Water Management for Power Systems RIC FWP

PIs: Eric Grol, McMahan Gray, Nicholas Siefert, Erik Shuster, Djuna Gulliver, Dustin McIntyre, Tim Skone

Technical Portfolio Lead: Nicholas Siefert

HQ Project Manager: Sam Thomas

Technology Manager: Briggs White

Senior Fellow: David Miller

May 17, 2021

NATIONAL ENERGY TECHNOLOGY LABORATORY

Water Management for Power Systems

Program Goal

The Water Management for Power Systems FWP seeks to reduce water consumption at both new and existing fossil power plants, as well as to decrease the cost of treating power plant effluent streams by converting them into valuable resources

Tasks:	Principal Investigator
• Task#2: Guiding R&D for Treatment of Fossil Power Plant Effluent Streams	Eric Grol
• Task#3: Selective Removal of Heavy Metals from Effluent Streams	McMahan Gray
• Task#4: Concentrating Wastewater Effluent Streams & Resource Recovery	Nicholas Siefert
• Task#5: Impact of Water Use of Power Systems	Erik Shuster
• Task#6: Biological Treatment of FGD Effluent Streams	Djuna Gulliver
• Task#7: Characterization of FGD Effluent Streams	Dustin McIntyre
• Task#8: Water Management for Fossil-Based Hydrogen Production	Timothy Skone

EPA Limits on Effluent vs. FGD Compositions

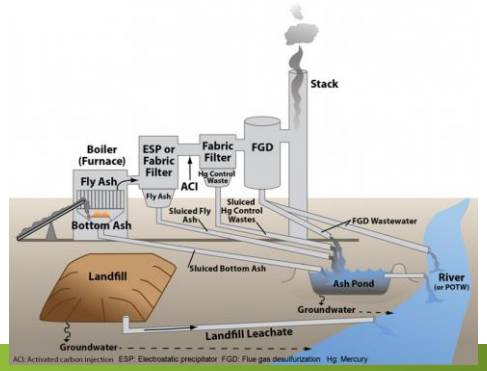
2020 New Final Ruling

Pollutant	Unit	Avg	Monthly Avg Lim
Arsenic, total	(ug/L)	5	9
Mercury, total	(ng/L)	13	34
Selenium, total	(ug/L)	16	29
Nitrate/nitrite as N	(mg/L)	2	3

EPA Data Collected during Initial Rule Making

Pollutant	Unit	PP June 22 2010	MF July 12 2010	A Aug 2 2010	BC June 2010
Arsenic, total	(ug/L)	160	937	120	240
Mercury, total	(ng/L)	2,080,000	166,000	50,300	291,000
Selenium, total	(ug/L)	15,000	3,400	1,500	6,600
Nitrate/nitrite as N	(mg/L)	160	72	14	16

Link to Aug 31, 2020 Ruling Published Oct 13 2020 to Federal Register



EPA ELG Final Rule: October 2020

TABLE XIV–1—LONG-TERM AVERAGES AND EFFLUENT LIMITATIONS AND PRETREATMENT STANDARDS FOR FGD WASTEWATER FOR EXISTING SOURCES (BAT/PSES)[a]

Subcategory	Pollutant	Long-Term average	Daily maximum limitation	Monthly average limitation
Requirements for all plants not in the VIP or subcategories specified below (BAT & PSES).	Arsenic (µg/L	4.98	18	8
	Mercury (ng/L)	13.48	103	34
	Nitrate/nitrite as N (mg/L).	2.14	4	3
	Selenium (µg/L)	15.87	70	29
Voluntary Incentives Program for FGD Wastewater (existing direct dischargers).	Arsenic (µg/L)	[b]5.0	5	NA
	Mercury (ng/L)	5.44	23	10
	Nitrate/nitrite as N (mg/L).	0.89	2.0	1.2
	Selenium (µg/L)	7.35	10	NA
	Bromide (mg/L)	0.200	0.2	NA
	TDS (mg/L)	86.06	306	149
Low utilization subcategory-AND-High FGD flow subcategory (BAT & PSES).	Arsenic (µg/L)	5.98	11	8
	Mercury (ng/L)	159	788	356

[a] BAT effluent limitations for EGUs that will permanently cease the combustion of coal by December 31, 2028, are based on the previously established BPT limitations on TSS and are not shown in this table. The BAT effluent limitations for TSS for these EGUs are: Daily maximum of 100 mg/L; and monthly average of 30 mg/L.
[b] Long-term average is the arithmetic mean of the quantitation limitations because all observations were not detected.
[c] Limitation is set equal to the quantitation limit for the data evaluated.
[d] Monthly average limitation is not established when the daily maximum limitation is based on the quantitation limit.

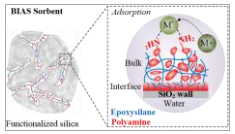
2020-19542.pdf (govinfo.gov)

Overview of RIC's Experimental Efforts

FGD Effluent

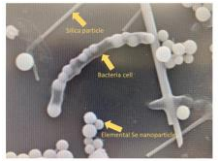
LIBS Sensor (Task 7) *Ending*

Cation Heavy Metal Removal: **Hg^{+2}**, Pb^{+2}, Cd^{+2}, Co^{+2}



Task 3

Anion Redox Removal: SeIV/VI to **Se**, AsIII/V to **As**, NIII/V to **N_2**



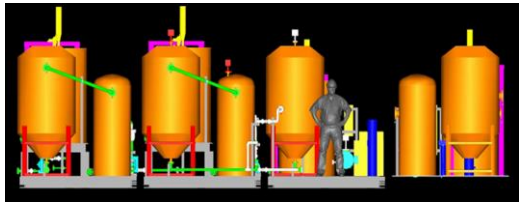
Tasks 6

LIBS Sensor (Task 7) *Ending*

To meet existing regulations

To recover resources and to achieve ZLD

New UF/NF/RO Treatment Skid



Task 4

Brine Concentration

Existing MVR

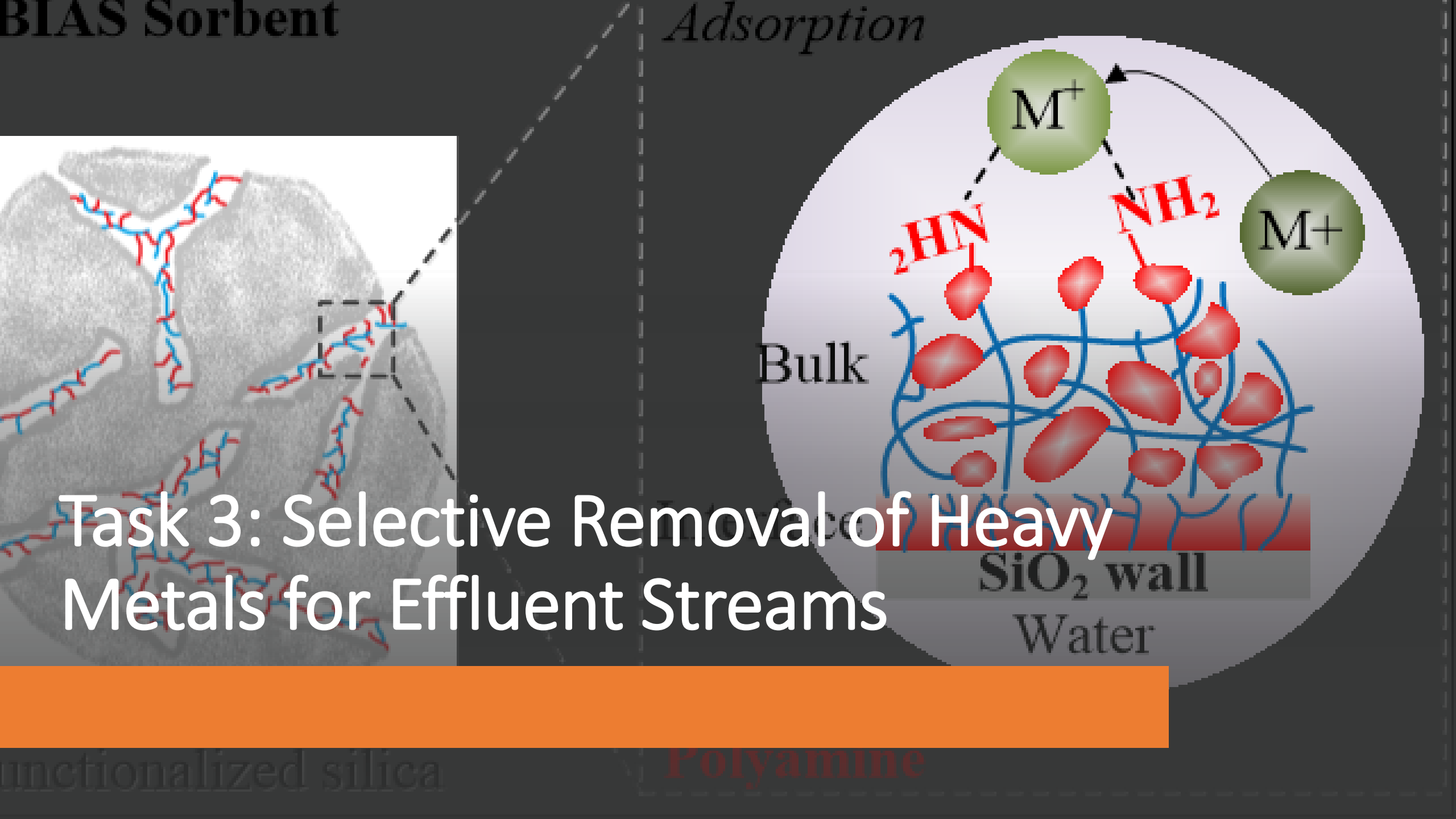
10-lb brine / Road Salt

Fresh Water Make-up

Fresh Water Make-up (Boron removal)

Limestone Make-up

Barite (Drilling Additive)



Task 3: Selective Removal of Heavy Metals for Effluent Streams

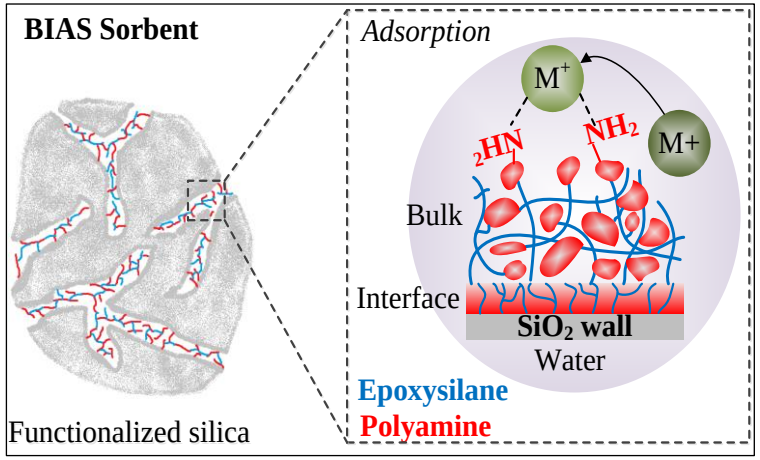
Task 3: Selective Removal of Heavy Metals for Effluent Streams

Objective

- Design and test low-cost sorbents selectively remove heavy metal and other regulated species from FGD effluent

Results

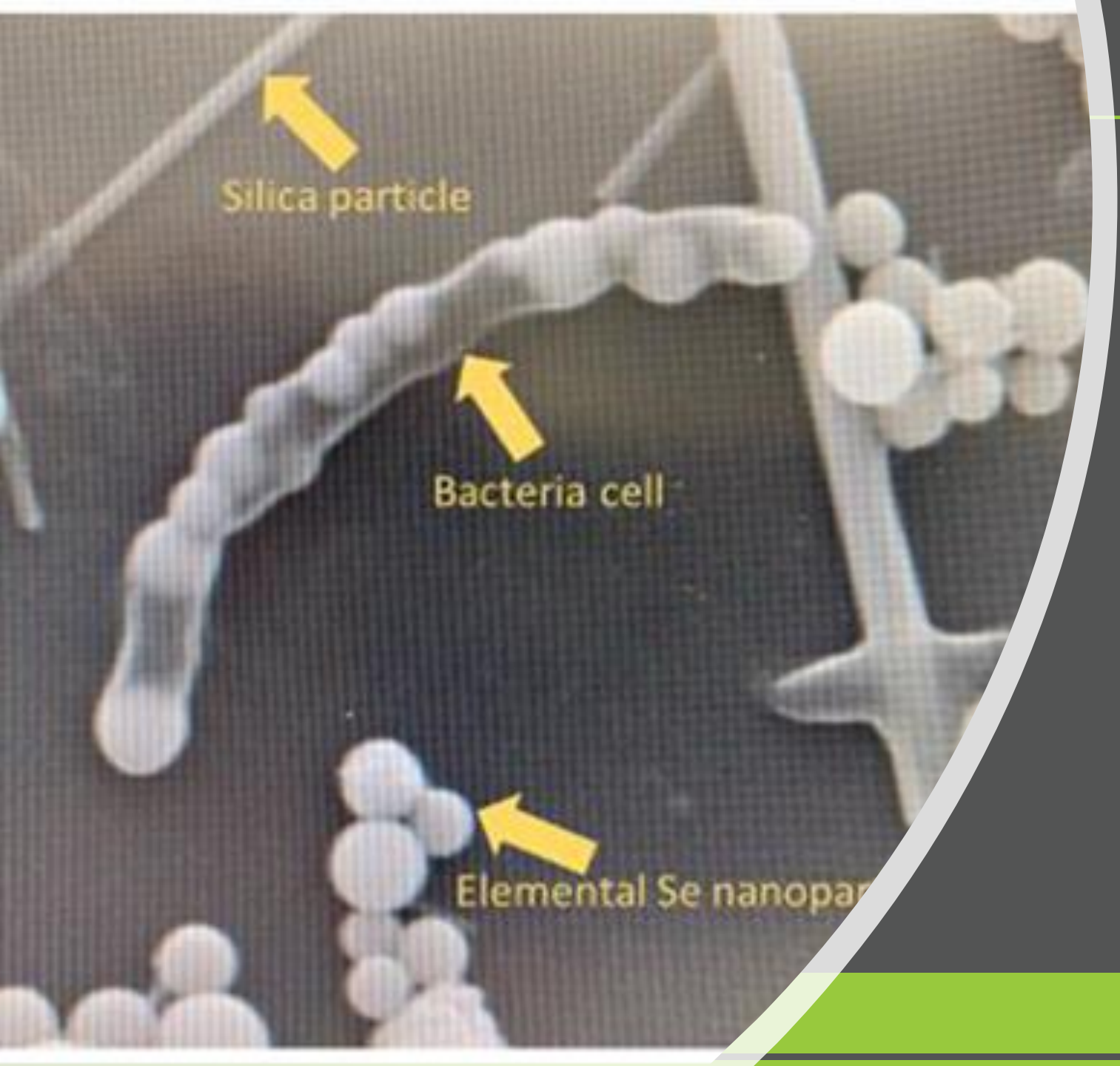
- Three NETL sorbents selectively reduced Se concentrations below the EPA discharge limit from Somerset FGD water.
- Two NETL sorbents selectively reduced Hg concentrations below the EPA discharge limit (<5.1 ppt) from Longview FGD water, while simultaneously removing 99% of Mn, 99% of Al, 95% of Co, 99% of Ni, and 60-93% of Cd.



Tech Transfer

1 Journal article, 2 presentations, 3 patent applications

1. M. L. Gray, B. W. Kail, W. C. Wilfong, Q. Wang, Stable immobilized amine sorbents for REE and heavy metal recovery from liquid sources. Published April 2018, WO2018071730A1 (**Licensed to PQ Corp.**)
2. B. W. Kail, M. L. Gray, W. C. Wilfong, Q. Wang, F. Shi, Metal-loaded Basic Immobilized Amine Sorbents for the Removal of Metal Contaminants from Waste water. Jul. 17, 2019, US 62875364 (**New: Licensed to Somerset Environment**)
3. M. L. Gray, B. W. Kail, W. C. Wilfong, Q. Wang, F. Shi. Multi-Functionalized Basic Immobilized Amine Sorbents for Removal of Metal Contaminants from Wastewater. Filed Jul. 18, 2019, US 62875829 (**New: Licensed to Somerset Environment**)



Task 6: Biological treatment of FGD effluent streams

Microbial Selenium Treatment of FGD Effluent

Enrichments of Anaerobic Selenium Oxyanion Reducers

Preom Sarkar ORISE

NATIONAL ENERGY TECHNOLOGY LABORATORY

Background

78.971 | 940.96 | 2.55 | 34

Se

Selenium

[Ar] $4s^2$ $3d^{10}$ $4p^4$

Nonmetal

+6 +5 +4 +3 +2 +1 -1 -2

Why should we care about selenium?

Chemical element selenium is a nonmental found in coal and is then released into the environment via coal fired powerplants. Small amounts of this element can cause detrimental ecological consequences. The EPA 2020 ELG rule seeks to limit the concentrations of selenium and other contaminants from steam electric power generating sources. **Currently it is known that biological treatment can remove dissolved selenium species, but not much is known about the organisms with this capability.**

Project Objective

Enrich + Identify + Characterize = Optimization

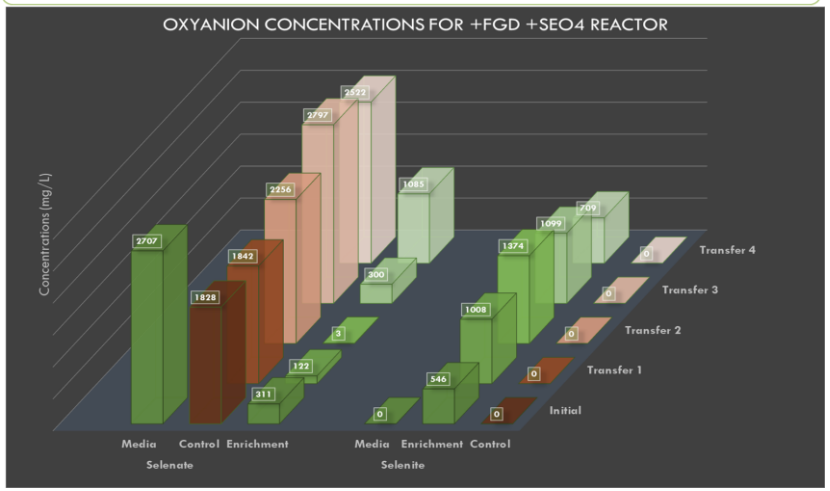
Experimental Design

SeO_4^{2-} (Selenate –Soluble) → SeO_3^{2-} (Selenite – Soluble) → Elemental Se (Nanospheres – Insoluble)

After 7 Day incubation, elemental selenium formation

Results and Analysis

IC Analysis

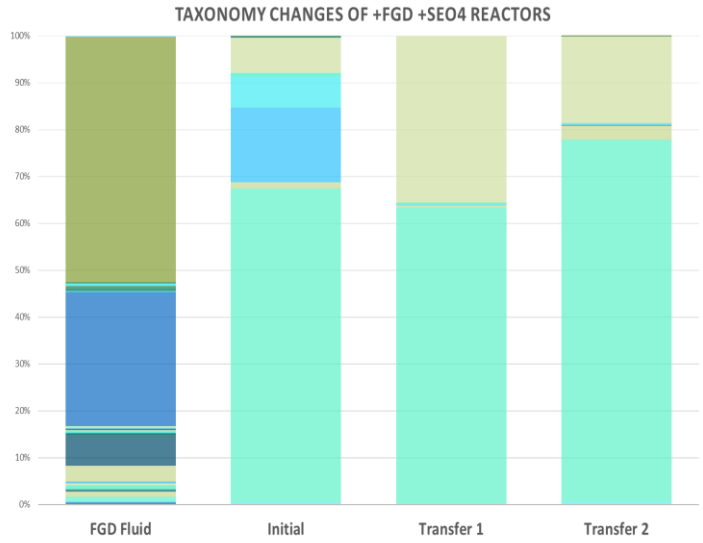


IC analysis shows evidence of up to 99.9% removal of selenate by microbes.

Unknown *bacillus* starts at 0.9% gets as high as 77% of community.

Unknown *anaerosolibacter* starts at 0.4% gets as high as 35% of community.

Taxonomy



U.S. DEPARTMENT OF ENERGY

Literature review completed: White paper summarizing current state of knowledge on biological FGD effluent treatment with implications and path forward. **"Biological Treatment of Flue Gas Desulfurization Wastewater"**

SEM Imaging of Microbial Processes

Applied to Microbial Selenium Treatment of FGD Effluent

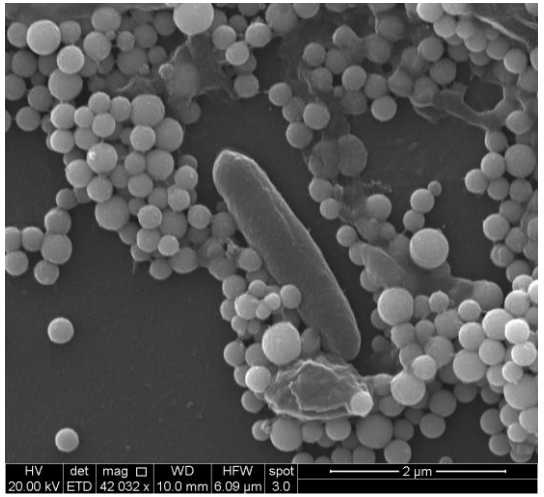
Meghan Brandi (LRST)

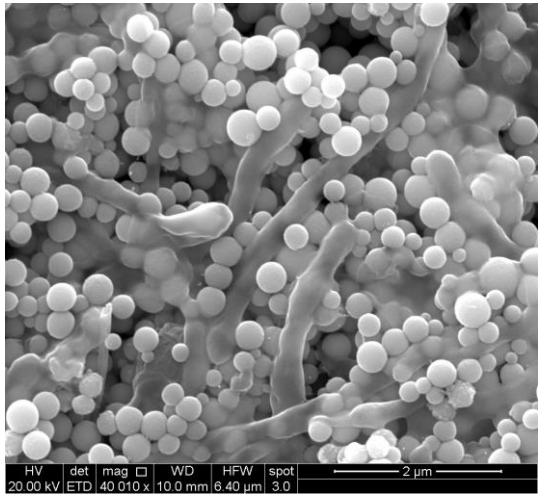
NATIONAL ENERGY TECHNOLOGY LABORATORY

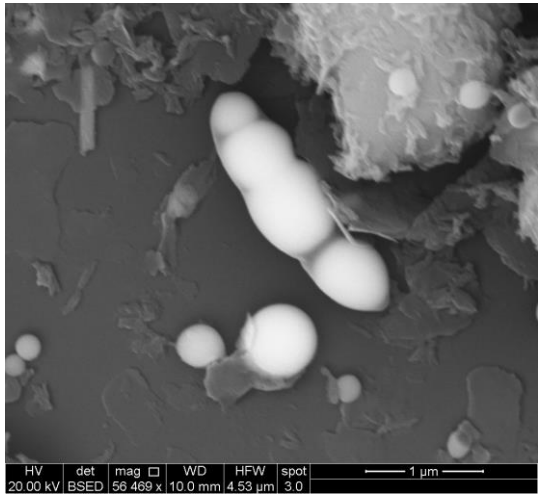
Scanning Electron Microscope

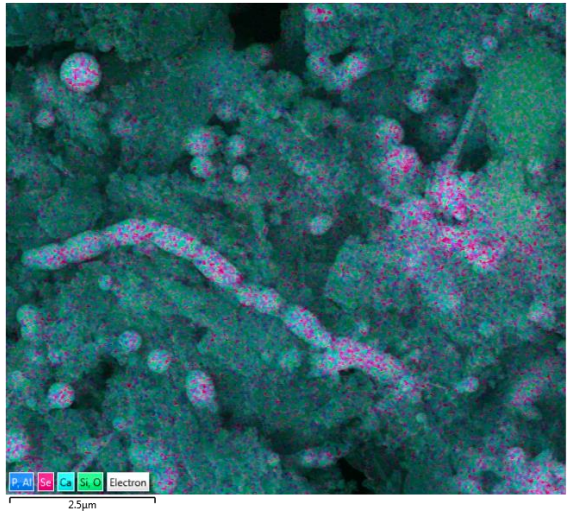
- Provides useful high-resolution visual element to research
- Biological samples require additional preparation

Nanospheres observed both attached to and within microbes:









Energy Dispersive Spectroscopy (EDS)

- Qualitative, semi-quantitative elemental analysis
- Capable of producing colorized phase maps, and much more

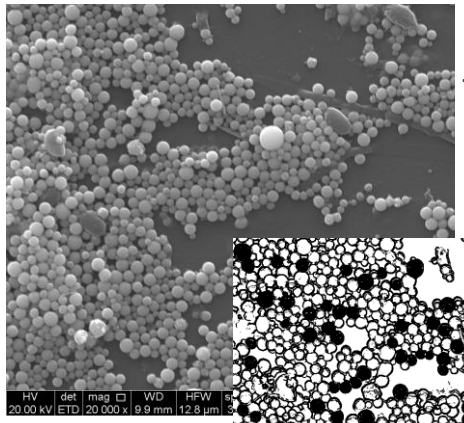
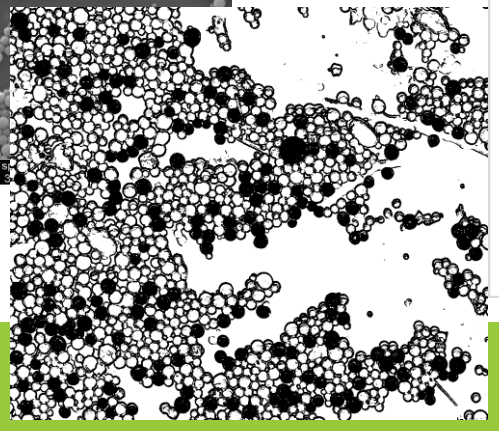
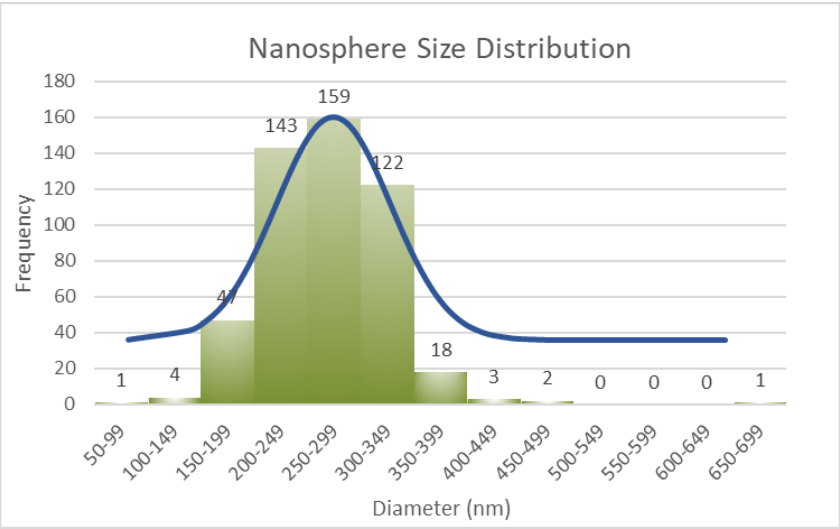
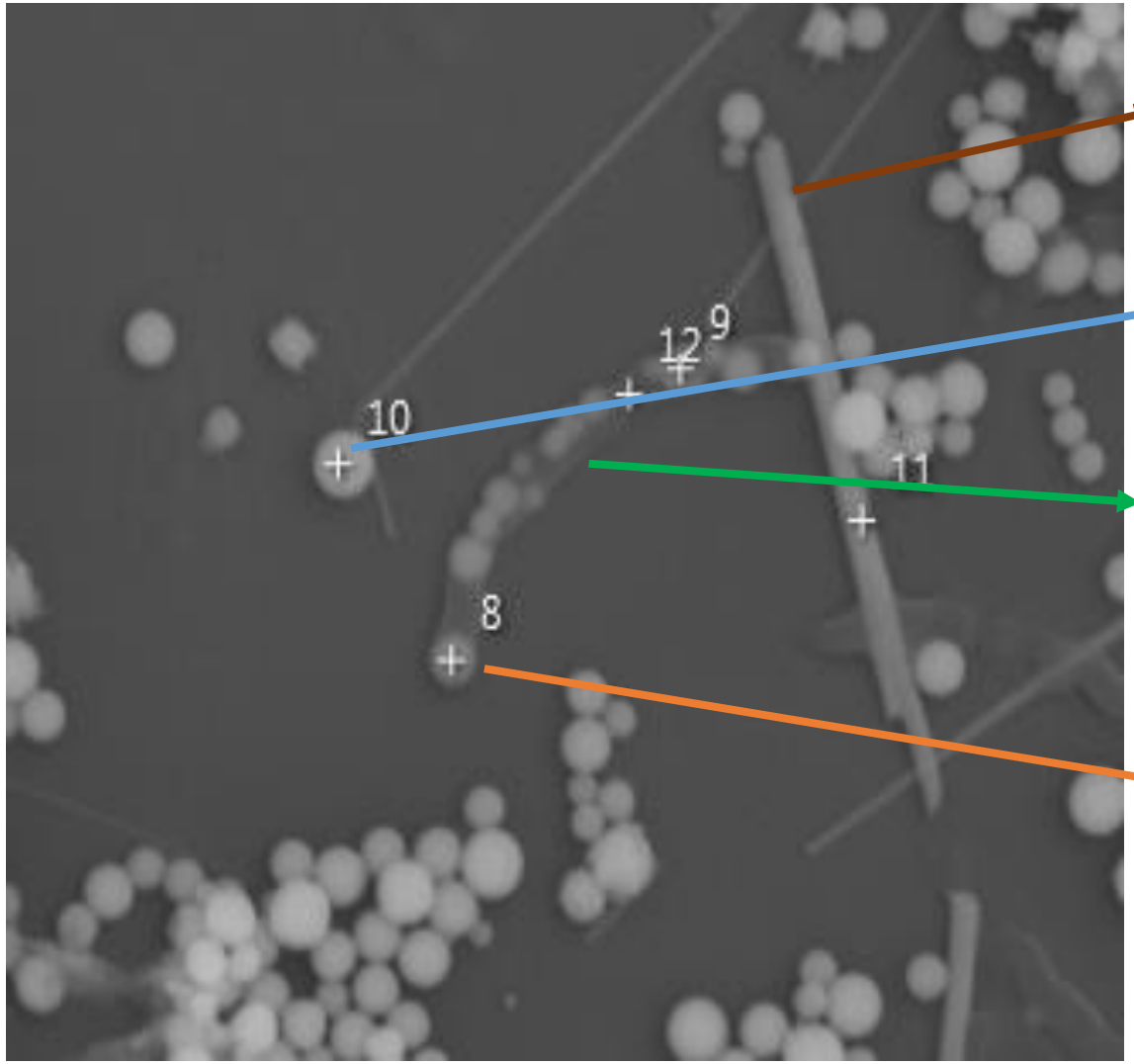


Image analysis for particle size distribution



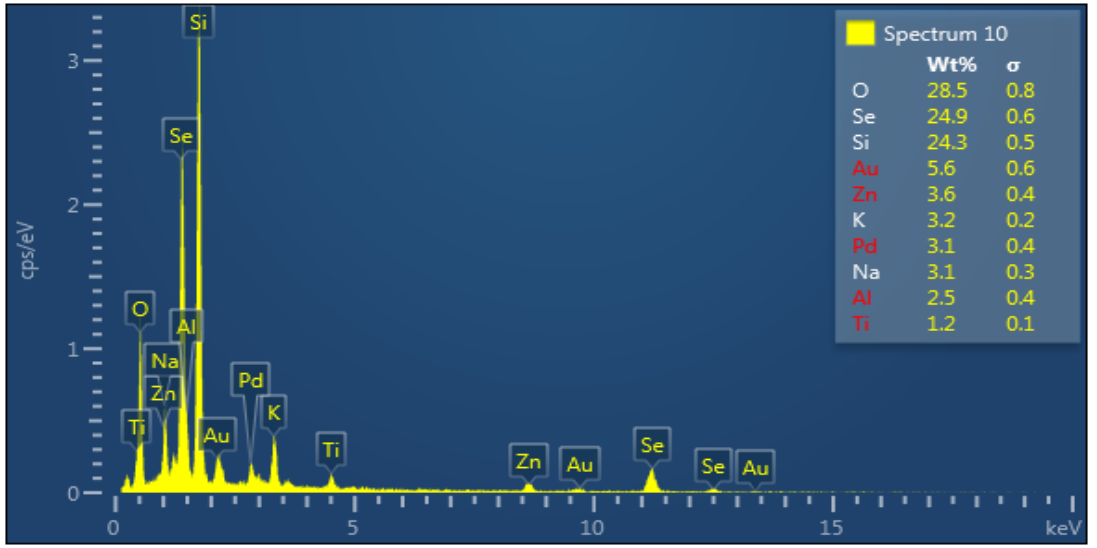


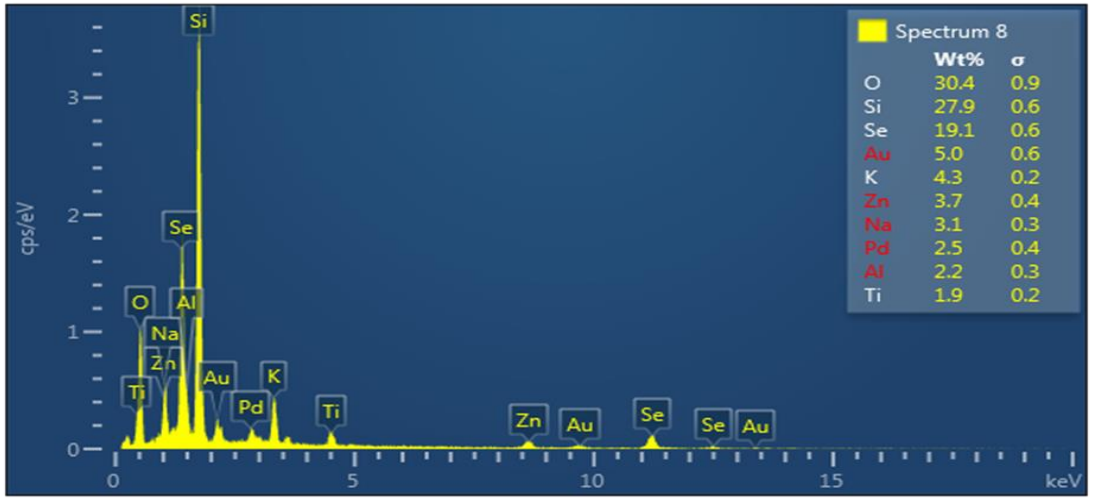
Precious Metals in Biological Nanoparticles



Silica

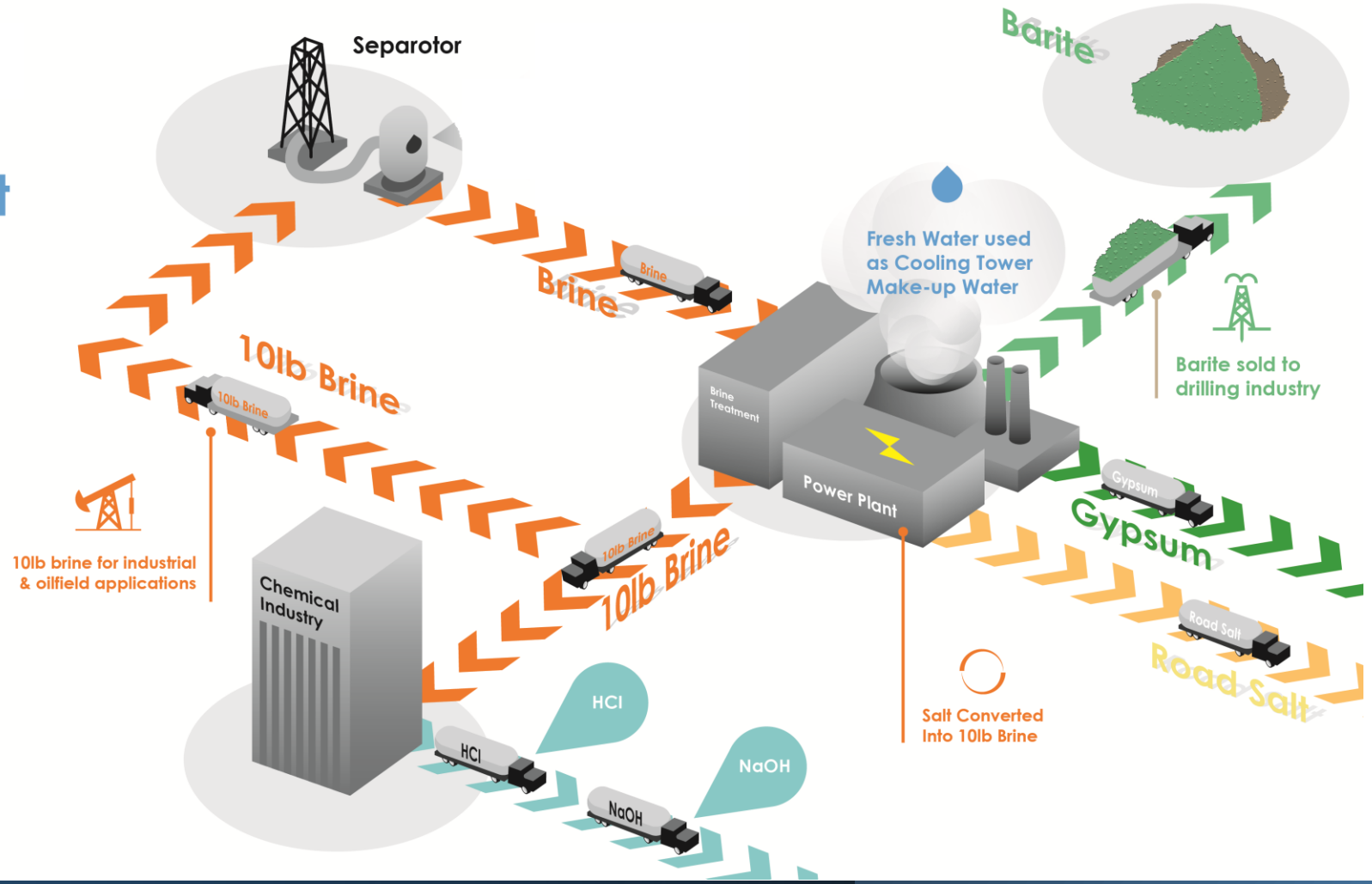
Bacteria





SEM/EDS shows that Se, Au, Zn, and Pd are all found in the nanoparticles (Si from background)

Water Treatment
Future Practice

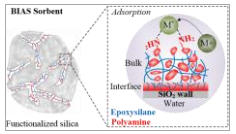


Task 4: Concentrating Wastewater Effluent Streams & Resource Recovery

Overview of RIC's Experimental Efforts

FGD Effluent

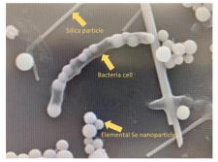
Cation Heavy Metal Removal: **Hg^{+2}**, Pb^{+2}, Cd^{+2}, Co^{+2}



Task 3

LIBS Sensor (Task 7) *Ending*

Anion Redox Removal: SeIV/VI to **Se**, AsIII/V to **As**, NIII/V to **N_2**



Tasks 6

To meet existing regulations

LIBS Sensor (Task 7) *Ending*

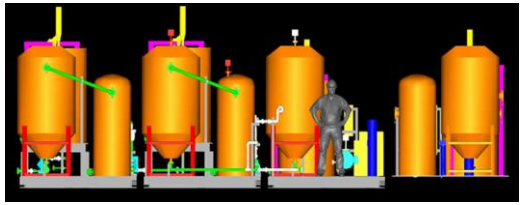
To recover resources and to achieve ZLD

10-lb brine / Road Salt

Brine Concentration

Existing MVR

New UF/NF/RO Treatment Skid



Task 4

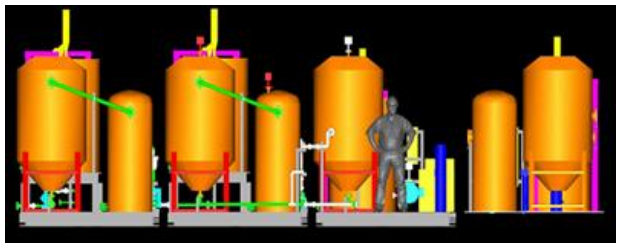
Fresh Water Make-up

Fresh Water Make-up (Boron removal)

Limestone Make-up

Barite (Drilling Additive)

Pilot Skid Designed to Operate on FGD Effluent



Optional Recirculation Stream with Bleed Stream

Input FGD Effluent

1

Solids Separation

2a

2b

Solids

Na_2CO_3

3a

Na_2CO_3 addition

3b

Ultrafiltration

4a

4b

$CaCO_3$

HCl

5a

5c

CO_2 vent

pH neutralization

5b

6b

Nanofiltration

NF Permeate

6a

Solids Separation

$BaSO_4$ $SrSO_4$

Ba/Sr rich Produced Brine (Simulated)

Ba/Sr rich Produced Brine (Real)

Extracted brine storage reservoir

Solids Separation

Reverse Osmosis

7a

7b

Mechanical Vapor Recompression

8a

8b

10 lb NaCl Brine

Water

Water

Limestone Make-up

10-lb brine / Road Salt

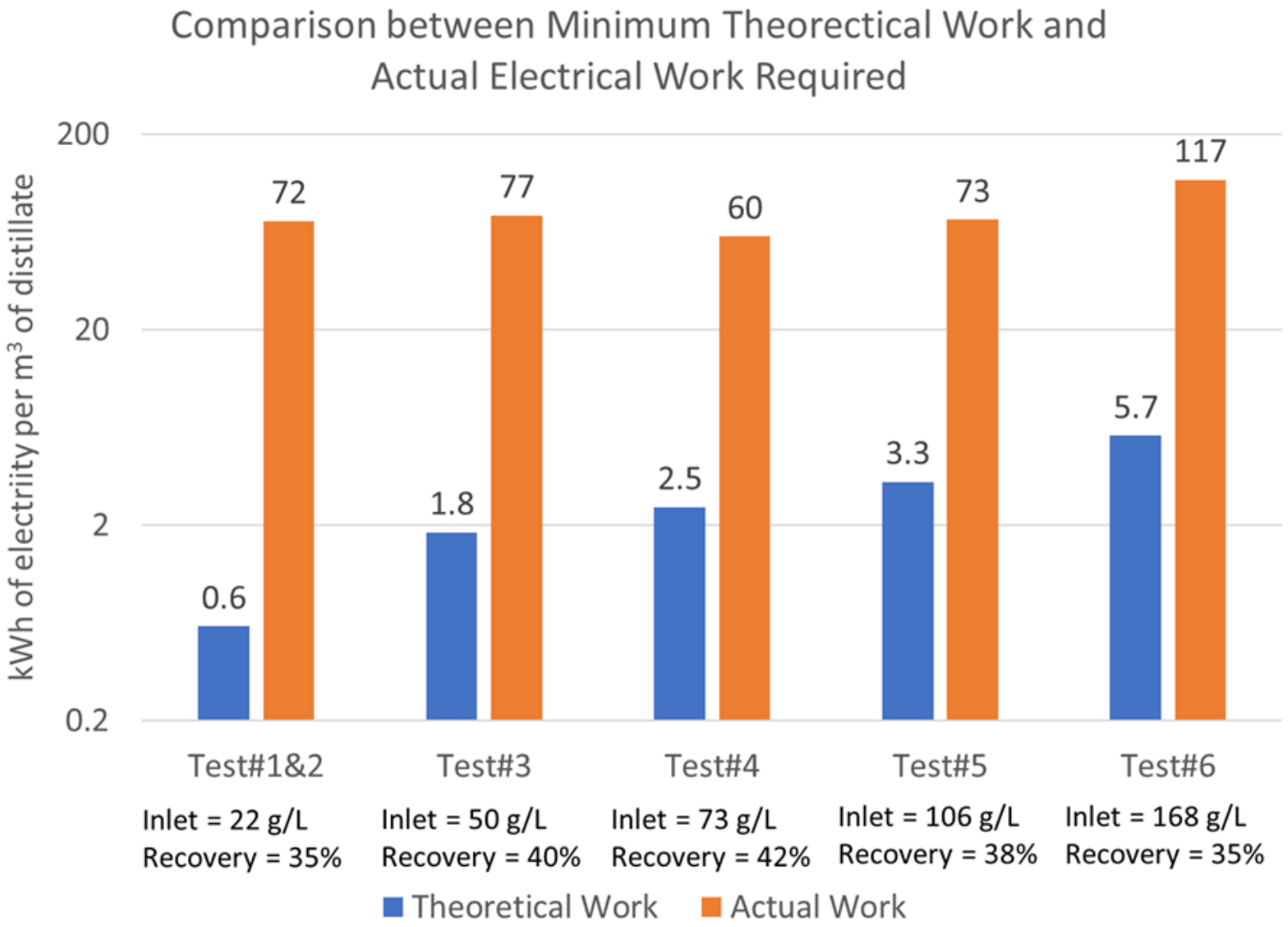
Fresh Water Make-up

Barite

15 gpm pilot design completed

Objective: To achieve ZLD, to reduce freshwater consumption, and to recover resources

Concentrating Wastewater Effluent Streams



Potential for additional MVR baseline testing in Summer 2021 at UND EERC BEST

Water Management for Power Systems

Program Goal

The Water Management for Power Systems FWP seeks to reduce water consumption at both new and existing fossil power plants, as well as to decrease the cost of treating power plant effluent streams by converting them into valuable resources

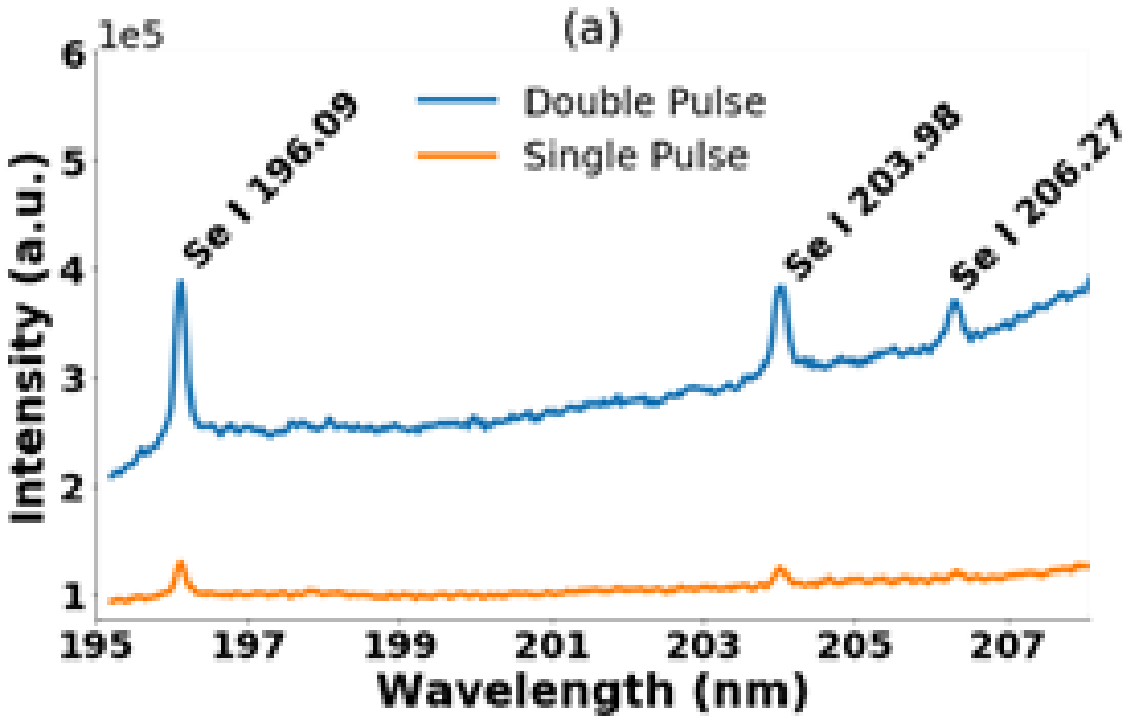
Tasks:	Principal Investigator
• Task#2: Guiding R&D for Treatment of Fossil Power Plant Effluent Streams	Eric Grol
• Task#3: Selective Removal of Heavy Metals from Effluent Streams	McMahan Gray
• Task#4: Concentrating Wastewater Effluent Streams & Resource Recovery	Nicholas Siefert
• Task#5: Impact of Water Use of Power Systems	Erik Shuster
• Task#6: Biological Treatment of FGD Effluent Streams	Djuna Gulliver
• Task#7: Characterization of FGD Effluent Streams	Dustin McIntyre
• Task#8: Water Management for Fossil-Based Hydrogen Production	Timothy Skone

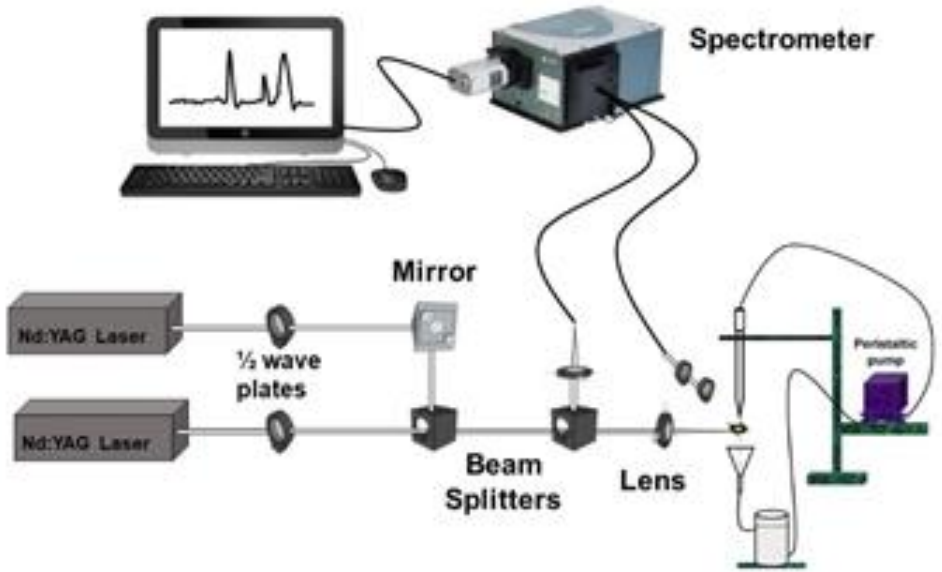
Back-up Slides

- Tasks 2, 5, 8 covered in May 10th presentations

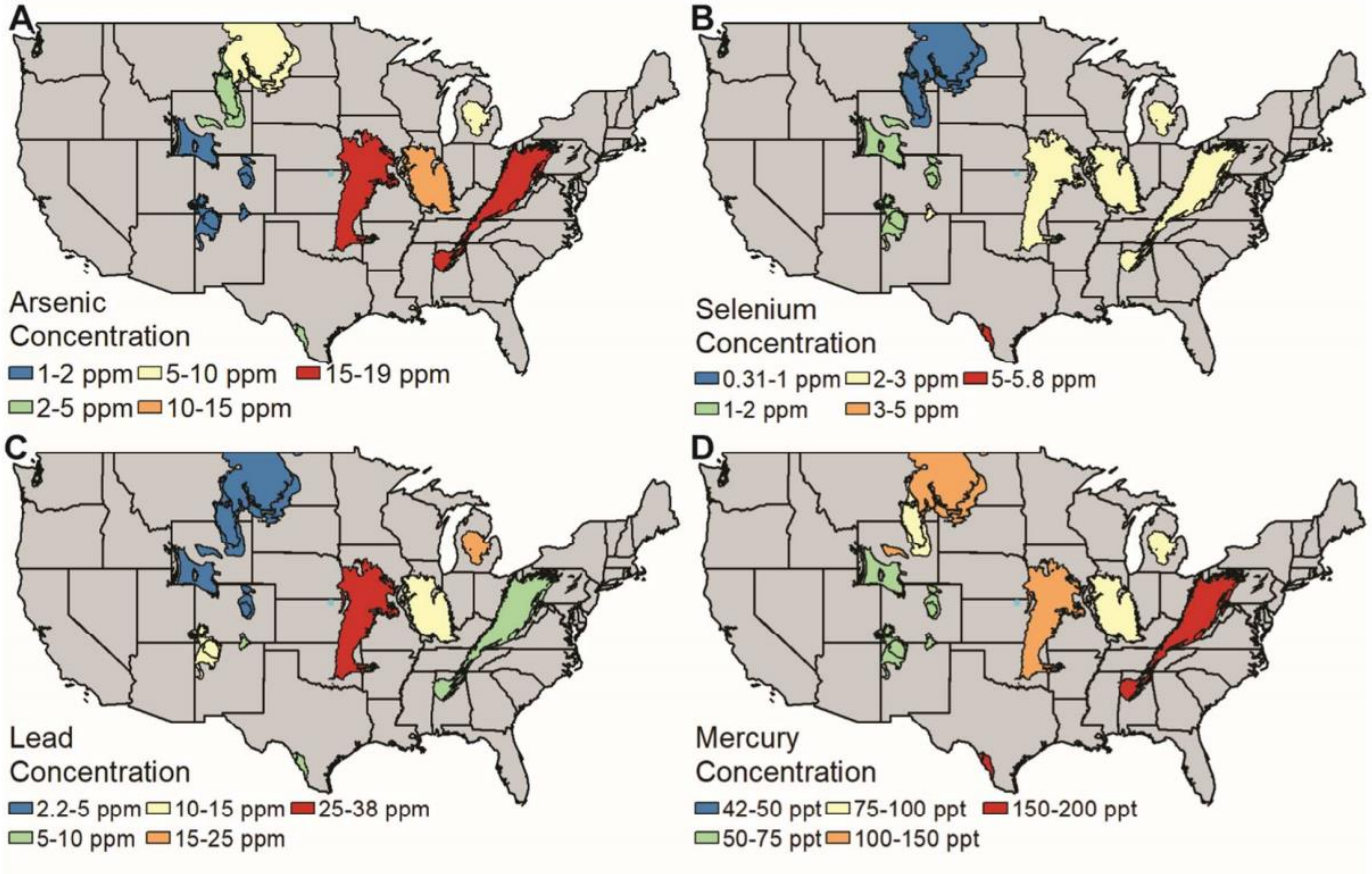
Acknowledgment: This material is based upon work supported by the Department of Energy's Office of Fossil Energy (DE-FE)

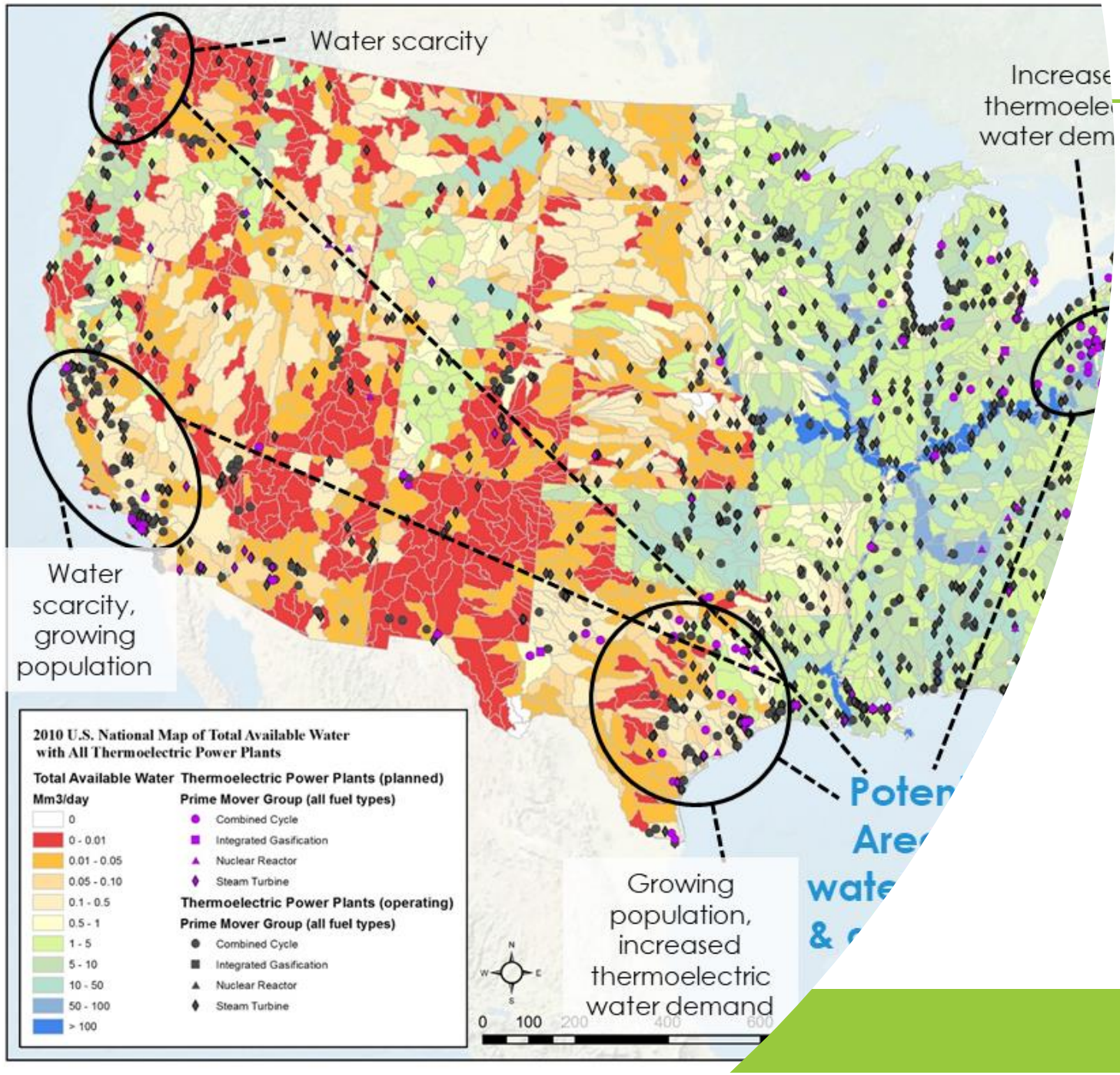
Task 7: LIBS calibration and measurement of FGD water elements





Task 2: Guiding R&D for Treatment of Fossil Power Plant Effluent Streams





NATIONAL ENERGY TECHNOLOGY LABORATORY

Task 5: Impact of Water Use of Power Systems

Task 8:
Water Management for Fossil-based H_2 Production

NATIONAL ENERGY TECHNOLOGY LABORATORY

December 4, 2020

Solutions for Today | Options for Tomorrow

U.S. DEPARTMENT OF ENERGY