Energy Technology Systems and Market Analyses

NATIONAL ENERGY TECHNOLOGY LABORATORY

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Solutions for Today | Options for Tomorrow

U.S. DEPARTMENT OF ENERGY

Acknowledgment and Disclaimer

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Characteristics of 21st Century Power Plant

Background

- **R&D technology portfolio performance and cost goals have been historically non-market-based**
  - Plants generally operated in a baseload condition
  - Efficiency, capital costs, and COE/LCOE sufficed as main metrics of importance
- **With higher penetration of intermittent resources, FE plants are often called upon to operate in a cycling mode to satisfy the load**
  - Performance and cost characteristics of FE technologies need to adapt to remain relevant and a viable part of the generation portfolio
    - Traditional cost and performance metrics such as efficiency and COE are no longer adequate to ensure technology deployment and sustenance
    - One size fits all design paradigm no longer works; regional markets required tailored solutions
- **Identifying ideal FE technology performance and cost characteristics of high value based on market dispatch is essential**
  - Development of next generation of 21st Century Power Plant (21CPP)
  - Deployment of advanced FE technologies to ensure grid reliability and resilience

Advanced Coal Technologies Under High VRE and Other Scenarios

Objective

The objective of this activity was to identify:

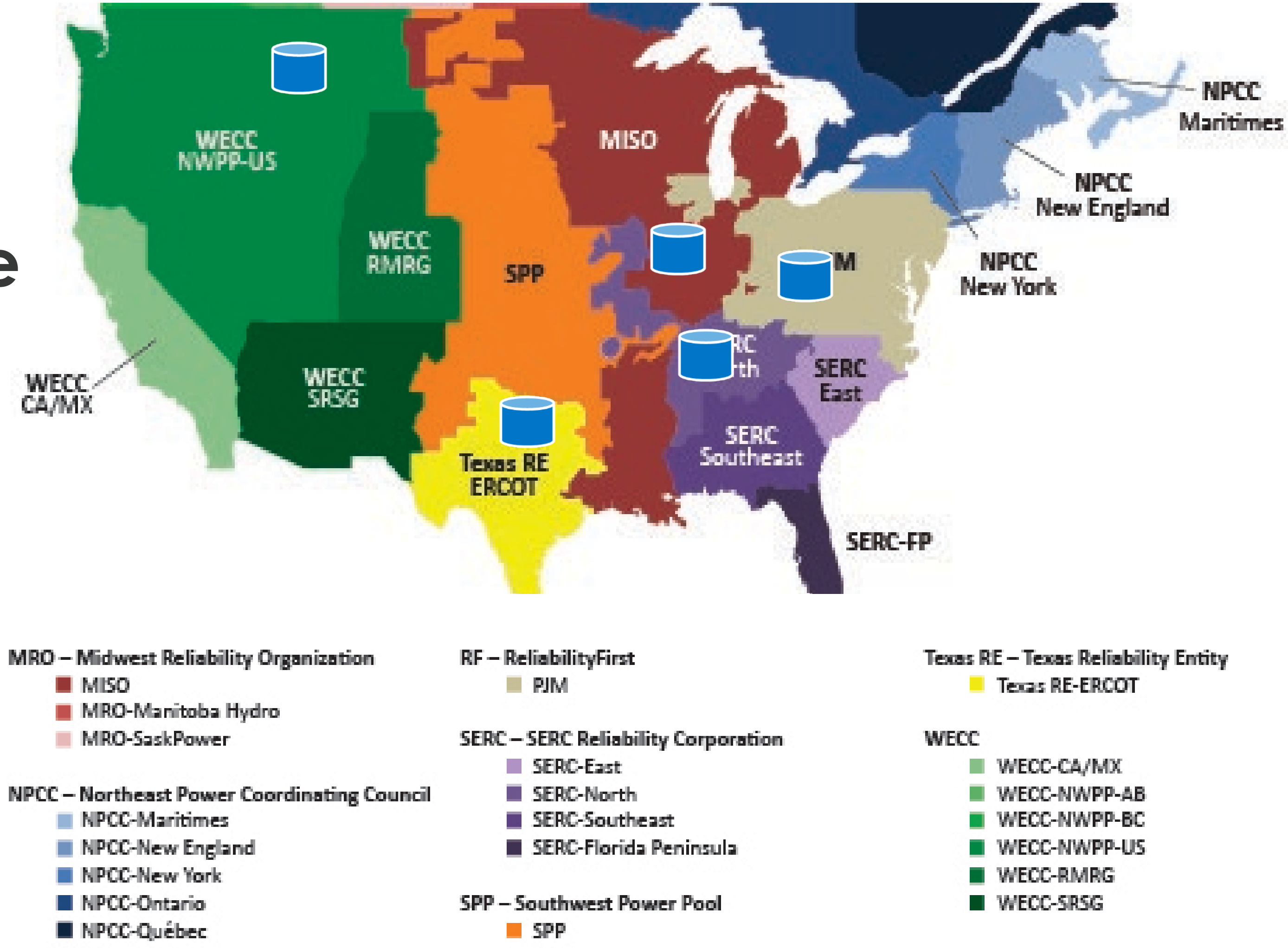
- *Desirable performance and operating characteristics* of the next generation of coal technologies based on regional market conditions and future scenarios
- *Operating and capital cost targets required for technology viability* of the next generation of coal technologies based on regional market conditions

What costs enable long-term viability of the coal generator with ideal performance in each region?

- *Net Cost of New Entry (Net CONE)*
- *Annual revenue requirement (ARR)*
- *Revenue streams from other markets to fill electricity generation troughs*

Dispatch Analysis Approach

- Scenarios examined the generation dispatch conditions of the power system from 2030 – 2035 in five test regions
- Security Constrained Economic Dispatch using PROMOD
- Allows enveloping of 21CPP operating characteristics



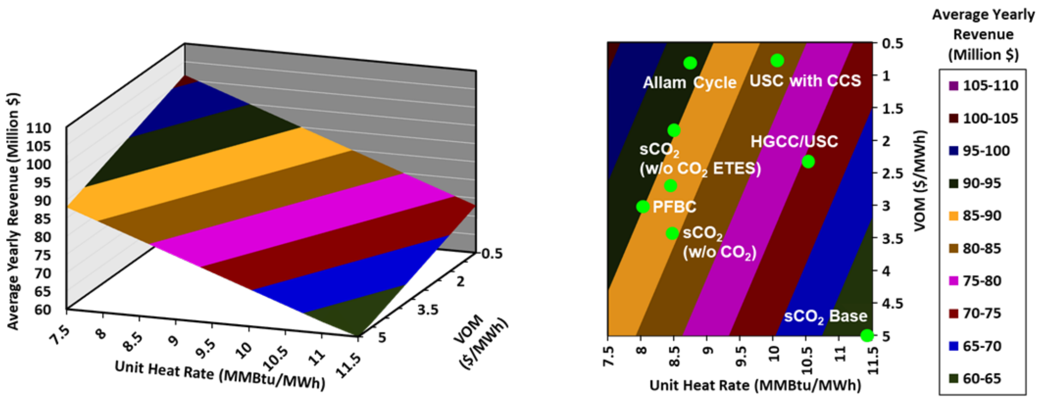
Economic Evaluation

- **Evaluation used two methods to determine the potential economic viability of the concepts evaluated,**
  - Annual Revenue Requirement (ARR) – determines the amount of revenue the plant must earn to break even
  - Cost of New Entry (CONE) - The CONE is the basis for the calculation of NetCONE which provides an estimation of the total revenue a new generator would need to deploy

Capacity Factor/Revenue Calculation

- Capacity factors and revenues determined by interpolating results of PROMOD modeling
- A multivariate regression method was used to fit surfaces to the variation of average annual revenue and CFs with HR and VOM for each of the fuel cost cases under the two VRE penetration scenarios
- Multivariate regression resulted in fits with R^2 values around 99 percent and represented the data to within 0.5 percent over most of the range

Six-year average annual revenue as a function of HR and VOM for the high VRE case scenarios at the improved fuel price (PJM)



Total Revenue Buildup

- Total revenue estimates developed by supplementing PROMOD projected electricity revenues with estimated ancillary service revenues and CO_2 capture incentive revenues, such as 45Q and EOR
- Assumed 90 percent CO_2 capture rate at $40/tonne; 45Q tax credit net of assumed transportation costs
- Ancillary services revenue source is accounted for by using a variety of methods depending on the region being modeled and information available

1. S&P Global, "What is Carbon Pricing", February 25, 2020, https://www.spglobal.com/en/research-insights/articles/what-is-carbon-pricing
2. Estimated from data in PJM 2019 State of the Market Report

Annual Revenue Requirement (ARR)

- **ARR is used to determine the long run average cost of capacity - the amount of revenue the plant must earn to break even**

$$ARR = \left(\frac{TOC \times r}{1 - (1 + r)^{-T}}\right) \div K + cf \times \left((f \times hr) + vom\right) \times 8{,}760$$

- **Value of ARRs and the predicted revenue in \$/MW-year were plotted at the CFs predicted by the modeling**
- **If the predicted revenue is greater than the ARR at that predicted CF, then the conceptual design would be able to cover its capital costs under those conditions**

NetCONE Requirements

- **Cost of New Entry (CONE) is the levelized investment and fixed costs of a new generator**

$$CONE = (TOC \times r) + fom$$

TOC = Total overnight cost ($)
r = effective charge rate (%)
fom = fixed O&M cost ($)

- **NetCONE is the CONE minus the expected net energy and ancillary service (E&AS) revenues**
  - A positive value of NetCONE represents the required additional revenue a new generator would need to have to be willing to enter the market
- **NetCONE usually represents the needed Capacity Payment value depending on the market structure**

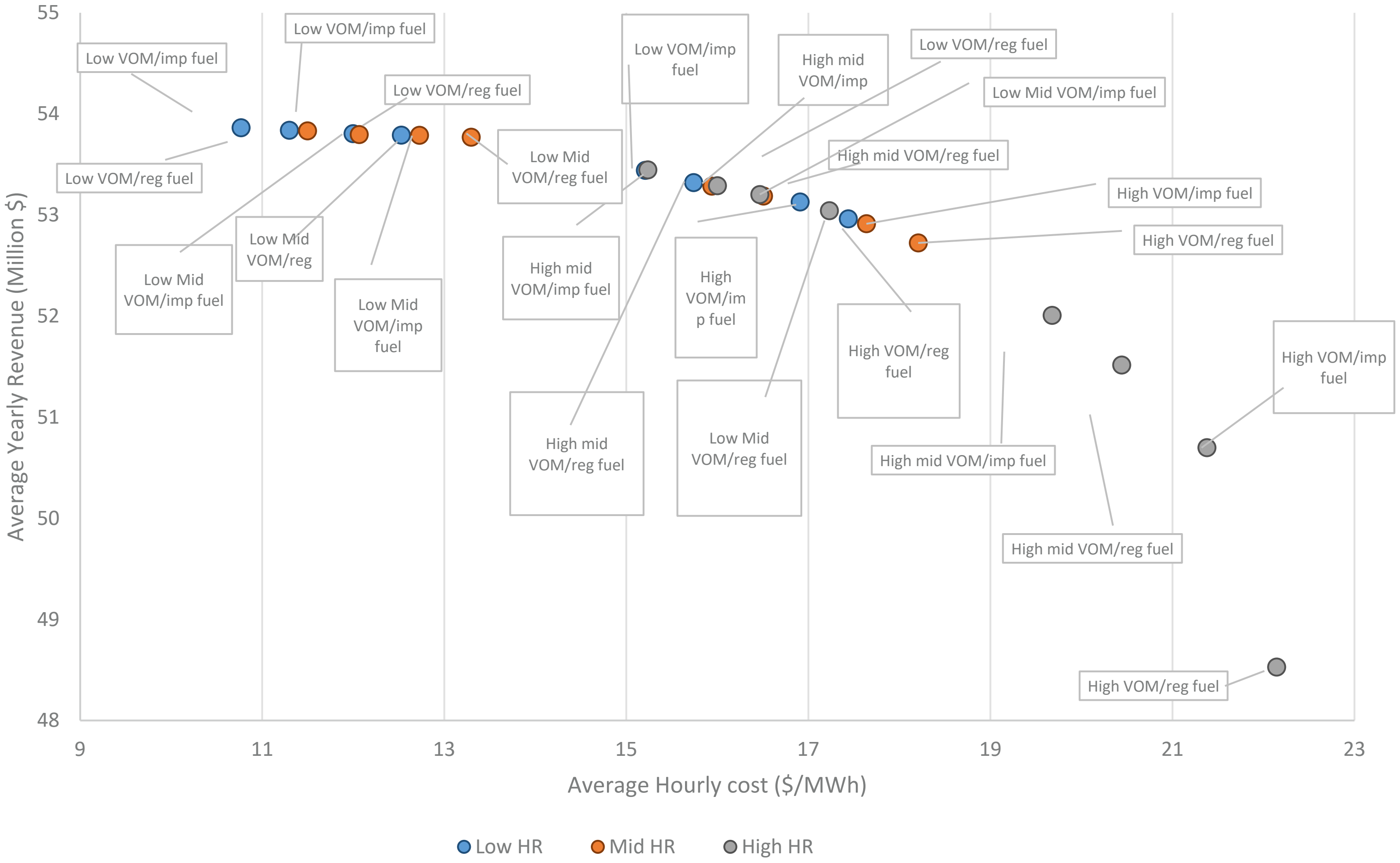
Summary of Results for 21CPP in Five Regions

- **Best case in each region (low HR, low VOM, and improved fuel price) resulted in baseload capacity factors; with ERCOT, PJM and SERC demonstrating over a 90% average**
- **Only the ultrasupercritical with CCS would meet or nearly meet the NetCONE and ARR requirements in PJM and/or the Northwest Power Pool (NWPP)**
- **Remainder of the technologies analyzed had costs too high to meet NetCONE and ARR, even with high CF, due to high capital cost**

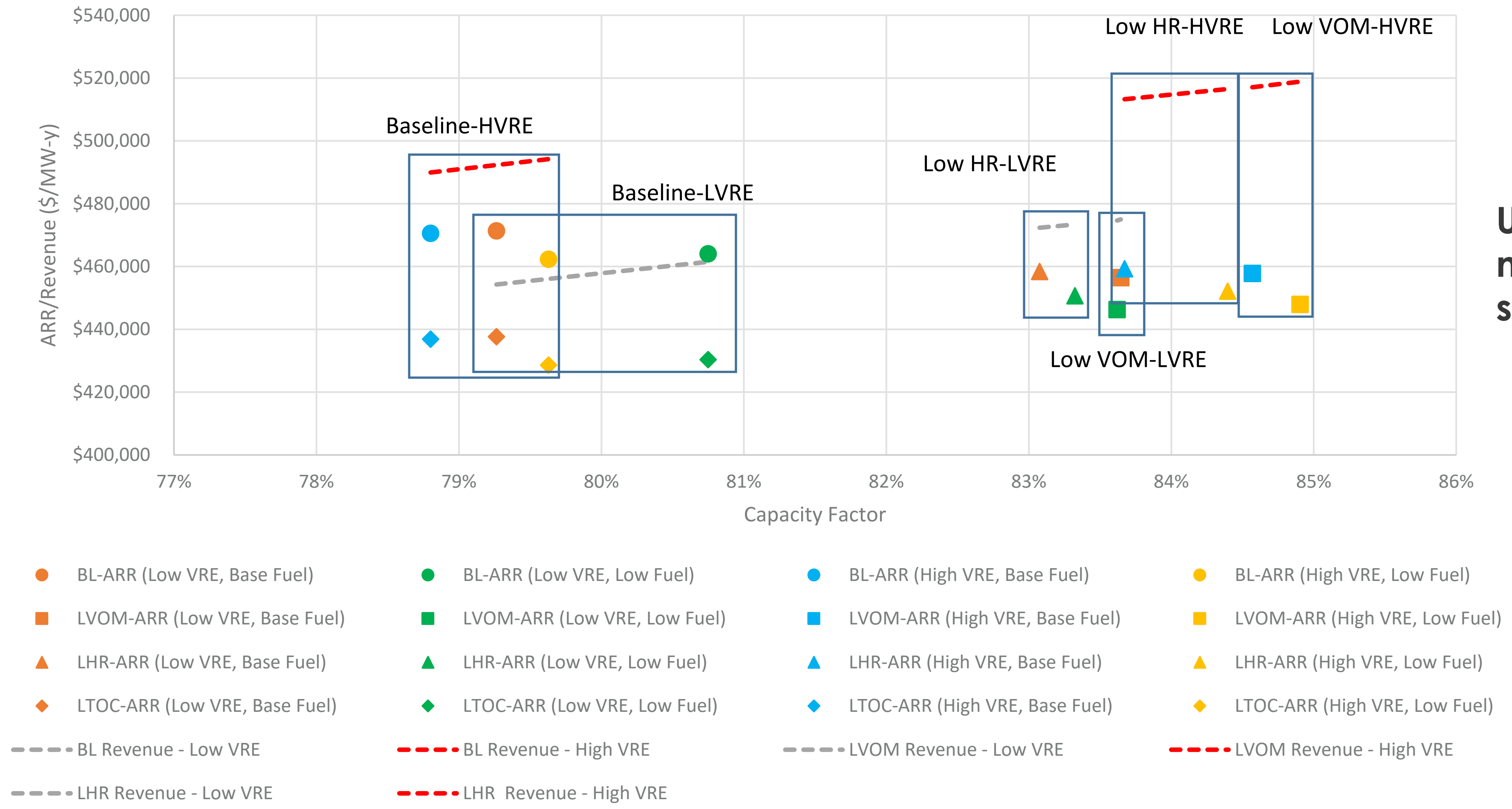
Sample regional results – NWPP

Dispatch revenue as a function of average hourly costs

- **Downward sensitivities on heat rate, variable operating costs, and fuel costs resulted in increased capacity factors and average annual revenues**



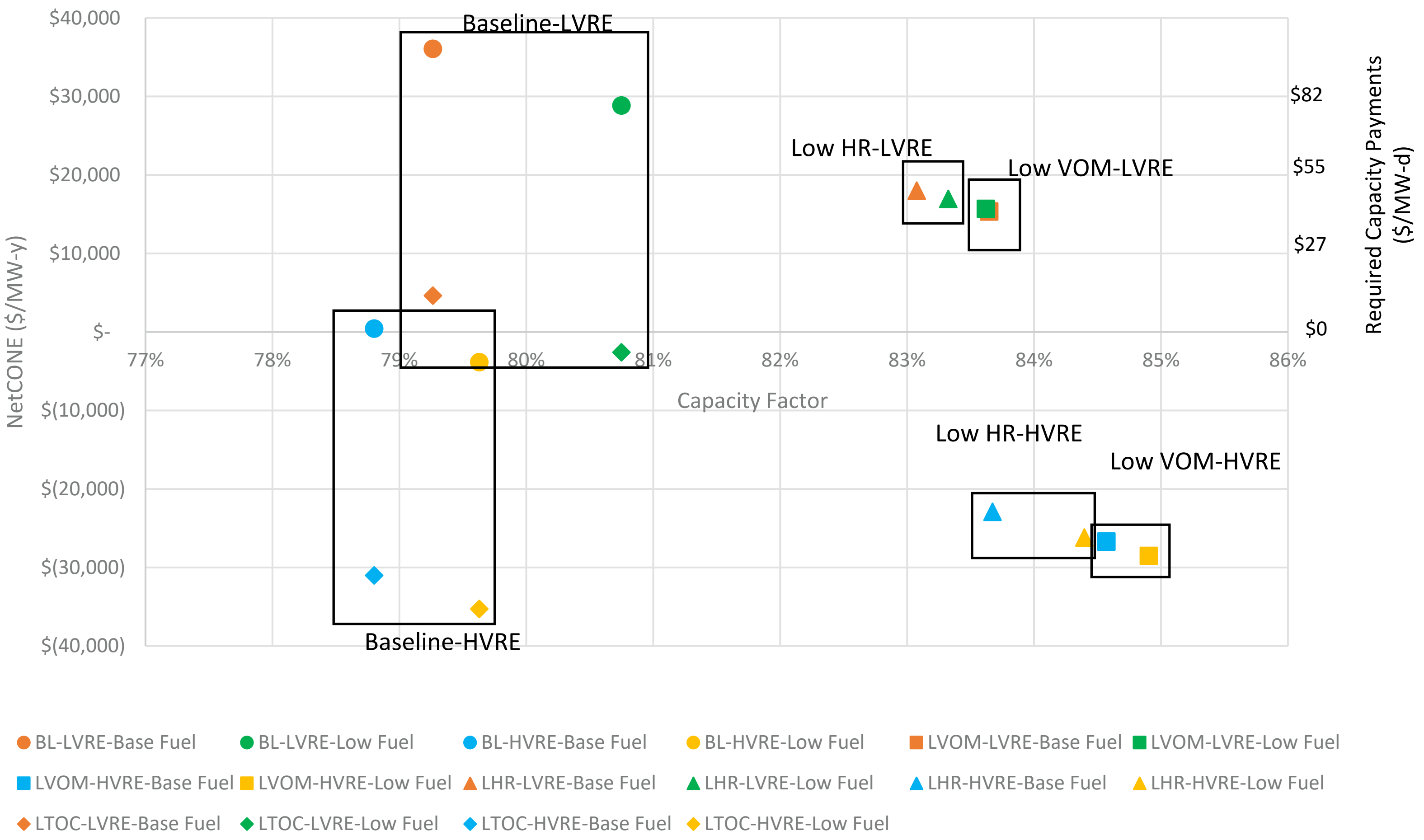
NWPP - USC Concept w/CCS: ARR Results



USC concept makes or nearly makes ARR under all sensitivities

* Dashed line above points indicates technology meets or exceeds ARR

NWPP - USC Concept w/CCS: NetCONE Results



USC concept makes NetCONE in high renewable scenarios

* Points above zero imply that the value of a capacity payment or additional revenue stream required for successful deployment of a new unit

NGCC with CCS Comparison

- In each of the electricity regions, the NGCC with CCS case (Case B31B) from the NETL Cost and Performance Baseline for Fossil Energy Plants was evaluated for comparison to 21CPP technologies
- Similarly, PROMOD modeling was used to generate estimates for revenue and capacity factor

Summary of B31B Results for Five Regions

Six-year average annual generation/capacity factor

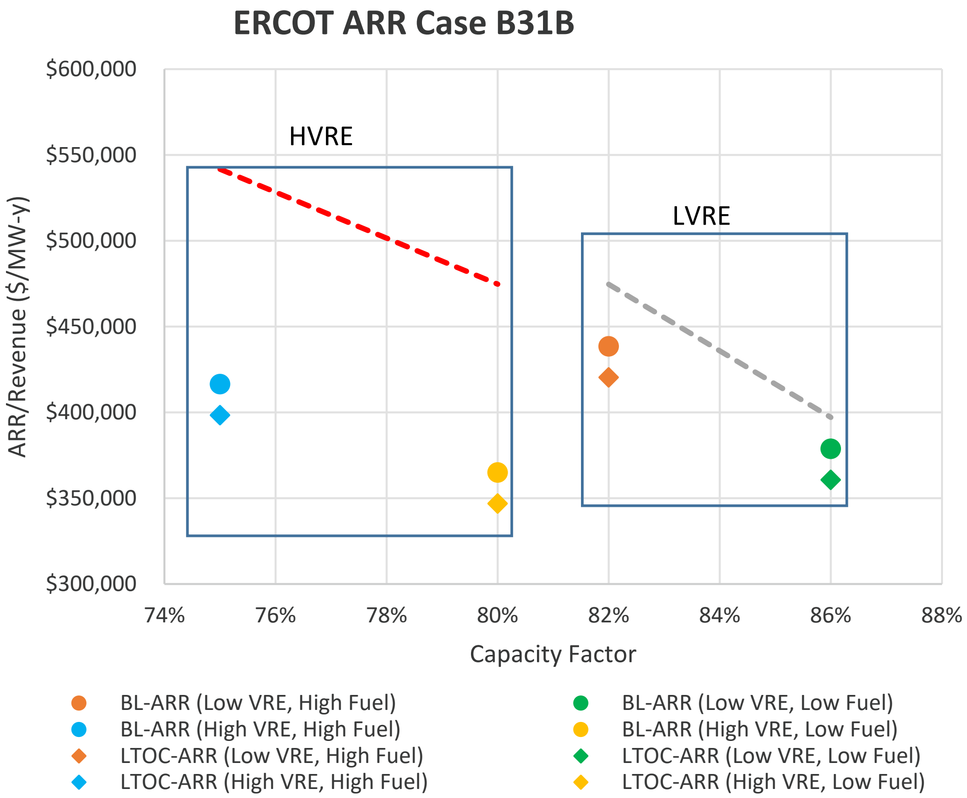
- Case B31B performed well under both the Low and high VRE scenarios in ERCOT and PJM
- In NWPP, B31B met NetCONE under high VRE scenarios, but fails to meet ARR

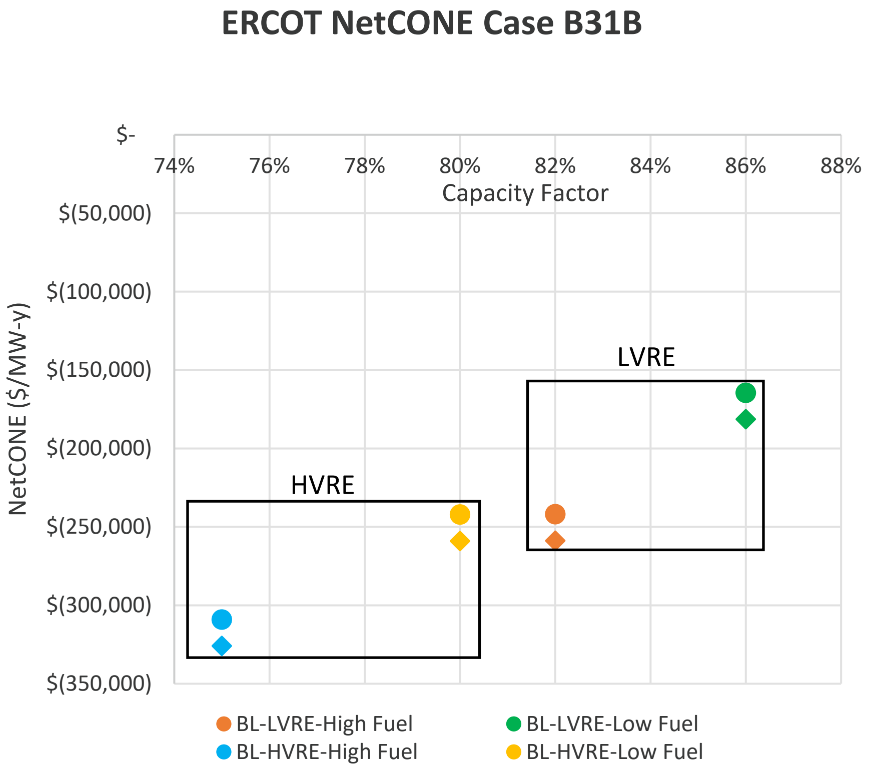
Scenario	Best Metric	ERCOT	MISO	PJM	NWPP	SERC
Low VRE	Generation (Thousand MWh)	4,859	1,992	5,257	2,258	1,952
	Capacity Factor (%)	86	35	93	40	34
	Revenue (Million $)	244.5	72.3	171.5	92.3	62.8
	(Meet) NetCONE Requirement	Yes	No	Yes	No	No
	(Meet) ARR Requirement	Yes	No	Yes[1]	No	No
High VRE	Generation (Thousand MWh)	4,554	1,125	4,244	2,936	2,390
	Capacity Factor (%)	80	20	75	52	42
	Revenue (Million $)	292	49	132	120	78
	(Meet) NetCONE Requirement	Yes	No	Yes	Yes	No
	(Meet) ARR Requirement	Yes	No	Yes	No	No

*A similar table was not included for 21CPP in this presentation because that portion of the study included evaluation of multiple technologies in multiple regions

ERCOT – Sample Results for Case B31B

- **Case B31B meets both ARR and NetCONE requirements under low and high VRE scenarios**





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Thank you!

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