THE ENERGY-WATER COLLISION

10 Things You Should Know

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ENERGY AND WATER are woven into our daily lives and strongly linked to one another. Producing energy uses water, and providing freshwater uses energy. Both these processes face growing limits and problems.[1] In most power plants, water cools the steam that spins the electricity-generating turbines. Refining transportation fuels requires water, as does producing fuels—for example, mining coal, extracting petroleum, or growing crops for biofuels. Using water in our homes and businesses requires getting it there, treating it, heating it, and more. Because of these links between energy and water, problems for one can create problems for the other. In places where using energy requires a large share of available water, or where water resources are scarce or stressed by competing pressures (such as the needs of farmers or of local ecosystems or, increasingly in many parts of the United States, by climate change), the energy-water connection can turn into a *collision*—with dangerous implications for both.

The 10 facts below summarize the water impacts of our energy choices—and ways to address them.

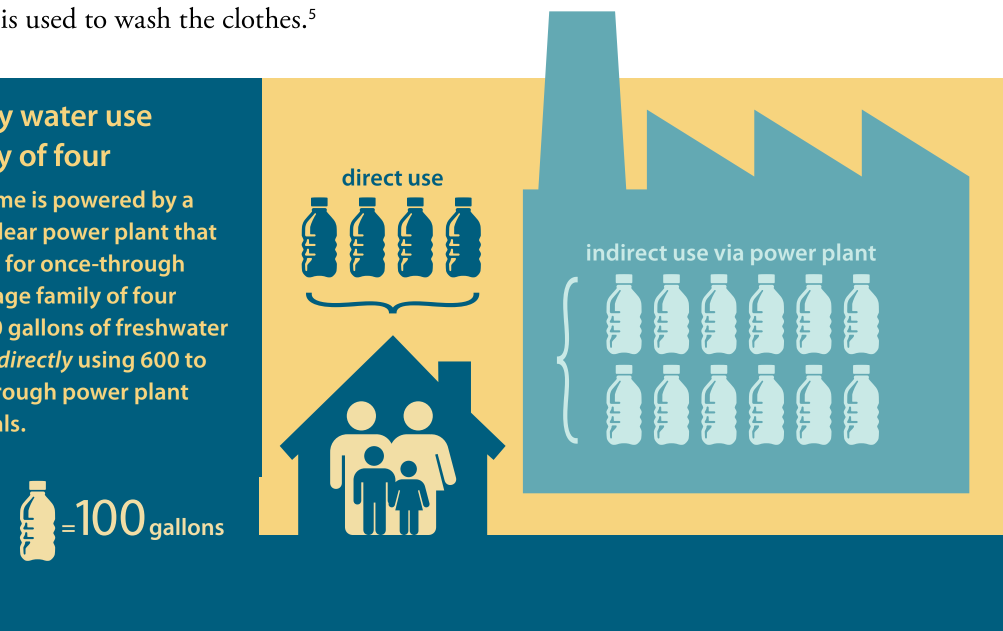
1 THIRSTY FOR POWER—Keeping U.S. power on each day requires more water than 140 New York Cities. The electric sector withdraws 143 billion gallons of freshwater per day.[2] More than half of the country's 104 nuclear power reactors use once-through cooling (see the text box on p. 4).[3] Each of these plants withdraws 25 to 60 gallons of water for each kilowatt-hour of electricity it generates.[4] Coal plants with similar cooling systems typically withdraw almost as much—20 to 50 gallons per kilowatt-hour—even without considering the water needed to mine coal or store coal waste from power plants (see the text box on p. 3). Those figures mean that for a nuclear or coal plant to generate the electricity for one load of hot-water laundry (using electric appliances), 3 to 10 times more water must be withdrawn at the plant than is used to wash the clothes.[5]

2 WITHDRAWAL SYMPTOMS—In the southeastern United States, power plants account for two-thirds of all withdrawals of freshwater. Nationally, the amount of freshwater withdrawn to cool power plants is roughly the same as that for crop irrigation.[6] In the Southeast, electricity's water withdrawals easily top agriculture's: power plants there withdraw an average of 40 billion gallons of freshwater every day, or 65 percent of the region's total.[7]

Some plants lose or "consume" large amounts of the withdrawn water to evaporation (see the text box on p. 2): a typical 600-megawatt coal-fired power plant consumes more than 2 billion gallons of water per year from nearby lakes, rivers, aquifers, or oceans.[8,9]

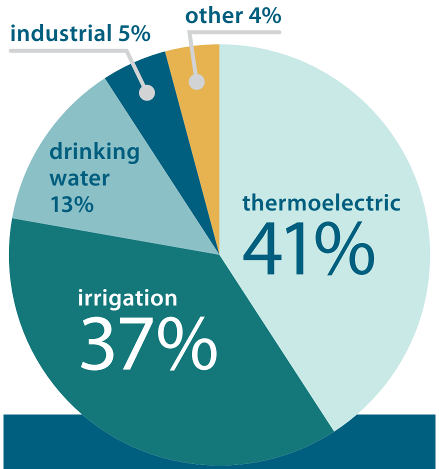
Average daily water use by U.S. family of four

Assuming its home is powered by a coal-fired or nuclear power plant that takes freshwater for once-through cooling, an average family of four directly uses 400 gallons of freshwater per day, while *indirectly* using 600 to 1,800 gallons through power plant water withdrawals.



3 IN HOT WATER—Water discharged from a coal or nuclear plant is hotter—by an average of 17°F in summer—than when it entered the plant.[10] Roughly one-third of all U.S. power plants use once-through cooling[11] and so return virtually all the water they withdraw. Still, these plants' significant water withdrawals can have a large impact on water quality, including temperature. Half of all coal plants report releasing water in the summer at peak temperatures of 100°F or more.[12] This thermal pollution can stress or kill fish and other wildlife. On Georgia's Chattahoochee River, for example, several thousand fish perished each summer until Georgia Power retrofitted its coal-fired plants with cooling towers in 2002.[13] Coastal power plants discharging warmed seawater can similarly harm local marine ecosystems.[14]

4 HIGH AND DRY—Water troubles can shut down power plants. Just since 2004, water stress has led at least a dozen power plants to temporarily reduce their power output or shut down entirely, and prompted at least eight states to deny new plant proposals.[15] During prolonged heat in the summer of 2010, for example, water temperatures in the Tennessee River hit 90°F, forcing the Browns Ferry nuclear plant to significantly cut the power output of all three of its reactors for nearly five consecutive weeks—all while cities in the region were experiencing high power demands for air conditioning.[16]



U.S. freshwater withdrawals

Power plants account for the largest share of freshwater withdrawals in the United States.

Understanding Power Plant Water Use

Water withdrawal: *The total amount of water taken from a surface- or ground-water source. In most cases, some fraction of that water will be returned to the water source and available for other withdrawals.*[18] Water withdrawal can become a large problem during drought and heat waves: water can be too warm, or levels too low, to cool the power plant, or the cooling water used by the plant can be made too warm to safely discharge.

Water consumption: *That part of withdrawn water that is not readily available for re-use because it is evaporated in power plants.* The amount of water consumed by power plants is a particular concern in water-constrained regions (including large parts of the western United States).

5 WHAT DOES CLEAN MEAN?—Clean energy can mean low carbon *and* low-water—or not. Increasing energy efficiency will allow us to meet our energy needs with less electricity—and thus with less water use at power plants. Shifting to certain renewable energy technologies, such as wind turbines and solar photovoltaic modules, means generating electricity with essentially no water at all. But water usage by other renewable energy options varies widely. Technologies that can be particularly water-intensive include concentrating solar power (CSP), bioenergy, geothermal, and hydroelectric. Some CSP plants use far less water per unit of energy than a typical coal or nuclear plant to cool steam; other CSP facilities use more.[17]

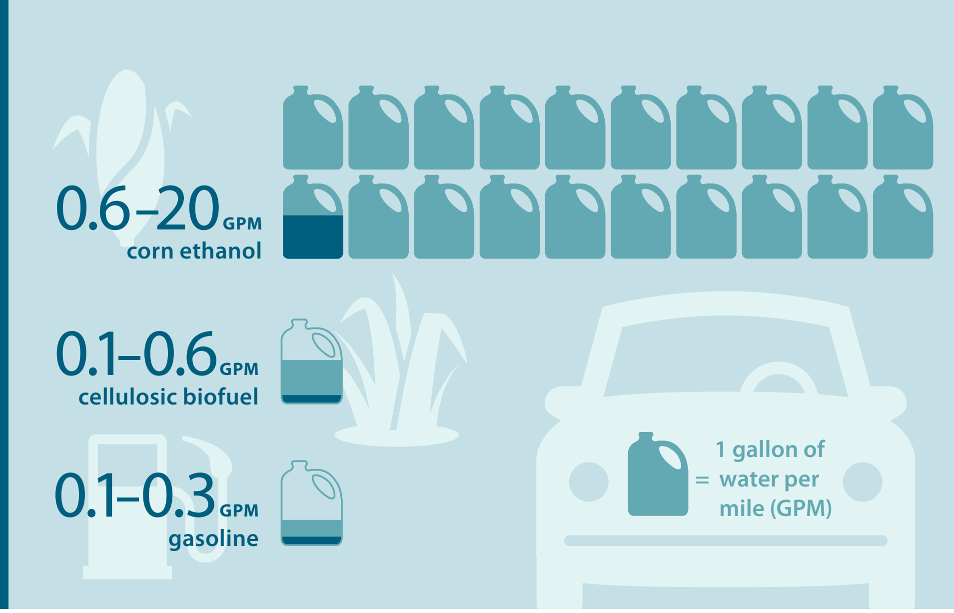
6 MPG OR GPM?—Powering your car with ethanol may use dozens of gallons of water per mile. The "water footprint" of conventional biofuels, such as corn ethanol, can be very large. Creating a single gallon of ethanol consumes, on average, about 100 gallons of freshwater. In some regions, however, ethanol production can take three or more times that amount—mostly depending on water needs for irrigation.[19] Water requirements for some other forms of biofuel are lower. Estimates indicate that it will require only 2 to 10 gallons of water to produce each gallon of "cellulosic" biofuel from drought-resistant grasses and waste wood.[20]

Nuclear Regulatory Commission

In 2007 and 2010, the Browns Ferry nuclear plant (Athens, AL) was forced to curtail power production of all three of its reactors. During these events, electricity needs were met by other power generators—though at higher prices. Such events illustrate the risks and costs that are "hard-wired" into today's electricity system: a lack of adequate water, or adequately cool water, can cripple power plants precisely when we most need electricity.

Water required to produce transportation fuels

Running a typical car (getting the equivalent of 24 miles per gallon of gasoline) on corn ethanol can require one-half to 20 gallons of water per mile—or more—depending on the water used for irrigation. "Cellulosic" biofuel would require less than one gallon of water per mile. Gasoline, while not a renewable resource, requires the least water: less than half a gallon for extracting and refining oil.



Unconventional fossil fuels—such as "liquid coal" or oil from tar sands or shale—can have serious water implications. A coal-to-liquids plant supplying 50,000 barrels of fuel per day would withdraw almost 5 billion gallons of water in a year[21]—a figure similar to the highest water use seen for gasoline—but does not account for the large volumes of water needed to mine and wash the coal before processing.

7 THE FLIP SIDE—California uses 19 percent of its electricity and 32 percent of its natural gas for water.[22] Just as energy production requires large amounts of water, the inverse is also true: substantial amounts of energy are used to pump, transport, treat, and heat the water we use every day. Nationwide, the EPA estimates, treating and distributing drinking water and wastewater together account for 3 percent of energy use. In some parts of the country, the energy toll is much higher. California's single biggest user of electricity is the State Water Project.[23] This system, serving 29 local water agencies, consumes enough to power more than 450,000 households[24]—or a city roughly the size of San Diego. Similarly, the Central Arizona Project, a 336-mile aqueduct delivering water to Phoenix and Tucson, is Arizona's largest electricity user.[25]

8 WATER UNREST—Water supply conflicts are growing across the United States. Particularly in the West, conflicts between competing water users—e.g., farmers, electric utilities, cities—are building. Such conflicts, many of which have an energy dimension, are expected to intensify, especially during periods of drought or other water stress.[26] Even without factoring in the exacerbating role of climate change, water supply conflicts involving several major Southwest cities—including Denver, Albuquerque, Las Vegas, and Salt Lake City—are considered highly likely by 2025.[27] Such tensions are not confined to arid regions. In the Southeast, for example, prolonged drought brought simmering disputes between Georgia, Tennessee, and other stakeholders over the rights to Tennessee River water to a boiling point in 2008.[28] By 2030, electric capacity is predicted to grow nearly 30 percent in the western United States and 10 percent in the Southeast,[29] a trend that would force the question: With what water?

9 CLIMATE COMPLICATIONS—As the climate changes, so does the water cycle. Increasing climate variability—extreme heat and extended drought, in particular—is already testing the resilience of energy and water systems in the Southwest and other regions. Further climate change will pose far-reaching challenges. The Northeast and Midwest can expect more spring flooding and extended summer drought.[30] In the Southeast, where both air and water temperatures are expected to rise,[31] instances where water is too warm to be used to cool power plants may become far more frequent. Other regions—notably the Southwest—can expect far less runoff and precipitation, especially in the warm months. Longer, more severe droughts will leave arid areas even drier.[32] With declining snowpack, for example, flows in the Colorado River are projected to decrease 20 percent below current averages by 2050.[33] The net effect nationally will be a more variable and unreliable water situation.[34]

Electricity and Water Pollution

Thermal pollution is not the only way thermoelectric power plants affect water. The arsenic, mercury, lead, and other toxic substances contained in the 120 million tons of coal plant waste produced every year can severely contaminate drinking water supplies.[35] Coal mining in the United States uses an estimated 80 million to 230 million gallons of water each day—the equivalent of 10 million to 20 million showers. The EPA estimates that strip mining of coal by mountaintop removal has buried almost 2,000 miles of Appalachian headwater streams—some of the most biologically diverse streams in the country.[36]

Natural gas-fired plants are less water-intensive than coal or nuclear plants. Still, extracting gas from shale deposits, such as those found in Texas, Pennsylvania, and New York, through a process known as hydraulic fracturing can potentially lower local water quality, as well as strain local water supplies.[37]

In the arid Southwest, population and water use have grown rapidly in the past couple of decades. This region may double its 2000 population by 2030, according to the U.S. Census Bureau, with potential accompanying increases in demand for water and electricity—and water for electricity. Complicating matters, changes in the region's climate are expected to lead to large drops in annual runoff and water availability by mid-century.

10 UNDOING THE ENERGY-WATER COLLISION— We have many tools at hand. A number of technologies offer strong opportunities to address the energy-water collision.

No-water energy: Using technologies such as wind and photovoltaics means doing away entirely with water use for electricity production.[38] Reducing the need for generating the electricity or transportation fuels in the first place—through more-efficient appliances, buildings, and vehicles, for example—not only saves money and reduces heat-trapping gases and other pollutants, but also eliminates the corresponding water use.

Low-water energy: Shifting old coal or nuclear plants using once-through cooling to more-water-efficient closed-loop cooling technologies would increase water *consumption*, potentially even doubling it, but would reduce water *withdrawals* by two orders of magnitude. Dry- and hybrid cooling options help address water consumption. Such technologies could be particularly important in water-constrained regions. Such cooling technologies would, however, reduce power plant efficiency and increase their costs—and, in the case of fossil-fuel-fired plants, do nothing to reduce emissions of heat-trapping gases.[39]

Several steps can be taken to reduce the water demand of some renewable energy options. CSP plants, for example, which are ideally sited in some of the country's sunniest—and driest—locations, are increasingly turning to dry cooling, despite the higher costs. For biofuels, minimizing reliance on irrigation and switching to low-water perennial crops—or even to waste from cities, farms, and forests—could make it possible to lower the water requirements of biofuel production and reduce heat-trapping emissions.

Given the many connections between energy and water, the choices we make in the near future about how we produce and use energy will determine not only the extent to which we mitigate the worst impacts of climate change, but also how resilient our energy system is to the variability of our water resources and the many competing demands for it. Smart choices now will mean lower risks, greater energy security, and strong environmental and economic benefits.

Power Plant Water Words

Thermoelectric: The conversion of thermal energy (heat) into electricity. Fossil fuel and nuclear power plants, as well as some forms of renewable electricity facilities, boil water to create steam that in turn spins electricity-generating turbines. These plants typically use water to cool the steam. In the United States, 90 percent of our electricity comes from thermoelectric power plants that require cooling.

Cooling technologies: The mechanisms used to cool steam in a power plant:

- **Once-through** systems withdraw water from nearby sources (e.g., rivers, lakes, underground aquifers, the ocean), circulate it through pipes to absorb heat from the steam, and discharge the warmer water back to the local source.[40]
- **Recirculating (closed-loop)** systems reuse cooling water rather than immediately releasing it back to the water source. Such systems withdraw comparatively small amounts of water but lose or "consume" most of it through evaporation.[41]
- **Dry-cooling** systems use air instead of water to cool the steam exiting a turbine. Dry-cooled systems can decrease total power plant water requirements by as much as 90 percent, though adding cost and decreasing efficiency.[42]
- **Hybrid cooling** systems use air for cooling most of the time, but can draw on water during particularly hot periods.

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This fact sheet, which draws from a growing body of research, is the first in our "Energy and Water Collision" series that explores the ways in which energy choices affect water resources in the United States, and how this will change in the face of global warming. To download a fully referenced version, visit the UCS website at *www.ucsusa.org/energy-water.*

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Endnotes

1 See, for example: United States Government Accountability Office (USGAO). 2009. Energy-water nexus: Improvements to federal water use data would increase understanding of trends in power plant water use; Department of Energy (DOE) and National Energy Technology Laboratory (NETL). 2009. Estimating freshwater needs to meet future thermoelectric generation requirements. NETL; Feeley, T.J., L.G. Lii, J.T. Murphy, J. Hoffmann, and B.A. Carney. 2005. Department of Energy/Office of Fossil Energy's Power Plant Water Management R&D Program summary. July.

2 Kenny, J.F., N.L. Barber, S.S. Hutson, K.S. Linsey, J.K. Lovelace, and M.A. Maupin. 2009. Estimated use of water in the United States in 2005: U.S. Geological Survey Circular 1344; NYC residents use approximately 1 billion gallons per day. New York City Department of Environmental Protection (NYCDEP). 2009. *History of drought and water consumption*. Online at *www.nyc.gov/html/dep/html/drinking_water/droughthist.shtml*, accessed on July 27, 2010.

3 Wheeler, B. 2010. *316(b) revisited: Examining the challenges facing nuclear power plants*. Online at *www.powergenworldwide.com/index/display/articledisplay/0858006563/articles/nuclear-power-international/volume-3/Issue_2/nucleus/316b_Revisited_Examining_the_challenges_facing_nuclear_power_plants.html*, accessed on July 27, 2010.

4 USGAO 2009.

5 Energy required to run a washer on hot/warm is the sum of the energy required to run the machine's motor (0.25 kilowatt-hour, or kWh) and the energy consumed by a water heater to heat 40 gallons of water from 10°C to 46°C (Maytag)—average of both hot and warm cycles. Using an electric water heater that operates at 90 percent efficiency, this would require about 7 kWh. A power plant using 20 gallons of water for each kilowatt-hour produced would require 145 gallons of water to produce 7.25 kWh, while a power plant using 60 gallons per kWh would require 435 gallons of water. Sources include: Environmental Protection Agency (EPA). 2010. *Indoor water use in the United States*. Online at *www.epa.gov/watersense/pubs/indoor.html*, accessed on July 30, 2010; EPA. 2009. *Life cycle cost estimate for 1 ENERGY STAR qualified residential clothes washer(s)*. Online at *www.energystar.gov/ia/business/bulk_purchasing/bpsavings_calc/CalculatorConsumerClothesWasher.xls*, accessed on July 30, 2010; Maytag. 2009. *Performance series front-loading automatic washer use & care guide*. Online at *www.maytag.com/assets/product/MHWE950WW_Use%20and%20Care_EN.pdf*, accessed on July 20, 2010; Multi-Housing Laundry Association. 2006. *Laundry room utility costs*. Online at *www.mla-online.com/workback.htm*, accessed on July 30, 2010.

6 Kenny et al. 2009.

7 Chandler, J., D. Creech, E. Metzger, S. Putt Del Pino, A. Tapia, and B. Taube. 2009. *Water and watts*. WRI Issue Briefs April:12; While the lower demand in the region for water for irrigating crops explains part of this figure (only 13 percent of the region's withdrawals go to agriculture), several Southeast states (Tennessee, North Carolina, and South Carolina) have the nation's highest *total* withdrawals for power plants. Kenny et al. 2009.

8 Based on 75 to 80 percent capacity factor, 541 gallons/megawatt-hour. Tellinghuisen, S., D. Berry, B. Miller, T. Hutchins-Cabibi, C. Benjamin, and N. Theerasatiankul. 2008. *A sustainable path: Meeting Nevada's energy and water demands*. Boulder, CO: Western Resource Advocates; Nationally, the total amount of freshwater consumed by power plants is equivalent to nearly half the amount consumed by households. Kenny et al. 2009.

9 Dealing with coal plants' carbon pollution problems can make them even thirstier. Carbon capture and storage (CCS) is a potential option for addressing coal-fired power plants' role as the country's single greatest source of heat-trapping emissions. However, this new technology would increase water consumption considerably; adding CCS to a new or existing coal plant is estimated to increase water consumption 35 to 95 percent or more compared with coal-fired power plants without CCS. This assumes wet-cooling technologies in each case. Woods, M.C., P.J. Capicotto, J.L. Haslbeck, N.J. Kuehn, M. Matuszewski, L.L. Pinkerton, M.D. Rutkowski, R.L. Schoff, and V. Vaysman. 2007. *Cost and performance baseline for fossil energy plants. Volume 1: Bituminous coal and natural gas to electricity. Final report*. NETL. See also Tellinghuisen et al. 2008.

10 Median summer peak temperature increases. NETL. 2007. NETL coal power plant database. Online at *www.netl.doe.gov/energy-analyses/hold/technology.html*, accessed on July 27, 2010.

11 DOE. 2006. *Energy demands on water resources: Report to Congress on the interdependency of energy and water*.

12 NETL 2007.

13 Schwarzen, C. 2000. Georgia power to build cooling tower to rectify fish kill problem. *Knight Ridder/Tribune Business News,* March 3.

14 In California, these environmental impacts have led to a new policy to phase out once-through cooling systems in all coastal power plants. The California State Water Board has established new technology-based standards to implement the federal Clean Water Act on existing coastal plants. California State Water Resources Control Board. 2010. *State water resources control board resolution No. 2010-2020*. Online at *www.swrcb.ca.gov/water_issues/programs/npdes/cwa316.shtml*, accessed on July 22, 2010.

15 Sovacool, B.K. 2009. Running on empty: The electricity-water nexus and the US electric utility sector. *Energy Law Journal* 30(11).

16 According to the Nuclear Regulatory Commission (NRC), between July 24 and August 27, 2010, the average power production of all three reactors at Browns Ferry was less than 60 percent of capacity. NRC. 2010. *Power reactor status reports for 2010*. Online at *www.nrc.gov/reading-rm/doc-collections/event-status/reactor-status/2010/index.html*, accessed on August 30, 2010.

17 Some concentrating solar technologies, such as dish/engine systems, do not involve water. See: USGAO 2009; DOE 2006; or Dennen, B., D. Larson, C. Lee, J. Lee, and S. Tellinghuisen. 2007. *California's energy-water nexus: water use in electricity generation*. University of California, Santa Barbara.

18 Kenny et al. 2009.

19 The 100 gallons of water per gallon of ethanol is the weighted average across the three largest corn-producing regions. Vehicle efficiency is adjusted based on energy content of a gallon of ethanol (67 percent that of gasoline), although in reality, vehicles use blends of ethanol and gasoline. The 20-gallons-per-mile figure is based on

water use in USDA Region 7 (North and South Dakota, Nebraska, and Kansas), where irrigation is used extensively. In other regions, such as Region 5 (Iowa, Indiana, Illinois, Ohio, and Missouri) where crops are primarily rain-fed, the average is 0.6 gallon per mile. Other studies have put the upper limit substantially higher (e.g., 50 gallons per mile for Nebraska). Sources include: Dominguez-Faus, R., S.E. Powers, J.G. Burken, and P.J. Alvarez. 2009. The water footprint of biofuels: A drink or drive issue? *Environmental Science & Technology* 43(9):3005–3010; Wu, M., M. Mintz, M. Wang, and S. Arora. 2009. *Consumptive water use in the production of ethanol and petroleum gasoline*. Argonne National Laboratory ANL/ESD/09-1. Online at *www.transportation.anl.gov/pdfs/AF/557.pdf*; King, C.W., and M.E. Webber. 2008. Water intensity of transportation. *Environmental Science & Technology* 42(21).

20 Wu et al. 2009.

21 DOE/NETL. 2006. *Emerging issues for fossil energy and water: Investigation of water issues related to coal mining, coal to liquids, oil shale, and carbon capture and sequestration*.

22 California Energy Commission. 2005. *California's water energy relationship*. Final staff report prepared in support of the 2005 IEPR proceeding, CEC-700-2005-011-SF. Sacramento, CA.

23 Webber, M.E. 2008. Energy versus water: solving both crises together. *Scientific American* 18(4).

24 The California State Water Project consumes 5.1 billion kWh. California State Water Project. 2010. *California state water project today*. Online at *www.water.ca.gov/swp/swptoday.cfm*, accessed on July 22, 1010.

25 Modeer, D.V. 2010. Confronting the intersection of water, energy, and air quality at the Central Arizona Project. *Journal of the American Water Works Association*.

26 Bureau of Reclamation. 2003. *Water 2025: Preventing crises and conflict in the West*.

27 The probability of conflicts is based on a combination of factors including population growth and the water requirements of endangered species. Multiple locations throughout the Southwest were considered "substantially likely" or "highly likely" to experience water conflict by 2025, without factoring in the highly relevant projected effects of climate change. Bureau of Reclamation 2003; Karl, T. R., J.M. Melillo, and T.C. Peterson. 2009. *Global climate change impacts in the United States*. U.S. Global Change Research Program (USGCRP).

28 USGCRP 2009; Webber 2008; and Ruhl, J.B. 2005. Water wars, eastern style: Divvying up the Apalachicola-Chattahoochee-Flint River Basin. *Journal of Contemporary Water Research & Education* 131:47–54.

29 Energy Information Administration (EIA). 2010. *Annual energy outlook 2010*. DOE/EIA-0383(2010). Washington, DC: DOE.

30 USGCRP 2009.

31 USGCRP 2009.

32 USGCRP 2009.

33 Overpeck, J., and B. Udall. 2010. Dry times ahead. *Science* 328(5986).

34 Milly, P.C.D., J. Betancourt, M. Falkenmark, R.M. Hirsch, Z.W. Kundzewicz, D.P. Lettenmaier, and R.J. Stouffer. 2008. Stationarity is dead: Whither water management? *Science* 319(5863): 573–574.

35 When the coal ash waste dike associated with the Tennessee Valley Authority's 1,500-megawatt (MW) Kingston Fossil Plant in Tennessee gave way on December 22, 2008, for example, it dumped an estimated 1.1 billion gallons of coal ash mixed with water into the Emory River. EPA. 2009. *Summary of past and current EPA response activities regarding the TVA Kingston coal ash spill*. Online at *www.epa.gov/region4/kingston/summary.html*, accessed on August 2, 2010.

36 EPA. 2010. EPA issues comprehensive guidance to protect Appalachian communities from harmful environmental impacts of mountain top mining. Press release, April 1. Online at *www.epa.gov/wetlands/guidance/pdf/appalachian_mtntop_mining_press_release.pdf*, accessed on July 27, 2010.

37 The EPA is currently studying the water impacts; however, water quality impacts of shale gas production to date are not well documented. The agency notes that along with the expansion of hydraulic fracturing, there have been "increasing concerns about its potential impacts on drinking water resources, public health, and environmental impacts in the vicinity of these facilities." It "agrees with Congress that there are serious concerns from citizens and their representatives about hydraulic fracturing's potential impact on drinking water, human health and the environment, which demands further study." EPA. 2010. *Hydraulic fracturing*. Online at *www.epa.gov/ogwdw000/uic/wells_hydrofrac.html*, accessed on July 27, 2010. The importance of water quantity as an issue depends on the yield of the well post-fracturing. For estimates of water quantity, see, for example: King and Webber 2008. Ground Water Protection Council and ALL Consulting note that, "some challenges exist with water availability and water management," but suggest the challenges are manageable. Ground Water Protection Council and ALL Consulting. 2009. *Modern shale gas development in the United States: A primer*. Washington DC: U.S. Department of Energy. April.

38 For more detailed treatments of options and implications, see: USGAO 2009, King and Webber 2008, and DOE 2006.

39 And indeed, given efficiency losses, may increase emissions.

40 Once-though systems have historically been the most popular because of their relative simplicity, low cost, and ease of siting power plants in places with abundant supplies of cooling water. Once-through cooling is now rarely implemented due to disruptions to local ecosystems and heightened difficulty in siting power plants near available water sources.

41 Most commonly, wet-recirculating systems use cooling towers to expose water to ambient air, and allow evaporation as the water cools back to an appropriate temperature. The water is then recirculated back to the condenser in the power plant. Because wet-recirculating systems only require water withdrawals to replace any water lost in the cooling tower, these systems have much lower water withdrawals than once-through systems.

42 Though no water is required for dry-cooling systems, power plants using dry-cooling systems also require water for system maintenance and cleaning. In power plants, lower efficiencies mean more fuel is needed per unit of electricity, and this in turn leads to higher greenhouse gas emissions. In 2000, 92 percent of all U.S. dry-cooling installations were in smaller power plants and most commonly in natural-gas-combined-cycle power plants. Small power plants are defined as having an electric generating capacity less than 300 MW. Dougherty, B., T. Page, and S. Bernow. 2000. *Comments on the EPA's proposed regulations on cooling water intake structures for new facilities*. Boston, MA: Tellus Institute.