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

Decarbonization of the water sector

swcc_ksa

نسابق المستقبل.. حيث الحياة

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1. Drive toward decarbonization globally

In 2016, 193 parties signed the Paris Agreement and pledged to reduce greenhouse gas (GHG) emissions to mitigate climate change and its impacts (UNTC, 2022). GHGs mainly result from the burning of fossil fuels, as well as other activities such as agriculture and farming. They prevent solar energy from radiating back into space, which in turn heats up the atmosphere. As a result, there can be more frequent and intense droughts, storms, heatwaves, rising sea levels, melting glaciers, and warming oceans, all of which impact our ecosystem.

Currently, five countries—China, the US, India, Russia, and Japan—are responsible for 55% of global GHG emissions. Around 66% are emitted by the top 11 countries, including Saudi Arabia (Figure 1).

To mitigate further climate change impacts, most of the top emitting countries have committed to becoming carbon-neutral by either 2050 or 2060. The remaining countries have committed to reduce GHG emissions in varying degrees (Figure 1).

GHG emissions globally are caused by the following:

44% electricity and heat generation

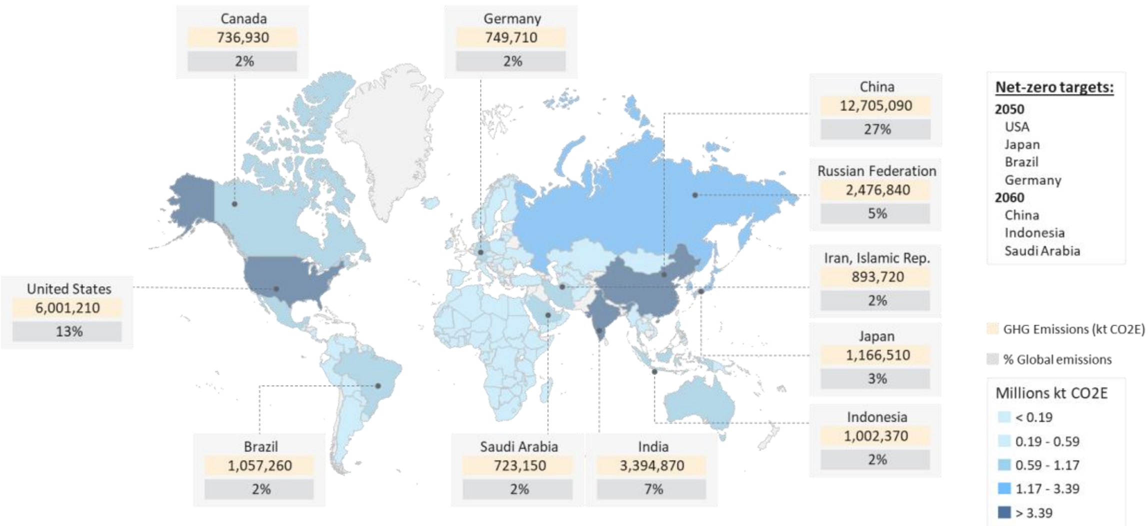
26% transportation sector

19% industrial sector

9% building sector

2% other sector

Figure 1: Top 11 GHG-emitting countries worldwide (2020)



Source: World Bank, 2020; NDC, 2021

2. The challenge: GHG emissions in the water sector

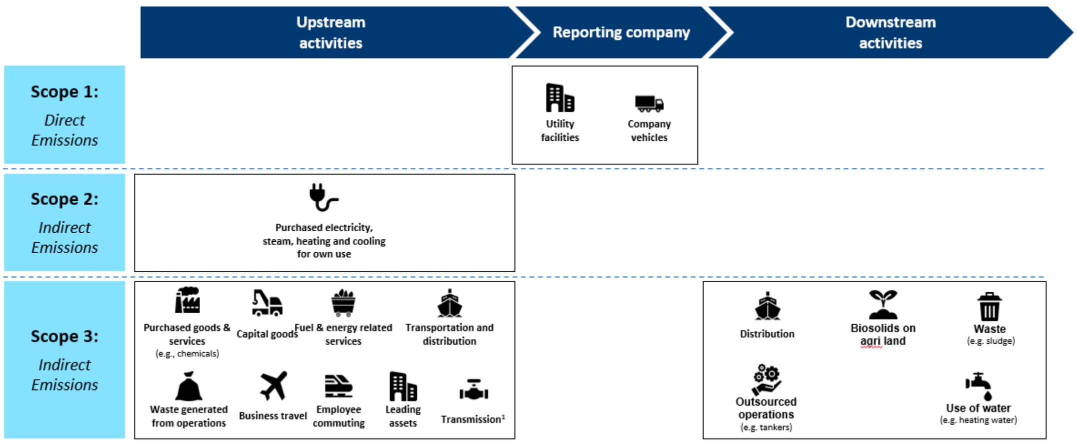
Globally, water and wastewater utilities are responsible for around 2% of GHG emissions (Water UK, n.d.), comparable to the GHGs emitted by the shipping or air transportation industries. However, these estimates can vary significantly, with some countries reporting GHG emissions between 3% and 7% of total emissions (Trommsdorff, et al., 2015).

2.1. Understanding GHG emissions in the water sector

To understand GHG emissions from a particular water or wastewater utility or activity along the value chain, three scopes need to be considered:

- Scope 1 emissions: GHG emissions over which the water or wastewater utility has direct control. These sources are controlled or owned by the utility (e.g., released gases from wastewater treatment and emissions associated with fuel combustion in boilers and vehicles).
- Scope 2 emissions: GHG emissions over which the water or wastewater utility has indirect control and that occur specifically as a result of purchased electricity, steam, heat, or cooling. As the utility uses this energy, resultant GHG emissions need to be accounted for by the utility, even though they physically occur at the facility generating energy.
- Scope 3 emissions: GHG emissions that occur indirectly as a result of the water or wastewater utility's upstream and downstream activities and that are not owned or controlled by the utility. There are 15 categories of scope 3 emissions across all sectors, with only selected categories of relevance for the water sector, e.g., chemicals purchased for operations, construction of assets, and business travel (see Figure 2) (CDP, 2022).[1]

Figure 2: Accounting for GHG emissions by scope



Source: Team analysis, Anglian Water Services (2022)

[1] The categories include: Purchase of goods and services; capital goods; fuel and energy activities not covered under scope 1 and 2; upstream transportation and distribution; waste generated in operations; business travel; employee commuting; upstream leased assets; downstream transportation or distribution; processing of sold products; end-of-life treatment of sold products; downstream leased assets; franchises and investments.

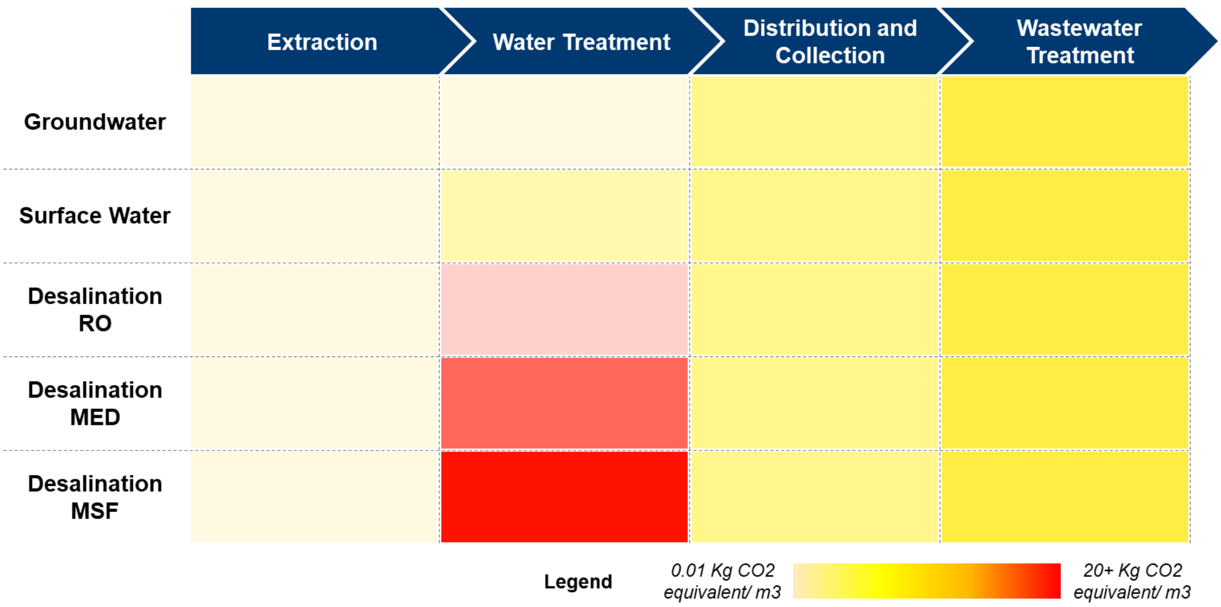
Depending on the country, utilities are only required to report their scope 1 and 2 emissions, as scope 3 emissions are more difficult to assess and lack, as of yet, a harmonized assessment methodology. However, as the impact of scope 3 emissions can be significant, increasing attention is being paid on expanding reporting requirements to cover them.[2] Today, more ambitious utilities report selected categories of scope 3 emissions, such as business travel, employee community, and purchased goods and services.

2.2. Uncovering GHG emission hotspots in the water value chain

The actual GHG emissions across the water value chain significantly depend on the specific location, technology, and energy input. However, it is possible to identify the most common GHG emission hotspots across the water value chain. The sections below further detail the key GHG emission sources for each step.

Figure 3 shows that desalination and wastewater treatment have by far the greatest emissions in the water value chain. The sections below further detail the key GHG emission sources for each step.

Figure 3: GHG hotspots across the water value chain, per water source



Source: Team analysis, Water UK (n.d.), Biswas and Yek (2016), Gov UK (2022)

[2] The UK regulator is phasing in mandatory standardized reporting of scope 3 emissions. However, until the assessment of scope 3 emissions is easier and a standardized methodology exists for all categories, only business travel, outsourced activities, and purchased electricity and heat (not covered in scope 2) will be required.

Water extraction

Energy is required to pump the water from the ground or from surface water bodies (lakes, rivers, dams, seawater). The amount of energy required, and thus GHG emissions, depends on the depth of the groundwater well, as well as on the distance required to pump surface water to the water treatment plant. The deeper the well and the greater the distance, the more energy is required.

Water treatment

GHG emissions from water treatment depend highly on the water source. Desalination has by far the highest GHG emissions. However, the magnitude of GHG emissions varies significantly—depending on the desalination technology chosen. The highest GHG emissions are caused by multi-stage flash desalination (MSF), with slightly lower GHG emissions for multi-effect desalination (MED). The switch from MED and MSF to reverse osmosis (RO) has a significant impact on GHG reduction, with RO emitting less than 8% and 10% of MED and MSF, respectively (Biswas and Yek, 2016). However, even if RO is chosen, it remains the highest GHG emitter in the water value chain due to its high energy consumption.[3]

The GHG emissions for treating ground and surface water depend highly on the water quality of the sources. Direct GHG emissions are caused by the water treatment process itself, i.e., through water treatment with ozone or activated carbon and by the disposal of resultant sludge in landfills. Indirect emissions include energy requirements and use of chemicals (Johnston and Karanfil, 2013). Generally, it can be said that groundwater requires less treatment—and thus less energy—than surface water. However, this is highly location-specific.

Water distribution and wastewater collection

The actual GHG emissions for distribution and collection depend greatly on the distance and altitude changes of the systems, as these factors impact the energy required to pump the water. Decentralized systems with short water supply and wastewater networks located in areas where gravity can be used to pump the water through the systems require the least energy. Systems that have long pipelines and may even require long transmission lines, e.g., from the desalination plant to demand centers or water transfers from one location to another, require far more energy to pump the water, especially if water needs to be pumped against gravity. This is the case in Saudi Arabia, where transmission lines cover hundreds of kilometers, pumping desalinated water from the Red Sea and Arabian Sea to the center and mountainous regions in the Kingdom. In addition, globally, the overall constitution of the pipes has an impact on GHG emissions, with leakages resulting in water wastage and thus requiring greater water production and pumping to meet water demand.

[3] GHG emissions in scope 3 are minimal compared to operational energy requirements.

Wastewater treatment

Wastewater treatment is responsible for around 70% more GHG emissions than groundwater and surface water treatment.[4] GHGs are emitted during the mechanical, biological, and chemical processes, as well as during the sludge treatment and disposal of centralized wastewater treatment plants (Nature, 2022). Further, wastewater treatment results in indirect GHG emissions due to the high energy usage in its processes, such as aeration and chemical inputs (Nature, 2022).

In addition, GHG emissions from the utility's vehicle fleet, administrative buildings, etc. need to be considered to get a full picture of overall emissions.

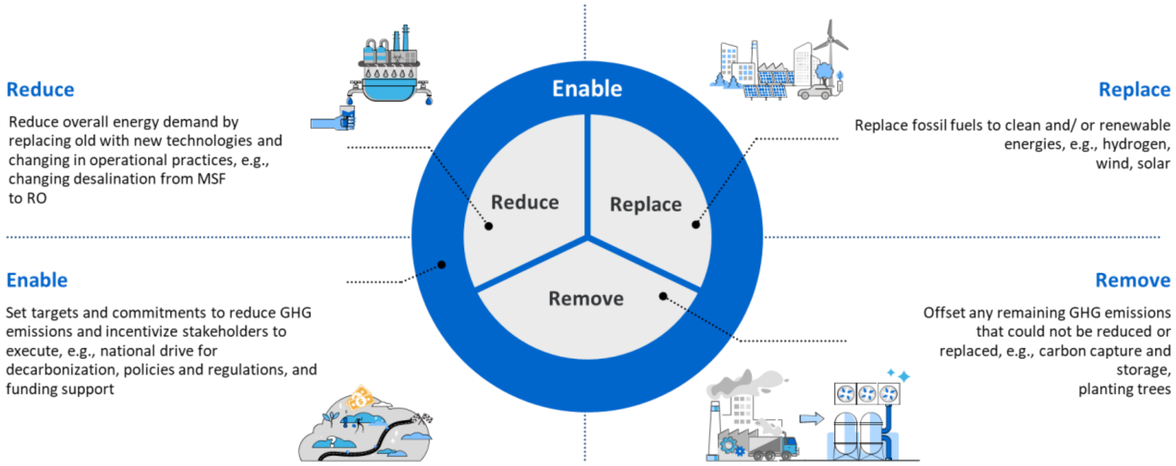
[4] Calculations based on UK Environment Agency Report: Greenhouse gas emissions of water supply and demand management options.

3. Water utilities' race toward net-zero

Considering recent trends to combat climate change, water utility companies worldwide have set ambitious decarbonization targets. Utility companies in 22 countries have specified dates to achieve net-zero carbon emissions, or climate neutrality, targets,[5] ranging from the years 2030 to 2050. In addition to utilities, cities are increasingly making net-zero commitments, e.g., by joining the UNFCCC Race to Net Zero campaign. To achieve the cities' net-zero targets, water and wastewater utilities will be required to reduce their emissions. Thus, it is likely that the number of utilities focusing on decarbonizing the water sector will increase significantly over the next several years.

As utility companies globally mobilize toward net-zero, it becomes essential to understand the key enabling factors required. While the identification of practical and cost-effective solutions for decarbonizing is key, an enabling environment is essential to allow these solutions to be implemented. The solutions typically fall under one of three main categories: (1) reduce energy demand, (2) replace fossil fuels with cleaner alternatives, and (3) remove carbon from the atmosphere by capturing emissions or offsetting carbon footprints. Each of these categories entails both longstanding, well-established solutions as well as emerging solutions that are still nascent and/or in their pilot phases. In addition, to create a conducive enabling environment, a national drive for decarbonization policies and regulations as well as funding support are required (see Figure 4).

Figure 4: Overview of solutions to move toward net-zero in the water sector



Source: Team analysis

[5] Net-zero means no carbon emissions; carbon- or climate-neutral means that carbon emissions are balanced by offsetting measures.

3.1. Reduce: Solutions that focus on reducing energy requirements

3.1.1. Energy-efficient desalination

Migration from MSF to RO

One of the more common solutions adopted globally, and particularly in the Middle East, is the migration from thermal desalination plants to RO. MSF is an energy-intensive procedure that involves pumping seawater from the source and flashing it through a series of heat exchangers at different pressures until it evaporates. The vapor is then picked up via condensate collectors to yield freshwater. RO, on the other hand, involves using energy to force water through a water-permeable membrane against osmotic pressure to yield freshwater, with salt left behind. MSF typically requires ~10–38 kWh per cubic meter of water produced, while RO requires ~2.5–7 kWh for the same production levels (DeFelice and MacDonald Gibson, 2013). Migration to RO desalination plants has recently become more prevalent, with countries in the GCC, particularly Saudi Arabia, driving the adoption.

3.1.2. Energy-efficient wastewater treatment

Energy recovery from wastewater treatment

An emerging technological measure to recover additional energy from wastewater treatment plants (WWTP) is the co-digestion of organic matter present in sludge. Sludge, a byproduct of WWT, is collected in an aerobic digester, which generates biogas. This is converted to electricity via fuel cell generators at a high temperature, which can then be channeled for additional WWT. This emerging trend is being adopted at a wide scale.

Algal wastewater treatment

The treatment of wastewater using algae has been a longstanding solution for decarbonization as it simultaneously treats water in a cleaner fashion while providing biomass to generate power. The process works by passing effluent through an algae-infused environment. This produces oxygen that aerobic bacteria consume to break down contaminants in water. Moreover, the algae growth yields a biomass that can be processed further to generate energy.[6]

3.1.3. Smart network management

Intelligent wastewater pumping stations

Recent technologies have also focused on reducing the energy-cost burden on pumping stations related to clog removal, which is the second-highest cost bucket in pumping stations

[6] Applied consistently, for example, in Spain, Ireland, and France.

(after power costs). Utilities in countries such as Sweden and the UK have doubled down on installing smart pumping stations that ensure efficiencies and minimize operation costs. Optimized pumping stations are designed strategically, placing pump (and pump pedestals) in a way that increases turbulence and re-suspends solids and debris. This process causes a higher percentage of solids to deviate from beneath the pumps, which improves energy efficiency (approximately 70% reduction in energy requirement) and reduces emergency clog-removal costs.

<u>AI-based wastewater management</u>

Technology has been leveraged to improve system efficiency and implement preventative measures on the wastewater management front. Utility companies are investing in sensor installations that use data analytics, AI, and machine learning to identify system faults before they occur, as opposed to the traditional reactive model. The data is fed to a central cloud server and detects trends and deviations in system performance (e.g., water levels, pump performance, hydraulic performance, operational performance) to mitigate incoming risks, ultimately preventing leakages and uplifting network efficiency. This solution has recently become more prevalent.[7]

3.1.4. Decentralized and small-scale systems

<u>Atmospheric water generation</u>

Atmospheric water generators (AWG) are devices that extract water vapor from humid ambient air and filter it, removing particles and bacteria, to produce potable water. They can be powered by solar energy, making them an interesting solution for remote areas, as they can save GHG emissions that would come from the construction of a water distribution system and the energy required to pump water to its destination. Commercial AWGs can generate between 1 and 10 m3/day, making them suitable for supplying potable water to villages, industrial sites, and other small-demand centers.

3.2. Replace: Solutions that focus on replacing fossil fuels with cleaner energy

This section focuses on selected solutions that replace fossil fuels with cleaner energies, i.e., natural gas and/or renewable energies.

[7] Adopted, for example, by United Utilities in the UK, which installed 19,000 of these sensors in their network in 2021.

Migration from liquid fuel to natural gas as an energy source

Utility companies are changing their energy mix by minimizing their dependency on liquid fuels and migrating toward natural gas, which leads to lower GHG emissions. This power generation from natural gas is prevalent in two forms: either to generate power on-site or to power the electrical grid that a desalination plant is connected to. In both scenarios, utilizing natural gas to generate power emits around 40% less GHG than its fuel alternative, holding all other variables constant (Clean Energy Compression, 2022). While this solution does not eliminate GHG emissions fully, nor does it leverage renewable energy, it has been adopted as an important step toward decarbonization, specifically for desalination in Saudi Arabia.

Solar-powered operations

One of the most common ways of shifting toward renewable energy in the water sector is the adoption of solar power. Solar power collection can either be conducted by the electricity-generating entity or by utility companies themselves. On-site solar collection systems are used to convert solar radiation to electricity via photovoltaic cells that can then be used for the utilities' electricity demand, e.g., for RO desalination. Utility companies worldwide[8] are scaling up on solar-powered desalination, installing solar panels in their facilities and reservoirs to both reduce their electricity costs and meet their sustainability targets. However, solar can only be used for a limited number of hours per day unless costly storage is added and thus needs to be supplemented with other energy sources.[9]

Wind-powered operations

Utility companies have begun using energy from wind farms to power their water facilities. Wind power, depending on wind availability, can be operated in one of three forms: island mode with no on-site power generation, island mode with on-site power generated, or in grid-parallel mode. In the first two forms, the utility's wind farm is not connected to the electrical grid and can operate with zero energy requirements or by locally generated power in case of minimal wind availability. The last form, which is typically used in areas with inconsistent levels of wind, involves connecting the utility to the electrical grid to account for the delta in energy requirements, whenever applicable.[10]

[8] Adopted in, for example, Saudi Arabia, UAE, Singapore, Australia, and New Zealand.

[9] In Saudi Arabia, for example, solar power can power operations around six or seven hours per day; adding storage increases costs beyond acceptable levels. (Source: SWCC)

[10] Adopted in, for example, the UK, the US, and Australia.

Transitioning to electric vehicles

Utility companies are also looking beyond their immediate operations. One of the most common areas that utilities have focused their decarbonizations efforts on is vehicle fleets. Some have committed to replacing their partial or entire fuel-based fleet of vehicles with electric vehicles.[11]

3.3. Remove: Solutions that capture emissions or offset carbon footprint

This section focuses on selected solutions that can be implemented to remove any remaining GHG emissions that could not be reduced or replaced with cleaner energy solutions.

Carbon capture and storage

Almost all the CO2 that is formed during power generation and industrial processes, such as desalination with MSF technology, can be captured and stored to avoid its release in the atmosphere. The captured CO2 can either be used to produce manufactured goods and in industrial processes, such as enhanced oil recovery for drilling,[12] or stored underground. If the CO2 needs to be transported to its usage or storage site, it must be compressed and chilled to make it liquid. It can then be transported via pipelines, trains, ships, or other vehicles. If it is stored, it can be injected into deep geological formations, such as former oil and gas reservoirs (Gonzales, Krupnick, and Dunlap, 2022).

Tree-planting initiatives

While bringing emissions down to zero is not always achievable, many companies have committed to launching tree-planting campaigns to offset unaddressed GHG emissions. This practice has been adopted on a global scale, and Saudi Arabia is planning to plant 10 billion trees across the country, predominantly irrigated by treated wastewater.[13]

[11] Adopted by utilities in Saudi Arabia, Australia, New Zealand, and Singapore.

[12] This method uses CO2 and water to drive oil up the well, which improves oil recovery and sequesters CO2 underground.

[13] Adopted also in the UK, which targets planting 11 million trees by 2030.

3.4. Enable: Creating the right enabling environment for decarbonization

3.4.1. National drive for decarbonization

Key drivers for any utility-level decarbonization efforts are the climate change mitigation commitments made by the national government and the strategy it decides to follow to reduce GHG emissions nationally.

Long-term national decarbonization strategy

Many countries that signed on to the Paris agreement have developed a long-term national decarbonization strategy that translates their commitments into possible pathways and related initiatives. These pathways, which typically focus on initiatives targeting different key sectors and their effects on various GHGs over time, can be industry-focused, building-focused, or transport-focused.[14]

Water sector decarbonization roadmap

While the long-term strategy provides the general direction, it falls short on sharing concrete actions per sector. To facilitate and accelerate the decarbonization process, a national water sector–specific strategy—or roadmap—can highlight GHG hotspots in the country and show actions utilities can take. This roadmap outlines the most practical and cost-effective solutions for the countries' water and wastewater sector. While each utility needs to draft its own decarbonization strategy, significant time and resources can be saved by outlining what solutions are possible and their related impact on GHG reduction and cost implication.[15]

3.4.2. Policies and regulation

Climate change policies, such as carbon taxes or cap and trade, are key tools to reduce GHG emissions. Carbon taxes consist of varying tax rates across fuels depending on their carbon intensity (e.g., USD/MT of carbon) to capture the external costs to society and the environment caused by GHG emissions. As fuels with higher GHG emissions are taxed more, market mechanisms are used to move toward clean energy.

Cap and trade sets a limit on the total amount of GHGs that can be emitted each year by entities that are part of the system. Those that can easily reduce their emissions and use less than their allowance

[14] See, for example, the long-term strategy of the USA in "Pathways to Net-Zero Greenhouse Gas Emissions by 2050" (the United States Department of State and the United States Executive Office of the President, 2021).

[15] See the Water UK's Net Zero 2030 Routemap (Gov UK, 2020).

can trade their excess emission credits, thus allowing for cost-effective abatement. The cap reduces over time so that overall GHG emissions fall.

In addition to policies, regulations can be passed to drive decarbonization efforts in the water sector. For example, the regulator can require water utilities to report their GHG emissions annually, following regulatory accounting guidelines, and compel utilities to develop and implement net-zero roadmaps.[16]

3.4.3. Funding support

While some measures to reduce GHG emissions can even save costs, utilities may be required to go beyond to achieve GHG-reduction targets. As GHG-reduction measures are not required for the utilities' main business operations—unless mandated by regulations—utilities sometimes face challenges to implement them. Government funding may be required to incentivize and support utilities as they implement GHG-reduction measures, which may entail high costs. This funding can take many forms and can be provided to advance research development and innovation (RDI) in one specific topic, such as a net-zero hydrogen fund,[17] or to fund pilots for the best innovation across broad topics around decarbonization identified in a competition, such as a carbon-zero challenge.[18] Alternatively, the government can fund utilities' net-zero investments that go beyond targets mandated by regulation.[19] Subsidies can also support net-zero investments, for example, providing subsidies for installing solar panels and wind farms.[20]

[16] Applied, for example, in the UK (Ofwat, 2022).

[17] Applied, for example, in the UK.

[18] Applied, for example, by Singapore's water agency Public Utilities Company (PUB).

[19] Currently considered by UK's water regulator Ofwat to be implemented in the Price Review for 2024.

[20] Applied in Germany, the US, Spain, Italy, China, Japan, the UK, France, and India, among others.

4. SWCC's decarbonization achievements and ambitions

The Saline Water Conversion Corporation (SWCC) is actively supporting the Kingdom's ambitious goals to reduce GHG emissions to zero by 2060 and has developed a program contributing to achieve net-zero carbon emissions. Desalination of seawater provides about 70% of potable (domestic) water supply in the Kingdom—and is one of the key six target sectors of the Kingdom to reduce GHG emissions.[21]

SWCC—responsible for desalination—aims to play an effective role in achieving the Kingdom's climate change commitments and ambitions within Vision 2030. SWCC has developed a program to significantly reduce carbon emissions by 2030.[22]

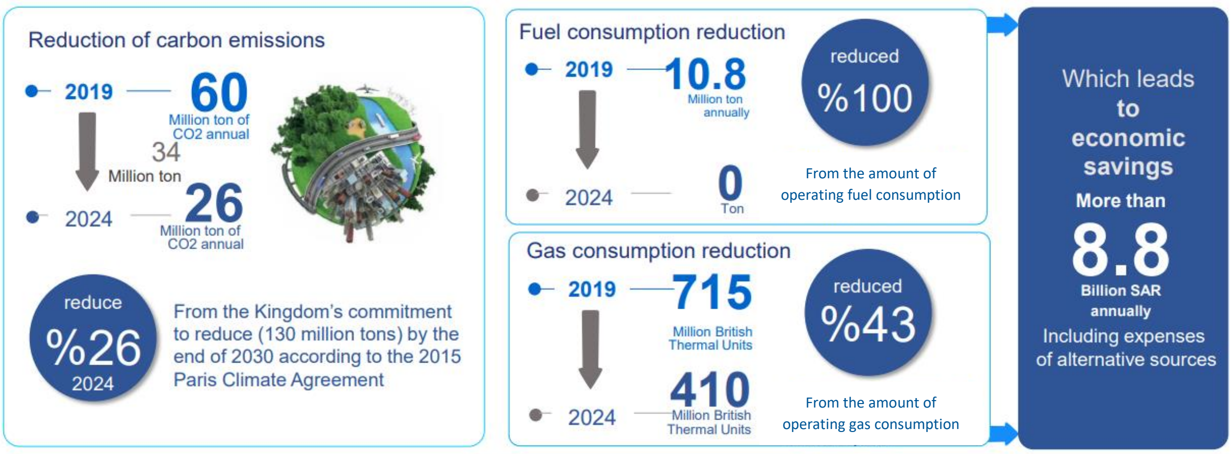
SWCC has studied the performance of its desalination production systems in-depth to understand current and future GHG emissions and its optimization potential. A series of win-win initiatives have been identified that improve energy efficiency and reduce GHG emissions while also reducing production costs to ensure water security for the Kingdom.

SWCC's ambitious goal to minimize carbon emissions

SWCC is the global leader in desalination and wants to go beyond with increasing energy efficiency, reducing costs, and increasing the sustainability of its operations.

SWCC has estimated that the baseline of total emissions from the production system amounts to 60 MT CO2e annually. By 2024, around 56% of emissions will be reduced, while the remaining 44% is planned to be managed by 2030.

Figure 5:—SWCC's GHG emissions reduced by year (MT CO2 equivalent/year)



Source: SWCC

[21] The targeted sectors to reduce GHG emissions in KSA include (1) oil and gas industries; (2) petroleum refineries; (3) petrochemical industries; (4) power generation and seawater desalination; (5) heavy industries, such as cement factories; and (6) methane from landfills. (Source: SWCC)

[22] SWCC focuses on scope 1 and 2 emissions.

4.1. SWCC's success stories in moving toward net-zero desalination

Transitioning to cleaner desalination technologies

SWCC is gradually replacing conventional, energy-intensive MSF and MED technologies with lower-energy-consuming RO technology. Further, the plants will be supplied with electricity from sources that reach 43% efficiency for the combined cycle power systems, and they have plans for capturing and reusing energy. This switch reduces the energy consumption per cubic meter of potable water generated from 15 kWh/m3 to just 3 kWh/m3—an 80% reduction,

SWCC is making swift progress in the replacement. To date, eight of the 13 thermal desalination plants—which together produce 94% of the water from thermal desalination plants—are either already replaced with RO or currently under construction and scheduled to be completed, at the latest, by 2024. The largest plants include Jubail (1 million m3/day), Khobar Phase 2 (630K m3/day), and Shuqaiq Phase 1 (400K m3/day). In addition, there are plans to replace three further plants from MSF to RO[23] and replace an old RO plant with a more efficient one[24].

Beyond reducing GHG emissions, the shift from MSF to RO also results in significant capital and operational cost savings. The construction of RO plants requires one-third of the capital expenditure when compared to an MSF plant with the same capacity.[25] Similarly, the switch from MSF to RO resulted in significant fuel savings, saving 8.8 billon SAR in total across all plants when considering the period of the operational plant lifetime (SWCC, 2022).

SWCC wins Guinness World Record for world's lowest energy consumption for a water desalination plant

SWCC set the new global record for energy consumption required for desalination. The mobile desalination plant called ***ProfMaster*** produces 5Km3/day and is in Jubail city. By using an eco-friendly reverse osmosis (RO) technology, it significantly reduces its total power consumption – it only consumes 2.271 kWh per cubic meter of desalinated water.

Source: https://www.guinnessworldrecords.com/news/commercial/2021/3/worlds-lowest-energy-water-desalination-plant-built-in-saudi-desert-653013

[23] Shuaiba 2 will be replaced by SHO-6; Yanbu 2 will be replaced by Yanbu 3 extension; Khobar 3 will be replaced by Khobar RO 3.

[24] Jubail RO will be replaced by Jubail RO3.

[25] MSF Capex amounts to 6 billion SAR; RO capex (latest plant) amounts to 2 billion SAR (SWCC).

Shutting down an old MSF technology plant

In 2020, the MSF plant Yanbu 1 was shut down, as the required water capacity could be provided by surrounding plants, such as Yanbu 3, that have greater energy efficiency and lower GHG emissions. This change resulted in saving 2.05 MT CO2e/year.

Switching from liquid fuel to natural gas

SWCC has two remaining MSF desalination plants that require liquid fuel or natural gas for their operations. Natural gas has significantly lower GHG emissions than liquid fuel. The first MSF plant in Ras Al-Khair has been operating on natural gas since 2014 and thus will not be counted as part of the decarbonization effort. The second MSF plant, Yanbu 3, will be switched from liquid fuel to natural gas in 2023. As a result, it is expected to save around 50 billion SAR over 15 years, while only a 400 million SAR capex investment was required to change the systems. This is expected to reduce 4.59 MT CO2e/year.

Adding on-site solar power as an electricity source

SWCC included solar power for the Al Khafjy plant (90K m3/year capacity, 60K m3/year operation). Now a 10 MWPV system is used to power the desalination plant. This has resulted in the reduction of 12,400 T CO2/year.

Similarly, solar power will be included in the new Jubail RO plant (1.0 Mm3/day), which is estimated to be completed in 2024. A solar PV system is under construction and will supply power of 110 MW as a clean energy source. This will result in a reduction of 311,000 T CO2/year. The cost for the solar power amounts to 327 million SAR (~3 million SAR/MW).[26]

Prioritizing using water from RO plants over MSF plants where possible

In areas where new RO plants have been built to eventually replace MSF plants and there is currently an oversupply of water due to seasonal demand, operational guidance was given to prioritize the production from RO plants and supplement water from MSF plants as required. This is the case for the new plants in Shuaiba 4 and Shuqaiq 1. This operational optimization has resulted in savings of 2.36 MT CO2/year.

[26] Land costs are not included, as land was available; expansion of the electricity grid was not required since the RO plant was built in the location of the previous MSF plant, which generates electricity and thus is well-connected.

4.2. SWCC's future ambitions

After completing the ambitious actions to reduce GHG emissions in the desalination sector in KSA, around 26 MT CO2e remain. About 87% of the remaining GHG emissions come from the last two remaining MSF plants, Yanbu 3 and Ras Al-Khair. The other 13% of GHG emissions are connected to the electricity required for operations and are accounted for as grid emissions.

SWCC is considering the following solution to reduce and remove the remaining GHG emissions:

Capturing and storing carbon

The largest share of the rest of the GHG emissions come from the two remaining MSF plants. While it would be an easy solution to replace them with RO plants and thus significantly reduce emissions—and costs—these will be kept, considering the importance of a mixed water supply for the Kingdom's water security.

One option to significantly reduce the GHG emissions from MSF plants is to capture and then store their GHG emissions. Depending on the procedure chosen and technical specifications, this process can capture around 80% to 90% of GHG emissions.

Under the Circular Carbon Economy National Program and supervision of the Ministry of Energy, SWCC is currently exploring whether to install technologies that capture and store carbon. Preparations are underway to include these technologies in the Ras Al-Khair and Yanbu production systems. Once implemented, this measure has the potential to reduce between 16 and 19 MT CO2/year.

Increasing the share of renewable energies

Around 3.4 MT Co2/year are emitted due to electricity usage. These emissions can be significantly reduced by shifting to renewable energies—with onsite renewable energies and by greening the national energy mix.

Under the National Renewable Energy Program, SWCC seeks to include more renewable energy, such as solar power, into its future production projects. This switch not only reduces GHG emissions but also reduces the cost of production. Solar energy can also be used to produce steam for the remaining thermal production systems (MSF), which will not be replaced with RO, to further reduce GHG emissions.

SWCC's carbon-neutral proposal includes the expansion of solar power to cover between 50% and 62.5% of energy requirements in three RO plants:

- Shuaiba (~2.8 Mm3/day current capacity, all complex)
- Al Khobar (~1.3 Mm3/day current capacity, all complex)
- Shuqaiq (~450K Mm3/day current capacity, all complex)

In addition, the Kingdom is planning to increase the utilization of natural gas in its energy mix, displacing liquid fuel, which has a higher emission factor. By 2030, the Kingdom aims that up to 50% of its electricity generation will be met by clean energy, significantly lowering the carbon intensity of domestic energy generation and its related cost. This switch is expected to reduce 27% of the indirect GHG emissions from SWCC's facilities.

Sequestering carbon with afforestation

To remove any remaining emissions, SWCC seeks to sequester carbon by planting trees. Under the Green Saudi Initiative, SWCC aims to plant 5 million trees in its facilities and residential areas. The memorandum of understanding between the Ministry of Environment, Water, and Agriculture and SWCC has been signed. This will result in a reduction of approximately 120,000 T CO2/ year.

Further, SWCC is exploring the potential of generating green hydrogen. The desalination process can be used to treat the water to the required standards, while solar power can be used as a green energy source.

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