Written Testimony of Kate Zerrenner, Senior Manager, Energy-Water Initiatives, Environmental Defense Fund, kzerrenner@edf.org

Hearing on Energy-Water Nexus

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What is the energy-water nexus?

Energy is used to secure, deliver, treat, and distribute water, while water is used to develop, process, and deliver energy. This inextricable connection is known as the energy-water nexus. The two sectors simply cannot function without each other, but currently neither fully considers the needs and impacts of the other, which is having huge impacts on the availability of both resources. There are steps that the electricity and water sectors can take right now to increase coordination and minimize waste and pollution.

Why does the nexus matter?

Estimates of water-related energy use range from 4-13% of the nation's electricity generation, but regional differences can be significant. In California, for example, as much as 19% of the state's electricity consumption is for pumping, treating, collecting, and discharging water and wastewater.[1] Energy consumption by public drinking water and wastewater utilities, which are primarily owned and operated by local governments, can represent 30-40% of a municipality's energy bill.

Regional differences are stark. For example, a residential home in Las Vegas may use 100 gallons per day for outdoor uses, while homes in Atlanta may use 21 gallons and in Seattle 9 gallons. Further, the most energy-intensive portions of water delivery are usually source pumping and wastewater treatment. EPA estimates that it takes an average of 1.5 kWh of energy to convey, treat, and distribute 1,000 gallons of drinking water in the US.[2] In the southern Los Angeles basin, the estimate is 9.9 kWh per thousand gallons.[3]

Energy-related water use is similarly large. Across the nation, roughly 85 percent of the energy we use today comes from nuclear or fossil fuel power plants[4], which requires 133 billion gallons of water per day or 41 percent of all U.S. freshwater withdrawals.

Not all electricity sources have the same water-intensity. Nuclear and fossil fuel plants, like coal plants, require significant amounts of water to produce electricity. Cleaner electricity resources, like wind and solar, require little to no water.

The energy-water nexus is a cascading problem. If drought conditions exist, there may be limited water for cooling, and therefore reduced power to move water. During hot and dry days, demand for air conditioning spikes, which increases the demand for power, which increases the demand for the diminishing water supply to cool the power system.

[1] http://fas.org/sgp/crs/misc/R43200.pdf
[2] Methodology and Assumption for Estimating Watersense Annual Accomplishments (EPA Watersense)
[3] Cohen, M.; Wolff, G.; Nelson, B.. Energy Down the Drain: The Hidden Costs of California's Water Supply; NRDC 2004
[4] http://www.eia.gov/totalenergy/

Climate concerns

Rising water stress and water supply uncertainties due to climate change and increasing competition add new costs to the water- and energy-intensive water and energy systems for private and public owners alike.

Energy generation is often focused in localized areas where water use is in competition with other users and ecosystems.[5] As the competition for water stiffens, the power sector is no guaranteed winner.

In American Water's Corporate Responsibility Report 2015-2016, the public utility notes that around 90% of their electricity consumption and over 80% of their GHG emissions come from their operational electricity use, largely for pumping water.[6] Research has shown that the average energy efficiency of existing water utility pumps in the field is approximately 55%, which means that about 45% of the energy used is lost to inefficiency. This waste represents significant climate pollution that is avoidable.

Tying water use to power sector policies and planning is likely to result in incentives to increase the use of less water-intensive renewable energy sources, such as solar PV and wind, which are also low-carbon.

It's worth noting water cannot be viewed through a "carbon lens." Unlike GHG emissions, water is not fungible: one unit of water is not equal to another as water withdrawn in an arid, urban area has completely different impacts and associated risks from water withdrawn in a rural, wet region.

Outdated models and silos

Energy and water policies at both the federal and state levels are outdated. For example, they were developed to support traditional central thermal power plants, which are both highly water- and energy-intensive processes. Moreover, the electric and water sectors are using business models with foundations that go back one hundred years.

Policy development, technological advancements, and investment opportunities for energy and water are largely independent rather than coordinated. Even municipalities that own and operate their water and electric utilities often have planning and management systems that operate as though under separate authorities.

Policy and regulatory barriers inhibit cross-sector coordination. The power sector operates under national reliability standards (top-down) while water is much more localized (bottom-up). Each sector has its own regulatory framework and oversight agencies at the state and federal levels, as well as workforce training structures that are not aligned with each other. Water planners typically assume they have the energy that they need, and energy planners assume they have the water that they need. A mismatch in planning objectives by different actors can prevent the beneficial siting and combing of technologies.

Further, federal law that has jurisdiction over the two sectors (the Clean Water Act for water and the Clean Air Act for air quality) can in some instances create a culture of risk aversion because of their punitive nature and the fact that they are sometimes in conflict.

[5] Withdrawal is the amount of the water taken from the water source, whereas consumption is the portion of that water used and not returned to the original source for reuse. It should be noted that water returned to its original source exists in a different condition than when it was first withdrawn, which can contribute to stress on the water supply. The electric sector withdraws more water than any other sector in the U.S., amounting to more than 40%.

[6] https://dnnh3qht4.blob.core.windows.net/portals/0/Customer%20Communications/American-Water-CR-Report.PDF?sr=b&si=DNNFileManagerPolicy&sig=GO0EOgONm4n86rOsHvLCM6iYXTTyNoDP0i3a6fcT3nA%3D

No single platform exists for sound, long-term decisions at the nexus of electricity and water, but those made in isolation will serve neither sector.

Market-driven versus public interest

To a large extent, the energy sector is market-based and run by private, often big companies acting on regional, national, or global markets. Energy efficiency is a driving force for development. Energy is priced on the market and there is a high awareness about energy prices among customers.

The water sector, on the other hand, is dominated by small public utilities acting on regulated markets at the local municipal level. Water is largely characterized by inefficient use or overuse, and incentives for technical advancements are insufficient. There is a low customer awareness of water prices, and marginal cost pricing or cost-recovery pricing is common. The price of water is set based on principles that include affordability and accessibility, and the price does not typically reflect the supply technique or treatment process. The existing water price also does not capture region-specific water conditions or relative water scarcity. As a result, the cost of water can be a small share of overall energy production cost, even for water-intensive users.

Energy and water utilities both experience long investment cycles subject to various levels of regulation, include both public and private actors, and operate under stringent performance expectations. Forward-looking water plans often look 50-60 years ahead, whereas energy plans may look 20-30 years ahead.[7] Private companies acting under market forces often dictate the location of energy infrastructure whereas water infrastructures are often located using more public interest criteria.

Driving up costs

Drought may cause thermoelectric power plants to seek additional water supplies, typically at the expense of reduced water consumption in other sectors, such as agricultural or municipal water use. Procurement of additional water supplies (and corresponding water infrastructure projects) also increases costs for electric consumers.

During recent droughts some power plants, including Luminant's 2,250 MW coal plant in Texas and Duke Energy's 2,200-MW nuclear station in North Carolina, extended their water pipes or added additional pumps in order to accommodate lower reservoir levels or reach new supplies.[8] All of the costs – whether for water rights, infrastructure additions, or purchased power during droughts – are typically passed on to consumers via electricity rate increases.

Quantity versus intensity

Water delivered in the public supply is typically treated to be safe for drinking, as designated by the U.S. Environmental Protection Agency (EPA), and might be pumped long distances from its point of extraction to its point of treatment. Once the water reaches its point of use, municipal customers will often heat, pressurize, cool, or waste (via leaks) water, all of which have important energy implications. Therefore, the volumes of water within the public supply are relatively low in comparison to other sectors, but the energy intensity of water is very high.[9]

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[7] King, Carey W., Stillwell, Ashlynn S., Twomey, Kelly M., and Webber, Michael E. *Coherence between energy and water policies*, prepared for the Organization for Economic Co-operation and Development. September 2010.
[8] http://www.ucsusa.org/sites/default/files/attach/2014/08/ew3-freshwater-use-by-us-power-plants.pdf
[9] http://www.ce.utexas.edu/prof/maidment/giswr2012/TermPaper/Sanders.pdf

While all water is energy intensive, some electricity sources, like nuclear and fossil-fueled energy, are water intensive. The best way to structure policies depends on the goal. If it is to conserve water, implementing more efficient irrigation systems or dry-cooling systems at power plants would provide large savings in water in these sectors.

However, if the goal is to conserve energy, reducing water use in the public supply would be advantageous. This is because the irrigation and thermoelectric power sectors, for example, withdraw large amounts of water, but these sectors do little to it – i.e. treatment and pumping are typically very minimal. The water is typically not heated or pressurized, meaning that the volumes are large, but the energy intensities are not.

In many cases, as the nation's energy system evolves and new infrastructure is deployed, there is a window of opportunity to incorporate water into energy policy discussions and vice versa. In order to make the most of this policy window, communication among actors across multiple sectors is essential. The current energy-water landscape is complex and fragmented. The nation's water and energy policies have developed independently of each other, and in many cases there are strong regional differences in policy frameworks and objectives.

Resilience

Today's water and power sectors are devoting more energy to short-term preparedness than to long-term resilience. Historically focused on providing safe, reliable, and available resources at the turn of a tap or the flip of a switch, these sectors must now navigate a transition to a new paradigm in which sustainability (environmental, economic, and social) and resilience (to acute disasters, chronic challenges, peak demand, and other global trends) become core values.[10]

There are hurdles to jump to enable both the water and energy sectors to help each other become more sustainable and resilient. A basic lack of cross-sector understanding exists—relating to operational needs and constraints and the absence of a common language. Electricity is measured in megawatt-hours (MWh) or megawatts (MW), and water is measured in gallons or acre-feet, neither of which is meaningful to the other sector.

When water from lakes or rivers becomes too scarce or hot to use for cooling, the energy-water nexus can turn into energy-water collisions. Because most power plant decisions are long-lived, our near-term choices commit us to risks for decades. The electricity sector transformation already underway offers an opportunity to make choices that reduce risk and collisions, enhance flexibility, and enhance resilience.

Starting to collaborate

All of the aforementioned hurdles are surmountable. Some can be addressed through short-term policy changes, and some will require a longer effort to change the direction of this cruise ship. To facilitate coordination, a targeted strategy can help to steer policies and processes toward a more sustainable goal.

Both sectors are starting to realize that not only is there a benefit to collaboration, but there is also an imperative to do so as resources in both sectors are coming under greater strain. In November 2014, the National Association of Regulatory Utility Commissioners (NARUC) adopted a resolution to work with appropriate federal authorities to pursue flexible regulatory reforms in energy efficiency in support of the

[10] http://www.johnsonfdn.org/sites/default/files/reports_publications/CNW_ResilientUtilities.pdf

energy-water nexus.[11] And the Western Governors Association has elevated energy-water issues in its planning discussions.

In a study by the Union of Concerned Scientists, it was determined that a low-carbon, water-smart pathway (in which energy efficiency would more than offset growth in electricity demand now projected for 2050, and renewable energy would produce 80% of the power needed to fulfill the remaining demand) could reduce water withdrawals by 97% and water consumption by 85% by 2050 and could also curb local increases in water temperatures from a warming climate. Meanwhile lower carbon emissions would help slow the pace and reduce the severity of climate change, including its long-term effects on water quantity and quality.[12] Renewables and energy efficiency can be a winning combination.

Like the steam that powers a turbine, the increasing tensions between water and energy can be harnessed to drive change and innovation.

The solutions will not lie in constructing some new institutional architecture for nexus governance, which may only compound the problems of inertia and complexity, but in pragmatic and flexible policies that allow for cross-sector collaboration in the strategies, investment planning, and operations of each sector. By using the strength of sectors to implement agreed-upon actions in projects and operations and using the mechanisms and capacities they already have in place and that are effective and accepted within the sector, better coordination and delivery for water and energy could be achieved.

Issues to Consider

Smart Grid & Smart Meters

It is estimated that it will take $325B over the next 20 years to install needed infrastructure replacements in the US water system, including new pipes and meters. One side effect of deteriorating infrastructure is water leaks, which contribute estimated $3.4B each year to water losses for municipalities.[13] Many of the benefits of a networked system, like a comprehensive smart water grid, requires scale to be realized – scale that requires an investment that is difficult in the capital-constrained environment of most water utilities.

While smart meters are increasingly deployed in electrical grids, monitoring of water infrastructure lags significantly. Networks of remote, automated leak detection could help in prioritizing repairs to aging water infrastructure, with concomitant energy savings, particularly in locales with high embedded energy costs of water, such as Southern California and the Southwest.

Nationwide, the amount of water that is lost each year is estimated to top 2 trillion gallons, according to the American Water Works Association, or about 14 to 18 percent (or one-sixth) of the water the nation treats. And utilities are unable charge customers for water that is lost before it gets to them. The data would enable better cost-benefit water planning, identify anomalies in the system, prioritize and inform policies and implementation efforts, identify conservation potential for customers, and provide a mechanism for customer feedback about the rate of consumption and impact of that consumption.

Making daily water use and cost of that use more transparent – and not an end-of-the-month billing surprise – allows users to make their own decisions on how to use the water they purchase more wisely. In

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[11] https://pubs.naruc.org/pub.cfm?id=53A0D354-2354-D714-5149-A219EC3E8A55

[12] http://www.ucsusa.org/sites/default/files/legacy/assets/documents/clean_energy/Water-Smart-Power-Full-Report.pdf

[13] Kenna, B. *Water Metering and Revenue Protection*; University of Southern Queensland, Australia, 2008.

one recent test, a city sampled 300 of its water meters and found they were 92% accurate. On a 13,750 water meter system, the inaccuracy of the older meters caused losses of almost $500,000 over a 12-month period.[14] With smart meters, the utility will be better able to account for the amount of water pumped and can decrease the lost revenue for unaccounted-for or leaked water.

Two-way smart meters with appropriate supporting infrastructure get water utilities part of the way there, but – just as an integrated electric system is much more efficient – a truly integrated system can do much more. A theoretical smart water grid begins at the water source, where smart meters, smart valves, smart pumps, and flood sensors are installed. Although discussions about meters are plentiful , integrative, strategic, and macro-level discussions of smart water grids are lacking in academic and other literatures.

Embedded energy in water projects

There is a real potential for the water sector to help shave peak electricity demand. Significant untapped potential for energy savings exists in programs focused on water use efficiency—the California Energy Commission (CEC) estimates that water efficiency programs could achieve 95% of the CEC's energy savings agenda at 58% of the cost.[15] Heating water consumed nearly 75% of the residential sector's and approximately 1/3 (35%) of the commercial sector's direct water-related energy, respectively[16]

Currently, no approved or agreed upon methodology exists for calculating and claiming energy savings resulting from water conservation and efficiency measures. Researchers at the University of Texas at Austin have attempted to quantify the energy embedded in the US public water supply, which is the primary water source of residential, commercial, and municipal users.

One such analysis concluded that energy use associated with the public water supply is 4.1% of the nation's annual primary energy consumption and 6.1% of national electricity consumption, but this analysis excluded energy requirements associated with water for agriculture, industrial, and self-supplied sectors (e.g., agriculture, thermoelectric, and mining). In this analysis, electricity consumption by public drinking water and wastewater utilities for pumping, conveyance, treatment, distribution, and discharge was 56.6 billion kWh, or 11.5% of primary energy and 21.6% of electricity consumption for water end-use, respectively, in 2009.[17] Further analysis concluded that direct water-related energy consumption was 12.6% of national primary energy consumption in 2010.[18] This amount of energy, 12.3 quadrillion BTUs, is the equivalent of annual energy consumption of about 40 million Americans.

Several studies have been completed to estimate water-related energy use at the state level. California, a state that uses 19% of its electricity and 32% of its natural gas to withdraw, collect, convey, treat, distribute, and prepare water for end-use, has been especially diligent in accounting its water-related energy use. While other states such as Massachusetts, Wisconsin, Iowa, and New York have also begun quantifying their water and wastewater utility energy consumption at the state level, the data are sparse for most states.[19]

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[14] Nikki Stiles, *Upgrading Water Meters Can Pay Off,* 3 WATER EFFICIENCY, May/June 2008, p. 32

[15] http://www.energy.ca.gov/2005publications/CEC-100-2005-007/CEC-100-2005-007-CMF.PDF

[16] Sanders and Webber, Evaluating the energy consumed for water use in the US, Environ. Res. Lett. 7

[17] http://proceedings.asmedigitalcollection.asme.org/proceeding.aspx?articleid=1636857

[18] http://iopscience.iop.org/1748-9326/7/3/034034/pdf/1748-9326_7_3_034034.pdf

[19] DOE 2011 Average energy intensity of public water supplies by location (kWh per million gallons) *Buildings Energy Data Book*

A recent study from Environmental Defense Fund and Pecan Street, Inc gathered first-of-its-kind granular data on the energy and water use of a group of Austin homes.[20] The study revealed the five appliances with the highest per use electrical requirements and therefore the highest water intensity: central HVAC, electric car charger, stand-alone freezer, refrigerator, and electric dryer. Powering ACs in July took 20 times as much water as in February, and the energy intensity of irrigations systems more than doubled. One standalone freezer came in second only to AC in July in water intensity (more than refrigerators). Solar panels reduced the water footprint of a house by 79%. Electric vehicles remained consistent but went from 1st to 3rd in water intensity, indicating the need for low-water clean energy to power EVs.

Wastewater treatment and energy

Most water and wastewater facilities were built decades ago when electricity costs were low enough to be of little concern. Facilities and equipment were designed to run continuously, without regard for wasted energy. Moreover, facility operators who could advocate for energy efficiency often are disconnected from those in the utility who pay the electricity bill.

At Wastewater treatment plants (WWTPs), energy is the second highest budget item after labor costs. Community drinking water and publicly-owned WWTPs use 75 billion kWh per year – as much as the pulp and paper and petroleum industries combined, or enough electricity to power 6.75 million homes.[21]

The non-standardized nature of small-scale energy generation projects at Waste water treatment plants (WWTPs) is one reason why electric utilities find it challenging to incorporate distributed generation sources into their portfolios. In addition, interconnection feeds and approval processes, as well as net metering policies, present hurdles to connecting distributed generation from WWTPs to the electric grid.

As large energy consumers, water utilities are in a position to use their purchasing power to encourage electric utilities to reduce their GHG emissions and water consumption by specifying, or even demanding, that their electricity be generated from clean energy sources. Water utilities could be a key player in any programs designed to cut harmful pollution.

Energy-water coordination at the policy and operations levels

Targeted regional workshops could bring together technologists, policy makers, and analysts/modelers who do not necessarily attend the same conferences. Standards work could also be of value; for example, interoperability protocols for automated demand response in wastewater treatment and other applications.

State and federal agencies do not always collect the same types of data at the same flow point in the system. Water managers at power plants that fill out forms for state data collection requirements sometimes do not know that similar forms for other reporting requirements exist or there is confusion over reporting the same information in different units for water volumes and flow rates, making it difficult to create consistent data sets. The combination of collecting and reporting of water data for energy systems using different units, locations of interest, and agencies makes even simple concepts unintelligible.[22]

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[20] http://blogs.edf.org/texascleanairmatters/files/2016/10/Water-Power-Measuring-Household-Water-and-Energy-Intensity.pdf

[21] http://www.epa.gov/region9/waterinfrastructure/training/energy-workshop/docs/2009/energystar-benchmark.pdf

[22] King, Carey W., Stillwell, Ashlynn S., Twomey, Kelly M., and Webber, Michael E. *Coherence between energy and water policies*, prepared for the Organization for Economic Co-operation and Development. September 2010.

Coming together to work through these problems could have a tremendous impact on the effectiveness of energy and water efficiency programs.

The Western Governors Association, the National Renewable Energy Laboratory, Sandia National Laboratory, and others are working to get water info into transmission planning. The data exists, although it is not always consistent across states and utilities, but it needs to be collected and communicated in a way that's useful for transmission planners.

There are also differences between the Sandia analysis of projected future water demand for power generation (steam electric) compared with the Texas State Water Plan. This should be addressed and checked in the next SWP planning cycle.[23] And while ERCOT (Texas's primary electricity market) conducts drought analysis, a more stringent water planning strategy could be done in conjunction with the Texas Water Development Board.

Strategic placement of renewable energy could get the biggest water-savings bang for one's buck. A recent study funded by Environmental Defense Fund, in collaboration with the Texas Army National Guard (TXARNG), mapped water stress and the potential for solar, wind, and geothermal energy at 60 of National Guard's Texas facilities.[24] By overlaying the water data with renewable energy, the lowest-hanging fruit become clear. For example, Fort Bliss Readiness Center in El Paso has both the highest solar potential and the most extreme category of future water stress. This kind of mapping could be done throughout the U.S., and the data could help inform more comprehensive energy decisions. In the case of TXARNG, that could mean allowing resources to go to other essentials like training and equipment.

In 2011, the Government Accountability Office (GAO) released a report, GAO-11-225[25], at the request of then-Ranking Member Eddie Bernice Johnson, on the energy-water nexus, and it contained findings and recommendations that could be pursued at the state and Federal level. With an updated review by GAO or another body that took a comprehensive look at all Federal programs and funding streams associated with the energy-water nexus, the Energy-Water Subcommittee as laid out in HR 34 could further streamline and enhance coordination of energy-water nexus activities across the government.

[23] http://www.ercot.com/content/committees/other/lts/keydocs/2014/DOE_LONG_TERM_STUDY_-_Final_Report_-_Volume_2.pdf
[24] http://blogs.edf.org/texascleanairmatters/files/2016/08/TXARNG-renewable-assessment-FINAL.pdf
[25] http://www.gao.gov/new.items/d11225.pdf