Technoeconomic Optimization of Waste Heat Driven Forward Osmosis for Flue Gas Desulfurization Wastewater Treatment

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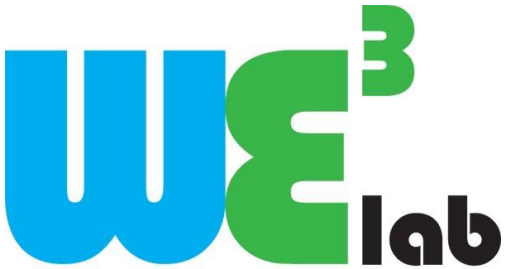
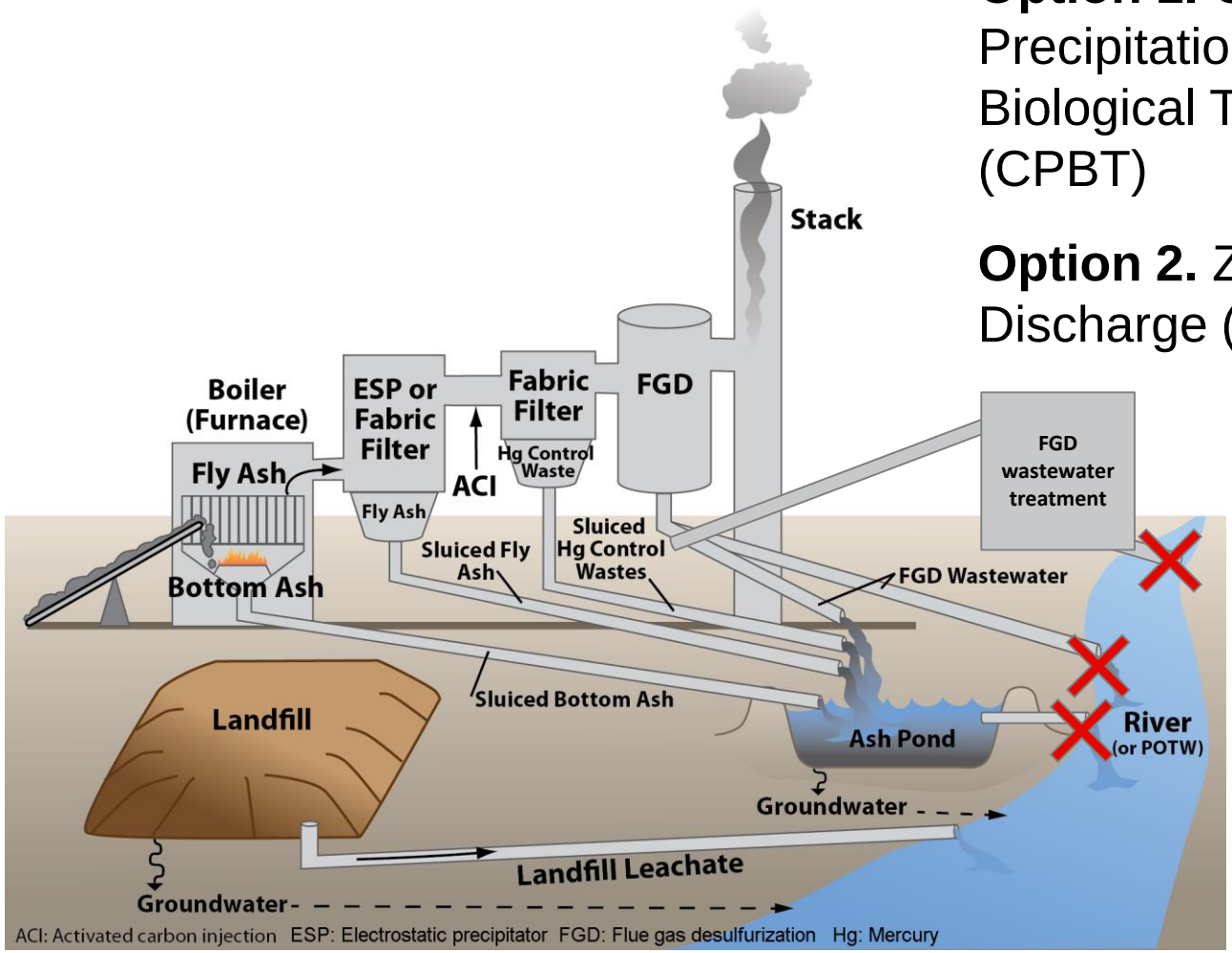


EPA Final Effluent Limitation Guidelines for Steam Electric Power Generation Facilities

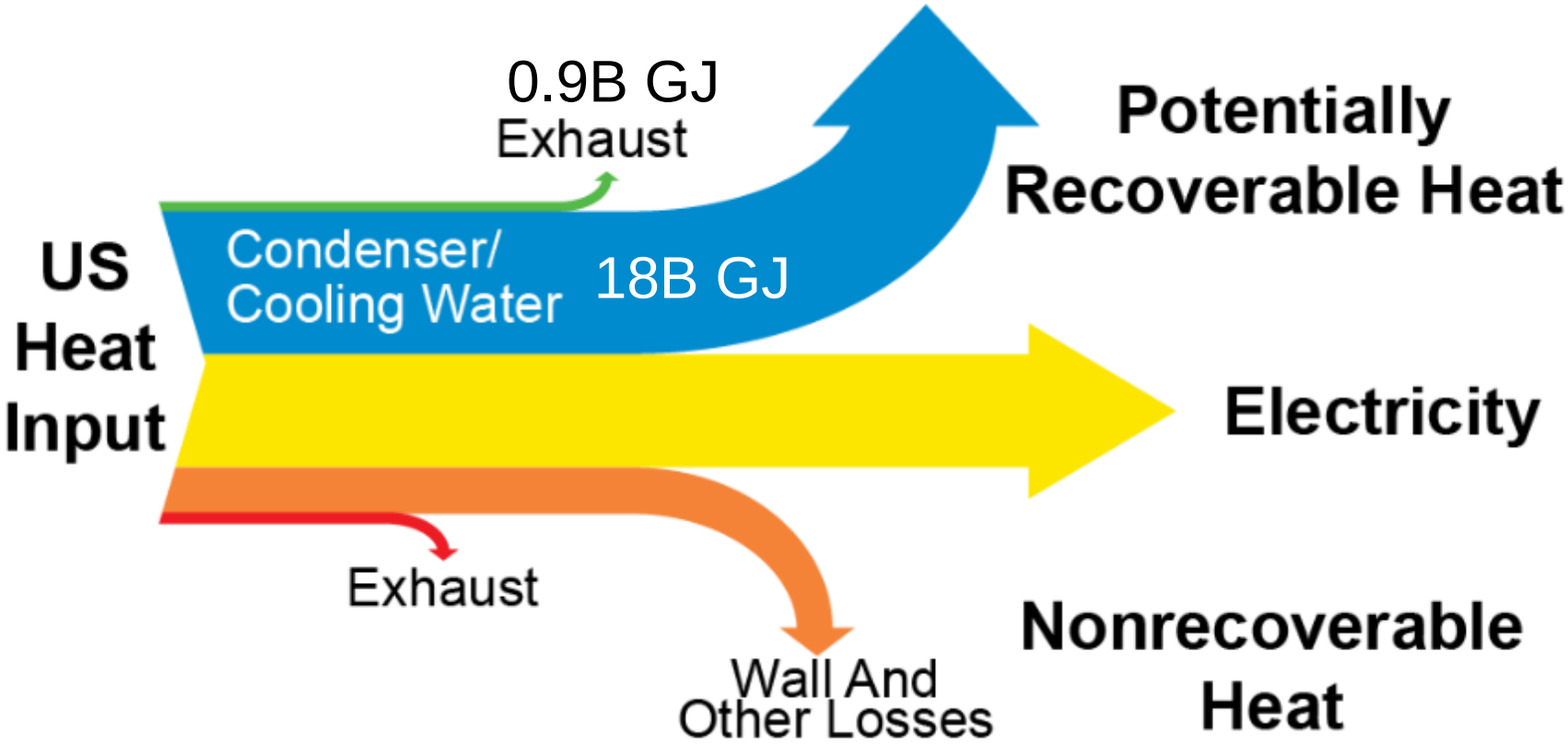
Option 1. Chemical Precipitation and Biological Treatment (CPBT)

Option 2. Zero Liquid Discharge (ZLD)



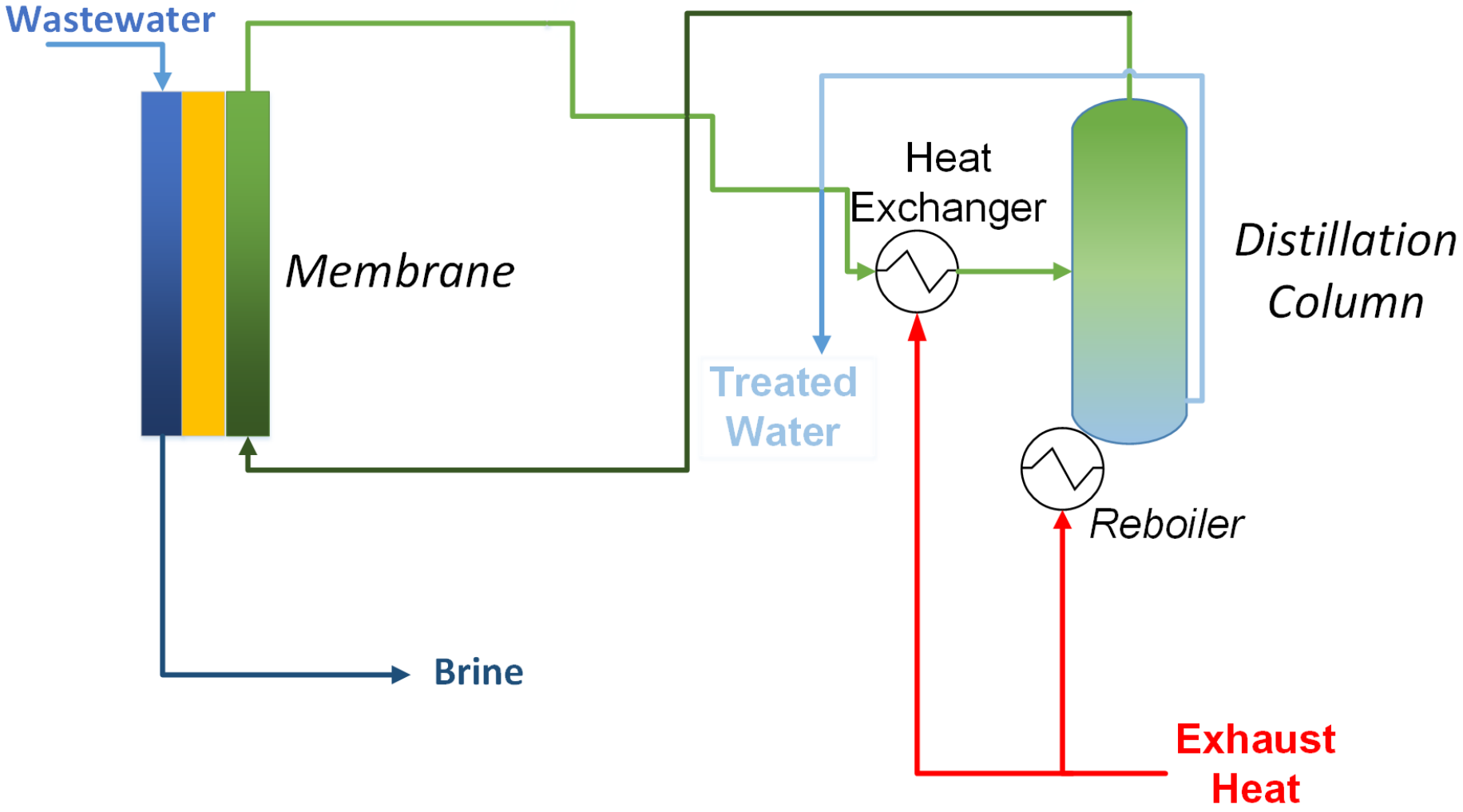
US EPA Final Effluent Guidelines for the Steam Electric Power Generating Category EPA 821-R-13-003, Sept. 2015

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

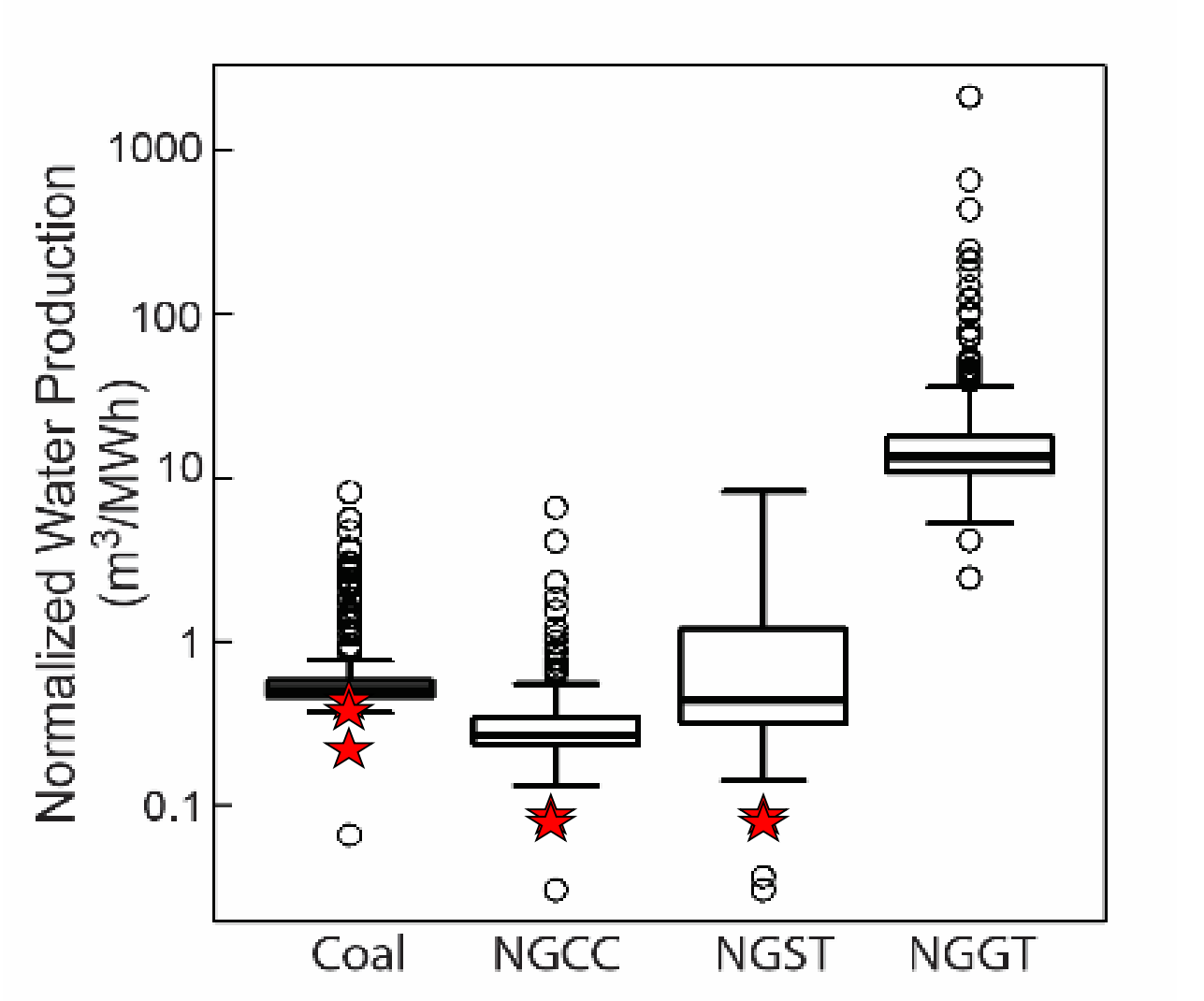


Gingerich and Mauter, *ES&T, 2015*

Forward osmosis utilizes waste heat to treat water



Theoretical Forward Osmosis Capacity Exceeds Non-Cooling Water Treatment Demands



Research Questions

We've shown that waste heat driven FO is technically feasible, but **FO also needs to be economically competitive**.

1. What is the **minimum cost** of waste heat driven forward osmosis to treat power plant wastewater and boiler feedwater?

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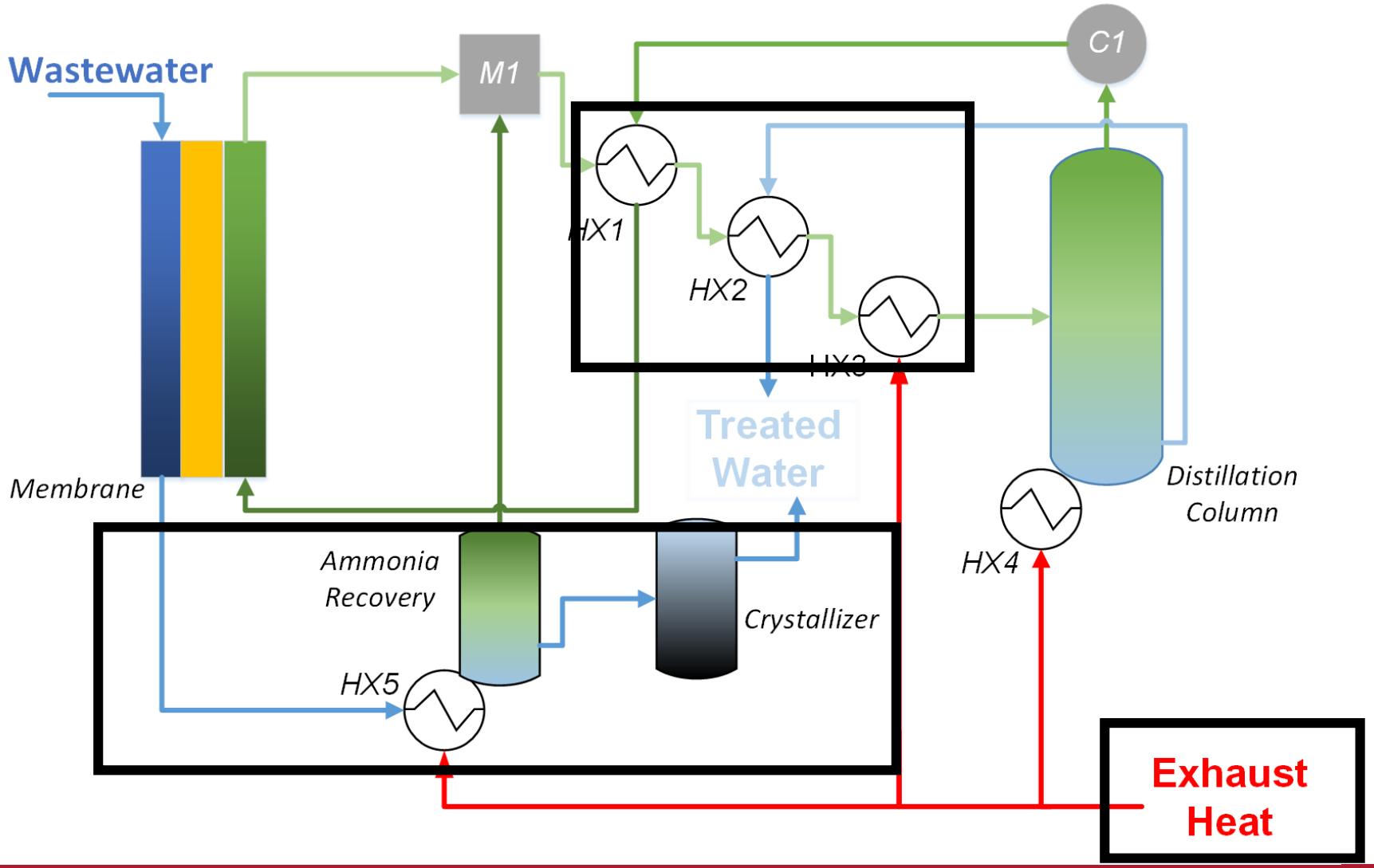
Forward osmosis and crystallization processes at power plants

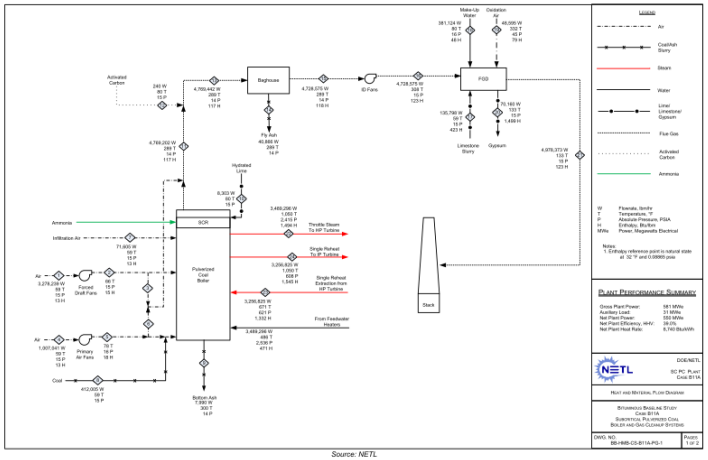


Overall modeling and optimization approach

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

CASE STUDIES – ZLD WASTEWATER

NETL Subcritical Coal w/o CC



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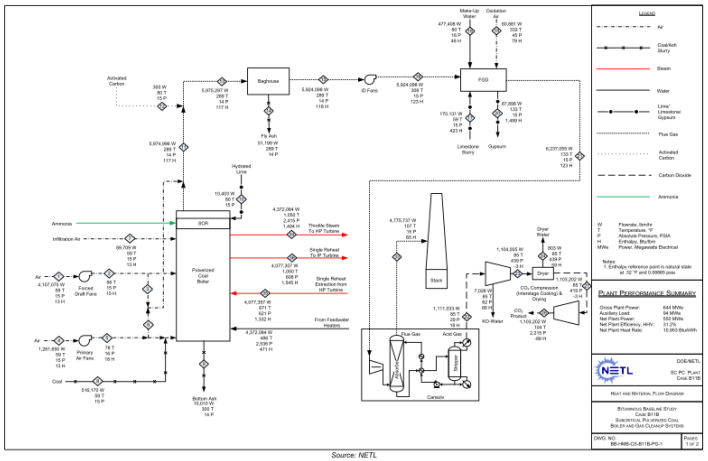
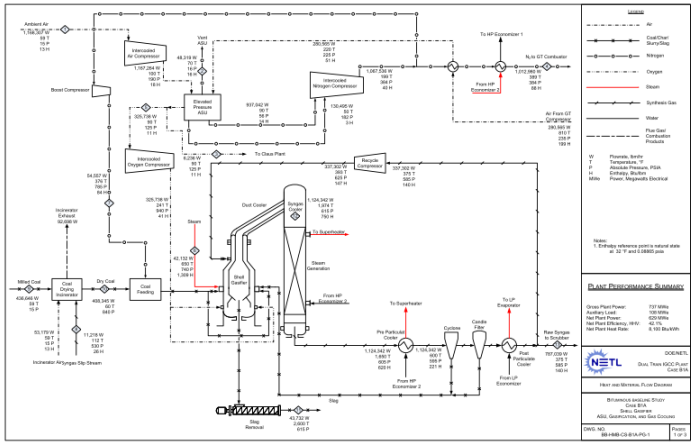


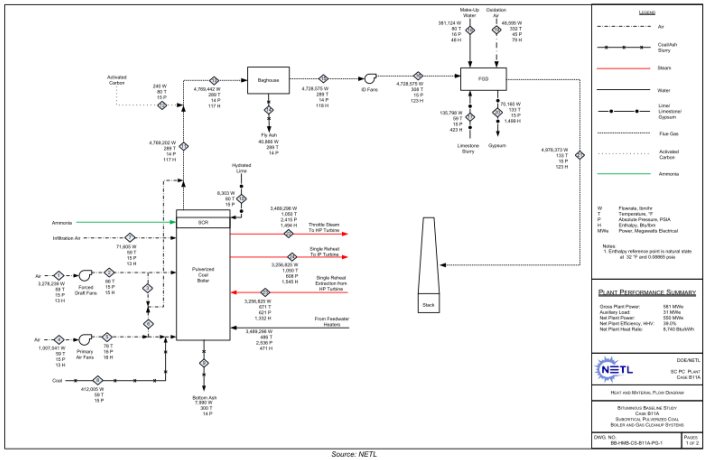
NETL Integrated Gasification



Subcritical Coal - Plant Bowen

Case Studies – Boiler Feedwater

NETL Subcritical Coal w/o CC



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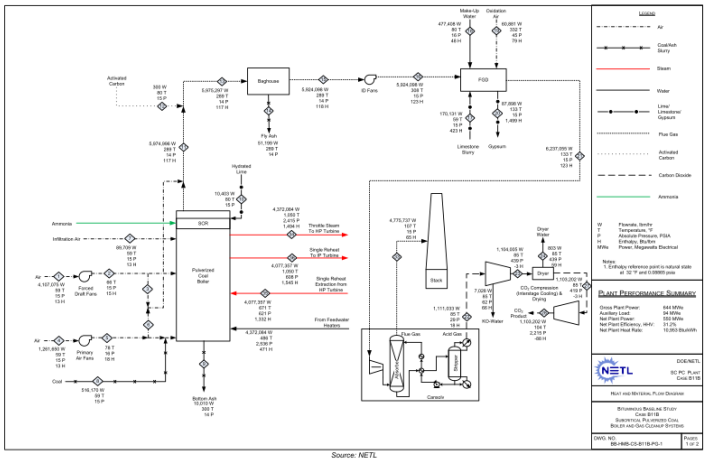

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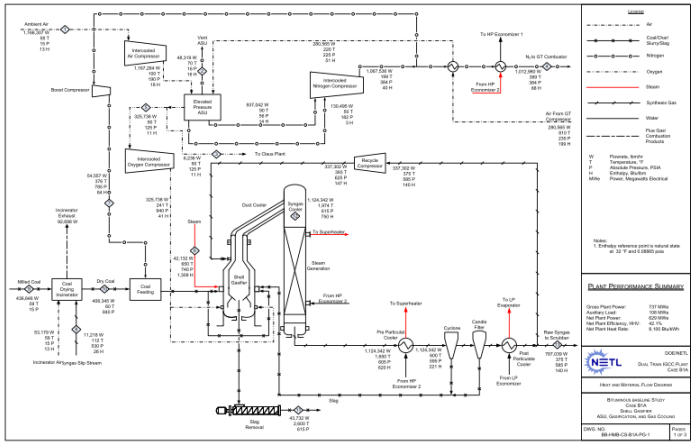
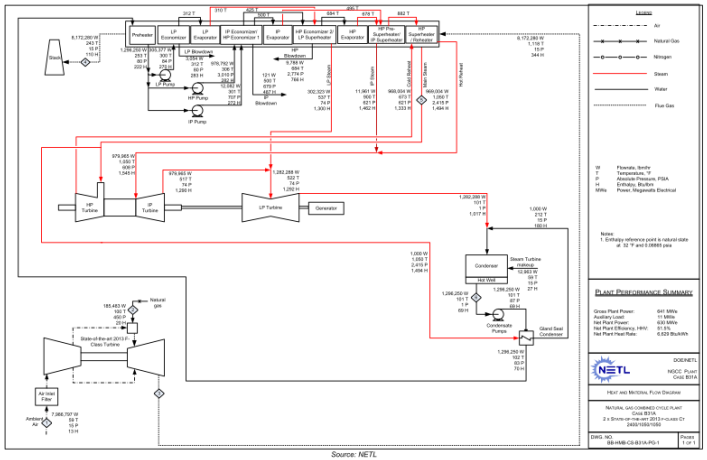
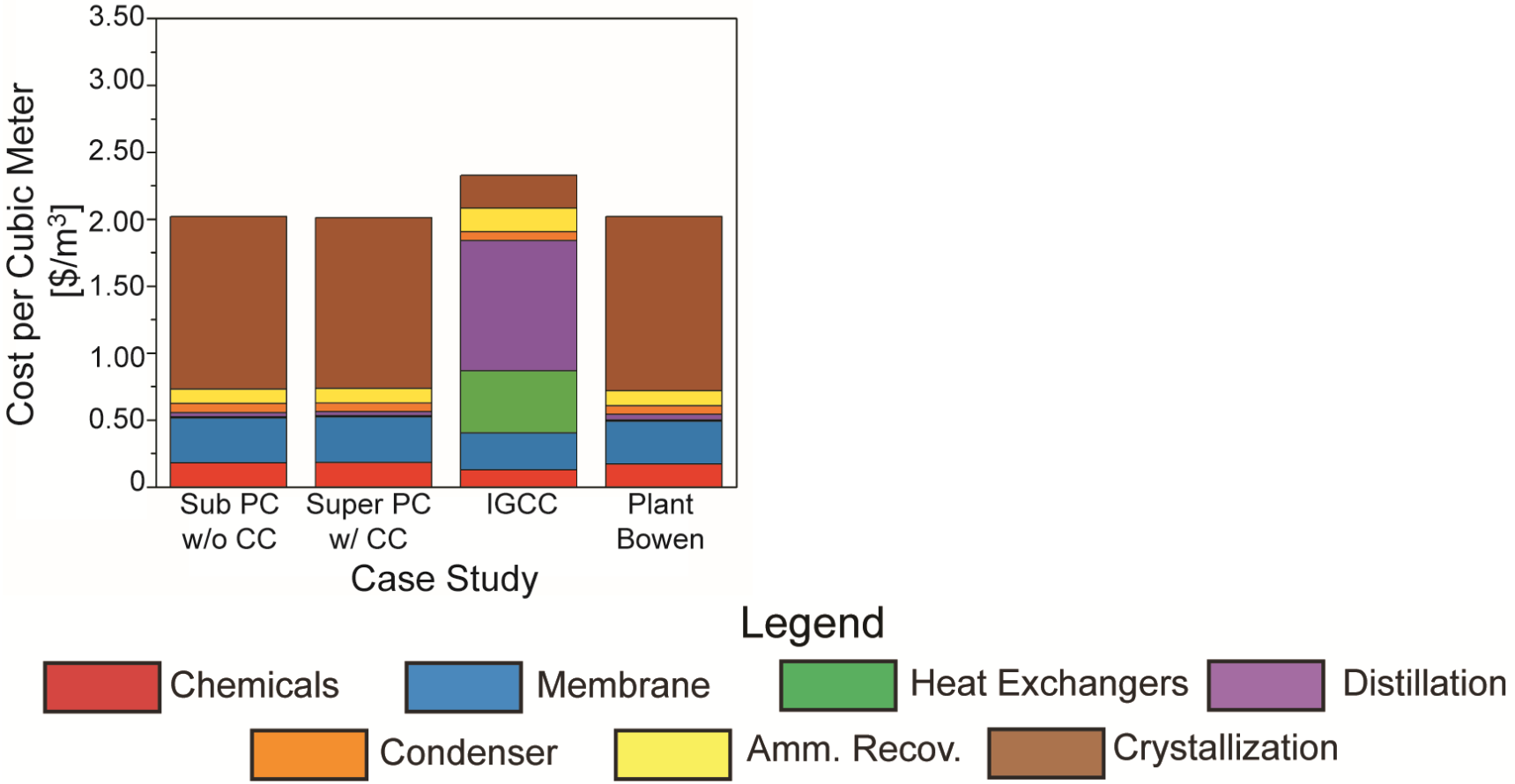


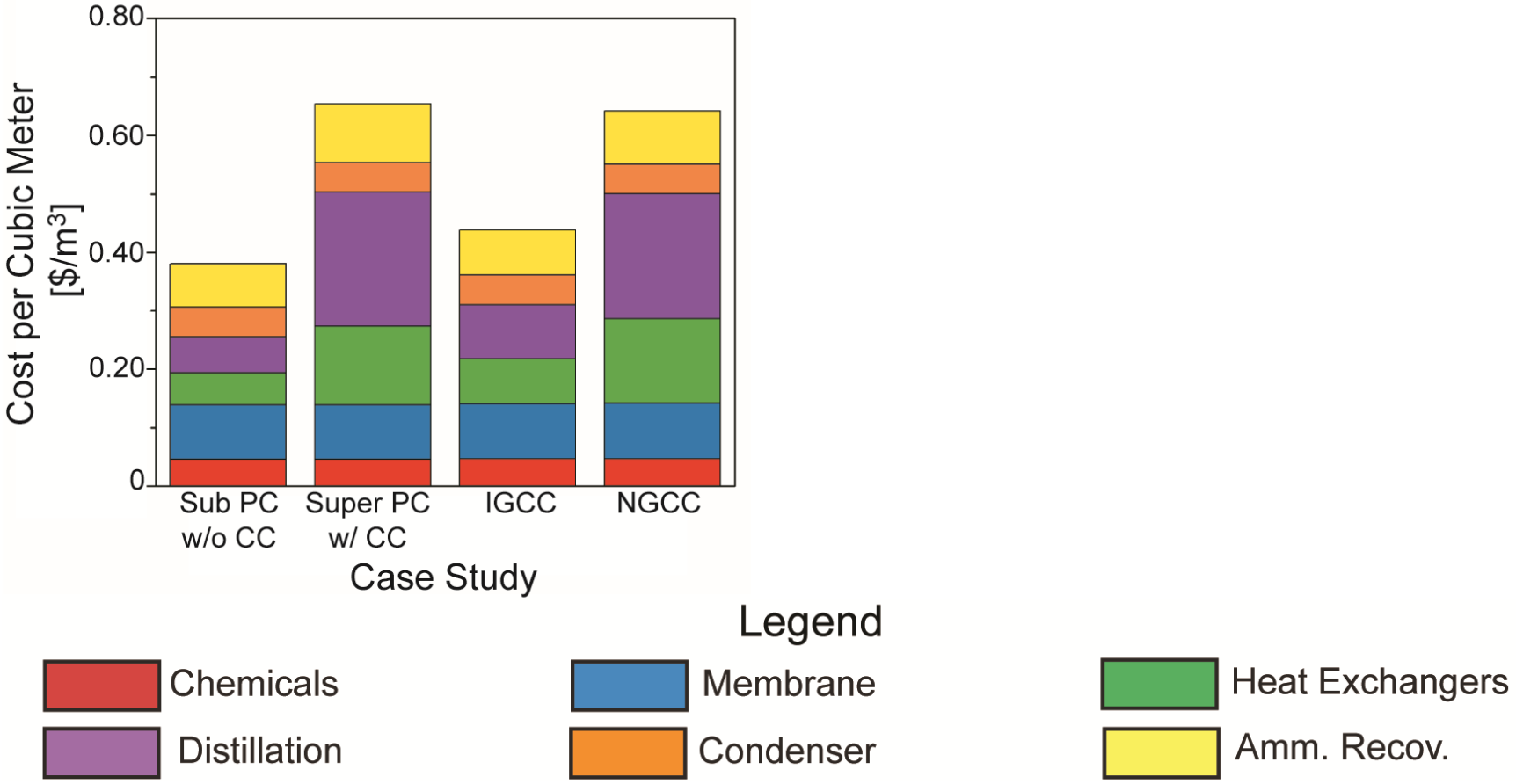
NETL Natural Gas Combined Cycle



Costs for treating wastewater to zero liquid discharge



Costs for treating boiler feedwater



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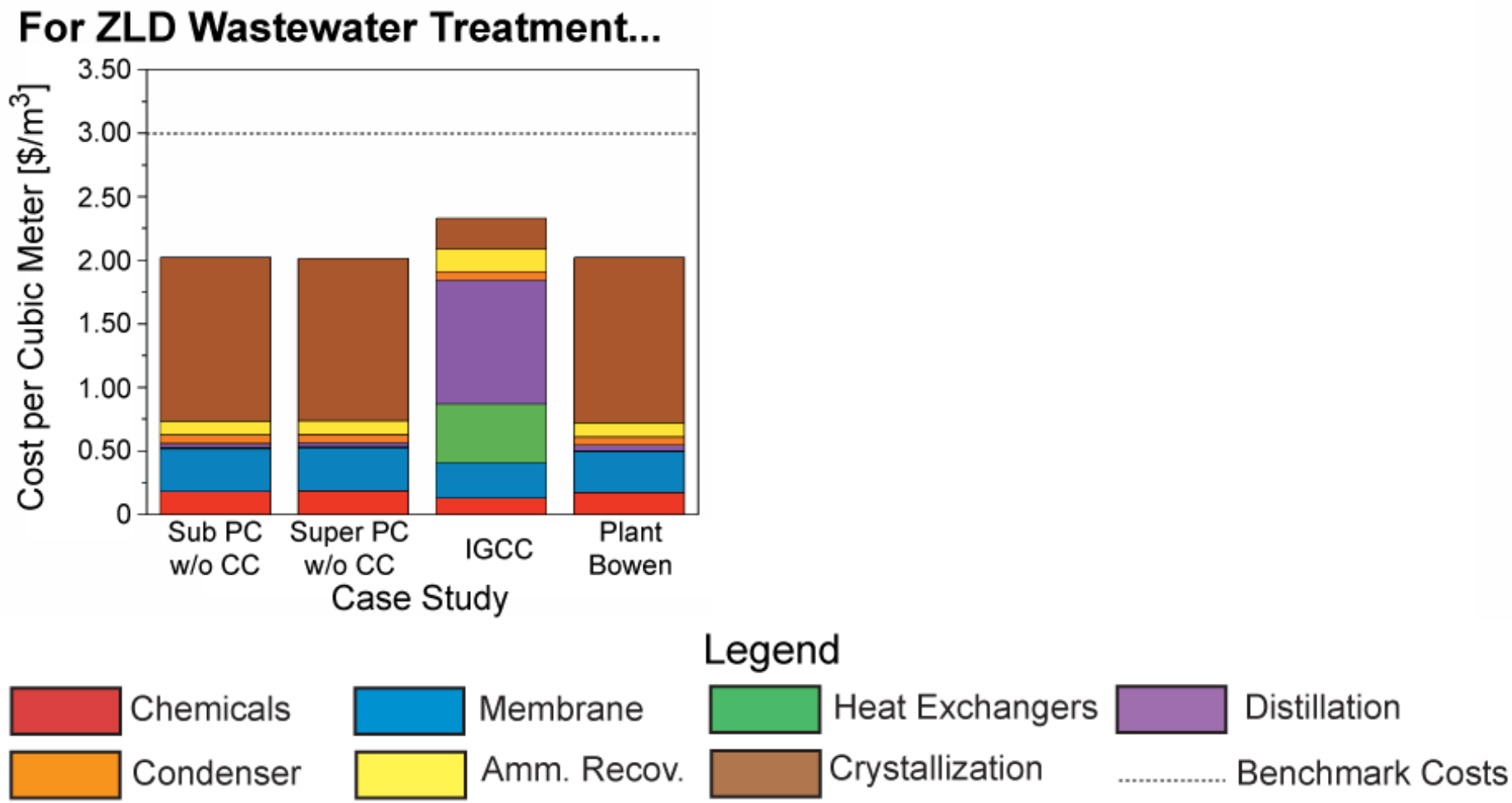
BEST AVAILABLE TECHNOLOGY BENCHMARKS

For ZLD wastewater:

Mechanical Vapor Recompression and Crystallization

MVCC Photo Credit: www.wateronline.com

FO IS COMPETITIVE FOR ZLD



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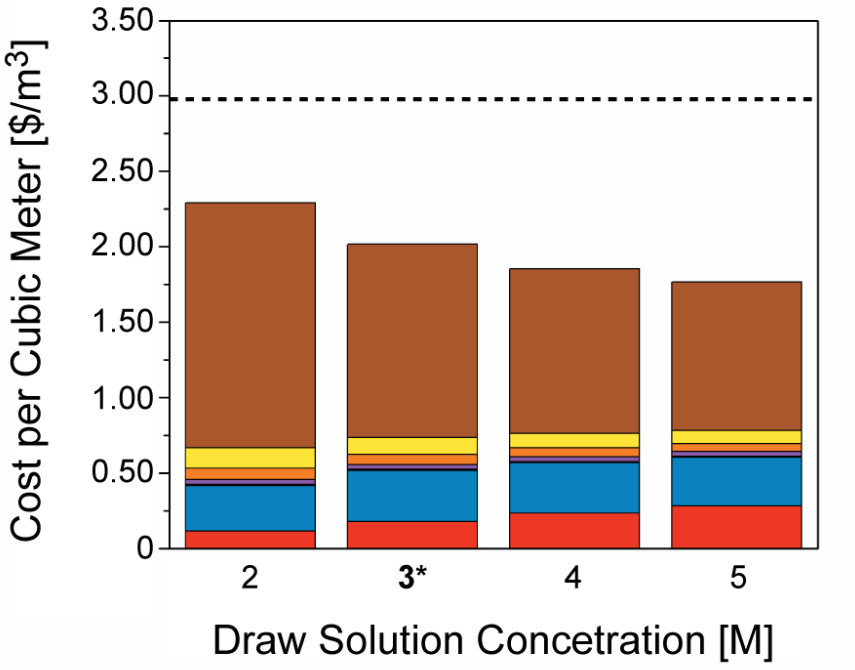
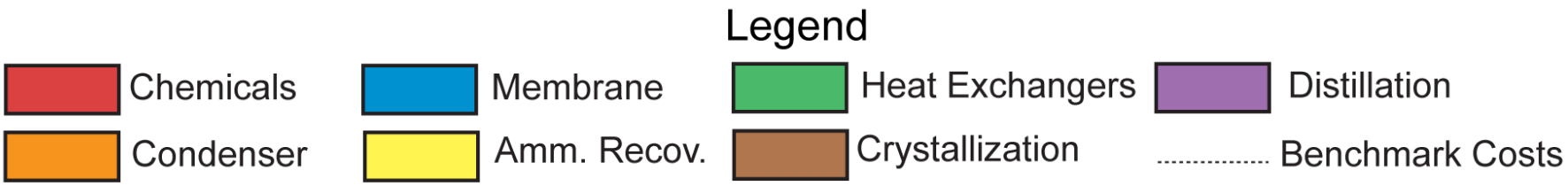
Sensitivity analyses on design and operating variables

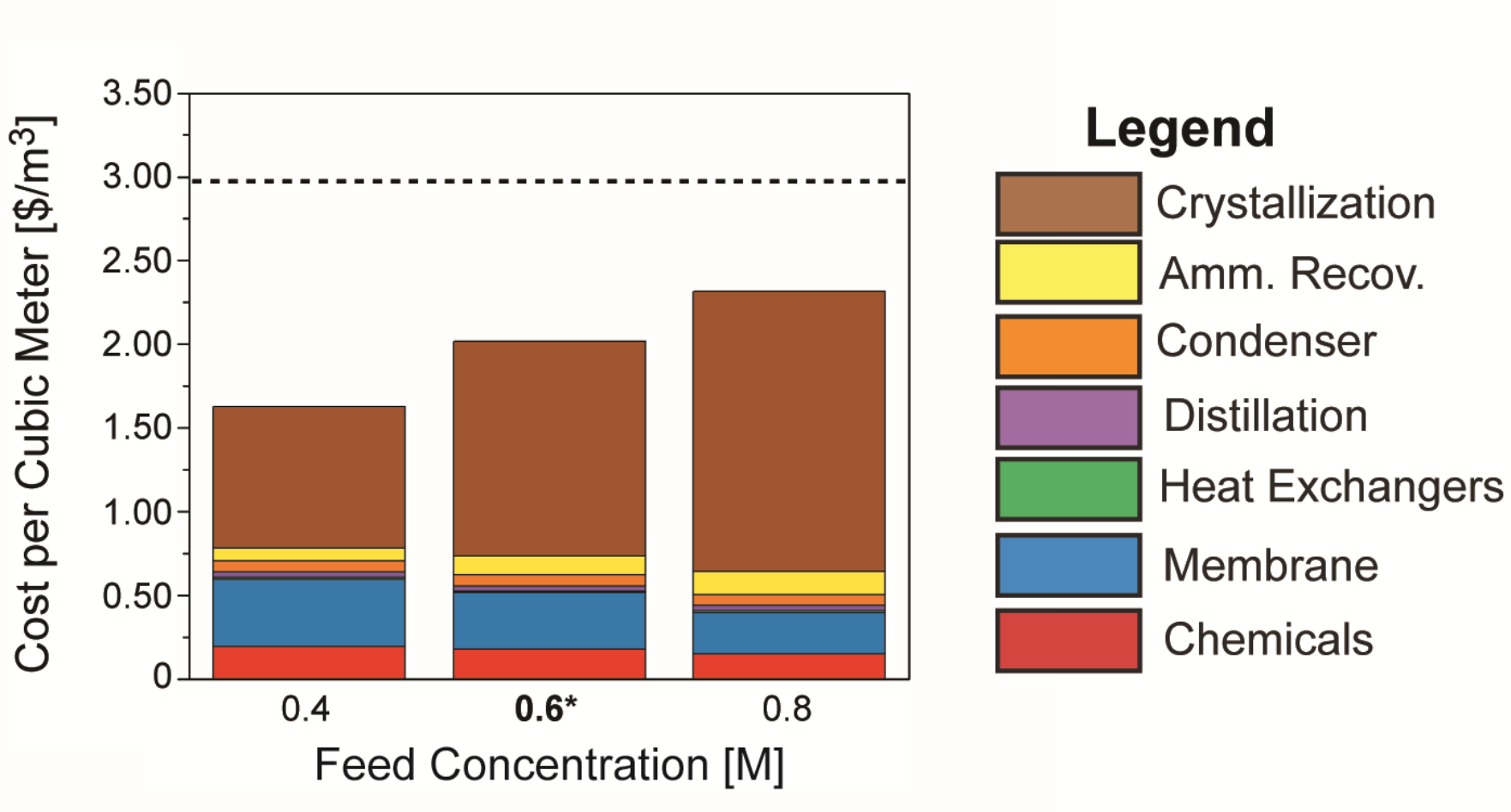
$$J_W = A(\pi_D - \pi_F)$$

COST 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.

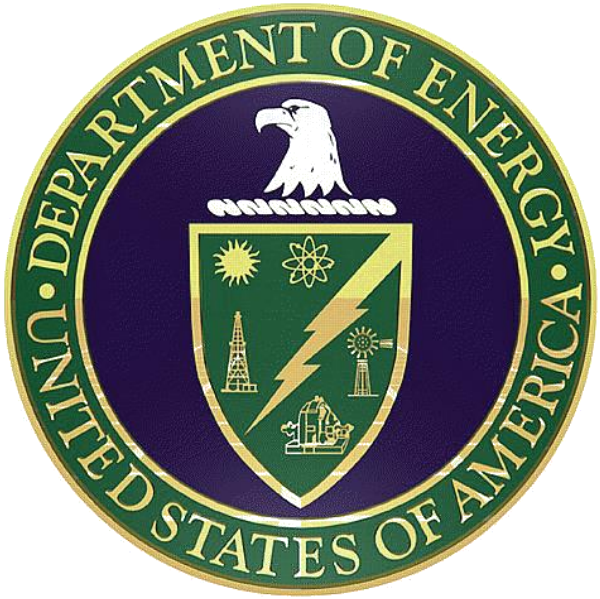
- Additional research needs for FO membranes:
  - Developing high flux membranes
  - Membranes that can handle cycling of wastewater purges
  - Membranes that can handle scaling

ACKNOWLEDGEMENTS

Colleagues in the WE3 Lab

Funding sources

- Department of Energy (DE-FE0024008)



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QUESTIONS?

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