Trends and Policy Issues For The Nexus of Energy and Water

Testimony of

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Testimony of Michael E. Webber, Ph.D.

Mr. Chairman and Members of the Committee, thank you so much for the invitation to speak before your committee on the nexus of energy and water. My name is Michael Webber, and I am the Associate Director of the Center for International Energy and Environmental Policy and Assistant Professor of Mechanical Engineering at the University of Texas at Austin. I am here to share my perspective on important trends and policy issues related to this nexus.

My testimony today will make four main points:

1. Energy and water are interrelated,
2. The energy-water relationship is already under strain,
3. Trends imply these strains will be exacerbated, and
4. There are different policy actions that can help.

I will briefly elaborate on each of these points during this testimony.

Energy and Water Are Interrelated

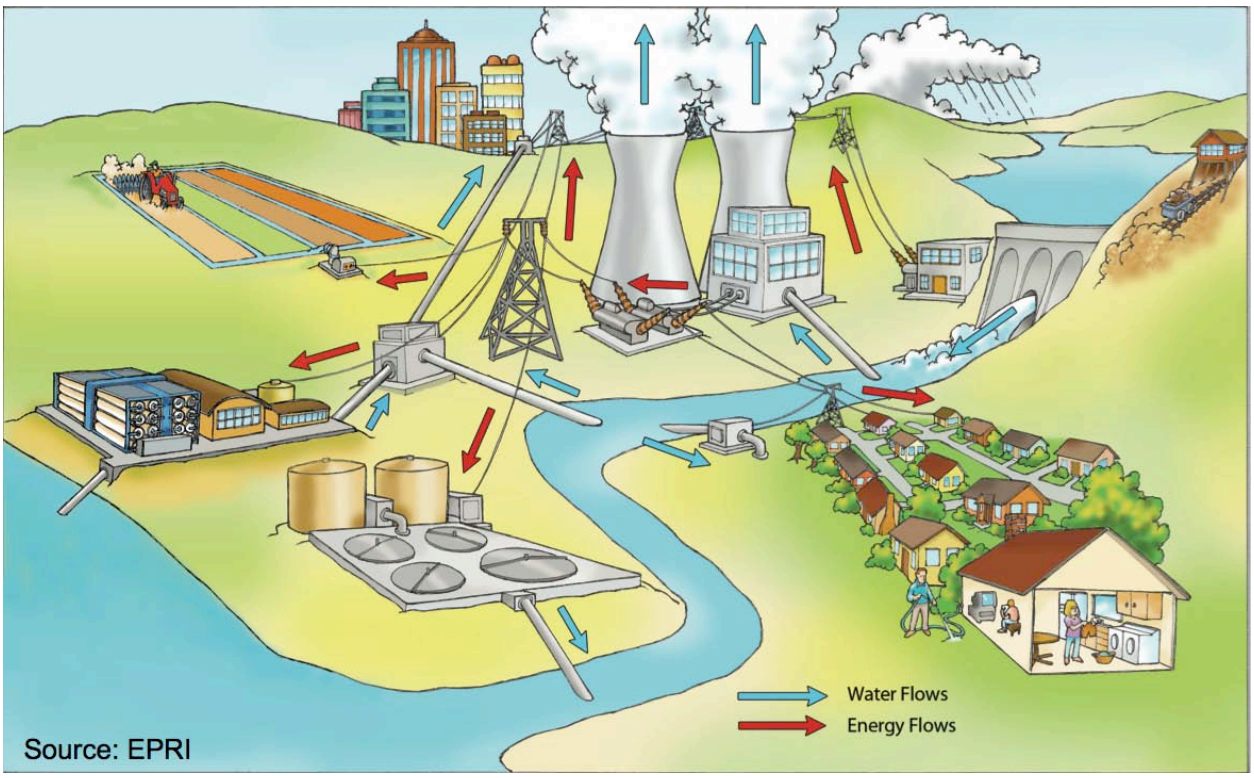

Figure 1. The energy and water systems are interrelated. We use energy for water and water for energy.[1]

Energy and water are interrelated: we use energy for water, and we use water for energy.

For example, we use energy to heat, treat and move water. Nationwide, the public water supply for the commercial and residential sectors requires about 6% of the nation's electricity and just over 4% of the nation's total energy consumption. If you also include the energy used for pumping and treating water in the agricultural and industrial sectors—for example for irrigation and process cooling—then the water system is responsible for approximately another 1% of national energy consumption.

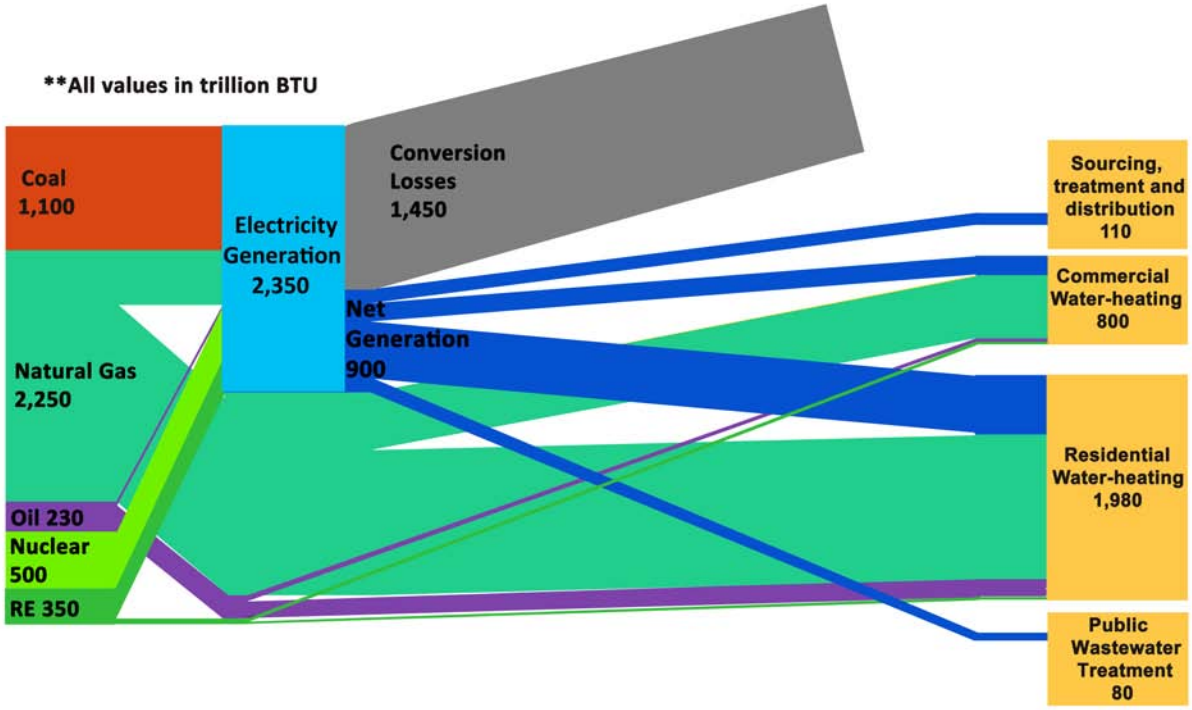

Figure 2. The public water supply system for the residential and commercial sectors requires 4.4% of national energy consumption, and 6% of national electricity consumption. The amount of primary energy consumption from different fuels is depicted on the left side of the figure. The energy is used for different purposes in the public water supply, as shown on the right side of the figure.[2] All numbers are listed in trillion BTU, and the mismatch between the energy inputs and outputs is a rounding error.

However, regionally, that number can be much higher. In California, where water is moved hundreds of miles across two mountain ranges, water is responsible for more than 19% of the state's total electricity consumption.[3] Similarly large investments of energy for water occurs wherever water is scarce and energy is available.

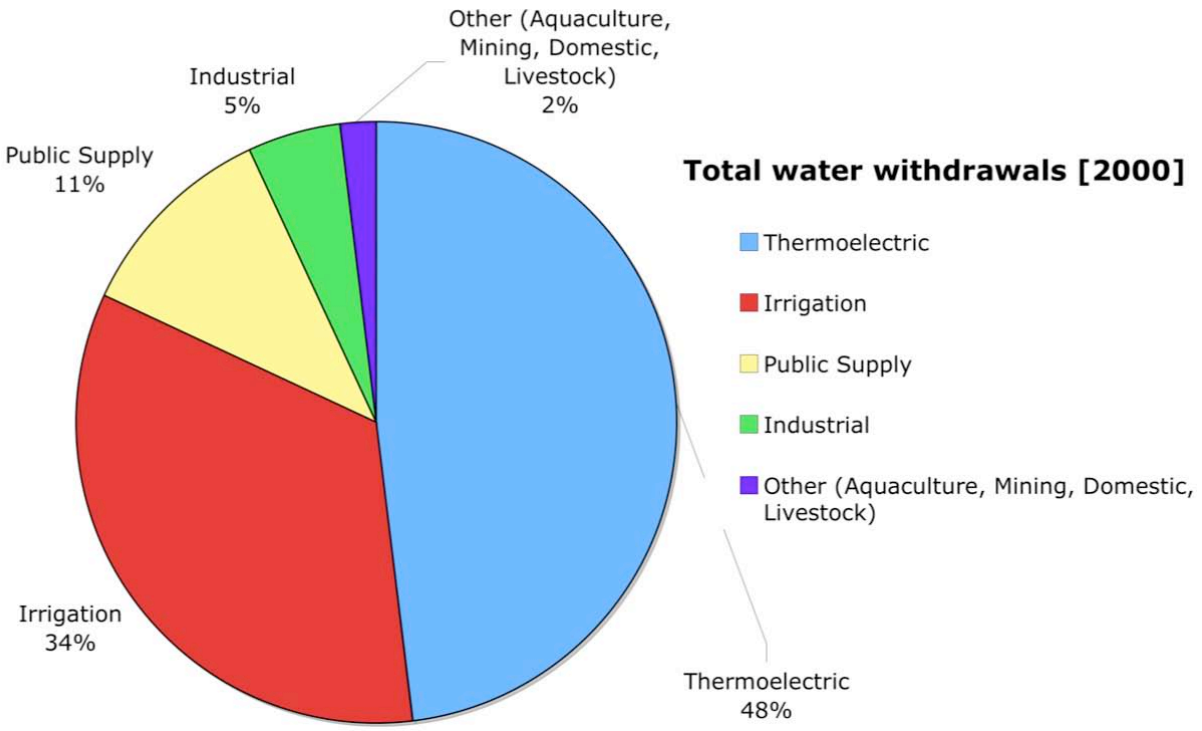

Figure 3. Approximately half of all water withdrawals in the United States are for cooling power plants in the thermoelectric sector. A fraction of this water is consumed, and the rest is returned to the water source.[4]

In addition to using energy for water, we also use water for energy. We use water directly through hydroelectric power generation at major dams, indirectly as a coolant for thermoelectric power plants, and as a critical input for the production of biofuels. The thermoelectric power sector—comprised of power plants that use heat to generate power, including those that operate on nuclear, coal, natural gas or biomass fuels—is the single largest user of water in the United States. Cooling of power plants is responsible for the withdrawal of nearly 200 billion gallons of water per day. This use accounts for 49% of all water withdrawals in the nation when including saline withdrawals, and 39% of all freshwater withdrawals, which is about the same as for agriculture.

The amount of water required by powerplants depends on the type of fuel, power generation process, and cooling technology. Nuclear is the most water-intensive, while solar PV, wind, and some uses of natural gas are very water lean.

Typically, anywhere between 1 to 40 gallons of water is needed for cooling for every kilowatt-hour of electricity that is generated. However, while power plants withdraw vast amounts of water, very little of that water is actually consumed; most of the water is returned to the source though at a different temperature and with a different quality. Thus, while power plants are major users of water, they are not major consumers of water, which is in contrast with the agriculture sector, which consumes all the water it withdraws.

Table 1. The water withdrawals and consumption for cooling power plants in the electricity sector depend on the fuel type, power generation technology, and cooling system.[5]

		Water Use and Cooling Technologies			
		Closed-Loop (cooling tower)		Open-Loop	
		Withdrawals [gal/kWh]	Consumption [gal/kWh]	Withdrawals [gal/kWh]	Consumption [gal/kWh]
Fuels & Technologies	**Nuclear**	1	0.7	42.5	0.4
	Solar CSP	0.8	0.8	---	---
	Coal	0.5	0.5	35	0.3
	Natural Gas *(Combined Cycle)*	0.23	0.18	13.8	0.1
	Natural Gas *(Combustion Turbine)*	Negligible	Negligible	Negligible	Negligible
	Solar PV	Negligible	Negligible	Negligible	Negligible
	Wind	Negligible	Negligible	Negligible	Negligible

The Energy-Water Relationship Is Already Under Strain

Unfortunately, the energy-water relationship introduces vulnerabilities whereby constraints of one resource introduce constraints in the other. For example, during the heat wave in France in 2003 that was responsible for approximately 10,000 deaths, nuclear power plants in France had to reduce their power output because of the high inlet temperatures of the cooling water. Environmental regulations in France (and the United States) limit the rejection temperature of power plant cooling water to avoid ecosystem damage from thermal pollution (e.g. to avoid cooking the plants and animals in the waterway). When the heat wave raised river temperatures, the nuclear power plants could not achieve sufficient cooling within the environmental limits, and so they reduced their power output at a time when electricity demand was spiking by residents turning on their air conditioners. In this case, a water resource constraint became an energy constraint.

In addition to heat waves, droughts can also strain the energy-water relationship. During the drought in the southeastern United States in early 2008, nuclear power plants were within days or weeks of shutting down because of limited water supplies. Today in the

west, a severe multi-year drought has lowered water levels behind dams, reducing output from their hydroelectric turbines. In addition, power outages hamper the ability for the water/wastewater sector to treat and distribute water.

While constraints in one resource introduce constraints on the other, the corollary of that relationship is also true: with unlimited energy, we could have unlimited freshwater; with unlimited water, we could have unlimited energy.

Trends Imply These Strains Will Be Exacerbated

While the energy-water relationship is already under strain today, trends imply that the strain will be exacerbated unless we take appropriate action. There are four key pieces to this overall trend:

1. Population growth, which drives up total demand for energy and water,
2. Economic growth, which can drive up per capita demand for both energy and water,
3. Climate change, which intensifies the hydrological cycle, and
4. Policy choices, whereby we are choosing to move towards more energy-intensive water and more water-intensive energy.

Population Growth Will Put Upward Pressure on Demand for Energy & Water

Population growth over the next few decades might yield another 100 million people in the United States over the next four decades, each of whom will need energy and water to survive and prosper. This fundamental demographic trend puts upward pressure on demand for both resources, thereby potentially straining the energy-water relationship further.

Economic Growth Will Put Upward Pressure on Per Capita Demand for Energy & Water

On top of underlying trends for population growth is an expectation for economic growth. Because personal energy and water consumption tend to increase with affluence, there is the risk that the per capita demand for energy and water will increase due to economic growth. For example, as people become wealthier they tend to eat more meat (which is very water intensive), and use more energy and water to air condition large homes or irrigate their lawns. Also, as societies become richer, they often demand better environmental conditions, which implies they will spend more energy on wastewater treatment. However, it's important to note that the use of efficiency and conservation measures can occur alongside economic growth, thereby counteracting the nominal trend for increased per capita consumption of energy and water. At this point, looking forward, it is not clear whether technology, efficiency and conservation will continue to mitigate the upward pressure on per capita consumption that are a consequence of economic growth. Thus, it's possible that the United States will have a compounding effect of increased consumption per person on top of a growing number of people.

Climate Change Is Likely To Intensify Hydrological Cycles

One of the important ways climate change will manifest itself it through an intensification of the global hydrological cycle. This intensification is likely to mean more frequent and severe droughts and floods along with distorted snowmelt patterns. Because of these changes to the natural water system, it is likely we will need to spend more energy storing, moving, treating and producing water. For example, as droughts strain existing water supplies, cities might consider production from deeper aquifers, poorer-quality sources that require desalination, or long-haul pipelines to get the water to its final destination. Desalination in particular is energy-intensive, as it requires approximately ten times more energy than production from nearby surface freshwater sources such as rivers and lakes.

Policy Choices Exacerbate Strain in the Energy-Water Nexus

On top of the prior three trends is a policy-driven movement towards more energy-intensive water and water-intensive energy.

We are moving towards more energy-intensive water because of a push by many municipalities for new supplies of water from sources that are farther away and lower quality, and thereby require more energy to get them to the right quality and location.

At the same time, for a variety of economic, security and environmental reasons, including the desire to produce a higher proportion of our energy from domestic sources and to decarbonize our energy system, many of our preferred energy choices are more water-intensive. For example, nuclear energy is produced domestically, but is also more water-intensive than other forms of power generation. The move towards more water-intensive energy is especially relevant for transportation fuels such as unconventional fossil fuels (oil shale, coal-to-liquids, gas-to-liquids, tar sands), electricity, hydrogen, and biofuels, all of which can require significantly more water to produce than gasoline (depending on how you produce them). It is important to note that the push for renewable electricity also includes solar photovoltaics (PV) and wind power, which require very little water, and so not all future energy choices are worse from a water-perspective.

Almost all unconventional fossil fuels are more water-intensive than domestic, conventional gasoline production. While gasoline might require a few gallons of water for every gallon of fuel that is produced, the unconventional fossil sources are typically a few times more water-intensive. Electricity for plug-in hybrid electric vehicles (PHEVs) or electric vehicles (EVs) are appealing because they are clean at the vehicle's end-use and it's easier to scrub emissions at hundreds of smokestacks millions of tailpipes. However, most powerplants use a lot of cooling water, and consequently electricity can also be about twice as water-intensive than gasoline per mile traveled if the electricity is generated from the standard U.S. grid. If that electricity is generated from wind or other water-free sources, then it will be less water-consumptive than gasoline. Though unconventional fossil fuels and electricity are all potentially more water-intensive than conventional gasoline by a factor of 2-5, biofuels are particularly water-intensive. Growing biofuels consumes approximately 1000 gallons of water for every gallon of fuel that is produced. Sometimes this water is provided naturally from rainfall. However, for a non-trivial and growing proportion of our biofuels production, that water is provided by irrigation.

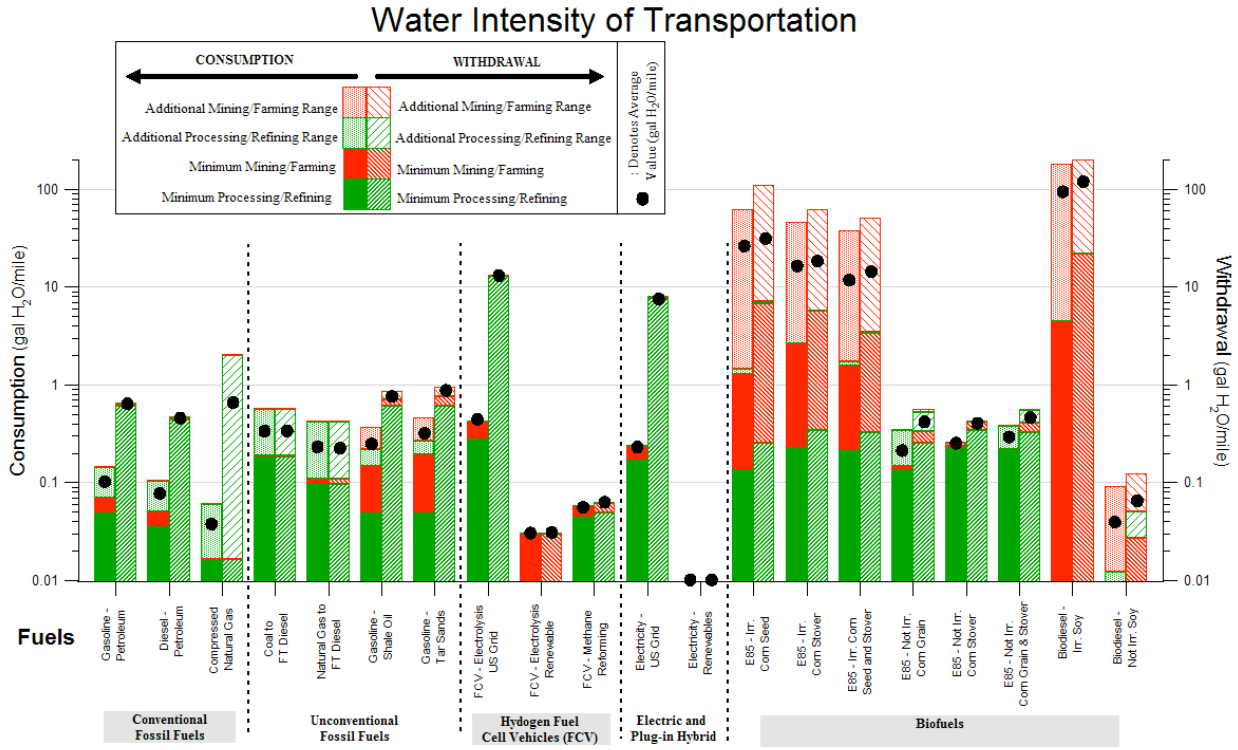

Figure 4. The water needs (in consumption (left-hand-side) and withdrawals (right-hand side)) for transportation fuels can be measured in gallons of water per mile traveled. The range includes 0 gallons of water per mile traveled for electric cars charged with solar or wind power to 0.2 gallons of water per mile traveled for conventional fossil fuels at the low end. Biofuels require much greater amounts of water, from 0.5 to 120 gallons per mile, depending on feedstock and whether irrigation is deployed.[6]

Note that for the sake of analysis and regulation, it is convenient to consider the water requirements per mile traveled. Doing so incorporates the energy density of the final fuels plus the efficiency of the engines, motors or fuel cells with which they are compatible. Conventional gasoline requires approximately 0.2 gallons of water per mile traveled, while irrigated biofuels from corn or soy can consume 20 to 100 or more gallons of water for every mile traveled.

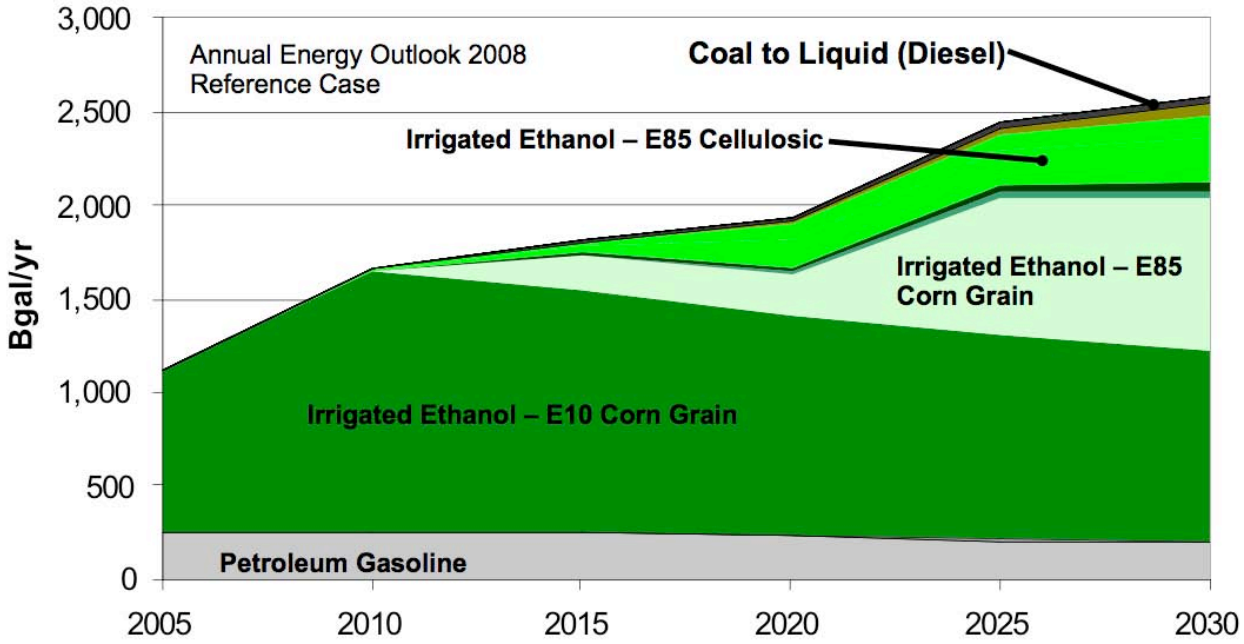

Figure 5. The water needs for producing transportation fuels are projected to grow dramatically (by trillions of gallons per year) primarily because of biofuels mandates.[7]

If we compare the water requirements per mile traveled with projections for future transportation miles and combine those figures with mandates for the use of new fuels, such as biofuels, the water impacts are significant. Water consumption might go up from approximately one trillion gallons of water per year to make gasoline (with ethanol as an oxygenate), to a few trillion gallons of water per year. To put this water consumption into context, each year the United States consumes about 36 trillion gallons of water. Consequently, it is possible that water consumption for transportation will more than double from less than 3% of national use to more than 7% of national use. In a time when we are already facing water constraints, it is not clear we have the water to pursue this path. Essentially we are deciding to switch from foreign oil to domestic water for our transportation fuels, and while that might be a good decision for strategic purposes, I advise that we first make sure we have the water.

There are Different Policy Actions That Can Help

Because there are many rivers, watersheds, basins and aquifers that span several states and/or countries, there is a need for federal engagement on energy-water issues.

Unfortunately, there are some policy pitfalls at the energy-water nexus. For example, energy and water policymaking are disaggregated. The funding and oversight mechanisms are separate, and there are a multitude of agencies, committees, and so forth, none of which have clear authority. It is not unusual for water planners to assume they have all the energy they need and for energy planners to assume they have the water they need. If their assumptions break down, it could cause significant problems. In addition, the

hierarchy of policymaking is dissimilar. Energy policy is formulated in a top-down approach, with powerful federal energy agencies, while water policy is formulated in a bottom-up approach, with powerful local and state water agencies. Furthermore, the data on water quantity are sparse, error-prone, and inconsistent. The United States Geological Survey (USGS) budgets for collecting data on water use have been cut, meaning that their latest published surveys are anywhere from 5 to 15 years out of date. National databases of water use for power plants contain errors, possibly due to differences in the units, format and definitions between state and federal reporting requirements. For example, the definitions for water use, withdrawal and consumption are not always clear. And, water planners in the east use "gallons" and water planners in the west use "acre-feet," introducing additional risk for confusion or mistakes.

Despite the potential pitfalls, there are policy opportunities at the energy-water nexus. For example, water conservation and energy conservation are synonymous. Policies that promote water conservation also achieve energy conservation. Policies that promote energy conservation also achieve water conservation.

Thankfully, the federal government has some effective policy levers at its disposal. I recommend the following policy actions for the energy-water nexus:

1. *Collect, maintain and make available accurate, updated and comprehensive water data, possibly through the USGS and EIA.* The Department of Energy's Energy Information Administration maintains an extensive database of accurate, up-to-date and comprehensive information on energy production, consumption, trade, and price available with temporal and geographic resolution and standardized units. Unfortunately, there is no equivalent set of data for water. Consequently, industry, investors, analysts, policymakers and planners lack suitable data to make informed decisions.

2. *Invest heavily in water-related R&D to match recent increases in energy-related R&D*. R&D investments are an excellent policy option for the federal government because state/local governments and industry usually are not in a position to adequately invest in research. Consequently, the amount of R&D in the water sector is much lower than for other sectors such as pharmaceuticals, technology, or energy. Furthermore, since energy-related R&D is expected to go through a surge in funding, it would be appropriate from the perspective of the energy-water nexus to raise water-related R&D in a commensurate way. Topics for R&D include low-energy water treatment, novel approaches to desalination, remote leak detectors for water infrastructure, and air-cooling systems for power plants. In addition, DoE's R&D program for biofuels should emphasize feedstocks such as cellulosic sources or algae that do note require freshwater irrigation.

3. *Encourage resource substitution to fuels that have water, emissions and security benefits*. Some fuel sources such as natural gas, wind, and solar PV are domestic, need much less water, and reduce emissions of pollutants and carbon.

4. *Support the use of reclaimed water for irrigation and process cooling*. Using reclaimed water for powerplants, industry, and agriculture can spare a significant

amount of energy and cost. However there are financing, regulatory and permitting hurdles in place that restrict this option.

5. *Support the use of dry and hybrid wet-dry cooling at powerplants.* Not all powerplants need wet cooling all the time. Finding ways to help plants upgrade their cooling to less water-intensive versions can spare significant volumes of water to meet public supply or in-stream flow requirements.

6. *Establish strict standards in building codes for water efficiency*. Building codes should include revised standards for low-flow appliances, water-heating efficiency, purple-piping for reclaimed water, rain barrels and so forth in order to reduce both water and energy consumption.

7. *Invest aggressively in conservation*. Water conservation can be a cost-effective way to save energy, and energy conservation can be a cost-effective way to save water. Therefore, conservation has cross-cutting benefits.

The energy-water nexus is a complicated, important issue, and so I am very pleased to know that you are being attentive to the matter.

Mr. Chairman, that concludes my testimony. I'll be pleased to answer questions at the appropriate time.

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