Desalination in the United States: A Sustainable Solution for Water Scarcity

By Dr. Jeff Kleck

Desalination is emerging as a critical technology to address the growing challenges of water scarcity in the United States. With increasing demand for freshwater due to population growth, industrial needs, and climate change, desalination offers a viable solution for augmenting the water supply. However, the widespread adoption of desalination requires an in-depth understanding of its costs, energy requirements, and regulatory landscape. This paper explores the economic and operational dimensions of desalination, focusing on freshwater demand, desalination costs, energy production, and regulatory considerations.

The Cost of Fresh Water and Water Demand:

Freshwater availability is becoming a pressing concern across the United States, with regions such as California and the Southwest experiencing severe droughts. The average cost of freshwater varies depending on location and source, with the national average cost for commercial and residential being $5.56 and $6.64 per 1,000 gallons respectively in 2023. The increase in cost of water has consistently outpaced the Consumer Price Index (CPI) since 2000 with some of the most extreme inflation in the last few years, and projections show no sign of a trend reversal.

According to the USGS, the three largest sectors of water use by withdrawals—water removed from available supplies—are thermoelectric power (41%), irrigation (37%), and public supply (12%). However, the USDA reports that agriculture accounts for 80–90% of consumptive water use, meaning the withdrawn water is not returned to its source. A significant portion of this water is embedded in agricultural goods that are exported abroad, resulting in a transfer of U.S. water resources to other countries. Additionally, several emerging industries—including artificial intelligence computing, hydrogen production, and rare earth materials processing—are highly water-intensive and could further reshape national water use patterns as they mature and scale.

The upward pressure on the price of freshwater from demand and the downward pressure on the price of desalinated water from innovation means that should trends continue, desalinated water will become as economical an option as freshwater.

References and Data Sources:
EPA Watersense, 2023; LBNL Keeping Pace With Water and Wastewater Rates, 2017; USGS Water Resource Mission Area, 2019; USDA Water Conservation in irrigated agriculture: Trends and Challenges In The Face of Emerging Demands, 2012

Costs of Desalinated Water:
There are two main kinds of water to desalinate: brackish water and sea water. Brackish water is cheaper to desalinate because it contains less salt. However sea water is more readily available and desalinating it has less environmental impact.

Typical Cost Distribution for a ~100,000 m³/day seawater reverse osmosis (SWRO) Desalination Project

Cost Category for SWRO	Percent of total cost
Capital (Construction, Financing, Depreciation)	35 – 45
Energy	30 – 40
Membrane Replacement	5 – 10
Chemicals (Pretreatment, Cleaning, Post-treatment)	5 – 10
Maintenance, Labor, and Other O&M	5 – 10

Note: This represents a hypothetical location with ~ 0.08 USD/kWh to 0.10 USD/kWh energy prices

The DOE determined the “practical minimum” energy consumption for seawater reverse osmosis (SWRO) to range from 5.67 kW per 1,000 gallons to 7.56 kWh per 1,000 gallons by assuming that a selected group of current (to 2017) R&D advancements were implemented into facility designs. In comparison, the “Current Typical” energy consumption was 11.34 kWh per 1,000 gallons to 15.12 kWh per 1,000 gallons. Because energy costs typically constitute 30-40% of the cost of desalinating water, this cost reduction from improving energy efficiency would result in an average 15-20% reduction in desalination cost.

Currently (2022), the DOE assumes a cost range of 3 USD to 6 USD for desalinating 1,000 gallons of water with SWRO for a properly scaled facility. Assuming the national average cost per kWh of 0.1261 USD in 2024, these energy reductions would result in an average cost savings of 0.71 USD to 0.95 USD per 1,000 gallons, making desalinated water cost competitive to freshwater which was sold to consumers at a national average of 5.56 USD and 6.64 USD per 1,000 gallons for commercial and residential respectively in 2023.

Energy production is fundamental to the economic feasibility of desalination, given its high power demands. Co-siting desalination facilities with small modular reactors (SMRs) offers a stable baseload power supply, enabling independent operation on a microgrid thereby removing the need to purchase power from a centralized grid. Additionally, using seawater for reactor cooling eliminates the need for separate cooling water and warms the seawater, reducing its viscosity and lowering the energy required for desalination. A Stanford University assessment of a California nuclear plant slated for decommissioning found that continuing operations to power a co-sited desalination plant could significantly reduce the cost of desalination compared to California's main desalination facility in Carlsbad, which purchases electricity from the grid.

References and Data Sources:
McGraw-Hill Professional Desalination Engineering: Planning and Design, 2013; DOE Bandwidth Study On The Use And Potential Energy Savings Opportunities In U.S. Seawater Desalination Systems, 2017; DOE Marine Energy & The Blue Economy, 2022; Stanford An Assessment Of the Diablo Canyon Nuclear Plant for Zero-Carbon Electricity, Desalination, and Hydrogen Production, 2021

Regulatory Environment
The regulatory landscape plays a key role in the viability of desalination. Local regulation affects the cost of power as well as the time and money needed to get a plant constructed. An example of this can be seen in the building of the United States' two major SWRO plants, the Claude "Bud" Lewis Carlsbad Desalination Plant in Carlsbad, California and the Tampa Bay Seawater Desalination Plant in Tampa Bay, Florida.

Construction timelines and costs:

1. Tampa Bay (Florida) Seawater Desalination Plant:
   1999-2003 (4 years), Request for proposals to facility completion date. Cost 184.12 million USD inflation adjusted to 2025.

2. Claude "Bud" Lewis Carlsbad (California) Desalination Plant:
   1998-2015 (17 years), Poseidon Resources (now Poseidon Water) meets with the city of Carlsbad for feasibility discussions to the facility completion date. Cost 761.98 million USD inflation adjusted to 2025.

Although the Florida facility has half the capacity of the California facility, ignoring economies of scale and doubling the Florida facility cost to account for this difference still results in only 48% of the California facility's cost. Additionally, the Florida facility was completed in less than a quarter of the time required for the California facility. While there was a four-year delay between the Florida facility's completion and its full-scale commercial operation - largely due to contractor-related technical issues - the Florida facility was operational before ground was broken on the California facility. Further, it was completed at a significantly lower capacity-adjusted price. California's regulatory burden is now so significant that there are plans in San Diego to build a new desalination plant in Rosarita Beach, Mexico, to circumvent California's regulatory environment. Regulation is also present as a hidden cost in other desalination inputs, such as electricity.

References and Data Sources:
Water World Tampa Bay Seawater Desalination Project - An Unfinished Story, 2003; DBIA Claude "Bud" Lewis Desalination Plant, 2016; EIA US Electricity Profile, 2023; Voice Of San Diego Border Report: Rosarito Desal Plant Could Finally Get off the Ground, 2024

Conclusion:
The availability of freshwater remains relatively stagnant, while demand continues to rise with no signs of slowing. As a result, water prices and water rights are becoming increasingly significant issues. Since extracting more water from the environment is not a viable long-term solution, desalination appears to be an inevitable component of future community water strategies. Failure to meet community water needs could lead to various consequences, such as limiting population growth, restricting the development of public green spaces, or hindering water-intensive industries.

For more information on desalination technologies and their role in addressing water scarcity, please contact Dr. Jeff Kleck at Jeff@OpenPowerEnergy.Net.

Citations:

- EPA: Watersense, 2023
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