المؤسسة العامة لتحلية المياه المالحة
Saline Water Conversion Corporation (SWCC)

Addressing water security in arid and water stressed regions Position Paper

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نسابق المستقبل.. حيث الحياة

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Introduction

Over the years, water was and still is an essential need for every civilization ever existed. Consequently, having sustainable water source is the main driver for choosing where to live or sometimes how to live. Throughout todays modern innovations and style of life, having an access to sustainable source of water is an essential strategic requirement for any habitable area around the world.

Over half of the world's countries are facing some kind of water stress, at least part of their region. Moreover, as the increased demand on freshwater, water stress is expected to rise even more. Hence the accessible fresh water is only less 1% of global water, which eventually will have negative amplifications on the economy, environment and social states of the world.

Since 70% of freshwater where been consumed over the past century, water security will force decision makers to take actions to deal with water stress in order to have more sustainable water sources, which will require taking measures across all the cause and effect factors of water scarcity. Geographically the kingdom of Saudi Arabia is one the most water- stressed countries in the globe, however one of kingdom's main target of the vision 2030 is taking the required actions to ensure the readiness of its water related infrastructure and institutions to meet the rapid expected increase of water demand.

Furthermore, this paper will provide the answers to the fundamental questions of water security, that includes Why Should We Focus on Water Security, What Are the Emerging Threats in Arid and Water-Stressed Regions, What Are the Actions Taken by Governments to Enhance Water Security and What Steps Is Saudi Arabia Taking to Ensure Water Security.

1. Why Should We Focus on Water Security?

1.1. Understanding Water Security

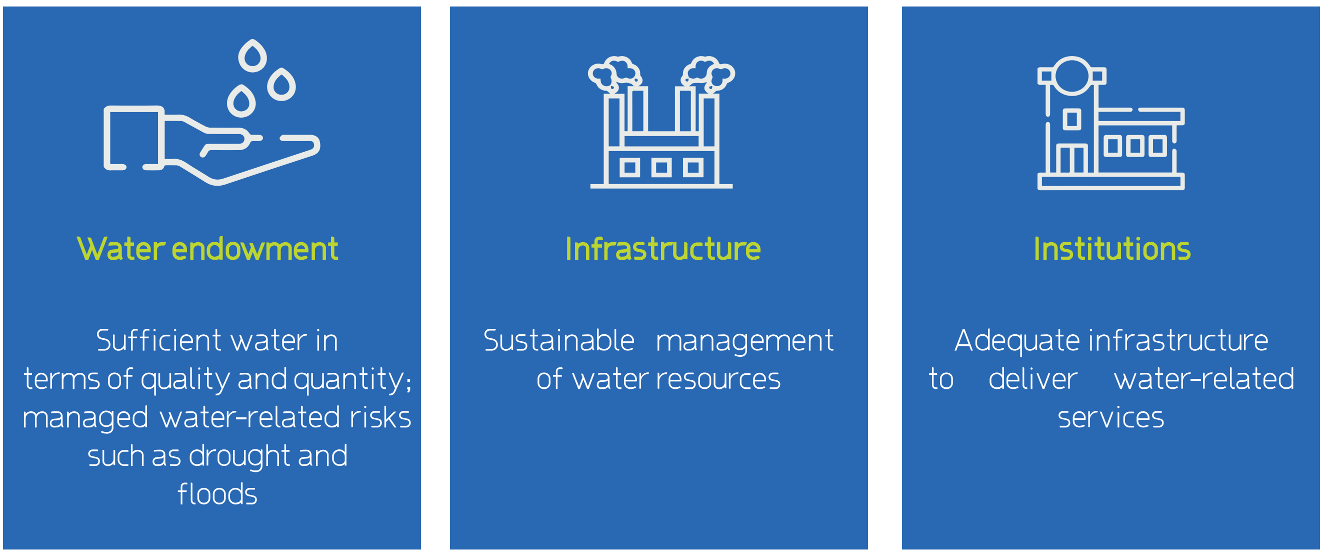
To achieve water security, several factors need to be considered, including water endowment, infrastructure, and institutions (Figure 1).

Sufficient water is required—in terms of quality and quantity—and water-related risks, such as drought and floods, need to be well-managed. In addition, adequate infrastructure is needed to deliver water-related services, such as water supply and wastewater treatment.

Finally, institutions need to be in place that allow for the sustainable management of water resources. While all components are of crucial importance to ensure water security, this paper will dive deeply into water stress to gain a better understanding on drivers and solutions.

> "Water security is defined as 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, environment, and economies
> —World Bank"

Figure 1: Three components of water security



Source: Modified from World Bank

1.2. Countries Facing Water Stress Globally

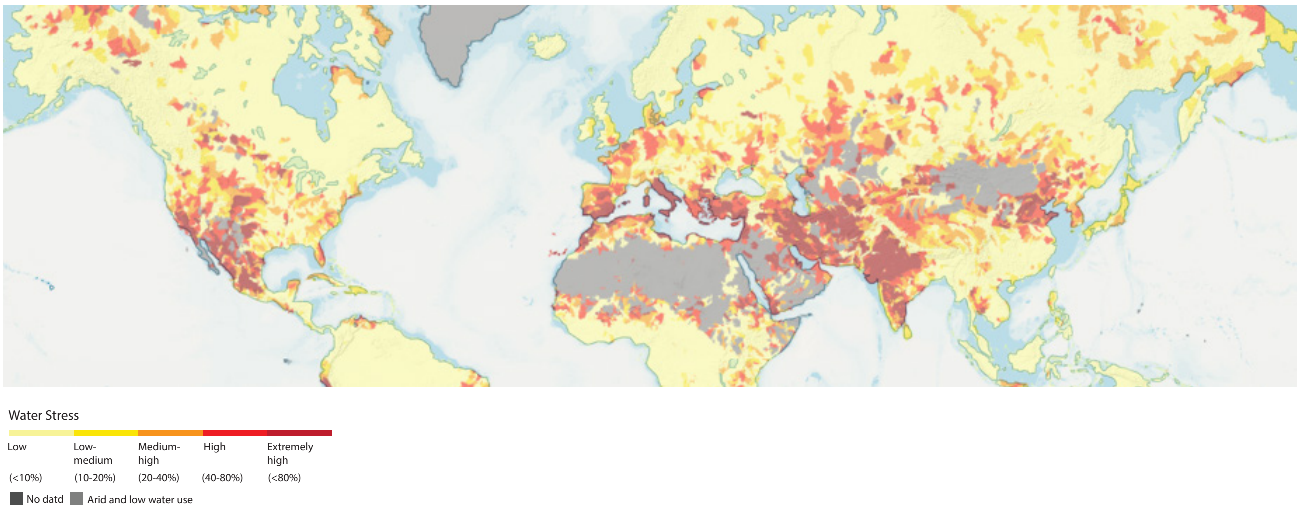
Water can be supplied from various sources, including surface and groundwater, rainwater harvesting, and desalination. In addition, there are emerging water sources, such as reusing treated wastewater and—for lower volumes in remote areas—atmospheric water generation. The largest water user is agriculture, responsible for around 70% of withdrawals globally (World Bank, 2020). Other water uses include household and urban demand,[1] as well as industries and mining.

Water stress depends on how much of the available water is used—ranging from “low water stress” (only 10% of available water is used) to “extremely high water stress” (more than 80% is used).

Today, at least 112 countries are facing high or even extreme water stress in at least part of their territory.[2] Countries in the Middle East and North Africa, as well as India, China, and the American West, are hardest hit (Figure 2). Around 83% of Global GDP is generated in countries in which part of their territories face high or extreme water stress.[3]

> “Around **83%** of Globally GDP is generated in countries in which part of their territories face high or extreme water stress”

Figure 2: Annual baseline water stress globally



[1] Urban demand includes municipal and commercial water uses, such as water for government buildings, shops, watering urban greenery, and firefighting.
[2] Based on river basins facing water stress; 81 countries have territories that are facing extreme water stress.
[3] Based on water stress data from WRI Aqueduct and GDP (2019, nominal) data from World Bank.

1.3. The Economic Impact of Water Stress

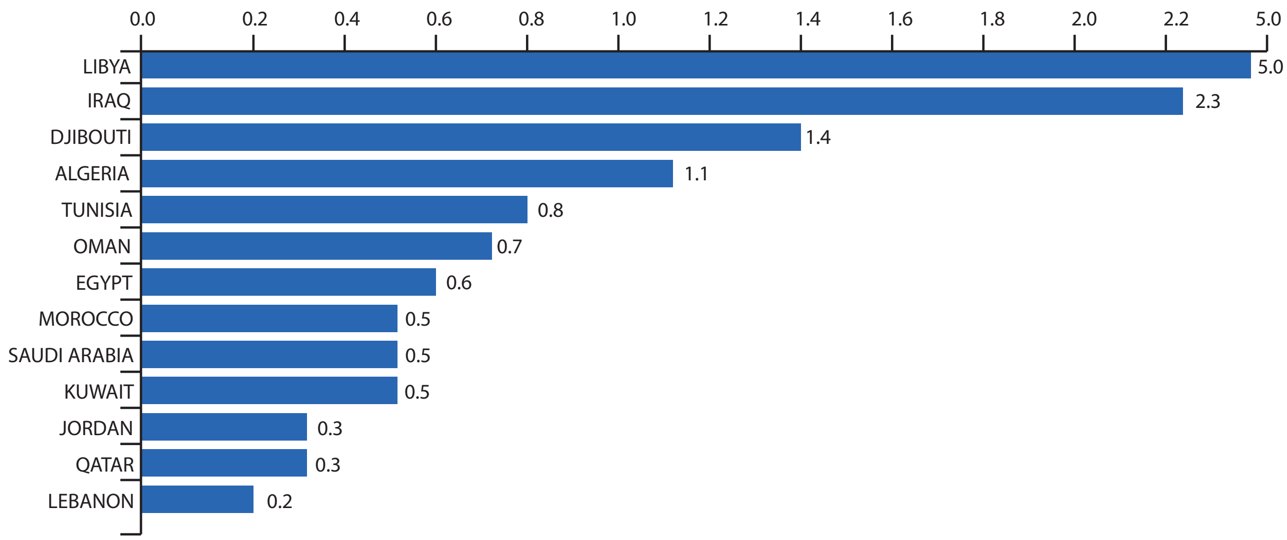
Water stress doesn't just impact people; it also has a real effect on the economy and GDP growth. When looking at insufficient water supply and sanitation for households alone, we see an average GDP impact of 1.02% annually across the Middle East (Figure 3).

> When looking at insufficient water supply and sanitation for households alone, we see an average GDP impact of **1.02%** annually across the Middle East

Libya is the worst affected, with an expected annual GDP impact of 5%, while Lebanon (0.2%), Qatar (0.3%), and Jordan (0.3%) are the least affected. However, when including the economic costs of reduced industrial production and reduced agricultural output because of water stress, the GDP impact is expected to be considerably higher.

In Indonesia, for example, water shortages were estimated to lower GDP by around 2.5% by 2045 if left unaddressed (World Bank, 2021).

Figure 3: Economic losses from inadequate water supply and sanitation in the MENA region (% of GDP)



Source: World Bank (2018) [4]

[4] Based on 2010 data.

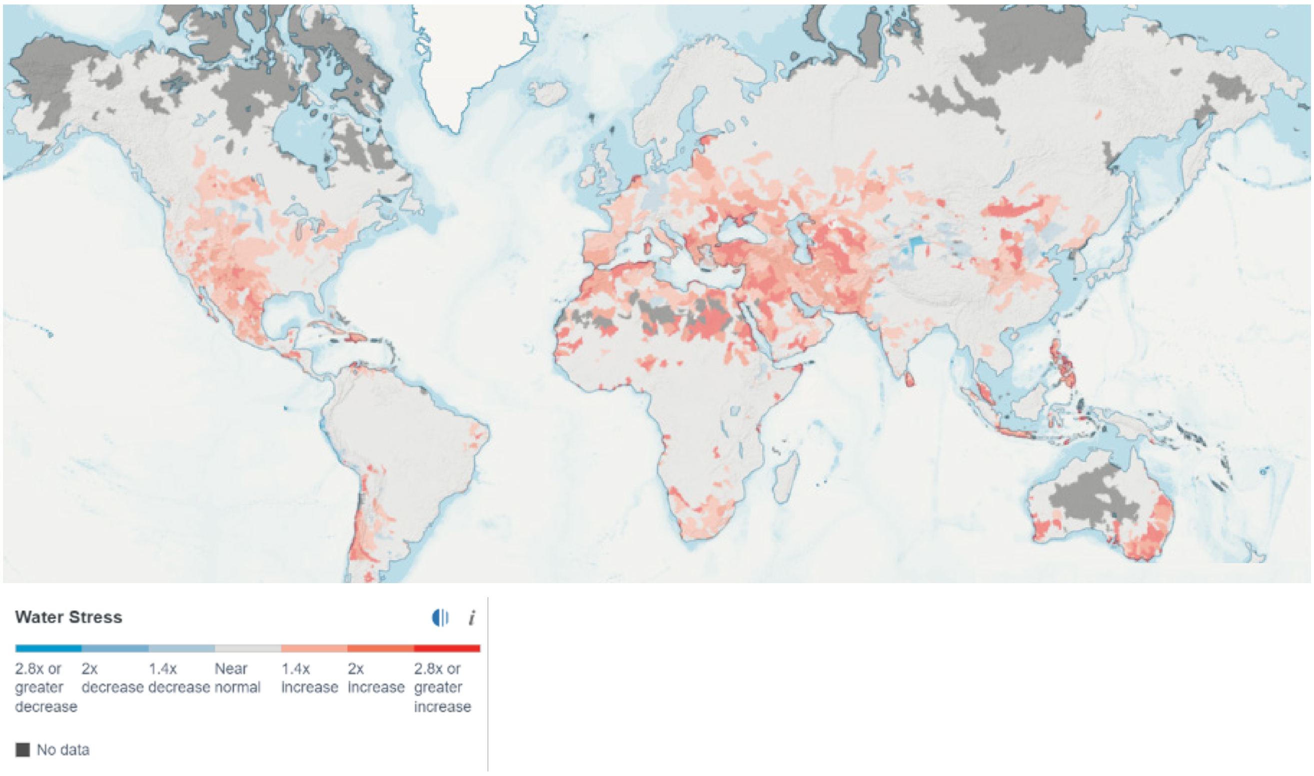
2. What Are the Emerging Threats in Arid and Water-Stressed Regions?

Population growth, expanding industries, and intensifying agriculture to feed the growing population are all putting pressure on water resources. In some regions, this is aggravated by a lower availability of water resources due to climate change.

> Overall, it can be expected that around **51%** of the global population will be exposed to high water risk by 2050, up from around 17% today (WWF, 2020).

In a "business-as-usual" scenario, nearly all countries will face either similar or increased water stress by 2040. Countries in the Middle East, North and Southern Africa, South Asia, the Western United States, parts of China, Indonesia, Latin America, and Australia, face the largest increase in water stress (Figure 4).

Figure 4: Changes to water stress by 2040 globally (business-as-usual scenario)



Source: WRI Aqueduct (2019)

While these numbers are alarming, the reality on the ground looks even more challenging, as threats like water pollution, insufficient infrastructure, non-revenue water, and aging infrastructure further aggravate water security.

2.1.1. Water Pollution

Water pollution—caused by a discharge of untreated municipal, industrial, and mining effluents as well as by agricultural runoff—is increasingly making available water supplies unfit for usage. In some cases, such as in Dhaka, Bangladesh, or Jakarta, Indonesia, [5] rivers are so polluted that water treatment would be expensive (World Bank, 2022). In others, like Lake Erie, part of the Great Lakes in the US, pollutants like the "forever chemical" make water treatment for consumption barely possible financially (US EPA, 2021). Groundwater over-abstraction can also result in the dissolution of minerals like arsenic, requiring water to undergo expensive treatment to make it safe for consumption, such as in Bangladesh.

2.1.2. Insufficient Infrastructure

Households not connected to water supply and wastewater, or receiving insufficient service, often take actions that impact overall water security—and mostly go unnoticed. Households with no (or unreliable) piped water connections typically rely on borewells, or tankers that draw water from borewells.

> "This mostly unmonitored groundwater abstraction can lead to falling ground-water tables, impacting overall water security."

Further, households lacking sewerage connections typically resort to on-site solutions, such as septic tanks. In some cases, such as Jakarta[6] (World Bank, 2021), septic tanks are built to purposefully leak to reduce the times they need to be emptied, saving costs. This, however, causes groundwater pollution and further impacts water security.

Agricultural water usage amounts to around 80% of water withdrawals globally. Yet most of the water usage is not monitored or regulated. This gives rise to inefficient irrigation practices and can lead to over-abstraction of groundwater.

[5] In these cases, water supplies either rely on groundwater or on surface water transfers from less polluted areas upstream.
[6] The first large infrastructure projects in Europe and the US were made starting in the mid-1800s.

2.1.3. Aging Infrastructure

While infrastructure-related water-security issues are mostly associated with the "developing world" aging infrastructure is increasingly becoming a challenge for "developed countries," which invested in water infrastructure over the past 100 to 150 years. The average life expectancy for reservoirs and dams is around 50 to 80 years; for water and wastewater treatment plants and pumping stations, it's around 60 to 70 years; and for drinking water distribution, as well as sewage and storm water collection systems, it's around 60 to 100 years[7] ("Average Life Expectancy of Select Infrastructure Types and Potential Climate-Related Vulnerabilities," n.d.).

A case in point is the US, where water and wastewater networks are approaching the end of their lifespans and upgrading these aging systems in now densely populated areas is proving to be challenging and costly.
To keep track of their infrastructure status and challenges, the US started publishing infrastructure report cards every four years ("America's Infrastructure Scores C-," 2021). Water-related infrastructure is poorly performing, receiving C- for drinking water infrastructure, D+ for wastewater infrastructure, D for stormwater infrastructure, and a D for dams.[8] Integrating asset-replacement considerations with planning is crucial to maintaining long-term water security.

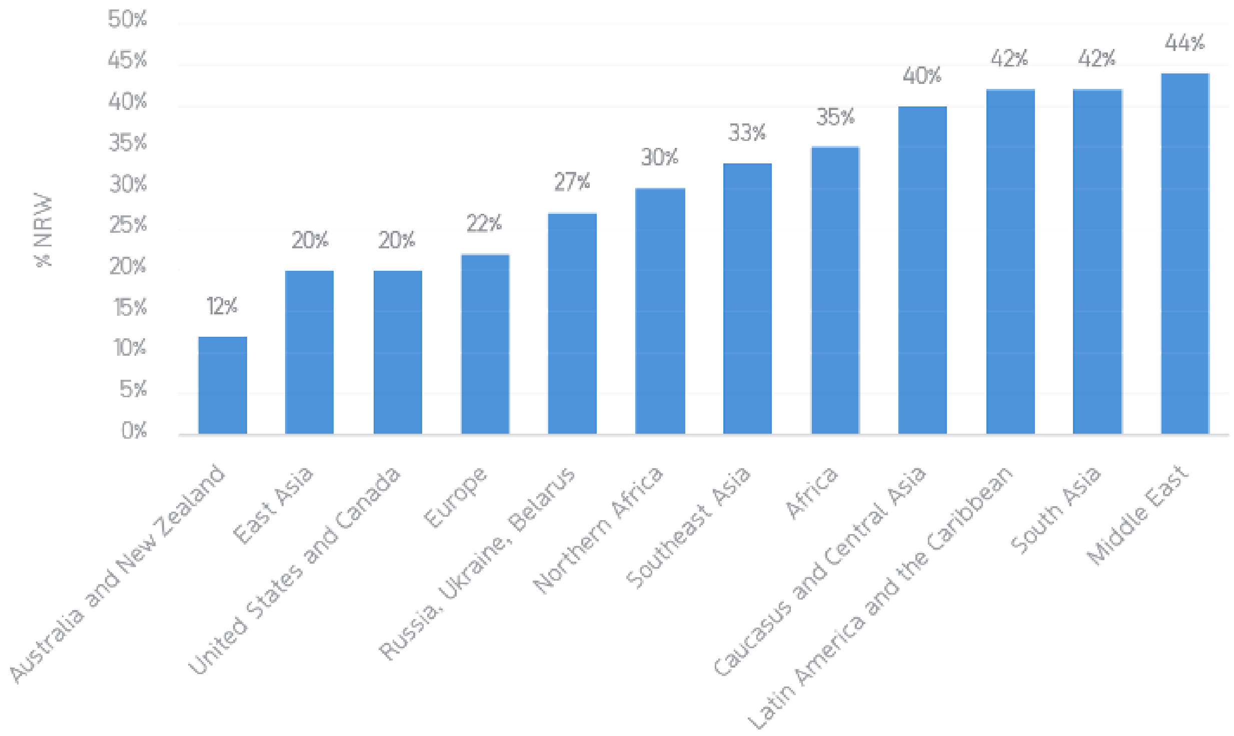
2.1.4. Non-Revenue Water (NRW)

> Globally, around **30%** of treated water is lost during distribution

Globally, around 30% of treated water is lost during distribution—with great differences across regions (Liemberger, and Wyatt, 2018). These physical losses are part of what is referred to as non-revenue water (NRW). NRW also counts commercial losses, i.e., unpaid water bills. While physical leakages directly impact water security due to the lower availability of water to meet demand, commercial losses indirectly impact water security as utilities have fewer resources to maintain and enhance the water and wastewater systems. NRW differs widely across regions, with the Middle East, South Asia, Latin America, and the Central Asia and Caucasus showing the highest losses—around 40% of water produced.[9] Australia and New Zealand, East Asia, Northern America, and Europe perform the best (Figure 5).
Australia's low NRW—10%, among the lowest across all countries—was driven by infrastructure investments to reduce water losses in light of the droughts Australia has been facing this over the past 10 to 15 years. One key reason for physical water leakages is aging infrastructure.

[7] These estimates vary by region, materials used, and climate conditions.
[8] The grades range from A (best) to F (worst); specifically, A = exceptional, fit for the future; B = good, adequate for now; C = mediocre, requires attention; D = poor, at risk; F = failing/critical, unfit for purpose. More details can be found here: https://infrastructurereportcard.org/making-the-grade/
[9] Based on data from Roland Liemberger and Alan Wyatt, 2018; NRW averages are weighted by population supplied.

Figure 5: Non-revenue water across the world (%)



Note: NRW averages weighted by population supplied

Source: Liemberger and Wyatt (2018)

NRW also comes at a cost to the economy, since costs spent on abstracting and treating water are being sunk to the ground. The International Water Association (IWA) has estimated that the cost of NRW amounts to US $39 billion per year globally.

[10] Depending on the location and level of NRW, reducing NRW is not only a move toward greater water security, but it's also cost-effective.

Based on rough estimates, IWA found that a reduction of one-third of NRW globally would result in savings of US $13 billion per year. The Total required costs to achieve this reduction amount to US $69 billion—meaning this investment would pay for itself in five years (Liemberger and Wyatt, 2018).

While these estimates are very high-level and NRW reduction potential and costs are very location-specific, it highlights the point that oftentimes NRW reduction is an attractive—yet overlooked—option for addressing water security.

> “ The International Water Association (IWA) has estimated that the cost of NRW amounts to US **$39 billion** per year globally ”

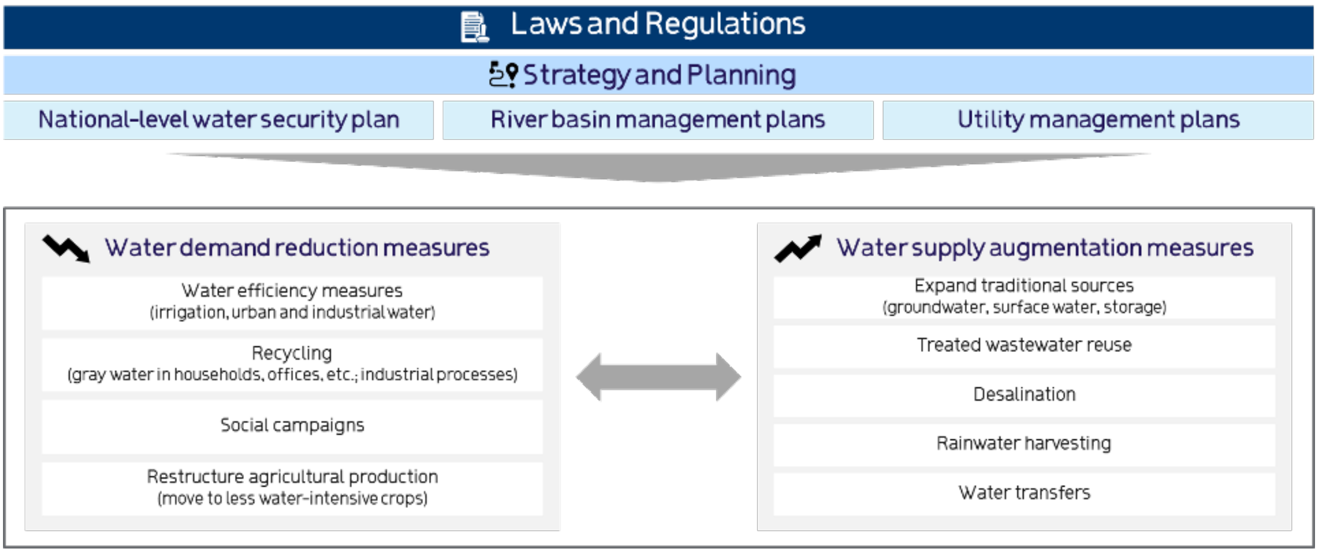
[10] Based on the production cost for water (USD/m3).

3. What Are the Actions Taken by Governments to Enhance Water Security?

Governments in water-stressed and arid countries are increasingly taking actions to ensure water security, including passing policies, laws, and regulations, as well as incorporating water-sector resilience into planning and focusing on water demand reduction and supply chain augmentation measures.

To gain a better understanding of these actions, four mature water sectors—in the UK, Spain, California, and Australia—were studied across four dimensions: (1) laws and regulations; (2) planning mechanisms; (3) water demand reduction measures; and (4) water supply augmentation measures (Figure 6).

Figure 6: Actions taken by governments to address water risks



Source: Team analysis

3.1. Laws and Regulations

As water security requires collective action from all water users, it is crucial to establish a governance framework that encourages or even enforces behaviors that support water security. To function efficiently and effectively, the roles of all players need to be clearly defined.

Typically, Ministries set the strategic direction, develop policies and laws. Regulators are responsible to ensure the enforcement of regulations. Operators, such as water and wastewater utilities ensure the on-ground execution of services provision, which can include planning, construction and operational activities. In some countries, there are also specialized government institutions, which support the government – oftentimes Ministries – on tasks related to planning and water security.

In water-abundant countries, the governance framework pays little attention to sustainable water abstraction and usage.

In California, for example, the Water Law requires that uses of the state's water must be both "reasonable and beneficial."[11] Building on the Water Management Act 2000 (NSW), water markets were created in selected river basins in New South Wales, Australia—for example, in the Murray Darling River Basin—to limit total water allocations and allow stakeholders to trade excess water use rights for market prices (" Acts & Regulations—Water in New South Wales," n.d.).

"However, as countries experience continuous episodes of water stress, laws and regulations are amended or newly introduced to consider the changing circumstances and to ensure long-term water security."

This incentivizes efficient water usage and reduces wastage, as the saved water can be sold.

In the UK and Spain, laws were recently amended considering increasing water stress. The UK Water Industry Act of 1991 was amended in 2014 to add a new focus on water resilience. Spain passed the Law on Climate Change and Energy Transition in 2021, which requires a "strategy that defines the guidelines and measures that must be considered in the planning and management of water in Spain to deal with the consequences of climate change." Further, Spain will amend the Water Law—along with the derived regulations, plans, and strategies—to increase investments aligned with the European Green Pact and promote water sector resilience.

[11] Article X, Section 2, Constitution of California. The law places a significant limitation on water rights by prohibiting the waste, unreasonable use, unreasonable method of use, or unreasonable method of diversion of water. However, the definition of "unreasonable" depends on circumstances, opinions of the State Water Resources Control Boards, or courts.

The law amendments have direct consequences on how the water sector is regulated. In the UK, for example, water companies are private and regulated by an economic regulator, OFWAT.

Following the Water Industry Act amendment, companies need to consider long-term planning of investments, actions to use water resources in a sustainable way, increase water efficiency, and reduce demand (Water Industry Act 1991).

OFWAT has also set concrete targets for water companies, including a 15% reduction of leakage over five years. In California, the Water Code requires all urban water suppliers to submit water loss audits to the Department of Water Resources as part of urban water management plans prepared once every five years.

To address any form of misreporting, Senate Bill 555 was passed in 2014, mandating water loss audits by certified water audit validators before submission (Water Loss Control, n.d.).

Beyond water companies and river basin organizations, water consumers are driven to reduce water demand. This is done either through introducing water efficiency considerations in building regulations, as the UK did ("Sanitation, Hot Water Safety and Water Efficiency: Approved Document G," 2016) or through temporary emergency regulations in times of dry weather or drought—for example, in the UK ("Drought," n.d.), California (Archie, 2022), Australia, and Spain (Enyedi, 2022).

3.2. Strategy and Planning

To ensure water security, first a solid understanding of the water risks—today and in the future—is required. Then, considering laws and regulations (section 3.1), clear action plans need to be developed across the country and for each water company and other water users.

Typically, a national-level water security plan sets the scene, which is then considered in river basin management plans,[12] where applicable, and/or in water company plans.

For example, in the UK, the Environment Agency published the National Framework for Water Resources, which identifies long-term water needs up to 2050 along with actions that need to be taken by water companies, the government, and others to ensure future water security.

[12] Applicable in, for example, countries in the European Union managed on the river basin level and following the best practice of integrated water resources management; river basin organizations are responsible for developing and submitting river basin management plans.
OFWAT is responsible for regulating the water sector in England and Wales.

The water findings of the national framework are further detailed by regional plans, which are developed by five regional groups[13] that bring together water companies and other stakeholders and identify required regional measures. Regional measures are further specified into measures that need to be taken by water companies in water resource management plans, which are submitted by water companies and approved by the economic regulator OFWAT.

In Spain, water resources are managed on the river basin level[14] by dedicated river basin organizations (RBOs). National-level laws, regulations, and plans, such as the Spain 2050 Strategy, Groundwater Action Plan and the National Water Treatment, Sanitation, Efficiency, Saving, and Reuse Plan (Plan DSEAR), are implemented through RBOs. RBOs are required to submit river basin management plans that capture current and future water supply and demand, convey possible risks, and identify measures that need to be taken to ensure a resilient future. To develop these plans, RBOs need to coordinate with all relevant stakeholders in the river basin, including water utilities.

In New South Wales, Australia, for example, Water Infrastructure NSW was established in 2020 as a separate agency under Department of Planning Industry and Environment (DPIE) to synchronize project planning, as well as leading and delivering key water infrastructure projects.

> "In some countries new institutions are created to enhance strategic planning and thus improve overall water security while reducing costs"

Before, projects were designed and delivered by the DPIE's water division, three gov-owned entities [15] and 93 local water utilities.

In the UK, The Regulators' Alliance for Progressing Infrastructure Development (RAPID) was set up in 2019 as a partnership comprising of three water regulators to drive the development of joint infrastructure projects. In the water-stressed countries and states analyzed, water companies/utilities are required to submit management plans that show their long-term water supply reliability,[16] reduction in leakages, and initiatives to reduce water demand. While in the past there was a strong focus on water supply augmentation measures, such as increasing water abstraction and building dams, the focus is shifting toward water demand reduction measures.

To ensure that all possible options to increase water security are considered, OFWAT now mandates water companies to include measures across four areas: (1) gray infrastructure,[17] (2) green infrastructure,[18] (3) behavior change, [19] and (4) response and recovery.[20]

Water companies/utilities hence can look at two broad categories of measures: (1) water demand reduction and (2) water supply augmentation.

[13] The five regions are North, West, Southeast, East, and West Country.
[14] River basin refers to the total area of land that is drained by a river and all of its tributaries.
[15] WaterNSW, Sydney Water and Hunter Water
[16] For example, in California, utilities need to prepare urban water management plans (UWMPs) every five years and consider a 20-year planning horizon; in the UK, water companies are required to submit water resource management plans every five years considering a planning horizon until 2035.
[17] Such as treatment, network, storage, and transfers.
[18] Such as ecoservices markets and catchment schemes.
[19] Such as improving customer use of water.
[20] Such as improving contingency planning.

3.3. Water Demand Reduction Measures

While the focus for enhancing water security often lies on increasing water supplies, significant improvements to water security can be made by reducing water demand—and these can also be more cost-effective than water supply solutions. Across all sectors, water demand can be reduced by (1) introducing or changing technology, (2) changing practices, or (3) changing land use.

3.3.1. Agricultural Water Demand Reduction

As agriculture globally uses around 70% of water withdrawals annually, it is also the sector in which major water savings can be realized (World Bank, 2020).
Efficiency can be increased by changing—or introducing—irrigation technologies, such as drip irrigation, and by improving the maintenance of irrigation systems to reduce leakages. Flood irrigation is the least efficient irrigation method, with around 70% of water being wasted (Dunn,2021).

Drip irrigation systems have an irrigation efficiency of 90% when compared to sprinkler systems, which range between 65% and 75%.[21] Shifting from conventional irrigation methods to drip irrigation can reduce water consumption by around 60% and increase crop yield by 90% (Chu, 2017).

“Shifting from flood irrigation to alternative wet and dry rice production, for example, has the potential to reduce water consumption by 15% to 25% and overall GHG emissions by **30%** to 70%, with no negative impact on yields”

Further, efficiency can be improved by changing agricultural practices. Shifting from flood irrigation to alternative wet and dry rice production, for example, has the potential to reduce water consumption by 15% to 25% and overall GHG emissions by 30% to 70%, with no negative impact on yields (“Rice Farming: Saving Water Through Alternate Wetting Drying (AWD) Method,” 2020). Further, practices such as conservation tilling, cover crops, and the use of compost and mulch can increase the soil’s water-holding capacity and thus reduce irrigation requirements. Whenever irrigation efficiency gains are insufficient to achieve water security—or are too costly to introduce—changes in cropping or land use patterns can reduce water demand. Shifting from water-intensive crops, such as rice or wheat, to less water-intensive but high-value crops, such as horticulture, or drought-tolerant crops can result in significant water savings. Further, it may be decided to change the land use and either shift agricultural production to another, less water-stressed, area or to choose to import the required agricultural produce instead.

[21] As drip irrigation is a low-pressure method, it also has lower energy requirements than sprinkler irrigation, while crop yields have been reported to increase.

3.3.2. Municipal Water Demand Reduction

Reductions in municipal water demand can be achieved by reducing household, commercial, and government water demand, as well as water required for urban landscaping. In addition, water can be saved by reducing leakages in water supply.

Technological changes, such as the introduction of water-efficient appliances in households and commercial and office buildings, including low-flush toilets and water-efficient showerheads, and introducing of recycling and reusing gray water can reduce water demand. In California, these measures shall lead to a 20% reduction in urban water demand (Urban WaterManagement Plans, n.d.).

Awareness campaigns targeted at citizens to reduce water demand have also proven to be successful. In 1996, Zaragoza, Spain, faced severe water shortages due to a drought and had to significantly reduce municipal water demand. As part of the Zaragoza water-saving city program, an awareness campaign was launched in combination with financial incentives to increase the purchase of water-efficient appliances, which resulted in voluntary commitments to reduce water consumption by residents and businesses. Within 15 years, water usage decreased by almost 30%—from 150 lpcd to 99 lpcd—despite a 12% increase in population(Water-Saving Program: Zaragoza, Spain, n.d.).

Further, tackling NRW has a large impact on reducing water leakages, and hence water demand, and water-stressed countries are increasingly taking action. For example, the UK targets to reduce NRW by 50% by 2050, and to achieve this, the economic regulator OFWAT has included mandatory NRW-reduction targets for water companies to the price reviews
(Environment Agency, 2020).

[22] Mandated by Model Water Efficient Landscape Ordinance, n.d.

3.3.3. Industrial Water Demand Reduction

Globally, around 19% of water is withdrawn for industrial uses (AQUASTAT—FAO's Global Information System on Water and Agriculture, n.d.). Industrial water demand can be reduced either by introducing water-efficient technologies and practices to industrial processes or by recycling and reusing water.

The choice of water-efficient technologies depends strongly on the industry. In textiles, for example, the choice of dyes used can reduce water consumption by 25% (Smith, 2017). Mining industries can install closed-loop systems to reduce the need for fresh intake water while simultaneously reducing pollution risks (Christiansen, 2021). Beverage companies can reduce the water requirements to produce one liter of a beverage by 29%.[23]

Further, while most industries use potable water for most of their processes, industrial water demand can be reduced if potable water is replaced—where possible—with recycled and gray water.[24]

Industries and their customers are becoming more aware of water stress impacting operations and are increasingly trying to reduce their water demand. Over the past years, companies have been more and more driven to apply ESG standards, which include water usage and pollution considerations, and disclose their performance in industrial operations. To create more awareness and increase the transparency of their actions, companies are now joining forces in international collaborations and/or disclosure projects. The Water Resilience Coalition, for example, is a CEO-led coalition driven by multinational companies, such as Coca-Cola, Diageo, Dow, Gap Inc, and Cargill, and pledges to have a net-positive water impact by 2050 (Call to Action, n.d.).[25] Further, companies representing over 64% of global market value disclose information on their activities around climate change, deforestation, and water security through the Carbon Disclosure Project (CDP Media Factsheet, 2022).

Finally, if water demand reduction and water supply measures are not sufficient, water-intensive and water-polluting industries can be relocated to less water-stressed areas.

[23] Coca-Cola, for example, reduced its water footprint for one liter of beverage from 2.7 liters in 2004 to 1.92 liters in 2017; https://www.coca-colacompany.com/news/improving-our-water-efficiency.
[24] Recycled water has been used for processes and can be reused; gray water is generated from showers and laundries.
[25] Net-positive water impact requires that companies reduce water stress in three dimensions: availability (quantity), quality, and access.

3.4. Water Supply Augmentation Measures

Whenever water demand reduction measures are not sufficient to meet demand, or become too costly, measures to augment water supplies need to be considered.

Water supply can be augmented by increasing existing water sources or adding new ones. Surface and groundwater abstractions can be increased, and storage can be built to make water available in the drier season. If required, water treatment plants need to be expanded or built new to treat the increased raw water before usage.

In addition, rainwater can be harvested and stored. This measure is mostly installed by water users directly in households, commercial and government buildings, and industrial sites.

In Chennai, India, for example, rainwater harvesting is mandatory for buildings exceeding a certain size to overcome the double challenge of floods during the rainy season and water scarcity in the dry season.

However, it can also be done on a larger scale to capture rainwater in catchments to recharge groundwater.

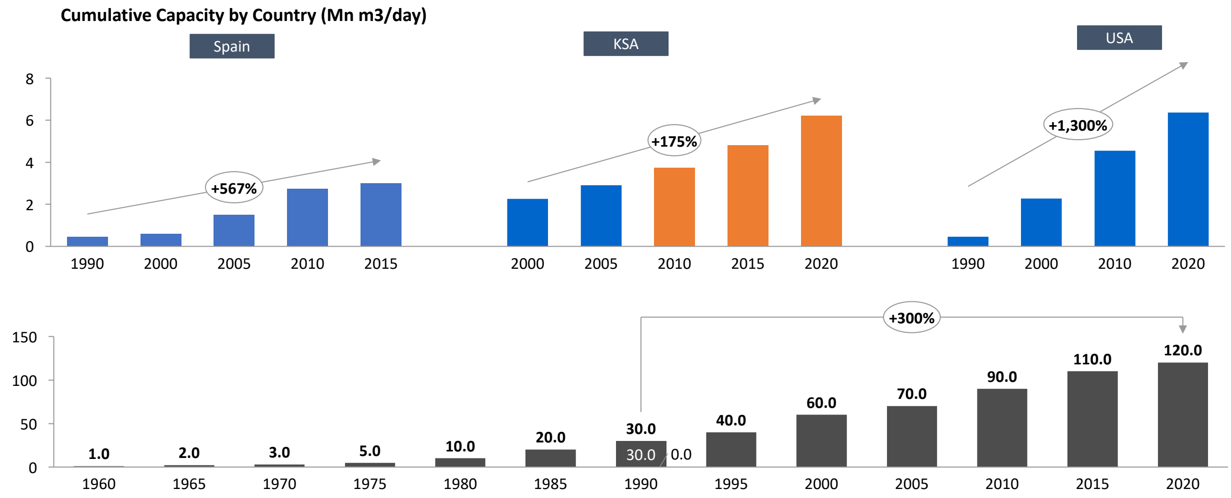
> “ Between 1990 and today, desalination capacity increased three times **(300%)** ”

Increasingly, desalination has been used by countries to complement traditional water sources. Desalination started to be used more widely in the eighties. Between 1990 and today, desalination capacity increased three times (300%). In that same time period, in Spain, the USA, and Saudi Arabia, desalination has also increased in importance and expanded nearly six times (567%), 13 times (1,300%), and nearly two times (175%), respectively (Figure 7). Desalination, however, has a large environmental footprint, high production costs, and extensive energy consumption.

The environmental costs of desalination include disruption of ecosystems, emissions and acidification, increased salinity, and temperature increase in the marine environment as a result of brine discharge.

> “ Advances in reducing energy consumption have been made—**SWCC** in Saudi Arabia won the Guinness World Record for the lowest energy-consuming desalination plant **(2.271 kWh/m3) (Kaddoura, 2021)**. ”

Figure 7: Comparison of desalination capacity across years globally



Source: SWCC (2022), U.S. Department of the Interior Bureau of Reclamation (2018), La Houille Blanche (2019), WWD (2021), APM Research Lab (2021), Smart Water Magazine (2022), Statista (2022)

Using treated wastewater is attracting more attention and is less costly and less environmentally damaging than desalination. The level of treatment for wastewater differs according to its intended usage—ranging from minimal treatment when used for agriculture and landscaping in Saudi Arabia to extensive treatment when used as "new water" for the drinking supply in Singapore. Globally, Spain ranks fifth in terms of wastewater-treatment capacity—27% of its wastewater is treated at the highest standard. Spain continues to place a strong focus on reuse, and it has just passed the 10 billion euro Plan DSEAR, which also focuses on water efficiency and water savings (Zarzo, 2021). In California, the request to build a new US $1.4 billion desalination treatment plant was rejected on the grounds of marine damage caused by brine disposal and because the water supply gap can be filled by reusing more treated wastewater (Trotta, 2022).

Emerging technologies, such as atmospheric water generation (AWG), can be used for small water demand areas that are not connected to the main water supply network, such as remote areas or small industrial uses. In this technology, water extracted from the atmosphere produces potable water. AWG ranges from household solutions to commercial solutions with a maximum generation capacity of around 10 m3/day (Atmospheric Water Generation Research, 2022).

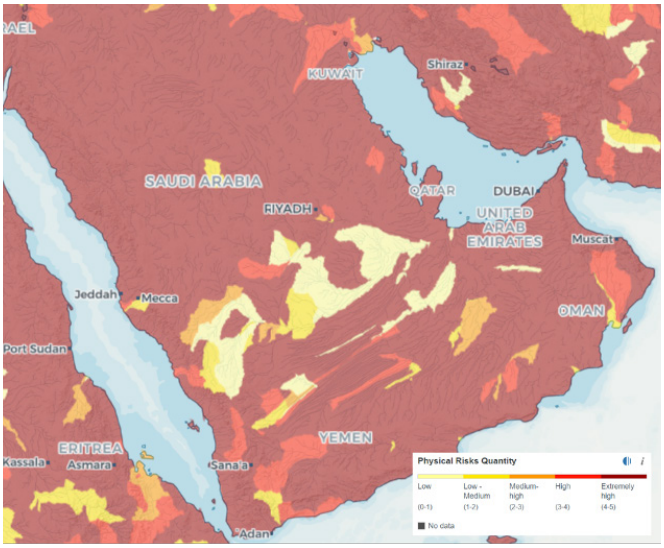
4. What Steps Is Saudi Arabia Taking to Ensure Water Security?

4.1. Saudi Arabia’s Water Scarcity Challenges

The Kingdom has limited natural water sources, with most of its total water supply sourced from non-renewable groundwater.

Almost all watersheds in Saudi Arabia are classified as facing extreme water risks, except for some areas in the south that have low water stress (Figure 8) [26]

Figure 8: Baseline physical water risks in Saudi Arabia [27]



Note: Map is based on high-level estimates, and an in-depth water risk assessment is required to fully understand water risks.
Source: WRI Aqueduct (2019)

In 2015, around 80% of total water was used for agriculture, of which the majority came from non-renewable groundwater sources.

Agricultural production in Riyadh, Qassim, Eastern Region, Taouk,

[26] Areas with low water stress include Ash Sharqiya, Makkah, Najran, Ar Riyad, Asir, Al Qassim, and Ha'il.
[27] Physical water risks include baseline water stress (used in Figure 2 and Figure 4), water depletion, inter-annual variability, seasonal variability, groundwater table decline, riverine and coastal flood risk, and drought risk. Full definitions can be found here: https://www.wri.org/applications/aqueduct/water-risk-atlas.

Ha'il, and Jouf rely nearly exclusively on non-renewable groundwater, with groundwater levels falling rapidly. Some areas in Saudi Arabia are predicted to see their reserves deplete in the upcoming years at the current rates of non-renewable groundwater abstraction. Qassim is expected to be the first province to deplete its exploitable non-renewable groundwater reserves, followed by Riyadh (MEWA, 2017).

The over-abstraction of nonrenewable groundwater can also cause a deterioration in water quality, such as an increase in total salinity. This causes drinking water to exceed thresholds for safe human consumption (MEWA, 2017).

While Saudi Arabia has made great progress in the reuse of treated wastewater over the past several years, there is still potential to further increase reuse to alleviate water supply pressures. In 2021, Saudi Arabia used only around 26% of the wastewater that has been treated with tertiary treatment (Adaa, 2022), while the USA and Singapore used 100% and Dubai 90% of tertiary treated wastewater (MEWA, 2017). The city of Riyadh is reusing around 50% of treated wastewater (Ouda, 2015). Currently, Saudi Arabia treats 86% of its wastewater to tertiary levels and 100% of wastewater treatment is targeted by 2030, paving the way to further increase reuse of treated wastewater (Adaa, 2022).

"

In response to its limited natural water sources, **Saudi Arabia** was a pioneer in desalinating water and continues to have the world's highest desalination capacity.

"

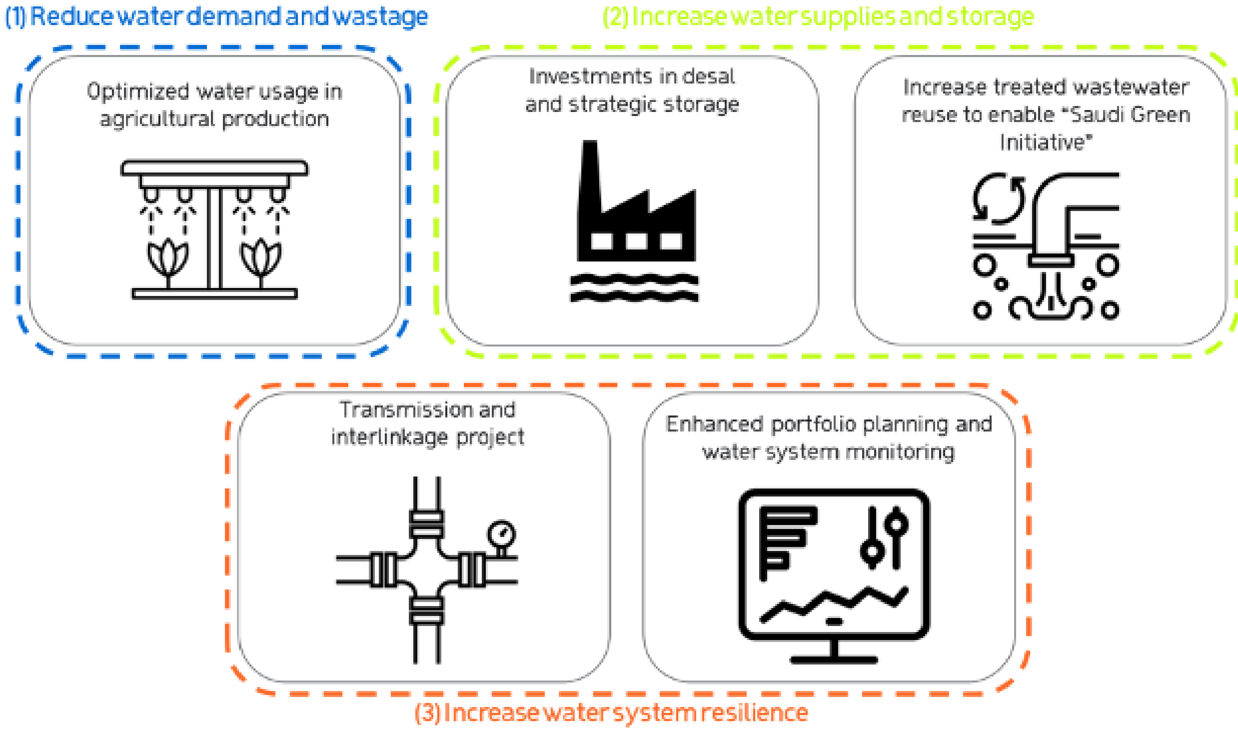
Today, around 75% of the municipal water supply comes from desalination (SWCC).[28] However, as desalination has higher financial, energy, and environmental costs than traditional water sources, such as renewable groundwater, further innovating desalination technology and finding the right water source mix is imporant for Saudi Arabia's water future.[29] Innovation around desalination is ongoing, and SWCC won the Guinness World Record for the lowest-energy-consuming desalination plant (2.271 kWh/m3) (Kaddoura, 2021).

To address the countries' water stress, there is potential to make water usage more efficient. In 2015, Saudi Arabia had an irrigation efficiency of 55% compared to 70% in best-in-class benchmarks—suggesting possible gains in further improving efficiency that can be realized (MEWA, 2017).[30] Further, as Saudi Arabia has one of the highest per capita water-consumption rates globally and around 40% of treated water is lost from leaking pipes, there is potential to reduce water demand (Liemberger and Wyatt, 2018).

4.2. Saudi Arabia's Plans and Actions to Increase Water Sector Resilience

To address Saudi Arabia's water challenges, the Kingdom is taking steps toward increasing water sector resilience across three key areas: (1) reduce water demand and wastage; (2) increase water supplies and storage; and (3) increase water system resilience (Figure 9).

[28] In 2015, desalination made up 10% of the total water supply mix (MEWA, 2017). Saudi Arabia has the world's highest desalination capacity.
[29] Environmental costs include disruption of the marine ecosystems through increased salinity and temperature increase caused by brine disposal and GHG emissions.
[30] No more recent data available. Given developments over the last few years, it can be expected to have increased.



4.2.1. Reduce Water Demand and Wastage

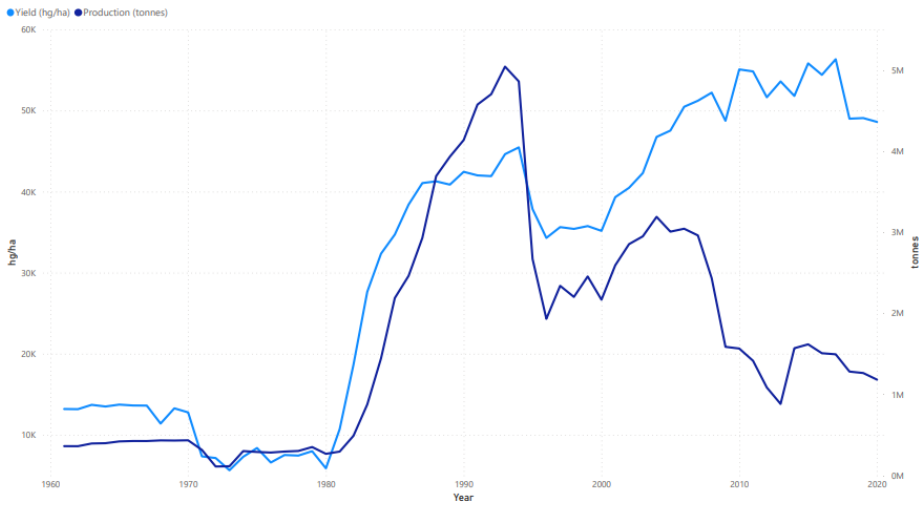
Optimize water usage in agricultural production by focusing on high-value, less water-intensive crops

In the past, Saudi Arabia's drive to achieve self-sufficiency in food production was backed by agricultural subsidies. In the 1990s, Saudi Arabia not only achieved self-sufficiency but was even the sixth largest exporter of wheat globally. Wheat, however, is a thirsty crop, and Saudi Arabia's farmers mostly relied on non-renewable groundwater. Once it became clear that the agricultural drive led to rapidly falling groundwater levels, it was decided to change the policy and phase out production of water-intensive crops—such as wheat and alfalfa—between 2008 and 2016 (Woertz, 2020).

Further, Vision 2030 targets increasing the proportion of renewable water consumption in the agricultural sector—compared to other sources that are predominantly non-renewable—from 9.49% in 2018 to 22.34% in 2030.

Figure 10 shows how the production of grains has decreased considerably following this policy shift, while the yield has increased—allowing the country to produce more crop per drop.

Figure 10: Grain production and yield in Saudi Arabia (1961–2020)



Source: FAOSTAT (2022) [31]

To ensure food security without exploiting scarce water sources, Saudi Arabia has started to import strategic food commodities that are water-intensive [32] (Investments—SALIC, n.d.).

In 2009, the King Abdullah Initiative for Overseas Agricultural Investment was launched with a USD 22.1 billion budget to ensure domestic supply of wheat and other key staples such as rice, feed barley, corn, soybean meal, seed oil, and sugar. As part of this initiative, the Saudi Agricultural and Livestock Investment Company (SALIC) was created in 2012 with the objective to make investments—and establish subsidiary companies—nationally and internationally in countries with comparative advantages to achieve food security [33] (SALIC, n.d.).

Strategic investments include farmland as well as investments to improve supply, storage, and processing of agricultural goods to ensure a steady food supply. In 2021, SALIC's revenues amounted to US $23 billion, and it handled more than 40 million tons of products. One of SALIC's most recent investments includes the acquisition of 35.43% of Olam Agri Holdings—a leading agricultural trading business globally that is focused on high-growth emerging markets—for US $1.2 billion ("SALIC Acquires 35.43% of the Global Food and Agri-Business Company Olam Agri," n.d.).

[31] "Grain" is listed as "cereal" in FAOSTAT
[32] These 12 food commodities include wheat, barley, rice, corn, soybean, fodder, red meat, poultry, aquaculture, edible oil, sugar, and dairy products.
[33] SALIC is owned by the Public Investment Fund (PIF).

This initiative also incentivizes Saudi companies to invest in farming in around 35 foreign countries across Africa, Eastern Europe, and East Asia ("Focus on Sustainability: ShiftingProduction to Less-Water-Intensive and Higher-Value Crops , " n.d.). It is supported by the government-backed Agricultural Development Fund (ADF), which provides loans required for agricultural projects in Saudi Arabia and abroad.

As a result of the initiative, imports of strategic food commodities increased drastically between 2000 and 2021. Wheat imports, for example, increased nearly eightfold (750%) (FAO, 2022).

In 2018, SALIC also acquired Ukrainian farming company Mriya, gaining access to one of the world's richest farming lands and top exporters of grain.

This provided Saudi Arabia with an additional 200,000 hectares (494,000 acres) of leased Ukrainian farming land and associated machinery and infrastructure (Olearchyk and Foy, 2018).

4.2.2. Increase Water Supplies

Increase investments in desalination plants and strategic storage

SWCC is investing in increasing its capacity to desalinate, transmit, and store water to meet increasing demand and further enhance water supply security (Figure 12).

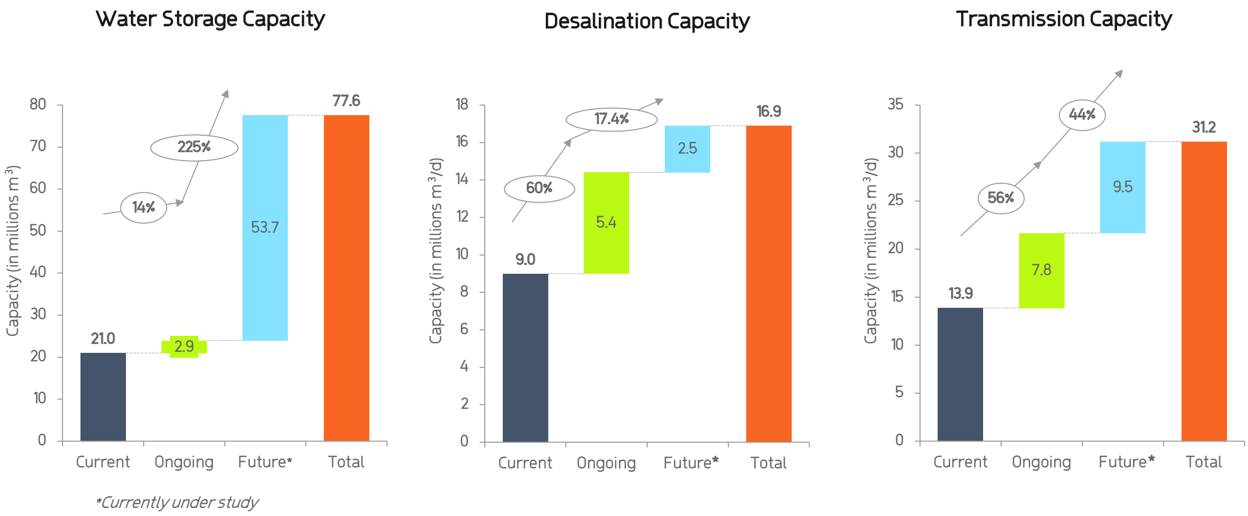
Today, Saudi Arabia can store 21 million m3, which is equivalent to 2.2 days of current
municipal water demand. Projects are ongoing to expand storage capacity by 14%, and the expansion of a further 225% is planned to reach seven days of strategic storage by 2030

On desalination, around 9 million m3 per day can be produced today where as the market share of SWCC is equal 66% of the total current production capacity, and projects to increase desalination capacity by 60% are under construction. Moreover, Saudi Arabia plans to increase desalination capacity by an additional 17.4% by 2030.

Given the vast geography of Saudi Arabia, transmission of desalinated water to its demand centers is of key importance. Today around 13.9 million m3 per day can be transmitted across the country.

This capacity is currently being increased by 56%, and a further 44% is planned by 2030.

Figure 12: Saudi Arabia's ongoing and future projects to increase water supply



Source: SWCC (2022)
Note: Transmission includes water sources from the private desalination sector as well as from groundwater; capacities include public and private sector projects; "future" refers to years 2027-2030.The market share of SWCC is equal 66% of the total current production capacity.

Moreover, SWCC has been developing innovative ways of increasing water supply and upgrading capabilities and offering solutions that qualified SWCC to lead the world in the field of power consumption in the desalination sector for instance, the construction of portable production unit which has the high efficiency and optimized power consumption that contribute to the reduction of cost of energy per cubic meter. Also, the production units in the portable ships which contribute to the diversity of ways of water supply which increase the water security and the flexibility to response to water demand.

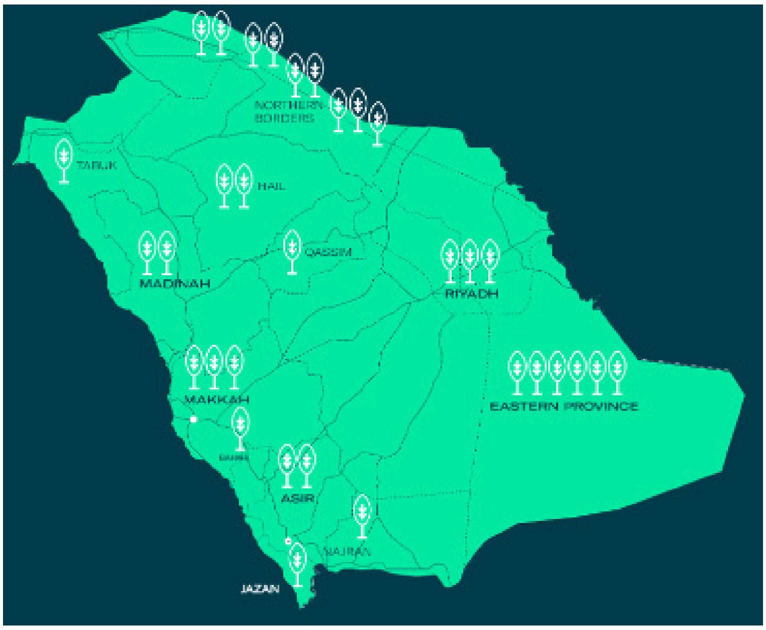
Increase treated wastewater reuse to enable the Saudi Green Initiative

The Saudi Green Initiative (SGI) shall pave the way for Saudi Arabia to become more sustainable and advance the fight against climate change. As part of the SGI, around 60 initiatives were launched to achieve three key targets: (1) reduce carbon emissions by 278 mtpa by 2030; (2) plant 10 billion trees across Saudi Arabia; and (3) protect more than 30% of total marine areas.

To achieve the ambitious target of planting 10 billion trees (Figure 11), considering Saudi Arabia's water-stressed situation, the plan is to increase treated wastewater and reuse it for irrigation. Vision 2030 targets achieving 100% treated wastewater, of which 70% will be reused. In 2021, 86% of wastewater is being treated, and 26.12% is being reused (Adaa, 2022).

> "Vision 2030 targets achieving **100%** treated wastewater, of which **70%** will be reused"

Figure 11: Areas across Saudi Arabia where 10 billion trees will be planted



Source: Saudi Green Initiative, n.d.

4.2.3. Increase Water System Resilience

Interlinkage of production and transmission projects to increase municipal water resilience

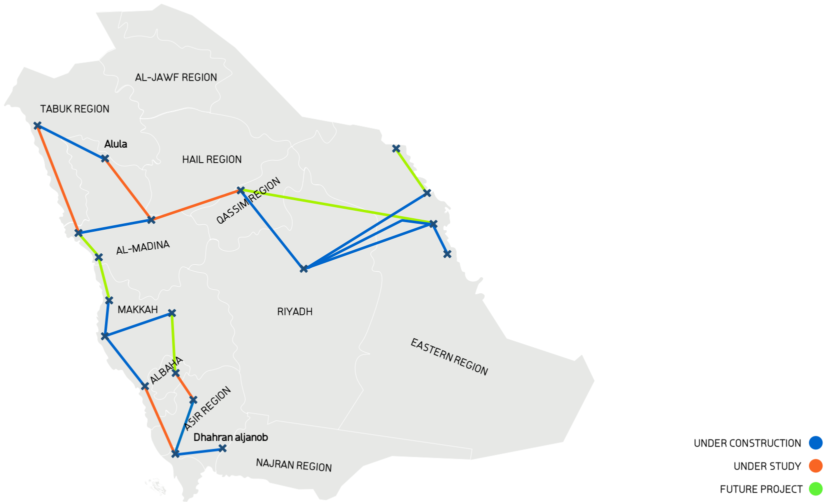
Around 80% of municipal water is supplied by desalination in Saudi Arabia, and given the high capital expenditure of desalination plants, usually a limited number of plants are responsible for the supply of a given city.[34] The capital of Riyadh, for example, located around 450 km from the Arabian Gulf, is supplied by desalination plants in two locations (Ras-Al Khair and Jubail). Makkah's water supply depends on two desalination plants, namely Rabigh (~600 km away) and Shoaiba (~200 km away). Thus, municipal water supply security is heavily dependent on the functioning of the desalination plant and its transmission lines.

Saudi Arabia is now exploring the option to interconnect water supply sources to allow for more flexibility in case one desalination plant or transmission line fails. The interconnection of systems shall also strengthen operational flexibility by making optimal use of production quantities, so that any surplus can be distributed across the system and/or stored in strategic storage points.

The interlinkages explored include "vertical interconnection," i.e., interconnecting supply sources across the East and West Coasts, and "horizontal interconnection," i.e., interconnecting supply sources between the East and West Coasts.

[34] Following MEWA's direction, the water supply for each city shall be based on at least two water sources.

Figure 13: Overview of ongoing, planned, and studied interconnection projects in Saudi Arabia



Source: **SWCC** (2022)

Figure 13 shows which interconnections are currently under construction (blue), planned (green), or being studied (orange).

The vertical interconnections include, for example, connecting Riyadh, Al Qassim, and Jubail along the East Coast, and Rabigh, Jeddah, Ras Mhasin, and Makkah along the West Coast. It is currently under study whether the systems across the East and West Coast shall be connected horizontally between Madinah and Buraydah.

Improve water system monitoring for planning and asset performance optimization

Given that the Kingdom's water supply is highly dependent on a few desalination plants and vast transmission lines, a real-time understanding of the performance of the water system is essential to ensure water security. Recognizing that you "can't manage what you don't measure," SWCC is currently implementing a smart metering project that shall monitor the water flows at the interception points across the value chain, i.e., between production, transmission, storage, and distribution. Once completed, the smart metering will help detect irregularities, such as large leakages, in real time and provide valuable information that can be used to optimize asset performance. In addition, SWCC is considering developing a smart grid that links its existing control centers for production and transmission and other systems into one platform. This platform shall also include a smart component that offers recommendations and planning support. Once implemented, the systems will enable improved decision making and optimize operations in the short-term as well as long-term planning. This improved water system monitoring will lead to a better real time understanding of the Kingdom's vast water infrastructure, improve production forecasting and system planning to increase overall water system resilience, and reduce costs of production, operation, and maintenance.

5. Conclusions

Countries across the world are facing water stress—and with economic and population growth, water stress is expected to increase even more in the future. Even today, water stress has a real effect on people's livelihoods, the economy and GDP growth. The impact of water stress is further aggravated by water pollution, making scarce resources unfit for usage, insufficient and infrastructure and non-revenue water.

However, countries can take actions to address water stress and ensure their long-term water security. Actions include measures to either reduce water demand or to increase water supply. These are anchored in national, river basin, or utility planning documents and driven by the legal and regulatory environment of the country.

The Kingdom of Saudi Arabia—one of the most water-stressed countries in the world—is taking a range of measures to ensure their water security as a foundation to achieve the socioeconomic transformation they target as part of Vision 2030. The Kingdom is (1) reducing water demand by optimizing water usage in agricultural production, (2) increasing water supplies by increasing desalination and strategic storage capacity as well as increasing usage of treated wastewater, and (3) increasing water system resilience by increasing transmission and interlinkage projects as well as by enhancing portfolio planning and water system monitoring.

Ensuring water security is a continuous effort, and mechanisms need to be in place to allow for monitoring water systems and assessing any potential threats to water security.

With increasing water stress across the world, water will soon emerge as a key limiting factor to socioeconomic development, giving countries that have invested in creating a water-resilient system a competitive advantage.

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المؤسسة العامة لتحلية المياه المالحة

Saline Water Conversion Corporation (SWCC)