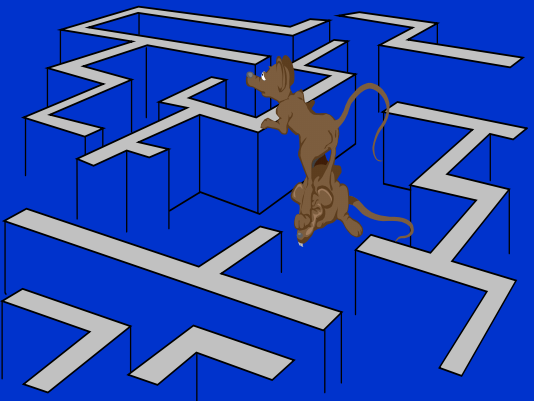
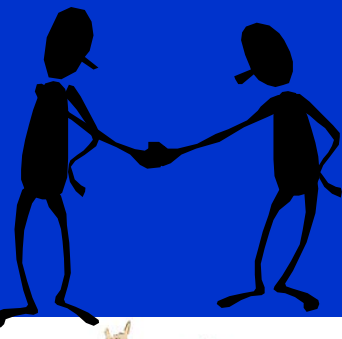
Carbon Policy
Where is the Light Good?



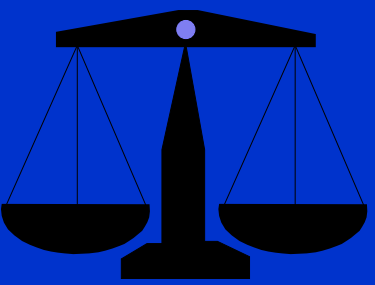


Richard O'Neill, Member
Chief Economic Advisor
Federal Energy Regulation Commission
richard.oneill@ferc.gov

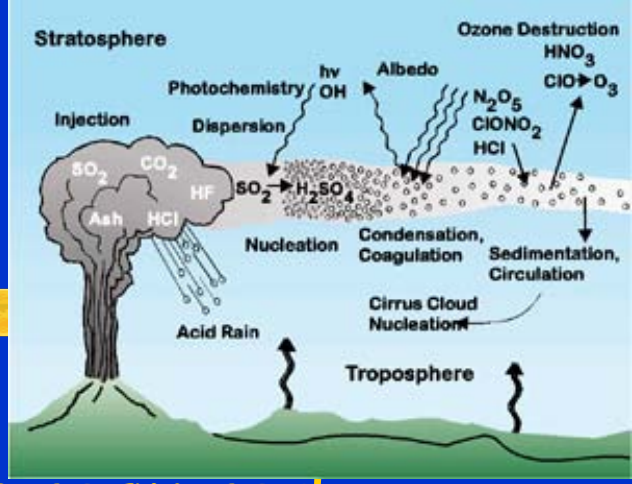
Harvard Electricity Policy Group.

December 9, 2010

Views expressed are not necessarily those of the Commission



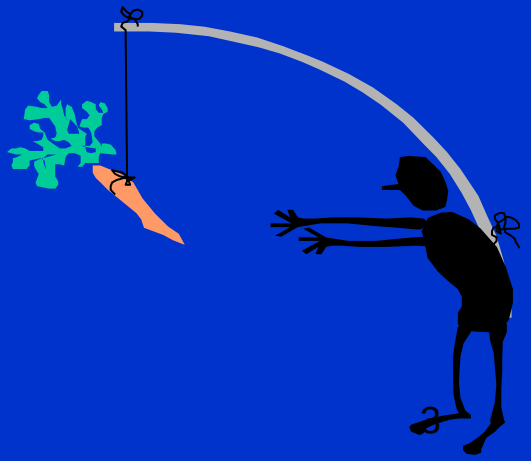
Cap And Trade Experience from SO2 Markets



- Title IV of the 1990 Clean Air Act required reductions in SO2 and NOx emissions
  - SO2 program affected 3,456 electric generators
  - NOx program affected 982 coal-fired generators
- Since 1995, the ARP has :
  - reduced SO2 and NOx emissions
  - improved water quality in lakes and streams.
- reduced implementation costs by allowing choose cost-effective compliance choices
- Prices much lower than anyone predicted

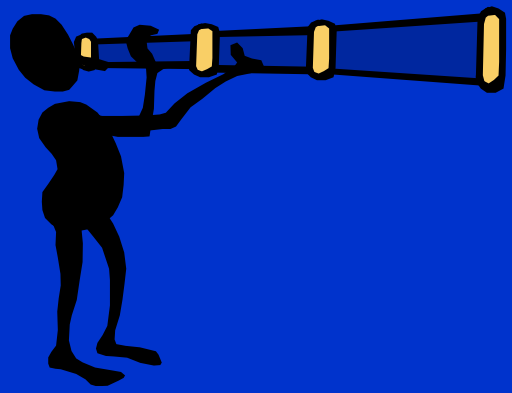
carbon policy in the US

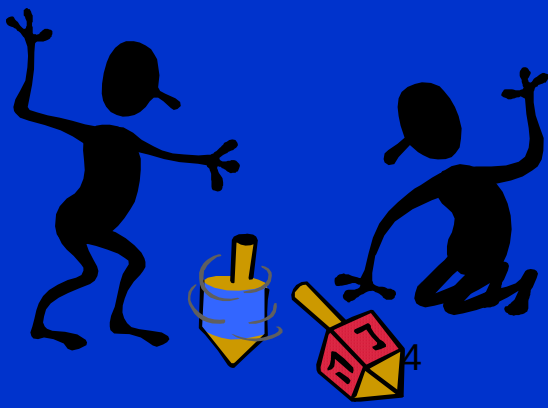
- A federal carbon price is not near
- Is there an effective federal carbon policy without a carbon price?
- what 'second best' 'two-fors' are achievable?
- Thinking a century ahead
  - Not Katrina
  - options approach
- The incentives matter
  - subsidize investment: weak
  - subsidize output: stronger
  - stimulate innovation



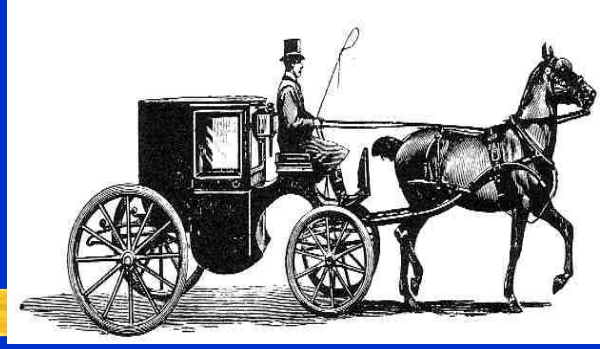
Can we pick winners?

- 19th century:
  - emissions problem for large cities
  - telephony
  - electricity
- 20th century
  - computer hardware
  - nukes
  - natural gas
  - energy





A 19th century environmental problem



- the principal emissions problem for large cities
  - the emissions of transportation engines (horses).
  - Luckily it was local and observable problem.
- 1894, Times of London's model estimates by 1950
  - every street would be nine feet deep in horse manure.
- Innovation available but apparently ignored
  - 1882 Edison's Pearl Street Station
  - 1885 Karl Benz had a practical automobile
- Was investing in horse manure clean up a good bet?
- Choosing winners is not usually good for innovation.

Late 19th Century paradigm shifts

- telephony:
  - Telegraph (Morse) v. (Bell)
  - telephone wins
  - internet and cell phones
- Electricity:
  - DC (Edison) v. AC (Westinghouse)
  - AC wins
  - smart grid

20th Century paradigm shifts

- Expensive to cheap fossil energy
  - Coal
  - oil
  - natural gas
- Economic regulation
  - command-and-control cost-of-service to
  - incentive based regulation
- computers
  - None to
  - big computers to
  - smaller and faster computers

New computer hardware paradigm

- 1945, **ENIAC** (30 tons)
  - 19,000 vacuum tubes, 1,500 relays, and 200 kW
  - 350 flops, 400 bytes
- 2008 IBM Roadrunner 1 Peta (10^{15}) FLOPs
- 2009 Cray Jaguar 1.8 Peta FLOPs
- Iphone more computing capacity the early super computers. 5×10^6 FLOPs; 16×10^9 bytes
- 1 year (3×10^7sec) becomes less than 1 second
- Will Moore's law continue?

Forecasting Nukes

- The Atomic Energy Act of 1954 (P.L. 83-703) allowed private development of commercial nuclear power
- Lewis L. Strauss: "Our children will enjoy in their homes electrical energy too cheap to meter."

  Chairman, Atomic Energy Commission before National Association of Science Writers, NYT, Sept. 17, 1954

- Fifty utilities built custom nuclear plants under cost-of-service regulation. The result

HISTORICAL U.S. CONSTRUCTION COST EXPERIENCE

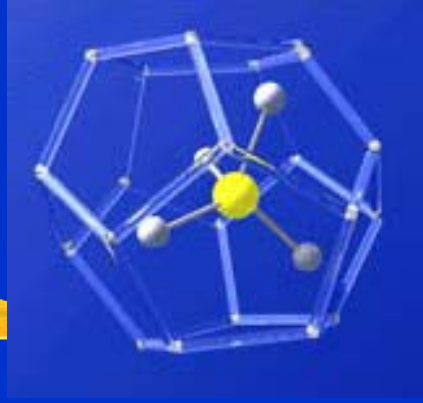
for nuclear plants under cost-of-service regulation

Construction Started	Estimated Overnight Cost	Actual Overnight Cost	% OVER
1966-67	$ 560/kWe	$1,170/kWe	209%
1968-69	$ 679	$2,000	294%
1970-71	$ 760	$2,650	348%
1972-73	$1,117	$3,555	318%
1974-75	$1,156	$4,410	381%
1976-77	$1,493	$4,008	269%

Source: U.S. EIA

too cheap to too expensive

forecasting natural gas



- Early 20th century: negative price
- 20th century predictions: running out almost all have been proved wrong
- 1978 Natural Gas Policy Act provided incentives for increased production
- In 1980, the average price forecast for 1995 was high by a factor of 5
- Underestimated the role of innovation:
  - 4-D seismic
  - Directional drilling
  - Hydraulic fracturing

'unconventional' natural gas resources in US

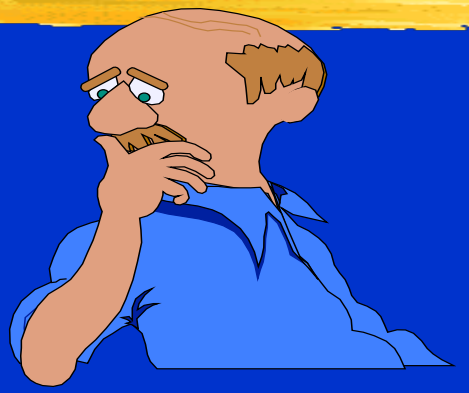
- 2009 proved reserves increased by 11%
  - highest level since 1971 s
  - shale gas plays account for 90%
- It's not resource depletion; It's technology

source	resource (tcf)		years supply	
	min	max	min	max
tight natural gas	309	1,800	15	90
shale gas	742	7,500	37	375
coalbed methane	163	1,000	8	50
geopressurized zones	1,000	49,000	50	2,450
methane hydrates	0	73,000	0	3,650
total	2,214	132,300	111	6,615

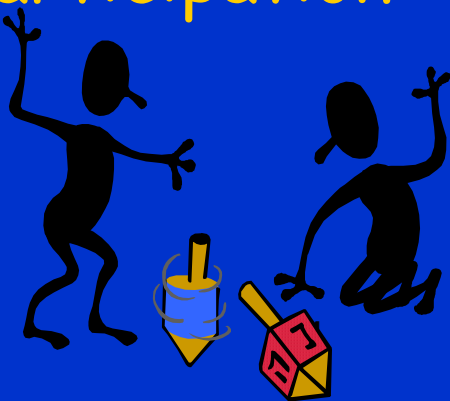
Forecasting: do we need more humility?

- Complex computer models
  - garbage in garbage out
  - understanding of the oracles (models)
- the longer the horizon, the greater the uncertainty
- nukes too cheap to meter
- baked it in mineral depletion

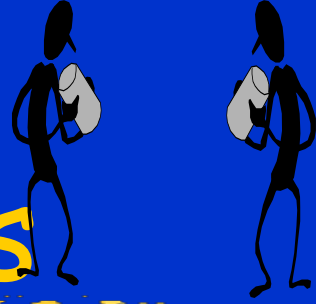
Consensus Energy Policy in the US



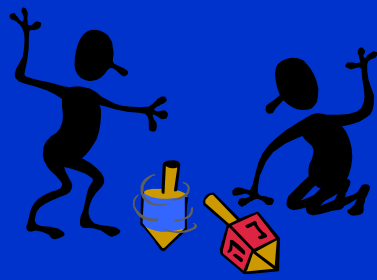
- Decrease
  - oil imports
  - pollution
- Increase jobs and innovation in
  - natural gas production (bridge fuel)
  - wind and solar
  - Energy efficiency and demand side participation
- 'Smarter' grids and appliances
- Cleaner more competitive markets
- Better regulation



"smarter" grid and variable energy resources

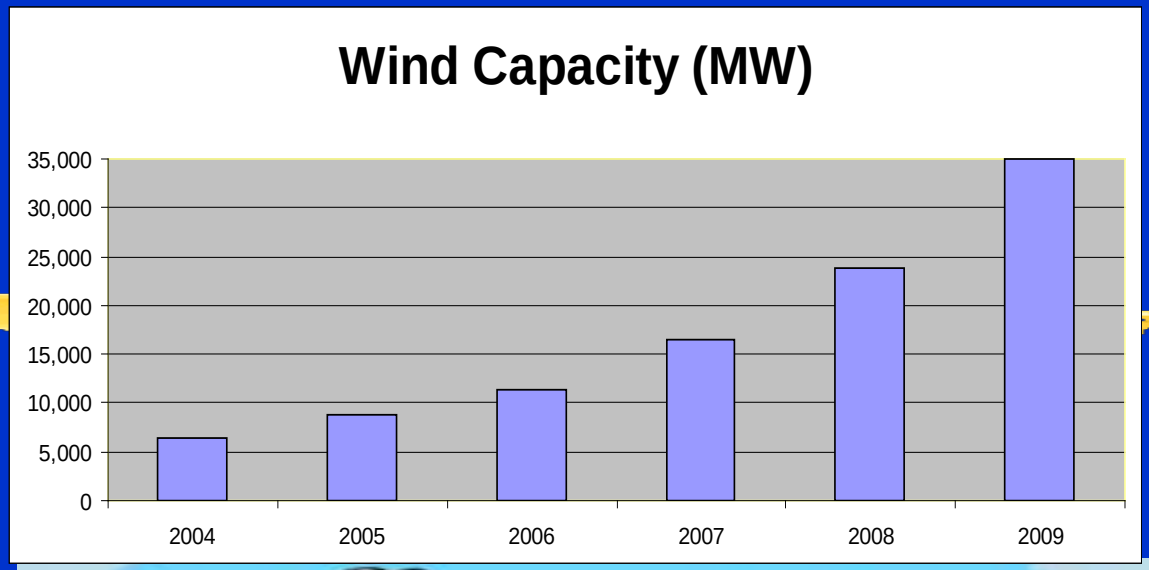


- Variable energy resources
  - Fuel is free but doesn't travel well; mostly capital costs
  - Stochastic weather-driven output
- Fossil energy resources
  - Fuel is not free but does travel; per MWh capital costs are smaller
  - Stochastic mechanical: 0-1
- a smarter grid becomes more important with increased
  - renewable energy, batteries, and
  - demand side market participation
  - Corrective switching
- smarter markets need to be re-examined
  - Ancillary service markets
  - Capacity markets

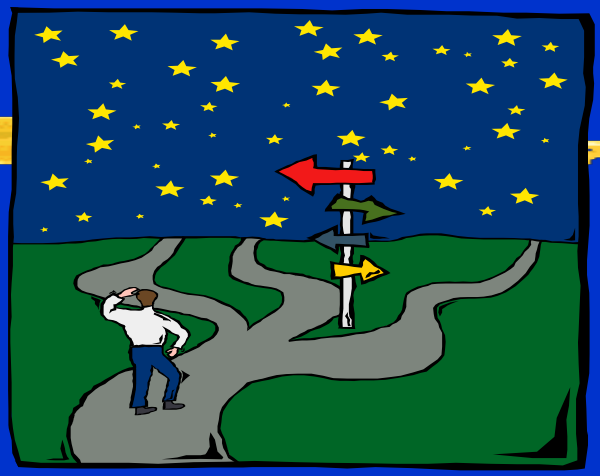


Batteries and Wind

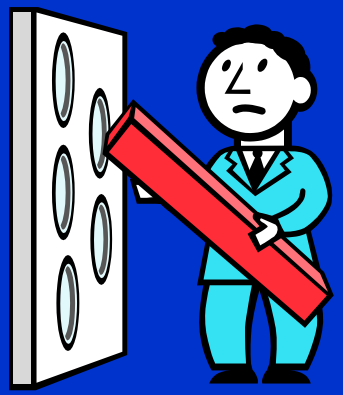
- Generally wind is strongest off-peak
- Prices can be as low as minus $30/MWh
- Ideal for battery charging
- Need smart grid with smart pricing



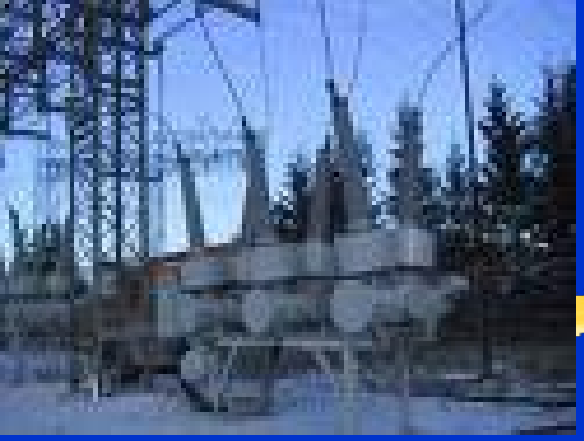
Independent System Operator market design



- Evolved using
  - traditions
  - economic theory,
  - power system operations heuristics and
  - operational experience.
- Operates markets with
  - simplifying assumptions
  - convex approximations



- often due to the inability to solve the more detailed design.
- **Savings of > $500 million/year**



Preventive to Corrective Reliability

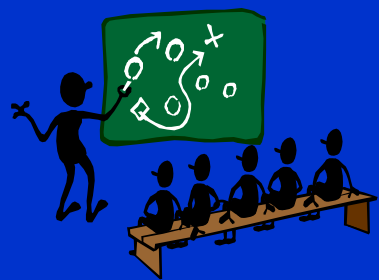
- Preventive (ex ante) absorb any contingency
  - Currently mostly preventative and capital intensive
  - Corrective solutions take too long to solve
- Corrective (ex post)
  - Corrective: Special Protection Systems
  - faster switching
  - Demand response to generation decline
- Optimize topology and dispatch
  - Open or close circuit breakers, PARs, FACTS
  - Potential 20% production costs savings

History of transmission investment

- Prior to restructuring transmission expansion was
  - centrally planned, developed, financed, owned and
  - operated by vertically integrated franchised monopoly
  - The costs were added to the utilities rate base and included in retail power rates.
- open access transmission has led to
  - increased competition in power markets
  - Merchant generators
- More recently
  - merchant transmission projects have appeared.
  - Multi-state planning

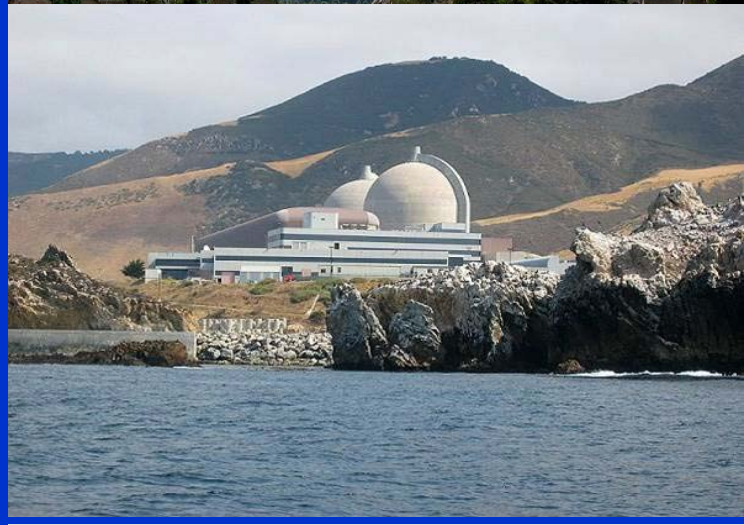
large-scale efficient transmission expansion

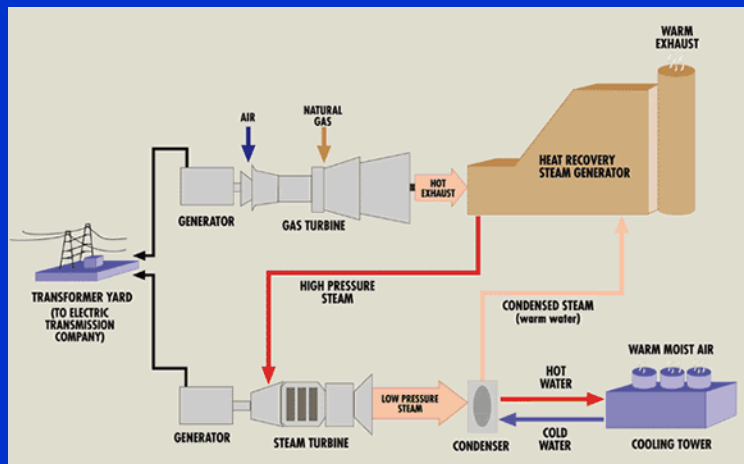
- Improve on existing planning models
  - Balance model complexity v.
  - computational burden
- Club good
  - Two part pricing
  - Transmission rights including flowgate
- Retain competitive market incentives
- Transmission planning auctions



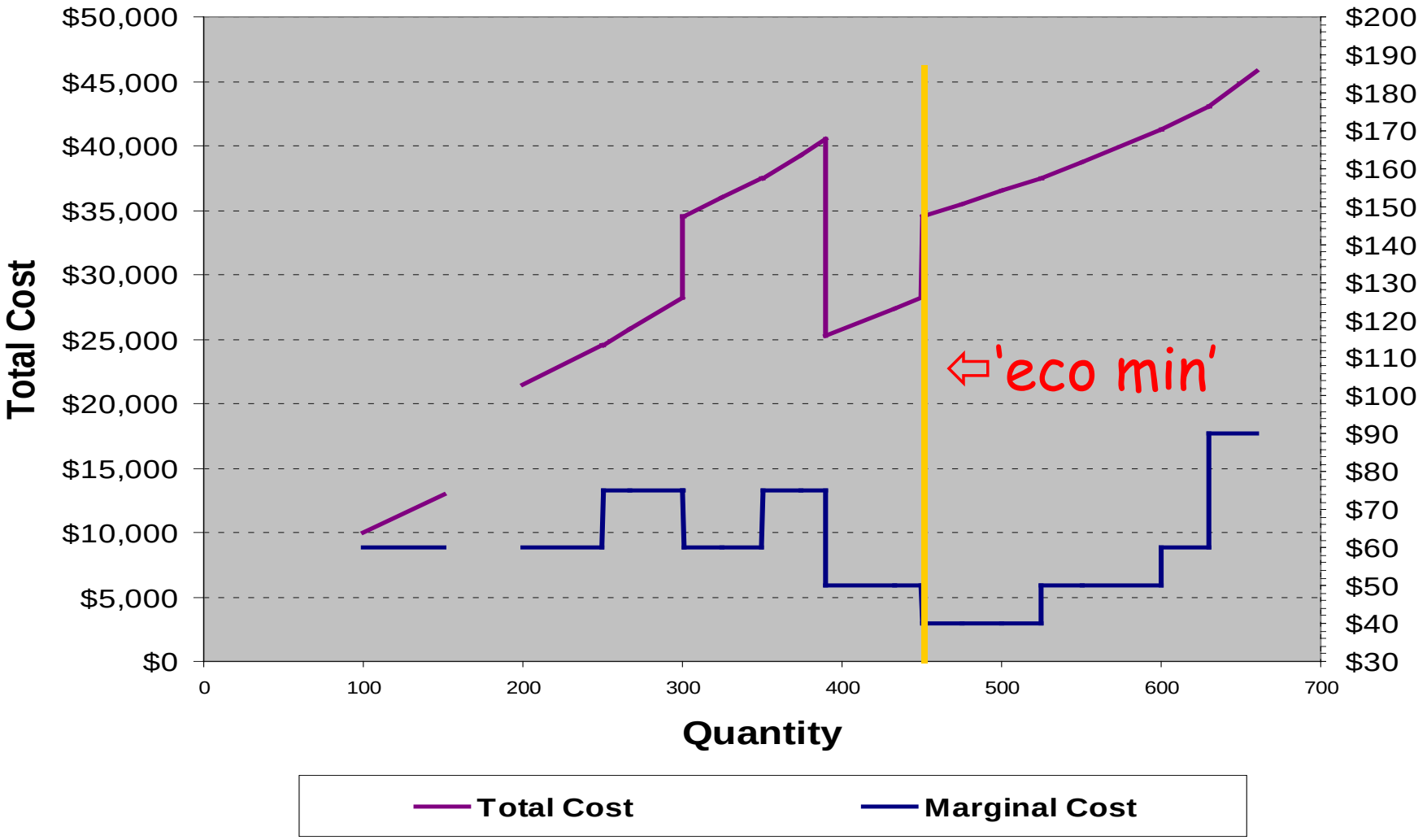
Open questions for coal plants

- EPA regs for existing plants
- Future of coal plants
  - 2007 231 new projects
  - 2010 123 had been cancelled
- Carbon Capture and Sequestration:
  - Does $30-50/ton make it uneconomic?
- More nukes?
  - high upfront capital cost
  - Low flexibility
- Combined Cycle Combustion Turbine
  - will the gas price stay low?
  - High flexibility

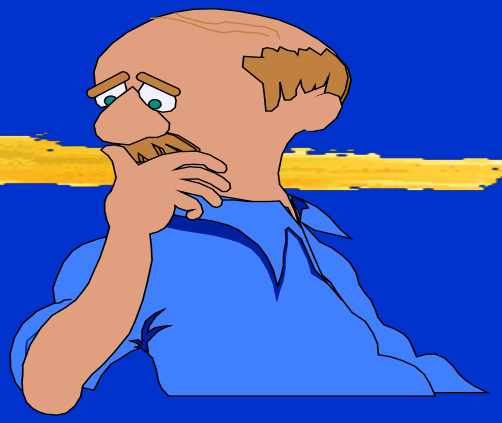




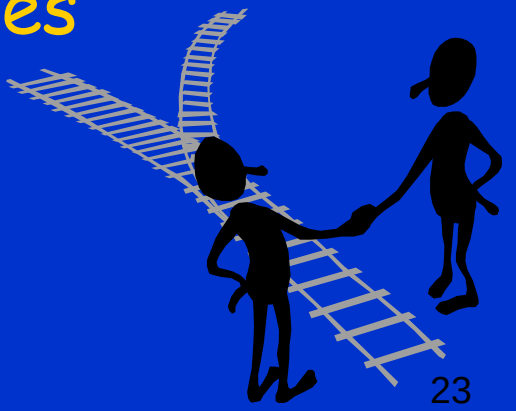
Total and Marginal Costs for combined cycle combustion turbine CCCT



Strategies



- Reducing oil imports
  - electric cars with dynamic charging
  - natural gas vehicles
- Energy efficiency and demand side participation
  - real time pricing matters
  - how low does the fruit hang?
- Separate efficiency and equity issues
- Risky bets
  - CCS
  - Bio-engineering



The politics of paradigm shifts

- *"there is nothing more difficult to take in hand, more perilous to conduct, or more uncertain in its outcome, than to take the lead in introducing a new order of things"*
  Niccolo Machiavelli