Effect of Drought on the Energy Sector

Testimony of

Michael E. Webber, Ph.D.
Deputy Director, Energy Institute
Associate Professor, Department of Mechanical Engineering
Co-Director, Austin Technology Incubator's Clean Energy Incubator
The University of Texas at Austin

April 25, 2013

Before the

Committee on Energy and Natural Resources

United States Senate

April 25, 2013

Mr. Chairman and Members of the Committee, thank you so much for the invitation to speak before your committee on the effects of drought on the energy sector. My name is Michael Webber, and I am the Deputy Director of the Energy Institute at the University of Texas at Austin. I am here to share my perspective on this issue.

This testimony will make a few key points:

1) The energy sector is heavily dependent on water,
2) Water constraints (from drought) can become energy constraints, and
3) There are technical and policy solutions available.

The Energy Sector's Dependence on Water Introduces Vulnerability to Drought

The energy sector uses a lot of water. Namely, water is needed for power generation and for fuels production.

For power generation, we use water directly through hydroelectric turbines at dams and indirectly as a coolant for thermoelectric power plants.

For fuels production, we use water to grow energy crops and to extract oil and gas.

Power Sector

The thermoelectric power sector—comprised of power plants that use heat to generate power, including those that operate on nuclear, coal, natural gas or biomass fuels—is the single largest user of water in the United States.

Cooling of power plants is responsible for 39% of non-consumptive freshwater use and is responsible for total withdrawals of nearly 200 billion gallons of water per day. [Kenny, 2009]

Because most of that water is returned to its source, the power sector is responsible for only 3% of national water consumption. [Kenny, 2009]

The amount of water used by power plants depends on the fuel (coal, gas, nuclear, wind, etc.), the power cycle (steam cycle, combined cycle, etc.), and the cooling technology (open-loop cooling, cooling tower, etc.). Typical water needs for power plants are summarized in the table below. [Stillwell, 2011] Nuclear is the most water-intensive, while solar PV, wind, and some uses of natural gas are very water lean.

Table 1. The water withdrawals and consumption for cooling power plants depend on the fuel type, power generation technology, and cooling system. [Stillwell, 2011]

Fuels & Technologies		Water Use and Cooling Technologies			
		Closed-Loop (cooling tower)		**Open-Loop**	
		Withdrawals [gal/kWh]	**Consumption [gal/kWh]**	**Withdrawals [gal/kWh]**	**Consumption [gal/kWh]**
	Nuclear	1	0.7	42.5	0.4
	Solar CSP	0.8	0.8	---	---
	Coal	0.5	0.5	35	0.3
	Natural Gas *(Combined Cycle)*	0.23	0.18	13.8	0.1
	Natural Gas *(Combustion Turbine)*	Negligible	Negligible	Negligible	Negligible
	Solar PV	Negligible	Negligible	Negligible	Negligible
	Wind	Negligible	Negligible	Negligible	Negligible

Consumptive water use is important because it has an impact on water availability for other users. Non-consumptive water use (i.e., withdrawal) is important because it can affect the power sector's reliability and impacts the environment through potential impingement of aquatic life and thermal loading of waterways.

If water is too scarce or too hot (from droughts and/or heat waves), then the electric grid might be less reliable as power plants might need to turn off or dial back to ensure safe operation and to comply with thermal discharge limits. These outages can have cascading effects through other sectors, affecting refineries, the gas distribution grid, water systems, and so forth, with significant risk to economic activity and human health.

For example, during the heat wave in France in 2003 that was responsible for approximately 10,000 deaths, nuclear power plants in France had to reduce their power output because of the high inlet temperatures of the cooling water. Environmental regulations in France (and the United States) limit the rejection temperature of power plant cooling water to avoid ecosystem damage from thermal pollution (e.g. to avoid cooking the plants and animals in the waterway). When the heat wave raised river temperatures, the nuclear power plants could not achieve sufficient cooling within the environmental limits, and so they reduced their power output at a time when electricity demand was spiking by residents turning on their air conditioners. In this way, a water resource constraint became an energy constraint.

In addition to heat waves, droughts can also strain the energy-water relationship. During the drought in the southeastern United States in early 2008, nuclear power plants were within days of shutting down because of limited water supplies. Droughts also lower water levels behind dams, reducing output from their hydroelectric turbines. Droughts triggered the massive power outage in India in 2012 that affected 600 million people, cutting off power for several weeks.

Because thousands of power plants are located in the region covered by last year's drought, the United States is vulnerable to a similar kind of widespread outage event.

There are several ways to reduce the vulnerability of the power sector to droughts and heat waves:

1. Installing and/or switching the fuel and conversion technology to lower-consuming options (for example, natural gas combustion turbines, natural gas combined cycle, wind, and solar PV all require less water than steam cycle plants powered by natural gas, coal, or nuclear)
2. Installing and/or switching the cooling technology to lower-consuming options (for example, dry cooling and hybrid wet-dry cooling require less water than conventional cooling, though they can reduce power plant performance)
3. Switching the water source (for example, to effluent from wastewater facilities or saline water)

These technical solutions face some policy or cost hurdles today.

Fuels Sector

The fuels sector—namely oil, gas, and biofuels production—also requires significant volumes of water. Water is used for conventional production for techniques such as waterflooding, which can increase productivity from reservoirs. Biofuels use water during photosynthetic growth.

Shale oil and gas production typically requires approximately 0.7—9 million gallons of fluids per well. Those wells also return significant volumes of wastewater comprised of drilling muds, flowback water, and produced water. [Nicot and Scanlon, 2012]

Major Shale Play	Median Water Use per Well (Mgal)
Barnett	2.8
Tx-Haynesville	5.7
Eagle Ford	4.3

*From Nicot and Scanlon, 2012 Table 1.

The lifecycle water intensity (see Figure 1) shows that conventional fossil fuels and unconventional natural gas are relatively water lean. However, unconventional petroleum and biofuels are relatively water intensive.

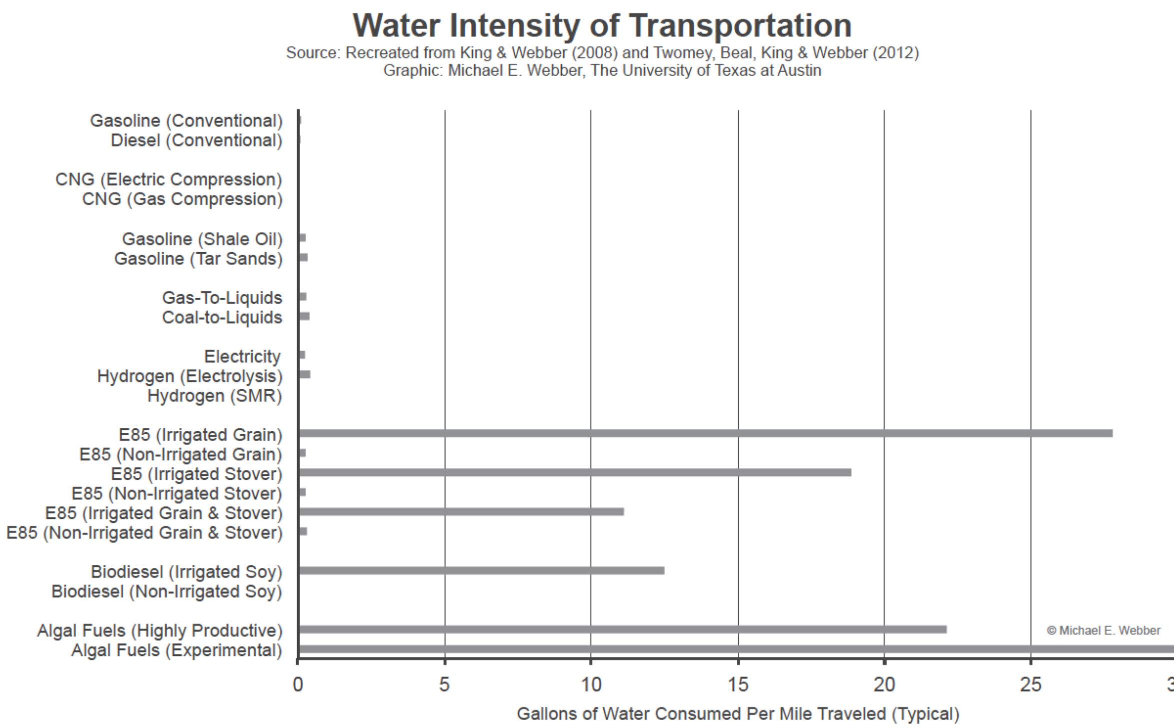

Figure 1. The water intensity of transportation (in gallons of water consumed per mile traveled) reveals that conventional fuels are comparatively water lean. [King, 2008; Twomey, 2012]

Because biofuels need so much water for their growth, they are particularly vulnerable to droughts. Just as traditional agricultural crops are hindered in times of drought, so are energy crops.

Droughts can also affect oil and gas production. This risk is important because the growth in production from shale formations has triggered an increase in water use from nearby basins and aquifers. [Nicot and Scanlon 2012]

It is important to note that despite the water used with hydraulic fracturing to produce natural gas from shale formations, natural gas use saves water because natural gas combined cycle power plants have less than half the water intensity of coal plants (See Figure 2). [Grubert, 2012]

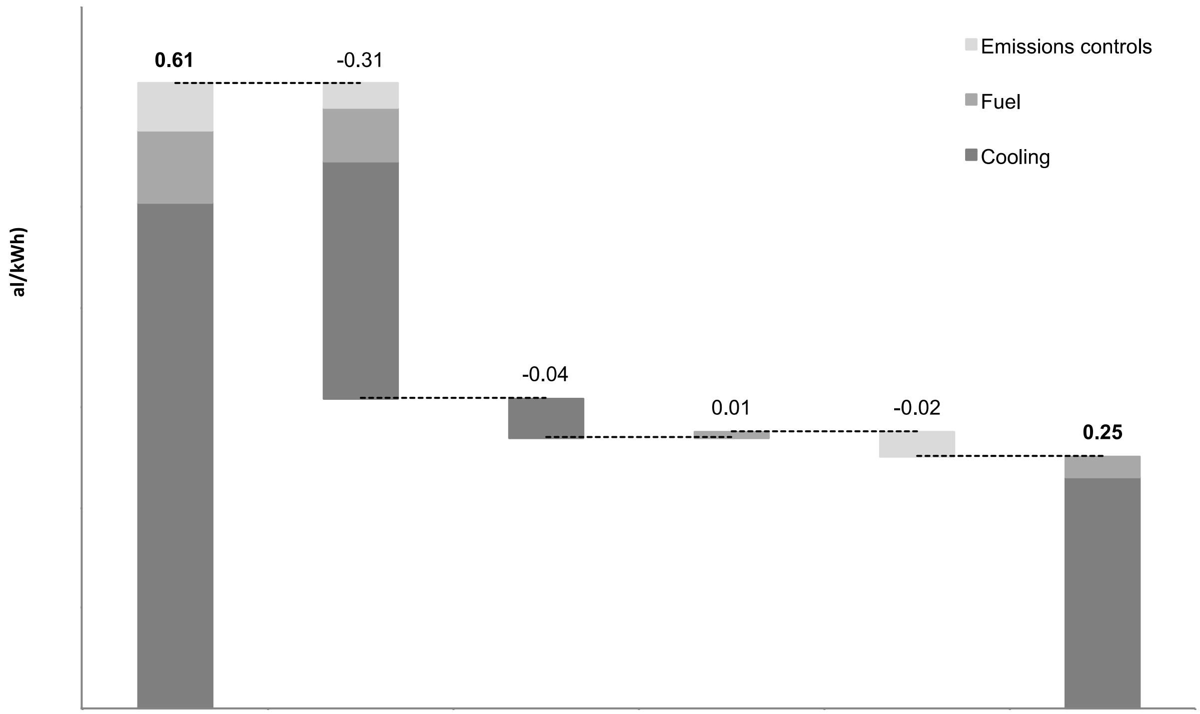

Figure 2. Conventional coal-fired power plants in Texas consume 0.61 gal/kWh. Because of efficiency advantages, different cooling designs, and avoided emissions controls, natural gas combined cycle plants use much less water than equivalent coal plants, even if the natural gas was produced by hydraulic fracturing of shale formations [Grubert 2012]

Though shale gas is water lean over its entire lifecycle, water scarcity from drought can constrain shale gas production. For example, the current drought that began in 2011 has led some groundwater conservation districts in Texas "to consider enacting specific water use restrictions against" hydraulic fracturing. [Allen 2013] Furthermore, droughts sometimes position the agricultural sector against the energy sector in a competition for limited water supplies.

There are several ways to reduce the risks that water scarcity will constrain oil and gas production from shale formations:

1. Water re-use from well-to-well to reduce the amount of freshwater that is needed
2. Waterless fracking
3. Enhanced technologies at the drilling pad to speed up drilling times and reduce the amount of water that is needed
4. Using effluent, brackish water, or greywater

There Are Policy Solutions Available

In addition to the technical solutions noted above, there are different policy actions that can help.

Because there are many rivers, watersheds, basins and aquifers that span several states and/or countries, there is a role for federal engagement on these issues. I recommend the following policy actions:

1. *Collect, maintain and make available accurate, updated and comprehensive water data, possibly through the USGS and EIA.* The Department of Energy's Energy Information Administration maintains an extensive database of accurate, up-to-date and comprehensive information on energy production, consumption, trade, and price available with temporal and geographic resolution and standardized units. Unfortunately, there is no equivalent set of data for water. Consequently, industry, investors, analysts, policymakers and planners lack suitable data to make informed decisions.

2. *Encourage fuel-switching to save water.* Some fuel sources such as natural gas, wind, and solar PV are domestic, need much less water, and reduce emissions of pollutants and carbon.

3. *Encourage water-switching to improve the energy sector's reliability.* Using reclaimed water for powerplants, industry, and agriculture can spare a significant amount of energy and cost. However there are financing, regulatory and permitting hurdles in place that restrict this option.

4. *Support the use of dry and hybrid wet-dry cooling at powerplants.* Not all powerplants need wet cooling all the time. Finding ways to help

plants upgrade their cooling to less water-intensive versions can spare significant volumes of water to meet public supply or in-stream flow requirements.

5. *Invest heavily in water-lean energy R&D*. R&D investments are an excellent policy option for the federal government because state/local governments and industry usually are not in a position to adequately invest in research. DoE's R&D program for biofuels should emphasize water-lean power plant cooling technologies, feedstocks such as cellulosic sources or algae that do not require freshwater irrigation, and advanced techniques for hydraulic fracturing. At the same time, the amount of R&D in the water sector is much lower than for other sectors such as pharmaceuticals, technology, or energy, so water R&D should be increased. [Kirshenbaum, 2012]

6. *Encourage water-lean shale production.* Supporting R&D for water-lean shale production techniques would also be valuable. Encouraging producers to reuse water and to perform on-site treatment of produced water would spare significant volumes of freshwater.

7. *Invest aggressively in conservation*. Water conservation can be a cost-effective way to save energy, and energy conservation can be a cost-effective way to save water. Therefore, conservation has cross-cutting benefits.

The vulnerability of the energy sector to droughts is important and not obvious, and so I am very pleased to know that you are being attentive to the matter.

Mr. Chairman, that concludes my testimony. I'll be pleased to answer questions at the appropriate time.

References

Allen, Taelor A. (2013). The South Texas Drought and the Future of Groundwater use for Hydraulic Fracturing in the Eagle Ford Shale. *Saint Mary's Law Journal*.

Kenny, Joan F., Nancy L. Barber, Susan S. Hutson, Kristin S. Linsey, John K. Lovelace, and Molly A. Maupin. (2009). *Estimated Water Use in the United States in 2005*. United States Geological Survey, Circular 1344. Reston, VA.

Kirshenbaum, S.R. and M.E. Webber, "Time for Another Giant Leap for Mankind," *Issues in Science and Technology*, Spring 2012.

Grubert, E.A., F.C. Beach and M.E. Webber, "Can switching fuels save water? A life cycle quantification of freshwater consumption for Texas coal- and natural gas-fired electricity," *Environmental Research Letters* 7 045801 (11pp) (2012).

King, C.W. and M.E. Webber, "The Water Intensity of Transportation," *Environmental Science and Technology* (2008).

Nicot, J. P. and Scanlon, B. R. (2012)."Water Use for Shale-Gas Production in Texas, U.S." *Environmental Science & Technology*. 46, 3580-3586.

Stillwell, Ashlynn S., Carey W. King, Michael E. Webber, Ian J. Duncan, and Amy Hardberger. (2011). "The Energy-Water Nexus in Texas." *Ecology and Society*. 16(1), 2.

TWDB. (2012). *Water for Texas 2012 State Water Plan*. Texas Water Development Board. Austin, TX.

Twomey, K.M., C.M. Beal, C.W. King, and M.E. Webber, "Biofuels: An Energy and Water Conundrum," *World Energy Monitor*, Volume 3, Number 3, March 2012.