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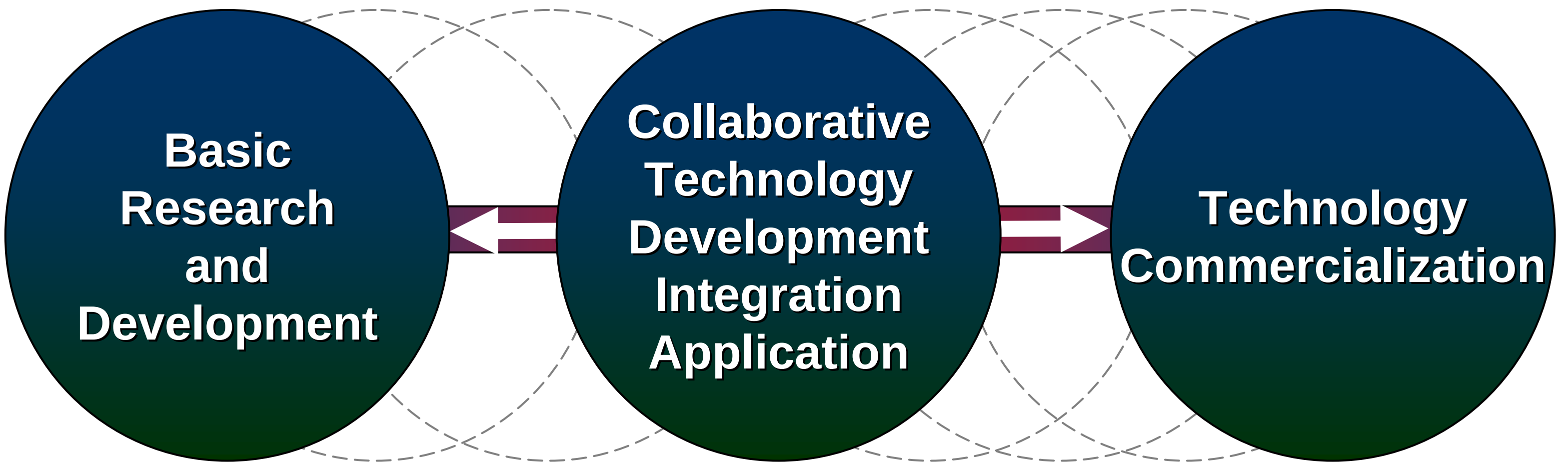
Electricity Technology in a Carbon-Constrained Future

March 15, 2007
PacifiCorp Climate Working Group

Bryan Hannegan
Vice President - Environment

EPRI Role



National Laboratories

Universities

EPRI

Suppliers

Vendors

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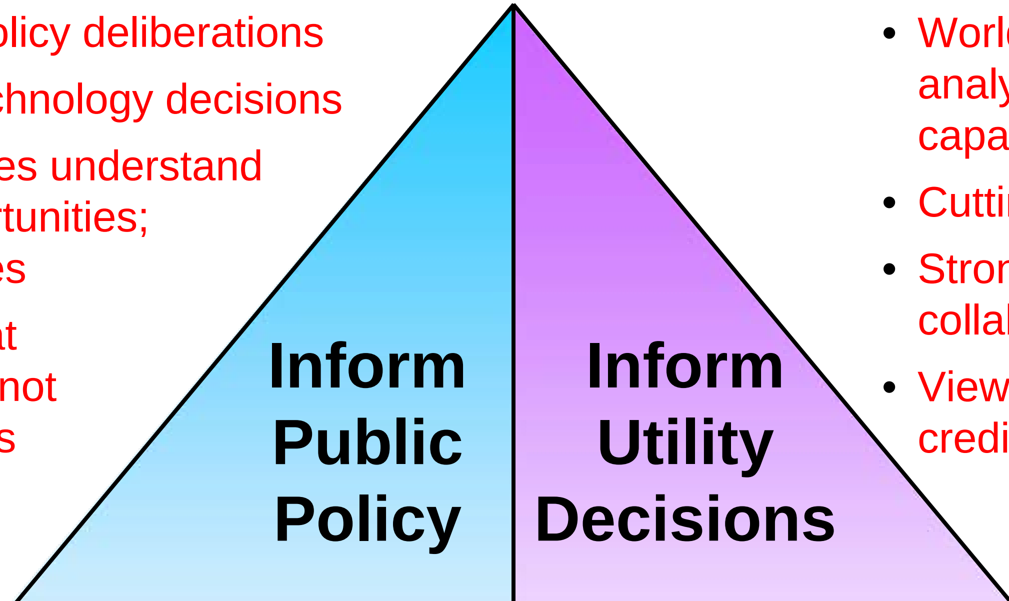
Global Climate Area Overview

Value

- Helps inform policy deliberations
- Helps guide technology decisions
- Helps companies understand risks and opportunities; create strategies
- Plays a role that companies cannot play themselves

Why EPRI?

- World class, in-house analytical and technology capabilities
- Cutting-edge research
- Strong role for industry collaboration
- Viewed as independent, credible, neutral



Program 102:

Identify components of least-cost strategies.

Analyze costs and benefits of major proposals.

Programs 102/103:

Examine role of technologies.

Identify ways to spur innovation.

Program 103:

Support utility analysis of emissions, reduction options, strategies and communication.

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Presentation Objective

Provide a factual framework for discussing:

I. Generation technologies and investment decisions in a carbon-constrained world

II. The technical feasibility of reducing U.S. electric sector CO_2 emissions

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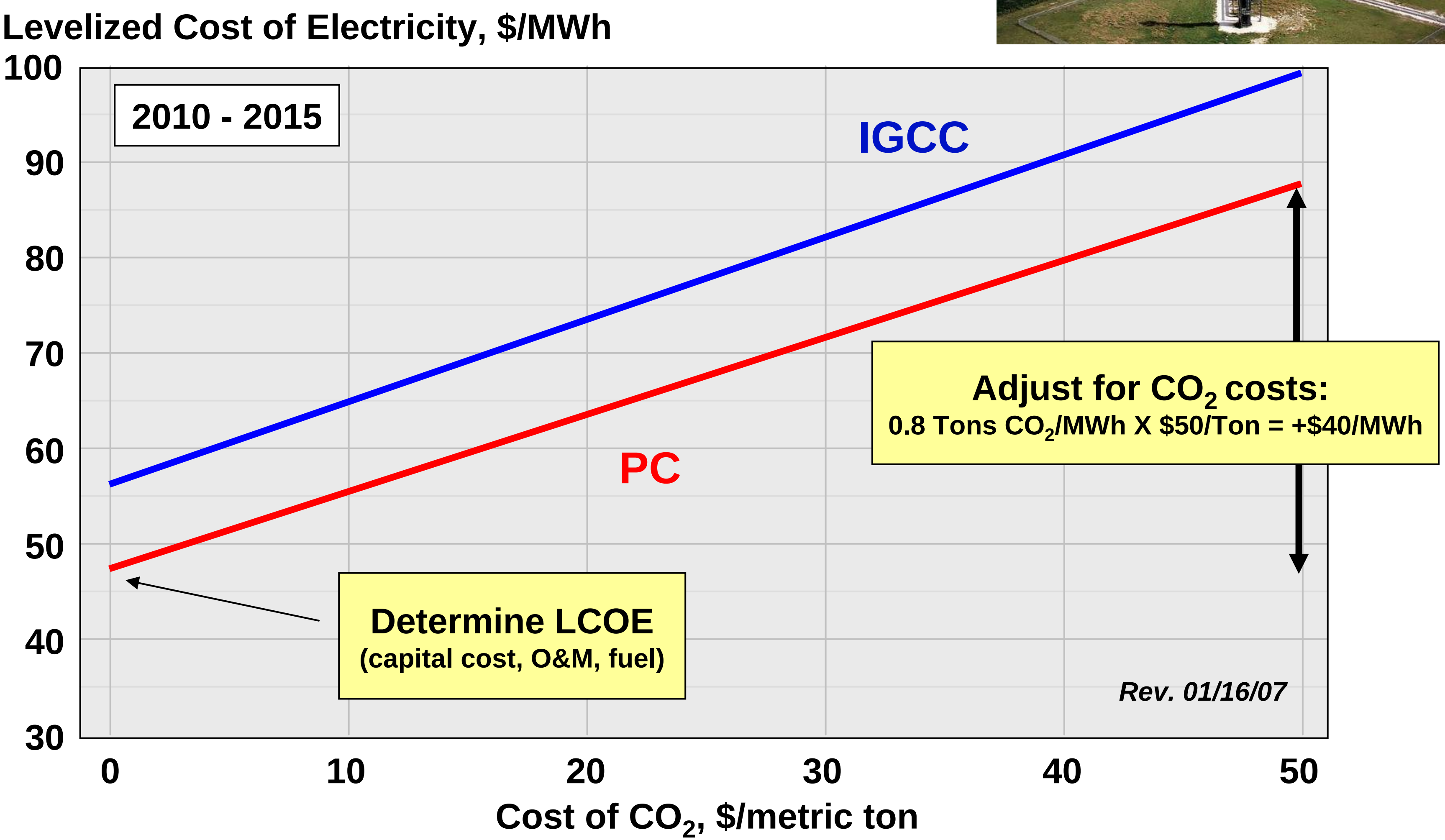
Example: Coal Generation



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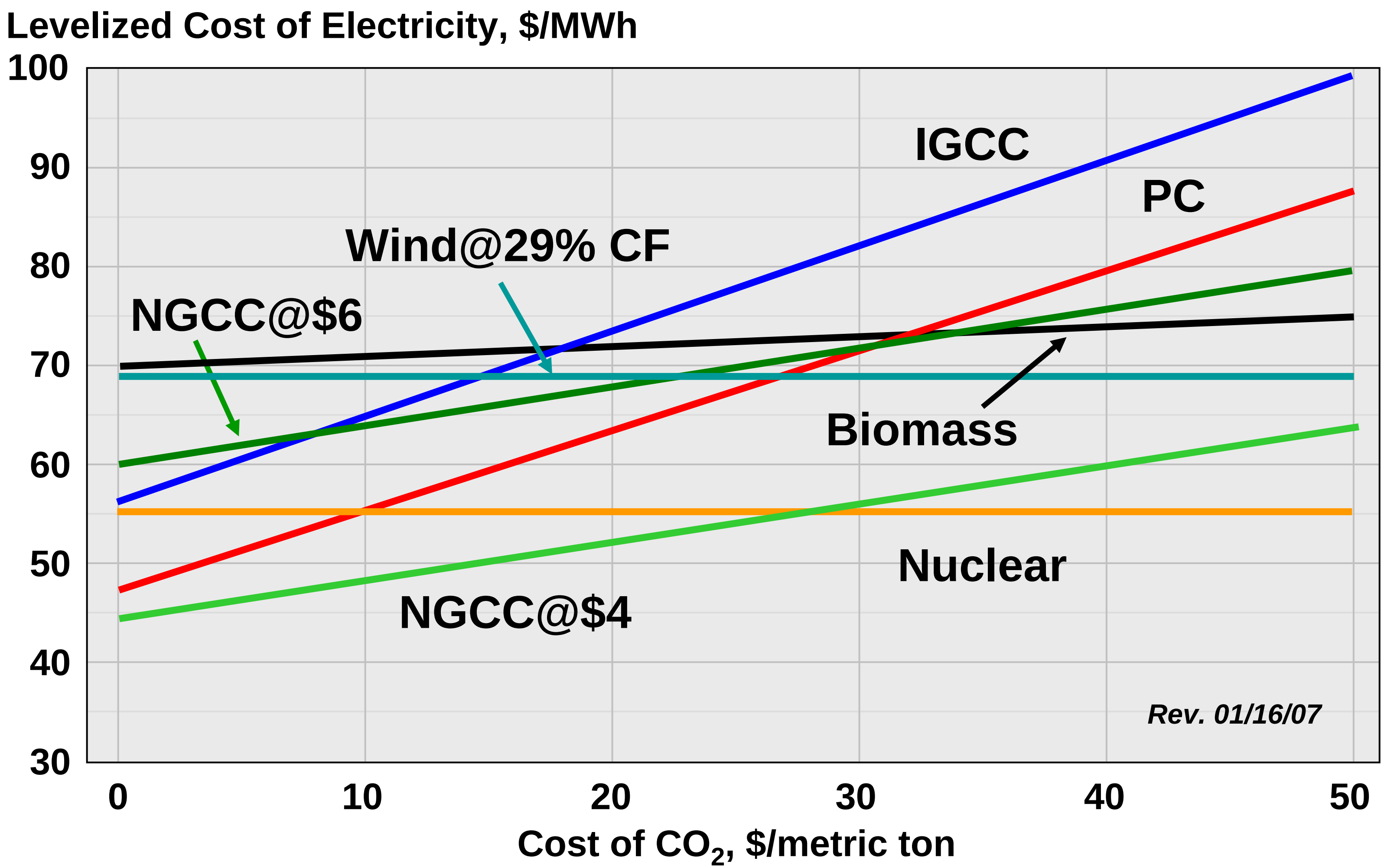
Comparative Costs in 2010-2015



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Near-Term Implications

- New advanced light water reactors have cost advantage, but unlikely to enter operation until after 2015

- Absent nuclear, most new base-load generation will utilize fossil technologies (NGCC, PC, and IGCC) without CO_2 capture and storage.
  - IGCC at present 10-20% higher than PC
  - Choice of PC vs. NGCC will depend on natural gas prices

- Renewables unlikely to extend beyond mandated requirement due to poor comparative economics

Very limited opportunity for significant economic CO_2 reduction!!!

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Key Technology Challenges

The U.S. electricity sector will need <u>ALL</u> of the following technology advancements to significantly reduce CO_2 emissions over the coming decades:

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.

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Average Annual Funding Needs (2005-30)

(including nuclear closed fuel cycle, CO_2 storage)

	Research	Development	Demonstration	Early Deployment	Enhanced Performance	Total
DISTRIBUTION INTEGRATION Smart grids and communications infrastructures to enable end-use efficiency and demand response, distributed generation, and PHEVs.	$25M/yr	$51M/yr	$64M/yr	$80M/yr	$0M/yr	$220M/yr
GRID INTEGRATION A grid infrastructure with the capacity and reliability to operate with 20-30% intermittent renewables in specific regions.	$40M/yr	$80M/yr	$70M/yr	$33M/yr	$117M/yr	$340M/yr
NUCLEAR Significant expansion of nuclear energy enabled by continued safe and economic operation of existing nuclear fleet; and a viable strategy for managing spent fuel.	$247M/yr	$493M/yr	$40M/yr	$0M/yr	$40M/yr	$820M/yr
ADVANCED COAL, CO2 CAPTURE and STORAGE Commercial-scale coal-based generation units operating with 90+% CO2 capture and storage in a variety of geologies.	$52M/yr	$91M/yr	$228M/yr	$249M/yr	$0M/yr	$620M/yr
Total (Public + Private Sectors)	$364M/yr	$716M/yr	$401M/yr	$362M/yr	$157M/yr	$2000M/yr

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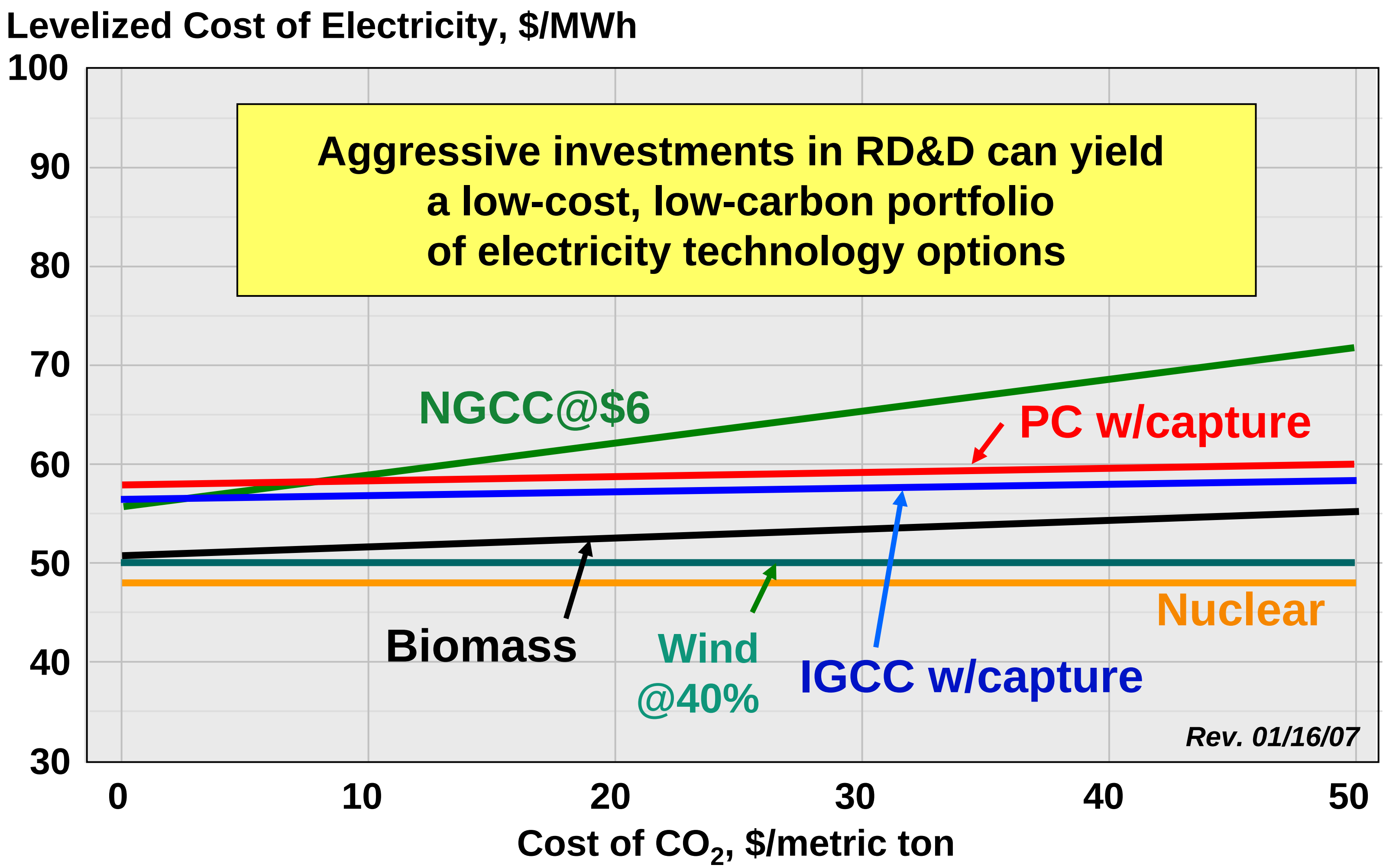
Comparative Costs in 2020-2025



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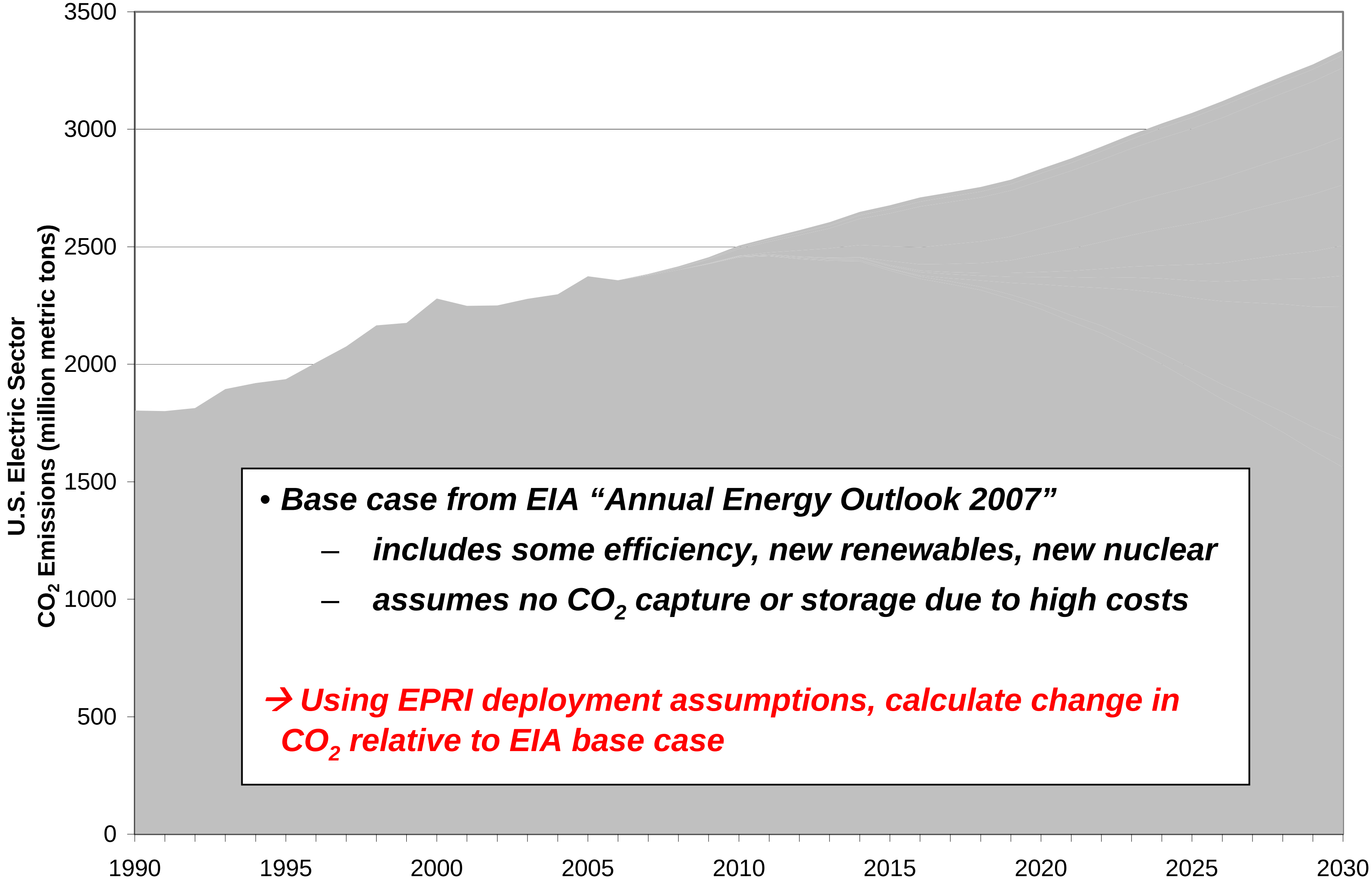
U.S. Electricity Sector CO_2 Emissions



- ***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

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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 potential regulatory and siting constraints. Additional economic modeling in progress

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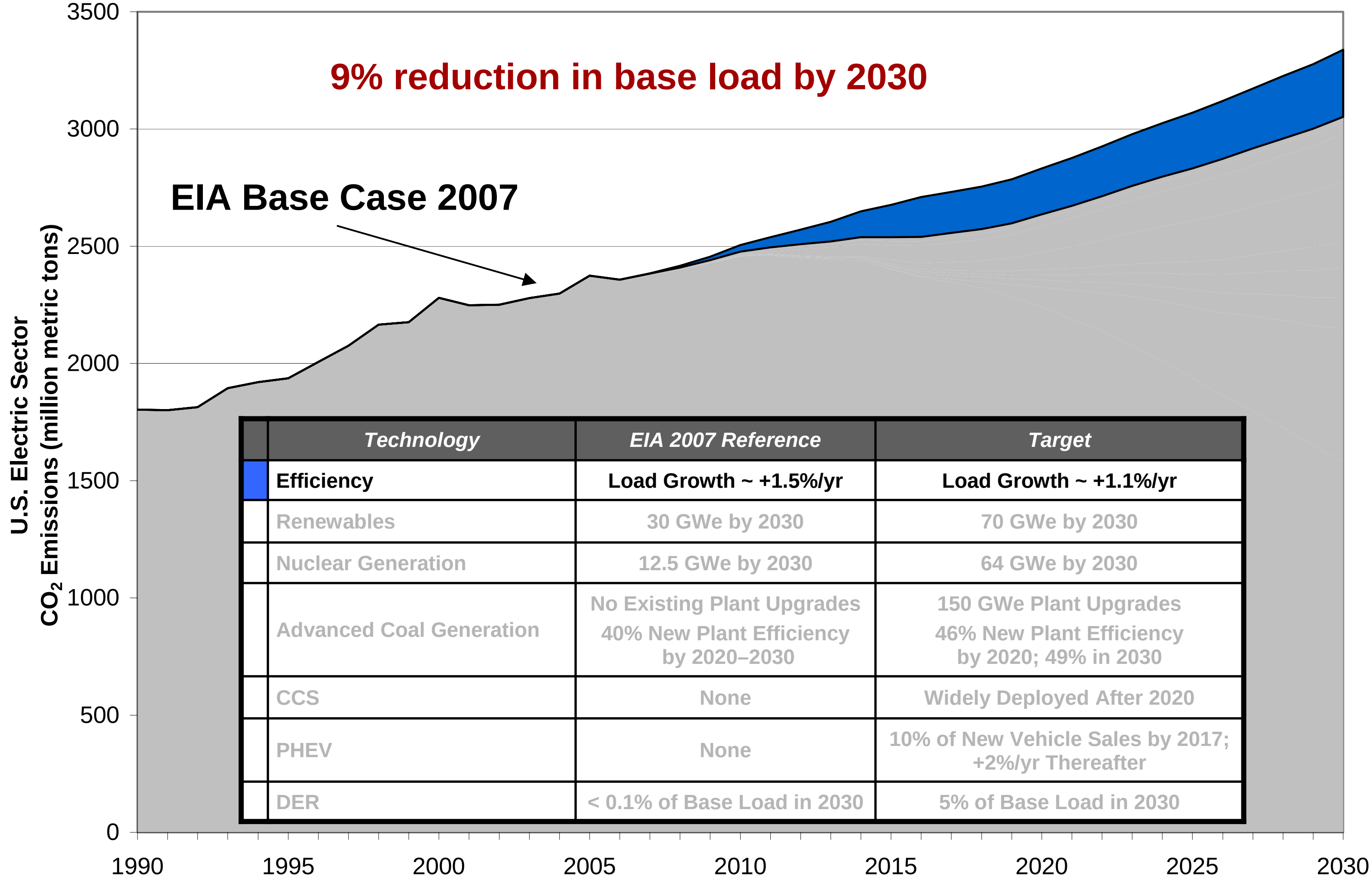
Benefit of Achieving Efficiency Target



Technology	EIA 2007 Reference	Target
Efficiency	**Load Growth ~ +1.5%/yr**	**Load Growth ~ +1.1%/yr**
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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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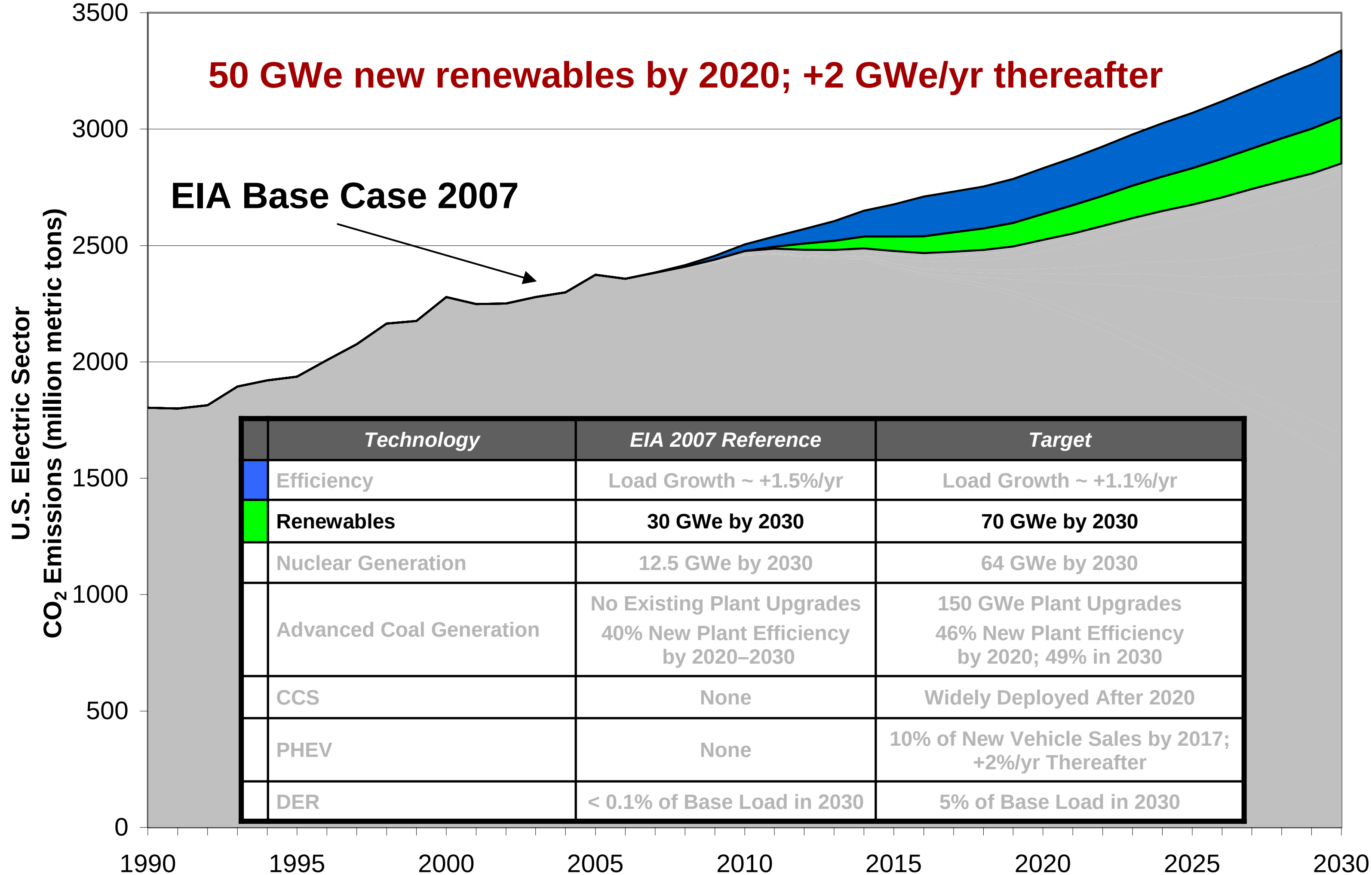
Benefit of Achieving Renewables Target



	Technology	EIA 2007 Reference	Target
	Efficiency	Load Growth ~ +1.5%/yr	Load Growth ~ +1.1%/yr
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	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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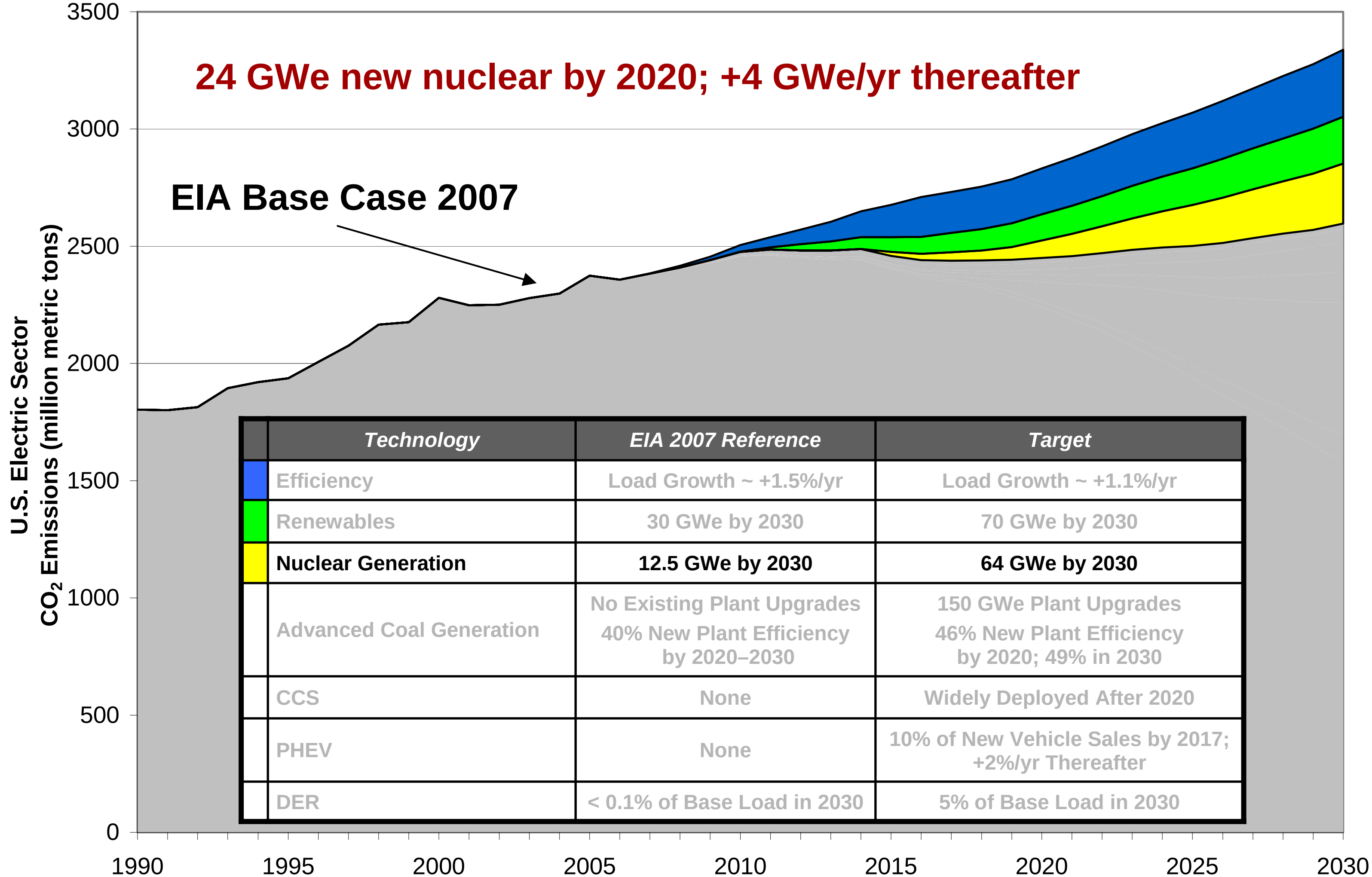
Benefit of Achieving Nuclear Generation Target



	Technology	EIA 2007 Reference	Target
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	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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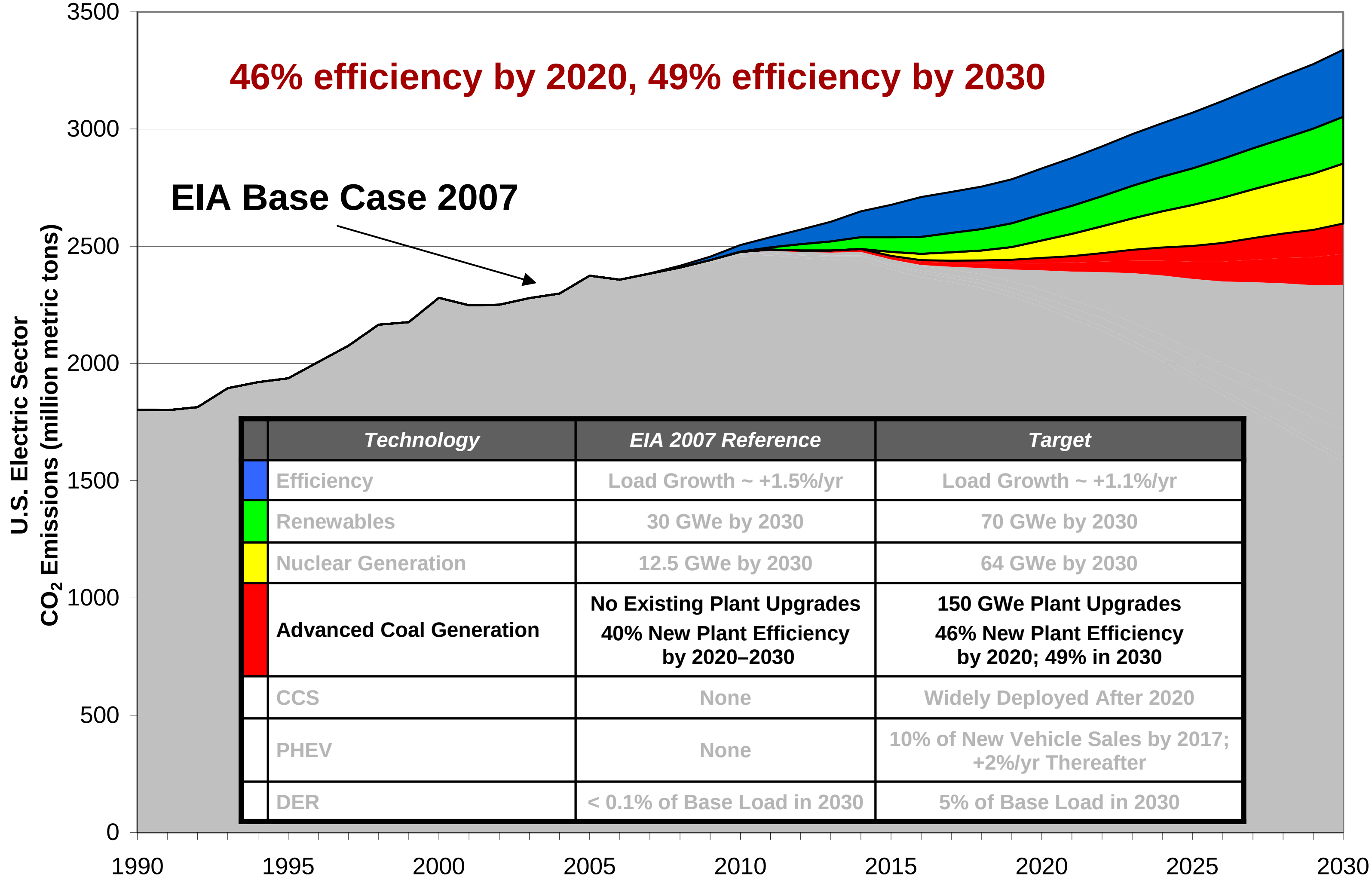
Benefit of Achieving Advanced Coal Generation Target



	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

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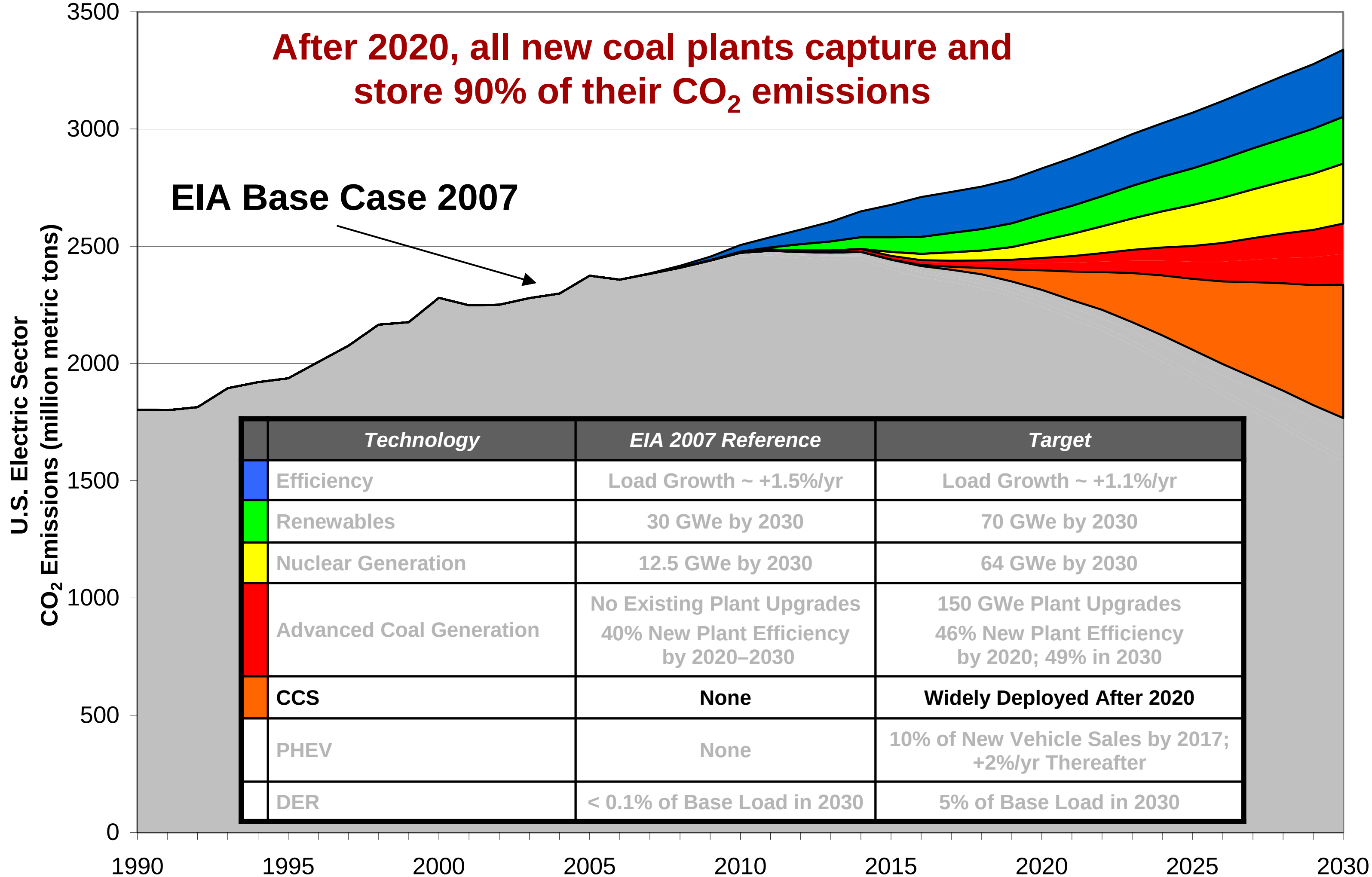
Benefit of Achieving the CCS Target



Technology	EIA 2007 Reference	Target
Efficiency	Load Growth ~ +1.5%/yr	Load Growth ~ +1.1%/yr
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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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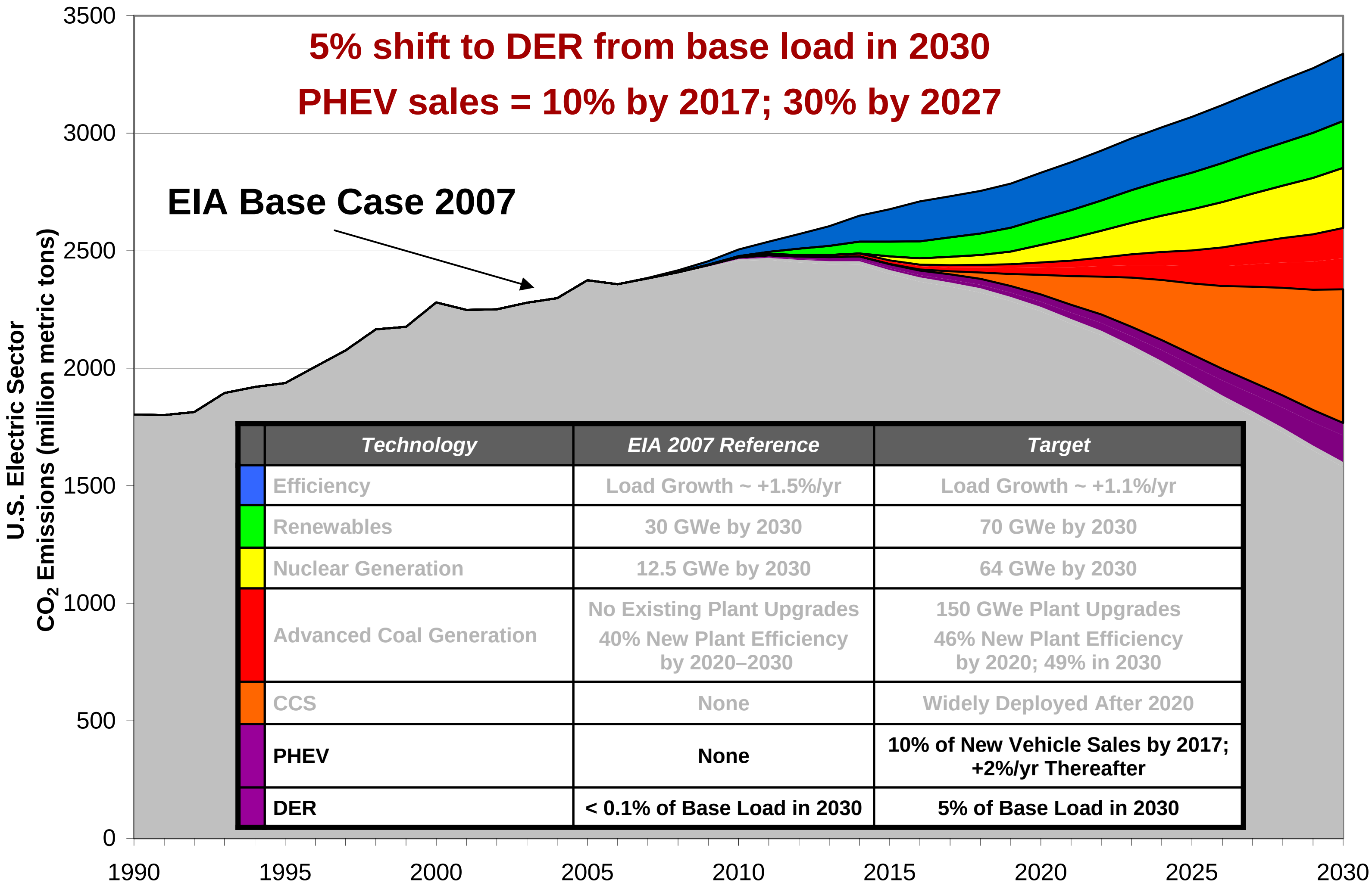
Benefit of Achieving PHEV and DER Targets



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**

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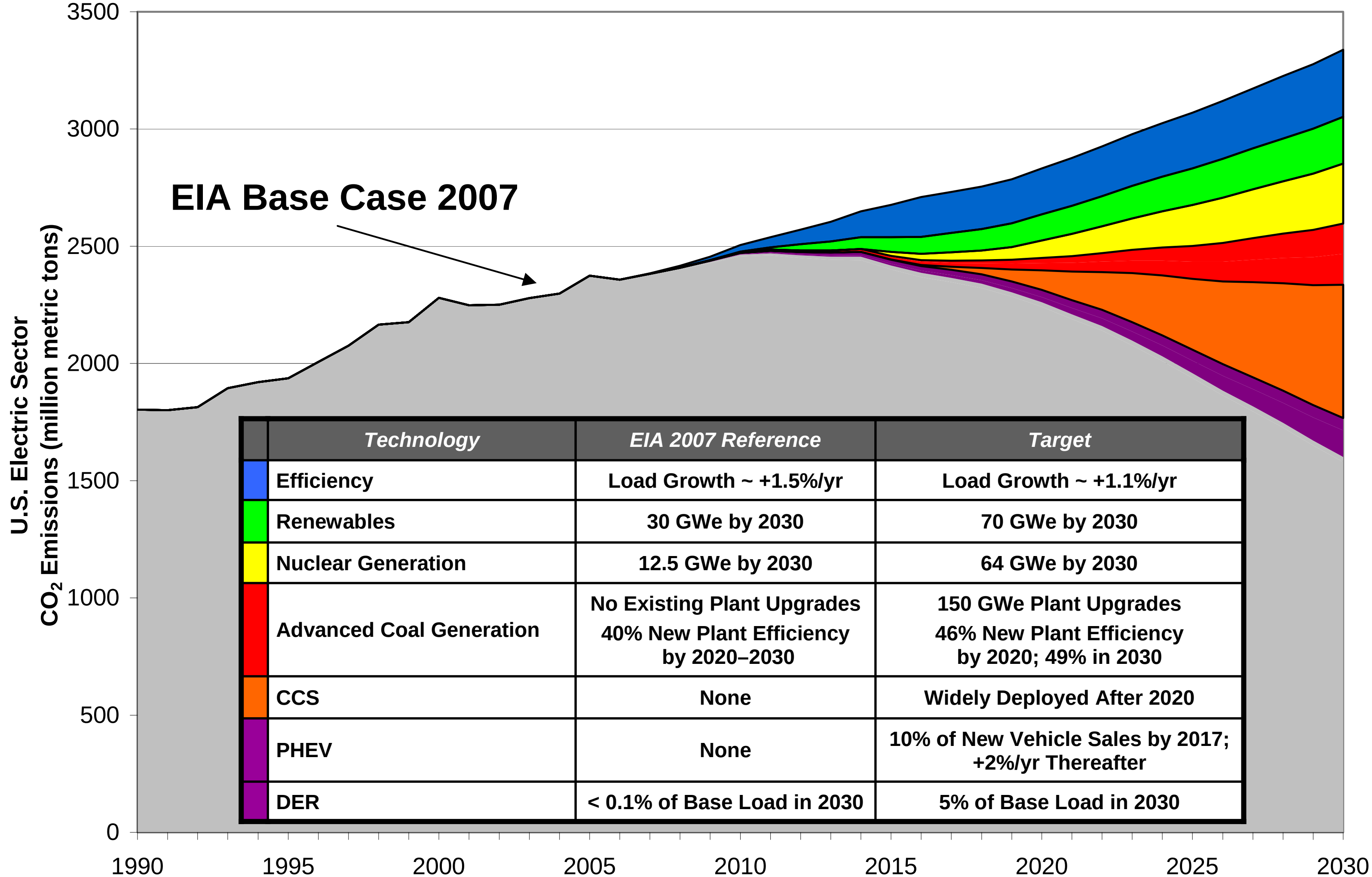
CO_2 Reductions … Technical Potential*



	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
(orange)	CCS	None	Widely Deployed After 2020
(purple)	PHEV	None	10% of New Vehicle Sales by 2017; +2%/yr Thereafter
(purple)	DER	< 0.1% of Base Load in 2030	5% of Base Load in 2030

** Achieving all targets is very aggressive, but potentially feasible.*

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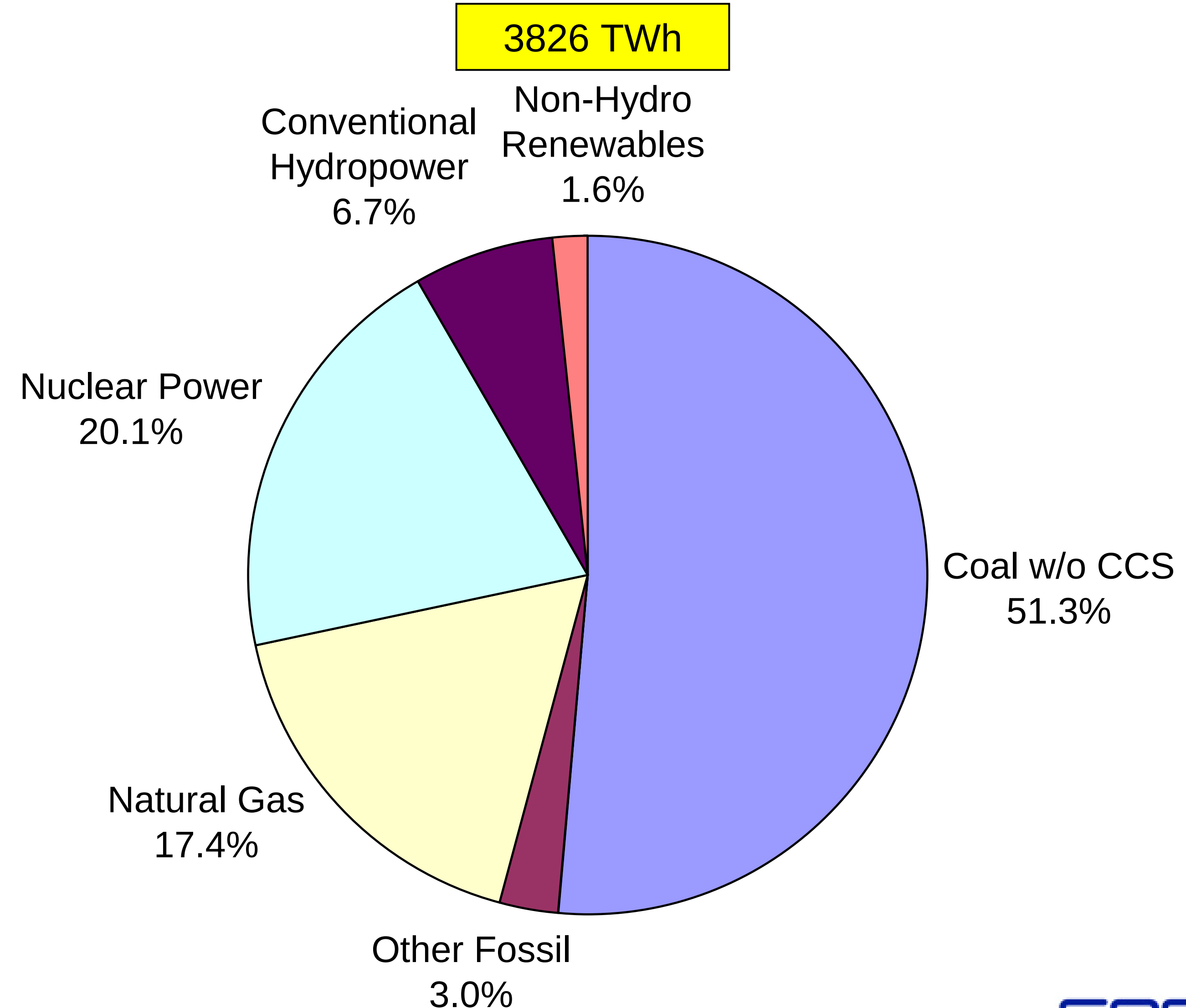
Total U.S. Electricity Generation: 2005 EIA



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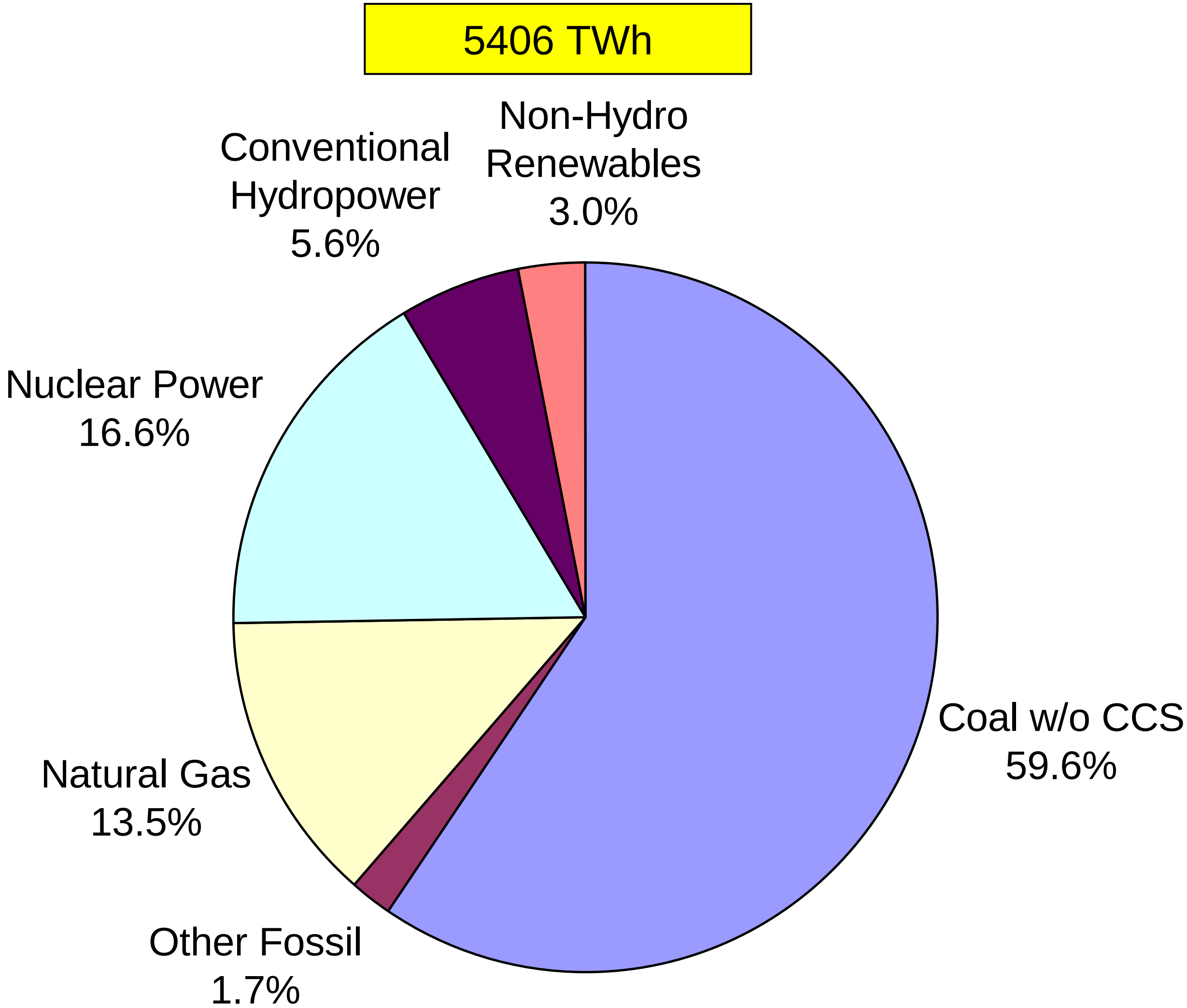
Total U.S. Electricity Generation: 2030 EIA Base Case



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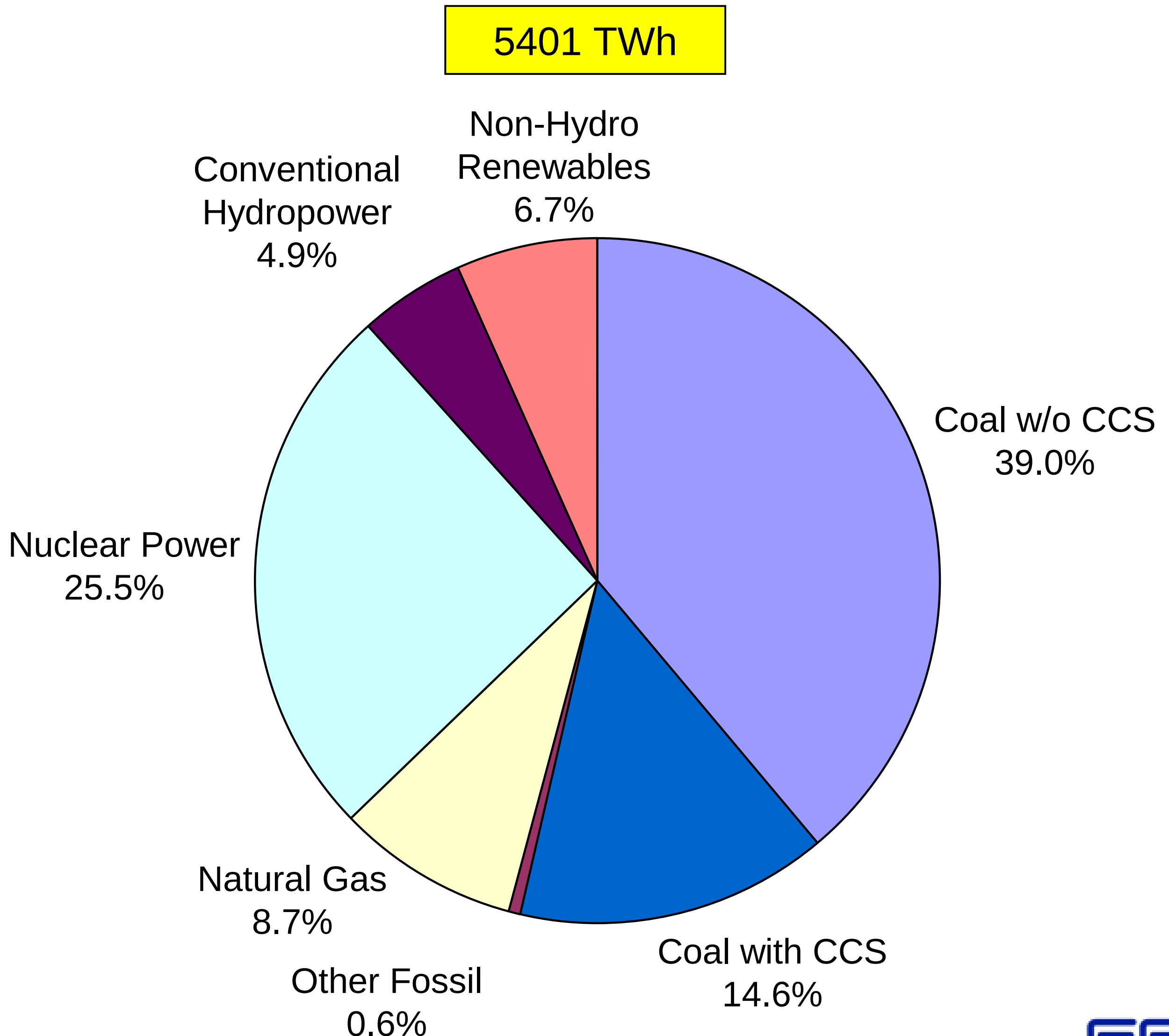
Total U.S. Electricity Generation: 2030 Advanced Technology Targets



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Key Technology Challenges

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