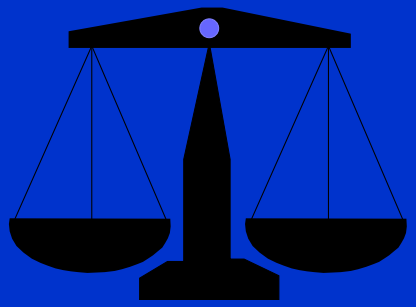
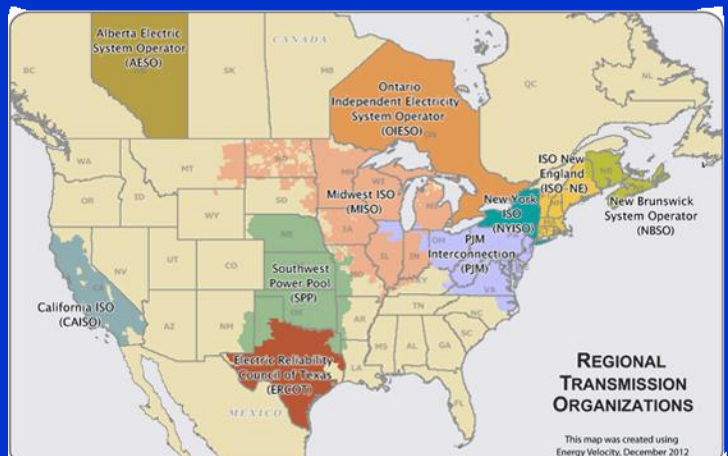


US Experience in Planning and Markets

Richard O'Neill
Chief Economic Advisor
Federal Energy Regulatory Commission

Transmission Planning and Delivery
Imperial College London
11-12 January 2013

Views expressed are not necessarily those of the Commission

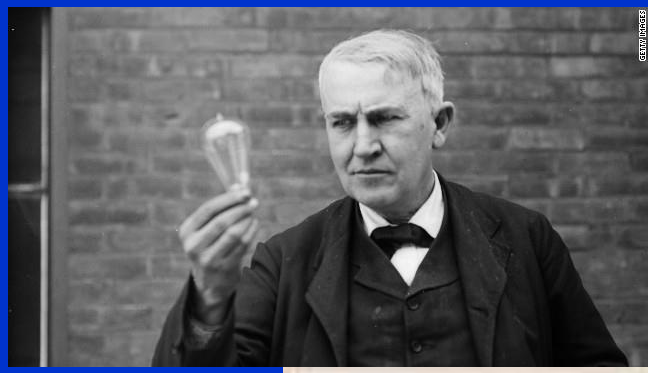


- Current markets are a product of the institutional history
- We need to learn from mistakes and move forward

The magical mystery tour is waiting to take you away, waiting to take you away

Electric Market Startup

- 1880-1905: innovation and competition
- 1882: Edison's Pearl Street Station
- Edison (DC) v Westinghouse (AC)
- competition: several alternate suppliers
- municipal regulation
  - Benchmark regulation
  - leads to corruption
- 1898 Sam Insull (a Brit)
  - Builds large holding company
  - **Franchised monopoly with cost-of-service**
  - Was it fear of competition?
- State commissions formed



First Electric Restructuring

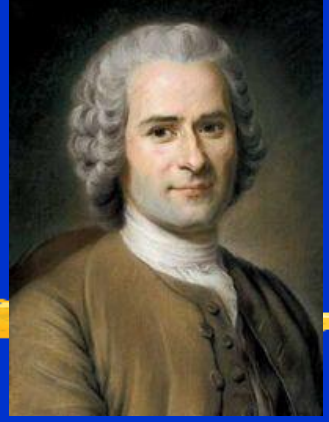
- 1905-78: Insull's legacy
- vertically integrated franchised monopoly with cost-of-service regulation
- state or local regulation of 90-95% of costs
- 1935: Federal Power Act to fill regulatory gap
  - Wholesale rates
  - Transmission rates

- 1935: PUHCA to control holding companies
  - To regulate multi-state holding companies

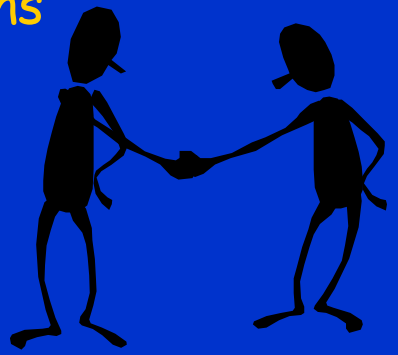
vertically integrated utilities

- information asymmetry/Black box
- Optimal dispatch????
- Integrated Resource Planning
  - Forecast demand growth
  - Decide to build a generator
  - Decide on a site
  - plan transmission to get new generation to market
  - Go to the state regulator for approval, for example, CWIP

Contracts



- 1762 Rousseau, *The Social Contract*
  - implicit agreement between the state and its citizens
- 1898 Insull's Regulatory bargain
  - Franchised monopoly
  - cost-of-service
- Contracts and property rights
  - not sacrosanct
  - Changes risk/reward
- Eminent domain for transmission
  - In electric, state level
  - in natural gas, FERC
- 1935 Just and reasonable prices
  - Not just and reasonable



The Nuke Story Part I

- 1954 Strauss (Chairman, Atomic Energy Comm): "Our children will enjoy in their homes electrical energy too cheap to meter."
- 1957 Price-Anderson Act reduced private liability
- 1979 accident at the Three Mile Island
  - heightened public concerns and spurred opposition
  - no new reactor orders placed.
  - 63 orders canceled
- Monopoly franchise results in 50 nuke plant owners
  - No competition to build or operate
  - Some better than others

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%

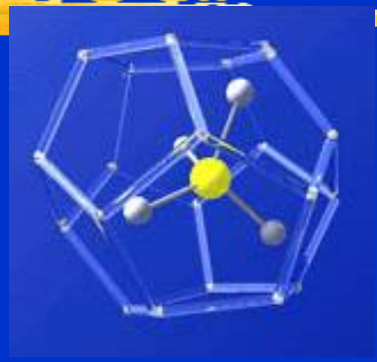
Source: U.S. EIA

too cheap to too expensive

Second Electric Restructuring

- 1978-96: groping toward competition and renewables
- 1978: Energy Policy Laws
- Public Utility Regulatory Policies Act (PURPA)
- Fuel Use Act
  - Manage fuel use
  - quickly repealed
- Natural Gas Policy Act

Natural Gas



- 1978 Natural Gas Policy Act
  - Partial wellhead deregulation
  - Ramsey pricing and fear of running out
- 1993 Natural Gas open access
  - Unbundling
  - Wellhead regulation
  - Easier pipeline Entry
- Declared the 'bridge fuel'

Public Utility Regulatory Policies Act (PURPA 1978)

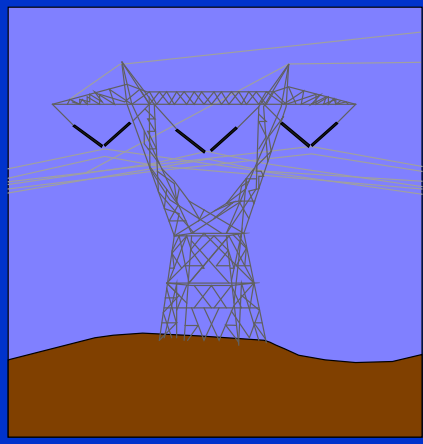
- provides 'feed-in' tariffs
  - For cogeneration technology, renewables and waste
  - At 'avoided costs' (marginal costs)
  - costs were passed-through in retail prices
- SoCal Edison and NIPSCo videos (rated R for violence)
  - Independent power will cause blackouts
- Several states embraced PURPA with gusto
  - concentrated in Cal, NJ, NY, PA, TX, and New England
  - required long-term contracts at high prices
  - roughly 60,000 megawatts came online
  - eventually 10 percent of total U.S. generation

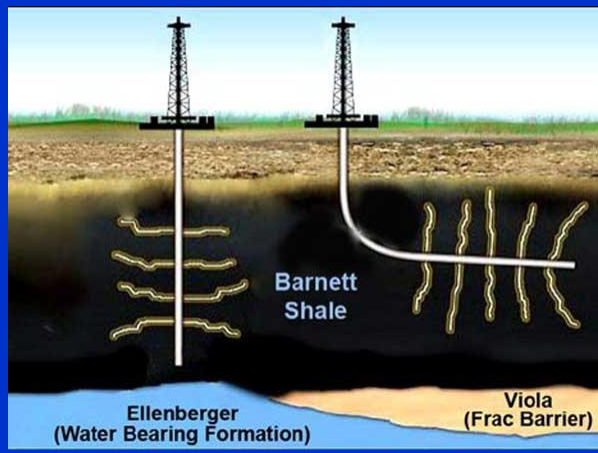
PURPA's impact and lessons

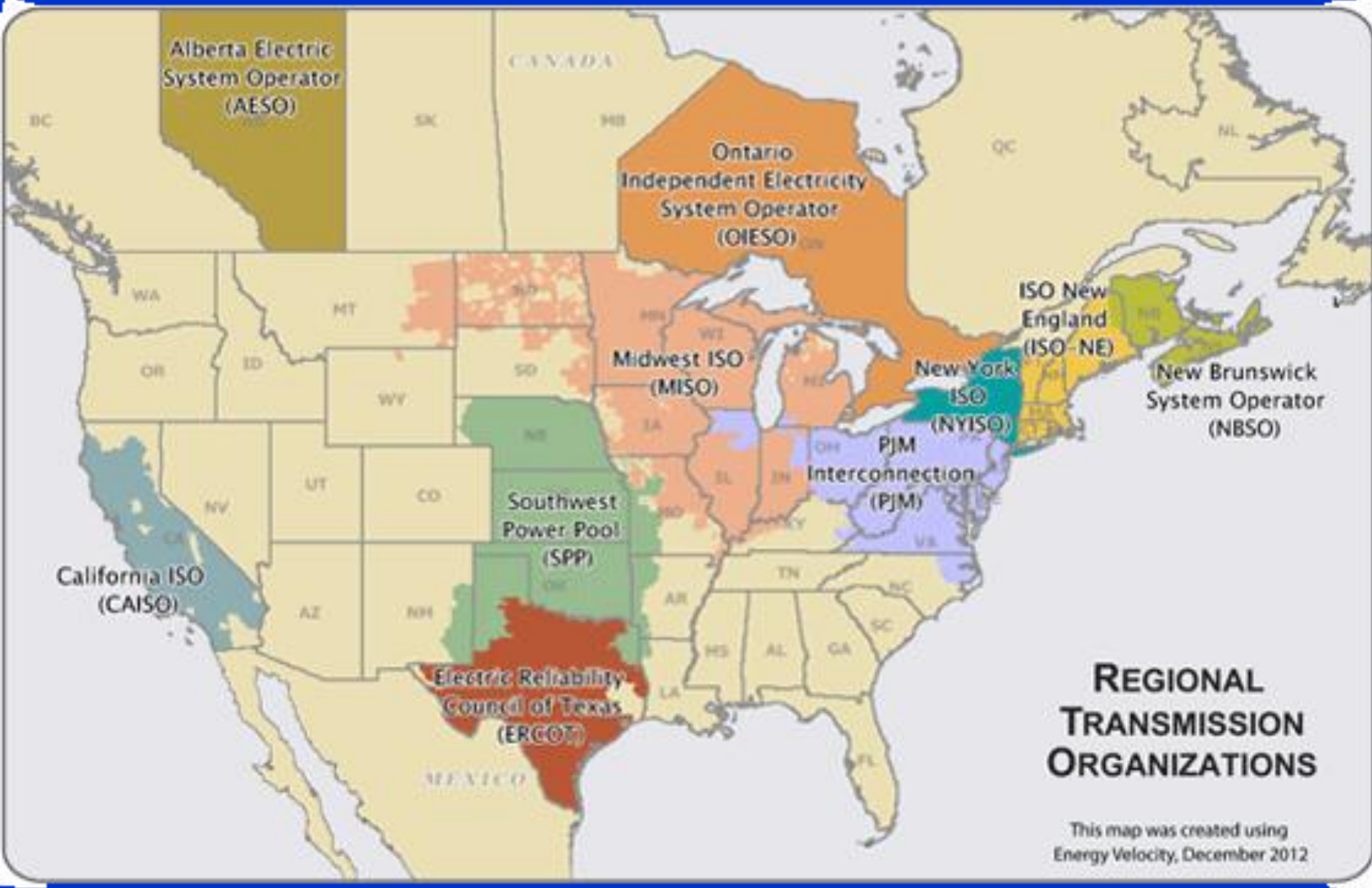
- changed prevailing views on vertical integration.
- became clear that non-utilities could
  - build and operate generators effectively and reliably
  - stimulated innovation in high-efficiency generation
- Feed-in tariffs were too generous
- created an IPP interest group for competition
- Changes the debate

Third Electric Restructuring

- 1996-present
- Vertically integrated utilities
  - Order 888 electric open access
  - Contract path access is sporadic
- Independent System Operators (ISOs)
  - Generation competition
  - Some transmission 'competition'
  - Better software
  - 2002 Standard Market Design (SMD)
- Natural gas
  - Shale gas !!!!!!!!!
  - LNG bi-polar mania






Alberta Electric System Operator (AESO)
CANADA
Ontario Independent Electricity System Operator (OIESO)
ISO New England (ISO-NE)
New Brunswick System Operator (NBSO)
Midwest ISO (MISO)
New York ISO (NYISO)
PJM Interconnection (PJM)
Southwest Power Pool (SPP)
California ISO (CAISO)
Electric Reliability Council of Texas (ERCOT)
MEXICO
REGIONAL TRANSMISSION ORGANIZATIONS
This map was created using Energy Velocity, December 2012

nuke history part II

- 1997 70% load factor under cost-of-service
  - Weak incentives to improve
- 1999: Poorly performing plants sold
- natural incentives in ISOs
- 2002 90% load factor
  - Nukes lower ISO prices
- Are nukes are making too money?
  - Two billion $ returned to in MD and IL customers
- 2012: cost over runs for new nukes!!!

All markets are regulated the question is how?

- public good magic wand;
  - easy cost allocation: tax
  - Lack of measurement
  - What is the market size?
  - are we over using the concept?

club goods

If you really like it you can have the rights
It could make a million for you overnight

- Reality is two part pricing or contracts
  - Contracts have multipart prices
  - Call options
  - Usage rates
- Allocation becomes a 'cooperative game'
  - Market size
  - Beneficaries pay
- When should the winners compensate the losers?

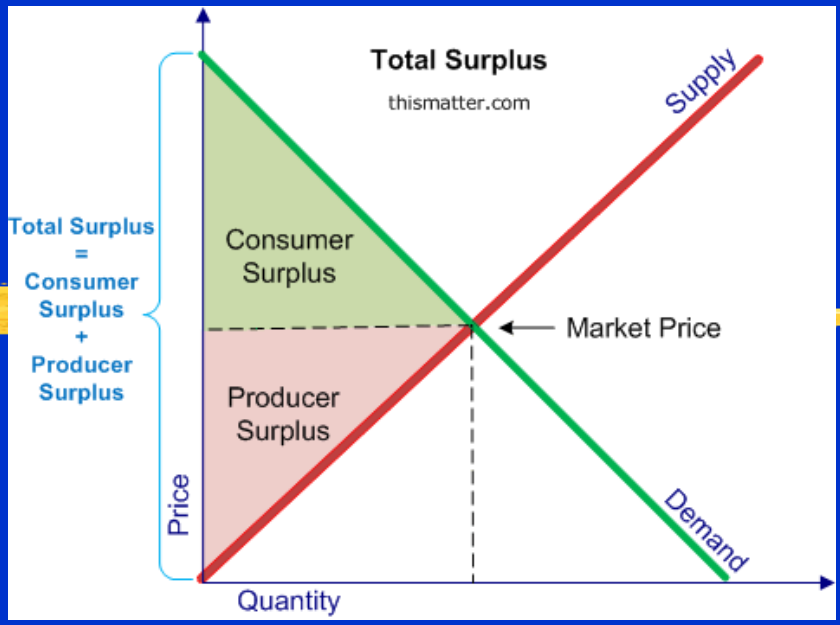
Alvin E. Roth

Lloyd S. Shapley

private goods

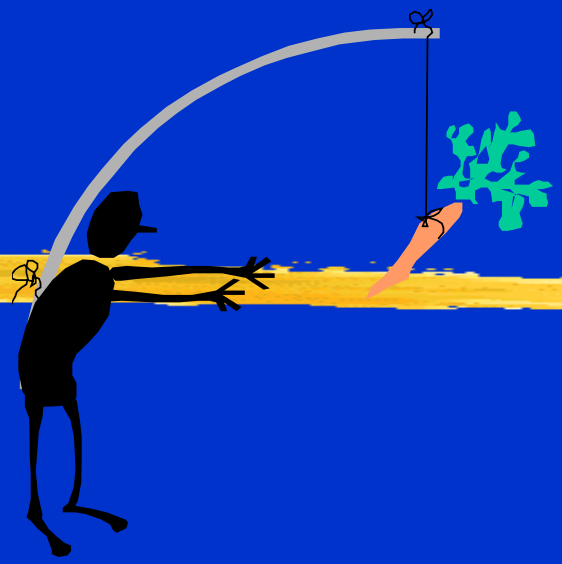
- Private good: power
  - Destroyed in consumption
  - Prevent others
  - LMPs
- Some argue that electricity is a public good.
- Are there property rights to a competitive market?

Market goals



- Greatest societal benefits
  - Maximum market surplus
  - Non-convex markets
- Distribution of benefits
  - Enough to finance new efficient projects
  - LMP (public price)
  - uplift (private price)
  - Uplift is generic for what's left over
- Currently Uplift is too generic
  - Voltage/reactive support (local)
  - Contingency real power reserves

Regulatory incentives



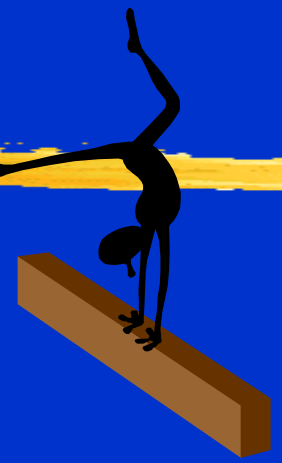
- cost-of-service
  - Maximize capital investment
  - Regulator reviews prudence
  - Inelastic demand/flat prices
- ISO markets
  - Pay LMP or FMP
  - Minimize costs
  - Regulator requires marginal cost bidding
  - Financial participants check market power in forward markets
  - Elastic demand is a goal

The Optimization Algorithm

- Underlying all these markets is a single optimization
- This model has the following features:
  - Steady-state ACOPF with important N-1 contingencies
  - Transmission switching/investment
  - Unit commitment of generators
  - Dispatch interval: from 5 minutes or less to a month or more
  - Telescoped dispatch horizon
  - Inter-period ramp rate constraints with time coupled pricing
  - Ancillary services co-optimization
  - Explicit stochastic contingency costs in the objective function
- difficult problem: binary variables and nonconvex continuous functions
- Offline stability analysis

And though the holes were rather small
They had to count them all

real-time market maximize societal benefits

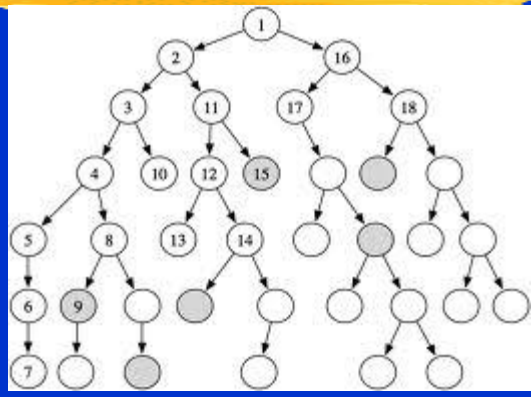


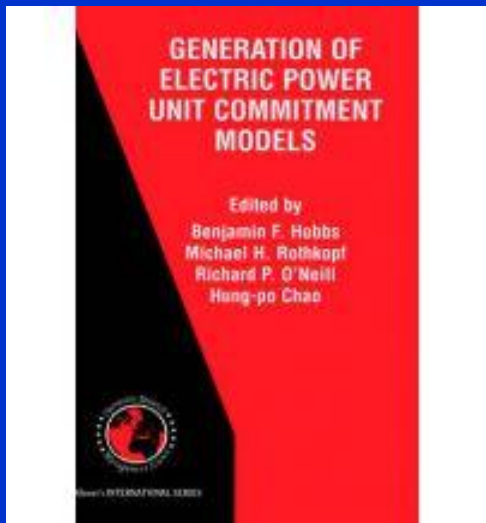
- Mostly private good (real power)
- For real-time market,
  - LMP dominates revenue distribution: 95+%
  - Low uplift for make-whole and reserves
- Lower uncertainty
- Reasonable approximation??????
  - Peanut-butter uplift
  - Bad incentives
- Non-cooperative game theory

Happy ever after in the market place

day-ahead market
maximize expected societal benefits

- Mostly private good (real power)
- For real-time market,
  - LMP dominates
  - Low uplift for make-whole and reserves
- Lower uncertainty
- Reasonable approximation???
- No investment cost
- Non-cooperative game theory



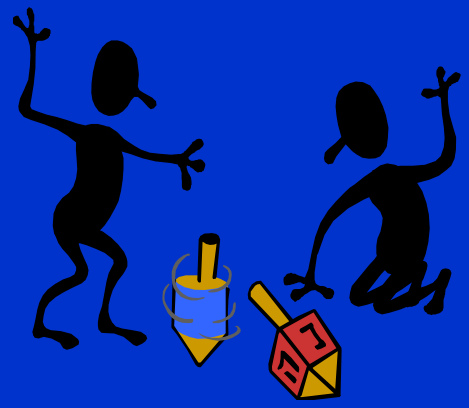


Long-term planning

How do we maximize societal benefits

- Mostly real option call
  - Who is in the club?
- For transmission expansion,
  - uplift may dominate
- Higher uncertainty
- Need better approximations
- High uplift/lumpy investment costs
- Cooperative game theory

Ad hoc, ad loc, and quid pro quo! So little time, so much to know!"



Let me tell you how it will be

Allocating transmission Uplift or call option

- Even new transmission lines may have congestion
- Revenue sources for owners
  - FMP flowgate marginal price
  - Uplift / call option contracts
- Uplift allocation: Beneficiaries pay
  - Cooperative game theory
  - Poor man's Shapley value

Alvin E. Roth

Lloyd S. Shapley

Merchant transmission

A long and winding road

- Approach
  - Assume all risk (no unwilling participants)
  - Resolve discrimination and sizing before construction
- HVDC to NYC
  - 2002: Cross sound cable
  - Neptune
- HVDC for distant wind and lower losses
  - Western states
- HVAC: Montana-Alberta Tie-Line (MATL)

Participant funding
Club good

- Argentina/NYISO approach
  - Participants agree to support
  - Through voting
- Limiting element
  - PJM get financial transmission rights
  - For example, wave trap
- Interconnection costs

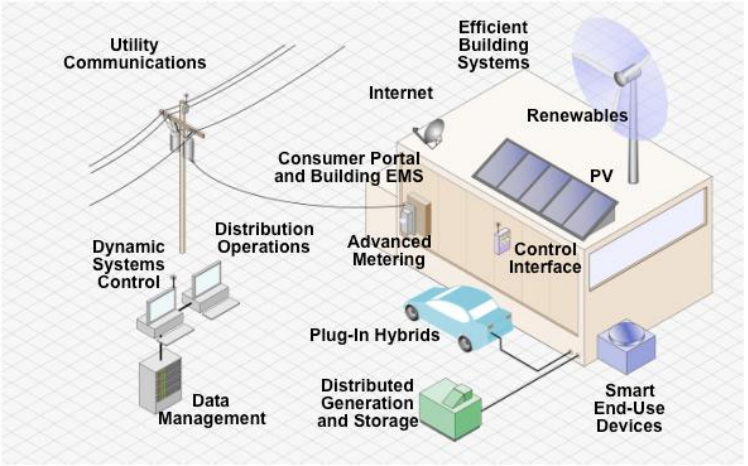
EPAct 2005 (551 pages)

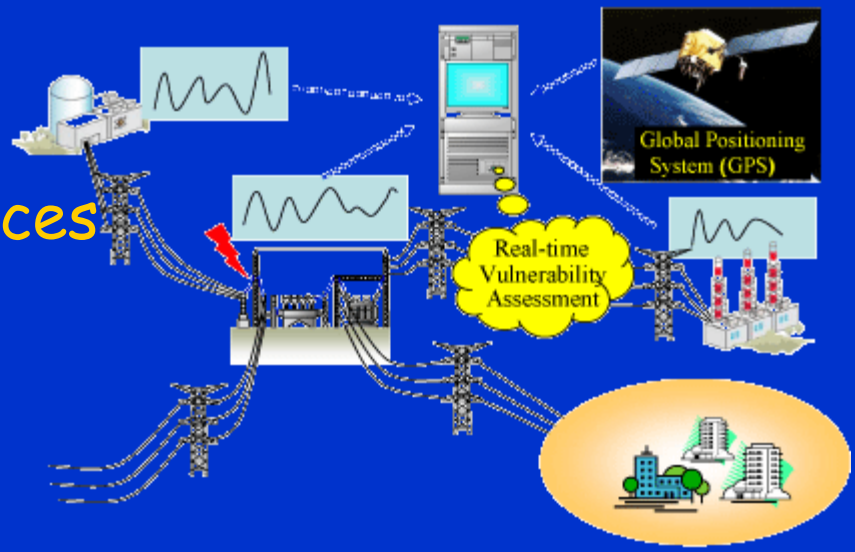
- Reliability becomes mandatory
  - comes out of the back room
  - the refuge of scoundrels?
- FERC siting of transmission facilities
  - Narrow authority
  - States still control the process
- Transmission incentives
  - provide a return on equity that attracts new investment
  - allow recovery of all prudently incurred costs

Smart grid

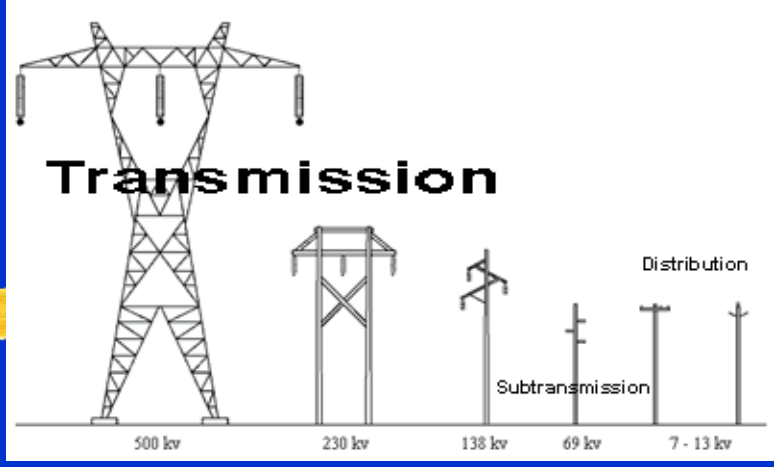
- Pre-meters: priced based on the number of light bulbs
- Meters allowed $/KWh
- Better and faster measurement
- better models need better software
- Greater market participation
  - For example, refrigerators
- Dispatchable distributed resources
  - Part of the solution
- Non-dispatchable resources
  - Part of the problem

Investment in "Smart Grid" electricity infrastructure will be needed….

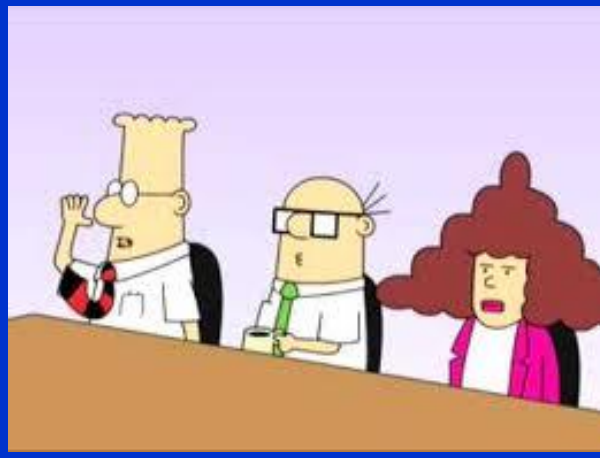


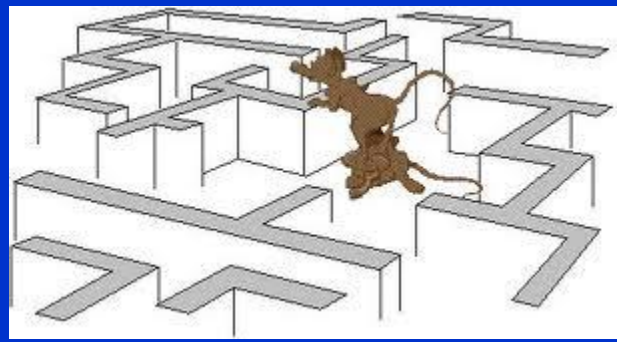


Order 1000 Federal IRP?

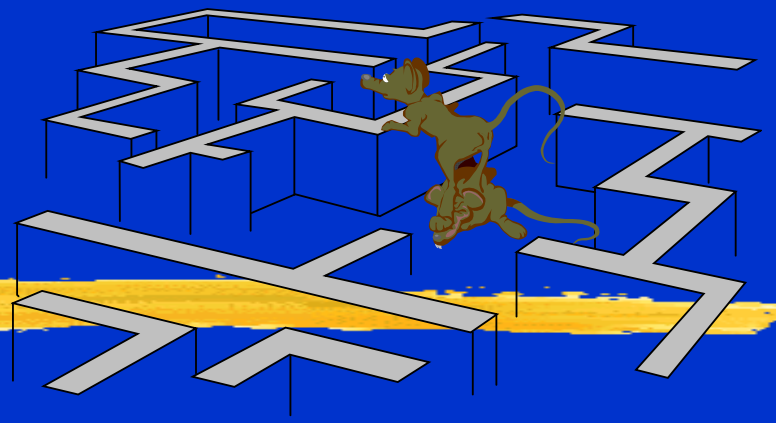


- No right of first refusal
- 'Reliability' investments Easier to justify
  - Value loss of load ('1 in 10'?) has a cost
- 'Economic' investments Seldom used
  - Harder to justify 'taking'
- 'Public policy' investments
  - Externalities not prices
  - Quantity constraints on markets
- In the end all are economic investments
- Beneficiaries-pay cost allocation
- Regular coffee and tea

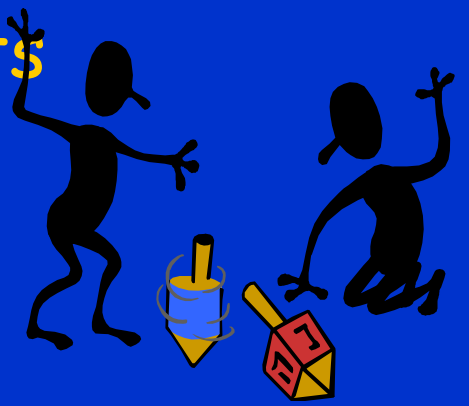




Optimal Planning

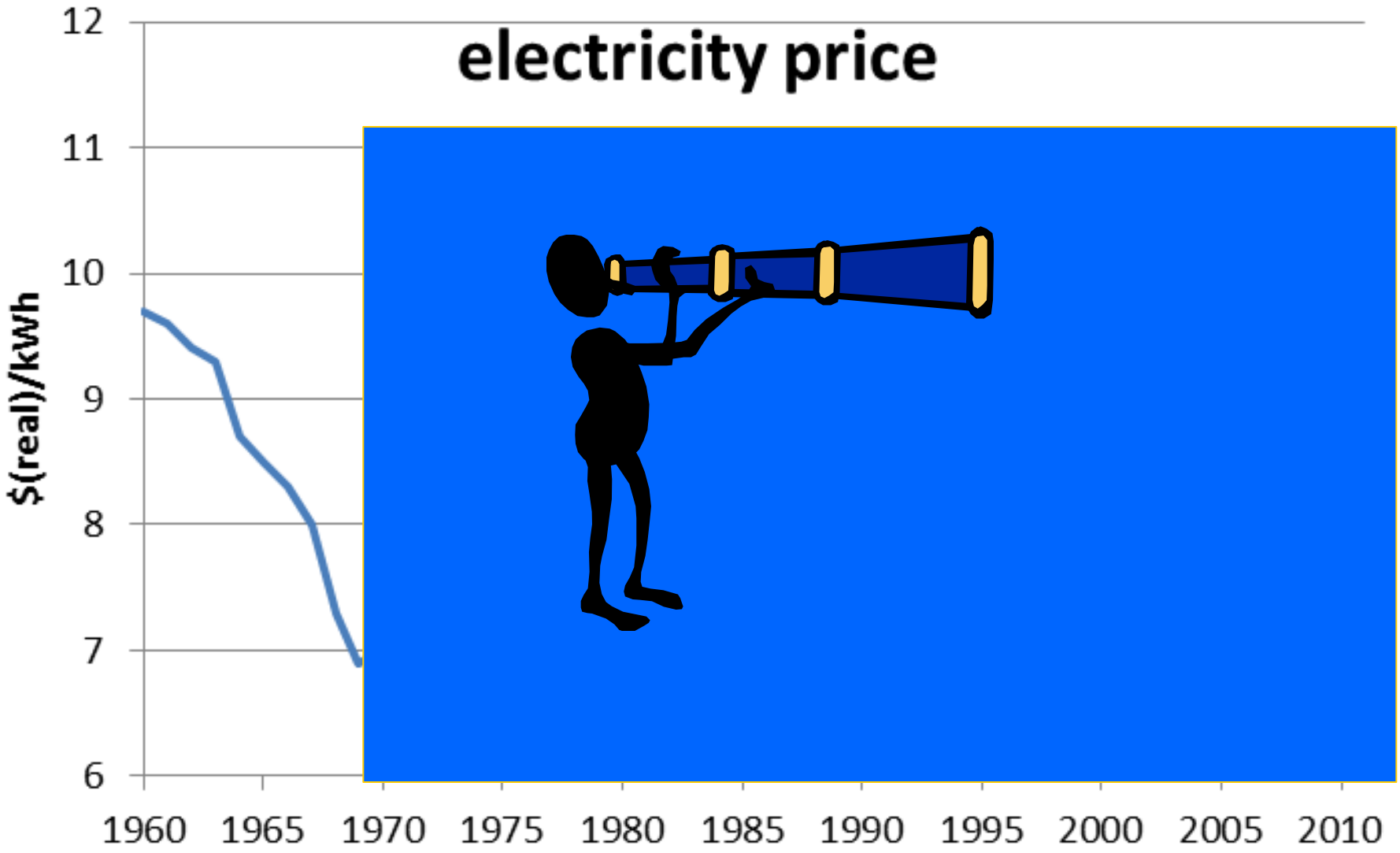


- Uncertainty: Project demand, technology and externalities
- Take bids for new transmission projects
- Solve max benefits problem
  - Find optimal topology
  - Find optimal generation mix
- Sign transmission investments contracts at bid costs
- allocate expected costs to beneficaries
- Allow for generation entry

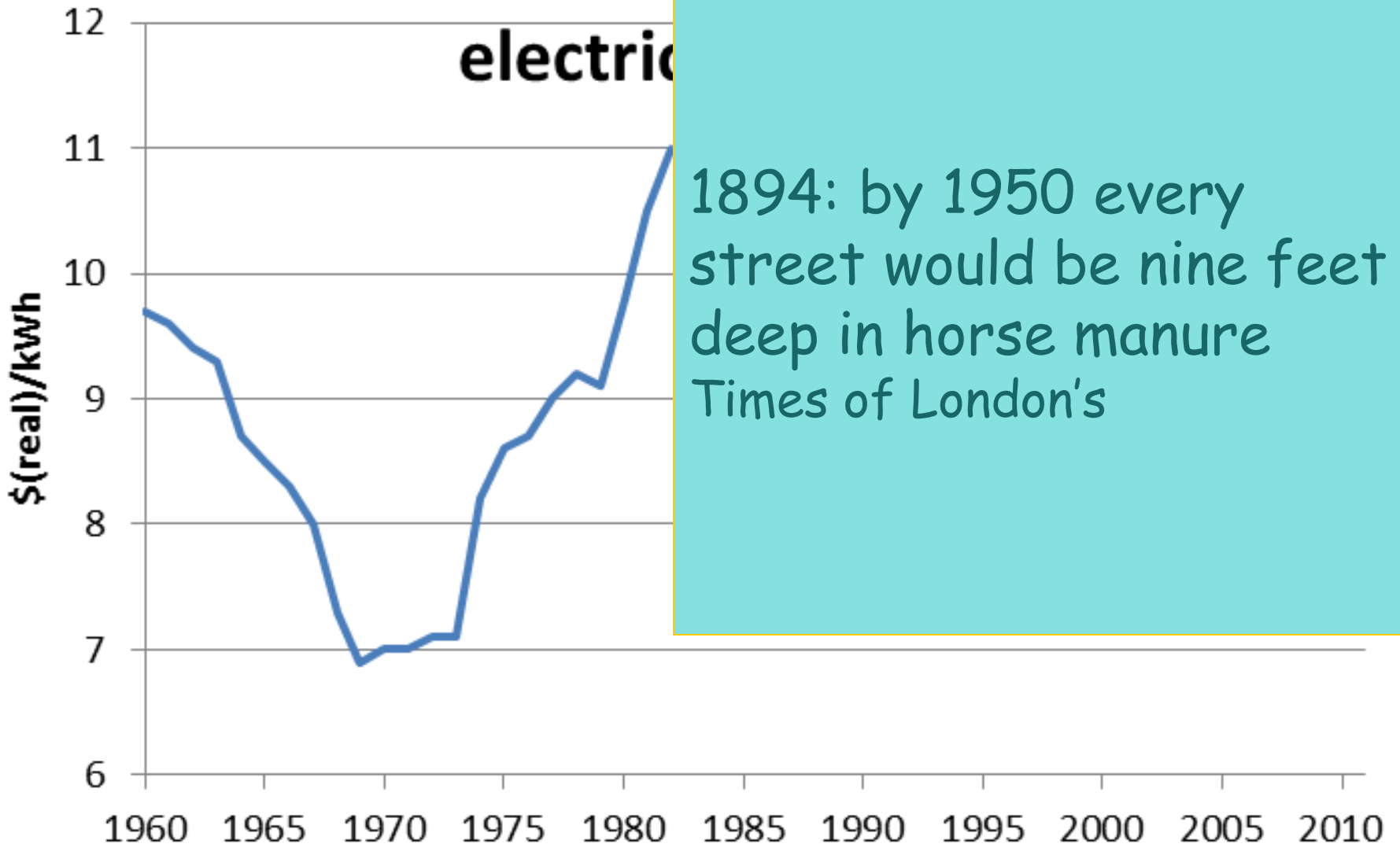


Forecasting can we?

The magical mystery tour is waiting
to take you away,
Waiting to take you away

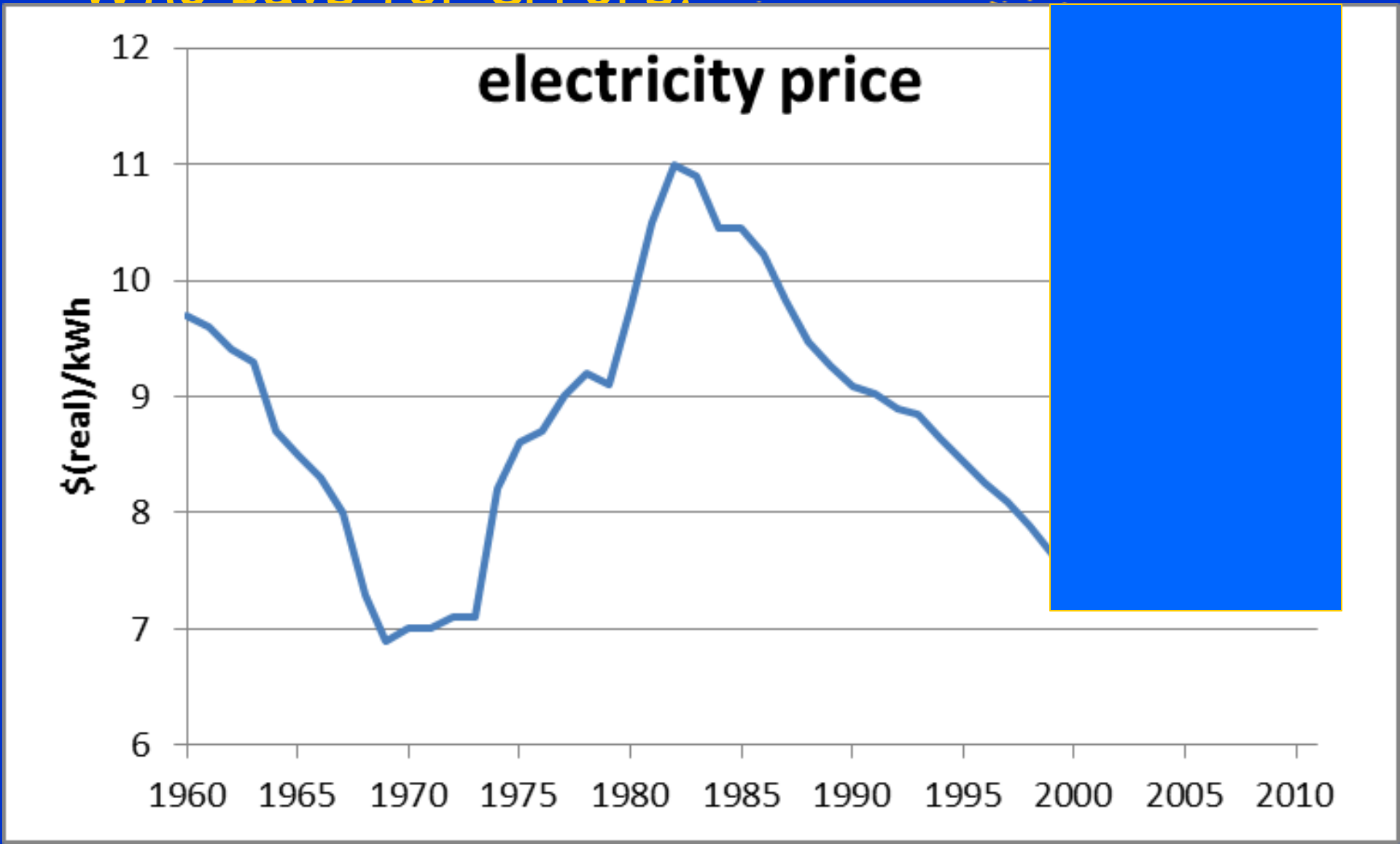


Forecasting
are we running out?

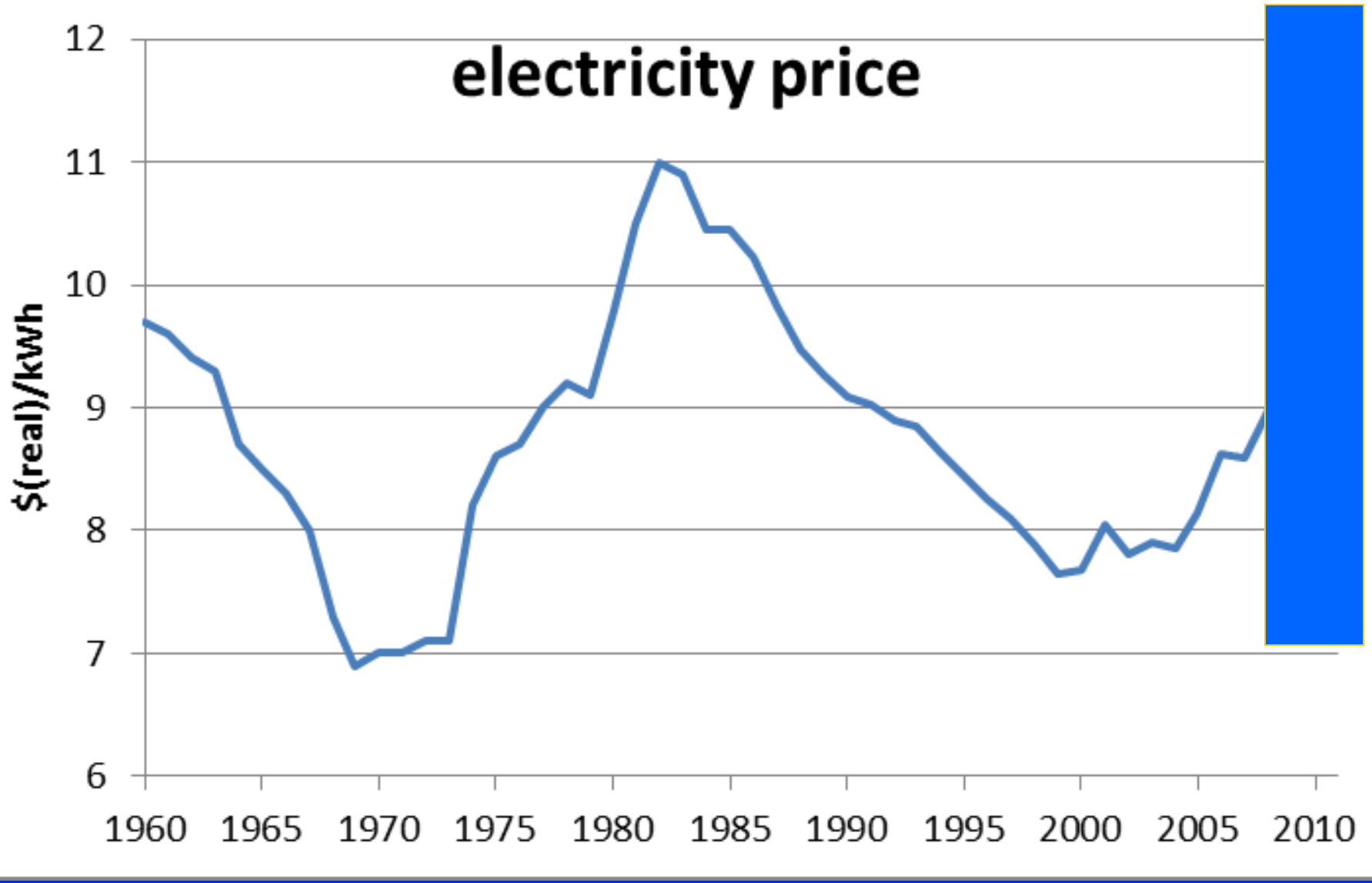


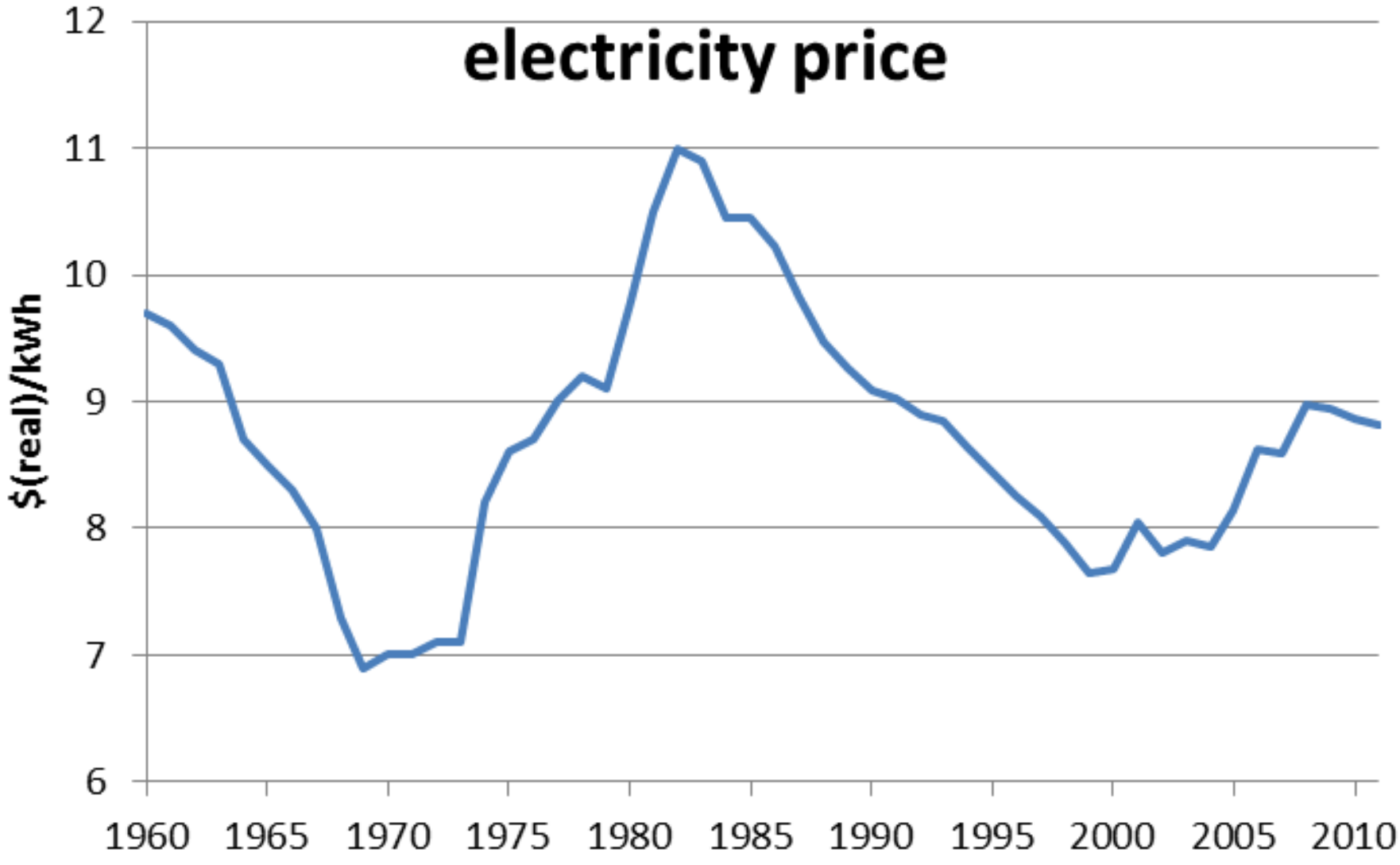
1894: by 1950 every street would be nine feet deep in horse manure
Times of London's

Forecasting
excess generation?
Who pays for errors?



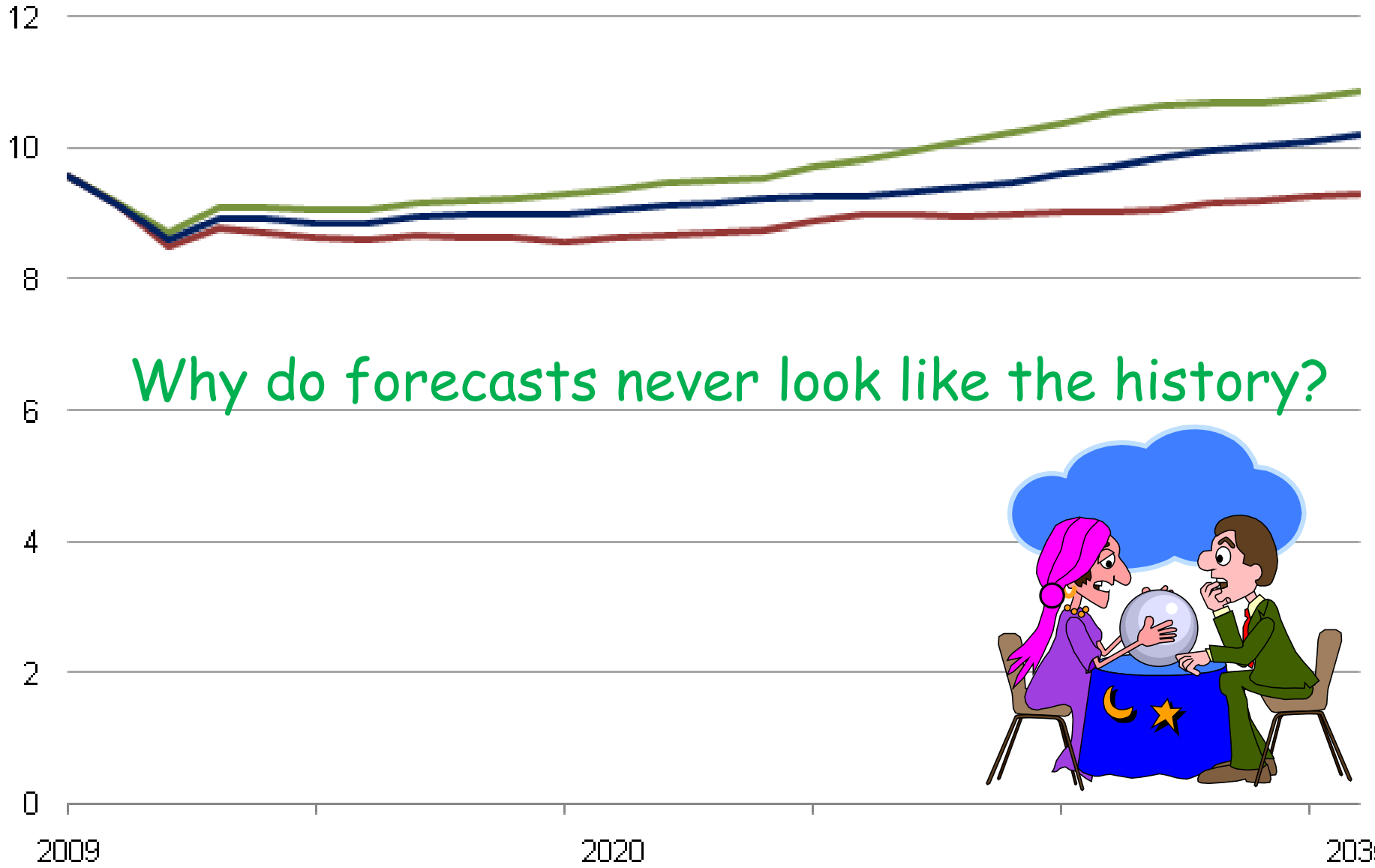
do we need more humility?




electricity price
$(real)/kWh
12
11
10
9
8
7
6
1960
1965
1970
1975
1980
1985
1990
1995
2000
2005
2010

Projected High, Reference, and Low Average Annual U.S. Retail Electricity Prices

(Inflation-adjusted 2008 cents per kilowatthour)



Why do forecasts never look like the history?

Interfaces are still messy

- Problem
  - Contract path fiction
  - Loop flow
- Solutions
  - Replace the contract path
  - Flowgate trading
  - Joint optimization