



**EPRI**

ELECTRIC POWER  
RESEARCH INSTITUTE

# **Electricity Technology in a Carbon-Constrained Future**

**December 18, 2007**

**U.S. Department of Energy**

**H<sub>2</sub> Technical Advisory Group**

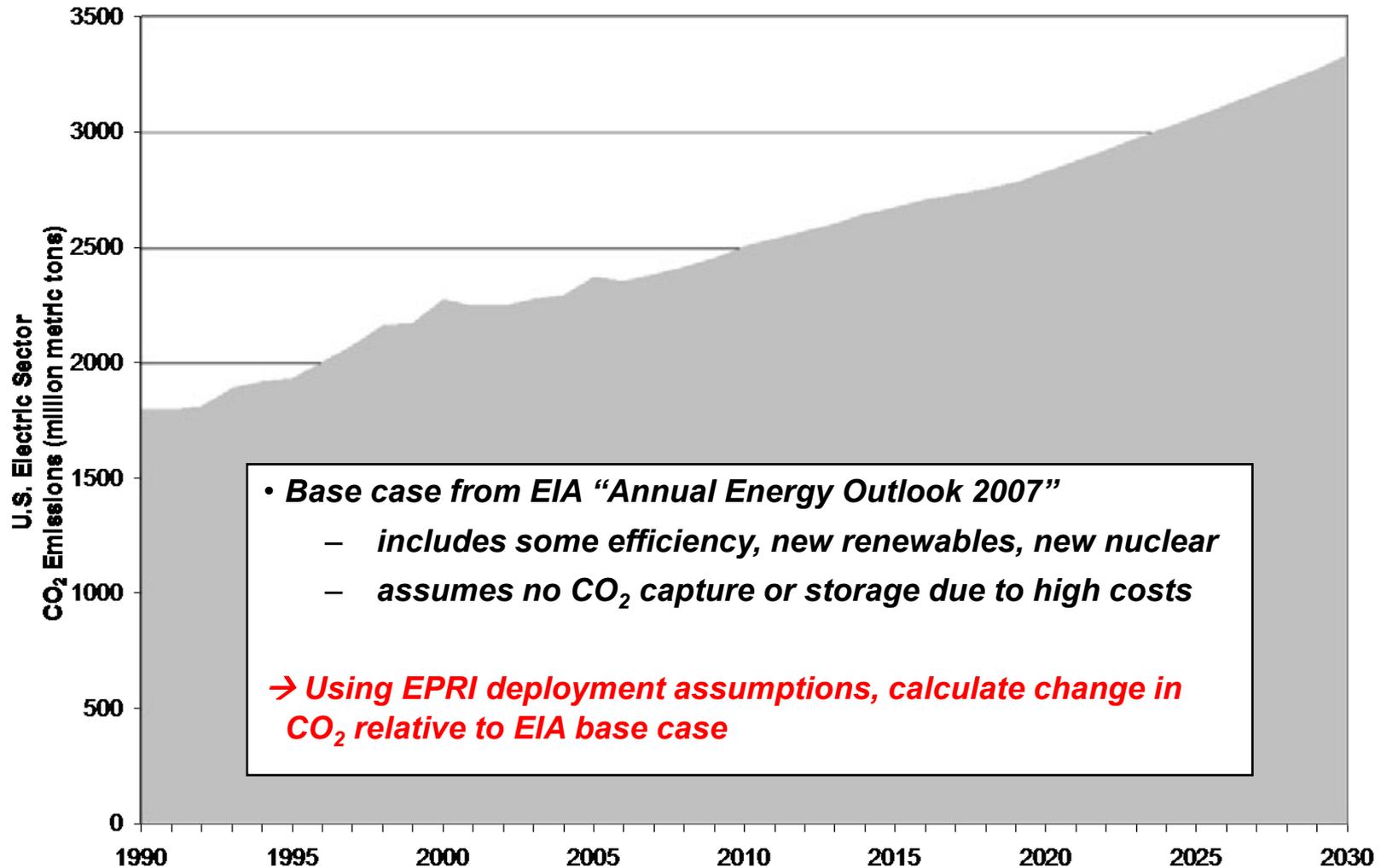
**Revis James**

**Director, Energy Technology Assessment Center**

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# **What CO<sub>2</sub> emissions reductions from the U.S. electricity sector are technically feasible?**

# U.S. Electricity Sector CO<sub>2</sub> Emissions

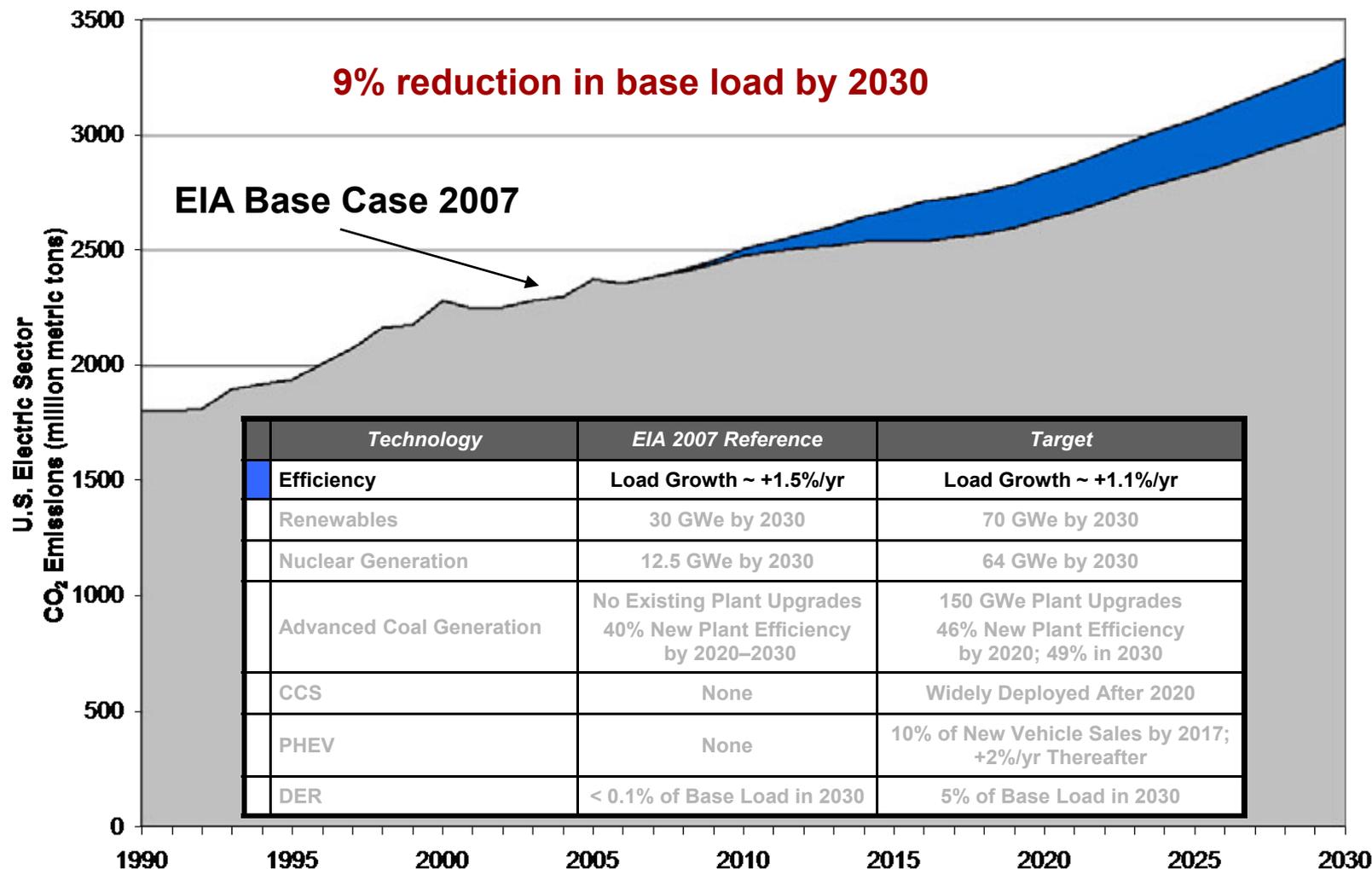


# Technology Deployment Targets

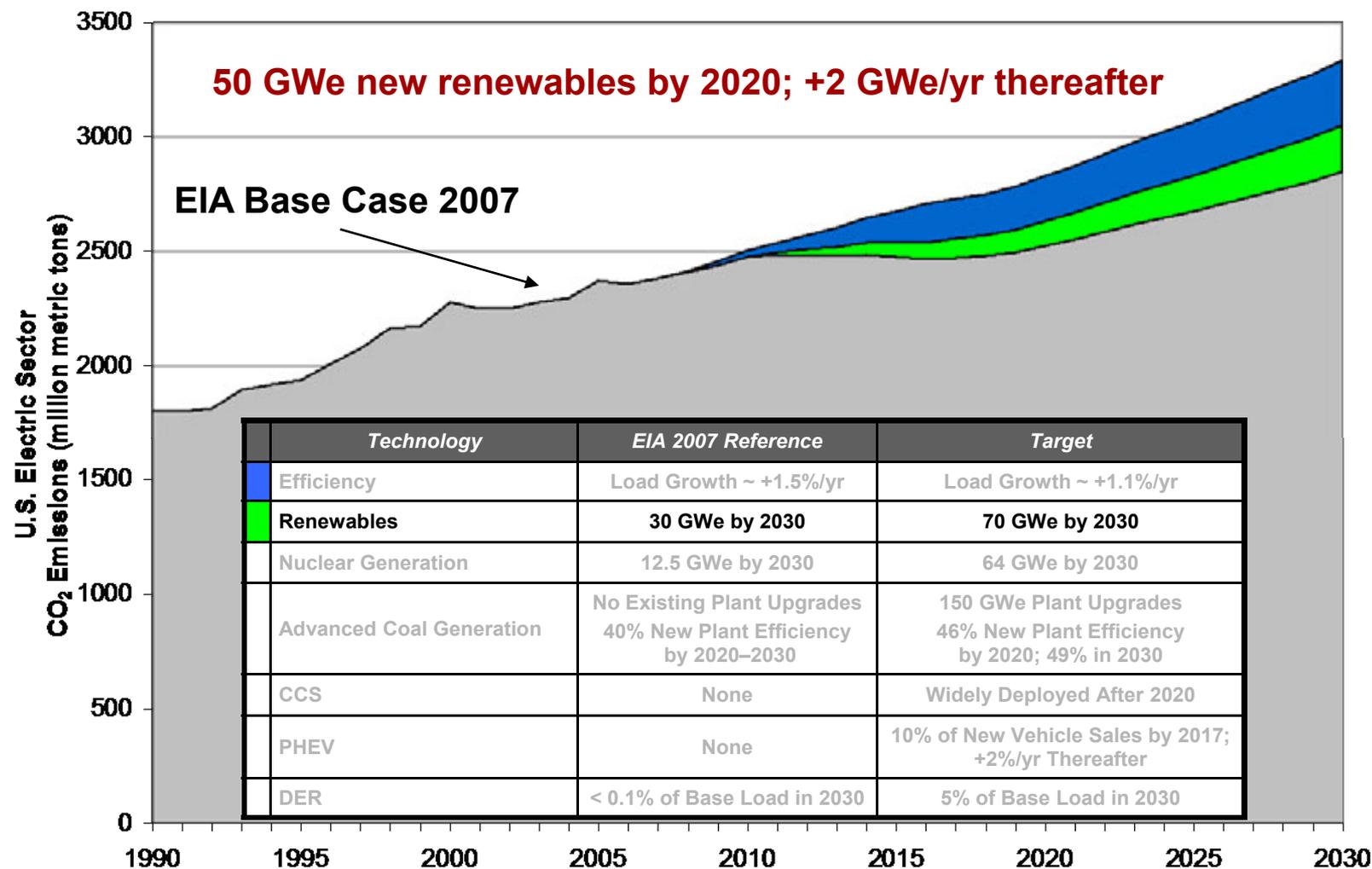
<b>Technology</b>	<b>EIA 2007 Base Case</b>	<b>EPRI Analysis Target*</b>
<b>Efficiency</b>	<b>Load Growth ~ +1.5%/yr</b>	<b>Load Growth ~ +1.1%/yr</b>
<b>Renewables</b>	<b>30 GWe by 2030</b>	<b>70 GWe by 2030</b>
<b>Nuclear Generation</b>	<b>12.5 GWe by 2030</b>	<b>64 GWe by 2030</b>
<b>Advanced Coal Generation</b>	<b>No Existing Plant Upgrades 40% New Plant Efficiency by 2020–2030</b>	<b>150 GWe Plant Upgrades 46% New Plant Efficiency by 2020; 49% in 2030</b>
<b>Carbon Capture and Storage (CCS)</b>	<b>None</b>	<b>Widely Available and Deployed After 2020</b>
<b>Plug-in Hybrid Electric Vehicles (PHEV)</b>	<b>None</b>	<b>10% of New Vehicle Sales by 2017; +2%/yr Thereafter</b>
<b>Distributed Energy Resources (DER) (including distributed solar)</b>	<b>&lt; 0.1% of Base Load in 2030</b>	<b>5% of Base Load in 2030</b>

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

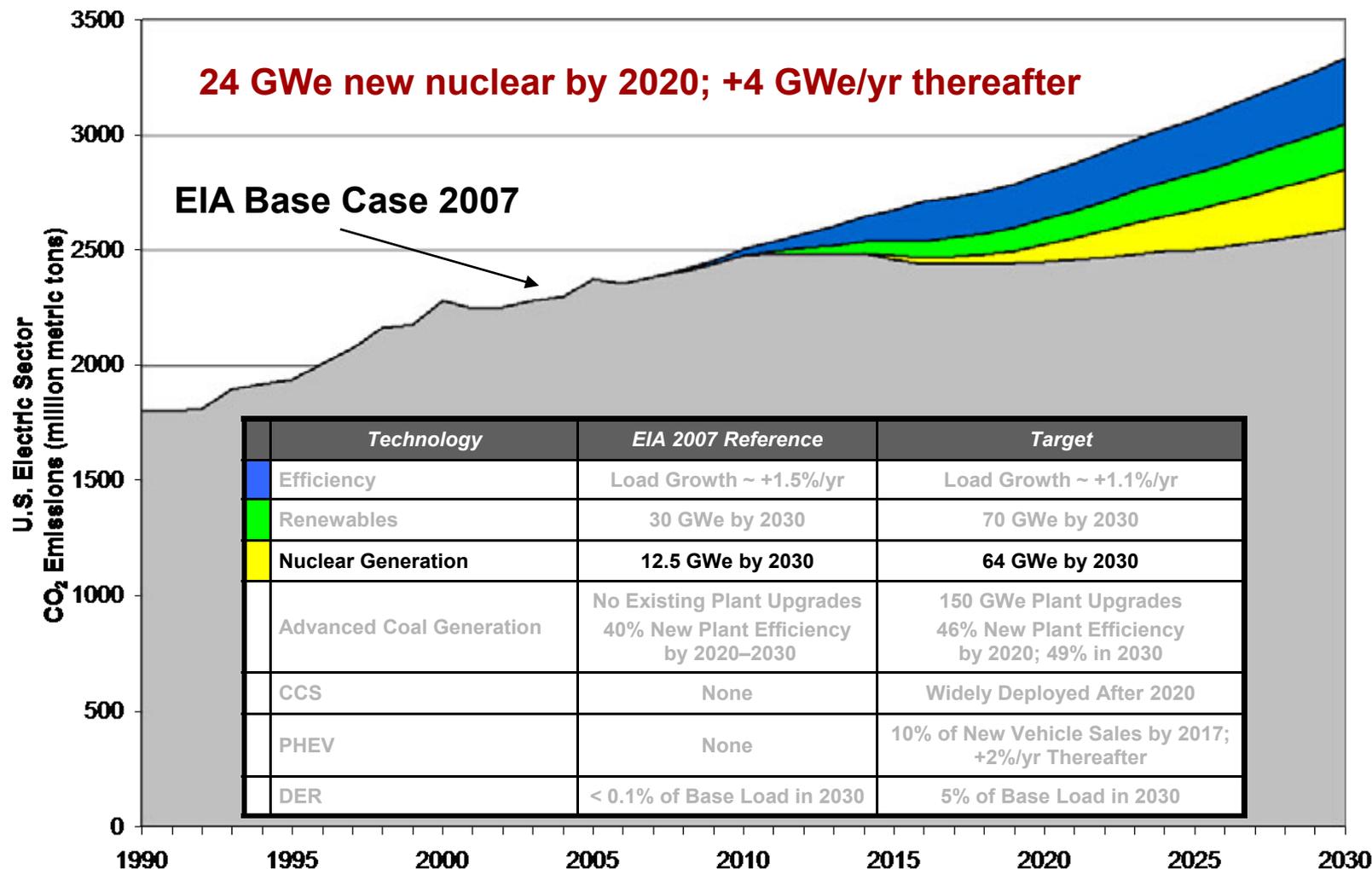
# Benefit of Achieving Efficiency Target



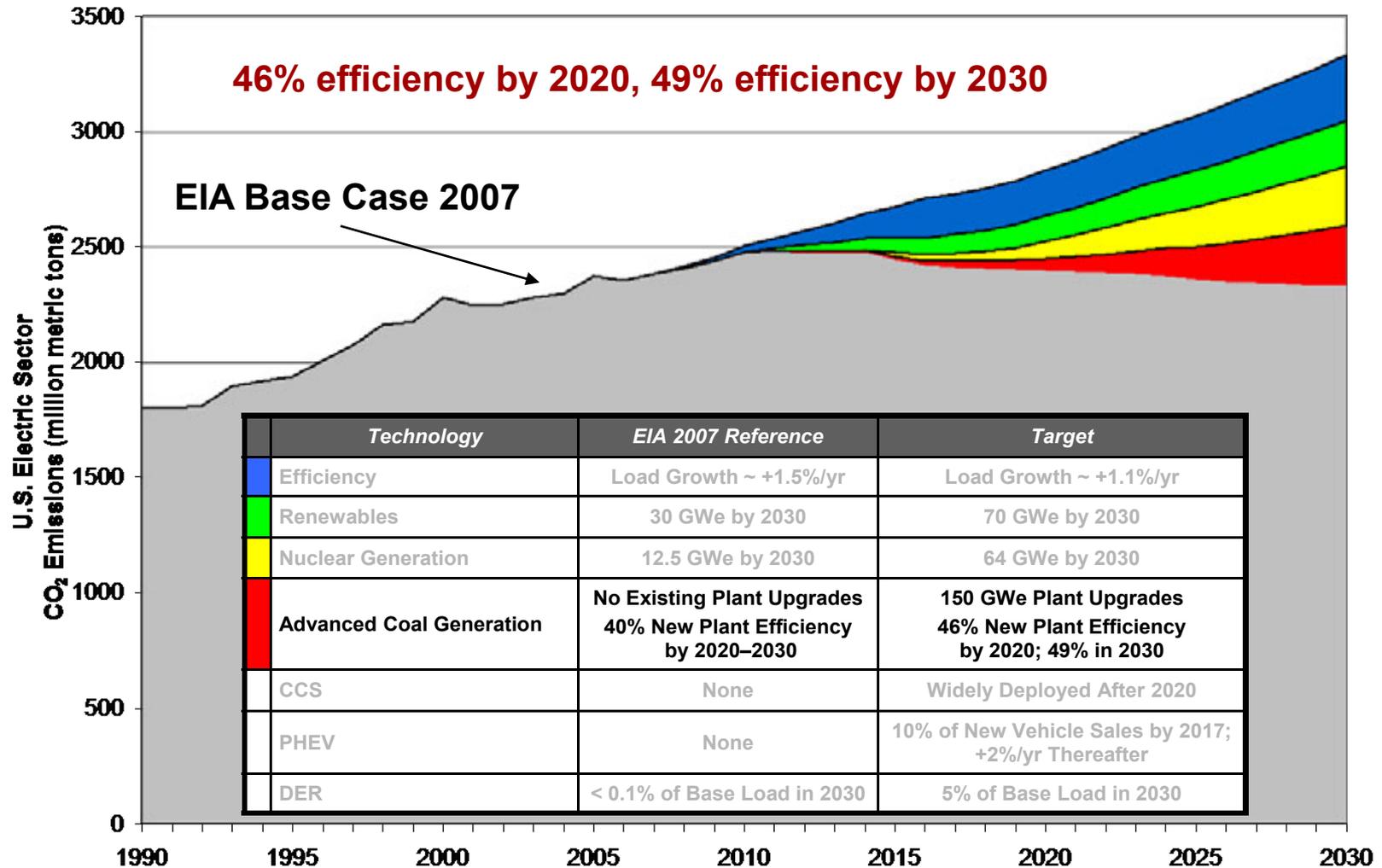
# Benefit of Achieving Renewables Target



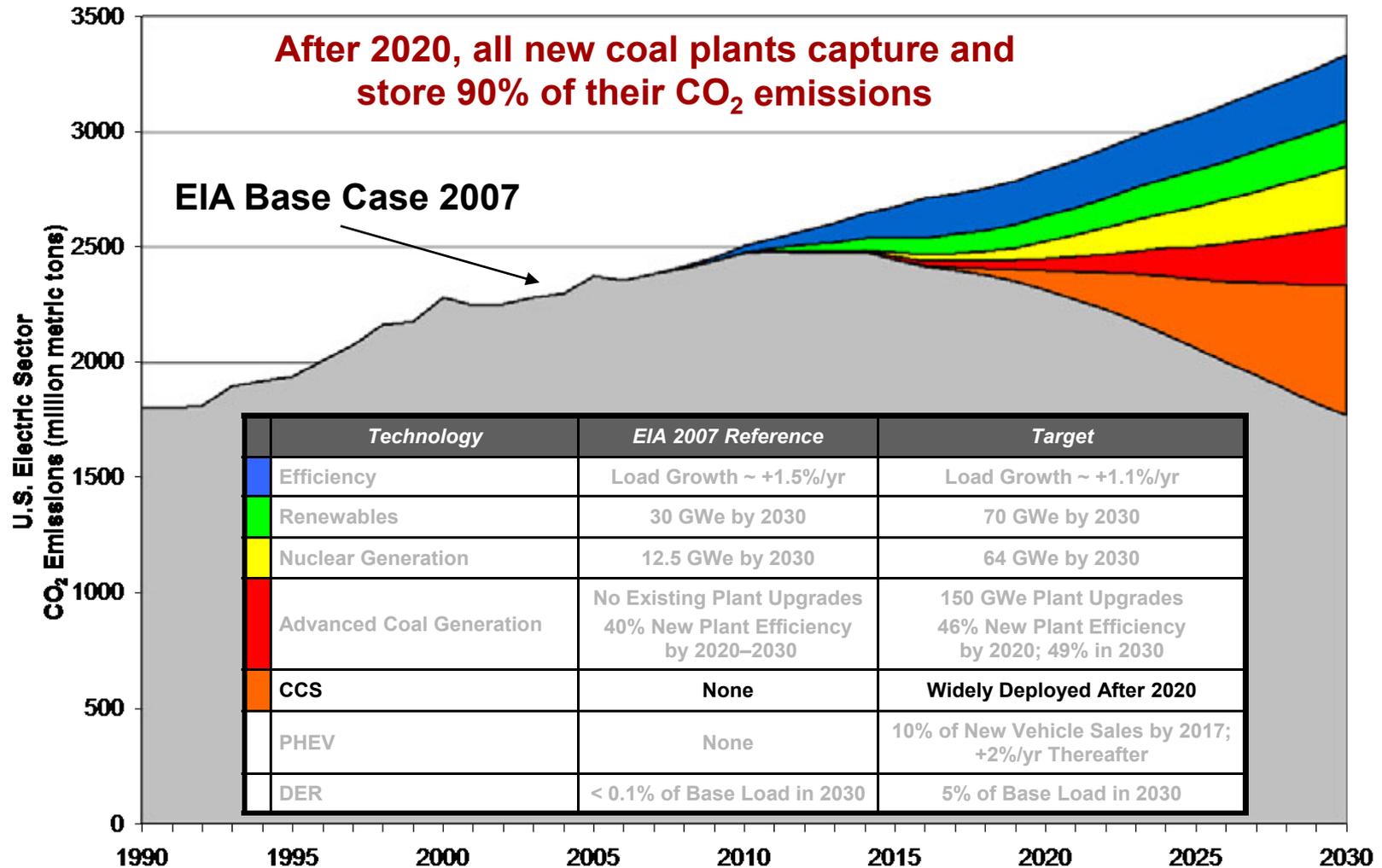
# Benefit of Achieving Nuclear Generation Target



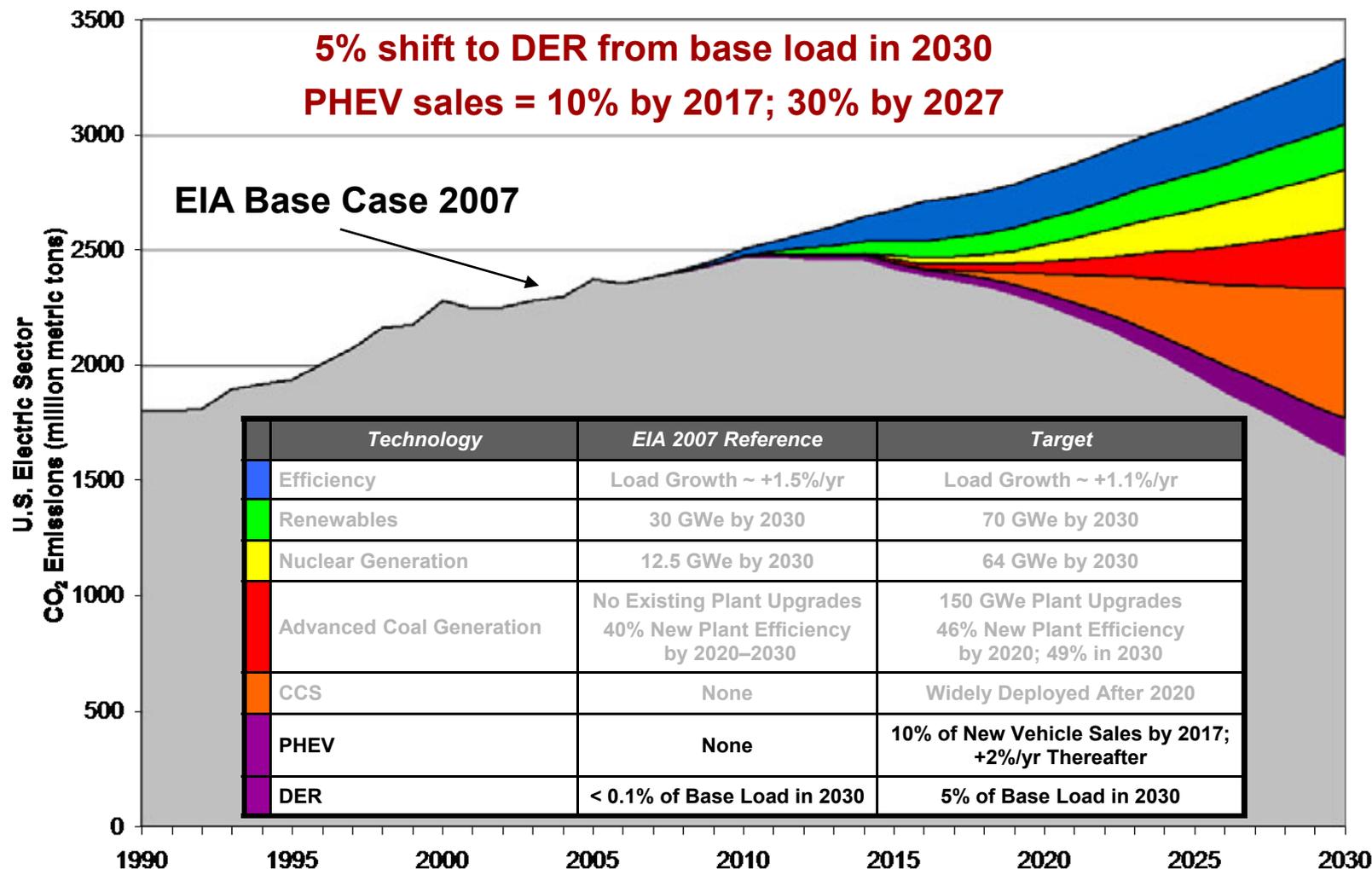
# Benefit of Achieving Advanced Coal Target



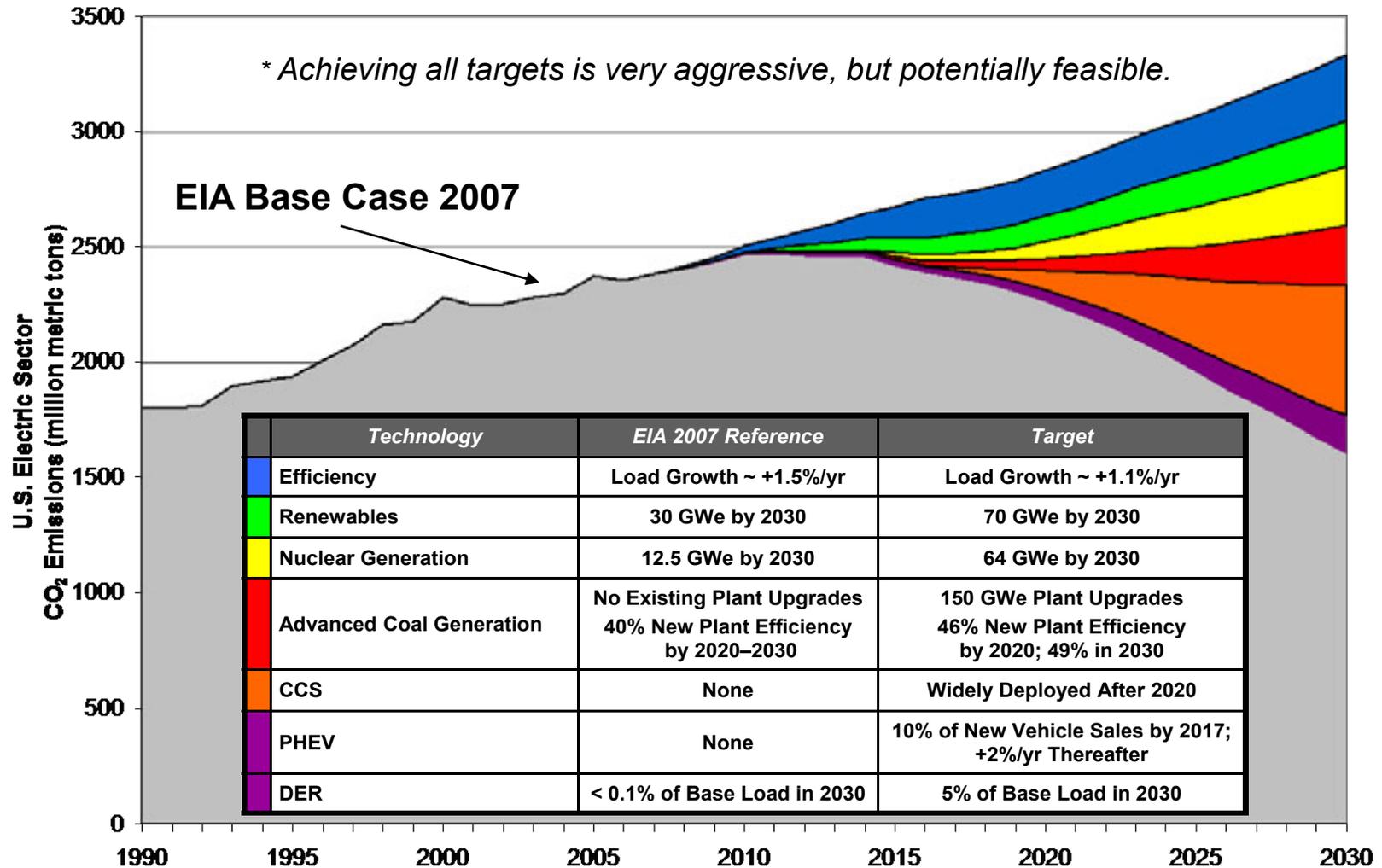
# Benefit of Achieving CCS Target



# Benefit of Achieving PHEV and DER Targets



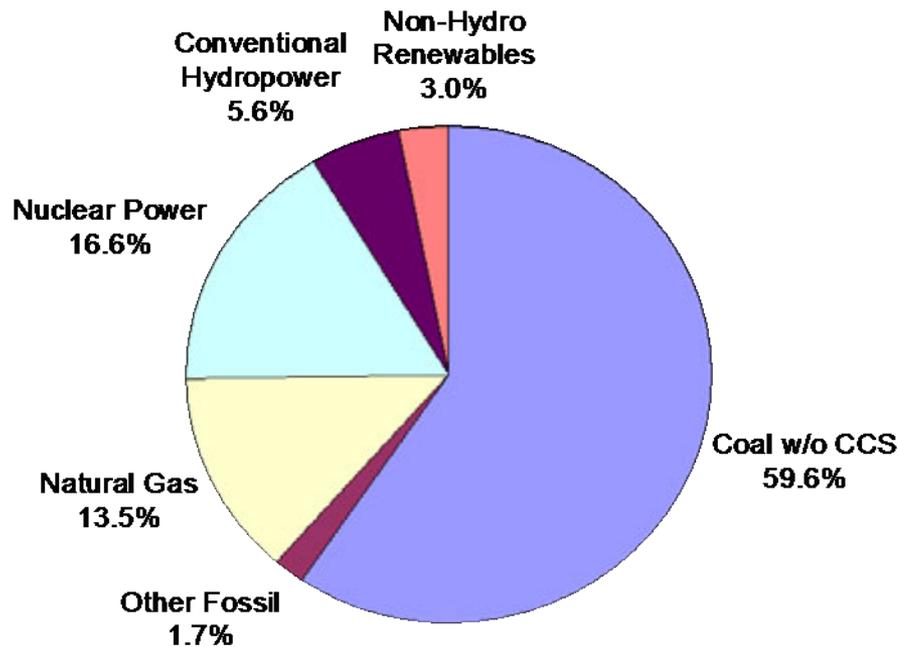
# CO<sub>2</sub> Reductions... Technical Potential\*



# U.S. Electricity Generation: 2030

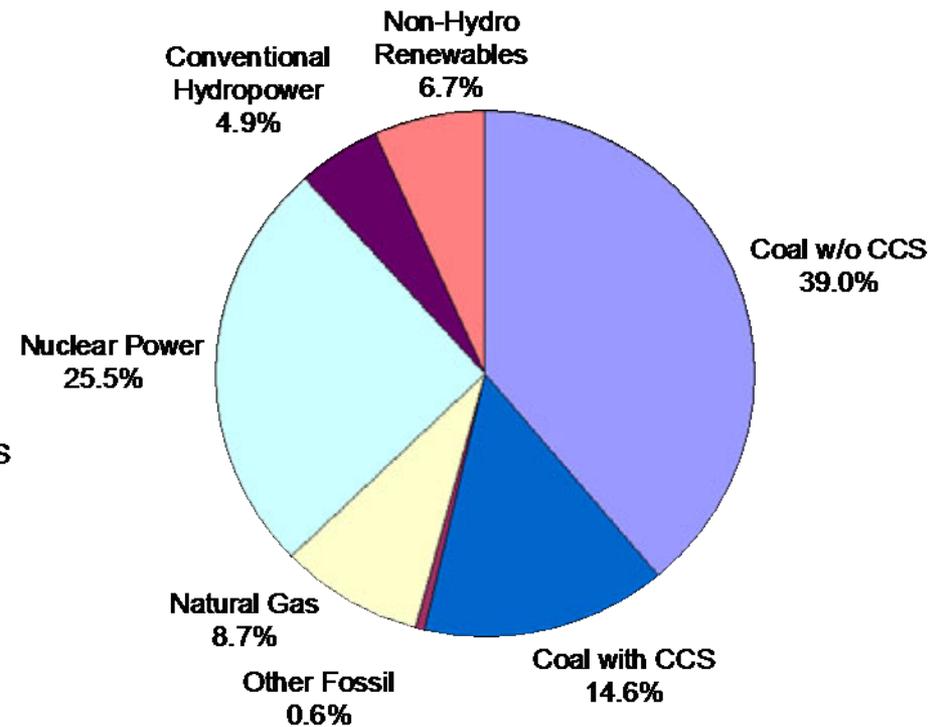
## EIA Base Case\*

5406 TWh



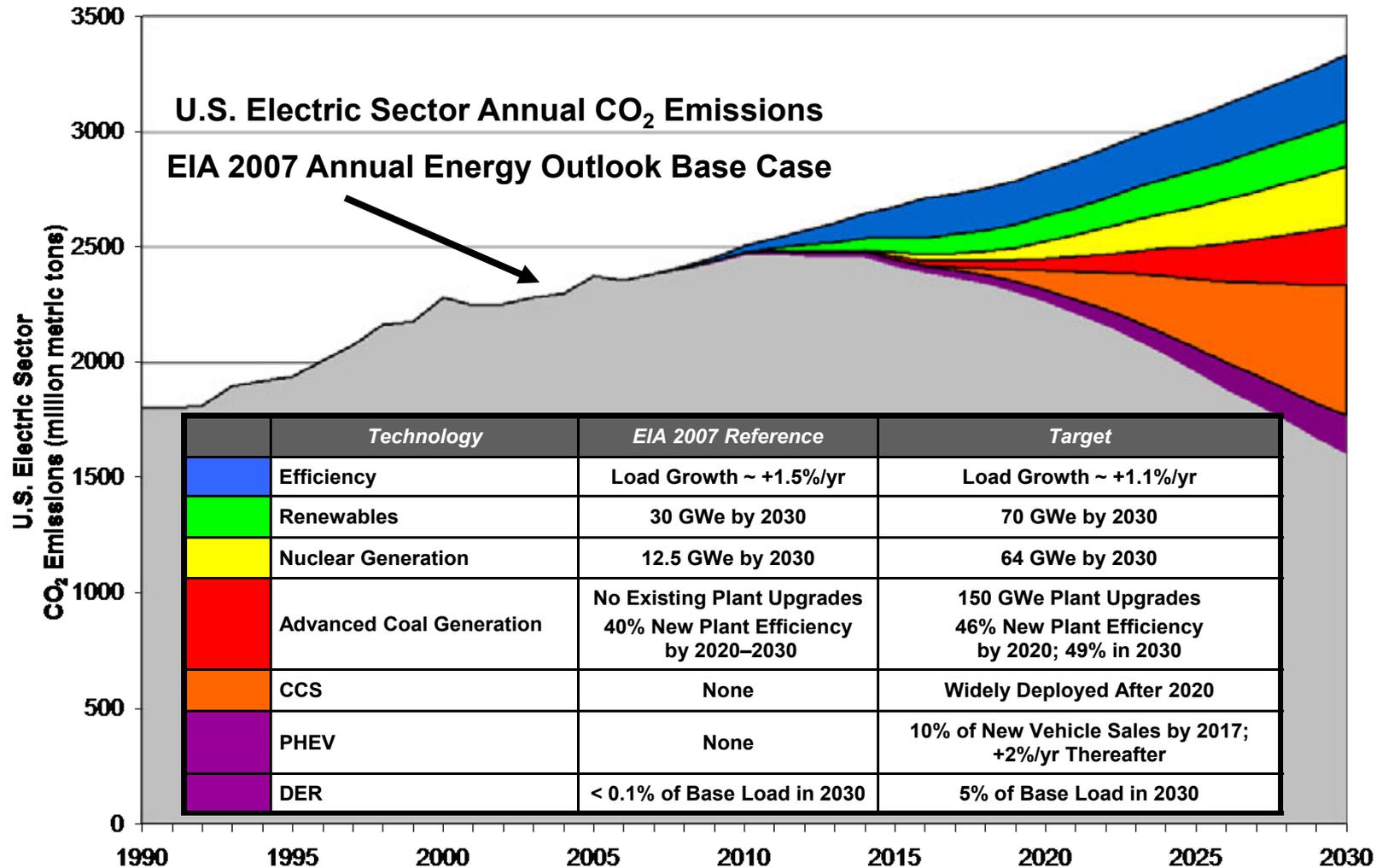
## Advanced Technology Targets

5401 TWh



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

# CO<sub>2</sub> Reductions ... Technical Potential\*



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

# Key Technology Challenges

**Significant cost-effective CO<sub>2</sub> 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<sub>2</sub> capture and storage in a variety of geologies.

# What are the economic impacts of different technology strategies for CO<sub>2</sub> emissions reductions from the U.S. electricity sector?

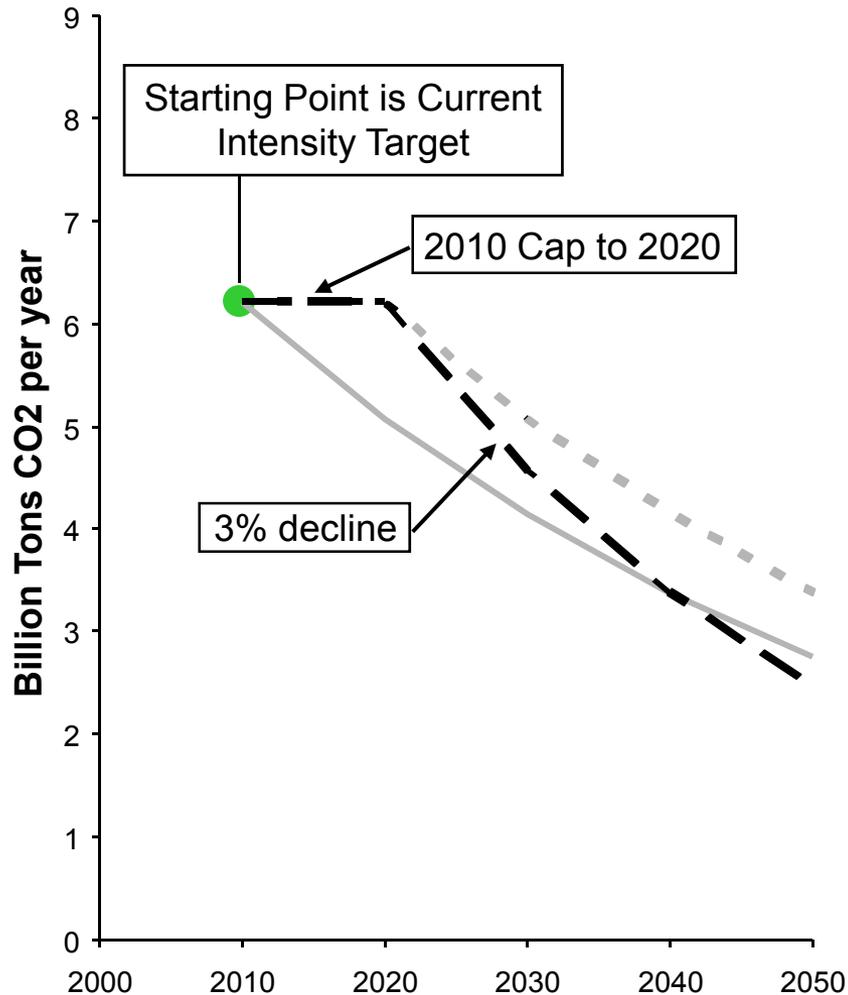
# Economic Assessment

## EPRI Economic Analysis Model (MERGE)

- Designed to examine economy-wide impacts of climate policy
- Each country or group of countries maximizes its own welfare
- Prices of each GHG determined internally within model
- Top down model of economic growth
- Technological detail in energy sector

**One of three models used by U.S. Climate Change Science Program and in many other international and domestic studies.**

# Assumed U.S. Economy-Wide CO<sub>2</sub> Constraint

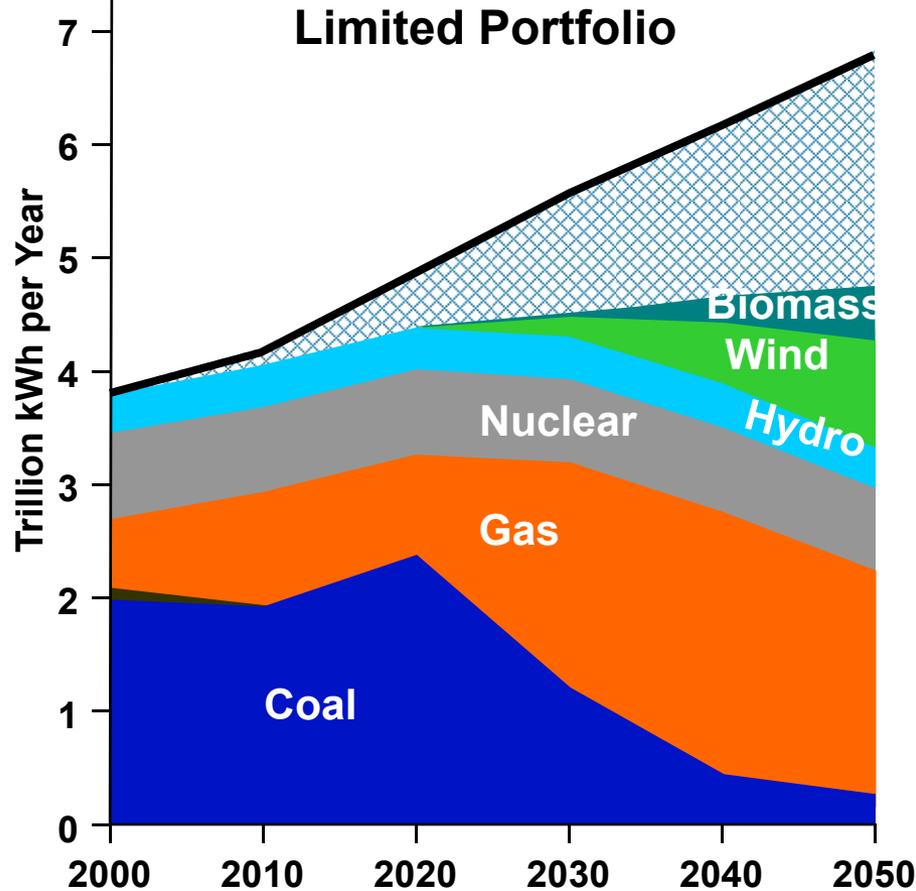


- Analyzed three different economy-wide CO<sub>2</sub> constraints
- PRISM electric sector CO<sub>2</sub> profile most closely modeled by economy-wide constraint which:
  - Caps emissions at 2010 levels until 2020
  - Requires 3% decline beginning in 2020

# Electricity Technology Scenarios

	<b>Full Portfolio</b>	<b>Limited Portfolio</b>
<b>Supply-Side</b>		
Carbon Capture and Storage (CCS)	Available	Unavailable
New Nuclear	Production Can Expand	Existing Production Levels
Renewables	Costs Decline	Costs Decline Slower
New Coal and Gas	Improvements	Improvements
<b>Demand-Side</b>		
Plug-in Hybrid Electric Vehicles (PHEV)	Available	Unavailable
End-Use Efficiency	Accelerated Improvements	Improvements

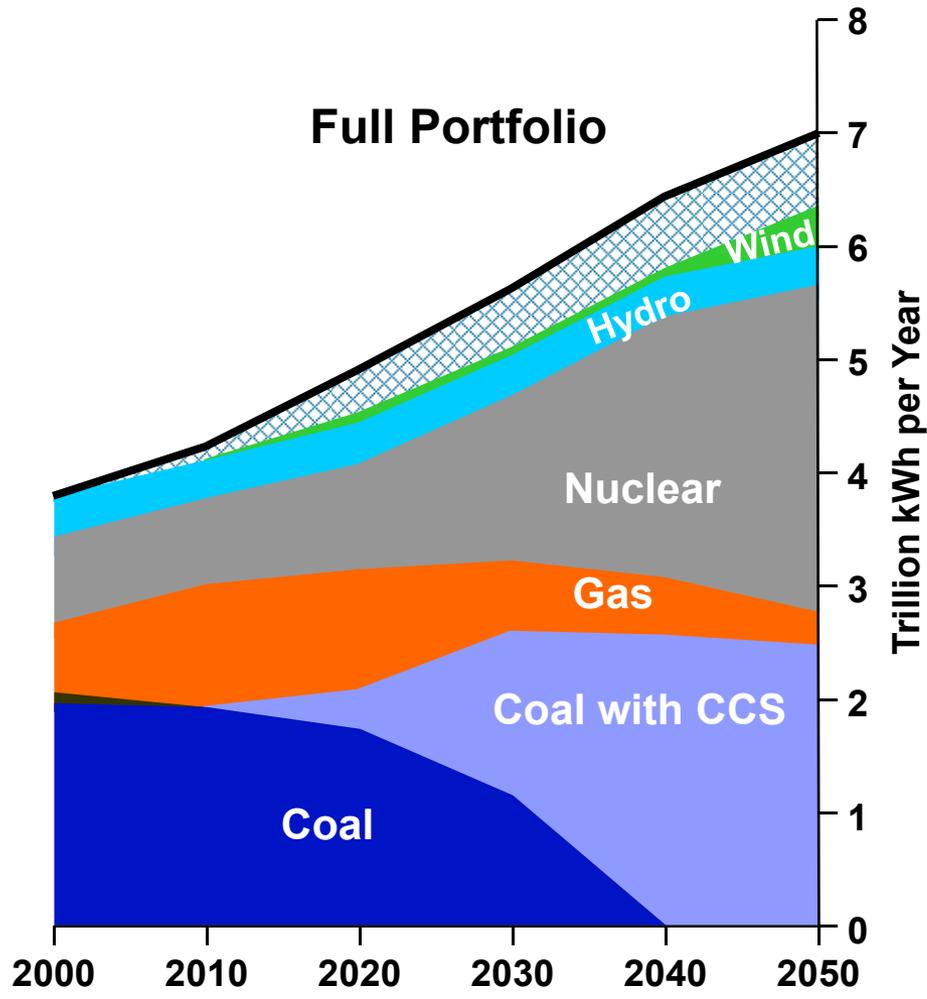
# Meeting Economy-wide Cap\* with Limited Portfolio



**With a less de-carbonized supply, electricity load must decline to meet the CO<sub>2</sub> emissions target**

**Gas (with half the CO<sub>2</sub> emissions intensity of coal) pays a significant CO<sub>2</sub> cost**

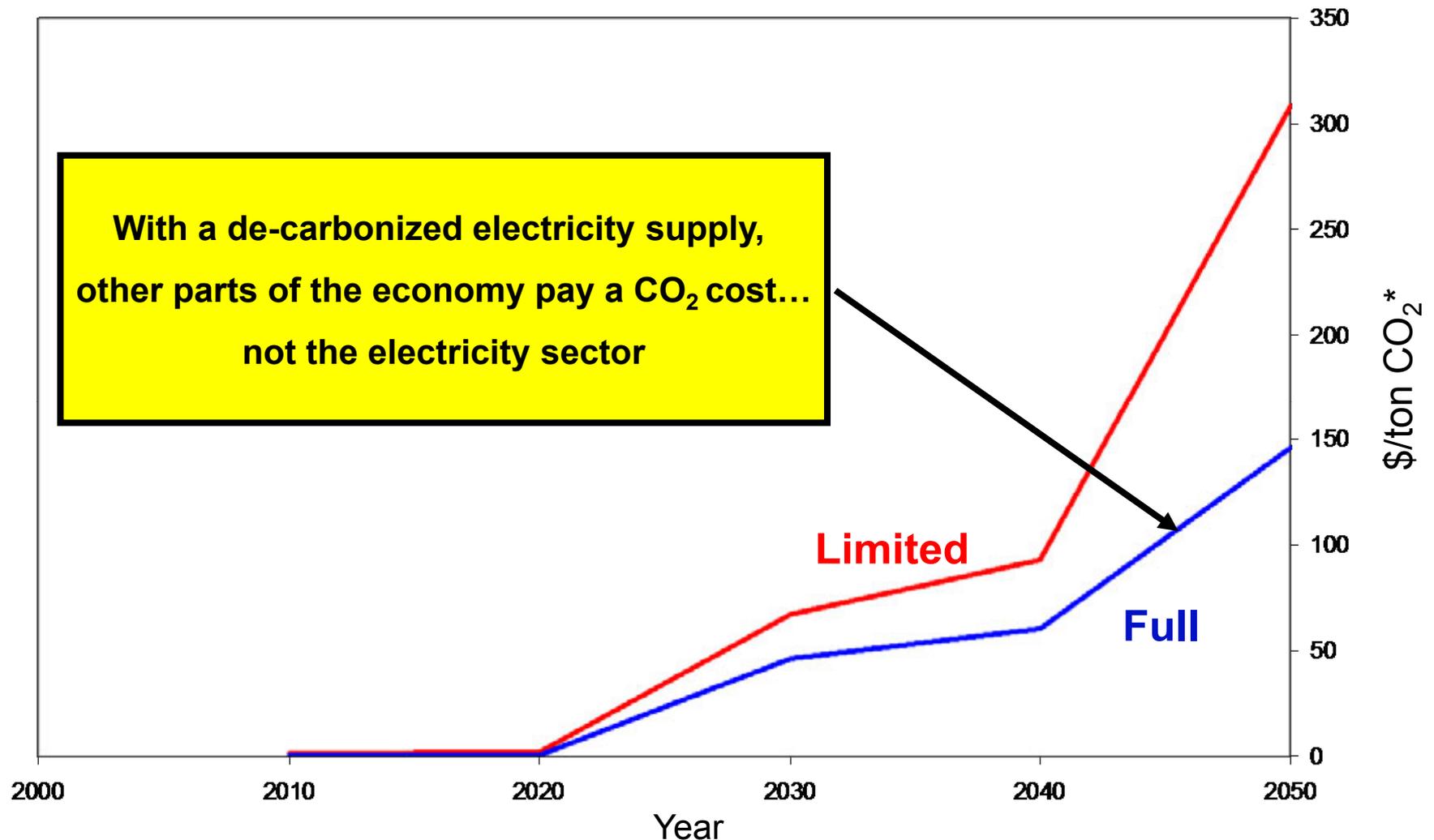
# Meeting Economy-Wide Cap\* with Full Portfolio



**The vast majority of electricity supply is CO<sub>2</sub>-free**

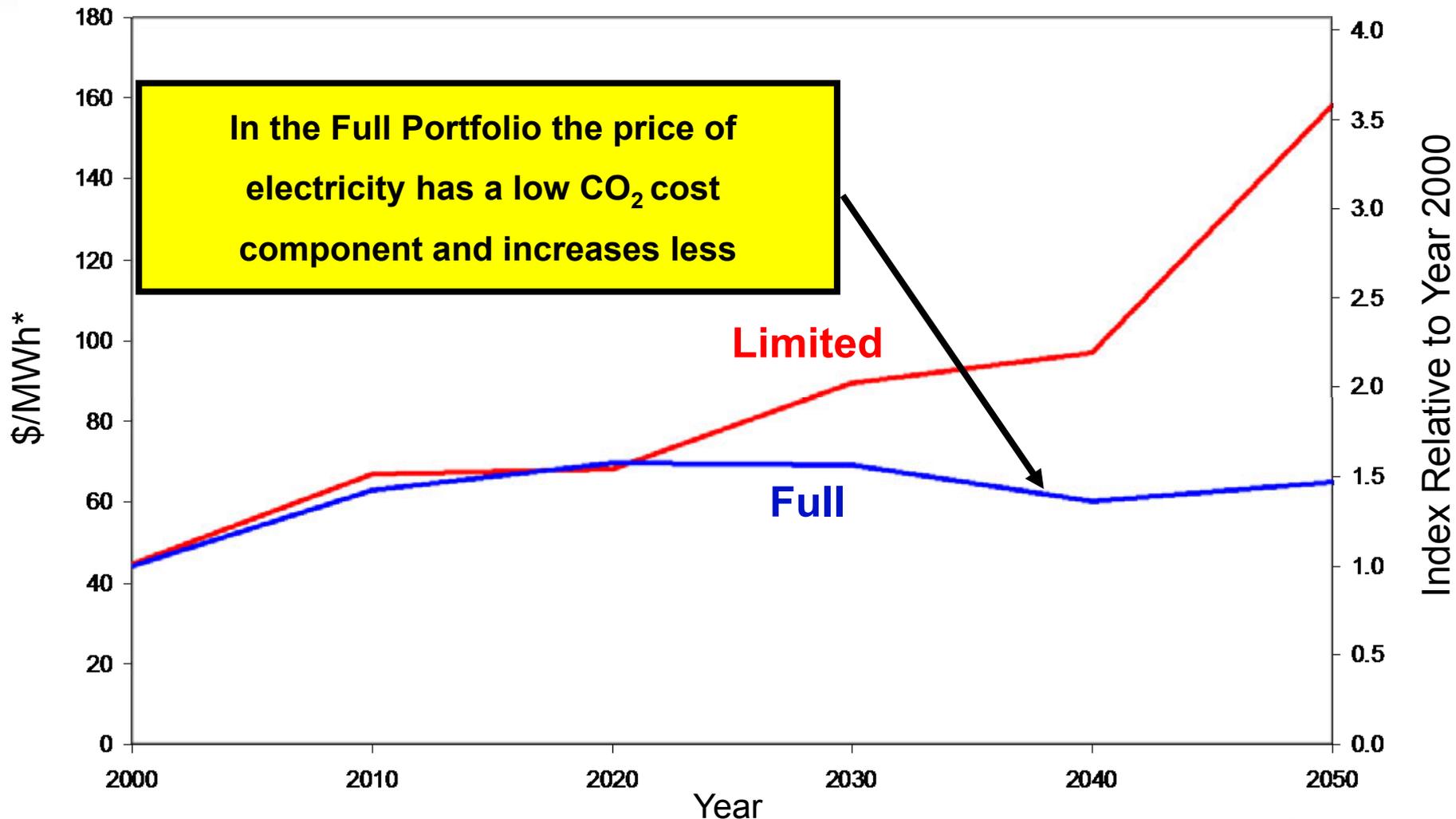
**Gas and non-captured coal are the only supply options paying a CO<sub>2</sub> cost**

# CO<sub>2</sub> Emission Cost : Economy-Wide



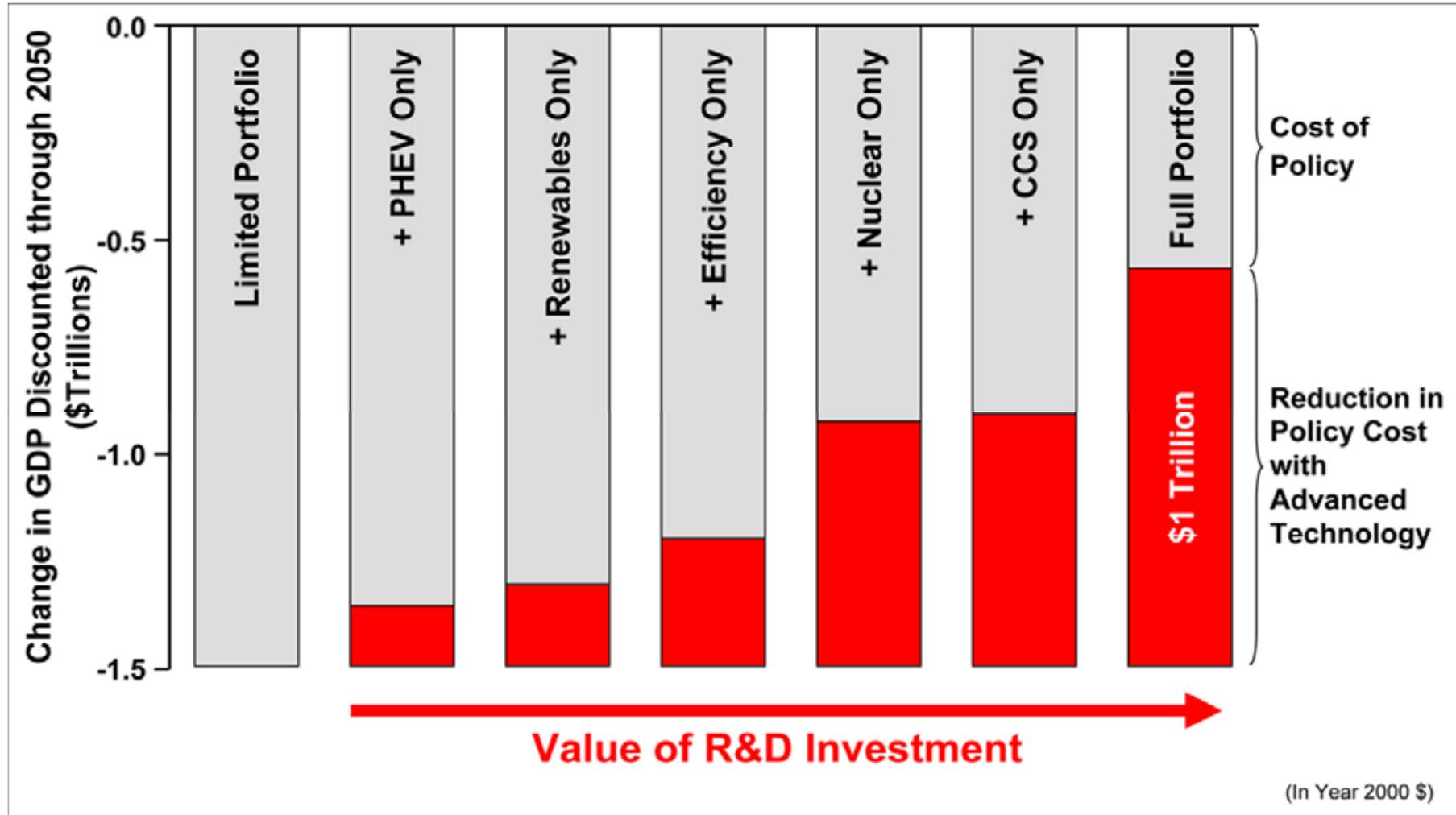
\*Real (inflation-adjusted) 2000\$

# Wholesale Electricity Price



\*Real (inflation-adjusted) 2000\$

# Full Technology Portfolio Reduces Costs of a CO<sub>2</sub> Emissions Reduction Policy by 60%



**How do we achieve the necessary technology capabilities to reduce electricity sector CO<sub>2</sub> emissions?**

# Key Technology Challenges

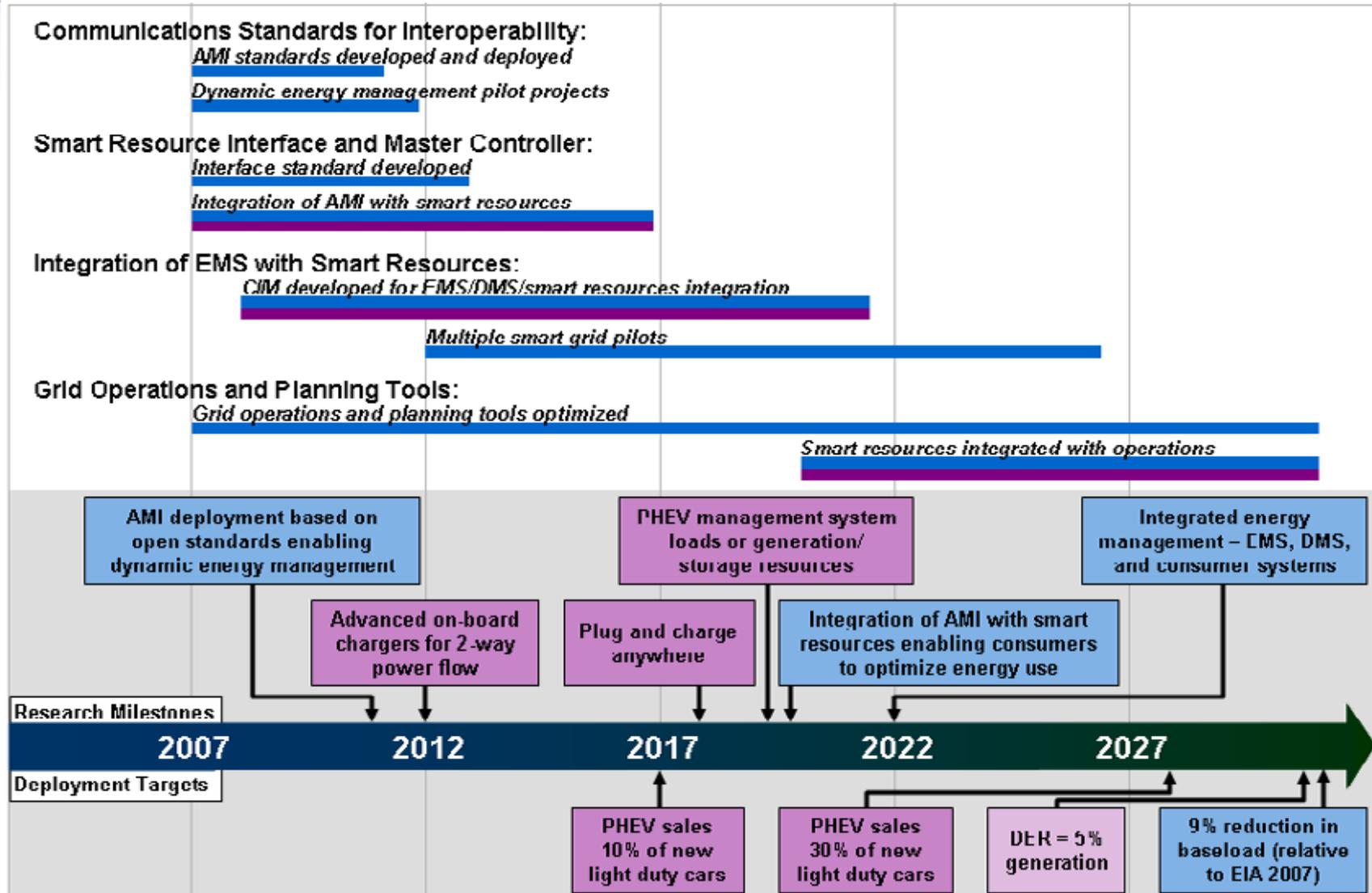
**ALL of the following technology advancements will be needed in order to have a full portfolio of technologies available for reducing CO<sub>2</sub> emissions over the coming decades:**

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<sub>2</sub> capture and storage in a variety of geologies.

**Provides the Basis for Four Technology Pathways**

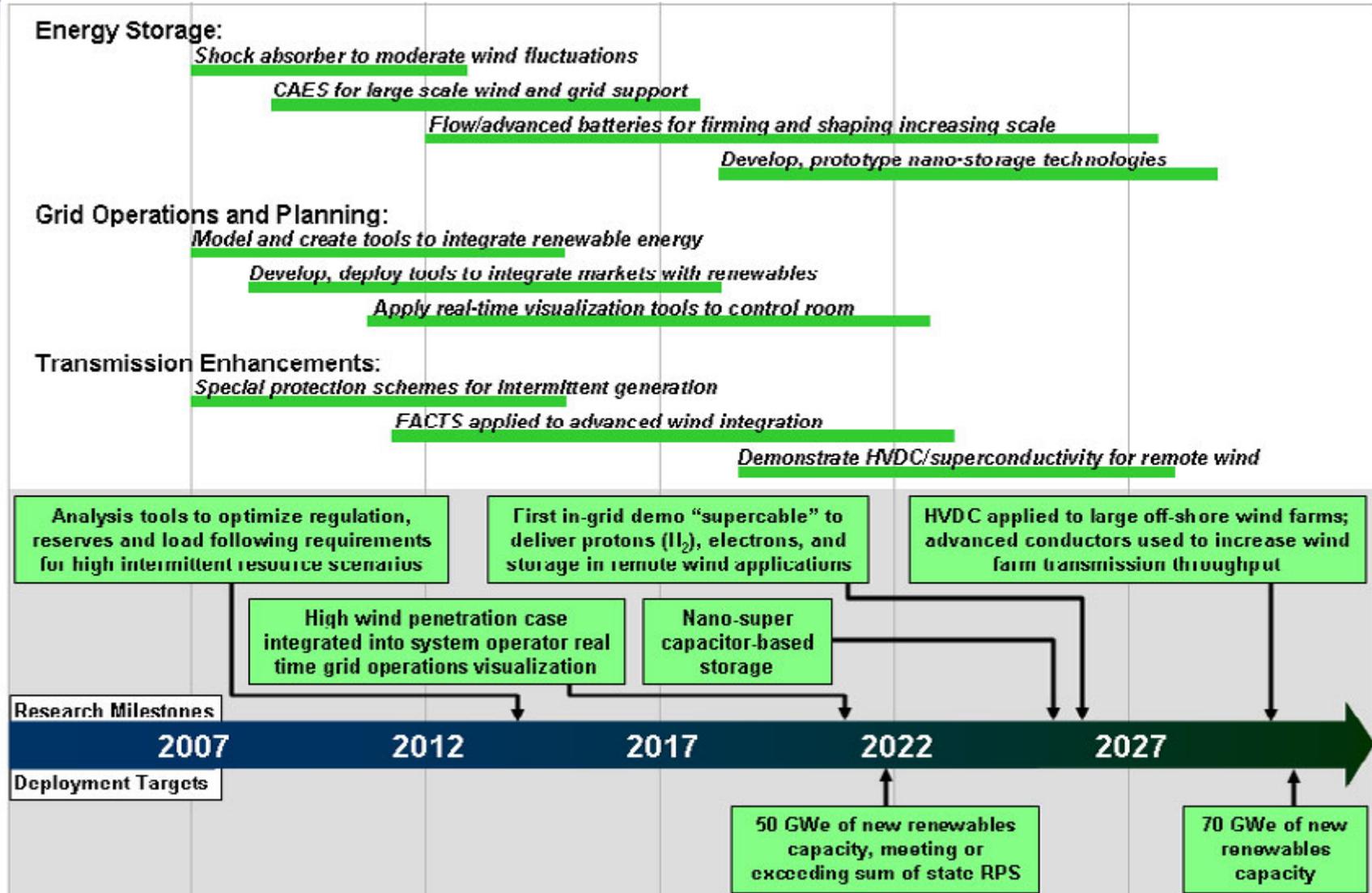
# Distribution Enabled Technology Pathway

## Efficiency, Distributed Energy Resources, Plug-In Hybrid Electric Vehicles

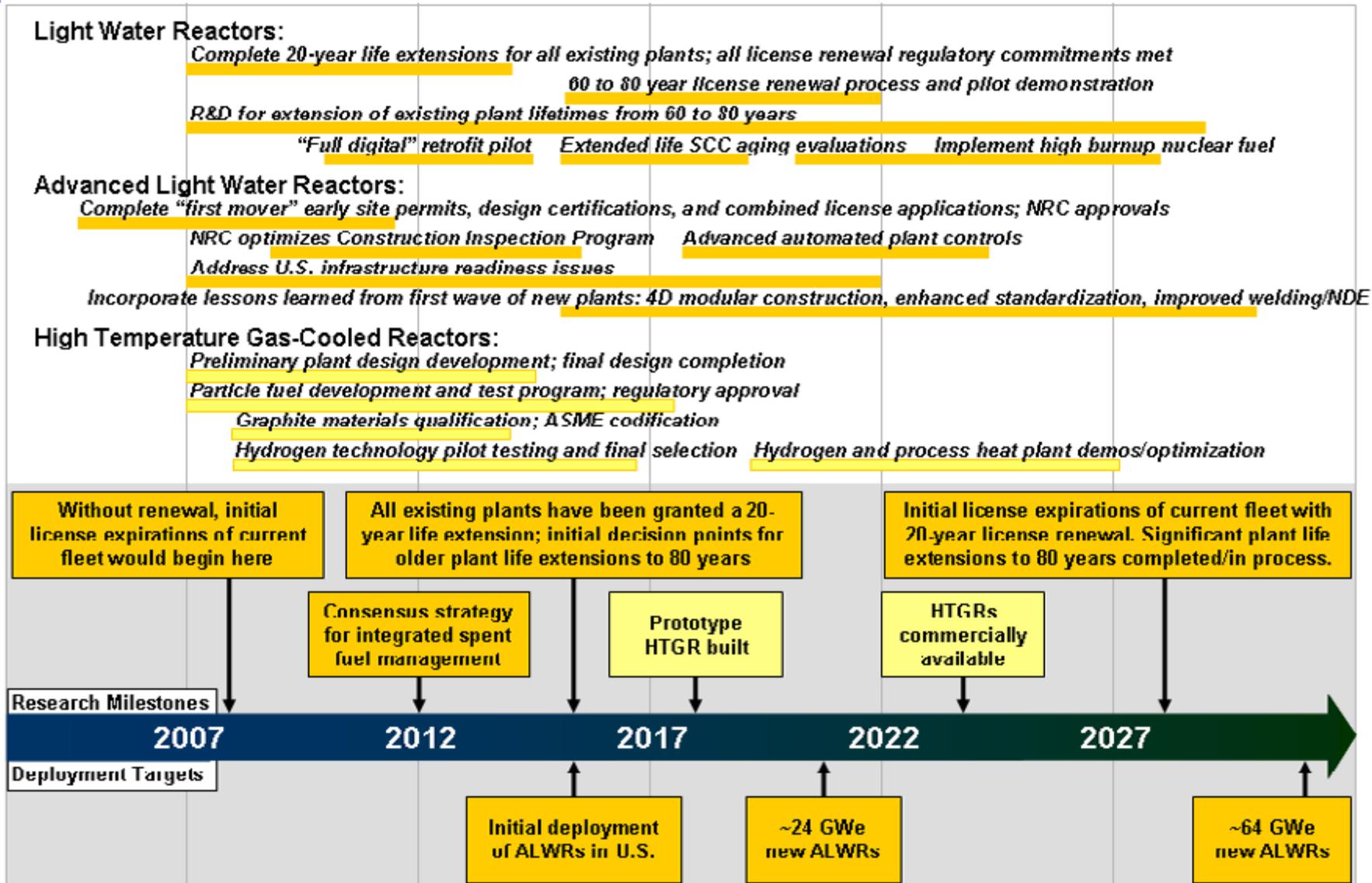


# Grid Enabled Technology Pathway

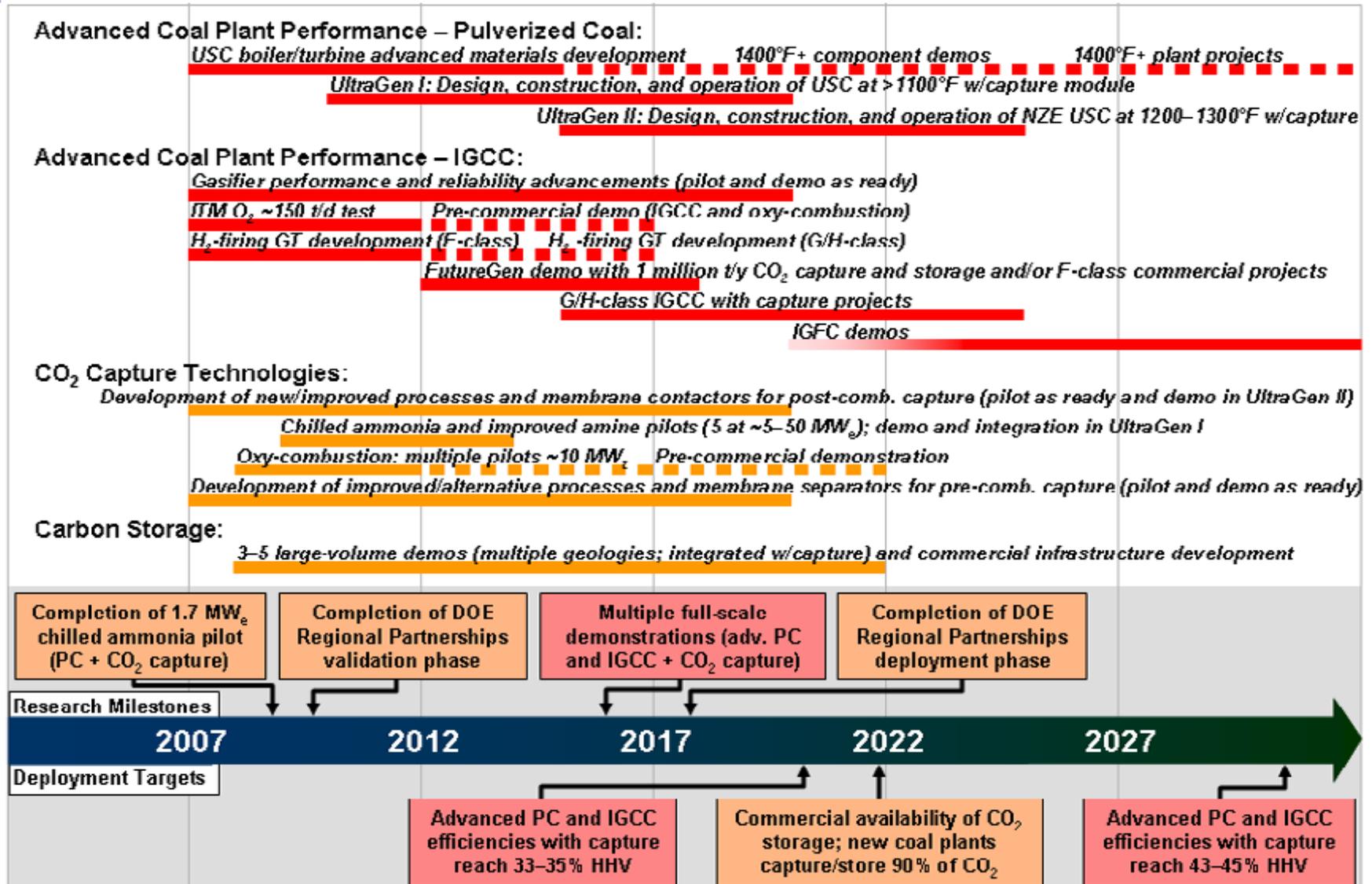
## Renewables Integration and T&D Efficiency Improvement



# Nuclear Technology Pathway



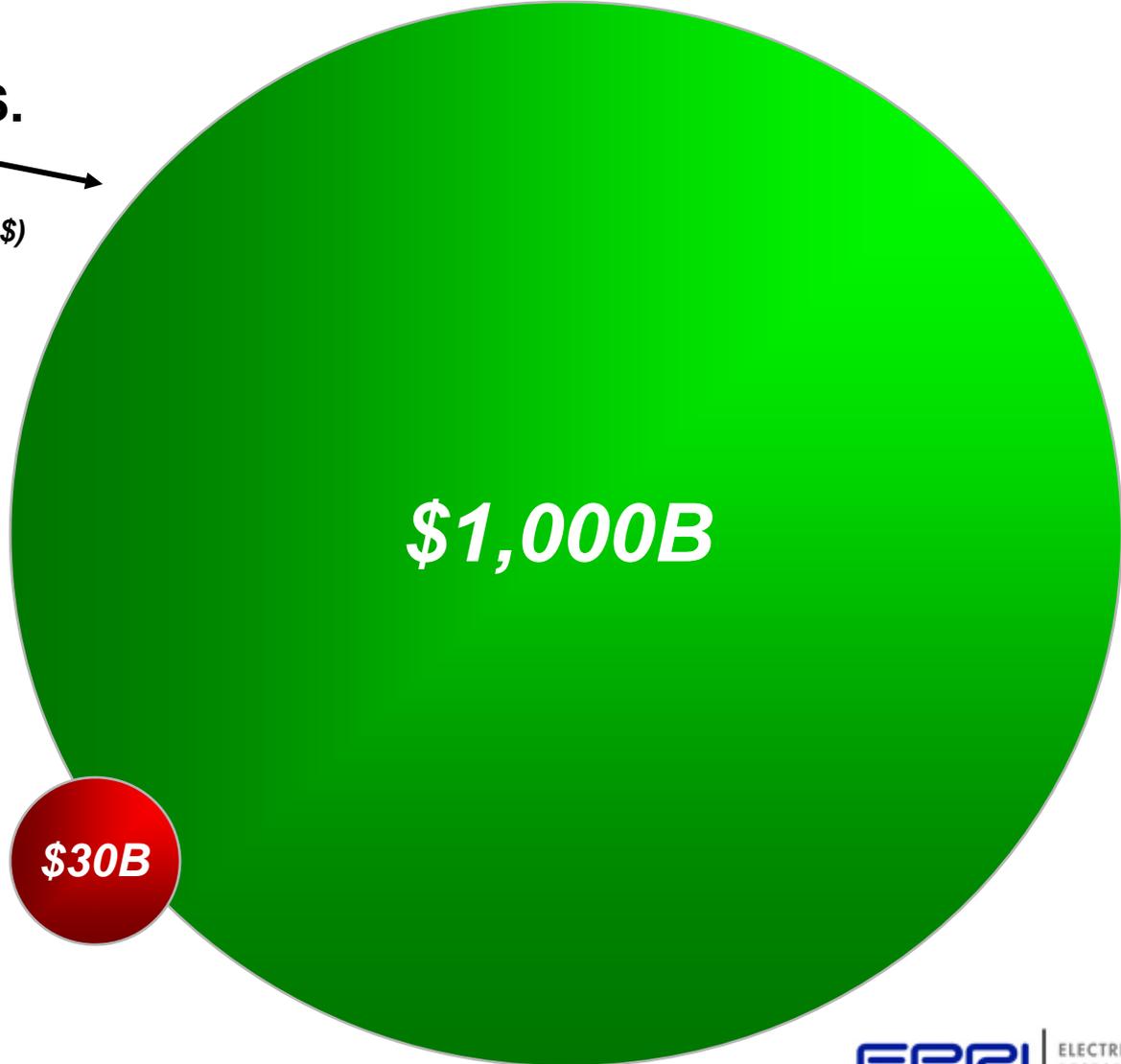
# Advanced Coal With CCS Technology Pathway



# Research, Development and Demonstration is a good investment

**Avoided Cost to U.S. Economy**

*(2000-2050, present value in 2000 \$)*



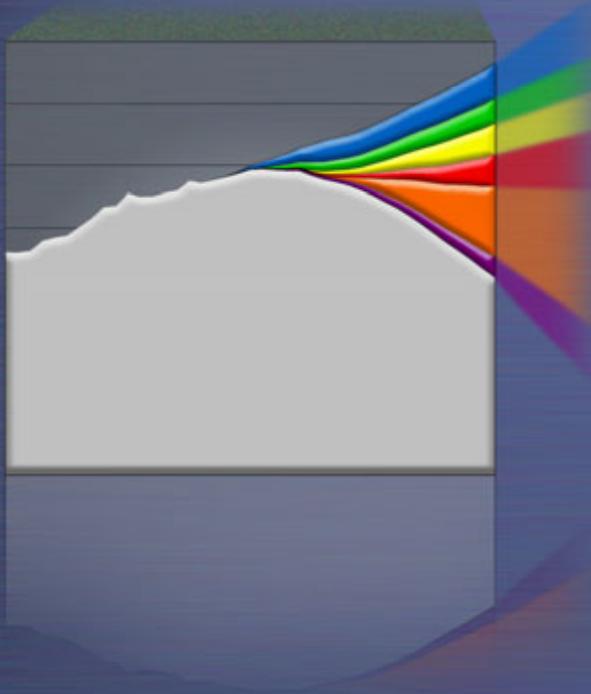
**\$1,000B**

**\$30B**

**RD&D Investment**

*(2005-2030, present value in 2000 \$)*

# Analysis to Action



<b>Technology Challenges</b>
1. Smart Grids and Communication Infrastructure
2. Transmission Grids and Associated Energy Storage Infrastructures
3. Advanced Light Water Reactors
4. Coal-Based Generation Units with Carbon Capture and Storage

<b>Demonstration Projects</b>
1. Smart Distribution System
2. Compressed Air Energy Storage
3. CCS using Chilled Ammonia
4. CCS using a Different Technology
5. Advanced Pulverized Coal Plant – UltraGen I
6. IGCC with CCS
7. Low-cost O <sub>2</sub> Production

# Conclusions

- The technical potential exists for the U.S. electricity sector to significantly reduce its CO<sub>2</sub> emissions over the coming decades.
- No one technology will be a silver bullet – a portfolio of technologies will be needed.
- Much of the needed technology isn't available yet – substantial R&D, demonstration is required.
- A low-cost, low-carbon portfolio of electricity technologies can significantly reduce the costs of climate policy.