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CCS…It's Time!

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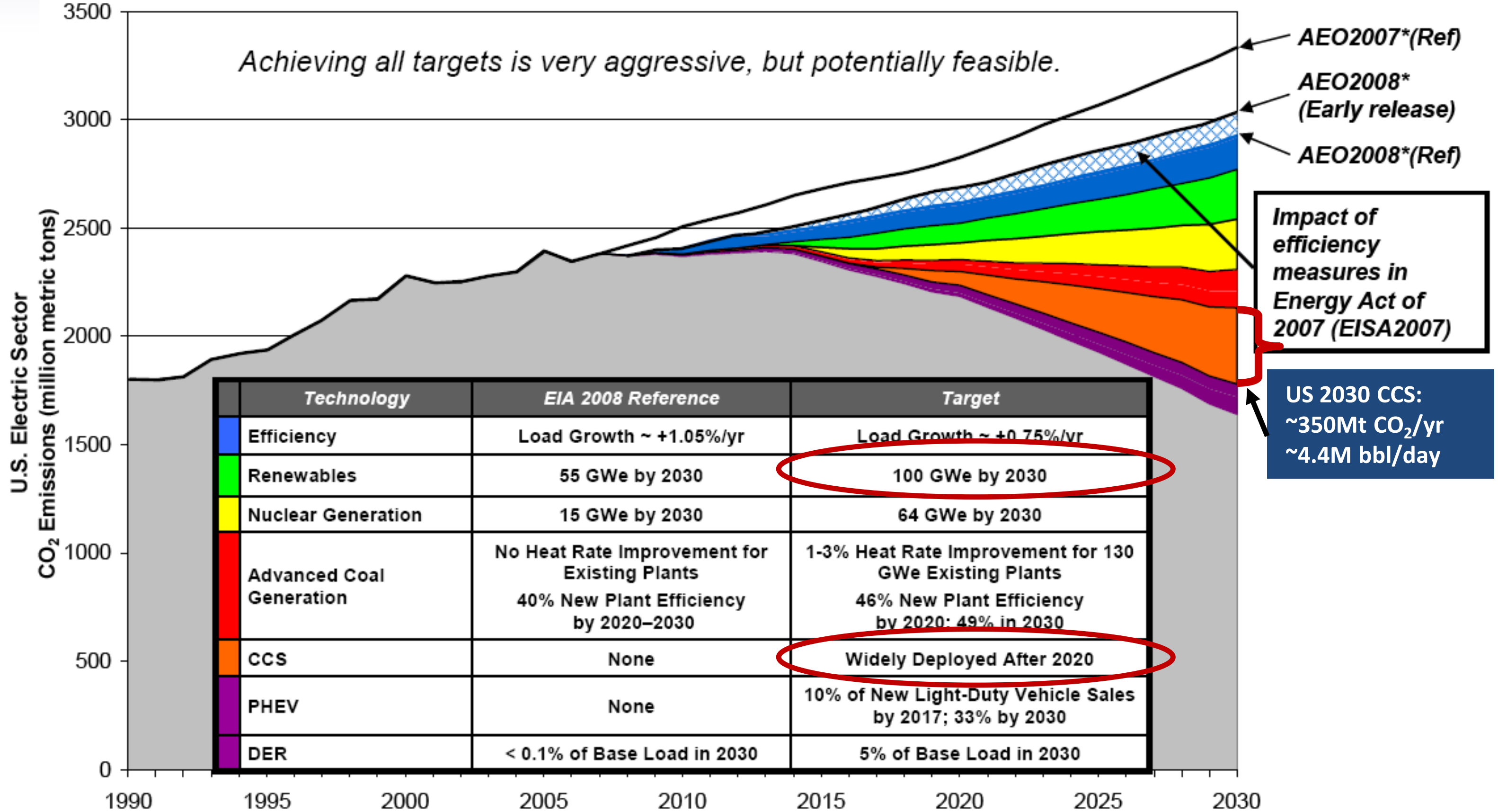
[From a talk at UT in Feb 2010]

CCS Needed *Quickly at Scale*

Analysis Framework… 2008 Prism



Technology	EIA 2008 Reference	Target
Efficiency	Load Growth ~ +1.05%/yr	Load Growth ~ +0.75%/yr
Renewables	55 GWe by 2030	100 GWe by 2030
Nuclear Generation	15 GWe by 2030	64 GWe by 2030
Advanced Coal Generation	No Heat Rate Improvement for Existing Plants 40% New Plant Efficiency by 2020–2030	1-3% Heat Rate Improvement for 130 GWe Existing Plants 46% New Plant Efficiency by 2020; 49% in 2030
CCS	None	Widely Deployed After 2020
PHEV	None	10% of New Light-Duty Vehicle Sales by 2017; 33% by 2030
DER	< 0.1% of Base Load in 2030	5% of Base Load in 2030

*Energy Information Administration (EIA) Annual Energy Outlook (AEO)

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EPRI ELECTRIC POWER RESEARCH INSTITUTE

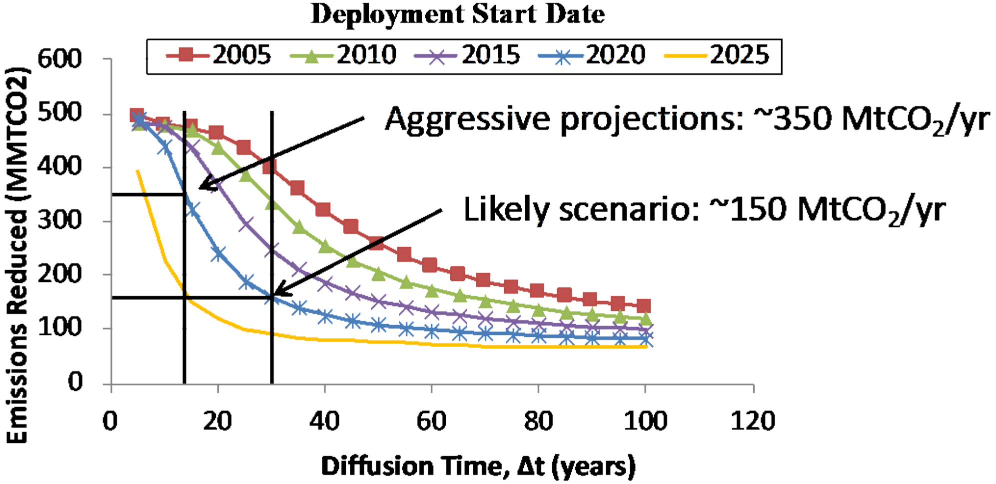
Source: Energy Technology Assessment Center, EPRI

Deep Decarbonization Expensive w/o CCS

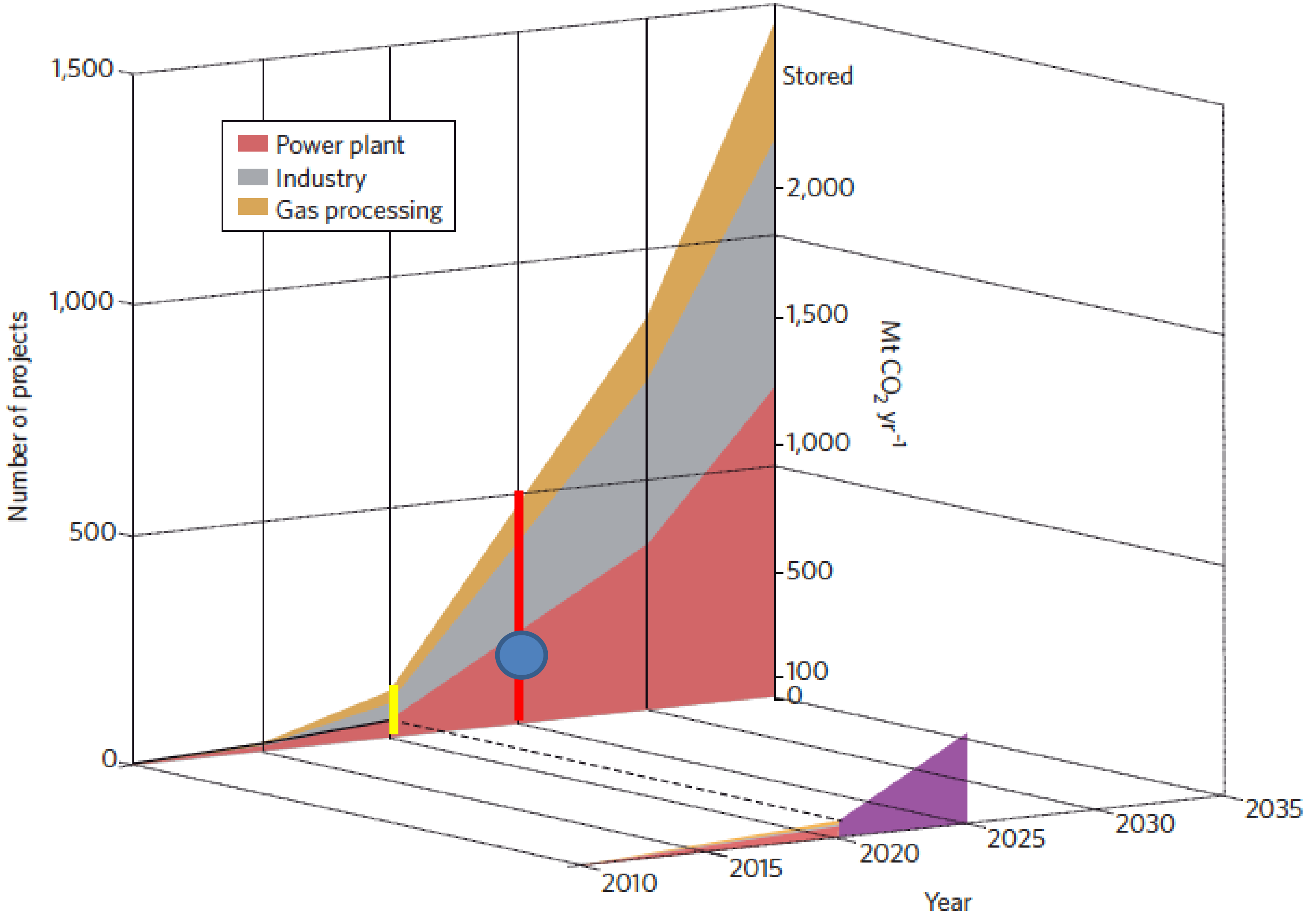
"Without CCS, the transformation of the power sector will be at least USD 3.5 trillion more expensive. In a "no CCS in power" scenario variant of the 2DS, **deployment of renewable technologies would need to be expanded by an additional 1900 GW by 2050** over and above the 2DS requirements. This is equivalent to around four times the total wind and solar PV capacity additions achieved in the last decade."

To meet CCS targets, investment and deployment needs to be ramped up, yet the reality on ground is quite different…

Source: Bistline and Rai, *Energy Policy,* 2010.

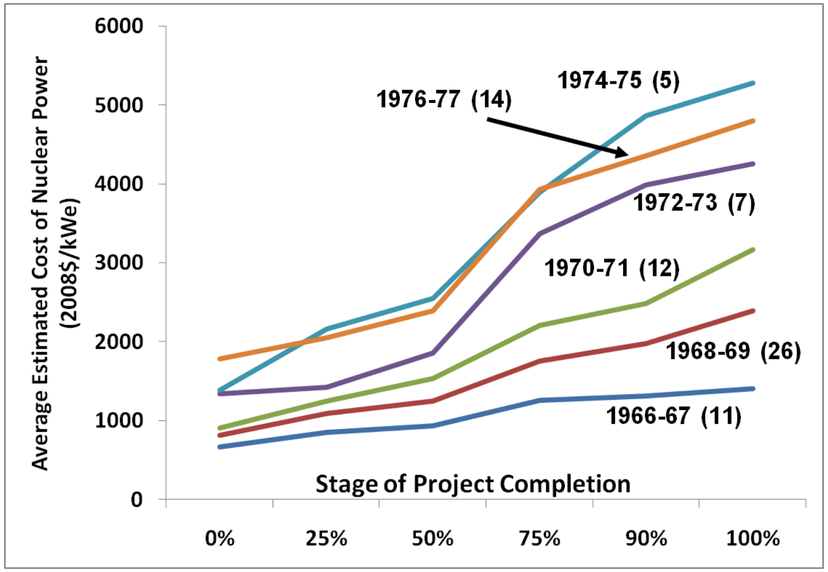


CCS Project Pipeline Growing Very Slowly

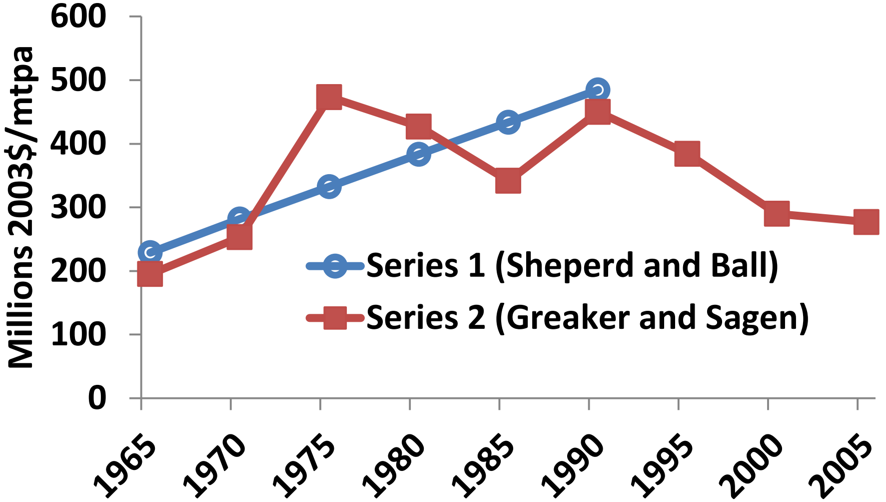


Source: Scott et al., *Nature Climate Change*, 2012.

With Increasing Unit Size, Cost Reductions May Not Automatically Hold For Capital Intensive Technologies



Average estimated cost of nuclear power



Unit cost of natural gas liquefaction plants

- Complex value chain: Cost increases due to unanticipated technological and regulatory bottlenecks; and market structure effects
- Appraisal optimism or "low balling"
  - Optimistic forecasts, understatement of costs
  - Once support secured and funds sunk, reveal true costs

Source: Rai et al., *Energy Policy,* 2010.

New Drivers (EOR, Chemicals, H_2, Innovations…) Driving a Portfolio of CCS Technologies

- Industry and academic collaboration extremely important
- Energy Institute's new ***Fueling a Sustainable Energy Transition*** *(FSET)* initiative

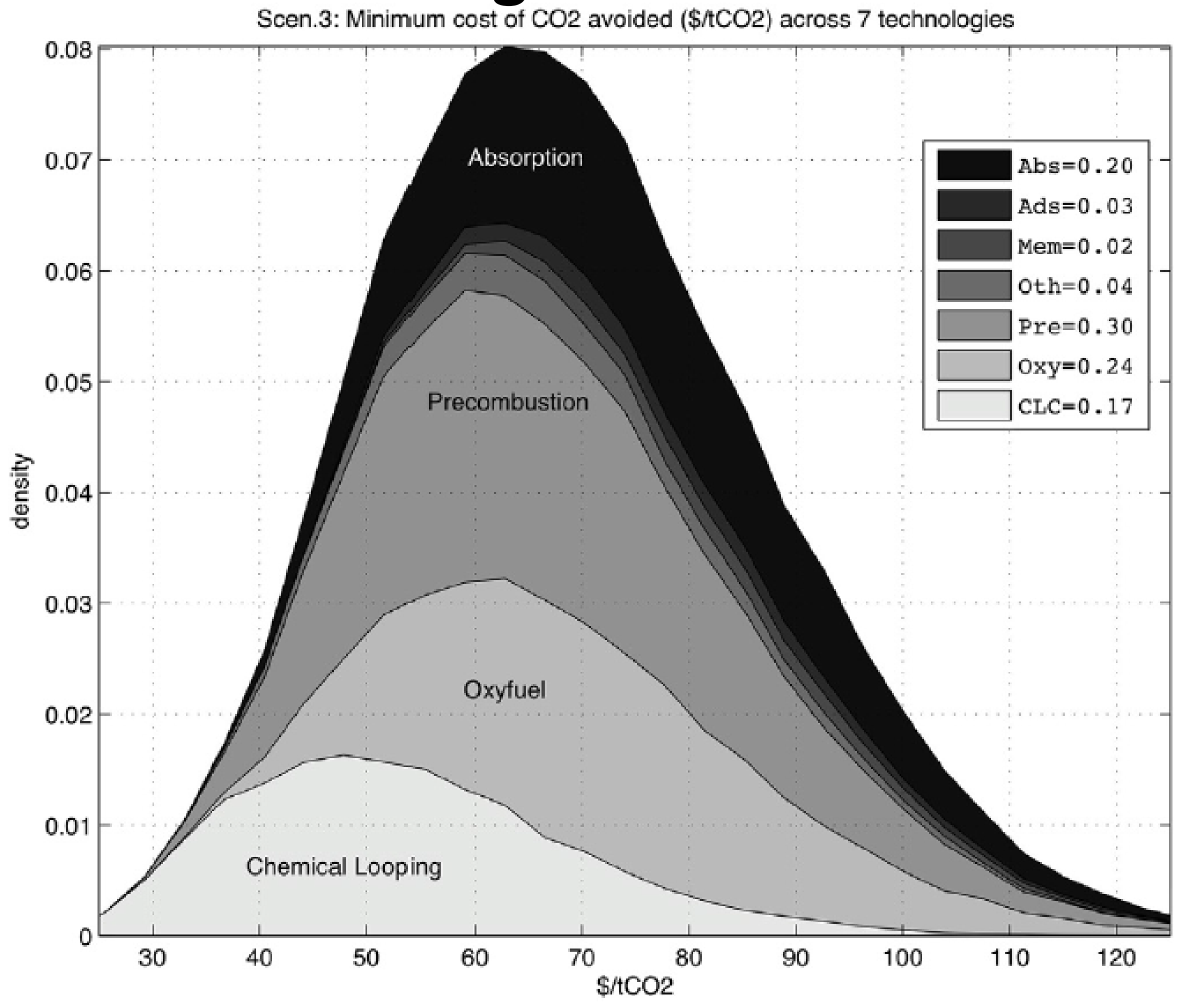


Fig. 8. Comparisons of probability distributions of minimum cost of CO_2 avoided ($/t$CO_2$) in 2025 across 7 technologies. Distribution of costs results from distribution of energy penalties and cost model assumptions. Legend shows portion of all instances in which each technology sets the lowest cost.

Source: Nemet et al., 2013.

Concluding Thoughts

- Need careful design of learning cycles between generations of the technology
- When scaling up, only technological improvements not sufficient. Experience with actual deployment across markets critical
- Attention on market structure and IP issues: Need competition and a number of technology suppliers. If China develops CCS technologies, good for the deployment of CCS globally
- Public participation and transparency must

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