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Each in his own opinion
Exceeding stiff and strong,
Though each was partly in the right,
And all were in the wrong!

- John Godfrey Saxe “The Blind Men and the Elephant”
Two basic functions of an Independent System Operator (ISO)

• Real-time Security-Constrained Economic Dispatch (SCED) with operating reserves.

• Manage the high-voltage transmission system

*ISOs must operate under both normal and emergency conditions.*
*ISOs not guaranteed to have the resources they need.*
Typical add-ons to ISO functions

SCED
- Forward markets (day-ahead, hour-ahead, fifteen-minute ahead)
- Unit commitment (advance warning for slow start units, look-ahead)
- Faster Settlement (5 minute settlement)
- Nodal markets (congestion pricing, loss pricing, basis-risk hedging)
- Ancillary Services (always part of real-time operations but different flavors)
- Flexibility products (ramp management, weather forecasting)

Transmission
- Transmission planning (economic and/or reliability criteria)
- Interconnection studies and queue management (always there but varies)
- Financial Transmission Rights (FTR) (these go hand-in-hand with nodal market)

Resource Adequacy??
- Capacity markets, fuel assurance payments, local/flexibility payments, ORDC
Seven US Centrally-Organized Markets

There are currently seven centrally-organized markets operating across the United States.
N ERC (reliability regulator) Stats on ISOs

<table>
<thead>
<tr>
<th>ISO</th>
<th>2019 Peak Demand</th>
<th>2019 Reserve Margin</th>
<th>Power Mix</th>
<th>Capacity Procurement</th>
</tr>
</thead>
<tbody>
<tr>
<td>ERCOT</td>
<td>75 GW</td>
<td>8.50%</td>
<td>Energy-Only (with ORDC)</td>
<td></td>
</tr>
<tr>
<td>CAISO*</td>
<td>53 GW</td>
<td>22.40%</td>
<td>Hybrid</td>
<td></td>
</tr>
<tr>
<td>SPP</td>
<td>52 GW</td>
<td>31.80%</td>
<td>Hybrid</td>
<td></td>
</tr>
<tr>
<td>MISO</td>
<td>125 GW</td>
<td>19.30%</td>
<td>Hybrid</td>
<td></td>
</tr>
<tr>
<td>PJM</td>
<td>151 GW</td>
<td>29%</td>
<td>Capacity Market</td>
<td></td>
</tr>
<tr>
<td>NYISO</td>
<td>32 GW</td>
<td>24.80%</td>
<td>Capacity Market</td>
<td></td>
</tr>
<tr>
<td>ISONE</td>
<td>25 GW</td>
<td>30.70%</td>
<td>Capacity Market</td>
<td></td>
</tr>
</tbody>
</table>

* Includes separate municipal loads but excludes 6 GW+ distributed PV

These are old-school stats on capacity, with capacity in pie charts capacity factor weighted...

Underlying markets go from fully vertical utility to completely restructured (separate retail, network and generation entities)

Federal Energy Regulatory Commission (FERC) is market regulator for all but ERCOT
Resource adequacy approaches

The energy generation mix is traditionally the purview of states, but always some tension with federal system (cooperative federalism)

• Hands-off
  Energy-only market creates exposure to high prices and motivates long-term hedging which finances new resources. Mix driven by economic equilibrium

• Capacity Markets
  Capacity seen as a “commons” with incentive for defectors, plus missing-money problem. Capacity markets/forward procurement put into place but endlessly re-litigated. States give up some power, especially in multi-state ISOs

• Hybrid Approach
  States actively ensure resource adequacy with some coordination with ISO to satisfy NERC requirements
What is the resource adequacy “elephant”? 

The basic idea is **deceptively simple**: the system operator always has enough levers to pull to prevent a system breakdown or black out.

Usually, some risk tolerance level is associated, like one event in ten years.

Traditionally combination of planning for peak and contingencies (N-1)

But today and in the future risk evaluation is more complex and holistic.
Old way of looking at power systems
Seasonal or yearly approach, not much day to day difference

(a) Low-Demand Baseline scenario – 2050 dispatch by time slice
But…. Challenges to this picture

- Cheap natural gas fuel changing unit economics
- Very cheap new solar and wind
- Rise of battery storage
- Demand-Side Resources
Moderate RE penetration: Most challenging week in three years of 33% Wind + Solar in US West
High RE Penetration: Three different modelled winter weeks in 90% clean CA grid
Resources now come in many flavors with associated down-sides (some flavors overlap)

- **Dispatchable Fuel Based** (coal/gas/uranium/oil/hydrogen)
  - Fuel availability constraints
  - Outages (forced and planned)
  - Transmission/congestion issues
  - High fixed costs or startup costs

- **Variable** (wind/solar/ocean)
  - Well, variable
  - Zero-marginal costs
  - Transmission/congestion issues

- **Clean Baseload** (energy efficiency/geo-thermal)
  - Not a lot of control

- **Energy Limited** (batteries/hydro & demand response)
  - Not always available
  - Market power issues
  - Can be buyer or seller

- **Distributed Energy Resources**
  - Overlaps with other resources but less visible/predictable
  - Jurisdiction issues and need aggregation
  - Less transmission/congestion needed
  - Capital commitments from a much larger pool of investors/users
The parts of the RA “elephant”

• Investment in new resources – Retirement of un-economic units
  Given that bulk power system takes a long time to build and deploy, how do you maintain the right economic equilibrium? How do you incent investment/retirement of right type at right place?

• Resource Availability
  Resources are variable, subject to planned or un-planned outages or energy limited.

• Resource Flexibility
  Some resources are much quicker to adjust their output or start/stop than others, many need commitment ahead of time.

• Risk management
  Diversity is good, some resource availability risks are correlated (e.g. pipeline issue, fire risks).

• Platform needs
  Need appropriate transmission infrastructure and market structures (market power issues, counter-party risk, derivatives).
Example: PJM

• Issues with capacity market
  • No current authorized tariff
  • Large flows for energy markets to capacity
  • Become a way to pay long-term costs

• Conflict with state policies

• Strong incumbent political power

• Used to be tech forward but mired in controversy

• Also wants to change energy market to accommodate block start and slow start
Example: New England

• Similar issues to PJM capacity market (e.g. MOPR)

• Very little coal, retiring nuclear, slow wind and transmission built-out and at the end of the natural gas pipelines $\rightarrow$ focus on fuel assurance

• Capacity markets are local, some historical payments (near Boston) amount to paying for 20 hours+ of $10,000/MWh energy

• Some tech progress, for example first distributed battery payments for capacity
Example: Texas

• Still committed to energy-only, even though 8.5% PRM vs 13.6% target last summer – still managed peak loads well in August/September

• Lots more wind and solar coming online at US $10-20/MWh

• Huge load growth due to O&G sector. Texas increase in CO2 emissions canceled out reductions from all 49 other states together.

• Nice balance of resource between inland wind/coastal wind/solar

• But mostly islanded system
Example: CA

• Everything eclipsed by fire-risk and public-service shutdown issues right now

• Leans on neighbors. Western Energy-Imbalance Market helps a lot but needs work

• Has a state-imposed resource adequacy mandate for *peak, local capacity, and ramping* but this is not working that well (especially the ramping)

• Big push for DG, electrification in buildings and vehicles will have interesting consequences (good or bad) for resource adequacy

• Lagging on demand-side participation relative to ambitious goals

• 90% RE by 2030 could be quite do-able. Managing huge amount of change but also reaping large economic rewards for being at the head of the pack for energy transition (e.g. Tesla multi-billion-dollar exporter)
The Future of Resource Adequacy

• Need to engage demand-side participation a lot more, especially dynamic pricing response
• Nodal and granular energy-only plus services and derivatives is probably best option to handle a changing technology mix and policy/investment environment
• Needs to be supplemented by organized voluntary products (e.g. day-head markets and long-term procurement)
• Policy-makers and market participants need to move away from a deterministic mindset (sufficient cap to meet peak) to a risk management mindset
• Lots of opportunity for better analysis of the key parts of the elephant and how the pieces fit together
Questions?