Flexibility and Control of Power Generation in Coal Plants: Solutions from the Dispatch Floor
AGENDA

• Xcel Energy: An Introduction
• Loads & Resources: The Problem
• Coal as a Flexible Resource: A Solution

Please contact me w/ questions & commentary

Keith Parks  
Senior Trading Analyst  
Xcel Energy  
1800 Larimer Street Suite 1000  
Denver CO 80202  
USA

W: +1 303 571 2831  
C: +1 303 859 2280  
E: keith.parks@xcelenergy.com
XCEL ENERGY

- No. 1 utility wind provider
- Top-ten utility for solar capacity
- Leader in emission reductions
- Nationally recognized in energy efficiency
- Member of the Dow Jones Sustainability Index
Xcel Energy Wind Generation Growth (current)

Ave Capacity Factor: 38%

Capacity MW

Renewable Energy Leadership

Xcel Energy Wind Energy

Megawatts

<table>
<thead>
<tr>
<th>Year</th>
<th>Megawatts</th>
</tr>
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<tbody>
<tr>
<td>2010</td>
<td>3,000</td>
</tr>
<tr>
<td>2016</td>
<td>6,000</td>
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<tr>
<td>2021</td>
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Xcel Energy Solar Energy

Megawatts

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<tr>
<td>2010</td>
<td>0</td>
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<td>3,000</td>
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Our Changing Energy Mix

2005
- Coal: 56%
- Natural Gas: 23%
- Nuclear: 12%
- Other Renewable: 6%
- Wind: 3%
- Other: 3%

2016
- Coal: 37%
- Natural Gas: 25%
- Nuclear: 13%
- Other Renewable: 6%
- Wind: 19%
- Other: 12%

2021
- Coal: 34%
- Natural Gas: 35%
- Nuclear: 12%
- Other Renewable: 12%
- Wind: 12%
- Other: 7%

Coal | Natural Gas | Nuclear | Wind | Other Renewable
Carbon Reduction Goals

Xcel Energy reductions on pace to surpass international climate goals

60% by 2030
with the right policy and technology
LOADS & RESOURCES
• Obligations and resources are maintained in balance at all times.
LOADS AND RESOURCES (APR/OCT)

- Expand focus to all hours of the year to manage uncertainty (Apr/Oct).
• Spread between daily high/low loads increase. Timing of ramps uncertain.
LOADS AND RESOURCES (2024)

- New paradigm: Flexible and Informed Grid
LOADS AND RESOURCES – A NEW PARADIGM

Traditional Utility Paradigm (w/ some RE)

VER forecasts ignored in commitment
VERs are must-take in dispatch
VERs penalized for deviations
Current reserves are sufficient

High Penetration Portfolio

VER forecasts integrated into planning
VERs are dispatchable
**VERs married with flexible resources**
Reserve products tailored for VERs
COAL AS A FLEXIBLE RESOURCE
I use the Pawnee Power Plant as an example. Though, the following slides are indicative of ALL our coal facilities.
The duty of our coal plants has changed significantly from pure baseload generation to heavy load following
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• Pawnee has three primary modes of operation
  – ECON MAX
  – AGC – Economic Dispatch
  – ECON MIN
• Traditional model of operation
• Requires 5 of 6 mills to be in operation
• Dispatch signal sent electronically every 4-seconds from EMS
  • Dynamic econ max/min and ramp rate limits
  • Economically dispatched relative to peers
  • Variable speed coal feeders and some overpressure enables dispatch
PAWNEE – TYPICAL DUTY

- Coal mills dynamically decommitted (3 to 4 mills in operation)
  - 30 minutes to remove a mill; 20 minutes to replace
  - Enables lower loads without decommitment
  - Working to enable AGC through economic min operation
IMPACTS

• Thermal Stresses on the Boiler Tubes
  – Load Following has minor long-term impact
  – Decommitment can have major cost implications long-term.

• Coal Mill Cycling
  – Roller makes contact with the coal mill table during the grind out process. Increases wear and tear.

• Flame Stability
  – Can be a concern at low loads. Streaming of natural gas into the flame helps provide stability.

• Emission Controls
  – NOx removal can be compromised at low loads as the temperature of the flue gas is reduced.
  – SO2 removal requires greater management of ammonia concentration.
WIND PLANT ON AGC

- 70% of Xcel Energy wind capacity is AGC capable
  - All wind farms with SCADA systems post-2007 are enabled
- Allows for real-time curtailment with incredible precision
- Wind farms provide the fastest ramping capability of all XE resources
CONCLUSION

• Coordinated system dispatch via **Automatic Generation Control** (or other automatic econ dispatch system) enables huge efficiencies

• Coal plants are **able to respond in real-time**.

• **Lower loads are possible** through coal mill cycling.

• Coal plants are able to dispatch with **variable speed feeders** and moderate use of **boiler over-pressure** (within strict limits)

• **Wind plants are capable of fast and precise generation control**.
PSCO WIND PENETRATION
PERCENT OF OBLIGATION LOAD

Xcel Energy
APRIL - COLORADO