DEVELOPING ADAPTIVE AND INTEGRATED STRATEGIES FOR MANAGING THE ELECTRICITY-WATER NEXUS

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INTRODUCTION

Existing and planned reliance on thermoelectric power plants—facilities that burn oil, natural gas, coal, and biomass, or fission atoms—depends too heavily on assumptions of widespread, abundant water resources. As the Union of Concerned Scientists has estimated, power plants in the United States take in almost *triple* the average amount of water flowing over Niagara Falls each minute to meet their cooling needs.[1] Or, put another way, on a typical day more than 500 *billion* liters of fresh water travel through power plants in the United States—more than twice the amount flowing through the entire Nile River.[2] Yet water is a critical constraint often overlooked in electricity and energy decisions. When considered, it challenges us to think more broadly about integrated resource planning, reliability challenges, and resource selection.

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[1] KRISTEN AVERYT ET AL., UNION OF CONCERNED SCIENTISTS, FRESHWATER USE BY U.S. POWER PLANTS: ELECTRICITY'S THIRST FOR A PRECIOUS RESOURCE 1 (2011) [hereinafter FRESHWATER USE], *available at* http://www.synapse-energy.com/Downloads/SynapseReport.2011-11.UCS.Freshwater-Use-by-US-Power-Plants.10-028.pdf.

[2] *The Coming Clash Between Water and Energy*, IEEE SPECTRUM (May 28, 2010, 12:25 PM), http://spectrum.ieee.org/energy/environment/the-coming-clash-between-water-and-energy.

The relationship between electricity generation and water is complex. Multiple sources of electricity, such as hydroelectric dams and thermoelectric power plants, consume and withdraw water in many ways, and water flows are often tightly coupled to energy flows. The U.S. Geological Survey reports that thermoelectric power plants—including coal, nuclear, and natural gas power plants—withdraw more fresh water than any other economic sector and they are the fastest growing users of fresh water resources in the country.[3] The U.S. Geological Survey further reports that 53% of all of the fresh, surface water withdrawn from the environment for human use in 2005 went to operating our water-reliant electricity industry; these numbers are conservative as they exclude water involved in hydroelectricity generation.[4] Worryingly, water use for thermoelectric power plants increased nearly five-fold from forty billion gallons per day in 1950 to 195 billion gallons per day in 2000.[5]

Why does electricity production use so much water? Electricity generation utilizes and affects water resources at multiple points of its fuel cycle, including upstream at coal mines and gas wells, onsite, and downstream through pollution. The most water-intensive of these phases is onsite—during the generation process—which is the focus of this article. Table 1 illustrates that coal-fired power plants, which account for about 40% of the electricity generated in the United States and even more in China, require between twenty-seven and forty gallons of water to produce one kilowatt hour ("kWh") of electricity. The actual water

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[3] JOAN F. KENNY ET AL., U.S. GEOLOGICAL SURVEY, ESTIMATED USE OF WATER IN THE UNITED STATES IN 2005, at 4, 7 tbl.2A (2009) [hereinafter 2005 U.S. GEOLOGICAL SURVEY], *available at* http://pubs.usgs.gov/circ/1344/pdf/c1344.pdf. The U.S. Geological Survey report for water usage through 2005 provides data for eight use categories: public supply, domestic, irrigation, livestock, aquaculture, industrial, mining, and thermoelectric power generation. *Id.* at 4; *see also* WENDY WILSON ET AL., RIVER NETWORK, BURNING OUR RIVERS: THE WATER FOOTPRINT OF ELECTRICITY 5 (2012), *available at* http://climateandcapitalism.com/wp-content/uploads/sites/2/2012/06/Burning-Our-Water.pdf.
The magnitude of the use from the power sector is relevant to power sector demands for several reasons. In part, it serves to underscore the dependence of the electricity sector on water resources. This has important implications for the vulnerability of the electricity system to either competing demands or constraining weather patterns. But because 90% of the water withdrawal is returned, the consequential impact on the residual resource on other human or environmental uses should be less than that of agricultural demands, for example, in which little is returned to surface water lakes and streams.

[4] 2005 U.S. GEOLOGICAL SURVEY, *supra* note 3, at 38.

[5] SUSAN S. HUTSON ET AL., U.S. GEOLOGICAL SURVEY, ESTIMATED USE OF WATER IN THE UNITED STATES IN 2000, at 40 tbl.14 (2004), *available at* http://pubs.usgs.gov/circ/2004/circ1268/pdf/circular1268.pdf.

consumption per kWh depends on the type of power plant and the fuel used. As coal-fired power stations generate 1957 billion kWh annually in the United States, they use about fifty-eight trillion gallons of water.[6] A conventional 500 megawatt ("MW") coal plant consumes about 7000 gallons of water per minute, the equivalent of seventeen Olympic-sized swimming pools every day.[7] The coal-fired 1800 MW San Juan Generating Station, operated by the Public Service Company of New Mexico, uses 7.3 billion gallons of water per year from the San Juan River.[8]

	Withdrawals	**Consumption**	**Withdrawals**	**Consumption**	**Total**
	(Combustion/Downstream)		(Production/Upstream)		
Nuclear	43	0.4	0	0.11	43.5
Coal (mining)	35	0.3	0.17	0.045	35.5
Coal (slurry)	35	0.3	0	0.05	35.3
Biomass/Waste	35	0.3	0.03	0.03	35.3
Natural Gas	13.75	0.1	0	0.01	13.9
Solar Thermal	4.5	4.6	0	0	9.1
Hydroelectric	0	0	0	4.5	4.5
Geothermal (steam)	2	1.4	0	0	3.4
Solar PV	0	0	0	0.3	0.3
Wind	0	0	0	0.2	0.2
Energy Efficiency	0	0	0	0	0

Source: Benjamin K. Sovacool & Kelly E. Sovacool, *Identifying Future Electricity Water Tradeoffs in the United States*, 37 ENERGY POL'Y 2763, 2763–73 (2009).

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[6] Benjamin K. Sovacool & Kelly E. Sovacool, *Identifying Future Electricity-Water Tradeoffs in the United States*, 37 ENERGY POL'Y 2763, 2764 (2009).

[7] Thomas J. Feeley, III, Director, Office of Pub. Affairs & Strategic Outreach, Nat'l Energy Tech. Lab., Presentation at the 28th International Technical Conference on Coal Utilization & Fuel Systems: Tutorial on Electric Utility Water Issues (Mar. 2003) (PowerPoint available at http://www.seca.doe.gov/technologies/coalpower/ewr/pubs/Clearwater031003.pdf).

[8] MICHAEL N. DIFILIPPO & KENT ZAMMIT, ELEC. POWER RESEARCH INST., USE OF PRODUCED WATER IN RECIRCULATING COOLING SYSTEMS AT POWER GENERATING FACILITIES: DELIVERABLE NUMBER 6, COST/BENEFIT ANALYSIS, at ES-1, vii (2004), *available at* http://www.netl.doe.gov/File%20Library/Research/Coal/ewr/water/41906CostBenefitAnalysis.pdf.

Table 1 also illustrates that nuclear reactors, in particular, require massive supplies of water to cool reactor cores and spent nuclear fuel rods. Much of the water is turned to steam, meaning substantial amounts are lost from the local water cycle entirely. For example:

> Southern Company's Joseph M. Farley nuclear plant in Dothan, Alabama, consumes about 46 million gallons of water per day (primarily as evaporative loss). In the arid West . . . the challenge of cooling nuclear plants is even more daunting. The Palo Verde plant in Arizona is capable of processing 90 million gallons of water for its cooling needs at the plant site each day. Plant operators must purchase treated effluent from seven cities in the Phoenix metropolitan area and had to construct a 35-mile pipeline to carry water from a treatment facility to the plant, which received 22.5 billion gallons of treated effluent in 2000.[9]

Outside of the United States, thermoelectric power plants are just as thirsty. In India, the average thermal power plant consumes over 1800 gallons of water per MWh, meaning a plant drains the equivalent amount of an Olympic-size swimming pool every twenty to thirty minutes.[10] In China, thermal power plants collectively pump more than thirty-four million gallons of water, fuel oil, and slurries *per minute*—the predominant use of this capacity being for water.[11] In France, the 3000 megawatt electrical ("Mwe") Civaux Nuclear Power Plant stores at least twenty *billion* liters of water upstream in reservoirs to ensure adequate supply during droughts.[12]

Considering these massive water needs, what can be done to minimize the water intensity of this sector, especially in the face of increasing electricity demand, drought, climate change, and changing patterns of precipitation? To provide an answer, this article begins by briefly describing cooling cycles in Part I and presents technological and policy options in Part II.

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[9] BENJAMIN K. SOVACOOL, CONTESTING THE FUTURE OF NUCLEAR POWER: A CRITICAL GLOBAL ASSESSMENT OF ATOMIC ENERGY 149 (2011) (footnotes omitted).

[10] GRACE BOYLE ET AL., GREENPEACE INDIA SOCIETY, ENDANGERED WATERS: IMPACTS OF COAL-FIRED POWER PLANTS ON WATER SUPPLY 5 (2012), *available at* http://www.greenpeace.org/India/Global/India/report/Endangered-waters.pdf.

[11] *McIlvaine: Chinese Will Buy Power Plant Pumps to Move 34 Million Gallons per Minute This Year*, WATERWORLD (Sept. 1, 2009), http://www.waterworld.com/articles/2009/09/mcilvaine--chinese.html.

[12] *Cooling Power Plants*, WORLD NUCLEAR ASS'N, http://www.world-nuclear.org/info/cooling_power_plants_inf121.html (last updated Sept. 2013).

I. THERMOELECTRIC COOLING CYCLES AND THEIR WATER IMPLICATIONS

Thermoelectric generation creates electricity by heating water until it becomes steam and using that steam to turn a turbine. After passing through a turbine, steam must be cooled, or condensed, back into water before it can be used again.[13] Although there are cooling systems that do not utilize water, all thermoelectric power plants require at least some water for system maintenance and cleaning. Nevertheless, cooling systems are the most water-intensive part of the thermoelectric generation process, presenting significant opportunities to reduce water withdrawals and consumptive use. Conventional thermoelectric power plants usually employ one of four types of cooling cycles when generating electricity.[14] Once-through cooling systems withdraw water from a source, circulate it through the plant, and return it to the surface body.[15] Re-circulating, or closed-loop and "wet tower" systems, withdraw water and then recycle it within the power system rather than discharge it.[16] "Dry" cooling systems, useful in arid areas, rely on air, rather than water, as the primary coolant medium.[17] "Hybrid" systems incorporate elements of both wet and dry cooling.[18] While once-through and re-circulating systems are the predominant cooling technologies, dry and hybrid systems constitute a distinct and growing niche.

As their name implies, once-through cooling systems only use water once; water passes through a condenser to absorb heat and it is returned at a higher temperature to a nearby water body. A portion of water withdrawals are consumed, or lost, by evaporation through steam. Plant operators often "treat" water by adding chlorine intermittently to control microbes that corrode pipes and materials.[19] Operators may also add several toxic and carcinogen-

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[13] *How It Works: Water for Power Plant Cooling*, UNION OF CONCERNED SCIENTISTS, http://www.ucsusa.org/clean_energy/our-energy-choices/energy-and-water-use/water-energy-electricity-cooling-power-plant.html (last updated July 15, 2013).

[14] *See* ELLEN BAUM, CLEAN AIR TASK FORCE, WOUNDED WATERS: THE HIDDEN SIDE OF POWER PLANT POLLUTION 2–3, 14 (2004), *available at* http://www.catf.us/publications/files/Wounded_Waters.pdf.

[15] *Id.* at 2.

[16] *Id.* at 3.

[17] *Id.*

[18] *Id.* at 14.

[19] *Id.* at 2.

ic chemicals, such as hexavalent chromium and hydrazine.[20] After passing through the plant, heated and treated water is discharged downstream from the point of intake into a receiving body of water. Since such cooling systems release heated water back to the source, further evaporative loss can occur as the temperature of receiving water bodies is increased.[21] Once-through cooling systems are more common in the eastern United States.[22] Once-through systems withdraw about 92% of the nation's water used for power plants,[23] and fifty-nine of the country's 103 nuclear reactors rely on this type of cooling, each drawing as much as one billion gallons of water into its cooling system per day (or more than 500,000 gallons per minute).[24]

Re-circulating, "wet tower," or closed-loop systems, withdraw much less water due to recycling but tend to consume more.[25] The recycling process requires more chemical treatment to eliminate naturally occurring salts and solids that accumulate as water evaporates.[26] To maintain plant performance, water is frequently discharged from the system at regular intervals into a reservoir or collection pond.[27] Plant operators call this water cooling-tower "blowdown."[28] Once the plants release this blowdown water, operators take in and treat fresh water with chlorine and biocides before it enters the cooling cycle.[29] Closed-loop systems rely on greater amounts of water for cleaning and therefore return less water to the original source.[30] Closed-loop systems are more common in the western United States.[31]

"Dry" cooling systems use air flowing through a cooling tower to condense steam, meaning they have relatively low water re-

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[20] *See id.* at 12 n.78.

[21] *See id.* at 2.

[22] *How It Works: Water for Power Plant Cooling*, *supra* note 13.

[23] 2005 U.S. GEOLOGICAL SURVEY, *supra* note 3, at 38.

[24] LINDA GUNTER ET AL., LICENSED TO KILL: HOW THE NUCLEAR POWER INDUSTRY DESTROYS ENDANGERED MARINE WILDLIFE AND OCEAN HABITAT TO SAVE MONEY 1 (2001).

[25] BAUM, *supra* note 14, at 3.

[26] *Id.*

[27] *Id.*

[28] *Id.*

[29] *Id.*

[30] *See id.* at 5.

[31] CLEAN AIR TASK FORCE & THE LAND AND WATER FUND OF THE ROCKIES, THE LAST STRAW: WATER USE BY POWER PLANTS IN THE ARID WEST 4 (2003) [hereinafter THE LAST STRAW], *available at* http://www.catf.us/publications/files/The_Last_Straw.pdf.

quirements. Rather, these systems require large facilities to provide sufficient air contact to cool the water used during the generation process. Dry cooling systems cost three to four *times* more than wet cooling systems.[32] As air is a less effective cooling medium than water, dry cooling can reduce average power generation by 3% to 9%.[33] This is especially problematic as it can limit power plant output when power demand is at its highest due to air conditioning electricity needs and peak summer demand. To mitigate this challenge, dry cooling systems are sometimes installed in conjunction with wet tower cooling to create "hybrid" systems that can use wet cooling during high temperatures and dry cooling during low temperatures.[34] While providing plant operators with greater operational flexibility, such systems require installation of both dry and wet cooling equipment.

The most water intensive energy source by far is nuclear power. Nuclear plants "need water to remove the decay heat produced by the reactor core and also to cool equipment and buildings used to provide the core's heat removal."[35] Service water must lubricate oil coolers for the main turbine and chillers for air conditioning—in essence cooling the equipment that in turn cools the reactor.[36] Even when plants are not producing electricity, service water needs can be quite high: 52,000 gallons of water are needed per

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[32] KRISTIN GERDES & CHRISTOPHER NICHOLS, NAT'L ENERGY TECH. LAB., DOE/NETL-402/080108, WATER REQUIREMENTS FOR EXISTING AND EMERGING THERMOELECTRIC PLANT TECHNOLOGIES 5 (rev. ed. 2009), *available at* http://www.netl.doe.gov/energy-analyses/pubs/WaterRequirements. pdf.

[33] JOHN S. MAULBETSCH ET AL., CAL. ENERGY COMM'N, COST AND VALUE OF WATER USE AT COMBINED-CYCLE POWER PLANTS 12 (2006), *available at* http://www.energy.ca.gov/2006publications/CEC-500-2006-034/CEC-500-2006-034.PDF; *see* C.S. TURCHI ET AL., NAT'L RENEWABLE ENERGY LAB., WATER USE IN PARABOLIC TROUGH POWER PLANTS: SUMMARY RESULTS FROM WORLEYPARSONS' ANALYSES 6 (2010), *available at* http://www.nrel.gov/docs/fy11osti/49468.pdf ("On hot summer afternoons dry cooling performance is at its least efficient."); *see also* B. KELLY, NAT'L RENEWABLE ENERGY LAB., NEXANT PARABOLIC TROUGH SOLAR POWER PLANT SYSTEMS ANALYSIS 14 (2006), *available at* http://www.nrel.gov/docs/fy06osti/40163.pdf (noting that turbine output is likely to decline on hot days in plants whose location is in a relatively dry area).

[34] TURCHI ET AL., *supra* note 33, at 6; *see* Jim Witkin, *In a Hot, Thirsty Energy Business, Water Is Prized*, N.Y. TIMES, Oct. 8, 2013, at F5 (noting the increasing prevalence of hybrid cooling systems and quoting Mike Hightower, leader of the Water for Energy project at the Energy Department's Sandia National Laboratories that plants can "switch between [wet and dry cooling methods] depending on the local weather conditions or water availability issues") (internal quotation marks omitted).

[35] UNION OF CONCERNED SCIENTISTS, ISSUE BRIEF: GOT WATER? 1 (2007), *available at* http://www.ucsusa.org/assets/documents/nuclear_power/20071204-ucs-brief-got-water.pdf.

[36] *Id.* at 8.

minute in the summer at the Hope Creek plant in New Jersey; 30,000 gallons per minute for the Millstone Unit 3 in Connecticut; and 13,500 gallons per minute for the Pilgrim plant in Massachusetts.[37] Electricity grids that rely heavily on nuclear power are particularly vulnerable to water shortages and droughts. In 2003, a major drought led to France losing between 7% and 15% of its nuclear electricity supply for five weeks, leading to large-scale load shedding and a cessation of electricity exports to Italy.[38] The cause of the load loss was twofold: first, there was not enough water to support the cooling process and, second, discharged water temperature exceeded environmental regulations.[39] Droughts in 2006 and 2009 caused similar problems; exacerbated by ongoing repairs and a worker's strike, up to twenty gigawatts ("GW") of nuclear generation was offline during parts of 2009.[40] While the major affected power plants in France were nuclear, this example demonstrates the vulnerability of thermoelectric generation to water shortages.

II. BUILDING ADAPTIVE CAPACITY AND RESILIENCE TO ADDRESS THE ELECTRICITY-WATER NEXUS

Despite the seriousness of the world's electricity-water challenges, local regulators, electric utilities, national planners, and even investors are well positioned to respond to such risks.[41] While there are many technologies and mechanisms available, this section argues that a combination of six would be most effective at avoiding future water shortages related to the electricity sector: (1) improving data collection and monitoring, (2) decreasing the water intensity of thermoelectric generation through technology, (3) placing a moratorium on new thermoelectric pow-

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[37] *Id.*

[38] Mike Hightower, Presentation at the EPRI Workshop: Energy and Water (July 8, 2008) (PowerPoint slides available at http://mydocs.epri.com/docs/AdvancedCooling/PresentationsDay1/2_EPRI%20EWN%20Presentation%20MMH%207-08%20Hightower.pdf).

[39] UNITED NATIONS ENVIRONMENTAL PROGRAMME, IMPACTS OF SUMMER 2003 HEAT WAVE IN EUROPE (2004), *available at* http://www.grid.unep.ch/products/3_Reports/ew_heat_wave.en.pdf.

[40] Robin Pagnamenta, *France Imports UK Electricity as Plants Shut*, TIMES (London), July 3, 2009, at 46, *available at* http://www.thetimes.co.uk/tto/business/industries/utilities/article2198065.ece.

[41] Benjamin K. Sovacool, *The Best of Both Worlds: Environmental Federalism and the Need for Federal Action on Renewable Energy and Climate Change*, 27 STAN. ENVTL. L.J. 397, 429–41 (2008) (arguing in favor of a "decentralized" mode of environmental policymaking).

er generation, (4) strongly promoting energy efficiency and demand-side management, (5) rapidly deploying wind turbines and solar photovoltaic panels, and (6) changing electricity prices so that electricity customers receive more feedback and information.

A. *Improve Data Collection and Coordination*

Even though water needs place a major constraint on thermoelectric generation, the quality and availability of data regarding water consumption is insufficient. Energy policy and data gathering in the United States do not account for the role of water in electricity production. While the Energy Policy Act of 2005 mentions the importance of water and energy, it does not provide any funding for research and development and only recommends that the U.S. Department of Energy ("DOE") release a report on the matter.[42] The U.S. Energy Information Administration ("EIA"), the main source of United States government data on energy and electricity, used to compile a national database of thermoelectric plants and water use based on "Form EIA-767." However, in 2005, budgetary constraints led to the termination of the process.[43] The replacement process, "Form EIA-860," only collects incomplete data on water use and has led to decreased data quality. Under the new system, many power plants do not provide information on their water consumption and source, or, if they do, provide vague information.

An analysis by the Union of Concerned Scientists looks at more than a decade's worth of water data related to United States electricity generation and identified "a number of gaps and apparent inaccuracies in federal data."[44] They concluded that "collisions and near-misses between energy and water needs" require more "accurate, up-to-date information" on water use at power plants.[45] The National Renewable Energy Laboratory similarly determined that federal agencies currently collect data that is inconsistent and incomplete.[46] Power plants that did not report their water use

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[42] *See* Energy Policy Act of 2005, 42 U.S.C. § 16319 (2006).

[43] *See* Letter from Arthur N. Marin, Exec. Dir., North East States for Coordinated Air Use Mgmt., to Jorge Luna-Camara, Energy Info. Admin. (May 30, 2007), *available at* http://www.nescaum.org/documents/nescaum-comments_eia-forms-2007-may30-final.pdf/.

[44] AVERYT ET AL., *supra* note 1, at 3 (emphasis omitted).

[45] *Id.*

[46] JORDAN MACKNICK ET AL., NAT'L RENEWABLE ENERGY LAB., A REVIEW OF

to EIA accounted for up to 30% of national withdrawals and up to 31% of consumption in the electricity sector for fresh water.[47] Importantly, the Union of Concerned Scientists noted that gaps in 2008 information included all nuclear power plants.[48] While some information and water consumption for electricity is simply missing, collected information has the problem of often containing discrepancies that undermine its usefulness.[49]

In other words, planners and regulators could measure water use by thermal plants, but are choosing not to, crippling the ability to prepare for drought and other disruptions. Understanding the source of water used at a power plant is critical for assessing both its vulnerability to drought as well as the long term viability of its water source. For example, in 2000, Arizona predominantly used groundwater for cooling, Nevada used an even mix of ground water and surface water, and Colorado used 90% surface water.[50] Using groundwater can reduce short term vulnerability to droughts compared to surface water because the water supply may not be impacted. However, heavy use could deplete groundwater resources over time, using up all of a power plant's cooling resource. Notably, the previous statistics on groundwater sources came from the terminated EIA Form 767; more recent statistics on water sources are difficult or impossible to identify. Understanding the water consumption patterns at power plants is particularly important when trying to plan for climate change. Precipitation patterns and water availability are projected to change significantly.[51] Comprehensive data on power plant water withdrawals and consumption could therefore assist adaptation measures and planning.

OPERATIONAL WATER CONSUMPTION AND WITHDRAWAL FACTORS FOR ELECTRICITY GENERATING TECHNOLOGIES 5 (2011), *available at* http://www.nrel.gov/docs/fy11osti/50900.pdf.

[47] AVERYT ET AL., *supra* note 1, at 3.

[48] *Id.*

[49] *Id.* at 4.

[50] THE LAST STRAW, *supra* note 31, at 2.

[51] THOMAS R. KARL ET AL., GLOBAL CLIMATE CHANGE IMPACTS IN THE UNITED STATES 41 (2009), *available at* http://downloads.globalchange.gov/usimpacts/pdfs/climate-impacts-report.pdf.

B. *Reducing Water Intensity Through Technology*

New technologies can reduce thermal plant water vulnerabilities by lessening water needs per kWh. There are several types of technological solutions, each with their sets of strengths and weaknesses: alternative cooling systems, untraditional sources of water, power plant water production, and increased water efficiency through plant design. Alternative cooling systems reduce water use by adapting cooling systems to local water constraints. Untraditional water sources include municipal waste water, treated coal mine drainage, and water recycled from plant processes. Power plants can produce water by capturing water in flue gas, desalinating seawater using waste thermal heat, and transforming water intensive procedures to dry processes. Improved plant design reduces water use by increasing overall plant efficiency.

Alternative technologies face unique constraints. There is no silver bullet solution; technology effectiveness will vary depending on local geographies, plant economies, and technology maturity. Innovative plant designs are already combining several of these solutions and demonstrating their practical applications. In China, Huaneng Xinjiang Energy Development Company is building a plant that uses supercritical coal-fired units, dry desulphurization technology, dry-cooling, reuse of water from an urban sewage process plant, and rainwater collection.[52] Together these technologies are expected to reduce water consumption to one-third of a conventional coal power plant.[53]

1. Alternative Cooling Systems

Most water used by thermal electric plants is used to cool water heated by the combustion process. As mentioned in Part I, the dominant technology, once-through cooling, simply runs water once through the cooling system. While effective, this system leads to high levels of water withdrawal. Alternative cooling systems, such as wet recirculating cooling, dry-cooling, and hybrid

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[52] NAT'L ENERGY TECH. LAB., REDUCING FRESHWATER CONSUMPTION AT COAL-FIRED POWER PLANTS: APPROACHES USED OUTSIDE THE UNITED STATES 62 (2011) [hereinafter REDUCING FRESHWATER CONSUMPTION], *available at* http://www.netl.doe.gov/technologies/coalpower/ewr/water/pdfs/Outside_US_Approaches%20NETL%201493.pdf.

[53] *Id.*

cooling, reduce fresh water use, provide social and environmental benefits, and increase siting opportunities. However, alternative cooling systems are less efficient and more costly than once-through cooling. As with many energy projects, the best time to implement a new technology is during construction; retrofitting power plants with new cooling systems can pose major challenges. Retrofits can be expensive, cause premature plant retirement, hinder system reliability, and negatively impact water treatment and distribution.[54]

Wet recirculating systems reuse cooling water multiple times, unlike once-through cooling. The most common system uses cooling towers to evaporate water from cooling water into the atmosphere.[55] Wet recirculating systems withdraw significantly less water than once-through cooling systems but have higher water consumption due to evaporation in the cooling towers. This system has lower plant efficiency and higher capital costs than once-through cooling. Wet recirculating cooling systems are already a mature technology as of 2008; 41.9% of the United States' thermoelectric generating capacity uses wet circulating systems with cooling towers, while 14.5% use it with cooling ponds.[56] Wet circulating systems are also beneficial because they reduce the size and temperature of the thermal plume from discharged plant water.[57]

Dry-cooling systems replace evaporative cooling towers in closed-loop systems with cooling towers that use air circulation to cool water.[58] Direct-acting dry-cooling, the most common dry-cooling technique in the United States, works like an automobile radiator with the steam in the tube cooled by air blown over the

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[54] WILLIAM MILLS ET AL., VIABILITY AND IMPACTS OF IMPLEMENTING VARIOUS POWER PLANT COOLING TECHNOLOGIES IN TEXAS 4-3 (2012), *available at* http://twri.tamu.edu/media/370735/goes%20with%20water%20value%20in%20power%20generation1_final%20report.pdf.

[55] U.S. GOV'T ACCOUNTABILITY OFFICE, GAO-10-23, ENERGY-WATER NEXUS: IMPROVEMENTS TO FEDERAL WATER USE DATA WOULD INCREASE UNDERSTANDING OF TRENDS IN POWER PLANT WATER USE 9 (2009) [hereinafter ENERGY-WATER NEXUS].

[56] *Id.* at 14.

[57] TIM HAVEY, TETRA TECH, INC., CALIFORNIA'S COASTAL POWER PLANTS: ALTERNATIVE COOLING SYSTEM ANALYSIS, 4-8 (2008), *available at* http://www.opc.ca.gov/webmaster/ftp/project_pages/OTC/engineering%20study/CA_Power_Plant_Analysis_Complete.pdf.

[58] U.S. DEP'T OF ENERGY, ENERGY DEMANDS ON WATER RESOURCES: REPORT TO CONGRESS ON THE INTERDEPENDENCE OF ENERGY AND WATER 37 (2006) [hereinafter ENERGY DEMANDS].

outside.[59] Dry-cooling significantly reduces or eliminates water needs and withdrawals. This has several advantages. Siting a thermal power plant requires a developer to weigh factors such as access to fuel, access to transmission, and fresh water availability.[60] Dry-cooling offers developers flexibility to choose sites without water resources but with good access to fuel and transmission.[61] In China, 35,000 MW of power plants used dry-cooling in 2008; these plants were often sited near coal mines to minimize the cost of transporting coal.[62] Dry-cooling minimizes regulatory barriers related to water use and thermal discharges. This can be especially beneficial in areas with high regulatory scrutiny or public opposition to freshwater withdrawals.[63]

Despite these benefits, several factors prevent widespread use. Only a small number of plants rely on dry-cooling as they lower plant efficiency and have the highest costs. Electricity production from the plant is reduced due to energy consumed by fans and pumps for the cooling system.[64] A dry-cooling system is estimated to use 0.81% of a power plant's output compared to 0.15% for once-through cooling and 0.39% for a wet recirculating system with cooling towers.[65] Dry-cooling relies on ambient air for cooling; plant efficiency and electricity production decrease during hot weather due to lower cooling system performance because of decreased evaporative potential.[66] Dry-cooling systems are best suited to wet, cool climates.[67] "Over the course of a year, the output of a plant with dry cooling will be about 2 percent less than that of a similar plant with evaporative closed-loop cooling," and "plant efficiency may decrease by up to 25 percent" in extremely hot weather.[68] Retrofit applications of dry-cooling systems are problematic due to increased stress on turbines and generators, increased air emissions, and the larger environmental footprints needed for construction and operation.[69] Dry-cooling systems sig-

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[59] BAUM, *supra* note 14, at 3.

[60] ENERGY-WATER NEXUS, *supra* note 55, at 22.

[61] *Id.*

[62] REDUCING FRESHWATER CONSUMPTION, *supra* note 52, at 38.

[63] ENERGY-WATER NEXUS, *supra* note 55, at 23.

[64] *Id.* at 23–24.

[65] *Id.* at 24.

[66] *Id.* at 24–25.

[67] ENERGY DEMANDS, *supra* note 58, at 40.

[68] *Id.* at 37.

[69] THOMAS J. FEELEY & BARBARA CARNEY, NAT'L ENERGY TECH. LAB., INNOVATIVE

nificantly increase capital costs. Operational costs of dry cooling can also be greater than wet recirculating systems, although savings from less water consumption could make up for this, depending on whether the utility pays for water and at what cost.

Hybrid cooling systems combine wet and dry-cooling technologies. The main advantage is flexibility. A hybrid cooling system can use the wet and dry-cooling systems separately or together. Using the systems together can increase water cooling efficiency while the dry-cooling system can be used to conserve water as needed.[70] Hybrid systems have higher cooling system performances during hot weather than dry cooling alone. However, this flexibility comes at a cost: a hybrid system needs both wet and dry-cooling systems installed, increasing capital costs. Using a hybrid system also eliminates the siting and regulatory benefits of using a dry-cooling only system. Further, a hybrid system can still face difficulties when the weather is hot and there are drought conditions due to decreased water availability (for wet cooling) and decreased evaporative potential (for dry cooling).

Newer technologies, such as using ice or high thermal conductivity foam to cool power plants, are currently not economically feasible.[71] As researchers from Siemens concluded, "it will take several years of development and continued focus on water resource management before systems such as this yield the level of return that will warrant their common use."[72] Therefore, research and development of newer technologies is needed—if successful, such systems can provide power plant developers with more cooling options to better capture different benefits and minimize tradeoffs than current technologies.

Several policies in the United States are poised to impact the cooling water systems of the country's generating fleet. Section 1326(b) of the Clean Water Act requires that the "location, design, construction, and capacity of cooling water intake struc-

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APPROACHES AND TECHNOLOGIES FOR IMPROVED POWER PLANT WATER MANAGEMENT 3 (2005), *available at* http://www.netl.doe.gov/publications/factsheets/program/Prog055.pdf.

[70] ENERGY-WATER NEXUS, *supra* note 55, at 13.

[71] *IEP-Water-Energy Interface Advanced Cooling Technology*, NAT'L ENERGY TECH. LAB., http://204.154.137.14/technologies/coalpower/ewr/water/adv-cooling.html (last visited Feb. 18, 2014).

[72] JOHN H. COPEN ET AL., PRINCIPLES OF FLUE GAS WATER RECOVERY SYSTEM 10 (2005), *available at* http://www.energy.siemens.com/us/pool/hq/energy-topics/pdfs/en/steam-turbines-power-plants/5_Principles_of_Flue_Gas.pdf.

tures" use technology that can best "minimiz[e] adverse environmental impact[s]."[73] Since the enactment of the Clean Water Act, states have been responsible for enforcing this requirement on a case-by-case basis due to the lack of a federal rule. In 2010, California approved a once-through cooling requirement for power plants.[74] This rule would affect almost 20,000 MW at nineteen power plants across the state, requiring plants to retrofit to closed cycle cooling or similar alternative technologies.[75] This represents the first major policy action to prescribe the use of closed-cycle cooling as a method to control the environmental impacts related to water consumption at thermoelectric power plants. Following the decision in *Riverkeeper, Inc. v. EPA*, the EPA was required to develop federal regulations under section 316(b).[76] The final regulations are due to be released in early 2014, and while not expected to require closed-cycle cooling, the regulations could put pressure on power plants to more closely manage their water intake.

2. Untraditional Sources of Water

Unlike domestic consumption or irrigation, power plant operations do not require clean, fresh water. With the right technology and system design, power plants can use a number of untraditional sources of water. Many power plants near the ocean already use sea water for cooling.[77] Researchers have investigated treating and reusing "impaired," "nonpotable," "produced," "brackish," "reclaimed," or "gray" water to cool power plants.[78] The most common applications include using secondary treated municipal waste water, passively treated coal mine drainage, and ash pond effluent. The alternative water sources available to different power plants vary depending on local conditions. While

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[73] 33 U.S.C. § 1326(b) (2006).

[74] CAL. CLEAN ENERGY FUTURE, ONCE-THROUGH COOLING PHASE-OUT 1 (2011), *available at* http://www.cacleanenergyfuture.org/documents/OTCPhaseout.pdf.

[75] *See id.*

[76] 475 F.3d 83, 130 (2d Cir. 2007) (requiring the EPA to develop new regulations defining "best technology available").

[77] R. GOLDSTEIN, ELEC. POWER RESEARCH INST., WATER USE FOR ELECTRIC POWER GENERATION 7-3 (2008), *available at* http://www.epri.com/abstracts/Pages/ProductAbstract.aspx?ProductId=000000000001014026.

[78] *See id.* at 7-1; *see also* J.A. VEIL, ARGONNE NAT'L LAB., USE OF RECLAIMED WATER FOR POWER PLANT COOLING 1 (2007), *available at* https://www.seca.doe.gov/technologies/coalpower/ewr/pubs/reclaimed%20water.pdf.

these water sources reduce freshwater withdrawals, they increase cost, can adversely affect cooling equipment, pose regulatory compliance issues, and are not accessible to all power plants.

Cost is perhaps the most important limitation to using alternative sources of water. The higher cost of alternative sources of water comes from treatment and transportation costs.[79] In order to use nontraditional water sources, new capital equipment is needed to treat the water to ensure it does not compromise plant equipment. Further, the sources of nontraditional water are often located far away from power plants. In the United States, systems utilizing mine water have extra capital costs as high as $5.7 million and operating costs as high as $1.4 million per year, resulting in an annualized cost of up to an additional seventy-nine cents per every 1000 gallons of water reused.[80] The costs of alternative water sources can also be hard to predict; two prototype systems using mine water in West Virginia had operating costs 119% and 193% higher than expected.[81]

Nontraditional water sources require special treatment to protect the power plant. Cooling equipment requires a certain water quality to ensure that it is not damaged by corrosion, scaling, fouling, foaming, or organisms.[82] At the fifty-seven power plants currently using reclaimed water in the United States, contaminants cause a variety of problems including: mineral scaling from calcium phosphate, stress cracking of metal heat transfer surfaces, and excessive biological growth on material surfaces.[83] Alternative sources of water, especially municipal gray water, require secondary treatment, filtration, and disinfection to remove minerals, chemicals, and organisms. The use of reclaimed water at the four-unit 1800 MW coal-fired San Juan Generating Station in New Mexico demonstrates the validity of these concerns. Researchers tested wet surface air cooling utilizing degraded water

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[79] GOLDSTEIN, *supra* note 77, at 1-1.

[80] THOMAS J. FEELEY & LYNN BRICKETT, NAT'L ENERGY TECH. LAB., STRATEGIES FOR COOLING ELECTRIC GENERATING FACILITIES UTILIZING MINE WATER: TECHNICAL AND ECONOMIC FEASIBILITY 2 (2005), *available at* http://www.netl.doe.gov/publications/factsheets/project/Proj363.pdf.

[81] JOSEPH J. DONOVAN ET AL., WRI 50: STRATEGIES FOR COOLING ELECTRIC GENERATING FACILITIES UTILIZING MINE WATER: TECHNICAL AND ECONOMIC FEASIBILITY PROJECT 69 (2004), *available at* http://www.netl.doe.gov/File%20Library/Research/Coal/ewr/water/WVU-WRI-Strategies-for-Mine-Water-Cooling-Final-Report.pdf.

[82] ENERGY-WATER NEXUS, *supra* note 55, at 31.

[83] VEIL, *supra* note 78, at 17.

on one of the units for 147 days, and found that a number of unexplained process leaks occurred.[84] Additionally, contaminants from the reused water interfered with the unit's ability to properly operate.[85] Overcoming these technological challenges and ensuring plant equipment is protected is critical to more widespread use of nontraditional water sources.

Lack of availability and the high cost of alternative water sources themselves can further limit their widespread adoption. Feasibility studies looking at expanding the pilot project at San Juan to all four generating units found that waste water would need to be collected and transported from a three-city area.[86] In addition, a collection center would need to be built along with an entirely new 28.5-mile pipeline to send the water from the collection center to the power plant.[87] A follow-up economic analysis found that this would cost an extra $4.52 to $13.64 for every thousand gallons of water.[88]

> Such a project, totaling an estimated $43.1 million, would only be profitable if water rates for the San Juan plant rose from $6.50 to $47 per acre foot. And, in the end, even if this project was completed, it would supply just 8.8 to 10 percent of the plant's water needs.[89]

Such projects are prohibitively expensive for most power plants. This example demonstrates that alternative water sources are not a universal solution but are dependent on local circumstances and economics.

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[84] ROBERT GOLDSTEIN & KENT ZAMMIT, ELEC. POWER RESEARCH INST., TECHNICAL PROGRESS REPORT: USE OF PRODUCED WATER IN RECIRCULATING COOLING SYSTEMS AT POWER GENERATING FACILITIES: DELIVERABLE NUMBER 12, at 26 (2006), *available at* http://www.netl.doe.gov/File%20Library/Research/Coal/ewr/water/41906-WSAC.pdf.

[85] *Id.*

[86] MICHAEL N. DIFILIPPO & KENT ZAMMIT, ELEC. POWER RESEARCH INST., SEMI-ANNUAL TECHNICAL PROGRESS REPORT: USE OF PRODUCED WATER IN RECIRCULATING COOLING SYSTEMS AT POWER GENERATING FACILITIES: DELIVERABLE NUMBER 2, INFRASTRUCTURE AVAILABILITY AND TRANSPORTATION ANALYSIS, at ES-1 (2004), *available at* http://www.netl.doe.gov/File%20Library/Research/Coal/ewr/water/41906Infrastructure.pdf.

[87] *Id.*

[88] MICHAEL N. DIFILIPPO & KENT ZAMMIT, ELEC. POWER RESEARCH INST., SEMI-ANNUAL TECHNICAL PROGRESS REPORT: USE OF PRODUCED WATER IN RECIRCULATING COOLING SYSTEMS AT POWER GENERATING FACILITIES: DELIVERABLE NUMBER 3, TREATMENT AND DISPOSAL ANALYSIS 35 tbl.3.9 (2004), *available at* http://www.netl.doe.gov/File%20Library/Research/Coal/ewr/water/41906Treatment-DisposalAnalysis.pdf.

[89] Benjamin K. Sovacool & Kelly E. Sovacool, *Preventing National Electricity-Water Crisis Areas in the United States*, 34 COLUM. J. ENVTL. L. 333, 374 (2009).

The lower water quality of alternative sources can also pose regulatory challenges. Power plants often discharge used water into a water source or evaporate used water. Waste water from sewage treatment plants can contain microorganisms and when taken from mineral extraction sites can contain higher concentrations of suspended particles. This means that reclaimed water can pose compliance challenges for water and air quality regulations.[90] Plant operators can come into compliance by chemically treating waste water before discharging it or evaporating it and disposing of the remaining solid waste in a landfill.[91] However, this means that the plant operators will incur additional costs from building holding ponds, landfill tipping fees, and the chemical treatment process.[92]

3. Power Plant Water Production and Efficiency

Power plants can reduce water withdrawals by producing their own water by capturing water vapor from flue gas, using thermal discharges to desalinate sea water, increasing cycles of concentration, and switching non-thermal water systems to dry systems.

Water is naturally present in all deposits of coal, constituting as much as 60% of its weight.[93] The coal combustion process thus releases water vapor that can be recovered from flue gas using liquid desiccant-based absorption systems or modified electrostatic precipitators.[94] These technologies, however, are not yet able to handle the large volumetric flow rates found at power plants. It is not known how water capture would interact with power plant emissions controls for mercury, sulfur dioxides, and nitrogen oxides.[95] No commercially available technology exists, systems would require massive and expensive equipment, they would likely be limited to high ambient temperatures, and they would al-

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[90] ENERGY-WATER NEXUS, *supra* note 55, at 31.

[91] *Id.*

[92] *Id.*

[93] *Power Plant Water Management: Water Extraction from Coal-Fired Power Plant Flue Gas Energy & Environmental Research Center*, NAT'L ENERGY TECH. LAB. [hereinafter *Water Extraction*], http://www.netl.doe.gov/research/coal/crosscutting/environmental-control/water-and-energy-interface/power-plant-water-management/water-reuse--recovery/flue-gas-water-extraction (last visited Feb. 18, 2014).

[94] *See id.*; *see also* THOMAS J. FEELEY & SARA M. PLETCHER, NAT'L ENERGY TECH. LAB, REDUCTION OF WATER USE IN WET FGD SYSTEMS 2 (2006), *available at* http://www.netl.doe.gov/publications/factsheets/project/Proj432.pdf.

[95] *Water Extraction*, *supra* note 93.

most certainly result in decreased power plant performance.[96] Even if the capture technologies were perfected, researchers expect that such innovations would reduce only 5% of evaporative water loss at power plants.[97] More research is needed and commercialization remains distant.

Diffusion driven desalination, a process that uses the excess waste heat from power plants to produce distilled water, can minimize the water needs of power plants situated in coastal areas.[98] This process is distinct from using sea water for cooling as it produces a new product and revenue stream: fresh water. Its application would be limited to power-producing facilities situated along ocean coastlines, immediately ruling out the bulk of power plants.[99] This technology is attractive as it eliminates the need for freshwater withdrawals. However, expanded use of diffusion-driven desalination is limited by ecological considerations, thermal effluent streams, and opposition to industry on coast lines.[100] Desalination to reduce water use is already occurring at power plants in China, India, South Africa, and Italy.[101]

Increasing cycles of concentration can reduce water use. Cycles of concentration ("COC") describes the proportion by which evaporation during cooling increases concentrations of solids in cooling water in wet recirculating systems.[102] Increasing the COC so that there are more solids in the water will reduce blowdown wa-

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[96] *Id.*

[97] FEELEY & PLETCHER, *supra* note 94, at 2.

[98] *See* JAMES F. KLAUSNER & RENWEI MEI, INNOVATIVE FRESH WATER PRODUCTION PROCESS FOR FOSSIL FUEL PLANTS: ANNUAL REPORT 1–4 (2004), *available at* http://www.osti.gov/bridge/servlets/purl/835262-XjApqw/native/835262.pdf.

[99] *Id.*

[100] *See* G. Prakash Narayan, *The Potential of Solar-Driven Humidification-Dehumidification Desalination for Small-Scale Decentralized Water Production*, 14 RENEWABLE & SUSTAINABLE ENERGY REVS. 1187, 1188–89 (2010); Benjamin K. Sovacool, *Running on Empty: The Electricity-Water Nexus and the U.S. Electric Utility Sector*, 30 ENERGY L.J. 11, 35 (2009); ELEC. POWER RESEARCH INST. & PUB. INTEREST ENERGY RESEARCH PROGRAM, USE OF DEGRADED WATER SOURCES AS COOLING WATER IN POWER PLANTS 4-1 (2003), *available at* http://www.energy.ca.gov/reports/2004-02-23_500-03-110.PDF (cataloging ecological concerns).

[101] REDUCING FRESHWATER CONSUMPTION, *supra* note 52, at 60–61.

[102] PAUL L. FREEDMAN & JOHN R. WOLFE, THERMAL ELECTRIC POWER PLANT WATER USES; IMPROVEMENTS PROMOTE SUSTAINABILITY AND INCREASE PROFITS 4 (2007), *available at* http://www.catawbariverkeeper.org/issues/energy-and-water-use/Freedman_Wolfe_PP_Water_Uses_091407.pdf; *see also* GEN. ELECTRIC *Chapter 31—Open Recirculating Cooling Systems*, *in* HANDBOOK OF INDUSTRIAL WATER TREATMENT, http://www.gewater.com/handbook/cooling_water_systems/ch_31_open.jsp (last visited Feb. 18, 2014) (explaining COC in greater detail).

ter use.[103] To do so will require materials that are resistant to scaling, corrosion, and fouling.[104] At the Essar Power plant in Gujarat, India, COC was increased from an average of 3.68 to 5 by replacing steel tubes with Cu-Ni material.[105] This saved 381 million liters annually and payback was less than a year.[106] One study estimated that doubling COC from 4 to 8 could reduce water use by 100 gallons per MWh.[107]

Power plants use water for many purposes; some of these systems can be converted to use dry instead of wet systems. One example is dry flue gas desulphurization. In order to meet air emissions requirements, power plants may install systems that desulphurize flue gas before it is emitted. Dry flue gas desulphurization can reduce water needs by not using water to remove sulfur. Due to the absence of water, dry scrubbers have lower pollutant removal efficiencies than wet scrubbers.[108] Bottom ash is noncombustible residue of coal combustion that settles out after combustion; wet handling systems cool and remove this bottom ash from the plant.[109] Dry bottom ash handling at coal plants can increase plant efficiency, decrease costs, and eliminate water needs. Higher investment costs for the dry system can be offset by simpler transport equipment, storage equipment, and the lack of expensive water treatment equipment.

4. Increasing Water Efficiency Through Plant Design

Power plant design plays a critical role in water withdrawals and consumption. Increasing the efficiency of water consumption within a power plant's processes through plant design can reduce overall water use. Supercritical coal plants consume 13% less water compared to subcritical coal plants.[110] This is due to lower steam pressure at subcritical coal plants, which increases steam flow and water cooling needs. Supercritical plants are a mature

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[103] *See* FREEDMAN & WOLFE, *supra* note 102, at 4–5.

[104] *Id*. at 4.

[105] FED'N OF INDIAN CHAMBERS OF COMMERCE AND INDUS., WATER USE AND EFFICIENCY IN THERMAL POWER PLANTS 16–17 (2011), *available at* http://www.ficci.com/spdocument/20147/ficci-Water-use.pdf.

[106] *Id.* at 17–18.

[107] FREEDMAN & WOLFE, *supra* note 102, at 4.

[108] *Id*.

[109] REDUCING FRESHWATER CONSUMPTION, *supra* note 52, at 44.

[110] *Id*.

technology and have lower overall costs when fuel cost is high. They have higher efficiency, higher flexibility, and lower lifecycle costs than subcritical plants. However, supercritical plants have higher maintenance costs, higher boiler stress and fatigue, and lower operational availability and reliability of steam turbines compared to subcritical plants.[111] Importantly, supercritical plants are more sensitive to feedwater quality, reducing the ability to use alternative water sources.[112]

C. *Change Permitting and Licensing*

A separate tool would be altering the permitting and licensing requirements for power plants so that they better incorporate water needs. We provide an overview of what four major countries—China, France, India, and the United States—can do to integrate water resource management into energy planning. We chose these case studies for several reasons. First, each country has a high reliance on thermoelectric generation. India and China are expected to have substantial load growth in addition to increasing constraints on water resources.[113] Planning for water challenges in these countries is critically important to avoid future water shortages. As the world's only country that relies predominantly on nuclear power, France faces serious electric reliability concerns due to water.[114] The United States was chosen because it is the world's second largest electricity producer and consumer (after China) and has a very large thermoelectric fleet.[115]

1. China

The current Chinese electricity regulatory framework does not have any stated requirements for considering water in plans for new electricity generation projects. The national body for electricity regulation, the State Electricity Regulatory Commission, does not appear to pay specific attention to water resources when un-

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[111] *Id*. at 19.

[112] *Id*.

[113] *Id*. at 7, 12.

[114] *See* Steve Kidd, *Nuclear in France—What Did They Get Right?*, NUCLEAR ENGINEERING INT'L (June 22, 2009), http://www.neimagazine.com/opinion/opinionnuclear-in-france-what-did-they-get-right.

[115] *See* REDUCING FRESHWATER CONSUMPTION, *supra* note 52, at 1.

dertaking its regulatory authority.[116] Furthermore, the agency responsible for permitting new generation, the National Energy Commission ("NEC"), is also devoid of any specific awareness of water resources when deciding to allow construction of new generation.[117] While the NEC's stated responsibilities loosely mention formulating and implementing policies that are related to environmental protection, nothing specifically referencing water concerns can be located. Complicating the issue is the partitioning of generation ownership that has occurred in recent years. Provincial governments are now claiming a greater share of generation ownership over the national government.[118] It is unclear how much permitting authority has been abdicated to the provincial governments from the NEC.

The framework requiring discrete awareness of water for permitting new generation is already in place. Explicitly mandating that permits will only be issued contingent on an acceptable plan that heeds attention to water is a solution that can be implemented with little change to the existing scheme. The NEC, or the provincial governments, can decline to issue permits unless water is expressly accounted for in the Environmental Impact Assessment that would be required for this type of development.[119] As mentioned previously, it is unclear if water considerations are required by the Environmental Impact Assessments and, if they are, what level of detail is sufficient for the assessment to be deemed acceptable. Mandating an extensive investigation into the hydrological impacts of new development would potentially relocate plants into areas that are better suited to handle the level of water withdrawals electricity generation requires.

A second solution, closely related to the first, is to bolster the existing Water Law with language requiring a hydrological as-

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[116] *See* U.S. ENERGY INFO. ADMIN., CHINA 32 (rev. ed. 2013), *available at* http://eia.gov/countries/analysisbriefs/China/china.pdf.

[117] *See National Energy Administration* (*NEA*), NAT'L DEV. & REFORM COMM'N—PEOPLE'S REPUBLIC OF CHINA, http://en.ndrc.gov.cn/mfod/t20081218_252224.htm (last visited Feb. 18, 2014).

[118] *See* ENVTL. PROT. AGENCY, CHINA'S ENERGY MARKETS: ANHUI, CHONGQING, HENAN, INNER MONGOLIA, AND GUIZHOU PROVINCES 16–19 (2012), *available at* http://www.epa.gov/cmop/docs/ChinaEnergyMarketsUpdate-Dec2012.pdf.

[119] *See* Press Release, Nat'l Dev. & Reform Comm'n (NDRC)—People's Republic of China, Program of Action for Sustainable Development in China in the Early 21st Century (Feb. 5, 2007), *available at* http://en.ndrc.gov.cn/newsrelease/t20070205_115702.htm.

sessment for electricity generation projects. The Water Law provides the Ministry of Water the ability to regulate the nation's water resources.[120] Since electricity generation consumes enormous amounts of water, this type of development should fall squarely within their mandated purview. Amending the Water Law to explicitly grant the Ministry authority to reject electricity development plans would seemingly prevent construction of generation in water-stressed areas.

2. France

In France, Electricity of France ("EDF") is in charge of the power supply for the entire country. This model, with a single responsible authority and one standard nuclear reactor design, allows for more flexible and efficient replication. The French licensing process is reflective of the national government's desire to pursue the goals of efficiency and flexibility in the site selection process, and the fact that EDF is the only utility involved facilitates more informal discussions with local authorities in the early stages of siting and licensing. When EDF selects a particular site, the official procedures for application of a construction permit begin, with most application materials sent to the Ministry of Industry for review.[121] An interministerial committee considers the results of the public inquiry process, with other government authorities tasked with reviewing various safety considerations.[122] Because it is responsible for all of mainland France, EDF is in a favorable position to devise plans that minimize the country's water use.[123] Alternatively, the permitting and licensing entities could ensure that comprehensive water assessments are done as a part of the licensing process.

Another possible outlet for consideration of water use in the permitting process is France's Nuclear Safety Authority ("ASN"). On June 13, 2006, the nuclear transparency and safety law,

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[120] Water Law (promulgated by the Standing Comm. Nat'l People's Cong., Aug. 29, 2002, effective Oct. 1, 2002) arts. 1–3 (China), *translated at* http://www.mwr.gov.cn/english/01.pdf.

[121] MICHAEL W. GOLAY ET AL., COMPARATIVE ANALYSIS OF UNITED STATES AND FRENCH NUCLEAR POWER PLANT SITING AND CONSTRUCTION REGULATORY POLICIES AND THEIR ECONOMIC CONSEQUENCES 27–28 (1977), *available at* http://dspace.mit.edu/bitstream/handle/1721.1/31297/MIT-EL-77-044WP-00830583.pdf?sequence=1.

[122] *Id.* at 29.

[123] *Id.* at 24–26.

known as the TSN law, created the ASN, an independent administrative authority with a new legal status comparable to that of its counterparts in other industrialized nations.[124] ASN regulation covers a wide variety of activities and installations including nuclear power plants. Under the nuclear program, ASN is tasked with regulating nuclear safety and radiation protection in order to protect workers, the public, and the environment from the risks involved in nuclear activities.[125] ASN advises the French government on regulation by commenting on draft decrees and ministerial orders, or by issuing technical regulatory decisions, potentially providing an alternative, independent authority that can make water use permitting a requirement of the nuclear installation licensing process.

3. India

Similar to China, India's electricity market is regulated by the Central Electricity Regulatory Commission ("CERC"), a national agency under the umbrella of the Ministry of Power.[126] CERC is the entity responsible for the development of the nation's grid and is vested with licensing and permitting power for new intrastate generation projects.[127] While the Central Water Commission ("CWC") is the primary authority for India's water resources, CERC is better positioned to be the linchpin for requiring water in the permitting process for power plants. To achieve this end, CERC should mandate that any new license or permit be accompanied with a detailed assessment on its projected hydrological impact. CERC should require this assessment be completed in conjunction with CWC to take advantage of its institutional knowledge about India's water resources. As with China, implementing this type of procedure should provide a sufficient balance between meeting projected growth in energy demand while mitigating developing water-intensive energy projects in water-stressed areas.

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[124] *About ASN*, AUTORITÉ DE SÛRETÉ NUCLÉAIRE (ASN), http://www.french-nuclear-safety.fr/index.php/English-version/About-ASN (last updated Sept. 13, 2013).

[125] *Id.*

[126] The Electricity Act, 2003, No. 36, Acts of Parliament, 2003 (India).

[127] *Id.*

4. United States

As discussed in a prior article:

> Unlike France and China, the United States has a highly fragmented electric utility industry, which is composed of three federal agencies, over seventy investor-owned power companies, and numerous municipal and rural power cooperative organizations. Although the United States as a whole is the world's biggest economy, each individual entity in the U.S. utility industry is typically by far smaller than their French or Chinese counterparts.[128]

In the United States, licensing for power plant facilities generally falls to the state public utility commissioners, except for hydropower facilities. The Federal Energy Regulatory Commission ("FERC") is responsible for issuing licenses for the construction of new hydropower projects and relicensing existing hydro projects.[129]

Projects that require the involvement of a federal agency are subject to the National Environmental Policy Act ("NEPA"), which President Richard Nixon signed into law on January 1, 1970.[130] By signing NEPA, President Nixon established the President's Council on Environmental Quality and set up procedural requirements for the preparation and monitoring of environmental impact statements.[131] To satisfy NEPA's requirements, a federal agency must prepare an Environmental Impact Statement ("EIS") conforming to regulatory requirements, or an Environmental Assessment ("EA") to determine whether an EIS is warranted.[132] If the proposed agency action falls within a congressionally created categorical exclusion, meaning it has been predetermined not to have a significant environmental impact, the agency does not have to prepare either document.[133]

> Parts of the Act [NEPA], as amended, set strict guidelines relating to the permitting, siting, and relicensing of thermoelectric power plants. While intended to create a relatively transparent decision-making process by giving states and local governments a voice in

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[128] Chi-Jen Yang, *A Comparison of the Nuclear Options for Greenhouse Gas Mitigation in China and in the United States*, 39 ENERGY POL'Y 3025, 3027 (2011).

[129] *Overview of FERC*, FED. ENERGY REGULATORY COMM'N, https://www.ferc.gov/about/ferc-does/overview.asp (last visited Feb. 18, 2014)

[130] Sovacool & Sovacool, *supra* note 6, at 2770.

[131] *Id.*; *see also* 42 U.S.C. § 4332 (2006).

[132] 40 C.F.R. §§ 1502.1–1502.25 (2013); 40 C.F.R. § 1508.9(a) (2013).

[133] 40 C.F.R. § 1501.4 (2013).

> federal decisions, the process has faced criticism for becoming more inefficient and ineffective over time. In some recent cases of power plant permitting in the northeast and the pacific northwest, public comments have been either discouraged or limited, exemptions created, or guidelines relaxed.[134]

The NEPA process could be strengthened by eliminating existing categorical exclusions and congressional refusal to impose future exclusions for thermoelectric plants so that water use is expressly considered in each project and permitting decisions are more comprehensive and open to public comment. "Many of the earliest debates over water use were instigated by the preparation and defense of [EISs], and an improvement of the permitting process would help serve as a crucial check on the approval of excessively water-wasteful power plants."[135]

There are significant differences in the way that states deal with private water withdrawals. For example, Alabama does not require permits even for large water users, and only asks for information about these activities for informational purposes.[136] Georgia requires permits, but has never turned one down for a power plant, citing historically sufficient water resources.[137] This was despite an acknowledgement in the state water management plan that "currently, we do not have good measurements of how much water is available from Georgia's streams and aquifers."[138] The plan calls for developing better data on available resources and use.[139] Many state regulatory agencies mirror the requirements of NEPA for state level projects. Under Texas law and the Texas Commission on Environmental Quality ("TCEQ") regulations, "state regulatory agencies may require a statement of environmental, social, and economic impacts for any proposed project to clarify that the project is not detrimental to the environment or to the public interest, health, or welfare."[140] TCEQ is additionally responsible for water quality permitting and a variety of water

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[134] Sovacool & Sovacool, *supra* note 6, at 2770–71.

[135] *Id.* at 2771.

[136] ENERGY-WATER NEXUS, *supra* note 55, at 34–35.

[137] *Id.* at 35.

[138] GA. WATER COUNCIL, GEORGIA COMPREHENSIVE STATE-WIDE WATER MANAGEMENT PLAN 5 (2008), *available at* http://www.georgiawatercouncil.org/Files_PDF/water_plan_20080109.pdf.

[139] *Id.*

[140] *Texas Environmental Impact Statement: What You Need to Know*, BLR, http://www.blr.com/Environmental/Emergency-Planning-Response/Environmental-Impact-Statement-in-Texas (last visited Feb. 18, 2014).

conservation programs, making it a likely candidate for the authority to make water licensing a requirement.[141]

III. PLACE A MORATORIUM ON NEW THERMOELECTRIC POWER GENERATION

Perhaps the simplest response regulators can take is to stop building new thermoelectric generation in areas where water shortages are expected to occur, or water prices are anticipated to rise rapidly. The addition of new conventional power plants has two inherent water-related risks that suggest electric utilities should no longer construct them: they are unable to withdraw water needed for normal operation in times of scarcity, and can cause new and worsen existing water shortages due to additional water demands.

The idea sounds radical, but there have been many calls for moratoriums on new thermal power plants in the past. In the United States, groups as diverse as the League of Women Voters,[142] the Union of Concerned Scientists,[143] and Trillium Asset Management[144] have called for halting new coal plants because of their carbon emissions or other environmental problems. California passed SB1368 in 2006, which stipulates that all new coal plants must have the same carbon emissions as combined cycle natural gas plants.[145] While not a direct moratorium, SB1368 is often called a de-facto ban on building new coal plants as no current coal plant can meet that standard.[146]

In India, the nongovernmental organization Greenpeace has called for a moratorium on granting environmental clearances to inland coal-fired thermal plants until their impact on water re-

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[141] *TCEQ Water Conservation Programs*, TEX. COMM'N ON ENVTL. QUALITY, http://www.tceq.texas.gov/permitting/water_rights/conserve.html/ (last visited Feb. 18, 2014).

[142] *Moratorium on New Coal-Fired Electric Power Plants Is Imperative to Address Global Warming*, LEAGUE OF WOMEN VOTERS (Aug. 2008), http://www.lwv.org/content/moratorium-new-coal-fired-electric-power-plants-imperative-address-global-warming.

[143] Press Release, Union of Concerned Scientists, So-Called "Clean Coal" Technology Offers Promise Along with Considerable Risks, New Report Finds, (Oct. 15, 2008), *available at* http://www.commondreams.org/newswire/2008/10/15-17.

[144] *Bank of America-Moritorium on Coal Financing*, TRILLIUM ASSET MANAGEMENT (2007), http://www.trilliuminvest.com/resolutions/moritorium-on-coal-financing/.

[145] NATURAL RES. DEF. COUNCIL, CALIFORNIA TAKES ON POWER PLANT EMISSIONS: SB 1368 SETS GROUNDBREAKING GREENHOUSE GAS PERFORMANCE STANDARDS (2007), *available at* http://www.nrdc.org/globalWarming/files/sb1368.pdf.

[146] *Id.*

sources has been taken into account.[147] Greenpeace also suggested placing a moratorium on allocating water to power generation in Vidarbha District in Maharstra State.[148] The Prayas Energy Group, a nonpartisan energy think tank, has also argued that "[t]here should be an immediate moratorium on any further grant of environmental clearances to [thermal power plants]."[149]

In Texas, there was a concerted effort to enact a moratorium on coal-fired plants due to worries over air pollution. In 2007, a coalition of over forty groups supported a bill that called for a "time out" for building new coal-fired power plants.[150] The bill was primarily aimed at halting the construction of nine new coal plants that would have worsened air quality.[151] It called for, among other things, a greater role for renewable energy in the Texas energy mix.[152] Other states have enacted moratoriums when faced with water scarcity issues. In an effort to address environmental and water concerns, the Idaho House Committee adopted a two-year moratorium on the construction of new coal plants in 2006.[153] Around the same time, Arizona also rejected a permit for a coal-fired plant based on water issues.[154] In addition, in 2007, the Kansas State Assembly considered, but ultimately voted down a moratorium on coal plants in the state.[155] One of the principle concerns was the effect that new plants would have on ground water supplies.[156]

There is a well-established precedent for state governments issuing moratoriums or refusing to issue permits for coal plants,

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[147] BOYLE ET AL., *supra* note 10, at 65.

[148] *Thirsty Coal Poses Risk to India's Farmers*, GREENPEACE INT'L (Aug. 7, 2012), http://www.greenpeace.org/international/en/news/features/Thirsty-coal-makes-hungry-people/?accept=05961e07fb00ed0f68e094406646c961.

[149] SHRIPAD DHARMADHIKARY & SHANTANU DIXIT, THERMAL POWER PLANTS ON THE ANVIL: IMPLICATIONS AND NEED FOR RATIONALISATION 17 (2011), *available at* http://www.ercindia.org/files/Prayas_Paper_TPP_Aug_2011.pdf.

[150] *See Momentum Building for Time-Out on Coal Plant Permitting*, TEXAS IMPACT (Feb. 17, 2007, 5:00 PM), http://texasimpact.org/rallywrapup.

[151] H. Con. Res. 43, 80th Leg. (Tex. 2007).

[152] *Id.*

[153] Erik Shuster, *NETL Fossil Energy "Issues Note*," NAT'L ENERGY TECH. LAB. (Sept. 26, 2007), http://www.netl.doe.gov/energy-analyses/pubs/Energy-Water%20Issue%20Note.pdf.

[154] *Id.*

[155] Scott Rothschild, *Coal Plant Moratorium Likely to Fail*, LJWORLD.COM (Jan. 29, 2007, 12:59 PM), http://www2.ljworld.com/news/2007/jan/29/coal_plant_moratorium_likely_fail/.

[156] *Id.*

and this trend is likely to continue. In the United States, state legislatures can pass statutes determining their energy mix indicating they have clear authority to enact moratoriums. By enacting a moratorium on new thermoelectric power plants on the basis of water constraints, states can prevent new water stresses and vulnerabilities. Drought prone regions in particular would benefit from preventing water consumption growth. Considering the impacts of climate change on precipitation patterns and variability, a moratorium could be an effective adaptation strategy, depending on local conditions.

One possible objection to a moratorium would be that future increases in electricity demand can only be reliably met by fossil-fueled and nuclear base-load power plants. While this concern is a legitimate one, the next two parts show that the promotion of energy efficiency, demand-side management ("DSM"), renewable energy, and improved feedback to electricity customers could offset the need to build any new thermoelectric capacity.

IV. PROMOTE ENERGY EFFICIENCY AND DEMAND-SIDE MANAGEMENT

An easy way to reduce water consumption from electricity is to reduce electricity consumption. Moratoriums on constructing new thermoelectric generators should be coupled with energy efficiency and DSM programs. This would help reduce the electricity demand that makes new plants necessary in the first place. It would also improve energy security, lower electricity and water prices, and enhance reliability. Experience strongly suggests that energy efficiency, DSM, and load management practices are the most economical and easily achievable responses to increased electricity demand, typically even cheaper than new generation. According to Amory Lovins, energy efficiency "is generally the largest, least expensive, most benign, most quickly deployable, least visible, least understood, and most neglected way to provide energy services."[157]

According to a recent DOE assessment, DSM lowers wholesale electricity prices by displacing the most expensive generation and

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[157] AMORY B. LOVINS, ENERGY END-USE EFFICIENCY 1 (2005), *available at* http://www.udel.edu/igert/JournalClub/JC5.pdf.

decreasing the total system demand.[158] The most expensive plants are called peaker plants, which often generate electricity at prices topping $6000 to $10,000 per installed kW.[159] A break-out of the cost shows that a 100 MW plant can cost $750 million to build and require seventy-five million dollars per year to operate. Given this, DSM should be profitable for *all* utilities.[160]

Notwithstanding its impressive potential, there is much more potential in energy efficiency and DSM than some ever imagined. The National Association of Regulatory Utility Commissioners ("NARUC") found cost-effective energy efficiency potential in *all* regions of the country, with the most untapped potential in the Northeast and South, where electricity costs are highest (meaning energy efficiency efforts are more economical than areas where energy is cheaper).[161] Another study projected that cost-effective energy efficiency programs could reduce consumption by around one trillion kWh by 2020, offsetting almost all projected growth in electricity use and the needed capacity additions to achieve it.[162] The Alliance to Save Energy found that aggressive investments in energy efficiency could free up enough electricity to mostly eliminate the need to construct more than 1300 power plants by 2020.[163] One study projected that a national DSM program aimed at reducing peak demand by just 5% would yield three billion dollars in net generation, transmission, and distribution savings per year and displace some 625 infrequently used peaking plants and associated delivery infrastructure.[164]

In situations where energy efficiency and DSM programs are unable to completely offset the need to construct new thermoelectric power plants, utilities could rely on wind turbines and solar panels to produce electricity. As Table 1 illustrated above, these

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[158] U.S. DEP'T OF ENERGY, BENEFITS OF DEMAND RESPONSE IN ELECTRICITY MARKETS AND RECOMMENDATIONS FOR ACHIEVING THEM, at vi (2006) [hereinafter BENEFITS OF DEMAND RESPONSE].

[159] *See, e.g.*, Consumer Powerline, Alternative Energy Conference (Apr. 23, 2008), http://www.enrg.lsu.edu/Conferences/altenergy2008/Izzi_AEC_2008.pdf.

[160] BENEFITS OF DEMAND RESPONSE, *supra* note 158, at 76–77.

[161] *See* RICHARD COWART, EFFICIENT RELIABILITY: THE CRITICAL ROLE OF DEMAND-SIDE RESOURCES IN POWER SYSTEMS AND MARKETS 24–25, 35 (2001).

[162] Antonia Herzog et al., *Renewable Energy: A Viable Choice*, ENVIRONMENT, Dec. 2001, at 8, 13.

[163] *National Energy Policy: Conservation and Energy Efficiency: Hearing Before the Subcomm. on Energy and Air Quality of the H. Comm. on Energy and Commerce*, 107th Cong. 79 (2011) (statement of David M. Nemtzow, President, Alliance to Save Energy).

[164] Ahmad Faruqui et al., *The Power of 5 Percent*, 20 ELECTRICITY J. 68, 71–72 (2007).

two technologies use almost no water to generate electricity, and need only a very small amount for cleaning and maintenance. Even more remarkably, looking at the marginal levelized cost of new power plants in 2007—that is, the cost of constructing, operating, maintaining, and fueling a new facility—offshore and onshore wind turbines produce electricity for between 2.6 and 5.6 ¢/kWh, making them two of the six cheapest sources of power.[165] Solar PV is the most expensive at 39 ¢/kWh, but not far behind expensive peaking plants that cost between 32.5 and 35.6 ¢/kWh to operate.[166] Wind, in other words, is already cheap, and solar (which is getting cheaper) is nearing parity with natural gas peaking facilities. Importantly, as water is often not priced according to its economic value, the higher water needs of coal, nuclear, and natural gas may not be reflected in their price (externalized), as discussed below, making renewable energy more competitive. Prices have consistently been decreasing for renewable electricity technologies. The cost for solar PV has decreased by an average of 7% annually for the last thirty years.[167] In 2011, solar PV and onshore wind "experienced dramatic price reductions" due to "economies of scale, technology advances, and others factors."[168]

Solar energy, for instance, is an increasingly viable option to diversify fuel resources and reduce the water intensity of electric generation. Rapidly decreasing costs have led a rapid expansion of installed capacity; total installed solar (PV and CSP) capacity increased from 4.5 GW in 2005 to over sixty-five GW today.[169] Between 2006 and 2011, solar PV grew by average of 58% annually; in 2011 alone, solar PV capacity increased by 74%.[170] This rapid growth is occurring in a growing number of countries as renewable energy technologies expand into new markets.[171] Despite this

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[165] Benjamin K. Sovacool, *Renewable Energy: Economically Sound, Politically Difficult*, 21 ELECTRICITY J. 18, 24 tbl.4 (2008).

[166] *Id.*

[167] Ramez Naam, *Smaller, Cheaper, Faster: Does Moore's Law Apply to Solar Cells?*, SCI. AM. (Mar. 16, 2011), http://blogs.scientificamerican.com/guest-blog/2011/03/16/smaller-cheaper-faster-does-moores-law-apply-to-solar-cells/.

[168] REN21, RENEWABLES 2012 GLOBAL STATUS REPORT 22 (2012), *available at* http://www.ren21.net/Portals/0/documents/activities/gsr/GSR2012_low%20res_FINAL.pdf.

[169] KRISTER AANESEN ET AL., SOLAR POWER: DARKEST BEFORE DAWN 3 (2012), *available at* http://www.mckinsey.com/client_service/sustainability/latest_thinking/solar_powers_next_shining.

[170] REN21, *supra* note 168, at 22.

[171] *Id.*

diversification, solar PV installations are mainly located in a few countries—Germany and Italy alone accounted for more than half of all installations at the end of 2011.[172] These two countries receive relatively little sunshine; rather favorable policies, specifically feed-in tariffs, have driven high levels of installation. This indicates that, with the right policy support, solar PV is poised to play an increasingly important role in electric generation. In the United States, PV is already playing an increasingly larger role. In 2013, solar PV is projected to have the second highest capacity installation of any fuel source, after natural gas.[173]

Similarly, wind energy is quickly emerging as a viable alternative power source. In 2011, wind power comprised 32% of newly installed generation capacity additions in the United States.[174] By the end of 2011, wind generated about 3.3% of electricity demand.[175] In addition to providing electricity, the wind industry supports up to 75,000 jobs.[176] As wind has grown, more components are being manufactured domestically—approximately 67% of a wind turbine came from domestic manufacturing in 2011 today compared with 35% in 2005.[177] Globally, wind has seen similar growth. By the end of 2012, there were 283 GW of wind installed, up from thirty-one GW in 2002.[178] This rapid growth has been accompanied by substantial cost decreases as wind reaches economies of scale and technology improves. From 2008 to 2012, costs declined by 20% to 25% in western markets and by as much as 35% in China.[179]

Nationally, commercially available wind and solar photovoltaic power generators could play a significant role in our electricity future. Wind and solar would only have to realize a fraction of this technical potential to reduce the impacts of water constraints on electricity reliability. Combined with a thermoelectric morato-

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[172] *Id.* at 48.

[173] *Solar to Be #2 Source of New Power in 2013*, SOLAR LOVE (Mar. 14, 2013), http://solarlove.org/solar-2-source-of-new-power-in-2013/.

[174] U.S. DEP'T OF ENERGY, 2011 WIND TECHNOLOGIES MARKET REPORT 4–5 (2012), *available at* http://www1.eere.energy.gov/wind/pdfs/2011_wind_technologies_market_report.pdf.

[175] *Id.* at 6.

[176] *Id.* at iv.

[177] *Id.* at v.

[178] REN21, RENEWABLES 2013 GLOBAL STATUS REPORT 50 (2013), *available at* http://www.ren21.net/portals/0/documents/Resources/GSR/2013/GSR2013_lowres.pdf.

[179] *Id.* at 51.

rium, solar and wind would only need to be installed at rates sufficient to cover load growth and plant retirements. Climatic impacts on the water system mean that wind and solar would act as both climate mitigation and adaptation technologies (to account for water stress).

V. CHANGE ELECTRICITY PRICES AND IMPROVE INFORMATION

Under the current system for pricing electricity, customers are often unaware that they are causing environmental impacts and rarely do they have to pay for them. If utilities instituted more accurate electricity pricing, altered electricity billing practices, and increased consumer education efforts, many of the worst water impacts could be avoided.

While time of day meters, and increasingly smart meters, are providing better price signals to some consumers, many remain unaware of daily, weekly, and seasonal changes in electricity prices, and instead see only a monthly electricity bill. This leads them to use electricity at peak hours when it is most expensive to generate. With greater penetration of smart meters, customers can be charged in "real-time," "interval metering," "time-of-use," or "seasonal" rates which more accurately reflect the cost of energy. Smart grid technology also provides better information to consumers, especially when coupled with smart appliances. By using this combination, consumers can see the cost of running specific appliances and determine how their bill could be decreased by using more efficient models.[180]

Through the Energy Policy Act of 2005 ("EPAct"), Congress recognized the importance of improving electricity pricing, and encouraged utilities to make time-based rate schedules available to any customers requesting it.[181] Essentially, the EPAct left it to state regulatory authorities to determine whether and how to implement these changes.[182] FERC estimates that advanced meters have about 22% penetration and potential capacity for demand response programs is about 72,000 MW, roughly 9.2% of United

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[180] *See* Stephanie M. Stern, *Smart-Grid: Technology and the Psychology of Environmental Behavior Change*, 86 CHI.-KENT L. REV. 139, 145–47 (2011).

[181] 16 U.S.C. § 2621(d)(14)(A) (2006); 42 U.S.C. § 1619(a)(1)(A)-(C) (2006).

[182] John Dernbach, *Stabilizing and Then Reducing U.S. Energy Consumption: Legal and Policy Tools for Efficiency and Conservation*, 37 ENVTL. L. REP. 10,003, 10,026 (2007).

States peak demand.[183] Advanced meter penetration is a good indicator for time-based rate schedules, as they are the key enabling technology.

Empirical evidence indicates that pricing electricity more accurately will greatly improve the efficiency of the electricity industry, provide customers with proper price signals, and reduce wasteful energy use. One study provided residents with daily electricity prices for a month and found a 10.5% reduction in electricity use.[184] Another analysis of residential electricity use from 1973 to 1980 found that "feedback" in the form of information detailing daily and weekly electricity prices reduced consumption between 6% and 20%.[185] When Princeton University researchers gave residents of Twin Rivers, New Jersey, information about their level of electricity and natural gas use on a daily basis, consumption dropped 10% to 15%.[186] Another study involved eight experiments tracking electricity use at 602 households over the course of many years.[187] In some experiments, feedback was given three to four times a week, and in one experiment it was given continuously and informed households of the cost of their consumption every half hour.[188] The researchers found that frequent, credible feedback about electricity prices resulted in 10% to 13% less electricity use than control groups.[189]

The cost of electricity does not necessarily reflect the true price of water. In the West, where droughts and water scarcity pose serious management challenges, the prior appropriation system dominates.[190] Under the prior appropriation system, water is

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[183] FED. ENERGY REGULATORY COMM'N, ASSESSMENT OF DEMAND RESPONSE AND ADVANCED METERS STAFF REPORT 1 (2012), *available at* http://www.ferc.gov/legal/staff-reports/12-20-12-demand-response.pdf.

[184] Willett Kempton & Linda L. Layne, *The Consumer's Energy Analysis Environment*, 22 ENERGY POL'Y 857, 858 (1994).

[185] Robin C. Winkler & Richard A. Winnett, *Behavioral Interventions in Resource Conservation: A Systems Approach Based on Behavioral Economics*, 37 AM. PSYCHOLOGIST 421, 426 tbl.1 (1982).

[186] Robert H. Socolow, *Saving Energy in the Home: Princeton's Experiments at Twin Rivers*, *in* SAVING ENERGY IN THE HOME: PRINCETON'S EXPERIMENTS AT TWIN RIVERS 1, 11 (Robert H. Socolow ed., 1978).

[187] LAWRENCE J. BECKER ET AL., PSYCHOLOGICAL STRATEGIES TO REDUCE ENERGY CONSUMPTION, at v (1979).

[188] *Id.* at v, 39–40.

[189] *Id.* at v.

[190] *See* Colorado v. New Mexico, 459 U.S. 176, 179 n.4 (1982).

treated as a commodity that can be owned.[191] A prior appropriation right entitles the owner to the first use of water, regardless of the needs of users down the line.[192] Many power plants in the West buy water rights and directly extract water from a water source. The cost of water is therefore a one-time capital expenditure instead of a cost that varies based upon supply and demand. Unlike marginally priced electricity, water rarely has time of use or seasonal rates. Water prices typically do not fluctuate according to supply and consumers correspondingly do not alter their behavior when water is scarce.

Beyond pricing, consumers could be provided with information on water consumption and direct education on how water is used in electricity. Providing information on water consumption to consumers can increase information and awareness of the electricity-water nexus. Including water consumption information on customer bills could disseminate this information. Water conscious consumers, particularly in drought prone areas, could be further motivated to reduce their electricity consumption. Such information could even increase public support for less water intense sources of energy. Direct education could similarly lead to reduced electricity and water use. Public education curriculums could include sections on the link between electricity and water. During periods of water stress, lawn watering restrictions could be accompanied by voluntary energy efficiency initiatives to reduce thermoelectric stress on water resources. The internet could be used as well; websites could be set to provide locally relevant information on the link between water and electricity, providing conscious consumers with information they can use to reduce personal water impacts.

CONCLUSION

Growing electricity demand, more frequent and severe droughts, and changing precipitation patterns make an electric utility system predicated on thermoelectric power plants increasingly vulnerable to water constraints. Our analysis shows that these vulnerabilities can be lessened by reducing the water intensity of thermoelectric generation, decreasing the electric grid's re-

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[191] *See id.*

[192] *See id.*

liance on thermoelectric generation, and improving data collection and dissemination on the link between electricity and water.

First, many technologies already exist to reduce the water intensity at thermal power plants. The most water intensive part of thermal plants, cooling cycles, can use commercially available recirculating and dry systems to reduce withdrawals. Alternative sources of water, including both waste water and water capturable in power plant processes, can displace fresh water use. More efficient power plants also use less water. Reducing the water intensity of thermal power plants would lessen the risks from water vulnerabilities while maintaining the current generation paradigm, but it faces challenges in cost and in retrofitting.

Second, taking actions to shift our electric grid away from reliance on thermoelectric plants can reduce water related reliability concerns. These actions could include placing a moratorium on new thermoelectric generation while increasing energy efficiency, demand side management, and renewable energy production. Moratoriums on some forms of thermoelectric power plants have already been called for. Energy efficiency can reduce load growth to the point where additional generation is not needed. Increasingly cost competitive solar PV and wind can displace current water intensive generation.

Third and finally, increasing and widening our understanding of how water constraints affect electricity will better enable us to address the challenge. The average individual—both private consumer, and even public official—is all too unaware of this close connection and does not behave accordingly. Government agencies are collecting data about water use at thermal plants that is inconsistent and incomplete. By improving data collection systems we can better understand past and potential conflicts. Importantly, this data can be used to inform policymakers who can then make better decisions about how to manage the electricity-water nexus.