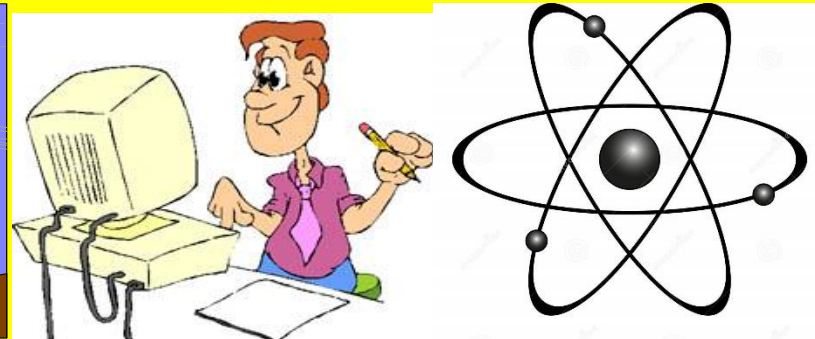
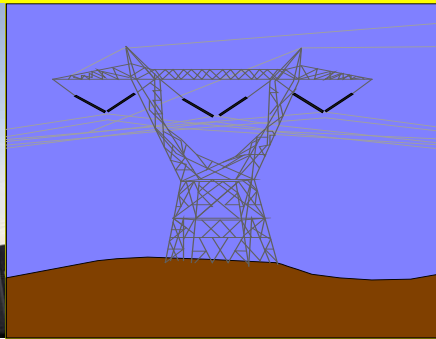
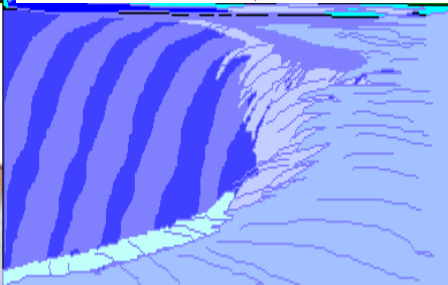


Future Transmission Planning

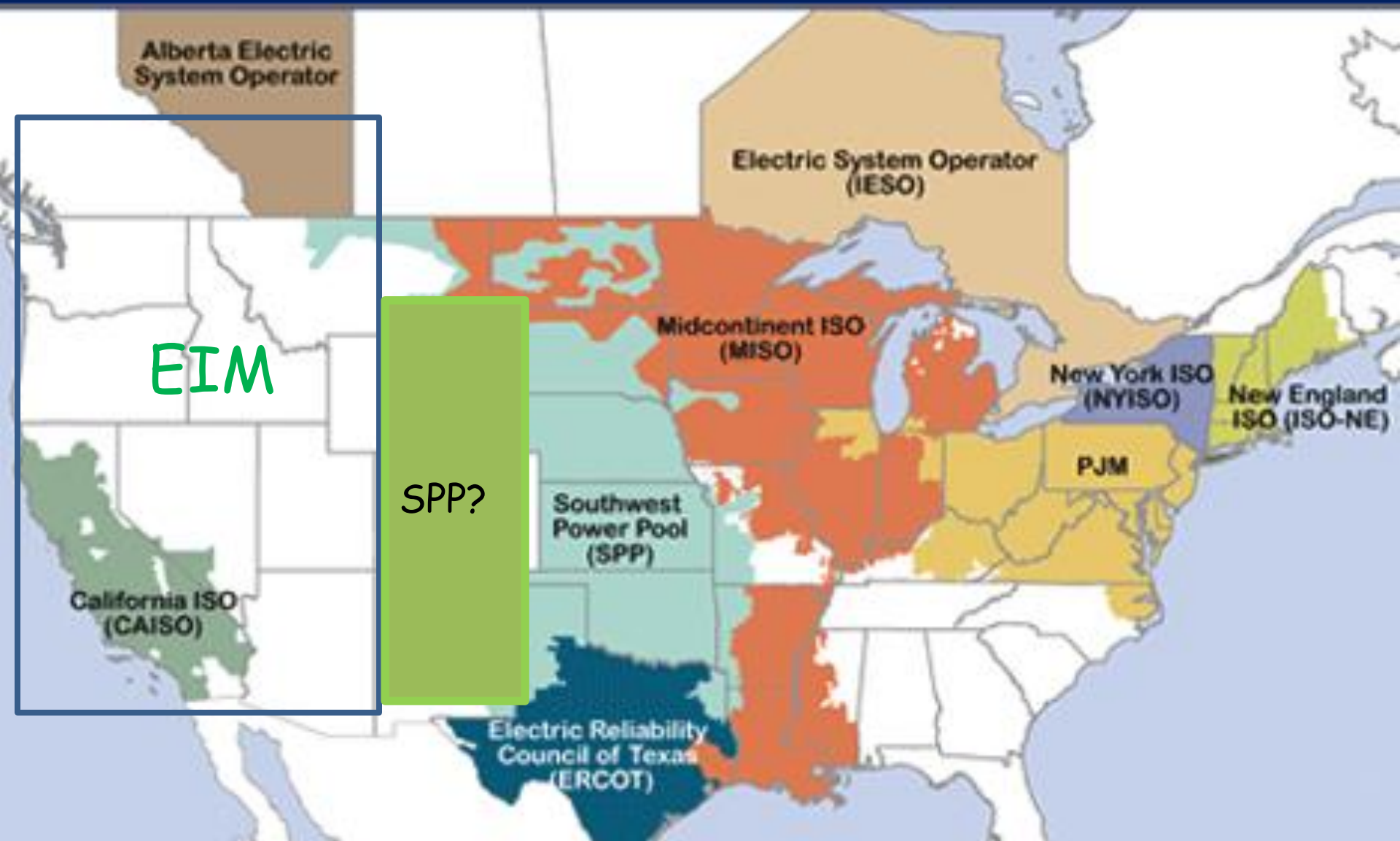


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ARPA-E
ESIG Spring Meeting
April 2020



the views expressed are
not necessarily those of
ARPA-E or the DOE

ISOs Dominate US Power Market and Continue to Grow



Background and future

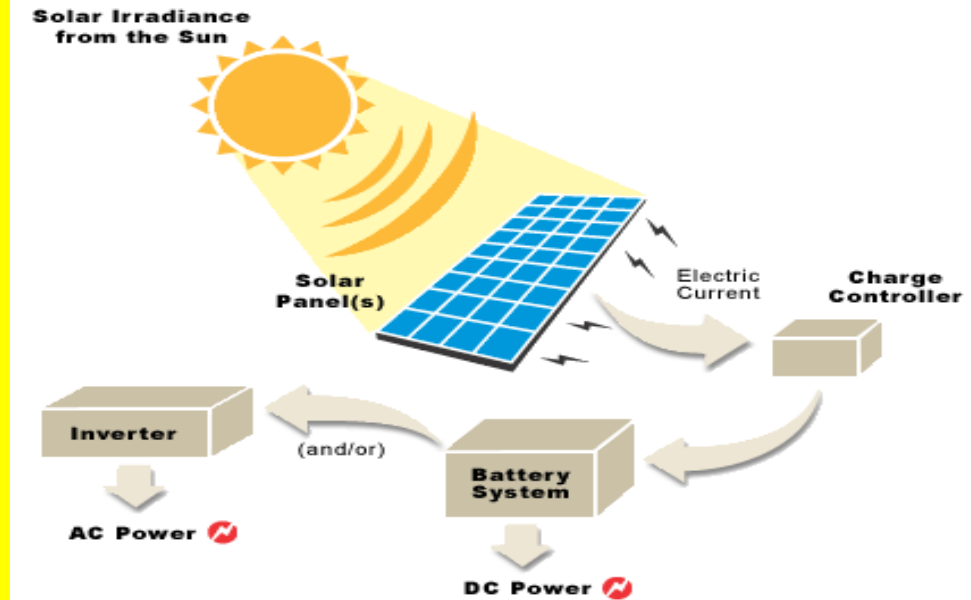
- ☞ Today generators offer and load is forecasted..
- ☞ Prices are more unpredictable and have higher variance
 - ☞ More higher prices
 - ☞ More lower prices
- ☞ TOU prices are no longer efficient.
 - ☞ It is not just peak shaving where is the peak?
 - ☞ It's to take advantage of lower prices
- ☞ Need price-responsive demand
- ☞ first century of electric power, generation followed load.
- ☞ second century of electric power, load follows generation.

New Technologies

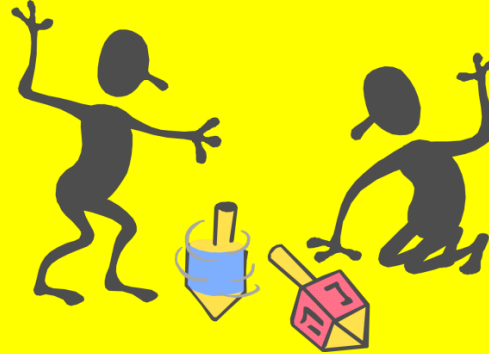
New Issues

(2000s)

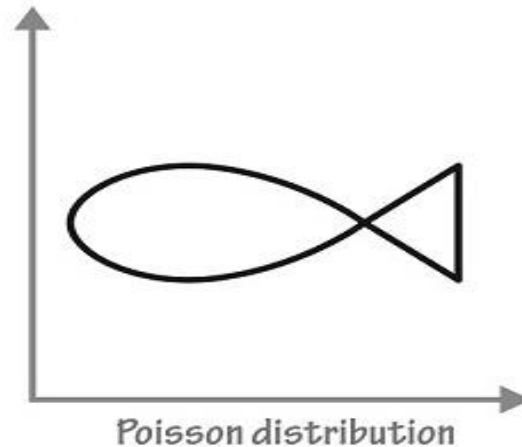
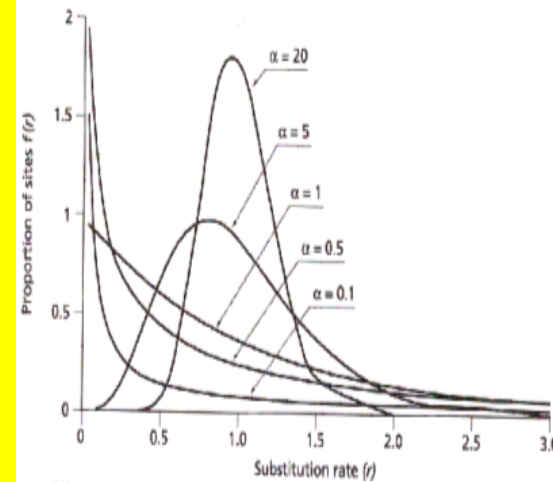
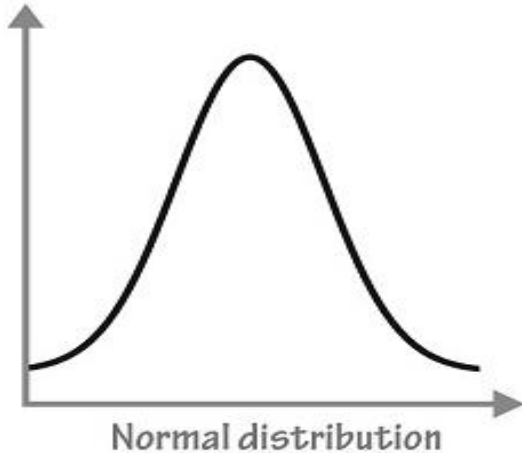
- ⇒ Solar and wind
- ⇒ Batteries
- ⇒ Electric cars
- ⇒ 'net load' = load-renewables
- ⇒ need
- ⇒ flexible generators
 - ⇒ Greater range [min, max]
 - ⇒ Faster ramp rate
- ⇒ Price-responsive demand
- ⇒ Smart controllable devices



Old Stochastics

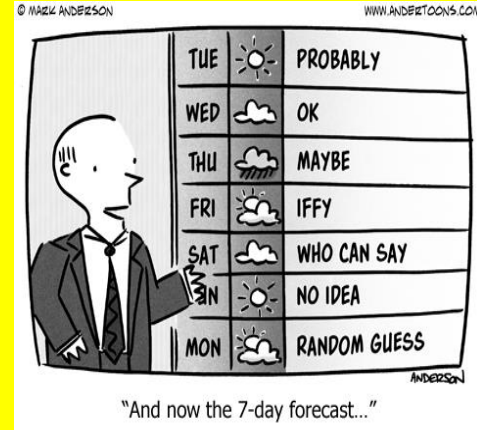


- ⇒ Binary generator failure
- ⇒ Demand = $f(\text{temperature})$
- ⇒ Peak is a hot afternoon in August
- ⇒ Could see it coming.
- ⇒ Off peak 'peaks', e.g., polar vortex
- ⇒ For dominant hydro systems (Brazil 75%),
 - ⇒ Need energy for N-year drought
 - ⇒ Need opportunity cost pricing
 - ⇒ Forward energy (not capacity) markets





Weather Stochastics



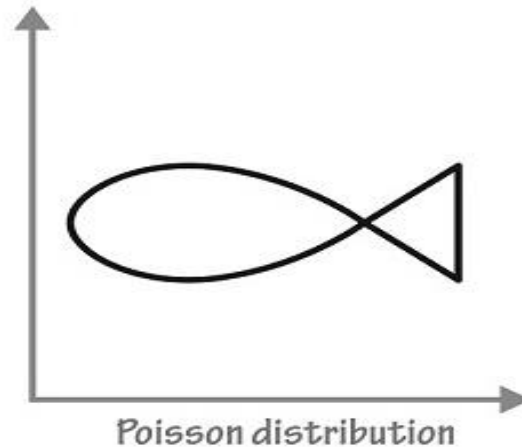
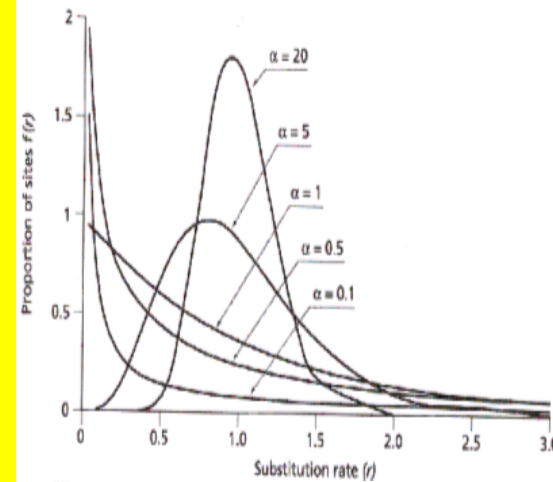
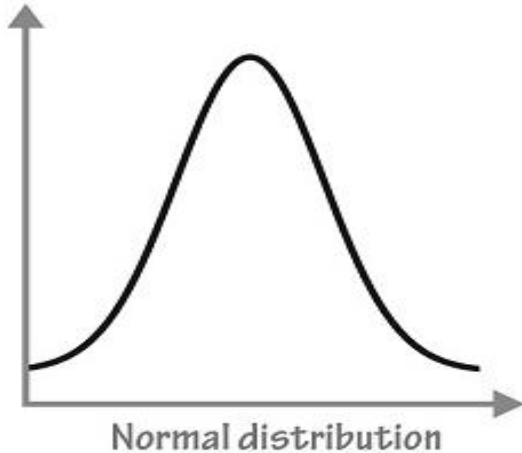
- ⇒ Bad/unexpected weather forecast is the largest contingency
- ⇒ Weather contingencies
 - ⇒ 70% of generator failures due in part to weather
 - ⇒ Transmission capability due in part to weather
- ⇒ new stochastics
 - ⇒ generator = $f(\text{temperature, operation, maintenance})$
 - ⇒ Demand = $f(\text{temperature, humidity})$
 - ⇒ Solar = $f(\text{sunshine})$
 - ⇒ wind = $f(\text{wind, shutdowns at } -20^{\circ}\text{F or max wind})$
 - ⇒ Hydro = $f(\text{rain, snow})$
- ⇒ Where and when is the peak?
 - ⇒ Cloudy and windless day
 - ⇒ Sunny and windy day



New Stochastics



- ⇒ For dominant renewables systems
 - ⇒ Need energy not capacity
 - ⇒ opportunity cost offers
 - ⇒ Forward energy markets
- ⇒ Flexibility
 - ⇒ Fast ramp and output range
 - ⇒ Price-responsive demand
 - ⇒ Hydro
 - ⇒ Batteries
 - ⇒ Transmission topology
- ⇒ Better pricing
 - ⇒ AIC pricing
 - ⇒ Price-responsive demand with Ramsay-Bouteux



Old model of transmission planning

- ☞ Utility decides to build a generator
 - ☞ names it after the current CEO
 - ☞ State commission does IRP and approves the generator
- ☞ Utility designs transmission to deliver it to native load
 - ☞ Uses state eminent domain
- ☞ Cost overruns > 2x
- ☞ Rate base everything: socialize costs and risks
- ☞ Send out flat price bills once a month to consumers
- ☞ Reliability model : 'keep the lights on'
 - ☞ 'one in ten' plus
 - ☞ ask or pay consumers to 'turn the lights off'

Transmission Planning Halfway House

- ➡ Market participant decides to build a generator
- ➡ Interconnection (Order 2003) designed for in a vertically integrated utility
 - ➡ Interconnection is not transmission, but we build transmission
 - ➡ Similar to hostage negotiation
 - ➡ Interconnector pays
- ➡ Design transmission to maximize expected market surplus?
 - ➡ Order 1000 competition has many loopholes
 - ➡ Utilities build most transmission with little oversight
 - ➡ Old software from the utility era
- ➡ Consumers pay for transmission not beneficiaries
- ➡ Transmission rights ??

Competitive transmission in ISOs

- the most controversial aspect of FERC Order 1000
- potential for significant customer savings:
 - limited to only 2% of. transmission investments in the last 5 years,
- competitive processes led to innovations in proposed solutions, low bids, cost caps, cost control measures, and innovative financial structuring
- Brattle study sponsored by LS Power
 - Winning bids average 40% below initial cost estimates
 - Non-competitive projects completed at 34% above initial estimates

Rethinking economic efficiency and regulation

- ➡ Plenty of legislation for increasing economic efficiency
- ➡ Transmission expansion and "interconnection".
 - ➡ designed using the old model
 - ➡ needs retooling
- ➡ Different pricing for transmission in interconnection process than transmission expansion. Makes no sense
- ➡ Order 1000 has significant loopholes to competition.
- ➡ term '1 in 10' it is almost vacuous
 - ➡ the value of load is based on the cost of a combustion turbine not the value of load
 - ➡ let load express its value

SPP topology optimization

- ➡ reconfigurations route flows around breached elements meeting reliability standards.
- ➡ 70% of constraints analyzed: single-action solutions on facilities below 345 kV led to an average 26% flow relief
- ➡ 95% of constraints analyzed: solutions led to 31% relief,
- ➡ SPP created an Op. Guide based on this analysis (Tupelo overloads, OK).
- ➡ estimated that topology optimization would reduce frequency of breached intervals from 34% (current) to 8%
- ➡ Annual RT market efficiency gains of \$18-44 million



Price-Responsive Demand



- ⇒ Price-responsive demand in day-ahead and real-time market
 - ⇒ Supply ancillary services
- ⇒ Entry when $\Delta \text{Consumer Surplus} > \text{Incremental Cost}$
 - ⇒ LMP is the 'convex' margin
- ⇒ No capacity charges
- ⇒ Price Signals are ex-post not a signal to change in the current market dispatch
- ⇒ price-responsive demand and reserves pricing reduces the missing money and need for capacity markets

Long-term Planning Uncertainty

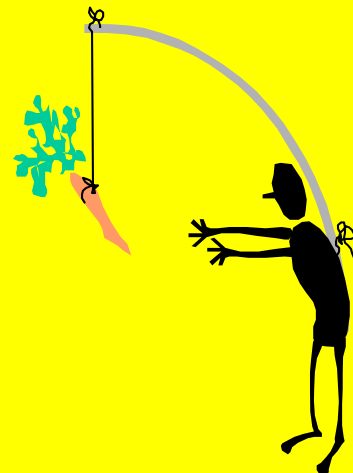
- ⇒ Epistemology: what do we know about the future?
 - ⇒ All forecasts are wrong; some are useful (George Box)
 - ⇒ No facts about the future (Lincoln Moses)
 - ⇒ Representation of uncertainty
 - ⇒ How good are the scenarios and probabilities
 - ⇒ Weather interactions: wind, sun, temperature, humidity
 - ⇒ All generator capacity 'failures' are a function of
 - ⇒ Weather
 - ⇒ Maintenance
- ⇒ Is weather the new common mode failure?

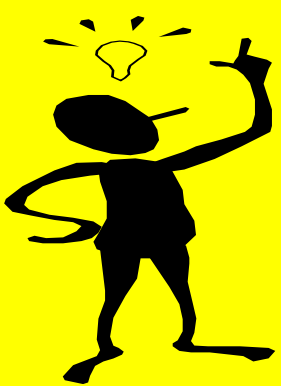


Transmission Expansion Planning Process

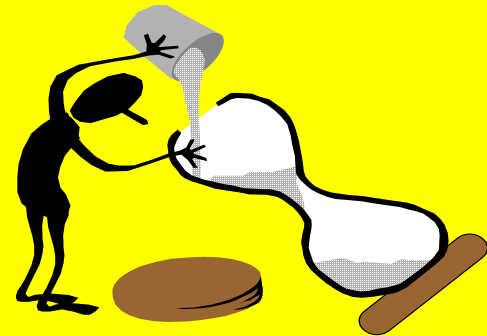


- ⇒ Economically efficient plan (EPAct2005)
- ⇒ legacy rules need a tune up
 - ⇒ All projects should pass a benefit-cost test
 - ⇒ stop peanut-buttered (broad cost allocation) rates
- ⇒ Cost allocation in proportion to benefits
- ⇒ How do you choose potential projects
- ⇒ How do they fit together
- ⇒ Iterative stakeholder process
 - ⇒ Larger voting role for 'beneficiaries'
- ⇒ models and solution times need improvement
- ⇒ More competition for new transmission





Software for ISO Market Efficiency

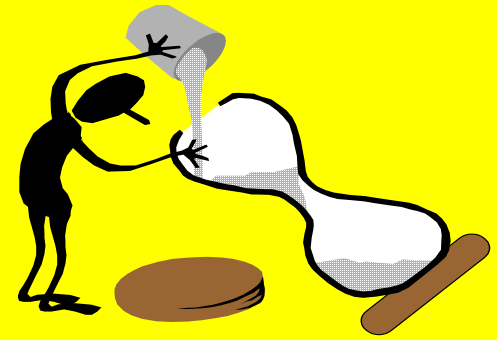


- ⇒ 1999 FERC on Unit Commitment. Try MILP you will like it.
- ⇒ 2005 PJM first to use MILP
- ⇒ 2015 SPP last to use MILP
- ⇒ MILP replaces Lagrangian relaxation
(saves ~ \$5 billion +/-yr)
- ⇒ The holy grail: mixed integer ACOPF
- ⇒ Transmission switching
 - ⇒ testing indicate ~\$5 billion +/-yr savings
- ⇒ Efficient software often has a Benefit/Cost > 100





ARPA-E OPF Competition



⇒ The holy grail: fast mixed integer SCACOPF

⇒ State of testing

⇒ Piecemeal approach

⇒ Hard to validate results

⇒ Small test problems

⇒ New issues

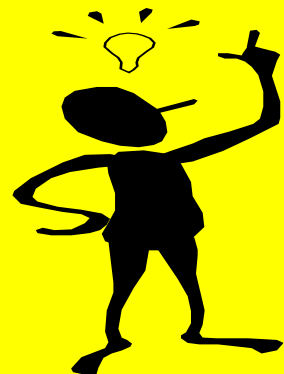
⇒ Renewables and uncertain weather

⇒ Price-responsive demand

⇒ Distribution optimization

⇒ the ARPA-E GO (OPF) over \$10 million in prizes

⇒ Second competition coming soon



Thank you

Questions