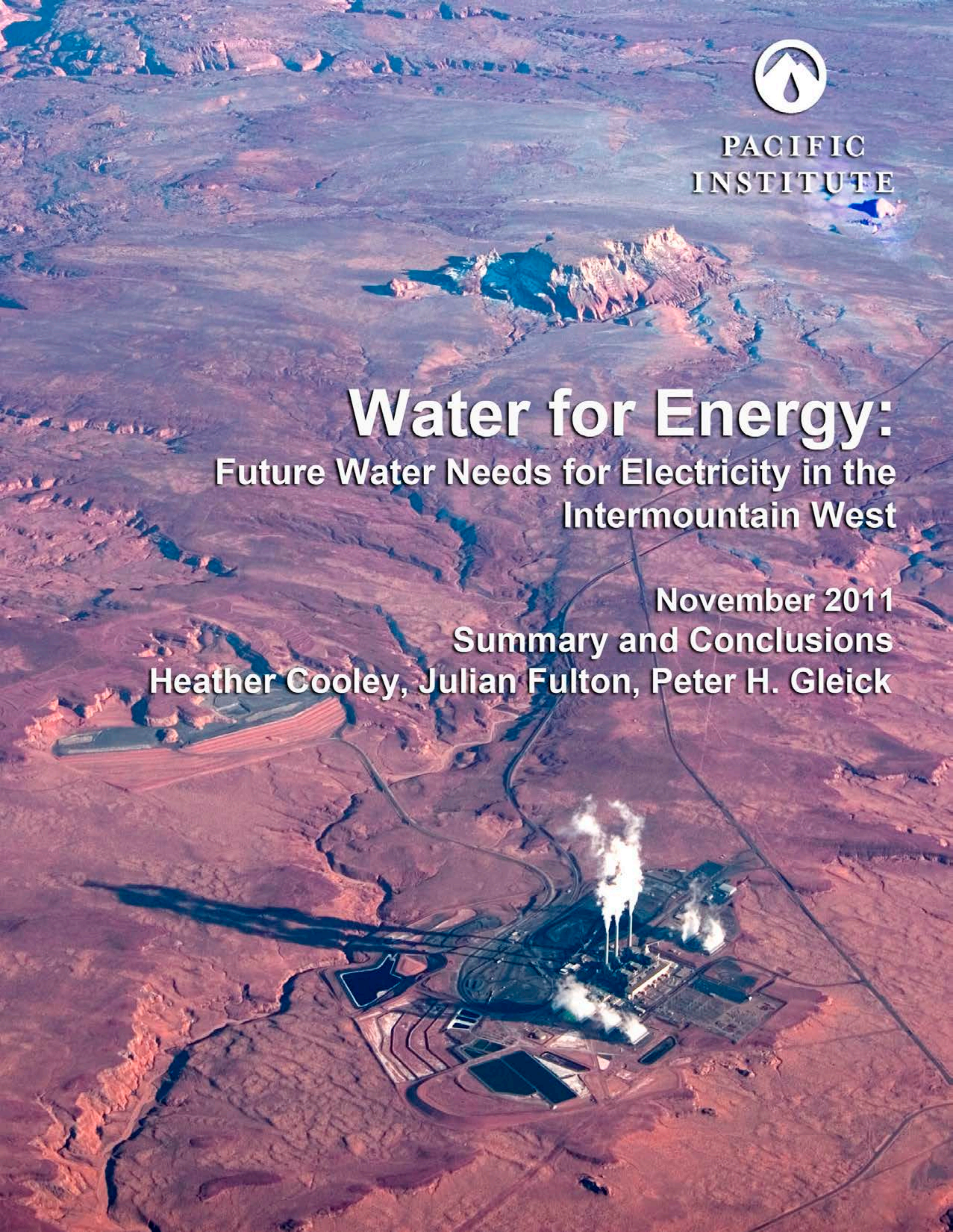

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Water for Energy:

Future Water Needs for Electricity in the Intermountain West

November 2011

Summary and Conclusions

Heather Cooley, Julian Fulton, Peter H. Gleick

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Water for Energy: Future Water Needs for Electricity in the Intermountain West

Introduction

In the past few years, there has been a growing interest in the complex connections between energy and water, typically called the energy-water nexus. For much of the 20th century, these two vital resources have largely been analyzed and managed separately, with different tools, institutions, definitions, and objectives. We now know, however, that there are very important links between water and energy and that long-term sustainable use of both resources requires more comprehensive and integrated study and management. The current report addresses the water implications of energy choices and offers some new insights into the water risks of different electricity futures.[1]

The energy sector has a major impact on the availability and quality of the nation's water resources (Table 1). Water is used to extract and produce energy; process and refine fuels; construct, operate, and maintain energy generation facilities; cool power plants; generate hydroelectricity; and dispose of energy-sector wastes. Some of this water is consumed during operation or contaminated until it is unfit for further use; often much of it is withdrawn, used once, and returned to a watershed for use by other sectors of society.

Energy use also affects water quality and ultimately human and environment health. The discharge of waste heat from cooling systems, for example, raises the temperature of rivers and lakes, which affects aquatic ecosystems. Wastewaters from fossil-fuel or uranium mining operations, hydraulic fracturing, boilers, and cooling systems may be contaminated with heavy metals, radioactive materials, acids, organic materials, suspended solids, or other chemicals.[2,3] Nuclear fuel production plants, uranium mill tailings ponds, and under unusual circumstances, nuclear power plants, have caused radioactive contamination of ground- and surface-water supplies.[4] Too often, however, these water-quality impacts are ignored or inadequately understood.

[1] While there are interesting challenges associated with the energy implications of our water choices, that topic is the focus of a different effort at the Pacific Institute.

[2] United States Environmental Protection Agency (EPA). 2011. Draft Plan to Study the Potential Impacts of Hydraulic Fracturing on Drinking Water Resources. Office of Research and Development. Washington, D.C.

[3] Urbina, I. (2011). Regulation Lax as Gas Wells' Tainted Water Hits Rivers. New York Times. February 26, 2011.

[4] United States Environmental Protection Agency (EPA). 2010. Health and Environmental Impacts of Uranium Contamination in the Navajo Nation.: EPA Progress in Implementing a 5-Year Cleanup Plan. Accessed on 1 June 2011 at http://www.epa.gov/region9/superfund/navajo-nation/pdf/5yrPlanProgRptAug2010.pdf.

Table 1. Connections between the energy sector and water quantity and quality

	Water Quantity Connection	Water Quality Connection
Energy Extraction and Production		
Oil and Gas Exploration (Conventional and Unconventional)	Water required for drilling, well completion, and hydraulic fracturing. Some unconventional oil and gas resources have especially high water demands.	Impact on shallow or deep groundwater quality.
Oil and Gas Production	Water required for enhanced oil recovery. Large volume of produced, impaired waters can be generated during production.	Produced water and spills can contaminate surface and groundwater with diverse pollutants.
Coal and Uranium Mining	Mining operations can generate large quantities of water.	Tailings and mine drainage can contaminate surface water and groundwater and destroy watersheds.
Biofuels and Ethanol	Water is used for growing biomass.	Pesticides and fertilizers can contaminate surface and groundwater.
Refining and Processing		
Traditional Oil and Gas Refining	Water used during oil and gas refinery operations.	Refinery operations can contaminate water.
Biofuels and Ethanol	Water used for refining into fuels.	Refinery wastewater produced.
Synfuels and Hydrogen	Water used for synthesis or steam reforming.	Wastewater produced.
Energy Transportation and Storage		
Energy Pipelines	Water used for hydrostatic testing.	Wastewater produced.
Coal Slurry Pipelines	Water needed for slurry transport; water not returned.	Slurry water is often highly contaminated.
Barge Transport of Energy	River flows and stages affect fuel delivery.	Spills or accidents can affect water quality.
Ocean Transport of Energy		Spills or accidents can affect water quality.
Oil and Gas Storage Caverns	Slurry mining of caverns requires large quantities of water.	Slurry disposal affects water quality and ecology. Contaminants can leak, polluting surface and groundwater.
Electric Power Generation		
Thermoelectric (Fossil, Biomass, Nuclear)	Water (surface or groundwater) is required for cooling and pollutant scrubbing operations.	Thermal and air emissions alter quality of surface waters and aquatic ecosystems.
Hydroelectric	Reservoirs lose water to evaporation.	Dams and reservoir operations alter water temperatures, quality, flow timing, and aquatic ecosystems.
Geothermal	Water (surface or groundwater) is required for cooling.	Thermal and air emissions alter quality of surface waters and aquatic ecosystems.
Solar Thermal	Water (surface or groundwater) is required for cooling.	Cooling systems can affect surface water and aquatic ecosystems.
Solar PV and Wind	Minimal water use for panel and blade washing during operation.	

Source: Modified from United States Department of Energy. 2006. Energy Demands on Water Resources. Report to Congress on the Interdependency of Energy and Water.

Conflicts between energy production and water availability are on the rise as the overall pressure on scarce water resources intensifies. Despite these concerns, water and energy policies are rarely integrated. Federal policies are being developed with little understanding or concern about the impacts on water resources. In particular, the federal government, through subsidies for corn production, has massively increased the production of ethanol, with little concern for the water supply and quality implications of this policy. Similarly, efforts to promote "clean" coal have ignored the water-intensity of capturing carbon.

This analysis offers some new insights into the water implications of electricity generation. Transportation fuels are not covered here, although we note that the water implications of transportation fuels are of growing concern due to a shift toward domestic fuel sources, especially biofuels. We also do not address the water implications of extracting and processing the primary fuels used to generate electricity, such as hydraulic fracturing, oil shale production, or other segments of the energy fuel cycle. Some of these impacts will be addressed in later work.

Figure 1. Intermountain West
Source: Produced by Matthew Heberger, Pacific Institute

Here, we focus on current and projected electricity generation within the Intermountain West, which is the area bound by the Rocky Mountains in the East and the Sierra Nevada and Cascade Mountains in the West (Figure 1). We note that water and energy concerns are not limited to the West, and examples of water-energy hotspots can be found throughout the United States. However, the Intermountain West is of particular interest for this study because it has a growing population (and demand for energy and water), a diverse fuel mix for power generation, and existing water resource constraints that are expected to worsen.

Conclusions

Water scarcity affects energy production.

Conflicts between energy production and water are on the rise as the overall pressure on scarce water resources grows. Water availability is beginning to affect energy production, even in areas not traditionally associated with water-supply constraints. For example:

- In September 2010, water levels in Lake Mead dropped to 1,084 feet, levels not seen since 1956, prompting the Bureau of Reclamation to reduce Hoover Dam's generating capacity by 23%. As water levels continued to drop and concerns about climate change intensified, dam operators were concerned that reductions in the electricity generating capacity would destabilize energy markets in the southwestern United States.[5]

- In August 2007, river flows and reservoir levels in the southeastern United States dropped due to drought, and in some cases, water levels were so low that power production was halted or curtailed, including at the Browns Ferry nuclear plant and at coal plants in the Tennessee Valley Authority system.[6]

- A seven-year drought reduced power production from the North Platte Project – which includes a series of dams and hydropower plants along the North Platte River from Nebraska to Wyoming – by about 50%, according to the executive director of the Wyoming Municipal Power Agency. The drought also reduced production in other thermo- and hydroelectric plants along the river.[7]

- The proposed Ely Energy Center, a 1,500-megawatt coal-fired power plant, would have consumed over 7.1 million gallons of water each day. Local Nevada residents and environmental groups opposed the proposal due, in part, to concerns about water consumption.[8] NV Energy abandoned the plan in 2009, citing economic and environmental uncertainties.[9]

- The Tennessee Valley Authority reported that it curtailed operations at some of its operating nuclear plants when temperature limits in the receiving waters below cooling water discharge pipes were exceeded due to drought.[10,11]

[5] Walton, B. 2010. Low Water May Halt Hover Dam's Power. Circle of Blue. Accessed on April 15, 2011 at http://www.circleofblue.org/waternews/2010/world/low-water-may-still-hoover-dam%E2%80%99s-power/
[6] Kimmell, T.J. and J.A. Veil. 2009. Impact of drought on U.S. steam electric power plant cooling water intakes and related water resource management issues. DOE/NETL-2009/1364, U.S. Department of Energy.
[7] LaMaack, Larry. 2006. Testimory to the Water and Power Subcommittee Hearings. http://naturalresources.house.gov/UploadedFiles/LemaackTestimony08.09.06.pdf
[8] Western Resource Advocates website. Nevada Coal Plant Proposals. http://www.westernresourceadvocates.org/energy/coal/nevada.php#3
[9] NV Energy. 2009. NV Energy Postpones Construction of Coal Power Facility in Nevada; Plans to Expedite North-South Transmission Line. Press Release. 9 February 2009.
[10] Weiss, M. 2008. Drought Could Force Nuke-Plant Shutdowns. Associated Press.
[11] Kimmell, T.J. and J.A. Veil. 2009. Impact of drought on U.S. steam electric power plant cooling water intakes and related water resource management issues. DOE/NETL-2009/1364, U.S. Department of Energy.

There is growing concern that these resource conflicts may intensify as a result of trends in energy use, water demand, and water availability. Population growth is concentrated in water scarce areas, increasing pressure on limited resources. This growth is also increasing demand for electricity. Furthermore, climate change is already affecting the supply of and demands for water throughout the region, and climate models find that the impacts and economic consequences of climate change will accelerate, particularly if efforts to reduce greenhouse gas emissions continue to be delayed.

Sustainable water and energy use requires integrated study and management.

Water and energy are deeply interwoven into our economy, environment, and society. Yet, for much of the 20th century, water and energy have largely been analyzed and managed separately, with different tools, institutions, definitions, and objectives. We now know, however, that there are very important and fundamental links between water and energy, and that long-term sustainable use of both resources requires comprehensive and integrated study and management. In addressing the water implications of energy choices, this report offers some new insights into the water risks of different electricity futures.

The focus of this analysis is the Intermountain West, which includes the area bounded by the Rocky Mountains to the East and the Sierra Nevada and Cascade Mountains to the West. States entirely or partially within this region include Washington, Oregon, Idaho, Montana, Wyoming, Nevada, Utah, Colorado, Arizona, New Mexico, and California. In this analysis, we evaluate water withdrawals and consumption for current (2010) electricity generation and for six future electricity-generation scenarios:

1. **Current Trends Scenario**: U.S. Energy Information Administration (EIA) "Reference" electricity generation scenario for 2035 with the current mix of cooling technologies;

2. **Current Trends + 25% Dry Cooling Scenario**: EIA "Reference" electricity generation scenario for 2035 with 25% dry cooling and 75% recirculating cooling;

3. **Current Trends + 50% Dry Cooling Scenario**: EIA "Reference" electricity generation scenario for 2035 with 50% dry cooling and 50% recirculating cooling;

4. **Expanded Renewables Scenario**[12]: EIA "Greenhouse Gas Price Economywide" electricity generation scenario for 2035 with current mix of cooling technologies;

5. **Expanded Renewables + 25% Dry Scenario**: EIA "Greenhouse Gas Price Economywide" electricity generation scenario for 2035 with 25% dry cooling and 75% recirculating cooling; and

6. **Expanded Renewables + 50% Dry Scenario**: EIA "Greenhouse Gas Price Economywide" electricity generation scenario for 2035 with 50% dry cooling and 50% recirculating cooling.

[12] The Expanded Renewables scenarios include energy-efficiency improvements and greater reliance on renewable energy systems.

Under a business-as-usual approach, water resource challenges are likely to intensify throughout the Intermountain West.

Our results indicate that under a business-as-usual approach, as modeled in the Current Trends scenario, water withdrawals and consumption are projected to increase across the Intermountain West (Figure 2). Total water withdrawals increase to 1,980 million gallons per day, or 2% above 2010 levels. Likewise, water consumption increases to 393 million gallons per day, 5% above 2010 levels. The largest increases in both withdrawals and consumption occur in the Rocky Mountain area, a region with limited available water sources.

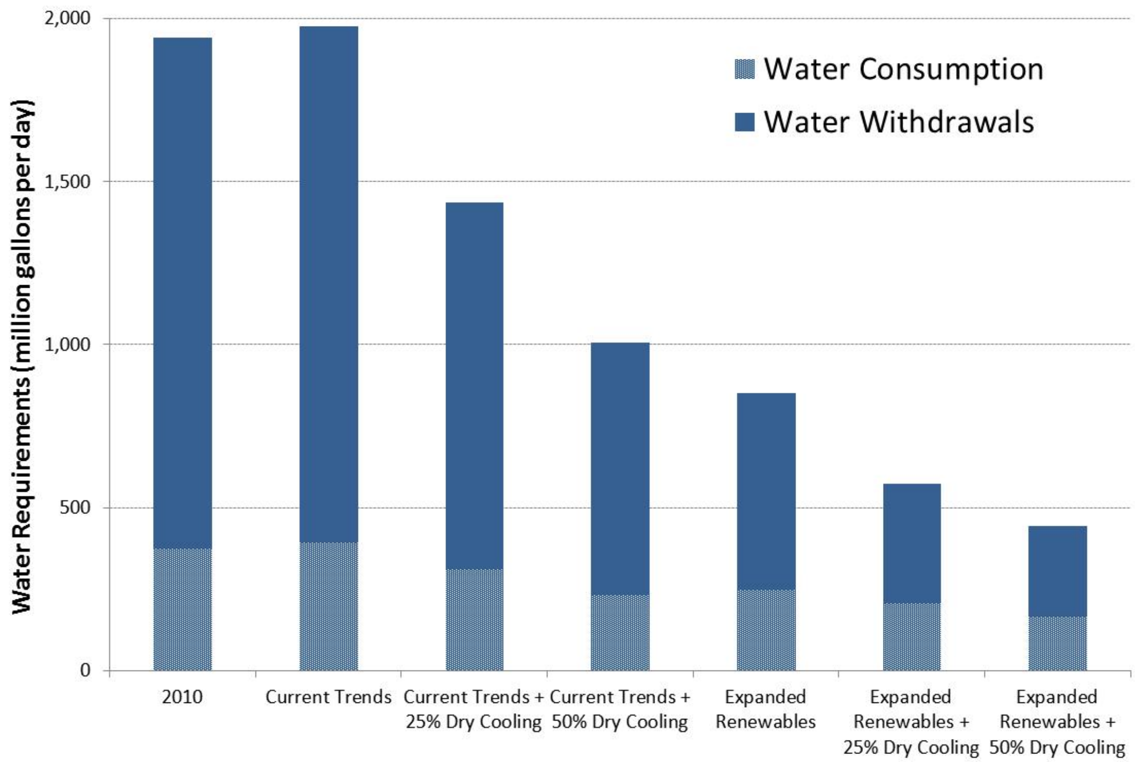

Figure 2. Water requirements for electricity generation in 2010 and in 2035 in six alternative scenarios.
Note: The full bar shows total water withdrawals for each scenario. Water consumption is shown as a proportion of the total withdrawals.

Electricity can be generated in the Intermountain West using less water, especially with the adoption of energy-efficiency improvements and dry cooling systems and greater reliance on renewables.

Expanding the use of dry cooling – either as the only cooling system at a given power plant or combined with a wet cooling tower as a hybrid system – produces large reductions in water withdrawals and consumption. Under the Current Trends + 25% Dry Cooling scenario, water withdrawals decline to 1,440 million gallons per day, 26% below 2010 levels. Likewise, water consumption declines to 310 million gallons per day, 17% below 2010 levels. By expanding the deployment of dry cooling to 50% of generation, additional water savings are possible.

Even greater savings can be achieved by expanding energy-efficiency efforts and relying more heavily on renewable energy systems. Under the Expanded Renewables scenario, water withdrawals decline to 853 million gallons per day, and water consumption declines to 247 million gallons per day. This results in a reduction a 56% reduction in water withdrawals and a 34% reduction in water consumption, compared to 2010 levels. Dry cooling systems can provide additional water savings. Under the Expanded Renewables and 25% Dry Cooling scenario, water withdrawals and consumption decline to 573 million gallons per day and 206 million gallons per day. This represents a 71% and 45% reduction in water withdrawals and consumption, respectively, compared to 2010 levels.

Extracting fuels for energy production has a water cost that must be evaluated.

This analysis also finds that while we can dramatically reduce the water requirements for electricity generation, there are other energy-related threats to regional water availability and quality that must be evaluated. In particular, most studies, including this one, have focused on the water requirements for electricity generation itself. In order to generate this electricity, however, more primary fuels, such as coal and natural gas, must be extracted and processed, processes which use and pollute water. Furthermore, some new energy extraction processes, such as hydraulic fracturing, are water intensive. More research and analysis are needed on the water requirements to extract and process the primary fuels needed to generate electricity.

Climate change will have major implications for water resources and electricity in the Intermountain West.

The impacts of climate change on water resources are already evident in the Intermountain West, including less precipitation and runoff, an earlier snowmelt, and more frequent and intense droughts. Climate models indicate that these impacts will accelerate, particularly if efforts to reduce greenhouse gas emissions continue to be delayed. Climate change will also have major implications for electricity production and use across the Intermountain West, which will, in turn, affect water resources. Warmer temperatures reduce the efficiency of thermal power plants and of transmission and distribution lines. More power will need to be generated, and more water withdrawn and consumed, to offset these efficiency losses. Likewise, reductions in hydropower generation and increases in electricity demand associated with warmer temperatures will increase demand for additional power generation and as a result, likely increase water withdrawals and consumption. Technologies that have been proposed to mitigate climate change, such as carbon capture and storage, might create additional demands on water resources. These impacts are not typically integrated in current electricity analyses; additional analysis is needed to better understand how climate change will affect electricity generation and ultimately water resources.

The production of electricity affects water quality and human and environmental health.

Finally, the production of electricity has a significant effect on water quality and ultimately human and environment health. The discharge of waste heat from cooling systems, for example, raises the temperature of rivers and lakes, which affects aquatic ecosystems. Wastewaters from fossil fuel or uranium mining operations, hydraulic fracturing, boilers, and cooling systems may be contaminated with heavy metals, radioactive materials, acids, organic materials, suspended solids, or other chemicals. For example, A *New York Times* analysis of Environmental Protection Agency data finds that power plants are the nation's biggest producer of toxic waste, and with efforts to reduce air pollution, many of these pollutants end up in our waterways.[13] In a single incident in Kentucky, a coal sludge impoundment collapsed and released an estimated 250 million gallons of coal sludge into surrounding waterways, disrupting local water supplies for days and devastating aquatic life along more than 100 miles of streambeds and associated floodplains.[14] Too often, water quality impacts are poorly understood and largely ignored.

Recommendations

Improve data, information, and education on impact of energy sector on water resources.

Water and energy analysts are often frustrated by the lack of available data on the water use and consumption of energy systems. In a recent report, the Government Accountability Office outlines some of the major shortcomings of federal data-collection efforts on water availability and use as they relate to planning and siting energy facilities.[15] The United States Geological Survey, for example, collects data on water withdrawals by power plants but not water consumption.[16] Streamflow gauges, which provide information on water availability, are disappearing. The EIA does not collect data on the use of advanced cooling technologies. No agency collects data on the use of alternative water sources, such as recycled water, for power production. Few data are available on the water-quality impacts of energy production, from energy extraction to generation. Many of these shortcomings are a result of budget cuts. State and federal agencies must enhance data collection and reporting capacities.

Accelerate efficiency improvements.

Improvements in water and energy efficiency can help meet the needs of a growing population, reduce or eliminate the need to develop capital-intensive infrastructure, and provide environmental benefits. Additionally, conservation and efficiency promote both water and energy security by reducing vulnerability to limits on the availability of these resources.

Promote renewable energy systems.

Shifting from conventional fossil fuels to less water-intensive renewable energy sources would reduce the water-intensity of the electricity sector, among other environmental benefits. This, in

[13] Duhigg, C. (2009). Cleansing the Air at the Expense of Waterways. New York Times (October 12, 2009).
[14] United States Environmental Protection Agency. 2001. Martin County Coal Corporation, Inez, Kentucky Task Force Report. Accessed July 1, 2010 from http://www.epa.gov/region4/waste/martincs.pdf.
[15] Government Accountability Office. 2009. Improvements to Federal Water Use Data Would Increase Understanding of Trends in Power Plant Water Use. Report to the Chairman, Committee on Science and Technology, House of Representatives. Washington, D.C.
[16] Prior to 2000, the USGS collected and reported water withdrawals and consumption. However, only data on withdrawals was reported in 2000 and 2005. For the 2010 analysis, the USGS will include both withdrawals and consumption.

turn, would help reduce pressure on limited water resources and reduce the electricity sector's vulnerability to water-supply constraints.

Establish cooling-technology requirements.

Prior to 1970, most thermoelectric plants were built with once-through cooling systems. New requirements set by the Environmental Protection Agency under Section 316(b) of the Clean Water Act have made permitting requirements for these cooling systems more stringent. Additionally, in regions with limited water resources, plant operators have, out of necessity, moved away from water-intensive cooling technologies. Federal and state governments should continue to tighten water-cooling technology requirements through federal and state permitting processes. As many of the power plants in the Intermountain West are already in compliance with 316(b) modifications, they must be motivated to further reduce their water impacts by moving to dry and hybrid cooling and other regionally appropriate technologies.

Promote switching to alternative water sources.

Alternative water sources can reduce freshwater requirements for electricity generation. Recycled municipal wastewater, for example, is a reliable water source that is available in relative abundance across the United States. In 2007, however, only 57 power plants, most of which were located in California, Florida, and Texas, were using treated municipal wastewater, suggesting that its use could be dramatically expanded and help reduce pressure on freshwater systems.[17] Other alternative water sources include produced water from oil and gas wells, mine pool water, and industrial process water.

Expand research and development efforts.

A number of strategies are available to reduce the tension between water and energy management. Key areas for research and development include technologies and management practices to promote the use of alternative water sources, including produced water, brackish groundwater, and municipal wastewater; application of dry and hybrid-cooling technologies for power plants; and improvements in power plant thermal efficiency.

[17] Argonne National Laboratory. 2007. Use of Reclaimed Wastewater for Power Plant Cooling. Argonne, Illinois.