# Stochastic Models, Auctions, Wind and Demand
# Should we guess who is coming the dinner?
# Should we set an extra place at the table?
# Should they have reservations?

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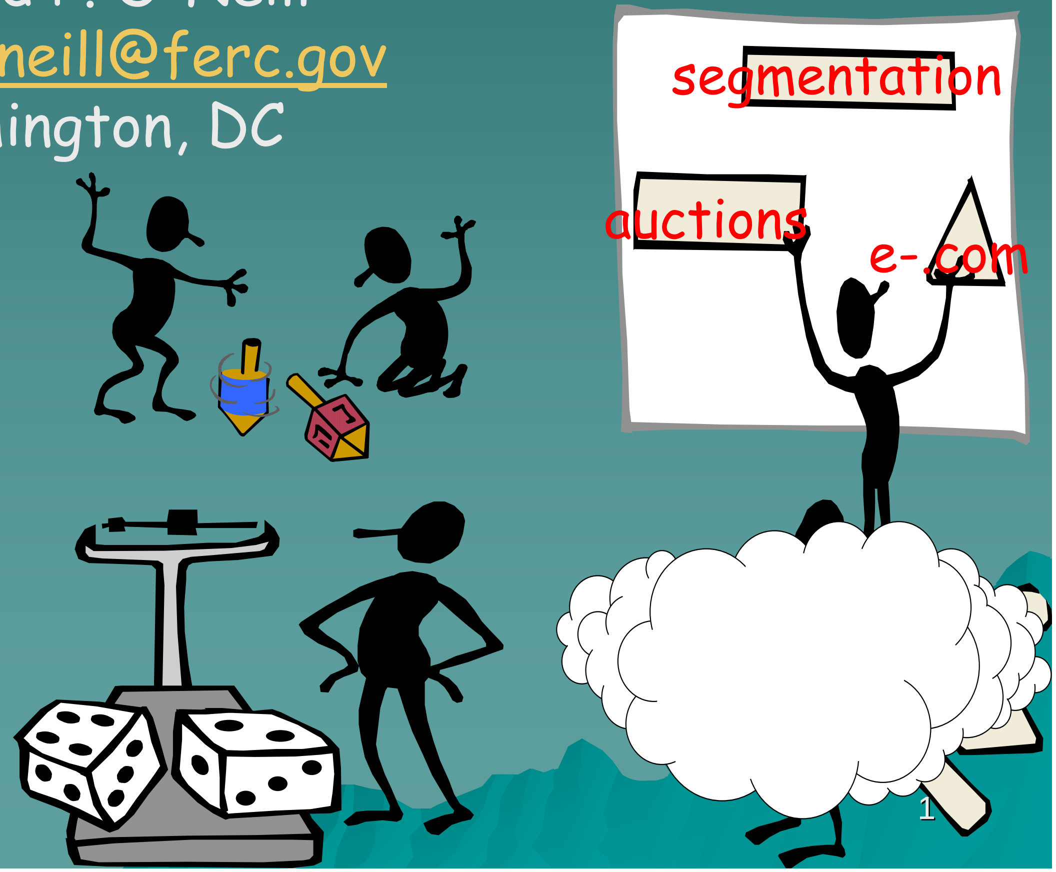


# Early contribution to statistical decision theory
## **Pascal's wager (hedge):**

- Pascal is unimpressed by *a priori* demonstrations that God exists.
  - "Endeavour ... to convince yourself, not by increase of proofs of God...", "we do not know if He is ...".
  - Pascal seeks *prudential* reasons for believing in God.
- we should wager that God exists because it is the *best bet*.

| | ***God exists*** | ***God does not exist*** |
|---|---|---|
| ***Wager for God*** | Gain all | Status quo |
| ***Wager against God*** | Misery | Status quo |

- decision theoretic formulation of the reasoning: Maximizes expected utility

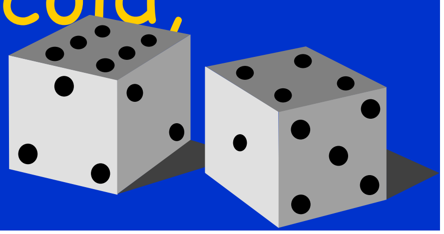
# RISK AND THE REGULATORY COMPACT

- Utilities are usually given risk premia in ROE
- Often these risks are not very specific.
- what risks are we compensating for?
  - cost passthoughs ⇨ PGA, FAC, uplift
  - loss of customers ⇨raise rates
  - recovery of stranded costs ⇨100%
  - prudence/used and useful?
- What are the compensated risks?
- Can we be more specific?

# Sources of risks

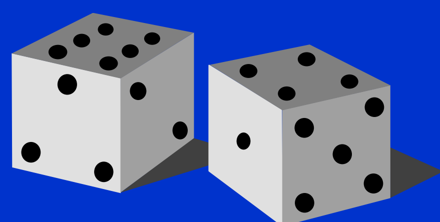
- Market: competition, demand, input markets ($CH_4$, NOx, $SO_2$, $CO_2$), liquidity, counterparty, incomplete contracts, contract breach, technology
- Regulatory: FERC, PUCs, EPA, State gov, Federal gov

- Financial: interest rates, bankruptcy, creditworthy
- Natural: rain, snow, storms, heat, cold, quakes



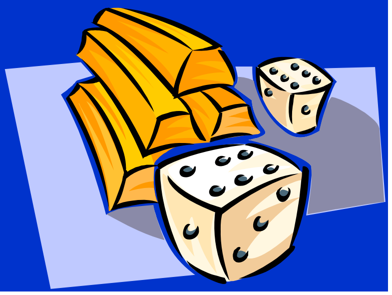
# Natural sources of risks

- Rain
- Snow
- Storms
- Heat
- Cold
- Wind
- earthquakes
- Volcanoes



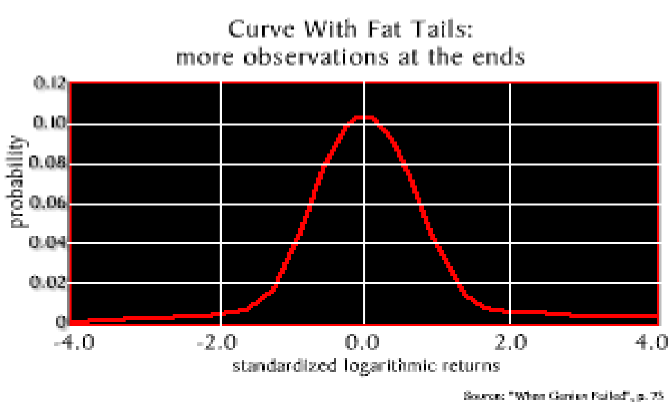

# False risk evaluation

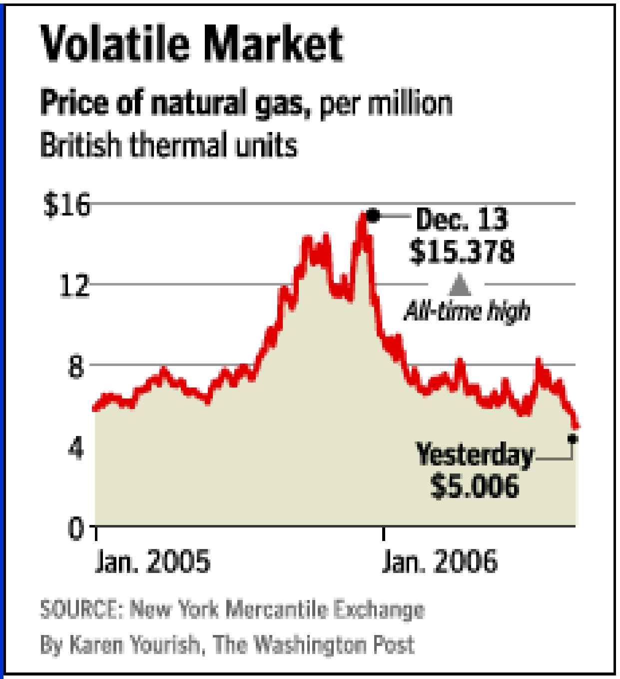
- Cognitive dissonance
- Controllable: air vs. car
- Catastrophic:
  - Nuclear
  - Drought
  - cancer
- Natural v. anthropogenic:
  - global climate: sun v. man
  - Radiation: sun v. cell phones
- Risk/benefit tradeoffs: drugs
- Imposed v. voluntary: smoking
- Trust v. distrust

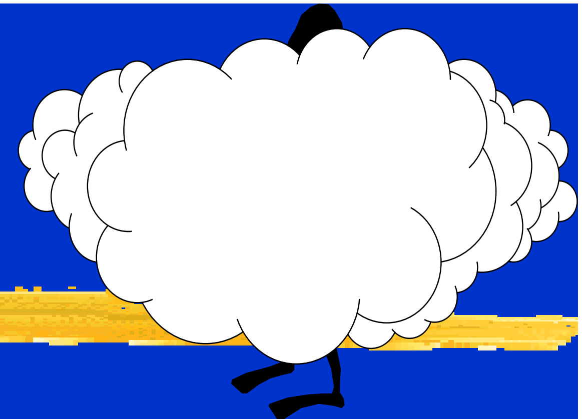
# Big betters/big losers

- Long Term Capital Management Trillion Dollar Bet
- Amaranth Advisors
  - 2005 made an estimated $1 billion on rising energy prices in
  - 2006 lost more than $6 billion
- MotherRock Energy Fund
  - a $400 million portfolio,
  - 2006 shut down after losing money on its bets that natural gas prices would fall

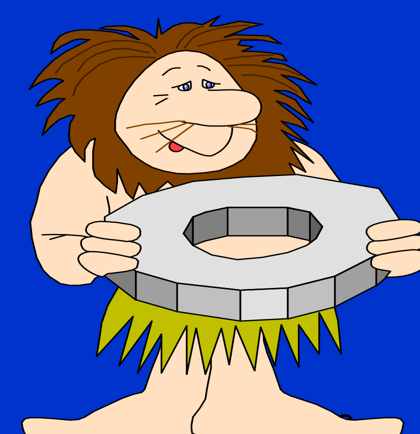


# Uncertainty



- How good is the data?
  - How are they measured?
- What are the important uncertainties?
  - How do they change the market outcome?
- Can the problem be solved?
- Is the market model correct?
  - Turn a stochastic problem into a deterministic equivalent
  - how are market participants compensated?
  - How to dealing with incomplete markets
- What are you buying and selling?
  - Option
  - Hedge
  - Commodity



# Different types of uncertainties

- Lumpy outage: $sd_t \approx sd_{t+1}$
  - e.g., equipment outage
  - sd is the standard deviation
- Time decreasing uncertainty: $sd_t < sd_{t+1}$
  - e.g., weather: heat, cold, wind, humidity
- demand, generation, transmission = f(weather)
- solution uncertainty finding the optimal solution and operator intervention.

# ISO market design a three-stage game

- First: The market design itself can be analyzed as a cooperative game
  - cooperation is encouraged
  - the market rules are decided by voting rules
  - This part is often taken as a given in the electricity market literature.

- The ISO operates several planning processes, reliability assessments, and rights and cost allocation systems
- The third stage is the markets themselves
  - Incomplete and indefinitely repeated

# Public goods or externalities?

- When is a public good not a public good?
- Should winners compensate the losers?
- Public goods need a market definition.
- What happens to those who do not benefit?
- This turns them into club goods since those outside the market don't pay
- Clubs have ownership and usage rights and fees
- We should analyze the expected positive and negative both social and pecuniary externalities?
- the Lindahl equations define the club membership.

| Good type | quantity | price |
|---|---|---|
| private | private | public |
| Public | public | Private |
| Club | | |
| membership | private | private |
| usage | private | public |

# Deterministic public goods

Buyer i given $p_i$: Max $_{q_i \geq 0}$ $u_i(q_i) - p_i q_i$

first order condition: $q_i^*[u'_i(q_i^*) - p_i] = 0$

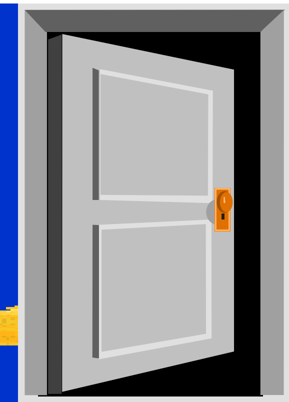
if $u'_i(q_i^*) < p_i$ $q_i^* = 0$ no benefit

if $u'_i(q_i^*) = p_i$ → $q_i^*$ benefit

Supplier: Max $_{q \geq 0}$ $\sum_{i,k} p_i q - c(q)]$

first order condition: $\sum_i p_i = c'(q)$

# Stochastic Club Goods two part tariffs



Membership of i given $p_i$ over k with prob $\rho_k$:

$\text{Max}_{\,qik} \sum_k \rho_k[u_i(q_{ik}) - p_i q_{ik}]$

first order condition: $\sum_k \rho_k[u'_i(q_{ik}^*) - p_i] = 0$

if $\sum_k \rho_k u'_i(q_{ik}^*) < p_i$, $q_i^* = 0$ no membership

if $\sum_k \rho_k u'_i(q_{ik}^*) = p_i$, $q_i^* > 0$ membership

$\sum_{i,k} \rho_k[u_i(q_{ik}) = q$

Club: $\text{Max}_{\,q \geq 0} \sum_{i,k} [\rho_k p_i q - c(q)]$

$q^*[\sum_i p_i - c'(q^*)] = 0$

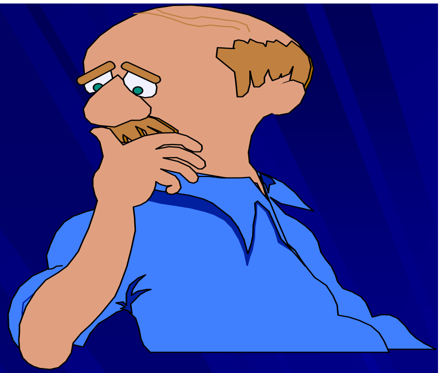
# Private, public and club goods

- real power is a private good.
- reactive power is a private good,
  - but we treat it as a semi public good
  - Pay opportunity costs
  - Creates regulatory must run generators
- Frequency is an interconnection-wide public good
- Voltage is a local public (club) good

# Energy Markets

| Energy Markets | Economic characterization | Engineering characterization | Pricing |
|---|---|---|---|
| Capacity | collective call option | reliability | one part market-clearing price |
| day-ahead market | private hedge | unit and energy commitment | two part market-clearing price |
| Residual unit commitment | public hedge reliability | additional unit commitment | one part (startup) pay as bid |
| Real-time market | private realization | energy | one part |

# Stochastic MIP unit commitment



K is the set of an random events, $k \in K$,

$\rho_k$ is the probably of =k and $\sum_k \rho_k = 1$.

Max $\sum_{i,k} \rho_k b_i q_{ik} + f_i z_i$

$\sum_i q_{ik} = 0 \qquad k \in K$

$q_{ik} - q^+_{ik} z_i \leq 0 \qquad k \in K$

$-q_{ik} + q^-_{ik} z_i \leq 0 \qquad k \in K$

$z_i \in \{0, 1\}, \{0, 1\}^n = Z, \quad i = 1,\ldots,n$

# The dual of the restricted model

Min $z_i^* \mu_i$

$p_k - \alpha_{ik} + \beta_{ik} = \rho_k b_i$

$q^-_{ik}\beta_{ik} - q^+_{ik}\alpha_{ik} + \mu_i = f_i$

expected market-clearing price is

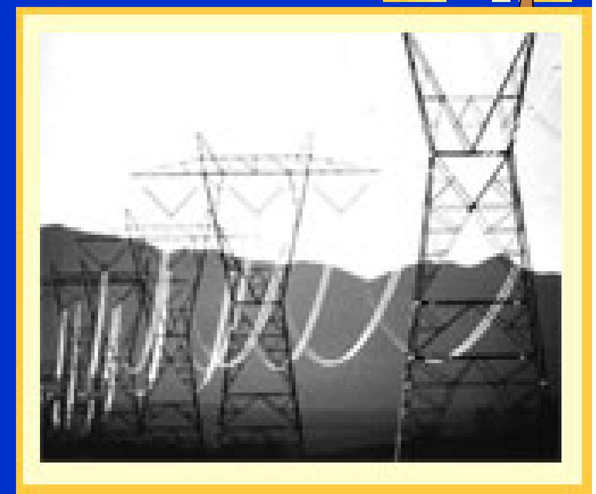
$p = \sum_k p_k - \alpha_{ik} + \beta_{ik} = \sum_k \rho_k b_{ik}^*$,

where $b_{ik}^*$ is the market clearing price in event k.

$\sum_k [q^-_{ik}\beta_{ik} - q^+_{ik}\alpha_{ik}] + \mu_i = f_i$

# transmission

- Is transmission a public good? No
- Is it a club good? Yes
- What are the property rights?
  - To congestion
  - For new club members



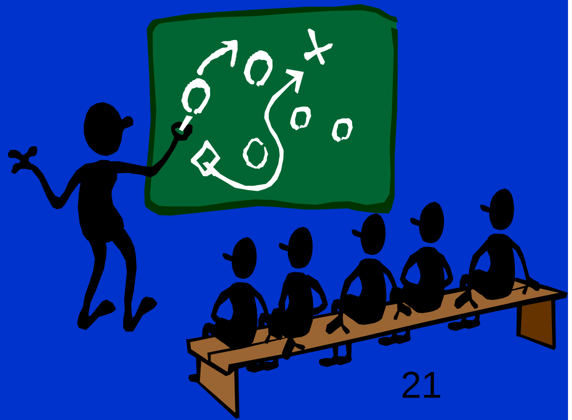
- SPP transmission market proposal: find a state core with side payments?
- NYISO modified Argentina approach voting
- Merchant transmission

# Transmission Markets

| Transmission Market | Economic characterization | Engineering characterization | pricing |
|---|---|---|---|
| Capacity | public good | reliability | cost/load |
| Allocation of rights | allocation | fairness | none |
| Hedge auctions | hedge | none | one part |
| day-ahead market | formal cash out | | one part |
| Real-time market | virtual cashout | energy | one part |

# Characterization of electricity markets

- Stochastic market models
  - Two stage models?
  - Chance-constrained?
  - Bad deterministic equivalent markets
- Make assumptions to get a deterministic market
- Chance-constrained model



# Loss of load probability

- 'One day in ten years'
- Design for LOLP < 1/3650
- Actually one event in ten years
  - increase reliability
- Should it be ac MWday or an outage event

# Bid strategy in the day-ahead market with stochastic outages

- **Parameters and assumptions:**
- day-ahead market residual demand curve is $p_D(y) = a-by$.
- Real-time market price with gen 1 is $p_R$.
- Real-time market price without gen 1 is $p_R^x = p_R + d$

| | capacity | Running cost | Probability of outage |
|---|---|---|---|
| Generator 1 | K | c | $\alpha$ |

# Decision Strategy:

- the generator must decide how much to offer, y into day-ahead market
- maximize expected profits: $\pi(y)$.
- $\pi(y)=$
  $p_D(y)y - p_R y(1-\alpha) + (p_R - c)K(1-\alpha) - p_R^x y\alpha$
- For the optimal strategy, $y^*$, $\pi'(y^*) = 0$.
- $y^* = (a-(p_R+d\alpha))/2b$.
- the monopoly result $y^* = (a-c)/2b$

# Demand, capacity, wind and smart markets

- If demand is price responsive,
  - Quantity risk is converted to price risk
  - Capacity markets become financial options
  - reliability markets have shorter lead times
- Wind can clear the real-time markets
- Electric vehicles becomes storage devices
- Smart market operator
  - Commits load, transmission and generation