Dry and Hybrid Cooling Systems Analysis Activity at NETL

Eric Grol

2019 Crosscutting Technologies Review Meeting
April 10, 2019

Disclaimer

NATIONAL ENERGY TECHNOLOGY LABORATORY

Outline

1. Power plant cooling background
2. Cooling system choice on power plant efficiency
3. Impact of ambient conditions on evaporative losses
4. Cost results

Power Plant Cooling Background

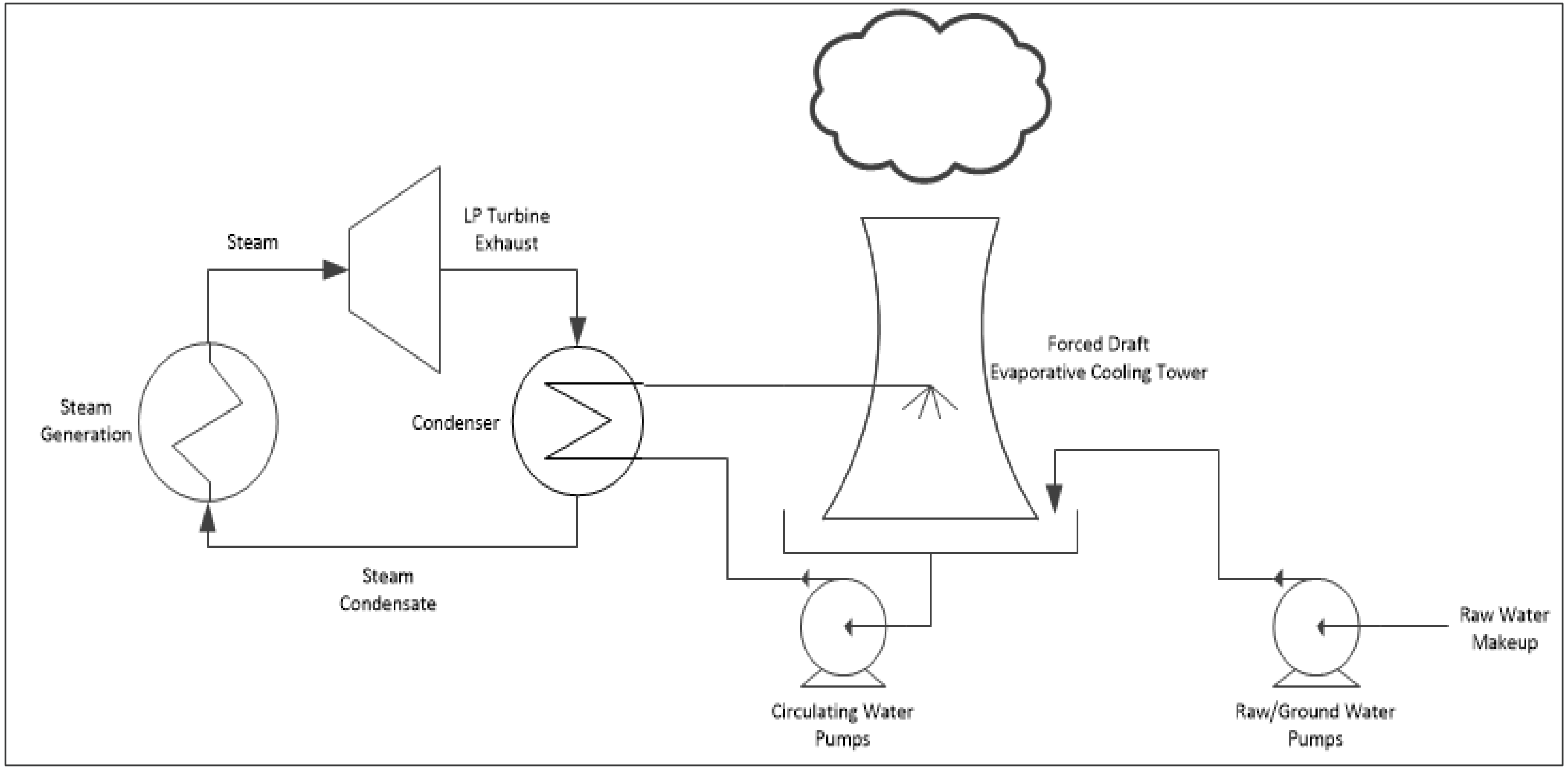
Advanced Cooling Systems Analysis

- "Cost and Performance Impact of Dry and Hybrid Cooling on Fossil Energy Power Systems" (publication pending)

- Wet recirculating, dry, and wet/dry hybrid cooling systems for PC and NGCC plants (with and without CO_2 capture) assessed over a range of ambient conditions

- Limitation of current study: Equipment sizing (and therefore auxiliary load and cost) established for ISO design point. This would change if the design point were for a hot, arid location.

Wet Evaporative Cooling Systems

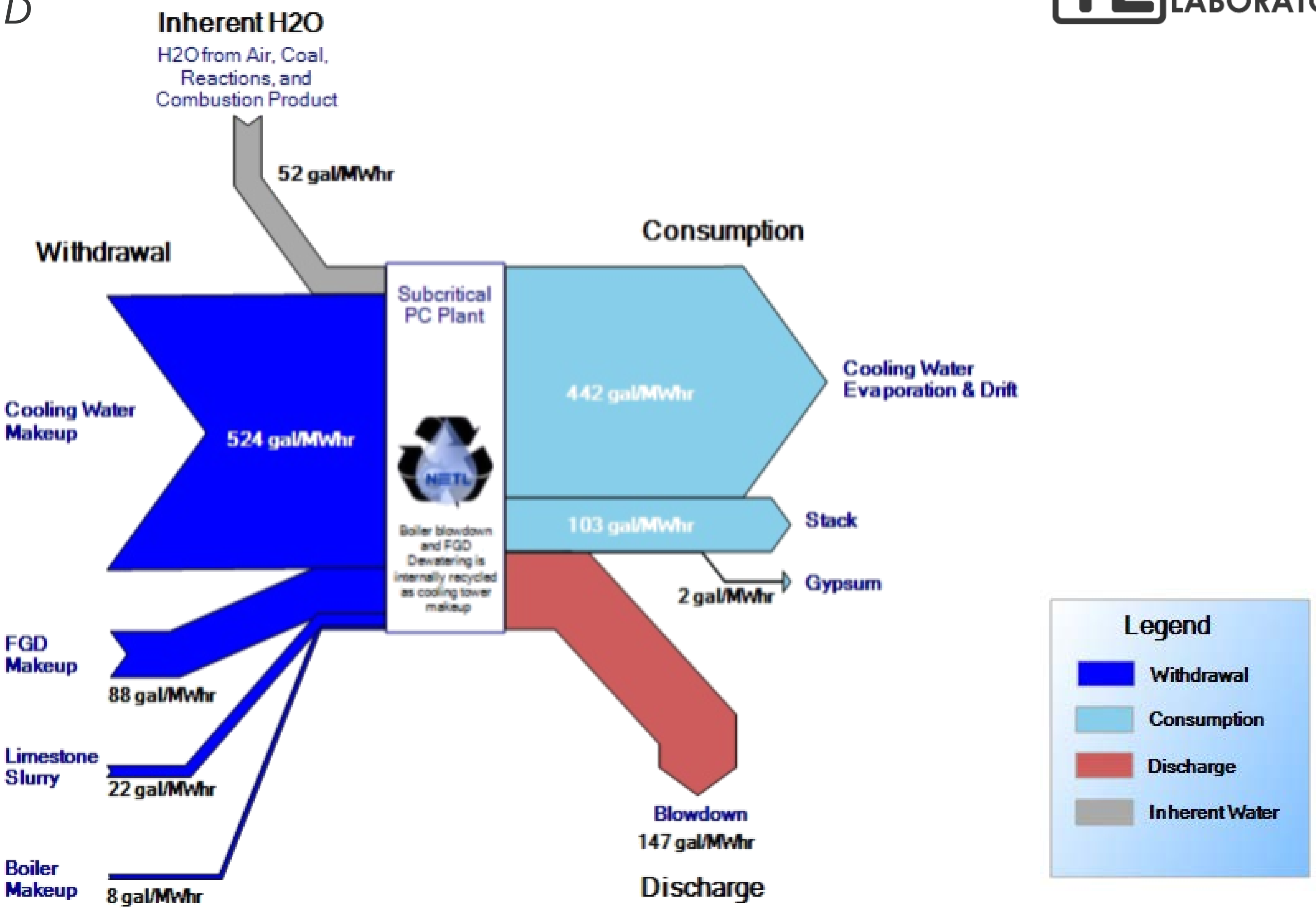


Source: NETL

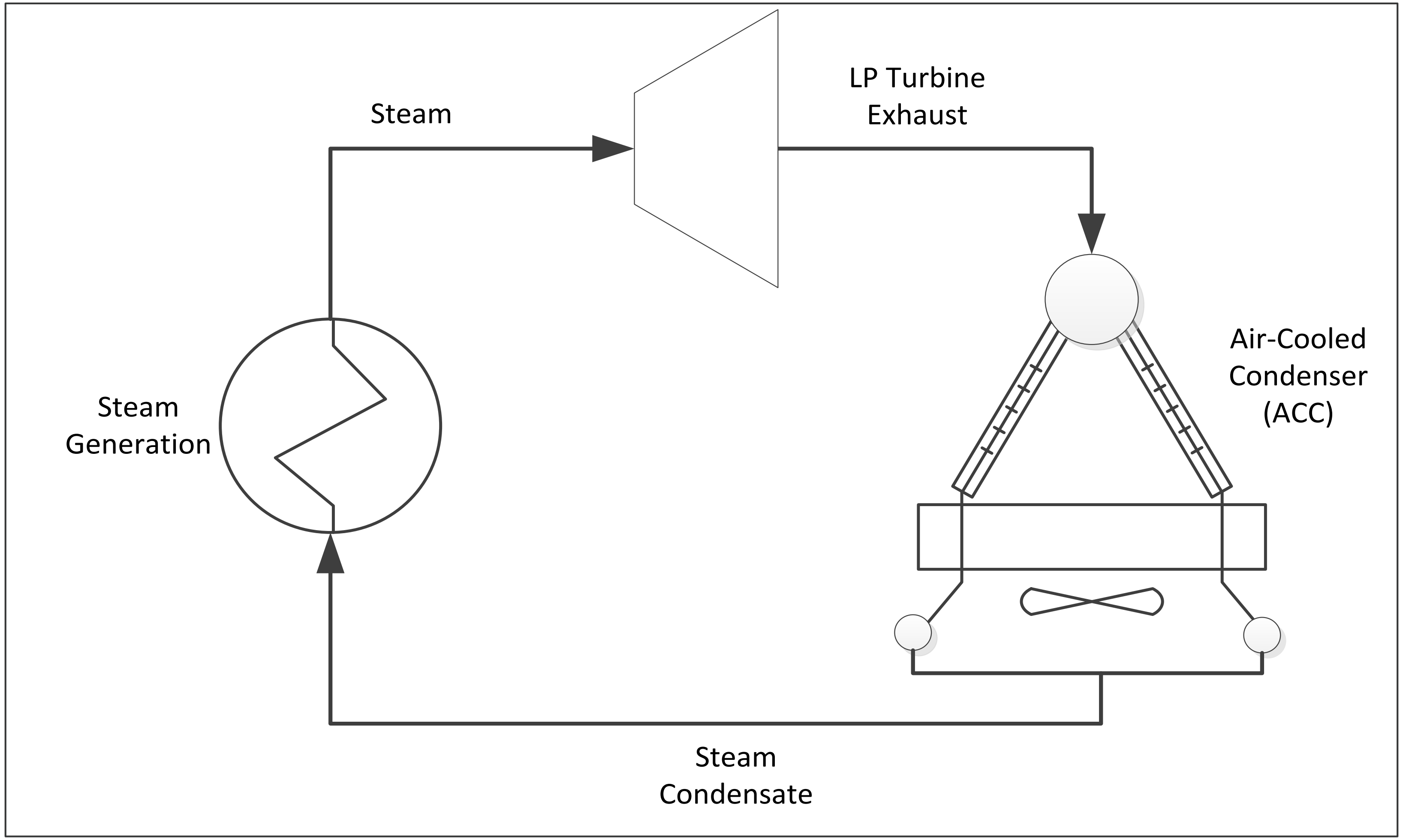
Subcritical PC Water Sankey Diagram

Recirculating Cooling & Wet FGD

In contrast to <u>once-through</u> cooling system which withdrawal on average 20,000 gal/MWhr and Consume ~0 gal/MWhr. Note the higher temperature water discharged from the plant will increase evaporation downstream but this in not reported within the plant boundary.



Dry Cooling Systems



Dry and Hybrid Cooling Study Case Matrix

Case	Site Conditions[1,2]		Unit Cycle	Steam Cycle	Combustion Turbine	Boiler Technology	Condenser Cooling Technology	CO_2 Separation
1 through 168	0 ft. Elevation 14.696 psia & 5280 ft. Elevation 12.1 psia	Midwestern ISO 59 F dry bulb 60% R.H. July Average High 85 F dry bulb 53, 69, & 84% R.H. January Average Low 20 F dry bulb 63, 70, & 74% R.H.	PC	3500/1100/1100	N/A	SC PC	Wet Evaporative Tower	No
			PC	3500/1100/1100	N/A	SC PC	Wet Evaporative Tower	Yes
			PC	3500/1100/1100	N/A	SC PC	Wet/Dry Parallel	No
			PC	3500/1100/1100	N/A	SC PC	Wet/Dry Parallel	Yes
			PC	3500/1100/1100	N/A	SC PC	Air Cooled Condenser (ACC)	No
			PC	3500/1100/1100	N/A	SC PC	Air Cooled Condenser (ACC)	Yes
			NGCC	2400/1050/1050	2 x State-of-the-art 2013 F-Class	HRSG	Wet Evaporative Tower	No
			NGCC	2400/1050/1050	2 x State-of-the-art 2013 F-Class	HRSG	Wet Evaporative Tower	Yes
			NGCC	2400/1050/1050	2 x State-of-the-art 2013 F-Class	HRSG	Wet/Dry Parallel	No
			NGCC	2400/1050/1050	2 x State-of-the-art 2013 F-Class	HRSG	Wet/Dry Parallel	Yes
			NGCC	2400/1050/1050	2 x State-of-the-art 2013 F-Class	HRSG	Air Cooled Condenser (ACC)	No
			NGCC	2400/1050/1050	2 x State-of-the-art 2013 F-Class	HRSG	Air Cooled Condenser (ACC)	Yes

[1]Average July high and January low temperatures for Pittsburgh, PA, https://weather.com/weather/monthly/l/USPA1290:1:US
[2]July and January relative humidity data for Pittsburgh, PA, https://www.currentresults.com/Weather/US/humidity-city-annual.php

Source: "Cost and Performance Impact of Dry and Hybrid Cooling on Fossil Energy Power Systems," NETL, publication pending

Cooling System Choice on Power Plant Derate*

Cooling System Choice on Power Plant Derate*

Wet Evaporative vs. Dry Cooling Comparison

1. **PC plant net power and efficiency are impacted more than NGCCs by dry cooling in the summer conditions. NGCCs are relatively insensitive.**

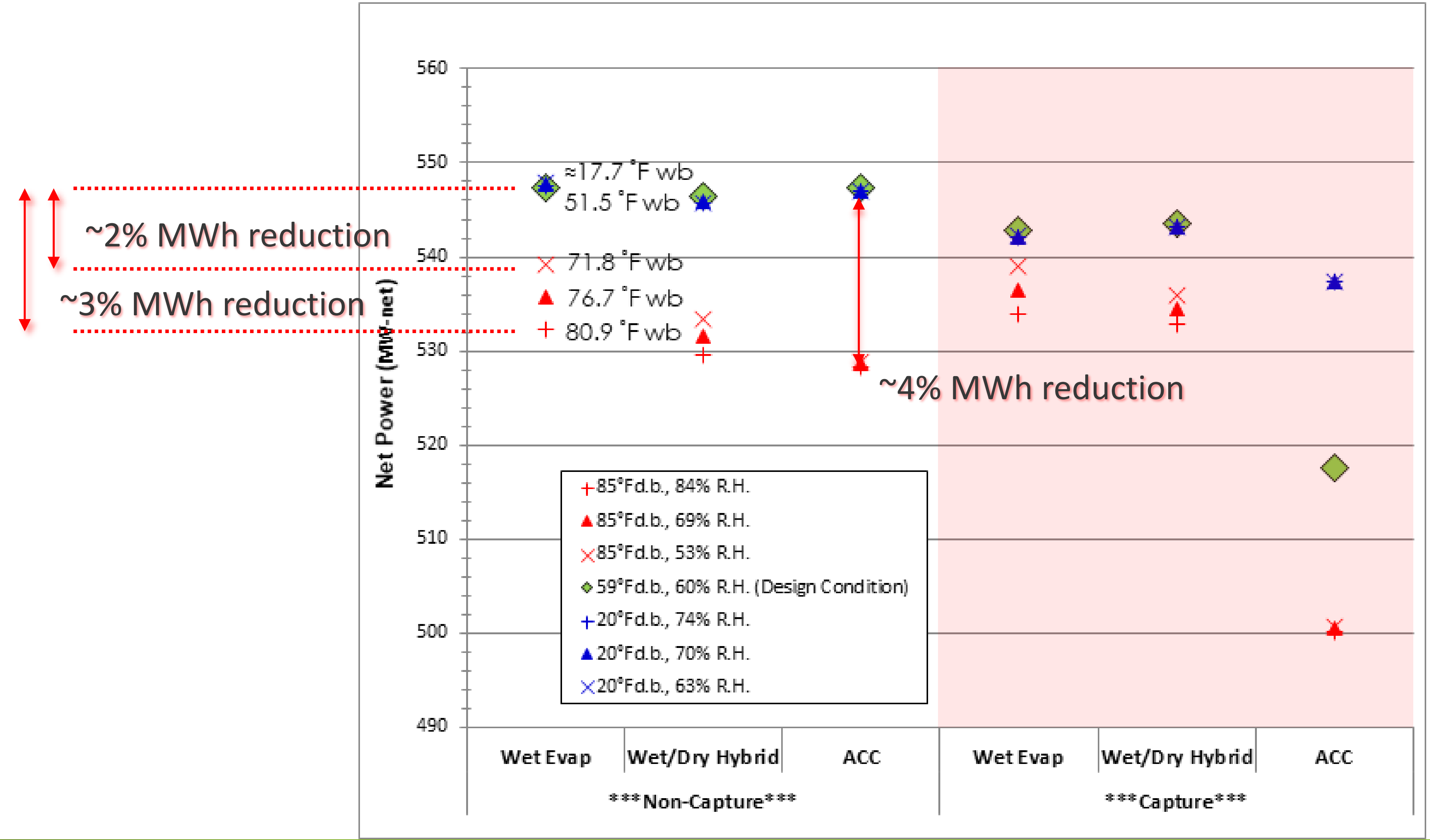
2. **NGCCs have the largest ambient condition-driven derate in absolute terms, regardless of the cooling technology type.**

3. **Large reduction in net power for PC plants with dry cooling and CO_2 capture:**
   i. Higher capture solvent temperature (approaches dry bulb) requires higher circulation rates to maintain 90% capture, increasing parasitic load
   ii. Increased auxiliary load due to dry cooling fan power

**Derate: Degree of reduction in net power generation due to operational change or equipment addition*

Cooling System Choice on Power Plant Derate

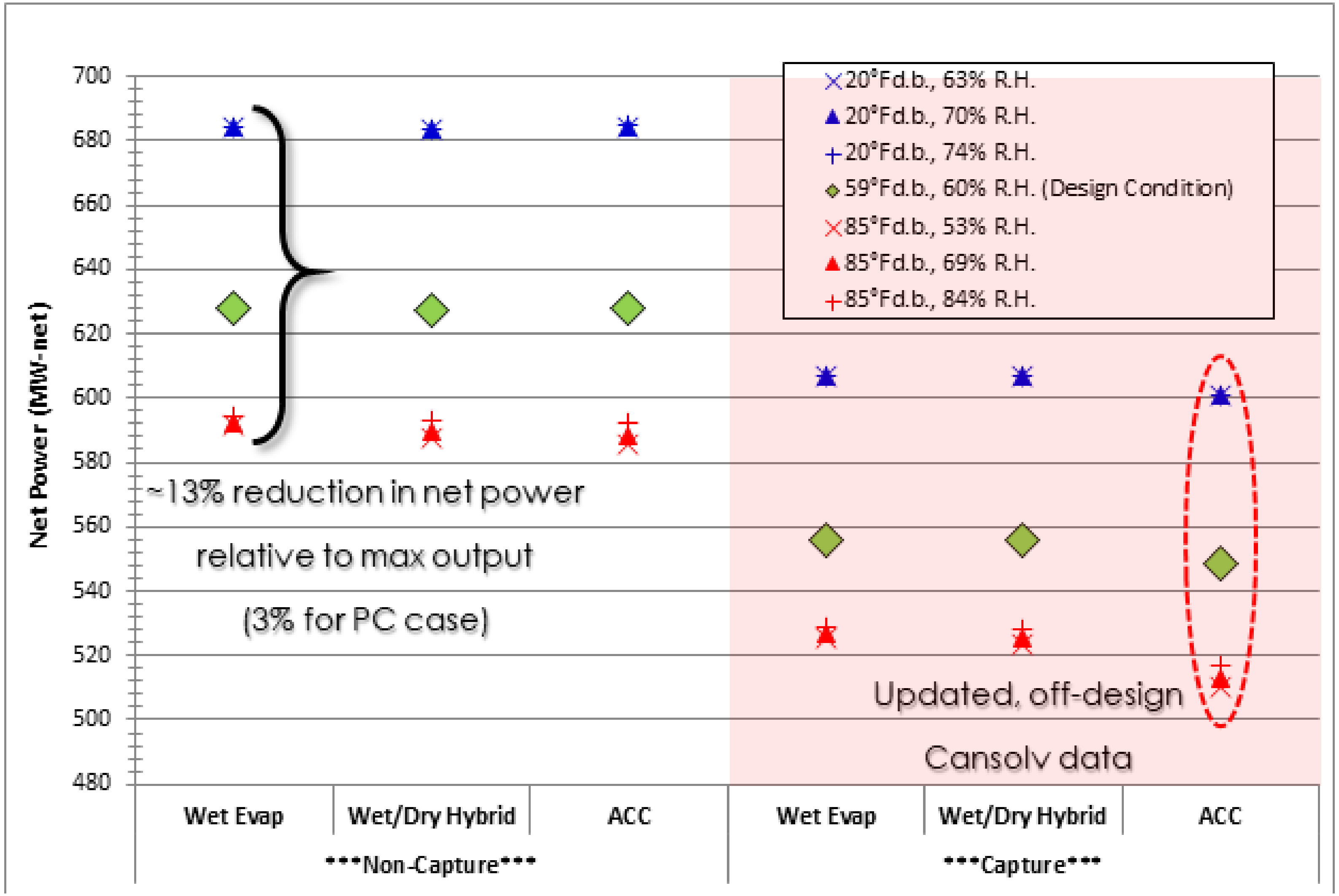
PC plants with dry cooling experience the greatest generation derate in summer conditions



Source: "Cost and Performance Impact of Dry and Hybrid Cooling on Fossil Energy Power Systems," NETL, publication pending

Cooling System Choice on Power Plant Derate

NGCC plants with dry cooling experience no significant generation derate in summer conditions



Source: "Cost and Performance Impact of Dry and Hybrid Cooling on Fossil Energy Power Systems," NETL, publication pending

Cooling System Choice on Power Plant Derate

NATIONAL ENERGY TECHNOLOGY LABORATORY

<u>Forthcoming dry cooling study to evaluate:</u>

1. Deployment of dry cooling systems on existing coal units likely to be in the western U.S. (water rights)

2. If dry cooling deployed at large scale, what is the extent of the regional derate in generation?

3. Derate in generation will be greatest during summer months (high dry bulb temperature), when MWh's needed the most (additional capacity needed?)

Impact of Conditions on Evaporative Losses

Impact of Conditions on Evaporative Losses

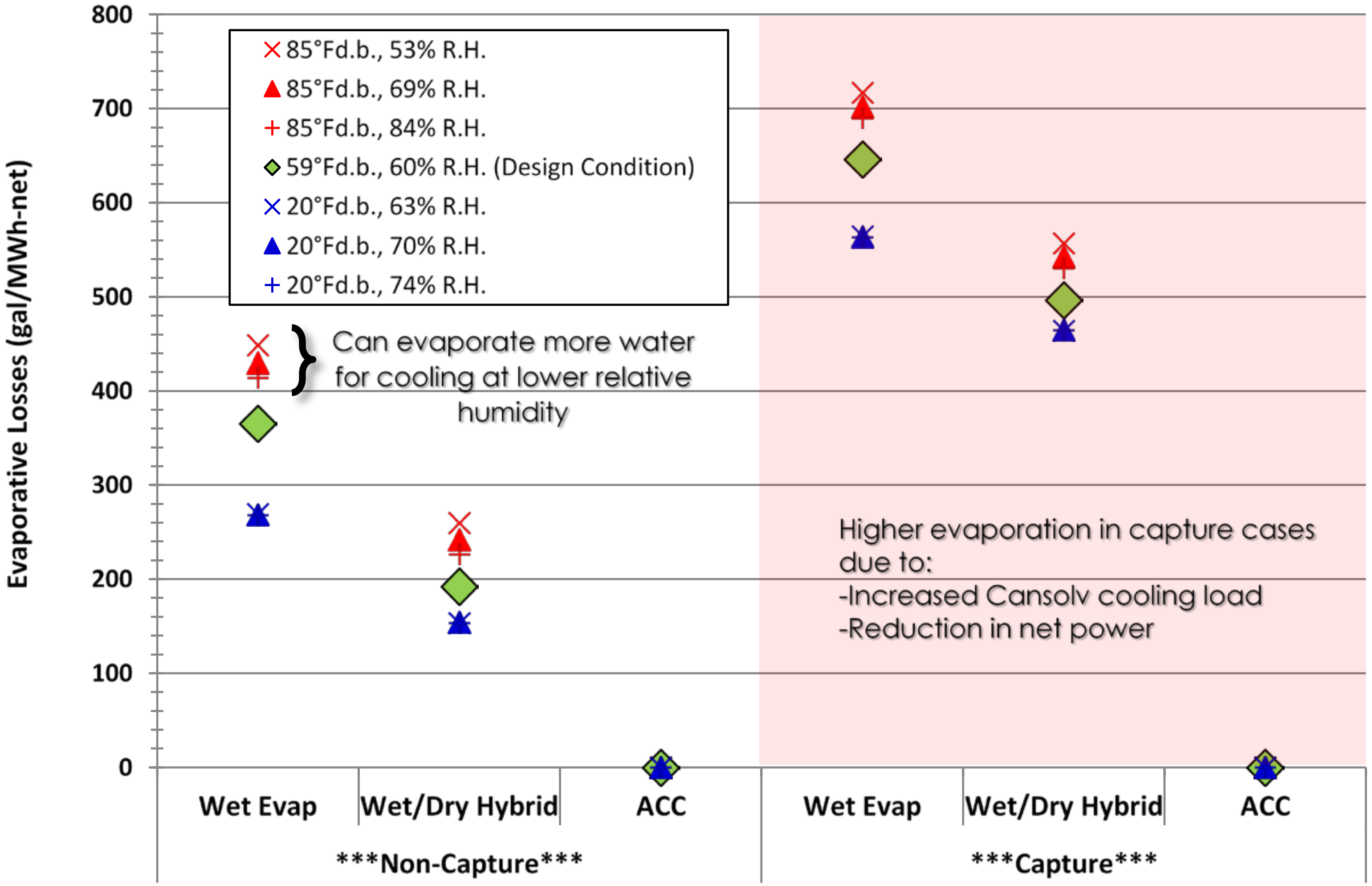
1. Regardless of plant type, evaporative losses always greatest at high temperature, low humidity

2. Evaporative losses eliminated from systems with strictly dry cooling systems, but this comes at a cost (extra equipment – air cooled heat exchangers + air cooled condenser)

3. Water use reduction in power systems is an objective, but large dry cooling parasitic load in hot conditions reduces MWh's generated

Impact of Conditions on Evaporative Losses

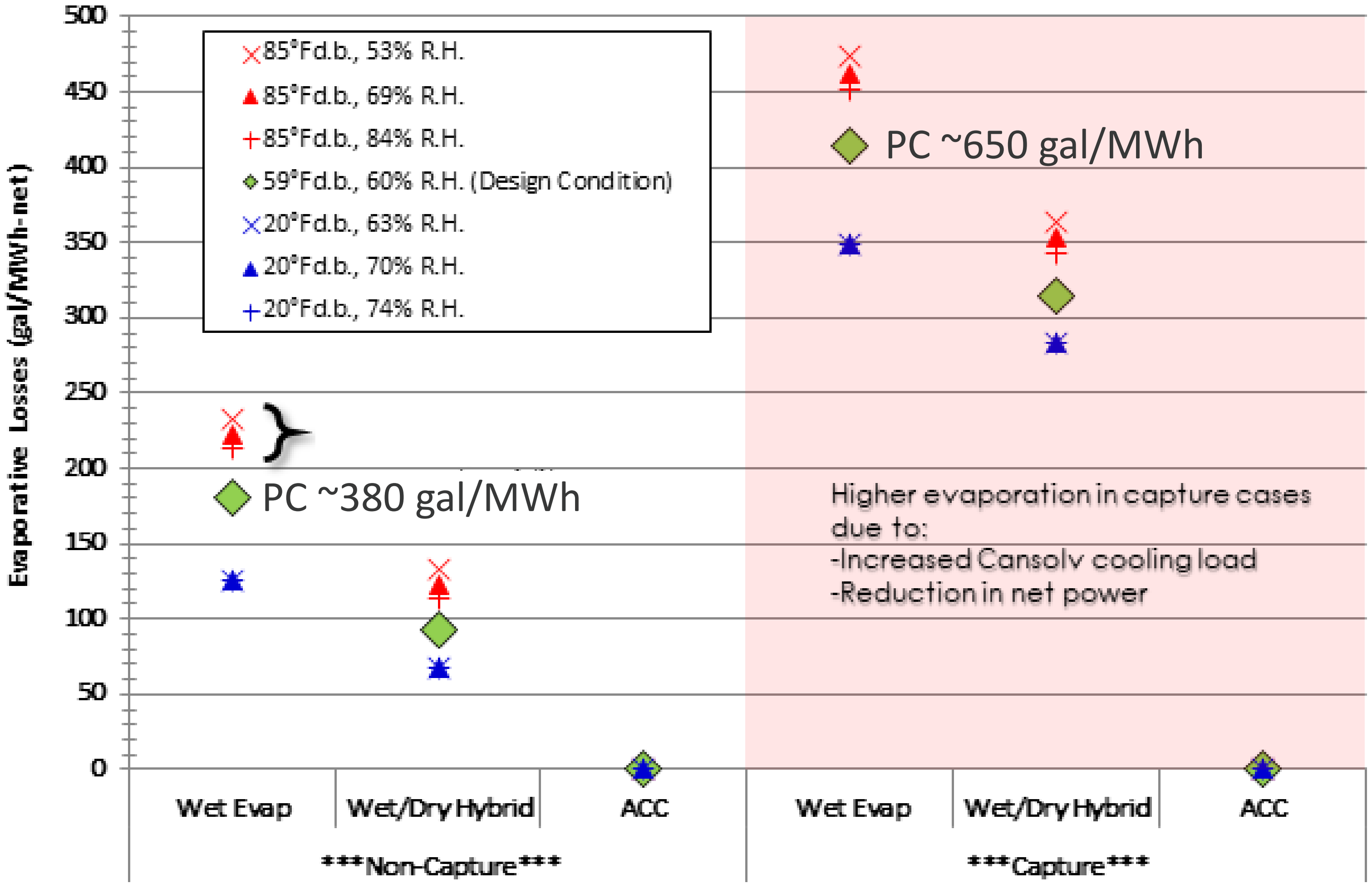
PC evaporative losses greatest at high temperature



Source: "Cost and Performance Impact of Dry and Hybrid Cooling on Fossil Energy Power Systems," NETL, publication pending

Impact of Conditions on Evaporative Losses

Similar to PC, NGCC evaporative losses greatest at high temperature



Source: "Cost and Performance Impact of Dry and Hybrid Cooling on Fossil Energy Power Systems," NETL, publication pending

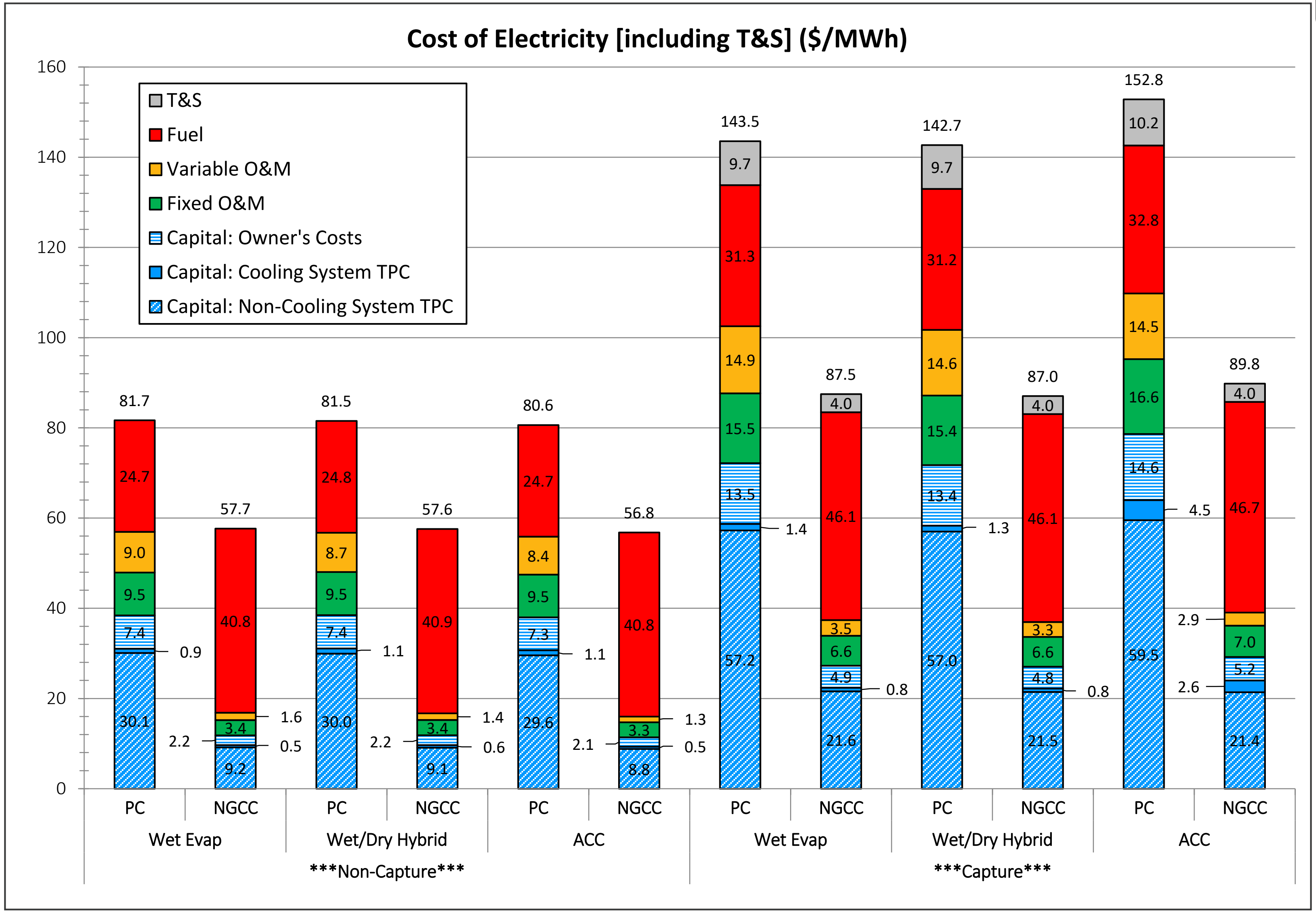
Cost Results

Cost Results

Perspectives on study cost results:

1. **Dry cooling equipment sized based on same set of ambient conditions(ISO) as wet evaporative for results comparison on a common basis; better assumption would've been to choose conditions where dry cooling is the likely design choice (water constrained areas)**
2. **Cost of electricity (COE) not static, it fluctuates based on generation (ambient conditions)**
   i. Summer/winter fluctuations for dry cooling > wet cooling, so dry cooling COE likely more variable than wet
   ii. Summer/winter net power fluctuations for NGCC > PC, so greater seasonal COE variation for NGCC than PC
3. **In reality, cost of power plant dry cooling is probably site-specific, and feedback/perspectives on the matter are welcome!**

Cost Results



Acknowledgements

- NETL site support contractors Eric Lewis (KeyLogic) and Drew O'Connell (Deloitte) for dry process modeling and cost analysis
- Travis Shultz for technical review and valuable feedback

Contact Information

Eric Grol

U.S. Deparment of Energy/National Energy Technology Laboratory

Eric.grol@netl.doe.gov

412-386-5463