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Partnering with

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The National Energy Technology Laboratory

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# THE WATER-ENERGY NEXUS



U.S. DEPARTMENT OF  
**ENERGY**



NATIONAL  
ENERGY  
TECHNOLOGY  
LABORATORY



# PERSPECTIVE

Water is a key element in almost every phase of energy exploration, development, and power generation — from the extraction and processing of coal, oil, and natural gas to the operation of thermoelectric power stations. Ensuring the efficient and environmentally sound use of water is a critical component of the research implemented and managed by the U.S. Department of Energy's (DOE) National Energy Technology Laboratory (NETL).

With its focus on enabling the discovery, development, and deployment of early-stage technology solutions that enhance the nation's energy foundation and protect the environment for future generations, NETL has taken the lead in managing an integrated research program directed at advancing our understanding of the critical link between water and fossil energy. Leveraging core capabilities, NETL partners with other national laboratories, academia, and the private sector to develop and commercialize technologies needed to continue the sustainable use of domestic fossil energy resources while protecting the environment for future generations.

## NETL WATER PARTNERSHIPS

In addition to performing its own research, NETL manages a portfolio of projects involving hundreds of external partners that represent strong, fruitful collaborations.



### Electric Utilities & Water Workshop Emerging Issues and R&D Needs



In July 2002, NETL sponsored the first workshop focused on emerging issues and national R&D needs associated with the link between water and thermoelectric power generation. Soon after, the Lab's Water Management R&D Program was established to lead a crucial national effort in promoting sustainable and efficient water and energy use by developing technology solutions and researching the intersections that exist in the water and energy sectors.



Longview Power Plant is a coal-fired power plant located near Madsville, West Virginia. The plant's single unit generates 700 net megawatts of electricity from run-of-mine coal and natural gas.



# WATER-ENERGY CHALLENGES

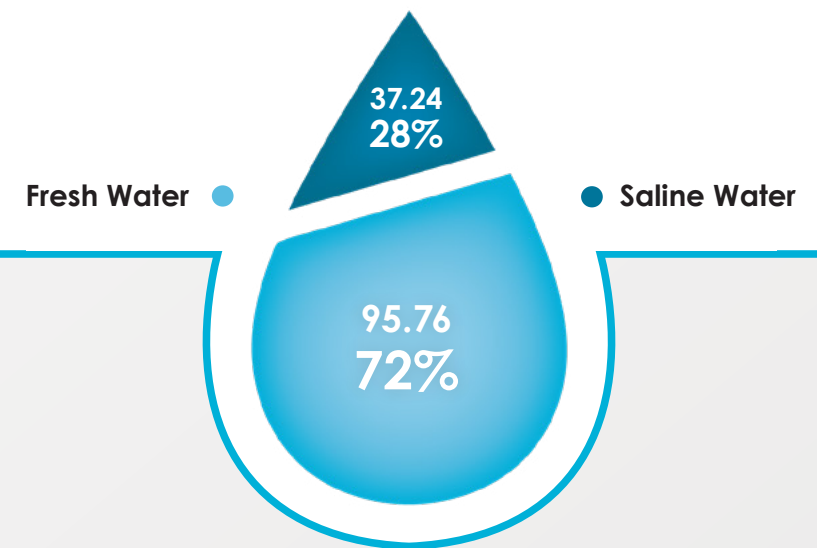
**Responsible domestic fossil energy production and use requires a more complete understanding of its impact on the nation's water resources. Competing demands for water by other sectors, regulatory and policy developments, climate and weather implications, and other factors have brought into sharp focus the need for the sustainable and efficient use of water for energy.**

According to a 2015 report from the U.S. Geological Survey, a total of 281 billion gallons of fresh water is withdrawn daily in the United States. Thermoelectric power accounts for approximately 34 percent (133 billion gallons) withdrawn and is primarily used for cooling. Of the 133 billion gallons of water withdrawn for power plants only 3 percent is consumed — not returned to its source — compared to the 62 percent consumed by irrigation. New and existing thermoelectric power plants must address a myriad of water-related challenges, particularly in regions where there are constraints on the availability of fresh water such as the arid west and southwest (Feeley, et al. "Water: A critical resource in the thermoelectric power industry." *Energy* 33, 2008.) Even parts of the Southeast, Midwest, Northwest, and Northeast are not immune to water availability and quality issues that can impact power generation.

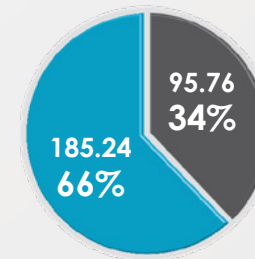
Significant amounts of water are also used in oil and gas exploration and production, particularly for unconventional supplies such as shale gas. From 2012 to 2014, it is estimated that about 4.54 billion gallons of water was used annually in recovering oil and natural gas. Conversely, oil and gas wells also produce large volumes of water along with hydrocarbons. This water is commonly referred to as "produced water." The yearly estimated volume of produced water from oil and gas operations in the U.S. is roughly 890 billion gallons. Reducing the volume of water needed in oil and gas production and managing the produced water that can contain elevated concentrations of harmful "constituents, such as salts," are two of the most pressing challenges for oil and gas industries.

As the demand for clean, fresh water increases in the United States as well as globally, so will the challenges to its efficient and environmentally sound use in enabling fossil fuels to continue to produce clean, affordable, and reliable energy.

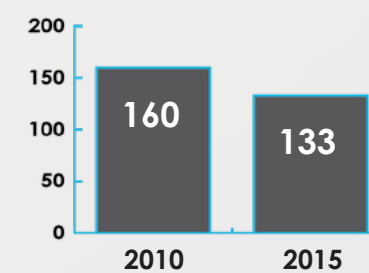
Daily Thermoelectric Power Withdrawals, 2015 (in billions of gallons)



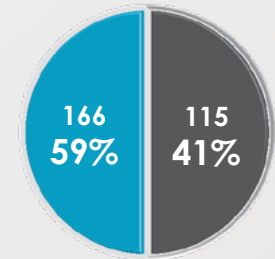
Total Freshwater Withdrawals, 2015



Withdrawals in 2015 for Thermoelectric Power



Total U.S. Water Withdrawals, 2015



2015 withdrawals were 18% less than in 2010, and represent the lowest withdrawal levels since before 1970.

LEGEND: ● Thermoelectric Power  
● Other

SOURCE: U.S. Geological Survey, "Estimated Use of Water in the United States in 2015," June 2018.



# WATER RESEARCH & INNOVATION AT NETL

NETL has taken the lead in designing and managing research and development that specifically focuses on the link between water and fossil energy. Since convening an inaugural workshop on power plants and water in 2002, the Laboratory has applied its capabilities to numerous energy and water issues that incorporate issues related to coal-based power generation, oil and natural gas development and extraction, carbon capture and storage and related topics.

NETL has established a robust portfolio of in-house and external water-related research projects and initiatives to ensure the environmentally sound and sustainable use of the nation's fossil energy resources. The work supports increased domestic manufacturing, improves infrastructure, enhances global competitiveness, revitalizes the workforce, and reinforces efforts to establish the United States' energy dominance.

## EXTERNAL PARTNERSHIPS

As DOE's only government-owned, government-operated laboratory, NETL possesses the program management expertise and authorities to convene, implement, and manage cost-sharing partnerships with American businesses, national research organizations, colleges and universities, and other government laboratories. Today, NETL has more than 30 active projects valued at more than \$100 million dedicated to research specifically directed at the link between energy and water.

## IN-HOUSE RESEARCH & ANALYSIS

Through its on-site world-class facilities and award-winning cadre of scientists and engineers, NETL can leverage its five core capabilities to address a variety of national water-for-energy research and technology challenges. A summary of each of these five core capabilities is provided below:

### Chemical Engineering

Pioneering efficient energy conversion systems that can enable sustainable fossil energy utilization.

### Applied Materials Science & Engineering

Developing and deploying affordable, high-performance materials designed for severe-service applications.

### Subsurface Science

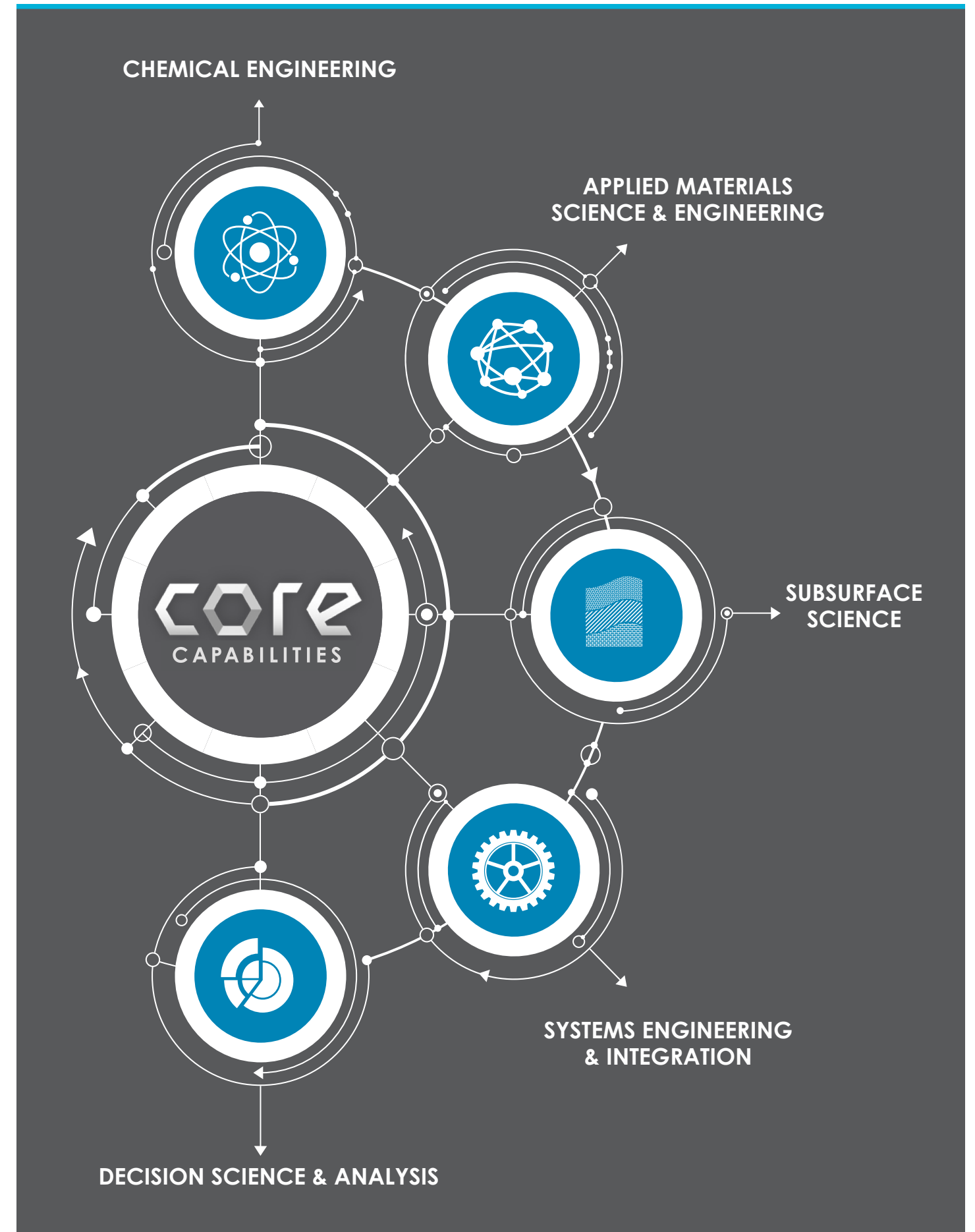
Enabling the sustainable production and use of fossil fuels through engineering of the subsurface.

### Systems Engineering & Integration

Accelerating technology innovation, development, and deployment to enable new clean energy technologies to gain market acceptance.

### Decision Science & Analysis

Utilizing multi-scale computational approaches to provide in-depth objective analyses in support of the DOE mission.





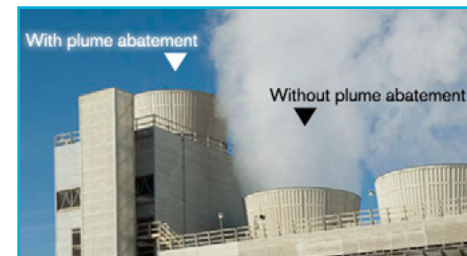
# TOOLS & TECHNOLOGIES

## NETL'S WATER-ENERGY RESEARCH PORTFOLIO

NETL and its partners have developed a number of advanced tools and technologies applicable to the recovery, treatment, and reuse of water for fossil energy production and power generation. Below are several examples of NETL's water-energy nexus success stories and active research projects.

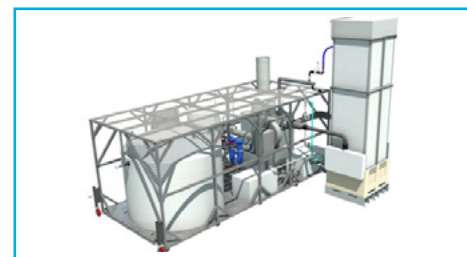
### Recovering Water from Power Plant Cooling Plumes

The ClearSky® Plume Abatement System developed by SPX in partnership with NETL is a commercial technology to minimize cooling plumes and reduce evaporative water loss. The ClearSky® moisture capture technology recovers an average of 18 percent of the water evaporated from a cooling tower, offering an economical and environmentally friendly solution for reducing the amount of water used by fossil fuel-fired power plants. The technology is being marketed worldwide, with a recent order placed for the system on a coal liquefaction facility in China.



### Water Treatment System Cleans Marcellus Shale Produced Water

Under an NETL-sponsored project, Altela Inc. successfully tested its AltelaRain® 4000 water desalination system on produced water at BLX, Inc.'s Sleppy hydraulic fracturing well site in Indiana County, Pennsylvania. During nine continuous months of operation, the unit treated 77 percent of the water produced by the well. As of March 1, 2011, over 275,000 gallons of Marcellus Shale frack flowback water were treated and purified at the well site, resulting in the production of more than 182,000 gallons of clean, distilled water. The treated water was shown to be suitable for re-use by well operators and could also be discharged to surface waterways without the need for further treatment, thus reducing the economic and environmental impacts of the well.



### Acid Mine Drainage Treatment Process for Source Water

With cost-share funding from NETL, Battelle conducted the first field demonstration of the Floatation Liquid-Liquid Extraction (FLLX) water treatment system at Fawn Mine in Sarver, Pa. Currently offered commercially by Winner Water Services as HydroFlex™, the technology treats acid mine drainage (AMD) contaminated water so that it can be used for hydraulic fracturing operations. HydroFlex was shown to reduce sulfate concentrations in AMD by up to 90 percent — a significant improvement over competing technologies.



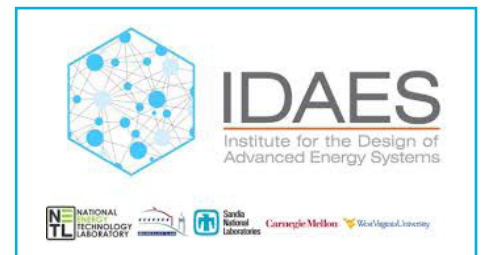
### Drying and Refining Coal for Increased Value and Reduced Emissions

The DryFining™ process was developed by Great River Energy in partnership with NETL to use excess heat from electricity generation to dry coal prior to combustion. In addition to using less cooling water to produce electricity, drying coal prior to combustion is more efficient and results in more electricity with less coal use and air emissions. Although coal drying is well known, the DryFining process is commercially viable because of the process using waste heat as the energy source.



### Advanced Systems Modeling and Simulation-Based Engineering

NETL is leading a multi-lab initiative called the Institute for the Design of Advanced Energy Systems (IDAES) to develop and employ process systems engineering models and computational tools to analyze advanced energy systems. IDAES is a valuable tool in supporting NETL's water-energy research. Models are currently being developed to track the partitioning of contaminants in various power plant wastewater streams. In addition, IDAES can be used to optimize water use within an entire power plant.



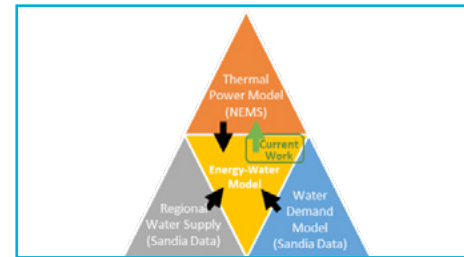
## Data-Driven Tool for Science-Based Decision Making

NETL's Energy Data eXchange (EDX) is a platform for data sharing and collaborative research, and includes an NETL-developed suite of tools for data visualization and analyses, such as the Variable Grid Method (VGM). NETL's VGM allows for better communication of uncertainties by combining flexibility of input with visual-spatial data output to facilitate understanding of the results and has been used to quantify and limit uncertainty in subsurface groundwater distribution.



## Water-Energy Model for National Energy Modeling System

NETL has developed a prototype model for the National Energy Modeling System (NEMS) that can be used to estimate the impact of fossil energy technologies on water resources. The model currently operates at a Hydraulic Unit Code 8 (HUC 8) sub-basin watershed level and has been beta tested under HUC 8 water demand-supply scenarios using data compiled by Sandia National Laboratory (partially funded by NETL) and the World Resources Institute.



## Novel Sorbents for Water Treatment

Dyes and pigments can be a major problem for water systems, and their removal can be difficult and expensive. NETL researchers are developing a method for imbedding polyamines within inexpensive, porous silica particles to remove organic-based colorants and other pollutants from a variety of water sources, including drinking water supplies, ponds, rivers, lakes, seawater, groundwater, textile waste water streams, food processing waste water streams, and coffee bean waste waters.



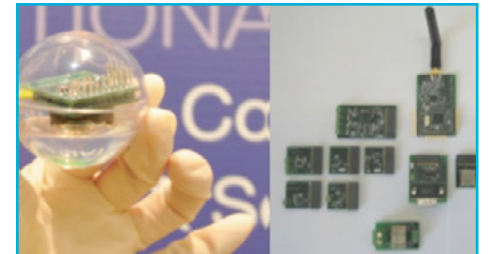
## A Unique, Split Laser System for Environmental Monitoring

Regulatory agencies, state and local governments, energy resource developers, research organizations, and others have a need for real-time, high-quality water data. Unfortunately, water quality monitoring solutions available today are expensive and labor intensive. NETL researchers are developing a more affordable, in situ monitoring tool based on laser induced breakdown spectroscopy (LIBS) by measuring the elemental concentrations in simulated brines. LIBS technology provides rapid elemental analysis without extensive sample collection or preparation. NETL has designed a simple, easy-to-fabricate, handheld LIBS system fully adaptable to field use and capable of measurements even in harsh environments.



## Wireless Network Sensors and Integrated Sensors for Water Quality

Under a Phase II Small Business Innovative Research grant, Sporian Microsystems Inc. is developing a low-cost, rapidly deployable, wireless, self-powered, real-time, in situ water quality monitoring technology. The device will measure key parameters associated with power plant water use, including temperature, turbidity, pH, total dissolved solids, scale forming minerals, and heavy metals. The detection system is based on Sporian's patented detection element comprised of molecularly imprinted polymers and ion imprinted polymers. Another company, NanoSonic, Inc., is developing wireless sensors for use in analyzing heavy metal chemistry for power generation facilities and, more broadly, for commercial use. The company will develop wireless networked sensors using conformal nanomembrane-based chemical field effect transistors (ChemFETs) to detect heavy metals in water, enabling efficient monitoring of heavy metals in water for environmental surveillance, location of pollution sources, and detection and mapping of chemical concentrations that are potentially harmful to people and/or destructive to agriculture.





# PARTNERING WITH NETL

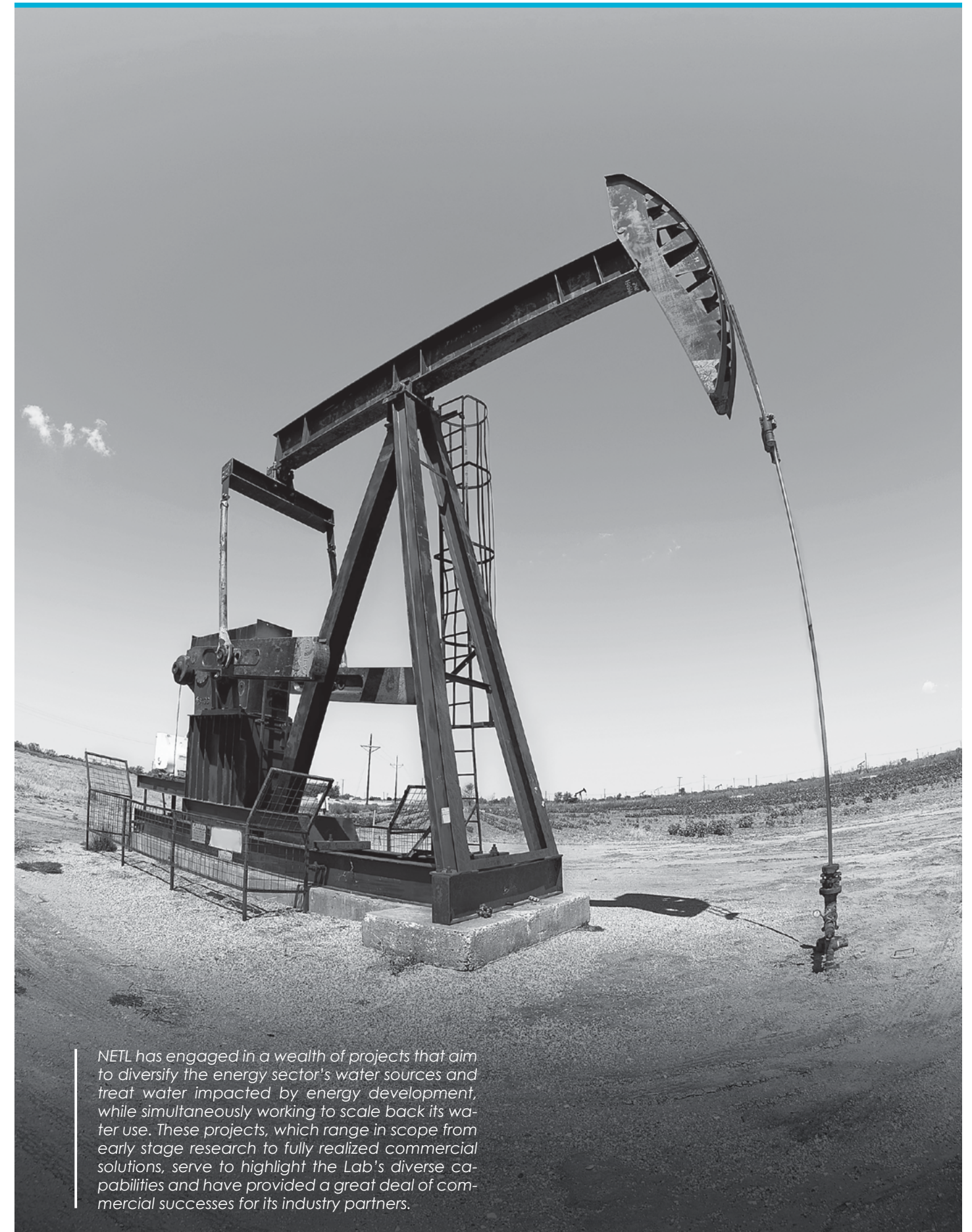
As a research convener, NETL's success in developing technology solutions that can be applied to the intersection of water and energy depends upon strong relationships and partnerships with public and private entities. From targeted competitive announcements to cooperative research and development agreements (CRADAs), NETL offers a variety of cost-shared funding and partnership arrangements to help move technology and intellectual property through the technology maturation cycle into the marketplace. For more information on opportunities to partner with NETL on water-energy topics, contact:

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## PARTNERSHIP WITH CHEVRON

The DOE's Office of Fossil Energy and Chevron Technology Ventures, a division of Chevron U.S.A. Inc. (CTV), announced an agreement to advance solutions to produced water issues. Produced water refers to the water that is co-produced with oil and natural gas from both conventional and unconventional (shale and tight) resources. When treated, produced water can be reused to offset water needed for many purposes, including agricultural use, mineral extractions, and processing and reuse in oil and gas production. – July 10, 2018

Under the Cooperation Agreement, DOE will provide technical expertise to CTV on the Chevron Tech Challenge for Produced Water, which seeks to develop cost-effective produced water management solutions applicable to U.S. oil and gas extraction.



NETL has engaged in a wealth of projects that aim to diversify the energy sector's water sources and treat water impacted by energy development, while simultaneously working to scale back its water use. These projects, which range in scope from early stage research to fully realized commercial solutions, serve to highlight the Lab's diverse capabilities and have provided a great deal of commercial successes for its industry partners.

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# NOTES

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