Reinhold Environmental Ltd.

2008 NOx-Combustion Round Table & Expo Presentation

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Advanced Coal and CO_2 Capture and Storage for Electricity Generation

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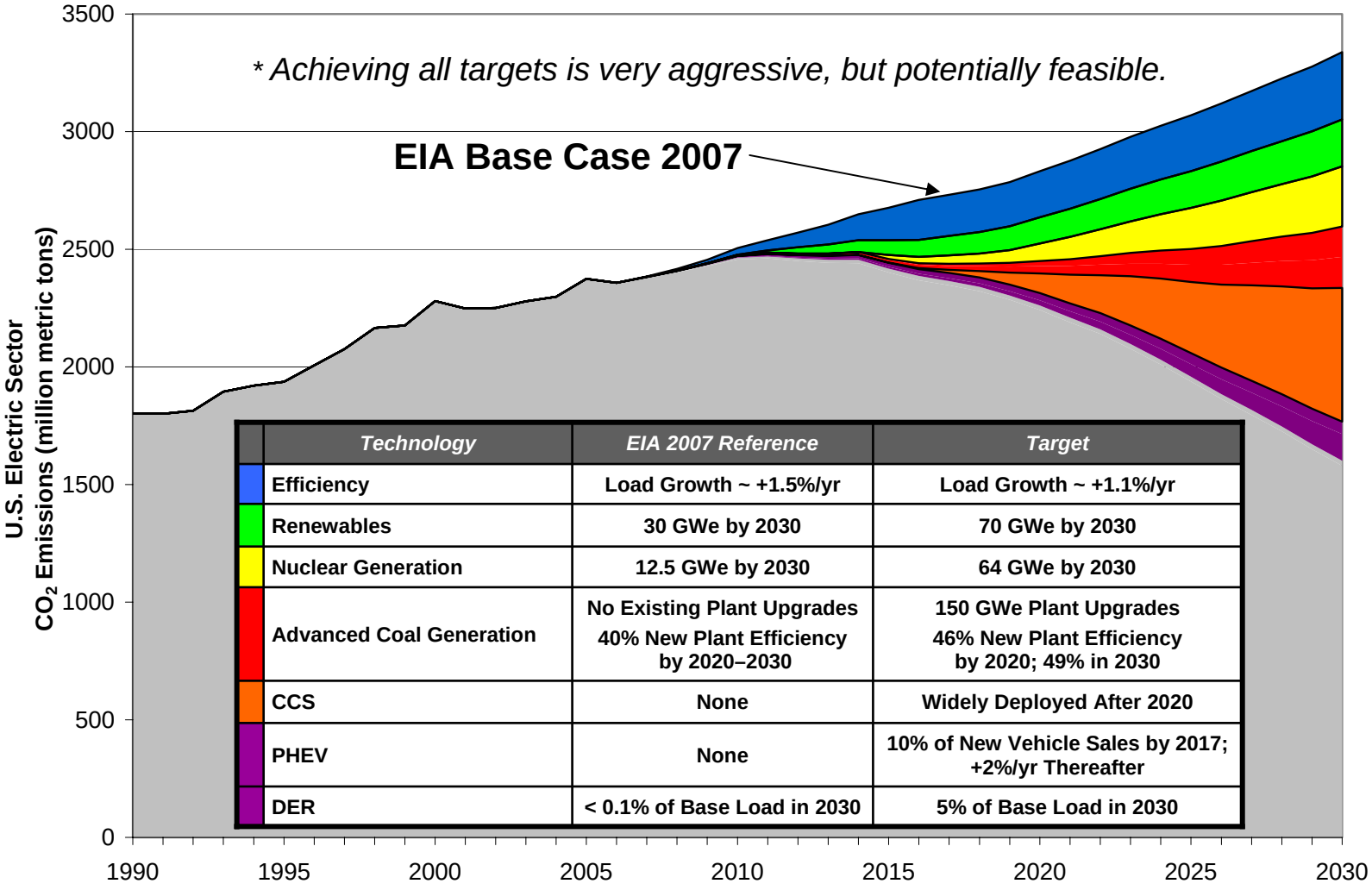
OVERVIEW

- The Promise of CO_2 Capture and Storage (CCS)
  - The Role of advanced coal and CCS for Electricity Generation
- The Challenge
  - Status of CCS from Coal-fired Power Plants
  - RD&D Needs to make Advanced Coal with CCS commercially available, affordable, acceptable
- The Payoff
  - Impact of technology in reducing cost of meeting climate goal

The Promise of CCS
CO_2 Reductions …Technical Potential* (U.S.)



Technology	EIA 2007 Reference	Target
Efficiency	Load Growth ~ +1.5%/yr	Load Growth ~ +1.1%/yr
Renewables	30 GWe by 2030	70 GWe by 2030
Nuclear Generation	12.5 GWe by 2030	64 GWe by 2030
Advanced Coal Generation	No Existing Plant Upgrades 40% New Plant Efficiency by 2020–2030	150 GWe Plant Upgrades 46% New Plant Efficiency by 2020; 49% in 2030
CCS	None	Widely Deployed After 2020
PHEV	None	10% of New Vehicle Sales by 2017; +2%/yr Thereafter
DER	< 0.1% of Base Load in 2030	5% of Base Load in 2030

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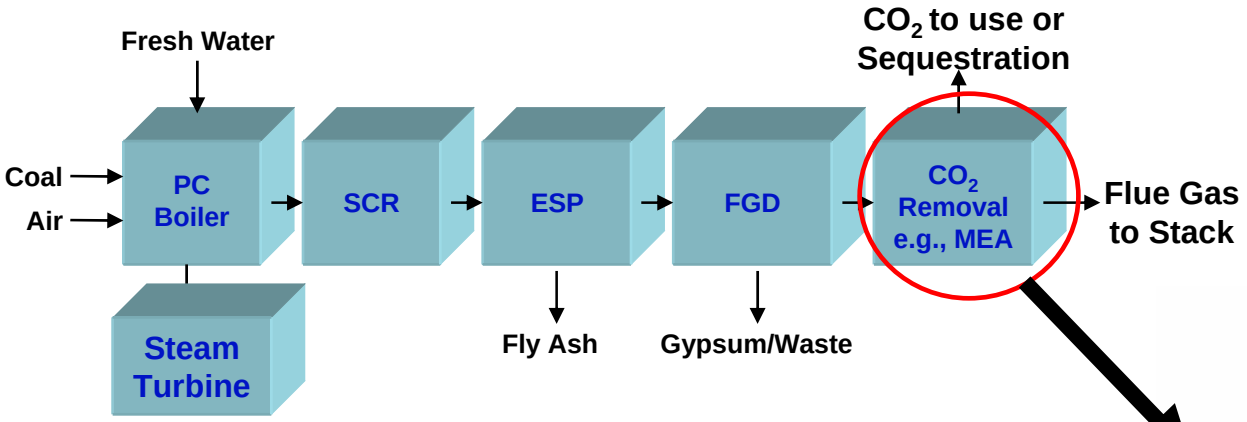
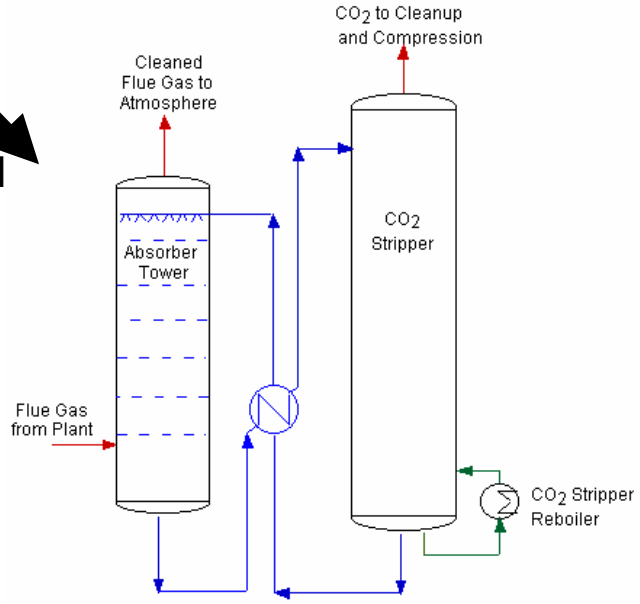
CO_2 Capture Can Be Done Today, But….

- It would increase the cost of electric power from coal significantly
- EPRI's current estimates
  - Cost of power from a pulverized coal plant with post-combustion capture would be 60-80% higher
  - Cost of power from an IGCC with pre-combustion capture would be 40-50% higher (but IGCCs start out with a higher cost, so won't necessarily be cheapest option with CCS)
  - Cost of oxy-combustion more difficult to estimate with certainty at this stage of development but overall cost of power probably similar to PC + post combustion capture
- Luckily, EPRI also estimates that with a concerted RD&D effort, the cost impact of CCS could decrease dramatically

The Challenge
Pulverized Coal with CO_2 Capture—Integration Issues



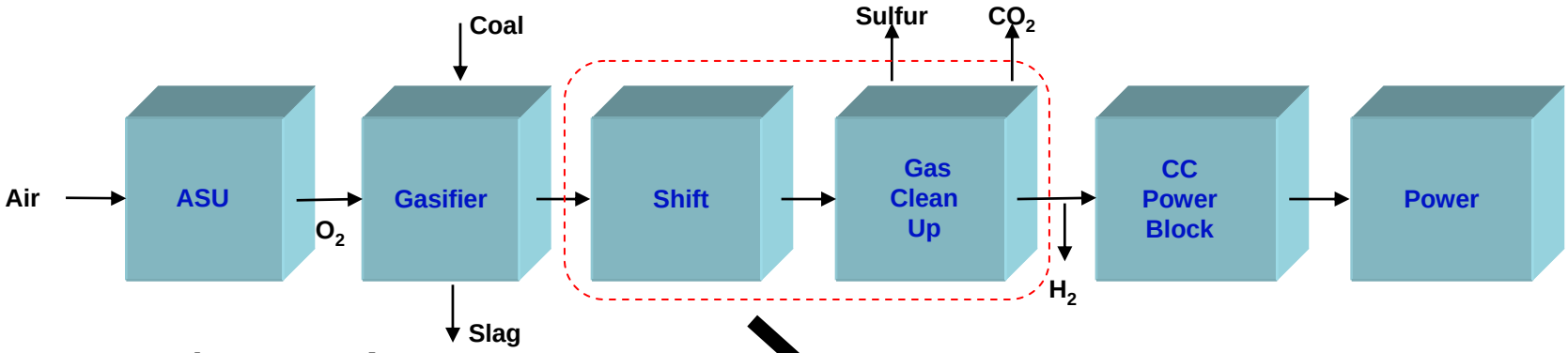
Output Penalty: Up to 30%



- Amine processes commercially available at relatively small scale; considerable re-engineering and scale-up needed (ultra-low inlet SO_2 and NO_2 also required)
- Steam extraction for solvent regeneration reduces flow to low-pressure turbine; significant operational impact
- Maximizing output and efficiency requires optimal heat integration
- Plot space requirements significant; back-end at existing plants often already crowded by other emission controls

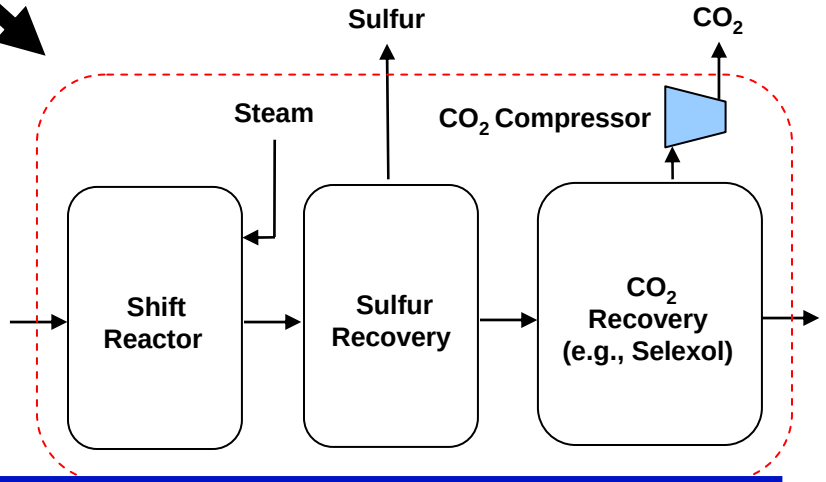
CO_2 Capture = $, Space, Ultra-Low SO_2, and Lots of Energy

The Challenge
IGCC with CO_2 Capture



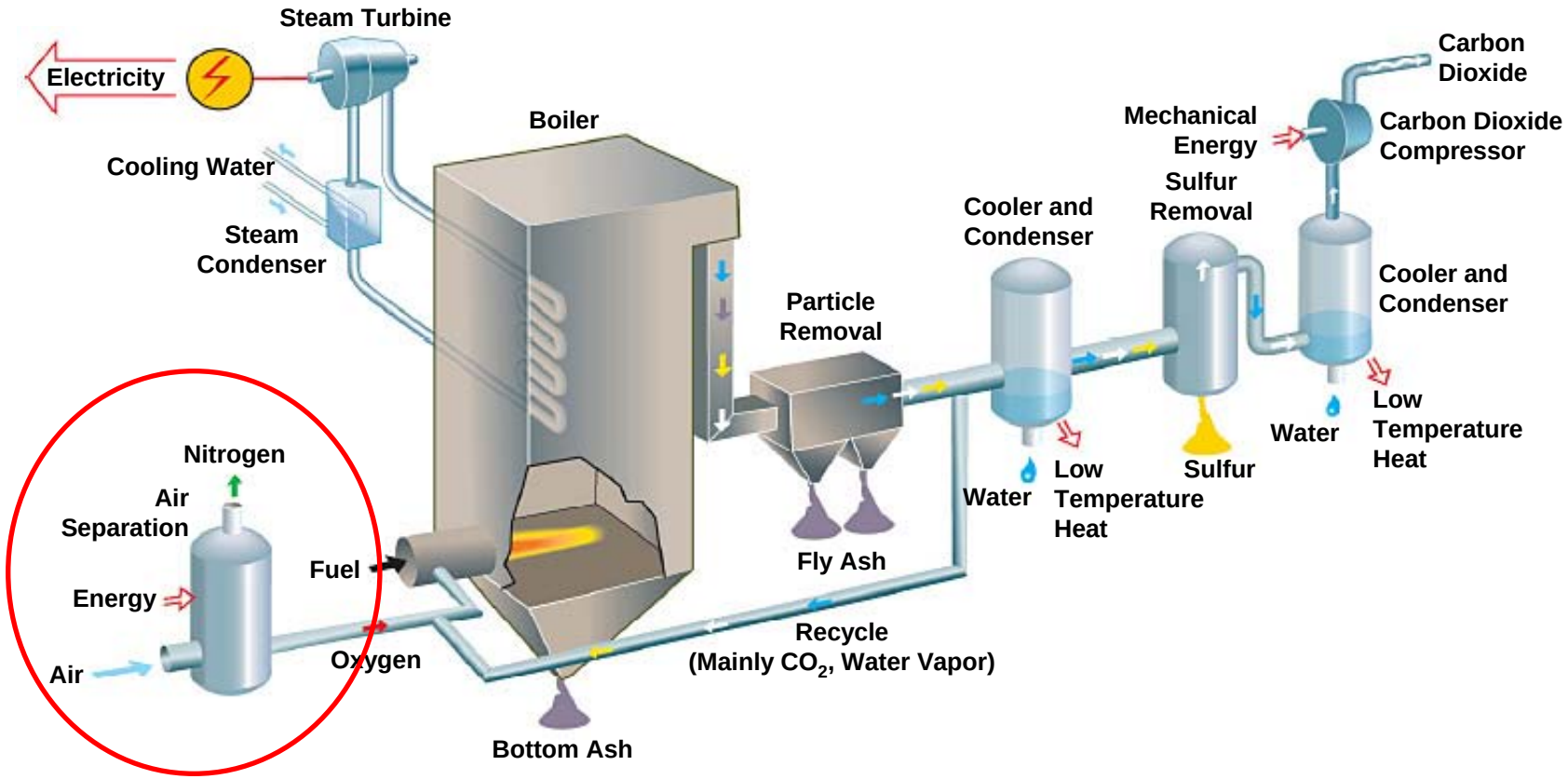
CO_2 Capture/Integration Issues

- Plot space and water demand for water-gas shift reactor; needs vary by gasifier type
- Equipment design given different syngas composition and heating value
- Little experience with H_2-firing gas turbines
- Need for new capture-optimized reference plant designs



CO_2 Capture = $, Space, Shift, H_2 Firing, CO_2 Removal, Energy

The Challenge
Another Approach for Pulverized Coal and Fluid-Bed Plants: Oxy-Combustion Capture



Significant Energy & Capital Required for O_2 Production

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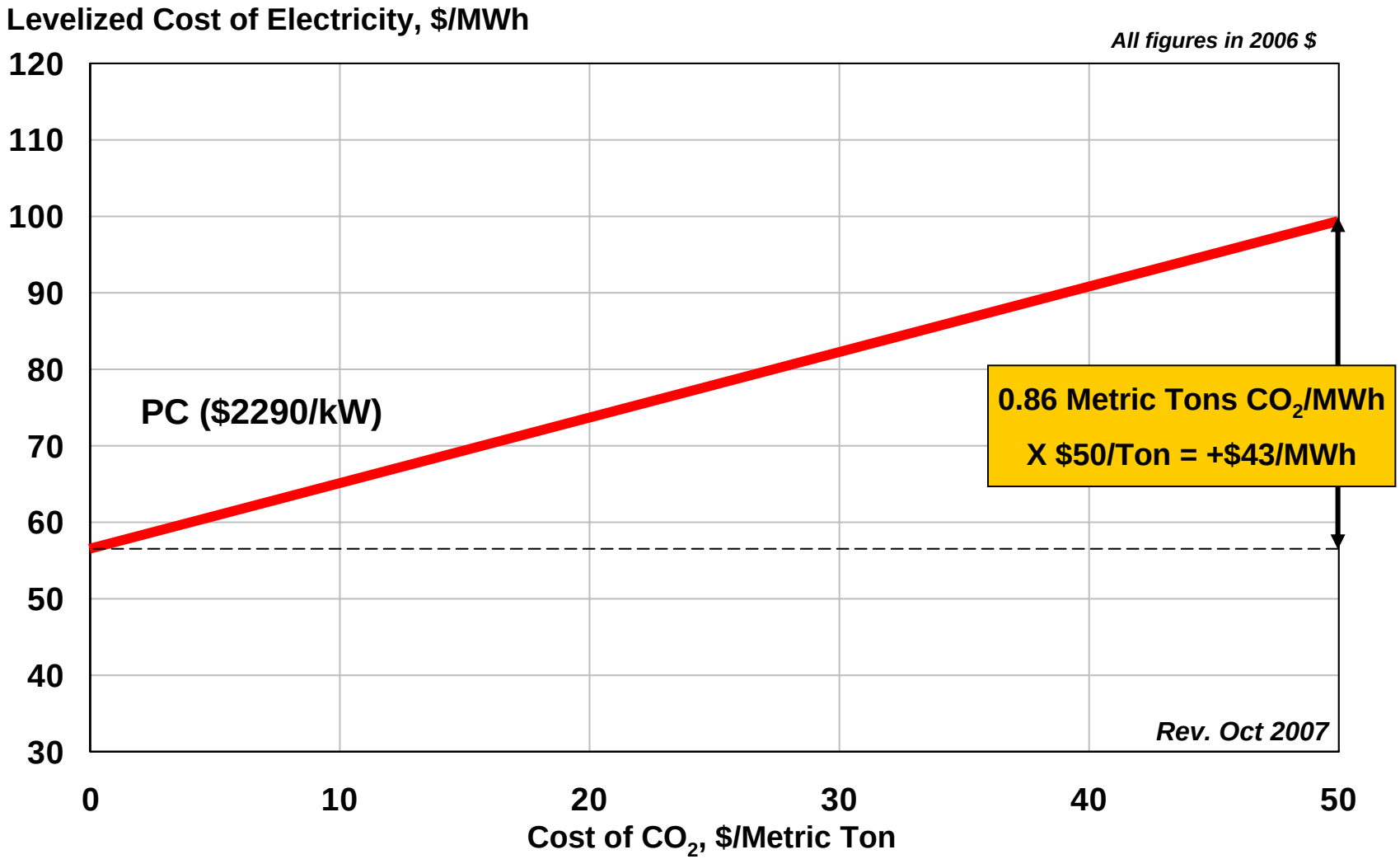
Pulverized Coal Combustion 2010–2015



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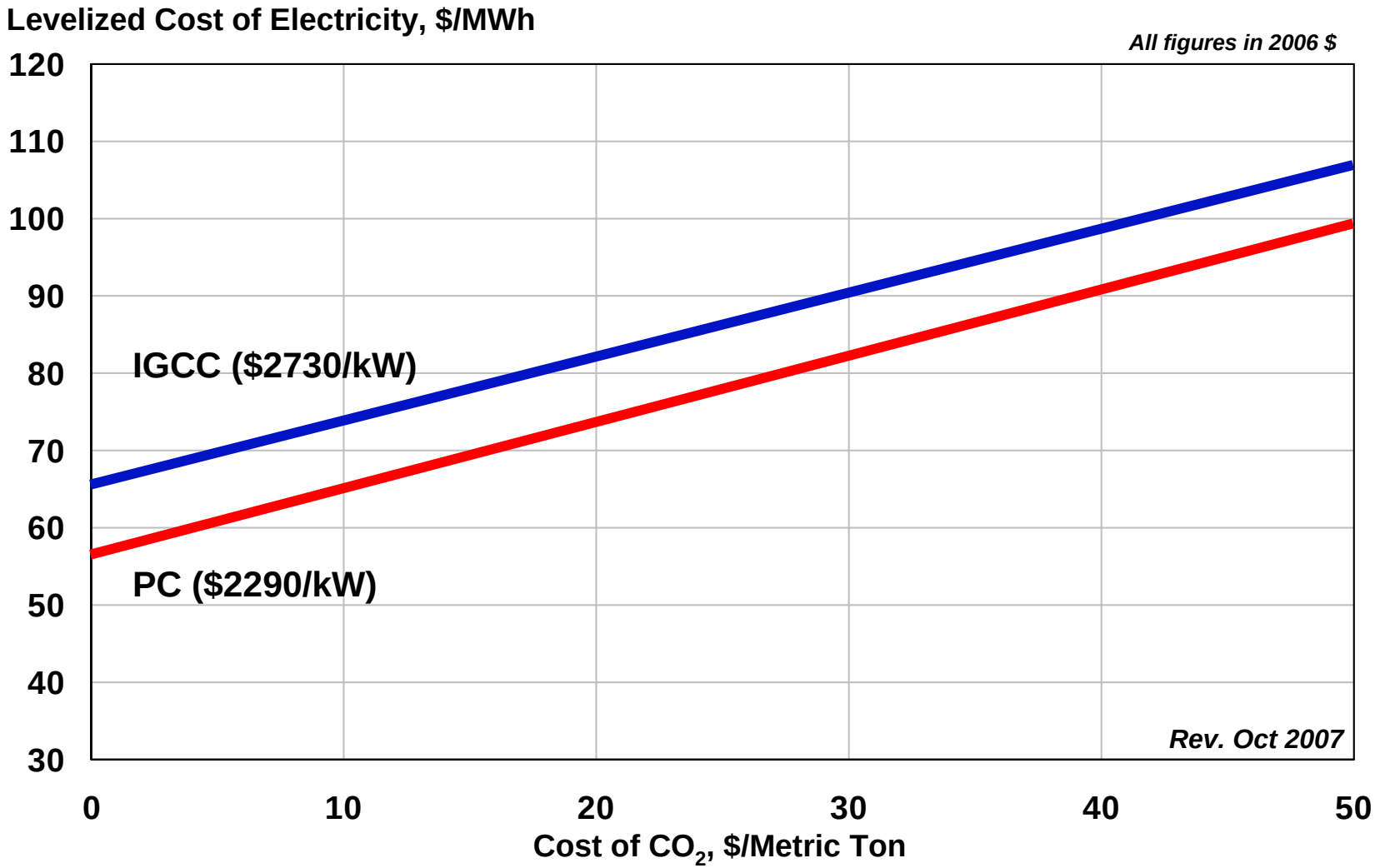
Comparison of PC and IGCC 2010–2015



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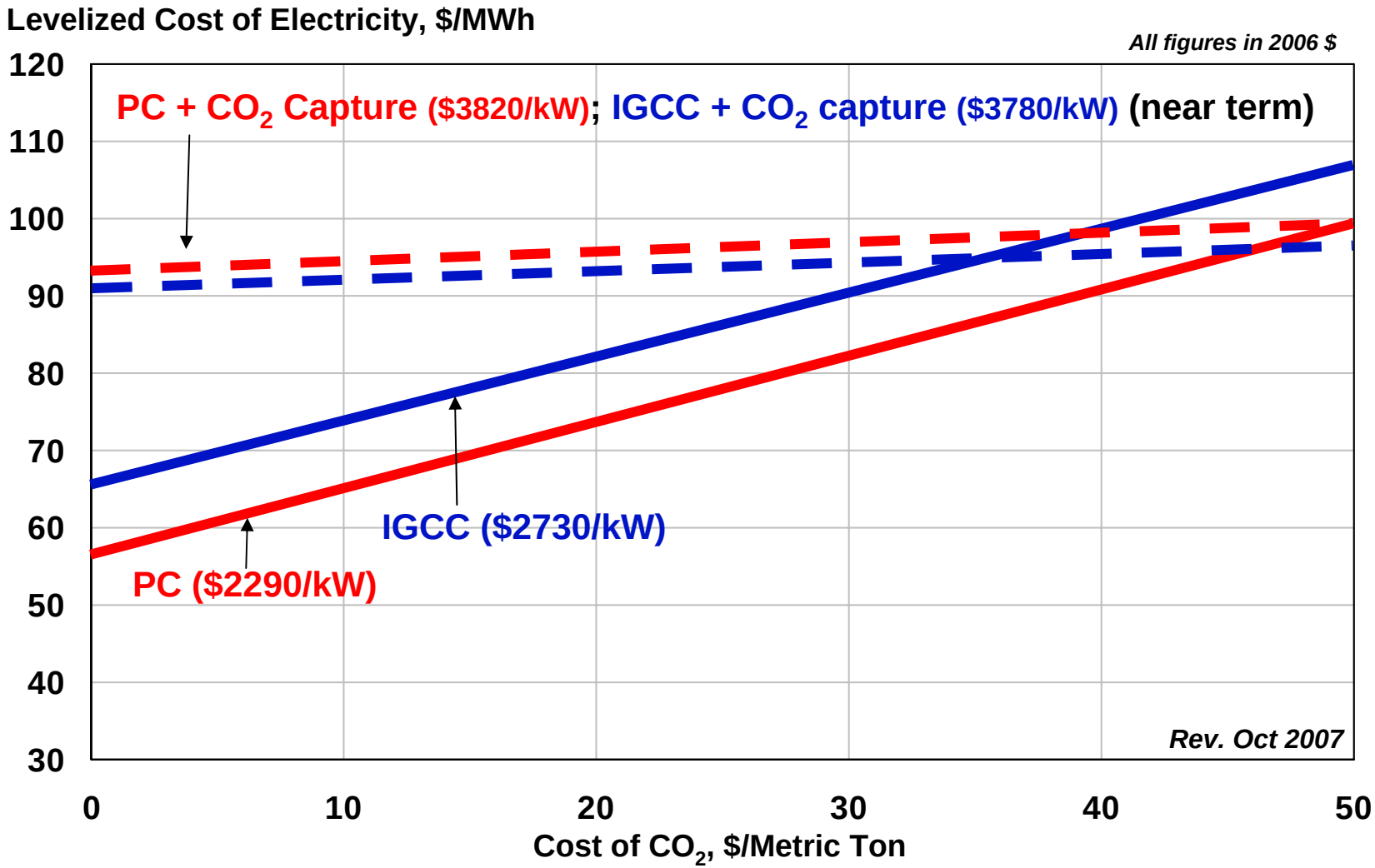
Integrated Gasification Combined Cycle, Pulverized Coal with CO_2 Capture



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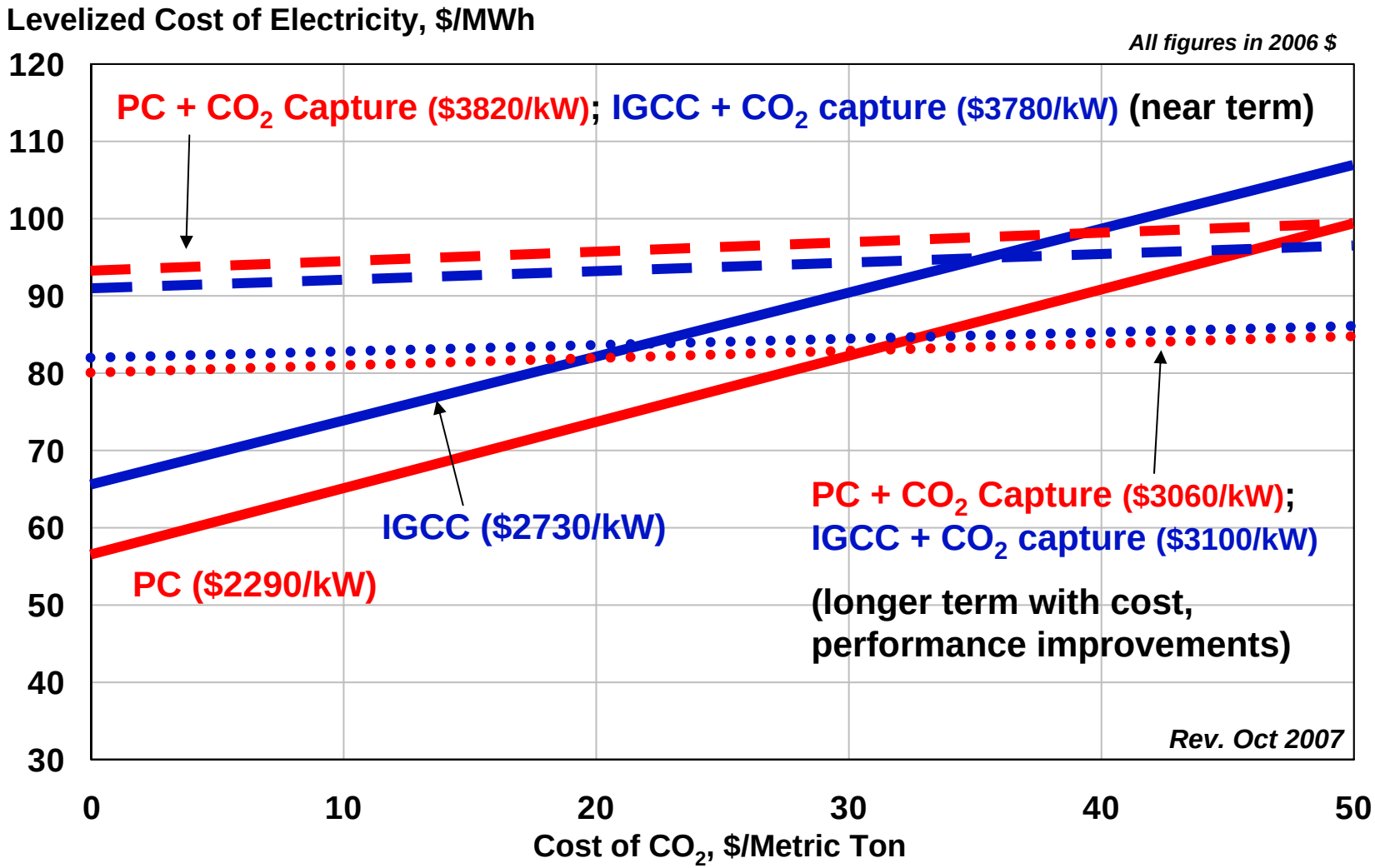
Impact of Anticipated Cost, Performance Improvements on PC, IGCC with CO_2 Capture



The Challenge
Developing a *full portfolio* of Advanced Coal with CCS Technologies

Full Portfolio - Four major technology efforts related to CO_2 emissions reduction from coal-based power systems must be undertaken:

1. Increased efficiency and reliability of integrated gasification combined cycle (IGCC) power plants
2. Increased thermodynamic efficiency of pulverized-coal (PC) power plants
3. Improved technologies for capture of CO_2 from coal combustion- and gasification-based power plants
4. Reliable, acceptable technologies for monitoring long-term storage of CO_2

Identification of mechanisms to share RD&D financial and technical risks and to address legal and regulatory uncertainties must take place as well.

RD&D Funding Needs for Advanced Coal Power Generation Technologies with CO_2 Capture

(Reference Sept 7,2007 Testimony S Dalton House Select Comm. on Energy Independence & Global Warming)

	2008–2012	2013–2017	2018–2022	2023–2027	2028–2032
Total Estimated RD&D Funding Needs *(Public + Private Sectors)*	$830M/yr	$800M/yr	$800M/yr	$620M/yr	$400M/yr
Advanced Combustion, CO_2 Capture	25%	25%	40%	80%	80%
Integrated Gasification Combined Cycle (IGCC), CO_2 Capture	50%	50%	40%		
CO_2 Storage	25%	25%	20%	20%	20%

SUMMARY

- Advanced coal power plant technologies with integrated CO_2 capture and storage (CCS) will be crucial to lowering electric power sector CO_2 emissions.

- The availability of advanced coal power and integrated CCS and of other technologies could dramatically reduce the projected increases in the cost of electricity under a carbon constraint.

- However, a sustained RD&D program at heightened levels of investment and the resolution of legal and regulatory unknowns for long-term geologic CO_2 storage will be required to achieve the promise of advanced coal with CCS technologies.

QUESTIONS?

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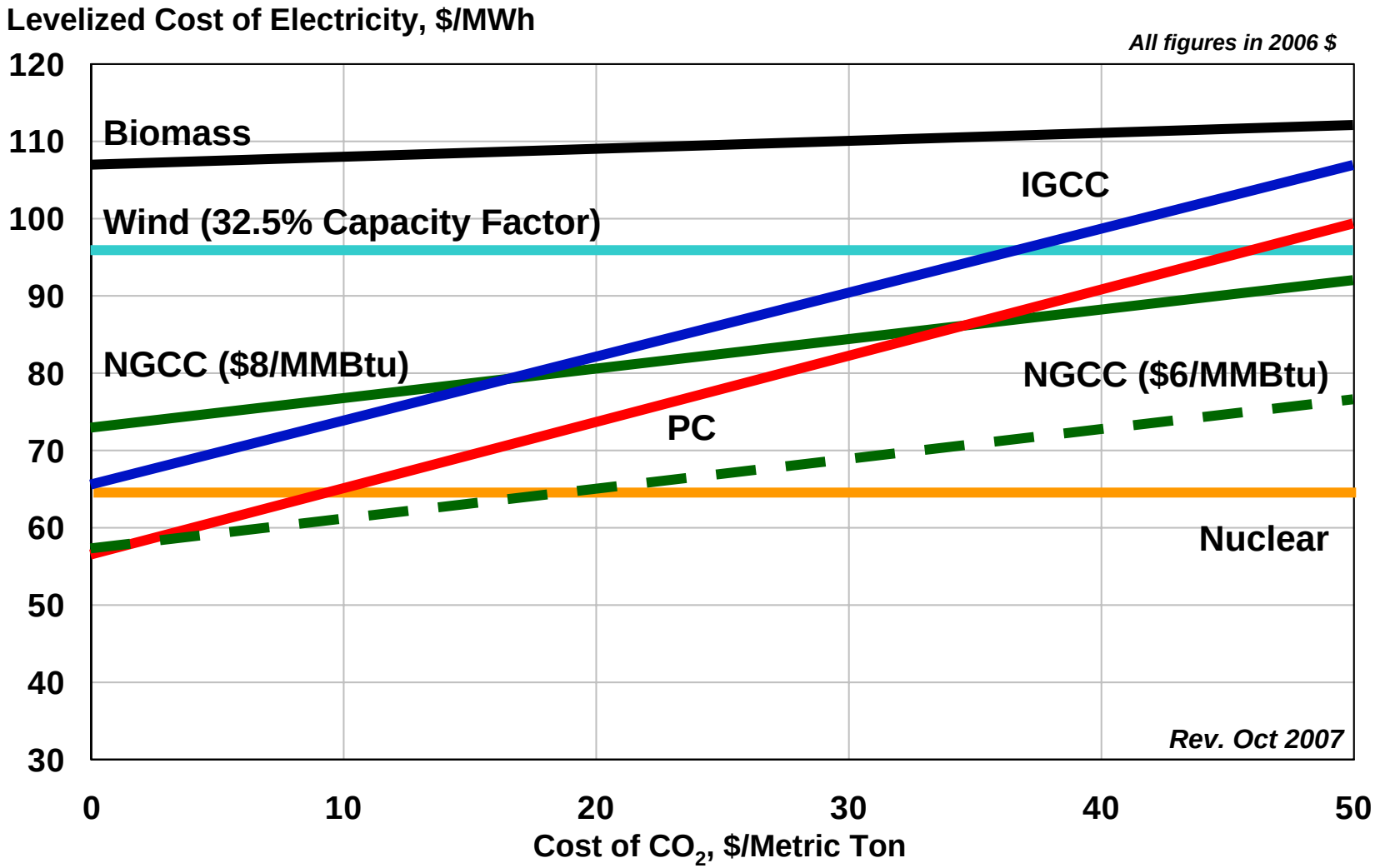
Background Slides

Comparative Levelized Costs of Electricity 2010–2015



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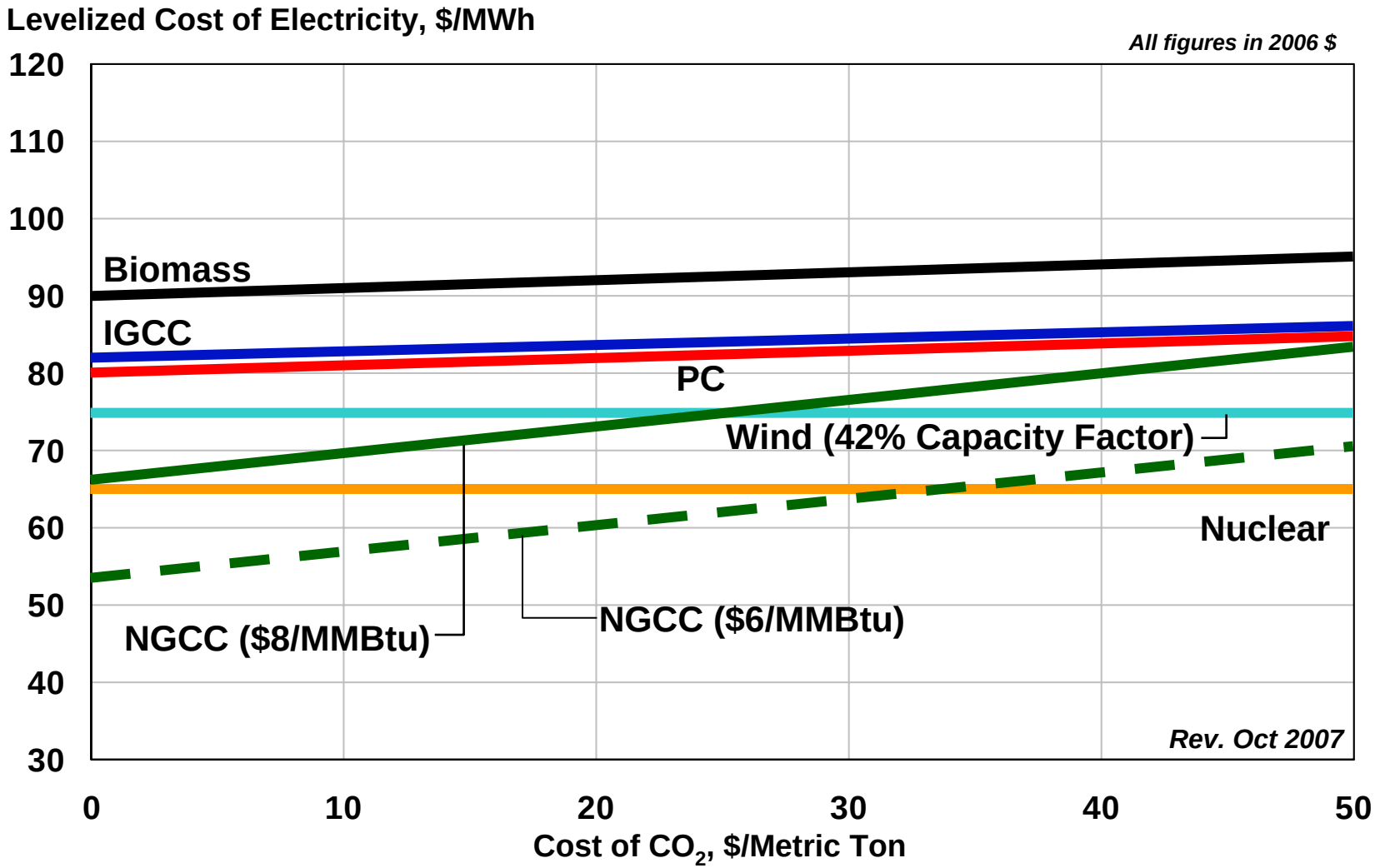
Comparative Levelized Costs of Electricity 2020–2025



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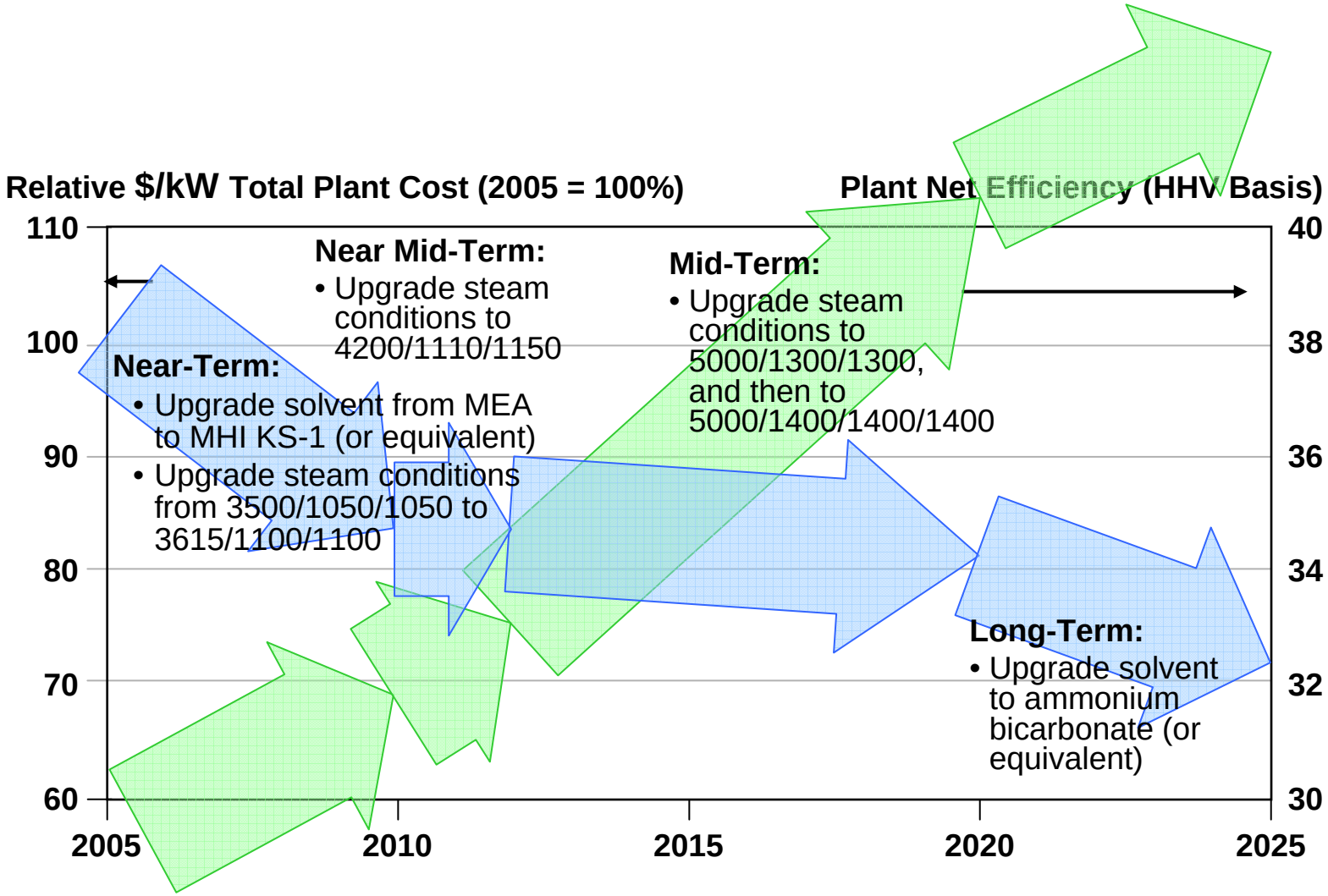
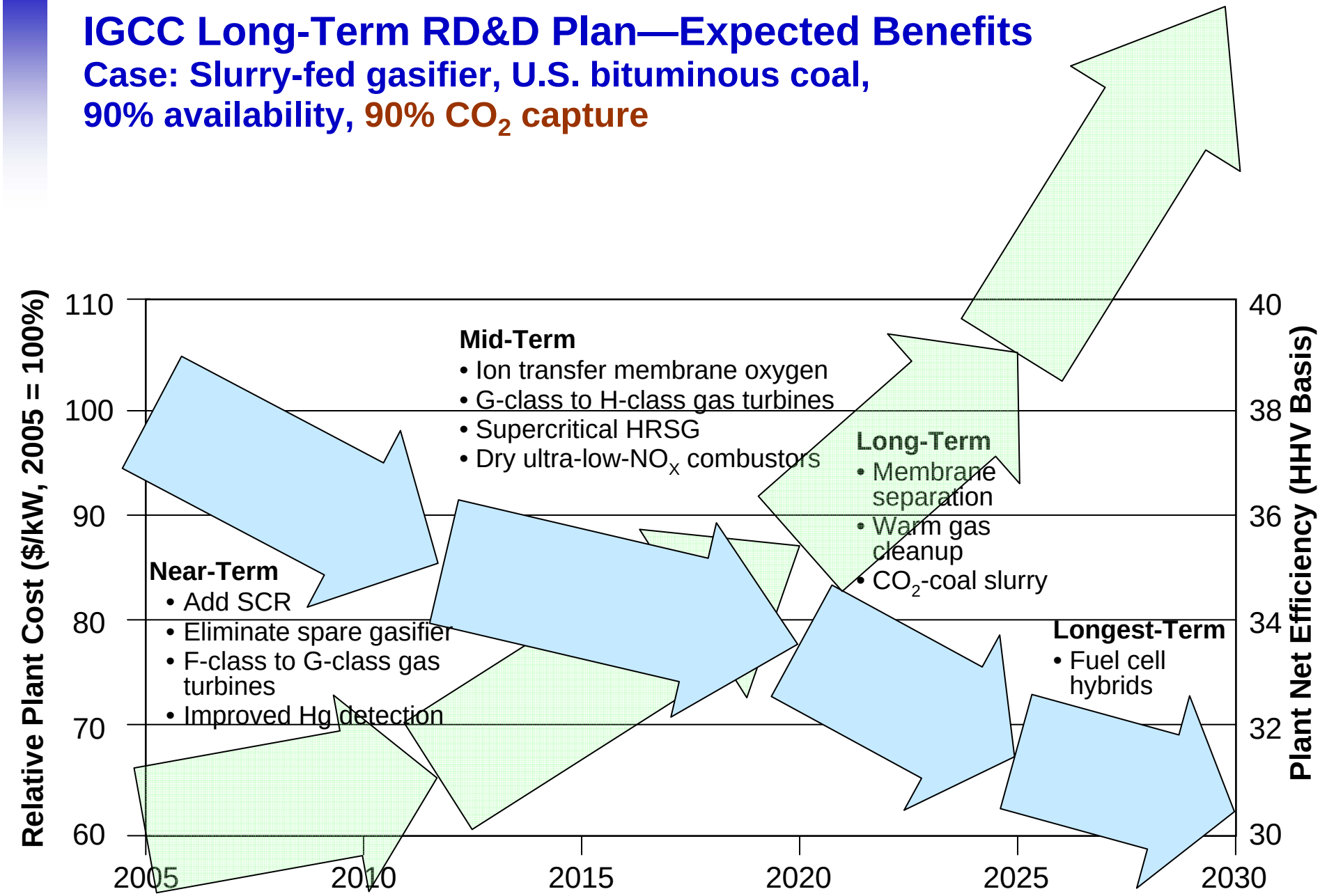
USC PC RD&D Augmentation Plan—Expected Benefits Case:
Pittsburgh #8 coal, 90% availability, 90% CO_2 capture



IGCC Long-Term RD&D Plan—Expected Benefits

Case: Slurry-fed gasifier, U.S. bituminous coal, 90% availability, 90% CO_2 capture



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