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Generation Options for New York State in a Carbon Constrained World

NYISO Environmental Advisory Committee

May 12, 2006

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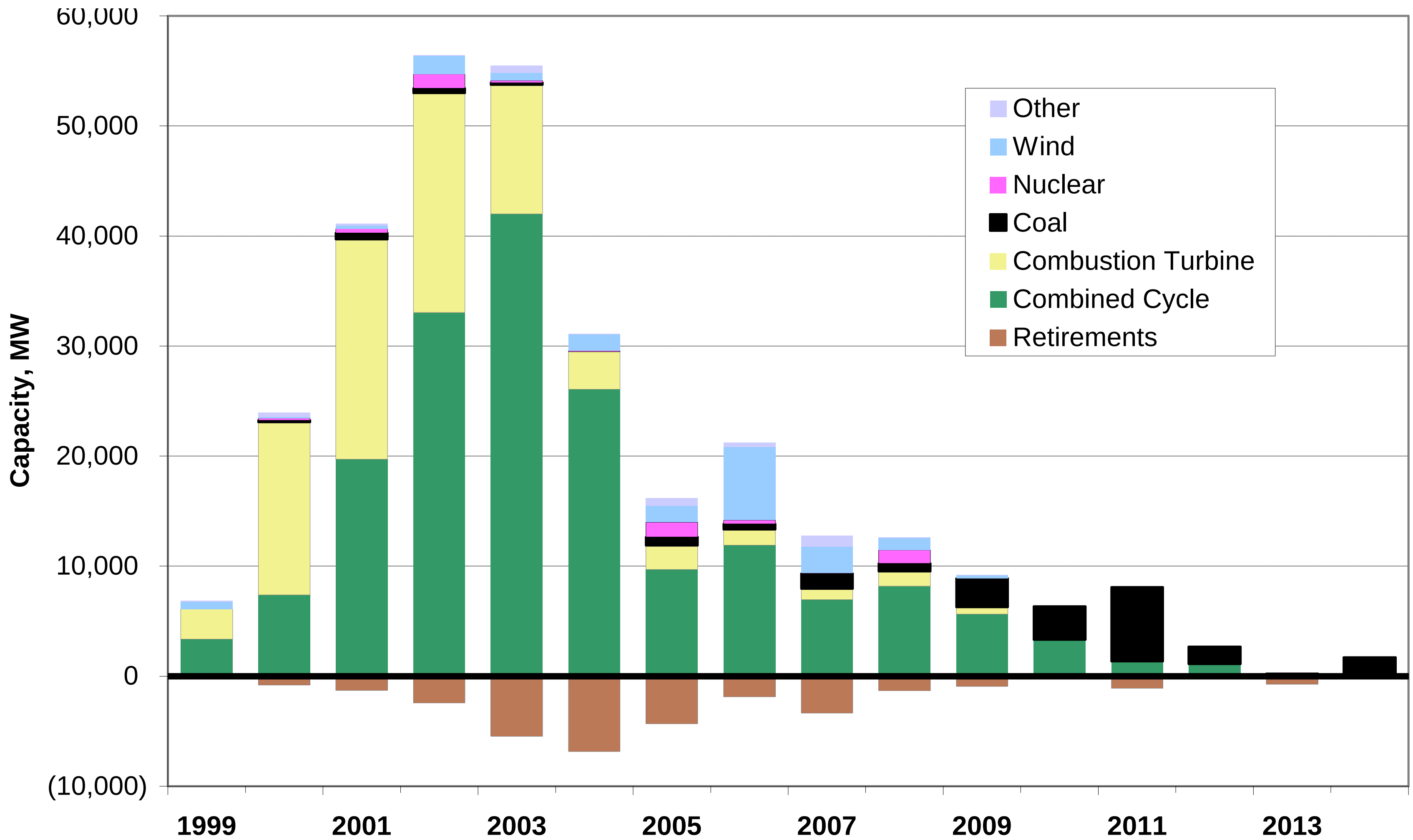
Director, Environment
Electric Power Research Institute

Presentation Overview

- Objective
  - Summarize cost and availability of future electric generation options for New York State
- Technologies
  - Central Station – coal, gas, wind, nuclear, biomass
  - Distributed generation – combustion turbines, microturbines, fuel cells, storage, tidal

U.S. Capacity Additions 1999-2014



Ref.: EPRI P67 Newsletter on New Power Plants, September 2005

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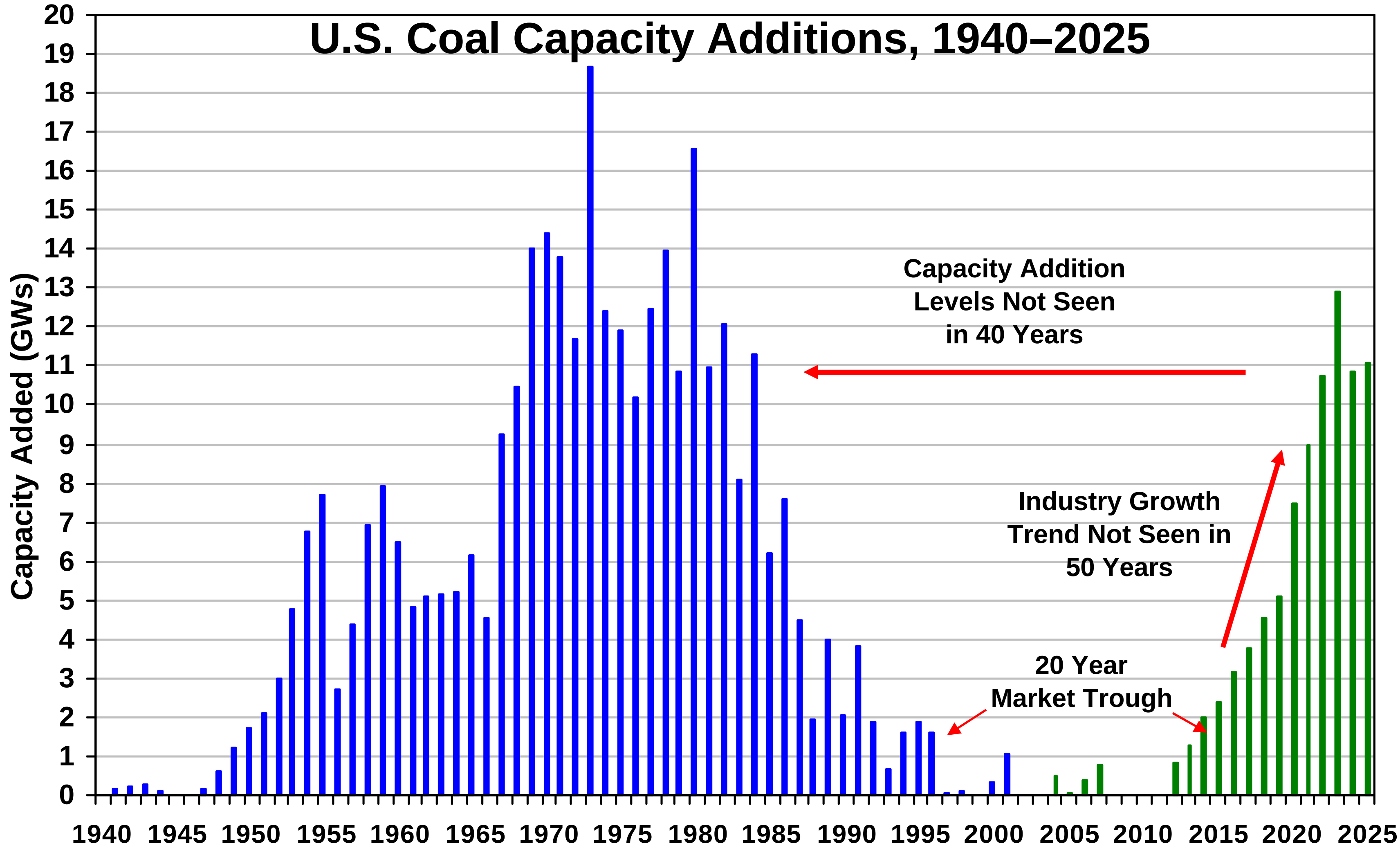
A New Question for Companies …
What Kind of Generating Capacity to Build

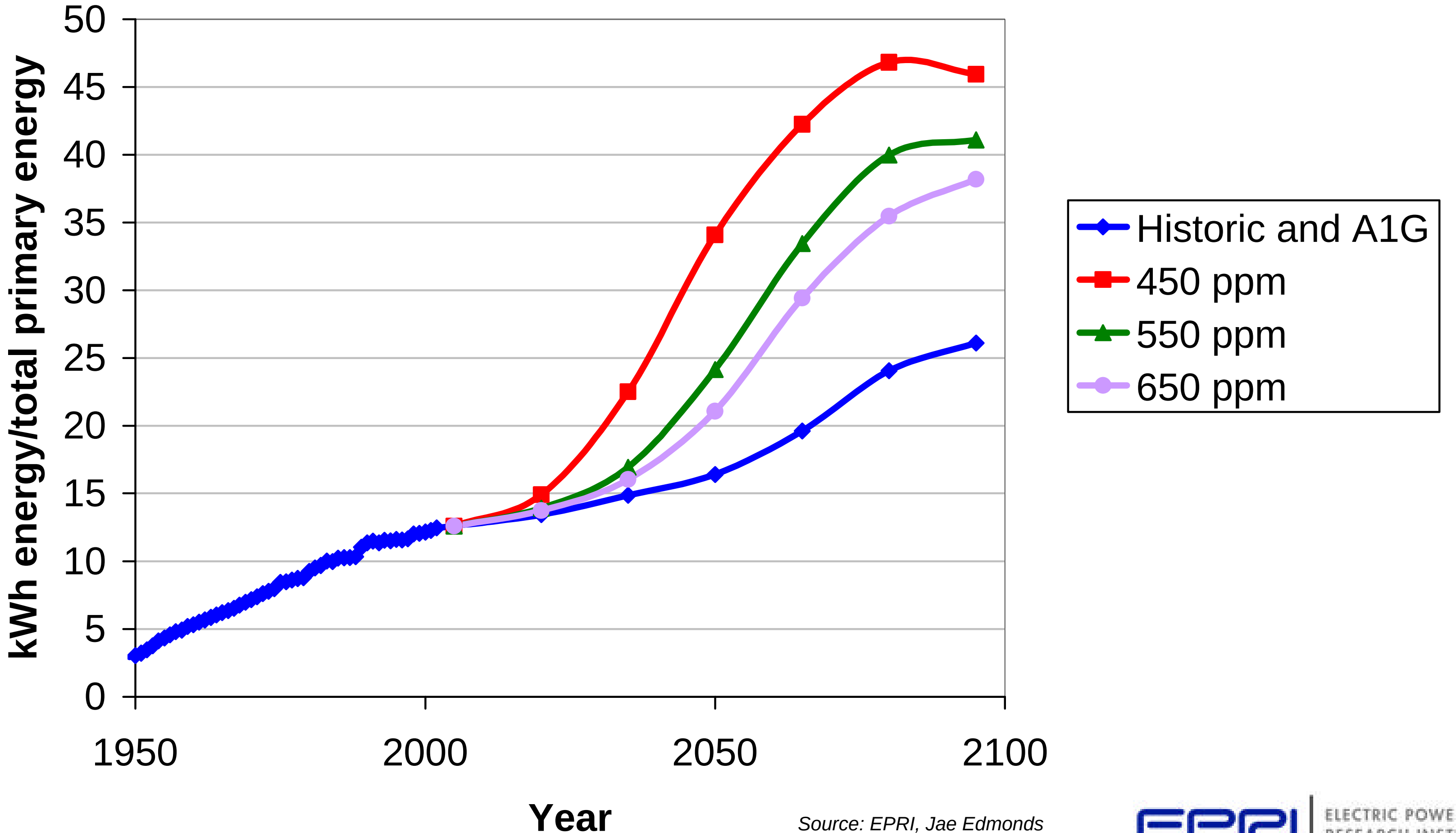


Source: AEP. Developed from U.S. Department of Energy NETL & Annual Energy Outlook 2005.

Why is Electricity Growth in the U.S. (Globally) Relatively Unaffected by Climate Policy?

1. Electricity displaces non-electric end-uses

Electricity's Share of U.S. Total Primary Energy

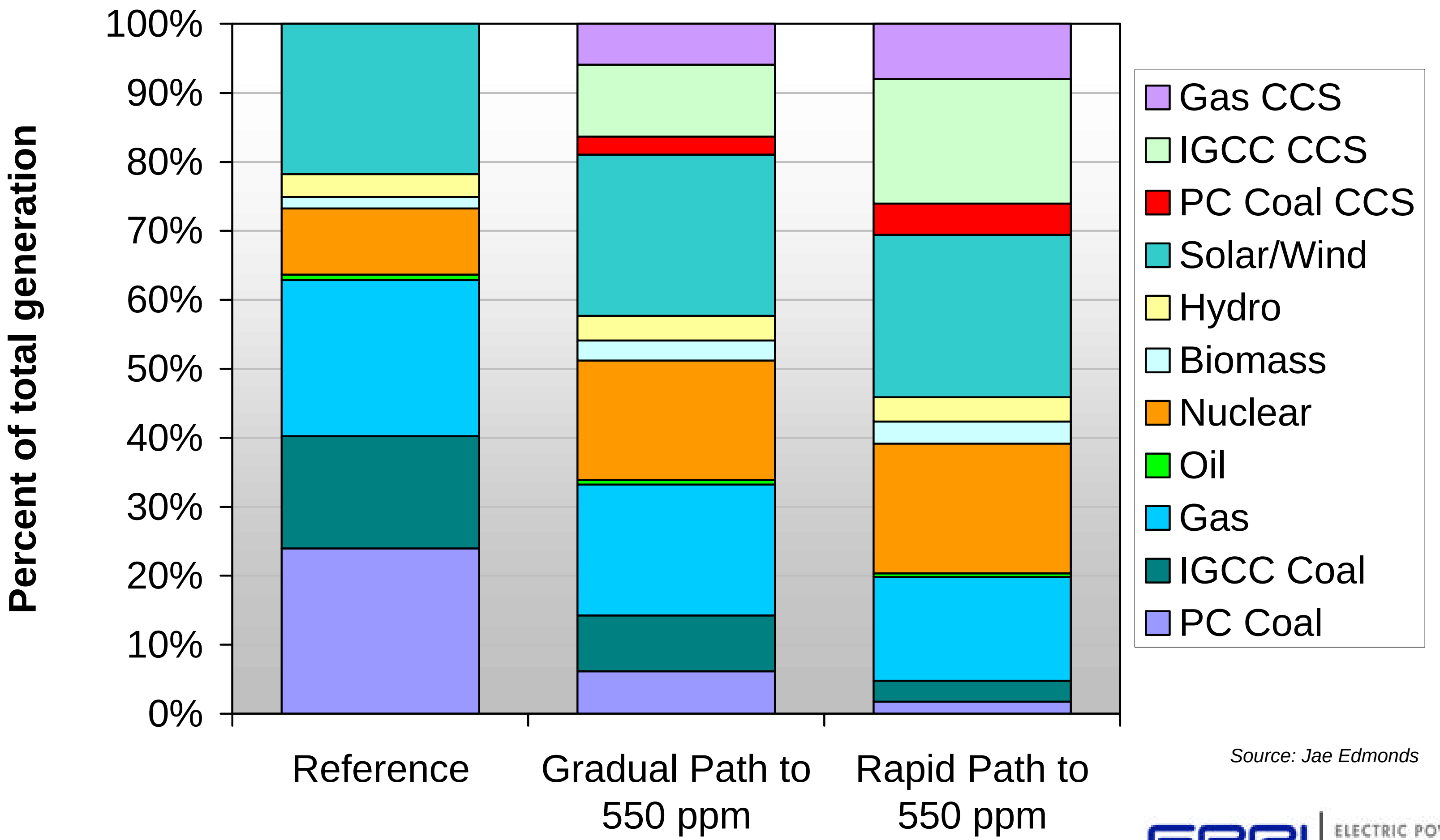


Source: EPRI, Jae Edmonds

Why is Electricity Growth in the U.S. (Globally) Relatively Unaffected by Climate Policy?

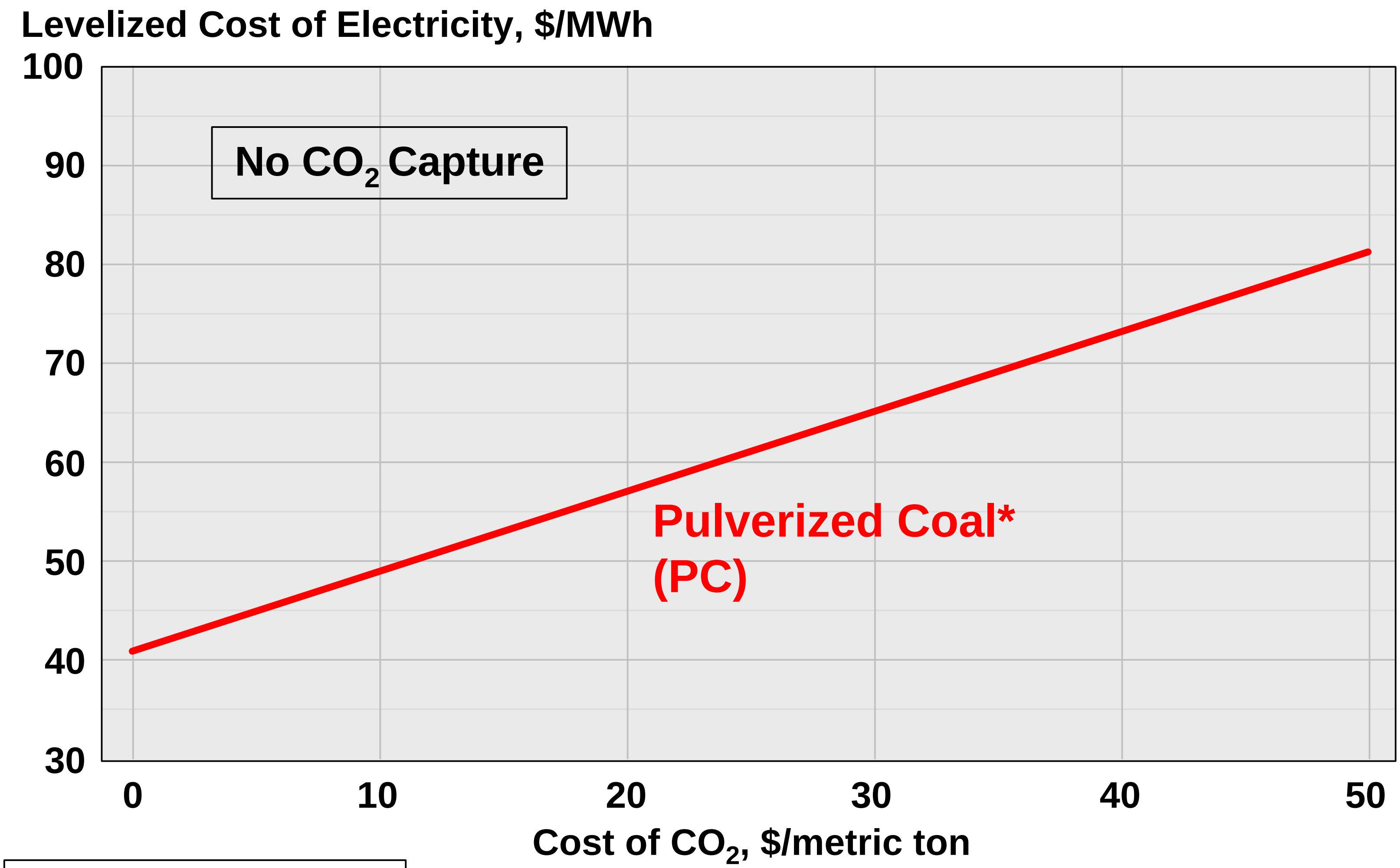
2. Electricity is decarbonized

2050 Fuel Shares for U.S. Electricity Generation (illustrative)



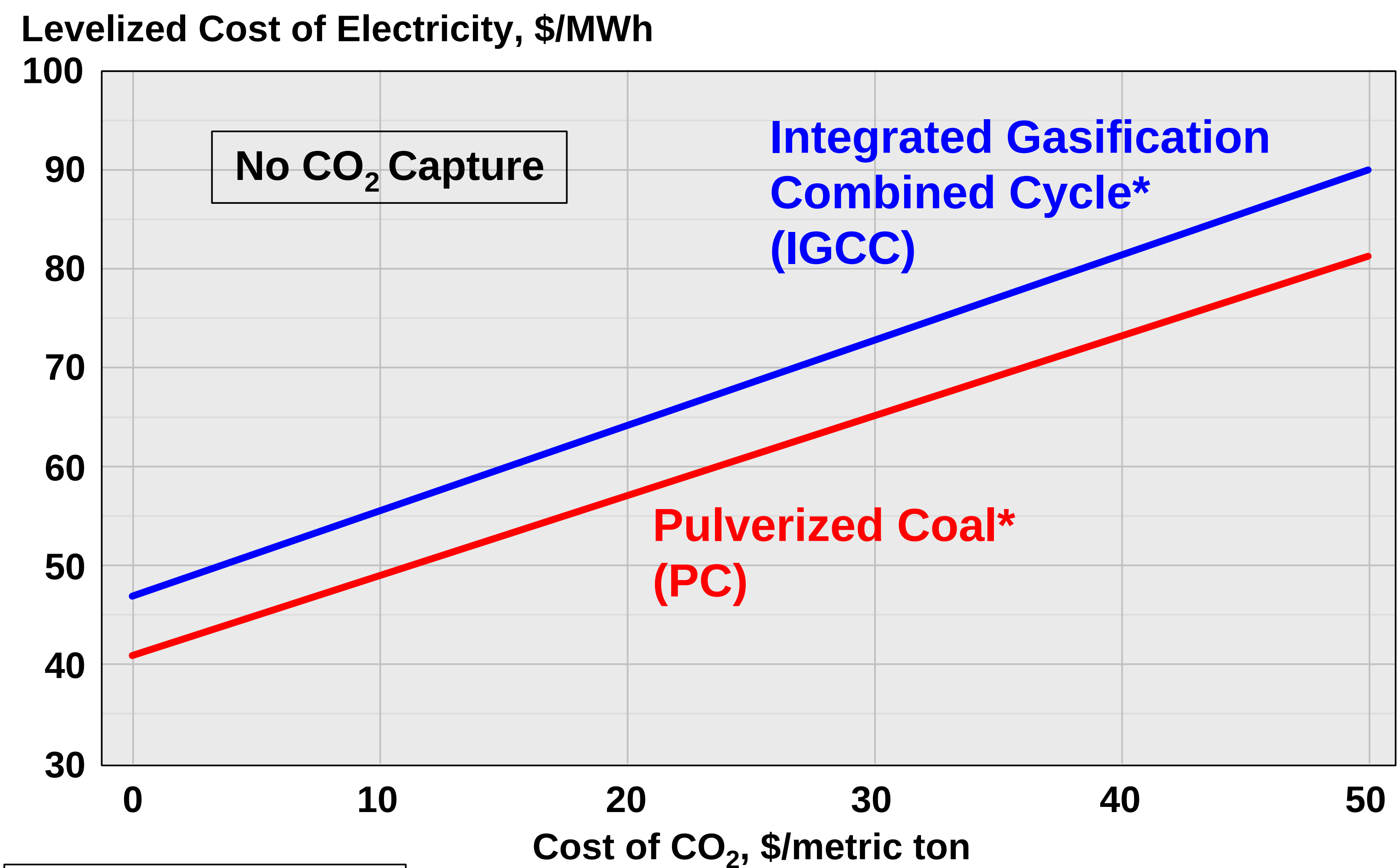
Source: Jae Edmonds

Pulverized Coal Technology in 2010



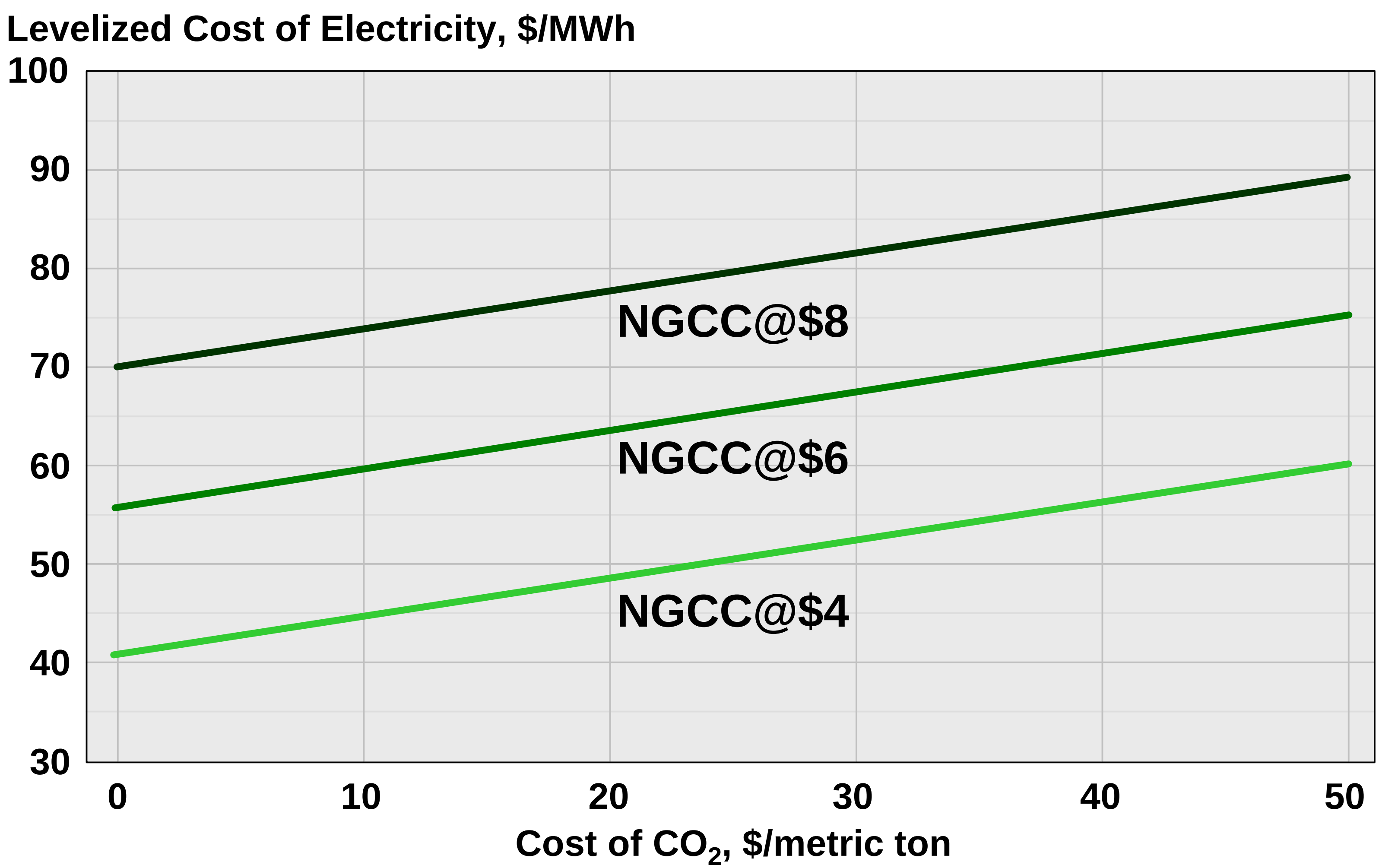
*Coal @ $1.50/mmBtu

Coal Technologies in 2010

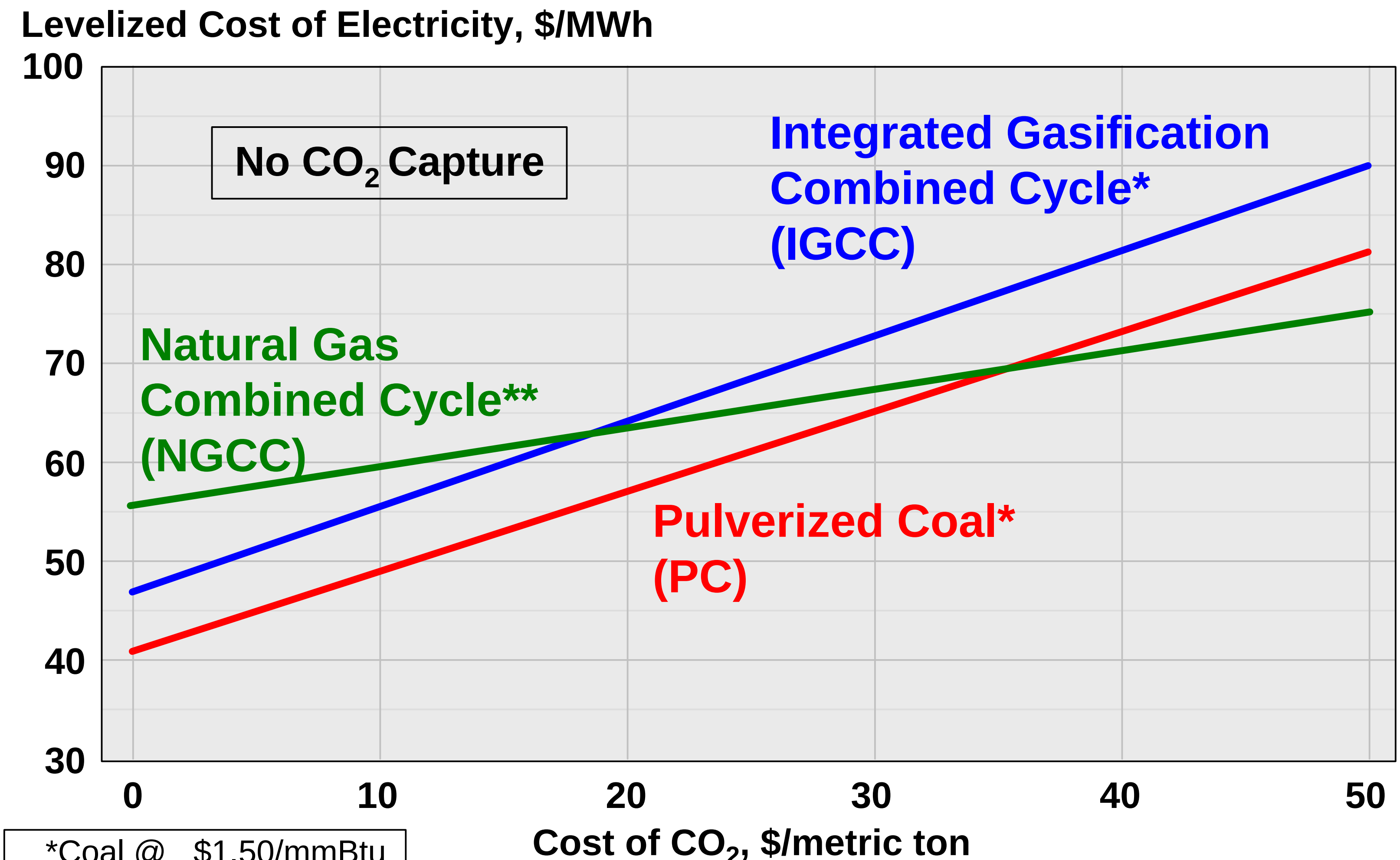


*Coal @ $1.50/mmBtu

Natural Gas Combined Cycle in 2010 Time Period



Fossil Fueled Technologies in 2010



*Coal @ $1.50/mmBtu

**Nat'l Gas @ $6/mmBtu

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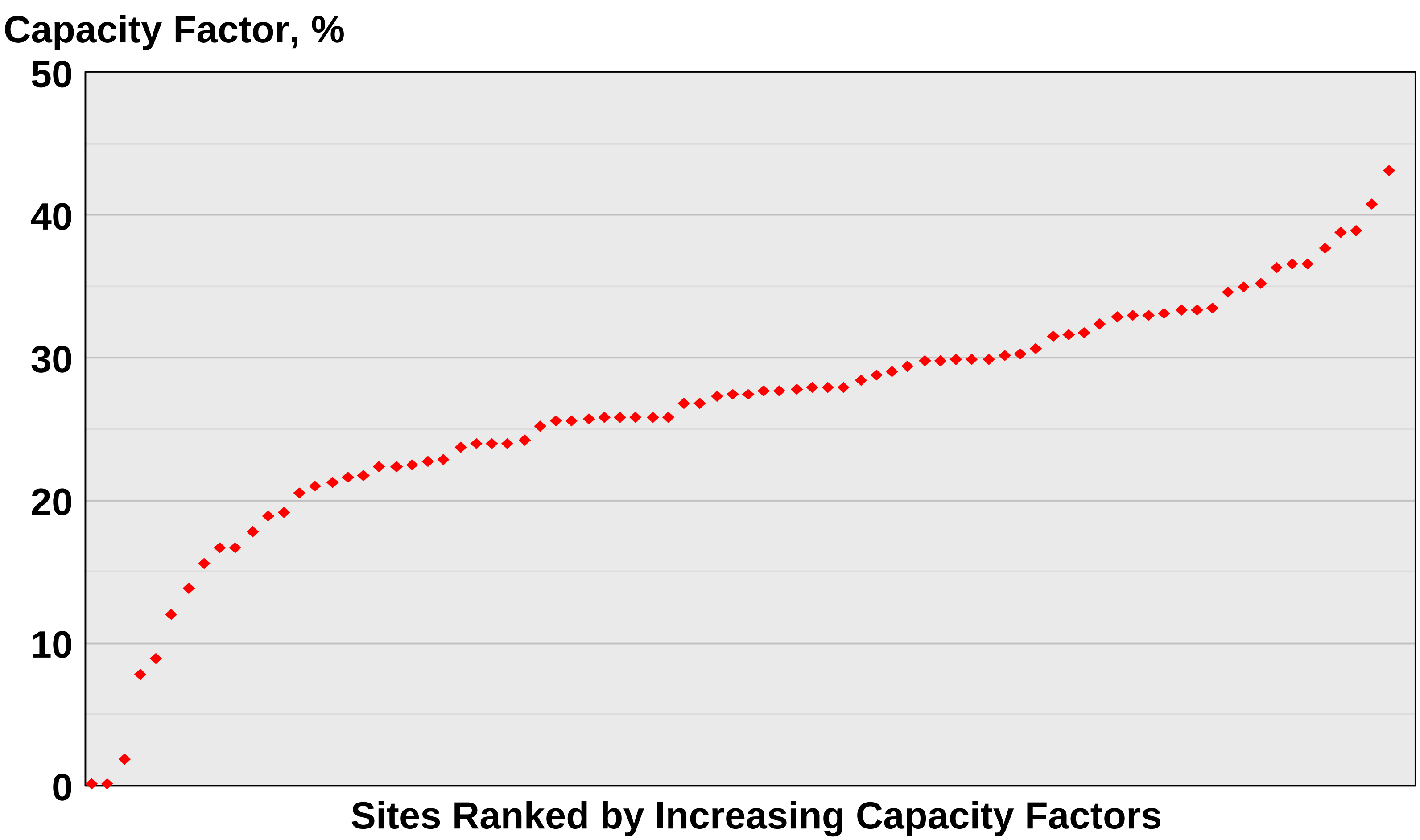
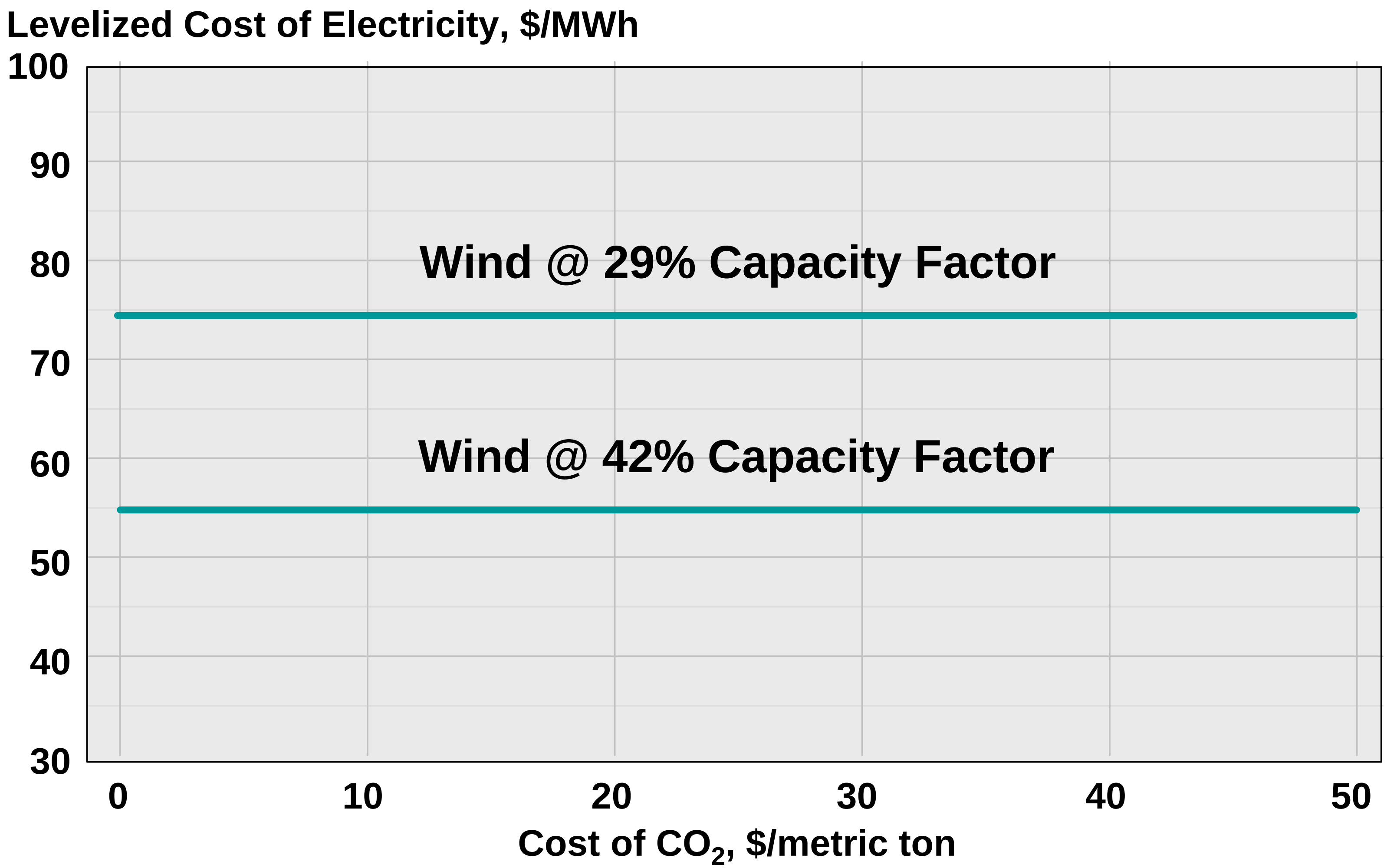
U.S. Wind Plant Capacity Factors, 2004

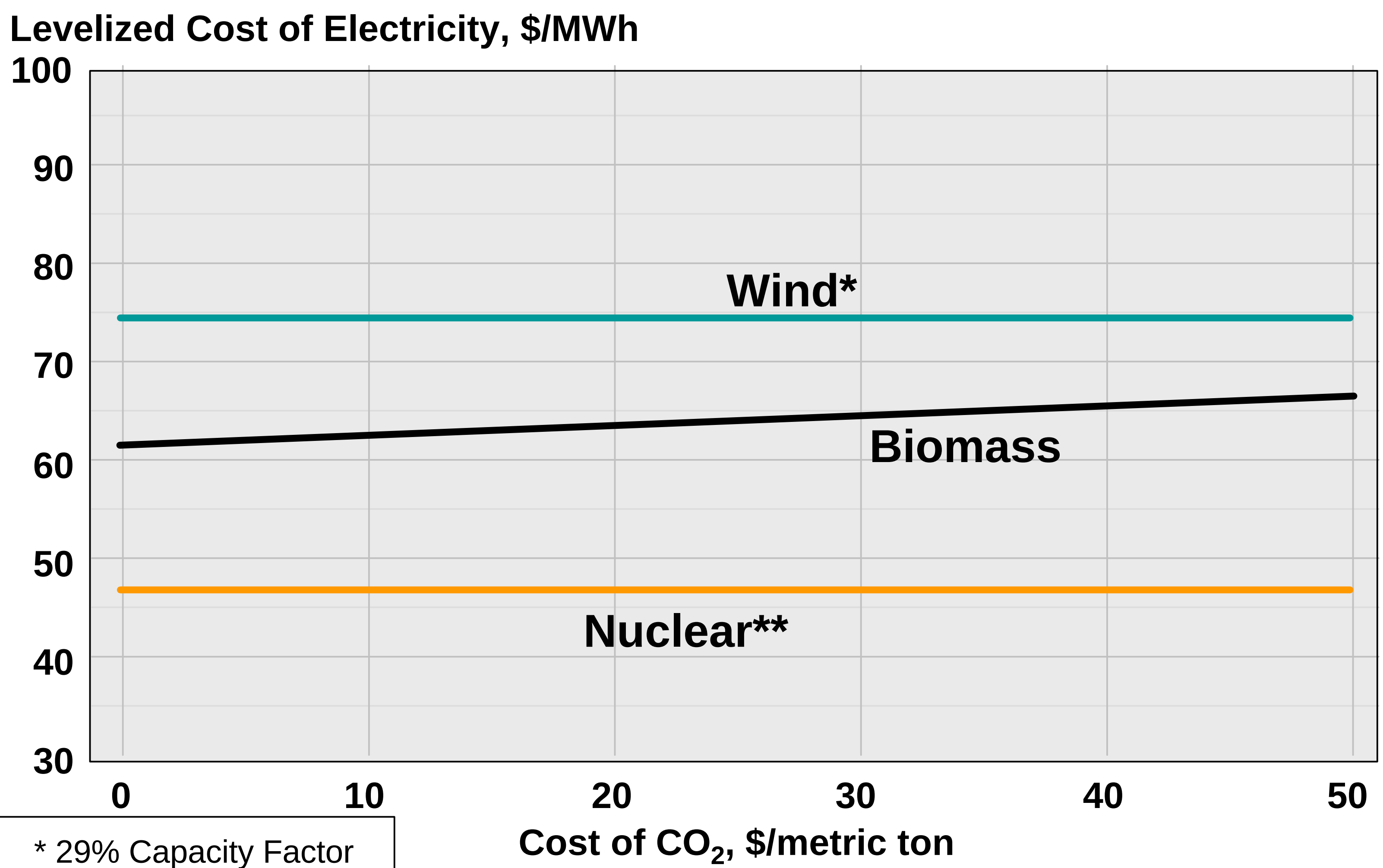


Source: EIA; EPRI Program 67 Newsletter, Energy Markets and Generation Response – Update on New Power Plants, September 2005

Non-CO_2 Emitting Technologies in 2010



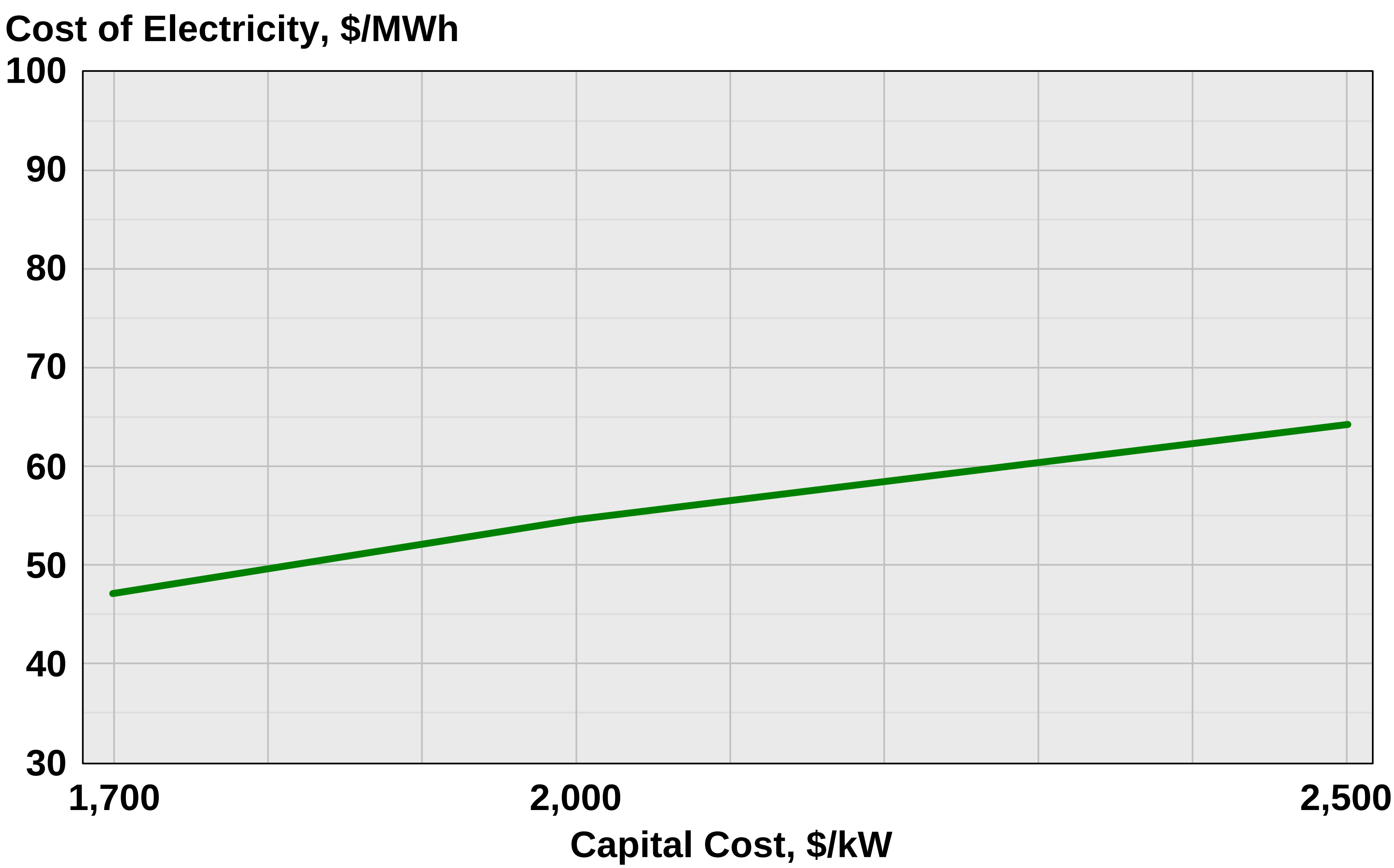
Non-CO_2 Emitting Technologies in 2010



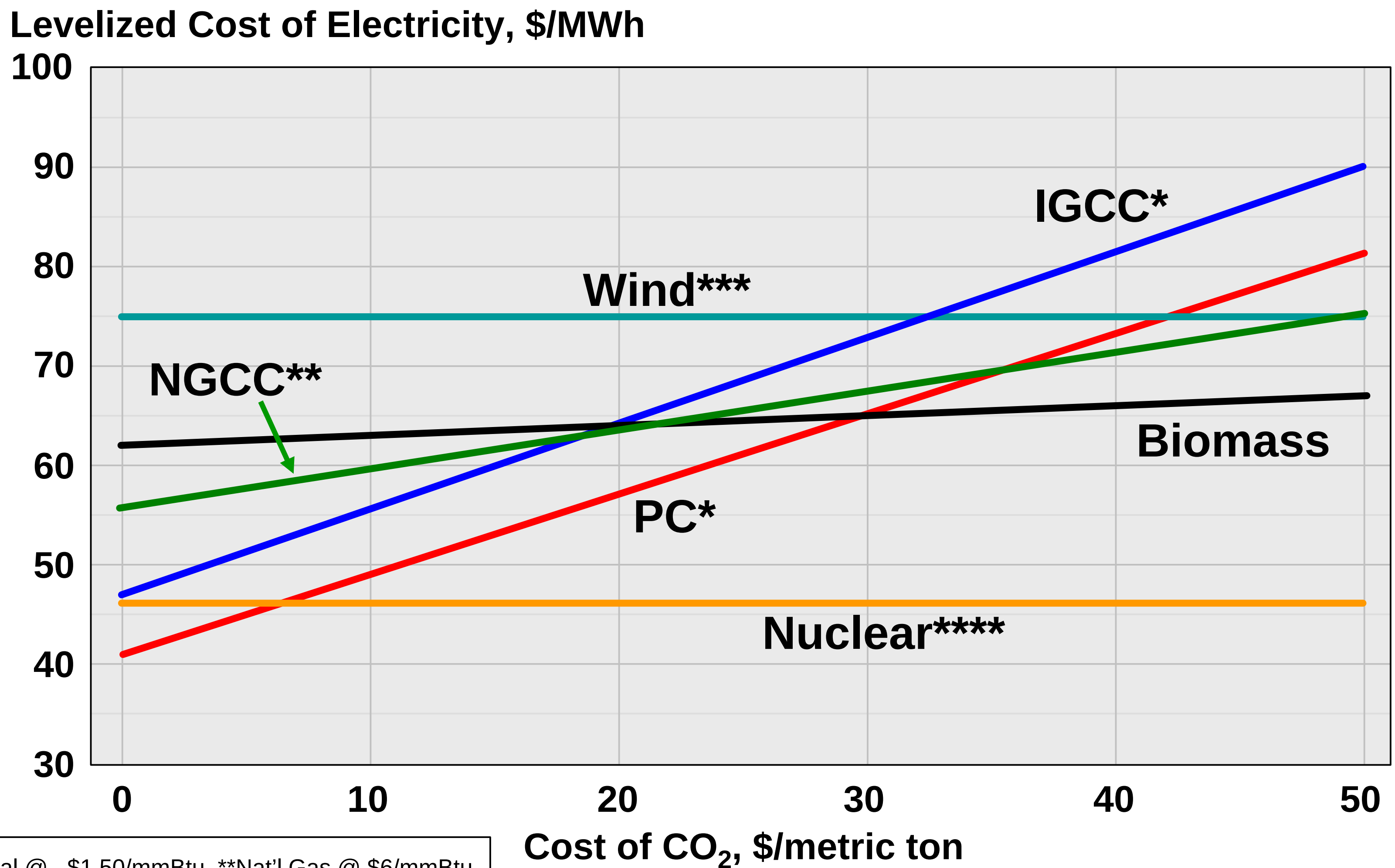
* 29% Capacity Factor

** $1700/kw capital cost

Cost Sensitivities of Future Nuclear Generation



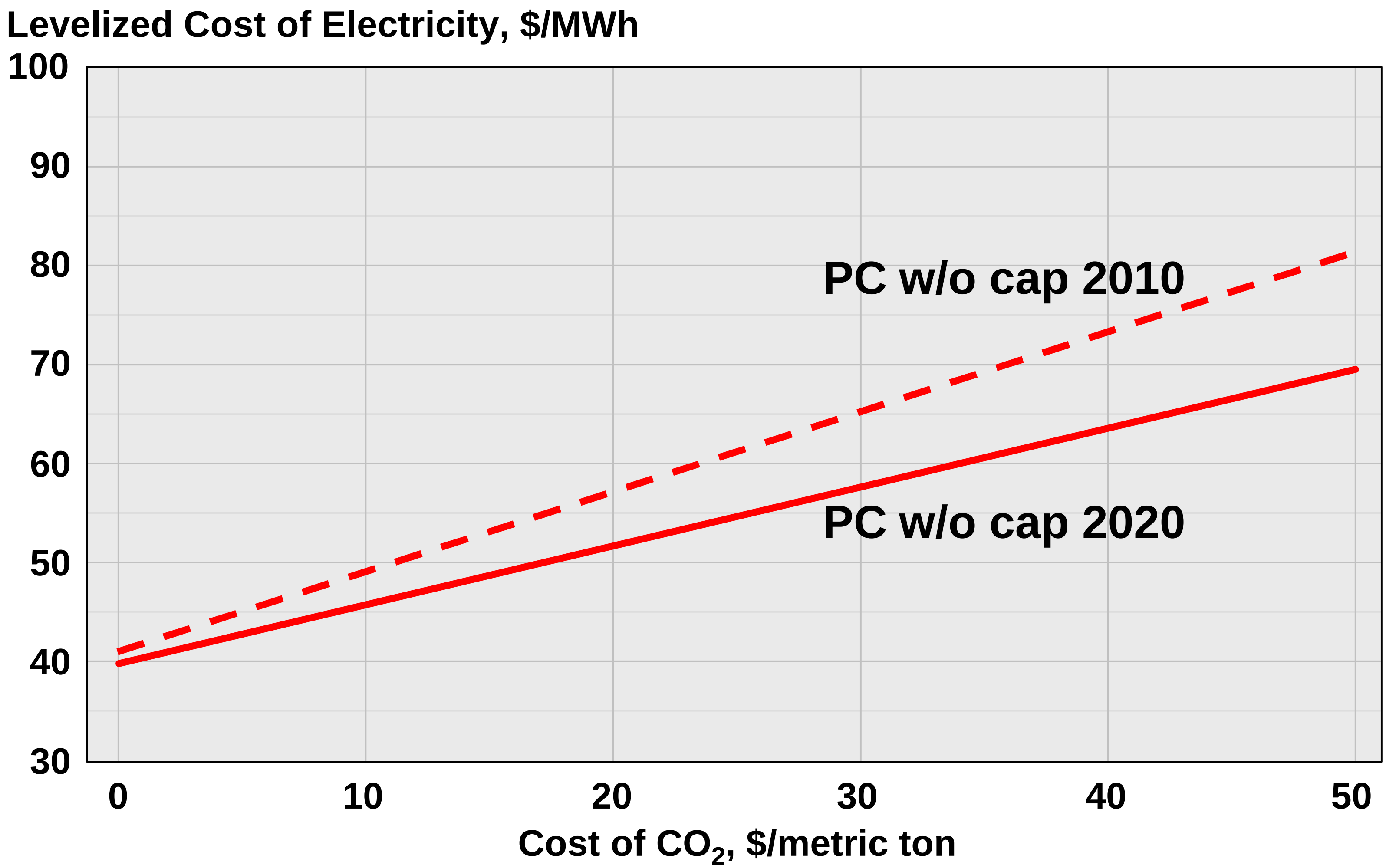
Comparative Costs of 2010 Generating Options



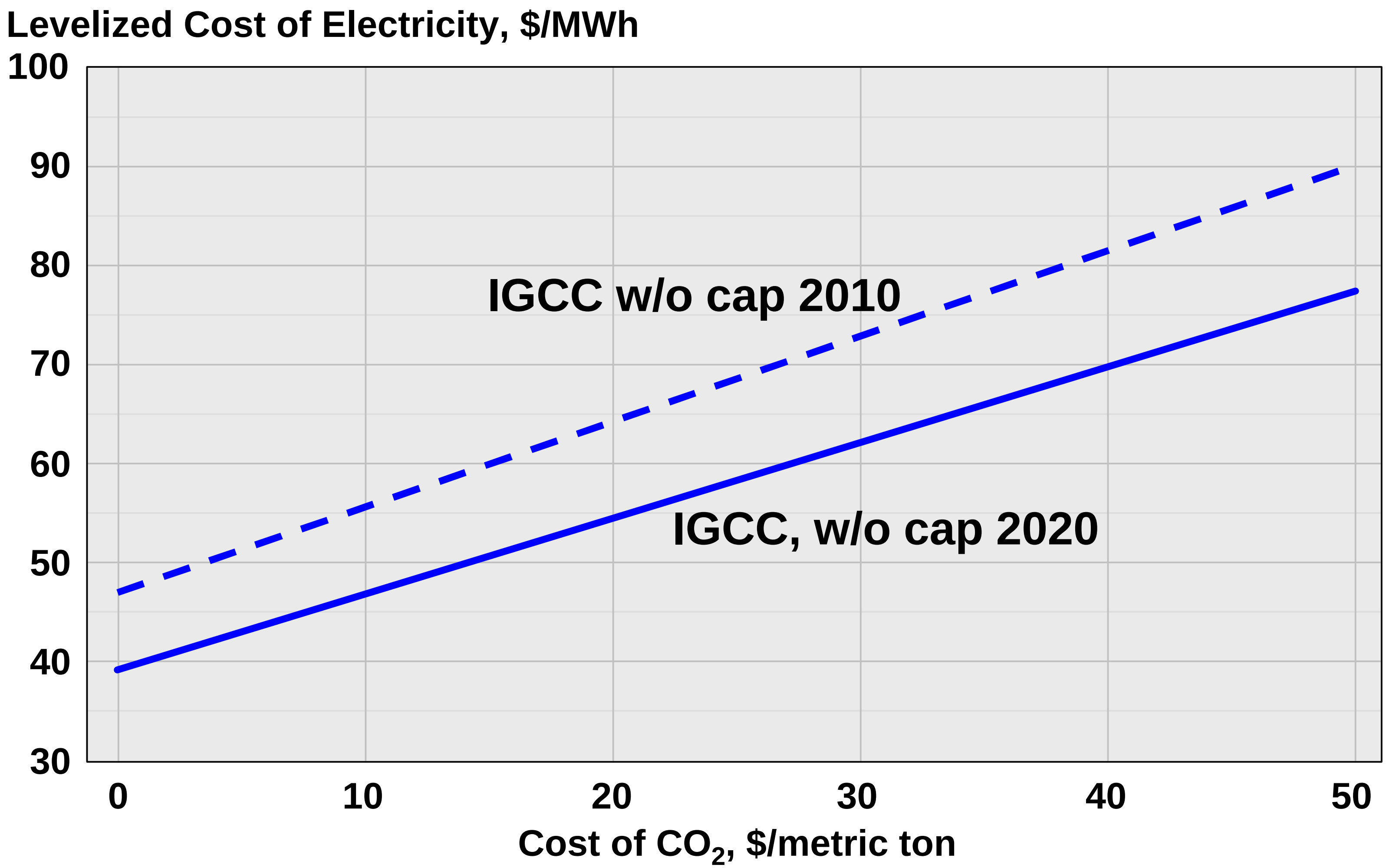
*Coal @ $1.50/mmBtu **Nat'l Gas @ $6/mmBtu
29% capacity factor *$1700/kw capital cost

What's Possible By 2020

What's Possible: Pulverized Coal w/o Capture



What’s Possible: IGCC w/o Capture



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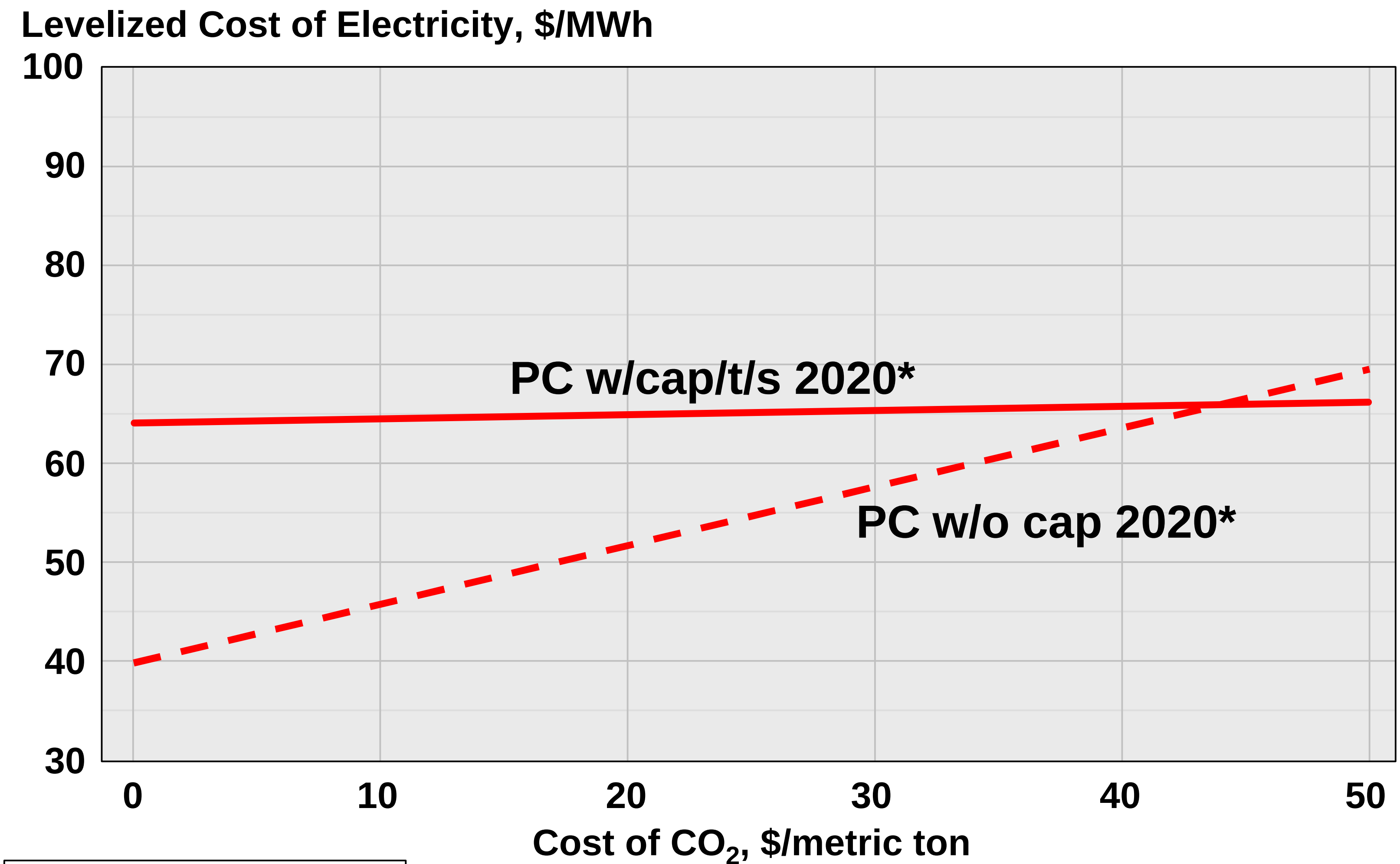
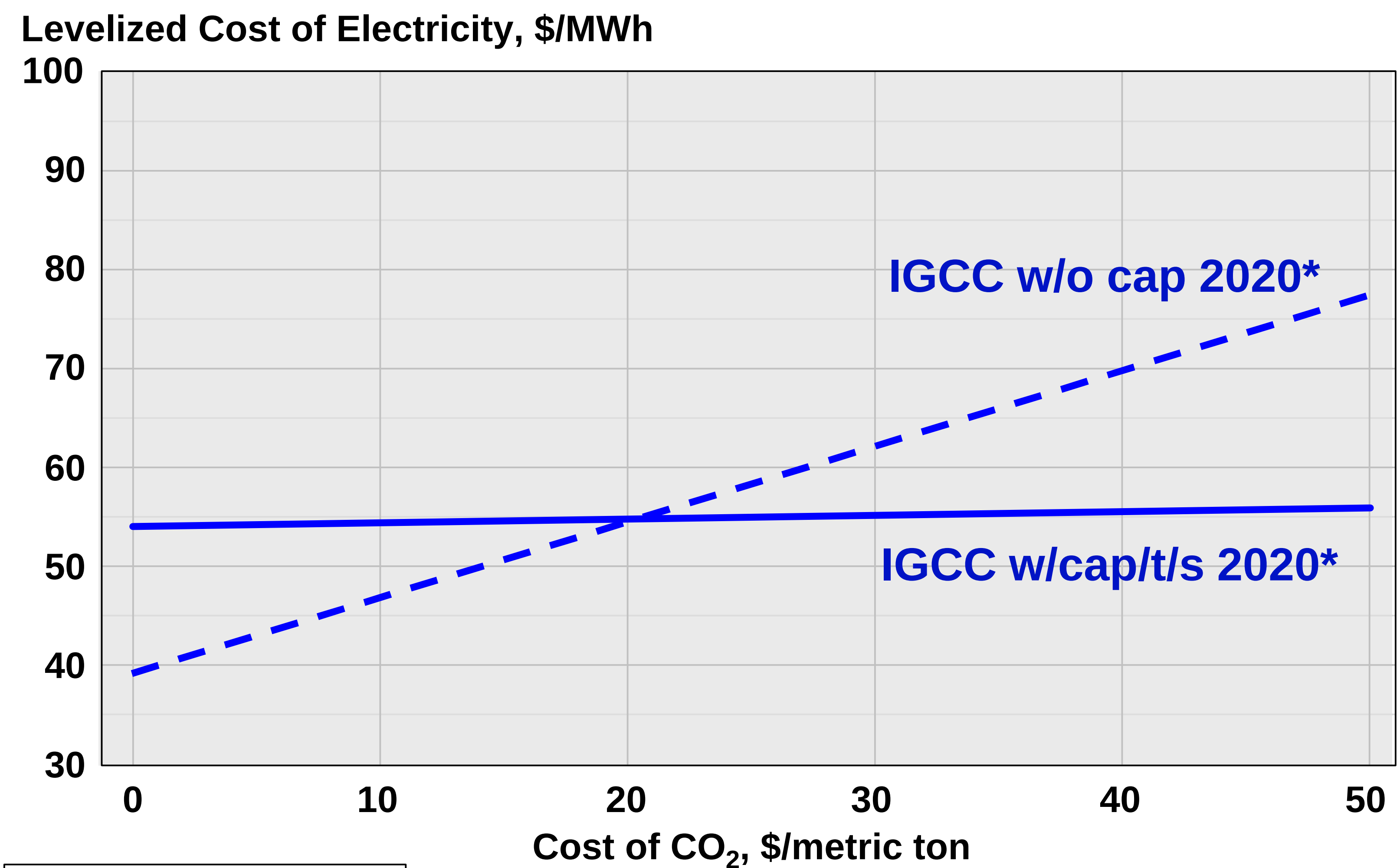
Pulverized Coal with CO_2 capture/transport/storage



*Coal @ $1.50/mmBtu

IGCC with CO_2 capture/transport/storage



*Coal @ $1.50/mmBtu

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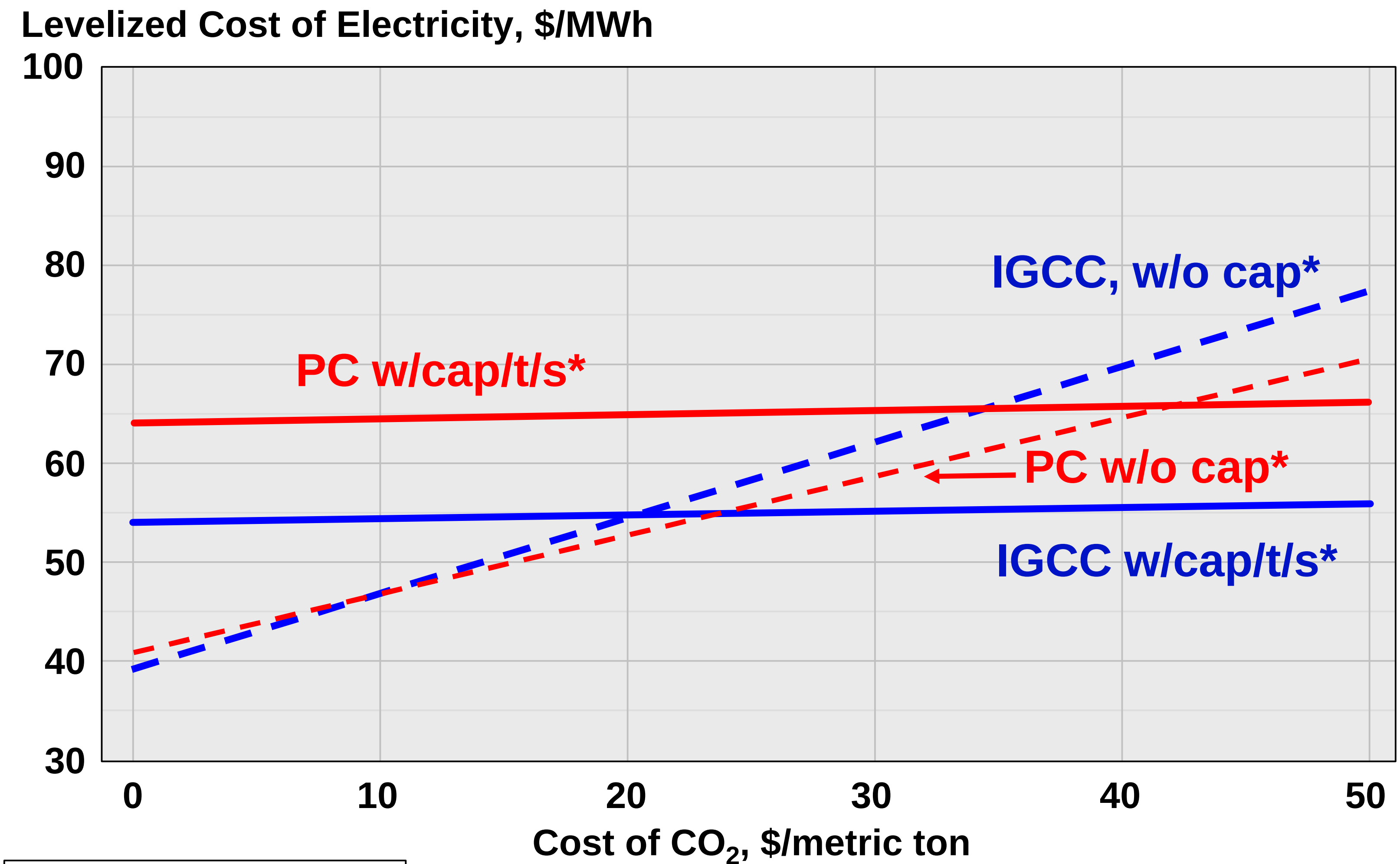
Comparison of IGCC and PC in 2020



*Coal @ $1.50/mmBtu

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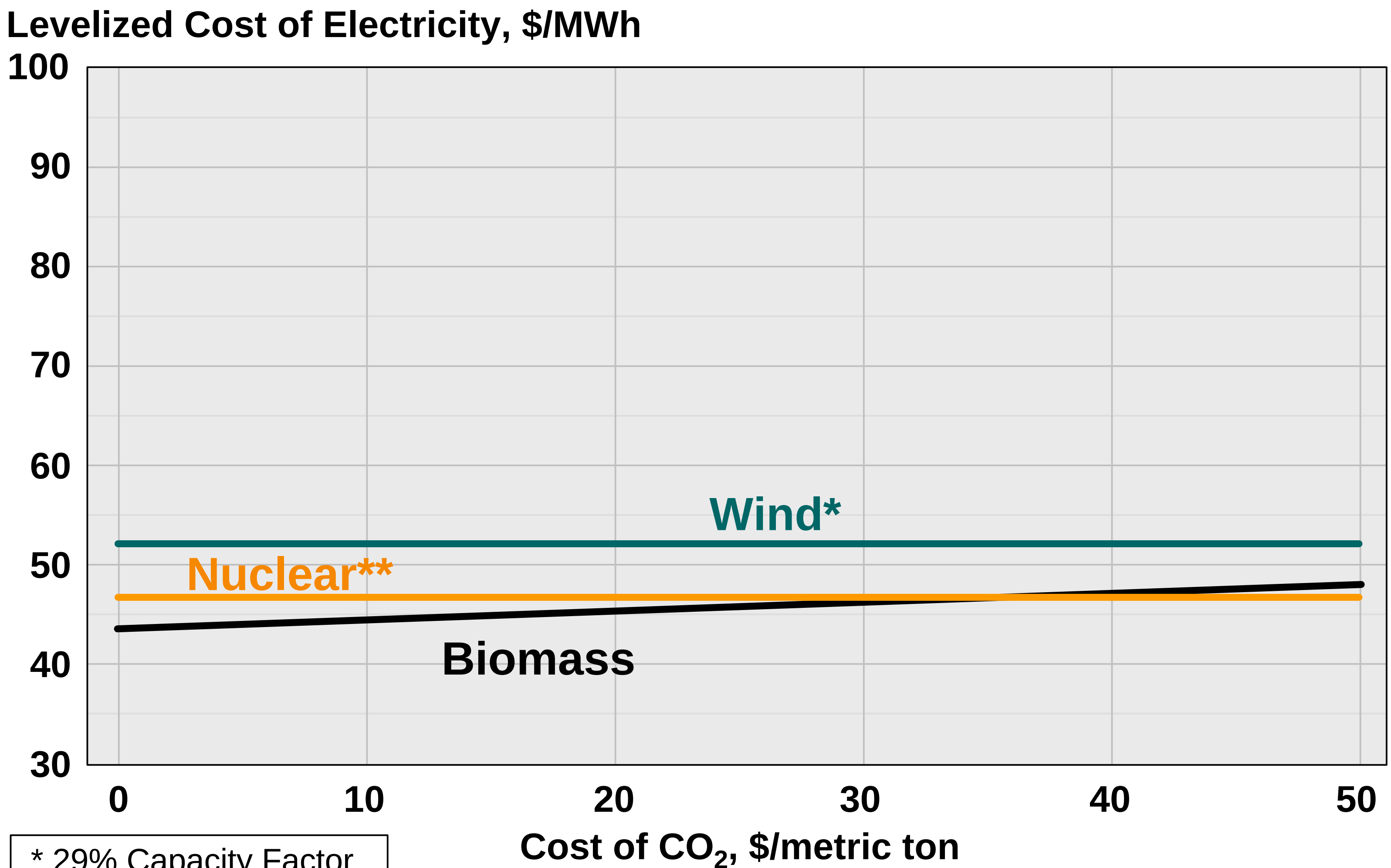
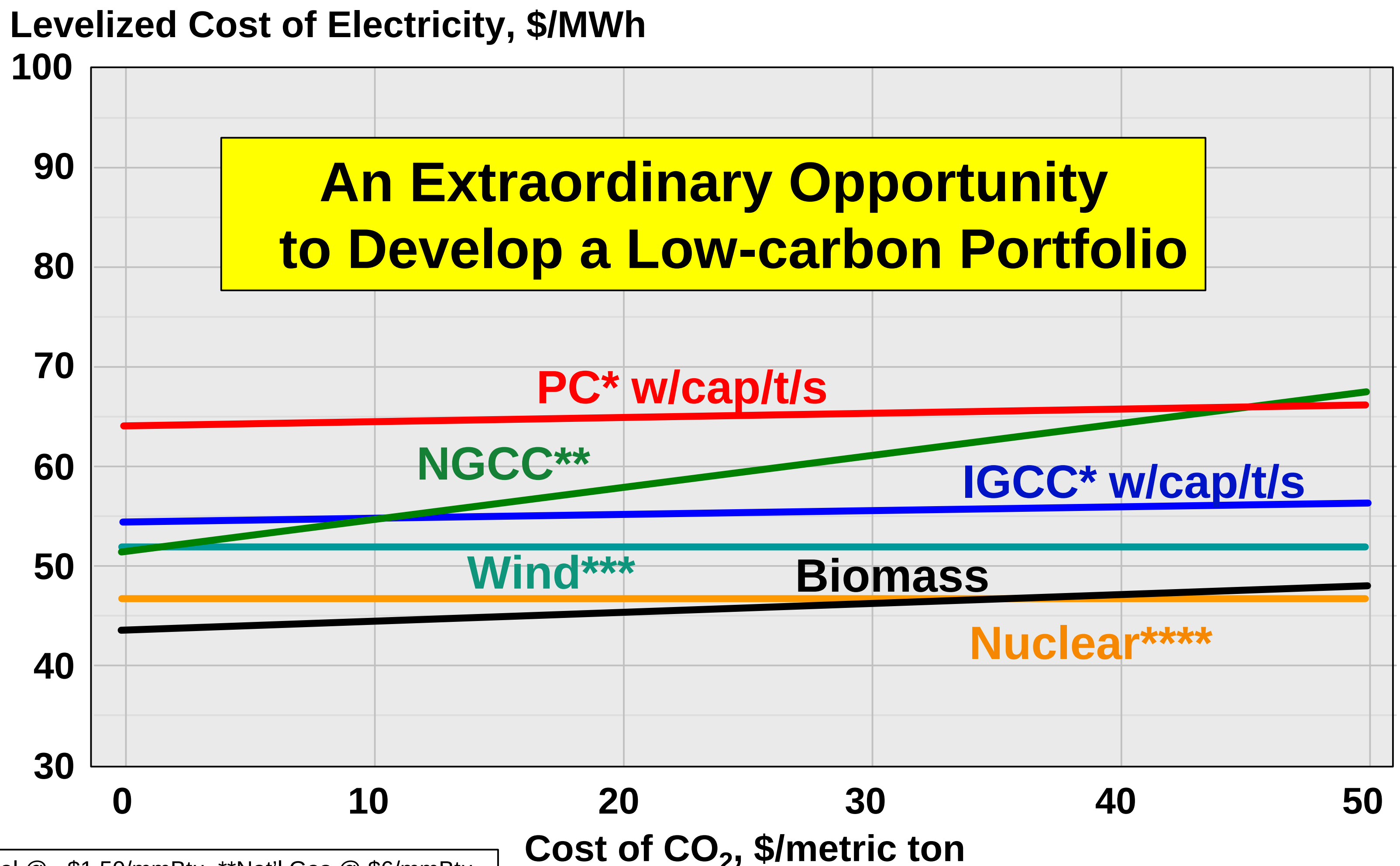
Non-CO2 Emitting Technologies in 2020



* 29% Capacity Factor

** $1700/kw

Comparative Costs of 2020 Generating Options



*Coal @ $1.50/mmBtu **Nat'l Gas @ $6/mmBtu

29% capacity factor *$1700/kw capital cost

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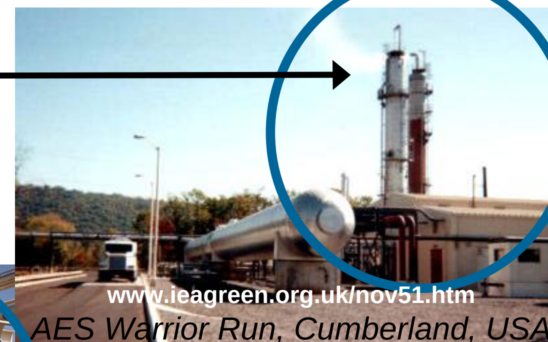
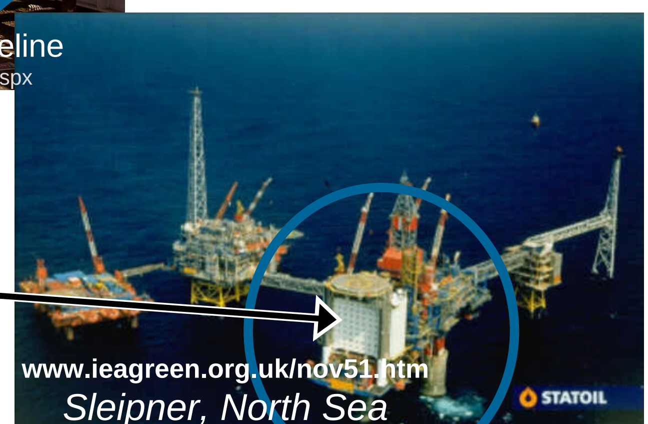
What About Carbon Capture and Storage?

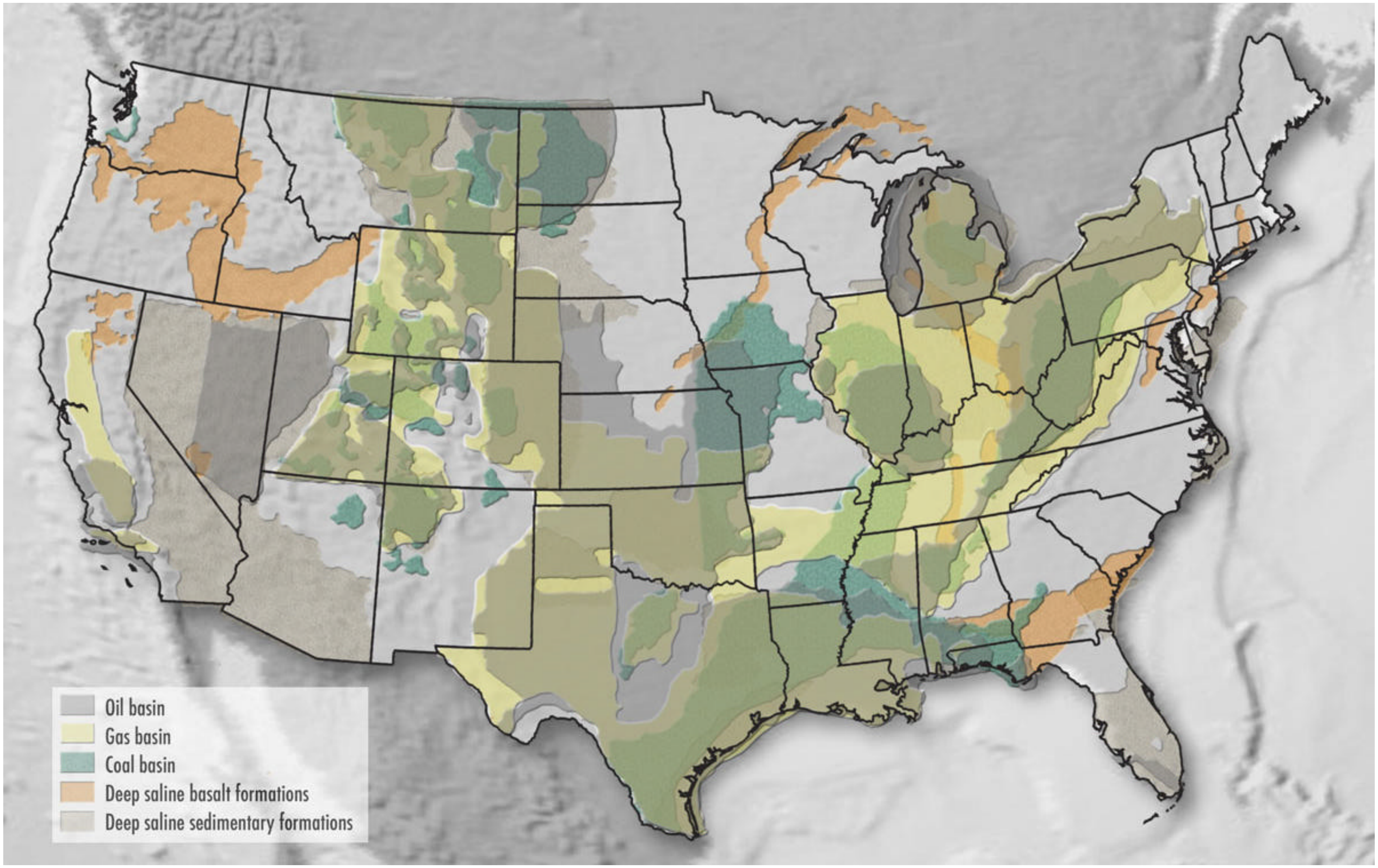
- CO_2 capture
- CO_2 transport
- CO_2 storage





Technology to perform all three tasks already exists, BUT not at scale

Carbon Storage Opportunities Differ By Region



Central Station Options Summary

- Four key uncertainties impacting near-term decisions on new generation:
  - Future cost of CO_2
  - Future price of natural gas
  - Spent nuclear fuel storage
  - CO_2 capture and storage

- Extraordinary opportunity to develop and demonstrate a very low emissions portfolio of generation technologies by operation by 2020.

Definitions - What Are Distributed Energy Resources?

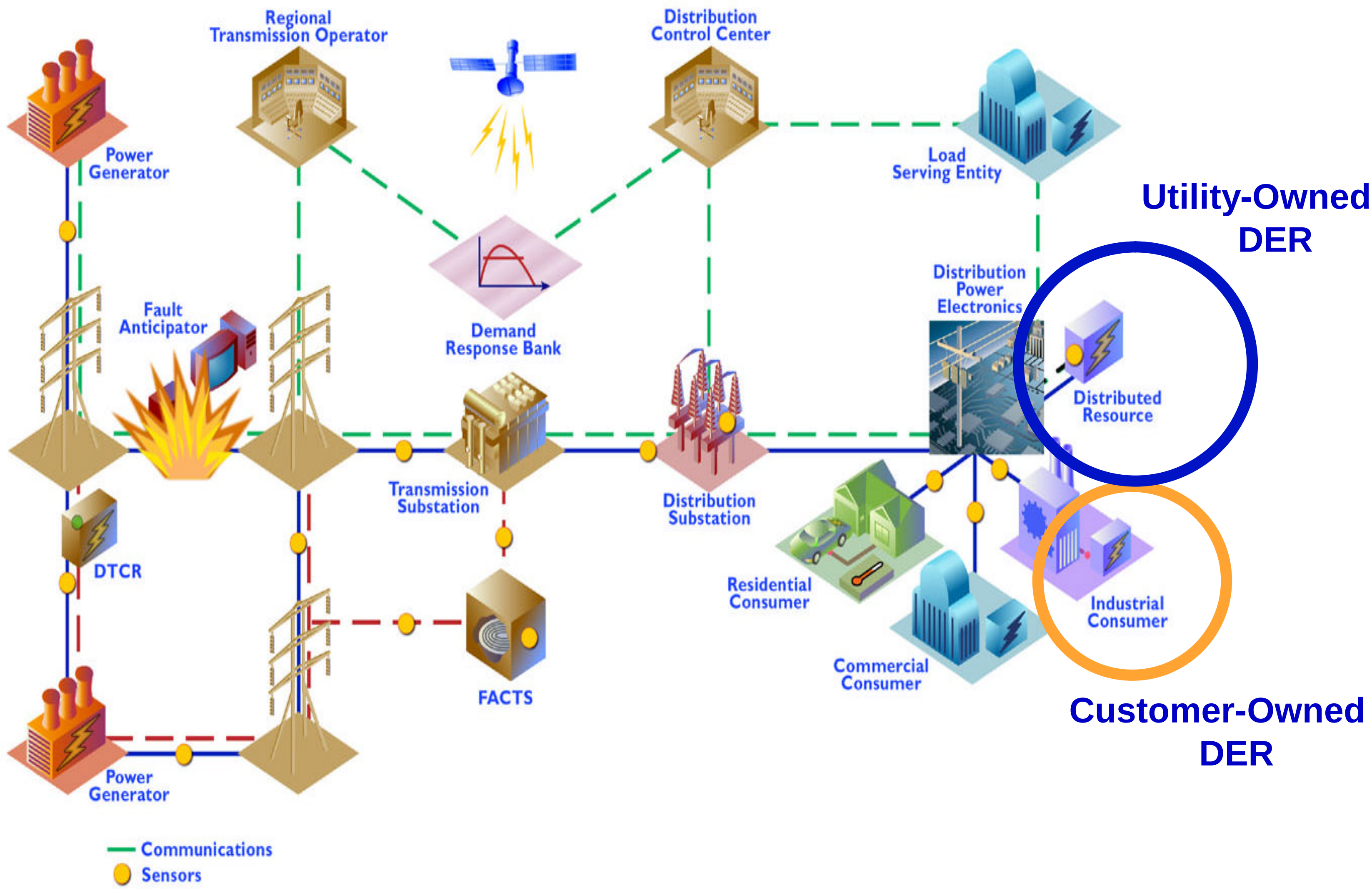
Distributed Resources (DER) =

Distributed Generation (DG)
+
Distributed Electric Energy Storage
+
Direct Load Control
+
Roof Top PV

Boundary Conditions

- End-User/Customer Location to Sub-transmission voltages
- Size Range (a few kW's to 100 MW)
- Many Ownership, Control, Costs, Benefits Regimes
- Many Operating Regimes: Peaker, Baseload; Combined heat & Power
- Many Technologies: Fossil, Storage, Renewable, Electric Storage

DER Plays a Key Role in the Future Delivery System



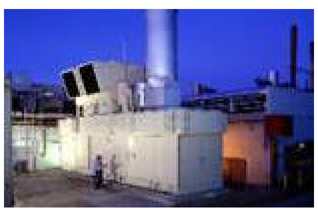
Overview of Distributed Generation Options

1 kW to 50,000 kW systems strategically placed can enhance grid reliability, improve energy efficiency / reliability to end users

Current Options

Aero-derivative CT's

- 25-60 MW
- 40+ % Eff.
- Modular



Small CT's

- 1-10 MW
- ~ 40% Eff

Diesel and IC Engines

- 0.3-2 MW
- 36% Eff.
- Low emissions

Emerging Trends

Microturbines

- 60-300 kW
- 25-30% Eff
- Packaged systems

Fuel Cells

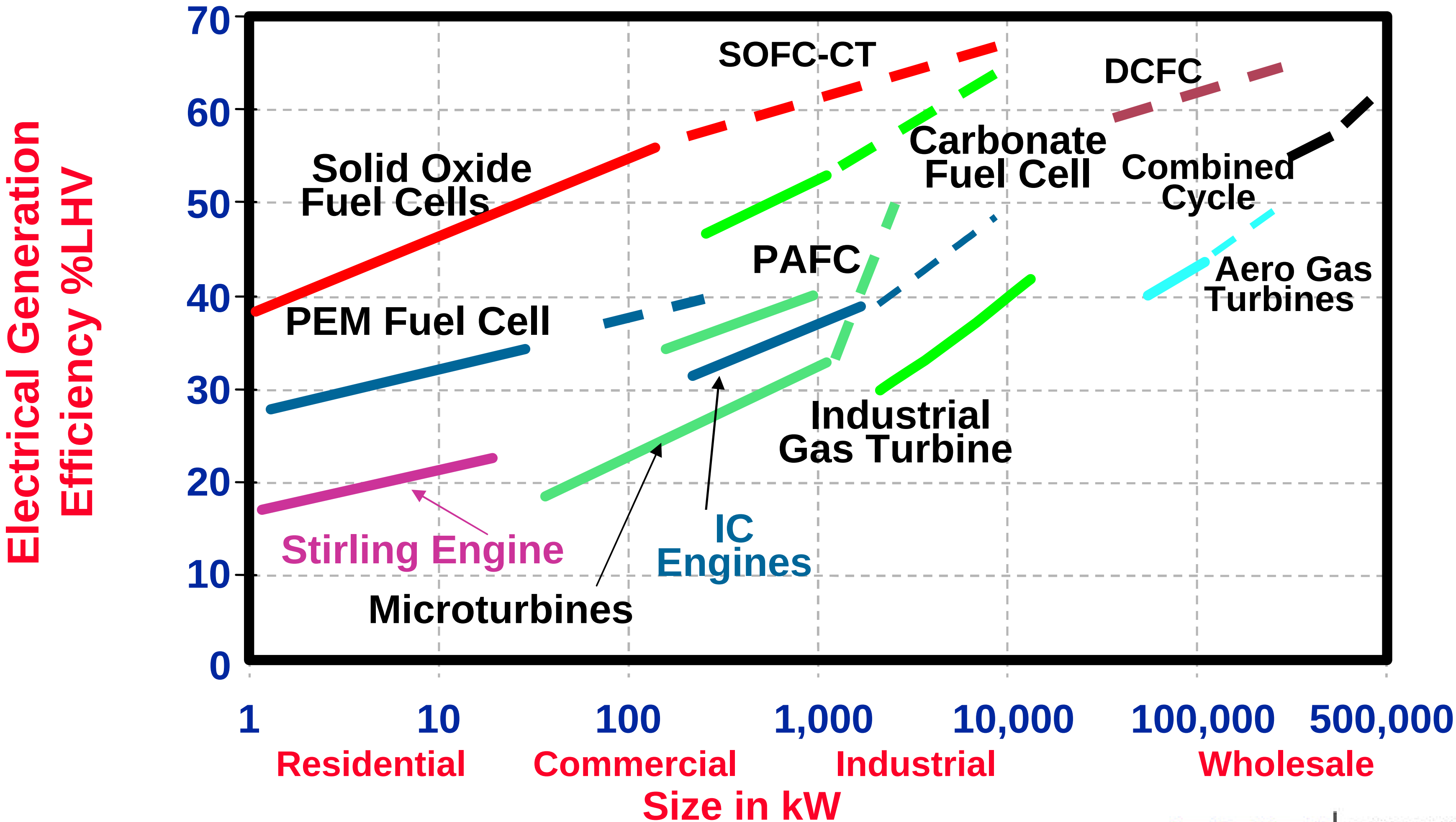
- 1 – 1,000 kW
- 30-65 % Eff
- Many on-site markets

Energy Storage

- Flow Batteries
- NiMH, NaS, Lithium Ion

Distributed Generation Technologies

Efficiency Status and Trends



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Overview
Status of Stationary Fuel Cell Power Systems

Polymer Electrolyte Membrane (PEMFC)

- 1-10 kW
- 25-40 % efficiency LHV
- $ 5,000 /kW

Molten Carbonate Fuel Cells (MCFC)

- 250- 1,000 kW
- 45 % efficiency
- $ 3,000-4,000 / kW

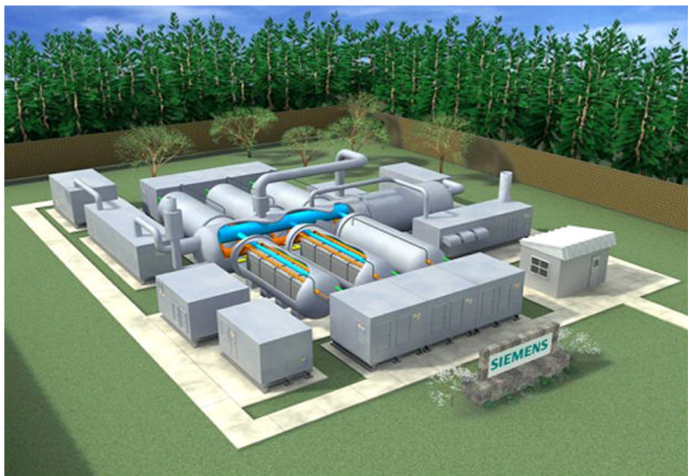
Phosphoric Acid Fuel Cells (PAFC)

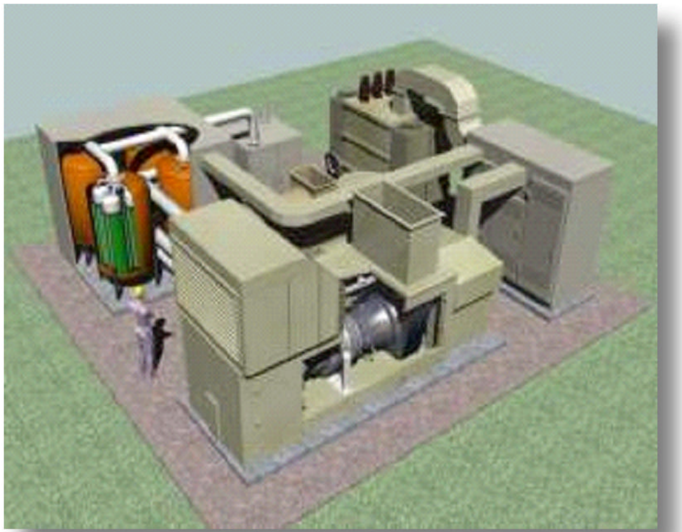
- 200-1000 kW
- 40 % efficiency LHV
- $ 3,500 / kW

Solid Oxide Fuel Cells (SOFC)

- 1-250 kW
- 45-48 % efficiency
- $10,000 - 20,000/kW

High Efficiency SOFC Hybrids under Development





1-15 MW **56-65% on natural gas** **Modular**

Fuel Cell Market Pathways

Efficiency, LHV

35-45

55

65

2006-2008

Early Markets

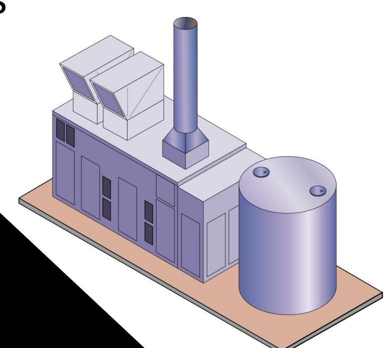
- Schools & Universities
- Government Buildings
- CHP; Free Fuel
- National Parks
- Military Bases
- State RPS Programs

Growth Markets

- Building CHP
- State Energy Efficiency Programs
- Non-attainment areas
- Mass Markets

2008-2010

- **5 kW – 75 kW PEMFC**
- **250 – 2 MW MCFC, and SOFC**
- **5- 40 kW SOFC**
- **$ 1,500-$2,000 / kW**



2010-2020

- **…/ – 250 kW PEMFC**
- **…0 – 3 MW MCFC, SOFC**
- **…2 – 50 kW SOFC**
- **2 MW + SOFC-CT**
- **<<$ 800 /kW**

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Overview
Status of Micro-Turbines

Ingersol Rand

- 250 kW
- 25-30 % efficiency LHV

Capstone

- 30-200 kW
- 25-30 % efficiency LHV

Elliott

- 100 kW
- 20-30 % efficiency

UTC Power/ Carrier PureComfort
240-360 kW with 100 Ton Chiller
25% Electric; 75% overall

Combustion Turbine & Micro Turbine Trends

2006

- Low Emissions Development
- Advanced Materials

Early Markets

- Combined Heat, Cooling
- Hotels
- Grocery
- Schools & Data Centers
- 25% Electrical Eff

--70-75% with CHP

2006-2008

- 240-500 kW – MTGs
- 1.5 – 10 MW CT's
- 80% Eff w/CHP

2010

45 % LHV
<< 5 ppm NOx

** Lower Heating Value*

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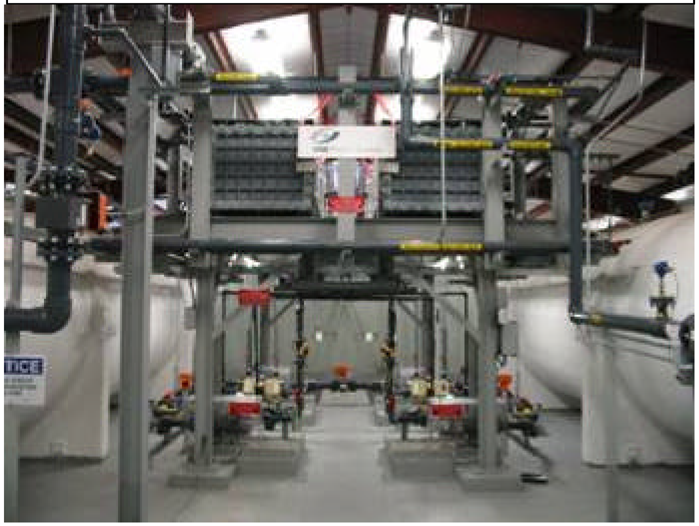
Overview Status of Energy Storage Systems

Vanadium Redox Battery (VRB)



-250 kW – 8 Hr
~ 2 MWh
-+/- 250 KVars

- 57 – 71 % round trip efficiency

Nickel Metal Hydride (NiMH)

- 20 kW - 2 Hr
- Round trip efficiency TBD

Sodium Sulfur (NaS)

-1 MW–7 Hr
~ 7 MWr

~ potential of 75 % round trip efficiency

2 MWh VRB Energy Storage System at PacifiCorp

Energy Storage System Trends

2006

- Advanced batteries are reaching commercial prototype stages
  - NaS furthest along
  - Others include NiMH, Zinc-Bromine, VRB and Lithium systems

Applications:

- Firming Renewables
- Distribution Grid Support
- Demand Response

2006-2008

- $300/kWh battery module cost
- Ac-dc-ac power cond. ~ $250/kW
- Round trip efficiency of 75%

2015

Integrated systems

Li-ion

NiMH

NaS

<$200 kWh

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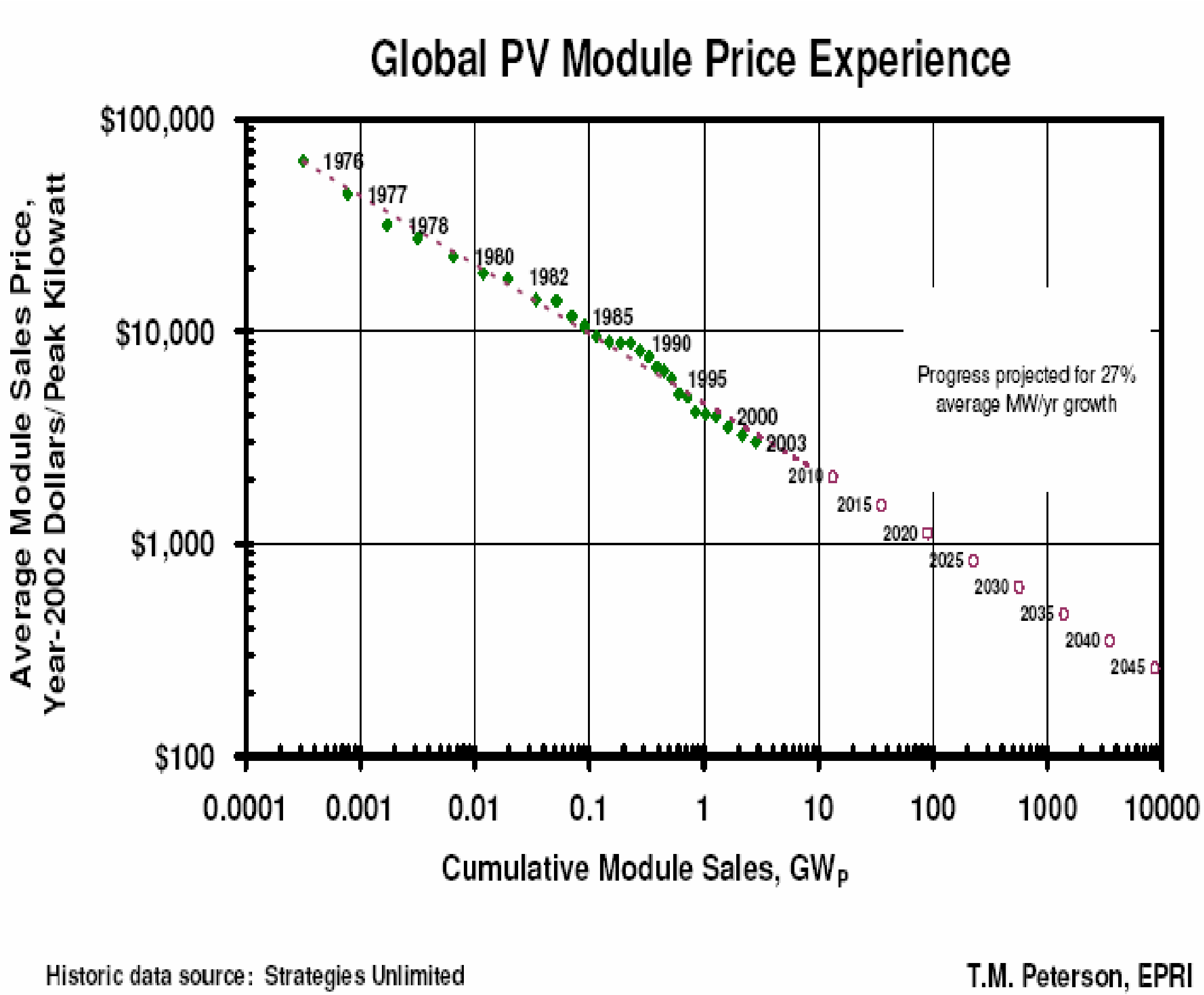
Historic PV module sales and price trend

- Installed system price ≈ 2x module cost
- No "guarantee" future will echo past…but also no evident cause for change
- Present expansion (40%/yr) driven by subsidized grid-connected markets



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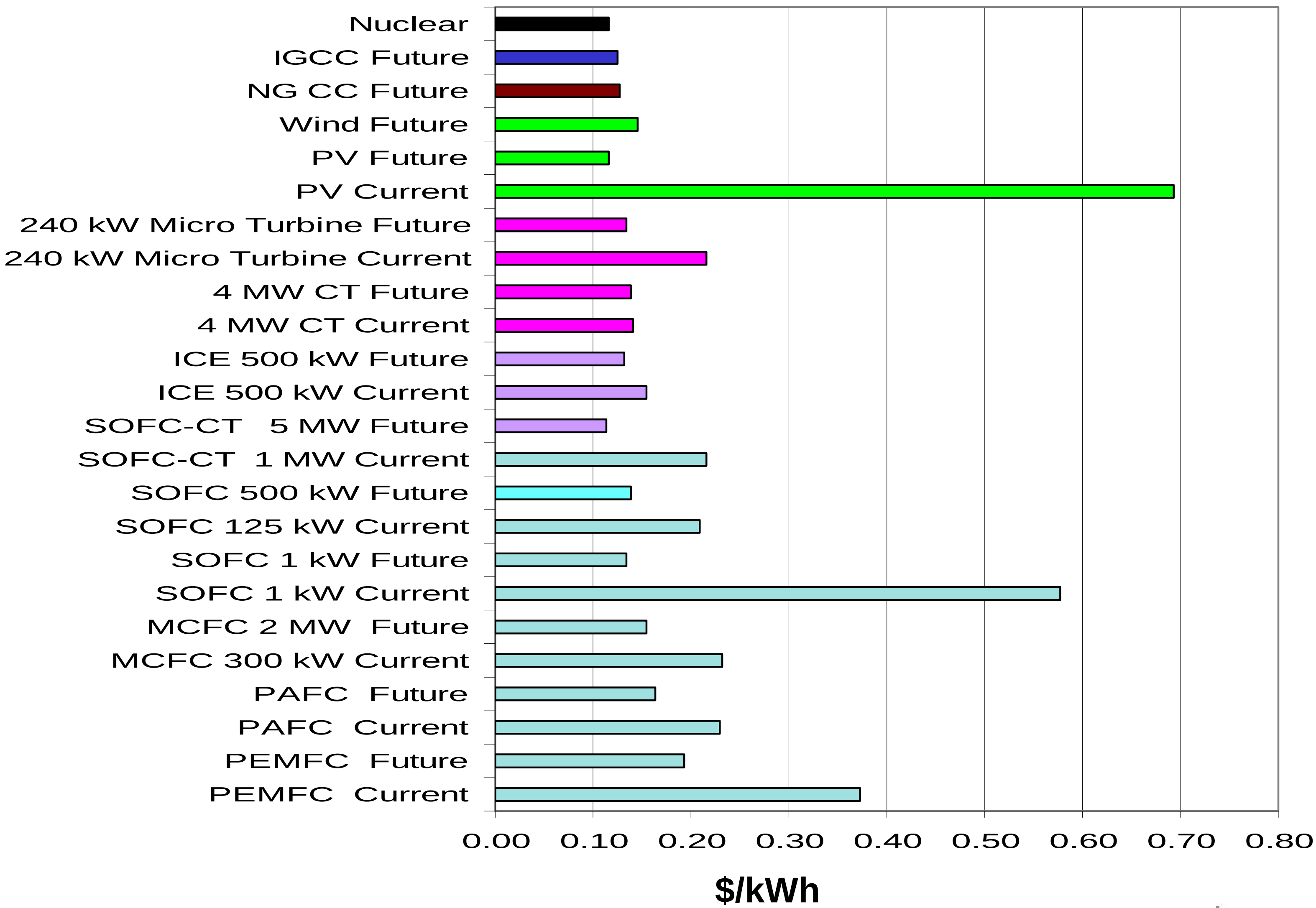
Comparative Cost of Delivered Electricity to End-Users

Assumptions: Costs to deliver Bulk Power: 7 cents/kWh
No Carbon Taxes considered
For DER: $10MMBtu N.G. 80% CF; 15% CC; no distributed benefits considered



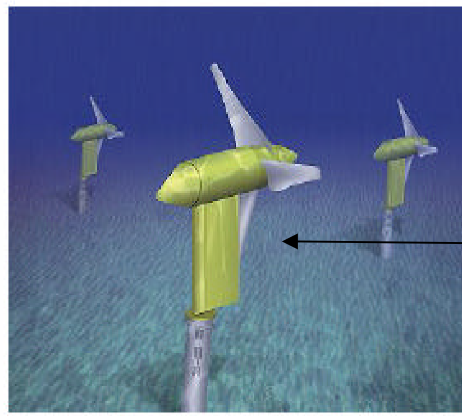
Roosevelt Island Tidal Energy (RITE) Project

Permitted by NY Dept of Env Cons and US Army Corps of Eng – April 2006

Hardware is built and will be installed by July 2006

Funded by NYSERDA, ConEd and Verdant (and maybe others)

Roosevelt Island, East River, NY - Verdant Horizontal Axial Turbines (6) @ 40kW each



First U.S. Tidal Installation – Clean; Submerged and not visible, Variable but predictable resource for ease of dispatching

First Tidal Installation Connected to the Grid in the World

First Tidal Array Installed in the World

First Tidal Environmental Monitoring (including fish) Program in the World

Win-Win-Win for Distributed Energy Resources

DER Customer

Win

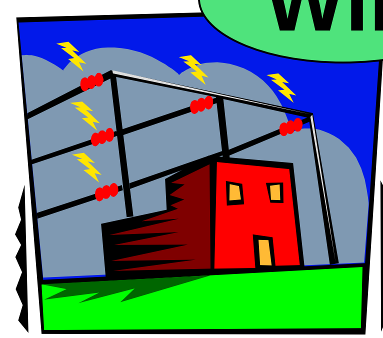
DG Benefits

Public Incentives

Innovative Regulation

Utility Shareholder & Other Customers

Win



Cost Savings

Shareholder Incentives

Cleaner Environment
Lower Total Costs

Society

Win

Website *http://www.epri.com/der-ppp/index.html*