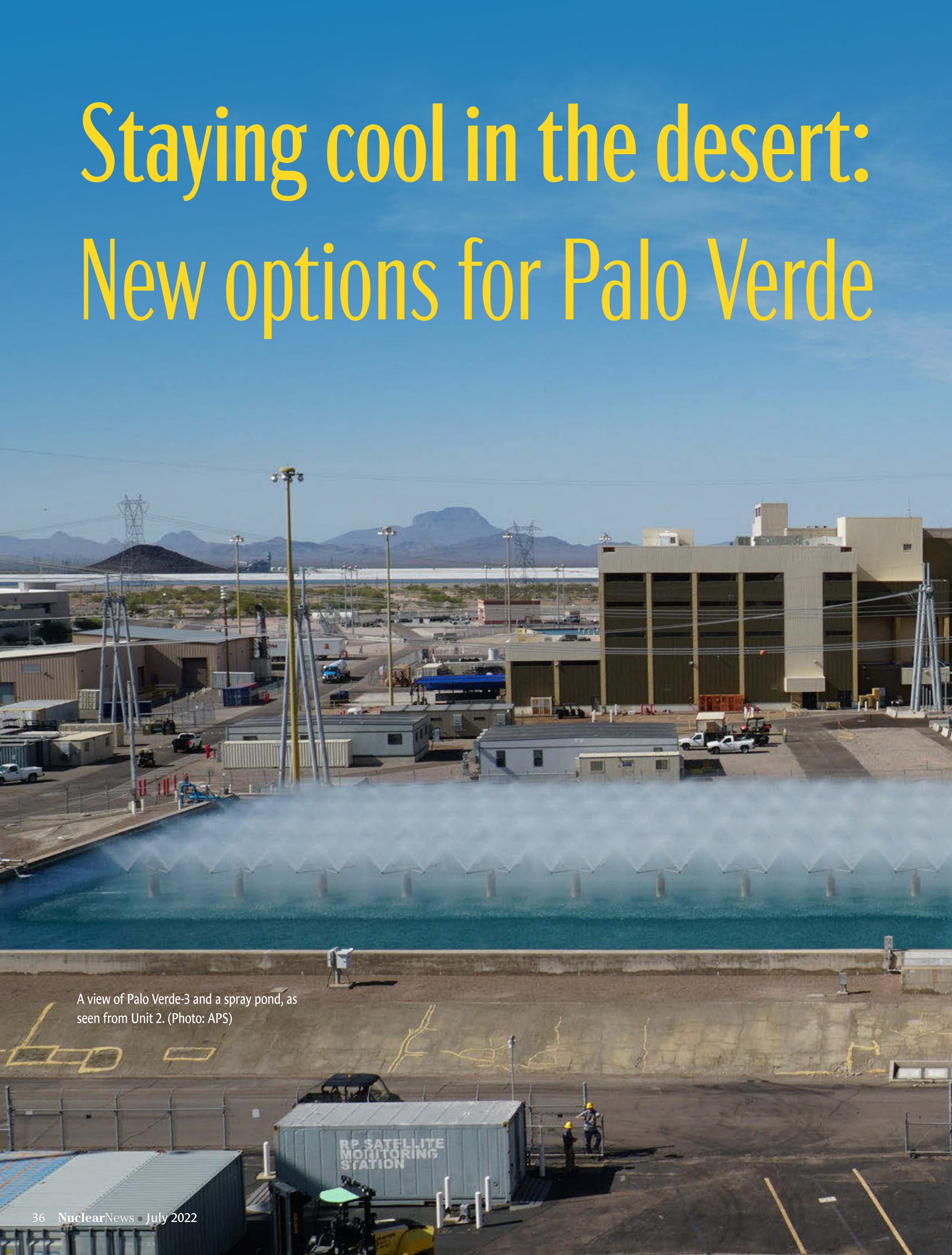
Staying cool in the desert: New options for Palo Verde



A view of Palo Verde-3 and a spray pond, as seen from Unit 2. (Photo: APS)

By Brad Berles

In the western part of Michigan, where I grew up and spent the early part of my career, water availability was rarely a concern or a topic that might appear in the news. Lake Michigan was a plentiful source of water, and Mother Nature always provided plenty of precipitation to keep things green. If anything, sometimes folks wished it would *stop* raining! So it was quite a big change in environment when in 2008 my career took me to the desert of Arizona and the Palo Verde Generating Station, with annual regional rainfall totals of three inches in a good year.

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An aerial view of the Palo Verde site, including two reservoirs (foreground) and evaporative ponds (background). (Photo: APS)

Palo Verde was constructed about an hour west of downtown Phoenix in the 1970s and 1980s: three 1400-MWe pressurized water reactors situated in the Sonoran Desert with no river, lake, or ocean in sight. Whereas all other nuclear plants have a body of water as a source of the cooling water necessary for the operation of a large generating station, Palo Verde had to come up with a unique method of obtaining water. The source turned out to be the 91st Avenue Wastewater Treatment Plant for the City of Phoenix, which is also supplied wastewater from the sewer systems of nearby Glendale, Mesa, Tempe, and Scottsdale. Additionally, the City of Tolleson supplies a small percentage of water to Palo Verde using the same systems. The treated effluent from these facilities is piped approximately 36 miles from the western Phoenix area to Palo Verde Water Resources (PVWR), located near the power plant in Tonopah. The route includes gravity flow in six miles of 114-inch pipe and 22.5 miles of 96-inch pipe to a pumping station, from which water completes the journey going uphill for eight miles in 66-inch pipe.

Once the water reaches PVWR, it goes through a softening process that adds lime, carbon dioxide, and soda ash in two-stage clarifier trains before additional filtering as the water reaches two large, lined reservoirs. The 45- and 85-acre reservoirs are essentially Palo Verde's lakes, providing more than one billion gallons of water for the three units, which is enough for 12 days of storage capacity in the hottest months of the year. The reservoirs are home to native waterfowl and some fish species, providing similar challenges to those most nuclear plants face in their cooling water makeup systems. From the reservoirs, the cooling water is pumped to the three units' circulating water systems, each consisting of three large cooling towers, which remove heat from the condensers. The makeup to the circulating water system, to account for water lost to the atmosphere, is roughly 18,000 gallons per minute (gpm) in the hottest months of the year; less is required during the cooler months. Water from PVWR is also sent to the nearby gas-fired Redhawk Generating Station, which like Palo Verde is operated by Arizona Public Service Co. (APS).

The table on the next page shows the benefits of the water softening process. While the softening process removes many chemicals that are harmful to the unit's condenser tubes, not all constituents can be treated. Chlorides and other chemicals that contribute to total dissolved solids (TDS) have operating limits that require a certain amount of circulating water to be blown down from the system to a group of evaporation

A clarifier at Palo Verde Water Resources. (Photo: APS)

Scale-Forming Constituents	Influent Quality (ppm)	Effluent Quality (ppm)
Alkalinity (as $CaCO_3$)	171	34
Calcium (as $CaCO_3$)	180	87
Magnesium (as $CaCO_3$)	137	28
Silica	17	4
Phosphate	11	< 0.3

ponds (remember, no river, lake, or ocean). These eight evaporation ponds provide 650 acres of surface area for evaporating water to the environment. Depending on the time of year, each unit will blow down between 500 and 800 gpm of water to the evaporation ponds. As the team at PVWR has improved chemistry, operating, and maintenance processes over the years, the cycles of concentration in the cooling towers continue to increase, averaging over 25 cycles in 2021. Currently, the same annual volume that is blown down is evaporated to the environment, preventing the need for additional evaporation ponds to be built.

Challenges in the Arizona water supply

As is widely known, the southwestern United States has been in extended drought conditions for a number of years. Lake Powell in northern Arizona has lowered to a point where real concern exists for continued operation of the 1320-MWe Glen Canyon Dam hydroelectric plant. The water levels have lowered to the point that restrictions in prior water agreements between the states supplied by the Colorado River have been implemented, directly impacting Arizona's water supplies. While these restrictions don't directly impact the supply of cooling water to Palo Verde, they certainly emphasize the importance of water to Arizona's growing population, its agricultural industry, and other businesses.

When Palo Verde was constructed over 35 years ago, the demand for treated effluent was low, and the cities participating in the agreement to supply treated effluent to Palo Verde were eager to have a demand for this water. Over the years, the use of treated effluent for golf courses, parks, and agriculture has grown considerably, and the value of that water has also increased. The initial water contract was intended for the original 40-year life of the plant, and when Palo Verde applied for a 20-year license extension from the Nuclear Regulatory Commission, the original water contract was renegotiated.

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Since 2010, Palo Verde's water costs have escalated at a rate of 10.5 percent per year. Beginning in 2026, Palo Verde will transition to a four-tiered water cost structure under which the water costs per acre-foot increase as more water is used in a month. Typically, seven months of the year will require some amount of water to be in tier 3 (about twice the 2021 water cost per acre-foot), with the remaining five months requiring water in the tier 4 price range (a 2.7-times increase over 2021). For reference, Palo Verde uses 70,000 acre-feet of water for cooling each year, and each acre foot is approximately 325,000 gallons. In 2021, annual water costs exceeded $12 million, and chemical costs for treating the water exceeded $9 million. Projecting forward to 2030, the cost of water is expected to double.

What options do we have?

Alternative sources of water in Arizona are not readily available or come with a lot of challenges. Over the years, Palo Verde has researched a number of ways to reduce water usage or obtain additional sources of water. In many cases, the cost of pursuing these opportunities outweighs the benefits from a financial perspective. However, in the ever-changing world of water in the Southwest, revisiting old ideas and listening to new ideas is a must. In addition, state and national governments are beginning to make funding sources available to help defray the cost increases that a private company or a local municipality may be facing.

Palo Verde's desire to explore potential solutions has led to a partnership with Sandia National Laboratories and the development of the Palo Verde Water Cycle Model. Using this tool, one can add or modify water sources (including volumes, chemical constituents, and costs), and the tool will provide the resulting changes in chemical usage/cost for water softening, blowdown rates from the cooling towers, and evaporation pond levels and will show the financial benefits or impacts from the change. Palo Verde is now using this model to evaluate different alternatives for decision-making purposes.

An option currently under evaluation is the use of dry cooling technology to supplement the existing wet cooling towers. Arizona's hot and dry environment makes dry cooling a challenge, when considering the size and cost of air-cooled systems. However, in 2021, Palo Verde and Sandia, utilizing a Department of Energy cost-share program, entered into an agreement to research the use of supercritical CO_2 as a cooling medium. The pilot system has been designed, construction has been completed, and testing is expected to begin in June 2022 just before this article reaches readers. After a number of months of data collection, the information will be analyzed for effectiveness of heat transfer and also electricity requirements under various environmental conditions. Using the results of

the analysis and the Palo Verde Water Cycle Model, an overall evaluation of the water savings, additional MWe gains through reduced circulating water temperatures, sizing, and costs can be completed. While the results are not currently known, we at Palo Verde are hopeful for a positive outcome.

Palo Verde is also considering the use of brine concentrate water from local municipalities as a source of water. The brine concentrate is a by-product of the groundwater reverse osmosis treatment some cities use for drinking water. However, the typical TDS value of the Palo Verde treated effluent supply is 900–1000 parts per million (ppm), and utilizing brine water to augment that would increase the chloride and TDS values and have downstream impacts on cooling tower chemical concentrations. With these impacts, additional blowdown volumes would challenge Palo Verde's evaporation pond capacities. Several enhanced evaporation technologies have been evaluated that would increase the rate of evaporation, providing an initial solution to the challenge. However, to further achieve plant goals of reducing overall water usage, Palo Verde is looking at water technologies that would treat the 27,000–30,000 ppm TDS blowdown water, recover a large percentage of high-quality water, and return it to the circulating water system.

Although current systems to address these challenges exist, companies and universities continue to research water treatment. With those potential advances in water recovery efficiency, future systems may prove to be more cost-effective while supporting water sustainability goals for Palo Verde and its owners.

While the ideas discussed in this article are the current areas of focus for Palo Verde, new ones are being identified and evaluated almost continuously. Taking a few minutes to listen to conceptual ideas or current products used elsewhere in the industry is always worth the time, while establishing and maintaining strong relationships with plant stakeholders in the community and in the water industry are also important. One never knows which email, text, or phone call may lead to the solution that saves thousands of gallons of water or millions of dollars annually. Water conservation is certainly a challenge, not only in Arizona but in the greater Southwest. PVWR is working to find solutions while remaining focused on the goals of supporting the generation of clean, reliable, and affordable electricity and reducing the water usage of Palo Verde, a resource that serves as the backbone to Arizona's sustainable energy future.

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Palo Verde Water Resources during a lunar eclipse in 2018. (Photo: APS)