Regional Organization for the Protection of the Marine Environment (ROPME)

ROPME POLICY BRIEF

ADAPTING DESALINATION PLANTS AND INDUSTRIAL COOLING WATER SYSTEMS TO CLIMATE CHANGE

Desalination and power plants are vital for the ROPME Sea Area (RSA) but they are at risk from climate change impacts on water quality, abundance of jellyfish and algal blooms, and physical risks from storm damage, erosion and flooding.

Key Adaptation Actions

- Intake location and design are key factors for adapting plants to changes in water quality.
- Reverse osmosis desalination plants are most sensitive to climate change risks and filtration and clearing systems and membrane screens may require modification.
- A regional Harmful Algal Bloom (HAB) and jellyfish forecasting system could be developed to provide early warning for plant operators.
- National regulators could make it a requirement for operators to conduct climate change risk assessments and develop adaptation plans.

2022

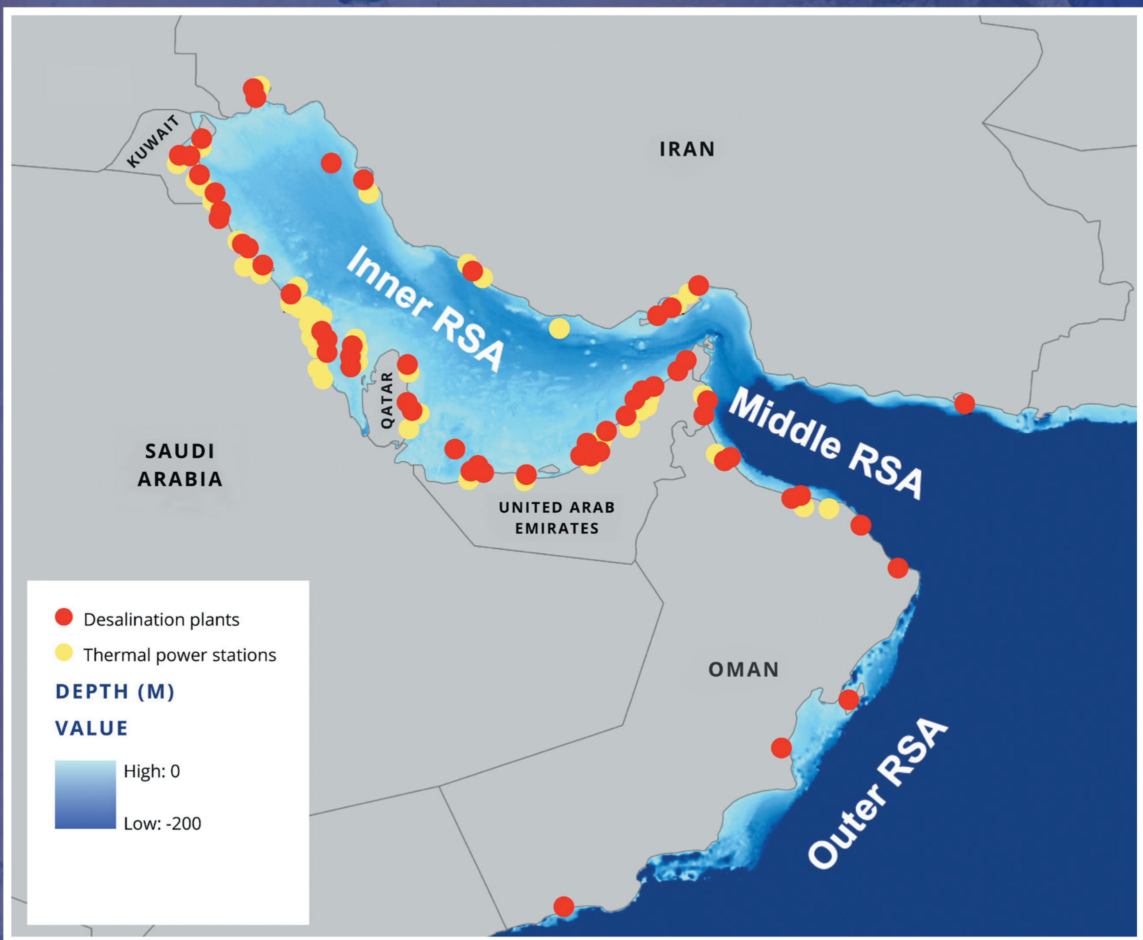
ROPME SEA AREA

The ROPME Sea Area (RSA) covers the territorial waters of the eight ROPME Member States: Bahrain, Iran, Iraq, Kuwait, Oman, Qatar, Saudi Arabia and the United Arab Emirates. The RSA is divided into three distinct Sub-Regions, the shallow, semi-enclosed Inner RSA, transitional waters of the Middle RSA and the oceanic Outer RSA.

A marine and coastal climate change risk assessment was conducted as part of the ROPME Regional Action Plan on Climate Change.

The effects of water quality changes on desalination plants and industrial cooling water systems was identified as a priority climate change risk. This document provides a summary of the climate exposure of desalination plants and industrial cooling water systems to changes in temperature, salinity and algal and jellyfish blooms. Physical risks to infrastructure and operations from flooding, erosion and storm damage are also highlighted.

MAP OF DESALINATION PLANTS (WITH A CAPACITY OF GREATER THAN 10,000 M^3/DAY) AND THERMAL POWER STATIONS WITHIN 5KM OF THE RSA COASTLINE[1].



DESALINATION PLANTS

Desalination is essential to the coastal cities and communities of the ROPME Sea Area. The introduction of desalination has enabled rapid economic growth in the region and accounts for almost all the potable water in several ROPME member states.

According to the GWI database, there are an estimated 1,453 desalination plants within 5km of the RSA coastline, with 1,335 desalination plants in the Inner RSA, 83 in the Middle RSA and 35 in the Outer RSA.

Desalination capacity in the region currently exceeds 25 million m^3 per day, and this may increase to over 80 million m^3 per day by 2050.

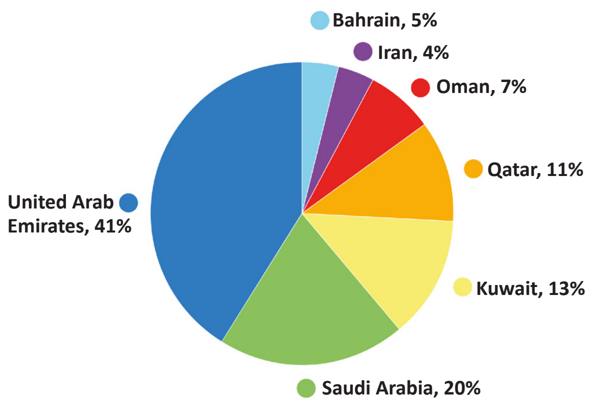
The 10 biggest desalination plants have a combined capacity of over 5 million m^3 per day, representing over 20% of capacity across the whole region.

THERMAL POWER STATIONS AND INDUSTRIAL COOLING WATER SYSTEMS

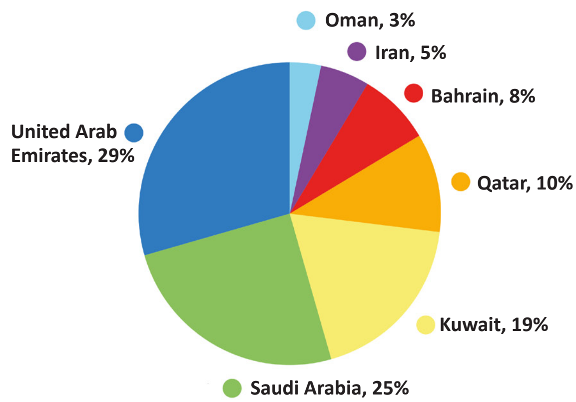
Thermal power stations are also essential to cities and communities around the ROPME coastline and these are predominantly water cooled. Eighty thermal power stations are located within 5 km of the coastline in the Inner RSA, and 9 in the Middle RSA. They have an estimated combined capacity of 96 GW, with 93% from gas, 6% from oil and 1% from nuclear. No power plants were identified in the Outer RSA.

RELATIVE PROPORTION OF THE TOTAL DESALINATION AND THERMAL POWER STATION CAPACITY ACROSS ROPME MEMBER STATES (LOCATED WITHIN 5KM OF THE ROPME COASTLINE)

DESALINATION PLANT CAPACITY

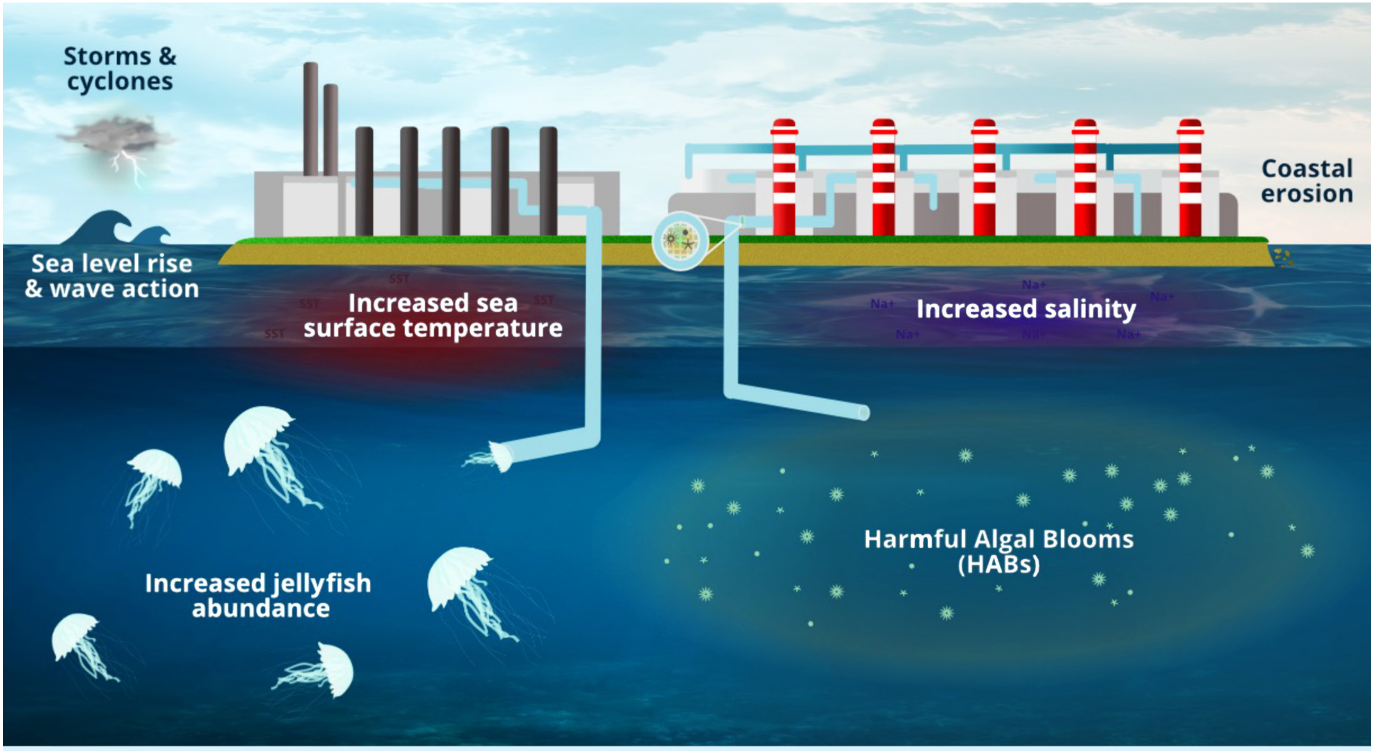


THERMAL POWER STATION CAPACITY



CLIMATE CHANGE RISKS TO DESALINATION PLANTS, THERMAL POWER STATIONS AND INDUSTRIAL COOLING WATER SYSTEMS

Climate change will affect seawater desalination plants and industrial seawater cooling systems in a number of ways, including impacts on water quality and physical damage to infrastructure.



RISK	IMPACT
Storms and cyclones, sea level rise and wave action	Physical damage to coastal infrastructure
Coastal erosion	
Increased sea surface temperature	Reduction in cooling efficiency
Increased salinity	Reduced efficiency of desalination plants
Increased jellyfish abundance	Blockage of intake screens, meshes and filters
Incidence of Harmful Algal Blooms	Blockage of media filters and membranes and impacts on the quality of water prodcued

CLIMATE CHANGE IMPACTS ON WATER QUALITY

Climate change will lead to an increase in coastal water temperature and salinity, reducing the efficiency of desalination plants and cooling systems. These changes will exacerbate the effects these plants already have on nearshore temperature and salinity, especially in the Inner RSA.

Climate change may lead to an increase in the frequency and extent of harmful algal blooms (HABs) and jellyfish blooms.

Dense algal blooms can disrupt desalination plants by clogging filters and fouling membrane surfaces. They can further disrupt desalination operations through the presence of algal neurotoxins and skin-irritating compounds that may persist in treated water, and cause a bad taste or odour.

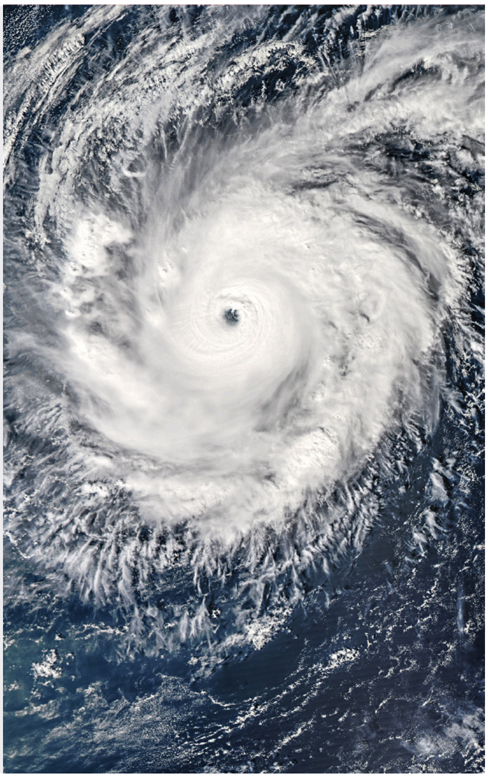
Jellyfish blooms can block and damage intake screens and generally affect seawater intakes for desalination plants and cooling water systems.

Climate change impacts are expected throughout the RSA. The semi-enclosed Inner ROPME Sea Area is more exposed to temperature and salinity increases, whereas the Middle and Outer ROPME Sea Areas are more exposed to algal and jellyfish blooms.

PHYSICAL RISKS FROM MARINE CLIMATE CHANGE

Physical risks include increased coastal erosion and flooding of coastal facilities due to long term sea level rise. Any increase in storm intensity and frequency may lead to physical damage of coastal facilities and more water turbidity events.

Sea-level rise will affect the whole ROPME Sea Area, although low-lying sedimentary coastlines more typical of the Inner RSA are more at risk from inundation and erosion than rocky coastlines. Cyclone risk is currently confined to the middle and outer ROPME Sea Area, but may extend further north in the future due to increasing sea temperatures.



FOCUS ON EXPOSURE TO TEMPERATURE AND SALINITY CHANGE

Ocean climate model outputs[2] have been used to evaluate the exposure of desalination plants and coastal power stations across the ROPME Sea Area (RSA) to projected changes in sea water temperature and salinity. The climate scenario analysis presented here compares changes by the 2040s to a baseline year of 2006.

Different model outputs and resolutions were available for the Inner RSA, and the middle and outer RSA. They are broadly comparable though as both applied the same high emission RCP8.5 climate change scenario.

The average and 98th percentile maximum increase in sea surface temperature by the 2040s due to climate change across all desalination plants in the Inner RSA is 1.72°C and 2.47°C respectively. Within the Inner RSA, the greatest temperature increases are projected along the shallow southern and western coasts. A greater increase is projected in the Middle RSA compared to the Outer RSA, with an average temperature increase less than 2°C across both sub-regions.

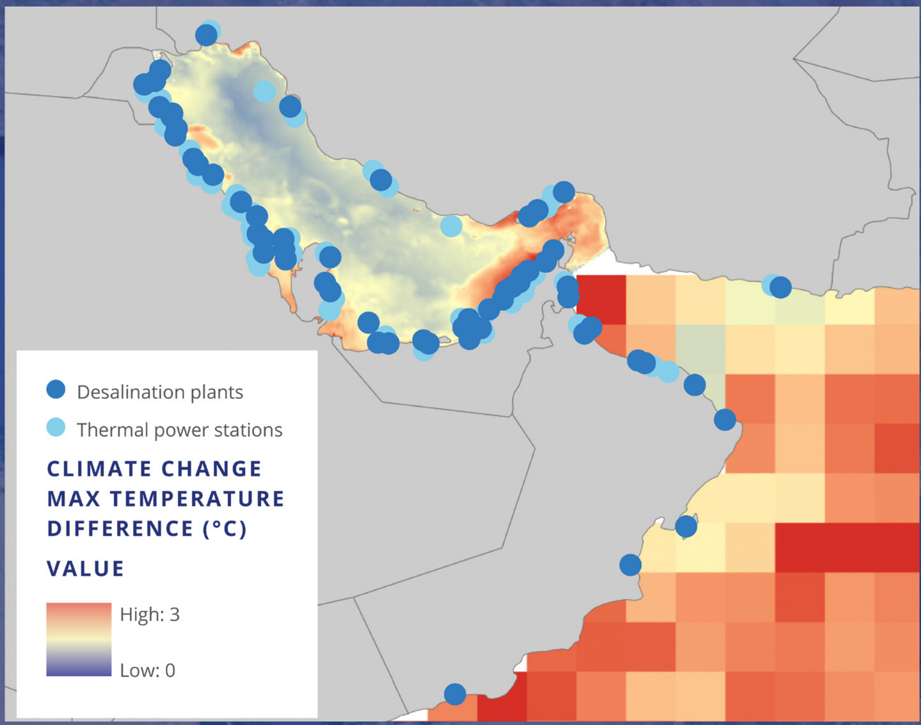
The average and 98th percentile maximum increase in surface salinity across all desalination plants due to climate change in the Inner RSA was 0.07 PSU and 0.87 PSU, respectively. There is a slight increase in average salinity for the Middle and Outer RSA (< 0.2 PSU), but this is negligible compared to the interannual variation. The average and 98th percentile temperature and salinity difference by ROPME member states is summarized in the table below.

Within the Inner RSA, the combined effects of desalination plants and climate change is expected to cause a greater increase in temperature and salinity in this sub-region. To account for this, an additional scenario was analysed that considers the combined impact of desalination discharges in combination with climate change. The combined effects are projected to lead to localised increases in sea surface temperature between 0.4 – 14.95°C, and a further increase in surface salinities between 0.1 – 11.44 PSU.

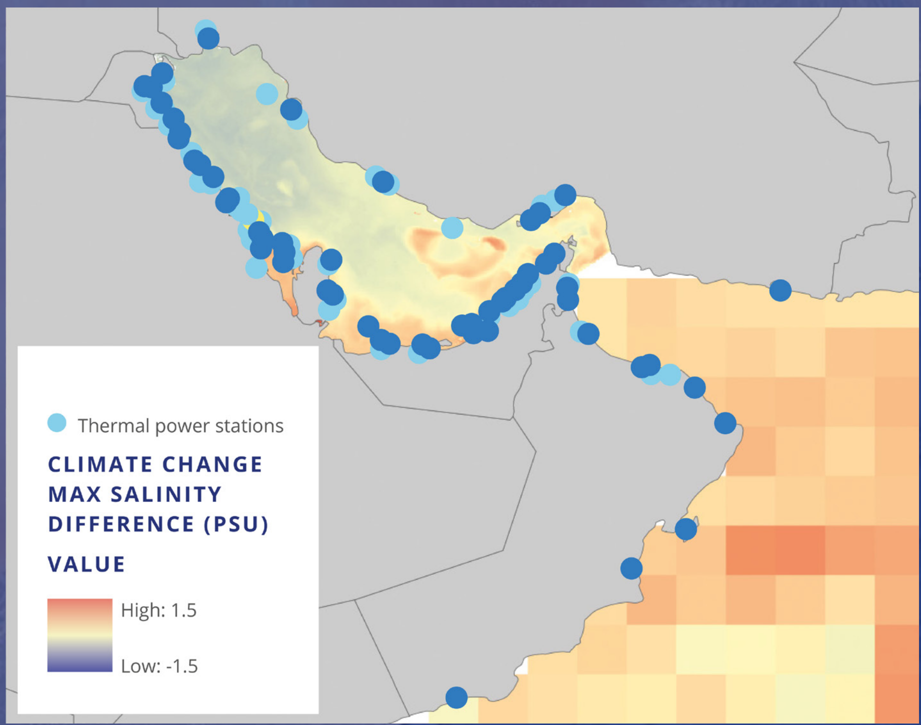
PROJECTED AVERAGE AND MAXIMUM (98TH PERCENTILE) DIFFERENCES IN SEA SURFACE TEMPERATURE AND SALINITY FOR ROPME MEMBER STATES BY 2040s

Country	Avg. Salinity Difference (PSU)	98th perc. Salinity Difference (PSU)	Avg. Temp Difference (°C)	98th perc. Temp Difference (°C)
Bahrain	0.33	0.45	1.69	1.85
Saudi Arabia	-0.14	0.43	1.67	1.90
Kuwait	-0.51	-0.30	1.20	1.46
Qatar	0.15	0.48	1.99	2.16
Iran	-0.16	0.22	1.61	2.48
UAE	0.49	0.95	1.91	2.76
Oman	0.17	0.66	1.76	4.23

MAXIMUM TEMPERATURE INCREASE BY 2040s DUE TO CLIMATE CHANGE



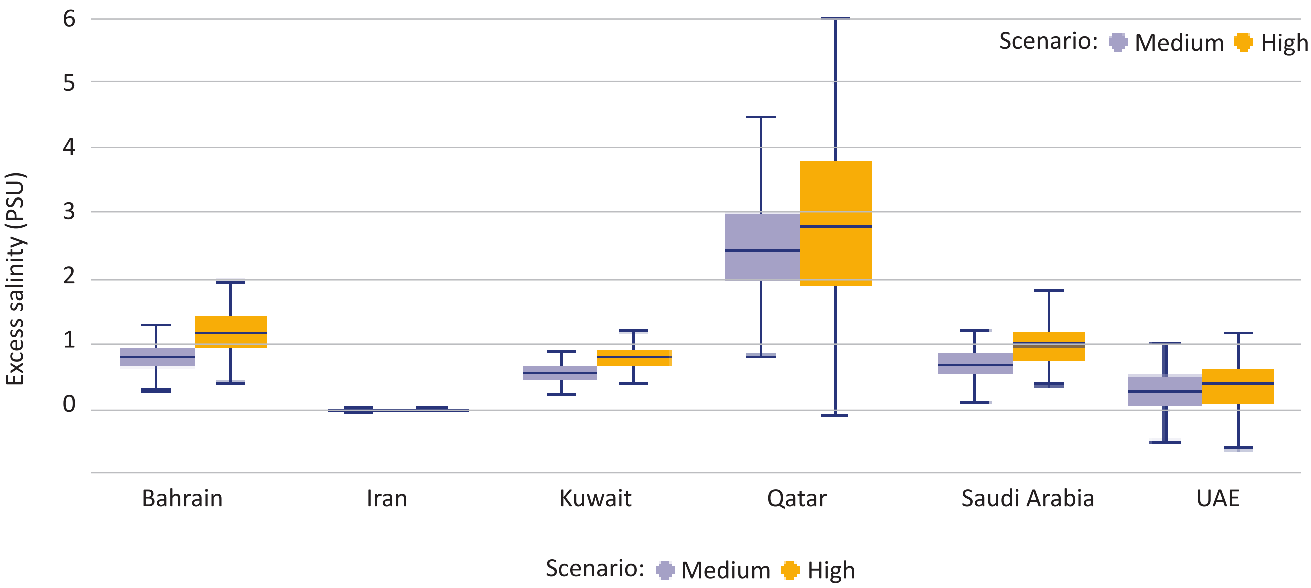
MAXIMUM SALINITY INCREASE BY 2040s DUE TO CLIMATE CHANGE



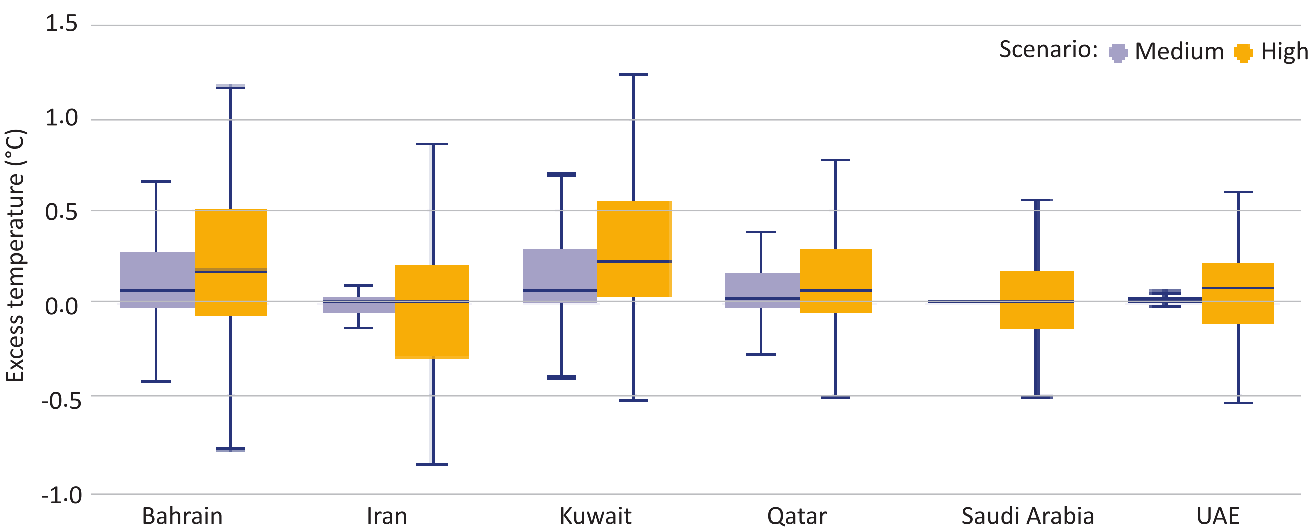
The figures below show how medium and high levels of growth by the desalination sector could affect salinity and water temperature by the 2040s. The effects of climate change are not shown.

The boxes represents the first, median and third quartiles. The whiskers represent the remaining distribution within 1.5 times the Interquartile range.

ADDITIONAL CHANGE IN AMBIENT SALINITY DUE TO DESALINATION OUTPUTS, EXCLUDING CLIMATE CHANGE EFFECTS, FOR THE LARGEST DESALINATION PLANT PER COUNTRY IN THE INNER RSA



ADDITIONAL CHANGE IN AMBIENT TEMPERATURE DUE TO DESALINATION OUTPUTS, EXCLUDING CLIMATE CHANGE EFFECTS, FOR THE LARGEST DESALINATION PLANT PER COUNTRY IN THE INNER RSA



FOCUS ON THE INCIDENCE OF ALGAL AND JELLYFISH BLOOMS

Algal and jellyfish blooms have increased in frequency across the RSA in recent years. This can affect industrial intakes due to clogging of intake screens and filters. Desalination plants can also be affected by algal blooms through clogging of membranes and by chemicals released into the water. The scale of blooms varies in space and time, and concentration at the intake can vary significantly over hours to days.

Algal blooms have led to desalination operations being suspended for days during HAB events due to clogging or high toxicity levels in the water. The dinoflagellate Noctiluca scintillans can also impact desalination plants by releasing ammonia into the surrounding water.

The occurrence of algal blooms is linked to a range of environmental factors including nutrient enrichment, temperature, oxygen levels, the seasonal monsoon and other human pressures. Although there has been an apparent increase in blooms in the RSA, the link with climate change has not been conclusively demonstrated. However, it is generally expected that algal blooms will increase in frequency across the RSA due to the effects of climate change on the environmental factors described above.

Reverse osmosis (RO) plants are more susceptible to disruption by algal blooms than thermal plants. As the number and proportion of RO plants is increasing, the desalination sector will become more vulnerable to any future increase in HABs.

Increases in jellyfish blooms have been linked to changes in water temperature, salinity, currents, increasing availability of hard substrates suitable for polyp settlement, oxygen depletion, eutrophication, and the effects of overfishing on marine food webs. Blooms are more common in the Inner RSA than the Middle RSA and are more sporadic in the Outer RSA. In the RSA, jellyfish blooms are often associated with seawater warming events, which can be accentuated by the local influence of thermal effluents from power plants.

Changes in temperature, salinity and currents are likely to impact size, distribution and frequency of jellyfish blooms with an increased incidence expected in the RSA in the future. However, the nature of these are hard to predict due to complex jellyfish life-cycles and the role of other human pressures.

RESILIENCE BUILDING AND ADAPTATION ACTIONS

The effects of climate change will increasingly impact the efficiency and resilience of desalination plants and industrial cooling water systems. Due to the critical role of desalination in supporting coastal communities in the ROPME Sea Area it is important to build resilience in the sector to climate change.

A ROPME cross-sectoral technical workshop was held to identify potential adaptation actions to support resilience building.

The primary adaptation actions relate to the design and operation of individual plants and are the responsibility of plant operators. However, there are also actions that can be taken at a national or regional level to help build resilience in this sector.

REGIONAL AND NATIONAL SCALE ADAPTATION OPTIONS

Human activities, such as desalination and sewage discharges, can combine with climate change to increase risk to desalination and cooling water intakes. Managing these additional human pressures on the marine environment at the national and regional level will make marine ecosystems more resilient to climate change impacts.

Short-term forecasts, and long-term predictions, of changes in water conditions and the incidence of HABs and jellyfish blooms are necessary for plant operators to respond to water quality 'events'. A recommendation from the workshop was the development of an early warning system for HABs and jellyfish blooms for each ROPME sub-region based on satellite remote sensing systems combined with hydrodynamic models.

Additional national or regional actions include placing a requirement on plant operators to undertake climate change risk assessments to inform plant level adaptation plans.

LOCAL SCALE ADAPTATION OPTIONS

At the scale of individual plants there are a range of adaption options that can be considered, although building adaptive capacity into new plants is easier then retrofitting existing plants.

A common approach for all plants is to consider the location of intakes to minimise exposure to adverse water quality conditions. This could include deep-water intakes, intakes buried below the sediment surface, or using headlands to isolate the intake from environmental impacts.

Another common issue is blockage of intakes. There are a range of intake designs and adaptations that can be used to reduce blockage risks, and the use of bubble curtains to reduce jellyfish intake is increasingly being applied.

Reverse osmosis desalination plants are particularly susceptible to clogging and blockage. Modifications to filtration and cleaning systems, and alternative membrane materials may be required to build resilience to HABs and increased levels of dissolved organic matter.

Increased ambient water temperatures for cooling water may require modifications to condenser design to maintain plant operating efficiencies. Moving from thermal based plants to RO plants should reduce local impacts associated with thermal impacts, however RO plants become less efficient at high salinities.

The choice of best adaptation options will vary between plants depending on the technology and systems used in each plants, so plants will need to develop individual adaptation plans.

Bubble curtain around intake. Courtesy CanadianPond.ca

NEXT STEPS

This Policy Brief, and the ROPME Marine Intakes Climate Resilience Workshop, form part of the ROPME Regional Action Plan on Marine Climate Change.

The ROPME Regional Action Plan is building coordinated regional understanding of the risks of climate change to biodiversity and society in the ROPME Sea Area and adaptation actions available to build resilience to climate change risks.

The outputs from the ROPME Regional Action Plan are designed to support Member States fulfil commitments under the Paris Agreement.

Copies of this Policy Brief, and of the other outputs from the ROPME Regional Action Plan are available from http://ropme.org/430_Tech_ Reports_Summary_EN.clx

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References for the databases for the Desalination and Power plants are:

- For the desalination database: Global Water Intelligence (GWI) DesalData database 2018 - https://www.desaldata.com/.
- For the power plant database: Global Energy Observatory, Google, KTH Royal Institute of Technology in Stockholm, Enipedia, World Resources Institute. 2019. Global Power Plant Database. Published on Resource Watch and Google Earth Engine. http://resourcewatch. org/ https://earthengine.google.com/

References for the models used for the climate projections are:

- For the Inner ROPME Sea Area: AGEDI. 2016. Final Technical: Regional Desalination and Climate Change. LNRCCP. CCRG/IO.
- For the Middle and Outer ROPME Sea Area: Collins, W.J., N. Bellouin, M. Doutriaux-Boucher, N. Gedney, T. Hinton, C. D. Jones, S. Liddicoat, G. Martin, F. O'Connor, J. Rae, C. Senior, I. Totterdell, S. Woodward, T. Reichler, J. Kim, 2008: Evaluation of the HadGEM2 model. M0et Office Hadley Centre Technical Note no. HCTN 74, available from Met Office, FitzRoy Road, Exeter EX1 3PB http://www. metoffice.gov.uk/publications/HCTN/index. html

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