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Energy-Water Nexus: The Energy Sector's Water Use

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Summary

Water and energy are critical resources that are reciprocally linked; this interdependence is often described as the water-energy nexus. Meeting energy-sector water needs, which are often large, depends upon the local availability of water for fuel production, hydropower generation, and thermoelectric power plant cooling. The U.S. energy sector's use of water is significant in terms of water withdrawals and water consumption. Thermoelectric cooling represented 38% of freshwater withdrawn nationally and 45% of all water (fresh and saline) withdrawn in 2010, and the broader energy sector's water use (including biofuels) represented around 14% of water consumed nationally. Energy-related water consumption is anticipated to continue to increase in coming decades as the result of more domestic biofuel and unconventional onshore oil and natural gas production. Policy makers at the federal, state, and local levels are faced with deciding whether to respond to the growing water needs of the energy sector, and if so, which policy levers to use (e.g., tax incentives, loan guarantees, permits, regulations, planning, or education). Many U.S. energy sector water decisions are made by private entities, and state entities have the majority of the authority over water use and allocation policies and decisions.

For fuel production, water is either an essential input or is difficult and costly to substitute, and degraded water is often a waste byproduct that creates management and disposal challenges. U.S. unconventional oil and natural gas production has expanded quickly since 2008, and U.S. natural gas and coal exports may rise. This has sparked interest in the quantities of water and other inputs "embedded" in these resources, as well as the wastes produced (e.g., wastewaters from oil and natural gas extraction) and how they are reused or disposed (e.g., concerns over induced seismicity from injection of oil and natural gas wastewaters). Much of the growth in water demand for unconventional fuel production is concentrated in regions with already intense competition over water (e.g., tight gas and other unconventional production in Colorado, Eagle Ford shale gas and oil in south Texas), preexisting water concerns (e.g., groundwater decline in North Dakota before Bakken oil development), or regions with abundant, but ecologically sensitive surface water resources (e.g., Marcellus shale region in Pennsylvania and New York).

Conventional hydropower accounts for approximately 8% of total U.S. net electricity generation, and more than 80% of U.S. electricity is generated at thermoelectric facilities that depend on cooling water. Water availability issues, such as regional drought, low flow, or intense competition for water, can curtail hydroelectric and thermoelectric generation. An assessment of the drought vulnerability of electricity in the western United States found broad resiliency, while also identifying the Pacific Northwest and the Texas grid at higher risk. Future withdrawals associated with electric generation may grow slightly, remain steady, or decline depending on a number of factors. These include reduced generation from facilities using once-through cooling because of compliance with proposed federal cooling water intake regulations or shifts in how electricity is generated (e.g., less from coal and more from certain natural gas technologies and wind).

Energy choices represent complex tradeoffs; water use and wastewater byproducts are two of many factors to consider when making energy choices. For many policy makers, concerns other than water—low-cost reliable energy, energy independence and security, climate change mitigation, public health, and job creation—are more significant drivers of their positions on energy policies.

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Water and energy are critical resources that are reciprocally linked. Energy is required for the pumping, conveyance, treatment and conditioning, and distribution of water and for collection, treatment, and discharge of wastewater. Likewise, as described in this report, meeting energy sector needs depends upon the local availability of water, often in large quantities, for mineral fuel production,[1] hydropower, and thermoelectric power plant cooling. This interdependence is often described as the water-energy nexus. This report addresses how the U.S. energy sector uses and relies on water; it provides summary descriptions divided into four topics: (1) Water for Energy Primer, (2) Fuel Production, (3) Electric Grid and Generation, (4) Policy Response Options and Considerations. CRS Report R43200, *Energy-Water Nexus: The Water Sector's Energy Use*, addresses the related topic of energy needs of the water sector.

Water for Energy Primer

Energy-Sector Water Use and Vulnerability Is Receiving Increased Attention

Available projections estimate that, by 2030, U.S. water consumption will increase by 7% above the level consumed in 2005; 85% of this growth is attributed to the energy sector (including biofuels).[2] The U.S. energy sector's use of water is significant in terms of water withdrawals and water consumption.[3]

- **Energy Sector:** While agriculture dominates U.S. water consumption (71%), the energy sector (including biofuels, thermoelectric, and fuel production) is the second-largest consumer at 14%, and domestic and public uses are third at 7%.[4] Multiple factors contribute to the energy sector being the fastest-growing water consumer. Biofuels produced from irrigated feedstocks play a significant role, as well as expanding production of onshore unconventional oil and natural gas and hydro-stimulation of aging wells.
- **Electric Generation:** Water dependence is a risk for hydroelectric and thermoelectric generation. During low-flow or high-heat events, water intakes and high water temperatures may harm or limit thermoelectric cooling. Thermoelectric cooling water represented 38% of freshwater withdrawn nationally in 2010[5] and almost 6% of water consumed nationally.[6] Also, the withdrawal and discharge of cooling water can harm aquatic organisms.

[1] In this report, production encompasses extraction and processing of fuels.

[2] This report complements CRS Report R41507, *Energy's Water Demand: Trends, Vulnerabilities, and Management*, by (name redacted), which analyses how and where the energy sector uses water in the United States.

[3] Consumption represents the water not available for immediate subsequent use. In the energy sector, water is consumed when it enters the atmosphere (e.g., power plant evaporative cooling towers), is lost to geologic formations, is sufficiently degraded to require permanent disposal, or needs treatment before use in freshwater applications or return to the environment.

[4] CRS Report R41507, *Energy's Water Demand: Trends, Vulnerabilities, and Management.*

[5] U.S. Geological Survey, *Estimated Use of Water in the United States in 2010* (Circular 1405: 2014). Thermoelectric cooling represented 91% of the saline water withdrawn nationally.

[6] D. Elcock, "Future U.S. Water Consumption: The Role of Energy Production," *Journal of the American Water Resources Association*, vol. 46, no. 3 (June 2010), pp. 447-480, hereinafter referred to as Elcock 2010. Some estimates put thermoelectric water consumption closer to 3%. Available data is anticipated to improve when the U.S. Geological Survey releases its five-year water use survey for 2010; the agency has stated that it is resuming its estimates (which had stopped with the 1995 data) of water consumption by thermoelectric power plants and released a report in (continued...)

- **Fuel Production:** Water is either an essential input or is difficult and costly to substitute; degraded water is often a waste byproduct. The potential for human-induced seismic events is receiving scientific and political attention because of concerns over the possible connection between oil and gas wastewater injection and the recent increasing frequency of earthquakes, particularly in the central and eastern United States.
- **Efficiency and Conservation:** Reducing energy demand through energy and water efficiency[7] and more water-efficient generation (e.g., electricity from wind,[8] photovoltaics, or natural gas) can reduce water demand. Current water efficiency incentives in fuel production include minimizing water management costs and reducing operational disruptions.
- **Embedded Water:** U.S. unconventional oil and natural gas production has expanded quickly due to the combined use of hydraulic fracturing and horizontal drilling techniques for well development.[9] This expansion has sparked interest in the quantities of water and other inputs "embedded" in energy resources.

Relevant Data and Research Are Improving; Significant Gaps Remain

In 2012, the Government Accountability Office, in *Energy-Water Nexus: Coordinated Federal Approach Needed to Better Manage Energy and Water Tradeoffs*, stated that "making effective policy choices will continue to be challenging without more comprehensive data and research."[10] Improving data on water use by the energy sector is challenging for a number of reasons. For example, much of the U.S. energy sector is private; data consistency, accuracy, and currency are problematic; and it is costly to maintain high-quality data for an evolving and dispersed industry.

While data challenges exist, access to relevant research and data is improving. The Department of Energy (DOE) disseminates energy-water related studies on a public online platform.[11] DOE released a report in 2014, *The Water-Energy Nexus: Challenges and Opportunities*, which

(...continued)

November 2013 on the improved methods that it will be using for determining those estimates.

[7] R. Young and E. Mackres, *Tackling the Nexus: Exemplary Programs that Save Both Energy and Water*, Washington, DC: American Council for an Energy-Efficient Economy, 2013.

[8] One study found that expanding the nation's electricity portfolio to 20% wind by 2030 would reduce water consumption by 1.2 billion gallons daily compared to expanding the current electricity mix. The water saved would be 41% in the Midwest/Great Plains, 29% in the West, 16% in the Southeast, and 14% in the Northeast (DOE, *20% Wind Energy by 2030: Increasing Wind Energy's Contribution to U.S. Electricity Supply*, July 2008, http://www1.eere.energy.gov/wind/pdfs/41869.pdf).

[9] Hydraulic fracturing is a technique developed initially to stimulate oil production from wells in declining oil reservoirs. The technique now is widely used to initiate oil and natural gas production in unconventional (low-permeability) formations that were previously inaccessible. Fracturing is currently used in more than 90% of new oil and natural gas wells. Hydraulic fracturing involves injecting large volumes of water, sand (or other propping agent), and specialized chemicals under pressure into a well to fracture the formations holding trapped oil or natural gas.

[10] U.S. Government Accountability Office (GAO), *Energy-Water Nexus: Coordinated Federal Approach Needed to better Manage Energy and Water Tradeoffs*, GAO-12-880, September 2012, http://www.gao.gov/assets/650/648306.pdf.

[11] The site links to over 150 items related to energy-water issues: http://en.openei.org/wiki/Water_and_energy_studies. Also the Energy Information Agency in recent years has increased the type and frequency of data collection on power plant cooling systems. More state level data is being collected; for example, the Railroad Commission of Texas required oil and natural gas operators to disclose on FracFocus (http://fracfocus.org/) water volumes and chemicals used for hydraulic fracturing after February 2012.

identified various data gaps and multiple technology research, development, and demonstration opportunities to increase the technological options available to reduce the water demands and impacts of the energy sector.[12] The reports mentioned in the box below provide additional information on the energy-water nexus while also identifying areas needing improved understanding. While these reports differ in their focus, they each mention the stresses that climate change places on the energy-water nexus.

Reports Linking Energy-Water Nexus to Climate Change

U.S. government reports and reports by stakeholders are increasingly addressing the links between energy, water, and climate change. Examples include the following reports:

- **January 2013, National Climate Assessment and Development Advisory Committee, draft *Third Climate Assessment Report*** (available at http://ncadac.globalchange.gov/). This draft report discussed how co-occurrence of heat waves and droughts can amplify impacts on water and electricity supply and demand, which can affect the energy sector in multiple and cascading ways. The report stated (p. 167 and p. 397, respectively) that "both episodic and long-lasting changes in water availability will constrain different forms of energy production," and "dependence of energy systems on land availability and water supplies will influence their development and constrain some options for reducing greenhouse gas emissions." It also noted (p. 387) that "jointly considering risks, vulnerabilities, and opportunities associated with energy, water and land use is difficult, but can improve the analysis of options for reducing climate change impacts." Recommendations for related research were included in a technical report developed to support the assessment effort (Pacific Northwest National Laboratory, *Climate and Energy-Water-Land System Interactions*, March 2012, http://www.pnnl.gov/main/publications/external/technical_reports/PNNL-21185.pdf).
- **July 2013, Department of Energy (DOE), *U.S. Energy Sector Vulnerabilities to Climate Change and Extreme Weather*** (available at http://energy.gov/sites/prod/files/2013/07/f2/20130710-Energy-Sector-Vulnerabilities-Report.pdf). The report (p. i) stated the following when discussing the impacts of climate change on the energy sector and the potential for cascading and compounding impacts:

  > Some of these effects, such as higher temperatures of ambient water used for cooling, are projected to occur in all regions. Other effects may vary more by region, and the vulnerabilities faced by various stakeholders may differ significantly depending on their specific exposure to the condition or event. However, regional variation does not imply regional isolation as energy systems have become increasingly interconnected. Compounding factors may create additional challenges. For example, combinations of persistent drought, extreme heat events, and wildfire may create short-term peaks in demand and diminish system flexibility and supply, which could limit the ability to respond to that demand.

  The report identified a number of opportunities to enhance information, tools, and practices to reduce the energy sector's climate vulnerabilities. Some of the opportunities identified (p. 44) included better regional and local characterization of climate trends and extreme weather relevant to the energy sector (e.g., water availability, likelihood and magnitude of droughts); better characterization of the aggregate vulnerabilities of the energy sector to climate change and interdependencies with other sectors leading to cascading impacts; improved understanding of potential uses and challenges of advanced cooling technologies and alternative water sources; and additional assessments of impacts to hydropower.
- July 2013, Alliance for Water Efficiency and the American Council for an Energy-Efficient Economy, *Water-Energy Nexus Research: Recommendations for Future Opportunities* (available at http://www.allianceforwaterefficiency.org/WE-WhitePaper-PR.aspx). Its recommendations included continuing investigations into the water-energy tradeoffs of differing resource development and management choices; identifying regulatory barriers to co-implementation of energy and water efficiency programs; developing water and energy industry-accepted protocols for efficiency programs; and assessing potential impacts to water supplies and quality from energy resource development and identifying solutions to mitigate these impacts.

[12] U.S. Department of Energy, *The Water-Energy Nexus: Challenges and Opportunities*, June 2014, http://energy.gov/downloads/water-energy-nexus-challenges-and-opportunities. The report identified the following water-for-energy technologies for more in-depth analysis: cooling, waste heat recovery, process water efficiency and quality, alternatives to freshwater in energy production, and hydropower.

Fuel Production

Unconventional Oil and Gas Production Often Concentrates Water Use Geographically and Temporally

Regional water resource opportunities and challenges for fuel production vary based on several factors, including (1) which fuel is being produced in the region, (2) the local and regional significance of its water use, and (3) regional conditions for management of wastewaters.

- Much of the growth in water demand for unconventional fuel production is concentrated in regions with already intense competition over water (e.g., tight gas and other unconventional production in Colorado, Eagle Ford shale gas and oil in south Texas), preexisting water concerns (e.g., groundwater decline in North Dakota before Bakken oil development), or abundant but ecologically sensitive surface water resources (e.g., Marcellus shale region in Pennsylvania and New York).
- The cumulative water needs of multiple drilling and fracturing operations may be locally or temporally significant.[13] Often many shale gas, tight gas, and tight oil wells are located in close proximity to each other as a formation is developed, with many wells being drilled and fractured from the same location. Water use for these wells is concentrated in the early stages of well development, usually in the first few weeks. Once the well is producing, little or no water is required unless refracturing is performed. How much water is used for well development is highly variable both across and within formations.
- Data on source water remain sparse. Groundwater often is used for shale operations when it is available and access is permitted. Surface waters also are used, but may require transport by truck. In cases of limited water access, well developers also have obtained water by purchasing it from municipalities or paying individual land owners for their supplies.

Available Data on Water Use Remain Problematic

As of mid-2013, gaps remained in the availability of authoritative and recent data on the amounts of freshwater consumed and wastewater produced in fuel production. Available data indicate the following:

- The amount of water needed per unit of fuel produced—referred to as the water intensity of a fuel—ranges from conventional natural gas at the lowest end (less than 1 gallons of water per MMBtu);[14] coal, unconventional gas, and uranium mining and enrichment next (roughly 1 to 10 gallons per MMBtu); oil next (10 to

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[13] For example, although hydraulic fracturing water use represented less than 1% of all water use in Texas, for some counties in the Barnett formation (north central Texas) it represented 10% to 30% of water use; in the Eagle Ford formation (south Texas), unconventional energy extraction was responsible for 38% of groundwater use. R. B. Jackson et al., "The Environmental Costs and Benefits of Fracking," *Annual Review of Environment and Resources*, vol. 39 (August 9, 2014), pp. 7.1-7.36.

[14] MMBtu represent 1 million British thermal units which is a commonly used unit of energy.

100 gallons per MMBtu);[15] and irrigated biofuels at the upper end (100 to 1,000 gallons per MMBtu).[16] The water intensity of conventional and unconventional oil produced using different techniques remains poorly documented. The water intensity for hydraulically fractured wells often is less notable than the concentrated, simultaneous demand for water for hydraulic fracturing in a region where many wells are being developed concurrently.

- Despite the recent increase in water demand for hydraulic fracturing, water use for stimulating oil production from conventional wells through water flooding and enhanced oil recovery have represented the largest water use by the oil and gas sector in the United States.[17] The use of these techniques is anticipated to increase; to what extent saline, wastewaters, or freshwater will be used is less clear. Limited data on production rates and quantities for many saline aquifers can be a disincentive to their use.
- Each fuel and production technique presents its own risks, potential water quality impacts,[18] and wastewater issues; also, some techniques may be more water-efficient but less efficient at recovering energy resources.[19] Data remain poor on the range of wastewater quantities and qualities derived from conventional and unconventional fuel production.

Fuel Production Remains Vulnerable to Water-Related Disruptions

The vulnerability of fuel production to freshwater availability is receiving attention in part because of increasing water demands (e.g., population growth) and concerns over changes to water supplies (e.g., drought and climate change).

- Instances of low flow and drought conditions have reduced the availability and increased the cost of water for operations in some locations (e.g., Susquehanna River basin in Virginia, West Virginia, and Pennsylvania, and Eagle Ford Shale region in Texas). No analysis is available of the risk posed by a multi-year drought in areas of intense water use for energy (e.g., North Dakota) and how to manage the risk.

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[15] Oil is produced by a variety of techniques, some of which can be particularly water-intensive (e.g., water flooding). Oil shale is largely not discussed herein. Oil shale is distinct from the tight oil produced from shale formations. Oil shale's near-term impacts on water resources are limited by the relatively small scope of anticipated near-term development (GAO, *Unconventional Oil and Gas Production: Opportunities and Challenges of Oil Shale Development,* Washington, D.C, 2012).

[16] International Energy Agency, *World Energy Outlook 2012,* Paris, 2012; E. Mielke, et al., *Water Consumption of Energy Resource Extraction, Processing, and Conversion*, Cambridge, Massachusetts: Harvard Kennedy School, 2010; World Energy Council, *Water for Energy*, London: World Energy Council, 2010.

[17] M. Matichich, *The Changing Value of Water to the US Economy: Implications from Five Industrial Sectors,* Boston: CH2M Hill, 2012. How much of the injected water is reused produced water from oil and gas operations is unknown.

[18] A discussion of water quality impacts is beyond the scope of this report. For a regional discussion of water quality concerns associated with shale gas, see CRS Report R42333, *Marcellus Shale Gas: Development Potential and Water Management Issues and Laws*, by (name redacted) et al. For a general discussion, see L. Allen, et al., Fossil Fuels and Water Quality, in P. Gleick, *The World's Water*. Vol. 7, Washington, DC: Island Press, 2012, pp. 73-96.

[19] Beyond water considerations, fuel production can have other development impacts (e.g., roads, housing). For example, see CRS Report R42611, *Oil Sands and the Keystone XL Pipeline: Background and Selected Environmental Issues*, coordinated by (name redacted).

- Fossil fuel transport also may be disrupted by water conditions, such as flood-induced pipeline breaks resulting from riverbed scouring, flood- or storm-related refinery or distribution system disruptions (e.g., Hurricane Sandy disruptions), and drought- or flood-impaired fuel transport. No analysis of energy sector transport risks is available.

Wastewaters Represent Management Challenges and Some Opportunities

Produced water—wastewaters (often saline) brought to the surface by oil and gas wells—represents the largest byproduct of fuel production. Approximately 2.3 billion gallons are produced daily from onshore oil and gas wells in the United States.[20] For oil wells, this represents an average ratio of 7.6:1 of produced water to oil produced. By 2025, as a result of aging wells with decreasing oil production, the ratio is expected to average 12:1 for onshore crude oil.[21]

- U.S. energy-related wastewaters are primarily from conventional oil and natural gas and coal bed methane (CBM).[22] Research indicates that shale gas may produce less wastewater per unit of recovered gas than conventional natural gas (although water inputs during unconventional well development often exceed those for conventional natural gas, as described above).[23] Disposal of shale wastewaters has received more attention recently than wastewaters from conventional production because of the rate of increase in shale development and its associated wastewaters in locations that are not accustomed to oil and natural gas development.
- Management of energy-related wastewaters is evolving rapidly, with different techniques dominating in different locations and raising concerns related to water quality and seismicity. Where deep wells for the permanent disposal of produced water are limited, producers increasingly are recycling and reusing produced water in fracturing operations. This reduces the amount of freshwater needed and relieves stress on disposal sites. At the same time, reuse of produced waters may increase the transport and handling of saline waters, potentially increasing a risk pathway for spills.
- The potential for human-induced seismic events associated with oil and gas wastewater injection is receiving scientific and political scrutiny in the context of the recent frequency of earthquakes, particularly in the central and eastern United States.[24] Over 300 earthquakes of magnitude (M) 3 or greater occurred between 2010 and 2012 in the central and eastern United States, compared to an average of 21 earthquakes per year of M>3 between 1967 and 2000.[25] The increase in

[20] This compares to an estimated 4.6 billion gallons per day of freshwater used for fuel production.

[21] Global Water Intelligence, Water's growing role in oil and gas, March 2011, http://www.globalwaterintel.com/archive/12/3/market-profile/waters-growing-role-oil-and-gas.html.

[22] CBM production generally requires the dewatering of a coal formation for the natural gas to be released; the quantity and quality of CBM produced waters varies widely across formations (e.g., salinities ranging from freshwater or more saline than seawater). For more on CBM water issues, see National Research Council, *Management and Effects of Coalbed Methane Produced Water in the Western United States*, National Academies Press, August 2010.

[23] B. Lutz, A. Lewis, and M. Doyle, "Generation, transport, and disposal of wastewater associated with Marcellus Shale gas development," *Water Resources Research*, 49 (2013).

[24] William I. Ellsworth, "Injection-Induced Earthquakes," *Science*, vol. 341 (July 12, 2013).

[25] Ibid., p. 1225942-1.

> seismicity seems to be correlated with the increase in the number of disposal wells, many of which are injecting wastewaters brought to the surface at shale oil and gas wells and in the use of hydraulic fracturing. Of the 30,000 injection wells in the United States used for wastewater disposal, however, only a few are correlated with seismicity of M > 3.[26] The largest seismic events associated with injection seem to involve faulting that is deeper than the wastewater injection, suggesting that transmission of pressure into the basement rocks elevates the potential for inducing earthquakes.[27]

Recent state actions and anticipated federal actions are affecting or are anticipated to affect the management of produced water.

- In Texas, produced water generally is disposed through deep-well injection (often on-site) or evaporation ponds; interest in reuse is increasing as the result of limited water availability in some regions (e.g., West Texas) and recent drought conditions. In May 2013, the Texas legislature clarified liability and ownership of produced waters transferred among oil and gas operators for purposes of recycling for a beneficial reuse.[28]
- Pennsylvania regulations constraining surface water disposal wastewaters from shale gas production and the limited in-state deep well-injection options have resulted in a rapid increase in the rate of produced water recycling for shale gas fracking.[29] Operators in Pennsylvania are required to prepare a wastewater source reduction strategy to maximize recycling and reuse.
- In August 2013, EPA proposed to discontinue efforts to establish discharge standards for wastewaters from CBM under the agency's Effluent Guidelines Program. EPA has been unable to identify a wastewater treatment technology that would be economically achievable.[30] The agency will continue with a rulemaking for wastewaters associated with shale gas extraction, which is expected to be proposed in 2015.

Electric Grid and Generation

Water availability issues, such as regional drought, low flow, or intense competition for water, can curtail hydroelectric and thermoelectric generation. Fuel and power plant choices and capital investments made in the near term are likely to establish the trajectories for electric generation's long-term water use and vulnerability.

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[26] Ibid., p. 1225942-2.

[27] Ibid., p. 1225942-6.

[28] H.B. 2767 (Texas). The Texas law would not affect potential liability under federal environmental law. Also in 2013, the Railroad Commission of Texas stopped requiring a recycling permit if operators are recycling on their own leases or transferring fluids to another operator's lease for recycling ("Railroad Commission Today Adopts New Recycling Rules to Help Enhance Water Conservation By Oil & Gas Operators," press release, March 26, 2013).

[29] J. Logan, et al., *Natural Gas and the Transformation of the U.S. Energy Sector: Electricity*. Golden, Colorado: Joint Institute of Strategic Energy Analysis, 2012, http://www.nrel.gov/docs/fy13osti/55538.pdf.

[30] EPA, *Economic Analysis for Existing and New Projects in the Coalbed Methane Industry*, EPA 820-R-13-006, July 29, 2013, http://water.epa.gov/scitech/wastetech/guide/oilandgas/unconv.cfm

Grid-Level Drought Vulnerability Exists in Select Basins

An assessment of the drought vulnerability of electricity in the western United States found the majority of basins showing limited disruption risk; also, most of this risk could be mitigated by known strategies, including maintaining excess generation and transmission capacity.[31] While identifying broad resiliency, the western U.S. assessment revealed two regions whose electric generation was at greater risk:

- The Pacific Northwest was shown to be vulnerable because of its heavy reliance on hydroelectric generation.
- The Texas grid was vulnerable because of heavy dependence on thermoelectric generation that relied on surface water for cooling, and because of the region's vulnerability to drought and poor connections to the other U.S. grids, which reduces the ability to purchase power to offset generation curtailment.

No similar assessment of grid drought vulnerability for the eastern United States has been performed. (See following section, "Thermoelectric Cooling Represents Difficult Tradeoffs," for a discussion of electric generation in the eastern United States.)

Recent drought experiences include the following:

- In the summer of 2011, high temperatures in Texas resulted in increased electricity demand. At the same time, the drought reduced the amount of water available for cooling electric generators. The grid operator put into effect its emergency action alert system, which at first recommended conservation by customers and later deemed customer conservation critical to avoid rotating outages. During a few days, the peak demand purchases in the real-time wholesale electricity market were at or near the market cap (i.e., $3,000 per megawatt-hour). In the end, only one Texas plant had water-curtailed generation; others were nearing curtailment when weather conditions improved.[32]
- During the drought of 2012, the mid-continent electric grid avoided major drought-related disruption. Some individual power plants curtailed operations due to water access problems or water temperature issues; others pursued regulatory waivers to continue operations at higher water temperatures or made cooling system investments. Lost generation at drought-impaired facilities was offset by other generation or purchasing power from other sources on the wholesale market.

[31] C.B. Harto, et al., *Analysis of Drought Impacts on Electricity Production in the Western and Texas Interconnections of the United States*, Argonne National Laboratory, Oak Ridge, Tennessee: U.S. Department of Energy, 2011.

[32] During and after the summer of 2011, Texas power plant operators reduced their low water vulnerability by building pipelines to alternative and impaired water sources, acquiring additional water rights, lowering water intake structures, and installing additional groundwater pumping capacity. Also, the Texas grid operator instituted changes to reduce its water vulnerability. All new generation facilities as of 2013 must provide proof of water rights before being included in grid planning (which largely determines grid access). Few data are available on the extent to which low-water renewable technologies may be used to mitigate the Texas grid's drought risks.

Hydropower Vulnerability Has Been Initially Assessed

In Section 9505 of P.L. 111-11, Congress required the Secretary of Energy to assess the risks posed by climate change for water supply to federal hydroelectric power generators and to update the assessment every five years. The August 2013 report found:

> Future changes to precipitation and runoff could potentially impact hydropower generation, water quality and supply, critical species habitat, and other important water uses that indirectly affect hydropower generation. At a national level, the median decrease in annual generation at federal projects is projected to be less than 2 billion kWh (2% of total), with a relatively high climate-model uncertainty. While these estimates are similar to the recently observed variability of generation from federal hydropower and may appear to be manageable, extreme water years (both wet and dry) will pose significantly greater challenges to water managers, especially in water systems that have more limited reservoir storage and operational flexibility.

For large reservoirs and reservoir systems, it is often the multi-year droughts that most harm generation,[33] as illustrated by summer 2013 conditions in the Colorado River Basin.

Thermoelectric Cooling Represents Difficult Tradeoffs

More than 80% of U.S. electricity is generated at thermoelectric facilities that depend on cooling water; these facilities withdrew 117 billion gallons of freshwater and 44 billion gallons of saline water daily in 2010, representing 45% of total water withdrawals.[34] The two common cooling methods for thermoelectric power plants are once-through cooling and evaporative cooling. Most once-through cooling is found at power plants located in the eastern United States and is associated with older facilities, or is at coastal facilities using saline waters. Newer facilities and those in more arid regions generally use evaporative cooling. DOE data indicate that 25% of proposed power plants are planning on using reclaimed wastewater for cooling, at least 22% are proposing fresh groundwater, and 17% are planning on dry cooling or generation technologies that do not require cooling.[35]

- Once-through cooling, while largely non-consumptive, requires water to be continuously available for power plant operations.[36] This reduces the ability for this water to be put toward other water uses and can make cooling operations vulnerable to low flows.
- Evaporative cooling withdraws much smaller volumes of water for use in a cooling tower or reservoir, where waste heat is dissipated by evaporating the cooling water. Evaporative cooling consumes more water at the facility than does once-through cooling.

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[33] For example, in 2012, hydropower production nationally was above average although drought conditions covered much of the continental United States. The Missouri River basin's strong hydropower generation in 2012 can be attributed to full reservoirs at the beginning of the year and the generation associated with releases of stored water to augment low river flows.

[34] U.S. Geological Survey, *Estimated Use of Water in the United States in 2010* (Circular 1405: 2014).

[35] U.S. Department of Energy, *The Water-Energy Nexus*.

[36] Once-through cooling pulls large quantities of water off a water body, discharges the power plant's waste heat into the water (which may raise the temperature of the withdrawn water by 10° to 20°F), and then returns the majority of the withdrawn water.

- Cooling technologies that consume less water and use degraded water supplies may reduce freshwater use. These options include dry cooling, hybrid dry-wet cooling, cooling with fluids other than freshwater (e.g., brackish groundwater, produced waters), and emerging technologies. While hybrid and dry cooling options may reduce water consumption, they can reduce operational efficiency (potentially increasing greenhouse gas emissions) and often are more costly.[37]
- Thermoelectric withdrawals were 20% less in 2010 than in 2005 for reasons including use of more water-efficient cooling technology by new power plants.[38] However, future withdrawals associated with electric generation may grow slightly, remain steady, or decline depending on a number of factors, including reduced generation from facilities using once-through cooling (industry actions resulting from proposed federal cooling water intake regulations)[39] or shifts in how electricity is generated (e.g., less from coal and more from certain natural gas technologies and wind).[40] In contrast, water consumption could increase, especially if more water-consumptive cooling is adopted (e.g., evaporative cooling) and if current carbon capture technologies are added to power plants.

Many Power Plants Produce Wastewaters

In addition to water for cooling purposes, many power plants also use water for handling solid waste, including ash, and for operating wet flue gas desulfurization scrubbers. According to the U.S. Environmental Protection Agency (EPA), in 2009, power plants discharged 0.7 billion gallons of wastewater daily. In 2013 EPA proposed revisions to Clean Water Act rules that govern wastewater discharges from such plants. The proposed rule would reduce the use of these process waters by 19%-58%, depending on the regulatory option selected when the rule is finalized.[41] A final rule is expected to be issued by September 2015.

Policy Response Options and Considerations

Policy makers at the federal, state, and local levels are deciding whether to respond to the growing water needs of the energy sector, and if so, which policy levers to use. In the United States, private entities make many of the energy sector's water decisions. Often federal entities lack authority over water use, and states have most of the water allocation authority. Instead of direct influence on water use, the public sector influences private water decisions through other routes (e.g., tax incentives, loan guarantees, permits, regulations, planning, and education). If action to manage energy-sector water issues is deemed appropriate, a range of options are

[37] The National Science Foundation and the Electric Power Research Institute have an ongoing research collaboration on water for energy to further advanced dry cooling for power plants.

[38] U.S. Geological Survey, *Estimated Use of Water in the United States in 2010* (Circular 1405: 2014), p. 40.

[39] See CRS Report R41786, *Cooling Water Intake Structures: Summary of the EPA Rule*, by (name redacted).

[40] Natural gas-fueled generation is often less water-intense and less water-dependent than coal-powered electricity. This is because many natural gas-fueled electric facilities use engine-based technology (National Energy Technology Laboratory, *Estimating Freshwater Needs to Meet Future Thermoelectric Generation Requirements* (2009 Update), 2009).

[41] EPA, *Technical Development Document for the Proposed Effluent Limitations Guidelines and Standards for the Steam Electric Power Generating Point Source Category*, EPA-821-R-13-002, April 2013, pp. 12-13 – 12-14.

available, as shown in **Table 1**: minimize water use, facilitate access to water, or improve decisions and data. Energy choices represent complex tradeoffs; water use and wastewater byproducts are two of many factors to consider. For many policy makers, concerns other than water—low-cost reliable energy, energy independence and security, climate change mitigation, public health, and job creation—are more significant drivers of their positions on energy policies.

Table 1. Policy Responses to Water Demands of Energy Sector

Water Demand Management Options	Water Supply Management Options	Options for Knowledge Development and Use
Minimize Energy Sector's Growth in Water Use	**Improve Energy Sector's Access to Water**	**Support Informed Decision-Making**
Promote water-efficient energy sources through standards, regulations, or incentives (e.g., rebates, water pricing)	Allocate sustainably available water, not otherwise allocated	Data and assessments; information sharing (e.g., data and research warehousing)
Promote water conservation and efficiency in the energy sector through standards, incentives, regulations, or pricing	Facilitate transfer of water from non-energy sectors (e.g., purchase of water from municipalities, or land owners; water markets)	Education, training, and dissemination of knowledge and information
Promote energy conservation and efficiency to reduce demand for energy and the embedded water		Integrated energy-water planning; coordination of research, decisions, and investments
Support research, development, scaling up, or adoption of technologies to reduce energy sector water use (e.g., public-private research collaborations)		Decision-support research and technical assistance; development of standard protocols and codes

Source: CRS.

Analyses quickly get complex when attempting to comprehensively evaluate energy-water tradeoffs. Some energy alternatives, such as solar photovoltaics and wind turbines, do not pose significant energy-water tradeoffs, but may pose other challenges, such as intermittent production or reduced dispatchability, which is the ability and ease with which output from an electric generation facility can be altered. Other energy tradeoffs include transport and storage. Some fuels are easier to store and use existing transport networks and multiple transport modes, while others may require new or expanded infrastructure investments (e.g., pipelines). Significantly, low-carbon energy is not necessarily low in water or environmental impact (e.g., new hydropower reservoirs, freshwater-cooled utility-scale solar), and specific carbon mitigation policies and actions may increase or decrease water consumption. Because of these complexities and the difficulty in comparing different types of impacts, analyses supporting decision-making are often incomplete. It is within this complex and confusing context that policy decisions that influence future energy and related water policies are being made.

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