Electricity market design with thoughts for New Zealand

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Goal of electricity markets: 
*Reliable electricity at least cost*

**Short-run efficiency**
- Least-cost operation of existing resources

**Long-run efficiency**
- Right quantity and mix of resources
Challenges of electricity markets

- Must balance supply and demand at every instant
- Physical constraints of network and resources
- Shocks in supply
  - Transmission line or generator outage
  - Intermittent resources: wind and solar
- Absence of demand response
- Climate policy
A successful market design

- Get the spot market right
  - Day ahead
    - Scheduling and unit commitment
  - Real time
    - Bid-based security constrained economic dispatch
- Forward trade to manage risk and support long-run investment
Day-ahead market

Unit commitment and scheduling
- Energy and ancillary services each hour of day
- Prices for energy and reserves; financially binding

Three-part offers from resources
- Startup cost
- Minimum-energy cost
- Energy offer curve

Virtual offers and bids
- Arbitrage day-ahead and real-time markets

Objective: maximize social welfare s.t. transmission and resource constraints
- Co-optimized energy and reserves
- Competitive equilibrium with locational marginal prices
- LMP = marginal value of energy at each location
Day-ahead market

Handling non-convexities, such as startup and minimum energy costs

• If total cost of unit not covered by energy & reserve revenue, then unit gets make-whole payment for shortfall
• Make-whole payments small in practice
• LMPs are approximate supporting prices

Procompetitive

• Allows small generators to optimally schedule
• Allows small participants to hedge real-time risk
Convergence Between Day-Ahead and Real-Time Energy Prices

<table>
<thead>
<tr>
<th>Year</th>
<th>Day-Ahead Price</th>
<th>Real-Time Price</th>
</tr>
</thead>
<tbody>
<tr>
<td>2011</td>
<td>$46</td>
<td>$43</td>
</tr>
<tr>
<td>2012</td>
<td>$29</td>
<td>$27</td>
</tr>
<tr>
<td>2013</td>
<td>$33</td>
<td>$32</td>
</tr>
<tr>
<td>2014</td>
<td>$40</td>
<td>$38</td>
</tr>
<tr>
<td>2015</td>
<td>$26</td>
<td>$25</td>
</tr>
</tbody>
</table>

Source: Potomac Economics
ERCOT Load with Real Time and Day Ahead Prices

- Real Time Price Average
- Day Ahead Price Average
- ERCOT Load ('0000 MWh)

5/1/2017 to 8/28/2017
• **52 inches** of rainfall in southeast Texas

• Harvey made landfall **multiple times**
  - **Category 4** near Port Aransas, Texas
  - **Tropical storm** in Cameron, Louisiana

• More than **42,000** lightning strikes

• Record number of tornado warnings in southeast Texas

**Transmission Damage**

STP-to-Whitepoint 345-kV transmission structures
Operating plan and adjustment period

- Generator submits operating plan for each resource
  - Online/offline, constraints
- Until 60 minutes before operating hour, plan can be adjusted
- System operator may commit additional resources for reliability, but these have a high offer floor ($1500/MWh)
Real-time market

Security constrained economic dispatch

Determines optimal dispatch and prices every five minutes

Financially and physically binding

Allows efficient settlement from forward positions
Ancillary services

Address supply/demand uncertainty:

- Regulation: online, responds in second
- Reg up, Reg down to maintain frequency of 60 Hz
- Responsive reserve: online, 10min response
- Non-spinning reserve: offline, 30min response

Need for reserves depends on market; products and quantities reviewed periodically
### Annual Ancillary Prices ($ per MWh)

<table>
<thead>
<tr>
<th>Service</th>
<th>Price</th>
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<tbody>
<tr>
<td>Responsive Reserve</td>
<td>10.87</td>
</tr>
<tr>
<td>Nonspin Reserve</td>
<td>6.92</td>
</tr>
<tr>
<td>Regulation Up</td>
<td>10.59</td>
</tr>
<tr>
<td>Regulation Down</td>
<td>6.01</td>
</tr>
</tbody>
</table>

**Source:** Potomac Economics
Scarcity pricing

• Reserves have value in avoiding load shedding
• Marginal value of reserves depends on
  – Value of Lost Load, e.g. $9000/MWh
  – Probability of Lost Load, e.g. 1 in extreme scarcity
• Load’s implicit preference for reliability given by operating reserve demand curve
Operating reserve demand curve
Forward contracts

- Forward contracts are essential to manage risk
  - California energy crisis 2000-2001
  - Forward provides hedge for load
  - Generator + fuel contract provides physical hedge for supply
- Scarcity pricing motivates forward contracts
- Forward contracting improves bidding incentives
- Congestion revenue rights are forwards in congestion rents
Three Markets

• Short term (5 to 60 minutes)
  – Spot energy market
    • Energy: day ahead, real time with congestion pricing
    • Reserves: 30m non-spin, 10m non-spin, 10m spin, freq. regulation

• Medium term (1 month to 3 years)
  – Forward energy market
  – Bilateral contracts

• Long term (4 to 20 years)
  – Capacity market (thermal system)
  – Firm energy market (hydro system)
  – Bilateral contracts (Texas, Nord Pool)

• Address risk, market power, and investment
Why not energy only?

- Market failure
  - Absence of demand side
- Practical realities
  - Price caps
  - Operator decisions
  - Missing money
Long-term market: *Buy enough in advance*
Purpose of market

- **Operational reliability**
- Pay no more than necessary
  - Induce just enough investment to maintain adequate resources
  - Induce efficient mix of resources
  - Reduce market risk
  - Reduce market power during scarcity
The four P’s to a successful design:

- Planning
- Product
- Pricing
- Performance
Planning

• How much do you need?
  – Transmission and generation
• Rating of resources
  – Contribution of resource during scarcity events
• Planning by experts, not politicians
• Planning responsive to new information
• Planning optimizes reliability tradeoff: more capacity vs. more blackouts
Product

- What is load buying?
  - Energy during scarcity period (firm energy)
- Enhance substitution
  - Technology neutral where possible
  - Separate zones only as needed in response to binding constraints
- Long-term commitment for new resources to reduce risk
• Good price formation
  – Advance purchase before project costs are sunk
  – Descending clock auction to encourage price discovery or sealed-bid due to lumpiness
  – Downward sloping demand curve for price stability (buy more when price is low)
Performance

• Strong performance incentives
  – Obligation to supply during scarcity events
    • Deviations settled at price > $5000/MWh
    • Penalties for underperformance
    • Rewards for overperformance
• Tend to be too weak in practice, leading to
  – Contract defaults
  – Unreliable resources
• Recent adopters: New England, PJM (and Texas within energy-only market)
Example long-term markets

- Great Britain, New England, PJM (thermal dominated)
  - Product
    - Capacity: Ability to supply energy during hours short of reserves
- Colombia and Brazil (hydro dominated)
  - Product
    - Firm energy: Ability to supply energy during dry periods
    - Reliability options that hedge load against prices greater than strike price (e.g. $200)
- Comparison of what load is buying
  - GB, PJM, New England: price coverage only during shortages
  - Colombia: price coverage during extended dry periods
  - Brazil: full price coverage from long-term contract with new entry and medium-term contracts with existing resources
- Generator exposure to the spot energy price
  Texas > PJM > New England > Colombia > Brazil
Forward markets address key problems of wholesale markets.

**Investment**
- Coordinated entry to have what is needed

**Risk**
- Lock in price for firm energy
- Both suppliers and demanders face less risk

**Market power**
- Suppliers/demanders in more balanced position entering spot
Issues that cannot be addressed by a capacity market

• Politically induced uncertainties
• Suboptimal wholesale market framework
  – Lack of locational pricing
  – Lack of appropriate reserve products recognizing a larger share of renewables
  – Lack of market integration of renewables
  – Problems in spot or medium-term markets
Figure 5: Comparison of All-in Prices Across Markets

Source: Potomac Economics
Transformation to renewables
• Last year 60% of new capacity in US is wind and solar
• Coal hasn’t been built in years
• Intermittent supply, zero marginal cost, no inertia
  – More uncertainty, worse price formation, faster response needed
  – Also best sites not where load is; transmission issues
• Today’s design easily handles moderate share of wind
Solution looking forward

• But what if >80% renewable
• Core design still works well
• *Battery storage* and more demand response (smart homes) will complement wind, solar
  – Flexible, smooth prices

*Need to encourage technology-neutral solutions!*
Incoherent and unstable climate policy

- Policy built on myriad of changing subsidies and emission restrictions makes planning difficult
- Uncertainty harms investment
- Policy based on carbon price would greatly reduce uncertainty
- Carbon price is a critical input in investment and retirement decision
Conclusion

• Electricity good example of the power of market design
  – Highly efficient spot market
  – Supporting extensive forward contracting
  – Competitive retail market to foster demand response

• Good governance remains important to make sure market design continues to improve and addresses new challenges like the transition to renewables