

REINHOLD ENVIRONMENTAL Ltd.



**2017 APC & Wastewater Round Table
& Expo Presentation**

July 17 & 18, 2017 in Charlotte, NC / Hosted by Duke Energy

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Reinhold Environmental APC Wastewater Round Table Meeting

Kristen Jenkins, P.E

July 18, 2017

TALK OUTLINE

- About Southern Research and the Water Research Center
- Energy-Water Nexus
- Water Research Case Studies

QUICK FACTS ABOUT SOUTHERN RESEARCH

- Founded in 1941 in Birmingham, Alabama
- 501(c) (3) Non-Profit
- Proven Team of 450 Scientists, Engineers and Technicians
- Discovered 7 FDA Approved Cancer Drugs, and developing drugs for Alzheimer's, Diabetes, Kidney Disease, Parkinson's, Tuberculosis, HIV and ALS
- Worked With NASA Since the First Manned Space Flight
- Deep history in air and water emissions control technologies
- Operating the state of Alabama's first solar research center

SOUTHERN RESEARCH -FOUR OPERATING DIVISIONS-



DRUG DISCOVERY



DRUG DEVELOPMENT



ENERGY & ENVIRONMENT



ENGINEERING

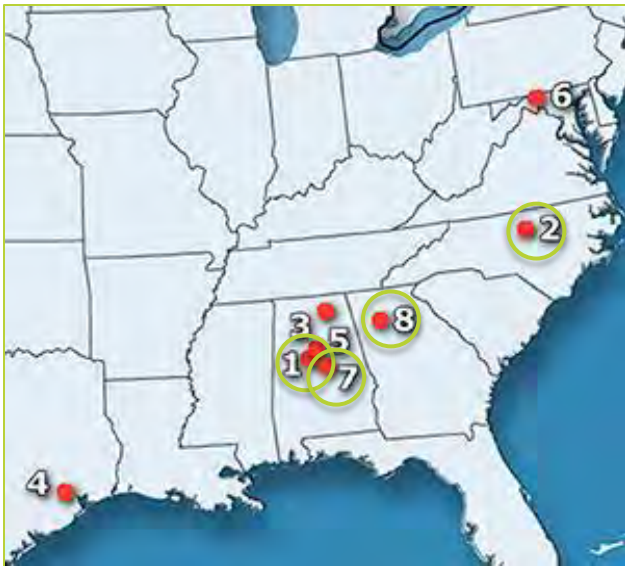
SR

ENERGY AND ENVIRONMENT –

TURNING INNOVATIONS INTO SOLUTIONS FOR CLEANER ENERGY, WATER AND AIR

- Modeling and paper evaluations to benchmark technologies
- Lab and field validation of new processes and equipment
- Technical and financial due diligence assessments to support investment decisions and development strategies
- Process analysis to identify development and operations risks
- Intellectual property creation to solve critical energy and sustainability problems

E&E REGIONAL FOOTPRINT ACROSS SOUTHEASTERN U.S.



Five Research Centers

- 50 engineers, scientists, technicians
- 3 Locations in Alabama
 - Birmingham (2) and Wilsonville
- Cartersville, Georgia
- Durham, North Carolina

WATER



Research Center



Courtesy Heartland Technology Partners



The WRC

- \$12M facility with investment from EPRI, Georgia Power Company, and Southern Research
- Co-located on the site of large coal-fired generating plant (Plant Bowen) in Cartersville, GA
- Concept – invest in infrastructure one time to cost-effectively research ways to treat, reuse, and conserve water. Heavy focus on flue gas desulfurization wastewater treatment.
- Active engagement from key members of US utility industry
- Extensive infrastructure
 - >10,000 ft² of space dedicated to water-related research
 - Weather enclosed environments, heavy equipment, utility vehicles, state-of-the-art analytical labs supporting fast-pace R&D, office space, process equipment



Georgia Power's Plant Bowen



WRC TREATABILITY TESTING INFRASTRUCTURE

- Physical/chemical pilot
 - Clarification
 - Dissolved Air Flotation
- Membrane Filtration
 - Flat sheet bench scale test unit
 - Pilot Reverse Osmosis
- Membrane Distillation Bench Unit
- Evaporator and Crystallizer
- Granular Media Reactors
- Filter Press
- 6-Port Jar Stirrer

6,000 ft² Dedicated to Pilot Testing - Indoor



Plug and Play Space



Photo Courtesy of Oasis, Inc.

WRC ANALYTICAL CAPABILITIES

- Ion Chromatography
- ICP-MS
 - Trace metals/metalloids
 - Speciation
- GC-MS
- Trace Mercury – Liquid and Solid
- Specialized Instruments/Expertise in Solids Analyses and Leaching
- Multiple Instruments for Wet Chemistry
- Method Development

Analytical Lab



ENERGY WATER NEXUS

ENERGY/WATER NEXUS

water needs
energy

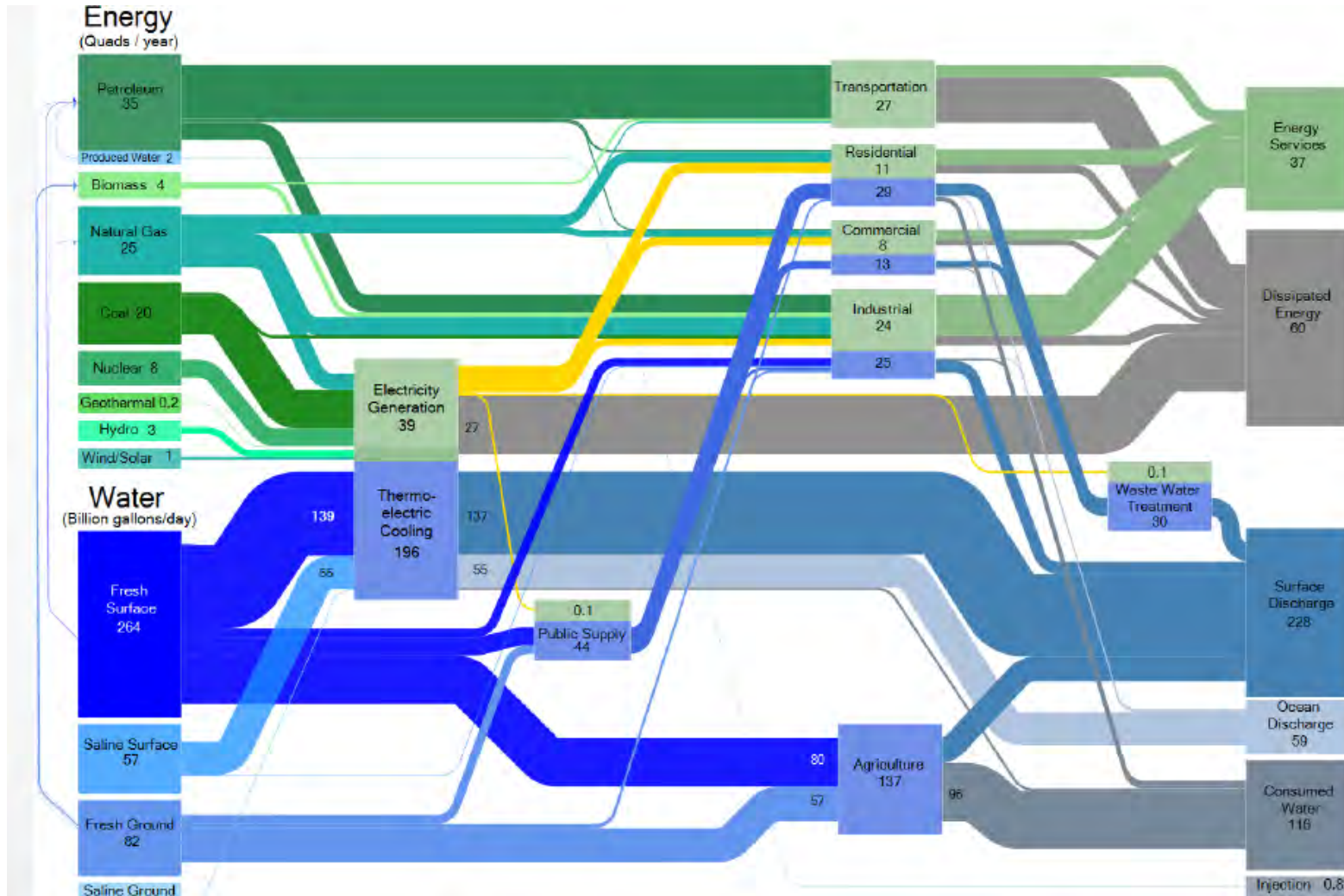
- extraction
- treatment
- transportation

energy needs
water

- hydropower
- thermoelectric cooling
- power plant operations
- fuel extraction and refining
- fuel production

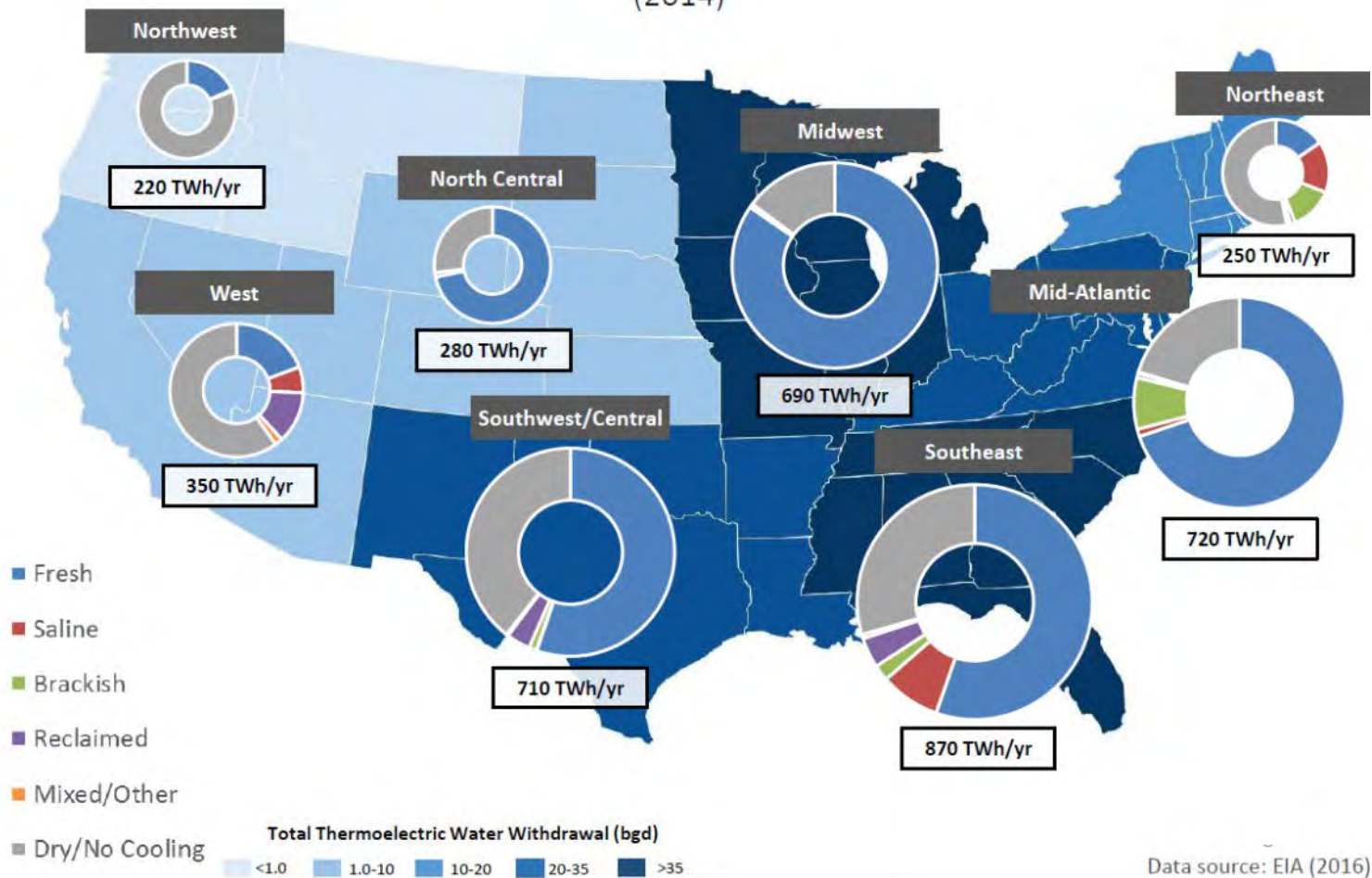
WATER – ENERGY NEXUS

SANKEY DIAGRAM



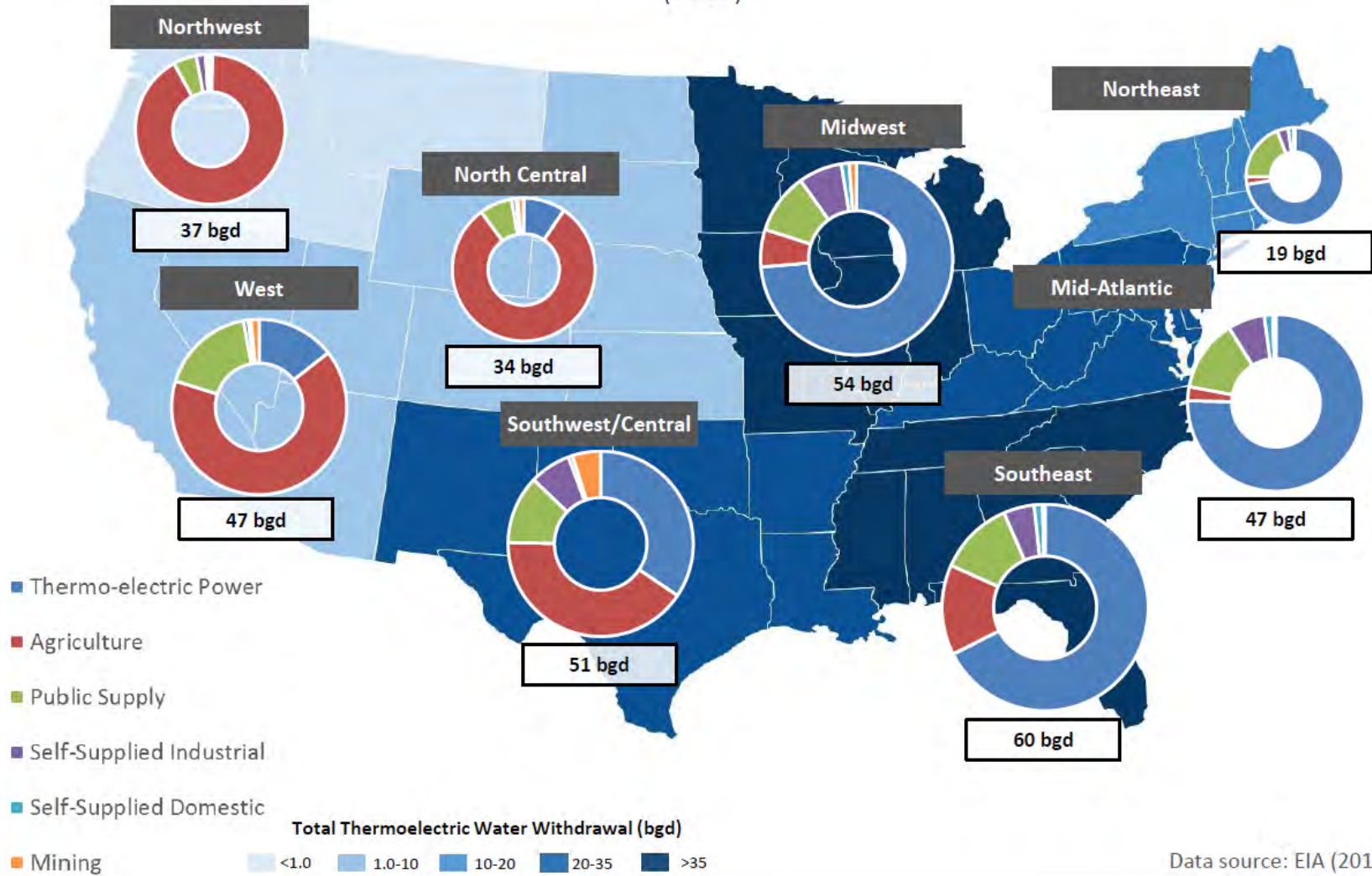
GENERATION BY WATER TYPE

(2014)



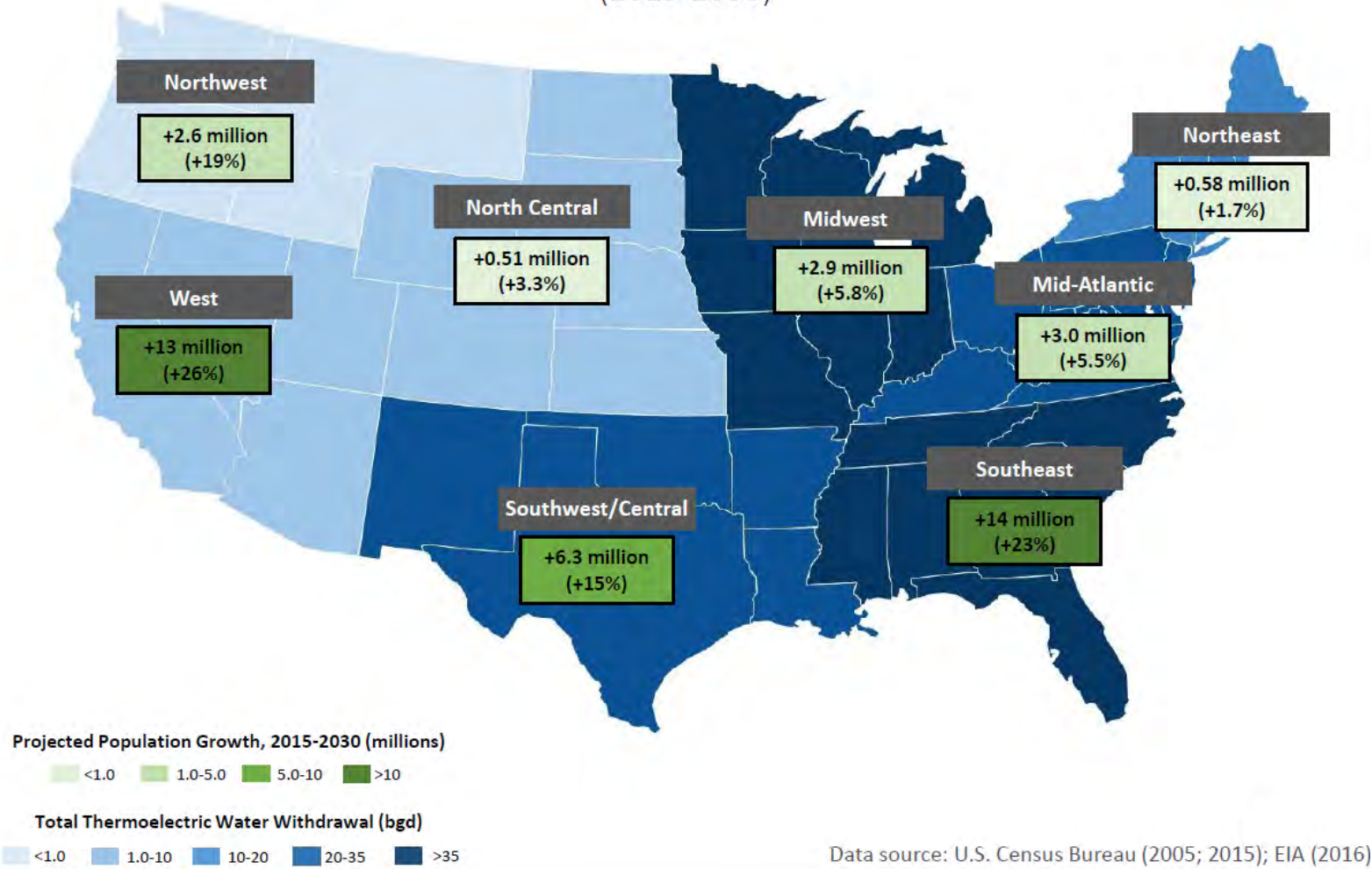
TOTAL WITHDRAWAL BY END USE

(2010)

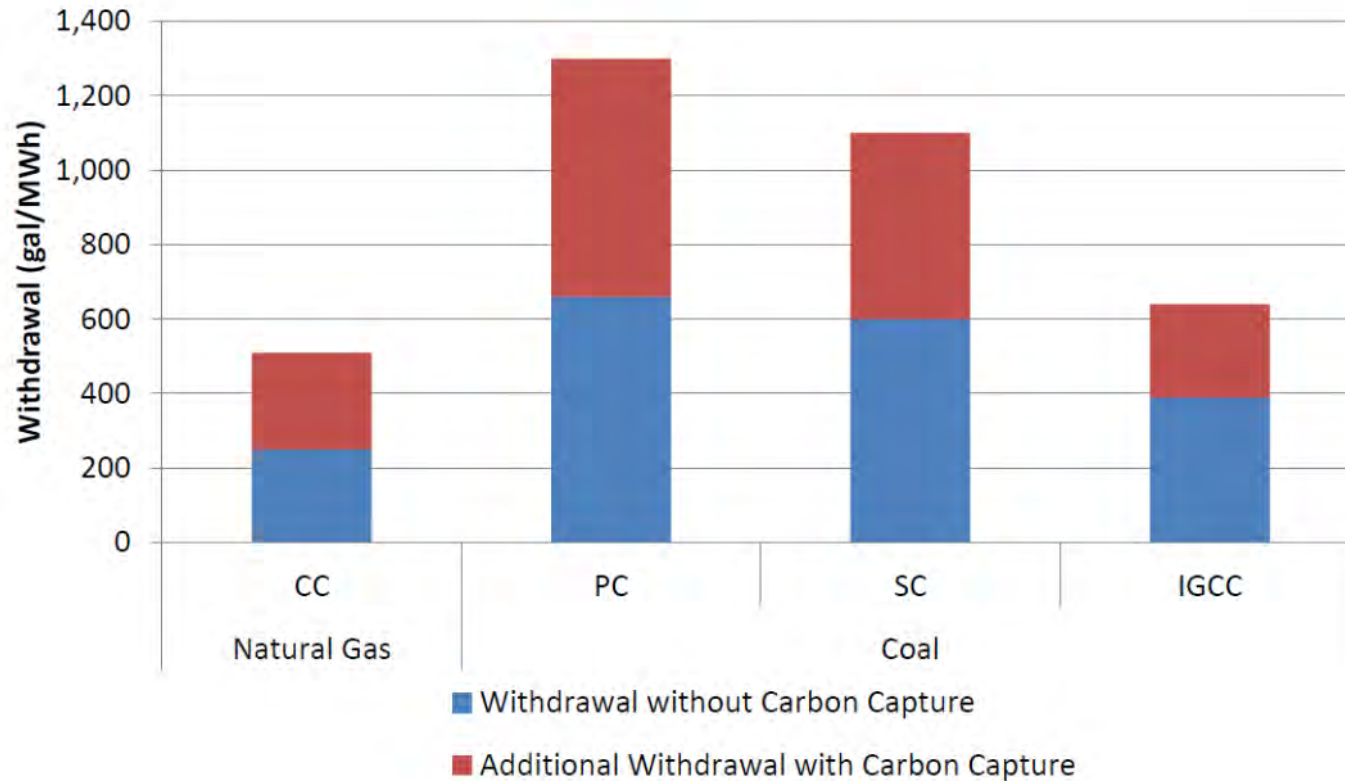


PROJECTED POPULATION GROWTH

(2015-2030)



WATER USE WITH CARBON CAPTURE

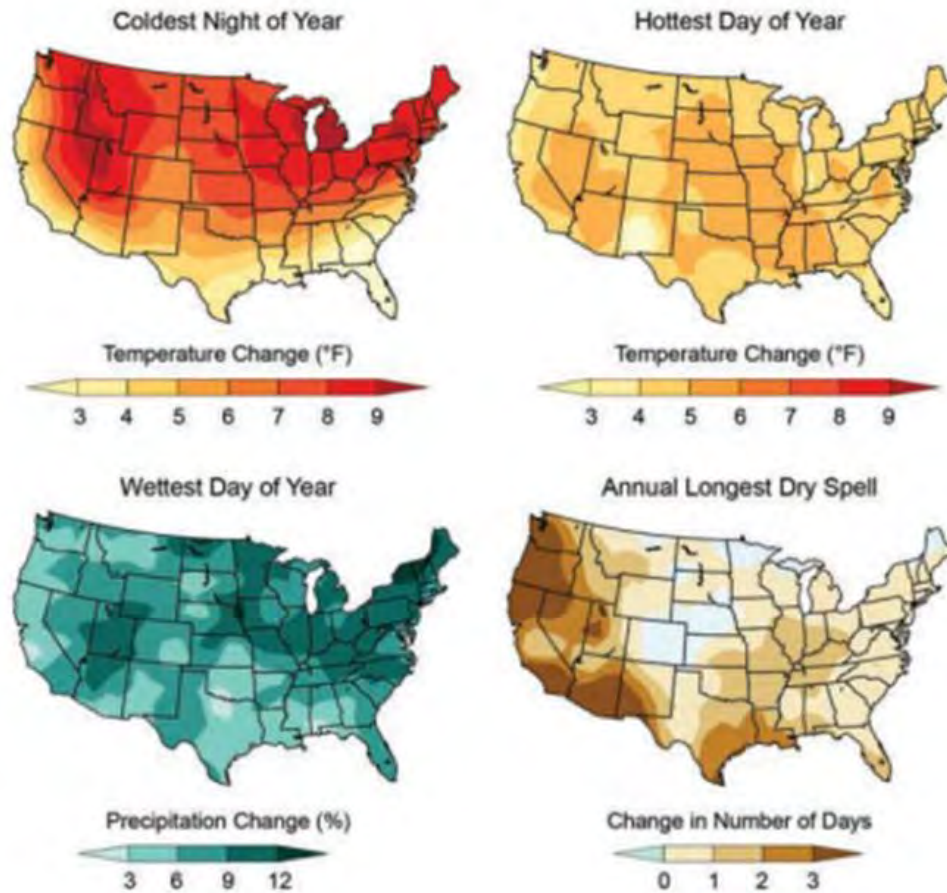


*These withdrawal figures are for recirculating cooling.

Abbreviations: CC: Combined Cycle; PC: Pulverized Coal; SC: Supercritical Pulverized Coal;
IGCC: Integrated Gasification Combined Cycle

Data source: Meldrum et al. (2013)

CLIMATE PROJECTIONS - EXTREMES



INCREASING REGULATION IN UTILITY INDUSTRY

- Coal Combustion Residuals regulation
- Water quality standards
 - Soluble parameters – Cl, sulfate, boron
 - Lower levels for metals – Hg, Se
 - Can drive to ZLD
- Revised Effluent Limitation Guideline
 - FGD with incentives for ZLD
 - Low Volume Wastes
 - Ash (no discharge)

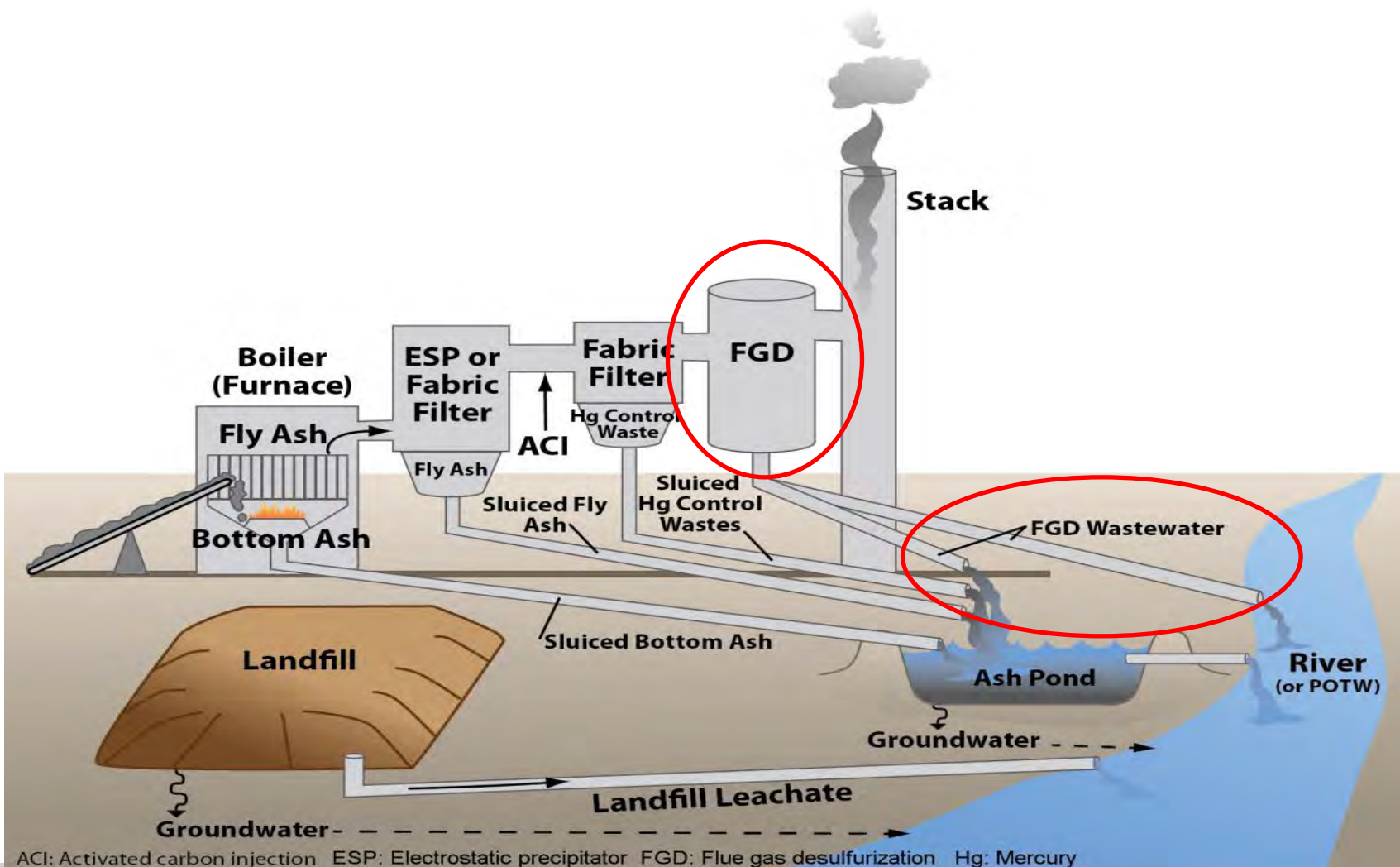
Waste Stream	Parameter	Daily Maximum	30-day Average
FGD Wastewater for Discharge	As (ug/L)	11	8
	Se (ug/L)	23	12
	Hg (ng/L)	788	356
	NO2/NO3 as N (mg/L)	17	4.4
FGD Wastewater Under Voluntary Incentive	As (ug/L)	4	
	Se (ug/L)	5	
	Hg (ng/L)	39	24
	TDS (mg/L)	50	24

WHAT DOES THIS ALL MEAN?

- Competing demands for water
- Water demands will change over time
 - Climate change
 - Population growth
 - Regulations
- Research needs
 - Treat and discharge in the short term
 - Long term – use of non-traditional water sources

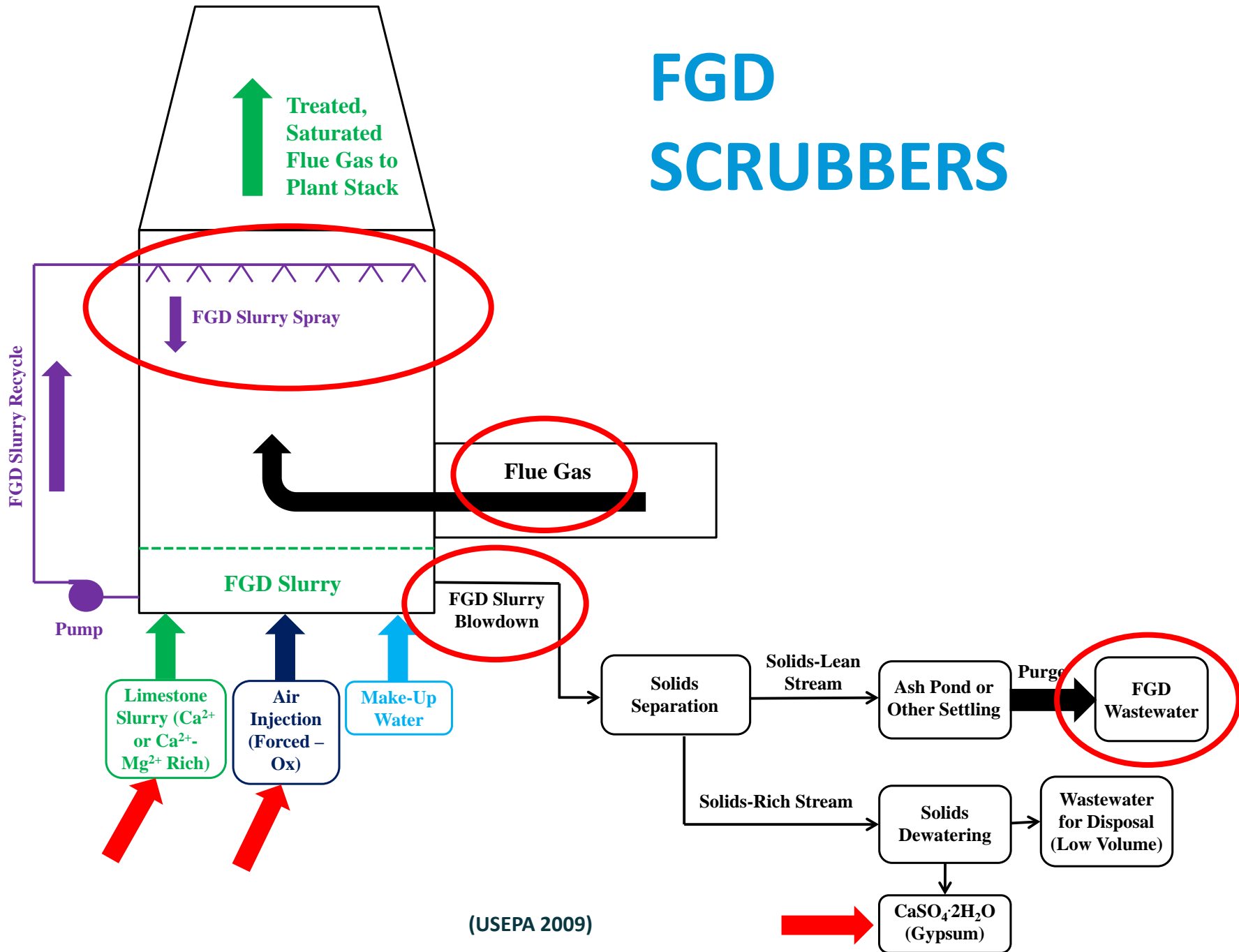
TREATMENT OF FGD WASTEWATER

KEY WATERS OF CONCERN AT COAL-FIRED POWER PLANTS



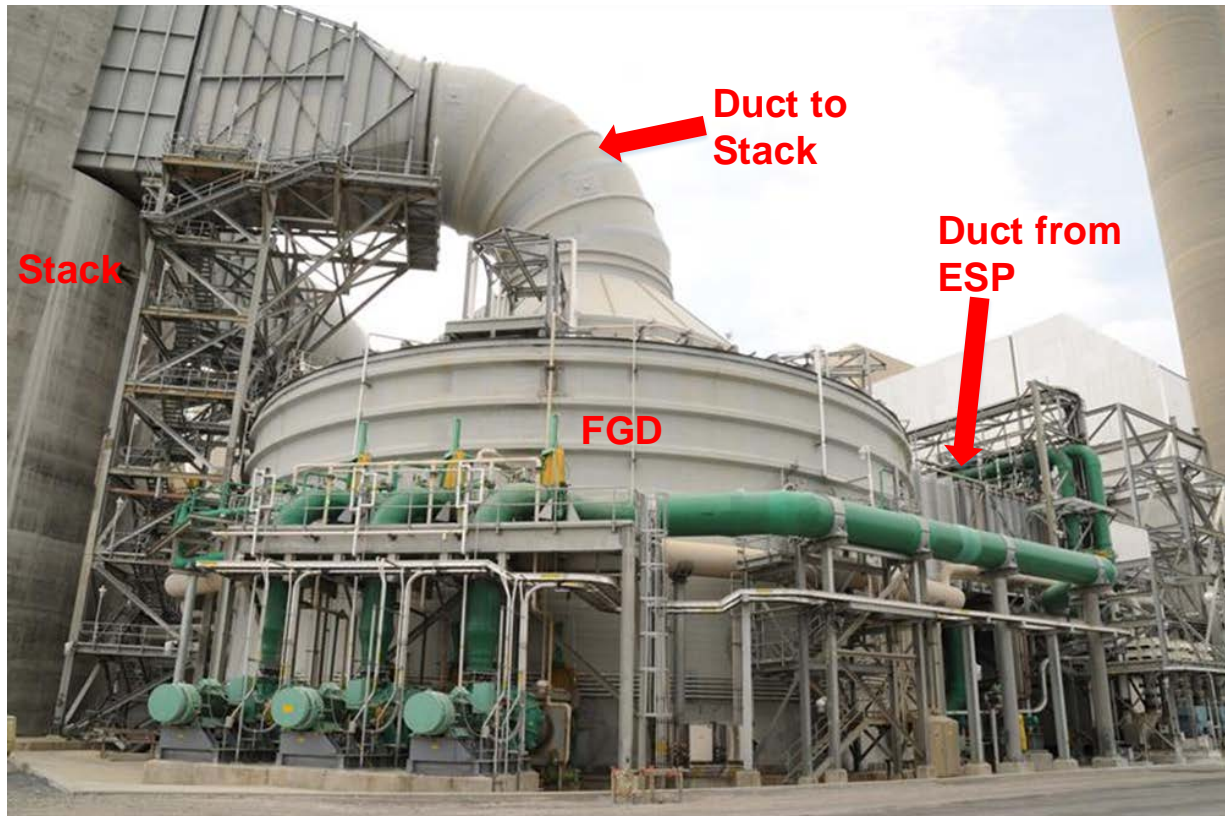
ACI: Activated carbon injection ESP: Electrostatic precipitator FGD: Flue gas desulfurization Hg: Mercury

FGD SCRUBBERS



(USEPA 2009)

FGD SCRUBBERS



Source of original photo - (PCL 2017), modified with text

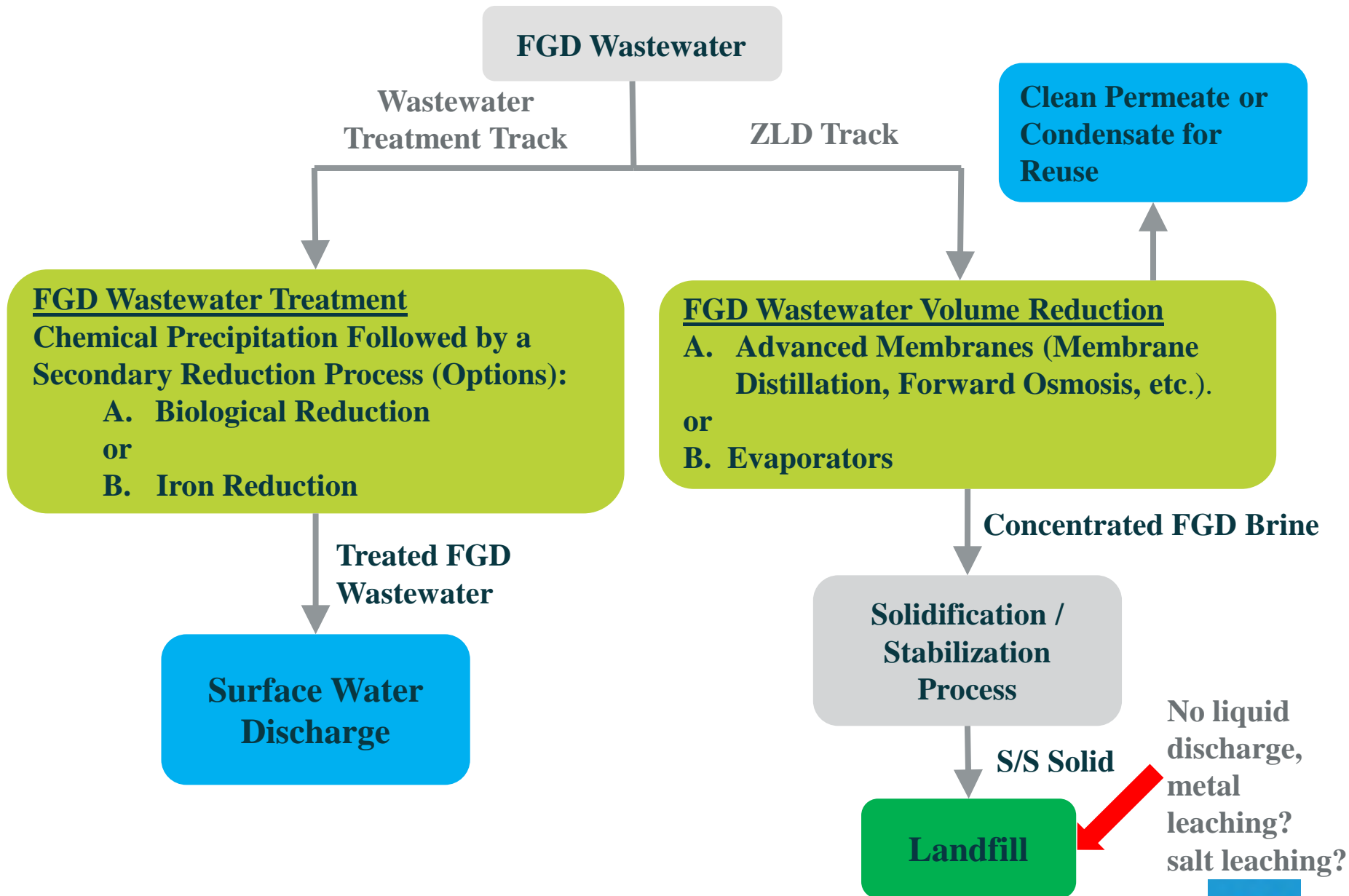
- Removes SO_x plus other components such as heavy metals.
- Metals accumulate in FGD systems including As, B, Hg, and Se.
- Per USEPA study for 26 plants, average FGD flowrate was approximately 600 gpd/MW
 - 1000 MW plant = 400 gpm

EXAMPLE FGD WASTEWATER COMPOSITIONS

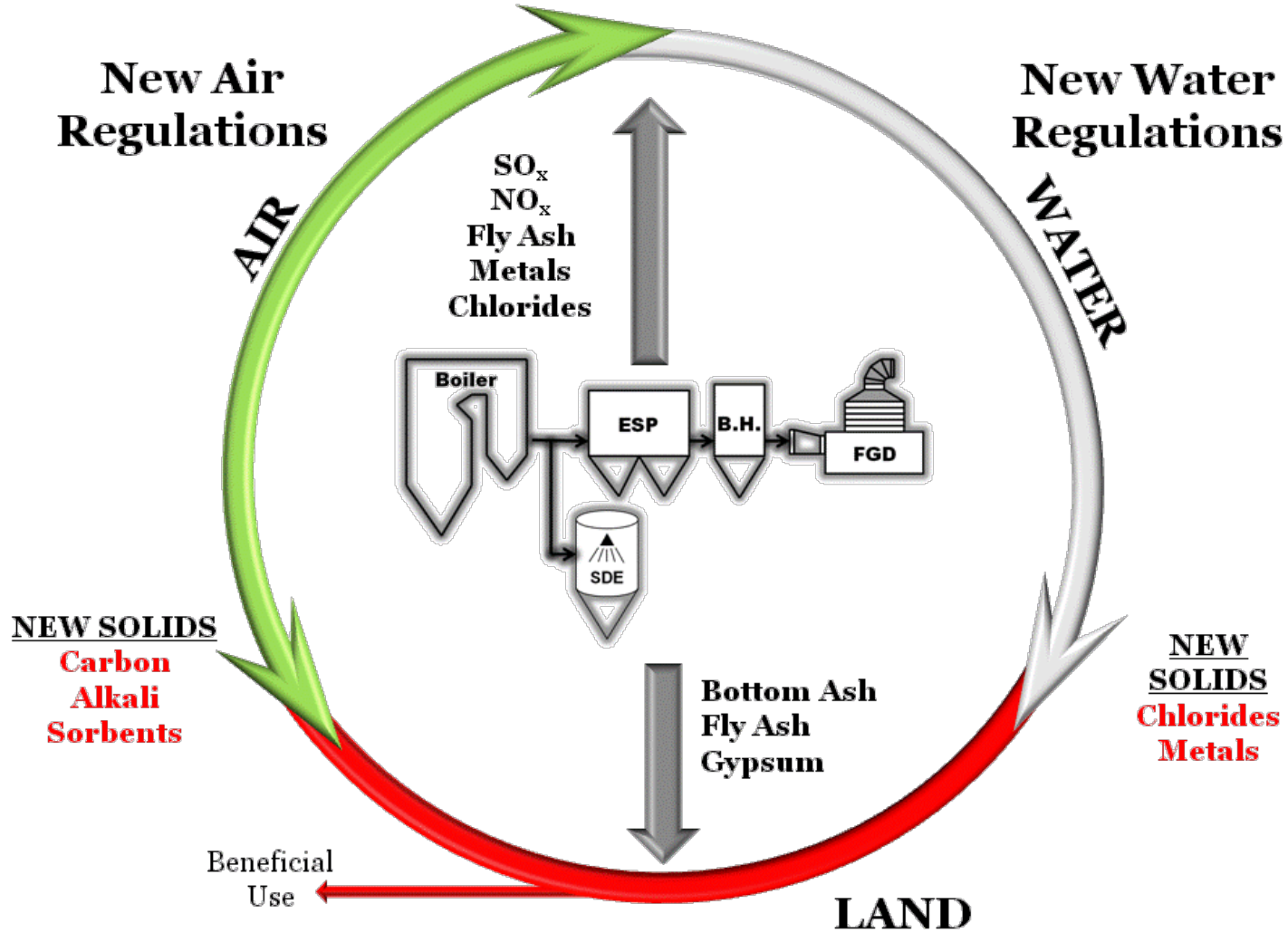
Component	Min Conc (mg/L)	Max Conc (mg/L)	ELG Limit – Discharge		ELG Limit – Reuse	
			Max Day	Monthly Avg	Max Day	Monthly Avg
Cl (mg/L)	1,100	13,000				
Mg (mg/L)	1,200	1,800				
NO3-/NO2-(mg/L)	<10	270	17	4.4		
SO4-2 (mg/L)	780	4,100				
Ca (mg/L)	1,000	10,000				
TDS (mg/L)	6,500	26,000			50	24
As (ug/L)	58	5,070	11	8	4	
Hg (ng/L)	<100	872,000	788	356	39	24
Se (ug/L)	400	21,700	23	12	5	



FGD WASTEWATER DISPOSAL OPTIONS



IMPACT OF NEW AIR AND WATER REGULATIONS



ZLD

Benefits

- Elimination of environmental wastewater discharge.
- Long term regulatory certainty.
- Maximization of water reuse.

Challenges

- Volume reduction is energy intensive process.
- Scaling issues for membrane and evaporators.
- Solid waste management.
- Difficulty in long-term stabilization of especially Se^{VI} and salts – especially Cl^-
- Meeting ELG limits for reuse outside of scrubber

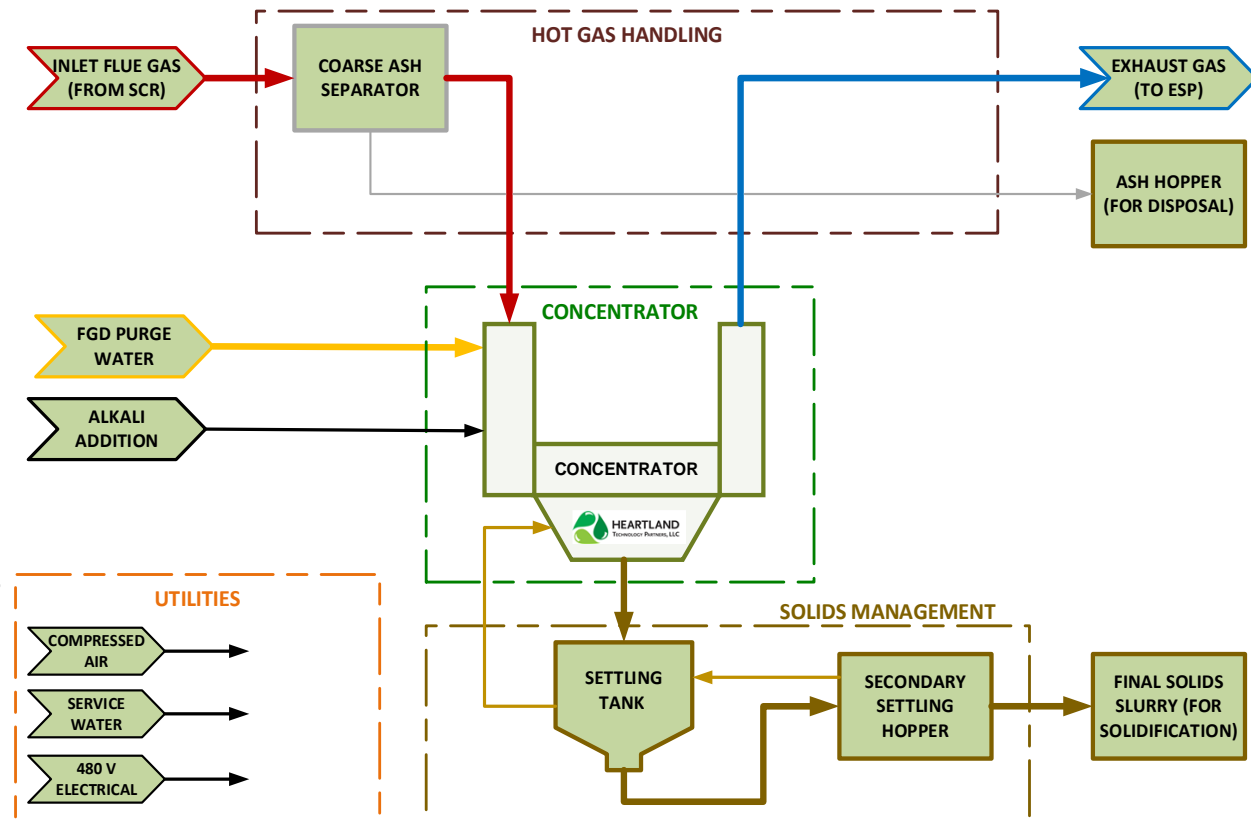


ADIABATIC EVAPORATION OF FGD WASTEWATER



HEARTLAND ADIABATIC EVAPORATOR

- Investigate:
 - Evaporation of FGD wastewater using adiabatic evaporator with flue gas as heat source.
 - Integration of adiabatic evaporator in plant operations.
 - S/S of concentrated FGD wastewater ZLD residuals.
- Operated 24-hours a day / 7-days week for 14 days



HEARTLAND ADIABATIC EVAPORATOR SUMMARY

Test Outcomes

- Technology successfully concentrated FGD wastewater resulting in:
 - Net water volume reduction of 90-95%.
 - TDS levels over 400,000 in the circulating fluid.
 - Brine slurry containing 70-80% total solids.
- Reduce mobility of metals through S/S

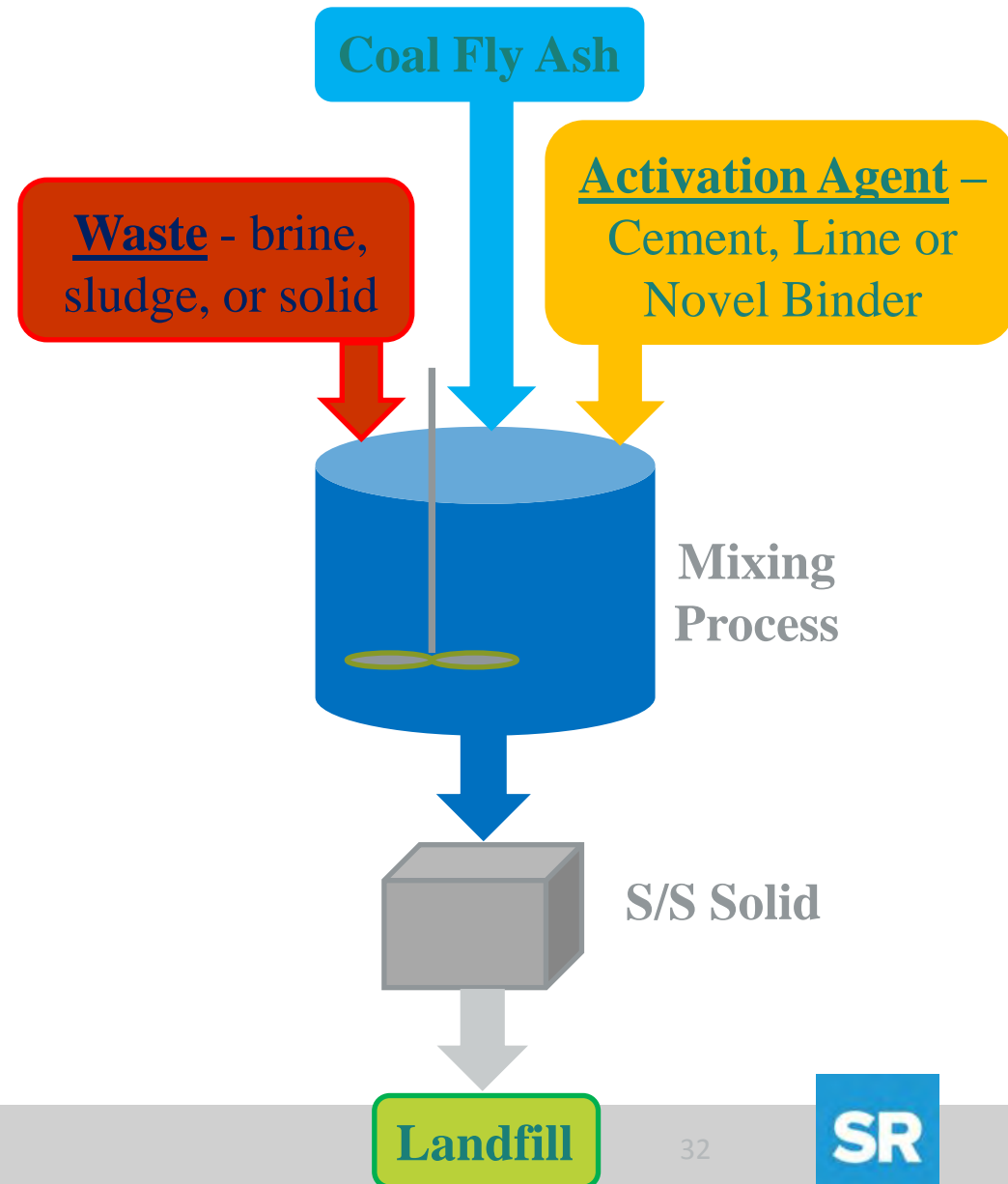
Further Research Needs

- Determine impacts of ducting saturated gas back into the duct (acid gases, duct corrosion issues).
- Define heat rate penalty associated with tapping the volume of flue gas needed.



SOLIDIFICATION/STABILIZATION TECHNOLOGY

- S/S includes mixing waste with coal fly ash and an activation agent
- S/S consists of two processes as follows:
 1. Solidification – physically encapsulating the waste and improving physical properties of waste
 2. Stabilization – converting contaminants to less mobile and less toxic form



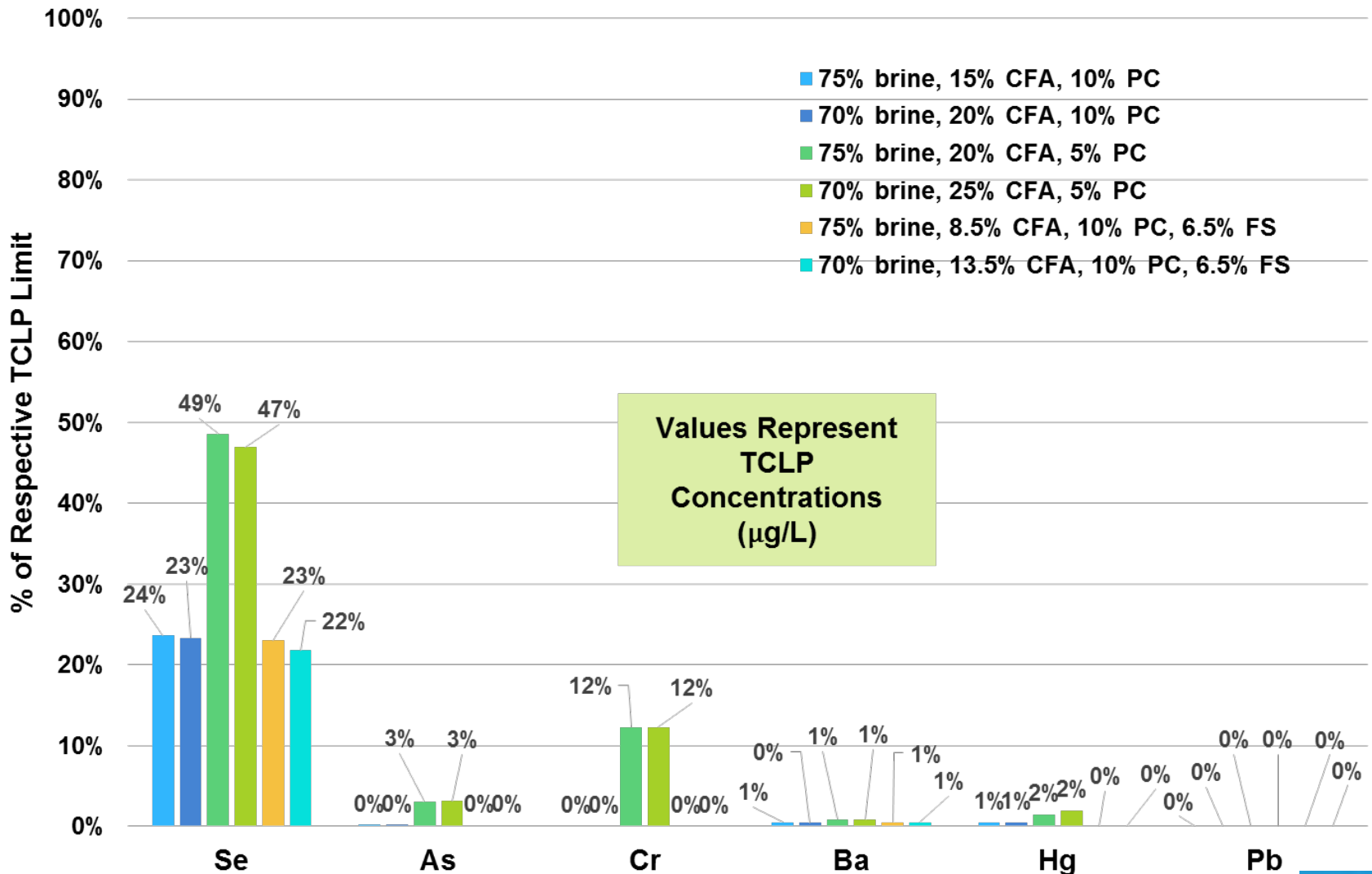
SOLIDIFICATION AND STABILIZATION

Parameter	Value	Unit
TDS of Liquid Phase	195,000	mg/kg
TSS of Brine Slurry	863,000	mg/kg
Density of Liquid Phase	1.24	kg/L
Density of Brine Slurry	1.65	kg/L

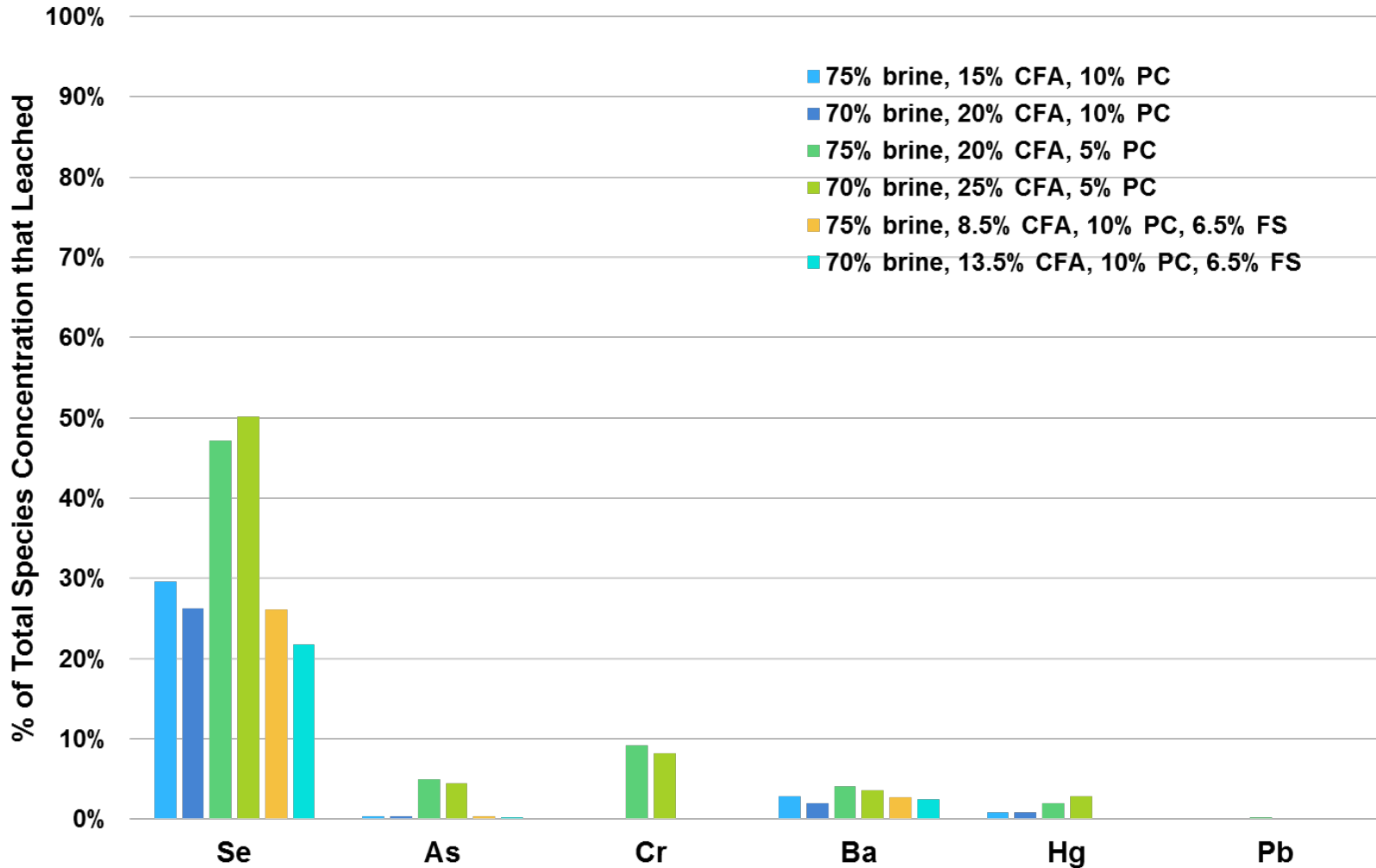
Mix No.	Brine Slurry (%)	CFA (%)	PC (%)	FS (%)
1	75	15	10	0
2	70	20	10	0
3	75	20	5	0
4	70	25	5	0
5	75	8.5	10	6.5
6	70	13.5	10	6.5



HEAVY METAL TCLP CONCENTRATIONS



HEAVY METAL LEACHED (%) FROM S/S SOLID

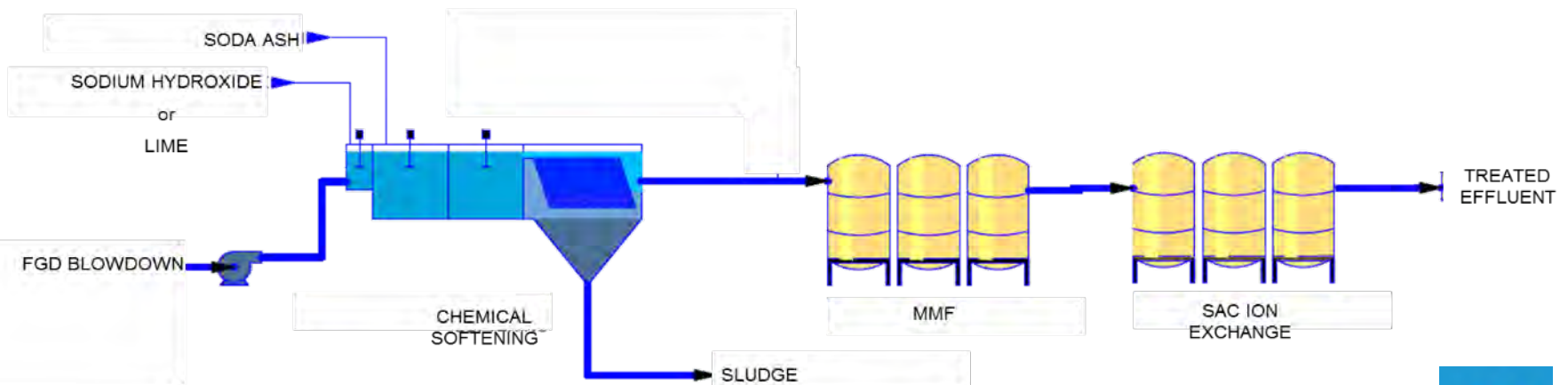


SOFTENING OF FGD WASTEWATER



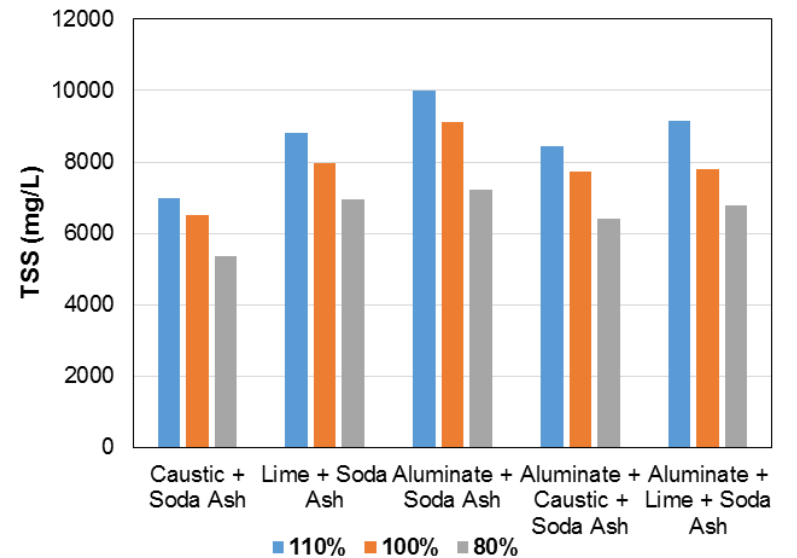
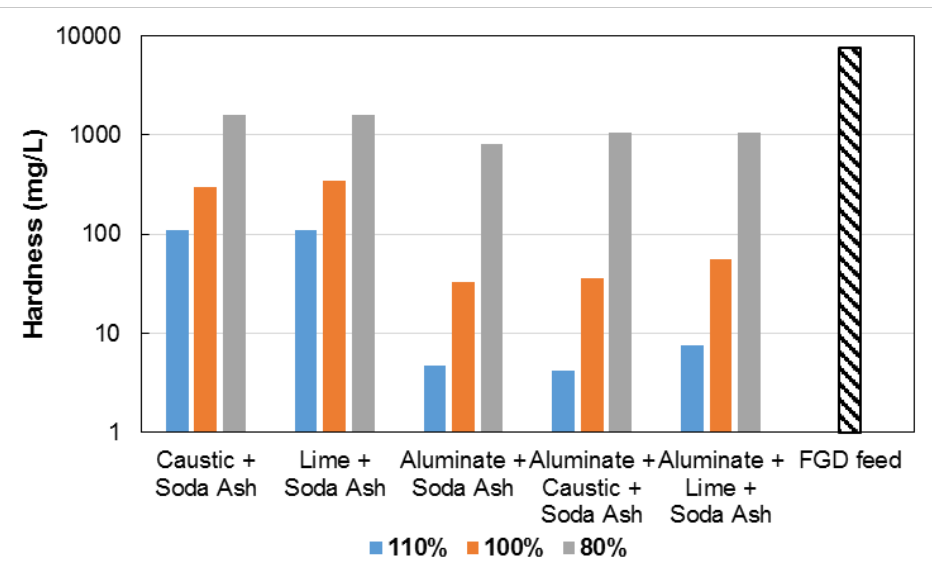
CHEMICAL SOFTENING OF FGD WASTEWATER

- Pilot test required chemical softening followed by media filtration and ion exchange
- Short term comparison of lime/soda ash softening to caustic/soda ash favored lime over caustic
- Bench testing performed to evaluate chemical doses required and enhancements with the addition of aluminate



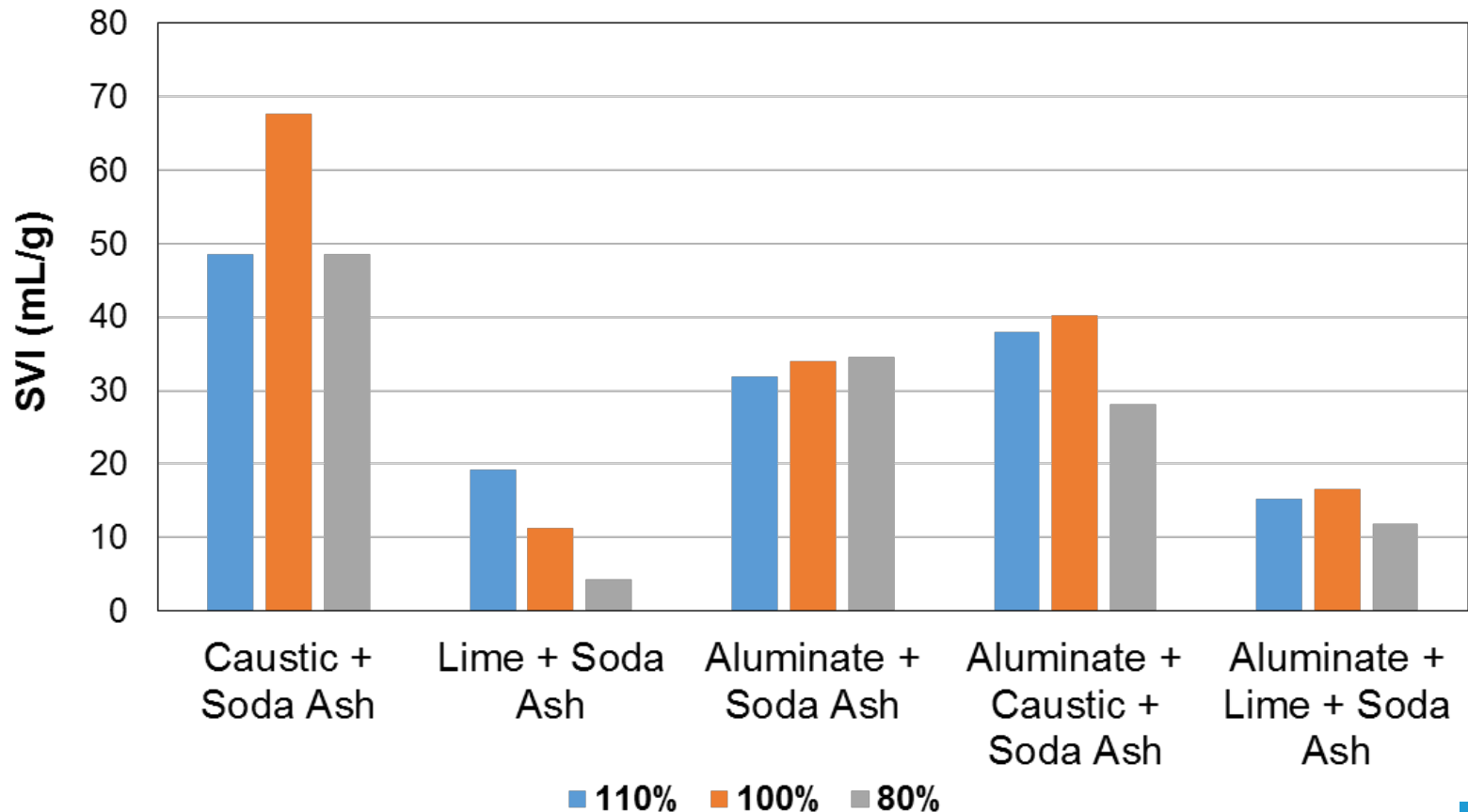
PRELIMINARY FINDINGS

- Hardness reduction improved significantly with NaAlO_2
- TSS in sludge increase due to CaCO_3 and $\text{Al}(\text{OH})_3$



PRELIMINARY FINDINGS

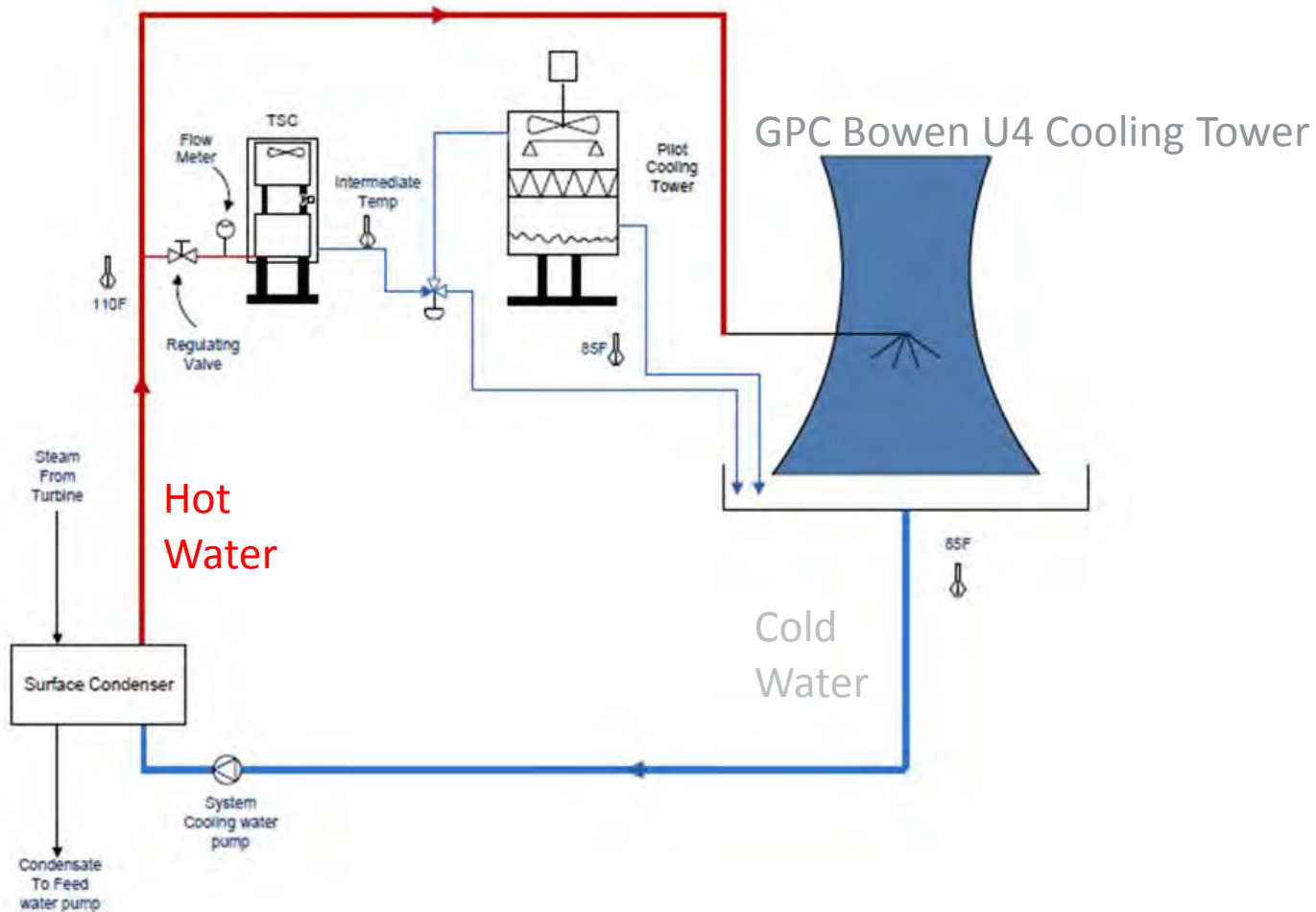
- Improved compaction with lime over caustic
- Adding lime to aluminate improved sludge compaction



HYBRID WET/DRY COOLING



Hybrid System – Configuration of Thermosyphon Pilot Unit



TSC and Pilot Cooling Tower Locations



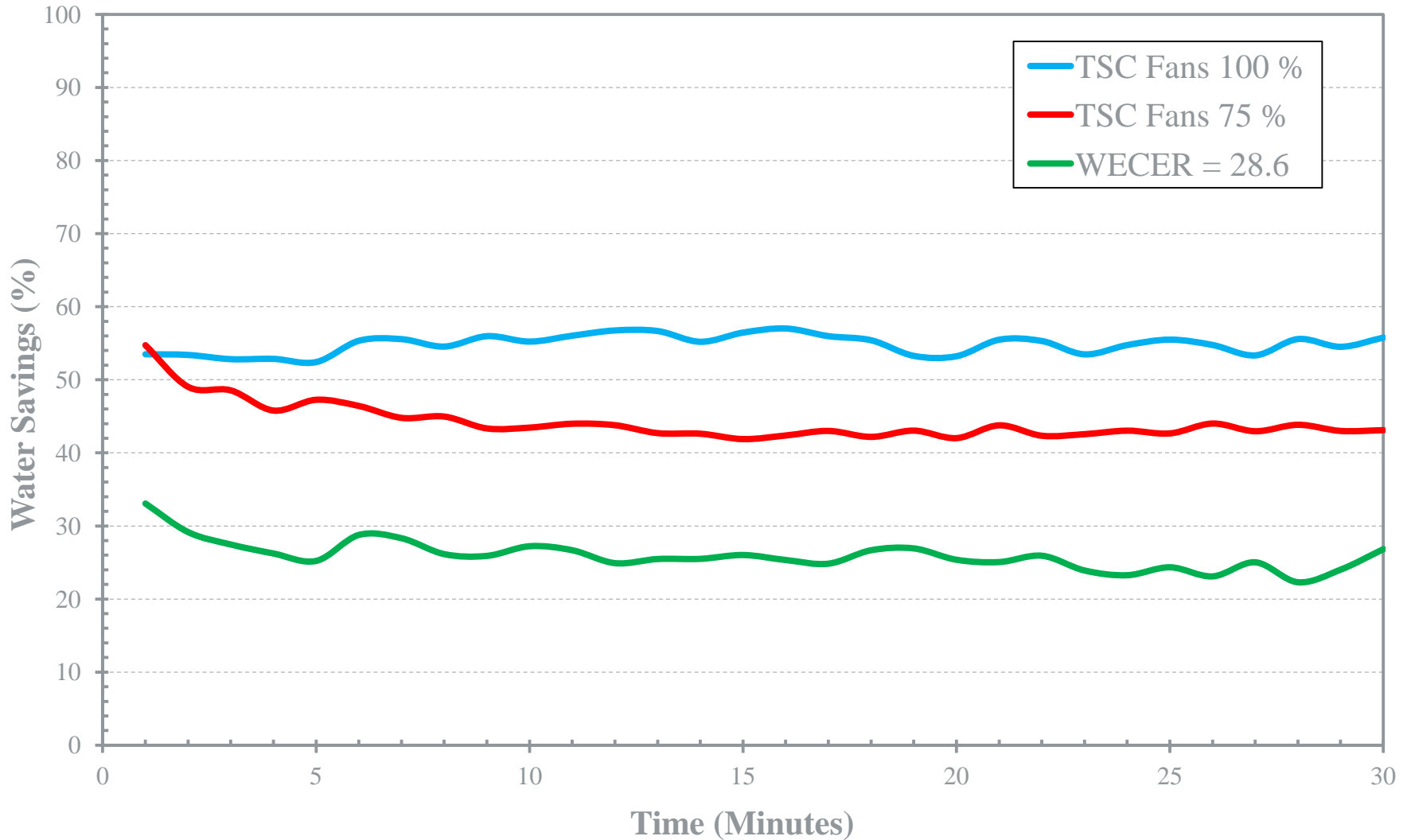
Small Pilot Cooling Tower

GPC Bowen U4 Cooling Tower

TSC

Hybrid System Water Savings – Initial Test Conditions

(August in Georgia, Flowrate = 375 gpm)



TREATMENT OF PRODUCED WATER FROM CARBON CAPTURE

TREATMENT OF PRODUCED WATER FROM CARBON CAPTURE

- Department of Energy funded project.
- Select candidate CO₂ sequestration reservoirs based on water chemistry and geologic properties
- Develop an integrated and adaptable concentration system
- Evaluate solidification & stabilization mixtures to immobilize residual contaminants
- Evaluate opportunities to valuable minerals, efficiently utilize CO₂, and recovered water
- Complete a technical readiness review and economic feasibility analysis

ACKNOWLEDGEMENTS AND DISCLAIMER



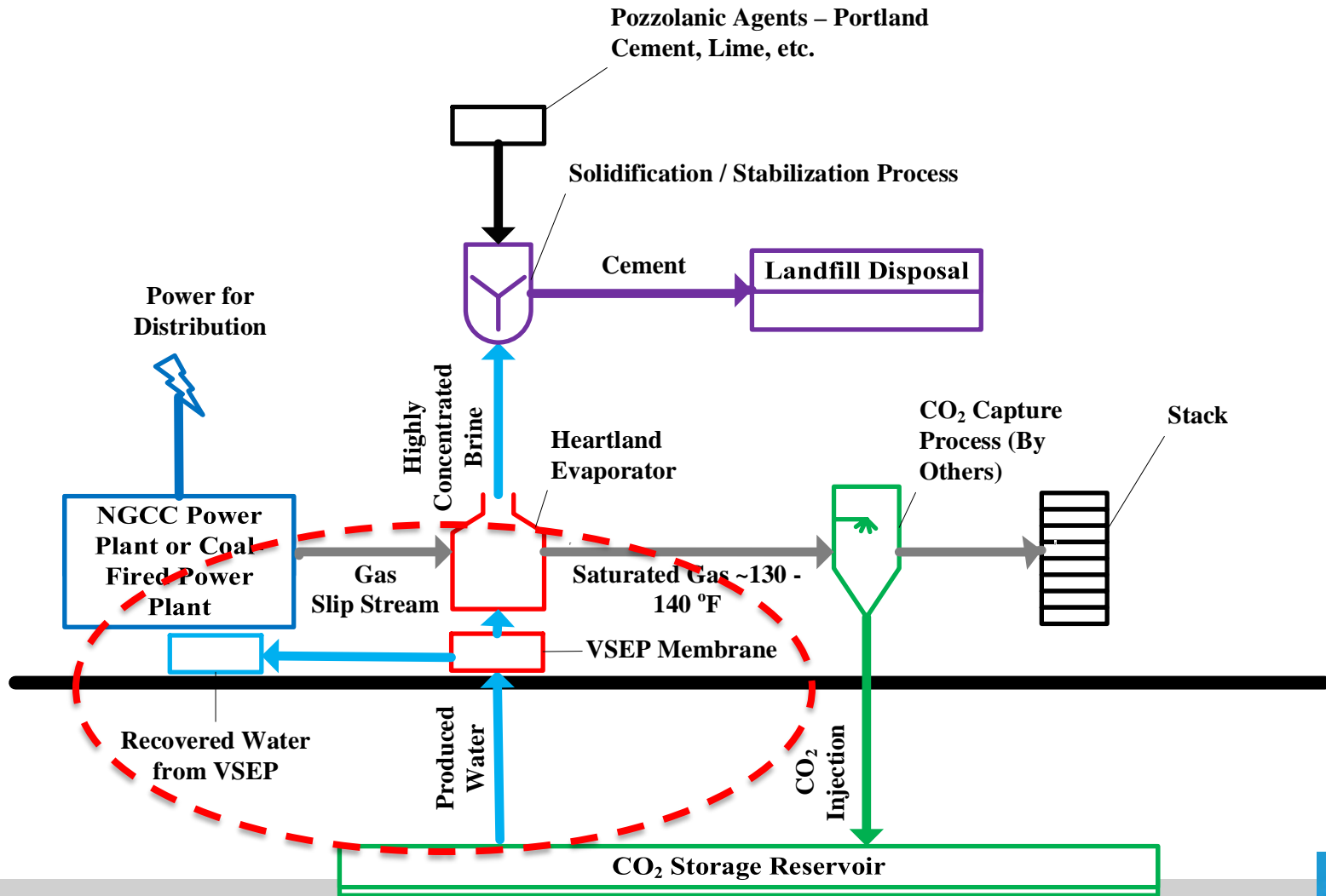
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FORMATION CHARACTERISTICS

Component (mg/L)	Keg Mountain	Mount Simon	San Andres
TDS	18,419	88,900	190,459
Ca²⁺	940	8,514	5,578
Na⁺	5,019	22,545	63,014
Mg²⁺	123	1,428	3,482
K⁺	587	758	519
Cl⁻	9,212	53,700	116,600
SO₄²⁻	499	1,219	1,166
HCO₃⁻	1,501	100	100

Process Overview



Scenario Evaluations

- **Coal Scenario**
 - 500 MW Illinois basin coal-fired power plant
 - 90% CO₂ capture
 - Waste heat flue gas upstream of air pre-heater utilized
 - Gas temperature = 650 °F with plant heat rate of 10,000 BTU/kWh
 - Concentrate produced water to 65% total solids
 - Assume 80% annual system capacity factor
- **Natural Gas Combined Cycle (NGCC) Scenario**
 - 500 MW (317 MW output from natural gas turbine / 183 MW supplemental HRSG turbine)
 - 90% CO₂ capture
 - Waste heat from downstream of gas turbine / upstream of HRSG utilized
 - Gas temperature = 1,149 °F
 - Concentrate produced water to 65% total solids
 - Assume 80% annual system capacity factor

Preliminary Results – Coal Scenario

Coal Scenario	Mount Simon	Keg Mountain	San Andres	Unit
Produced Water Processed	3,397,769	4,279,066	3,397,769	GPD
Heartland Feed	3,397,769	1,069,766	3,397,769	GPD
% of Flue Gas Required	192	60	168	%
Plant Derate	99	32.7	86	MW
Slurry Produced	370	125	618	GPM

Preliminary Results – NGCC Scenario

NGCC Scenario	Mount Simon	Keg Mountain	San Andres	Unit
Produced Water Processed	1,370,932	1,370,932	1,370,932	GPD
Heartland Feed	1,370,932	342,733	1,370,932	GPD
% of Turbine Exhaust Required	29	7	25	%
Steam Turbine Electrical Derate	55	14.6	48	MW
Slurry Produced	94	26	201	GPM

CLOSING THOUGHTS

- Close the loop on release of metals and other pollutants to the environment
- Develop technologies for use of non-traditional water sources
 - Membranes – Forward osmosis, Membrane Distillation
 - New materials – carbon-nanotubes
 - Membrane production
 - Softening with membranes
- Reduce energy and cost of concentration technologies



*Come see us in the
Exhibit Hall!! –
Booth #50*

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