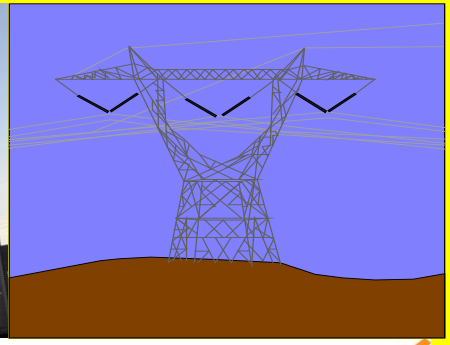
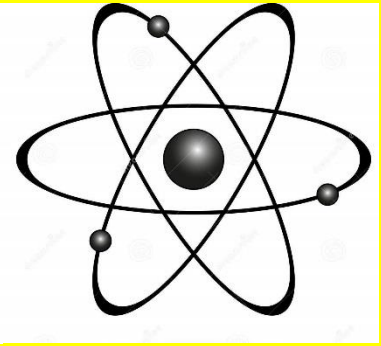
Future Transmission Planning





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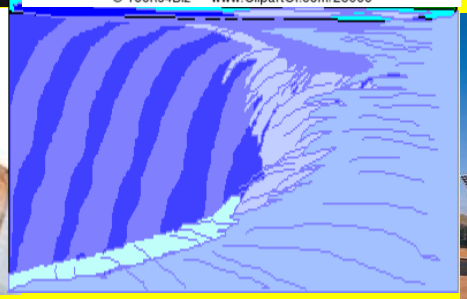
April 2020



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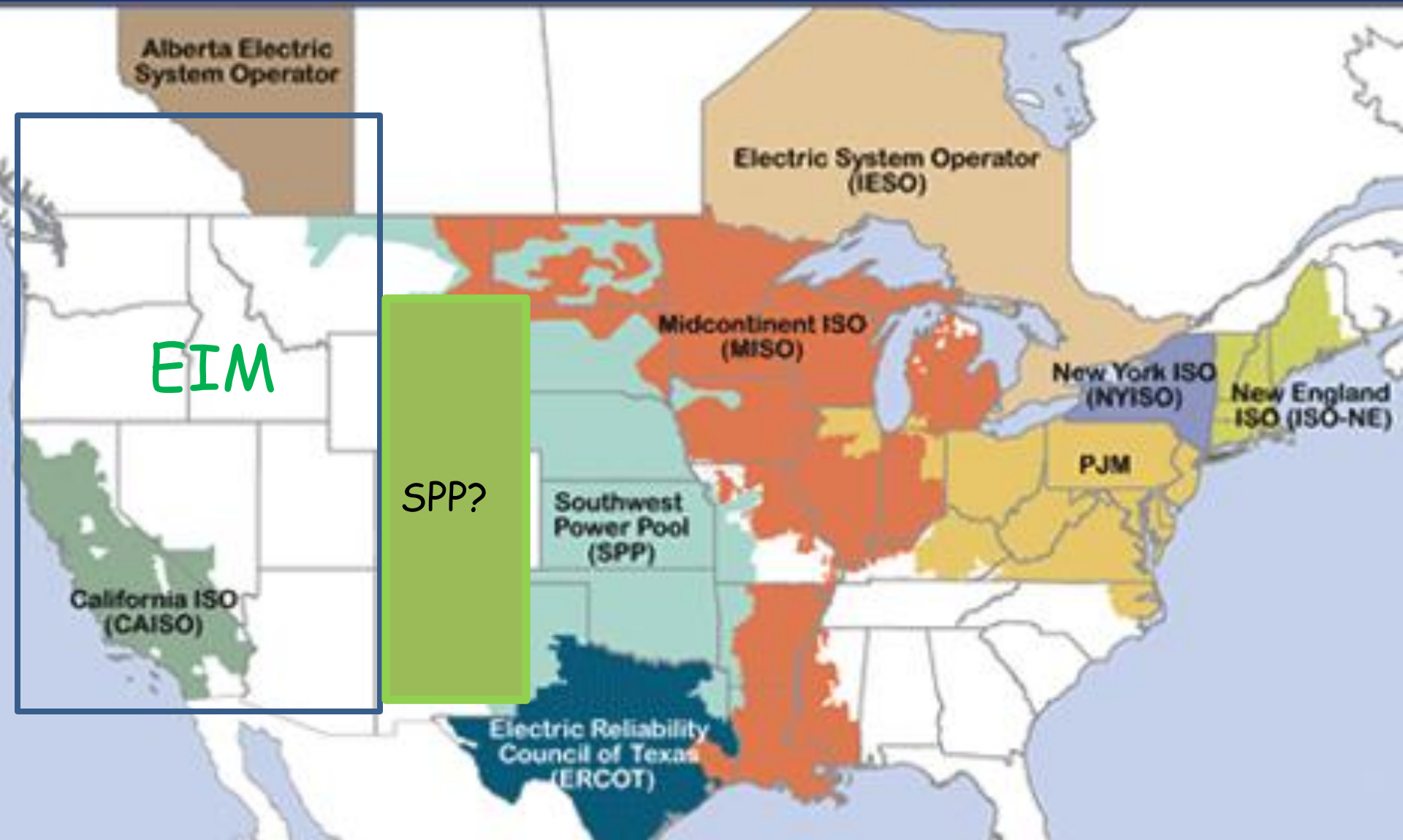
ISOs Dominate US Power Market and Continue to Grow



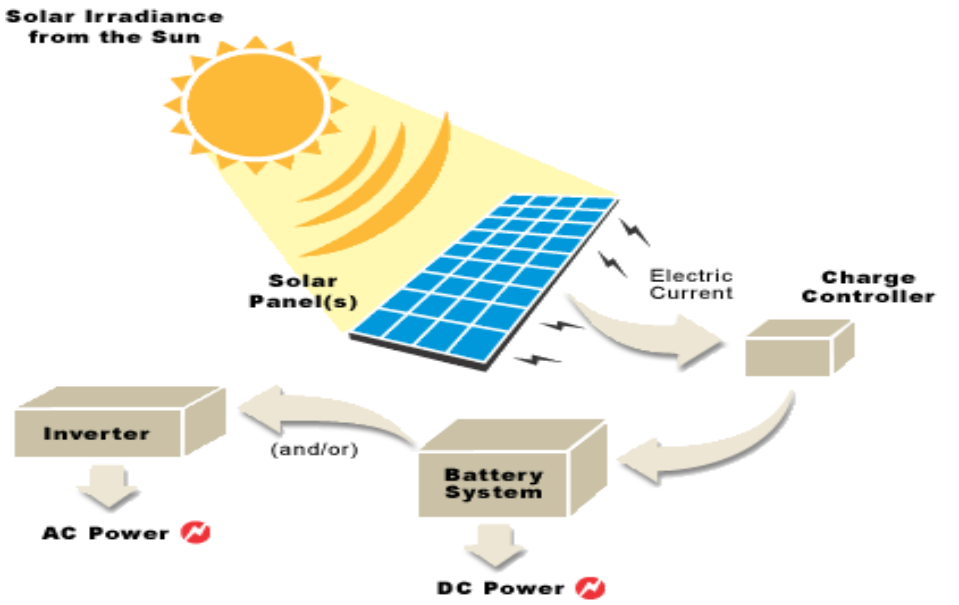
Background and future

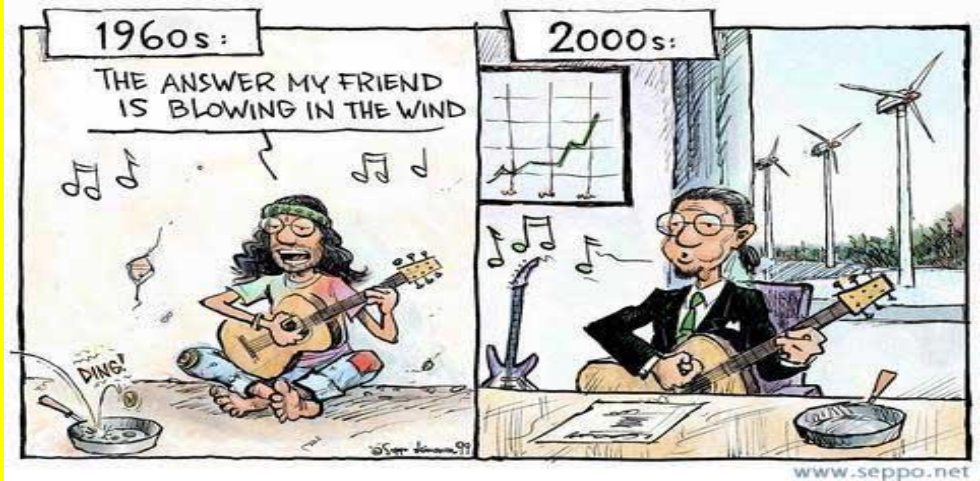
- Today generators offer and load is forecasted..
- Prices are more unpredictable and have higher variance
  - More higher prices
  - More lower prices
- TOU prices are no longer efficient.
  - It is not just peak shaving where is the peak?
  - It's to take advantage of lower prices
- Need price-responsive 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



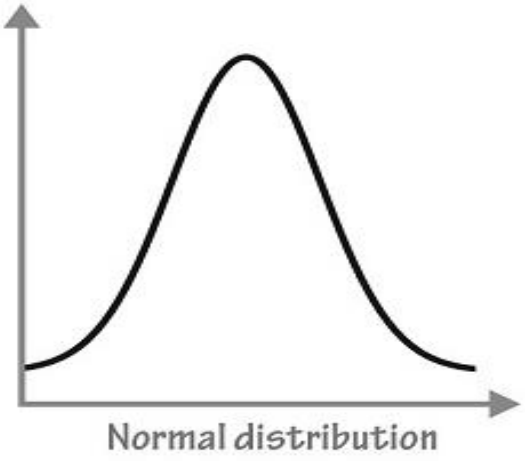


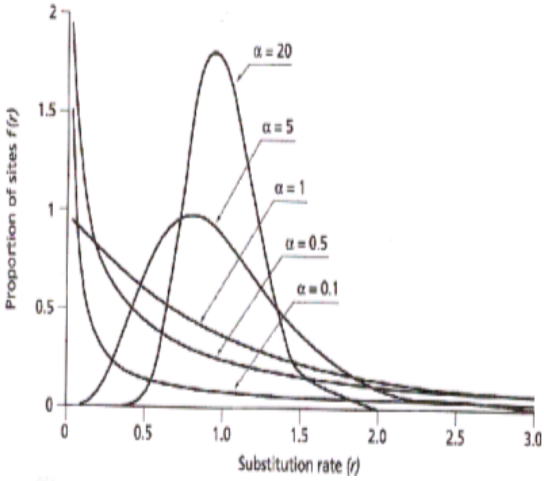
Old Stochastics

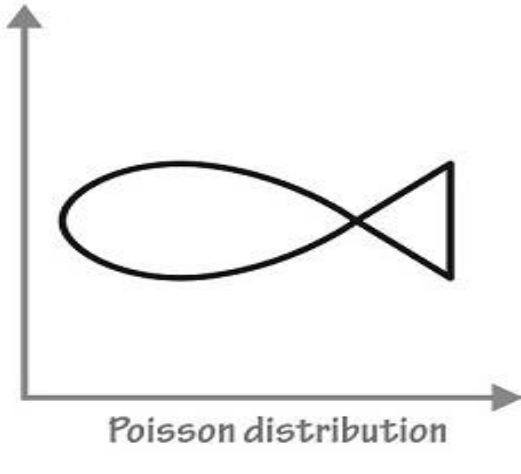
- ⇨ Binary generator failure
- ⇨ Demand = f(temperature)

- ⇨ Peak is a hot afternoon in August
- ⇨ Could see it coming.
- ⇨ Off peak 'peaks', e.g., polar vortex

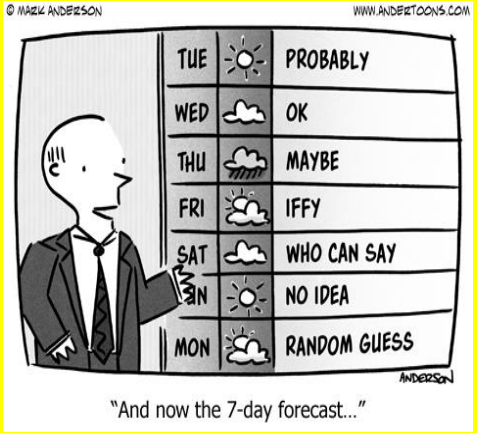
- ⇨ For dominant hydro systems (Brazil 75%),
  - ⇨ Need energy for N-year drought
  - ⇨ Need opportunity cost pricing
  - ⇨ Forward energy (not capacity) markets







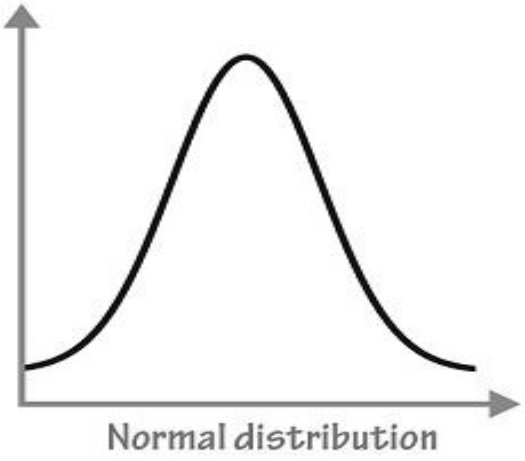
Weather Stochastics

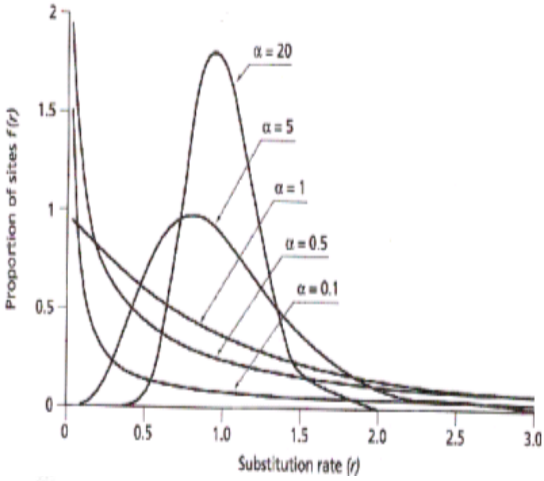


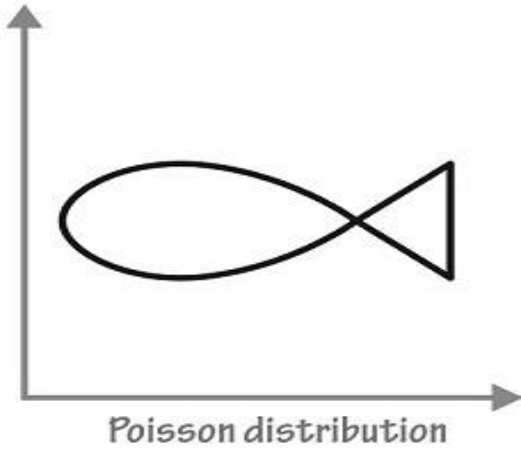
- Bad/unexpected weather forecast is the largest contingency
- Weather contingencies
  - 70% of generator failures due in part to weather
  - Transmission capability due in part to weather
- new stochastics
  - generator = f(temperature, operation, maintenance)
  - Demand = f(temperature, humidity)
  - Solar = f(sunshine)
  - wind = f(wind, shutdowns at -20°F or max wind)
  - Hydro = f(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

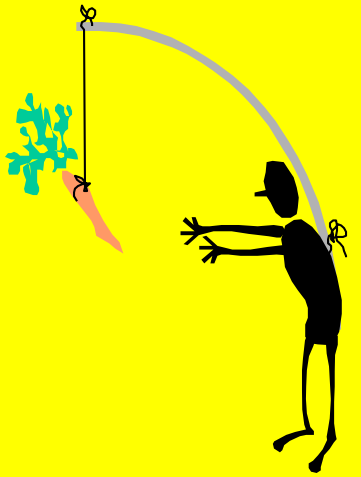
- Price-responsive demand in day-ahead and real-time market
  - Supply ancillary services
- Entry when ΔConsumer Surplus > Incremental Cost
  - LMP is the 'convex' margin
- No capacity charges
- Price Signals are ex-post not a signal to change in the current market dispatch
- price-responsive demand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

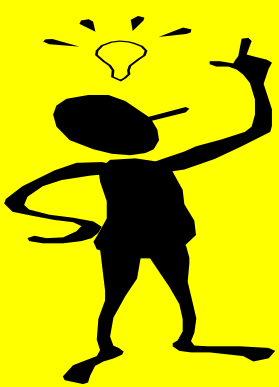
Long-term Planning Uncertainty

- 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?

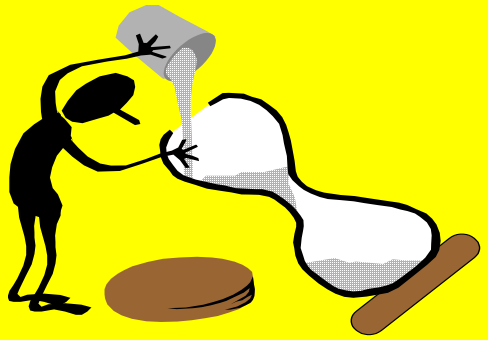
Transmission Expansion Planning Process

- 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



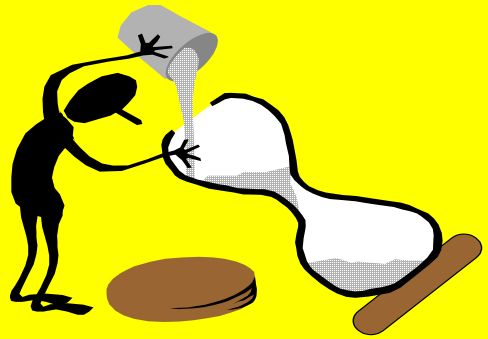


Software for ISO Market Efficiency



- 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