Incentivizing Carbon Capture Retrofits of the Existing PC and NGCC Fleet

Kristin Gerdes

Office of Program Performance and Benefits

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Acknowledgments
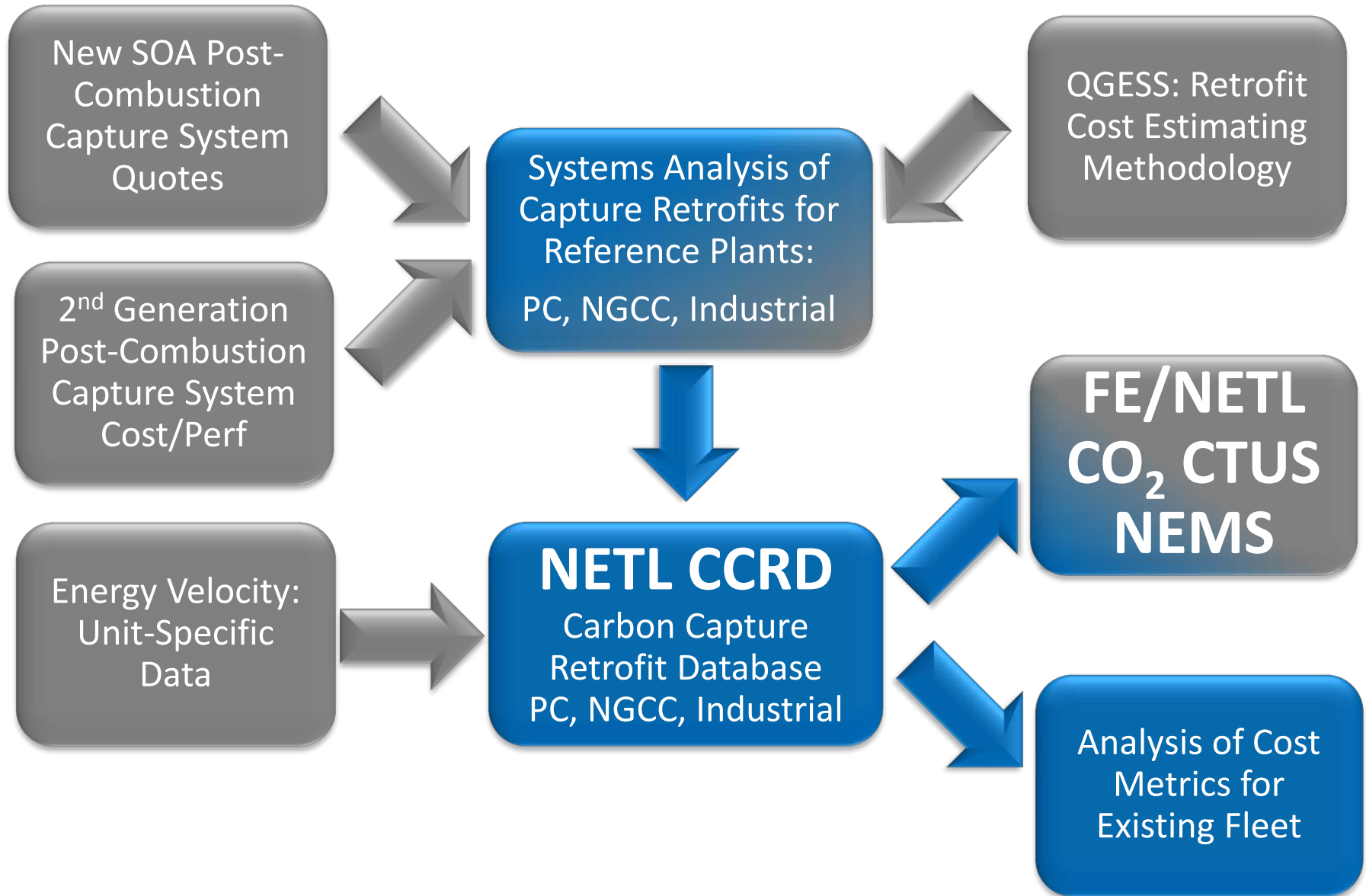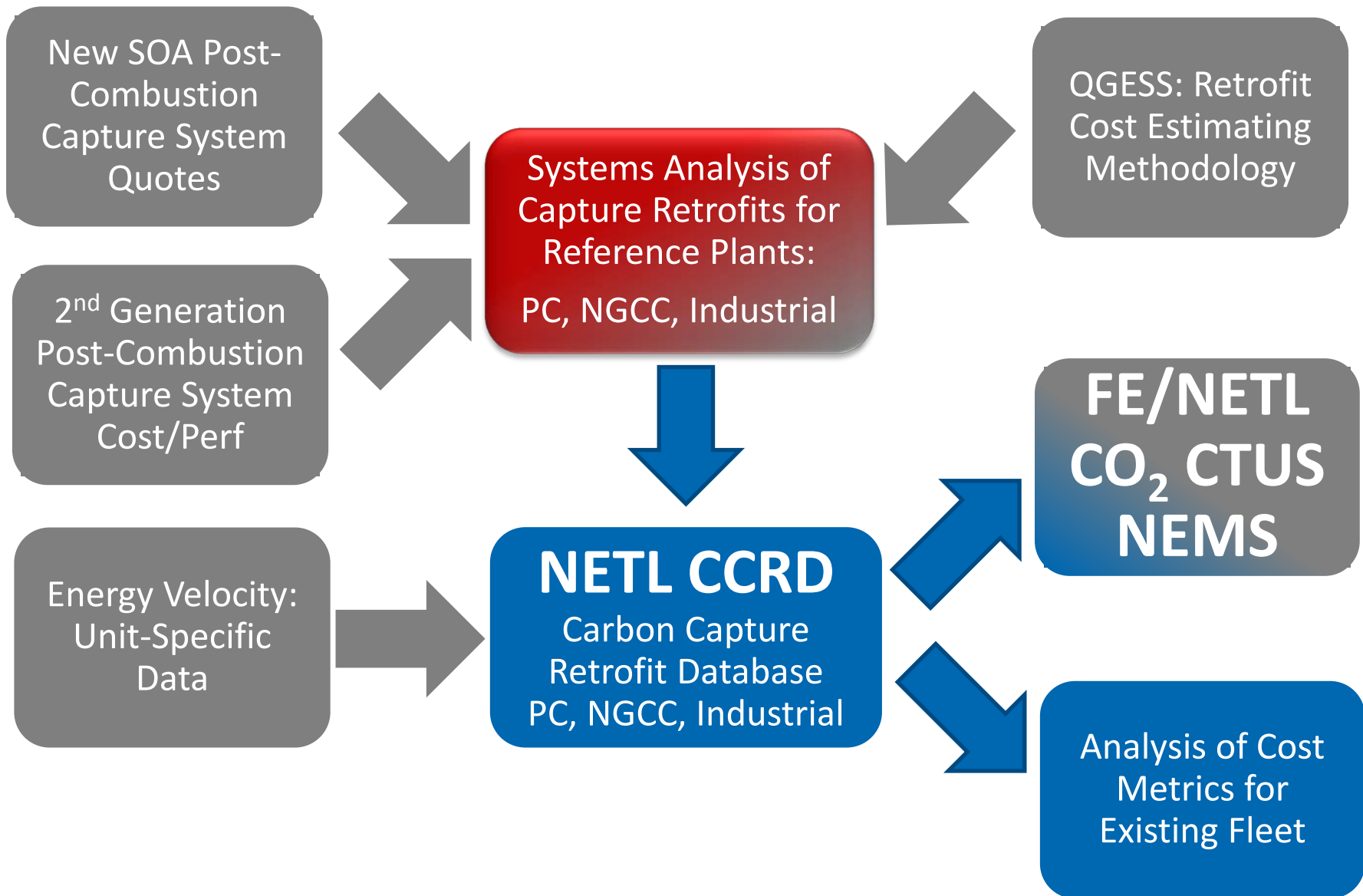
- **NETL**
  - John Wimer
  - Michael Matuszewski
  - Robert Stevens
- **Booz Allen**
  - Vincent Chou
  - Norma Kuehn
  - Mark Woods

NETL Carbon Capture Retrofit Analyses

New SOA Post-Combustion Capture System Quotes

2nd Generation Post-Combustion Capture System Cost/Perf

Energy Velocity: Unit-Specific Data

Systems Analysis of Capture Retrofits for Reference Plants:

PC, NGCC, Industrial

QGESS: Retrofit Cost Estimating Methodology

NETL CCRD
Carbon Capture Retrofit Database
PC, NGCC, Industrial

FE/NETL CO$_2$ CTUS NEMS

Analysis of Cost Metrics for Existing Fleet

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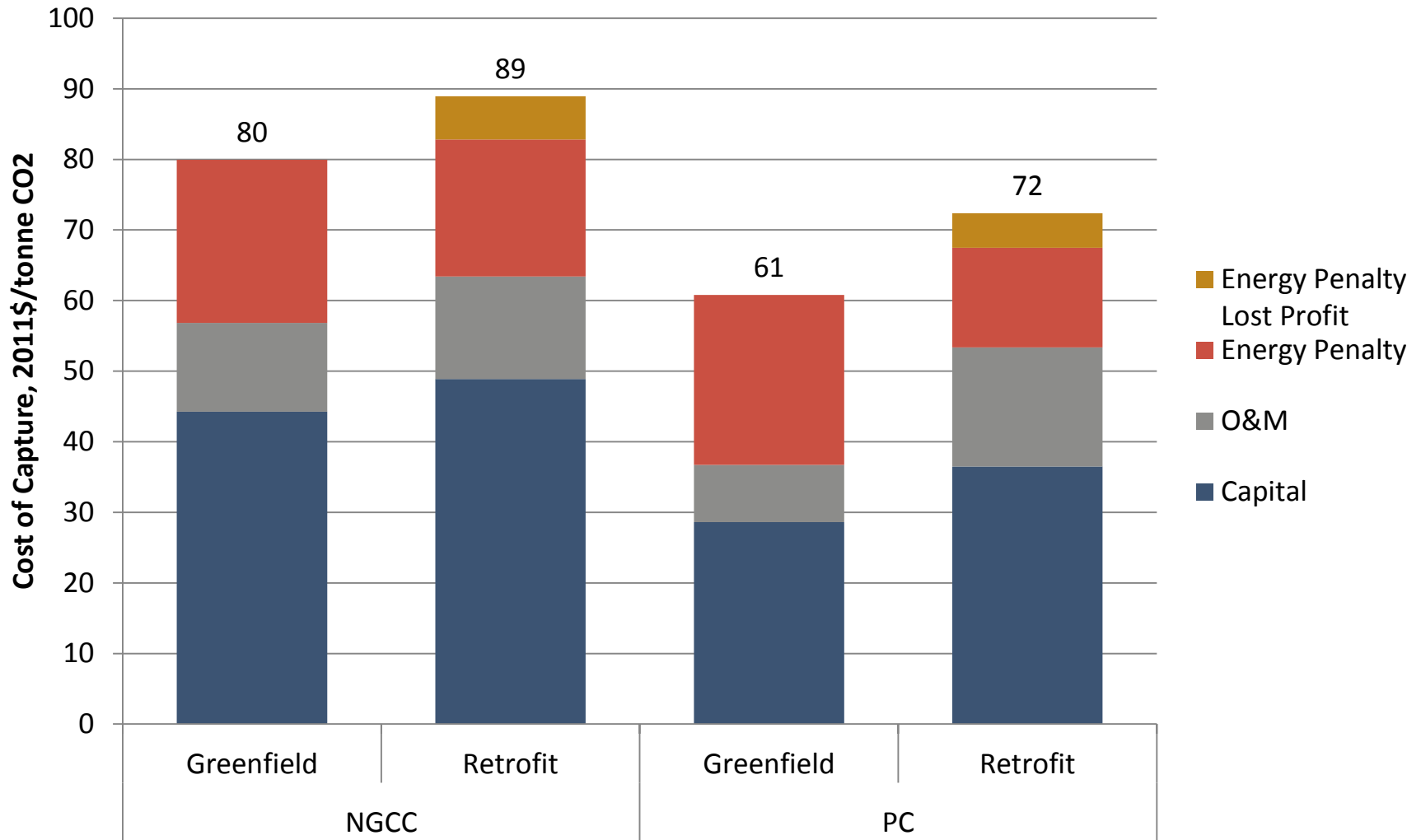
Reference Capture Plants: *Cost of Electricity*

DRAFT Results
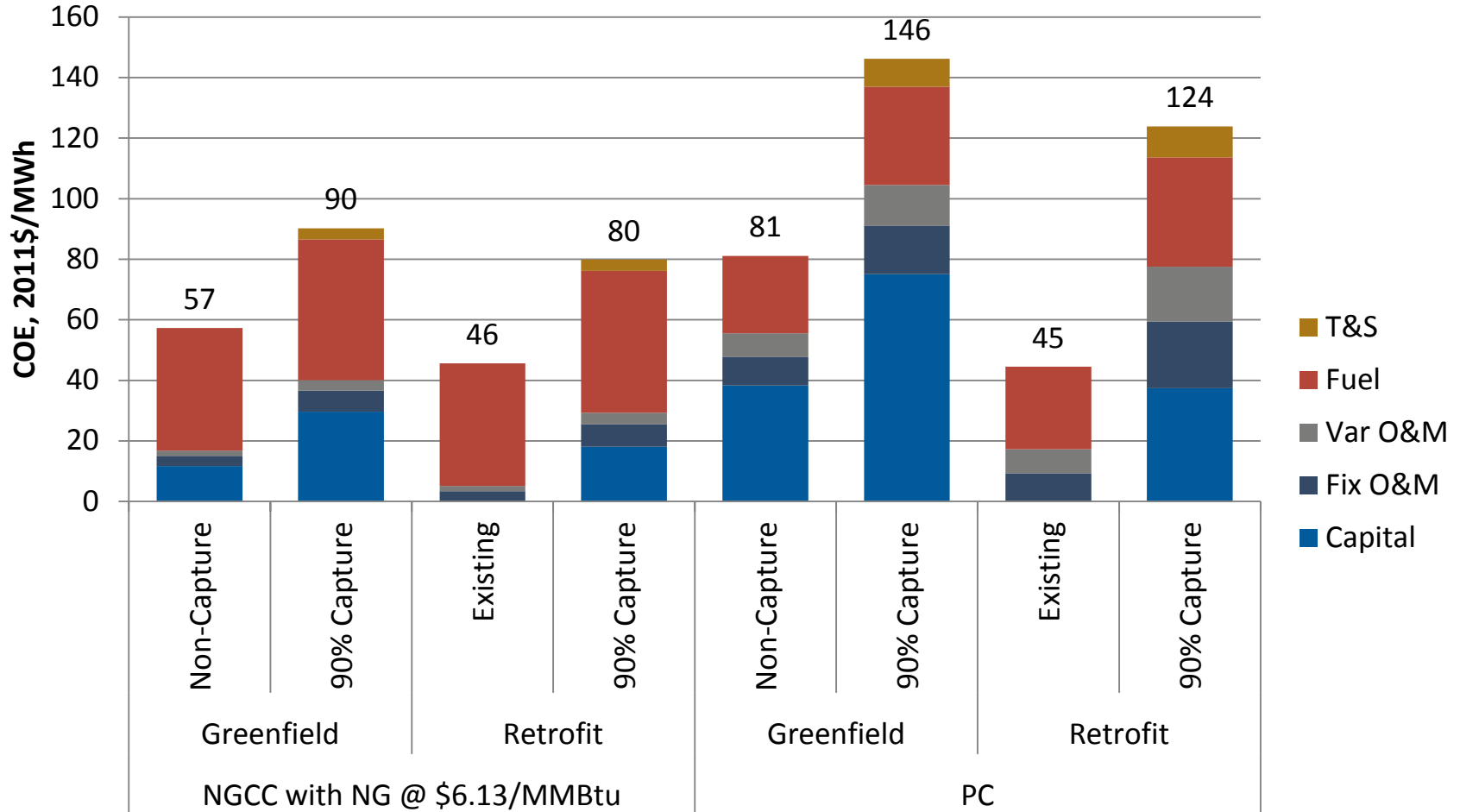
Cost of Capture for CCS Retrofits

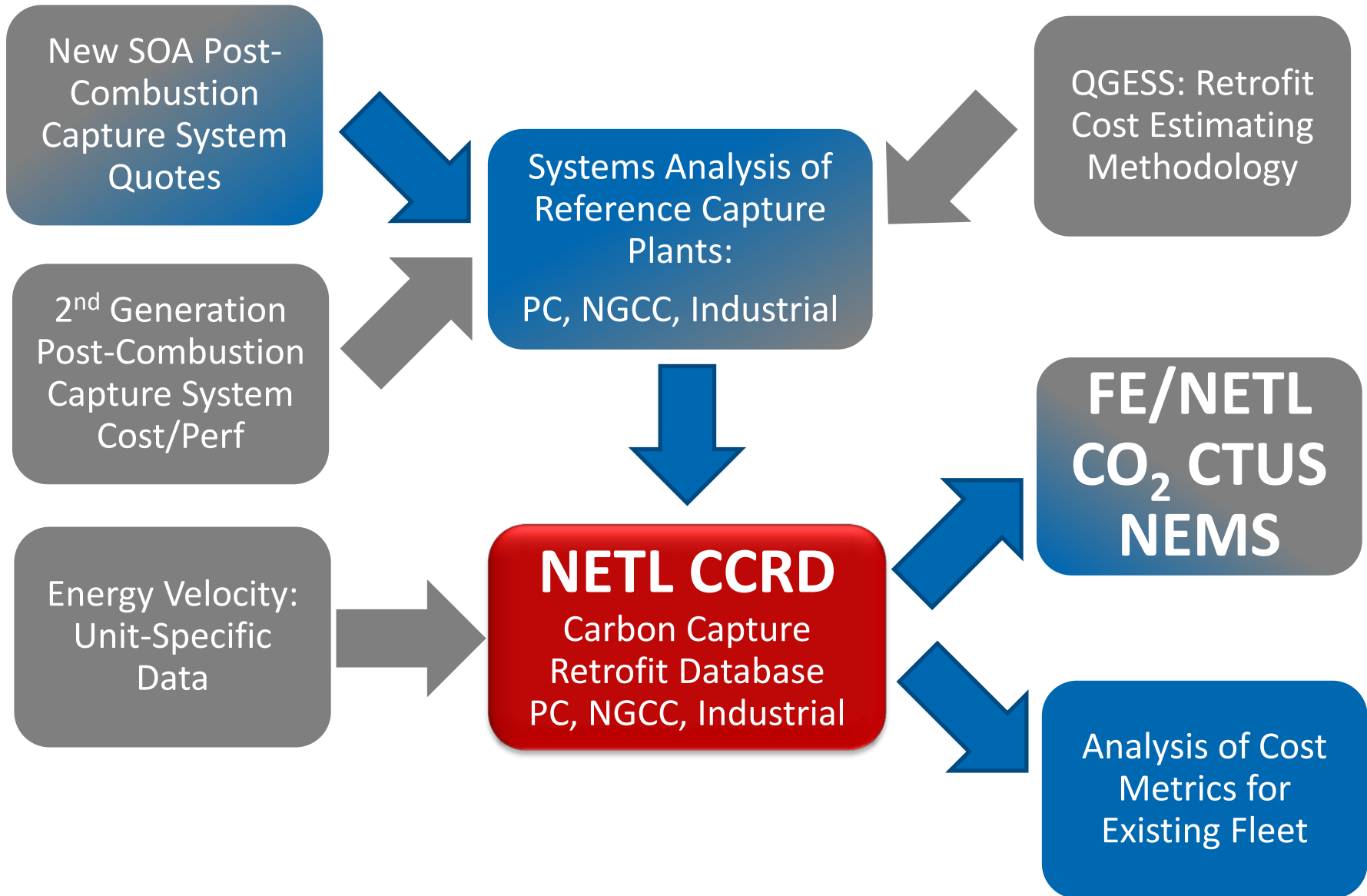- **Retrofitting with CCS economically incentivized via sale of CO_2 if:**

$$\text{Annualized Capital and Incremental O\&M Costs for Retrofit} + \text{Annual Revenues Foregone Due to Lost Generation (Derate)} \leq \text{Annual Revenues from Sale of Captured } CO_2$$

- **When normalized by CO_2 captured, the above becomes:**
  - Cost of capture
  - Minimum CO_2 plant gate price for which CCS retrofits are incentivized

Above assumes same capacity factor pre- and post-retrofit

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Reference Capture Plants: *Cost of Capture*

NG Price = $6.13/MMBtu
Market Power Price = $60/MWh

DRAFT Results

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Incentivizing CCS Retrofits with EOR Revenues

- **Retrofitting with CCS economically incentivized via sale of CO_2 if:**

$$\text{Annualized Capital and Incremental O\&M Costs for Retrofit} \quad + \quad \text{Annual Revenues Foregone Due to Lost Generation (Derate)} \quad \leq \quad \text{Annual Revenues from Sale of Captured } CO_2$$

  - When normalized by CO_2 captured, the above becomes the cost of capture or the minimum CO_2 plant gate price for which CCS retrofits are incentivized

- **NETL Carbon Capture Retrofits Database (CCRD) provides retrofit assessments for entire fleet**

NETL Retrofit Studies: Incremental cost and derate of retrofits for example plants

→ $ per lb CO_2

AEO/NEMS: Projected electricity price *(to estimate lost revenues)*

→ kWh lost per lb CO_2

Ventyx Energy Velocity: Unit-specific data

→ $ per Mwh
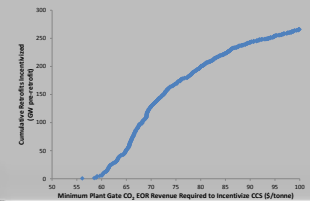
→ Output, CO_2 emissions, heat rate, etc.

NETL CCRD
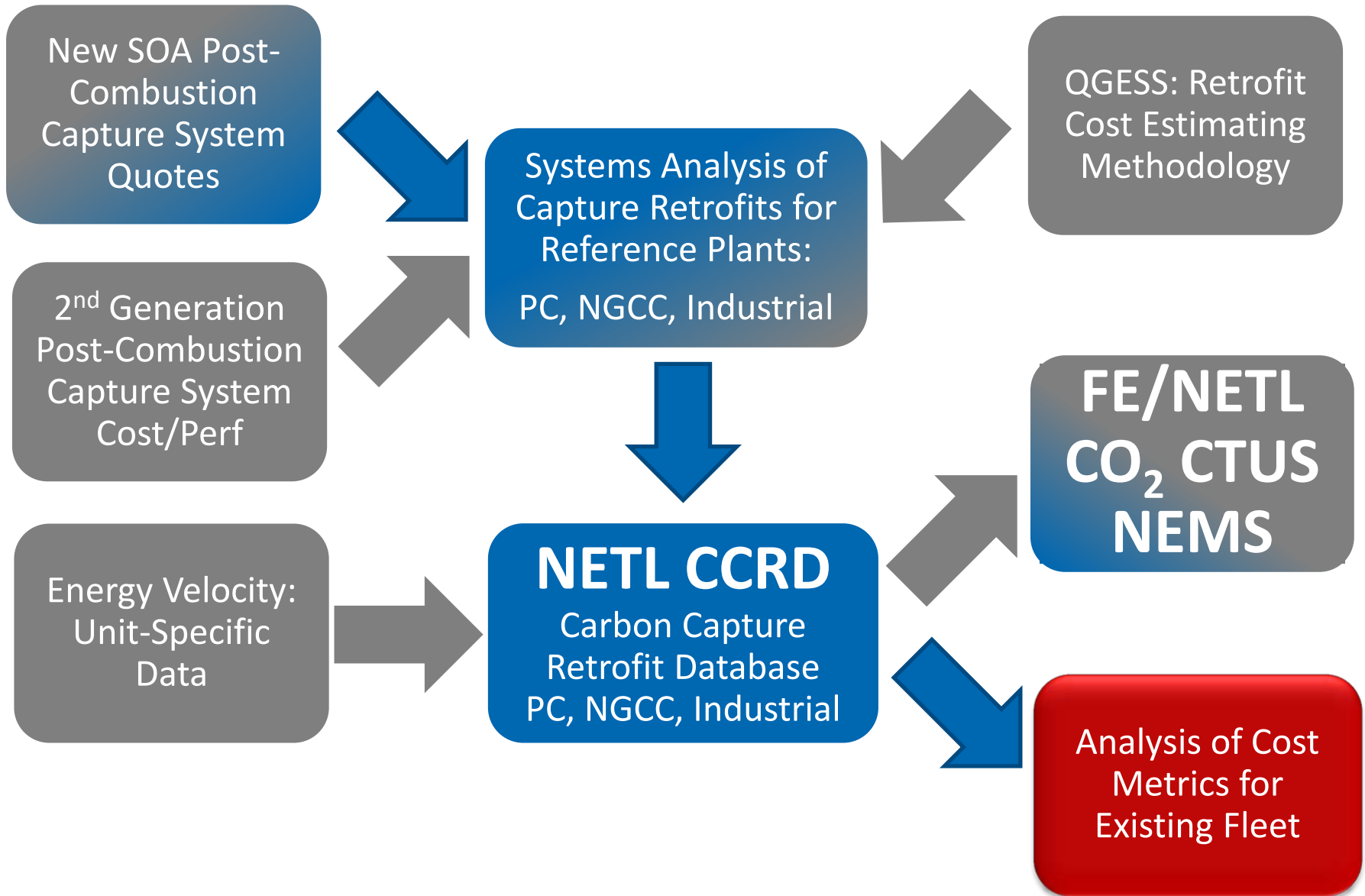*PC, NGCC, Industrial Sources*

Scales retrofit costs and calculates derates and lost revenues for units in entire fleet

CO_2 Supply Curves: Minimum CO_2 plant gate price for which CCS retrofits are incentivized for each unit in the fleet

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Analysis of Cost Metrics for Existing Fleet

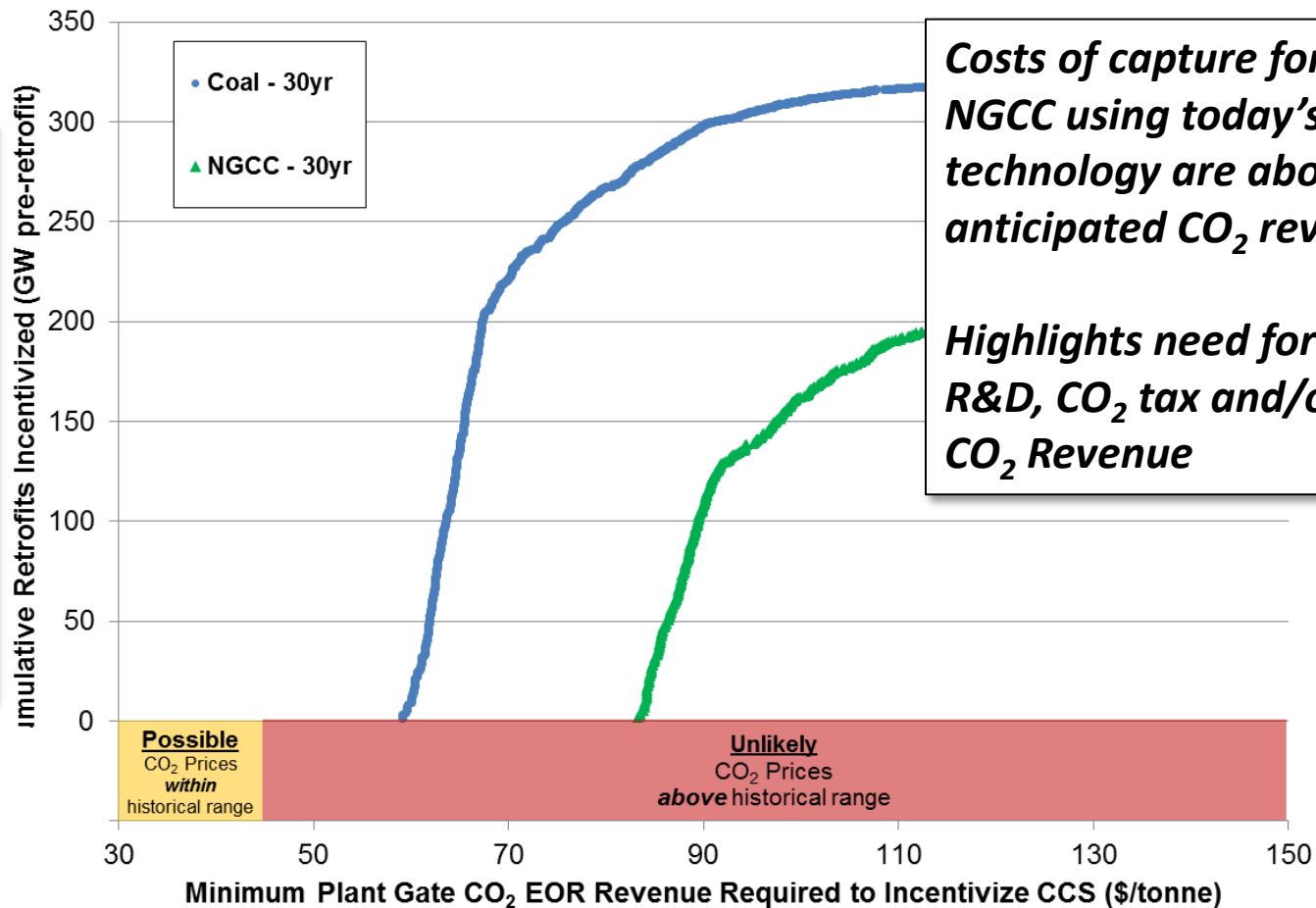# Minimum Plant Gate CO_2 EOR Revenue to Incentivize CCS – Year 2030
Coal Plants

- *Same CF pre- and post- retrofit @ historical value*
- *30-yr economic life*
- *$75/MWh* power price*
- *$138/bbl oil**

2nd Generation technology provides ~24% decrease in CO_2 price

- State-of-the-Art
- 2nd Generation

Cumulative Retrofits Incentivized (GW pre-retrofit)

Probable CO_2 Prices *below* historical range

Possible CO_2 Prices *within* historical range

Unlikely CO_2 Prices *above* historical range

Minimum Plant Gate CO_2 EOR Revenue Required to Incentivize CCS ($/tonne)

*NEMS Projections. Capital costs reflect ~15% premium due to increase in oil prices.

Minimum Plant Gate CO$_2$ EOR Revenue to Incentivize CCS – Year 2017

- *SOA Capture Technology*
- *Same CF pre- and post- retrofit @85%*
- *30-yr economic life*
- *$60/MWh power price*
- *~$100/bbl oil*

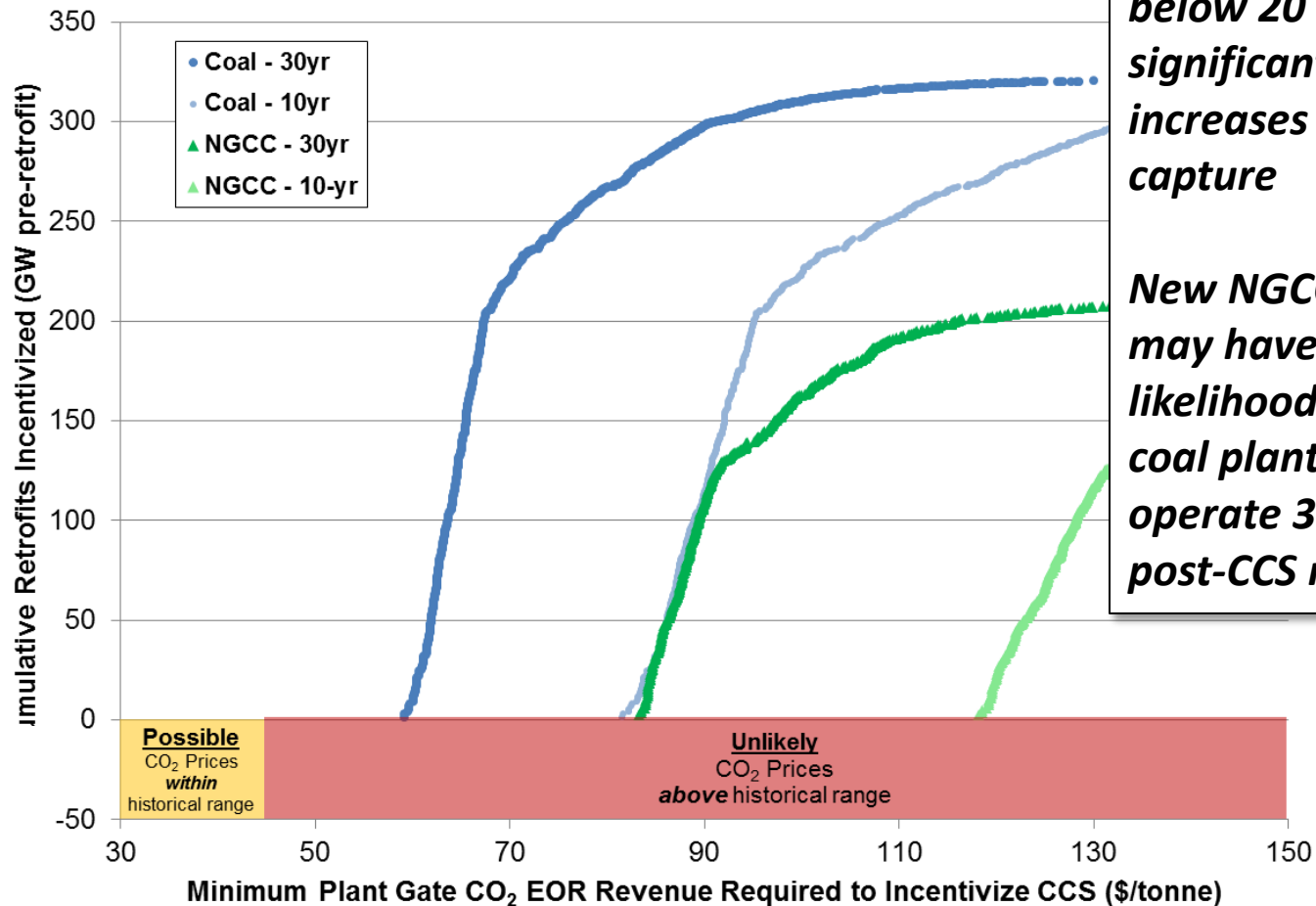*Costs of capture for PC and NGCC using today's CCS technology are above anticipated CO$_2$ revenues*

Highlights need for capture R&D, CO$_2$ tax and/or higher CO$_2$ Revenue

Minimum Plant Gate CO$_2$ EOR Revenue to Incentivize CCS – Year 2017
Economic Life Sensitivity

An economic life below 20 years significantly increases cost of capture

New NGCC plants may have greater likelihood over coal plants to operate 30 years post-CCS retrofit

- *SOA Capture Technology*
- *Same CF pre- and post-retrofit @85%*
- *$60/MWh power price*
- *~$100/bbl oil*

Legend:
- Coal - 30yr
- Coal - 10yr
- NGCC - 30yr
- NGCC - 10-yr

Y-axis: Cumulative Retrofits Incentivized (GW pre-retrofit)

X-axis: Minimum Plant Gate CO$_2$ EOR Revenue Required to Incentivize CCS ($/tonne)

Possible CO$_2$ Prices *within* historical range

Unlikely CO$_2$ Prices *above* historical range

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Minimum Plant Gate CO$_2$ EOR Revenue to Incentivize CCS – Year 2017
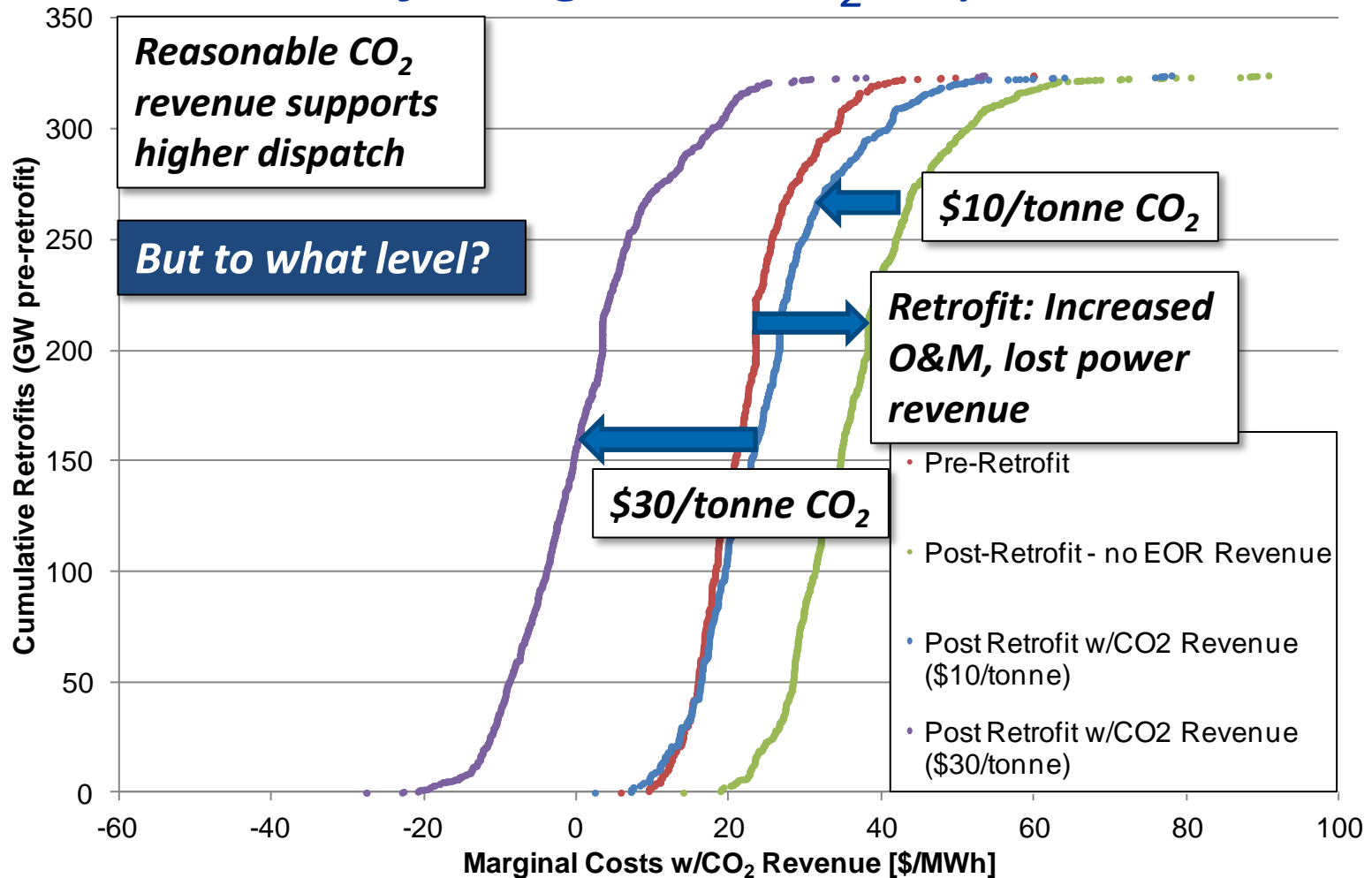## *Capacity Factor Sensitivity*
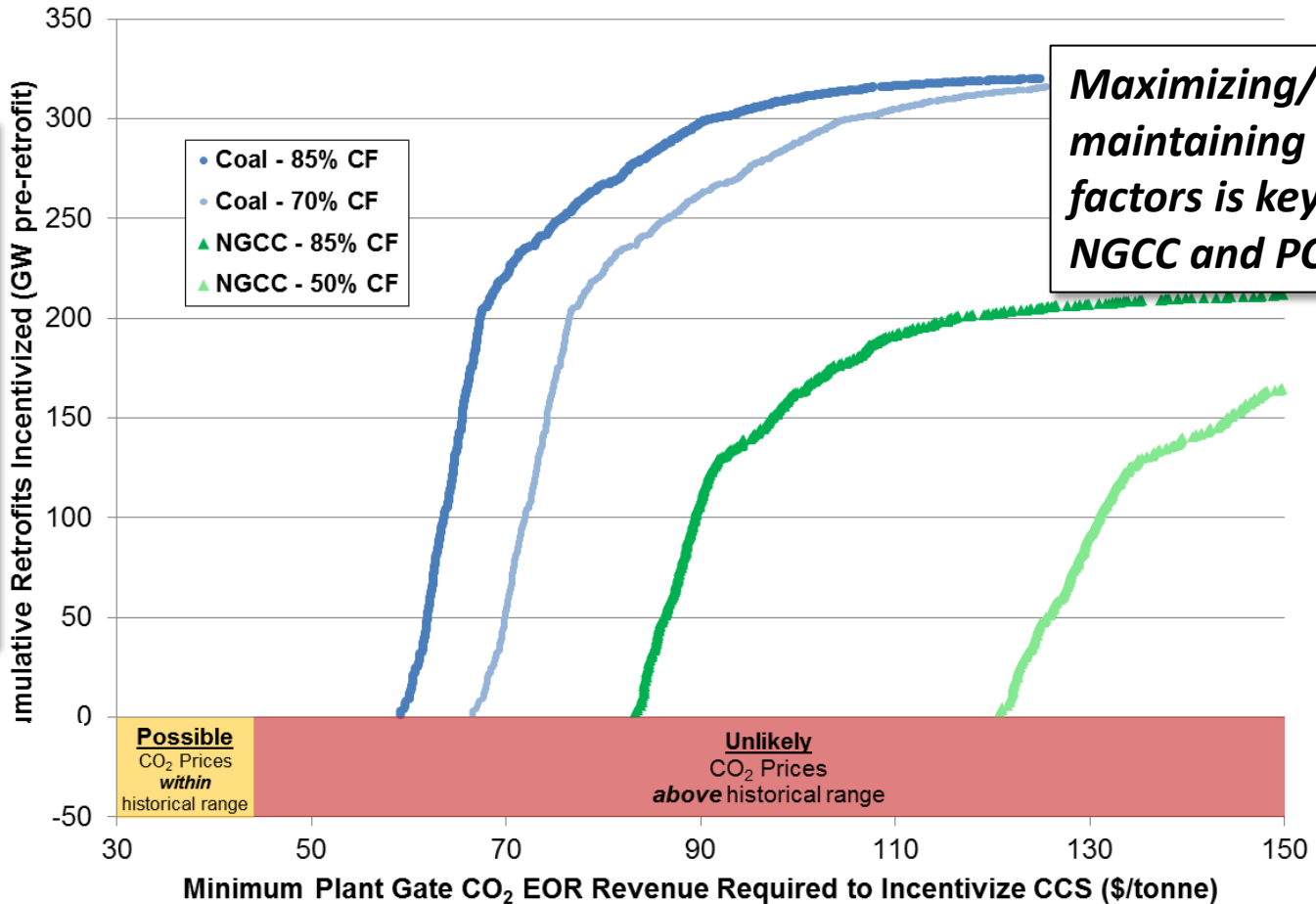
- *SOA Capture Technology*
- *Same CF pre- and post-retrofit*
- *30-yr economic life*
- *$60/MWh power price*
- *~$100/bbl oil*

Maximizing/ maintaining capacity factors is key for both NGCC and PC plants

Legend:
- Coal - 85% CF
- Coal - 70% CF
- NGCC - 85% CF
- NGCC - 50% CF

Y-axis: Cumulative Retrofits Incentivized (GW pre-retrofit)

X-axis: Minimum Plant Gate CO$_2$ EOR Revenue Required to Incentivize CCS ($/tonne)

Possible CO$_2$ Prices *within* historical range

Unlikely CO$_2$ Prices *above* historical range

Incremental Marginal Cost Trends
Retrofitting SOA CO$_2$ Capture

Reasonable CO$_2$ revenue supports higher dispatch

But to what level?

$10/tonne CO$_2$

Retrofit: Increased O&M, lost power revenue

$30/tonne CO$_2$

Legend:
- Pre-Retrofit
- Post-Retrofit - no EOR Revenue
- Post Retrofit w/CO2 Revenue ($10/tonne)
- Post Retrofit w/CO2 Revenue ($30/tonne)

Y-axis: **Cumulative Retrofits (GW pre-retrofit)** — 0, 50, 100, 150, 200, 250, 300, 350

X-axis: **Marginal Costs w/CO$_2$ Revenue [$/MWh]** — -60, -40, -20, 0, 20, 40, 60, 80, 100
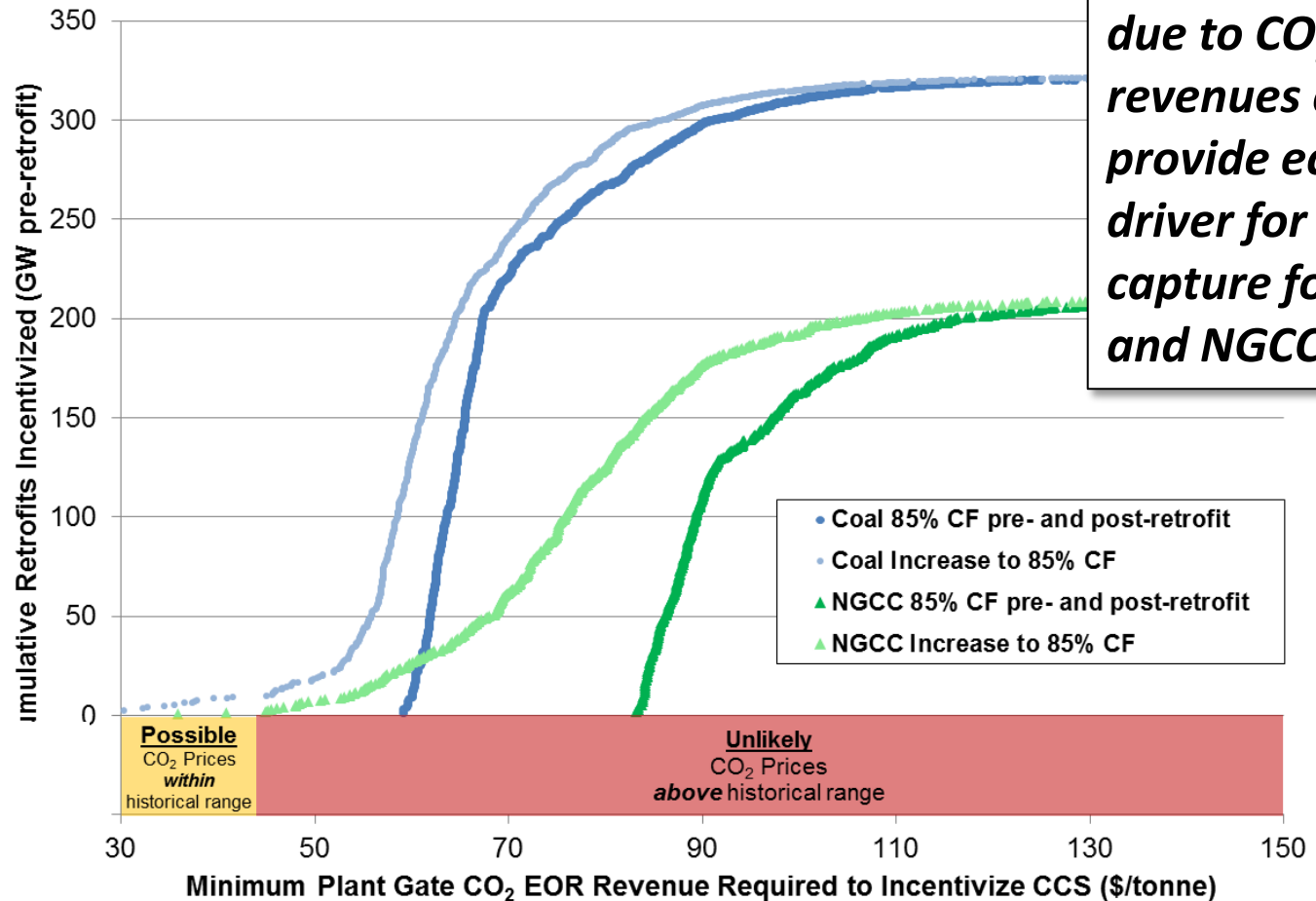
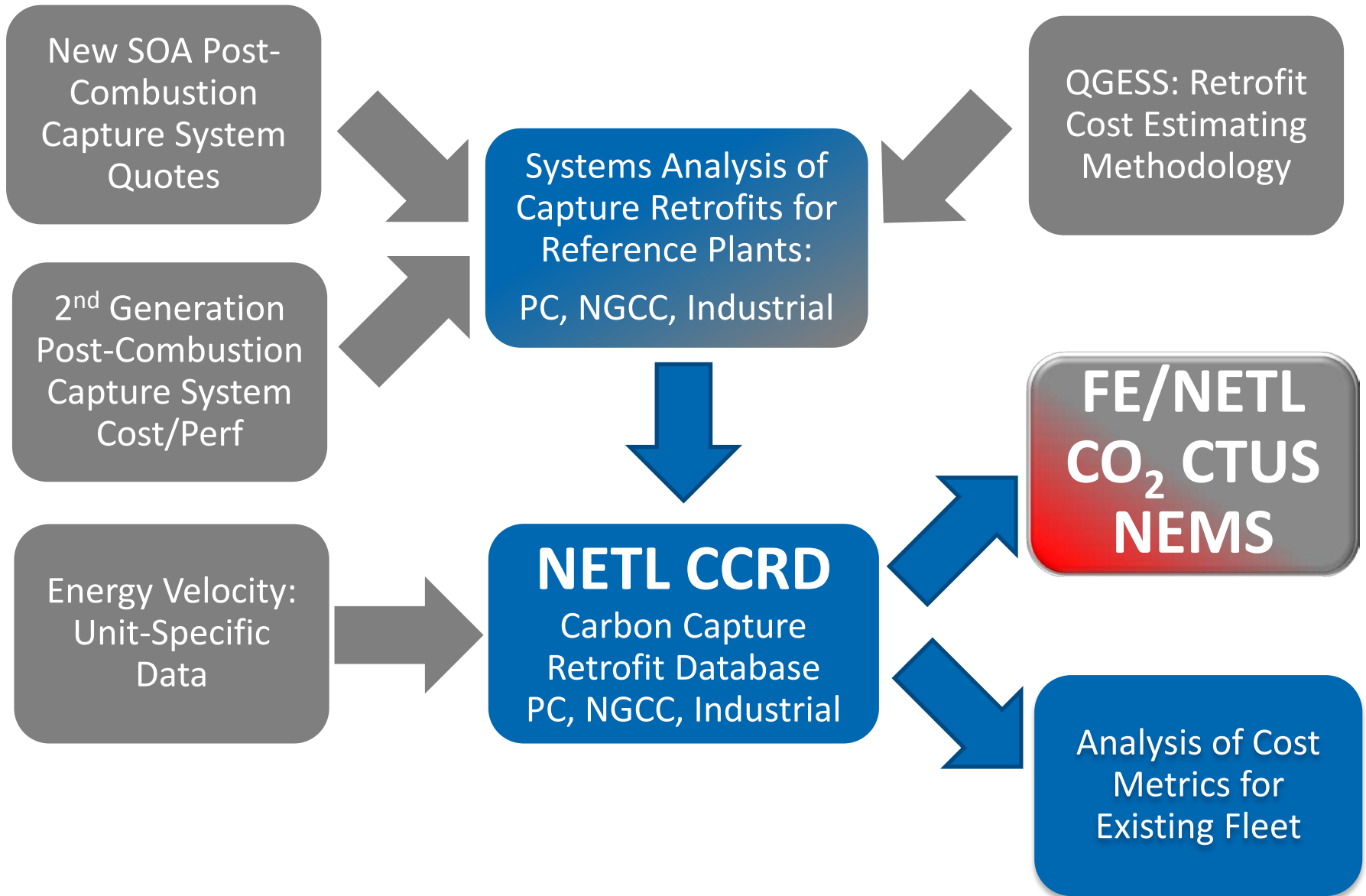# Minimum Plant Gate CO$_2$ EOR Revenue to Incentivize CCS – Year 2017
Impact of Dispatch

- *SOA Capture Technology*
- *30-yr economic life*
- *$60/MWh power price*
- *~$100/bbl oil*

Shift in dispatch due to CO$_2$ EOR revenues can provide economic driver for CO$_2$ capture for PC and NGCC
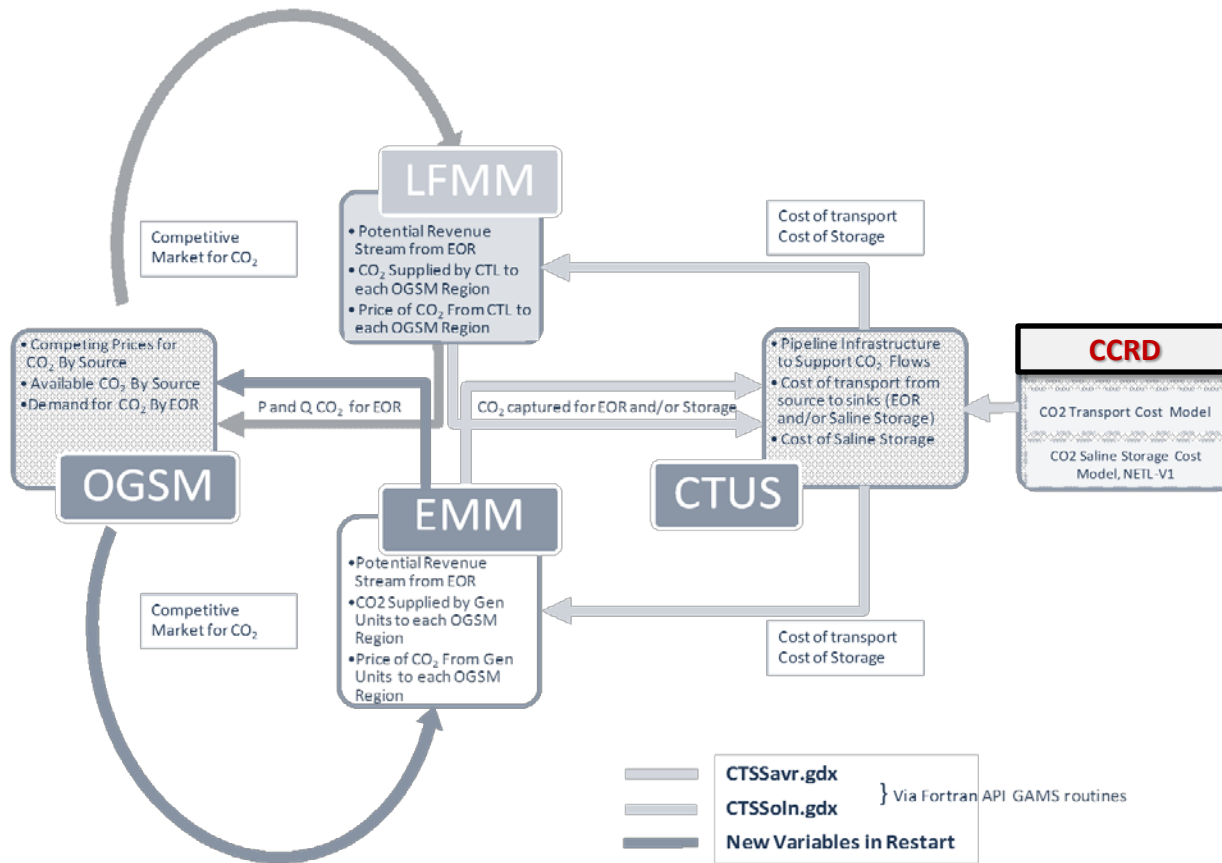

Legend:
- Coal 85% CF pre- and post-retrofit
- Coal Increase to 85% CF
- NGCC 85% CF pre- and post-retrofit
- NGCC Increase to 85% CF

Y-axis: Cumulative Retrofits Incentivized (GW pre-retrofit)

X-axis: Minimum Plant Gate CO$_2$ EOR Revenue Required to Incentivize CCS ($/tonne)

Possible CO$_2$ Prices *within* historical range

Unlikely CO$_2$ Prices *above* historical range

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Evaluating Retrofits in NEMS
CO₂ CTUS NEMS Model Structure

NETL's CO_2 Capture, Transport, Utilization and Storage (CTUS) model adds capability to NEMS to model NGCC retrofits using data from the NETL Carbon Capture Retrofits Database (CCRD).

Decision to retrofit based on region-specific power generation needs, EOR and CO_2 storage opportunities, and CO_2 pipeline build-out requirements.

Conclusions

Compared cost of CO_2 retrofits to minimum CO_2 price in EOR market

- **Even with EOR revenues, state-of-the-art technology unlikely to promote significant retrofits for NGCC or PC**

- **2nd gen improvements reduce cost of capture by ~25% and significantly increase potential of deployment**

- **NGCC and PC retrofit trade-offs**
  - Capture technology applied to PC plants provides significantly lower cost of capture
  - Economic life of retrofit for aging coal fleet compared to economic life of new NGCC deployments may partially close cost of capture gap
  - Shift in dispatch due to CO_2 EOR revenues can provide economic driver for CO_2 capture for PC and NGCC
  - CO_2 capture R&D success needed for both PC and NGCC plants!

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