ELECTRIC POWER RESEARCH INSTITUTE

Electricity Technology in a Carbon-Constrained Future

Utah Climate Change Symposium
May 8, 2007

Bryan Hannegan, Ph.D.
Vice President - Environment

Presentation Objective

Provide a factual framework for discussing:

I. Generation technologies and investment decisions in a world with carbon constraints

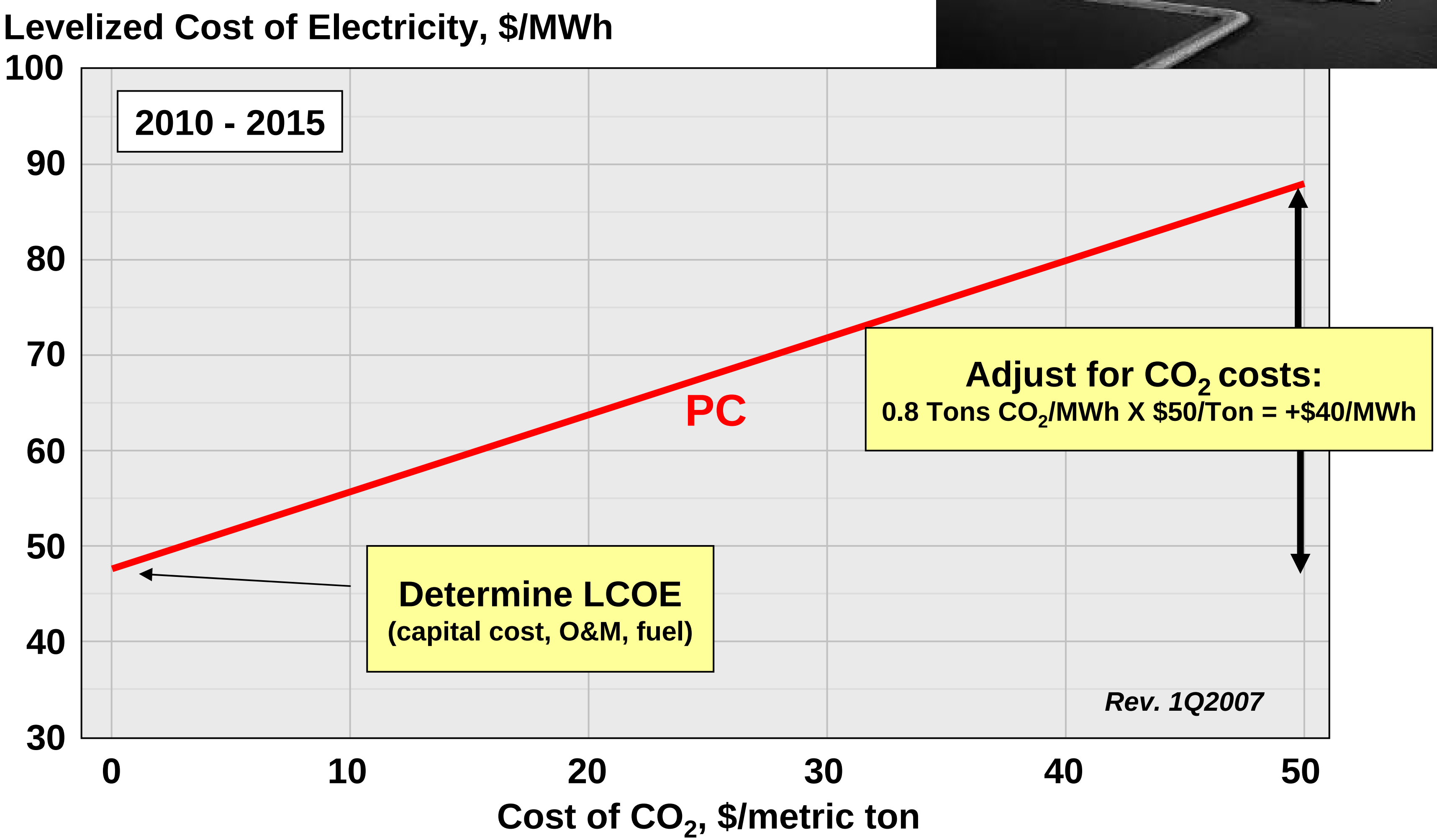
II. R&D needs to achieve a low-cost, low-carbon portfolio of electricity technologies

III. Technical feasibility of using this portfolio of technologies to reduce U.S. electric sector CO_2 emissions

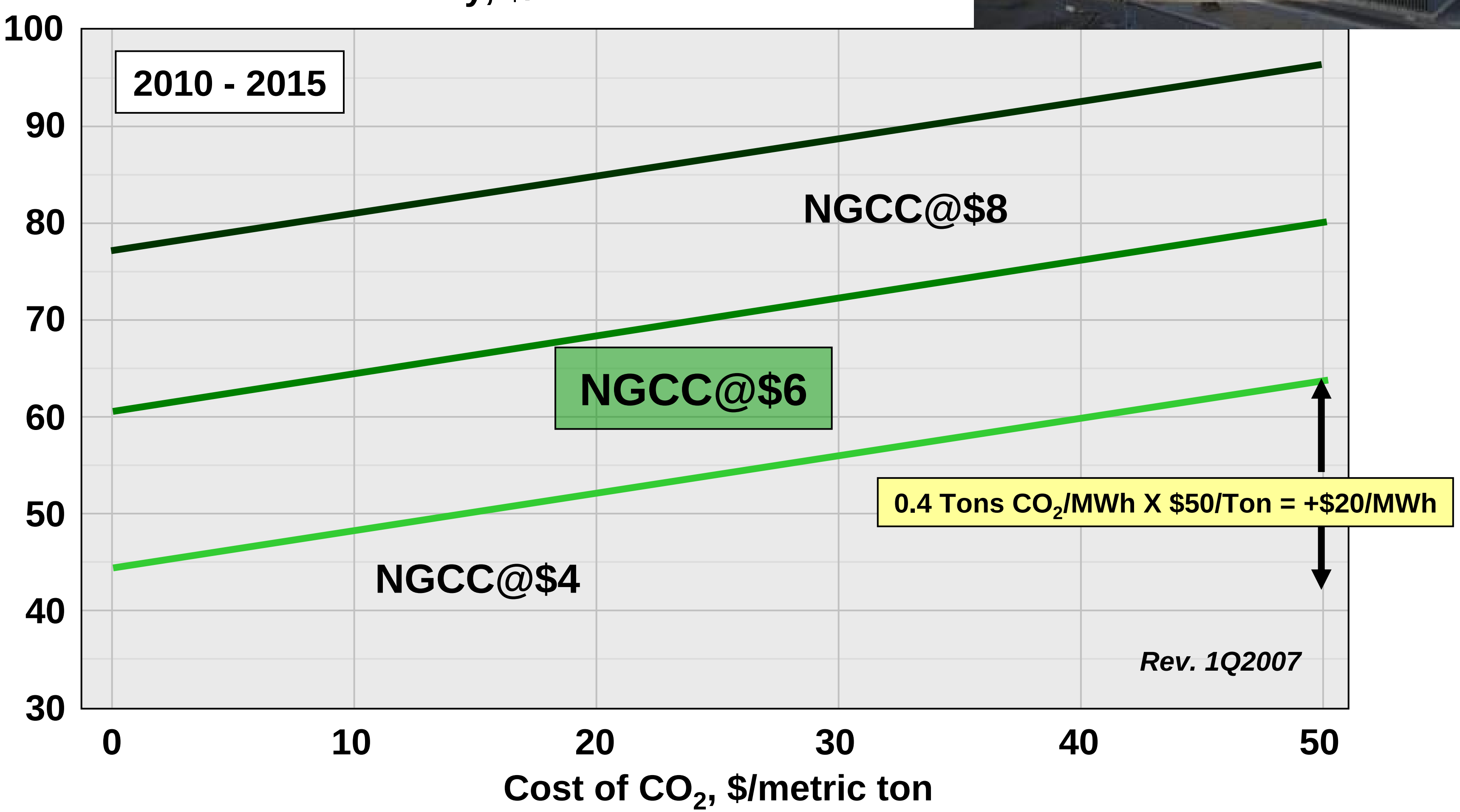
IV. Economic implications of achieving significant CO_2 reductions with/without low-cost, low-carbon technologies

EPRI | ELECTRIC POWER RESEARCH INSTITUTE

Pulverized Coal



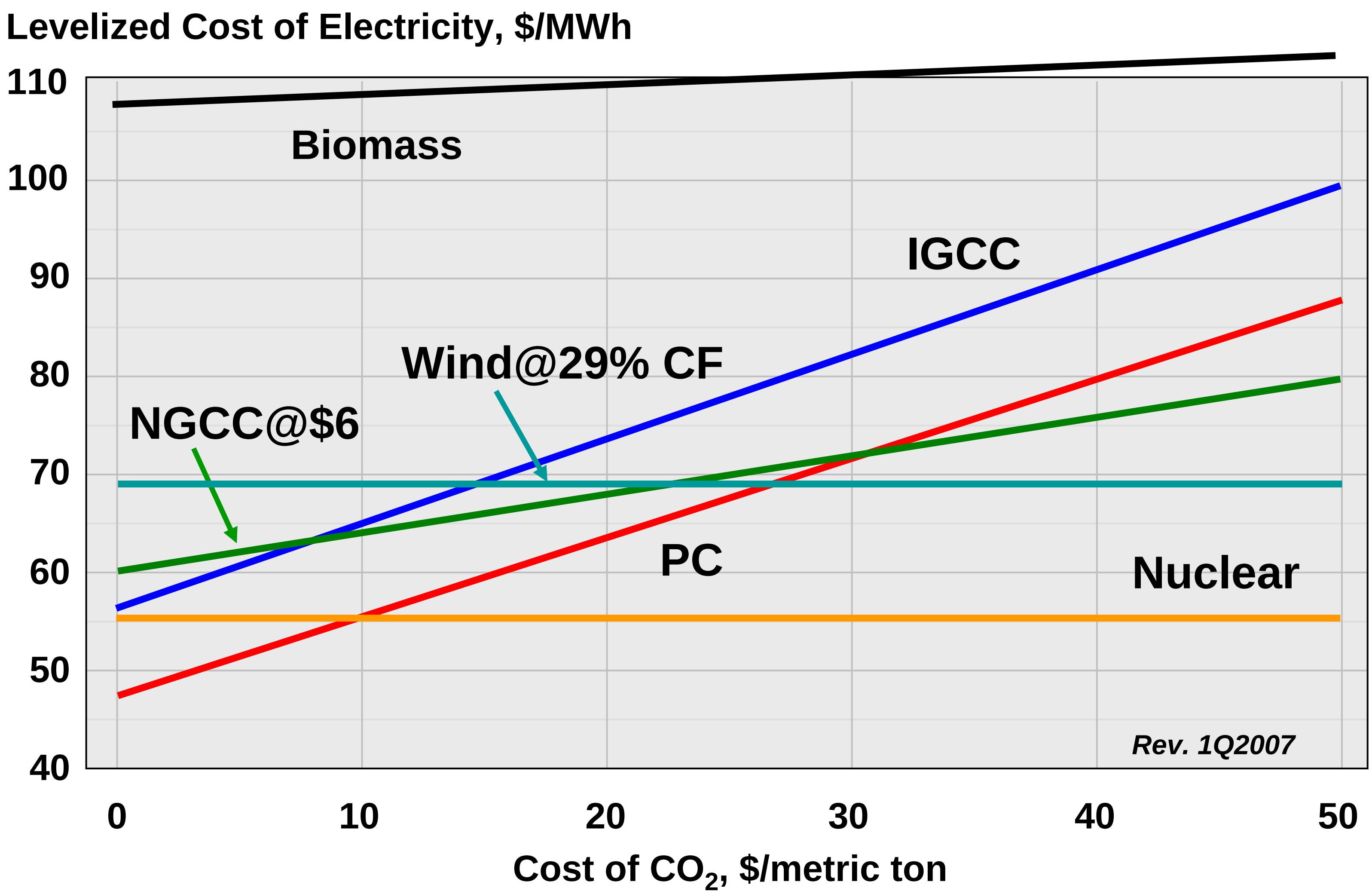
Natural Gas Combined Cycle



EPRI | ELECTRIC POWER RESEARCH INSTITUTE

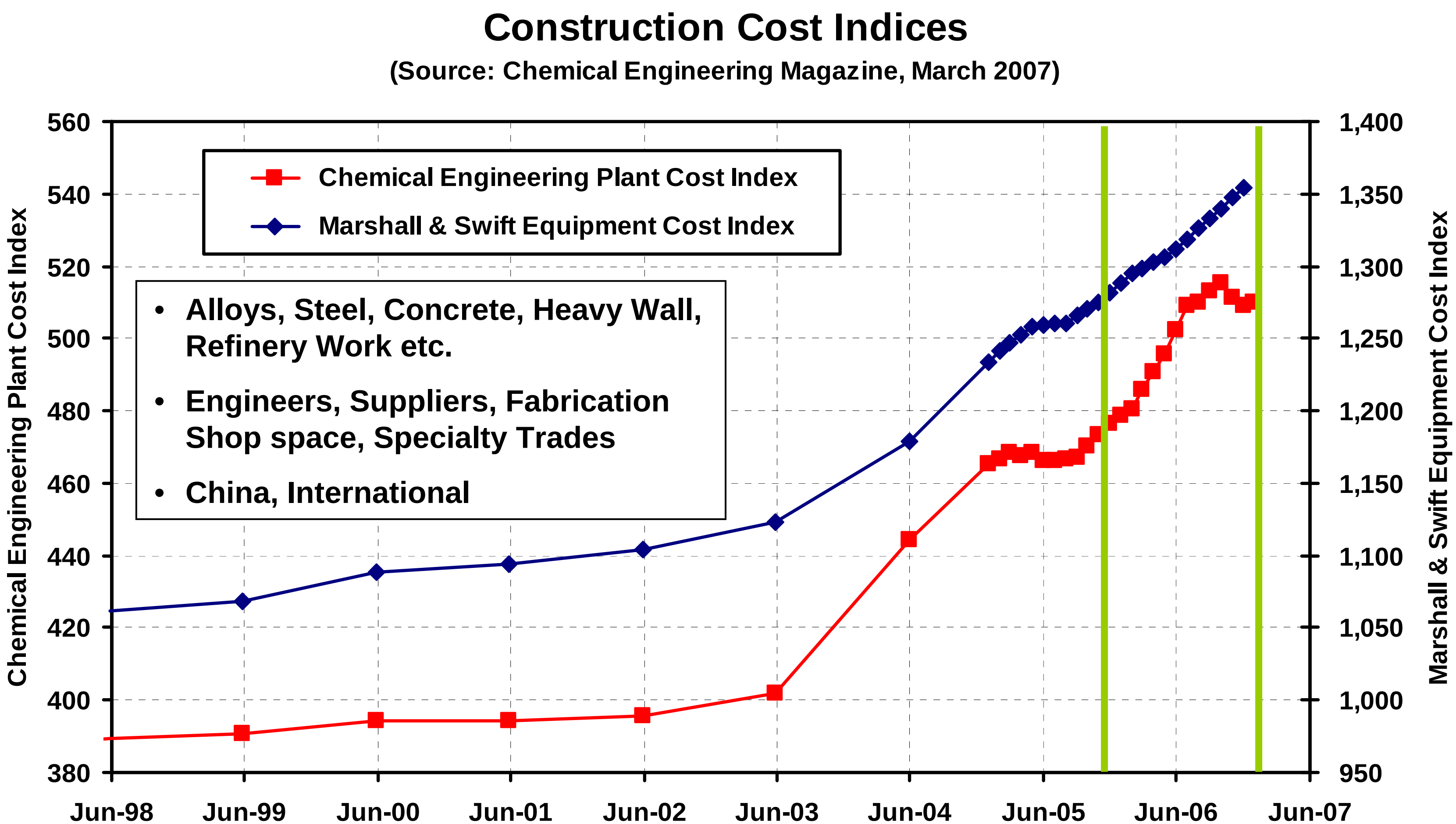
Comparative Costs in 2010-2015

$100/kW capital cost → $1.7 MWh LCOE



ELECTRIC POWER RESEARCH INSTITUTE

Recent Cost Escalation



Currently revising our work based on available cost data

EPRI ELECTRIC POWER RESEARCH INSTITUTE

Near-Term Implications

- New advanced light water reactors have cost advantage, but unlikely to enter operation until after 2015
- Renewables unlikely to extend beyond mandated requirement due to poor comparative economics
  - Exception is good wind with tax incentives (but limited in scale)
- As a result, most new base-load generation will utilize fossil technologies **without CO_2 capture and storage**
  - PC vs. IGCC economics a function of coal type, other factors
  - Gas vs. coal choice depends on future gas prices, capital costs

Very limited opportunity for significant economic CO_2 reduction!!!

EPRI | ELECTRIC POWER RESEARCH INSTITUTE

Presentation Objective

Provide a factual framework for discussing:

I. Generation technologies and investment decisions in a world with carbon constraints

II. R&D needs to achieve a low-cost, low-carbon portfolio of electricity technologies

III. Technical feasibility of using this portfolio of technologies to reduce U.S. electric sector CO_2 emissions

IV. Economic implications of achieving significant CO_2 reductions with/without low-cost, low-carbon technologies

ELECTRIC POWER RESEARCH INSTITUTE

Key Technology Challenges

Significant cost-effective CO_2 reductions from the U.S. electric sector will require ALL of the following technology advances:

1. Smart grids and communications infrastructures to enable end-use efficiency and demand response, distributed generation, and PHEVs.

2. A grid infrastructure with the capacity and reliability to operate with 20-30% intermittent renewables in specific regions.

3. Significant expansion of nuclear energy enabled by continued safe and economic operation of existing nuclear fleet; and a viable strategy for managing spent fuel.

4. Commercial-scale coal-based generation units operating with 90+% CO_2 capture and storage in a variety of geologies.

EPRI | ELECTRIC POWER RESEARCH INSTITUTE

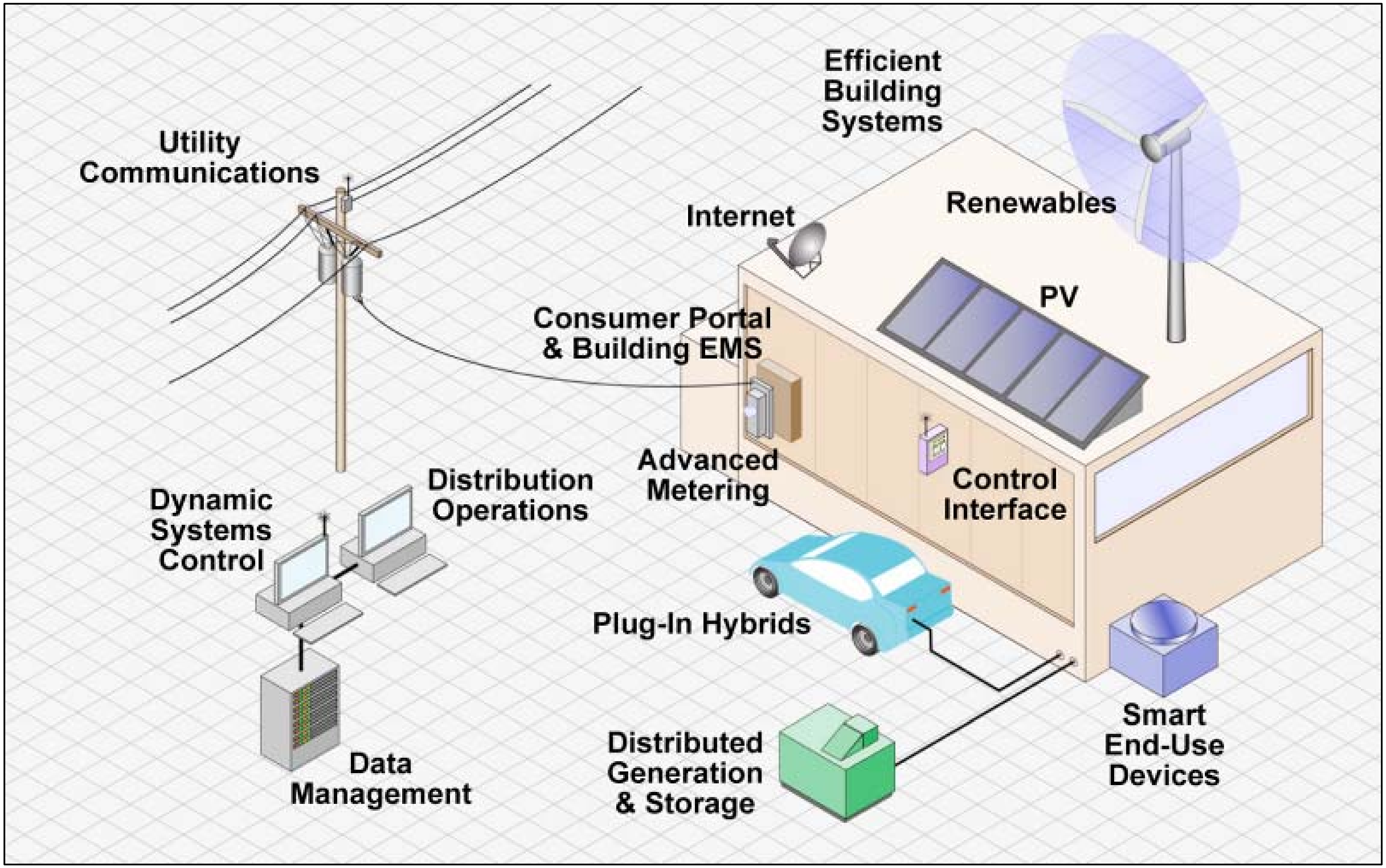
Average Annual Funding R&D Gap

million $/yr

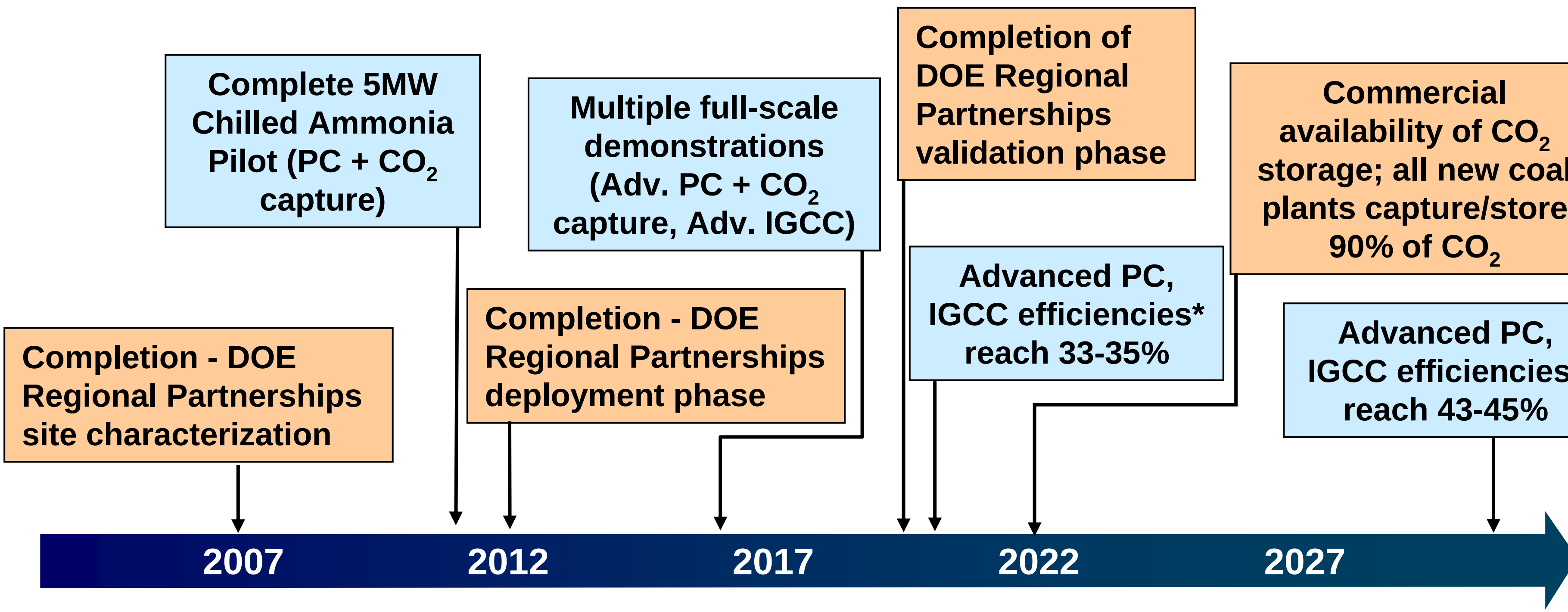
	2007-2011	2012-2016	2017-2021	2022-2026	2027-2031	Avg
ENABLE ENERGY EFFICIENCY & DER Smart grids and communications infrastructures to enable end-use efficiency and demand response, DER (i.e. Solar PV) and PHEVs. Improve equipment efficiency.	$310	$290	$240	$140	$120	$220
GRID INTEGRATION WITH RENEWABLES A grid infrastructure with the capacity and reliability to operate with 20-30% intermittent renewable generation in specific regions.	$400	$370	$330	$300	$300	$340
NUCLEAR Significant expansion of nuclear energy enabled by continued operation of the existing nuclear fleet and a viable strategy for managing spent fuel. Includes new RD&D for ALWR deployment support.	$170	$170	$170	$100	$100	$140
ADVANCED COAL, CO_2 CAPTURE and STORAGE Commercial-scale coal-based generation units operating with ~90% CO2 capture and storage in a variety of geologies.	$480	$800	$800	$620	$400	$620
Total	$1360	$1630	$1540	$1160	$920	$1320

V3 ;4-19-07 HC

Example: Dynamic Energy Management

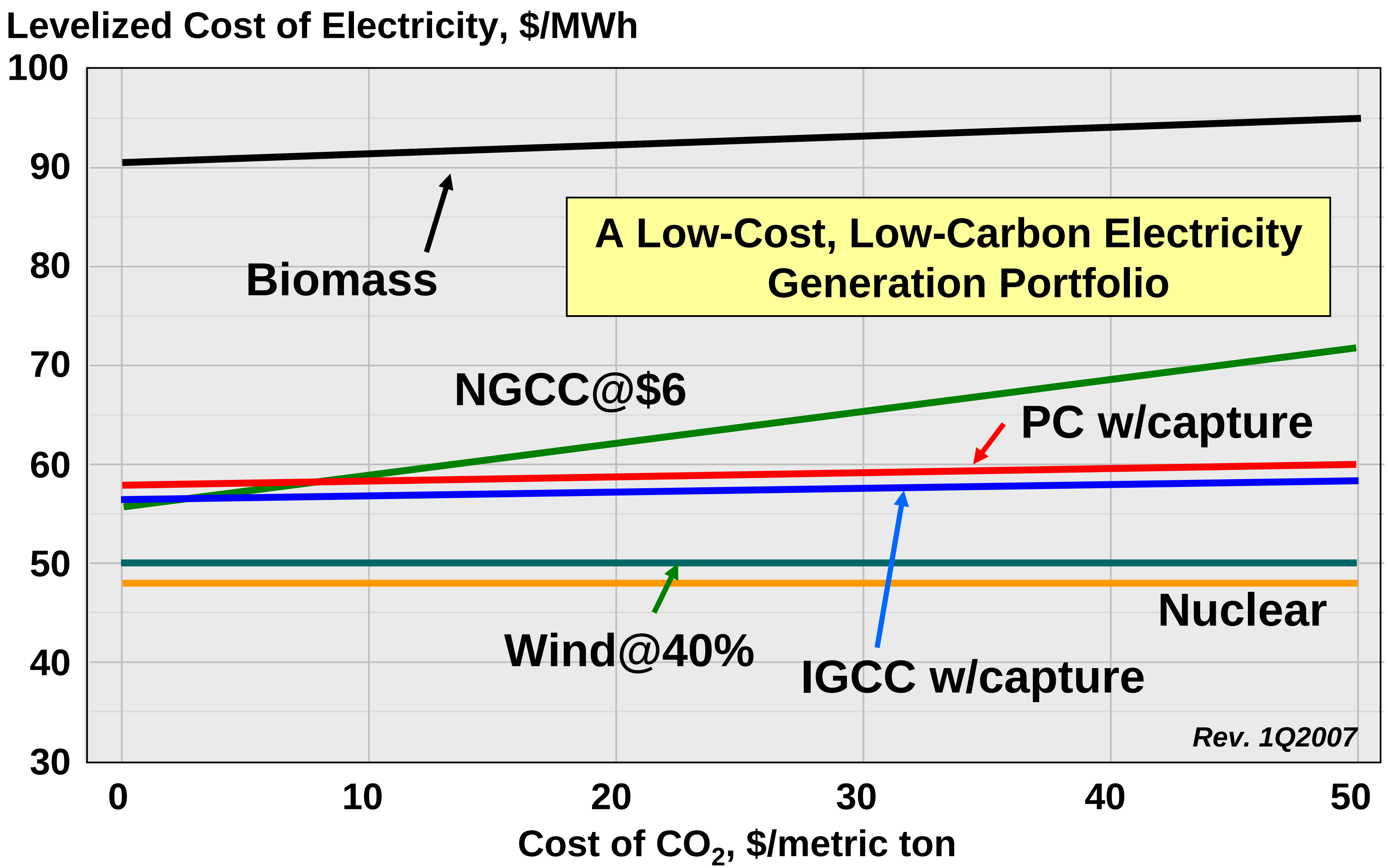


Timeline: Advanced Coal with CCS



*These are target efficiencies for plants including CO_2 capture

Comparative Costs in 2020-2025



EPRI | ELECTRIC POWER RESEARCH INSTITUTE

Presentation Objective

Provide a factual framework for discussing:

I. Generation technologies and investment decisions in a world with carbon constraints

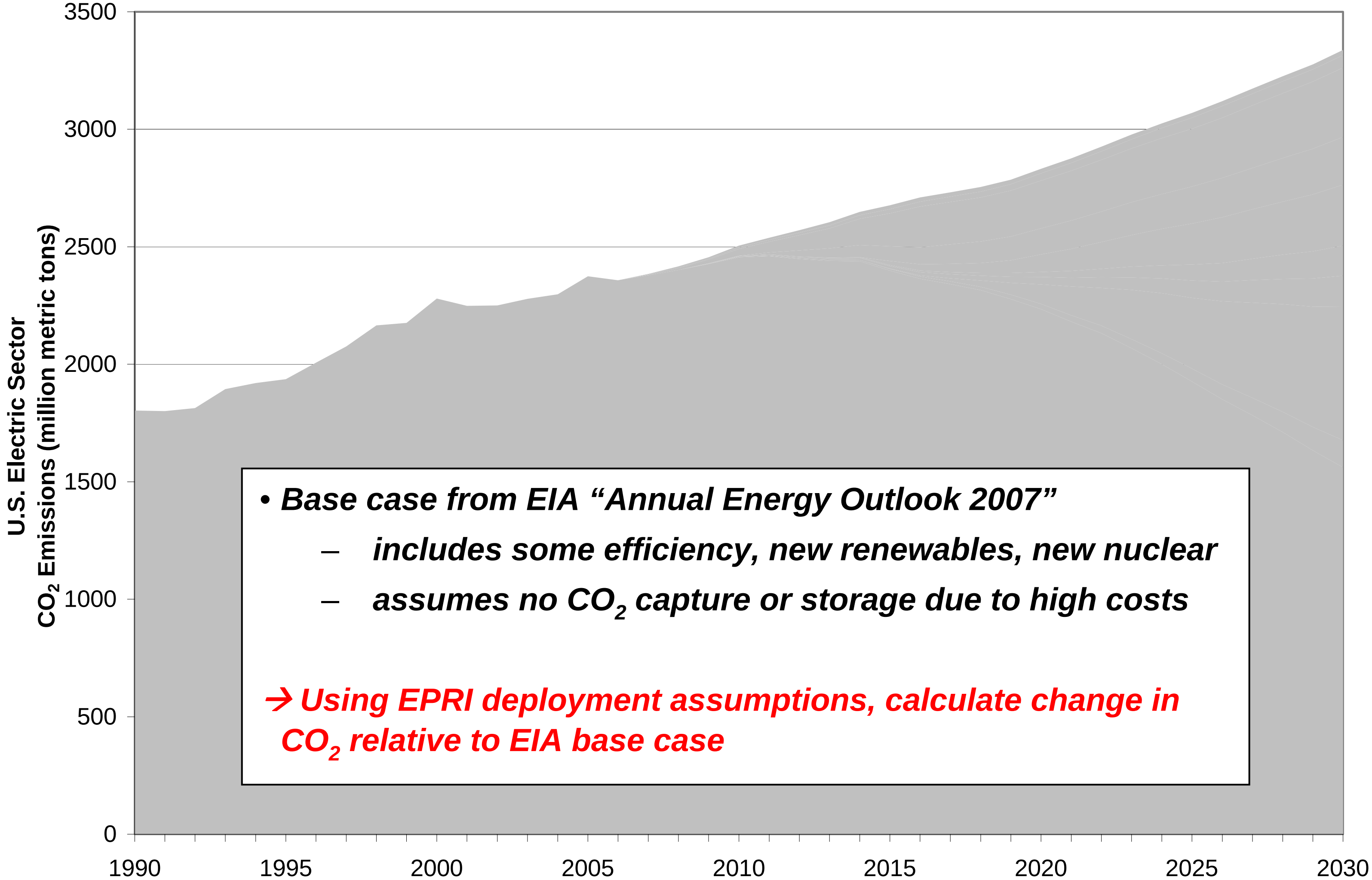
II. R&D needs to achieve a low-cost, low-carbon portfolio of electricity technologies

III. Technical feasibility of using this portfolio of technologies to reduce U.S. electric sector CO_2 emissions

IV. Economic implications of achieving significant CO_2 reductions with/without low-cost, low-carbon technologies

ELECTRIC POWER RESEARCH INSTITUTE

U.S. Electricity Sector CO_2 Emissions



- ***Base case from EIA "Annual Energy Outlook 2007"***
  - ***includes some efficiency, new renewables, new nuclear***
  - ***assumes no CO_2 capture or storage due to high costs***

→ Using EPRI deployment assumptions, calculate change in CO_2 relative to EIA base case

EPRI | ELECTRIC POWER RESEARCH INSTITUTE

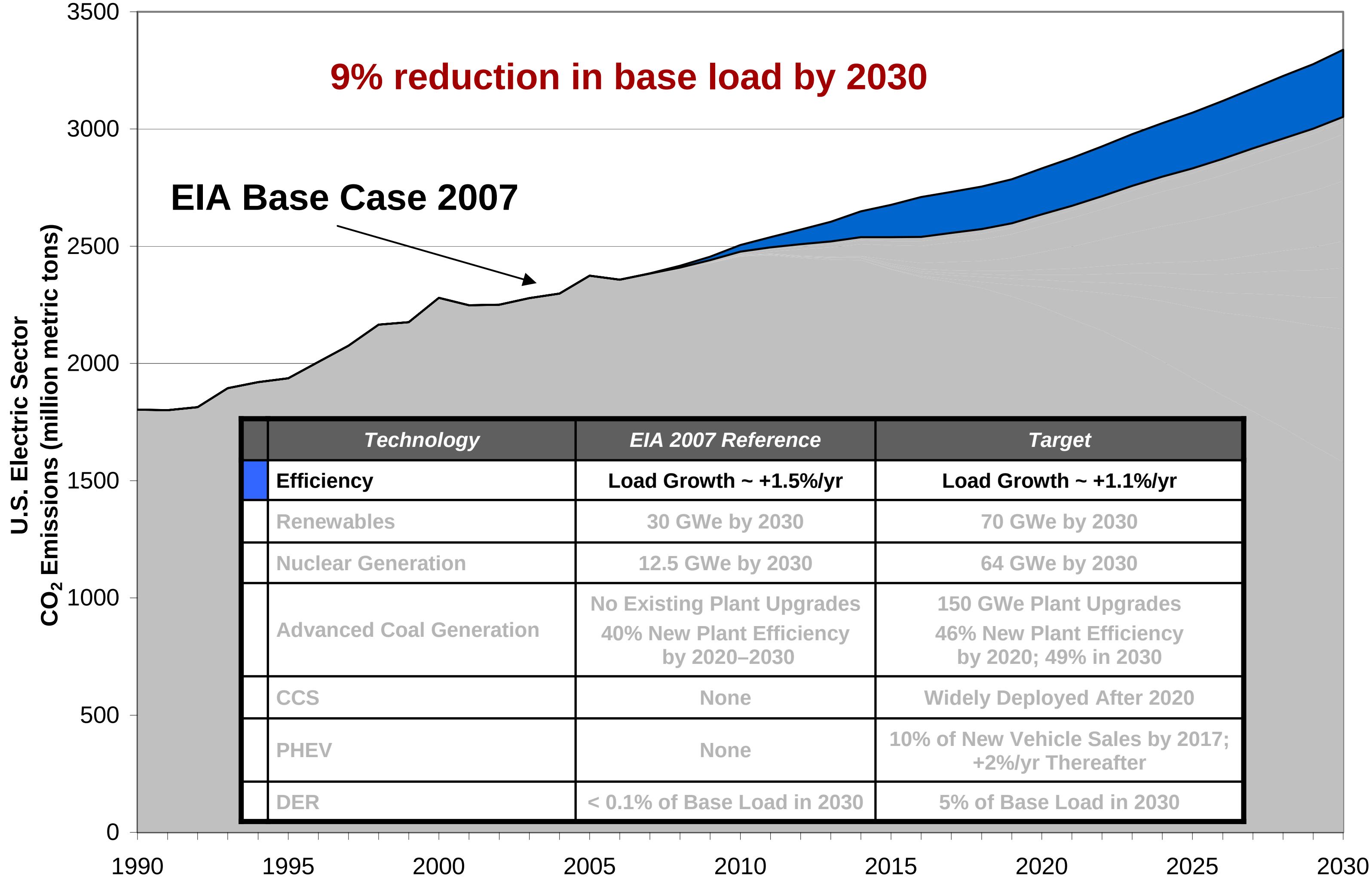
Technology Deployment Targets

Technology	*EIA 2007 Base Case*	*EPRI Analysis 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**
Carbon Capture and Storage (CCS)	**None**	**Widely Available and Deployed After 2020**
Plug-in Hybrid Electric Vehicles (PHEV)	**None**	**10% of New Vehicle Sales by 2017; +2%/yr Thereafter**
Distributed Energy Resources (DER) ***(including distributed solar)***	**< 0.1% of Base Load in 2030**	**5% of Base Load in 2030**

EPRI analysis targets do not reflect economic considerations, or potential regulatory and siting constraints.

EPRI ELECTRIC POWER RESEARCH INSTITUTE

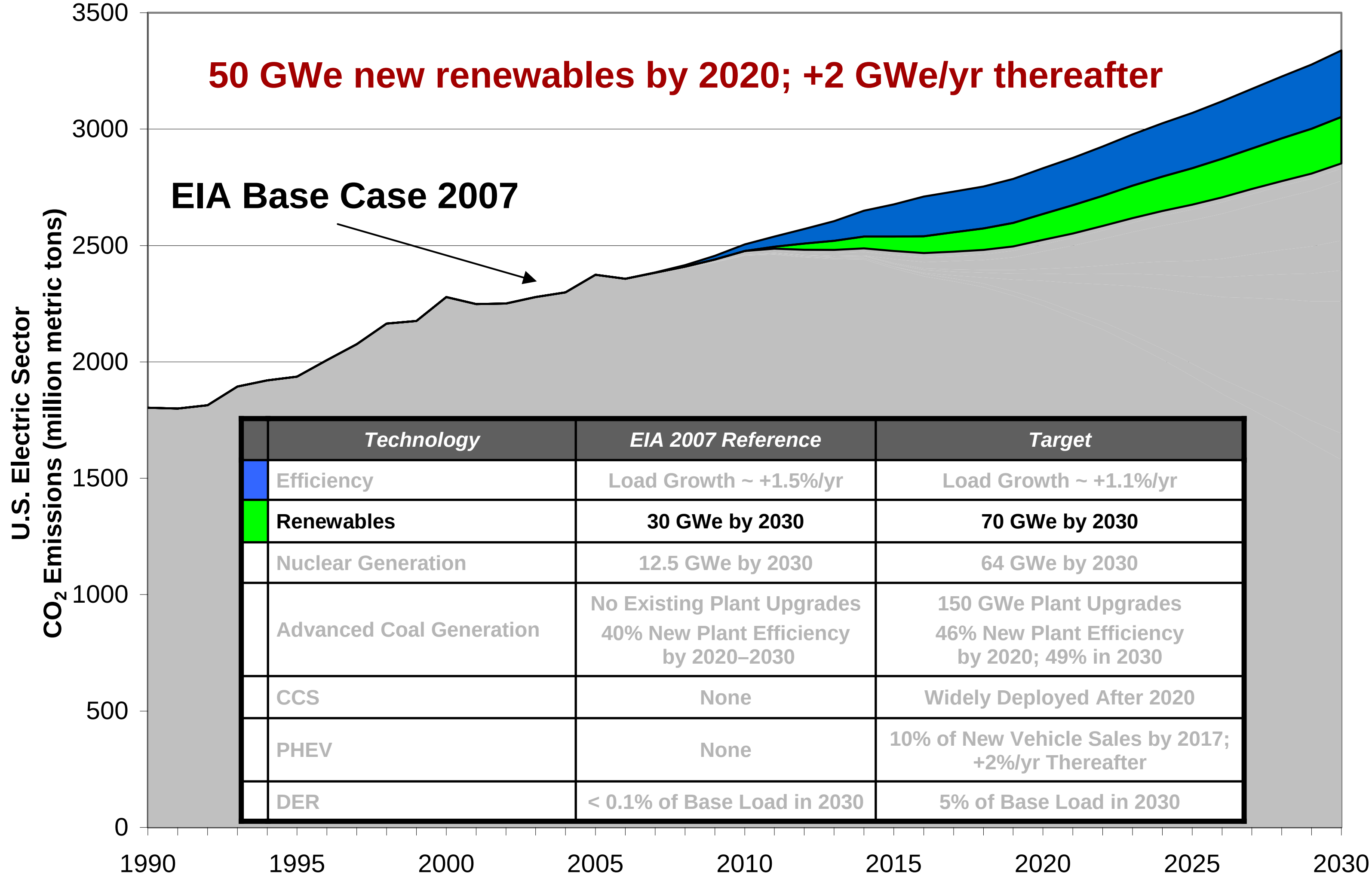
Benefit of Achieving Efficiency Target



	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

EPRI ELECTRIC POWER RESEARCH INSTITUTE

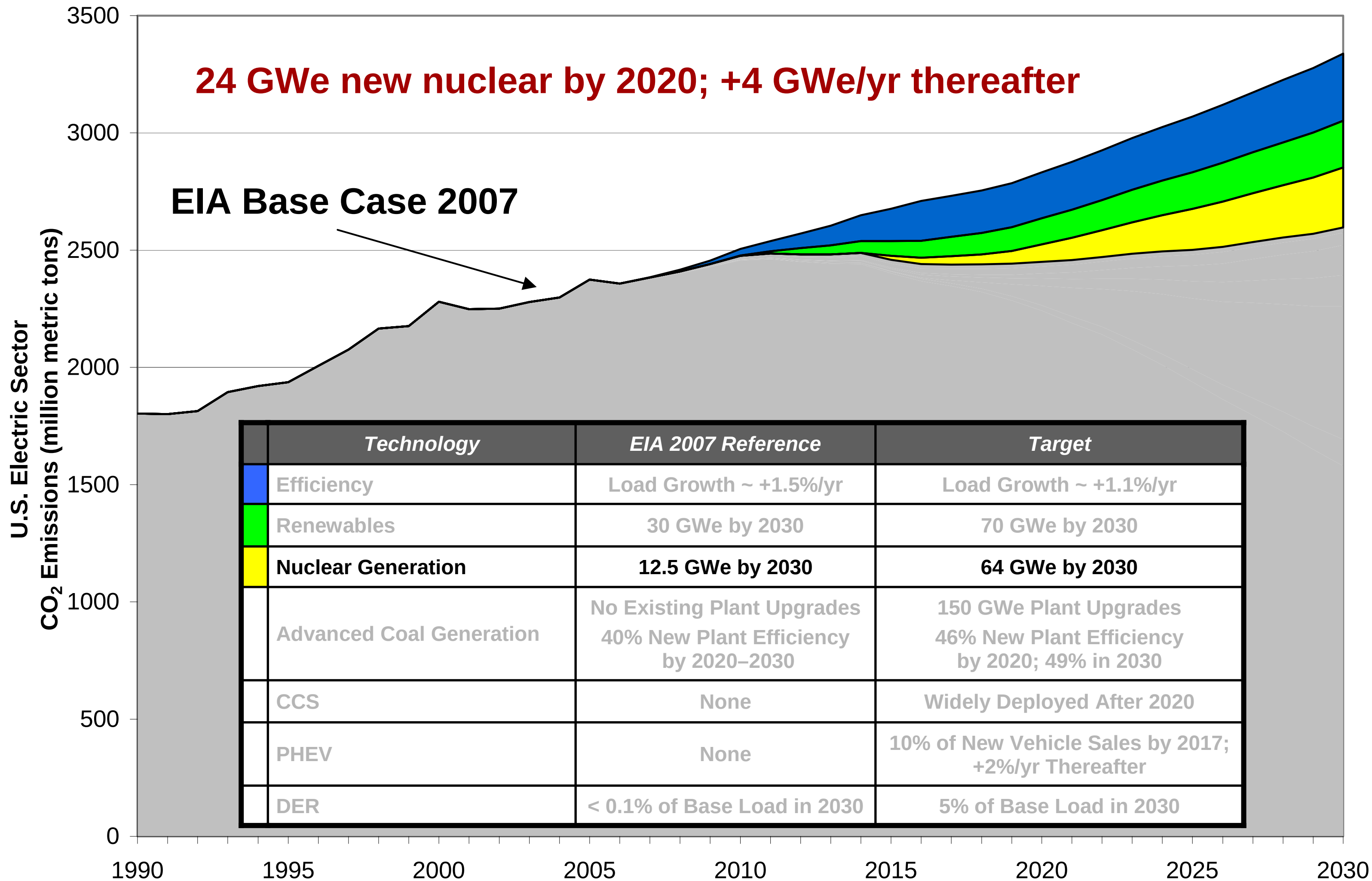
Benefit of Achieving Renewables Target



	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

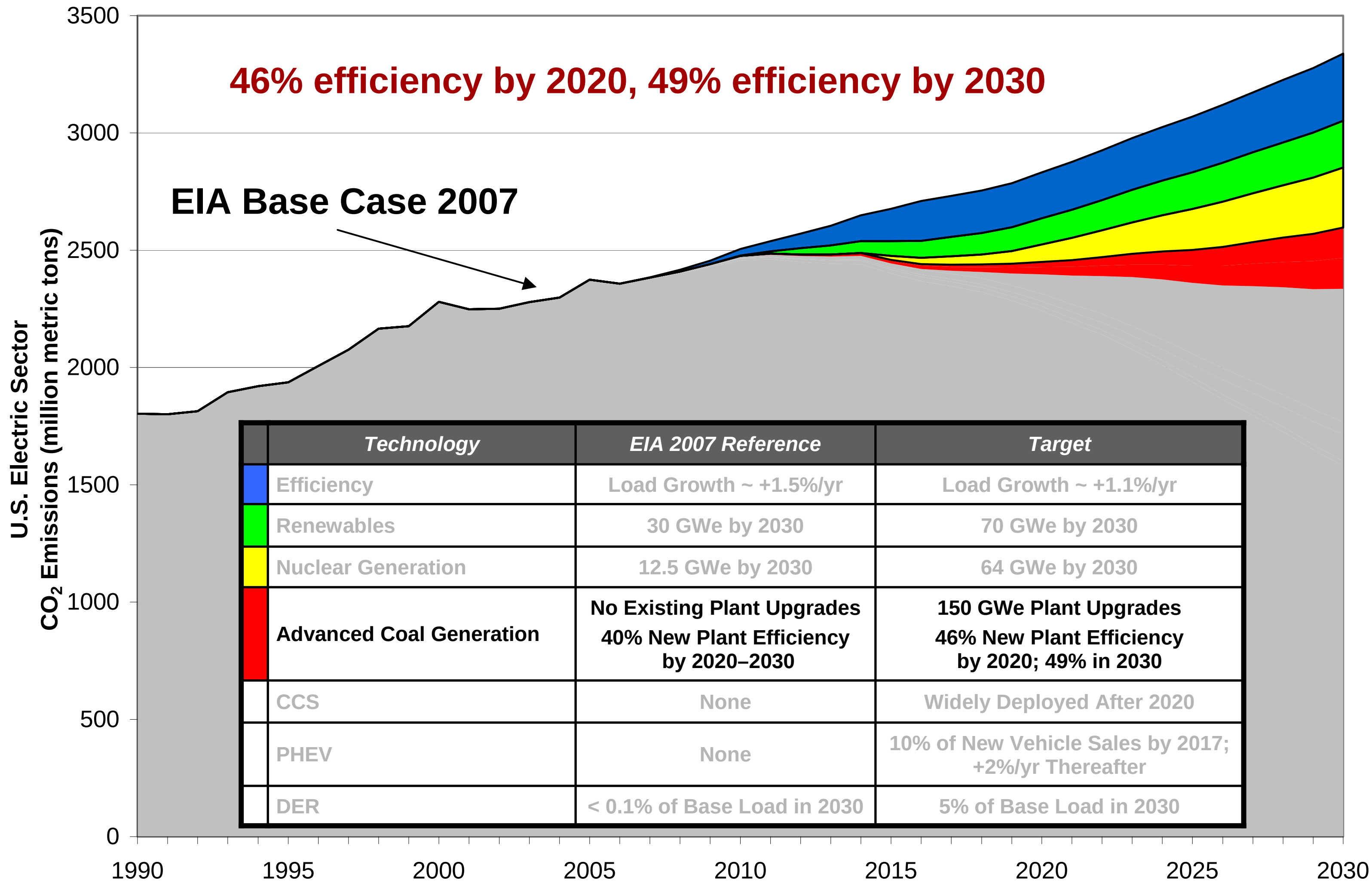
ELECTRIC POWER RESEARCH INSTITUTE

Benefit of Achieving Nuclear Generation Target



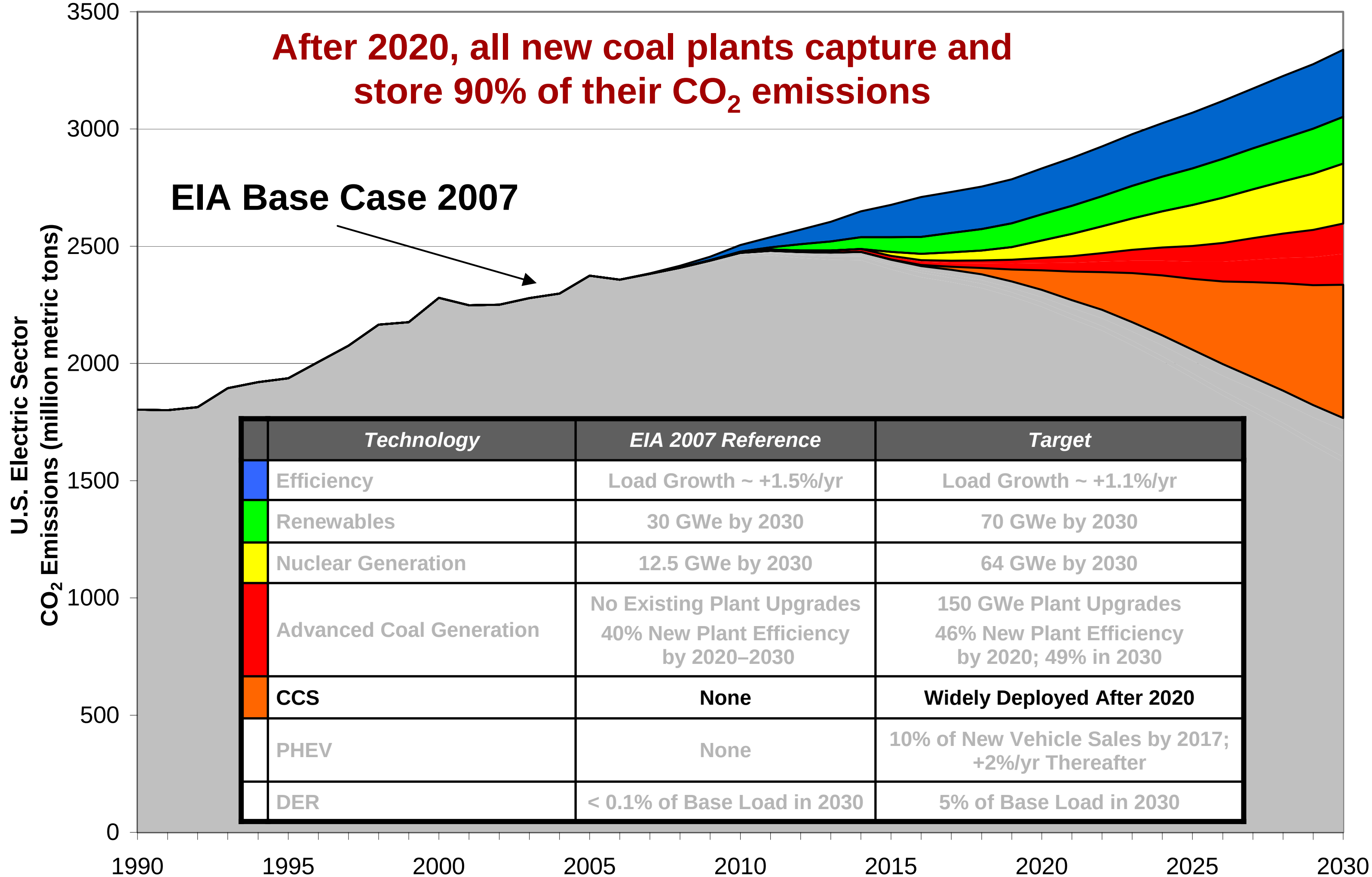
	Technology	EIA 2007 Reference	Target
	Efficiency	Load Growth ~ +1.5%/yr	Load Growth ~ +1.1%/yr
	Renewables	30 GWe by 2030	70 GWe by 2030
	Nuclear Generation	**12.5 GWe by 2030**	**64 GWe by 2030**
	Advanced Coal Generation	No Existing Plant Upgrades 40% New Plant Efficiency by 2020–2030	150 GWe Plant 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

Benefit of Achieving Advanced Coal Target



	Technology	EIA 2007 Reference	Target
(blue)	Efficiency	Load Growth ~ +1.5%/yr	Load Growth ~ +1.1%/yr
(green)	Renewables	30 GWe by 2030	70 GWe by 2030
(yellow)	Nuclear Generation	12.5 GWe by 2030	64 GWe by 2030
(red)	**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

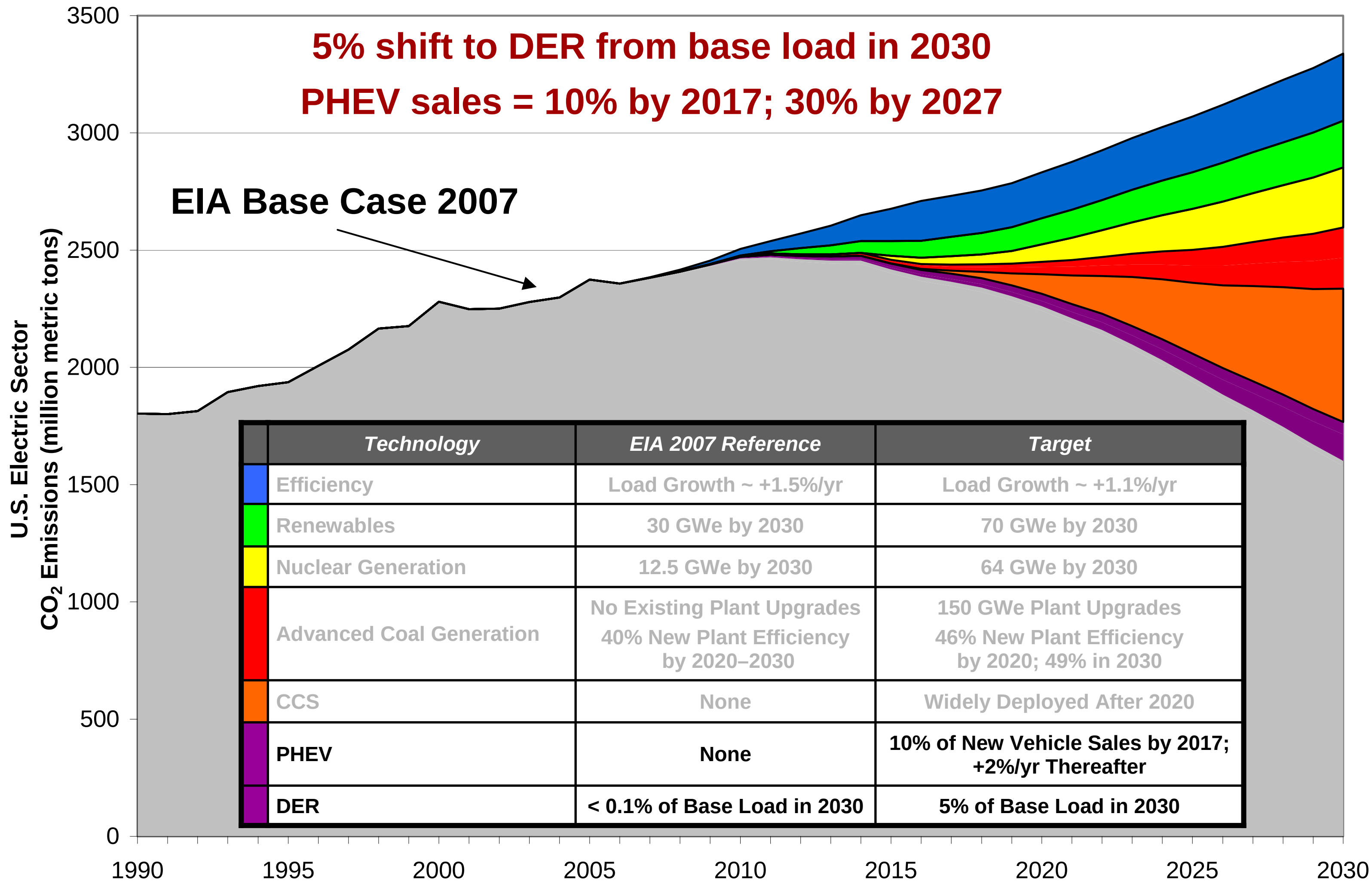
Benefit of Achieving CCS Target



	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

EPRI ELECTRIC POWER RESEARCH INSTITUTE

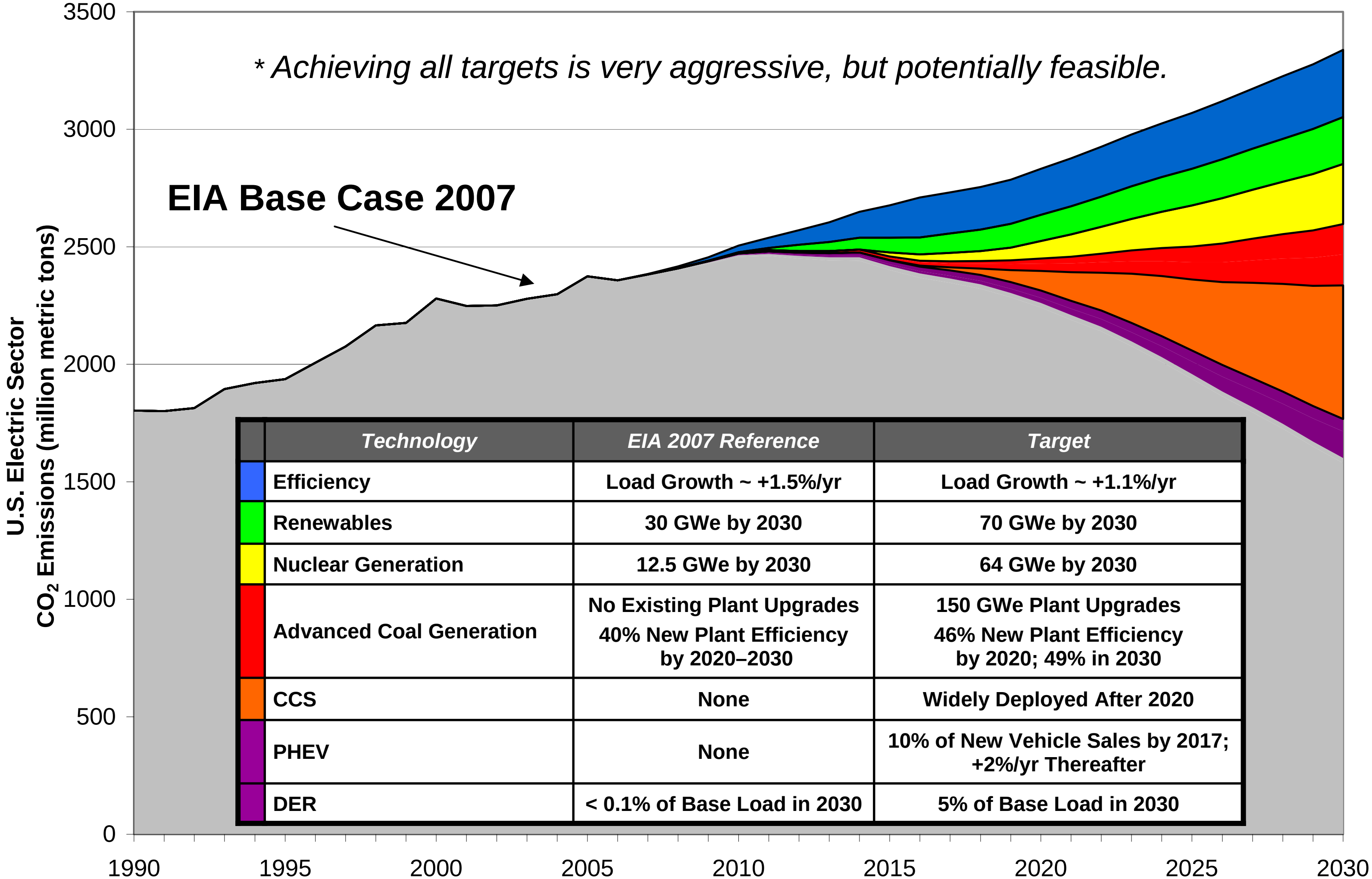
Benefit of Achieving PHEV and DER Targets



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**

EPRI | ELECTRIC POWER RESEARCH INSTITUTE

CO_2 Reductions … Technical Potential*

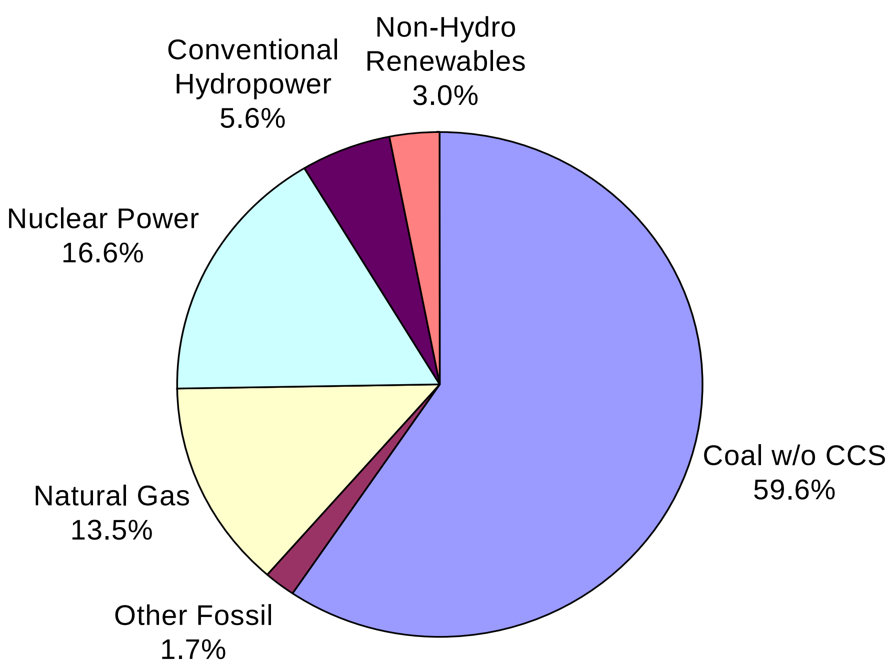


Technology	EIA 2007 Reference	Target
Efficiency	Load Growth ~ +1.5%/yr	Load Growth ~ +1.1%/yr
Renewables	30 GWe by 2030	70 GWe by 2030
Nuclear Generation	12.5 GWe by 2030	64 GWe by 2030
Advanced Coal Generation	No Existing Plant Upgrades 40% New Plant Efficiency by 2020–2030	150 GWe Plant Upgrades 46% 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

U.S. Electricity Generation: 2030

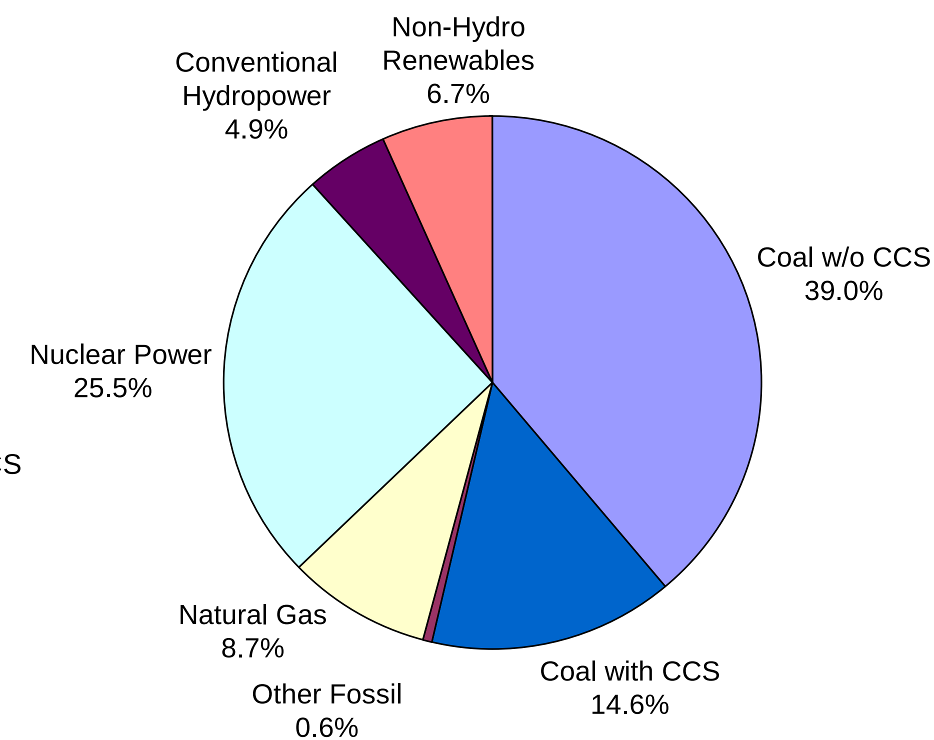
EIA Base Case*

5406 TWh



Advanced Technology Targets

5401 TWh



** Base case from EIA "Annual Energy Outlook 2007"*

Presentation Objective

Provide a factual framework for discussing:

I. Generation technologies and investment decisions in a world with carbon constraints

II. R&D needs to achieve a low-cost, low-carbon portfolio of electricity technologies

III. Technical feasibility of using this portfolio of technologies to reduce U.S. electric sector CO_2 emissions

IV. Economic implications of achieving significant CO_2 reductions with/without low-cost, low-carbon technologies

EPRI ELECTRIC POWER RESEARCH INSTITUTE

Preliminary Economic Results in Brief

Absent advanced electricity technologies, CO_2 constraints result in

- *Price-induced conservation and "demand destruction"*
- *Fuel switching to natural gas*
- *Higher electricity prices*
- *High cost to U.S. economy*

With advanced electricity technologies, CO_2 constraints result in

- *Growth in electrification*
- *Continued use of coal (w/CCS) and nuclear*
- *Lower, more stable electricity prices*
- *50-66% lower cost to U.S. economy*

Results insensitive to CO_2 constraints and capital cost assumptions