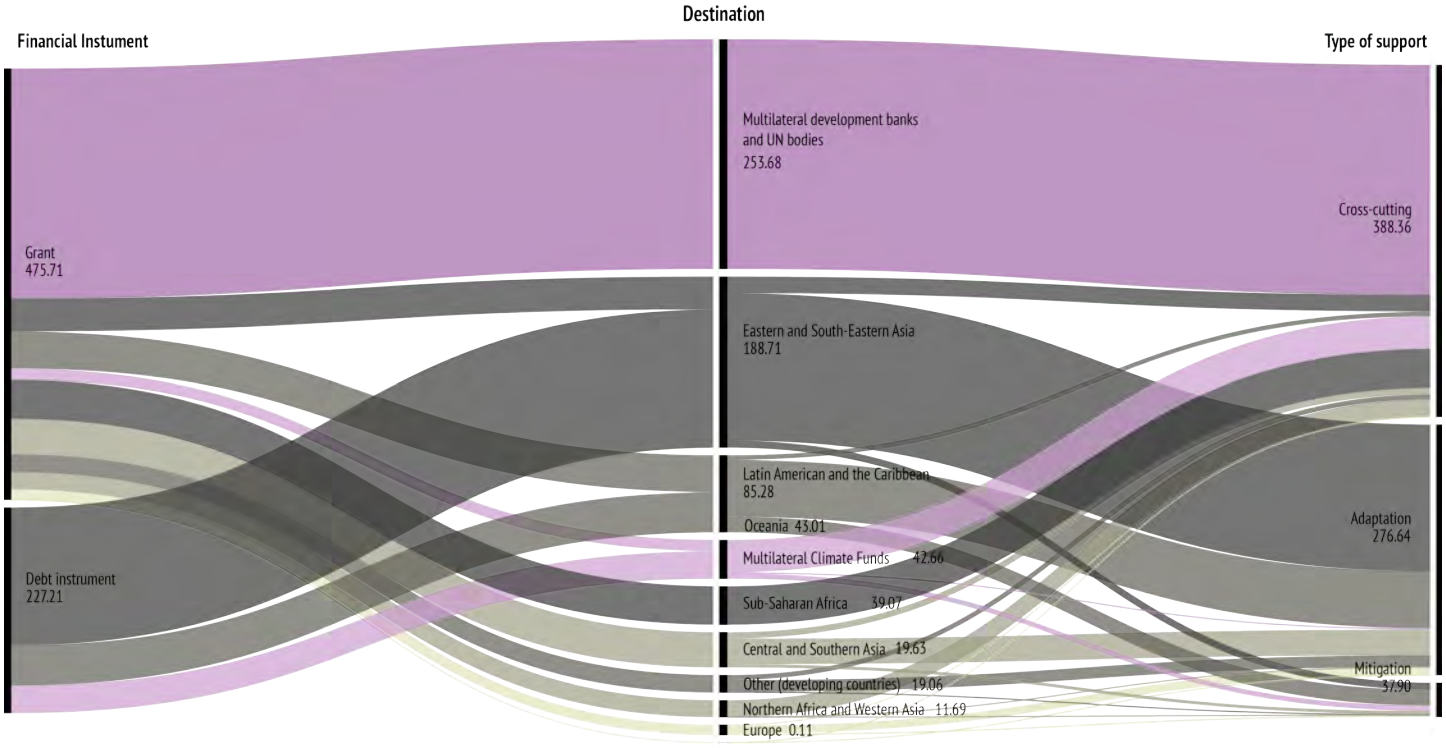
2002 — **KYOTO PROTOCOL - 1ST PERIOD**
No target

2016 — **PARIS AGREEMENT - 1ST NDC**
37% GHG reduction by 2030, with reference to a specific business-as-usual scenario

2020 — **PARIS AGREEMENT - NDC UPDATE**
24.4% GHG reduction by 2030, with respect to 2017 levels

INTERNATIONAL CLIMATE FINANCE ASSISTANCE

The diagram shows climate-related development finance provided by South Korea in 2017-2018. The total amount is 702 million USD, mainly in the form of grants. The majority is directed to bilateral channels, in particular in Eastern and South-Eastern Asia.



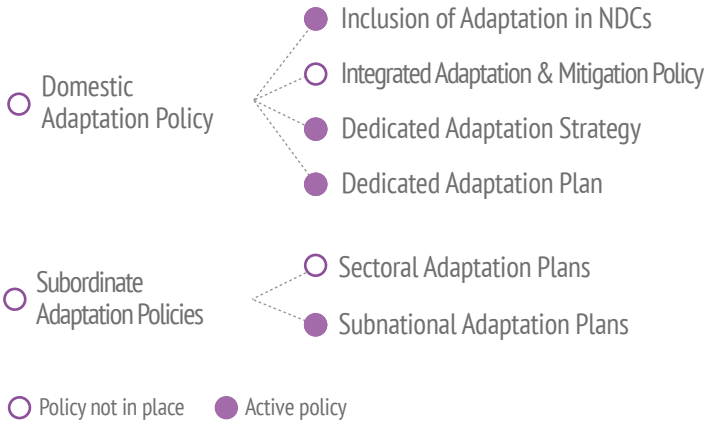
SUSTAINABLE RECOVERY POLICY

The Global Recovery Observatory reports that South Korea spent 685.79 billion USD in 2020. In particular, 186,84 billion USD was devoted to the post-covid recovery. 26,7% of this was dedicated to sustainable recovery, in particular electric mobility, renewable energy, building retrofitting, and nature conservation

685.79 billion $	186.84 billion $	53.97 billion $
Total Spending	Recovery Spending	Green Spending

DOMESTIC ADAPTATION POLICY

South Korea included adaptation in its NDC. The country adopted both a National Adaptation Strategy and a National Adaptation Plan. Sub-national administrations have to develop their own adaptation plan.



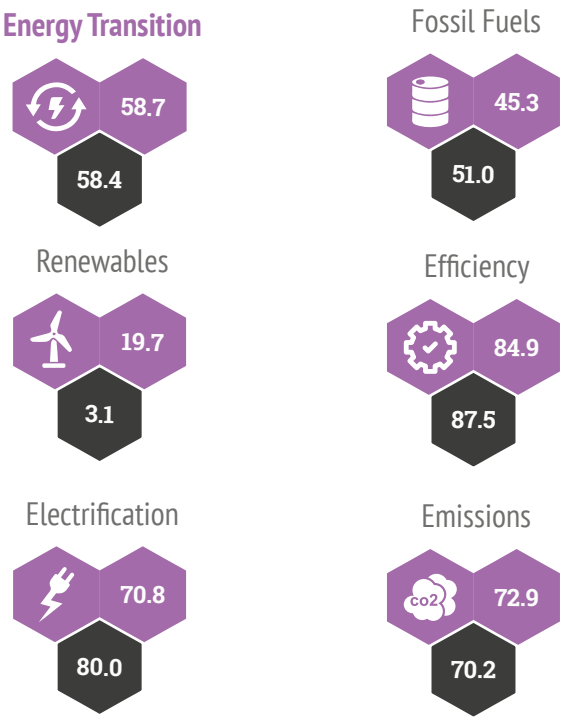
ENERGY TRANSITION

South Korea is performing well in the Electrification and in Efficiency domains, revealing how digitalization is one of the main enablers of the energy transition. However, much still needs to be done in terms of increasing electricity generation from renewable energy sources.

Investing in renewables can also help improve urban air quality and reduce CO2 and other emissions, which hinder the fight against climate change. With regards to the Fossil Fuels indicator, performance is above average.

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

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



ADAPTATION POLICY HIGHLIGHTS

TRANSNATIONAL INITIATIVES

Transboundary Diagnostic Analysis for the Yellow Sea Large Marine Ecosystem

The objective of this regional project is to achieve adaptive ecosystem-based management of the Yellow Sea Large Marine Ecosystem bordered by China, South Korea and North Korea by fostering long-term sustainable institutional, policy and financial arrangements

NATIONAL INITIATIVES

Web-Based Supporting Tool for climate change vulnerability assessment (VESTAP)

The VESTAP is a tool to visualize a full database of impacts and vulnerability assessment. The database includes 455 impacts of future climate data simulated with RCP 4.5 and 8.5, atmospheric environment data and other social statistics

Korea Adaptation Center for Climate Change (KACCC)

KACCC aims to enhance the climate resilience in all the sectors across the country and develop science-based adaption strategies

SUBNATIONAL INITIATIVES

Daegu Climate Change Adaptation Strategies

The "Daegu Climate Change Adaptation Strategies" is an official plan established to seek out vulnerable areas and prepare countermeasures. Daegu has been establishing and implementing these strategies every five years since 2012

Promise of Seoul

The Promise of Seoul is a comprehensive integrated strategy to both mitigation and adaptation. It covers all areas of climate change, including energy, air quality, transportation, resource recycling, water, ecology, urban agriculture, health, safety and urban planning