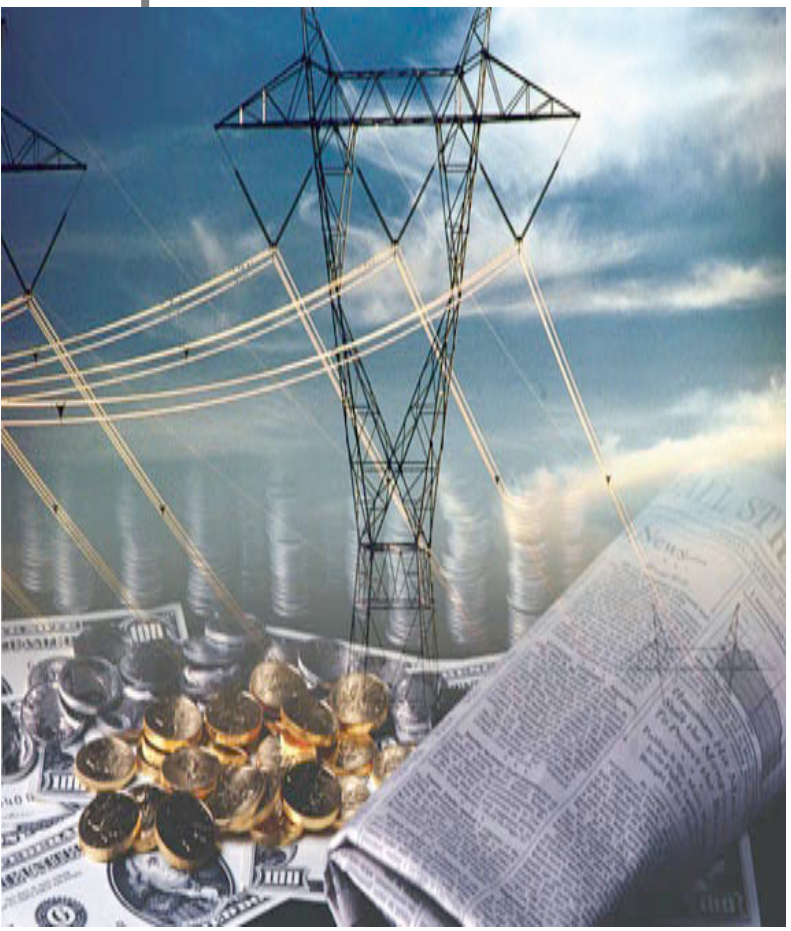

Power Market Assessment for New Nuclear Generation

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Study Objectives

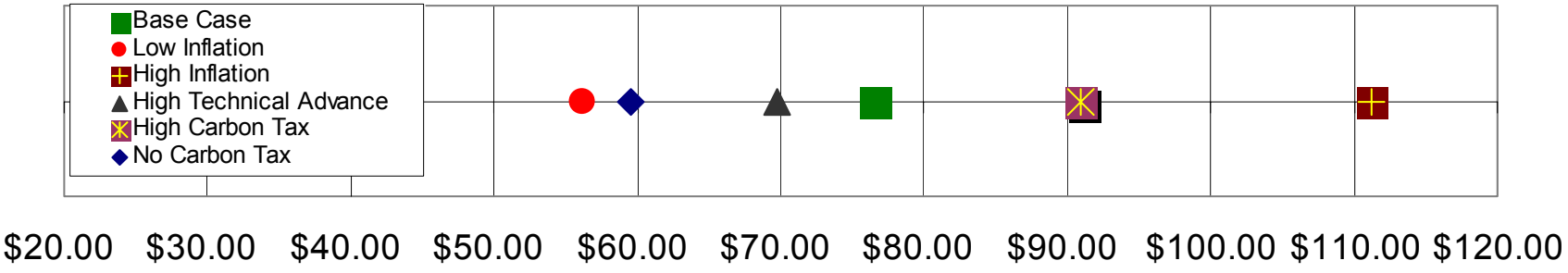
- Quantify projected power market prices for energy produced by a prospective nuclear generating unit coming online 2010-2015 and operating 40 years
- Qualify key drivers of power prices over plant's operating life
- Assess comparative economics for three candidate plant locations
  - Savannah River, SC
  - Portsmouth, OH
  - Idaho Falls, ID

Outline

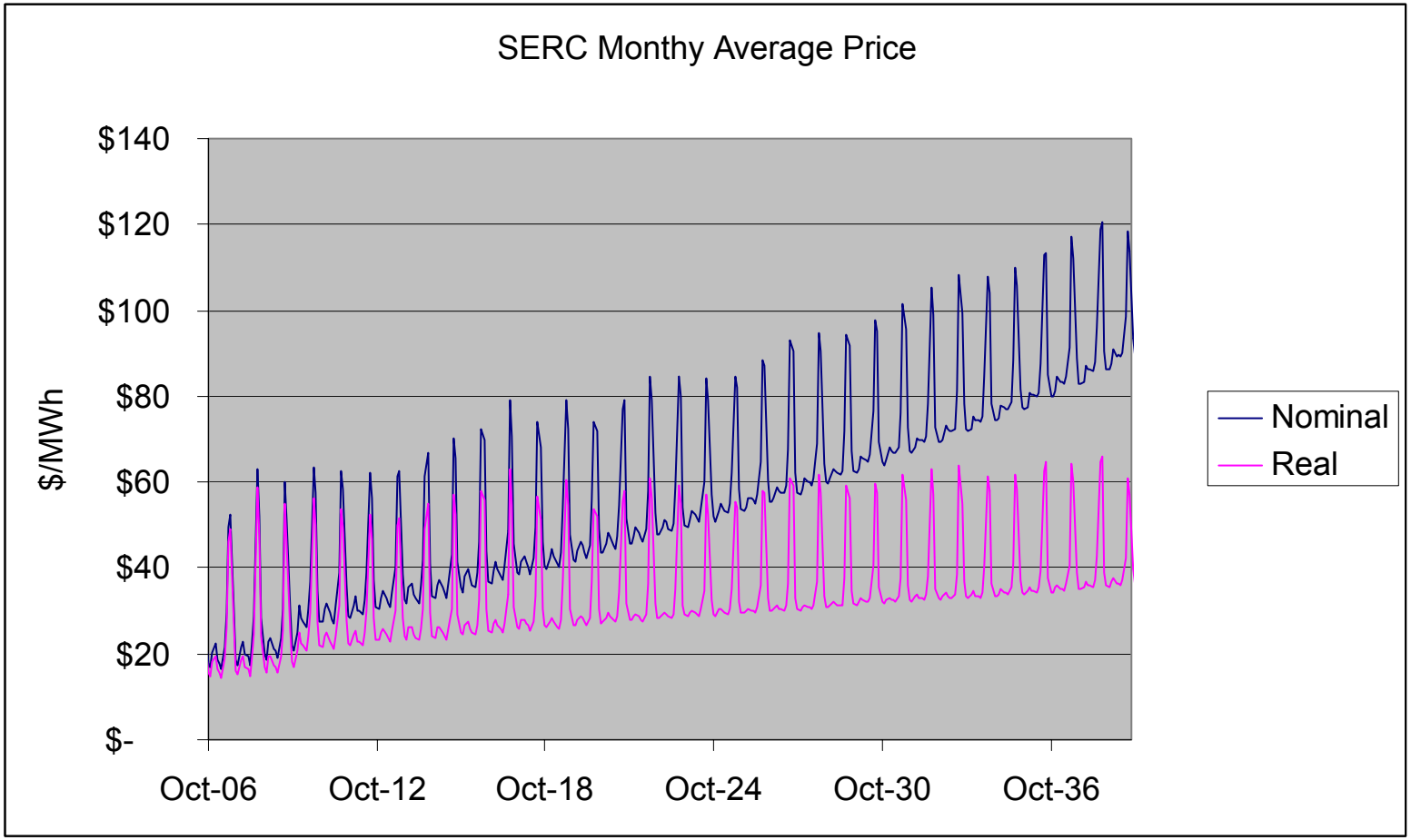
- Results summary
- Methodological approach
- Sensitivity analysis and Assumptions
- Regional findings
- Detailed Results

Summary of findings

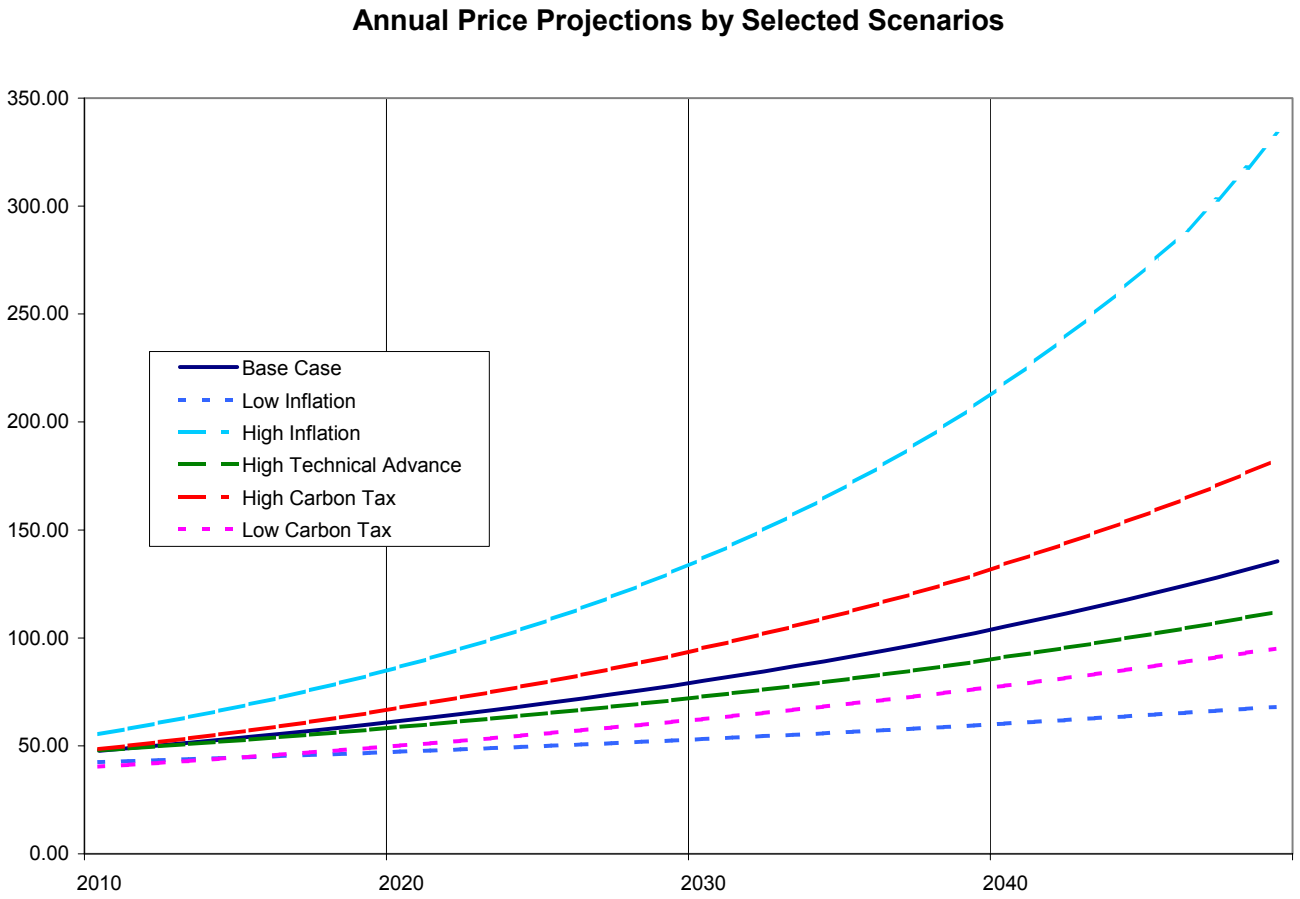
- Nominal base case electricity price projection, levelized 2010-2050: $77/MWh
  - Range: from $56 to as high as $111
- Prospective markets for three regions indistinguishable by 2050
  - Some factors work against WSCC in early years...
- Analysis showed broad range of cases due to uncertainty in:
  - Inflation
  - Capital costs of new units
  - Gas price escalation
  - Rate of technical advance in new generation
  - Valuation of carbon constraints due to climate policy



Prices grow over time due to inflation and real fuel cost growth, but offset by technical advances in new generation



Analyses show a broad range of plausible price trajectories, due to several fundamental uncertainties



Methodology approach accounts for uncertainties

"Forecasting is very difficult, especially if it involves the future."
Mark Twain

Issue	Last 50 years
Basic fuel of choice can change	Coal → oil → nuclear → coal → gas
Preferred technologies can change	Boilers → LWRs → gas CTs → gas Combined cycles
Price levels	Deflation to double digit inflation, averaging 4%/yr 1950-2000
Market structure	Regulation → competition → market regulation & ISO/RTOs
Environmental regulation	Particulates → SO2 → NOx → PM10, Mg → Carbon Tax
Loads Prices	1960-2000 energy sales +500% Prices real down 23%

While future is uncertain, our expectations are founded on solid information

What we know now:

- Current technology parameters (costs and heat rates of CC's and coal) for the most likely candidates
- Technology advances over time (evolution and revolution)
- Fuel prices are volatile but trends have been weak
- Seen aggressive market entry when profits are good
- There is widespread global concern about climate change

Basic approach and assumptions

- Prices will be set by competitive market
- Loads will grow in all markets leading to the need for new generating capacity
- Builders of new capacity will require sufficiently high prices to cover their capital and operating costs
- Profits above normal capital costs are not sustainable as they will bring in new entrants which will reduce prices and profits
- Nuclear generating units will have sufficiently low operating costs that they will dispatch at the bottom of the stack thus
  - Returns will be driven by average prices independent of daily/seasonal variability and volatility
- Economics of entry by new generation will provide a cap (upper bound) on average power prices over time
  - If below, entry discouraged until load growth raises prices again
  - If above entry threshold, new generation will lower prices
  - Disequilibrium conditions will not be sustained long term

Analytical methodology

- Price calculations based on analysis of entry costs for new generation using a simple financial model for competitive merchant generator
- Each year model calculates an “entry threshold” price needed to make entry worthwhile each year
  - Current year technology, its cost, and fuel prices
  - Effect of technology improvement on future cost recovery
  - Financing costs (cost of debt and equity, taxes)
- Entry threshold for 70% capacity factor entrants caps average prices for base load nuclear units with higher capacity factors
- Base case result is the lower of coal and gas threshold entry prices, levelized over the 2010-2050 time horizon
- Levelized price can be interpreted as single fixed contract price over candidate nuclear unit’s operating life

Economics of entry – Candidate technologies

1. Gas-fired combustion turbine combined cycle
   - Current technology of choice
   - ~$500/kW, 250-400 MW units
   - ~6,800 heatrate, 1-2 year build time
   - Lots of recent experience building
2. Advanced coal on threshold of viability
   - ~$1,100/kW, 250-500 MW units
   - ~9,000 heatrate, 3-5 year build time
   - Not much recent experience w. building
3. Fuel cells – look like small efficient CC's
4. Advanced solar, desktop cold fusion, other miracles

Gas CC's and advanced coal are entry candidates

- Relative economics depend on assumptions about capital cost, carbon taxes, gas price escalation
- CCs lowest cost at first, but compound real escalation of gas prices dominates long-run making coal possibly cheaper
- Expect market to install what's cheapest when time comes
- Lowest cost option puts upper bound on market price
- New entrants assumed to have capacity factors of 70%, prices lower than entry threshold remaining 30% of time
- Dynamics of boom-bust will increase price volatility but not greatly affect average price levels over time

Sensitivity analysis focused on five long-term price drivers

Price Driver	Low	Base Case	High
General inflation	**1.5%**	**3%**	**5%**
Technology cost ($/kW)	**$450 CC $1,000 coal**	**$500 CC $1,100 coal**	**$1,300 coal**
Rate of tech advance	**0.1%/yr**	**0.5%/yr**	**1.0%/yr**
Gas price escalation	**0%**	**1.1%/yr**	**2%/yr**
Carbon tax equivalent	**$0**	**$25/tonne C.**	**$50/tonne C.**

A sixth key uncertainty is the long term fuel-technology outlook... Will gas or coal technologies dominate new generation?

- If gas dominates the key driver will be the price of gas itself
- Carbon policy becomes less important in a gas-dominated world
- If coal dominates carbon policy will be a critical driver
- Also regional price differences in coal may tend to be stickier (see below)

Inflation assumptions

- Market prices for valuation and finance are typically nominal, not real
  - Inflation influences ongoing cash flows once an investment has been made
- Inflation affects entry price thresholds
- Inflation averages:
  - 1950-2000 → 4%/yr
  - 1990-2000 → 2.4%/yr
- Base case assumed to be 3%/yr
- Sensitivity cases are 1.5% for low, 5% for high

Capital cost assumptions

- Gas CC capital costs are uncertain within narrow range
  - Cost of manufacturing vs. price sold
  - Prices higher in boom cycle, lower in bust cycle
- Recent prices approximately $500/kW, may be as low as $450/kW in normal market
- Coal cost of highly environmentally controlled pulverized coal boiler was in $1,500/kW range in past
- Technical advances in manufacturing and low demand brought prices to $1,100/kW range
  - May go as low as $1,000, or to $1,300 for advanced units

Technical advance assumptions

- Technical advance rates work to lower capital cost and heat rates for new units
- Technical advances have been a key factor in past, but specifics for long-term are speculative
- 2050 is a long way off...
- Analysis used broad range of assumptions
  - 0.1% (we're close to as good as we'll ever get)
  - 0.5% (base case – meets aggressive objectives)
  - 1.0% (a lot can happen in 50 years)

Technical advance assumptions & implications

	Gas CC		Advance Coal	
	Capital Cost	Heatrate	Capital Cost	Heatrate
2002	$500	7,000	$1,100	9,000
2050 @				
0.1%/yr	$477	6,672	$1,048	8,578
0.5%/yr	$393	5,503	$865	7,075
1.0%/yr	$309	4,321	$679	5,556

Some changes sufficiently dramatic over time to represent fundamental changes in the technology, e.g., fuel cells

Escalation in fuel prices

- Coal prices declining with increased mining productivity and shrinking demand, assume 1%/yr decline in coal prices (to $0.7 in 2050)
- Gas prices volatile but mild upward trend, assume real escalation of:
  - 2%/yr (as used by climate policy analysts)
  - 1.1%/yr (assumption of EIA Energy Outlook to 2020)
  - 0.0%/yr (technical progress keeps defeating resource depletion effects through drilling technology, new resource discoveries, and LNG in a world awash with natural gas)

Implications of gas price assumptions
Real price outlook

	Gas Price
2002	$3.0
2050 @	
0.0%/yr	$3.0
1.1%/yr	$5.1
2%/yr	$7.8

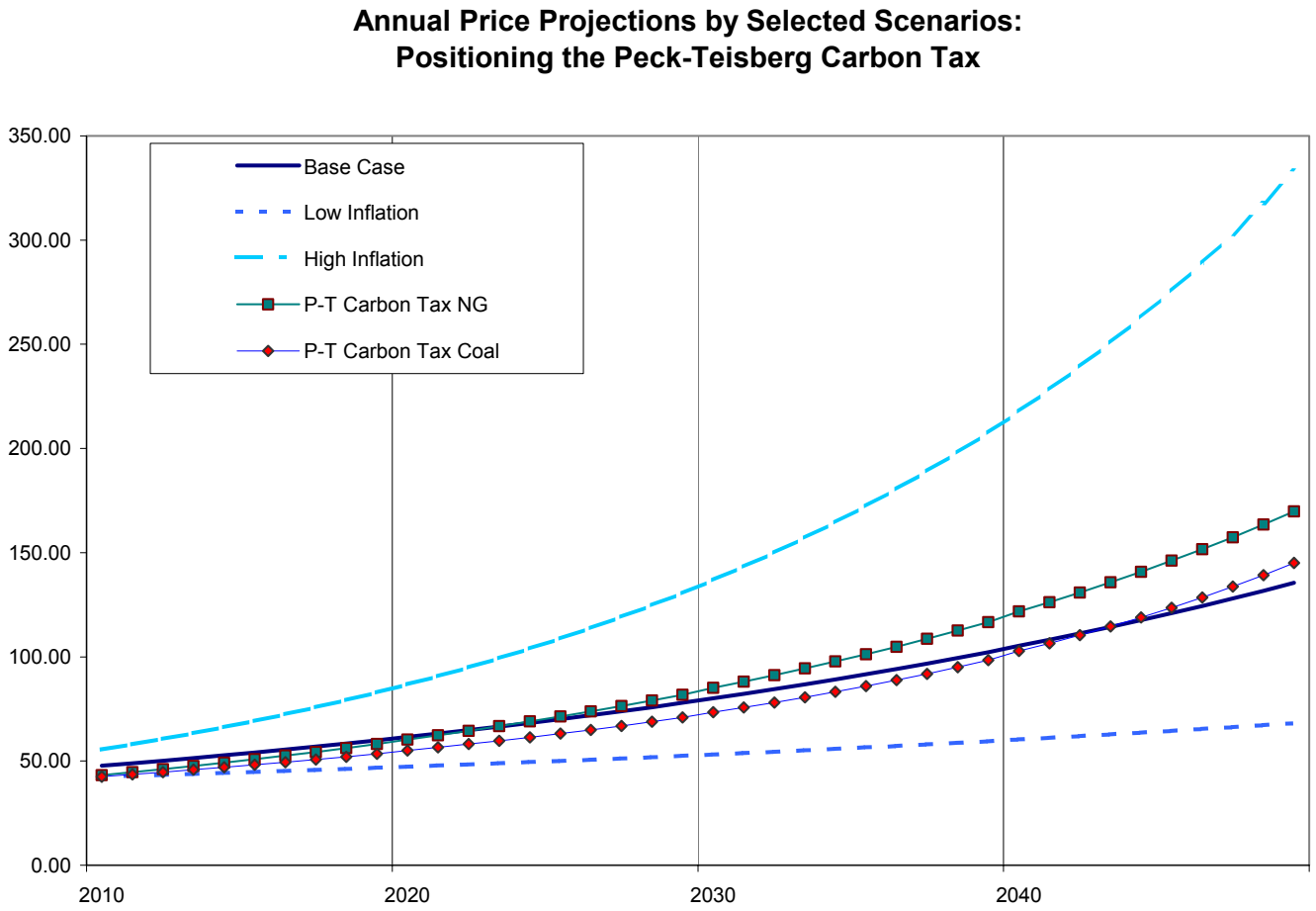
Carbon tax assumptions

- Climate change a worldwide concern
- Difficult to imagine U.S. will not participate eventually
- Many forms of policy (cap & trade, taxes, offset) result in a shadow price on emissions affecting generating costs and thus market prices
- We use a tax as a proxy for as yet undefined policy
- Tax assumptions based on large proprietary study with joint participation of industry and environment groups
- $25/tonne C. in 2010 (+2%/yr esc.) approaches 650ppm in 2100 atmospheric concentration target (base case)
- Need $50/tonne to hit 550ppm target (high case)
- May never happen ($0/tonne is low case)

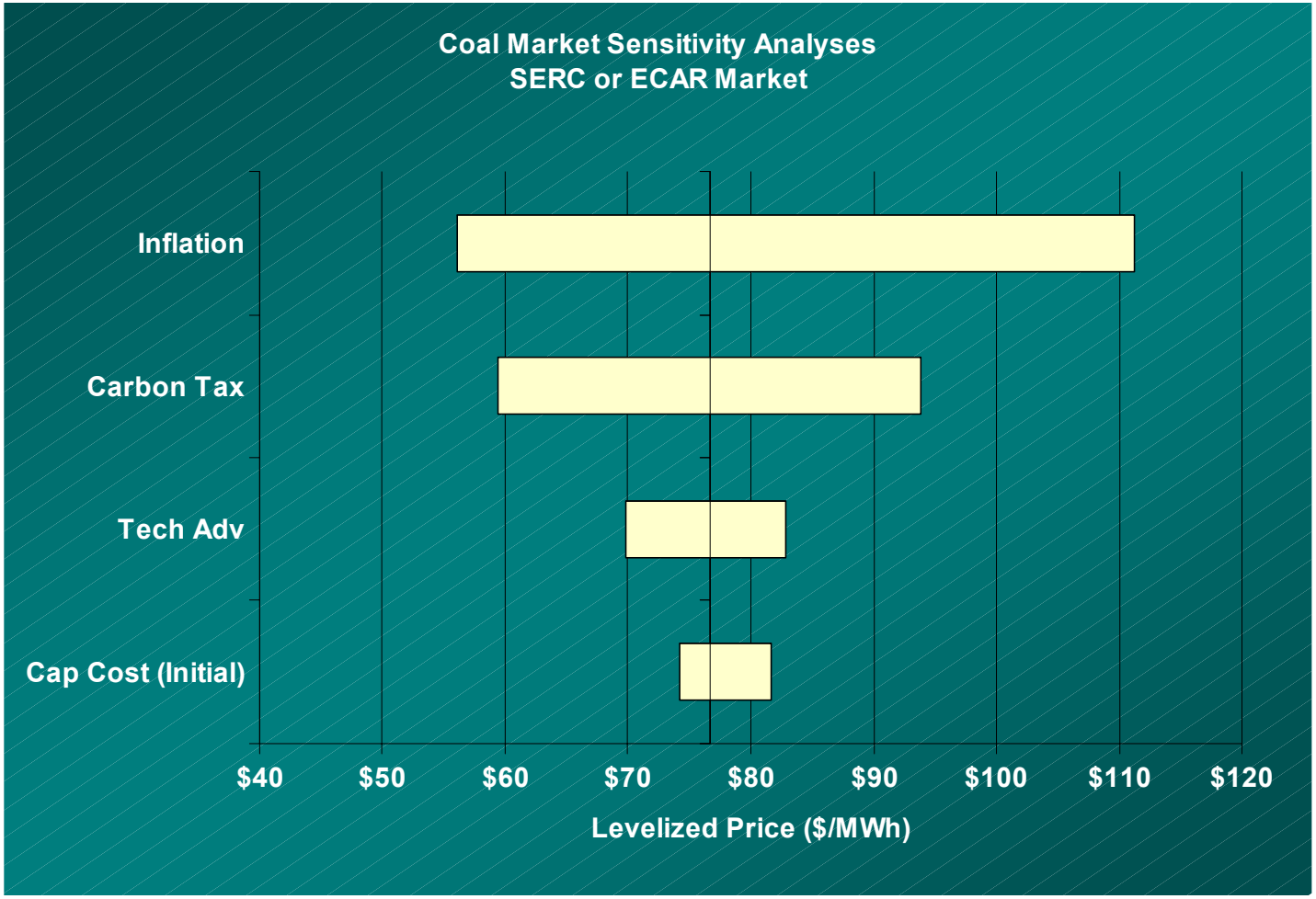
Carbon tax assumptions: An alternative approach

- An interesting idea is offered by Stephen Peck (former EPRI VP) and Thomas Teisberg (University of Virginia)
- "A Long Term Permit Program for Long Term Climate Change Mitigation", Peck and Teisberg
  - Start the tax small (~$6.50/ton) and escalate more steeply (to over $200/ton {2010 dollars} in 2070
  - Escalation rises at the real interest rate (5%) plus the rate of natural carbon depletion from the atmosphere (1%) - 6% real
  - Effect is to make an emitter indifferent over time as to when reduction occurs...
- The levelized price falls reasonably within the range of assumptions made above

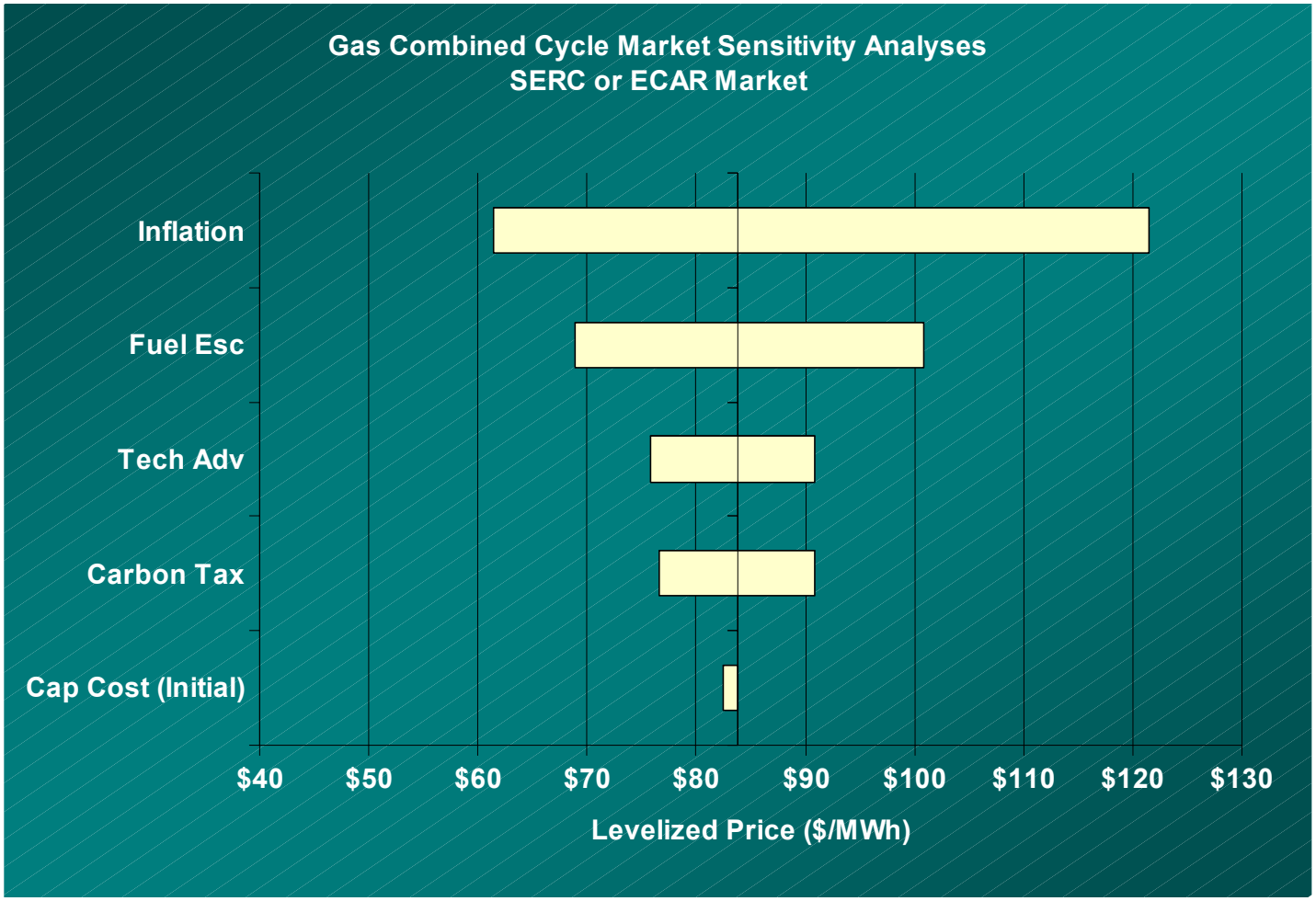
The Peck-Teisberg carbon tax is consistent with other approaches...



Tornado diagrams show relative importance of key price drivers for advanced coal unit

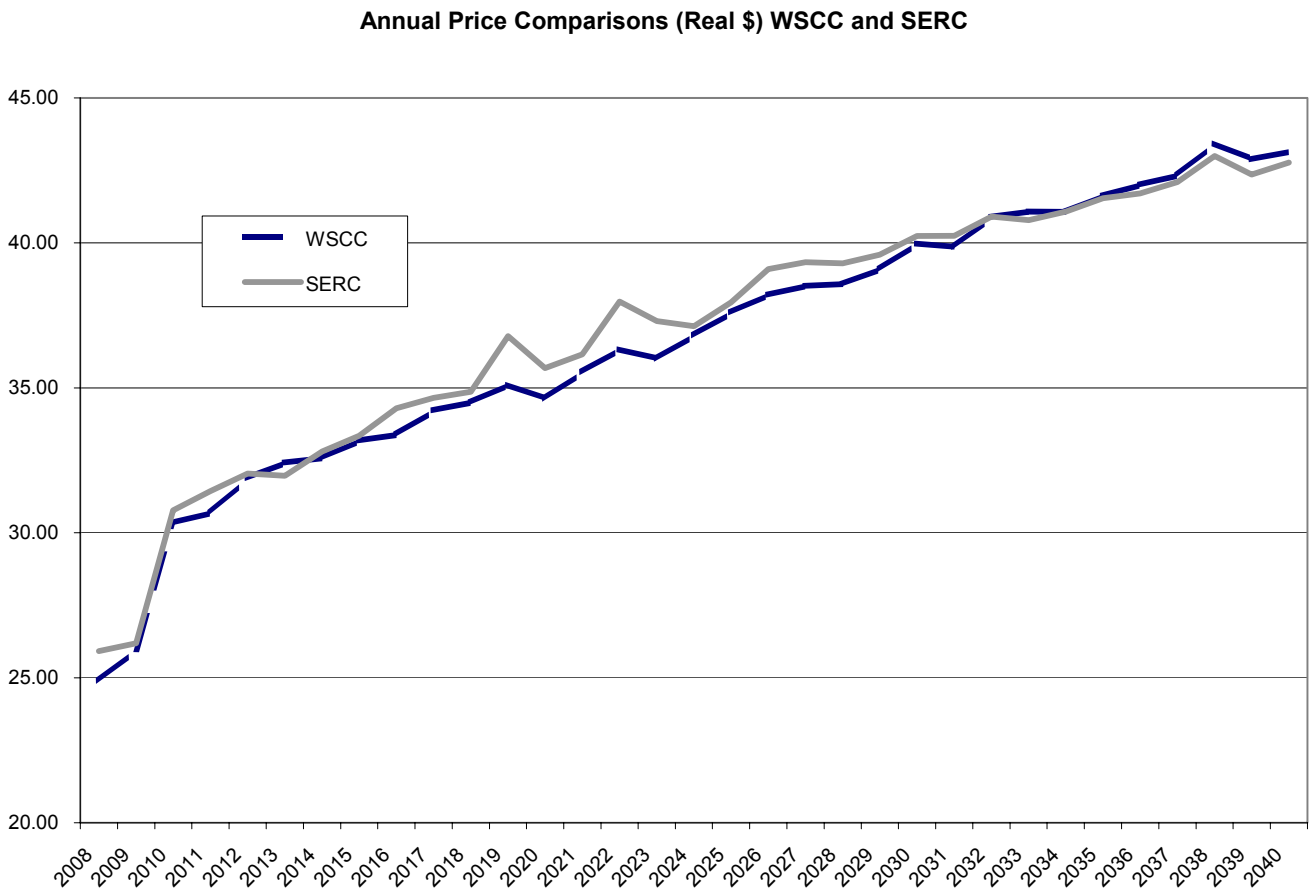


Tornado diagrams show relative importance of key price drivers for gas CC



Regional findings

By 2050, there is little basis to expect permanent, material differences in prices between the three regions



Regional findings II

- Key drivers are mostly region-neutral
  - inflation
  - gas price escalation
  - capital costs of new units
  - rate of technical advance
  - climate policy
- Possible exceptions - risk factors
  - coal price differentials - expected slightly lower in the West
    - due to PRB coal influence
  - technology capital costs - expected slightly higher in the West
    - allow for permanent stickiness due to land, water, labor tightness
  - transmission constraints in the West
    - plant in Idaho, load in California...
- Disequilibrium factors
  - may cause short term constraints of various kinds, but are unlikely to persist fifty years regardless of origin...
  - they can play a role in early years of the plant life cycle...

Regional Findings III
Coal Price Differentials

- In the medium term, if gas prices escalate, and carbon tax stays low, advanced coal technology could begin to dominate new generation
- Western coal is generally cheaper than Eastern coal (Powder River influence), so this differential could be important
- WSCC electric prices could then begin to fall relative to the Eastern regions
  - There is potentially close to a 20% gap by 2010, as much as 12% by 2025, shrinking thereafter as demand pressures close the coal price gap
- In this scenario WSCC looks less attractive, at least for a time...

Regional Findings IV
Technology Costs and Constraints

- It may be more expensive to build capacity in the West
  - historical pressures on land use, labor scarcity, water use, etc...
  - this could tend to drive prices up
    - for a transitional period, or...
    - perhaps permanently
- At the same time, there is today a more serious transmission problem in the West than in ECAR or SERC
  - plant site in Idaho, key load in California
  - in the East, the sites are much better connected
  - if construction pressures remain for plants, they'll be even worse for T-lines
- In the medium term the transmission constraints may dominate
- Its hard to imagine, on the other hand, a permanent gap...

Disequilibrium conditions

- Overall, it is unlikely that permanent disequilibrium conditions can be sustained in any region over fifty years...
- There is some potential for “boom-bust” cycles in capacity addition in any of the regions, over the next fifty years
  - This will result in some short term oscillation of the electricity price around the long term trend, but on average the trend should prevail
  - In the long term needed capacity will get into the regions, although not necessarily smoothly year-by-year
- Still today’s constraint environment will persist for a time
  - transmission “stickiness” in the West...
  - coal prices in the West...
- Best guess:
  - Disequilibrium will play a role early in plant life cycle (through 2020-25)
  - After that regional differences will begin to smooth out

Detailed results

	Base Case		Inflation				Price of Fuel		Technical Advance				Carbon Tax			
			Gas	Gas	Coal	Coal	Gas	Gas	Gas	Gas	Coal	Coal	Gas	Gas	Coal	Coal
	2002	2002	2002	2002	2002	2002	2002	2002	2002	2002	2002	2002	2002	2002	2002	2002
Capital Cost ($/kW)	500	1,100	500	500	1,100	1,100	500	500	500	500	1,100	1,100	500	500	1,100	1,100
O&M Cost ($/MWh)	4.00	8.00	4.00	4.00	8.00	8.00	4.00	4.00	4.00	4.00	8.00	8.00	4.00	4.00	8.00	8.00
Heat Rate (btu/kWh)	7,000	9,000	7,000	7,000	9,000	9,000	7,000	7,000	7,000	7,000	9,000	9,000	7,000	7,000	9,000	9,000
Availability (percent)	70%	70%	70%	70%	70%	70%	70%	70%	70%	70%	70%	70%	70%	70%	70%	70%
Gas Price ($/mmbtu)	3.00	1.20	3.00	3.00	1.20	1.20	3.00	3.00	3.00	3.00	1.20	1.20	3.00	3.00	1.20	1.20
Rate of Tech. Advances	0.5%	0.5%	0.5%	0.5%	0.5%	0.5%	0.5%	0.5%	0.1%	1.0%	0.1%	1.0%	0.5%	0.5%	0.5%	0.5%
General Inflation Rate	3.0%	3.0%	1.5%	5.0%	1.5%	5.0%	3.0%	3.0%	3.0%	3.0%	3.0%	3.0%	3.0%	3.0%	3.0%	3.0%
Fuel Price Escalation (real)	1.1%	-1.0%	1.1%	1.1%	-1.0%	-1.0%	0.0%	2.0%	1.1%	1.1%	-1.0%	-1.0%	1.1%	1.1%	-1.0%	-1.0%
carbon content	30	56	30	30	56	56	30	30	30	30	56	56	0	30	0	56
	NG	Coal	NG	NG	Coal	Coal	NG	NG	NG	NG	Coal	Coal	no tax	NG	no tax	Coal
2010	$45	$48	$40	$53	$42	$55	$43	$48	$45	$46	$48	$48	$42	$48	$40	$55
2020	$63	$62	$49	$89	$47	$87	$56	$70	$65	$60	$64	$59	$58	$68	$50	$73
2030	$88	$80	$58	$150	$53	$137	$72	$104	$95	$80	$86	$73	$81	$95	$62	$98
2040	$123	$105	$71	$253	$60	$218	$95	$156	$137	$106	$118	$91	$111	$134	$78	$133
2050	$171	$139	$85	$428	$69	$349	$124	$232	$200	$141	$163	$115	$154	$189	$97	$181
Price Growth Rate	3.4%	2.7%	1.9%	5.4%	1.2%	4.7%	2.7%	4.0%	3.8%	2.9%	3.1%	2.2%	3.3%	3.5%	2.2%	3.0%
Levelized Price	$83.74	$76.64	$61.43	$121.36	$56.12	$111.20	$68.85	$100.87	$90.87	$75.86	$82.81	$69.78	$76.60	$90.88	$59.49	$93.78