Estimation of the Market Equilibrium and Economically Optimal Reserve Margins
FOR THE ERCOT REGION, 2018 UPDATE

PRESENTED TO
ercot
SAWG

PRESENTED BY
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Agenda

Problem Statement and Approach

Analytical Results
- Market Equilibrium Reserve Margin
- Economically Optimal Reserve Margin
- Physical Reliability Metrics
- Comparison to 2014 Study Results

Sensitivities

Appendix
- Model Validation
- Key Assumptions
Problem Statement
What are the MERM and EORM in ERCOT?

Estimating the MERM and EORM inform whether ERCOT’s market will support sufficient reserve margins from an economic perspective (the modeling also informs reliability implications).
Modeling Approach

Simulation Period: 2022 (8760 hours)
Simulations per Reserve Margin: 9,500
  — 50 outage draws
  — 38 weather years
  — 5 non-weather load forecast errors

Topology
  — ERCOT, Mexico, SPP, and Entergy footprints
  — Connected through existing DC-Ties

Installed Capacity
  — Baseline capacity consistent with ERCOT’s 2018 LTRA submissions
  — Higher and Lower Reserve Margins modeled by adding and subtracting generic CC/CT capacity from baseline

Baseline ERCOT Installed Capacity by Resource Type

Source: 2018 Report, Figure 2

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Market Equilibrium Reserve Margin

ERCOT Projected 2022 Market Equilibrium Reserve Margin

- Marginal Unit Net Energy Revenue
- Cost of New Entry

Source: 2018 Report, Figure ES-1 and Figure 5
Year-to-Year Volatility in Annual Average Price and Revenue

Source: 2018 Report, Figure 6
Note: Marginal Unit Net Energy Revenue represents the net revenue from a mix of added CCs and CTs (77:23 ratio)
Economically Optimal Reserve Margin

Total System Costs across Planning Reserve Margins

Economically Optimal Reserve Margin at 9.0%

Source: 2018 Report, Figure 8
Physical Reliability Metrics

Reliability Metrics that Vary with Reserve Margins

(a) LOLE

(b) LOLH

(c) Normalized EUE

Source: 2018 Report, Figure 10
Emergency Event Frequencies

Average Annual Frequency of Emergency Events

Event Frequency (events/yr) vs. Reserve Margin (% ICAP)

- Emergency Generation
- 30-min ERS
- 10-min ERS
- TDSP
- Load Shed
- Market Equilibrium
- Reserve Margin
- 0.1 LOLE

Source: 2018 Report, Figure 12
Drivers of the MERM Change from 2016 to 2022 Model

- 2014 MERM Base: 11.5%
- Reserve Margin Accounting: 0.9%
- Lower Cost of New Entry: 1.0%
- Increase in Renewables: 0.6%
- Lower Gas Prices: 0.5%
- Change in Weather Year Weighting: 0.75%
- Lower Forced Outage Rate: 1.0%
- Other: 0.3%
- 2018 MERM Base: 10.25%

Source: 2018 Report, Figure 7
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## Sensitivity to Key Uncertainties

<table>
<thead>
<tr>
<th>Variable</th>
<th>Base Case Assumption</th>
<th>Sensitivity Range</th>
</tr>
</thead>
<tbody>
<tr>
<td>Renewables Penetration</td>
<td>9.6 GW new renewables</td>
<td>-10.7 GW/+29.6 GW of renewables*</td>
</tr>
<tr>
<td>High Gas Price</td>
<td>Henry Hub: $3.26</td>
<td>Henry Hub: $6.25</td>
</tr>
<tr>
<td>Gross CONE</td>
<td>CT: $89/kW-year</td>
<td>-10% / +25%</td>
</tr>
<tr>
<td></td>
<td>CC: $95/kW-year</td>
<td></td>
</tr>
<tr>
<td>VOLL</td>
<td>$9,000/MWh</td>
<td>$5,000 to $30,000/MWh</td>
</tr>
</tbody>
</table>
| Weighting of Historical Weather Years | Equal probability (2.5%) on last 38 years | (1) 10% most last 10 years  
(2) Probabilities based on Pareto distribution fit to weather years based on number of consecutive days with weather over 100 degrees  
(3) Probabilities equal to 2014 EORM base case |
| Forward Period and Load Forecast Uncertainty | 3 years | 0 years to 2 years                                    |

Source: 2018 Report, Table 4 & Table 5  
Note: * -20.3 GW/ + 20 GW from the Base Case assumption
Summary of Sensitivity Results

Sensitivity of the MERM to Study Assumptions

Source: 2018 Report, Figure 15
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  − Model Validation
  − Key Assumptions
Modeled vs. Actual Combined-Cycle Net Energy Revenues

Source: 2018 Report, Figure 3
Model Validation (2 of 2)

Average Modeled vs. Historical Expected Net
Energy Revenues by Reserve Margin

Source: 2018 Report, Figure 4
Reference Technology Assumptions

Higher reserve margin cases add reference technology that represents a mix of H-Class combined cycles and combustion turbines consistent with recent additions and announced new builds (77:23)

### Reference Technology Cost and Summer Performance Characteristics

<table>
<thead>
<tr>
<th></th>
<th>Simple Cycle</th>
<th>Combined Cycle</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Plant Configuration</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Turbine Configuration</td>
<td>GE 7HA.02</td>
<td>GE 7HA.02</td>
</tr>
<tr>
<td></td>
<td>1 x 0</td>
<td>2 x 1</td>
</tr>
<tr>
<td><strong>Heat Rate (HHV)</strong></td>
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<td></td>
</tr>
<tr>
<td>Base Load (Btu/kWh)</td>
<td>9,274</td>
<td>6,312</td>
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<tr>
<td>Max Load w/ Duct Firing</td>
<td>n/a</td>
<td>6,553</td>
</tr>
<tr>
<td><strong>Installed Capacity</strong></td>
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<td></td>
</tr>
<tr>
<td>Base Load (MW)</td>
<td>352</td>
<td>1,023</td>
</tr>
<tr>
<td>Max Load (MW)</td>
<td>n/a</td>
<td>1,152</td>
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<tr>
<td><strong>Gross CONE</strong></td>
<td>($/kW-yr)</td>
<td>($/kW-yr)</td>
</tr>
<tr>
<td></td>
<td>$89</td>
<td>$95</td>
</tr>
</tbody>
</table>

Source: 2018 Report, Table 2
CONE Sensitivity Results

MERM Sensitivity to Cost of New Entry

Marginal Unit Net Energy Revenue

Market Equilibrium Reserve Margin

$/kW-yr

6% 8% 10% 12% 14% 16%

Reserve Margin (% ICAP)

Source: 2018 Report, Figure 14
Dr. Newell is the co-leader of the firm’s electricity practice, with 20 years of experience in electricity wholesale markets, the transmission system, and RTO/ISO rules. He supports clients throughout North America in matters involving wholesale market design, generation asset valuation, transmission development, integrated resource planning, and demand response programs.

Rebecca Carroll has nearly ten years of experience in energy economics and electricity market modeling. She has supported a broad range of clients on system planning, market rules development, retail gas and electric choice, power plant and transmission line valuations, regulatory hearings, and arbitration proceedings.

Mr. Carden has over 18 years of experience in production cost simulations for risk analysis and reliability planning for power supply options, coupled with diverse utility management experience. Under Kevin’s leadership, Astrapé Consulting has provided consulting services to utilities nationwide.
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