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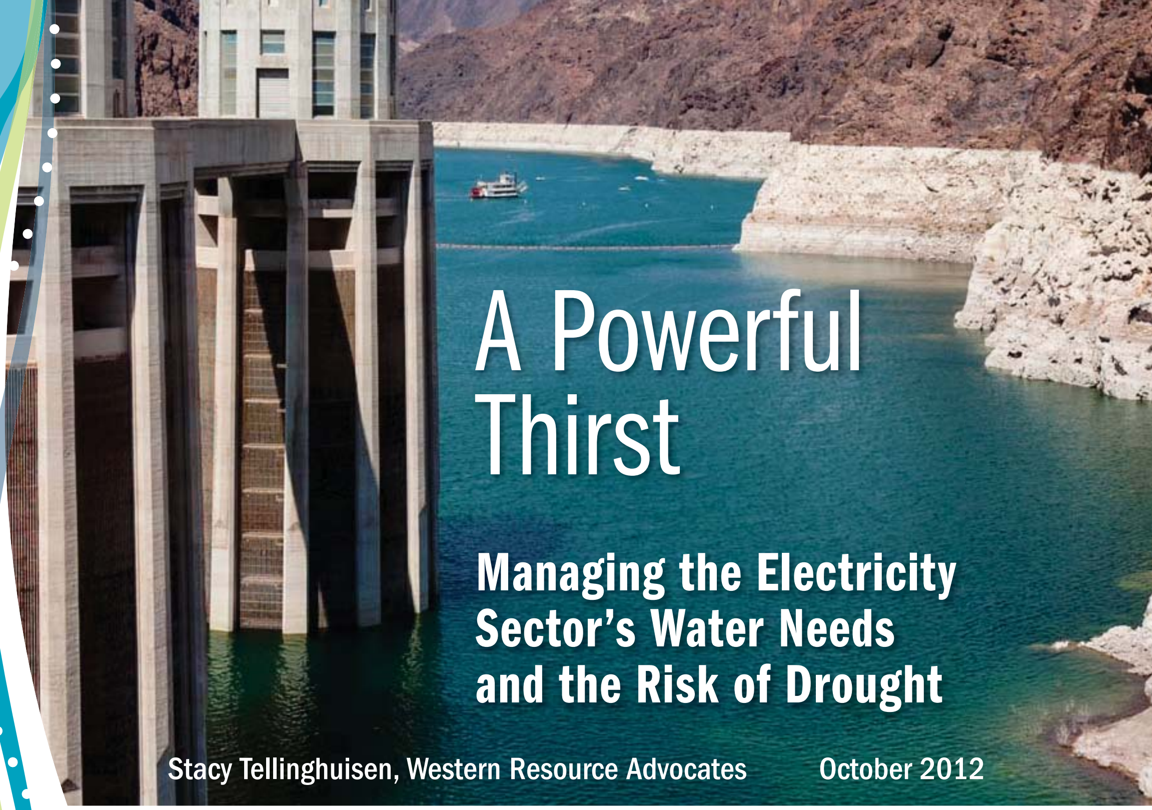

A Powerful Thirst

Managing the Electricity Sector's Water Needs and the Risk of Drought

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Hoover Dam. Photo: Shutterstock

Preparing for drought is essential. Electric utilities and regulators can take critical steps to better prepare for and mitigate the impacts of future droughts.

Drought has many impacts—it can reduce water supplies for urban areas, decrease crop yields in irrigated agriculture, and deplete stream flows. Recent droughts have had unexpected—and unprecedented—impacts on the energy sector, impacting both electricity demands and power plants' ability to meet them.

Preparing for drought is essential. Electric utilities and regulators can take critical steps to better prepare for and mitigate the impacts of future droughts. These steps include:

- Providing more comprehensive information about water use in utilities' long-term planning
- Valuing the water used for electricity generation, both today and in the future
- Analyzing the value of water-efficient renewable energy resources, energy efficiency, and dry-cooled power plants as a hedge against the risk of drought
- Acting upon the preceding steps

The drought of 2012 was unprecedented in many ways. As of September 25, 2012, drought affected over 65% of the continental U.S., the largest area affected since the 1950s (Figure 1). The entire Interior West was affected by some level of drought. While the drought has not (yet) affected power plants in the region, it has underscored the importance of preparing for—and managing—the risk of drought. This paper outlines how drought can affect the energy sector and describes the effects of drought on electricity generation in two recent case studies—Texas in 2011 and Australia from 2000 to 2010. We highlight how clean energy policies implemented in recent years in the Interior West have reduced water use by the energy sector and, in turn, reduced its exposure to drought. Finally, we provide recommendations for mitigating the impact of future droughts on the West's energy sector.

Background – The Impacts of Drought on the Energy Sector

Drought has multiple effects on the power sector. It reduces electricity generated at hydropower plants and is often correlated with hotter air temperatures and higher electricity demands (due to increased air conditioning loads). In addition, drought may affect the ability to operate thermoelectric power plants, which generate the vast majority of our electricity and require reliable water supplies. These plants use coal, natural gas, or nuclear fuels to produce steam, which turns a turbine and generates electricity. Most thermoelectric plants use water — in either a wet-recirculating cooling system or a once-through cooling system — to cool and condense steam. In the Interior West, power plants with sizeable water demands are located throughout the region; the Palo Verde Nuclear

FIGURE Nº 1 AREA OF CONTINENTAL U.S. AFFECTED BY DROUGHT IN 2012

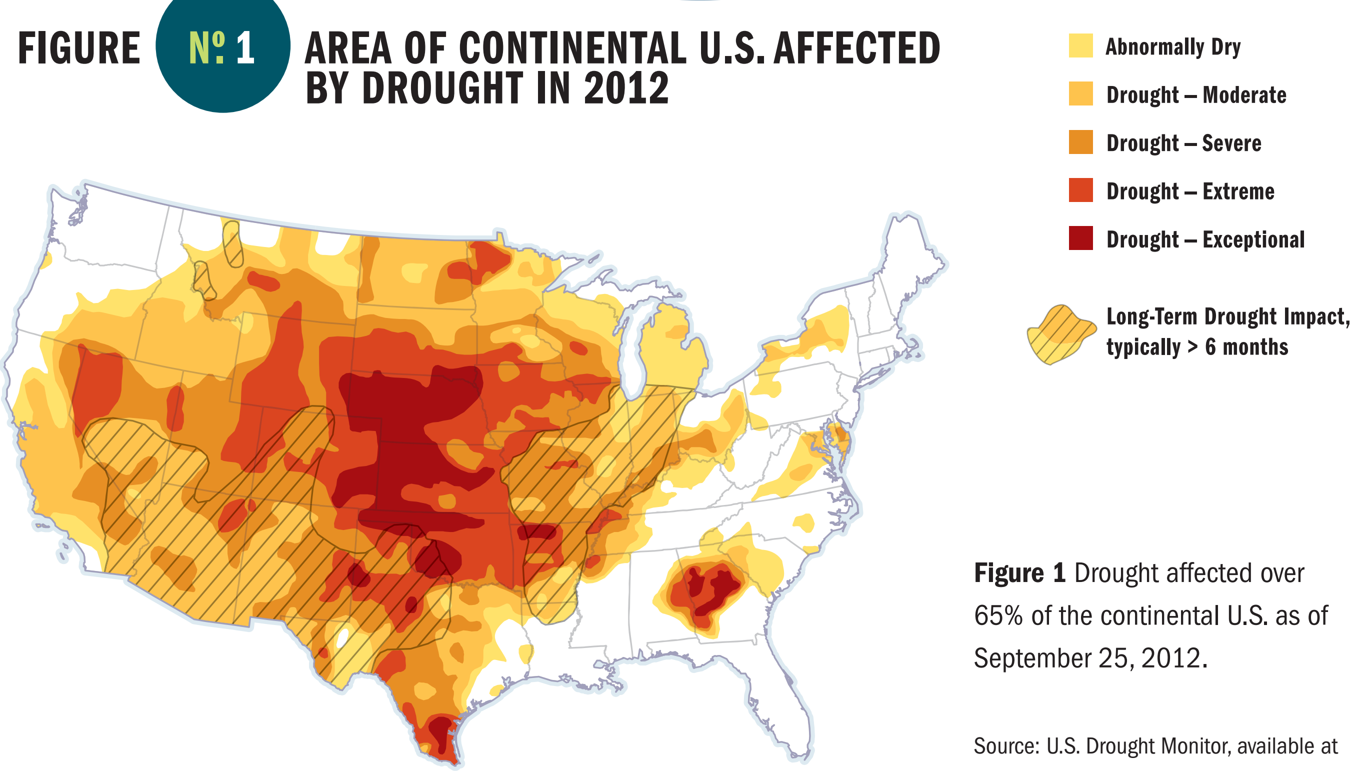


Figure 1 Drought affected over 65% of the continental U.S. as of September 25, 2012.

Source: U.S. Drought Monitor, available at http://www.droughtmonitor.unl.edu/archive.html.

Generating Station (AZ), Navajo Generating Station (AZ), and Jim Bridger coal plant (WY) have the largest water demands (Figure 2). The water needed for electricity generation varies considerably, depending on the fuel source, the design of the power plant, and cooling technology; Table 1 lists typical water-intensity figures for plants in the Interior West. In wet-recirculating cooling systems, common in the Interior West, power plants often rely on cooling reservoirs. Drought can shrink cooling reservoirs, reducing the quantity and quality of water available for cooling. Eastern and coastal power plants often rely on once-through systems; drought may increase the temperature of plants' water supplies (rivers, bays, or reservoirs), which reduces the effectiveness of cooling systems and may restrict the plants' ability to discharge heated water. In the southeastern U.S. in 2007, in France in 2006, and in various parts of the U.S. in 2012, drought and high temperatures resulted in many thermal plants curtailing generation.[1]

1 For in-depth analyses of drought impacts on the energy sector, see, for example, the following: 1) Harto, C.B., Y.E. Yan, Y.K. Demissie, D. Elcock, V. Tidwell, K. Hallett, J. Macknick, M.S. Wigmosta, and T.K. Tesfa. 2011. *Analysis of Drought Impacts on Electricity Production in the Western and Texas Interconnections of the United States*. Argonne National Laboratory, ANL/EVS/R-11/14. December. 2) Poch, Leslie, Guenter Conzelmann, and Tom Veselka. 2009. *An Analysis of the Effects of Drought Conditions on Electric Power Generation in the Western United States*. National Energy Technology Laboratory. DOE/NETL-2009/1365. April.

FIGURE Nº 2 WATER USE BY POWER PLANTS IN THE WEST

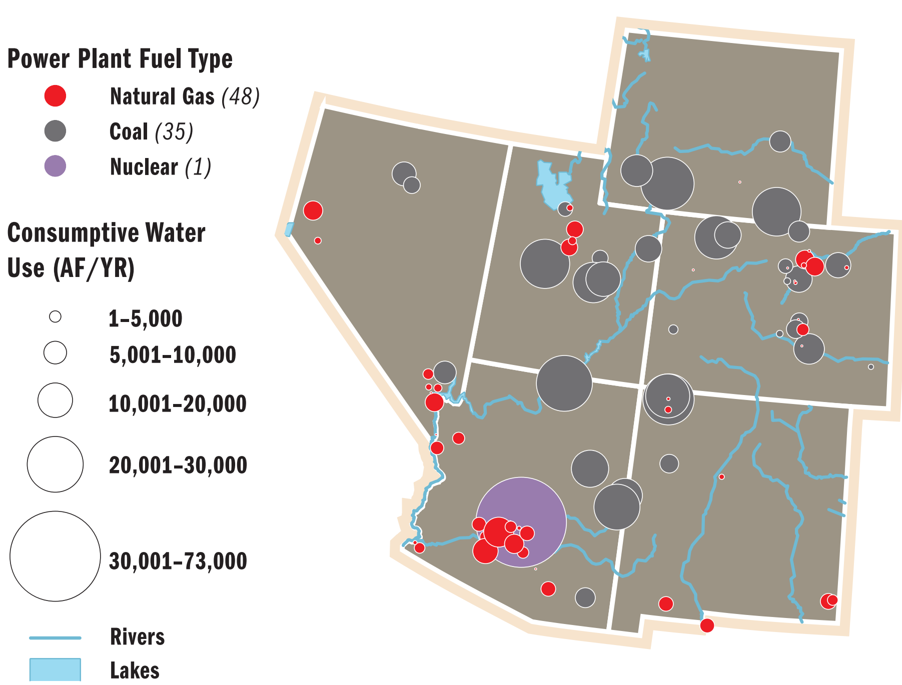


Figure 2 Map illustrates the location and relative water use of the region's thermoelectric plants in 2010. Map was developed by WRA using electricity generation data from U.S. Energy Information Administration (2010) and water intensity data from numerous sources. For coal and nuclear plants, data sources and assumptions are summarized in Table 1; the water intensity of natural gas plants relies on data from Macknick et al. (2011).

TABLE Nº 1 TYPICAL WATER CONSUMPTION RATES FOR POWER GENERATION IN THE INTERIOR WEST.

Generation Technology	Water Consumption (gallons per MWh)	Assumptions	References
Coal	548	Median of Cholla 1-3, Four Corners, Springerville, San Juan 1 & 2, Navajo, Arapahoe, Cherokee, Comanche, Hayden, Pawnee, Reid Gardner	(a, b, c, d, e)
Mohave plant	560	Actual reported water usage and generation for 2005	(f, g)
Natural gas	300	90% combined-cycle (median of Redhawk, Luna, Fort St. Vrain plants) and 10% combustion turbine (median of Tucson Electric Power's combustion turbines and Sundance combustion turbine) *Note: None of these combined-cycle plants is dry-cooled*	(a, b, c)
Nuclear	762	Palo Verde NGS	(a)
Geothermal	221	Binary plant with hybrid cooling	(h)
Concentrating solar power	850	Nevada Solar One	(i)

References:

a. Arizona Public Service. April 2012. Integrated Resource Planning Filing, historical data, p. 59.

b. Tucson Electric Power. April 2012. Integrated Resource Planning Filing, historical data, p. 29.

c. Public Service Company of Colorado. 2011. Electric Resource Plan, pp. 2–78.

d. NV Energy. October 2012. Data response to Western Resource Advocates.

e. U.S. Energy Information Administration. 2011. Form EIA-923, "Electric Power Generation and Fuel Consumption, Stocks, and Receipts."

f. U.S. Energy Information Administration. 2005. Form EIA-767, "Steam-Electric Plant Operation and Design Report."

g. U.S. Environmental Protection Agency. 2005. *eGRID2007, Version 1.0 Plant File*.

h. Macknick, Jordan, Robin Newmark, Garvin Heath, and K.C. Hallett. 2011. *A Review of Operational Water Consumption and Withdrawal Factors for Electricity Generating Technologies*. Golden, Colo.: National Renewable Energy Laboratory. March. NREL/TP-6A20-50900.

i. Solar Energy Industries Association. "Water Use Management." Accessed October 12, 2012. http://www.seia.org/policy/power-plant-development/utility-scale-solar-power/water-use-management.

Wind farm in Texas. Photo: Shutterstock

Reduced hydroelectric generation, increased electricity demands, and limited cooling water supplies for thermoelectric plants all stress the power system and have secondary impacts on electricity costs, greenhouse gas emissions, and the ability of utilities to meet customers' demands. According to one analysis, "impacts from drought manifest themselves most often economically, in terms of increased costs that can significantly impact local economies," while power shortages are rare.[2] This is because power providers have, in the past, been able to access additional water supplies for thermal plants, through temporary or permanent water purchases[3] or by extending intake pipes,[4] or have generated additional energy at more water-efficient (but historically more expensive) natural gas plants. If drought does curtail operation at a power plant, however, a utility may need to purchase power from other generators or ask customers to reduce loads. Reduced hydro generation may have similar impacts, which result in higher greenhouse gas emissions.

Despite the close ties between reliable water supplies and energy generation, water has played a relatively minor role in utilities' decisions to build new thermoelectric power plants. In the future, the impact of energy choices on water resources will have increasing importance, for two reasons:

1. Most water supplies in the West are now fully or over-allocated, leaving little "wiggle room" for managing water shortages in a time of drought.

2. Climate change is projected to reduce available water supplies and increase the frequency and intensity of drought.[5]

While drought has most commonly affected large coal or nuclear power plants that employ once-through cooling systems, the drought in Texas in 2011 and Australia between 2000 to 2010 demonstrated that even power plants with more efficient, recirculating cooling systems are vulnerable to drought. Both regions' experiences can provide useful lessons for utilities and regulators in the arid Interior West.

2 Harto et al. 2011 (see previous note).

3 For example, the Laramie River Station in Wyoming, which paid farmers for groundwater and began constructing a 17-mile pipeline to access that water in 2004. Source: Union of Concerned Scientists. 2011. *The Energy Water –Collision: Power and Water at Risk*. June. http://www.ucsusa.org/assets/documents/clean_energy/ew3/power-and-water-at-risk-with-endnotes.pdf.

4 Navajo Generating Station extended its cooling water intake pipes in 2005, as water levels in Lake Powell fell due to an extended drought. Source: U.S. National Park Service. 2007. "Finding of No Significant Impact: A Water Intake Project for the Navajo Generating Station, Glen Canyon National Recreation Area."

5 Thomas R. Karl, Jerry M. Melillo, Thomas C. Peterson, and Susan J. Hassol, eds. 2009. *Global Climate Change Impacts in the United States*. Cambridge, U.K.: Cambridge University Press.

Case Study: Drought in Texas

In 2011, Texas experienced one of the most extreme droughts in the state's history. The drought affected all sectors of society — agriculture, municipal users, and the energy sector. In December 2011, sources of cooling water supplies were at historic lows for almost 11,000 megawatts (MW) of generating capacity,[6] and, had drought conditions not eased, Texas regulators projected up to 3,000 MW of capacity could have been curtailed by May 2012,[7] with potentially extensive forced outages.[8] In the end, a small power unit — 24 MW — was curtailed because of water shortages,[9] and one large power plant reportedly curtailed generation at night in order to maintain sufficient water supplies for cooling during peak daytime demands.[10]

Drought not only impacted water supplies for power plants, but also likely contributed to higher average temperatures and record high electricity demands because of increased air conditioning loads.[11]

Texas water and power managers had several responses, including the following:

- To maintain reliability, power providers brought 470 MW of capacity out of mothballed status.[12]

6 Electric Reliability Council of Texas. 2011. "Seasonal Assessment of Resource Adequacy for the ERCOT Region Winter 2011-2012." Draft 1 report, December 1. http://www.ercot.com/content/news/presentations/2011/SARA%20-%20Winter%202011-12_V7.pdf.

7 Electric Reliability Council of Texas. 2011. "ERCOT NEWS: October Board Meeting Highlights." Press release, October 20. http://www.ercot.com/news/press_releases/print/451.

8 For reference, Texas' peak load in August 2011 was 68,294 MW. U.S. Energy Information Administration. 2011. "Texas Heat Wave, August 2011: Nature and Effects of an Electricity Supply Shortage." September 9. http://www.eia.gov/todayinenergy/detail.cfm?id=3010.

9 Electric Reliability Council of Texas. 2011. "ERCOT NEWS: October Board Meeting Highlights." Press release, October 20. http://www.ercot.com/news/press_releases/print/451.

10 Galbraith, Kate. 2011. "Drought Could Pose Problems for Texas Power Plants." *The Texas Tribune,* September 16.

11 a) Nielsen-Gammon, John W. (professor of atmospheric sciences and Texas state climatologist). 2012. Testimony before the Texas Senate Business & Commerce Committee, January 10. In *The 2011 Texas Drought: A Briefing Packet for the Texas Legislature, October 31, 2011*. http://www.senate.state.tx.us/75r/Senate/commit/c510/handouts12/0110BI-JohnNielsen-Gammon.pdf. b) Electric Reliability Council of Texas. 2011. "Power Watch - Conservation Needed." News release, August 2. http://www.ercot.com/news/press_releases/show/411.

12 a) Fainter, John (for Association of Electric Companies of Texas). 2012. "Drought Impacts on Electric Generation." Testimony before the Texas Senate Business & Commerce Committee, January 10. http://www.senate.state.tx.us/75r/Senate/commit/c510/handouts12/0110-AECT.pdf. b) Doggett, Trip (for ERCOT). 2012. "Impact of Drought Conditions on Electric Generation." Testimony before the Texas Senate Business & Commerce Committee, January 10. http://www.senate.state.tx.us/75r/Senate/commit/c510/handouts12/0110-ERCOT.pdf.

- The Texas Commission on Environmental Quality suspended or curtailed over 1,200 (primarily agricultural) water rights, but did *not* suspend out-of-priority (junior) water rights for municipal or power generation needs.[13]

In addition, market electricity prices rose dramatically in August 2011, during the height of the drought and peak electricity demands: real-time electricity prices on Texas' wholesale market hit the state's market cost cap of $3,000/MWh on five days in August. In fact, for much of the month, electricity costs far exceeded costs in the month of August in prior years.[14]

Certain factors may have exacerbated the impact of drought on the electricity sector in Texas. Texas' transmission grid covers a small geographic region compared to the western grid, and drought impacted power plants throughout Texas in 2011. In the Western Interconnect power grid, in contrast, drought rarely impacts the entire region at the same time, which means the system as a whole may be more resilient to drought.

Texas' wind generation—which uses no water—may have mitigated the impacts of drought on the power sector. Texas has over 10,000 MW of wind capacity, a portion of which was generating energy when demands peaked (and thermoelectric cooling supplies were severely depleted) in August 2011.

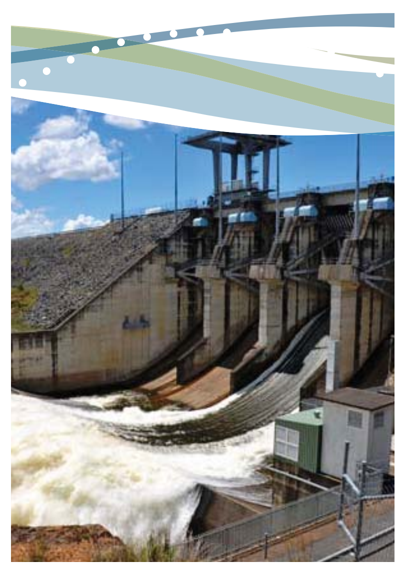
Case Study: Drought in Australia

Southeastern Australia has a climate similar to that of the southwestern U.S. and experiences regular droughts and water scarcity; from roughly 2000 to 2010, southeastern Australia experienced what some called a "one in a thousand year drought."[15] Like the drought in Texas, it affected all sectors of society—municipal, agricultural, environmental, and industrial. Water shortages appear to have had a much greater effect on both hydroelectric and thermoelectric power facilities in Australia than in Texas, likely a result of the duration of drought. Specifically:

From roughly 2000 to 2010, southeastern Australia experienced what some called a "one in a thousand year drought."

- Drought conditions plagued the country for several years, peaking in 2007.

- A key reservoir on the Brisbane River, Wivenhoe Reservoir, provides water for both municipal needs in the city of Brisbane (population of over 2,000,000) and power plants. Electricity generation at two coal plants that rely on the reservoir, Tarong (1,400 MW) and Tarong North (443 MW), was curtailed in 2007 in order to protect municipal water supplies. As a



Wivenhoe Dam. Photo: Shutterstock

13 Shaw, Bryan W. (for Texas Commission on Environmental Quality). 2012. Testimony before the Texas Senate Business & Commerce Committee, January 10. http://www.senate.state.tx.us/75r/Senate/commit/c510/handouts12/0110-TCEQ.pdf.

14 U.S. Energy Information Administration. 2011. "Texas Heat Wave, August 2011: Nature and Effects of an Electricity Supply Shortage." September 9. http://www.eia.gov/todayinenergy/detail.cfm?id=3010.

15 Vidal, John. 2006. "Australia Suffers Worst Drought in 1,000 Years." *The Guardian,* November 7. http://www.guardian.co.uk/world/2006/nov/08/australia.drought.

result, production and employment at the coal mine that feeds the Tarong plants also were cut. Operations at a third coal plant, Swanbank B (500 MW), also were curtailed.[16]

- The Western Corridor Recycled Water Scheme, a recycled water pipeline, was constructed to transfer recycled water to the Wivenhoe Reservoir, and managers of the Tarong plant built facilities to capture storm water and reclaim water from the site's ash collection facility.

- Electricity prices soared.

Much like Texas, southeastern Australia is familiar with and prepares for drought, yet the recent drought had unprecedented impacts on the electricity sector.

Western Clean Energy Policies Mitigate Drought

In the Interior West, various factors have led to reductions in greenhouse gas emissions[17] and water use by the electricity sector in recent years. Among those factors are state and federal regulatory policies, including states' renewable energy and energy efficiency standards, and decisions to retire coal-fired power plants like the Mohave Generating Station. Because of these factors, along with decreased electricity demand during the economic recession and the low cost of natural gas for power generation, Western Resource Advocates estimates that water use by the Interior West's electricity sector has been declining since about 2008[18] (Figure 3).

While the retirement of the Mohave Generating Station created the largest volume of water saved over the 2005–2010 period, incremental investments in renewable energy and energy efficiency also have led to important water savings (Figure 4). **In total, clean energy investments made over the 2006–2010 period now save an estimated 6.3 billion gallons per year (19,400 AF per year). That volume could meet the annual needs of approximately 78,000 households.**[19]

Western Resource Advocates' analysis of water savings reflects numerous assumptions. The most critical assumptions relate to the water intensity of electricity, summarized in Table 1. Some of the combined-cycle natural gas

16 Of note, all of the power plants affected — Tarong, Tarong North, and Swanbank B — rely on wet-recirculating cooling systems. Source: Smart, Alan and Adam Aspinall. 2009. *Water and the Electricity Generation Industry: Implications of Use.* Waterlines Report Series No. 18. Canberra, Australia: Australia National Water Commission. August.

17 Berry, David. 2012. *Descending from the Pollution Plateau: Why Carbon Dioxide Emissions Are Declining in the Mountain West and How to Keep it that Way*. Boulder, Colo.: Western Resource Advocates. August.

18 The trend reflects a peak in 2007, even though actual estimated water use peaked in 2008.

19 One AF typically meets the consumptive water needs of two to four households.

FIGURE Nº 3 ESTIMATED WATER USE FOR POWER GENERATION IN THE MOUNTAIN WEST

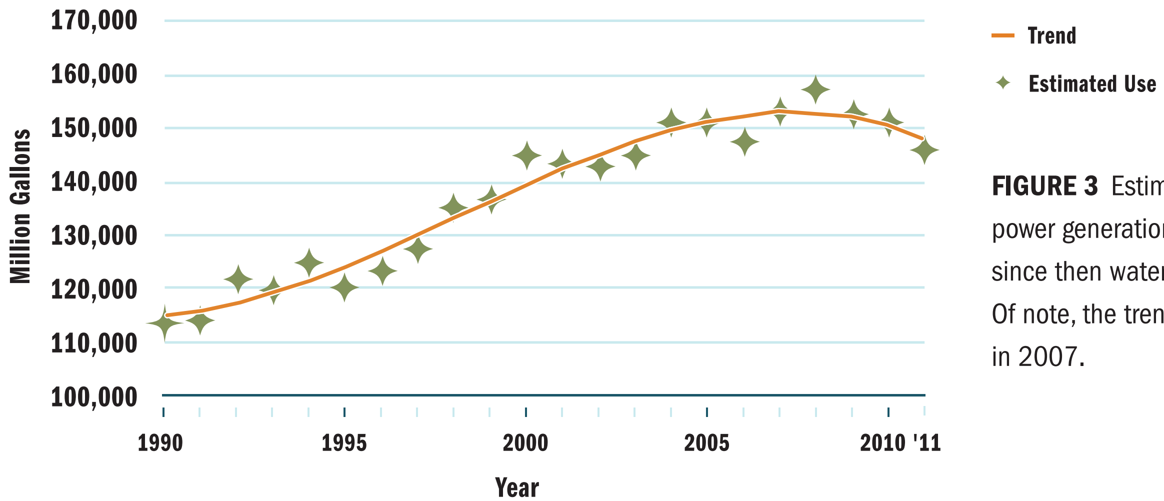


FIGURE 3 Estimated water use for power generation peaked in 2008; since then water use has declined. Of note, the trend reflects a peak in 2007.

FIGURE Nº 4 CHANGE IN WATER USE FROM PREVIOUS YEAR DUE TO CLEAN ENERGY EVENTS: MOUNTAIN WEST

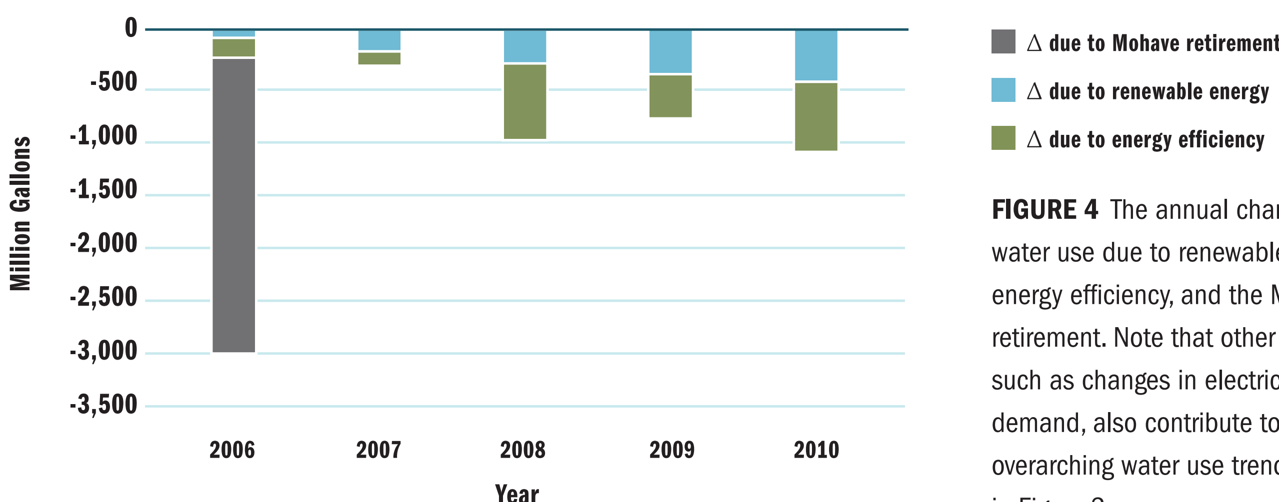


FIGURE 4 The annual change in water use due to renewable energy, energy efficiency, and the Mohave retirement. Note that other factors, such as changes in electricity demand, also contribute to the overarching water use trends shown in Figure 3.

The Navajo Generating Station relies on water from Lake Powell on the Colorado River. Photo: Shutterstock

plants built in recent years employ dry cooling; this analysis does not reflect that shift in cooling systems.[20] Other key assumptions include the following:

- Electricity generated at the Mohave Generating Station (retired on December 31, 2005) was replaced entirely with generation at natural gas plants.

- Renewable energy and energy efficiency displaces electricity generated at natural gas plants.[21]

Recent decisions to retire water- and carbon-intensive power plants in the near future will produce additional water savings. For example, the retirement of coal-fired units at the Cherokee Generating Station (CO), Valmont Generating Station (CO), and Four Corners Power Plant (NM) will all reduce water use. Similarly, we expect that future investments in renewable energy and energy efficiency will continue to displace electricity generation—and water use—at natural gas plants. To the extent that these savings eliminate the need to develop coal or nuclear plants in the future, the long-term water savings may be even greater.

20 Overall, the shift to dry cooling reduces the total water used by the electricity sector. For calculating the water savings from clean energy policies, the shift to dry cooling is more complicated: If dry-cooled gas plants displaced generation at Mohave, we would see even greater water savings, but water savings would be smaller if renewable energy and energy efficiency displaced electricity generated at dry-cooled gas plants (rather than conventional wet-cooled plants).

21 Details on these assumptions are described in the following: Berry, David. 2012. *Descending from the Pollution Plateau: Why Carbon Dioxide Emissions Are Declining in the Mountain West and How to Keep it that Way*. Boulder, Colo.: Western Resource Advocates. August.

Conclusions

In 2012, drought affected almost two-thirds of the continental U.S.; in the Southwest, many rivers saw low or record low levels of runoff. While the most obvious and immediate impacts of the drought are on agriculture, stream flows, and municipalities, power plants have also been affected by extreme droughts. In the Interior West, policies that have supported renewable energy, energy efficiency, and the retirement of older coal plants have contributed to a reduction in the energy sector's water demands. These water savings are valuable; along with efforts to conserve water in the municipal and agricultural sectors, they can help mitigate the risk of future water shortages.

In addition to continuing policies that support water-efficient forms of energy, several strategies can help reduce the likelihood that utilities in the southwestern U.S. will see energy-water conflicts like those that occurred in Texas and Australia. These strategies apply to both utilities and regulators:

1. Utilities should analyze and report current and future water use in resource plans.

2. Utilities should comprehensively value the water used for current and future energy generation.

3. Regulators and utilities should analyze and recognize the benefits of water-efficient electric energy resources, which provide a hedge against the potential impacts of drought on the electric system.

4. Utilities, regulators, and state or federal agencies developing long-range energy plans should act upon these analyses.

To some extent, utilities in the West are beginning to pursue these strategies today. For example, Arizona Public Service (APS), Public Service Company of Colorado (or Xcel Energy), and Tri-State Generation and Transmission, based in Colorado, report water used for current and future proposed plants in their resource plans, as well as the water intensity of future portfolios. In their 2012 Integrated Resource Plans, APS and NV Energy report a cost[22] of the water use associated with future resource portfolios. To date, however, no utility or regulator has expressly addressed the risk of water shortages or analyzed the hedge value of water-efficient electricity supplies.

22 APS' resource plan reflects the price of recycled water at its Red Hawk Plant. Using water for power generation impacts other water needs – urban, agricultural, and environmental. These impacts may not be adequately reflected in the price of purchasing water or developing a new power supply. To account for this, NV Energy modeled the opportunity cost of using water for power generation in its 2012 resource plan.

Including water use data in electric utilities' resource plans provides critical information to utilities, regulators, and stakeholders. Most importantly, it allows them to compare and weigh the impacts of future portfolios on water resources. To that end, utilities need to model the impact on costs of reduced power output at some power plants due to water scarcity, taking into account a range of probabilities of future drought, and to compare these cost impacts to the incremental costs of hedging against water scarcity through increased deployment of low water-use resources.[23] Care should be taken to avoid discounting away future costs of potentially disruptive droughts. From the perspective of people enduring drought, the costs are real and undiscounted.

Wind power, solar photovoltaics, energy efficiency, and dry-cooled thermoelectric plants all reduce the water needs of the electricity sector.

Wind power, solar photovoltaics, energy efficiency, and dry-cooled thermoelectric plants all reduce the water needs of the electricity sector. Renewable sources of energy and energy efficiency have no greenhouse gas emissions, and therefore do not contribute to climate change, one of the driving forces behind more frequent and intense droughts. While drought is likely to be an ongoing challenge for water and energy managers, investments made today can help mitigate the impacts of future droughts.

23 The benefits of low water-use resources, such as energy efficiency and renewable energy, include price stability and reduced pollution. The incremental costs of these resources should therefore be considered in light of their multiple benefits and not just in reference to drought mitigation.

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Western Resource Advocates is a nonprofit conservation organization dedicated to protecting the West's land, air, and water.

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