Comparison of Water Use by Energy Generation Types

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Introduction:
The energy sector is heavily dependent on water resources and is sensitive to ongoing changes in water availability and concerns of future water scarcity. Both energy generation and water availability are key to successful daily life and both need to be prioritized. This report will present the water use data (withdrawal and consumption) for different energy generation types to highlight the options that use the least amount of water. Low water use methods not only decrease water use, aiding in climate change mitigation, but also can decrease the overall cost of energy generation and consumption. This report compares nonrenewable, thermoelectric power plants to renewable energy sources.

Disclaimer:
Reporting for water use is very limited and inconsistent for power plants. Due to this, some of the information in this report is outdated or sampled from a small sample pool, meaning exact numbers may not be entirely accurate. However, the overall trends and conclusions presented in this report are accurate and should be considered in decision making.

Terminology:
- Water withdrawal: water removed from the ground or diverted from a surface-water source for use, most of which is returned to the original source (1)
- Water consumption: the part of water withdrawn that is evaporated, transpired, incorporated into products or crops, consumed by humans or livestock, or otherwise lost to the system (1)
- Thermoelectric power plants: generate electricity by either burning fossil fuels or using nuclear fission to boil pure water, creating steam that drives turbines that generate electricity (2)
- Once-through systems: water moves once through the condenser, typically draws water directly from a source and discharges the water back to the source at a higher temperature
- Wet cooling towers: water moves through a condenser and then to a tower where it evaporates

Methodology:
This report will be split into water use data for nonrenewable energy and renewable energy. For nonrenewable energy we looked at water withdrawal and water consumption rates for thermoelectric power plant cooling systems. We focused on water used in the cooling process, as this is where the majority of water is used for thermoelectric plants (2). Major components of thermoelectric data include: the energy source, generator technology, and cooling system type (2). Changes in any of these categories affects water use.

Findings:

Water use data for thermoelectric power plants was pulled from a National Library of Medicine 2010 case study conducted in Texas that compiled thermoelectric plant data from around the state (2). Using Texas as a case study allows for a relatively accurate representation of the entire United States, due to Texas' diverse climatic conditions. Texas' generator technologies also reflect those used throughout the United States.

The case study obtained data from the EIA, TCEQ, and TWDB databases. Table 1 shows water consumption and withdrawal rates by fuel type, generator technology type, and cooling system type. When comparing the gallons per kilowatt per hour (gal/kWh), coal plants have the highest water consumption rate (0.54 gal/kWh), while nuclear plants have the highest withdrawal rate (36 gal/kWh).

In terms of generator technology type, steam turbines have both the highest water consumption and withdrawal rates (0.52 gal/kWh and 36 gal/kWh respectively). Finally in comparing the cooling systems, once-through systems consume and withdraw at the highest rate (0.48 gal/kWh and 49 gal/kWh respectively). When looking at individual power plants in the San Antonio area, those affiliated with CPS Energy (as seen in Table 2) the same trends occur: coal plants and plants using steam turbines tend to use the most water.

Water use data for renewable energy plants was sourced from a study conducted by the National Renewable Energy Laboratory (4). The study looks at data from the public and private sectors across the United States to compare water consumption rates of different renewable energy sources. As seen in Table 3, concentrated solar power (CSP) and Nuclear consume the highest amounts of water. The Tower cooling method for both CSP and Nuclear consumes the most water, with an average of 0.897 and 0.672 gal/kWh respectively. Photovoltaic solar (PV) and Wind consume the least water; their consumption being basically zero.

Table 1. 2010 Texas Net Electricity Generation Requiring Cooling and Cooling Water Consumption and Withdrawal Amounts and Intensities/Rates (2)

Grouping		N	NetG	Consumption		Withdrawal	
			(TWh)	*(kaf)*	*(gal/kWh)*	*(kaf)*	*(gal/kWh)*
Fuel	Nuc	4	41	59.0	0.46	4,619	36
	Coal	39	151	248.4	0.54	12,273	27
	NG	379	160	115.5	0.23	9,289	19
	Oth	21	2	3.8	0.57	4	0.60
Gen Tech	ST	175	219	349/1	0.52	24,316	36
	CC	268	135	77.6	0.19	1,867	4.5
Cool	OT	115	171	251.9	0.48	25,986	49
	T	328	183	174.8	0.31	198	0.35
All	All	443	354	427	0.39	26,184	24

N: Number of generators; NetG: Net Generation; TWh = million MWh; kaf: acre-foot; NG: Natural Gas; Nuc: Nuclear; Oth: Other; Gen Tech: Generation technology; Cool: Cooling system type; ST: Steam Turbine; CC: Combined cycle; OT: Once-through; T: Wet cooling tower

Table 2. Average Monthly Water Consumption and Withdrawal Amounts and Rates for CPS Energy Affiliated Plants (3)

Plant Name	Fuel	Gen Tech	Withdrawal		Consumption	
			(kaf)	*(gal/kWh)*	*(kaf)*	*(gal/kWh)*
O.W. Sommers I	Natural Gas	ST	2, 386.16	54.33	36.41	0.63
O.W. Sommers II	Natural Gas	ST	1,961.93	27.27	26.64	0.33
South Texas Project	Nuclear	ST	22.78	NA	372.86	NA
J.K. Spruce I	Coal	ST	4,242.18	30.03	58.98	0.37
J.K. Spruce II	Coal	ST	4,985.37	50.51	75.60	0.38
Rio Nogales Power Project	Natural Gas	CC	30.30	NA	25.42	NA

kaf: acre-foot; Gen Tech: Generation technology; ST: Steam Turbine; CC: Combined cycle

Table 3. Renewable Energy Sources and Water Consumption (4)

Fuel Type	Cooling Technology	Technology	Median Consumption (gal/kWh)	N
PV	N/A	Utility scale PV	0.001	3
Wind	N/A	Wind turbine	0	2
CSP	Tower	Trough	0.906	18
		Power tower	0.786	4
		Fresnel	1.00	1
	Dry	Trough	0.078	11
		Power tower	0.026	1
	Hybrid	Trough	0.338	3
		Power tower	0.170	2
Geothermal	Tower	Flash	0.015	4
	Dry	Flash	0.005	1
		Binary	0.270	1
		EGS	0.505	1
	Hybrid	Binary	0.461	2
Nuclear	Tower	Generic	0.672	6
	Once-through	Generic	0.269	4
	Pond	Generic	0.610	2

PV: Photovoltaic solar; CSP: Concentrated Solar Power; N: Sample size

Conclusion:

The data in this paper shows that many renewable energy sources consume significantly less water than nonrenewable, fossil fuel alternatives. While both CSP and nuclear (the highest water renewable water consumers) consume more water than nonrenewable options, all other forms of renewable energy consume less water than the lowest, nonrenewable consumer of water—natural gas. Photovoltaic solar and wind energy generation consume next to no water.

With water scarcity becoming a reality and water prices increasing, the importance of water conservation is key both for the environment and for economic purposes. For these reasons, it is important for energy providers and energy users to be mindful of their water consumption and to consider switching how their energy is generated.

References:

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