THE SOUTHWEST WATER-ENERGY NEXUS

A White Paper on Power Generation and Water Consumption in Arizona, USA

CHEYENNE FORD

INTRODUCTION

The southwestern U.S. is experiencing a significant increase in demand for both energy and water, driven by population growth and economic development. This is particularly evident in Arizona where water availability is becoming an increasingly critical issue with ongoing drought and the dry years outpacing the wet years.[i] August 2024 was one of the hottest and driest months on record over the past 130 years, leading to an increased use of electricity and demand for more water.[ii] Annually, Arizona uses 1,526.9 trillion Btu of energy and electricity demand is expected to grow by 60% over the next 30 years.[iii,iv] Arizona is most reliant on groundwater, which provides 41% of the state's water needs. Agriculture is the largest consumer of water (72%), followed by municipal (22%) and industrial uses (6%).[v]

Historically, Arizonans have withdrawn groundwater faster than it can be replenished, leading to concerns about water supply, increased cost for pumping and drilling, and a decrease in water quality due to more salts and minerals at greater depths.[vi]

This white paper evaluates the water required to generate energy for Arizona's 7.36 million residents and explores the feasibility of alternatives to fossil fuels and coal. The paper also notes data gaps and opportunities for additional research.

BACKGROUND

In 1980, Arizona enacted the Groundwater Management Act (Code) to secure groundwater availability and support economic sustainability. The Code had three main goals:

1\. Control severe overdraft occurring in many parts of the state

1\. Allocate the state's limited groundwater resources effectively

2\. Augment groundwater through water supply development.[vii]

In 1986, the Ford Foundation selected Arizona's Groundwater Management Code as one of the 10 most innovative programs in state and local government.[viii] The Code established the three levels of water management:

1\. General provisions are the lowest level of management that apply statewide.

2\. Irrigation Non-Expansion Areas (INAs)

THIS white paper **EVALUATES** the **WATER REQUIRED** to **GENERATE ENERGY** for Arizona's **7.36 MILLION RESIDENTS** and explores the **FEASIBILITY** of **ALTERNATIVES** to **FOSSIL FUELS** and coal.

require measuring devices on non-exempt wells, registration of existing wells, and annual withdrawal reporting of all non-exempt wells.

3. Active Management Areas (AMAs) have the most extensive level of terms and include the Assured Water Supply Program (any new subdivision must demonstrate a 100-year assured water supply) and conservation requirements for large municipal water providers, agriculture, and industries.[ix]

AMAs and INAs each have unique water conservation goals. For example, Phoenix, Prescott, and Tucson AMAs aim to achieve safe yield by 2025 with no more groundwater withdrawn than is being replaced annually. The Pinal AMA focuses on sustaining agricultural production for economic stability. The Santa Cruz AMA has already achieved safe yield and is working to ensure local water tables avoid long-term declines.[x]

The ADWR can designate new AMAs and INAs if necessary to protect the water supply. Residents can also vote to create INAs or AMAs. Areas of the state that are not under active management have few restrictions on groundwater use and local communities are being impacted by new large groundwater pumpers.[xi] The ADWR Water Use program tracks and estimates total withdrawal volume for municipalities of public and private water suppliers located outside of Active Management Areas.[xii]

Another management tool employed by Arizona includes the Renewable Portfolio Standard (RPS) which sets targets for states and requires increased production of energy from renewable sources such as wind, solar, biomass, and geothermal. Arizona established its RPS in 2006 and set a goal of 15% renewables by 2025.[xiii]

RESEARCH FINDINGS

Power Plants and Water Recycling

Electric utilities conserve water by recycling it. Unlike most coal-powered systems that use once-through cooling, natural gas facilities typically use closed-loop, recirculating systems to minimize water loss.[xiv] Large-scale power plants (25 MW or more) must recycle cooling water.xv Facilities built after 1984 must recycle water 15 or more times to conserve fresh water. Pre-1985 facilities must achieve only seven or more cycles.[xvi] In Arizona, 283 of the 364 operable large-scale power plants were established post-1984, and 22 pre-1985 power plants have already been retired.[xvii]

> Large-scale **POWER PLANTS,** have **GRANDFATHERED** rights

Power Plants and Water Usage

Industrial subsectors, including large-scale power plants, have grandfathered rights (GFR) or General

Plant Name (NG & SUB)	2022 Water Withdrawal Volume (million gallons)	Located in AMA/INA?
Agua Fria (NG)	342	YES
Apache Station (NG & SUB)	103736	NO
Cholla (SUB)	2152	YES
Coronado (SUB)	1648	NO
Desert Basin (NG)	486	YES
Gila River Power Block 1 (NG)	1174	NO
Gila River Power Block 2 (NG)	1347	NO
Gila River Power Block 3 (NG)	1095	NO
Gila River Power Block 4 (NG)	1344	NO
H Wilson Sundt Generating Station (NG)	415	YES
Kyrene (NG)	556	YES
Mesquite Generating Station Block 1 (NG)	929	YES
Red Hawk (NG)	1536	YES
Santan (NG)	1456	YES
Springerville (SUB)	3158	NO
West Phoenix (NG)	938	YES
Total (Millions of gallons)	**122,312**	**NG = natural gas**
Total (Acre-feet)	**375,362**	**SUB = sub-bituminous coal**
Would supply this many homes per year	**866,119**	

Figure 1. Total reported water withdrawal volume by electric utilities in Arizona (EIA, 2022)

Industrial Use (GIU) permits where they can pump the amount it was entitled to receive on June 12, 1980, unless it has obtained a GFR or a GIU permit.[xviii] Conservation requirements for these subsectors are to avoid waste and make diligent efforts to reuse and recycle water. But with no mandatory requirements to report water usage of these subsectors, there is limited data available on how much groundwater is being withdrawn each year. The U.S. Energy Information Administration (EIA) provides independent statistics, forecasts and analysis. As of August 2024, the most recent water data available for electric utility plants is from 2022. Only 16 of 57 electric utility plants in the state have provided water data to EIA (Figure 1).[xix] The volume of

With **NO** mandatory **REQUIREMENTS** to **REPORT WATER USAGE** of these subsectors, there is **LIMITED DATA AVAILABLE** on **HOW MUCH GROUNDWATER** is being **WITHDRAWN EACH YEAR.**

water withdrawals varies significantly depending on the type of fuel and cooling system used. For this white paper, we chose to compare the reported withdrawal volume per electric utility plant and the number of homes that could be supplied per year in Arizona.

With the reported water withdrawal of only 16 plants, 866,119 homes in Arizona could be supplied with water for a year (Figure 2). There are approximately 3.1 million homes in Arizona meaning 16 plants could provide enough water for 27.9% of homes in the state. Of note, Agua Fria and Springerville report data for solar energy generation but both plants use a combination of coal, natural gas, solar, battery storage and distillate fuel oil without specifying water usage of each fuel source.

<u>Land requirements of electrical power generation</u>

The total amount of land needed to produce energy and where the energy is being produced is another factor to consider. While most natural gas and coal plants are in mostly urban areas in Arizona, utility-scale solar and battery storage is expanding to rural areas such as Pima, Pinal and Santa Cruz counties.[xx] New solar facilities are helping Arizona meet its RPS but the indirect impacts on habitat are still largely unknown. Trout Unlimited and partners recently highlighted the physical land requirements of different types of electric power generation in the U.S. and the cost of electric power to fish and wildlife habitat.[xxi] Researchers at Princeton University recently estimated that the current footprint of all types of energy production in the U.S. is approximately 81 million acres.[xxii]

> With the reported **WATER WITHDRAWAL** of only **16 PLANTS, 866,119 HOMES** in **ARIZONA** could be **SUPPLIED** with **WATER** for a **YEAR.**

$$\frac{(v)gal.*10^6}{325{,}851} = total\ (acre - feet)$$

$$\frac{(v)gal.*10^6}{(w)*(x)*(y)} = \frac{withdrawal\ volume\ in\ millions\ of\ gallons}{(gal.per\ capita\ per\ day)*(avg.household\ size)*(days\ per\ yr.)} = z$$

$$z = total\ \#\ of\ homes\ supplied\ for\ 1\ year\ by\ withdrawal\ volume$$

$$v = total\ withdrawal\ volume$$

$$w = gal.per\ capita\ per\ day\ (GPCD)for\ AZ = 146$$

$$x = avg.household\ size\ for\ AZ = 2.65$$

$$y = days\ per\ yr. = 365$$

$$z = \frac{(v)gal.*10^6}{(w)*(x)*(y)} = \frac{122{,}312\ gal.*10^6}{(146)gal.*(2.65)*(365)} = 866{,}119\ homes$$

Figure 2. Calculation for deriving total number of homes that could be supplied with water for one year by withdrawal volume of water from coal and natural gas plants.

Case Study 1: Potential Effects of Solar on Wildlife

Utility-scale solar can lead to loss of habitat and cause disturbance to the natural environment of fish and wildlife.[xxiii][xxiv] Utility-scale solar can also have a negative effect called the "lake effect," where the large array of reflective panels appears to be a body of water, causing water birds to land where they can die on impact.[xxv] In 2020, Chock RY, Clucas B, Peterson EK, et al. evaluated the potential effects of solar power facilities on wildlife from an animal behavior perspective. The authors focused on animal behavior to identify population responses before mortality.

The study resulted in several key takeaways:

- We need to learn more about how the perception of solar impacts attraction or avoidance of these spaces to certain species.
- Movement and habitat use in and around solar facilities is largely unknown (impact on resident species vs migratory species).

Solar facilities can alter spatial cues and memorized patterns of where to seek food, therefore making it necessary to know more about species' trophic levels and impacts on fitness-associated behaviors (i.e. foraging, predation, and competition).[xxvi]

Case Study 2: Water Usage for Solar Technology

In 2013, Frisvold and Marquez estimated the water usage for meeting 100% of energy needs with solar by 2025 and 2035. This study focused on the Renewable Portfolio Standards of five western states (Arizona, California, Colorado, Nevada, New Mexico) and evaluated the feasibility of different types of utility-scale solar technologies including concentrated solar power (CSP), photovoltaic (PV), dish, and thin-film.[xxvii][xxviii] The researchers considered two scenarios: The first assessed water requirements if the most water-intensive solar was used to meet all future demands across 5 western states and the second evaluated a combination of solar options that would collectively utilize less water than coal, natural gas and nuclear.

Key takeaways include:

- Water requirements for solar technologies vary in their water usage.
- Meeting future solar demands would require 0.30 million acre-feet of water (MAF) in 2025 and 0.33 MAF in 2035.
- The weighted average water use for scenario two was 228 gal/MWh which is lower than natural gas (325 gal/MWh), coal (577 gal/MWh), and nuclear plants (759 gal/MWh) being operated by Arizona Public Services, Tucson Electric Power, and the Salt River Project in 2008.
- Treating water to reclaimed standards requires less energy than it does to treat water to drinking standards. Effluent would be an alternative to using groundwater for cooling, but effluent is often generated in urban areas, far from CSP facilities.

More **WATER DATA** is **NEEDED** to make **AN INFORMED DECISION** and **GAIN** a larger **SENSE** of **HOW MUCH GROUNDWATER** is being **WITHDRAWN** by **UTILITIES.**

CONCLUSION

Water usage in Arizona will continue to be an ongoing issue. We must find best management practices to conserve water at the utility scale and continue to research the impacts of energy production. Although the future of groundwater resources has been at the forefront of state legislation since the implementation of the 1980 Groundwater Management Act, several problematic issues remain. Lack of regulation in regions located outside of AMAs has led to the over-pumping of groundwater. Currently, utilities don't need to report how much water is being withdrawn (pumped) for cooling systems. While the EIA has limited water information on utility scale energy production in the state of Arizona, our research on the available water data for 16 of the 57 electric utility plants in the state showed that enough water to support 866,119 homes is being used to cool 16 plants.

More water data is needed to make an informed decision and gain a larger sense of how much groundwater is being withdrawn by utilities. The data for 10 of 16 plants included in this white paper came from facilities in an AMA. We know that electric utilities located outside of AMAs are pumping more water based on the reported withdrawal volumes of the six plants. One plant of concern is Apache Station, which reportedly pumps nearly 104 million gallons of water per year to produce a max capacity of 660 MW. In comparison, the Cholla facility withdraws 2.152 million gallons of water to produce a max capacity of 426 MW per year.[xxix] RPS set a precedence for future electric utility development, thus the choices that are being made now are important.[xxx] Overall, improved water management practices in areas located outside of AMAs and more comprehensive reporting throughout the state are essential to ensure sustainable water use in Arizona's energy sector.

Endnotes

[i] Villarreal, Y. (2022, April 1). *Arizona's 27-year drought. A guide.* AZ Luminaria. http://azluminaria.org/2022/04/01/arizonas-27-year-drought-a-guide/

[ii] Arizona Department of Water Resources. (n.d.). *Drought Status.* https://www.azwater.gov/drought/drought-status

[iii] U.S. Energy Information Administration. (2022). *U.S. Energy Information Administration - EIA - Independent Statistics and Analysis*. https://www.eia.gov/state/seds/data.php?incfile=/state/seds/sep_fuel/html/fuel_te.html&sid=US

[iv] Farley, G. (2023, December 13). *AZ Energized: The Future of Power in Arizona.* https://www.commonsenseinstituteus.org/arizona/research/energy-and-our-environment/az-energized-the-future-of-power-in-arizona

[v] Arizona Water Facts. (n.d.). *Water Your Facts | Arizona Water Facts*. Arizona Water Facts. Retrieved September 18, 2024, from https://www.arizonawaterfacts.com/water-your-facts

[vi] Arizona Department of Water Resources. (n.d.). *Overview of the Arizona Groundwater Management Code*. https://www.azwater.gov/sites/default/files/media/Arizona%20Groundwater_Code_1.pdf

[vii] Arizona Department of Water Resources (ADWR). *(2024, August 6). Active Management Area Overview.* State of Arizona. https://www.azwater.gov/ama/active-management-area-overview

[viii] Arizona Department of Water Resources (ADWR). (2024, August 6). *Active Management Area Overview.* State of Arizona. https://www.azwater.gov/ama/active-management-area-overview

[ix] Arizona Department of Water Resources (ADWR). (2024, August 6). *Active Management Area Overview.* State of Arizona. https://www.azwater.gov/ama/active-management-area-overview

[x] Arizona Department of Water Resources. (2016). *Active Management Areas Factsheet.* https://www.azwater.gov/sites/default/files/2022-12/AMAFACTSHEET2016%20%281%29.pdf

[xi] Paul, H. (2018, October 2). *10 Things You Should Know About Arizona's Groundwater Management Act | Audubon.* https://www.audubon.org/news/10-things-you-should-know-about-arizonas-groundwater-management-act

[xii] United States Geological Survey. (2017, March 9). Arizona Water Use | U.S. *Geological Survey.* https://www.usgs.gov/centers/arizona-water-science-center/science/arizona-water-use#overview

[xiii] *Renewable Energy Standard and Tariff | Arizona Corporation Commission.* (n.d.). Prod 15.1. Retrieved September 19, 2024, from http://azcc.gov/utilities/electric/renewable-energy-standard-and-tariff

[xiv] Frisvold, G. B., & Marquez, T. (2013). Water Requirements for Large-Scale Solar Energy Projects in the West. *Journal of Contemporary Water Research & Education, 151*(1), 106–116. https://doi.org/10.1111/j.1936-704X.2013.03156.x

[xv] Arizona Department of Water Resources (ADWR). (2024). *Commercial & Industrial.* State of Arizona. https://www.azwater.gov/conservation/commercial-industrial

[xvi] Arizona Department of Water Resources (ADWR). (2024). *Commercial & Industrial.* State of Arizona. https://www.azwater.gov/conservation/commercial-industrial

[xvii] United States Energy Information Administration. (n.d.). *Form EIA-860 detailed data with previous form data (EIA-860A/860B).* Retrieved September 18, 2024, from https://www.eia.gov/electricity/data/eia860/

[xviii] Arizona Department of Water Resources (ADWR). (2024). *Commercial & Industrial.* State of Arizona. https://www.azwater.gov/conservation/commercial-industrial

[xix] U.S. Energy Information Administration. (2022). *Electricity Data Browser.* EIA Beta. https://www.eia.gov/beta/electricity/data/browser/#/topic/1?agg=0,2,1&fuel=1004002&pt=&pm=&sec=8&geo=0000000001&wd=&ws=&wsn=&wt=&freq=A&datecode=2022&tab=water-volume&start=2001&end=2023&ctype=linechart&ltype=pin&maptype=0&pin=&linechart=ELEC.PLANT.GEN.160-ALL-ALL.A&columnchart=ELEC.PLANT.GEN.160-ALL-ALL.A

[xx] Wichner, D. (2023, November 24). *Arizona electric co-ops catching up on renewables with major projects*. Arizona Daily Star. https://tucson.com/news/local/business/tucson-arizona-energy-solar-renewable/article_5d353d58-8878-11ee-87dc-23f97306b651.html

[xxi] Theodore Roosevelt Conservation Partnership, Trout Unlimited et al. (2024, September). *Energy development and land use: fish and wildlife platform.* https://www.tu.org/wp-content/uploads/2024/09/Energy-Statement-Sept-24.pdf

[xxii] E. Larson, C. Greig, J. Jenkins, E. Mayfield, A. Pascale, C. Zhang, J. Drossman, R. Williams, S. Pacala, R. Socolow, EJ Baik, R. Birdsey, R. Duke, R. Jones, B. Haley, E. Leslie, K. Paustian, and A. Swan, Net-Zero America: Potential Pathways, Infrastructure, and Impacts, Final report, Princeton University, Princeton, NJ, 29 October 2021. https://netzeroamerica.princeton.edu/the-report

[xxiii] Chock, R. Y., Clucas, B., Peterson, E. K., Blackwell, B. F., Blumstein, D. T., Church, K., Fernández-Juricic, E., Francescoli, G., Greggor, A. L., Kemp, P., Pinho, G. M., Sanzenbacher, P. M., Schulte, B. A., & Toni, P. (2021). Evaluating potential effects of solar power facilities on wildlife from an animal behavior perspective. Conservation Science and Practice, 3(2), e319. https://doi.org/10.1111/csp2.319

[xxiv] Smallwood, K. S. (2022). Utility-scale solar impacts to volant wildlife. *The Journal of Wildlife Management, 86*(4), e22216. https://doi.org/10.1002/jwmg.22216

[xxv] Chock, R. Y., Clucas, B., Peterson, E. K., Blackwell, B. F., Blumstein, D. T., Church, K., Fernández-Juricic, E., Francescoli, G., Greggor, A. L., Kemp, P., Pinho, G. M., Sanzenbacher, P. M., Schulte, B. A., & Toni, P. (2021). Evaluating potential effects of solar power facilities on wildlife from an animal behavior perspective. *Conservation Science and Practice, 3*(2), e319. https://doi.org/10.1111/csp2.319

[xxvi] Chock, R. Y., Clucas, B., Peterson, E. K., Blackwell, B. F., Blumstein, D. T., Church, K., Fernández-Juricic, E., Francescoli, G., Greggor, A. L., Kemp, P., Pinho, G. M., Sanzenbacher, P. M., Schulte, B. A., & Toni, P. (2021). Evaluating potential effects of solar power facilities on wildlife from an animal behavior perspective. *Conservation Science and Practice, 3*(2), e319. https://doi.org/10.1111/csp2.319

[xxvii] *Renewable Energy Standard and Tariff | Arizona Corporation Commission.* (n.d.). Prod 15.1. Retrieved September 19, 2024, from http://azcc.gov/utilities/electric/renewable-energy-standard-and-tariff

[xxviii] Frisvold, G. B., & Marquez, T. (2013). Water Requirements for Large-Scale Solar Energy Projects in the West. *Journal of Contemporary Water Research & Education, 151*(1), 106–116. https://doi.org/10.1111/j.1936-704X.2013.03156.x

[xxix] U.S. Energy Information Administration. (2022). *Electricity Data Browser.* EIA Beta. https://www.eia.gov/beta/electricity/data/browser/#/topic/1?agg=0,2,1&fuel=1004002&pt=&pm=&sec=8&geo=0000000001&wd=&ws=&wsn=&wt=&freq=A&datecode=2022&tab=water-volume&start=2001&end=2023&ctype=linechart&ltype=pin&maptype=0&pin=&linechart=ELEC.PLANT.GEN.160-ALL-ALL.A&columnchart=ELEC.PLANT.GEN.160-ALL-ALL.A

[xxx] Frisvold, G. B., & Marquez, T. (2013). Water Requirements for Large-Scale Solar Energy Projects in the West. *Journal of Contemporary Water Research & Education, 151*(1), 106–116. https://doi.org/10.1111/j.1936-704X.2013.03156.x

[xxxi] Chock, R. Y., Clucas, B., Peterson, E. K., Blackwell, B. F., Blumstein, D. T., Church, K., Fernández-Juricic, E., Francescoli, G., Greggor, A. L., Kemp, P., Pinho, G. M., Sanzenbacher, P. M., Schulte, B. A., & Toni, P. (2021). Evaluating potential effects of solar power facilities on wildlife from an animal behavior perspective. Conservation Science and Practice, 3(2), e319. https://doi.org/10.1111/csp2.319

[xxxii] Smallwood, K. S. (2022). Utility-scale solar impacts to volant wildlife. *The Journal of Wildlife Management, 86*(4), e22216. https://doi.org/10.1002/jwmg.22216

[xxxiii] Chock, R. Y., Clucas, B., Peterson, E. K., Blackwell, B. F., Blumstein, D. T., Church, K., Fernández-Juricic, E., Francescoli, G., Greggor, A. L., Kemp, P., Pinho, G. M., Sanzenbacher, P. M., Schulte, B. A., & Toni, P. (2021). Evaluating potential effects of solar power facilities on wildlife from an animal behavior perspective. *Conservation Science and Practice, 3*(2), e319. https://doi.org/10.1111/csp2.319