Evaluation of NGCC with Capture for Long Duration Energy Storage (LDES)

Paul Myles,[1,2] John Brewer,[1] Dale Keairns[1,2]

[1]National Energy Technology Laboratory [2]NETL support contractor

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Overview

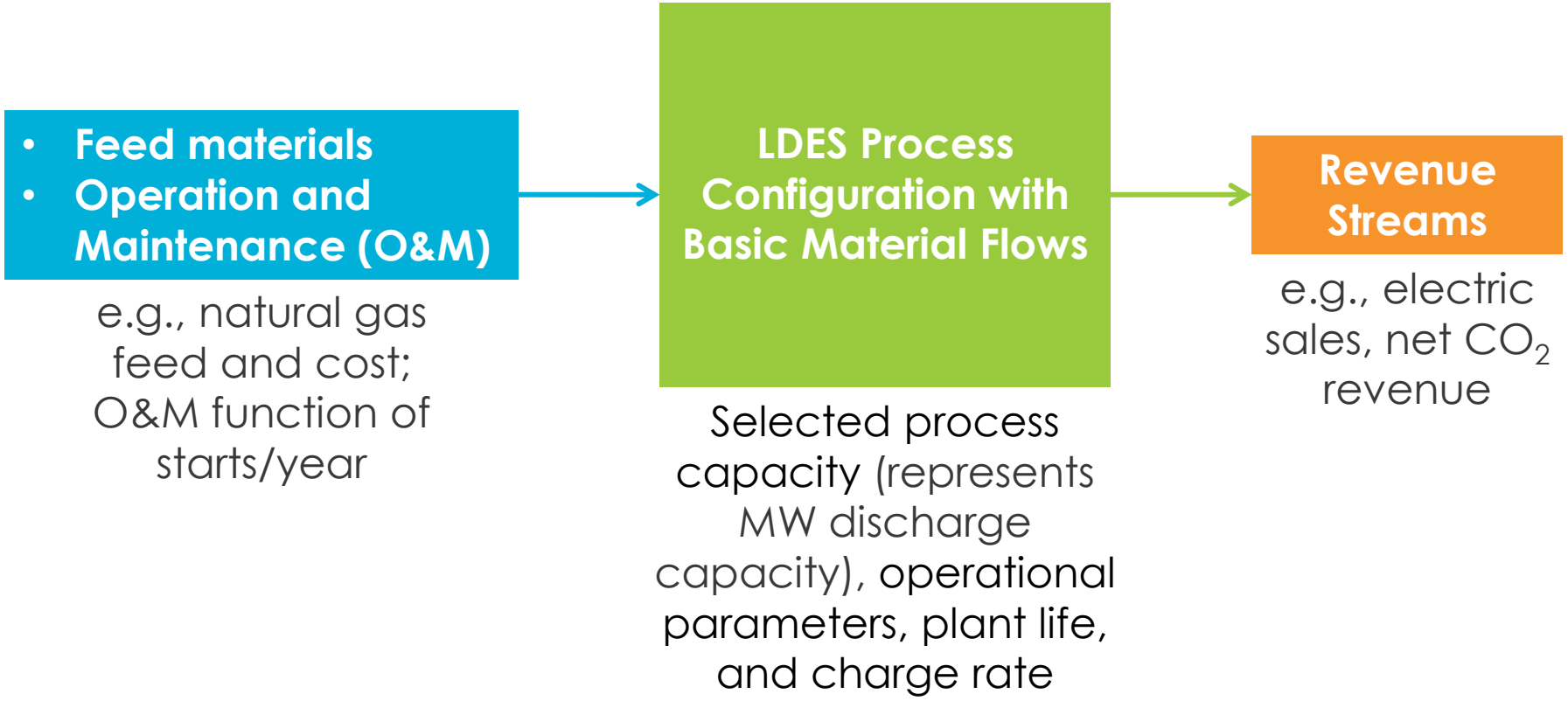
- Question: What are the lowest cost options for long-duration energy storage (LDES) when variable renewable electricity (VRE) provides the greater portion of electricity to the grid?
- It was determined to evaluate the use of two accepted economic analysis methodologies (Annual Revenue Requirement and Cost of New Entry) to identify the electricity price points required for economic success of an LDES concept
- Analysis shows that during operational hours for a natural gas combined cycle (NGCC) acting as an LDES resource at 15% capacity factor (CF)
  - Average power prices would have to be >$230/MWh without CO_2 revenue
  - Average power prices would have to be >$217/MWh with CO_2 revenues @ $40/tonne

Economic Evaluation

- This presentation focuses on the economic evaluation of a new NGCC plant with carbon capture operating at a 15% CF (selected as a reference case example)
- The evaluation used two methods to determine the potential economic viability of the concept evaluated,
  - Annual Revenue Requirement (ARR) – determines the amount of revenue the plant must earn to break even
  - Cost of New Entry (CONE) –the basis for the calculation of NetCONE, which provides an estimation of any additional capacity revenue a new generator would need to enter the market beyond ARR

Approach

Project Revenue Requirements to Meet Capital and Operating Costs



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

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

TOC = total overnight cost; r = effective charge rate (%); T = expect plant life (y); K = plant capacity (MW); *cf* = capacity factor; *f* = fuel price ($/MMBtu); *hr* = heat rate (MMBtu/MWh); *vom* = non-fuel variable O&M cost ($/MWh)

- Value of ARRs and the predicted revenue in $/yr were plotted for the reference CF (15%)
- If the predicted revenue is greater than the ARR at that CF, then the conceptual design would be able to cover its capital costs under those conditions
- ARR equation was modified to include costs/revenues associated with CO_2 capture for LDES screening

Data source: Penn State University, EBF 483, Introduction to Electricity Markets

NetCONE Requirements

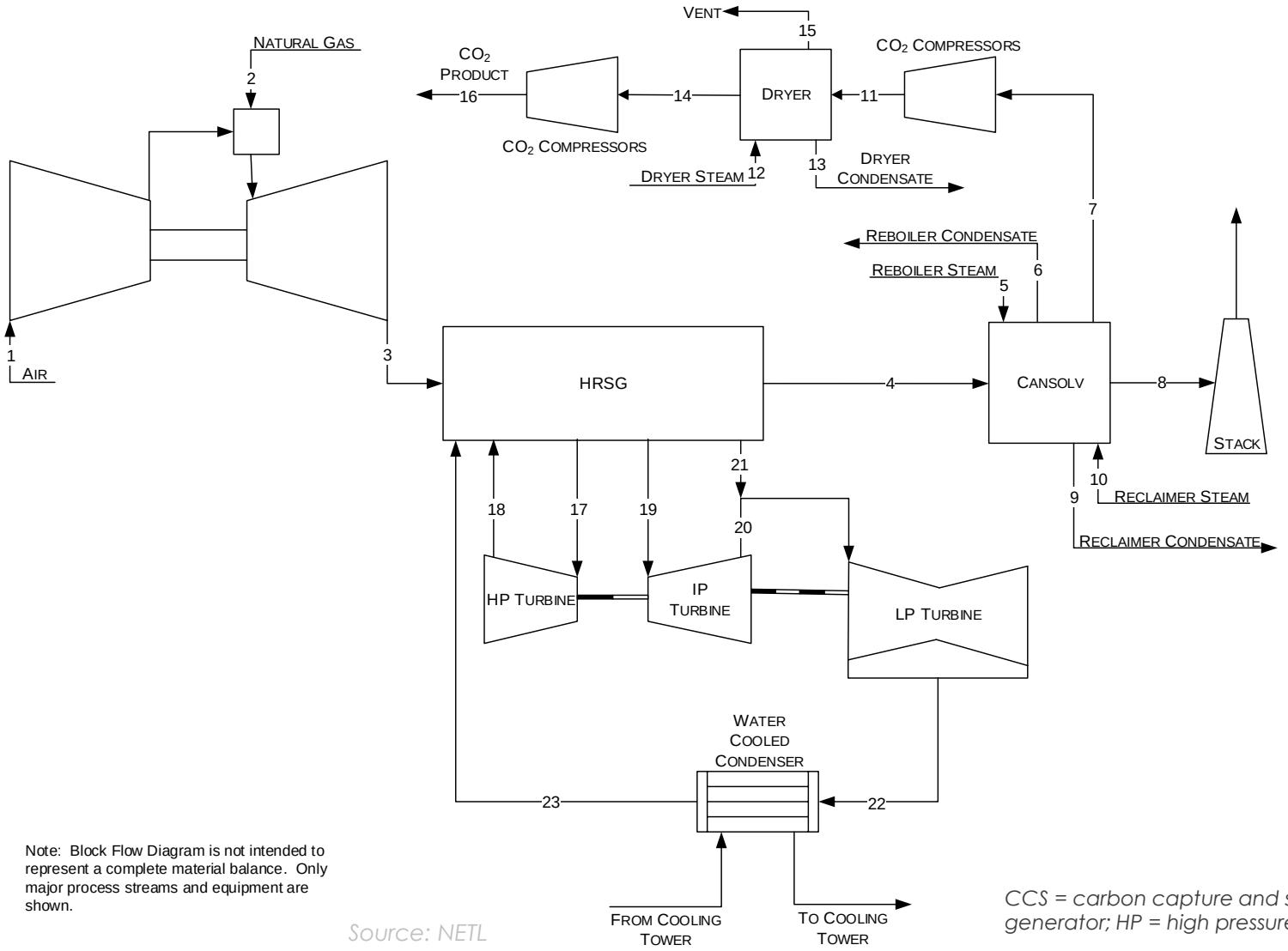
- The CONE is the levelized investment and fixed costs of a new generator and represents the total annual net revenue that a new generator would need to recover its capital investment and fixed costs

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

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 receive to be willing to enter the market
- This additional revenue usually comes from a capacity payment depending on the market structure

NGCC, 90% CCS, 15% CF



Note: Block Flow Diagram is not intended to represent a complete material balance. Only major process streams and equipment are shown.

Source: NETL

CCS = carbon capture and storage; HRSG = heat recovery steam generator; HP = high pressure; IP = intermediate pressure; LP = low pressure

NGCC System ARR Analysis

- NGCC with carbon capture cost and performance from NETL Bituminous Baseline Report Case B31B[1]
- System includes
  - 690 MW gross, 646 MW net output
  - Heat rate of 7,159 Btu/kWh
  - 90% carbon capture system
- Total overnight cost of $1,557,531,000
- Modified variable O&M (VOM) of $2.15/MWh
- Plant life of 40 years
- Effective charge rate of 7%

[1] *Cost and Performance Baseline for Fossil Energy Plants Volume 1: Bituminous Coal and Natural Gas to Electricity, September 24, 2019*
https://www.netl.doe.gov/projects/files/CostAndPerformanceBaselineForFossilEnergyPlantsVol1BitumCoalAndNGtoElectBBRRev4-1_092419.pdf

NGCC Operational Model

- Plant will provide on-demand 646 MW to the grid
- Plant will operate at an overall CF of 15% (1,314 hrs/yr, i.e., ~2 months continuous or 55 separate days)
- The plant will not operate 85% of the time

ARR Methodology

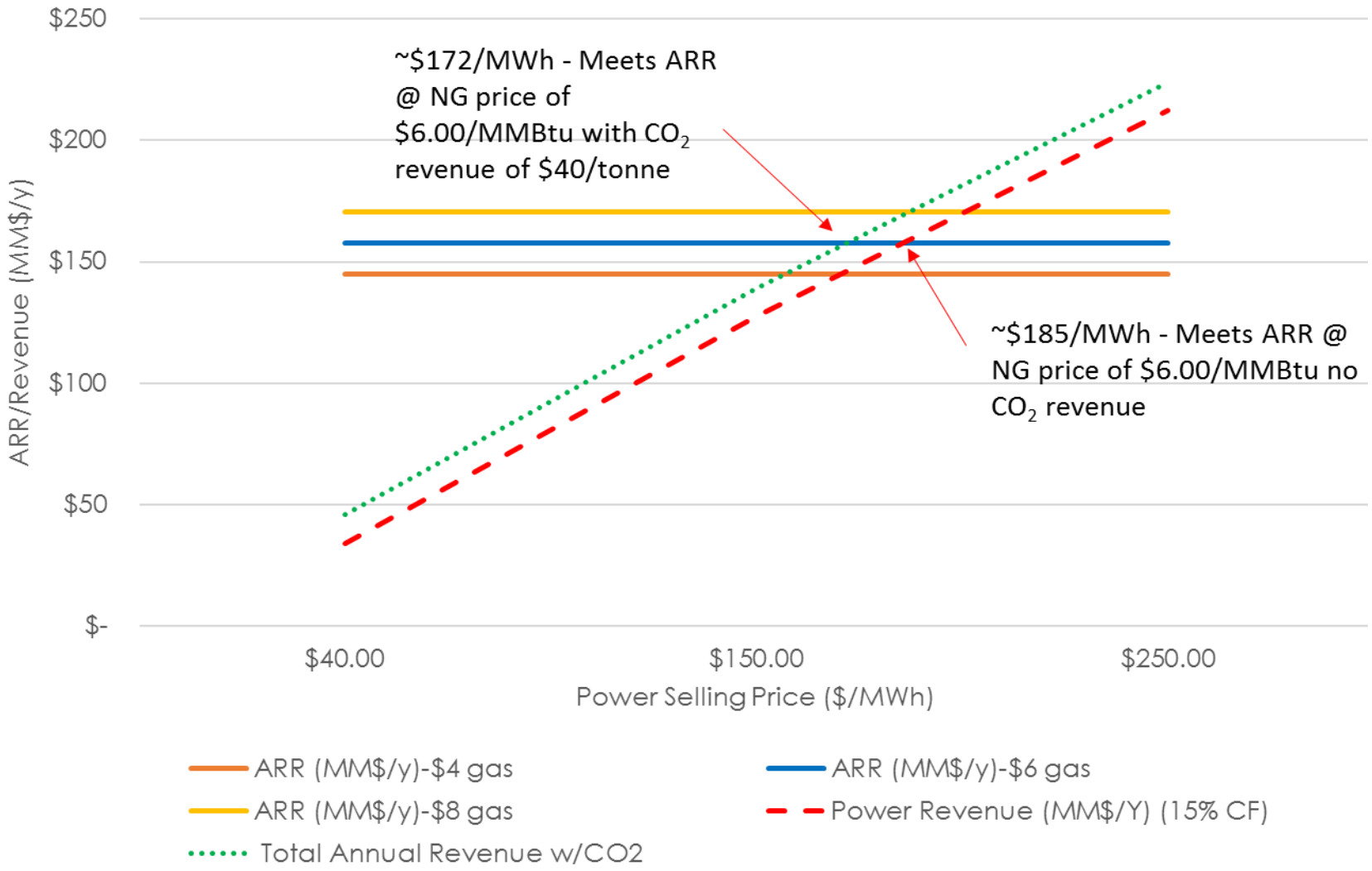
- ARR for the plant costs was spread over entire operational period at 90% availability (7,884 hrs/yr)
- Plant cost ARR was calculated on a $/yr basis
- NGCC VOM was based on the B31B reported values modified to match Cost Accounting Standards Board (CASB) standards
- Cost removed from the VOM as per CASB were added to the fixed costs
- NGCC marginal cost ARR was spread over 1,314 hrs/yr (15% CF) and was calculated on a $/yr basis
- The total ARR on a $/yr basis was calculated by adding the plant cost and marginal costs on a $/yr basis

Revenue Calculations

- Power revenues are calculated on a $/yr basis
- NGCC revenues are based on electricity to the grid 15% of the time (1,314 hrs/yr) and the price of electricity (assumed $40–250/MWh)
- CO_2 revenues calculated at a CO_2 capture rate of 90% and at an assumed CO_2 price of $40/tonne (Note that the CO_2 revenue is going to the plant operator)
- Total annual facility revenue is calculated by summing the results of electricity and CO_2 revenues
- Sensitivities to CO_2 revenues and fuel price were examined

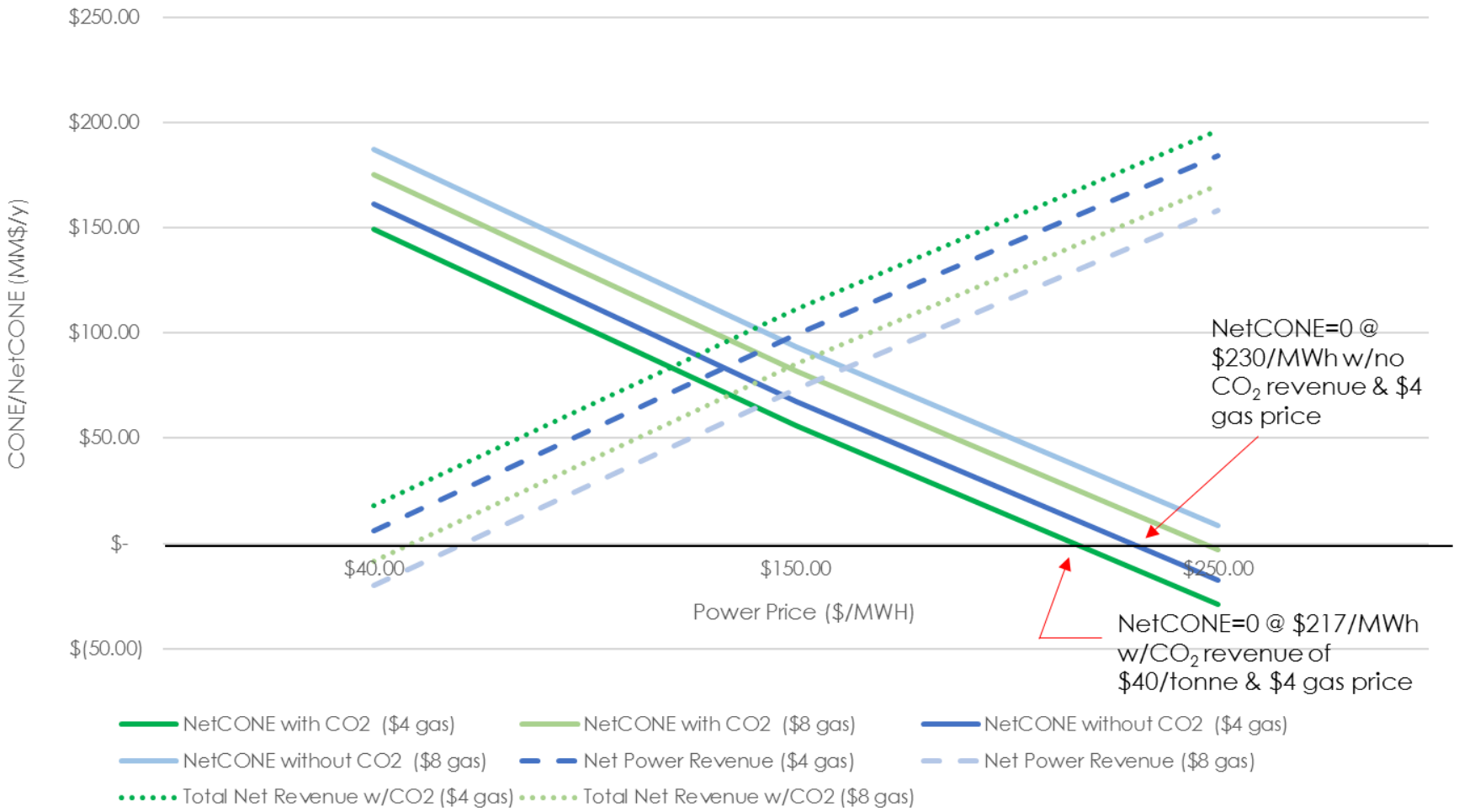
646 MW_{net} NGCC ARR Analysis (15% CF)

- System ARR impacted by natural gas price
- Revenue w/CO_2 includes $40/tonne for captured CO_2
- System does not meet ARR requirements at gas prices above $6/MMBtu and average power prices below $172/MWh
- System does not meet ARR requirements at any gas price above $4 at average power prices below ~$156/MWh with $40/tonne CO_2 revenue



646 MW_{net} NGCC NetCONE Analysis (15% CF)

- Positive NetCONE values represents required capacity payments
- Revenue w/CO_2 includes $40/tonne for captured CO_2
- System does not meet NetCONE requirements below average power prices of $217/MWh with and $230/MWh without CO_2 revenue @ $40/tonne with $4 gas price
- System does not meet NetCONE requirements below average $250/MWh



Findings (Assuming Energy-Only Market)

- A 646 MW_{net} NGCC unit operating at a 15% CF can meet the ARR requirements with $6.00/MMBtu gas with a power selling price > $172/MWh with CO_2 revenue of $40/tonne or when the power selling price is >$185/MWh with no CO_2 revenue
- The NGCC plant would require a power selling price of >$156/MWh to meet ARR requirements with gas a gas price of $4.00/MMBtu
- The plant would require a power selling price > $217/MWh with CO_2 revenue of $40/tonne or when the power selling price is >$230/MWh with no CO_2 revenue to meet NetCONE requirements
- Overall, the plant would require a power selling price greater than $217–230/MWh (depending on potential CO_2 revenue) to meet both criteria and be viable at 15% CF
- As CF increases, the required selling price decreases

Note: These findings only apply to this specific case and assumptions. Important parameters such as plant size, CFs, plant operations, O&M cost, and electricity markets regulations, etc., greatly impact the results

Findings

		With $40/tonne CO_2 revenue	Without $40/tonne CO_2 revenue
Independent System Operator (ISO)		**Number of Hours >$217/MWh**	**Number of Hours >$230/MWh**
ISO New England (ISO-NE)	Nominal	0	0
	Real (2020)	0	0
New York ISO (NYISO)	Nominal	0	0
	Real (2020)	0	0
PJM Interconnection (PJM)	Nominal	0	0
	Real (2020)	0	0
Midcontinent ISO (MISO)	Nominal	0	0
	Real (2020)	0	0
Electric Reliability Council of Texas (ERCOT)	Nominal	76	75
	Real (2020)	61	57
Southwest Power Pool (SPP)	Nominal	0	0
	Real (2020)	0	0
California ISO (CAISO)	Nominal	0	0
	Real (2020)	0	0

Using NGCC at 15% CF for LDES is not attractive using IHS's most recent well-accepted power 2035 forecast

Average Power Price Necessary to Make NetCONE Revenue Requirement at Projected Hours			
ISO		**Power Price >$217/MWh**	**Power Price >$230/MWh**
ERCOT	Nominal	$3,403/MWh	$3,448/MWh
	Real (2020)	$4,239/MWh	$4,537/MWh

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Questions/ Comments

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CONTACT:
Name: Rigel Woodside
Rigel.Woodside@netl.doe.gov