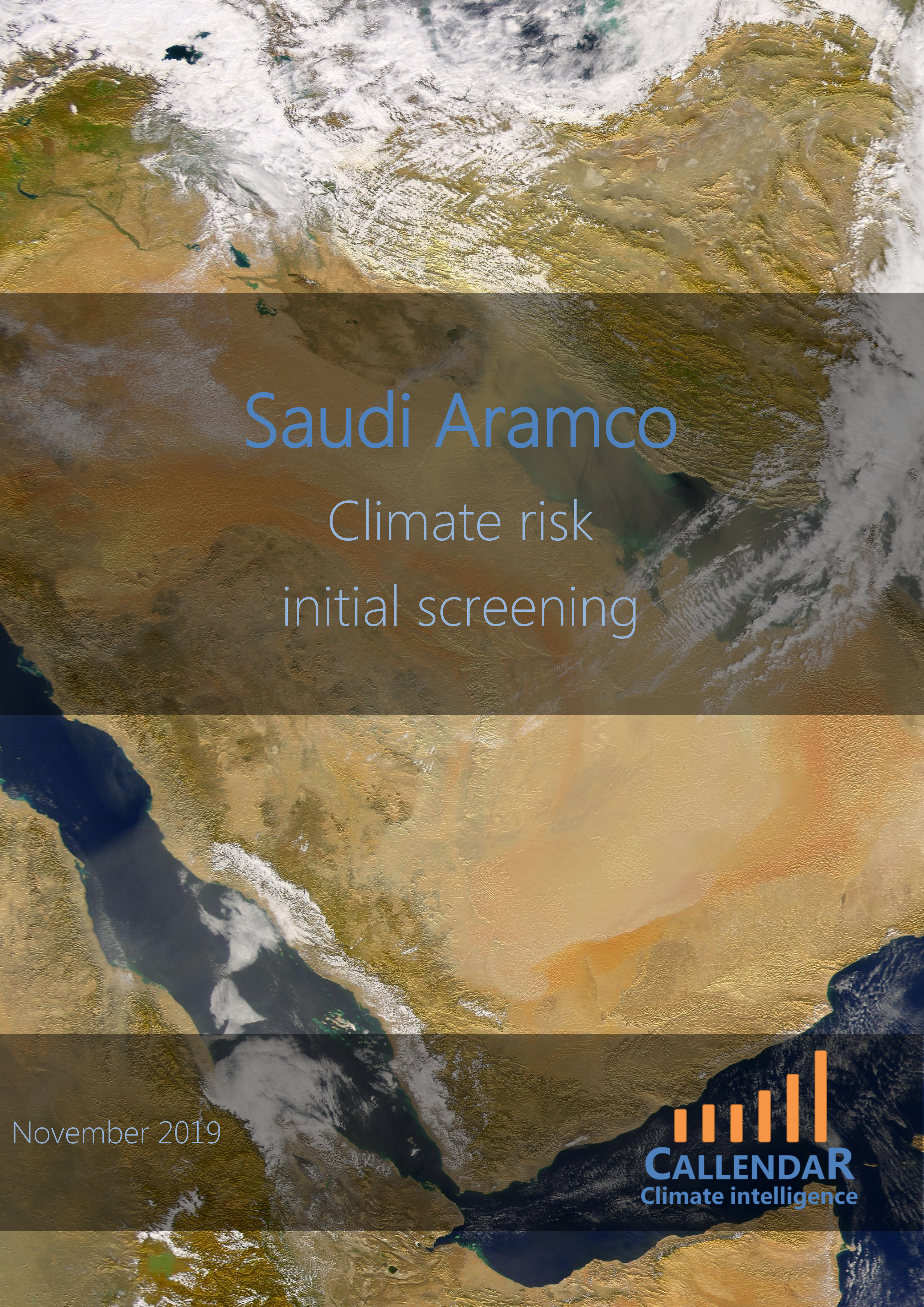


# Saudi Aramco

## Climate risk initial screening

November 2019

CALLENDAR
Climate intelligence

# Table of content

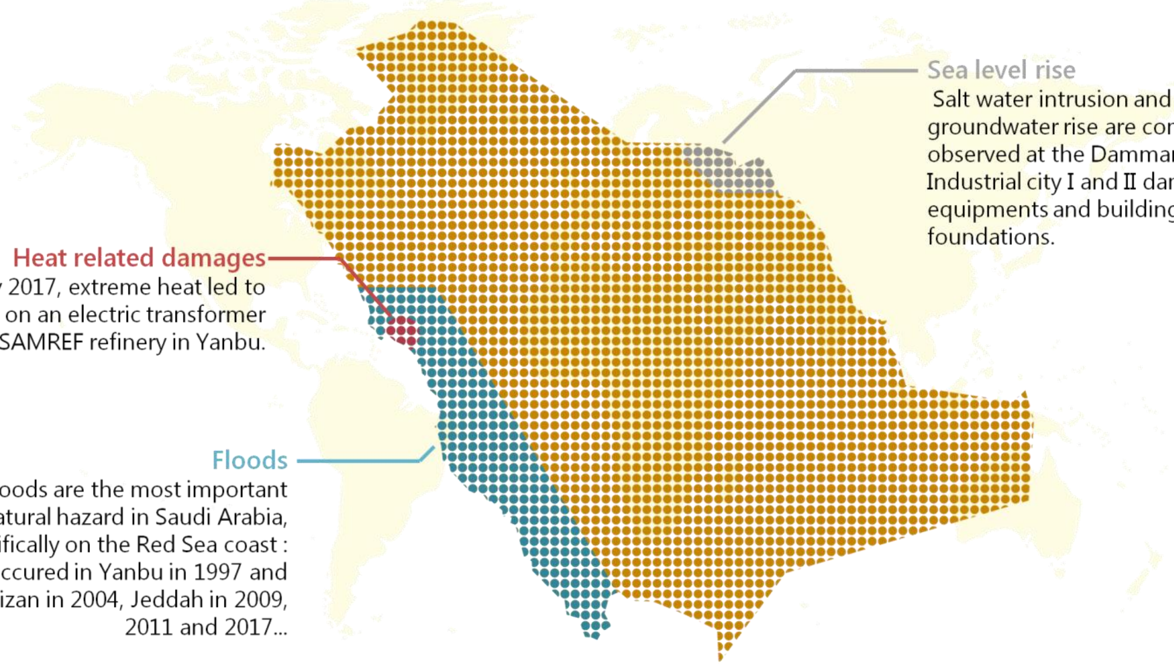
# Executive summary

In the prospectus published prior to its initial public offering, Saudi Aramco acknowledges that climate change may have damaging impacts on its activity and financial results. This report's aim is to provide an overview of the nature and scale of these risks by 2035. It is based on a bibliographical study and previously unpublished quantitative elements provided by projections made by 7 climate models.

The report shows that Saudi Aramco's operations in Saudi Arabia and around the world are vulnerable to weather events. Some of these risks have already materialized in several cases and even been taken into account in the decisions and operation of the company. These include:

- Floods that affected refineries operated by Saudi Aramco, notably in Yanbu (Saudi Arabia) or Port Arthur (USA),
- Extreme heat and the damages it can cause to equipment and personnel.

**Example of climatic events affecting Saudi Aramco's operations**



**Sea level rise**
Salt water intrusion and groundwater rise are commonly observed at the Dammam Industrial city I and II damaging equipments and building foundations.

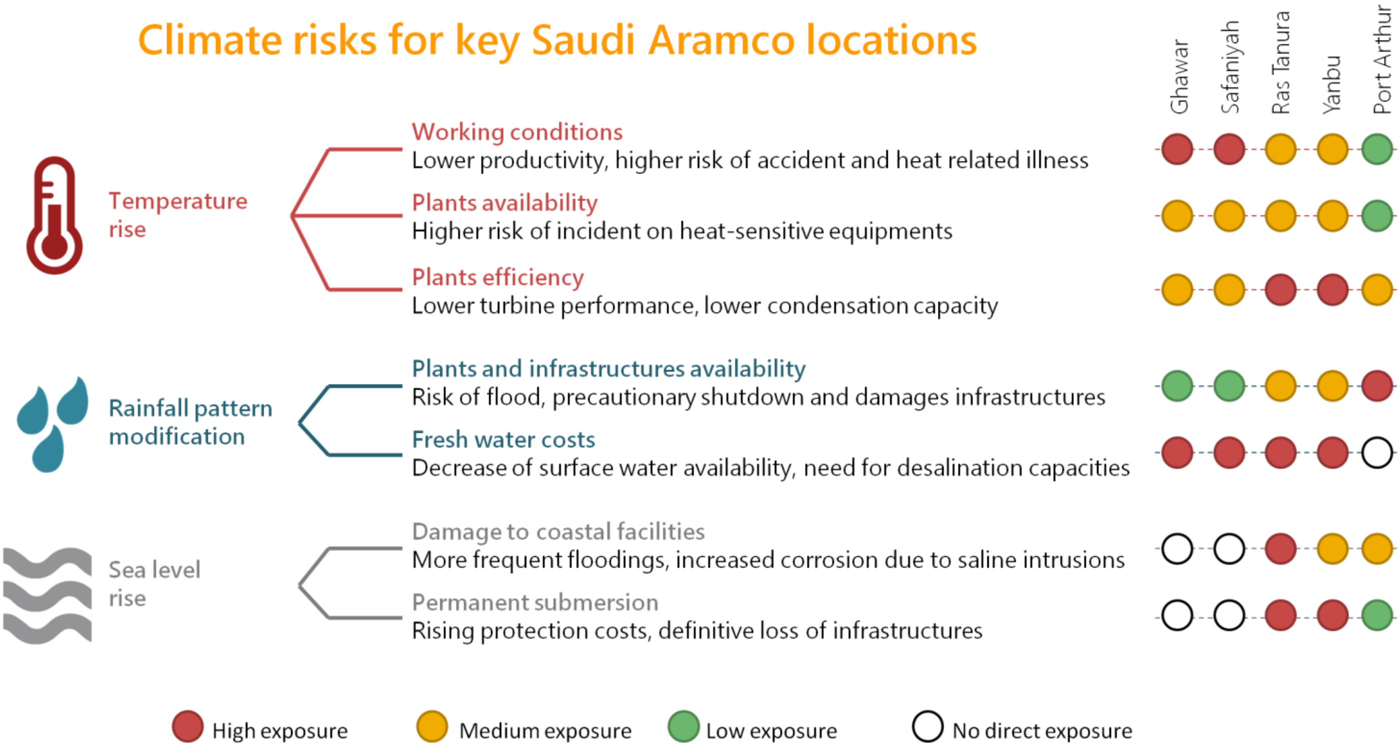
**Heat related damages**
In July 2017, extreme heat led to a fire on an electric transformer inside SAMREF refinery in Yanbu.

**Floods**
Floods are the most important natural hazard in Saudi Arabia, specifically on the Red Sea coast : floods occured in Yanbu in 1997 and 2011, Jizan in 2004, Jeddah in 2009, 2011 and 2017...

Other risks are likely to appear or be amplified by climate change and it is unclear whether or not the company recognizes and tries to mitigate them. These include:

- Sea level rise and its impact on coastal facilities,
- The effect of temperature increase on yield, valorization and availability of process, particularly in refining.

Climate change is forcing these phenomena leading to more frequent or more severe occurrence and can make it more difficult for Saudi Aramco to operate. As the company is active in areas that are particularly prone to hazards like floods and extreme heat, this trend may degrade its competitiveness compared to others, less exposed oil and gas companies. In addition, it indirectly exacerbates geopolitical, environmental, regulatory and reputational risks.



**Climate risks for key Saudi Aramco locations**

| | | Ghawar | Safaniyah | Ras Tanura | Yanbu | Port Arthur |
|---|---|---|---|---|---|---|
| Temperature rise | **Working conditions**<br>Lower productivity, higher risk of accident and heat related illness | 🔴 | 🔴 | 🟡 | 🟡 | 🟢 |
| | **Plants availability**<br>Higher risk of incident on heat-sensitive equipments | 🟡 | 🟡 | 🟡 | 🟡 | 🟢 |
| | **Plants efficiency**<br>Lower turbine performance, lower condensation capacity | 🟡 | 🟡 | 🔴 | 🔴 | 🟡 |
| Rainfall pattern modification | **Plants and infrastructures availability**<br>Risk of flood, precautionary shutdown and damages infrastructures | 🟢 | 🟢 | 🟡 | 🟡 | 🔴 |
| | **Fresh water costs**<br>Decrease of surface water availability, need for desalination capacities | 🔴 | 🔴 | 🔴 | 🔴 | ○ |
| Sea level rise | **Damage to coastal facilities**<br>More frequent floodings, increased corrosion due to saline intrusions | ○ | ○ | 🔴 | 🟡 | 🟡 |
| | **Permanent submersion**<br>Rising protection costs, definitive loss of infrastructures | ○ | ○ | 🔴 | 🔴 | 🟢 |

🔴 High exposure 🟡 Medium exposure 🟢 Low exposure ○ No direct exposure

In the medium term, the aridification of the Saudi climate could restrict Saudi Aramco's development. In a context of growing demand and gradual depletion of fossil water resources, access to fresh water, which is essential for refining, will have to rely more and more on desalination plants. Desalination already consumes a significant part of Saudi hydrocarbon production, thus degrading the financial and energy return on investment of its exploitation. This specificity could create a physical limit to the adoption of techniques with high water consumption and/or low energy return on energy invested ratio such as hydraulic fracturing and as result prevent Saudi Aramco from fully exploiting its oil and gas reserves.

Finally, this study identifies needs for further research to better assess the impact of climate change on the medium and long-term value of Saudi Aramco.

# Introduction

Launched on November 3, 2019, the IPO process of the Saudi national oil company, Saudi Aramco, is expected to be one of the largest financial transactions in history.

If the Saudi government is aiming for a valuation of $2 trillion, the value of the company is uncertain: Goldman Sachs estimates it between $1.6 and $2.3 trillion, Bank of America between $1.2 and $2.3 trillion and Bernstein between $1.2 and $1.5 trillion[i].

Regardless of the model used, these assessments are based on a projection of the company's earnings over the next few decades. They incorporate many hypotheses, including in highly uncertain areas such as oil prices or the changing geopolitical situation in the Persian Gulf.

The effects of climate change on hydrocarbon production, transport and processing does not appear to have been factored among the trends that may influence Saudi Aramco's long-term profitability. The existence of material risks is nonetheless confirmed by recent events, such as the unavailability of nearly a quarter of U.S. refining capacity as a result of Hurricane Harvey in 2017[ii] or an estimated production loss of 500,000 barrels per day during the Niger Delta flood in 2012[iii].

In the prospectus published on November 10, Saudi Aramco acknowledges that climate change can have negative effects on its activity and financial results[1] but without providing further details on the nature of the risks and their magnitudes.

The aim of this paper is to provide an overview of the physical risks caused by climate change to Saudi Aramco's activity by 2035. This assessment is based on a bibliographical study and previously unpublished quantitative elements provided by projections made by 7 climate models[2].

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[1] "Existing and future climate change concerns and impacts, including physical impacts to infrastructure [...] could [...] have a material adverse effect on the Company's business, financial position and results of operations."

[2] See methodological annex for details.

# Temperature

## Origin and nature of risks

The ambient temperature influences the proper functioning and performance of hydrocarbon production, transportation and refining facilities. Temperature-sensitive equipment includes, for example, compressors, Joule-Thompson low temperature separation and slug catchers[iv, v] as well as power lines and electrical equipment. Heat also accelerates corrosion especially in saline environments.

Beyond the unavailability of temperature-sensitive equipment and increased maintenance costs, heat can cause incidents affecting operations. It appears, for example, to have caused the fire of an electrical transformer in July 2017 at the SAMREF refinery in Yanbu, a joint venture of Saudi Aramco and Exxon[vi].

Gas production and transport are particularly sensitive to external temperature. LNG liquefaction trains must bring natural gas to a temperature of -162°C to condense it. The first stage of the LNG train is particularly sensitive to abnormal heat but each stage of the cooling process is dimensioned according to the site characteristics including a maximum temperature estimated on the basis of past weather records. If this "design temperature" is reached, the plant operator may to some extent reduce throughput to increase refrigeration capacity, but beyond certain thresholds flow reductions run into other technical problems without a simple solution. Once these thresholds have been exceeded, **adapting the facilities or even processes to an increase of the maximum temperature is possible but requires generally costly investments**, especially if the new pressure required exceeds the maximum allowed pressures for the equipment.

A similar problem exists for refineries: refrigeration is needed to condense and liquefy LPG production. **Recent developments in refineries to improve conversion yield have led to the saturation of condensation units for light components. Any increase in maximum temperature therefore results in a loss of value** either by reducing flow or by decreasing the splitting capacity and thus the valorization of crude oil or condensate.

Increased frequency and intensity of heat waves can also have indirect effects through the degradation of roads and asphalt pavements, rail tracks and freight facilities, vehicles and buildings. The health status of workers can also be affected: over the course of the century, temperatures in Saudi Arabia could rise to exceed thresholds for human body adaptation[vii].

## Projected warming by 2020-2050

Weather observations indicate an increase in temperature in Saudi Arabia in the order of 0.5°C per decade between 1985 and 2010[viii]. Over the next few decades, this trend is expected to continue and accelerate if greenhouse gases emissions are not reduced. **The increase in temperatures is expected to be particularly pronounced in on-shore oil-rich areas exploited by Saudi Aramco (Ghawar, Khurais, and Shaybah)**.

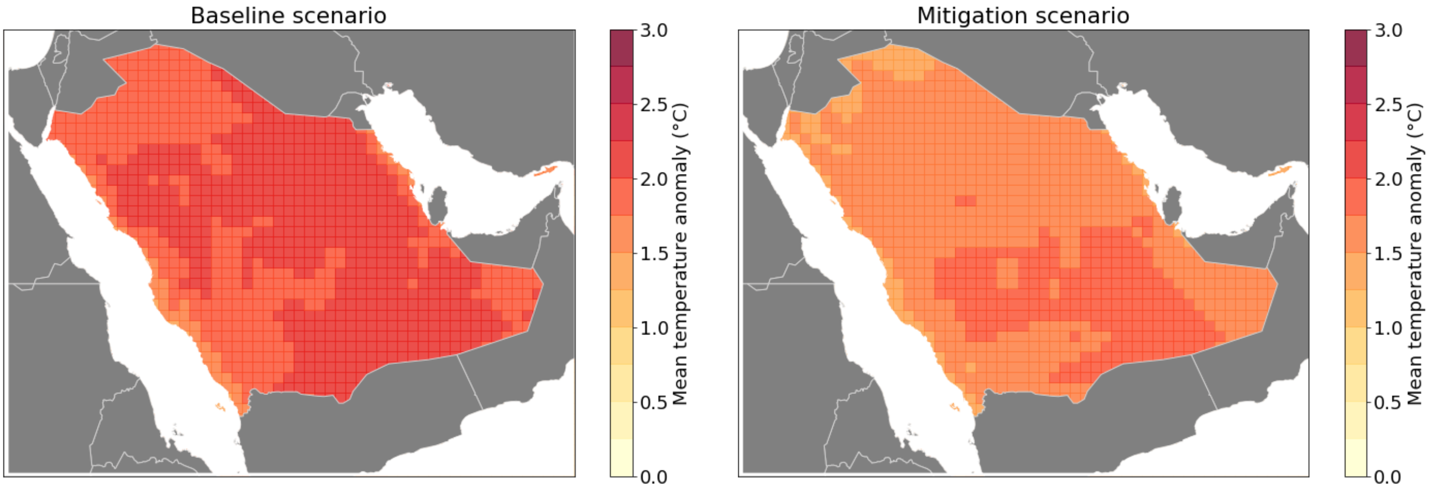

Figure 1: Mean temperature change between 2020 and 2049 compared to 1976-2005 without (left) and with (right) emissions reductions

The increase in temperature is generally higher between February to September, including during the summer period which is already the warmest.

## Local temperature change

The table below details the temperature changes expected for some important sites in Saudi Aramco's business in Saudi Arabia:

| | Baseline scenario | | | Attenuation scenario | | |
|---|---|---|---|---|---|---|
| | **Median projection** | Higher projection | Lower projection | **Median projection** | Higher projection | Lower projection |
| **Ras Tanura**<br>Refinery and terminal | **+1.5°C** | +2.3°C | +1.2°C | **+1.4°C** | +1.8°C | +1.2°C |
| **Yanbu**<br>Refinery and terminal | **+1.6°C** | +2.2°C | +1.2°C | **+1.3°C** | +1.8°C | +1.1°C |
| **Ghawar**<br>World largest oil field | **+2.0°C** | +2.5°C | +1.3°C | **+1.7°C** | +2.1°C | +1.3°C |
| **Safaniyah**<br>Off-shore oil field | **+1.6°C** | +2.3°C | +1.2°C | **+1.4°C** | +2.0°C | +1.2°C |

Figure 2: Temperature change between 2020 and 2049 compared to 1976-2005 in annual average, median projection, more pessimistic projection and more optimistic projections

## Impact on productivity and work conditions

The negative effect of high temperatures on labor productivity is widely documented. Temperature above 35°C especially with a high humidity causes heat stress and restricts workers' physical function and capabilities and as a result productivity. In an optimistic emission scenario (RCP2.6), **the International Labor Organization estimates that by 2030 the heat will cause Saudi industry to lose the equivalent of 0.8% of working hours** (compared to 0.3% in 1995)[ix]. These losses will be higher for outdoor work, with for example 1.6% of the hours lost in construction, and in coastal areas due to higher humidity. In addition **extreme heat during work is an occupational hazard: it increases the risk of accident and can lead to heatstroke**[x, xi].

As a result high temperatures add a constraint on the organization of work and can limit or even completely eliminate outdoor interventions capabilities during heat waves. As heat stress increases rapidly in the summer as soon as the sun rises[xii], strenuous work must be carried out early in the morning or even before sunrise. Heavy interventions that cannot be interrupted for 8 hours must be suspended during heat waves. It is notable that Saudi regulations prohibit outdoor work between 12pm and 3pm except in the oil sector[xiii].

**The Kingdom of Saudi Arabia has also taken regulatory measures to prevent work when temperatures exceed 50 degrees Celsius. This once rarely reached threshold is expected to be exceeded several times a year by 2035** on the eastern coast where a large part of Saudi Aramco's operations are located.

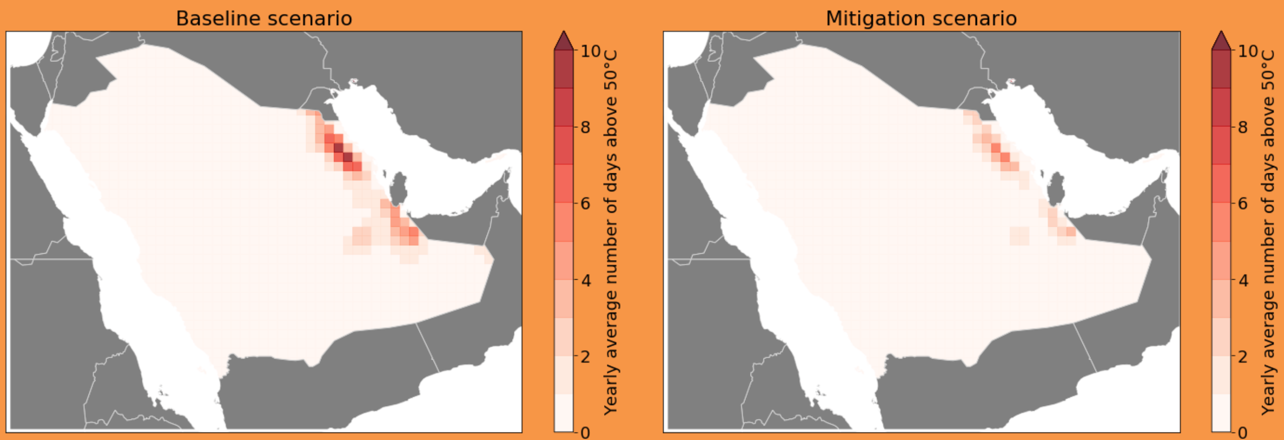

Figure 3: Yearly average number of days with maximum temperature of 50°C or higher between 2020 and 2050 without (left) and with (right) emissions reductions

For instance, in the Ghawar region, the country's largest oil field, the median projection indicates that the 50°C threshold will be exceeded 2 days per year on average between 2020 and 2050 in the baseline scenario. However, several models give a significantly higher frequency, between 6 and 10 days per year on average. A more detailed statistical study would be needed to accurately assess this phenomenon.

# Sea level rise

## Origin and nature of risks

According to the Intergovernmental Panel on Climate Change, the average rise in ocean levels was 3.6 mm per year between 2006 and 2015. This increase is expected to continue to reach 4 to 15 mm per year in 2100 depending on greenhouse gases emissions[xiv].

This global rise is not evenly distributed and can vary locally according to non-climatic factors such as natural land movement, land subsidence due to extraction of underground resources and sediment transport induced by natural or anthropogenic factors. **Local data indicate that sea levels are rising rapidly in the Persian Gulf[xv] and that the Saudi coasts are vulnerable due to their low elevation[xvi].**

In addition to the prospect of permanent submersion, sea level rise raise more immediate risks for coastal installations: temporary flooding, erosion, salt water intrusion and groundwater rise... These risks are already materializing in Saudi Arabia: floods and rising groundwater are regularly observed in Dammam Industrial City I and II, damaging roads and building's foundations[xvii].

For oil installations, these phenomena carry risks comparable to those of floods, including soil erosion and exposure of underground pipeline. The salt content of the water also makes even short-term submersions particularly damaging to industrial infrastructure and equipment.

## Significant risks and costs as soon as 2030

**Sea level rise is expected to be quick in the Arabic sea, where many of Saudi Aramco's operations are located**, compared to other coastal areas in the world. On the east coast of Saudi Arabia, the most cited projection[xviii] indicates an median sea level rise of 14 cm in 2030 compared to 2000 for the baseline scenario with a 90% confidence interval between 2 cm to 26 cm and a median increase of 13 cm [+4, +22] in the mitigation scenario. Recent assessments[xix] including more accurate modeling of ice sheet behavior confirm this order of magnitude.

The vulnerability of coastal facilities to this phenomenon depends on their elevation above sea level. According to bias-corrected elevation data[xx], sea level rise could significantly alter the environment of some facilities operated by Saudi Aramco. The Ras Tanura region in particular may be largely submerged as soon as 2030, including the northern part of the peninsula where all existing accesses, the airport and some of the company's buildings are located. The area around the Yanbu refineries, including access roads to the south and part of the city could also be permanently submerged. The city of Jizan faces a similar threat.

Regarding Saudi Aramco's facilities themselves, **the Ras Tanura refinery and terminal and some of Yanbu facilities, including the Luberef site, could face temporary flooding with a return time of about one year**. Outside Saudi Arabia, the Motiva refinery in Port Arthur (USA) and FREP in Quanzhou (China) are also exposed to more frequent flooding.

In addition to flood damage and production losses, rising sea levels will necessarily result in **significant protection and adaptation costs and higher insurance premiums** for coastal facilities.

Uncorrected elevation data tend to show much lower risks. However, these data, based on satellite observations, frequently overestimate elevation. It would be useful to conduct local surveys in order to accurately assess the risk and to devise an adaptation strategy.

# Flood

## Origin and nature of risks

Flooding is the main natural hazard in Saudi Arabia[xxi]. Despite an arid climate and the absence of a permanent river, Saudi Arabia has many wadis. These intermittent streams are characterized by violent floods sometimes accompanied by mudslides.

Theses hazards pose a significant risk to oil facilities and infrastructure in general. In the oil sector, a flood risk requires the implementation of unit shutdown procedures. These precautionary shutdowns are intended to avoid an unplanned shutdown, which would be much more costly in terms of pollution and equipment damage: the cost of such an incident is rarely less than $10 million. **This procedure was implemented during the 2011 floods at a refinery in Yanbu, on the west coast of Saudi Arabia**[xxii].

Floods are also a threat for transportation facilities. Exposed pipeline sections, including valves, pumping stations and river crossings are particularly vulnerable. Underground sections can also be damaged, especially if high water speed can cause soil erosion and lead to exposure of buried pipes. This kind of accidents occurred for example in Portugal in 2000[xxiii] or in Texas in 1994[xxiv].

## Motiva refinery in Port Arthur (USA)

Outside of Saudi Arabia, **the risk of flooding is particularly high for the Port Arthur refinery, which is 100% owned by Saudi Aramco** since 2017 through its subsidiary Motiva. The refinery, the largest in North America with a capacity of 600,000 barrels per day, was flooded in 2017[xxv] and 2016[xxvi]. The risk is significant enough to have been taken into account in investment decisions: Motiva want to reach a refining capacity of 1 to 1.5 million barrels per day in the United States, but the company **dropped plans to expand the Port Arthur refinery in 2018** and is looking for another site[xxvii].

## Possible increase in flood risks

**A study of Saudi Arabia's 50-years flood plains[xxviii] allows to distinguish two types of risk: a direct risk to the Yanbu petrochemical complex and an indirect risk, notably to the Ras Tanura terminal and refinery, Jizan refinery and the Riyadh refinery**. The East-West Pipeline, linking Ras Tanura to Yanbu, is also likely to be exposed to flood damage.

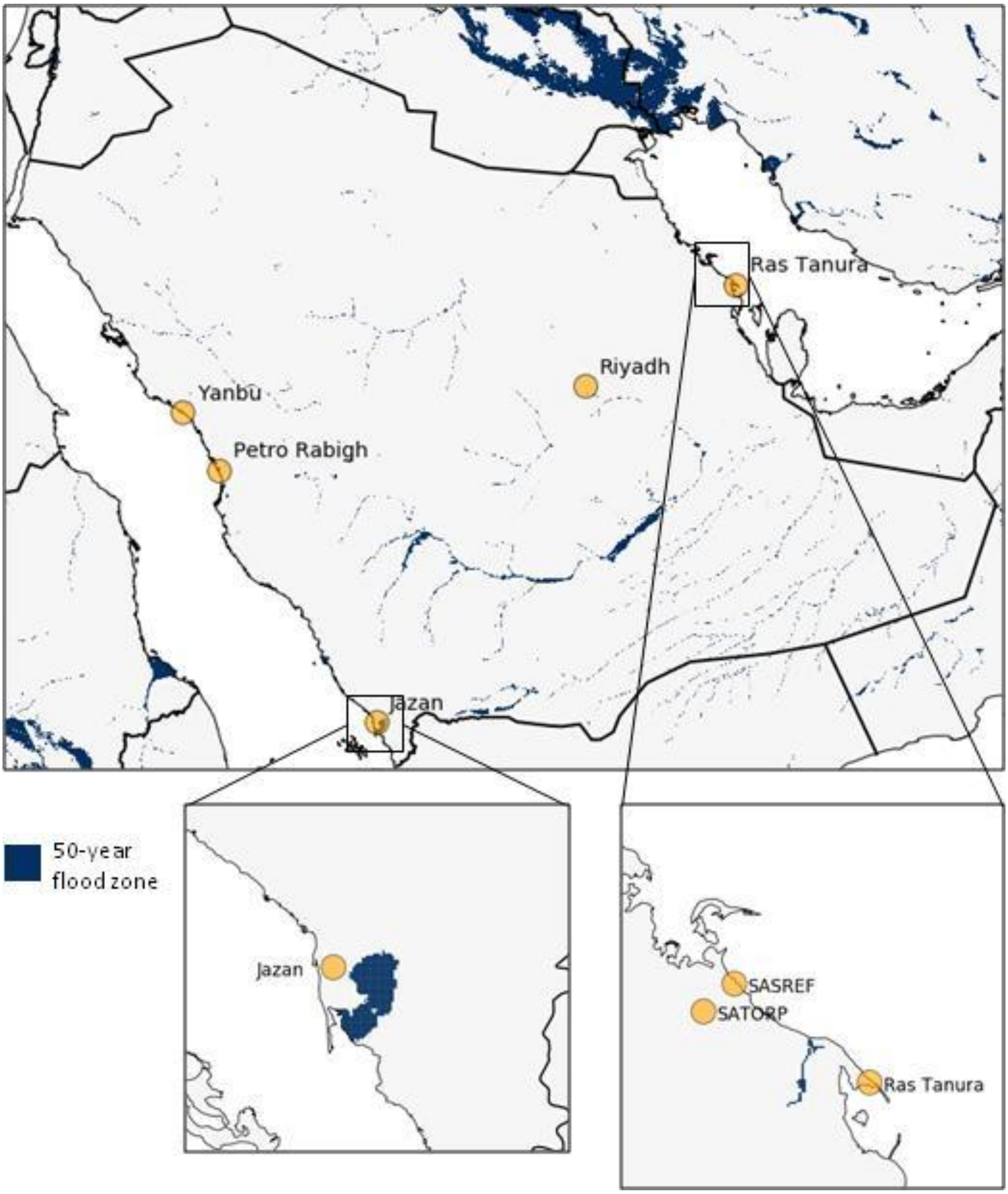

Figure 4: Map of 50-year flood zones in Saudi Arabia and key sites exploited by Saudi Aramco

The Yanbu petrochemical complex on the Red Sea is bordered to the north by a flood zone. The complex includes 3 refineries exploited by Saudi Aramco in joint-ventures with foreign oil companies, for a total capacity of 1,200,000 barrels per day. Its operations have already been suspended during previous floods.

The Ras Tanura and Riyadh refineries are also located near flood zones. Even without directly threatening the facilities, floods can have an indirect impact by affecting the infrastructure (roads, power lines, pipelines…) adjacent to these refineries. This is particularly the case for the Ras Tanura refinery and terminal as they are located on a peninsula whose access is partially closed by a flood zone. A new refinery in Jizan, due to become fully operational this year, is also bordered by a flood plain on its south and east side.

The highly irregular hydrological regime of wadis is almost entirely linked to precipitation. As a result **the evolution of flood hazards in Saudi Arabia in the context of climate change is linked to changes in precipitation patterns**, especially in the frequency and intensity of high or prolonged rain events. **An intensification of wet-season rain events has already been registered in weather observations**[xxix]. Climate models show that this trend will probably continue in Jizan area and more broadly in the Assir massif along the Red Sea where rainfalls during the 5% wettest days are expected to increase significantly. Projections do not give clear signal for the rest of Saudi Arabia.

# Fresh water resources

## Origin and nature of risks

Water is essential to the oil industry, especially at the production and refining stages. In production, water is used to cool machines, such as drills, and evacuate sludge and debris. Water can also be injected into wells to increase pressure and stimulate hydrocarbon recovery, a technique that is commonly used in Saudi Arabia. **Hydraulic fracturing is also very water-intensive, Saudi Aramco has recently invested in this technique, including by building a new desalinization plant**[xxx].

Roughly one ton of water is required to produce one ton of refined products. **Any restriction on the ability to draw groundwater or to desalinize seawater therefore reduce refining capacity or requires investments** in improving steam condensate recycling or even improving efficiency of strippers.

## The Saudi Arabian water-energy nexus

Due to the aridity of the climate and to limited fossil water resources, Saudi Arabia relies on desalination plants for approximately 70% of its water consumption[xxxi]. This creates a very strong dependence between sea water desalination and hydrocarbon production:

- Desalination requires energy, usually in the form of electricity. In Saudi Arabia, approximately two thirds of the electricity is produced from oil and one third from natural gas. As a result, desalination plants are responsible for a large part of the domestic oil consumption[xxxii]. The availability and price of water are therefore correlated with those of hydrocarbons.
- Oil production, on the other hand, is the country's second largest consumer of water after agriculture. Desalinated water is also needed to cool the turbines used in electricity generation.

**This relation forms a water-energy system with a rate of energy return on energy invested (EROEI) lower than that of the oil chain alone**. It can hinder the use of techniques with low EROEI, such as hydraulic fracturing.

According to some analysis, this system is not sustainable in the medium term: even without taking into account the effects of climate change, Saudi oil production may not be sufficient to meet the growth of its water needs within two decades[xxxiii]. In any case, by abandoning wheat production after decades of efforts to achieve self-sufficiency[xxxiv], Saudi

Arabia gave a clear signal of conflicting interests at play for water access and of the priority it intend to give to industrial needs and residential sectors on agriculture.

The efficiency of the thermal power plants used to generate the electricity needed for desalinization decreases as the temperature rises. Rising water temperatures above 30°C and increasing salt concentrations can also degrade the efficiency of desalination plants and increase their energy consumption[xxxv, xxxvi]. Assuming unchanged technology, **global warming should therefore lead to an increase in the amount of energy needed to produce desalinated water and a deterioration of the efficiency of the Saudi water-energy system**.

# Projected changes in precipitations and aridity

Climate change is expected to result on average in increased rainfall in Saudi Arabia with local declines in coastal regions and the north of the country.

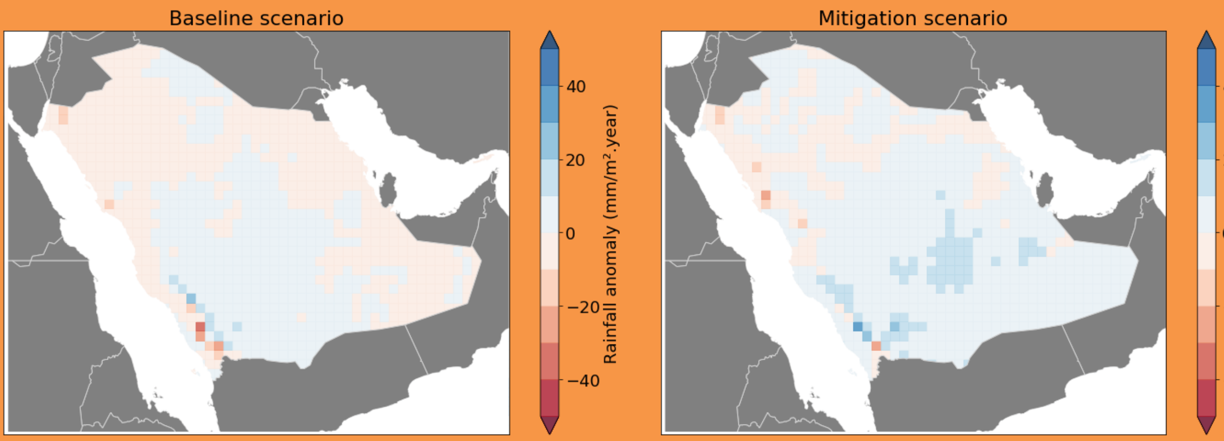

Figure 5: Change in yearly precipitations between 2020 and 2049 compared to 1976-2005 (mm/m².year) without (left) and with (right) emissions reduction

However, the increase of temperature and therefore evaporation is projected to compensate the increase in precipitation. According to climate models, without emissions reductions, aridity should increase almost everywhere in Saudi Arabia between 2020 and 2050. In the mitigation scenario, aridity is projected to increase in the northern half of the country and along the Red Sea.

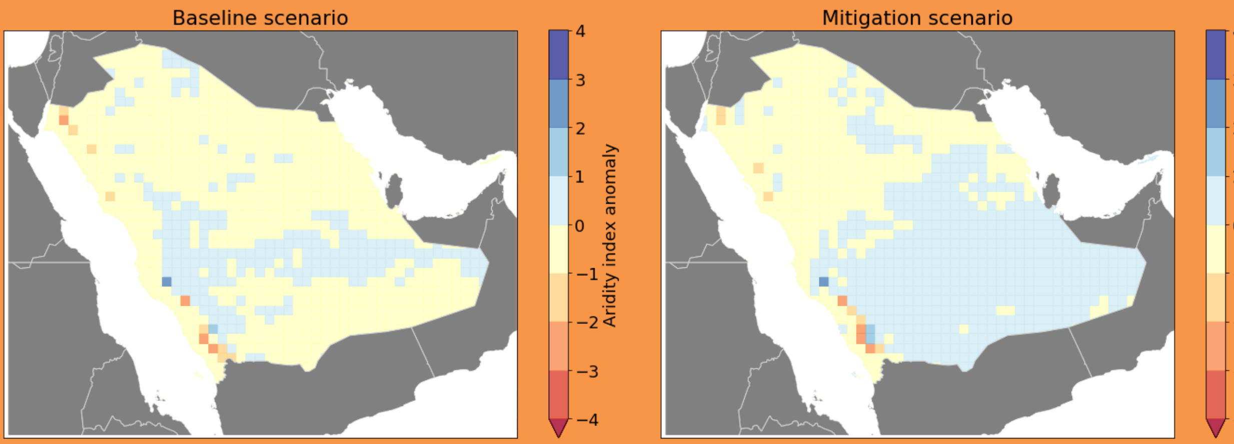

Figure 6: Change in the Martonne aridity index between 2020 and 2049 compared to 1976-2005 without (left) and with (right) emissions reduction

As a result, **the surface water resource is expected to decline in both quantity and quality**[xxxvii]. This trend could contribute to increased water stress and conflicts of use. However, given the small share of surface water in Saudi consumption, its direct effects on Saudi Aramco's activity in the country should be limited.

# Conclusion

This preliminary screening shows that climate change is going to be a significant challenge over the course of the next two decades for Saudi Aramco. Rising temperatures and extreme events, mostly floods, have the potential to damage facilities and reduce their availability and yields especially in refining. Extreme heat may become disruptive for workers and equipments alike. Competition for the access to fresh water and sea level rise will probably create additional costs and may limit the company future development.

| | | Production | | Refining | | |
|---|---|---|---|---|---|---|
| | | Ghawar<br>Reserves :<br>58 billion barrels | Safaniyah<br>Reserves :<br>34 billions barrels | Ras Tanura<br>Capacity :<br>550 000 barrels/d | Yanbu<br>Capacité :<br>1,200,000barrels/d | Port Arthur<br>Capacité :<br>600 000 barrels/d |
| Temperature | Working conditions | High exposure | High exposure | Medium exposure | Medium exposure | Low exposure |
| | Plants availabilty | Medium exposure | Medium exposure | Medium exposure | Medium exposure | Low exposure |
| | Plants efficiency | Exposition modérée | Exposition modérée | High exposure | High exposure | Medium exposure |
| Rainfall | Plants availability | Low exposure | Low exposure | Medium exposure | Medium exposure | High exposure |
| | Fresh water availability | High exposure | High exposure | High exposure | High exposure | No direct exposure |
| Sea level rise | Damage to coastal facilities | No direct exposure | No direct exposure | High exposure | Medium exposure | Medium exposure |
| | Permanent submersion | No direct exposure | No direct exposure | High exposure | High exposure | Low exposure |

Figure 7 : Climate risks exposure for Saudi Aramso's key assets

This report also identifies gaps in currently available information and needs for further research. In particular, it would be useful to:

- Map safe operating temperatures for production, transport and refining equipments in order to identify, and potentially adapt, the processes that are the most likely to be disrupted by rising temperature,
- Assess more precisely the frequency and magnitude of future extreme rain events and heat waves,
- Conduct local elevation surveys to evaluate the vulnerability of coastal facilities and evaluate the feasibility and cost to protect them against sea level rise,
- Assess the level of convergence of models and tails of probability in order to identify less likely but potentially more damaging events,
- Expand the study to indirect risks that could affect Saudi Aramco, for example, through its stakeholders or regional instability.

We believe that addressing these gaps would help determining Saudi Aramco long-term value. In addition, it may prove beneficial for the company as it would give it a chance to start adapting its operation to future climate change impacts.

# Methodological annex

Unless otherwise specified, the values presented in this report are the median projections computed from a sample of 7 datasets from the CORDEX experiment. These projections are made by combining two models: a general climate model (GCM), which simulates global climate change based on the chosen emissions scenario, and a regional climate model (RCM), which provides a better spatial resolution. The spatial resolution of the projections used is 0.44 degrees, or about 50km.

The following datasets were used:

| GCM | RCM | Time step |
|---|---|---|
| CNRM-CERFACS-CM5 | SMHI-RCA4 | Daily |
| IPSL-CMA5-MR | SMHI-RCA4 | Daily |
| MIROC-MIROC5 | SMHI-RCA4 | Daily |
| MOHC-HadGEM2-ES | SMHI-RCA4 | Daily |
| NCC-NorESM1-1 | SMHI-RCA4 | Daily |
| NOAA-GFDL-ESM2M | SMHI-RCA4 | Daily |
| QCCCE-CSIRO-Mk3-6-0 | SMHI-RCA4 | Daily |

The use of multiple models is aimed at reducing the uncertainty associated with modeling imperfections. The median is preferred to the average as it is less affected by outliers and skewed data. When necessary, extremes projections were mentioned to give an order of magnitude of the uncertainties.

Two emission scenarios from the IPCC's 5th report were used to take into account the uncertainty about future actions to reduce greenhouse gas emissions:

- The RCP8.5 scenario ("baseline scenario") representative of a continuation of current emissions growth without additional efforts to constrain them resulting in a $CO_2$ concentration of more than 1370 ppm in 2100 (compared to about 280 in 1750).
- The RCP4.5 scenario ("mitigation scenario") which leads to a stabilization of the $CO_2$ concentration in the atmosphere around 650 ppm in 2100 and implies significant efforts to transform energy systems, land use and the global economy.

The values presented in this report are averages over a 30-year period (January 1, 1976 - December 31, 2005 for the reference period, January 1, 2020 - December 31, 2049 for projections). This long period is intended to limit uncertainties related to natural climate variability.

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