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Freshwater use by U.S. power plants: Initial insights into the energy-water nexus

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Note: This article was distilled from the report "Freshwater Use by U.S. Power Plants: Electricity's Thirst for a Precious Resource" (Averyt et al. 2011), a product of the Union of Concerned Scientists' Energy and Water in a Warming World (EW3) initiative. A slightly different version of this article appeared in the Spring 2012 *Ogmius,* the quarterly newsletter of the Center for Science and Technology Policy Research (CSTPR), CIRES, University of Colorado.

Every minute, all the power plants in the United States take in about three times as much water as flows over Niagara Falls. The nation's thermoelectric power plants—which boil water to create steam, which in turn drives turbines to produce electricity—withdraw as much water as farms, and more than four times as much as all U.S. residents. That means lighting rooms, powering computers and TVs, and running appliances requires the withdrawal of more water, on average, than the total amount we use in our homes—washing dishes and clothes, showering, flushing toilets, and watering lawns and gardens. Simply, generating electricity requires a lot of water.

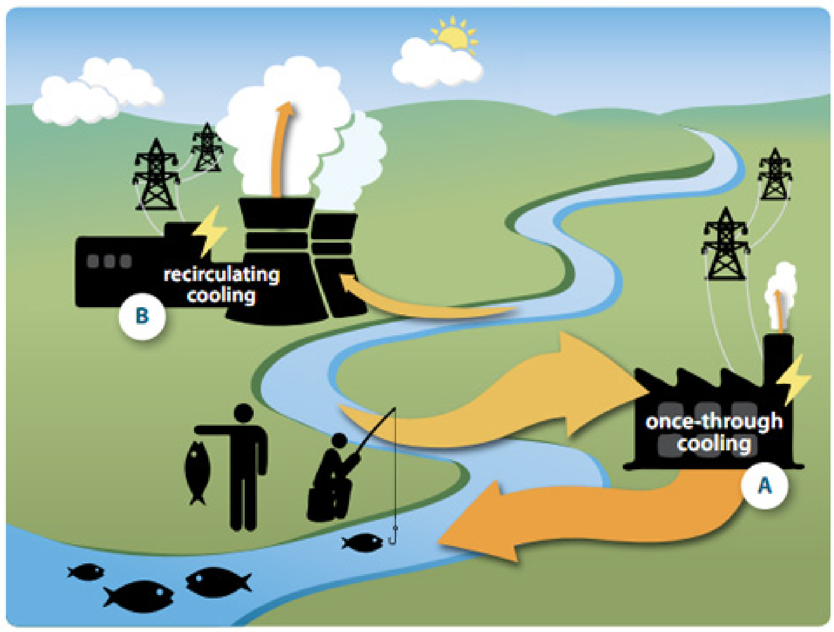

Figure 1. Schematic showing ***once-through cooling*** *(A), which withdraws much more water but consumes a very small fraction of the withdrawals, and* ***recirculating cooling*** *(B), which withdraws much less water, but consumes much of the withdrawn water. (Source: "Freshwater Use by U.S. Power Plants," Averyt et al. 2011).*

The amount of water necessary depends on the type of power plant: a nuclear power plant uses eight times as much water per kilowatt-hour (kWh) as a natural gas plant, and about 10% more than a coal-fired power plant. Some renewable technologies also require water. Thermal solar plants use as much water as a coal plant per kWh, but wind power uses little to no water. So choices about fuel type and cooling technology have implications for local and regional water sources, and low-carbon does not always mean low-water.

In parts of the U.S., water demand from power plants is combining with pressure from growing populations and other needs and straining water resources—especially during droughts and heat waves. The current drought in Texas is creating tension among farmers, cities, and power plants across the state. At least one plant had to cut its output, and some plants had to pipe in water from new sources. The state power authority warned that several thousand MW of electrical capacity might go offline if the drought persists into spring of 2012. Proposed power plants have also taken hits over water needs. Local concerns about water use have scuttled planned facilities in Arizona, Idaho, Virginia, and elsewhere. Developers of proposed water-cooled concentrating solar plants in California and Nevada have run into opposition, driving them toward dry cooling instead.

Unfortunately, identifying potential vulnerabilities associated with the nexus between water and energy resources has been problematic, as annual water use statistics reported by power plant operators to the U.S. Energy Information Administration (EIA) contain significant inconsistencies, errors, and gaps. Recognizing this problem, we profiled the water use characteristics of virtually every electricity generator in the U.S., and estimated water use (withdrawal and consumption) of those generators based on their reported annual generation in 2008.

Our results show that power plants that did not report their water use to the EIA accounted for 28–30% of total freshwater withdrawals by the electricity sector, and at least 24–31% of freshwater consumption. Some regions of the country did better than others. State-wide reported freshwater use by power plants fell outside the bounds suggested by our analysis in 22 states for withdrawal, and in 38 states for consumption. The discrepancies were especially large in the Lower Colorado River and Southeast-Gulf regions, where plant operators reported consumption five times greater—and withdrawals 30% less—than median water-use values would suggest. Such inconsistencies in data can significantly hinder efforts to assess risks to both electricity and water systems.

Fortunately, comparison of our analysis with the reported data allowed us to specify where the EIA can improve its water data intake process so that the information is more useful for planning in the energy and water sectors. Indeed, the EIA is addressing many of the issues outlined in our analysis in its 2010 dataset.

Based on our analysis, every *day* in 2008, water-cooled thermoelectric power plants in the United States withdrew 60 billion to 170 billion gallons (180,000 to 530,000 acre-feet) of freshwater from rivers, lakes, streams, and aquifers, and consumed 2.8 billion to 5.9 billion gallons (8,600 to 18,100 acre-feet) of that water. Our nation's large coal plant fleet alone was responsible for 67% of those withdrawals, and 65% of that consumption. Power plants withdrew 84% of their cooling water from rivers and lakes; the balance came mainly from the ocean.

Plants in the East generally withdrew more freshwater per kWh than plants in the West: freshwater withdrawal intensity was 41 to 55 times greater in Virginia, North Carolina, Michigan, and Missouri than in Utah, Nevada, and California. The difference is caused by the relative lack of water-efficient technologies in Eastern cooling systems, and the use of non-traditional water sources (e.g., wastewater) by some Western power plants.

Using the results of our analysis, we assessed the

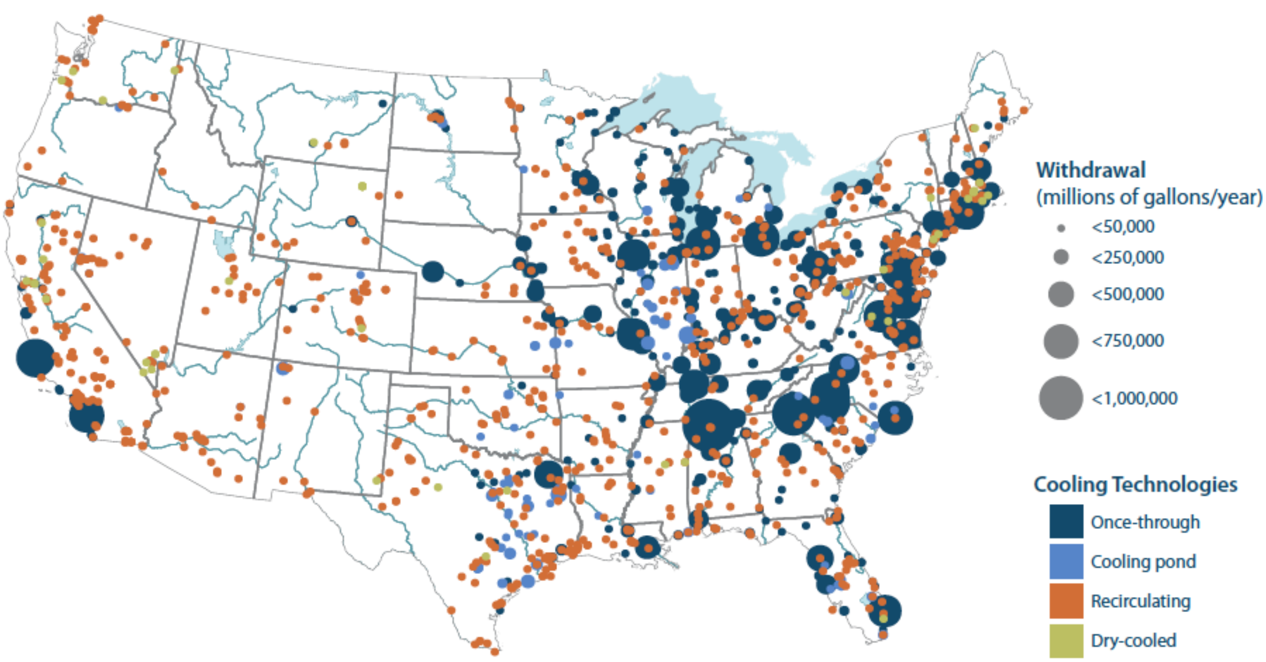

Figure 2. Estimated water withdrawals for U.S. power plants in 2008, based on median NREL values for plant water use as a function of capacity. Nearly all plants in the Intermountain West are coal-fired; most use recirculating cooling and thus have much lower withdrawals than the "once-through" plants common in the eastern U.S.—though a much higher proportion of the withdrawn water is actually consumed. See box on Page 3. (Source: "Freshwater Use by U.S. Power Plants," Averyt et al. 2011)

Power plant water use in the Intermountain West

While water *withdrawals* for power plants in Wyoming, Utah, and Colorado pale in comparison to most eastern states (Figure 2), *consumption intensity* (water consumed per kWh produced) in the Intermountain West is among the highest nationally —about 0.5 gallons per kWh—because of the prevalance of coal plants using recirculating cooling in this region. Total estimated water consumption by power plants in each of the region's three states is about 25 billion to 50 billion gallons per year, or 75,000 to 150,000 acre-feet per year.

A single large power plant can account for much of the water consumed in that watershed. For example, in the Bitter Creek Basin in southwestern Wyoming, the Jim Bridger coal-fired plant consumes about 10 billion gallons (30,000 acre-feet) annually, which is reflected in the high water stress score for that basin as shown in Figure 3.

stress that power plant water use placed on water systems across over 2,000 U.S. watersheds using the Water Supply and Stress Index (WaSSI). Based on our analysis, in 2008, 400 out of 2,106 watersheds across the country were experiencing water-supply stress. Power plants, by tapping these water resources for cooling purposes, appeared to substantially contribute to water-supply stress in about 80 of these watersheds (Figure 3; orange, red, and dark red shades).

These initial water stress results should serve as an indicator of places to dig deeper and really take a critical look at the nature of water supply and demand, and the role of electric power. For example, in the Intermountain West, water stress from power plant use is indicated only in a small number of basins. But conflicts over water involving the energy sector may become more problematic in the future. Water availability in the region is a zero-sum game: surface waters are generally over-allocated, and groundwater levels are consistently declining. This leaves little room to accommodate increasing demands for water resources that growing populations will bring, and the imminent deleterious impacts to water supplies driven by climate change.

Resources

The full report, "Freshwater Use by U.S. Power Plants: Electricity's Thirst for a Precious Resource" (Averyt et al. 2011), is available as a PDF from the Union of Concerned Scientists website here: http://www.ucsusa.org/clean_energy/technology_and_impacts/impacts/freshwater-use-by-us-power-plants.html

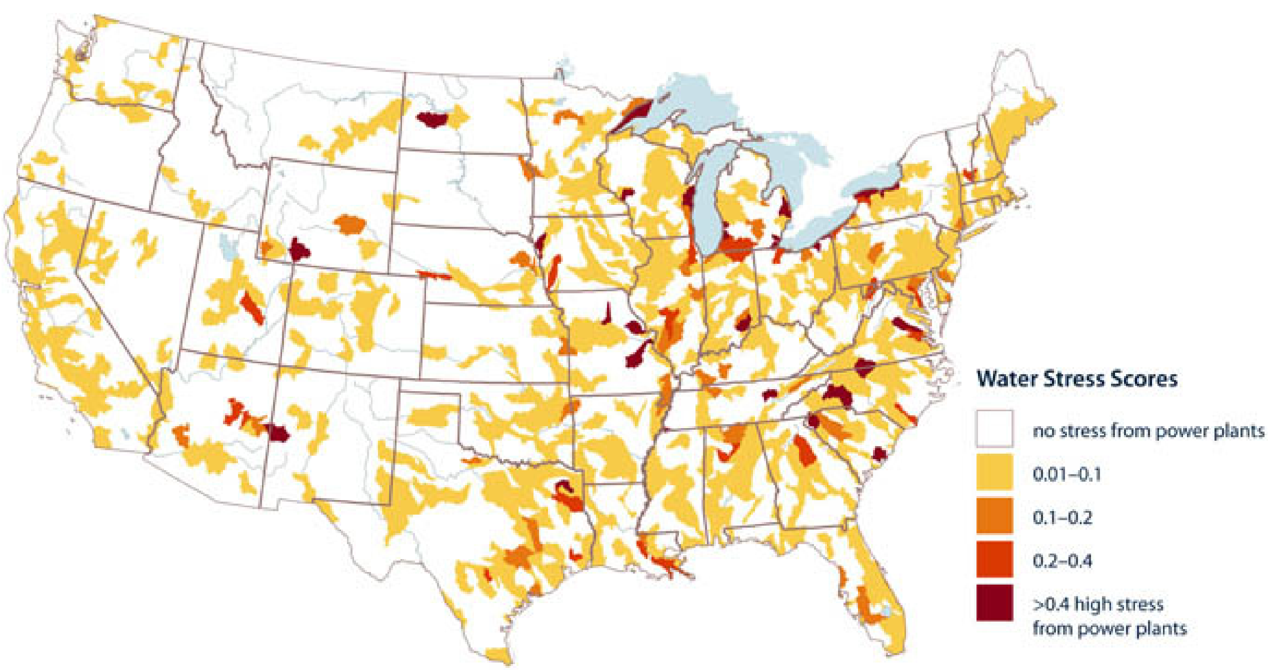

Figure 3. The Water Supply Stress Index (WaSSI) was calculated for all basins in the U.S. both with and without power plant water use. The darker shades indicate increasing relative contributions of power plant water use to overall water stress in that basin. (Source: "Freshwater Use by U.S. Power Plants," Averyt et al. 2011).