



INFRASTRUCTURE, SAFETY,
AND ENVIRONMENT

***Costs of Achieving a 25 Percent
U.S. Renewable Electricity Mandate***

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Stanford Energy Modeling Forum

July 6, 2011

Renewable Electricity Mandate One Instrument to Reduce GHG Emissions

- **U.S. government and state governments have considered employing mandate to provide specified percentage of electricity from renewable sources**
- **Mandates increase costs by compelling utilities and generating companies to substitute a higher cost technology (renewables) for a lower cost technology (coal)**
- **How much is such a mandate likely to cost?**
- **What would be the likely reduction in emissions of greenhouse gases?**

Questions and Answers

- **What would be the economic costs of imposing a 25% national renewable electricity mandate by 2025?**
- **The cost of producing electricity would rise by approximately \$35B**

Methodology

- **Take EIA 2025 demand forecast as given**
 - 4,550 terawatt hours (TWh) of total electricity use, including transmission losses
 - 25% of this figure is 1,138 TWh
- **Construct renewables supply curve**
 - Renewables, primarily hydro, already provide 392 TWh annually
 - Assign existing renewable generation a cost equivalent to low-cost baseload coal
 - Assume renewables displace coal according to 2009 dispatch curve
 - Displace highest cost coal first with lowest cost renewables
- **Calculate net change in emissions of carbon dioxide**

Hydroelectric Plants Produced 270 TWh or 7% of U.S. Electricity in 2009

- **Represents existing baseload capacity**
- **EIA projects growth to 297 TWh in its reference case**
 - **Likely represents improvements to existing facilities**
- **Wave and tidal power not yet technically mature for wide-spread deployment**

***Biomass Produced 26 TWh;
0.7% of U.S. Electricity in 2009***

- **Biomass may be co-fired with coal or burned in dedicated plants**
- **The EIA provided their biomass supply curves for use in this analysis**
 - **New biomass electricity includes**
 - **16 TWh of co-fired capacity displacing 3.6% of coal**
 - **Remainder in dedicated facilities**

Barriers to Significantly Expanded Geothermal Electricity Are Technical and Economic

- Taps heat and steam in natural geologic formations to produce electricity
- Produced 15 TWh in 2009 (0.4%)
- Enhanced geothermal systems have technical and economic barriers
- We use an EIA estimate of 9 GW of capacity available by 2030 for less than \$0.12/kWh

Wind Energy Currently Provides The Bulk of Non-hydroelectric Renewable Electricity

- **Wind produced 71 TWh (2%) of U.S. electricity in 2009 from an installed capacity of 34 GW**
- **Intermittency is key barrier to increased integration**
- **We built a cost curve for new wind based on estimates of the wind resource base, capital, and operating costs from EIA**
 - **Included an integration charge of \$10/MWh to account for needed grid-based backup**
- **Offshore wind is too expensive to factor into our supply curve**

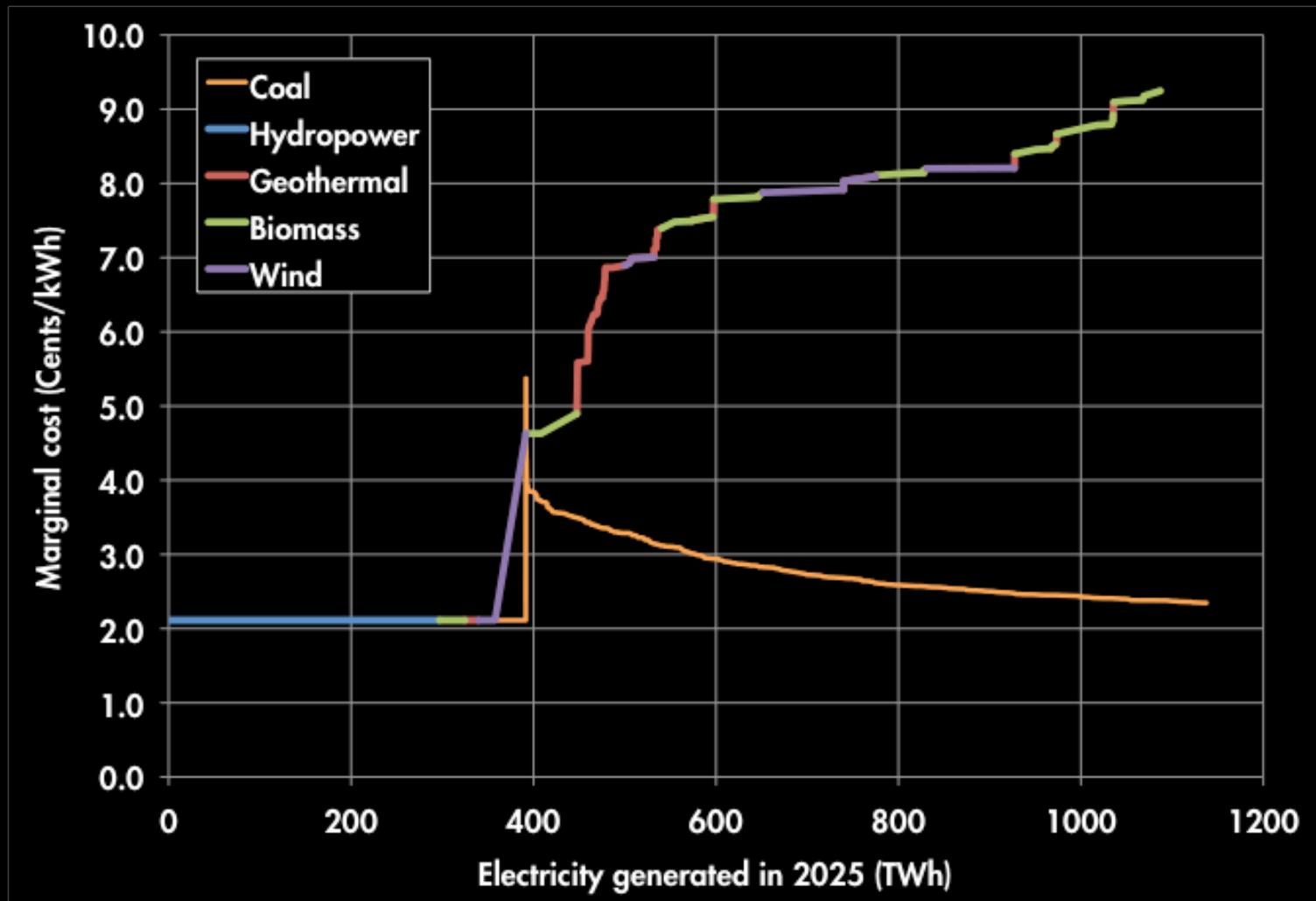
Calculating Cost of Capital

- **Assumed 70/30 split borrowing versus equity**
- **Calculated real rate of return on bonds rated BAA from 1998 to 2009 (5.43 percent)**
- **Calculated real rate of return on equity for utilities over same period (8.7%)**
- **Calculated weighted average of cost of capital (6.41 percent real rate of return)**

Solar Power Costs of \$0.13/kWh Are Greater than Other Renewables

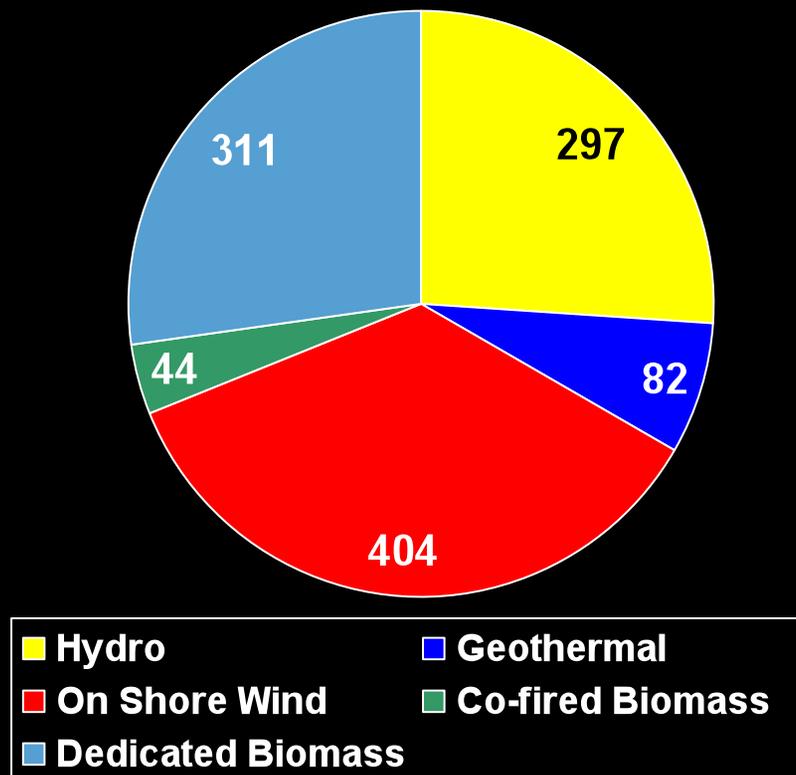
- **Resource base is essentially unlimited**
 - **0.25% of continental U.S. could supply 4,000 TWh**
- **Concentrating solar power converts sunlight to heat to produce electricity**
 - **Significant advances are possible**
- **However, solar does not contribute to our projected supply of renewable electricity due to its cost**
- **Photovoltaic (PV) systems are more expensive and suffer from significant intermittency problems**

Electricity from Renewables Would Cost 4.9–9.2 cents/kWh at an Additional Cost of \$34.8 Billion/year

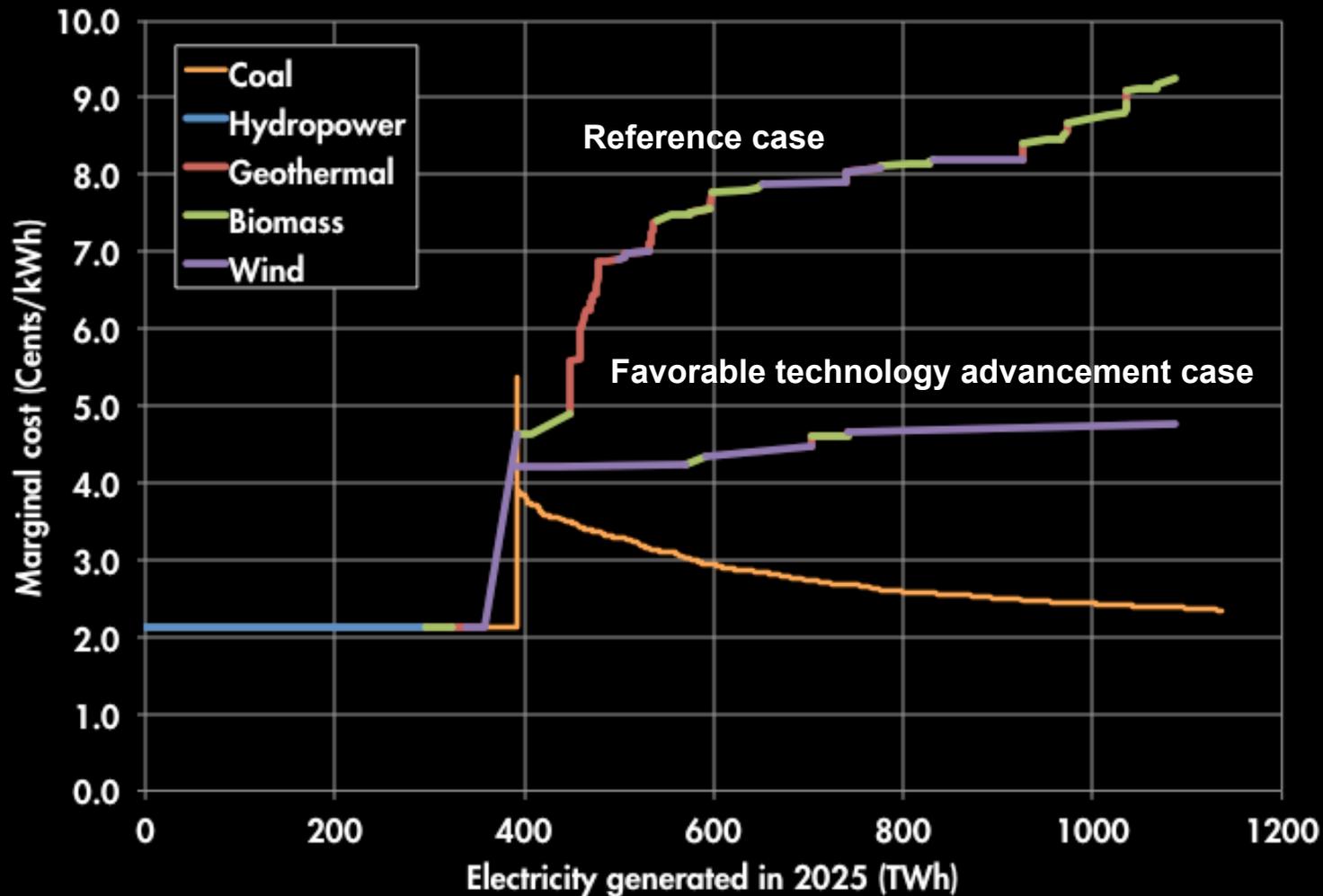


Wind Primary Renewable Source for Electricity

Shares of Renewables TWh



Economic Costs Drop to \$13 Billion/year if Renewable Technologies Advance Rapidly

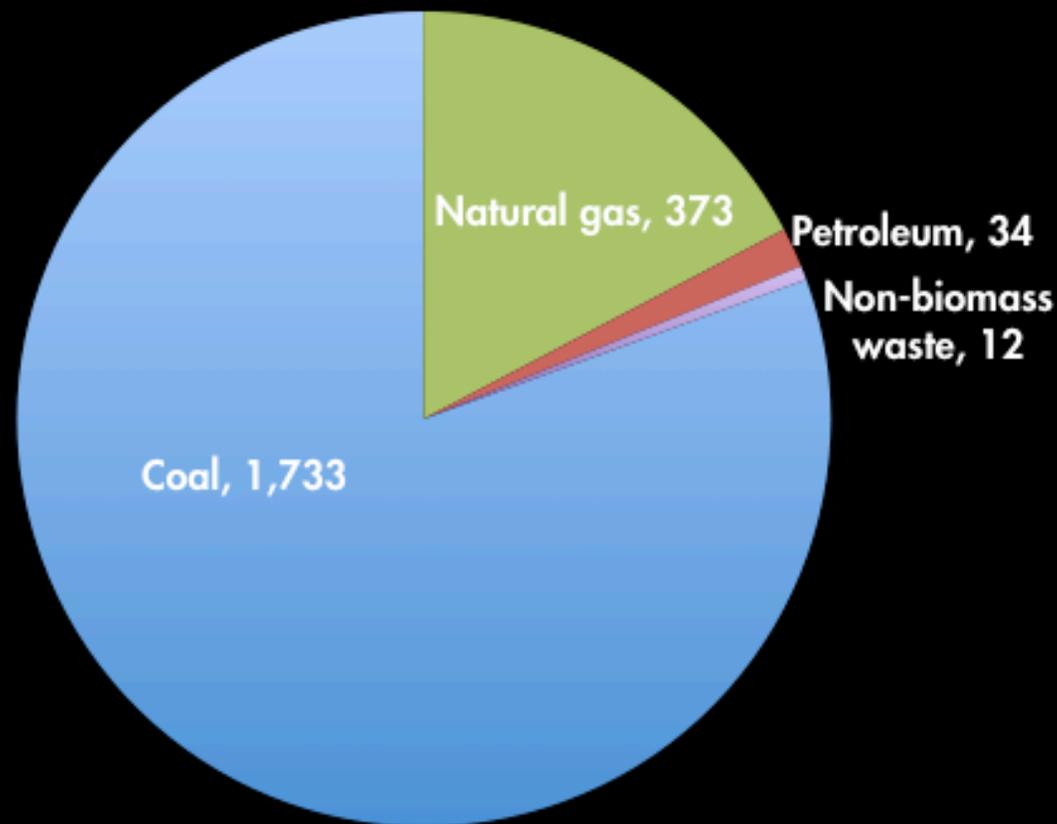


Questions and Answers

- **What would be the economic costs of imposing a 25% national renewable electricity mandate by 2025?**
- **The annual cost of producing electricity would rise by approximately \$35B**
- **What would be the reduction in emissions of greenhouse gases, and at what cost?**
- **Up to 700 million metric tons of CO₂ eq. at a marginal cost of \$70/metric ton**

Coal Dominates CO₂ Emissions from Electric Power

Emissions of Carbon Dioxide from the Electric Power Sector,
2009 (Million metric tons CO₂)



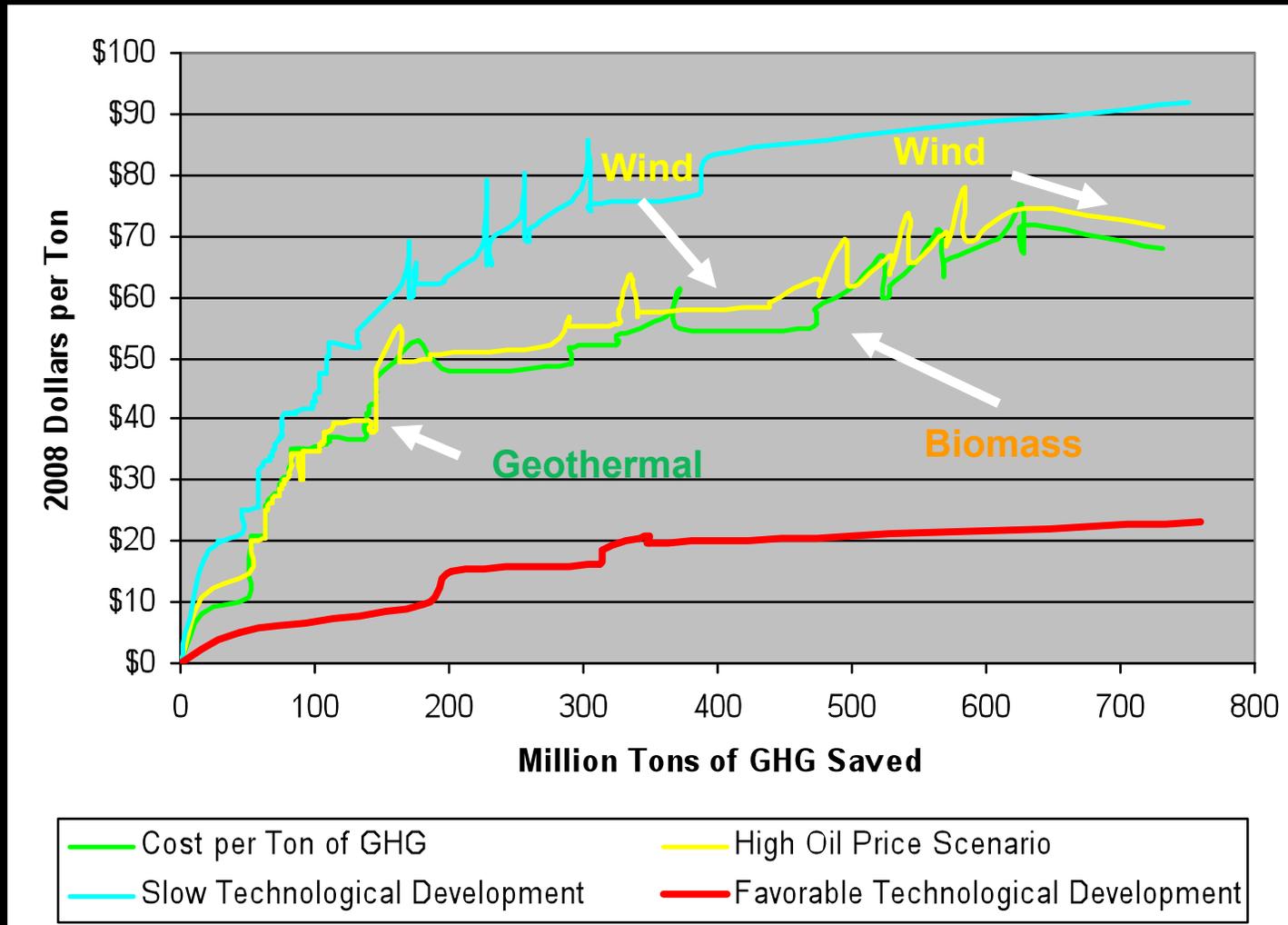
Life Cycle GHG Emissions from Renewables Are Small but Can Be Highly Uncertain

- **Turbine production, construction and decommissioning account for wind energy's GHG emissions**
 - **Wind variability may reduce efficiency of grid-connected fossil-fuel assets that provide makeup power**
 - **Intermittency of wind may require dedicated natural gas combustion turbines to provide backup**
- **GHG emissions due to land-use changes can dominate the life cycle emissions of biomass**
- **For open-loop systems GHG in geothermal reservoirs can dominate emissions if vented to atmosphere**

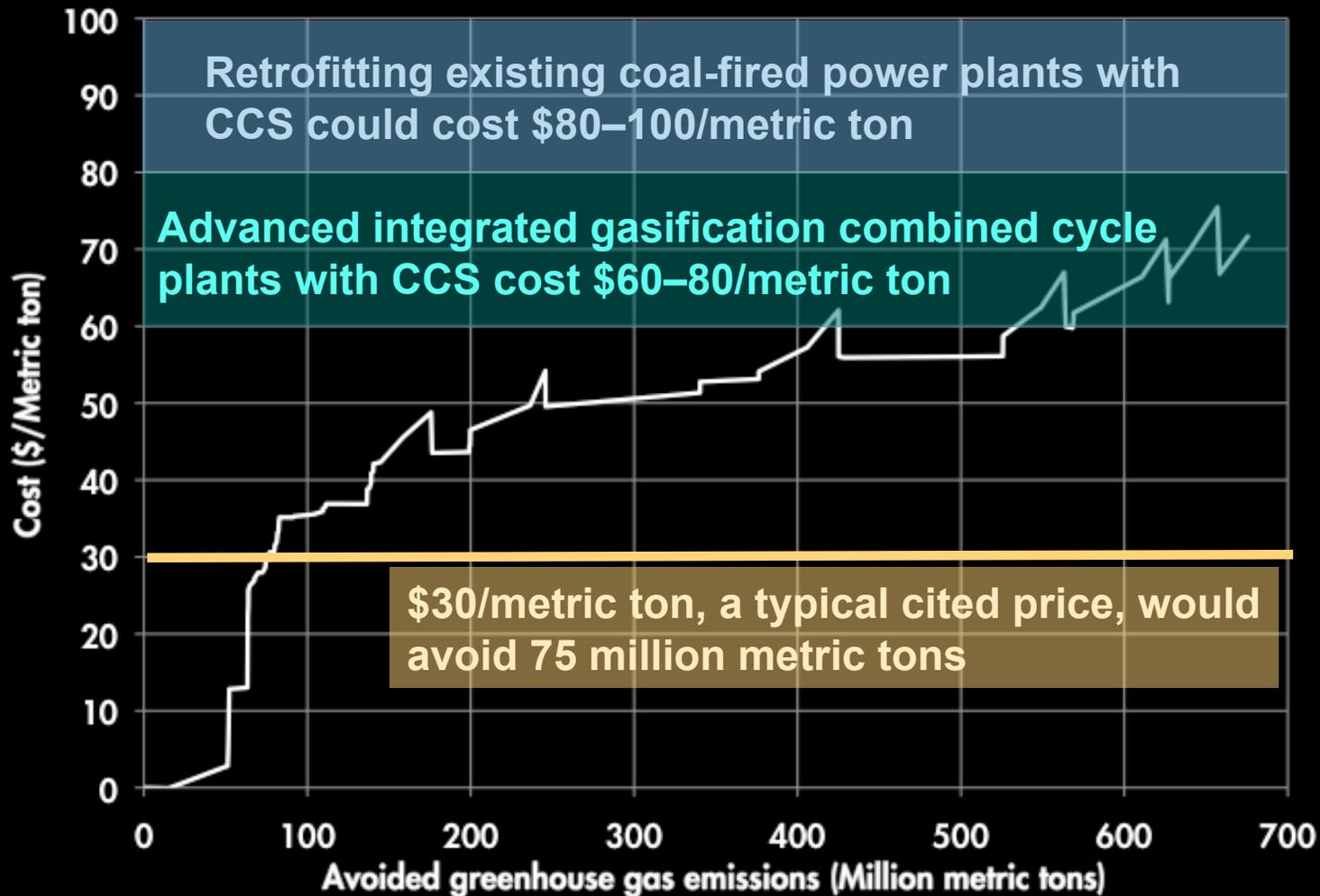
We Estimated Saved GHG by Assuming That Renewables Displace Coal

- **Use average coal-fired electricity generation emissions factor of 1.021 kg/kWh based on 2010 *Annual Energy Review* and Argonne National Lab**
- **Take difference between coal-fired average and life cycle GHG emissions for renewable technologies**
- **Cost per ton of CO₂-equivalent avoided are derived from differences in generation cost**

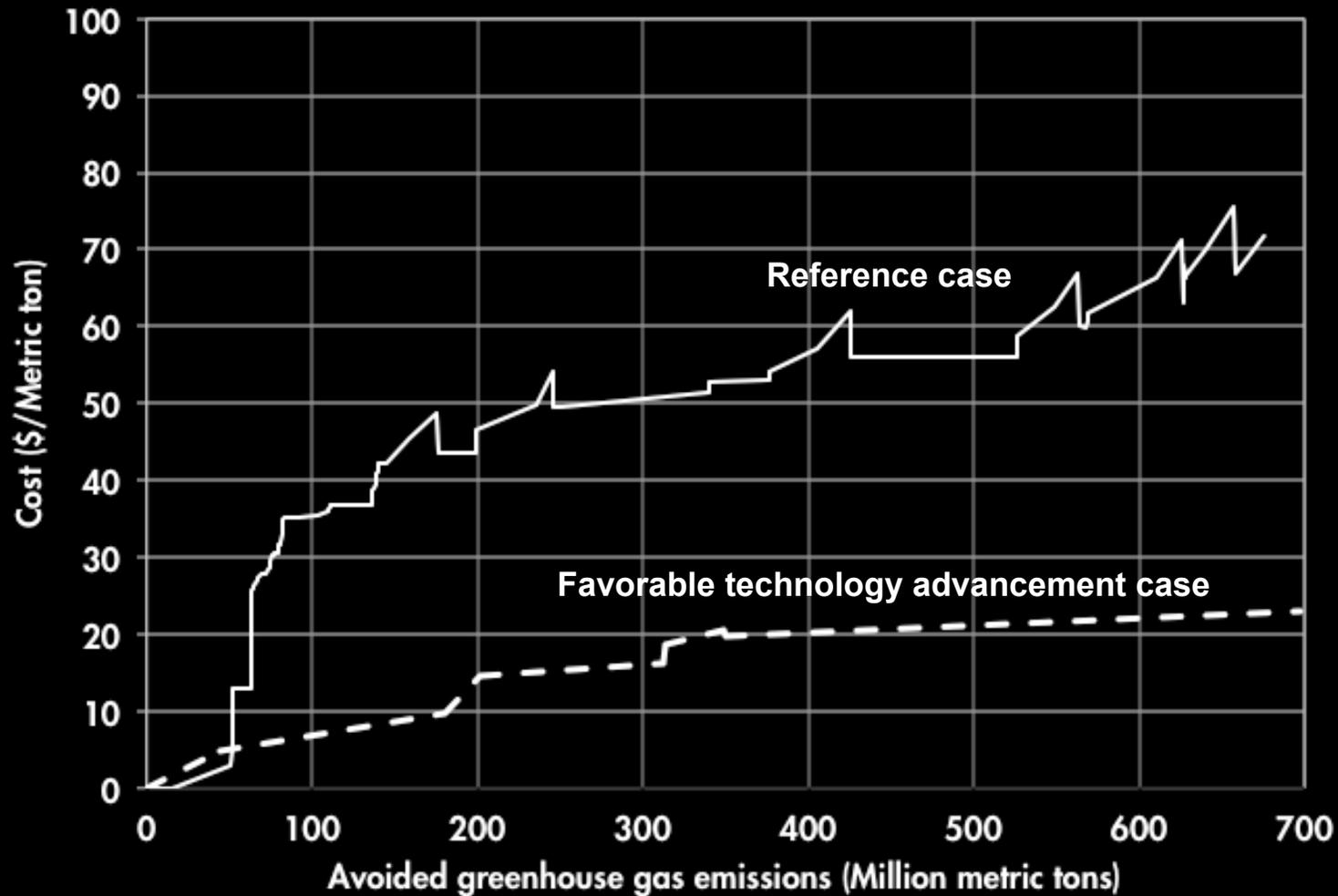
A Renewable Mandate for Electric Power Generation May Be an Expensive Way to Reduce GHG Emissions



However, whether \$70/Metric Ton CO₂ Is Expensive Depends on Your Perspective



Avoided GHG Costs Drop to \$23/Metric Ton if Renewable Technology Advances Rapidly



Conclusions

- **Cost of reducing greenhouse gas emissions by substituting renewables for coal would increase electricity prices by 3 to 5 times in our base case**
- **Total cost \$35 billion**
- **Biomass, wind most cost-effective near term renewable technologies**
- **Reductions in cost of wind power through higher efficiency would dramatically reduce costs of mandate**
- **But costs per ton of reduced GHG emissions run \$60 to \$70 per ton; other methods may be more cost effective**



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