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CHANGING WHAT'S POSSIBLE

Extracting Flexibility from Price Sensitive Loads and Beyond through Bid-in Demand

Are we halfway there yet? Let's have two-sided markets

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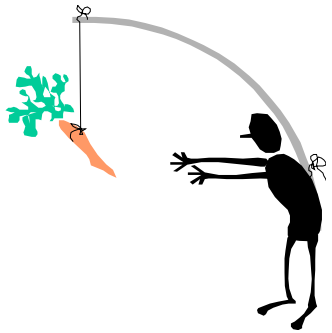


Demand Response (DR) Programs

- DR programs have not changed much in a century
- Baseline gaming issues
- Consumer value is not the cost of a combustion turbine
- Most consumers see invariant flat or stale prices (TOU prices are stale)
- Most consumers just consume, get a monthly bill, and then maybe complain
- Consumers prices do not reflect current conditions
- Many studies conclude consumers (rich or poor) respond to price.

- DR programs need to be reexamined in the light of current technology

Give consumers the option of bid-in demand (BID)?

- It is not traditional demand response (DR)
  - No baselines
  - No stale prices
  - Consumer value is not the cost of a combustion turbine

- bid-in demand is comparable to the generator model
  - allows consumers to participate in ISOs (RTOs) markets in the same way as do generators and storage
  - Consumers bid the value of consumption, max and min operating levels, ramp rates, …
- Each consumer can express its value. It is most likely < 1000 $/MWh
- Modified as needed by consumers, for example, tranching

- For residential, more money for other activities (budget)
- For Industrials it is the net back from the product value
  - At what electricity price do you stop making profit

DR Programs

- May be significant barriers to consumer participation
- Is there uncertainty in determining the value of consumption?
  - Residential YES
  - Commercial maybe
  - Large industrial users No
- Industrial Tensions
  - Plant operators prefer steady-state operation
  - Finance people prefer higher profits
  - Steady-state consumption is not usually optimal
  - Energy management is not a high priority

ISO bid-in demand messages

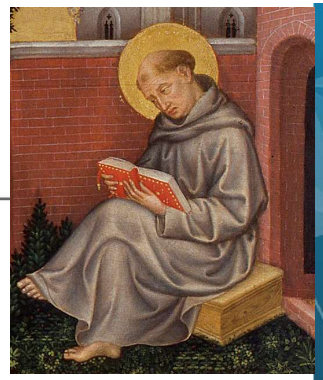
The market, the economy and the environment are better off

The consumers are better off (more profitable)

There is no need for ISO control

Prices should be crowd-sourced

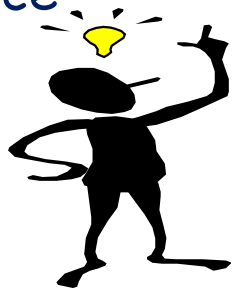
U.S. Natural Gas and Electricity Markets



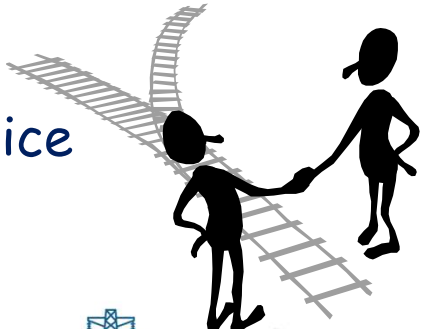
- 1935 - 1980s cradle-to-grave state/federal regulation 'cost-of-service' to produce 'just and reasonable rates'.
  - Just prices have been debated at least since the Roman empire
- Retail prices regulated by state commissions
- Regulatory incentives skewed to capital investment (AJ effect)
- 20th century, vertically integrated utility franchised monopolies dominated electricity markets
  - Least cost dispatch was less important as they could pass their costs to customers
  - demand was forecasted
- A 'sleepy' FERC regulated wholesale commodity and interstate transmission prices

U.S. Natural Gas and Electricity Markets

- 1980s FERC reexamines cradle to grave regulation
- Result was strong regulation where there is market power.
- Otherwise let regulated competition set 'jandr' rates/prices.
  - Unbundle energy commodity sales from transmission service
  - make transmission service open-access
  - create monitored and transparent auction markets
  - Allow secondary and financial markets



- 1992 FERC requires open access natural gas; worked well
- 1996 FERC requires open access to electricity transmission
  - Some power pools did not like the proposed rules
  - Created the ISO option that is now the dominant choice



Design Criteria for ISOs

not possible to achieve all (Myerson–Satterthwaite theorem)

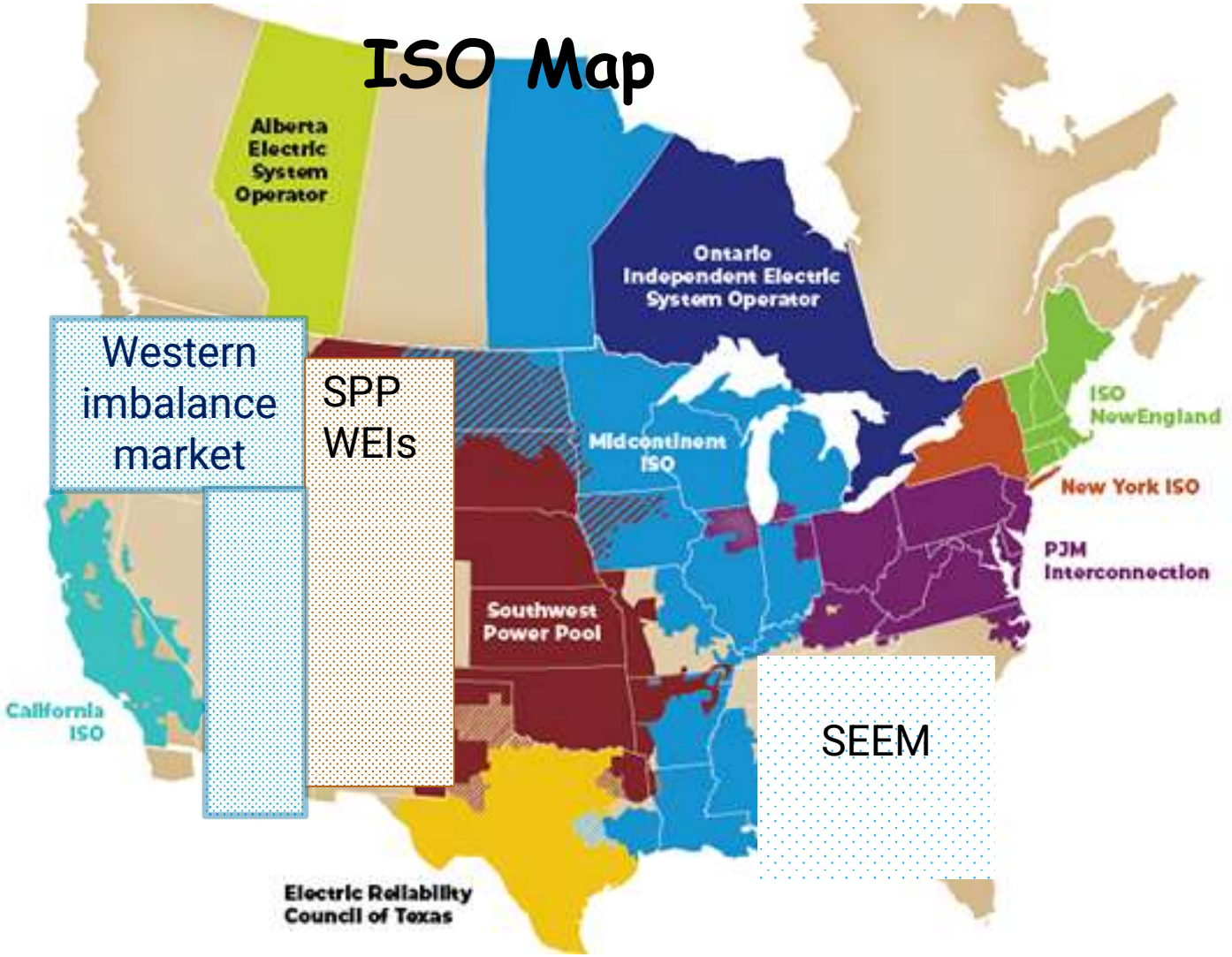
Property	Explanation	ISO auctions
Individual Rationality	no person should lose money	Make-whole payments
Balanced Budget	Self-contained settlements	Revenue neutral
Economic efficiency	maximize social welfare	Uses optimization algorithm
Truthfulness / Incentive compatibility	the true value is an efficient strategy	Market monitoring and mitigation
Transparency	Public prices	LMPs only
Good entry and exit signals	For dispatch and investment	weak
Honor the physics	dispatch must be physically feasible	dispatch must be physically feasible
Markets are non-convex	declining average costs and nonlinear flow	Need price discrimination

try to come close

Electricity Auction Market growing pains

- ISOs established for competition efficiency that includes reliability
- Goal is to make the price signals consistent with efficient operations
- 1997 PJM starts (first ISO)
  - an auction market for power sales over an open transmission network with market power mitigation
  - solvers use legacy Lagrangian Relaxation algorithms for dispatch
  - detailed bidding for generators
  - point forecast for consumers (infinite value).
- ISO Markets Learning Curve
  - Assume convexity -> marginal price not IR -> two-part pricing: 'clearing price' with make-whole payments
  - Assume no congestion-> zonal pricing -> Nodal (greater detail)
  - No demand side -> Missing money -> capacity market (bad pedigree)
  - No demand side -> Price caps -> need participating demand side

ISO Map



ISO markets now account for ~ 70% of the US consumption

$ billions change hands daily.

Saving > $100B/yr with bid-in demand and increased reliability

Independent System Operators (ISO) Auction Markets

- Day-ahead market financially hedges the real-time prices
  - Run for the next day energy and reserves dispatch
  - Nodal pricing for the first 24 hourly periods
  - Demand is forecasted creating a vertical demand curve
  - Day-ahead for dispatch hedge for the real-time market.

- Real-time market for optimal physical balancing
  - Run every 5 minutes with a several-period look-ahead
  - Price only for the next period
  - Limited commitment and decommitment options
  - Demand is forecasted with a vertical demand curve

- Transmission rights (revenue adequacy)
- Capacity markets (formed to solve the missing money)
  - poor granularity

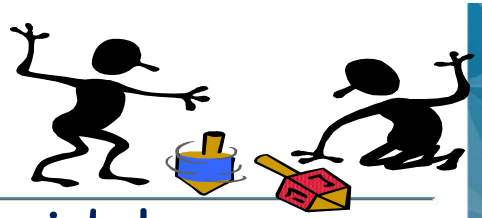
ISO Pricing

- Capacity market (missing money) prices are too high
  - Not needed in theory
  - What is the capacity of …?
- Energy market prices are more granular but too low
- Locational marginal price
  - Great for convex markets
  - For non-convex markets: LMP + make-whole payment
  - LMP is no longer 'marginal'
  - AIC pricing has no make-whole payment and better incentives in time and space
- Consumers should set the scarcity price
  - very little consumer participation
  - Create an ORDC to set the scarcity price when there is not enough generation
  - With elastic demand, consumers to set scarcity price

Assumptions about the future

- more renewables
- More flexible consumption devices,
  - Residential, e.g., EVs and PVs
  - Commercial, e.g., storage, heating and cooling
  - Industrial, process control
- Extreme weather events will not go away
- Reliability and resilience are part of efficient operations
- Broad view of storage: fuel, EV, consumer inventory, …
- Prices will be more variable

Stochastics and non-convexities



- Forecasting weather is not rolling dice or dreidels
  - We know the probability distribution of dice or dreidels
  - the probability distribution of weather is estimated from data
  - Estimates improve over time
- In the day-ahead market, stochastics are crowdsourced
  - What is the probability of producing/consuming
  - What is the price in the real-time market?
  - The ad-hoc approaches are not working
- day-ahead market auction crowdsources over time and space
  - bid-in demand
  - Stochastics
  - Unit commitment
  - Complementarities
  - Reliability

Better Vocabulary

out	in
Generation adequacy	System adequacy
N-1	Extreme weather
DR program	bid-in demand
Minimize costs	Maximize efficiency (surplus)
Value of DR	bid-in demand
Stacking of DR programs	bid-in demand
Calculating value	Crowdsourcing value
Static forecasted load	Dynamic efficient bid-in demand
Monthly prices	Hourly prices
Capacity markets	Energy markets with bid-in demand
Capacity value	Energy value
Separate markets	Co-optimization
Device specific DR	consumer specific consumption
Control	Dispatch signals

Current consumer participation
We only have half the market

- Some large consumers buy a forecast or hedge and schedule accordingly
  - All forecasts are wrong some are useful
  - This takes away the existing market flexibility and is less profitable
- Some do not know they are better off being in the market.
- Most consumers do not see the price when it is high or when it is low.
-
- DR programs target peak consumption
- DR programs give little attention to off-peak consumption
- Some DR programs are inefficient. Some very inefficient.
- Lots of studies

Issues in Consumer Participation

- There are many DR programs today - consultants 'stack them'
- Less than 3 % of demand is bid-in demand
- Many consumers do not know
  - they are better off being in the market.
  - how to bid into the market
- Many consumers see
  - barriers to participation
  - ISOs as hostile or indifferent to bid-in demand
- Saving CO_2 admissions today is more valuable than CO_2 tomorrow.
- Storage adds costs; bid-in demand adds profits.
-

Solutions To Consumer Participation

- start educating consumers and state commissions on the benefits of bid-in demand.
- Not bidding could be considered greenwashing.
- lower barriers to participation
- design more flexible future and replacement assets
- with a carbon tax and/or increasing renewables the carbon reduction becomes even greater and low carbon becomes more correlated with low prices.
- The strategy of bidding-in demand is both more profitable and lower-carbon.

Design of New Devices

- With a few exceptions, consumer assets for designed with the assumption of constant electricity prices and steady-state operations
- Flexibility, Flexibility, Flexibility
- Internet connected
- Secured
- Good candidates
  - Electrolysis
  - Liquefaction
  - Data centers
  - Air separation

- New technology in batteries, cement and chemicals requires more electricity.

Day-ahead Market Participation

- Necessary for efficient 'time-shifting' of consumption
- Schedule consumer to take advantage of the crowdsourced information (collective wisdom)
  - Away from high prices to low prices
  - Honoring the consumer's constraints
- Cannot lose money
- Perfect hedge against real-time market prices
- Market and consumer are better off
- Most likely greener.
- Consumption should be measured at the bus not device
- bid-in demand dispatch is a perfect hedge and profitable

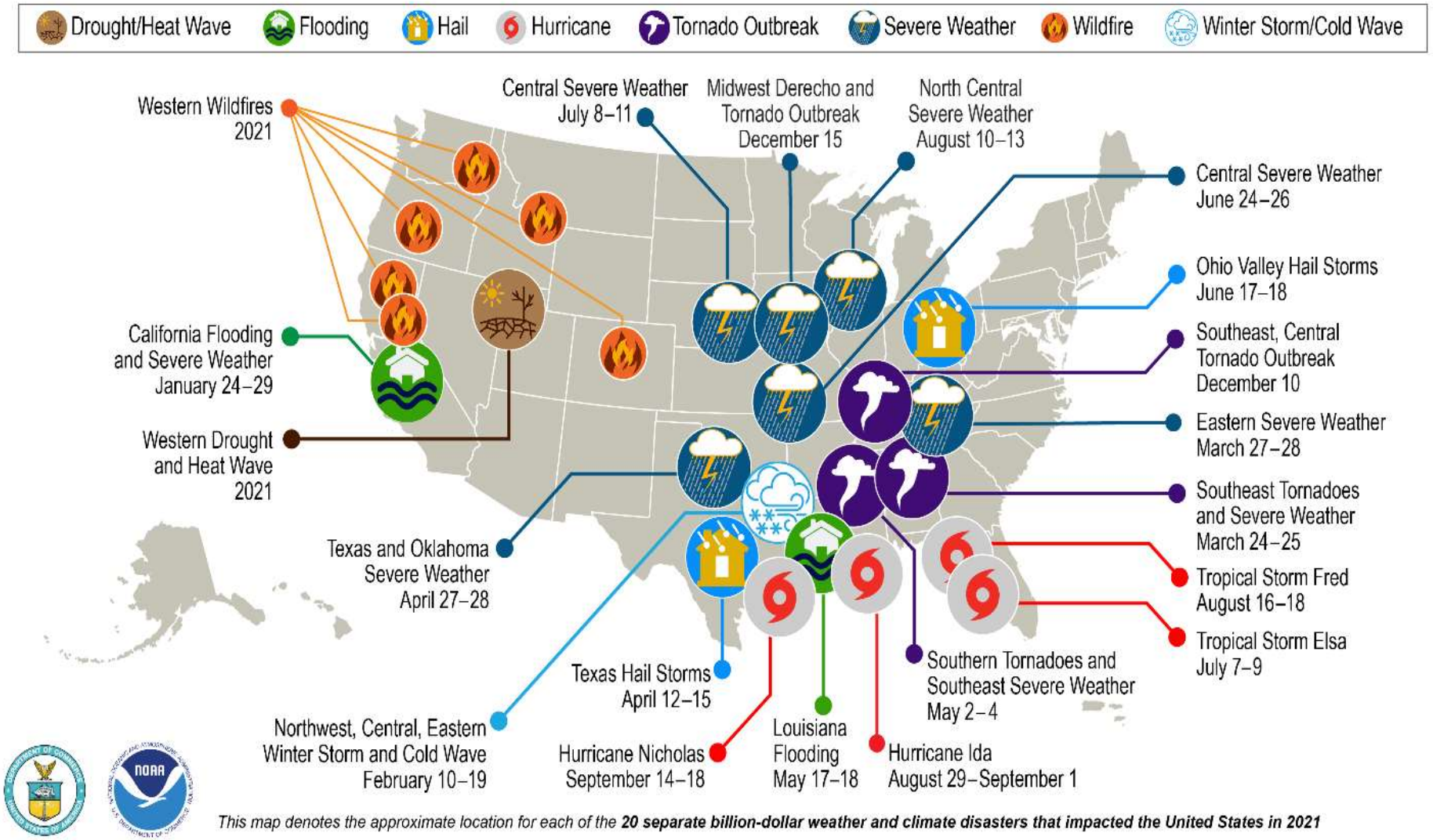
Scarcity Prices Should Be Set By Consumers

- Before Uri, $9000/MWh was the scarcity price.
- After Uri, Texas reduced its administrative scarcity pricing to $5000/MWh.
- Will they do it again?
- If administrative rules set the price, the market is inefficient and subject to never ending debate
- Scarcity prices should be crowdsourced (Hayek's collective intelligence) through consumer market bidding
- No industrial or large commercial consumer would pay these prices for every long (hours not days).
- The prices are not politically or economically sustainable.
- Hedging could become very expensive

Capacity Markets

- In theory with bid-in demand not needed
- Amber alerts alone are not a good procurement strategy
- Price Gouging bad; scarcity pricing good
- no control unless it is granted by market participant
- Capacity prices are more than 20% of energy costs.
- Scarcity prices stimulate investment on both side of the market

U.S. 2021 Billion-Dollar Weather and Climate Disasters



*This map denotes the approximate location for each of the **20 separate billion-dollar weather and climate disasters that impacted the United States in 2021***

EXTREME WEATHER should be part of market efficiency.

- N-1 contingency standard is not enough.
- in the past 3 years, 56 of U.S. weather events with losses > $1 billion.
- from 1980 to 2021, $2.155 trillion of U.S. weather event damages (NOAA)
- Some weather events cannot be completely avoided.
- Some can be managed with a focused systemic economic approach.
- Generators alone are not enough in an extreme weather event.
- Most consumers
  - are not fully aware of the consequences,
  - do not see ISO prices.
  - must see and set the price of staying on the system
  - be prepared to reduce consumption or get off the system.
- 12/24-25/2022, PJM the price was > $1400/MWh.

The Need for Bid-in Demand

- market is more efficient with bid-in demand

- The last old system vestige is forecasted demand
- Single point implies infinite value and never sets price
- Does not does not take advantage of low and negative prices

- current approach is a demand curve for reserves shortages

- Consumers pay less and capacity market prices are lower
- Full bid-in demand has no capacity obligation

- result is sustainable prices, and greater reliability/resilience

- issues: human inertia, nonprofit ISOs, computational problems, latency of stale prices

Thank you for listening

Questions

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