G20 CLIMATE RISK ATLAS

Impacts, policy, economics

cmcc

SAUDI ARABIA

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

SAUDI ARABIA
CLIMATE

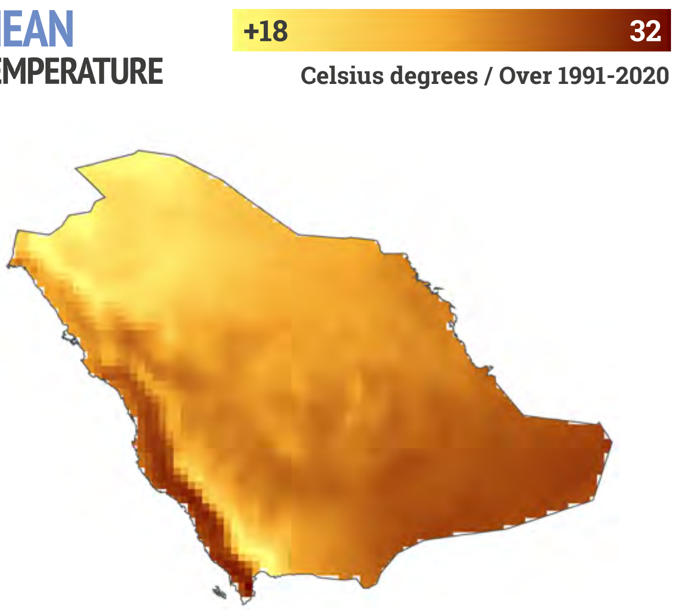
OVERVIEW

Saudi Arabia presents a predominantely desert climate which is extremely hot during the day and then drops in temperature at night. Exceptions include the province of Asir on the western coast, which features a semi-arid climate, and the highlands just north of Yemen, which are characterised by a small area of humid and mild temperature conditions with long summers. These variations are mainly related to the influence of a subtropical high-pressure system.

TEMPERATURE

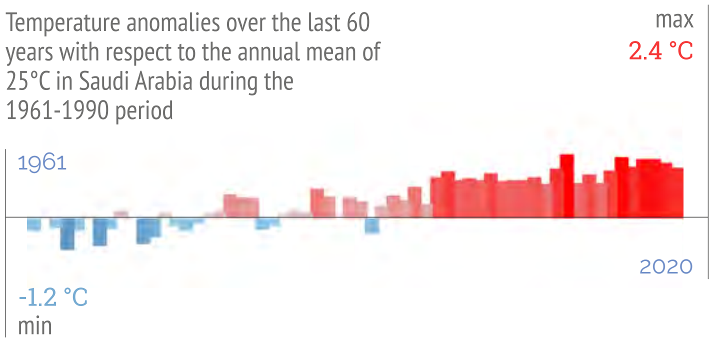
The temperature regime in Saudi Arabia is quite homogeneous with values typical of the desert climate (above 18°C) across the country. The warmest areas are found on the western coast. Summers are very hot throughout the country.

MEAN TEMPERATURE



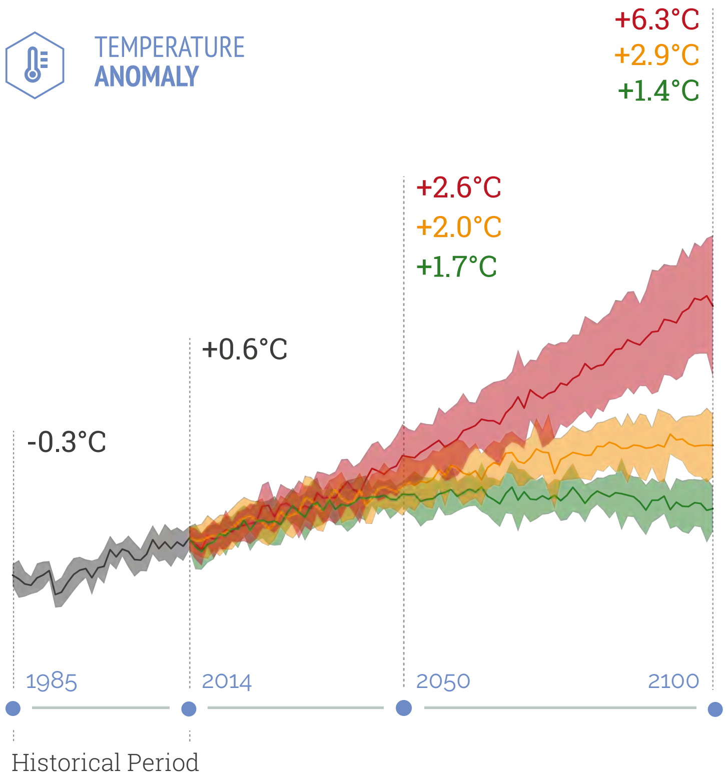
TEMPERATURE TREND

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



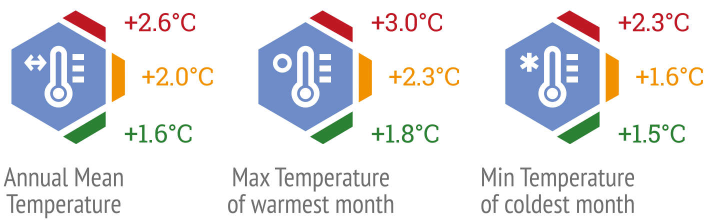
TEMPERATURE PROJECTIONS

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



EXPECTED VARIATION FOR TEMPERATURE AT 2050

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



PRECIPITATION

Saudi Arabia sees little rainfall throughout the country.
However, some weather systems move southward along the Red Sea trough and provide winter precipitation as far south as Mecca and even Yemen. In this specific area, precipitation reaches up to 200 to 250 millimetres per year.
Recently, some cities experienced flooding events which were exacerbated by the country's ongoing urbanization.

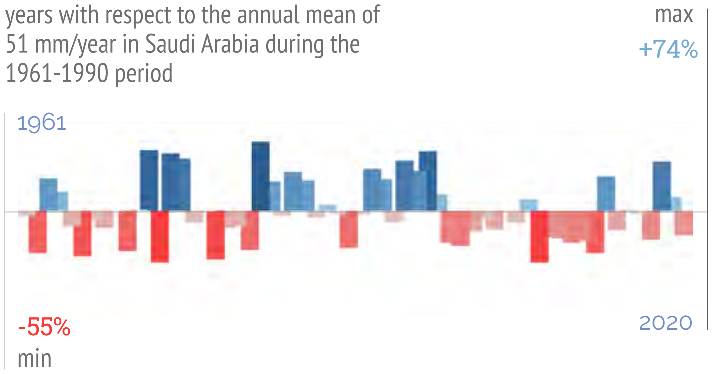
MEAN PRECIPITATION

15 — 885

mm/year / Over 1991-2020

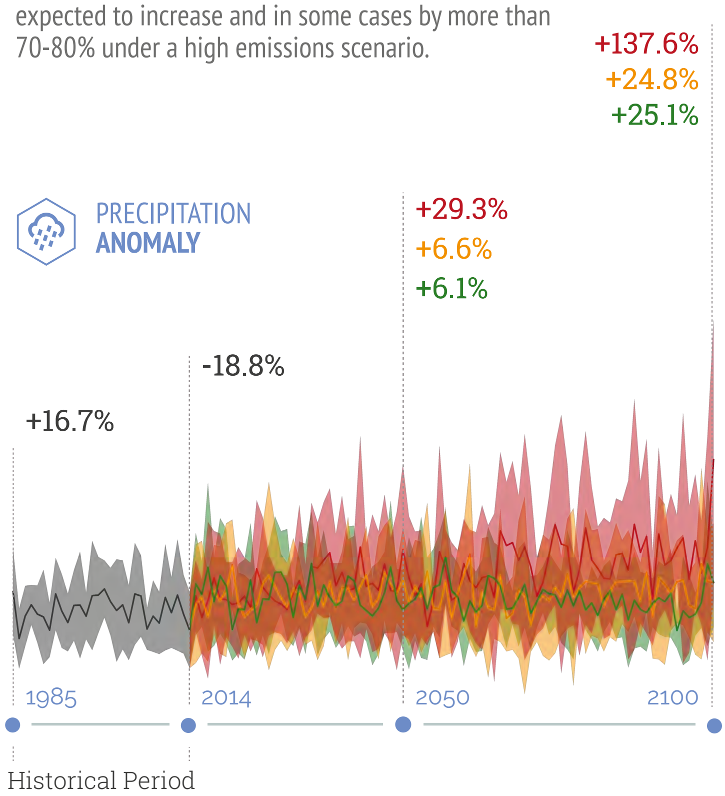
PRECIPITATION TREND

Precipiation anomalies over the last 60 years with respect to the annual mean of 51 mm/year in Saudi Arabia during the 1961-1990 period



PRECIPITATION PROJECTIONS

Precipitation trends show a significant variability also due to the scarce amount of precipitation. The trend is expected to increase and in some cases by more than 70-80% under a high emissions scenario.



EXPECTED VARIATION FOR PRECIPITATION AT 2050

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

Annual total precipitation	+28.3%	+15.9%	+13.6%
Precipitation of wettest month	+30.0%	+16.1%	+12.5%
Precipitation of warmest quarter	+43.5%	+16.2%	+29.2%

VARIATION OF SPECIFIC CLIMATE INDICATORS

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

Agricultural drought proportion of time	% of time	+37%	+23%	+18%
Hydrological drought proportion of time	% of time	+20%	+14%	+11%
Heatwave duration	% of time	+4,242%	+774%	+284%
Runoff increase	% of area	+27%	+13%	+5%
Agricultural drought frequency	% of change	+88%	+58%	+33%
Hydrological drought frequency	% of change	+11%	+9%	+18%
Heatwave frequency	% of change	+100%	+69%	+41%
Runoff decrease	% of area	+9%	+2%	+1%

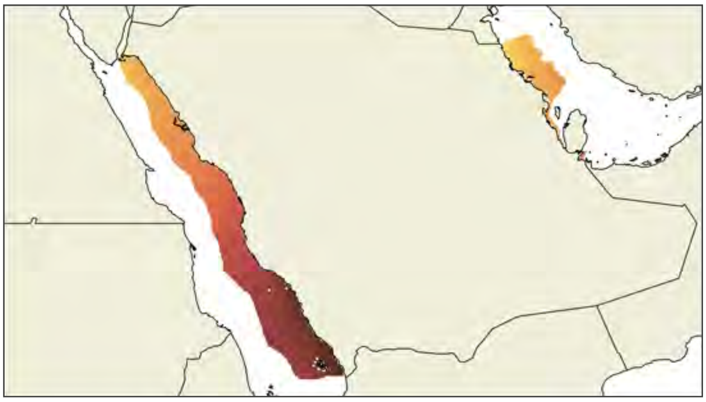
SAUDI ARABIA
OCEAN

OCEAN IN SAUDI ARABIA

Saudi Arabia's marine exclusive economic zone (EEZ) is mainly subtropical with warm water temperatures and a wide ensemble of ecosystems such as mangrove swamps, seagrass beds, and coral reefs. The country's coastal systems are naturally divided into two areas: the Persian Gulf and the Red Sea.

CURRENT CLIMATE CONDITIONS

Mean sea surface temperature reflects the Tropical climate regime, with sigthly colder water in the northern areas.

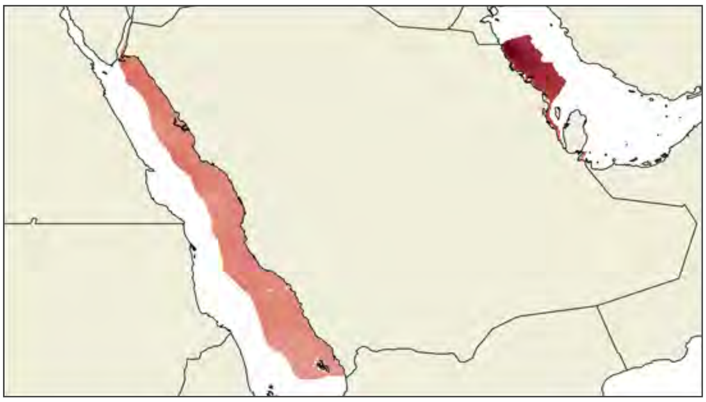


MEAN

SEA SURFACE TEMPERATURE

Celsius degrees / Over 1991-2020

TREND



Surface temperature trends indicate a general warming of 0.3°C per decade in the Persian Gulf , with increased gains up to 0.5°C per decade in the Red Sea.

FUTURE PROJECTIONS

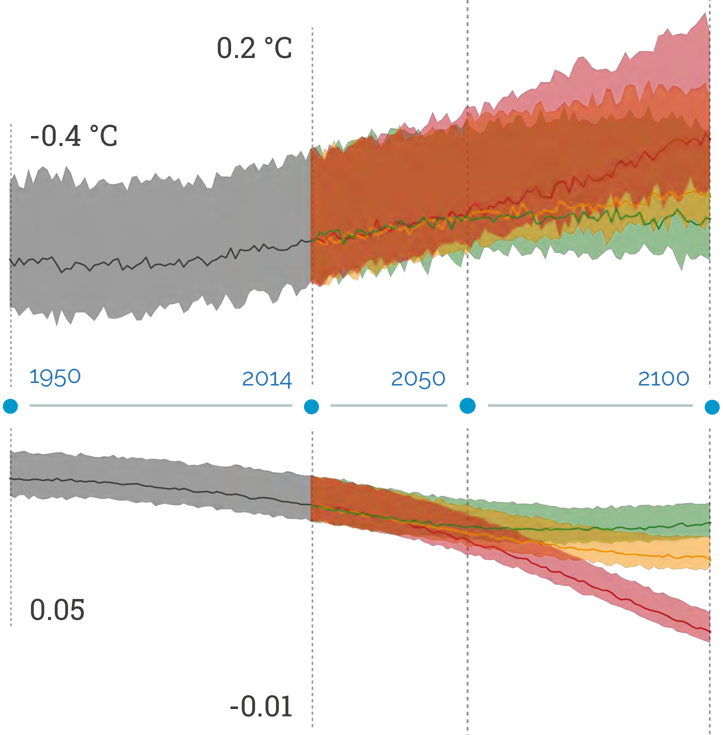
Projected annual changes within the marine EEZ for the two most significant marine indicators of climate change: sea surface water temperatures and pH.

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

+3.9 °C
+2.1 °C
+1.2 °C

SEA SURFACE TEMPERATURE **ANOMALY**

+1.6 °C
+1.3 °C
+1.2 °C



SEA SURFACE pH **ANOMALY**

-0.08
-0.11
-0.14

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

-0.08
-0.17
-0.34

ECOSYSTEM INDICATORS AT 2050

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

Persian Gulf

Red Sea

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

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

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

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

	Persian Gulf				Red Sea			
Temperature	24.64°C	+2.15 °C	+1.73 °C	+1.66 °C	27.69°C	+1.48 °C	+1.18 °C	+1.08 °C
pH	8.13	-0.15	-0.11	-0.09	8.07	-0.14	-0.11	-0.08
Oxygen	208.22 mmol/m³	-3.97 %	-3.08 %	-2.43 %	200.79 mmol/m³	-2.82 %	-2.23 %	-1.59 %
Chlorophyll	0.13 mg/m³	-3.1 %	-15.5 %	+59.69 %	0.12 mg/m³	-0.83 %	-5 %	-7.5 %

FISH CATCH POTENTIAL

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

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

While no specific data is available for the Saudi Arabian EEZ, a decrease in potential catch between 20 and 30% for the Red Sea and between 10 and 20% for the Arabian Sea at mid century have been projected under high emissions scenarios.

ANALYSIS DETAILS

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

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

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

SAUDI ARABIA
COASTS

OVERVIEW

Saudi Arabia is the largest country of the Arabian Peninsula, with a shoreline running approximately 1,760 kilometres along the Red Sea and 560 kilometres along the Arabian Gulf, with over 1,000 islands, and more than 7,000 kilometres of shoreline. Most of the shoreline is bordered by the Arabian Desert, or mountains on the southern part of the Red Sea coast and combines sandy beaches and rocky shores, with lower coastal plains prevalent in the coastal region of the Persian Gulf. Large parts of the Red Sea and some parts of the Persian Gulf coast are bordered by coral reefs, and, to a lesser extent, mangroves. Most of the coastal population is concentrated in the cities of Jeddah and the Dammam metropolitan area.

Shoreline Length — 7,352 km

Sandy Coast Retreat at 2050 — -66.2 m

CLIMATE CHANGE HAZARDS

Coastal hazards such as erosion, storm tide inundation and permanent flooding, can have strong adverse impacts on coastal regions, with loss of sandy shores, damage to settlements, infrastructure and ecosystems. Climate change can exacerbate these impacts due to rising sea levels and increasing impacts of waves and storms. Climate change impacts on the coastal zone of Saudi Arabia are mainly driven by rising sea levels and possible changes in storms intensity and direction affecting the Red Sea and the Persian Gulf. Possible impacts of sea level rise may include salt water intrusion into low lying areas and aquifers, erosion of sandy shorelines and possible inundation of low lying areas, in particular around the Persian Gulf region, characterized by lower coastal sedimentary plains compared to the Red Sea coast. In particular, the urban areas around Damillimetresam are likely to experience the impact of sea level rise.

SEA LEVEL RISE

Relative sea level rise in Saudi Arabia has been observed over the past century with a yearly average increase of 3.74 millimetres per year. More specifically, the Red Sea area has seen a rise of approximately 3.88 millimetres per year, whereas in the Persian Gulf it has been of 3.6 millimetres per year. The latest IPCC projections indicate that, by 2050, global sea levels may rise between 0.18 metres, under a low emissions scenario, and 0.23 metres, under a high emissions scenario.

EXTREME SEA LEVEL

On average, one in 100 extreme sea level events are expected to rise from 0.87 metres at present day to 1.07 metres by 2050 under a medium emissions scenario.

Observed and projected sea level rise at 2050 — 3.74 mm/year; 0.23 m; 0.18 m

Current and projected extreme sea level at 2050 — 0.87 m; 1.15 m; 1.07 m

OBSERVED STORMS

In the northern part of the Red Sea, wind and waves of the same intensity are present throughout the year, whereas the central and southern zones are characterized by a marked seasonality. In general, a decrease in wave energy has been observed in the southern part of the Red Sea, whereas there is uncertainty regarding changes in the central and northern areas. The Persian Gulf wave climate is mainly driven by winds from the north and north-east quadrant, with relatively low variability in the past decades.

FUTURE STORMS

In both the Red Sea and the Persian Gulf, changes in the weather and wind forces may alter the wave climate. In the Persian Gulf, it appears that under a range of climate change scenarios changes in the wave climate will be of low significance, with a decrease of approximately 9.5% by 2100 under a high emissions scenario. On the other hand, the Red Sea is expected to see an increase in wave height by 2100 under the same scenario. It is also clear that rising sea levels will cause an increase in the frequency of extreme sea level events.

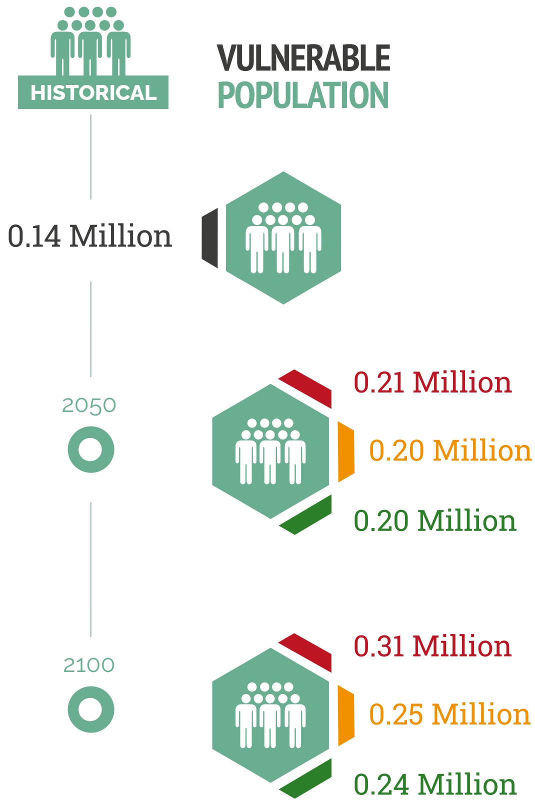
VULNERABILITY AND RISK

Both the Red Sea and Arabian Gulf coast of Saudi Arabia may be impacted by increasing hazards driven by climate change. In the Red Sea, the shoreline is mostly resistant to erosion and inundation by seawater due to its inherent hard nature and the relatively high relief.

However, increasing urbanization may create problems unless new development integrates climate adaptation standards. For example, large parts of Jeddah may suffer from the impacts of sea level rise, including erosion and saltwater intrusion.

The most densely populated area of Saudi Arabia is found along the coast of the Arabian Gulf, with abundant industrial, residential and commercial buildings, and infrastructure situated on lower coastal areas.

Estimates indicate that a 1 metre sea level rise may affect approximately 650 square kilometres of land. Under a medium emissions scenario, the population exposed to the annual coastal flood level is expected to increase from 140,000 to 200,000 by 2050.



INFLUENCE OF SEA LEVEL RISE ON EXTREME SEA LEVEL

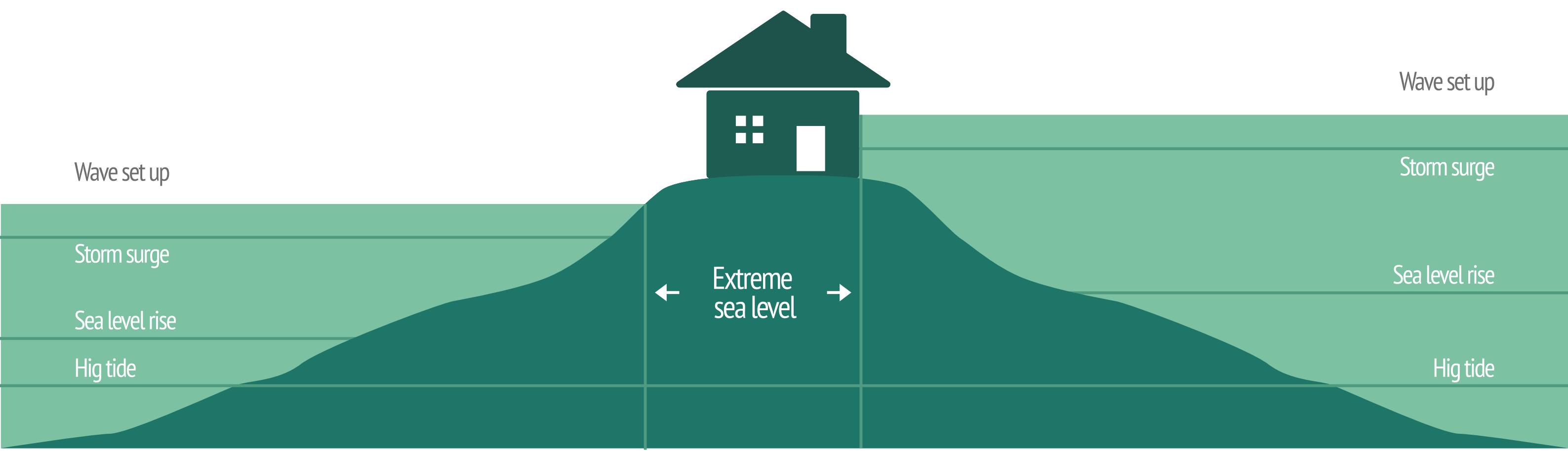
Present and future sea level rise are a consequence of carbon induced global warming causing melting ice and ocean expansion due to heat accumulation.

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

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

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

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



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

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

SAUDI ARABIA
WATER

OVERVIEW

With limited rainfall throughout the year, water resources in Saudi Arabia are relatively scarce. Water supply is distributed between seawater desalination (50% of drinking water supplies), mining of non-renewable groundwater (40%), and surface water from the mountainous southwest of the country (10%).

Although Saudi Arabia does not have any permanent rivers, it does have numerous wadis (valleys) which are riverbeds that occasionally channel flood waters. Most of the historic aquifers have dried up.

Saudi Arabia stores approximately 150 million cubic metres of water in more than 200 dams found in the Wadi Bisha, Wadi Jizan, Wadi Fatima, and Najran among others.

Renewable internal freshwater resources — 2 billion m^3

Renewable internal freshwater resources per capita — 73 m^3

Saudi Arabia's total internal renewable water is estimated to be 2.4 billion cubic metres per year. The water demand in 2009 was 18.51 billion cubic metres, of which 83.5% was used for agriculture. From 2004 to 2009, agricultural water demand decreased by 2.5% per year, and domestic and industrial water demand increased by 2.1% and 2.2% per year. Between 1999 and 2008, domestic water subscribers increased by 22.7%, whereas annual domestic water consumption tripled. Industrial water demands also increased, going from 56 to 713 million cubic metres per year between 1980 and 2009.

CLIMATE CHANGE HAZARDS

Climate change is an important factor for sustainable water resource management in arid and semi-arid countries, and it can affect water resources due to rising temperatures, higher rates of evapotranspiration and altered rainfall patterns. This leads to changes in the water cycle, alterations of surface runoff and groundwater storage, as well as drought and flood occurrence.

The demand for water resources has been increasing in Saudi Arabia in recent decades due to a large population increase, from approximately 5 million in the early 1970s to almost 35 million at present day. This is the main water risk driver, which, coupled with future climate change, can challenge the sustainability of water resources use in the country.

KEY POINT RUNOFF

The source of surface water in Saudi Arabia is seasonal precipitation. The largest quantity of runoff occurs in the western region, which represents approximately 60% of total runoff, although it covers only 10% of the total area of the country. The remaining 40% of runoff occurs in the far south of the western coast covering 2% of the total area. The total runoff in Sudi Arabia is estimated ar 2.2 billion cubic metres per year, most of which infiltrates to recharge the shallow aquifers located along the river valleys and beneath the alluvial fans and plains in various areas.

Changes in runoff may also be influenced by the increasing urbanization and population in the country, with a strong linear correlation between the level of urbanization and both peak discharge and runoff volume. According to modelled projections, an increase in temperature by 1°C and 5°C may reduce surface runoff by 115-184 million cubic metres and 600-960 million cubic metres per year respectively. If temperatures rise by 1.5°C, 2°C or 4°C, 1%, 2.1% or 9% of the area of the country will likely experience an increase in runoff, while 5%, 12.7% or 27% of the surface of the country will likely experience a decrease in runoff, respectively.

2050 — Changes in annual runoff, % of change: -42.0% / -6.0%

2050 — Runoff increase, % of area: +9.0% / +1.0%

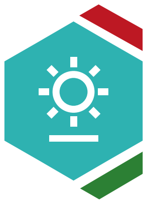
KEY POINT DROUGHTS

Drought events in Saudi Arabia occur mostly due to a deficit of rainfall in the dry season (June to September). The past decades have been influenced by climate change, with annual rainfall below normal for 25 years out of 40, with severe droughts occurring 28% of the years between 1978 and 2017.

Climate change will affect rainfall and consequently droughts in Saudi Arabia. It is estimated that rainfall in the northern part of the country will decrease by an average of 10 millimetres per year, exacerbating the existing drought conditions. In contrast, precipitation in the central and southern regions may increase by 2050. Despite increased rainfall in some areas, evapotranspiration is also expected to increase during this same time, and less than half of the water lost to evapotranspiration will be replenished by rainfall, leaving surface water resources still limited.

2050

Severe drought likelihood increase
% of change



+49.0%

+27.7%

2050

Hydrological drought frequency
% of change

+11.0%

+9.0%

2050

Groundwater Recharge
% of change

-29.3%

+21.4%

KEY POINT GROUNDWATER

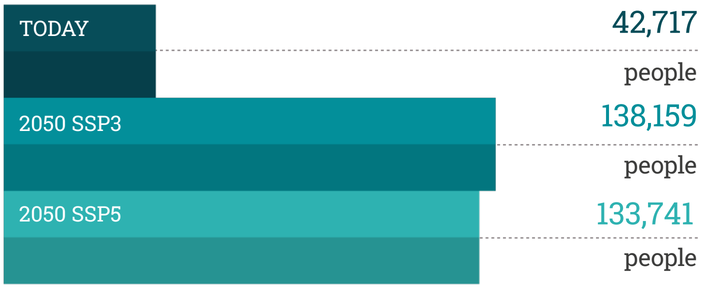
Non-renewable groundwater reserves in Saudi Arabia are estimated to be 259.1-760.6 billion cubic meters with an effective annual recharge of 886 million cubic meters. 80% of water supply demand is met through groundwater. In the past three decades, groundwater exploitation in Saudi Arabia has increased, reaching 17 billion cubic metres per year. The net annual groundwater recharge is very low compared to the rate of withdrawal, with the declining groundwater levels also impacting water quality. Global warming will affect rainfall and temperature, which can have effects on groundwater reserves. In the near future, there will be less groundwater in Saudi Arabia due to the impact of climate change and the increase in annual temperature. For example, by 2050 under a medium emissions scenario there will be a possible reduction in rainfall by about 20% in the northern areas where most of the groundwater reserves are concentrated, with impacts on their potential to recharge. At the country level, a -0.4%, -5.1% and -29.3% change of the annual groundwater recharge for the period 2045-2055 compared to the timeframe 2015-2025 is expected respectively under low, medium and high emissions scenarios.

KEY POINT FLOODS

Floods in Saudi Arabia are rare, however hazardous flash flooding has caused widespread damage and loss of life in the past in numerous urban areas. The desert city of Riyadh, capital of the Kingdom and home to 7.6 million people has been hit by more than ten flash floods in the past thirty years, resulting in more than 160 deaths. Desert urban centres are more at risk in the absence of rivers and drainage outlets to sea, and with rapid population growth, urbanization, and transformation of large areas of sandy desert into concrete, increasing surface runoff speed and volume.

Extreme daily precipitation is expected to change by the middle of this century 2050, with an increase over the western parts of Saudi Arabia in August, particularly along the coast of the Red Sea and surrounding the Asir Mountains, and a reduction over approximately the same area in November. Other areas are expected to experience changes in extreme rainfall, however the trends vary across the country.

POPULATION AFFECTED BY RIVER FLOODS

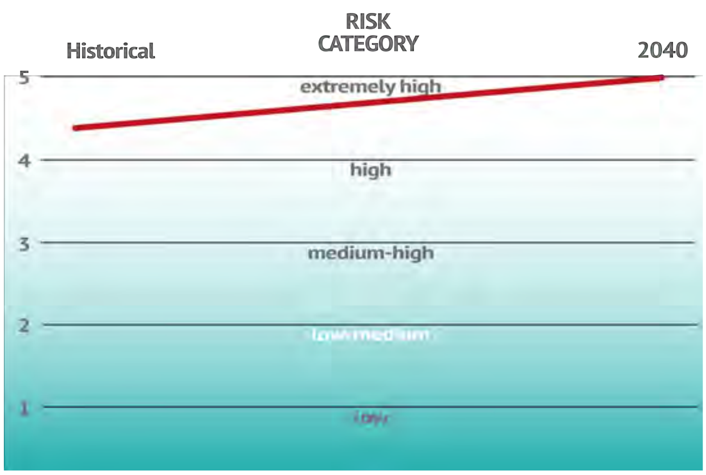


RISK INDICATORS

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

WATER STRESS

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



SAUDI ARABIA AGRICULTURE

OVERVIEW

The Kingdom of Saudi Arabia is characterized by arid to semi arid climates, due to low rainfall and extremely high temperatures. Agriculture contributes only a small share of national GDP.

Less than 2% of country's land is arable and used for crops, of which half is rainfed dry farming (mostly in Asir), two-fifths is used for tree crops and the remainder is intensively used for irrigated agriculture in several districts, such as Riyadh, Al-Qa īm, Al Jawf and near Al-Hasa, for instance. Saudi Arabia is a top producer and exporter of dates, second only to Egypt. The main cultivated grain is wheat, with production covering domestic self-sufficiency. Other cultivated crops include barley, sorghum, maize, vegetables and fruits. Agriculture consumes more than 80% of total water withdrawal, mostly from groundwater resources.

1.4 Mt
Dates

0.5 Mt
Wheat

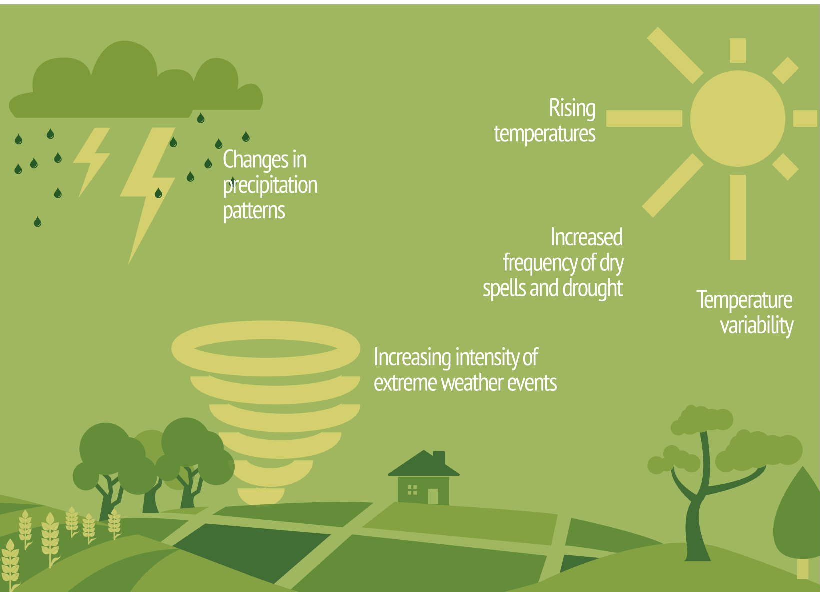
0.5 Mt
Barley

0.7 Mt
Fresh Fruits

	Added Value of Agriculture, Forestry and Fishing	Share of Agriculture Value added in Total GDP	Agricultural land	Area Equipped for Irrigation
2000	12,032 USD Million	3.3 %	3,785 Thousand HA	1,616 Thousand HA
2018	17,416 USD Million	2.6 %	3,629 Thousand HA	1,620 Thousand HA

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.

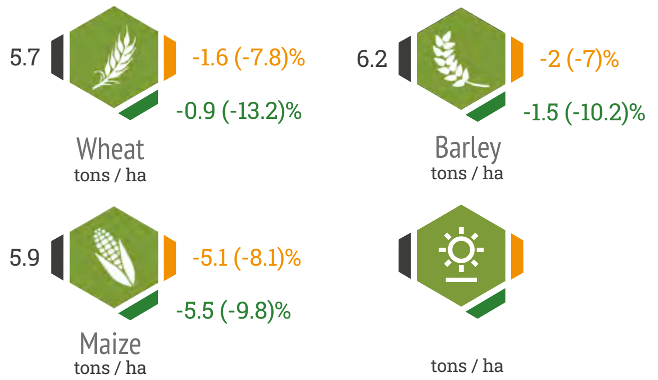


CROP PRODUCTIVITY

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.

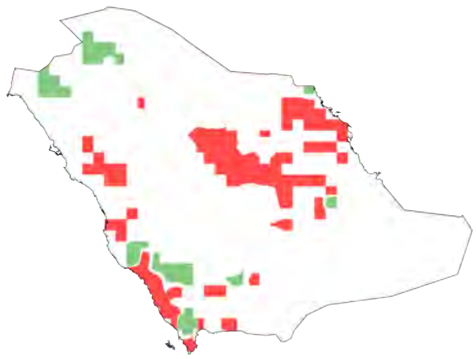


2050

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.

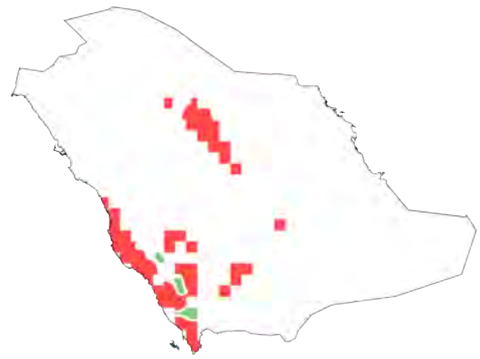
CHANGE IN WHEAT

– = +



CHANGE IN MAIZE

– = +



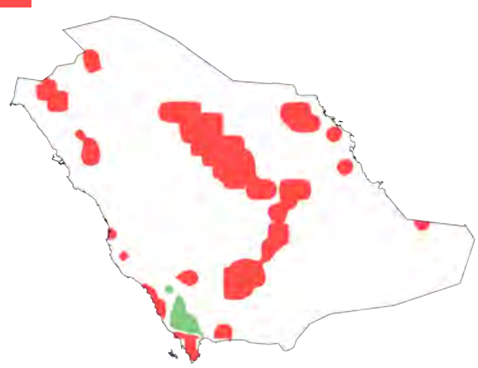
Almost 95% of Saudi Arabia will remain climatically suitable for date palm cultivation in the coming decades. However, a significant reduction in climatic suitability is expected towards the end of the century. Increasing temperatures will severely affect the yield of wheat, barley and sorghum especially in warmer areas and at lower elevation. Crop production is particularly vulnerable to temperature and water availability during the grain maturing stage. Climate risks for wheat productivity and yield stability are more limited for early-maturity varieties of wheat or wheat planted at earlier dates, since these may avoid high-temperature stress (above 30°C) at flowering. Potato cultivation is expected to increase slightly in productivity (5 to 8%).

ADAPTATION IN AGRICULTURE AND WATER RESOURCES

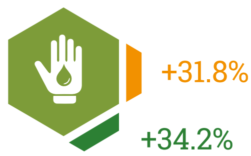
Saudi Arabia has implemented generous subsidies that favor domestic food crop production through irrigation development. Cereal production relies entirely on irrigation and available water resources. Higher future temperatures will, in general, increase water demand for agriculture. Most water withdrawal is from groundwater resources which are difficult to renew in the short term, causing a major depletion of underground water aquifers. There is a growing recognition for the need to promote sustainable water uses that can secure finite water resources over the long term.

CHANGE IN WATER DEMAND

– = +



Agriculture Water Demand
% of change



2050

It will be essential to promote water use efficiency, crops and cultivars with lower water demand and the use of treated wastewater in the irrigation of permitted crop systems.

SAUDI ARABIA FORESTS

FORESTS IN SAUDI ARABIA

Forest areas in Saudi Arabia are currently very limited, except for mangroves in coastline areas. These ecosystems are crucial to the carbon cycle ("blue carbon").

FORESTED AREA AND CARBON STORAGE

Mangroves absorb carbon from the atmosphere, which is then stored in the living biomass and the sediments of coastal areas known as "blue carbon". Worldwide, mangrove deforestation contributes to approximately 0.3% of total anthropogenic CO_2 emissions making this phenomenon a climate change accelerator. Mangroves can be considered the most important forest ecosystems of Saudi Arabia. Their distribution is patchy and fragmented and they do not form continuous populations. They are generally restricted to bays, narrow channels, and inland faces of offshore islands. In recent decades the total coverage of Saudi Arabia's Red Sea mangrove forests, which is larger than those of the Persian Gulf, is increasing. These forests grow in the most unfavorable conditions (high salinity values, rivers non-existent, rainfall minimum, hard bottom and very oligotrophic sea), which makes them very vulnerable. Land use changes, in particular the conversion into shrimp farms, rising population, coastal development, industrial waste and effluents and many other factors, contribute to the loss of carbon stock. Furthermore mangroves cannot survive rapid sea level rise.

	Forested area	Carbon stock
1990	1 Mln ha (Million hectares)	51 Tons/ha (Tons of Carbon per hectare)
2020	1 Mln ha (Million hectares)	51 Tons/ha (Tons of Carbon per hectare)

FIRES IN SAUDI ARABIA

During the last two decades, the total land area affected by fire was approximately 2,880 hectares.

BURNING
2.9 THOUSAND HECTARES

EMITTING
0.015 TERAGRAMMES OF CARBON PER YEAR

AGRICULTURE FIRE EMISSIONS CONTRIBUTED TO 50% OF TOTAL FIRE RELATED CARBON EMISSIONS

CASE STUDY: WILDFIRES

In October 2020 a wildfire in the Asir region threatened high value juniper woodlands. Wildfire impacts on vegetation differ across tree species, affecting recovery and the services they provide. Analysis carried out in western Saudi Arabia after forest fires revealed that species such as Acacia origena recover much better than junipers and oleas. Therefore, climate change impacts on fire regimes should be kept in mind in order to safeguard services provided by specific forest types such as the cultural and touristic value of juniper forests.

FUTURE BURNED AREA

Under a low emissions scenario, models project a generalized decrease in burned area. This trend might be emphasized under a medium emissions scenarios, and is more pronounced in central and western areas.

Burned Area
km² per year

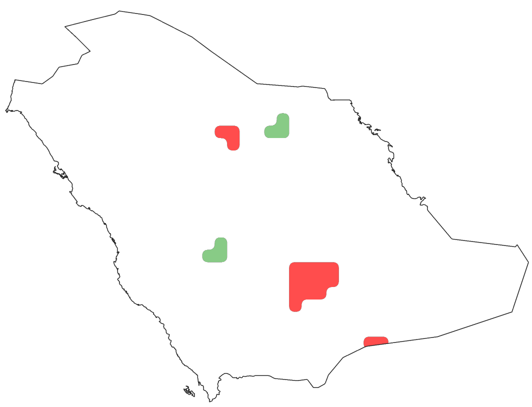
2050

-124

-81

Decrease in burned areas for a low emissions scenario in 2050

Increase in burned areas for a low emissions scenario in 2050



SAUDI ARABIA URBAN

OVERVIEW

In Saudi Arabia, 80% of the population lives in urban areas, a number which has increased by 170% since 1960. However, growth rates are slowing down, with an urbanization rate of 90% expected for 2050.

25% of the urban population lives in the only agglomeration with more than 5 milion inhabitants, the capital city, Riyadh. Future growth is expected in cities, with Jeddah reaching the 5 million inhabitants threshold by 2035.

Built up areas cover only 0.32% of Saudi Arabia (6,175.21 square kilometers).

Population in Urban Areas

2020: 29,255,576

2050: 34,142,975

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

Urbanization Rate

2020: 84.3%

2050: 90.4%

OVERVIEW OF KEY CLIMATE IMPACTS IN URBAN AREAS

Saudi Arabian cities are mainly vulnerable to the impacts of heatwaves, flooding following rare events of intense rainfall, and sea level rise.

HEATWAVES AND HEAT STRESS

Temperatures in Saudi cities are increasing, also due to the transformation of urban morphologies. Heat related health impacts from rising temperatures in cities are worsened by high levels of air pollution.

In 2017 all urban areas in Saudi Arabia registered unsafe levels of the air pollution indicator PM 2.5. In 2015, PM 2.5 concentrations (106·2 µg/m3) were the second highest in the world after Qatar. Air pollution shortens average lifespan in the country by 1.5 years.

Increasing mean and summer temperatures, and duration of heatwaves are expected for the whole country. Under a scenario of 4°C warming, duration of heatwaves could increase by more than 4,000%.

Frequency, intensity and duration of heatwaves may be even higher for urban areas due to the difficulties of large scale models in capturing the specific urban geography and representing the urban heat island effect under all scenarios considered.

Cooling Degree Days (% of change), 2050

+51.4%

+21.7%

+15.9%

Heatwave frequency (% of change), 2050

+99.6%

+68.7%

+40.8%

Heatwave duration (% of time), 2050

+4,242%

+774%

+284%

RAPID URBANIZATION

Traditional Saudi Arabian cities with narrow streets provide protection from extreme temperatures during daytime and help cooling down during night time, leading to lower temperatures than the surrounding desert areas. Saudi Arabia's massive urbanization has adopted western urban models with wider and asphalted streets.

As a result, surface temperatures in most urban areas of Riyadh have continued to increase between 1985 and 2015, approaching desert values. High temperatures in urban areas worsen the impact of high levels of air pollution. In 2017, the entire population was exposed to pollution levels above WHO thresholds.

2017

Population exposed to air pollution 100.0%

COASTAL FLOODING

Just under 5% of all urban residents live in areas that are less than 5 meters above sea level. Several major cities are situated along the coastlines of the Gulf of Persia and the Red Sea, among these, the country's second largest city, Jeddah. Development along the coastline is growing at a pace of 1% per year, putting further assets at risk from coastal inundation.

Projected sea level rise

2050: 0.23 m / 0.18 m

2100: 0.77 m / 0.38 m

FLOODING

Despite low mean precipitation values, Saudi Arabian cities are exposed to flood risks from occasional intense precipitation. A flash flood which hit the city of Jeddah in 2009 caused more than 100 victims and destroyed entire settlements. Victims were situated mainly in the unplanned expansion areas of the city, which coincide with valleys and temporary water courses (Wadis) conveying additional water masses as run-off from the mountains.

Projections for future precipitation patterns show relatively small increases in annual mean, versus significant increases in mean values for the warm season. These mean values cannot seize short term intense precipitation events like the one described for Jeddah, which are expected to become more frequent and can cause major damage, particularly in exposed and unplanned areas around the cities.

2050

Runoff increase
% of area

+9%
+2%
+1%

SURFACE SEALING AND FLOODS

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

UNCONTROLLED URBANIZATION

Unplanned expansion of cities and urbanization of flood prone areas such as temporary water courses (Wadis) and low lying coastal areas, increases exposure of urban assets to extreme events.

According to World Bank data, in 2018, 16% of the urban population lived in informal settlements.

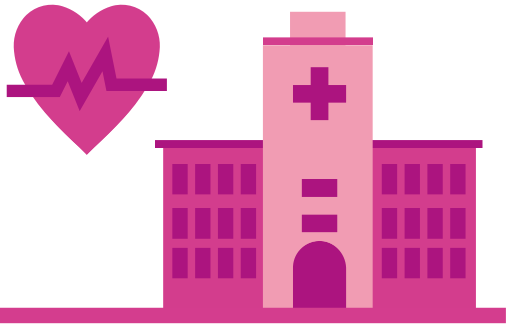
2010

% of urban population
Population living in slums 16.2%

2018

% of total population
Urban population living in areas where elevation is below 5 meters 4.6%

SAUDI ARABIA
HEALTH



OVERVIEW

Saudi Arabia has warmed at a 50% higher rate than the rest of the landmass in the Northern Hemisphere. The most significant health impacts connected to this change will likely occur from heat-related mortality, given the high-temperature increases expected.

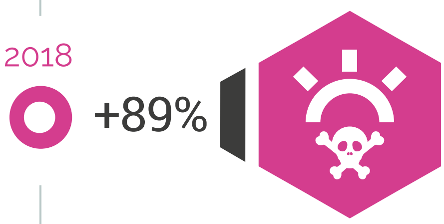
Rising temperatures are likely to increase thermal stresses and extreme weather disasters resulting in increased mortality. Elevated ambient temperatures and humidity are also projected to increase incidences of vector-borne diseases such as malaria.

HEAT RELATED MORTALITY

Thermal discomfort has increased in most parts of Saudi Arabia from 1990 to 2018. In 2018, there was an 89% increase in heat-related deaths in Saudi Arabia compared to the 2000 to 2004 baseline.

Heat-related mortality

% change with respect to 2000-2004



IMPACTS ON LABOUR

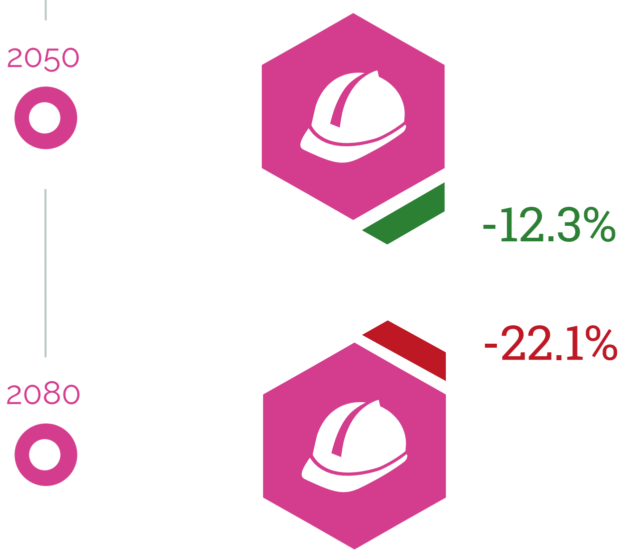
Labour is directly affected by changes in environmental conditions. Warming affects both the number of hours worked (labour supply) and on the productivity of workers during their working hours (labour productivity). Both labour supply and productivity are projected to decrease under future climate change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

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

Total labour is expected to decline by 12.3% under a low emissions scenario, and by 22.1% under a medium emissions scenario.

Impact on total labour

% change with respect to 1986-2005 baseline



CLIMATE CHANGE AND DENGUE

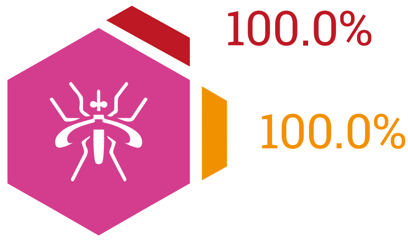
Dengue has spread throughout the tropical world over the past 60 years and now affects over half the world's population. Globally, vectorial capacity for both dengue vectors (A. aegypti and A. albopictus) has been rising steadily since the 1980s, with nine of the ten highest years occurring since 2000.

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

Dengue suitability

% of population at risk

2050



CLIMATE CHANGE AND ZIKA

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

DENGUE AND ZIKA: POPULATION AT RISK

Nearly all of Saudi Arabia's population will be at risk of transmission-suitable mean temperature for dengue and Zika by 2050 under both medium and high emissions scenarios.

Zika suitability

% of population at risk

2050

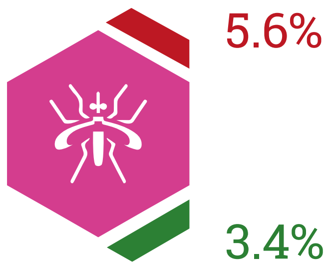
CLIMATE CHANGE AND MALARIA

Though Saudi Arabia has managed to reduce malaria transmission, the changing climate is projected to bring an increase. 3.4% of the Saudi Arabian population will be at risk of malaria under a low emissions scenario in 2050, whereas 5.6% will be at risk under a high emissions scenario.

Malaria suitability

% of population at risk

2050



POLLUTION AND PREMATURE MORTALITY

In 2017, annual deaths attributable to PM2.5 were estimated at 8,536, representing 9% of the total annual deaths in Saudi Arabia. 315,200 disability-adjusted life years were attributable to PM2.5.

SAUDI ARABIA ENERGY

ENERGY SYSTEM IN A NUTSHELL

Saudi Arabia owns 17.2% of world oil reserves. Oil is the focus of its economy and the main source of wealth, and dominates exports and internal energy use. Energy production in 2018 was 3 times total primary energy supply.

The Saudi government is aware of the need to diversify away from oil in a decarbonizing world: in March 2021, it announced the target of generating 50% of its energy from renewables by 2030, investing massively in solar power generation.

0.14
ktoe/US$
Energy intensity

72.0%
AC Share in electricity consumption

ENERGY SUPPLY

In Saudi Arabia, 84% of the energy produced is exported. Domestically, oil (62.7% in 2018) and to a lower extent, natural gas (37.2%) account for almost the totality of energy supply, leaving a meagre 0.01% to renewables (mainly solar pilot projects and biofuels). There is no hydropower generation of any significance in the country.

CLIMATE CHANGE TODAY

INCREASING TEMPERATURES

Summer temperatures in Riyadh increased by 2.65 to 3.07°C between 1980 and 2020. This called for extra epower capacity to cope with increasing demand, and in 2015 about 1.2 gigawatts of electricity were added for every 1°C increase.

OIL AND GAS

Thus far, oil and gas infrastructures has shown remarkable resiliance to extreme temperatures.

ENERGY DEMAND

In Saudi Arabia, energy is used mainly by industrial sectors (53% of total final consumption in 2018, including non-energy uses accounting for 20% of total demand), transport (31% of final demand), residential demand (9%) and the tertiary sector (7,4%), whereas agriculture has a slim 0.8% share. Air conditioning's contribution to residential electricity demand is extremely high: 72% in 2017.

FUTURE ENERGY DEMAND

Overall projected demand in Saudi Arabia will increase due to increasing cooling needs, reaching about 853 PJ (237 billion Kwh) by 2050 under a medium emissions scenario.

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

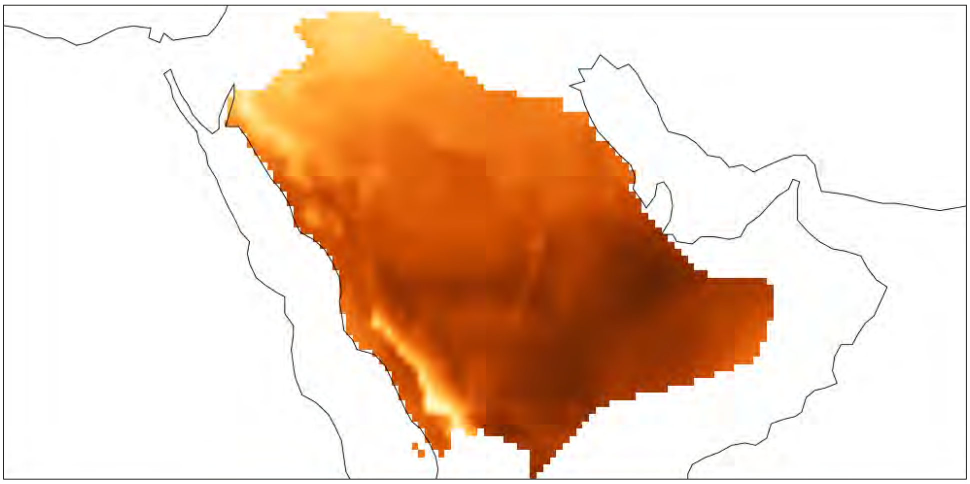
2050

+ 237.09

COOLING NEEDS

Extreme increases in cooling needs are expected all over the country, particularly in the south. The minimum projected anomaly (280 CCD) is 66 CCDs higher than the maximum anomaly for Germany.

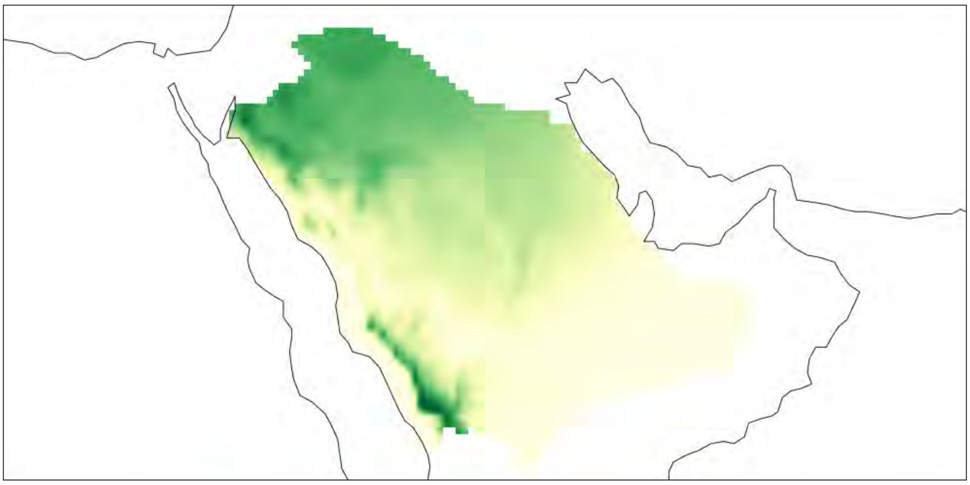
COOLING DEGREE DAYS



HEATING NEEDS

Moderate decrease in heating degree days are expected in the north and on the Red Sea coastal range (Asir region, with the city of Abha, hosting a population slightly over 1 million and a popular destination for domestic tourism).
Negligible changes in the rest of the country.

HEATING DEGREE DAYS



FUTURE ENERGY SUPPLY

The future configuration of the Saudi Arabian energy mix is likely to be determined by the evolution of the country's energy policies and hence is outside the scope of this report.

Saudi Arabia has historically shown a low degree of interest in decarbonization, but the recent target on renewables may imply some significant, albeit still minoritarian, diversification away from fossil fuels for internal energy uses.

This is likely to result in fossil fuels (and their vulnerabilities) keeping their relevance for the next couple of decades, while carbon free sources and their vulnerabilities will probably gain relevance from 2030 in the second half of the century.

EXPECTED IMPACTS OF CLIMATE CHANGE

To the best of our knowledge, there are no country-specific studies on climate change impacts on Saudi energy infrastructure. Increasing frequency of flash floods caused by heavy precipitations, coastal storm surges, and increasing frequency of sandstorms- all phenomena expected for Saudi Arabia under a changing climate - are likely to pose threats to such infrastructure.

SAUDI ARABIA ECONOMY

OVERVIEW

Saudi Arabia ranks 17th in terms of GDP in the G20 group. The COVID 19 crisis had a severe impact on the economy, whereby in 2020 real GDP declined by 4.1%. This trend has been reversed and in 2021 real GDP has grown by 2.9%.

IMPACTS ON GDP

There is a high degree of variability across macroeconomic estimates of the overall economic impact of climate change for Saudi Arabia.

They range from increase in GDP per capita (0.26%) under a low emissions scenario in 2030 to a loss in GDP potentially larger than 12% in 2050 under a high emissions scenario.

2050

1.05/12.2%

-0.38/4.8%

GDP Loss

% change w.r.t baseline

2100

3.35%

0.78%

SECTORAL ECONOMIC IMPACTS

IMPACTS ON INDUSTRY AND INFRASTRUCTURE

Floods and sea level rise can pose a significant threats to infrastructure located along the coast. This can be particularly problematic for coastal infrastructure that is instrumental to Saudi Arabia's import-export activities, such as harbours, fossil fuel terminals, and refineries.

A key coastal infrastructure for the Saudi Arabian economy and society is water desalination: 50% of the national water demand is met by desalinated water. Saudi Arabia holds 15% of the world's desalination capacity. Desalination plants are usually regarded as an adaptation tool to tackle water shortages caused by climate change. However, if the salted brine resulting from the process is not treated sustainably, it may result in severe pollution of the sea water in which it is discharged, and hence result in maladaptation.

Salt brine has intrinsic economic value as source of salt and metals, however, 80% of salt brine from coastal plants is discharged back into the sea. An interesting feature of desalination plants is that, in areas with high levels of insolation, they can be operated using solar energy instead of fossil fuels. This provides to fossil-fuel-rich, tropical countries such as Saudi Arabia with an interesting opportunity to promote faster decarbonization.

FLOODS DAMAGES

Floods can result also from sudden and intense precipitations all over the country and generate significant damages.

The 2009 flooding of Jeddah, caused by intense precipitation and compounded by the inadequacy of the drainage system, caused 150 deaths and high, but unquantified, economic losses to private properties, transport infrastructure and means of transport.

IMPACTS ON AGRICULTURE

Despite the prevalence of a desertic or very hot and dry climate, agricultural production does take place in Saudi Arabia in suitable areas and accounted for 2.2% of GDP in 2019. There are no projections available about the economic impacts on this sector, only qualitative inferences can be drawn from agronomic studies.

Overall, by the end of the century yields of fruit trees and crops will drop by 5% to more than 25%. Dates are a very relevant crop in Saudi Arabia, both as a key ingredient of the local diet and as an export cash crop: in 2109 Saudi Arabia was the second world producer of dates, with over 1.5 million tons in 2019 and the fourth world exporter with almost 230 million USD in exports.

A recent study finds that, whereas by 2050 most (95%) of the land currently suitable for dates palm tree cultivation will still be able to support this crop, by 2100, the suitable land for the cultivation of dates may shrink substantially, to 25% - 15% of its current extent, and this is likely to turn Saudi Arabia into a net importer of dates – with an almost complete loss of revenues from the exports of this crop.

IMPACTS ON ENERGY

As with all other economic sectors, energy supply and energy networks in Saudi Arabia will undergo more intense stress from extreme weather events, in particular the increasing occurrence of sand storms, and sea level rise for coastal oil and gas terminals and refineries.

Economic impacts of shifts in household and firm energy demand (see chapter on energy) are difficult to predict and will mostly lead to redistribution effects. In the case of Saudi Arabia, the already pervasive cooling needs will further intensify, bringing about a likely significant increase in energy bills.

IMPACTS ON TOURISM

The tourism sector, which accounts for about 7% (1.6% in terms of direct receipts only) of Saudi Arabia's GDP can in principle be affected by climate change.

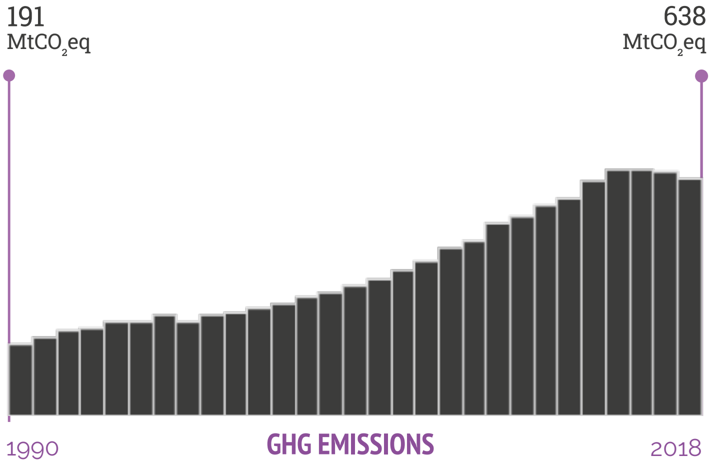
This can happen directly, through the impact of changing climatic features on the thermal comfort of tourists; and indirectly through the impact of increased chances of extreme events or worsened ecosystem conditions, and, consequently, on the attractiveness of the destination. In a hot country like Saudi Arabia outdoor climatic conditions from the human comfort's point of view are already sub-optimal and projected to worsen substantially in the future.

Nonetheless, the vastly predominant motivation to visit Saudi Arabia is religious since the destinations of the hajj, the traditional Muslim pilgrimage, are located in this country. Accordingly, the number of visitors is not expected to vary significantly due to climate change. However, health issues due to increasing temperatures are expected to become more frequent, particularly during the 2040's when the hajj will take place during summer months.

SAUDI ARABIA
POLICY

OVERVIEW

In 2018, Saudi Arabia was the 13th largest emitter among G20 countries. However, it was also 3rd in terms of emissions per capita. Although Saudi Arabia's emissions have grown massively in recent decades, since 2016 they have slowly started to decrease.



INTERNATIONAL COMMITMENTS

Saudi Arabia ratified the Paris Agreement in 2016. According to its NDC, Saudi Arabia is committed to reduce its yearly emission by 130 $MtCO_2eq$ between 2021 and 2030.

CLIMATE POLICY COMMITMENTS CHRONOLOGY

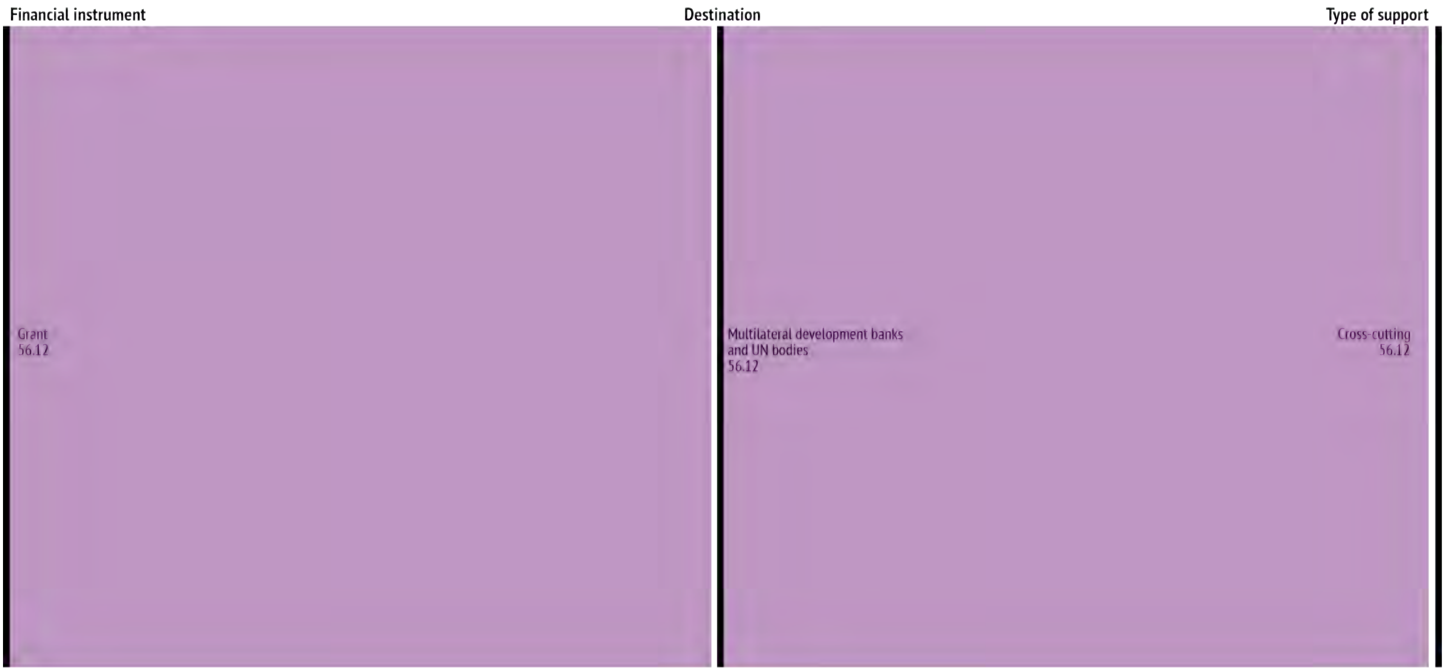
2005 — **KYOTO PROTOCOL - 1ST PERIOD**
No target

2016 — **PARIS AGREEMENT - 1ST NDC**
An annual abatement of 130 $MtCO_2eq$ between 2021 and 2030

PARIS AGREEMENT - NDC UPDATE
No further update

INTERNATIONAL CLIMATE FINANCE ASSISTANCE

OECD DAC data on climate-related development finance shows that Saudi Arabia provided 56 million USD in 2017-2018. This sum is devoted entirely to multilateral institutions and it addresses cross-cutting initiatives.



SUSTAINABLE RECOVERY POLICY

According to the Global Recovery Observatory, Saudi Arabia's total public investments in 2020 account for more than 62 billion USD. 4.21 billion USD are reported as investments for the post-covid recovery. No resources are explicitly dedicated to a sustainable recovery.

62.13
billion $
Total Spending

4.21
billion $
Recovery Spending

DOMESTIC ADAPTATION POLICY

Saudi Arabia included adaptation in its NDC. The country recently adopted an integrated policy for both mitigation and adaptation. This legal framework does not foresee specific sectoral or sub-national adaptation plans.

Domestic Adaptation Policy
- ● Inclusion of Adaptation in NDCs
- ● Integrated Adaptation & Mitigation Policy
- ○ Dedicated Adaptation Strategy
- ○ Dedicated Adaptation Plan

Subordinate Adaptation Policies
- ○ Sectoral Adaptation Plans
- ○ Subnational Adaptation Plans

○ Policy not in place ● Active policy

ADAPTATION POLICY HIGHLIGHTS

TRANSNATIONAL INITIATIVES

Middle East Green Initiative

The initiative aims to plant 50 billion trees across the Middle East.

NATIONAL INITIATIVES

Saudi Green Initiative

It is a national initiative that aims to raise vegetation cover, reduce carbon emissions, combat pollution and land degradation, and preserve marine life. Among its goal there is an objective to plant 10 billion trees in Saudi Arabia and to increase protected areas to more than 30% (including marine and coastal ecosystems)

Center of Excellence for Climate Change Research (CECCR)

The CECCR was established in 2010 with a mandate to carry out state-of-the-art research in the field of weather, climate and climate change.

SUBNATIONAL INITIATIVES

Al Baydha Project

It is a land restoration, poverty-alleviation, and heritage preservation program, based on principles of permacultural and hydrological design.

Riyadh Green project

The Green Riyadh project will contribute in increasing the per capita share of green space, and raise total green spaces through planting trees around all city features and facilities as well as in all its provinces. All of the greening will be watered by recycled water from an irrigation network.

ENERGY TRANSITION

Its status of major global oil producer has an impact on the energy transition trajectory of Saudi Arabia. The country has not yet entered into a visible process of transformation of its energy sector, as demonstrated by its position in the bottom part of the ranking. Specifically, Saudi performances are negatively affected by the predominant role of fossil fuels, and in particular of oil.

These performances are reflected in the still very limited contribution of renewables to energy and electricity mixes. Massive extractive activities and reliance on oil products as the main energy input result in negative performance in the Emissions indicator, a domain in which Saudi Arabia performs worse than the G20 average.

On the contrary, the results achieved by the country in the Electrification domain are slightly above the group's average, thanks in particular to the availability of energy/fossil resources used for generation, which ensure universal and stable (though very high pollutant) access to electricity. Similarly, the Saudi's decent performances with respect to the Efficiency indicator, is the result of an economy largely based on the financial rents from the energy sector, rather than an intensive use of energy and economic and industrial input.

	G20 AVERAGE	COUNTRY
Energy Transition	58.7	44.2
Fossil Fuels	45.3	22.9
Renewables	19.7	0.0
Efficiency	84.9	85.5
Electrification	70.8	71.5
Emissions	72.9	41.1

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

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