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EXECUTIVE SUMMARY

Water-Smart Power

STRENGTHENING THE U.S. ELECTRICITY SYSTEM IN A WARMING WORLD

A Report of the Energy and Water in a Warming World Initiative

The heat waves and drought that hit the United States in 2011 and 2012 shined a harsh light on the vulnerability of the U.S. power sector to extreme weather, and revealed water-related electricity risks across the country. Today's electricity system cannot meet our needs in a future of growing demand for power, worsening strains on water resources, and an urgent need to mitigate climate change. We can, however, design an electricity future that begins to shed some of these risks. The key is to understand what a low-carbon, "water-smart" electricity future looks like—and to make decisions that will set and keep us on that path.

The heat waves and drought that hit the United States in 2011 and 2012 shined a harsh light on the vulnerability of the U.S. electricity sector to extreme weather. During the historic 2011 drought in Texas, power plant operators trucked in water from miles away to keep the plants running, and disputes deepened between cities and utilities seeking to construct new water-intensive coal plants. In 2012, heat and drought forced power plants, from the Gallatin coal plant in Tennessee to the Vermont Yankee nuclear plant on the Connecticut River, to reduce their output or shut down altogether. That summer, amid low water levels and soaring water temperatures, operators of other plants—at least seven coal and nuclear plants in the Midwest alone—received permission to discharge even hotter cooling water, to enable the plants to keep generating. These consecutive summers alone revealed water-related electricity risks across the country.

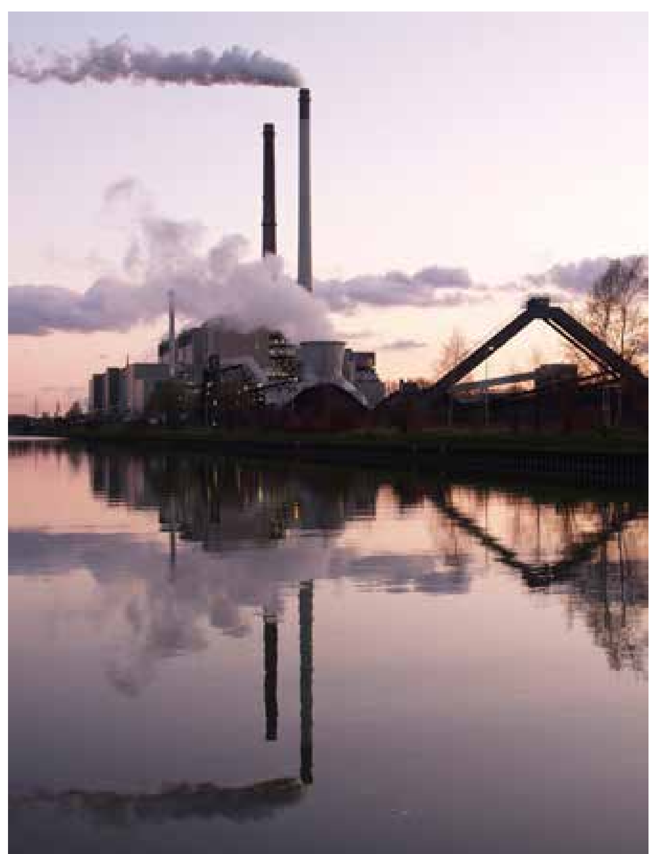
The power sector has historically placed large demands on both our air and water. In 2011, electricity generation accounted for one-third of U.S. heat-trapping emissions, the drivers of climate change. Power plants also accounted for more than 40 percent of U.S. freshwater withdrawals in 2005, and are one of the largest "consumers" of freshwater—losing water through evaporation during the cooling process—outside the agricultural sector.

The electricity system our nation built over the second half of the twentieth century helped fuel the growth of the U.S. economy and improve the quality of life of many Americans. Yet we built that system before fully appreciating the reality and risks of climate change, and before converging pressures created the strain on local water resources we see today in many places. This system clearly cannot meet our needs in a future of growing demand for electricity, worsening strains on water resources, and an urgent need to mitigate climate change.

We can, however, use fuel and technology options available now to design an electricity future that begins to shed some of these risks. We can also expand our options by making strategic investments in energy and cooling technologies. The key is to understand what a low-carbon, "water-smart" electricity future looks like—which electric sector decisions best prepare us to avoid and minimize energy-water collisions, and to cope with those we cannot avoid—and to make decisions that will set and keep us on that path.

This report is the second from the Energy and Water in a Warming World Initiative (EW3), organized by the Union of Concerned Scientists to focus on the water implications of U.S. electricity choices. The first, *Freshwater Use by U.S. Power Plants,* documented the energy-water collisions already occurring because of the dependence of U.S. power plants on water. In that research, we found that past choices on fuel and cooling technologies in the power sector are contributing to water stress in many areas of the country.

Like the first report, this one stems from a collaboration among experts from universities, government, and the nonprofit sector. *Water-Smart Power* reflects comprehensive new research on the water implications of electricity choices in the United States under a range of pathways, at national, regional, and local levels. The report aims to provide critical information to inform decisions on U.S. power plants and the electricity supply, and motivate choices that safeguard water resources, reduce carbon emissions, and provide reliable power at a reasonable price—even in the context of a changing climate and pressure on water resources.



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Power plants, cooling water, and carbon. **Power plants that use water take different approaches to meeting their cooling needs. Some withdraw large amounts of water but put most of it back—though hotter. Others withdraw much less but consume (evaporate) most or all of it. Many power plants are both heavy water users and large carbon emitters. That means they put pressure on local water resources directly while contributing to climate change and its effects on water.**

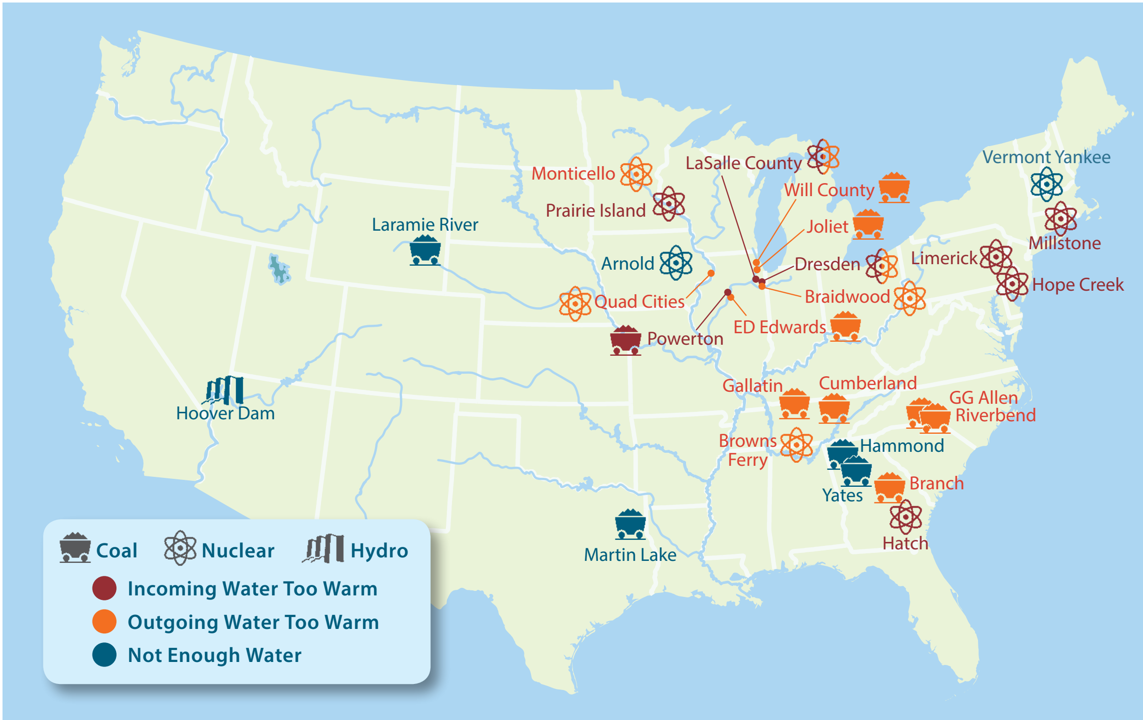

FIGURE 1. Energy-Water Collisions

Power plant dependence on water can create a range of problems, including for the plants themselves. Plants have recently run into three kinds of challenges: incoming cooling water that is too warm for efficient and safe operation, cooling water that is too hot for safe release into nearby rivers or lakes, and inadequate water supplies. In response, operators must reduce plant output or discharge hot water anyway, at times when demand for electricity is high and rivers and lakes are already warm.

Source: Spanger-Siegfried 2012.

Note: Selected events, 2006–2012.

The Challenges We Face

Our examination of today's electricity-water landscape reveals prominent challenges:

- **Energy-water collisions are happening now.** Because of its outsized water dependence, the U.S. electricity sector is running into and exacerbating growing water constraints in many parts of the country. The reliance of many power plants on lakes, rivers, and groundwater for cooling water can exert heavy pressure on those sources *and* leave the plants vulnerable to energy-water collisions, particularly during drought or hot weather. When plants cannot get enough cooling water, for example, they must cut back or completely shut down their generators, as happened repeatedly in 2012 at plants around the country.

- **As the contest for water heats up, the power sector is no guaranteed winner.** When the water supply has been tight, power plant operators have often secured the water they need. In the summer of 2012, for example, amid soaring temperatures in the Midwest and multiple large fish kills, a handful of power plant operators received permission to discharge exceptionally hot water rather than reduce power output. However, some users are pushing back against the power sector's dominant stake. In Utah, for example, a proposal to build a 3,000-megawatt nuclear power plant fueled grave concerns about the impact of the plant's water use. And in Texas, regulators denied developers of a proposed 1,320-megawatt coal plant a permit to withdraw 8.3 billion gallons (25,000 acre-feet) of water annually from the state's Lower Colorado River.

- **Climate change complicates matters.** Energy-water collisions are poised to worsen in a warming world as the power sector helps drive climate change, which in turn affects water availability and quality.

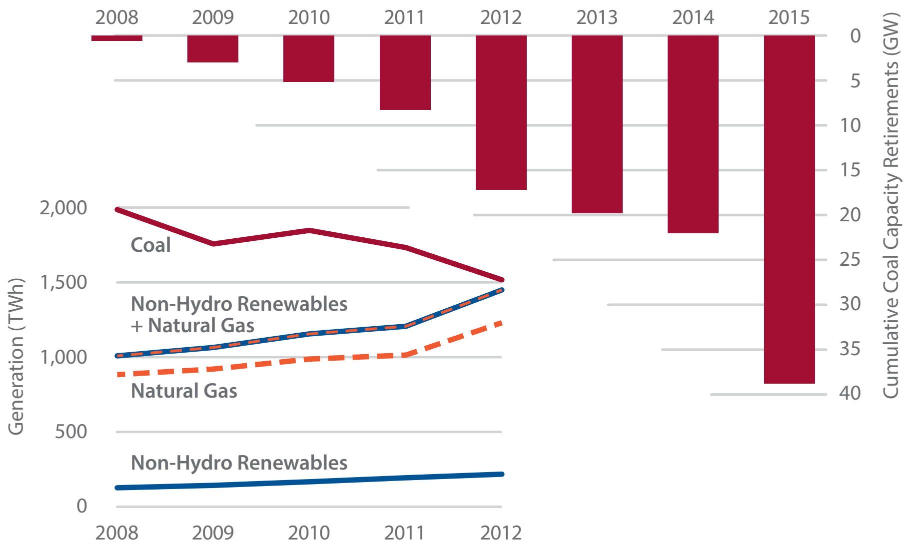

FIGURE 2. Electricity Sector in Transition: The U.S. Electricity Mix and Retiring Coal Plants

Growing amounts of power from natural gas and non-hydro renewables—along with declining amounts of power from coal plants—have challenged coal's dominance in the U.S. electricity mix (left axis). In 2008, coal supplied almost half of U.S. electricity. By 2012, that share had dropped to 37 percent, while natural gas and renewable energy together supplied more than 35 percent. Tens of thousands of megawatts of coal generators are slated for retirement, unable to compete economically (right axis). What we build in their place will help determine our future water resources. (TWh = terawatt-hours, or million megawatt-hours; GW = gigawatts, or thousands of megawatts) Sources: EIA 2013a; SNL 2013.

> Climate change is already constraining or altering the water supply in many regions by changing the hydrology. In the Southwest, for example, where the population is growing rapidly and water supply is typically tight, much of the surface water on which many water users depend is declining. Scientists expect rising average temperatures, more extreme heat, and more intense droughts in many regions, along with reductions in water availability.

These conditions—heightened competition for water and more hydrologic variability—are not what our power sector was built to withstand. However, to be resilient, it must adjust to them.

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Change Is Under Way

Building an electricity system that can meet the challenges of the twenty-first century is a considerable task. Not only is the needed technology commercially available now, but a transition is also under way that is creating opportunities for real system-wide change:

- **The U.S. power sector is undergoing rapid transformation.** The biggest shift in capacity and fuel in half a century is under way, as electricity from coal plants shrinks and power from natural gas and renewables grows. Several factors are spurring this transition to a new mix of technologies and fuels. They include the advanced age of many power plants, expanding domestic gas supplies and low natural gas prices, state renewable energy and efficiency policies, new federal air-quality regulations, and the relative costs and risks of coal-fired and nuclear energy.

Heat and drought ahead. **Energy-water collisions are poised to worsen in a warming world as the power sector helps drive climate change, which in turn affects water availability and quality. Scientists expect rising average temperatures, more extreme heat, and more intense droughts in many regions, along with reductions in water availability.**

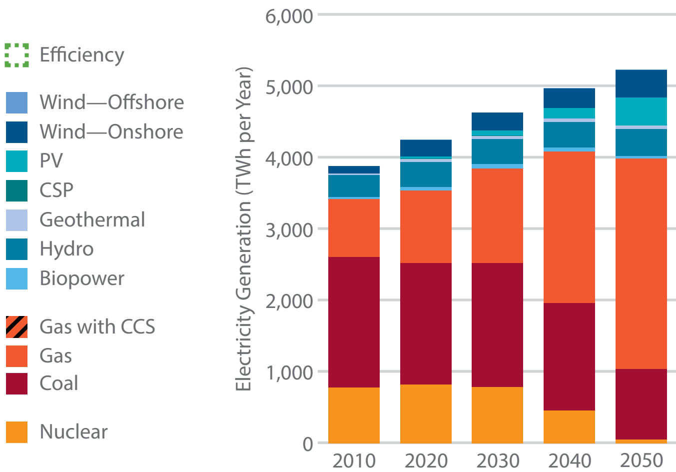


FIGURE 3. U.S. Electricity Mix under Business as Usual, 2010–2050

The electricity mix would change markedly over the next several decades under a business-as-usual pathway, given the rapid transformation already under way. Coal power would drop significantly, based on coal plant retirements that have already been announced, pressure from low natural gas prices, and state and federal policies to protect public health and drive energy innovation. Nuclear power would disappear, as existing plants reach the end of their lives and new reactors would be unable to compete economically. Natural gas would dominate the electricity mix, supplying almost 60 percent of U.S. power by 2050. (PV = solar photovoltaics; CSP = concentrating solar power) Source: Clemmer et al. 2013.

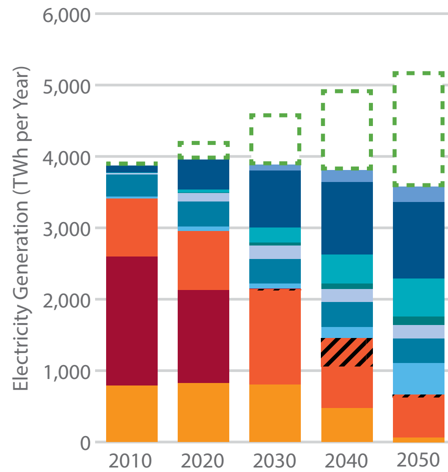


FIGURE 4. U.S. Electricity Mix under the Renewables-and-Efficiency Scenario

One option for swift and deep cuts in carbon emissions from the power sector is significant reliance on energy efficiency and renewable energy. Under our renewables-and-efficiency scenario, the use of more efficient heating, cooling, lighting, and other technologies would more than offset projected growth in electricity demand by 2050, while deeply reducing carbon emissions. Renewable sources such as wind, solar, and geothermal could supply 80 percent of the remaining electricity demand. Source: Clemmer et al. 2013.

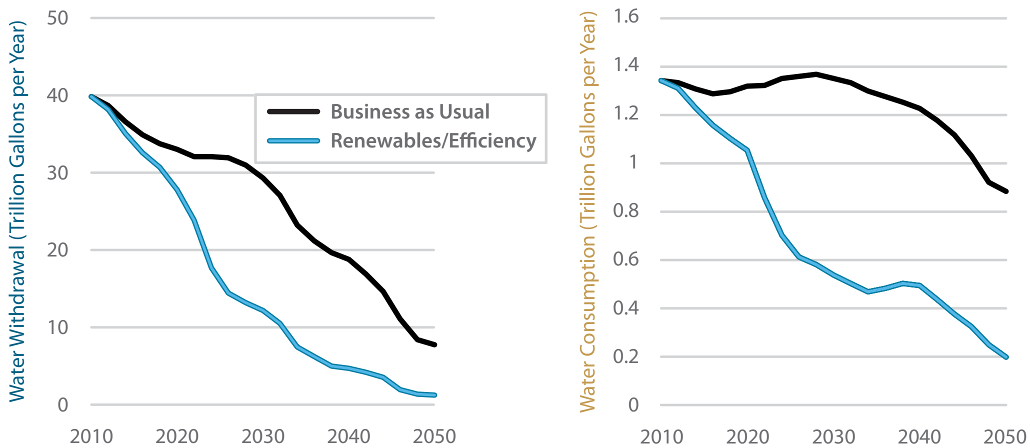
- **This presents an opportunity we cannot afford to miss.** Decisions about which power plants to retrofit or retire and which kind to build have both near-term and long-term implications, given the long lifetimes of power plants, their carbon emissions, and their water needs. Even a single average new coal plant could emit 150 million tons of carbon dioxide over 40 years—twice as much as a natural gas plant, and more than 20 million cars emit each year. Power plants that need cooling water will be at risk over their long lifetimes from declining water availability and rising water temperatures stemming from climate change, extreme weather events, and competition from other users. And power plants, in turn, will exacerbate the water risks of other users.

Decisions in the Power Sector Matter

Choices, however, are important only if they lead to different outcomes. To analyze the impact of various options for our electricity future on water withdrawals and consumption, carbon emissions, and power prices, under this new research we focused on several key scenarios. These included "business as usual" and three scenarios based on a strict carbon budget—to address the power sector's contributions to global warming. Two of those three scenarios assumed the use of specific technologies to make those significant cuts in carbon emissions.

To explore the outcomes of these scenarios we used two models: the Regional Energy Deployment System (ReEDS) and the Water Evaluation and Planning (WEAP) system. With these two models and our set of scenarios, we analyzed the implications of water use in the power sector under different electricity pathways for the entire nation, for various regions, and for individual river basins in the southwestern and southeastern United States.

Our distinctive approach and new research—along with previous work—shows that our electricity choices will have major consequences over the coming decades,



Source: Macknick et al. 2012b.

FIGURE 5. Power Plant Water Use under the Renewables-and-Efficiency Case, 2010–2050

Dramatic reductions in water use by the power sector are possible—and necessary in a water-constrained future. Water use would drop much further under a renewables-and-efficiency scenario than under business as usual—and much more quickly. By 2030, under the former, both withdrawals (left) and consumption (right) would be less than half of today's levels. By 2050, under the renewables-and-efficiency scenario, withdrawals would be 97 percent below today's levels. Water consumption would drop by 85 percent, and be almost 80 percent below business as usual in 2050. Power plants would withdraw 9 trillion gallons (28 million acre-feet) less per year than under business as usual—as much as is now withdrawn for all uses in Pennsylvania, Maryland, New Jersey, and West Virginia combined.

especially in water-stressed regions. Through this research, we have learned that:

- **Business as usual in the power sector would fail to reduce carbon emissions, and would not tap opportunities to safeguard water.** Because such a pathway for meeting future electricity needs would not cut carbon emissions, it would do nothing to address the impact of climate change on water. Changes in the power plant fleet would mean that water withdrawals by power plants would drop, yet plants' water consumption would not decline for decades, and then only slowly. The harmful effects of power plants on water temperatures in lakes and rivers might continue unabated, or even worsen. Greater extraction of fossil fuels for power plants would also affect water use and quality.

- **Low-carbon pathways can be water-smart.** A pathway focused on renewable energy and energy efficiency, we found, could deeply cut both carbon emissions and water effects from the power sector. Water withdrawals would drop 97 percent by 2050—much more than under business as usual. They would also drop faster, with 2030 withdrawals only half those under business as usual. And water consumption would decline 85 percent by 2050. This pathway could also curb local increases in water temperature from a warming climate. Meanwhile lower carbon emissions would help slow the pace and reduce the severity of climate change, including its long-term effects on water quantity and quality.

- **However, low-carbon power is not necessarily water-smart.** The menu of technologies qualifying as low-carbon is long, and includes some with substantial water needs. Electricity mixes that emphasize carbon capture and storage for coal plants, nuclear energy, or even water-cooled renewables such as some geothermal, biomass, or concentrating solar could worsen rather than lessen the sector's effects on water.

- **Renewables and energy efficiency can be a winning combination.** This scenario would be most effective in reducing carbon emissions, pressure on water resources, and electricity bills. Energy efficiency efforts could more than meet growth in demand for electricity, and renewable energy could supply 80 percent of the remaining demand. Although other low-carbon paths could rival this one in cutting water withdrawals and consumption, it would edge ahead in reducing groundwater use in the Southwest, improving river flows in the Southeast, and moderating high river temperatures. This scenario could also provide the lowest costs to consumers, with consumer electricity bills almost one-third lower than under business as usual.

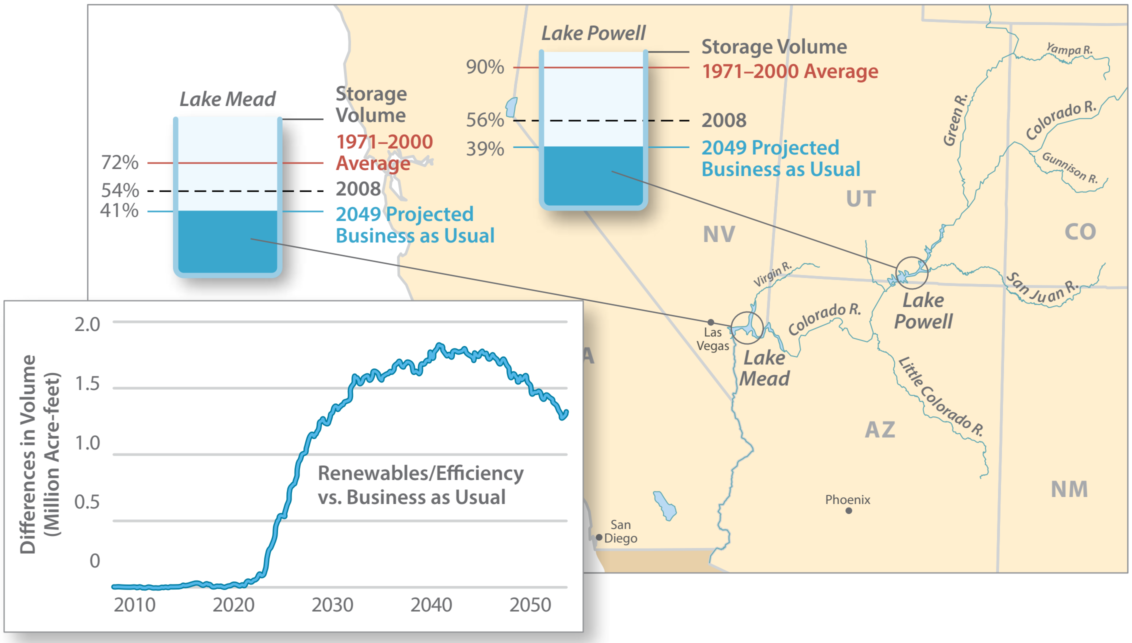


FIGURE 6. The Impact of Electricity Choices on Reservoir Levels in Lake Mead and Lake Powell

Electricity choices that consume less water leave more for other uses. These choices can also markedly affect cumulative water supplies. Water levels in the Southwest's major reservoirs, Lake Mead and Lake Powell, have been well below capacity for many years, and could drop farther during extended droughts. Lower water consumption each year under the renewables-and-efficiency scenario (inset) could mean almost 600 billion gallons (1.8 million acre-feet) more stored water in those reservoirs by 2040, compared with business as usual. That amount is nearly 4 percent of the storage capacity of those two reservoirs, and more than 13 percent of the average annual natural flow of the Colorado River. Sources: Yates, Meldrum, and Averyt 2013; NRCS 2008.

Electricity choices affect river flows and temperatures. **Water-smart electricity choices can reduce the impact of the power sector on river flows and water temperatures. Under the renewables-and-efficiency scenario, flows of the Chattahoochee River below Georgia's Wansley power plant would be 5 percent to 10 percent higher in summer and fall by 2025 than under the business-as-usual case. The Coosa River above Alabama's Weiss Lake would be 3° F (2° C) to 13° F (7° C) cooler in mid-summer in the decade from 2030 to 2039 than under business as usual, because coal plants, including those upstream, would have been phased out by then.**

Toward a Water-Smart Energy Future

Water-smart energy decision making depends on understanding and effectively navigating the electricity-water-climate nexus, and applying best practices in decision making:

- **We can make decisions now to reduce water and climate risk.** Fuel and technology options already available mean we can design an electricity system with far lower water and climate risks. These include prioritizing low-carbon, water-smart options such as renewable energy and energy efficiency, upgrading power plant cooling systems with those that ease water stress, and matching cooling needs with the most appropriate water sources.

- **Electricity decisions should meet water-smart criteria.** These criteria can point decision makers to options that reduce carbon emissions *and* exposure to water-related risks, make sense locally, and are cost-effective.

- **Actors in many sectors have essential roles to play.** No single platform exists for sound, long-term decisions at the nexus of electricity and water, but those made in isolation will serve neither sector. Instead, actors across sectors and scales need to engage. For example: plant owners can prioritize low-carbon options that are water-appropriate for the local environment. Legislators can empower energy regulators to take carbon and water into account. Consumer groups can ensure that utilities do not simply pass on to ratepayers the costs of risky, water-intensive plants. Investors in utilities can demand information on water-related risks and seek low-carbon, water-smart options. Researchers can analyze future climate and water conditions and extremes, allowing planners to consider low-probability but high-impact events. And scientists and engineers can improve the efficiency and reduce the cost of low-water energy options.

Understanding and addressing the water impact of our electricity choices is urgent business. Because most power sector decisions are long-lived, what we do in the near term commits us to risks or resiliencies for decades. We can untangle the production of electricity from the water supply, and we can build an electricity system that produces no carbon emissions. But we cannot wait, nor do either in isolation, without compromising both. For our climate—and for a secure supply of water and power—we must get this right.

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Locking in risk—or resilience. **New power plants will replace retiring plants to help meet future electricity demand. The impact of the water use and carbon emissions of those new plants will reverberate for decades. But power production does not have to use water or produce carbon. Electricity options that do neither, such as wind and solar photovoltaics, are spreading quickly and are poised for even wider use.**

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The full text of this report is available online at *www.ucsusa.org/watersmartpower.*

The Energy and Water in a Warming World initiative (EW3) is a collaborative effort between the Union of Concerned Scientists and a team of independent experts to build and synthesize policy-relevant research on the water demands of energy production in the context of climate variability and change. The initiative includes core research collaborations intended to raise the national profile of the water demands of energy, along with policy-relevant energy development scenarios and regional perspectives.

This report is based primarily on the research of the EW3 energy-water futures collaborators listed to the left. The research appears in a special issue of *Environmental Research Letters:* Focus on Electricity, Water and Climate Connections.

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