



**PROMOTING AN EU-GCC  
CLIMATE CHANGE AGENDA:  
WATER SECURITY PRIORITIES**



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WATER SECURITY PRIORITIES**

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## Executive Summary

This research paper addresses the water security challenges in the GCC countries within the context of climate change. It highlights the climate change impacts on water security in these countries and their priority adaptation actions, as indicated by the countries' national communication reports to the United Nations Framework Convention on Climate Change (UNFCCC) and Nationally Determined Contributions (NDCs). Key areas of cooperation opportunities and convergences between the GCC countries and the EU in the climate change agenda are highlighted, with particular reference to the EU's Green Deal 2020.

From a development perspective, the main water security challenges in the GCC countries are the continuing increases in water scarcity and the continuous depletion and quality deterioration of the region's groundwater resources on the one hand, and on the other the increasing financial, economic and environmental costs associated with the reliance on non-conventional water resources, namely desalination to compensate for the water shortages and meet the rapidly increasing sectoral water requirements. An additional challenge is the inadequate Utilisation of treated wastewater which represents major lost opportunities under the water scarcity conditions of these countries. From a risk-based perspective, the principal challenge for water security in the GCC countries is securing domestic water supplies during emergencies and disasters. These current challenges are expected to be aggravated in the future if the current external and internal forces driving the demand for water continue. These include the rapid population and urbanisation growth rates, agricultural policies, the prevailing general subsidy systems, low water efficiencies in both supply and use and inadequate recycling and limited reuse.

The vulnerability of the water sector to climate change is considered to be high and climate change is expected to act as an additional stress factor on the already heavily stressed water sector in the GCC countries. This would lead to higher levels of uncertainty in the planning and management of the water sector in the region. Yet climate change also presents an opportunity to address the water security challenges in the GCC countries and to enhance their adaptive capacity.<sup>1</sup> It is imperative for the GCC countries to enhance the efficiency of their water

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<sup>1</sup> Adaptive capacity refers to "the ability of a (human) system to adjust to climate change (including climate variability and extremes), to moderate potential damages, to take advantage of opportunities, or to cope with the consequences." Adaptive capacity is a function of available financial resources, human resources and adaptation options, and will differ between risks and sectors. Here, adaptive capacity relates to the opportunity climate change avails to deal better with water scarcity and adapt to, in a manner that would also serve resilience to climate change.



management systems and to adapt to the impacts of climate change if their water sectors are to continue to serve their socio-economic developments.

In the past few decades, the GCC countries have addressed their water security challenges by focusing on the supply-side management, manifested by the expansions in desalination, groundwater abstraction, surface water harvesting and the reuse of treated wastewater. The climate change agenda represents an opportunity for the GCC countries to review and reform their current water management policies and practices and to implement a shift towards water sector efficiency and demand-side management. These can be introduced by the development of integrated water management plans with a strong emphasis on demand management and efficiency to close the gap between supply and demand and to adapt to the anticipated impacts of climate change on the water sector. The strategic aim is to establish an efficient and a resilient water management system that can cope with future water challenges and uncertainties.

To achieve greater water security, the GCC countries have to complement their currently practiced supply-side management efforts with a number of efficiency and demand management interventions. These include a reduction in per-capita water consumption, reducing leakage in the distribution network in the municipal sector, controlling agricultural water consumption, increasing irrigation efficiency, and reusing treated wastewater to reduce the stress on groundwater resources. The main enablers for achieving such shift towards demand management and efficiency and enhance the adaptation to climate change are capacity development (institutional and individual), stakeholders awareness raising, water sector governance improvement including the formulation of modern water legislation, and private sector participation.

Moreover, as the reliance on desalination and wastewater treatment technologies will continue to increase in the future, acquiring and localising these technologies in the GCC countries will become an imperative strategic objective, to ensure their sustainability as sources of water, to provide added value to the GCC economies and to enhance their security. Furthermore, R&D efforts in localising desalination technologies must also concentrate on the development of renewable energy to power desalination so as to reduce their greenhouse gases (GHGs) emissions and to mitigate the impacts of desalination on the surrounding marine environment.

These management and adaptation actions, R&D investment areas and enablers coincide with many of the EU's water scarcity and drought policies and provide many opportunities for cooperation and partnerships between the EU and the GCC countries. In addition, the EU's Green Deal plan can provide an additional framework for closer cooperation and technology transfer between the EU and the GCC countries in renewable energy desalination and energy efficiency in the water sector, as well as in the application of a circular economy, particularly when related to municipal wastewater management. Such cooperation and partnerships are in line with the EU's objective in leading international efforts, its advocacy for a global sustainable path and its readiness to support developing countries' efforts in fighting climate change by building a better resilience in adapting to its impacts via alliances and partnerships.



## 1. Introduction

Achieving “water security”<sup>2</sup> in the GCC countries continues to be a challenging task due to natural and anthropogenic factors. Situated in one of the most water-scarce regions of the world and experiencing one of the world’s highest population and urbanisation growth rates, coupled with rapidly changing life styles and consumption patterns, the GCC countries are facing enormous challenges and high costs in the provision of water to meet their ever-increasing water demands.

Despite the severity of these challenges, the GCC countries have done well in the provision of this commodity to their populations. Thanks to their strong economies and substantial financial and energy resources, a safe, affordable and stable domestic water supply has been established in each country. Currently all the GCC countries have achieved almost 100% access to safe and affordable drinking water (GCC-STAT, 2019). However, the municipal water supply systems rely heavily on desalination, which is associated with substantial financial costs and they are energy-intensive, affecting both the economies and the environments of the GCC countries. Furthermore, the municipal water supply systems are at risk to many threats that make them highly vulnerable to interruption shocks and inefficiencies that affect their sustainability over the long run.

Moreover, to fulfil the requirements of agricultural water demands, the GCC countries have relied heavily on groundwater resources. A major concern is that the majority of these groundwater resources are non-renewable (also called fossil groundwater), are being extensively mined and are rapidly depleting, while the remaining limited and renewable groundwater resources are being over-exploited beyond their replenishment rates, leading to their quality degradation due to saltwater intrusion. The loss of groundwater resources will have dire consequences for the GCC countries in terms of the loss of long-term strategic water supplies and the cost of the replacement water, with heavy impacts on water security.

Furthermore, while the GCC countries have provided commendable sanitation services, their wastewater treatment capacities are overwhelmed by the generated wastewater volumes, leading to the discharge of the treated or partially treated wastewater into the sea or wadis, thereby increasing pollution. In addition, despite the operation of modern treatment facilities with tertiary and advanced treatment capabilities, the potential reuse of the generated treated wastewater is not fully developed and most of this water is not used, a major lost opportunity under these countries’ scarcity conditions.

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<sup>2</sup> As will be defined in the coming sections water security is addressed from both “developmental” perspective and “risk-based” perspective.



Against this background of water sector conditions and security challenges, global climate change and climate variability will pose a major “incremental stress” on the already stressed water management system in the GCC countries. They are also introducing higher degrees of uncertainty in the planning and management of water resources. A relatively recent regional assessment of the impacts of climate change on the Arab countries (RICCAR, 2017) indicated that climate change, manifested by increasing temperatures, a general decrease in precipitation, rising sea levels and increasing frequencies of floods and droughts, will increase the vulnerability of the water sector in all Arab countries. Furthermore national GCC vulnerability assessment studies indicate that climate change is expected to reduce surface water resources and groundwater recharge due to a reduction in precipitation, will result in deterioration in the quality of coastal aquifers due to sea level rise, will increase agricultural and domestic water demands due to rises in temperature and increase the frequency of destructive incidents due to extreme rainfall events. In other words, climate change will aggravate water conditions in the GCC countries and will impact their water security.

While climate change poses many additional challenges to water resource management in the GCC countries, it also presents many opportunities to address water security challenges and to enhance their adaptive capacities. Now is probably an opportune moment for the GCC countries to review and reform their current water management policies and practices and to establish an efficient and resilient water management systems that can cope with future water challenges and uncertainties.

This study highlights climate change impacts on the water sector and its security in the GCC countries and their proposed actions to adapt to climate change. It starts with the definition of the term “water security” and what it means within the context of the GCC countries (Section 2) and it gives an account of the current conditions in the water sector and the main water security challenges in the GCC countries (Section 3). This is followed by a summary of international and regional assessments of the water sector’s vulnerability to climate change in the GCC countries (Section 4). Then the individual countries’ assessments of their water sectors’ vulnerabilities to climate change are examined in more detail (Section 5). Current and proposed climate change adaptation activities, options and activities are studied in Section 6. These have been obtained from the countries’ national communication reports to the United Nations Framework Convention on Climate Change (UNFCCC) and their Nationally Determined Commitments (NDCs). Finally, the study attempts to identify key opportunities for cooperation between the GCC countries and the European Union in the climate change agenda: the European Green Deal 2020 (Section 7).



## 2. Water Security

Water security, like food, energy, health and environmental securities, are unconventional security issues. While conventional security generally refers to protecting states, groups and individuals from military threats when the threshold of force and violence is fairly clear and defined responsible institutions deal with these threats, these unconventional security issues have no similar clarity of definition nor institutions to deal with them (Bedeski, 1992). Yet these issues represent a growing area of threats to national well-being, they contain no direct military component, no adequate military response can be designed and, in most cases, no designated institutions exist to deal with these threats. Therefore, it is important in addressing unconventional security threats to identify clearly what is meant by water security, its dimensions and its measurement framework.

### Definition, Framework, and Measurement

The term "water security" has a wide range of perspectives and meanings and covers many issues. It varies from one country to another, from one spatial scale to another (city, country, group of countries) and even from one institution to another within a given country. For example, for a downstream country of a shared river basin - such as Syria, Iraq and Egypt - water security is frequently referred to in the context of securing water rights in the shared river basin. For some countries, the term is associated with protecting the domestic water supply from adversarial actions (e.g., the USA's Homeland Security perspective). In other countries, such as Canada, water security is meant not only to ensure water supplies to humans and economic activities, but also for ecosystem health. In the GCC countries the term water security is repeatedly used by officials when referring to securing domestic water supplies during emergencies.

The literature outlined below indicates that there are many definitions for water security. Many of these definitions focus on water physical quantity or are weighted more towards it. An example of a very simple definition that focuses only on the physical quantity is the "Water Poverty Indicator", which looks at the annual per capita share of internal renewable freshwater resources in a given country (Falkenmark, 1989). A more elaborate definition for water security, which has been widely referred to in relevant literature is the one given by Grey and Sadoff (2007): "The availability of an acceptable quantity and quality of water for health, livelihoods, ecosystems and production,

coupled with an acceptable level of water-related risks to people, environments and economies." The Global Water Partnership (GWP - 2012) has defined a very comprehensive view of the state of water security as: "It is a world where every person has enough safe, affordable water to lead a clean, healthy and productive life. It is a world where communities are protected from floods, droughts, landslides, erosion and water-borne diseases. Water security also means addressing environmental protection and the negative effects of poor management."

Water security, therefore, can be shown to have the following four main dimensions or aspects: 1) the provision of an appropriate quantity and quality of water for human activities (basic needs and economic activities); 2) coping with water related hazards and emergencies; 3) preventing harm to the ecosystem; and 4) managing water efficiently.

Currently there is no consensus on a measurement framework for water security due to its complex nature. Surveys of scientific literature indicate that measurement frameworks for water security are still at the development stage and the topic has emerged as an active research area.<sup>3</sup> Example of these frameworks are the Maplecroft Water Security Index<sup>4</sup> (Maplecroft, 2010), the Global Water Security Index (Gain et al., 2016), the National Water Security Index (ADB, 2013; GWP, 2014), the City Water Security Index (Babel et al., 2020) and more recently the MENA Water Security Profile (World Bank, 2018).

A relevant example is that of the Asian Development Bank, which developed a water security framework consisting of five key dimensions (ADB, 2013): 1) Household water security (access to a water supply, sanitation and hygiene); 2) Economic water security (water productivity in the consumer sectors); 3) Urban water security (urban supply, wastewater treatment and flood damage); 4) Environmental water security (river health and vulnerability/resilience to any alterations of the natural flow) and 5) Resilience to water-related disasters and emergencies. It should be noted that this framework is designed for the countries of Southeast Asia, which have different challenges from those facing the GCC countries. For example, environmental water security is measured by indicators of river health and vulnerability caused by alterations to natural flow, while there are no rivers in the GCC countries.

## Approaches for Addressing Water Security

In general, there are two approaches to addressing water security (GWP, 2014): 1) A developmental approach, which seeks to improve water security over time through a combination of policies, reforms and investment projects. It advocates the improvement of governance and management, the establishment of strong institutional and societal capacities and investments in R&D and technology; and 2) A risk-based approach, which seeks to manage risks and reduce vulnerability to water-related disasters and emergencies, based on the process of risk assessment and management. These two approaches are complementary and need to be pursued simultaneously and in a balanced manner, with interdisciplinary collaboration across all sectors, communities and borders. Implementing these two approaches jointly aims to establish an "efficient" and "resilient" water resources management system.

This study addresses water security from these two perspectives, as climate change will have an impact on both, although more focus will be given to the development approach.

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<sup>3</sup> It is worth noting that a "Water Security Journal" (<https://www.journals.elsevier.com/water-security>) was established in 2017.

<sup>4</sup> <https://www.maplecroft.com/risk-indices/water-stress-index>

### 3. Water Resources, Utilisation and Challenges in the GCC Countries

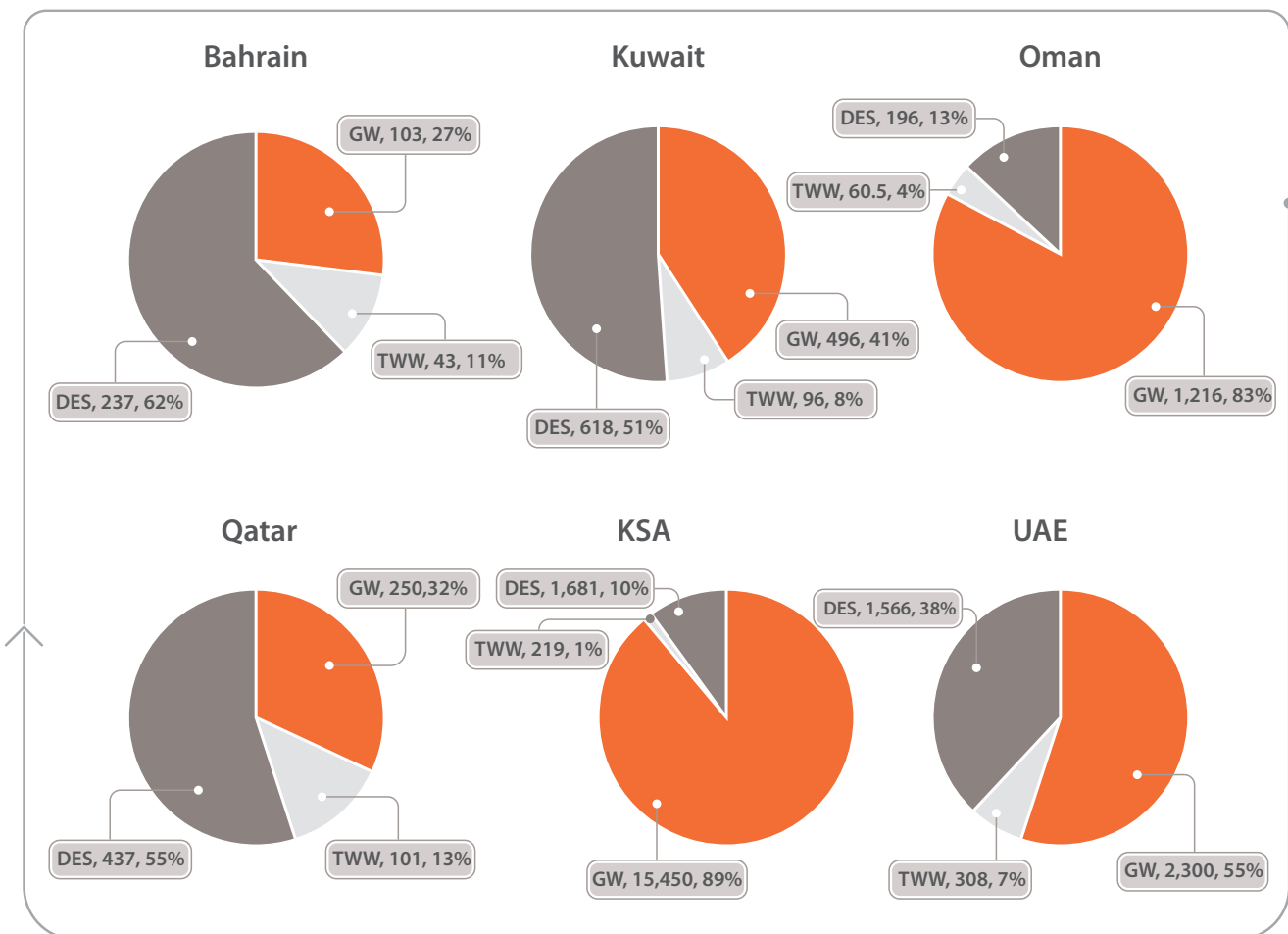
This section briefly presents the main water supply sources and the main water use sectors in the GCC countries, followed by their main water security challenges from developmental and risk-based perspectives.

#### 3.1. Water Resources in the GCC Countries

The GCC countries are located in one of the driest regions in the world. With the exception of coastal strips and mountain ranges, the region is essentially desert with a harsh environment. It is characterised by low and erratic rainfall (70-150 mm/yr) and high evaporation rates exceeding 3,000 mm/yr, creating unfavourable conditions for a perennial surface water system to exist.

The GCC countries' overall water requirements are met mainly by groundwater abstraction and surface water harvesting (78%), desalinated water production (19%) and to a lesser extent by the reuse of treated wastewater (3%) (Al-Zubari, et al. 2017). However, these percentages differ per country (Figure 3.1). Groundwater is the main component of the water budgets of Saudi Arabia, Oman and the UAE, while desalination represents the dominant water budget component for the smaller countries of Kuwait, Qatar and Bahrain.

**FIGURE 3.1** Water Resources used in the GCC countries, 2012-2015



**Note:** GW=groundwater; DES=desalinated water; TWW=treated wastewater. First value shows resources used in millions of cubic meters, while the second value shows the percentage contribution of the total water used.



## Surface Water and Groundwater

Due to their locations, topography and limited areal extents, Bahrain, Kuwait and Qatar either have no surface water or it is too small to be relied on. However, for Oman, Saudi Arabia and UAE, which are relatively large and have mountainous areas, there are good sources of surface water (Table 3.1). Major efforts are made in these countries to capture surface water runoff by dam construction. The total dam capacity in these three countries is about 2.4 billion cubic meters (BCM) and these dams serve multiple purposes: flood control, water supply, groundwater recharge and irrigation.

**Table 3.1. Available conventional water resources in the GCC countries and groundwater abstraction, in million cubic meters (MCM).**

Country	Annual Rainfall (mm)	Annual Evaporation (mm)	Available Surface Runoff (MCM)	Groundwater (MCM)	
				Groundwater Recharge <sup>1</sup>	Nonrenewable reserve <sup>3</sup>
Bahrain	80	1,650-2,050	-	110 <sup>2</sup>	Negligible
Kuwait	110	1,900-3,500	-	160 <sup>2</sup>	N/A
Oman	20-300	1,900-3,000	102	900	102,000
Qatar	75	2,000-2,700	-	50	Negligible
KSA	70-500	3,500-4,500	2,400-3,695	3,850	428,400
UAE	89	3,900-4,050	150	190	N/A

(1) Recharge figures represent recharges to shallow alluvial aquifers; (2) recharge to aquifers in Kuwait and Bahrain occurs by the underflow from equivalent aquifers in Saudi Arabia and recharge is variable depending on the hydraulic gradient between the two countries. Indicated figures represent steady state conditions; (3) non-renewable reserves estimates are based on AGFUND/WB (2005). Annual rainfall and evaporation figures are obtained from Al-Alawi and Abdulrazzak, 1994.

Groundwater in the GCC countries is divided into two types: renewable and non-renewable aquifers. Renewable groundwater is developed in the shallow alluvial deposits along the main wadi channels and the flood plains of drainage basins. In some countries, such as Saudi Arabia and Oman, renewable shallow groundwater is a vital natural resource for potable water supply for both urban and rural populations. The recharge of these aquifers depends on recent precipitation events, with an estimated total recharge rate of about 5.2 BCM. These groundwaters have been heavily over-extracted by amounts that considerably exceed their recharge rates in all the GCC countries. This has resulted in a considerable decline in groundwater levels/depletion and significant saltwater intrusions (by seawater or up-coning) into freshwater aquifers, resulting in the degradation of the water supplies, the abandonment of wells and agricultural lands and the cessation of flows from springs.

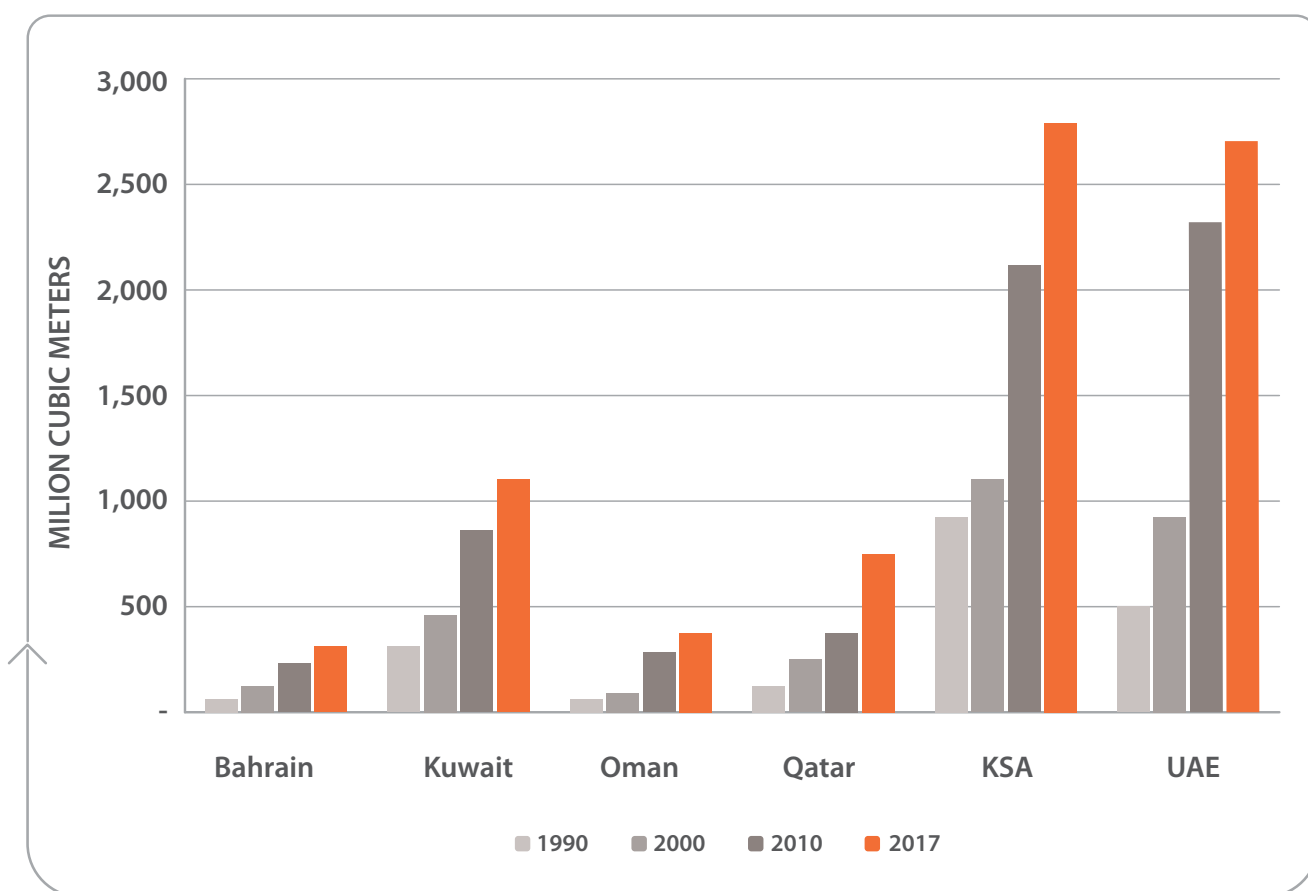


Non-renewable or fossil groundwater is developed in the deep sedimentary layers that store significant amounts of groundwater that is thousands of years old, laid down during the rainy Pleistocene and Pliocene geological periods. The majority of these are located in Saudi Arabia and Oman. The quality of the deep aquifers varies greatly, being suitable for domestic consumption in only a few areas, with most being used for agricultural purposes. The fossil groundwater, which has a finite usable reserve, is being mined extensively by the agricultural sector and its water demands are resulting in a rapid depletion of reserves, which is manifested in a sharp decline in water levels and quality. In Saudi Arabia, it is estimated that about 35 percent of non-renewable groundwater resources was already depleted by 1995 due to ambitious agricultural policies favouring the maximisation of local food production to achieve food security (Al-Turbak, 2003).

## Desalination

Desalination technology was introduced in the GCC countries in the mid-1950s and has developed very rapidly to counteract the shortage and quality deterioration in groundwater resources and to meet the qualitative requirements of the drinking/domestic water standards. At present municipal water supplies in major cities of the GCC rely mainly on desalinated water, which is used either directly or is blended with groundwater. Figure (3.2) shows the development of the desalination capacity in the GCC countries, which increased from about 2 BCM in 1990 to about 8 BCM in 2017, with the majority of this capacity installed in Saudi Arabia and the UAE. All the GCC countries are embarking on major desalination expansion projects to meet population and urbanisation growth, a trend expected to continue in the future.

**FIGURE 3.2** Trends in desalination capacity in the GCC countries, 1990-2017



Source: GCC-STAT, 2018.



The primary desalination process used in the GCC countries is the thermal process, namely the Multi-Stage-Flash (MSF) and the Multiple Effect Distillation (MED) technologies. Reverse Osmosis (RO) technologies, both in seawater and brackish water, have been gradually adopted with some relatively large plants now in operation in some countries.

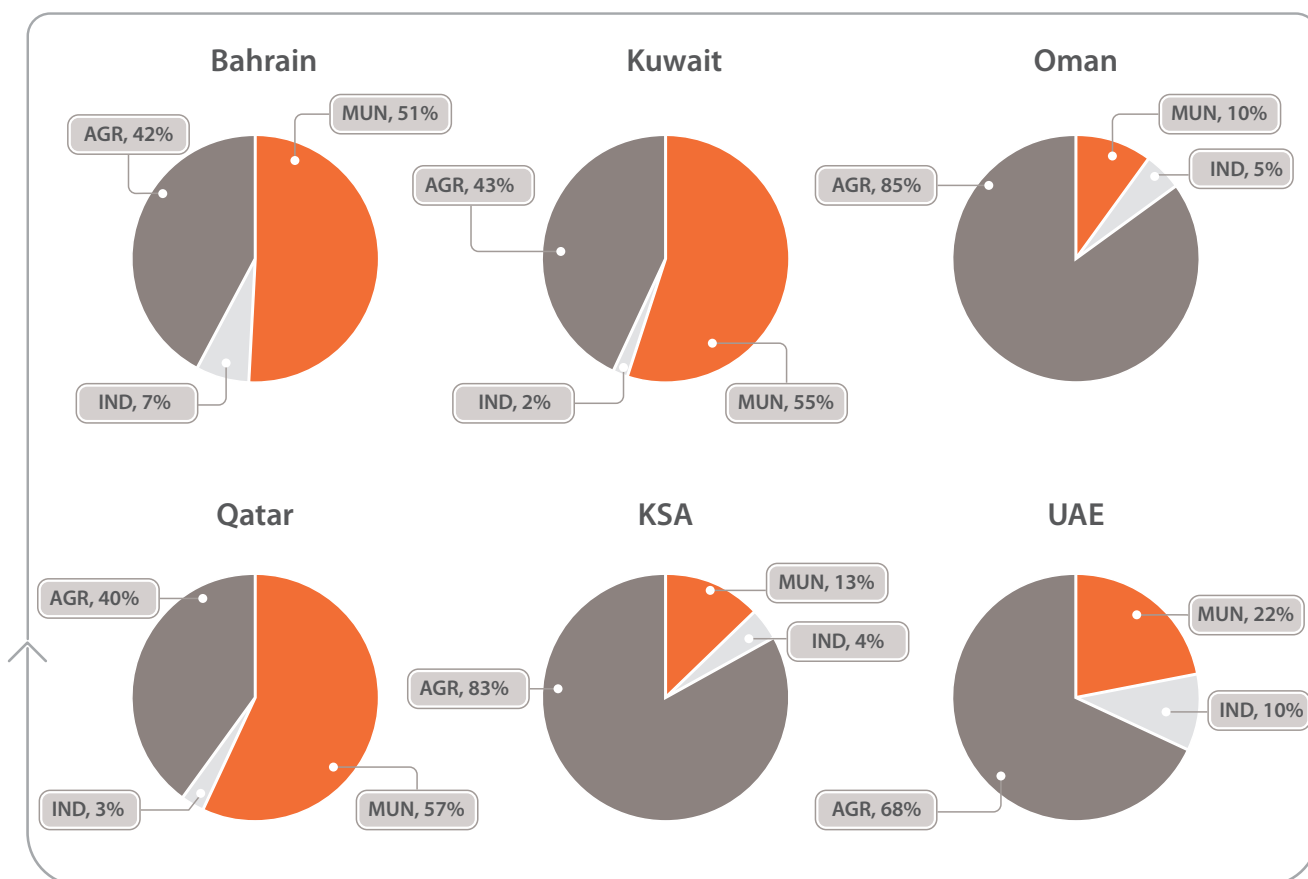
### Treated Municipal Wastewater

Treated wastewater in the GCC countries constitutes an increasing water source, driven by the escalating water consumption in urban areas. At present all the six GCC countries are operating modern treatment facilities with tertiary and advanced treatment capabilities (activated sludge followed by disinfection). The total designed treatment capacity of the major treatment facilities has increased from 1.1 BCM/yr in the mid-1990s to more than 2 BCM/yr currently. Most of the wastewater systems in the GCC are centralised, however, in the past few years some countries have started to move to a decentralised wastewater system.

### 3.2. Water Use in the GCC Countries

During the last four decades, the total water demands in the GCC countries have increased dramatically as a result of the high population growth, urbanisation, and agricultural and industrial developments. The total water use for all sectors in the GCC countries increased from about 6 BCM in the 1980s to more than 30 BCM in 2015. Overall, the main water consumer in the GCC countries is the agricultural sector (77%), followed by the Municipal sector (18%) and the Industrial sector (5%) (Al-Zubari, et al. 2017). At the countries' level, the agricultural sector is dominant in the countries of Oman, Saudi Arabia and the UAE, while it represents only about 40% of the total water demands in Bahrain, Kuwait and Qatar (Figure 3.3).

**FIGURE 3.3** Sectoral water use in the GCC countries in 2012-2015 (as a percentage of the total water use)

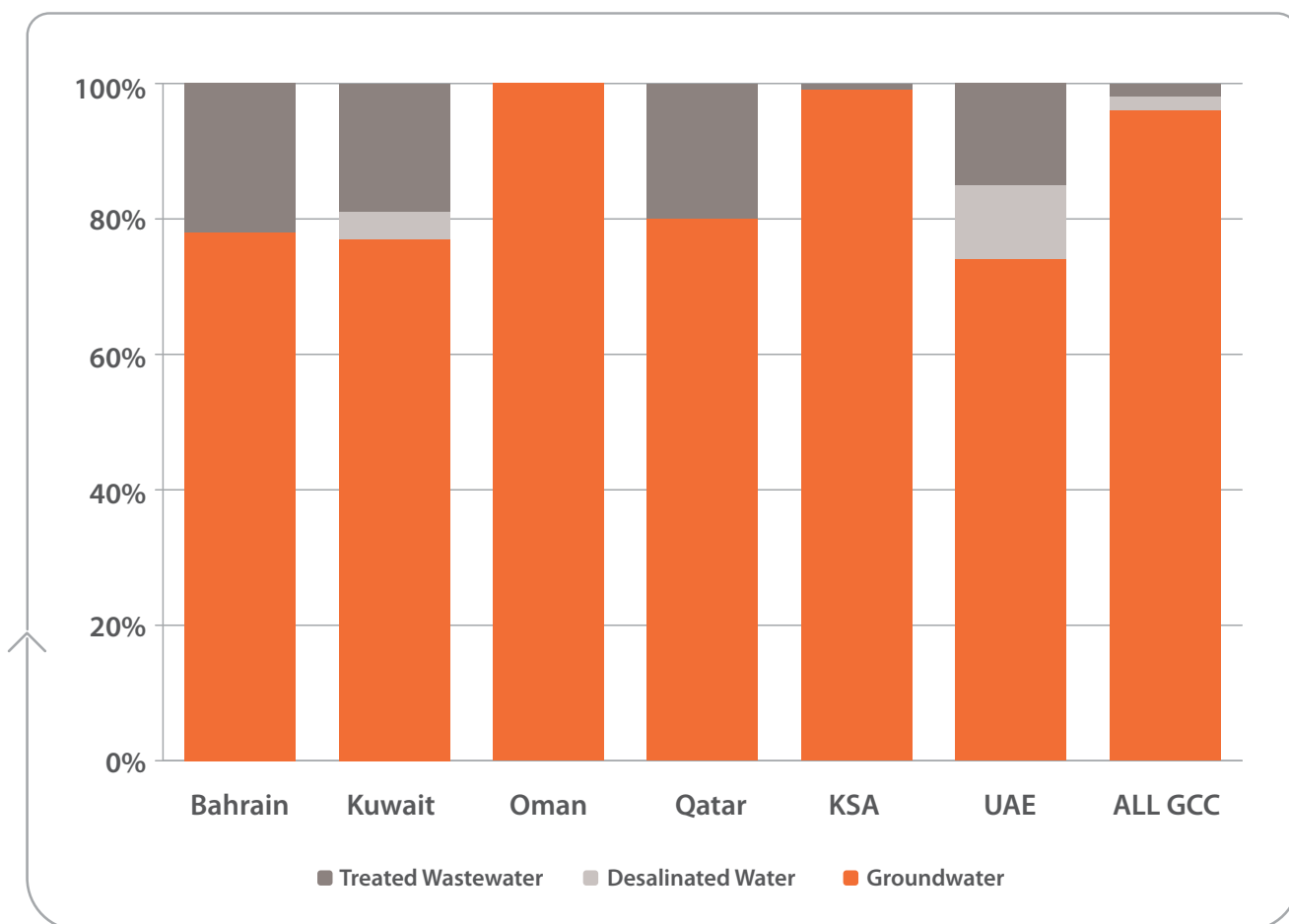


Note: AGR=agricultural sector; MUN=municipal sector; and IND=industrial sector.

## Agricultural Sector

Starting in the 1980s, the economic policies in most of the GCC countries have given priority and support to the development and expansion of irrigated agriculture. Food security is the major economic goal and it is used to justify the expansion of certain grains and crops characterised as water intensive. These economic policies in some countries encouraged the over-pumping of groundwater for irrigation use.<sup>5</sup> The policies also resulted in substantial increases in groundwater abstraction volumes. In all the GCC countries, the abstracted volumes have far exceeded the renewable amounts of groundwater and the water deficit has been met by either over-drafting renewable groundwater resources or by the mining of non-renewable groundwater sources. Moreover, the agricultural water consumption is exaggerated due to low irrigation efficiencies (i.e. the predominance of traditional irrigation methods), cultivating high water consuming crops (e.g., cereals and fodders), unrestricted groundwater abstraction rights and the absence of water metering and tariffs for groundwater use in agriculture. The agricultural sector in the GCC countries relies mainly on groundwater (overall groundwater contribution is 87%) and is complemented by treated wastewater (Figure 3.4), the percentage of which has been increasing with time. The GCC countries have ambitious plans for the reuse of treated wastewater in the agricultural sector to replace the deteriorating groundwater.

**FIGURE 3.4** Agricultural sector water sources in the GCC countries, percentage contribution (2012-2015)

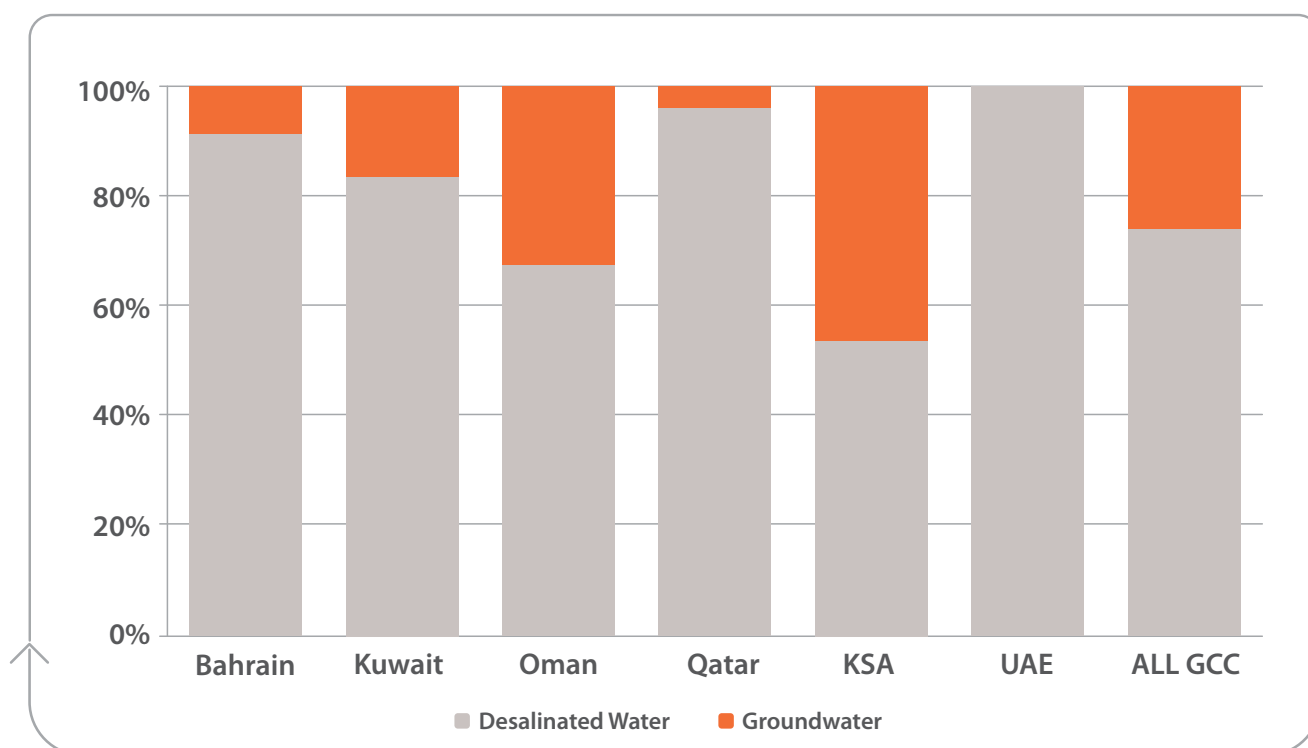


<sup>5</sup> Subsidised prices of gasoline and electricity, Subsidised credit for buying water pumps and irrigation equipment, exemptions of tariffs on imported fertilizers and equipment, Subsidised prices of certain agricultural products and protection against foreign competition in the domestic markets are all examples of the tools used to implement these agricultural-based economic policies. It is obvious that none of these policies has been subject to serious assessment in terms of their impact on the sustainability of groundwater resources.

## Municipal<sup>6</sup> /Domestic Sector

Driven by population growth and urbanisation, municipal water consumption in the GCC countries has been rapidly increasing. Over a period of about 30 years the total municipal water consumption in the GCC countries has more than quadrupled, from about 1 BCM in 1980 (Al-Alawi and Abdulrazak, 1994) to more than 5.8 in 2016 (GCC Water Statistics Report). The water demands of the municipal sector have been also exaggerated by the generally low efficiency of both the supply and demand-sides. On the supply-side many GCC countries experience relatively large percentages of network losses, while on the demand-side the per capita water consumption in the domestic sector in many GCC countries is high, reaching more than 500 litres per day. In addition, recycling and the reuse of water in the municipal sector is almost negligible. As indicated earlier, to meet these escalating municipal water demands the GCC countries have resorted heavily to desalination. Currently almost all of the municipal water supply systems rely on desalination in the GCC countries (Figure 3.5).

**FIGURE 3.5** Sources for domestic water supply in the GCC countries



Source: Al-Zubari et al., 2017.

## Industrial sector

Since the 1990s the industrial sector in the GCC countries has been expanding rapidly due to governmental diversification policies to non-oil industries. These non-oil industries, including steel production, mining, cement factories, the food industry and many others, are expected to increase water consumption in the sector. The total water consumption in the industrial sector in the GCC countries increased from about 321 MCM in the mid-1990s, representing about 1.3% of the total water consumption of these countries, to about 1.3 BCM in 2010, and represented about 5.3% of their total water consumption. The main sources for the sector are groundwater and desalinated water.

<sup>6</sup> Municipal water is the water supply by the municipal distribution network. The municipal sector includes household (or domestic), commercial, government, public buildings, etc. In the GCC countries, the domestic sector is the main component of the municipal sector.



### 3.3. Water Security Challenges in the GCC Countries

As indicated earlier, water security issues are addressed from two perspectives: developmental and risk based. From a “developmental perspective”, the overall water security challenges in the GCC countries are the continuous increase in water scarcity<sup>7</sup> and the continuous depletion and quality deterioration of the region’s groundwater resources on the one hand and on the other the increasing financial, economic and environmental costs associated with the reliance on non-conventional water resources, namely desalination, to compensate for the water shortage caused by the rapidly increasing sectoral water requirements. From a “risk-based perspective”, the main challenge facing the water sector is securing domestic water supplies during emergencies and disasters, resulting from activities that can be land-based or marine-based, natural or man-made, intentional or accidental.

These challenges are expected to grow with time if the current internal and external driving forces of the water sector continue in the future. Internal driving forces include generally low water efficiencies in supply and end use and inadequate recycling and limited reuse, while external driving forces include rapid population and urbanisation growth rates, the prevailing general subsidy system and increasing food demands. Climate change and variability are expected to act as additional driving forces that would put more stress on the current water management system in the GCC countries and would increase its vulnerability (refer to Section 4). These water security challenges are presented in more details in the following sections.

#### Meeting Municipal Water Demands and Associated Cost

In view of the limited natural water resources in the GCC countries and the rapid increases in population, urbanisation and various socio-economic activities, it is expected that desalination will continue to play an ever-increasing role in the water supply portfolio in the region. Currently all the GCC countries are embarking on major desalination expansion projects. Collectively, the GCC countries have the highest concentration of desalination capacities worldwide, possessing over 40% of the world’s desalination capacity. This percentage is expected to increase in the future.

However, while the GCC countries have been able to meet the rising municipal water demands in

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<sup>7</sup> Generally measured in per capita renewable water resources; the GCC countries have one of the lowest per capita share of freshwater resources globally, with values much below the threshold of absolute water scarcity of 500 m<sup>3</sup>/year, which continues to drop rapidly with increasing populations. Average per capita freshwater availability in 2020 is calculated at about 93 m<sup>3</sup>/year.



quantity and quality by the expansion of desalination plants, this has been associated with enormous financial, economic and environmental costs. These costs are manifested by: 1) the required energy (oil and gas) for desalination water production<sup>8</sup> (including its opportunity costs); 2) the financial and energy/electricity costs of every stage in the operation of the water cycle system (i.e., production, transmission and distribution); and 3) the environmental costs in terms of thermal brine discharge by desalination plants, its impact on the surrounding coastal and marine environment and the air pollution caused by burning fossil fuels, its impact on human health and the environment and its contribution to greenhouse gases. In addition to these costs, there are other externalities related to municipal water consumption, the most important of which are the increasing volumes of the generated municipal wastewater, represented by the financial and energy costs of the wastewater treatment process. In addition, there are environmental costs when hydraulic loading occurs, as this impacts treatment efficiency and increases carryover volumes to the coastal and marine environments, thereby impacting biodiversity.

The financial costs of the municipal water sector are being increased by two factors: the heavy subsidies for municipal water services and consumption, resulting in insignificant cost recovery percentages, and the high percentages of non-revenue water (NRW)<sup>9</sup>. Overall, the total amount of water subsidies is quite high for the majority of the GCC countries, both in terms of budgetary amounts and as a share of their oil export revenues. The low cost recovery of the sector creates a heavy financial burden for the municipal sector on the fiscal budget and also makes the sector captive to government allocations, which are susceptible to oil-price volatility, eventually influencing the sector's general performance. Given recent trends in the growth of water demands, the future fiscal burden is likely to be substantial in the GCC countries. On the other hand, in many GCC countries NRW is high and represents an additional major factor that affects the financial sustainability and economic efficiency of the municipal water sector.

One of the measures that has been taken to reduce the cost and to alleviate the financial burden is privatisation. The majority of the GCC countries have moved to privatising production, whereby many desalination plants are built as independent water and power projects (IWPP) and water is purchased by the government. In addition, some countries<sup>10</sup> have reformed their water pricing policies in an attempt to enhance their cost recovery as well as to provide a price-signalling mechanism to influence water users to make their consumption patterns more rational. On the technology level, many countries have started to adopt Reverse Osmosis desalination technologies in their new desalination plants to reduce energy consumption and environmental impacts.

At a higher strategic level, despite the introduction of desalination in the region in the 1950s, the increasing reliance on this technology in providing water supply and the significant current and future share of desalination capacity in the world, desalination remains an imported technology in the region. The desalination industry provides limited added value to the economies of the GCC countries in terms of localised operations and maintenance, plant refurbishment, fabrication, the manufacture of key spare parts and qualifying local labour and professionals to work in the desalination industry.

There are a number of government-sponsored initiatives in the region to localise desalination, reducing its costs and lowering its environmental impact. The most important of these are King

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<sup>8</sup> The currently adopted thermal desalination technology is energy-intensive, claiming with alarming rates a sizable portion of energy resources and threatening the main sources of income of the GCC countries. The majority of the desalination plants are cogeneration power desalination plants (CDPD), with energy costs representing about 85% of their running costs, as well as placing a strain on the environment.

<sup>9</sup> Non-revenue water (NRW) comprises three components: real losses (leakage), apparent losses (metering inaccuracies, data-handling errors, and theft) and unbilled authorised consumption (exemptions).

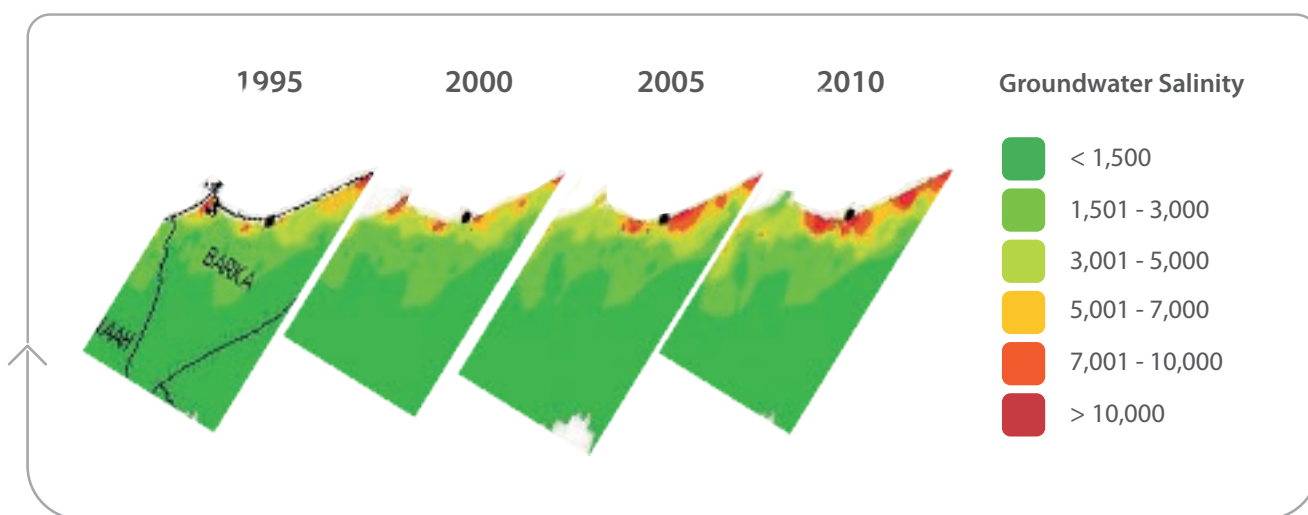
<sup>10</sup> In 2016, there has been a revision of the municipal water tariff in Saudi Arabia, UAE, and Bahrain.

Abdulaziz City for Science and Technology (KACST) in Saudi Arabia and MASDAR in the UAE. The KACST initiative was launched in 2010 and aims to use solar energy to desalinate seawater at a low cost to contribute to Saudi Arabia's water security and national economy. The MASDAR renewable energy water desalination programme is another initiative in the region. The initiative currently consists of launching a renewable energy desalination pilot programme to research and develop energy-efficient, cost-competitive desalination technologies that are suitable to be powered by renewable energy.<sup>11</sup>

### Rapid Depletion and Quality Deterioration of Groundwater Resources

Groundwater reserves, in both renewable shallow and non-renewable deep aquifers, represent a major source of the overall water supply in the GCC countries. Currently groundwater contributes to about 78% of the total water supply in the GCC countries and constitutes the main water source for the agricultural sector. It also contributes to the municipal/domestic water supply (either directly or when blended with desalinated water) in some GCC countries, such as Oman and Saudi Arabia. However in the last four decades rapid population growth, ambitious agricultural policies in several countries and the increase in economic activities, coupled with inadequate levels of management, have led to extensive groundwater withdrawals, leading to over-exploitation in all of the GCC countries. Currently all countries are experiencing a deficit, which is manifested by continuous water level declines and the degradation of water quality due to salinisation (Figure 3.6). In addition to their over-exploitation and quality deterioration, groundwater resources in the region are being threatened and polluted by numerous point and non-point sources of pollution generated from anthropogenic (i.e., agricultural, industrial, and domestic) activities (see for example Rizk (2014)).

**FIGURE 3.6** Groundwater salinisation by seawater intrusion in south Al-Batinah, Sultanate of Oman. Salinity is in mg/L



Source: Al-Amri, et al., 2014.

The deterioration of the groundwater quality has become a critical security issue throughout most of the GCC countries. As the quality of groundwater deteriorates, either by over-exploitation or direct pollution, its uses diminish, thereby reducing groundwater supplies, increasing water shortages and intensifying the problem of water scarcity in these countries. The deterioration of the groundwater quality will result in the loss of sizeable strategic reserves that could be relied upon during emergencies to provide domestic water and will have dire consequences on the GCC

countries' socio-economic development, particularly in the agricultural sector, and will increase health risks.

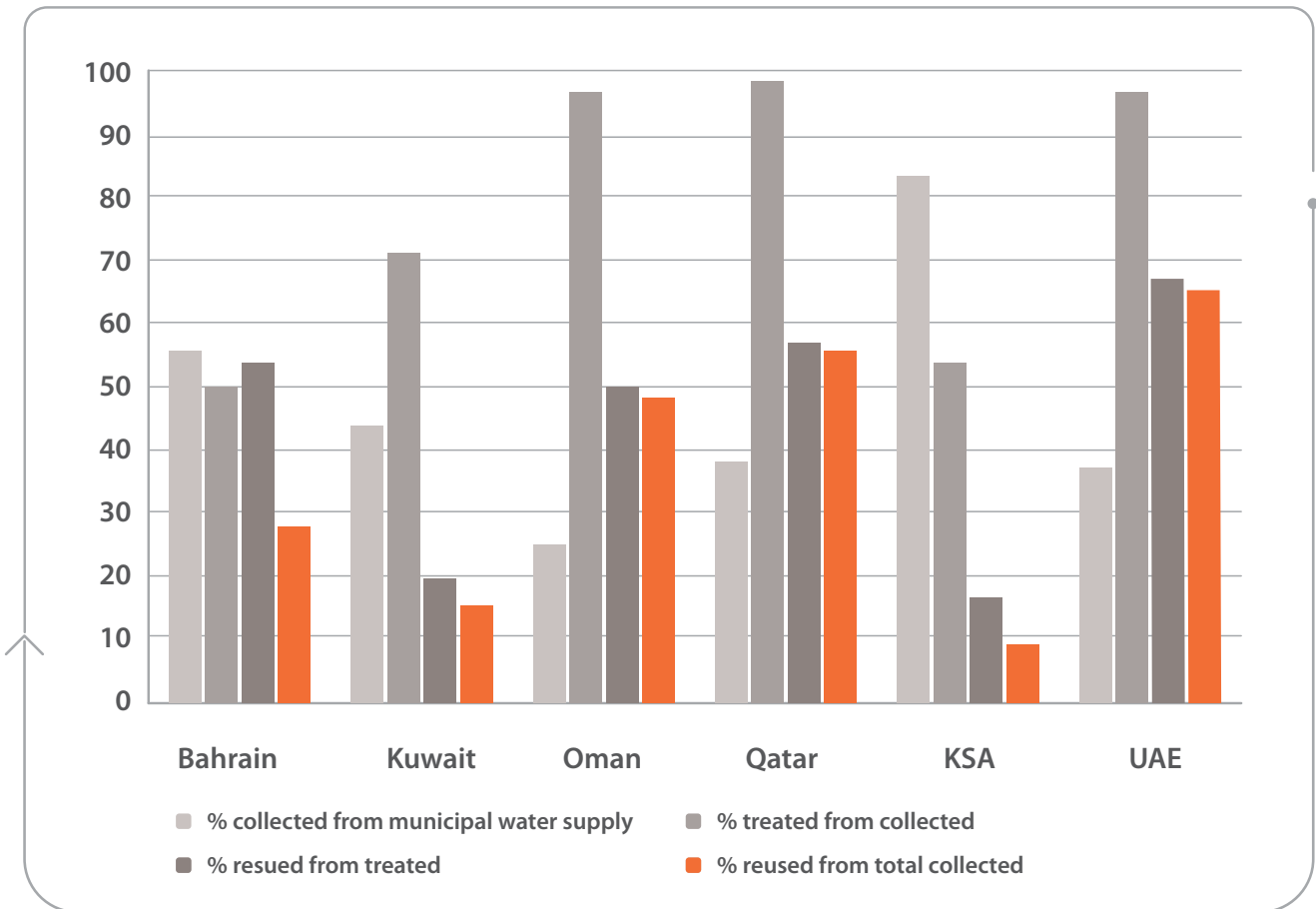
Agricultural development policies are the main driving force behind the volumes of water consumed in the agricultural sector, which are also exacerbated by the predominance of traditional irrigation methods leading to low irrigation efficiencies, the cultivation of high water consuming crops, the lack of water tariffs for groundwater abstraction and high-energy subsidies used for pumping groundwater. Traditional irrigation methods are still the dominantly practiced method in the majority of the GCC countries (60-75% of irrigated areas), leading to high water losses (irrigation efficiencies reported at 25-40%). These losses represent huge volumes of water when compared to the amount of water used by the agricultural sector. Moreover, in the last two decades, there has been a general trend towards cultivating fodder crops, mainly alfalfa, in the region, which is a water-intensive crop. This trend is attributed to the fact that alfalfa is a salt-tolerant crop, a cash crop, and is grown all the year round with high local demand. In most of the countries, there are no flow meters installed on groundwater wells and in all the GCC countries there are no charges for groundwater consumption, both of which encourage wasteful water use. Such conditions make it difficult to monitor and control groundwater abstraction. The degradation of the quality of irrigation water leads to a reduction in productivity and eventually to desertification and the loss of agricultural lands. These conditions not only lead to the loss of groundwater resources but also undermine the future sustainability of the agricultural sector itself.

### **Inadequate Utilisation of Wastewater (Lost Opportunities)**

The GCC countries have made substantial progress in providing basic sanitation services to the majority of their populations, especially in the urbanised areas, which is a commendable effort given their rapidly increasing populations and urbanisation. Currently wastewater in the GCC countries constitutes an increasing water source, driven by escalating water consumption in urban areas, and its share in the overall water budget has been increasing with time, though at slow rates in some countries. However treated wastewater reuse remains at an early stage of development and the potential for the use of the generated wastewater has not been fully integrated within the overall water resources management plans.

The main management challenge in the wastewater sector in many GCC countries is the low efficiency of wastewater recovery and the large mismatch between wastewater treatment levels and treated wastewater reuse. In 2017, although the GCC countries treated about 66% of the collected municipal wastewater, the reuse of this treated wastewater was only about 35% (Figure 3.7). In some countries much of the treated wastewater, even when treated to a tertiary level, is discharged unused into the sea, the wadis and artificial lagoons. There are many constraints that lead to this low level of reuse, including social, health risks and logistical/infrastructure constraints. Under the water scarcity conditions of the GCC countries, such low recovery and reuse rates represent major opportunities lost. However, all the countries have ambitious plans for the expansion in the use of treated wastewater as a strategic alternative source to meet their future demands for irrigation water and to reduce groundwater stress.

**FIGURE 3.7 Wastewater sector dynamics in the GCC countries in 2017**



Source: GCC-STAT, 2018.

Another major challenge facing the management of the municipal wastewater sector in some of the GCC countries is the limited infrastructure and the capacity to keep up with hydraulic and biological loadings driven by rapidly increasing municipal water demands. This is caused mainly by the lack of integrated urban water management and planning between the water supply and wastewater sectors.

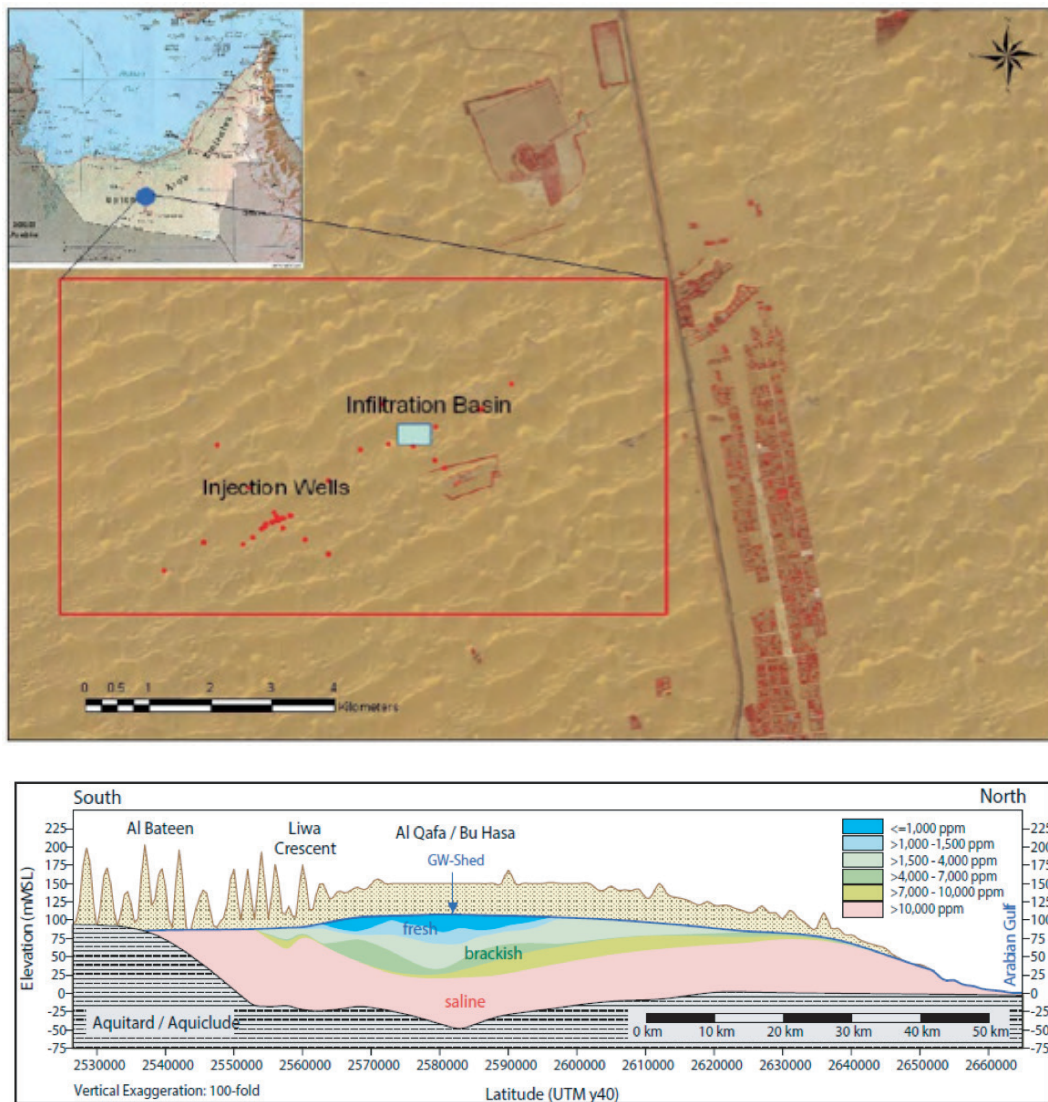
### High vulnerability of the Domestic Water Supply System

From a risk-based perspective, the main challenge facing the water sector is securing domestic water supplies during emergencies. The domestic water supply systems in the GCC countries depend heavily on desalination plants, ranging from 100% in the UAE to about 55% in Saudi Arabia, with an overall regional dependency of about 75% (Figure 3.5). Most of the desalination plants' feed water is from the Arabian Gulf (except for Oman and western Saudi Arabia). Desalination plants are highly vulnerable and at risk from a number of threats that might occur from various activities in the closed Arabian Gulf. These activities can be land-based or marine-based, natural or man-made, intentional or accidental. They include marine pollution (e.g., oil spills, chemical spills and red tides), marine contamination (e.g., nuclear and wastewater), natural disasters (e.g., hurricanes and seawater flooding) and combat (e.g. the targeting of desalination facilities). Other risks to the municipal water supply system are power outages, the hacking of the ICT and SCADA systems and the intentional contamination of drinking water supply systems (Al-Zubari et al, 2017).



In response to the numerous threats to their domestic water supply systems, the majority of the GCC countries are implementing plans that aim to increase their strategic reserves through storage reservoirs, both above and under the ground, as well as internal national gridding and transmission. Moreover, some GCC countries have implemented Aquifer Storage and Recovery (ASR) schemes whereby surplus desalinated water is stored in aquifers for emergency situations, such as in the Abu Dhabi Emirate (Dawoud, 2019) as illustrated in Figure 3.8.

**FIGURE 3.8** Selected site for ASR pilot project (Northern Liwa) and showing a hydrogeological cross-section for the selected area



Source: Dawoud, 2019.

In addition the GCC water grid mega project was proposed in 2014 to address emergency situations that may arise in the events of pollution affecting desalination and to enhance the overall security of the water supply system in the GCC at the regional level. While the project has been viewed as strategic, the relatively high estimated cost of the project and later its operational and maintenance costs, made the GCC countries reconsider and review the project. The GCC UWS 2035 recommended the study of bilateral water gridding between neighbouring GCC countries within the GCC Water Grid project. However, until today, no concrete steps have been taken in this direction between any two GCC countries.



A recently emerging threat to the water supply system in the GCC countries is the COVID-19 pandemic, which has introduced a number of risks that have not been experienced before in the GCC countries. The pandemic has raised the issue of the shortage of human resources to high levels, in terms of the risk of disruption to the water supply systems, compared to those related to infrastructural disruptions. The challenge of the shortage of human resources occurred for a number of reasons, including staff movement restrictions due to curfews (partial and complete), flight suspensions, borders closing and a 14-day home self-isolation period (for those arriving from countries affected by COVID-19 or who have been in close contact with probable or confirmed COVID-19 cases).

In response the GCC countries have taken several actions to maintain their work forces to ensure that the drinking water service is operational, which is critical in containing COVID-19 and protecting the population from other public health risks. The most important of these actions is considering the workers in the water supply and wastewater sectors to be “essential” workers, like health, police, army and other workers whose physical presence in their work places is crucial in order to allow them to be there physically during curfew hours. This has been complemented by having only the most critical jobs physically present in the work place (approximately 20-30% of the work force), with the rest of the work force performing their work remotely from their homes, relying on virtual electronic communication channels.

As the desalination industry has not matured yet in the region and remains an imported technology, large percentages of key spare parts, chemical additives and consumable reagents related to the technology have to be imported. During the COVID-19 pandemic a major concern has been the shortage of these critical items for the operation of the desalination plants for a number of reasons, including low stockpiles, borders closing and the stoppages in factories in exporting countries due to the pandemic. In response some GCC countries have started to increase their reliance on consumables produced locally or in other GCC countries. While significant disruption in key spare parts and consumables has not been experienced, a shortage of these remains a concern with the protraction of the COVID-19 pandemic.

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The most important of these actions is considering the workers in the water supply and wastewater sectors to be “essential” workers, like health, police, army and other workers”

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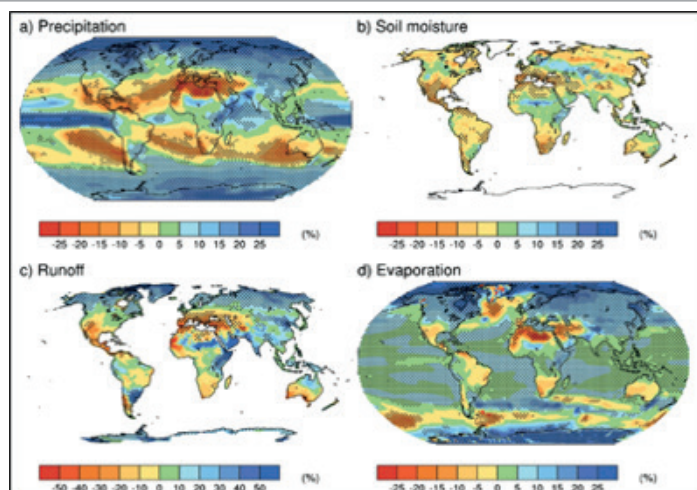




## 4. International and Regional Assessments of Climate Change impacts on Water Resources in the GCC Countries

The potential impacts of climate change on the water resources and the water sector in the GCC countries were assessed in a number of studies as part of assessment exercises at the global and regional levels. The first of these was the IPCC Fourth Assessment Report (AR4), which identified the Arab/MENA region as the region most severely affected by climate change. This is particularly because the effects will accentuate the already severe water scarcity and most Global Circulation Models (GCMs) project that much of the Arab region will undergo significant reductions in precipitation levels and increases in temperatures that will increase evapotranspiration rates (Parry et al. 2007). Bates et al. (2008) indicated that GCMs simulations, using a middle path, greenhouse gases emissions scenario (SRES A1B), showed that 80% of these models (15 GCMs) agree on the direction of the change over the northern part of the Arab region. They agree less, however, about the Arabian Peninsula, particularly its southern parts (Figure 4.1). Evans (2009) analysed the impact of climate change on the northern parts of the MENA region (including the North Arabian Peninsula), using simulation results from 18 GCMs under the SRES A2 emissions scenarios, and confirmed that most of the Arab region will become warmer and will undergo a significant reduction in precipitation.

**FIGURE 4.1** Fifteen model percentage mean changes in:  
a) precipitation; b) soil moisture; c) runoff; and d) evapotranspiration



Changes are annual means:  
scenario A1B, period 2090-2099  
relative to 1980-1999 (Bates et  
al., 2008).

In 2012 a study by the World Bank (2012a) assessed the impact of climate change on water resources in the Arab countries. The study downscaled the output of nine GCMs for the A1B SRES scenario covering the Arab region to simulate the hydrological parameters of runoff, groundwater and soil moisture and demand-supply dynamics for each country. The results indicated that the majority of the Arab countries were already experiencing deficits in internal and external renewable water resources and that by mid-century all Arab countries will face serious water deficits as demand and supply continue to diverge.

In 2012 another study by the World Bank, entitled "Climate Change Adaptation in the Arab Region" (World Bank, 2012b), assessed the potential effects of climate change on the Arab region and outlined possible approaches and measures to prepare for its consequences. The study concluded that climate change is projected to reduce natural water supplies in most of the region and will exacerbate the already precarious high water deficit across the Arab region, as well as increasing the occurrence and intensity of extreme flooding. The report called for immediate action, which included a combination of good water management and climate adaptation measures. It indicated that the impacts of these projections can be moderated or avoided by adopting long-term adaptation strategies. These include optimising supply-side management, implementing demand-side management, improving water governance, upgrading disaster risk management, modifying agricultural policies and enhancing cooperation in shared water resources. For the GCC countries these include enhancing desalination capacities, reusing wastewater and developing strategic reserves, while pursuing aggressive efficiency and water-demand management programmes.

In 2014 the IPCC published its Fifth Assessment Report (AR5; IPCC, 2014), which built on and updated its AR4. The report projected that the global mean surface temperature is likely to increase by at least 1.1o C by the end of the 21st century under a moderate scenario or up to 4.8o C under a high-end scenario, relative to the 1986-2005 reference period. The IPCC is virtually certain that there will be more frequent hot temperature extremes over most land areas as global mean surface temperatures increase.

The first in-depth and detailed study to assess the impacts of climate change on water resources in the Arab region (Arab Climate Change Assessment Report (ACCAR)) was conducted in 2017 by the regional Arab initiative of RICCAR<sup>12</sup> (UNESCWA, et al. 2017). It is considered to be the first regional assessment to assess comprehensively the impacts of climate change on water resources in the Arab region as a single geospatial unit, by generating ensembles of regional climate and hydrological modelling projections until 2100. It was also the first report to conduct an integrated assessment of climate change impacts as they affect the socio-economic and environmental vulnerabilities of the Arab countries, hence making it very relevant to the topic of water security.

The ACCAR presented regional climate modelling (RCM) and regional hydrological modelling (RHM) projections for the Arab region until 2100, based on climate scenarios adopted by the IPCC in its AR5 (2014), namely RCP4.5 and RCP8.5.<sup>13</sup> It examined the impacts of climate change on shared water resources as well as on the vulnerability of water, agriculture, ecosystems, human settlements and people to climate change in the Arab region. Flood frequency, drought, crop productivity (water available for crops, livestock and plants) and human health (including water available for drinking) were also examined under these two scenarios.

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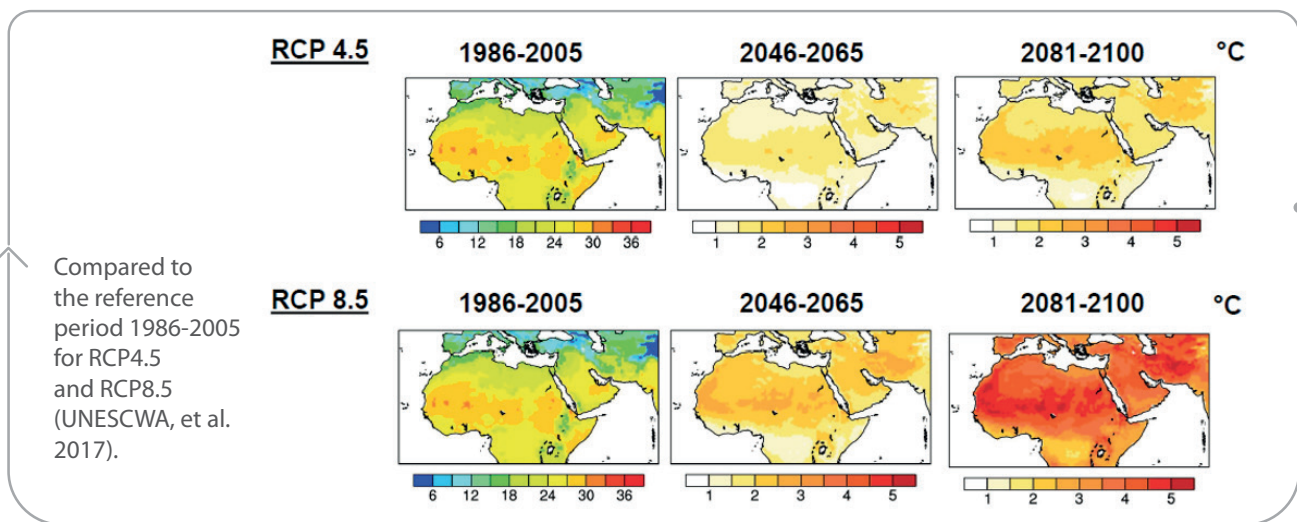
<sup>12</sup> Regional Initiative for the Assessment of Climate Change Impacts on Water Resources and Socio-Economic Vulnerability in the Arab Region.

<sup>13</sup> RCP = Representative Concentration Pathways are greenhouse gas concentration trajectories of CO2 equivalent (not emissions) in parts per million by volume, adopted by the IPCC in its fifth assessment report (AR5) in 2014. AR5 has four projections titled: RCP2.6, RCP4.5, RCP6.0, RCP8.5.



The key findings of the assessment study are that temperatures in the region are increasing and are expected to increase until the end of the century. The average mean change in temperature for RCP4.5 shows an increase of 1.2o C to 1.9o C by mid-century and 1.5o C to 2.3o C by the end of the century. For RCP8.5, temperatures may increase from 1.7o C to 2.6o C by mid-century and 3.2o C to 4.8o C towards the end of the century. The highest increases in average mean temperatures are expected to be in the non-coastal areas and include the central and western Arabian Peninsula. As annual means of temperature are generally not sufficient to assess the impacts of climate change, projections of temperature extreme climate indices and seasonal peaks were produced to provide greater insight into the implication of temperature. These projections indicated that the number of very hot days of over 40o C (SU40) will increase significantly across the Arab region until the end of the century.

**FIGURE 4.2** Changes in mean annual temperature for the time periods 2046-2065 and 2081-2100

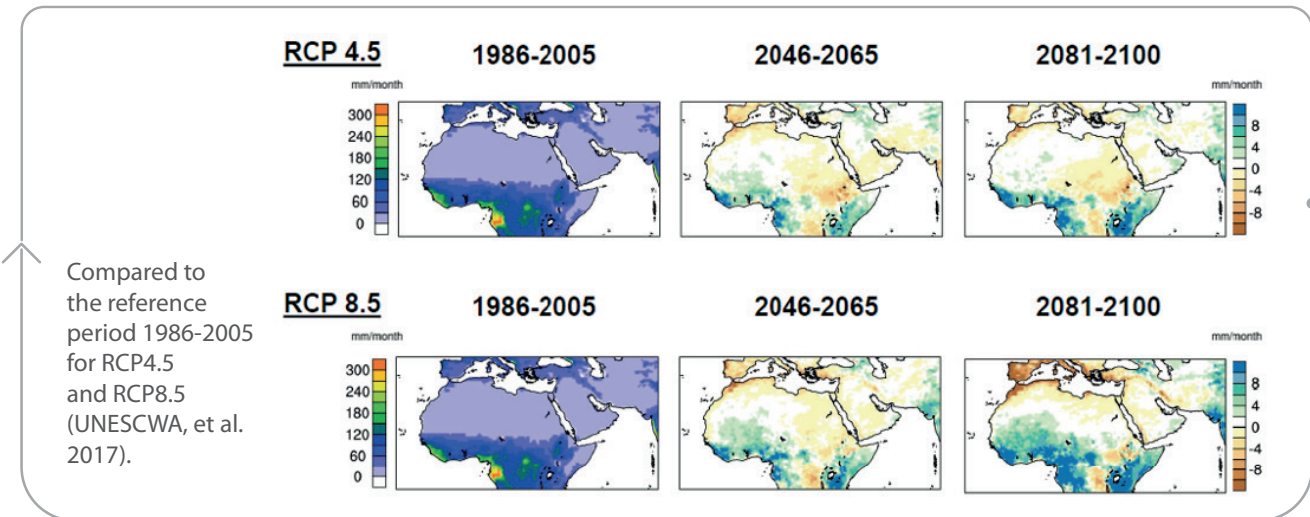


Furthermore, the report indicated that precipitation trends will decrease across the region until the end of the century. However, some areas, although limited, including the south-eastern Arabian Peninsula, will show increasing precipitation trends. Again, this general trend of precipitation is indicated by the report to be better understood by looking at projections of extreme climate indices and at smaller scales of analysis. In this regard, the impacts of climate change in terms of extreme events in the Wadi Diqah River basin in Oman, among other basins, were investigated in terms of extreme temperature and precipitation indices and extreme drought and flood events. Projections for precipitation indicators<sup>14</sup> indicate an increase in precipitation intensity and heavy precipitation days, together with an increasing number of consecutive dry days for future periods under both RCPs.

<sup>14</sup> Precipitation indicators used in RICCAR are: maximum lengths of dry spell (CDD) in number of days/year; maximum lengths of wet spell (CWD) in number of days/year; 10 mm precipitation days (R10) in number of days/year; 20 mm precipitation days (R20) in number of days/year; simple precipitation intensity index (SDII) in mm/day.



**FIGURE 4.3** Changes in the mean annual precipitation for the time periods 2046-2064 and 2081-2100



The vulnerability of the water sector to climate change in the Arab region was investigated using the IPCC approach that was put forward in its Fourth Assessment Report (AR4). Vulnerability is a function of a system's climate "exposure", "sensitivity" and "adaptive capacity" to cope with climate change effects. Exposure indicators are derived from regional climate modelling and regional hydrological modelling results, while sensitivity indicators are classified in three dimensions: population, natural and man-made systems. Adaptive capacity indicators are categorized into six dimensions: knowledge and awareness, technology, infrastructure, institutions, economic resources and equity. Exposure indicators were developed for five differing periods and climate scenarios: a reference period, future mid-century based on a moderate scenario (RCP4.5), future mid-century based on an extreme scenario (RCP8.5), future end-of-century based on a moderate scenario (RCP4.5) and future end-of-century based on an extreme scenario (RCP8.5). Sensitivity and adaptive capacity indicators were assumed to be static, using the most recent available countries' information for all future climate scenarios.

Vulnerability assessments included five sectors: water (water availability), biodiversity and ecosystems (areas covered by forests and wetlands), agriculture (water available for crops and livestock), infrastructure and human settlements (inland flooding areas) and people (water available for drinking, health conditions due to heat stress and employment in the agricultural sector). The key findings from the vulnerability assessment are that vulnerability has a stronger correlation to changes in precipitation than to temperature, and, of the three components of vulnerability, "adaptive capacity" has the strongest influence.

In its assessment of the Arab region's subdomains, the study indicated that the vulnerability of the Arabian Gulf region (the central and eastern Arabian Peninsula) to climate change is relatively moderate compared to the rest of the region. This is explained partly due to that the projected precipitation of the region will not significantly change, and also due to its relatively high adaptive capacity in comparison to other regions. Future analysis and assessment of the vulnerability of the infrastructure and human settlements to extreme weather events manifested by flood events,<sup>15</sup> including flash floods, has shown an increasing trend over the region, particularly for highly populated areas. The vulnerability assessment of the people sector has shown that the vulnerability related to water available for drinking in the Arabian Gulf region will increase but will remain moderate, primarily due to the region adaptive capacity strengthened essentially by its

<sup>15</sup> Represented by events of heavy precipitation days using the exposure indicators R10 and R20.



economic and energy resources. Despite the projected decrease in water availability (manifested by precipitation and runoff), the Arabian Gulf region's capabilities in providing drinking water by expanding desalination will overcome this constraint.

However, the financial, economic and environmental costs associated with desalination expansion would be significant. Desalination is an energy-intensive process, more costly to produce than conventional water resources, and is associated with many environmental problems, manifested by the impact of their thermal brine discharges in the surrounding coastal and marine environments and of air pollution by burning fossil fuels and their impacts on human health and the environment (Al-Zubari, et al. 2017). A study (AGEDI, 2016) investigating the environmental impacts of desalination under climate change conditions associated with RCP8.5 and involving modelling the Arabian Gulf's physical parameters indicated that the Arabian Gulf is already one of the most stressed marine environments on earth and that under climate change the Arabian Gulf will become even more highly stressed, quite apart from any environmental impacts associated with increasing desalination. Moreover, to continue desalination using fossil fuel energy will lead to an increase in the GHGs emissions, which might conflict with the NDCs commitments of the Arabian Gulf countries and with the Paris Agreement's goals.

The above vulnerability assessments provided the general anticipated impacts of climate change on the water sector in the Arab region. It showed that the Gulf region has a relatively higher adaptive capacity in comparison to other sub-regions, which is a detrimental factor in lowering the vulnerability. The following section (Section 5) provides more details on the vulnerability of the water sector to climate change in the GCC countries, as indicated by the countries' climate change national communication reports to the IPCC. Moreover, the vulnerability assessment is followed by a summary and synthesis of the recommended adaptation measures obtained from the same reports and also from the GCC countries' nationally determined contributions (NDCs) to the Paris 2015 Climate Change Agreement to reduce GHGs emissions. The selected sectors for the vulnerability assessment and the recommended adaptation measures can probably be taken as the priority areas and the agenda for climate change action in the water sector.

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Desalination is an energy-intensive process, more costly to produce than conventional water resources, and is associated with many environmental problems ”



## 5. Climate Change Vulnerability Assessments of the Water Sector in the GCC Countries

The United Nations Framework Convention on Climate Change (UNFCCC) is an international environmental treaty adopted in 1992 and put into effect in 1994, with 197 Parties. The objective of the treaty was to "stabilise greenhouse gas concentrations in the atmosphere at a level that would prevent dangerous anthropogenic interference with the climate system."<sup>16</sup> Nevertheless, the findings of the Intergovernmental Panel on Climate Change reports (IPCC) have enumerated various changes within the climate system; in fact, the fifth IPCC assessment report in 2014 reinstated that the "warming of the climate system is unequivocal, and since the 1950s, many of the observed changes are unprecedented over decades to millennia. The atmosphere and ocean have warmed, the amounts of snow and ice have diminished, sea level has risen, and the concentrations of greenhouse gases have increased" (IPCC, 2013). Observed warming of the Earth's surface is attributed to human activities and to restrain global average temperature rises countries will need to focus on how to raise the ambition for climate action. The 2015 Paris Agreement asserted a global framework to avoid dangerous climate change temperature increases and it also aimed to strengthen countries' abilities to deal with the impacts and support them in their efforts. The Agreement was unprecedented in the near unanimity of the nations it brought together on this issue.

All the GCC countries are signatories to UNFCCC and to the Paris Agreement and, due to the climate change threats that have been felt across the region, countries have shown increasing levels of participation in global negotiations. The Climate Change National Communication reports prepared periodically by the countries comprise four sections: Greenhouse Gases Inventory, GHG Mitigation, Vulnerability, and Adaptation. The vulnerability and adaptation sections are made for selected sectors, including the water sector. These reports contain the impacts and threats of climate change on the water sector and the recommended adaptation measures needed to alleviate these impacts on the sector and to enhance its resilience as envisioned by the governments. They also reflect, in general, the priority water topics and issues that the countries have chosen to address. Table 5.1 provides a summary of these communication reports to date. Bahrain, Kuwait, and Qatar have focused their vulnerability assessments on the municipal/domestic water supply sector, followed by the groundwater resources of which the agricultural sector is its main user. Saudi Arabia, Oman and the UAE focused more on assessing the impacts of climate change on their surface water and groundwater resources, followed by the municipal/domestic water supply sector.

<sup>16</sup>The United Nations Framework Convention on Climate Change

**Table 5.1 GCC Countries Climate Change National Communication Reports**

Country	No. of Reports and Year of submission
Kingdom of Bahrain	Initial National Communication Report (INC) - 2005 Second National Communication Report (SNC) - 2012 Third National Communication Report (TNC)- submission in progress (in 2020)
State of Kuwait	Initial National Communication Report (INC) - 2012 Second National Communication Report (SNC) - 2019
State of Qatar	Initial National Communication Report (INC) - 2006
United Arab Emirates	Initial National Communication Report (INC) - 2007 Second National Communication Report (SNC) - 2010 Third National Communication Report (TNC) - 2013 Fourth National Communication Report (FNC) - 2018
Sultanate of Oman	Initial National Communication Report (INC) - 2013 Second National Communication Report (SNC) - 2019
Kingdom of Saudi Arabia	Initial National Communication Report (INC) - 2005 Second National Communication Report (SNC) - 2011 Third National Communication Report (TNC) - 2016

The initial climate change communication report for Bahrain was published in 2005 (Bahrain INC, 2005) and contained a very general assessment on the impact of a sea level rise on the already over-exploited groundwater system in Bahrain, in that a rise in sea level will cause an increase in seawater intrusions, which would further aggravate groundwater quality deterioration. Furthermore, an increase in temperature is expected to lead to higher levels of water consumption in the agricultural and household sectors, which would further strain the scarce freshwater supplies in Bahrain. The findings of the initial vulnerability assessment raised serious issues of great national concern regarding the water sector and particularly towards groundwater. In the second national communication of Bahrain (Bahrain SNC, 2012), a detailed assessment of the impact of a sea level rise on groundwater was made using mathematical simulation modelling. The assessment concluded that a sea level rise will create additional pressure on an already stressed groundwater system. The vulnerability assessment indicated that balancing decreasing water supplies and increasing water demands on a long-term, sustainable basis, while promoting national development, was a major challenge to Bahrain’s water sector. The Third National Communication report (Bahrain TNC 2020) addressed the impacts of climate change on Bahrain’s municipal water supply system, due to an increase in temperatures, leading to an increase in per capita water consumption using dynamic modelling. An assessment of the impacts of a sea level rise on the infrastructure of desalination plants (inlets/outlets) was also conducted.

The first national communication of Kuwait (Kuwait INC, 2012) focused on the impact of climate change, manifested in temperature increases, on the municipal water supply system and it used dynamic modelling to predict the impact of temperature increases on consumption and evaluated the effectiveness of specific management interventions to reduce the costs associated with the system. The vulnerability assessment indicated that water resource management is an already critical planning challenge for Kuwait and that balancing domestic water supply and demand will become an even greater challenge with climate change. The development of new water management policies to enhance the sector’s resilience to climate change should be a high priority. Building on the initial communication, the second national communication (Kuwait SNC, 2019) used the results of the initial communication in conducting economic scenarios by evaluating the costs and benefits of four policies to promote sustainable water management (reforming water tariffs, improving overall municipal water efficiency by the installation of water saving devices, leak reduction and improving irrigation efficiency), as well as the co-benefits

resulting in lower CO<sub>2</sub> emissions. The assessment concluded with the need to adapt the concept of integrated water resource management (IWRM) and to address national policies that stabilise the gap between supply and demand.

Qatar has produced only one communication report - the initial national communication report in 2011 (Qatar INC 2011). The report recognised the effects emerging from climate change on its already scarce freshwater resources. Further desertification, temperature increases, lower precipitation and sea level rises will all increase water needs in a water-scarce country. Demand will be met by extra water desalination, although energy needs and consumption are bound to increase. The current use of groundwater is principally for agricultural uses and it is 'orders of magnitude' greater than its rate of replenishment. The evaluation recommended a further investigation into policies and mechanisms that can stabilise or diminish the gap between supply and demand within the water sector.

The UAE produced its first national communication in 2007 (UAE INC, 2007). In this report, a downscaling of GCM (AIM) outputs of temperature and precipitation to a regional level and then to eight cities in the UAE quantified the exposure to climate change. The average global sea level rise was used in the assessment. The study focused on the vulnerability of surface water and groundwater resources and indicated that decreasing rainfall will lead to less availability of surface runoff and groundwater (with more reliance on non-conventional water resources and increasing energy demands), while sea level rises will result in increasing soil and water salinity in coastal aquifers by salt intrusion (eventually impacting the agricultural sector). The conclusion of the UAE's initial communication report was that a severe shortage of water resources associated with projected increases in air temperatures, leading to increases in potential evapotranspiration, is likely to be the most significant impact of climate change on the water sector. In the second national communication (UAE SNC, 2010) a similar exercise was made in downscaling, by using nine GCMs for one greenhouse emissions scenario (SRES2A). However, the assessment

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In this report, a downscaling of GCM (AIM) outputs of temperature and precipitation to a regional level and then to eight cities in the UAE quantified the exposure to climate change.

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focused on evaluating the water supply-demand balance of the water system under climate change. It applied a water flow accounting methodology to analyse the supply-demand balance in the face of climate change in the Abu Dhabi emirate to the year 2050. The main conclusions were that current patterns of water use are unsustainable, the irrigated agriculture policy needs strategic reconsideration, climate change only marginally affects the future water supply/demand and reducing future water demand should be a strategic priority.

The UAE's third national communication report (UAE TNC, 2013) represented a continuation of the previous report and was built on its findings. The report initiated a quantitative, national-level assessment to evaluate the vulnerability of the UAE's range of water resources to long-term regional climate change and socioeconomic growth, using dynamic modelling (Water Evaluation and Planning, WEAP model). The report also explored the vulnerability of renewable groundwater supplies using the NOAH land surface model along with a groundwater flow model (MODFLOW) to assess the vulnerability of the Arabian Peninsula's transboundary groundwater resources due to sea level rises. The 2018 Fourth National Communication report (UAE FNC 2018) reinforced the importance of climate change adaptation as a priority policy for the UAE and proclaimed that the National Climate Change Plan, launched in 2017, identified water resource management as a key issue in moving forward to minimise risks and to improve adaptive capabilities within the sector.

Oman published its first national communication report in 2013 (Oman INC 2013). The report provided an overview of baseline conditions for water development constraints. It indicated that measures to balance supply and demand are a government priority, that the deterioration of groundwater quality is due to saltwater intrusion and that pollution is a major concern even without climate change occurring. Climate change is expected to aggravate these already serious challenges of balancing supply and demand. The report indicated that water availability and groundwater deterioration have been identified as major development constraints. The second national communication report (Oman SNC, 2019) conducted a detailed vulnerability assessment for surface and groundwater. Future climatic projections on Oman (temperature and rainfall) were made by downscaling a GCM under RCPs, and a vulnerability assessment of extreme rainfall and surface water was made. In addition, a vulnerability assessment of groundwater to sea level rise and seawater intrusion and the resulting quality deterioration using two aquifers (one used for agriculture and the other for municipal water supply) was conducted. The assessment indicated that there was an overall increase in destructive events during the period 2009-2014 in Oman and that in certain parts of in Oman there was a strong increase in extreme rainfall events. The likelihood of more frequent and intensive wadi flows correlates closely with future patterns of more frequent extreme weather events with climate change. Furthermore, the saltwater-freshwater line is projected to shift inland due to sea level rises and this will result in an increase in groundwater salinity and will salinize agricultural land, making it unsuitable for cultivation. The report recommended that effective actions should first involve the development and implementation of an IWRM system that accounts for the interdependency of water and other sectors of the economy.

Saudi Arabia submitted its first national communication report in 2005 (Saudi Arabia INC, 2005). The water resources assessment was based on climatic change scenarios which were developed to predict temperature, precipitation and relative humidity values in 2050 and 2100 using two different models (MAGICC for 2020-2050 prediction, GCM IPCC database 2070-2100). The study addressed the impacts of higher temperatures and lower rainfall on groundwater recharge and surface water, the impacts of temperature increases on irrigation, domestic and industrial water demands and the overall water stress. Furthermore, the study looked at the socio-economic impacts associated with increasing water demands and decreasing water resources. The second national communication of Saudi Arabia was published in 2011 (Saudi Arabia SNC, 2011). An RCM (PRECIS) was used to develop climate change scenarios to predict changes in precipitation, temperatures, wind speeds and relative humidity across Saudi Arabia between 2070 - 2100



(evapotranspiration changes were estimated using the FAO-approved Penman-Monteith approach). The possible effects of climate change on water availability and quality and their implications in Saudi Arabia were investigated, specifically the impacts of higher temperatures and lower rainfall on groundwater recharge and surface water, increases in temperature on irrigation and domestic and industrial water demands, and the overall impact on water stress in Saudi Arabia. Similar to the second report, the third communication report (Saudi Arabia TNC, 2016) used an RCM (PRECIS) to develop climate change scenarios to predict changes in precipitation, temperatures, wind speeds, relative humidity between 2070 and 2100 and also sea level rises between 2030 and 2080. Changes in evapotranspiration were also estimated using the FAO-approved Penman-Monteith approach. The possible effects of climate change on water availability and quality in Saudi Arabia were investigated, and the implications of these changes on future water resource management were outlined. Specifically, these are changes in the hydrological cycle (by modelling) and the impact of climate change on the Water Supply (groundwater recharge and surface water and irrigation water supplies).

An assessment of climate change impacts on the water resources in Saudi Arabia indicated clearly that most regions in Saudi have high vulnerability levels for climate change impacts on water resources. Any increases in temperature will result in increasing the evaporation rates and decreasing the available water supplies from annual precipitation by lowering the annual recharge to aquifers and lowering the surface runoff. In addition, rises in domestic and industrial water demands are expected to occur. The impacts of climate changes on water resources in Saudi Arabia are expected to have significant effects on socio-economic conditions in the Kingdom. The welfare, development and survival of urban and rural communities and the sustainability of the national economy are directly affected by the impacts of climate change on water resources. The report concluded by suggesting that closing the gap between water supply and demand is a priority in the water sector, to reduce vulnerability and demand.

In general the vulnerability assessments of the water sector to the impacts of climate change in the GCC countries have indicated that water resources in the GCC countries are in a critical condition and under enormous stresses due to rapid population and urbanisation growth, agricultural policies, inefficient management and irrational consumption patterns. They are facing serious challenges and increasing costs in balancing water supply with demands. The main impacts anticipated from climate change are the reduction in surface runoff and groundwater recharge due to an overall reduction in precipitation, a deterioration in coastal groundwater quality due to seawater intrusions, increases in the agricultural and domestic sectors' water demands due to temperature increases and increases of destructive events (flash floods) due to increases in extreme rainfall events.





## 6. Climate Change Adaptation Options in the GCC Countries

People of the region have coped for thousands of years with the challenges of aridity, water scarcity and limited natural resources. However, climate change is now introducing additional challenges. The message is clear: over the next century climate change will impact several viable aspects such as water, biodiversity and health and the climate of the region will experience unprecedented extremes. Temperatures will continue to reach record highs and in many places there will be less rainfall. Water availability will be reduced and, with a growing population, the region may not have sufficient supplies of water to irrigate crops, support industry and provide drinking water. Climate change will not only challenge the status quo, it will threaten the basic pillars of development.

The national communication reports for the GCC have addressed such concerns and the studies carried out have focused on the need to adapt to climate change as a necessity and not a choice. Water scarcity and challenges facing the water sector are comprehensively detailed within the reports, with many of the countries initiating actions and technologies to adopt and implement, many of which are common among all the GCC countries, particularly those related to supply and demand management techniques. Annex (I) summarizes the adaptation sections of the national communication reports of the GCC countries.

In Bahrain, adaptation studies indicated the need to formulate a national water policy and strategy based on IWRM principles and to deal with climate change by introducing a demand-side water management system (e.g. introduce water tariffs, water conservation technologies, expand the use of leak detection technologies, awareness raising etc.). On the supply-side, it was recommended that groundwater management and adaptation efforts should focus on groundwater recharge by treating wastewater and on the demand-side to limit groundwater withdrawal by using economic tools and regulations in the agricultural sector, the main groundwater user. In the municipal sector, adaptation measures should focus on the reduction of per capita water consumption using a combination of tools (awareness raising, reforming water tariffs, issuing legislations/building codes for water use efficiency, including water saving devices) and controlling distribution network leakage. Strengthening the institutional capacity in water resources management and planning has been indicated as an essential enabler to establish an adaptive water management system in Bahrain.

Similarly, in Kuwait and Qatar the development of national water management policies that emphasise demand management and efficiency have been recommended to be the first and most important step in adapting to the impacts of climate change. In Kuwait, the main management steps were indicated to be, reforming water tariffs, improving overall municipal water efficiency by installing water saving devices, reducing leaks, expanding the reuse of treated wastewater and improving irrigation efficiency. The following are indicated as enablers for climate change adaptation: education and training on climate change, stakeholders' awareness raising, fiscal incentives for adaptation and science and R&D in the field of climate change and water resources - these were identified as the main enablers for climate change adaptation. In Qatar, the potential areas for adaptation to climate change in the domestic water supply sector are thought to be improved efficiency for the cogeneration of water and power facilities, energy efficient Building Codes and appliances standards and to introduce water efficiency measures in the agricultural sector.

In response to existing pressures on its water resources, the UAE embarked on a number of water resource management options that included the planning and construction of more desalination and wastewater treatment plants, the restoration of traditional falaj systems,<sup>17</sup> the building of recharge dams and the introduction of water saving technologies in the agricultural sector. Nevertheless, this would not withstand the needs for adaptation to climate change. The formulation and implementation of an integrated water management and planning system has been seen as an important step in this direction. To establish a demand-supply balance, it is necessary to reduce per capita water consumption in the municipal/domestic sector. This can be achieved through the implementation of a combination of strategies (subsidy reforms, awareness, water saving devices and appliances, green building codes etc.) and by reducing irrigation water consumption through climate-smart agriculture that enables organic hydroponic farming. On the supply-side, strategies to reduce supply-demand

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Water resources in the GCC countries are in a critical condition and under enormous stresses due to rapid population and urbanisation growth, agricultural policies, inefficient management and irrational consumption patterns. ”



<sup>17</sup>Falaj refers to water that runs through a channel dug in the earth

imbalances include the increase in the use of treated wastewater, artificial recharges of groundwater by treated wastewater and the construction of desalination plants. Important enablers for the efficient management of the water sector and its adaptation to climate change are seen to be the fostering of long-term partnerships between government and businesses in green market development and the commercialisation of innovative technologies in desalination and waste management.

Oman has a relatively bigger agricultural sector than the other GCC countries with a higher contribution to the national economy. Oman has been relying heavily on groundwater resources, but the deterioration of groundwater quality and the increasing demand on desalination plants has become evident in recent years. Oman's adaptation reports indicated the development and implementation of IWRM plans to ensure the supply and demand balance for renewable water resources to be an essential step towards adapting to climate change in the water sector. The key adaptation measures are indicated as: improving the knowledge for managing vulnerable groundwater resources (data and economic benefits of adaptation); improving the management of treated sewage, especially by implementing managed aquifer recharges with treated wastewater in coastal aquifers and improving the management of surface water (expanding gauge stations' monitoring, updating flash flood hazard maps). The main enablers for adaptation were recommended to be: strengthening the capacity to manage water resource risks (improve technical capacities, coordination, data exchanges, accessing funding); and improving the governance and adaptation policies (integrate climate change vulnerability into policymaking and planning, enhance ministerial collaboration).

In Saudi Arabia, the government has supported different programmes to minimise the impacts of possible climate changes on the water supplies, in order to satisfy the growing demands in the domestic, agricultural and industrial sectors. To reduce vulnerability and demand on the water sector three priorities are set in relation to adaptation: 1) The reduction of uncertainties in hydro-meteorological trend predictions; 2) The protection and restoration of ecosystems; and 3) Closing the gap between water supply and demand. A number of suggested strategies were indicated to reduce the gap between supply and demand. On the demand-side these are the reviewing of the existing policies of the agriculture and water sectors and regulating water consumption, while on the supply-side the strategies include the development of non-conventional water resources (i.e., desalination plants and treated wastewater) and the re-use of reclaimed wastewater and agricultural drainage water. Due to the vast geographic area of Saudi Arabia and its different regional characteristics, adaptation studies indicated that far more detailed studies are needed for the different areas of the country. The development of a multi-criteria decision-making (MCDM) tool and a decision support system (DSS) for water management and planning has been recommended for future studies. Building up the national capacity in the water sector has been indicated as the main enabler for the efficient management of the water sector and its adaptation to climate change.

Prior to attending the Climate Change Conference in Paris in 2015, governments were invited to submit voluntarily their intended nationally determined contributions (INDC) to the Paris 2015 Climate Change Agreement. INDCs were meant to reference countries' future emission reduction targets and their plans on how to adapt to the impacts of climate change. After the declaration of the Paris Agreement, INDCs are now known as nationally determined contributions (NDCs). Before attending the conference, the GCC countries submitted their NDCs, which represented countries' efforts and commitments in mitigating GHGs emissions, but many are related to the water sector adaptation plans and correspond to their national communication reports outcomes. The table provided in Annex 2 demonstrates the NDCs relating to the GCC water sector, which can be taken as the on-going priority strategies of these countries.

Because the GCC countries rely heavily on desalination plants for their domestic water supplies, which are energy-intensive and most of the GHGs emissions originate from them, mitigating the GHGs emission in the water sector is done either with technological improvements in the desalination plants or by reducing the volumes of water produced by the desalination plants by reducing the consumption of the domestic sectors. The majority of the countries plan to increase their desalination plants' efficiency in terms of energy consumption. These are represented mainly by moving from thermal to membrane technologies. A reduction of the desalination plants' production is achieved by reducing network leakage, raising consumer awareness, water saving devices and legislation.

In conclusion, it is imperative for the GCC countries to enhance the efficiency of their water management systems and to adapt to the impacts of climate change, if their water sectors are to continue to serve their socio-economic developments. The recommended management interventions and climate change adaptation measures of the GCC countries have focused on the development of integrated water management plans, with a strong emphasis on demand management and efficiency to close the gap between supply and demand and to adapt to the anticipated impacts of climate change on the water sector. Reductions in per capita water consumption, reductions of distribution network leakage in the municipal sector, controlling agricultural water consumption, increasing irrigation efficiency and reusing treated wastewater are all important policies. They will complement the currently practiced supply-side management policies of expanding desalination plants and the treatment of wastewater, groundwater artificial recharges and dam constructions. The main enablers for achieving such shifts towards demand management and efficiency and enhancing the adaptation to climate change are capacity development of the water sector (institutional and individual), raising stakeholders' awareness, water sector governance improvements and private sector participation.

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The majority of the countries plan to increase their desalination plants' efficiency in terms of energy consumption.

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## 7. GCC-EU Potential Partnership and Cooperation Areas

Although Europe is considered to have adequate water resources, water scarcity and drought are becoming increasingly frequent. It is expected that water demands will outstrip the available water resources in many parts of the EU. Furthermore, it is anticipated that rising temperatures due to climate change will further deteriorate the water situation in Europe, making water a major concern in all of the European countries. The EU's stated policy in addressing the challenge of water scarcity and droughts (WS&D) is to ensure access to good quality water in sufficient quantities for all Europeans and to ensure the good status of all its water bodies. The objective is to prevent and to mitigate water scarcity and drought situations, with the priority to move towards a water-efficient and water-saving economy.<sup>18</sup>

In 2007 the EU identified an initial set of policy options to increase water efficiency and water savings.<sup>19</sup> These were: 1) Putting the right price tag on water; 2) Allocating water and water-related funding more efficiently; 3) Improving drought risk management; 4) Considering additional water supply infrastructures; 5) Fostering water efficient technologies and practices; 6) Fostering the emergence of a water-saving culture in Europe; and 7) Improving knowledge and data collection.

A periodic policy review has been carried out for the strategy for water scarcity and droughts and its policy options. The last one was completed in 2012 and became part of the "Blueprint to Safeguard European Waters", which was adopted by the European Commission in 2012. The following are the main blocks of the water scarcity and drought policy review:<sup>20</sup>

- Water efficiency (water efficiency of buildings, the reduction of leakages in distribution systems, water efficiency in agriculture and halting desertification);
- Better planning (demand management, land use planning, drought observation and early warning systems, data collection and indicator development, enhancing the integration of WS&D in the River Basin Management Plans (RBMPs) and in sectoral policies); and
- Adequate implementation instruments (financing water efficiency, water pricing and funding, water allocation, research and technological opportunities, education and awareness).

<sup>18</sup> Water Scarcity & Droughts in the European Union, [https://ec.europa.eu/environment/water/quantity/scarcity\\_en.htm](https://ec.europa.eu/environment/water/quantity/scarcity_en.htm).

<sup>19</sup> Commission of the European Communities. 2007. Addressing the challenge of water scarcity and droughts in the European Union. Communication from the Commission to the European Parliament and the Council, COM(2007) 414. Available at: <https://eur-lex.europa.eu/legal-content/EN/TXT/PDF/?uri=CELEX:52007DC0414&from=EN>.

<sup>20</sup> European Commission. 2012. Water scarcity and droughts in the European Union. Report from the commission to the European Parliament and the Council: Third Follow up Report to the Communication on water scarcity and droughts in the European Union COM (2007) 414 final-SEC (2011) 338 final. Available at: [https://ec.europa.eu/environment/water/quantity/pdf/special\\_report.pdf](https://ec.europa.eu/environment/water/quantity/pdf/special_report.pdf).

It can be seen that there are large convergences and overlaps between the EU's policies and the GCC's implemented and proposed adaptation measures, which focus on water efficiency and demand management in the agricultural and urban sectors as well as in terms of policy enablers and instruments such as stakeholders awareness and education, data needs, modelling capabilities and water pricing. These represent the main opportunities for cooperation between the EU and the GCC countries.

Moreover, in December 2019, the European Union launched its "European Green Deal," aimed at reaching carbon neutrality by 2050 (EU Commission 2019). The European climate agenda or plan consists of 10 main points<sup>21</sup> and touches upon many areas and sectors. A number of these have a particular relevance to the water security of the GCC countries and their policies and efforts in adapting to climate change. Among these points is the overarching objective of the European Green Deal of "Climate Neutral Europe", in which the EU will aim to reach net-zero GHGs emissions by 2050. To achieve such an objective, the EU will issue a number of directives: the Renewable Energy Directive and the Energy Efficiency Directive. These two directives could be relevant and useful for the GCC countries for required policies in these two areas. As indicated earlier, desalination is the main source of drinking water supply in the GCC countries and is expected to continue to play an ever-increasing role in the water supply portfolio in the region due to the scarcity of conventional water resources and the rapid increases in population and urbanisation. However desalination technology used in the GCC countries is energy-intensive and is based on fossil fuels (refer to Section 3.1). At the national level, all the GCC countries possess and implement programmes related to diversifying their energy sources, with targets for a renewable energy share in their energy mix and also for programmes for energy efficiency. The GCC countries can learn from the EU experience in implementation of the renewable energy and energy efficiency directives.

A major opportunity exists for cooperation between the GCC and the EU in the field of R&D and capacity development in desalination and water treatment. This can be initiated by establishing an advanced joint R&D research programme, aimed at diversifying energy resources and reducing their negative environmental impacts, and education and training programmes in the fields of desalination and water treatment technologies. The ultimate objective would be to localise these industries in the GCC countries, enhancing their contributions to the economy and increasing the GCC countries' level of water security.

Furthermore, and under the concept of adaptation actions with mitigation co-benefits, the water conservation programmes can also serve as areas of collaboration since they are advocated by the GCC countries as key aspects to increasing climate change resilience, reducing GHG emissions and assisting with the protection of water resources. The GCC countries and the EU have a good cooperation potential in these three areas.

The other area of potential cooperation between the GCC countries and the EU is the "Circular Economy" plan, particularly that related to municipal wastewater. As indicated earlier, treated wastewater in the GCC countries constitutes an increasing water source driven by the escalating water consumption in urban areas. However, the reuse potential of the generated wastewater is not fully developed. Moreover, large volumes of wastewater sludge are being produced without any beneficial Utilisation and most of the generated sludge ends up in landfills. Recycling and reuse are central to the circular economy approach and the beneficial use of wastewater and wastewater sludge, including nutrients utilisation, energy recovery, fertilizers and resources' recovery is an increasingly important subject for the GCC countries and represents a potential area of cooperation with the EU.

<sup>21</sup> These plans are: Climate Neutral Europe; Circular Economy; Building Renovation; Zero Pollution; Ecosystem and Biodiversity; Farm to Fork Strategy; Transport; Money; R&D and Innovation; and External Relations. For more details: [https://eur-lex.europa.eu/resource.html?uri=cellar:b828d165-1c22-11ea-8c1f-01aa75ed71a1.0002.02/DOC\\_1&format=PDF](https://eur-lex.europa.eu/resource.html?uri=cellar:b828d165-1c22-11ea-8c1f-01aa75ed71a1.0002.02/DOC_1&format=PDF)



Such cooperation between the GCC countries and the EU will fulfil the latter's objectives in building alliances and partnerships, while leading international efforts and advocacy for a globally sustainable path. The EU can use its influence, expertise and financial resources to mobilise such partnerships and cooperation.



## 8. Conclusion and Recommendations

In the GCC countries the main water security challenges from a developmental perspective are the continuous increase in water scarcity and depletion and the deterioration in quality of the region's groundwater resources on the one hand, and on the other the increasing financial, economic and environmental costs associated with the reliance on non-conventional water resources, namely desalination, to compensate for the water shortages and meet the rapidly increasing sectoral water requirements. In addition, an emerging challenge is the major lost opportunity resulting from the inadequate use of treated wastewater. From a risk-based perspective, the principal challenge for water security in the GCC countries is securing domestic water supplies during emergencies and disasters. These challenges are aggravated by many internal and external drivers which if they continue would increase the water security challenges in the future. Internal driving forces include generally low water efficiencies in both supply and use, inadequate recycling and limited reuse, while the external driving forces include rapid population and urbanisation growth rates, agricultural policies and the prevailing general subsidy system.

The national communication reports of the GCC to the IPCC have indicated that the vulnerability of the water sector to climate change and variability is high and that it is expected to act as an additional stress on the already heavily stressed water sector in the GCC countries, which would worsen its conditions. In addition, it will introduce higher degrees of uncertainty in the planning and management of the water sector in the region. However, climate change also presents an opportunity to address the water security challenges in the GCC countries and to enhance their adaptive capacities. The national communication reports and NDCs clearly indicate that it is imperative for the GCC countries to enhance the efficiency of their water management systems and to adapt to the impacts of climate change if their water sectors are to continue to serve their socio-economic developments.

In the past few decades, the GCC countries have introduced several actions towards enhancing their water sector efficiencies and performances and to manage their supply and demand better. However, the majority of these actions focus on supply-side management. Probably now is an opportune moment for the GCC countries to review and reform their current water management policies and practices and to implement a shift and more focus on efficiency and demand-side



management. This shift can be initiated by the development of integrated water management plans with a strong emphasis on demand management and efficiency to close the gap between supply and demand and to adapt to the anticipated impacts of climate change on the water sector. The strategic aim is to establish efficient and resilient water management systems that can cope with future water challenges and uncertainties.

The main areas of management interventions to achieve greater water security in the GCC countries are the reduction of per capita water consumption and a reduction of distribution network leakage in the municipal sector, controlling agricultural water consumption and increasing irrigation efficiency and reusing treated wastewater to reduce the stress on groundwater resources. These demand-side management interventions are to complement the currently practiced supply-side engineering policies that are represented by expanding desalination plants and the treatment of wastewater, dam constructions and groundwater artificial recharges. The main enablers for achieving such shifts towards demand management and efficiency and enhancing the adaptation to climate change are capacity development (institutional and individual), raising stakeholders awareness, improvement of water sector governance, including the formulation of modern water legislation, and private sector participation.

Moreover, as the reliance on non-conventional water supplies, i.e., desalination and wastewater treatment, will continue to increase in the future, acquiring and localising these technologies in the region will become an imperative strategic objective to ensure their sustainability as a sources of water, to provide an added value to the GCC economies and to enhance their security. Furthermore, as desalination is energy-intensive, mainly based on fossil fuels, and is associated with negative environmental externalities (GHGs and pollution to the marine environment), the development of renewable energy to power desalination and to mitigate the impacts of desalination on the surrounding marine environment will need to be prioritised in any R&D related to desalination.

The above management and adaptation actions, R&D investment areas and enablers represent the main opportunities for cooperation and partnerships between the EU and the GCC countries. Moreover, the EU Green Deal can provide an additional framework for closer cooperation and technology transfer between the EU and the GCC countries in the area of renewable energy desalination and energy efficiency in the water sector, as well as in the application of a circular economy, particularly that related to municipal wastewater management. Such cooperation and partnership is in line with the EU's objective to lead international efforts and advocacy for a global sustainable path, its readiness to support developing countries' efforts in fighting climate change and creating better resilience in adapting to its impacts by building alliances and partnerships. The EU can use its influence, expertise and financial resources to mobilise such partnerships and cooperation.



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## National Climate Change Communications Reports to the UNFCC of the GCC Countries

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Environment Public Authority, 2019, Second National Communication, Chapter 2, Vulnerability and Adaptation: Water Resources, State of Kuwait.

### State of Qatar

Ministry of Environment, 2011, Initial National Communication, Chapter 2, Vulnerability and Adaptation: Water Resources, State of Qatar.

### Sultanate of Oman

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### Kingdom of Saudi Arabia

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## Annex I. Summary of GCC National Communication Reports regarding Water Sector Vulnerability Assessment & Adaptation recommendations

Sector/source	Bahrain		Kuwait	
	Vulnerability	Adaptation	Vulnerability	Adaptation
<b>Groundwater resources</b>	<b>INC, 2005</b> No vulnerability assessment. General statements on the groundwater vulnerability to sea level rises and general increases in water consumption in agriculture and household sectors due to increasing temperatures, further straining the freshwater supplies	<ul style="list-style-type: none"> <li>• Formulation of IWRM plan to rationalize water use and protect groundwater from salinisation</li> <li>• Legalization and institutionalization of treated wastewater reuse</li> </ul>		
	<b>SNC, 2012</b> Groundwater vulnerability to sea level rises (simulation modelling for future scenarios)	<ul style="list-style-type: none"> <li>• Implementation of demand-side management to reduce groundwater withdrawal</li> <li>• Implementation of managed aquifer recharge (MAR) by treated wastewater to enhance groundwater storage</li> </ul>		
<b>Municipal Water Supply sector</b>	<b>TNC, 2020</b> Municipal water supply system's vulnerability to temperature increases (dynamic modelling of water supply (WEAP), evaluating the effectiveness of specific management interventions (reducing per capita water consumption and leakage) by using financial, economic and environmental cost indicators	<ul style="list-style-type: none"> <li>• Formulation of an integrated, comprehensive national water strategy principles accounting for CC.</li> <li>• Development and management of shared groundwater resources</li> <li>• Reduction of per capita municipal water consumption using available tools (awareness raising, reforming water tariff, issuing legislations /building codes for water use efficiency including water saving devices)</li> <li>• Control and reduction of leakage</li> <li>• Strengthening institutional capacity in water resources management and planning</li> </ul>	<b>INC, 2012</b> Impact of CC on municipal water resources (dynamic modelling of municipal water supply system (WEAP) and evaluating the effectiveness of specific management interventions including reduction per capita water consumption and leakage reduction	<ul style="list-style-type: none"> <li>• Development of new water management policies emphasizing demand management and efficiency</li> <li>• Reforming water pricing policy (moving from current flat rate to block rate)</li> <li>• Introduction of water conservation technologies</li> <li>• Public awareness raising</li> <li>• Strengthening institutional capacity in water resources management and planning</li> </ul>



<b>Water sector (municipal and agricultural)</b>			<b>SNC,2019</b> Building on the INC 2012, vulnerability assessment is made by evaluating the cost and benefit of 4 policies to promote sustainable water management (reforming water tariffs, improving overall municipal water efficiency by the installation of water saving devices, leak reduction and improved irrigation efficiency), as well as the co-benefits resulting in lower CO2 emissions (Note: no impact assessments of CC were made on the water system)	In addition to implementing the suggested four policies (reforming water tariffs, improving overall municipal water efficiency, leak reduction+ and improving irrigation efficiency) to achieve sustainable water management system, the following are indicated as enablers for CC adaptation: education and training on CC, raising stakeholders awareness, fiscal incentives for adaptation and science and R&D in the field of CC and water resources
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Sector/source	Oman		Qatar	
	Vulnerability	Adaptation	Vulnerability	Adaptation
<b>water sector (municipal, industrial, agricultural)</b>	<b>INC, 2013</b> No vulnerability assessment was undertaken. A baseline conditions assessment was made for future vulnerability assessment. Major water development constraints were identified as supply-demand imbalance and groundwater quality deterioration	Implementing IWRM plans with the objectives of <ul style="list-style-type: none"> <li>• Ensuring supply and demand balance for renewable water resources</li> <li>• Pursuing water security during droughts by treated wastewater reuse</li> <li>• Promoting sustainable resources use in all sectors</li> <li>• Enhancing the water supply by water harvesting and managed aquifer recharges and expansion in desalination and treated wastewater</li> <li>• Increasing water supply efficiency by reducing losses</li> <li>• Implementing integrated watershed management</li> <li>• Reforming legislation and institutions to conserve and protect water resources</li> <li>• Enhancing public awareness on water scarcity</li> </ul>	<b>INC, 2011</b> No vulnerability assessment was undertaken. Indication of impact of CC on domestic water consumption (and resulting increases in energy and CO2 emissions) and groundwater by agricultural consumption	Potential adaptation areas are indicated as <ul style="list-style-type: none"> <li>• In domestic water supply: improved efficiency for cogeneration of water and power facilities, energy efficient Building Codes, energy-efficient appliances standards</li> <li>• In groundwater agriculture: water efficiency measures</li> <li>• Implementing in a balanced manner supply and demand-side water management strategies</li> </ul>



<p><b>surface water &amp; groundwater</b></p>	<p><b>SNC,2019</b></p> <ul style="list-style-type: none"> <li>• Future climatic projections on Oman (temperature and rainfall) were made by downscaling a GCM under RCPs</li> <li>• Vulnerability assessment of extreme rainfall and surface water showing more intensities and destructive flooding (using 1 hour extreme rainfall events) and projections of return periods of flash floods using one representative wadi for flow simulation</li> <li>• Vulnerability assessment of groundwater to sea level rises and seawater intrusions and resulting quality deterioration using two aquifers (used for agriculture and municipal water supply)</li> </ul>	<p>Development and implementation of IWRM with key adaptation measures of:</p> <ul style="list-style-type: none"> <li>• <b>Improve knowledge for managing vulnerable groundwater resource</b> (conducting vulnerability assessments on different aquifers and improving data and including economic benefits of adaptation)</li> <li>• <b>Improve management of treated sewage</b> (managed aquifer recharge by TSE in coastal aquifers and establishing water quality standards and designing monitoring)</li> <li>• <b>Improve management of surface water</b> (expand gauge stations monitoring, update flash flood hazard maps, assess flash flooding risks under CC, install storm drainage infrastructure in projected flash flood zones) <b>strengthen capacity to manage water resource management risks</b> (improve technical capacities, coordination, data exchange, accessing funding, e.g., GCF)</li> <li>• <b>Improve governance and adaptation policy</b> (integrate CC vulnerability into policymaking and planning, enhance ministerial collaboration)</li> </ul>		
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Sector/source	UAE		KSA	
	Vulnerability	Adaptation	Vulnerability	Adaptation
<b>Surface water &amp; Groundwater</b>	<p><b>INC, 2007</b></p> <p>Downscaling of GCM temperature and precipitation outputs (AIM) to regional level and then to eight cities in UAE (assumed the average global sea level rise)</p> <ul style="list-style-type: none"> <li>• Surface water vulnerability: decreasing rainfall leading to less availability of surface runoff and groundwater (more reliance on non-conventional water resources and increasing energy demands)</li> <li>• Sea level rises increasing soil and water salinity in coastal aquifers by salt intrusions (impacting eventually the agricultural sector)</li> </ul>	<p><b>Ongoing water resource management options:</b></p> <p><b>A. Enhancing supply</b></p> <ul style="list-style-type: none"> <li>• More desalination and wastewater treatment plants</li> <li>• Restoration of traditional falaj systems</li> <li>• Building of recharge dams</li> </ul> <p><b>B. Water conservation measures</b></p> <ul style="list-style-type: none"> <li>• Irrigation technology to water usage, etc..</li> </ul> <p><b>Future recommended options:</b></p> <ul style="list-style-type: none"> <li>• <b>Supply-side:</b> adjusting the operation of existing and planned water supply infrastructure (re-engineering of structures), effective usage of TSE.</li> <li>• <b>Demand-side:</b> enhance water application practices in the water sector to reduce demand (especially agriculture)</li> <li>• <b>Improve monitoring</b> in the areas of meteorology, hydrology, and climate.</li> </ul>		

<p><b>All water resources</b></p>	<p><b>SNC, 2010</b></p> <p>Downscaling of GCM temperature and precipitation outputs to UAE (max, median and min of 9 GCMs for SRES2A GHG emission scenario)</p> <ul style="list-style-type: none"> <li>• Water supply-demand balance under CC, main conclusions:</li> <li>- Current patterns of water use are unsustainable</li> <li>- Irrigated agriculture policy needs strategic reconsideration</li> <li>- CC only marginally affects future water supply/demand</li> <li>- Reducing future water demand represents a strategic priority</li> </ul>	<p>Develop a comprehensive integrated water management and planning system+ and narrow the growing gap between water supply and water demand by strategies on</p> <p><b>demand-side</b></p> <ul style="list-style-type: none"> <li>- To lower per capita water consumption by 50% by 2012, through:</li> <li>- Public awareness programme for water conservation.</li> <li>- Implementation of high efficiency water use devices, strategies+ and measures in all new construction</li> <li>- Retrofits for certain applications of high efficiency water use, across all water sectors</li> <li>- Implementing pay-per-unit water metering system for all users</li> <li>- Decrease amenity area and summer watering by 20%</li> <li>- To decrease forestry and agricultural area by 30% after 2015</li> </ul> <p><b>supply-side</b></p> <ul style="list-style-type: none"> <li>- Increase Utilisation of TSE artificial recharge of groundwater by TSE</li> <li>- Construct additional desalination plants</li> </ul>	<p><b>INC, 2005</b></p> <p>Climatic change scenarios were developed to predict temperature, precipitation and relative humidity values in 2050 and 2100 using two different models (MAGICC for 2020-2050 prediction, GCM IPCC database to predict for 2070-2100).</p> <ul style="list-style-type: none"> <li>• Impacts of CC (higher temperatures and lower rainfall) on groundwater recharge and surface water</li> <li>• Impacts of CC (temperature increases) on irrigation water demands</li> <li>• Impacts of CC (temperature increases) on domestic and industrial water demands</li> <li>• Impact of CC on water stress</li> <li>• Socio-economic impacts (from increasing water demands)</li> </ul>	<p>Ongoing activities</p> <ul style="list-style-type: none"> <li>• Development of groundwater and surface water based on assessment studies</li> <li>• Construction of dams for water storage and groundwater recharge</li> <li>• Building desalination plants</li> <li>• Establishment of the Ministry of Water and Electricity in July 2001 to improve national planning</li> <li>• Development and implementation of water protection and conservation regulations (well drilling permissions, drilling supervision and specifications etc.)</li> <li>• Construction of wastewater treatment plants &amp; TSE reuse in irrigation</li> <li>• Introduction of advanced water conservation support policy at the residential level</li> <li>• Leakage detection and control schemes in major cities</li> <li>• Implementation of irrigation water conservation schemes for large and small farms</li> <li>• Changing agricultural policies to reduce groundwater pumping</li> </ul>
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	<p><b>TNC,2013</b></p> <p>Work in progress: A quantitative national-level assessment was in the planning stages to assess the vulnerability of the UAE's range of water resources to long-term regional CC and socioeconomic growth. These include the need to conduct assessments of</p> <ul style="list-style-type: none"> <li>• Vulnerability of the UAE's range of water resources to long-term regional CC and socioeconomic growth (WEAP) that will take place during the period 2013-2015</li> <li>• Explore the vulnerability of renewable groundwater supply in Al Ain along the Hajar Mountains (NOAH)</li> <li>• Assess vulnerability of the Arabian Peninsula's shared/transboundary groundwater resources due to sea level rises associated with long-term CC and socioeconomic growth using WEAP-MODFLOW models.</li> </ul>	<p>Once the assessment is complete, it should inform potential adaptation strategies that could be implemented, both within the UAE and within regional transboundary groundwater cooperation framework.</p>	<p><b>SNC, 2011</b></p> <p>RCM (PRECIS) was used for developing CC scenarios to predict changes in precipitation, temperatures, wind speeds and relative humidity across Saudi Arabia for 2070-2100. Changes in evapotranspiration were estimated using the FAO-approved Penman-Monteith approach. Possible effects of CC on water availability and quality in Saudi Arabia were investigated, and the implications of this change on future water resource management outlined. Specifically:</p> <ul style="list-style-type: none"> <li>• Impacts of CC (higher temperatures and lower rainfall) on groundwater recharge and surface water</li> <li>• Impacts of CC (temperature increases) on irrigation water demands</li> <li>• Impacts of CC (temperature increases) on domestic and industrial water demands</li> <li>• Impact of CC on water stress</li> </ul>	<p>Adaptation to CC in the water sector needs to be incorporated into overall policy framework. To reduce vulnerability and demand:</p> <ul style="list-style-type: none"> <li>• Reduction in uncertainties in Hydro-Meteorological Trend Predictions</li> <li>• Protection and restoration of ecosystem</li> <li>• Close the supply-demand gap, by: <ul style="list-style-type: none"> <li>- Reviewing the existing policies of the agriculture and water sectors and regulating water consumption</li> <li>- Reconsidering the administrative organization of the water sector and consolidating all agencies</li> <li>- Supporting a computerized central database covering all aspects of water use</li> <li>- Expanding and upgrading the hydrological and hydro-geological monitoring network</li> <li>- The use of advanced methods and technologies for the conservation of renewable surface and groundwater resources</li> <li>- Updating hydro-geological studies</li> <li>- Improving water fees collecting system</li> <li>- Enhancing the private sector's role in water services</li> </ul> </li> <li>• Development of non-conventional water resources, including the construction of desalination plants</li> <li>• Implementation of projects for the re-use of reclaimed wastewater and agricultural drainage water.</li> <li>• Build national capacity in the water sector.</li> </ul>
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<p><b>Water resources</b></p>	<p><b>FNC, 2018</b>  Conducted a multi-year project (2013-2016) to study impacts of CC at the local, national and regional levels, including on terrestrial and marine ecosystems, coastal zones, food security and water resources.</p>	<p>Key findings informed the development of the National CC Plan which focused on:</p> <ul style="list-style-type: none"> <li>• Water efficiency (subsidy reform, TSE efficient management, smart meter instalments, green building code that sets water and materials specifications, climate-smart agriculture that enables organic farming, hydroponic farming.</li> <li>• Foster long-term partnerships between government and business in green market development and commercialisation of innovative technologies such as water management and desalination technologies and waste management technologies</li> </ul>	<p><b>TNC, 2016</b></p> <p>Similar to 2NC 2011 report, RCM (PRECIS) was used to develop CC scenarios to predict changes in precipitation, temperatures, wind speeds, relative humidity for 2070-2100 and also sea level rises for 2030-2080. Changes in evapotranspiration were estimated using the FAO-approved Penman-Monteith approach.</p> <p>Possible effects of CC on water availability and quality in Saudi Arabia were investigated, and the implications of this change on future water resource management outlined. Specifically, these are:</p> <ul style="list-style-type: none"> <li>• Changes in the hydrological cycle (by modelling)</li> <li>• Impact of Climate Change on Water Supply (groundwater recharge and surface water and irrigation water supply)</li> </ul>	<p>To conduct more detailed studies on the impact of climate change on:</p> <ul style="list-style-type: none"> <li>• The decrease in surface rainfall and runoff in different parts of Saudi Arabia</li> <li>• The decrease in groundwater recharge in more detailed studies at local aquifers at different parts of Saudi Arabia</li> <li>• Risk assessment on the reuse of TSE</li> <li>• The design of early monitoring and warning systems</li> </ul> <p>A multi-criteria decision-making (MCDM) tool and decision support system (DSS) for IWRM should be developed for future studies</p>
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## Annex II. NDCs Plans related to the GCC water sector

Plans/ Actions Anticipated	Bahrain	Kuwait	Qatar	UAE	Oman	KSA
Upgrading water distribution networks to minimise water leakage	✓					✓
Increasing the efficiency of CPDPs/ more efficient forms of desalination		✓	✓	✓	✓	✓
Raising public awareness on the rationalization of water consumption	✓	✓				
Using modern techniques to rationalize human consumption of water	✓	✓				
Upgrading wastewater treatment plants to improve treated wastewater quality			✓			✓
Formulation of National Water Act and legislation	✓		✓			
Economic incentives for water conservation			✓			
Formulation of IWRM plans focusing on demand-side management	✓			✓		✓
Capacity development					✓	✓
Technology Transfer	✓				✓	✓

## About the Authors

Prof. Waleed K. Al-Zubari holds the academic position of Professor of Water Resources and the Coordinator of the Water Resources Management Program and of the UN Water Learning Center for the Arab Region at the Arabian Gulf University (AGU). He currently serves as the chairperson of the Technical Advisory Committee of the Water Resources Council of the Kingdom of Bahrain. He obtained his MSc degree in 1987 in the field of groundwater mathematical modelling from Ohio University and PhD degree in 1990 in the same field from Colorado State University. Since joining AGU in 1990, he has taught many courses in Water Resources Management and Planning in Arid Regions and Hydrogeology, published more than 100 research papers in peer-reviewed journals, conferences, and seminars, and supervised more than 50 MSc and PhD theses. His research interests include management of the Water-Energy-food Nexus; water resources governance, planning and management; use of numerical models in the management of groundwater systems; and the impacts of climate change on the water sector. He has conducted more than 40 contractual research studies and serves as a consultant for many UN and international organizations. He served as the Editor-in-Chief of the regional Arab Gulf Journal of Scientific Research (2006 – 2010). He currently serves as the Vice-President of the GCC Water Science and Technology Association and is the Chairman of its Scientific Committee.

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