Avoiding Water-Intensive Energy Production: How to Keep the Water Running and the Lights On

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Editors' Summary

The confluence of growing water demand and global warming impacts are stressing U.S. water supplies. Water shortages pose a major threat to the reliability and affordability of U.S. electricity because 96% of the nation's power comes from thermoelectric and hydropower facilities that require sufficient water to function. State legislatures, energy-planning agencies, and water boards should work in concert to encourage deployment of technologies that will reduce the amount of water needed to produce electricity. Deployment of water-efficient energy facilities is suitable under both riparian and prior appropriation water systems.

Water supply and energy production are inextricably linked. Thermoelectric power generators—including nuclear, coal, natural gas, petroleum, biomass, municipal solid waste, geothermal steam, and concentrating solar—account for 89% of the U.S. power supply.[1] These facilities, which rely on water to drive and cool their turbines, are responsible for 41% of all U.S. freshwater withdrawals, more than any other sector.[2] Hydropower facilities are also completely reliant on freshwater to power their turbines and account for 6.7% of U.S. power generation.[3] Thus, about 96% of U.S. power comes from sources that require sufficient water resources to function. At the same time, the use of fossil fuels to produce electricity contributes to global warming that impacts water supplies.

This Article argues that state legislatures, energy-planning agencies, and water boards should work in concert to encourage deployment of technologies that will reduce the amount of water needed to produce energy. Part I describes how traditional thermoelectric and hydropower facilities use water. Part II discusses the looming problems of water shortage and excessive water heat, the implications of these problems for our electricity reliability in light of our dependence on water-intensive power sources, and the opportunity cost of assigning water to support a power plant. Part III compares emerging thermoelectric technologies and other power sources, such as wind and solar photovoltaics, in order to show which options are most viable in various conditions. Finally, Part IV makes recommendations to encourage the deployment of water-efficient energy facilities under both riparian and prior appropriation water systems.

I. How Power Facilities Use Water

This part of the Article describes how traditional thermoelectric and hydropower facilities withdraw and con-

Author's Note: The views expressed here are the personal views of the author and do not necessarily reflect the views of current or past employers.

1. U.S. Energy Information Administration (EIA), Electricity Net Generation: Total (All Sectors), 1949-2009, http://www.eia.doe.gov/cneaf/electricity/epm/epm_sum.html (last visited Sept. 18, 2011) [hereinafter EIA Electricity Net Generation]; Paul Torcellini et al., Consumptive Water Use for U.S. Power Production, NREL/TP-550-33905 (2003), *available at* http://www.nrel.gov/docs/fy04osti/33905.pdf.
2. Joan F. Kenny et al., Estimated Use of Water in the United States in 2005, U.S. Geological Survey Circular 1344 37 (2009), *available at* http://pubs.usgs.gov/circ/1344/. By comparison, other sectors with major withdrawals include agricultural irrigation at 37% and public supply at 13%.
3. EIA Electricity Net Generation, *supra* note 1. The only actual withdrawal from hydropower facilities is from increased surface water evaporation from reservoirs since the rest of the water is returned to the river. Torcellini et al., *supra* note 1, at 2.

sume water, the issues raised by the unconsumed water that the facilities discharge, and the implications of various fuel choices.

A. *Thermoelectric Power Plants*

Thermoelectric generating facilities, which account for 89% of U.S. power generation, use an energy source to turn water into steam.[4] The steam then drives a turbine that generates electricity. These facilities also use water to cool and condense the steam at the turbine exhaust. There are two main types of traditional thermoelectric power plants: open-loop; and closed-loop.

1. Open-Loop Thermoelectric Facilities

Most thermoelectric facilities built before 1970 use an open-loop (also known as once-through) cooling process, whereby they withdraw water for cooling and discharge the heated water back to the source.[5] These open-loop facilities are situated adjacent to water surfaces and account for 42.7% of U.S. thermoelectric capacity.[6] While they account for 92% of water withdrawals for thermoelectric generation, they only actually consume 1% of withdrawn water through evaporative loss.[7] Both the withdrawal and discharge of water by open-loop plants have potential environmental consequences.[8] Aquatic life can be harmed when it makes contact with water intake screens, slips through those screens into the cooling system, or is exposed to warm discharge water.[9] Under §316(a) of the Clean Water Act (CWA),[10] state permits for thermoelectric facilities must set thermo discharge limits that protect downstream ecosystems from excessive heat. In addition, CWA §316(b) requires that the location, design, construction, and capacity of cooling water intake structures reflect the best technology available for minimizing adverse environmental impacts.[11]

2. Closed-Loop Thermoelectric Facilities

Most thermoelectric facilities built since the mid-1970s use a closed-loop (also known as recirculation) process, whereby the heated cooling water is pumped through cooling towers or evaporative cooling ponds, allowed to cool, and then reused.[12] These facilities currently account for 41.9% of U.S. thermoelectric capacity.[13] They withdraw less than 5% of the water withdrawn by open-loop systems, but most of that water is consumed through evaporation.[14] While closed-loop systems do not present the discharge problems posed by open-loop facilities, their greater overall consumption means that less water is available for downstream consumptive uses or to support the downstream ecosystem.

3. Fuel Types for Thermoelectric Facilities

The choice between an open-loop and closed-loop structure is the most important determinant of a power plant's water intensity, or the amount of water required to produce a unit of energy. However, fuel choice is also important. Thermoelectric facilities can run on a host of energy sources, including nuclear, coal, natural gas, petroleum, biomass, municipal solid waste, geothermal steam, and concentrating solar. The following chart shows the water consumption of open-loop and closed-loop facilities using these fuel sources.

In addition to imposing different water requirements at the electricity generation stage, different amounts of water are required to produce these fuels. A community's selection of a fuel for its energy facility may have little bearing on its own water resources since the fuel production may occur far away. However, given the national nature of our water choices, even more distant water implications are worth noting. The uranium that powers nuclear plants has the most water-intensive production process of any thermoelectric fuel, requiring 45-150 gallons per megawatt hour (gal/MWh).[15] In addition to water used to mine the uranium, the process of converting the raw ore to finished reactor fuel involves several steps that use water, including milling, enrichment, and fuel fabrication.[16] Production of coal fuel is also water-intensive, requiring 5-70 gal/MWh.[17] Underground coal mines use water to cool the cutting surfaces of mining machinery and prevent friction-

4. EIA Electricity Net Generation, *supra* note 1.
5. U.S. Department of Energy (DOE), Energy Demands on Water Resources, Report to Congress on the Interdependency of Energy and Water 18 (2006), *available at* http://www.sandia.gov/energy-water/docs/121-RptToCongress-EWwEIAcomments-FINAL.pdf [hereinafter Energy Demands]. Only 10 open-loop cooling plants have been built since 1980. *Id.*
6. National Energy Technology Laboratory (NETL), Estimating Freshwater Needs to Meet Future Thermoelectric Generation Requirements 13 (2008), *available at* http://www.netl.doe.gov/technologies/coalpower/ewr/pubs/2008_Water_Needs_Analysis-Final_10-2-2008.pdf [hereinafter NETL].
7. Kenny et al., *supra* note 2, at 38.
8. Energy Demands, *supra* note 5.
9. *Id.*
10. 33 U.S.C. §§1251-1387, ELR Stat. FWPCA §§101-607.
11. *Id.* §1326(b); *see also* U.S. Environmental Protection Agency (EPA), Cooling Water Intakes (§316b), http://water.epa.gov/lawsregs/lawsguidance/cwa/316b/basic.cfm (last visited Sept. 13, 2011) (discussing EPA's rulemaking regarding the best available technology requirement).
12. Energy Demands, *supra* note 5, at 19.
13. NETL, *supra* note 6, at 11.
14. *Id.*
15. World Economic Forum, Thirsty Energy: Water and Energy in the 21st Century 22 (2009).
16. *Id.*
17. *Id.* at 21.

Water Intensity of Thermoelectric Facilities in Gallons per Megawatt/hour (gal/MWh)

	Open-Loop		Closed-Loop (Tower)		Closed-Loop (Pond)	
Plant-Type	**Steam Condensing Withdrawal**	**Steam Condensing Consumption**	**Steam Condensing Withdrawal**	**Steam Condensing Consumption**	**Steam Condensing Withdrawal**	**Steam Condensing Consumption**
Nuclear	25,000-60,000	~400	500-1,100	400-720	800-1,100	~720
Fossil/Biomass/ Municipal Solid Waste	20,000-50,000	300	300-600	300-480	500-600	~480
Geothermal Steam	NA	NA	~2,000	~1,400	NA	NA
Solar Trough (concentrating solar)	NA	NA	760-920	760-920	NA	NA
Solar Tower (concentrating solar)	NA	NA	~750	~750	NA	NA

Source: U.S. Department of Energy, Energy Demands on Water Resources, Report to Congress on the Interdependency of Energy and Water 38 (2006).

induced ignition of coal dust or gas.[18] Surface coal mines use water to control dust from the mining process and on roads entering the mines.[19] Water is also generally used as a cleansing agent to reduce ash and sulfur content in bituminous coal.[20] However, water contamination, rather than use, is the primary concern in coal mining. Coal mining that involves mountaintop removal fills in streams with displaced rock and soil.[21] Drainage that seeps from coal mines and mining waste can also lead to the contamination of downstream water with dissolved metals that include lead, zinc, copper, arsenic, and selenium.[22] Production of traditional oil and gas resources requires little water; in fact, more water is actually produced in the process.[23] However, production of shale gas uses significantly more water than traditional gas production, requiring 34-51 gal/MWh.[24] Biomass thermoelectric facilities often utilize forest or agricultural waste material.[25] No irrigation is used to produce the forest waste, and the agricultural waste does not require any water beyond that used to produce the primary crop.[26] Conventional geothermal relies on naturally heated water or steam to produce the energy, but no additional water is required for the production of that energy source.[27] While sunlight is the energy source for concentrating solar, a thermodynamic fluid (molten salt or oil) is required to transfer the sun's energy into electricity.[28] Production of the thermodynamic fluid can itself require water.

B. *Hydropower Facilities*

Hydropower facilities utilize river water flow and dams to run water through turbines that generate electricity. Water flow through these turbines averages 3,160 billion gallons per day (bg/d), or nearly 10 times the total U.S. water withdrawals from rivers.[29] The U.S. Geological Survey does not report this water flow through hydroelectric turbines as withdrawn water because it remains in the river and, in fact, can be used multiple times by successive dams.[30] Where hydropower projects involve large storage reservoirs, evaporation can result in 3.8 bg/d in consumption.[31] Despite the lack of withdrawal and minimal consumptive use, hydropower facilities require an enormous amount of available water to function. As such, those non-hydropower facilities that consume river water can affect the viability of hydropower facilities.

II. Risks of Relying on Water-Intensive Power Sources

This part of the Article first shows that the confluence of growing water demand and global warming impacts are stressing U.S. water supplies. It then discusses how water shortages affect the availability and affordability of power in communities that continue to rely on thermoelectric facilities. Finally, it warns that those communities will be forced to make tough choices between competing water uses.

18. *Id.* at 20.
19. *Id.; see also* Energy Demands, *supra* note 5, at 53 (explaining that surface mining of western coal requires less water than underground mining of eastern coal).
20. World Economic Forum, *supra* note 15, at 20.
21. *Id.*
22. *Id.* Exposure to water and oxygen acidifies the drainage from coal mines and mining waste. The acidic drainage water dissolves some metals that are present in the rock and soil. These metals are then carried throughout the watershed and can be absorbed by plant and animal life in the food chain. *Id.*
23. World Economic Forum, *supra* note 15, at 17.
24. *Id.* at 18 (converting source unit of gallon per million British thermal units (gal/MMBtu) to gal/MWh).
25. Union of Concerned Scientists, The Energy-Water Collision: Managing the Rising Tide of Biofuels 4 (2010), *available at* http://www.ucsusa.org/assets/documents/clean_energy/biofuels-and-water.pdf.
26. *Id.*
27. U.S. DOE, Energy Efficiency and Renewable Energy (EERE), Geothermal Technology Program, Geothermal Basics, http://www1.eere.energy.gov/geothermal/geothermal_basics.html (last visited Sept. 18, 2011).
28. U.S. DOE, EERE, Energy Basics, Thermal Storage Systems for Concentrating Solar Power, http://www.eere.energy.gov/basics/renewable_energy/thermal_storage.html (last visited Sept. 18, 2011).
29. Energy Demands, *supra* note 5, at 20.
30. *Id.*
31. *Id.*

A. *The One-Two Water Punch: Shortages and Excessive Heat*

Both water shortages and excessive water temperatures can affect the cost and availability of power from thermoelectric facilities. Water shortages are caused largely by increasing demand and global warming impacts. Climate change also exacerbates the heat waves that cause problematic increases in water temperatures.

1. Water Shortages

Between 1950 and 2005, the increase in U.S. water withdrawals outpaced population growth, with water demand growing from 180 bg/d to 410 bg/d (127%) and population increasing from 150.7 million to 300.7 million (100%).[32] Thermoelectric facilities that powered economic growth and quality of life improvements drove the growing demand for water in that period, with a fivefold withdrawal increase of 40 bg/d to 201 bg/d.[33] By comparison, irrigation withdrawals only increased from 89 bg/d to 128 bg/d during that same period due to efficiency improvements.[34] Although the U.S. Department of Agriculture projects that overall water demand will only increase 7% by 2040, the U.S. Government Accountability Office (GAO) warns that this estimate could be conservative.[35]

Increasing water demand is especially troubling in light of global climate change that is reducing water supplies in some places. In 2007, the Intergovernmental Panel on Climate Change (IPCC) released its Fourth Assessment Report, which found that droughts have become longer and more intense and have affected larger areas since the 1970s.[36] The IPCC projected that warming in western mountain regions would cause decreased snowpack and reduced summer flows,[37] exacerbating competition for overallocated water resources.

As withdrawals from surface and groundwater sources outpace the rate of replenishment, many communities face serious water shortages. According to a recent GAO survey, even under normal conditions, water managers in 36 states anticipate water shortages in localities, regions, or statewide within the next 10 years.[38] Under drought conditions, 46 state water managers expect shortages during that period.[39]

2. Excessive Heat

The 2007 IPCC report also found that 11 of the 12 preceding years ranked among the 12 highest temperature years on record, and that hot days, hot nights, and heat waves have become more frequent over the last 50 years.[40] High ambient temperatures can cause freshwater to become so warm that §316(a) of the CWA, described in Part I, precludes the discharge of any warm cooling water from open-loop thermoelectric facilities. This problem could become more pronounced, given that the IPCC projects a continued increase in the number, intensity, and duration of heat waves over the course of this century.[41]

B. *Power Reliability Risks*

In the face of rising water stress and temperatures, our dependence on water-intensive electricity generators threatens the reliability of our power supply. Thermoelectric power plants can be forced to shut down or reduce output in order to divert water to other purposes or avoid violating thermo effluent limits. Beyond quantity and temperature constraints, operation of thermoelectric facilities becomes impossible if the water level of the river or lake supplying cooling water falls below the placement of cooling water intake structures.[42] Areas that rely on hydropower are at particular risk during periods of drought because less hydropower can be generated. This in turn results in a larger demand on thermoelectric facilities, which at the same time are contending with the more limited water supply.[43]

In recent years, water stress and excessive heat have led at least one dozen power plants to temporarily reduce their power output or shut down entirely.[44] During a 2002 drought, lawmakers in Idaho withheld water from five large coal- and gas-fired power plants in order to preserve sufficient freshwater for drinking and irrigation.[45] Also in 2002, a Georgia state judge reduced the amount of water Georgia Power could withdraw from the Chattahoochee River due to drought conditions.[46] In Nevada, the 1,580 MW coal-fired Mohave Generation Station was forced to close in 2005 due to lack of groundwater.[47] Low water on

32. Kenny et al., *supra* note 2, at 42.
33. *Id.* at 42.
34. *Id.*
35. U.S. GAO, Freshwater Supply: States' Views of How Federal Agencies Could Help Them Meet the Challenges of Expected Shortages, GAO-03-514 Highlights (2003), *available at* http://www.gao.gov/new.items/d03514.pdf [hereinafter U.S. GAO Freshwater Supply].
36. IPCC Fourth Assessment Report: Climate Change 2007: Working Group I Summary for Policymakers 6 (Susan Solomon et al. eds., Cambridge Univ. Press 2007), *available at* http://www.ipcc.ch/pdf/assessment-report/ar4/wg1/ar4-wg1-spm.pdf [hereinafter IPCC WG I].
37. Neil Adger et al., Summary for Policy Makers, Contribution of Working Group II to the Fourth Assessment Report of the Intergovernmental Panel on Climate Change Summary for Policymakers 14 (M.L. Parry et al. eds., Cambridge Univ. Press 2007), *available at* http://www.ipcc.ch/pdf/assessment-report/ar4/wg2/ar4-wg2-spm.pdf [hereinafter IPCC WG II].
38. U.S. GAO Freshwater Supply, *supra* note 35, at 5.
39. *Id.* For a list of the 16 major metropolitan areas most likely to face severe water shortages, see Benjamin K. Sovacool, *Running on Empty: The Electricity-Water Nexus and the U.S. Electric Utility Sector*, 30 Energy L.J. 11, 24 (2009).
40. IPCC WG I, *supra* note 36, at 5.
41. IPCC WG II, *supra* note 37, at 18.
42. Ellen Baum, Wounded Waters: The Hidden Side of Power Plant Pollution 13 (Clean Air Task Force 2004), *available at* http://www.catf.us/resources/publications/files/Wounded_Waters.pdf.
43. *Id.*
44. Sovacool, *supra* note 39, at 25-32.
45. *Id.*
46. Baum, *supra* note 42.
47. Sovacool, *supra* note 39, at 25-32.

the Missouri River often leads to blocked screens, reduced efficiency, and lower power generation at thermoelectric facilities.[48] During a summer 2010 heat wave, water temperatures in the Tennessee River hit 90°F. To avoid violating thermo effluent standards, the Browns Ferry nuclear plant was forced to run at less than 60% capacity for nearly five consecutive weeks, at a time when the region faced high electricity demand for air conditioning.[49]

All these examples show that the United States faces serious electricity reliability concerns as a result of its dependence on water-intensive power sources in water-stressed areas or areas prone to excessive heat.

C. Opportunity Cost: Alternative Water Uses

There are always opportunity costs when a community allocates water to support a power plant, instead of assigning it to public supply, agricultural, recreational, or environmental uses. The economic losses that droughts impose on various economic sectors and the environment demonstrate that those sectors would benefit greatly if less water were needed for thermoelectric facilities, especially in times of water scarcity.

While national estimates are not available, regional and state estimates provide some insight into the economic costs of insufficient water supplies for various non-power sectors. Agricultural sectors are perhaps hardest hit during water shortages. A summer 1998 drought cost the agriculture and ranching sectors of Oklahoma and Texas and eastward to the Carolinas $6 to $9 billion.[50] The Susquehanna River Basin Commission reported that a 1999 drought cost the state of New York $2.5 billion and Pennsylvania $500 million in crop losses, with some farmers losing as much as 70 to 100% of their crops.[51] The Washington State Department of Ecology estimated that a 2001 drought cost between $270 million and $400 million in damages to the state's agricultural production and a loss of 4,600 to 7,500 agricultural jobs.[52] Other sectors also suffer when they cannot obtain sufficient water. In March 2002, New Jersey suspended distribution of water for construction or use by any new structure in three townships, a move that was costly to building suppliers and other construction-related businesses.[53]

Insufficient water can also result in environmental losses, including damages to plant and animal species, wildlife habitat, and water quality. For example, diminished flows into the Florida Everglades have resulted in significantly reduced habitat for the wildlife population and a 90% reduction in the population of wading birds.[54] While the CWA and the Endangered Species Act[55] establish some baseline requirements regarding water quality and quantity, excessive use of water for electricity production during times of plenty means less water is reserved in reservoirs for environmental purposes during periods of shortfall. Further, the stringency of water quality and quantity requirements often depends on the designated use of the area, meaning that environmental degradation is more likely when areas that are assigned a lower designated use experience water shortages.

Non-power sectors could experience water shortages during times of drought, even if no water were used for thermoelectric power facilities. However, any reduction in water needed to produce power will help insulate other sectors from more excessive losses. Even when there is no drought, reducing our reliance on water-dependant power sources would make more water available to other sectors, thus allowing them to deliver greater economic benefits. More economic analyses are needed on the economic benefits that non-power sectors would produce if they were to receive some of the water that is currently allocated to thermoelectric facilities.

Unfortunately, the United States is at a crossroads where it is at risk of devoting more scarce water to thermoelectric facilities rather than less. The U.S. Energy Information Administration recently projected that U.S. electricity demand will grow by 31% between 2009 and 2035.[56] Even if demand-side efficiency improvements curb this increase, new power facilities will be required to replace retiring facilities and meet new demand. Indeed, some of this new power generation could come from advanced, supercritical boilers and turbines that deliver greater fuel efficiency, but operate at a higher temperature and thus require more water for cooling purposes.[57] The economic losses suffered by non-power sectors during water shortages show that any continued or additional commitment of water resources for electricity generation will close out other important economic opportunities.

III. Alternative Technologies

While Part I described traditional open-loop and closed-loop thermoelectric facilities and fuel options, there are also alternative technologies that have the potential to reduce the water intensity of energy production. This part of the Article describes these technologies, which include advanced cooling for thermoelectric facilities, combined-cycle gas turbines, and renewable electricity options. Each description summarizes how the technology works, evaluates its water usage, and discusses other benefits and drawbacks of the technology.

48. Energy Demands, *supra* note 5, at 30.
49. U.S. Nuclear Regulator Commission, Power Reactor Status Reports for 2010, http://www.nrc.gov/reading-rm/doc-collections/event-status/reactor-status/2010/ (last visited Sept. 7, 2011).
50. U.S. GAO Freshwater Supply, *supra* note 35, at 67.
51. *Id.* at 68.
52. *Id.*
53. *Id.*
54. *Id.* at 70.
55. 16 U.S.C. §§1531-1544, ELR Stat. ESA §§2-18.
56. U.S. EIA, Annual Energy Outlook 73 (2011), *available at* http://www.eia.gov/forecasts/aeo/pdf/0383(2011).pdf (last visited Sept. 20, 2011).
57. NETL, Advanced Research, High Performance Materials, Ultrasupercritical, http://www.netl.doe.gov/technologies/coalpower/advresearch/Ultrasupercritical.html (last visited Sept. 24, 2011).

A. *Advanced Cooling for Thermoelectric Power Plants*

The two main advanced cooling technologies for thermoelectric power plants are dry cooling and hybrid cooling. These technologies can be applied to all the traditional thermoelectric facilities that require water, including nuclear, coal, oil, biomass, municipal solid waste, geothermal steam, and concentrating solar.

1. Dry Cooling

Dry cooling is a newer technology for closed-loop facilities that replaces evaporative cooling towers with dry cooling towers, using ambient air instead of water to provide cooling capacity. While this approach virtually eliminates water use, the need to maintain the desired steam-condensation temperature raises operational control challenges.[58] Dry cooling also reduces a plant's efficiency, so that more fuel input is required per unit of electricity output.[59] This is because dry cooling can approach only the ambient air temperature, while evaporative cooling approaches the lower dew-point temperature, thus providing more effective cooling.[60] While dry cooling is generally only about 2% less efficient over the course of one year, its relative inefficiency increases to up to 25% in hot, arid weather when energy demand is highest.[61] Decreased plant efficiency means increased fuel use and higher emissions.[62] As a result, plant operators must pay more for the fuel itself, as well as for costly pollution control technology. Dry cooling systems are also larger than wet closed-loop systems, and their size makes them more expensive to construct, install, operate, and maintain.[63] One study estimates that dry cooling will increase the cost of electricity over evaporative cooling by only 2-5%,[64] while another predicts a larger increase of 6-16%.[65] The cost penalty is highest when the plant is located in a hot climate where the inefficiency is more pronounced.[66]

2. Hybrid Cooling

Hybrid cooling involves a closed-loop system that combines dry and wet cooling to reduce water use relative to wet systems while improving hot-weather performance relative to dry systems.[67] The most promising approach for conserving water with this technology involves a parallel wet-dry system that employs both a dry tower and a conventional wet tower, with the latter handling the majority of cooling during hot weather.[68] While this approach helps reduce efficiency losses, it delivers reduced water savings as compared to dry cooling since it still involves a wet cooling tower. Also, the need to balance steam flow between two separate cooling systems makes operational control even more challenging than in dry cooling systems.[69] Finally, hybrid cooling also appears to be most effective for small power plants. In the United States, most hybrid cooling systems are at units that have generating capacities of less than 100 MW.[70]

B. *Combined-Cycle Gas Turbines*

Gas-powered turbines provide about two-thirds of the power generated by these facilities, while the hot exhaust is used to produce steam that drives a turbine that provides the rest of the generation.[71] Since the facilities only rely on water to condense steam, they use about one-half as much water as traditional thermoelectric plants.[72]

There are two kinds of combined-cycle gas turbines: Natural Gas Combined Cycle (NGCC); and Integrated Gasification Combined Cycle (IGCC).[73] NGCC has become more common in recent years because it produces less air pollution than traditional coal facilities, but the popularity of these plants has been curbed by uncertainty regarding future natural gas prices.[74] The water savings from these facilities are also undermined by the emerging practice of extracting natural gas from shale deposits, which can affect water quality and strain water supplies in local communities.[75] IGCC power plants are fueled by coal that has been converted to synthetic gas.[76] Unfortunately, the fuel conversion process is costly and itself requires water.[77] While both kinds of combined-cycle gas turbines have the potential to curb global warming emissions where they incorporate carbon capture and storage, that technology demands additional water and as yet is commercially unproven.[78]

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58. Wayne C. Micheletti & John M. Burns, Emerging Issues and Needs in Power Plant Cooling Systems 5-6 (U.S. DOE 2002), *available at* http://www.netl.doe.gov/publications/proceedings/02/EUW/Micheletti_JMB.PDF.
59. Energy Demands, *supra* note 5, at 37; *see also* Micheletti & Burns, *supra* note 58, at 5-6.
60. Energy Demands, *supra* note 5, at 37.
61. *Id.*
62. *Id.*
63. Micheletti & Burns, *supra* note 58, at 5.
64. John S. Maulbetsch, Water Conserving Cooling, Status and Needs 15 (2006).
65. Energy Demands, *supra* note 5, at 40.
66. *Id.*
67. *Id.*
68. *Id.*
69. Micheletti & Burns, *supra* note 58, at 5.
70. *Id.* at 6.
71. Energy Demands, *supra* note 5, at 41.
72. *Id.*
73. *Id.*
74. *Id.* Coal is a more affordable raw fuel, at an average input cost of $2.07 per MMBtu in 2008, compared with $9.11 per MMBtu for natural gas. U.S. EIA, Table 4.1. Receipts, Average Cost and Quality of Fossil Fuels: Total (All Sectors), 1995 through August 2009, http://www.eia.doe.gov/cneaf/electricity/epm/table4_1.html. It should be noted that 2008 represented an unusually costly year for natural gas, with the chart showing an average cost of $6.94 per MMBtu in 2006 and $7.11 per MMBtu in 2007, though the erratic nature of natural gas prices creates its own "cost" in the form of uncertainty.
75. John Rogers & Erika Spanger-Siegfried, *The Energy-Water Collision*, Catalyst, Fall 2010, at 7, 8.
76. U.S. DOE, Gasification Technology R & D, http://www.fossil.energy.gov/programs/powersystems/gasification/index.html (last visited Sept. 20, 2011).
77. Energy Demands, *supra* note 5, at 41.
78. *Id.*

C. Renewable Electricity

Several renewable energy technologies require no freshwater to operate. Geothermal hot water systems that are air-cooled, solar thermal power with integrated storage, biomass facilities, and ocean energy systems provide consistently dispatchable power, though they carry high manufacturing and deployment costs.[79] Wind power and solar photovoltaic modules are more cost-effective than these other technologies.[80] There were 36,698 MW of installed wind capacity as of the third quarter of 2010,[81] and there were 1,676 MW of installed photovoltaics at the end of 2009.[82] Although these two electricity sources are intermittent and must be backed up by other generating systems, connecting modest amounts of intermittent renewable energy sources to the grid has not undermined grid stability since electricity demand fluctuates throughout the day.[83] In fact, solar photovoltaics provide power when it is most needed, during the hottest part of the day.[84] There is also potential for improved storage capacity for intermittent energy sources.[85] Broader deployment of these technologies will require overcoming transmission challenges since the best energy sources are often located far away from population centers.

D. Tough Choices

Ensuring that all new thermoelectric facilities are closed-loop is a simple way to curb the water withdrawals needed to meet electricity demand, though that approach will increase overall consumption. To reduce both water withdrawals and consumption, utilities could also deploy some of the emerging technologies discussed above. Each of these technology options brings benefits and challenges. Dry cooling virtually eliminates a plant's water withdrawal and consumption, but the efficiency losses in hot weather make it most suitable for cooler climates. Hybrid cooling delivers more modest reductions in water demand and imposes serious operational challenges, but it can function effectively in warmer climates. Combined-cycle gas turbines powered by natural gas or synthetic coal gas can reduce water demand within the facilities, but natural gas prices are uncertain, synthetic coal gas is costly, and both fuels require water to produce. Although several renewable energy technologies can eliminate water consumption, some of them present cost barriers, and the more affordable wind and solar options pose transmission and storage challenges. The potential for increased power costs is a consideration in assessing all these options. However, these technologies could become more cost-competitive if energy-planning agencies consistently account for future water availability and alternative uses for water in deciding how to meet electricity needs.

IV. Addressing Water Issues When Selecting Power Plants

This part of the Article first describes how energy-planning entities fail to adequately consider water availability in deciding whether to approve new power plants or upgrades and then makes recommendations to address this oversight. It next suggests legislation and changes to current water board procedures that could reinforce the selection of more water-efficient power sources.

A. Improving the Current Energy Facility Selection Process

State public utility commissions (PUCs) are consumer protection entities that determine whether a utility will be able to pass on to ratepayers the capital investment cost of constructing or upgrading a power plant.[86] When a utility wants to build or upgrade a power plant, it must make the case to the PUC that the proposed action will deliver affordable, reliable electricity to the public for years to come. The PUC holds public hearings, at which experts and the public can weigh in on the merits and downsides of any proposed options. The PUC's decision can be critical to the viability of a proposed new facility or upgrade because a utility will be reluctant to proceed without an assurance that it can recover its capital investment.

Although water use and consumption have not traditionally been significant factors in decisions related to the selection of power plants,[87] a new trend toward greater coordination between water and power regulators may be emerging. A survey conducted by the Center for Energy and Environmental Policy in 2007 found that three states (California, New York, and Wisconsin) had integrated

79. *Id.* at 41-42.

80. *Id.* Unlike focused or concentrating solar power, solar photovoltaic modules do not require water to produce electricity. Union of Concerned Scientists, The Energy and Water Collision: Ten Things You Should Know, *available at* http://www.ucsusa.org/assets/documents/clean_energy/10-Things.pdf.

81. American Wind Energy Association, 3rd Quarter 2010 Market Report 1 (2010), *available at* http://www.awea.org/documents/reports/2010_third_quarter_report.pdf.

82. Solar Energy Industries Association (SEIA), About Solar Power, http://www.seia.org/cs/about_solar_energy/industry_data (last visited Sept. 3, 2011) [hereinafter SEIA].

83. Energy Demands, *supra* note 5, at 42.

84. *Id.*

85. SEIA, *supra* note 82; *see also* Gene Berry, Present and Future Electricity Storage for Intermittent Renewables 1 (2010), *available at* http://www.pewclimate.org/docUploads/10-50_Berry.pdf; George Marsh, *From Intermittent to Variable: Can We Manage Wind Power?*, Renewable Energy Focus, Nov. 30, 2009, *available at* http://www.renewableenergyfocus.com/view/5595/from-intermittent-to-variable-can-we-manage-wind-power/.

86. Upgrades are essentially renovations required to keep an older plant running that could result in greater production of electricity, emissions, or demand for water. A PUC's rejection of an upgrade proposal will often lead utilities to propose construction of a new facility. In general, water conservation advocates resist upgrades to old facilities since new facilities are more likely to employ closed-loop cooling or other technologies that significantly reduce water withdrawals.

87. Clean Air Task Force and Land and Water Fund of the Rockies, The Last Straw: Water Use by Power Plants in the Arid West 6 (Hewlett Found. 2003), *available at* http://www.catf.us/publications/reports/The_Last_Straw.pdf.

water-energy programs.[88] The survey also found that 10 states (Alaska, Connecticut, Hawaii, Idaho, Maine, Nebraska, Nevada, New Mexico, Texas, and Virginia) had made some commitment to coordination on water and energy, either within the state or as part of a regional initiative.[89] This increased coordination is probably the reason that some utilities have begun to consider water availability in deciding what new facilities or upgrades to approve. Since June 2004, water stress has led at least eight states to deny new power plant proposals.[90] Unfortunately, most PUCs still do not consistently consider future water availability, despite the energy reliability and cost implications discussed in Part II.[91] Even where states have established commissions to develop state water goals or climate-adaptation plans, their PUCs often fail to consider the missions and findings of these commissions in making electricity choices.[92]

To ensure more consistent consideration of water resource issues, PUCs should coordinate with other agencies and commissions to develop an integrated resource plan that addresses a range of resource considerations. Even better, state legislatures could explicitly require PUCs to consider current and future water availability in evaluating proposed energy facilities. Such a requirement would not stray from the PUCs' traditional role in addressing cost and reliability issues since, as shown in Part II, failure to consider water constraints has already resulted in plant shutdowns during periods of peak demand.

Even with such an explicit legislative requirement regarding a PUC's consideration of water availability, energy and water experts, as well as the general public, will need to be vigilant in demanding that PUCs emphasize water considerations in their evaluative process. Indeed, outside experts will often be needed to present water availability issues to PUCs through public comments and hearings. The PUCs should also consider adding water experts to their staffs to flag water considerations internally and respond to issues raised by external water experts.

B. How Smart Water Appropriation Can Encourage Smart Power Choices

State legislatures should also require that PUCs make approval of a proposed power plant or upgrade contingent on a commitment from the local water board that it will allocate water for all or most of the life of the power plant. Water boards should, in turn, resist allocation of water to new power plants or upgrades that are likely to result in unnecessarily excessive water demands. This tougher stance by water boards, combined with a legislative requirement of sufficient water allocations, will force PUCs to reject water-intensive energy proposals.

This section makes recommendations for how legislatures and water boards in the major water appropriation categories—riparian and prior appropriation—can discourage PUCs from allocating water to energy facilities that lack water-saving technologies.

1. Riparian Systems

The riparian doctrine is dominant in the eastern United States. Originally, this system provided that all landowners adjacent to a water body have a right to reasonable use of that water, regardless of which landowners were the first-in-time to use the water.[93] All permitted sectors receive proportionally less water during times of shortage.[94] Riparian systems are now heavily modified; modern legislation requires that one obtain a permit from a water board for most types of water use, and use is no longer restricted to riparian landholders.[95] In assessing whether a proposed new power plant or upgrade constitutes a reasonable use, the water board must weigh the rights of a utility fairly and equitably with the rights of other water users. The 1997 Regulated Riparian Model Water Code, developed by the American Society of Civil Engineers, recommends that the permitting agency consider criteria such as positive and negative impacts of the diversion, efficiency of the proposed use, and preservation of minimum flows and levels.[96] That code recommends that permitting agencies grant fixed-term permits ranging from 20 to 50 years, for a period of time representing the economic life of any necessary investments.[97] In order to encourage selection of water-efficient electricity facilities, riparian water boards should reassess the meaning of reasonable use and relate the duration of the permit to the level of water-efficiency technology employed.

It is becoming increasingly unreasonable to assign water rights to a water-wasting energy facility when, as highlighted in Part II, every gallon diverted from agricultural, municipal, and other uses imposes real economic costs. As water shortages grow more frequent and severe, they will exacerbate these opportunity costs and make wasteful allocations even less reasonable. In order to reduce water stress, water boards in riparian states should be rigorous in evaluating whether allocating water for a proposed energy facility or upgrade actually constitutes a reasonable use. Specifically, they should set a floor, or minimum level of

88. Young-Doo Wang, *Integrated Policy and Planning for Water and Energy*, 142 J. Contemp. Water Research & Educ. 46, 48 (2009).
89. *Id.*
90. Sovocool, *supra* note 39. For example, water considerations played a role in the Arizona Corporation Commission's (equivalent of PUC) to reject two out of three proposed gas-fired power plants that came up for review within a three-month period in 2001. Global Power Report 2001, *North America: Arizona Corp, Commission Turns Down Caithness' 720-MW Big Sandy Project*, Dec. 7, 2001.
91. Sovocool, *supra* note 39, at 15-16.
92. Telephone Interview with Barbara Freese, Clean Energy and Climate Advocate, Union of Concerned Scientists (Nov. 21, 2010).
93. Joseph L. Sax et al., Legal Control of Water Resources: Cases and Materials 27-37 (Thomson West 1986).
94. *Id.*
95. *Id.* at 102.
96. *Id.* at 105-07 (excerpting The Regulated Riparian Model Water Code, Water Laws Committee, Water Resources Planning & Management Division, American Society of Civil Engineers (1997). §§1R-1-01 through 1R-1-14).
97. *Id.* at 115.

water-efficiency technology, that must be employed for a proposed energy facility or upgrade to qualify as reasonable. The water board could rely on internal experts to set a floor, but it might be less controversial to create a panel of academic experts and representatives of various interest groups to advise the water board on an appropriate technology floor. The water board could also provide notice of its proposed water-efficiency technology requirement and allow for public comments before making the requirement final. The panel and public comment period would allow the water board to consider the views of both experts and the public in deciding an appropriate floor for the water-efficiency of proposed energy facilities.

Even with such a floor, the reasonable-use requirement on its own will be insufficient to encourage the deployment of more costly, cutting-edge water-efficiency measures. Therefore, water boards should also create a sliding scale for the duration of fixed water allocation permits, with the longest duration applying to energy facilities that employ the best technologies to curb water demand and the shortest permits applying to the most water-intensive energy facilities. This approach will force utilities and PUCs to favor new, more water-efficient energy facilities because they cannot count on having sufficient water available for the life span of an inefficient facility. Whenever a wasteful energy facility's short-term permit expires, the water board could opt to reallocate its water, especially if the facility's technology is shown to have become obsolete since the original water permit was granted. PUCs would be motivated to avoid this risk by favoring the most water-efficient proposals. Alternatively, the PUC could warn utilities that if they are denied renewal of a short-term water permit for a water-wasting energy facility, they will not be allowed to pass on to consumers the additional capital costs that would be required to build a more efficient facility. Although very unlikely, some foolhardy utilities might accept that risk and then declare bankruptcy if they are denied a permit renewal. Thus, PUCs should strongly favor water-efficient energy facilities that the water board will deem worthy of a long-term water allocation permit that lasts for the life of the facility.

2. Prior Appropriation Systems

Western states employ prior appropriation systems that link water rights to the temporal order of claims, rather than adjacent land ownership.[98] Parties who obtain water rights first generally have seniority for the use of water over those who obtain rights later, thus the system is often succinctly described as "first-in-time, first-in-right."[99] There are three elements for assertion of a water claim under prior appropriation systems: the user must *divert* available water from a natural stream with an *intent* to appropriate it for a *beneficial use*.[100] In modern times, water claimants must perfect their rights by applying for a permit from a local water board.[101] The board will typically grant the permit if the three requirements are met and the appropriation is not detrimental to the public welfare.[102] In order to encourage selection of more water-efficient energy facilities under prior appropriation systems: (1) PUCs must recognize the extreme risks posed by water-wasting facilities in prior appropriation states; (2) state legislatures must assign preference to water-efficient facilities; (3) water boards must challenge inefficient facilities as failing to meet the beneficial use element of appropriation; and (4) legislatures must apply market mechanisms that allow utilities and junior appropriators to share the cost of required water-efficiency improvements.

PUCs should generally be extremely cautious in approving water-intensive energy facilities in prior appropriation states where the utility is a junior appropriator. Unlike the riparian doctrine, where all water users share the shortage in proportion to their permitted allocation rights, prior appropriation systems place the burden of shortages on those who last obtained a legal right to use the water. Thus, a utility that is a junior appropriator may have to shut a plant down entirely in a prior appropriation system during times of shortage, while a similar facility in a riparian system might continue to operate at a reduced capacity.

Opponents of additional capital investments in water-efficiency technologies could counter that even water-efficient systems could be left without any water in a prior appropriation system. Of course, renewable electricity systems that require no water would be able to function regardless of shortages. But what about dry cooling systems that require a very small amount of water for uses other than cooling? In some modern prior appropriation systems, legislatures have passed statutes giving preference to electric utilities and other water users that meet essential public needs.[103] These preference laws may seem inconsistent with the "first-in-time, first-in-right" approach of prior appropriation, but state water rights are generally understood to be conditional, subject to legislative change.[104] While there is certainly a social utility argument for ensuring reliable electricity production, there is an equally strong argument for ensuring that electricity producers use water-saving technologies. As such, state legislatures should amend laws giving a blanket water preference to energy producers, so that preference is contingent on the use of water-efficient technologies. Although some courts have found the application of preference statutes over prior rights to be a taking of property requiring compensation,[105] water-efficient energy facilities would only need a little water, and the cost of compensating senior appropriators would be minimal.

Prior appropriation water boards should also more aggressively question whether an allocation to a water-

98. *Id.* at 124-26.
99. *Id.* at 126.
100. David H. Getches, Water Law in a Nutshell 88 (West Pub. Co. 1997).
101. Sax et al., *supra* note 93, at 215.
102. *Id.* at 234.
103. Getches, *supra* note 100, at 104-05.
104. Joseph L. Sax, *The Constitution, Property Rights, and the Future of Water Law*, 61 U. Colo. L. Rev. 257, 258-59 (1990).
105. Getches, *supra* note 100, at 105.

wasting energy facility constitutes a beneficial use, much as water boards in riparian states should apply a rigorous evaluation of reasonable use. The beneficial use requirement encompasses both the purpose of the use and the requirement that the means of use not be wasteful.[106] While many prior appropriation states have passed statutes establishing that power generation serves a beneficial purpose,[107] a water board could adopt a policy that water-intensive energy facilities are too wasteful to qualify as a beneficial use. This policy would, of course, conflict with the historical tendency of water appropriators to argue "once beneficial, always beneficial."[108] Under that traditional approach, an energy facility that is reasonably water-efficient at the time of initial allocation will forever be entitled to the same amount of water, even after its technology becomes outdated.[109] More recently, some courts and scholars have challenged that approach as allowing absurd water waste. For example, in *State Department of Parks v. Idaho Department of Water Administration*, the Supreme Court of Idaho held that "the concept of what is or is not a beneficial use must necessarily change with changing conditions."[110] Most challenges to beneficial use on efficiency grounds have focused on inefficient agricultural practices—such as poorly lined ditches or excessive irrigation—rather than energy production. To address water disputes stemming from inefficient agricultural practices, legislatures have provided that no more than a certain number of acre-feet of water per acre may be lawfully applied to irrigation. State legislatures in prior appropriation states could use the same approach to prevent water-wasting energy production, setting a floor for the water-efficiency technology that a new or upgraded energy facility must employ in order for the electric utility's water allocation to qualify as a beneficial use. Legislatures would need to periodically update this minimum efficiency requirement to reflect the latest technological advances. In order to withstand legal challenges, such statutes should include a thorough "purpose" section that highlights how reducing the water intensity of energy facilities would improve energy reliability and boost the economic output of other sectors.

Legislatures in prior appropriation states can also establish market mechanisms that ensure periodic water-efficiency improvements at existing energy facilities. Where an energy facility's outdated technology leads to water waste, the legislature could require the utility to either pay for water-saving technology upgrades or buy out junior appropriators who lack access to water as a result of the utility's inefficient facility. Alternatively, the legislature could require junior appropriators to pay for the cost of adding water-saving technology to the energy facility or risk going without water, though this is likely to be a highly unpopular option. A hybrid of these approaches would require the utility to make water-efficiency improvements, but allow it to recoup some of those capital costs by selling the resulting saved water to junior appropriators. While any of these approaches could make existing energy facilities more water-efficient, this hybrid approach would actually give the utility an incentive to develop new water-saving technologies and deploy them at the time of plant construction, when those technologies are most affordable. It would also prevent a situation where junior appropriators opt to shut down rather than pay for costly water-efficiency improvements by allowing them to pay for just the portion of the saved water that they can afford to buy from the utility.

V. Conclusion

Water shortages are already prevalent and are expected to become more frequent and severe as a result of excessive demand and global warming. Fortunately, there are technologies available today—including dry cooling, hybrid cooling, combined-cycle gas turbines, and renewable electricity options—that could drastically reduce the water intensity of U.S. energy facilities. In order to encourage the deployment of these technologies in both riparian and prior appropriation water systems, state legislatures, PUCs, and water boards must unite around the shared goal of reducing the water intensity of electricity production. In the end, water is only one factor in deciding what energy facility is right for a community. Energy-planning agencies must also consider factors such as overall cost, air pollution, global warming impacts, and job creation, among others. However, water availability issues must be considered as well to ensure that communities have access to affordable, reliable power and also have water available for other needs.

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106. *Id.* at 154.
107. *Id.* at 98.
108. Sax et al., *supra* note 93, at 155.
109. *Id.*
110. 530 P.2d 924, 931 (Idaho 1974); *see also* Eric Frefogle, *Water Rights and the Common Wealth*, 26 Envtl. L. 27, 42 (1996), stating:

> [b]eneficial use, as it stands today, is an affront to attentive citizens who know stupidity when they see it; who know, for instance that no public benefit arises when a river is fully drained so that its waters might flow luxuriously through unlined, open ditches onto desert soil to grow surplus cotton and pollute the river severely.