The cost of new power plants

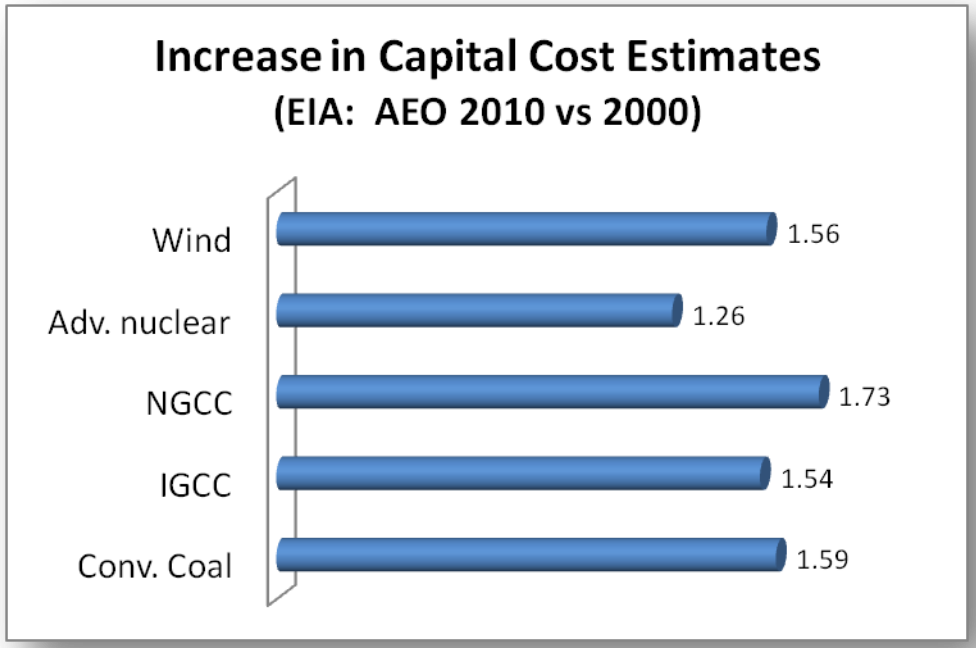
L.D. Carter
For USCSC

Today we will discuss the changing costs for producing electricity

- Why was a review needed?
- How was the analysis framed?
- What sources of information were used?
- What is the answer?
- What factors could significantly change the answer?
- What is the industry actually building?
- What is worth remembering?

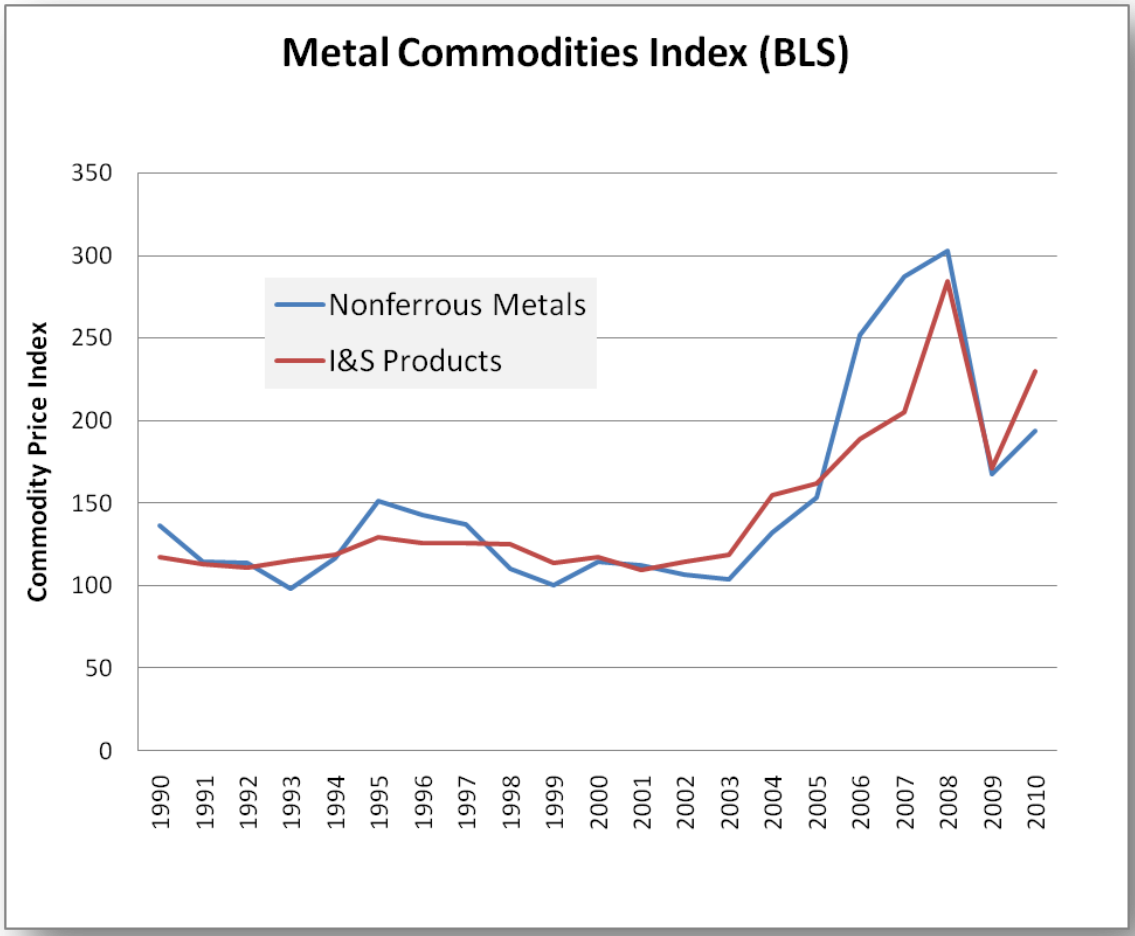
Power plant economics have changed over the past decade

- Traditional sources like EIA have generally raised estimates of power plant costs beyond inflation
- Reported prices for actual new plants varied by a factor of two for specific technologies, and sometimes change by over 50% for a single unit
- Carbon constraints will change relative costs



Prices have escalated beyond inflation

- IHS CERA reported in 2009 that new power plant prices had roughly doubled since 2000.
- Bureau of Labor Statistics provided insights into why.



http://stats.bls.gov/xg_shells/ro4xgppihi.htm

We need to view costs in a carbon constrained world

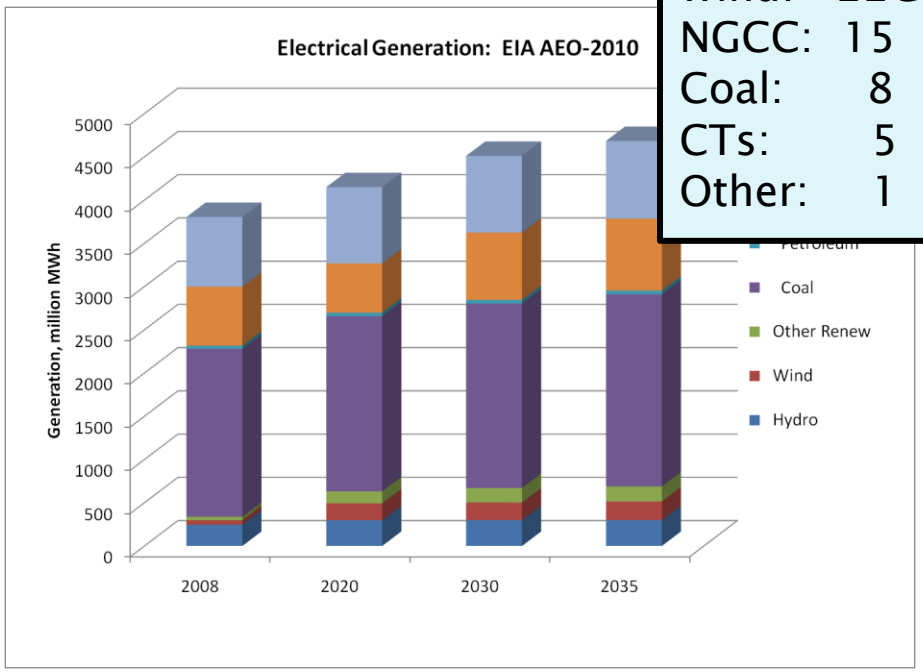
- The study borrows from EPA's analysis of HR 2454, passed by the House in June 2009
- EPA estimated allowance prices ranging from $16 – 100/tonne CO2 for 2012-2050 (2005 $s)
- This cost study assumes that new units come on line in 2020
- Average allowance price for 2020-2050 = $50/tonne

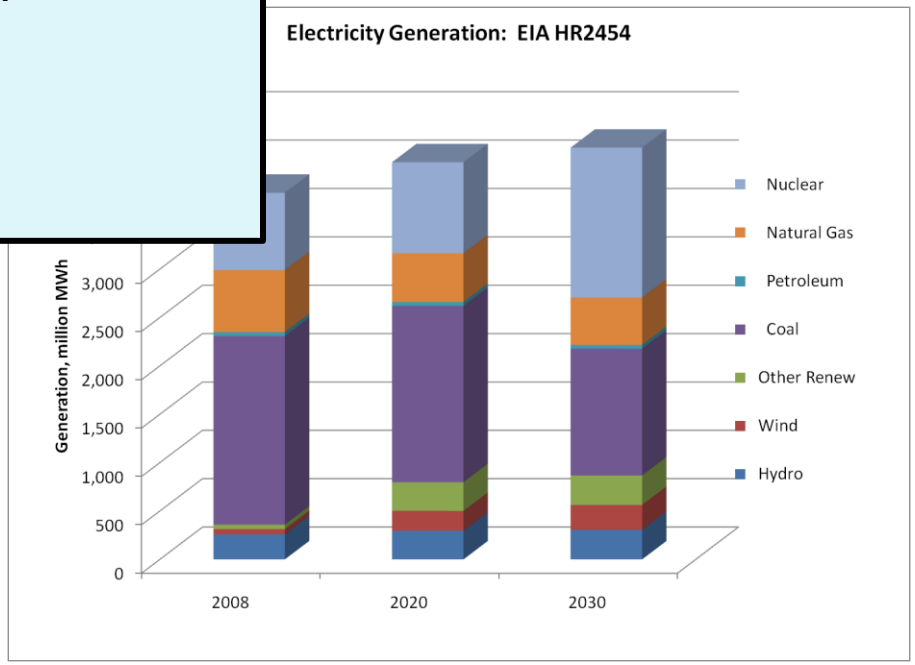
Coal, gas, nuclear and wind were deemed representative of new units

EIA AEO2010
additions since 2007

Wind: 22GW
NGCC: 15
Coal: 8
CTs: 5
Other: 1

Without Climate Lim ... imate Limits



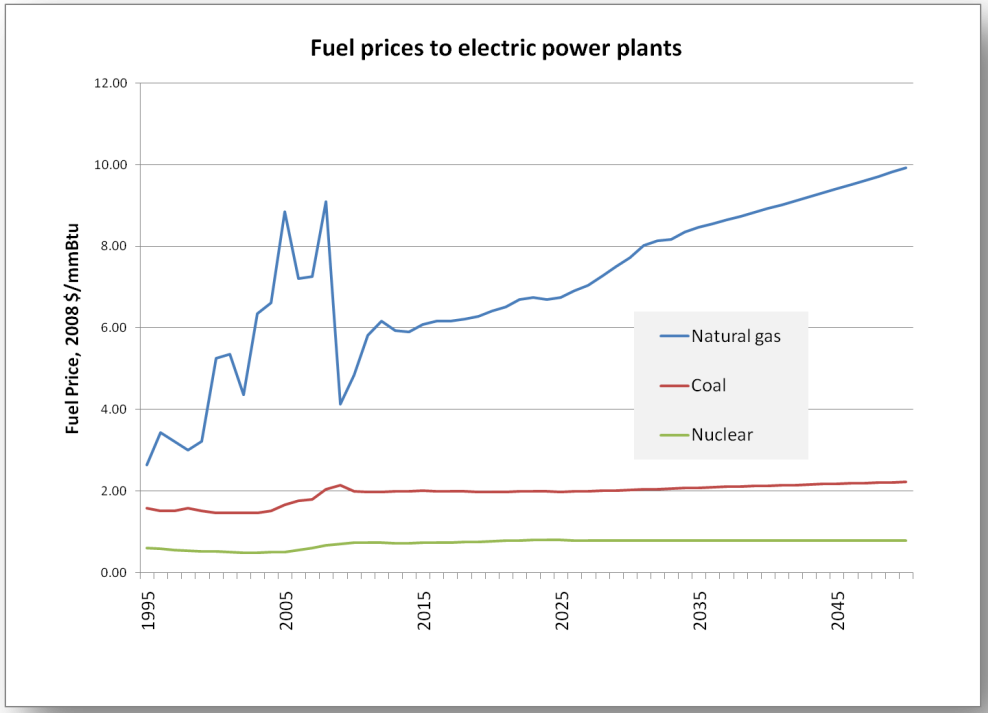


Primary metrics are Capital Cost and Levelized Cost of Electricity

- Capital cost is expressed as “Overnight” costs, which exclude interest during construction and certain other costs, but are most commonly cited in reports – (TPC, TPI, TCR)
- Levelized COE includes
  - Repayment of capital
  - Operation and Maintenance
  - Fuel
  - Carbon fee
  - Analogous to your mortgage payments, plus house maintenance, plus utility bills, but in constant $s.

Fuel costs were taken from EIA, and extrapolated beyond 2035

- The period of 2020–2050 was assumed
- Note historic volatility of natural gas and stability of coal and nuclear fuel prices
- 2020–2050 averages (2008 $/mmBtu)
  - Gas: $8.25
  - Coal: $2.09
  - Nuclear: $0.79



The overall approach was to review comparative reports and announced project costs

- Reports which considered multiple technologies have the advantage of using consistent assumptions, and avoiding site-specific anomolies
- Announced project costs have the advantage of greater cost analysis, and they are real, at least for a point in time
- CRS Power Plants: Characteristics and Costs, was unique because it gleaned generic costs from announced project cost data.

- An important element of this report was to consider possible variations in key assumptions, by technology

Primary references included

- EIA – AEO2010
- CRS – Power Plants: Characteristics and Costs
- DOE – Cost and Performance Baseline for Fossil Energy Plants
- NAE – America's Energy Future
- Multi-Power Pool Study – Joint Coordinated System Plan, 2008.
- Report includes over 90 citations.

Announced prices are useful but not dispositive

- Detailed capital cost information on specific projects is typically proprietary, and companies usually do not define what is included in publicly reported capital costs
- Specific situations can be atypical, like adding a unit to an existing site.
- Announced costs often include escalation up to the point of construction, and interest charges during construction
- Announced costs often change prior to and during construction, especially for new designs. The report cites specific cases where reported prices rose above initial estimates by
  - 20-50% for coal units
  - 100% for a nuclear unit

General Findings

- Cost estimates from even a few years ago do not reflect current market conditions.
- Most reports give EIA's data high credibility and either use them directly, or as a starting point
- I found EIA's estimates to be reasonable, but applied two adjustments:
  - Nuclear plant costs have increased for "next generation" units, and continue to be in flux
  - EIA incorporates certain wind energy costs in separate stages of their modeling process, so they do not appear in the tabulated costs
- Cost of electricity from new plants will be much higher than from existing plants
- In the absence of Loan Guarantees, financing costs for nuclear units may be higher than for other options.
- Each technology has significant cost uncertainties, and could enjoy improvements from RD&D.

"Best Guess" summary results show comparable COE for most options

Technology	Capital Cost ($/kW)	V ($/			0/tCO2 Charge $/kWh)	Levelized COE ($/MWh)
SCPC	2223				0.041	113
SCPC w CCS	4051				0.006	130
IGCC	2569	2.9			0.041	121
IGCC w CCS	3776	4.54			0.005	117
NGCC	968	2.04			0.018	97
NGCC w CCS	1932	3.01			0.002	119
Adv Nuclear	4500	0.51			-	127
Wind	2266	0.00	30.98	9,884	-	131

NOTE that for fossil technologies, CCS costs more than the assumed cost of allowances, so absent incentives, or performance standards, paying the "tax" is 15-
CCS

Nuclear is $700/kw above EIA due to other studies & reported costs.

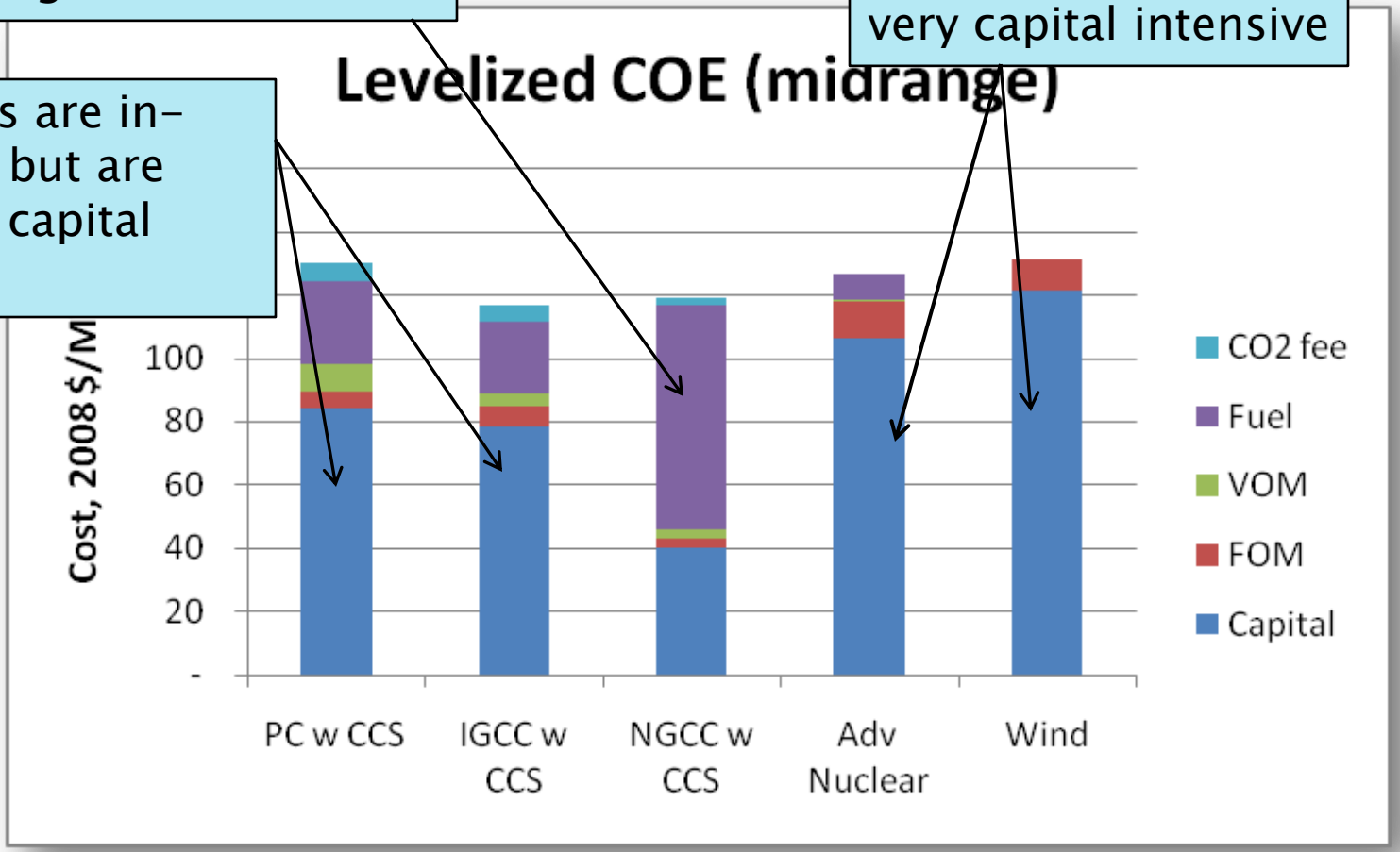
Wind estimate includes $300/kw for transmission addition.

A picture facilitates understanding of i haracteristics

NGCC costs depend largely on the price of gas

Wind and Nuclear technologies are very capital intensive

Coal Units are in-between, but are relatively capital intensive



EIA has also calculated LCOE

Technology/Fuel	CapFac	US Average Levelized Cost of Electricity for plants entering service 2010, 2008 $/MWh CC	FOM	VOM&F	Transm	Total	$50/t L Analysi Total	
Conv Coal	85	69	4	24	4	100	113	106
Adv Coal	85	81	5	20	4	111	121	
Adv Coal & CCS	85	93	6	26	4	129	117	
Conv NGCC	87	23	2	55	4	83	97	80
Adv NGCC	87	22	2	52	4	79		
Adv NGCC & CCS	87	44	3	63	4	113	119	
Conv Comb Turbine	30	41	5	83	11	140		
Adv Comb Turbine	30	39	4	70	11	124		
Adv Nuclear	90	95	12	9	3	119	127	112
Wind	34	131	10	-	8	149	131	96
Wind–Offshore	39	160	24	-	7	191		
Solar PV	22	377	6					
Solar Thermal	31	224	22					
Geothermal	90	88	23					
Biomass	83	73	9					
Hydro	51	104	4					

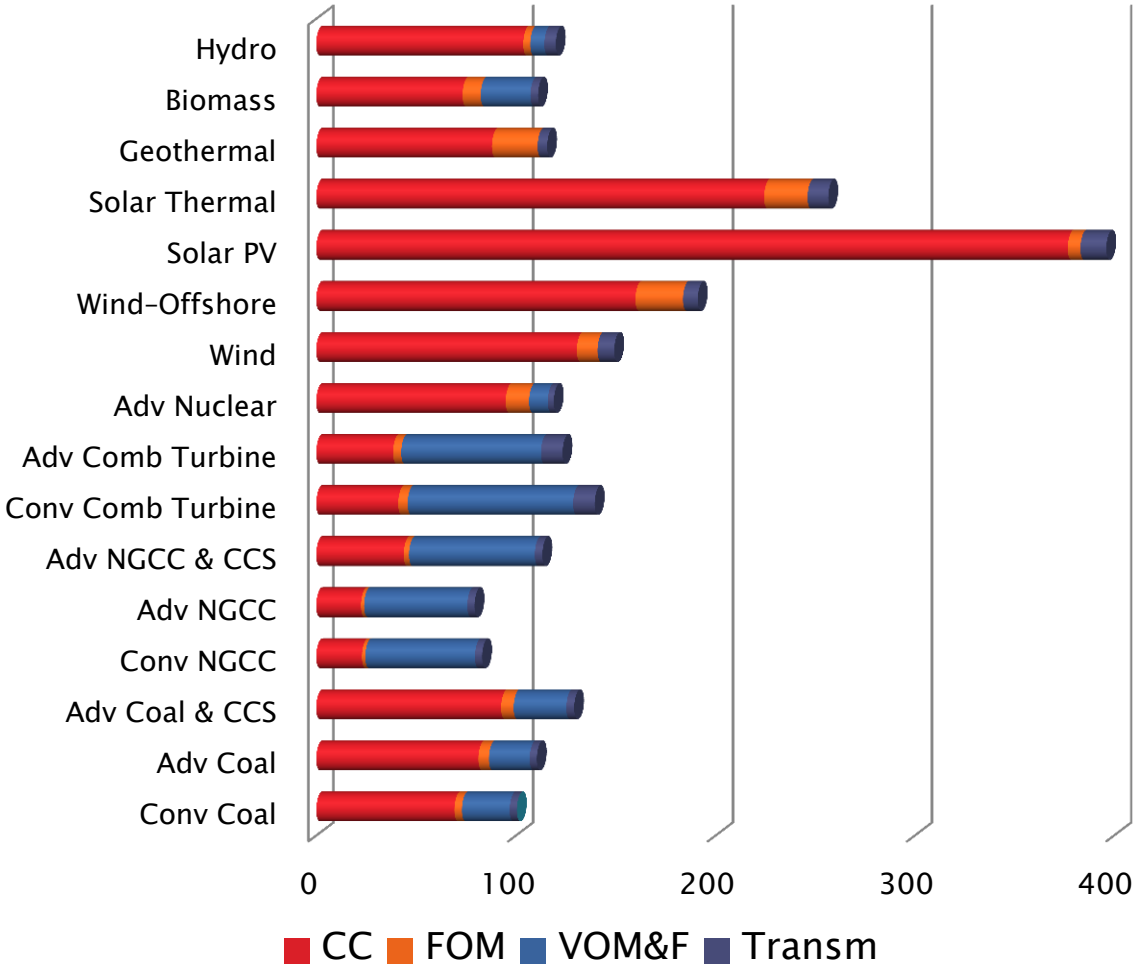
In general agreement, when carbon fee added, except for wind.

Similar differential for Figure 63 from EIA AEO2010. Perhaps due to "US average".

http://www.eia.doe.gov/oiaf/aeo/electricity_generation.html

EIA Presentation of Levelized COE

w/AEO-2010 (Data in 2008 $/MWh)



Source: http://www.eia.doe.gov/oiaf/aeo/electricity_generation.html

Uncertainty analysis is an important element of cost prediction

- Some reports conduct scenario analysis to evaluate how a changed assumption might influence technologies – such as:
  - Alternative carbon prices
  - Alternative costs of capital
  - Alternative economic growth rates
- This study examined uncertainties most important to each technology, although some affected multiple technologies.

Key issues associated with future prices for coal-based power include

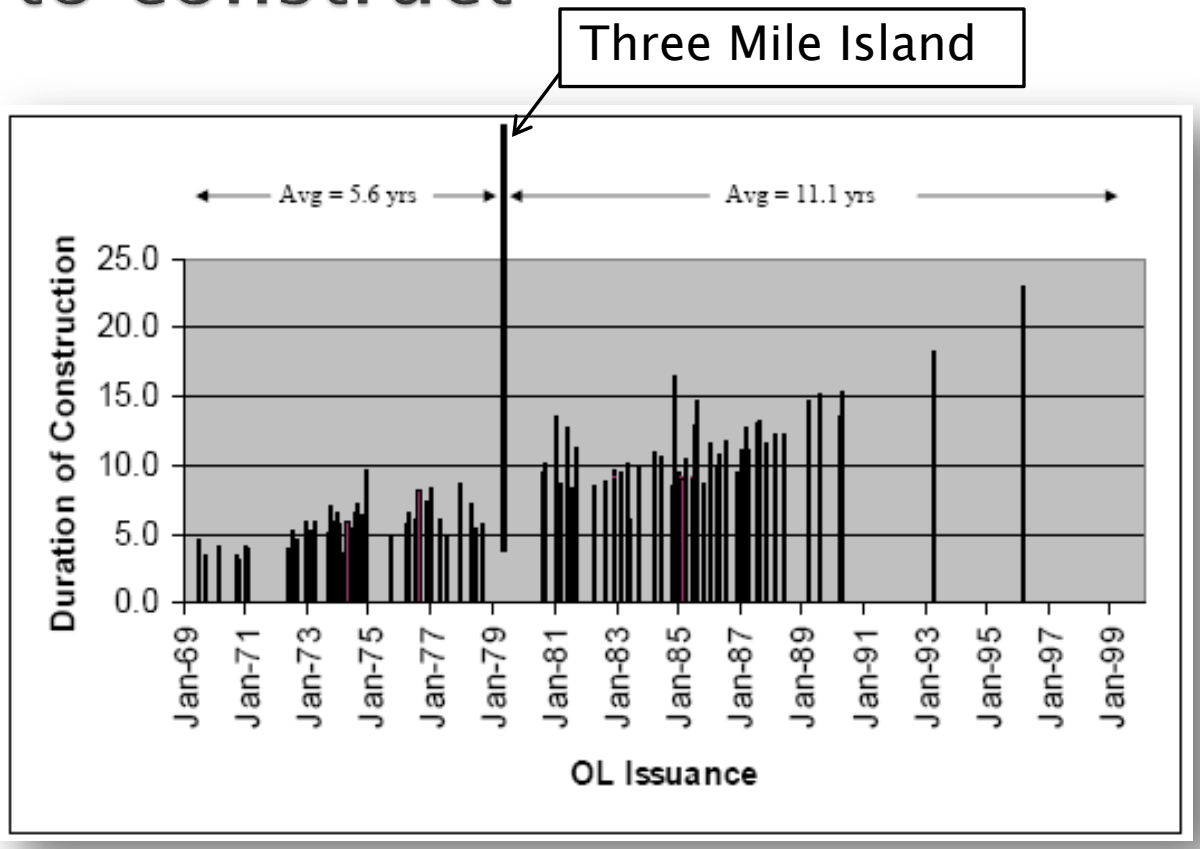
- Coal systems will be dominated by supercritical pulverized coal (SCPC) systems with post-combustion CCS, or Integrated Gasification Combined Cycle (IGCC) systems with pre-combustion CCS.
  - SCPC systems cost less, but the incremental cost of CCS is greater than IGCC
  - IGCC w/CCS may be a little less than SCPC w/CCS.
- CCS remains a large uncertainty
  - There are only 7 CO2 CCS projects globally that exceed 1 million tpy – None on commercial-scale power plants
  - 6 are at natural gas processing plants; the other is the Dakota Gasification (SNG) plant which feeds EOR.
  - A 600 MW coal-based power plant will store about 4-5 million tpy CO2
  - DOE projects the cost of power plants w/CCS to decrease dramatically due to RD&D
- IHS CERA reported their non-nuclear power plant capital cost index increased 60% between 2002 and 2009 (nuclear was more)
- This escalation was reflected in projected capital cost of several coal units (without CCS) which rose 40-80% above initial estimates

Nuclear power looks to next generation

- Over 20 licensing applications are before NRC
- Only Advanced designs qualify for tax incentives and loan guarantees
  - Advanced designs are large – limited fabrication facilities
  - Advanced designs may receive greater NRC scrutiny
- Escalation matters: 84% of COE is capital
  - Both IHS CERA and recent announced plant capital cost estimates show large increases in recent years
  - MIT Future of Nuclear Power doubled nuclear capital cost estimates from 2003 report, to 2009 update
- Financing matters
  - "Without loan guarantees we will not build nuclear power plants." – M.J. Wallace, Co-CEO, UniStar Nuclear, quoted in NY Times, 7-31-2007.
  - "We would expect that the plant operators would default on the borrowing that financed its capital costs." – p.12, CBO Cost Estimate report on nuclear loan guarantee proposed for S. 14, 5-7-2003.
  - Moody's June 2009 report implied "a more negative rating position" for companies borrowing to fund nuclear units.

US reactors built after 1980 took about twice as long to construct

Extended construction periods often result from required design changes. Those changes and interest charges can impact costs.



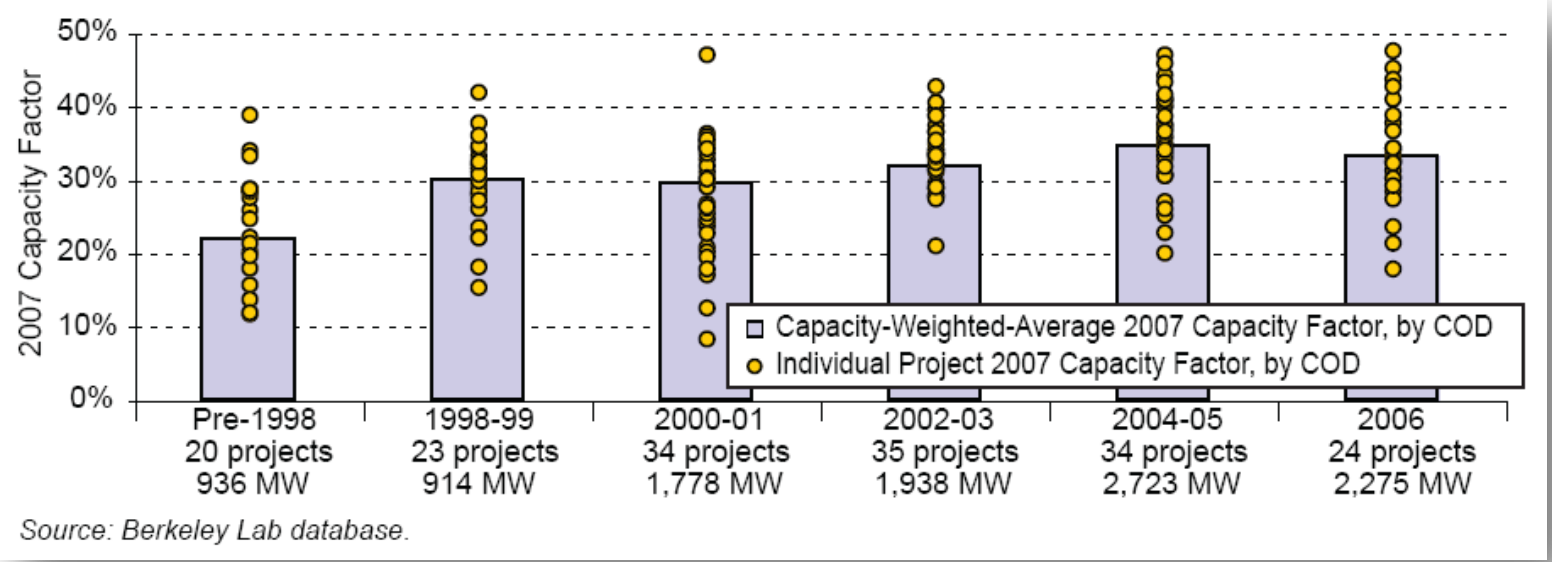
Source: NRC presentation, 2009.
(OL = operating license)

Important parameters for future nuclear costs include

- Short construction cycles, expedited NRC reviews, and low industry escalation are keys for low capital costs
- Indirect cost issues include fabrication capacity, and financing.
  - Some reports indicate that only Japan Steel Works can produce “ultraheavy” forgings (600 ton ingots) for large next-generation reactors. (22 over past 5 years)
  - Will a substantial number of units receive federal loan guarantees?

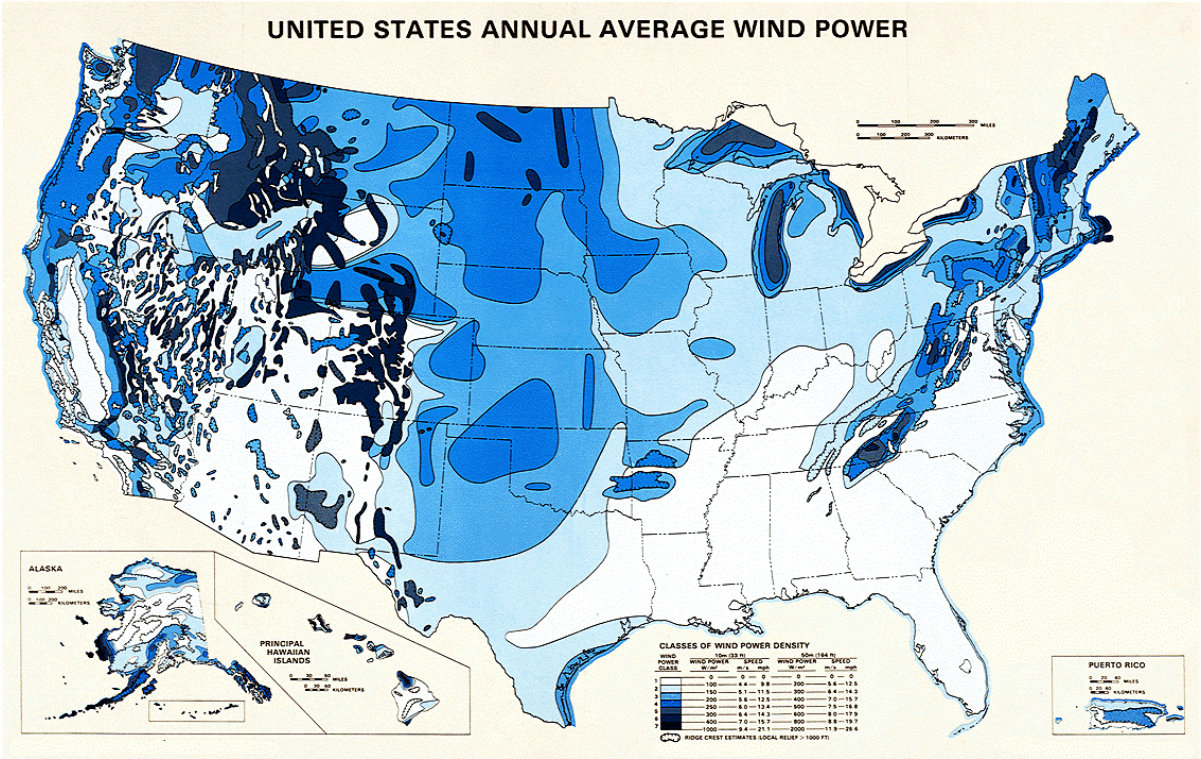
Wind energy is a little different

- Wind energy is intermittent, less than half the capacity factor of other technologies considered
  - How should backup power be considered?
  - Power pools credit ~ 15% of nameplate against peak demand
  - "lowest during the summer peak, … produced mostly at night"



COD is *commenced operation date*

- Best wind resources are in the West
  - How should long distance transmission be considered?
  - Multi-Power Pool study recommended $350/kw adder for transmission costs. NAE cited $300/kw median cost.



Source: NREL

Key wind uncertainties are

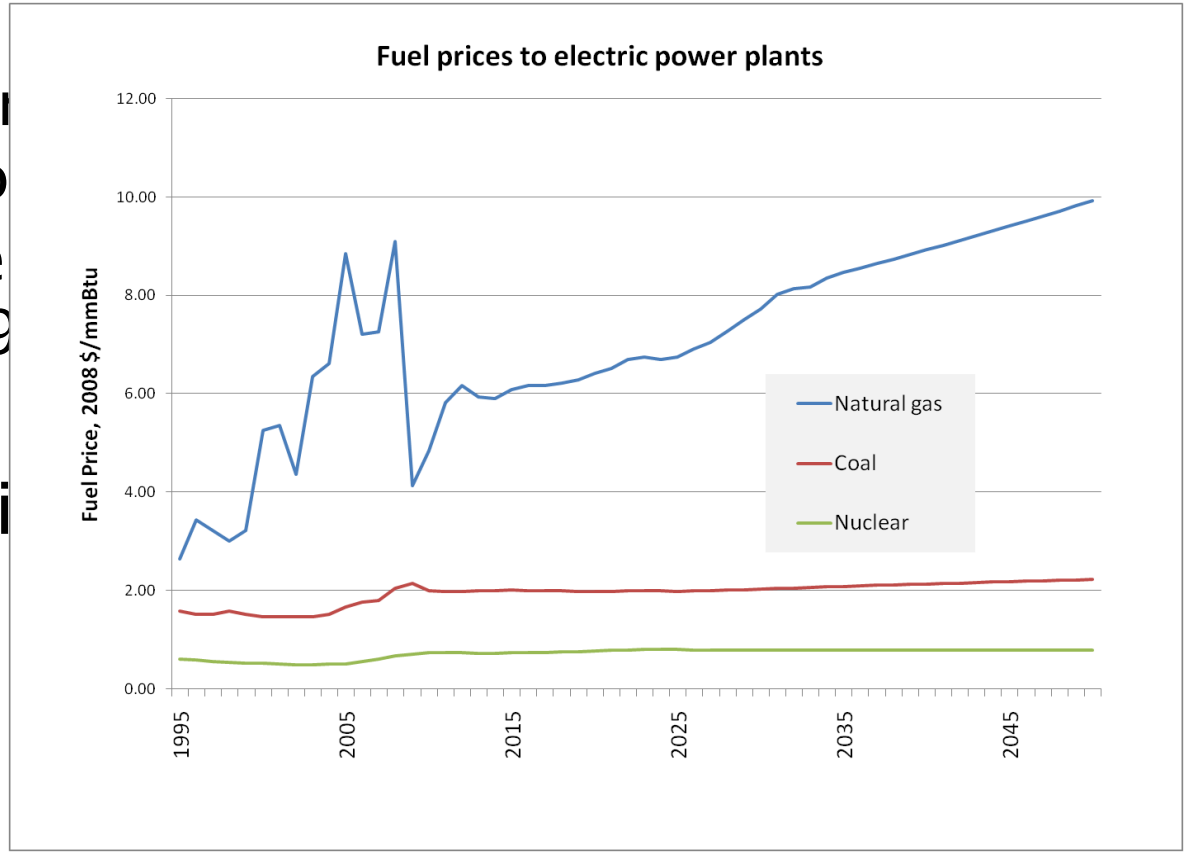
- Assumed capacity factors (improved technology versus consumption of best sites)
- Incorporation of backup power costs
- Incorporation of transmission costs

Natural gas enjoys important advantages

- NGCC has relatively low capital costs, short construction time, low environmental impacts, and is economical at moderate scale.
  - This allows owners to closely follow increases in demand, and reduces likelihood of overbuilding.
  - CO2 emissions per kWh are about one-half that of coal.
  - Technology is mature, reliable, and dispatchable.

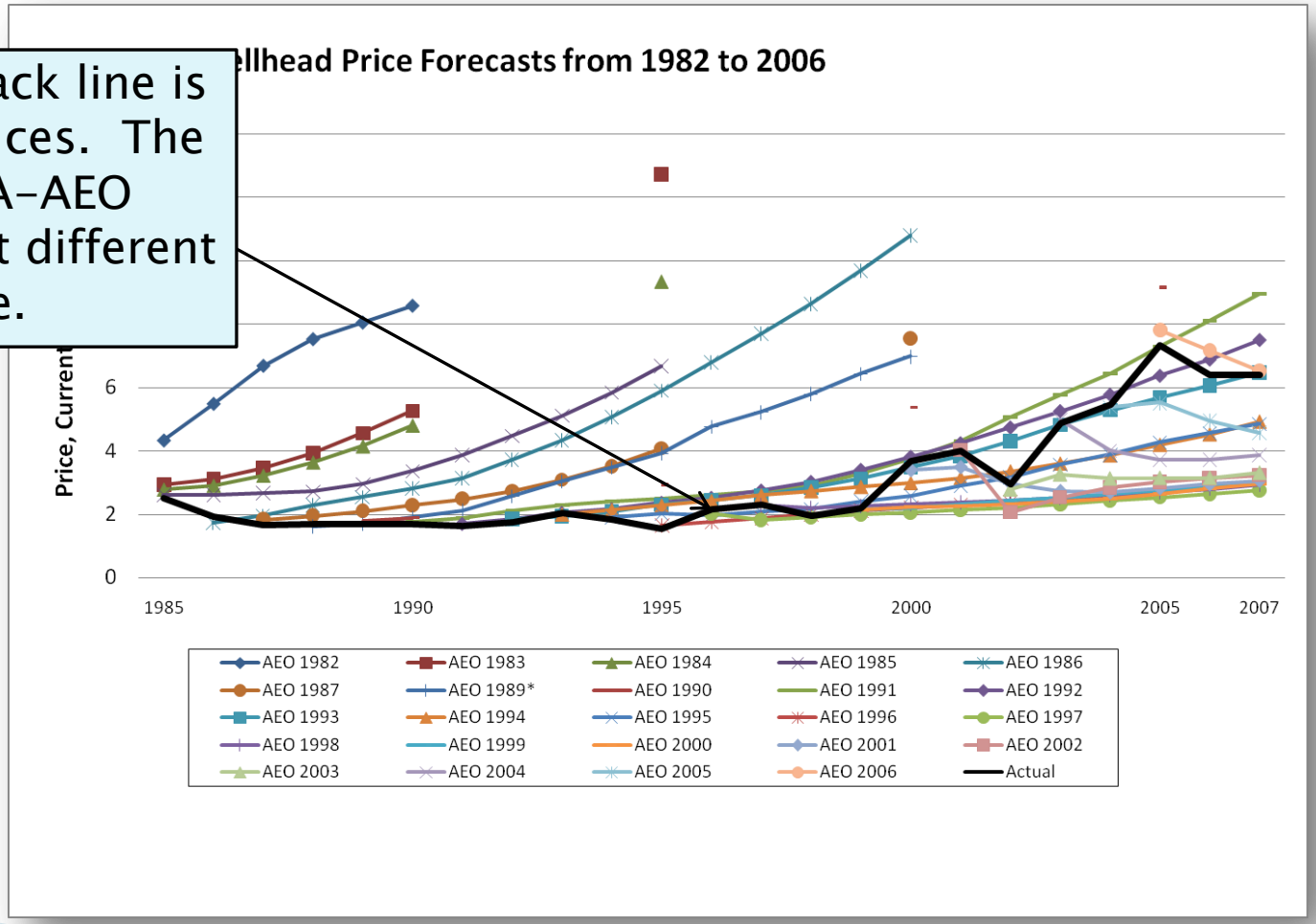
Issues related to NGCC are primarily

- Will need to use CCS to meet aggressive climate goals
  - Raises costs ar
    common to co
  - NETL estimate
    vs SCPC is $29
- The price and
  more uncertai



In general, predicting natural gas prices has proved challenging

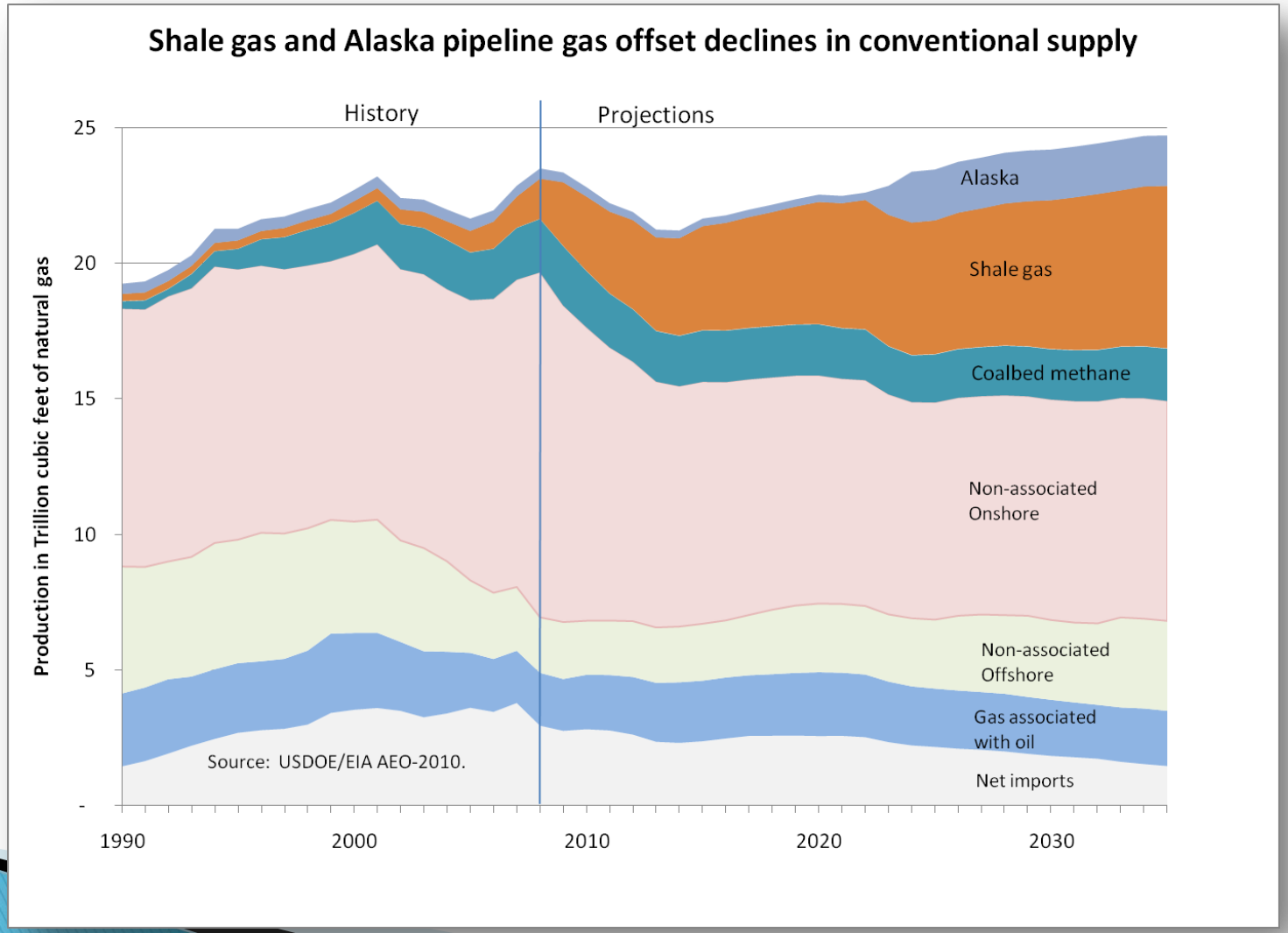
The heavy black line is actual gas prices. The others are EIA-AEO predictions at different points in time.



For NGCC, uncertainties are largely

- Whether and when CCS is added, along with the issues that travel with CCS
- Availability and price of natural gas
- Price escalation is an issue, but less than for other technologies

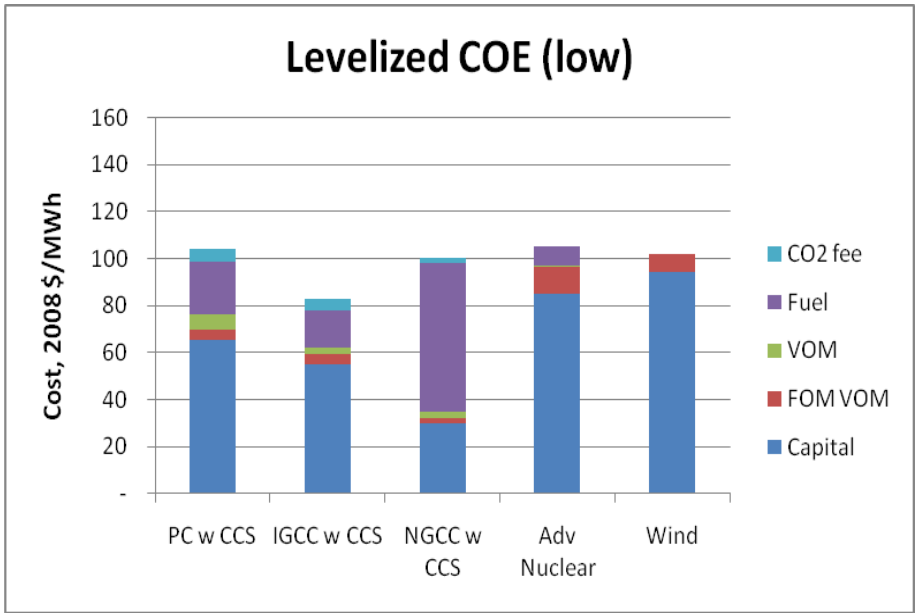
EIA projects Shale gas gains to offset conventional gas losses over the next 12 years

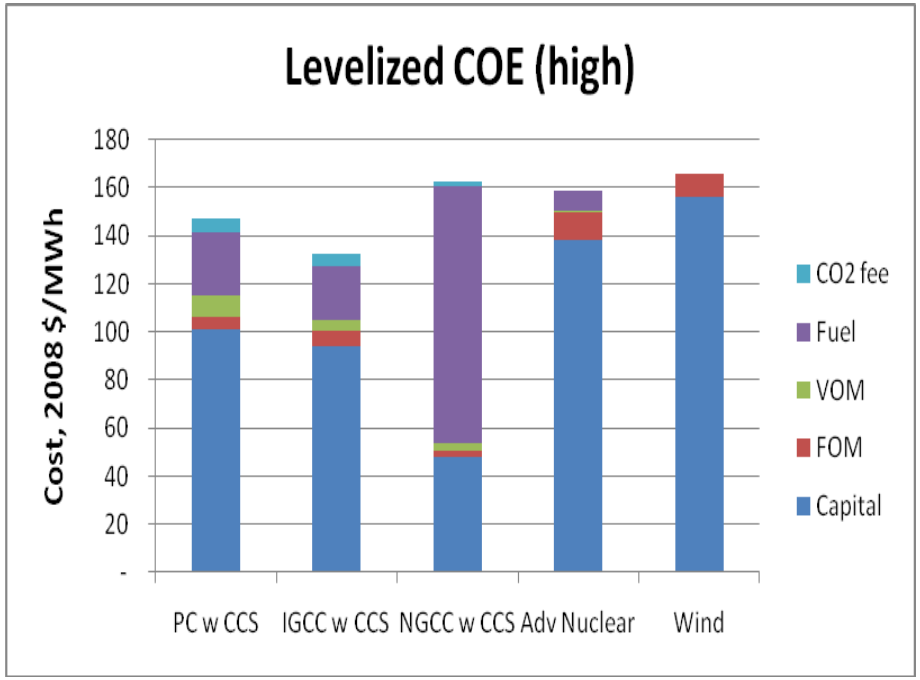


Rolling uncertainties together

Technology & Fuel	Low cost estimate	Mid-range estimate	High cost estimate
SCPC-coal	50% reduction in the incremental cost of CCS, based on R&D progress.	EIA 2010, adjusted for CCS with NETL-2007.	20% higher capital costs based on general escalation.
IGCC-coal	30% reduction in the overall cost of IGCC, based on R&D progress.	EIA 2010	20% higher capital costs based on general escalation.
NGCC	50% reduction in the incremental cost of CCS, based on R&D progress.	EIA 2010, gas prices for 2020-2035, extended to 2050 by rate of change between 2031-35.	20% higher capital costs based on general escalation. 50% higher price for natural gas.
Nuclear	20% reduction in capital cost, based on expedited permitting, "normal" cost of capital, experience with advanced nuclear designs.	NAE 2009, 2% risk premium on cost of capital, based on Moody's and MIT-2009.	30% higher capital costs based on the upper range in currently reported capital costs.
Wind	Improved capacity factor (45% vs 35%), based on additional remote siting in optimal wind areas.	EIA 2010, plus $300/kW transmission cost based on NAE 2009 and JCSP 2008.	Included capital cost of backup combustion turbine, per CA Energy Commission.

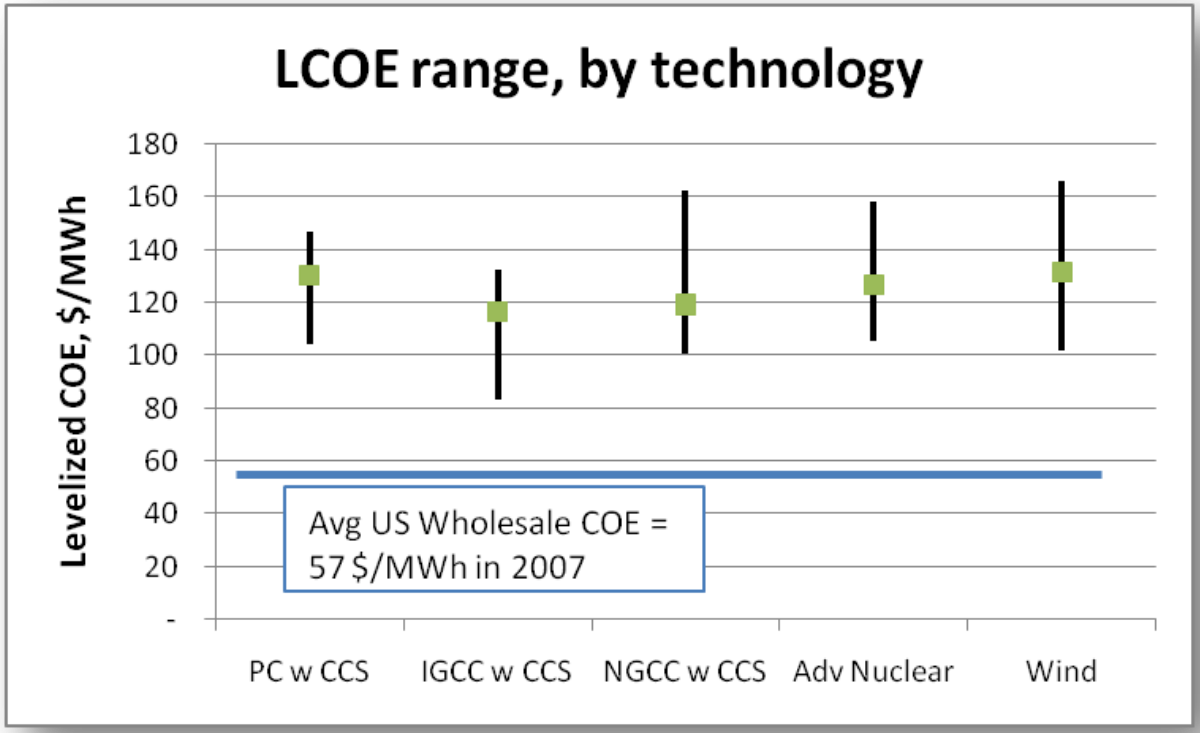
Comparison of low and high





Putting it all in one picture

- Successful RD&D can pay a large dividend
- But cost of low carbon technologies is going to be much higher than existing fleet
- "New" electricity will cost about twice "existing" electricity



(Green boxes reflect "best guess" and bars reflect range of optimism and pessimism.)

A logical question

- Might be: if competing technology costs are about the same, why has almost all recent new capacity been natural gas and renewables?
  - Large incentives exist for renewable power, and many states mandate a minimal RES.
  - Natural gas has low capital cost, and increased gas prices often can be passed through to ratepayers. If carbon limits are passed, emissions are lower than coal, fees can likely be passed through to ratepayer, and cost of abandonment is much less than coal.
- Subsidies & regulatory provisions will influence markets when options are otherwise close in price.

A partial review of incentives includes

- Approximately $21/MWh tax credit for renewable energy-electricity, 1st 10 years of operation [42 USC Sec. 13317]
- $18/MWh tax credit for nuclear – 6GW limit, 1st 8 years of operation. [IRC 45J]
- 80% loan guarantees for power plants using various technologies, including nuclear, renewable, and CCS [EPACT 2005, Title 17]. Lower Interest rate & D/E change ➔ ~ 30% reduction in COE.
- Accelerated depreciation of wind (5 year, DDB), and 1-yr "bonus depreciation" of 50% of investment. [IRC 168(e)(3)(B)(vi)]
- 30% investment tax credits for solar electric [IRC 48(a)]
- 30% ITC for manufacturers of renewable energy technology, CCS (limited to $2.3B) [IRC 48C]
- 30% ITC for systems with CCS (power and industrial) [IRC 48A and 48B]
- PTC for initial 75million tons of CO2 stored [IRC 45Q]
- Most of the above are limited by time or total amount.
- Additionally, renewable projects may be eligible for Renewable Energy Credits (RECs), which may sell for $15-20/MWh.

Takeaways

- In general, DOE/EIA estimates of power system costs are consistent with other estimates, and reported costs for actual systems. This study used somewhat higher values for nuclear and wind.
- When comparing costs, one should consider GHGs.
- Electricity from new power generation systems will cost about twice as much as current generation.
- Different technologies are helped/hurt by different types of factors.
- Significant cost reductions are possible via continued RD&D.
- Financial incentives and regulations influence technology choice.

Questions or comments …

"The Paper": Prospecting for Power: The cost of meeting increases in electricity demand, US Carbon Sequestration Council, May 2010. (www.uscsc.org)

L.D. Carter
Carter1819@comcast.net
703-772-9976