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Review of ERCOT Premise Forecast

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ERCOT Premise Forecast Evaluation

In December 2013, ERCOT engaged Itron to evaluate a new long-term forecasting framework. The framework includes a neural network (NN) model for each ERCOT zone (Zone) estimated over multiple historic periods and forecasted with a range of historic weather patterns. Within the NN, the key growth driver is a single index created by weighting together three premise count forecasts.

Itron's evaluation addresses the following three issues.

1. **Premise Forecast.** Underlying ERCOT's Growth Index is a forecast of premise counts. Itron's evaluation examines potential economic drivers to forecast the premise counts relative to ERCOT's initial proposal of using a historic five year average growth rate.

2. **Growth Index.** The key growth driver in the NN model is a growth index created as a weighted average of ERCOT's residential, business, and industrial class premise forecast. Itron's evaluation examines the weighting scheme and identifies issues and potential improvements.

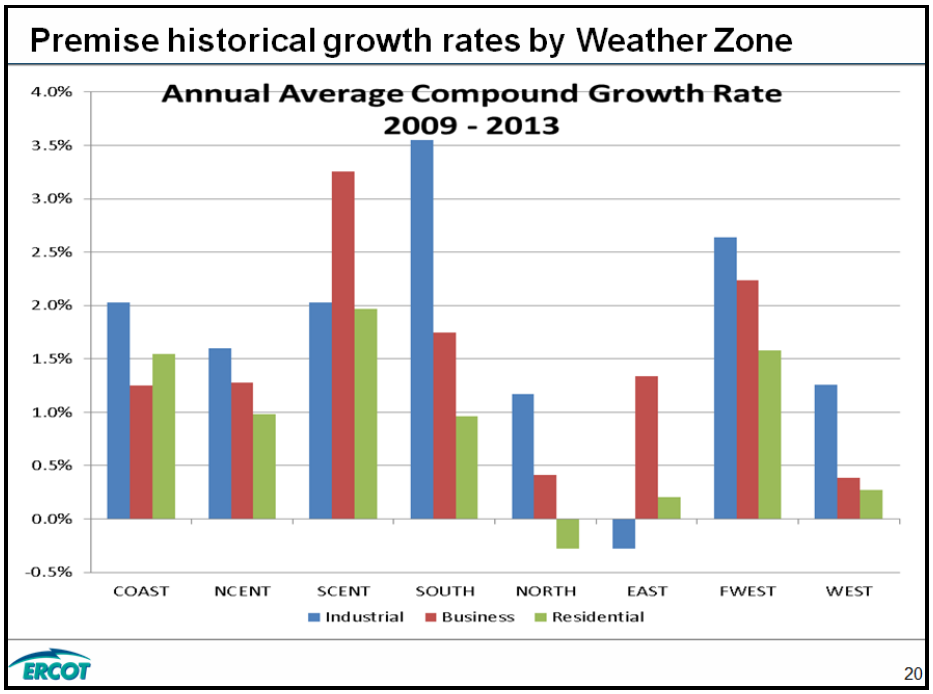
3. **Multiple NN Models.** ERCOT's framework uses a NN model which is used to obtain multiple sets of parameters based on different historical time periods. The estimated parameters are applied to multiple historic weather scenarios to create a distribution of forecast. Itron's evaluation discusses the NN model, multiple sets of parameters, and the historic scenarios.

In this Summary, Itron addresses the Premise Forecast and presents a preliminary discussion on the Multiple NN Models. The Growth Index issue will be addressed in a second, separate Summary document. Based on the evaluation of the Growth Index, the recommendations on the Multiple NN Model may be impacted.

1. Premise Forecast

The main growth driver in the ERCOT framework is a growth index developed from the residential, business, and industrial premise forecast. The premise forecast is created by calculating the historic five year annual average compound growth rate and applying the growth rate through the forecast horizon. These growth rates, shown in Figure 1, are based on ERCOT's December 10, 2013 presentation.

Figure 1: ERCOT Premise Growth Rates



Itron's evaluation of the premise forecast began by screening all available economic drivers provided by ERCOT to determine whether improvements can be made. Drivers were tested using a series of regression models estimated through different time horizons and evaluated based on relative accuracy and stability. The evaluation for each class is discussed below.

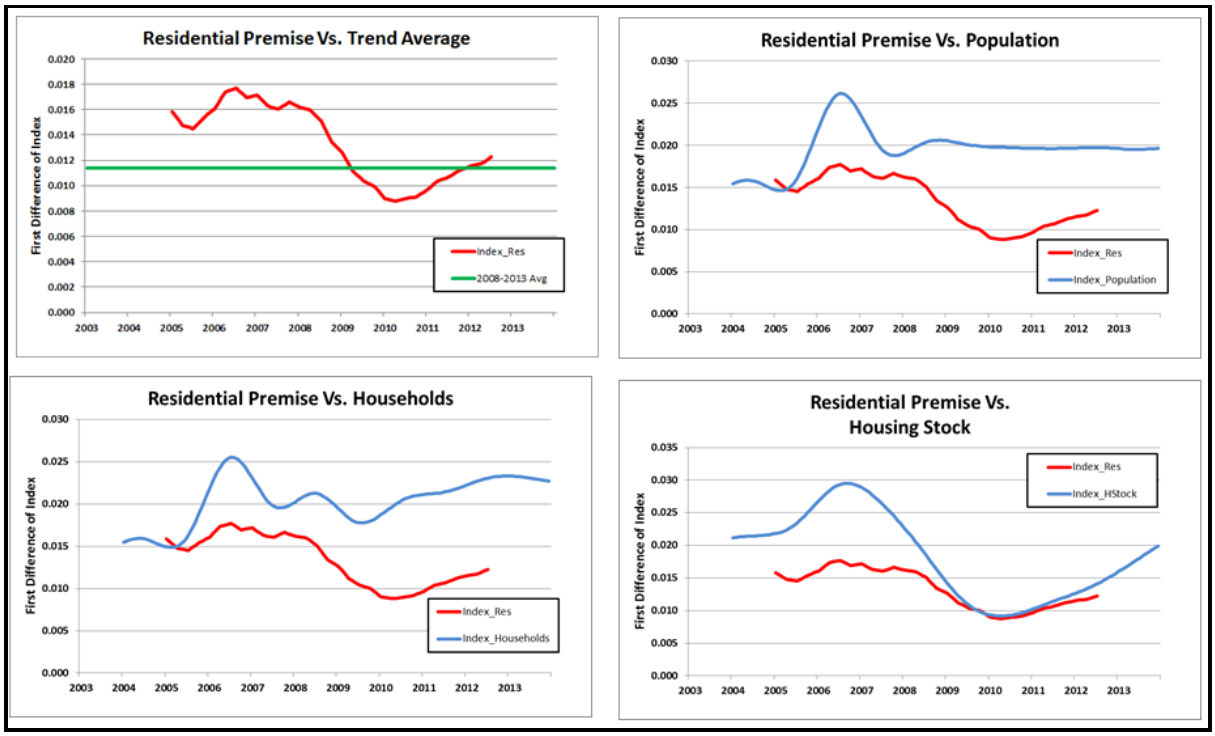
Residential Premise Forecast

Residential premises represent residential customers on the ERCOT system. Initially, Itron screened all drivers provided by ERCOT and reduced the evaluation to consider the following three economic drivers for the residential class:

- Households,
- Population, and
- Housing Stock.

Households and population are traditional drivers used by utilities to forecast residential customers. Housing Stock represents the number of physical homes regardless of whether the homes are occupied. Figure 2 displays the economic drivers on an annual difference basis. The red line shows the annual change in residential premises. The blue lines show the annual change in the economic drivers. The green line represents the five year average growth rate.

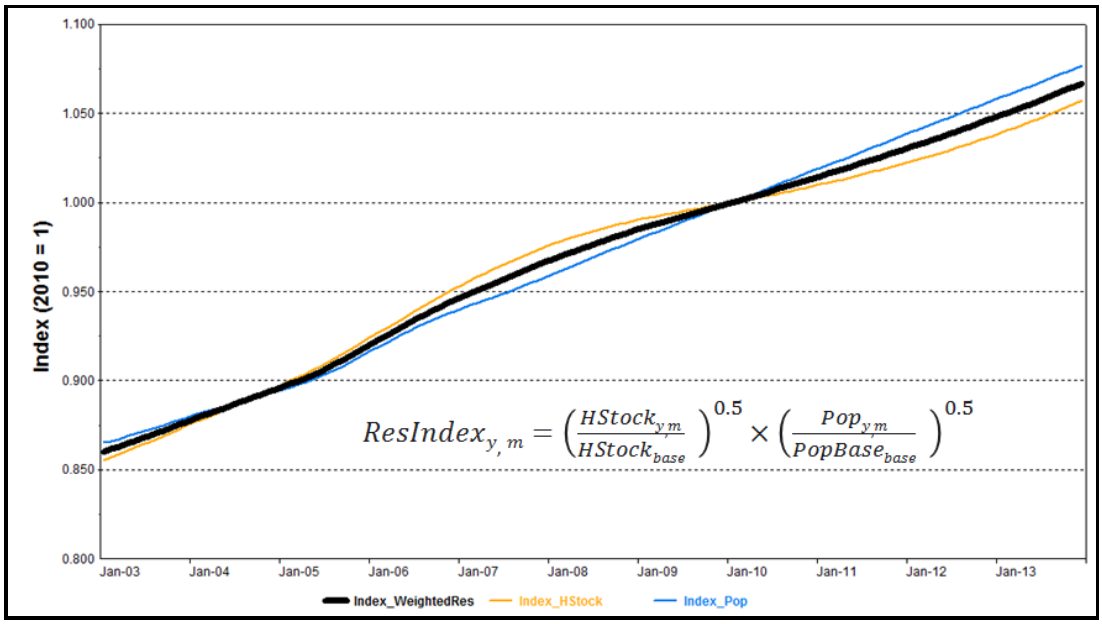
Figure 2: Residential Economic Drivers – Annual Growth



While each driver was tested individually, Itron developed a geometrically weighted average (Weighted Index) to test whether improvements could be made to a single driver approach. The weighted index method is used by PJM and other utilities to capture multiple economic effects without risking multicollinearity in the regression model.

Figure 3 displays the weighted index for the ERCOT system along with each of its contributing economic indices (population and housing stock). The weighted index is depicted by the thick black line and each contributing economic variable with a thin line. The construction of the index is shown within Figure 3.

Figure 3: Residential Premise Index



The test to determine whether any of the candidate drivers or weighted index improved the forecast over the five year average was conducted by examining accuracy and stability in three scenarios.

- **Scenario 1 (03-'13).** In this scenario, the regression model for each driver was developed for all available data from 2003 through 2013. Accuracy and stability values are reported using all data from 2003 through 2013.

- **Scenario 2 (09-'13).** This scenario captures the relationship of each driver post-recession. The models are estimated with data from 2009 through 2013 with accuracy and stability values calculated on data from 2009 through 2013.

- **Scenario 3 (F'09-'13).** This scenario is an out-of-sample test. Models are estimated with data from 2003 through 2008. Estimated parameters are applied to data from 2009 through 2013 to determine how well the driver forecasts across data not used in model estimation. Accuracy values are shown for the 2009 through 2013 time frame. Stability values are derived from the 2003 through 2008 estimation range.

Accuracy and stability are key considerations in selecting a forecast driver. Accuracy values measure how close the model predicts the actual values. In the scenarios, accuracy values are reported as Mean Absolute Percent Errors (MAPEs). Stability considers whether the driver preforms consistently over different ranges of time. In this analysis, the elasticity of the candidate drivers was reported over the different timespans. To the extent that the elasticity is stable, the summary Coefficient of Variation (CV) value will show a low number.

The results of the scenarios are shown in Figure 4 with the scenarios listed across the top and the models listed on the left axis. The strongest model is the weighted index (Res_Wgt) as indicated by the lowest MAPE and CV values. This model is an improvement over the five year average (Res_Trend model).

Figure 4: Residential Scenario Results

Accuracy

ERCOT Residential MAPE Comparison

Model		03-'13	09-'13	F '09-'13	Avg
Res_Pop		0.29%	0.06%	1.16%	0.50%
Res_HH		0.32%	0.03%	1.15%	0.50%
Res_Hstock		0.29%	0.02%	0.88%	0.40%
Res_Trend		0.35%	0.06%	1.36%	0.59%
Res_Wgt		0.07%	0.03%	0.08%	0.06%

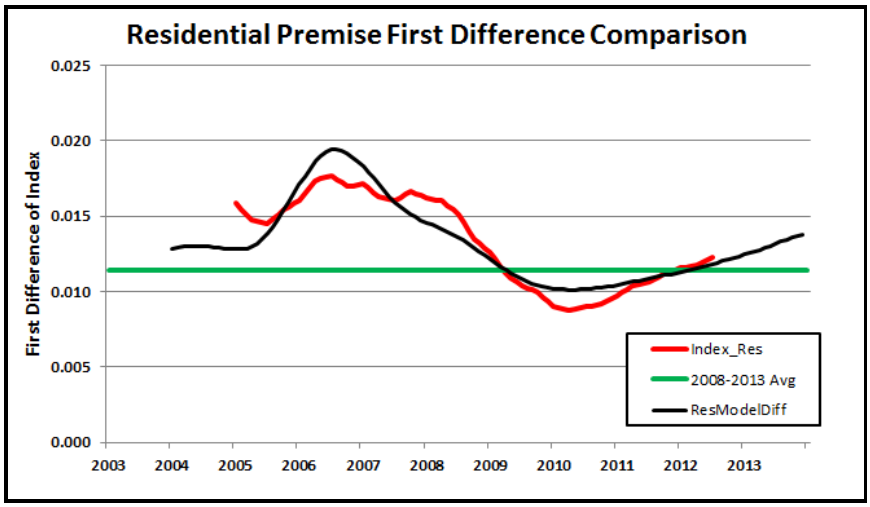
Stability

Elasticity

Model		03-'13	03-'08	09-'13	CV
Res_Pop		0.647	0.749	0.520	0.18
Res_HH		0.641	0.746	0.449	0.25
Res_Hstock		0.718	0.631	0.930	0.20
Res_Trend		0.073	0.060	0.080	0.14
Res_Wgt		0.687	0.686	0.674	0.01

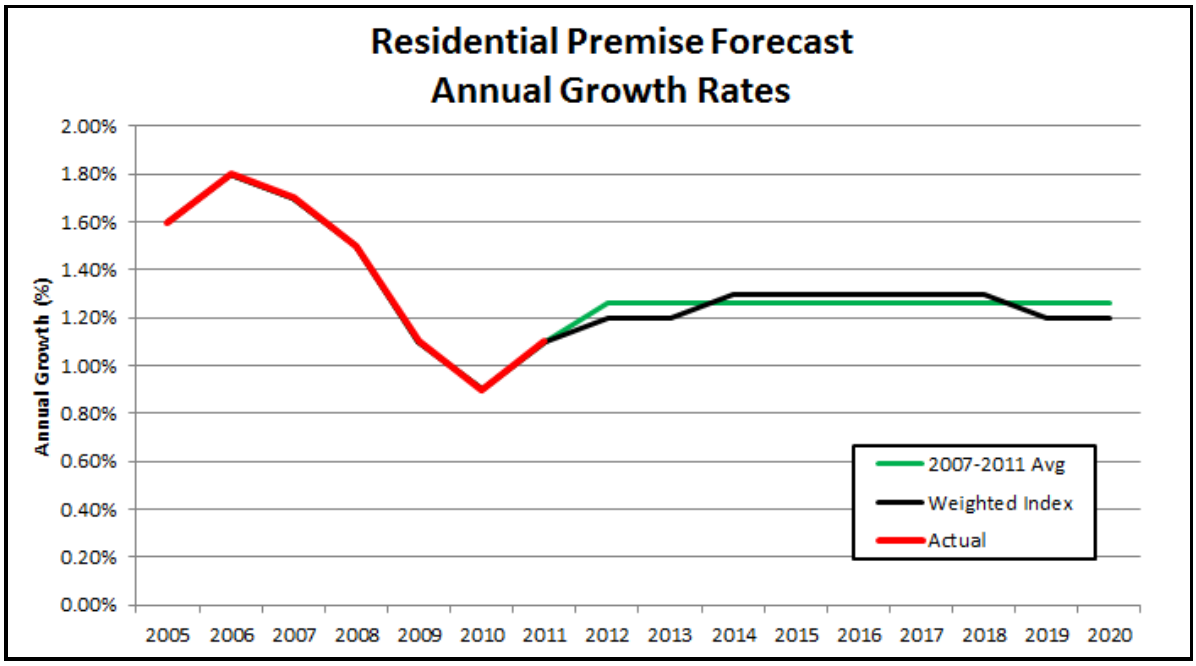
The overall model fit is best seen in Figure 5. This figure shows the weighted index model (Index_Res) and the five year average against the historical premise counts as annual differences.

Figure 5: Residential Premise Index Model Fit



The forecasted growth rate of the weighted index model compared to the five year average is shown in Figure 6. While the results are similar, the weighted index model shows slight variations in the forecast due to the changes in the population and housing stock forecasts.

Figure 6: Residential Premise Index Forecast Results



Recommendation. While the analysis and discussion presented in this section are at the ERCOT system level, Itron conducted the test for each ERCOT zone. In six of the eight zones, the weighted index outperforms the five year average method in accuracy and stability. In the two remaining zones, the results were similar due to extremely low historic growth. Based on these tests and analysis, Itron makes the following recommendations.

1. **Residential Economic Index.** The weighted index models demonstrate a strong improvement over the Time Trend (five year average) in model accuracy and stability at both the ERCOT-level and Regional Level. Itron recommends that ERCOT implement a weighted index approach as the base approach to Residential Premise forecast. The index should be comprised of Housing Stock and Population and use equal weights.

2. **Low Growth Zones.** Forecasting premises with low growth using a statistical model presents difficulties in obtaining significance. For Zones with 2004-2012 Compound Annual Growth rate less than 1.0% (West and North), Itron recommends that ERCOT continue to use the five year growth rate method.

Business Premise Forecast

Like residential premises, business premises represent commercial customers (non-industrial and non-residential) on the ERCOT system. For this class, Itron screened all drivers provided by ERCOT and reduced the evaluation to consider the following five economic drivers for the business class:

- Employment (Non-Farm),
- GDP,
- Labor Force,
- Population, and
- Housing Stock.

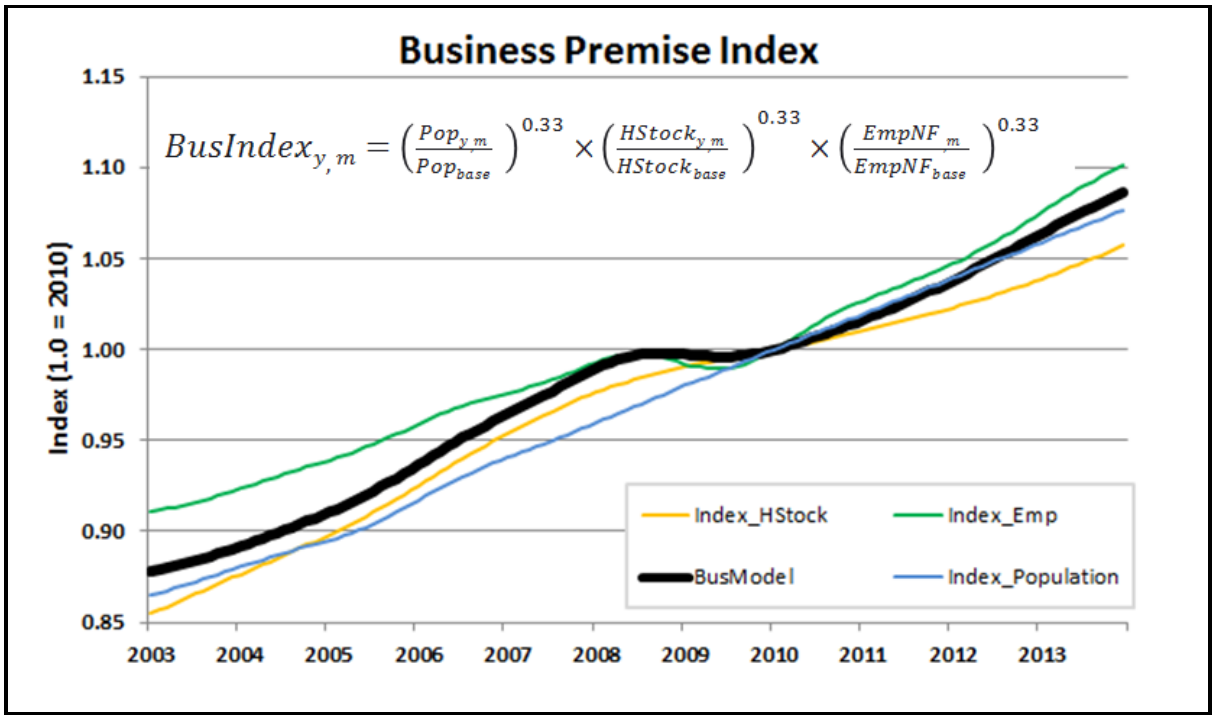
Employment and GDP are traditional drivers used by utilities to forecast business customers. Labor Force includes employed and unemployed in a region and is less volatile to changes in the economy. While housing stock and population are used in the residential premise model, these drivers are also examined due to the historic relationship between commercial and residential customers. Figure 7 displays the economic drivers on an annual difference basis. The red line shows the annual change in business premises. The blue lines show the annual change in the economic drivers. The green line represents the five year average growth rate.

Figure 7: Business Economic Drivers – Annual Growth

While each driver was tested individually, Itron developed a geometrically weighted average (Weighted Index) to test whether improvements could be made to a single driver approach. The weighted index method is used by PJM and other utilities to capture multiple economic effects without risking multicollinearity in the regression model.

Figure 8 displays the weighted index for the ERCOT system along with each of its contributing economic indices (population, housing stock, and non-farm employment). The weighted index is depicted by the thick black line and each contributing economic variable with a thin line. The construction of the index is shown within Figure 8.

Figure 8: Business Premise Index



The test to determine whether any of the candidate drivers or weighted index improves the forecast over the five year average was conducted by examining accuracy and stability using the same three scenarios and criteria defined in the residential premise evaluation.

The results of the scenarios are shown in Figure 9 with the scenarios listed across the top and the models listed on the left axis. The strongest model is the weighted index (Bus_Wgt) as indicated by the lowest MAPE and CV values. This model is an improvement over the five year average (Bus_Trend model).

Figure 9: Business Scenario Results

Accuracy

ERCOT Business MAPE Comparison

Model	03-'13	09-'13	F '09-'13	Avg
Bus_Pop	0.41%	0.26%	1.68%	0.78%
Bus_GDP	0.47%	0.21%	1.13%	0.60%
Bus_Emp	0.41%	0.26%	0.98%	0.55%
Bus_Labor	0.73%	0.40%	4.19%	1.77%
Bus_Hstock	0.21%	0.18%	0.37%	0.25%
Bus_Trend	0.45%	0.26%	1.82%	0.84%
Bus_Wgt	0.12%	0.12%	0.20%	0.15%

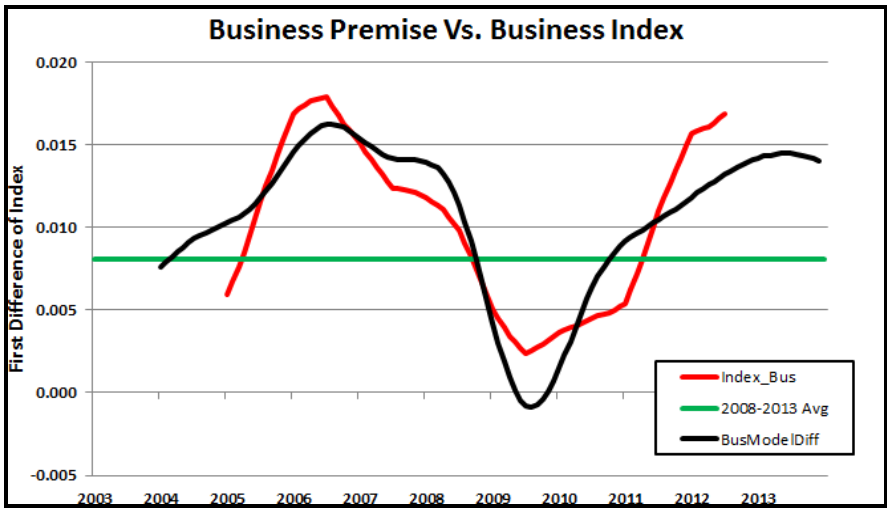
Stability

Elasticity

Model	03-'13	03-'08	09-'13	CV
Bus_Pop	0.47	0.60	0.48	0.15
Bus_GDP	0.30	0.35	0.18	0.32
Bus_Emp	0.67	0.79	0.43	0.29
Bus_Labor	0.51	0.95	0.43	0.45
Bus_Hstock	0.52	0.51	0.86	0.32
Bus_Trend	0.05	0.05	0.07	0.22
Bus_Wgt	0.55	0.52	0.58	0.05

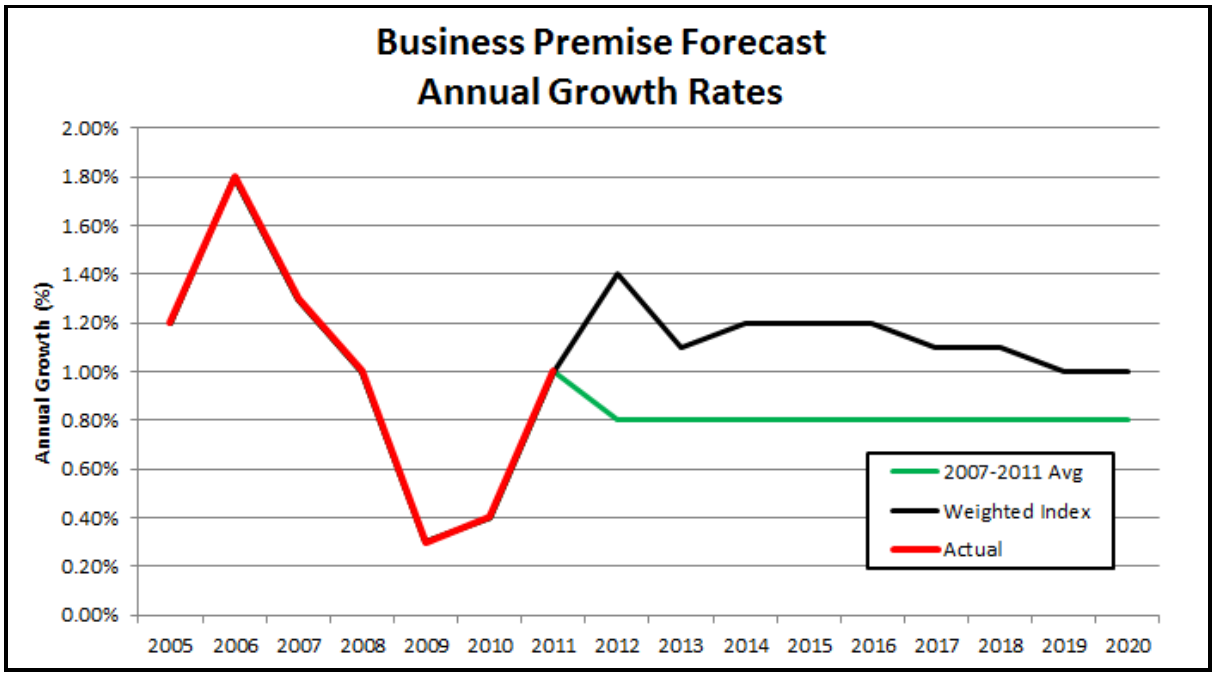
The overall model fit is seen in Figure 10. This figure shows the weighted index model (Index_Bus) and the five year average against the historical premise counts as annual differences.

Figure 10: Business Premise Index Model Fit



The forecasted growth rate of the weighted index model compared to the five year average is shown in Figure 11. While the results are similar, the weighted index model shows higher forecast due to the anticipated growth in non-farm employment, population and housing stock.

Figure 11: Business Premise Index Forecast Results



Recommendation. While the analysis and discussion presented in this section are at the ERCOT system level, Itron conducted the test for each ERCOT zone. In all but one of the zones, the weighted index outperforms or is comparable to the five year average method. Based on these tests and analysis, Itron makes the following recommendations.

1. **Business Economic Index.** The weighted index models demonstrate a strong improvement over the Time Trend (five year average) in terms of both model accuracy and stability at both the ERCOT-level and Regional Level. Itron recommends that ERCOT implement a weighted index approach as the base approach to Business Premise forecast. The index should be comprised of Non-Farm Employment, Housing Stock and Population and use equal weights.

2. **Far West Zone.** Unlike the other zones, the Far West zone does not show forecast improvement when using the weighted index compared to the five year average method. This result implies that the Far West Zone has been growing linearly and is not as subject to economic variations as the other zones. Itron recommends that ERCOT continue to use the five year average for this zone.

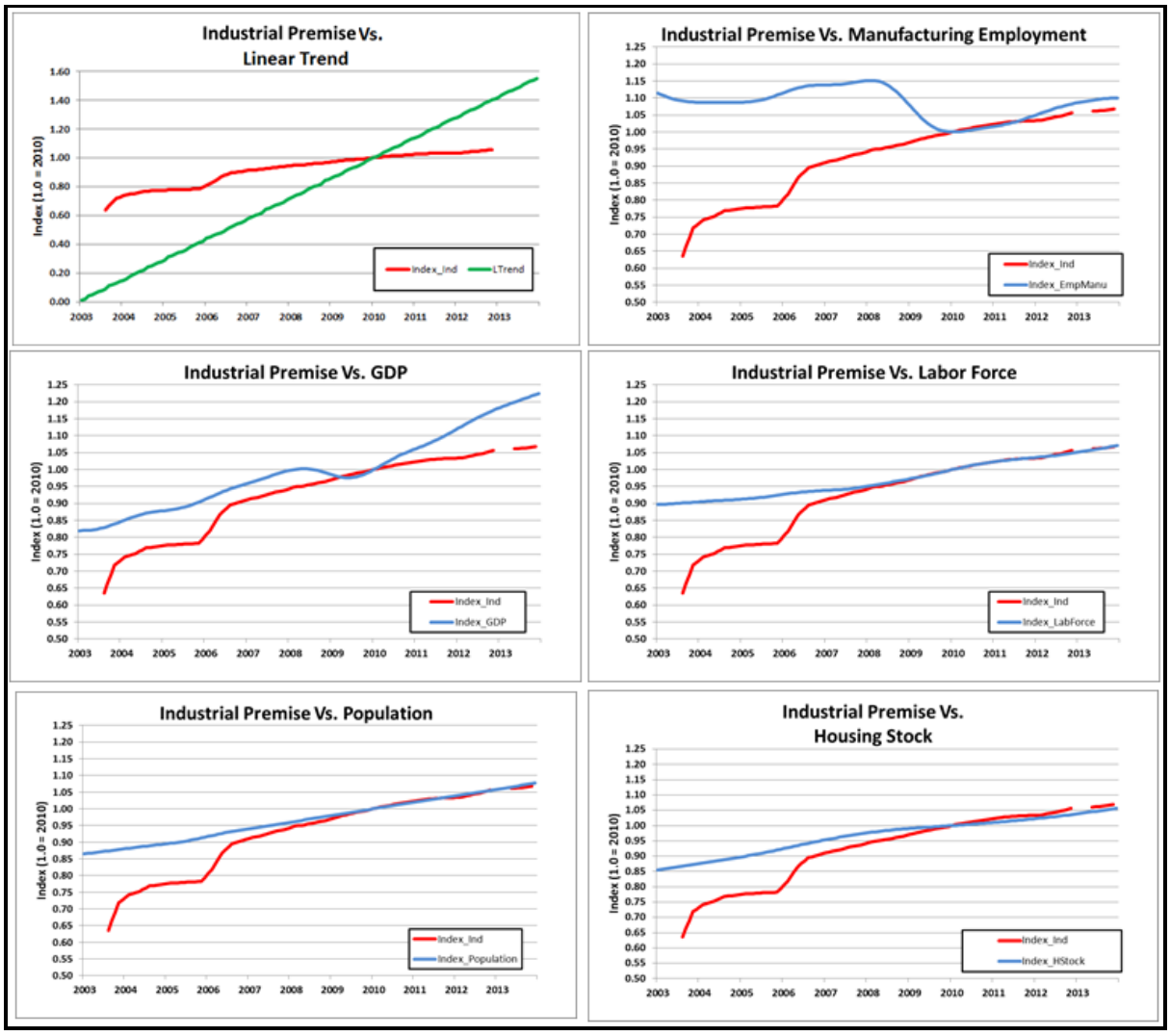
Industrial Premise Forecast

For the Industrial class, Itron screened all drivers provided by ERCOT and reduced the evaluation to consider the following five economic drivers for the business class:

- Manufacturing Employment,
- GDP,
- Labor Force,
- Population, and
- Housing Stock.

Manufacturing employment and GDP are traditional drivers used by utilities to forecast industrial customers. Labor Force includes both employed and unemployed in a region and is less volatile to changes in the economy. While housing stock and population are used in the residential model, these drivers are also examined due to their stability and approximation of building growth. Figure 12 displays the economic drivers indexed to 2010 values. The red line shows the industrial premises. The blue lines show economic drivers. The green line represents a linear trend used to approximate a five year average growth rate model.

Figure 12: Industrial Economic Drivers



The primary issue in the historic industrial premise counts shown in Figure 12 is the dramatic premise increase in 2006. ERCOT explained the increase as a result of class definitional changes.

To resolve the 2006 data issue, the test scenarios were modified around the data shift. The scenarios are defined below.

- **Scenario 1 (04-'12).** In this scenario, the regression model for each driver is developed for all available data from 2004 through 2012. While accuracy values are reported using all data from 2004 through 2012, high MAPE values are expected due to the data shift in 2006.

- **Scenario 2 (07-'12).** This scenario captures the relationship of each driver after the 2006 data shift. The models are estimated with data from 2007 through 2012 with accuracy values calculated on data from 2007 through 2012.

- **Scenario 3 (F'11-'12).** This scenario is an out-of-sample test. Models are estimated with data from 2007 through 2010. Estimated parameters are applied to data from 2011 through 2012 to determine how well the driver forecasts across data not used in model estimation. Accuracy values are shown for the 2011 through 2012 time frame.

For this class, only accuracy results are reported in Figure 13. At best, population and housing stock show potential as forecast drivers, however unrealistic elasticities due to the data shift in 2006 and near linear growth after 2006 render the models unviable. An examination of all models show similar results.

Figure 13: Industrial Scenario Accuracy Results

ERCOT Industrial MAPE Comparison					
Model		04-'12	07-'12	F '11-'12	Avg
Ind_Pop		2.23%	0.43%	1.45%	1.37%
Ind_GDP		3.15%	2.04%	4.17%	3.12%
Ind_ManEmp		8.30%	2.02%	4.57%	4.96%
Ind_Labor		3.69%	0.36%	0.68%	1.58%
Ind_Hstock		0.86%	0.52%	0.69%	0.69%
Ind_Trend		2.45%	0.45%	1.53%	1.48%

Recommendation. While the analysis and discussion presented in this section are at the ERCOT system level, Itron conducted the test for each ERCOT zone using housing stock as the driver variable. Results at the zone level are consistent with the results at the system level. Based on these results, Itron makes the following recommendations.

1. **Five Year Average.** Itron recommends that ERCOT continue to use the five year average method to forecast industrial premises. While housing stock contains potential as a driver variable unrealistic model results confirm that no change to the ERCOT method is warranted at this time.

2. **Future Consideration.** The primary issue in the industrial premise forecast is the 2006 data issue. By removing data prior to 2006, the historical series is significantly shortened resulting in difficulty fitting a statistical model. Itron recommends that ERCOT revisit the industrial class and consider the weighted index method in two or three years when more data are available.

2. Neural Network (NN) Models

ERCOT's forecasting framework uses a NN model for each load zone. The NN model includes weather, seasonal, day-type, and growth variables. The model is estimated iteratively over alternative historic periods which are created by removing random sets of the historical data. This process creates a distribution of parameters for each variable. The weather variable parameter distribution is applied to a range of historic weather years to create multiple of forecasts. Assuming that 30 sets of parameters are created and 10 historic years of weather are applied to the parameters, 300 forecasts would be created. The multiple forecasts represent a distribution of possible futures.

Model Specification

The primary challenge of applying a NN model to a long-term forecast is creating a stable explanatory model. NN models, by nature, are difficult to explain due to the multiple interactions among variables. Stability issues arise when interactions between variables are not intuitive.

In Itron's initial discussions with ERCOT, the range of forecasts presented implied instability. While Itron did not attempt to evaluate the NN model specification, the instability appeared to result from the interaction of the growth variable with other variables in the nonlinear nodes.

Itron recommends that ERCOT reexamine the NN model specification and isolate the growth variable to obtain a more stable forecast. By isolating the growth variable, ERCOT will also improve the explanatory nature of the model highlighting the primary growth driver.

Multiple Models

Assuming that the model specification is stable and the growth variable is isolated, the use of multiple sets of parameters based on subsets of historical data rather than a single set of parameters based on all historic data is not significant. Technically, variation in the parameters reveals uncertainty in the parameter values. A well specified, stable model should result in similar parameters regardless of the estimation period reducing parameter uncertainty. When using multiple sets of parameters, a wide range of parameter values suggests instability and invites questions concerning the model specification.

The traditional utility approach to long-term forecasting of electricity is to develop a regression model that relates energy use by customer type to weather and economic conditions. The forecast is developed in two parts. First, customer counts are forecasted using an econometric model designed to capture how the number of customers change with respect to key economic conditions. Second, average use is forecasted using an econometric model capturing key drivers of how customers use electricity. In places were customer counts are not available, a single regression model is used to combine customer growth and average use changes. Within ERCOT's

framework, customer growth and average use are simultaneously included into a single neural network model instead of a regression model.

In Itron's experience, no Independent System Operator (ISO) or major utility use NN models to forecast long-term growth. Instead, Itron's clients use a regression framework due to the explanatory power of the model and simplicity. Itron recommends that ERCOT explore keeping its framework but replacing the NN model with a regression model to determine whether the NN model has a significant advantage.

Multiple Weather Scenarios

Within the ERCOT framework, each parameter set is forecast using a range of historic weather years. The resulting forecast captures weather uncertainty based on actual historic patterns. This method has been successfully applied at other utilities, and most notably at PJM. Itron recommends that ERCOT continue to capture weather uncertainty through this simulation method.

Recommendation

ERCOT's overall framework of using multiple sets of parameters, multiple historic weather years, and a NN model specification should yield realistic results once model specification instability is addressed. Itron expects that ERCOT's results will show a stable long-term forecast driven by the growth index and contained within a tight distribution of parameter uncertainty. This distribution will expand when applying historic weather scenarios capturing weather uncertainty.

Applying the traditional approach (regression model) or a single NN model will yield a similar forecast tied to the growth variable but will remove the distribution around the parameter uncertainty. However, using the traditional approach or the single NN model with the weather scenarios will continue capture weather uncertainty.

Itron recommends the following:

1. **Re-specify the NN Model**. Itron recommends that ERCOT re-specify the NN model to isolate the growth index and obtain a stable model.

2. **Regression Model.** Itron recommends that ERCOT explore using a regression model to validate any advantage of a NN model over a traditional approach.

3. **Weather Simulation.** Itron recommends that ERCOT continue to use the historic weather simulations to capture weather uncertainty.

3. Summary

ERCOT's forecasting framework includes three key components. The framework begins with a long term forecast of premises by class and zone. Next, the premise forecasts are weighted together into a single growth driver. Finally, a neural network (NN) model is used to create the long term forecast based on multiple model estimation periods and weather scenarios.

In this summary, Itron evaluates the premise class forecasts by exploring alternative economic drivers that improve the forecast beyond a five year average method. Additionally, Itron provides its preliminary recommendations on the NN model as final recommendations may depend on the premise forecast weightings. Itron's evaluation of the premise forecast weights is not available at this time.

A summary of Itron's recommendations is presented below.

Residential Premise Recommendations

1. **Residential Economic Index.** The weighted index models demonstrate a strong improvement over the Time Trend (five year average) in model accuracy and stability at both the ERCOT-level and Regional Level. Itron recommends that ERCOT implement a weighted index approach as the base approach to Residential Premise forecast. The index should be comprised of Housing Stock and Population and use equal weights.

2. **Low Growth Zones.** Forecasting premises with low growth using a statistical model presents difficulties in obtaining significance. For Zones with 2004-2012 Compound Annual Growth rate less than 1.0% (West and North), Itron recommends that ERCOT continue to use the five year growth rate method.

Business Premise Recommendations

1. **Business Economic Index.** The weighted index models demonstrate a strong improvement over the Time Trend (five year average) in terms of both model accuracy and stability at both the ERCOT-level and Regional Level. Itron recommends that ERCOT implement a weighted index approach as the base approach to Business Premise forecast. The index should be comprised of Non-Farm Employment, Housing Stock and Population and use equal weights.

2. **Far West Zone.** Unlike the other zones, the Far West zone does not show forecast improvement when using the weighted index compared to the five year average method. This result implies that the Far West Zone has been growing linearly and is not as subject to economic variations as the other zones. Itron recommends that ERCOT continue to use the five year average for this zone.

Industrial Premise Recommendations

1. **Five Year Average.** Itron recommends that ERCOT continue to use the five year average method to forecast industrial premises. While housing stock has potential as a driver variable, unrealistic model results confirm that no change to the ERCOT method is warranted at this time.

2. **Future Consideration.** The primary issue in the industrial premise forecast is the 2006 data issue. By removing data prior to 2006, the historical series is significantly shortened resulting in difficulty fitting a statistical model. Itron recommends that ERCOT revisit the industrial class and consider the weighted index method in two or three years when more data are available.

Neural Network (NN) Model Recommendations

1. **Re-specify the NN Model**. Itron recommends that ERCOT re-specify the NN model to isolate the growth index and obtain a stable model.

2. **Regression Model.** Itron recommends that ERCOT explore using a regression model to validate any advantage of a NN model over a traditional approach.

3. **Weather Simulation.** Itron recommends that ERCOT continue to use the historic weather simulations to capture weather uncertainty.