Economics of Flexibility

Mike Caravaggio
### Understanding Flexibility

**California and Texas**

#### Near Zero Marginal Costs and Variability of Supply

**Spring Day CAISO (March 13, 2021)**

<table>
<thead>
<tr>
<th>Spring Day CAISO</th>
<th>Demand</th>
<th>Net Load</th>
<th>Implication</th>
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<td>Minimum Demand</td>
<td>16,700 MW</td>
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<td>Lower minimum loads, more on/off operation</td>
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<td>~2900 MW/ hr</td>
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<td>Daily Total Energy</td>
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<td>Mileage (5 min)</td>
<td>21,200 MW</td>
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**Generation Supply Curve - ERCOT**

- Natural Gas
- Solar
- Uranium
- Water
- Wind
### Financial Implications

#### Economics of Flexibility

#### Driven by Renewables

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1. **Annual Capacity Factors Drop**
   - Renewables cover more and more annual energy needs

2. **Dispatchable Capacity need does not drop as fast as CF**
   - Windless Nights

3. **Flexible operation**
   - Driven by renewable variability, and very low energy prices when renewable energy is available (Sunny / Windy, Spring days)

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<th>Cost Element</th>
<th>Drivers</th>
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<td>Capital Cost $/kW</td>
<td>1,2</td>
<td>Low-capacity factors mean long payback times if relying on energy payments (debt repayment)</td>
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<tr>
<td>Annual Fixed Costs ($/kW)</td>
<td>1,2</td>
<td>Low-capacity factors mean difficult to cover annual fixed costs (going forward costs)</td>
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<tr>
<td>Variable O&amp;M Costs ($/MWh)</td>
<td>1,2,3</td>
<td>Good trade-off for these to be higher if they allow for more flexible operation and/or allow for Capital and Annual Fixed Costs to be minimized</td>
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Externalities significantly impacting costs / operation includes fuel prices, changing regulations.

Retrofits for flexibility are possible but economics can be challenging (especially for ramp rate)

Defining Characteristics
- Safety
- Reliability
- Availability
- Environmentally Responsible

Economic Viability

Increasing Relative (Marginal) Cost of Generation

Spectrum of Flexible Operation
- Baseload
- Load Following (Weekend)
- Cycling (Weekend)
- Cycling (Two-Shift)
- Extended Shutdowns (week / month / season)

Operating Mode
- Baseload
- Load Following
- Cycling (Weekend)
- Cycling (Two-Shift)
- Extended Shutdowns

Defining Characteristics
- Maximum Load
- Minimum Load
- Ramp Rate
- Operating Reliability
- Cost
- Start Reliability
- Startup Speed
- Minimum Load
- Ramp Rate
- Operating Reliability
- Cost
- Preservation of Equipment
- Availability of Equipment (Startup Speed)
- Cost

Energy Market
Balancing Markets
Capacity Market

Fuel Changes (Lower-Cost Fuels)

Lower Minimum Load

Retrofit for flexibility are possible but economics can be challenging (especially for ramp rate)
Key Days for Dispatchable Generation (Flexible Thermal)
Increasingly defined by Variable Renewable Energy

Net Load Peak Days
- All units required to meet the peak
- Hottest or coldest days
  - Hot days limit output and efficiency
  - Cold days reliability concerns

Net Load Minimum Days
- Units needed to turn down or shut down but prepared to respond
  - Can be offline for days before being required
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Days / Hours with limited Renewable Energy and High Demand
Very High Electricity Prices

Days / Hours with an Abundance of Renewable Energy and Low Demand
Near Zero Electricity Prices
Asset Integrity & Flexible Operation – “Bow Wave Effect”

- Most asset integrity issues arising from increased operational flexibility are ‘bow wave’
  - Do not result in immediate operational limits, damage is being accumulated but it is not simple to quantify
  - By the time damage is apparent it may have become very costly to correct

**Complexity feeds the wave**

*Complexity tends to increase with flexibility*