

### Advanced Remediation Technologies – Water Management Program Overview

October 25, 2022



# **ART-WM Background**



#### Historically, NETL water programs have operated under multiple directorates:

- The FECM Water Management for Power Systems program has operated under NETL's Crosscutting Research Program (FE-20).
- While never a formal "program," Produced Water Treatment R&D projects have operated within NETL Oil & Gas upstream research (FE-30).





# Water Management and Produced Water have been Integrated within FE-30 (Advanced Remediation Technologies).

- Both programs have a demonstrated record of projects that advance the water technology space and successfully reach the commercial market.
- Technology developments across both groups are interoperable and can produce additional complimentary projects to reduce environmental impacts from fossil fuels and impacts to freshwater resources.

#### Key Program Areas:

- Remediation of legacy waste from fossil-based power generation and O&G activities.
- Recovery of critical minerals, rare earths, and other beneficial resources from associated waste streams.
- Water recycling and reuse.



## Advanced Remediation Technologies Water Management (ART-WM) Overview



- Sustainable water management responding to increased water demand from decarbonized power generation.
- Providing alternative water resources in water-stressed areas by treating wastewaters from fossil energy activities and making those treated wastewaters available to end-users outside the fossil energy industry
- Reducing environmental impacts of fossil fuel generation during the transition to clean energy

# *Objectives*

- Remediation of wastewaters associated with coal power generation
- The characterization, treatment, and management of produced water during oil and gas operations
- The **recovery** of critical minerals and rare earths, and other beneficial resources from fossil energy associated waste streams and effluent waters.



- Develop, scale, and deploy technologies
- Inform decision-makers
- Prioritize R&D for maximum impact
- Engage regional stakeholders
- Accelerate innovation in the water-energy sector

# **ART-WM** is a Unique Integration of Water Programs

All water related R&D within the FECM portfolio will be executed by ART-WM, representing the first combined program of its type within DOE

## ART-Water Management R&D Program (ART-WM)



Based on project data as of 10/01/2022

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# Water Management for Power Systems Project Portfolio

#	Project Portfolio							
1	Techno-Economic Modeling of Treating Energy Influent and Effluent Wastewater Streams							
2	Selective Removal of Heavy Metals for Effluent Streams							
3	Concentrating Wastewater Effluent Streams and Resource Recovery							
4	US Water-Energy Nexus Modeling							
5	Biological Treatment of FGD Effluent Streams							
6	Characterization of FGD Effluent Streams							
7	National Energy Water Treatment & Speciation (NEWTS) Database							
8	Flue-Gas Desulfurization Effluent Management Using an Innovative Low-Energy Biosorption Treatment System to Remove Key Contaminants (ES Engineering Services, LLC; Completion Date: 12/31/2022)							
9	Electrodialysis Reversal Pilot Test (ION Clean Energy, Inc.; Completion Date: 04/30/2023)							
10	Improvement of Coal Power Plant Dry Cooling Technology Through Application of Cold Thermal Energy Storage (University of North Carolina Charlotte; Completion Date: 06/30/2023)							
11	Advanced Dry-Cooling with Integrated Enhanced Air-cooled Condenser and Daytime Load-Shifting Thermal Energy Storage for Improved Powerplant Efficiency (University of Cincinnati; Completion Date: 01/31/2024)							
12	Clean Water Production in Cooling Towers (Infinite Cooling, Inc.; Completion Date: 07/01/2024)							
13	Application of Heat Transfer Enhancement (HTE) System for Improved Efficiency of Power Plant Condensers (Interphase Materials, Inc.; Completion Date: 07/31/2022)							
14	Enhanced Cooling Tower Technology for Power Plant Efficiency Increase and Operating Flexibility (GTI; Completion Date: 09/30/2022)							
15	Water Recovery from Cooling Tower Plumes (Infinite Cooling, Inc.; Completion Date: 09/30/2022)							
16	Wastewater Recycling Using a Hygroscopic Cooling System (UND-EERC; Completion Date: 09/30/2022)							
As of	As of October 1, 2022 RIC Extramural Recently Completed							

As of October 1, 2022

RIC

Recently Completed



# **Produced Water Project Portfolio**

#	Project Portfolio			
1	An Optimization Framework for Produced Water Management and Beneficial Reuse			
2	Produced Water Characterization			
3	Produced Water Research Partnership			
4	Hydrogen-Recovery Using an Al-ARC-Plasma Learning Operational System (HALO) for Oilfield Waste Transformation to Value Added Products (Oceanit; Completion Date: 11/13/2022)			
5	A New Membrane Based Treatment Process for Reclaiming and Reutilization of Produced Water (TDA Research, Inc.; Completion Date: 02/05/2023)			
6	Development of Novel Ligands Used in Ion Flotation for Produced Water Value Extraction (Glycosurf, LLC; Completion Date: 02/13/2022)			
7	Mesofluidic Inline Separation for Produced Water Treatment (PNNL; Completion Date: 06/29/2023)			
8	Non-Fouling, Low Cost Electrolytic Coagulation & Disinfection for Treating Flowback and Produced Water for Reuse (University of Arizona; Completion Date: 06/30/2023)			
9	First and Produced Water Initiatives* (Ground Water Protection Council; Completion Date: 09/30/2023)			
10	Produced Water Management Through Geological Homogenization, Conditioning, and Reuse (UND-EERC; Completion Date:: 1/31/2022)			
11	Fouling-Resistant, Chlorine-Tolerant Zwitterionic Membranes for Treatment of Produced Water in the Permian Basin (ZwitterCo, Inc.; Completion Date: 5/31//2022)			
12	Resource Recovery and Environmental Protection in Wyoming's Greater Green River Basin Using Selective Nanostructured Membranes (University of Wyoming; Completion Date: 5/31/2022)			
13	Magnetic Nanoparticle Extraction of Lithium from Produced Waters (PNNL; Completion Date: 9/30/2022)			

\*Congressionally directed work managed by NETL

As of October 1, 2022



Recently Completed



#### **ART-WM Currently Funds Projects in 13\*\* States\*** Data from VUE pulled 10/2022



State	Total Projects	T	otal Award Value (M)
AZ	Z 1		1.17
CA	1	\$	0.94
СО	2	\$	2.59
HI	1	\$	0.20
MA	1	\$	1.59
NC	1	\$	1.82
OH	1	\$	1.87
PA**	4	\$	12.78
UT	1	\$	0.21
WA	1	\$	0.49

\*\*All projects listed in PA are work completed by NETL-RIC. This work is reported in the VUE in PA but the map has been updated to show work on these projects also taking place in ND, OR, and WV.

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U.S. DEPARTMENT OF

Fossil Energy and Carbon Management

\*Not included in these totals is Congressionally-Directed work by the Ground Water Protection Council to maintain and improve RBDMS and FracFocus, (a \$32M DOE investment since 2016). This effort is managed through NETL.

# **ART-WM Capabilities and R&D Infrastructure**

### The ART-WM portfolio is coordinated across four

### R&D areas:

- 1. Advanced treatment processes
- 2. Biological and chemical characterization
- 3. Advanced computing systems, artificial intelligence, and big data
- 4. Systems, lifecycle, and technoeconomic analysis

## Development of physical treatment and digital tool

### <u>infrastructure</u>

- Produced Water Optimization Initiative (PARETO)
- <u>National Energy Water Treatment and Speciation (NEWTS)</u> <u>database</u>
- Brine Extraction Storage Test Site (BEST)
- National Energy Modeling System (NEMS) Water
- Chemical and biological characterization @ NETL









### Advanced computing systems, artificial intelligence, and big data at ART-WM

Biological Characterization Database	Organics Characterization	NEWTS	PARETO	
<ul> <li>Data crawl/curation</li> <li>Database development</li> <li>Exploratory data analysis</li> <li>Network analysis</li> </ul>	<ul> <li>Data crawl, curation</li> <li>Database development,</li> <li>Primary data acquisition (field sampling)</li> <li>Exploratory data analysis</li> <li>Predictive models for chemical transformation</li> </ul>	<ul> <li>Primary data acquisition/field sampling</li> <li>Integrating ML for outlier identification, classification, interpolation, outlier identification</li> <li>Predicting REE concentrations, determining brine origin</li> </ul>	<ul> <li>Optimal network design</li> <li>Algorithms and formulations to enhance the scalability and computational efficiency network design and operation problems.</li> <li>ML-assisted decision- making, forecasting</li> </ul>	



# How does ART-WM develop new projects/programs?

	Scout opportunity spaces	Refine concepts	Characterize technical challenges	Hypothesize solutions	Develop solutions	Scale solutions
Capability dependency by stage	$\bigcirc \bigcirc \bigcirc \bigcirc \bigcirc \bigcirc$					
What will we do?	<ul> <li>Value chain mapping and market insights (segmentation, sizing,</li> <li>Solution baseline (rough costs, vendor landscape)</li> <li>Competitive analysis (emerging tech, strengths/weaknesses)</li> </ul>	<ul> <li>Identify customer needs</li> <li>Map value chain challenges/opportunities</li> </ul>	<ul> <li>Articulate technical challenges (organic/bio, inorganic, tech dev, and generalized data)</li> </ul>	<ul> <li>Design concepts</li> <li>Articulate market fit</li> <li>Understand system content</li> </ul>	<ul> <li>Test concepts</li> <li>Identify partnerships</li> <li>Perform cost-benefit analysis</li> <li>Gather program data</li> </ul>	<ul> <li>Identify addressable sources</li> <li>Identify synergies</li> <li>Engage customers</li> <li>Pilot test</li> </ul>
What will we produce?	<ul> <li>Focus market segments/ water types</li> <li>Competitive insights</li> <li>Estimate of general societal need(s)</li> </ul>	<ul> <li>Solvable challenges</li> <li>Unmet needs</li> <li>Unrealized opportunities</li> <li>Estimate of specific societal need(s)</li> </ul>	<ul> <li>Scientific/technical challenges</li> <li>Current solutions and room for improvement</li> <li>Estimate of societal impact of solution</li> </ul>	<ul> <li>Technical concept(s)</li> <li>MVP of solution to problem</li> </ul>	<ul><li>Technical prototype(s)</li><li>Business case</li></ul>	<ul> <li>Priority customers</li> <li>Catalogue of addressable sources</li> <li>Pilot plan</li> </ul>
How will we decide to continue?	The opportunity space has 1 or more attractive market segments where we have the capabilities to deliver value	There are 1 or more compelling unmet customer needs/value chain challenges that we believe we can address	We believe we can overcome the scientific/technical challenges and deliver a solution that improves upon existing solutions	Our technical concept could be feasibly produced, and addresses needs/challenges identified earlier	Our technical prototype could be feasibly produced while remaining economically viable, and continues to address needs/challenges identified earlier	We have a working prototype that we can bring to bear within identified market/customer segments on an agreed upon timeline
Traditiona	al capability Ma urce Ed	arkets and Techno- conomic Analysis	Characterization	Systems an optimiza	alysis, tion	tion development creatment, software

# **Recent Activities**

#### AN OPTIMIZATION FRAMEWORK FOR PRODUCED WATER MANAGEMENT AND BENEFICIAL REUSE (FWP-1022477)



Goal: Develop a modeling and optimization application to identify cost-effective and environmentally sustainable produced water management, treatment, and reuse solutions. PARETO will help with the:

- **Buildout** of the produced water infrastructure
- Management of produced water volumes
- Selection of effective treatment technologies
- Placement and sizing of treatment facilities
- Identification of beneficial water reuse options
- Distribution of treated produced water for reuse

#### WATER MANAGEMENT FOR POWER SYSTEMS (FWP-1022428)



Goal: Lead the critical national R&D effort directed at removing barriers to sustainable, efficient water and energy use at fossil power plants by developing technology solutions and enhancing the understanding of the relationship between energy and water resources. NETL will work to overcome the following challenges:

- **Reduce freshwater consumption** by 50%.
- Lower the cost of treating fossil power plant effluent streams by 50%.

#### PRODUCED WATER CHARACTERIZATION (FWP-1025013)

This work will focus on the critical national R&D effort directed at characterizing produced water associated with sustainable oil and gas development. The work proposed is aligned with DOE-FECM's Program goals to reduce freshwater consumption and to recover valuable resources from both effluent and alternative influent water streams.

#### PRODUCED WATER RESEARCH PARTNERSHIP (FWP-1025012)

Leveraging its core capabilities, competencies, and authorities, NETL will partner with universities and industry to **develop and increase to commercial readiness** the technology needed to treat and manage produced water from oil and natural gas operations.



# **EY 22 Program Highlights**

- Release of RFI "Water Research and Development for Produced Water and Legacy Wastewaters Associated with Thermal Power Plants"
  - Diverse respondents from industry, academia, national labs, non-profits, and research centers
- Founding member of FECM Artificial Intelligence Community of Interest
- Engagement and coordination with water-energy working groups within DOE and across federal agencies
- Engagement with key produced water and power systems stakeholders
- Quarterly release of Water-Energy Nexus Newsletter

U.S. Department of Energy Seeks Information on Water Research Needs Related to Produced Water and Legacy Wastewaters Associated with Thermal Power Plants



# **EY 22 Program Highlights**

#### **Produced Optimization Initiative (PARETO)**

- Produced water management optimization framework incorporated water quality analysis, pipeline hydraulics modeling, treatment solutions, and enhanced documentation for beginners
- Completed initial case study with industry partner and expanded engagement with industry
- Developed new partnership with GWPC and expanded project scope to include water-sharing
- 2022 Hart Energy Meritorious Engineering Award

#### National Energy Water Treatment and Speciation (NEWTS)

Database Team released the first set of public data on September 30, 2022, which included three large datasets with EPA FGD power plant effluent, USGS brackish water, and USGS produced water compositions

 Compositions from >4,000 FGD power plant effluent streams, >15,000 of the most complete and highest salinity brackish waters, and >15,000 of the most complete and high salinity produced water compositions were released in the format and speciation necessary for easy input into aqueous chemistry modeling software, such as OLI Studio & Geochemist Workbench.



# **EY 22 Program Highlights**

### **Treatment Technologies**

- Developed sorbent materials/pretreatment process with removal rate of Se species, heavy metals, and NO<sub>3</sub><sup>-</sup>/NO<sub>2</sub><sup>-</sup> by over 90%
- Development of novel microbial treatment of FGD wastewater, including removal and recovery of selenium
- TDC/RIC/WVU generated API-grade barite (critical mineral) from co-treatment
- TDC/RIC/UND EERC BEST: Pilot tested 4 water treatment technologies

## Systems Analysis

- Evaluated feasibility of alternative cooling water sources
- Calculating the true cost of water use across all phases of electricity generation to provide incentive for water use efficiency
- Prioritizing commercializing promising portfolio technologies to expedite availability of water reduction technologies on the market
- Established regional variation and national loadings of trace elements in landfill leachate



2021

# **Extramural Successes**

### WATER MANAGEMENT FOR POWER SYSTEMS



Application of Heat Transfer Enhancement (HTE) System for Improved Efficiency of Power Plant Condensers

- **Demonstrated success from testing at full-scale** across HVAC chillers, industrial heat exchangers, engine cooling, and a power plant condenser.
- Test data revealed the reduced heat rate can save an ~\$190k in fuel costs and 12,800 less tons CO2 produced.



#### Flue-Gas Desulfurization Effluent Management Using Innovative Low-Energy Biosorption Treatment System to Remove Key Contaminants

- Down-selected to adsorption media that demonstrates 90% selenium removal.
- Completed testing protocol for demo scale set-up.
- Procured and installed biosorption treatment system at Plant Bowen.

### PRODUCED WATER



#### Fouling-Resistant, Chlorine-Tolerant Zwitterionic Membranes for Treatment of Produced Water in the Permian Basin

- Validated filtration capabilities for various applications (e.g., dairy wastewater).
- **Determined product end uses**: gas plants, cropland irrigation, and surface water augmentation.
- **Finalized logistics for upcoming produced water testing** with the BGNDRF facility in Alamogordo, NM (Q2 FY2022).



# A New Membrane Based Treatment Process for Reclaiming and Reutilization of Produced Water

- **Demonstrated process technical viability** to reduce TDS and TOC of produced streams to low concentrations.
- Technoeconomic analyses conducted found that the TDA system can provide produced water treatment for <\$3/barrel.</li>