Power Markets in an Era of Low-Marginal Costs

Resources for the Future and NREL Workshop

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Renewables are Becoming Super Inexpensive (and nuclear sometimes, too)

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Renewables: Where are We?
Sunny outlook for competitiveness of renewables

Share of generation from new renewable energy projects that do not require subsidies by technology in New Policies Scenario

Increasing shares of new wind & solar PV projects become competitive over time

Source: IEA World Energy Outlook, 2016
Further cost reductions for wind and solar PV

Global wind & solar PV capacity additions & capital cost reductions across regions by scenario to 2040

Capital cost reductions from 2015 to 2040

- Wind onshore
- Wind offshore
- Solar PV utility
- Solar PV buildings

Capacity additions, 2016-2040

- Wind onshore
- Wind offshore
- Solar PV utility
- Solar PV buildings

Cost to build wind projects is projected to fall by 10-60% by 2040, while solar PV capital costs decline by 20-70%
Greater policy support boosts prospects for solar PV, wind

Solar PV & wind generation in New Policies Scenario, 2040

Stronger policies on solar PV & wind help renewables make up 37% of electricity generation in 2040 in our main scenario – & nearly 60% in the 2 °C Scenario.

Source: IEA World Energy Outlook, 2016
Next frontiers: heat and transport

Renewable energy use by sector in New Policies Scenario

Today renewables in electricity & heat use are nearly at par; by 2040, largest untapped potential lies in heat & transport

Source: IEA World Energy Outlook, 2016
Electric vehicles grow from 1.3 million in 2015 to over 150 million by 2040 in our central scenario; in 2 °C Scenario EV stock rises to over 700 million by 2040.
Subsidies on different tracks

Estimates for global fossil-fuel subsidies consumption subsidies & subsidies for renewables

Drop in fossil-fuel prices & in value of subsidies has raised prospects for reform; fall in technology costs has boosted effectiveness of subsidies for renewables.

*Source:* IEA World Energy Outlook, 2016
Renewables may balance other sources in power generation by 2040

World power generation capacity by type in New Policies Scenario

Renewables account for nearly half of total installed capacity by 2040, up from 31% today

Source: IEA World Energy Outlook, 2016
Energy Prices:

Where are we on prices? Do we really know?
Figure 3. Average PJM Aggregate Real-Time Generation Supply Curves in summer 2015 and 2016

Source: PJM, Energy Price Formation and Valuing Flexibility (June 2017)
Power System Prices on U.S. West Coast With Seasonal Hydro Flows

POWER SYSTEM DATA
Week Ending July 8, 2017

<table>
<thead>
<tr>
<th>STREAMFLOW CONDITIONS</th>
<th>Mar</th>
<th>Apr</th>
<th>May</th>
<th>June</th>
<th>July</th>
</tr>
</thead>
<tbody>
<tr>
<td>Natural Streamflow at The Dalles</td>
<td>272%</td>
<td>179%</td>
<td>151%</td>
<td>119%</td>
<td>105%</td>
</tr>
<tr>
<td>Critical Year Natural Streamflow at The Dalles</td>
<td>56.2%</td>
<td>56.3%</td>
<td>78.2%</td>
<td>77.0%</td>
<td>83.0%</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>FEDERAL HYDRO GENERATION</th>
<th>Mar</th>
<th>Apr</th>
<th>May</th>
<th>June</th>
<th>July</th>
</tr>
</thead>
<tbody>
<tr>
<td>2016/2017 Federal Hydro Generation (MW/mo.)</td>
<td>11953</td>
<td>11781</td>
<td>11810</td>
<td>12483</td>
<td></td>
</tr>
<tr>
<td>2015/2016 Federal Hydro Generation</td>
<td>10655</td>
<td>11066</td>
<td>9764</td>
<td>8384</td>
<td></td>
</tr>
<tr>
<td>5 Year Average Federal Hydro Generation</td>
<td>10269</td>
<td>10306</td>
<td>10380</td>
<td>9944</td>
<td></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>HISTORIC PRICES (ICE HLH month average)</th>
<th>Mar</th>
<th>Apr</th>
<th>May</th>
<th>June</th>
<th>July</th>
</tr>
</thead>
<tbody>
<tr>
<td>2017 Mid-C Prices in $/megawatt-hour</td>
<td>13.17</td>
<td>12.78</td>
<td>16.88</td>
<td>15.75</td>
<td>31.90</td>
</tr>
<tr>
<td>2016 Mid-C Prices in $/megawatt-hour</td>
<td>13.03</td>
<td>12.14</td>
<td>14.58</td>
<td>21.71</td>
<td>31.15</td>
</tr>
</tbody>
</table>

For week ending July 8th $/megawatt-hour $22.59-$48.79
Historic Natural Gas Wellhead Price Projections *(in color each year)* and Actual *(in black)*
3 Price Formation
# FERC Market Reforms

<table>
<thead>
<tr>
<th>Price Caps</th>
<th>Uplift</th>
<th>Fast Start Units</th>
</tr>
</thead>
<tbody>
<tr>
<td>Amending $1,000 nationwide cap</td>
<td>Cost allocation of uplift</td>
<td>Fast start unit pricing</td>
</tr>
<tr>
<td></td>
<td>(Dock. RM 17-2-000)</td>
<td>(Dock. RM 17-3-000, Dec. 2016)</td>
</tr>
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</table>
Energy Market Bias?

Energy Market or Capacity Market or both?

- Toward lower cost resources? (PJM)
- Secondary auction for transfer of capacity between retiring and RE resources (ISO-NE)
- Two-stage capacity market to remove “subsidized” resources from setting quantity or price (PJM)
## Capacity to do what?

<table>
<thead>
<tr>
<th>Energy</th>
<th>Services</th>
<th>Quality</th>
</tr>
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<tbody>
<tr>
<td>where?</td>
<td>reserves?</td>
<td>supply?</td>
</tr>
<tr>
<td>when?</td>
<td>frequency?</td>
<td>less demand?</td>
</tr>
<tr>
<td>dispatchable?</td>
<td>voltage?</td>
<td>carbon?</td>
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<tr>
<td>variable?</td>
<td>ramp rate?</td>
<td>jobs?</td>
</tr>
<tr>
<td>risks?</td>
<td></td>
<td>risks?</td>
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Peak Load Consistently Overstated

Energy efficiency and DERs are flattening load growth
Resource adequacy base needs to build generation (and transmission and distribution) on accurate estimates of peak load

Experience with various “capacity mechanisms”

- **Extent of capacity intervention**
  - ERCOT
  - NYISO
  - PJM
  - ISO-NE
  - NEM
  - SWIS

- **Avg annual new-build as % of 2014 peak**

- **Ratio of actual to target reserve margins (2015)**

Source: RAP, published from system operator data
Figure 2. Comparison of Price Setting Methods

Today: Only flexible units allowed to set price

Alternative: Any unit needed can set price

Inflexible unit offer: 100 MW @ $40
Flexible unit offer: $20 + $0.1/MW

Source: PJM, Energy Price Formation and Valuing Flexibility (June 2017)
PJM: Capacity Meets ICAP before DR and EE is counted

Source: Brattle Group
Robustness to Alternate Futures & Assumption of Risk as between Consumers and Market Participants

In an energy only market, “high penetration of zero or low-marginal cost generation might not signal future scarcity and could misrepresent the returns and level of risk associated with new investment. On the other hand, the cost of capital and inherent preference for smaller projects with shorter construction periods [in a energy market!] suggests the energy-only market might be more robust to alternative futures than one that locked in large scale investments.”

Price Formation

The wholesale market design question

How can locational prices better reflect system conditions and value resources needed to meet changing system conditions throughout the day? (PJM)

Source: PJM, Energy Price Formation and Valuing Flexibility (June 2017)
Pricing to Consumers

The retail and rate design question

How can consumer prices of service -- total service including generation, distribution, transmission and supply-side services -- reflect the temporal and geographic variation in costs of service and supply.

Why focus only on prices? Is there a role for consumer incentives such as peak-time rebates or local demand-side management and DERs?
How Much” Depends on “What Kind”
Fundamentals are Changing
## What Characteristics are Needed?

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<td>ramp rate?</td>
<td>jobs? risks?</td>
</tr>
<tr>
<td>risks?</td>
<td>*for, from, or to consumers,</td>
<td>*enable</td>
</tr>
<tr>
<td>*wholesale/retail delivery?</td>
<td>LSEs, utilities?</td>
<td>customers as resources?</td>
</tr>
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“Bigger,” “faster” markets

Source: National Renewable Energy Laboratory (U.S.), 2013
Generation: Just one piece of the puzzle

Source: IEA Energy Technology Perspectives 2014
The image shows two sets of data for the utilization of plant capacity in two different scenarios: Legacy and Transformed.

### Legacy (MWh produced)
- **Baseload**: 62% of capacity
- **Mid-merit**: 11% of capacity
- **Peak**: 2% of capacity

### Transformed (MWh produced)
- **Baseload**: 96% of capacity
- **Mid-merit**: 39% of capacity
- **Peak**: 96% of capacity

The diagrams illustrate the annual capacity (MWh) for each category (Idle and Used) in the Legacy and Transformed scenarios.
Power Sector Carbon Pricing

- CA and RGGI operational
- Shadow Carbon Pricing
- Carbon Pricing: Zero emission objectives through PJM’s Energy Markets? (PJM)
- IMAPP / Dynamic Clean Energy Market (ISO-NE)
- Carbon Pricing (NYISO)
- Energy Imbalance Market Subregional Carbon Pricing-Framework (CAISO)
There are other important markets – that directly impact flexibility in the electricity market

How coordinated are the electricity and natural gas markets?
“PJM also has observed that resources using natural gas as their primary fuel tend to acquire gas on an inflexible basis, given the economic advantage of so doing and the limited availability of pipeline transportation products”

PJM, Energy Price Formation and Valuing Flexibility, PJM 2017
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