Water Management for Power Systems

Systems Analysis Tasks

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National Energy Technology Laboratory

U.S. Department of Energy
National Energy Technology Laboratory
Resource Sustainability Project Review Meeting

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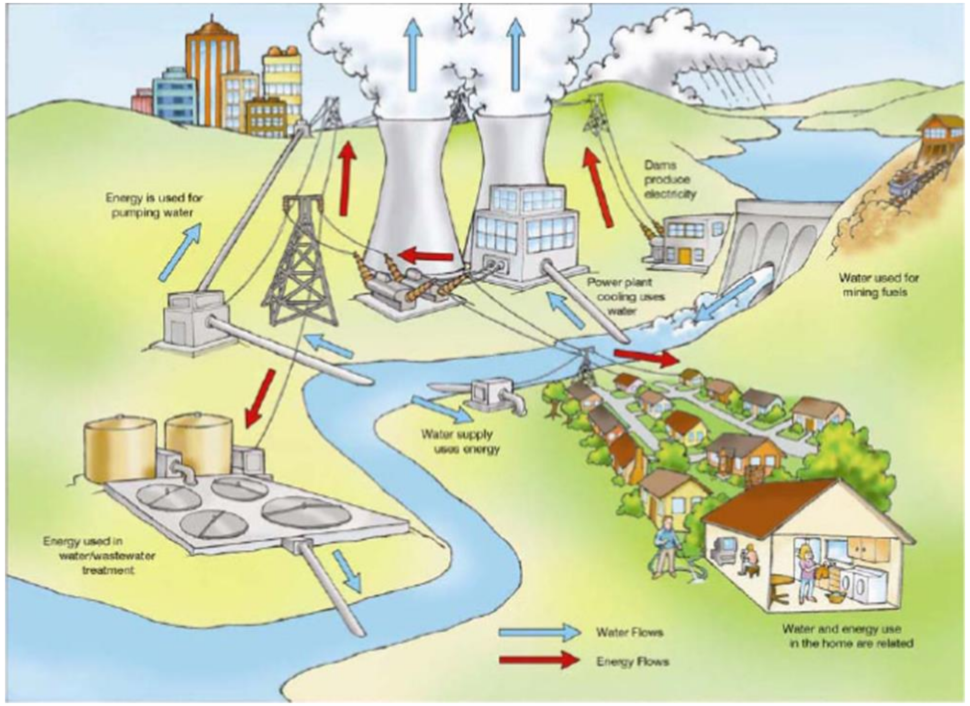
Water management for power systems: role of systems analysis

- Interdependency of water and energy resources under uncertainty:
  - Transitioning electricity infrastructure
  - Changing regulations, temperature, water availability, and demand
- Deliver the NETL mission: an environmentally sustainable and prosperous energy future

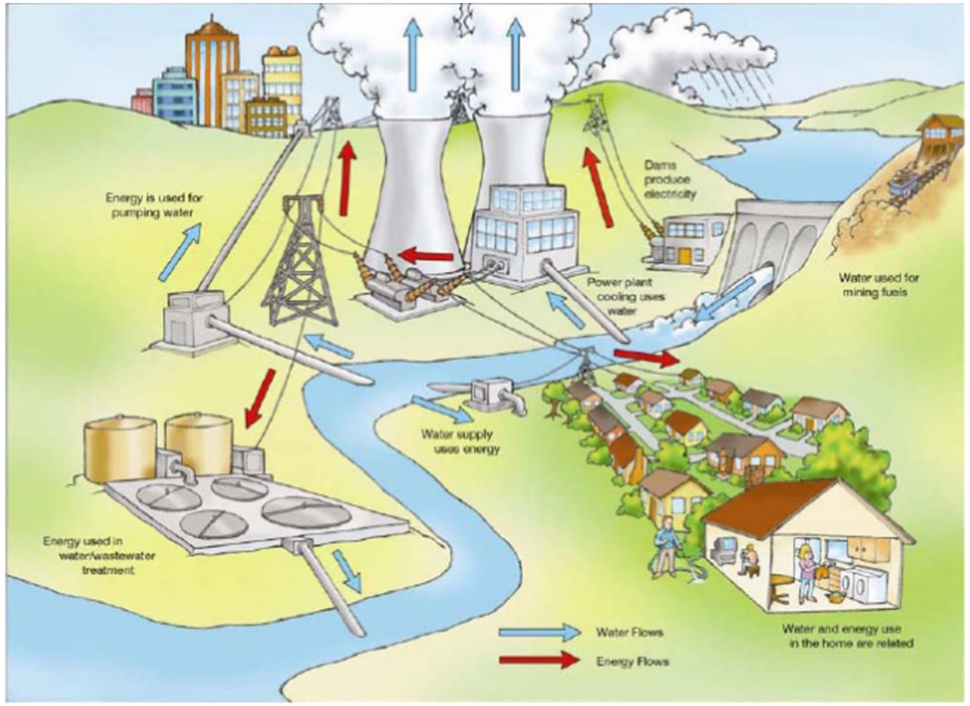


Source: Hamiche, Ait Mimoune, Amine Boudghene Stambouli, and Samir Flazi. "A review of the water-energy nexus." Renewable and Sustainable Energy Reviews 65 (2016): 319-331.

Water management for power systems: role of systems analysis

Lower the cost of treating fossil power plant effluent streams

- Understand fate of heavy metals at CFPPs.
- Baseline the commercially available processes for treating these streams.
- Guide R&D towards the most effective advanced concepts and technology.



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Water management for power systems: role of systems analysis

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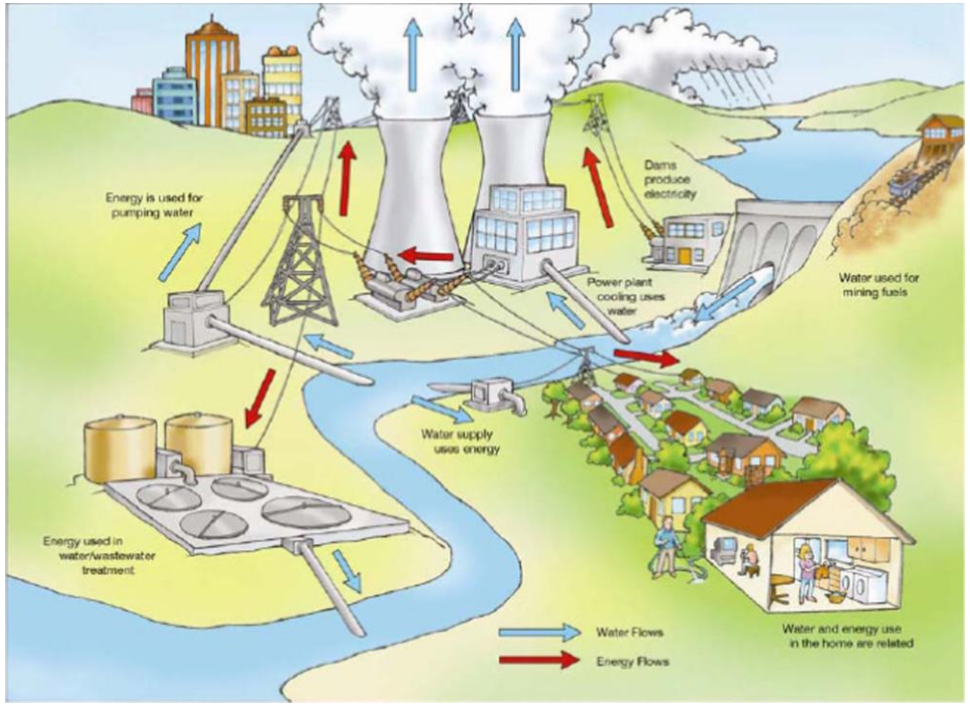
Reducing freshwater consumption

- Advanced cooling tower options for CFPP systems.
- Alternative water options as a function of location.
- Impacts of water stresses (i.e. generation deficits, curtailment, electricity prices, equipment stresses, and change in emissions).



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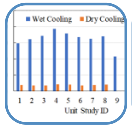
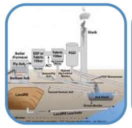
Water Management for Power Systems EY22 Field Work Proposal

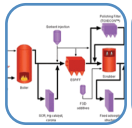
Techno-Economic Modeling of Treating Energy Influent and Effluent Wastewater Streams (Task 2)



Evaluate non-traditional water sources for cooling against dry cooling.



Determine best practices for landfill leachate treatment



Conduct analyses related to bromide emissions in CFPP wastewater streams

U.S. Water-Energy Nexus Modeling (Task 5)

Technology to Market Assessment for Water Management R&D

Water Pricing for Electricity Productions (True Cost of Water)

Previous work modeling treatment of energy wastewater streams

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2018

Cost and Performance Impact of Dry and Hybrid Cooling on Fossil Energy Power Systems

2019

TECHNO-ECONOMIC ANALYSIS AND EVALUATION OF WET FGD WASTEWATER TREATMENT PROCESSES AT EXISTING PLANTS

MITCH MUELLER, DANNY RELLERGERT,
MIKE PRESTON, JESS VANWAGONER, MARC TURNER

2020

ANALYSIS GUIDELINES FOR DRY COOLING R&D

ERIC LEWIS

2020

ANALYSIS GUIDELINES FOR FGD WASTEWATER TREATMENT FROM EXISTING SOURCES

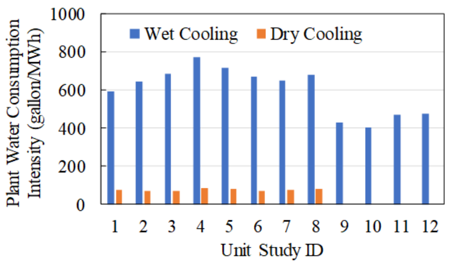
MARC TURNER

2021

TECHNO-ECONOMIC ANALYSIS OF CHEMICAL PRECIPITATION FOLLOWED BY LOW HYDRAULIC RESIDENCE TIME BIOLOGICAL TREATMENT, INCLUDING ULTRAFILTRATION

CHAD ABLE

Techno-Economic Modeling of Treating Energy Influent and Effluent Wastewater Streams



Evaluate non-traditional water sources for cooling against dry cooling.

Treatment of Brackish Water for Fossil Power Plant Cooling

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Objective

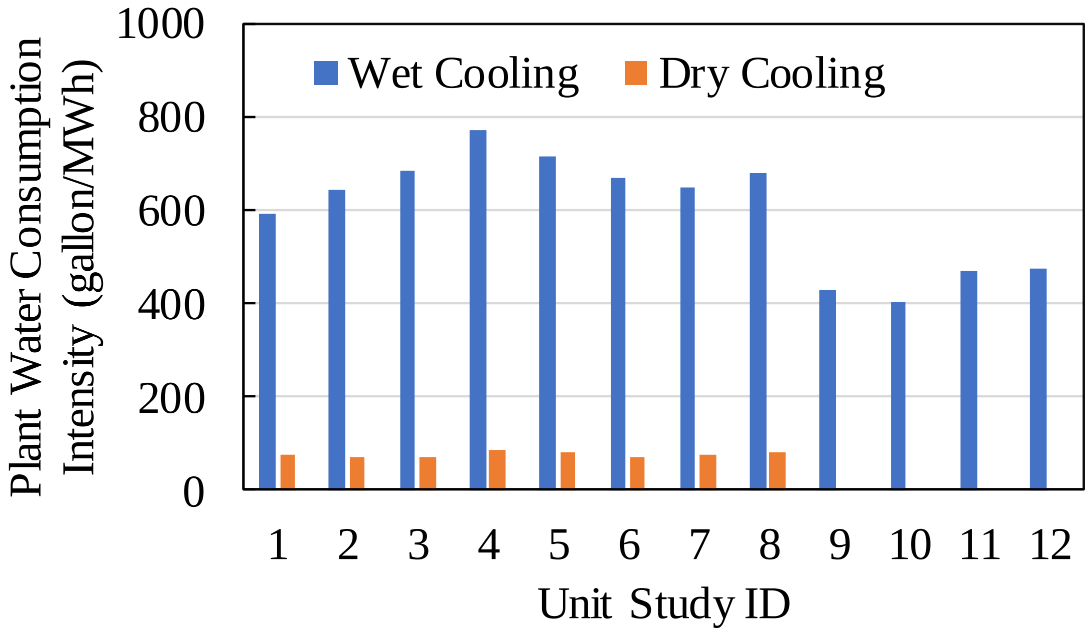
- Evaluate treatment and use of brackish water for power plant wet cooling systems, as an alternative to dry cooling.
- Phase 3 of a multi-year effort
  - Phase 1/EY19 - dry cooling retrofits on coal systems in Arizona (AZ) and New Mexico (NM)
  - Phase 2 - EY20 dry cooling retrofits on NGCC in AZ and NM)

Approach

- Literature review to determine “typical” brackish water concentration
- Screening analysis to evaluate candidate treatment technologies
- New brackish water treatment module built into IECM

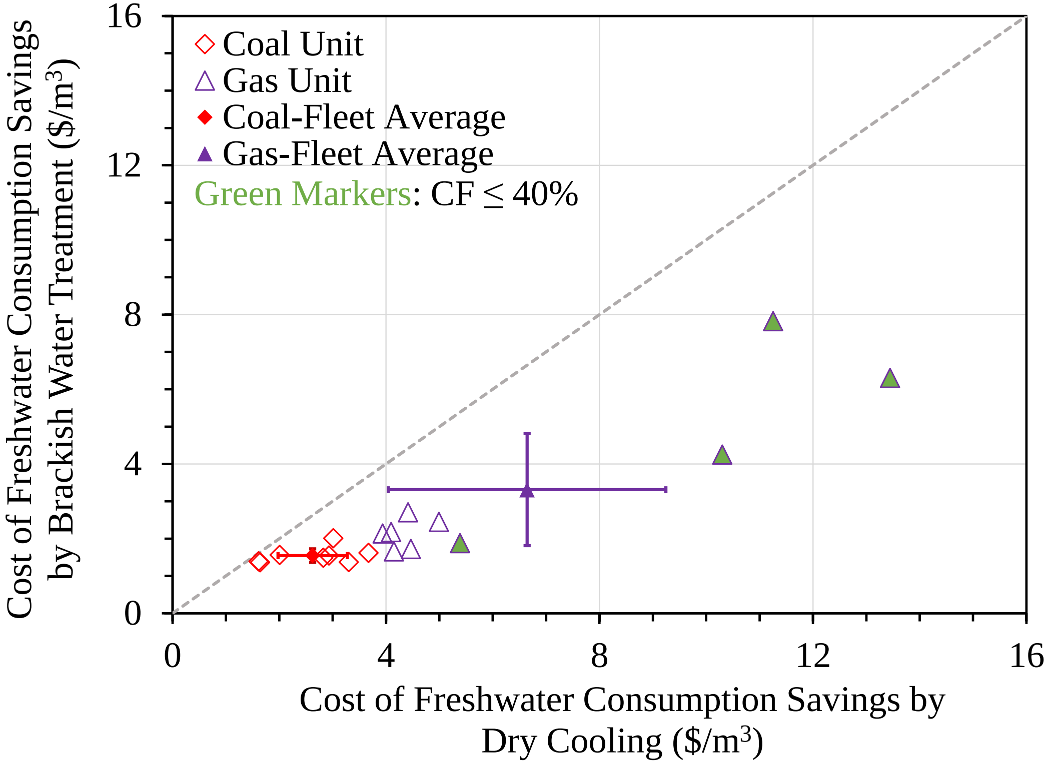
Outcome

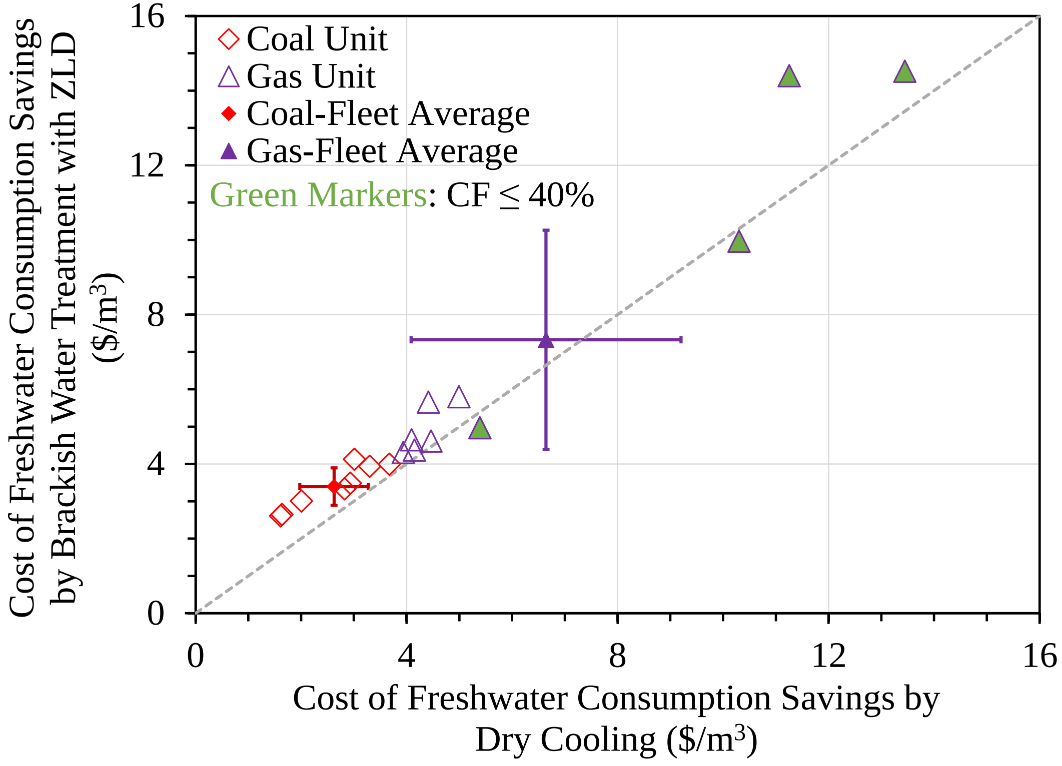
- Evaluate cost, operational issues, and opportunities for power plant cooling without freshwater withdrawal



Phase 1 (Coal Power Plants) Dry Cooling Retrofit Water Use

Substituting freshwater with brackish water is lower cost than dry cooling in non-ZLD scenarios





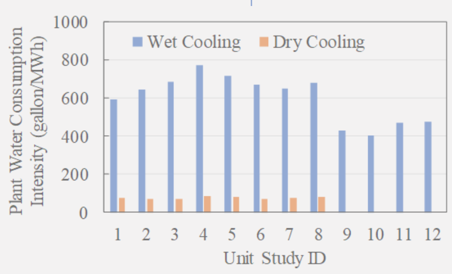
ZLD = zero liquid discharge

Brackish water sufficient, but economic feasibility dependent on brine management

- Sufficient brackish water resources available as makeup water for wet fossil power plant cooling in Arizona and New Mexico
- Cost of freshwater consumption savings by brackish water treatment without ZLD is $\$1.9/m^3$ and $\$3.7/m^3$ on average for coal- and gas-fired EGUs, respectively
- Deployment of current ZLD technology for brine disposal increases energy penalty and cost of consumptive freshwater savings

EGU = Electricity utility steam generating unit; ZLD = zero liquid discharge

Techno-Economic Modeling of Treating Energy Influent and Effluent Wastewater Streams



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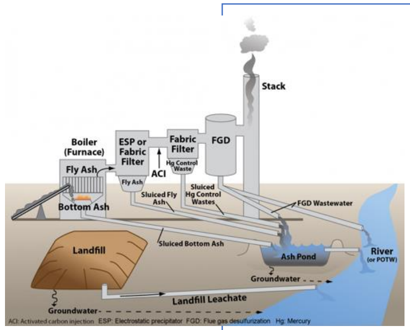


Determine best practices for landfill leachate treatment

Treatment Technology Assessment for Landfill Leachate

Objective

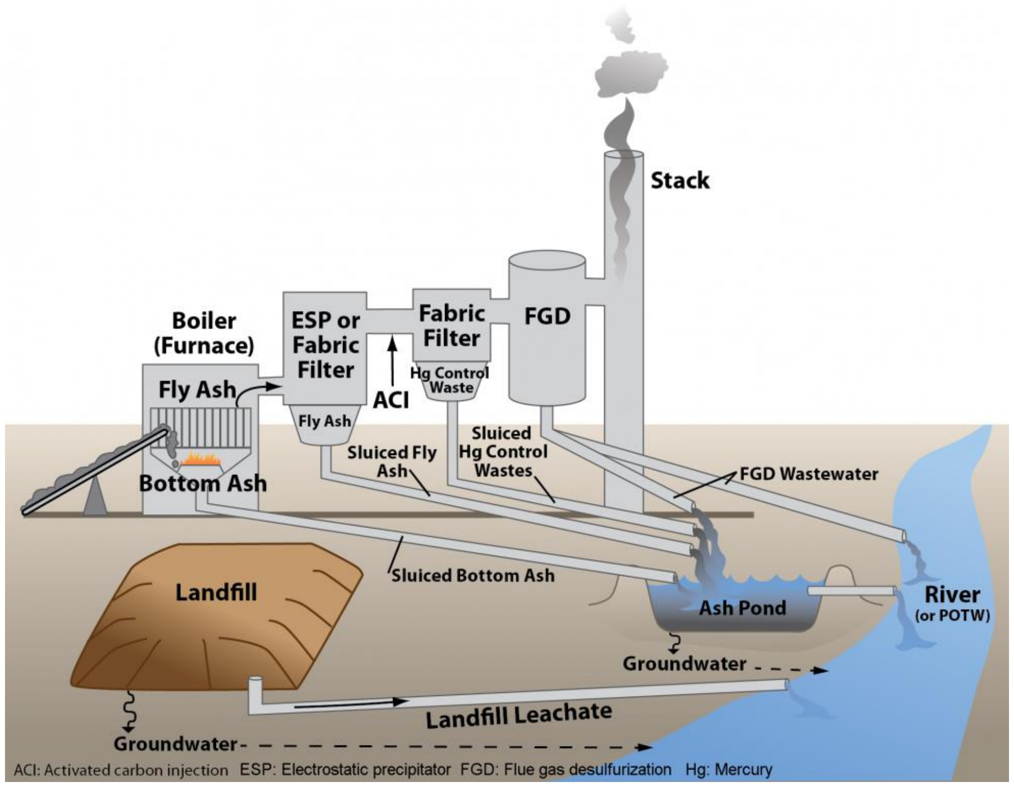
- Coal ash pond wastewaters include landfill leachate and wastewater generated during ash pond closure
- Water quality and treatment volumes for ash pond closures are unknown

Approach

- Assess water quality standards that apply to ash pond wastewaters generated during closure
- Determine the range of pollutant concentrations in ash pond wastewater, and what technologies can achieve environmental compliance
- Determine the potential wastewater volume that needs to be treated, and can this water be treated and reused

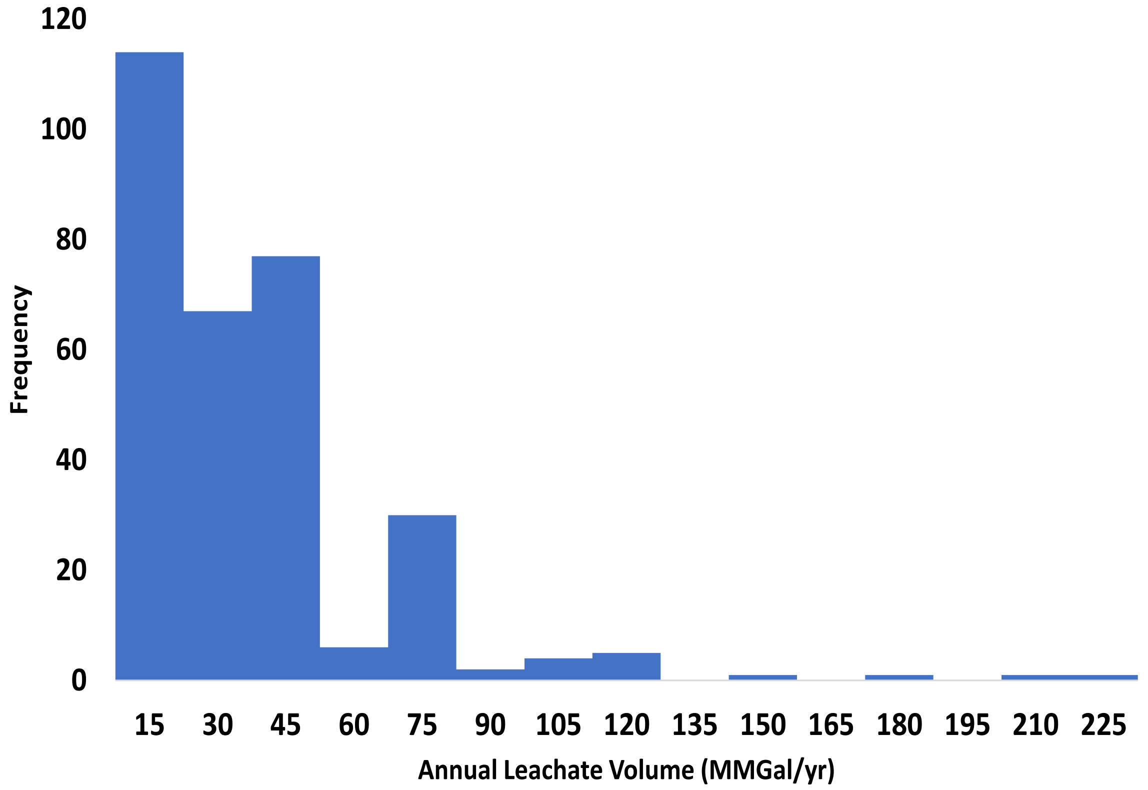
Outcome

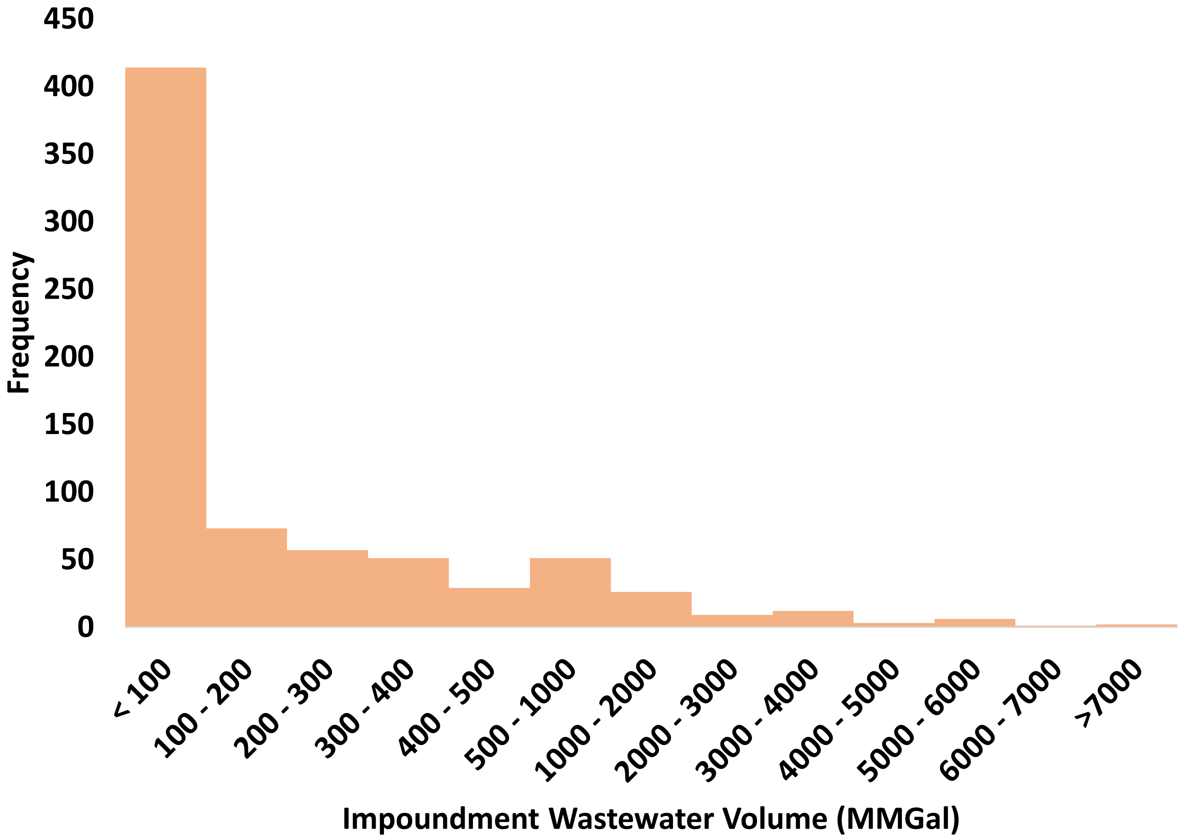
- Evaluate treatment technology needs and market size under possible wastewater quality emission standards for coal ash impoundments closures.



Coal-Fired Power Plant Wastewater Streams (Source: EPA)

Leachate volumes vary widely, dependent on impoundment size and precipitation





Significant treatment costs are expected to meet regulatory requirements

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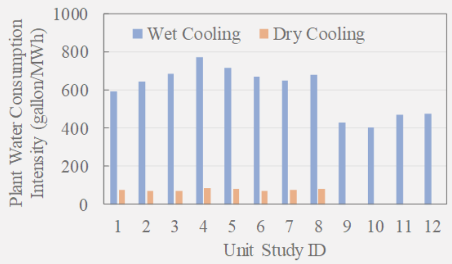
- Impoundment closures referenced in Coal Combustion Residuals rule expected volumes ~190–240 billion gallon/3-year, significantly greater than Landfill leachate volumes of ~10 billion gallons per year
- Leachate will require significant treatment for TSS, arsenic, and mercury to meet the new Effluent Limitations Guidelines, and impoundments will only require treatment for arsenic.
- Treatment costs can vary widely depending on expected flow rate—from $15/kgal to $100s/kgal.
- Mineral recovery could reduce the cost of treatment and potentially recover valuable constituents.

Techno-Economic Modeling of Treating Energy Influent and Effluent Wastewater Streams



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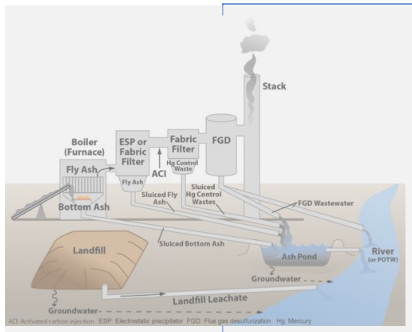

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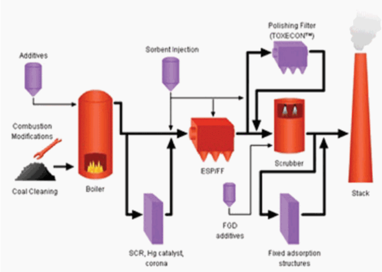


Conduct analyses related to bromide emissions in CFPP wastewater streams

Analysis of Bromides in Wastewater Streams from Coal-Fired Power Plants

Objective

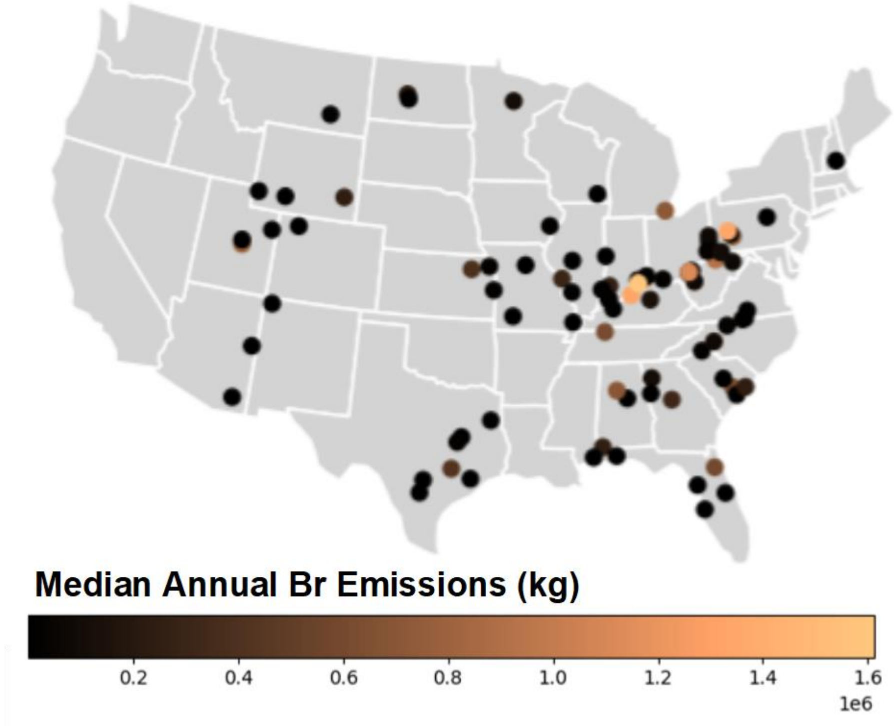
- Bromides in coal plant wastewater streams may be mandatory in future effluent limitation guidelines revisions

Approach

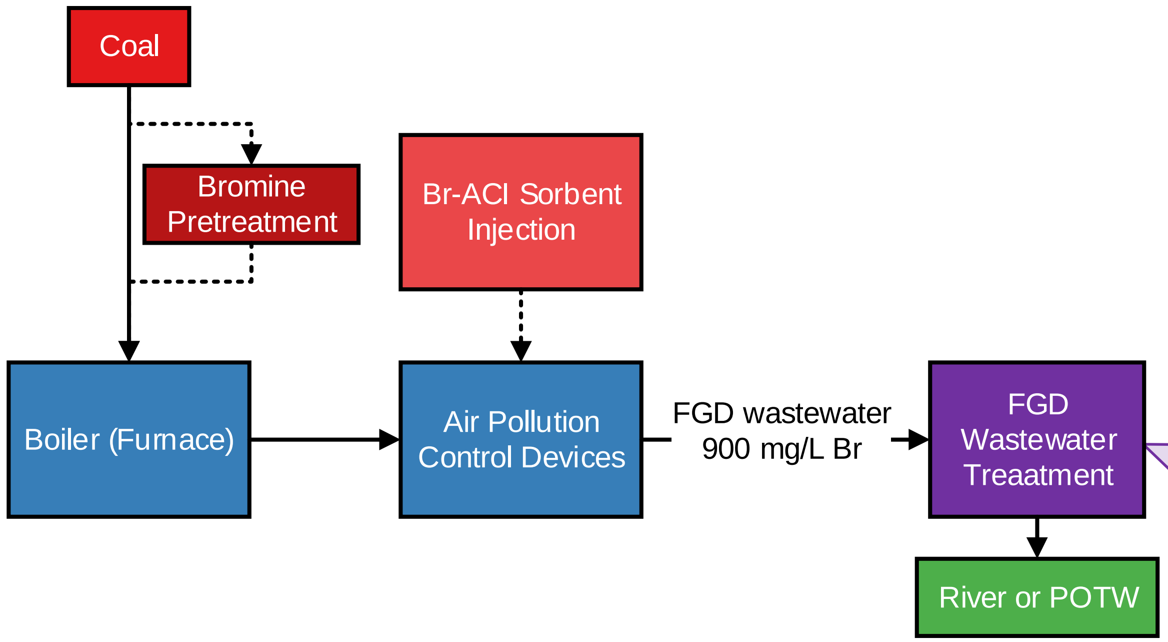
- Determine origin of bromides (coal feed, water makeup, carbon injection for control of Hg emissions in flue gas)
- Establish best bromide control options (back-end treatment trains, zero liquid discharge)
- Study existing coal units with local or state-enforced bromide limitations
- Calculate probabilistic range of possible bromide effluent concentrations

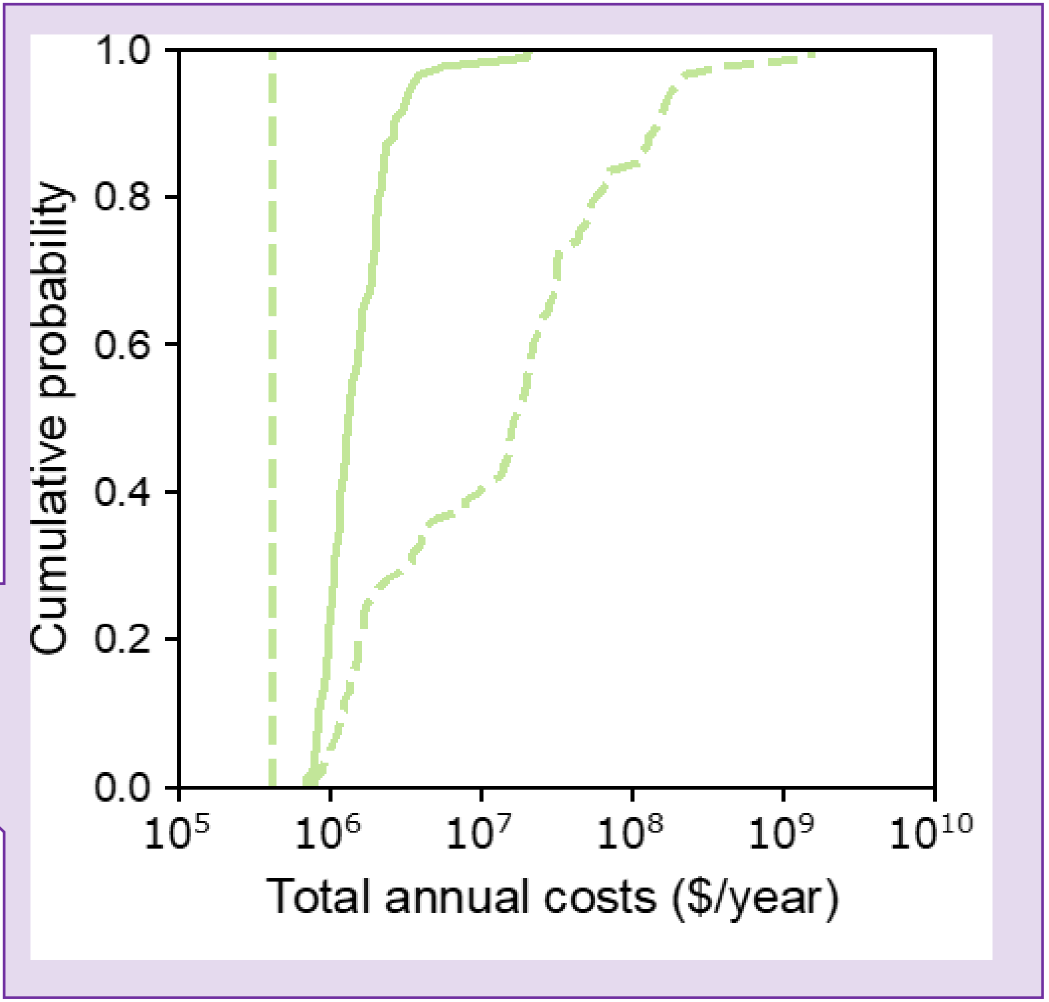
Outcome

- Enhance DOE's knowledge of this developing area early, to inform decision making as bromine regulations develop



Treatment costs are not well described by the average plant





FGD = flue gas desulfurization; POTW = publicly owned treatment works; ACI = Activated carbon injection

Significant treatment costs are expected to meet regulatory requirements

- The Steam Electric Power Generating Point Source Category limit of 0.2 mg/L would involve a >99.8% removal at flow rates optimized for safe concentration ranges of chlorides.
- Annual costs of bromide treatment range from $61.3 million to $333 million in 2021 U.S. dollars.
- Costs are highly dependent on the annual capacity factor of the plant.

Future directions: New water-energy domains

Current Expertise

- Wastewater Treatment
- Techno-economic Assessment

New Domains

- Produced water treatment + valorization
- Water costs and opportunities for low-carbon generation

Water Management for Power Systems EY22 Field Work Proposal

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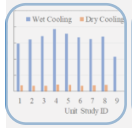
Techno-Economic Modeling of Treating Energy Influent and Effluent Wastewater Streams (Task 2)



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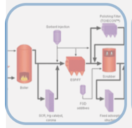


Conduct analyses related to bromide emissions in CFPP wastewater streams

U.S. Water-Energy Nexus Modeling (Task 5)

Technology to Market Assessment for Water Management R&D

Water Pricing for Electricity Productions (True Cost of Water)

Previous work on water-energy nexus modeling

NATIONAL ENERGY TECHNOLOGY LABORATORY

Water-Energy Prototype Model for the NEMS Modeling Platform: Thermoelectric Water Demand and Its Implications on Regional Electricity Market

Erik Shuster[1], Arun K. S. Iyengar[1], Lessly Goudarzi[2], Dale Keairns[1], Christa Court[3], Charles Zelek[1]

2017

2020

Regional and seasonal water stress analysis of United States thermoelectricity

Uisung Lee [a,*], Joseph Chou [b], Hui Xu [a], Derrick Carlson [b], Aranya Venkatesh [b], Erik Shuster [c], Timothy J. Skone [c], Michael Wang [a]

[a] *Systems Assessment Center, Energy Systems Division, Argonne National Laboratory, 9700 South Cass Avenue, Lemont, IL, 60439, United States*
[b] *Contractor to National Energy Technology Laboratory, 626 Cochran Mills Road, Pittsburgh, PA, 15236, United States*
[c] *National Energy Technology Laboratory, 626 Cochran Mills Road, Pittsburgh, PA, 15236, United States*

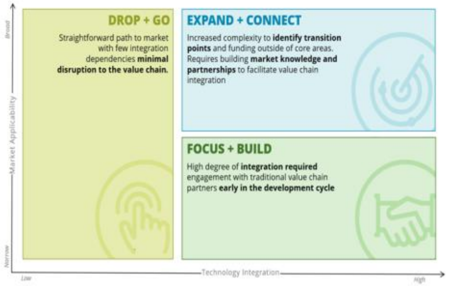
2022

Effects of Short-Term Water Constraints on Electricity Dispatch: A Case Study of ERCOT and SPP Regions

Yash Kumar, Rachel Hoesly, Aranya Venkatesh, Erik Shuster, and Arun Iyengar*

ESTIMATING FRESH WATER NEEDS TO MEET FUTURE THERMOELECTRIC GENERATION REQUIREMENTS AND PROGRAM WATER SAVING BENEFITS – 2022 UPDATE

U.S. Water-Energy Nexus Modeling



Technology to Market Assessment for Water Management R&D

Technology to Market Assessment for Water Management R&D

Objective

Prioritize promising portfolio technologies for focused, needs-based support that can increase their likelihood of making a market impact

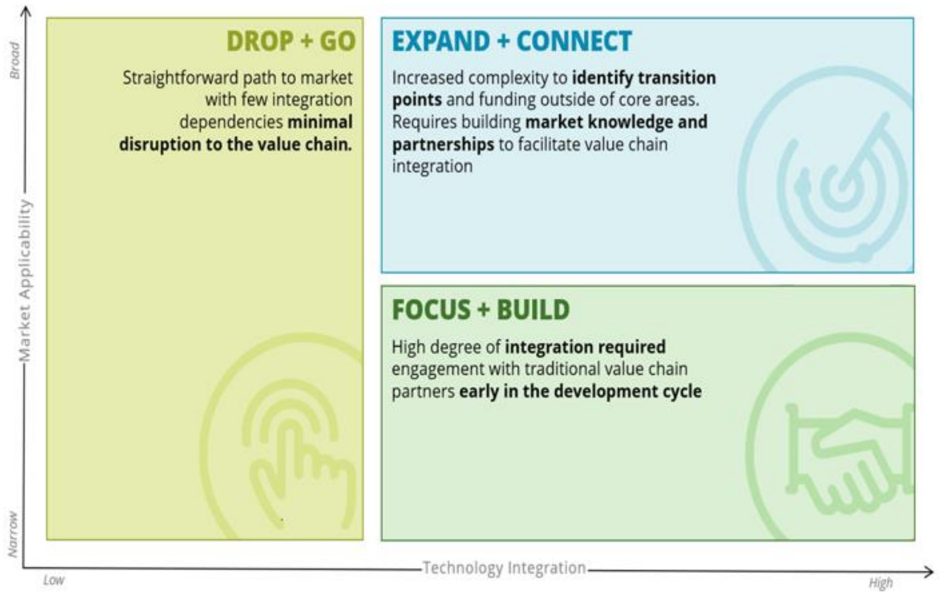
Approach

- Evaluate both NETL in-house R&IC research and extramural projects
- Utilize a three-step process for making go-to-market recommendations for technologies in the Water Management FWP

Outcome

- Tech-to-Market Analysis (October 2022)

Evaluating a technology's commercialization difficulty



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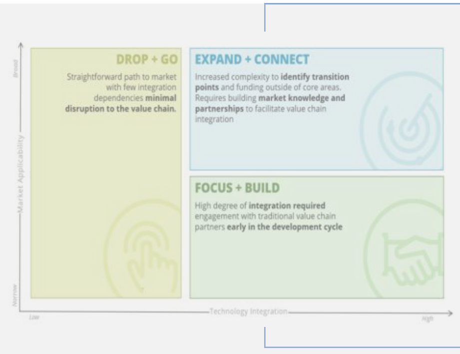

Technology to Market Assessment for Water Management R&D

Water Pricing for Electricity Productions (True Cost of Water)

Water Pricing for Electricity Production

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Objective

This project will look at the future impact of not investing in water resource management today and provide incentive and understanding to electricity generators of the benefits of making investments to improve water use efficiency.

Approach

Quantify the full cost of water in electricity generation by calculating the true cost of water use across all phases of electricity generation.

Outcome

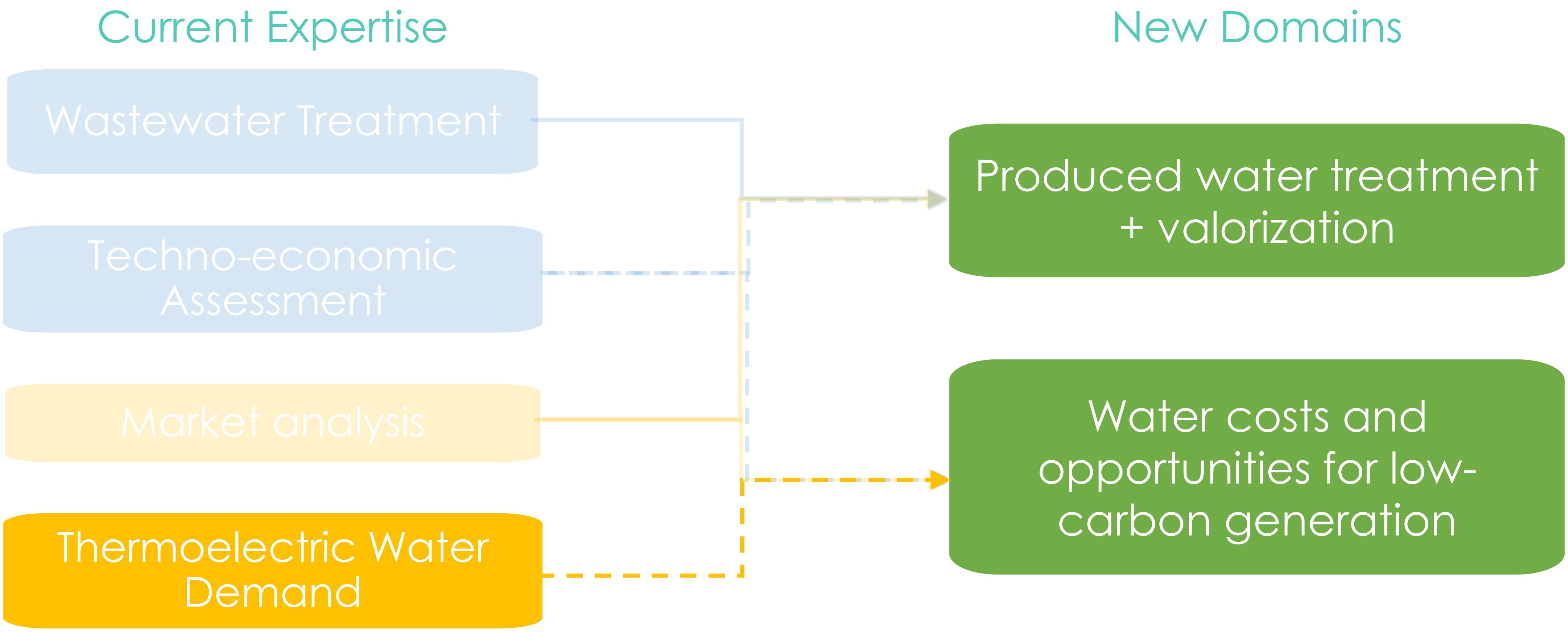
- Water Pricing Analysis/Final Report (March 2023)

Related to increasing water scarcity and stressors caused by demand that is outpacing supply

Materializes due to increasing water prices such as the need to source alternative water supply

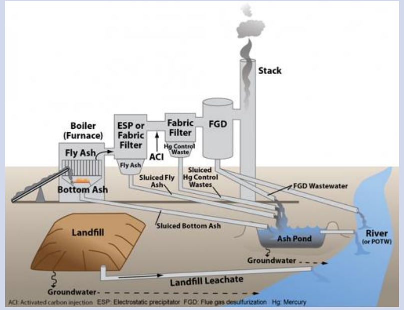
Impact of more stringent water treatment, wastewater management, and water use restrictions

Future directions: New water-energy domains



Key takeaways

Lower the cost of treating fossil power plant effluent streams



- Determined technology costs and performance needs to control bromide emissions from flue gas desulfurization wastewater
- Established regional variation and national loadings of trace elements in landfill leachate and ash pond closure

Reduce freshwater consumption

- Evaluated feasibility of alternative cooling water sources
- Prioritized promising portfolio water reduction technologies for commercialization
- Incentivized water efficiency by determining the true cost of water use

Thank you

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