Arizona Water Demand Analysis by Land Use Category

Prepared for

Arizona Solar Energy Industries Association
7144 E. Stetson Drive, Suite 300
Scottsdale, AZ 85251

By

WestWater Research, LLC
4747 N. 7th Street, Suite 412
Phoenix, AZ 85014

October 9, 2024

Executive Summary

This report provides an analysis of water consumption of various land uses in Arizona, offering insight into how land use decisions impact water resource commitments in the arid Southwest. Understanding these differences is crucial for decision making in areas facing water scarcity and where efficient resource allocation is essential. The objectives of this analysis were to develop proxy water use estimates for land use types that might be considered alternative to the development of solar projects in Arizona, to highlight the differences in the water demands of each land use type and by power generation facility type, and to clarify the disparities in water demand to enable decision-makers to promote efficient water use and sustainable land development across the region.

In particular, this report summarizes the water demands of various land use categories in Arizona in comparison to the relatively low water demands of solar projects. Alternative land uses including irrigated agriculture, subdivision development, industrial, and commercial are found to consistently require larger volumes of water than solar. From a water conservation perspective, solar is a preferred land use in the arid Southwest because of its modest water footprint. To demonstrate the benefits of solar, this analysis quantifies the water demands of alternative land uses based on data from Arizona Department of Water Resources (ADWR or "the Department") and other publicly available sources.

The results of the analysis clearly demonstrate that water use by solar facilities is significantly lower than that of potential alternative land uses in Arizona. Average water use across all sectors analyzed in this effort is 3.4 acre-feet[1] per acre (AF/acre), which is 100 times the use of solar (0.03 AF/acre). In particular, data centers were found to use 6.3 AF/acre on average, which is 200 times the amount used by solar. Metro Phoenix is the second-largest data center market in the nation in large part because of the availability of power and land[2]. In conclusion, compared to other land use categories evaluated, water use by solar is negligible. When compared to water requirements of natural gas and nuclear power generation facilities, these power sources require 25-100 times the water requirements of solar facilities to produce one megawatt (MW) (4.3 AF/MW for natural gas and 18.7 AF/MW for nuclear compared to 0.16 AF/MW for solar).

[1] One acre-foot equals 325,851 gallons.

[2] H2 2023 North American Data Center Report. August 27, 2024. JLL. https://www.us.jll.com/en/trends-and-insights/research/na-data-center-report?utm_source=public-relations&utm_medium=ol&utm_campaign=am-us-industries-data-centers-outlook&utm_content=byline

Appendix A of this report summarizes the data and methodology to estimate water demands of the various sectors analyzed and details the findings of the data analysis.

Summary of Findings

Water use in Arizona is categorized under three main sectors: municipal, industrial, and agricultural. According to ADWR, 74%[3] of the state's total annual water use is irrigated agriculture followed by municipal use at 20%[4]. Industrial water use accounts for only 6% of the state's total water use. Industrial use of land across Arizona is also minimal relative to other uses. In Maricopa and Pinal counties, industrial uses account for only 0.47% of total land use[5]. Solar generation projects are a type of industrial use that require a minimal volume of water[6]. Such low water requirements may be a reason there is no ADWR conservation program for solar facilities, programs that seek to regulate water use for a variety of facilities and water use types[7]. This analysis provides context on solar water use as compared to other water uses in Arizona.

WestWater compiled sector-level water use data reported to ADWR and from other sources within the state's Active Management Areas (AMAs) to develop and analyze proxy water demand estimates of annual average water use by relevant alternative land uses. Alternative land uses include agriculture, residential (subdivisions), manufacturing, data centers, and industrial uses. Industrial uses include large turf facilities, primarily golf courses, dairy operations, cattle feedlot operations, and power generation facilities.

Estimated water use for each sector by acre and MW (as applicable) is summarized in **Table 1**. The highest estimated water use across all AMAs during the 2019-2023 analysis period was attributed to data centers at 6.3 AF/acre, followed by turf and agricultural irrigation at 4.1 AF/acre, and manufacturing at 3.6 AF/acre. Natural gas and nuclear power facilities, for which water use data were reported to ADWR, require 4.3 AF/MW and 18.7 AF/MW, respectively. Solar facility water use is extremely low in terms of both a per acre and per MW

[3] Agriculture, Conservation. Arizona Department of Water Resources https://www.azwater.gov/conservation/agriculture#:~:text=Irrigated%20agriculture%20is%20the%20largest,of%20the%20available%20water%20supply

[4] Conservation. Arizona Department of Water Resources. https://www.azwater.gov/conservation/public-resources#:~:text=About%2020%20percent%20of%20the,most%20of%20this%20is%20residential.

[5] Land Use Explorer (2022). Maricopa Association of Governments. https://geo.azmag.gov/maps/landuse/

[6] Water Impacts of High Solar PV Electricity Penetration. National Renewable Energy Laboratory. September 2015.

[7] Active Management Areas Management Plans (2023) https://www.azwater.gov/ama/ama-management-plans

comparison. Solar water use is estimated to be 0.03 AF/acre and 0.16 AF/MW. **Figure 1** and **Figure 2** provide additional summaries of water use from this analysis.

Table 1: Summary of Water Use in Arizona by Sector

Sector	Average Use
AF/acre	
Solar	**0.03**
Feedlots	1.4
Dairy	2.2
Subdivisions	2.3
Manufacturing	3.6
Irrigation	4.1
Golf Course	4.1
Data Centers	6.3
AF/MW	
Solar	**0.16**
Power (Natural Gas)	4.3
Power (Nuclear)	18.7

Figure 1: Arizona Water Use per Acre by Facility Type

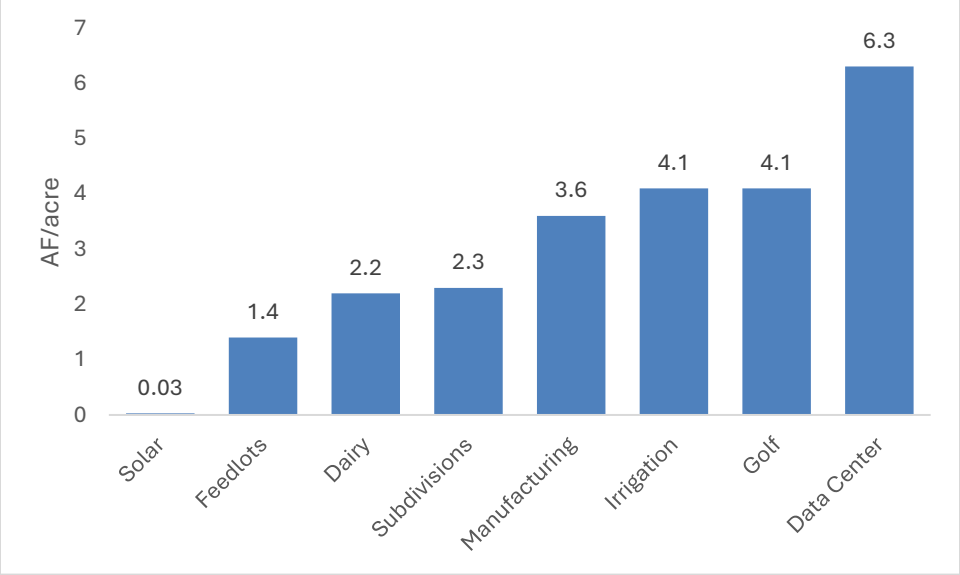
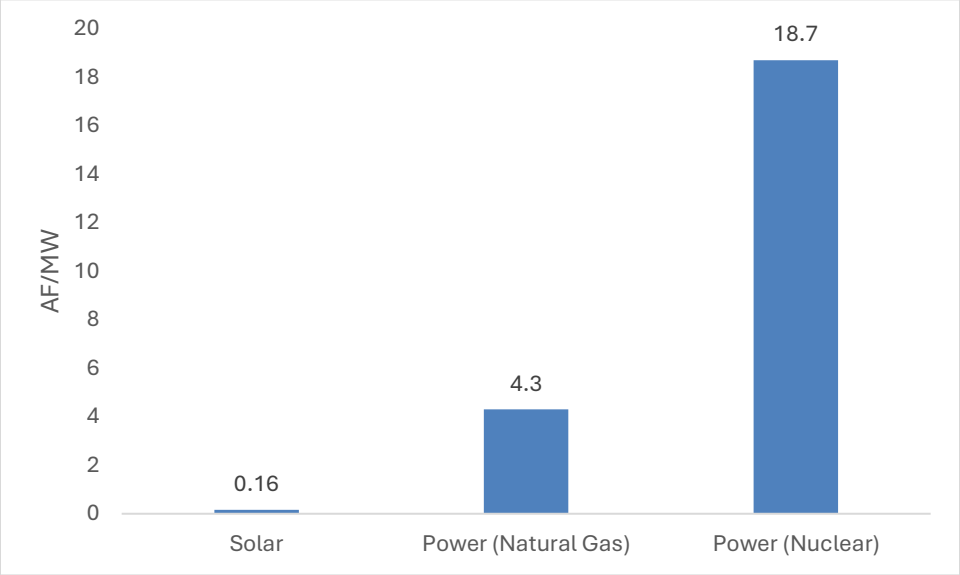


Figure 2: Arizona Water Use per MW – Solar, Natural Gas, and Nuclear

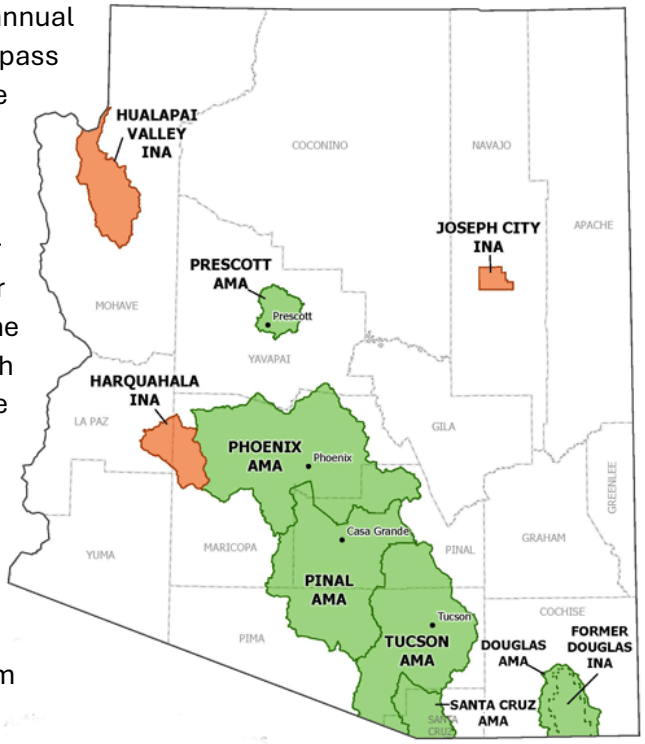


Conclusions

The results of this analysis clearly demonstrate that water use by solar facilities is significantly lower than that of potential alternative land uses. In fact, solar water use is virtually zero, which cannot be said of any other alternative land use. Other land uses utilized water at significantly higher rates than solar facilities. Average water use across the sectors analyzed for this effort is 3.4 AF/acre, which is 100 times the use of solar facilities (0.03 AF/acre). In particular, data centers were found to use 6.3 AF/acre on average, which is 200 times the amount used by solar. Nuclear power was found to use 18.7 AF/MW, which is 100 times the amount used by solar (0.16 AF/MW). As compared to the other water use estimates, solar facility water use is negligible.

Appendix A: Data and Methodology

This analysis primarily utilizes AMA annual report data from ADWR. AMAs encompass the most populated areas of the state and account for approximately 80% of statewide water use[8]. Within the AMAs, water use exceeding a certain volume is highly regulated and therefore water may only be utilized pursuant to a water right. For these reasons, AMAs are the only areas of the state for which comprehensive, up-to-date water use data are available. In addition, the management plans detail several mandatory conservation programs for various water use types. Water users within AMAs are required to annually report the water use, and facilities that fall into a required conservation program must report supplemental use information.



ADWR data include total use by irrigation rights and various industrial subsectors including golf courses, feedlots, dairy, and power. Supplemental data were also provided including, as applicable, associated irrigation acres, acres of landscaped area, number of animals, volume of product produced, and amount of power generated. Although ADWR data are only available for the AMAs, as it is the most robust water use dataset within Arizona, these values are used as a proxy for other water use in the same sectors in Arizona.

In addition, data from the Central Arizona Groundwater Replenishment District (CAGRD) and Census Bureau (CB) were used to develop water use estimates for subdivisions[9]. This included 2018-2022 CAGRD data on the number of new CAGRD member land lots and their projected water demand. Lot size data from the CB Survey of Construction in 2021 were also used[10]. In addition to these sources, this analysis also utilized the ADWR Supply and Demand

[8] Arizona Department of Water Resources, "Active Management Areas," Fact Sheet, (March 2016).

[9] CAGRD Reports and Information (2011-2022). Central Arizona Groundwater Replenishment District. https://cagrd.com/operations/cagrd-reports-and-information/

[10] Characteristics of New Housing (2021). Unites States Census Bureau. https://www.census.gov/construction/chars/sold.html

Assessments methods appendix [11] to develop water use sector demand estimates. Governmental reports and other publicly available information were referenced to develop manufacturing and data center water demands.

WestWater developed estimates of annual water use for the following sectors and subsectors: Irrigation, Golf Course, Feedlots, Dairy, Subdivisions, Manufacturing, Data Center, and Power. Solar water use can be captured in two ways: 1) volume by acre and 2) volume per amount of power produced. To develop water use estimates that are comparable to solar use, WestWater used two common units. For water use that is associated with the size of the land, water estimates are developed per acre. For the power sector, water use is not directly related to the size of the land where the facility is sited. Instead, the volume of water is expressed as AF/MW.

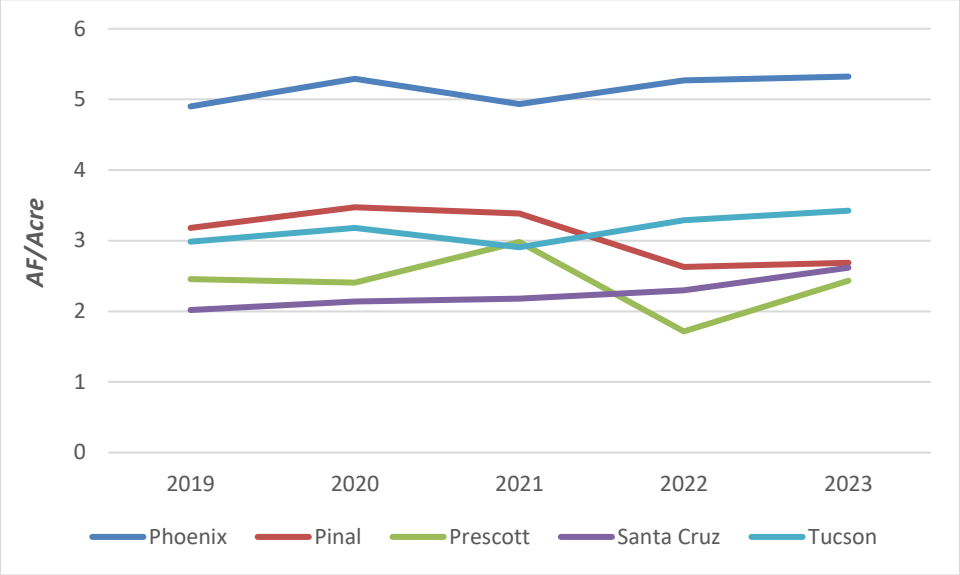
Irrigation

To develop estimates for irrigation water, ADWR annual report data were filtered to irrigation rights or rights that fall under the base or best management plans' conservation programs. Once the data were filtered, the total reported annual use in AF was divided by the number of acres associated with each right. Although some annual reports include irrigated acres, it is not required by the Department. As a result, this estimate does not necessarily represent water use per irrigated acre, although it may be representative of agricultural land.

Irrigation water use varies by AMA as summarized in **Figure 3**. The Phoenix AMA had the highest water use, averaging 5.1 AF/acre over the 5 years of reported data. The Santa Cruz and Prescott AMAs had the lowest use, with an average of 2.3 AF/acre and 2.4 AF/acre respectively. Overall, the average irrigation use across all years and AMAs was **4.1 AF/acre**.

[11] Supply and Demand Methods Appendix (2023). Arizona Department of Water Resources. https://www.azwater.gov/sites/default/files/2023-12/2023_MethodsAppendix_1.pdf

Figure 3: Irrigation Average Water Use by AMA, 2019-2023 (AF/Acre)

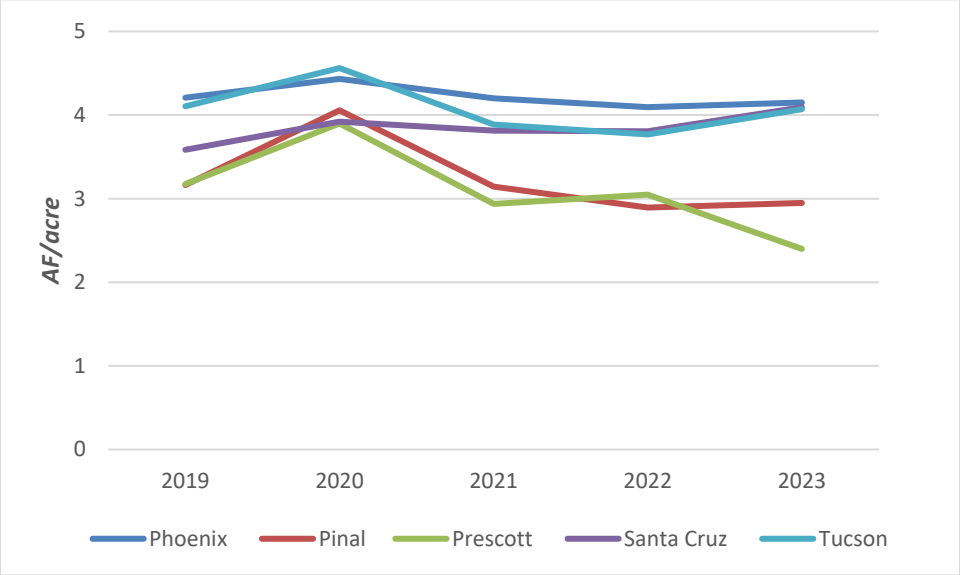


Golf Course

The industrial water use sector consists of various turf subsectors including golf. Turf related facilities are required to report up-to-date data on the number of turfed, low water use, and water surface acres present. These acres were summed to determine total acreage for golf. The total reported annual water use was then divided by the total number of acres for golf for an AF/acre estimate by facility.

Water use by golf courses is typically related to the amount of high intensity water use (turf and water features) and the efficiency of irrigation infrastructure. The 5-year average water use for golf courses ranges from 3.2 AF/acre to 4.2 AF/acre across the AMAs. Overall, golf course water use averages **4.1 AF/acre**. Golf water use is lower on courses in the Prescott AMA, where precipitation tends to be higher. Water use by turf for golf courses is summarized in **Figure 4**.

Figure 4: Golf Course Water Use by AMA, 2019-2023 (AF/Acre)



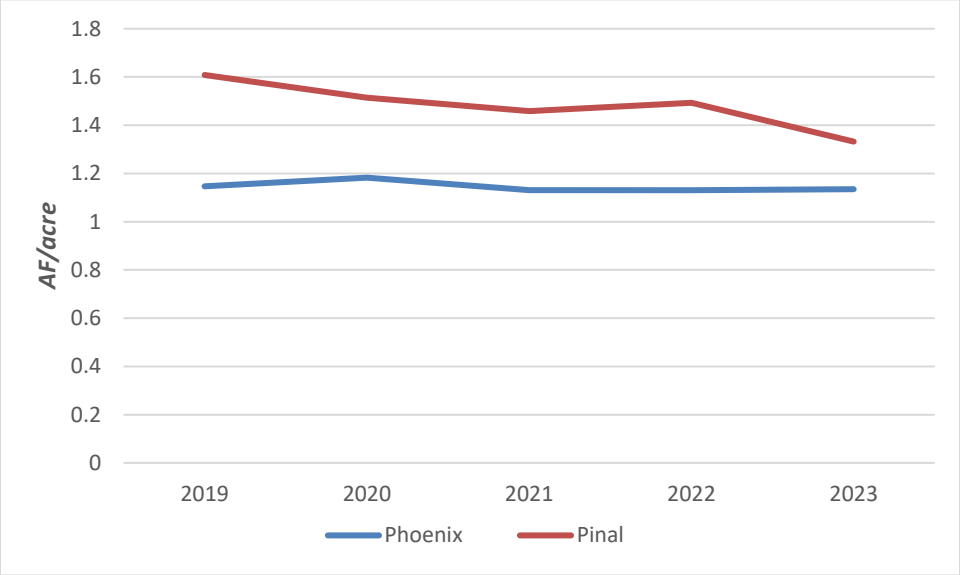
Feedlots/Dairy

ADWR annual reports for feedlots include data on the number of animals at each facility by month. These data were summed to develop an annual number of animals per facility. The total reported water use was then divided by the number of animals at each facility for an AF/animal estimate. Feedlot designs include one acre of land per 100 heads of cattle, which includes space for pens, alleys and feed roads[12]. To determine a per-acre estimate for feedlots, the volume of AF per animal was multiplied by the number of animals per acre. ADWR data for feedlots were reported in the Phoenix and Pinal AMAs.

Feedlots use slightly more water in the Pinal AMA and average 1.5 AF/Acre, as compared to 1.1 AF/acre in the Phoenix AMA, as summarized in **Figure 5**. Across all facilities and all years, the average feedlot use is **1.4 AF/acre**.

[12] Planning and Designing Cattle Feedlots (2021). Kansas State University Agricultural Experiment Station and Cooperative Extension Service. https://bookstore.ksre.ksu.edu/download/planning-and-designing-cattle-feedlots_MF2316

Figure 5: Feedlot Average Water Use, 2019-2023 (AF/Acre)



Dairy use was estimated based on ADWR's Supply and Demand Assessments (SDA) methods. The ADWR SDA estimates a range of water use per type of cow, including water use for consumption, dust suppression, and other facility uses. The estimates range from 0.02 to 0.04 AF/animal/year, with lower water use representing calves and the highest water use reflecting use by lactating cows. The average water use among all animal types was 0.03 AF/animal/year. Dairy facilities require one acre per 75 heads of cattle[13]. Using the ADWR SDA method and assuming 75 animals per acre results in an estimated water use of **2.2 AF/acre**.

Subdivisions

CAGRD Annual Operations Reports from 2018-2022 were used as the basis for developing subdivision water use estimates. These reports include estimates of projected annual demand for new member lands, including the number of new subdivisions and lots by region (East Phoenix, West Pheonix, Pinal, and Tucson). The number of lots per subdivision varies widely and was not used to develop a per acre estimate. Average lot size is also variable, however, data from the CAGRD and CB were used to estimate average lot sizes in Arizona. CAGRD estimates average lot sizes of approximately 9,000 square feet (sq ft) and 12,000 sq ft in the Phoenix and Tucson areas respectively[14]. The CB conducts a Survey of Construction,

[13] Relocation And Expansion Planning for Dairy Producers (1999). Kansas State University Agricultural Experiment Station and Cooperative Extension Service. https://krex.k-state.edu/server/api/core/bitstreams/dd52978b-e561-41c5-95a4-19ab46eb0c63/content

[14] Central Arizona Groundwater Replenishment District Membership Water Demand Analysis (2020), Water Resource Consulting, Contract No. C85195

which includes data on lot size for new builds across several regions15. In the West region, new builds averaged approximately 10,000 sq ft. Given the range of average lot sizes, this analysis used a range of 9,000 to 12,000 sq ft. The annual water use per lot was divided by the average acres per lot to develop a subdivision per acre estimate.

Water use by subdivisions ranged from 1.5 AF/acre to 3.0 AF/acre. The highest water use was in east Phoenix. As the number of lots per acre decreased the water use per acre also decreased. Subdivision water use is estimated to range from 1.9AF/acre to 2.5 AF/acre and average **2.3 AF/acre**, as summarized in **Table 2**.

Table 2: Average Water Use by Lot Size (AF/Acre)

Average Lot Size (square feet)	East Phoenix	Pinal	Tucson	West Phoenix	Average
	AF/acre				
9,000	3	2	2.3	2.8	2.5
10,000	2.7	1.8	2	2.5	2.3
12,000	2.3	1.5	1.7	2.1	1.9

Manufacturing Facilities

Arizona is becoming a hub for manufacturing, in large part due to significant federal and state investment and favorable economic and geographic conditions. There are little to no annual water use report data on manufacturing facilities in publicly available datasets, such as those maintained by ADWR and relied upon in this analysis. Taiwan Semiconductor Manufacturing Company (TSMC) and Intel are two major companies with facilities in Arizona who have publicly provided estimates of their facility water usage. TSMC estimates using 4.75 million gallons per day (MGD) or 5,321 AF annually at its 1,100-acre facility, equivalent to 4.8 AF/acre. Intel estimates using 1.5 MGD or 1,680 AF annually at its 700-acre facility, equivalent to 2.4 AF/acre[16]. Together these facilities use an estimated **3.6 AF/acre** annually on average.

Data Centers

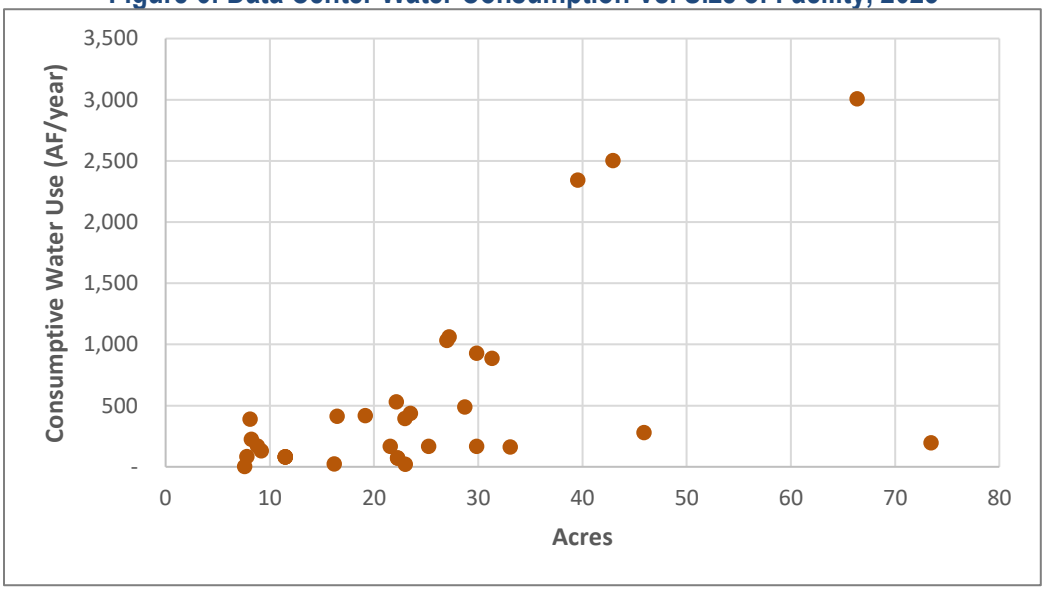
As data center facilities are relatively new in Arizona, ADWR does not collect annual reports from these water users. However, data can be collected from company sustainability reports, local water management plans, press releases, and news articles. Water use information for 30 facilities was collected by WestWater from across the United States. Of

[16] AZ Central Article: *How much water will TSMC Arizona use? Probably a lot less than you think.* Joanna Allhands. June 12, 2024. TSMC Arizona is on track to use a lot less water than you think (azcentral.com)

this dataset, two facilities are in Arizona. Data center water use is influenced primarily by size of the facility and the amount of power used at the facility. To develop a comparable water use estimate to other land uses, total water use for each facility was divided by size of the facility in acres.

Water use was correlated with total size at the facility as shown in **Figure 6**. Water use by size ranged from 0.5 AF/acre to 59.2 AF/acre, with an average of 18.6 AF/acre. The two facilities in Arizona had similar per acre water use, averaging **6.3 AF/acre**.

Figure 6: Data Center Water Consumption Vs. Size of Facility, 2023



Power

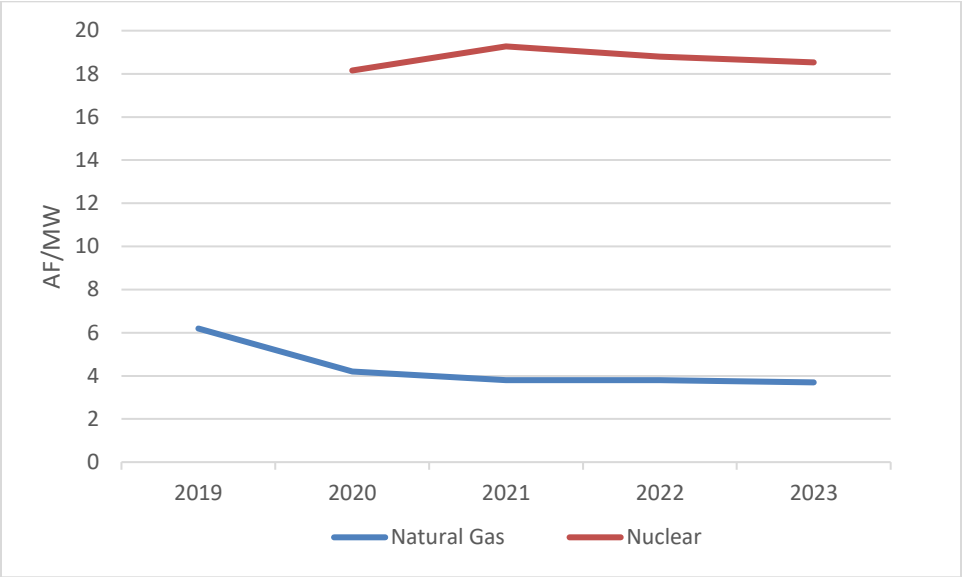
ADWR annual report data were used to estimate water use for the power subsector consisting of nuclear and natural gas. While there are other power generation facility types in Arizona outside the AMAs, this analysis only considers those AMA facilities whose water use is reported to ADWR. ADWR data also included information on power generated at each facility by month. However, these data were inconsistently reported and the units used were often unclear. To ensure a comparable unit, ADWR used publicly available information on each of the facilities to determine the MW capacity.[17] The total water use was divided by the generating capacity of each facility to estimate an AF/MW.

ADWR collects annual report data for eight power facilities in the AMAs, including one nuclear and seven natural gas facilities. Water use was filtered to the type of facility as the difference in reported use across facility type was vast. Over the five-year analysis period,

[17] SRP Power Generation Sources (2024). Salt River Project. https://www.srpnet.com/grid-water-management/grid-management/power-generation-stations

water use at Arizona natural gas power facilities ranged from 3.7 AF/MW to 6.2 AF/MW and averaged **4.3 AF/MW**. In contrast, the Arizona nuclear facility used more water, averaging **18.7 AF/MW**. Water use by power facilities is summarized in **Figure 7**.

Figure 7: Power Facility Average Water Use, 2019-2023 (AF/MW)



Solar

Because solar facilities use such a small amount of water, ADWR does not require annual water usage reporting and therefore data are limited. In general, ADWR-exempt uses account for less than 100 AF of water per year[18].

The National Renewable Energy Laboratory (NREL) completed a study on water supply and demand conditions impacting the solar industry, which includes estimates of solar water use[19]. The study includes water consumption estimates for photovoltaic (PV) solar. PV is a non-thermal renewable energy technology that does not require water but can use a relatively small amount of water primarily for washing panels. This technology is commonly used in solar facilities because it is a renewable, non-polluting, and inexhaustible energy source. The estimated median water use rate for solar is 25 gallons per megawatt hours (MWh) or 0.0001 AF/MWh, which represents the volume of water per unit of electricity generation. NREL demonstrates that solar uses water at a rate of virtually zero to produce electricity.

[18] Industrial Program | Arizona Department of Water Resources (azwater.gov)

[19] Water Impacts of High Solar PV Electricity Penetration. National Renewable Energy Laboratory. September 2015.

Most solar projects in the Southwest US are never washed during operation, however for this analysis, the NREL water use per MWh estimate was utilized to evaluate an example 200 MW solar project on 1,200 acres. A facility of this size is generally in the range with recent power purchase contracts announced by Arizona Public Service and Salt River Project, two of Arizona's largest electric utilities. According to FreeingEnergy, one MW of solar power produces 2,146 MWh of solar energy[20]. In this example, the total water use of the facility would be equivalent to 32.9 AF. Over a 200 MW, 1,200-acre facility, this equates to an annual water use estimated to total **0.16 AF/MW** and **0.03 AF/acre**.

[20] FreeingEnergy. How many MWh of solar energy comes from a MW of solar panels? https://www.freeingenergy.com/math/solar-pv-gwh-per-mw-power-energy-mwh-m147/#:~:text=On%20average%2C%20across%20the%20US,of%20solar%20energy%20per%20year.