Forecasting Renewable Energy

Brad Nebergall
Renewable Resources = 1,202 MW

- **Hydro Projects Totaling 607 MW**
  - WAPA Allocation 580 MW
  - Small hydro PPAs 27 MW

- **Seven Utility Scale Renewable Projects Totaling 452 MW**
  - Cimarron Solar 30 MW COD November 2010
  - Kit Carson Wind 51 MW COD November 2010
  - Colorado Highlands Wind 91 MW COD December 2012 & Sep. 2013
  - Carousel Wind 150 MW COD July 2016
  - San Isabel Solar 30 MW COD December 2016
  - Alta Luna Solar 25 MW COD January 2017
  - Twin Buttes II Wind 75 MW COD December 2017

- **Member Generation**
  - 143 MW operating or under development as of October 2018
2017 Renewable Generation

*WAPA does not qualify for NM RPS and WAPA large hydro does not qualify for Colorado RES. Excludes state multipliers.

By Technology

- Hydro: 56%
- Wind: 35%
- Solar: 7%
- Biomass: 0.5%
- Recycled Energy: 1.5%

By Source

- WAPA: 53.2%
- Basin: 10.9%
- Tri-State PPAs: 30.3%
- Member Policy 115 Projects: 4.8%
- Member Net-Metered Generation: 0.8%
Wind & Solar Generation

452 MW of Utility Scale

GWh/Year

In 2017, 30% of the energy consumed by Tri-State member systems’ retail customers came from renewable resources.

<table>
<thead>
<tr>
<th>Year</th>
<th>Renewable %</th>
<th>Additions</th>
</tr>
</thead>
<tbody>
<tr>
<td>2016</td>
<td>27%</td>
<td>Carousel Wind &amp; Member</td>
</tr>
<tr>
<td>2017</td>
<td>30%</td>
<td>San Isabel, Alta Luna &amp; Member</td>
</tr>
<tr>
<td>2018</td>
<td>32 - 33%</td>
<td>Twin Buttes II Wind &amp; Member</td>
</tr>
</tbody>
</table>
Aggregated Wind: August 1, 2018

- Twin Buttes II
- Carousel Wind
- Colorado Highlands
- Kit Carson
Aggregated Solar: August 1, 2018

The graph shows the aggregated solar energy production for Alta Luna, San Isabel, and Cimarron over a 24-hour period from 12:00 AM to 10:00 PM on August 1, 2018. The production peaks during the afternoon hours, with Alta Luna producing the most energy.
Wind + Solar: August 1, 2018
Forecasting & Energy Imbalance
Load & Resource Forecasting

- Forecasting Error causes Energy Imbalance
  - Balancing Authorities (BAs) charge for the error hourly
- Tri-State retains outside firm to forecast member load
  - Neural network that gets better based on experience
- Forecasting error creates expense
  - Intermittent renewable generation (wind/solar) is major source
- Tri-State requires our wind and solar operators to forecast generation as part of the PPA
  - Member generation provides no forecast but we estimate
  - “Hidden” cost
### Example Of Hourly Energy Imbalance

<table>
<thead>
<tr>
<th>RESOURCES</th>
<th>LOAD</th>
</tr>
</thead>
<tbody>
<tr>
<td>Gas &amp; Coal</td>
<td>Member Load 360 MW</td>
</tr>
<tr>
<td>Wind &amp; Solar</td>
<td>3rd Party Sales 75 MW</td>
</tr>
<tr>
<td>Purchases</td>
<td>Losses 10 MW</td>
</tr>
<tr>
<td>Total Resources</td>
<td>Total Obligations 445 MW</td>
</tr>
<tr>
<td>350 MW</td>
<td></td>
</tr>
<tr>
<td>50 MW</td>
<td></td>
</tr>
<tr>
<td>25 MW</td>
<td></td>
</tr>
<tr>
<td>425 MW</td>
<td></td>
</tr>
</tbody>
</table>

Hourly Energy Imbalance = 20 MW

*Buy 20 MW from the balancing authority for a high price*
Energy Imbalance

- Buy High, Sell Low. We work hard to minimize EI
- EI Accounts with PNM, WAPA, PAC & PSCO (2) all with slightly different terms and conditions
- Reported Monthly in Operations Memo

<table>
<thead>
<tr>
<th>COMPANY</th>
<th>PURCHASES</th>
<th>SALES</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>MWh</td>
<td>AMOUNT</td>
</tr>
<tr>
<td>EI-PSCO &gt; TSGT NSA</td>
<td>8,971</td>
<td>$223,479</td>
</tr>
<tr>
<td>EI-PNM &gt; TSGT NITSA</td>
<td>3,043</td>
<td>$83,887</td>
</tr>
<tr>
<td>EI-WAPA &gt; TSGT</td>
<td>(20,526)</td>
<td>($522,251)</td>
</tr>
<tr>
<td>EI-PAC &gt; TSGT NITSA</td>
<td>15</td>
<td>$2,672</td>
</tr>
<tr>
<td>EI-BHCT &gt; TSGT</td>
<td>319</td>
<td>$6,742</td>
</tr>
<tr>
<td>EI-PSCO &gt; TSGT BAASA</td>
<td>2,247</td>
<td>$54,064</td>
</tr>
</tbody>
</table>

Tri-State May 2018 Board Meeting
## EI Improvements 2016 vs. 2017

<table>
<thead>
<tr>
<th></th>
<th>Total MWh Reduction</th>
<th>Penalty MWh Reduction</th>
<th>Total Penalty Reduction</th>
<th>% Reduction in Penalty $</th>
</tr>
</thead>
<tbody>
<tr>
<td>WAPA</td>
<td>131,095</td>
<td>113,148</td>
<td>$223,451</td>
<td>66%</td>
</tr>
<tr>
<td>Net PSCO</td>
<td>11,312</td>
<td>6,461</td>
<td>$ 44,909</td>
<td>22%</td>
</tr>
</tbody>
</table>

WebAccounting Improvements:
- Metering
- Internal Coordination
- External Energy Imbalance Bills & Calculations
- Forecasting
Typical Forecasting Terms

- 15 minutes before each hour operator must provide an energy forecast for the next hour
- Error is calculated each quarter
- Forecast error is Mean Average Percent Error (MAPE)
- If the quarterly MAPE exceeds X%, then operator owes Tri-State $Y for each 1% error over X%
Mean Average Percent Error (MAPE)

- Calculated for each hour
- Forecast provided before the start of each hour

Forecast MWh – Actual MWh

Nameplate MW
Summary

- Intermittent renewable generation is a major source of forecasting error
- Forecasting error is a hidden cost of integration
- Buyers attempt to shift the responsibility to operators
- Better forecasting makes intermittent generation more competitive