Energy and Water: Connection and Conflict

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Energy and water are two fundamental building blocks of the U.S. economy. Power plants need water to operate. Electric water pumps move water around the country, especially in the West. Because energy and water are inextricably linked, they are in a constant interplay of supply and demand where a change in the availability one resource can impact the usage of the other and vice versa. Especially during droughts, water scarcity can cause conflict as drinking and agriculture needs increasingly compete against energy needs.

Energy's Thirst for Water

Energy's thirst for water manifests itself in several ways. To produce electricity in nuclear and fossil-fueled power plants requires substantial volumes of water. Extracting and processing raw materials such as coal and natural gas requires water, but doing so also risks polluting and contaminating surface and groundwater sources. This not only could jeopardize drinking water supplies, but could also undermine future energy production if current water sources become scarce or rendered unusable. The nation's energy system is one of the largest consumers of water, a relationship that cannot be sustained into the future as the U.S. population grows and the climate changes. (Figure 1)

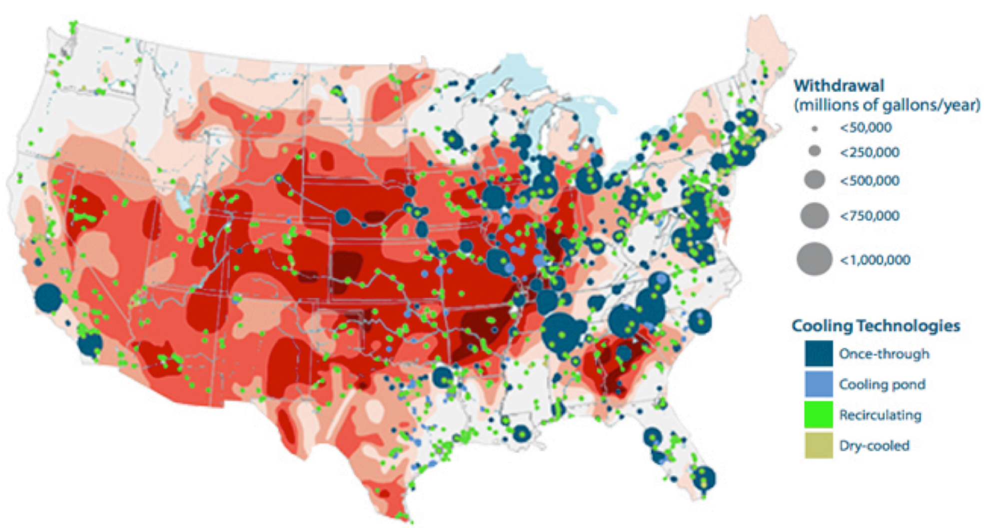

Figure 1: Location of Power Plant, Water Withdrawals, and Cooling Technologies on U.S. Drought Levels

Drought intensity levels are shown from light to dark red corresponding to abnormally dry (short-term dryness or lingering water deficits), moderate drought (some crop damage; imminent water shortages), severe drought (crop losses likely; water shortages common), extreme drought (major crop losses; widespread water shortages), exceptional drought (widespread crop losses; water emergencies) respectively. These drought levels reflect values from the National Drought Monitor as of August 2, 2012. *Source: Union of Concerned Scientists (2011), Freshwater Use by U.S. Power Plants: Electricity's Thirst for a Precious Resource; http://www.cnn.com/interactive/2012/07/us/drought/index.html*

Electricity Production

- In the United States, nuclear and fossil-fueled power plants *withdraw* 143 billion gallons of freshwater[1] every day from rivers, lakes, stream, and aquifers. This is roughly equivalent to the daily domestic water usage of 140 New York Cities[2] or the daily water needed to irrigate the fields of nearly 17 Nebraskas.
- These same plants *consume* 2.2 to 5.9 billion gallons of water every day[3], primarily through evaporation of steam generated to turn their turbines. While substantially less than the amount withdrawn, consumed water is a problem in areas where water supplies are already stretched since this water is lost to other users in the region such as farmers.
- U.S. coal plants alone were responsible for 67% of the water withdrawals and 65% of the consumption in 2008[4]. However, nuclear power plants require the most water on a per plant basis (Figure 2).

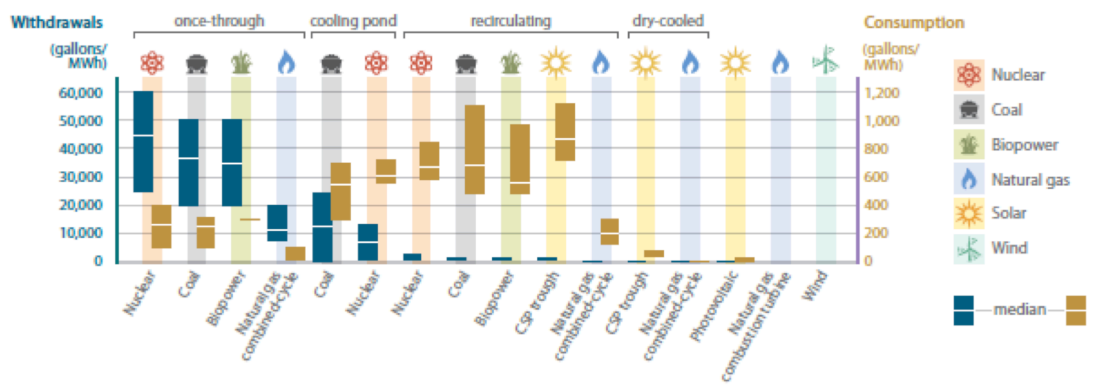

Figure 2: Water Use by Fuel Type

A plant's withdrawal is the amount of water that it takes from a river, lake, ocean, groundwater aquifer, or municipal water system. During use, this water either evaporates or is drained back to the source. The amount of water lost to evaporation is a plant's water consumption. Withdrawal volumes can influence the number of fish and other aquatic species sucked into intake structures, impact the temperature of the water body when it is returned, or deplete groundwater resources. Consumption volumes matter because water that evaporates is not available for other uses. *Source: Union of Concerned Scientists (2011), Freshwater Use by U.S. Power Plants: Electricity's Thirst for a Precious Resource*

- Since 2004, water supply problems have led at least a dozen power plants to temporarily reduce their power output or shut down entirely and prompted at least eight states to deny new plant proposals.[5]

Extraction and Refining

- Mountaintop removal mining has buried almost 2,000 miles of Appalachian streams, contaminating drinking water and destroying aquatic ecosystems[6].

[1] USGS (2009). *Estimated Use of Water in the United States in 2005*. United States Geological Survey (USGS Circular 1344).
[2] UCS (2010). *The Energy-Water Collision: 10 Things You Should Know*. Union of Concerned Scientists.
[3] UCS (2011a). *Freshwater Use by U.S. Power Plants: Electricity's Thirst for a Precious Resource.* Union of Concerned Scientists.
[4] *Ibid*.
[5] B.K. Sovacool (2009). Running on empty: The electricity-water nexus and the US electric utility sector. *Energy Law Journal, 30*(1), 11-51.
[6] EPA (2010). EPA issues comprehensive guidance to protect Appalachian communities from harmful environmental impacts of mountain top mining. Press release, April 1.

- Producing uranium for nuclear power plants has contaminated U.S. surface and groundwater supplies in 14 states[7].
- The overall water needs for hydraulic fracturing and shale mining are still unknown. Their needs may challenge supplies and infrastructure, especially in parts of the West where water supplies are already limited. Nonetheless, companies have acquired rights to billions of gallons of water to remove oil from Western Colorado's tar shale, setting up future conflicts with other important water users such as farmers and municipalities[8].

Future Trends

- By 2035, U.S. primary energy consumption is projected to increase an additional 9% over 2010 levels[9], which will also require additional water use.
- Over 85% of our electric power is still projected to come from nuclear and fossil-fueled power plants in 2035.[10]
- In addition, water-intensive oil and natural gas production from unconventional sources in the United States is increasing rapidly due to technological advances in the industry.
- The energy sector is the fastest-growing water consumer in the United States. Studies predict that the energy sector will be responsible for 85% of the growth in water consumption between 2005 and 2030.[11]
- To meet future energy demand, the United States needs to ensure that water resources are easily accessible and reliable.

Global Warming Threatens U.S. Energy Supply

The energy-water connection directly intersects with global warming in two specific ways. First, the extraction, treatment, and distribution of water requires energy which in turn produces global warming pollution. Second, global warming is already impacting sea level, snowpack, rainfall patterns, and drought. These increasingly challenging conditions will constrain water resources, putting future energy supply at risk.

Energy's Impact on Climate

- The combustion of fossil fuels to generate electricity is the largest single source of CO_2 emissions in the nation, accounting for nearly 40% of total 2010 CO_2 emissions, which is equivalent to about 2,258 million metric tons[12] or approximately the CO_2 emitted by 513 million cars in a year[13].
- Coal-fired power plants are the largest source of global warming pollution in the U.S. electric power sector. Even newer coal plants produce more than double the amount of carbon emissions of a new natural gas combined cycle plant (2,464 compared to 1,076

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[7] World Information Service on Energy (2012). *Decommissioning Projects – USA*. Retrieved from http://www.wise-uranium.org/udusa.html

[8] S. Lipsher (2008). *Colorado's oil shale draws Shell's interest*. Retrieved from http://www.chron.com/business/energy/article/Colorado-s-oil-shale-draws-Shell-s-interest-1785278.php

[9] EIA (2012c). *Annual Energy Outlook 2012, Table A2: Energy consumption by sector and source*. Energy Information Administration.

[10] EIA (2012d). *Annual Energy Outlook 2012, Table A8: Electricity supply, disposition, prices, and emissions*. Energy Information Administration.

[11] N. Carter (2011). *Energy's Water Demand: Trends, Vulnerabilities, and Management*. Congressional Research Service (CRS Publication No. R-41507).

[12] EPA (2012). *Inventory of U.S. Greenhouse Gas Emissions and Sinks: 1990 – 2010*. Environmental Protection Agency.

[13] A.H. Rosenfeld & S. Kumar (2001). *Tables to Convert Energy or CO2 to Familiar Equivalents*. Retrieved from http://www.energy.ca.gov/commissioners/rosenfeld_docs/Equivalence-Matrix_2001-05.pdf

lbCO_2e/MWh).[14] U.S. coal accounts for approximately 70% of CO_2 emissions from U.S. power plants and 34% of CO_2 emissions from total U.S. fossil fuel energy use.

- Methane gas that escapes from natural gas fields, also referred to as fugitive gas emissions, are also a concern given that methane has over 23 times the global warming impact of CO_2. Studies by scientists at the National Oceanic and Atmospheric Administration (NOAA) indicate that natural gas drilling might generate twice as much global warming pollution as previously estimated.[15]

Climate's Impact on Energy

- Based on observational records, temperatures have warmed roughly 1.33°F (0.74ºC) during the last century averaged over all land and ocean surfaces**,** according to the Intergovernmental Panel on Climate Change. More than half of this warming—about 0.72°F (0.4°C)—has occurred since 1979. Because oceans tend to warm and cool more slowly than land areas, continents have warmed the most (about 1.26° F or 0.7º C since 1979), especially over the Northern Hemisphere[16].
- According to NASA records, the first 11 years of the 21st century experienced notably higher temperatures compared to the middle and late 20th century. Nine of the top 10 warmest years globally have occurred since 2000.
- Based on observational data, the five fastest warming states — Rhode Island, Massachusetts, New Jersey, Arizona and Maine — warmed at rates twice the continental United States average of 0.127°F per decade over the last 100-year period.[17]
- The IPCC (International Panel for Climate Change) predict a global rise of between 1.1ºC and 6.4ºC (1.98ºF – 11.52ºF)[18] by 2100. The best estimate of global temperature increase is between 1.8°C and 4°C (3.24ºF – 7.2ºF).[19]
- Due to temperature increases and changes in precipitation, more frequent droughts in most of the continental United States are expected by 2050.[20]
- Water scarcity, lower summer river flows, and higher river water temperatures due to global warming could lead to a 4.4 to16% decrease in power plant capacity by 2060[21].
- This year's extreme weather may be a preview into global warming. NOAA reported that for the continental United States, the August 2011-July 2012 period was the warmest 12-month period since record keeping began in 1895[22]. This broke the record set in June 2012 which in turn broke the record in May 2012. The past fourteen months have featured the United State's 2nd warmest summer, 4th warmest winter, and warmest

[14] T. Skone (2012). *Life Cycle Water Withdrawal and Consumption in the Thermoelectric Power Industry*. DOE National Energy Technology Laboratory. Presented to the U.S. House of Representatives, May 30, 2012.
[15] E. Shogren (2012). *Fracking's Methane Trail: A Detective Story*. National Public Radio. Retrieved from http*://www.npr.org/2012/05/17/151545578/frackings-methane-trail-a-detective-story*
[16] https://www2.ucar.edu/faq/very-frequently-asked
[17] C. Tebaldi et al. (2012). *The Heat Is On: U.S. Temperature Trends*. Climate Central. Retrieved from http://www.climatecentral.org/wgts/heat-is-on/HeatIsOnReport.pdf
[18] Meehl *et al.*, Chap. 10: Global Climate Projections, Sec. 10.ES: Mean Temperature, in IPCC AR4 WG1 2007.
[19] Meehl *et al.*, Chap. 10: Global Climate Projections, Sec. 10.ES: Mean Temperature, in IPCC AR4 WG1 2007.
[20] K. Strzepek et al. (2010). Characterizing changes in drought risk for the United States from climate change. *Environmental Research Letters, 5*(4), 1-9.
[21] M. van Vliet et al. (2012). Vulnerability of US and European electricity supply to climate change. *Nature Climate Change,* Vol. advance online publication (03 June 2012), doi:10.1038/nclimate1546
[22] http://www.ncdc.noaa.gov/sotc/national/2012/7

spring on record[23]. Every state in the lower 48 states had warmer than average temperatures for the period, except Washington, which was near normal.[24]

- In July 2012, almost 65% of the continental United States was experiencing drought[25], and the country has also been plagued by strong storms and devastating wildfires, which are consistent with scientific predictions of the impacts of global warming[26].
- According to an August 2012 study published in the journal *Nature Climate Change,* observations now confirm what climate models have previously predicted: Drought will become more severe in the United States in the coming decades, and climate change will amplify drought frequency and intensity[27].

Regional Impacts

Taking into account projected increases in population, power generation, and water demand, as well as climate change forecasts of temperature and available precipitation, 14 states face an extreme or high risk to water sustainability, with limitations on use expected as demand exceeds supply by 2050.[28] The Southwest, Great Plains, and Southeast will be particularly challenged.

The West/Southwest[29]

- Electricity generating capacity throughout the West and Northwestern Canada is expected to grow by 22% between 2010 and 2035.[30]
- Large hydroelectric facilities including the Hoover and Glen Canyon Dams depend on reservoirs that have recently had record-low water levels due to extensive droughts,[31,32] leading to substantially reduced electricity output.
- Rapidly growing cities have been forced during extended drought and record-breaking heat to revert to unsustainable groundwater pumping in order to meet municipal water needs.[33] Water supply conflicts involving these cities are considered highly likely by 2025[34], particularly since many share the same water resources from the Colorado Basin.

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[23] http://www.ncdc.noaa.gov/sotc/national/2012/7

[24] http://www.ncdc.noaa.gov/sotc/national/2012/7

[25] http://droughtmonitor.unl.edu/

[26] http://epw.senate.gov/public/index.cfm?FuseAction=Hearings.Testimony&Hearing_ID=c0293eca-802a-23ad-4706-02abdbf7f7c3&Witness_ID=cba9c00e-6d03-4da7-a87e-7080bfdbb3bd

[27] http://www.eenews.net/climatewire/2012/08/15/9,

[28] S. Roy et al. (2010). *Evaluating Sustainability of Projected Water Demands under Future Climate Change Scenarios*. Tetra Tech, Inc. Retrieved from http://rd.tetratech.com/climatechange/projects/doc/Tetra_Tech_Climate_Report_2010_lowres.pdf

[29] Includes Arizona, Colorado, Nevada, New Mexico, and Utah

[30] EIA (2012e). *Annual Energy Outlook 2012, Table 57: Electricity Generating Capacity by Electricity Market Module Region and Source*. Energy Information Administration.

[31] U.S. Bureau of Reclamation. *Lake Mead at Hoover Dam, elevation (feet)*. Retrieved from http://www.usbr.gov/lc/region/g4000/hourly/mead-elv.html

[32] U.S. Bureau of Reclamation. *Upper Colorado Region water operations: Current Status: Lake Powell*. Retrieved from http://www.usbr.gov/uc/water/crsp/cs/gcd.html

[33] T. Hutchins-Cabibi et al. (2006). *Water in the urban Southwest: An updated analysis of water use in Albuquerque, Las Vegas, and Tucson*. Western Resource Advocates.

[34] UCS (2011b). *The Energy-Water Collision: Power and Water at Risk*. Union of Concerned Scientists.

The Great Plains[35]

- Electricity generating capacity in Texas is expected to grow by 19% between 2010 and 2035 and by 7% in Nebraska, Kansas, Oklahoma, and parts of Missouri, Arkansas, Louisiana, and New Mexico.[36]
- The agriculture sector, which is the energy sector's largest competitor for water resources, is an important part of the Great Plains states' economies. States will have to make tough decisions regarding water prioritization.
- Water demand for hydraulic fracturing in the Eagle Ford formation will increase 10-fold by 2020, and double again by 2030[37]. A single company that currently has 10 wells in the area is planning to drill another 200 in 2012, increasing the water demand the equivalent of the water usage for about 50,000 people for one year[38]. Since agriculture currently uses approximately 60% of water, the additional demand for water for hydraulic fracturing may exacerbate tensions between farmers and the energy sector.
- Given the 2012 drought, water is starting to become an issue for the oil companies in Harper County Oklahoma with restrictions on water withdrawals from some streams starting in early July. Because there is not much groundwater available companies must seek privately owned supplies from farmers and adjacent municipalities. The price of water has gone up to as much as 25 cents a barrel (1 barrel is 42 gallons)[39].

The Southeast[40]

- Electricity generating capacity throughout much of the Southeast is expected to grow by 12% between 2010 and 2035.[41]
- Coal and nuclear power plants that rely on once-through cooling are responsible for 66% of freshwater withdrawals in the Southeast.[42] Plants have to cut output or sometimes shutdown completely if water levels become too low for withdrawal, the water is too warm to cool the plant, or the discharged water is too warm to return to its source.
- During prolonged heat in the summer of 2010, Browns Ferry nuclear plant in Alabama had to cut power by 50% for five consecutive weeks.[43]
- During the 2007-08 drought, South Carolina sued North Carolina over a plan by certain North Carolina cities to withdraw water from the Catawba River.[44]

Solutions

Although the interconnection between energy and water creates challenges for the United States, there are near-term solutions and technologies we can utilize now that will enhance the efficient use of our water and energy resource. These include:

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[35] Includes Arkansas, Kansas, Nebraska, Oklahoma, and Texas
[36] EIA (2012e).
[37] http://www.bloomberg.com/news/2011-06-13/worst-drought-in-more-than-a-century-threatens-texas-oil-natural-gas-boom.html
[38] http://www.bloomberg.com/news/2011-06-13/worst-drought-in-more-than-a-century-threatens-texas-oil-natural-gas-boom.html
[39] http://www.eenews.net/public/energywire/2012/07/30/1; Dai (2012) Increasing drought under global warming in observations and models, Nature Climate Change, doi:10.1038/nclimate1633

[40] Includes Alabama, Florida, Georgia, Kentucky, Mississippi, North Carolina, South Carolina, Tennessee, and Virginia
[41] EIA (2012e).
[42] UCS (2011b).
[43] NRC (2010). *Power Reactor Status Report for July 27, 2010*. Nuclear Regulatory Commission. Retrieved from http://www.nrc.gov/reading-rm/doc-collections/event-status/reactor-status/2010/20100727ps.html
[44] USA Today (2008). *Drought spreading in Southeast*. Retrieved from http://www.usatoday.com/weather/drought/2008-02-11-drought_N.htm

- **Increasing development of water-free energy technologies such as renewables**: Wind and photovoltaic solar electricity generation require practically zero water. Solar, wind and other forms of renewable energy offer an alternative to fossil fuel and nuclear power plants that require large amounts of water both to generate electricity and to extract uranium, coal and natural gas.
- **Increasing efficiency of energy and water systems, stretch local water supplies**: Fixing leaks in public drinking water systems prevents water loss and saves energy required to move it through the system. We can also maximize our existing resources by stretching local water supplies through water recycling.
- **Exploring alternative water sources for electricity generation**: Recycled municipal wastewater is a reliable water source that is available in relative abundance across the United States. Other alternative water sources include waste water from oil and gas wells, mine pool water, and industrial process water.
- **Innovatively financing the solutions:** Extend the federal tax credits for new water-free renewable energy projects. A federal renewable electricity standard (RES) will also help renewables flourish.
- **Encouraging investment in innovation:** Technology can help save water and energy in a myriad of ways, from the appliances we use, to the homes and offices we live and work in, to the cars and trucks we drive. As we invest in upgrading our aging energy and water infrastructure, we must incentivize public and private investment in smart sensors, new optimization software, highly efficient pumps, and other innovative technology. Efficiency will stretch our existing energy and water resources at a fraction of the cost of expensive new power plants, pipes, pumping stations, and water treatment plants.