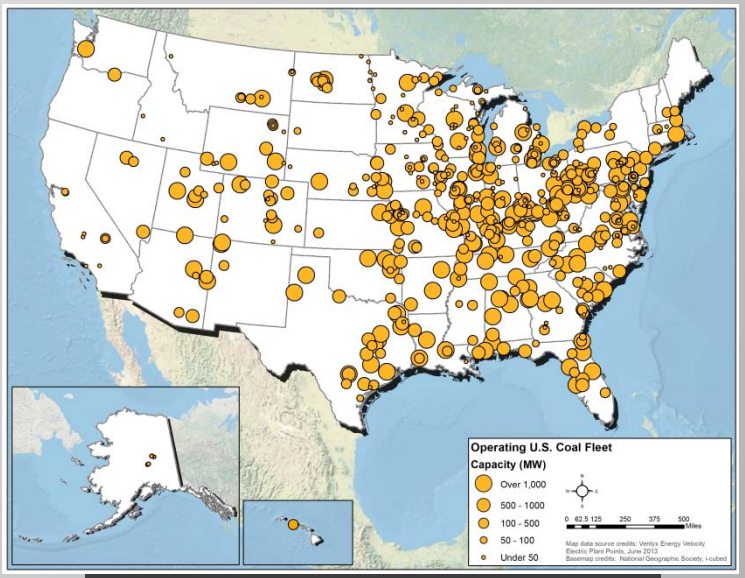
Economic Feasibility of CO_2 Capture Retrofits for the U.S. Coal Fleet: *Impacts of R&D and CO_2 EOR Revenue*

Michael Matuszewski



the ENERGY lab

2013 CO_2 Capture Technology Meeting

July 11th, 2013

U.S. DEPARTMENT OF ENERGY | National Energy Technology Laboratory

Objectives

In a 2nd Generation CO_2 Capture Market (2030) with No Carbon Regulations, Compare BAU to Retrofit for EOR

- **Determine Economic Feasibility of today's Carbon Capture Retrofits in an Enhanced Oil Recovery (EOR) market**
  - Capture CO_2 and sell for enhanced oil production
- **Determine how 2nd generation capture technologies can improve retrofit economics**
  - Cost to capture CO_2 at plant gate
- **Assess economic sensitivity to key market variables**
  - Economic life, dispatch, oil prices

** Image from www.clker.com*

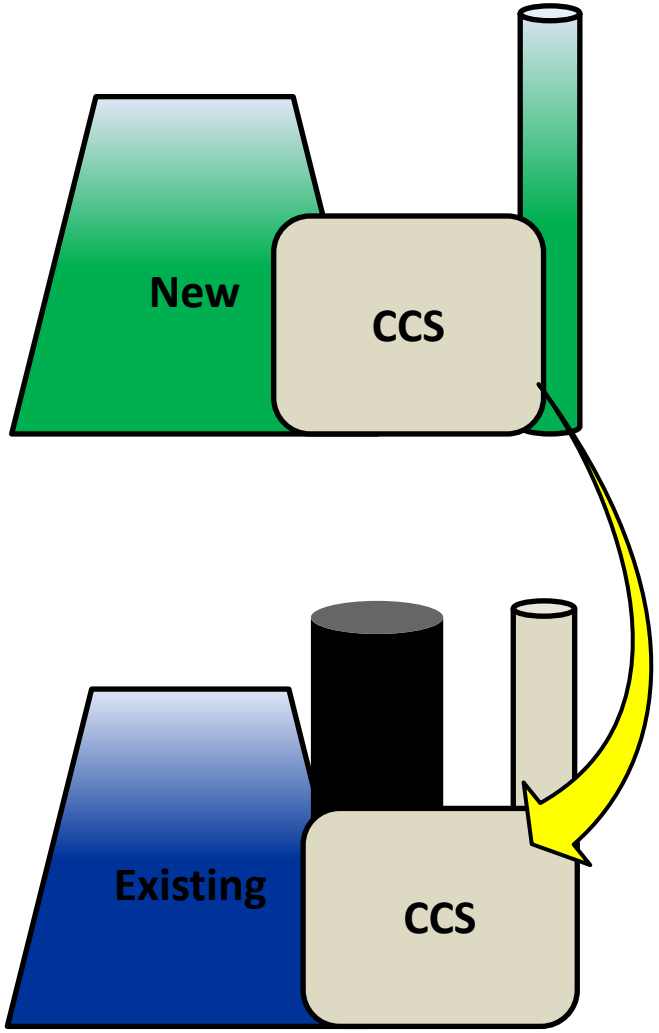
Executive Summary

- **Database of design and operational details for existing PC units allows extrapolation of CO_2 retrofit cost and performance**
  - ~1,350 units comprising 324 GW of nameplate generation
  - Capital, operating cost and performance extrapolations
  - This analysis evaluates only CO_2 capture - no criteria pollutant costs
- **2nd gen capture technology reduces fleet-wide captured costs by ~25%**
  - 2030 projected oil prices ($138/bbl) may further promote capture
  - 2nd gen may increase candidate retrofit GW's ***five-fold*** over SOA
- **EOR revenue promotes more competitive dispatch**
  - With EOR revenue, CO_2 capture may ***increase*** dispatch in power markets
  - Reasonable CO_2 prices ($10-$30/tonne) can eliminate marginal cost increases due to capture

2nd Generation Projections

Overview

- **By convention, technology evaluations performed on <u>baseline greenfield plant</u>**
  - Conceptual, 550MW greenfield installation
  - Includes benefits of A-USC Steam cycle
- **2nd generation CO_2 capture performance projections based on greenfield plant capture technology contributing to target of $40/tonne captured**
- **Apply same capture technology to <u>baseline existing plant</u>**
  - Retain existing limitations such as fixed steam cycle, current heat rate, etc.
  - Cost of lost power generation
  - Often requires additional equipment & effort
  - Consequently, ***existing plant cost of captured is generally >$40/tonne greenfield target*** (@ constant CF, no EOR)



Extrapolating Results to the Existing Fleet

Existing Plant Database

- **Data on 1,355 individual PC units (324 GW)**
- **Key information:**
  - Unit ID, Nameplate Capacity, Heatrate, CO_2 Emissions, Capacity Factor
- **CO_2 Generation Allows Calculation of:**
  - CO_2 Captured, Capital Costs, Fixed O&M*, Variable O&M**
- **Heatrate and Nameplate Capacity Allow Calculation of:**
  - Post-Retrofit Output, Lost Power Revenue***
- **Capacity Factor Allows Calculation of:**
  - Cost of CO_2 Captured, Incremental COE/Marginal Costs

*Proportional to TPC
** Proportional to amount of CO_2 Captured
***Assuming a market price of electricity

Baseline Existing Plant

A <u>baseline existing plant</u> is established for conceptual evaluation of retrofitted CO_2 technologies on a consistent basis

- Allows evaluation of system-wide effects on power plant
- Isolates net power generation penalty due to CO_2 capture retrofit

Baseline Existing Plant is equivalent to a subcritical pulverized coal plant without carbon capture, as defined in NETL report "*Cost and Performance Baseline for Fossil Energy Plants*" (Case 9)

** Image from www.clker.com*

Technology Comparison

- **Baseline PC Plant Retrofit (comparison to 2012)**

	Technology Vintage		
Metric	2005*	***2012****	Example 2nd Gen.
Net Energy Penalty [kWhnet/lb CO_2 Captured]	0.181 **(+26%)**	***0.144***	0.143 **(-1%)**
Reference Capital Cost [$/tpd CO_2 Capt. @ full load]	$55,400 **(-17%)**	***$66,400***	$48,000 **(-28%)**
Incremental Fixed O&M [$/tpd CO_2 Capt. @ full load]	$1,828 **(-5%)**	***$1,926***	$1,872 **(-2.8%)**
Incremental Variable O&M [$/tpd CO_2 Capt. @ full load]	$2.59 **(-50%)**	***$5.13***	$4.75 **(-7%)**
CO_2 Capture Basis [tpd]	11,216	***11,216***	11,216

Basis

** Based on amine technology*

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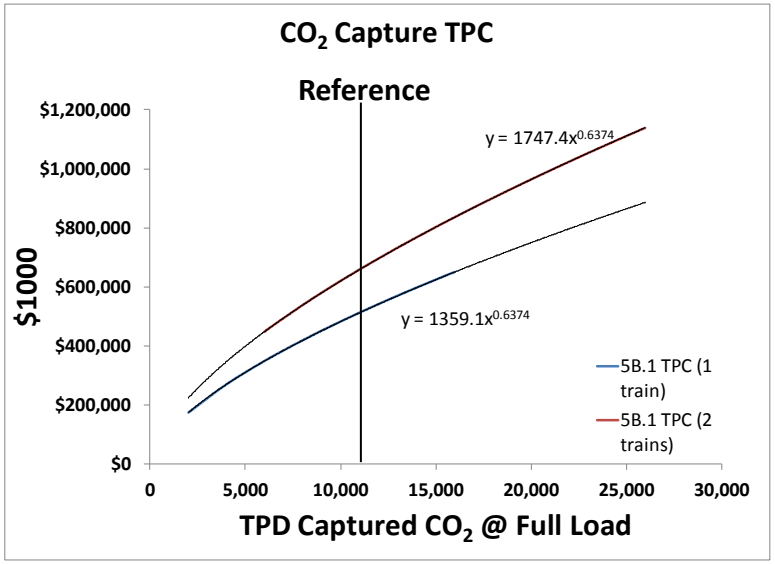
Not used

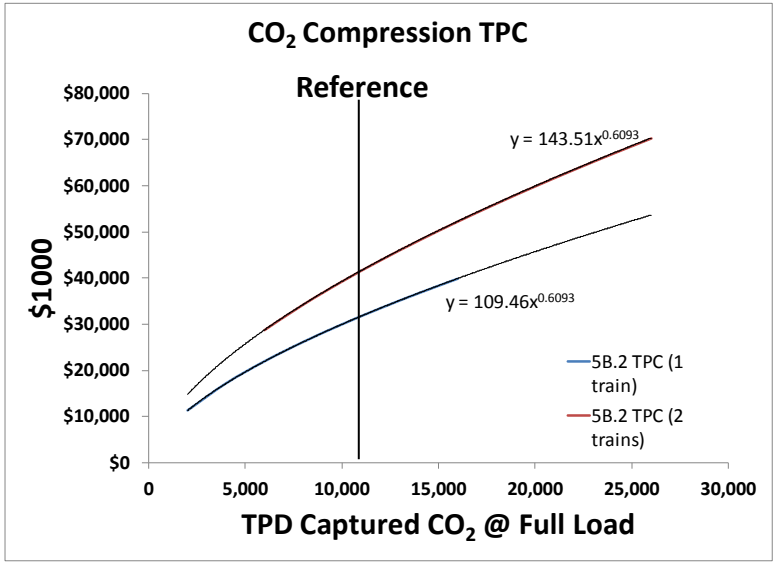
Evaluated in this work

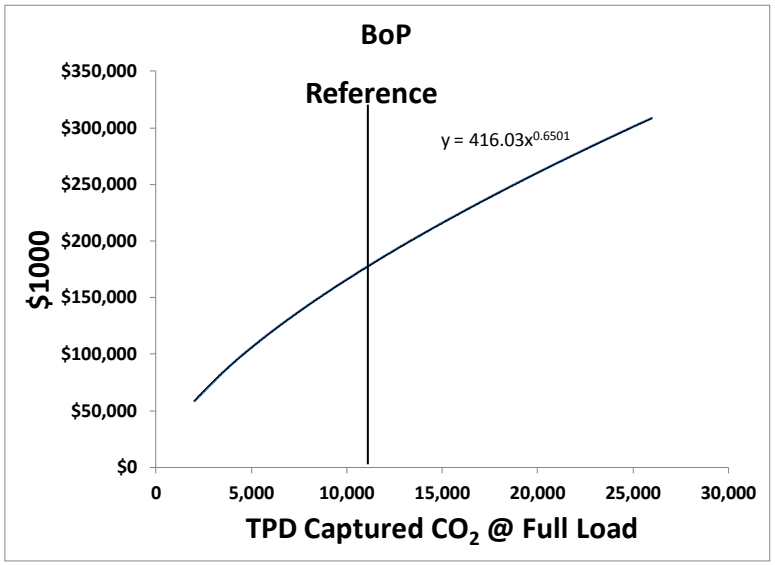
Basis

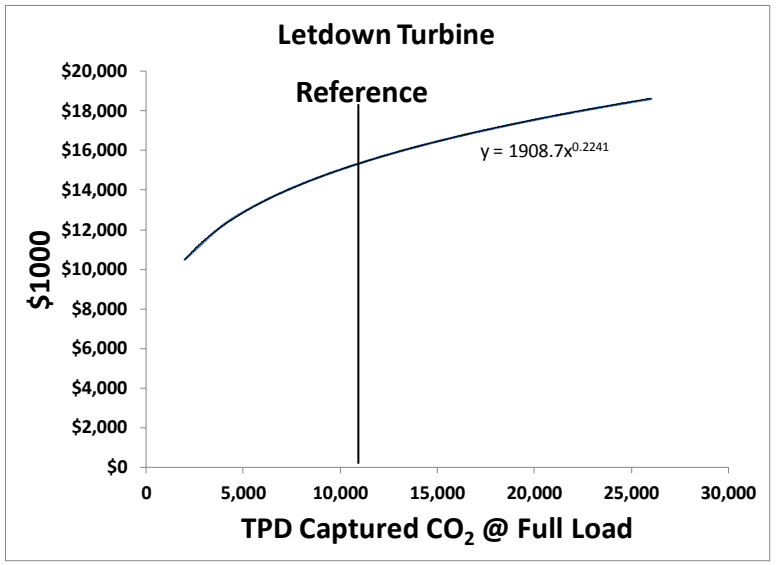
** Based on amine technology*

Equipment Cost Scaling (2011 dollars)

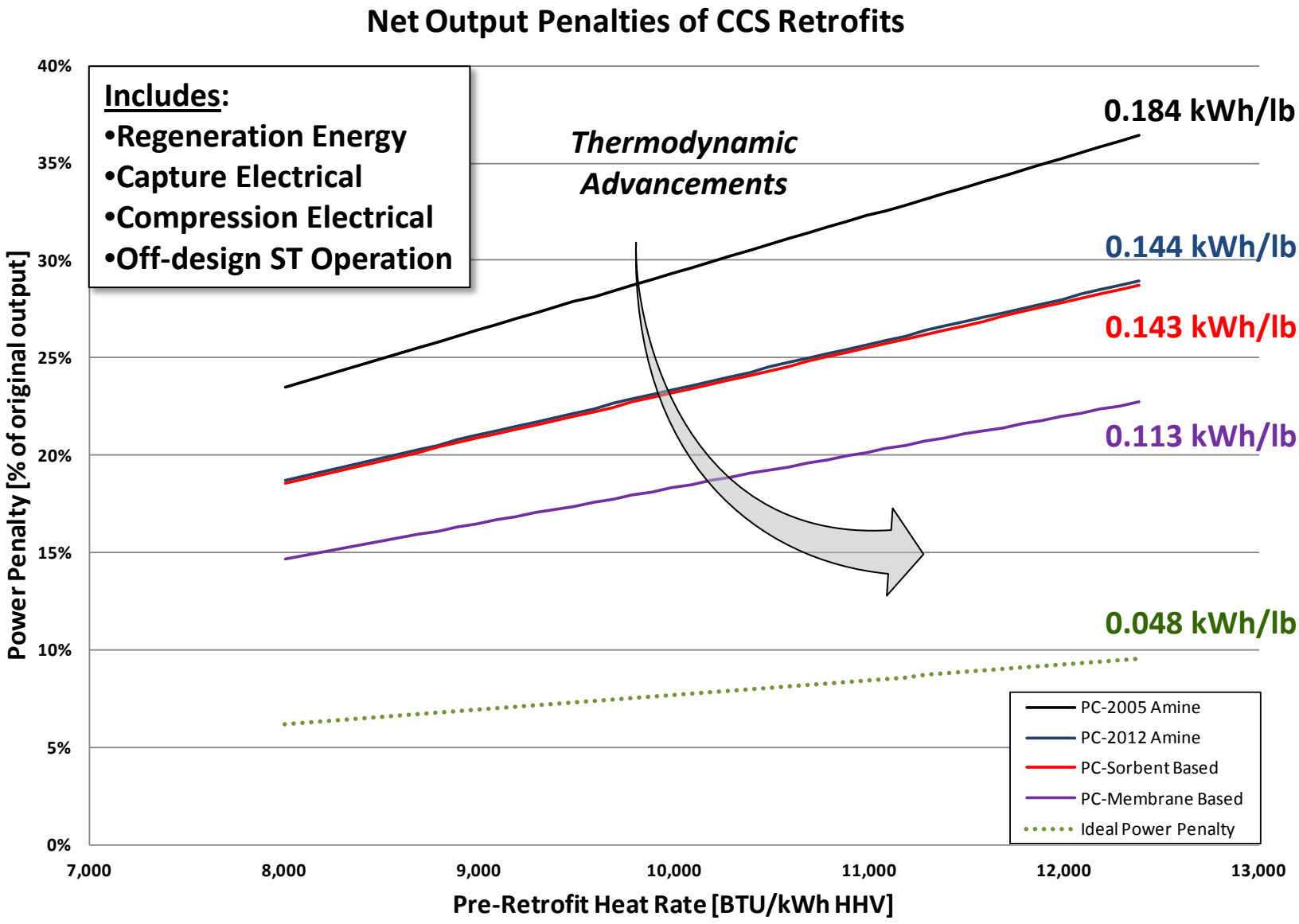








Net Derate Projections*



As evaluated on baseline existing plant. Does not include balance of plant improvements

CO_2 Captured Cost Metric

$$CapturedCost = \frac{CCF * TOC + LP * PP * 8760 * CF + FOM + VOM * CF}{Annual CO_2 Captured}$$

Cost of lost power generation

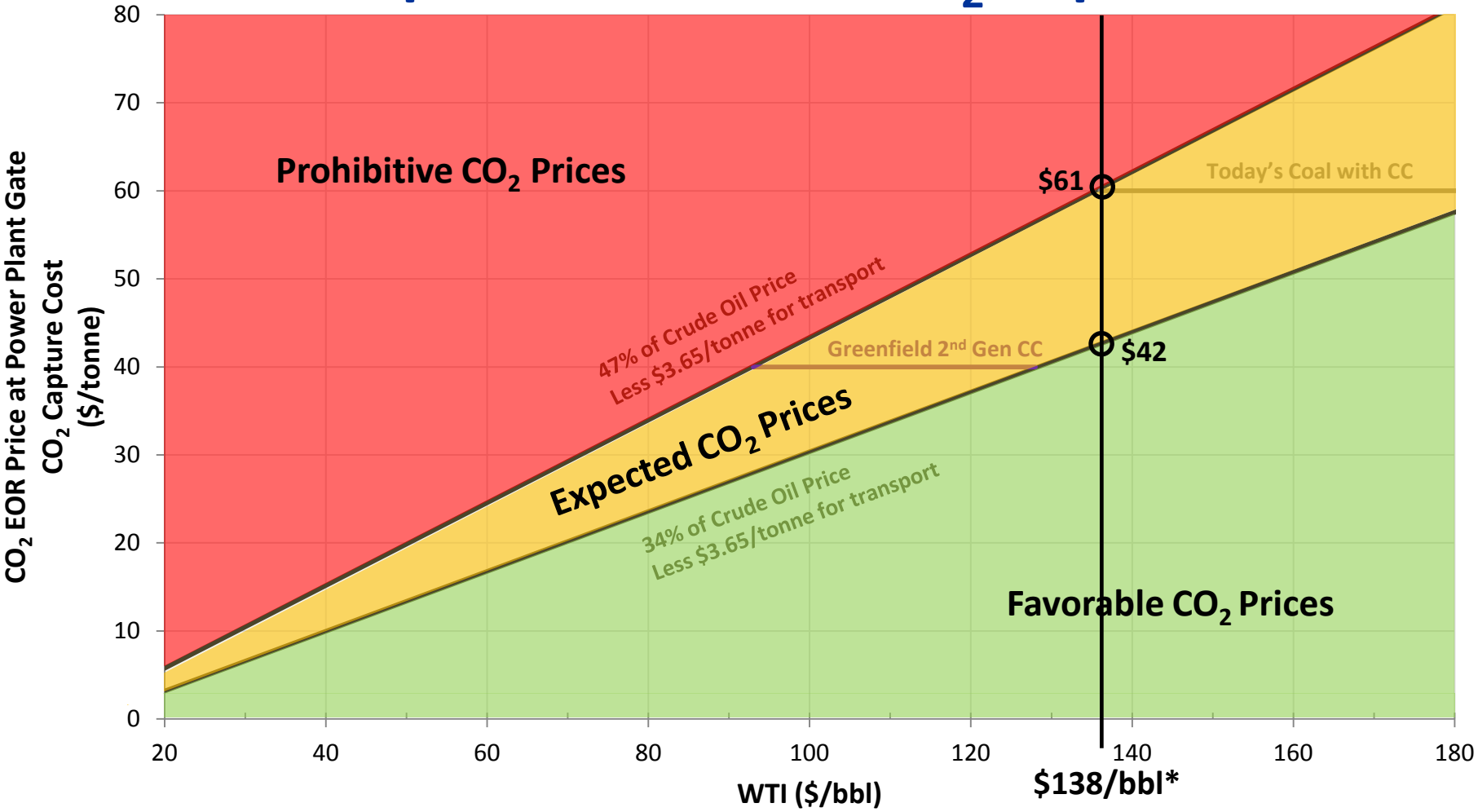
- **Where:**
  - Captured Cost [=] $/tonne
  - TOC = Total Overnight Cost [=] $
  - CCF = Capital Charge Factor [=] yr^{-1}
  - LP = Lost Power [=] MW
  - PP = Market Power Price [=] $/MWh
  - CF = Capacity Factor [=] (fraction)
  - FOM = Fixed O&M [=] $/yr
  - VOM = Variable O&M [=] $/yr @ 100% load
  - Annual CO_2 Captured [=] tonnes/yr

Plant-gate cost to capture CO_2 defined as key metric for retrofit evaluation in EOR market.

Existing Plant Retrofit Projections

2030 EOR Market with No CO_2 Regulations

2030 Oil Prices May Support EOR CO_2 Prices that are Equal to or Above CO_2 Capture Costs

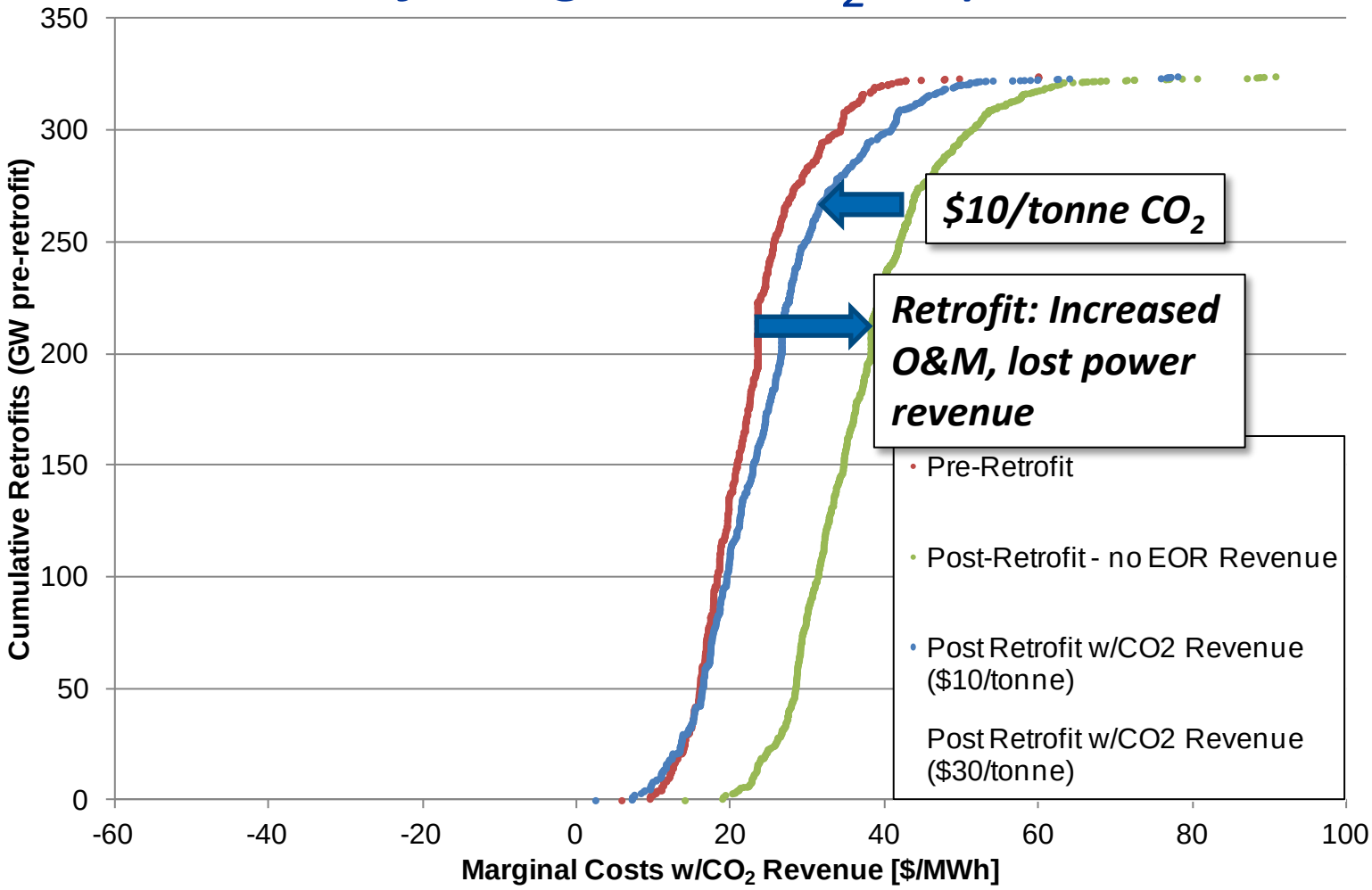


From 2008 to mid-2011, the average annual new contract price for CO_2 ($/MSCF) at the Denver City, Texas "hub", varied between 1.8% and 2.5% of the average annual WTI Crude oil price ($/bbl) in the corresponding years. Expressed in $/tonne, this is 34% to 47% (at standard conditions of 60 °F and 14.7 psia). (The non-averaged contract prices ($/MSCF) varied between 1.4 and 3.3% of the oil price between 2008 and mid-2011.) Source: Chaparral Energy "US CO2 & CO2 EOR Developments" Panel Discussion at CO_2 Carbon Management Workshop December 06, 2011. Estimated 100 km pipeline transport cost of $3.65/tonne is subtracted to convert the historical "hub" price to an estimated power plant gate price.

*NEMS Projection

Incremental Marginal Cost Trends

Retrofitting SOA CO_2 Capture



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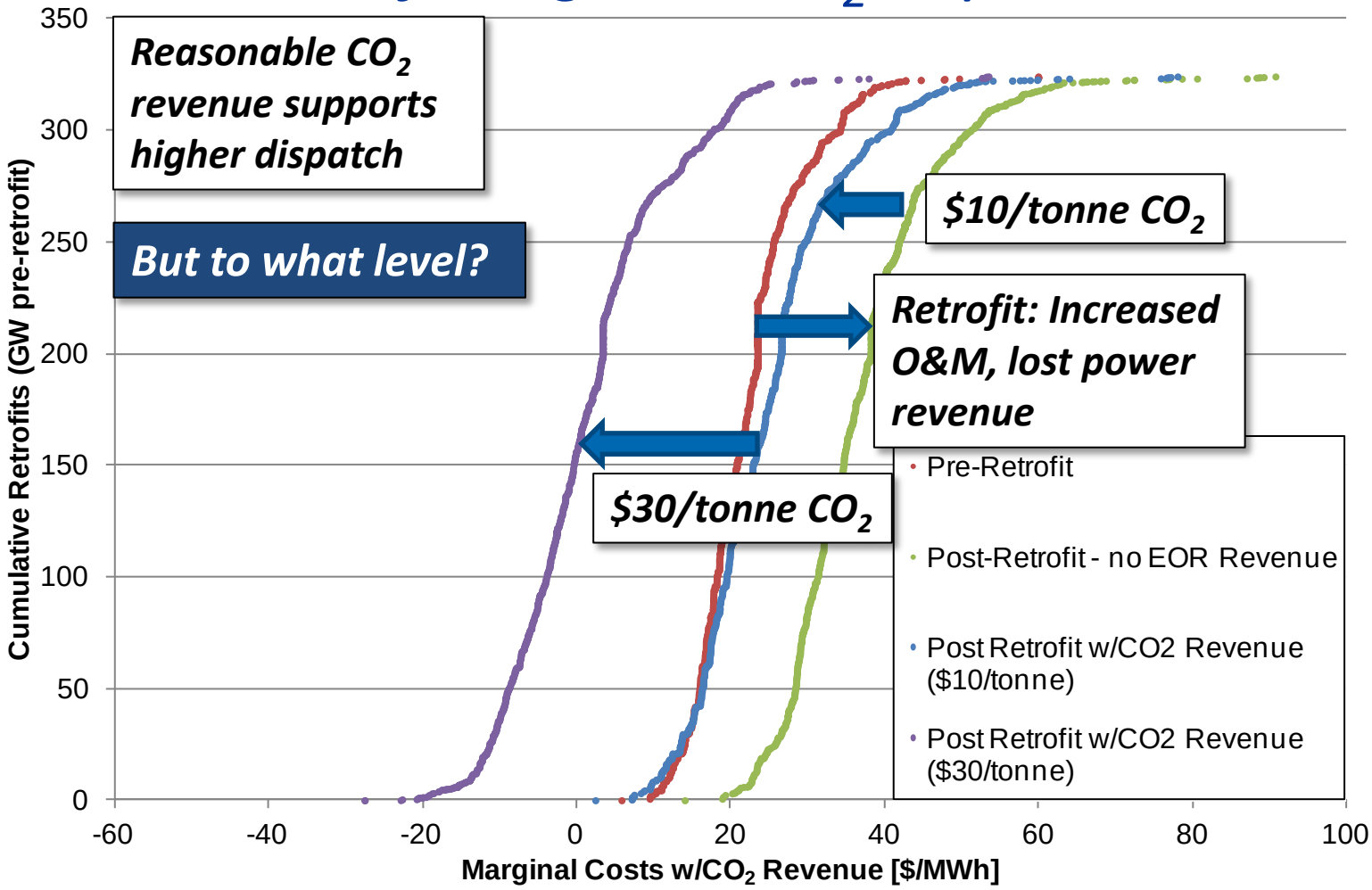
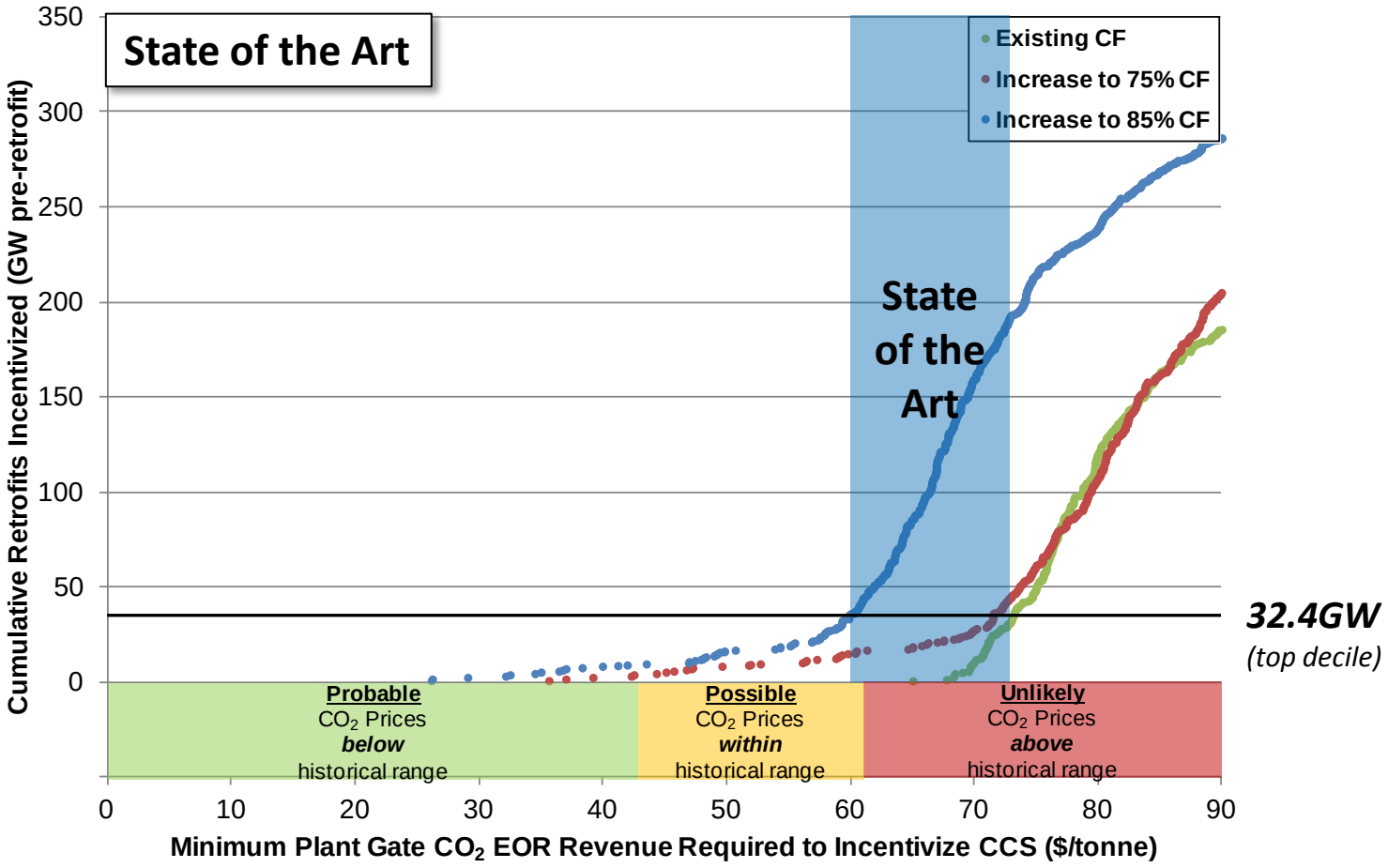


Effect of Dispatch - 2030

Capacity Factor Parameter Sensitivity

- ***30yr CCF***
- ***$75/MWh* power price***
- ***$138/bl oil****



32.4GW
(top decile)

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

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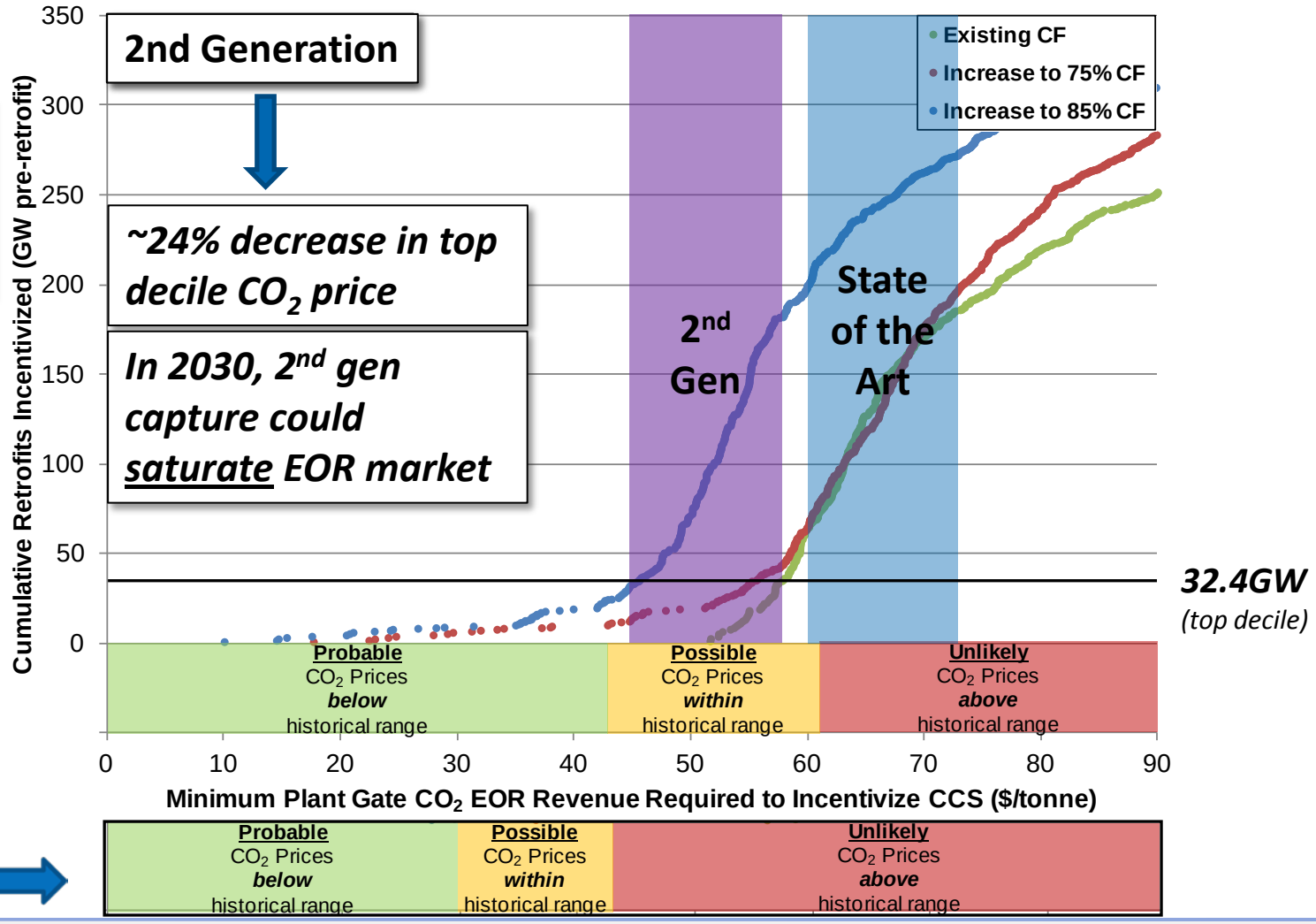


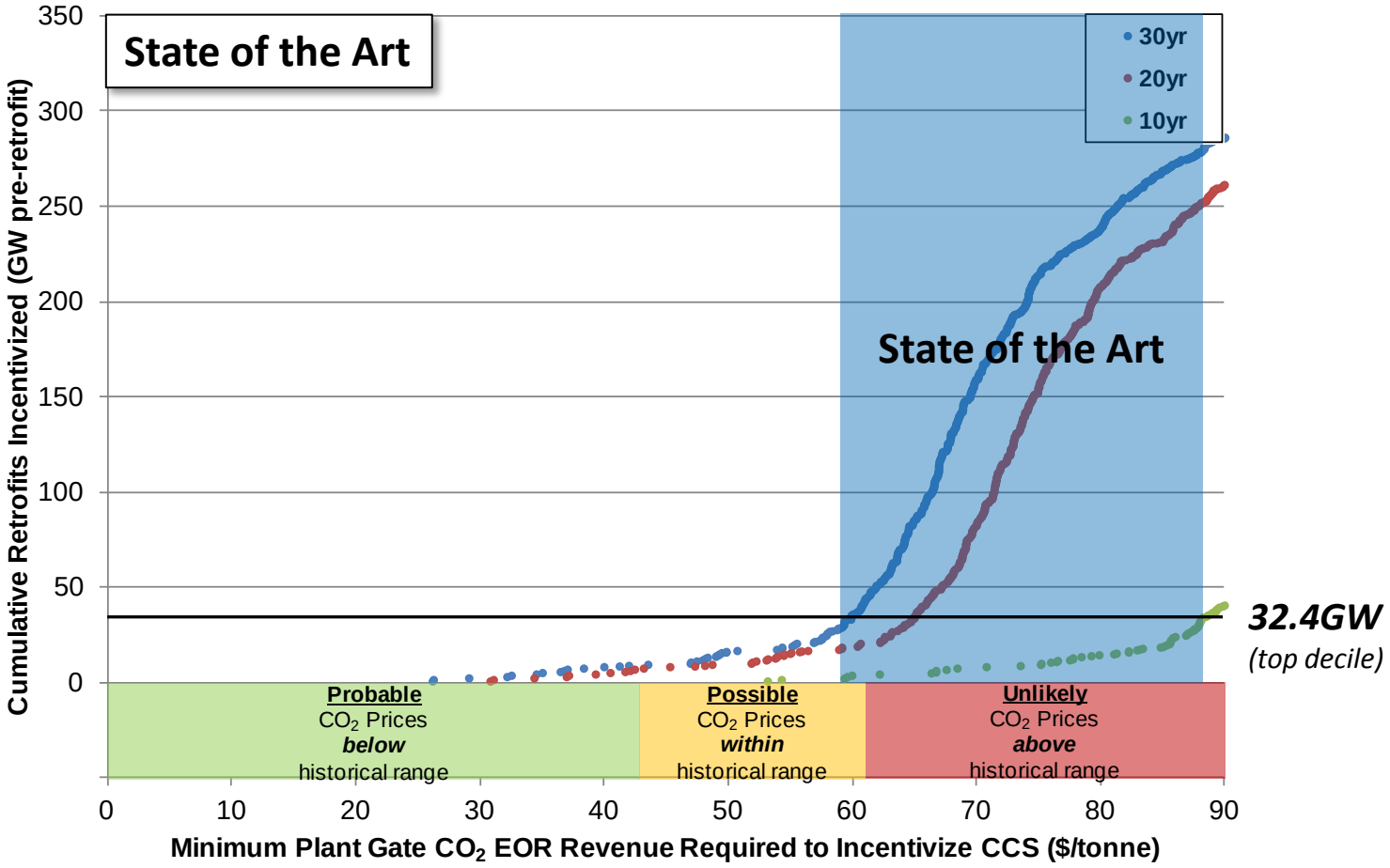
Note shift from EOR revenues @ $100/bbl

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

Effect of Capital Recovery Period - 2030

Capital Charge Factor Parameter Sensitivity

- ***85% CF***
- ***$75/MWh power price***
- ***$138/bbl oil***



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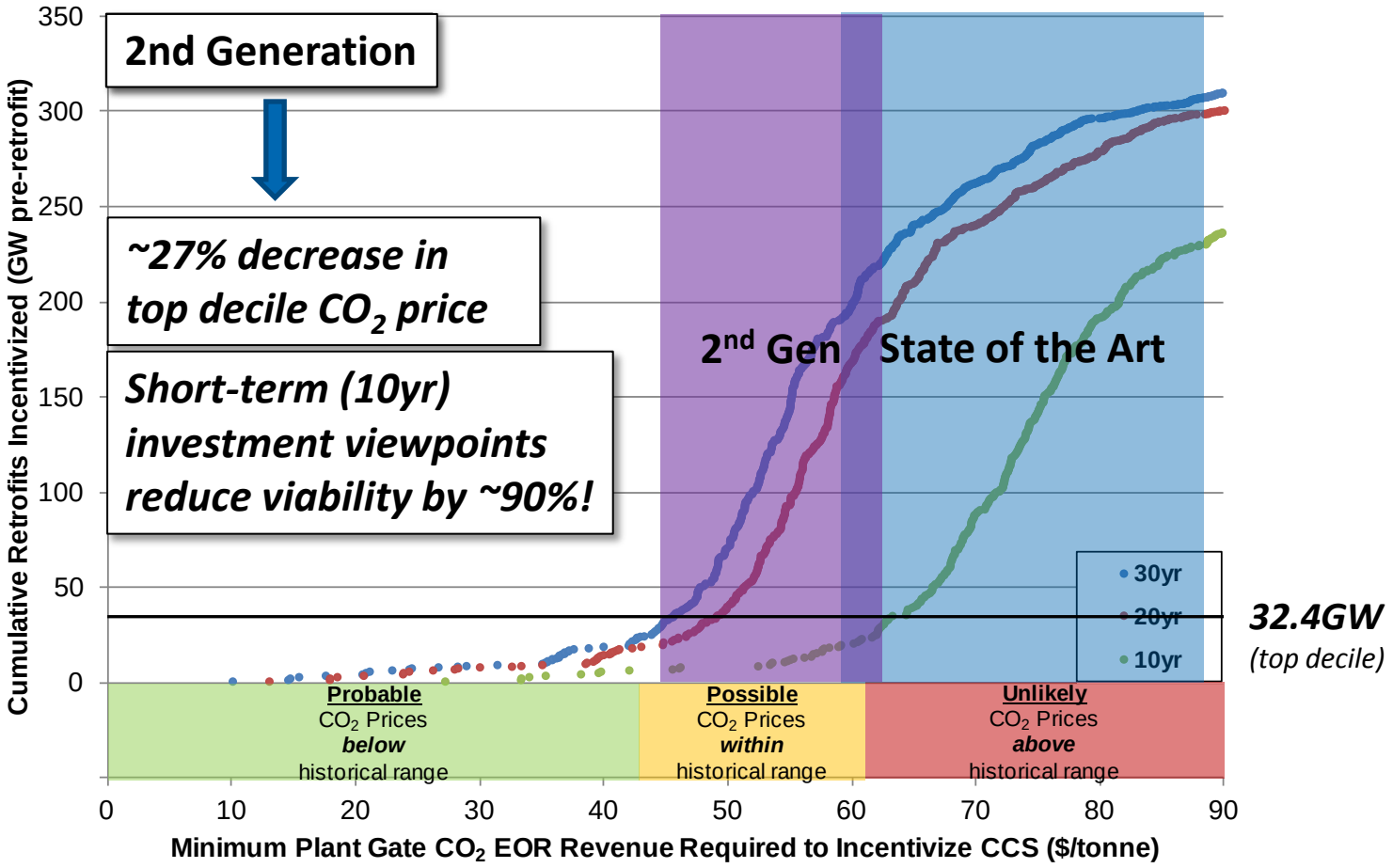

Conclusions

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

Bounding scenario: Calculations indicate <u>best case</u> for BAU vs. retrofit

- **In 2030, SOA technology promotes 0-45GW of economic retrofits***
- **2nd gen improvements increase potential *up to five-fold (25-215GW)****
  - CO_2 contract price relationship to price of WTI crude
- **EOR market while limited in size, is an excellent transition step for proving out carbon capture and reducing risk for future installations**
- **Still need help for "slam dunk" EOR scenario**
  - Need CO_2 capture R&D success!
  - Dispatch is essential – and likely achievable
  - Regulatory drivers encouraging CO_2 capture should also support a long-term (30yr) investment viewpoint
- **EOR revenue will offset lost power revenue, reducing marginal costs**
  - $10/tonne nearly offsets marginal cost increases for entire fleet
  - $30/tonne ***eliminates*** marginal costs (≤$0/MWh) for ~150GW

**Range dictated by capital recovery period range (10-30yrs) assuming fleet-wide CF increase to 85%*

Acknowledgements

- **NETL**
  - John Wimer – Project Guidance
  - Kristin Gerdes – Sensitivity Analyses
  - Robert Stevens – 2nd Gen Technology Projections
- **Booz Allen Hamilton**
  - Vince Chou – Cost and Performance Extrapolation
- **Leonardo Technologies Inc.**
  - Massood Ramezan – Project Guidance
  - Connie Zaremsky – Database Management
  - Eric Lopert – Data Generation

Questions?