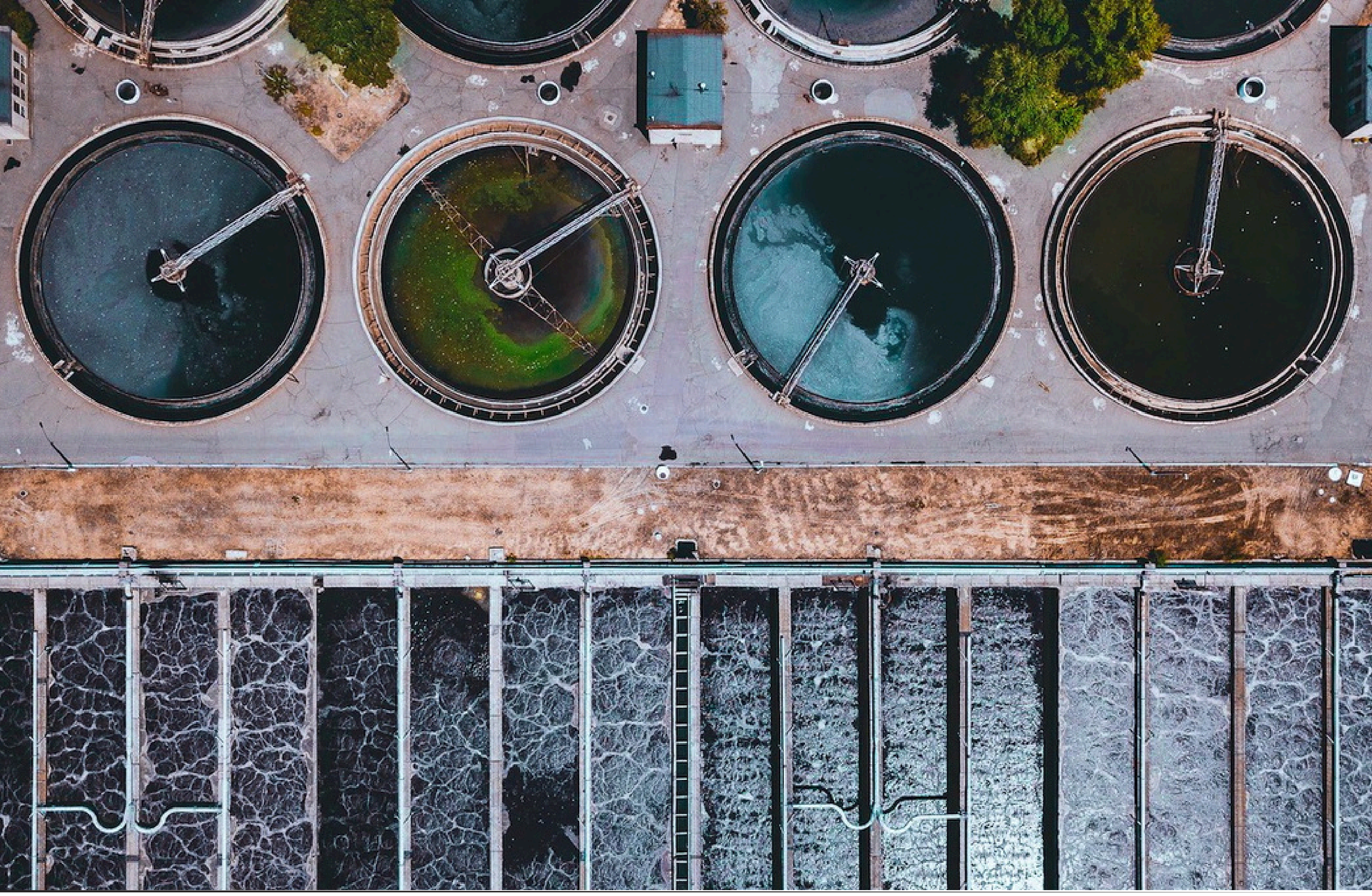

Brief No. 15.2

The Disruptive Power of Desalination

Regional and Domestic Security Risks of Increased Reliance on Desalinated Water

Anna Glass, Research Fellow

PIPS

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PIPS Brief 15.2

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Anna Glass

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Project on International Peace & Security (PIPS)
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The Disruptive Power of Desalination:

Regional and Domestic Security Risks of Increased Reliance on Desalinated Water

Anna Glass (Research Fellow)

Desalination plants are attractive options for countries looking to diversify their access to fresh water due to the negative effects of climate change. Yet, the placement of desalination infrastructure has political implications. Like the past building of railroad lines and irrigation canals, governments can use desalination infrastructure to disadvantage domestic groups, increase influence over disputed territory, or intensify transboundary divides. They also can exploit desalination infrastructure's vulnerability to physical attack. States and international organizations should recognize the destabilizing socio-political implications of desalination infrastructure placement when funding projects. Neglecting these implications risks amplifying existing conflicts, thus hindering efforts towards political and environmental stability in water-scarce regions.

Introduction

Engineering advancements and freshwater shortages have increased interest in the development of desalination capability.[1] As of 2019, more than 300 million people receive their water from desalination plants, which provide potable water by removing salt and impurities from ocean water.[2] Economic viability and environmental risks are at the forefront of criticisms regarding the use of desalination debate.[3] This paper addresses the international security risks associated with the adoption of desalination technology, especially in fragile regions where access to water is limited.

Widespread use of desalination technology presents three major security considerations for the international development community. First, the proliferation of desalination technology may increase the potential for discord and conflict between coastal and landlocked states. Second, states may unintentionally or strategically exclude minority or rural communities from desalinated water access. Finally, desalination plants and pipelines are critical, highly centralized infrastructure that can be targeted or attacked during conflict, potentially endangering many non-combatants.

After explaining these risks, this paper will use geospatial analysis to forecast fragile regions that are susceptible to water security issues and by extension, desalination weaponization. The international community can address these security risks on two fronts. The first is strategic involvement in the placement of desalination plants. The second prompts the international community to prepare for inevitable second-order effects of increased reliance on desalinated water.

The Inevitable Proliferation of Desalination

> *Climate change does not respect borders; it does not respect who you are—rich and poor, small and big. Therefore, this is what we call 'global challenges,' which require global solidarity.*
>
> Ban Ki-Moon[4]

Desalination, the process of removing salt and minerals from seawater, is on the rise.[5] The process uses heat and pressure to convert seawater into suitable industrial and drinking water.[6] Desalination has often been regarded as a technology that remained perpetually twenty years in the future. However, a notable transformation has occurred over the past decades as desalination has transitioned from a specialized technology to a widely adopted solution.[7]

Desalination is considered an ideal climate change adaptation strategy because it enhances water security through reliability.[8] The technology has met demands for climate-resilient water access despite economic and environmental tradeoffs. Desalinated water remains more expensive than many other freshwater sources but has become an attractive option because it provides "drought-proof" water access.[9] Prohibitive costs, energy requirements, and environmental impacts are barriers to desalination proliferation.[10] The process has substantial energy requirements, and most desalination plants use fossil fuels that contribute to global emissions.[11] Further, desalination's high-salinity byproduct, brine, pollutes the surrounding soil and ocean and causes environmental damage in areas highly dependent on arable land for survival.[12] Yet, costs to produce desalinated water lower each year, while freshwater extraction becomes difficult in water-scarce regions.[13] Usable freshwater accounts for only 3% of the earth's water, while oceans hold the other 97% of earth's water.[14]

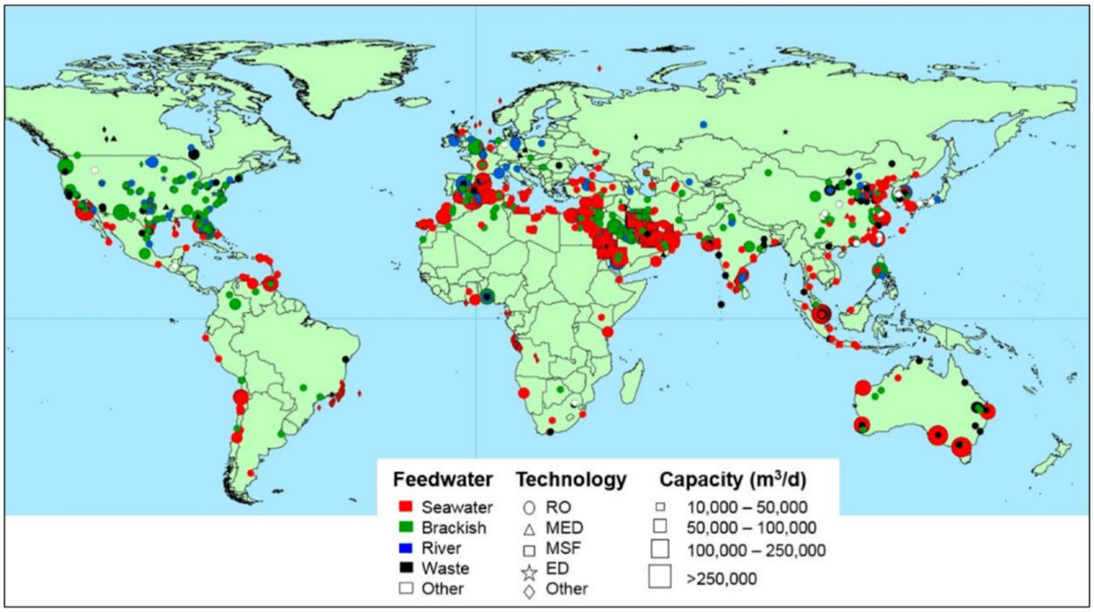
Harnessing ocean water through desalination can alleviate potable water insecurity for the 2.1 billion people who lack readily available safe water access.[15] In the last 20 years, the number of desalination plants has tripled from approximately 5,000 to 15,000 operational plants.[16]

The Middle East and North Africa produce the most desalinated water worldwide.[17] Both economically developed and economically developing countries are increasing their capacity to produce desalinated water.[18]

Desalination will likely proliferate to meet global water needs for several reasons:

- *Desalination is among the most proposed solutions for freshwater scarcity*.[19] Global desalination capacity has grown, on average, 7.5% per year since membrane-based technologies dominated less efficient thermal technologies in the late 1990s.[20] While water conservation, water recycling, and rainwater harvesting are other common, climate-resilient responses, desalination has the greatest potential for total water production and is more resilient to drought.[21] Most countries have adopted desalination in some capacity, through large production plants and small micro plants.[22] Nearly all countries in the Middle

Figure 1: World Map of Desalination Plants Reproduced from Curto 2021[23]



Map reproduced from Curto, Domenico, Vincenzo Franzitta, and Andrea Guercio. "A Review of the Water Desalination Technologies." *Applied Sciences* 11, no. 2 (January 2021): 670. https://doi.org/10.3390/app11020670.

East and North Africa produce water using desalination, through big plants and small micro plants that serve small and large communities.[24] For many nations, desalination is an attractive option that is used in tandem with current freshwater provision strategies and other climate adaptations.[25]

- *Rapid engineering advancements mitigate environmental and economic concerns.* Energy requirements and environmental tradeoffs are barriers to desalination infrastructure development.[26] Global stakeholders have made significant investments toward research and development of sustainable desalination technology.[27] Recent engineering advancements include new methods to desalinate water such as forward osmosis and membrane distillation, and more efficient technical components like the double-acting batch piston tanks and solar-powered desalination systems.[28] Together, technological advancements decrease energy usage, brine production, and are projected to lower costs, "by 20% in the next five years, and by up to 60% in the next 20 years."[29]

- *Total consumption of desalinated water exceeds groundwater and surface water consumption in many countries*.[30] The largest producers of desalinated water are wealthy enough to afford the technology. In the United Arab Emirates, many freshwater aquifers have become saline, catalyzing desalinated water production, which now accounts for 90 percent of all consumption in the country.[31] In Kuwait, desalination provides 92 percent of drinking water and 61 percent of overall water supply.[32] Saudi Arabia, the world's largest producer of desalinated water, obtains 70 percent of its potable water used in cities from desalination.[33] It is important to highlight slower growth rates in countries where capacity is limited. Desalination capacity in Libya and Tunisia, for example, trails behind their wealthier neighbors, though efforts to increase desalination capacity are constant.[34] Water consumption trends in Middle Eastern and North African nations suggest that desalinated water will provide most of all drinking and industrial water for many populations.[35]

- *Desalination provides a supplemental water source in countries with varying and diverse levels of water scarcity.* Countries facing extreme freshwater scarcity or frequent droughts are primary candidates for desalination infrastructure.[36] However, countries with a more stable water supply also have chosen to construct desalination plants. Australia uses desalination plants to supplement its freshwater supply during periods of drought.[37] Israel produces a surplus of desalinated water which it then exports to neighbors such as Jordan.[38] The increased aridification of the U.S. West has catalyzed discussions about implementing large-scale desalination plants along the coast.[39] Catastrophic freshwater scarcity in Arizona has even prompted proposals for shared desalination plants between the U.S. and Mexico.[40]

Desalination currently provides 1% of the world's drinking water, and this capacity is expected to double by 2030.[41] Yet, there are reasons why desalination has not replaced other methods of water access. These barriers include high environmental and economic cost. Large-scale desalination infrastructure requires sustained energy usage and demand for water that inhibits its construction in many places.[42]

Populations that have adopted desalination technology are near the coast, wealthy, and energy rich.[43] Adoption of desalination will look different in regions with low state capacity and less access to coastline.

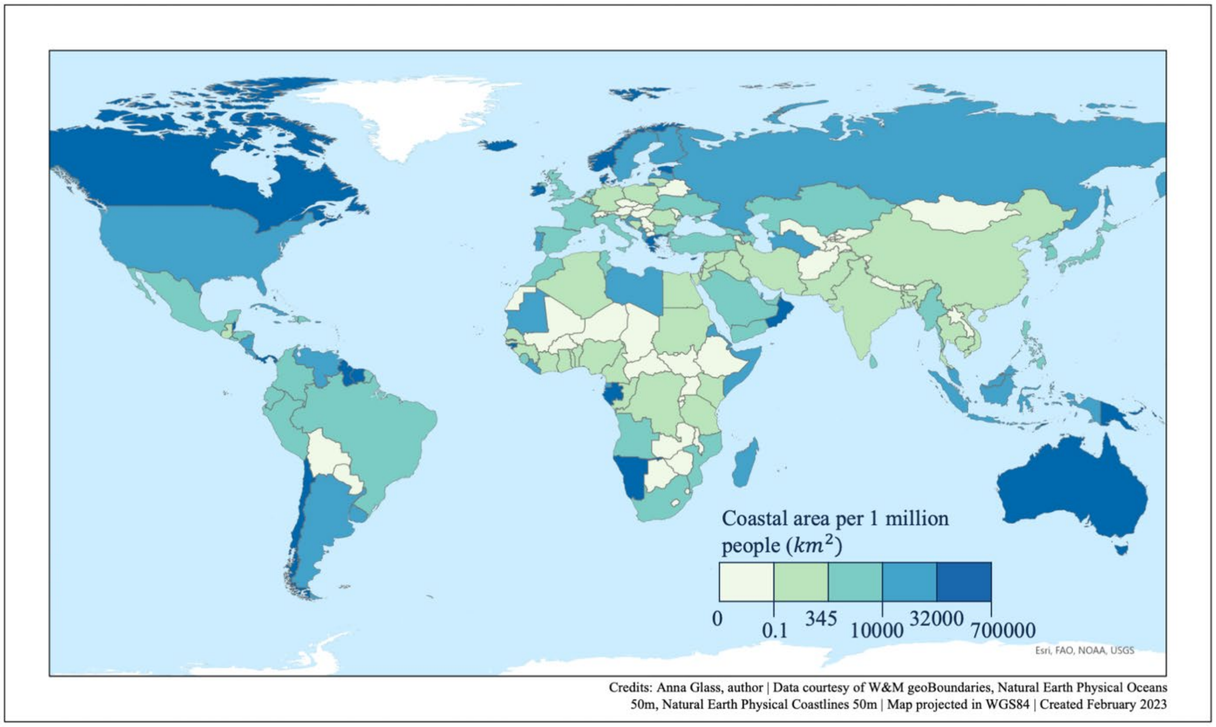
Desalination Creates Geographical Winners and Losers

> *Where [desalination] works is if the country has the economy to support it, and if it has access to the coast, and if the population is on the coast, and if you're using it for drinking water and if there's no choice.*
>
> Aaron T. Wolf, Ph.D.[44]

Previously unusable seawater will soon be a vital natural resource that only certain communities can harness. Desalination plants require access to the coast to produce fresh water, which means that landlocked states and inland communities may be excluded from the benefits of desalination.[45] Access to water defines a state's capacity to promote a thriving population, engage in manufacturing and industry, and adapt to climate change.[46] Desalination plants give coastal states a strategic advantage over inland states in areas where there is high demand for water and limited freshwater sources.[47]

Figure 2 is a visual representation of the geographical "winners" and "losers"—those who can benefit from desalination unilaterally, and those who must rely on water sharing and transcontinental pipelines to use desalinated water. For each country, the map represents coastal area, the area 10 kilometers inland from an ocean or sea and within a state's political boundary, divided by the country's total population. These two metrics provide a rote measurement of access to coast per person. An overlay of world population density reveals further inequalities between coastal and inland communities within a state.

Figure 2: Coastal Area per One Million People by Country



In areas with high population density and limited freshwater sources, such as the Middle East or parts of Africa, coastal regions have an advantage in access to ocean water resources. Close-to-the-coast desalination plants benefit large, often wealthy, coastal population centers, but marginalize the swaths of people living inland.[48] Vast differences in access worsen existing tensions between coastal and inland communities and could incentivize states to engage in aggressive tactics to gain control over strategic coastal areas. Desalination proliferation necessitates regional collaboration to promote equitable access to freshwater.

Overlooked Risks of Desalination Proliferation

Water is life, and its weaponization holds genocidal potential.

Charlotte Grech-Madin, Ph.D.[49]

Economic and environmental considerations have long been at the forefront of the desalination debate, but the strategy's domestic and regional security risks and opportunities are under-explored.[50] Three types of security considerations should underpin careful expansion of desalination technology. States may use desalination infrastructure to gain leverage over neighbors; states may use desalination to privilege certain domestic groups over others; and desalination infrastructure presents an easy physical target for adversaries.

States May Use Desalination Infrastructure Dependency for Coercion

Desalination development could alter current freshwater sharing agreements, create imbalances between coastal and landlocked states, and provide a coercive tool for control over contested areas.

Desalination may resolve or worsen historical tensions surrounding freshwater sharing. Transboundary water resources have historically caused conflict because they are overused and under-regulated.[51] Desalination reduces a state's reliance on contentious transboundary rivers, but it is unclear whether this augments the water supply enough to mitigate freshwater disputes.[52] Many freshwater export discussions have been halted due to financial and environmental obstacles. In some cases, desalination will halt pressures for freshwater exports altogether.[53] For example, Singapore allowed a 50-year water import agreement with Malaysia to expire after declaring that the state would use desalination plants to become self-sufficient.[54] Increased reliance on desalinated water may prompt states to revisit binational water sharing agreements.

Desalinated water sharing agreements are already proving different from freshwater sharing agreements. Canada and the United States have considered large-scale water sharing since 1959 but faced financial obstacles and political controversy preventing implementation.[55] However, growing desperation for water security has led to new trade and infrastructure relationships. Currently, the United States and Mexico are advancing plans for a shared desalination plant and other water infrastructure along the border.[56] States engaged in transboundary water sharing will become interdependent. Landlocked states relying on coastal water exports may feel pressure to maintain and grow current alliances. In 2015, Israel and Jordan signed the "Red-Dead" deal to build a joint desalination plant and to replenish the shrinking Dead Sea with water from Israel's Red Sea.[57] The project marked a historic step toward using seawater sharing for diplomacy.[58] However, diplomatic tensions, financial hurdles, and political instability in Israel stalled the project, leading Jordan to withdraw from the agreement.[59]

States may use desalination pipelines to assert influence in a contested region by creating dependency on them for a life-giving resource or by making a region viable for settlement and agriculture. Adversaries can force linkages with communities in contested regions by constructing critical infrastructure like desalination pipelines. Once desalination pipelines provide critical resources to surrounding populations, it may be difficult to remove the pipelines or transition control to another entity. In February 2023, the state TASS news agency reported that Russia is constructing 200 kilometers of water pipelines in the contested Donbas region inside Ukraine, which has suffered widespread damage on water pipelines and electrical grids from Russian attacks.[60] Because of these attacks, the region is uniquely vulnerable to dependence on Russian-built water pipelines as Russia attempts to assert control in Ukraine.[61]

Future monitoring of these fragile alliances related to seawater sharing or desalinated water restrictions may provide insights into the potential for stability or conflict. Vested stakeholders like the US should take these considerations into account when offering development aid or assistance to emerging economies seeking to establish plants in the future.

States May Use Desalination to Privilege Certain Social Groups Over Others

Low state capacity and political bias toward certain groups can lead states to prioritize building desalination pipelines in high priority areas, neglecting disadvantaged communities.[62] Without regulations to encourage equitable water distribution internally, states may strategically or unintentionally privilege certain groups over others. This presents two primary concerns: First, disadvantaged and unrecognized groups will face additional hurdles in implementing or benefiting from desalination infrastructure. Second, the water access gap between typically urban coastal groups and typically rural inland groups will widen.[63]

The first groups to benefit from desalination will likely be wealthy and politically powerful, while rural communities continue to face water shortages and inadequate infrastructure. Desalinated water can reach inland areas through newly constructed pipelines or existing water access pipelines.[64] However, even if a state has an established national water grid, the cost to transport water is prohibitively high in inland areas and highlands, ranging from $0.05-0.06 per cubic meter.[65] Water extracted exclusively from the coast, as opposed to inland freshwater bodies, may need to travel longer distances to reach inland populations. Costs increase when transporting desalinated water over land with frequent elevation changes, and it's common for elevation to increase moving inward from the coastline.[66] Wealthy population centers close to the coast will be the first to receive consistent access to desalinated water, worsening the disparities in safely managed drinking water between urban and rural areas.

The high cost to transport desalinated water from the coast will limit its integration into the national water grid, providing a convenient excuse to privilege some groups and neglect others. Israel, an early adopter of desalination technology, offers an early illustration of this risk. Maps of the Israeli national water grid and pipeline system reveal that the state has built desalination infrastructure along the Dead Sea, but halted construction at the border with the West Bank.[67] Israel has authority to approve all water infrastructure projects in its occupied territories, subjecting the West Bank and Gaza to a convoluted permit process that hinders their ability to construct or improve their water resources in practice.[68]

The historical and geographical factors that have perpetuated water inequality will reemerge in the distribution of desalinated water. Insufficient international and state standards surrounding equitable water access allow both intentional and unintentional water deprivation to continue. Incorporating equitable standards into international aid funding for desalination plants provides an opportunity to combat histories of water discrimination.

Desalination Infrastructure Presents an Easy Target for Adversaries

Physical attacks on desalination infrastructure pose greater risks and consequences compared to attacks on freshwater infrastructure. As water resources dwindle and conflicts surge, attacks on water infrastructure have become a common conflict strategy.[69] Desalination infrastructure possesses unique vulnerabilities due to its location, technical components, and energy dependence that make it susceptible to severe physical attacks. Desalination plants, pipelines, and energy systems are all potential targets.

Desalination plants' fragile engineering design and centralized location make the infrastructure vulnerable to attack. While they share some vulnerabilities with freshwater processing plants, such as intricate technology, volatile chemicals, and large-scale automated systems that attract cyberattacks, desalination plants have their own distinctive dangers.[70] Desalination plants' coastal location makes them vulnerable to both naval and aerial attack. Their intake systems are easily obstructed, increasing the risk of debris, oil spills, or intentional sabotage.[71] The high-pressure pumps used in reverse-osmosis plants are especially prone to sealant issues, resulting in flooding and contamination if seals fail.[72] Previous attacks on desalination plants, like the Iraqi attack on Kuwait's primary plant, demonstrate the devastating consequences.[73] Because each plant is a centralized water source for thousands, an attack on one plant could disrupt water provision for entire regions.

Desalination pipelines, like freshwater distribution grids, are susceptible to cyber-attacks.[74] Israel's costal desalination plants have been the target of both physical and cyber-attack highlighting the prevalence of the strategy.[75] Countless examples of cyberattack on water systems prove it is an effective and disruptive attack strategy.[76] Pipelines present the greatest challenge to desalination plant security, as they are difficult to defend due to their remote locations.[77] Pipelines are vulnerable to physical attacks, such as sabotage or vandalism, resulting in significant damage and disruption to the water supply.[78] The vulnerability of pipelines to physical attack highlights the importance of implementing robust security measures to protect water infrastructure.

Warring states and insurgent groups may also target the energy sources that underpin water distribution. Desalination's high energy dependence makes it vulnerable to these attacks. In 2019, Houthi rebels targeted a Saudi oil plant not only to disrupt oil production but also to target a nearby desalination facility.[79] A study from the Center on Strategic and International Studies predicts that enemy forces could attack energy systems to disrupt desalinated water provision while minimizing direct escalation.[80] Russia's targeting of energy grids in Ukraine showcases the dual vulnerability of depriving people of both energy and water.[81] Nuclear-powered desalination plants introduce additional uncertainties, as their limited usage raises questions about potential deterrence or invitation for attacks.[82] Violent extremist organizations or factions may also seek nuclear proliferation as an outcome, amplifying the risks associated with nuclear-powered desalination.

Dependence on desalination infrastructure can reshape water usage patterns by increasing reliance on centralized water resources and risking water shortages during disruptions. During the First Gulf War, Iraq jeopardized all desalination plants along the Persian Gulf by releasing millions of gallons of oil into the water.[83] While the spill was contained through a U.S. airstrike, it highlighted that Saudi Arabia's reliance on desalinated water would leave the capital city with only a three- to four-day water reserve if the plant failed.[84] Desalination plants provide critical water resources, but also create potential for catastrophic water wars.

Multilateral Approaches to Desalination Security

> *The failure to invest in water and security now could mean that the United States and other international actors will pay billions later to respond to crises.*
>
> Joshua W. Busby, Ph.D.[85]

Multilateral Opportunities to Mitigate Risk and Anticipate Second Order Effects

Some actors will take advantage of emerging desalination technology to reinforce legacy discrimination, assert coercive control over less resourced groups, and carry out physical attacks that disrupt widespread resource provision. On the other hand, states and multilateral bodies can use desalination as a climate-resilient resource to facilitate bilateral cooperation and break down long-standing barriers in the water access gap. The United States has an interest in remaining at the forefront of responding to security issues in water access, situated at the nexus between public diplomacy and technology. Desalination is the next manifestation of this issue.

There are opportunities to mitigate risk during the construction of desalination plants and anticipate the second order effects of increased reliance on desalination.

- *Monitor emerging and falling alliances.* Monitoring potential geopolitical shifts resulting from desalination technology is essential for understanding the future of water diplomacy. This can be achieved through tracking diplomatic engagements, trade agreements, and cooperative initiatives focused on water resources. The international community may also benefit from considering how recent geopolitical shifts may have been impacted by changing dynamics in water sharing and water scarcity.

- *Address existing inefficiencies and inequalities in the water access system*. The most significant barrier to mitigating these risks is the persistent presence of underlying inequalities and inefficiencies in the current water access system. These inequalities stem from equitable access to infrastructure, high levels of non-revenue water, and insufficient care for groundwater resources. In many cases, it is wise to address these issues before making the same mistakes when implementing expensive, shiny climate adaptations such as desalination. By first addressing the root causes of inequality, it is possible to lay the foundation for a more equitable and resilient water access system.

- *Integrate socio-economic factors into suitability analyses when placing future desalination plants*. A careful analysis of geographic, hydrological, and socioeconomic factors is essential to identify suitable locations and promote equity for desalination projects. In cases where equity is not achieved, these sorts of analyses provide a baseline to provide supplemental support to communities left behind. Often, marginalized members of society remain uninformed of the benefits of infrastructure projects like desalination plants.

Monitoring the equitable distribution impacts of desalination plants sheds light on desalination's impact on the water access gap.

- *Integrate security risk considerations into the design and implementation of desalination projects.* Investing in technological advancements that minimize the chances of physical attacks on desalination plants is vital, as is preparing to respond effectively to such attacks. Research and development should focus on enhancing security measures, including surveillance systems, early warning mechanisms, and robust physical protection for critical infrastructure. Simultaneously, intelligence agencies and security forces should work closely with the international development community to anticipate potential attacks, assess vulnerabilities, and develop response plans.

- *Monitor and evaluate the impacts of desalination projects.* It is important to monitor and evaluate the impacts of desalination projects over time to ensure that they are sustainable and meet their intended objectives. This could involve developing robust monitoring and evaluation frameworks. More data could inform how desalination plants affect the quality of life of the individuals using it, or how brine build-ups affect arable land in coastal nations.

China's Untold Role in Global Desalination Development

China's domestic investment in desalination technology, coupled with its growing presence in water-scarce regions, raises important considerations for the international community. While there is currently no evidence of international investment from China in desalination, the Chinese government aims to establish its domestic companies as leaders in the desalination market.[86]

The international security community should monitor China's involvement in desalination technology and anticipate that desalination may become a part of the Belt and Road Initiative. China's investment in large-scale infrastructure projects is often followed with violations to labor rights and increased debt risks.[87] The international community can promote fairness in the distribution of new resources like desalinated water. To do so, democratic and human rights-oriented nations can position themselves to provide this technology for low-income countries.

All states and international funding organizations should be mindful of the political implications of desalination infrastructure when assessing funding and construction proposals. If ignored, the second-order effects of desalination infrastructure may complicate the United States' ability to operate and provide development assistant in certain regions. International conversations about the future of desalination investment abroad may encourage new ideas and collaboration based around shared goals of transparency, equity, and sustainability that underpin U.S.-led development projects.

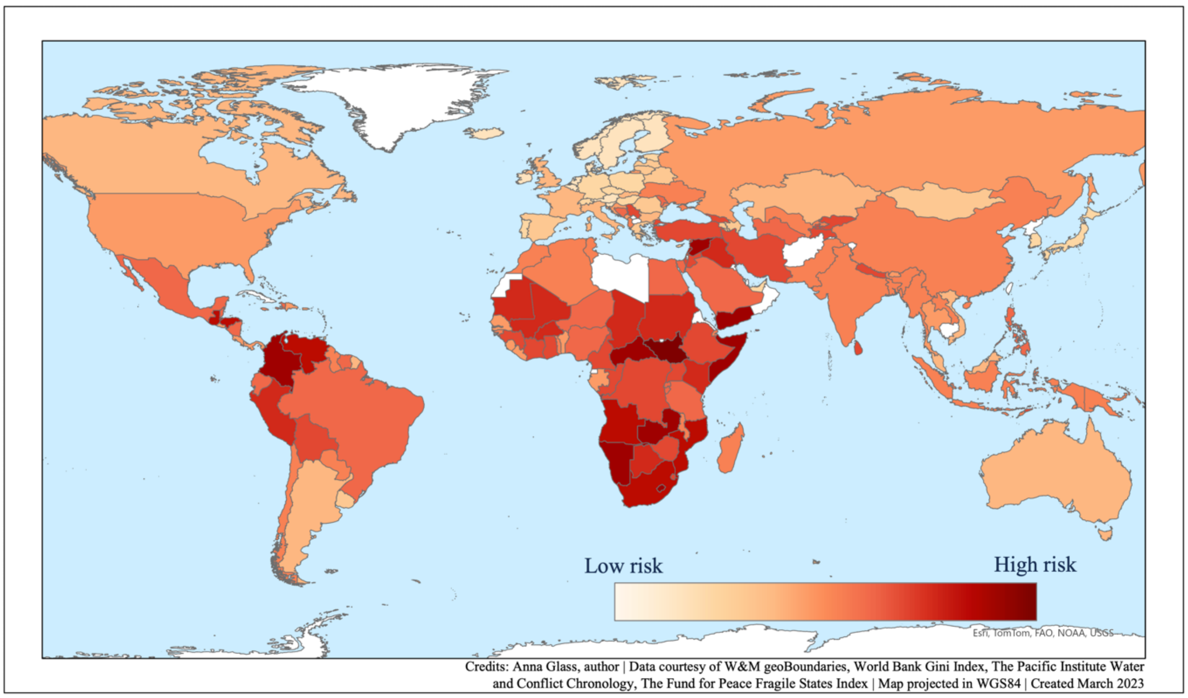
The international development community has an opportunity to draw on lessons from past infrastructure development projects. Future approaches to embracing desalination should minimize the potential for emerging water technologies to facilitate domestic and regional security risks.

Conclusion

Desalination infrastructure placement has potential destabilizing effects. Proposals to integrate desalination into climate resilience strategies may outrun the international community's ability to anticipate negative effects. As climate change transforms access to water globally, the U.S. and its allies must remain at the forefront of foreign aid investments that facilitate equitable and sustainable water access. Figure 3 identifies regions that are vulnerable to worsened political and environmental stability due to hastily implemented desalination adaptations. Regions identified face both fragile political environments and dire freshwater scarcity.

Fragile countries with histories of conflict over freshwater, high economic inequality, and political instability may be vulnerable to conflict involving desalination infrastructure. Figure 3 identifies these regions by converting each metric into an ordinal category from 1-5 and overlaying the metrics to create an overall Risk Index for each country. Using the Fragile States Index, the Pacific Institute Water and Conflict Chronology, and the Gini Index as proxies for these three metrics, we can project high risk for desalination-related conflict in the Middle East and North Africa (See Appendix X for maps of each factor considered in the Risk Index).

Figure 3: Aggregate Risk Index



Desalination is a crucial climate adaptation. However, without first addressing underlying inequalities and instabilities in water access, adopting desalination risks amplifying existing conflicts. The international aid community should take the lead in developing monitoring and evaluation strategies, siting plans, and comprehensive aid strategies that can allow this climate adaptation to proliferate while facilitating equitable futures.

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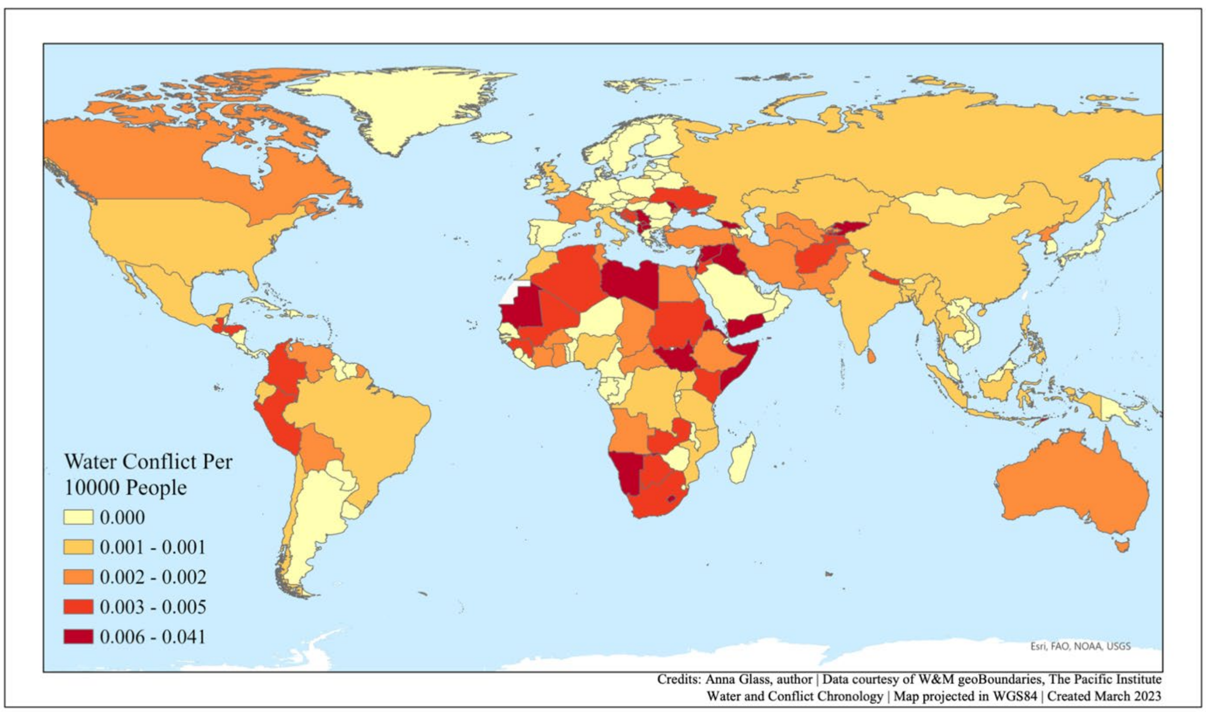
Appendix A

Risk Index Methodology

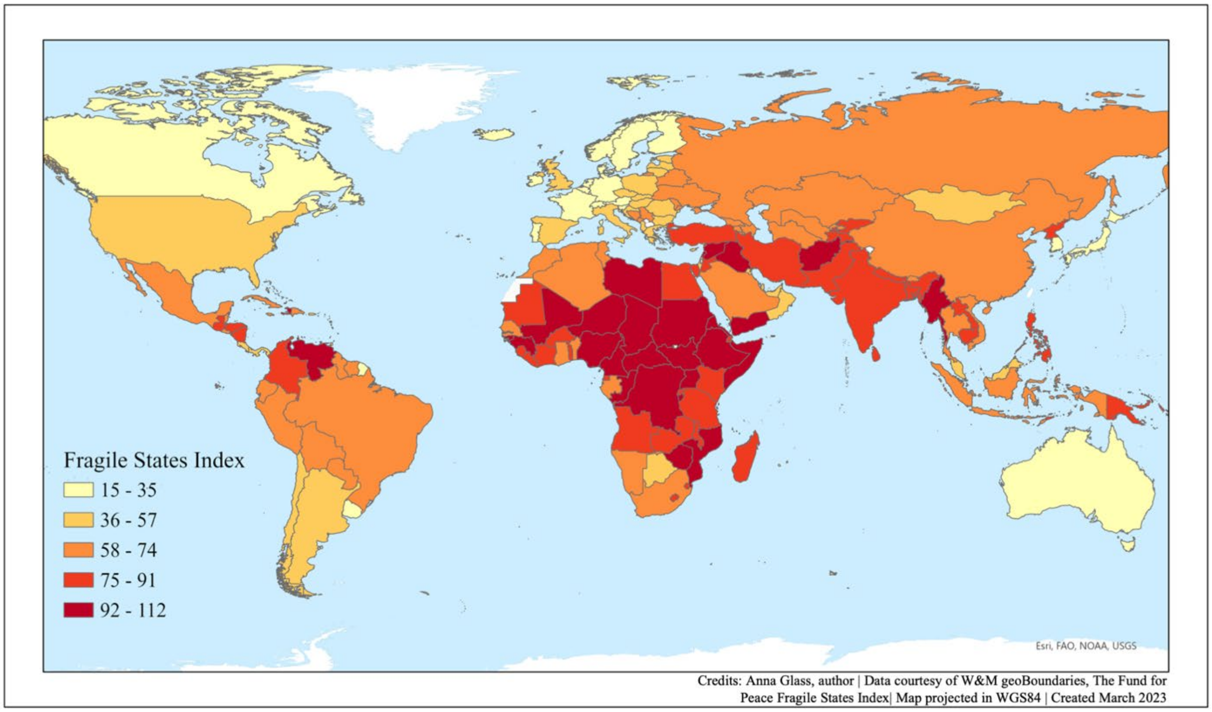
The Desalination Risk Index map was created by combining three map layers in ArcGIS Pro. The three layers selected are the Fragile States Index, the Pacific Institute Water and Conflict Chronology, and the Gini Index. Together, these layers act as a proxy for the likelihood that water-related conflict and inequitable resource distribution may result from the adoption of desalination technology. This map, in tandem with Figure 2: Access to Coastal Area serves as a preliminary visualization of areas to watch for future security risks related to desalination infrastructure. Below are maps of each of the individual layers with explanations for their selection. The Pacific Institute Water and Conflict Chronology is a comprehensive database of water-related conflicts, ranging from water as a trigger for conflict to water as a weapon during conflict. All conflicts from 1980 onward were extracted to capture recent political history. Then, a count of the total number of conflicts in each country was created and normalized by population. Finally, each country was given an ordinal category from one to five using Jenks Natural Breaks optimization, a standard data clustering method to determine different classes of values within an irregularly distributed dataset.

Figure 4: Number of Water Conflicts Since 1980, Normalized by Total Population



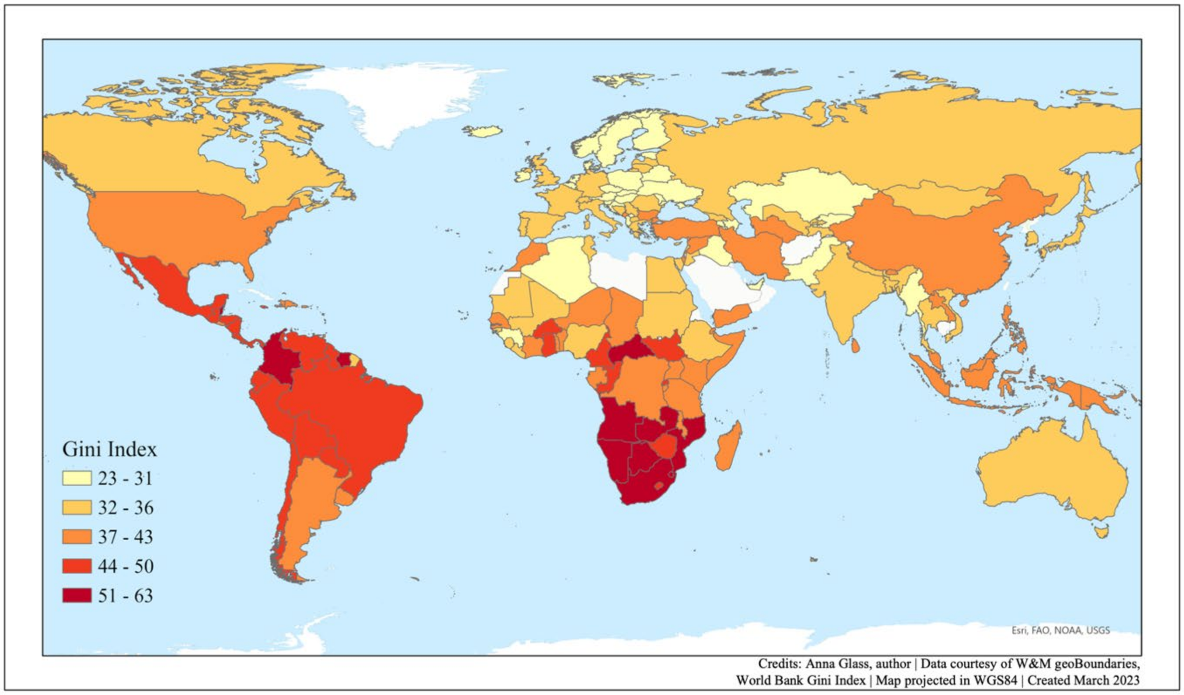
The Fragile States Index (FSI) is an annual report that aims to assess states' vulnerability to conflict or collapse by ranking all sovereign states with membership in the United Nations where there is enough data available for analysis.[88] The indicators used in the FSI include security apparatus, factionalized elites, group grievance, economic decline and poverty, uneven economic development, human rights, demographic pressures, refugees and IDPs, external intervention, state legitimacy, public services, and human flight.[89] The FSI helps predict conflict by reflecting a country's ability to maintain stability, as one consistent theme is the strong correlation between state fragility and conflict.[90] To obtain this layer, the overall Fragile States Index score was joined to each country polygon, then broken into classes from one to five using Jenks Natural Breaks.

Figure 5: Fragile States Index



The Gini Index is a measure of inequality that compares the income or wealth distribution of a population to a perfectly equal distribution.[91] It is a summary measure of income inequality that provides a convenient summary of the degree of inequality. Higher inequality may indicate that a state is likely to overlook marginalized and rural groups during the provision of desalinated water. The data for this map comes from the most recent measure from the World Bank Poverty and Inequality Platform. Data are based on primary household survey data obtained from government statistical agencies and World Bank country departments.[92] Each of the most recent Gini Index metrics were joined to the country polygon and categorized using Jenks Natural Breaks.

Figure 6: Gini Index



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[1] Robbins, Jim. "As Water Scarcity Increases, Desalination Plants Are on the Rise." *Yale E360* (June 11, 2019). https://e360.yale.edu/features/as-water-scarcity-increases-desalination-plants-are-on-the-rise.

[2] "Desalination" *Water Science* School, United States Geological Survey (September 11, 2019). https://www.usgs.gov/special-topics/water-science-school/science/desalination.; Robbins, Jim. "Desalination Is Booming as Cities Run out of Water." *Wired* (June 27, 2019). https://www.wired.com/story/desalination-is-booming-as-cities-run-out-of-water/

[3] "Desalination" in *Powering the Blue Economy: Exploring Opportunities for Marine Renewable Energy in Maritime Markets* (April 2019). https://www.energy.gov/sites/default/files/2019/09/f66/73355-7.pdf.; "Encyclopedia of Desalination and Water Resources: Energy Requirements of Desalination Processes." https://www.desware.net/Energy-Requirements-Desalination-Processes.aspx.; Herndon, Andrew. "Energy Makes Up Half of Desalination Plant Costs: Study." *Bloomberg.com* (May 1, 2013). https://www.bloomberg.com/news/articles/2013-05-01/energy-makes-up-half-of-desalination-plant-costs-study.;

[4] Ki-moon, Ban. "Remarks at 'Momentum for Change' Initiative | United Nations Secretary-General." (December 6, 2011). https://www.un.org/sg/en/content/sg/speeches/2011-12-06/remarks-momentum-change-initiative.

[5] Robbins, Jim. "As Water Scarcity Increases, Desalination Plants Are on the Rise." *Yale E360* (June 11, 2019). https://e360.yale.edu/features/as-water-scarcity-increases-desalination-plants-are-on-the-rise.

[6] SaniWater. "Comprehensive Overview of The Types of Desalination Technologies for Water Treatment Process," February 9, 2021. https://saniwater.com/comprehensive-overview-of-the-types-of-desalination-technologies-for-water-treatment-process/.; There are two main types of desalination technologies: membrane and thermal desalination. Membrane desalination uses reverse osmosis (RO), forward osmosis (FO), electro-dialysis (ED), and nano-filtration (NF) technologies, while thermal desalination uses multi-stage flash distillation (MSF), multi-effect distillation (MED), and mechanical vapor compression (MVC) technologies.

[7] Cosín, Carlos. "The Evolution of Rates in Desalination (Part I)." Text. Smart Water Magazine, January 15, 2019. https://smartwatermagazine.com/blogs/carlos-cosin/evolution-rates-desalination-part-i.; Robbins, Jim. "As Water Scarcity Increases, Desalination Plants Are on the Rise." *Yale E360* (June 11, 2019). https://e360.yale.edu/features/as-water-scarcity-increases-desalination-plants-are-on-the-rise.

[8] Williams, Joe. “How Do We Know If Our Adaptations to Climate Change Are Successful?” Advanced Science News, December 14, 2020. https://www.advancedsciencenews.com/how-do-we-know-if-our-adaptations-to-climate-change-are-successful/.

[9] Dhakal, Nirajan, Sergio G. Salinas-Rodriguez, Jamal Hamdani, Almotasembellah Abushaban, Hassan Sawalha, Jan C. Schippers, and Maria D. Kennedy. “Is Desalination a Solution to Freshwater Scarcity in Developing Countries?” *Membranes* 12, no. 4 (March 31, 2022): 381. https://doi.org/10.3390/membranes12040381.; “Seawater Desalination - an Overview | Sciencedirect Topics.” https://www.sciencedirect.com/topics/engineering/seawater-desalination.

[10] Ibrahim, Yazan, Roqaya A. Ismail, Adetola Ogungbenro, Tom Pankratz, Fawzi Banat, and Hassan A. Arafat. “The Sociopolitical Factors Impacting the Adoption and Proliferation of Desalination: A Critical Review.” *Desalination* 498 (January 15, 2021): 114798. https://doi.org/10.1016/j.desal.2020.114798.

[11] Do Thi, Huyen Trang, Tibor Pasztor, Daniel Fozer, Flavio Manenti, and Andras Jozsef Toth. “Comparison of Desalination Technologies Using Renewable Energy Sources with Life Cycle, PESTLE, and Multi-Criteria Decision Analyses.” *Water* 13, no. 21 (January 2021): 3023. https://doi.org/10.3390/w13213023.

[12] Panagopoulos, Argyris, Katherine-Joanne Haralambous, and Maria Loizidou. “Desalination Brine Disposal Methods and Treatment Technologies - A Review.” *Science of The Total Environment* 693 (November 25, 2019): 133545. https://doi.org/10.1016/j.scitotenv.2019.07.351.

[13] Bienkowski, Brian. “Desalination Is an Expensive Energy Hog, but Improvements Are on the Way.” The World. May 15, 2015. https://theworld.org/stories/2015-05-15/desalination-expensive-energy-hog-improvements-are-way.; “Seawater Desalination - an Overview | Sciencedirect Topics.” https://www.sciencedirect.com/topics/engineering/seawater-desalination.

[14] “Water Facts - Worldwide Water Supply | ARWEC| CCAO | Area Offices | California-Great Basin | Bureau of Reclamation.” (November 4, 2020). https://www.usbr.gov/mp/arwec/water-facts-ww-water-sup.html.

[15] “2.1 Billion People Lack Safe Drinking Water at Home, More than Twice as Many Lack Safe Sanitation.” (July 12, 2017). https://www.who.int/news/item/12-07-2017-2-1-billion-people-lack-safe-drinking-water-at-home-more-than-twice-as-many-lack-safe-sanitation.

[16] Jones, Edward R., Manzoor Qadir, ”The State of Desalination and Brine Production.” *Encyclopedia of Life Support Systems.* https://www.eolss.net/Sample-Chapters/C08/E6-107-17.pdf.; “Climate Impacts on Water Resources.” Overviews and Factsheets. https://19january2017snapshot.epa.gov/climate-impacts/climate-impacts-water-resources.; “Freshwater and Climate Change.” *MIT Climate Portal.* https://climate.mit.edu/explainers/freshwater-and-climate-change.

[17] Ibid.

[18] Walschot, Maureen, David Katz. ”Desalination and Transboundary Water Conflict and Cooperation: A Mixed-Method Empirical Approach.” *ResearchGate*. (June 2022). https://www.researchgate.net/publication/361426930_Desalination_and_Transboundary_Water_Conflict_and_Cooperation_A_Mixed-Method_Empirical_Approach.

[19] Dhakal, Nirajan, Sergio G. Salinas-Rodriguez, Jamal Hamdani, Almotasembellah Abushaban, Hassan Sawalha, Jan C. Schippers, and Maria D. Kennedy. “Is Desalination a Solution to Freshwater Scarcity in Developing Countries?” *Membranes* 12, no. 4 (March 31, 2022): 381. https://doi.org/10.3390/membranes12040381.; Robbins, Jim. “As Water Scarcity Increases, Desalination Plants Are on the Rise.” *Yale E360.* (June 11, 2019). https://e360.yale.edu/features/as-water-scarcity-increases-desalination-plants-are-on-the-rise.

[20] Ibid.

[21] Voutchkov, Nikolay. “Desalination – Past, Present and Future.” *International Water Association*. (August 17, 2016). https://iwa-network.org/desalination-past-present-future/.

[22] UNEP. “Five Things to Know about Desalination,” January 11, 2021. http://www.unep.org/news-and-stories/story/five-things-know-about-desalination.

[23] Curto, Domenico, Vincenzo Franzitta, and Andrea Guercio. “A Review of the Water Desalination Technologies.” *Applied Sciences* 11, no. 2 (January 2021): 670. https://doi.org/10.3390/app11020670.

[24] Ibrahim, Yazan, Roqaya A. Ismail, Adetola Ogungbenro, Tom Pankratz, Fawzi Banat, and Hassan A. Arafat. “The Sociopolitical Factors Impacting the Adoption and Proliferation of Desalination: A Critical Review.” *Desalination* 498 (January 15, 2021): 114798. https://doi.org/10.1016/j.desal.2020.114798.

[25] Padmanathan, Paddy. “Can Desalination Be a Sustainable Solution to the Water Crisis?” *World Economic Forum.* (June 29, 2022). https://www.weforum.org/agenda/2022/06/technology-and-entrepreneurship-can-quench-our-parched-world/.; “The Role of Desalination in an Increasingly Water-Scarce World,” *World Bank.* (March 2019). https://doi.org/10.1596/31416.

[26] Cooley, Heather. "Desalination and Energy Use… Should We Pass the Salt?" *Pacific Institute* (blog). (May 28, 2013). https://pacinst.org/desal-and-energy-use-should-we-pass-the-salt/.
[27] "Department of Energy Invests $5 Million in Desalination Technology to Deliver Freshwater to Communities Across America." *Office of Energy Efficiency & Renewable Energy.* (July 27, 2021).; "DWR Contributes $16 Million to Support Desalination Research, Improved Energy Efficiency," September 28, 2021. California Department of Water Resources. https://water.ca.gov/News/Blog/2021/September/DWR-Contributes-16-Million-to-Support-Desalination-Research.; Efrat, Tomer. "IDE Water Technologies Invests in R&D, Sustainability in Seawater Desalination and Water Treatment" *Business Wire.* (September 21, 2022). https://www.businesswire.com/news/home/20220920006200/en/IDE-Water-Technologies-Invests-in-RD-Sustainability-in-Seawater-Desalination-and-Water-Treatment.; Energy.gov. "Department of Energy Invests $5 Million in Desalination Technology to Deliver Freshwater to Communities Across America." July 27, 2021. https://www.energy.gov/eere/articles/department-energy-invests-5-million-desalination-technology-deliver-freshwater. ; "DWR Contributes $16 Million to Support Desalination Research, Improved Energy Efficiency," *California Department of Water Resources*. (September 28, 2021). https://water.ca.gov/News/Blog/2021/September/DWR-Contributes-16-Million-to-Support-Desalination-Research..
[28] Ahmed, Farah Ejaz, Abdullah Khalil, and Nidal Hilal. "Emerging Desalination Technologies: Current Status, Challenges and Future Trends." *Desalination* 517 (December 1, 2021): 115183. https://doi.org/10.1016/j.desal.2021.115183.; "Breakthrough in Reverse Osmosis May Lead to Most Energy-Efficient Seawater Desalination Ever." *Purdue University.* (May 12, 2021). https://www.purdue.edu/newsroom/releases/2021/Q2/breakthrough-in-reverse-osmosis-may-lead-to-most-energy-efficient-seawater-desalination-ever.html.; Chandler, David L. "Solar-Powered System Offers a Route to Inexpensive Desalination," *MIT News*. (February 14, 2022). https://news.mit.edu/2022/solar-desalination-system-inexpensive-0214.
[29] Voutchkov, Nikolay. "Desalination – Past, Present and Future." *International Water Association*. (August 17, 2016). https://iwa-network.org/desalination-past-present-future/.
[30] Murden, Robert. "Water in Saudi Arabia: Desalination, Wastewater, and Privatization." *USSBC* (blog). (January 7, 2021). https://ussaudi.org/water-in-saudi-arabia-desalination-wastewater-and-privatization/.
[31] Lucente, Adam. "Dubai to Build New Reservoirs for Desalinated Water" *Al-Monitor.* (June 8, 2022). https://www.al-monitor.com/originals/2022/06/dubai-build-new-reservoirs-desalinated-water.
[32] "Water Resources in Kuwait." *Fanack Water*. (December 24, 2020). https://water.fanack.com/kuwait/water-resources-in-kuwait/.
[33] "Water Resources" *The Embassy of The Kingdom of Saudi Arabia*. https://www.saudiembassy.net/water-resources.
[34] Altaeb, Malek. "Desalination in Libya: Challenges and opportunities." *Middle East Institute.* (December 20, 2021). https://www.mei.edu/publications/desalination-libya-challenges-and-opportunities.; "Tunisia Targets 650 Million M3/Day Desalination Capacity to Alleviate Water Stress." *Zawya*. (March 24, 2023). https://www.zawya.com/en/projects/utilities/tunisia-targets-650-million-m3-day-desalination-capacity-to-alleviate-water-stress-nuecneiv.
[35] Goergen, Roman. "The Future of Desalination." *Geographical.* (August 2, 2022). https://geographical.co.uk/science-environment/the-future-of-desalination.; Ortiz, Raphaelle. "Desalination: the future of water?". *Volvamos a la fuente* (blog). (May 7, 2021). https://blogs.iadb.org/agua/en/desalination-the-future-of-water/.; Padmanathan, Paddy. "Can Desalination Be a Sustainable Solution to the Water Crisis?" *World Economic Forum.* (June 29, 2022). https://www.weforum.org/agenda/2022/06/technology-and-entrepreneurship-can-quench-our-parched-world/.
[36] Cho, Renee. "A 1,000 Year Drought Is Hitting the West. Could Desalination Be a Solution?" *State of the Planet*. (August 26, 2021). https://news.climate.columbia.edu/2021/08/26/a-1000-year-drought-is-hitting-the-west-could-desalination-be-a-solution/.; Dhakal, Nirajan, Sergio G. Salinas-Rodriguez, Jamal Hamdani, Almotasembellah Abushaban, Hassan Sawalha, Jan C. Schippers, and Maria D. Kennedy. "Is Desalination a Solution to Freshwater Scarcity in Developing Countries?" *Membranes* 12, no. 4 (March 31, 2022): 381. https://doi.org/10.3390/membranes12040381.
[37] Australian Associated Press. "Sydney's Desalination Plant Set to Expand as Drought Continues." *The Guardian*, August 11, 2019, sec. Australia news. https://www.theguardian.com/australia-news/2019/aug/11/sydneys-desalination-plant-set-to-expand-as-drought-continues.; Heggie, Jon. "Solving Italy's Water Problem: It's Time to Fix the Dripping Tap," *National Geographic.* (June 22, 2020). https://www.nationalgeographic.com/science/article/partner-content-solving-the-water-problem-in-italy.

[38] Heggie, Jon. "Solving Italy's Water Problem: It's Time to Fix the Dripping Tap," *National Geographic.* (June 22, 2020). https://www.nationalgeographic.com/science/article/partner-content-solving-the-water-problem-in-italy.; Katz, Shaina. "Worldwide Water Crises: Israeli Innovations Can Help." *The Washington Institute.* (March 11, 2022). https://www.washingtoninstitute.org/policy-analysis/worldwide-water-crises-israeli-innovations-can-help.
[39] Cho, Renee. "A 1,000 Year Drought Is Hitting the West. Could Desalination Be a Solution?" *State of the Planet*. (August 26, 2021). https://news.climate.columbia.edu/2021/08/26/a-1000-year-drought-is-hitting-the-west-could-desalination-be-a-solution/.; Daoust, Quinne. "Desalination in the American West." *American Security Project.* (July 5, 2022). https://www.americansecurityproject.org/desalination-in-the-american-west/.
[40] Leggate, James. "Arizona Advances $5.5B Mexico Desalination Plant Proposal." *ENR Southwest.* (December 23, 2022). https://www.enr.com/articles/55659-arizona-advances-55b-mexico-desalination-plant-proposal.
[41] Voutchkov, Nikolay. "Desalination – Past, Present and Future." *International Water Association*. (August 17, 2016). https://iwa-network.org/desalination-past-present-future/.
[42] A major barrier for adopting desalinated water may be that the freshwater scarcity within a country is not great enough to catalyze the expensive infrastructure investment. An illustrative case is the city of Santa Barbara in the U.S. West. The city built a desalination plant to respond to ongoing drought. However, by the time construction was completed, the need for supplemental freshwater had decreased to a point where the city could not maintain the plant, resulting in its demolition. Often, desalination enters the dialogue when freshwater scarcity is dire—and not a moment sooner. Yet, in strategic, freshwater-scarce regions, desalination accounts for most total water consumption. Communities may implement desalination as a primary water source or operate plants in tandem with traditional freshwater extraction. Through varying scales of use and mechanisms, desalination proliferation is inevitable.
[43] Ibrahim, Yazan, Roqaya A. Ismail, Adetola Ogungbenro, Tom Pankratz, Fawzi Banat, and Hassan A. Arafat. "The Sociopolitical Factors Impacting the Adoption and Proliferation of Desalination: A Critical Review." *Desalination* 498 (January 15, 2021): 114798. https://doi.org/10.1016/j.desal.2020.114798.; Voutchkov, Nikolay. "Desalination – Past, Present and Future." *International Water Association*. (August 17, 2016). https://iwa-network.org/desalination-past-present-future/.
[44] *Aaron Wolf on Water Management, Agriculture, and Population Growth in the Middle East*. https://soundcloud.com/ecspwwc/aaron-wolf-on-water-management.
[45] Voutchkov, Nikolay. "Desalination – Past, Present and Future." *International Water Association*. (August 17, 2016). https://iwa-network.org/desalination-past-present-future/.
[46] "Climate Change and Food Security: Risks and Responses." Food and Agriculture Organization of the United Nations, 2016. https://www.fao.org/3/i5188e/I5188E.pdf.; US EPA, OP. "Climate Adaptation and Source Water Impacts." Overviews and Factsheets, July 5, 2022. https://www.epa.gov/arc-x/climate-adaptation-and-source-water-impacts.; UN-Water. "Water and Climate Change." https://www.unwater.org/water-facts/water-and-climate-change.
[47] Walschot, Maureen, David Katz. "Desalination and Transboundary Water Conflict and Cooperation: A Mixed-Method Empirical Approach." *ResearchGate*. (June 2022). https://www.researchgate.net/publication/361426930_Desalination_and_Transboundary_Water_Conflict_and_Cooperation_A_Mixed-Method_Empirical_Approach.
[48] Ibrahim, Yazan, Roqaya A. Ismail, Adetola Ogungbenro, Tom Pankratz, Fawzi Banat, and Hassan A. Arafat. "The Sociopolitical Factors Impacting the Adoption and Proliferation of Desalination: A Critical Review." *Desalination* 498 (January 15, 2021): 114798. https://doi.org/10.1016/j.desal.2020.114798.
[49] Grech-Madin, Charlotte. "Water and Warfare: The Evolution and Operation of the Water Taboo." *International Security* (April 20, 2021), 45 (4): 84–125. https://doi.org/10.1162/isec_a_00404.
[50] Katz, David. "Desalination and Hydrodiplomacy: Refreshening Transboundary Water Negotiations or Adding Salt to the Wounds?" *Environmental Science & Policy* 116 (February 1, 2021): 171–80. https://doi.org/10.1016/j.envsci.2020.11.012.; Wilson, Nicole J., Leila M. Harris, Joanne Nelson, and Sameer H. Shah. "Re-Theorizing Politics in Water Governance." *Water* 11, no. 7 (July 2019): 1470. https://doi.org/10.3390/w11071470.
[51] Petersen-Perlman, Jacob D., Jennifer C. Veilleux, and Aaron T. Wolf. "International Water Conflict and Cooperation: Challenges and Opportunities." *Water International* 42, no. 2 (February 17, 2017): 105–20. https://doi.org/10.1080/02508060.2017.1276041.; "Transboundary Water Conflicts – International Waters – Training Modules." https://blogs.ubc.ca/internationalwaters/water-society-territories-conflicting-uses/5-transboundary-water-conflicts/.
[52] Walschot, Maureen, David Katz. "Desalination and Transboundary Water Conflict and Cooperation: A Mixed-Method Empirical Approach." *ResearchGate*. (June 2022).

https://www.researchgate.net/publication/361426930_Desalination_and_Transboundary_Water_Conflict_and_Cooperation_A_Mixed-Method_Empirical_Approach.
[53] Ibid.; Walton, Brett. “Singapore Will Cut Water Imports from Malaysia, Pursue Self-Sufficiency.” *Circle of Blue* (blog). (May 20, 2010). https://www.circleofblue.org/2010/world/singapore-will-cut-water-imports-from-malaysia-pursue-self-sufficiency/.
[54] Ibid.
[55] McNiven, James. "Bulk Water Exports: Environmental Concerns and Business Realities.” *OpenSIUC*. (July 12, 2005).
https://opensiuc.lib.siu.edu/cgi/viewcontent.cgi?referer=&httpsredir=1&article=1035&context=ucowrconfs_2005.
[56] Leggate, James. “Arizona Advances $5.5B Mexico Desalination Plant Proposal.” *ENR Southwest.* (December 23, 2022). https://www.enr.com/articles/55659-arizona-advances-55b-mexico-desalination-plant-proposal.; “U.S.-Mexico Border Water Infrastructure Grant Program.” *United States Environmental Protection Agency*. (August 29, 2022). https://www.epa.gov/small-and-rural-wastewater-systems/us-mexico-border-water-infrastructure-grant-program.
[57] Times of Israel. “Israel, Jordan Unveil $800m Joint Plan for ‘Red-Dead’ Canal.”
http://www.timesofisrael.com/israel-jordan-unveil-800m-joint-plan-for-red-dead-canal/.
[58] Ibid.
[59] Times of Israel. “After Years of Delays, Jordan Said to Nix Red Sea-Dead Sea Canal with Israel, PA.”
https://www.timesofisrael.com/after-years-of-delays-jordan-said-to-nix-red-sea-dead-sea-canal-with-israel-pa/.
[60] “Russia Building 200-Km Water Pipeline to Donbas, TASS Agency Says,” *Reuters.* (February 13, 2023).
https://www.reuters.com/article/ukraine-crisis-russia-waterpipeline-idUSL1N34T02Q.
[61] Ibid.
[62] Ibrahim, Yazan, Roqaya A. Ismail, Adetola Ogungbenro, Tom Pankratz, Fawzi Banat, and Hassan A. Arafat. “The Sociopolitical Factors Impacting the Adoption and Proliferation of Desalination: A Critical Review.” *Desalination* 498 (January 15, 2021): 114798. https://doi.org/10.1016/j.desal.2020.114798.
[63] The rural water access gap refers to the lack of access to clean water and safe wastewater disposal that many rural communities face. About 2.2 billion people globally do not have safely managed drinking water services. Rural communities have higher rates of water contamination and lower access to national infrastructure support. Minority and low-income populations disproportionately live in these rural areas. Of those who lack basic water access, 80 percent live in rural areas.
[64] Day, April. “Desalination of Inland Underground Water May Prove Pivotal in Meeting Community Water Needs” April 13, 2017. https://savethewater.org/desalination-inland-underground-water-may-prove-pivotal-meeting-community-water-needs/.
[65] Voutchkov, Nikolay. “Desalination – Past, Present and Future.” *International Water Association*. (August 17, 2016). https://iwa-network.org/desalination-past-present-future/.; Zhou, Yuan, and Richard S. J. Tol. “Evaluating the Costs of Desalination and Water Transport: COSTS OF DESALINATION AND WATER TRANSPORT.” *Water Resources Research* 41, no. 3 (March 2005). https://doi.org/10.1029/2004WR003749.

Table 1: Forecast of Desalination Costs for Medium and Large Size Projects, adapted from the International Water Association

Parameter for Best-in Class Desalination Plants	Year 2016	Within 5 Years	Within 20 Years
Cost of Water (US$/m^3)	0.8-1.2	0.6-1.0	0.3-0.5
Construction Cost (US$/MLD)	1.2-2.2	1.0-1.8	0.5-0.9
Electrical Energy Use (kWh/m^3)	3.5-4.0	2.8-3.2	2.1-2.4
Membrane Productivity (m^3/membrane)	28-47	35-55	95-120

[66] Ibid.
[67] Fanack Water. “Water Infrastructure in Israel.” https://water.fanack.com/israel/water-infrastructure/.

[68] Hibrawi, Reema. “Israel’s Problematic Role in Perpetuating Water Insecurity for Palestine.” *Atlantic Council* (blog). (June 28, 2019). https://www.atlanticcouncil.org/blogs/menasource/israel-s-problematic-role-in-perpetuating-water-insecurity-for-palestine/.
[69] “Five Threats to the Water That Sustains Our Farms,” *United Nations Environment Programme.* (July 12, 2022). http://www.unep.org/news-and-stories/story/five-threats-water-sustains-our-farms.
[70] “Compromise of U.S. Water Treatment Facility | CISA,” February 12, 2021. https://www.cisa.gov/news-events/cybersecurity-advisories/aa21-042a.; Jones, Seth G., Joseph S. Bermudez Jr, Danika Newlee, and Nicholas Harrington. “Iran’s Threat to Saudi Critical Infrastructure: The Implications of U.S.-Iranian Escalation,” August 5, 2019. https://www.csis.org/analysis/irans-threat-saudi-critical-infrastructure-implications-us-iranian-escalation.
[71] Ibid.
[72] “High-Pressure Water Pump Mechanical Seal Failure Investigation.” *Hydrocarbon Processing.* https://www.hydrocarbonprocessing.com/magazine/2018/august-2018/special-focus-fluid-flow-and-rotating-equipment/high-pressure-water-pump-mechanical-seal-failure-investigation.
[73] Chibani, Achref. “The Costs and Benefits of Water Desalination in the Gulf.” Arab Center Washington DC, April 12, 2023. https://arabcenterdc.org/resource/the-costs-and-benefits-of-water-desalination-in-the-gulf/.; Linden, Olof, Arne Jernelöv, and Johanna Egerup. “The Environmental Impacts of the Gulf War 1991.” International Institute for Applied Systems Analysis, April 2004. https://core.ac.uk/download/pdf/33898896.pdf.
[74] Rajput, Prashant Hari Narayan, Pankaj Rajput, Marios Sazos, and Michail Maniatakos. “Process-Aware Cyberattacks for Thermal Desalination Plants.” In *Proceedings of the 2019 ACM Asia Conference on Computer and Communications Security*, 441–52. Asia CCS ’19. New York, NY, USA: Association for Computing Machinery, 2019. https://doi.org/10.1145/3321705.3329805.
[75] Kramer, Isaac, Yaara Tsairi, Michael Buchdahl Roth, Alon Tal, and Yair Mau. “Effects of Population Growth on Israel’s Demand for Desalinated Water.” *Npj Clean Water* 5, no. 1 (December 27, 2022): 1–7. https://doi.org/10.1038/s41545-022-00215-9.
[76] Boubaker, Khobeib Ben. “Water Industry: A Look Back at Twenty Years of Cyber Attacks.” *Stormshield* (blog), August 30, 2021. https://www.stormshield.com/news/twenty-years-of-cyber-attacks-on-the-world-of-water.; Times of Israel. “Cyber Attacks Again Hit Israel’s Water System, Shutting Agricultural Pumps,” July 17, 2020. https://www.timesofisrael.com/cyber-attacks-again-hit-israels-water-system-shutting-agricultural-pumps/.; Tuptuk, Nilufer, Peter Hazell, Jeremy Watson, and Stephen Hailes. “A Systematic Review of the State of Cyber-Security in Water Systems.” *Water* 13, no. 1 (January 2021): 81. https://doi.org/10.3390/w13010081.
[77] Farr, Andrew. “High Tech, High Stakes: How Vulnerable to Cyberattacks Is U.S. Water Infrastructure?” April 11, 2022. https://waterfm.com/how-vulnerable-to-cyberattacks-water-infrastructure/.
[78] Wéber, Richárd, Tamás Huzsvár, and Csaba Hős. “Vulnerability Analysis of Water Distribution Networks to Accidental Pipe Burst.” *Water Research* 184 (October 1, 2020): 116178. https://doi.org/10.1016/j.watres.2020.116178.
[79] “Yemen Houthis Attack Saudi Energy Facilities, Refinery Output Hit.” *Reuters.* (March 20, 2022). https://www.reuters.com/world/middle-east/saudi-led-coalition-says-four-houthi-attacks-hit-targets-kingdom-no-casualties-2022-03-19/.
[80] Jones, Seth G., Joseph S. Bermudez Jr, Danika Newlee, and Nicholas Harrington. “Iran’s Threat to Saudi Critical Infrastructure: The Implications of U.S.-Iranian Escalation,” *Center for Strategic and International Studies*. (August 5, 2019). https://www.csis.org/analysis/irans-threat-saudi-critical-infrastructure-implications-us-iranian-escalation.
[81] Koshiw, Isobel. “Russia Carries out More Mass Strikes on Ukraine’s Energy Infrastructure.” *The Guardian.* (December 16, 2022). https://www.theguardian.com/world/2022/dec/16/russia-begins-mass-air-strike-in-apparent-move-to-destroy-ukraines-power-grid.
[82] Diaz-Maurin, François. “Why the World Must Protect Nuclear Reactors from Military Attacks. Now.” *Bulletin of the Atomic Scientists* (blog). (December 15, 2022). https://thebulletin.org/2022/12/why-the-world-must-protect-nuclear-reactors-from-military-attacks-now/.
[83] Jones, Seth G., Joseph S. Bermudez Jr, Danika Newlee, and Nicholas Harrington. “Iran’s Threat to Saudi Critical Infrastructure: The Implications of U.S.-Iranian Escalation,” *Center for Strategic and International Studies*. (August 5, 2019). https://www.csis.org/analysis/irans-threat-saudi-critical-infrastructure-implications-us-iranian-escalation.; Kennedy, Michael J., Melissa Healy. “Iraqis Torch Scores of Oil Facilities in Kuwait: Gulf War: At Least 150 of the Emirate’s Wells Are Set Ablaze. Allies Continue to Hammer Enemy Forces.,” *Los Angeles Times.* (February 23, 1991). https://www.latimes.com/archives/la-xpm-1991-02-23-mn-1492-story.html.

[84] DeNicola, Erica, Omar S. Aburizaiza, Azhar Siddique, Haider Khwaja, and David O. Carpenter. "Climate Change and Water Scarcity: The Case of Saudi Arabia." *Annals of Global Health*, Climate Change, Global Health and Human Rights, 81, no. 3 (May 1, 2015): 342–53. https://doi.org/10.1016/j.aogh.2015.08.005.; Sage-Passant, Lewis. "Water Security: The Fragile Desalination Infrastructure of the Arabian Gulf." *Encyclopedia Geopolitica* (blog). (September 6, 2018). https://encyclopediageopolitica.com/2018/09/06/water-security-the-fragile-desalination-infrastructure-of-the-arabian-gulf/.
[85] Busby, Joshua. "Water and U.S. National Security." Council on Foreign Relations, 2017. https://www.cfr.org/sites/default/files/pdf/2017/01/Discussion_Paper_Busby_Water_and_US_Security_OR.pdf.
[86] Feng, Bree. "Water Desalination Grows in China." Chemical & Engineering News, October 20, 2014. https://cen.acs.org/articles/92/i42/Water-Desalination-Grows-China.html.; Reuters. "China Makes Desalination Push to Ease Water Scarcity." *Reuters*, June 3, 2021, sec. China. https://www.reuters.com/world/china/china-makes-desalination-push-ease-water-scarcity-2021-06-02/.; Wines, Michael. "China Takes a Loss to Get Ahead in the Business of Fresh Water." *The New York Times*, October 26, 2011, sec. World. https://www.nytimes.com/2011/10/26/world/asia/china-takes-loss-to-get-ahead-in-desalination-industry.html.
[87] Council on Foreign Relations. "China's Massive Belt and Road Initiative." https://www.cfr.org/backgrounder/chinas-massive-belt-and-road-initiative.
[88] "Fragile States Index | The Fund for Peace." https://fragilestatesindex.org/.
[89] Ibid.
[90] "Fragile States and Conflict," March 27, 2010. https://www.crisisgroup.org/global/fragile-states-and-conflict.
[91] Lamb, Evelyn. "Ask Gini: How to Measure Inequality." Scientific American. https://www.scientificamerican.com/article/ask-gini/.; "Glossary | DataBank." https://databank.worldbank.org/metadataglossary/gender-statistics/series/SI.POV.GINI.
[92] World Bank Open Data. "World Bank Open Data." https://data.worldbank.org.