# THE ENERGY WATER NEXUS: DRIER WATTS AND CHEAPER DROPS

## HEARING

BEFORE THE

SUBCOMMITTEE ON ENERGY

OF THE

COMMITTEE ON SCIENCE, SPACE, AND TECHNOLOGY

HOUSE OF REPRESENTATIVES

ONE HUNDRED SIXTEENTH CONGRESS

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# C O N T E N T S

**March 7, 2019**

# THE ENERGY WATER NEXUS: DRIER WATTS AND CHEAPER DROPS

**THURSDAY, MARCH 7, 2019**

HOUSE OF REPRESENTATIVES,
SUBCOMMITTEE ON ENERGY,
COMMITTEE ON SCIENCE, SPACE, AND TECHNOLOGY,
*Washington, D.C.*

The Subcommittee met, pursuant to notice, at 10 a.m., in room 2318 of the Rayburn House Office Building, Hon. Conor Lamb [Chairman of the Subcommittee] presiding.

**COMMITTEE ON SCIENCE, SPACE, AND TECHNOLOGY**
**SUBCOMMITTEE ON ENERGY**
**U.S. HOUSE OF REPRESENTATIVES**
**HEARING CHARTER**

*The Energy Water Nexus: Drier Watts and Cheaper Drops*
Thursday, March 7, 2019
10:00AM EST
2318 Rayburn House Office Building

## PURPOSE

The purpose of the hearing is to examine energy and water nexus issues in support of H.R. 34, the "Energy and Water Research Integration Act of 2019," as introduced by Chairwoman Eddie Bernice Johnson and Ranking Member Frank Lucas at the beginning of the 116th Congress. This legislation ensures that the Department of Energy considers water intensity in energy research and development activities and energy intensity in water production and use. The hearing will focus on current issues and opportunities for efficiency improvements.

## WITNESSES

- **Dr. Vincent Tidwell** is a Principle Member of Technical Staff at Sandia National Laboratories. Dr. Tidwell has more than 20 years of experience conducting and managing research on basic and applied projects in water resource management, nuclear and hazardous waste storage and remediation, and collaborative modeling. Currently, he is leading several studies that address issues concerning the energy-water nexus, including support for long-term transmission planning in the Western and Texas interconnections, climate impacts on energy-water relations, and international energy-water pinch points. Dr. Tidwell was a Lead Author for the Land-Water-Energy cross-sectorial chapter for the 2014 National Climate Assessment.[1]

- **Ms. Kate Zerrenner** is a Senior Manager at the Environmental Defense Fund (EDF). Ms. Zerrenner leads EDF's Texas and national energy-water nexus efforts, and develops and implements strategies to promote energy and water efficiency in Texas. Her work aims to address financial, regulatory, and behavioral barriers to advancing clean energy options that reduce climate change impacts, water intensity, and air pollution. Prior to

[1] "Vincent Tidwell Biography." Green is Good. Accessed 27 Feb 2019. https://greenisgoodshow.com/guest/sandia-national-laboratories-dr-vincent-tidwell/

joining EDF, Ms. Zerrenner worked at the U.S. Government Accountability Office analyzing U.S. action on climate change and the voluntary carbon offset market; SAIC, on climate change projects for the U.S. Department of Energy and the U.S. Environmental Protection Agency; and the U.S. Department of Energy.[2]

- **Dr. Richard Bonner** is the Vice President of Research & Development of Advanced Cooling Technologies. Dr. Bonner has led research programs involving the thermal and fluid sciences, including several programs related to the Energy-Water Nexus. He has published more than 45 papers, 1 patent, and 4 patent applications. Dr. Bonner has also led advanced thermal product development programs, from concept to production, for over 125 customers covering a wide range of commercial industries.

- **Dr. Ramen P. Singh** is the Associate Dean for Engineering at OSU-Tulsa, and a Professor and Head of the School of Materials Science and Engineering at Oklahoma State University. Dr. Singh's research focuses on the failure mechanics of advanced and complex material systems. His research has been funded by the National Science Foundation, NASA, the Oklahoma Center for the Advancement of Science & Technology, the Oklahoma Transportation Commission, the US Army Research Office, the Department of Energy, and industry.

- **Dr. Michael Webber,** Dr. Michael E. Webber is based in Paris, France where he serves as the Chief Science and Technology Officer at ENGIE, a global energy and infrastructure services company. Dr. Webber is also the Josey Centennial Professor in Energy Resources and Professor of Mechanical Engineering, at the University of Texas at Austin. He is the author of *Thirst for Power: Energy, Water and Human Survival*, published in 2016.[3]

## BACKGROUND

The energy-water nexus is a growing area of concern. Generally, this term refers to the fact that the production of energy requires large volumes of water while the treatment and distribution of water is also dependent upon readily available energy. Both energy and water are under considerable stress in the United States, particularly in the southwest and western regions of the country.

[2] "Kate Zerrenner Biography." Environmental Defense Fund. Accessed 27 Feb 2019. https://www.edf.org/people/kate-zerrenner
[3] "Michael Webber Biography." Webber Energy Group. Accessed 27 Feb 2019. http://www.webberenergygroup.com/people/michael-webber/

In 2012, the Science, Space, and Technology Committee asked GAO to identify key energy water nexus issues that Congress and federal agencies should consider when developing policies for energy and water resources. GAO reviewed five reports related to the energy water nexus that GAO previously released (the first released in 2009) to create a new summary report. It recommended that DOE create an energy water nexus program, with involvement from other federal agencies. This was asked of the DOE by Congress in the Energy Policy Act of 2005.[4]

The Department of Energy created the Energy Water Nexus Crosscut Team in late 2012. In 2014, DOE published *The Water-Energy Nexus: Challenges and Opportunities*, which outlined future energy water nexus work for DOE. After the release of this report, DOE hosted a roundtable series (six in total) to enable stakeholder dialogue.[5]

Although the current Administration eliminated coordinated support for this research area in 2017, there are a few related initiatives within DOE today. The Water Security Grand Challenge is a broad initiative announced in October 2018 "to advance transformational technology and innovation to meet the global need for safe, secure, and affordable water."[6] In December 2018, DOE released a funding opportunity announcement for an Energy-Water Desalination Hub in accordance with funds appropriated by Congress in FY 2017, FY 2018, and FY 2019. The goal of this Hub is to create affordable freshwater utilizing energy efficient technologies.[7] And most recently, in February 2019, DOE announced a prize competition "to spur innovation in wave energy-powered desalination systems."[8]

## THE ENERGY AND WATER RESEARCH INTEGRATION ACT OF 2019

The Energy and Water Research Integration Act of 2019 (H.R. 34) directs the Secretary of Energy to integrate water considerations into the Department of Energy's (DOE) research, development, and demonstration programs in order to: (1) advance energy technologies and practices that would minimize freshwater withdrawal and consumption, increase water use efficiency, and utilize nontraditional water sources; and (2) improve the understanding of the energy required to provide water supplies and the water required to provide energy supplies throughout the United States. The bill also requires the Secretary of Energy to work with other relevant agencies, nongovernmental organizations, and State and local governments to develop

[4] GAO 2012. ENERGY-WATER NEXUS Coordinated Federal Approach Needed to Better Manage Energy and Water Tradeoffs. https://www.gao.gov/assets/650/648306.pdf
[5] "Energy Water Nexus Crosscut." DOE. https://www.energy.gov/energy-water-nexus-crosscut
[6] "Water Security Grand Challenge." DOE. https://www.energy.gov/eere/water-security-grand-challenge
[7] "Department of Energy Announces $100 Million Energy-Water Desalination Hub to Provide Secure and Affordable Water." DOE. https://www.energy.gov/articles/department-energy-announces-100-million-energy-water-desalination-hub-provide-secure-and
[8] "DOE Announces Prize Competition for Wave Energy Water Desalination." DOE. https://www.energy.gov/articles/doe-announces-prize-competition-wave-energy-water-desalination

and regularly update a Strategic Plan which includes technical milestones for achieving and assessing progress toward these objectives.

Finally, the bill requires the Secretary of Energy, in coordination with other relevant agencies, to create an Energy-Water Subcommittee of the Secretary of Energy Advisory Board to oversee these activities. The Subcommittee must consist of representation from each program within the Department and each Federal agency that conducts research relevant to this area, as well as representatives from research and academic institutions, States, and industry with expertise in technologies and practices relating to the energy-water nexus. The Subcommittee is also tasked with: (1) making recommendations on the development of data collection and data communication standards and protocols; (2) recommending improvements to Federal water use data to increase understanding of trends in energy generation and fuel production; and (3) recommending best practices for utilizing information from existing monitoring networks to provide uniform water and energy use and infrastructure data.

Chairman LAMB. This hearing will come to order. Without objection, the Chair is authorized to declare a recess at any time.

Good morning. Welcome to today's hearing titled, "The Energy Water Nexus: Drier Watts and Cheaper Drops." I'd like to thank our panel of witnesses for being here today. I'd also like to thank both Chairwoman Johnson and Ranking Member Lucas for introducing the *Energy and Water Research Integration Act of 2019*, which addresses the energy-water nexus issues that we'll be discussing today. I think it is tremendous that our Committee's leadership has started this year off with a major piece of legislation that is bipartisan, and I commend them for that.

The connection between energy and water is indisputable. It takes a lot of water to produce energy and a lot of energy to produce clean water. Large-scale power plants mainly use water as a cooling source. I've seen this back home. We have a nuclear power plant and a coal-fired power plant right next to each other in my district that use a lot of water on the Ohio River. A substantial amount of this is used to produce other common fuel sources like oil and gas, which produces a lot of wastewater, also a significant issue in western Pennsylvania where I'm from where we have a lot of natural gas drilling taking place.

The *Energy and Water Research Integration Act of 2019* aims to decrease energy and water intensity when we use these resources by integrating water production use and treatment considerations throughout DOE's (Department of Energy's) R&D (research and development) programs. Reducing the water intensity of energy and the energy intensity of water production will help our environment and, most importantly, it should decrease the utility bills for our people back home.

This is not a new field of research. Congress instructed DOE to create a program to address this back in 2005 with the *Energy Policy Act*, and in 2012 the Department created the Energy-Water Nexus Crosscut team. This created a plan for future work in research at DOE. They have held a series of roundtable discussions, including some with the witnesses who are here today, and we thank you for filling us in on those. Unfortunately, this team was disbanded at the beginning of this Administration.

The Administration has recently launched an initiative that focuses on water production and announced two new funding opportunities for desalination, but these are only some components of I think the overall nexus that we need to be addressing.

So restoring a focus to this connection we view as crucial. Global energy consumption and water demand will continue to go up and likely will for decades into the future. This is exacerbated by climate change, meaning it's going to get worse and more difficult to solve, which is why I think we need a whole-of-government and of course bipartisan approach on this.

The relationship between energy and water we also know is very specific to particular regions. In the west when temperatures are high, water use for cooling power plants is much less efficient or not even available when there are severe droughts. Sea-level rise affects the water sources along the coast, increasing the need for energy-efficient water treatment capabilities. Weather can affect the demand for energy like extreme winter weather events experienced back home in my district where we have plenty of water but often have some very cold temperatures. This threatens both the energy and water infrastructure.

So efficiency measures would help mitigate all of these problems, and that's where our discussion will focus today. We are going to look at the nexus between energy and water, but also talk about some solutions that are innovative. One of the witnesses we have here today, Dr. Richard Bonner, has led many projects related to water use and energy production at a small business in my home State of Pennsylvania, so I will use my prerogative to welcome you, Dr. Bonner, as a fellow Pennsylvanian. We're thrilled to have you here. His projects have been funded through various government programs such as ARPA-E (Advanced Research Projects Agency - Energy), which we view as a program that's vital to our energy research and development. We need more innovative projects like yours in this field, and we all look forward to your testimony.

[The prepared statement of Chairman Lamb follows:]

## OPENING STATEMENT

Chairman Conor Lamb (D-PA)
Energy Subcommittee
House Committee on Science, Space, and Technology
*The Energy Water Nexus: Drier Watts and Cheaper Drops*
March 7, 2019; 10:00am
2318 Rayburn House Office Building

Good morning and I'd like to thank our panel of witnesses for being here today. I'd also like to thank both Chairwoman Johnson and Ranking Member Lucas for introducing the Energy and Water Research Integration Act of 2019, which addresses the energy water nexus issues we will be discussing today. I think this is one of the great ways that our committee's leadership has been working to start this Committee off on the right foot this year – with bipartisan legislation.

The interconnection of energy and water is indisputable. It takes a lot of water to produce energy, and it takes a lot of energy to produce clean water. Large scale power plants mainly use water as a cooling source. A substantial amount of water is used to produce many common fuel sources, such as oil and gas, and these processes create a substantial amount of wastewater. It also takes a significant amount of energy to treat that wastewater.

The Energy and Water Research Integration Act of 2019 aims to decrease energy and water intensity when we utilize these resources by integrating important water production, use, and treatment considerations throughout DOE's relevant R&D programs. Reducing the water intensity of energy, and the energy intensity of water production, will help our environment and decrease utility bills for our constituents back home.

This is not a new field of research. Congress instructed the Department of Energy to create a program to address these issues over a decade ago, in the Energy Policy Act of 2005 and in 2012, the Department created the Energy Water Nexus Crosscut Team. This team created a plan of future work and research for DOE, and the Department has held a series of roundtable discussions with stakeholders, including some of the witnesses here today, to ensure the issues were being addressed properly.

Unfortunately, this team was disbanded at the beginning of this Administration. Although the Administration recently launched a broad initiative that focuses on water production and announced two funding opportunities for desalination technologies, these are only components of the overarching energy water nexus.

Restoring a comprehensive focus into this connection and sector is critical. Global energy consumption and water demand continue increasing and likely will for decades into the future. This demand is exacerbated by climate change, and will evolve as this phenomenon continues in the years and decades ahead.

The relationship between energy and water is also regionally specific. In the West, when temperatures are high, water used for cooling power plants is less efficient – or worse, not available – when there are severe droughts. Sea level rise affects the water sources along the coast, increasing the need for energy efficient water treatment capabilities. Weather can also increase the demand for energy – like the extreme winter events experienced back home in my district – and threaten both energy and water infrastructure.

Energy and water efficiency measures would help mitigate these problems.
The discussion today will focus not only on energy water nexus issues, but also highlight innovative solutions to address those issues. One of the witnesses here today, Dr. Richard Bonner, has led many projects related to water use in energy production at a small business in my home state of Pennsylvania, Advanced Cooling Technologies. These projects have been funded through various government programs, such as ARPA-E, a program vital to innovative energy

research and development that we discussed in a hearing held by this subcommittee held last week. We need more innovative projects in this field of research, and I look forward to the testimony from our witnesses here today.

Chairman LAMB. And now the Chair recognizes my Republican colleague and friend, Mr. Weber, for an opening statement.

Mr. WEBER. Thank you, Mr. Chairman.

Today, we will hear from a panel of experts on the challenges in the U.S. energy-water nexus and discuss the Department of Energy's (DOE) role in enabling fundamental research and development in support of these critical resources.

A sustainable supply of both energy and water is essential to the maintenance of U.S. economic health, environmental stability, and national security. Water is needed to produce energy, and energy is required to extract, treat, and transport water. This fundamental and tightly intertwined relationship is often referred to as the energy-water nexus. We see the energy-water nexus at work in the production of fossil fuels and biofuels, and in the functioning of thermoelectric power plants across our great country.

Historically, energy and water systems in the United States have been planned and managed separately. Today, it is clear that no matter what the future cross-section of the U.S. energy market looks like or will look like, we will need to develop an integrated approach to these two systems. A number of Federal agencies have supported research and development efforts related to the energy-water nexus, including the Environmental Protection Agency (EPA), the Department of the Interior (DOI), and the Department of Energy (DOE).

With its strong expertise in energy technologies and world-leading, I might add, fundamental science capabilities, DOE is uniquely suited to lead the national energy-water nexus conversation. The Department enables high level use-inspired basic research that supports our understanding of today's evolving energy-water nexus throughout its national laboratory system.

At the National Renewable Energy Laboratory (N-REL), DOE funds research into a wide portfolio of advanced technology solutions to today's energy-water nexus concerns, including desalination using renewable energy technologies and the reduction of water needs for solar technologies.

At the National Energy Technology Laboratory (NETL), DOE funds research in advanced cooling and water treatment technologies, nontraditional water use, and modeling tools to evaluate the impact of fossil energy development on both surface and subsurface water resources.

And at Sandia National Laboratories—you all have heard of that, right? At Sandia National Laboratories researchers are focused on creating new water supplies using advanced technologies. Sandia also supports research that develops and provides decisionmaking tools to U.S. institutions that control the supply and demand of both water and energy.

Recently, the Trump Administration has taken a number of steps to prioritize research in the energy-water nexus. In October 2018, Secretary Rick Perry announced the launch of a DOE-led Water Security Grand Challenge, which will incentivize the development of new technologies to address critical U.S. water security challenges.

Then in December, DOE announced $100 million in funding for an Energy-Water Desalination Hub focused on early stage research and development. This hub will explore nontraditional water sources and provide desalination technologies that are both cost-competitive and energy-efficient.

I want to thank the Chairman for holding this hearing today and the witnesses for providing their testimony, and I'm looking forward to learning more about this important research in our hearing today.

Mr. Chairman, I yield back.

[The prepared statement of Mr. Weber follows:]

# Opening Statement of Energy Subcommittee RM Randy Weber: Energy Subcommittee Hearing on Energy-Water Nexus

Mar 7, 2019

Opening Statement

Today, we will hear from a panel of experts on the challenges in the U.S. energy-water nexus and discuss the Department of Energy (DOE)'s role in enabling fundamental research and development in support of these critical resources.

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Then in December, DOE announced $100 million in funding for an Energy-Water Desalination Hub focused on early-stage research and development. This hub will explore non-traditional water sources and provide desalination technologies that are both cost competitive and energy efficient.

I want to thank the Chairman for holding this hearing today and the witnesses for providing their testimony, and I'm looking forward to learning more about research in this important area today.

Chairman LAMB. Thank you. And the Chair now recognizes Chairwoman Johnson for an opening statement.

Chairwoman JOHNSON. Thank you very much, Mr. Chairman. And good morning and welcome to our witnesses.

I'm delighted that we're holding this hearing—it's very timely—to bring attention to the interplay between water, one of our most valuable natural resources, and our energy systems. Our energy and water systems are intrinsically interconnected. Not only does energy play an important role in the extraction, treatment, and transportation of water, but water is also used in many stages and types of electricity generation.

In my home State of Texas, we face a multitude of issues at the energy-water nexus, for example, large amounts of water are used during the process of fracking for oil and gas extraction. However, the needs of the large oil and gas industry can be at odds with the needs of the agricultural community, where farmers struggle to conserve water and energy to save costs, especially in the face of increasingly extreme droughts in the State. Of course, water is an important resource for energy and agriculture, but it's also critically important for the people.

My own city of Dallas, which is inland, is the fastest-growing metropolitan area in the United States, which puts a strain on our already limited water resources in the State. Moreover, all of these issues are exacerbated by our rapidly changing climate. These days, we regularly withstand harsh droughts, extreme heat, hurricanes, and wildfires. This uptick is extreme—in extreme weather events is causing water, food, and energy insecurity, which only increases the urgency with which we must act.

For these reasons, I have been working for many years in Congress to address this important issue through my work in developing the *Energy and Water Resource Integration Act*. This Congress, I reintroduced that bipartisan bill with my colleague and friend Ranking Member of the Full Committee, Lucas. It instructs the Department of Energy to incorporate the consideration of water use and treatment into all of its relevant research, development, and demonstration programs, and to establish additional coordination functions to ensure that we are giving this issue adequate attention and resources moving forward.

I want to thank you, Mr. Lamb, for convening this panel. I'm very pleased to see the strong representation of witnesses, and especially from Texas today. I look forward to having a robust discussion and I—as I complete my statement, I will say that I do have to attend a Subcommittee on Water in the Transportation Committee, so I will dip out in a little bit.

Thank you, and I yield back.

[The prepared statement of Chairwoman Johnson follows:]

## OPENING STATEMENT

**Chairwoman Eddie Bernice Johnson (D-TX)**

House Committee on Science, Space, and Technology
Subcommittee on Energy Hearing
*The Energy Water Nexus: Drier Watts and Cheaper Drops*
March 7, 2019

Good morning and welcome to our witnesses. Thank you, Chairman Lamb, for holding this timely hearing to bring attention to the interplay between water, one of our most valuable natural resources, and our energy systems.

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In my home state of Texas, we face a multitude of issues at the energy-water nexus. For example, large amounts of water are used during the process of fracking for oil and gas extraction. However, the needs of the large oil and gas industry can be at odds with the needs of the agricultural community, where farmers struggle to conserve water and energy to save costs, especially in the face of increasingly extreme droughts in the state. Of course, water is an important resource for energy and agriculture, but it also is critically important for people. My own city of Dallas, Texas is the fastest growing metropolitan area in the U.S., which puts strains on our already limited water resources in the state.

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I again want to thank Mr. Lamb for convening this panel. I am very pleased to see the strong representation of witnesses from Texas here today, and I look forward to having a robust discussion on how we can best address these critical issues at the nexus of energy and water.

With that, I yield back.

Chairman LAMB. Thank you, Madam Chairwoman.

And the Chair now recognizes Ranking Member Lucas for an opening statement.

Mr. LUCAS. Thank you, Chairman Lamb, for holding this hearing today, and thank you to our witnesses for being here.

There might not be two more important and interconnected pieces in our daily health and economic stability than water and energy. Water is used to produce energy, and energy is required to treat and distribute clean water. Both are essential, and both depend on the other.

That is why this Congress I joined my colleague, Chairwoman Johnson, in introducing H.R. 34, the *Energy and Water Research Integration Act*, which will be the subject of today's hearing. This bill will improve our understanding of the relationship between water use and energy production while encouraging the development of innovative technologies that could improve efficiency and production in both sectors.

It's important to remember that many of the issues surrounding the energy-water nexus are regional and so require consideration of local factors. For example, in Oklahoma agriculture is clearly a third part of the relationship. While agriculture is the single largest consumer of water, it is also a critical piece of the national economy and contributes indirectly to the energy sector through the production of biofuels.

Additionally, oil and gas operations, especially horizontal drilling and hydraulic fracking, which are vital in the pursuit of cleaner energy markets, require large volumes of water and can also produce water. While this presents localized water treatment challenges, it also leads to opportunities for beneficial reuse of water through fluid lifecycle management.

Today, Raman Singh will provide—Doctor I should say—Raman Singh will provide a valuable perspective from the research community on ways to improve water management and energy efficiency by developing carbon- and water-neutral fossil energy technologies. I look forward to hearing how his collaborative multi-university effort, led by Oklahoma State, can conduct transformative research while working with industry to safely implement new approaches to the field. This research can also complement the work being conducted at our national labs.

I'm pleased to see DOE pursuing work in this area, both through the multi-agency Water Security Grand Challenge and the recently announced DOE Energy-Water Desalination Hub. By focusing on early stage R&D, this hub will work to develop novel filtration membranes that can transform brackish or produced water into water communities can reuse. Because of the complex relationship between energy and water systems, this challenge will require a multi-disciplinary approach. Interactions between chemists, engineers, geologists, legislators, and others will be required, along with collaboration between government, industry, and universities. I believe the legislation introduced by Chairwoman Johnson and myself can help to streamline and prioritize this work.

I thank our witnesses for being here today, and I look forward to our discussion this morning. And with that, I yield back, Mr. Chairman.

[The prepared statement of Mr. Lucas follows:]

# Ranking Member Frank Lucas Opening Statement at Energy Subcommittee Hearing on Energy-Water Nexus

Mar 7, 2019

Thank you, Chairman Lamb, for holding this hearing today and thank you to our witnesses for being here.

There might not be two more important and interconnected pieces to our every day health and economic stability than energy and water. Water is used to produce energy, and energy is required to treat and distribute clean water. Both are essential, and both depend on the other.

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Today Dr. Raman Singh will provide a valuable perspective from the research community on ways to improve water management and energy efficiency by developing carbon and water neutral fossil energy technologies. I look forward to hearing how this collaborative multi-university effort, led by Oklahoma State, can conduct transformative research while working with industry to safely implement new approaches in the field.

This research can also complement the work being conducted at our national labs. I'm pleased to see DOE pursuing work in this area, both through the multi-agency Water Security Grand Challenge and the recently announced DOE Energy-Water Desalination Hub. By focusing on early stage R&D, this hub will work to develop novel filtration membranes that can transform brackish or produced water into water communities can reuse.

Because of the complex relationship between energy and water systems, this challenge will require a multi-disciplinary approach. Interactions between chemists, engineers, geologists, legislators, and others will be required along with collaboration between government, industry, and universities.

I believe the legislation introduced by Chairwoman Johnson and myself can help to streamline and prioritize this work.

I thank our witnesses for being here today, and I look forward to our discussion this morning.

Chairman LAMB. Thank you, sir.

If there are Members who wish to submit additional opening statements, your statements will be added to the record at this point.

Now, I'd like to introduce our witnesses. First, we have Dr. Vincent Tidwell, who is a Distinguished Member of the Technical Staff at Sandia National Laboratories. Dr. Tidwell has more than 20 years of experience conducting and managing research on basic and applied projects in water resource management, nuclear and hazardous waste storage and remediation, and collaborative modeling. Currently, he is leading several studies that address issues concerning the energy-water nexus, including support for long-term transmission planning in the western and Texas interconnections, climate impacts on energy-water relations, and international energy-water pinch points. Dr. Tidwell was a lead author for the Land, Water, Energy cross-sectoral chapter of the 2014 National Climate Assessment.

Ms. Kate Zerrenner—did I get that right?

Ms. ZERRENNER. Close enough.

Chairman LAMB. Close enough. I'm sorry about that. Is a Senior Manager at the Environmental Defense Fund (EDF). Ms. Zerrenner leads EDF's Texas—can you just say it so that I make sure I get it right?

Ms. ZERRENNER. Zerrenner.

Chairman LAMB. Zerrenner, thank you. Ms. Zerrenner leads EDF's Texas and national energy-water nexus efforts and develops and implements strategies to promote energy and water efficiency in Texas. Her work aims to address financial, regulatory, and behavioral barriers to advancing clean energy options that reduce climate change impacts, water intensity, and air pollution.

Prior to joining EDF, Ms. Zerrenner worked at the U.S. Government Accountability Office analyzing U.S. action on climate change and the voluntary carbon offset market, SAIC, on climate change projects for the U.S. Department of Energy and the U.S. Environmental Protection Agency and the U.S. Department of Energy.

Dr. Richard Bonner is the Vice President of Research and Development of Advanced Cooling Technologies. Dr. Bonner has led research programs involving the thermal and fluid sciences, including several programs related to the energy-water nexus. He has published more than 45 papers, one patent, and four patent applications. Dr. Bonner has also led advanced thermal projects development programs from concept to production for over 125 customers covering a wide range of commercial industries.

We also have Dr. Michael Webber, who's based in Paris, France, where he serves as the Chief Science and Technology Officer at ENGIE, a global energy and infrastructure services company. Dr. Webber is also the Josey Centennial Professor in energy resources and Professor of mechanical engineering at, you guessed it, the University of Texas at Austin. There's a heavy Texas imprint on our hearing today. Mr. Ranking Member, if I didn't know any better, I would suspect a conspiracy was afoot. But we do have a Pennsylvanian on the panel, so I know we're safe.

Mr. WEBER. Yes, but he spells his name wrong.

Chairman LAMB. Dr. Webber is the author of Thirst for Power: Energy, Water, and Human Survival published in 2016. We're guessing he picked up the second B somewhere in Paris probably, and then that switch to Texas is where it falls off.

The Chair now recognizes Ranking Member Lucas for the introduction of our final witness.

Mr. LUCAS. Thank you, Chairman.

It is with great pleasure I introduce one of my constituents as our witness today, Dr. Raman Singh. He holds a number of academic positions, including Associate Dean of Engineering at Oklahoma State-Tulsa; Head of the School of Materials Science and Engineering at the College of Engineering, Architecture, and Technology at Oklahoma State University (OSU); and the Director of the Helmerich Advanced Technology Research Center at OSU-Tulsa campus.

His research has been funded by the National Science Foundation, NASA (National Aeronautics and Space Administration), the Oklahoma Center for Advancement of Science and Technology, the Oklahoma Transportation Commission, the U.S. Army Research Office, the Department of Energy, and industry. And prior to joining OSU, Dr. Singh was a postdoctoral scholar at the California Institute of Technology, a faculty member of the State University of New York at Stony Brook. Dr. Singh holds M.S. and Ph.D. degrees in mechanical engineering and applied mechanics, both from the University of Rhode Island, and a bachelor of technology degree in mechanical engineering from the Indian Institute of Technology.

Thank you, Dr. Singh, for both being at Oklahoma State and being here with us today. And I yield back, Mr. Chairman.

Chairman LAMB. Thank you, Ranking Member.

As our witnesses should know, you will each have 5 minutes for your spoken testimony. Your written testimony will be included in the record for the hearing. When you all have completed your spoken testimony, we will begin with questions. Each Member will have 5 minutes to question the panel.

We will start with Dr. Tidwell.

**TESTIMONY OF DR. VINCENT TIDWELL, DISTINGUISHED MEMBER OF THE TECHNICAL STAFF, SANDIA NATIONAL LABORATORIES**

Dr. TIDWELL. Chairman Lamb, Ranking Member Weber, and distinguished Members of the Committee, I thank you for this opportunity to testify here before you this morning on this critical issue of energy and water nexus. Again, my name's Vincent Tidwell, and I'm with Sandia National Laboratories.

I want to start on a personal note as I had the opportunity to view the energy-water nexus firsthand. This past week while I was on vacation I traveled from Albuquerque, New Mexico to Park city, Utah. And on this trip I crossed the San Juan, the Colorado, and the Green Rivers, along with the Rio Grande. I also passed numerous power plants, hydropower dams, oil and gas plays and coal mines. The relation between these important resources was evident. Equally evident was the critical role these resources play in the economy, livelihood, culture, and environment of the communities that they serve. These resources are our heritage, so thank you for your concern and interest in securing these resources for generations to come.

There are three points I'd like to make this morning. First is a challenge. Energy-water nexus is expressed in varied ways that often depend on location. Second is an opportunity. We can manage the nexus through integrated planning involving coordinated action between water and energy managers. My third point again highlights an opportunity, in this case, to harness the deep expertise of our national laboratories, academia, industry, and other Federal agencies to develop advanced water treatment technologies to make new sources of water available at competitive costs.

To my first point, place really matters when it comes to the energy-water nexus. For example, in the west we've had difficulty in siting new power plants due to limited water supply. While in the east, we have had problems in times of drought with existing power plants having to operate differently due not to limited water supply but because of elevated water temperatures. Drought affects hydropower everywhere, but it's a particular issue in the northwest where hydropower counts for over 60 percent of all generation capacity.

On the other end of the spectrum we see penetration of wind in the plains States and solar in the southwest, which has drastically changed and reduced our energy-water burden in these regions. This variation simply reflects the geographic differences in our energy, water, and climate systems, underscoring the need for deep understanding of these linkages with broad nationwide participation.

To my second point, integrated planning provides an important platform for managing the nexus. As a personal example, I've led a team of researchers, including my colleague Dr. Webber to bring State water managers together with energy managers from the Nation's three interconnections to help integrate water into their long-term transmission planning, specifically identifying where water might limit the siting of new thermoelectric power generation or where drought might impact the operations of existing power plants or hydropower assets.

Beyond integrated resource planning, though, we need to integrate waste stream management. Significant quantities of water and energy are required to manage waste, including emissions scrubbers, carbon capture systems, and produced water management. But we don't have to consider these as waste as new technologies are emerging to extract value from these streams such as latent heat, biogas, potable water, and commercial chemicals.

My final point again addresses an opportunity, that of advanced water treatment technology. In 1961 President Kennedy said if "we could ever competitively at a cheap rate get fresh water from salt water, it would be in the long-range interest of humanity, which would really dwarf any other scientific accomplishment." Today, there are over 18,000 desalination plants and operations around the world, but desalination is still not cheap. Why? The source waters are highly variable. We're also having to deal with other contaminants beyond salt, as we find in our municipal industrial wastewaters, produced water, and agricultural return flows.

There's also the confounding issue of concentrate management. That is, what do we do with the salts when we separate them?

Toward this need, the DOE has issued a call for an energy-water desalination hub, which will invest in early stage R&D. This provides an unprecedented opportunity to coordinate expertise across Federal, academic, and industrial research complexes to develop new materials and new processes that will fundamentally change the way we treat water in the future.

In conclusion, the energy-water nexus is a complex and nuanced issue. While we are making progress, more work is needed. And I want to stress that we have the opportunity to do more than simply avoid future problems but rather we can radically change the way our energy systems depend on fresh water while creating new sources of water at competitive prices.

Thank you for convening this hearing, and I look forward to your questions.

[The prepared statement of Dr. Tidwell follows:]

Committee on Science, Space and Technology
United States House of Representatives
March 7, 2019

Testimony of Dr. Vincent Tidwell, Sandia National Laboratories[1]

Chairman Lamb, Ranking Member Weber, and distinguished members of the Committee, I thank you for the opportunity to testify today on this critical issue of the energy-water nexus. Last week while on vacation, I had the opportunity to travel from Albuquerque, New Mexico to Park City, Utah. On this trip I crossed the San Juan, Colorado and Green Rivers along with the Rio Grande. I also passed numerous power plants, hydropower dams, oil and gas plays and coal mines. The relation between these important resources was evident. Equally evident was the critical role these resources play in the economy, livelihood, culture and environment of the communities they serve. These resources are our heritage. Thank you for your concern and interest in securing these resources for generations to come.

It is no secret that energy production is the largest user of water in the United States, and in turn a significant fraction of energy in the U.S. is used to treat and move water. This energy-water nexus is a complex system that my colleagues and I in the research community have sought to understand. We in turn use this knowledge to develop advanced technologies and tools to support water and energy policymakers and planners. While our focus today is on the nexus of energy and water we must not lose sight that the connections go far beyond. Energy and water are tightly coupled to land, food and agriculture. In fact, most all of our nation's critical infrastructures are dependent in one way or another on these key resources.

There are three major points I'd like to make with my testimony this morning:

1. Challenges and opportunities related to the energy-water nexus are expressed differently in different regions.
2. Integrated planning improves coordination between water, energy and environmental managers jointly addressing issues of resource sustainability, waste management and supply chain security.
3. Harnessing the research and development capabilities of our National Laboratories, academia, private industry and federal agencies, we can develop advanced water treatment technologies that make new sources of water cost competitive, reducing our reliance on freshwater.

[1] Sandia National Laboratories is a multi-mission laboratory managed and operated by National Technology and Engineering Solutions of Sandia LLC, a wholly owned subsidiary of Honeywell International Inc. for the U.S. Department of Energy's National Nuclear Security Administration under contract DE-NA0003525. SAND2019-2446 O

## Place Matters

It is often said that all water issues are local. Much the same can be said of the energy-water nexus where challenges and opportunities are expressed differently in different regions. Consider that difficulty in permitting new thermoelectric power plants due to limited freshwater availability is largely an issue of the Western U.S. In contrast, disruption of thermoelectric power generation by drought is limited to the East. Here, the issue is not with sufficient water but cooling water discharge that exceeds permitted thermal loads. Although drought impacts hydropower production nationwide, effects are most acute in the Northwest where hydropower accounts for 60% of all electric generation capacity. Management of oil and gas produced water is an issue where there is a lack of deep well injection or where such injection threatens seismic activity. Penetration of wind in the Plains States and solar in the Southwest has significantly reduced the water burden associated with electric power generation in these regions. Natural hazards display a geographic preference with threat of wildfire in the West, hurricane along the Gulf and Atlantic Coast, while the threat of drought and flooding are relatively ubiquitous. Energy use for agricultural irrigation and transbasin conveyance is largely limited to the Western U.S. These regional expressions of the nexus reflect the geographic character of the underlying energy-water systems; specifically, regional differences in water availability, water use, natural occurrence of energy resources, technology deployment, water/energy policy, culture and other. This complexity calls for a deep understanding of the linkages and dynamics relating these critical resources and their associated infrastructure. Broad participation across the U.S. is required to fully appreciate the full geographic context.

## Integrated Planning

The expressions of the energy-water nexus, as previously noted, have started people talking. Talking in ways that historically has not happened. I am speaking of integrated planning where energy, water and environmental managers work together to manage these interacting resources. Sandia, aided by other National Laboratories and Dr. Webber, have helped bring the nation's three large electric interconnections (Western Electricity Coordinating Council, Eastern Interconnection Planning Cooperative, and the Electric Reliability Council of Texas) together with state water managers to integrate water into long-term transmission planning. Specifically, we have provided data, modeling and analysis to determine where the availability of fresh water or the cost of a non-fresh sources of water might limit the siting of new thermoelectric generation. We have also helped identify potential changes in water supply, electricity demand, and hydropower scheduling due to a changing and variable climate. Beyond integrated resource planning, management of produced waste streams must be considered. Significant quantities of water and energy are required in the management of generated wastes. Examples include emission scrubbers, carbon capture and sequestration systems, produced water disposal, and concentrate management from desalination systems. Regulation and technology largely drive waste management decisions; however, new technologies are emerging to extract value from these waste streams such as utilizing waste heat from a power plant to drive water desalination, extracting biogas from wastewater/landfills, and production of building materials from scrubber blowdown and/or coal ash. DOE and the National Labs are going even deeper to integrate supply chain security into resource planning. Water and energy are embedded throughout the supply chain in fuels extraction, fuel processing, fuel/water transportation and water treatment. Not only are these uses important considerations to the overall water budget, but these supply chain elements are often geographically separated, thus experiencing unique risks throughout the chain.

## Advanced Water Treatment Technology

There is significant opportunity for technology to radically change the way we view the energy-water nexus. While there are numerous potential roles for technology, I will focus my comments on water treatment. In 1961 President Kennedy said, "if we could ever competitively, at a cheap rate, get fresh water from salt water, that it would be in the long-range interests of humanity which would really dwarf any other scientific accomplishment." President Kennedy's better-known ambition from that same year, "that this nation should commit itself to achieving the goal, before this decade is out, of landing a man on the moon and returning him safely to the Earth" proved in the end the easier of the two. Nevertheless, there are over 18,000 desalination plants in operations around the world; however, I don't believe anyone would characterize desalinated water as cheap. Part of the reason for this lingering challenge is the sheer breadth of the problem. We are dealing with heterogeneous source waters with salinities that differ across several orders of magnitude (e.g., brackish to seawater). There are other contaminants beyond salt found in municipal/industrial wastewaters, produced water from oil and gas production, and agricultural return flows. Each requires a treatment system tuned to the unique characteristics of the source water as well as the particular demands of the use case. There is also the confounding issue of concentrate management, that is what do we do with the separated salts and other contaminants? Sandia has helped provide technical leadership by developing of two desalination roadmaps that prioritized needed research. Subsequently, the National Laboratories, academia, industry and other federal agencies have invested in R&D across the technology development spectrum. What has been missing is a coordinated effort across these individual and disparate projects. Toward this need, the DOE released a plan for an Energy-Water Desalination Hub (DE-FOA-0001905) with the goal to "to advance technologies that will enable pipe parity water for a range of non-traditional water sources using energy-efficient, water-efficient, cost-competitive, and manufacturable technologies." More importantly the Hub will provide a platform for coordinated federal, academic and industrial research. This effort will focus on early stage R&D in four distinct thrusts:

- New materials such as membranes and corrosion resistant materials;
- New processes including desalination, pre/post treatment, and concentrate management systems;
- Modeling and simulation supporting technology development and evaluating competitiveness of emerging technologies; and
- Integrated data and analysis to establish metrics and track progress.

Close integration with industry will be key in selecting and nurturing new technologies to a point where industry can carry the innovation to the point of commercialization. Alternative waters at competitive prices will help secure our nation's water and energy future.

## Conclusion

Thank you again for the opportunity to share my testimony about this important topic. The energy-water nexus is a complex and nuanced issue with implications for two resources that underpin our national security. We are making progress in areas of integrated planning and advanced technology development, but more work is needed. I want to stress that this work is more than simply avoiding unintended consequences of a complexly coupled system; rather, we have the opportunity to completely reimagine our energy and water future. We are striving for an energy system that is not dependent on freshwater in our water limited regions. Likewise, we envision a future where non-traditional water sources like brackish water, seawater, produced water and wastewater can be treated at cost competitive levels. Such changes will have impact well beyond the energy and water sectors, influencing our economy and national security.

Thank you for convening this hearing, and I look forward to your questions.

Dr. Vincent Tidwell is a Distinguished Member of the Technical Staff at Sandia National Laboratories. He has over 20 years of experience conducting and managing research on basic and applied projects in water resource management, collaborative modeling and the energy-water nexus. He played a lead role in realizing a new Crosscut Program on the Energy-Water Nexus within DOE. Recently he led a multi-institutional team to integrate water into long-term transmission planning in the US and identified potential pinch points where water stress could impact energy production internationally. He and colleagues are combining critical infrastructure protection models with climate integrated assessment models to evaluate the resilience of our nation's infrastructure. He is an adjunct professor at the University of New Mexico, New Mexico Tech, and the University of Arizona. He served on Governor Richardson's Blue Ribbon Task Force on water and is a Lead Author for the Water, Energy and Land Use chapter in the 2014 National Climate Assessment (NCA) and the Energy Chapter in the 2018 NCA.

Chairman LAMB. Thank you, Dr. Tidwell. Ms. Zerrenner?

**TESTIMONY OF KATE ZERRENNER,**
**SENIOR MANAGER, ENVIRONMENTAL DEFENSE FUND**

Ms. ZERRENNER. Thank you. Chairman Lamb, Ranking Member Weber, Members of the Committee, thank you for inviting me here today.

Again, my name is Kate Zerrenner. I'm a Senior Manager of Energy-Water Nexus Initiatives at Environmental Defense Fund, Texas office.

Our energy choices matter, so coal, natural gas, and nuclear all use vast amounts of water. Solar PV, wind use negligible amounts, energy efficiency uses none, and that matters because about 85 percent of our current energy resources come from nuclear and fossil fuel, and that requires about 133 billion gallons of water per day or about 41 percent of total U.S. freshwater withdrawals.

And the energy-water nexus is a cascading problem. And with extreme weather energy-water nexus can quickly turn into energy-water collisions. With climate change, this is intensifying the extremes in our weather. For example, in a drought, waters for cooling is more limited, reducing the power needed to move water, air conditioning spikes during hot and dry days increasing the demand for power, which increases demand for diminishing the water supply to cool that power system. And this matters because of resilience.

So when we're looking at States like mine like Texas, we suffered a multiyear drought from 2010 to 2015, which was only ended by catastrophic flooding that we endured for 3 years, culminating in Hurricane Harvey. So building resilient systems matters. It matters to make sure that, as we see these drought and flood cycles, which we're used to in Texas but they're getting more extreme. So like an athlete on steroids, climate change may not necessarily be causing these extreme weather events, but they are enhancing their performance.

So some of the ways we've addressed this in Texas is we're looking at some specific solutions. Two legislative sessions ago—you may remember this, Ranking Member—we passed a bill requiring the State to look at using solar and wind to desalinate brackish groundwater on State-owned lands. The study was finished and done by the Webber Energy Group and found nearly 200 cost-effective sites on State-owned lands, which is significant because about 98 percent of the State of Texas is privately owned, so 194 cost-effective sites for using solar and wind to desalinate brackish groundwater.

We've also—EDF has partnered with the Pecan Street Project, which is a nonprofit that looks at energy and water from the smart technology perspective, and we looked at the end-user results of what the energy intensity of our water systems and the water intensity of our energy systems in the home are. A lot of people aren't aware of the amount of water they're using when they turn their clothes dryer on, for example. And one of the things we found is that in homes with solar panels, for example, the water footprint of those homes decreased by nearly 80 percent with solar panels on their homes. So there is a significant impact on our water in terms of how we use our energy and vice versa.

The key to all of this is data. That Pecan Street Project was the first of its kind to do very granular data collection so that we actually know what we're looking for. We know what we're trying to address. EDF partnered with the Texas Army National Guard to model and map 60 of its 90-plus installations across the 10 climate zones of Texas. And what we did is we took the climate data in a water scarcity solar potential, wind potential, energy efficiency potential, geothermal potential, and electricity prices and overlaid all of these things together so we could give the Texas Army National Guard the data they needed to invest smartly into what made the most sense in terms of the water scarcity, the solar potential. For example, El Paso came out on top with water scarcity and solar potential, so they can then take that to the appropriators and say we need to invest in solar in our installations in El Paso, and then they can use money that would otherwise be spent on electricity bills to be spent on things like training and equipment. So there are real-world implications for the choices we make in terms of our water and our energy choices.

The Federal Government has a fantastic role to play here. Data collection, standards, streamlined reporting, all of those things can be done with—H.R. 34 helps to lay that groundwork.

In 2011 Chairwoman Johnson requested GAO (Government Accountability Office) to do a report on the energy-water nexus. I would say an updated report of that nature would be warranted. It has been 8 years. A comprehensive review of both Federal programs and funding streams throughout the Federal Government could help increase the coordination across the Federal agencies that work on energy-water nexus issues.

And with that I close, and I look forward to any questions. Thank you.

[The prepared statement of Ms. Zerrenner follows:]

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

**Hearing on Energy-Water Nexus**

**Submitted to the Energy Subcommittee of the Committee on Science, Space and Technology Committee of the United States House of Representatives**

**7 March 2019**

**What is the energy-water nexus?**

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

**Why does the nexus matter?**

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

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

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

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

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

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

**Climate concerns**

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

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

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

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

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

**Outdated models and silos**

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

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

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

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

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

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

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

**Market-driven versus public interest**

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

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

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

**Driving up costs**

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

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

**Quantity versus intensity**

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

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

[8] http://www.ucsusa.org/sites/default/files/attach/2014/08/ew3-freshwater-use-by-us-power-plants.pdf

[9] http://www.ce.utexas.edu/prof/maidment/giswr2012/TermPaper/Sanders.pdf

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

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

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

**Resilience**

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

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

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

**Starting to collaborate**

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

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

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

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

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

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

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

**Issues to Consider**

*Smart Grid & Smart Meters*

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

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

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

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

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

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

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

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

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

**Embedded energy in water projects**

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

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

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

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

[14] Nikki Stiles, *Upgrading Water Meters Can Pay Off,* 3 WATER EFFICIENCY, May/June 2008, p. 32
[15] http://www.energy.ca.gov/2005publications/CEC-100-2005-007/CEC-100-2005-007-CMF.PDF
[16] Sanders and Webber, Evaluating the energy consumed for water use in the US, Environ. Res. Lett. 7
[17] http://proceedings.asmedigitalcollection.asme.org/proceeding.aspx?articleid=1636857
[18] http://iopscience.iop.org/1748-9326/7/3/034034/pdf/1748-9326_7_3_034034.pdf
[19] DOE 2011 Average energy intensity of public water supplies by location (kWh per million gallons) *Buildings Energy Data Book*

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

**Wastewater treatment and energy**

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

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

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

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

**Energy-water coordination at the policy and operations levels**

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

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

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

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

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

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

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

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

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

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

[23] http://www.ercot.com/content/committees/other/lts/keydocs/2014/DOE_LONG_TERM_STUDY_-_Final_Report_-_Volume_2.pdf

[24] http://blogs.edf.org/texascleanairmatters/files/2016/08/TXARNG-renewable-assessment-FINAL.pdf

[25] http://www.gao.gov/new.items/d11225.pdf

**Kate Zerrenner**
**Senior Manager, Energy-Water Initiatives**
**Clean Energy Program**
**US Climate and Energy**
**Texas Regional Office**
**Environmental Defense Fund**

Kate Zerrenner helps develop and implement strategies to promote energy and water efficiency and climate change solutions in Texas and leads EDF's multi-year campaign to influence and enact state and national energy and water efficiency policy, including breaking down financial, regulatory and behavioral barriers. She directs regional efforts to improve options for clean energy choices that create jobs, reduce climate change impacts, water intensity and air pollution. Her expertise includes a sound understanding of technologies and policies affecting traditional energy generation, energy efficiency business models, and the energy-water nexus. She designs and implements non-regulatory, legislative and policy strategies to increase energy and water efficiency (business models, technological, and financing options) and clean energy options to reduce climate change pollution and water intensity and encourage clean and sustainable energy choices. She collaborates with key stakeholders and legislative sponsors on passage of clean energy and energy-water legislation, including drafting legislative language and providing oral and written testimony. Kate also serves on the Advisory Board of the Smart Cities Council, Water Online's Water Intelligence Panel, and as a technical advisor for the City of San Antonio SA Climate Ready process.

Prior to joining EDF, Kate worked at the U.S. Government Accountability Office analyzing U.S. action on climate change and the voluntary carbon offset market; SAIC, on climate change projects for the U.S. Department of Energy and the U.S. Environmental Protection Agency; and U.S. Department of Energy on the Energy Policy Act of 2005. She has also worked for the Texas Sunset Advisory Commission and the U.S. Commission on National Security/21st Century (Hart-Rudman Commission) at the U.S. Department of Defense. She holds a Master's degree in International Energy and Environmental Policy and Economics from the Johns Hopkins University's School of Advanced International Studies, a Master's in Comparative Politics from the University of Glasgow in Scotland, and a Bachelor's degree from the University of Texas.

Chairman LAMB. Thank you. Dr. Bonner?

## TESTIMONY OF DR. RICHARD BONNER, VICE PRESIDENT OF RESEARCH AND DEVELOPMENT, ADVANCED COOLING TECHNOLOGIES INC.

Dr. BONNER. I would first like to thank the Committee and its leadership for the opportunity to testify on the energy-water nexus.

I've worked at Advanced Cooling Technologies, a small business located in Lancaster, Pennsylvania, for over 13 years. The company started in 2003 and has grown to 130 employees. The company was predominantly funded through the government-sponsored research programs in its early days. Today, it still relies on government funding for many of its new technology-development initiatives. I currently serve as the Vice President of R&D at Advanced Cooling Technologies.

I've closely led several research programs related to the energy-water nexus while serving as a principal investigator. In the ARPA-E ARID (Advanced Research in Dry cooling) program, I led the development of a technology that could effectively cool power plants using air instead of water. Our technology is analogous to a DVR but for heat. We demonstrated that you can store cold energy at night and later cool the power plant during the day when the ambient temperature is warm and the electricity demand from the grid is the greatest.

Through the Department of Energy's Small Business Innovative Research program, we've developed non-wetting coatings and surface structures to improve condensation to more effectively remove heat from the steam circulating through power plant steam turbines.

In another effort funded through the Department of Energy's Fossil Energy Crosscutting Research program, we are developing longer-life non-wetting coatings that are capable of being replenished to maintain their cooling effectiveness for decades.

Researchers in our R&D group are looking to solve other key water issues as well. Through the Department of Energy's Small Business Innovative Research program, we're looking at new ways to desalinate water. Through another Department of Energy-funded program, we are developing new ways to collect sunlight to use the energy to directly drive the desalination of brine.

Finally, for the U.S. Department of Agriculture we're looking at ways to desalinate brackish water and use the water to directly feed the roots of plants by using a system of underground plumbing. This innovation may make it possible for the agricultural industry to tap into the vast amounts of brackish water available, which will free up freshwater supplies for other critical applications.

Recently, I was invited by the Arizona Public Service Company to tour the Palo Verde generating station. Palo Verde is the Nation's largest net power generating station. The nuclear power plant is located in the desert regions of Arizona, not near any bodies of water, which makes it unique. Their current water solution is quite interesting. The power plant water is completely supplied by treated sewage that is purchased from several local large municipalities. However, the demands on this water supply are causing the municipalities to increase the price of this precious water supply, which will ultimately lead to an increase in the cost of power for the region. I met with their senior engineering team to present some of the water reduction and cooling solutions that we have developed, and we hope to begin working with them in the next few months.

Without the substantial funding and experience gained through the numerous government-sponsored research programs that I mentioned, we would not be talking with the Arizona Public Service Company to solve their water and cooling problems. The government-sponsored funds are critical to small businesses such as ours so we can take our ideas and mature them to the levels demanded by the marketplace.

Finally, I would like to discuss some recommendations to the Committee about some legislative features that would help industry better solve the energy-water nexus problem. I want to first remind and impress upon the Committee with—the scale with which power plants operate. It is simply massive. Further, power plants are not built every day. As a matter of fact, they're not built often at all in the United States anymore. This makes the often-mentioned R&D valley of death that much more deadly for companies, universities, and national labs as they try to commercialize their research in this area.

So how do you go from the bench top in a lab to power plant-sized systems, and how can the government help? I suggest that any legislation in this area should aim to address these questions by allowing some portion of the funding through scale-up and subscale demonstrations perhaps as a follow-on for successful programs. I have seen this follow-on type of program work very well in the SBIR (Small Business Innovation Research) programs. I could see something similar for some of your other funded efforts.

I also want to discuss the cost-share requirements that have been common for many of the Department of Energy-funded programs as of late. Given the difficulties of scaling up and the large follow-on investment that is required by companies to reach utility scales, the R&D cost-share requirements seem to unnecessarily hinder industry's flexibility to use financial resources where they are needed most. I recommend that the cost share be eliminated or at the very least changed to allow the companies to get their cost-share credit through non-R&D-based investments. These alternative investments could include capital spending on related production equipment, intellectual property protection, or perhaps sales and marketing.

It has been my privilege to testify in front of you today. Thank you again for the opportunity. I look forward to answering any of your questions.

[The prepared statement of Dr. Bonner follows:]

Testimony on "The Energy Water Nexus: Drier Watts and Cheaper Drops"

Dr. Richard W. Bonner III
March 7, 2019

I would first like to thank the committee and its leadership for the opportunity to testify on the Energy-Water Nexus.

I have worked at Advanced Cooling Technologies, a small business located in Lancaster, Pennsylvania, for over 13 years. The company started in 2003 and has grown to 130 employees. The company was predominantly funded through government sponsored research programs in the early days, and today it still relies on government funding for many of its new technology development initiatives. I currently serve as the Vice President of R&D at Advanced Cooling Technologies.

I have closely led several large research programs related to the Energy-Water Nexus while serving as the principal investigator. In the ARPA-E ARID program, I led the development of a technology that could effectively cool power plants using air instead of water. Our technology is analogous to a DVR for heat: we demonstrated that you can store cold at night, and later cool the power plant during the day when the ambient temperature is warm and the electricity demand from the grid is the greatest. Through the Department of Energy's Small Business Innovative Research program, we have developed non-wetting coatings and surface structures to improve condensation to more effectively remove heat from the steam circulating through power plant steam turbines. In another effort funded through the Department of Energy Fossil Energy Crosscutting Research Program, we are developing longer life non-wetting coatings that are capable of being replenished to maintain their cooling effectiveness for decades.

Researchers in our R&D group are looking to solve other key water issues. Through the Department of Energy's Small Business Innovative Research program, we are looking at new ways to desalinate water. Through another Department of Energy funded program, we are developing new ways to collect sunlight to use the energy to directly drive the desalination of brine. Finally, for the U.S. Department of Agriculture, we are looking at ways to desalinate brackish water and use the water to directly feed the roots of plants by using a system of underground plumbing. This innovation may make it possible for the agricultural industry to tap into the vast amounts of brackish water available, which will free up fresh water supplies for other critical applications.

Recently, I was invited by the Arizona Public Service Company to tour the Palo Verde Generating Station. Palo Verde is the nation's largest net power generating station. The nuclear power plant is located in the desert regions of Arizona, not near any large bodies of water. Their current water solution is interesting. The power plant water is completely supplied by treated sewage that is purchased from several large municipalities. However, the demands on this water supply are causing the municipalities to increase the price of this precious water supply, which will ultimately lead to an increase in the cost of power. I met with their senior engineering team to present some of the water reduction cooling solutions that we have developed, and we hope to begin working with them in the next few months. Without the substantial funding and experience gained through the numerous government sponsored research programs that I mentioned, we would not be talking with the Arizona Public Service Company to solve their water and cooling problems. The government sponsored funds are critical to small businesses, such as ours, so that we can take our ideas and mature them to the levels demanded by the marketplace.

Finally, I would like to discuss some recommendations to the committee about some legislative features that would help industry better solve the Energy-Water Nexus problem. I want to first remind and impress upon the committee with the scale with which power plants operate: it is simply massive. Further, power plants are not built every day, as a matter of fact, they are not built often at all. This makes the often mentioned "valley of death" that much more deadly for companies, universities and national labs as they try to commercialize their research. How do you go from the bench top in a lab to power plant sized systems? Any legislation in this area should aim to address this question, by allotting some portion of the funding for scale-up and sub-scale demonstrations, perhaps as a follow on for successful programs. I also want to discuss the cost share requirements that has been common for many of the Department of Energy funded programs as of late. Given the difficulties of scaling up, and the large follow on investment that is required by companies to reach utility scale, the R&D cost share requirements seem to unnecessarily hinder industry's flexibility to use financial resources where they are needed most. I recommend that cost share be eliminated or at the very least, changed, to allow the companies to get their cost share credit through non-R&D based investments, such as capital spending on related production equipment.

It has been my privilege to testify in front of you today. Thank you again for the opportunity. I look forward to answering any of your questions.

**RICHARD W. BONNER III**
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Dr. Bonner has led many cross-disciplinary advanced research programs at the forefront of the thermal fluid sciences. Topics of interest include dropwise condensation using wettability gradients, micro-scale phase change materials, atomic layer deposition on micro-channel coolers, nanofluid coolants, novel heat pipe architectures, and thermoelectric heat exchangers amongst others. Dr. Bonner has secured over $12M of government funded research projects as a PI. He has also authored 45 papers and one issued patent. Dr. Bonner has contributed to ACT's start-up success by initiating and managing several R&D and product development groups at ACT. As the Manager of ACT's Custom Products Group, which served commercial and industrial product markets, Dr. Bonner served over 125 different customers. These customers span a wide range of industries, and include companies such as Alstom, Apple, Caterpillar, Ford, Intel, Keurig, Rheem, Roche, etc. He currently serves as ACT's Vice President of R&D, overseeing the company's $6M per year externally funded research portfolio. He also chairs ACT's Product Planning Committee, which plans the organizations IR&D and new product development activities. Dr. Bonner also served as a Director for the AIChE's Transport and Energy Processes (TEP) Division.

Chairman LAMB. Thank you. Dr. Singh?

**TESTIMONY OF DR. RAMAN P. SINGH, ASSOCIATE DEAN FOR ENGINEERING AT OSU-TULSA AND PROFESSOR AND HEAD OF SCHOOL OF MATERIALS SCIENCE AND ENGINEERING, OKLAHOMA STATE UNIVERSITY**

Dr. SINGH. Good morning. It's my honor and privilege to be here. I'm the Head of the School of Materials Science and Engineering at Oklahoma State University, and I also direct the Helmerich Research Center. I do have to apologize. I'm not a native Oklahoman, but in my own defense, I got to Oklahoma as soon as I could, and I've managed to raise two daughters in Tulsa. And they will both end up going to college in Oklahoma right now.

I'm leading and building a consortium of multiple universities led by Oklahoma State involving Caltech, the University of Utah, Northeastern State University, and the University of Tulsa, along with several industry partners and Sandia to look at the safety and sustainability of fossil fuel production and consumption. And it is with regards to that that I'm going to talk about the produced water and the water issue today, which is only one aspect of what we are looking for in our consortium.

My perspective is that the prosperity of any nation, prosperity of our Nation ultimately depends on our ability to safely and sustainably produce and consume energy. And the bulk of our energy today, even though you don't realize it, comes from fossil fuels. There will be a future where we will displace these fossil fuels with renewables, but there has to be a bridge. And the way we see technology today, this bridge primarily comes from natural gas produced through hydraulic fracturing. It's a significant resource that we have. It's the cleanest-burning fossil fuel with the least impact on greenhouse gas production.

But this is where water comes in because you require water to essentially break rock in terms of hydraulic fracturing. You require large amounts of water, and more often than not, this water is fresh water. And then the process itself produces water, which is known as produced water, which is stuff that comes out of the ground along with the production of shale oil and shale gas. And it is highly contaminated. It carries a lot of salt, and by itself, dealing with produced water has led to other engineering challenges by itself.

There are three areas of technology that I want to focus on. The first one is the hydraulic fracturing process itself. I think there are significant opportunities in trying to minimize the amount of fresh water that's used in this process and at the same time increasing the efficiency in which we are able to recover materials.

Right now, the recovery rates are typically 10 to 20 percent, so we—and this is where all the projections are made, so we are recovering only about 1/10 of what is possible in terms of shale oil and shale gas. There is some research that has gone on. The way I look at it is water is not the only way to break rock. It's a good way and it's a simple way, but there are other ways which involve combination of rocks, and this is a research area that I have been focused on.

The other aspect is what do you do with the produced water that comes out? Now, electrical or solar desalination of produced water is expensive. It's very highly energy-dense. But the idea that we're looking at is that we want to try and get it clean enough to drink. We don't have to get it clean enough to drink. We have to get it clean enough so that we can use it for something else and look upon it as a resource rather than a waste that needs to be disposed.

There are a lot of membrane filtration technologies based on ceramic nonporous membranes that are being pursued. This is some work that we're doing at Oklahoma State. And the idea is that you get it to the point where the number of total dissolved solids—that's how you track how contaminated the water is—is down to a point where you could perhaps use it for industrial processes, you could use it for agriculture or rangelands without trying to get it clean enough to drink.

And the other resource that is fairly interesting from the perspective of produced water is being able to extract chemicals from it. I'll give you an example. Lithium, the demand for lithium has been growing tremendously. It will continue to grow as we move more toward an electrical-based economy simply because of battery storage requirements. We import all of our lithium today. If we were to be able to extract 50 percent of the lithium that comes out in produced water, we would become a net exporter of lithium without introducing any other mining operations as far as lithium is concerned. And that's just one example of what can be pulled out.

Unfortunately, the problem is very complex. I mean, I'm an engineer. I like to think like an engineer. I like to believe that all problems of the last 100 years have been caused by engineers and all solutions came by engineers, too, right, so—but a problem this requires, you know, a nexus between engineers, legislators, regulators, industry, academia, and so forth, and that's where I think this Committee can play a tremendous role in terms of setting the tone in the direction we need to go forward. So it's been an honor and a privilege for me to be here, and I would be welcome in taking any questions. Thank you.

[The prepared statement of Dr. Singh follows:]

# A Transformative Approach Towards Produced Water: Ensuring a Safe and Sustainable Energy Future

**Hearing on "The Energy Water Nexus: Drier Watts and Cheaper Drops"**
**Subcommittee on Energy**
**House Committee on Science, Space, and Technology**
**March 7th, 2019**

**Raman P. Singh, Ph.D.**
**Oklahoma State University**

## Vision

Oil and natural gas production offers significant benefit through job creation, energy for economic and social development, tax revenue, and energy security. Despite environmental challenges in production and utilization, fossil fuels continue to serve as a critical source of energy for the nation and the world. For example, in 2017, 65.8% of the energy consumed in the United States came from such sources. Furthermore, new discoveries continue to revise upwards the estimates of proven reserves. For example, as recently as December 2018, the USGS reported that the Permian Basin's Wolfcamp shale and Bone Spring formation hold the "largest potential oil and gas resources ever discovered." This trend is not going away in the foreseeable future. However, the mitigation of associated hazards, such as induced earthquakes, freshwater consumption, potential contamination of aquifers due to reinjection, and management of greenhouse gases (GHG) such as $CO_2$ and $CH_4$, all continue to be a major obstacles.

A transformative approach to the use of water in unconventional oil & gas production is critical to the continuation of the social and economic benefits of fossil fuels while ensuring safety and sustainability, as we transition to more renewable forms of energy. This testimony reflects the vision of a collaborative multi-university effort, led by Oklahoma State University, towards developing technologies that envision a transformative cradle-to-grave carbon- and water-neutral energy platform based on a sustainable fossil fuels future as the bridge to renewable energy. Three technological areas are presented below:

### Enhanced Unconventional Recovery of Subsurface Fluids

Despite the significant growth in subsurface fluid recovery for energy production from unconventional resources, recovery factors are still estimated to be <10%. Increased recovery factors will directly reduce the environmental impact of hydrologic fracturing. Hydraulic fracturing, while well adapted and developed for recovery from unconventional oil and gas resources, is not the only way to break rock. Alternative schemes involving dynamic loading have been used in mining and other rock blasting applications, and have been demonstrated in the lab for shale. For hydraulic fracturing, the fracture patterns results from fluid-pressure driven cracking. These patterns depend on the rock fabric and in situ stresses, and cannot be directly controlled by the operator. Also, the pressure fields decay rapid out from the source location. To generate more rock stimulation using current hydraulic fracturing techniques requires high-pressures, use of a large amount of fracturing fluid, and fracturing at multiple sources. An alternative is to augment hydraulic fracturing by dynamic loading conditions. This approach can result in both increased recovered factors and reduce the amount of water needed for hydraulic fracturing.

## Produced Water Desalination and Treatment

The reuse of produced water (PW), a by-product of the oil and gas extraction processes, can serve as an alternative water supply for irrigation and other uses. Typically 2–8 $m^3$ of PW is extracted per day throughout the lifetime of a well and annually, 2.4–3.2$\times 10^9$ $m^3$ of PW is generated in the United States. Treatment and any beneficial utilization of PW is challenging, as it includes oil, suspended solids, carcinogenic hydrocarbons, trace metals, in addition to a very high total dissolved solids (TDS) concentration ($\sim$5500–300,000 ppm).

Research thrusts are needed to develop a modular desalination systems to enable energy efficient purification of PW to different water quality levels with zero liquid discharge. The levels range from <3000 ppm TDS (similar to surface waters) by filtration to <300 ppm TDS (drinking water quality) by evaporation–condensation. A modular system is equally suited for centralized desalination with its advantage in economies of scale, and for decentralized systems, which could be scaled to meet local PW needs.

- Pre-treatment by electrocoagulation of PW for removal of metals, colloidal solids and particles, and soluble inorganic pollutants. Enhanced electronic conductivity of high TDS PW is an advantage in this case. We high surface area electrodes which are not limited by the formation of impermeable oxide film, e.g. electrodes made from submicron size powders of different materials. Establishing adequate electronic conductivity between the base-electrode surface and the particles is a key challenge.
- Develop ultra/nanofiltration membranes using alternative materials for desalination. These include low-cost ceramic membranes and laminar graphene oxide (GO) membranes supported over polymer/ceramic substrates.
- Desalination by evaporation followed by condensation involves phase change, and is energy intensive. This can be eased by the use of multi-effect humidification–dehumidification (HDH) approach using vortex tube for heating of dry air and cooling of humid air, and innovative technologies for enhancing evaporation kinetics and energy efficiency. Rapid drying fabrics made with hydrophobic–hydrophilic fibers can be developed to increase gas-liquid surface area to enhance evaporation kinetics.

## Using Produced Water as an Alternative to Mining

The above treatment train for PW enables extraction of beneficial industrial chemicals and rare elements from the concentrate streams. The major constituents of PW include chlorides, sodium, calcium, and sulfates that are key feedstocks for the chlor-alkali industry and gypsum production. Trace elements include Li (30–130 mg/L), Sr (300–3000 mg/L) and Mg (80–1700 mg/L). Conventionally, Li is extracted from brines, slowly concentrated by wind and solar driven evaporation over 1–2 years. Competing ions such as Mg must be precipitated by the addition of CaO prior to precipitating the Li as $Li_2CO_3$ with a Li recovery of 50–70%. Use of various technique for PW desalination and treatment and aid in concentratrating the PW brines prior to Li precipitation. Using a rough estimate, at 50% recovery, we can extract 4500 Mt Li from PW, which exceeds the 3400 Mt imported by the US in 2017.

## Challenges

The practical implications of these efforts necessitate an emphasis on engineering system development supported by fundamental science and discovery driven research to address gaps in fundamental knowledge and technology platforms. There are extremely high levels of trans-disciplinary complexity involved in developing and implementing these engineering systems. This necessitates a diverse interdisciplinary team of engineers and scientists working together to observe, understand, and model a multitude of physical phenomena that occur over a wide spectrum of time and length scales. In addition, multi-societal factors require a confluence of engineers, chemists, hydrologists, geologists, geophysicists, geomechanicians, social scientists, economists, legislators, and regulators. Furthermore, meaningful interactions are needed across a variety of stakeholders including universities, local governments, and industry.

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Dr. Raman P. Singh serves as the Associate Dean for Engineering at OSU-Tulsa and as the Head of the School of Materials Science and Engineering in the College of Engineering, Architecture and Technology at Oklahoma State University (OSU). He also serves as the Director of the Helmerich Advanced Technology Research Center on the OSU-Tulsa campus and is appointed as the Helmerich Family Endowed Chair Professor of Engineering. Raman holds M.S. and Ph.D. degrees in Mechanical Engineering and Applied Mechanics from the University of Rhode Island, and a B.Tech. degree in Mechanical Engineering from the Indian Institute of Technology–Kanpur, India. Prior to joining OSU in 2006 he was a faculty member at the State University of New York at Stony Brook, and before that a post-doctoral scholar at the California Institute of Technology.

Raman's research interests are in the failure mechanics of advanced and complex material systems, with an emphasis on the development of new techniques for material failure characterization. His academic interests are in recruiting, mentorship, and retention of non-traditional and underrepresented student groups. His research has been funded by the National Science Foundation, NASA, the Oklahoma Center for the Advancement of Science & Technology, the Oklahoma Transportation Commission, the US Army Research Office, the Department of Energy, and industry. He has authored or co-authored several archival journal publications and conference proceedings, and holds two patents. He is an active member of the Society of Experimental Mechanics (SEM) and serves as an Associate Technical Editor for *Experimental Mechanics*. He is also a member of the American Society of Mechanical Engineers (ASME) and The Minerals, Metals & Materials Society (TMS). Besides academia, Raman enjoys travel, restoring cars, backpacking, photography, and spending time with his two daughters.

Chairman LAMB. Thank you, Dr. Singh. I'm glad you said that because the next time I go home and someone tells me that the politicians in Washington are screwing everything up in this country, I'm going to say, no, I have it on very good authority it's the engineers.

So, Dr. Webber, go ahead.

**TESTIMONY OF DR. MICHAEL WEBBER, CHIEF SCIENCE AND TECHNOLOGY OFFICER AT ENGIE, AND PROFESSOR AT UT AUSTIN**

Dr. WEBBER. Thank you very much. Chairman Lamb and Ranking Member Weber, I appreciate the opportunity to submit testimony today. As you've heard, the energy-water nexus presents unique challenges and invites crosscutting solutions. Because the energy system depends so extensively on water and the water system depends so extensively on energy, they are both vulnerable to cascading failures from one sector to another. For example, a water constraint can become an energy constraint, and an energy constraint can become a water constraint. If water is not available at the right place and time with the right quantity and quality, then the power sector might struggle to generate and deliver electricity. And if energy is not available because of blackouts, then the water sector struggles to treat and deliver water. That means the energy-water nexus is a resilience challenge for planners. Thankfully, it also invites crosscutting solutions, especially for conservation and efficiency, namely in saving water saves energy and saving energy saves water, which avoids environmental impact and improves resilience.

For my remarks I will focus on two aspects: The energy use for the water system and specific challenges related to managing wastewater from oil and gas production, building on Dr. Singh's comments.

The combined water and wastewater system is a hallmark of a modern society, and because the economic and public health benefits are so extensive, they are the most important public investments a society can make. These water and wastewater systems also require vast sums of energy for pumps, blowers, chemicals, and mechanical equipment. We use more energy in our buildings to heat water, and industry uses even more energy to treat that water further, for example, to make ultra-pure water for semiconductor fabrication or to make steam for use in refineries. All told, about 13 percent of national energy consumption is for direct water and steam services. About 1/3 of that or about 4 percent of national energy consumption is just to heat water in our homes and businesses. That is about twice the amount of energy that Sweden uses to run their entire country. So we use a lot of energy just in heating the water.

As a result, water heating represents an opportunity for saving energy and avoiding emissions. In most parts of the United States, shifting from electric heating toward natural gas heating or solar water heating reduces energy use and $CO_2$ emissions. And if we clean the grid up similar to what we have in the Pacific Northwest that's mostly hydro, then electric water heating would be an excellent option as well.

Incentives and information guides to encourage adoption of more efficient appliances that use heated water like dishwashers and clothes washers will continue to provide nontrivial savings. According to one study, the average U.S. household could save hundreds of dollars on their electricity and water bills by making those appliance upgrades with the types of upgrades that pay for themselves, meaning they save money in addition to reducing consumption. In addition, wisely managing the end uses of water and energy would improve the resilience and efficiency of military installations, which makes this a national security issue also.

The water sector's energy needs can also be used to integrate higher fractions of renewables into the power sector. Water treatment, wastewater treatment, and modern desalination plants that use reverse osmosis are particularly electricity-dependent. They can be ramped up and down and operate flexibly, which makes them a good companion for variable resources like wind and solar. Furthermore, it is much easier and cheaper to store water than to store electricity. For example, you can use simple water tanks to store water instead of expensive batteries. And that means integrating renewables with the water sector can help make the electricity sector more resilient while providing valuable grid services and speeding the adoption of clean forms of power.

Another issue, as you heard, is the amount of wastewater produced alongside oil and gas extraction. Unfortunately, water and wastewater are often moved by trucks, which are less efficient, dirtier, and more destructive to communities and more destructive to roads than pipelines. Building a pipeline-based wastewater collection system would improve the safety and impose much less environmental risk compared with truck-based movement. Such a system would also reduce the cost for oil and gas production, helping propagate the ongoing boom in places like west Texas. A water pipeline network would also enable specialized capabilities with economies of scale for treating this very dirty water, which would open up the case for water recycling and reuse while avoiding disposal by underground injection.

The Federal Government can help. Uncertainty about gaining right-of-ways on Federal lands make it harder for developers to build these wastewater collection networks, which inhibits the construction of treatment and recycling systems, leaving underground disposal as a primary wastewater management option and putting pressure on aquifers. Facilitating pipeline construction would help accelerate the adoption of better management pathways.

In addition, policy stability and certainty is important for developers making decisions to invest in long-lived assets. Policy shifts from year to year and government shutdowns increase those costs and delay the projects that have environmental benefit.

A couple closing comments is that in addition to facilitating the development of water collection networks, the Federal Government has other actions it can take. Encouraging the Department of Energy to have water in mind for its programs is a good place to start. And encouraging water planners to keep energy in mind is also important. In addition, data collection and sharing programs can make a big difference. Data on urban water use is particularly scarce in comparison with our energy data, which makes it harder to manage usage or improve resilience. The EIA (Energy Information Administration) dataset set the gold standard for energy data, and we need something similar for water, perhaps by creating the agency with that task or by expanding the EIA's mandate to include tracking of water demand and supply.

And last, one of the most important policy levers for the Federal Government is to sponsor R&D. Incremental improvements will not solve these challenges quickly enough, so there's a need to scale up the effort. The U.S. innovation system is the best in the world, so it makes sense to leverage those strengths to our advantage.

Thank you for the opportunity to share my thoughts. I'd be happy to answer any questions.

[The prepared statement of Dr. Webber follows:]

Testimony for the *Energy Subcommittee* of the
*House Science, Space and Technology Committee (116th Congress)*

hearing on

**The Energy Water Nexus: Drier Watts and Cheaper Drops**
Thursday, March 7, 2019 - 10:00am
2318 Rayburn House Office Building

By

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*Josey Centennial Professor in Energy Resources, The University of Texas at Austin*
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Dear Chairman Lamb and Ranking Member Weber, I appreciate the opportunity to submit testimony for this hearing on energy, water, and their interconnections.

My name is Michael Webber, and I presently serve in two roles. I'm the Josey Centennial Professor in Energy Resources at the University of Texas at Austin and also the Chief Science and Technology Officer at ENGIE, which is a global energy and infrastructure services firm. At the University of Texas I have supervised more than two dozen PhD students over the last decade who have studied energy and water in collaboration with national labs, environmental groups, municipal water companies, and some of the world's most prominent energy companies. At ENGIE, I oversee their research activities, which includes 900 staff and an annual budget of more than $200 million. By way of introduction, ENGIE is a diversified energy and infrastructure services firm with 160,000 employees active in 70 countries. With 115 Gigawatts of installed capacity, it is the largest independent power company in the world. It also has built 5% of the world's seawater desalination facilities. ENGIE has a large presence in the United States, with 4500 employees and more than $3 billion in revenues for low-carbon power generation, energy storage, and other services.

It is from this mix of academic and corporate experience that I offer my remarks today.

The energy-water nexus presents unique challenges and invites cross-cutting solutions.[1] Because the energy system depends so extensively on water and the water system depends so extensively on energy, they are both vulnerable to cascading failures from one sector to the other.[2] For example, a water constraint can become an energy constraint, and an energy constraint can become a water constraint. If water is not available at the right place and time with the right abundance or temperature, then the power sector might struggle to generate and deliver electricity. If energy is not available, then the water sector struggles to treat and deliver water. Thus, the interdependence of energy and water is ultimately a resilience question for planners.

Thankfully, the interdependence also offers up the opportunity for cross-cutting solutions, especially for conservation and efficiency. Because of their interconnections, saving water saves energy and saving energy saves water. Reducing the energy intensity of the water system and the water intensity of the energy system avoids environmental impact and improves infrastructure resilience.

The energy-water nexus is extensive, so I will focus on two aspects: 1) the energy use for the water system, which invites the opportunity for integrating renewable energy, and 2) specific challenges related to managing wastewater from oil and gas production.

*Energy for Water, Wastewater and Steam*

The combined water and wastewater system is a hallmark of a modern society. Because of their economic and public health benefits, investing in networks to treat and distribute drinking water and collect and sanitize wastewater are among the most important and beneficial public investments a society can make. These systems also require vast sums of energy for pumps, blowers, chemicals and mechanical equipment. Beyond that, we use much more energy in our buildings to heat water for bathing, cleaning, cooking and sterilization. Industry will also often invest more energy to treat water even further, for example to make ultrapure water for semiconductor fabrication or to make steam for use at refineries.

All told, according to Professor Kelly Sanders at the University of Southern California, about 13% of national energy usage is consumed for direct water and steam services.[3] About one-third of that energy, or about 4% of national energy consumption, is just for water heating in our homes and businesses. That is about twice the amount of energy that Sweden consumes for running their entire country.[4] Because we use so much energy for water heating, it represents an important opportunity for saving energy and avoiding emissions. Considering today's mix of fuels in the power sector, shifting from electric towards natural gas or solar water heating offers significant energy and $CO_2$ emission reductions in most US regions.[5] However, in regions where the electricity mix is very clean, for example the Pacific Northwest, which is predominantly powered by hydroelectric dams, electric water heating is an excellent option. Cleaning up the grid in general by replacing coal power plants with wind, solar, nuclear or renewable natural gas would make electric water heating even cleaner. Incentives and information guides to encourage adoption of more efficient appliances that use heated water, such as dishwashers and clothes washers, would also continue to provide non-trivial savings. According to Professor Ashlynn Stillwell at the University of Illinois, the average U.S. household could save 7600 kWh of electricity and nearly 40,000 gallons of water by making appliance upgrades that have negative abatement cost, meaning they save money in addition to reducing consumption.[6]

As Professor Corey James from the U.S. Military Academy at West Point found, managing the end-uses of water wisely also improves the resiliency and efficiency of military installations, which provides security benefits.[7] So, this issue is bigger than just how we use energy and water in our homes.

Another opportunity is to use the water sector's energy intensity to integrate higher fractions of renewables into the power sector. Water treatment, wastewater treatment, and modern desalination plants are particularly electricity dependent. They are also systems that can be operated flexibly, meaning they can be ramped up and down to match when electricity is available. That makes them a convenient companion for variable resources such as wind and solar power.[8] Furthermore, it is much easier and cheaper to store water than to store electricity. For example, simple tanks instead of expensive batteries can be used. Thus, by integrating renewables with water treatment and production, the water sector can help make the electricity sector more resilient while providing valuable grid services and speeding the adoption of cleaner forms of power.

***Managing Wastewater From Oil and Gas Production***

Another relevant issue for the energy-water nexus is the amount of water produced alongside oil and gas extraction. The ongoing boom in oil and gas production has yielded important economic and security benefits for America's energy supply while bringing forth cheap natural gas that displaced coal in the power sector, simultaneously reducing emissions and costs. However, the water and wastewater challenges that accompany this boom present some important environmental risks that are worthy of greater investment of money and attention.

Handling significant volumes of wastewater with high levels of total dissolved solids requires energy for collection, pumping, treatment and disposal. In some locations there is energy available, such as the energy contained in flared gas, for on-site treatment.[9] However, generally speaking, wastewater needs to be collected for centralized treatment as a way to achieve specialized capabilities with economies of scale.

Unfortunately, water and wastewater are often moved by trucks, which are less efficient, dirtier, more disruptive to communities, and more destructive to roads than pipelines. Building a pipeline-based wastewater collection system would improve the safety and pose much less environmental risk compared with truck-based collection. Thus, by enabling the construction of a vast water collection pipeline network, the environmental risks and energy requirements for wastewater treatment would go down. Such a system would also reduce the costs for energy production, helping to propagate the energy, environmental and security benefits of the energy boom in places like west Texas.

The federal government has important roles to play. The nascent water re-use and water recycling industry only works for oil and gas if you can build a pipeline network (to avoid trucks, reduce costs, improve economies of scale, etc.). But, uncertainty about gaining right-of-ways on federal lands make it harder for developers to build wastewater collection networks. This uncertainty and other barriers to water pipeline systems inhibit the ability to build treatment and recycling systems, leaving underground disposal as the primary wastewater management option and putting pressure on aquifers as sources of water for hydraulic fracturing. Facilitating water pipeline construction would help accelerate the adoption of better water management pathways. As noted earlier, those treatment systems are compatible with renewable sources of power. Thus, ironically, the oil and gas sector's water clean-up needs can help expedite the adoption of renewable energy.

Because there is significant oil and gas production on federal lands, it is also important for the federal government to operate efficiently and predictably. Events such as the government shutdown introduces uncertainty and delays major capital investments that are required for water collection and treatment systems. In addition, policy whiplash from presidential administration to administration raises costs for developers. Just as keeping the government open and functional would reduce costs for oil and gas producers while helping to bring forward environmental solutions, policy stability and certainty is important for planning projects with long-lived assets.

***Recommendations and Closing Thoughts***

In addition to facilitating the development of water collection networks and treatment systems for the energy sector, the federal government has other actions it can take to improve the resilience, efficiency and cost of energy and water. Encouraging the Department of Energy to have water in mind for its programs is a good place to start. Encouraging water planners to keep energy in mind is also important. In addition, data collection and sharing programs can make a big difference.

Data on urban water resources are scarce,[10] especially in comparison with our data collection on energy usage. As a consequence, consumers and planners are hamstrung in their efforts to manage their usage or improve system resilience. After the first energy crisis in the early 1970s, the U.S. government created the Energy Information Administration to collect data on our energy production, movement and usage. Before that, data had been limited and policymakers recognized that it was hard to improve the situation without more rigorous facts at their disposal. The EIA datasets are the gold standard worldwide and help illuminate opportunities to improve the efficiency and resilience of the nation's energy supplies. We need something comparable for water, perhaps by creating an agency tasked with collecting water data or by expanding the EIA's mandate to track water demand and supply.

Lastly, one of the most important policy levers for the federal government is to sponsor R&D. Incremental improvements will not solve these challenges quickly enough, so there is need to scale-up the effort dedicated to creating stable and resilient energy and water supplies for the nation's industries and communities at lower cost and impact. Notably, the U.S. Department of Energy is pursuing a national research effort intended to lower the cost and energy requirements of desalination and treatment of non-traditional water sources. I recommend that the House Science Committee endorse this investment and other bold initiatives that prioritize innovation, conservation, and efficiency as a pathway to improving the energy-water relationship.

Thank you for the opportunity to share my thoughts. I would be happy to answer questions.

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Chairman LAMB. Thank you. We will now begin our round of questions, and the Chair recognizes himself for 5 minutes.

Dr. Tidwell, I wanted to ask you, many people have identified how water issues vary across the country, especially as climate change gets worse and worse and becomes more apparent. I can give you a local example. You know, I know you've talked about out west there's often droughts and water shortage. In western Pennsylvania where I live, the problem is often too much water. We're having very intense and more frequent rainstorms. We are a very hilly area. And interestingly, someone told me there's roughly 5,000 water systems in the United States, the continental United States for treatment and drinking water. About 1,000 of them exist in the 10 counties of southwestern Pennsylvania. It's an interesting historical legacy. It makes it very hard to coordinate our efforts when it comes to water treatment.

So I was curious if you could just give us a very brief insight on how we can help to encourage the regional cooperation as necessary in these different areas?

Dr. TIDWELL. Thank you, Chairman, for that question. Certainly, I think one of the low-hanging fruits that we have for this energy-water nexus is this very problem of integrated planning and bringing different groups together. Certainly, the opportunities that we face with these small systems, there are rural water industrial groups that help these systems and to provide them with the tools that they can then use and work with their local constituents I think would be one important place.

Another important place as we go forward is going to be in the development of workforce skills as many of these smaller areas don't—are not able to employ folks with the necessary skills. And so going forward, we're going to need to develop a trained workforce as some of these more complex technologies come in place to treat water, to manage our water systems and our wastewater systems. So I think——

Chairman LAMB. That's a fantastic point. Thank you very much.

Dr. Webber, I wanted to ask you about the pipelines for hydraulic fracturing and wastewater, big issue in western Pennsylvania where we're doing a lot of hydraulic fracturing. I'm not familiar with pipelines being constructed near where we live for the actual wastewater. Most of it is being trucked out, and it does cause a lot of impact on the local communities. Are there areas where they have successfully built a pipeline network for this?

Dr. WEBBER. This is a good point. Water and wastewater is primarily moved by trucks, and the trucks are a source of discontent with a lot of the communities because they change the rural lifestyle. They add a lot of noise, a lot of dust. They lead to traffic accidents and deaths and road impact. Pipelines generally are much more expensive to build but much safer and cheaper to operate once you have them built, and there are some nascent water and wastewater collection systems out in New Mexico and west Texas primarily, maybe a little bit in the Bakken shale in North Dakota as well.

So there are some examples where you have concentrated production of oil and gas and you have a policymaking process where it's easier to build and the land is also flatter and easier to build on, say, than the Appalachian Mountains and other places. It's easier to build, and then that reduces the cost for sourcing the water, collecting the water, treating the wastewater, that kind of thing. So there are some examples.

When I talk to oil and gas operators, I think they'd like to see more water and wastewater systems built because it would reduce cost and do less damage.

Chairman LAMB. Do we have any policy levers at our disposal on the Federal level to try to encourage that, and in an area like mine that is topographically a little bit different than the southwest?

Dr. WEBBER. I think the—a lot of these decisions are made at the local level or the State level, so often it's State-level policymakers, but there are some Federal levers at play whenever you're on Federal lands, for example. As you get further west, you get to BLM (Bureau of Land Management) lands, for example, and then the Federal levers become much more important. Most of it's at State-level decisionmaking, but there's a role for the Federal Government to play in convening the State-level policymakers in sharing data and information that they can't collect themselves. So I think there is a role for the Federal Government, but it requires cooperation at the local and State level as well.

Chairman LAMB. Thank you very much. And last question very quickly, Dr. Singh, you mention alternatives to water for hydraulic fracturing. Just in sort of 10 seconds or less, are we close on any other fluids besides water or I guess non-fluid solutions?

Mr. WEBER. Turn your mic on, please.

Dr. SINGH. I think water will continue to be the major driving fluid, but the amount of water that's used can be cut down a lot. And plus some of the produced water can be recycled and used back at the source itself or—for that. Does that answer your question?

Chairman LAMB. It does. Thank you very much.

I now recognize Mr. Weber for 5 minutes.

Mr. WEBER. Thank you, Mr. Chairman.

I'm going to give you something to read here about purple pipe. Very quickly, Dr. Tidwell, have you ever heard of purple pipe?

Dr. TIDWELL. Yes, sir, I have.

Mr. WEBER. Ms. Zerrenner, is that right?

Ms. ZERRENNER. Right.

Mr. WEBER. Right that it's right or right that you've heard about pipe?

Ms. ZERRENNER. Both.

Mr. WEBER. OK, good. Dr. Bonner?

Dr. BONNER. I haven't heard about it.

Mr. WEBER. Dr. Singh?

Dr. SINGH. No, I haven't.

Mr. WEBER. Dr. Webber?

Dr. WEBBER. Yes, and I've written extensively about it and done research on purple pipe.

Mr. WEBER. Really? OK. You know that it's a system that takes from the home or business—it's not necessarily wastewater from the toilet, for example, but it may be from the sink or dishes or whatever, and it treats it to the extent that it doesn't have to be drinkable but it could be used for irrigation and other things like that. And I thought perhaps that might be part of you all's focus today. But we'll go there later.

Now, I am from Texas, as Dr. Webber knows, and I often say that any State worth its salt has a desalination plant. And some of you all will get that on the way home. And we have one in Texas. Back in my days in the Texas State Legislature, I had the opportunity to tour a large-scale desalination plant in Brownsville. Have any of you been to that plant? She has but you all haven't. Ladies are always leading the way. Have you all noticed that, gentlemen? It's OK to say yes. OK. I want to get you all softened up here.

I've seen firsthand the amount of electricity required to convert brackish water to potable water. Dr. Singh and Dr. Tidwell, as you know, DOE recently announced $100 million in funding for an energy-water desalination hub that we talked about focused on early stage research and development to explore those uses for nontraditional water sources and to develop new desalination technologies. So a couple of questions for you, and I'll start with you, Dr. Tidwell. Will the research funded by this hub focus on reducing the energy necessary to be used in those current desalination plants? Your thoughts?

Dr. TIDWELL. Yes, sir, that's a good question. And, yes, I think there are opportunities to help with existing plants. One would be—one example would be with improved membrane technology that would help reduce fowling, so that would be one example where we——

Mr. WEBER. So the product—the output—the product would be cleaner, easier. But do you know what the number one energy driver is in a desal plant—or need is in a desal plant?

Dr. TIDWELL. It's the pressurization of the——

Mr. WEBER. It's the pumps.

Dr. TIDWELL. Pump——

Mr. WEBER. The pumps there in Brownsville—and I'm going back now 10 years. It must have been this big around——

Dr. TIDWELL. Yes, sir.

Mr. WEBER [continuing]. And the electricity required to drive those is really tremendous.

Dr. TIDWELL. Which is forcing the water through those membranes

Mr. WEBER. Correct.

Dr. TIDWELL [continuing]. So anything that can help improve that permeability——

Mr. WEBER. Right.

Dr. TIDWELL [continuing]. Is—would help reduce——

Mr. WEBER. Efficiency, get more water out a little cheaper.

Dr. TIDWELL. Yes, sir.

Mr. WEBER. Because they're bringing water. And I think it was a 12-inch pipe. Now I'm going from memory, you know, from the Gulf of Mexico into Brownsville, and the distance you have to bring requires of lot of electricity and a lot of pumps. Do you agree with that, Dr. Singh, that that focus will be on increasing the efficiency?

Dr. SINGH. Yes, I agree because conventional desalination requires—it's very energy-intensive.

Mr. WEBER. Yes.

Dr. SINGH. And the only reason you would do that is if you had no other source of potable water. There are technologies based on electrocoagulation, which can clean up what's going in before the membranes kick in. There are technologies using ceramic membranes, which can increase the efficiency, but that efficiency will need to go up.

Mr. WEBER. Right. And of course that's going to depend, let's face it, on the cost of electricity, right? And so I think we could all agree that the lower the price of natural gas is, the cheaper that energy companies can produce energy. That, in and of itself, will have a reduction in the cost of desalination. Would you all agree with that? Absolutely, you bet you. So fracking is a good thing. I'm glad we all agree on that.

In your opinion, Dr. Tidwell, what impact could this hub have on your research? What would your role be?

Dr. TIDWELL. Most of my work is around modeling and analysis, and so importantly, understanding how climate change affects the resilience of our energy-water systems and integrating uncertainty in those changing climates, changing demands for water, changing technology, and how we can plan for a robust, resilient system going forward into the future.

Mr. WEBER. How about you, Dr. Singh? Your research—how would you correlate this—correspond—how would this impact you?

Dr. SINGH. Two areas of research, one would be increasing efficiency of basically breaking up rock to increase extraction efficiencies not only for fracking but also for geothermal systems. And the second aspect would be—which we haven't talked about today, would be releasing the mitigation due to induced seismicity or reinjection, so these are the two areas that would be affected the most.

Mr. WEBER. OK. Thank you. Mr. Chairman, I yield back.

Chairman LAMB. Thank you. I now recognize Ms. Horn for 5 minutes.

Ms. HORN. Good morning. Thank you all for your testimony. And Dr. Singh, as a fellow Okie, it's good to see you here today.

So I have a couple of lines of questioning, and I want to start with you because I think you brought up a couple of important points. As I'm sure it comes as no surprise to anyone, both water and energy are big issues in my home State, as well as that of the Ranking Member of the Full Committee. So I wanted to follow up on some of the points that you made about the need for interdisciplinary work because part of the challenge with fracking is—and the challenges that we've seen in Oklahoma with earthquakes and things like that comes from the wastewater reinjection more so than just the breaking up of the rock itself. So I wanted to see if in your research you had looked at the impact that that might have of taking the water in addition to taking it out and reusing it, the impact in other areas for energy production.

Dr. SINGH. I don't understand the other-areas part, but I can talk a little bit about the reinjection. Reinjection right now is not very well understood. I mean, the way—we have a traffic light system in which if they feel that there is something that's going to happen, reinjection stops. And this reinjection problem is not necessarily a problem that's limited to fracking. Induced seismicity also happens in geothermal fields—in some geothermal fields in Europe in technology—energy production technology that is quote/unquote "much greener" than fracking.

So there is—there were initially some concerns in terms of how clean does the produced water need to be for it to be reused for fracking, but that concern is not because of reinjection. That concern is mainly from being able to control the chemistry to allow the fracking process to be more efficient.

Ms. HORN. And if the technology continues to develop to take the wastewater from the fracking process to be more usable, potable even if it's not drinkable, what impact does that have on the amount of reinjection that would have to occur?

Dr. SINGH. So to give you some numbers, a fracking operation and the well in its lifetime will take about, you know, 2 to 8 million gallons of water. We produce about 60 times produced water every day than that's used in the city of Washington, D.C. So some of that will go back as—for reinjection, but that's not the only solution. The other solution also has to be to look upon produced water as a resource to use it for other purposes. And in Oklahoma that, for example, could be agriculture or rangelands and not necessarily cleaning it up all the way for human consumption.

Ms. HORN. Thank you. The second area—and I'm going to open this up because I think it may be best for Dr. Tidwell but if anyone else has thoughts on this, in Oklahoma, in addition to the municipal, State, and other Federal issues, we have 39 tribes, federally recognized tribes in the State of Oklahoma, so this energy-water nexus also impacts issues surrounding tribal sovereignty and water usage and water rights. So I'm wondering if you could talk more about policy recommendations or areas that you see emerging with this Federal, State, local, tribal lands issue.

Dr. TIDWELL. Thank you, Congresswoman. I—this is a very important issue. I think at the end of the day, what it really boils down to is improved communication across all of these different entities. One of the important aspects of particularly the Indian water rights is that in many cases in the west they hold rights or their rights haven't been fully adjudicated, so they play a very important role in how future water might play out in many cases in the western United States. And so they are an important player that we need to bring to the table, as well as the States. The States ultimately have jurisdiction over their water.

I might mention that DOE also has numerous programs for helping to support energy development on Native American land. So all of these particular activities need to be coordinated and, you know, integrated planning is a very important part of all that.

Ms. HORN. Thank you. Mr. Chairman, I yield back.

Chairman LAMB. Thank you. And I recognize Ranking Member Lucas for 5 minutes.

Mr. LUCAS. Thank you, Mr. Chairman.

As I mentioned in my opening statement, there's an abundance of natural gas resources in my district and in many parts of the great State of Oklahoma, as we discussed. But also as a farmer, I understand and appreciate the importance of the reliability of water, and I'm particularly interested in the research partnerships and results in these areas.

So I turn to you, Dr. Singh. In your testimony, you expressed the same sentiment by saying, "Meaningful interactions are needed across a variety of stakeholders, including universities, local governments, and industry." Can you give us some examples of that collaboration that you and/or Oklahoma State and industry stakeholders have been a part of that's generated beneficial results?

Dr. SINGH. I'll give you one small example, and this came about from our discussion with ONEOK. ONEOK transports a lot of natural gas that's produced. In the winter to transport this natural gas across pipelines, they have to add methanol to—as an antifreeze basically. Now, at the same plant they're flaring methane and burning it into—you know, burning it away. So one technology that came about—and this is research now that's being done and this actually involves partnership with a very eminent chemist at Caltech is to take the onsite methane, convert it into methanol, use that methanol instead of pumping methanol to the stations and then discarding it at the other end.

The only reason this came about was because I was in discussion with the ONEOK researcher and talking about issues, and this is a very specific example, I understand, but I think in terms of my perspective at the Helmerich Research Center, a lot of this discussion has been driven by industrial advisory boards in identifying the problems that academia can solve.

Mr. LUCAS. So let's touch on that for just a moment, the industrial advisory boards. Your experiences with the interaction and—are there ways that perhaps we could help encourage that collaboration?

Dr. SINGH. Yes. I think for us especially as academia when we seek out, let's say, Federal or State-level funding, when that funding specifically mandates convergence type of research or the—you know, talking to various stakeholders in terms of the probability of getting funded, then that pushes, you know, multiple people to the table, and that has been helpful in our case.

Mr. LUCAS. I can't help but, Dr. Singh, touch for a moment on the topic of fracking and injection wells, which is a very sensitive subject in our great State of Oklahoma. In my home area typically the oil and gas products come out in the particular area I'm at, and it varies of course in the 10-, 12-, 13,000-foot range. And historically, fracking has gone on in my home area at least since the early 1970s, not as aggressive as the hydraulic fracking, the improved technology, but fracking's gone on. We've never had earthquakes or that sort of stuff. The injection well process that's come along in recent years where again typically in my area the material comes out at 12-, 13,000 feet, but it goes back into an injection well at 5,000 feet or so. We seem to have a different kind of a lubricating zone there so to speak under the earth.

Wouldn't you agree that the Oklahoma Corporation Commission, the entity with primary jurisdiction in our State, has been very aggressive in how they've responded to these issues about the seismic issues that have come from it, how they put limitations on certain areas and this, that, and the other?

Dr. SINGH. Yes, and I think a lot of that comes from a lack of scientific understanding as to exactly what goes on. I think it's a problem that can be managed. A similar analog would be to say all fossil fuels are bad and stop consuming them tomorrow, which means we would come to a standstill as a country, so——

Mr. LUCAS. Exactly. Therefore, it's fair to say that the Oklahoma Corporation Commission is trying to respond in a way until technology can catch up, until we can do the things we need to do to be able to address this process. Thank you, Doctor, for being here today.

And with that, Mr. Chairman, I yield back.

Chairman LAMB. Thank you, Mr. Lucas. Who's next?

I recognize Mr. Casten for 5 minutes.

Mr. CASTEN. Thank you, Mr. Lamb. Thank you to the panel. The—Dr. Webber, you had mentioned in your written testimony about creating sort of an Energy Information Administration for water. I'm an energy geek. I love EIA. I think it's a great idea. I should mention by way of background in my prior life, I ran a number of clean energy companies where we went into industrials, tightened up their energy envelope and, among other things, ended up running all of the energy and water assets at Kodak Park in Rochester, a 50-million-gallon-a-day water intake permit and it was kind of a cool job for the 12-year-old boy inside me.

I mention that because energy metering is pretty robust because at every point in the energy system people pay for things. There are revenue meters. Buyers and sellers want accuracy. Water metering is terrible. The internal metering is shoddy. They're not calibrated very often. It doesn't—often doesn't exist. And it's basically a problem that the water's too cheap that it's not worth the time to meter. If we were to create a Water Information Administration, I'd like your sense, number one, of realistically how many meters do we need to put in? Because to my mind, it's a metering problem first. And, number two, as you look at water data, where are you skeptical given the meter gaps? Because in my experience you got to put plus or minus 20, 30 percent error bars on a lot of the water data you see.

Dr. WEBBER. That's a great question, great context. I think the water metering world lags behind the energy metering world, and the water data world lags behind the energy data world. Energy typically is more expensive. It's also more central to other economic and national security aspects. But, frankly, if we go back 50 years, the energy data was pretty bad, too. It wasn't until the 1970s and the energy crises that we created the EIA to start tracking it more closely because there was a sense of urgency and importance to it. And then once we started tracking data with more fidelity in place in times, we tracked it daily, weekly, with prices, total consumption by fuel and by location, by industry and sector, then we could spot opportunities for efficiency and savings. When we get to that level of data I think for water we can spot other opportunities, but when water's too cheap or we don't feel a sense of urgency, it's hard to do that.

I think in the specifics of the question of metering, we have about 100 million households. We probably need a smart water meter for every household, so maybe 100 million smart water meters. Plus we need them throughout the distribution networks because 10 to 40 percent of treated municipal water is lost from when it leaves the plant to arrives at the home, which means we also need meters throughout these distribution networks to track those losses so we can get repairs done quickly and avoid all that lost water and all the energy embedded in it.

So there's a lot of opportunity for data, data platforms, smarter meters, better meters. Right now, the meters are not very smart or they're read by hand or they have these errors or they're not metered at all in some cities in the United States, so this is a big opportunity, and the EIA lays the blueprint for how to do it if you had a WIA (Water Information Administration), for example.

Mr. CASTEN. Related—and anyone on the panel who's got a thought on this—you've layered on top of that that we have fairly good—subject to everything we just said, fairly good data for surface water, and some reasonable concern about falling snow melt I think on a per-decade basis, where since 1967, we're losing about 11 percent of our snowpack every year—up every decade rather. The data on groundwater is a lot worse and, you know, there's been places in northern California I'm aware of where the water coming out of aquifers is now exceeding the salinity levels that they can land apply, which, I mean, this is Beyond Thunderdome kind of territory. How confident are you that we have good data on the water—the sort of the prehistoric water if you will? And what should we be doing as a government to make sure we have a good handle on that?

Dr. WEBBER. Yes, the fossil water some people call it. So we have much better view of the surface water. We can see, we can measure it. The below-groundwater we don't see as well. We don't have great metering systems in most places, so we wait until the well goes dry or the well goes salty, and we know there's a problem. And NASA is a big partner for this because they can measure water content of aquifers from space more readily than we can from the ground ironically, so there's partnerships with the national labs and NASA and the agencies.

I think ramping up on just a water tracking system would be useful because then everyone can make decisions and planners can make better informed decisions about where to put their capital based on where the water problems are.

Mr. CASTEN. OK. And last question with the little bit of time we've got left for Ms. Zerrenner if I'm saying your name right there. You had mentioned how much water the—you know, the nuclear and fossil fuel industry uses, and I used to tell people all the time if you want to understand the problems with our energy system, draw a power plant. And everybody draws a cooling tower. However, that's really specific to the open-loop systems. Do you have any estimate of how much of our fossil nuclear sector is closed-loop and what we might be able to do to encourage more closed-loop water systems on the fossil side?

Ms. ZERRENNER. Yes, I—Michael may know the exact numbers. I don't know the exact numbers, but we're seeing more and more movement in that direction. So it's a—we see an average of the amount used by coal and nuclear and natural gas because of the differences and the different types of cooling. You have also—besides closed-loop and open-loop you also have dry cooling and wet cooling. And the dry cooling uses—so they use a lot more water—they use a lot less water, but they also are less efficient, so you have some tradeoffs there. So you're creating some issues around that. But really we want to see more energy efficiency, which uses no water. If we make our systems more efficient, they are also more resilient.

We saw other issues like during Hurricane Harvey where the wind turbines continued to turn in the Gulf of Mexico but the grid was down, so they didn't have anything to connect to. So thinking in terms of microgrid systems and making those more efficient as well, there's—there are lots of moving pieces to this. I—but I don't have the exact number——

Mr. CASTEN. OK.

Ms. ZERRENNER [continuing]. Of the system.

Mr. CASTEN. Well, and I'm out of time, but just make a plug for cogeneration while we're out here because so much of that—that's what we did in Rochester, and the fact that George Eastman built a power plant in 1880 that's twice as efficient as the U.S. power grid today is a lesson I think we can all learn from.

Thank you. I yield back.

Chairman LAMB. I recognize Mr. Biggs for 5 minutes.

Mr. BIGGS. Thanks, Mr. Chairman. I thank all the members of the panel for being here today.

Dr. Bonner, I was interested in your paragraph in your written statement and then your testimony with regard to Palo Verde nuclear generating station in Tonopah, and you were just there recently?

Dr. BONNER. Yes, it was in the last month, yes.

Mr. BIGGS. Yes, so you were there during the good weather time, so——

Dr. BONNER. It was nice.

Mr. BIGGS [continuing]. Good for you. I hope you get out there in the summer and experience what real heat's about.

So you mentioned in your statement that there's competing demand for the water, and we're talking effluent I assume?

Dr. BONNER. Yes.

Mr. BIGGS. OK. And so I think I know what they are but maybe you want to elaborate on what some of those competing demands because Tonopah's—most people don't know this—where the Palo Verde generating station is is in a remote part of Maricopa County. Maricopa County has got—Arizona has got 7 million people in it, and Maricopa County has 5 million people in Maricopa County. It's an odd State. We only have 15 counties. And where you went is really remote. There's no water supply, as you mentioned. But what are the competing demands for effluent in basically an urban area that has 5 million people in it?

Dr. BONNER. Right. I think part of the water is to go back to the town for its own purposes, but I think the copper industry also uses a lot of water as well in that area. And other industries, it's a very—it's a growing area. There's a lot of like retirement homes and stuff being put up there, too, people moving there, and that demand is just causing more needs on the water. And I think the—a lot of the contracts that were negotiated for that water when the plant was built were 30 years ago. And I think the municipalities are under the impression that they gave it away too cheaply, especially now with how the local area is growing, and they're trying to get more out of it.

Mr. BIGGS. Yes. You didn't mention golf courses, but there's a lot of golf courses in the valley, so——

Dr. BONNER. Yes, it's part of the retirement part——

Mr. BIGGS. Yes. So as we take a look at that and the demands, you indicated that you are working on ways to mitigate the—either the cooling cost or what exactly—I'm not sure what you were working on, but I assume that you're trying to find a way to lower costs either by reduction in the use of the effluent or some other cooling mechanism, so——

Dr. BONNER. Right.

Mr. BIGGS [continuing]. Can you elaborate on that for us?

Dr. BONNER. Sure. So Palo Verde, which is, what, cooling towers, right, so all the water or at least 95 percent of it goes to evaporation and the rest of it goes to evaporation ponds. So our concept would—in order to get rid of water be some sort of dry cooling technologies. And we were at an air condenser—air-cooled condenser users group a few months ago. That's where we sort of made the first connection. They saw some of our concepts that we developed on the ARPA-E ARID program where we can use salts to essentially store heat at night, and then during peak demand when it's hot at three o'clock in the afternoon, you can dissipate the heat to that basically nighttime temperature but dissipate it during the day. And by doing that, you can use no water but you can also get temperatures that are similar to what you get in a wet cooling tower, so you don't have the efficiency issues that Ms. Zerrenner was talking about. If you try especially in somewhere like Arizona to dissipate directly to air, usually you're talking about at least a 15-percent decrease in power efficiency. And I suspect in Arizona even to reach that you're talking about a very, very large air-cooled condenser system using traditional technologies that would be not even close to cost-competitive to what they currently do.

Mr. BIGGS. So I guess that leads me to—the logical next question is, what would it cost to retrofit to something that's air-cooled? I'm not asking for a bid. I'm just—you know, a ballpark.

Dr. BONNER. Right. I think it's—when I was there talking with them and we were in the room with some other air-cooled condenser companies, I think you're talking about at least 10 times more expensive than a wet cooling tower in terms of capital cost, so it's substantial.

Mr. BIGGS. But does it offset over time with the usage costs with the rising cost of effluent?

Dr. BONNER. It probably would, yes. It would offset over time. But I think the——

Mr. BIGGS. That's the salesman in you saying that, right?

Dr. BONNER. Yes, a little bit. Yes. Well, the paybacks are longer than what you would—than what the stakeholders want to see.

Mr. BIGGS. Right. OK. Thank you very much. I'll yield back.

Chairman LAMB. Thank you. I recognize Mr. McNerney for 5 minutes.

Mr. MCNERNEY. Well, I thank the Chair. I thank the witnesses. It's very interesting. I've got a lot of questions, and they're not really mean questions either, so I look forward to your answers.

Dr. Bonner, as water becomes scarcer in the west and southwest, I really liked hearing about the alternative cooling techniques for the Palo Verde Nuclear Generation statement. How would that work? I mean, how would the technology you're talking about reduce water consumption at a nuclear plant?

Dr. BONNER. Right. So, again, our—overall for dry cooling you're dissipating heat to air, so it doesn't use any water at all, right? It—you're not going to be taking any fresh water and evaporating it, so it's similar to how most things—most air conditioners would be cooled or most electronics would be cooled. The heat eventually sinks to air.

Mr. MCNERNEY. So it's—you're—basically what the prior question was is——

Dr. BONNER. It's a very similar——

Mr. MCNERNEY. OK.

Dr. BONNER [continuing]. Answer to that, yes.

Mr. MCNERNEY. Thank you. Dr. Webber, your testimony recommended a scale-up effort of the R&D in the field of water-energy nexus. I've proposed a piece of legislation last Congress that put a lot of effort into that issue. Could you elaborate on what you envision for a scaled-up effort?

Dr. WEBBER. Yes, thank you for your support of R&D, and I think there's an opportunity for more. If you look at the scale of the problem for the energy sector, which is a multitrillion-dollar sector around the world, the few billions of dollars a year we spend on Federal R&D seems very small by comparison. And if you look at water, it's even more stark because we spend less than $1 billion a year on water research. And that includes a lot of the environmental water quality issues. So I think there's an opportunity for many more investments to be made in better water treatment systems, the membranes that Dr. Tidwell mentioned earlier, better pumps that were called out earlier for the desalination systems, the variable speed drive pumps. There could be all sorts of work under the chemistry. There's a variety of things that we can do to look at the water side and reducing the energy intensity of water but also, as Dr. Bonner mentioned, looking at the water intensity of energy in kind of a new materials or heat exchanger designs or cooling systems for the power sector, as well as looking at new techniques to reduce the water intensity of oil and gas production.

There's a lot of opportunity for R&D. It's something that industry has stepped away from over the last few decades. The industry looks really more at applied R&D rather than basic R&D or fundamental science, so there's room for the Federal Government to fill that gap, and industry has been calling for it, along with academics and national labs. So I think just the level of funding and the sense of urgency around it has room for stepping up.

Mr. MCNERNEY. Great. I was kind of intrigued by your statement that water is cheaper to store than energy. So do you see a practical way of using that to store—to store energy or to use energy-water more efficiently?

Dr. WEBBER. Yes, so there are a couple of examples. I'll take the water heating example. There's a lot of electricity that goes into water heating. A lot of our water heaters are on around-the-clock whether we need them or not, and so we could turn off water heaters if we need to save power. And turning off the water heaters is the same as discharging power from a battery. It has the same effect on the grid. In France they have a peak demand that's 1/10 of what the United States has. They have a peak demand of 100 gigawatts of electrical power. In the United States we have 1,000 gigawatts. In France they can turn off 3 gigawatts worth of electric water heaters to save 3 gigawatts or 3 nuclear power plants' worth of power for the grid. That's about the same as having a lot of batteries doing the same thing, but it's a lot cheaper to turn off a water heater than, say, turn on a battery.

We could do the same thing in the United States where we use water systems in a flexible way, turn them on and off, ramp them up and down to achieve the same benefits for the grid that a battery might do, but it's a lot cheaper to turn something on and off than build, buy, install, and operate a battery.

Mr. MCNERNEY. Well, I was thinking more in terms of desal or, you know, you can use electricity to desal and store that——

Dr. WEBBER. Yes.

Mr. MCNERNEY [continuing]. And use it rather than—so that's a really good match for renewables, which are intermittent.

Dr. WEBBER. Absolutely. So you can ramp desalination up and down, you can ramp water treatment or wastewater treatment up and down and ramp them up and down to match when the renewables are available. In that case, the water system can help speed up the adoption of those renewables.

Mr. MCNERNEY. Mr. Chairman, I don't know how much time I have, so I'm going to continue to talk until you stop me, but I don't think I'm running out of time yet.

Chairman LAMB. Go for it.

Mr. MCNERNEY. All right, thanks.

Dr. Singh, you mentioned the hydraulic fracturing is essentially the cleanest, but the problem in my mind is that just a small amount of natural gas fugitive emissions cause natural gas to be dirty compared to other forms of fossil fuel. Can you address that?

Dr. SINGH. Yes, that's correct. So natural gas, of all fossil fuels, is probably the cleanest when you burn it.

Mr. MCNERNEY. When you burn it.

Dr. SINGH. Any form of carbon that's burned or any form of carbon essentially leads to carbon dioxide and so does natural gas. I mean, so do we when we breathe in and out. The problem is methane, so methane is about 20 times as potent as a greenhouse gas as carbon dioxide is, and that's why a lot of methane flaring takes place because instead of venting it into the air. So there are a lot of technologies in which—in terms of which—and can be captured rather than wasted into the environment, so that's—that can be minimized by capture rather than simply venting or, you know, leakage.

Mr. MCNERNEY. Right. But I've heard that if only 2 percent of natural gas that's captured is leaked through——

Dr. SINGH. Right.

Mr. MCNERNEY [continuing]. Pipeage or fracking leakage or whatever, that it's—it's undone all the good that's created by the efficiency of burning gas. Is that an accurate number?

Dr. SINGH. I would have to look at the numbers, but it probably is an accurate sentiment in the sense that you don't want to leak a lot of natural gas. Natural gas is not difficult to contain. I mean, it—and you don't want to leak any fossil fuel into the environment, but you're right in the sense that 2 percent of natural gas would be 40 percent of carbon dioxide being leaked into the air.

Mr. MCNERNEY. So how would you—I mean, how difficult is it to stop any leakage in the entire system?

Dr. SINGH. I think technologies do exist, right, so we don't see big natural gas leakages in houses where we heat and cook and eat——

Mr. MCNERNEY. Yes.

Dr. SINGH [continuing]. So the technology exists, and I think the industry has been fairly diligent in terms of preventing natural gas leakage, not necessarily by the most, you know, useful means. The one way that's done right now is just simply by flaring it and converting it into carbon dioxide and dumping that.

Mr. MCNERNEY. Right.

Dr. SINGH. So I don't see any technological challenges in terms of preventing that. There are technological challenges in terms of capturing it at the source and not burning it and using it for something else, but then there are chemists who are working on converting it at the source into other value-adding chemicals such as methanol or—and people are even thinking of going all the way down to ethylene and then it becomes a precursor for the petrochemical industry.

Chairman LAMB. Thank you. I'll now recognize Ms. Fletcher for 5 minutes.

Mr. MCNERNEY. Well, I haven't yielded yet, but I'll yield back, Mr. Chairman.

Mrs. FLETCHER. Thank you, Mr. Chairman. Thank you. And I'll actually follow up on that question because I am interested in some of the technology surrounding the conversion of methane. Can you finish maybe answering that question, or follow up about what you see as the most promising technologies for capturing methane, and how you think that that can address the concerns about methane emissions?

Dr. SINGH. OK. So I'm a mechanical engineer. I'm going to talk on the behalf of a chemist. This is actually technology coming out of a very brilliant chemist called Harry Gray at Caltech. He is I think well up into his 70s or early 80s, I don't know, and he's been working on catalytic conversion. So the idea between catalytic conversion is it's much less energy-intensive than anything else. And he's been able to synthesize these new catalysts, which he creates in a plasma furnace. He tried to explain it to me, and I understood about 10 percent of it. But the idea is not only to convert methane, the idea is to convert methane, the idea is to convert carbon dioxide and get to the point where you're simply pulling these things out of the air and converting them into value-added hydrocarbons up the chain using electrocatalysis.

Mrs. FLETCHER. And what phase of sort of research and development is this, this concept that he's developing right now?

Dr. SINGH. I think he is maybe a few years from a desktop-type prototype, so the idea behind these technologies is that they are very modular, and you could implement them at a lab scale, at a bench scale, on a skid path that gets rolled out to a pad and be deployed. So they're not—the science has been proven. The technology is being developed. And they're fairly simple beyond—once you have the catalyst figured out, the rest of the technology is fairly simple.

Mrs. FLETCHER. OK. Thank you. And I have a general question, kind of flowing from this for the panel. I know we have such limited time, but one of the things I was wondering about is how some of this technology and research is being developed, and how industry has innovated or is working with some of the researchers to address some of these challenges.

Dr. BONNER. Yes, so as I'm representing industry, we work with universities quite often on a lot of the grants and funding that we've gotten.

Chairman LAMB. Could you turn your mic on, Dr. Bonner?

Dr. BONNER. I think I have, so sorry. Yes. So representing industry, you know, we do work with universities quite often on a lot of the projects. With ARPA-E, for example, we were working with Lehigh University and University of Missouri to address various fundamental aspects of the technology. And I would say probably more than half of the technologies and programs we work on do involve university support.

Mrs. FLETCHER. And, Dr. Webber, did you have a comment here, too?

Dr. WEBBER. Yes, I was going to say that oftentimes our best advances from a society occur when there is collaboration across the different sectors, so we have industrial, academic, and government collaboration around projects, and that often happens, as Dr. Bonner mentioned.

I think another aspect is to try to take these good ideas, develop, and commercialize them, and there's different ways to do that. Creating more effective tech transfer offices at the national labs, which has been underway for decades, and also improving those systems for universities to get technologies out of the lab and into the field is useful.

The larger companies in the energy sector and water sector are really good at commercialization and scale-up. They tend to be less good at the innovation, so they tend to collaborate with universities or acquire companies who are innovative to get there. So there's room for that, and the more we collaborate, the better it goes is the short story on that.

Mrs. FLETCHER. Great, thank you. And, Ms. Zerrenner, this perhaps ties into some of your testimony that I was able to look at before I was here. In your written testimony you talked about coordination between the energy and water sectors, and said that we really need to update policies there. And so can you share your thoughts on how we can better kind of break down these silos between the energy and water sectors, encourage better planning between them, and work on some of these commercialization projects as well?

Ms. ZERRENNER. Sure. So a good example we have where the coordination really works is in San Antonio where the municipally owned water and electric utilities plan alongside each other. They attend each other's planning meetings. They know that each is each other's biggest customer, and then they recognize that and follow through with that. So, for example, we have at a wastewater treatment facility in San Antonio biogas capture and that uses that to power the wastewater, so that's on a very local level.

But in the Federal system, understanding—and I mentioned this in the oral testimony. Understanding where the funding streams are across the Federal Government would be very helpful.

Mrs. FLETCHER. Yes.

Ms. ZERRENNER. At this point I don't—I haven't seen anything, and I—when I was in the stakeholder process with DOE on the energy-water nexus roundtables I talked about this as well, is that I haven't seen any across-the-government assessment or review of the different funding streams where they go into each, so it's—you're looking at it as a comprehensive view. So the whole idea of the energy-water nexus is it's a system, so if we're not looking at it as a system, we're not addressing the systemic challenges, so the funding streams is really important because that also ties in then to the work programs. So also you want to know where all the programs are within the Federal Government, but you also want to know where the funding streams are.

And I understand that Committee process. You're going to have your Appropriations Subcommittee for water is going to be separate than Energy, but wherever those coordination—cross-coordinations can happen, I think that's really key. And some places where we don't tend to think of plugging in like USDA (United States Department of Agriculture), they have a big part to play in the energy-water nexus space. They needed to be plugged into this, not just DOE, not just EPA, so we have USDA, USGS (United States Geological Survey). That's another really important player in this space. There are a lot of places where this happens, and sometimes they could be really small. We're talking also about health impacts when we're talking about energy and water, so there may be some HHS (Department of Health and Human Services) issues that need to come up, and looking at a comprehensive across-the-government view, you may also find places where there are gaps that you need to fill. So I think that's a really critical piece.

Mrs. FLETCHER. Thank you. And I yield back my time.

Chairman LAMB. Before bringing this hearing to a close, I do want to thank each of our witnesses for coming all this way and appearing before us today. We really appreciate it.

The record will remain open for 2 weeks for any additional statements from the Members and any additional questions the Committee may ask of the witnesses.

The witnesses are now excused, and the hearing is adjourned. Thank you.

[Whereupon, at 11:29 a.m., the Subcommittee was adjourned.]

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