S. HRG. 111–19

ENERGY-WATER NEXUS

HEARING

BEFORE THE

COMMITTEE ON ENERGY AND NATURAL RESOURCES UNITED STATES SENATE

ONE HUNDRED ELEVENTH CONGRESS

FIRST SESSION

TO

RECEIVE TESTIMONY ON ISSUES RELATED TO S. 531, A BILL TO PROVIDE FOR THE CONDUCT OF AN IN-DEPTH ANALYSIS OF THE IMPACT OF ENERGY DEVELOPMENT AND PRODUCTION ON THE WATER RESOURCES OF THE UNITED STATES, AND FOR OTHER PURPOSES

MARCH 10, 2009

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WATER-ENERGY NEXUS

TUESDAY, MARCH 10, 2009

U.S. SENATE,
COMMITTEE ON ENERGY AND NATURAL RESOURCES,
Washington, DC.

The committee met, pursuant to notice, at 10:02 a.m. in room SD–366, Dirksen Senate Office Building, Hon. Jeff Bingaman, chairman, presiding.

OPENING STATEMENT OF HON. JEFF BINGAMAN, U.S. SENATOR FROM NEW MEXICO

The CHAIRMAN. Why don't we go ahead and get started. Senator Murkowski is on her way, but has been delayed a little bit.

As I think most people who follow the activities of this committee are aware this is a continuation of a series of energy related hearings. The subjects that we have addressed in previous hearings involve matters that we'd had a lot of work in the committee related to before. Today however, we're dealing with something of a new subject. It involves issues likely to intensify in the coming years.

Energy production requires substantial amounts of water. This is of course a resource that's becoming increasingly scarce in several parts of the country. Whether it involves electricity generation or fuel production the choice of fuel stock can dramatically influence the amount of water that's needed as part of the process of producing that energy. That nexus is starting to emerge in permitting decisions around the country.

Similarly acquiring, treating and delivering water itself consumes a very large amount of energy. Improving water use efficiencies may yield multiple benefits in the form of reduced water demand during times of shortage and reduced energy consumption with the intended cost savings that result from that reduced energy consumption. So given the importance of these issues the need to highlight the relationship between water and energy, Senator Murkowski and I introduced S. 531, the Energy and Water Integration Act of 2009.

I believe this bill is a good first step toward integrating energy and water policy. We may need to do more. I look forward to today's testimony to help inform our understanding on these issues.

Developing new policies that integrate energy and water solutions will become increasingly vital as populations grow and environmental needs increase and a changing climate continues to affect our energy and water resources. We're lucky to have a group of well qualified witnesses here today to give their views on the bill, discuss the energy water connects—the energy water nexus in general. We appreciate their being here.

I'm sure Senator Murkowski will have some opening comments when she arrives. Let me ask if Senator Corker has any opening comments he wants to make before we start.

[The prepared statement of Senator Mark Udall follows:]

PREPARED STATEMENT OF HON. MARK UDALL, U.S. SENATOR FROM COLORADO

Mr. Chairman, I am very pleased to be able to participate in today's hearing on the water-energy nexus.

Water plays a critical role in the production of the energy that powers our society, especially energy derived from fossil fuels. For example, many coal-fired electric plants burn coal to heat water and produce steam—it is this steam that actually generates the power. To undergo this process, not only is water pulled from the local environment, but some of it also evaporates and is lost.

Energy production, as we all know, is very important. But there are other critical ways that we use water every day, including drinking and cleaning. Water also plays a vital role in our food production, for both grain and livestock.

These many uses of water unfortunately can cause conflict because water is a limited resource. Especially in the arid west, who has access to water determines who will succeed.

In recent years, that conflict has become more noticeable as the western U.S. has experienced severe drought conditions. The impacts of drought are costly in both lives and dollars. Drought conditions set the stage for wildfires, crop failures, decline in recreation and tourist activities, impacts on energy production, and other harmful effects.

That does not mean that the federal government should become a water regulator and create winners and losers based on water rights.

It does mean that all of us—from individuals to businesses to government—should work to make our water use more efficient, especially when it comes to energy production.

I am looking forward to hearing today's witnesses discuss these ideas. Thank you all for being here.

STATEMENT OF HON. BOB CORKER, U.S. SENATOR FROM TENNESSEE

Senator CORKER. It's rare that I would do that as you know. But since Lisa is not here I might just make a couple. I first of all support us using all types of energy in this country. Really appreciate the Chairman's efforts, mostly, in that regard.

I have found recently though when you look at water resources and you start talking about renewables the definition can be a little clouded. I know that for instance, renewable solar energy is less efficient and uses more water than nuclear, nearly ten times as much as many coal plants. So when you look at solar use in many of the drier parts of our country where there's a lack of water, you really wonder how renewable it is.

The largest solar concentrating plant in the U.S. has been proposed for almost Gila Bend, Arizona. I don't want to pronounce it incorrectly. But they use between 940 and 1080 gallons to produce one megawatt hour or about 1,000 homes.

The largest nuclear plant in the United States is in Palo Verde in Arizona which uses 800 gallons to produce a megawatt an hour. It's the only one that actually uses municipal waste water to do so. The most efficient water using power plant in Arizona is in Springerville which is a coal plant. It's more efficient because it's at a cooler location, yada, yada, yada.

So I think it's interesting, Mr. Chairman that we're having this hearing. Again, I support all types of energy uses. But I think it's very important to understand whether renewables in some cases especially in climates, it sometimes calls them to be more efficient in some ways, actually, is very depletive of water over time.

So I thank you for having this hearing. I'm sorry for making an opening statement which is rare.

The CHAIRMAN. Thank you for the comments. I'm sure we can get into those issues with the witnesses. So let me just briefly introduce the witnesses.

Carl Bauer is the Director of the National Energy Technology Laboratory in the Department of Energy. Thank you for being here.

Stephen Bolze is with GE Power and Water in Schenectady, New York.

Peter Gleick. Is that the correct pronunciation?

Mr. GLEICK. It is.

The CHAIRMAN. Gleick is with the Pacific Institute in Oakland, California.

Michael Webber is with the Center for International Energy and Environmental Policy at the University of Texas in Austin.

Lon House, Dr. House, is with Water and Energy Consulting in Cameron Park, California.

So thank you all very much for being here. If you'd each take five or 6 minutes and give us your views on this set of issues and what we need to think about as we try to construct policy in this area. We would appreciate it.

Mr. Bauer.

STATEMENT OF CARL O. BAUER, DIRECTOR, NATIONAL ENERGY TECHNOLOGY LABORATORY, DEPARTMENT OF ENERGY

Mr. BAUER. Thank you, Mr. Chairman, members of the committee.

I'd like to present a little bit of the Department of Energy's work in water and kind of an overview of some of the issues. I strongly agree with the observation that water and energy are codependent and intertwined in a very, very substantial way. Simplistically one might suggest that power generation from thermal sources, which is 90 percent of our electricity uses consumes 3 percent of the Nation's water, withdraws 40 percent, but consumes 3 percent.

Treating water, pumping, moving waste water consumes 6 percent of the Nation's electricity. So that gives you an indication of the interdependence. Production accounts for, as I said, 40 percent of the withdrawal, but is often confused to suggest that's the use.

That water often goes back to its source, although there's a thermal loading on it. So it's important to realize that there's a consumption aspect of water use and energy production. Then there is withdrawal and kind of a borrowing and putting it back and making it available again. So there's an opportunity for water management in a different way than we presently practice to get more use out of the same water availability.

As to the largest consumers of water and power generation—I can't confirm your facts Senator Corker; and I don't dispute them, possibly the water use in the production of photovoltics is a part of that number. It's fairly high.

But the largest consumer, on a routine basis for large power generation, are nuclear plants that consume 40 percent more than the pulverized coal plants which is the majority of the coal fleet. Although the IGCC power generation capacity, of which there are two operating plants in the country, consume about 40 percent less than the coal fleet. So I'm using the coal fleet as kind of a baseline standard. Then natural gas combined cycle plants consume about 40 percent less than—20 percent less than IGCC or 60 percent less than the coal fleet.

So our power generation fleet is very dependent on water for its efficiency and operation both for making the steam for efficient operation of it.

The CHAIRMAN. Could you just clarify? You made this distinction between consumption of water and withdrawal of water which is recycled.

Mr. BAUER. Yes, sir.

The CHAIRMAN. Are the figures you just gave us consumption?

Mr. BAUER. The figures I just gave you are consumption.

The CHAIRMAN. Consumption.

Mr. BAUER. So of that 3 percent that is consumed that's kind of how the different plants would utilize it. That figure of 3 percent is based on the existing fleet and the existing——

The CHAIRMAN. The three percent? Tell us again what that is?

Mr. BAUER. The existing fleet removes about 40 percent of the water that's available. It uses it and it puts it back in the lake, or the stream, or the river, wherever it is. It consumes 3 percent of the total water available.

That is if you look at a plant with cooling towers, you see the white plume of steam and evaporated water. That would be considered consumed because you can't use it again until it rains. If I look at agriculture, they——

The CHAIRMAN. Three percent of the water that is consumed in the country is consumed——

Mr. BAUER. By power.

The CHAIRMAN. By power production.

Mr. BAUER. That's correct.

The CHAIRMAN. One kind or another. Then you gave us statistics as to how nuclear compares——

Mr. BAUER. Right.

The CHAIRMAN [continuing]. To coal and other things.

Mr. BAUER. That's right. Yes, sir. The whole point of that is while there's a large amount of water that's needed, much of it is not lost for further use. So that's important as you consider the impacts of power generation.

You can't generate the power without the water. But the water isn't damaged and not available for use in the largest portion of it. So there's opportunities to handle that water.

Presently we remove everything in parallel and put it back and it's kind of strange how it takes place. So that's a possible opportunity. For example, if it's thermal loaded which it would be after going through the cooling system, it still would be used for irrigation because the thermal load is not so great based on the standards that must be met not to harm plants.

So instead of agriculture and power generating taking out the same source, in parallel you may get more use out of the water if you did some kind of a serial managed distribution of it. I'm not trying to meddle there. I'm just suggesting there are ways to look at trying to skin the cat a different way.

One of the challenges I think that faces energy and water is the one that we all know is going on, and I'm about to run out of time here, which is the challenge of greenhouse gas management. The use of existing technologies to capture CO_2 out of the fossil fleet will substantially increase the power generation to parasitic make-up because the present technologies were never designed for the magnitude of removal.

They are better than they were 10 years ago. We are working at DOE to rapidly improve them. But the separation technology requires a lot of energy. It also requires some additional water for the MEA cycles, monoethanolamine.

That would also have impact on water because it would use more water and actually use it and consume it, not just utilize it. But it would also probably increase the cost of electricity substantially. With my time running out I would just like to make the point that a doubling of the price of electricity will probably raise the price of water from 25 to 40 percent depending on the distance the water is transferred.

So for example Southern California gets water from Northern sources. It would have a 40 percent increase in the price of water to the consumer there if the price of electricity were to double. If I were up in a Northern portion of California, probably not more than a 25 percent range. It's the same across the country. So it isn't geographic and distance location because the electricity is all about handling the water, treating the water and cleaning the water.

I thank you very much for your time. I will stand by to answer questions as appropriate.

[The prepared statement of Mr. Bauer follows:]

PREPARED STATEMENT OF CARL O. BAUER, DIRECTOR, NATIONAL ENERGY TECHNOLOGY LABORATORY, DEPARTMENT OF ENERGY

Thank you, Mr. Chairman and Members of the Committee. I appreciate the opportunity to provide testimony on the U.S. Department of Energy's (DOE's) research program directed at reducing power plant water use as it relates to carbon capture efficiency and optimization.

Of particular concern is the potential implication on freshwater requirements in a future in which carbon dioxide (CO_2) capture technology is required to be installed on coal-based power systems. DOE's National Energy Technology Laboratory (NETL) projects that, in the absence of successful development of new advanced CO_2 capture and water management technologies, implementation of today's CO_2 capture technologies would significantly increase freshwater consumption by fossil-based power plants.

In the absence of climate legislation, the latest Annual Energy Outlook from the Energy Information Administration forecasts that CO_2 emissions from the electric power sector would contribute over 40 percent of the Nation's annual energy-related emissions of CO_2 (equivalent) by 2030. Coal-based power plants would emit 84 percent of the power sector's emissions under the reference case scenario and, significantly, 95 percent of the cumulative CO_2 emissions from coal-fired plants, through 2030, would stem from existing coal-fired plants (Figures 1-3, Appendix).* An addi-

* All figures have been retained in committee files.

tional 15 percent of power generation sector emissions emanate from combustion of natural gas. A carbon control regime that seeks to dramatically limit CO_2 emissions from the power generation energy sector will eventually need to encompass both existing and new coal-fired plants as well as natural gas-fired power plants. The comparative economics of retrofitting existing plants and adding new natural-gas and coal-based plants with carbon capture will come to the forefront.

Energy and water are indeed inextricably linked. Most Americans do not realize that they use more water turning on lights and running appliances each day than they do directly through washing their clothes and watering their lawns. This is because thermoelectric power generation facilities require large volumes of freshwater to operate, ranking just behind agricultural irrigation in terms of total freshwater withdrawal. These thermoelectric plants contribute over 90 percent of the Nation's electricity and, in the process, account for about 40 percent of the Nation's freshwater withdrawal and about 3% of the Nation's freshwater consumption (Figure 4, Appendix).

It is important to distinguish between water withdrawal and consumption. Withdrawal is the removal of water from any water source or reservoir, such as a lake, river, stream, or aquifer for human use; for power plants, the primary purpose of this withdrawal is cooling. Consumption, on the other hand, is that portion of the water withdrawn that is no longer available for use because it has evaporated, transpired, been incorporated into products and crops, or consumed by humans or livestock. Note that water withdrawal rates are two orders of magnitude greater than consumption (136 billion gallons per day versus 4 billion gallons per day). This illustrates that most water withdrawn in power generation is not consumed, but returned to its source.

By comparison, nuclear power plants consume approximately 40 percent more water, and natural gas combined cycle plants consume approximately 60 percent less water than equivalent contemporary subcritical Pulverized Coal (PC) technology. Moreover, advanced technology coal plants offer the opportunity to significantly reduce the consumptive footprint, with integrated gasification combined cycle technologies—or IGCC—offering the greatest reduction at 40 percent less than that of a subcritical PC (Figures 5-6, Appendix).

Although a number of commercially available cooling technology options—for example hybrid and dry cooling technologies—can reduce or mitigate water consumption for all generating options, they all result in added cost and increased complexity. In areas where water use is constrained, such as the arid Southwest or the currently droughtafflicted Southeast, increases in water consumption need to be met with careful consideration. Water withdrawal permitting requirements give the private sector the incentive it needs to advance existing cooling technology options, with the exception of the uncertainty associated with future requirements for carbon capture.

Using today's technologies, efforts to capture carbon from the existing coal and natural gas plants, or from new fossil plants, would cause increases in water consumption—a big concern for some regions—and may increase the cost of electricity, a concern for all.

Capturing carbon from fossil plants requires the addition of several energy intensive processes, for example processes that use solvents to capture CO_2, require energy to regenerate the solvent so it can be used again. Once the CO_2 is captured, it must be compressed for sequestration or beneficial re-use, with compressors usually having significant operating power requirements. These processes are common to both conventional fossil-based combustion processes as well as to advanced technologies such as IGCC. NETL estimates that the added energy requirements for these processes results in a significant increase in net plant auxiliary load, known as parasitic power, resulting in a decrease in net plant power output of 15 percent to 30 percent. The requirement for additional systems could have significant reliability implications.

NETL analyses indicate that efforts to capture 90 percent of carbon emissions by using current near-commercial carbon capture and storage (CCS) technologies on PC plants would more than double the amount of water consumed per unit of electricity generated. Studies of this consumptive footprint have indicated that IGCC with CCS has a comparative advantage, with water consumption significantly lower than that of postcombustion CCS technologies. Importantly, IGCC with 90 percent CCS can have a consumptive footprint lower than that of a conventional PC power plant without CCS. Furthermore, the greatly reduced carbon footprint of IGCC with CCS and its low-water consumption compared to nuclear power plants may tend to focus future generation technology choices on capital costs related to water consumption as well as on CO_2 emissions.

For instance, advanced coal systems with 90 percent capture emit CO_2 at rates substantially below that of existing and new Natural Gas Combined Cycle (NGCC) units. A comparable NGCC plant would capture over 65 percent of its emissions in order to release CO_2 at similar rates. The implementation of CCS on natural gas-fired plants would increase water demand in states such as California, where natural gas exceeds 50 percent of in-state generation. The use of today's post-combustion CO_2 mitigation technologies could have substantial economic impacts. IGCC technology would not increase the use of water relative to conventional post-combustion coal power without carbon capture. Ongoing research and development efforts for more cost-effective capture technology, including improved water-efficiency, deserves continued attention and support.

NETL actively collaborates with other parties from industry, academia, state, and other Federal departments and national laboratories in efforts to mitigate the impact of carbon capture on water supply. Such activities have included recent collaborations with the Office of Electricity Delivery and Energy Reliability, and the North American Electric Reliability Corporation in analyzing the potential impact of the Clean Water Act 316(b) legislation on the Nation's power supply and reliability.

NETL funds a significant amount of water-related extramural research, focusing on technologies to reduce carbon capture water use. Activities are further detailed in the Appendix.

NETL actively works with the Environmental Protection Agency on drinking water issues related to CO_2 injection.

Alongside NETL's expertise in power systems, such research and collaboration plays a vital role in understanding the complex interactions among energy, water, and the environment in the United States.

In conclusion, DOE's Existing Plants, Emissions, and Capture Program has a successful track record and a promising future that will ultimately mitigate the impact of carbon capture on water supply.

Mr. Chairman, Members of the Committee, this completes my statement. I would be happy to respond to any questions you may have.

The CHAIRMAN. Thank you very much. Mr. Bolze, go right ahead.

STATEMENT OF STEPHEN BOLZE, PRESIDENT AND CHIEF EXECUTIVE OFFICER, POWER & WATER, GE ENERGY, SCHENECTADY, NY

Mr. BOLZE. Thank you, Mr. Chairman and members of the committee. My name is Steve Bolze. I'm the President and CEO of GE's power and water business.

It's a pleasure to appear before this committee and discuss a critically important issue that's often overlooked, the use of water in the energy sector and also to offer GE's support of the Energy and Water Integration Act of 2009. If I could leave the committee with only two thoughts it would be these.

One, 45 percent of all fresh water withdrawals in the United States are used for industry.

Secondly, that percentage can and should decrease through the wider adoption of advanced water treatment technologies and reuse.

Federal policies that include incentives that reduce the capital cost of installing advanced water treatment equipment, similar to those provided for the deployment of renewable energy technologies would drive significant water and energy savings. You've already witnessed the success of your policies in launching the U.S. into the world leader in wind generation. Similar actions are needed and possible to set us up the path to leadership in water reuse.

Do you recognize the connection between energy and water? In fact in 2008 we integrated our power and water businesses to better meet customer needs and address these significant challenges. I run our power and water business which represents over 30,000 employees. We operate in 140 countries and had 2008 revenue of 23 billion.

Based on our experiences of over 50,000 customers globally, we believe there are significant energy and water savings to be gained by further studying the connections between energy and water. That we all know we need water for everything. In fact it is said our economy runs on water.

Unfortunately water demand already exceeds supply in many parts of the world. As the world's population continues to grow many more areas are expected to experience the imbalance in the near future. The situation is no different here in the United States where most states expect water shortages over the next decade.

The growing shortage of water also addresses our Nation's energy picture. Energy and water are codependent. In simplest terms energy is required for making water, as was mentioned earlier. Water is essential for making energy.

Globally to give you a sense the demand for both these resources are projected to grow. With energy demand doubling and water demand tripling over the next 20 years. Fortunately we believe that industry can reuse much more water than it does today thereby freeing up scarce water resources for community purposes.

We also believe that increased water reuse would result in lower overall energy consumption. With advanced technology funding will result in greater efficiencies than achievable today. For example GE is working with the University of Wyoming to develop advanced coal gasification. Such a process would enable customers to more cleanly use low rank coals, but also achieving 30 percent reduction in water consumption.

In short we believe that this committee can play an essential part in helping to drive more water reuse in the United States. To that end we would like to offer the following three specific recommendations to the committee.

First, support of the NAS Study. We believe that it would be valuable for the National Academy of Sciences to conduct a study on how the development of energy impacts our Nation's water supply as recommended in the draft legislation. GE would welcome an opportunity to contribute technical and market insights to the study.

Second, incentives to accelerate more reuse. While we support the concept of the NAS Study to conform efficiencies available we believe that as we have seen in places like Singapore, Australia and other parts of the world. Incentives are necessary to drive greater reuse in the U.S. with our customers. Our feedback from our industrial customers across the Nation is that an investment tax credit of 30 percent would drive substantial increases in industrial water reuse.

Third, advanced technology funding support. We support a continued commitment by Federal Government to conduct research and important desalination and would welcome an opportunity to partner with the public entities in this effort.

So thank you for conducting this important hearing and for the opportunity to present this testimony. I look forward to your questions and working with you a little longer term to help on greater water and energy efficiencies. Thank you.

[The prepared statement of Mr. Bolze follows:]

PREPARED STATEMENT OF STEPHEN BOLZE, PRESIDENT AND CHIEF EXECUTIVE OFFICER, POWER & WATER, GE ENERGY, SCHENECTADY, NY

Mr. Chairman and members of the Committee, my name is Steve Bolze and I am the president and CEO of GE Energy's Power & Water business.

It is a pleasure to appear before your committee today to discuss a critically important but often overlooked issue—the use of water in the energy sector.

If I could leave the committee with only two thoughts it would be these. First, 45% of all fresh water withdrawals in the United States are used by industry. Second, through the leadership of this Committee and your colleagues, that percentage can and should decrease—especially through the establishment of incentives that reduce the capital cost of installing water management equipment, similar to those that Congress has provided for the deployment of renewable energy technologies.

You have already witnessed the success of your policies in catapulting the United States into a world leader in wind generation. Similar actions are needed and possible to set us on a path to leadership in the area of water reuse.

GE has long recognized the connection between energy and water. In fact, in 2008 we integrated GE's water and power generation businesses to better meet customer needs and address significant global challenges. GE Power & Water is a global leader with more than 100 years of industry experience. Our global team of more than 30,000 employees operates in 140 countries around the world, and had 2008 revenues of $23 billion. As the following chart shows, GE Power & Water offers a diverse portfolio of products and services including renewable energy technologies such as wind, solar, and biomass, and fossil power generation, gasification, nuclear, oil & gas, water, transmission, and smart meters.*

I appreciate the opportunity to be here today to offer GE's support for the Energy and Water Integration Act of 2009. We believe that it would be valuable for the National Academy of Sciences to conduct a study on how the development of energy affects our nation's water supplies. In addition, we believe it would be beneficial for the federal government to identify best available technologies to minimize the use of water in the production of electricity. We believe that there are significant energy and water savings to be gained in the area.

THE ENERGY-WATER NEXUS

Although energy gets a tremendous amount of attention, it seems like many people take clean water for granted. Perhaps that is because they have never been in a situation where quality water was not available when and where needed. The simple reality is that we need water for everything.

Water is not only the lifeblood for humans, but it's also the lifeblood of industry. In fact, it could be said our economy runs on water. Unfortunately, water demand already exceeds supply in many parts of the world. And, as the world's population continues to grow at an unprecedented rate, many more areas are expected to experience this imbalance in the near future[1].

The situation is no different here in the United States, where most states expect water shortages during the next decade. Energy and water are co-dependent. In simplest terms, energy is required for making water and water is required in the production of energy. Globally, the demand for both of these crucial resources is projected to grow at an alarming pace, with energy demand doubling[2] and water demand tripling[3] in the next 20 years, as shown in the figure below.*

As we prepare to meet the future electricity demands here in the U.S., it is estimated that water demands related to electricity production will almost triple from 1995 consumption levels. In addition, the deployment of technologies to meet expected carbon emission requirements will increase water consumption by an additional 1-2 billion gallons per day.[4]

Importantly, it is estimated that 45% of freshwater withdrawals in the United States is used for industrial purposes."[5] And nearly 90% of all industrial water—

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* All charts have been retained in committee files.

[1] Greenfacts.org

[2] DOE / EIA-0384 (2004)

[3] NETL 2006

* All figures have been retained in committee files.

[4] NETL 2006

[5] USGS. Estimated Use of Water in the United States in 2000, USGS Circular 1268, March 2004

or 39% of all freshwater withdrawals—is used for the generation of power.[6] Although power generation facilities in the United States today withdraw 136 billion gallons per day (GPD), they only consume 4 billion GPD (lost through evaporation, etc.). The vast majority of the water is used for once-through cooling water applications, and then returned to the receiving stream. Once-through cooling, however, consumes large amounts of energy to pump the water, and it also elevates the temperature of the receiving stream.[7] It is often less expensive to pull water from a river or the ground than it is to reuse it.[8] In addition, many power plants in the United States use potable water from municipal systems to meet their cooling and other needs.[9] This places strains on community systems. If the cooling water needs could be met with reused wastewater, however, significant benefits would result.

The following chart shows how water-intensive it is to produce electricity in a representative steam turbine plant. Water is required for virtually every aspect of producing electricity. An average 1,000 megawatt power plant—like the one pictured here—requires more than 5 million gallons of water per day.[10]

And, not surprisingly, it's not just inside the power plant where tremendous quantities of water are used in connection with the production of energy. The water intensive process begins with the production of oil. We understand from some of our customers who are major oil companies that they consume an estimated 7 to 10 barrels of water to process one barrel of crude oil from the well to the gas pump.[11] Some oil recovery processes are particularly water-intensive, including Steam Assisted Gravity Drainage (SAGD), which uses 30-40 barrels of water to produce one barrel of oil.[12]

In many cases, the impaired wastewater from these processes is injected into deep wells, completely removing it from the hydrological cycle. Today, the US will consume over 20 million barrels of crude oil and petroleum products[13], which will require 6 billion gallons of water to produce.[14] Technologies are available today that can enable oil producers to reuse water many times over, greatly reducing water demand and protecting the environment, but they need the incentives to drive the right behavior.

The good news is that technology advances in both power generation and water treatment are reducing the amount of water necessary to produce electricity. A recent EPRI study states that "the larger the shift from coal and nuclear to natural gas, the greater decrease in water consumption for power generation (possibly as much as a 50% drop relative to the base case and a 35% drop relative to today's use)". This report also emphasizes that "water availability can constrain electricity generation siting and power production, both directly and indirectly."[15]

We believe that there is also good news on the coal front. The new GE IGCC coal generation plant is more efficient relative to water consumption than a traditional sub-critical coal-fired power plant. In Wyoming, for example, GE is working with the University of Wyoming to develop advanced coal gasification technology including a unique dry feed injection process. The development of this dry feed process will enable customers to more cleanly use lower rank coals from Wyoming, Colorado, Montana, Utah, South and North Dakota, while taking advantage of a 30% reduction in water consumption, through the use of IGCC (Integrated Gasification Combined Cycle) technology.

PROMOTING GREATER REUSE OF WATER

According to the WateReuse Association, the US today reclaims and reuses about 6% of its wastewater.[16] In some countries, the level of water reuse is much higher. For example, Israel today is reusing 70% of its wastewater.[17] Singapore is reusing

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[6] USGS. Estimated Use of Water in the United States in 2000, USGS Circular 1268, March 2004

[7] USGS, Estimated Use of Water in the United States in 2000, USGS Circular 1268, March 2004

[8] USGS, Estimated Use of Water in the United States in 2000, USGS Circular 1268, March 2004

[9] Wade Miller, Executive Director, WateReuse Association (2009)

[10] Calculation based on EPRI Standards

[11] Conversations with GE Customers

[12] Conversations with GE Customers

[13] 13 EIA (Energy Information Administration) http://www.eia.doe.gov/basics/quickoil.html

[14] (20MM bbls oil x 42 gal/bbl x 7 gal H2O/bbl oil)

[15] EPRI—Water & Sustainability (Volume 3): U.S. Water Consumption for Power Production—The Next half Century

[16] National Data Base of Water Reuse Facilities, WateReuse Association (2008)

[17] US EPA 2004 Guidelines for Water Reuse

15%, but plans on doubling this amount to 30% in 2010.[18] Australia currently reuses about 8% of its wastewater, but it has set a national target of reusing 30% by 2015.[19]

A number of countries around the world have enacted incentives to encourage more reuse.[20] Singapore, for example, has created a Water Efficiency Fund that provides up to 50% of the capital cost of water recycling facilities.[21] To the extent that incentives exist in the United States, they tend to be at the local level.

We believe that industry can reuse much more water than it does today. In addition, it is clear that we can harness more municipal wastewater to provide for industrial needs. Rather than municipal wastewater plants treating and discharging water back to a receiving stream, by adding an incremental treatment process, either at the wastewater plant or at the industrial plant, this water can meet the needs of many industrial processes, including power plant cooling.

Some 11.4 trillion gallons per year of municipal wastewater is being treated in the United States. Some communities are already treating this wastewater and using it for applications including power plant cooling water (e.g., Burbank, Las Vegas, Phoenix).[22] A recent DOE-sponsored study looked at 110 new power plants proposed for construction in 2007 and found that municipal wastewater treatment plants located within a 25 mile radius from the proposed power plants could satisfy 97% of the new power plant cooling water needs. On average, one large wastewater treatment plant can completely satisfy the cooling demand for each of these power plants. Incentives to collocate municipal wastewater treatment plants and power generation plants in the future would go a long way toward providing sustainable sources of water, reducing freshwater withdrawal and energy consumption.

A great example of this type of public-private partnership is in Tempe, Arizona, where demand for quality-reclaimed water is gaining momentum in water-challenged Arizona as commercial and industrial growth is increasing. Application of a GE technology solution enabled Tempe to realize 2.5 billion gallons of water per year through water reuse. The reclaimed water exceeds the state's Class A+ water reuse requirements, which allows it to be used in the widest variety of reuse applications. This water is now being used to meet the needs of a neighboring power plant as well as a new recreational lake.[23]

A recent survey by the WateReuse Association of its more than 390 organizational members for the purpose of identifying water reuse and desalination projects that are permitted and "ready-to-go" demonstrates that: 1) there is a robust demand for water reuse and desalination projects; and 2) communities across the U.S. are in need of federal support to undertake these projects. The survey identified more than 270 "ready-to-go" projects in 11 states with aggregate construction costs amounting to more than $5 billion.[24] This level of construction activity would, if fully funded, translate into as many as 185,000 new jobs.[25] These new drought-proof supplies would provide a long-term reliable supply for the economic future of these communities and at a lower cost than depending on expensive imported water supplies from other watersheds.[26]

Finally, we also believe that there are significant opportunities to reduce water consumption in the production of oil and natural gas. For example, to help minimize the environmental impacts and operating costs of their activities, heavy oil producers in Alberta are dramatically reducing their water consumption by using GE Water & Process Technologies' ecomagination-certified, "produced water" evaporating system in the oil production process.

We also believe that—in general—reusing water will reduce energy consumption. By way of example, we calculated that an average sized 1,000 MWh power plant that installs a water reuse system for cooling tower blow-down recovery would re-

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[18] Source Ministry of Environment Website

[19] Wade Miller, Executive Director, WateReuse Association

[20] Addressing Water Scarcity Through Recycling and Reuse: A Menu for Policymakers" May 28, 2008 (http://www.gewater.com/who_we_are/press_center/pr/05282008-Paper.jsp)

[21] Addressing Water Scarcity Through Recycling and Reuse: A Menu for Policymakers" May 28, 2008 (http://www.gewater.com/who_we_are/press_center/pr/05282008-Paper.jsp)

[22] "Reuse of Internal or External Wastwaers in the Cooling Systems of Coal-Based Thermoelectric Power Plants, Radisav Vidic, Univ of Pittsburgh & David Dzombak, Carnegie Melon Univ Oct 2008

[23] http://www.gewater.com/who_we_are/audio-video/index.jsp

[24] "Providing Safe, Secure and Sustainable Solutions for America's Water Needs," The WateReuse Association, January 2009

[25] "Providing Safe, Secure and Sustainable Solutions for America's Water Needs," The WateReuse Association, January 2009

[26] "Providing Safe, Secure and Sustainable Solutions for America's Water Needs," The WateReuse Association, January 2009

duce the energy demand to produce, distribute and treat water by a net 15%, or enough to power over 350 homes for a year.[27]

GE'S COMMITMENT

At GE, we also see the importance achieving water and energy efficiencies across our own portfolio of businesses. In 2005, GE launched a global environmental initiative called ecomagination, which is our commitment to do the five major things showed on the chart below.

ECOMAGINATION IS A COMMITMENT TO

Double our research investment . . . to $1.5B
More ecomagination products . . . $20B target
Reducing greenhouse gas emissions. . By 30%
Reduce water consumption by 20% by 2012
Keep the public informed

With respect to energy, we have committed to reduce our greenhouse gas emissions by 30% on a normalized basis (allowing for projected growth of GE's businesses), or 1% in absolute terms from 2006 to 2012. In addition, we have committed to reducing our water consumption by an absolute 20% during the same time frame. At the same time, we're working with our customers around the world to help them achieve similar efficiencies.

In addition, GE is doubling its level of investment in clean research and development from $700 million in 2005 to more than $1.5 billion by the year 2010. This research effort is focused on helping our customers meet pressing energy and water challenges.

GE'S WHITE PAPER ON WATER REUSE POLICY OPTIONS

We believe that even though governments in water scarce regions are looking for ways to expand water recycling and reuse, they often have difficulty finding information on the policy options from which they might choose. So, on May 28, 2008, GE issued a white paper entitled "Addressing Water Scarcity Through Recycling and Reuse: A Menu for Policymakers," which draws on examples from around the world.

Although this white paper provides only a representative sample and does not provide an exhaustive list of programs and policies, the four major types of policies being used to increase water recycling and reuse include the following[28]:

A. Education and Outreach

- Recognition awards and certification programs
- Information dissemination and educational outreach efforts
- Reporting of water consumption, discharge, and reuse data

B. Removing Barriers

- Modifying local regulations that require that all water meet potable standards
- Revising plumbing codes to allow dual piping
- Alleviating stringent permitting and inspection requirements for recycled water

C. Incentives

- Direct subsidies
- Reductions in payments to the government
- Payments for reintroduction of recovered water
- Pricing mechanisms
- Regulatory relief for recycled water users
- Government procurement of water recycling/reuse equipment
- Structuring of water rights to reduce the use of potable water

D. Mandates and Regulation

- Requiring utilities to develop plans for recycled water
- Restricting potable water to human or food related uses
- Requiring the use of recycled water for certain large volume activities, e.g., irrigation
- Requiring water recovery systems

[27] Internal GE Calculation March 2009
[28] Addressing Water Scarcity Through Recycling and Reuse: A Menu for Policymakers" May 28, 2008 (http://www.gewater.com/who__we__are/press__center/pr/05282008-Paper.jsp)

GE'S POLICY RECOMMENDATIONS GOING FORWARD

A. The NAS Study

We believe that it would be valuable for the National Academy of Sciences (NAS) to conduct a study on how the development of energy impacts our nation's water supplies, as recommended in the draft legislation. GE would welcome an opportunity to contribute technical and market insights to the study.

B. Incentives to Accelerate More Reuse

While we support the concept of an NAS study to confirm the efficiencies achievable, we believe that—as we have seen in places like Singapore—incentives are necessary to drive greater water reuse in the U.S. Our feedback from our industrial customers across the nation is that an investment tax credit of 30% would drive substantial increases in industrial water reuse.

C. Advanced Technology Funding Support

Finally, we support a continued commitment by the federal government to conduct research in the important field of desalination, and we would welcome an opportunity to partner with public entities in this effort.

Thank you for holding this important hearing, and for the opportunity to present this testimony. I look forward to your questions now, and working with you over the longer term to help accomplish greater water and energy efficiencies.

The CHAIRMAN. Thank you very much.
Dr. Gleick.

STATEMENT OF PETER H. GLEICK, PRESIDENT, THE PACIFIC INSTITUTE, OAKLAND, CA

Mr. GLEICK. Mr. Chairman, Senators, thank you very much for the opportunity to come today to talk to you about this issue. I want to make three points.

The first is energy requires water, sometimes a lot of water.

The second is that water, the water systems of the United States require energy and sometimes a lot of energy.

The third is that the failure to consider both energy and water together leads us to inefficiencies to make bad policies to do things that we shouldn't perhaps otherwise do. For that reason I applaud this bill which encourages the Nation to consider water and energy together in a more integrated way. It's a very important first step forward.

So first, energy requires water. As we've heard already every energy system in the United States requires some amount of water to produce the kilowatt hours of energy that we require. But not all energy systems require the same amount of water. Typically, fossil fuel and nuclear energy systems require more water per unit energy than do renewables.

But as Senator Corker mentioned that's not always the case. Solar thermal, geothermal, often requires more water per unit energy than some of the traditional sources. Solar photovoltaics and wind require almost no water.

So as we develop our energy policy, if we're smart, we will think about the water implications and add those into the mix when we decide what we're going to do and where we're going to do it. Renewables in one place may make a lot of sense. But they may not in another place. Senator Corker's point is apropos there.

Second, the Nation's water system requires energy to move water, to treat water, to clean water, to distribute water and to use water. All of those things require energy. But like the energy system not each aspect of our water system requires the same amount of energy. It takes different amounts of energy to move water or to treat it with different kinds of systems or to use water in the home.

So when you think about how to save energy and to save water, thinking about the two things together makes a lot of sense. We want to do the things on the water side. But save the most amount of energy.

In my testimony, in my written testimony, Figure four, I believe, is a pie chart that shows an example of the energy required to move water to San Diego, to use water in San Diego. It takes a lot of energy to move it from Northern California to San Diego, to treat it once it's there, to distribute it, to use it in the home, to collect it and then treat it again in the waste water plant. For a place like San Diego a significant portion of that pie is moving the water from Northern California to Southern California. You have to pump it over the Tehachapi Mountains or you have to move it from the Colorado River.

A significant amount of energy is also required everywhere to use water, mostly in the home, hot water for heating, for showers, for washing machines, for dishwashers. It turns out a big fraction of the energy required for water is in the home. As a result policies that save water, better washing machines, low flow shower heads.

We have national standards for those. Also save a tremendous amount of energy. So thinking about these two things together is incredibly important.

Finally I offer in my written testimony some specific comments on the bill. Most of them are very minor. I'm not going to go over them here.

One example though is in Section 6 in the required sector section. You might strengthen the requirement that we look at water use efficiency in a sense as an energy efficiency savings. The State of California concluded that some of the cheapest ways to save energy may turn out not to be energy efficiency programs, but water efficiency programs.

You can save energy cheaper by saving hot water. That's a great example of thinking about things together. Maybe coming up with a different answer than you would otherwise have come up with.

I also have a set of conclusions in my written testimony. Again, I'm not going to go through them. But let me highlight four.

The first is let's pursue new appliance efficiency standards at the national level. We have appliance efficiency standards, mostly from an energy point of view. We could do better from a water point of view as well and save both energy and water.

The second is let's pursue smart labeling of water efficient appliances as we've done in the energy sector with the Energy Star program. We're starting to do with water appliances as well.

The third is let's promote research and development for traditional energy sources to figure out how to cut their water use.

We're going to be using fossil fuels, nuclear for a long time. They use a lot of water. Let's see if we can figure out how to cut their water use. Both withdrawals and consumption are important.

Finally, let's promote research and development and speed development of renewable energy systems which we're trying to do anyway from a climate point of view in order to save water as well.

Thank you for the opportunity to testify. I'd be happy to answer any questions at the appropriate time.

[The prepared statement of Mr. Gleick follows:]

PREPARED STATEMENT OF PETER H. GLEICK,[1] PRESIDENT, THE PACIFIC INSTITUTE, OAKLAND, CA

Mr. Chairman, Senators: thank you for inviting me to offer comments on the critical connections between energy and water in the United States. Water use and energy use are closely linked: Energy production uses and pollutes water; water use requires significant amounts of energy. Moreover, the reality of climate change affects national policies in both areas.

Limits to the availability of both energy and water are beginning to affect the other, and these limits have direct implications for US economic and security interests. Yet energy and water issues are rarely integrated in policy. Considering them together offers substantial economic and environmental benefits and I support the effort to do this in the Energy and Water Integration Act of 2009.

INTERNATIONAL AND DOMESTIC WATER AND ENERGY CHALLENGES

As we enter the 21st century, pressures on both our national water and energy resources are growing. Some recent headlines from around the nation tell the story:

Drought Could Force Nuke-Plant Shutdowns
The Associated Press, January 2008
Sinking Water and Rising Tensions
EnergyBiz Insider, December 2007
Stricter Standards Apply to Coal Plant, Judge Rules; Activists Want Cooling Towers for Oak Creek
Milwaukee Journal Sentinel, November 2007
Journal-Constitution Opposes Coal-Based Plant, Citing Water Shortage
The Atlanta Journal-Constitution, October 2007
Maryland County denies cooling water to proposed power plant
E-Water News Weekly, October 2007
Water woes loom as thirsty generators face climate change.
Greenwire, September 2007

Other nations are also feeling the challenges of energy and water problem: The Mayor of London recently rejected plans for a desalination plant on the grounds that it would require too much energy. A new desalination plant in Perth, West Australia, was build under the condition that new, renewable energy systems also be built in order to minimize its greenhouse gas contributions. A major wind farm was built to supply part of that plant's energy demand. The energy bill to operate the British water company, Thames Water, amounted to 17% of their total operating costs in 2007 and those costs are rising. Nuclear power plants in France were derated during drought because of temperature limits in rivers to protect ecosystems.

THE NATION'S ENERGY SYSTEM REQUIRES WATER

Water is used in every phase of the energy cycle, as shown in Figure 1.* A substantial fraction—nearly 40%—of the nation's water withdrawals are used in the generation phase to cool power plants and produce energy. This is the largest single withdrawal of water in the United States. While most cooling water is not "consumed," this level of water use is putting more and more pressure on regional supplies, and it may not be possible to satisfy all of the expected water needs of newly proposed powerplants. In arid and semi-arid regions, power-plant water demand can be a substantial fraction of limited regional supplies.

Far more water is required for nuclear and fossil-fuel energy systems than for most renewable energy systems, depending on cooling system type (see Figure 2). Moreover, some new fossil-fuel sources require substantial amounts of water during mining and processing, or contaminate large volumes of water making it unavailable for use for other purposes. These differences must be taken into account in national energy policy decisions.

[1] Dr. Gleick is President of the Pacific Institute, Oakland, California. He is an elected member of the U.S. National Academy of Science and a MacArthur Fellow. His comments reflect his own opinion.
* Figures 1–4 have been retained in committee files.

THE NATION'S WATER SYSTEM REQUIRES ENERGY

Capturing, treating, moving, distributing, and using water also require energy. Figure 3 shows the energy inputs for different phases of our water systems. To give you an idea for how substantial some of these energy demands can be, the single largest user of energy in the State of California is the State Water Project (SWP), which moves water from the mountains in the northern part of the state to the coastal cities in the south. The SWP uses an average of 5 billion kWhre per year. In order to pump 1 acre-foot of water (326,000 gallons) through the state system to Los Angeles requires an average of 3,000 kWhre of electricity. Figure 4 provides a pie chart breaking down the total energy required for water use in San Diego, showing the substantial amount of energy to move water to the region, and the even larger amount of energy to use water. Most of this energy goes to provide hot water, and substantial energy savings are possible by reducing hot water use. This startling assessment of the energy costs of water use can also be seen in the following estimate: Running the hot-water faucet for five minutes uses as much energy as burning a 60W incandescent light bulb for 14 hours.

The growing understanding of these connections is beginning to lead to new state and national policies. California is beginning to regulate greenhouse gas emissions, including emissions from water utilities. The California Energy Commission recently calculated that 95% of the energy savings of proposed energy-efficiency programs could be saved at 58% of the cost through water-efficiency programs instead and this is leading to a rethinking of funding priorities for energy efficiency.

WATER AND ENERGY EFFICIENCY SHOULD BE LINKED: CLOTHES WASHERS

Year	Energy Use kWhr per Load	Energy Use per Household (kWhr/year)
1980 to 1990	3.9	1,540
1990 to 1998	3.0	1,190
Water-Efficient Washers	1.6	630

Source: Pacific Institute, 2004

Table 1: The energy efficiency of washing machines has increased in recent years, and new machines also save significant amounts of water. Source: Pacific Institute, 2004. "Energy Down the Drain." Oakland, California.

Another indication of the links between energy and water use can be seen in Table 1, which shows how improvements in the efficiency of washing machines has led to a substantial reduction in energy use per load, and per household. New washing machines can cut energy demands by over 60% compared to earlier models, and they also save substantial amounts of water.

As noted by the California Air Resources Board:

> Water is one of the few sectors in California's economy where the same policies can serve both preventative and adaptive global climate change goals. Making more efficient use of water will reduce our demands on water resources and shrink the energy consumption associated with water conveyance, pumping, heating and treatment. California water policies can therefore help the State to adapt to the effects of climate change while also minimizing GHG emissions.
>
> *California Air Resources Board (February 11, 2008), "Technologies and Policies to Consider for Reducing Greenhouse Gas Emissions in California."*

SPECIFIC COMMENTS FOR CHANGES IN THE "ENERGY AND WATER INTEGRATION ACT OF 2009"

Finally, I'd like to offer specific comments on the proposed bill. I commend the sponsoring Senators for proposing this bill, and these suggestions for corrections or modifications are modest. As my preceding testimony should make obvious, I strongly support the need to both analyze the links between water and energy and to develop national policies that can minimize the unnecessary use of both resources.

Section 5(c)(2)C should read ". . .to reduce the volume and cost of desalination concentrated wastes and to dispose of those wastes in an environmentally sound manner;"

Section 6 should generally refer to water-related energy "use" rather than "consumption."

Section 6. The amended text of Section 205 of the Department of Energy Organization Act should include a call to both collect and disseminate information on energy use as follows:

> "(1) IN GENERAL.—Not less than once during each 3-year period, to aid in the understanding and reduction of the quantity of energy used in association with the use of water, the Administrator shall collect and disseminate information on energy use in various sectors of the economy that are associated with the acquisition, treatment, delivery, and use of water."
>
> Section 6. In the "Required Sectors" section, the following should be added after "(D) domestic purposes."
>
> "The assessment described in paragraph (1) shall also contain an analysis of the potential to reduce energy use through improvements in water-use efficiency."

CONCLUSIONS AND RECOMMENDATIONS

Water and energy are tightly linked, but these links are poorly understood and rarely used in policy.

- Decision makers and corporations should better integrate energy issues into water policy and water issues into energy policy.

The failure to link these issues will inevitably lead to disruptions in the supply of both water and power.

Water efficiency efforts can save substantial water (and energy) at lower cost, and faster, than new "supply."

- Water efficiency should be given a higher priority by resource planners.
- Implement water efficiency programs at all levels designed to capture multiple benefits.

The climate implications of both water and energy policy are significant.

- There are large opportunities for fast, cost-effective reductions in emissions.

National policies can help address both water and energy challenges. In particular,

- Phase out irrigation, energy, and crop subsidies that promote wasteful use of water and energy.
- Pursue smart labeling of water efficient appliances that also save energy.
- Pursue new appliance standards.
- Promote research and development for traditional energy sources that reduce water withdrawals and consumption.
- Promote research and development for renewable energy sources that use little to no water.
- Use alternative water sources such as reclaimed or saline water for power plant cooling.
- Encourage biofuels development that uses little water or discourage water-intensive biofuels.

I congratulate you for considering this vital issue and for helping to raise national attention on the need to re-evaluate and re-focus efforts on sustainably managing both our precious freshwater and energy resources. Thank you for your attention.

The CHAIRMAN. Thank you very much.

Dr. Webber.

STATEMENT OF MICHAEL E. WEBBER, PH.D., ASSISTANT PROFESSOR, DEPARTMENT OF MECHANICAL ENGINEERING AND ASSOCIATE DIRECTOR, CENTER FOR INTERNATIONAL ENERGY & ENVIRONMENTAL POLICY, THE UNIVERSITY OF TEXAS AT AUSTIN, AUSTIN, TX

Mr. WEBBER. Mr. Chairman and members of the committee, thank you so much for the invitation to testify today. My name is Michael Webber and I'm Associate Director of the Center for International Energy and Environmental Policy at the University of Texas at Austin. My testimony today will make four main points.

The first of which energy and water are interrelated which you've heard about from everyone so far.

The second point is the energy/water nexus is already under strain. That means we have vulnerabilities in the system where constraints in one sector can create constraints in the other. Water shortages or heat waves can create water constraints that become energy constraints as power plants either dial back or turn off. Energy constraints can create water constraints if you don't have the power you need for the water or waste water treatment sector.

The third point is trends imply these strains will only become exacerbated because of population growth which puts upper pressure on demand for energy and water. Economic growth which puts upper pressure on per capita demand for energy and water. As we get richer we eat more meat which is very water intensive. We have big homes that we air condition. That's very energy intensive.

The third trend that exacerbates this strain is global climate change which creates a greater intensity and frequency of droughts and heat waves which create those strains I just mentioned.

The fourth trend that creates the exacerbation of these strains are policy choices we're making that don't consider the energy and water impacts of the other. I'll go into more detail on that in just a second.

The fourth point that I'd like to make is that there are different policy actions at the Federal level that can help.

Coming back to the policy choice trends. We're making movement as a Nation by choice, by policy choice, toward more energy intensive water and more water intensive energy. For example we're moving toward more energy intensive water.

We're raising the environmental standards for water and waste water for good reason. But there are energy impacts of those choices. Also as municipalities face water constraints they push for new supplies of water from distant, low quality sources which implies long haul pipelines or deeper aquifer production or desalination all of which require more energy.

We're also moving toward more water intensive energy. We're moving toward energy choices that require more water. For example, nuclear power which is great from a carbon and domestic perspective, but it requires more water than coal and natural gas in most cases.

There is some good news. We're also moving toward solar photovoltaics and wind which require no energy, as Dr. Gleick mentioned. No water, excuse me.

Another important policy choice we're making is in the area of transportation fuels. We're focusing on a wide suite of transportation fuels almost all of which require more water to produce depending on how you make them. For example unconventional fossil fuels from oil shale, coal to liquids, gas liquids and tar sands all require more water than conventional gasoline.

Electricity for plug in hybrid electric vehicles, if made from thermal electric power plants requires more water as well. If that electricity is made from wind or solar photovoltaics, it's better from a water perspective. Hydrogen could also be more water intensive if made from the standard grid. Then the real example is biofuels which require a lot of water to produce.

So if we looked at how many gallons of water are required per mile traveled, biofuels require something like 20 gallons or more of water per mile traveled compared to a tenth or two-tenths of a gallon of water for conventional gasoline. Biofuels can be 100 to 1,000 times more water intensive. If that biofuel is made from natural rainfall, maybe we don't care.

But if it's made from irrigation it can have water impacts. So if you commute here ten miles and then commute home ten miles and you drive on E85 from irrigated corn ethanol. You're responsible is about 400 gallons of water consumed to meet the fuel for your car and your commute.

Overall if you look at the Energy Policy Act 2005 and the Energy Independence Security Act 2007, we have mandated essentially that water consumption will go up because of the targets for biofuels. If we look just at the E10 mandate worth 15 billion gallons a year from corn based ethanol that will push our transportation fuel's water use from a trillion gallons of water a year today to roughly two and a half trillion gallons of water per year in 2022. That means all water consumption for transportation fuels will grow from about 3 percent of national consumption today to about 7 percent.

This is a big jump. We need to make sure we have the water. So we're making policy choices that don't consider this nexus and might only exacerbate the strains.

The fourth point is that there are a variety of different policy actions that can help because rivers, watersheds, basins and aquifers can span several states and countries there's a need for Federal engagement on energy water issues. There are some policies pitfalls. For example energy water policymaking are disaggregated. They have different funding oversight mechanisms. There are many agencies and committees that touch energy and water, but none with clear authority.

Water planners often assume they have the energy they need. Energy planners often assume they have the water they need. Those assumptions might break down.

Energy has a top down structure with strong Federal agencies. Water has an inverted structure with strong local or State agencies. The data on water quantity are sparse, out of date, inconsistent and error prone, unfortunately.

We can't even agree on which units to use. In the East we use gallons. In the West we use acre feet. So this results in errors in the data. That's difficult for policymakers.

There are some policy opportunities at the energy water nexus. Firstly is conservation. Water conservation, energy conservation are synonymous. Policies that promote water conservation achieve energy conservation as a byproduct. Policies that promote energy conservation achieve water conservation as a byproduct.

Secondly we need to collect, maintain and make available accurate, updated, comprehensive, water data probably through the U.S. Geological Survey. The Energy Information Administration has extensive data on energy production, use, trade consumption of all sorts. We need an equivalent source of data for water.

We need to establish Federal oversight for water quantity. The EPA has oversight of water quality.

We need to establish strict standards of building codes for water efficiency as Dr. Gleick said.

We need to invest very aggressively in water related R and D to match increases in energy related R and D. High R and D targets might be novel approaches to desalination, air cooling systems from power plants or biofuels that don't require fresh water irrigation, for example, cellulosic sources or algae.

We need to support these to reclaim the water power plants for industry and also agriculture.

Lastly I think we need to reconsider water markets. Water is widely expected to be free and unlimited. Consequently we waste it. We need to find a way to value water appropriately while accomplishing our goals for social justice, human rights making sure water is available.

In summary this is a complicated issue. I'm very pleased to know that you're paying attention. Mr. Chairman, that concludes my testimony. I'd be happy to answer questions later.

[The prepared statement of Mr. Webber follows:]

PREPARED STATEMENT OF MICHAEL E. WEBBER, PH.D., ASSISTANT PROFESSOR, DEPARTMENT OF MECHANICAL ENGINEERING AND ASSOCIATE DIRECTOR, CENTER FOR INTERNATIONAL ENERGY & ENVIRONMENTAL POLICY, THE UNIVERSITY OF TEXAS AT AUSTIN, AUSTIN, TX

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 appear here today to share with you 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

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. Water heating alone is responsible for 9% of residential electricity consumption in the U.S. And, nationwide, water and wastewater treatment and distribution combined require about 3% of the nation's electricity. 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 approximately 15% of the state's total electricity consumption. Similarly large investments of energy for water occurs wherever water is scarce and energy is available.

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. On average, 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.

THE ENERGY-WATER RELATIONSHIP IS ALREADY UNDER STRAIN

Unfortunately, the energy-water relationship introduces vulnerabilities whereby constraints of one resource introduces 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 constraints.

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 weeks of shutting down because of limited water supplies. Today in the west, a severe multi-year drought has lowered water levels behind Hoover Dam, introducing the risk that Las Vegas will lose a substantial portion of its drinking water at the same time the dam's hydroelectric turbines quit spinning, which would cut off a significant source of power for Los Angeles. In addition, power outages hamper the ability for the water/wastewater sector to treat and distribute water. Thus, strain in the energy-water nexus is very real in the United States and is here today.

It is important to note that while constraints in one resource introduce constraints on the other, the corollary of that relationship is also true. That is, both resources can be enabling for the other: 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. Las Vegas, San Diego and Dallas are already considering some version of these options, all of which are extremely energy-intensive. Desalination in particular is alarming because it is approximately ten times more energy-intensive than production from surface freshwater sources such as rivers and lakes. Some areas are considering a combination of desalination plus long-haul pipelines, which has a compounding effect for energy use.

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 increasingly strict treatment standards for water and wastewater, which requires more energy than traditional approaches that met prior standards. In addition, instead of a push for water efficiency and conservation, many municipalities are pushing for new supplies of water starting with sources that are farther away and lower quality, and thereby require more energy to get them to the right quality and location.

For a variety of 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 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, 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. Hydrogen can also be more water-intensive than gasoline, depending on how it is produced. If made from steam methane reforming or electrolysis from water-free electrical sources such as wind, then hydrogen is no worse than gasoline (and potentially much better). However, if hydrogen is made from electrolysis using electricity from the standard U.S. grid, then producing hydrogen might consume more than 25 gallons of water and withdraw more than 1000 gallons for every gallon of gasoline equivalent energy that is produced. Though unconventional fossil fuels, electricity and hydrogen are all potentially more water-intensive than conventional gasoline by up to a factor of 10 or so, biofuels are particularly water-intensive. Growing biofuels consumes more than 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 proportion of our biofuels production, irrigation is used. Irrigated biofuels from corn or soy can consume twenty or more gallons of water for every mile traveled.

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.

If we compare the water requirements per mile traveled with projections for future transportation miles and combined those figures with mandates for the use of new fuels, such as biofuels, the water impacts are startling. 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) conducted its last survey on water consumption in 1995 and its last published data on water withdrawals are from 2000. 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. It is my opinion that robust energy and water policies should begin with conservation because of the cascading cross-over benefits they offer.

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. 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, analysts, policymakers and planners lack suitable data to make informed decisions.
2. Establish federal oversight for water quantity. The Environmental Protection Agency has oversight of water quality, but it's not clear if any agency has oversight of water quantity.
3. 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.
4. 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.

5. Support the use of reclaimed water at powerplants, industry and agriculture. Using reclaimed water for powerplants, industry and agriculture spares a significant amount of energy. However there are financing, regulatory and permitting hurdles in place that restrict this option.

6. Rethink water markets. Water is widely expected to be free and unlimited, even though water is a limited resource that we should value highly. Consequently, it is worthwhile to consider implementing water markets that balance our competing needs to meet our social justice and human rights goals (that is, everyone needs water to survive, whether rich or poor), while also meeting our need to discourage water waste through high prices. Block pricing, whereby the first amount of water usage is cheap or free in order to meet our survival needs, after which the price escalates significantly in order to curtail water use for non-critical purposes, might be a fruitful approach.

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.

The CHAIRMAN. Thank you very much.
Dr. House.

STATEMENT OF LON W. HOUSE, PH.D., ENERGY ADVISOR, THE ASSOCIATION OF CALIFORNIA WATER AGENCIES, CAMERON PARK, CA

Mr. HOUSE. Good morning. My name is Lon House. I'm the Energy Advisor to the Association of California Water Agencies. I'm the Water Energy Consultant to the California Public Utilities Commission. I'm a Water Energy Researcher for the California Energy Commission.

I'm going to be talking about one of the issues that this bill addresses which is the amount of energy that's in the water. The SB 531 calls for several studies to collect data on energy uses and water delivery and treatment. That's a very good first step.

We did it backward in California. We went out and started water energy pilots. It got bogged down because we didn't have defensible data on how much energy was actually in the water that were being saved by these pilots. So I just wanted to congratulate you guys on doing things sequentially and in the correct order and getting the data there first.

There is a lot of energy in the water in the United States. On the electricity side about 18 percent of all the electricity in the U.S. is used somewhere in the water, on the water side. The water systems use about 4 percent to procure the water, treat it, distribute it, collect the waste water.

The residential consumers use about five and a half percent. Agricultural/industrial sector uses about another eight and a half percent to treat and process their water. The projections of energy use in this area, as you've heard are anticipated to increase faster than the rate of population due primarily to accessing previously unused water sources and increased treatment requirements.

As other parties on this panel have said one of the nice things about water is anytime that you save water, you're going to save energy because there is energy in the water. There's three principles ways that my testimony goes into detail about how to solve this.

One is to reduce the amount of energy that's embedded in the water delivered. This is to reduce the amount of energy, improve the efficiency of the water systems that are delivering, supplying and treating that water.

The second is to reduce the amount of energy used by the customers and the amount of water used by the customers. As I've previously stated the end use is actually a higher usage of electricity than the water delivery systems.

Then the third thing that I wanted to highlight is to increase the amount of renewable energy generated by the water agencies. In California the water agencies in California have a peak demand of about 2,800 megawatts. We have over 3,000 megawatts renewable generation, the water agencies have.

I would just like to leave you real quickly with a couple of recommendations.

One is that you currently have on appliances the energy star program. You also have the EPA water sense program, but those are never combined. So that would be one of the things that you could do is on water appliances. Then a customer could look at that and say, this is how much water I'm saving and how much energy I'm saving from that particular appliance.

You could produce legislation that would encourage the use of renewable energy resources to address the energy needs associated with various aspects of water energy use. The Energy Efficiency and Conservation block grant program in the 2008 Energy bill exclude water systems. You could change that so that water systems could have access to that particular money.

I would encourage that this committee look at Federal agencies and require Federal agencies to use life cycle costing and to include water and energy savings in their evaluation of new technologies, particularly for things such as new pumps and things like that.

Then the last thing I would leave you with is there is still a lot of work that could be done in this area. The Federal agencies, the Department of Energy and the EPA could and should expand research on improving the efficiency of water supplies, water systems, water and waste water treatment and in water use.

Thank you for allowing me to provide these comments.

[The prepared statement of Mr. House follows:]

PREPARED STATEMENT OF LON W. HOUSE, PH.D., ENERGY ADVISOR, THE ASSOCIATION OF CALIFORNIA WATER AGENCIES, CAMERON PARK, CA

Thank you Mr. Chairman and members of the Committee. I appreciate the opportunity to address this important legislation. My name is Lon W. House, Ph.D. I am the president of Water and Energy Consulting[1], and I serve as the Energy Advisor to the Association of California Water Agencies. I am the Water-energy consultant for the California Public Utilities Commission, and I am a Water-energy researcher for the California Energy Commission.

The bill, S 531, calls for several studies to collect data on energy usages in water delivery and treatment. This is a laudable effort that should provide valuable information for future reference. In addition to the steps taken in your bill, there are other immediate opportunities to save water and energy that could be implemented now. My testimony is going to provide suggestions in this area. I recognize some of these suggestions are out of the scope of this committee but I am offering them

[1] Address: 4901 Flying C Road, Cameron Park, Ca 95682. email: lonwhouse@waterandenergyconsulting.com. Phone: 530.676.8956.

for your consideration as a member of the finance committee Mr. Chairman and Ranking Member Murkowski's role on the Appropriations Committee.

ENERGY IN WATER

The use of water requires energy: energy to procure, treat and distribute freshwater, and collect and treat wastewater, as well as the energy the customer puts into water to heat/cool, pressurize, and treat the water for their use. Nationwide, residential consumers alone use 5.5 percent of all the electricity in the U.S. to heat, treat, and pressurize water for their domestic use[2]. The commercial, industrial, and agricultural sectors can use another 8.5 percent of the electricity consumed nationally for their water processing and treatment[3]. The water and wastewater sector consumes about 4 percent of electricity used in the U.S. to supply water to customers and treat the wastewater produced[4].

PROJECTIONS OF ENERGY USE IN WATER

There is an increasing need to address water conservation and associated energy conservation in the water sector. There are areas of the U.S. that are subject to chronic water shortages[5], and the energy used for providing and using water is expected to significantly exceed population growth. In the next decade, water systems are expected to add significant amounts of new electrical load as they access previously unused water sources and address increased treatment requirements[6]. Over the next 45 years, electricity demand associated with supplying water and its treatment is expected to double, alongside population growth. Irrigation pumping and industrial uses (excluding mining), however, are projected to triple in that same time frame[7].

WATER PROGRAMS HAVE DUAL WATER AND ENERGY IMPACTS

Water conservation and efficiency programs have several characteristics that make them more attractive than simple energy conservation programs.

Water efficiency saves water and energy—energy efficiency saves only energy

Every time you save water you also are saving the energy that was previously used to treat and distribute that water. Water conservation and efficiency programs give you a double environmental impact for your dollar.

Water efficiency savings are more permanent

Energy efficiency tends to reduce the rate of increase in energy use. This is due to the substitution effect, where the energy savings that are realized with a more efficient appliance or application are often replaced by the energy use of another appliance (the energy savings that come from a more efficient refrigerator are replaced when the customer buys a new flat screen TV). However, when a customer buys a more efficient clothes washer or installs low water landscaping, they don't usually turn around and use that water somewhere else in their house.

The following graph shows that California, through billions of dollars of investments in energy efficiency, has managed to stabilize its per capita electricity usage.* By comparison, California has reduced its per capita water usage by 50 percent in the last 40 years. The state's total annual water consumption has remained the same since 1970 even as its population has doubled to nearly 37 million. Its per capita water use has plunged to less than half of what it was then.

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[2] U. S Household Electricity Report, Table US-1, Energy Information Administration, available at: http://www.eia.doe.gov/emeu/reps/enduse/er01_us.html (for residential use) and http://www.eia.doe.gov/cneaf/electricity/epm/table5_1.html for total electricity consumption.

[3] California Energy Commission (CEC), 2005. "California's Water-Energy Relationship." Final Staff Report, June 2005 CEC-700-2005-011 http://www.energy.ca.gov/2005publications/CEC-700-2005-011/CEC-700-2005-011-SF.PDF

[4] EPRI, Electric Power Research Institute, 2002. Water and Sustainability (Volume 4): U. S. Electricity Consumption for Water Supply & Treatment—The Next Half Century, No. 1006787, Palo Alto, California.

[5] U.S. Government Accountability Office (GAO) "Freshwater Supply: States' View of How Federal Agencies Could Help Them Meet the Challenges of Expected Shortages", GAO-03-514, July 9, 2003

[6] House, L. W.2007. "Will Water Cause The Next Electricity Crisis?" Water Resources Impact 9 (1), January 2007.

[7] "Energy Demands On Water Resources", Report To Congress On The Interdependence Of Energy And Water, U.S. Department Of Energy, December 2006.

* Graphs have been retained in committee files.

WATER SYSTEMS HAVE AN INTEREST, ABILITY, AND PROCLIVITY TO INVEST IN MORE RENEWABLE GENERATION

Water and wastewater systems have a unique opportunity to significantly increase the amount of renewable generation available. They have electrical load (pumping and treatment facilities), available land (for solar and wind), fuel sources (for biogas), and multiple sites for hydroelectric generation. Already in California, water and wastewater agencies have renewable generation over 3,000 MW of existing capacity, with more than 1,000 MW of additional capacity under consideration. Across the nation, these systems have the facilities, professional staff, and local leadership capability to play a foundational role in transforming the nation's energy policy if the proper incentives are available and current impediments are reduced.

DEMAND/GENERATION STATISTICS OF CALIFORNIA WATER AGENCIES

DEMAND AND DEMAND RESPONSE

Water agencies in California currently~2,800+ MW maximum demand
Water agencies curtail approximately 400+ MW of on-peak demand

WATER AGENCY GENERATION

500+ MW of existing standby generators available
Hydro—2,547 MW existing, +255 MW new small in-conduit potential
Biogas—57 MW, +36 MW new potential
Wind—1 MW, + unknown potential
Natural gas engines—existing~100 MW, +200 MW additional potential
Solar—18 MW installed, 48 MW under construction, +500 MW being reviewed by water agencies.

OPTIONS FOR ENERGY REDUCTIONS IN WATER SECTOR

Looking at water systems comprehensively (addressing both the consumer and the supply systems) and ensuring conservation, efficiency, and renewable generation projects are designed in tandem creates even greater efficiency and conservation opportunities which can result in significant water and energy savings and dual benefits to the environment.

There are three principle implementation areas within the water sector: 1) reduce the energy embedded in water delivered, 2) reduce the energy in the water used by customers and amount of water used by customers, and 3) increase the amount of renewable generation by water agencies.

1. Reduce the energy embedded in water delivered

Provide incentives to water systems to invest in more efficient system configuration, components, and operation to improve energy efficiency and to reduce peak electric demand.

Energy Efficiency (system redesign and retrofitting of equipment, low-friction pipe, high efficient pumps, adjustable speed drive motors, SCADA [Supervisory Control And Data Acquisition] system installation with real-time pump and process integration, efficient lighting, increased efficiency treatment options). 25% of industrial electricity use and 50% of municipal and wastewater use is due to pumps. High efficiency pumps are typically 20% more efficient. Purchasers typically use lowest installed cost—not lifecycle cost, and purchase the less efficient options. Pumps have a 15-20 year typical life, so the pumps purchased today will be consuming electricity for a long time. Variable Frequency Drives (VFDs) are also a good option on pumps with varying demand to reduce electricity consumed.

Peak Electric Demand/Demand Response (increased storage, aggregation of water system utility accounts, SCADA system installation, improvements to primary/secondary water and wastewater treatment). All water systems have some sort of water storage to accommodate varying demands for water throughout the day. They can use that storage to reduce their pumping during the electrical peak demand periods. In California, the water agencies in the state typically reduce their electrical demand by 400 MW during on-peak hours[8]. Increased water storage facilities could result in hundreds of MWs of additional on-peak electrical demand reduction.

Improve leak detection and reduce system loss (SCADA improvements, Automated Meter Reading (AMR)/Advanced Metering Infrastructure (AMI) installation). There is always some leakage within water systems, due to the necessity to maintain a

[8] House, L.W., "Water Supply Related Electricity Demand in California", Demand Response Research Center Report, LBNL-62041, December 2006.

pressure differential between inside the system and outside the system. As systems age they develop more leaks. The development of relatively inexpensive AMI and AMI allows almost instantaneous feedback on water movement throughout the water distribution system and can allow leaks to be identified and addressed rapidly.

Increase energy utility investments in water system efficiency and demand response. One of the frustrations in California has been the relative lack of ability of water systems to participate in utility energy conservation programs[9]. While this is slowly changing, the utility energy conservation programs typically address energy systems they are familiar with—air conditioning, lighting, heating, etc.—that do not apply to water system efficiency improvements. The ability of increased water system storage to reduce peak electrical demands likewise has been neglected by utility programs.

Increase use of recycled water. The use of recycled water for agricultural, industrial and commercial purposes and for outdoor irrigation results in significant reductions in the demand for water from the environment and in the amount of energy needed by the water sector. The wastewater has to be treated anyway. If that water can be used in lieu of additional fresh water it saves not only all that water but all the energy associated with providing the additional fresh water. California has a state policy that no fresh water can be used for electrical production if there are available alternatives—including recycled water—recycled water is a major component of existing and future water supplies. Capture and use of stormwater and rainwater. The use of stormwater and rainwater to supplement fresh water sources can significantly enhance available fresh water supplies and are often at energy costs lower than other new sources of fresh water.

Increase research on improving energy efficiency of water systems

Improvements in the energy efficiency of water systems will have long lasting results. Additional research needs to be accomplished in the following areas.

> Reductions in energy requirements of new water supplies (desalination, membrane technology, well head treatment, integrated water system planning, natural treatments systems)
>
> Reductions in energy requirements of water distribution and service systems
>
> Reductions in energy requirements of wastewater treatment and recycled water systems.

2. Reduce the energy in the water used by customers and amount of water used by customers

Provide incentives that encourage customers to more efficiently use existing water supplies and to reduce water demand which saves both water and energy.

New appliance efficiency standards (residential and commercial clothes washers, dishwashers, clothes dryers, pool and spa pumps and heaters, showerheads and faucets, toilets, urinals, landscaping irrigation). New appliance standards should be evaluated based upon the contributions of both their water and energy savings.

Rebates/grants/tax credits for efficient appliances that go beyond current standards (aggressive production tax credits spur market share growth for the most energy and water efficient appliances, combine ENERGY STAR and WATERSENSE labeling). More efficient water-using appliances save both water and energy—directly, as in the case of water heaters, dishwashers, clothes washers—indirectly, by reducing water use as in the case of high efficiency toilets. Incentives for increased efficiency should involve both water and energy savings.

Improve leak detection (AMR/AMI installation). The development of relatively inexpensive AMI and AMI allows almost real-time water consumption information, which makes customer leak detection virtually instantaneous, as the following graph illustrates. This allows customer leaks to be identified and fixed much more rapidly than has been the case in the past.

Incorporate water efficiency requirements into new construction and upon resale (LEED standards, plumbing fixtures, appliances, landscape and landscape irrigation, cooling towers, decorative and recreational water features). New construction and transfer of ownership presents a unique opportunity to reduce water consumption which, once accomplished, continues to save water and energy for an extended period of time.

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[9] House, L.W. "Public Versus Private Customer Perspectives on Participation in Demand-side Programs", Strategic Planning for Energy and the Environment, Volume 27, No. 3, Winter 2008, pg 59-66.

Increase electric and gas utility programs in water programs. There is a need to increase electric and gas utility programs in water efficient appliances and processes. Allowing energy utilities to partner with water systems on water conservation projects as part of their energy saving portfolios has tremendous potential. California has a pilot program through the California Public Utilities Commission (CPUC) that allows the investor owned energy utilities (IOUs) to partner with water providers to implement jointly funded programs designed to save energy via water savings[10]. This pilot focuses on efforts that conserve water, use less energy-intensive water, make delivery and treatment systems more efficient, and determine actual water savings and actual energy savings.

3. Increase the amount of renewable energy generated by water agencies.

Provide incentives and remove impediments for water systems to become more energy self-sufficient and, where possible, to feed renewable power into the grid. It should be noted that the majority of water systems are government owned, and traditional incentives such as tax credits have limited effectiveness. About 85 percent of the fresh water systems serving more than 10,000 people in the U.S. are publicly owned, and about 91 percent of systems serving more than 100,000 people are publicly owned. Nearly all of the wastewater treatment plants are owned by public institutions (municipalities or specially designated districts)[11].

Rebates/grants for renewable generation including small hydroelectric, in-conduit hydroelectric, solar, biogas and wind generation. California has a couple programs in this area: the California Solar Initiative (CSI) that deals primarily with solar and the California Self Generation Incentive Program which deals with other types of renewables. For the CSI, California has two levels of incentives—one for tax paying entities that can take advantage of tax credits, and another higher incentive level for those entities that cannot use tax credits. There are constraints in both these programs that result in less renewable generation developing than would otherwise be the case. Specifically, there is a low maximum size allowed (on the order of 1 MW per installation) that results larger projects not being developed, and the requirement that all energy produced must be used on site also truncates the size of these installations.

Tax Credits that promote private public partnerships for renewable energy installation and energy production. The ability of public entities to use tax credits like the CREBS (Clean Renewable Energy Bonds) to develop renewable energy projects provides access to money that would otherwise be unavailable to the public entities. PG&E (Pacific Gas & Electric Company) recently filed an Application for Photovoltaic Program with the CPUC in which they are seeking partnerships in the development of solar projects with guaranteed prices for the solar electricity.

Net Energy Metering programs allow the offset of retail rates with the renewable generation. Net Energy Metering (NEM) tariffs in California allow renewable generation to be credited against retail rates for electricity at the specific location. A major disadvantage of this program is that any electricity generated in excess of use is not compensated for. This results in much smaller renewable projects (particularly solar) than may be economically attractive, as there is no ability to sell excess electricity generated to the utility.

Remote Net Metering Programs that allow renewable generation at one location to be credited against a portion of retail rates another system location. California's AB (Assembly Bill) 2466 is called the Local Government Renewable Energy Self-Generation Program and is codified as Section 2830 of the Public Utilities Code. It allows government entities to generate renewable energy at one location, and have it credited against part (the generation part only) of retail rates at another location. It's size limit is1 MW and the inability to access any other incentives in the development of the renewable project are limiting its usefulness.

Renewables Feed-In Tariffs that provide a utility standard contract with specified renewable energy price. California's Assembly Bill (AB) 1969 added Public Utilities Code Section 399.20, authorizing tariffs and standard contracts for the purchase of eligible renewable generation from public water and wastewater facilities. It has size limitations (1 MW) and the inability to access any other incentives in the development of the renewable project is resulting in less renewable generation that could be developed.

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[10] A.07-01-024 et. al.

[11] USEPA, 2002. Community Water System Survey, United States Environmental Protection Agency, Office of Water, Washington, D.C., December 2002, EPA 815-R-02-005A.

CONCLUSION AND RECOMMENDATIONS

Thank you for this opportunity to discuss these issues before this Committee. I would like to make the following suggestions.

1. Legislation should recognize and encourage the economic and environmental benefits associated with the energy efficiency-water use efficiency/conservation. Two practical things that could be done now are to combine the DOE energy star program with the EPA Watersense program for water using appliances, and promote the use of recycled water, especially where its use would result in a lower overall energy footprint and have positive environmental impacts.
2. Legislation should encourage the use of renewable energy sources to address energy needs associated with all aspects of water use—recognizing that most of the water systems are publicly owned. Expand the energy efficiency and conservation block grant program in the 2007 energy bill to allow water agencies to be eligible units of local governments. Expand the funding for the CREBS bond program.
3. Legislation should encourage federal agencies to identify opportunities to advance energy and water efficiency, including alternative/renewable sources of energy. Federal installations should be required to use life cycle costs in the procurement process, and take into consideration both the water and energy savings that result from more efficient technologies and processes.
4. Federal Agencies (the Department of Energy and the Environmental Protection Agency) should expand research on improving the energy efficiency of water supplies, water systems, water and wastewater treatment, and in water use.

The CHAIRMAN. Thank you very much. Why don't we call on Senator Murkowski for any comments she has at this point before we go to questions.

STATEMENT OF HON. LISA MURKOWSKI, U.S. SENATOR FROM ALASKA

Senator MURKOWSKI. Thank you, Mr. Chairman. It's taken me a little bit longer to move today so I apologize. But I appreciate the opportunity to hear the testimony from the witnesses today on this issue of energy and water and how the two relate.

I think we're all interested in the connection between the two. All forms of energy, fuel extraction, fuel refinement, energy production, energy distribution it all comes together with water and affects our water resources in some manner. So by identifying the relative linkages between energy and water systems and our key research needs I think we certainly get a greater return on our investment research in the development, the commercialization of energy and water technologies.

I think we recognize that an energy technology that is cheap to produce and has zero emissions is useless if it's really going to consume more water than we can supply. I don't think that we think about that in the general course of our discussion about our energy consumption. We need to be thinking about it.

So I'm pleased to see that we're placing this emphasis on the water use efficiency and recognize that the work that we're doing in our legislation is going to be focusing on this. So I appreciate the comments from the gentlemen this morning.

The CHAIRMAN. Did you want to go ahead and ask questions or do you want me to ask some first and then you? How would you like to? Ok.

Let me start and ask a few questions. One of the issues Senator Corker raised in his opening comments was that solar thermal requires a great deal of water. I think some of you have made reference to that.

I'm not clear though as to whether this is consumption of water or whether this is just use of water. Because my impression is that for example our large utility in New Mexico was getting ready to put in a solar thermal facility or at least they hope to. I thought that the water they would be using in that operation would be largely recycled. That was my impression.

Any of you have an opinion on that? Dr. Webber.

Mr. WEBBER. For a solar thermal system you have a loop of water you use for the process loop to create the power and then a cooling loop. You have two different loops of water. The cooling loop is important for solar thermal. It does use a lot of water for cooling, the way coal or other hot power plants might.

It's not clear how much water needs because we don't have many data points or many examples, actually and so existing power plants use more water, as was noted earlier. However some new data I just got last week from the National Renewable Energy lab in Golden, Colorado from the Department of Energy suggests that solar thermals needs less water than coal and nuclear. I'll be happy to get those data out after this.

So it's not clear. It definitely needs water, solar thermal does for its cooling loops. Solar photovoltaics generally do not is the main distinction.

The CHAIRMAN. Dr. Gleick.

Mr. GLEICK. Yes, if I might add just a quick point. Systems like solar thermal and fossil fuels and nuclear require a lot of water for cooling. The amount of water they consume depends largely on the type of cooling system they have.

The cheapest cooling systems to install consume the most water. More expensive cooling systems can be put in that recycle a lot of the water in the cooling systems. So in part the answer to your question depends on what we're willing to spend for the cooling system which in part depends on how scarce the water is in the particular place we're building the plants.

The CHAIRMAN. Ok. Dr. House.

Mr. HOUSE. This last week we just ran into exactly this issue in California. There's a big solar thermal facility that's proposed to go in Southern California. They were proposing like Dr. Gleick says wet cooling which is evaporative cooling.

Now they're having to come back because you know California has a policy that no fresh water can be used for power plant production if there's an alternative. So this solar thermal facility is now having to come back and it's considerably more expensive. But they're having to go to recycle or to what they call dry cooling towers because of the amount of fresh water that they were proposed to use.

The CHAIRMAN. Ok. Let me ask you, Mr. Bolze. Your suggestion, that we consider an investment tax credit of 30 percent to drive increased water reuse.

We are being urged to increase the investment tax credit for cogeneration of heat and power from 10 percent to 30 percent. You're suggesting that a similar tax credit would be appropriate for in this area. That it would result in substantial savings in energy.

Could you just elaborate on that?

Mr. BOLZE. Yes. What I wanted to point out is some feedback that we get from our customer base around the world. To give you a sense in our written testimony I laid out that there's some numbers that says that the U.S. reuses about 6 percent of its water on the industrial side. To give you a sense, Australia is about 8 percent. But they have incentives in the plate to get that to 30 percent by 2013.

Singapore is at 15 percent, going to 30 percent by 2010. Israel is at 70 percent. So as we look at it there is opportunities, clearly, to reuse more of the water that's used in industrial and power generation.

To the point that I brought up on investment tax credits——

The CHAIRMAN. Let me just ask on that.

Mr. BOLZE. Yes.

The CHAIRMAN. Do you have the specific policies that each of those countries has put in place to increase water reuse? Could we get access to that?

Mr. BOLZE. We do. We have a white paper.

The CHAIRMAN. Ok.

Mr. BOLZE. That we've had out for about 6 to 9 months. There are a variety of different policies. Not every country employs the same policy. But there are a number of different ones. But we can provide that.

The CHAIRMAN. That would be great if you would.

Mr. BOLZE. Back to the investment tax credits, of our over 50,000 customers today, I would say that less than 1 percent are really applying any material reuse of water. When you really bore into that it comes down to economics. Right now, today, it's less expensive to pull water from ground river, municipal systems than it is to invest in water reuse.

That's why we support the NAS study in laying the associate economics of that. We as a company have not studied that, but our customers say as you look at a tax credit it allows them to look at that more holistically. So that was the point we were trying to raise.

The CHAIRMAN. Good. Senator Murkowski.

Senator MURKOWSKI. You know they always say that water is the next oil in terms of the fight and the competition. I truly believe that we're going that way. When you understand how all that we're trying to do as we move to this new world of renewables and recognizing that you can't get there from here without significant water. The phrase water becomes the new oil is even more realistic.

Tell me where we need additional Federal engagement on the energy/water issues. Mr. Webber, you alluded to it saying you know, we're not even using the same unit measures in parts of the country. What should we be doing from the Federal perspective?

Are there any institutions that should be specifically involved or strengthened to provide for more effective policy? I throw that out to anyone of you.

Mr. WEBBER. There are several agencies that I think should be involved. The Department of Energy certainly is already involved in the energy/water nexus. They should continue that. They may lead on some R and D efforts.

The United States Geological Survey has taken the, sort of, lead on collecting data related to water, water quantity at least. I'd like to see that role expanded and continued. The data collection that they offer, unfortunately is limited and infrequent. I think that needs to be done in a much more systematic and supported way.

Those data would be very valuable for people like us having these discussions. So that's one easy way for Federal Government to engage. Because you have the capacity for data collection and management that states would have difficulty with.

Senator MURKOWSKI. I have a comment on that. Several years ago I introduced legislation that would enhance and build the stream monitoring gauges in the State of Alaska. We recognize that if we want to do anything more with development we've got to know what the baseline is. We don't have any baseline.

I know that we're at a disadvantage in my State. But I think that we're similarly disadvantaged throughout the rest of the Nation in understanding what those real resources are. Any other comments to the question?

Dr. Gleick.

Mr. GLEICK. Yes, if I might add a few. I think that there are many issues among water and energy that are local. But there are a lot of series of Federal responsibilities.

One thing we might consider is phasing out irrigation energy crop subsidies that promote wasteful use of water and energy together. Another is, and I've made these recommendations already. Smart labeling of appliances, better appliance efficiency standards, research and development on energy technologies that reduce water demands.

The concept of using alternative sources of water for power plant cooling has come up. But I think probably should be pursued more aggressively. The example of the Palo Verde nuclear plant, it's the only plant in the country, nuclear plant that uses reclaimed water for cooling.

There's an opportunity to use recycled or reclaimed water for cooling in a lot of places or brackish ground water that we can't use for irrigation or other things. Look at other sources of water for meeting some of our energy needs. We should encourage biofuels development only when it's not water intensive.

Dr. Webber talked about that. There have been a number of Federal policies on the energy side that have not integrated the water issue and if had integrated them together we would of perhaps made a different choice.

Then finally this issue of a water census has come up on the House side. There is some legislation proposing that the U.S. do a comprehensive assessment of the water resources of the Nation both what we have and what we use and how we use it. We don't have such a census.

The USGS is the perfect place to do such a thing. They do work in both of those areas, water availability and water use. But we ought to be doing a regular census of how much water we use and where and how. That would help on the energy side as well.

Senator MURKOWSKI. Thank you. Thank you, Mr. Chairman.

The CHAIRMAN. Senator Corker.

Senator CORKER. Thank you, Mr. Chairman. I think this is an outstanding hearing. I think the testimony has been most useful.

The census issue you just mentioned, Dr. Gleick. We had an issue in our State where folks were considering shipping water down to another city which was, you know, in my opinion, not intelligent. Because if you look at the whole issue of sustainability.

I mean the energy uses into the future are going to be huge. I think the comment you just made about maybe having an inventory of that, if you will, for the future and for cities and states to be using that as a measurement as to their sustainability into the future is something I think is very important. So you know, here today we've talked about the fact that wind and solar voltaic uses no water. Biofuels which we actually are pursuing heavily in our State uses a lot of water. Ok, I think that's good for all of us to know.

Our State also uses a lot of coal to be candid. We use a lot of nuclear power also. We have a lot of discussions here in Washington about carbon sequestration, capture and sequestration. I'm a skeptic. It's sort of like when donkeys fly we'll be doing that on a commercial basis.

But it seems to me the whole issue of water makes that even more difficult. Because when you capture, as Dr. House was talking about, the fact is when you capture electricity it uses more electricity to do that. It makes it less efficient, if you will.

But then second a lot of water is used in that process. I wondered if each of you or those of you who wish to might respond to how you think water usage really plays into the whole issue of carbon capture and sequestration?

Mr. WEBBER. So I'll make a couple comments. Firstly you often use water as a process chemical to stress separate out the carbon dioxide. You bubble your smokestack gases through a solution that has water. That's one way water shows up.

That itself is water and then it becomes parasitology, you already heard, where it lowers the efficiency of the power plant. So that affects your total water use per kilowatt hour that's useful. Then you can impact water quality if you don't sequester carefully. So you have to be careful how you sequester and where you store your CO_2 when you liquefy it and put it into the system.

In Texas we've been doing carbon sequestration injection for advanced oil recovery for a few decades. In a lot of the permeating centers around water quality ensuring you don't pollute the water systems. So it's an important, complicated system. You start to see energy/water/carbon tradeoffs.

There are some simple synergies, things that are good for energy that reduce energy, also reduce carbon and reduce water and vice versa. But now we have these more complicated interactions where things that are good for carbon, like biofuels, might be bad for water. But things that are good for water, like dry cooling. If you don't do it right, it might be bad for carbon.

So we have to be very thoughtful about this. There's definitely very complicated relationship, but they can't all be overcome. But you do have to sort of pay attention ahead of time.

Mr. HOUSE. One of the things that the water agencies in California says, you know we have a little more rigorous goal on greenhouse gases than the rest of the country has. But, so one of the things that the water agencies in California do, and is, they're determining their carbon footprint. This is where the renewables comes in.

What they're doing is we're building renewables to basically offset the amount of electricity that we're using. In my testimony I have a description of what kind of technologies are out there and how much the water agencies are doing. But one of the things which, the two things which has really happened is one is that the water agencies, the largest single group of solar installations of the State and the other is that for biogas, basically it will be impossible to flair biogas from waste water treatment facilities.

So what the water agencies are doing is they're taking that and they're running it through generators now and they're using biogas to do that. So at least, I think that from that one market segment which is for a particular water industry. They have, at least in California, and I think the rest of the country, they have the space and they have the interest to try and offset their carbon emissions completely or fairly significantly through the installation of renewable generation on their locations.

Mr. GLEICK. Senator, you're asking a great question. I don't know of any real research that's been done on the water implications of sequestration. It may have been done. But if it hasn't, it's a great example of the need to look at water when you make an energy decision.

Sequestration is one of the many solutions we're going to have to think about in dealing with carbon. Obviously the best way to get carbon out of the atmosphere is not to put it there in the first place. If we have to sequester carbon it's going to be very expensive to do. It's considered an option but we have to think about the implications.

The final point is here, you pointed out about the census. One of the reasons why this is a national, should be a national, not a local or a State effort that I give a water census. It's precisely because we have State boundaries. Our watershed boundaries don't pay attention to State boundaries.

Water crosses political borders. So you don't want a State doing a census. You want a watershed census.

The Colorado River is shared by seven states. A lot of the rivers in the Southeast are shared by multiple states. It's the perfect example of where a Federal role in doing an evaluation of how much water we have, where it is and who uses it, is appropriate.

Mr. BOLZE. Senator, the only thing I would add is again, as was mentioned earlier, looking at energy, water and the carbon issues are interrelated, obviously. We don't have any specific data around on carbon sequestration. We're obviously involved with some projects to look at that with our customer base.

But I agree with your point. It needs to be studied as they look at that investment. I think, as was mentioned earlier, carbon sequestration is used in a number of areas and has been for a number of years in the area of enhanced oil recovery.

As our customer base, some of the customer base looks at carbon sequestration, they have to look at the economics of that sequestration system that has to be put into place and how that works for the total cost of, you know, their output of production. So I agree with your point. It's got to be looked at, not only for coal gasification or for coal plants with carbon sequestration, but also with all of the various energy options.

I believe those economics will vary based on location, obviously climate, location because the technologies perform differently and it also is dependent on the water scarcity in that specific region.

Mr. BAUER. I would just add that there is carbon sequestration work at the Department of Energy in which NETL, National Energy Technology Laboratory leads and coordinates the regional partnerships across the country. Water and the impact of sequestration injection is part of those considerations. Having said that, there is data coming out, but there's a great sensitivity to that as Dr. Webber pointed out, a good example is the EOR. It's been done for decades where water is one of the issues that must be dealt with in a permitting process. So obviously water is something that must be dealt with.

There is another side of this; in the bill it talks about the nexus of energy and water, but it kind of emphasizes the energy side of it. I think the dependence of water on the availability of energy must be considered as well. Because as Steve just said, if you don't have the energy to move the water, you don't have the water.

So the quantity of energy needed has to be traded off against how you deal with it, which is all the variables we have to deal with in both water, carbon dioxide and energy. They have to interplay both on the banks of technical and potential, positive or negative results. But also the economic impacts are substantial and have to be considered in the tradeoffs.

Senator CORKER. Mr. Chairman, thank you. Thank you all.

The CHAIRMAN. Thank you. Senator Udall.

Senator UDALL. Thank you, Mr. Chairman. I would like to welcome the panel. Thank the chairman and the ranking member for holding this important hearing. The water supplies are important in all parts of our country. But certainly in the West we, as in the Rocky Mountain West, we really know, living in an arid climate, the challenges that we face.

I think you can measure society's health with a number of different metrics. The energy supplies for one, based on where the accessibility, the affordability, the predictability, you could do the same thing with water and water supplies. The two are interrelated as our hearing is showing us here today.

Dr. Gleick, I note of some interest to you, you talked about the potential we had some 100 years ago or 150 years ago to organize the West in particular on watersheds. There's a well known Civil War Major, one armed veteran, Major Powell who made that very proposal. We're now trying in the West to govern ourselves based on his principles.

It's an opportunity lost. Nonetheless we have to move forward. So I appreciate your making that point.

I have been in an Armed Services hearing, so forgive me for arriving a bit late. I know the Chairman pursued a question around whether incentives for water reuse. I wanted to follow on with the panel with this question.

Are there regulations and policies that stand in the way of increased water reuse and recycling for industry, business and homes? What are these and how could Congress address these issues? Would anybody on the panel like to dive in and take a shot at answering that question?

Dr. House, you? California experiences would be informative.

Mr. HOUSE. In California water reuse really isn't much of an issue because we do it and particularly in Southern California. If you look at the new sources of water supply that we're looking at, conservation is Number 1 and reuse is Number 2. Within a few years, probably within the next decade there will probably be no waste water that has been treated that's sent out to the environment, to the ocean anymore.

We're using it. There's something like 250 cities that are using it on parks and it's used for agriculture. It's used for, as I said earlier, for power plant treat, for power plant water use. Basically the policy basically prohibits the use of fresh water at power plants in California.

What that's done is it forced the number of the new power plants to go to reclaimed water. Then the other thing that is happening particularly in the Southern part of the State is that the reclaimed water is used for aquifer recharge. So at least in California and I can't speak for the rest of the country, but reclaimed water and water reuse is one of the building blocks to get to the future for the State.

Senator UDALL. So from your experience there are no Federal laws or policies that get in the way of the policies that you're pursuing in California proper?

Mr. HOUSE. I am unaware of any. The one thing that does sort of come into this depending on what you use the reclaimed water for, you have to treat it to a much lower standard if you're going to use it say, in a power plant than if you're going to use it to recharge an aquifer. So for example, if you used it to recharge an aquifer you basically have to treat it to drinking water standards, the waste water, to drinking water standards before you put it back into the aquifer.

So it does have some impact upon the level of treatment that you use depending upon what the use of the recycled water is.

Senator UDALL. Other panelists.

Mr. BOLZE. Senator, just addressing the other side of your question in terms of are there additional policies or such or what are the policy options that are available. I had mentioned earlier that we have a white paper that just addresses what are some of the other options for water scarcity, addressing water scarcity through recycling and reuse. We can make that available.

What I boil it down to is a couple things. Some of which we've talked about. One of which is just around education outreach which is just a little more visibility around the various water usages and statistics by location. I know this committee is looking at that as part of its legislation.

Second of which is, as we talked about is some countries around the world are looking at direct incentives be those for investment tax credits. Some are looking at accelerated depreciation policies. There's different ways to do that. I wouldn't say there's one that's perfect but there are a variety of ways to look at direct incentives.

The third of which is some countries are looking at mandates and regulations around specific water reuse or percent reuse.

I think the fourth of which has to do with your earlier question which is around removing barriers, if they do exist, be it at the local level, the State level, the Federal level and such.

So I think there are a variety of different options. What we have seen as we talk to people, not only in the United States but around the world is there's different ways to go at this. But right now I would say the biggest issue we hear back from our customers is again back to the point of the economics of using/reusing water that's been say treated for industrial purposes verses then going and getting new water from the ground or wells etcetera. The economics better supports going out and using new water. So just some options for the committee.

Senator UDALL. Thank you.

The CHAIRMAN. Thank you very much. Senator Bennett.

Senator BENNETT. Thank you, Mr. Chairman. It has been a very useful hearing. It raises all kinds of questions.

Let me ask a probably stupid one, but one that occurs to me. Mr. Bauer, you indicated and I think that the vocabulary of the panel indicates that water is reused. There is a difference between use and consumption because it goes, evaporates and then it comes down in rain.

That raises the question is there a finite amount water in the planet that is disappearing as a result of human activity?

Mr. GLEICK. Senator, there's no such thing as a stupid question.

Senator BENNETT. Just stupid people who ask them.

[Laughter.]

Mr. GLEICK. No. The amount of water on the planet is fixed. What's not fixed is where it is and when it is.

Senator BENNETT. Alright.

Mr. GLEICK. It moves in and out of stocks of water, lakes, ground water, oceans and flows of water, flows in the river, rainfall. It's constantly in motion. It's a hydrologic cycle.

What we worry about is two things. Withdrawal of water, just the total amount of water that is withdrawn to do something. For power plant cooling it's a tremendous amount——

Senator BENNETT. When it is withdrawn from your first statement, it doesn't disappear?

Mr. GLEICK. Not always.

Senator BENNETT. Ok.

Mr. GLEICK. There are problems with withdrawal, only withdrawal, not consumption if you're in a place that just doesn't have much water where there are already demands for water. You just can't withdraw anymore. You can't build a new power plant because all the water is spoken for.

Senator BENNETT. So you're talking location?

Mr. GLEICK. That's a location question. In other places the consumption of water which is a small fraction for power, a much smaller fraction, is typically steam that goes to the atmosphere. It goes and it disappears in the watershed that use it and it comes down as rainfall, maybe 1,000 miles away.

Senator BENNETT. Ok.

Mr. GLEICK. It doesn't disappear but it's no longer useable where you had it.

Senator BENNETT. Alright now it comes down as rainfall. Two thirds of the world is ocean and we have not yet found a really economic way to use all the water in the ocean. Desalination is very expensive and very difficult.

Does this mean there is, by virtue of human activity a trend away from water on land that we use toward being absorbed in the oceans? If we go back to your first point that the whole thing doesn't go away, but the location changes?

Mr. GLEICK. No. If you consume water in a watershed it doesn't affect how much water that watershed gets next year or next month. That's not, unless you're changing the climate, and there's long term changes.

Senator BENNETT. Yes. Right.

Mr. GLEICK. It all ends up in the ocean, goes back. In the end it comes back again. So the comsumpted use of water doesn't affect the long term renewability of the water in a watershed.

Desalination, 97 percent of the planet's water is salt water.

Senator BENNETT. Right.

Mr. GLEICK. We do know how to desalinate. The technology is well understood. It's, as you say, expensive.

We will use desalination more and more where we're willing to pay for it if we evaluate it on equal footing with recycled water with conservation and if they see when it's cost effective. I think we'll see more of that.

Senator BENNETT. Alright. Dr. House? Thank you for that. That's helpful to me.

Mr. House, you said there are no Federal requirements that get in your way of water. You treat it to various levels, an industrial level, a culinary level, so on. I've had complaints from municipalities along the Wasatch front that's a provincial term for people whose cities are at the foot of the Wasatch Mountains on the west side of it. They are required by Federal law to clean up the water that goes through their municipality to drinking water standards when it comes out the back end of the pipe.

When it comes out the back end of the pipe it immediately goes into the Great Salt Lake where obviously it is not drinkable. Is this just unique to Utah or do you have Federal requirements that get in the way of your reusing water that raise the cost?

Mr. HOUSE. No. There are Federal requirements for various types of water. In the situation that you're talking about is kind of unique because what I was talking about is the reuse of the water. So in California what we typically do is we take the water. We treat it to some level to our standards.

Senator BENNETT. Yes, yes.

Mr. HOUSE. Then we reuse it. In your case that water is not being reused.

Senator BENNETT. I know. The Fed standard doesn't pay any attention to where it goes after it comes out of the pipe.

Mr. HOUSE. Nope.

Senator BENNETT. If it did then it would say, well you don't have to do that. It could be to perhaps what you would call an industrial level. So should the Federal law be adjusted to say we have to pay attention to the use rather than just say when it comes out of the end of the pipe it always has to be of drinking level quality?

Your comment to Senator Udall indicated that maybe there is that kind of flexibility. My experience is that there's not.

Mr. HOUSE. I don't know exactly what—and I'm not here to make policy.

Senator BENNETT. No, I understand that. You're here to inform us.

Mr. HOUSE. But the use of that water, the reclaimed water is very useful. I think the solution would be to find something that would use that water in the Salt Lake area. Then you don't have cleaning up water.

I know that in California we have a lot of issues to in the area where I live they not only have to treat the water to drinking water standards, they have to cool it before they send it back into the environment because it's a trout stream. So I know that the water agency gripes about that. So, you know, we've got to cool this water to a certain temperature before we can put it back into the stream.

But those are policy issues that you guys deal with.

Senator BENNETT. Ok, yes. Doctor.

Mr. GLEICK. Senator, there is nothing at the Federal level that prohibits you from not putting the water in Great Salt Lake, but reusing it. What the barriers are, as we've discussed financial, sometimes structural because there's no pipe to get the water from where we have it treated to where we could use it for outdoor irrigation or for flushing toilets. We don't even have to use it for drinking.

But the challenge is overcoming those barriers. The challenge is finding financial incentives so that it now makes sense not to throw it in Great Salt Lake, but to reuse it locally rather than finding a new source of pristine water that's maybe more expensive. It's a financial challenge rather than a regulatory one.

Senator BENNETT. Yes. Ok. Thank you, Mr. Chairman.

The CHAIRMAN. Senator Barrasso.

Senator BARRASSO. Thank you very much, Mr. Chairman. If I could Dr. Webber, you had mentioned that water consumption for transportation fuels is going to be more than double because of the new fuel mandates. I was reading a Wall Street Journal. It was an editorial from October 2007. It talked about ethanol plants consume roughly four gallons of water to produce each gallon of fuel.

But it goes on to say that when you count the water needed to grow the corn one gallon of ethanol requires a staggering 1,700 gallons of water. I wondered if I could ask you to comment on that? Then a little bit about what you think this whole impact is going to be on our water supply nationally, worldwide over the next decade how this may impact different issues of farming, ranching and others?

Mr. WEBBER. I think you're exactly right. Early on the people that focus on how much water was needed for processing or upgrading to the feed stock, bio feed stocks into fuels. It's a few gallons of water per gallon of fuel which is not so different than gasoline or unconventional fossil fuels.

The difference is on the growth side where you're producing the feed stock. It needs anywhere from 400 to 1,700 gallons of water per gallon of fuel. That water has to come from somewhere.

Most of that water comes from rainfall. But about 15 to 20 percent of those crops are produced from irrigation. When you're using irrigation you're taking it from surface sources, rivers or lakes or from aquifers. So you can affect water supply issues.

So there's no question that biofuels are very water intensive. In some parts of the world you have the water so it's not a problem. But in some places the water is strained. You have to take it from aquifers or other finite sources.

So these trends toward biofuels that require irrigation can be problematic on the water supply system. However there are ways to grow biofuels without irrigation. You can use other sources. It doesn't have to be corn. You can use cellulosic sources or non irrigated sources. Feed stocks can grow in different types of land, that kind of thing.

So we should be attentive, I think, to the type of feed stock we're using for sure.

Senator BARRASSO [continuing]. Solar power the other day Senator Kyle was talking about, you know, where the sun is in Arizona. But due to the lack of water it could be much more difficult to because of the water demands for using solar power.

Mr. WEBBER. It depends on whether you're using solar panels that are photovoltaic power or solar thermal. Solar thermal needs water for cooling, certainly.

Senator BARRASSO. Ok.

Mr. WEBBER. It's not clear exactly how much it needs compared to coal or nuclear power.

Senator BARRASSO. Ok. Mr. Bolze, if I could. You note in the last paragraph of your testimony you said there is also good news on the coal front. Since we know that coal is the most available, abundant, reliable and secure source of energy we have in the United States. Can you talk a little bit about that? Because you do mention, you know the dry feed injection process and efforts to really keep down the use of water in the carbon sequestration.

Mr. BOLZE. That's correct. There is a lot of technology on today for advanced uses of coal as a power source and doing it with in mind with water consumption in mind. One of the things we had mentioned earlier was as in the State of Wyoming we have a relationship with the University of Wyoming to develop advanced coal gasification.

This is for the use of what are called lower rank coals. So many of the western states, Wyoming, Colorado, Montana, Utah, South and North Dakota have these coals and as we can utilize advanced technologies we can use that for power generation. We can do it in a way that has much less water consumption than existing coal plants.

That technology still needs to be, you know, further developed. We are building one of those plants today with eastern coals. But it's one that's getting a lot of attention. I think back to the purpose of one of things we're going through here is as our customers look at those investments. You have to look at both the energy as well as the water consumption issues associated with that investment.

Senator BARRASSO. From the standpoint of lower rank coal you're talking about the number of British thermal units, the BTUs.

Mr. BOLZE. That's correct.

Senator BARRASSO. It's under 9,000 or 8,500.

Mr. BOLZE. That is correct. That plays into how our customers look at the cost of generating power because how much BTU can you get out of that specific coal resource.

Senator BARRASSO. Then though the Wyoming call it, the areas you described are also low sulfur coal.

Mr. BOLZE. That has to play a factor as part of the decision also. Correct.

Senator BARRASSO. Ok, thank you. Thank you, Mr. Chairman.

Mr. BOLZE. Thank you.

Senator BARRASSO. Thank you.

The CHAIRMAN. Senator Shaheen, you just arrived. You haven't had a chance to ask questions. Did you want to go ahead or do you want us to see if there are other questions here before you——

Senator SHAHEEN. Why don't you do that?

The CHAIRMAN. Ok. Let me just ask one other question that I'm confused on. I think one of you, maybe it was you, Mr. Bauer, talked about an increase in the price of electricity results in an increase in the price of water. I believe that was the testimony.

I'm just not exactly clear how that cause and effect works. Could you just elaborate on that?

Mr. BAUER. Yes, sir. Thank you for the question. Recognizing that water is very energy dependent as we've all spoken to this morning, and largely electricity dependent, as you raise the price of electricity the cost of electricity to move the water, treat the water, handle the water goes up.

So there's a substantial component of water cost, a doubling, for example. The doubling of the price of electricity would probably raise the price of water by about 25 to 40 percent depending on how far the water had to be transferred, as we spoke about earlier in the panel. So it's just a simple connection of the——

The CHAIRMAN. So it's the use of the energy, the electricity——

Mr. BAUER. Right.

The CHAIRMAN [continuing]. To move the water and utilize the water that drives up the price of the water.

Mr. BAUER. Yes, sir. It's not, at least not initially a direct relationship to how much water is being utilized by the generation of electricity. It's purely the price of electricity that's caused by whatever raises the price, whether it's different kinds of technology, whether it's greenhouse gas influence in the price of producing electricity.

Those will all also have a substantial impact on water. Yet we need the energy to have the water. So it was just to make that point of another form of interconnection that we have to realize as we think about these things.

The CHAIRMAN. Ok. Do all of you agree with that interconnection?

Mr. GLEICK. Yes. In my testimony I mentioned that the British Water Company, Thames Water recently calculated that that 17 percent or 20 percent of their operating costs are energy costs. As the price of energy goes up their operating costs go up. That in turn forces them to raise the price of water to their customers, exact same relationship.

The CHAIRMAN. Ok. Yes, Dr. House.

Mr. HOUSE. This actually plays into the looking at new water sources too. Because one of the reasons that desalination is so expensive is because it uses huge amounts of electricity. So when a water agency is looking at what their sources of water are now, at least in California, they're also determining what the energy input to those various sources of water are to determine what, not only embedded energy they have coming out. But determine how sensitive they are to changes in the price of energy.

Mr. GLEICK. If I might add to that. There's a National Academy of Science study that just came out a year ago on desalination. They made a number of observations, but two in particular.

The energy required to desalinate has been going down as the technology is improved. That has driven the cost of desalination down. But in recent years the cost of desalination seems to be curving upward again.

In part because the cost of energy is going up because it takes so much energy to desalinate a gallon of water it's very sensitive to how much we pay for energy. If the costs of energy, in the long run, is going to go up, that's going to keep the cost of desalination very high.

The CHAIRMAN. I remember reading about a year or two ago about a project. I think in Perth, Australia where they I gather have a wind farm that produces the energy that they need to run a large desal plant. Provide a lot of the water that the city uses from that. Any of you give us more detail on that?

Mr. GLEICK. Yes. The Perth Desalination Plant is one of the largest in the world. It's relatively new.

Because the Australians are particularly sensitive to greenhouse gas emissions in that region they made a commitment to build wind turbines to power, not necessarily all, but a very large fraction of the energy to provide the energy for that desalination plant. I think they built 80 megawatts of wind turbines that provides a substantial amount of the energy required for that plant. We could do the same thing.

We've recommended in California in fact that if they want to consider encouraging desalination that they do it in a way that doesn't increase greenhouse gas emissions because California has a very strict policy to try and reduce greenhouse gas emissions. That they encourage the construction of renewables in order to power those sorts of water facilities.

The CHAIRMAN. Dr. House.

Mr. HOUSE. I would just second that one of the main regulatory agencies in California that deals with desalination is the Coastal Commission. They just approved a big desalination facility down in the southern part of the State. But just as Peter was saying they are required to be carbon neutral. So they were required in order to get approval for desalination to mitigate all of their carbon emissions through offsets and purchases of renewable power.

Mr. BOLZE. Just Senator, one thing I wanted to add to your question. You brought up the Perth plan. Australia as a whole though is experiencing water scarcity issues as many of you all know similar to parts of the United States

They're at 8 percent reuse today. They have set a target for 30 percent reuse by the year 2015. Again they're addressing it through a number of policies. One of which are State by State level incentives. Some of which are grants. That's not all of it.

But they've set that as a priority. The Perth project that was discussed was part of it. One of the things as we look through this, we talked about there's different numbers, but the approximate 6 percent reuse in the United States.

As we talk to our customers, as we look through that, our view is that given a large majority of that water is used for once through cooling, is you can get to numbers that are anywhere between 20 to above 50 percent, less water usage for energy production just through some of these new technology applications.

The CHAIRMAN. That's on a typical coal plant you're talking about or——

Mr. BOLZE. No, that's an aggregate because again when we talk about the water usage a lot of it is mentioned by a number of the panelists has to do with the ones through cooling. So as you get associated with policies and incentives for water reuse technology, you can capture that water for reuse and then less overall water usage.

The CHAIRMAN. Ok. Senator Murkowski, did you have additional questions?

Senator MURKOWSKI. Yes. I do, Mr. Chairman. In this morning's news, I don't even know where this came out of. It's an article from Denver, Shell had requested water rights from the Yampa River in Northwest Colorado for use in oil shale production.

Not an unusual story in and of itself but as you go through there's a comment here that it's anticipated that it could take a year for the water court to review Shell's application letters ofopposition and all that goes with that. But it caused me to wonder as I was reading that. You mentioned the water census and just an understanding of what it is that we have in terms of that resource.

You have these water courts that are looking at water flow and water rights as negotiated under compacts. But when they're doing that they're not really looking at the big energy picture in terms of the impacts that we may have on our use. I'm just wondering if this process that we currently have for litigation of water rights and who gets what whether there's any consideration given to what we're trying to do with movement toward renewable energy resources.

You're all kind of smiling in a way that makes me think that the question is really either weird or there's an issue out there. Dr. Gleick?

Mr. GLEICK. Not only is it not a weird question—I'll tell you why I'm smiling. I'm smiling because it's a key question. The whole question of water rights, especially in the Western United States is central to a lot of the debates we've been having for a hundred years about water and now energy policy.

In Colorado, the fact that they're even considering granting more water rights on a system that, as Senator Udall knows is enormously stressed already by the water rights we've given out, which probably in the long run exceed the water that's available is part of the difficulty that we're having. In Australia they had a terrible drought. One of the things they've done is they've revamped their water rights system. Something that some of us might wish we could do in the United States, but aren't holding our breath for.

So you're asking the right question.

Senator MURKOWSKI. But this goes back to my question in the first round is there what needs to be done from the Federal policy. It sounds to me like we don't have much of a connection between our energy policy and our water policy in this country. Is that correct?

Mr. GLEICK. Yes and this bill helps address that in part by requiring really for the first time that we start to integrate the thinking. That we think about energy and water together when we think about water and energy together. Part of it is understanding the connections. Then part of it is ultimately developing the kinds of policies that either are in the bill or that some of us have recommended to then change national policy to save both water and energy together.

Senator MURKOWSKI. Let me ask you one final question, Dr. Gleick. I understand that you have spent considerable time just looking at the relationship of water and war in the Middle East. Can you give us any lessons here in national security of course as it relates to energy is absolutely key?

How does water fit into the national security issue itself and what have you learned over there that we can take home here? You've got a minute, 20 seconds.

[Laughter.]

Mr. GLEICK. I appreciate the question. It's another good one. It's worthy of a hearing of its own.

There's a very strong connection between water and conflict, a very long history going back 5,000 years. For students of history we have on one of our websites a chronology, the Water Conflict Chronology, that describes examples throughout history of conflicts over water. The short answer is I actually think we're more likely to see conflicts over water issues than over oil in the long run, although obviously there are political tensions over both.

I think there's solution to both. I think there are ways of reducing conflicts over energy crossing borders and water crossing borders. But it requires more than a minute answer.

Senator MURKOWSKI. We'll come back to you in another hearing. Dr. Webber.

Mr. WEBBER. Yes, I want to make a positive following comment. Water scarcity can be a source of war but water availability can be a source of peace. There's the other way. We can use our technology and our prowess as a Nation to improve our foreign policy and use this instrument of foreign policy to help bring clean water and clean energy to different parts of the world.

So there's the positive side to this as well. There's definitely the conflict side.

Senator MURKOWSKI. Thank you. Thank you, Mr. Chairman.

The CHAIRMAN. Senator Shaheen.

Senator SHAHEEN. Thank you. I remember meeting with the Eastern Canadian Premier which the New England Governors do on a regular basis. How surprised they were that we in New England weren't thinking about what our water issues were going to be in the future.

Clearly we need to start thinking about that now. But I want to ask you about the coal technology and the carbon capture technology. Given the amount of water that that's going to take—and the fact that at least to date much of the storage has been in places where there are certain fault lines that allow us to store the carbon, do you have any analysis or wisdom about what we ought to be thinking about as we're trying to make the two of those match?

Because I guess as I look at the geography of the country it seems like many of the places where we can do the storage are not going to be places where they have a lot of water. So is that a false notion? What should we be thinking about as we're looking at trying to expand and deal with those coal technologies?

Mr. BAUER. Many of the places that have potential for carbon long term storage, CO_2 long term storage at deep levels in saline formations, saline aquifers, do have water there on the surface where the water might be utilized for cooling. Some areas are well equipped. The Ohio Valley for example, and other portions of the internal portion of the country. In New England there's not a lot of opportunity for carbon storage, except perhaps offshore until you get to Western New York.

So it varies. So the question is do you have the water on the surface to use for thermal power generation where thermal power generation exists. Are there places to put the CO_2?

The answer is it geographically depends. I'm not trying to be foolish about that. But it does. You're very right about that.

One of our projects through the regional partnerships is looking in the Southeast for substantial storage in saline aquifers. That project looks at the fact that if we put CO_2 in there we should see some increase in pressure in the aquifer. They're actually bringing the saline water up and desalinating as a further source of drinking water.

You have the issue of—and going back to Dr. Webber's earlier statement about EOR and making sure you're respecting water and properly putting the CO_2 away so there is no harm to any forms of drinking water or future drinking water. That is a question, do you use the saline reservoir as a future drinking water source? In this case it would be definitely, it's even being planned to be a future water source with greatest impressions with substantial quantity of CO_2 which will further help the pump to bring the water to the surface over 8,000 feet. Then you would desalinate up there.

Now that does have an energy penalty. So many of these things, I think, come back to the technological breakthroughs we can make to accomplish the water source, this even goes to the issue on war and conflict. Part of the challenge in China and India is good drinking water.

That takes energy. If you have people who don't even have an electric light bulb in their house you don't have a lot of energy for good drinking water. So you have very poor quality water.

So if we can take technologies that address multiple issues that can help to conserve both energy and water and make it available.

Mr. BOLZE. Senator, just a couple additional points I'd like to point on. It's very much location dependent as you would imagine. Many people are studying where those aquifers are to store the carbon and where the location is verses where the power is needed as well as where the water needs are.

We have a partnership with a company called Schlumberger that kind of looks through how you map that out. There are other people that are looking at that also. But I think the other side of it too is when you get into the costs of—as our customers look at a coal plant or other ways with carbon sequestration is not only is it the water consumption, but it's also the percent carbon capture.

There's a big issue between let's say equivalency to an existing coal plant or to a natural gas combined cycle plant or to a zero emissions plant. The huge cost differences as you step up that curve as well as water consumption. So I think there are a number of aspects we have to look at. It's not an easy question. But it is the right question to look at.

Senator SHAHEEN. Thank you.

The CHAIRMAN. Senator Bennett.

Senator BENNETT. Thank you very much. We have an energy source in this country that is going unused. As some people have described it as equivalent of Saudi Arabia and that's probably an overstatement and that is the power that is generated at night, that goes unused today a power plants does not shut down.

Dr. Webber in your very excellent piece for Scientific American, you talk about the amount of water involved in a plug in electric hybrid. But if the plug in electric hybrid is charged at night off power that is lost anyway because it's not used that changes the equation. I'm assuming that you wrote this as if it were charged during the daytime because our meters charge so much per kilowatt hour regardless of when we do it.

Utilities are trying to find ways with SMART meters to get people to use the washing machines and so on at other times and change the economic incentive for when you use your facilities. Now as I have listened to this panel I think there are a lot of uses of energy tied to water that are not time sensitive. I wonder if anybody has done any kind of thinking about or studies on the question of what lowering the cost of getting the kind of water we need if it could be all tied to those periods of time when the power generation is basically going to waste?

You run a nuclear plant 24 hours a day. You have to. Then at night the electricity is not being used because the plants are shut down and people are asleep and so on.

Is there any kind of data? Are there any kind of data on this? Are there any kind of incentives, Dr. House, in California to try to move in the direction, not just of getting people to use their washing machine at night, but to take advantage of this significant power source which we already pay for and don't use? So?

Mr. WEBBER. I think the plug in hybrid point is very important. The numbers I used for the article are national averages. The type of electricity used for plug in hybrids determines how water intensive or carbon intensive your electricity is. That varies a lot all over the Nation.

Some parts of the Nation use a lot of coal. Some use a lot of nuclear. Some use a lot of wind. So the profile for your plug in hybrid will vary, will be very different in Cleveland than Austin than Seattle.

Generally plug in hybrids are very appealing for a lot of reasons. Generally there is an environmental ease of scrubbing the emissions from 1,500 power plants as opposed to 100 million tailpipes. So there's an environmental advantage to plug in hybrids.

You can use this excess power at night. Not all parts of the Nation have excess power. In Texas we turn our power up and down to match the load. In some parts of the Nation they make excess and throw it away.

The appeal of plug in hybrids partly is also that wind tends to be more available at night, at least continentally in the Nation. So plug in hybrids match well with wind which is great. So there is some time sensitivity.

Senator BENNETT. I worry about wind on the grid because the wind doesn't always blow. If it suddenly stops you——

Mr. WEBBER. Yes, the wind doesn't always blow. It is variable. You usually know about 30 hours in advance if it's going to turn off. What we're finding in Texas sometimes the gas turbines don't always spin either.

Senator BENNETT. Yes.

Mr. WEBBER. So we have all sorts of availability problems. Sometimes the wind doesn't blow then the gas turbines shut off and then you have a blackout. So there's a time sensitivity of when energy is available that matches available plug in hybrids.

For example it matches well with water. The way we tend to do water markets is that price for water is the same every minute of the day, every day of the year, every year of the decade even if water is not available. So we could have smarter, more time sensitive prices that reflect supply and demand.

Particularly we see increased water demand in the summer for irrigation.

Senator BENNETT. Yes.

Mr. WEBBER. The prices don't reflect that. So there are time sensitivity issues. Also the variability of some of these renewable sources, like wind and solar match well with water because we don't need water to be continuously treated all the time. We can sort of store it up.

Senator BENNETT. Right.

Mr. WEBBER. So wind and solar match really well with water treatment, desalination, like we heard about in Perth, Australia for example.

Mr. HOUSE. The water systems are very well situated to do this demand response. In California in my testimony I talk about how the water agencies in California dropped 400 megawatts every summer afternoon because when you build a water system what you want to do is you want your water treatment facility to be working pretty much around the clock. But you have these bimodal peaks in your water supply.

So what all the water systems do is they have some place to store this water. What we're doing in California to a large extent is that you're using the water out of storage during the summer on peak period. One of the frustrations has been that there is a lot more that we could do.

But there aren't really incentives that were set up for—the water systems were built with the storage for water supply. They weren't really built with the storage for energy use. It is difficult, particularly due to the sort of the WIP saw that occurs with rate that the water agencies say, I'm not going to build another storage facility because I'm not sure that I'll be able to amortize this over a long enough period of time.

Senator BENNETT. I see.

Mr. HOUSE. But if you could get some sort of stability there's another probably 600 megawatts of on peak curtailment that could be done in the State of California from existing sites if there was an incentive that was permanent enough that the water systems would say it would build additional storage and reduce their on peak electrical.

Senator BENNETT. I have a source. The Chairman has heard me on this. It's my hobby horse, tidal power.

I've been in Lagrange, France where they have a tidal system. Unlike wind you know to the second when the tide is not going to be rising or falling. They built that system 40 years ago.

It is so reliable when I took the tour of it they said we have nobody here at night and on weekends. It just operates. They know exactly when it is. They know exactly how much power it's going to generate in what periods of time.

I think that tides rising and falling in the Gulf of California which is very close to the California grid is something that California really ought to look at in cooperation with Mexico because it could provide you with the kind of thing that Australia is talking about the tremendous amount of power that is going to be there as long as the moon revolves around the Earth. If the moon ever stops we're going to have bigger problems than water, available to do exactly the kind of thing you're talking about.

Thank you, Mr. Chairman.

The CHAIRMAN. Senator Udall.

Senator UDALL. Thank you, Mr. Chairman. It's been a fascinating hearing. We see over and over again the nexus between water use and energy use, technology, national security. It's fascinating.

I note that my good friend from Utah, Senator Bennett comes from a pioneer family. He himself has been a pioneer in promoting hybrid vehicle technologies. In fact I'm not going to get myself in trouble outing him, but he drove one of the most interestingly designed cars that Honda first produced, the Insight. But I note his passion about this opportunity and the way it does link to water supplies.

When he talked about this unused resource I did think perhaps Senator Bennett would talk about oil shale which is there are enormous oil shale beds in our three states. Senator Barrasso has left, but Utah, Wyoming and Colorado. The story that Senator Murkowski just referenced in the Denver paper yesterday.

I'm still a fan of newspapers by the way. You can't hold up a Blackberry with a headline. But the headline yesterday from the New York Post says, Water Plan Hits Wall of Foes.

For the record I just wanted to note that the objections that were filed to Shell's plan included the Steamboat Springs water court which is where the objection was filed. It came from a coal company, a power company, an agricultural ditch company and Cross Mountain Ranch which is a hunting resort. I think Senator Bennett knows of that particular ranch.

So this points out the challenges that we face in the West that Dr. Gleick is so well aware of and I think so many of you on the panel. I did want to note for the record before that I mentioned John Wesley Powell. People may have thought why am I mentioning this obscure Civil War Major, but he was the first head of the United States Geological Survey. The survey has led much of the understanding of the geography, topography, water resources in the West.

Senator BENNETT. Mr. Chairman, if I could just quickly.

Senator UDALL. Please.

Senator BENNETT. Where I come from there is an old adage. You referred to the pioneers. It's better to be ahead of the ditch than ahead of the church.

[Laughter.]

Senator BENNETT. Indicating how important water really is.

Senator UDALL. I'm going to borrow that. Add to the repertoire that we have about water and the water fights in the West. Dr. House, you talked and I think many of the panel have talked about desal. The Chairman has as well.

Would you comment on the brine in the salt byproduct and the challenges we face in disposing of it if we pursue a more broad based and aggressive desalination policy. Is it a problem on a large scale?

Mr. HOUSE. I think it depends on what you mean by large scale. Most of the facilities, at least in California, one of the things that was particularly happening. The sun in California is going because we're chronically short of water and we're using the, they're called de-salters, but they're using brinish water.

This is in as opposed to the ones on the coast that actually uses salt water. At least it's been my experience that they don't really have that much of an issue with that it comes out generally in a solid form. They can take it in a solid form. They use a land disposal for it.

I know that there's been some discussions about disposing of it in the oceans. There's some questions that some of the environmental groups have raised of, oh well, is it going to increase the salinity in a particular area. The whole Pacific Ocean it's probably not. But if you've got one particular bay or something it may.

But that has not been one of the issues that has been very much discussed at all. So it appears that they, at least for right now. Remember these are fairly localized plants and there isn't a huge, huge amount of it.

If you had the 30 desal facilities that are being proposed for California coast it may become more of an issue. But it's a local issue. They use land disposal of it.

Senator UDALL. Other theories? Dr. Gleick.

Mr. GLEICK. If I might just add to that. It is a potential problem, the disposal of brine from desal. But it's a solvable problem with money.

If you're building a desalination plant on the coast you're dumping the brine in the ocean. It's possible to dispose of brine in the ocean in a very responsible manner that diffuses back to normal ocean salinity very quickly. In fact in Perth, Australia in the desalination plant they built dispersal of brine system that's very effective and I think very environmentally benign. But it costs more money to do it that way.

Brine disposal inland for de salting brackish water is more of a problem because you don't have the ocean to diffuse it into. You have to dispose of it either by evaporating off the rest of the water and producing a solid or one of the things they've done in El Paso where they've just built a desalination plant for brackish water is they're pumping it down, sort of like carbon sequestration, deep probably 2,000 feet into a saline aquifer to get rid of it. It stays down there. That's a safe way to dispose of the brine.

But again, it's just more expensive. It's another way to simply say doing desalination right costs a little more money than doing it wrong.

Senator UDALL. As I understand it some of the CSPs, concentrated solar powered technologies use the salt that holds the thermal product of the sun's efforts. I imagine though there's a lot more salt that we produce through de-salt technologies that you could use in that technology. Then maybe about the kind of salt that's used for——

Mr. GLEICK. Yes, but those are also typically closed systems.

Senator UDALL. Yes.

Mr. GLEICK. Where the salt just cycles. You heat it up and then you cool it down. So that's a great question whether first of all, it's the same kind of salt. Then second of all if you built enough solar thermal plants whether you could use the salt from brackish water desalination plants.

Senator UDALL. In the end it's a different salt.

Mr. GLEICK. It's a different salt.

Senator UDALL. Ok. It was worth a try. I know in the end technology that's best imitates Mother Nature. There's an increasing interest in what's called industrial ecology.

The Scandinavians have been pioneers in this regard. We are, in our own way, when you develop technology. But again technology is best that imitates Mother Nature. It recycles, hopefully on a shorter timeframe some of the products and byproducts of all of our uses as a modern society.

Thank you, Mr. Chairman.

The CHAIRMAN. Thank you. Senator Shaheen, did you have additional questions?

Senator SHAHEEN. No but I wanted to pick up on Dr. Webber's point about water being a potential for peace as well as war because we have an inventor, an entrepreneur in New Hampshire named Dean Cayman, who has developed a facility about the size of that desk over there which can clean water either from the ocean or from any other place. The point that he always makes is, you know, the cost of cleaning that water would be less than the cost of one missile. So I think it's a really important point to follow up on and to thank.

We ought to be structuring some of our policies in that direction. Thank you for raising it, Dr. Webber.

The CHAIRMAN. Thank you all very much. I think it's been very useful testimony. We'll try to proceed with this legislation and maybe find some more ways to improve it based on your suggestions. Thank you.

[Whereupon, at 11:45 a.m. the hearing was adjourned.]

[The following statements were received for the record.]

AMERICAN RIVERS,
Washington, DC, March 20, 2009.

Hon. JEFF BINGAMAN,
Chairman, Committee on Energy and Natural Resources, 304 Dirksen Senate Office Building, Washington, DC.

Hon. LISA MURKOWSKI,
Ranking Member, Committee on Energy and Natural Resources,304 Dirksen Senate Office Building, Washington, DC.

DEAR CHAIRMAN BINGAMAN AND RANKING MEMBER MURKOWSKI: On behalf of American Rivers' 65,000 members and supporters across the nation, thank you for your leadership in addressing the important relationship between water and energy in S. 531, the Energy and Water Integration Act of 2009. American Rivers strongly supports this legislation and appreciates the committee holding a hearing on the bill on March 10.

Water and energy are two of the fundamental building blocks of our society. Both are intricately connected with the health of our environment and our economy. The information that will be gathered as a result of the studies in this bill will help lead to the development of policies that will encourage the most efficient and responsible use of our valuable natural resources.

As the Energy and Natural Resources Committee moves forward with this legislation, we ask you to keep in mind that water and energy are both fundamentally local resources. Recent water supply crises in the Southeast and elsewhere tell us that these issues are moving to the forefront in all parts of the country. We believe that the studies called for in your bill will ultimately prove most useful if they consider regional differences alongside the general issues.

While the studies in S. 531 are valuable, we urge Congress to also take action to reduce our water and energy demands. First, by directing federal agencies to improve the management of forests and watersheds on public land, we can lower the cost—in both dollars and kilowatts—of securing reliable supplies of fresh water. Forests are our nation's best and least expensive water infrastructure, providing natural filtration and storage for two-thirds of the nation's water supply.

Thank you again for recognizing the interdependent relationship between water and energy. We look forward to working with you and your staff on this important legislation.

Sincerely,

REBECCA R. WODDER,
President.

STATEMENT OF PETER WILLIAMS, PH.D., CHIEF TECHNOLOGY OFFICER, "BIG GREEN INNOVATIONS", IBM

INTRODUCTION

The energy-water nexus poses critical issues for the USA, from the perspectives of energy security, competition for water resources and respect for the environment. The Energy and Natural Resources Committee's consideration of the matter is therefore extremely timely. IBM is pleased to submit this testimony both on the energy-water issue generally and more specifically on the draft bill now under consideration that is intended to integrate decision-making on energy and water.

IBM believes strongly in making our planet and its infrastructure "smarter"—providing more instrumentation, control systems, enhanced communications, data management, and analytic and visualization capabilities, to create systems that can adapt and respond as human and planetary needs change. This perspective has underlain our work on energy management and so-called "smart grid", as recently represented, for example, by the testimony of IBM's Allan Schurr to the Select Committee on Energy Independence and Global Warming[1]. It has also informed our work in the water management area to create large-scale "Smart Water" solutions for the management of entire water resources (rivers, watersheds, aquifers) and water infrastructures, often using software and know-how derived originally from our smart grid work. Our experience has led us to the conclusion that water and energy issues are inextricably linked and that they need to be managed as such. They both require the application of "smarter planet" technologies referenced above to enable effective understanding of trends and issues, and thus to enable informed and effective decision-making.

The comments that follow focus primarily on the relationship between water and electricity generation. We have not focused on the use of water in creating transportation fuels (for example, the water requirements of fermentation-based methods for making bio-fuels), as these are not directly within our area of expertise.

WATER AND ELECTRICITY

It is not the intention of this testimony to repeat the factual knowledge already available to the Committee, but some key points will serve to set the scene. First, electricity generation is dependent upon copious water availability, and is at risk when water resources fail:

- Thermo-electric power generation, the backbone of America's current energy supply, accounts for some 40% of all freshwater withdrawals in the United States, roughly equivalent to water withdrawals for agricultural irrigation[2].
- Thermal generation is highly susceptible to water shortages. In the summer of 2006, the Tennessee Valley Authority had briefly to shut down its plant at Browns Ferry, Alabama, while other plants (such as the Harris and McGuire plants in South Carolina) came close to this. Plants in Spain and France were also either shut down for up to a week in 2006, or operated on reduced output[3].
- Hydropower generation is vulnerable to fluctuating water levels, for example in 2001 when electricity output from the Columbia River basin was cut to the point where activities such as aluminum smelting were also curtailed.

Second, water movement and treatment requires large amounts of energy:

- Water movement and treatment in the US consumes some 100 million MW hours per year—this is approximately 3-4% of all electricity generated nationwide. Of this, some 95% is used for pumping[4][5], and the balance used for water treatment. In places energy needs are much higher—in California, for example, due to the impact of that state's climate and geography some 19% of its electricity is used to move or treat water.[6]
- Desalination of water, now being looked at as an increasingly viable response to water shortages, is highly energy intensive—taking from 9.8 to 16.5 KWh per thousand gallons of fresh water produced from seawater and 3.9-9.8 KWh per thousand gallons from brackish water, depending on the type of process[7]. (To put that in perspective, the average household water use for a family of 4 is about 280 gallons per day[8], and the average electricity consumption per house-

[1] Testimony of Allan Schurr, Vice President of Strategy and Development, IBM Global Energy and Utilities, before the Select Committee on Energy Independence and Global Warming Hearing on "Get Smart on the Smart Grid: How Technology Can Revolutionize Efficiency and Renewable Solutions", February 25, 2009

[2] "Energy Demands on Water Resources—Report to Congress on the Interdependency of Energy and Water", US Department of Energy, December 2006, page 9

[3] These examples all relate to nuclear plants, which may be particularly susceptible to water shortages because of the very high volumes of water they use. The issue applies to all thermal generation however.

[4] EPRI statistics quoted in "Greenhouse Gas Reduction as an Additional Benefit of Optimal Pump Scheduling for Water Utilities", S Bunn, 2007, page 4

[5] "Energy Demands on Water Resources", op cit, page 25

[6] "California's Water Energy Relationship", California Energy Commission, November 2005, page 8

[7] "California's Water Energy Relationship, op cit, page 36

[8] http://www.drinktap.org/consumerdnn/Default.aspx?tabid=85 (website produced by American Waterworks association)

hold is 29 KWh per day[9]. It can be seen that desalination will represent a non-trivial increase in energy needs.)

Third, demands on water availability from energy production are set to intensify, just at the time when water resources themselves are coming under stress

- The Energy Information Administration has projected that, absent significant energy conservation, energy demand will increase by 50% over the 25 years from 2006[10].
- Some renewable energy supplies, for example utility scale solar thermal, also need water supplies for their operations. Their targeted location in the arid Southwest US is problematic for water availability.
- Some regions have seen groundwater levels fall between 300 and 900 feet over the past 50 years as withdrawals have exceeded natural recharge rates[11] (with corresponding increases in pumping energy requirements as water needs to be lifted through ever greater heights).
- The growing interest in recycling water will probably require more energy-intensive reverse osmosis filtration and other types of water treatment, which will probably increase the energy needs of water management.
- While surface water withdrawals have remained relatively constant over the last 20 years at around 260 billion gallons per day, pressures to maintain stream flows for fisheries have created severe contention for available water[12] (for example the Klamath, Sacramento, and San Joaquin Rivers in California), while climate change is imposing considerable uncertainties about future water availability patterns.
- While many thermo-electric plants return much of the water they use, it is frequently warmer than when it was extracted, which has sometimes severe impacts on local river ecosystems. Intake pumps may also kill large numbers of fish, as was recently declared for example at Indian Point nuclear power station near New York[13]—cooling system amendments are expected cost of the order of $1.6bn. It is also well documented that dams for hydro-power can damage fish populations.

Putting these facts together, the picture is, frankly, alarming. Electricity generation uses large amounts of water; moving water uses large amounts of energy; and demands for both energy and water are set to increase beyond the capacity of current water resources, and of the environment, to support them. The proposed Energy and Water Integration Act 2009 is therefore both relevant and timely.

1MANAGING ENERGY AND WATER: LESSONS FROM IBM'S WATER AND ENERGY MANAGEMENT ACTIVITIES

This section sets out two examples from IBM's clients and our own operations, that offer lessons for managing the energy-water nexus.

Example 1: Island of Malta

The Mediterranean island nation of Malta (population 400,000) depends on imported fossil fuel for its entire energy supply, while the country depends on electrically powered desalination for over half its water supply. Rising sea levels threaten its sub-surface water resources. IBM is working with EneMalta and the Water Services Corporation to enable the country to become the first in the world to build a nationwide smart grid and fully integrated electricity and water management system. The system will contain 250,000 interactive energy and water meters and thousands of sensors on both the energy grid and the water infrastructure to enable proactive management that anticipates problems, and optimizes water and energy supply together. The system will also provide Maltese citizens with better information on their water and energy consumption, enabling them to make better decisions about the resources they use.

While Malta is a far smaller, more concentrated and more homogenous country than the USA, its overall problem will become increasingly familiar to certain communities in the US over time. There are accordingly a number of lessons from this work that the Committee may care to note. First, there is the notion that water and electricity generation should be managed increasingly as a single integrated system,

[9] http://www.eia.doe.gov/emeu/reps/enduse/er01__us__tab1.html, data from 2001(website produced by Energy efficiency Administration)
[10] Quoted in "Energy Demands on Water Resources", op cit, page 10
[11] "Energy Demands on Water Resources", op cit, page 33
[12] "Energy Demands on Water Resources", op cit, page 31
[13] Ruling of New York State Department of Environmental Conservation, reported on August 26th 2008.

given their interdependencies, based in Malta's case on active collaboration between the agencies concerned. In the US that would translate to collaboration on an area by area basis, but the principle would still stand. For example:

- Water agencies would work to minimize their energy consumption. This would almost certainly require new levels of collaboration between agencies, given the high levels of fragmentation that exist in the US water industry today.
- Energy generators would continue to work with water agencies to coordinate their intake and outfall requirements with other demands on the water resource in question. For example, both could work to integrate the data and models they use for decision-making, to ensure decisions that they complement one another.
- Both would work together to promote joint conservation goals and to establish in the minds of the public, business and agriculture an understanding that "water conservation is energy conservation, and energy conservation is water conservation". Combined metering programs like Malta's would be a good way to do that (as well as, potentially, a way to share infrastructure and data, while reducing both costs and inconvenience to homeowners and businesses).

Second, the work in Malta will enable consumption information to be collected in much greater frequency and on a much finer spatial mesh, and distributed to a much wider selection of stakeholders than hitherto. This greater "granularity" of information is the key to effectively identifying consumption trends and issues, identifying resource losses and infrastructure malfunctions, and so enabling the effective co-management of the water and energy infrastructures on the island. The same applies here in the US:

- Consistent adoption of advanced meter infrastructures for energy and water throughout the US would increase the granularity of usage information, and provide a platform with which to understand and then influence demand levels (by increasing consumer visibility into use patterns and by enabling time differentiated pricing). It would also, in many cases, reduce costs and increase water and energy agency revenue by cutting down on losses, and because the newer meters tend to be more accurate.
- The same principle applies to our understanding of the impact of energy generation on surface and groundwater resources—more gauges, sensors and meters equate to better understanding of the interactions, and thus better decisions, especially if they are integrated to form a single sensing infrastructure for each water resource. In practice, sensors from various agencies operating on the same water resource report separately—there is little integration; and the number of flow gages in the US is currently decreasing, not increasing[14]. If anything, therefore, the country is moving in the opposite direction to that needed.

Example 2: Energy "Harvesting" in IBM's Semiconductor Plants

IBM manufactures semiconductors, which means that we use relatively large amounts of energy and water in each of our fabrication plants. The two are linked, because much of the water we use is ultra-pure (10,000 times purer than drinking water), having been treated by reverse osmosis filtration. This is very energy intensive (it is also the primary means of desalinating seawater and is the reason why that process is also very energy intensive).

We have, however, become very effective at managing our water and energy consumption downwards. Taking our Burlington, VT plant as an example, between 2001 and 2007, we reduced our energy consumption from 520 million to 450 million KWh per year—the savings are enough to power about 2,500 homes. Similarly in the same period we reduced our water usage from 4.5 million gallons of water per day to 3.5 million. These results were achieved despite the fact that product output volumes in the plant increased by 33% over the period in question.

While industrial water usage is only 5% of the US total[15], the methods we used to achieve these reductions are instructive in the context of the Committee's present interests. First, we systematically set out to harvest energy from the pressure and or temperature in water as it is used in the plant. For example, we systematically harvest temperature in water, via heat exchangers, for cooling purposes, while also recycling water as we do so. Over time this has allowed us to reduce energy and water consumption in tandem. We also use pressure from the public supply to pro-

[14] For example, as reported to the Advisory Committee on Water Information, at its meeting of 2/10/09

[15] "Energy Demands on Water Resources", op cit, page 18

vide at least some of the pressure needed for our water filters. Formerly, water came in from our supplier and was piped to a holding tank—all the pressure in the water was thereby lost, meaning that it had to be (expensively, and energy-intensively) re-pressurized to force it through the filter membranes. By working with the supplier to create a direct linkage from the water main to the filters, we saved significant amounts of energy and cost.

This is relevant to energy and water management in the USA as a whole, because large amounts of kinetic energy exist in the pipes and water-mains of the nation's water systems. For example, wherever pressure reduction valves are used today in water mains, it may be possible to replace these with reaction turbines that generate energy as they reduce the flow to the required pressure. The amounts of energy generated, especially in large, high pressure water mains, are not trivial—as long ago as 1998 2MW systems were operating in Scotland and Germany, and examples existed of water treatment plants being wholly self-powered in this way[16]. We have been unable to ascertain how systematically turbines of this type are deployed in the USA, but we recommend that this should be investigated. At the very least they may offer the potential to break or weaken the link between conventional energy availability and water movement and treatment.

Second, IBM takes great care to optimize the maintenance and operation of equipment in the plant, based on the ability to track energy consumption continuously, machine-by-machine. We do not believe that most water agencies operate in this way, especially with the operation of their pumps and valves. As noted above, water pumping uses about 3% of the nation's electricity output; regular optimization of pumps, valves and pumping schedules supported via commercially available software has demonstrated energy savings of 6-11% in 4 US water agencies (in some cases where extensive effort had already been expended on pump management), plus significant demand shifting from peak to off-peak electricity generation periods. If replicated nationally, the energy saving would be between 3 and 5.5 million MWh per year[17].

Still on the subject of maintenance and optimization, an EU report estimated that in clean water, pump performance degrades by 1% per year (and faster in wastewater)—but that most water agencies, in Europe at least, do little to manage this. Reconditioning pumps, by polishing interior surfaces to remove roughness caused by degradation, was estimated to improve pump efficiency by 5-18%; matching pump wear and status to duty cycles can increase that figure to 10-20%[18]. Combining this with the figures in the previous paragraph suggests that, in principle, perhaps a quarter to a third of the total national electricity requirement for water movement could be saved from these sources alone.

Third, IBM's own management of water and energy relies on extremely detailed measurement. As stated, we track energy usage, continuously, by individual machine. We track water usage via sensors for key water parameters such as flow, temperature, pressure, organics, metals and particle content, collecting 400 million packets of data per day from 5000 discrete points. In both cases we undertake regular trending and correlation analyses, and monitor processes via 80 statistical control points to ensure that process performance (including water and energy consumption) remains within the tolerances set.

Again, while there may be specific exceptions, we do not believe that this level of detailed control is undertaken regularly in water operations; and while power generation is extensively instrumented, the general level of analytics is not as advanced as modern software tools would allow. It may be argued that controlling water and energy requires operations over a much larger physical area than a single plant; and that the value proposition for investing in controls of this type in the semiconductor industry is different than water or energy—computer chips are relatively more expensive, especially given that water is not usually priced effectively in the first place. However, given the growing issues that the nation faces with its energy and water supplies, and thus their strategic value even if the financial value is not aligned, we believe that a move towards this type of control philosophy and technology is warranted.

[16] "Pumps as Turbines and Induction Motors as Generators for Energy Recovery in Water Supply Systems", AA Williams, NPA Smith, C Bird and M Howard, Water and Environment Journal, Vol 12, Issue 3, pp175-178, 1998

[17] Bunn, op cit, page 8.

[18] European Commission, "Study on improving the energy efficiency of pumps", February 2001, AEAT-6559/ v 5.1, quoted in L Reynolds and S. Bunn, "Reducing Energy Demand in Water Supply through Real-Time Scheduling and Operation"—paper delivered to Aqua Enviro Conference, Birmingham, England, March 2008.

COMMENTS ON TEXT OF ENERGY AND WATER INTEGRATION BILL

Building on the arguments above, we have a number of comments to offer on the draft of the Bill. These comments should be taken in the context of IBM's strong support for the intentions of the Bill and are intended constructively. We will be happy to help frame specific provisions, if requested.

WATER MANAGEMENT PRACTICES, NOT JUST PROJECTS

The Bill potentially offers an opportunity to establish sound energy management practices in the water industry. Section 4 of the present draft seems to focus on the energy impact of specific reclamation projects by Federal agencies, to the exclusion of the day-to-day activities of state and local water agencies—which, we demonstrated earlier, can consume significant amounts of energy.

We would therefore suggest supplementing the Federal project focus with a requirement for the National Academy of Sciences, working in cooperating with the water industry, to assess and confirm the potential benefit of energy and water management "best practices" at the state and local level such as pump optimization and scheduling; pump and valve maintenance; and energy harvesting, in particular from (but not restricted to) the use of turbines to replace flow reduction valves. There may well be other best practices that could be identified. The Bill should also call on the NAS to publicize its results to state and local water agencies, perhaps via the various water industry associations.

In addition, while Section 6 addresses the issue of information on water related energy consumption in various sectors of industry, we suggest that the focus on state and local water agencies should be sharpened. This could be achieved by promoting energy used per gallon of water supplied, and each gallon treated, as a key performance metric for each water agency (making due allowance for the fact that wholesale and retail supply agencies will have different profiles). Energy directly generated by an agency from its own renewable sources or from its own harvesting of water pressure or temperature would be excluded—the focus here is on energy supplied via the grid. With a common set of industry metrics, water agencies could then report to the Department of Energy on their energy usage, just as they report on water quality today to the EPA; league tables could then be published to encourage public review and cost improvement programs.

THE ROLE OF INFORMATION TECHNOLOGY

We have shown above and in other testimony to Congress[19] how advanced information technology—metering and sensing, analytics, visualization—can improve the management of the energy grid, water, and the connections between them. The proposed Bill does not directly address the benefits potentially available from IT, and we therefore suggest supplementing the provisions in Section 7 as follows.

The Bill should task the NAS with reporting to Congress on the information items required to make effective operational decisions on energy generation and energy and water usage, where that information should come from, and the obligations of various tiers of agency to make sure it is available.

The NAS should also consider the technologies that might be required to generate the information in question. On this last point, we would anticipate that the NAS would look, as a minimum, at:

- The potential role of advanced meter infrastructures for water in assisting in the management of water and energy demand, as well as in providing information to enable improved operational decision making.
- The role of optimization software for integrated energy and water management in supporting decisions that balance energy and water needs.
- The recommendations for automated sensing of water quality and flow around energy generation activities, to generate a "real time" picture of the impact of those activities.
- Information and data standards for using the information generated.

Focusing directly on water, we would also suggest that the NAS consider the scope to replicate appropriate smart grid concepts in water management across the nation. This would cover demand prediction, blending of water sources, optimal routing and storage strategies, optimal discharge rates and times, and so on—the point being that "optimal" in this context includes energy consumption alongside water pressure, quality and other more traditional water agency concerns.

[19] Allan Schurr, op cit.

CONCLUSION

In summary, in this testimony we have sought to demonstrate the value of advanced information technology in improving day-to-day management decision-making on issues of energy and water management interdependence, and in enabling, in particular, the reduction in energy consumption by the water industry. We will be pleased to answer any follow up questions that the Committee may have on the comments we have made here.

APPENDIX

Responses to Additional Questions

Responses of Peter H. Gleick to Questions From Senator Bingaman

Question 1. Several of you talked about the opportunity to reduce energy consumption by reusing or conserving water. Mr. Bolze, your testimony specifically references that the U.S. presently reclaims and reuses 6% of its wastewater compared to other countries with much higher percentages.

Can each of you comment on the magnitude of potential you see for significant water savings yielding significant energy savings in this country? Are we just at the tip of the iceberg with respect to the water & energy savings possible through water conservation efforts? Has any established entity quantified the potential?

Answer. I know of no one who has quantified the potential for overall energy savings from improving water use efficiency, nationwide, but regional and local studies suggest that the savings are both significantly large, and cost-effective. A study done at the Pacific Institute offers some specific examples and numbers for the western United States. This study is available at:

http://www.pacinst.org/reports/energy__and__water/index.htm.

Question 2. As discussed today, one of the hurdles to coordinated energy and water policy is that energy policy is developed at a national level and water policies are more local and regional in nature.

How much of an impediment is that to integrating energy and water policy and what other impediments do you see to this goal?

Answer. While it is true that there is sometimes a mismatch between federal and local authority in the water/energy areas, there are important actions appropriate for the federal government to take. In particular, effective water efficiency and energy efficiency standards for appliances (such as those in the 1992 National Energy Policy Act) need to be updated. In addition, federal agencies such as the U.S. Army Corps of Engineers and the U.S. Bureau of Reclamation are responsible for significant local water management and they have both failed, to date, to integrate energy and water policies in their operations and management.

Question 3a. You stated in your testimony that the California Energy Commission recently found that 95% of their desired energy savings could be achieved for roughly half the cost through water conservation programs instead.

Do these programs focus on domestic water conservation or do they have industrial and agricultural components as well?

Answer. The focus of the CEC energy estimates was overall water conservation and efficiency, but most of their analysis was addressing urban (residential, industrial, commercial, and institutional) water use. More effort needs to be put into evaluating savings in the agricultural sector (pumping and delivery, in particular).

Question 3b. Follow-up: In terms of domestic water conservation, Dr. House recommended combining EPA's WaterSense program with DOE's EnergyStar program. What do you think of this, or similar strategies, which combine water and energy conservation efforts into single programs?

Answer. I support far better integration of EPA's energy and water efficiency programs in order to both avoid duplication and to maximize benefits.

Responses of Peter H. Gleick to Questions From Senator Murkowski

Question 1. Please describe how the United States can satisfy all the expected water needs of newly proposed power plants, including concentrated solar, in arid and semi-arid regions.

Answer. We cannot. Newly proposed power plants are proposed without considering water constraints. What this means is that some of those plants will not be built, or conflicts over water are growing. Another critical solution, however, is to require power plants with significant water demands to use “dry cooling” systems that use little water. I note that even though there was some discussion at the hearing about the water-intensity of solar thermal/concentrated solar, actual proposal for such plants are increasingly looking at “dry cooling” to reduce water demands enormously. Thus not ALL solar thermal uses a lot of water.

Question 2. Are there any regions in the country that are not expecting a significant water problem in the next decade?

Answer. All regions will have challenges, though not all regions with have scarcity. In some places, water problems will be associated with contamination and water quality, not quantity. The places with challenges will also be determined by future patterns of population growth and development, which are hard to forecast.

Question 3. Please describe how policies aimed at climate mitigation and adaption may affect policies developed in the energy and water sectors, and, specifically, the energy-water nexus.

Answer. Efforts to reduce greenhouse gas emissions must take into account water—such as the water for renewable energy systems (typically, but not always, less than from traditional power plants).

Question 4. Please describe the impact on energy use with stricter treatment standards for water and wastewater. Are there any energy related tradeoffs that may occur with stricter treatment standards?

Answer. There is a good chance that improving water quality standards and the development of new treatment systems will increase the energy “footprint” of water by moving to more energy intensive systems. Conversely, smart planning to decentralize new wastewater systems may lead to a decrease in energy requirements. The point is to plan in advance for the energy implications in order to avoid these bad tradeoffs and find the good ones.

Question 5. Please describe the impact of energy policies and regulations on water demands and its availability.

Answer. The key link, addressed in my written testimony and oral remarks, is the water demand for power plant cooling.

Question 6. As we further examine the interrelationship between water and energy, what type of qualitative data do you believe is needed to better understand the connections to biodiversity and ecological health?

Question 7. How can we encourage coordination and collaboration of research, development and policy efforts in the energy-water domain, with a view to cross-cutting learning?

Answer. Absolutely: I strong urge better integration and coordination at the federal level among the diverse agencies involved in energy and water in the U.S.

Question 8. Please describe the linkages between energy and water consumption, as a society becomes more affluent. How do measures to improve water use efficiency and energy efficiency correlate, as societies become more affluent?

Answer. Some argue that as the economy grows, societies inevitably use more water and energy. This is not inevitable. Total water use in the United States has leveled off and even declined in the last two decades, while population and GNP have all risen sharply. Thus we must NOT assume that water demands and energy demands must rise forever—indeed, resource, economic, and environmental constraints argue for improving efficiency and quality of life while minimizing waste and additional resource use.

Question 9. Please describe how water resource constraints can become energy constraints.

Answer. As described in my written testimony, limits on water can limit water available to cool power plants, which can lead to short-or long-term constraints on energy production. I offer several examples from the headlines of recent cutbacks in energy because of water scarcity.

Question 10. Please describe how the California Energy Commission came to their number that 95% of the energy savings of proposed energy-efficiency programs could be saved at 58% of the cost through water-efficiency programs instead. How is California going to rethink the prioritization of funding energy efficiency projects in light of these numbers?

Answer. This was work from the CEC and I recommend asking this of those authors.

Question 11. How do you weigh the ecological impacts of seawater use for energy production verses inland facilities, that likely use fresh water?

Answer. No good comparison has been done on this, but two reports address the ecological costs of desalination—one from the Pacific Institute; the other from the U.S. National Academy of Sciences. The Institute report is available here: http://www.pacinst.org/reports/desalination/index.htm. The NAS report is available from the National Academy Press and is called “Desalination: A National Perspective.”

This report offers explicit and valuable advice on appropriate (and inappropriate) national research priorities for desalination.

RESPONSES OF STEPHEN BOLZE TO QUESTIONS FROM SENATOR BINGAMAN

Question 1. Several of you talked about the opportunity to reduce energy consumption by reusing or conserving water. Mr. Bolze, your testimony specifically references that the U.S. presently reclaims and reuses 6% of its wastewater compared to other countries with much higher percentages.

Can each of you comment on the magnitude of potential you see for significant water savings yielding significant energy savings in this country? Are we just at the tip of the iceberg with respect to the water & energy savings possible through water conservation efforts? Has any established entity quantified the potential?

Answer. Based on what other countries have accomplished—and are setting out to accomplish—we believe that the United States can reuse significantly more water than it does today.

We also believe that greater water reuse would translate into reduced energy consumption.

Even though we are not aware of any entity that has quantified this potential, the WateReuse Association estimates that our nation can easily double the amount of water it is reusing between now and 2015 (from 6% to 12%), based on current trends. In addition, with the advent of a 30% Investment Tax Credit, the percentage of reuse would almost certainly be much higher.

Question 2. As discussed today, one of the hurdles to coordinated energy and water policy is that energy policy is developed at a national level and water policies are more local and regional in nature.

How much of an impediment is that to integrating energy and water policy and what other impediments do you see to this goal?

Answer. Energy and water policies are closely related, and policies developed in one of these areas—whether at a national or more local level—could affect the other.

So, we believe that it is important to develop the policies in a coordinated way so as to avoid unintended consequences.

With respect to the question of whether the national nature of energy policy and the more local nature of water policies is an impediment to a coordinated approach, we believe that this would be an appropriate topic for the NSA study envisioned by the Energy and Water Integration Act of 2009.

Question 3. Increasing our reclamation and reuse of wastewater was recommended multiple times by this panel. You specifically mentioned Israel's impressive reuse rate of 70%.

In addition to lack of incentives in the U.S., do you feel that public perception of so-called gray water is a barrier to its use?

Answer. We have both industrial and municipal customers around the world. In our experiences with these customers, we have not seen a great level of concern about gray water on the industrial side. On the municipal side, however, we have seen concern about gray water reuse for drinking water and agricultural purposes.

Therefore, we do think there's a real and meaningful opportunity to drive greater industrial water reuse via incentives.

We have not formally evaluated the perception issues related to gray water, but we would refer you to the WateReuse Association, which we believe has done a lot of work in this area.

Question 4. A recent by Ceres and the Pacific Institute stated that it is critical that companies begin to treat water risks as a strategic challenge. The report outlines the physical, reputational, and regulatory risks to businesses and investors associated with water scarcity.

In addition to the GE's commitment to reduce water consumption by 20% by 2012, what steps have you taken to analyze your water-related business risks?

Answer. GE recognizes that it is important to evaluate water-related business risks. Consequently, we consider near-and long-term water availability issues when we plan expansions both here in the United States and elsewhere in the world.

Question 5. Your testimony indicates that financial incentives are necessary to drive greater water reuse in the U.S.

Based on your understanding of the market, is it your sense that the relatively low-cost of water and the lack of a water supply crisis in certain regions of the country are resulting in less demand for water reuse systems in the short-term? Are companies and utilities starting to look at water and energy together in evaluating ways to cut costs

Answer. Not all areas are water scarce, and even within water scarce areas, not all communities are experiencing water scarcity.

Also, the economics vary widely depending on whether a customer is pulling water from a river or a municipal system, for example.

But, we are convinced that a broad-based federal incentive that could be applied when and where it makes sense would definitely help drive much greater reuse.

More specifically, we believe from our experiences with our tens of thousands of industrial customers that a 30% investment tax credit would drive substantial water reuse across our nation.

RESPONSES OF STEPHEN BOLZE TO QUESTIONS FROM SENATOR MURKOWSKI

Question 1. Please describe how the United States can satisfy all the expected water needs of newly proposed power plants, including concentrated solar, in arid and semi-arid regions.

Answer. A recent DOE-sponsored study looked at 110 new power plants proposed for construction in 2007 and found that municipal wastewater treatment plants located within a 25 mile radius from the proposed power plants could satisfy 97% of the new power plant cooling water needs.

On average, one large wastewater treatment plant can completely satisfy the cooling demand for each of these power plants.

In addition, wind and photo voltaic solar power generation technologies use essentially no water.

Question 2. Are there any regions in the country that are not expecting a significant water problem in the next decade?

Answer. Although we have not conducted an independent study of this issue, the sources we relied on in preparing our written testimony (GAO; WateReuse Association), suggest that water scarcity will play out in different ways in different parts of the country.

In any event, the GAO 2003 map that we included in our written testimony shows that—at least at the local level—every region on our nation will likely experience some level of water shortages during the next decade.

Question 3. Please describe how policies aimed at climate mitigation and adaption may affect policies developed in the energy and water sectors, and, specifically, the energy-water nexus.

Answer. Energy, climate and water policies are closely related, and policies developed in any one of these areas could affect the other two. So, we believe that it is important to develop the policies in a coordinated way so as to avoid unintentional consequences.

We also believe that this is an appropriate topic for the NSA study envisioned by the Energy and Water Integration Act of 2009.

Question 4. Please describe the impact on energy use with stricter treatment standards for water and wastewater. Are there any energy related tradeoffs that may occur with stricter treatment standards?

Answer. Although stricter standards may in some cases require greater energy, we believe that such energy demands can be minimized through concerted energy-water nexus research and development..

Question 5. Please describe the impact of energy policies and regulations on water demands and its availability.

Answer. Energy and water policies are closely related, and policies developed in one of these areas could affect the other. So, we believe that it is important to develop the policies in a coordinated way so as to avoid unintended consequences. We also believe that this is an appropriate topic for the NSA study envisioned by the Energy and Water Integration Act of 2009.

Question 6. As we further examine the interrelationship between water and energy, what type of qualitative data do you believe is needed to better understand the connections to biodiversity and ecological health?

Answer. We have not independently studied this issue, but we would refer you to the WaterReuse Foundation in hopes that they can provide you with this information.

Question 7. How can we encourage coordination and collaboration of research, development and policy efforts in the energy-water domain, with a view to cross-cutting learning?

Answer. The Federal government's role in providing structure and oversight will help accelerate new technology developments in a more coordinated way.

However, if we want to truly accelerate technology development, it is going to take a community of government, the national labs, academia and industry working together.

Industrial companies like GE have R+D pipelines and a direct path to market for new solutions.

Working together with Federal government and other key stakeholders, we will have the community we need to successfully carry out a national clean water research and development initiative.

We also believe that this would be an appropriate subject for an NSA study.

Question 8. Please describe the linkages between energy and water consumption, as a society becomes more affluent. How do measures to improve water use efficiency and energy efficiency correlate, as societies become more affluent?

Answer. It is generally understood that as societies become more affluent, the demand for water and energy becomes greater. And, as demand increases, so does the need for greater efficiency.

Question 9. Please describe how water resource constraints can become energy constraints during the next decade.

Answer. Energy and water are co-dependent. In simplest terms, energy is required for making water and water is required in the production of energy. Globally, the demand for both of these crucial resources is projected to grow at an alarming pace, with energy demand doubling and water demand tripling in the next 20 years.

As we prepare to meet the future electricity demands here in the U.S., it is estimated that water demands related to electricity production will almost triple from 1995 consumption levels. In addition, the deployment of technologies to meet expected carbon emission requirements will increase water consumption by an additional 1-2 billion gallons per day.

RESPONSE OF STEPHEN BOLZE TO QUESTION FROM SENATOR STABENOW

Question 1. Collocation of water treatment facilities and power plants. Mr. Bolze, you suggested in your testimony that there be incentives for municipal wastewater treatment plants to be built alongside power generation plants so that the wastewater can meet the cooling demand of the power plants. Could you explain the incentives and technologies this requires? Would such collocation also help to keep costs down for both facilities?

Answer. Rather than municipal wastewater plants treating and discharging water back to a receiving stream, by adding an incremental treatment process, either at the wastewater plant or at the industrial plant, this water can meet the needs of many industrial processes, including power plant cooling.

From an incentive standpoint, we believe that a 30% investment tax credit would enable all industrial water users—including power plants—to reuse significantly more water than they do today. We base this belief on feedback from our 50,000 industrial customers around the world.

From a technology standpoint, greater reuse is achievable through chemical pretreatment combined with advanced membrane-based technologies (microfiltration, nanofiltration, ultrafiltration, and reverse osmosis), and in some cases, advanced thermal technologies (Zero Liquid Discharge).

RESPONSES OF LON W. HOUSE, PH.D., TO QUESTIONS FROM SENATOR BINGAMAN

Question 1. Several of you talked about the opportunity to reduce energy consumption by reusing or conserving water. Mr. Bolze, your testimony specifically references that the U.S. presently reclaims and reuses 6% of its wastewater compared to other countries with much higher percentages.

Can each of you comment on the magnitude of potential you see for significant water savings yielding significant energy savings in this country? Are we just at the tip of the iceberg with respect to the water & energy savings possible through water conservation efforts? Has any established entity quantified the potential?

Answer. Federal Facilities: Estimates of 24% of Federal water use can be saved using cost-effective, existing "off the shelf" technologies, primarily domestic water fixtures[1]. Even more can be saved using advanced technologies and improved process water using equipment such as cooling towers, steam systems, and irrigation. The GSA found that federal water conservation potential is estimated at 121 million gallons per day[2].

[1] "Update of Market Assessment for Capturing Water Conservation Opportunities in the Federal Sector", Pacific Northwest National Laboratory, PNNL-15320, August 2205

[2] Water Management Guide: A Comprehensive Approach for Facility Managers" , General Services Administration, available at: http://www.gsa.gov/gsa/cm__attachments/GSA__DOCUMENT/waterguide__new__R2E-c-t-r__0Z5RDZ-i34K-pR.pdf

Water Systems: The most promising areas for intervention within water supply systems are: improving the pumping system, managing leaks, automating system operations, and regular monitoring (preferably with metering of end use)[3]. While the water and energy savings are system specific (but can reach 30%), it should be noted that these improvements often pay for themselves in months, most do so within a year, and almost all recover their costs within three years.

Customer Use: There are multiple state and regional estimates of water conservation potentials. In California, the state Department of Water Resources, in its current draft of the California Water Plan, is using estimates of agricultural water conservation savings potential of 2 million acre-ft per year (with an investment of $75 million per year)[4] and urban water savings potential of 2.1 million acre-ft per year (35% of total use)[5].

Question 2. As discussed today, one of the hurdles to coordinated energy and water policy is that energy policy is developed at a national level and water policies are more local and regional in nature.

How much of an impediment is that to integrating energy and water policy and what other impediments do you see to this goal?

Answer. Appliances/Plumbing Fixtures: There are a number of federally regulated appliances or equipment in the water sector. "Federally-regulated commercial and industrial equipment" is commercial and industrial equipment for which there exists a test method and an energy conservation standard prescribed by or under EPAct. "Federally-regulated consumer product" is a consumer product for which there exists a test method and an energy conservation standard prescribed by or under NAECA.

One issue that should be addressed is the methodology on how the federal standards are established. EO 13211 requires federal agencies to conduct an analysis of energy and use it to develop a statement of energy effects in any proposed rulemaking. However, only direct energy use included. In particular, while energy savings are used in the determination of standards for hot water using appliances and equipment there is not a consideration of the energy savings associated with cold water savings (e.g., with toilets).

Buildings: There are proposed green building ANSI standards including ASHRAE Proposed ANSI Standard 189.1P Standard for the Design of High-Performance Green Buildings Except Low-Rise Residential Buildings, GreenGlobes-Green Building Initiative (GBI) Proposed American National Standard 01-2008P, and Green Building Assessment Protocol for Commercial Buildings and National Association of Home Builders (NAHB) National Green Building Standard[6].

Recycled/Reclaimed Water: Regulations on the use of recycled water vary across the U.S.A. There are no national standards. California has the most stringent regulations, as set by the Department of Public Health ("multiple barrier" approach).

The California State Water Resources Control Board recently adopted a Recycled Water Policy in which established goals to increase recycled water by an additional million acre-ft of water per year by 2020 and substitution of as much recycled water for potable water as possible by 2030[7].

It is important to note that water issues are generally local/regional issues and there is a need to be able to respond to these issues on a much smaller scale than at the national level. The Association of California Water Agencies recently adopted water conservation and efficiency policy principles that state it succinctly:

> Water conservation and water use efficiency programs must have the flexibility to adjust to widely varying local circumstances. . . . Effective water conservation and water use efficiency programs must be responsive to local circumstances, including changing water supply sources, water uses and demands, and water reliability challenges."[8]

Question 3. While the majority of water-related electricity use is by end users to pressurize, heat, cool and condition the water, treatment of water is still a signifi-

[3] "WATERGY: Energy and Water Efficiency in Municipal Water Supply and Wastewater Treatment", The Alliance to Save Energy, February 2007.

[4] "California Water Plan Update 2009—Draft", Volume 2 Resource Management Strategies, Chapter 2, Table 2-2.

[5] "California Water Plan Update 2009—Draft", Volume 2 Resource Management Strategies, Chapter 3.

[6] Alliance for Water Efficiency, available at: http://www.allianceforwaterefficiency.org/Green__Building__Introduction.aspx

[7] http://www.waterboards.ca.gov/water__issues/programs/water__recycling__policy/docs/final__policy__021109.pdf

[8] "Water Conservation and Water Use Efficiency Policy Principles", Association of California Water Agencies, adopted March 27, 2008.

cant area of energy consumption. Programs which encourage water conservation can minimize costs of both drinking water and wastewater.

Which treatment type—drinking water treatment or wastewater treatment—has the greatest potential for reduction of energy intensity?

Follow-up: In addition to water conservation and efficiency programs, are there additional policies, incentives, or technologies that could further minimize either drinking water or wastewater treatment?

Answer. There are two responses: improving the efficiency of the treatment process, and increasing the amount of renewable generation provided by the water/wastewater treatment facilities.

Improve Treatment Efficiency: Water treatment facilities can decrease their energy use by 10-20% energy savings thru treatment process optimization and another 10-20% energy savings thru equipment modifications[9]. The following table* provides a summary of typical standard equipment and high-efficiency equipment available for water/wastewater treatment systems[10]. Drinking water typically starts with cleaner water, but is generally treated to a higher quality (at least in the past). Wastewater is generally "dirtier" than fresh water when it starts the process, and the increased emphasis upon recycling water use generally makes the wastewater treatment slightly more expensive. However, as the industry shifts to lower quality water for potable water, the energy requirement differences between fresh and waste water are becoming increasingly blurred.

Increase Renewable Energy: Water/wastewater treatment facilities have several characteristics that make them ideal locations for certain types of renewable generation: they have a large amount of electricity use on site; they are comfortable with up-front capital expenditures for long lived projects; and they usually have a lot of open land available at the site (treatment facilities maintain a buffer of land around the treatment plant for aesthetic and siting purposes).

Solar—most of the over 200 kW solar generation facilities in California are located at treatment facilities for the above mentioned reasons. Indeed, one of the criticisms of the current California solar program is that the renewable generation is limited to the amount of electricity the treatment facility uses annually. The water agencies have the space and inclination to install more solar generation if they could be compensated for the excess electricity generated.

Biogas—shifting wastewater treatment from aerobic to anaerobic treatment systems allows the wastewater treatment facility to generate significant amounts of biogas (methane) for use in producing electricity (via internal combustion engines, microturbines, or fuel cells) and reduces the amount of natural gas used to keep their digester beds warm. In California, the majority of wastewater treatment facilities are using their own biogas for generation, and the remainder of the facilities are in the process of converting to biogas generation in order to meet Greenhouse Gas limit requirements. This biogas generation is not limited to municipal water treatment. Farms, dairy plants, and heavy industries could reduce or eliminate their energy bills by running their high-strength organic wastewater streams through treatment systems that generate methane biogas. In California, several of the electric utilities have contracts to purchase biogas generated by dairy farms and biogas produced electricity.

Question 4a. You advocate the installation of Advanced Metering Infrastructure (AMI) as it is relatively inexpensive, and can provide cost savings through the rapid identification of water leaks.

Can you estimate how expensive it would be to install such infrastructure throughout California?

Answer. The investor owned electric utilities in the state are spending $4 billion on Advanced Meter Reading (AMR) / Advanced Metering Infrastructure (AMI) installations for their customers, so this may serve as a reasonable estimate (except that the electric utility systems are significantly more expensive that the AMR/AMI systems considered by the water systems). A lot of the AMR/AMI infrastructure is currently being installed in California water systems anyway. Through a California Energy Commission study it was determined that over one-half of the water agencies in the state have some level of AMR on their system, and for 34% of the water systems AMR is the predominant type of water meter[11]. Additionally, over 75% of

* All tables and figures have been retained in committee files.

[9] ACEEE Water and Wastewater Energy Road Map, American Council for an Energy Efficient Economy, available at: http://www.aceee.org/industry/water.htm.

[10] "Municipal Water Treatment Plant Energy Baseline Study" submitted to Pacific Gas and Electric Company by SBW Consulting, August 28, 2006

[11] CEC 500-07-022

the water systems in California are interested in adding more AMR or AMI to their systems in the next several years.[12]

Question 4b. Follow-up: Could cost-savings from improved leak detection and reduced system loss offset the price of AMI in a reasonable timeframe?

Answer. Administrative impacts are currently the primary reasons for selecting AMR among the water systems in California. The overwhelmingly dominant benefit expected from AMR is reduced meter reading costs, followed by more efficient billing and increased customer service. Operational benefits: the use of AMR in conservation programs, loss detection, and in increasing safety/security for personnel followed administrative benefits as reasons for selecting AMR. The operational benefits from AMR are expected to change as systems become more familiar with the technology and due to changes in tariff design, as water conservation becomes increasingly more important in California and as more water systems switch from traditional tariff design to water budget tariffs.[13]

Question 5. Your testimony notes that a number of current financial incentives for renewable energy do not work for publicly-owned water systems.

Notwithstanding that problem, have California water agencies proceeded with developing renewable energy supplies to integrate into their systems? If so, what benefits are driving this integration?

Answer. Compensating Incentives for Non Tax Payers: In California, we have adjusted the financial incentives for solar installation to provide increased incentive levels for those customers who do not pay taxes and cannot take advantage of tax credits, as the following table shows. This table is the incentive payments for solar installations in California under the California Solar Initiative (CSI). Note that the payments are higher for government/non-profits to account for their lack of ability to take advantage of tax incentives.

Power Purchase Arrangements: As the CSI rebates (above) continue to drop but the tax incentives do not, the water agencies in California are increasingly using Power Purchase Arrangements (PPA) as a means of procuring solar power rather than owning the solar systems themselves. Under a PPA, a water agency agrees to purchase electricity from a solar generation installation on its land. The owner of the generation equipment takes advantage of the accelerated depreciation and tax credits in determining the price of the electricity sold to the water agency.

Remote Net Metering Programs: Allow renewable generation at one location to be credited against a portion of retail rates at another system location. California's Assembly Bill (AB) 2466 is called the Local Government Renewable Energy Self-Generation Program and is codified as Section 2830 of the Public Utilities Code. It allows government entities to generate renewable energy at one location, and have it credited against part (the generation part only) of retail rates at another location. It is still under development but the size limit of 1 MW and the inability to access any other incentives in the development of the renewable project are limiting its usefulness.

Renewables Feed-In Tariffs: Provide a utility standard contract with specified renewable energy price. California's Assembly Bill (AB) 1969 added Public Utilities Code Section 399.20, authorizing tariffs and standard contracts for the purchase of eligible renewable generation from public water and wastewater facilities. It has size limitations (1 MW) and the inability to access any other incentives in the development of renewable projects is resulting in less renewable generation that could be developed. However, several small in-conduit hydroelectric generation projects are being developed under this program.

RESPONSES OF LON W. HOUSE, PH.D., TO QUESTIONS FROM SENATOR MURKOWSKI

Question 1. Please describe how the United States can satisfy all the expected water needs of newly proposed power plants, including concentrated solar, in arid and semi-arid regions.

Answer. Providing sufficient water for power plants that use significant amounts of water in arid/semi-arid regions of the country will continue to be a challenge (PV solar, certain types of concentrating solar such as the Stirling engines, and wind use negligible amounts of water in their operation).

Water use for solar has become an issue in California. The Beacon Solar Energy Project is a proposed concentrated solar electric generating facility proposed on an approximately 2,012-acre site in Kern County, California. The project will use parabolic trough solar thermal technology to produce electrical power using a steam

[12] House, L. W., "Smartmeters and California Water Agencies: Overview and Status", California Energy Commission, in press.

[13] Ibid.

turbine generator (STG) fed from a solar steam generator (SSG). The SSG receives heated heat transfer fluid (HTF) from solar thermal equipment comprised of arrays of parabolic mirrors that collect energy from the sun.

As the California Energy Commission Status Report #6 notes " . . . one issue, use of potable water for power plant cooling, was highlighted in the Committee's scheduling order because 'The Committee is interested in alternative cooling technologies and alternative cooling water sources that may be used at the plant to reduce the projects need for groundwater. . ."[14]

Question 2. Are there any regions in the country that are not expecting a significant water problem in the next decade?

Answer. While there are the chronic water shortage problem areas such California and the desert Southwest, we are seeing water problems in areas that previously never experienced them, such as the Southeast. A recent article stated that 36 of the states are facing water shortages within the next decade[15]. Combine shortage problems with climate changes with current concerns about radionuclides and pharmaceuticals in the water and there are virtually no major areas of the country that are immune to water problems in the next decade.

Question 3. Please describe how policies aimed at climate mitigation and adaption may affect policies developed in the energy and water sectors, and, specifically, the energy-water nexus.

Answer. In California, Green House Gas (GHG) emission targets are pushing water utilities to improve efficiency of operation (to reduce energy consumption), increase water conservation programs (to reduce water provided and the associated energy used), are converting wastewater treatment to biogas operation (to reduce methane emissions) and are increasing renewable generation, primarily solar and small hydroelectric.

Question 4. Please describe the impact on energy use with stricter treatment standards for water and wastewater. Are there any energy related tradeoffs that may occur with stricter treatment standards?

Answer. It is a truism that all of the increased treatment requirements increase energy use over past operations. As we control to lower and lower allowable limits, increase the number of contaminants treated for, and are investigating treating for even more problem chemicals such as radionuclides and pharmaceuticals, the treatment process and energy requirements for the treatment are increasing significantly. Combine increased treatment requirements for these contaminants with using poorer and poorer quality water for water supply (such as brackish or sea water) and in the next decade water systems are expected to add significant amounts of new electrical load as they access previously unused water sources and address increased treatment requirements[16].

A recent AWWA article details the increased energy costs associated with water regulations, finding that the 18 National Primary Drinking Water Regulations adopted between 1975 and 2006 cost 1.8 billion kWh per year in increased energy use and an additional $187 million per year in costs.[17]

Question 5. Please describe the impact of energy policies and regulations on water demands and its availability.

Answer. The impact depends upon the generation technology used and the water used. Certain renewables such as PV solar and certain concentrating (non thermal) solar, wind, and hydroelectric generation do not materially impact water demands. If recycled water is used, the impact on fresh water is reduced. The largest geothermal generation field in the world, the Geysers in Northern California, is being "fueled" by recycled water from the City of Santa Rosa. Many of the new generation facilities in California likewise are using recycled water.

Question 6. As we further examine the interrelationship between water and energy, what type of qualitative data do you believe is needed to better understand the connections to biodiversity and ecological health?

- The goal of Study 2 is to characterize and quantify the relationships between water and energy use by water and wastewater agencies, and to determine the range of magnitudes and key drivers of embedded energy in water.

Study 3: End-Use Water Demand Profile Study

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[14] available at: http://www.energy.ca.gov/sitingcases/beacon/documents/index.html

[15] "At Least 36 U.S. States Face Water Shortage", by David Gutierrez, Natural News, March 31, 2008.

[16] House, L. W.2007. "Will Water Cause The Next Electricity Crisis?" Water Resources Impact 9 (1), January 2007.

[17] "Drinking Water Regulations: Estimated Cumulative Energy Use and Costs", by S. J. Reiling, Journal AWWA, March 2009.

• Study 3 is designed to provide accurate hourly water use profiles. End-use Water Demand Profile study measures cold water demands of six end-use (customer) categories:

1. Residential (Normal and Low-income, Single-family)
2. Residential (Low-income, Multi-family)
3. Commercial
4. Industrial
5. Public Buildings
6. Agriculture

The final analysis is the Embedded Energy in Water Pilot Programs measurement and verification. The focus is on verifying and quantifying the water and energy saved as a result of water-use reduction measures. There are a host of measures being tested, ranging from pH controllers to laundry ozone retrofits to high efficiency toilets to recycled water use to leak detection. These studies/programs are underway, and results expected in 2010.

Question 7. How can we encourage coordination and collaboration of research, development and policy efforts in the energy-water domain, with a view to cross-cutting learning?

Answer. Federal responsibility for water (primarily with the Environmental Protection Agency) and for energy (primarily with the Department of Energy) reside in different federal agencies (the Department of Interior is heavily involved with water supply and energy in the western states).

—Joint studies and research on the water and energy can be initiated
—These agencies should be required to address both water and energy as part of their on-going mandate (the EPA should evaluate energy impacts when developing water policy and regulations and the DoE should address water impacts of energy policy and regulations).

There is considerable value associated with developing the science, research, and monitoring techniques to address new generation products, and associated water pollution before the fact, as opposed to investing in costly remedial work after the water has become contaminated. California has initiated a Green Chemistry Initiative which seeks to eliminate or reduce the use of toxic substances in products and manufacturing processes rather than managing wastes at the end of a product's lifecycle[19] that could be followed on a national level.

Question 8. Please describe the linkages between energy and water consumption, as a society becomes more affluent. How do measures to improve water use efficiency and energy efficiency correlate, as societies become more affluent?

Answer. Energy use tends to increase with increasing affluence. Water use tends to increase initially with a rise in affluence, and then stabilize. It is axiomatic that water consumes energy and energy consumes water. Saving water will save energy, but saving energy does not necessarily save water. These two resources have fundamentally different characteristics that influence policy decisions.

—There are very limited sources of additional fresh water available (primarily desalinization of sea water) but there are a host of options available for the creation of electricity.
—As stated in my previous testimony, water conservation tends to result in more consistent and stable savings as compared to energy conservation, primarily because new technologies are constantly being developed to use electricity. The energy use in California has tracked the population growth, while water use has remained flat for the last 30 years.
—Water issues tend to be localized (or regionalized) while energy concerns tend to be more national (the price and availability of oil has national implications while the price and availability of water in Los Angeles primarily concerns Los Angelians.

In my opinion, the water crisis is a more pressing matter than the energy crisis, because there are fewer options available to address it.

Question 9. Please describe how water resource constraints can become energy constraints.

Answer. Depending on the type of cooling tower, the cooling process for thermal electrical generators can account for up to 90%-95% of total plant water use[20]. However, there are options that can significantly reduce the amount of fresh water used

[19] http://www.dtsc.ca.gov/PollutionPrevention/GreenChemistryInitiative/index.cfm.

[20] "Comparison of Alternate Cooling Technologies for California Power Plants", California Energy Commission. 2002, CEC500-02-079F

in electricity production. As the following table shows, two states, Florida and California, have the majority of power plants using reclaimed water[21] with Texas close behind.

On June 19, 1975, amid concerns about the diminishing availability of fresh water in California, the State Water Resources Control Board (SWRCB) adopted its "Water Quality Control Policy on the Use and Disposal of Inland Waters Used for Powerplant Cooling" (Resolution No.75-58)[22]. Resolution 75-58 states that from a water quantity and quality standpoint, the source of power plant cooling water should come from the following sources (in order of priority): (1) wastewater being discharged to the ocean, (2) ocean water, (3) brackish water or natural sources of irrigation return flow, (4) inland wastewaters of low total dissolved solids (TDS), and (5) other inland waters. Where the SWRCB has jurisdiction, use of fresh inland waters for power plant cooling will be approved by the Board only when it is demonstrated that the use of other water supply sources or other methods of cooling would be environmentally undesirable or economically unsound. Additionally, California Water Code Section 13550 et seq. requires the use of effluent for industrial purposes, especially for cooling, where it is available. In 1997, the siting agency in the state, the California Energy Commission (CEC), and the SWRCB entered into a Memorandum of Understanding in order to coordinate the review of projects for which a regional water quality control board or the SWRCB have authority.

The use of dry cooling versus wet cooling for power plant operations has the following impacts:

—the use of dry cooling reduces plant water requirements by about 90%,
—an associated increased plant capital cost of about 5% to 15% of the total plant cost for the dry cooling system,
—energy out reductions of 1% to 2%, and
—capacity reduction of 4% to 6%.[23]

Question 10. What percentage of water used in California comes from reused water?

Answer. Currently 6% of the water use in California is from reclaimed water, but that percentage is projected to increase to 20% in the next two decades. The following table lists recycled water use in California in 2002.

Recycled water use has increased sharply since 2000, in part due to the increased use by electric power plants.

The state water plan developed by the Department of Water Resources, the California Water Plan[24], lists 1,670 acre-ft per year of recycled water in its future portfolio of available water for consumption.

Question 11. Please explain the energy requirements of reused water compared to freshwater use in California, particularly in southern California.

Answer. While there is a considerable range in the energy requirements of fresh water, recycled water tends to have a much narrower spread, as the following table illustrates[25].

As the following table[26] shows, for the Inland Empire Utilities Agency, recycled water has the lowest energy intensity of any of the water sources available. This relationship is typical for water agencies in Southern California.

Question 12. How do the figures for water reuse compare to other states, and or nations with limited water supplies?

Answer. The majority of water reuse in the U.S. occurs in four southern and western states. As the response to Question 9 states, the water reuse in these states is driven not only by a shortage of fresh water, but also by the extensive use of reclaimed water for power plant use.

Question 13. How do you weigh the ecological impacts of seawater use for energy production verses inland facilities, that likely use fresh water?

Answer. For humans, fresh water is more valuable that salt water. As stated in response to Question 9 above, it is very difficult to site a power facility inland in California that uses fresh water without going to some alternative form of cooling

[21] "Use of Reclaimed Water for Powerplant Cooling", Argonne National Laboratory, ANL/EVS/R-07/3, August 2007.
[22] www.swrcb.ca.gov/plnspols/wqplans/pwrplant.doc
[23] "Cost and Value of Water Use at Combined-Cycle Power Plants", California Energy Commission, CEC-500-2006-034, April 2006
[24] http://www.waterplan.water.ca.gov/
[25] "California's Water—Energy Relationship", California Energy Commission, CEC-700-2005-011-SF, November 2005.
[26] Ibid.

or water. California is also in the midst of evaluating a ban on once through cooling for power plants located on the coast due to its environmental impact.[27]

RESPONSE OF LON W. HOUSE, PH.D., TO QUESTION FROM SENATOR STABENOW

Question 1. Water scarcity in non-arid regions. When we talk about water supply, we often think immediately of California and the arid Southwest. Yet the groundwater situation around the Great Lakes is poor and we're facing major groundwater depletion around population centers like Chicago, Milwaukee, and Detroit. Furthermore, those areas have faced additional pressure on supply due to compacts with Canada restricting water extraction from the Great Lakes. I have also been told that in Michigan, a power plant application was denied due to lack of water availability. Could you expand upon this a bit more, to explain why the Great Lakes region also requires better water efficiency, although one might not realize it?

Answer. Clean fresh water is a premium resource. The use of such a valuable resource to carry heat away from a power plant may not be the highest and best use, particularly when there are a number of alternative ways to either produce the power or dispose of the heat.

Even in areas of perceived water abundance such as the Great Lakes area, there is conflict over water policy and use[28]. In 2008, the governments of the eight states in the Great Lakes basin adopted the Great Lakes—St. Lawrence River Basin Water Resources Compact (the Compact)[29], which was recently ratified by the federal government to finalize the agreement[30]. The Compact puts strict limits on water use in an attempt to minimize future threats to the region[31]. One of the major objectives of the Compact is water conservation and efficiency goals and programs. These goals and programs are attempts to minimize water use and create sustainable use of the water within the Great Lakes area.

RESPONSES OF CARL BAUER TO QUESTIONS FROM SENATOR BINGAMAN

Question 1. The Energy-Water Research & Development Roadmap process was initiated in 2005 at the request of Congress, and 5.531 directs DOE to complete the process. What is the current status of the Roadmap, and when do you anticipate its completion?

Answer. DOE participates in the energy-water nexus team, a collaborative effort among many DOE National Laboratories. The team conducted a series of roadmapping workshops and examined issues at the nexus of energy and water. A Roadmap has been completed in "final draft" form and is being reviewed and refined by DOE Headquarters.

Question 2. Your testimony notes that combining IGCC with carbon capture and storage (CCS) technologies results in a generating facility with a greatly reduced carbon footprint and relatively low water consumption. Taking into account electricity output, carbon footprint, and consumptive water use, is it your view that future research and development efforts should focus on combined IGCC-CCS facilities if we are trying to integrate energy and water policies?

Answer. While IGCC may offer significant advantages over the existing fleets' aging pulverized coal technology in terms of its efficiency, ability to capture carbon, and water consumption, it is not a universal solution. IGCC is primarily an option applicable to new coal-fired power plants; however, the existing fleet of approximately 300 GW will likely be with us for a long time. Therefore, more affordable, efficient carbon capture and storage (CCS) technology applicable to these existing pulverized coal (PC) plants needs to be developed, such as post-combustion carbon capture and conversion of PC plants to oxy-combustion technology.

For the same reason, it is important for DOE to continue its CCS water management research effort that is applicable to both IGCC and PC power plants. As stated in the testimony, an IGCC power plant's water consumption is approximately 40 percent less than that of a subcritical PC power plant without CCS. NETL analyses indicate that using current near-commercial CCS technologies on PC plants would more than double the amount of water consumed per unit of electricity generated.

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[27] http://www.waterboards.ca.gov/water__issues/programs/npdes/cwa316.shtml

[28] "The Great Lakes Water Wars", by Peter Annin, Island Press, August 2006.

[29] "The Great Lakes-St Lawrence River Basin Water Resources Compact", Final Report, August 15, 2007.

[30] Signed October 3, 2008, by President Bush. The U.S. House of Representatives voted to approve the Compact by a 390 to 25 vote on September 23rd. The U.S. Senate approved the Compact on August 8, 2008.

[31] The Compact prohibits all new or increased diversions from the Basin

While the water consumption for IGCC with CCS also increases, IGCC still has a comparative advantage, with water consumption significantly lower than that of post-combustion CCS technologies.

It should also be noted that the comparison of IGCC to PC technology is site specific. For new coal plants using Western coals at high altitudes, the cost differences between IGCC and supercritical pulverized coal (PC) combustion are relatively small. For example, for IGCC at 5000 feet site elevation, the air density is down by 13 percent, causing IGCC gas turbine generator output to be reduced by 13 percent, and also impacting gas turbine efficiency, as well as the efficiency of the air separation unit. As a result, at high altitudes, the cost advantages of supercritical PC with CCS over IGCC may heavily influence the choice of technology, if adequate supplies of water are available.

Question 3. Your testimony provides valuable information about the current energy/water R&D efforts taking place at NETL, specifically as they relate to carbon capture and storage, and the impacts of CCS on water availability and quality. Can you comment on other R&D activities throughout DOE that relate to the energy/water nexus?

Answer. While the Office of Fossil Energy and NETL have been actively pursuing water R&D specific to CCS, as outlined in my testimony, the amount of R&D in the Department of Energy targeted specifically at water issues has been limited. Water technology development opportunities tend to be relatively low risk, incremental change, with incentives for the private sector from regulatory drivers. However, the Department has aggressively pursued development of renewable energy technologies, such as solar and wind, that have very low consumptive water requirements, which will be an important option for our energy future, particularly in water-limited areas.

Question 4. Current carbon capture technologies would increase freshwater withdrawal and consumption by fossil-based power plants. You state that pulverized coal plants that capture 90% of carbon emissions use twice as much water per unit of electricity generated. Can you provide more details on how this additional water is consumed, and potential areas for reducing water consumption in the CCS process?

Answer. The additional water consumed for a pulverized coal-fired power plant with CCS is due primarily to the increased cooling duties of the CCS process. In general, as the cooling duty of the wet recirculation cooling system increases, more water is consumed by evaporation. In particular, the following three factors increase the duty of the cooling system: (1) additional cooling capacity for the further cooling of the flue gas before it enters the CCS process; (2) additional cooling water to cool the absorption solvent; and (3) cooling water to remove heat from the compression stages of the CO_2 compressor.

Furthermore, these additional loads also lower the power output of the plant, resulting in less net electricity generation. For example, if CCS were added to a subcritical power plant originally designed to provide 550-MW-net power, it would deliver approximately 15 percent less electricity to the grid. The lower net output and higher consumptive water use results in the marked increase in water consumption on a net output (gal/MWh net) basis.

DOE is directing research at advanced CCS technologies that have the potential to reduce water use. Dry and hybrid cooling technologies can also be incorporated into CCS plant designs—although at added cost and reduced performance—to lessen the load on the cooling tower and therefore reduce water consumption.

Question 5 One of the primary goals of this legislation is to integrate decision-making related to energy and water. The policy and regulatory framework for these resources is currently under the purview of a variety of agencies at the federal, state, and local levels. Recognizing that allocating and managing water typically falls under state jurisdiction, what role can the federal government, through the Departments of Energy, play in the successful integration of energy and water policy?

Answer. The Department of Energy's (DOE's) role is focused on the development of advanced energy system technology to meet cost, greenhouse gas (GHG) emissions, water use, and environmental goals. It is important that the selection and development of these advanced technologies be guided by achieving energy and water goals. This understanding is gained through integrated energy system analyses that provide an understanding of the life-cycle cost, water requirements, and environmental impacts of an energy system. The DOE is implementing technology R&D and systems analysis projects that will provide technology and understanding to support the states in their planning, allocation, and management of water resources. The DOE must take an active role in disseminating these results to regulators and other Federal, state, and local agencies, as well as to the general public. DOE will continue to work very closely with other agencies where they have the lead role in setting regulations. An example is the recent work where DOE worked closely with the Environmental Protection Agency as they developed their proposed rule for carbon dioxide geologic sequestration wells in the Underground Injection Control Program under the Safe Drinking Water Act. That draft rule was published by EPA in July 2008.

RESPONSES OF CARL BAUER TO QUESTION FROM SENATOR MURKOWSKI

Question 1. Please describe how the United States can satisfy all the expected water needs of newly proposed power plants, including concentrated solar, in arid and semi-arid regions.

Answer. Satisfying the expected water needs of newly proposed power plants requires an understanding of each region's situation. Two important parameters to be considered include the current and forecasted competing needs for water (e.g., public, electric power, agriculture, industry) in a region, and the cost and performance of technology choices for that region. The DOE is carrying out R&D on a wide range of advanced technologies for electric power focused on minimizing water requirements. These technologies range from advanced integrated coal gasification fuel cell plant concepts that have minimal water consumption requirements, since they do not utilize a steam turbine cycle, to the use of solar energy systems with essentially no water consumption. DOE also carries out systems studies to analyze the integration of an electric power energy system concept into the region's requirements and constraints. Satisfying expected water needs also requires a long-term view. This perspective is provided through an understanding of the life-cycle cost, water requirements, and environmental impacts of an energy system.

Question 2. Are there any regions in the country that are not expecting a significant water problem in the next decade?

Answer. There is data that suggests that all regions of the continental United States are at risk of strain on freshwater resources. As described in a 2003 GAO survey (GAO-03-514), water managers of nearly every state indicated that under average water conditions, some degree of potential freshwater shortage is likely in the coming decade. Since then, many regions have experienced drought conditions, particularly the arid West and Southeast, and are presently experiencing acute water availability issues.

Credibly projecting future water problems requires adequate estimates of freshwater supplies and future water needs of competitive water-use sectors. DOE collects design and operating data for the existing fleet of thermoelectric power plants. In DOE systems analyses, detailed water balances are evaluated for conventional and advanced coal-based technologies including carbon capture. Based on these analyses and Energy Information Administration (EIA) annual projections of future energy supply and demand, DOE estimates water needs for a range of future energy scenarios, including scenarios with carbon constraints. EIA's recent trend for forecasting new thermoelectric power generation, through 2030, has been to show declines in demand, due, in part, to increased reliance on efficiency and demand response. This is tending to alleviate the concern for related increases in water demand from the power sector. While these projections provide future water demand of only one water-use sector, these results still indicate that the Southeastern and Southwest regions are most at risk for an increase in water use by this sector. However, all regions show increased water consumption, and given the 2003 survey results provided by GAO, suggest that all regions continue to be at risk for water problems in the coming years. It is difficult to project future water problems, given uncertainties associated with climate change impacts on precipitation patterns, changes in energy production/generation in response to climate regulations, and other regional factors such as population growth and shifts in regional domestic, industrial, or agricultural water demand. As such, the Department recognizes the importance to accurately characterize the water requirements of various energy technologies to aid in answering questions related to water demand over the next decade.

Question 3. Please describe how policies aimed at climate mitigation and adaption may affect policies developed in the energy and water sectors, and, specifically, the energy-water nexus.

Answer. In general, policies aimed at climate mitigation will raise the cost of energy. As that cost rises, the cost of treating water, both for drinking and for reuse or disposal, will rise. Given the population increase in the Desert Southwest, for example, relatively costly schemes for desalination of brine for human use will become even more costly, as these technologies are energy-intensive. In addition, the use of carbon capture and sequestration (CCS) at fossil plants, whether coal or natural gas, requires incremental energy capacity and water for the added process. In cases where the water used must be reclaimed, as in California, the process will become even more energy intensive. Nuclear plants, which may become more desirable due to their low carbon footprint, consume even more water per unit of energy produced than a fossil-energy plant with CCS. In non-drought afflicted areas, such as the Midwest and Mid-Atlantic, the cooling water requirements of CCS are not an issue with respect to water availability, most of the time. However, clean air and clean water policies sometimes conflict. For example, the installation of SO_2 scrubbers leads to more water discharges from power plants. For pulverized coal plants, this issue would be exacerbated by CCS retrofits, as the scrubber must be larger to more stringently remove sulfur. In addition, for reliability, large-scale renewable energy requires an almost equivalent matching amount of simple-cycle gas turbines, likely without CCS. Such turbines will be run inefficiently to account for wind variability and/or run intensively during peak demand periods when the wind capacity factors are low, such as the month of August. New baseload power—either fossil with CCS or nuclear—brings along increased water needs and must be dealt with to help make energy supply more reliable.

Question 4. Please describe the impact on energy use with stricter treatment standards for water and wastewater. Are there any energy related tradeoffs that may occur with stricter treatment standards?

Answer. Stricter treatment standards for water and wastewater could have the potential to impact energy use. Energy requirements for water supply and treatment range broadly from 1,900 to 23,700 kWh per million gallons of water. Whether stricter treatment standards would require significant levels of additional energy use would likely be project-specific and dependent on the methods of treatment required to meet this standard. For example, chemically-based treatment systems could require minimal energy use, compared to filtration-based treatment systems, such as reverse osmosis, which require significant energy use.

Question 5. Please describe the impact of energy policies and regulations on water demands and its availability.

Answer. It is estimated that the deployment of carbon capture systems using today's pulverized coal technology would approximately double the water consumed per Megawatt-hour generated by pulverized coal power plants. NEIL has initiated an aggressive RD&D program to significantly improve the overall technical and economic performance of CO2 capture technology that would result in a reduction in the water consumption. Using IGCC technology with CCS—building on the existing gasification and CCS technology used at the Dakota Gasification Company's Beulah, North Dakota facility—would significantly reduce the water consumption.

In general, where water availability is an issue, power plant use of water will be an issue. A similar statement may be made with respect to water quality. Nonetheless, it bears repeating that power consumption of water is quite small relative to agriculture and public consumption. Broadly speaking, current Federal energy policy affects water demand in the following ways: the ethanol mandate increases water demand because ethanol plants are very water intensive; a new Phase II of Rule 316(b) of the Clean Water Act could increase water consumption due to the construction of recirculating systems to replace or substitute for once-through systems, and natural gas production leads to produced water that may affect groundwater quality. At the present time, current state-level regulations and permitting practices have a larger effect on power plants and associated water demands than do Federal ones, since states have jurisdiction over siting. Advancing renewable portfolio standards in many states could reduce the use of water, as both wind and biomass use is less water-intensive in generation than coal or natural gas. However, this will come at a tradeoff with cost and reliability, and, in the case of biomass, water benefits may be partially offset on a life-cycle basis by increased irrigation.

Question 6. As we further examine the interrelationship between water and energy, what type of qualitative data do you believe is needed to better understand the connections to biodiversity and ecological health?

Answer. We believe that it would be valuable to quantify how different types of ecosystems and water flows react to changing land use for energy applications. The development of interagency collaboration between Federal agencies with expertise in energy-related water and biodiversity systems—as well as with state energy, environmental, climate, and geological agencies—would be necessary in that regard. DOE currently participates in a number of inter-agency working groups organized around issues (and technologies) of interest that crosscut the missions of participating departments. Creating a focus for more formal coordination among Federal departments and state agencies who share a common interest could be a first step in fostering the more effective stewardship, production, and use of energy resources and force a broader view of the interrelationship of energy, water, biodiversity, and the planet's ecological health.

Question 7. How can we encourage coordination and collaboration of research, development and policy efforts in the energy-water domain, with a view to cross-cutting learning?

Answer. Coordination and collaboration needs to play a vital role in addressing the complex interactions among energy, water, and the environment in the United States. DOE actively collaborates with other parties from industry, academia, state, and other Federal departments in analyzing and attempting to mitigate the impact of energy production on water supply.

Question 8. Please describe the linkages between energy and water consumption, as a society becomes more affluent. How do measures to improve water use efficiency and energy efficiency correlate, as societies become more affluent?

Answer. Energy consumption is correlated with affluence for poor and mid-income countries, but amongst more affluent countries there is less correlation between wealth and energy consumption. Enhanced water quality comes from not only the direct reduction of pollution but also at the cost of greater energy intensity for water treatment. Therefore, enhanced water-use efficiency will offset a portion of that increased energy intensity. Refurbishing existing fossil plants to higher efficiency levels would immediately reduce energy intensity per gallon used. Greater end-use efficiency of lights and appliances and buildings may reduce the growth in consumption of energy and therefore of water associated with energy production.

Question 9. Please describe how water resource constraints can become energy constraints.

Answer. Water constraints can most certainly lead to energy constraints. Most existing baseload generation is thermoelectric (nuclear and coal) and hydro. Without adequate water resources, these plants cannot operate at full capacity. Any water restrictions could cause a unit to reduce its output or temporarily go offline, as seen in the summer of 2007 and described below. Satisfying peak energy demand during a sustained drought can be especially difficult. Unfortunately, drought conditions and peak energy demand usually occur at the same time.

A February 19, 2009, report, Thirsty Energy: Water and Energy in the 21g Century, by the World Economic Forum and Cambridge Energy Research Associates (CERA) describes the problem (page 30): "Although power plants are not generally charged for water, their permits designate the amount of water they are allowed to remove and consume from a water body and the quality of the water that must be returned to the water body, including a maximum temperature. The amount of water the power plant is allowed to withdraw or consume is based on providing enough water for all uses, including maintaining the environmental and ecological quality of the water source."

In times of severe stress, the availability of water for power plant usage becomes an issue. For example, the recent drought in the Southeast during the summer of 2007 forced a Southeast U.S. power company to reduce power for some of their units and take other units offline at times to comply with temperature discharge restrictions.

RESPONSE OF CARL BAUER TO QUESTION FROM SENATOR STABENOW

Question 1. Interoffice coordination on water efficiency at DOE. What is the Department's approach to the impact of energy production on water? In the various offices that focus on nuclear power, fossil fuels, and EERE (including both renewable energy and biofuels), are there synergies work together to share information and implement policy to improve water efficiency in energy production?

Answer. Coordination and collaboration plays a vital role in addressing the complex interactions among energy and water in the United States. DOE actively collaborates with other parties from industry, academia, state, and other Federal departments and national laboratories in analyzing and attempting to mitigate the impact of energy production on water supply. Statutorily, the Environmental Protection Agency, through the Clean Water Act, Safe Drinking Water Act, and Resource Conservation and Recovery Act, has regulatory authority for water issues on the federal level. The US DOE, however, is often part of relevant interagency review processes, such as review of Section 316B of the Clean Water Act, which regulates Cooling Water Intake Structures. As you suggest, synergies do exist between thermal power generation technologies (fossil and nuclear) regarding their water usage requirements and the potential for alternative cooling approaches.

The DOE actively researches energy-water issues associated with coal plants. Other DOE Offices, such as EERE, are developing energy technologies that require very little water for power generation. DOE's national laboratories also collaborate in ongoing research efforts, for studying the impacts of power technologies upon water systems. A valuable ongoing collaboration is DOE's participation in what is known as the Energy-Water Nexus Team—a multi-laboratory team consisting of 12 National Laboratories and the Electric Power Research Institute (EPRI). The Energy-Water Nexus Team has hosted several regional needs assessment workshops and more focused workshops on gaps analysis and technology innovations. These workshops have involved wide representation from government, industry, interested organizations, and academia, and have provided input and perspectives on emerging regional and national energy and water needs and challenges, as well as energy and water science and technology research directions.

RESPONSES OF MICHAEL E. WEBBER TO QUESTIONS FROM SENATOR BINGAMAN

Question 1. Several of you talked about the opportunity to reduce energy consumption by reusing or conserving water. Mr. Bolze, your testimony specifically references that the U.S. presently reclaims and reuses 6% of its wastewater compared to other countries with much higher percentages.

Can each of you comment on the magnitude of potential you see for significant water savings yielding significant energy savings in this country? Are we just at the tip of the iceberg with respect to the water & energy savings possible through water conservation efforts? Has any established entity quantified the potential?

Answer. It is my determination that water conservation is fertile territory for the nation to save both water and energy. We have much further to go in terms of conservation. The water and wastewater sector is responsible for 3% of the nation's electricity use. Residential water heating is responsible for another 3-4% of the nations' electricity use. Combining all other end-uses and forms of energy, it's likely that water consumption is responsible for at least 10% of the nation's energy consumption. Therefore, reducing water consumption can have significant cross-over benefits for energy consumption. Please note that it would be valuable to quantify these magnitudes more precisely. Regional studies (e.g. for the state of California) have already been performed, but a national estimate has not been conducted to my knowledge.

Question 2. As discussed today, one of the hurdles to coordinated energy and water policy is that energy policy is developed at a national level and water policies are more local and regional in nature.

How much of an impediment is that to integrating energy and water policy and what other impediments do you see to this goal?

Answer. The mismatch in policymaking and regulatory structures for water and energy creates important hurdles for formulating integrated energy-water policies. For example, no agency is responsible for water quantity at a federal level (the EPA is responsible presumably for water quality), which complicates the policymaking for water issues that span municipalities, counties, or states. If several local governments wish to take a watershed approach to resource management, it would be useful for them to have federal agencies to work with, akin to the energy industry, which has the FERC, DoE, and others. Other impediments include the mismatched market structures. Energy markets are becoming deregulated and competitive, whereas most water markets remain controlled by government monopolies, and so the policy context in which they operate are different.

Question 3. In your testimony, you mention that the current trend in energy production, with the exception of wind, solar, and low-irrigation biofuel crops is moving us toward more water-intensive energy sources. This is especially true for transportation fuels as we explore the use of domestically available unconventional fossil fuels, and irrigated biofuel crops.

Which energy sector—electricity generation or transportation fuel production—do you feel has the greatest potential to reduce its water intensity in the near term?

Follow-up: What emerging energy technologies have the greatest potential to achieve water savings, and what is necessary to encourage broader deployment?

Answer. The electricity sector has greater ability to change its water use in the near term because they have several cooling options available. Power plants that use once-through cooling can switch to cooling towers. Power plants that use cooling towers (with water) can switch to those that are either dry-cooling towers that use air, or hybrid towers that use a combination of air and water. Because these technologies already exist and have been demonstrated, it is easier for them to make the switch (though there might be significant capital costs or parasitic losses to efficiency from cooling techniques that are less water-intensive). For the transportation fuels industry, the key breakthrough would be developing biofuels that require much smaller water inputs per unit of useful energy that is produced, primarily by switching away from energy crops such as corn, which are particularly water-intensive. These breakthroughs might be in the realm of bioengineering, genetic modifications, catalytic conversion techniques, and so forth. In addition, conservation technologies are particularly valuable and cost-effective.

Question 4a. You state in your testimony that the transition to new fuels might increase water consumption from one trillion gallons per year to a few trillion gallons of water per year.

Is there any future scenario where water use might actually be reduced in the transportation sector, such as a significant transition to hybrid or plug-in hybrid vehicles with a large increase in renewable-based electricity generation, particularly wind?

Answer. Widespread electrification of the transportation sector along with a shift towards electricity sources that do not require much water (natural gas, solar PV, wind, etc.) could reduce the amount of water that is used for transportation fuel production. Staying with a conventional mix of petroleum-based gasoline and diesel, but using less of it through stricter fuel economy standards and reductions in vehicle miles traveled, could also lessen the total amount of water required for transportation fuels production.

At the hearing, there was discussion about solar thermal, and how much water it consumes relative to coal, natural gas, and nuclear generation.

Question 4b. Can you provide additional information on that subject for the record?

Answer. Most power plants that use heat to generate steam require cooling, and that cooling is usually provided by water. Nuclear, coal, natural gas, oil and solar thermal (concentrating solar power) power plants all use water for cooling, except for a few instances where dry cooling is used instead. Tables 1.1 and 1.2 below (from "The Energy Water Nexus in Texas," by Ashlynn S. Stillwell, et al., April 2009), compare the water requirements for different fuels and cooling methods. Concentrating solar power (CSP) has similar water requirements as solar power, withdrawing approximately 840 gallons of cooling water per MWh of electricity that is generated, and consuming the same amount. CSP withdraws less water than typical nuclear power plants, but consumes more. CSP uses more water than both coal and natural gas. Solar PV and wind use much less water.

The references for Tables 1.1 and 1.2 are as follows:

17. Goldstein, R. and W. Smith. electric Power Research Institute. Water & Sustainability (Volume 3): U.S. Water Consumption for Power Production—The Next Half Century. 1006786. Palo Alto, CA, March 2002.

25. National Renewable Energy Laboratory. Parabolic Trough Power Plant System Technology.Online. Available: http://www.nrel.gov/csp/troughnet/power plant systems.html. Accessed:October 13, 2008.

26. Gleick, Peter H. "Water and Energy." Annual Review of Energy and the Environment, vol. 19, (1994), pp. 267-299.

27. Woods, Mark C., et al. National Energy Technology Laboratory. Cost and Performance Baselinefor Fossil Energy Plants, Volume 1: Bituminous Coal and Natural Gas to Electricity. Pittsburgh,PA, August 2007.

Table 1.1. Water withdrawal reported volumes for different fuels and cooling technologies. Air-cooling requires negligible water and is compatible with all of the technologies listed. [17, 25-27]

Fuel Technology			Cooling Technologies – Water Withdrawal (gal/MWh)				
			Open-Loop	Closed-Loop Reservoir	Closed-Loop Cooling Tower	Hybrid Cooling	Air-Cooling
	Thermal	Coal	35,000 (±15,000)	450 (±150)	550 (±50)	between	<100
	Thermal	Nuclear	42,500 (±17,500)	800 (±300)	950 (±150)	between	<100
	Thermal	Natural Gas Combustion Turbine	negligible	negligible	negligible	negligible	negligible
	Thermal	Natural Gas Combined-Cycle	13,750 (±6,250)	155† (±25)	230	between	<100†
	Thermal	Integrated Gasification Combined-Cycle	not used	not used	400† (±110)	between	<100†
	Thermal	Concentrated Solar Power	not used	not used	840† (±80)	between	<100†
	Non-Thermal	Wind	none	none	none	none	none
	Non-Thermal	Photovoltaic Solar	none	none	none	none	none

†Estimated based on withdrawal and consumption ratios

Table 1.2. Water consumption reported volumes for different fuels and cooling technologies. Air-cooling requires negligible water and is compatible with all of the technologies listed [17, 25-27]

Fuel Technology			Cooling Technologies – Water Consumption (gal/MWh)				
			Open-Loop	Closed-Loop Reservoir	Closed-Loop Cooling Tower	Hybrid Cooling	Air-Cooling
	Thermal	Coal	300	385 (±115)	480	between	60 (±10)
	Thermal	Nuclear	400	625 (±225)	720	between	60 (±10)
	Thermal	Natural Gas Combustion Turbine	negligible	negligible	negligible	negligible	negligible
	Thermal	Natural Gas Combined-Cycle	100	130† (±20)	180	between	60† (±10)
	Thermal	Integrated Gasification Combined-Cycle	not used	not used	350† (±100)	between	60† (±10)
	Thermal	Concentrated Solar Power	not used	not used	840 (±80)	between	80† (±10)
	Non-Thermal	Wind	none	none	none	none	none
	Non-Thermal	Photovoltaic Solar	none	none	none	none	none

†Estimated based on withdrawal and consumption ratios

RESPONSES OF MICHAEL E. WEBBER TO QUESTIONS FROM SENATOR MURKOWSKI

Question 1. Please describe how the United States can satisfy all the expected water needs of newly proposed power plants, including concentrated solar, in arid and semi-arid regions.

Answer. The water needs for new power plants in arid and semi-arid regions might be met by: 1) using dry-or hybrid wet-dry cooling instead of traditional water cooling, and 2) using reclaimed water for cooling.

Question 2. Are there any regions in the country that are not expecting a significant water problem in the next decade?

Answer. Water scarcity and abundance is inherently geographic in nature, and predicting the future of this resource is fraught with error. However, generally speaking the Pacific Northwest, upper Midwest and Northeast are more water-rich than the rest of the nation. Other regions are prone to droughts or perpetual scarcity.

Question 3. Please describe how policies aimed at climate mitigation and adaption may affect policies developed in the energy and water sectors, and, specifically, the energy-water nexus.

Answer. Because water and energy are inherently linked, there are synergies from conservation. That is, water conservation will automatically cause energy conservation, and energy conservation will cause water conservation. Consequently, policies that promote energy conservation for the same of climate mitigation are also likely to achieve water conservation. Conversely, policies that promote water conservation are also likely to achieve energy conservation, which is good for climate mitigation.

Question 4. Please describe the impact on energy use with stricter treatment standards for water and wastewater. Are there any energy related tradeoffs that may occur with stricter treatment standards?

Answer. Water and wastewater treatment require energy. As we tighten environmental standards for water and wastewater treatment, there might be energy impacts, in that more advanced treatments typically require more energy. However, water and wastewater treatment becomes more efficient each year, and so it's not clear whether the pace of tightening treatment standards will outpace efficiency gains. Furthermore, there are many opportunities for reducing energy demands by the water and wastewater sectors, for example by capturing and using bio gas produced from anaerobic digestion of sludge and retrofitting plants with the most efficient pumps and blowers.

Question 5. Please describe the impact of energy policies and regulations on water demands and its availability.

Answer. Many energy policies affect water demands. The push for nuclear power, solar CSP, coal-to-liquids, and biofuels might increase demand for water. The push for wind, solar PV and conservation might reduce demand for water. These contrasting policy directions will surely affect water availability, though these effects will inherently be geographic in nature, depending on where the power or fuels production takes place.

Question 6. As we further examine the interrelationship between water and energy, what type of qualitative data do you believe is needed to better understand the connections to biodiversity and ecological health?

Answer. Generally, quantitative data would be more valuable than qualitative data. Getting additional data on water resources to match the fidelity of data on energy would be very valuable. Right now, data collections related to water resources and use re sparse, often inaccurate, and typically out of date.

Question 7. How can we encourage coordination and collaboration of research, development and policy efforts in the energy-water domain, with a view to cross-cutting learning?

Answer. There are many opportunities to coordinate and collaborate on the scientific and R&D aspects of the energy-water nexus. Right now, no federal agency has clear responsibility for this issue, and consequently the science is not coordinated. It's likely that OSTP can play a positive role in coordinating the scientific program of the energy-water nexus. USGS can play a leading role in collecting, maintaining and distributing relevant data related. Other agencies such as NASA can also contribute critical information through its remote sensing capabilities.

Question 8. Please describe the linkages between energy and water consumption, as a society becomes more affluent. How do measures to improve water use efficiency and energy efficiency correlate, as societies become more affluent?

Answer. As developing societies become more affluent, their energy and water consumption grow considerably, as we are seeing worldwide today. The story is more complicated for industrialized societies. As industrialized societies become more affluent, their overall energy and water use per unit of economic activity often drops, primarily because energy-and water-intensive industries (such as manufacturing) get replaced with different sectors that use less water and energy (such as finance or other service sectors). In addition, affluent societies are better able to afford efficient technologies, thereby sparing some water and energy consumption. However, a counter-trend to the society-wide change in water and energy use is that as individuals become more affluent, they tend to consume more energy (to air condition large homes, for example) and water (because they eat more meat). It's not always clear whether the growth in individual energy and water consumption will outpace or match the lessening energy- and water-intensity of industry. Consequently, the net effect is sometimes difficult to predict.

Question 9. Please describe how water resource constraints can become energy constraints.

Answer. Because the power sector (and increasingly, the fuels production sector) requires so much water, water constraints can become energy constraints. For example, droughts might limit the availability of cooling water for power plants. If the water levels in a reservoir drop below intake pipes to cooling systems, then power plants might be forced to shut down. In addition, heat waves, which raise the temperature for surface water sources, might restrict the total output from power plants if they are bound by thermal pollution limits. That is, power plants cannot return their cooling water to the source at a temperature that induces harm to the ecosystem. If the cooling water starts off at a higher temperature, then the power plant has less cooling capacity available, and thus might be forced to dial down its output. In this way, droughts and heat waves introduce water constraints that can become energy constraints.

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