Solutions for Today | Options for Tomorrow

2020 Water Technologies Project Review Meeting

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NATIONAL ENERGY TECHNOLOGY LABORATORY

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CROSSCUTTING TECHNOLOGY RESEARCH

Presentation Outline

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1. Why is condenser research important?
2. Condenser research relevance to FE's mission
3. Standardized condenser research and analysis guidance
4. On Working Collaboratively
5. Other NETL/SEA water analysis work

CROSSCUTTING TECHNOLOGY RESEARCH

Why Condenser Research

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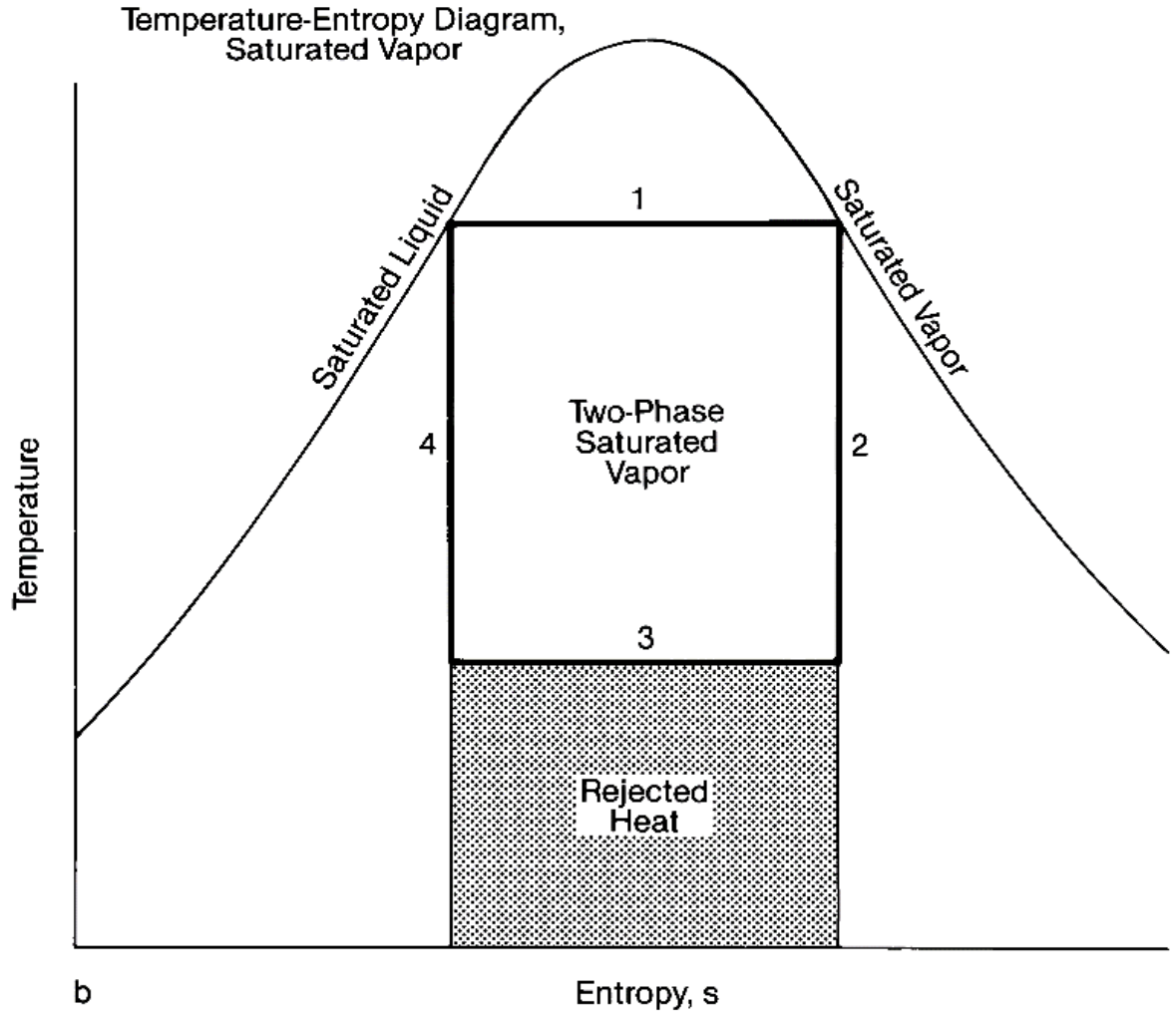
- Improves power cycle efficiency
- Reduces air emissions (CO_2, SO_2, NOx, PM, etc.) on Lb/MWh basis
- Reduces wet cooling tower water consumption (less waste heat discharged to the atmosphere at the cooling tower)
- Can be applied to any fossil generation source (coal or natural gas combined cycle)
- It's a Fossil Energy research priority

Carnot Cycle

$$\eta = 1 - \frac{T_C}{T_H}$$

- T_C = temperature of heat sink
- T_H = temperature of heat source

- Improve cycle efficiency by increasing steam temperature, or reducing temperature at which heat is rejected



Power Plant Condenser Operation

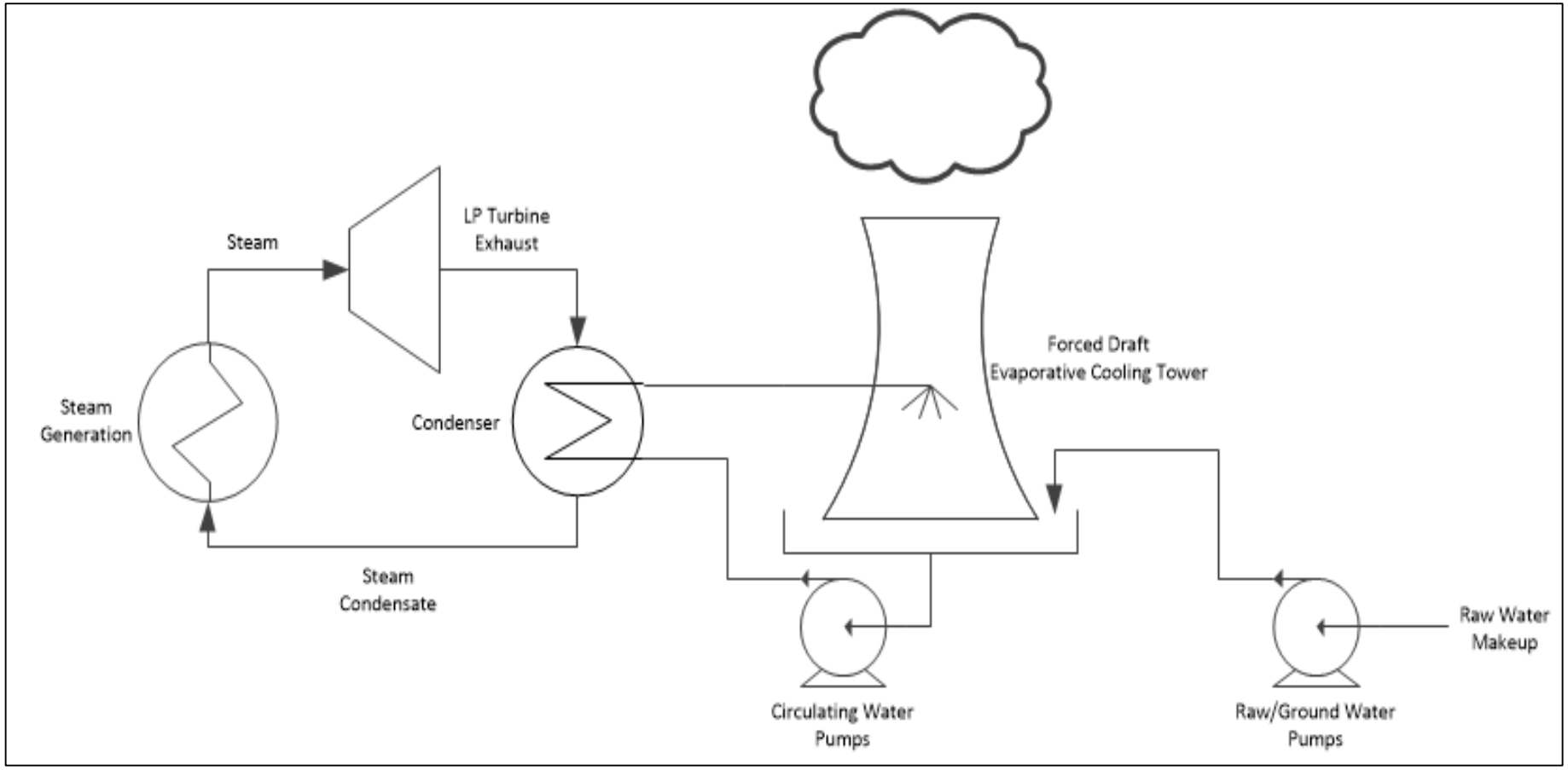
- **Condenser pulls a vacuum, allowing for conversion of more steam heat to work**

- **Without a condenser, power plant would operate much less efficiently**

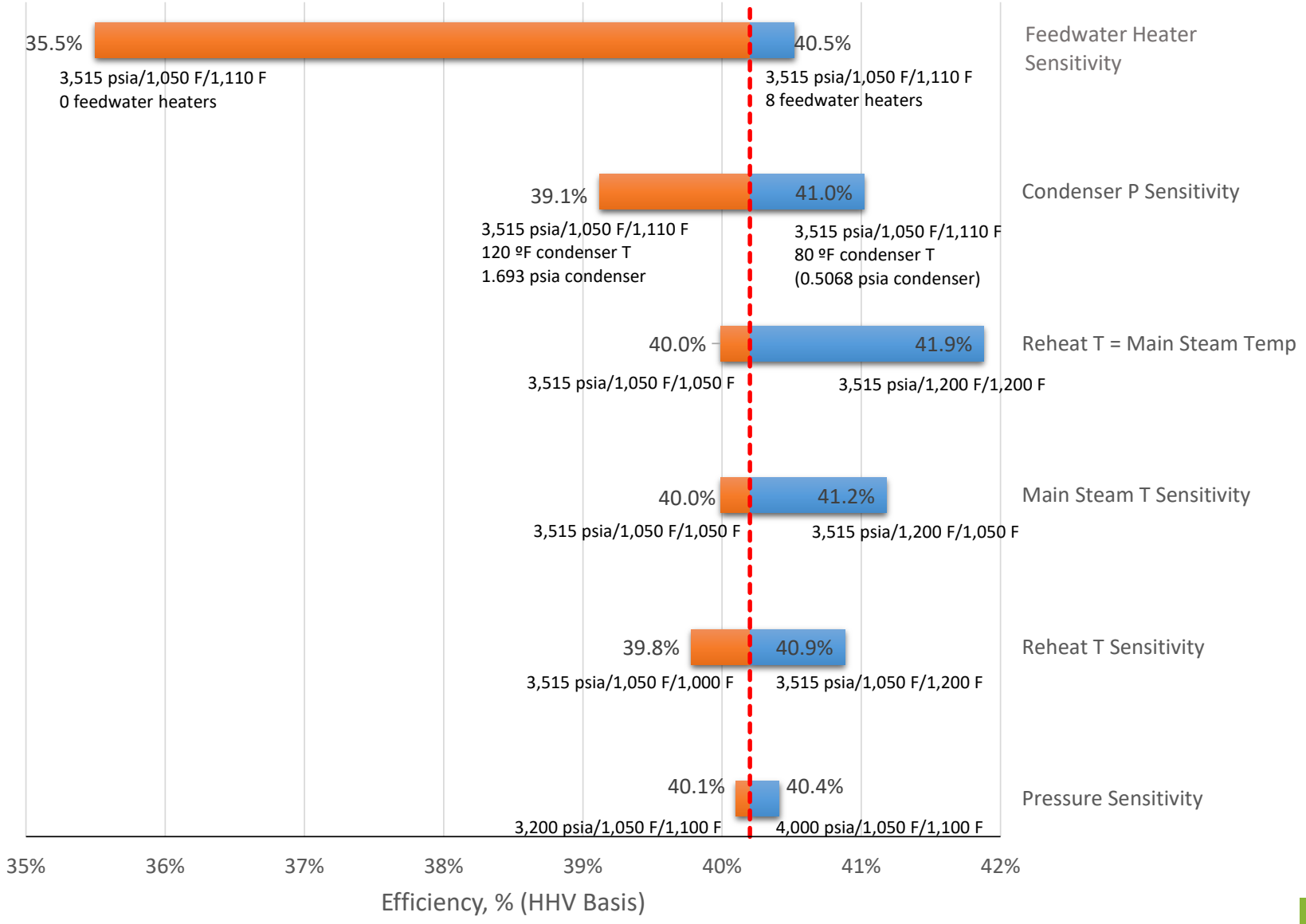
Steam Exhaust Conditions Comparison[1]

	Condenser at Atmospheric Conditions	Condenser at Vacuum
LP Turbine Exhaust Pressure	14.7 psia	0.98 psia
Steam Saturation Temperature	212 °F	101 °F
LP Steam Discharge Enthalpy	1,150 Btu/lb	~1,105 Btu/lb
Net System Efficiency (HHV)	33.4%	40.3%

Condensers in Power Generation



Impact of Condenser on Efficiency



Relevance to FE's Mission

- **Condenser research is relevant to FE's mission in the following ways:**

1. Safely and cost-effectively enable environmental stewardship of fossil energy-based conversion systems[1]
   - "Creating a viable technology for the global marketplace requires ensuring that emissions from power generation, including CO_2, are at low levels and that water used to remove low-temperature waste heat (which often represents more than 50 percent of energy consumed by a power plant) is minimized while maintaining cost-competitiveness."[1]

2. Condenser improvements are a potential compliance strategy for EPA's Affordable Clean Energy rule

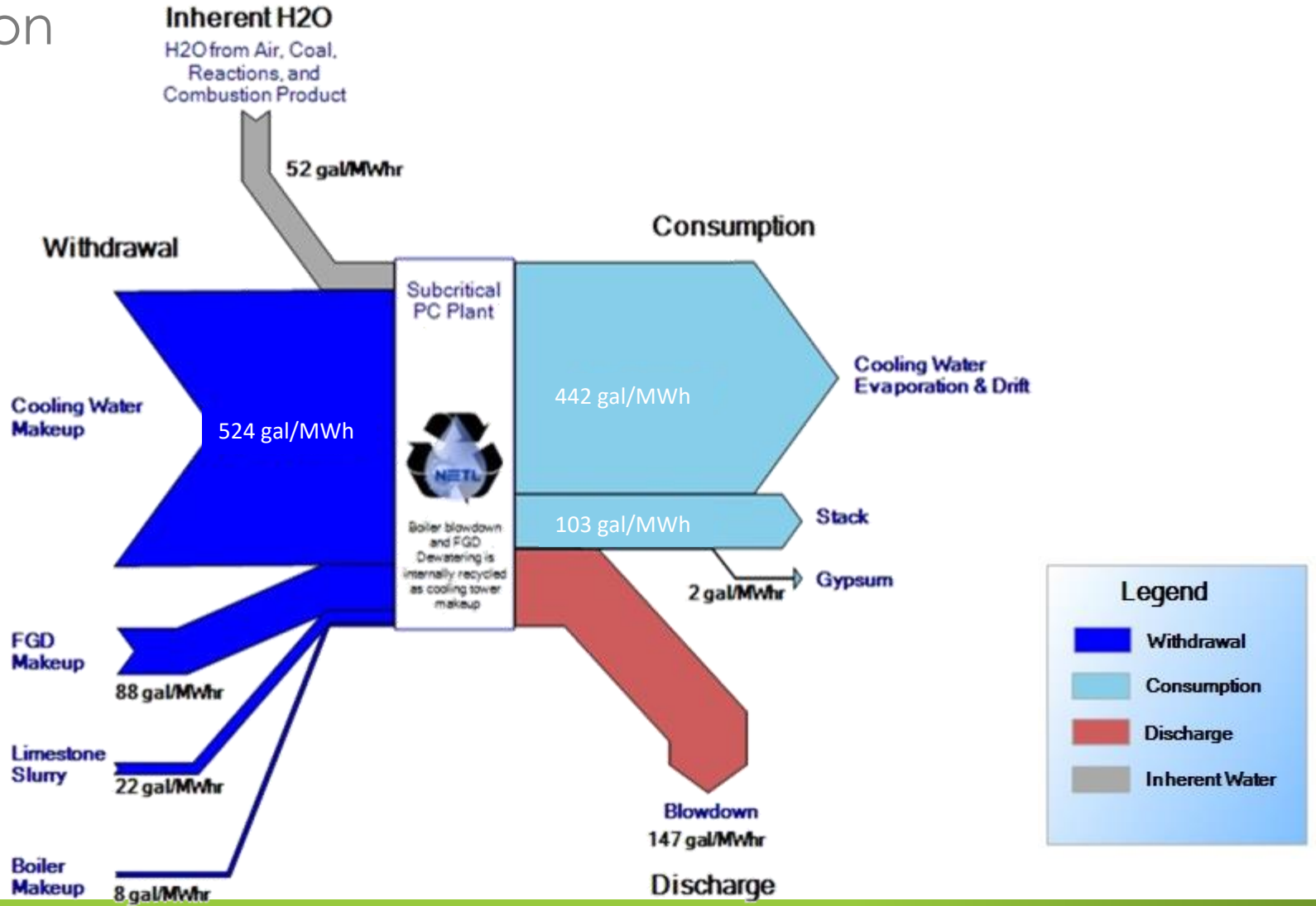
1. "U.S. Department of Energy Office of Fossil Energy: 2018 – 2022 Strategic Vision"

Office of Clean Coal Strategic Vision

- **Improve efficiency of existing coal-fired power plants from 31% (2017 baseline) to 32.5%**
- **Improve environmental performance (CO_2, SO_2, NOx, etc) of transformative, next generation power systems by improving efficiency**
- **Improve water efficiency and reduce fresh water use in thermoelectric power plants**

Importance of Water-Related R&D

Condenser Improvements Reduce Cooling Water Consumption



Importance of Water-Related R&D

Affordable Clean Energy Rule – Heat Exchanger Improvements

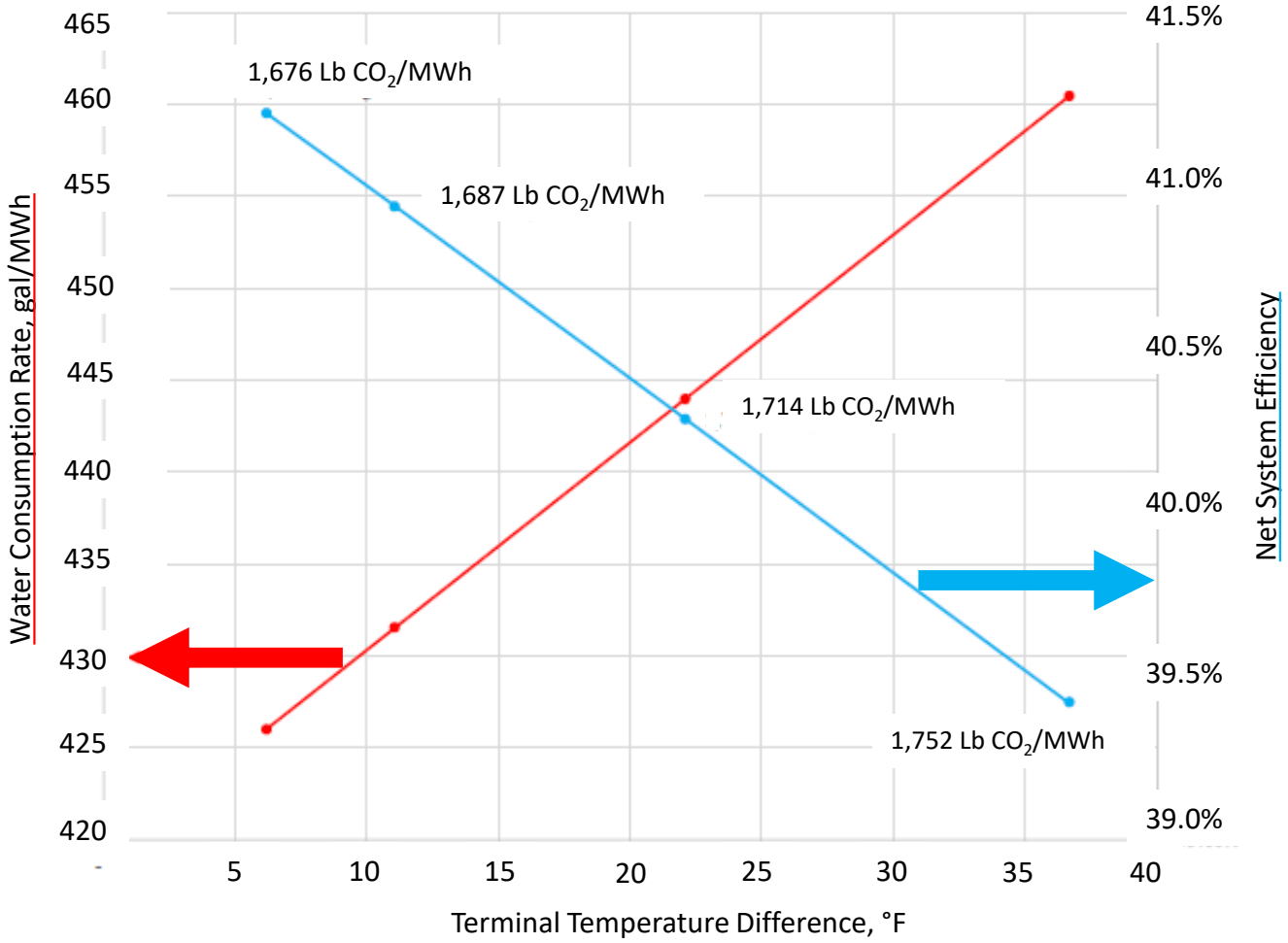
- **The Affordable Clean Energy (ACE) Rule:**
  1. Is a federal regulation that limits emissions of CO_2 from existing (**NOT** new) coal-fired power plants in the United States

  2. EPA must base CO_2 emission reductions on the performance of the **B**est **S**ystem of **E**mission **R**eduction (BSER)
     - A "system of emission reduction" can be a piece of add-on control technology, or a method of operation

  3. EPA's suite of BSER options includes improvements to the power plant's condenser, which improves generation efficiency (and reduces water consumption)

Importance of Water-Related R&D

Affordable Clean Energy Rule – Heat Exchanger Improvements



Condenser improvement example: as terminal temperature difference ↓, CO_2 emissions and water consumption rates ↓

Standard Condenser Research Guidance

Standard Condenser Research Guidance

- **NETL issued standardized analysis guidance for dry cooling[1], FGD wastewater treatment[2]**
- **Provide suggested conditions for analysis (ambient conditions, wastewater compositions, etc.) so that research is done on a common basis**
- **Establish minimum reporting requirements**
- **Existing condenser guidance already available in previous NETL studies**

1. Analysis Guidelines for Dry Cooling R&D
2. Analysis Guidelines for FGD Wastewater Treatment from Existing Sources

Condenser Analysis Guidelines

Suggested Ambient Conditions for Analysis[1]

Ambient dry bulb, °F	59
Ambient wet bulb, °F	51.5
Relative Humidity, %	60
Cooling Water Temperature, °F	60

Process Parameters for Surface Condensers[2]

	Parameter Value	Range	Notes
Pressure, psia	0.982	0.43 – 5.8	Operating pressure depends on coolaing water temperature. Design parameter is for ISO condition cooling water
Terminal Temperature Difference, °F	21	21 – 23	TTD higher than typical to account for lack of summer design condition

1. Cost and Performance Baseline for Fossil Energy Plants Volume 1: Bituminous Coal and Natural Gas to Electricity
2. Quality Guidelines for Energy System Studies: Process Modeling Design Parameters

Establishing Research/Analysis Guidance

- **Purpose of condenser research to reduce sink temperature (want to discharge heat at the lowest temperature possible)**

- **Low TRL work (materials characterization) is highly important but NETL needs to be able to quantify the R&D benefit – let's work collaboratively to figure out how to do this**
  - Change in thermal heat transfer coefficient?

- **For those projects with host sites, could reporting requirements include change in turbine backpressure?**

Other Water Related Analysis Work

Recent NETL Water-Related Studies

- Analysis Guidelines for FGD Wastewater Treatment from Existing Sources
- Analysis Guidelines for Dry Cooling R&D
- Techno Economic Analysis and Evaluation of Wet FGD Wastewater Treatment Processes at Existing Plants
- Cost and Performance Impact of Dry and Hybrid Cooling on Fossil Energy Power Systems

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Please don’t hesitate to reach out!