Fifth Annual Conference on Carbon Capture & Sequestration

Steps Toward Deployment

CCS Economic Analyses

Comparing Coal IGCC with CCS and Wind-CAES Baseload Power Options in a Carbon-Constrained World

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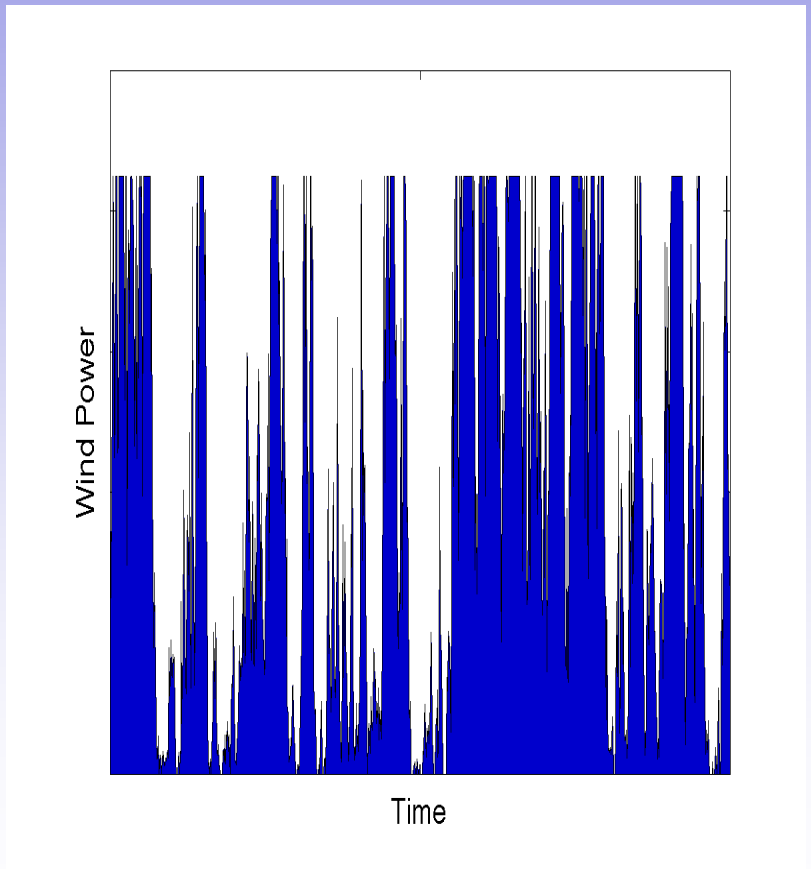
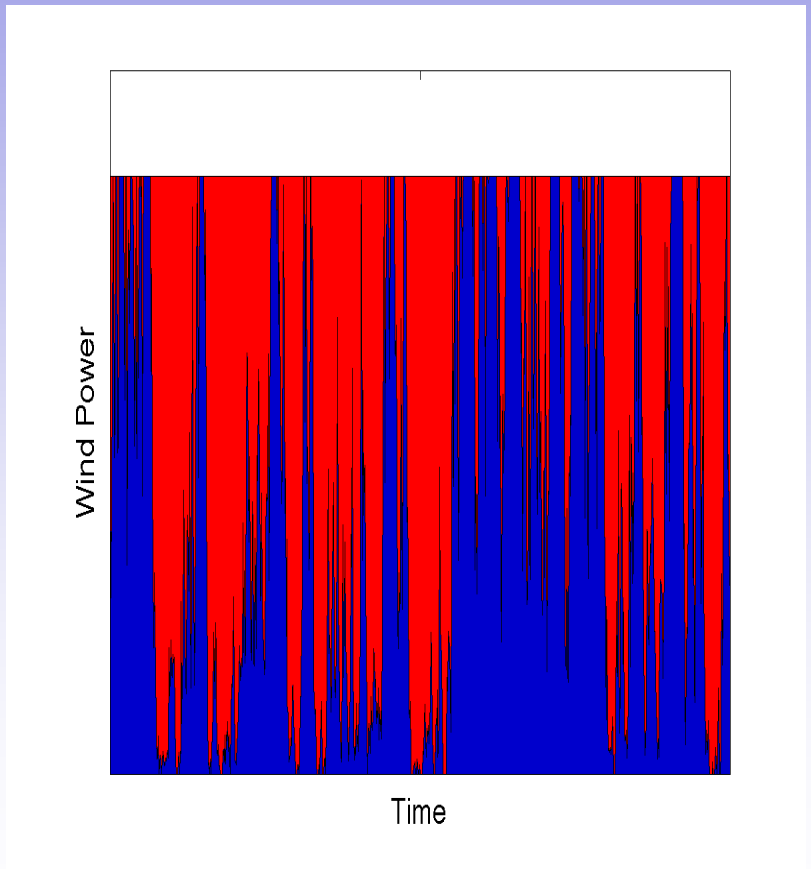
Outline

- Wind and Coal Comparison
- Strategies for Baseload Wind
- Dispatch Cost and Capacity Factor
- Generation Costs of Coal and Wind

Coal vs. Wind?



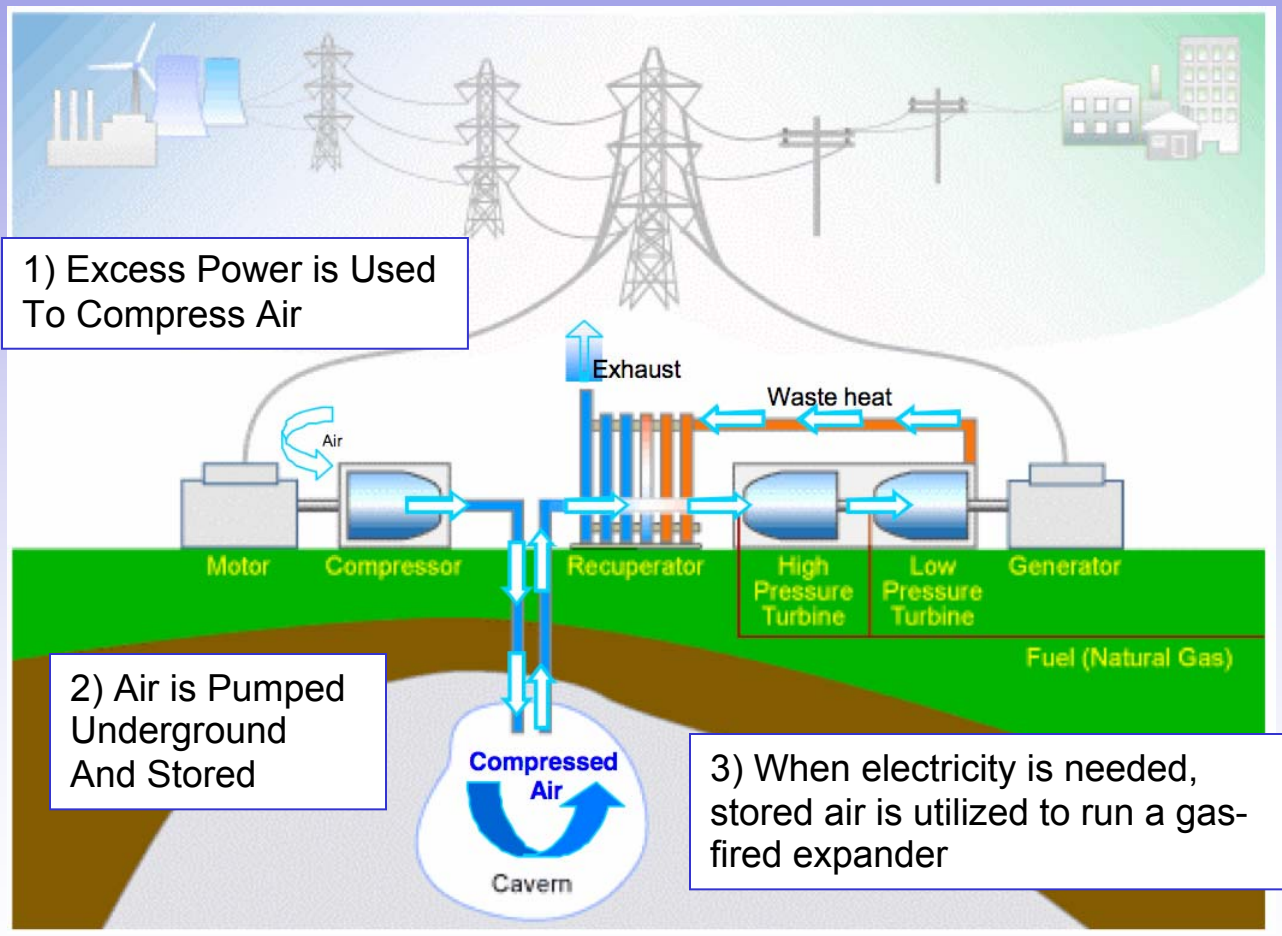
Coal vs. Wind?



Baseloading Wind

- Backup:Natural Gas (SC/CC)
  - Low Capital Cost
  - Fast Ramping
- Storage: CAES
  - Low Cost Bulk Storage
  - Potential for Widespread Availability

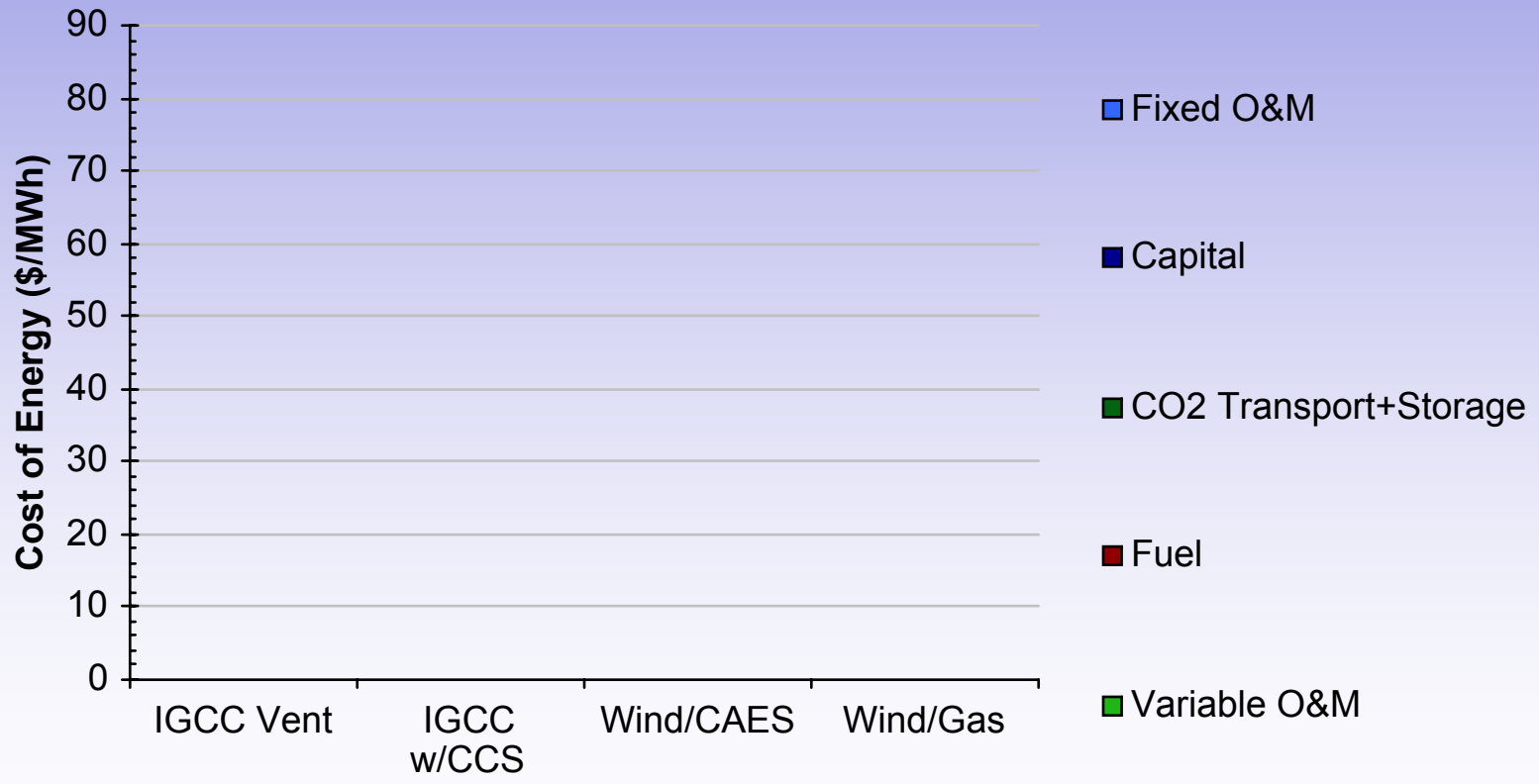
Compressed Air Energy Storage (CAES)



Basic Assumptions

- 15% Levelized Capital Charge Rate
- 85% Capacity Factor for All Systems
- IGCC Costs, GE Entrained Flow Quench Gasifier (FWE 2003)
  - IGCC-V: OCC $1135/kW, LHV Eff 38%
  - IGCC-C: OCC $1428/kW, LHV Eff 31.5%
- Wind/CAES Costs
  - $923/kW Wind, $453/kW, $1.75/kWh CAES
- Gas Turbine Costs
  - $234/kW SC, $571/kW CC
- Fuel Costs, $2002 (EIA 2006)
  - Natural Gas $5.05/GJ HHV
  - Coal $1.31/GJ HHV

Generation Costs for Baseload Options



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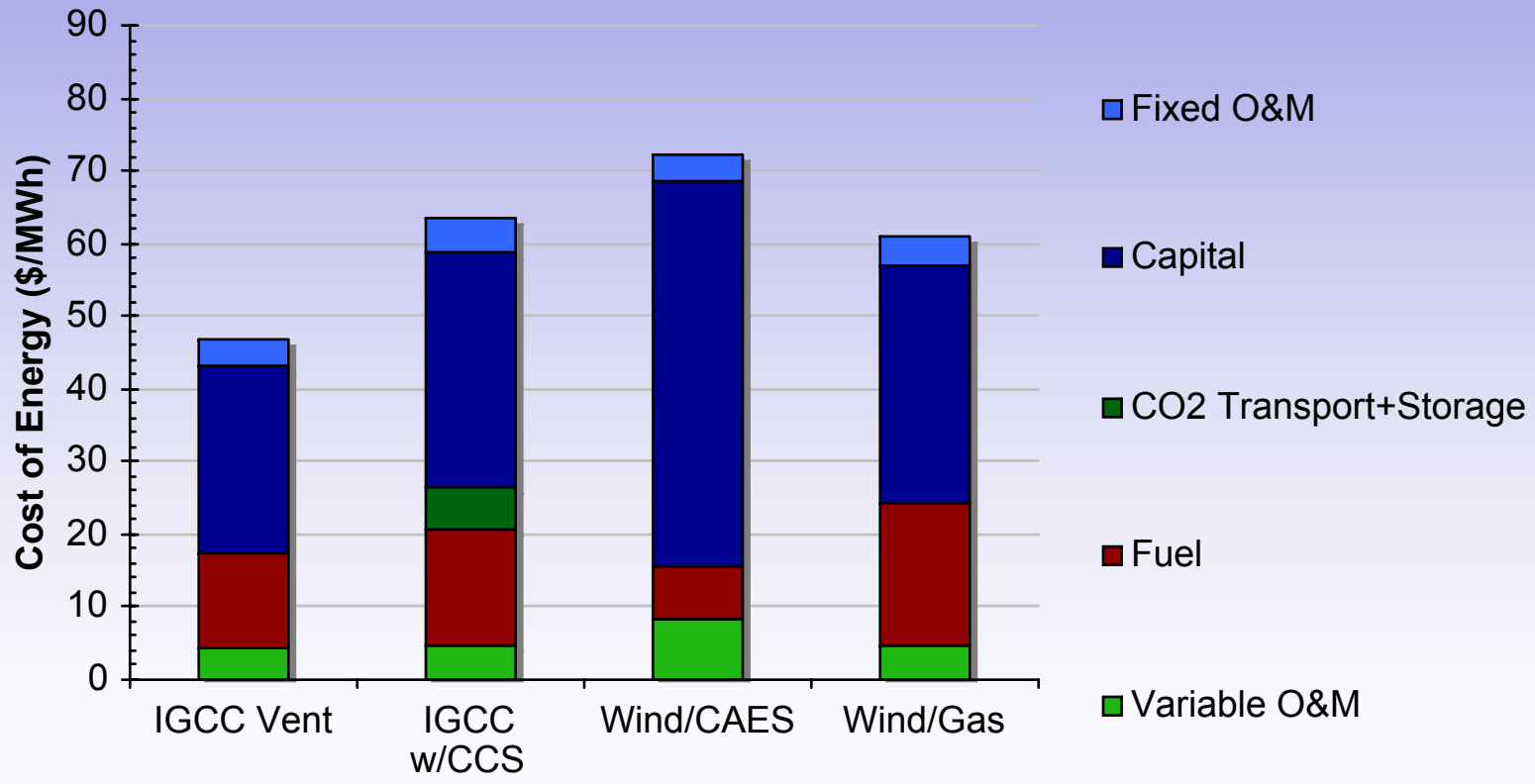
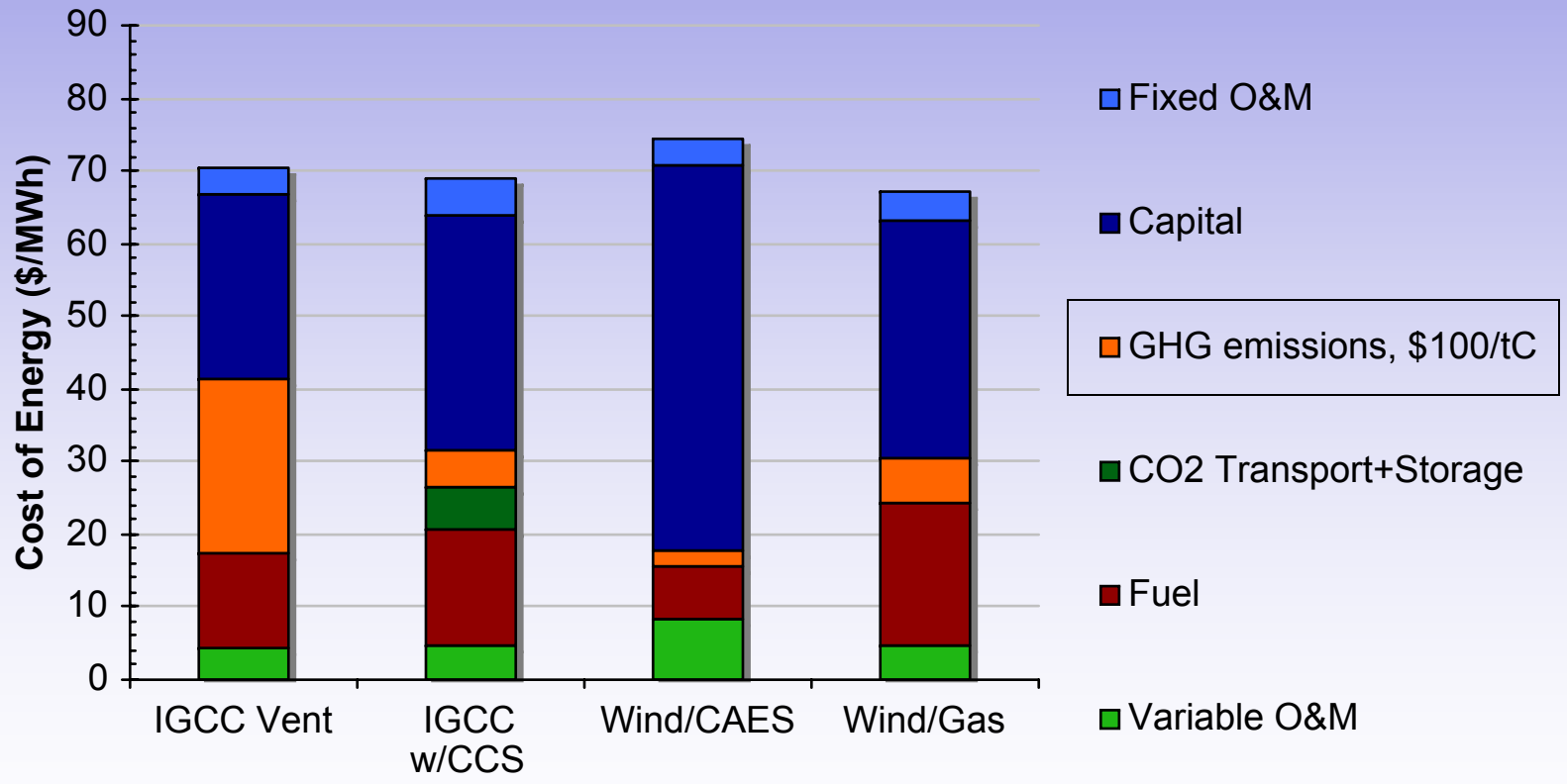


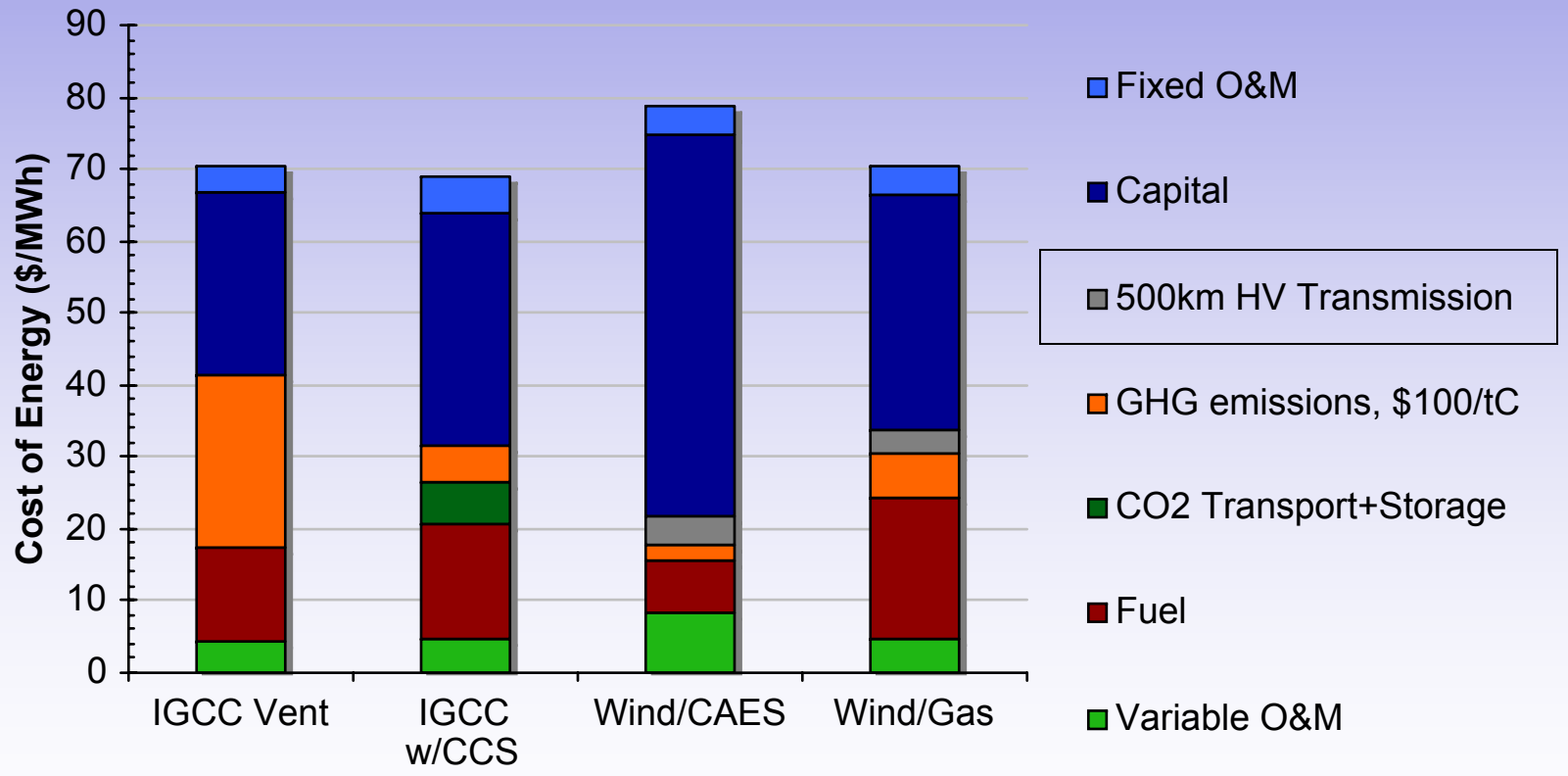
- **No valuation of GHG emissions**
- **No Transmission Costs**

Generation Costs for Baseload Options

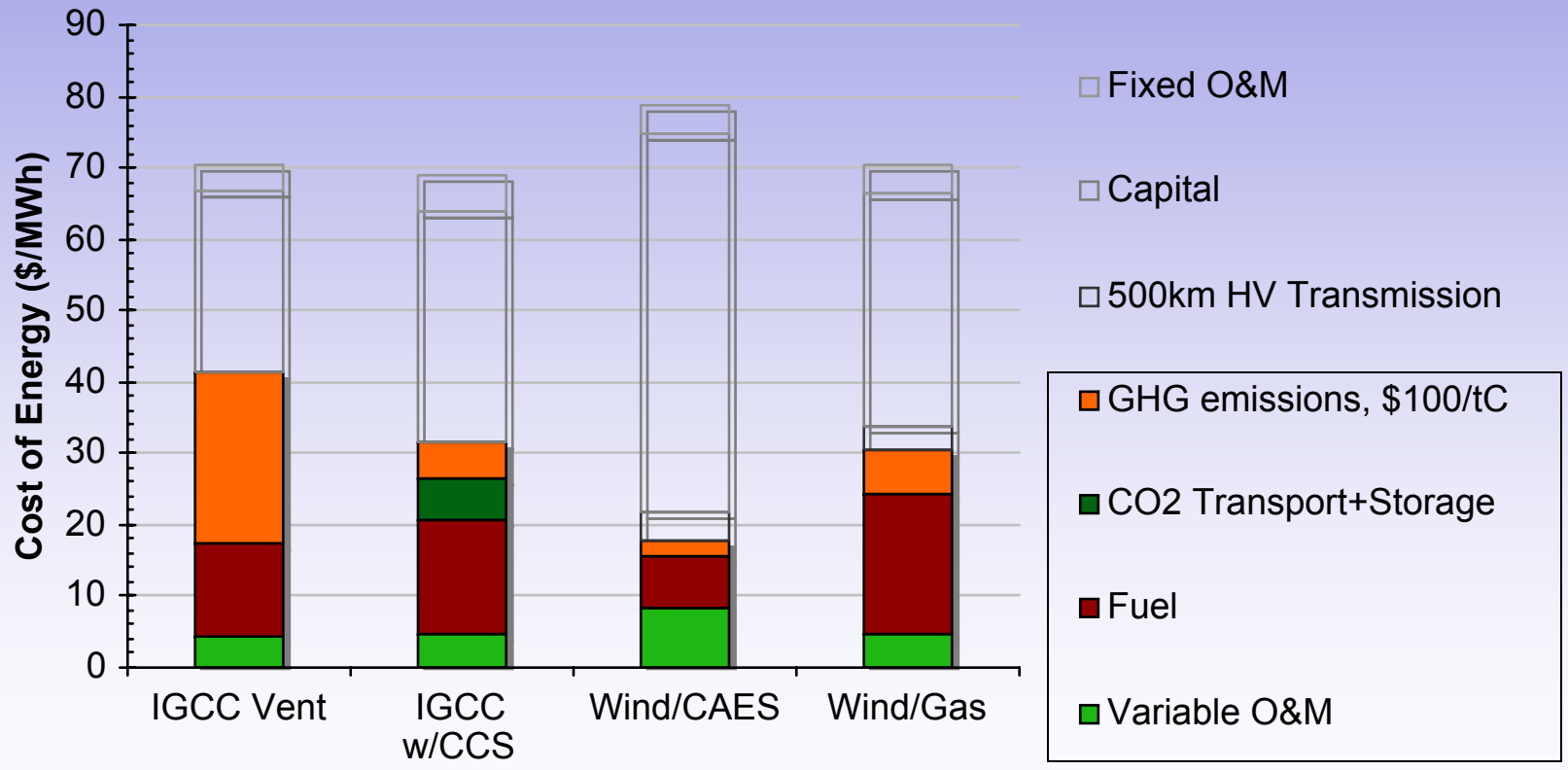


237 gC/kWh **53 gC/kWh** **23 gC/kWh** **62 gC/kWh**

Generation Costs for Baseload Options



Generation Costs for Baseload Options

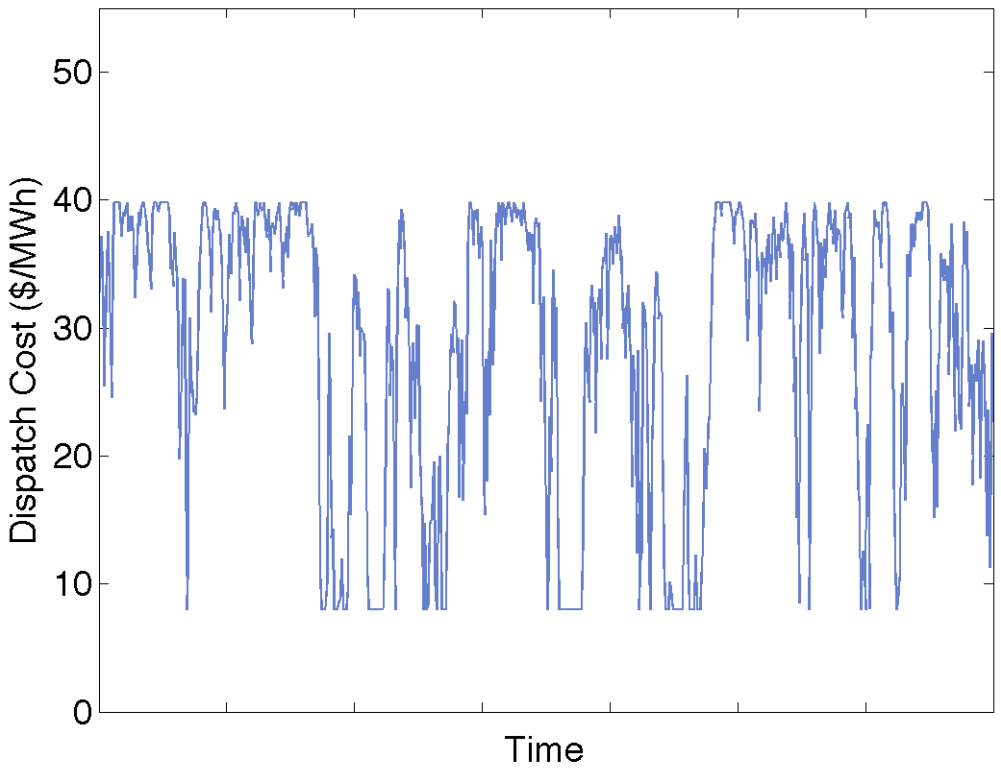


Highlighting Dispatch Costs

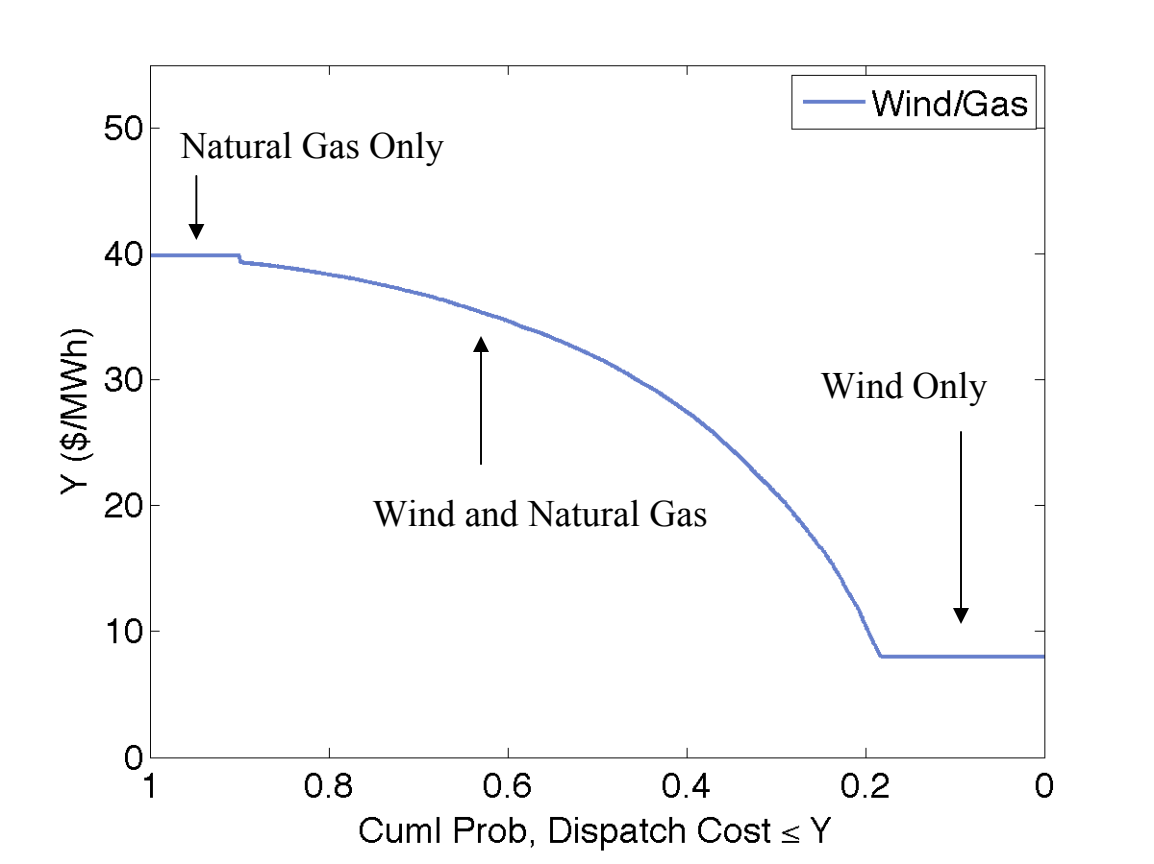
Dispatch Cost Concerns

- **Dispatch Cost**: fuel + variable operations and maintenance + greenhouse gas emissions price + CO_2 transport + storage (short-run marginal cost)
- Actual capacity factors determined in economic dispatch
- Systems called on based on dispatch cost
- Baseload viability requires competitive dispatch costs to sustain large capacity factors

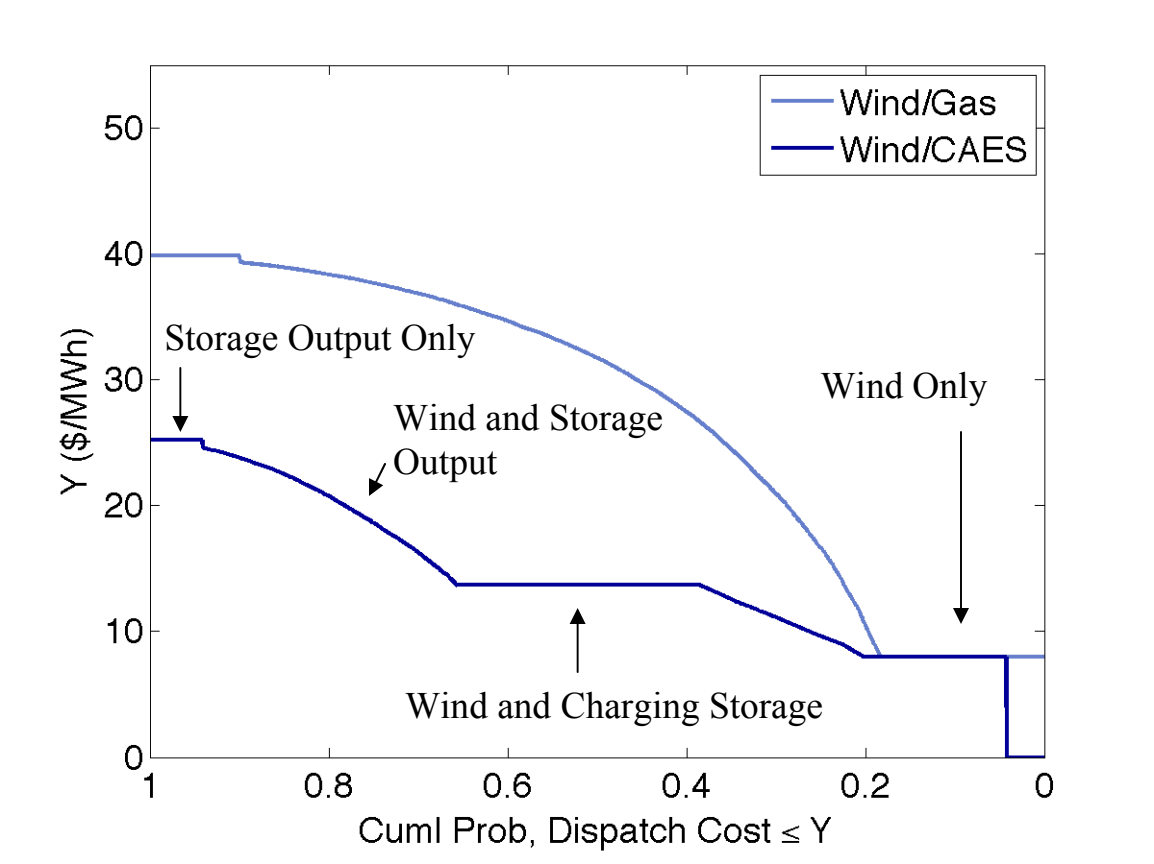
Variable Dispatch Cost



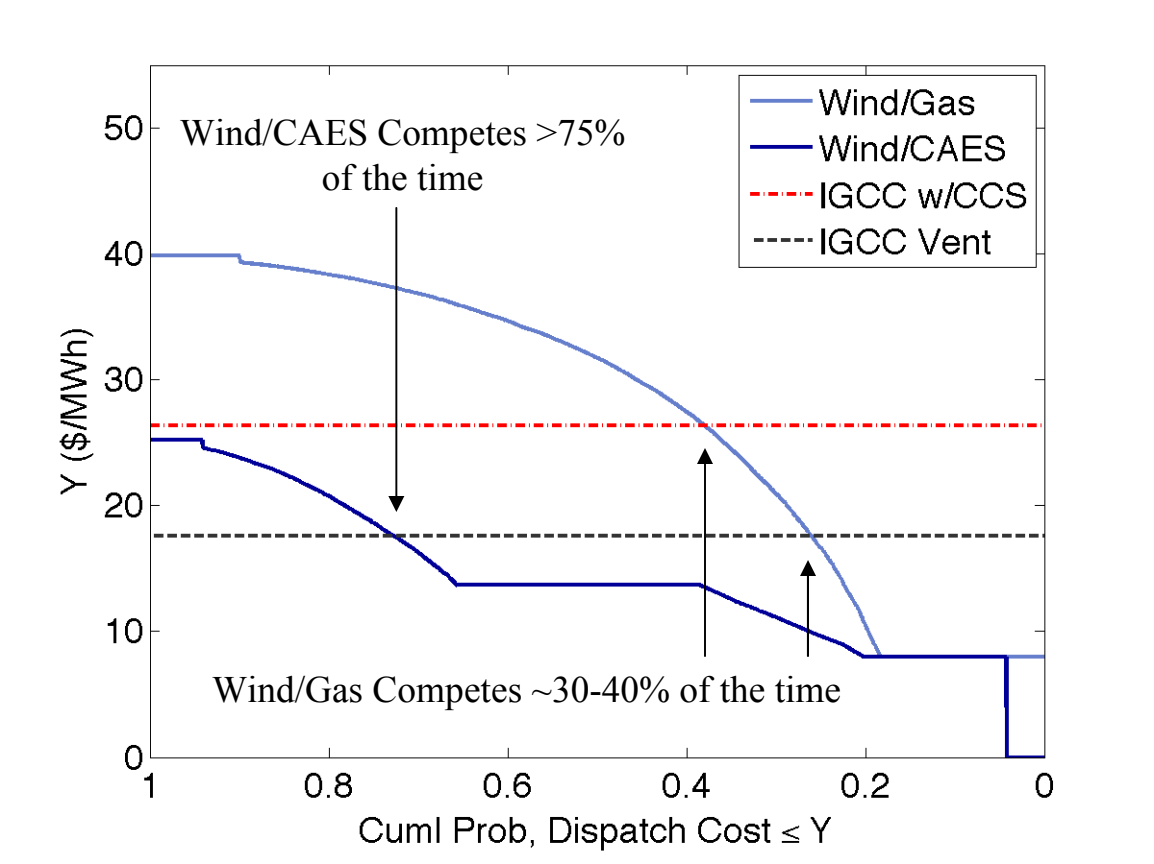
Variable Dispatch Cost: Wind/Gas



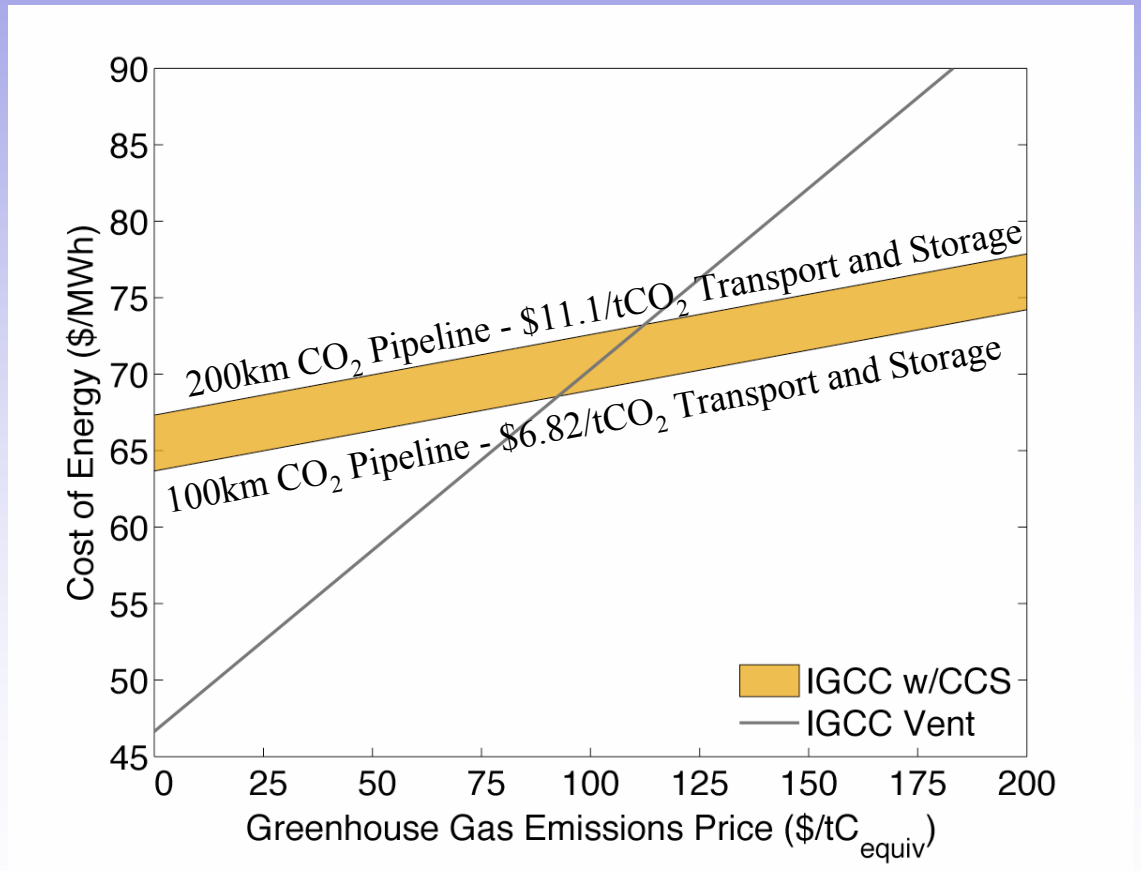
Variable Dispatch Cost: Wind/CAES



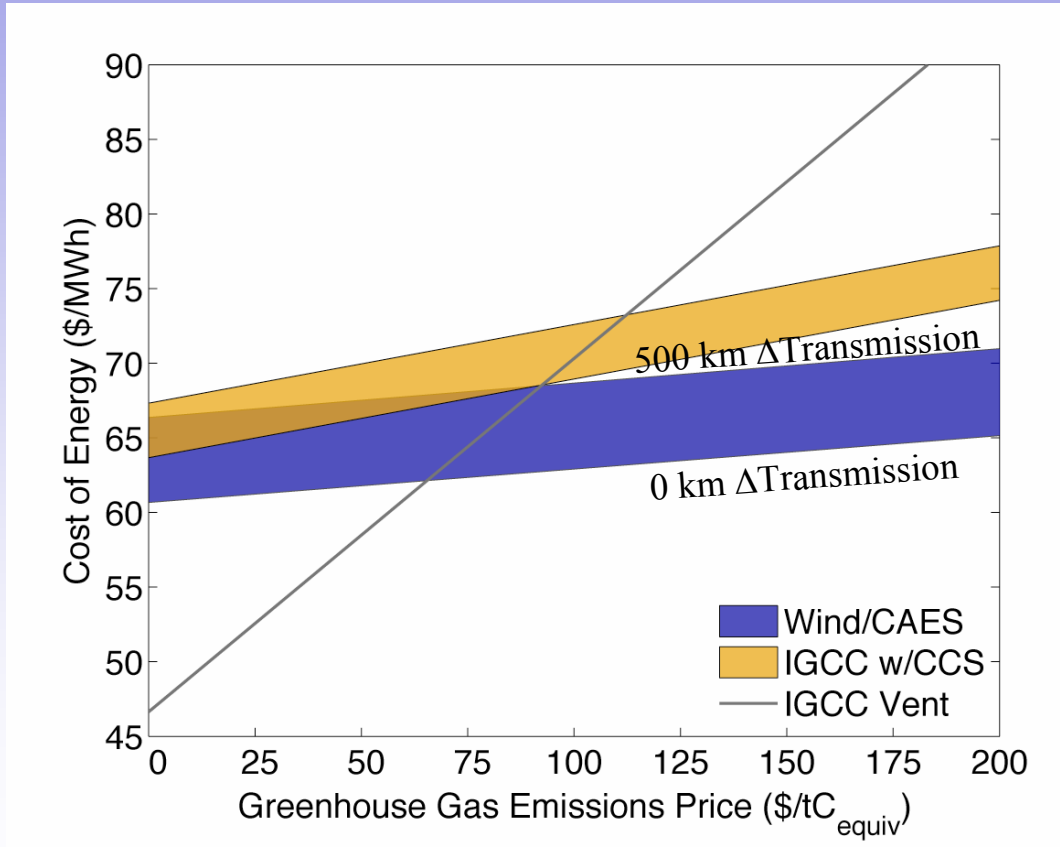
Dispatch Cost for Baseload Options



Generation Costs Revisited



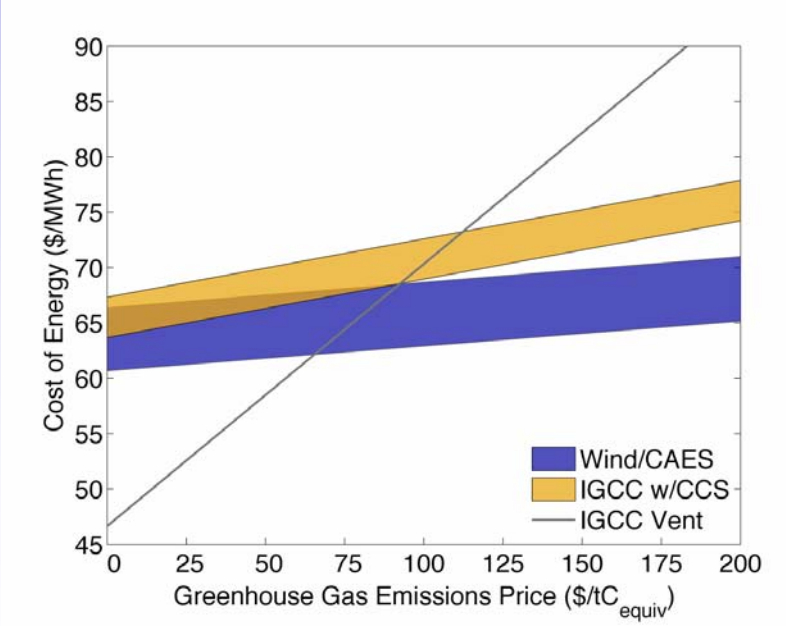
Generation Costs Revisited



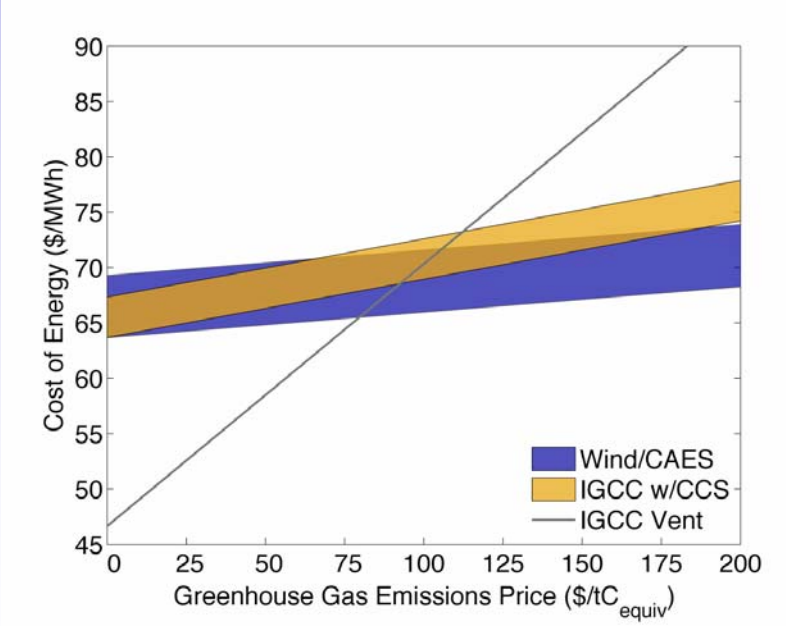
Class 5 Winds, 1.9¢/kWh Wind Production Tax Credit (PTC), Current Capital Costs

Generation Costs: Current vs. Projected

Current Conditions
Class 5 Winds, Production Tax Credit (PTC),
Current Capital Costs



Projected
Class 4 Winds, no Production Tax Credit (PTC),
Capital Cost Reductions for Wind and CAES



Conclusions

- Backup enables wind to participate in baseload
- High dispatch cost makes wind/gas unviable
- Wind/CAES has the potential to compete in dispatch and produce electricity at rates comparable to IGCC w/CCS
- Wind resource quality and remoteness as well as GHG emissions price will be critical factors

Energy Storage Options

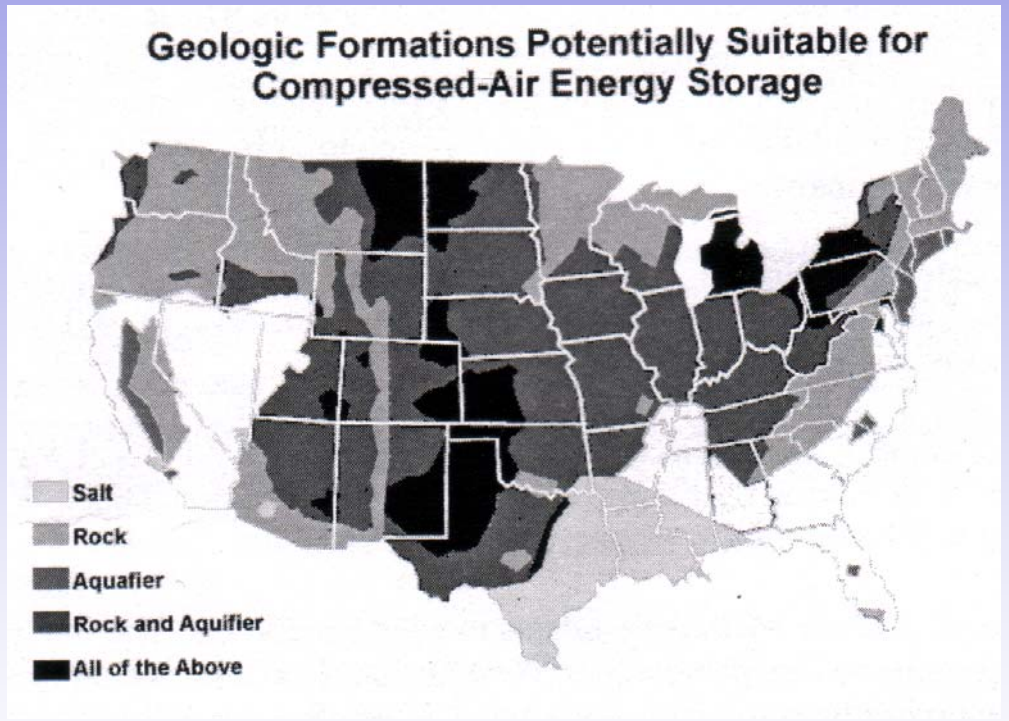
Source: PCAST, 1999 and EPRI/DOE, 2003

Technology	Capacity ($/kW)	Storage ($/kWh)	**Cost of 20 hrs. storage ($/kW)**
Compressed Air Energy Storage (CAES) (300 MW)	**440**	**1**	**460**
Pumped hydroelectric	900	10	**1100**
Advanced battery (10 MW)	120	100	**2100**
Flywheel (100 MW)	150	300	**6200**
Superconductor (100 MW)	120	300	**6100**

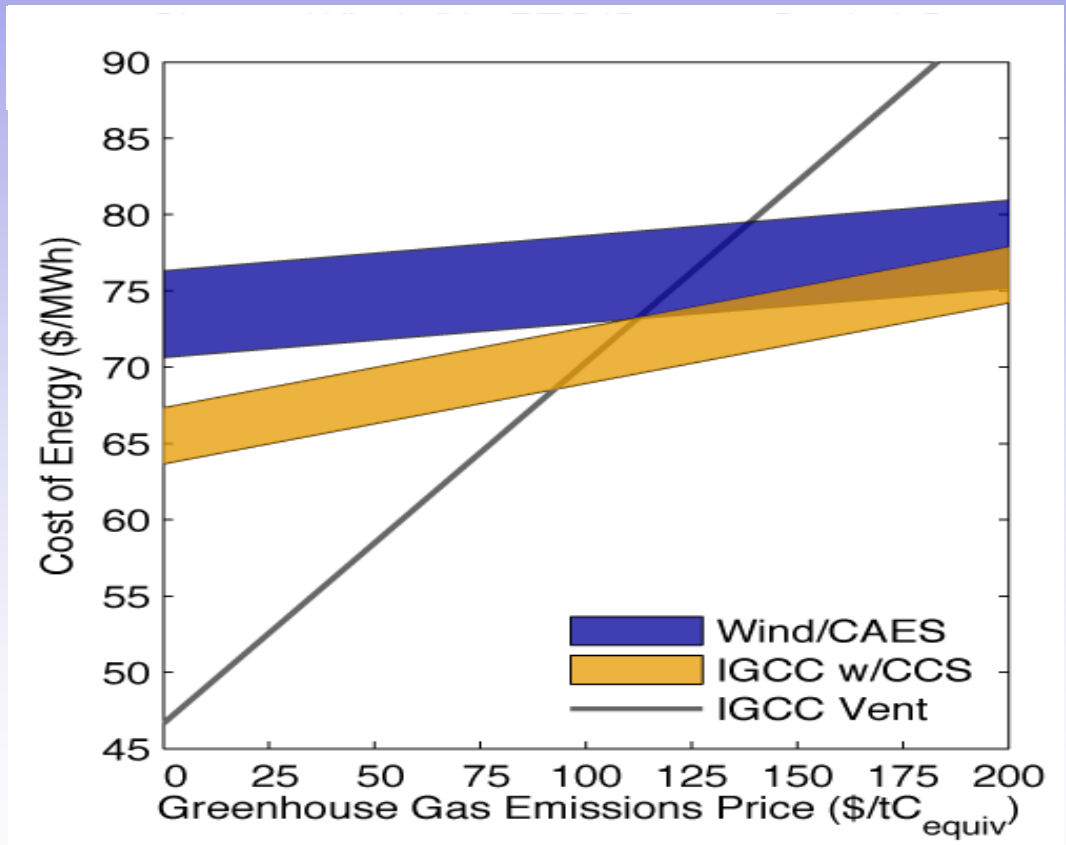
CAES is clear choice for:
Several hours (or more) of storage
Large capacity (> ~100 MW)

Availability of CAES

- Suitable geology for compressed air storage found over 80% of the area of the USA
- Locations coincident with high quality wind resources (e.g. Great Plains where much of the new capacity for coal generation is being planned)
- Availability of fuel source is an additional constraint for wind/CAES implementation



Generation Costs - no PTC



Class 5 Winds, **No Wind Production Tax Credit (PTC),** Current Capital Costs

Variable Dispatch Cost at $100/tC