# Evaluating the Techno-Economic Feasibility of Forward Osmosis Processes Utilizing Low Grade Heat: Applications in Power Plant Water, Wastewater, and Reclaimed Water Treatment

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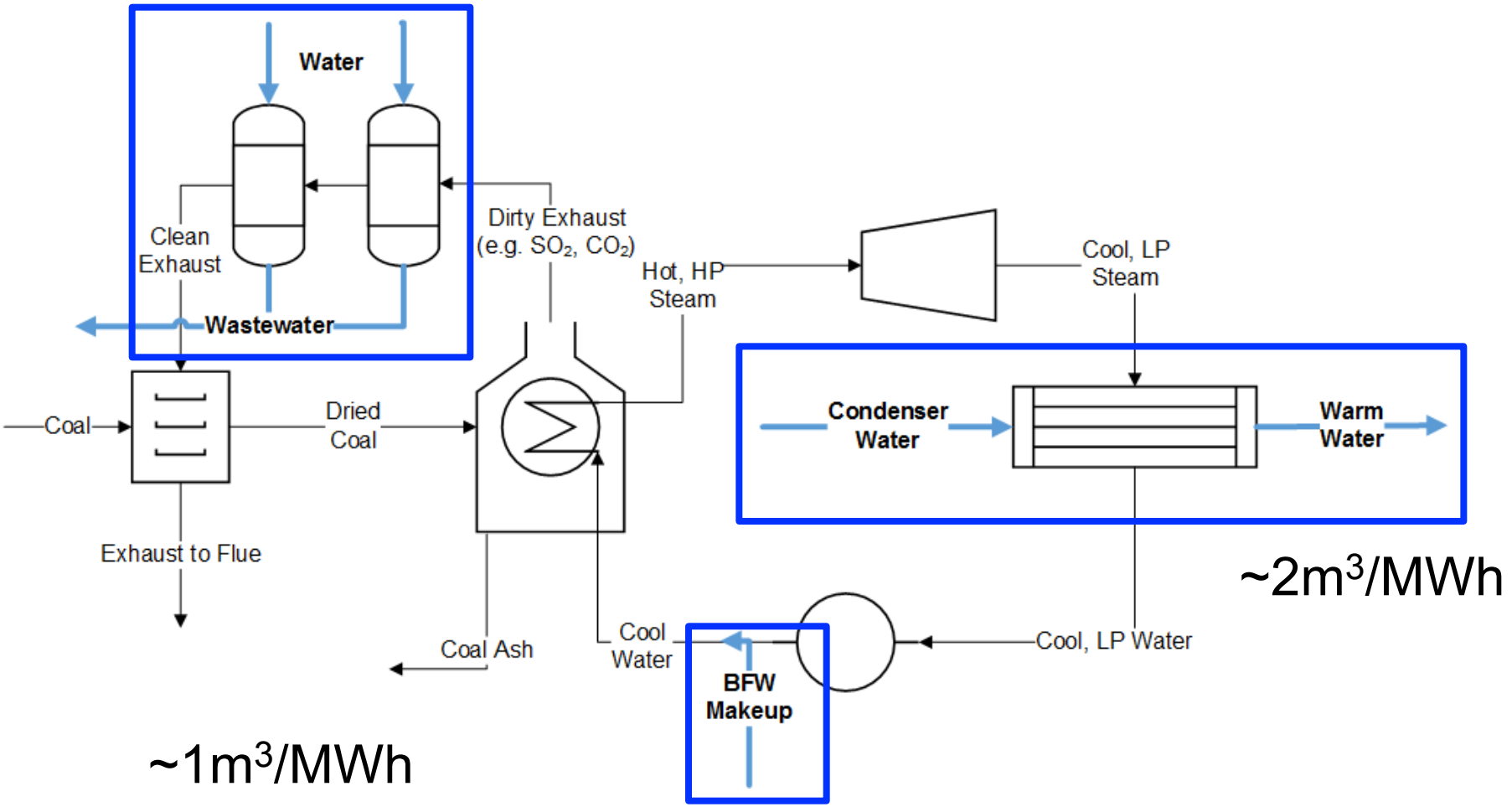
Water & Energy Efficiency for the Environment

# Water Treatment needs at Coal Fired Power Plants (CFPPs)



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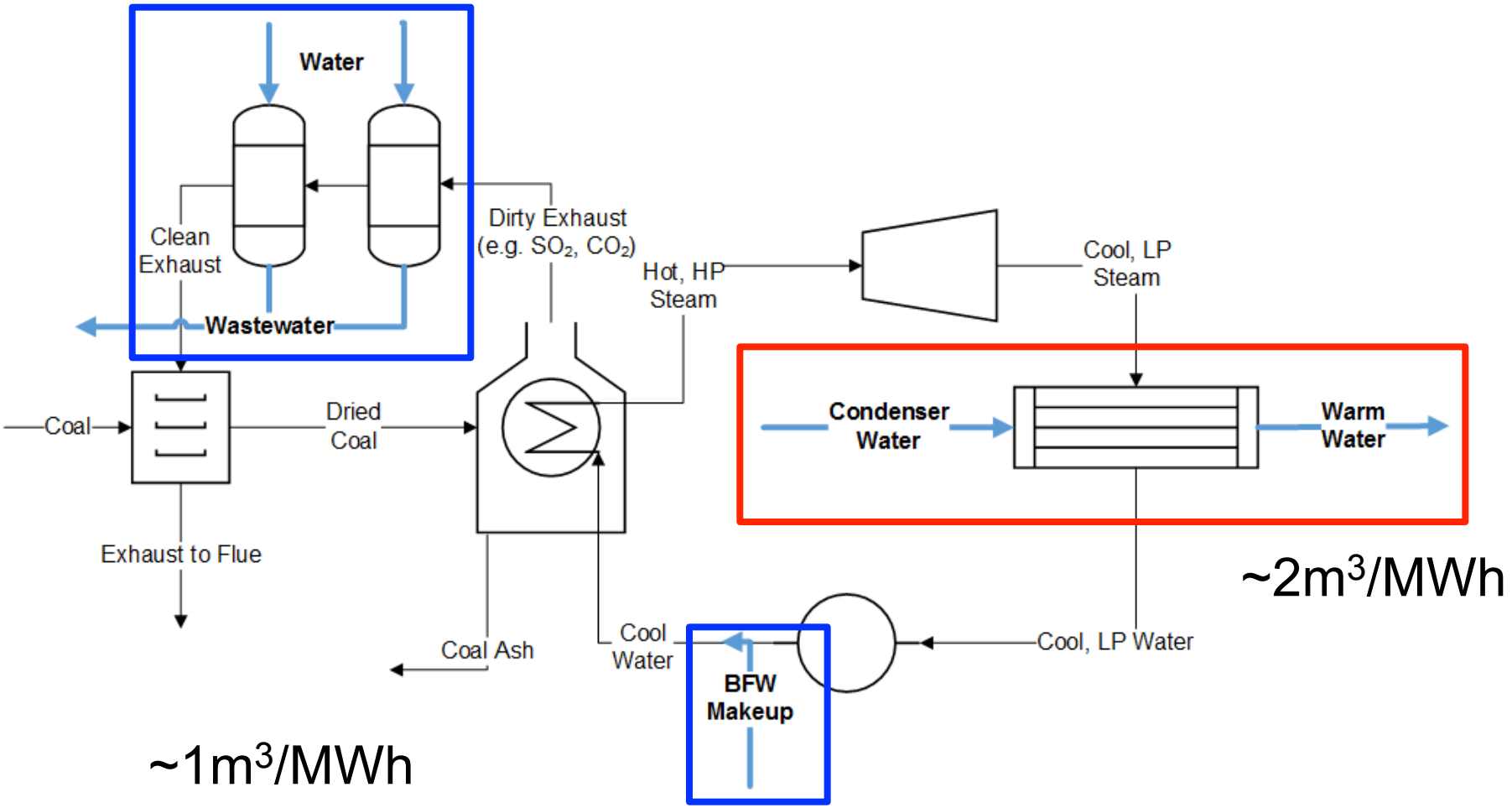
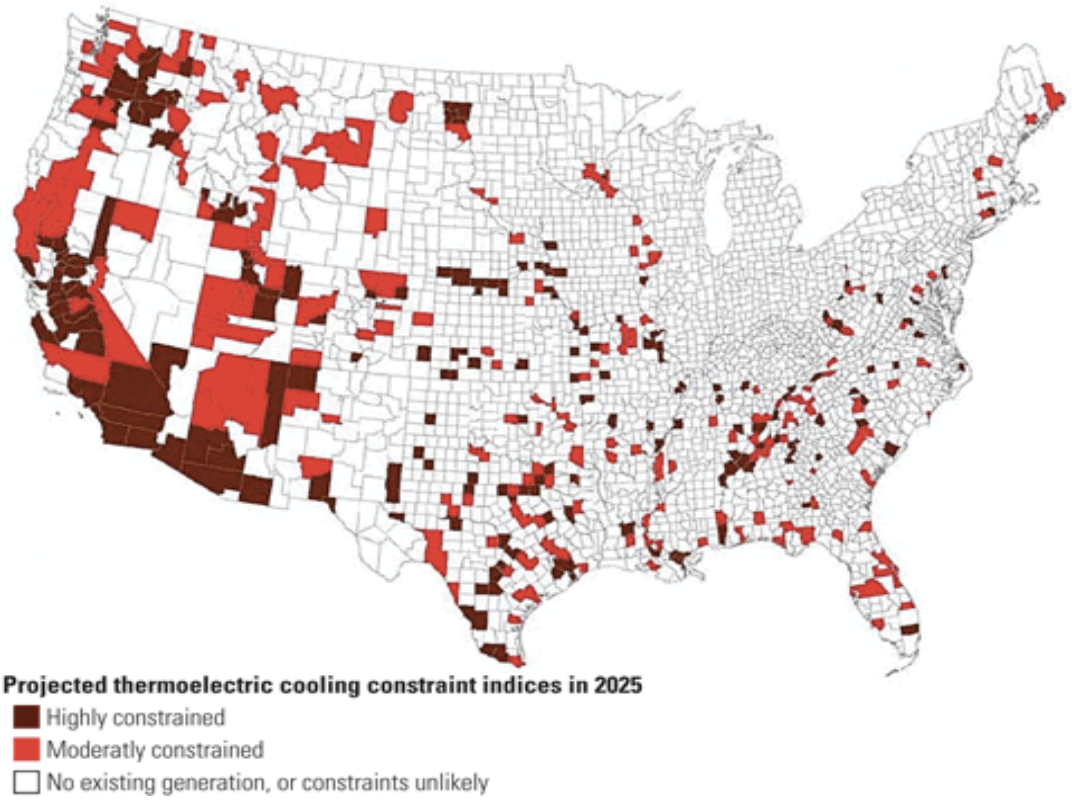


# Conventional Sourcing of Power Plant Waters Will Face Limitations Under Future Climate and Population Scenarios




*But wastewater reuse is limited by incoming waster quality*

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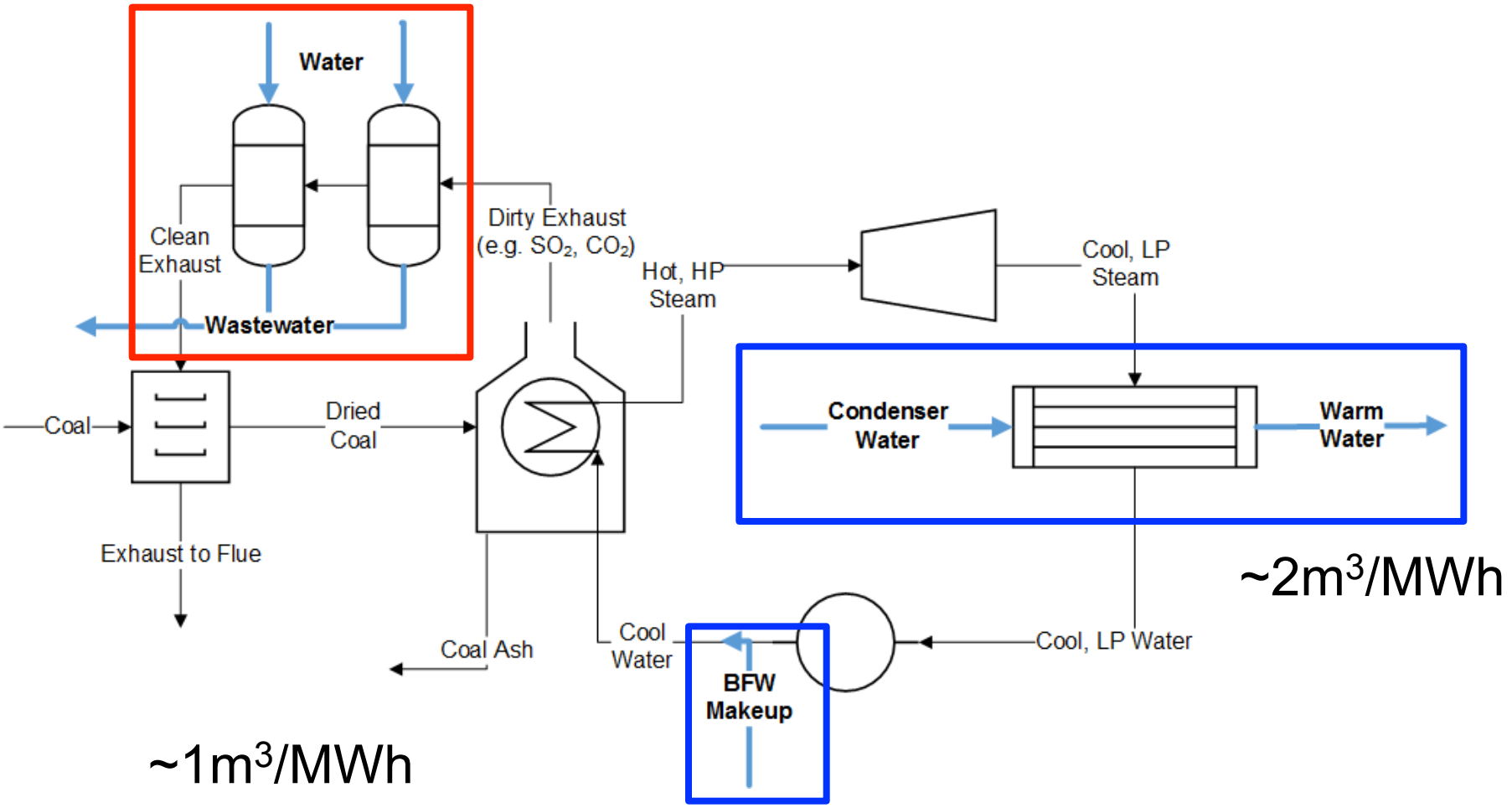
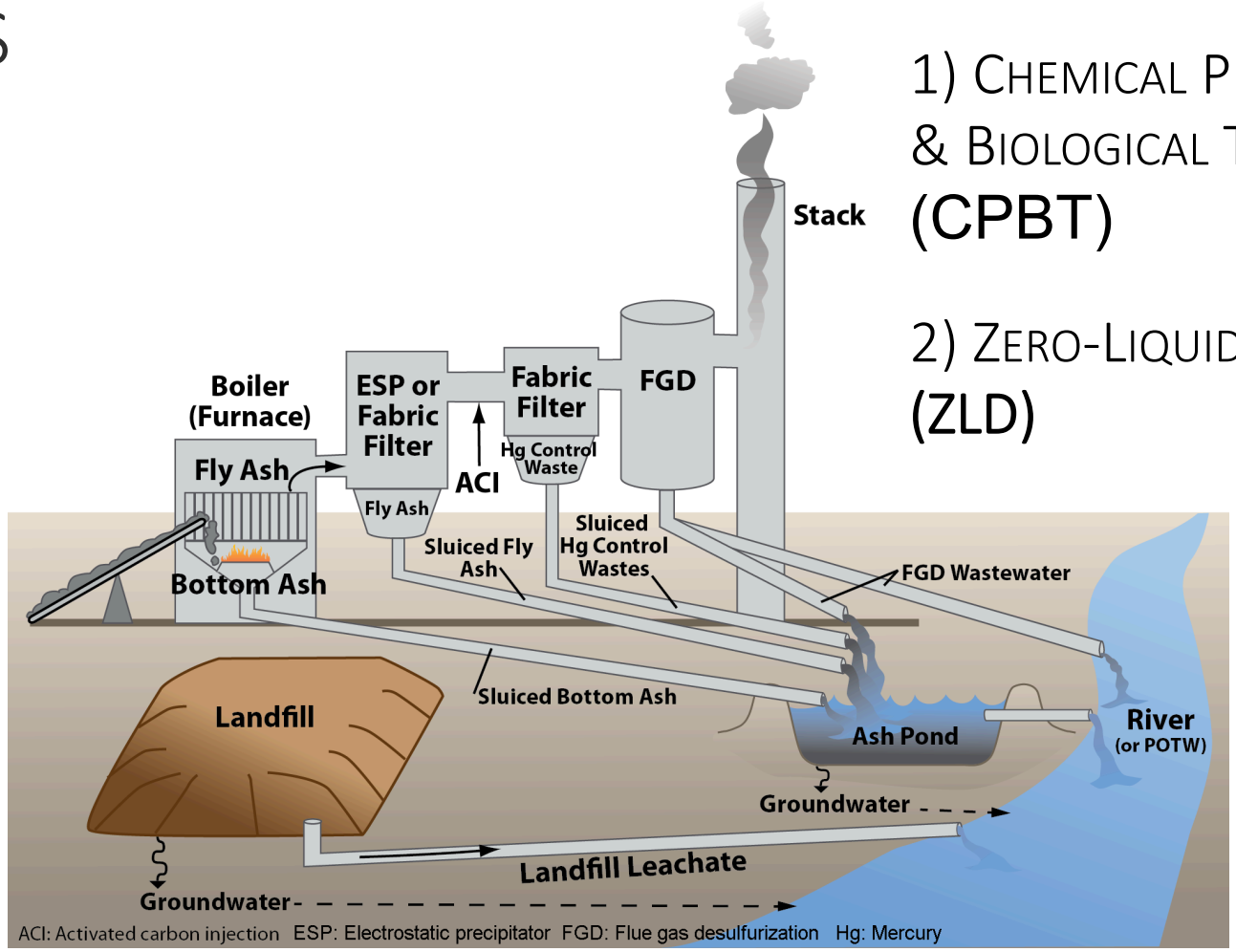


# CFPPs have been Significant Sources of Aqueous Pollution

# Effluent Limitations Guidelines will significantly increase the need for wastewater treatment at CFPPS



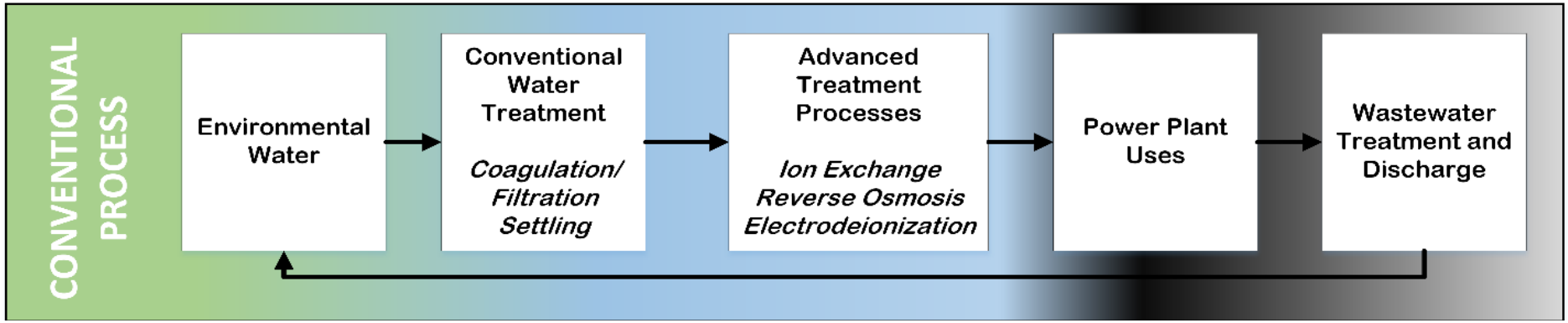

1) Chemical Precipitation & Biological Treatment (CPBT)

2) Zero-Liquid Discharge (ZLD)

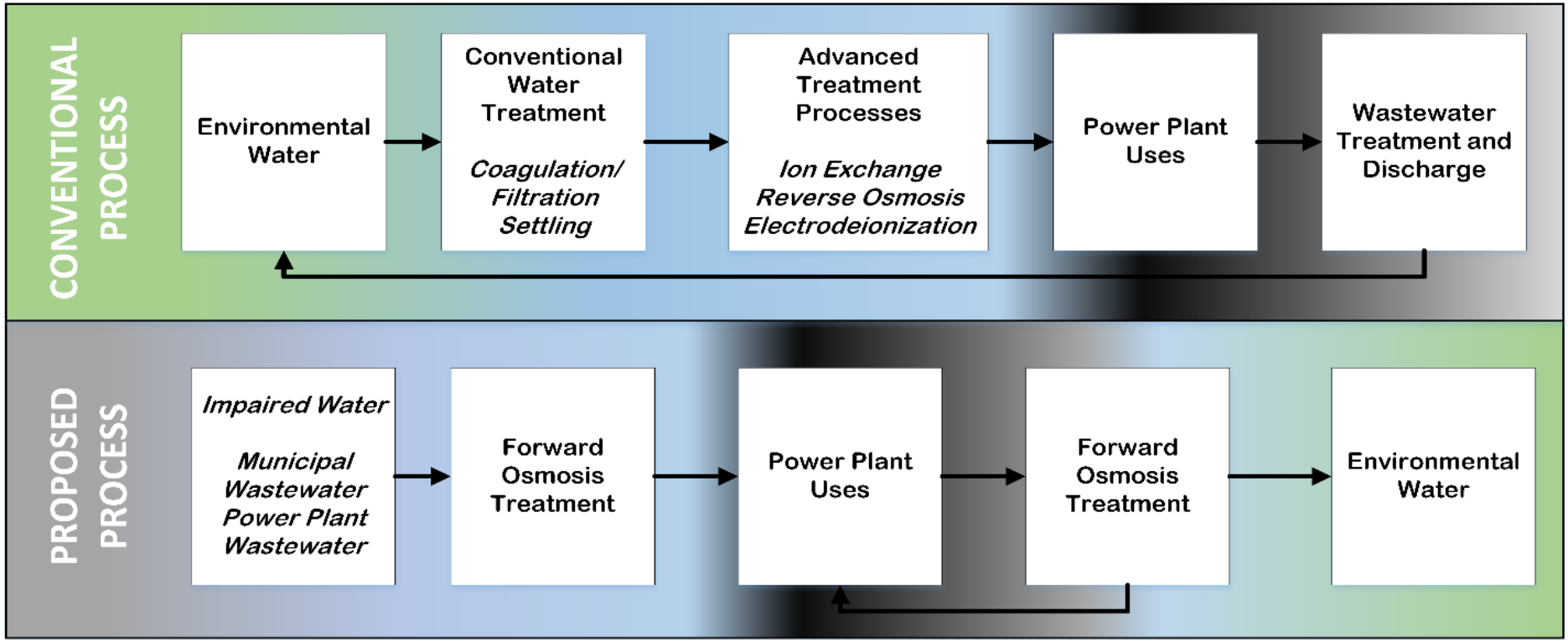


US EPA Proposed Effluent Guidelines for the Steam Electric Power Generating Category EPA 821-R-13-003, April 2013

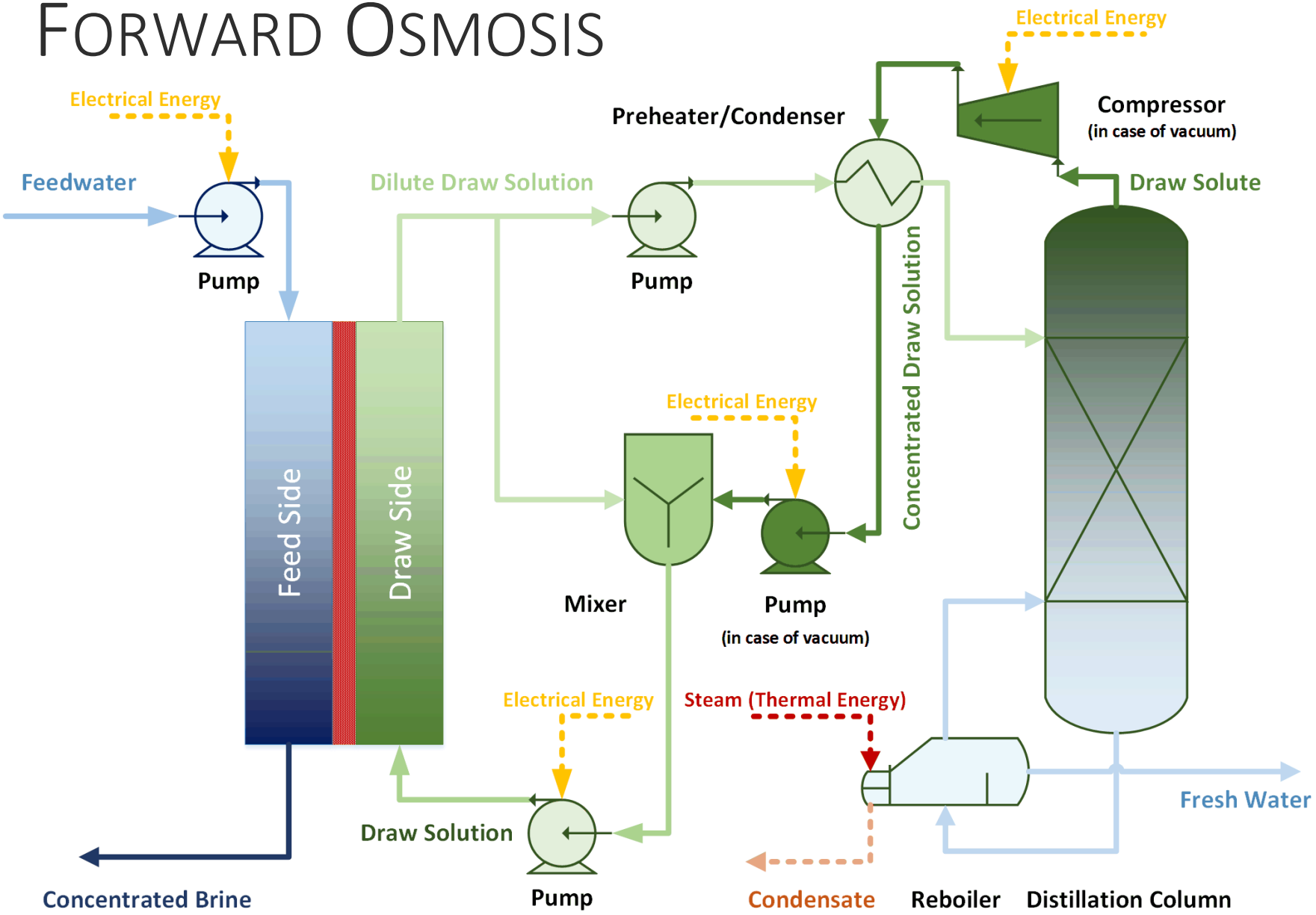
# CONVENTIONAL APPROACHES TO WATER MANAGEMENT NEED TO EVOLVE



# Novel approaches that use impaired water sources and waste heat driven water treatment, such as Forward Osmosis (FO) are imperative



# Forward Osmosis




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

# Low Temperature Heat to Meet Water Treatment Demand: An Assessment of Policy, Process, and Economic Constraints

- What is the quantity, quality, and spatial-temporal availability of waste heat?
- What is the water treatment capacity of US power plants using waste heat driven processes?
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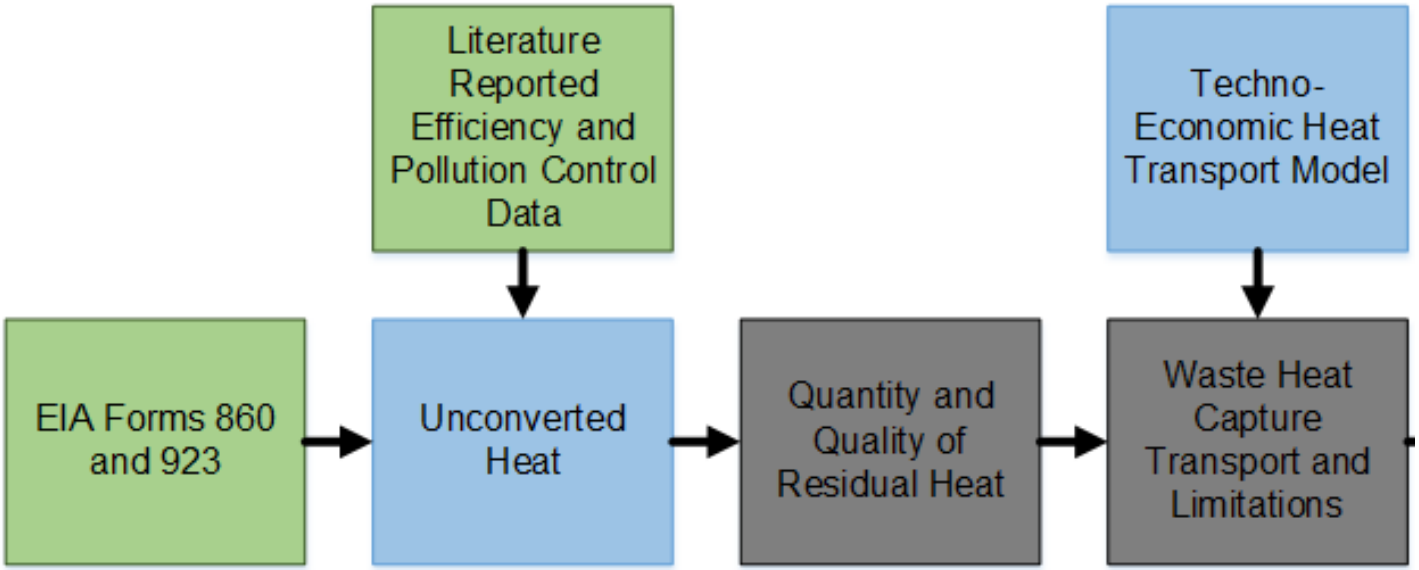
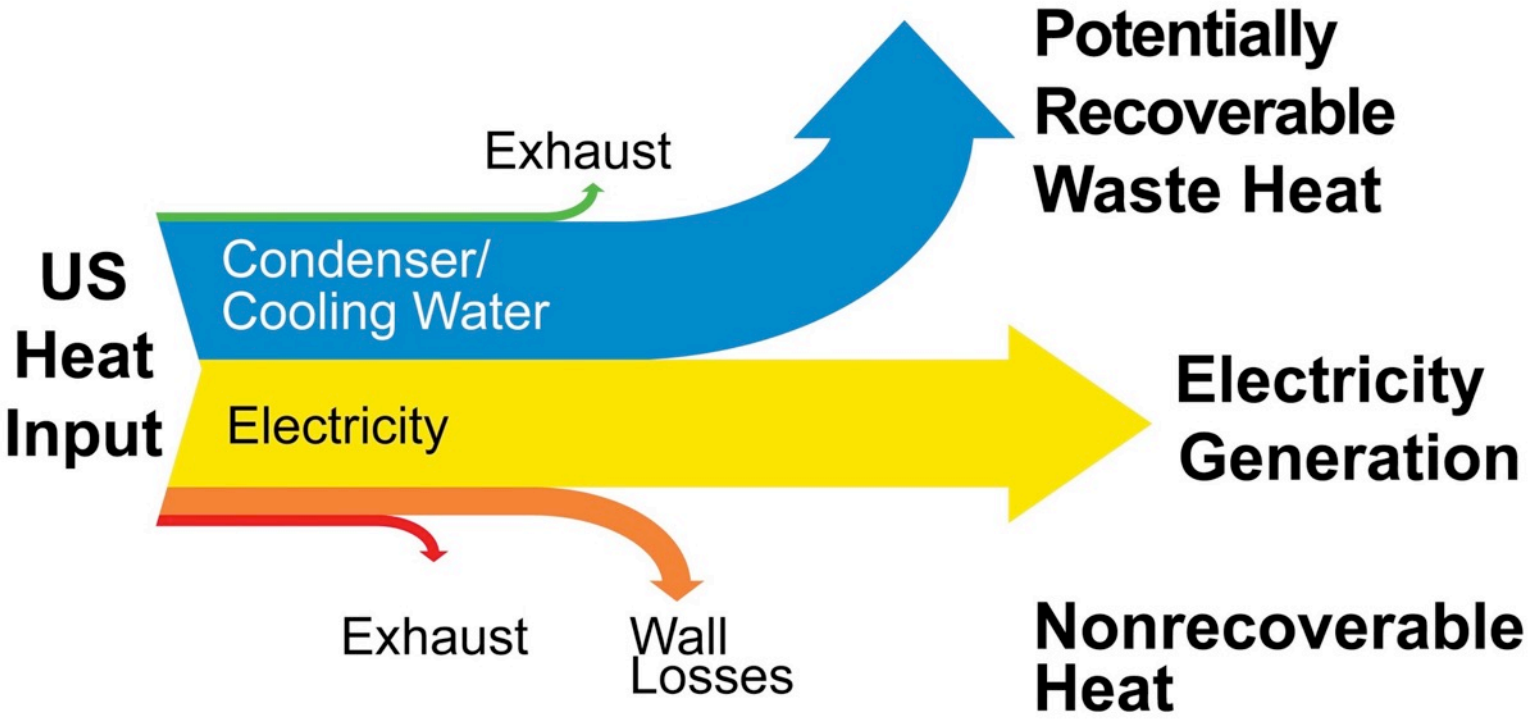
# Determining the Quantity, Quality, and Availability of Residual ("Waste") Heat





Gingerich and Mauter, *ES&T, 2015*

# 20% OF THE FUEL ENERGY IS NON-RECOVERABLE
# 45% (18.9 BILLION GJ) IS POTENTIALLY RECOVERABLE





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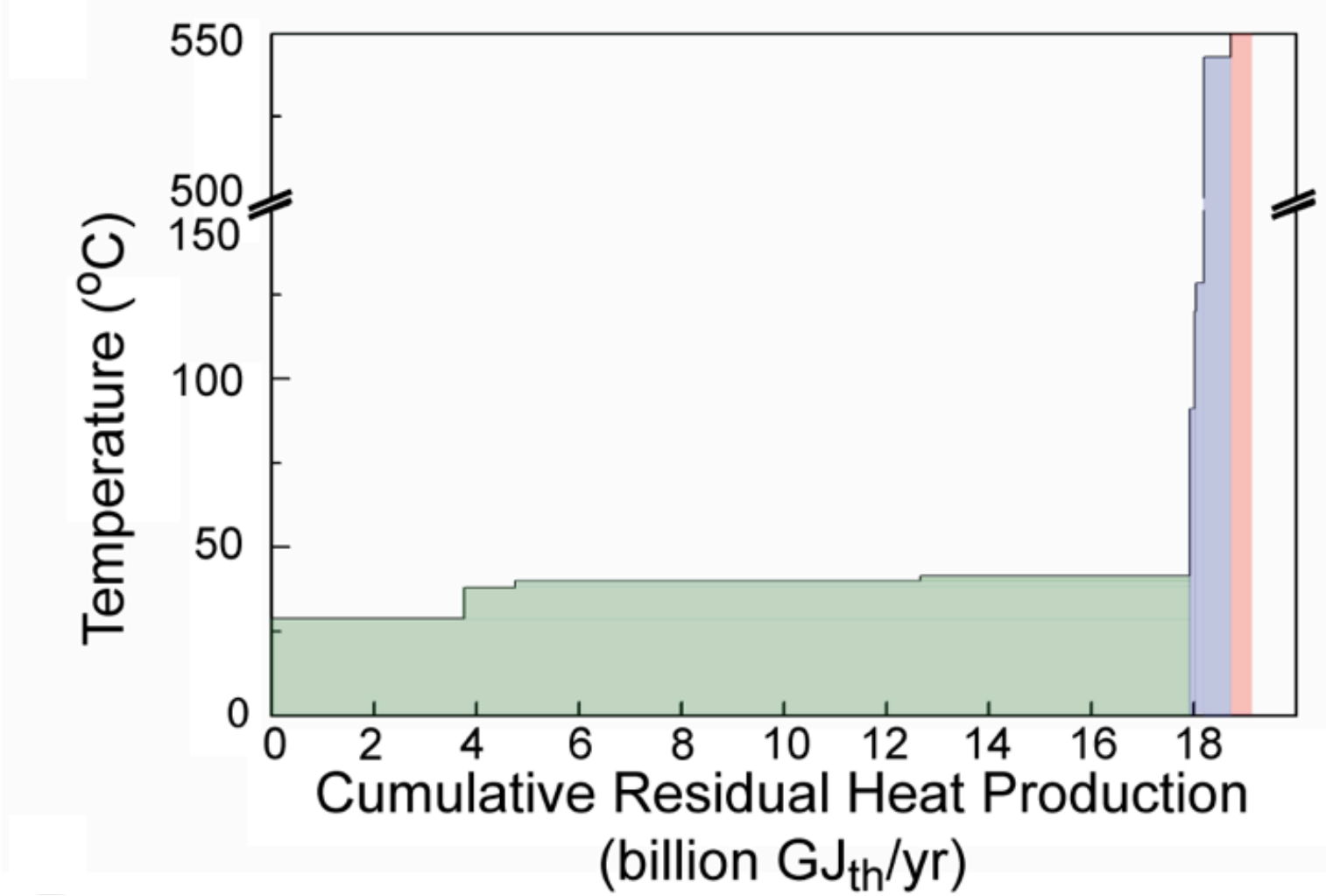
# 18.9 BGJ of Potentially Recoverable Unconverted Heat; 4% at Useful Temperatures



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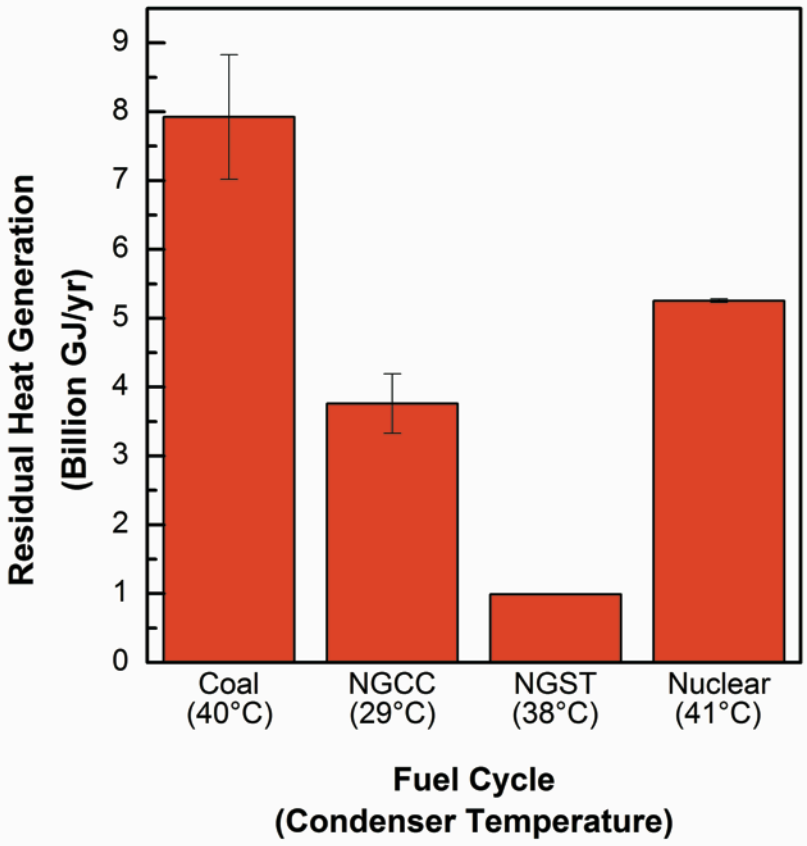
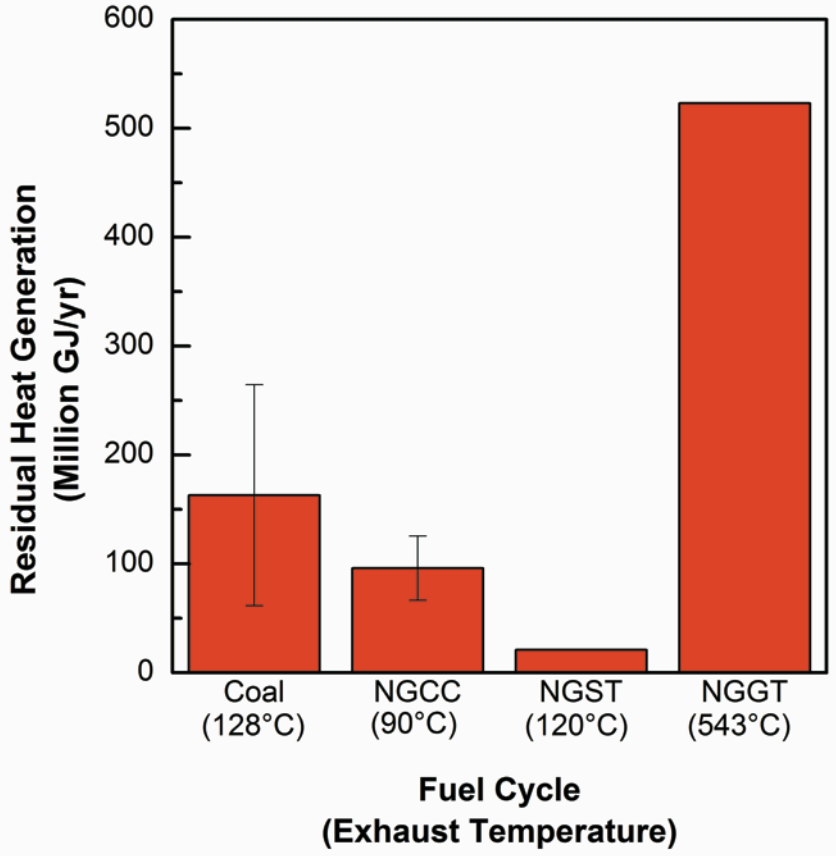
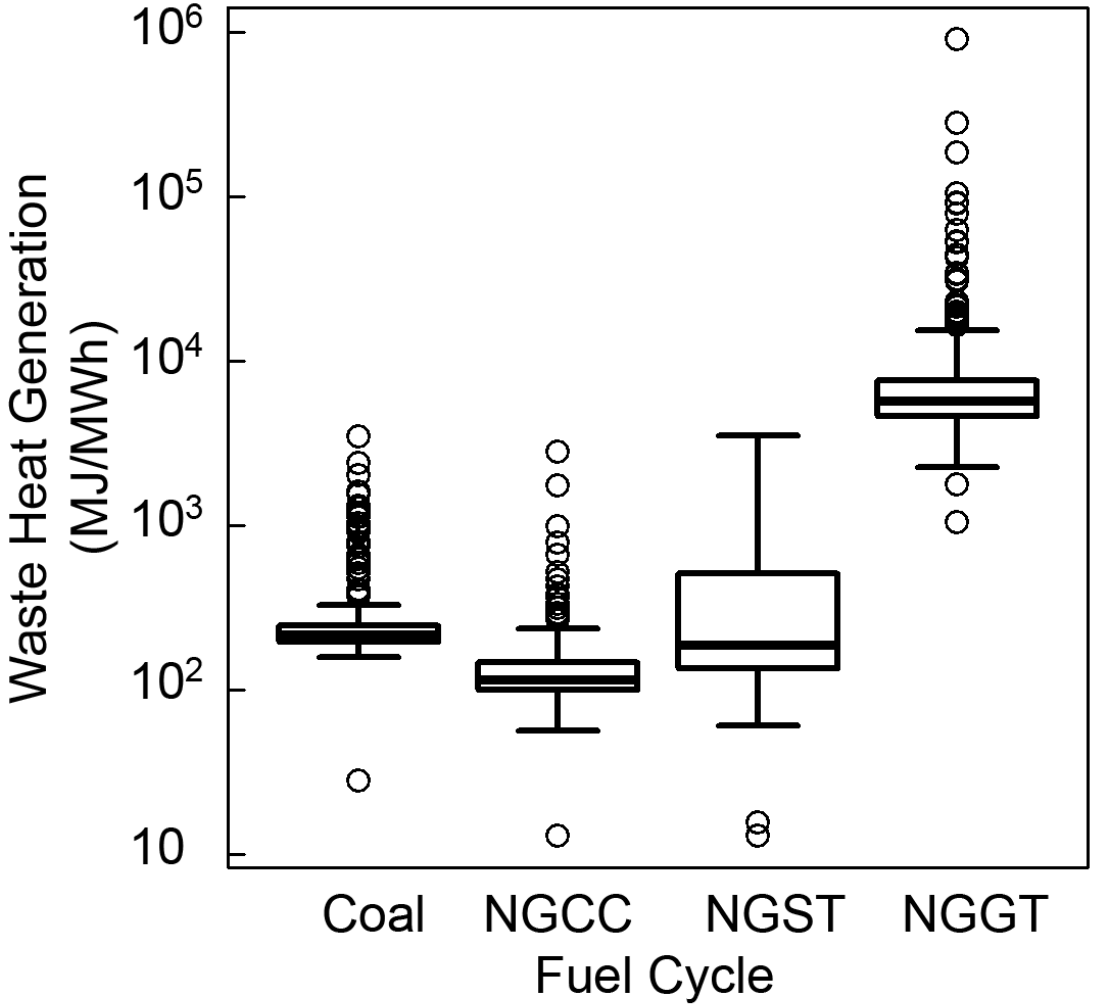





Gingerich and Mauter, *ES&T, 2015*

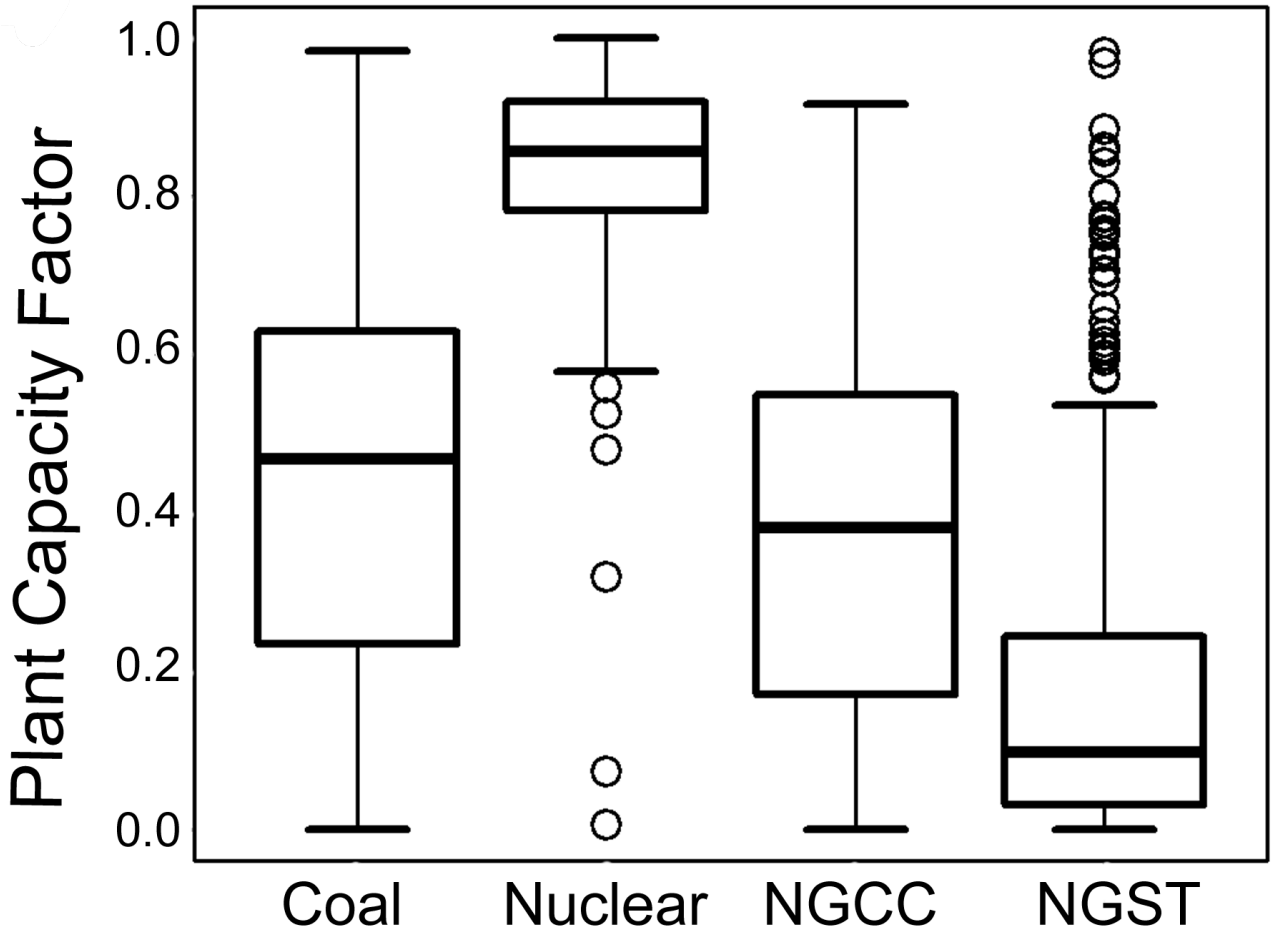
# GENERATOR LEVEL EXHAUST WASTE HEAT GENERATION






Gingerich and Mauter, *ES&T, 2015*

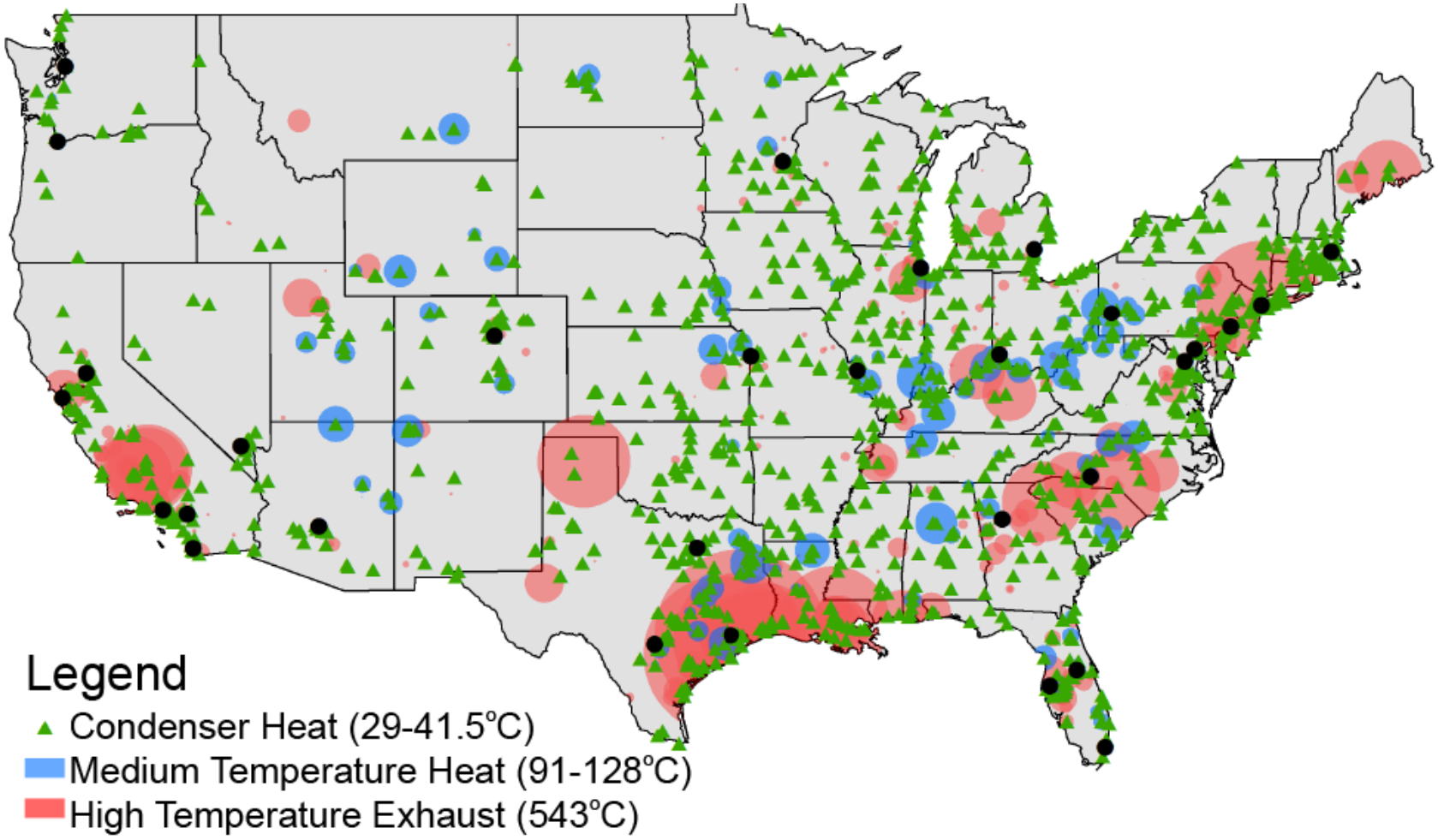
# TEMPORAL AVAILABILITY MAY LIMIT WASTE HEAT APPLICATIONS






Gingerich and Mauter, *ES&T, 2015*

# Economic Feasibility of Off-site Applications Limited by Heat Quality, Capacity Factor, Low Price of Natural Gas






Gingerich and Mauter, *ES&T, Under Review*

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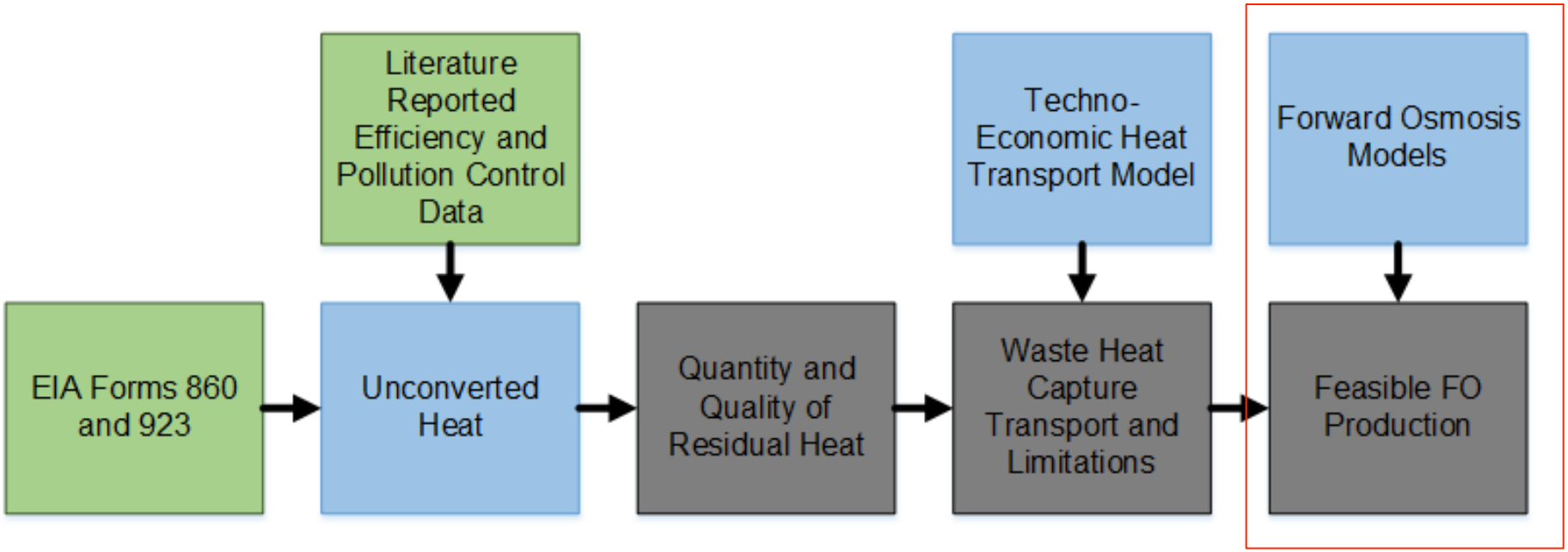
# If waste heat is available, FO may offer efficiency gains, flexibility, cost savings

| Desalination Method | GOR | Equivalent Work, KWh/$m^3$ |
|---|---|---|
| Direct distillation | 1 | 595 |
| Multi-stage Flash (MSF) | 8-12 | 21-58 |
| Multi-effect Distillation (MED) | 8-14 | 15-58 |
| Forward Osmosis (FO) | 4-16 | 3-8 |

Note: GOR= kg $H_2O$/kg Steam


Moon and Lee, WASET, Vol.6, 2012

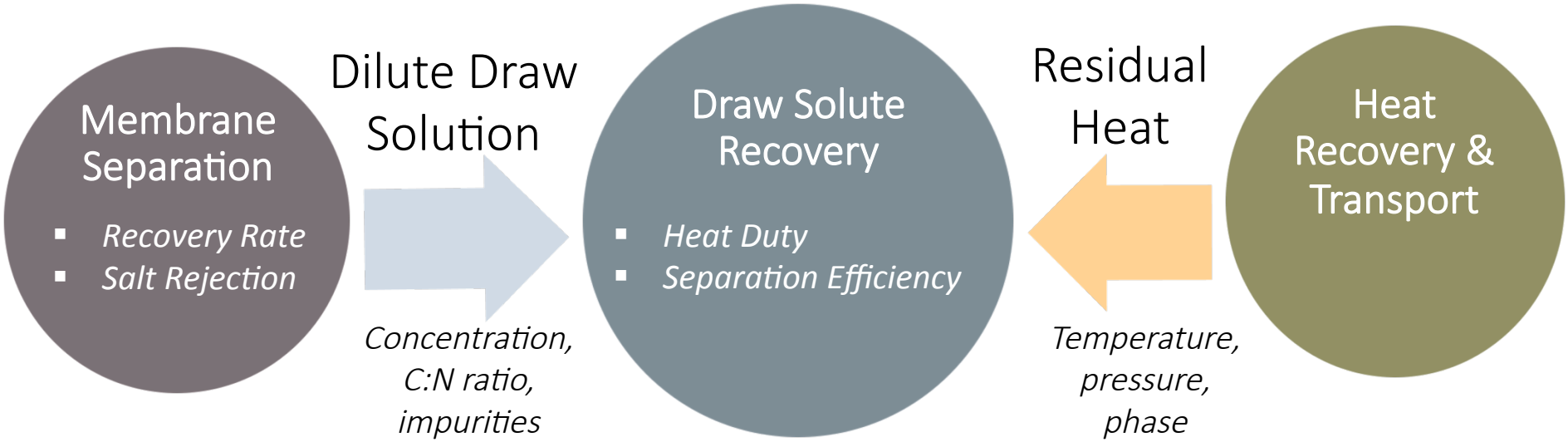
# Water Treatment Capacity of FO Systems Utilizing Power Plant Waste Heat



# Water Treatment Capacity of FO Systems Utilizing Power Plant Waste Heat

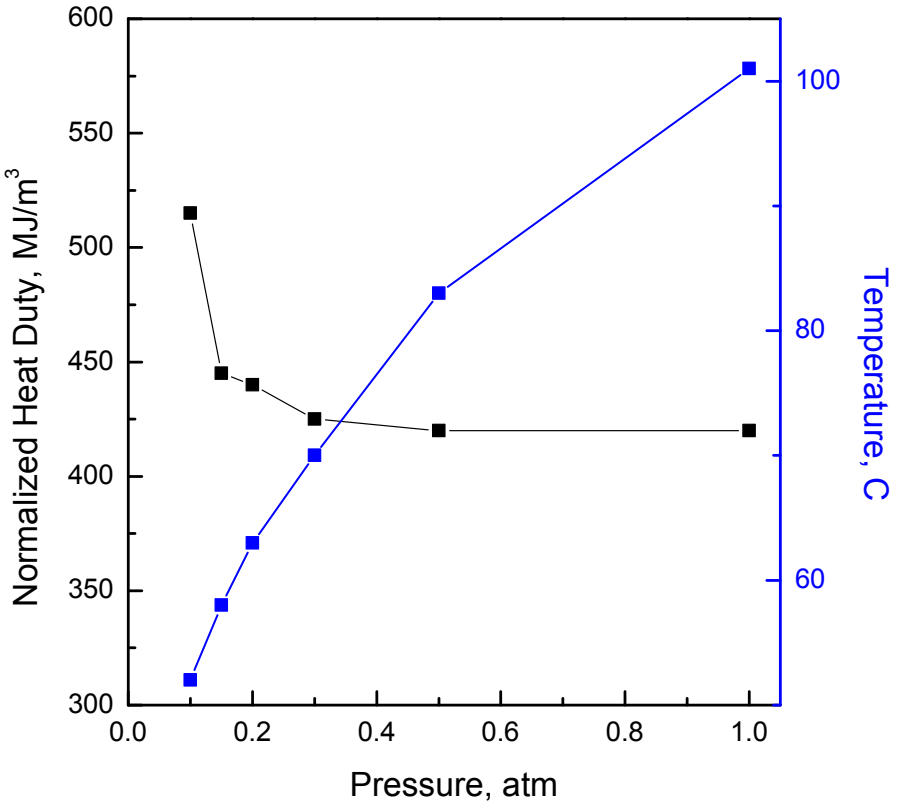
- Quantitative comparison of draw solute recovery (DSR) methods for thermolytic salts
- Comprehensive process model for DSR system
- Sensitivity analysis to ascertain which factors influence cost and performance of system
- Water treatment capacity of US power plants using waste heat driven processes

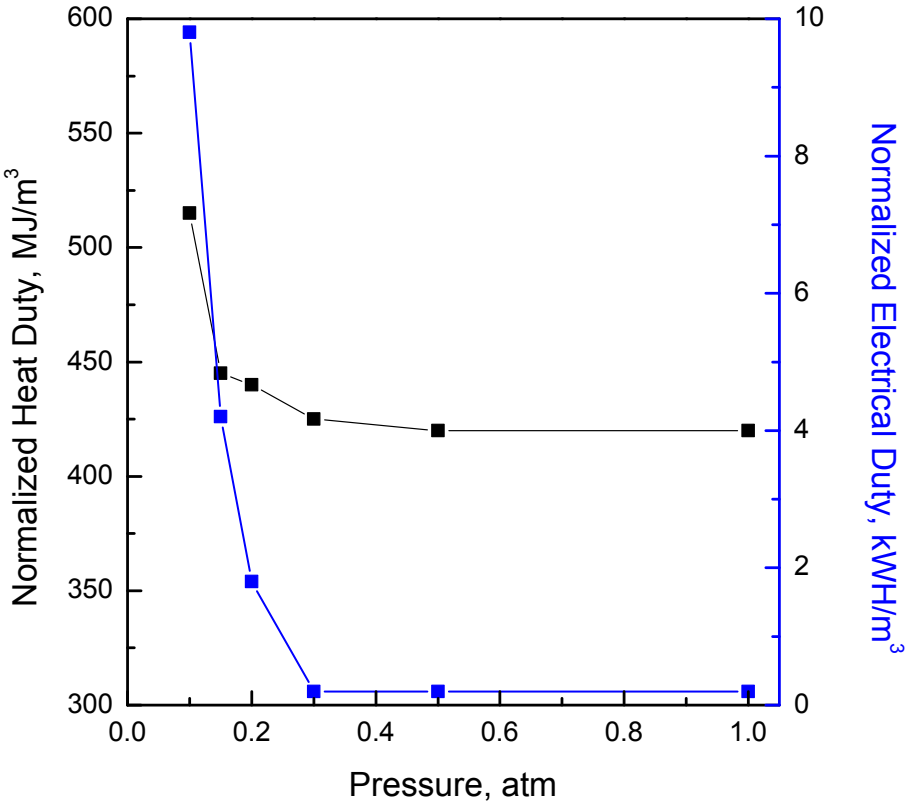
# MATHEMATICAL MODEL OVERVIEW



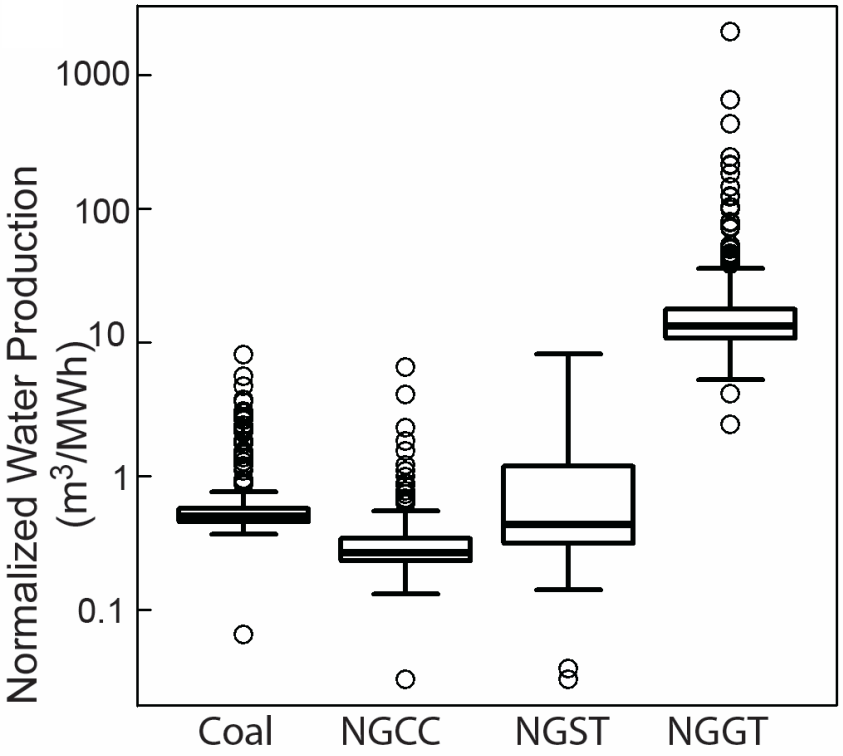

 Zhou, Gingerich, and Mauter, *I&ECR, 2015*

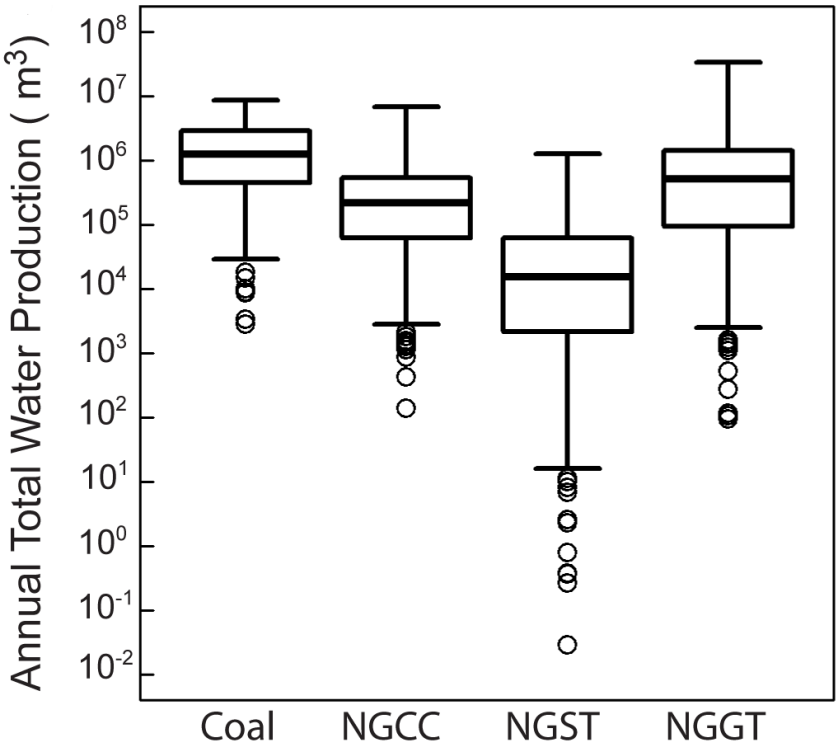
# Draw Solute Recovery Model: Energy intensity is highly dependent on the quality of the heat



# 1.9 BILLION $M^3$ OF ANNUAL WATER TREATMENT CAPACITY AT US POWER GENERATION FACILITIES




Sorek Desalination Plant = 415,000 m³/day

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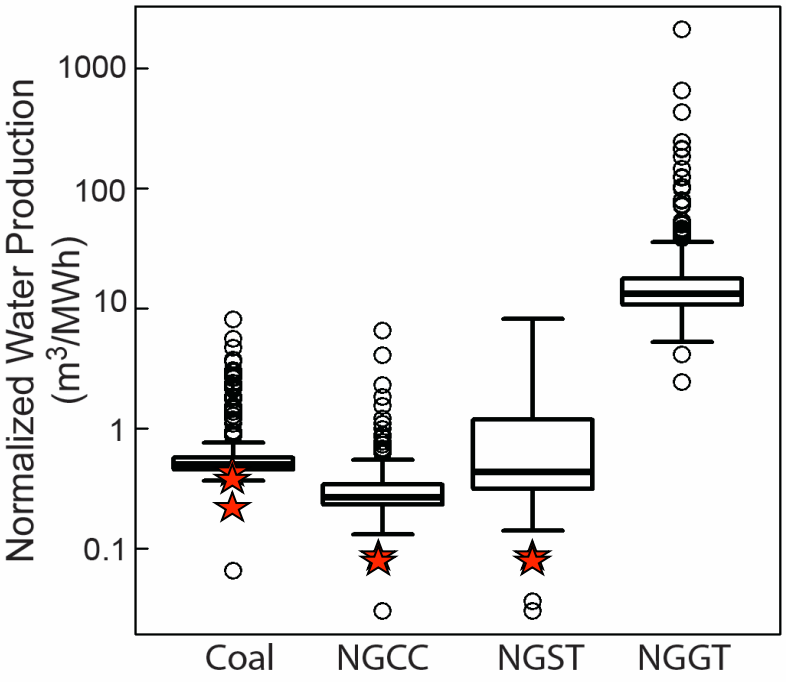
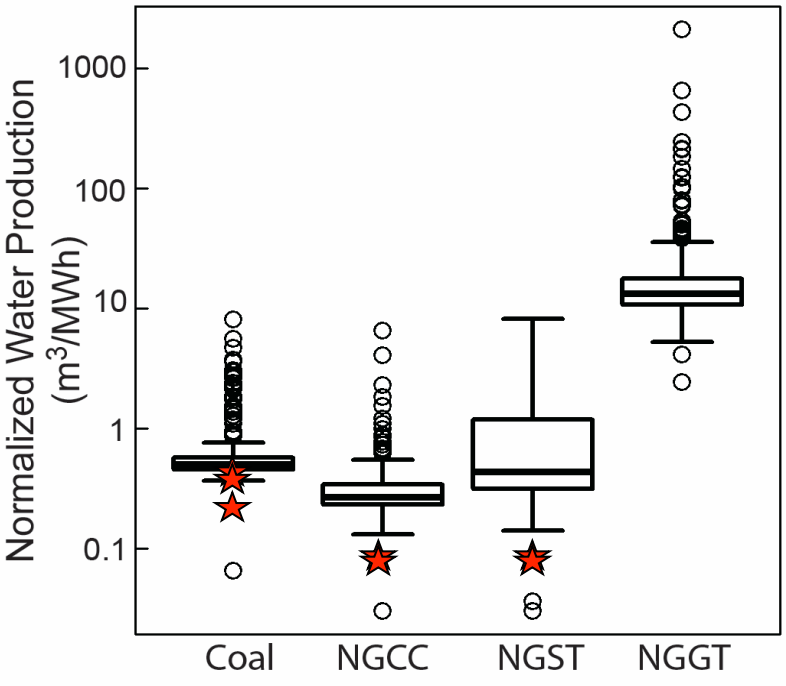
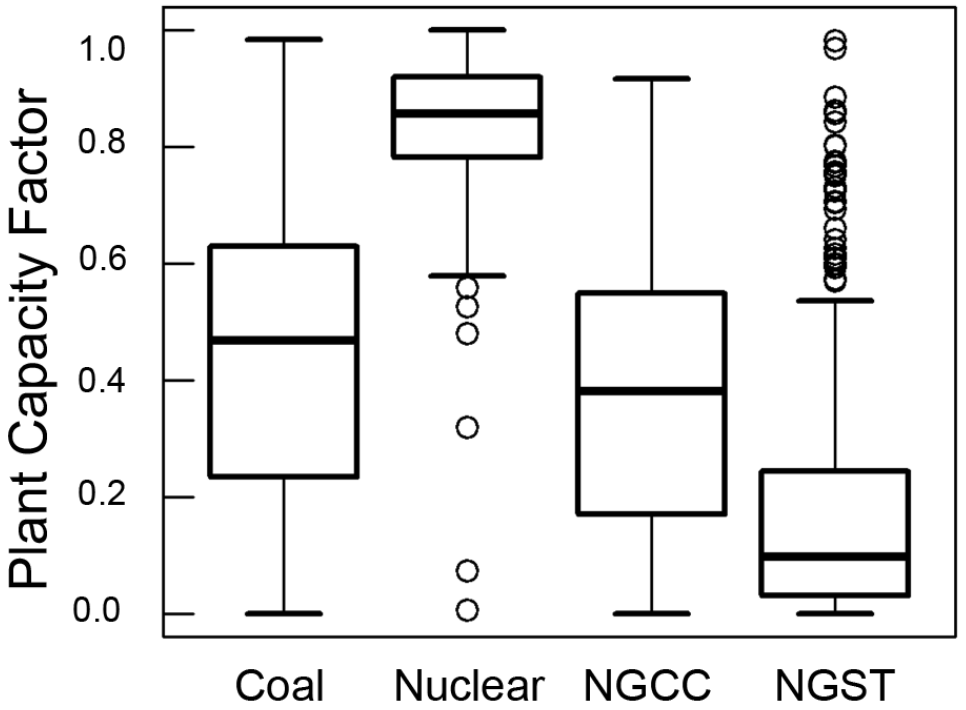
# Theoretical Forward Osmosis Capacity Exceeds Non-Cooling Water Treatment Demands



# Significant Uncertainty about the Resiliency and Performance of Membrane-Based Systems in Highly Intermittent Operation



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# Evaluating the Techno-Economic Feasibility of Forward Osmosis Processes Utilizing Low Grade Heat

- Quantity, quality, and spatial-temporal availability of waste heat is best suited for **on-site applications.**
- Water treatment capacity of US power plants using waste heat driven processes is **sufficient** to meet water treatment demands from FGD wastewater and boiler make-up water
- Allocating steam from other sources to augment heat supply is **unlikely to be economically feasible**.

# BIBLIOGRAPHY


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# Acknowledgements