Potential Load Forecast Changes

Load Analysis Subcommittee
August 6, 2019
Weather Conditions
- Weighted average temperature, humidity & wind speed
- 30+ weather stations across PJM.

Economic Conditions
- Gross Domestic Product
- Gross Metropolitan Product
- Real personal income
- Population
- Households
- Non-manufacturing employment

End-Use Characteristics
- Cooling Equipment saturation and efficiency
- Heating Equipment saturation and efficiency
- Other Equipment saturation and efficiency

Calendar / Solar Data
- Day of week
- Month
- Weekends / Holidays
- Distributed solar generation

Diagram:
- Weather Conditions
- Economic Conditions
- Calendar
- Solar Data
- End-use Characteristics
Non-weather Sensitive Load
Non-weather Sensitive Load

- Non-weather sensitive load is what load would have been absent the impacts of Cooling and Heating equipment.
  - Calculated by modeling shoulder month load (Mar-May; Sep-Nov) and accounting for heating and cooling, growth, and weekends

\[
\text{Load} = f(\text{Heating}, \text{Cooling}, \text{Yearly Binaries}, \text{Weekend Binaries})
\]

Non-weather sensitive load = Yearly Binaries
Non-weather Sensitive Load

Summer Peak

Winter Peak

Delivery Year

MW

Non-weather Sensitive
Weather Sensitive

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Non-weather Sensitive Load

- Non-weather sensitive load makes up 55-65% of Summer Peak load and 65-80% of Winter Peak load.

- Under or overstating non-weather sensitive load can lead to over or understating weather sensitive load. This is critical to understanding load uncertainty or the spread in seasonal peak distributions.
• Driver variables should be aligned with the type of load they are trying to represent (i.e. non-weather sensitive drivers should be driving non-weather sensitive load).

• The current model represents non-weather sensitive load through the use of calendar variables and the Other Equipment Index coupled with the Economic Index. The latter is responsible for explaining historical and forecast growth trends.
Model Changes
Current Process

Load
Day-type
Economics
End-Use Characteristics
Weather

Load Forecast
Distribution

Model Estimation

Weather Simulation
Proposed Process

First Model

Estimated Base Load
Day-type Economics
End-Use Characteristics

Model Estimation

Forecasted Base Load

Second Model

Load Forecast Distribution

Weather Simulation

Model Estimation

Base Load Weather End-Use Characteristics
Change #1: End-Use Characteristics

• Current
  – Equipment indexes are computed for Residential and Commercial sectors based on information from the EIA/Itron. These are then weighted according to Residential and Commercial energy sales from EIA 861 for the last 5 years.

• Proposed
  – Further leverage EIA 861 data. Use to calibrate Equipment Indexes. Historic and forecast weights of different sectors vary over time.
Change #1: Using EIA 861 Data

Residential

Customers = f(Households)

Use = f(Appliance Saturation, Efficiency, Income per HH, Population per HH)

Commercial

Energy = f(Appliance Saturation, Efficiency, Working Age Population)

Industrial

Energy = f(Goods-Producing Output, Electricity Used Per Output)

End-Use Drivers
Change #1: Considering Industrial Intensity

Industrial Energy Intensity - Energy Use Per Output

Sources: EIA, Moody's Analytics
Change #1: Equipment Indexes

Equipment Indexes

Index (1998 = 1.0)

Year


Cool  Heat  Other
Change #2: Modeling Non-weather Sensitive Load

• Current
  – Regression model includes variable (Other Equipment Index combined with Economic Index) to represent non-weather sensitive load trends.

• Proposed
  – Estimate non-weather sensitive load. Forecast using Other Equipment Index and use this as an input to the model.
Change #2: Modeling Non-weather Sensitive Load

Modeling Non-Weather Sensitive Load

History

Forecast

Index (1998 = 1.0)

Non-Weather Sensitive Load

Other End-Use Index

Year

Change #2: Modeling Non-weather Sensitive Load

• Forecast of non-weather sensitive load is then used as a model input, interacted with monthly, day of the week, and holiday binaries to reflect calendar effects.

  – In addition, two new concepts were created.

    • Winter Evening – Takes a value of 1 in the Winter when the peak occurs after 12pm

    • Summer Evening – Takes a value of 1 in the Summer when the peak occurs after 2pm
Change #3: New Weather Specification

- **Current**
  - Summer: CDD, Lag CDD, Four-part Temperature-Humidity Index (THI) Spline
  - Winter: HDD, Lag HDD, Four-part Wind-Adjusted Temperature (WWP) Spline

- **Proposed**
  - Single multi-part weather variable comprised of a combination of CDD, HDD, THI, WWP depending on the season. Polynomial structure depending on the season.
Change #3: Building Weather Variables

- Weather variables used:
  - Summer – CDD, Lag CDD, max daily THI
  - Winter - 3 Hr MA WWP at time of peak, Average Daily WWP, Lag Average Daily WWP, and Minimum Daily WWP
Seasonal regression models are run on load for each weather variable. Sum of Squared Errors (SSE) is saved and then the reciprocals are used as the weights (i.e. the less the error, the higher the weight). The end result is a single weather variable for each season that is a weighted composite.
Change #3: Summer Weather Variable
Change #3: Summer Weather Variable

- Shape of load to weather response suggests two inflection points, which would indicate using a cubic polynomial. The weather variable is combined with the Cooling Equipment index.

  - Cooling Equipment Index \times\text{Summer Weather Variable}
  
  - (\text{Cooling Equipment Index} \times\text{Summer Weather Variable})^2
  
  - (\text{Cooling Equipment Index} \times\text{Summer Weather Variable})^3
Change #3: Winter Weather Variable
Change #3: Winter Weather Variable

- Shape of load to weather response suggests single inflection point, which would indicate using a quadratic polynomial. The weather variable is combined with the Heating Equipment index.
  - Heating Equipment Index x Winter Weather Variable
  - (Heating Equipment Index x Winter Weather Variable)^2
Change #3: Shoulder Months

- March through May and September through November get treated is either a Summer type day or a Winter type day depending on the type of conditions.
  - May and September more likely to be treated like Summer.
  - March and November more likely to be treated like Winter.
Change #4: Distributed Solar Treatment

• Current
  – Calculate an average capacity factor at time of peak by season (e.g. HE17 in the Summer). Multiply this by installed capacity to get daily peak reduction attributed to solar. Create gross load peak distribution and then reduce by solar.

• Proposed
  – Calculate historical daily capacity factors. Multiply this by installed capacity and reduce gross load in the forecast simulation.
Change #4: Distributed Solar Treatment

Summer Daily Solar Capacity Factor at Peak

- Seasonal Average
- Daily Observations

Daily Peak Capacity Factor

0.6
0.5
0.4
0.3
0.2
0.1
0
Change #5: Explicit treatment of Plug-in Electric Vehicles

• Current
  – No treatment of plug-in electric vehicles. Captured only in how it implicitly impacts historic loads.

• Proposed
  – Explicit treatment of plug-in electric vehicles. Would make assumptions about type and time of charging and add to forecasted load. Preliminary adjustment included on later slides. Still a work in progress, additional presentation on the topic.
Change #6: Treatment of forecast adjustment requests

• Current
  – Try to calculate how much of adjustment request is baked into forecast, and then add the remainder to the forecast.

• Proposed
  – When request is specific to a sector, bake into the end-use variables. Let the change flow through to the forecast with no additional post model adjustment.
Change #6: Forecast adjustment example

Dominion Forecast Adjustment Example

- Other Equipment Index (incl. Data Centers)
- Other Equipment Index (w/o Data Centers)
Change #6: Forecast adjustment example

APS Forecast Adjustment Example

Index (1998 = 1.0)

Year

Other Equipment Index (incl. Fracking)
Other Equipment Index (w/o Fracking)
Peak Results
PJM RTO Summer Peak Forecast

MW

170,000
160,000
150,000
140,000
130,000
120,000


Actual
Current WN
Proposed WN
2019 Forecast
Proposed Forecast (before PEVs)
Proposed Forecast (after PEVs)
Change in RTO Summer Peak Forecast

- Percent Difference
- Year

- 2019
- 2024
- 2029
- 2034

- No PEVs
- Including PEVs
Comparison to Other Regions

Regional Forecasts

Index (First Year = 1.0)

Sources: NERC ES&D, PJM
Changes in Zonal Summer Peak Forecasts

Percent Changes in Mid-Atlantic Zones

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Changes in Zonal Summer Peak Forecasts

Percent Changes in Western and Dominion Zones

- AEP
- APS
- ATSI
- COMED
- DAYTON
- DEK
- DLCO
- EKPC
- PJM West
- DOM
- PJM RTO
PJM RTO Winter Peak Forecast

- Actual
- Current WN
- Proposed WN
- 2019 Forecast
- Proposed Forecast (before PEVs)
- Proposed Forecast (after PEVs)
PJM RTO Winter Peak Forecast

Change in RTO Winter Peak Forecast

-12% -10% -8% -6% -4% -2% 0%
2018 2023 2028 2033
No PEVs Including PEVs
Changes in Zonal Winter Peak Forecasts

Percent Changes in Mid-Atlantic Zones

-20% -15% -10% -5% 0% 5%

AE BGE DPL JCPL METED PECO PENLC PEPCO PL PS RECO UGI EMAAC SMAAC MAAC

2023 2028 2033
Changes in Zonal Winter Peak Forecasts

Percent Changes in Western and Dominion Zones

-20% -15% -10% -5% 0% 5%

2023 2028 2033

AEP APS ATSI COMED DAYTON DEOK DLCO EXPC PJM West DOM PJM RTO
Energy Results
Accuracy and Supporting Items
Summer Accuracy – Zero Year Forecast

Summer Forecast Model Error on Top 10 Summer Days
Zero Years Out
Mean Absolute Percent Error

- Proposed Model
- Current Model

Forecast Vintage

Summer Forecast Model Error on Top 10 Summer Days
Zero Years Out
Mean Percent Error

- Proposed Model
- Current Model

Forecast Vintage
Summer Accuracy – Three Year Out Forecast

Summer Forecast Model Error on Top 10 Summer Days
Three Years Out
Mean Absolute Percent Error

Summer Forecast Model Error on Top 10 Summer Days
Three Years Out
Mean Percent Error
Summer Accuracy – Zero and Three Year Out Forecasts

Summer Forecast Model Error on Top 10 Summer Days
Zero and Three Years Out
Mean Percent Error

- Proposed Model (Zero Years Out)
- Current Model (Zero Years Out)
- Proposed Model (Three Years Out)
- Current Model (Three Years Out)

Forecast Vintage

-4% -2% 0% 2% 4% 6% 8%
Winter Accuracy – Zero Year Forecast

Winter Forecast Model Error on Top 10 Winter Days
Zero Years Out
Mean Absolute Percent Error

- Proposed Model
- Current Model

Winter Forecast Model Error on Top 10 Winter Days
Zero Years Out
Mean Percent Error

- Proposed Model
- Current Model
Winter Accuracy – Three Year Out Forecast

Winter Forecast Model Error on Top 10 Winter Days
Three Years Out
Mean Absolute Percent Error

Winter Forecast Model Error on Top 10 Winter Days
Three Years Out
Mean Percent Error

Forecast Vintage


Proposed Model
Current Model


Proposed Model
Current Model
Winter Accuracy – Zero and Three Year Out Forecasts

Winter Forecast Model Error on Top 10 Winter Days
Zero and Three Years Out
Mean Percent Error

- Proposed Model (Zero Years Out)
- Current Model (Zero Years Out)
- Proposed Model (Three Years Out)
- Current Model (Three Years Out)

Forecast Vintage


Error Percentage
-8% -6% -4% -2% 0% 2% 4% 6%

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Energy Accuracy

Energy Forecast Model Error
Zero and Three Years Out
Mean Percent Error

- Proposed Model (Zero Year)
- Current Model (Zero Year)
- Proposed Model (Three Year)
- Current Model (Three Year)

Forecast Vintage


-4% -2% 0% 2% 4% 6% 8%
Current Energy Model Tracking 2019

Year to Date:
Energy -2.9% below current forecast

RTO monthly energy tracking

RTO monthly degree days
Year to Date:
Energy -0.5% below proposed forecast
Non-weather Sensitive Load and Drivers

- Non-Weather Sensitive Load
- Current NWS Driver (Other Equipment Index x Economics)
- Other End-Use Index

Index (1998 = 1.0)

Year


Non-weather Sensitive Load
EconIndex = ResWt x (HH_y,m / HH_{base})^{0.47} x (Pop_y,m / Pop_{base})^{0.26} x (Inc_y,m / Inc_{base})^{0.27}
+ ComWt x (NMEmp_y,m / NMEmp_{base})^{0.47} x (GDP_y,m / GDP_{base})^{0.20}
  x (GMP_y,m / GMP_{base})^{0.16} x (Pop_y,m / Pop_{base})^{0.17}
+ IndWt x (GDP_y,m / GDP_{base})^{0.47} x (GMP_y,m / GMP_{base})^{0.53}

From PJM Manual 19
Current Model Economic Drivers

- GDP
- GMP
- Non-Manuf Emp
- Households
- Population
- Real Personal Income

Index (1998Q1 = 1.0)

Year:
- 1998
- 2003
- 2008
- 2013
- 2018
- 2023
- 2028
- 2033
Estimation Period Discussion

• Sensitivities posted with an estimation period of January 1, 2009 to August 31, 2018.

• This can be appropriate if results are reasonable.
  – Current model produces unreasonable results with a shortened estimation period. This is evidenced by model coefficients in many zones that are negative that should be positive.
• Information shared thus far used a 10 year estimation period in the final model.

• Selected 10 years because it both produced reasonable results and was more accurate.
New Model – Summer/Winter Accuracy Comparison Using Different Estimation Periods

Summer Forecast Model Error on Top 10 Summer Days
Zero Years Out
Mean Absolute Percent Error

Winter Forecast Model Error on Top 10 Winter Days
Zero Years Out
Mean Absolute Percent Error
New Model – Summer/Winter Forecast Comparison Using Different Estimation Periods
Timeline

2019

Aug. 6
Review with Load Analysis Subcommittee

Sep. 12
Review with Planning Committee

Sep. - Dec.
Develop/Review Manual 19 Language

2020

Publish 2020 Load Forecast