



New Coal Power R&D Goals

Enabling Coal with CCS to be an Affordable, Competitive Option

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National Energy
Technology Laboratory

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Outline

- **Introduction**
 - Purpose
 - 2nd-Generation and Transformational Technologies
 - Timeline for RD&D and Deployment
- **“Market-Based” Goals for 2nd-Generation Coal Power Plants with CCS**
 - Methodology and Scenarios for Goal Setting
 - Market Opportunity for CO₂ Sales to EOR
- **Capture Program Contribution to Targets**

Purpose

- **How can FE R&D help maintain a balanced energy supply for our nation's energy and economic security through use of its abundant domestic coal resources?**
- **Determine cost and performance requirements for future coal power plants to compete with other advanced power generation options**
 - Initially for 2nd-Generation technologies (2025-2030)
 - Looking forward towards Transformational (2035-2040)
- **Evaluate both new coal power plants with CCS and CO₂ capture retrofits of existing coal-fired power plants**
- **Based on market requirements, validate/set new long-term goals for FE's Coal Power R&D Program**

Advanced Coal Power Technologies

Aspects Applicable to Natural Gas

*Today's
IGCC*

Advanced IGCC

*Advanced Pre-
combustion
Capture*

*Integrated Gasification
Fuel Cells (IGFC)*

*Pulse
Combustion*

*3100 F H₂
Turbine*

*Transformational
H₂ Production*

State-of-the-Art

2nd-Generation

Transformational

*Today's
Supercritical
PC*

*Advanced Ultra-
Supercritical (AUSC) PC*

*Advanced Post-combustion
Capture*

AUSC Oxycombustion

*Transformational
CO₂ Separation*

*Chemical
Looping*

*Direct Power
Extraction*

Supercritical CO₂ Cycles

Pressurized Oxycombustion

CCRP Technology Development Timeline

An Aggressive Schedule

2nd-Generation

2020

- R&D Complete
- Major Components Ready for Demonstration

2025

- Initial Deployments of Components and Integrated Systems

2030

- Deployments Attain Full “Nth-of-a-Kind” Potential of R&D Cost and Performance Targets

Transformational

2030

- R&D Complete
- Major Components Ready for Demonstration

2035

- Initial Deployments of Components and Integrated Systems

2040

- Deployments Attain Full “Nth-of-a-Kind” Potential of R&D Cost and Performance Targets

Matrix of Market and Policy Scenarios

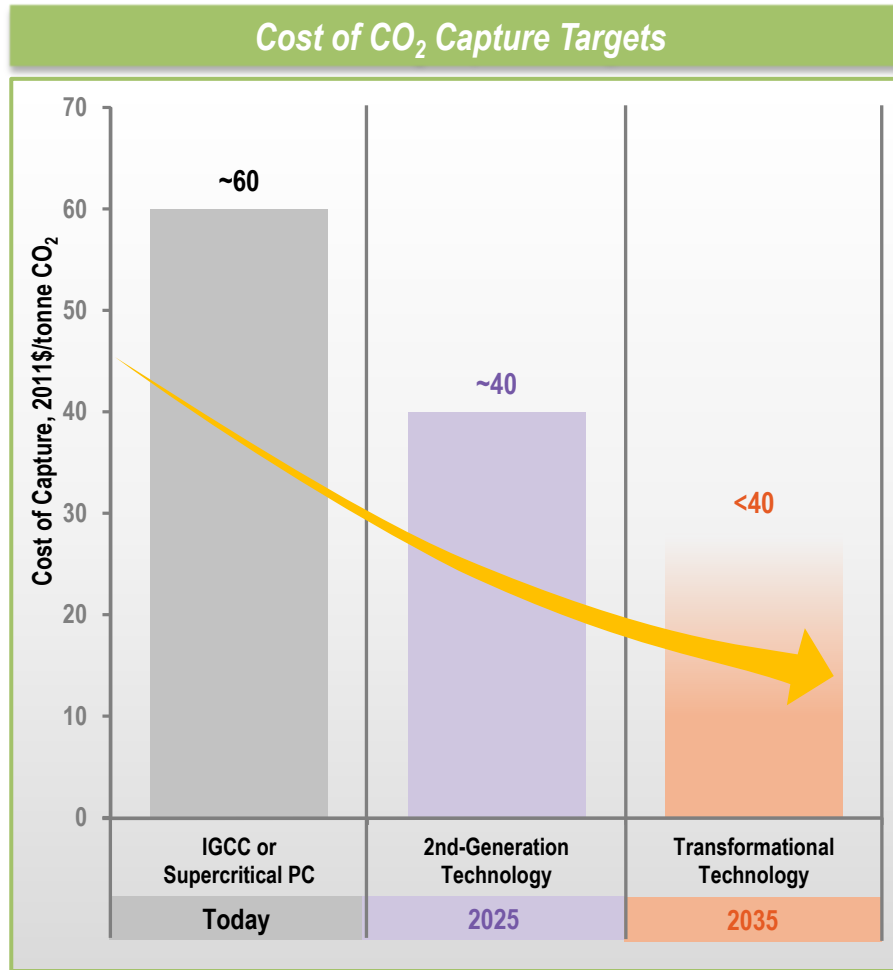
Two Time Horizons Considered for Setting R&D Goals for Coal with CCS

***EOR Revenues Needed
for Coal to Compete?***

		Yes	No
<i>Economy-Wide Regulation-Based Cost for Carbon Emissions?</i>	No	<u>2025-2030</u> 2 nd -Generation Coal Power competes with CO ₂ EOR revenue	
	Yes		<u>2035-2040</u> Transformational Coal Power competes without CO ₂ EOR revenue

Clean Coal Research Program Goals

Driving Down the COE and Cost of CO₂ Capture of Coal Power with CCS

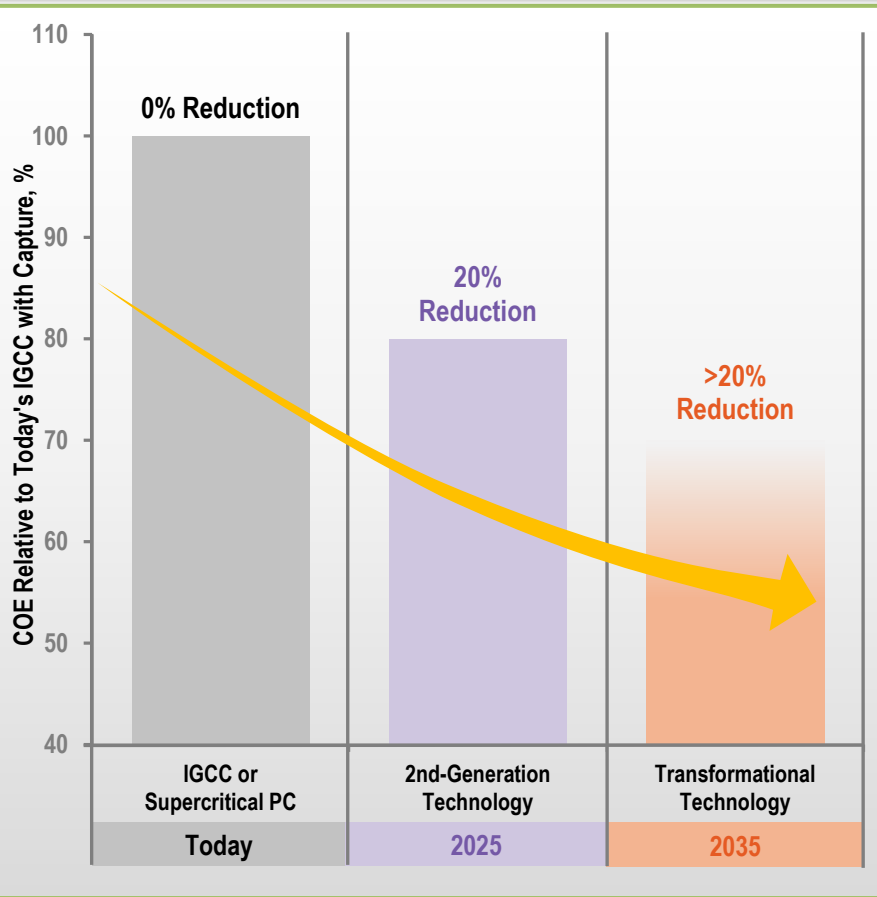


Goals shown are for greenfield plants. Costs are nth-of-a-kind, are for the first year of plant operation, and include compression to 2215 psia but exclude CO₂ transport and storage costs. Today's capture costs are relative to Today's SCPC without CO₂ capture. 2025 and 2035 capture costs are relative to an A-USC PC without CO₂ capture.

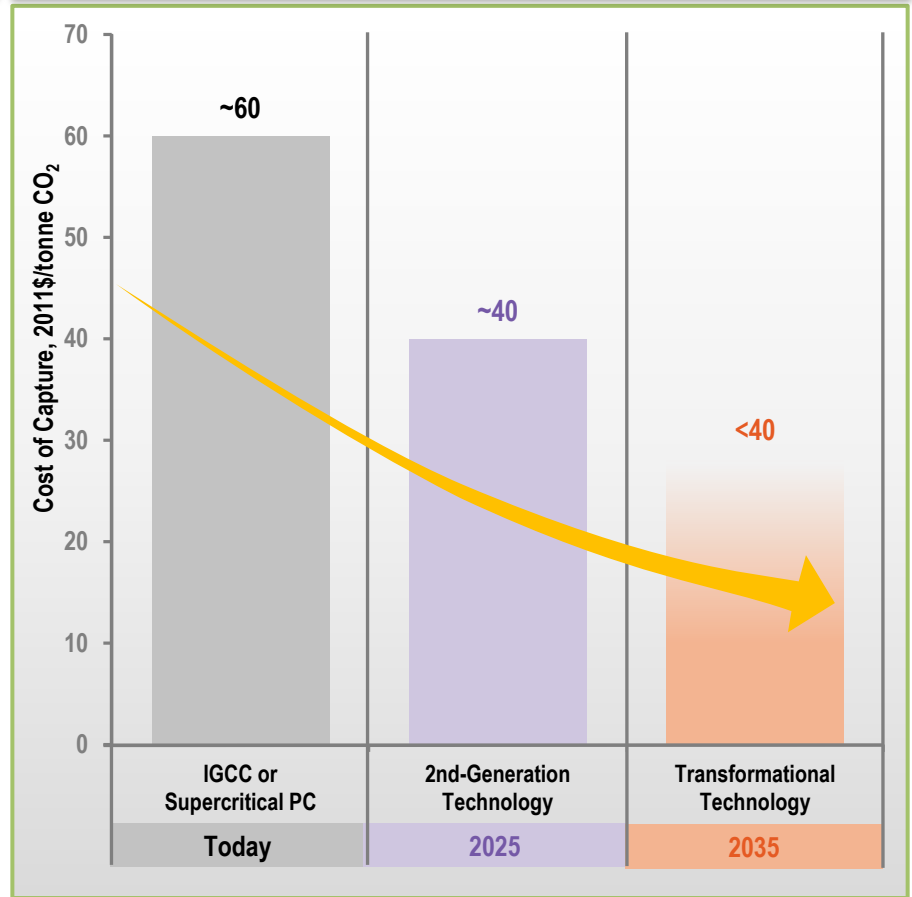
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Driving Down the COE and Cost of CO₂ Capture of Coal Power with CCS

Cost of Electricity Reduction Targets



Corresponding Cost of CO₂ Capture Targets



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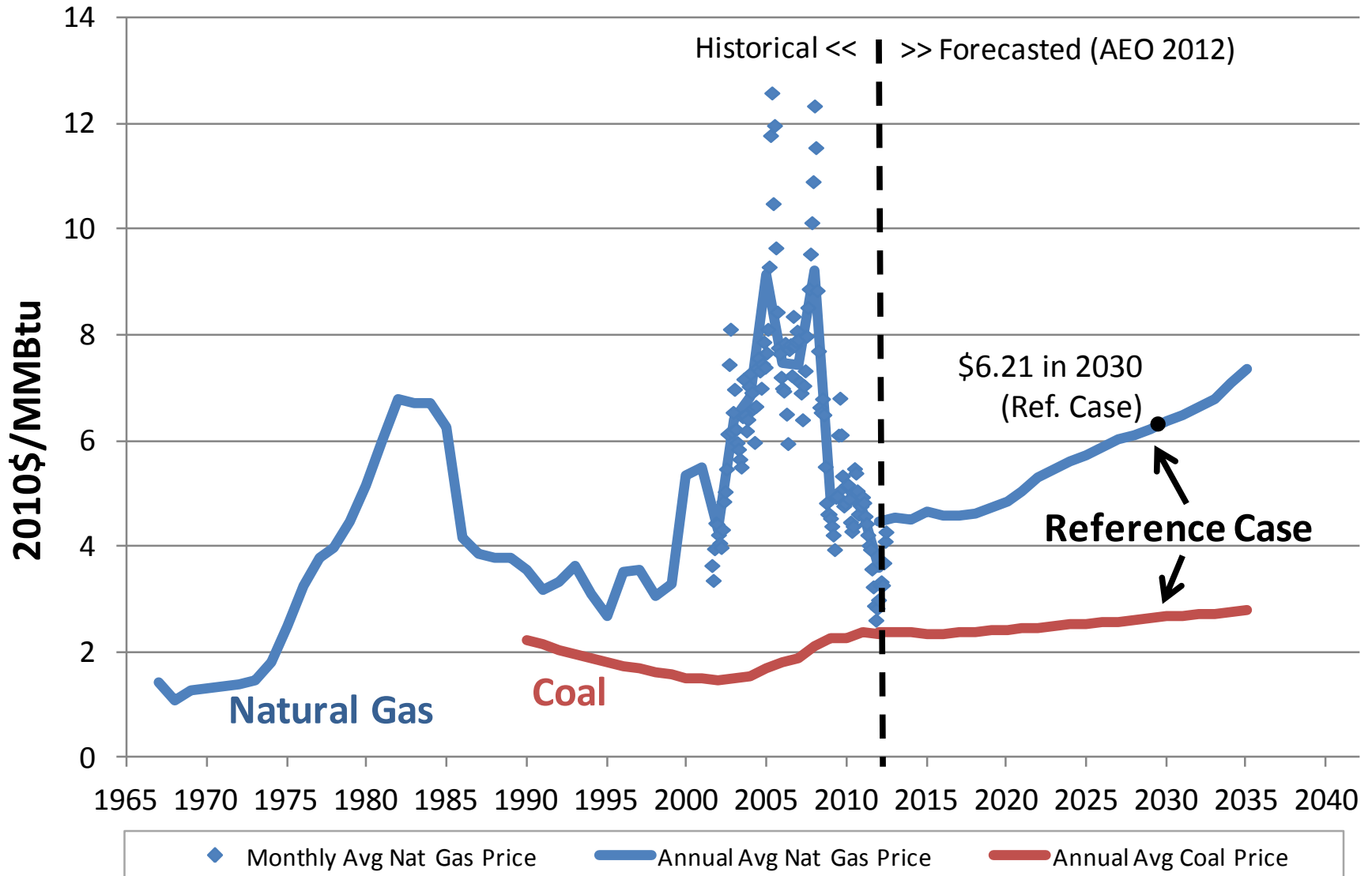
“Market-Based” Goals for 2nd-Generation Coal Power Plants with CCS

2nd Generation Goals

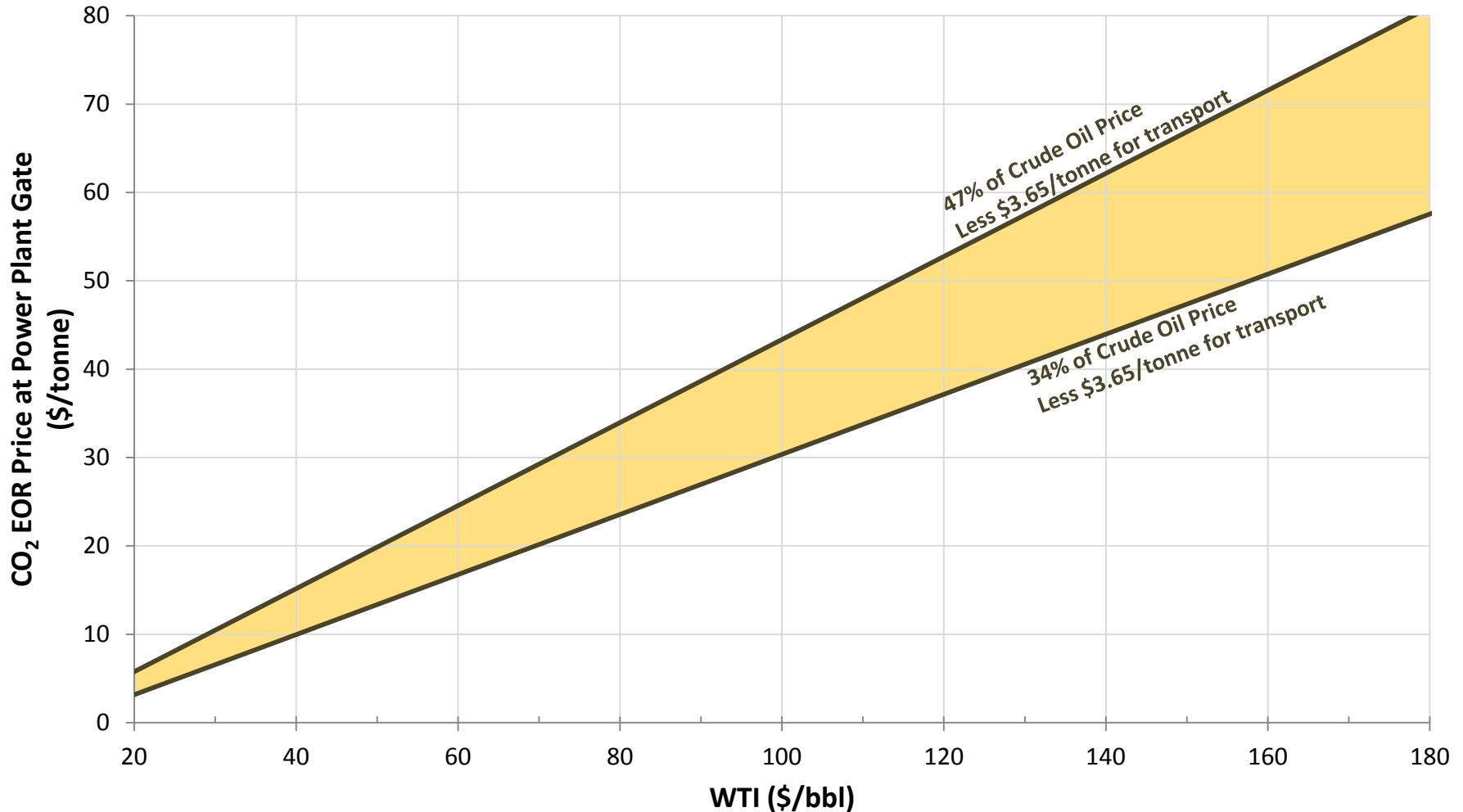
Methodology and Scenarios

- **Data and projections from DOE/EIA's National Energy Modeling System (AEO 2012 version) used to examine competitiveness of 2nd-Generation coal plants with CCS under different scenarios**
 - **NOAK 2nd-Generation coal plants assessed in 2030, Reference Case**
- **Key scenario variables include forecasted natural gas price and oil price**
- **NEMS competes the full array of power generation options, including coal, NGCC, nuclear and renewables, with advancements projected through 2040**
- **Deployment largely driven by levelized cost of electricity (LCOE)**

Delivered Fuel Costs to U.S. Electric Utilities

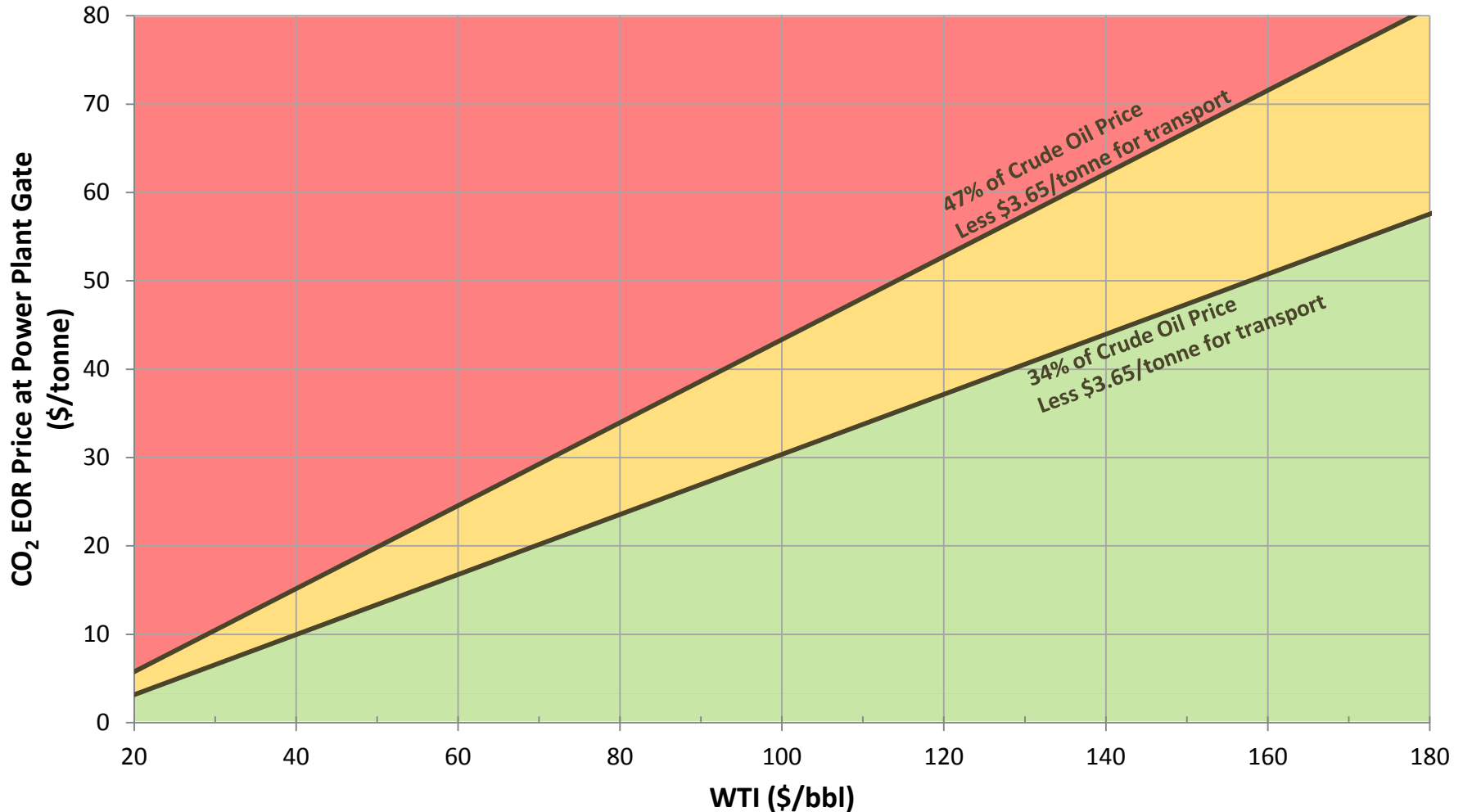


Future Oil Prices May Support EOR CO₂ Prices that are Equal to or Above CO₂ Capture Costs



From 2008 to mid-2011, the average annual new contract price for CO₂ (\$/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 CO₂ 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.

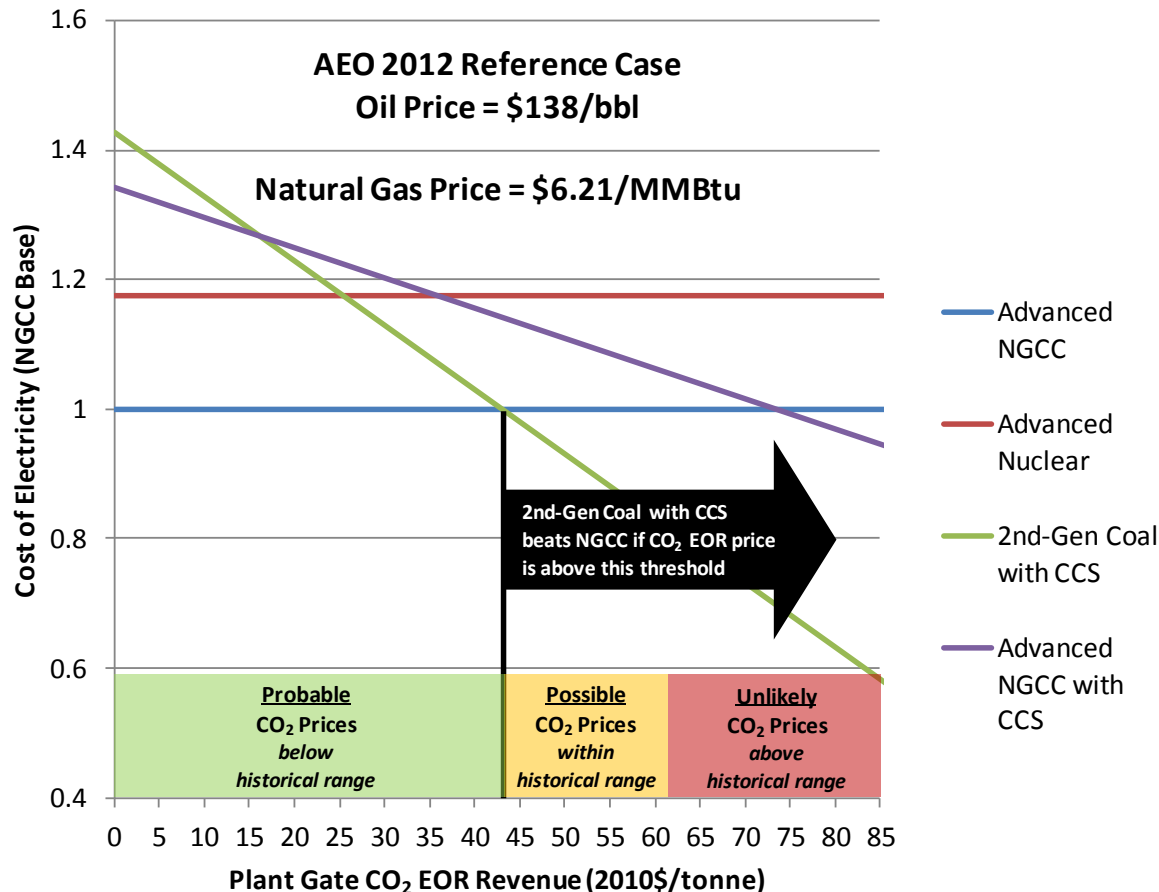
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Effect of CO₂ EOR Revenues on Competitiveness of 2nd Generation Coal Power in 2030 Electricity Market

2nd Generation coal power with CCS is competitive with advanced NGCC (with or without CCS) and advanced nuclear when the price of CO₂ for EOR is at the low end of, or below, its historical range.

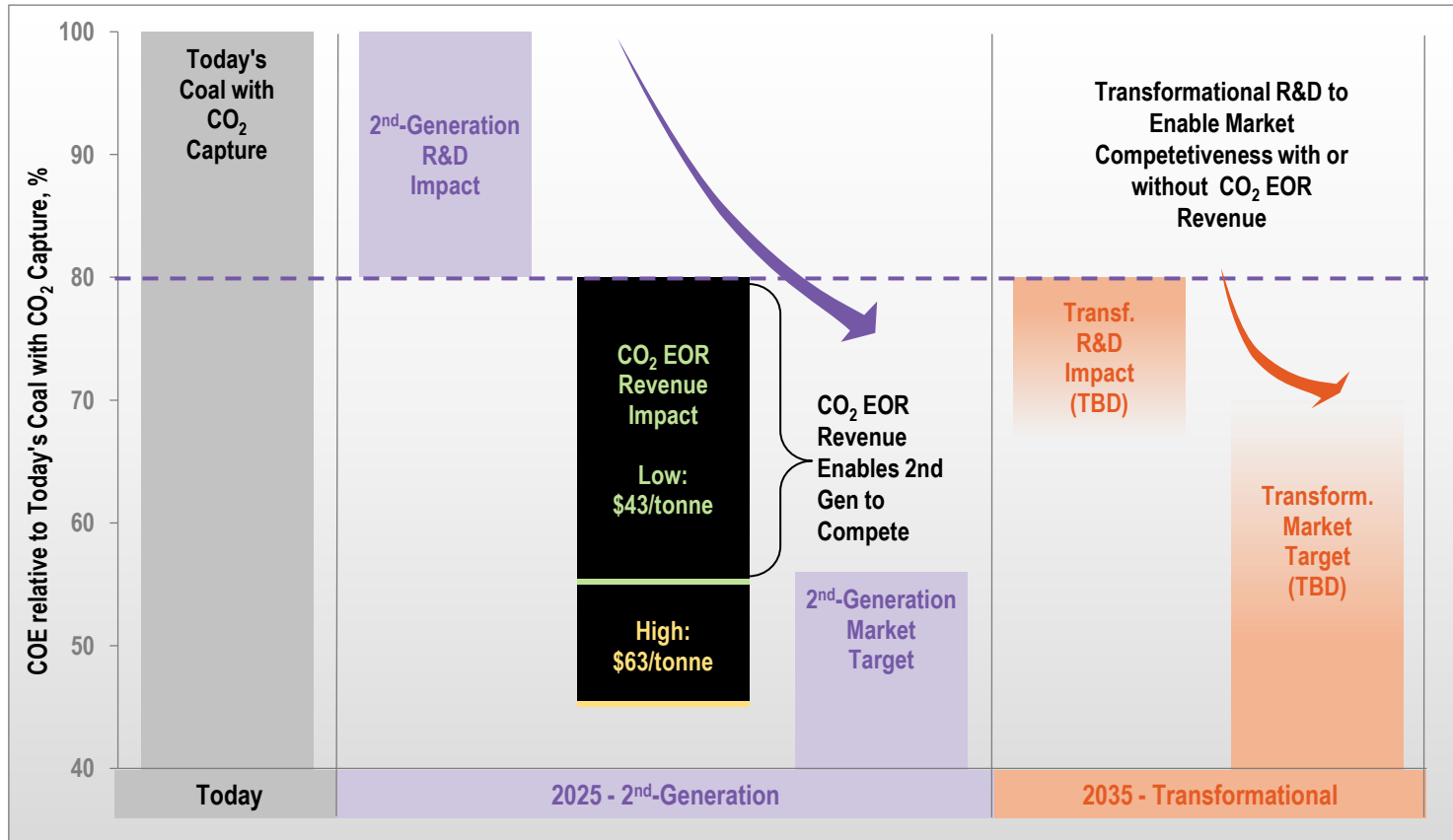


Impact of Further Turbine Advances: Upgrading to an advanced J-Class shifts the required CO₂ EOR revenue for 2nd Gen/NGCC parity from \$43/tonne to \$48/tonne.

Impact of Turbine and Post-Combustion Capture Advances: J-Class NGCC with 2nd Gen post-combustion capture technology would still not result in the lowest cost COE with any CO₂ EOR revenue.

Pathway to Enabling Coal Power with CCS

R&D & CO₂ Utilization for EOR

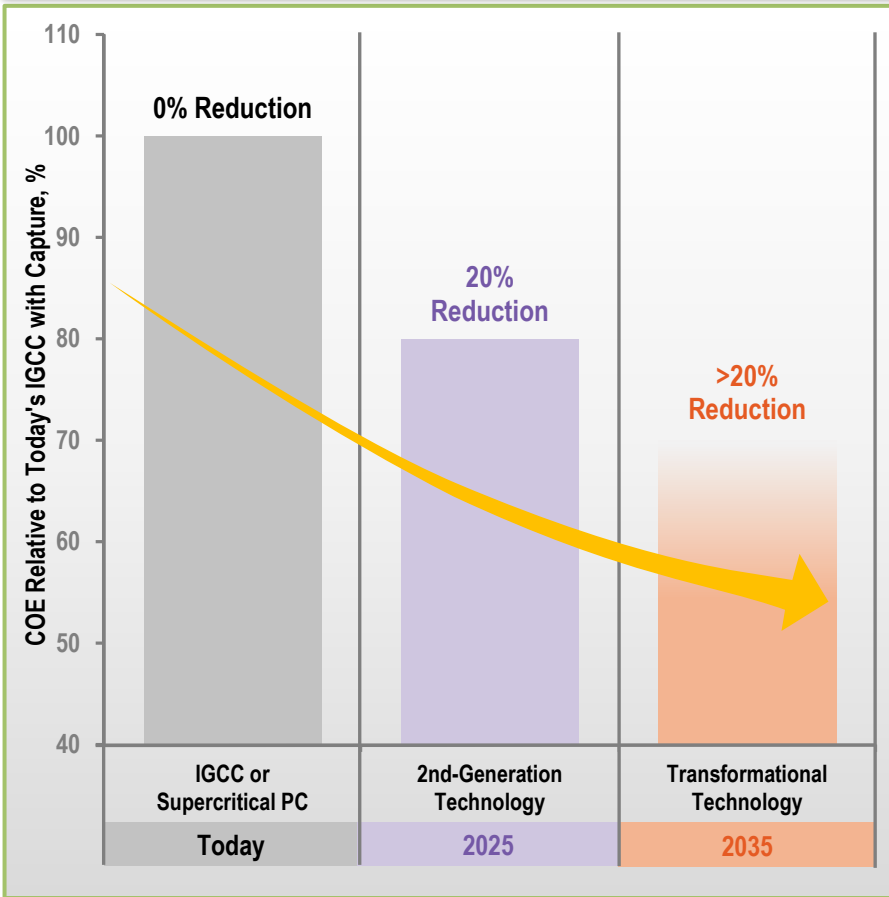


- Costs are nth-of-a-kind, are for the first year of plant operation, and include compression to 2215 psia but exclude CO₂ transport and storage costs.
- CO₂ EOR revenue range of \$43-63/tonne represents plant gate prices and is based on AEO 2012 projected oil price (\$138/bbl in 2030 Reference Case) and range of historical CO₂-to-oil price ratios.
- "2nd-Generation Market Target" based on lowest COE in AEO 2012 for competing baseload technologies, NGCC (Reference case). Market target for Transformational Technologies anticipated to be higher than in 2025 due to higher NG prices and economy-wide price on CO₂ emissions.

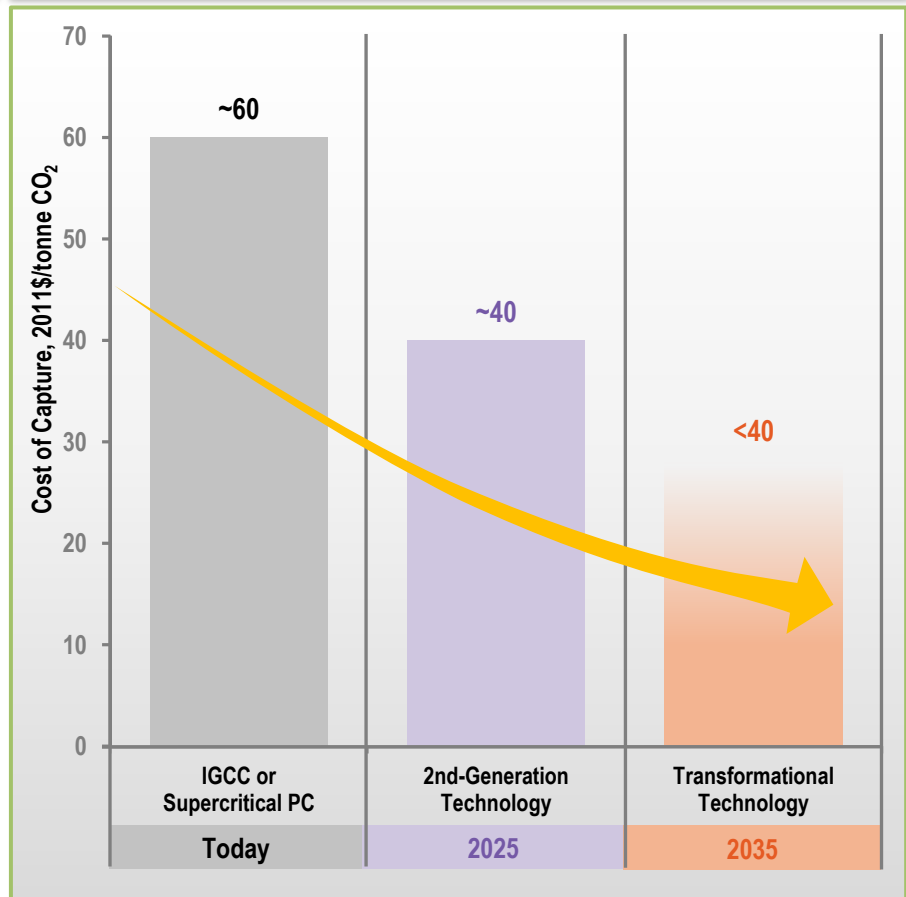
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Cost of Electricity Reduction Targets



Corresponding Cost of CO₂ Capture Targets

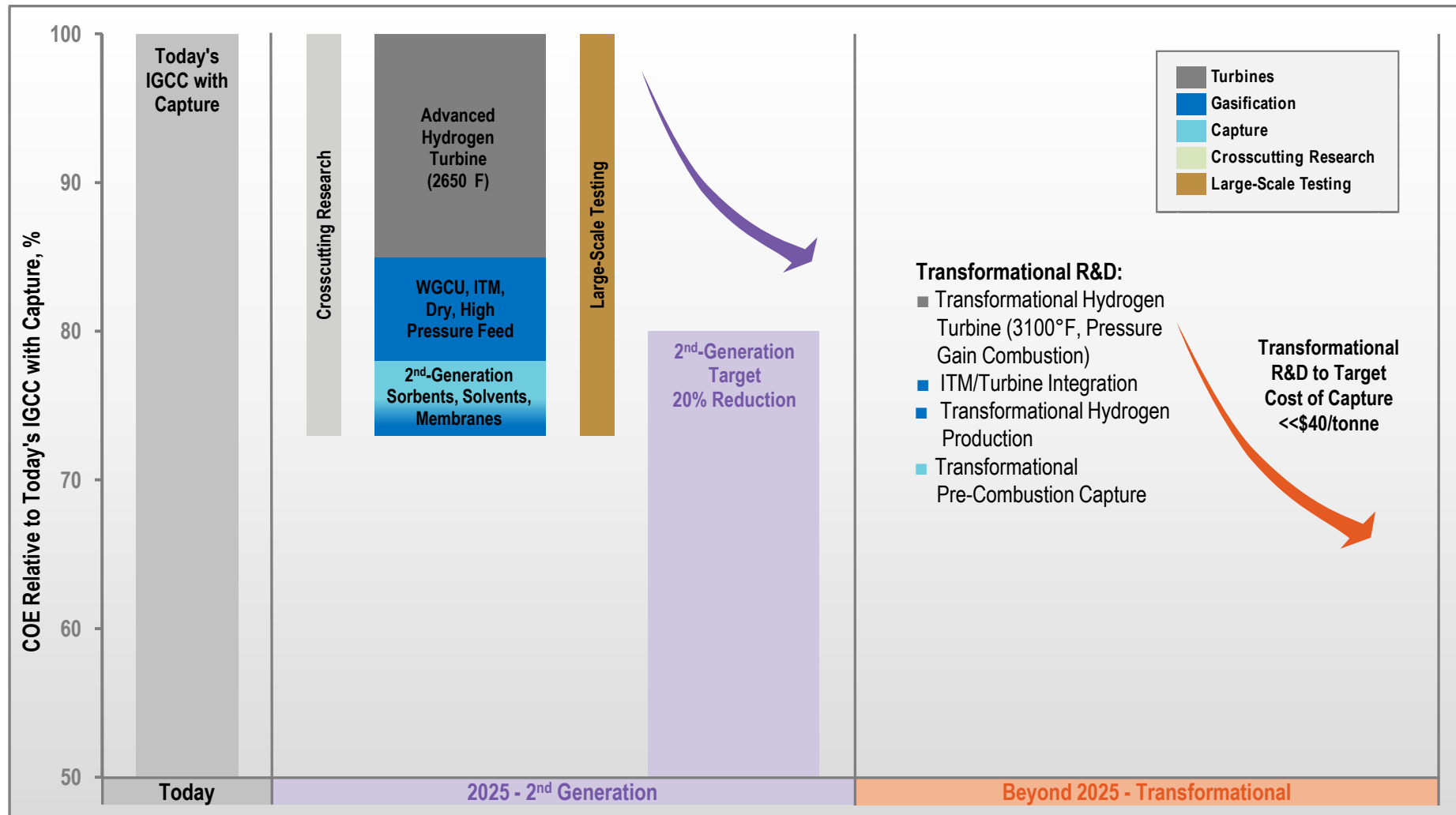


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Capture Program Contribution to 2nd-Generation Targets

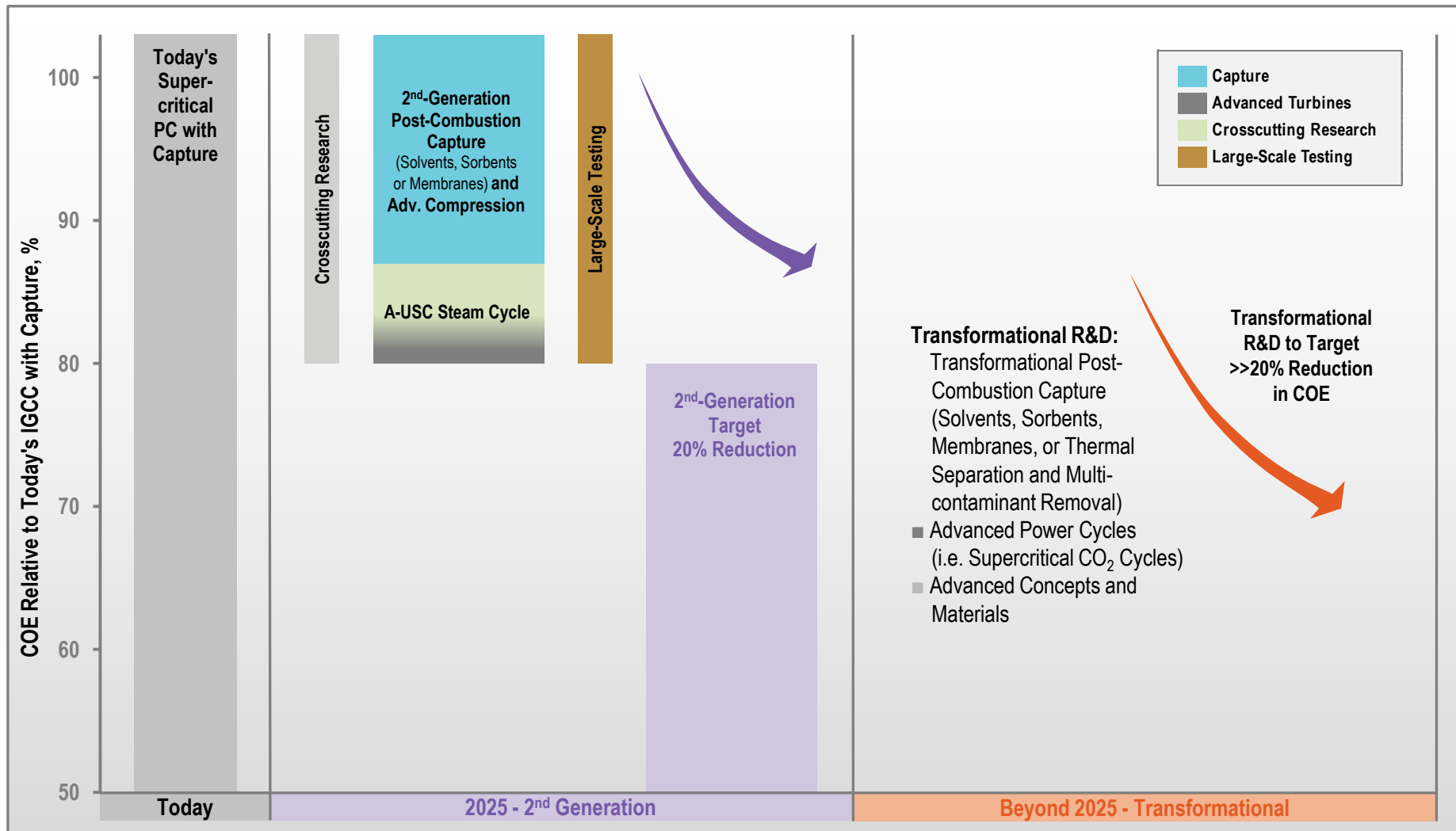
R&D Driving Down the Cost of Electricity

IGCC with Pre-Combustion Capture



R&D Driving Down the Cost of Electricity

Greenfield Post-Combustion Capture Plants

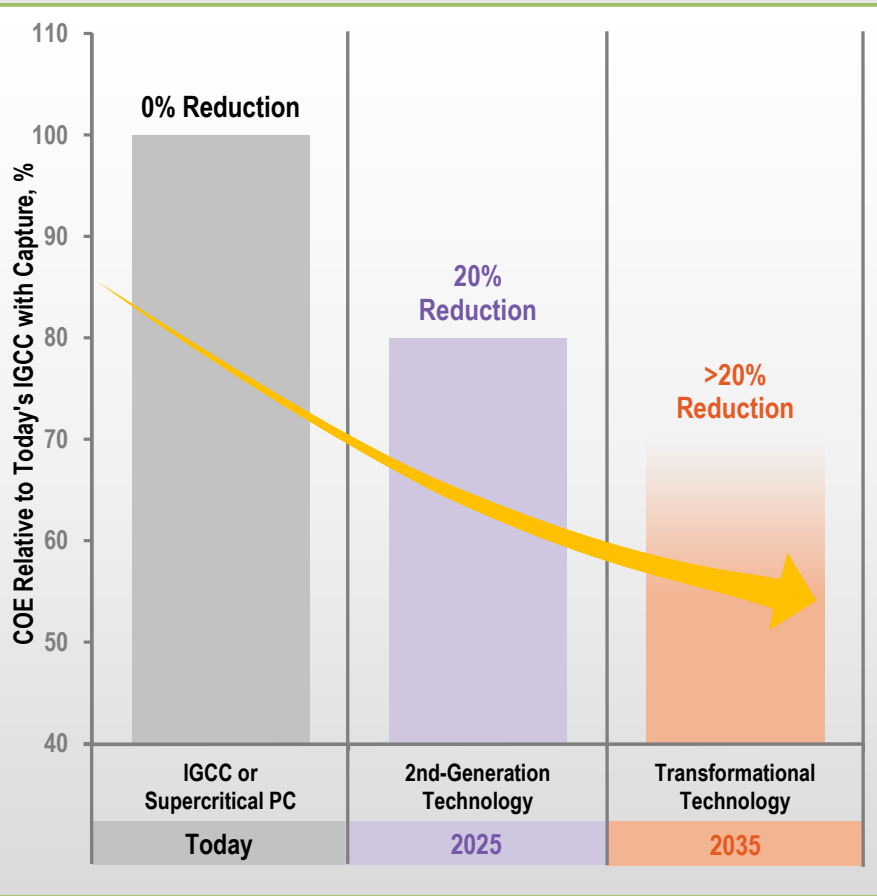


Impact of Goals on CCS Retrofits of Existing Fleet

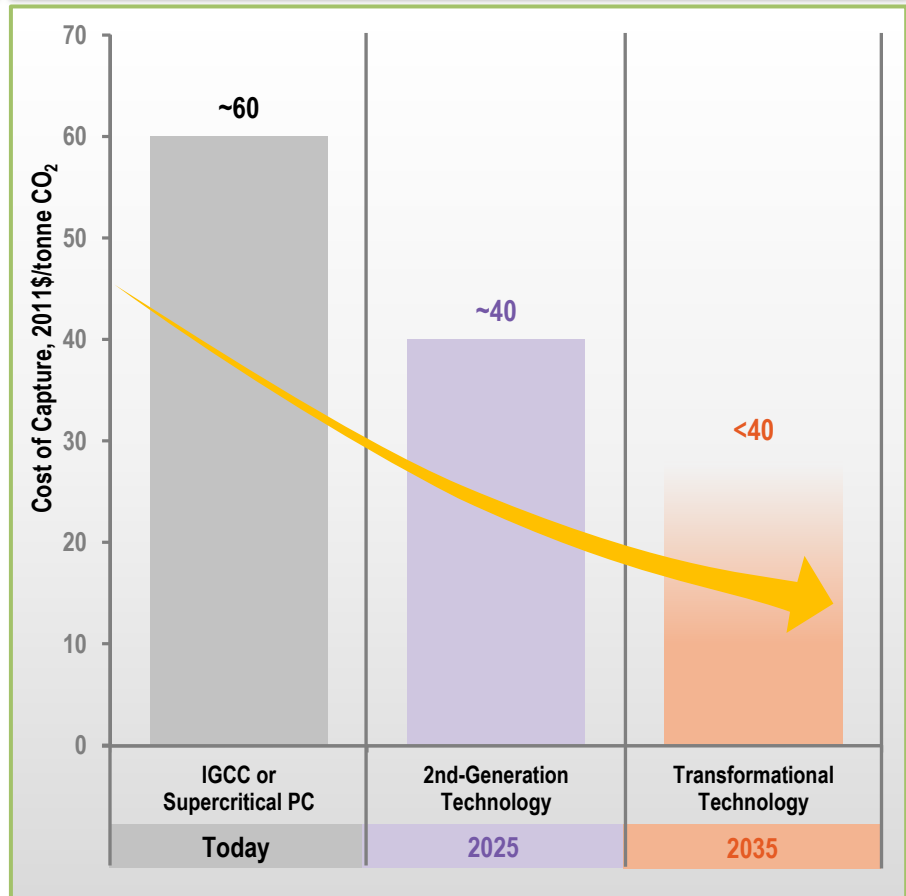
- COE and cost of capture vary for each unit in the existing fleet
- 1. Identify system that meets 2nd-Generation goal for greenfield post-combustion capture plant
- 2. Apply appropriate technologies to example existing plant
- 3. Extrapolate to existing coal-fired power plant fleet
- 4. Assess market competitiveness for entire fleet accounting for effect of plant derate
- Analysis to be presented by M. Matuszewski during Thursday's session on System Studies and Modeling
 - “Economic Feasibility of CO₂ Capture Retrofits for the U.S. Coal Fleet: Impacts of R&D and CO₂ EOR Revenue”

QUESTIONS

Cost of Electricity Reduction Targets



Corresponding Cost of CO₂ Capture Targets



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