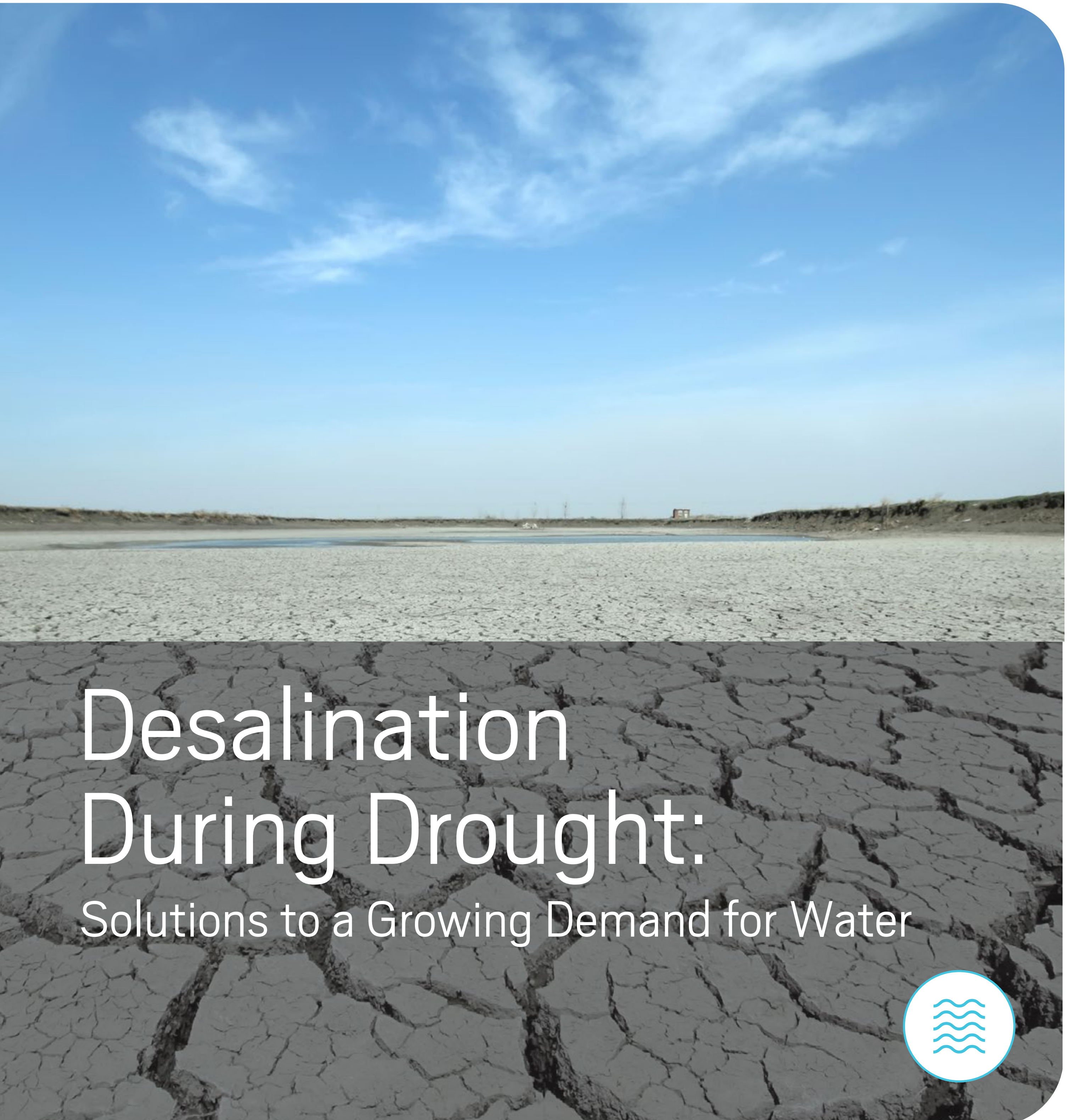

Desalination During Drought:

Solutions to a Growing Demand for Water

energy recovery™

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Executive Summary

Clean drinking water is fundamental to all life. As 2015 marks the end of the United Nations' International Decade of Action recognizing water and sanitation as a basic human right, it also marks the beginning of a new era of water supply and usage across the state of California.

Since a statewide drought began four years ago, California lawmakers have struggled to find rainfall-independent solutions. This is not the first time California has turned to desalination as part of a larger plan to tackle decreasing water levels and drought conditions. The multiple-year drought in the 1980s led to the construction and opening of the Charles E. Meyer Desalination Plant in Santa Barbara. When rainfall returned just three months after the plant opened, the facility was mothballed. Forward-thinking experts kept up plant maintenance in the meantime, knowing it would not be the last time such measures would be considered or implemented.

There are also costs and other types of resource usage issues to consider. For instance, much of Southern California's drinking water travels hundreds of miles from its origin in the Colorado River, transported using a massive and expensive aqueduct and conveyance system. With this current drought comes an opportunity to revisit tabled solutions and better prepare future plans to make desalination part of a larger framework to continue to keep California watered.

Desalination is not a silver bullet. But technology has improved the process and subsequently lowered the cost. Stuart White, director of Sydney, Australia's Institute for Sustainable Futures, has called the need to plan for future plants "desalination readiness." In Australia, as in many other arid, desert-like parts of the world, desalination has become a necessary and useful part of a plan to increase water resiliency and drought preparedness. The capacity of large desalination plants is quantified by how many millions of gallons of water per day (MGD) the plant produces, with Sorek, the world's largest seawater reverse osmosis plant located south of Tel Aviv, producing 165 MGD. The largest desalination plant using membrane technology, which typically uses energy recovery devices, is Magtaa in Algeria, with a capacity of 132 MGD.

In the following pages, we'll consider the success stories of desalination in California coastal cities, in Israel, and in Perth, where desalination helped pull the Australian city back from the brink of disaster during a decades-long drought. We'll also look at other examples that circle the globe. Spain recycles 17 percent of its effluent, the second highest percentage world-wide after Israel, which treats 86 percent of its wastewater and irrigates more than half its crops with treated effluent. Domestically, states with desert climates, including Texas, are considering adding desalination plants to their resource management portfolio as a way to stay ahead of disaster and move ahead with progressive, affordable technological solutions to an age-old problem.

Introduction

California is the nation's most populous state and the third largest state by area, with 38 million residents spread across nearly 164,000 square miles. Already, the state oversees a complex system of complementary technologies and processes that collect, treat, and distribute clean water across the entire state. This solution set includes mountain runoff to rivers and lakes, groundwater pumped from aquifers, recycled gray water, storm-water capture, and a variety of conservation efforts. Across the state, cities have issued moratoriums on lawn watering, swimming pool levels, frequent car washes, and other water-intensive activities and industries.

Clean drinking water requires energy, no matter its source. The costs include transport, treatment and purification, distribution, and residuals management and disposal. California's agriculture sector demands much of the state's arid land and an estimated 80 percent of the state's developed water supply. But the problem in managing the state's agricultural water use is unusually complex. According to an April 2015 report from the Pacific Institute, a major challenge in California involves the lack of reliable, robust water use data. For example, even though the California Department of Water Resources generates estimates of agricultural water use that are used by the state for long-term planning efforts and budgeting, these estimates are not based on observed or measured usage. "Data on agricultural production and water use are not collected at all, or are collected by individual irrigation districts, counties, and a variety of state and federal agencies using a range of tools from voluntary reporting at the field level to remote sensing from satellites," the report's author, Heather Cooley, wrote. "In order to truly understand the risks and opportunities for water use in California, more and better data are needed."

A drought is even more costly to the state. A 2015 study by the University of California, Davis, found that in 2015 alone, the drought would cost the state's agriculture sector $2.7 billion and upwards of 18,000 jobs. These aren't mere projections. This current drought has forced the state of California to come to a critical turning point in assessing how it will move forward with the tools necessary to survive this drought, as well as others that will surely follow.

Desalination, as is explained in a later section, uses a relatively simple process to make use of one of California's most abundant and obvious resources: the Pacific Ocean.

California Drought: A Brief History

California's conflicts between its arid climates and water-reliant industries and urban areas are the stuff of legend. In 1974, water scarcity was the stuff of Hollywood neo-noir, a plot device in Chinatown, a fictional film about the real-life California Water Wars. Desalination may make for fine filmmaking, but the state's precarious relationship with water is serious business. California's semi-arid regions depend upon mountain snowfall and accumulation and the resulting runoff to replenish groundwater and to fill rivers and streams and, by extension, reservoirs.

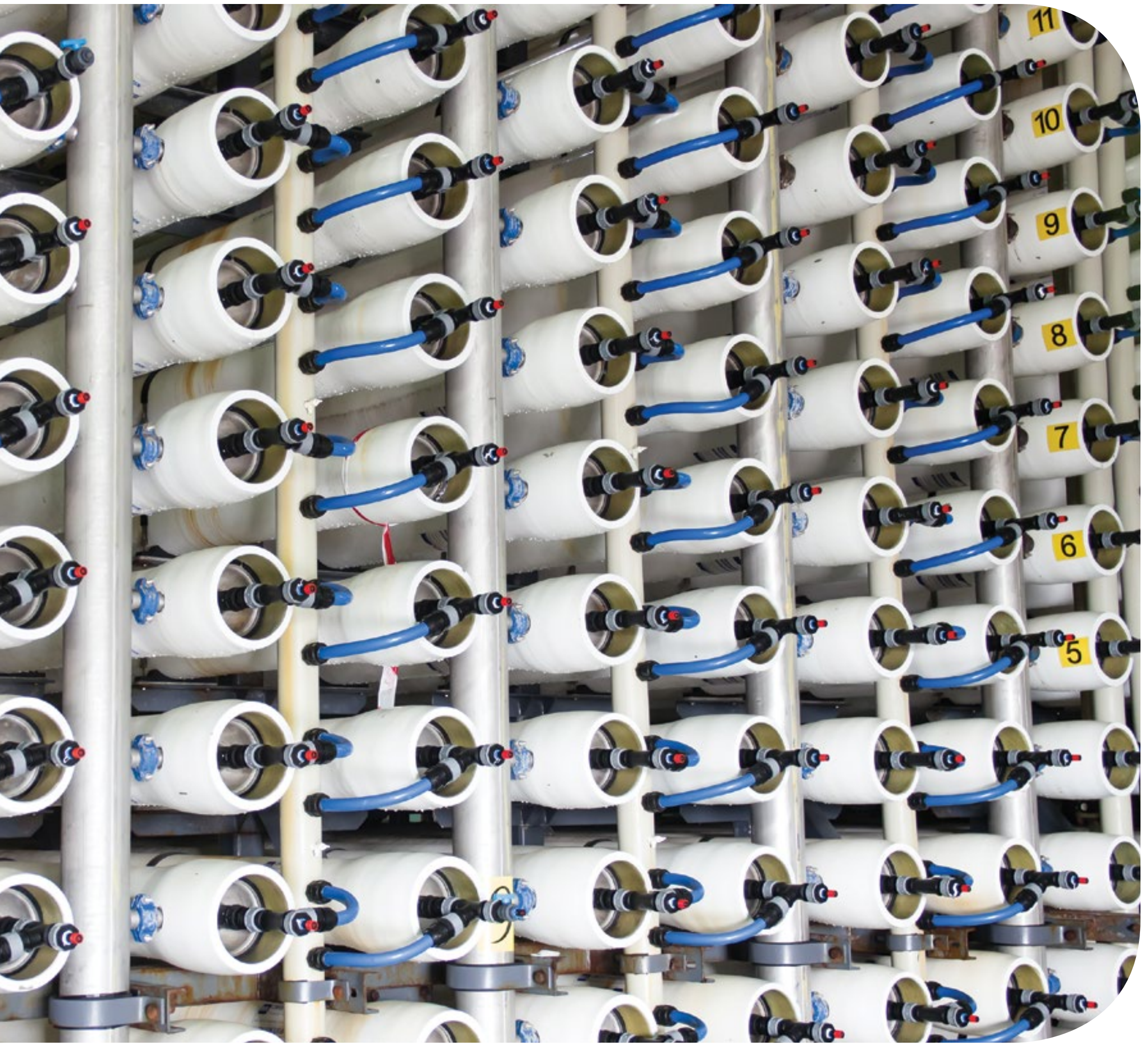
This latest is the worst drought in 163 years, though the area now known as California did experience two mega-droughts in an earlier era. The first, which began in the year 850, lasted for a whopping 240 years. Fifty years after the first mega-drought finally ended, another 180-year drought choked the region.

California has experienced a number of droughts in the past half century, including spans from 1976 to 1977 and 1987 to 1992. Constructed in 1963, the California Aqueduct system altered the landscape for farmers in the Central Valley. Despite its bounty of agriculture, the Central Valley is a semi-arid climate. The region receives an average of just 10 inches of rain per year.

Statewide, Californians use a similar amount of water as residents did in the 1970s, meaning despite our greater numbers, our overall usage per capita has decreased and efficiency has improved. But we're still taxing the system. California receives an average of 22 inches of rainfall annually, which translates to roughly 60 trillion gallons. In 2013, California received the least annual rainfall in any year since it became a state in 1850. In the four-year period from July 2011 to June 2015, California received the equivalent of one year's worth of rain. Between 1971 and 2000, California's average total precipitation was 22.2 inches.

In August 2014, Jay Famiglietti, senior water cycle scientist at NASA's Jet Propulsion Laboratory and a professor at the University of California, Irvine, noted that most top water experts—including Governor Jerry Brown's state drought manager—believe water reserves will run dry within the next two years. In December 2014, Famiglietti told the Los Angeles Times, "We need 11 trillion [gallons of water] just to get back to our normal, dry conditions."

More recently, scientists have compared this current three-year drought with the seven-year Dust Bowl of the 1930s, when millions of Americans left drought-stricken farms in the Midwest and South and relocated to California. This comparison is particularly striking given that historically, most of the nation's produce was cultivated in the areas impacted by the Dust Bowl. Today, California is the nation's leader in production. Golden State farmers produce more than two-thirds of the nation's fruit and nuts and more than a third of its vegetables.



The drought doesn't just impact the food and drinking water supplies. Natural ecosystems already suffering when water is diverted for municipal or agricultural use are taxed with an extra burden during a severe drought. During a drought, because soil moisture is reduced and dry brush can catch fire more easily, wildfires are often more frequent and severe. These emergencies further deplete water reserves, further taxing an already fragile system. Wildfires also cost the state millions in resource consumption and untold amounts in lost tourism dollars when, for example, state and national forests burn. The domino effect is unstoppable.

Asking consumers to cut back on their water usage has been effective in the short term. But as we've seen in the past few years, reducing the state's overall water consumption is simply not enough.

Why Desalination?

California has been moving toward adopting desalination on a wider scale for well over a decade. After it was placed on the ballot in 2002, Proposition 50 was passed into law, allowing state officials to borrow $3.44 billion through the sale of general obligation bonds in order to fund water projects, including water management, disinfection, and desalination. The Department of Water Resources was tasked with creating the California Desalination Task Force in order to streamline recommendations on the use of seawater, estuarine water, and brackish groundwater desalination as part of a comprehensive plan to keep the state from the brink of a water-related disaster. Since then, desalination has been included in the California State Water Plan with funds allocated by Proposition 50 to test and build desalination plants along the state's lengthy coastline.

Desalination solves several key problems that plague other means of bringing water into the state. Much of the state's urban water use comes with a high transport cost. For example, the majority of Southern California's water comes from the Colorado River by way of a massive, expensive aqueduct and conveyance system known as the State Water Project. Imported water is expensive, and it comes with both an unpredictable price tag and unpredictable supply fluctuations. For example, regulations governing the operations of the various pumps that keep the aqueduct running require that water stop flowing south when certain species are present in the water, which means the agriculture districts and water agencies that get their water from the State Water Project rarely get the volume they expect.

Meanwhile, the state's groundwater reserves are being overdrawn. Until 2014, California was the only Western state without legislation about groundwater pumping and usage. Excessive, unregulated deep drilling into groundwater aquifers up to 2,500 feet below the surface is literally drying up the Central Valley's remaining water sources and also pushing the limits of the surrounding land, which can sag when aquifers shrink. Some estimates suggest that of the 125 million acre-feet of Central Valley groundwater depleted in the past century, 20 million acre-feet of that loss occurred in the past decade. The state's new groundwater regulation, which will put limits on groundwater use and require some amount of reporting, won't go into effect until 2020. Furthermore, many believe it will do little to protect groundwater reserves.

By contrast, ocean water is abundant and not reliant on weather or ground conditions. Pilot programs often test the most difficult operating conditions to ensure a desalination processing plant's maximum efficiency. Perhaps most important, desalination comes with a fixed price. The initial cost to build a desalination plant can be high, but the savings over time make desalination a solid value proposition for the parched state that cannot rely on stable transport costs or other methods of importing water that have unpredictable, highly variable associated costs.

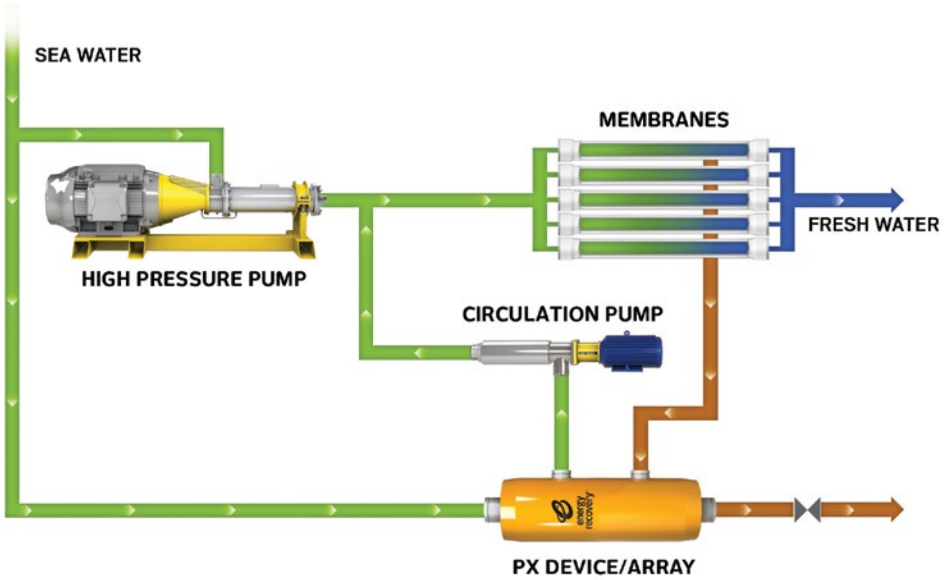
A 2012 report by the Virginia nonprofit WateReuse found that for California residents, the average residential monthly charge for drinking water was $36.39 per 1,500 cubic feet of water, or about $3.24 per 1,000 gallons. At that time, water imported from the Bay Delta and Colorado River cost $2.45 per 1,000 gallons, with projections that the cost would increase an additional 15 percent by 2015 due to additional expenditures needed to comply with water quality regulatory requirements. By contrast, desalination-produced drinking water was estimated to cost between $2.91 and $3.70 per 1,000 gallons. Desalination plants built along the coast would serve a majority of California residents, who live within an hour's drive of the Pacific Ocean. That doesn't even include the potential for inland desalination plants that could process estuarine and brackish groundwater.

A 2013 study conducted by the California Department of Water Resources found that the cost of desalinated seawater starts at roughly $2,000 per acre-foot, or half the amount of water a California family of five uses in a given year. However, the long-term, cost-saving proposition offered by desalination plants could not only save the state millions in emergency funding for this current drought, which stretches into the future without an end date, but also provide emergency backup in the future should the water crisis deepen.

Despite being relatively new in California and in the United States, desalination has been a reliable, proven solution for several decades in arid coastal regions around the world, including areas experiencing drought or other water shortages. There are currently more than 21,000 desalination facilities operating in more than 120 countries, including India, China, and Australia. Saudi Arabia relies on desalination for more than 70 percent of its drinking water. Every single day, the combined output of desalination facilities around the world is more than 3.5 billion gallons of potable water.

How Desalination Works

Many modern desalination plants, including large ones like the new Carlsbad Desalination Plant and smaller facilities like Sand City, use a multi-step conversional process known as reverse osmosis (RO) or seawater reverse osmosis (SWRO). In SWRO, raw seawater is pumped through filters into holding tanks before being highly pressurized and pushed through a semi-permeable membrane, which separates water molecules from salt and other solid matter, rejecting 99+% of the salts. The remaining water molecules are pushed through and filtered into potable water. Every two gallons of seawater yield approximately one gallon of fresh drinking water. It is the same process bottling plants use to produce clean, safe drinking water from a wide range of sources.



Subsurface water intakes at coastal desalination plants minimize the amount of larvae, fish eggs, and other marine life captured in the seawater intake process. The brine by-product is sometimes, although not always, diluted with saltwater before it is returned to the ocean. The salt and minerals extracted from the process are not used for other purposes. It is important to note that as the quality of water in each region varies, so do desalination methods and their efficacy. The total cost of water processed at desalination facilities varies widely, heavily dependent on the cost of power to run operations. Costs also depend on whether the freshly processed water will replace existing water sources or act as an entirely new source for development and growth.

As stated previously, desalination plant capacity is typically measured in millions of gallons of drinking water produced per day (MGD). Plants such as Carlsbad are on track to produce 50 MGD. When operating at full capacity, desalination plants can run 24 hours a day, seven days a week, continuously producing clean, fresh drinking water. Reverse osmosis is not the only method for desalinating water, but it is the most energy-efficient desalination solution, and the energy necessary for the process has declined dramatically over the past four decades. Desalination plants offer enormous processing capacity. For that reason, they are becoming one part of a larger solution to supplying water to drought-impacted areas that need or demand it most.

How Energy Recovery Fits In

Part of what has made desalination more affordable and energy efficient over the past few decades has been the introduction of energy recovery devices, or ERDs.

Energy Recovery has patented the most widely used ERD, the PX Pressure Exchanger. The PX Pressure Exchanger captures hydraulic energy from the high-pressure reject stream of seawater reverse-osmosis processes and transfers this energy to low-pressure feed water. Our PX devices have only one moving part and are made of a high-purity, aluminum oxide ceramic that's corrosion-proof, three times as abrasion-resistant as steel. Because the PX consumes no electrical power, the overall energy consumption of the seawater reverse-osmosis process is significantly reduced.

Over two decades, Energy Recovery has earned a leading position in the global water market for the PX, with more than 15,000 devices operating on all seven continents, saving customers more than $1.4 billion every year.

This year, Energy Recovery will introduce the newest version of the product, the PX Prime. In the forthcoming version of the device, the company has improved performance across a variety of factors, including fluid mixing, energy efficiency, back pressure requirements, capacity, turndown, noise, and starting torque. All of these improvements add to the efficiency of the reverse osmosis process, making this a more economically viable solution to combat the ongoing drought.

Desalination During Drought: The Cases of Australia, Israel, Spain, and California

A number of nations and regions have relied on desalination plants as part of a larger emphasis on water resiliency and also to survive drought conditions. In the 1990s, Australia was in the midst of its worst droughts on record. Between 1997 and 2007, the city of Perth saw a 21 percent decline in rainfall. Flow to streams (and thus into storage) dropped 65 percent. When the Kwinana Desalination Plant opened in April 2007, it was the first of its kind in Australia. At the onset, it provided 40 MGD, which was then 20 percent of Perth's daily water consumption.

Desalination has since become a saving grace for the entire nation, especially in Australia's densely populated coastal cities. At capacity, the Sydney plant generates more than 66 MGD, providing 15 percent of Sydney's water supply. A second Perth plant, the Southern Seawater Desalination Plant, located south of Perth in Binningup, went online in 2011 and was operating at full capacity by 2013. Annually, it provides Perth with more than 26 million gallons of drinking water. The plants at Perth—as well as major plants including the Adelaide facility, the Cape Preston plant in Western Australia, and the Victorian Desalination Plant that serves Melbourne—also happen to use Energy Recovery's PX Pressure Exchanger devices.

Spain, the world's eighth-largest economy and the fastest growing in the European Union, offered a home to Europe's first desalination plant in 1964, located on Lanzarote in the Canary Islands. By the mid-2000s, Spain became the fourth-largest user of desalination technology worldwide after Saudi Arabia, Kuwait, and the United Arab Emirates; it proved a critical benefit during the drought that hit the country hard in 2005. But the benefits of desalination plants in Spain have gone well beyond serving more than 8 million residents with water per day. They have enabled the country's historically parched Mediterranean coastal region to thrive and become the nation's agricultural breadbasket.

In just a decade, Israel has also used desalination to quietly, but effectively, turn its water woes into a revolutionary surplus. The small nation now relies on desalination for nearly half of its drinking water. Israeli plants, most of which use the PX Pressure Exchangers, have come with hefty price tags upwards of $300 million but operate with such high levels of energy efficiency that they are some of the most cost-efficient in the world. Owing to their expertise, Israeli engineers have been asked to advise on numerous California projects, including Carlsbad.

The Sand City, California, facility can act as a small-scale model for larger plants. Built in 2007 for a total of $14 million, the Sand City plant uses PX Pressure Exchangers and is uniquely positioned along an area of the coast that traps seawater in a freshwater coastal area, naturally diluting the salt levels and offering an intake water supply that, due to its lower salt content, requires less energy to filter into clean drinking water.

Carlsbad and New Plants

The new Carlsbad Desalination Plant is ideally located with proximity to the ocean and co-located with the Encina Power Station. The plant will utilize Energy Recovery's PX-Q300 pressure exchanger, and the intake pump station delivers 100 MGD of seawater to the plant. Half of all the water processed by the plant will be converted to drinking water, accounting for 7 to 10 percent of San Diego County's drinking water, with service to more than 300,000 residents. After it goes through the reverse osmosis process, the remaining 50 MGD of brine will be put back into a channel and further diluted with seawater prior to its release back into ocean. This additional measure protects the local marine life and keeps the bay healthy and resilient. As it currently stands, the $1 billion Carlsbad plant is slated to be online by the end of 2015.

Carlsbad is just one of several major projects underway in the state. A dozen California coastal communities are currently considering desalination plants or are in the early stages of moving forward to approve construction and operations. Among them, the proposed Monterey Peninsula plant, which comes with a $320 million price tag, will alleviate the region's thirst for a more robust water supply. Just north up the coast, Cambria opened a small desalination plant in November 2014 to serve its surrounding community.

Dusting Off Mothballed Plants

California has considered desalination as part of a drought solution for several decades. In the late 1980s and early 1990s, the city of Santa Barbara spent $35 million to build a desalination plant that finally went online in 1992. But when rainfall returned three months after construction was completed, the facility was mothballed, never given a chance to demonstrate its filtration power. Its filters were sold to Saudi Arabia. In the decades since, forward-thinking executives kept up scheduled maintenance on the plant.

The Santa Barbara plant may have been online only a short time, but it helped support the case that converting seawater into clean drinking water is an efficient process that can be a relatively simple and ultimately necessary part of a broad, strategic plan to combat prolonged drought conditions. In May 2014, the Santa Barbara City

Council authorized a contract for $746,025 for preliminary design services to reactivate the plant. The construction contracts are scheduled to be awarded in the summer of 2015, with a full timeline still pending as to when the plant could come back online. When it does, it will provide up to 30 percent of Santa Barbara's drinking water.

Many plants are somewhere between proposal and completion, and several others, like the Santa Barbara facility, were built several decades ago and are simply waiting to be fully operational. The 10,000-resident town of Morro Bay offers another example of a SWRO plant pushed back online every time there's a water shortage. The plant was brought online in 1995, but its permits expired in 1999. The facility was then retrofitted for just over $1 million and now functions primarily—if intermittently—as a brackish water treatment facility. Another plant in the nearby town of Marina was built in 1997 for $7 million and later shuttered due to rising energy costs.

Local economies see a major infusion of cash by bringing these plants online. The San Diego County Water Authority (SDCWA) projects that the three-year Carlsbad construction project supported 2,500 local jobs, a figure that can be considered in projections for other future plants in California. There are three dozen desalination-related companies operating in San Diego County alone, employing several thousand people in a variety of jobs that contribute to the local, state, and federal economy.

Challenges

As the price of desalination decreases, and as the energy efficiency of the process increases, the barriers to implementing desalination as part of a comprehensive water supply solution significantly decrease.

As energy efficiency has increased, the concerns about the carbon footprint associated with desalination have also begun to evaporate. The most vocal and active opponents of coastal desalination plants in California have been environmental lobby groups such as the Sierra Club, nonprofit organization San Diego Coastkeeper (formerly San Diego Baykeeper, and part of the international Waterkeeper Alliance), and the Malibu-based nonprofit Surfrider Foundation. In the past, Surfrider campaigned to stop desalination plant construction, claiming that open ocean intakes and the discharge from cooling water intakes at coastal power plants can harm marine life because large fish become trapped in the intake screens, and small animals can be killed during the cooling process. But the foundation abandoned its legal challenges, mostly mounted in San Diego Superior Court, several years ago. The Carlsbad plant construction has continued on schedule.

More recently, groups like the California Coastal Protection Network (CCPN) have raised concerns about desalination being treated as a panacea rather than a last resort. The CCPN voices concerns but has not mounted any legal action.

In response to those concerns, agencies working together on desalination plant planning and construction have looked at ways to offset potential damage to the marine ecosystem. In particular, Carlsbad may serve as an example in the final push to move the Huntington Beach plant into the construction phase. The Carlsbad plant was approved to use open-water intake in exchange for a Poseidon-funded $23 million newly created 66-acre preserved wetland. This type of good-faith exchange could set an important precedent that other desalination plants could follow.

Some lawmakers still grudgingly agree with organizations like the CCPN, though they plan to forge ahead as desalination has attracted a relatively wide base of support and promises to combat the critical water shortages. For example, speaking about the Monterey facility, Carmel mayor and former associate deputy administrator at the Environmental Protection Agency Jason K. Burnett has called desalination the community's last resort.

Perhaps the biggest challenge in bringing desalination facilities online lies with the permitting, a lengthy process that the California Coastal Commission (CCC) can stretch out years before crews can even break ground. Permitting can be one of the biggest stumbling blocks, which is why expediting the process

is critical given current drought conditions. The decade-long debate over the proposed Huntington Beach plant next to the AES power plant reached a standstill when Poseidon Water withdrew its permit application at a November 2013 CCC meeting, with the option to redraw plans and resubmit at a later time. The San Diego permitting process took nearly a decade. And despite backing from the Scripps Institution of Oceanography, permitting for the Carlsbad plant was equally lengthy due to similar pushbacks from the CCC.

In order to reduce the environmental damage from overpumping, the state water board mandated that by the end of 2016, pumping from the Carmel River must be reduced by 70 percent.

Moving Forward

Since 2011, Californians have racked up an 11 trillion gallon water deficit. Governor Brown's proposed emergency drought and water infrastructure funding, which will fund a mix of short-term relief efforts and long-planned water management projects, earmarks up to $272.7 million from the $7.5 billion water bond approved by voters in 2014.

Construction and management companies continue to partner with local governments and work closely with the California Coastal Commission, which oversees the permitting processing.

Already, there have been several positive steps forward that benefit all involved parties. To neutralize the carbon footprint of the San Diego facility, Poseidon Water has offered to pay into a state program to fund projects that offset greenhouse gas emissions. Poseidon also funded a multimillion-dollar wetlands project to help offset the potential environmental damage the Carlsbad desalination plant could have on the area.

Even if the drought abates in the near future, California's water woes will not evaporate. California is already home to 38.8 million people, by 2014 estimates. The Census Bureau estimates that until at least 2050, California will continue to be the fastest-growing state in terms of population, by which time the population may reach 60 million people. Even by 2020, the state population is expected to reach 50 million.

Demands on the state's agriculture sector also continue to grow. Even if those desperate for water reduce their reliance on the water table, over-pumping groundwater can permanently alter the state of aquifers in which soil compaction reduces the space between clay particles, providing less room for groundwater.

It's crucial that as more information is made available about desalination plant energy use and environmental impact, the California governor's office will be able to respond quickly and effectively and focus on moving the state and its residents forward with the best possible water resource portfolio.

About Energy Recovery

Energy Recovery (NASDAQ:ERII) develops award-winning solutions that harness unused pressure energy to improve reliability and availability of industrial pumping systems. Our technology protects vulnerable equipment and saves substantial energy and maintenance costs for operators within the oil & gas, chemical, and water industries. With more than 16,000 devices worldwide, our products save clients more than $1.5 billion (USD) annually. Headquartered in the San Francisco Bay Area, Energy Recovery has offices in Shanghai and Dubai.

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