NATIONAL ENERGY TECHNOLOGY LABORATORY

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WATER-ENERGY NEXUS NEWS

U.S. DEPARTMENT OF ENERGY | OFFICE OF FOSSIL ENERGY AND CARBON MANAGEMENT | NATIONAL ENERGY TECHNOLOGY LABORATORY

An Update on the National Energy Technology Laboratory's Water-Energy Research and Related Activities

IN THIS ISSUE

Highlights: NETL-RIC and EPA Sign MOU for Produced Water Characterization

The National Energy Technology Laboratory (NETL) Research and Innovation Center (RIC) signed a memorandum of understanding (MOU) with the Environmental Protection Agency's (EPA) Center for Computation Toxicology and Exposure (CCTE) in December 2022. The point of contact (POC) for this effort is Alexandra "Ale" Hakala, an environmental geochemist and acting senior fellow for NETL Geologic and Environmental Systems, which is housed within RIC.

The purpose of this MOU is to establish an arrangement for cooperation on produced water characterization. Detailed water characterization is needed to properly design produced water management and will also further understanding of how beneficial reuse of these waters (e.g., water for irrigation) will affect the environment, soil chemistry, water supplies, and wastewater volume reduction efforts requiring deep well injection for disposal.

This MOU will help EPA-CCTE and NETL-RIC exchange produced water samples and leverage each other's respective research capabilities; these include characterization of the produced water samples' bulk chemical properties, including but not limited to inorganic and organic chemistry and bulk fluid properties (pH, Eh, total dissolved solids [TDS]), toxicology analysis, and microbial ecology. These research efforts will help achieve a more holistic understanding of the effects of treated produced water on human health and the environment.

This work is part of the U.S. Department of Energy (DOE) Office of Fossil Energy and Carbon Management (FECM) Water Management Program's goal for facilitating beneficial reuse of produced water beyond oil and gas (O&G) operations in order to reduce the need for freshwater resources, especially in the water-scarce regions of the United States.

Project Highlight: Pilot-Scale Production Nears for Rare Earth Elements from Acid Mine Drainage

Developing a profitable process to obtain rare earth elements (REEs) and other critical minerals (CMs) from acid mine drainage (AMD) helps to solve multiple problems: first, reducing the nation's dependence on insecure, international sources of these strategically necessary minerals; second, incentivizing required environmental management of AMD wherever coal has been mined; and third, providing jobs for displaced coal workers.

A project (DE-FE0031834) conducted by the West Virginia University Research Corporation in partnership with the West Virginia Department of Environmental Protection to build and run a pilot-scale facility near Bismarck, West Virginia's Mount Storm coal-fired power plant is doing just that, and it is nearing fully operational status. Other partners include Virginia Tech, TenCate Corp., L3Eng, and Rockwell Automation.

DOE has been pursuing a REE/CM production capability from coal-based resources through NETL since presentation of a Report to Congress in 2015: Feasibility of Recovering Rare Earth Elements from Coal and Coal By-products. Preparing the groundwork for the present pilot-scale facility were projects including a regional survey assessing the content, distribution, and form of REE/CM in AMD and related treatment byproducts (DE-FE0026444); design, development, and testing of a bench-scale process to extract, purify, and concentrate REE/CM from AMD treatment byproducts (DE-FE0026927); and development and testing of preconcentrate REE/CM from raw AMD (DE-FE0031524).

Recovery of REEs and CMs from AMD has now been demonstrated to produce an economically attractive feedstock. Processing has produced REEs at or above targeted purity levels: 2.0% total REE (TREE) from the upstream concentrator and at least 80% (in fact, more than 90%) mixed rare earth oxides (MREO) from downstream processing. Appreciable quantities of other selected CMs including manganese, lithium, zinc, cobalt, and nickel are also anticipated.

The pilot plant will bring these processes together in a continuous stream, processing up to 500 gallons of AMD per minute and producing clean, treated, dischargeable water and TREE at a rate of about 500 kg per year as MREO, in an economically feasible process. The upstream (pre-) concentrator is currently operational. The downstream acid leaching/solvent extraction plant is currently producing over 85% pure MREO. Parametric testing and optimization for yield and profitability are underway.

The processes integrated in this project for AMD treatment and REE/CM production are likely to be extensible to non-coal mining sources of AMD as well. For example, the AMD/REE profile from copper mining appears almost identical to that of coal. It may be possible to apply processing components to other coal-related sources of REE/CM such as fly ash.

Ultimately, commercialization of this technology will offset the costs of AMD treatment and create economic opportunities and jobs for coalfield residents while establishing a domestic source of REE/CM to secure a reliable, affordable supply. If the wider application of these processes finds a market, such benefits will be extended.

For more information about this project, please click here or contact Mark Render at Mark.Render@netl.doe.gov.

Highlights: NETL Uses Machine Learning to Expand Oil and Gas Modeling Capabilities Including the Impact on Subsurface Water

NETL is conducting research in the machine learning (ML) space to generate the capability to explore how subsurface resource development decisions, particularly related to unconventional O&G production in shales and tight rock, may have implications related to produced water—a byproduct of O&G development that requires management. In support of this effort, NETL's Energy Systems Analysis Team recently completed and published two studies that use deep ML approaches to forecast production at unconventional O&G wells: Evaluating the Impact of Proprietary Oil & Gas Data on Machine Learning Model Performance Using a Quasi-Experimental Analytical Approach, published in 2022, and Evaluating Production Implications of Pressure Maintenance in Unconventional Oil and Gas Wells Using a Machine Learning Modeling Approach - Case Study in the Permian Basin, published in 2023. Both studies focus on dynamic modeling of combined oil, water, and natural gas production for horizontal wells in the Permian Basin (West Texas, U.S.) using ML-based approaches that utilize both publicly available and operator-specific O&G datasets.

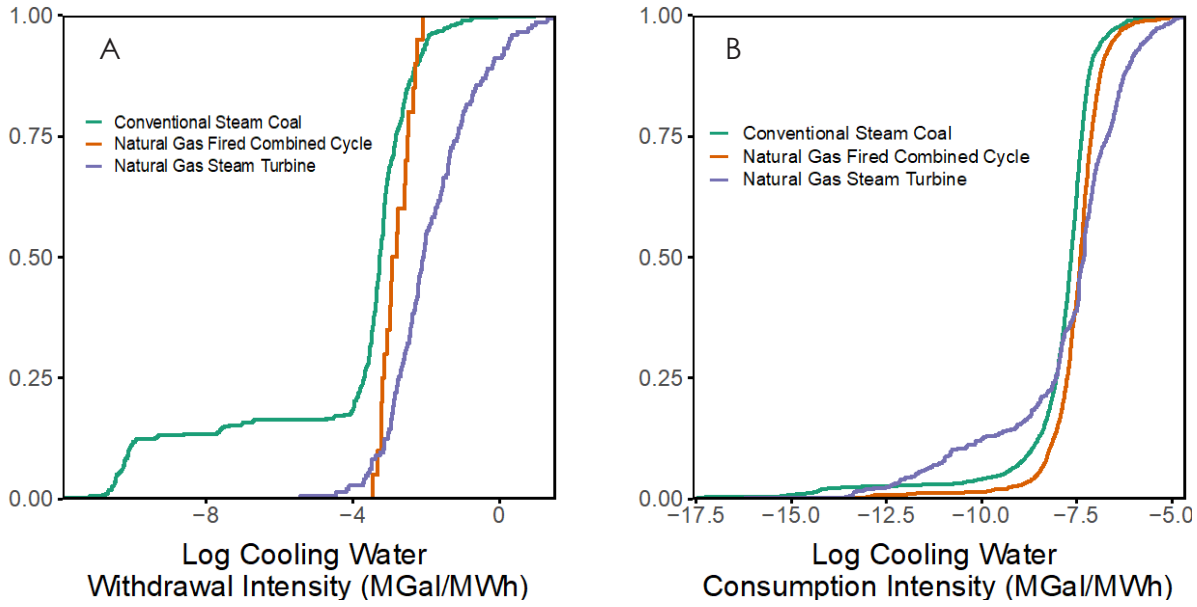
Models are designed to jointly predict daily oil, gas, and water production over a five-and-a-half-year producing timeframe as a function of key well completion, placement, and development attributes. Key features in the dataset include geologic properties from well log data, detailed well hydraulic fracturing data and wellbore orientation, artificial lift design data, and well operating conditions, including time-dependent downhole pressure. Best-performing models can predict daily production for oil, water, and gas with accuracy on the order of 79 percent (for water and gas) to 86 percent (for oil). The 2023 study implemented the best performing ML-based model to evaluate its utility for modeling varying drawdown strategies and their associated implications on oil, water, and gas production. The study findings largely support that the application of the deep learning-based model can offer utility in evaluating the effect of pressure drawdown strategies on total hydrocarbon and water production from shale reservoirs—a finding that associates with the increasing interest and adoption of data-driven approaches as important complements to more traditional O&G reservoir development decision-support strategies. The three-stream fluid predictions that resulted from the various pressure management cases evaluated within the study largely trend with notional expectations of unconventional O&G operations undergoing either rapid or more sustained pressure management strategies. Results demonstrate that aggressive and rapid drawdown cases tend to provide earlier peak O&G production relative to the more sustained pressure management cases. However, the more sustained pressure cases produce larger cumulative volumes of oil, gas, and water overall.

The models applied in these NETL studies were largely used to explore one specific aspect of unconventional O&G operations. The sort of rapid and accurate modeling provided through ML in these studies points to much larger analytical potential that can be leveraged and realized to help assess the multitude of completion, design, and production implications associated with unconventional O&G operations. Shale O&G development also carries concerns for water usage, induced seismicity correlated with wastewater disposal through subsurface injection, and flaring (and possible venting) of produced natural gas. The model output from these NETL studies can directly provide the needed insight to support the formulation of water management and/or remedial strategies based on the volumes of fluids expected from unconventional O&G development operational conditions if applied fit-for-purpose for real-world sites. The advancement in data analytics and ML combined with the prevalence of digital datasets and advanced computing resources affords a multitude of opportunities for O&G operators to apply these types of techniques toward improving reservoir management and operational decisions.

Highlights: NETL Water Analysis Considers Impact of Non-Steady-State Operation on Cooling Water Consumption at Coal- and Natural Gas-Fired Power Plants

Increased renewable energy penetration in the electricity grid in coming decades will result in more frequent cycling at thermal power plants. Simultaneously, thermal power plants may face water scarcity with declining availability of cooling water. Therefore, to enhance thermal power plants' resiliency to water shortages, it is important to understand how non-steady conditions due to cycling will impact cooling water consumption and withdrawal intensity. Non-steady operation at power plants has been previously shown to decrease power plant thermal efficiency. Energy balance models have also demonstrated that a decrease in thermal efficiency is expected to increase cooling water consumption intensity. Furthermore, past work has used operating hours data to show idling and cycling gaps where cooling systems operate more than corresponding generators. As a result, an increase in cycling behavior may impact cooling water consumption and withdrawal intensity.

A recently released study by NETL's Strategic Systems Analysis and Engineering directorate used data from the Energy Information Administration and Environmental Protection Agency to quantify the impact of cycling cooling water consumption intensity for recirculating cooling systems and withdrawal intensity for once-through cooling systems using energy balance and statistical approaches. In a novel application of a fixed-effects model to study the effect of temperature on cooling water consumption and withdrawal intensity, the study finds temperature was consistently expected to increase consumption intensity and withdrawal intensity. Non-steady-state conditions do not increase cooling water consumption intensity with statistical significance across unit types. However, additional validation of cooling water data is required to confirm these observed trends due to the sensitivity of these findings to model form and concerns with data quality of the dependent variables, cooling water consumption, and withdrawal.



Cumulative distribution function for monthly cooling water withdrawal intensity (A) and consumption intensity (B) across the 2017 fleet by unit type

In the News

DOE Awards $5 Million Toward Desalination Pilot Program to Advance Water Security

DOE, in partnership with the National Alliance for Water Innovation (NAWI) hub, announced 11 pilot projects across five states that were selected for negotiation to develop pilot systems that will design, build, operate, and test desalination and water reuse treatment systems that produce clean water from non-traditional water sources, such as brackish water, seawater, produced and extracted water, and wastewater. Please click here for the full list of selected projects.

DOE Awards $9 Million to 12 Projects to Advance Desalination and Water Reuse Technologies Across the U.S.

DOE and NAWI announced the selection of 12 projects that will improve the energy efficiency of desalination and water reuse technologies across the country; drive decarbonization of the water and wastewater sectors through innovative technologies to treat, use, and recycle water to bolster a circular economy; and provide the United States with climate-resilient, cost-effective water supplies. Please click here for the full list of selected projects.

DOE to Invest More Than $18 Million to Treat Wastewater, Recover Valuable Minerals

FECM and NETL announced more than $18 million in available funding for research and development projects that focus on the characterization, treatment, and management of produced water—or wastewater associated with O&G development and production—as well as management of legacy wastewater associated with coal-based thermal electric power generation facilities, primarily coal combustion residuals waste streams. This funding opportunity announcement closed in April 2023, with recipients expected to be announced in Autumn 2023.

NETL Researchers Create Technology to Detect Aluminum Impurities in Rare Earth Element Sources

Aluminum is a critical element used in thousands of important products, but it can often interfere with quick and effective extraction of valuable REE from coal waste byproducts. Because aluminum interferes with the recovery of REE from some sources, NETL researchers developed an effective, renewable technology that can detect aluminum in liquids for removal, clearing the way for effective recovery of REE.

NETL Team Uses Microwaves to Cut Costs of Direct Air Capture Technologies

NETL researchers have reported the successful use of microwaves to accelerate sorbent regeneration—results that can lead to substantial reduction of expensive water and energy requirements of some promising direct air capture technologies. NETL Researcher Fan Shi said the microwave-accelerated regeneration of sorbents does not require steam regeneration and a heat exchanger, which makes it an attractive process for CO_2 capture in water-stressed regions of the United States.

NETL Demonstrates New Pipeline Sensor Technologies in a Pilot-Scale Field Test

NETL's pipeline sensor team recently completed successful field tests of an extensive new collection of fiber optic sensor and surface acoustic wave sensor technologies for natural gas pipeline monitoring that can help ensure safer and more secure natural gas pipeline delivery and mitigate greenhouse gas methane emissions. The team has successfully monitored gas flow and leaks, internal water and corrosion, and pipeline conditions such as pressure and temperature changes.

Conferences and Events

These upcoming conferences and events align with NETL's water-energy research efforts.

2023 World Environmental & Water Resources Congress

Description: The 2023 World Environmental & Water Resources Congress will feature 10 concurrent technical tracks over five days. Approximately 800 leading engineers and scientists from around the world attend the conference to discuss the latest research, case studies, and evolving best practices in water resources and the environment.
Date: May 21–25, 2023
Location: Henderson, Nevada
Website: https://www.ewricongress.org/

SPE Workshop: Full Life Cycle Management of Produced Water

Description: The Society of Petroleum Engineers (SPE) is hosting two days of interactive presentations, informative discussions, and networking with other industry experts to expedite, facilitate, and provide a forum for discussion and cooperation on water life cycle and strategy. Produced water accounts for the largest volume byproduct associated with O&G production. An effective full life cycle management program of produced water that improves operational efficiency, optimizes cost, and maximizes it as a resource is critical for the success of upstream development.
Date: May 23–24, 2023
Location: Galveston, Texas
Website: https://www.spe.org/events/en/2023/workshop/23agal/management-of-produced-water.html

LET 2023: Achieving Sustainability Through Water Technology

Description: The International Water Association's Leading Edge Conference (LET) on water and wastewater technologies is designed to be the place for sharing the latest insights into how pioneering science, technological innovation, and leading practices will shape the major transformation in water management that is underway. The wastewater treatment track energy positive wastewater technologies session focuses on energy generation, recovery and balances from heat, electricity, hydrogen, ammonia, sludge, and innovative technologies in wastewater treatment plants.
Date: May 29–Jun. 2, 2023
Location: Daegu, South Korea
Website: https://iwa-let.org/

ACE23

Description: The American Water Works Association's Annual Conference and Exposition (ACE) is the world's premier water conference. More than 10,000 attendees from 80 countries and 450 exhibitors come together to learn, connect, and be inspired to solve global water challenges.
Date: Jun. 11–14, 2023
Location: Toronto, Ontario, Canada
Website: https://www.awwa.org/ace

Clearwater Clean Energy Conference

(47th International Technical Conference on Clean Energy)

Description: The Clearwater Clean Energy Conference offers participants approximately 200 technical presentations in four days. The program presents an extensive overview of emerging, evolving, and innovative technologies, fuels, and/or equipment in the power generation industry.
Date: Jul. 23–28, 2023
Location: Clearwater, Florida
Website: https://clearwatercleanenergyconference.com/

Researcher Spotlight

Madison Wenzlick | Research Scientist | Madison.Wenzlick@netl.doe.gov

Madison Wenzlick is a site-support contractor supporting RIC's Structural Materials Team. Previously, Wenzlick was a Mickey Leland Energy Fellow and Postgraduate Researcher for NETL. She holds a Master of Science in Mechanical Engineering from Carnegie Mellon University and a bachelor's degree in Engineering Physics from Fordham University. Wenzlick is a co-principal investigator supporting the National Energy Water Treatment and Speciation (NEWTS) Database. NEWTS provides easily accessible and usable water-quality datasets on energy-related wastewater streams, which are typically disparate and difficult to find, as an open-source database of significant benefit to the research community and the public. This database provides a tool for scientists to understand, model, and treat energy-water streams. Wenzlick says, "I am excited to leverage my data science expertise and knowledge of water management techniques to contribute to the creation of the NEWTS database." Wenzlick explains that NEWTS will enable researchers to easily identify and curate data related to energy-water streams and improve the management design process.

> *"I am excited to leverage my data science expertise and knowledge of water management techniques to contribute to the creation of the NEWTS database."*

Wenzlick's research interests include energy systems, materials science, and sustainability. Her work at NETL initially focused on addressing management techniques for produced water from O&G operations. She created a process flow model of a mechanical vapor recompression unit used to desalinate high-salinity brine and generate fresh water; this was then leveraged in a full process flow model and cost benefit analysis for treating O&G produced water—around 50% of which is currently a waste stream. Additionally, Wenzlick contributes to projects in Energy-Water, Materials Performance, and Geological and Environmental Science Divisions at NETL. She has been working on materials data science for extreme environment materials characterization and design (eXtremeMAT) for the past four years under the mentorship of leading researchers at NETL. She has supported the development of a materials data collection, organization, and analysis framework. Wenzlick contributed to the creation of a materials database on the mechanical properties, heat treatment, composition, and processing data of alloys. Further, she works to develop statistical and ML models using Python and scikit-learn to predict the tensile and creep properties of steels based on experimental and derived data. Wenzlick has helped guide the projects of Mickey Leland Energy summer fellows working with NETL teams and has served as a mentor for the program on projects related to Energy-Water management.

Wenzlick has authored and co-authored several publications, including a recent water-related book chapter: Standard Water Treatment Techniques and their Applicability to Oil & Gas Produced Brines of Varied Compositions in "Solid–Liquid Separation Technologies Applications for Produced Water" and an article investigating advanced treatment techniques: Techno-economic analysis of converting oil & gas produced water into valuable resources.

Water-Energy Publications

Below are several water-related journal articles, reports, and patents authored or co-authored by NETL staff.

JOURNAL MANUSCRIPTS:

Cost optimization of low-salt-rejection reverse osmosis

Adam A. Atia, NETL; Jeff Allen, National Renewable Energy Laboratory (NREL); Ethan Young, NREL; Ben Knueven, NREL; Tim Bartholomew, NETL (FEBRUARY 2023)

▸ https://www.sciencedirect.com/science/article/abs/pii/S0011916423000395?via%3Dihub

Aqueous Bromide Discharges from U.S. Coal-Fired Power Plants: Points of Origin, Concentration Ranges, and Effluent Treatment Costs

Alison G. Fritz, NETL; Chad Able, NETL; Meagan S. Mauter, Stanford University; Eric Grol, NETL (FEBRUARY 2023)

▸ https://pubs.acs.org/doi/abs/10.1021/acs.energyfuels.2c03364

Energy-efficient and water-saving sorbent regeneration at near room temperature for direct air capture

T. Ji, NETL; H. Zhai, University of Wyoming/Carnegie Mellon University; C. Wang, Johns Hopkins University; C.M. Marin, NETL; W.C. Wilfong, NETL; Q. Wang, NETL; Y. Duan, NETL; R. Xia, University of Delaware; F. Jiao, University of Delaware; Y. Soong, NETL; F. Shi, NETL; M. Gray, NETL (MARCH 2023)

▸ https://www.sciencedirect.com/science/article/abs/pii/S2589234723000076?via%3Dihub

REPORTS:

I-WEST: On the road to carbon neutrality in the Intermountain West – Phase One Final Report

Intermountain West Energy and Sustainability Transitions (I-WEST) Initiative Partners, DOE (DECEMBER 2022)

▸ https://iwest.org/wp-content/uploads/2022/12/I-WEST-Phase-One-Final-Report.pdf

Strategies for Achieving the DOE Hydrogen Shot Goal: Thermal Conversion Approaches

Shannon McNaul, NETL; Charles White, NETL; Bob Wallace, NETL; Travis Warner, NETL; H. Scott Matthews, NETL; Jinliang N. Ma, NETL; Massood Ramezan, NETL; Eric Lewis, NETL; David Morgan, NETL; Megan Henriksen, NETL; John White, NETL; Christopher Munson, NETL; Robert Stevens, NETL; Travis Shultz, NETL (JANUARY 2023)

▸ https://www.netl.doe.gov/energy-analysis/details?id=f0bcf766-8e55-464d-a8ff-e6ca808b3ba4

PATENT:

Low-cost fiber optic sensor array for simultaneous detection of multiple parameters

Chenhu Sun, NETL; Ping Lu, NETL; Ruishu Wright, NETL; Paul R. Ohodnicki, NETL

▸ https://netl.doe.gov/node/12415 and https://patents.google.com/patent/US11268984B2/en

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Get Social with Us

There are several ways to join the conversation and connect with NETL's Water-Energy Research Program:

Partnering with NETL

NETL's partnership activities are central to DOE's core mission. NETL utilizes a complete suite of contractual vehicles, as well as its inherent authority as a GOGO laboratory, to pursue technology development and eventual transfer of technology to the marketplace. NETL's success in developing technology solutions that can be applied to the intersection of water and energy depends upon strong relationships with both public and private entities. From targeted competitive announcements to cooperative research and development agreements, NETL offers a variety of cost-shared funding and partnership arrangements to help move technology and intellectual property through the maturation cycle into the marketplace.

For more information on partnering with NETL in the water-energy space, contact:

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https://netl.doe.gov/water-energy-research

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