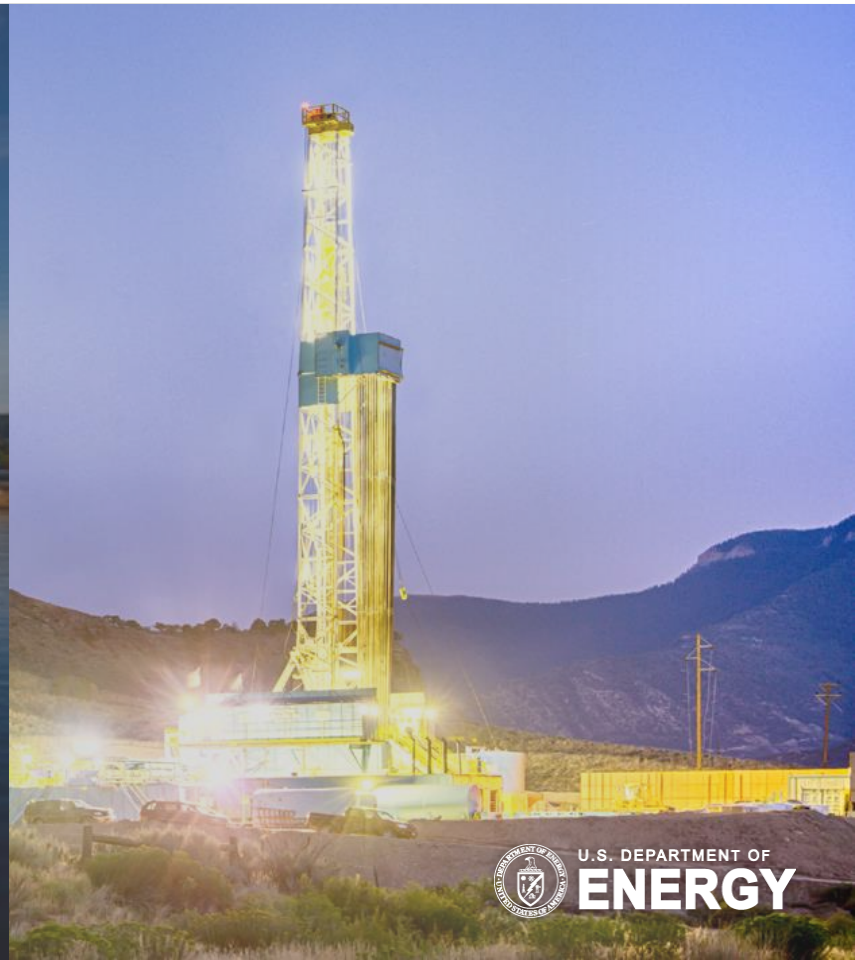
GWPC Annual Forum

A Research Perspective on the Water-Energy Nexus



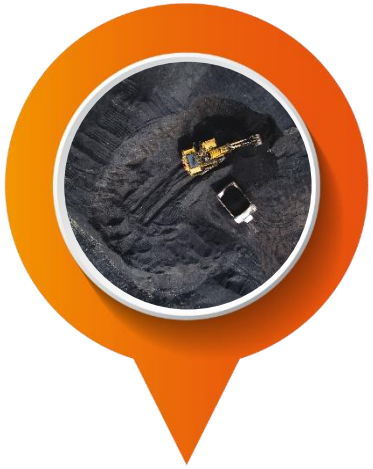
Thomas J. Feeley, III
Strategic Partnerships Water-Energy Lead
September 16, 2019
Oklahoma City, Oklahoma

Solutions for Today | Options for Tomorrow

Water & Energy Inextricably Linked

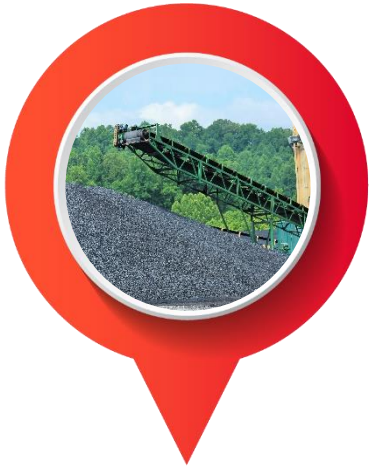
Water needed/impacted throughout fossil-energy lifecycle

EXTRACTION



- Mining
- Drilling/Fracking
- REE Recovery
- AMD/Produced Water

PROCESSING



- Coal Cleaning
- Fuel Upgrading
- REE Recovery
- Coal Conversion

TRANSPORT

- Barge
- Coal-water Slurry
- Fresh /PW

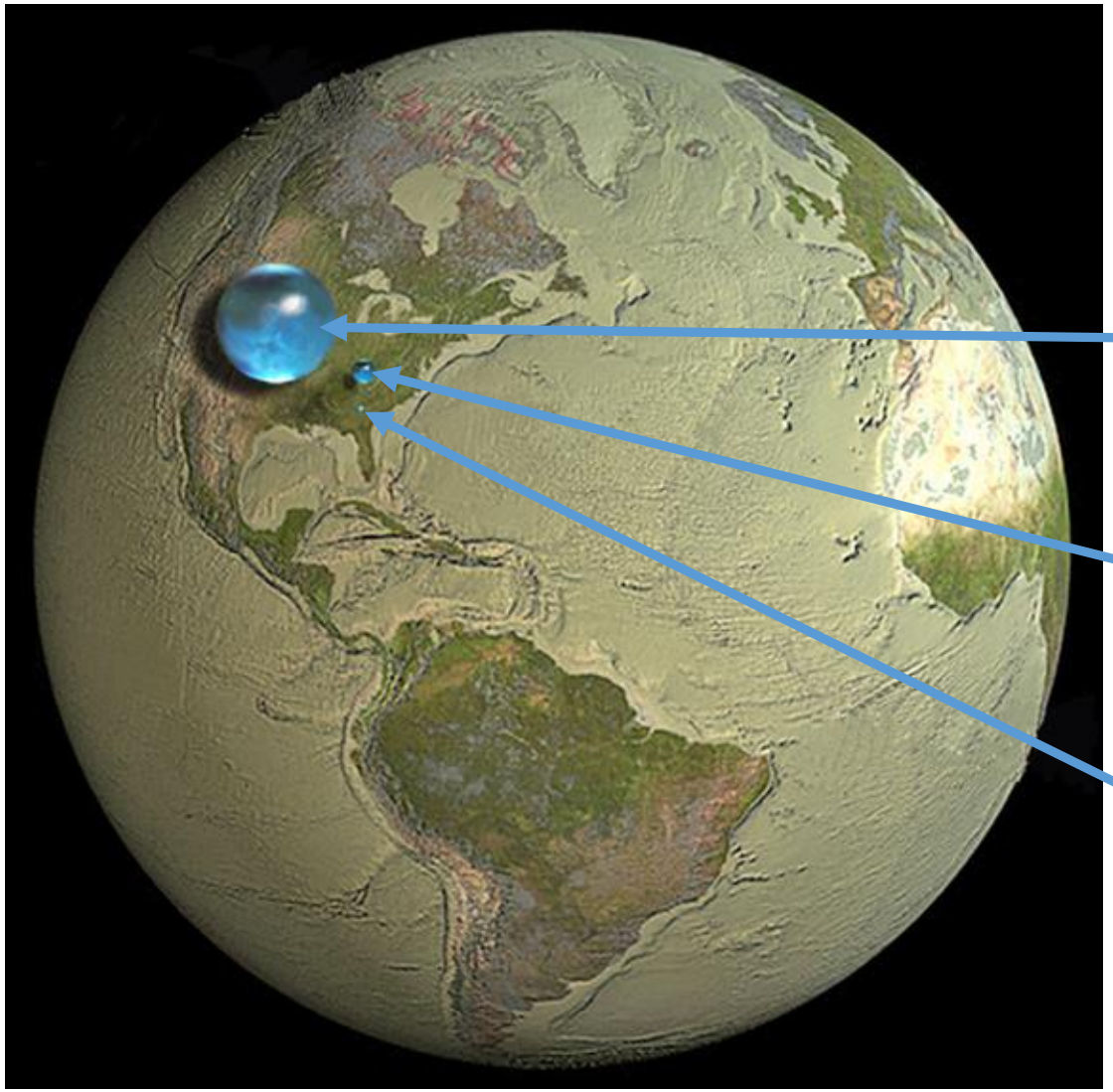
UTILIZATION

- Cooling
- Steam cycle

ENVIRONMENTAL MANAGEMENT

- Wet Scrubbing
- CO_2 Capture/Storage
- Byproduct Disposal/Reuse
- PW Treatment
- ZLD/Water Treatment

Global Water Availability



Only ~2.5% of global water is fresh, with ~99% tied up in ice caps, locked deep in earth, contaminated, or otherwise unavailable

332,500,000 mi^3 -- All water above, in, and on earth

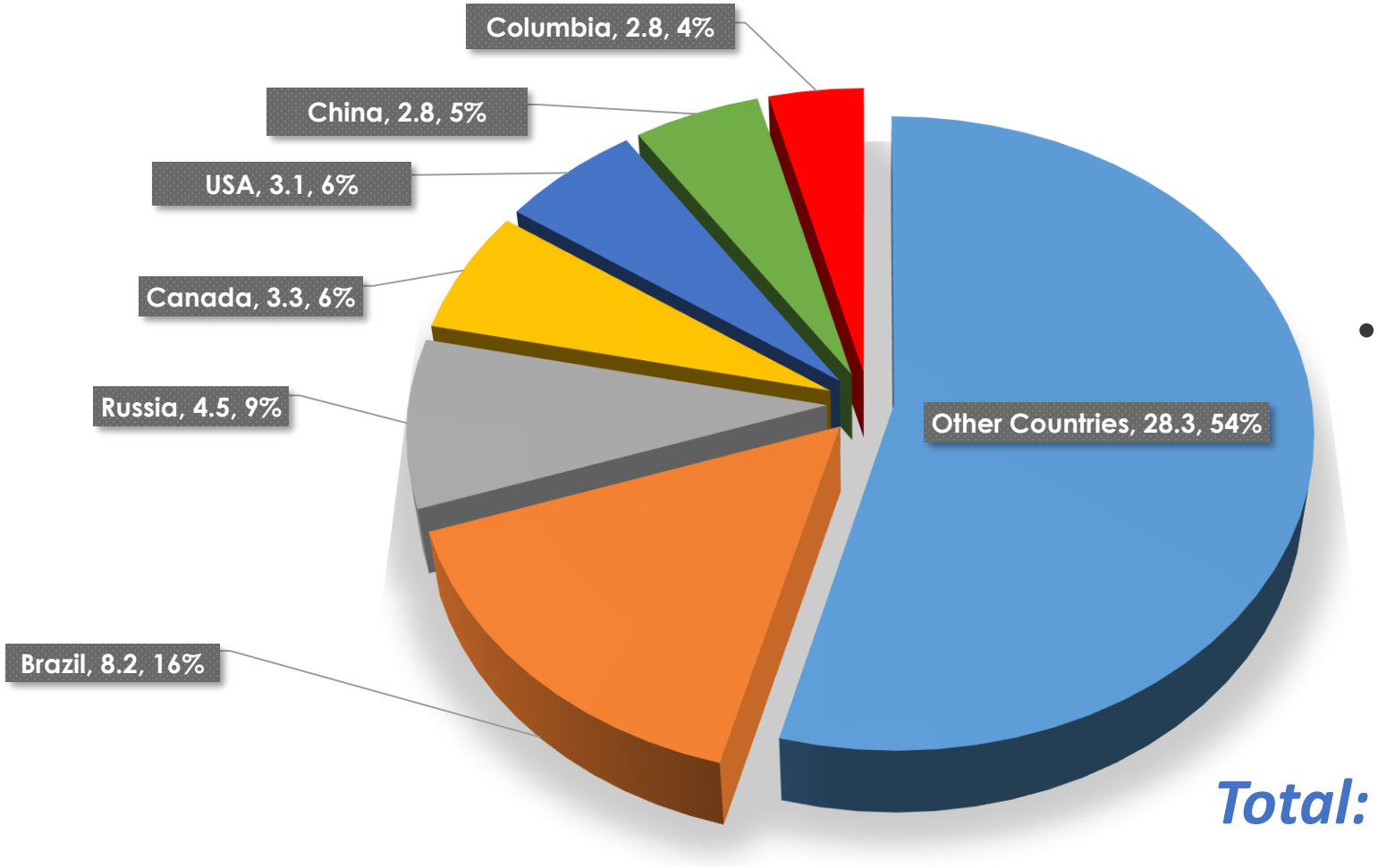
2,551,000 mi^3 -- Liquid fresh water in lakes, rivers, swamps, and groundwater

22,399 mi^3 -- Liquid fresh water in lakes and rivers

Mi^3 = cubic mile (1.1 trillion gal); Earth: 260 billion mi^3

Source: USGS, https://www.usgs.gov/special-topic/water-science-school/science/how-much-water-there-earth?qt-science_center_objects=0#qt-science_center_objects

World Renewable Fresh Water Resources

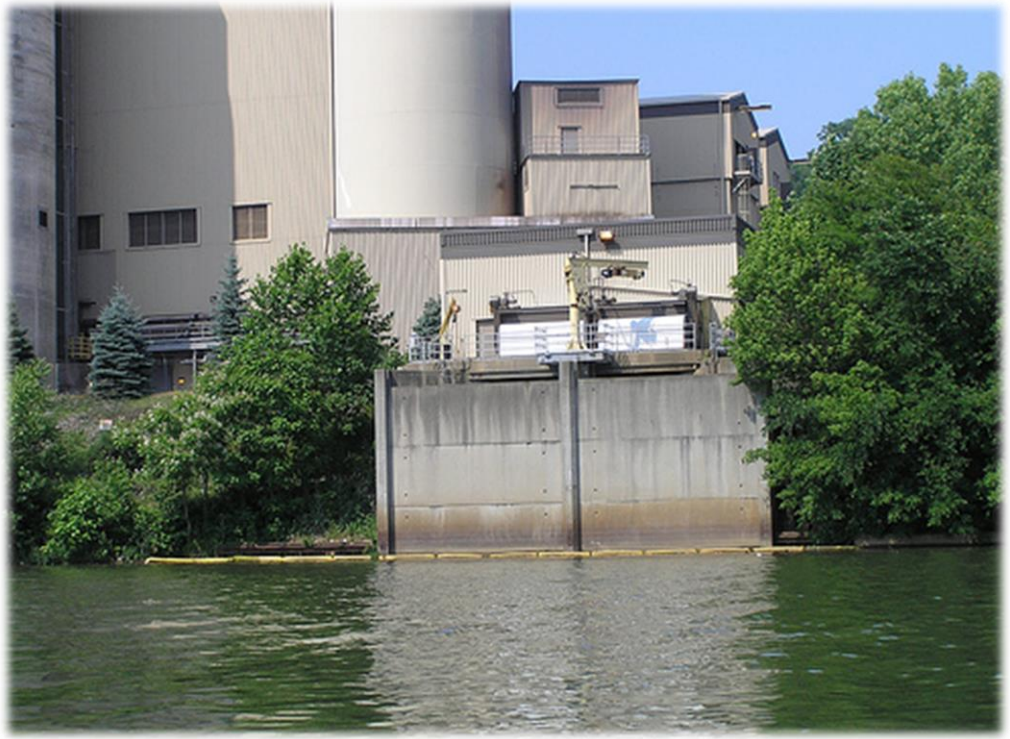


- U.S. – 3.1 tm^3
  - ~8,846 m^3 per capita
  - m^3 = 264 gallons

Total: 52.3 trillion m^3 (12,547 mi^3)

Water Withdrawal vs. Consumption

Important to distinguish between the two when discussing fossil energy



≠

WITHDRAWAL (USE)

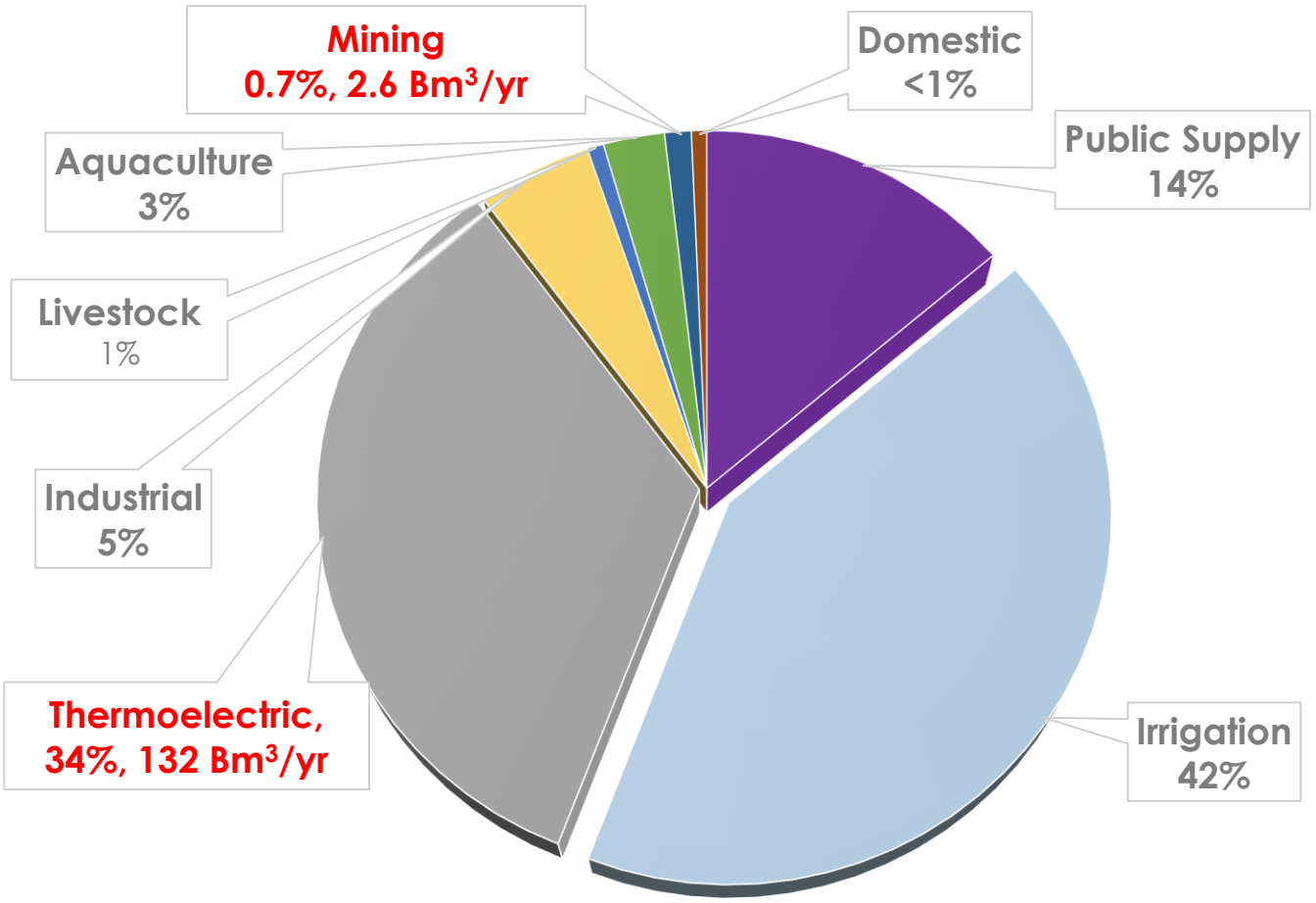
Water removed from ground or diverted from surface water source for use.

CONSUMPTION

Fraction of water withdrawn that is not returned to source, e.g., water evaporated from cooling towers.

Energy-Related U.S. Freshwater Withdrawal

Thermoelectric generation is second largest water withdrawal sector



- **Total** U.S. freshwater withdrawal is **389B m³/year**

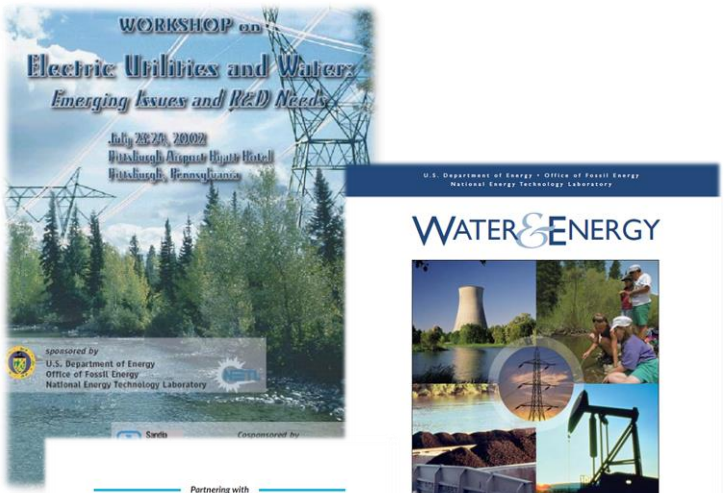
- **Mining**, which includes oil and natural gas recovery and coal extraction, accounts for **~0.7%** of total U.S. freshwater withdrawals **(~55% groundwater)**
- **Thermoelectric** (primarily cooling) accounts for **~34%** of total freshwater withdrawals **(~100% surface water)**
- **Agriculture** accounts for nearly 80% of nation's consumptive use

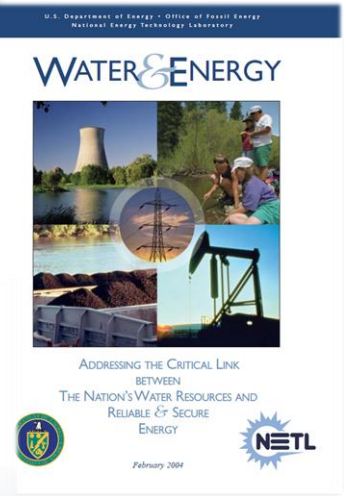
Sources: USGS, "Estimating Use of Water in the United States in 2015," and USDA Economic Research Service

History of Water-for-Energy R&D at NETL

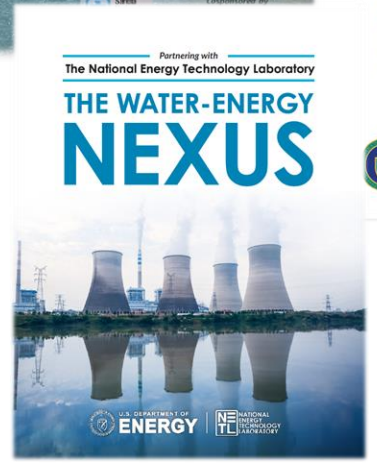
Started in early 2000s as part of NETL's Innovations for Existing Plants Program

2002 Workshop





2004 Brochure

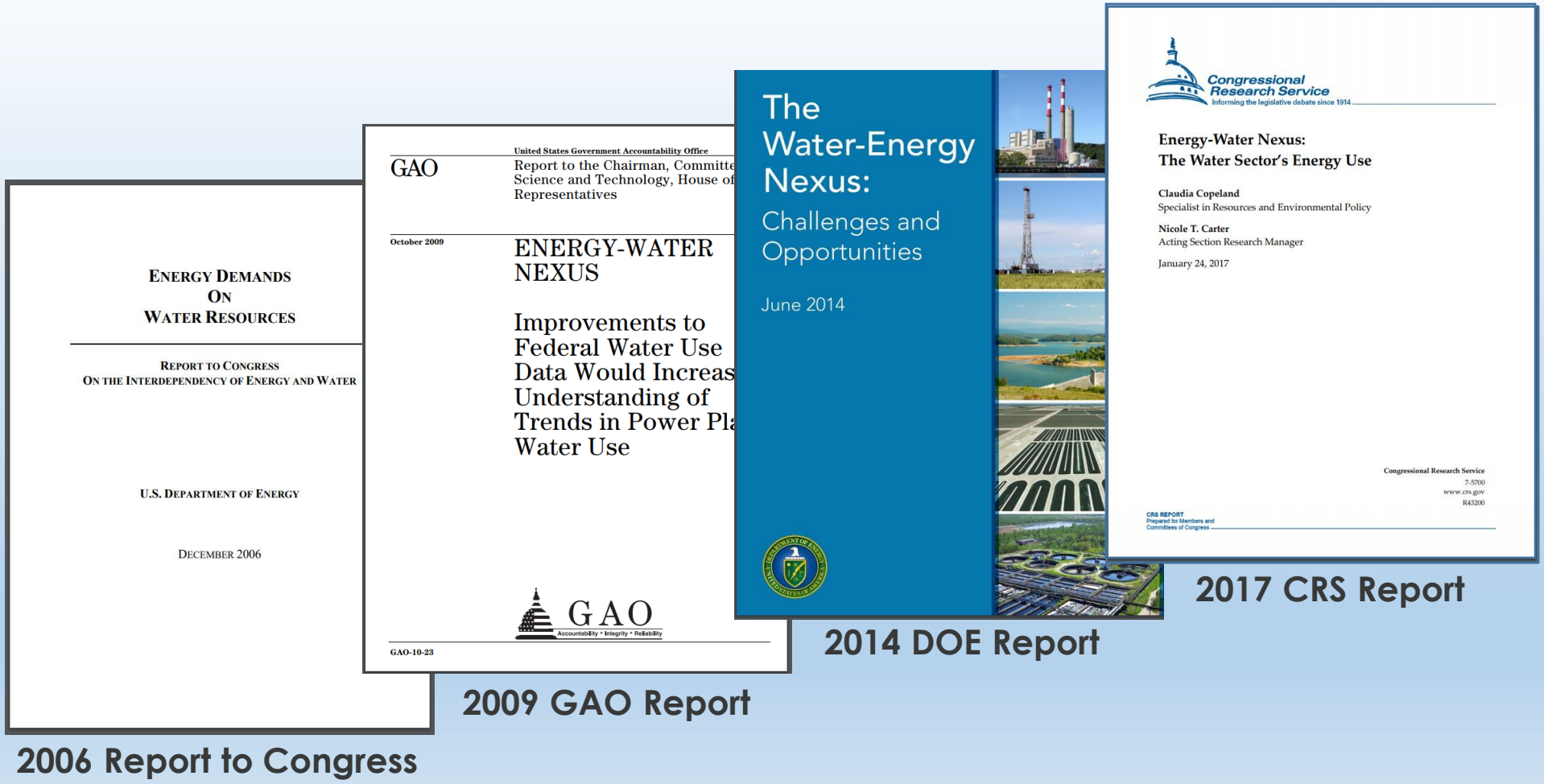


2018 Brochure

- Prior to 2000 NETL had a loose collection of a few water projects primarily related to former BOM AMD research absorbed by Lab
- In 2002, NETL sponsored 1st public workshop on emerging water issues and research needs associated with thermoelectric power generation
- Research focused initially on water availability and quality affecting the existing fleet of coal-fired power plants
- Since then R&D has expanded to include water issues across NETL's carbon capture & storage, unconventional oil & gas development, rare earths recovery, and related fossil energy programs

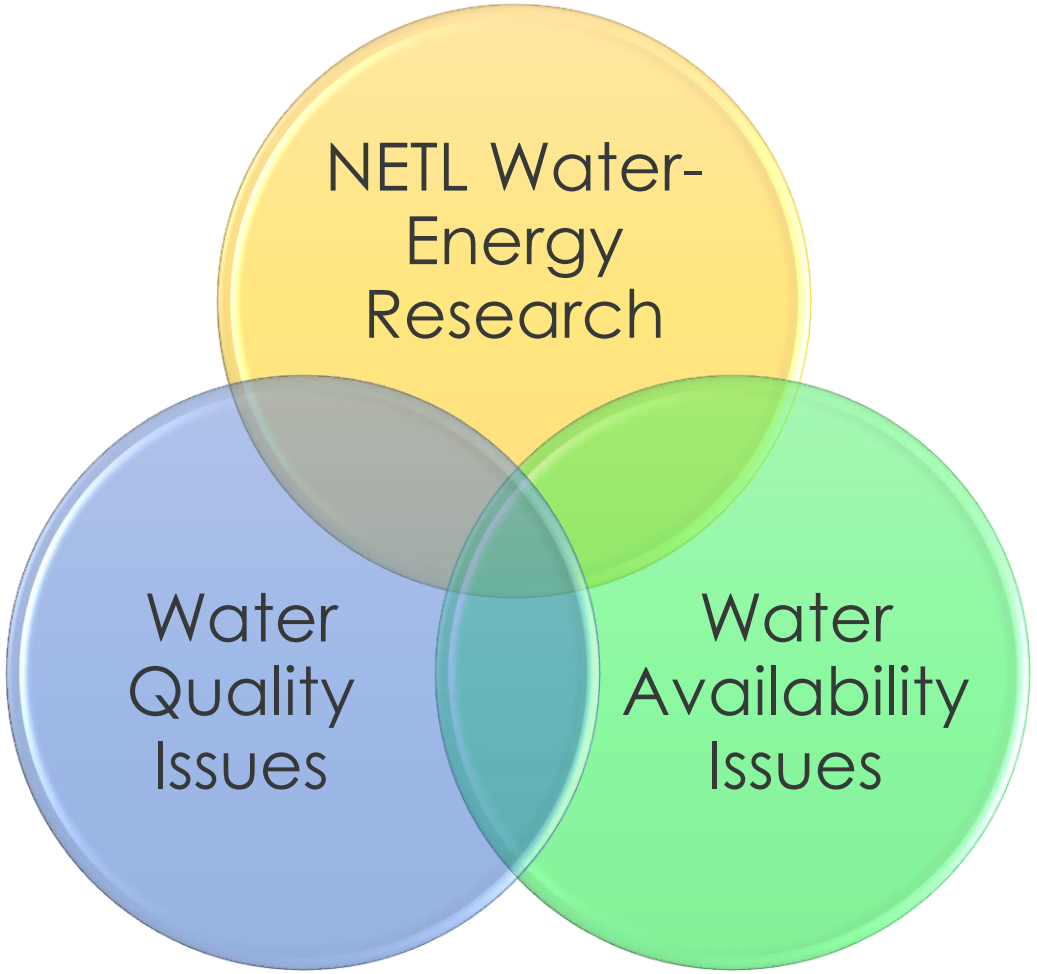
NETL's Water-for-Energy Research

NETL's research has contributed to several key government water-energy reports



Water-for-Energy Research at NETL

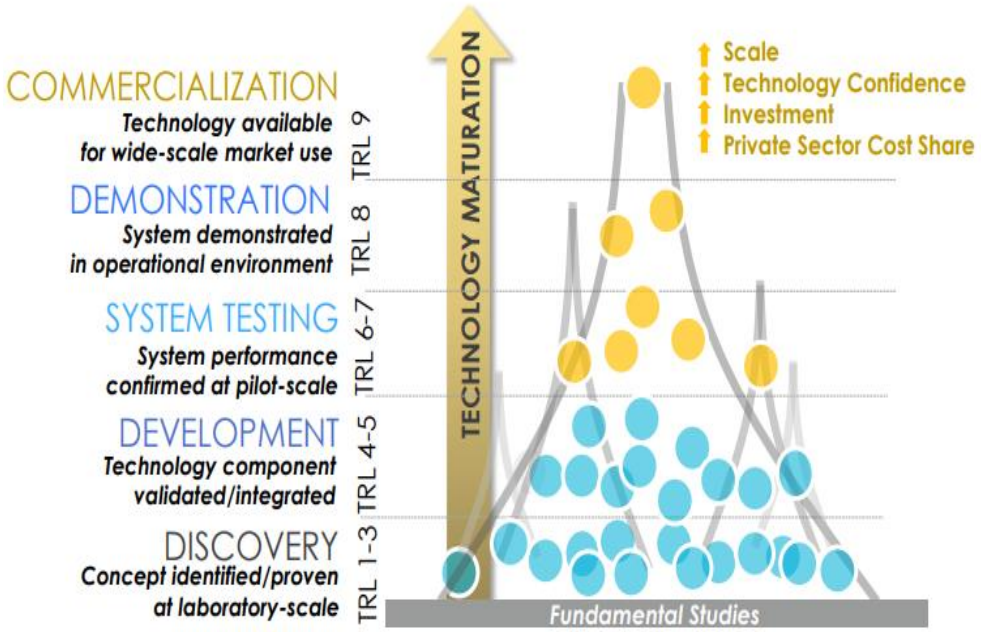
NETL's research addresses **water availability** and **quality issues**, with many projects overlapping both areas.



Driven by local and regional issues

Water Research & Innovation at NETL

Research focused on availability and quality Issues



Water research conducted from discovery through demonstration.

NETL has established robust portfolio of intramural (in-house) and extramural water-related research projects directed at availability and quality issues.

Work is being conducted across the following areas:

- **ADVANCED COOLING TECHNOLOGY**
  - Wet, dry, and hybrid cooling
- **NON-TRADITIONAL WATER RECOVERY & USE**
  - Recovery/reuse of mine water, AMD REE recovery, coal drying, flue gas moisture recovery
- **WATER TREATMENT & DETECTION TECHNOLOGY**
  - Desalination, PW treatment, advanced sensors, novel sorbents, power plant effluents; As & Se detection
- **DECISION SCIENCE & MODELING**
  - Modeling, analysis, and decision-making tools

NETL's Water-Energy Research

Partnering key to success

Since 2003, **NETL** and its partners have developed a number of advanced tools and technologies applicable to the recovery, treatment, and reuse of water from fossil energy production and power generation.

$100 Million+

NETL's active water-energy research portfolio

30+

Active projects in water-energy research

~$2-$3 million/year over past 2 decades

Industry

Sporian Microsystems, Inc.; Porifera; Groundwater Protection Council; EPRI; gti; NanoSonic (Putting nanotechnology to work); oceanit; RTI International; Altela (Treating water naturally.); SPX Cooling Technologies

Academia

Ohio University; University of Illinois at Urbana-Champaign; EERC (Energy & Environmental Research Center); West Virginia University; The University of Texas at Austin; UNM; University of Kentucky; Lehigh University

National Labs & Non-Profits

Sandia National Laboratories; Berkeley Lab; Argonne National Laboratory; Groundwater Protection Council; Lawrence Livermore National Laboratory

Current Water-Energy Project Examples

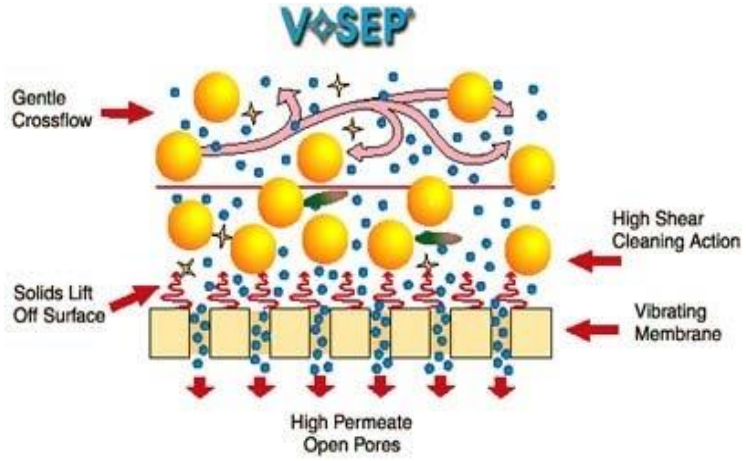
NATIONAL ENERGY TECHNOLOGY LABORATORY

Southwest Research Institute

Developing non-water-based and non CO_2-based stimulation technologies that can be used instead of, or in tandem with, water-based hydraulic fracturing fluids to reduce water usage and the volume of flowback fluids.

Southern Research Institute

Developing technology to treat CO_2 sequestration produced waters with high total dissolved solids not treatable using traditional membrane processes.



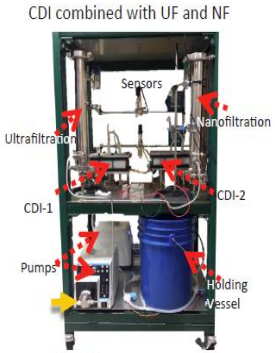
University of Kentucky and *Duke Energy*

Developing advanced electrocoagulation with air-based flotation for removing regulated species from FGD wastewater.

UKy-CAER Separation Modules

Iron-based Electrocoagulation

In-house developed zeolite membrane



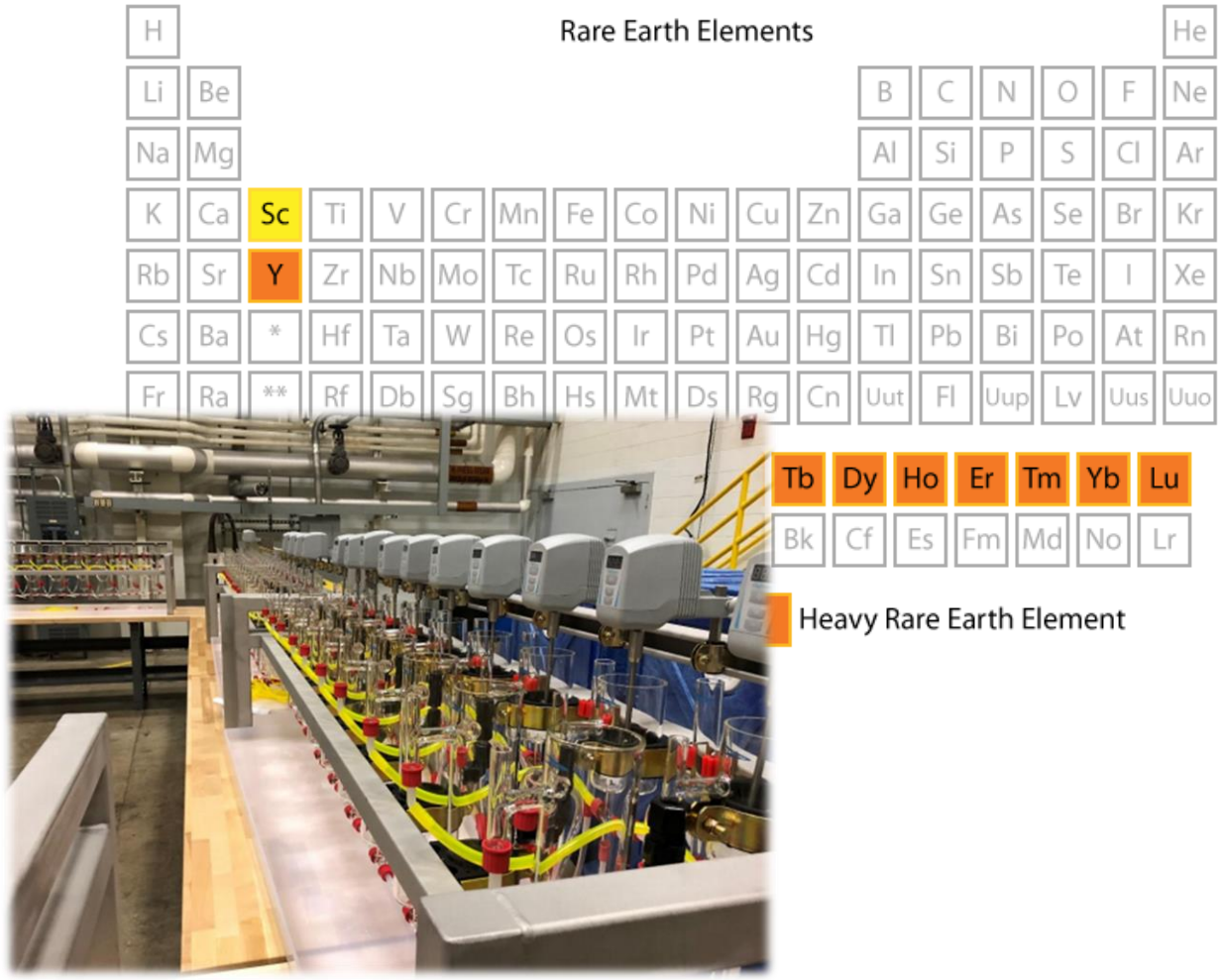
Continuous operation using CDI, UF, and NF

Rare Earth Elements Recovery

Addressing AMD and recovering rare earths

- Team from NETL, University of Pittsburgh, and Hedin Environmental Inc. assessing recovery of rare earth elements from seventeen active and passive AMD treatment sites.

- WVU and partners will design and build bench-scale process to recover REE from raw and treated AMD water and solids.

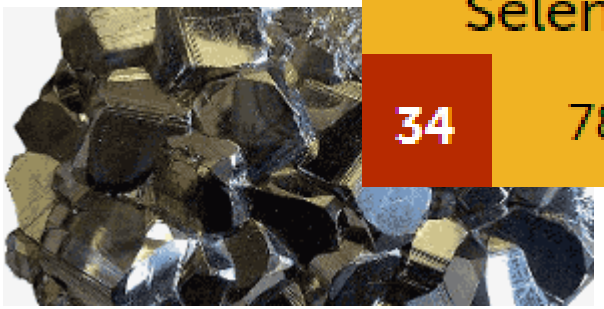


WVU Rare Earth Element Laboratory

Detection & Measurement Research

Two recent university selections

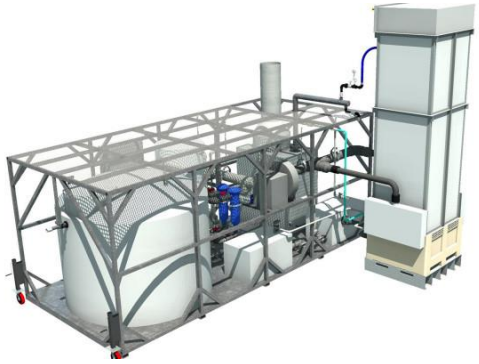
- **Application of Novel Analytic Method(s) to Determine Arsenic and/or Selenium Concentrations in Fly Ash Waste Streams Generated from Coal Combustion**
  - *Characterization of Arsenic and Selenium in Coal Fly Ash to Improve Evaluations for Disposal and Reuse Potential*—Duke University (Durham, NC) to investigate chemical forms of arsenic and selenium in coal fly ash and improve methods of characterization.
  - *Elucidating Arsenic and Selenium Speciation in Coal Fly Ashes*—Georgia Tech Research Corp. (Atlanta, GA) to systematically characterize arsenic and selenium speciation within coal fly ashes, using synchrotron X-ray spectroscopic and microscopic techniques.



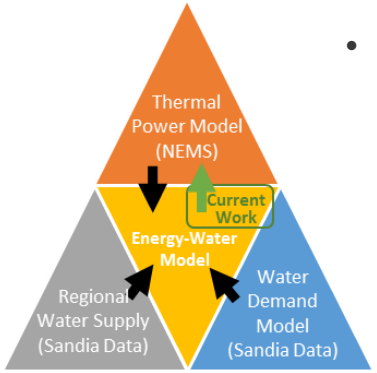
Water-Energy Partnership Success Stories

NETL-funded technologies in the marketplace

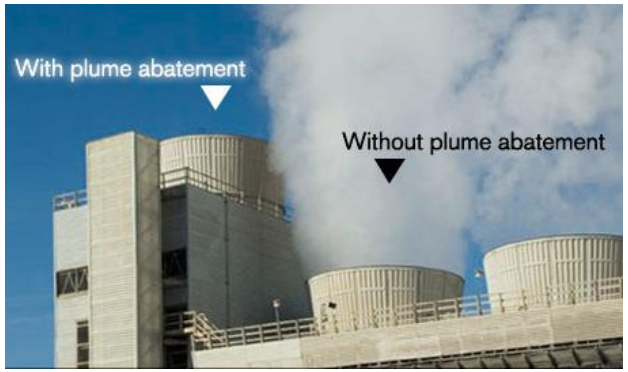
- **HydroFlex™** is a solvent-extraction process to treat coal ash slurries and CCR containment ponds effluents.
- Significantly reduces sulfates, metal, and other contaminants left behind by lime pretreatment
- Marketed by Winner Water Services (a Battelle Company)



- **AltelaRain®** is a modular water distillation/decontamination system that treats highly challenging fluids such as produced water.



- NETL developed **National Energy-Water Model prototype** for EIA's National Energy Modeling System (NEMS*) that forecasts water needs for power generation under various demand and supply scenarios.



- The **SPX ClearSky™ Plume-Abatement System** achieved nearly 20% water recovery during field testing at San Yuan Generating Station.
- SPX Cooling Technologies has more than 80 plume-abatement installations worldwide.

*NEMS is a computer-based energy-economy modeling system managed by DOE's Energy Information Agency

Recent Water-Energy Funding Announcements

Important components of DOE's Water Security Grand Challenge

Energy-Water Desalination Hub

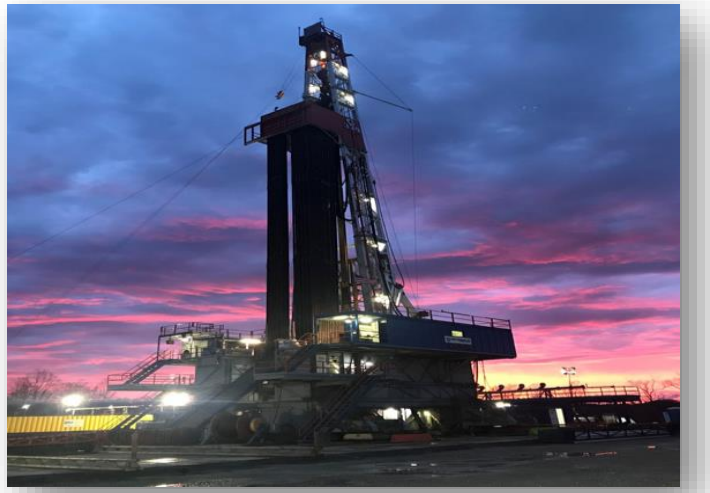
Establish an Energy Innovation Hub in Energy-Water Desalination to accelerate transformational advances in science and engineering focused on reducing the energy and cost requirements of desalination to provide clean and safe water

5/7/19 – Closing Date

Low-Cost, Efficient Treatment Technologies for Produced Water

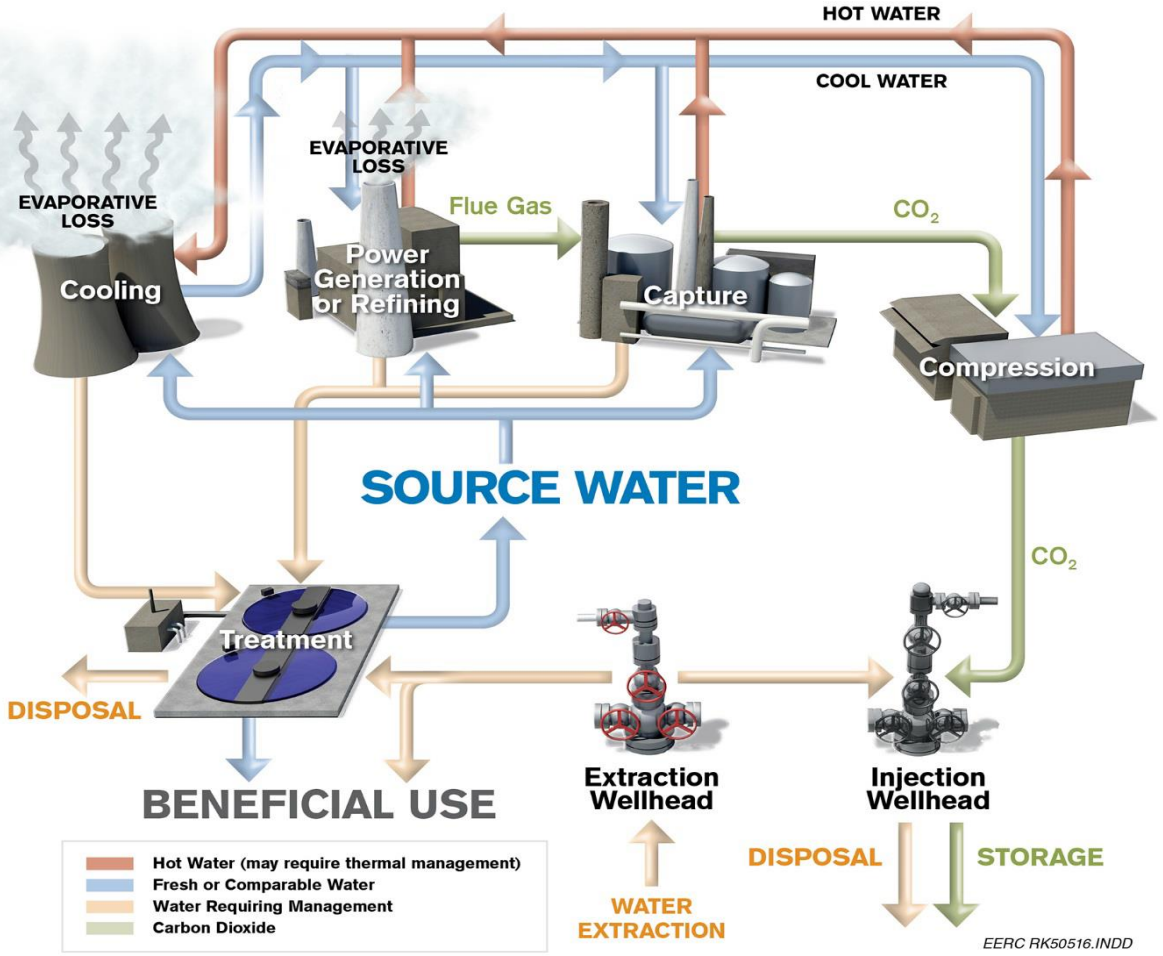
Accelerate development of potential process modifications, combinations or enhancements, or altogether new alternative processes and technologies-- including techno-economic analyses--that could achieve significant reduction in quantity of produced water injected underground.

07/10/19 – Closing Date



Water Use and Carbon Capture & Storage

Opportunities to treat and reuse extracted water from CO_2 storage



- Water required to operate carbon capture technologies such as amine-based systems.
- Water can also be extracted during geological CO_2 storage to manage subsurface pressure.
- Can we reduce parasitic power (reduce cooling demand) and water needed for capture?
- Can "extracted water" from CO_2 storage be recovered, treated, and reused?

Brine Extraction Storage Test (BEST)

Managing subsurface pressure & resulting extracted water from CO_2 storage

- R&D directed at managing CO_2 plumes and related subsurface pressure impacts of storage in saline formations that could result in fluid displacement
- Brine extraction wells are one approach to manage formation pressure
- Brine Extraction Storage Test (BEST) program conducting validation testing of brine injection (surrogate for CO_2) and extraction and **brine treatment**
- BEST facilities located in North Dakota and Florida
- EERC is seeking companies to pilot-test water treatment technologies at the ND BEST facility
  https://undeerc.org/_files/docs/best-wb-water-treatment.pdf

BEST Facility in North Dakota

Future Potential Research Opportunities

Applying "big data" to water-energy issues

- **How can machine learning/artificial intelligence be applied in treatment and management of water in fossil energy production and use?**
  - Produced water/flowback water treatment
  - Brine extraction and treatment from CO_2 storage
  - Power plant cooling water management
  - Effluent treatment from power generation
  - Management of discharge from coal ash impoundments
  - Treatment of rare earth recovery effluents

Energy Sect. Perry visited NETL on August 12 to discuss Lab's AI/ML capabilities

Thomas J. Feeley, III

Strategic Partnerships
Water-Energy Lead

thomas.feeley@netl.doe.gov

QUESTIONS?

Get Social With Us At: **www.NETL.DOE.gov**

@NETL_DOE

@NETL_DOE

@NationalEnergyTechnologyLaboratory