SETTING THE STANDARD

POSITION STATEMENT

ENERGY-WATER NEXUS

ISSUED BY
ASME Board on Government Relations of Public Affairs and Outreach
Center for Research and Technology of Knowledge & Community

This position statement represents the views of the ASME Board on Government Relations (BGR) and the Center for Technology and Research Development (CRTD) and is not necessarily a position of ASME as a whole.

PS12-24 | JUNE 2012

Energy-Water Interdependencies Issue

The American Society of Mechanical Engineers (ASME) Board of Government Relations (BGR) and the Center for Research and Technology Development (CRTD) recommend the development of a national policy that addresses the interdependencies of reliable sources and efficient uses of energy and water. As worldwide demand for both energy and water continues to increase, policies are needed that consider the interdependencies of these critical resources. Trends in energy and water supplies indicate that threats and concerns to energy production as well as quantity and quality of water within the U.S. could reach a crisis situation within the next 10-15 years.

EXECUTIVE SUMMARY

The energy-water-nexus represents a strategic issue for maintaining as well as improving the quality of life in the U.S. and around the globe. Energy is used to treat drinking water, filter and decontaminate wastewater, heat and cool our homes and office buildings, heat up materials for manufacturers and generate steam within power plants.

Potable water is a scarce critical resource that is the lifeblood for every living thing on earth. Over the past several decades, the electrification of many of our devices has helped our economy achieve new levels of productivity and economic expansion, while also exposing areas where improvement is needed in order to sustain progress. As demand increases for more energy, as well as water, one of the key areas for improvement is the relationship between energy usage and water consumption: the "energy-water nexus."

According to the US Environmental Protection Agency (EPA)[1], the U.S. is dependent upon more than 155,000 public water systems for drinking water. Community water systems[2] have been an underinvested asset in the U.S. for decades, compounding the eventual cost to all Americans and threatening the reliability of our water infrastructure. The funding gap for supporting our water infrastructure continues to rise each year. It is imperative that states and municipalities begin now to engage utilities and local stakeholders to develop a roadmap that makes a concerted effort to assess their water needs today as well as decades into the future.

Policymakers at all levels need to understand the significant interrelation between

energy and water and enact policies that reflect this reality. The Energy Information Administration (EIA) estimates that by 2030, the world will be using 50 percent more energy than it uses today.[3] The U.S. may also need 50 percent more water to feed our growing energy demands.[4] This will require new power plants to support not only economic growth, but swelling populations as well. Better information on water use, particularly industrial and residential use, will be necessary in order to effectively manage this resource. With better data, utilities and governments can effectively strategize how they will plan to manage their energy and water use with minimal effect to their citizens.

Innovation in the energy sector. for adapting to water resource constraints and growing energy demands will be crucial to the U.S. Thermoelectric power plants facilities that use heat to generate power) require varying amounts of water and are the largest users of water, defined by fresh water withdrawals from water resources in the U.S.[5] The challenge is to continue to provide enough energy for growing populations, while also conserving water. Creative policies, with buy-in from all stakeholders, are needed for reduced water usage solutions, without disruptions in energy delivery or service.

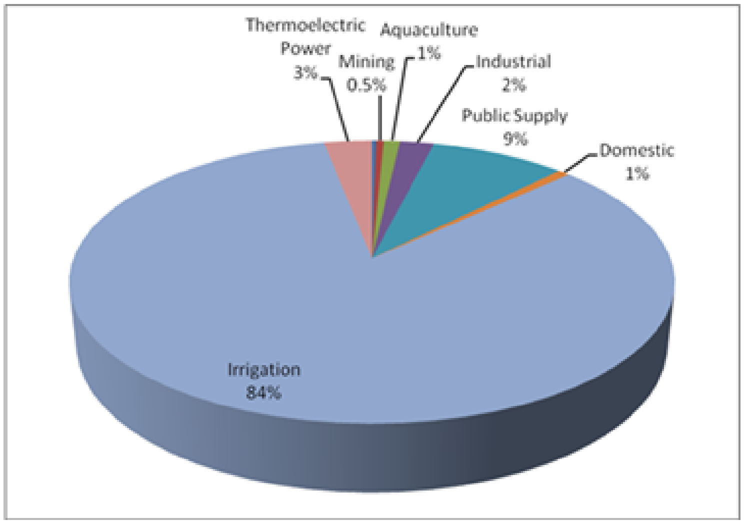
Currently, some hybrid-cooling systems in a few power plants are striking the right balance of plant efficiency, cost-effectiveness, water usage and environmental impact. More test plants are needed to demonstrate the effectiveness of these systems.

Although the water infrastructure within the U.S. has served the nation well for nearly centuries, it is now in dire need of repair and modernization. Substantial increases in infrastructure spending are needed to reflect the migratory shifts in population and the overall decline of the infrastructure itself. Prudent updates will improve energy and water usage, and enhance commerce-related activities.

Background

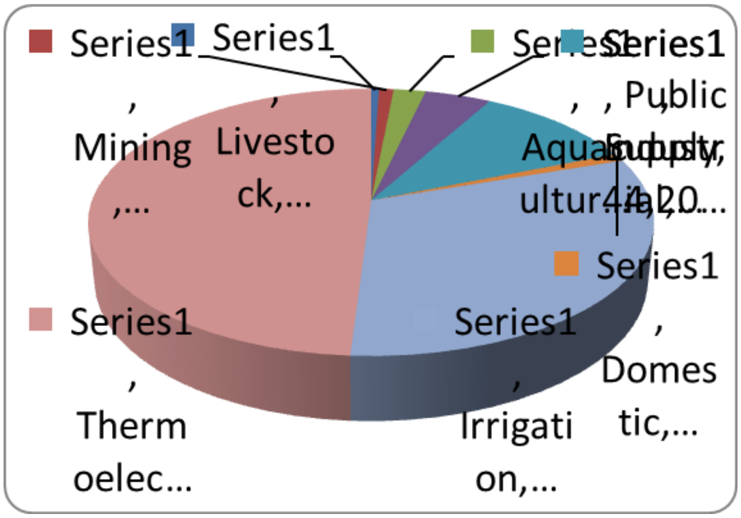
According to the Department of Interior (DOI), approximately 3 percent of all freshwater consumption in the U.S. is related to thermoelectric power production;[6] Figure 1 shows the freshwater consumption in the U.S. Ultimately, providing water relies on energy (usually electricity) and providing primary fuels or generating electricity is also reliant on water. Herein is the “energy-water nexus” – the cross-cutting impacts of water supply and energy production and their interdependency.

Fig. 1 – U.S. Freshwater Consumption (estimated) in 2005



The DOI further estimates that each day 49 percent of the water withdrawn is for thermoelectric power production.[7] The Department of Energy (DOE) estimates that freshwater needs for future electricity production will increase between 28 percent and 49 percent by 2030 depending on the type of cooling technology utilized.[8] Figure 2 depicts the percentages of freshwater withdrawals by each economic sector in the U.S as of 2005.

Fig. 2 – U.S. Freshwater Withdrawals in 2005



Energy and water are inextricably linked, energy production requires water, and water production, processing, distribution, and end-use requires energy. Water filtration systems, at both residential/commercial and industrial wastewater treatment facilities, require energy to efficiently take-in, filter, and redistribute water.

In the U.S., two laws govern much of the use of water: (1) The Safe Drinking Water Act (SDWA), and the (2) Clean Water Act (CWA).

Originally passed by Congress in 1974, and last amended in 1996, the SDWAis the main federal law that ensures the quality of Americans' drinking water. The SDWA authorizes the EPA to set national standards for maximum allowable contaminant levels within drinking water.[9] In addition to regulating the treatment of drinking water, the SDWA also provides grants for water improvement projects.[10]

The SDWA also regulates the use of injection wells through a program called the Underground Injection Control program.[11] These include wells used by energy companies conducting oil and gas exploration. Recently, the EPA, and a number of states, are studying the potential effects of hydraulic fracturing technology (fracking) and of potentially regulating that process. Fracking is a process whereby water and a chemical cocktail mix are injected into shale rock to extract oil and natural gas. Currently the EPA and SDWA do not regulate hydraulic fracturing technology although it is now being regulated by some states.

The CWA governs the discharge of pollutants into U.S. bodies of water, as well as the handling of wastewater discharged from publicly owned treatment facilities. Under the law, industrial and municipal wastewater treatment facilities must obtain and comply with National Pollutant Discharge Elimination System (NPDES) permits to control pollutants that facilities may discharge into the nation's surface waters.[12]

Water Treatment

Water treatment systems play a critical role in supplying drinking water. The basic components of clean water infrastructure are collection systems and treatment works. There are currently more than 155,000 public water systems providing water to 292 million Americans via 52,000 community water systems and another 21,400 non-community water systems.[13] Section 1401(4) of the SDWA defines public drinking water systems (PWS) as systems designed to provide "water for human consumption through pipes or other constructed conveyances to at least 15 service connections or serves an average of at least 25 people for at least 60 days a year."[14] Human consumption means "drinking, bathing, showering, cooking, dishwashing, and maintaining oral hygiene."[15] There are three main types of PWS: Community drinking water systems, Non-transient Non-community Water System (NTNCWS), and Transient Non-Community Water System (TNCWS). Private, individual household wells, are not regulated by EPA.

Below are figures provided by the EPA breaking down each PWS subset:[16]

System	Total Number in U.S.	Total U.S. Population served
Community drinking water systems	52,873	300 million
Non-transient Non-community Water System (NTNCWS)	19,400	6.4 million
Transient Non-Community Water System (TNCWS)	87,672	13.1 million

Generally, water treatment plants consist of several filtration and chemical processes, including the use of nets for removing large debris, chemical treatment in processes like coagulation and sedimentation, and filters comprised of sand, gravel, and charcoal to remove smaller waste particles (similar to many types of water filters found in home faucets).[17] After being thoroughly filtered for bacteria and disinfected, the water is stored in a closed tank or reservoir, allowing time for disinfection. National Primary Drinking Water Regulations (NPDWRs or primary standards) are legally enforceable standards that apply to public water systems. Primary standards protect public health by limiting the levels of contaminants in drinking water.[18] Eventually, the treated water is pressurized for distribution through water infrastructure: pumps, pipes, tanks, valves, hydrants, and meters that support delivery of water to the customer and control flow and water pressure. Treatment plants generally have an expected life of between 20–50 years before they require expansion or rehabilitation.[19]

Signs of Stress

Although water treatment systems have worked effectively in the U.S. for nearly centuries, there are growing signs that this infrastructure is in critical need of being updated. Many cities are heavily reliant upon pipeline infrastructure that was built in the nineteenth century.[20] An analysis by the EPA estimated a 20-year capital gap for clean water infrastructure spending of $122 billion ($6 billion per year) in 2001 dollars.[21] In 2010 alone the total water funding gap was $55 billion, and expanding rapidly.[22]

A large part of water infrastructure deals with piping systems. Pipes transport water back-and-forth among treatment centers, hydrants, faucets and other areas of flow distribution. Older cast-iron pipes have an average useful life of about a century, which means they are now passing their intended shelf-life.[23] In parts of the eastern U.S., the usage for some pipes is approaching 200 years.

Many of these older pipe systems need to be updated. According to the American Society of Civil Engineers (ASCE), each day leaking pipes account for an estimated 7 billion gallons of lost water.[24] The EPA estimates there are more than 240,000 water main breaks each year in the U.S.[25]

Leaky water pipes can mean that as much as 50 percent of the water being delivered could be lost. In 2003, the Congressional Budget Office estimated that $19.4 billion would need to be invested annually in order to keep pace with the current infrastructure problems of the system.[26] Thus far, that figure has not been met by the federal government.

In addition to pipes, the entire U.S. water infrastructure lacks sufficient investment. According to a recent report by the ASCE, at the current pace of underinvestment within the U.S., the need for capital investment in water infrastructure could balloon to $195 billion by 2040.[27] The economic effects, however, will be felt much sooner. By 2020, the water infrastructure deficit could cost businesses and households an additional $206 billion in increased costs, as well as put 700,000 U.S. jobs on the line.

Water Needs Energy and Energy Needs Water

A 2009 report by the River Network estimated water-related energy use is at least 521 million MWh a year or 13 percent of the nation’s electricity consumption.[28]

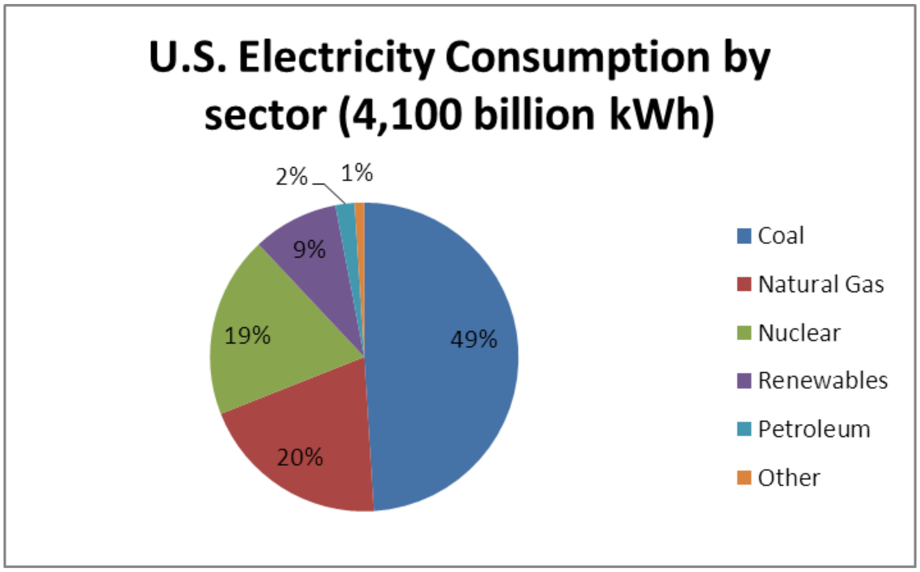
Water and wastewater utilities are typically the largest consumers of energy in municipalities, often accounting for up to 40 percent of total energy consumed.[29]

Careful analysis undertaken at the request of ASME shows a direct link between energy production and increased water usage. As more energy production is sought, more water is needed to supplement the increase demand; likewise, as more water is needed, there is an increase in the demand of energy to supply the water.

Thermoelectric power - power that is generated by the use of heat (nuclear, coal, natural gas, solar, thermal or biomass fuels)[30] - accounts for around 3.3 percent of total freshwater consumption (more than 3 billion gallons per day) and represents over 20 percent of nonagricultural water consumption

According to a report issued by the National Renewable Energy Laboratory (NREL), approximately 89 percent of the energy produced in power plants is generated by thermoelectric systems which evaporate water during the cooling of the condenser water. The rest comes from hydroelectric plants, although this figure has slightly declined as renewable electricity power plants have gone online.[31]

Fig 3 – US Electricity Generation[32]



Electric Power and Water

The largest industrial user of cooling water is the steam electric power industry.[33] In 2005, withdrawal of water for cooling represented 44 percent of water withdrawn nationally and 6 percent of water consumed.[34] There are four cooling technologies for thermoelectric plants: once-through, closed-loop or wet cooling, dry cooling, and hybrid cooling.[35] According to a 2006 Department of Energy (DOE) report, in the U.S. 43 percent of thermal electric generating plants uses once-through cooling, 42 percent wet recirculating cooling, 14 percent cooling ponds and 1 percent dry cooling.[36]

Once-through, or open-loop cooling, is the process whereby large volumes of water are withdrawn from the water source (e.g. a reservoir, lake or a river), flowing through a heat exchanger to condense the steam in a single/multi pass system before being returned to the source.[37] Compared to other cooling systems, open-loop cooling consumes less water per MWh within the power plant, typically between 100 and 400 gal/MWh.[38] The main advantages of open-loop technology are that it is cost-effective compared to dry, or hybrid cooling, and it has low net water consumption.[39] Open-loop wet cooling withdraws a lot of water but consumes relatively little of what it withdraws, while closed-loop wet cooling withdraws less water but consumes a larger proportion of what is withdrawn.[40] There are also aquatic life concerns with open-loop cooling, which can potentially use high salinity water. Due to the potential impact upon water ecosystems, the U.S. Environmental Protection Agency (USEPA) has undertaken the task of preparing a rule on open-loop cooling. Section 316(B) of the CWA requires that the location, design, construction and capacity of cooling water intake structures reflect the best available control technology (BACT) for minimizing adverse environmental impact, specifically fish impingement.[41] This proposed regulation[42] may restrict the future use of this process.

Closed-loop wet cooling is commonly used for many newer power plants. The process involves the use of a cooling tower. The cooling tower withdraws water from a source, condenses steam in a heat exchanger, and then recycles cooling water within the cooling tower. Cooling towers dissipate heat through evaporation of the cooling water. Closed-loop cooling recycles the water within the system, which holds the advantage of requiring less water. However, 80 percent or more of the water cycled through the system is consumed through evaporation, typically at the rate of 110 to 850 gal/MWh making it water intensive.[43]

Air-cooling is a waterless alternative process and opens possibilities for plants to be sited in arid locations or away from fresh sources of water. Air-cooling may involve cooling towers with a closed circuit, or high forced draft air flow through a finned assembly like a car radiator.[44] While air-cooling does not use water, the tradeoff is that these power plants also have a lower cooling efficiency than water cooling, emit more emissions, and cost more to construct and operate.[45]

Hybrid plants use a combination of both water cooling and air cooling; they are a newer technology for power plants. The advantage of a hybrid plant is the significant reduction in water consumption as compared to open-loop cooling; it also provides flexibility to plant operators for the environment around the power plant. The disadvantages are that this technology is not yet widely deployed and it is capital intensive.[46]

Energy and Water by Electricity Source

The chart below was compiled by data from the Virginia Water Resources Research Center. This chart shows the amount of water necessary for each power generation resource to produce 1,000 kilowatt-hours (KWh) (or 1 megawatt-hour (MWh)) of electricity.[47] Some resources that require almost no water in operation, like wind and solar, were excluded from this chart.

Power Generation Technologies	Water Consumption Efficiency (gallons per MWh)
Natural Gas	100-180
Geothermal	1,400
Solar thermal	760-920
Fossil fuel thermoelectric	300-480
Nuclear	400-720
Coal Integrated Gasification Combined Cycle	200

Energy generation accounts for an estimated 27 percent of all water consumed in the U.S. outside the agricultural sector (Electric Power Research Institute 2008).[48] Electricity, gas, coal, and nuclear power plants together consume more than 20% of non-agricultural water.[49] Aside from solar thermal, nuclear can be the most water-intensive electricity source, while wind and photovoltaic (PV) solar renewable energy sources use almost no water.[50] Gas-fired power plants consume about half the average amount of water that is required to support the cooling of coal or oil power plants for the same amount of electricity. Advanced coal-fired power technologies have water consumption rates comparable to coal steam turbine plants, assuming closed-loop cooling technologies for all. New advanced coal facilities may also include carbon-capture and sequestration (CCS) technologies. CCS would substantially increase water consumption if applied to power generation.[51] Nuclear consumes roughly three times more water than gas-fired plants and 1.5 times more than coal- or oil-fired plants.[52]

Traditional wind and PV solar technologies, while consuming almost no water, can be directly utilized to generate electricity.[53] These technologies only represent a small percentage, about 3 percent, of the entire U.S. electricity portfolio. However, as the chart above indicates, solar thermal or concentrated solar power (CSP) is very water intensive. This is a challenge because the most economically viable region of the country for CSP is in a semi-arid climate, i.e. the southwestern U.S. Therefore, in addition to prudent deployment of renewable energy systems in favorable topographies, it is important to develop cooling systems utilizing traditional technologies that require less water, emit fewer emissions, and can account for swelling populations with growing energy demands.

Conclusion

The strong interaction between energy and water will demand an equally strong policy. Moving forward, public policy should be tailored to account for water use as a metric related to overall sustainability of a particular energy system, or an energy resource roadmap. Similarly, better data on current water use, in all sectors of the economy, as well as energy, is necessary in order to better educate the public about their use of water and allow stake holders to make better informed decisions regarding this resource. Coordination at federal, state and local levels, will be crucial, as will innovation in the energy sector. Creative policies can enable industrial best practices that will ultimately lead to lower-water consumption, without disruptions in energy delivery or service.

[1] Public Drinking Water Systems: Facts and Figures http://water.epa.gov/infrastructure/drinkingwater/pws/factoids.cfm

[2] "Community water system means a public water system which serves at least 15 service connections used by year-round residents or regularly serves at least 25 year-round residents." (40 CFR §141.2)

[3] EIA Predicts 50% Increase in World Energy Consumption by 2030 http://redgreenandblue.org/2008/06/30/eia-predicts-energy-50-increase-in-world-energy-consumption-by-2030/

[4] Congressional Research Service: Energy's Water Demand: Trends, Vulnerabilities, and Management http://www.fas.org/sgp/crs/misc/R41507.pdf

[5] Estimating Use of Water in the United States in 2005, Department of the Interior, 2009.

[6] Ethanol, University of Illinois, Urbana-Champaign, Illinois, March 2009.

[7] Estimating Use of Water in the United States in 2005, Department of the Interior, 2009.

[8] Estimating Freshwater Needs to Meet Future Thermoelectric Generation Requirements, Department of Energy/National Energy Technology Laboratory, 2008.

[9] Primary Drinking Water Standards at 40 CFR Part 141.

[10] Understanding the Safe Drinking Water Act http://water.epa.gov/lawsregs/guidance/sdwa/upload/2009_08_28_sdwa_fs_30ann_sdwa_web.pdf

[11] See 40 CFR Part 144

[12] Summary of the Clean Water Act http://www.epa.gov/lawsregs/laws/cwa.html

[13] THE U.S. CONFERENCE OF MAYORS – MAYORS WATER COUNCIL Trends in Local Government Expenditures on Public Water and Wastewater Services and Infrastructure: Past, Present and Future http://www.usmayors.org/publications/201002-mwc-trends.pdf

[14] Definition of a Public Water System http://water.epa.gov/infrastructure/drinkingwater/pws/pwsdef2.cfm

[15] Id.

[16] Public Drinking Water Systems: Facts and Figures http://water.epa.gov/infrastructure/drinkingwater/pws/factoids.cfm

[17] GAO Energy-Water Nexus, Amount of Energy Needed to Supply, Use, and Treat Water Is Location-Specific and Can be Reduced by Certain Technologies and Approaches http://www.gao.gov/assets/320/316893.pdf

[18] Drinking Water Contaminants http://water.epa.gov/drink/contaminants/index.cfm

[19] The Clean Water and Drinking Water Infrastructure Gap Analysis http://www.epa.gov/awi/pubs/816r02020/816r02020.pdf

[20] Drinking Water Infrastructure Key Points

[21] U.S. Water Infrastructure Needs & the Funding Gap http://water.epa.gov/infrastructure/sustain/infrastructureneeds.cfm

[22] GAO Energy-Water Nexus, Amount of Energy Needed to Supply, Use, and Treat Water Is Location-Specific and Can be Reduced by Certain Technologies and Approaches http://www.gao.gov/assets/320/316893.pdf

[23] Aging of Water Mains Is Becoming Hard to Ignore http://www.nytimes.com/2009/04/18/us/18water.html

[24] Experts: U.S. water infrastructure in trouble http://edition.cnn.com/2011/US/01/20/water.main.infrastructure/index.html

[25] Aging of Water Mains Is Becoming Hard to Ignore http://www.nytimes.com/2009/04/18/us/18water.html

[26] Congressional Budget Office (CBO) Future Investment in Drinking Water and Wastewater Infrastructure http://www.cbo.gov/sites/default/files/cbofiles/ftpdocs/40xx/doc4034/01-30-waterletter.pdf

[27] American Society of Civil Engineers (ASCE) Failure to Act: The Economic Impact of Current Investment Trends in Water and Wastewater Treatment Infrastructure http://www.tisp.org/tisp/file/ASCE%20-%20Water%20Infrastructure%20-%20Exec%20Summary(1).pdf

[28] The Carbon Footprint of Water http://www.rivernetwork.org/sites/default/files/The%20Carbon%20Footprint%20of%20Water-River%20Network-2009.pdf

[29] Water & Energy Efficiency http://water.epa.gov/infrastructure/sustain/waterefficiency.cfm

[30] Deep Shale Natural Gas: Abundant, Affordable, and Surprisingly Water Efficient http://www.energyindepth.org/wpcontent/uploads/2009/03/MMantell_GWPC_Water_Energy_Paper_Final.pdf

[31] Consumptive Water Use for U.S. Power Production December 2003 http://www.nrel.gov/docs/fy04osti/33905.pdf

[32] Energy-Water Nexus in Texas http://www.edf.org/sites/default/files/Energy_Water_Nexus_in_Texas_1.pdf

[33] http://www.netl.doe.gov/technologies/coalpower/ewr/water/pdfs/EP%20Final%20Report.pdf

[34] Id.

[35] Water Consumption of Energy Resource Extraction, Processing, and Conversion http://belfercenter.ksg.harvard.edu/files/ETIP-DP-2010-15-final-4.pdf

[36] Cooling power plants http://www.world-nuclear.org/info/cooling_power_plants_inf121.html

[37] Energy-Water Nexus in Texas http://www.edf.org/sites/default/files/Energy_Water_Nexus_in_Texas_1.pdf

[38] Id.

[39] Water Consumption of Energy Resource Extraction, Processing, and Conversion http://belfercenter.ksg.harvard.edu/files/ETIP-DP-2010-15-final-4.pdf

[40] THE WATER-ENERGY NEXUS Adding Water to the Energy Agenda http://www.worldpolicy.org/sites/default/files/policy_papers/THE%20WATER-ENERGY%20NEXUS_0.pdf

[41] Water: Cooling Water Intakes (316b) http://water.epa.gov/lawsregs/lawsguidance/cwa/316b/basic.cfm

[42] National Pollutant Discharge Elimination System--Cooling Water

[43] Energy-Water Nexus in Texas http://www.edf.org/sites/default/files/Energy_Water_Nexus_in_Texas_1.pdf

[44] Cooling power plants http://www.world-nuclear.org/info/cooling_power_plants_inf121.html

[45] Water Consumption of Energy Resource Extraction, Processing, and Conversion http://belfercenter.ksg.harvard.edu/files/ETIP-DP-2010-15-final-4.pdf

[46] Id.

[47] How Much Water Does It Take to Make Electricity? http://spectrum.ieee.org/energy/environment/how-much-water-does-it-take-to-make-electricity

[48] Water Consumption of Energy Resource Extraction, Processing, and Conversion http://belfercenter.ksg.harvard.edu/files/ETIP-DP-2010-15-final-4.pdf

[49] THE WATER-ENERGY NEXUS Adding Water to the Energy Agenda http://www.worldpolicy.org/sites/default/files/policy_papers/THE%20WATER-ENERGY%20NEXUS_0.pdf

[50] Water Consumption of Energy Resource Extraction, Processing, and Conversion http://belfercenter.ksg.harvard.edu/files/ETIP-DP-2010-15-final-4.pdf

[51] Id.

[52] THE WATER-ENERGY NEXUS Adding Water to the Energy Agenda http://www.worldpolicy.org/sites/default/files/policy_papers/THE%20WATER-ENERGY%20NEXUS_0.pdf

[53] Deep Shale Natural Gas: Abundant, Affordable, and Surprisingly Water Efficient http://www.energyindepth.org/wp-content/uploads/2009/03/MMantell_GWPC_Water_Energy_Paper_Final.pdf

---

RELEASE DATE: 6/29/2012