EPRI | ELECTRIC POWER RESEARCH INSTITUTE

Generation Technology Options in a Carbon-Constrained World

Prepared by the
Energy Technology Assessment Center

(Reference: EPRI Report 1022782)

Levelized Cost of Electricity Analysis

Objectives

- Provide a useful generic basis for comparison of technologies for base load generation.
- Provide **strategic** comparisons of technologies over plant lifetimes.
- Evaluate sensitivities of levelized cost of electricity (LCOEs) to potential CO_2 costs and other parameters.

Levelized Cost of Electricity Analysis

Analytical Basis

- Utilize EPRI capital cost data and methodologies to calculate levelized costs of electricity (LCOEs) in constant 2010 $.
  - Incorporate key assumptions needed for calculations – capital cost, fuel cost, fixed and variable O&M, plant life, fuel type and energy content, cost of money.
  - No production or investment tax credits assumed for any technologies.
- Assume that current technology parameters and costs are representative of 2011–2015.

Levelized Cost of Electricity Analysis

Analytical Basis

- The weighted average cost of capital (WACC) on a real dollar basis, after tax, is 5.0%, and technology-specific plant lifetimes and accelerated depreciation schedules are used.
- Mercury, SO_x/H_2S and NO_x removal are included in PC and IGCC Technologies. NO_x removal is included in NGCC Technology.

Levelized Cost of Electricity Analysis

Capital Cost Estimating Approach

- Costs are to be reported in reference year (December 2010) dollars:
  - No cost escalation to startup date included
- Plant site is assumed to be clear and level
- Cost estimate assumes mature technology:
  - Plant is assumed to operate as designed (no allowance for field modifications)
  - Extra costs for 1st-of-a-kind demonstration not included

Levelized Cost of Electricity Analysis

Cost Basis

- Total Plant Cost (TPC):
  - Sometimes referred to as Engineering, Procurement, and Construction Cost (EPC), or Overnight Capital Cost
  - All process and support facilities; fuel handling and storage; water intake structure and wastewater treatment; offices, maintenance shops, and warehouses; step-up transformer and transmission tie-in
- Owner's Costs:
  - Pre-production costs, working capital, land, license fees, interest during construction
- Project-specific Costs:
  - Project development, utility interconnections, legal/financial consulting, owner's project management

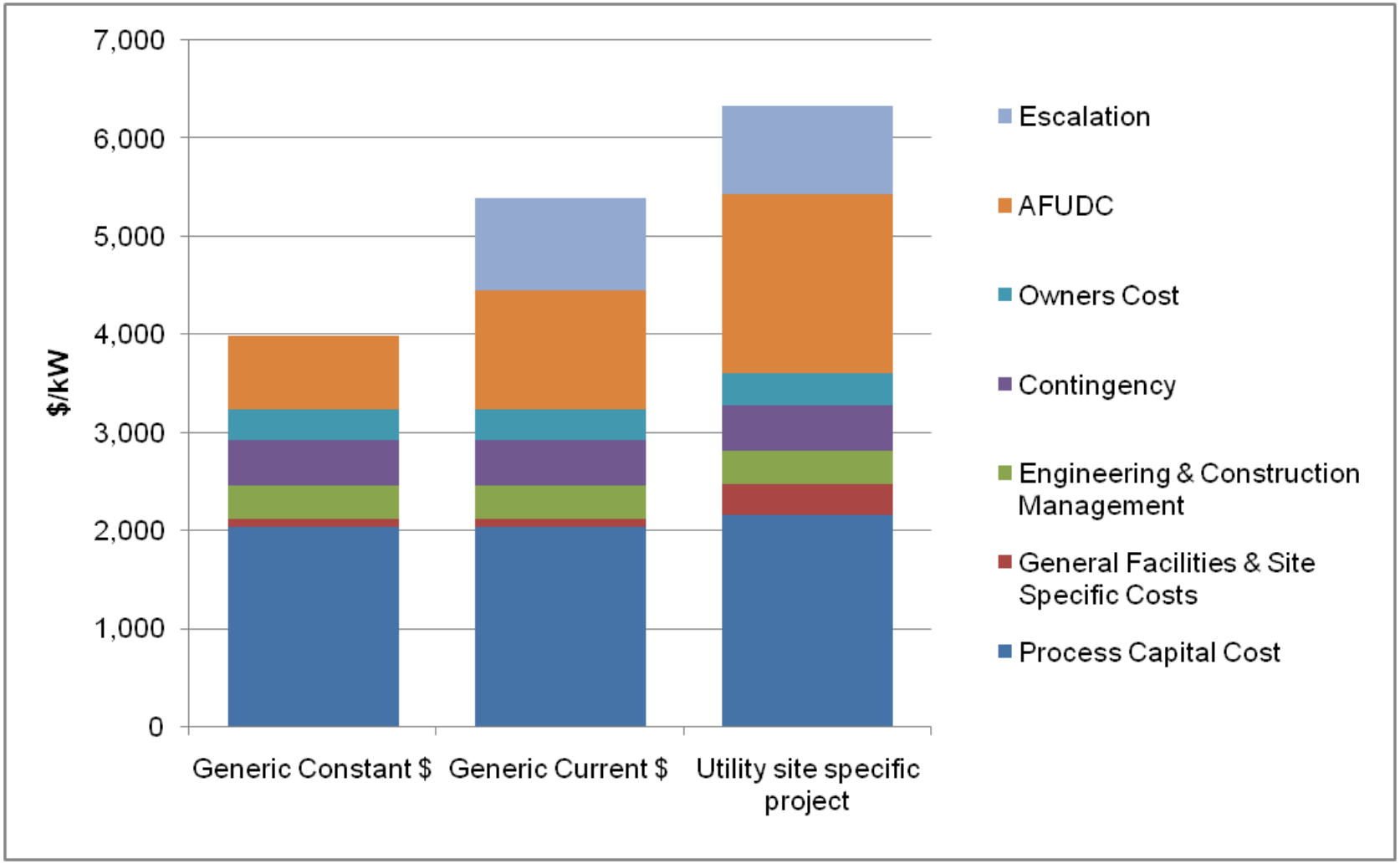
- **Total Capital Requirement (TCR), or "All-In" Costs**
  - **TCR = TPC + Owner's Costs + Project Specific Costs**

Levelized Cost of Electricity Analysis

Capital Cost Estimate Summary

- Total Capital Requirement (TCR) can be significantly higher than Total Plant Cost (TPC):
  - Typical EPRI Owner's Costs add about 3–11% to TPC
  - Interest during construction adds another 4–36% to TPC
- The adder for project-specific costs varies widely:
  - Depends on project and site-specific requirements
  - Roughly equivalent to 10–15% of TPC
- When comparing capital cost estimates:
  - It is important to know if values are in constant year dollars vs. future year dollars
  - It is important to know which components of cost are included/excluded

Magnitude of Cost Estimates* can be Very Different Site Specific vs. Generic Constant $, Current $



*** Data shown for illustrative purposes only**

Levelized Cost of Electricity Analysis

Technology Assumptions

- Near Term – 2010 to 2015
  - Modest extrapolation of today's technology.
  - Based on foreseeable technology development.
- Longer Term – 2020 to 2025
  - Assume that established R&D objectives are achieved, and technology development is successful.
  - Estimated reductions in costs are based on assessment of potential technology improvements.

Levelized Cost of Electricity Analysis

- Individual technology slides
  - Range of LCOEs presented as shaded region
  - Solid line represents median
  - Solid line and dashed line represent upper and lower bounds of fuel price, respectively

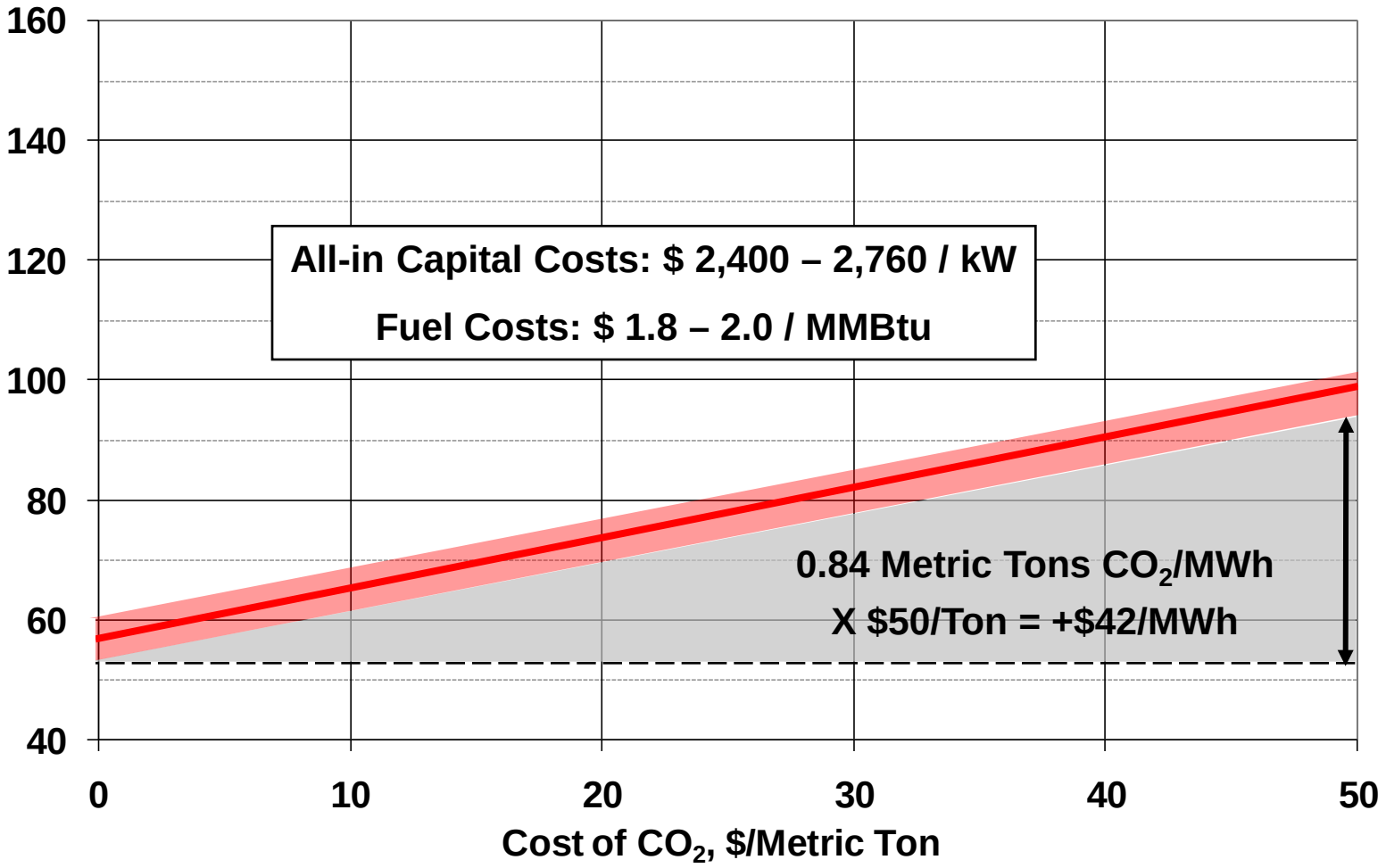
- Technology summary slides
  - NGCC and biomass LCOE is presented as shaded region, principally reflecting the range of fuel prices
  - Solar is not included due to high LCOE beyond scale of chart

Near-Term: 2015

Pulverized Coal Combustion – 2015

Levelized Cost of Electricity, $/MWh

All costs are in December 2010 $

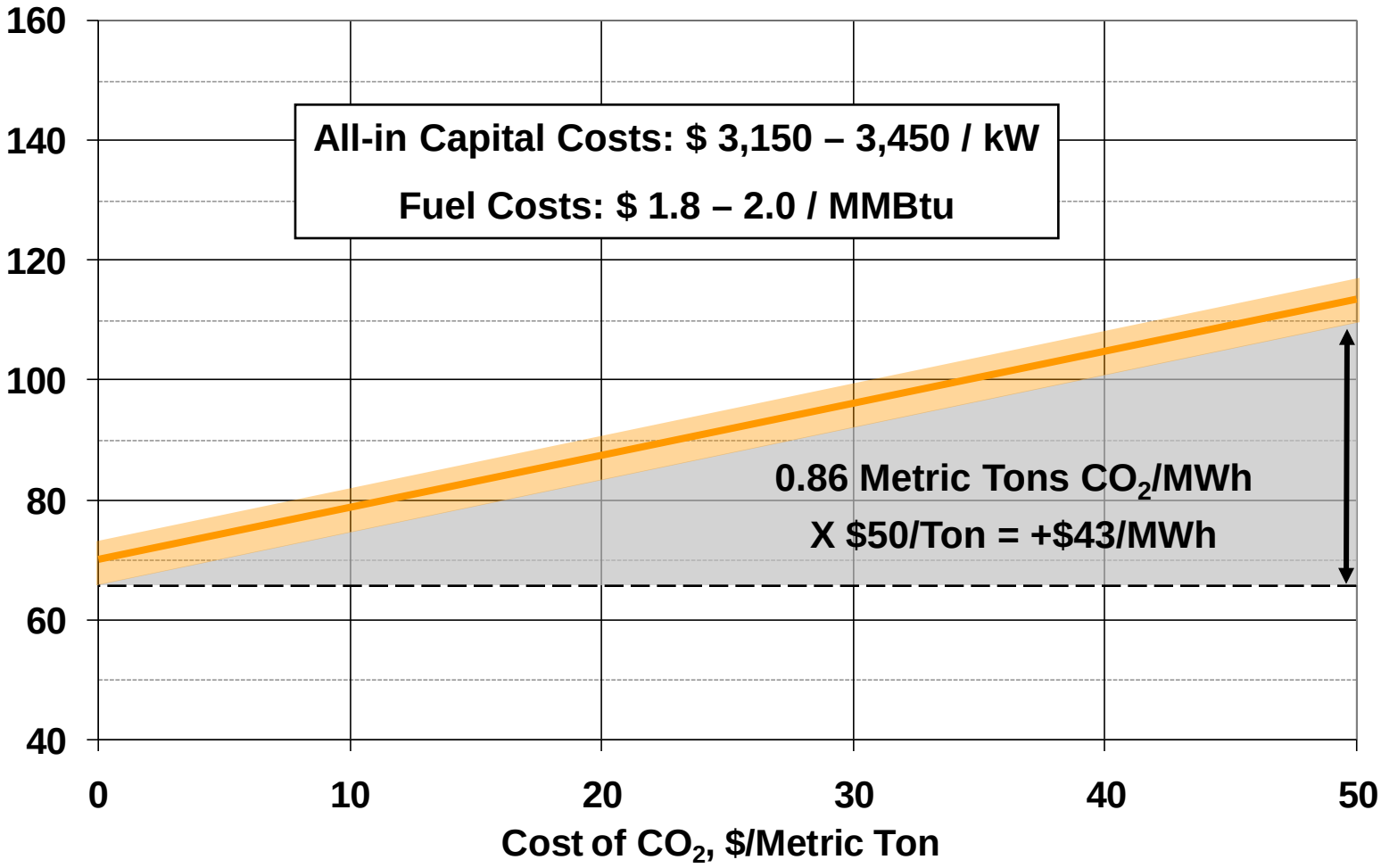


EPRI ELECTRIC POWER RESEARCH INSTITUTE

Integrated Gasification Combined Cycle (IGCC) Coal Combustion – 2015

Levelized Cost of Electricity, $/MWh

All costs are in December 2010 $

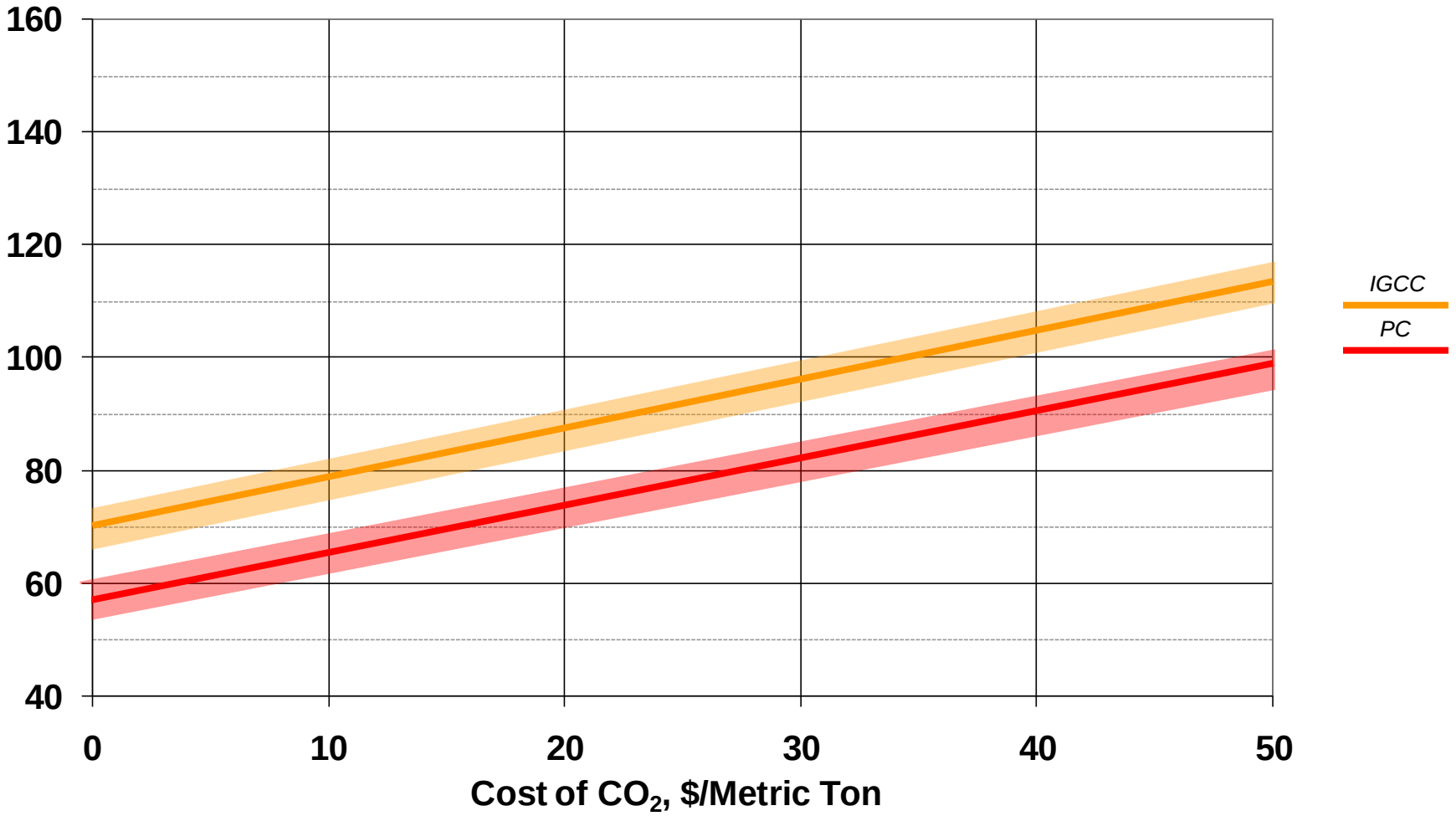


EPRI ELECTRIC POWER RESEARCH INSTITUTE

Coal Combustion and Gasification Comparison – 2015

All costs are in December 2010 $

Levelized Cost of Electricity, $/MWh

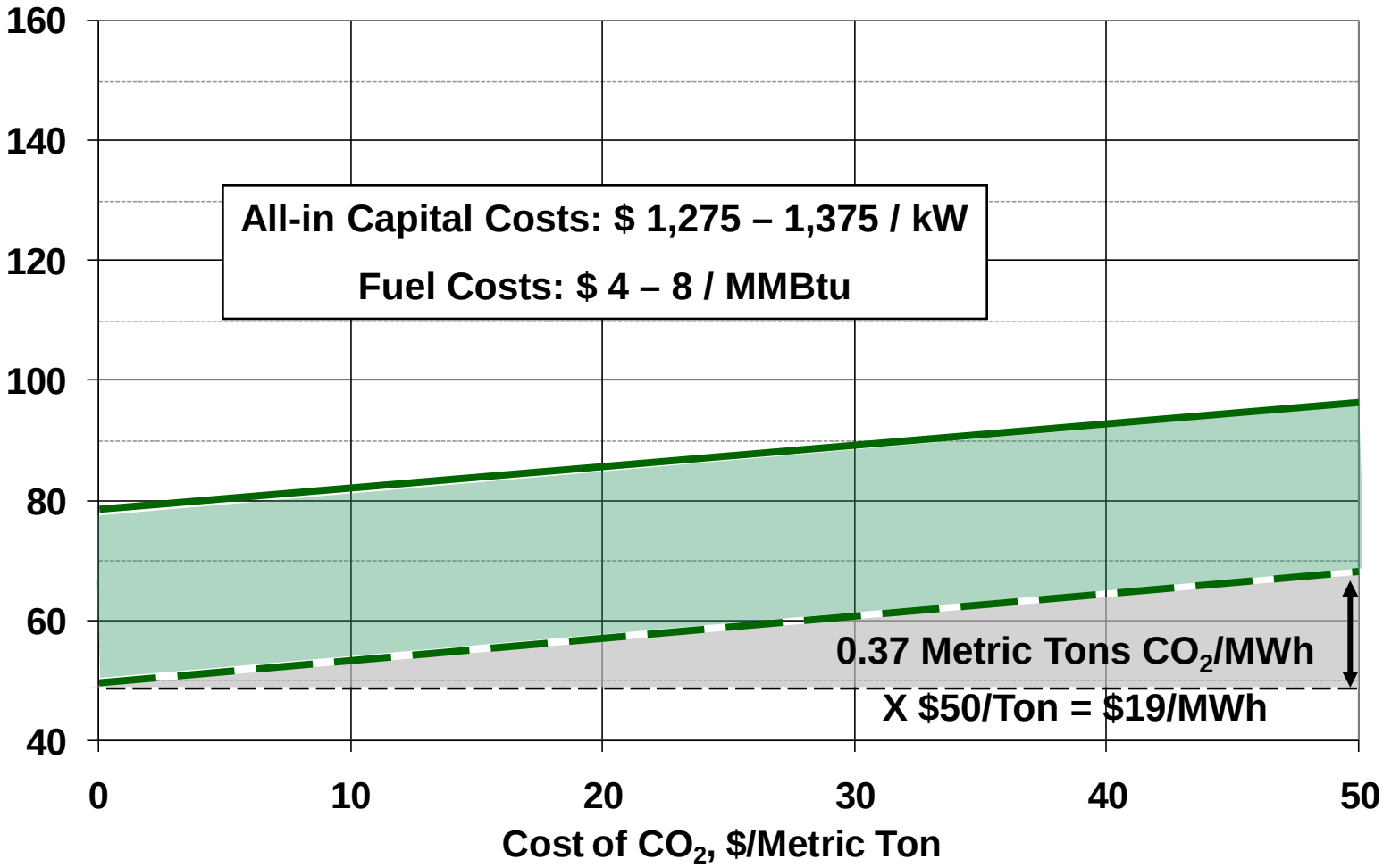


EPRI ELECTRIC POWER RESEARCH INSTITUTE

Natural Gas Combined Cycle (NGCC) Fuel Cost Sensitivity Comparison – 2015

Levelized Cost of Electricity, $/MWh

All costs are in December 2010 $

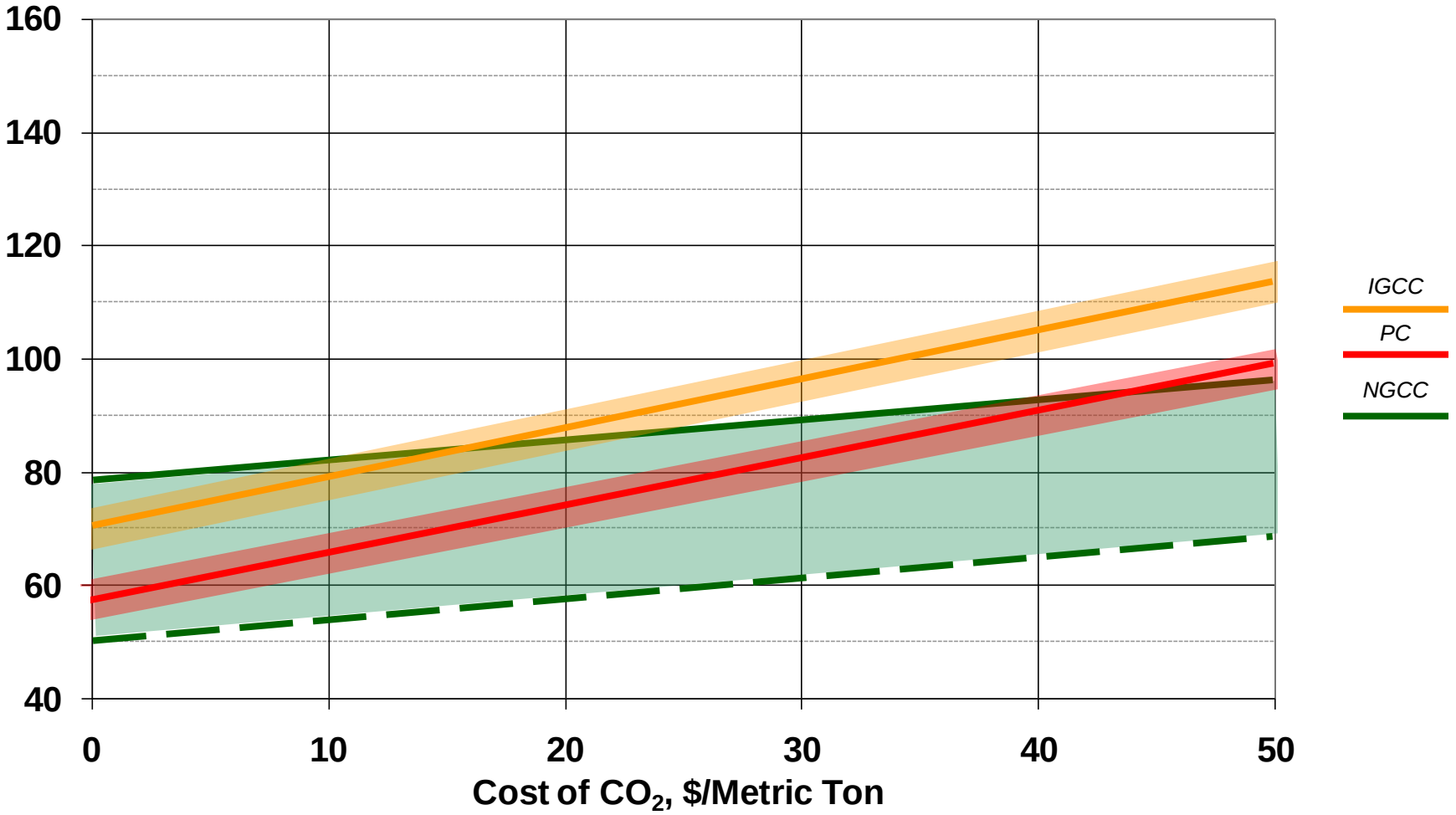


PC, IGCC, NGCC Comparison – 2015



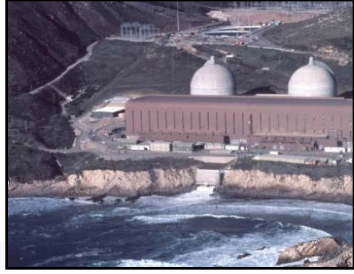
Levelized Cost of Electricity, $/MWh

All costs are in December 2010 $



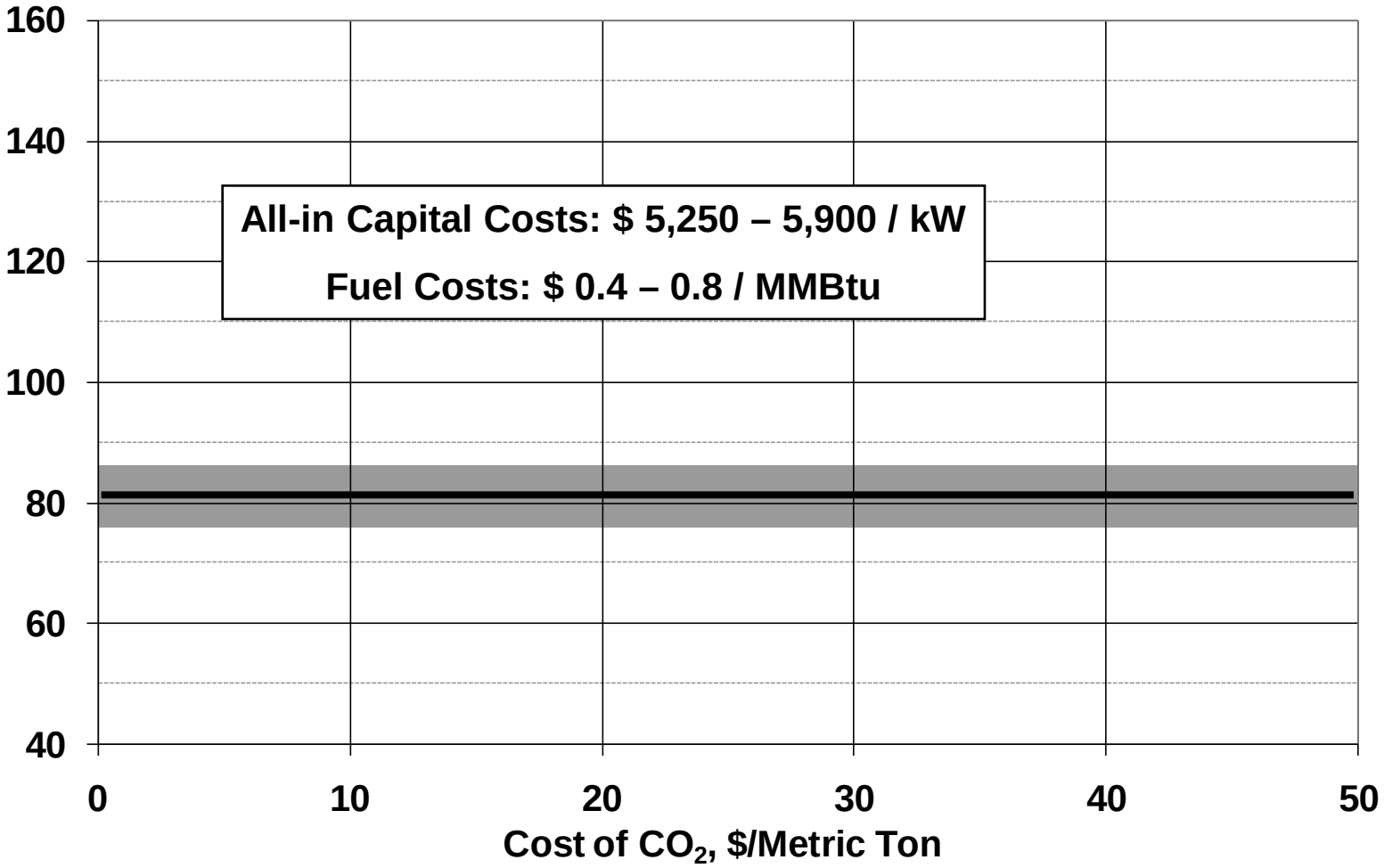
EPRI ELECTRIC POWER RESEARCH INSTITUTE

Nuclear – 2015



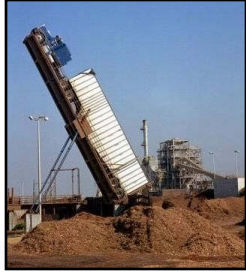
Levelized Cost of Electricity, $/MWh

All costs are in December 2010 $



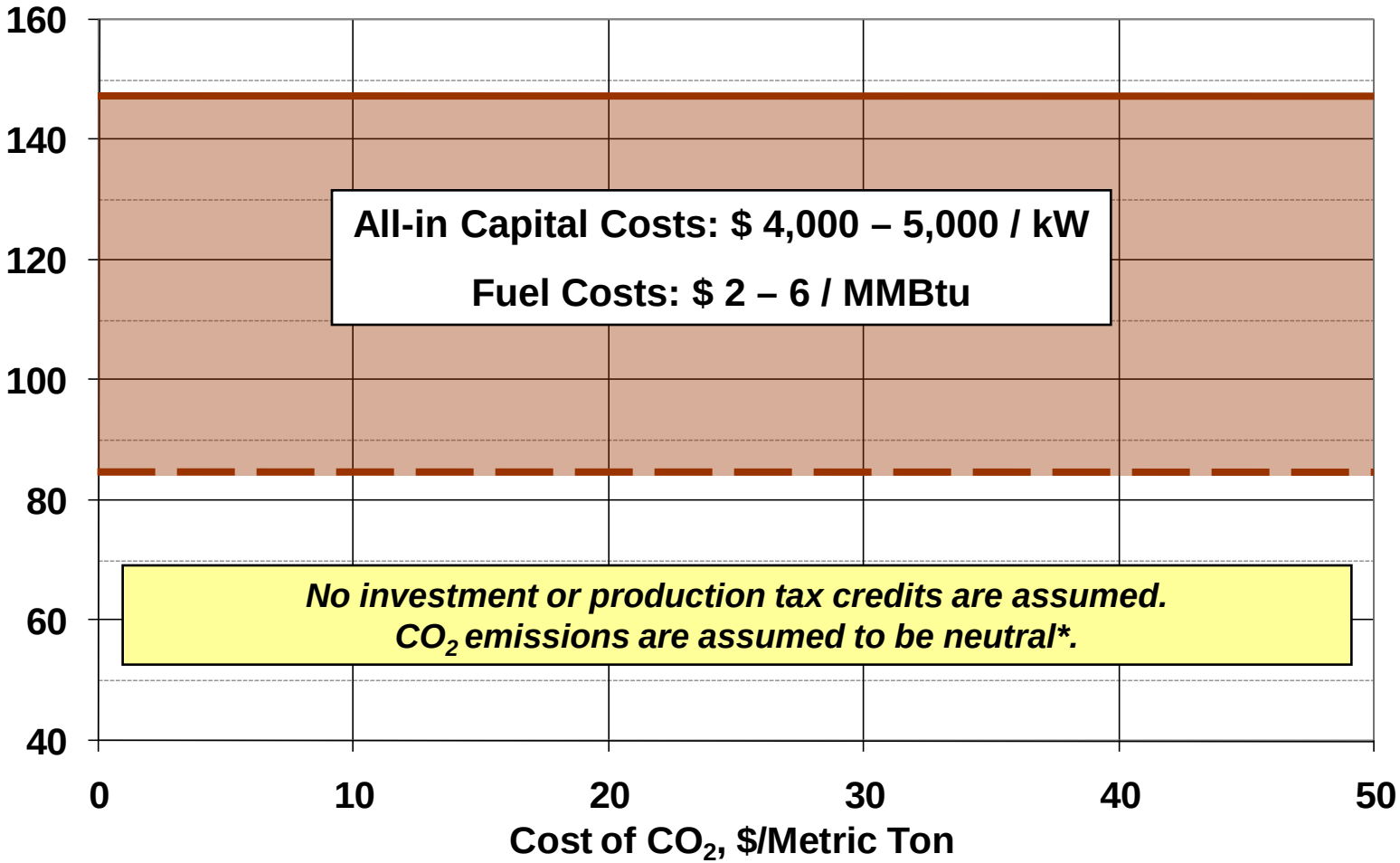
EPRI ELECTRIC POWER RESEARCH INSTITUTE

Biomass – 2015



Levelized Cost of Electricity, $/MWh

All costs are in December 2010 $



***Biomass emissions can vary significantly based on fuel source and life-cycle emission assumptions. Conventionally, the release of carbon from biogenic sources is assumed to be balanced by the uptake of carbon when the feedstock is grown, resulting in zero net CO_2 emissions over some period of time.**

Wind – 2015

Levelized Cost of Electricity, $/MWh

All costs are in December 2010 $

160
140
120
100
80
60
40

All-in Capital Costs

Off Shore Wind: $ 3,250 – 4,200 / kW

On Shore Wind: $ 2,120 – 2,825 / kW

No investment or production tax credits are assumed.

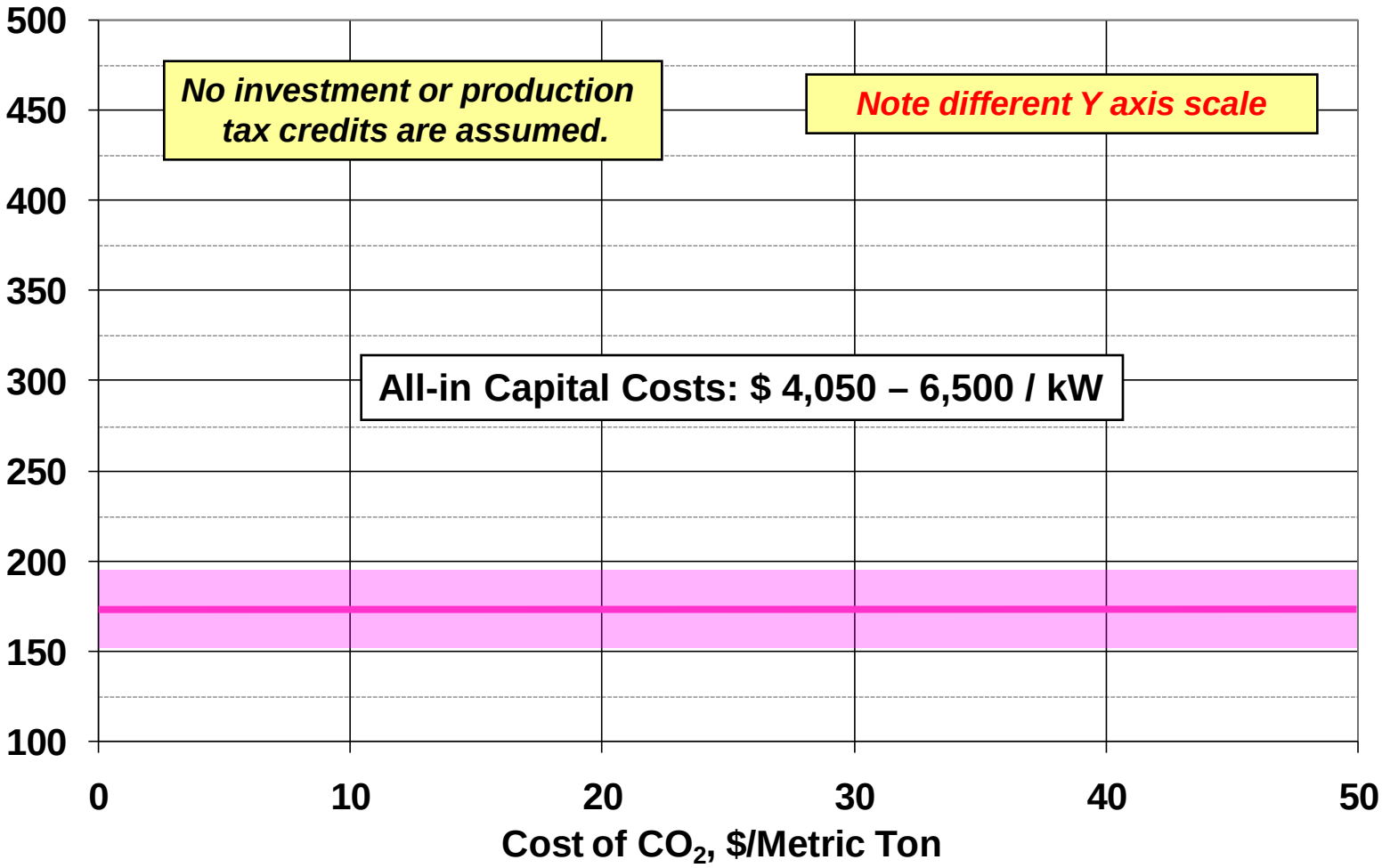
0 10 20 30 40 50

Cost of CO_2, $/Metric Ton

Concentrating Solar Thermal – 2015

Levelized Cost of Electricity, $/MWh

All costs are in December 2010 $

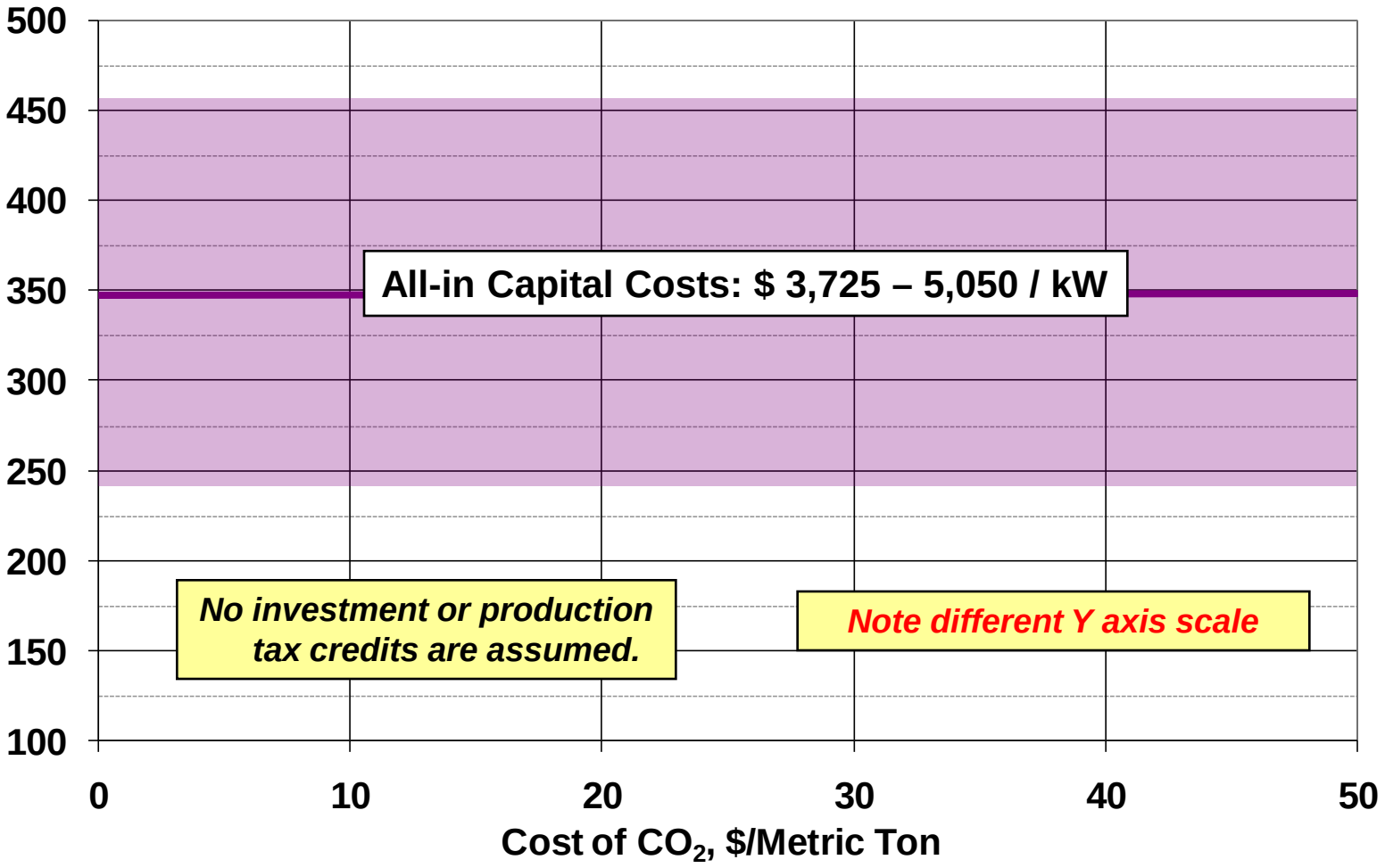


EPRI ELECTRIC POWER RESEARCH INSTITUTE

Solar Photovoltaic – 2015

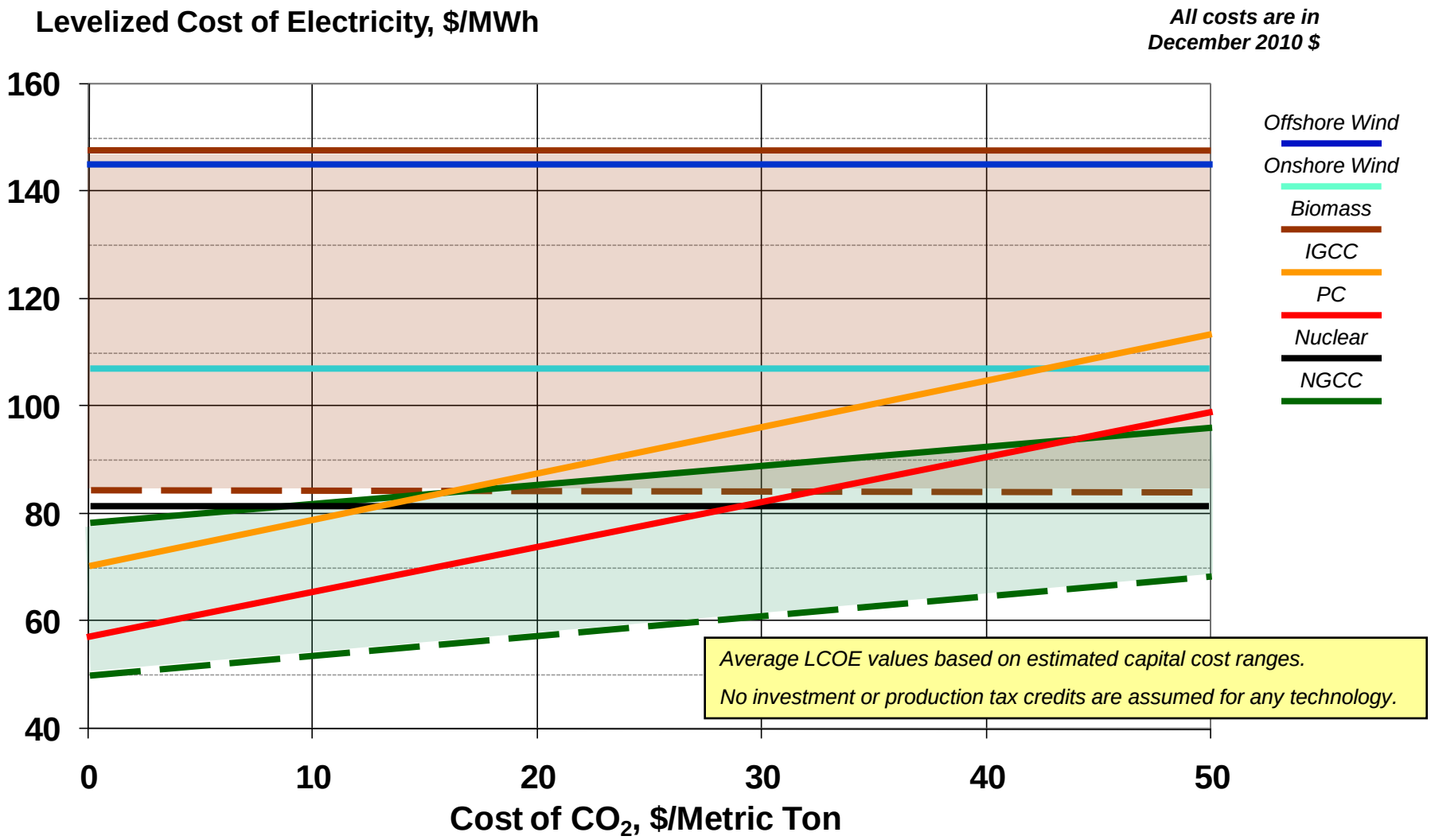
Levelized Cost of Electricity, $/MWh

All costs are in December 2010 $



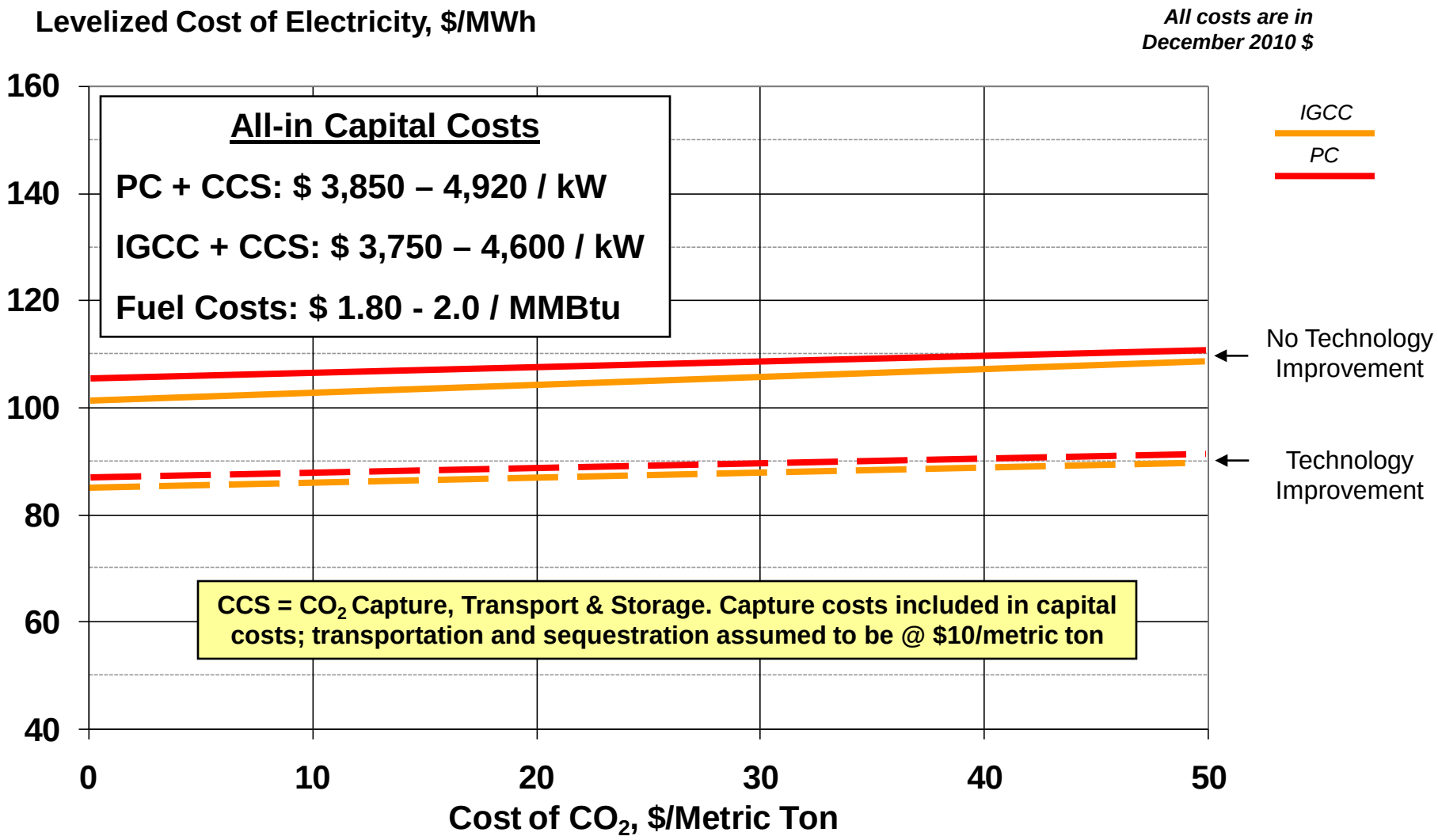
EPRI ELECTRIC POWER RESEARCH INSTITUTE

Comparative Levelized Costs of Electricity – 2015

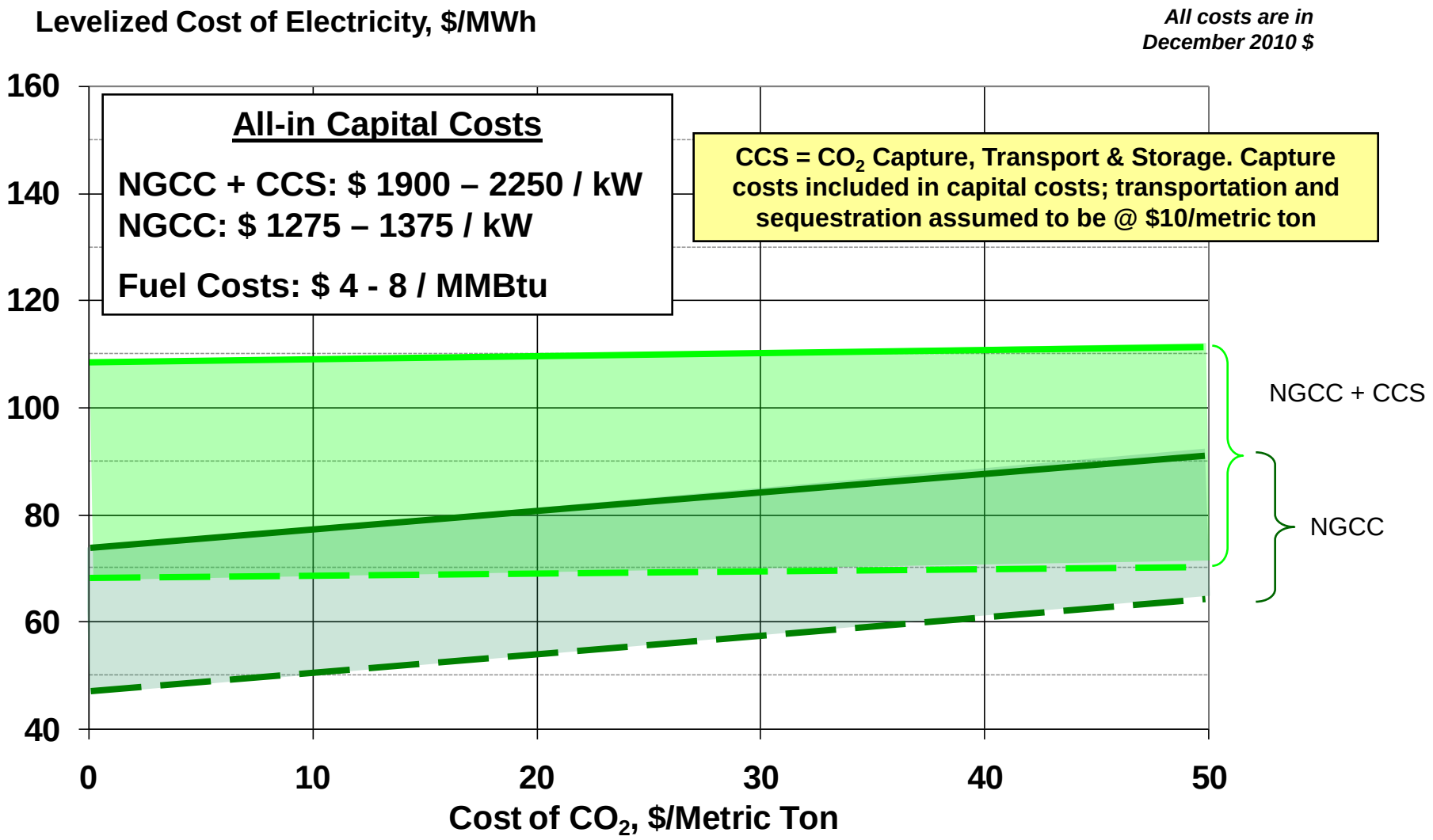


Longer-Term: 2025

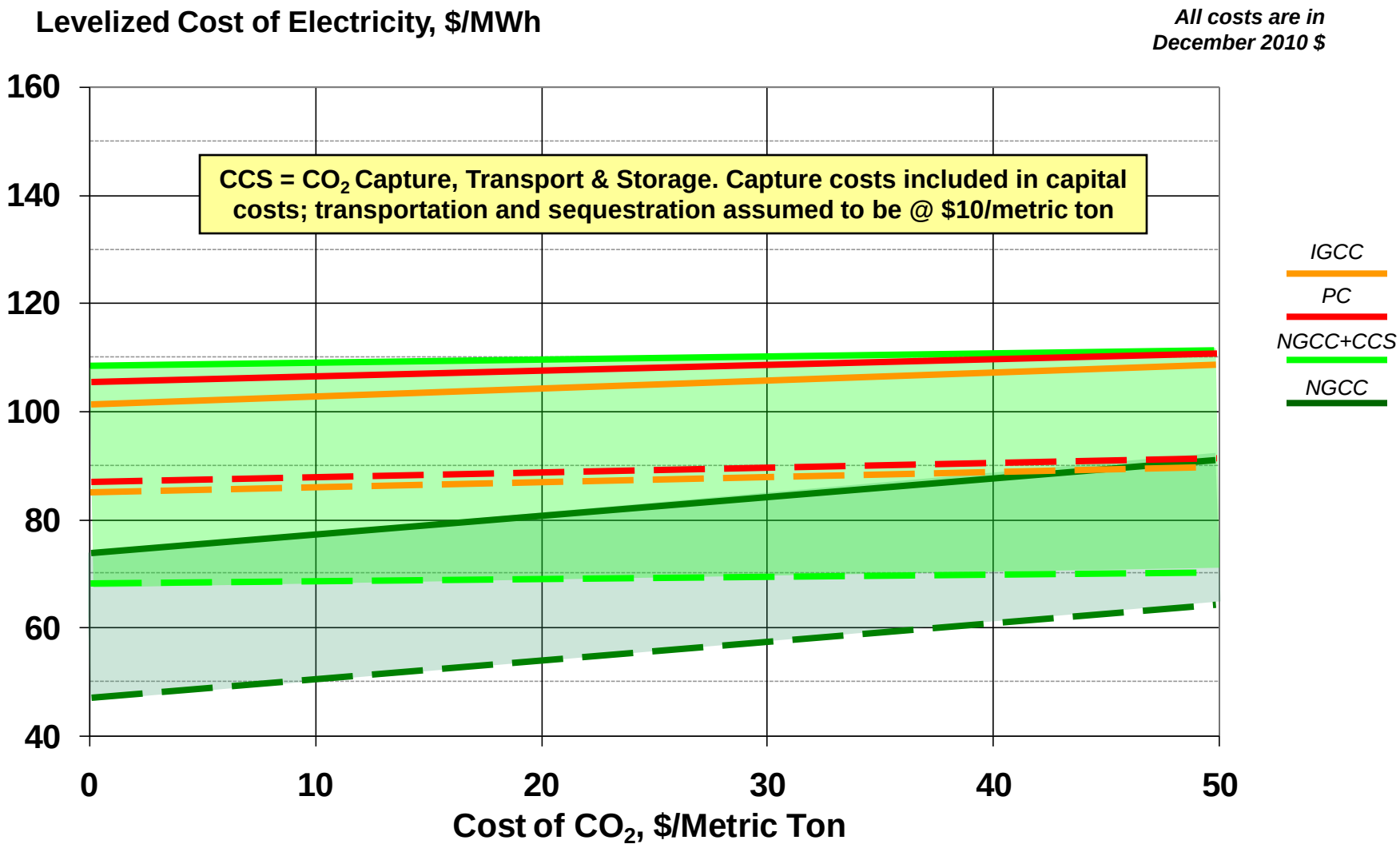
Coal, 2025—Impact of CO_2 Capture, Transport & Storage (CCS) and Cost and Performance Improvements on Levelized Cost of Electricity



NGCC, 2025—Impact of CO_2 Capture, Transport & Storage (CCS) on Levelized Cost of Electricity



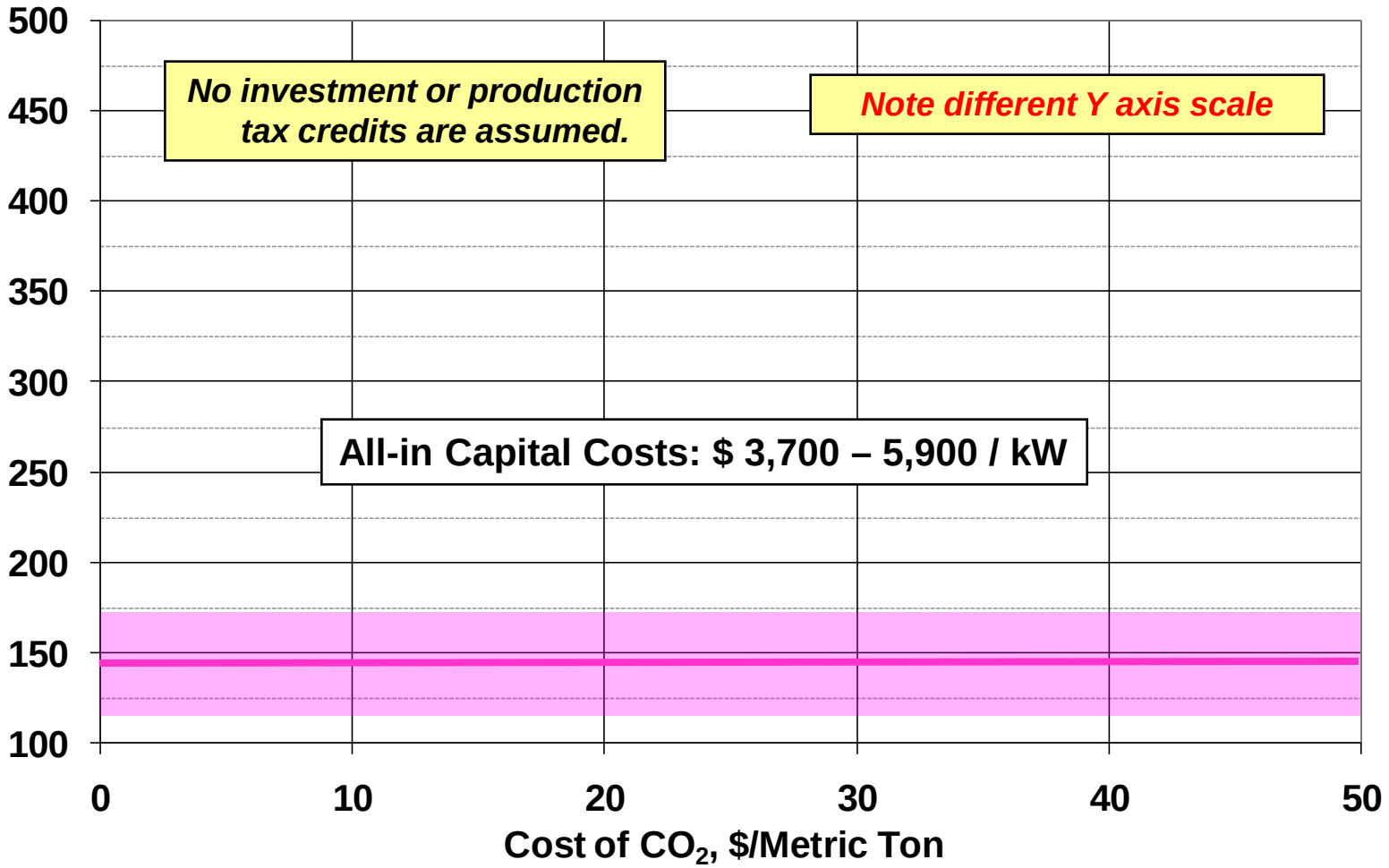
PC, IGCC, NGCC, 2025—Impact of CO_2 Removal, Transport & Storage (CCS) and Cost and Performance Improvements on Levelized Cost of Electricity



Concentrating Solar Thermal– 2025

Levelized Cost of Electricity, $/MWh

All costs are in December 2010 $

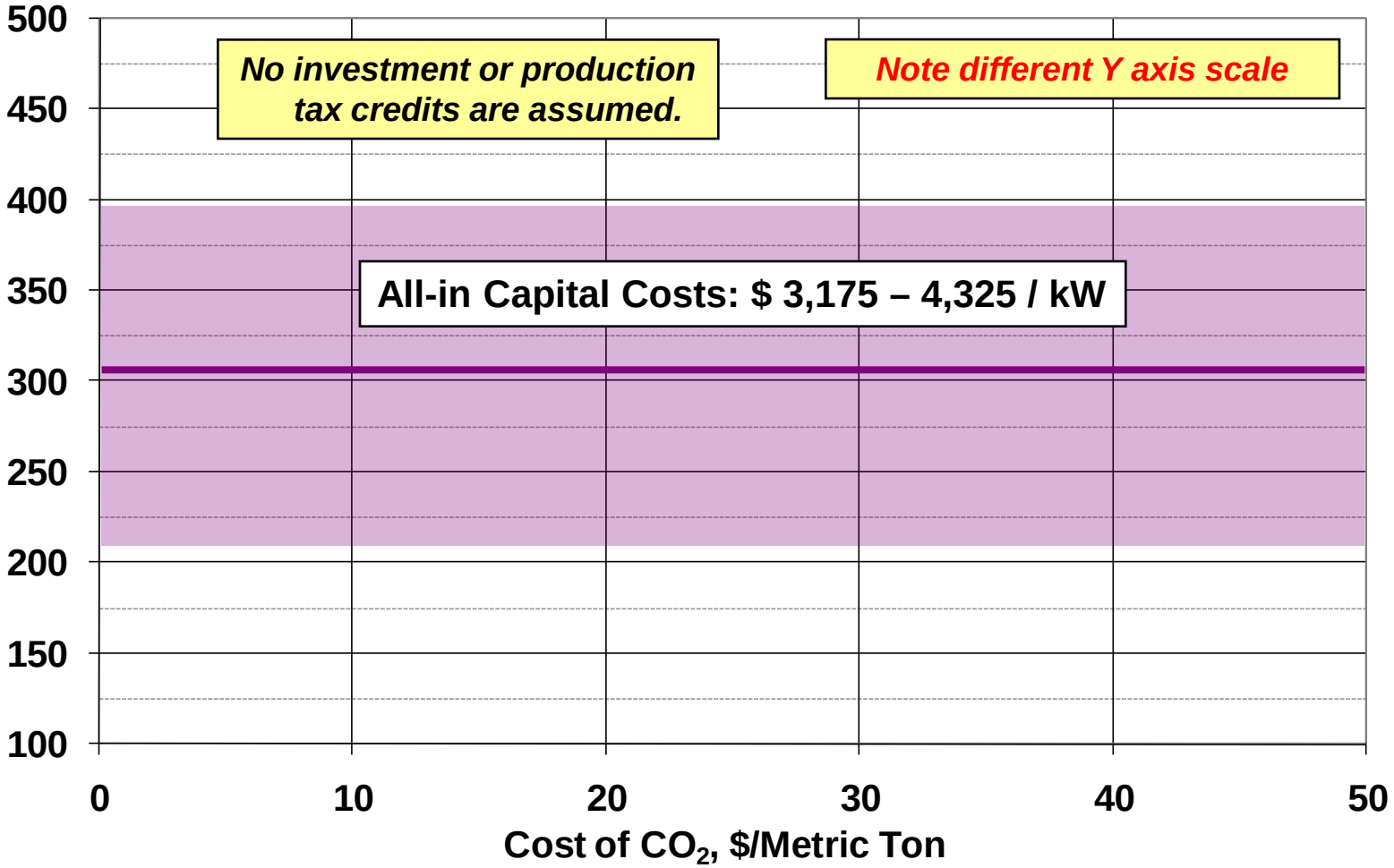


EPRI ELECTRIC POWER RESEARCH INSTITUTE

Solar Photovoltaic – 2025

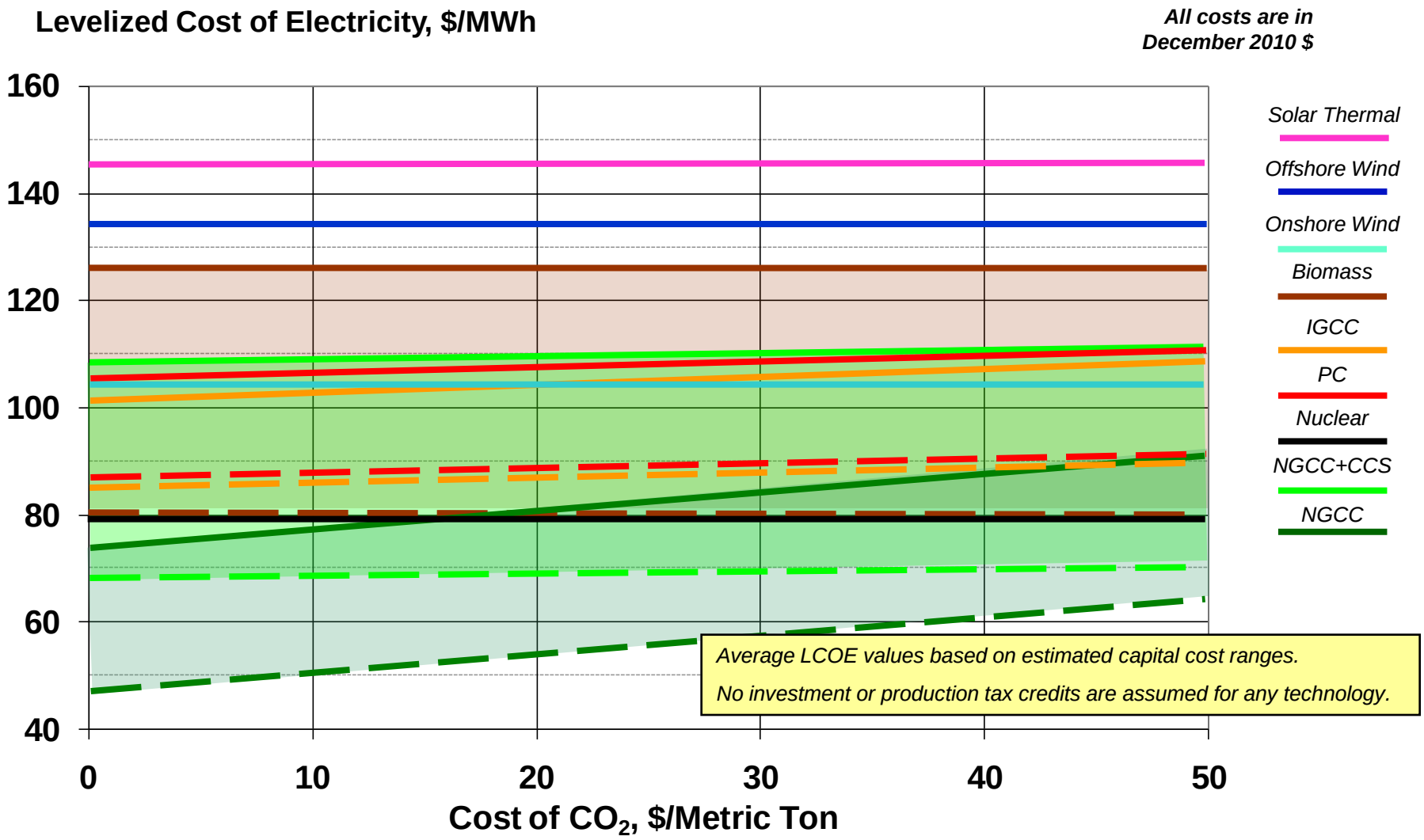
All costs are in December 2010 $

Levelized Cost of Electricity, $/MWh



EPRI ELECTRIC POWER RESEARCH INSTITUTE

Comparative Levelized Costs of Electricity – 2025



Closing Thoughts

- Several key uncertainties impact near-term and long-term project decisions and research priorities:
  - Stringency of future CO_2 emissions reduction programs
  - Future price of natural gas (high sensitivity and variability)
  - CO_2 capture and storage technology development and costs
  - Siting requirements
  - Renewable energy technology development
  - Technology-driven escalations and reductions in plant costs
- Demonstrates importance of developing and demonstrating a portfolio of low cost generation technologies.

Together…Shaping the Future of Electricity