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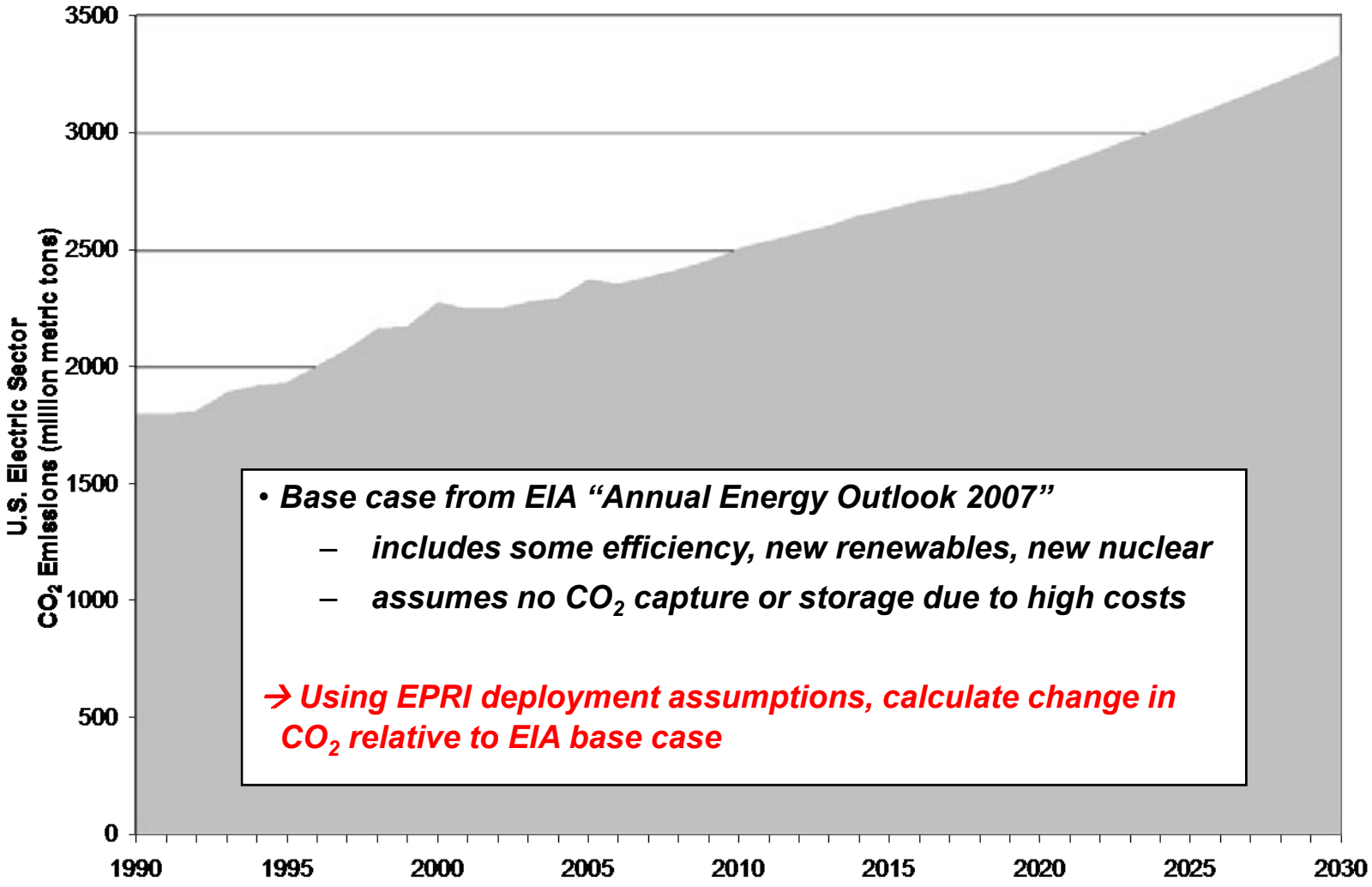
Electricity Technology in a Carbon-Constrained Future

December 18, 2007
U.S. Department of Energy
H_2 Technical Advisory Group

Revis James
Director, Energy Technology Assessment Center

What CO_2 emissions reductions from the U.S. electricity sector are technically feasible?

U.S. Electricity Sector CO_2 Emissions

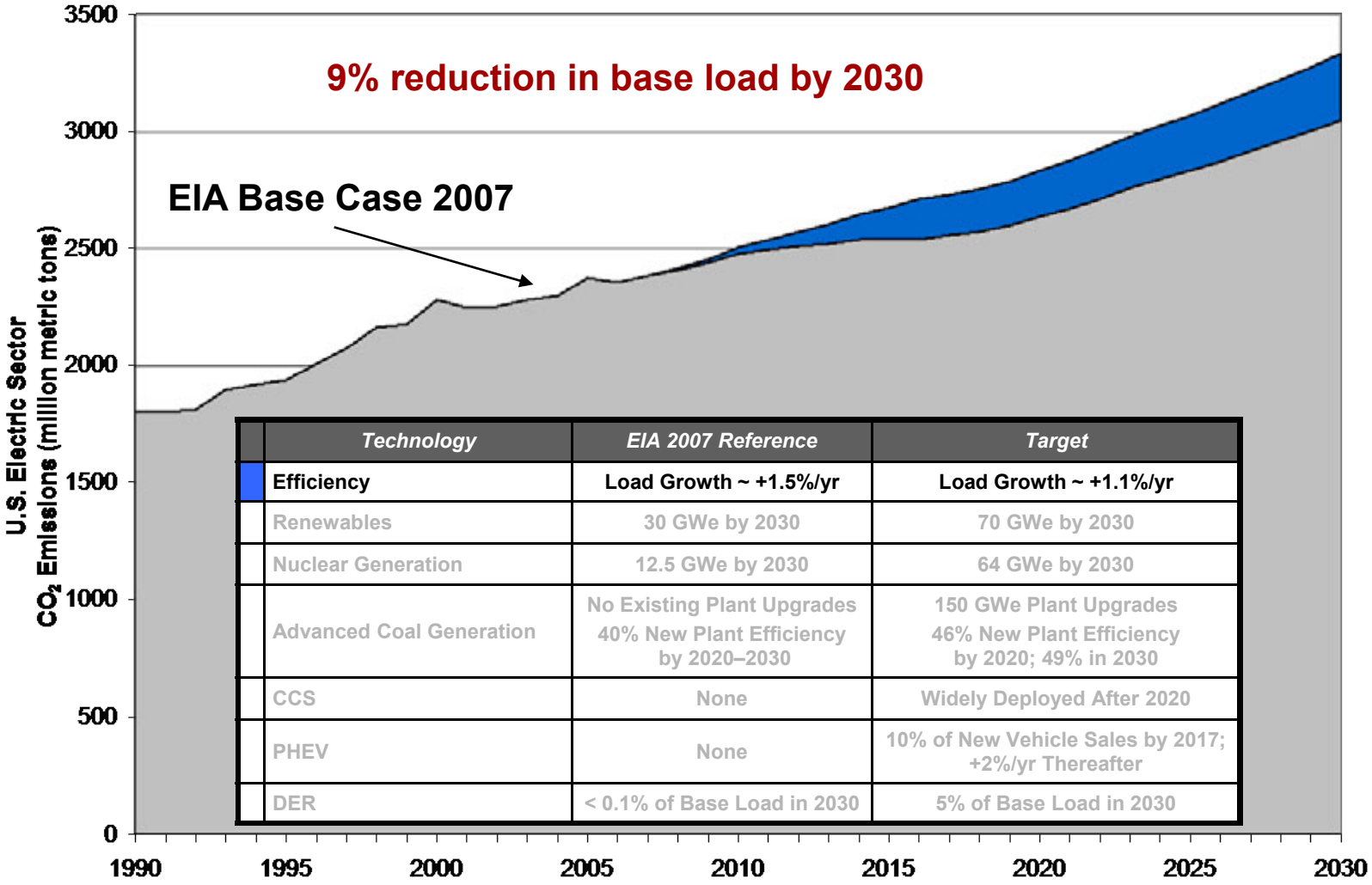


Technology Deployment Targets

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.

Benefit of Achieving Efficiency Target



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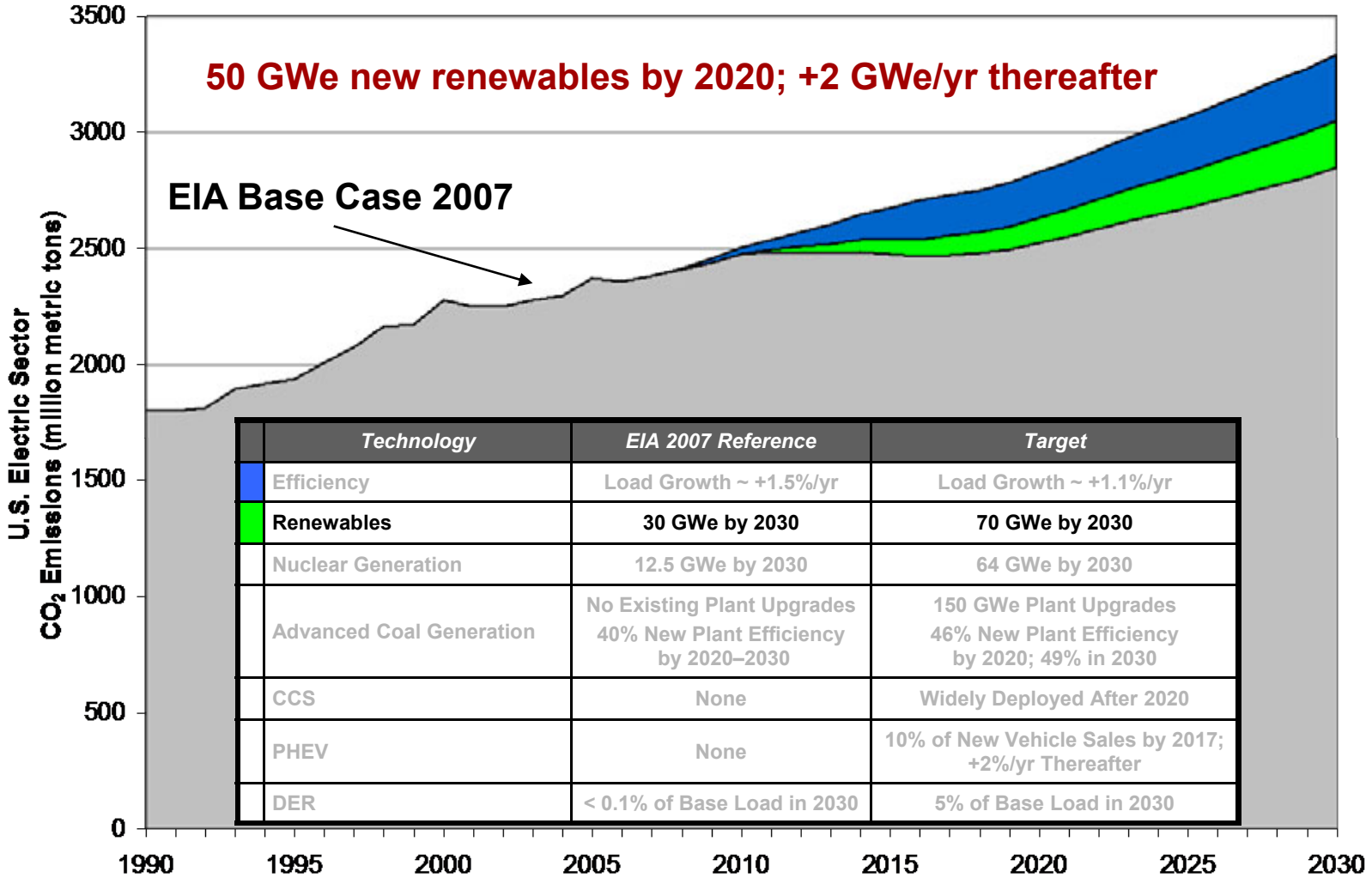
Benefit of Achieving Renewables Target



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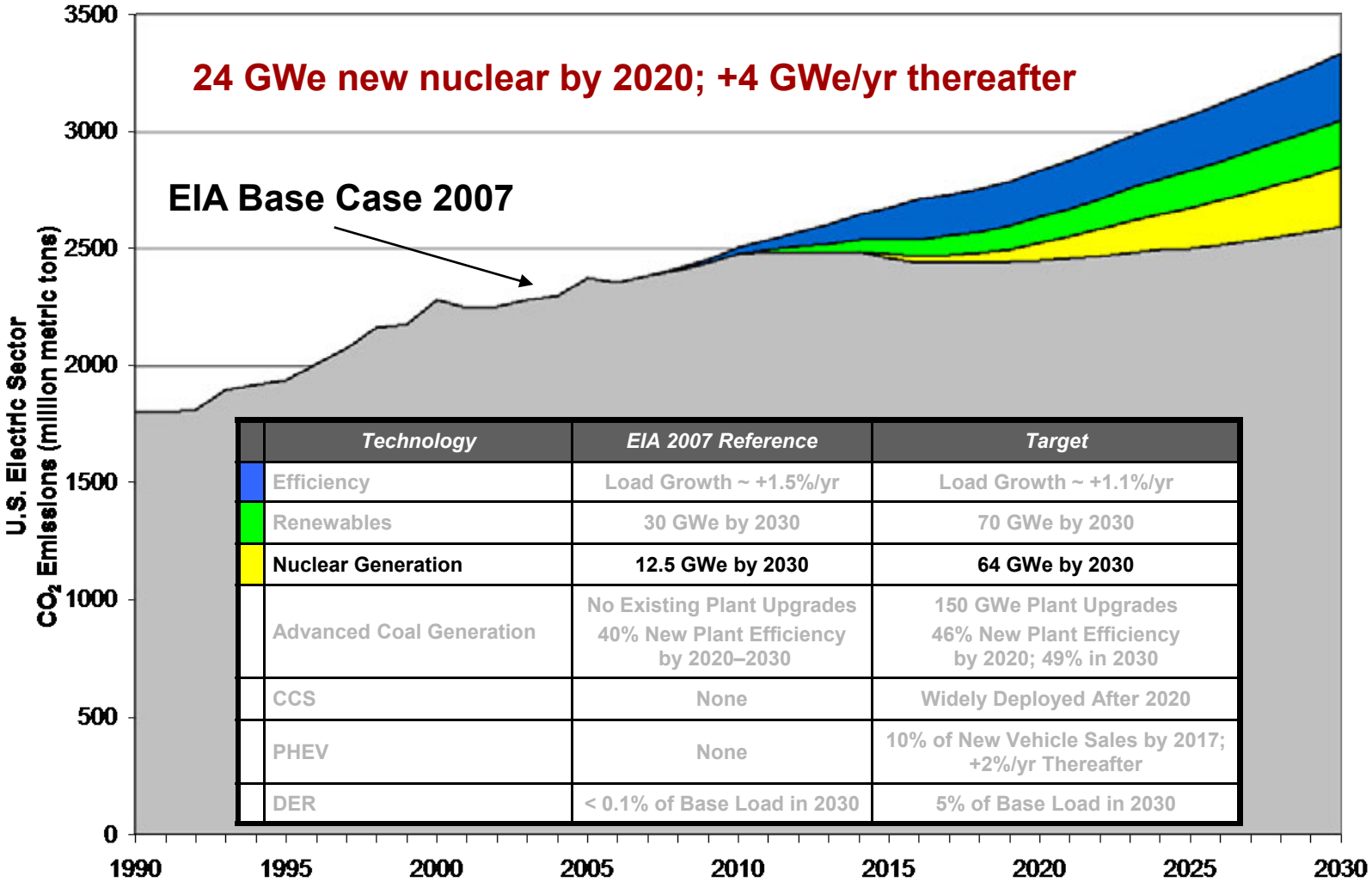
Benefit of Achieving Nuclear Generation Target



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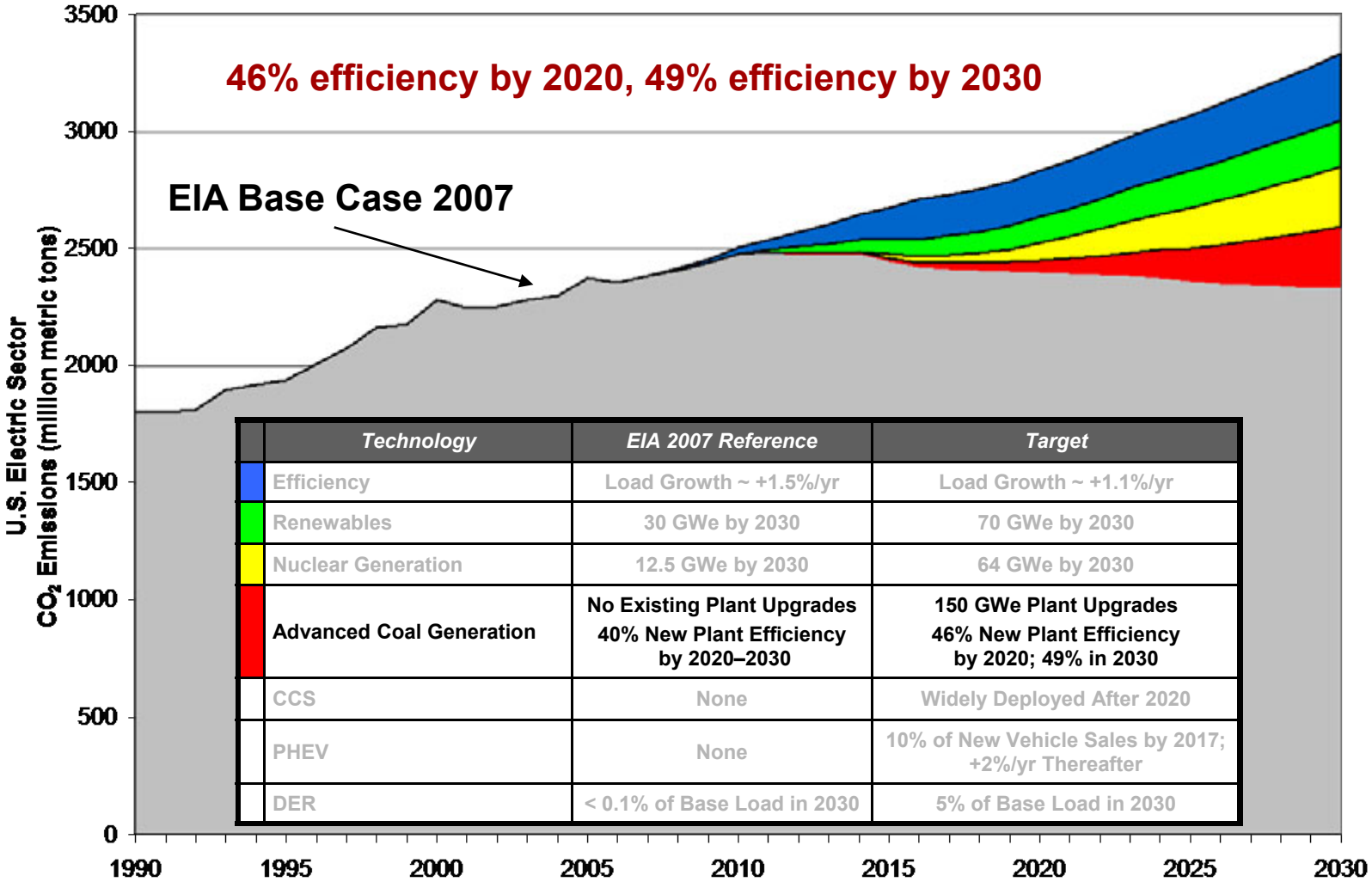
Benefit of Achieving Advanced Coal Target



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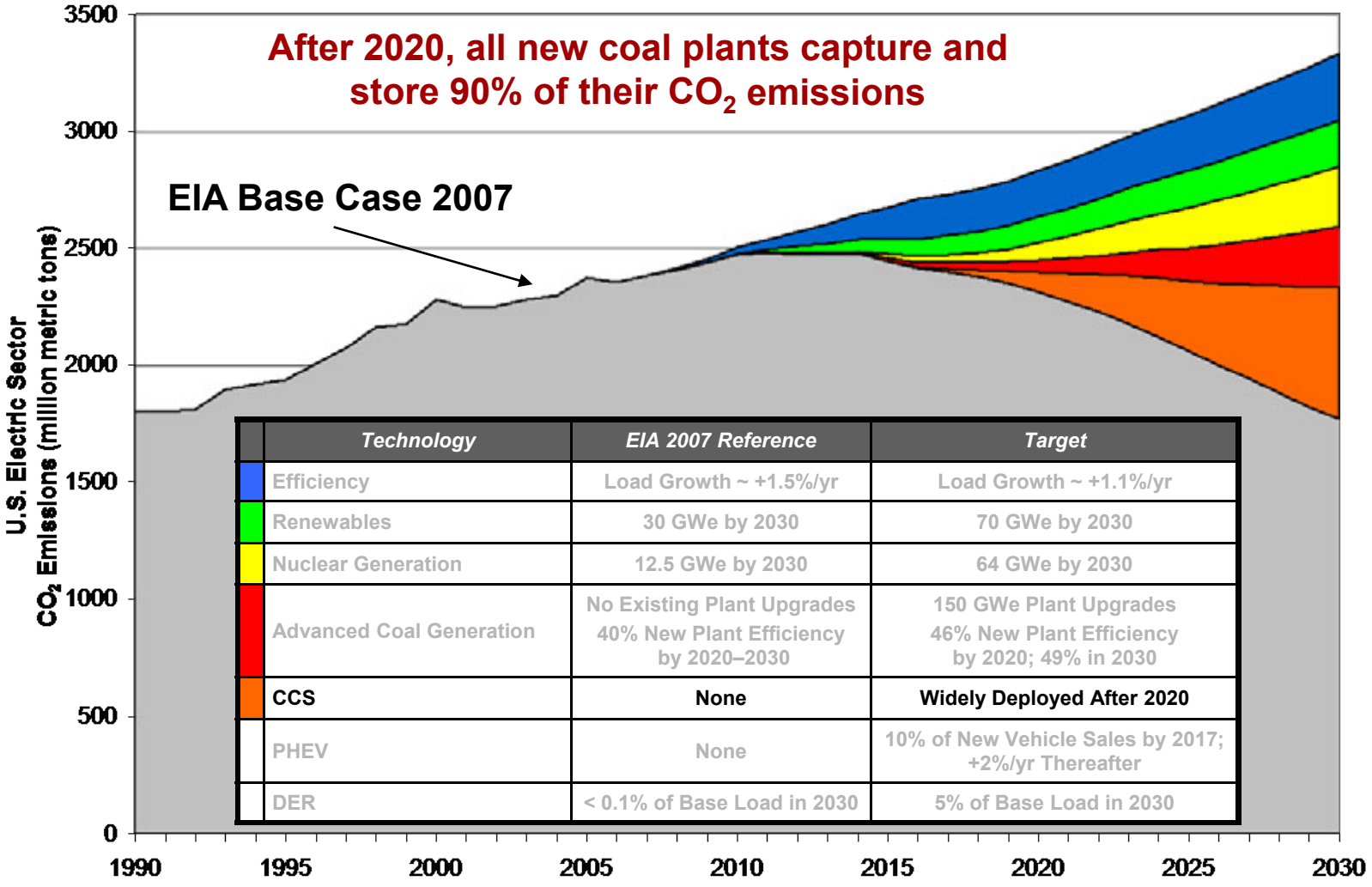
Benefit of Achieving CCS Target



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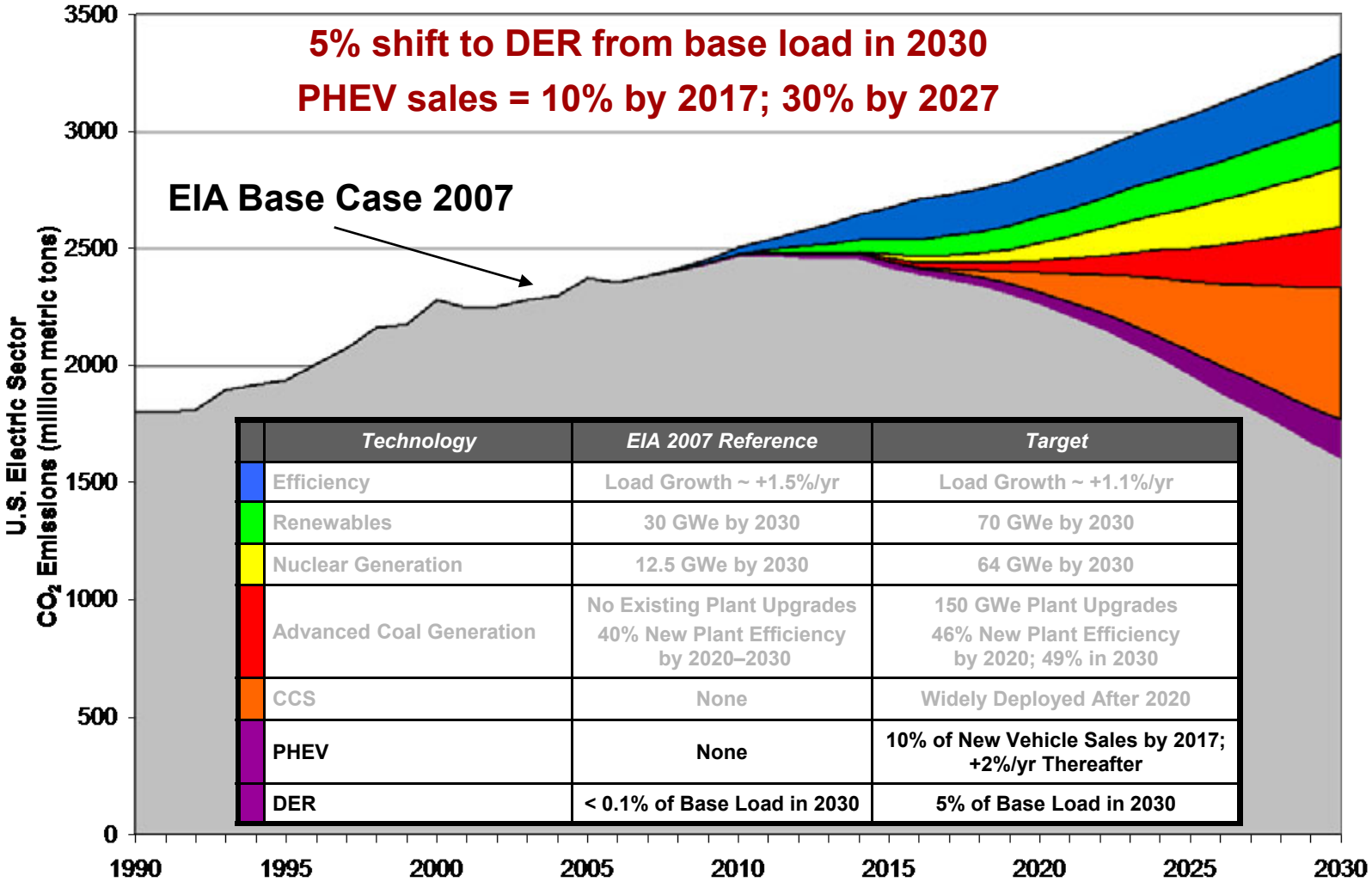
Benefit of Achieving PHEV and DER Targets



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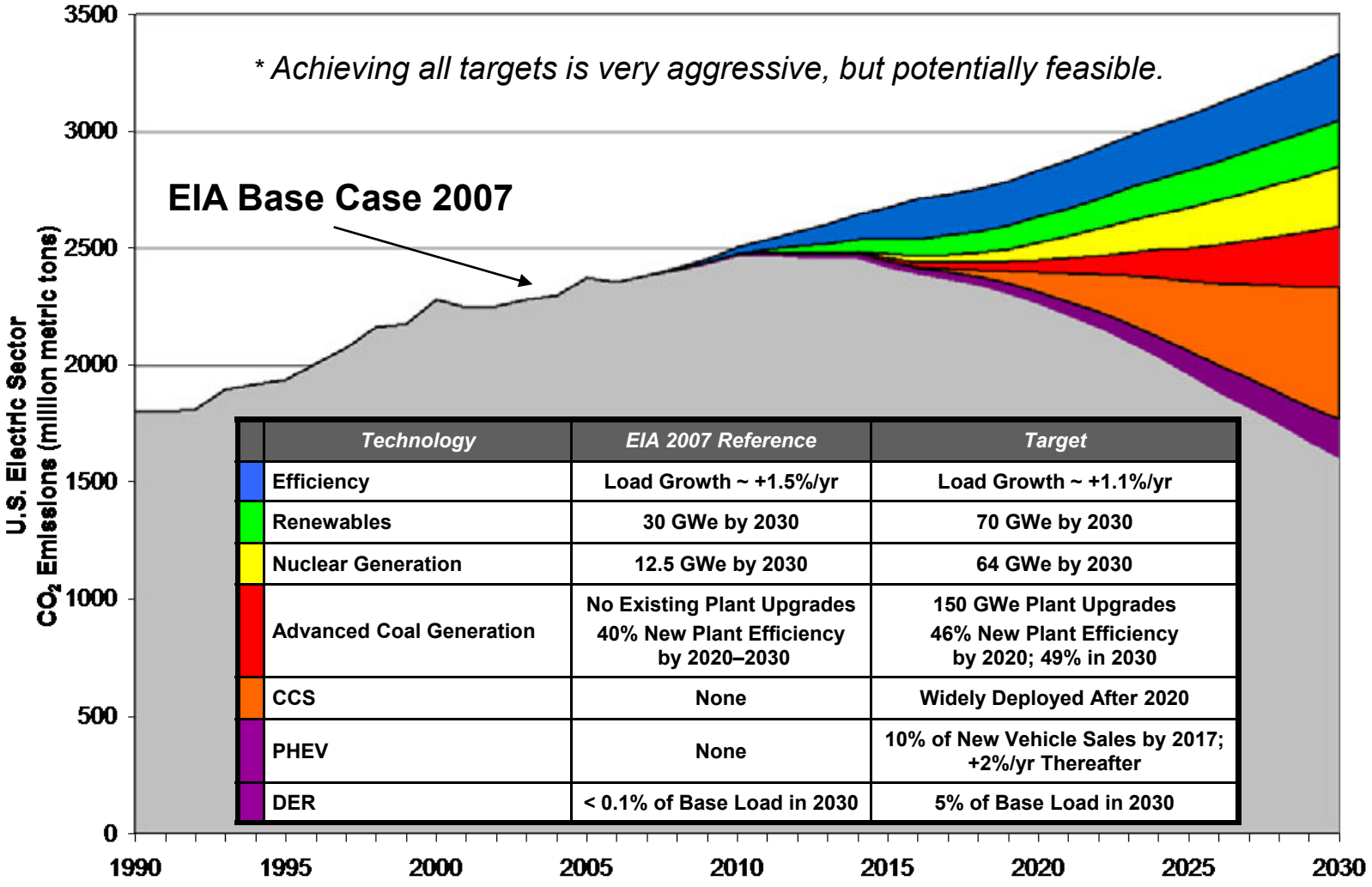
CO_2 Reductions… Technical Potential*



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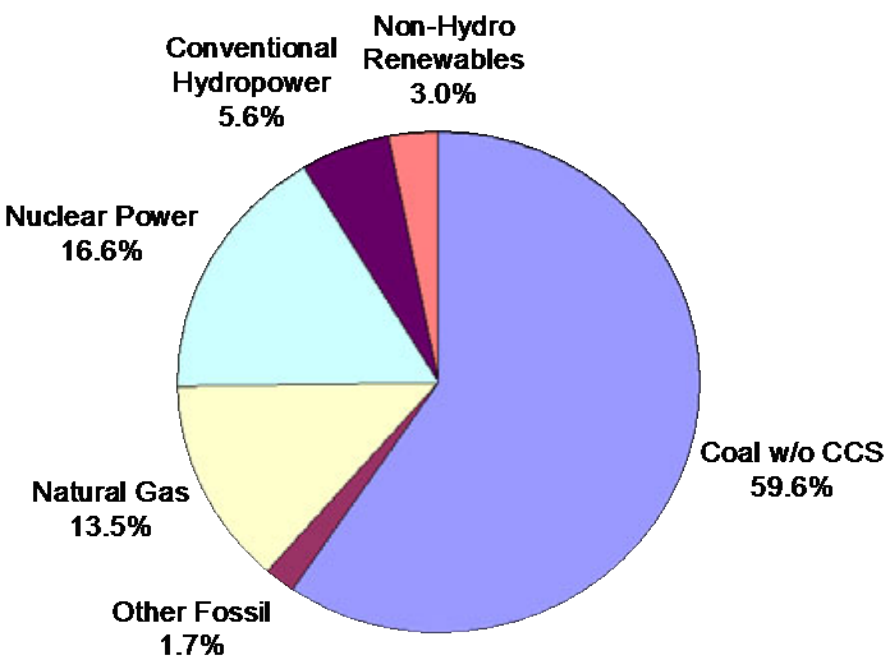
U.S. Electricity Generation: 2030

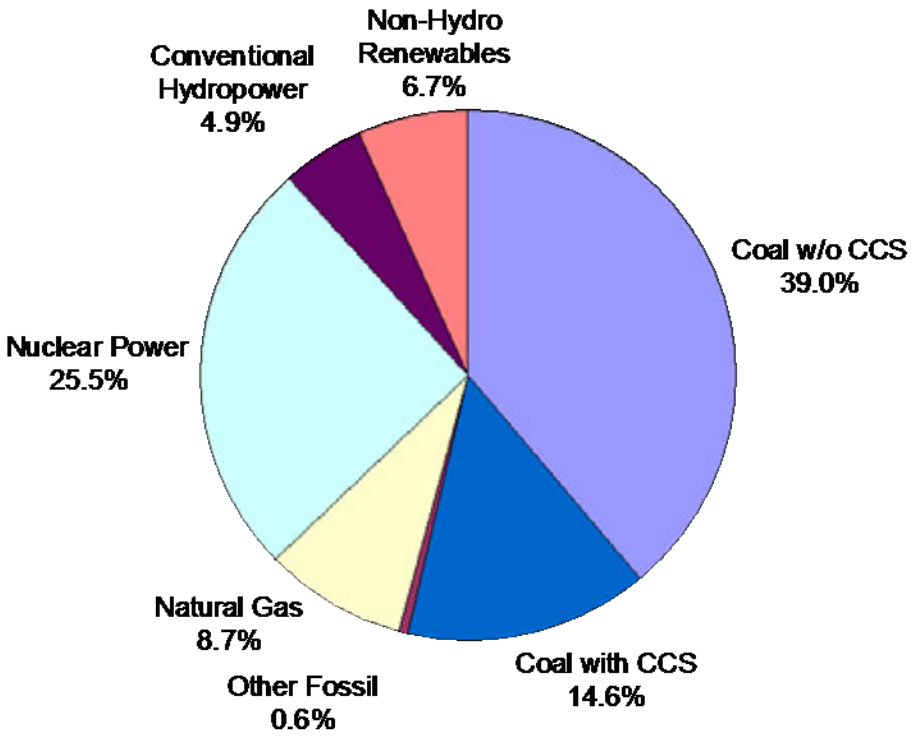
EIA Base Case*

5406 TWh



Advanced Technology Targets

5401 TWh



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

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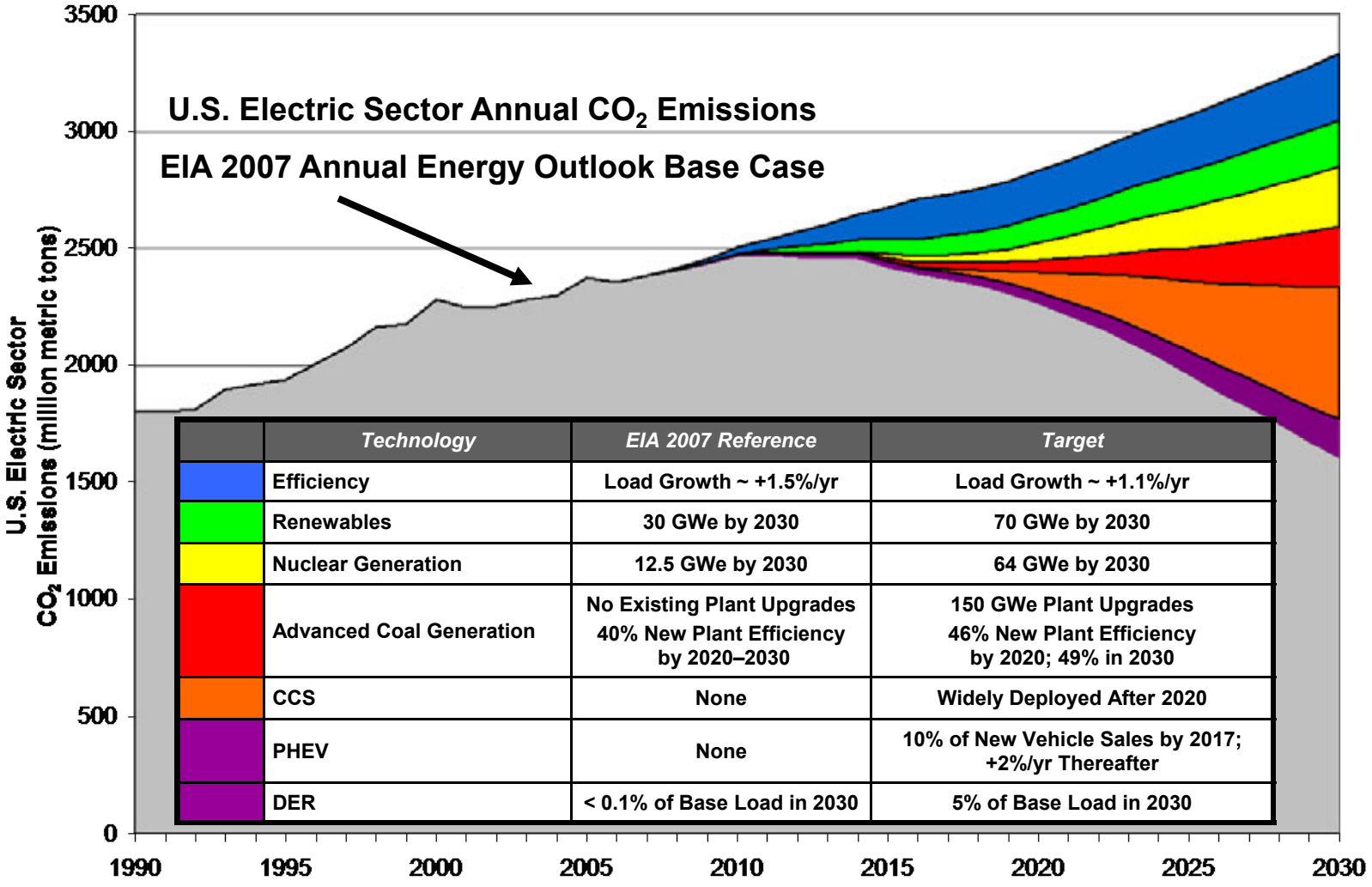

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** Achieving all targets is very aggressive, but potentially feasible.*

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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.

What are the economic impacts of different technology strategies for CO_2 emissions reductions from the U.S. electricity sector?

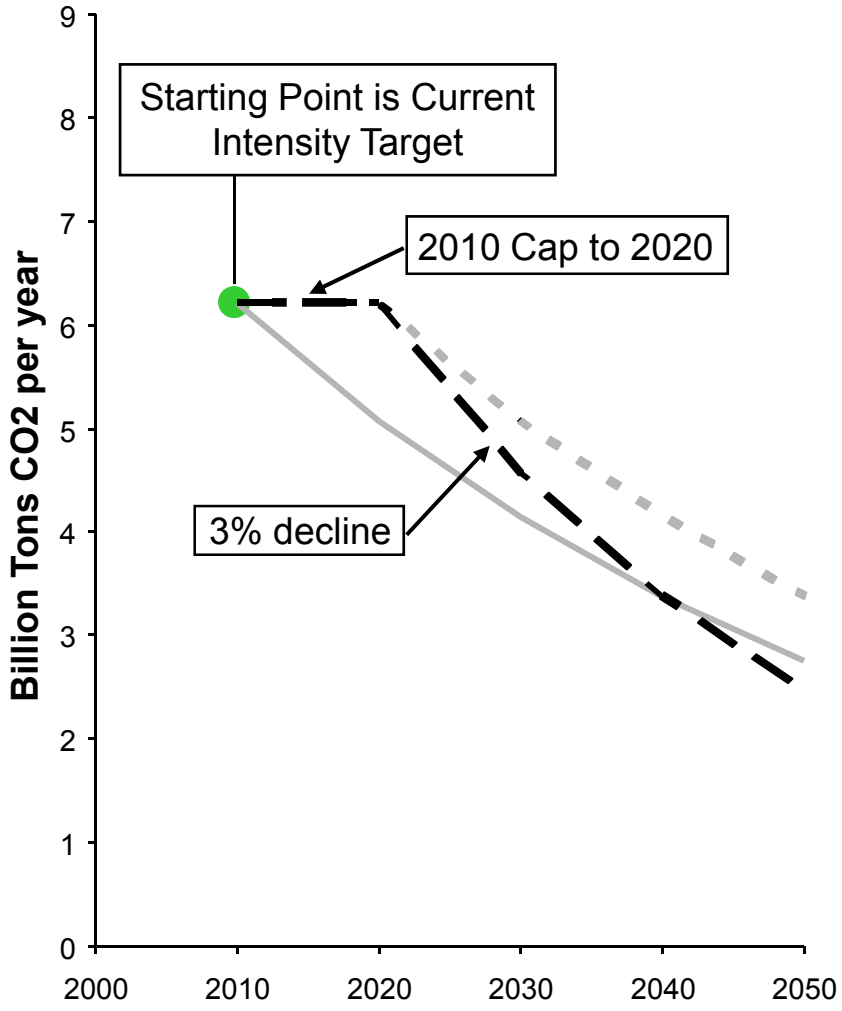
Economic Assessment

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_2 Constraint

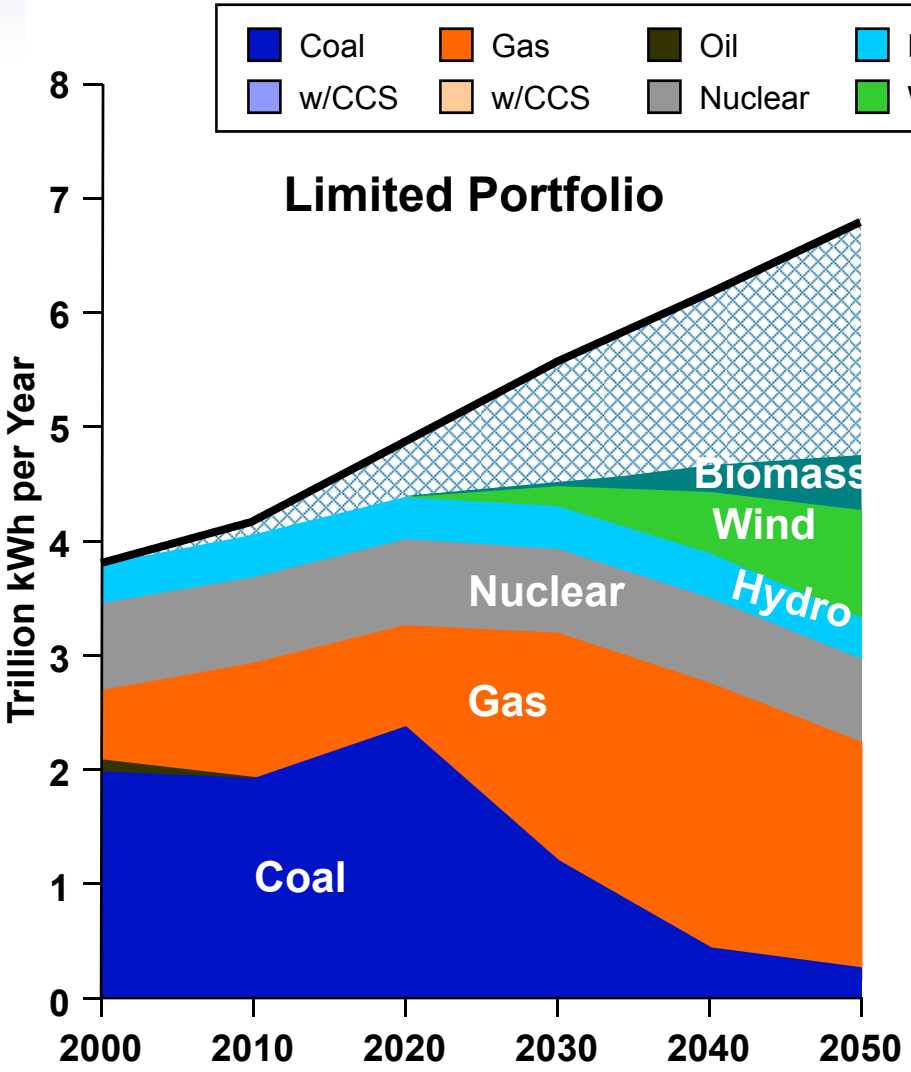


- **Analyzed three different economy-wide CO_2 constraints**
- **PRISM electric sector CO_2 profile most closely modeled by economy-wide constraint which:**
  - *-Caps emissions at 2010 levels until 2020*
  - *-Requires 3% decline beginning in 2020*

Electricity Technology Scenarios

	Full Portfolio	Limited Portfolio
Supply-Side		
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
Demand-Side		
Plug-in Hybrid Electric Vehicles (PHEV)	Available	Unavailable
End-Use Efficiency	Accelerated Improvements	Improvements

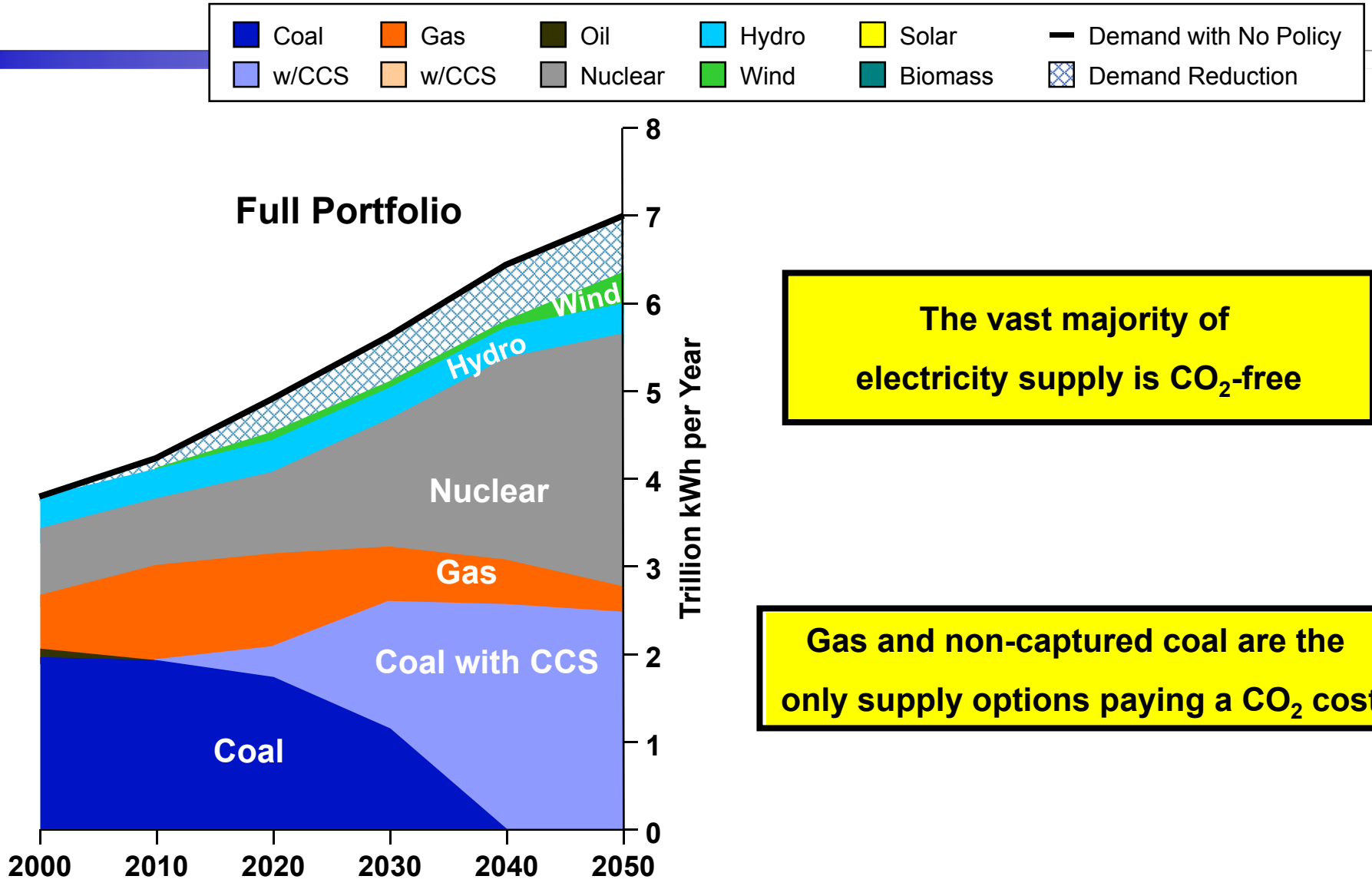
Meeting Economy-wide Cap* with Limited Portfolio



With a less de-carbonized supply, electricity load must decline to meet the CO_2 emissions target

Gas (with half the CO_2 emissions intensity of coal) pays a significant CO_2 cost

Meeting Economy-Wide Cap* with Full Portfolio



The vast majority of electricity supply is CO_2-free

Gas and non-captured coal are the only supply options paying a CO_2 cost

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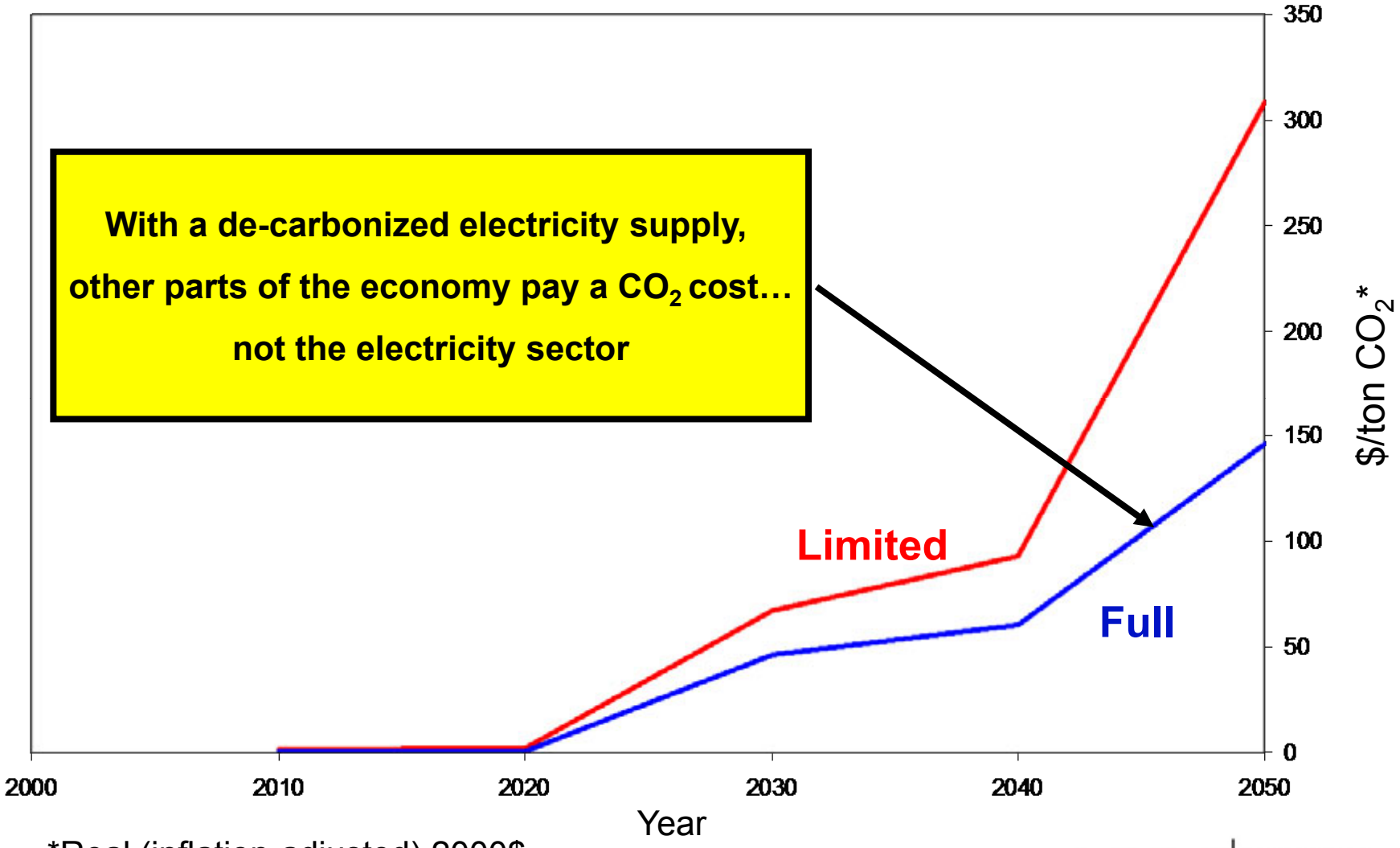
CO_2 Emission Cost : Economy-Wide



*Real (inflation-adjusted) 2000$

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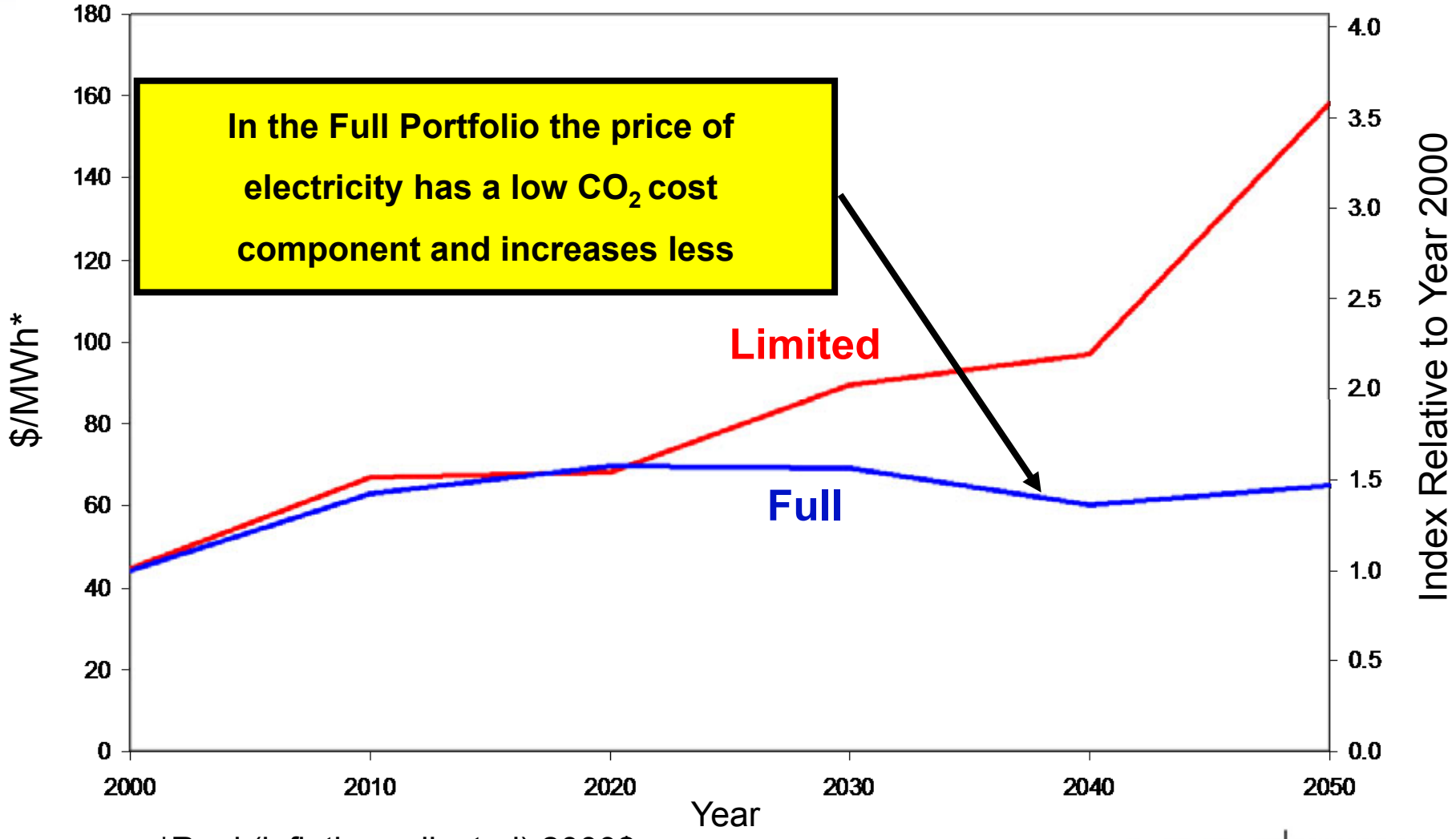
Wholesale Electricity Price



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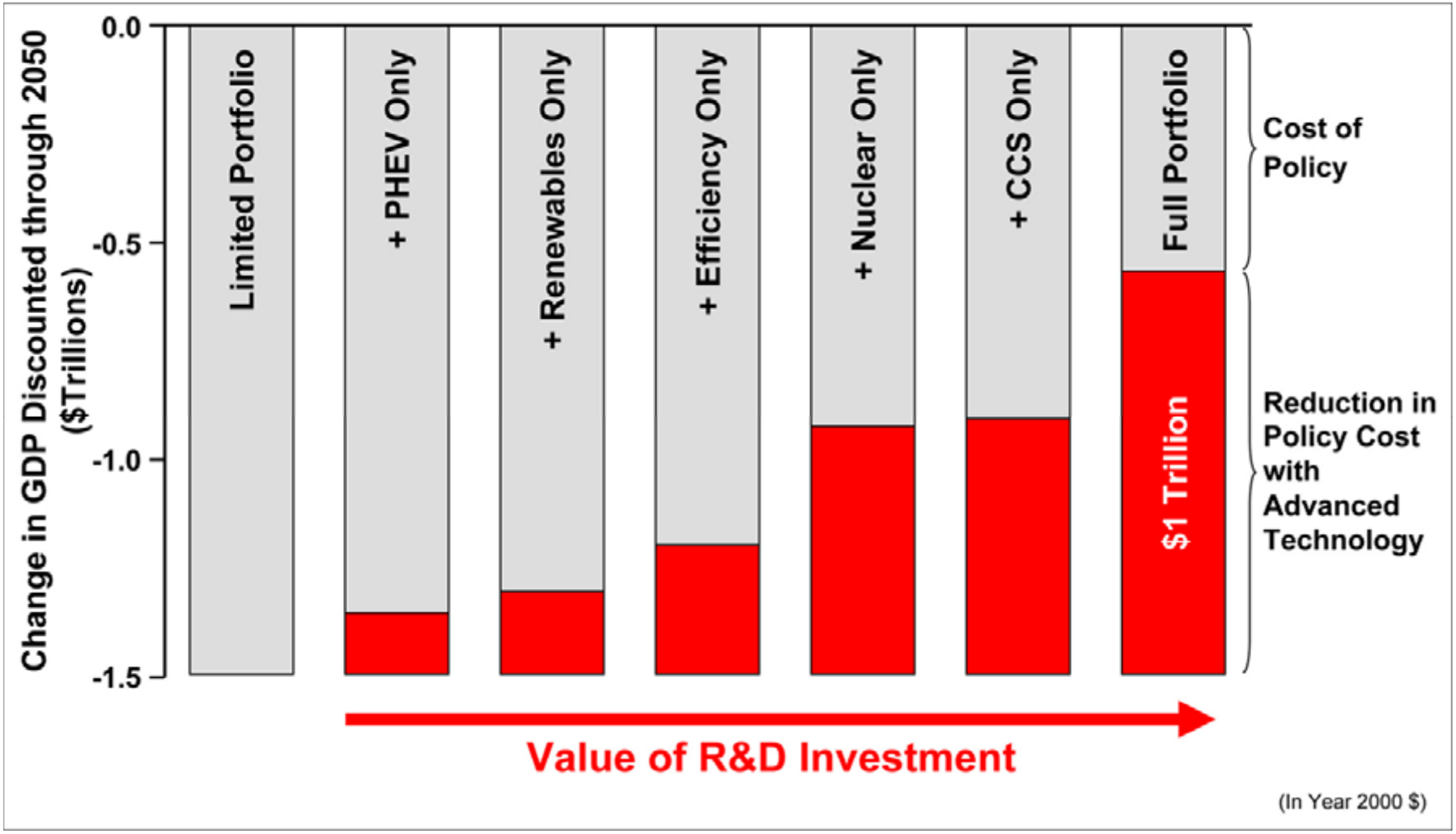
Full Technology Portfolio Reduces Costs of a CO_2 Emissions Reduction Policy by 60%



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How do we achieve the necessary technology capabilities to reduce electricity sector CO_2 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_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.

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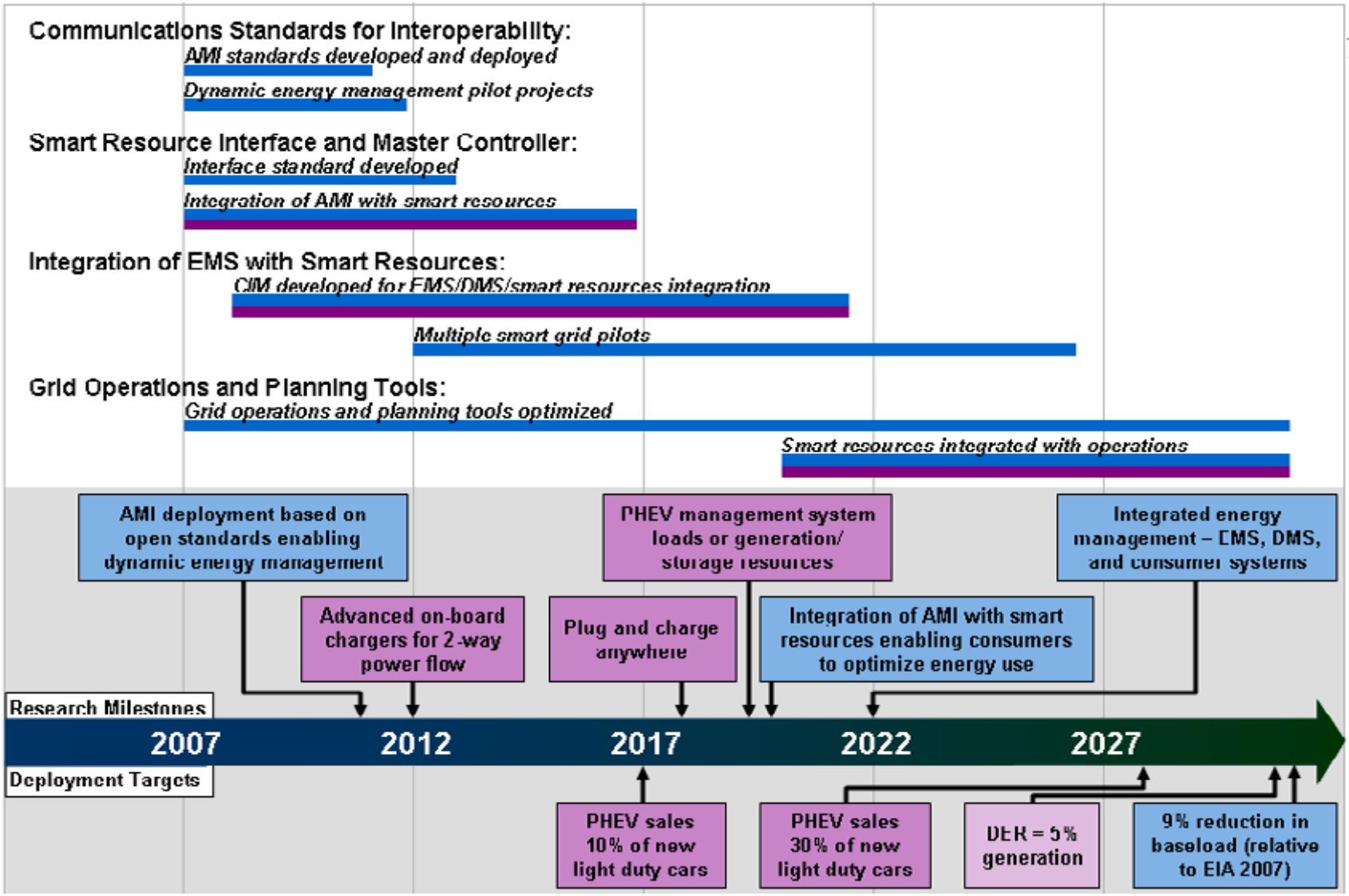
Provides the Basis for Four Technology Pathways

Distribution Enabled Technology Pathway

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



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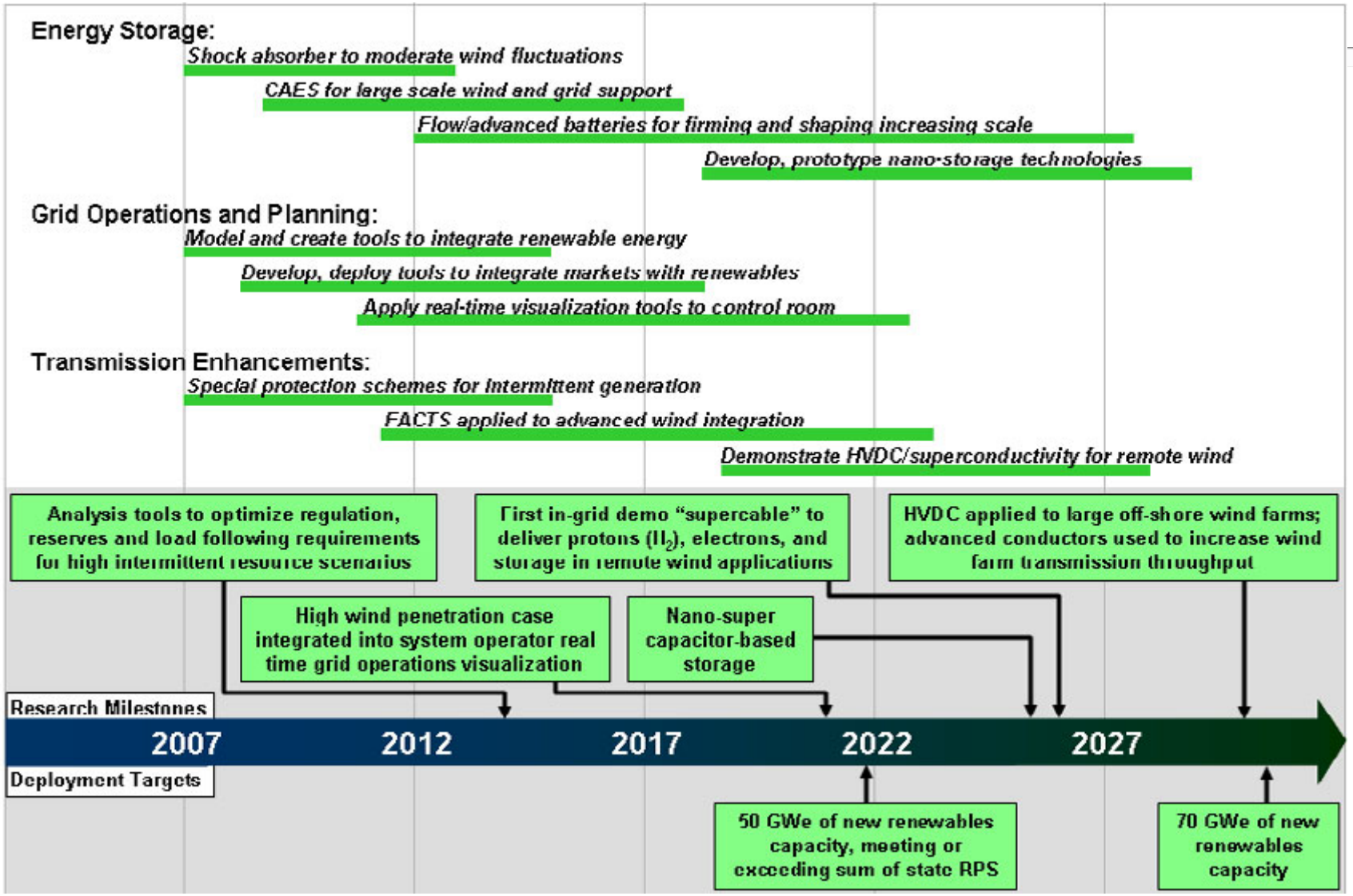
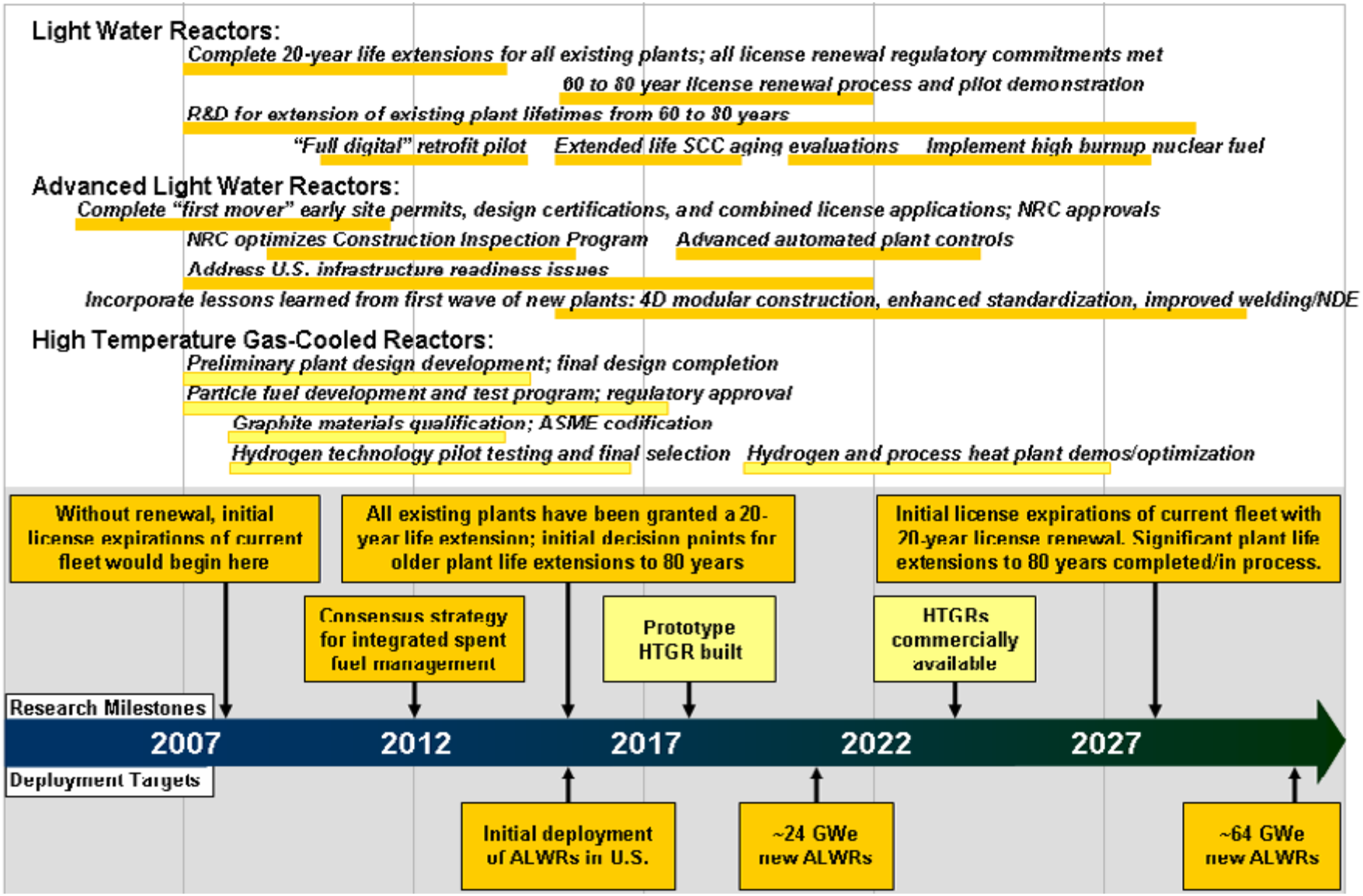
Grid Enabled Technology Pathway

Renewables Integration and T&D Efficiency Improvement



Nuclear Technology Pathway



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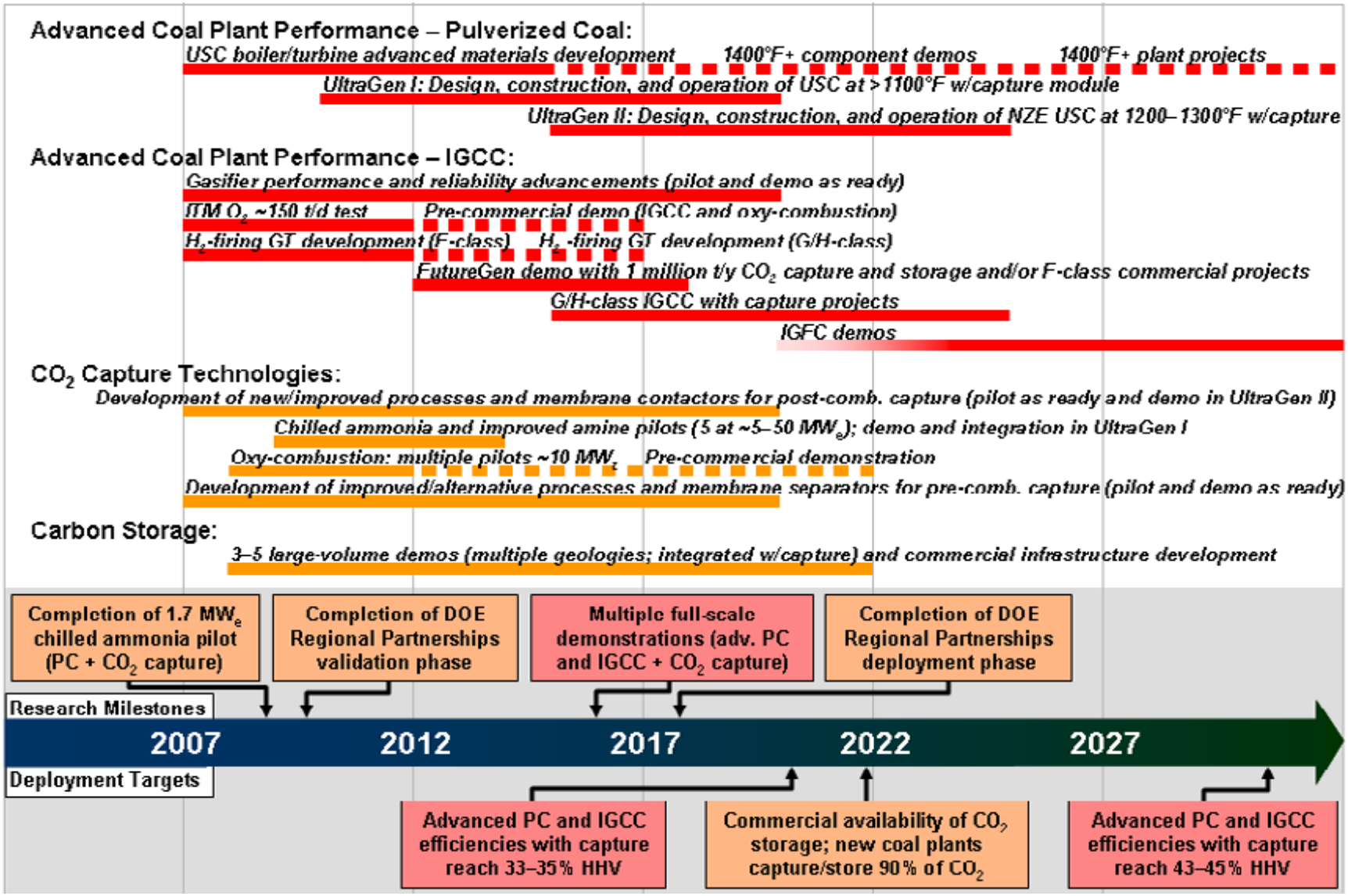
Advanced Coal With CCS Technology Pathway



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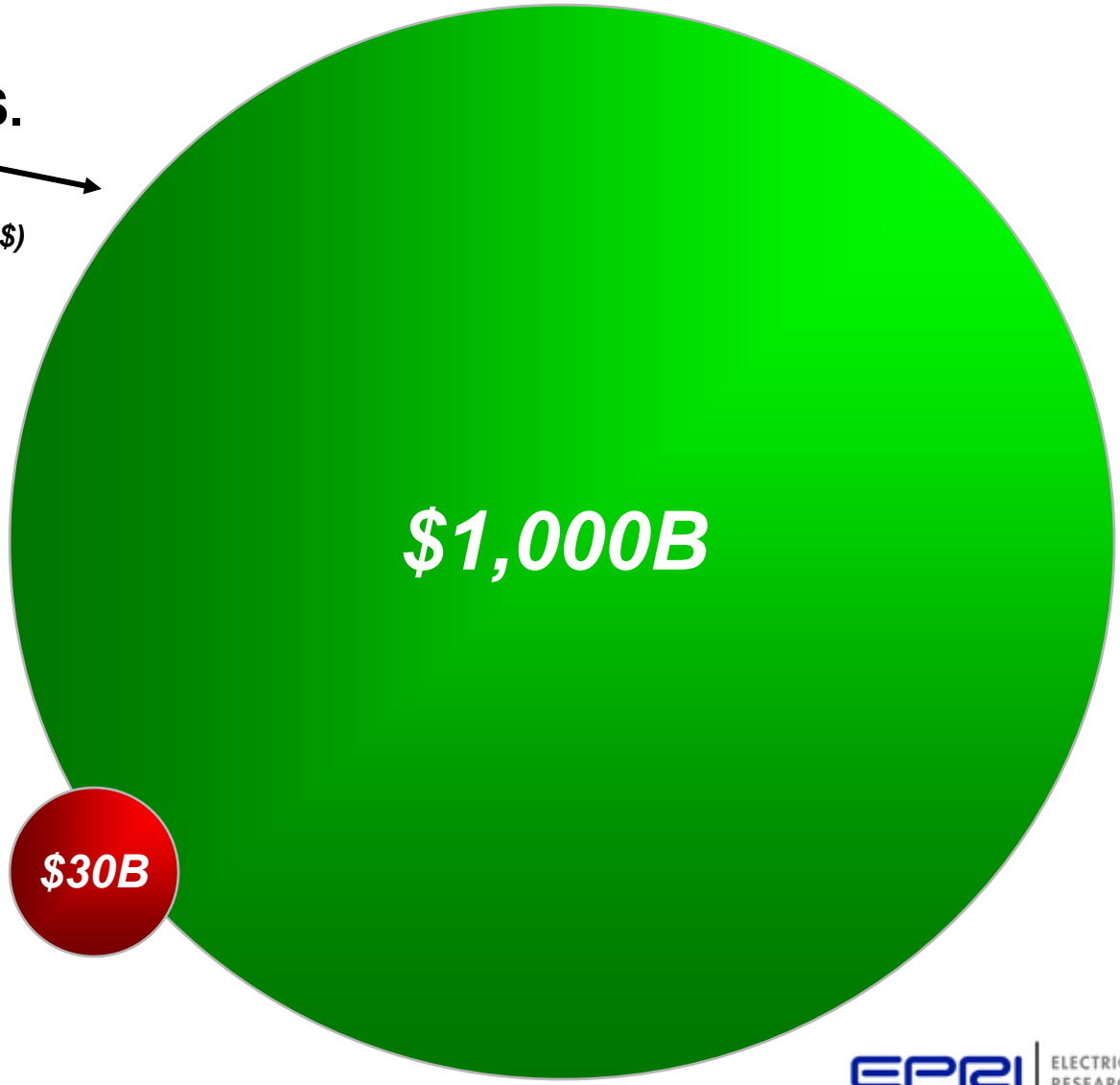
Research, Development and Demonstration is a good investment

Avoided Cost to U.S. Economy

(2000-2050, present value in 2000 $)



RD&D Investment

(2005-2030, present value in 2000 $)

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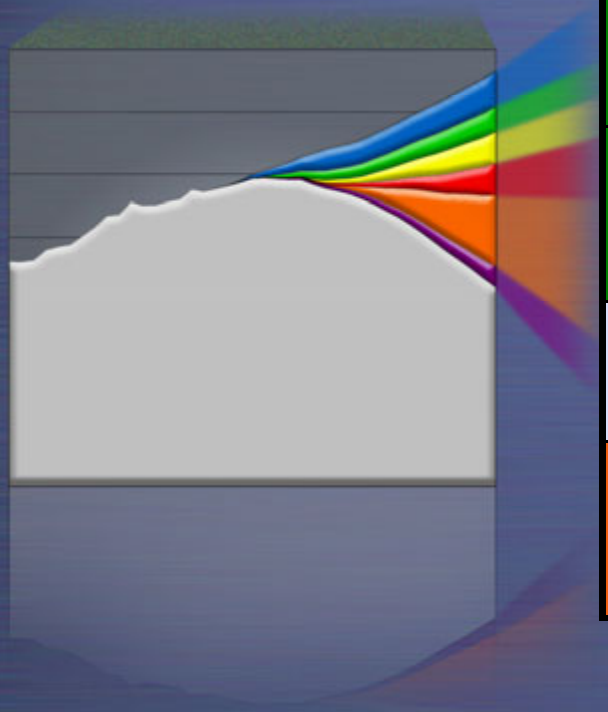
Analysis to Action



Technology Challenges

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

Demonstration Projects

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_2 Production

Conclusions

- The technical potential exists for the U.S. electricity sector to significantly reduce its CO_2 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.