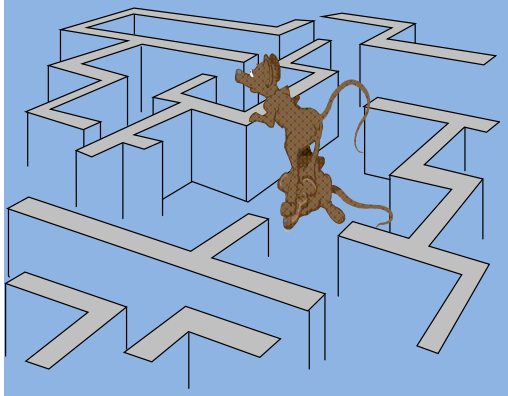
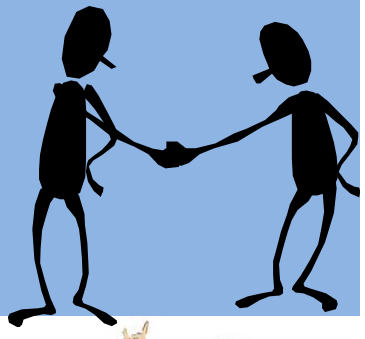
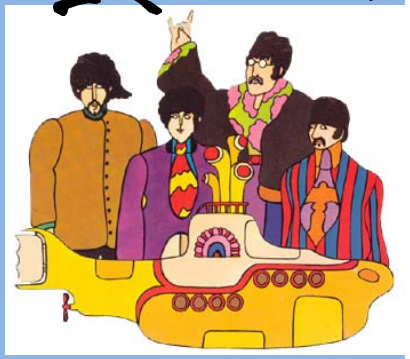
Assessing Regulatory Models



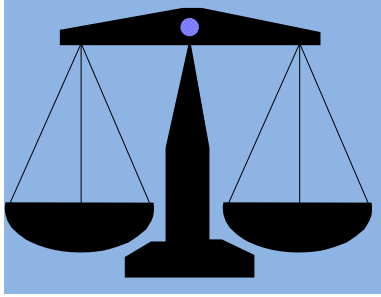
Richard P O'Neill
Federal Energy Regulatory Commission



National Academy of Science
Washington, DC
April 23, 2013



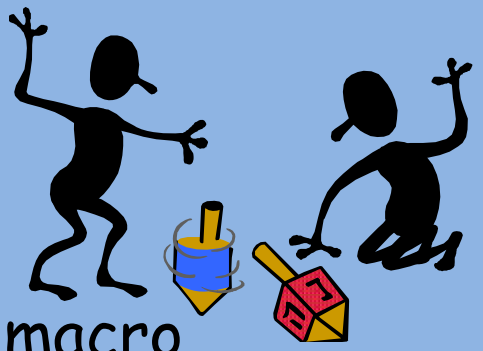
Views expressed are not necessarily those of the Commission



What regulatory models have that physical models do not?

- Human behavior
  - altruism or greed, choose greed
  - Rational behavior? Profit/value seeking
  - We do not know how to model altruism
  - If not what kind of irrational behavior?
  - Represented by software 'agents' or bots?

- What information is available to market participants
  - Current, for example, Nash equilibrium
  - Future uncertainty



- Macro economic model: Newton's laws
  - In electric power markets, 'DC' model is macro
- Micro industry model: quantum behavior
  - In electric power markets, 'AC" model is micro

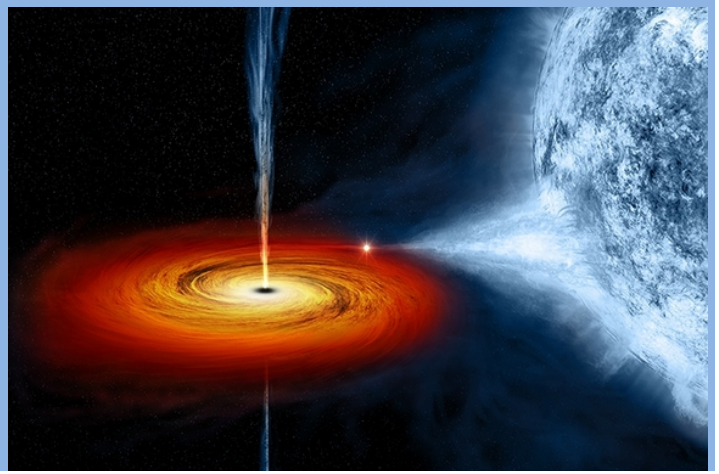
Physical v. Regulatory models

- Physical models discover or replicate behavior
  - Free of human behavior
  - Innovation is to find better physical models
- Where and how does innovation happen?
  - Electric light bulb
  - Computer
  - Iphone
  - Horizontal drilling
- Regulatory models regulate human behavior
  - Usually have a physical model embedded
- Experimental economics for validation of theories

Economic impact of regulatory models

- what is the cost to society of an inaccurate model? Billions of $$$$
  - Health care
  - Energy
  - Climate change

- When does a new basic science model have direct economic consequences?
  - Higgs boson
  - Black holes
  - Age of the universe



Computing

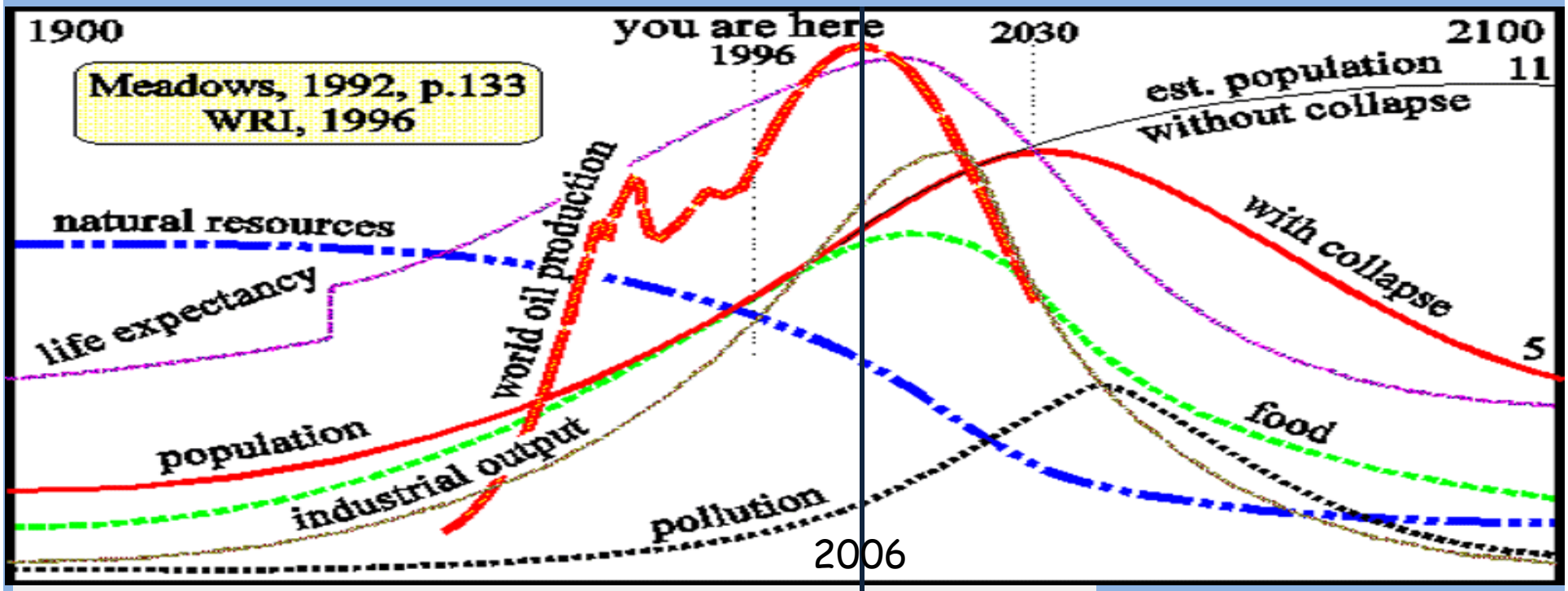
- Back of the envelope
- Logarithms
- Slide Rules
- Women with Friden calculators
- Keypunch and computers (Kilo)
- Faster computers (Mega)
- Faster computers (Giga)
- …

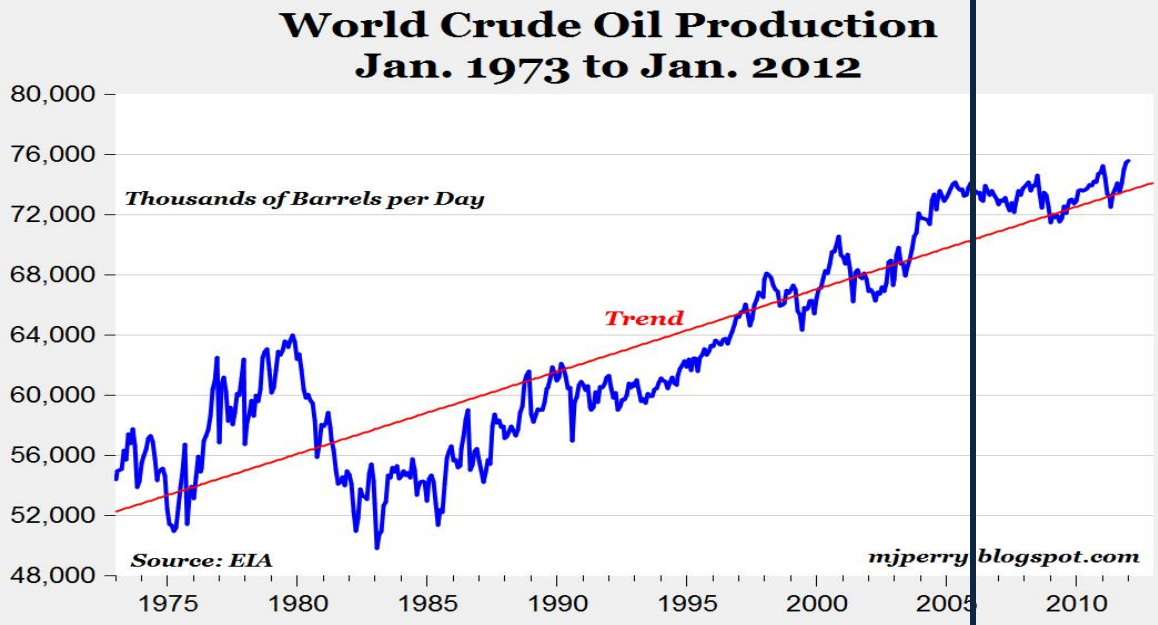
Computers and Modeling

- Back of the envelope is replicable and understandable
- Faster computers allow for large models
- Large regulatory models are often
  - Poorly documented
  - Harder to understand
  - Can often be controlled with obscure parameters

- Second generation analysts
  - Often 'run' the models; become chauffeurs
  - Often do not fully understand the model
  - What's under the hood?

- For example, Club of Rome model
  - Make up relationships between variables
  - Coefficient of technological optimization


1900
you are here
1996
2030
2100
Meadows, 1992, p.133
WRI, 1996
est. population
without collapse
11
natural resources
world oil production
life expectancy
with collapse
5
food
population
industrial output
pollution
2006


World Crude Oil Production
Jan. 1973 to Jan. 2012
80,000
76,000
72,000
68,000
64,000
60,000
56,000
52,000
48,000
Thousands of Barrels per Day
Trend
Source: EIA
mjperry.blogspot.com
1975
1980
1985
1990
1995
2000
2005
2010

Statistical Analysis

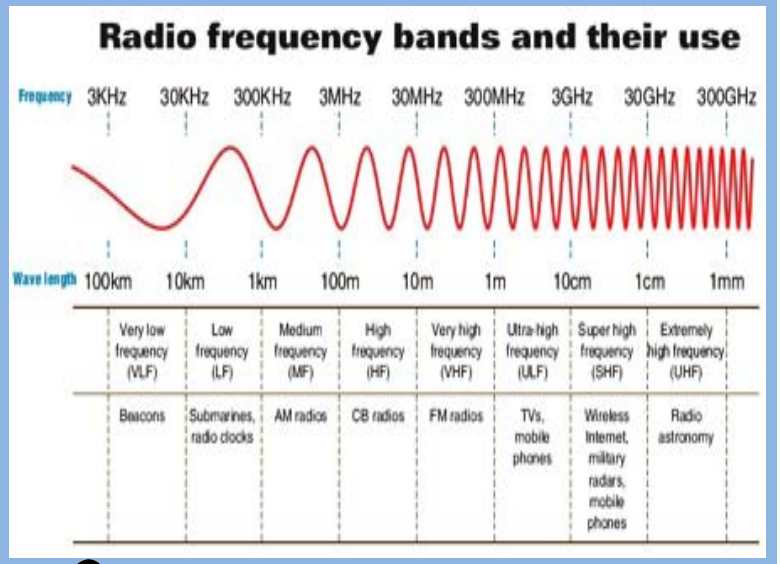
- Greater data uncertainty
  - 10^{-2} is good 10^{-4} is great
- Difficult to replicate
  - Forecasts are almost always wrong
  - Need to quickly rationalize why you were wrong
  - Need to reforecast quickly
- Big data: data mining Google v. CDC
  - Google's data and analysis is so good as an early warning signal, the Center for Disease Control has made it an official partner.
- hypothesis testing
  - what do degrees of freedom mean?
  - What does significant mean?

Four Types of Regulation Models

- ⇨Environment and Safety
  - ⇨internalize externalities
  - ⇨indirect economics
- ⇨Policy development
  - ⇨Forecasting
  - ⇨Budgeting
- ⇨ Economic regulation: just and reasonable
  - ⇨price regulation: just and reasonable
  - ⇨structure regulation: antitrust
- ⇨Selling and Buying government assets

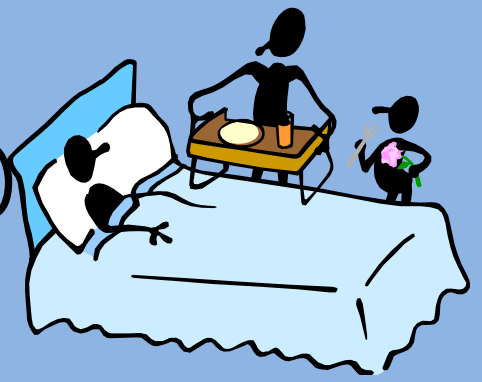
Selling and buying government assets

- government sells its assets via auctions
  - Oil and gas
  - Timber
  - Grazing
  - Spectrum
  - T-Bills and securities
- Spectrum
  - Old approach: are you worthy?
  - New approach: auctions
- How does society get the best value?
  - Auctions
- What are the auction rules?
  - First price, Vickrey
  - Sealed bid, English, Dutch

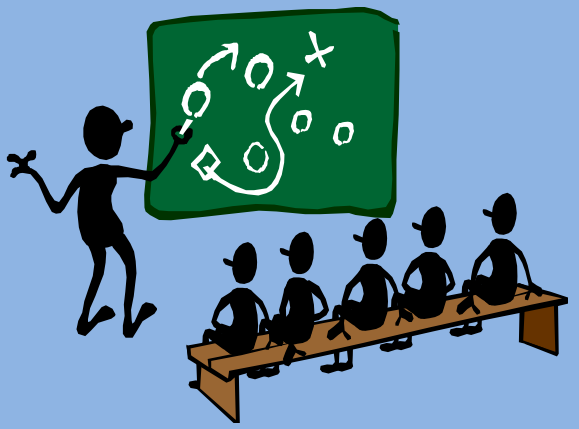


Environment and Safety

- ⇨internalize externalities
  - ⇨Price output
  - ⇨Limit output: cap and trade
- ⇨indirect economics
  - ⇨for example, best available technology
- ⇨Estimation
  - ⇨value of human life or lost wages
  - ⇨probability of harm
  - ⇨damage function (severity of harm)
  - ⇨cigarette smoking cost-benefit



Policy Development



- models are
  - scenarios about the uncertain future
  - the minimum ante for entry into the debate
  - weapons in the political debate
- Who did the work? What is their agenda?
  - Tell me the sponsor and I'll tell you the results.
  - Look for 'man bites dog' analysis.
  - When was the last time an NAS study did not recommend more research?

Project Independence Evaluation System (PIES)

- First 'large scale' equilibrium model for energy
- In the heat of time deadlines for proposing 1978 energy legislation
- the Distillate eater
  - Too much distillate fuel consumption.
  - Change conversion rate to make it uneconomic
  - Not enough distillate
  - Force a minimum amount of electricity from distillate
  - Huge over consumption of distillate
  - Results frozen by the White House
- Texas undertook an extensive evaluation of PIES
- Progeny still used by EIA today

Energy Forecasting

- Resource economics: finite resources
  - Hoteling models assume we are running out
  - We are running out of the sun but does this worry us?
  - Depends on assumptions for example, USGS recoverable reserves
  - How much do we have left? 10, 100, 1000 years?
  - To date it's a 'loves and fishes' story
- Innovation misses in natural gas forecasts
  - 1980s: deep gas (15000 ft. +) and abiogenic gas
  - 1990s: horizontal drilling
  - 2000s: Shale gas; horizontal drilling and fracting
  - 2010s: Methane hydrates?

Wellhead Gas Price Forecasts from 1980 to 1990

(1995 $/Mcf)

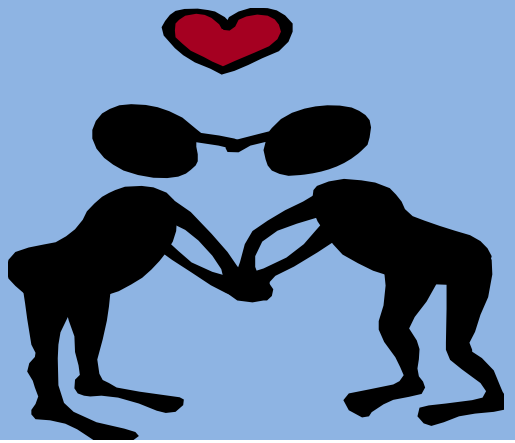
Forecast	Forecast 15 Years Out	Forecast 10 Years Out		Forecast 5 Years Out		
	for 1995 in 1980	for 1990 in 1980	for 1995 in 1985	for 1985 in 1980	for 1990 in 1985	for 1995 in 1990
EIA	5.98	5.19	5.90	3.45	4.11	2.65
DOE	8.06	6.72	5.95	5.60	3.82	2.74
DRI	15.46	11.23	4.28	5.60	2.80	2.39
AGA	--	6.34	3.63	7.65	3.27	2.42
Average	9.84	7.37	4.94	5.57	3.50	2.67
Actual	1.59	1.96	1.59	3.44	1.96	1.59
Avg/Act	6.19	3.76	3.11	1.62	1.79	1.68

Sources: Energy Information Administration (EIA), Department of Energy (DOE), Data Resources Incorporated (DRI), American Gas Association (AGA) and Gas Resources Institute (GRI).

Market Structure Regulation

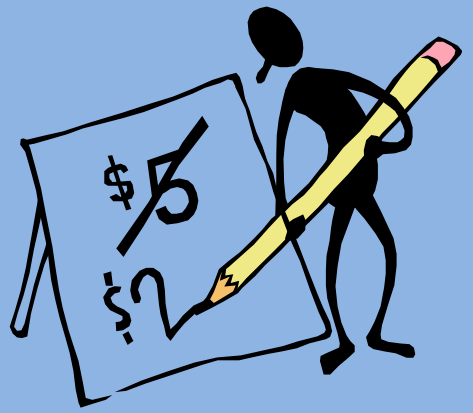
- All markets are regulated. The question is how?
  - Property laws
  - Contract laws

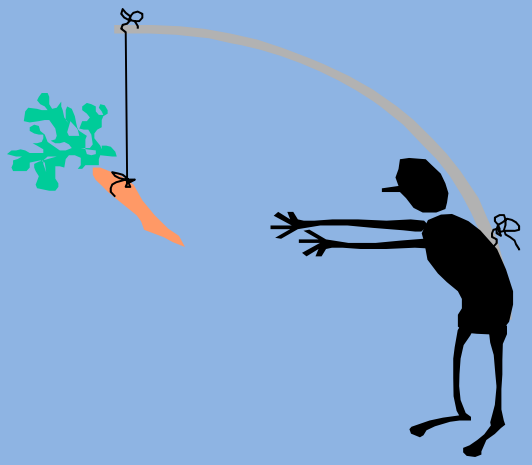
- Antitrust
  - You can earn your way to the market power through innovation
  - You can't by merger
  - Market share testing



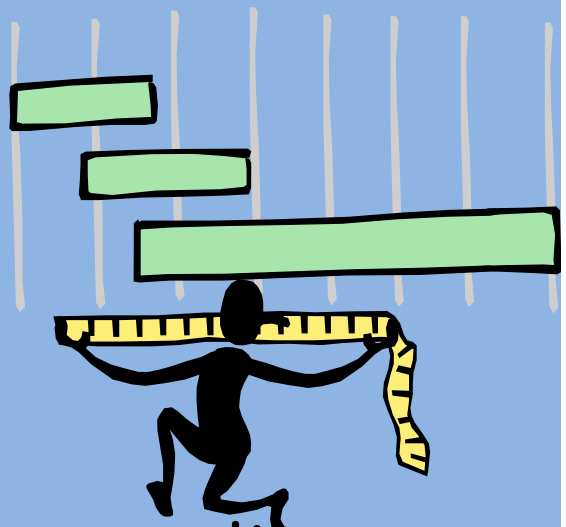
Market Price Regulation

- ⇨Control prices to control market power
- ⇨The law
  - ⇨just and reasonable prices
  - ⇨No undue discrimination
- ⇨Maximize benefits to society
- ⇨Distribute benefits
- ⇨Assuming rational behavior
  - ⇨Incentives for compatible behavior
  - ⇨mitigating market power
    - ⇨cost-of-service
    - ⇨market rules

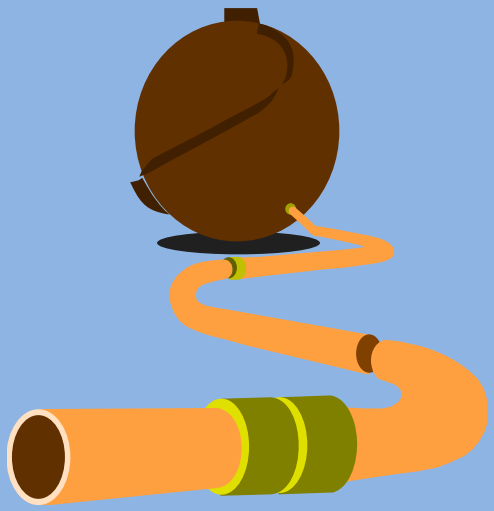




Benchmark (statistical) competition

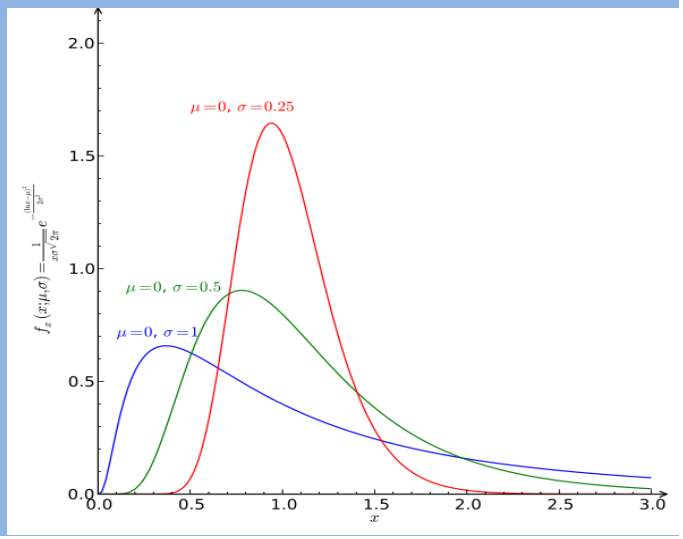


- Benchmark competition for spatial monopolies
- Compete against the 'average' monopolist
- Converges to efficient markets
- Good data and validation are key
- Current: Oil pipeline rates
- Candidates
  - Gas pipelines
  - Transmission and distribution



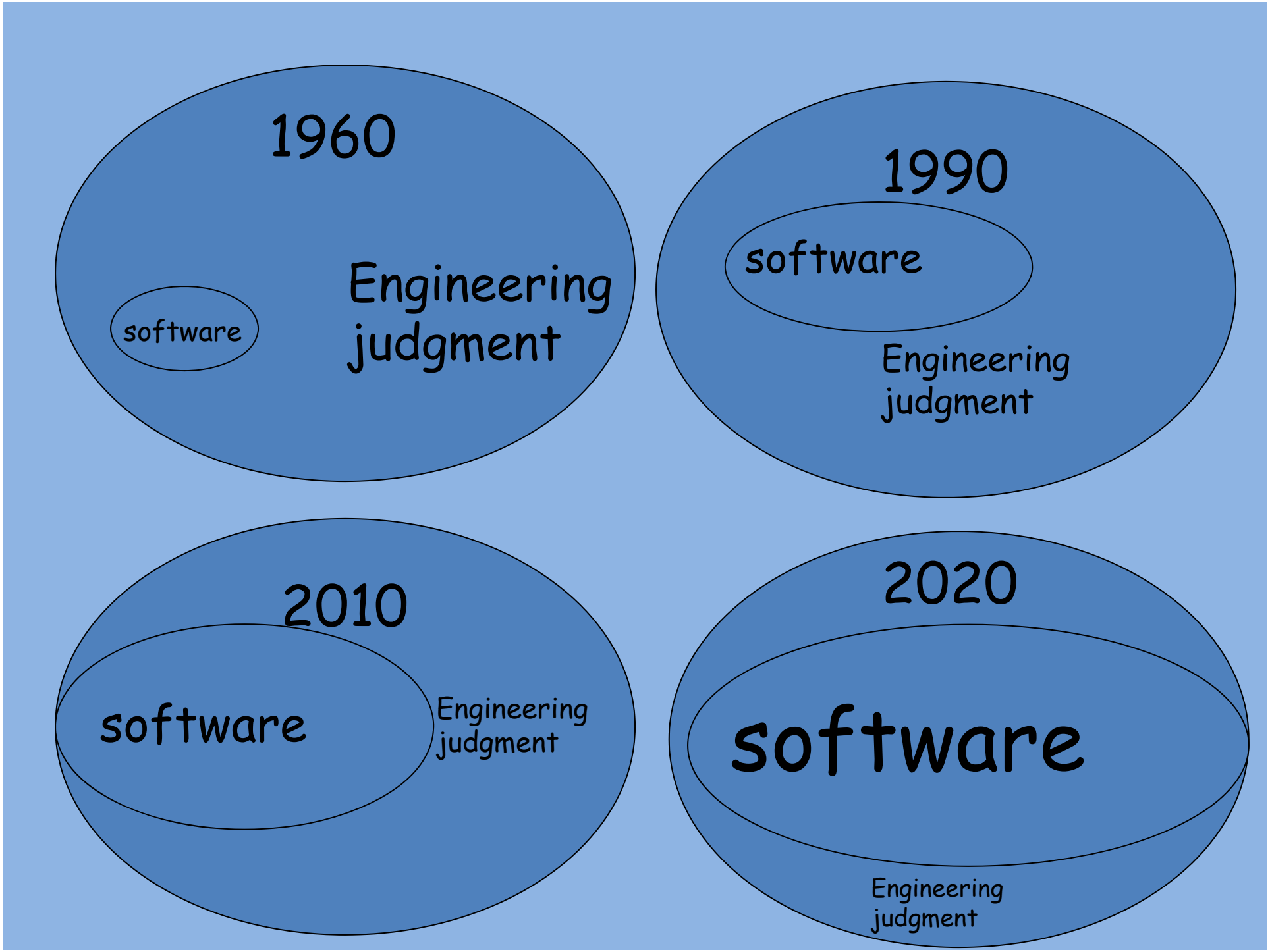
Validating Regulatory Models

- Documentation. Does it accurately reflect the software?
- Stress testing.
  - What is the reasonable range of the model?
  - Most are very narrow.
- Moving target: Most models are constantly revised and 'tuned'?
- Resource distribution
  - Beta has all moments
  - Lognormal (broken mirror)
  - Angels dancing on a pin
  - Wasteful science



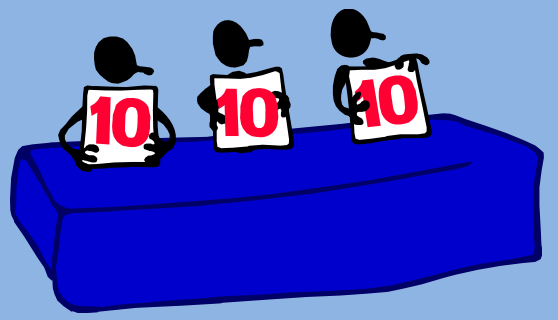
Electricity fictions, frictions, paradigm changes and politics

- 19th century competition: Edison v. Westinghouse
- 1905 Chicago 47 electric franchises
- 20th century: Sam Insull's deal
  - franchise 'unnatural' monopoly
  - cost-of-service rates
  - Incentives for physical asset solution
- 1927 PJM formed a 'power pool'
- 1965 Blackout:
  - Edward Teller: "power systems need sensors, communications, computers, displays and controls"
- 2013 still working on it

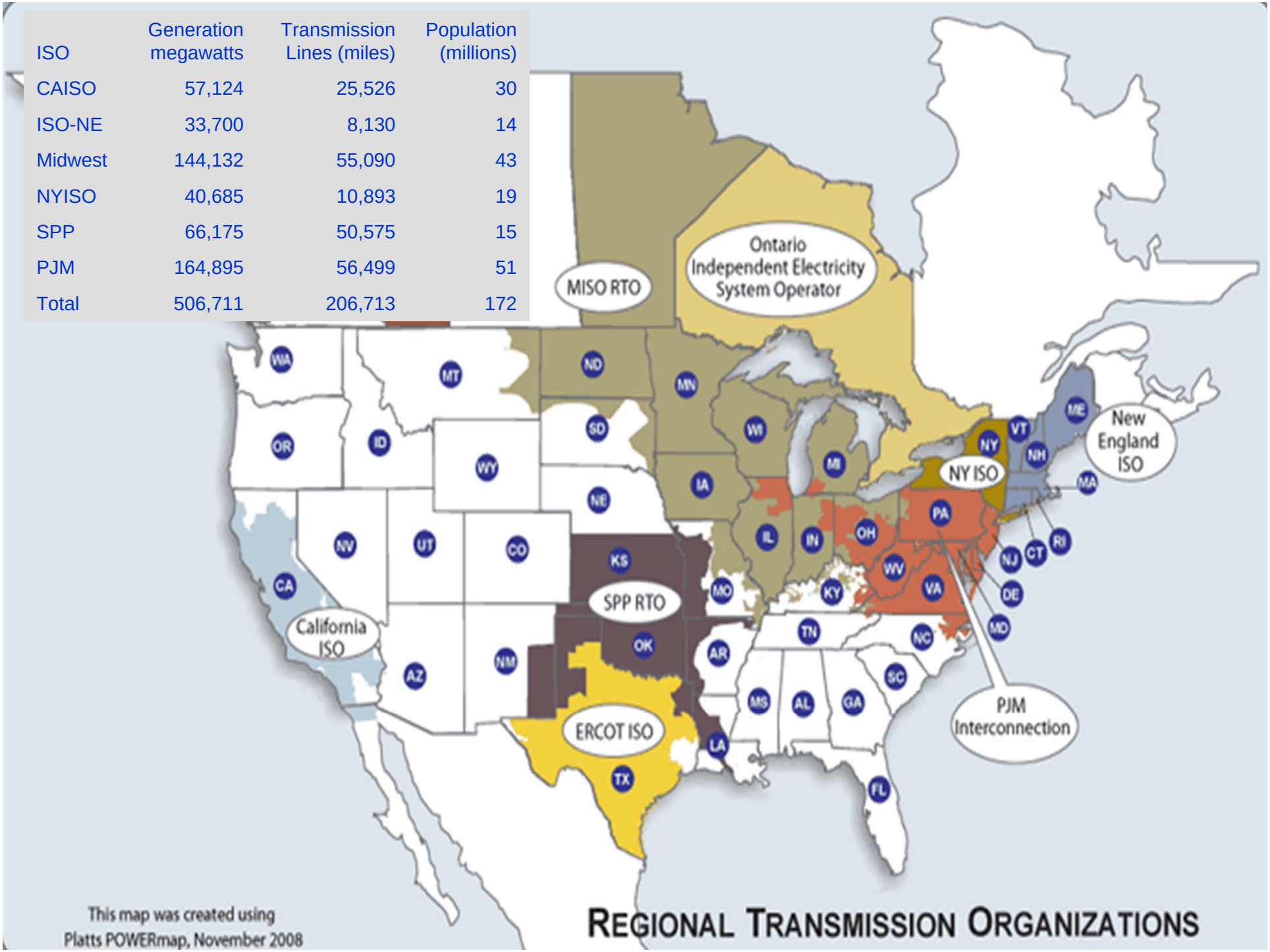

1960
software
Engineering judgment
1990
software
Engineering judgment
2010
software
Engineering judgment
2020
software
Engineering judgment

Wholesale Electric Power Markets in ISOs

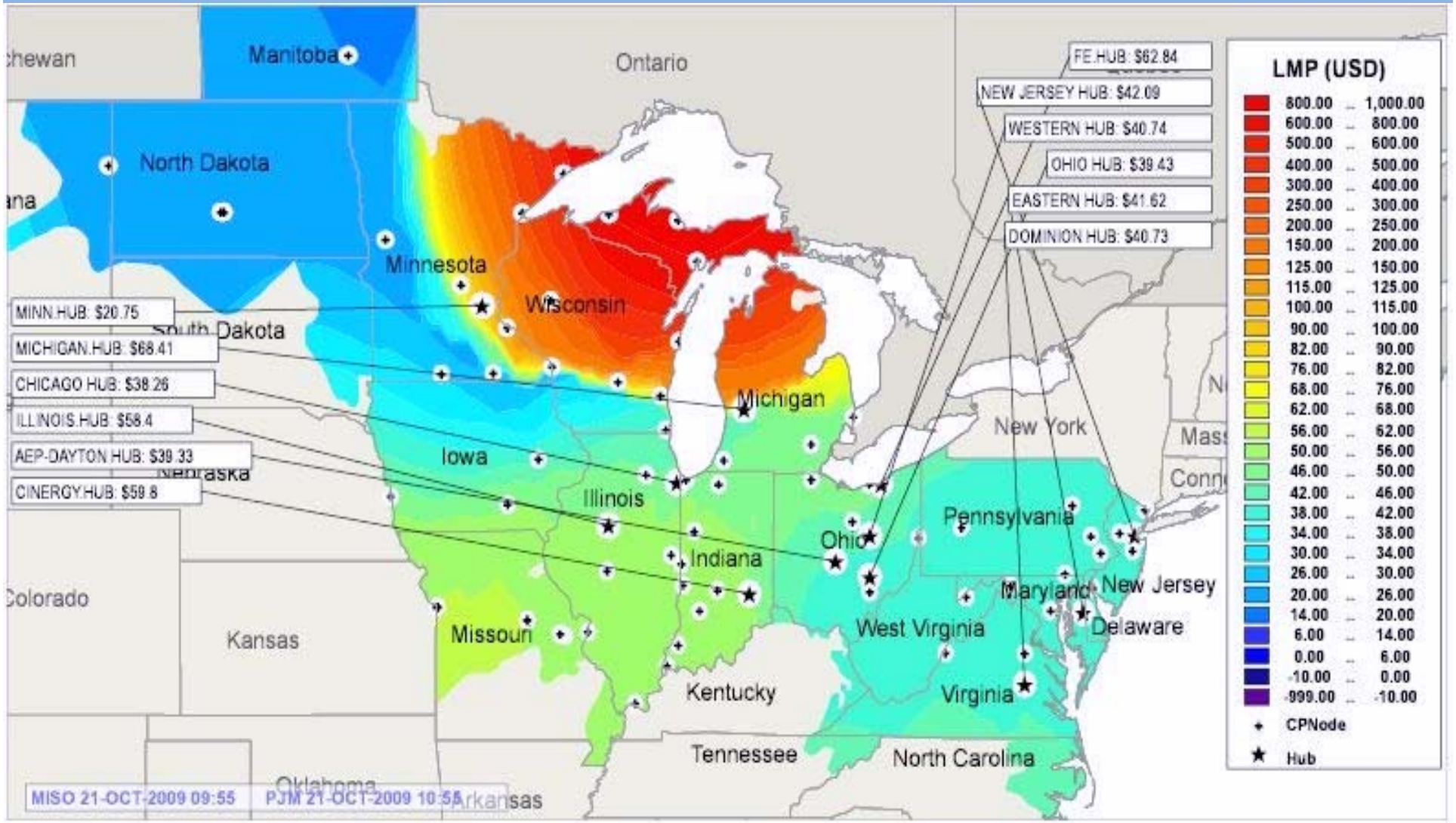
- ⇨ are regulated auctions with market power mitigation
- ⇨ ISOs accounts about 2/3 US power …
  - ⇨ PJM operates 150 Giga Watt market over 10 states
- ⇨ Model improvements have saved billions (benefit/cost > 100)
- ⇨ Still rough approximations and data issues



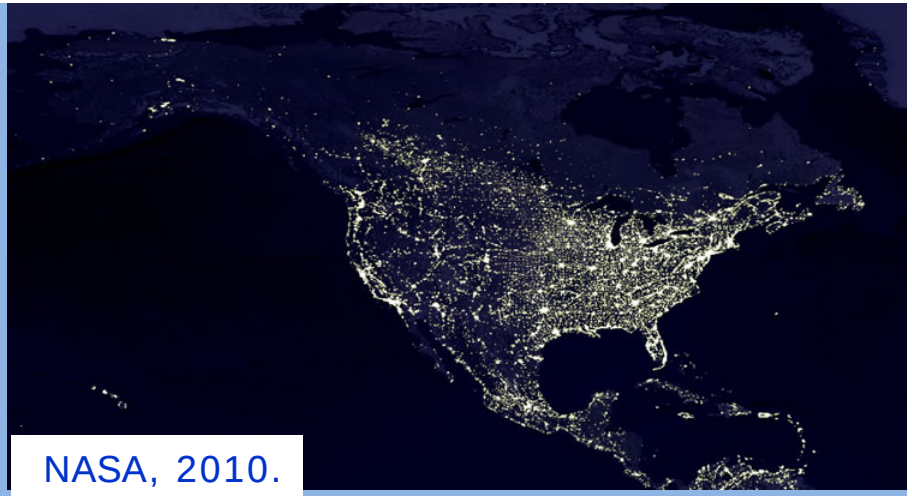
ISO	Generation megawatts	Transmission Lines (miles)	Population (millions)
CAISO	57,124	25,526	30
ISO-NE	33,700	8,130	14
Midwest	144,132	55,090	43
NYISO	40,685	10,893	19
SPP	66,175	50,575	15
PJM	164,895	56,499	51
Total	506,711	206,713	172



PJM/MISO 5 minute LMPs
21 Oct 2009 9:55 AM

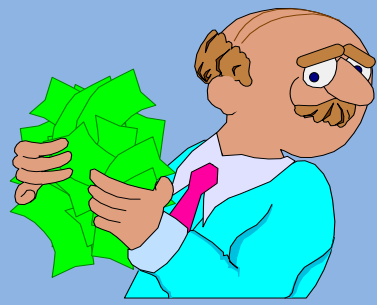


The Potential Impact...



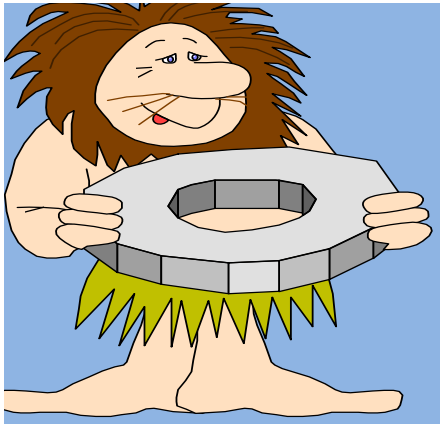
NASA, 2010.

- World Gross Production (2009): 20,000 TWh
- United States Gross Production (2009): 4,000 TWh
- At $30/MWh: cost $600 billion/year (world)
  - cost $120 billion/year (US)
- At $100/MWh: cost $2,000 billion/year (world)
  - cost $400 billion/year (US)
- In US 1% savings is about than $1 to $4 billion/yr
- FERC strategic goal: Promote efficiency through better market design and optimization software

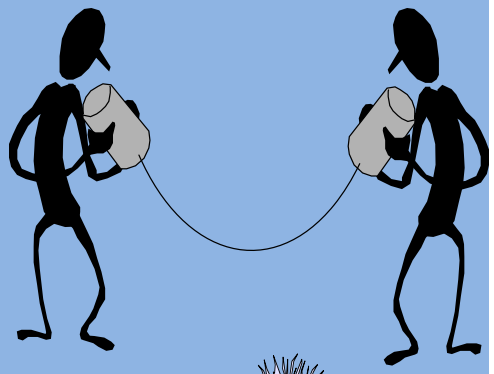


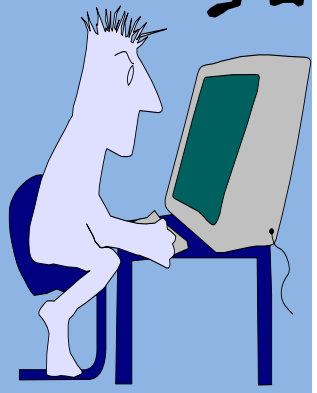
Source: IEA Electricity Information, 2010.

☹ **money can't buy me love**

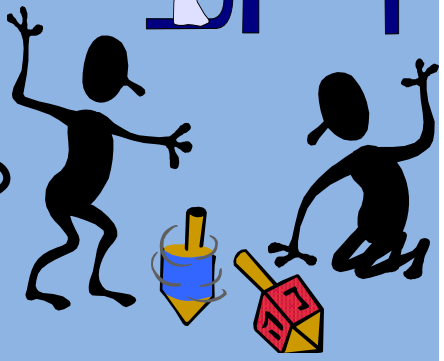


Paradigm change Smarter Markets 20??



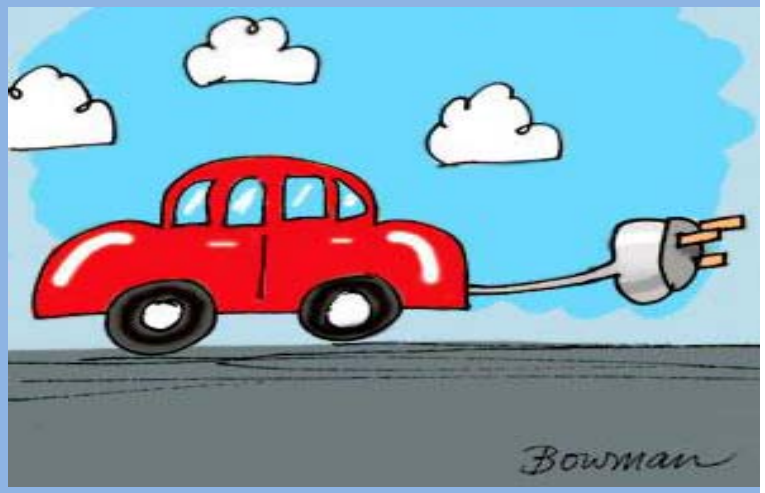


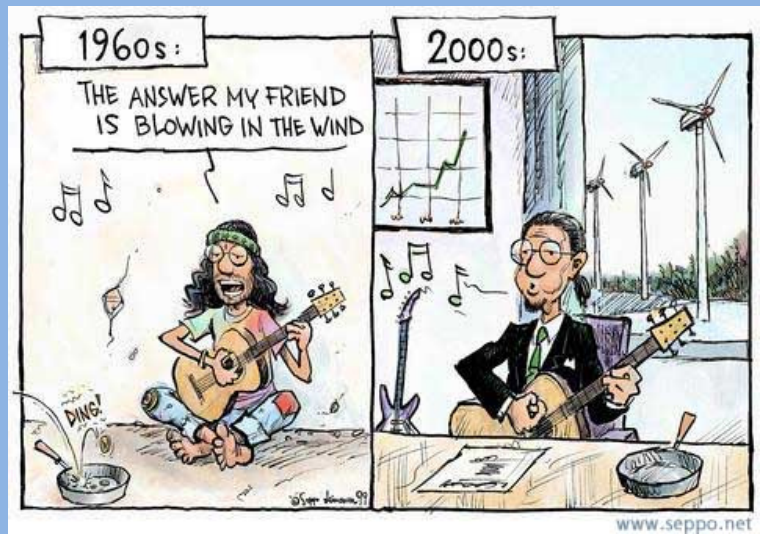
- What will be smarter?
  - Generators, transmission, buildings and appliances
  - communications, software and hardware
  - markets and incentives
- what is the 21st century market design?
  - Locationally and stochastically challenged:
    - Wind, solar, hydro
  - Fast response: batteries and demand
  - Harmonize wind, solar, batteries and demand
  - Greater flexibility more options



new technologies need better markets

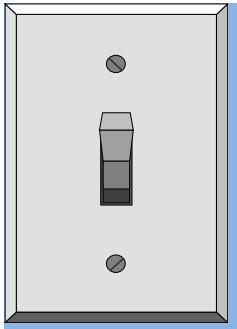
- Batteries, flexible generators, topology optimization and responsive demand
- optimally integrated
- off-peak
  - Generally wind is strongest
  - Prices as low as -$30/MWh
- Ideal for battery charging





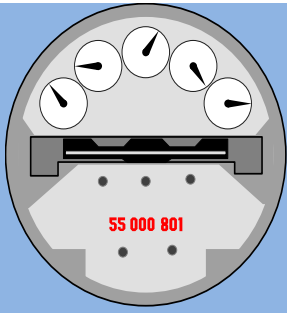
ISO Markets and Planning

- **Four main ISO Auctions**
  - Real-time: for efficient dispatch
  - Day-ahead: for efficient unit scheduling
  - Generation Capacity: to ensure generation adequacy and cover efficient recovery
  - Transmission rights (FTRs): to hedge transmission congestion costs
- **Planning and investment**
  - Competition and cooperation
- All use approximations due to software limitations



End-use consumers

got to get you into my life



- Consumers receive very weak price signals
  - monthly meter; 'see' monthly average price
  - On a hot summer day
    - wholesale price = $1000/MWh
    - Retail price < $100/MWh
  - results in market inefficiencies and
  - poor purchase decisions for electricity and electric appliances.

He's as blind as he can be just sees what he wants to see

- Smart meter and real-time price are key
- Solution: smart appliances
  - real time pricing, interval meters and
  - Demand-side bidding
- Large two-sided market!!!!!!!!!

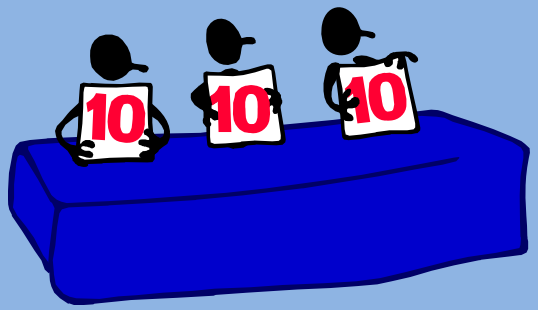
Enhanced wide-area planning models

- more efficient planning and cost allocation through a mixed-integer nonlinear stochastic program.
- Integration into a single modeling framework
- Better models are required to
  - economically plan efficient transmission investments
  - compute cost allocations
- in an environment of competitive markets with locationally-constrained variable resources and criteria for contingencies and reserve capacity.

MIP Paradigm Shift

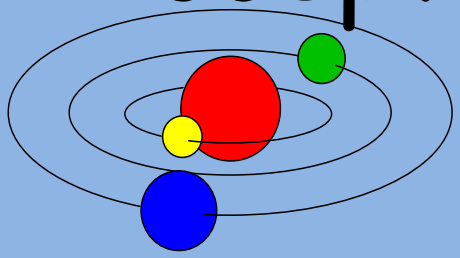
Let me tell you how it will be

- Pre-1999
  - MIP can not solve in time window
  - Lagrangian Relaxation
    - solutions are usually infeasible
    - Simplifies generators
    - No optimal switching

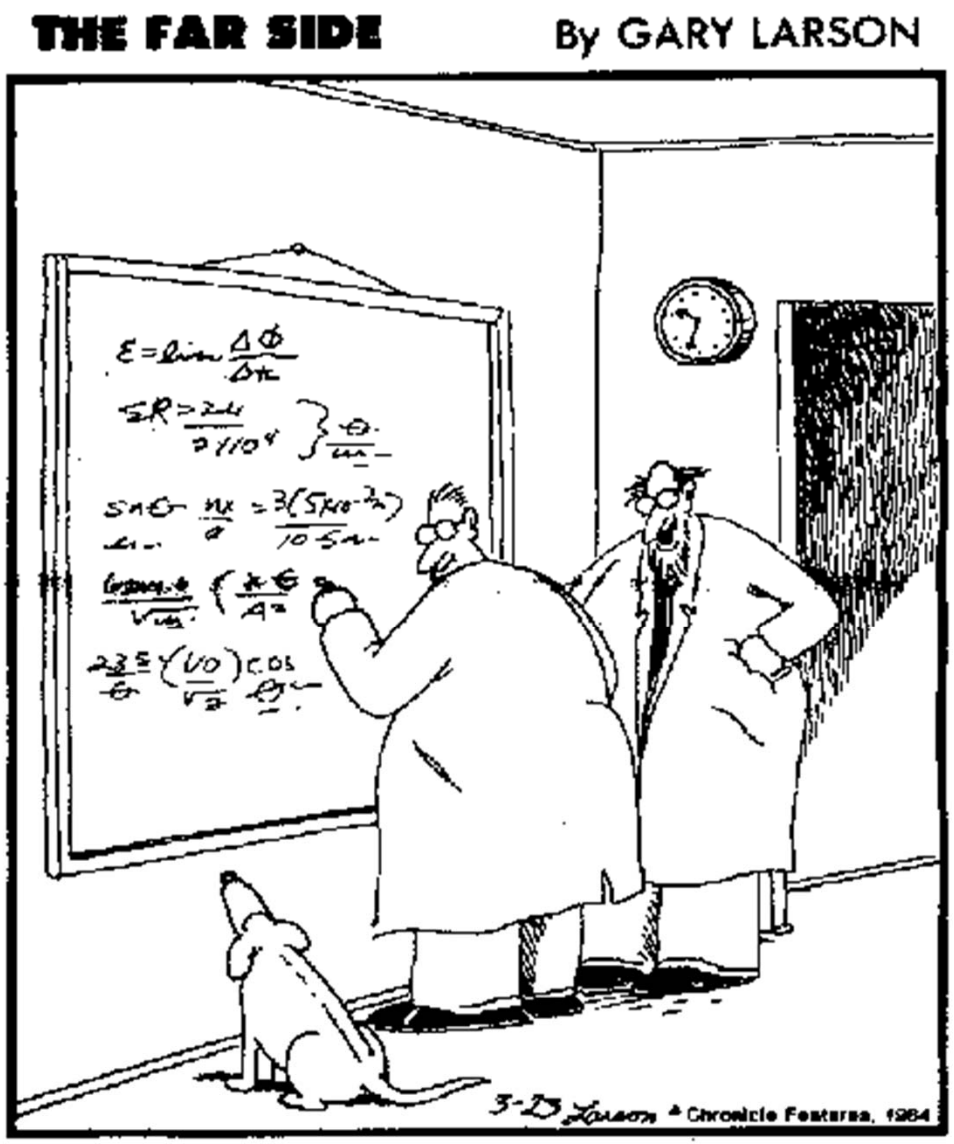


- 1999 unit commitment conference and book
  - MIP provides new modeling capabilities
  - New capabilities may present computational issues
  - Bixby demonstrates MIP improvements
- 2011 MIP creates savings > $500 million annually
- 2015 MIP savings of > $1 billion annually

Acceptance of Paradigm Shifts

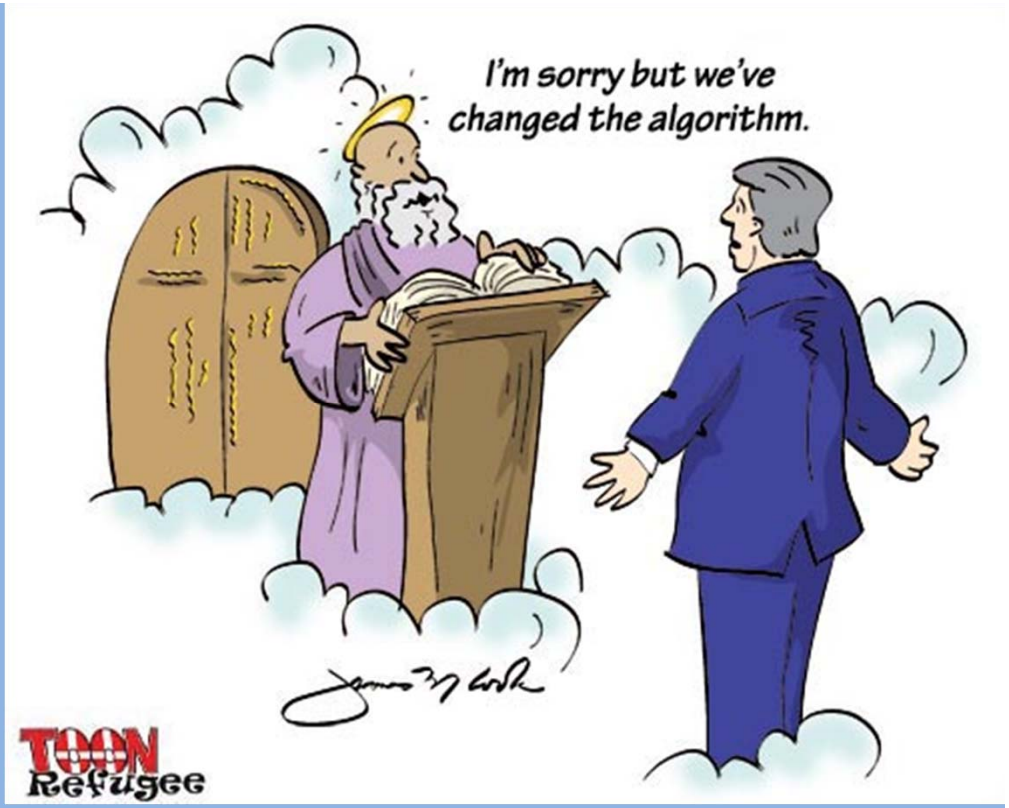


"A new scientific truth does not triumph by convincing its opponents and making them see the light, but rather because its opponents eventually die, and a new generation grows up that is familiar with it." Max Planck



"Ohhhhhhh . . . Look at that, Schuster . . . Dogs are so cute when they try to comprehend quantum mechanics."

Market Design



"Everything should be made as simple as possible … but not simpler." Einstein

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