Load Forecasting Review

Calvin Opheim
Manager, Forecasting & Analysis
Electric Reliability Council of Texas
Outline of Today’s Presentation

• Defining the Problem
• National and Regional Trends
  – GDP versus energy and demand
  – Energy per customer
• ERCOT Trends
  – Non-farm employment historical data
  – Non-farm employment forecasts
• New Load Forecast Methodology
  – Approach
  – Weather normalization changes
• Review of Error Statistics
Defining the Problem—Load Forecast Accuracy

With normal weather, will ERCOT’s 2014 peak be 69,807 MW?

2011 forecast based on Moody’s base scenario (2012-2021)
2012 forecast based on Moody’s low scenario (2013-2022)
Defining the Problem—Load Forecast Accuracy

Will Peak Demand grow nearly twice as fast over the next 10 years compared to the previous 10 years?

2011 forecast based on Moody’s base scenario (2012-2021)
2012 forecast based on Moody’s low scenario (2013-2022)
National Trends

**GDP VS. ELECTRIC RELATIONSHIP**

**Index Comparison**
GDP vs Electric Consumption

- Slow breakdown of GDP/Electric relationship
- Divergent since 2010

Source: Energy Trends Benchmarking Survey 2013, Mark Quan, November 2013
National Trends

Average use is declining

- Downward trend in average use for the residential and commercial sectors
- Energy efficiency is making an impact

Source: Energy Trends Benchmarking Survey 2013, Mark Quan, November, 2013
Consumers Actively Reducing Energy Consumption

- Lighting accounts for approximately 20% of annual residential electric use and almost 30% of commercial consumption

<table>
<thead>
<tr>
<th></th>
<th>LED</th>
<th>CFL</th>
<th>Incandescent</th>
</tr>
</thead>
<tbody>
<tr>
<td>Watts Per Bulb</td>
<td>10</td>
<td>14</td>
<td>60</td>
</tr>
<tr>
<td>Annual kWh</td>
<td>11</td>
<td>15</td>
<td>65</td>
</tr>
</tbody>
</table>

*Source: Customer Value and Utility Mindset, Martin Day, November, 2013*
## National and Regional Trends

### Sales Growth Forecast – Next Ten Years

#### 2013 Survey Result

<table>
<thead>
<tr>
<th>Region</th>
<th>Residential</th>
<th>Commercial</th>
<th>Industrial</th>
<th>System</th>
<th>Peak</th>
</tr>
</thead>
<tbody>
<tr>
<td>Canada</td>
<td>0.80</td>
<td>1.04</td>
<td>1.04</td>
<td>0.83</td>
<td>0.70</td>
</tr>
<tr>
<td>Midwest</td>
<td>0.44</td>
<td>0.48</td>
<td>0.99</td>
<td>0.64</td>
<td>0.70</td>
</tr>
<tr>
<td>Northeast</td>
<td>0.38</td>
<td>0.54</td>
<td>(1.64)</td>
<td>0.41</td>
<td>0.66</td>
</tr>
<tr>
<td>South</td>
<td>1.11</td>
<td>1.34</td>
<td>0.97</td>
<td>1.06</td>
<td>0.81</td>
</tr>
<tr>
<td>West</td>
<td>0.96</td>
<td>0.87</td>
<td>1.17</td>
<td>1.12</td>
<td>1.14</td>
</tr>
<tr>
<td><strong>Total</strong></td>
<td><strong>0.78</strong></td>
<td><strong>0.93</strong></td>
<td><strong>0.91</strong></td>
<td><strong>0.85</strong></td>
<td><strong>0.77</strong></td>
</tr>
</tbody>
</table>

Consistent 1% growth range

#### 2012 Survey Result

<table>
<thead>
<tr>
<th>Region</th>
<th>Residential</th>
<th>Commercial</th>
<th>Industrial</th>
<th>System</th>
<th>Peak</th>
</tr>
</thead>
<tbody>
<tr>
<td>Canada</td>
<td>0.70</td>
<td>1.85</td>
<td>1.54</td>
<td>NA</td>
<td>0.60</td>
</tr>
<tr>
<td>Midwest</td>
<td>0.37</td>
<td>0.71</td>
<td>0.93</td>
<td>NA</td>
<td>0.69</td>
</tr>
<tr>
<td>Northeast</td>
<td>2.70</td>
<td>1.17</td>
<td>1.53</td>
<td>NA</td>
<td>4.89</td>
</tr>
<tr>
<td>South</td>
<td>1.03</td>
<td>1.21</td>
<td>0.52</td>
<td>NA</td>
<td>0.88</td>
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<tr>
<td>West</td>
<td>1.37</td>
<td>1.47</td>
<td>0.57</td>
<td>NA</td>
<td>1.18</td>
</tr>
<tr>
<td><strong>Total</strong></td>
<td><strong>0.95</strong></td>
<td><strong>1.20</strong></td>
<td><strong>0.84</strong></td>
<td>NA</td>
<td><strong>0.99</strong></td>
</tr>
</tbody>
</table>

Source: Energy Trends Benchmarking Survey 2013, Mark Quan, November, 2013
Summary of National Trends

- Changing the Relationship Between GDP and Energy Use
  - Declining energy use per customer due to:
    - Active energy efficiency
    - Passive energy efficiency
    - Change in behavior
    - Distributed generation

- Results in Lower Long-Term Forecasts
Annual Energy & Peak Demand (2003-2013)

Total Growth for Period: Demand 12%, Energy 16%
Comparison of Historical Peak Demand Forecasts

Actual and forecast peak demand

Year

2011 forecast based on Moody’s base scenario (2012-2021)
2012 forecast based on Moody’s low scenario (2013-2022)

Oil and Gas Boom begins 2010
15% increase over the previous ten years
10-Year Average Annual Growth Rate – Peak Demand

15% increase over the previous ten years

2011 forecast based on Moody’s base scenario (2012 – 2021)
2012 forecast based on Moody’s low scenario (2013 – 2022)
Comparison of Historical Peak Demand Forecasts

2011 forecast based on Moody's base scenario (2012-2021)
2012 forecast based on Moody's low scenario (2013-2022)
Comparison of Historical Energy Forecasts

Actual and forecast annual energy

- 2011 forecast based on Moody’s base scenario (2012-2021)
- 2012 forecast based on Moody’s low scenario (2013-2022)

Oil and Gas Boom begins 2010
18% increase over the previous ten years

2011 forecast based on Moody’s base scenario (2012-2021)
2012 forecast based on Moody’s low scenario (2013-2022)
10-Year Average Annual Growth Rate – Energy

- Year Average Annual Growth Rate
- 2011 forecast based on Moody’s base scenario (2012 – 2021)
- 2012 forecast based on Moody’s low scenario (2013 – 2022)

18% increase over the previous ten years
Changing Relation Between Load and Non-Farm Employment

• **Price Responsive Load**
  - Combination of 2011 scarcity pricing and PUC’s decision to increase System-Wide Offer Caps is changing behavior
    - Commercial & industrial loads with prices indexed to the ERCOT wholesale market are increasing their price response flexibility
    - Load-serving entities (LSE) are investing in demand response as insurance against wholesale market exposure
  - ERCOT Staff, working with LSEs, are attempting to quantify this behavior; starting with summer 2013 data
  - 4 CP impact

• **Energy Efficiency Upgrades**
  - Energy Star appliances
  - Conversions to CFL and LED lighting
2012 Summer Peak
4 CP & Price Response Impacts (June 26)

- Impacts shown are based on aggregated transmission load values for ~430 premises.
- Not estimated based on an analysis of individual premises.

- Difference represents the 4 CP & Price Response impacts of ~900 MW on an aggregated basis.
- Transmission charges based on 4 CP usage apply to Munis, Co-ops, and Loads with >700 kW of peak demand in retail choice areas.
- This data is an example of observed 4 CP and price response impacts.
Previous Model – What We’ve Learned

• Historical Revisions Impact Forecast Years
  – Moody’s forecast for Calendar Year (CY) 2013 was increased by 2% in order to align with the revised historical values for CY 2012

• Economic forecasts tend to be too optimistic, resulting, in a tendency for models to over-forecast.

• The relationship between energy usage and non-farm employment is changing.
  – Some refer to this as the “jobless economic recovery”
Previous Model – What We’ve Learned

<table>
<thead>
<tr>
<th>Year</th>
<th>Non-Farm Employment (000s)</th>
<th>Annual Growth Rate</th>
</tr>
</thead>
<tbody>
<tr>
<td>2012</td>
<td>9,728</td>
<td>1.8%</td>
</tr>
<tr>
<td>2013</td>
<td>9,932</td>
<td>2.1%</td>
</tr>
<tr>
<td>2014</td>
<td>10,219</td>
<td>2.9%</td>
</tr>
<tr>
<td>2015</td>
<td>10,545</td>
<td>3.2%</td>
</tr>
<tr>
<td>2016</td>
<td>10,805</td>
<td>2.5%</td>
</tr>
<tr>
<td>2017</td>
<td>10,961</td>
<td>1.4%</td>
</tr>
<tr>
<td>2018</td>
<td>11,072</td>
<td>1.0%</td>
</tr>
</tbody>
</table>
Economist View / Dilemma

Source: Energy Trends Benchmarking Survey 2013, Mark Quan, November, 2013
New Load Forecast Methodology
Based on Premise Level Forecasts

- Energy relationships will now be based on premise counts by customer class (residential, commercial, and industrial)
  - Historical energy relationships will no longer be based on non-farm employment values
  - Growth rate of premises is smoother than Moody’s non-farm employment forecasts
  - Premise forecasts based on data from 2009 - 2013
Based on Premise Level Forecasts

• **Benefits**
  – Historical premise accounts will be very stable and not subject to significant changes as were exhibited by non-farm employment revisions

• **Challenges**
  – Model uses the historical relationship of premises in competitive area to total load in a weather zone (which includes competitive and NOIE load)
Premise Historical Growth Rates by Weather Zone

Annual Average Compound Growth Rate 2009 - 2013

- COAST
- NCENT
- SCENT
- SOUTH
- NORTH
- EAST
- FWEST
- WEST

Industrial
Business
Residential
Based on Neural Networks

• Daily energy forecasted using Neural Network Models

• Benefits
  – Able to determine/account for variable interactions more robustly when compared to linear regression models
  – All predictor variables are used as inputs in each network node
  – More detailed/precise model formulation
Neural Network Model Diagram
Based on Neural Networks

• **Forecasts based on multiple model simulations instead of a single model**
  – Neural Network models were developed with 20% of the historical data being withheld from model development
  – The data being withheld was determined randomly
  – Randomly withholding data mitigates over-fitting of the data
  – The model’s accuracy was determined based on how well it predicted the sample holdout data
  – Process was repeated thirty times (model convergence)

• **Benefits**
  – In statistics, repeated sampling gives a more accurate estimate than a single sample
  – Improves the robustness of the forecast
Model Building Process

• Historical data was divided into three sets
  – Model building (60%)
  – Model validation (20%)
  – Model testing (20%)

• This process is a best practice in using neural networks
Test Data Set

• The creation of the load forecast began by first randomly assigning 20% of the historical data to the test data set.

• The test data was not included in model building or model validation.

• After model building is complete, the test data set is used to determine the accuracy of the model.
Validation Data Set

• The next step is randomly assigning 20% of the historical data to the validation data set
  – A validation set is determined for each of the 30 models that were created for each weather zone
  – Each validation set is different
  – This approach ensures a robust validation of the models that are being evaluated
Validation Data Set

• The validation data was not included in model building

• After model building is complete, the validation data set is used to determine the accuracy of the forecast model
  – Model performance is quantified for the validation data set
  – The model may be updated based on results from the validation evaluation
Model Building Data Set

• All historical data that was not assigned to the validation data set or the test data set is used to create various forecast models.

• Iterative process – this process is conducted multiple times during the creating of models.
Normal Weather Determination

- The determination of normal weather forecast will now be based on model output using actual load and actual weather data
  - Data was used from 2002–2013 (12 years of historical data)
  - Seeing that 2002 is the oldest historical calendar year for ERCOT’s load data, the weather normalization process is based on 12 years of data
  - Forecasts were created by using each historical weather year in the model
    - Results were ordered and then averaged (Rank and Average methodology)

- Benefits
  - More accurately reflects historical weather patterns
  - More accurately reflects load diversity at time of peak (results in a somewhat lower peak forecast than the previous approach)
Benefits of New Forecasting Methodology

• The neural network model decouples the growth in demand and energy.

• Multiple neural network models allow the calculation of forecast sensitivities.

• Historical premise counts are not subject to revision as exhibited by non-farm employment.

• Able to determine/account for variable interactions more robustly when compared to linear regression models.

• More detailed/precise model formulation.

• Improvements in weather normalization to better reflect geographical weather diversity.
Review of Load Forecast Error Statistics
Mean Absolute Percentage Error (MAPE)

\[ \text{MAPE} = \left| \frac{(\text{actual} - \text{predicted})}{\text{actual}} \right| \times 100 \]
Regional Forecast Comparisons

- Coast
- North Central
- South Central
- South
Coast Forecast Comparison: 7 Highest Peak Days

MW


Actual 1-node 5-nodes
Coast Forecast Comparison: 7 Highest Peak Days

<table>
<thead>
<tr>
<th>Date</th>
<th>MAPE 1-node</th>
<th>MAPE 5-nodes</th>
</tr>
</thead>
<tbody>
<tr>
<td>8/7/2013</td>
<td>1.00</td>
<td>0.50</td>
</tr>
<tr>
<td>8/23/2011</td>
<td>1.20</td>
<td>0.60</td>
</tr>
<tr>
<td>8/16/2011</td>
<td>0.80</td>
<td>0.40</td>
</tr>
<tr>
<td>8/2/2011</td>
<td>0.60</td>
<td>0.30</td>
</tr>
<tr>
<td>8/1/2013</td>
<td>1.90</td>
<td>0.60</td>
</tr>
<tr>
<td>8/5/2011</td>
<td>0.50</td>
<td>0.40</td>
</tr>
<tr>
<td>8/27/2011</td>
<td>1.50</td>
<td>0.50</td>
</tr>
</tbody>
</table>
North Central Forecast Comparison: 7 Highest Peak Days

<table>
<thead>
<tr>
<th>Date</th>
<th>Actual</th>
<th>1-node</th>
<th>5-nodes</th>
</tr>
</thead>
<tbody>
<tr>
<td>8/3/2011</td>
<td>27,000</td>
<td>26,000</td>
<td>25,000</td>
</tr>
<tr>
<td>2/3/2011</td>
<td>22,000</td>
<td>21,000</td>
<td>20,000</td>
</tr>
<tr>
<td>8/7/2013</td>
<td>24,000</td>
<td>23,000</td>
<td>22,000</td>
</tr>
<tr>
<td>8/6/2012</td>
<td>26,000</td>
<td>25,000</td>
<td>24,000</td>
</tr>
<tr>
<td>7/26/2011</td>
<td>23,000</td>
<td>22,000</td>
<td>21,000</td>
</tr>
<tr>
<td>8/31/2011</td>
<td>25,000</td>
<td>24,000</td>
<td>23,000</td>
</tr>
<tr>
<td>7/21/2011</td>
<td>24,000</td>
<td>23,000</td>
<td>22,000</td>
</tr>
</tbody>
</table>
North Central Forecast Comparison: 7 Highest Peak Days

MAPE


1-node 5-nodes
South Central Forecast Comparison: 7 Highest Peak Days

MW


Actual 1-node
South Central Forecast Comparison: 7 Highest Peak Days

The bar chart shows the Mean Absolute Percentage Error (MAPE) for each day from August 3, 2011, to August 20, 2011. The days with the highest MAPE are 7/27/2011 and 8/20/2011, indicating peak load days. The lowest MAPE was on 8/2/2011.
South Forecast Comparison: 7 Highest Peak Days

![Bar chart showing the comparison of actual and forecasted peak days between 2011 and 2013. The x-axis represents the dates, and the y-axis represents the peak days in MW. The bars are color-coded: blue for actual, red for 1-node, and green for 5-nodes. The dates shown are 2/3/2011, 8/30/2012, 8/10/2012, 6/27/2012, 8/6/2013, 9/4/2012, and 9/6/2012.]
South Forecast Comparison: 7 Highest Peak Days

MAPE


<table>
<thead>
<tr>
<th>Date</th>
<th>1-node</th>
<th>5-nodes</th>
</tr>
</thead>
<tbody>
<tr>
<td>2/3/2011</td>
<td></td>
<td></td>
</tr>
<tr>
<td>8/30/2012</td>
<td></td>
<td></td>
</tr>
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<td>8/10/2012</td>
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<td>6/27/2012</td>
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<td></td>
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<td>8/6/2013</td>
<td></td>
<td></td>
</tr>
<tr>
<td>9/4/2012</td>
<td></td>
<td></td>
</tr>
<tr>
<td>9/6/2012</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Legend: 1-node, 5-nodes
Forecast Comparison: All Test Data

MAPE

January  | February | March   | April   | May     | June    | July    | August  | September | October  | November | December | Total

1-node  | 5-nodes  | 1-node  | 5-nodes | 1-node  | 5-nodes | 1-node  | 5-nodes | 1-node   | 5-nodes | 1-node  | 5-nodes | 1-node  | 5-nodes

Legend:
- 1-node
- 5-nodes
Questions