HIGH CO_2 CAPTURE RATE COST AND PERFORMANCE FOR F- and H-CLASS NATURAL GAS COMBINED CYCLES (NGCC)

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Attribution

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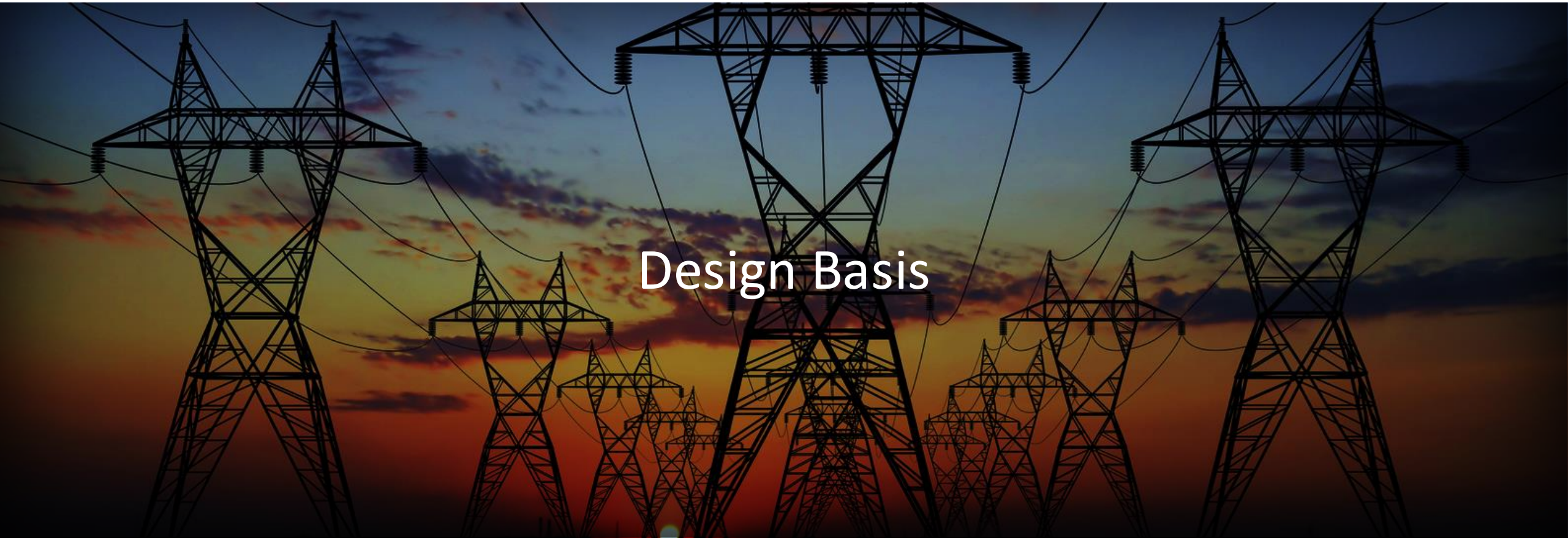
Agenda

- Overview
- Design Basis
- NGCC Performance Results
- NGCC Cost Results
- 97% Capture Rate Analysis
- Sensitivity Analysis
- Future Work

Overview

- This work is an in-progress update to the 2019 report Cost and Performance Baseline for Fossil Energy Plants Volume 1: Bituminous Coal and Natural Gas to Electricity
- The F-class NGCC base plant performance and cost from the 2019 report remains unchanged.
- This update includes:
  - Addition of H-Frame NGCC cases
  - Updated Shell Cansolv performance and cost data
  - Extended capture rates above 90% to include 95% and 97% capture
  - The 97% cases are included in an appendix, requiring further evaluation


Design Basis

Site and Fuel Characteristics[1]

Parameter	Value
Location	Greenfield, Midwestern U.S.
Topography	Level
Size (IGCC and PC), acres	300
Size (NGCC), acres	100
Transportation	Rail or Highway
Slag (IGCC) and Ash (PC) Disposal	Off-Site
Water	50% Municipal and 50% Ground Water

Component		Volume Percentage
Methane	CH_4	93.1
Ethane	C_2H_6	3.2
Propane	C_3H_8	0.7
n-Butane	C_4H_{10}	0.4
Carbon Dioxide	CO_2	1.0
Nitrogen	N_2	1.6
Methanethiol[A]	CH_4S	$5.75x10^{-6}$
	Total	100.0

	LHV	HHV
kJ/kg (Btu/lb)	47,201 (20,293)	52,295 (22,483)
MJ/scm (Btu/scf)	34.52 (927)	38.25 (1,027)

[A]The sulfur content of natural gas is primarily composed of added Mercaptan (methanethiol [CH_4S]) with trace levels of hydrogen sulfide (H_2S) [14]
Note: Fuel composition is normalized, and heating values are calculated using Aspen

Parameter	Value
Elevation, m (ft)	0 (0)
Barometric Pressure, MPa (psia)	0.101 (14.696)
Average Ambient Dry Bulb Temperature, °C (°F)	15 (59)
Average Ambient Wet Bulb Temperature, °C (°F)	10.8 (51.5)
Design Ambient Relative Humidity, %	60
Cooling Water Temperature, °C (°F)[A]	15.6 (60)
Air composition based on published psychrometric data, mass %	
N_2	75.055
O_2	22.998
Ar	1.280
H_2O	0.616
CO_2	0.050
Total	100.00

[A]The cooling water temperature is the cooling tower cooling water exit temperature. This is set to 4.8°C (8.5°F) above ambient wet bulb conditions in ISO cases.

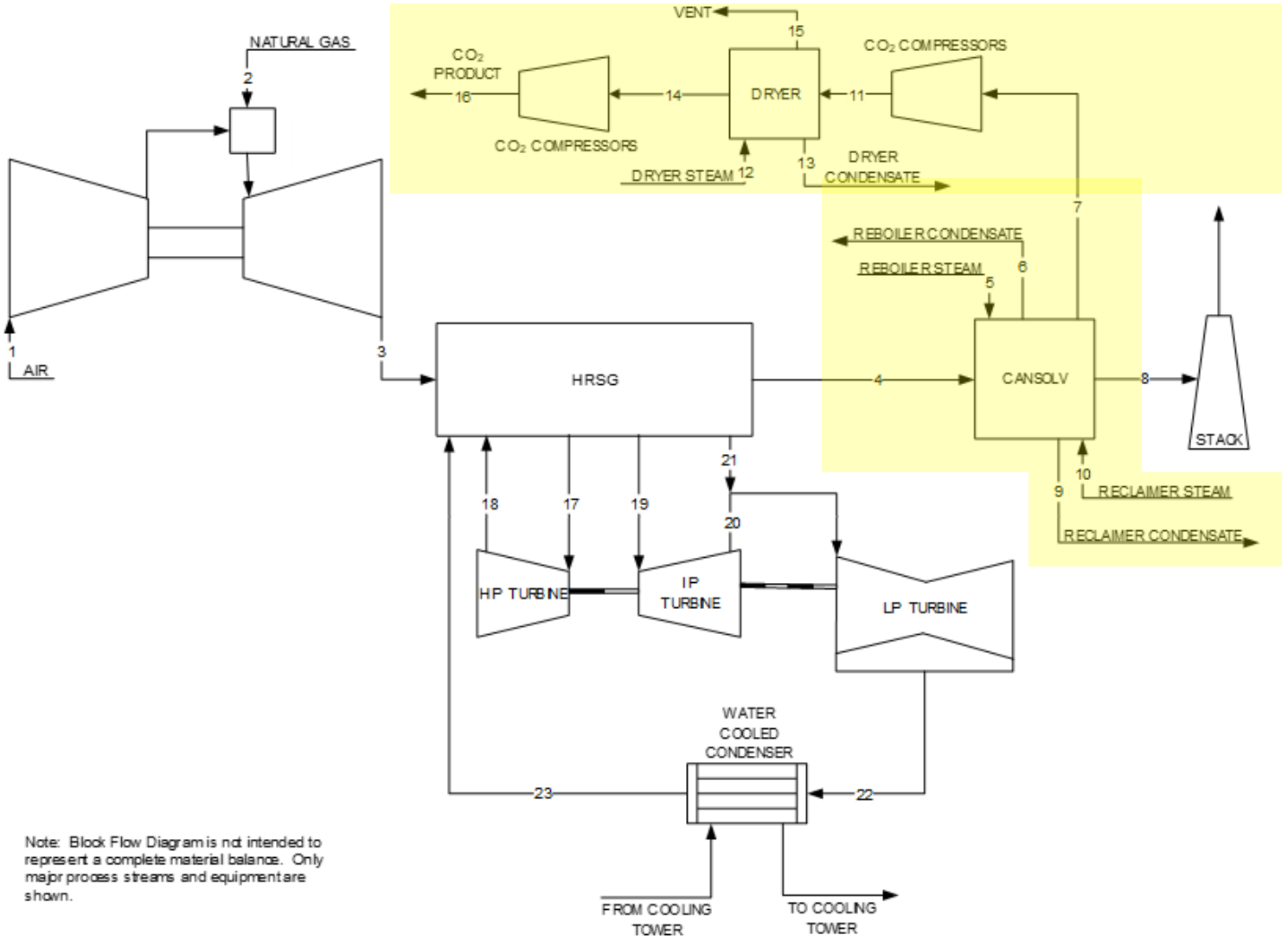
1 - National Energy Technology Laboratory, "Quality Guidelines for Energy System Studies: Specification for Selected Feedstocks," U.S. Department of Energy, Pittsburgh, PA, 2019.

Case Configuration Summary

- While the study includes IGCC and PC plant cases, only NGCC presented here
- Both with and without CO_2 capture

Case	Plant Type	Steam Cycle, psig/°F/°F	Combustion Turbine	Gasifier/Boiler Technology	Sulfur Removal	Particulate Matter Control	CO_2 Separation	Capture Rate	Process Water Treatment
B31A	NGCC	2400/1085/1085	2 x State-of-the-art 2017 F-Class	HRSG	N/A	N/A	N/A	N/A	N/A
B31B.90							Shell Cansolv	90%	
B31B.95								95%	
B32A		2700/1085/1045	2 x State-of-the-art 2017 H-Class				N/A	N/A	
B32B.90							Shell Cansolv	90%	
B32B.95								95%	

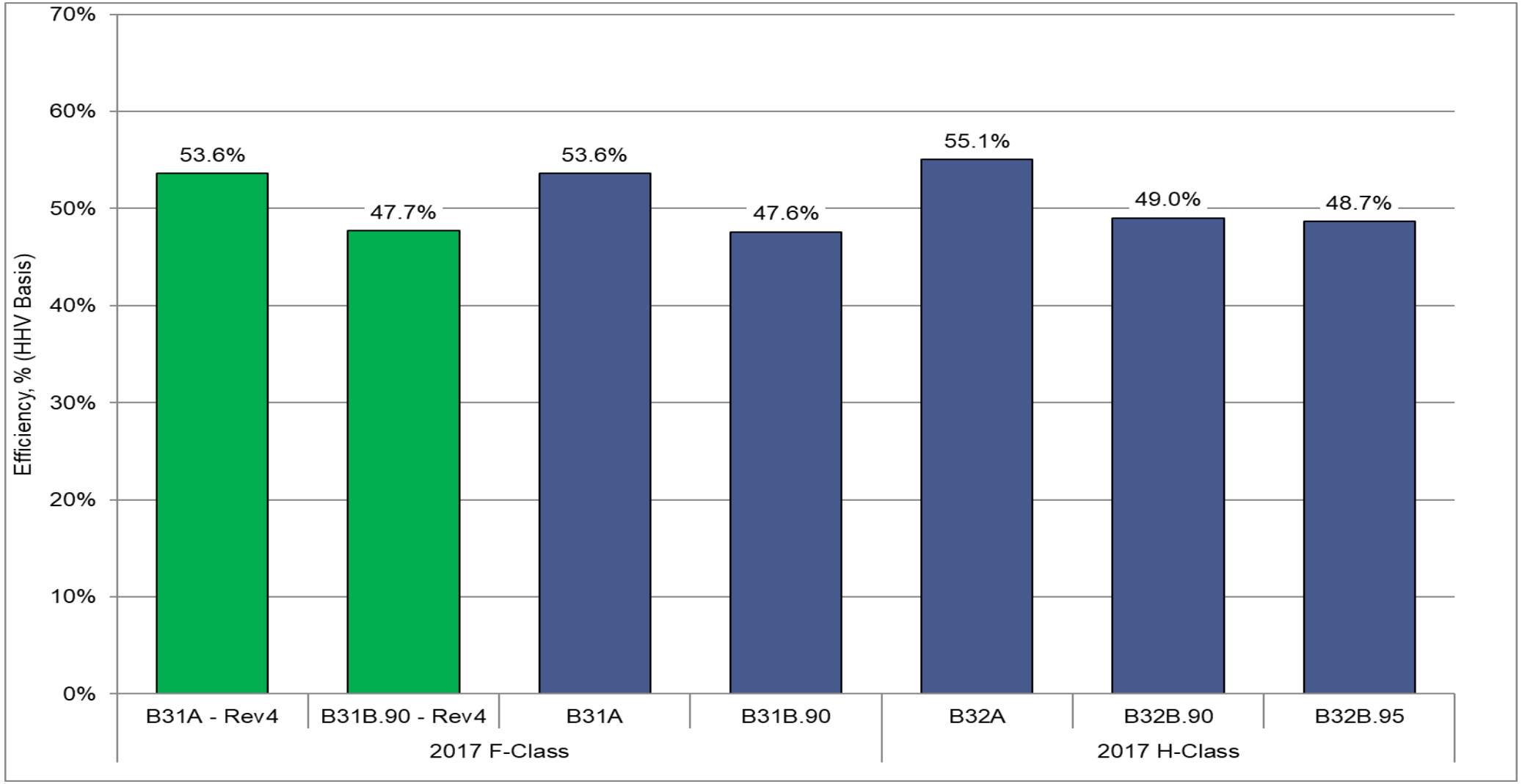
NGCC with CCS Configuration



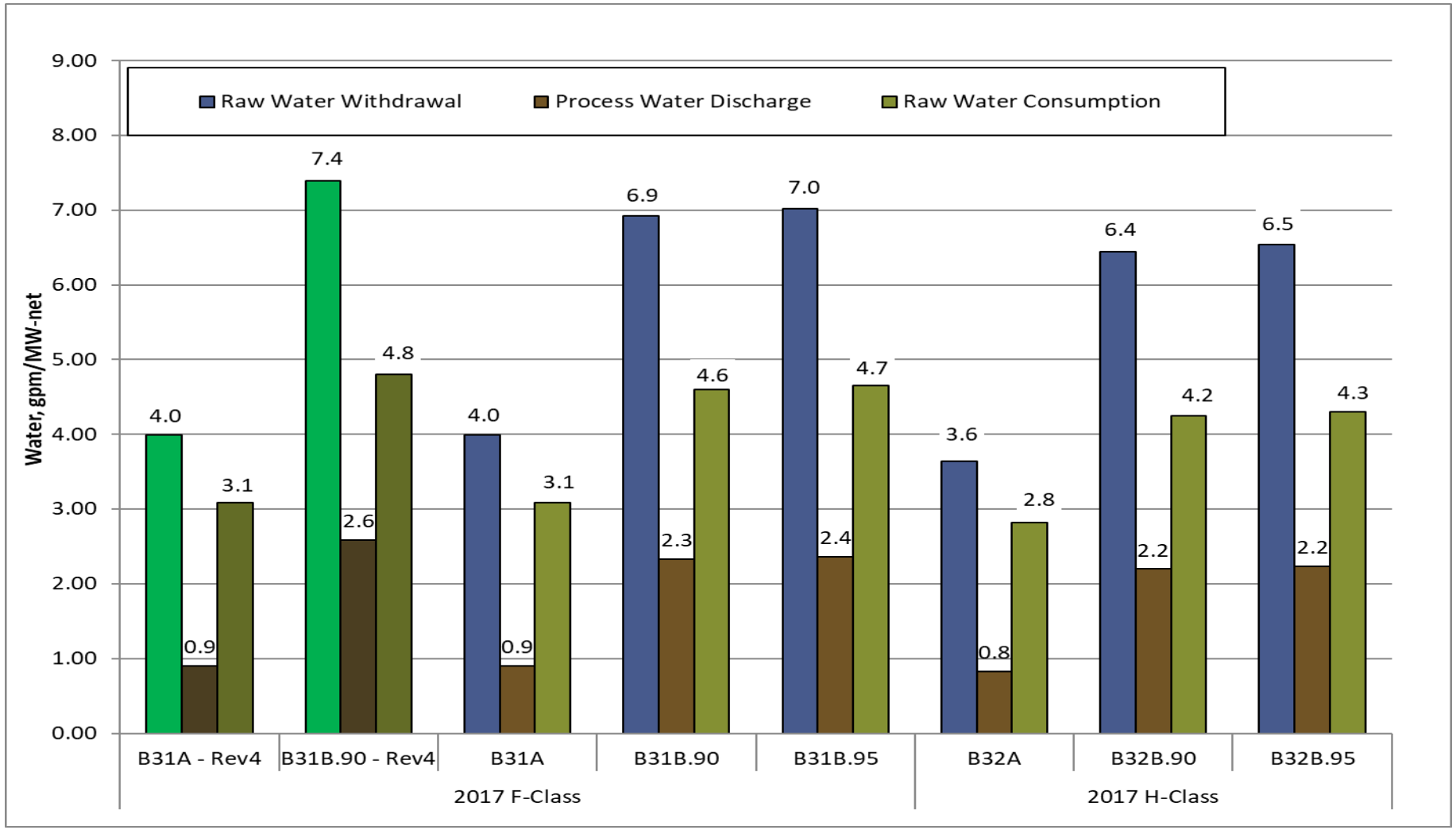
Source: NETL

NGCC Performance Results

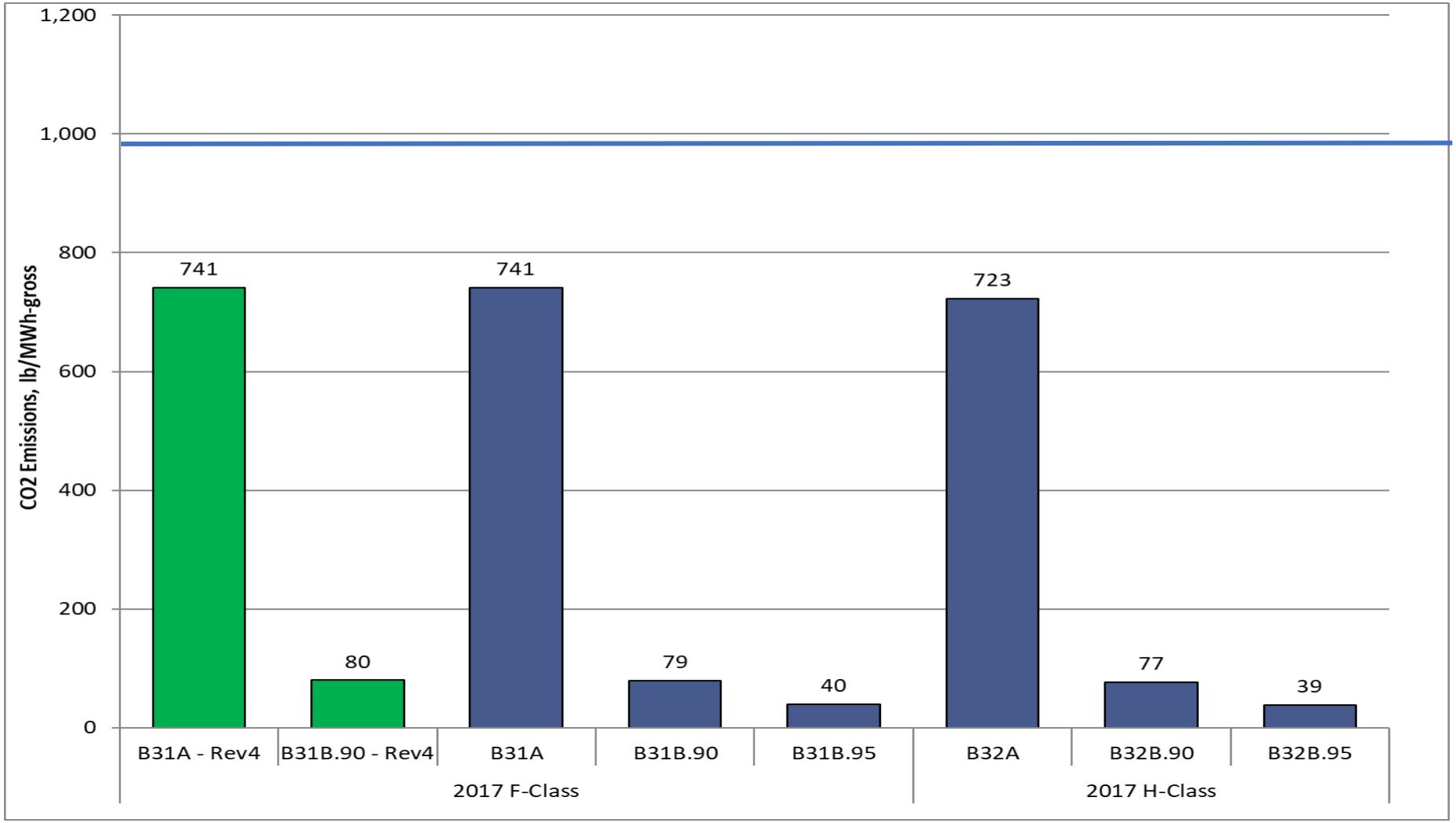
NGCC Net Plant Efficiency



NGCC Raw Water Withdrawal and Consumption



NGCC CO_2 Emissions



NGCC Emission limit: 1000 lb/MWh-gross

[1]Office of the Federal Register, "Proposed Rules Vol. 83 No. 244," 20 December 2018. [Online]. Available: https://www.govinfo.gov/content/pkg/FR-2018-12-20/pdf/2018-27052.pdf. [Accessed 6 June 2019].

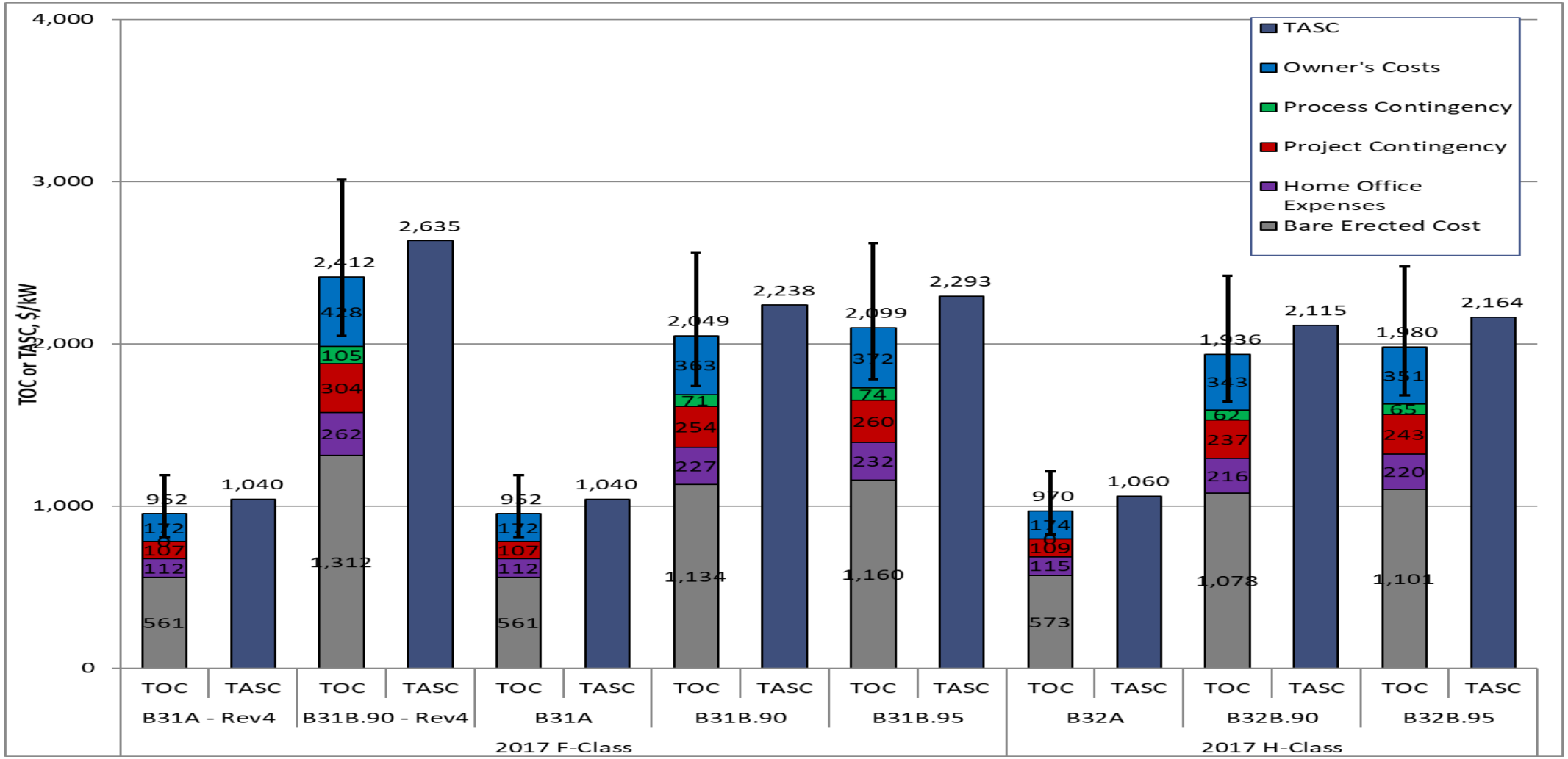
NGCC Cost Results

Special Considerations On Reported Costs

- Capital Cost Estimates
  - NGCC -15/+25, Class 4 AACE Classification
- Costs for Mature Technologies and Designs
  - NGCC plant
- Costs for Emerging Technologies and Designs
  - CO_2 Capture Systems
- Other Factors
  - Site/project Specific
- Future Cost Trends
  - Effect of R&D

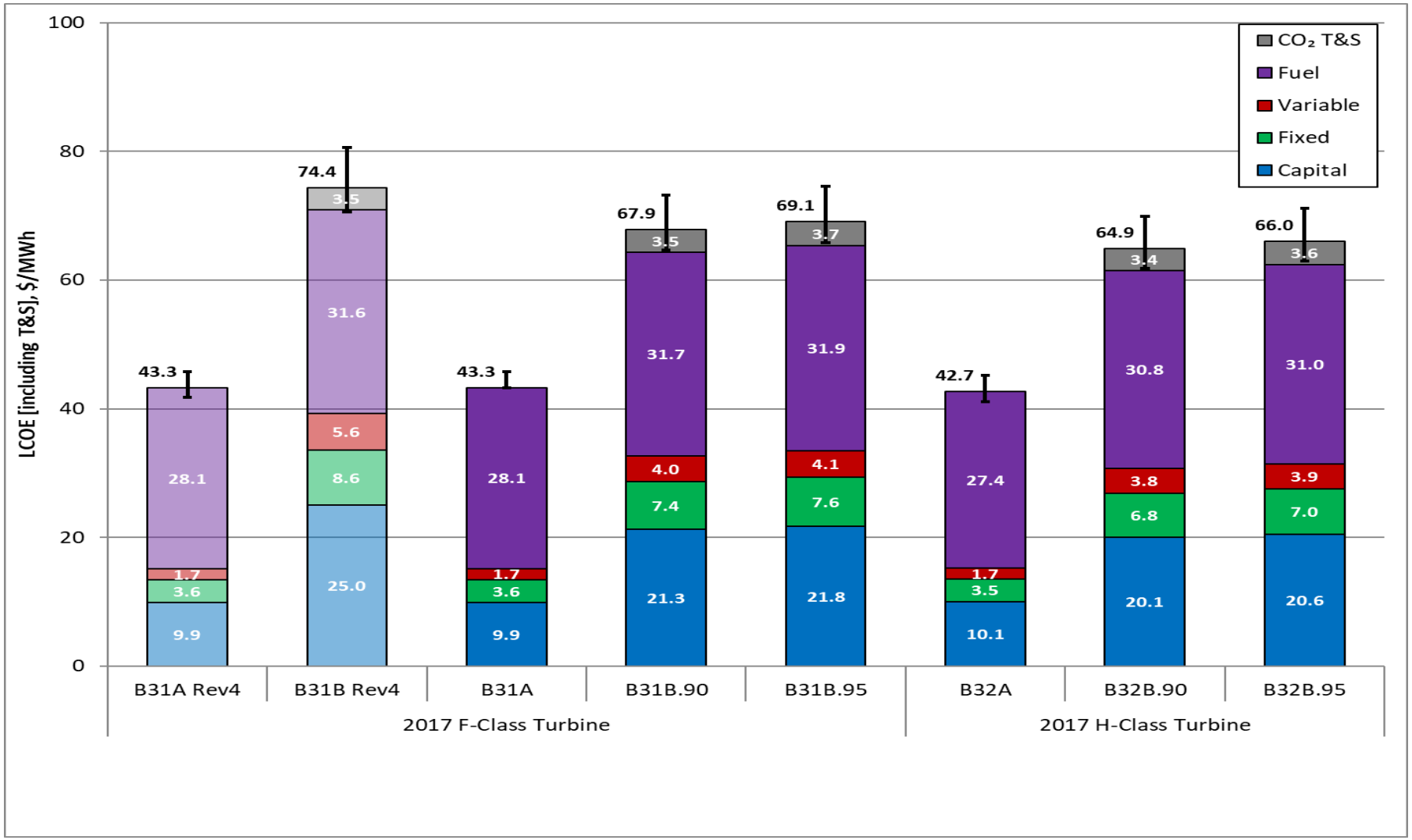
Capital Cost Comparison

Total Overnight Cost (TOC) and Total As-spent Cost (TASC)

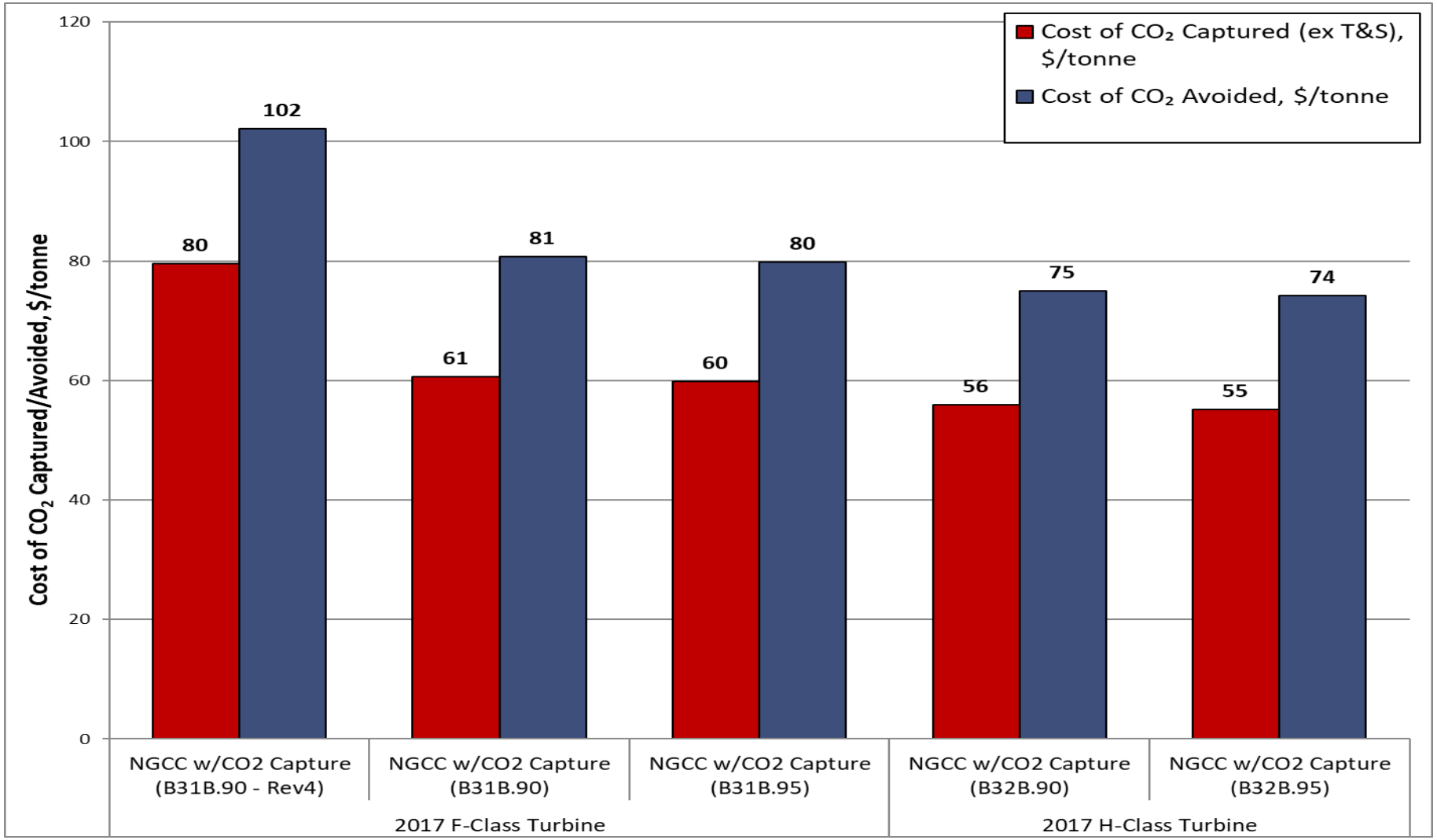


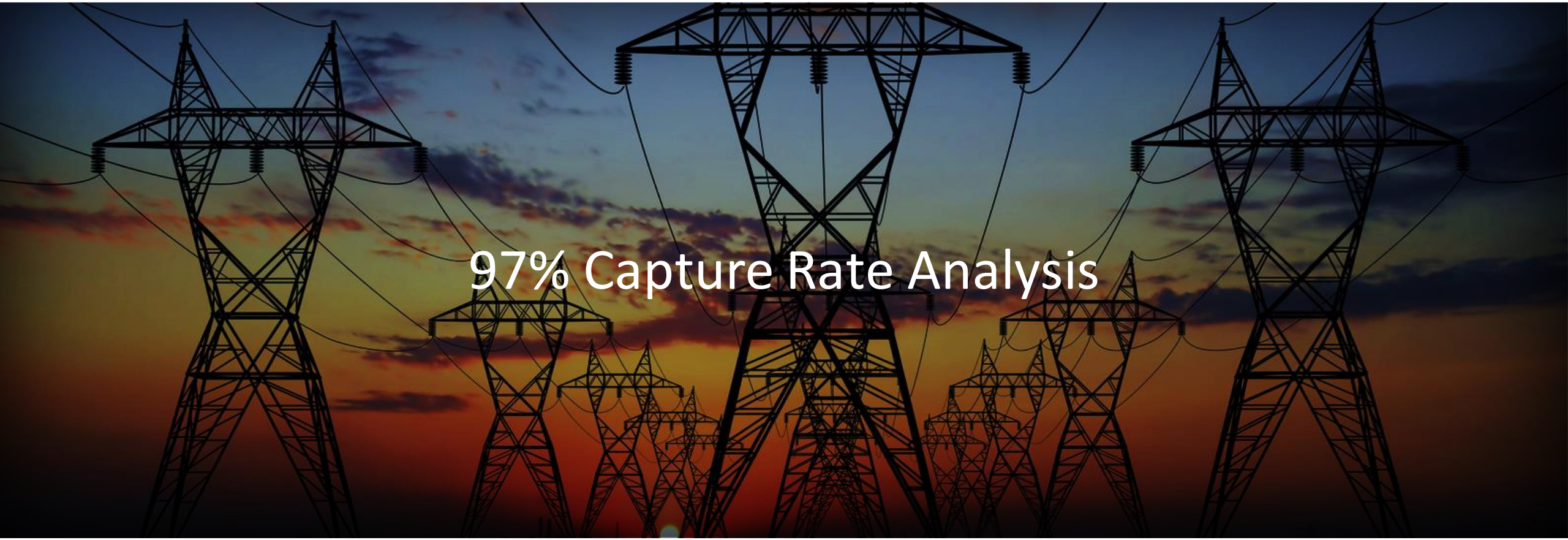
LCOE Breakdown

85% Capacity Factor, $4.42/MMBtu NG Price, 2018$



Cost of CO_2 Captured/Avoided Penalty





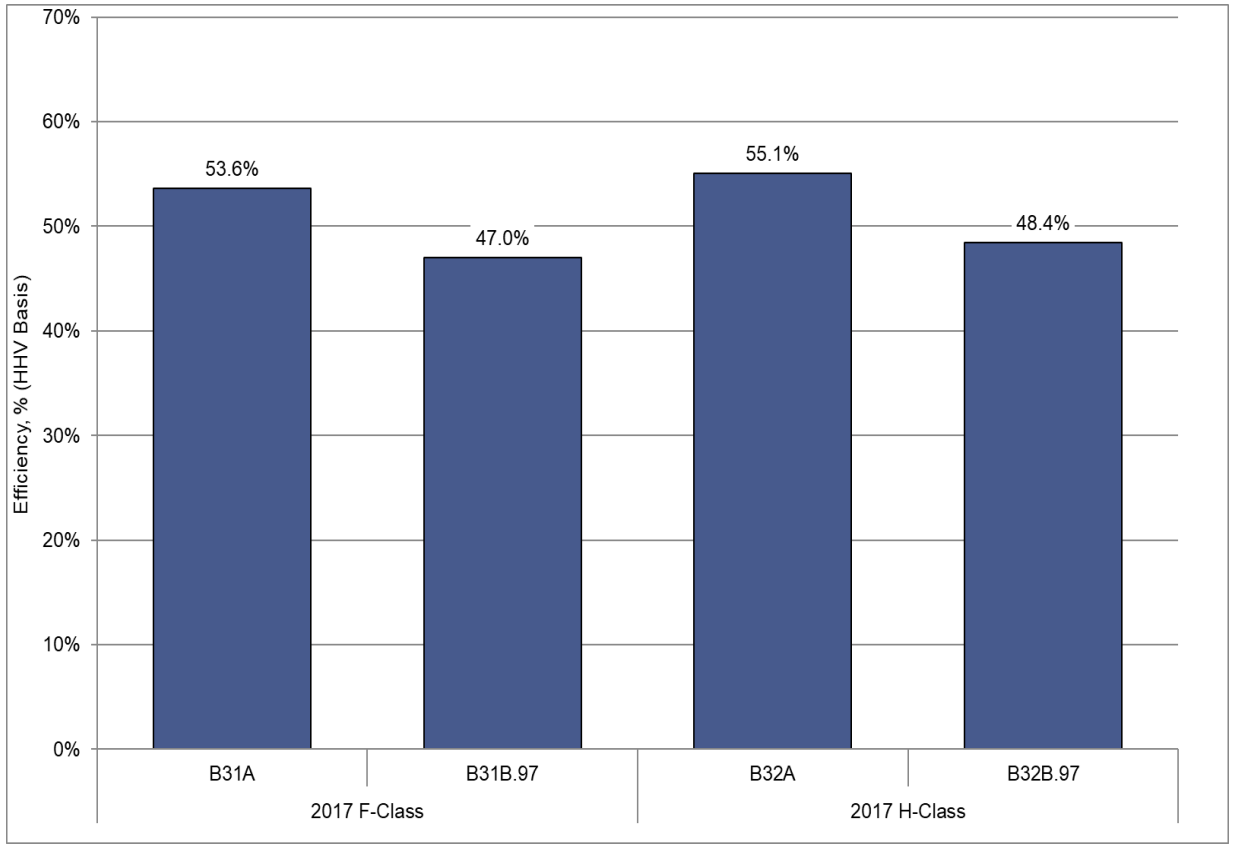
97% Capture Rate Analysis

Distinction Between 95% Capture and Higher Rates

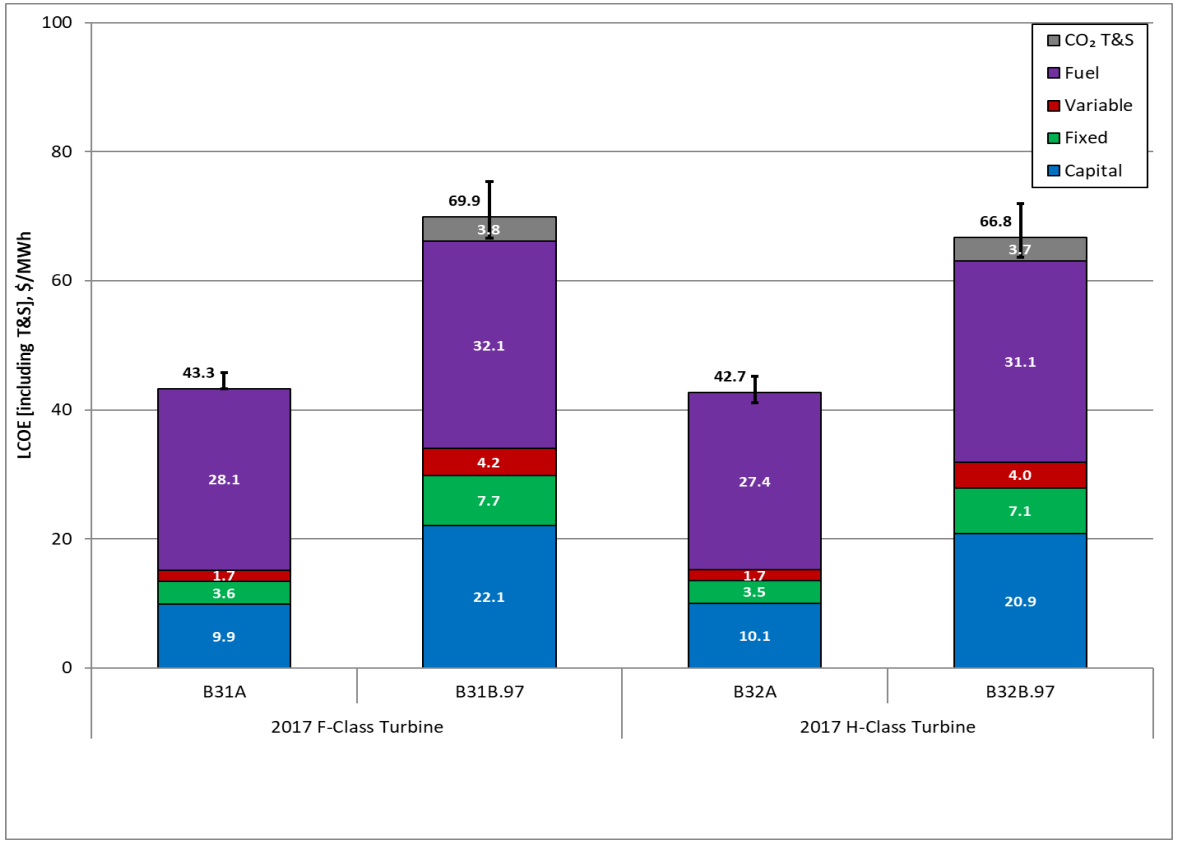
- Commercial-scale demonstration of solvent-based post-combustion CO_2 capture systems at power generation facilities (specifically PC plants) has shown the ability to capture 90% of the CO_2 in the flue gas stream.
- Field-testing of post-combustion CO_2 capture technology as well as vendor and industry feedback on projects currently in the planning stages (including FEED projects sponsored by DOE) indicate that capture rates as high as 95% are feasible for both coal- and natural gas-fueled electricity generating units.
- Technology suppliers (as reflected in vendor-supplied information provided to DOE for this study that included cost and performance estimates for both NGCC (97%) and PC (99%) study cases) as well as subject matter experts acknowledge and support that solvent-based post-combustion CO_2 capture technologies are capable of achieving CO_2 removal rates beyond 95% on low-purity streams representative of fossil-fueled combustion.
- Although technoeconomic analyses of deep decarbonization ($\geq$ 99%) of combustion flue gas have been published by others, the relatively limited experience with design and operation of capture systems that can routinely, reliably, and economically achieve very high removal rates requires further study. Technoeconomic analysis of the higher capture rates (97% NGCC and 99% PC) will be included in the appendices of the subject report.

NGCC with 97% CCS

HHV Efficiency

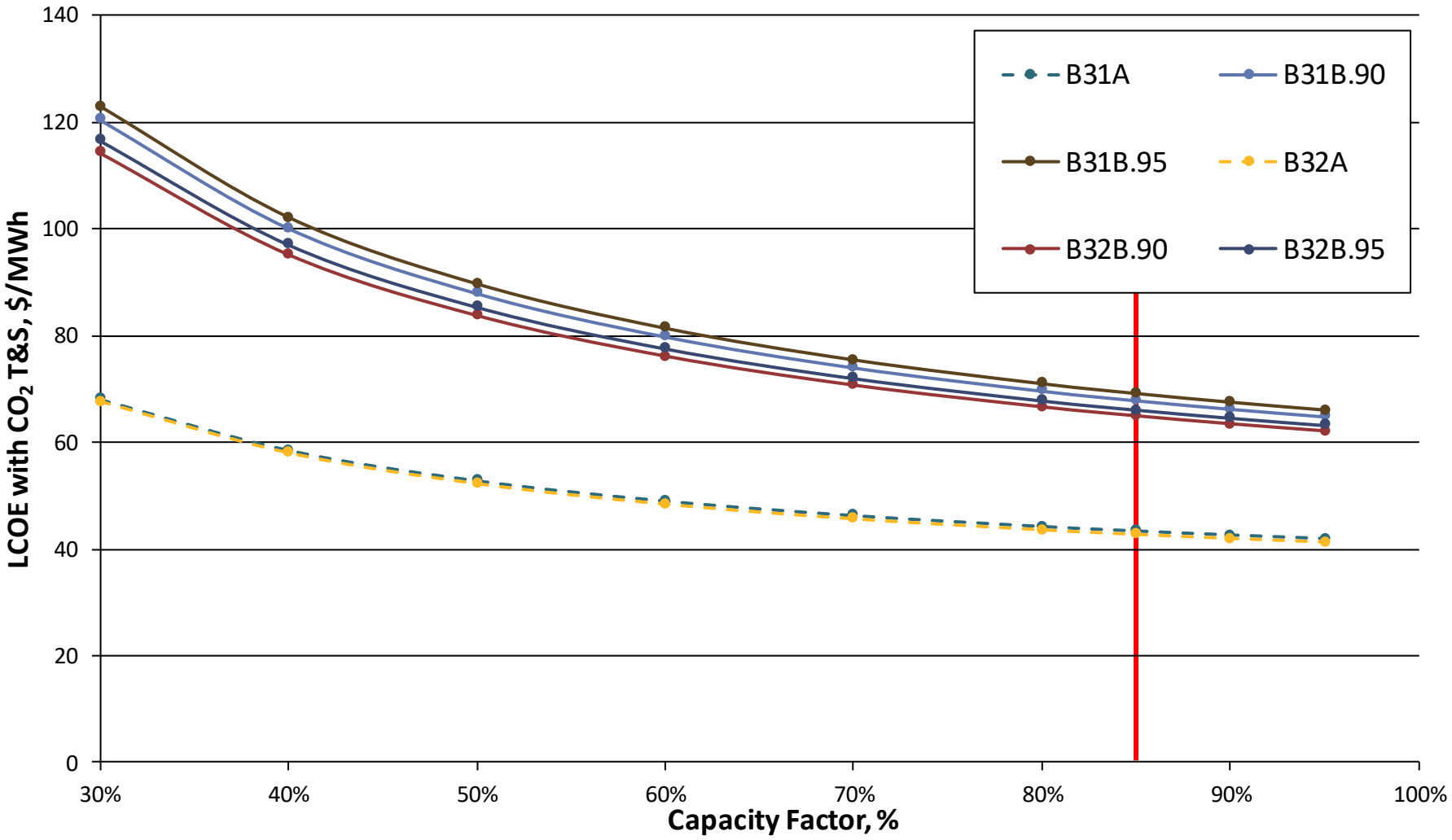


LCOE

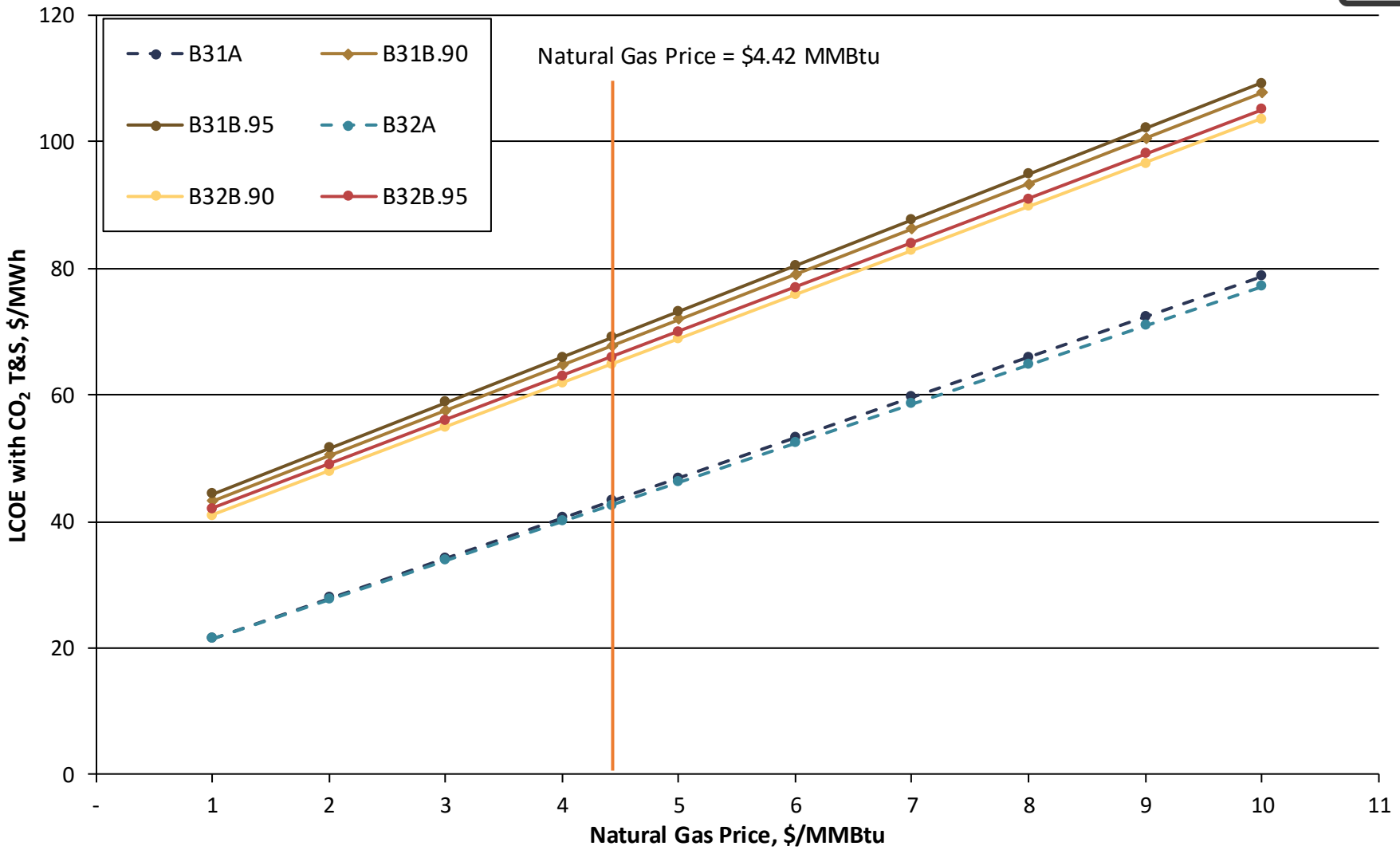



Sensitivity Analysis

Sensitivity to Capacity Factor



Sensitivity to Fuel Cost




Future Work

Future Work

- Cost and Performance Baseline for Fossil Energy Plants Volume 1: Bituminous Coal and Natural Gas to Electricity – Revision 4A
  - To be published late September 2022
- Other related/derivative studies underway:
  - Cost and Performance of Retrofitting NGCC Units for Carbon Capture and associated Carbon Capture Retrofit Database (CCRD) - late 2022
  - Eliminating the Derate of Carbon Capture Retrofits and associated CCRD - late 2022/early 2023
  - Detailed cost sensitivity for NGCC with CCS - 2023
  - Technoeconomic and Life Cycle Analysis of Bio-Energy with Carbon Capture and Storage (BECCS) Baseline – late 2022
    - Update to include capture system performance and cost, and a 100% biomass case
  - Cost of Capturing CO_2 from Industrial Sources - Revision 1 and associated CCRD - September 2022

Questions/ Comments

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