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Let’s Be More Flexible: Rules and Tools for a Modern Power Grid

RAP Roundtable Discussion

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Sources of Flexibility

- Flexible generation
- Existing storage
- RE curtailment
- Flexible loads
- Markets
- Thermal storage
- Electricity storage

Penetration of variable renewable energy

Flexibility cost
Questions?

Please send questions through the Questions pane.
1 Lay of the Land
Wind Costs Dropped a Decade Ago

Wind Cost Per Kwh (US)

22x Price Decline

55¢ / kwh

2.5¢ / kwh
Solar Is Following Close Behind

Source: SunShot, US Department of Energy
This Year’s News is the Battery Cost Slide

Source: BloombergNEF. Data adjusted to be in real 2018 dollars.
Existing Plants vs. Xcel Bids

Existing Plant Average Fuel and O&M from USEIA Table 8.4 Electric Power Annual 2016

COAL

GAS

NUCLEAR

SOLAR

WIND

$.037/kWh

$.030/kWh

$.025/kWh

$.029/kWh

$.018/kWh

Fuel   O&M   Xcel Bids
Xcel Energy Plan

Wind: $.011/kWh
Solar: $.023/kWh
Solar plus storage: $.030/kWh

Image credit: Jeffrey Beall, Wikimedia
2 Why is Flexibility Important? Examples from Around the Country
## Solar + Storage in Hawaii

<table>
<thead>
<tr>
<th>Project</th>
<th>Island</th>
<th>Developer</th>
<th>Size</th>
<th>Storage</th>
<th>Cost per kWh</th>
</tr>
</thead>
<tbody>
<tr>
<td>Waikoloa Solar</td>
<td>Hawaii</td>
<td>AES</td>
<td>30 MW</td>
<td>120 MWh</td>
<td>$0.08</td>
</tr>
<tr>
<td>Kuihelani Solar</td>
<td>Maui</td>
<td>AES</td>
<td>60 MW</td>
<td>240 MWh</td>
<td>$0.08</td>
</tr>
<tr>
<td>Hale Kuawehi</td>
<td>Hawaii</td>
<td>Innergex</td>
<td>30 MW</td>
<td>120 MWh</td>
<td>$0.09</td>
</tr>
<tr>
<td>Millili I Solar</td>
<td>Oahu</td>
<td>Clearway</td>
<td>39 MW</td>
<td>156 MWh</td>
<td>$0.09</td>
</tr>
<tr>
<td>Waiawa Solar</td>
<td>Oahu</td>
<td>Clearway</td>
<td>36 MW</td>
<td>144 MWh</td>
<td>$0.10</td>
</tr>
<tr>
<td>Hoohohana</td>
<td>Oahu</td>
<td>174 Power Global</td>
<td>52 MW</td>
<td>208 MWh</td>
<td>$0.10</td>
</tr>
<tr>
<td>Puuoha Solar</td>
<td>Maui</td>
<td>Innergex</td>
<td>15 MW</td>
<td>60 MWh</td>
<td>$0.10</td>
</tr>
</tbody>
</table>

**Source:** Hawaiian Electric
Maui Electric Rates, Fuel, and New Supply

<table>
<thead>
<tr>
<th>Category</th>
<th>Cents/kWh</th>
</tr>
</thead>
<tbody>
<tr>
<td>Retail Rate</td>
<td>30</td>
</tr>
<tr>
<td>Fuel - Peaker</td>
<td>18</td>
</tr>
<tr>
<td>Fuel - CCCT</td>
<td>12</td>
</tr>
<tr>
<td>Solar + Storage</td>
<td>3</td>
</tr>
</tbody>
</table>
Texas Wind Resources and Solar Resources have Complementary Load Capacity Profiles

Combined, They Produce a Smoother Profile that Approximates System Needs
Adding Transmission in Texas

Increasing Resource and Geographic Diversity Has Significantly Reduced Curtailments and Stabilized Prices

Source: U.S. Energy Information Administration, based on the Electric Reliability Council of Texas (ERCOT) for curtailments and SNL Energy for electricity prices
The Western EIM Increases Diversity and Adds Flexibility
Western EIM Economic Benefits Growing

Cumulative Curtailments Avoided:
More than 700 GWhs

Avoided Emissions:
More than 300,000 Tons
New England: Expensive Peaks

Source: MA DOER, State of Charge report
What Flexible Capabilities do Advanced Technologies Provide?
Supply Side: Inverter-Based Technologies Provide Important System Benefits
Taking Notice at NARUC

The Electricity Committee and Energy Resources and Environment Committee have acknowledged the importance of flexible resources.

(1) Utilities and utility commissions should be well educated about the different types of quantitative models that exist today …

(2) Planning frameworks and modeling tools that are publicly and commercially available should model the full spectrum of services that energy storage and flexible resources are capable of providing …
Wind, Solar, and Batteries are Valuable in Real Time

<table>
<thead>
<tr>
<th>Inverter-Based</th>
<th>Synchronous</th>
<th>Demand Response</th>
</tr>
</thead>
<tbody>
<tr>
<td>Wind</td>
<td>Solar PV</td>
<td>Storage/Battery</td>
</tr>
<tr>
<td>![Diagram](source: <a href="http://www.milligangridsolutions.com">www.milligangridsolutions.com</a>)</td>
<td>![Diagram](source: <a href="http://www.milligangridsolutions.com">www.milligangridsolutions.com</a>)</td>
<td>![Diagram](source: <a href="http://www.milligangridsolutions.com">www.milligangridsolutions.com</a>)</td>
</tr>
</tbody>
</table>

These services also contribute to frequency restoration, but are also considered essential reliability services on their own.

Source: www.milligangridsolutions.com
You May Have Noticed that Inverter-Based Technologies Excel at being Fast

Source: www.ascendanalytics.com
Demand Side: New Services Are Available
Load-Side Resources to “Shape” the Demand Curve
Load-side Resources Can “Shift” Demand To Times When Surplus Power is Available
Load-Side Resources Can “Shift” Demand

dollars per megawatthour

real-time average hourly price

24 hour of the day
Ice Storage Air Conditioning
Limited Curtailment Can “Shed” During Critical Hours

Responsive Load Can “Shimmy” To Meet Short-Term Grid Needs

Charging is varied UP and DOWN from a “bid in” base line.

Source: PJM
Flexibility Strategies for the Demand Side Now Span Many Timescales

What Tools Do We Need to Optimize Flexibility?
Retail Pricing and Price-Responsive Demand

Your electricity bill

Your service plan: Standard Rate

Charges for electricity services

Cost of electricity you used

Customer account charge
Delivery service charge
Environmental benefits surcharge
Federal environmental improvement surcharge
System benefits charge
Power supply adjustment*
Getting Around Demand Charges
STEM: 12 kW Savings Off 68 kW Peak
## Fort Collins: Smart Residential Rate

<table>
<thead>
<tr>
<th></th>
<th>Summer</th>
<th>Winter</th>
</tr>
</thead>
<tbody>
<tr>
<td>Customer Charge</td>
<td>$ 6.78</td>
<td></td>
</tr>
<tr>
<td>Off-Peak</td>
<td>$ 0.069</td>
<td>$ 0.067</td>
</tr>
<tr>
<td>On-Peak</td>
<td>$ 0.241</td>
<td>$ 0.216</td>
</tr>
<tr>
<td>Tier Charge (Over 700 kWh)</td>
<td>+ $.0194 / kWh</td>
<td></td>
</tr>
</tbody>
</table>

### Diagrams

**Non-Summer** (October-April)
- Off-Peak: 9PM-2PM
- On-Peak: 7PM-5PM

**Summer** (May-September)
- Off-Peak: 9PM-2PM
- On-Peak: 7PM-5PM
BG&E TOU Pilot

Excludes weekends and holidays, which are billed at off-peak rates. Holidays include New Year’s Day, President’s Day, Good Friday, Memorial Day, Independence Day, Thanksgiving, Christmas and the Monday following if any of these holidays fall on a Sunday.
Controlled Loads
Efficient Building Code
High-efficiency Heat Pump with Air Exchangers
Smart Charging  Electric Vehicles

VEHICLE CHARGING

PEAK DEMAND (KW)

6.6
Grid-Integrated Heat Pump Water Heater

Peak Demand (KW)

4.4
Smart Appliances

Peak Demand (kW): 4.5
Uncontrolled Household Loads Could Add Up To A Lot

![Diagram showing peak demand in kW]

- **Lights / Minor Appliances**: 3 kW
- **Major Appliances**: 4.5 kW
- **Water Heat**: 4.4 kW
- **EV**: 6.6 kW
- **Space Conditioning**: 4 kW

Total peak demand: 22.5 kW
Flexibility Dramatically Cuts Peak Demand

Shift EV, Water Heat, Major Appliances, and Pre-Condition Spaces

![Diagram showing peak demand with categories: Lights / Minor Appliances, Major Appliances, Water Heat, EV, and Space Conditioning. The total peak demand is 22.5 kW with individual demands as follows: Lights / Minor Appliances 3 kW, Major Appliances 4.45 kW, Water Heat 4.4 kW, EV 6.6 kW, and Space Conditioning 4 kW.]

Image credit: https://electriqpower.com/powerpod/
Controlled Water Heaters

The CTA 2045 socket enables any control network to connect to any new water heater.
Open Planning and Market Processes
Flexibility Needs Must be Modeled and Capabilities Compensated

... Make It So

Image credit: Getty Images
Regulators Can Make a Difference:
By Opening Procurement to Solar, Wind and Storage (Like Colorado)

<table>
<thead>
<tr>
<th>Generation Technology</th>
<th># of Bids</th>
<th>Bid MW</th>
<th># of Projects</th>
<th>Project MW</th>
<th>Median Bid Price or Equivalent</th>
<th>Pricing Units</th>
</tr>
</thead>
<tbody>
<tr>
<td>Combustion Turbine/IC Engines</td>
<td>30</td>
<td>7,141</td>
<td>13</td>
<td>2,466</td>
<td>4.80 USD/kW-mo</td>
<td></td>
</tr>
<tr>
<td>Combustion Turbine with Battery Storage</td>
<td>7</td>
<td>804</td>
<td>3</td>
<td>476</td>
<td>6.20 USD/kW-mo</td>
<td></td>
</tr>
<tr>
<td>Gas-Fired Combined Cycles</td>
<td>2</td>
<td>451</td>
<td>2</td>
<td>451</td>
<td>11.30 USD/kW-mo</td>
<td></td>
</tr>
<tr>
<td>Stand-alone Battery Storage</td>
<td>28</td>
<td>2,143</td>
<td>21</td>
<td>1,614</td>
<td>11.30 USD/kW-mo</td>
<td></td>
</tr>
<tr>
<td>Compressed Air Energy Storage</td>
<td>1</td>
<td>317</td>
<td>1</td>
<td>317</td>
<td>11.30 USD/kW-mo</td>
<td></td>
</tr>
<tr>
<td>Wind</td>
<td>96</td>
<td>42,278</td>
<td>42</td>
<td>17,380</td>
<td>18.10 USD/MWh</td>
<td></td>
</tr>
<tr>
<td>Wind and Solar</td>
<td>5</td>
<td>2,612</td>
<td>4</td>
<td>2,162</td>
<td>19.90 USD/MWh</td>
<td></td>
</tr>
<tr>
<td>Wind with Battery Storage</td>
<td>11</td>
<td>5,700</td>
<td>8</td>
<td>5,097</td>
<td>21.00 USD/MWh</td>
<td></td>
</tr>
<tr>
<td>Solar (PV)</td>
<td>152</td>
<td>29,710</td>
<td>75</td>
<td>13,435</td>
<td>29.50 USD/MWh</td>
<td></td>
</tr>
<tr>
<td>Wind and Solar and Battery Storage</td>
<td>7</td>
<td>4,048</td>
<td>7</td>
<td>4,048</td>
<td>30.60 USD/MWh</td>
<td></td>
</tr>
<tr>
<td>Solar (PV) with Battery Storage</td>
<td>87</td>
<td>16,725</td>
<td>59</td>
<td>10,813</td>
<td>36.00 USD/MWh</td>
<td></td>
</tr>
<tr>
<td>IC Engine with Solar</td>
<td>1</td>
<td>5</td>
<td>1</td>
<td>5</td>
<td>36.00 USD/MWh</td>
<td></td>
</tr>
<tr>
<td>Waste Heat</td>
<td>2</td>
<td>21</td>
<td>1</td>
<td>11</td>
<td>36.00 USD/MWh</td>
<td></td>
</tr>
<tr>
<td>Biomass</td>
<td>1</td>
<td>9</td>
<td>1</td>
<td>9</td>
<td>36.00 USD/MWh</td>
<td></td>
</tr>
<tr>
<td><strong>Total</strong></td>
<td><strong>430</strong></td>
<td><strong>111,963</strong></td>
<td><strong>238</strong></td>
<td><strong>58,283</strong></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
By Soliciting Cost-Effective Solar and Storage Bids (like Nevada)
By Opening up Wholesale Markets to Aggregated DERs and Storage (Like California)

The CAISO initiated the Electricity Storage and Distributed Energy Resources (ESDER) Initiative in 2014 to:

Enhance the ability of ISO connected and distribution-connected resources to participate in ISO markets

Phase 3 was completed in 2018 and market participation enhancements included providing a bidding mechanism that allows behind the meter resources to offer load using and load curtailing service
And by Inviting Advanced Technology Alternatives when Fossil Retires …

The PG&E and East Bay Clean Energy project, the Oakland Clean Energy Initiative (OCEI), replaces a retiring 165 MW Dynegy gas peaker, obviates need for 115 kV and 230 kV transmission.

The combination of resources includes:

- 25-40 MW combination of EE, DR, PVDG (minimum 19 MW of load reducing response)
- 10 MW/40 MWh storage
- Substation upgrades and line re-ratings
… Saving Ratepayers Money and Reducing Emissions
By Using Demand Response to Manage Seasonal Loads

If there is a significant increase in energy prices or energy demand in the summer months, typically between June and September, your PeakRewards device may receive a signal to cycle your air conditioner up to your chosen cycling level (50%, 75% or 100%).

Source: Baltimore Gas & Electric
By Designing Pricing to Reflect Grid Management Needs at the Regional, Utility, Zonal, Nodal, and Circuit Levels
Questions?

Please send questions through the Questions pane.
Summary

• Flexibility helps meet reliability needs at lower cost while adding significant amounts of renewables.

• Technology changes, new capabilities, and forms of grid interactivity are valuable opportunities for the electric sector.

• This is an opportunity for regulators to provide policy guidance to help realize the many benefits of a more flexible grid.
About RAP

The Regulatory Assistance Project (RAP)® is an independent, non-partisan, non-governmental organization dedicated to accelerating the transition to a clean, reliable, and efficient energy future.

Learn more about our work at raponline.org