EVALUATING THE TECHNO-ECONOMIC FEASIBILITY OF FORWARD OSMOSIS PROCESSES UTILIZING LOW GRADE HEAT

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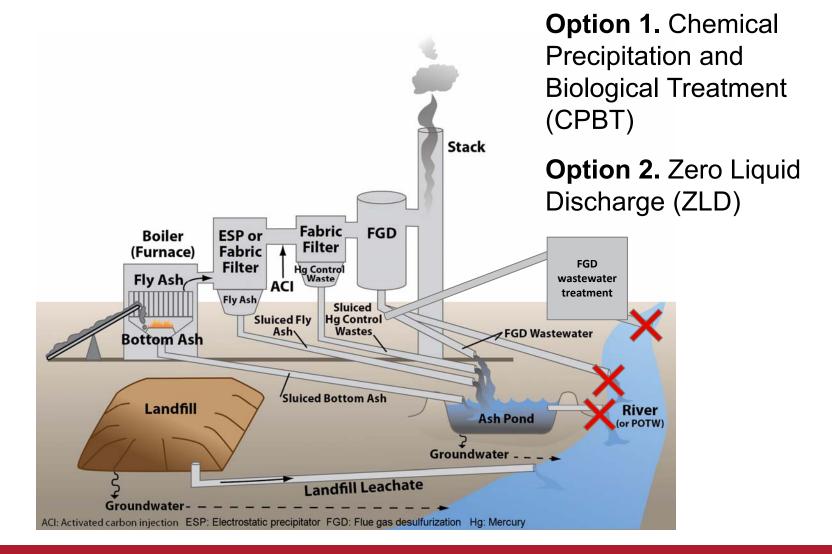
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EPA FINAL EFFLUENT LIMITATION GUIDELINES FOR STEAM ELECTRIC POWER GENERATION FACILITIES

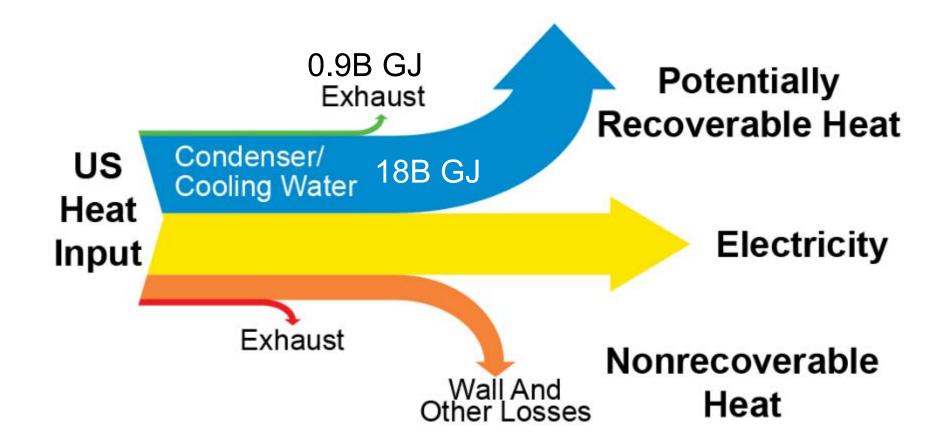


US EPA Final Effluent Guidelines for the Steam Electric Power Generating Category EPA 821-R-13-003, Sept. 2015

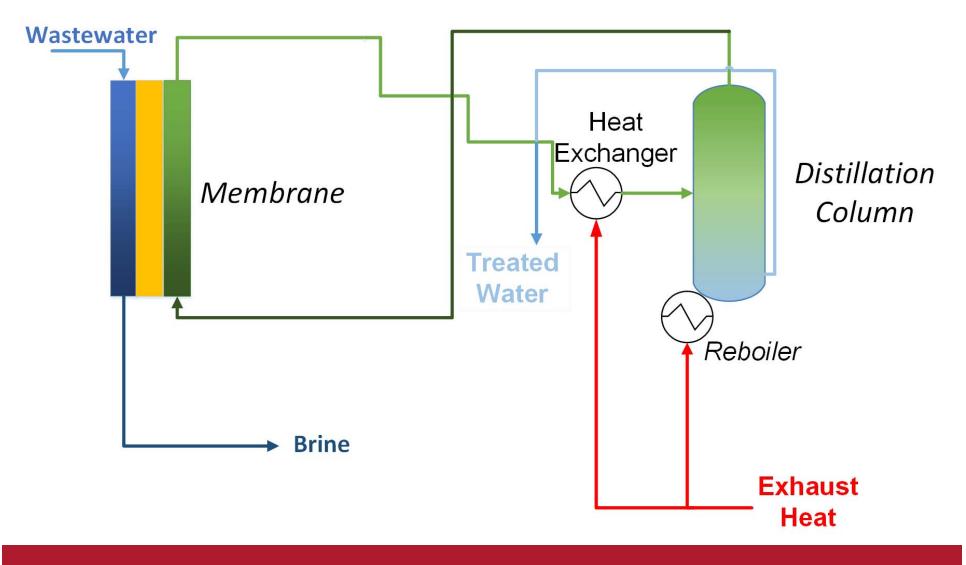
Carnegie Mellon University

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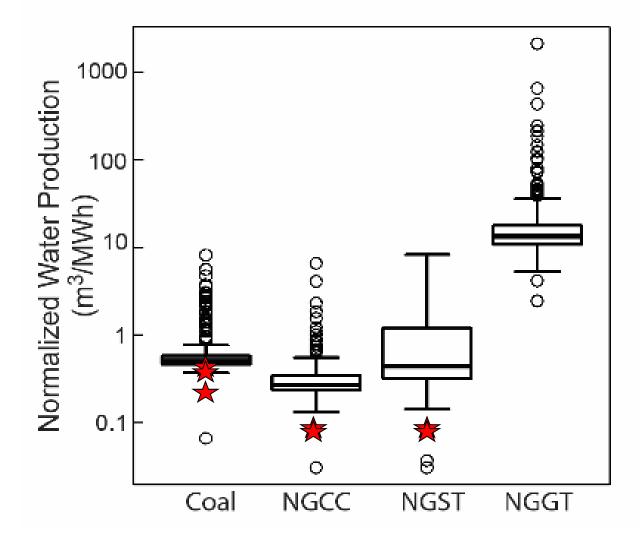
18.9 BILLION GJ OF POTENTIALLY RECOVERABLE HEAT IS AVAILABLE FROM THERMAL POWER PLANTS



FORWARD OSMOSIS UTILIZES WASTE HEAT TO TREAT WATER



THEORETICAL FORWARD OSMOSIS CAPACITY EXCEEDS NON-COOLING WATER TREATMENT DEMANDS

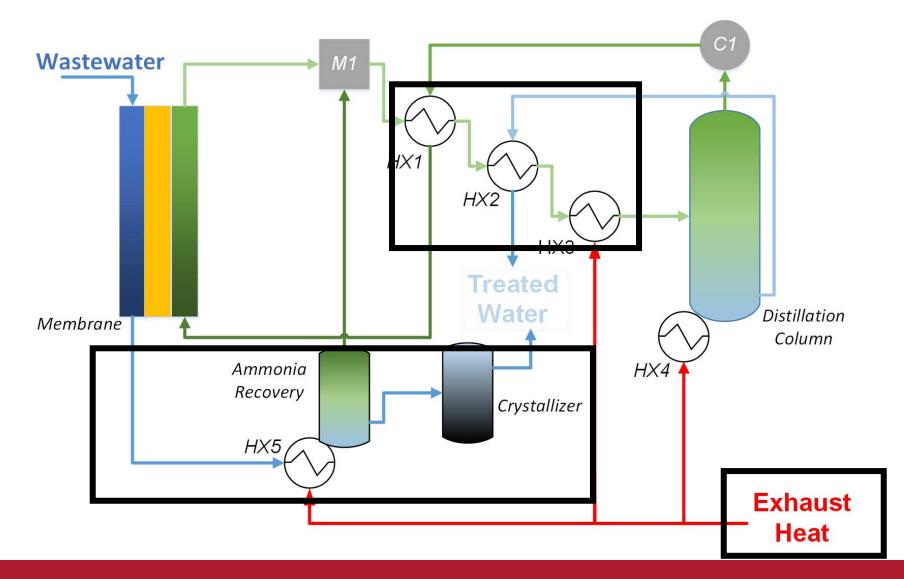


Zhou, Gingerich, and Mauter, *I&ECR, 2015*

- What is the minimum cost of waste heat driven forward osmosis to treat power plant wastewater and boiler feedwater?
- 2. How does the cost of forward osmosis compare to currently installed technologies?
- 3. How **sensitive is the cost** as a result of changes in operating conditions?

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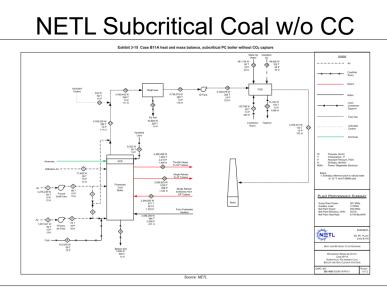
FORWARD OSMOSIS AND CRYSTALLIZATION PROCESSES AT POWER PLANTS



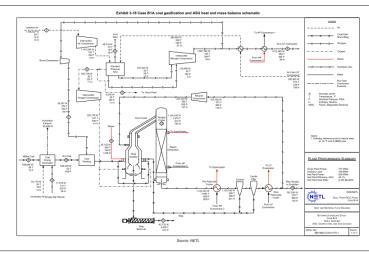
OVERALL MODELING AND OPTIMIZATION APPROACH

Inputs	Technical Model	Economic Model	Output
System Materials			
Energy Availability			
Feed Characteristics			
Draw Characteristics			

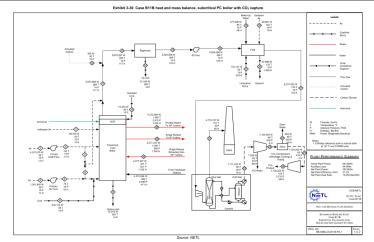
CASE STUDIES – ZLD WASTEWATER



NETL Integrated Gasification



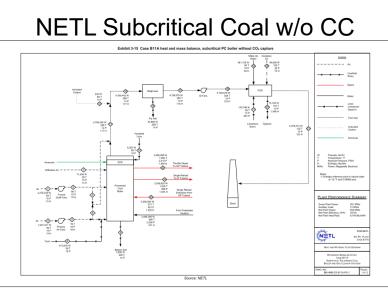
NETL Supercritical Coal w/ CC



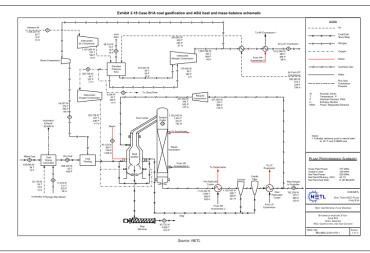
Subcritical Coal - Plant Bowen



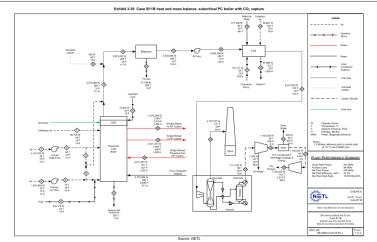
CASE STUDIES – BOILER FEEDWATER



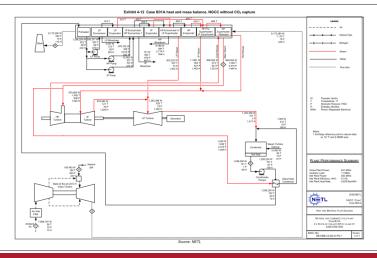
NETL Integrated Gasification



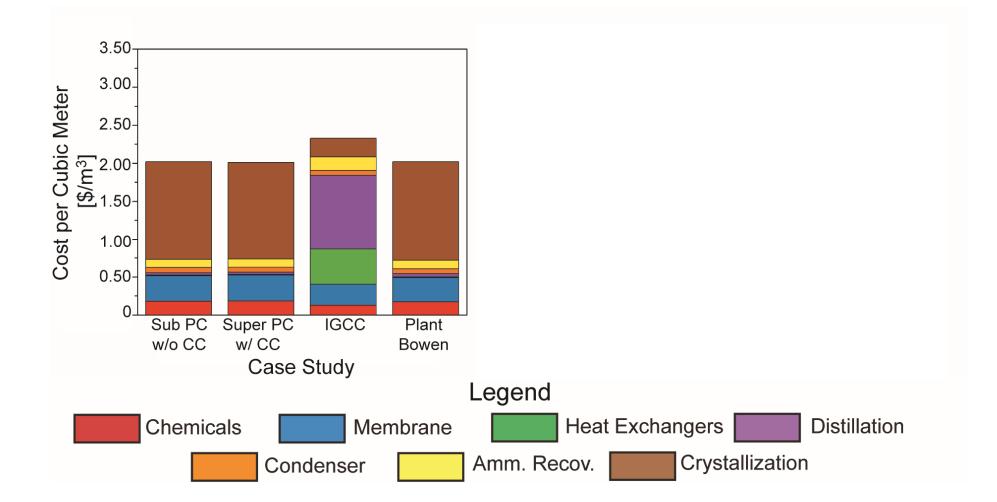
NETL Supercritical Coal w/ CC



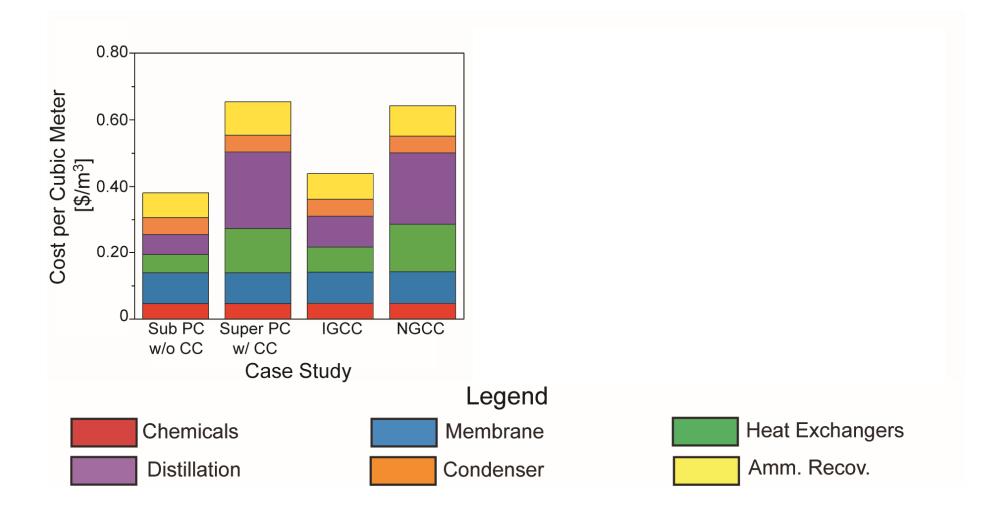
NETL Natural Gas Combined Cycle



COSTS FOR TREATING WASTEWATER TO ZERO LIQUID DISCHARGE



COSTS FOR TREATING BOILER FEEDWATER



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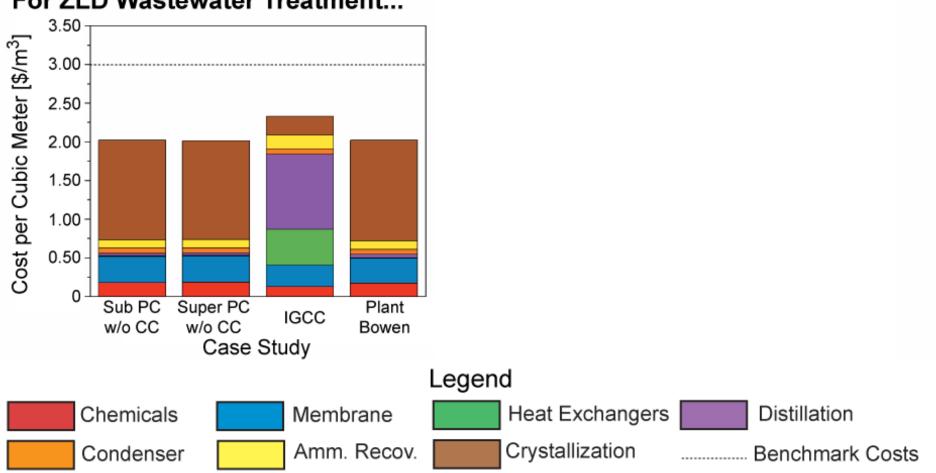
BEST AVAILABLE TECHNOLOGY BENCHMARKS

For ZLD wastewater:



Mechanical Vapor Recompression and Crystallization

FO IS COMPETITIVE FOR ZLD



For ZLD Wastewater Treatment...

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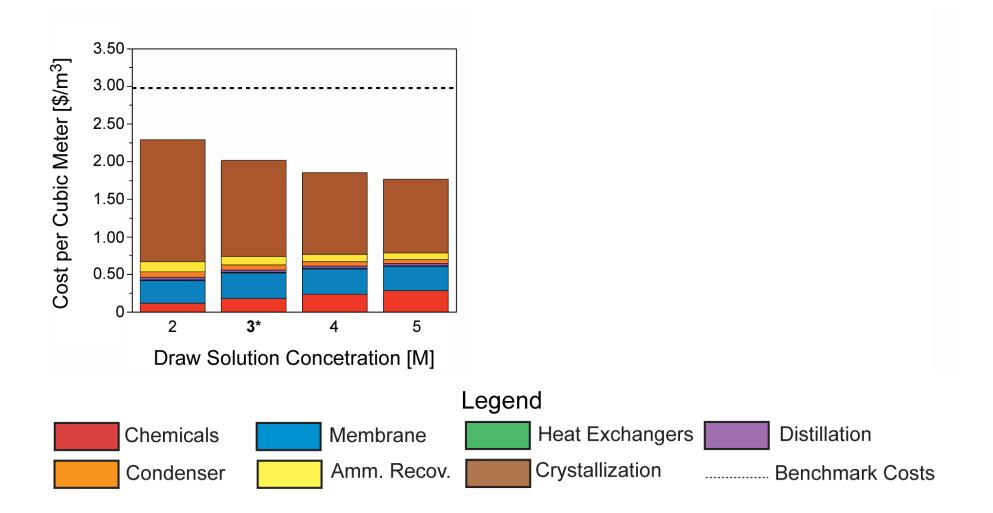
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SENSITIVITY ANALYSES ON DESIGN AND OPERATING VARIABLES

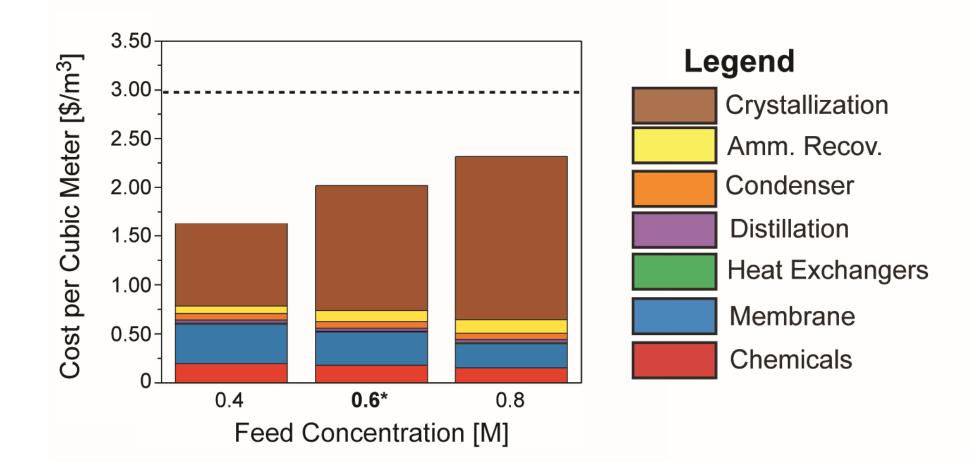
$$J_W = A(\pi_D - \pi_F)$$



$COST \ \mbox{is robust over range of decision variables}$



FEED CONCENTRATION INCREASES LEADS TO COST INCREASES



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CONCLUSION/RESULTS

 Treatment with conventional "best available technologies" leads to suboptimal economic decisions for zero liquid discharge processes.

- Additional research needs for FO membranes:
 - Developing high flux membranes
 - Membranes that can handle cycling of wastewater purges
 - Membranes that can handle scaling

ACKNOWLEDGEMENTS

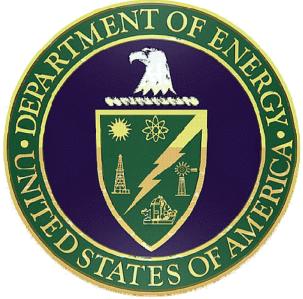
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Colleagues in the WE3 Lab

• Tim Bartholomew

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QUESTIONS?