



# 2023 Load Forecast Supplement

PJM Resource Adequacy Planning Department

January 2023

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## Introduction and Overview

This document serves as a supplement to the 2023 PJM Load Forecast report. It is intended as a reference, to provide details of the processes used to develop the load forecast and the data and assumptions used. It describes the load forecast model that produces the forecast as well as non-model adjustments to it.

This document acts as a resource to help describe the load forecast process. For details such as parameter estimates and model outputs, additional resources are available on the PJM website:

<https://www.pjm.com/planning/resource-adequacy-planning/load-forecast-dev-process.aspx>.

In addition, in 2022, PJM engaged with Itron for guidance in establishing an hourly forecast model. After a multi-month engagement with PJM, Itron staff presented at the Load Analysis Subcommittee and listened to stakeholder feedback (<https://www.pjm.com/-/media/committees-groups/subcommittees/las/2022/20220728/item-03---itron-review-and-recommendations-for-pjm-load-forecast-model.ashx>). Their final report can be found here (<https://www.pjm.com/-/media/committees-groups/subcommittees/las/2022/20220912/pjm-model-review-final-report-from-itron.ashx>) and should be viewed in conjunction with PJM documentation.

## Sector Models

Sector models are a key part of the load forecast process, providing insights into why load trends are happening. The job of a forecaster is to use models to understand what has happened such that they can make an informed judgment about the future. Looking at total peak and energy trends over time only tells us part of the story: what is happening. Sector models can give us greater insight into why things are happening.

Sector models are where we incorporate the independent assumptions on economic trends and end-use adoption and efficiency. The load forecast process considers three sectors: Residential, Commercial, and Industrial. Each sector has its own set of models and inputs.

### Residential

The Residential Sector model is actually two models, a customer model and an average use model. The product of these two concepts—customers and average use—provides total residential use. Total Residential use is considered according to the three use classes of Heating, Cooling, and Other.

Customers are modeled for each zone as a function of households. Monthly customer data is obtained from the EIA 861 dataset. Households are an economic concept, with quarterly history and forecast provided by Moody's Analytics. The relationship of customers to economics is defined by the below equation.

Equation 1. **Residential Customers**

$$customers = B_1 * households + AR(1)$$

Average use per customer is modeled as a function of Heating, Cooling, and Other. Average use data is obtained from the EIA 861 dataset. Heating, Cooling, and Other are functions of end-use concepts provided by Itron (based on data from the EIA's Annual Energy Outlook) and economic concepts that are provided by Moody's Analytics

(household size and real household income). The relationship of average use to Heating (xheat), Cooling (xcool), and Other (xother) is defined by the below equation.

Equation 2. **Residential Average Use**

$$use_t = B_0 * xheat_t + B_1 * xheat_{t-1} + B_2 * xcool_t + B_3 * xcool_{t-1} + B_4 * xother_t$$

The table below provides a list of residential end-uses and indicates how they are allocated to Heating, Cooling, and Other. For each end-use, data provided by Itron includes saturation (% of customers with device), efficiency (relative efficiency of device), and intensity (use per device accounting for saturation and efficiency).

Table 1. **List of Residential End-Uses and Assignment**

| <u>Bucket</u> | <u>Use Type</u> | <u>Definition</u>                                 |
|---------------|-----------------|---------------------------------------------------|
| Heating       | EFurn           | Electric furnace and resistant room space heaters |
| Heating       | HPHeat          | Heat pump space heating                           |
| Heating       | GHPHeat         | Ground-source heat pump space heating             |
| Heating       | SecHt           | Secondary heating                                 |
| Cooling       | CAC             | Central air conditioning                          |
| Cooling       | HPCool          | Heat pump space cooling                           |
| Cooling       | GHPCool         | Ground-source heat pump space cooling             |
| Cooling       | RAC             | Room air conditioners                             |
| Other         | EWHeat          | Electric water heating                            |
| Other         | ECook           | Electric cooking                                  |
| Other         | Ref1            | Refrigerator                                      |
| Other         | Ref2            | Second refrigerator                               |
| Other         | Frz             | Freezer                                           |
| Other         | Dish            | Dishwasher                                        |
| Other         | CWash           | Electric clothes washer                           |
| Other         | EDry            | Electric clothes dryer                            |
| Other         | TV              | TV sets                                           |

|         |         |                                                |
|---------|---------|------------------------------------------------|
| Heating | FurnFan | Furnace fans                                   |
| Other   | Light   | Lighting                                       |
| Other   | Misc    | Miscellaneous electric appliances <sup>1</sup> |

Heating (xheat) is a function of heating end-uses as identified in the above table with adjustments for weather, real income per household, population per household, and building shell efficiency.

Equation 3. **Residential Heating Variable (xheat)**

$$xheat_t = sae_{heat_t} * hdd_{in_t}$$

Where

$$sae_{heat_t} = (EFurn_t + HPHeat_t + GHPHeat_t + SecHt_t + FurnFan_t) * (Population\_per\_houeshold_t)^x * (Income\_per\_household_t)^y * Structural\_Heating_t$$

Where x and y are elasticities provided by Itron and Structural\_Heating is a measure of building size adjusted for relative building shell efficiency.

and

$$hdd_{in_t} = \frac{hdd_t}{hdd_{2016}}$$

Cooling (xcool) is a function of cooling end-uses as identified in the above table with adjustments for weather, income per household, population per household, and building shell efficiency.

Equation 4. **Residential Cooling Variable (xcool)**

$$xcool_t = sae_{cool_t} * cdd_{in_t}$$

Where

$$sae_{cool_t} = (CAC_t + HPCool_t + GHPCool_t + RAC_t) * (Population\_per\_houeshold_t)^x * (Income\_per\_household_t)^y * Structural\_Cooling_t$$

<sup>1</sup> Residential end-use data has always included a category referred to as Miscellaneous, which represented a catch-all of the non-named appliances listed. In 1998, Miscellaneous represented about a fifth of non-weather sensitive uses and now represents about half; a trend spurred as much by growth in Miscellaneous as declines in non-Miscellaneous end-uses.

Where  $x$  and  $y$  are elasticities provided by Itron and  $\text{Structural\_Cooling}$  is a measure of building size adjusted for relative building shell efficiency.

and

$$cdd\_in_t = \frac{cdd_t}{cdd_{2016}}$$

Other (xother) is a function of other end-uses as identified in the above table with adjustments for income per household, and population per household.

Equation 5. **Residential Other Variable (xother)**

$$xother_t = sae\_other_t * Days\_Idx_t$$

Where

$$sae\_other_t = (EHeat_t + ECook_t + Ref1_t + Ref2_t + Frz_t + Dish_t + CWash_t + EDry_t + TV_t + Light_t + Misc_t) * (Population\_per\_household_t)^x * (Income\_per\_household_t)^y$$

Where  $x$  and  $y$  are elasticities provided by Itron

and

$$Days\_Idx_t = \frac{Days\_in\_Month}{30.42}$$

The results of Equation 2 (Residential Average Use) are fitted values, which includes historical weather. For comparability in heating and cooling trends over time, this then needs to be transformed to be on a consistent weather basis.

Equation 6. **Formulation of HeatUse, CoolUse, and OtherUse**

Heating and Cooling are adjusted to be consistent with 2016 weather for all years.

$$HeatUse_t = B_0 * norm\_xheat_t + B_1 * norm\_xheat_{t-1}$$

$$CoolUse_t = B_2 * norm\_xcool_t + B_3 * norm\_xcool_{t-1}$$

$$OtherUse_t = B_4 * xother_t$$

where  $B_0$ ,  $B_1$ ,  $B_2$ ,  $B_3$ , and  $B_4$  are from Equation 3

and

$norm\_xheat$  and  $norm\_xcool$  are the same as  $xheat$  and  $xcool$  but using 2016 weather

Total residential use then is the product of customers and each of these defined average use terms.

### Equation 7. Total Residential Use

$$ResHeat_t = Customers_{quarter,year} * HeatUse_{quarter,year}$$

$$ResCool_t = Customers_{quarter,year} * CoolUse_{quarter,year}$$

$$ResOther_t = Customers_{quarter,year} * OtherUse_{quarter,year}$$

## Commercial

The starting point for analysis is Commercial energy provided through the EIA 861 dataset. The Commercial models utilize two sets of data: economic and end-use. Economic concepts used are service sector employment, working-age population, and real services output, and are provided by Moody's Analytics. End-use concepts are provided by Itron (based on data from the EIA's Annual Energy Outlook), and are summarized in the following table.

Table 2. List of Commercial End-Uses and Assignment

| <u>Bucket</u> | <u>Use Type</u> | <u>Definition</u>      |
|---------------|-----------------|------------------------|
| Heating       | Heating         | Heating                |
| Cooling       | Cooling         | Cooling                |
| Other         | Ventilation     | Ventilation            |
| Other         | WtrHeat         | Water Heating          |
| Other         | Cooking         | Cooking                |
| Other         | Refrig          | Refrigeration          |
| Other         | Lighting        | Lighting               |
| Other         | Office          | Office Equipment (PCs) |
| Other         | Misc            | Miscellaneous          |

### Equation 8. Commercial Use

$$use_t = B_0 * xheat_t + B_1 * xheat_{t-1} + B_2 * xcool_t + B_3 * xcool_{t-1} + B_4 * xother_t$$

Where

$$xheat_t = Heat_t * ComEconVar_t * hdd_{in_t}$$

$$xcool_t = Cool_t * ComEconVar_t * cdd_{in_t}$$

$$xother_t = Other_t * ComEconVar_t$$

*Heat*, *Cool*, and *Other* are end-use intensities from categories in the above table. *ComEconVar* is a 30/30/40 weighed combination of services employments, real services output, and working-age population, respectively.

For comparability in heating and cooling trends over time, this then needs to be transformed to be on a consistent weather basis.

#### Equation 9. Formulation of HeatUse, CoolUse, and OtherUse

Heating and Cooling are adjusted to be consistent with 2016 weather for all years.

$$Com\_Heat_t = B_0 * norm\_xheat_t + B_1 * norm\_xheat_{t-1}$$

$$Com\_Cool_t = B_2 * norm\_xcool_t + B_3 * norm\_xcool_{t-1}$$

$$Com\_Other_t = B_4 * xother_t$$

where B0, B1, B2, B3, and B4 are from Equation 8

and

*norm\_xheat* and *norm\_xcool* are the same as *xheat* and *xcool* but using 2016 weather

## Industrial

The starting point for analysis is Industrial energy provided through the EIA 861 dataset. Industrial modeling utilizes two sets of data: economic and intensity. The economic concept used is real industrial output, using data from Moody's Analytics. Intensity data is pulled from national data from EIA on electricity per real output.

Real industrial output is an aggregate of output in goods-producing industries (see list). Moody's Analytics currently only forecasts employment for these series at the metro area level, not output. However, output is available at the state level and thus output at the metro level is imputed by using state productivity (output divided by employment).

#### Equation 10. Metro Area Real Industrial Output

$$Output_{sector,metro,year}$$

$$= Employment_{sector,metro,year}$$

$$* Output_{sector,state,year} / Employment_{sector,state,year}$$

$$Output_{metro,year} = \sum_{sector} Output_{sector,metro,year}$$

where metro areas are assigned to states based on location

And Sectors are defined as follows:

Natural Resources and Mining

Construction

Manufacturing – Machinery

Manufacturing - Transportation Equipment

Manufacturing - Chemicals; Energy; Plastics and Rubber

Manufacturing - Electronic and Electrical

Manufacturing - Furniture and Miscellaneous

Manufacturing - Metals and Mining

Manufacturing - Textile; Fiber and Printing

Industrial intensity is defined as industrial energy use per real output. The concept is based on national data, but is customized to zones through the availability of sector detail. Historical and forecast energy use by sector is compiled from the EIA Annual Energy Outlook (AEO) and the EIA Manufacturing Energy Consumption Survey (MECS). Economic data by sector is provided by Moody's Analytics as was described in the prior paragraph. Zonal industrial intensity series are then a weighted average of national sector indexes.

Equation 11. **Zonal Industrial Intensity**

$$Intensity_{year} = \sum_{sector} (Output_{sector,year} / Total\ Output_{year}) * Intensity_{sector,year}$$

Discussed above are the types of inputs considered, but as discussed in Itron's model review<sup>2</sup> it is challenging to fit all zones with a structural end-use model. Candidate models that consider the above described variables are constructed, and are evaluated on a zone-by-zone basis for goodness of fit and reasonableness. Reasonableness checks include items such as ensuring coefficients have the right sign and how the model performs on out-of-sample observations. Zonal industrial model selections are provided in supplemental posted materials. Each zone results in an Industrial Base component (*Ind\_Other*) and in some cases an Industrial Cooling component (*Ind\_Cooling*).

Equation 12. **Industrial Cooling**

<sup>2</sup> See pages 15 and 16 for Itron's discussion of Industrial modeling: <https://www.pjm.com/-/media/committees-groups/subcommittees/las/2022/20220912/pjm-model-review-final-report-from-iron.ashx>

$$Ind\_Cooling_t = B * CDD_{2016}$$

Where  $B$  is the coefficient on the cooling term in the industrial model. Cooling is included in zones for which it has a positive coefficient, and excluded for which it does not.

## Usage Indexes

Heat, Cool, and Other Usage Indexes need to be constructed using the results from the Residential, Commercial, and Industrial Sector Models. First, monthly results are rolled up into single measures.

### Equation 13. Monthly Results

$$Heat_t = Res\_Heating_t + Com\_Heating_t$$

$$Cool_t = Res\_Cooling_t + Com\_Cooling_t + Ind\_Cooling_t$$

$$Other_t = Res\_Other_t + Com\_Other_t + Ind\_Other_t$$

At this point, *Other* is essentially complete and is simply converted from a monthly frequency to a daily frequency with each day's value within a month equal to the respective monthly value. *Heat* and *Cool* though at this point are still reflective of 2016 weather patterns in HDD and CDD. A 365 day moving average is taken of each to calculate *HeatIdx* and *CoolIdx*, such that these can later be interacted with hourly heating and cooling weather variables to capture weather sensitive load over time.

## Weather Variables

Weather variables are defined at the zone level. Zonal weather is a weighted average of weather stations, defined below<sup>3</sup>.

<sup>3</sup> Weather station weights are provided by Electric Distribution Companies (EDCs).

Table 3. Weather Station Assignment

| <u>Zone</u> | <u>Weather Station</u> | <u>Weight</u> | <u>Zone</u> | <u>Weather Station</u> | <u>Weight</u> |
|-------------|------------------------|---------------|-------------|------------------------|---------------|
| AE          | ACY                    | 100.0%        | JCPL        | ACY                    | 25.0%         |
| AEP         | CAK                    | 15.1%         | JCPL        | EWR                    | 75.0%         |
| AEP         | CMH                    | 23.4%         | METED       | ABE                    | 50.0%         |
| AEP         | CRW                    | 22.6%         | METED       | PHL                    | 50.0%         |
| AEP         | FWA                    | 22.7%         | PECO        | PHL                    | 100.0%        |
| AEP         | ROA                    | 16.2%         | PENLC       | ERI                    | 50.0%         |
| APS         | IAD                    | 30.0%         | PENLC       | IPT                    | 50.0%         |
| APS         | PIT                    | 70.0%         | PEPCO       | DCA                    | 100.0%        |
| ATSI        | CAK                    | 46.5%         | PL          | ABE                    | 25.0%         |
| ATSI        | CLE                    | 30.0%         | PL          | AVP                    | 25.0%         |
| ATSI        | PIT                    | 8.5%          | PL          | IPT                    | 25.0%         |
| ATSI        | TOL                    | 15.0%         | PL          | MDT                    | 25.0%         |
| BGE         | BWI                    | 100.0%        | PS          | EWR                    | 100.0%        |
| COMED       | ORD                    | 100.0%        | RECO        | EWR                    | 100.0%        |
| DAYTON      | DAY                    | 100.0%        | UGI         | AVP                    | 100.0%        |
| DPL         | ILG                    | 70.0%         | VEPCO       | IAD                    | 33.3%         |
| DPL         | WAL                    | 30.0%         | VEPCO       | ORF                    | 33.3%         |
| DQE         | PIT                    | 100.0%        | VEPCO       | RIC                    | 33.3%         |
| DUKE        | CVG                    | 100.0%        |             |                        |               |
| EKPC        | CVG                    | 25.0%         |             |                        |               |
| EKPC        | LEX                    | 49.0%         |             |                        |               |
| EKPC        | SDF                    | 26.0%         |             |                        |               |

## Cooling and Heating Degree Variables

One of Itron's recommendations was to consider an alternative construction of the Temperature-Humidity Index (THI) that the 2023 Load Forecast adopts<sup>4</sup>. THI values are then translated to CD1, CD2, and CD3 in order to allow the forecast the flexibility to capture different relationships of load to weather under different conditions (a spline). The goal in defining cut points for CD2 and CD3 is to try have it hot enough to capture any potential inflection points but not so hot such that there is limited ability to make a good statistical inference.

### Equation 14. Temperature-Humidity Index and Cooling Degrees Formulas

$$THI_t = temperature_t + 0.55 * (humidity_t/100 - .4) * max(temp_t - 58, 0)$$

Base-points are set for each hour to calculate CD1, CD2, and CD3

| Hour Ending | Base Point |
|-------------|------------|
| 1           | 65         |
| 2           | 65         |
| 3           | 65         |
| 4           | 65         |
| 5           | 65         |
| 6           | 65         |
| 7           | 65         |
| 8           | 65         |
| 9           | 65         |
| 10          | 65         |
| 11          | 65         |
| 12          | 70         |
| 13          | 70         |
| 14          | 70         |
| 15          | 70         |
| 16          | 70         |
| 17          | 70         |
| 18          | 70         |
| 19          | 70         |
| 20          | 70         |
| 21          | 65         |
| 22          | 65         |
| 23          | 65         |
| 24          | 65         |

<sup>4</sup> See p32-33 of <https://www.pjm.com/-/media/committees-groups/subcommittees/las/2022/20220912/pjm-model-review-final-report-from-itron.ashx>. Itron says the new formulation is "about the same in terms of accuracy... we believe that the alternative definition is easier to understand, because it is consistent with our intuition that higher levels of humidity make it feel hotter than the drybulb air temperature. As a result, the following recommendation is based more on convenience and consistency with common sense than performance improvement."

$$CD1_t = \max(THI_t - \text{Base\_Point}_{HE}, 0)$$

$$CD2_t = \max(THI_t - \text{Base\_Point}_{HE} + 10, 0)$$

$$CD3_t = \max(THI_t - \text{Base\_Point}_{HE} + 15, 0)$$

Heating degree variables are then also used.

#### Equation 15. Heating Degrees

Base-points are set for each hour to calculate HD1 and HD2

| Hour Ending | Base Point |
|-------------|------------|
| 1           | 55         |
| 2           | 55         |
| 3           | 55         |
| 4           | 55         |
| 5           | 55         |
| 6           | 55         |
| 7           | 55         |
| 8           | 55         |
| 9           | 55         |
| 10          | 55         |
| 11          | 55         |
| 12          | 60         |
| 13          | 60         |
| 14          | 60         |
| 15          | 60         |
| 16          | 60         |
| 17          | 60         |
| 18          | 60         |
| 19          | 60         |
| 20          | 60         |
| 21          | 55         |
| 22          | 55         |
| 23          | 55         |
| 24          | 55         |

$$HD1_t = \max(\text{Base\_Point}_{HE} - THI_t, 0)$$

$$HD2_t = \max(\text{Base\_Point}_{HE} - 10 - THI_t, 0)$$

These Cooling Degree and Heating Degree variables are used both contemporaneously as well as lagged transformations (Lag6CD, Lag24CD, Lag6HD, Lag24HD), interacted with weekend day-type (WkEndCD, WkEndHD), and interacted with seasons (SpringCD, FallCD, SpringHD, FallHD).

## Additional Weather Variables

In the 2022 Load Forecast and earlier iterations, PJM used Wind-Adjusted Temperature as the primary winter weather variable. Itron recommendations included adding broader consideration of wind to capture its impacts across the year. In addition, Itron also indicated that PJM should include cloud cover<sup>5</sup>.

Equation 16. **Wind and Cloud Variables**

$$WindHD_t = WSP_t * \min(HD1_t/60, 1)$$

$$WindCD_t = WSP_t * \min(CD1_t/60, 1)$$

Where  $WSP$  is a 3-period centered moving average of wind speed

$$CloudHD_t = Cloud_t * \min(HD1_t/60, 1)$$

$$CloudCD_t = Cloud_t * \min(CD1_t/60, 1)$$

Where  $Cloud$  is a 3-period centered moving average of wind speed

## Forecast Model

### Model Specification

Starting with the 2023 Load Forecast, for each zone, we have 24 hourly models. In each model, load is the dependent variable. In the history, we start with metered load and then re-constitute with load management addbacks, load drops associated with peak shaving programs, and distributed solar generation estimates.

Each regression model has the same set-up, with load modeled against input variables: Weather Variables, Calendar effects, and Economic and End-Use considerations. Variable names align with documentations in the posted statistical appendix and are grouped below based on whether they are related to non-weather (XOther), heating (XHeat), or Cooling (XCool)<sup>6</sup>.

Equation 17. **Forecast Model Specification**

$$load = \sum_{variables} B_{variable} * variable$$

<sup>5</sup> See p34-36 of Itron report: <https://www.pjm.com/-/media/committees-groups/subcommittees/las/2022/20220912/pjm-model-review-final-report-from-itron.ashx>

<sup>6</sup> See p36-37 for Itron's discussion of model construction and variable interactions: <https://www.pjm.com/-/media/committees-groups/subcommittees/las/2022/20220912/pjm-model-review-final-report-from-itron.ashx>

## Where

### Calendar-type variables (Interacts with XOther)

|                  |         |              |                |
|------------------|---------|--------------|----------------|
| Intercept_XOther | JanWalk | Wednesday    | XMasDay        |
| Jan              | FebWalk | Thursday     | NYEve          |
| Feb              | MarWalk | Friday       | NYDay          |
| Mar              | AprWalk | Saturday     | WkAfterNewYear |
| MarDST           | MayWalk | MLK          | WkDayBeforeHol |
| Apr              | JunWalk | PresDay      | WkDayAfterHol  |
| May              | JulWalk | GoodFri      | Phase1         |
| Jun              | AugWalk | MemDay       | Phase2         |
| Jul              | SepWalk | July4th      | Phase3         |
| Aug              | OctWalk | LaborDay     | Phase4         |
| Sep              | NovWalk | Thanks       | binary1        |
| Oct              | DecWalk | FriAThanks   | binary2        |
| Nov              | Monday  | WkBeforeXMas | trend1         |
| NovDST           | Tuesday | XMasEve      | trend2         |

### Heating-type Variables (Interacts with XHeat)

|            |          |
|------------|----------|
| HD1        | SpringHD |
| HD2        | FallHD   |
| Lag6HD     | WindHD   |
| Lag24HD    | CloudHD  |
| Lag24CD_HD | MA10_HDD |
| WkEndHD    | MA28_HDD |

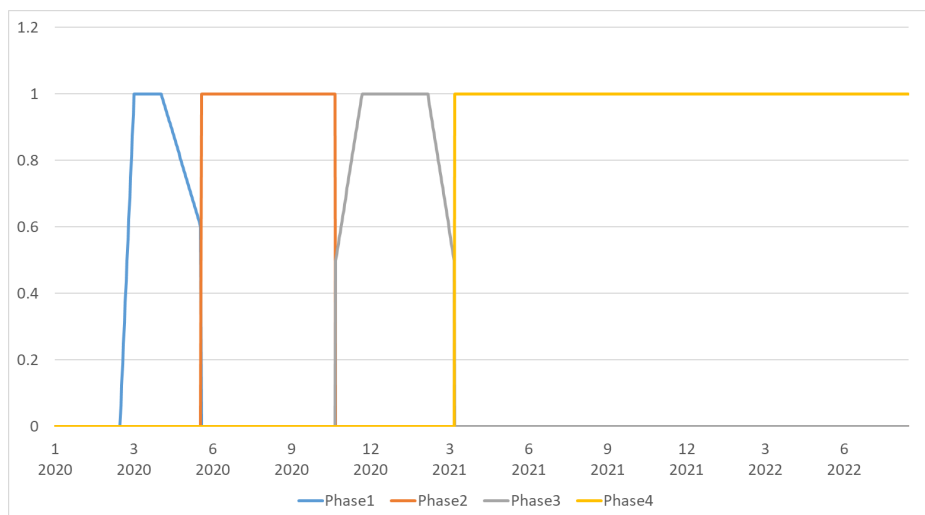
### Cooling-type Variables (Interacts with XCool)

|            |          |
|------------|----------|
| TD1        | SpringCD |
| TD2        | FallCD   |
| TD3        | WindCD   |
| Lag6CD     | CloudCD  |
| Lag24CD    | MA10_CDD |
| Lag24HD_CD | MA28_CDD |
| WkEndCD    |          |

## Binary and Trend Variables

COVID-19 had a large impact on electricity demand. Some of this impact is captured in aspects of the model construction via the economic inputs in the sector models. Nevertheless, it is often advisable in periods such as these to provide some controls for the abnormal event. In the 2022 Load Forecast, the forecast model used the Moody's Analytics Back-to-Normal Index, which is a series that provides a glimpse into the progression of the pandemic at the state level. The 2023 Load Forecast employs an approach where a series of binaries are used *Phase1* through

*Phase4.* *Phase4* extends through the end of the model estimation period and returns to 0 after. This will continue to be re-visited each year.



In addition to COVID treatments, *binary1/binary2* and *trend1/trend2* variables are defined for each zone. These are intended to help tune the model and capture abnormal events in the residuals after specifying the model. None of these trends are extended into the forecast period, so their effect is on the model parameterization and not on assumptions of future trends. Contained in the supplemental materials are hourly residual plots of before and after the inclusion of these additional model variables.

## Simulation

Once the load model is estimated, forecasts for each PJM transmission zone are produced by solving the hourly zonal equations, moving through the year day by day and hour by hour applying historical weather patterns (including conditions for distributed solar generation), as well as forecast adjustments (data centers and peak shaving), behind-the-meter battery storage, and electric vehicles .

To model the most likely weather conditions (often referred to as normal or peak-eliciting weather), a weather rotation technique is used to simulate a distribution of hourly load scenarios generated by historical weather observations, representing actual weather patterns that occurred across the PJM control region.

To enhance the simulation process, each yearly weather pattern is shifted by each day of the week moving forward six days and backwards six days, providing 13 different weather scenarios for each historical year. For early January and late December dates, data from the same calendar year is applied. The table below illustrates the shift of

weather data across the scenarios.

|        | Weather Scenarios |            |            |            |            |            |            |                 |            |            |            |            |            |
|--------|-------------------|------------|------------|------------|------------|------------|------------|-----------------|------------|------------|------------|------------|------------|
|        | Rotate Forward    |            |            |            |            |            |            | Rotate Backward |            |            |            |            |            |
| Date   | A1995             | B1995      | C1995      | D1995      | E1995      | F1995      | G1995      | H1995           | I1995      | J1995      | K1995      | L1995      | M1995      |
| 1-Jan  | 1/1/1995          | 1/2/1995   | 1/3/1995   | 1/4/1995   | 1/5/1995   | 1/6/1995   | 1/7/1995   | 12/31/1995      | 12/30/1995 | 12/29/1995 | 12/28/1995 | 12/27/1995 | 12/26/1995 |
| 2-Jan  | 1/2/1995          | 1/3/1995   | 1/4/1995   | 1/5/1995   | 1/6/1995   | 1/7/1995   | 1/8/1995   | 1/1/1995        | 12/31/1995 | 12/30/1995 | 12/29/1995 | 12/28/1995 | 12/27/1995 |
| 3-Jan  | 1/3/1995          | 1/4/1995   | 1/5/1995   | 1/6/1995   | 1/7/1995   | 1/8/1995   | 1/9/1995   | 1/2/1995        | 1/1/1995   | 12/31/1995 | 12/30/1995 | 12/29/1995 | 12/28/1995 |
| 4-Jan  | 1/4/1995          | 1/5/1995   | 1/6/1995   | 1/7/1995   | 1/8/1995   | 1/9/1995   | 1/10/1995  | 1/3/1995        | 1/2/1995   | 1/1/1995   | 12/31/1995 | 12/30/1995 | 12/29/1995 |
| 5-Jan  | 1/5/1995          | 1/6/1995   | 1/7/1995   | 1/8/1995   | 1/9/1995   | 1/10/1995  | 1/11/1995  | 1/4/1995        | 1/3/1995   | 1/2/1995   | 1/1/1995   | 12/31/1995 | 12/30/1995 |
| 6-Jan  | 1/6/1995          | 1/7/1995   | 1/8/1995   | 1/9/1995   | 1/10/1995  | 1/11/1995  | 1/12/1995  | 1/5/1995        | 1/4/1995   | 1/3/1995   | 1/2/1995   | 1/1/1995   | 12/31/1995 |
| 7-Jan  | 1/7/1995          | 1/8/1995   | 1/9/1995   | 1/10/1995  | 1/11/1995  | 1/12/1995  | 1/13/1995  | 1/6/1995        | 1/5/1995   | 1/4/1995   | 1/3/1995   | 1/2/1995   | 1/1/1995   |
| -      | -                 | -          | -          | -          | -          | -          | -          | -               | -          | -          | -          | -          | -          |
| 25-Dec | 12/25/1995        | 12/26/1995 | 12/27/1995 | 12/28/1995 | 12/29/1995 | 12/30/1995 | 12/31/1995 | 12/24/1995      | 12/23/1995 | 12/22/1995 | 12/21/1995 | 12/20/1995 | 12/19/1995 |
| 26-Dec | 12/26/1995        | 12/27/1995 | 12/28/1995 | 12/29/1995 | 12/30/1995 | 12/31/1995 | 1/1/1995   | 12/25/1995      | 12/24/1995 | 12/23/1995 | 12/22/1995 | 12/21/1995 | 12/20/1995 |
| 27-Dec | 12/27/1995        | 12/28/1995 | 12/29/1995 | 12/30/1995 | 12/31/1995 | 1/1/1995   | 1/2/1995   | 12/26/1995      | 12/25/1995 | 12/24/1995 | 12/23/1995 | 12/22/1995 | 12/21/1995 |
| 28-Dec | 12/28/1995        | 12/29/1995 | 12/30/1995 | 12/31/1995 | 1/1/1995   | 1/2/1995   | 1/3/1995   | 12/27/1995      | 12/26/1995 | 12/25/1995 | 12/24/1995 | 12/23/1995 | 12/22/1995 |
| 29-Dec | 12/29/1995        | 12/30/1995 | 12/31/1995 | 1/1/1995   | 1/2/1995   | 1/3/1995   | 1/4/1995   | 12/28/1995      | 12/27/1995 | 12/26/1995 | 12/25/1995 | 12/24/1995 | 12/23/1995 |
| 30-Dec | 12/30/1995        | 12/31/1995 | 1/1/1995   | 1/2/1995   | 1/3/1995   | 1/4/1995   | 1/5/1995   | 12/29/1995      | 12/28/1995 | 12/27/1995 | 12/26/1995 | 12/25/1995 | 12/24/1995 |
| 31-Dec | 12/31/1995        | 1/1/1995   | 1/2/1995   | 1/3/1995   | 1/4/1995   | 1/5/1995   | 1/6/1995   | 12/30/1995      | 12/29/1995 | 12/28/1995 | 12/27/1995 | 12/26/1995 | 12/25/1995 |

This approach has two key advantages. One, by rotating the data on the calendar, peak-producing weather will be applied to peak producing days. Two, by producing scenarios over a wide range of weather conditions, the weather rotation method is able to identify both the probable and possible levels of future peak load.

The process is repeated for the remaining years of historical weather data. The 2023 Load Forecast uses 29 years of weather history that results in 377 (29 weather years x 13 days) separate forecast simulations for each year in the forecast horizon. These simulations produce a frequency distribution of NCP demands by zone.

For each weather scenario, monthly NCPs are determined by obtaining the maximum NCP for the month. Seasonal NCPs are determined as the maximum over the summer/winter/spring/fall months. For each season, the ratio of each month's peak to the highest monthly peak is taken, and then each month's ratio is multiplied by the seasonal peak. In this way, one of the month's peaks is the seasonal peak while still preserving the relationship between monthly peaks.

For purposes of system planning, only a couple of the values in the forecast distribution are used. After ranking the scenario forecasts from lowest to highest MW value, the median value is selected as the base (or 50/50) forecast. This is the value used for most system planning studies. The 90th percentile (or 90/10) result is used for studies where the system is assumed to be at system emergency conditions.

## Coincident Peaks

Hourly results from the method described above are rolled up to the the entire PJM RTO and Locational Deliverability Areas (LDA). Weather rotation provides an additional benefit for identifying coincident peaks - the natural diversity of weather patterns that impact the PJM footprint is simulated. This is a more plausible approach to peak forecasting than traditional methods which tend to have all weather stations having peak producing weather on the same day. Using the latter approach would overstate the PJM or LDA peak forecast by minimizing diversity.

Monthly RTO/LDA peaks are determined by obtaining the maximum for each scenario for each month (377 possible peaks). Seasonal RTO/LDA peaks are determined over the summer/winter/spring/fall months by obtaining the maximum for each scenario for each season (377 possible peaks). For each season, the ratio of each month's peak

to the highest monthly peak is taken, and then each month's ratio is multiplied by the seasonal peak. From this distribution, the median result is used as the base (50/50) forecast; the values at the 10th percentile and 90th percentile are assigned to the 10/90 and 90/10 weather bands.

At this point, the values of the overall RTO peaks are set, but not the contribution of each zone. To determine the final zonal RTO/LDA-coincident peak forecasts, each zone's average contribution across the peak distribution is calculated and applied to the RTO forecast.

## Assumption Development

### *Weather*

The 2023 Load Forecast uses historical weather data from 1993 to 2021 as the basis for constructing forecasts. No explicit assumption is being made about Climate Change, and thus the assumption is that future weather will resemble past weather.

### *Vendor Data*

The 2023 Load Forecast relies on vendor and government sources.

For economic and demographic forecasts, PJM consults with Moody's Analytics and used their September 2022 forecast vintage. Zonal charts for concepts used have been posted with the supplemental materials.

For end-use saturation/efficiency/intensity projections, PJM is a member of the Itron Energy Forecasting Group (EFG) that provides Census level history/projections for Residential/Commercial sectors. Their work derives from the Energy Information Administration's 2022 Annual Energy Outlook.

For distributed energy resources (BtM solar and storage), IHS Markit provides a BtM solar and storage additions forecast. This is combined with historical Generation Attribute Tracking System (GATS) data in order to provide cumulative nameplate capacity by zone. UL provides zonal solar production estimates, which are used in both determining historical performance and expectations of future performance.

### *Plug-in Electric Vehicles*

Several publicly available pieces of information are used to determine both the counts of electric vehicles as well as charging behavior. State registration data (2016-2021) from the Department of Energy is gathered<sup>7</sup> and is then combined with more localized data from various sources<sup>8</sup> to distribute EV totals to zones within each state. In states

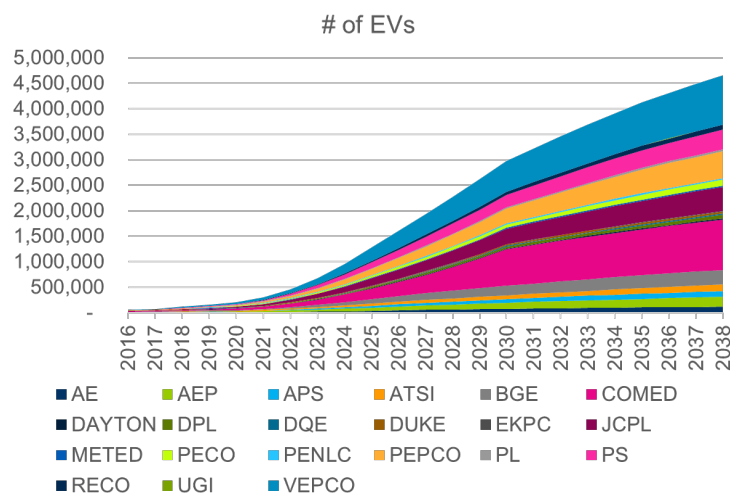
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<sup>7</sup> <https://afdc.energy.gov/vehicle-registration>

<sup>8</sup> New Jersey and Virginia (<https://www.atlasevhub.com/materials/state-ev-registration-data/>); Maryland (<https://opendata.maryland.gov/Transportation/MDOT-MVA-Electric-and-Plug-in-Hybrid-Vehicle-Regis/qtcv-n3tc>); Pennsylvania (<https://www.penndot.pa.gov/ProjectAndPrograms/Planning/EVs/Pages/default.aspx>); Illinois (<https://www.ilsos.gov/departments/vehicles/statistics/electric/home.html>)

in which this localized data is not available, EVs are shared to zones based on that zone's share of residential customers.

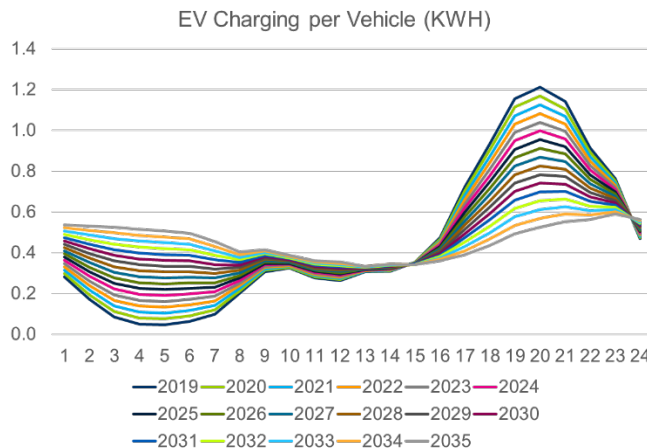
Forecasts of EVs by states are then driven by state targets<sup>9</sup> where identified and EIA 2022 AEO assumptions of EV sales when not. State EV totals are then shared to zones based on zonal household and real personal income trends relative to the state (i.e. a zone with faster growth in either these concepts will get a higher share).



For charging per vehicle, data is gathered from the Department of Energy's Electric Vehicle Infrastructure Projection Tool<sup>10</sup>. This tool allows the user to examine charging shapes based on setting different assumptions. The assumption is made that, over time, policies will be enacted that mitigate peak impact, shifting charging over time away from those hours that are most impactful to the peak. Failure for these policies to materialize could lead to higher peak impacts than are currently in the baseline forecast.

<sup>9</sup> Compiled from <https://afdc.energy.gov/laws>, identifying policies for DC (Clean Energy DC Act), MD (ZEV Sales Requirement), IL (CEJA related goal of 1 million by registered by 2030), NC (ZEV Deployment Goal; 1.25 million by 2030), NJ (ZEV Sales Requirement), and VA (ZEV Sales Requirement).

<sup>10</sup> <https://afdc.energy.gov/evi-pro-lite/load-profile>



## Behind-the-Meter Battery Storage Operation

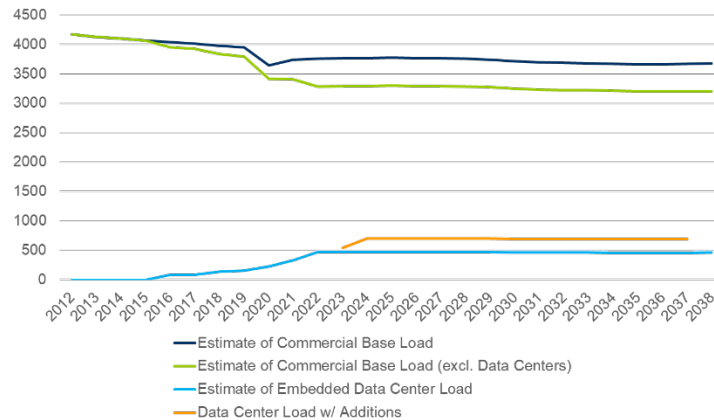
As indicated above, the amount of behind-the-meter battery storage is based on a forecast from IHS Markit. The methodology for their forecast is based on an attachment model (storage installed with solar), and thus are assumed to be used in conjunction with distributed solar. The assumption is made that batteries are of 2 hour duration and will charge when there is enough solar production to cover the battery charge and discharge at peak when solar production is lower (later in the day). An hourly shape is constructed on a monthly basis by looking at average hourly capacity factors from distributed solar and typical peak hours.

## Exogenous Factors

PJM annually solicits information from its member Electric Distribution Companies (EDC) for large load shifts (either positive or negative) that are known to the EDC but may be unknown to PJM. Once the request has been verified per the guidelines in Attachment B of Manual 19, PJM works towards accounting for it in its load forecast. Each request is considered on a case-by-case basis, with particular caution paid to avoid double-counting anticipated load increases or decreases. With each forecast adjustment, PJM quantifies the MW impact on the forecast that is due to this request.

## AEP – Data Centers

AEP requested that PJM consider load additions related to significant growth in data centers. AEP provided forecasted data center additions as well as historical cumulative data center information. Hourly information was not included in the data provided.

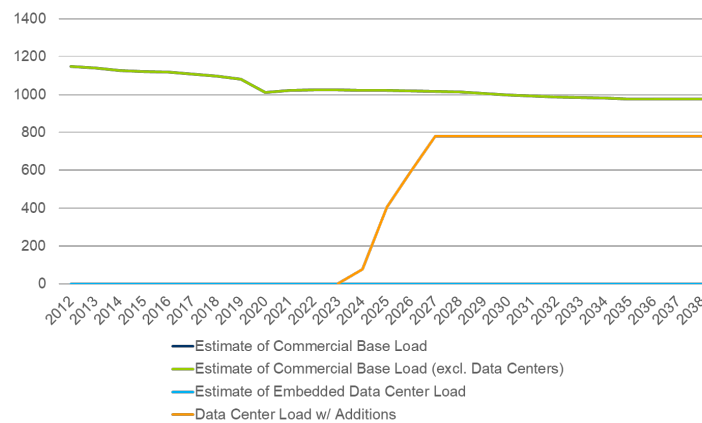


First, we try to calculate the amount that is embedded by taking the historical amount provided by AEP and growing it forward based on the implied growth in commercial base load from the forecast model (light blue line). This step is taken to avoid double-counting load increases that the model is already anticipating. Data center load (existing plus additions) are considered (the orange line) with the forecast adjustment equaling this less the amount considered embedded.

PJM had multiple meetings with AEP staff to discuss this adjustment, and it is anticipated that there might be more data center load forthcoming. PJM will continue to be in contact with AEP to understand these trends as they develop.

## APS – Data Centers

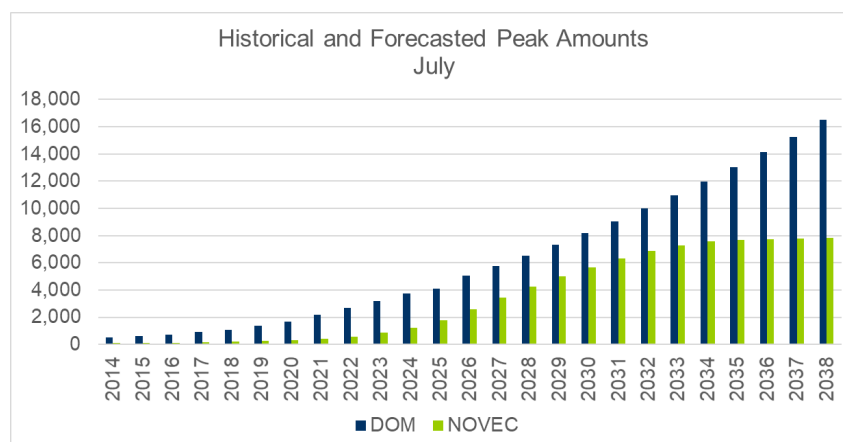
First Energy requested PJM consider load additions related to significant growth in data centers. These sites are coming online in 2023 and growing through 2027. The load is predominately due to a single site called Quantum Loophole. The 2023 Load Forecast considers nearly 800 MW, though there is considered to be potential for significantly more. PJM has been and will continue to be in contact with First Energy to follow this development.



First, we try to calculate the amount that is embedded. With no existing site and declines in implied commercial base load (dark blue and green lines), we conclude that there is no embedded (light blue line). This step is taken to avoid double-counting load increases that the model is already anticipating. Data center load (existing plus additions) are considered (the orange line) with the forecast adjustment equaling this less the amount considered embedded.

## Dominion – Data Centers

Dominion requested that PJM consider a forecast adjustment to account for the growth of data centers in northern Virginia. This adjustment has been in place in some form since the 2014 Load Forecast Report. Dominion and Northern Virginia Electric Cooperative (NOVEC) provide PJM with historical hourly information as well as forecasted peak information. In past years, forecasts have been provided for the next five years with PJM extrapolating to beyond years based on a linear trend. In consideration of the rapid growth and to try and get a more realistic expectation, PJM requested longer-term projections this year<sup>11</sup>.

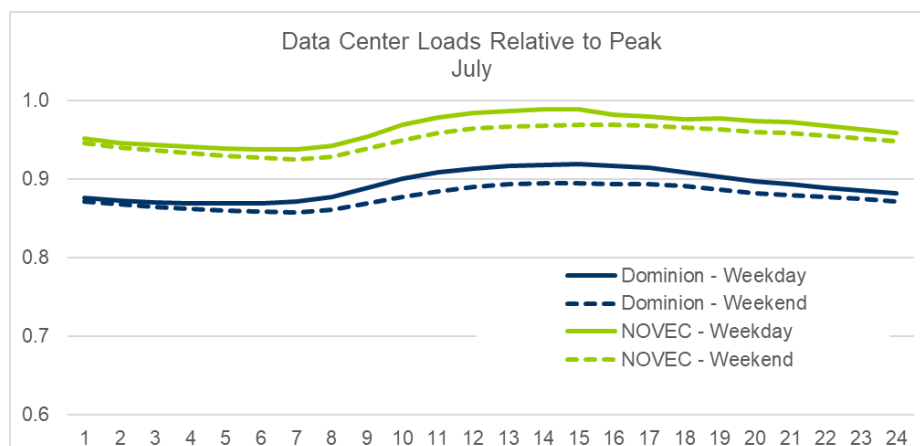


With the data provided, steps are now take to isolate the impact on the final forecast to mitigate double-counting concerns. Facility data is first removed from the historical data. This is done in both the historical hourly data used to feed the final load forecast model as well as the Commercial sector data used to help inform our understanding on usage trends.

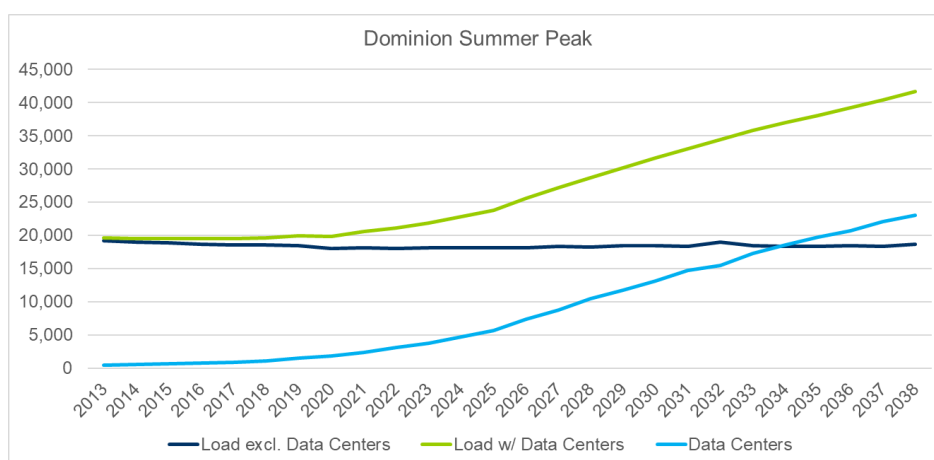
Given that we have hourly historical data center data and the PJM forecast model is hourly, forecasted hourly loads are derived. For each of Dominion and NOVEC, by month and weekday/weekend, historical hourly data center loads are calculated as a share of the provided monthly peaks. This provides us with a weekday and weekend shape that can be applied to the forecasted monthly peaks<sup>12</sup>.

<sup>11</sup> NOVEC provided projections through 2037. PJM used the growth rate in 2037 to obtain figures for 2038.

<sup>12</sup> Dominion shares are lower than NOVEC shares due to a difference in how monthly peaks were shared with PJM, not because of an inherent difference in the operation of data centers within their footprints. Dominion provided monthly data center peaks on a non-coincident basis, whereas NOVEC provided on a coincident basis.

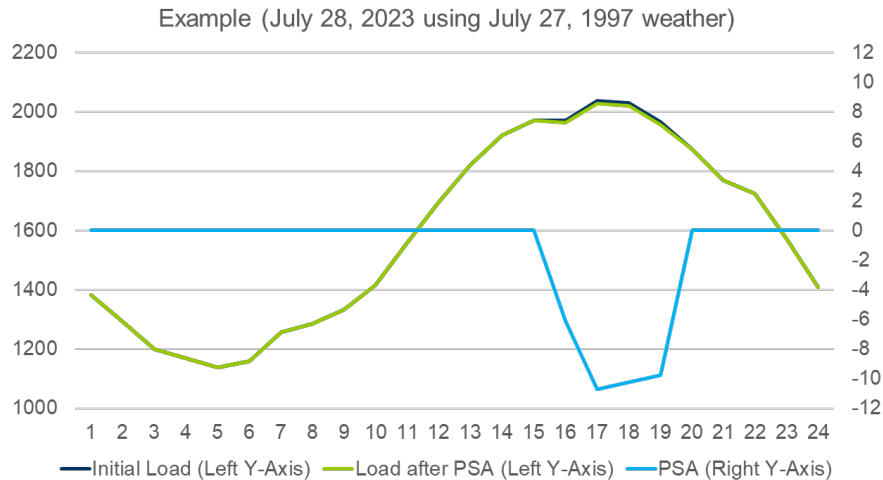


The final forecast needs to be re-constituted with the expected data center amount as the forecasted hourly loads coming from the model exclude data centers (dark blue line in below chart). Monthly peak amounts are combined with the calculated hourly shapes (light blue line in below chart) and these are added to the modeled forecast. The resulting forecast (green line in below chart) includes both non-data center load and data center load.



## EKPC – Peak Shaving Adjustment

EKPC requested a peak shaving adjustment that will begin with the 2023 Delivery Year. EKPC provides PJM with weather triggers as well as program response matrixes for their three programs (smart thermostats, air conditioning switches, and water heater switches). In the forecast simulation process, on days that exceed the trigger, the programs are enacted. The chart below shows an example of program implementation in the forecast. On this day in the forecast, the program is triggered and reduces load in HE16 through HE19 resulting in a peak reduction of 10MW.



In the first year of implementation, 100% compliance is assumed. After summer 2023 PJM will evaluate actual performance against expected performance, and use this to calculate a performance factor that would then be subsequently applied in future forecast iterations.

## NRBTMG to DR

PJM was notified of existing Non-Retail Behind-the-Meter Generation (NRBTMG) transitioning to participate as Demand Response starting in 2023. For the 2023 Load Forecast, these zones are adjusted upward to facilitate these resources' participation in RPM.

- AEP: 18 MW
- ATSI: 55 MW
- PPL: 25 MW

## Additional Model Detail

### Calendar Variables

The forecast model includes a number of variables to capture calendar effects, represented primarily as either binary variables or fuzzy binary variables. Binary variables take a value of 1 or 0, whereas fuzzy binary variables have values ranging from 0 to 1. There is also a graduated variable to take into account the effect of the week leading up to Christmas and the week after the New Year.

Day of Week (=1 when that day, 0 otherwise)

|        |         |           |          |        |          |
|--------|---------|-----------|----------|--------|----------|
| Monday | Tuesday | Wednesday | Thursday | Friday | Saturday |
|--------|---------|-----------|----------|--------|----------|

Month (=1 when that month, 0 otherwise) and DST variables:

|     |     |     |        |     |        |     |
|-----|-----|-----|--------|-----|--------|-----|
| Jan | Feb | Mar | MarDST | Apr | May    | Jun |
| Jul | Aug | Sep | Oct    | Nov | NovDST |     |

Holiday variables are coded such that they have values for more than one day, and for some holidays, these values can differ year to year depending on the day of the week the holiday is observed. These variables are included because generally these days would be expected to have lower than normal loads.

**MLK**   **PresDay**   **MemDay**   **LaborDay**

*MLK* (Martin Luther King Day), *PresDay* (Presidents' Day), *MemDay* (Memorial Day), and *LaborDay* (Labor Day)

|                    | Value |
|--------------------|-------|
| Day before Holiday | 0.2   |
| On Holiday         | 1     |
| All other days     | 0     |

**GoodFri**   **Thanks**

*GoodFri* (Good Friday) and *Thanks* (Thanksgiving Day)

|                | Value |
|----------------|-------|
| On Holiday     | 1     |
| All other days | 0     |

**July4th**

*July4th* (Independence Day)

|                | Value by Day of Week |         |           |          |        |          |        |
|----------------|----------------------|---------|-----------|----------|--------|----------|--------|
|                | Monday               | Tuesday | Wednesday | Thursday | Friday | Saturday | Sunday |
| July 2         | 0.10                 | 0.00    | 0.00      | 0.15     | 0.15   | 0.10     | 0.15   |
| July 3         | 0.70                 | 0.25    | 0.15      | 0.20     | 0.80   | 0.20     | 0.20   |
| July 4         | 1.00                 | 1.00    | 0.80      | 1.00     | 1.00   | 0.40     | 0.30   |
| July 5         | 0.80                 | 0.15    | 0.15      | 0.25     | 0.70   | 0.30     | 0.15   |
| July 6         | 0.00                 | 0.00    | 0.00      | 0.00     | 0.10   | 0.20     | 0.00   |
| All other days | 0.00                 | 0.00    | 0.00      | 0.00     | 0.00   | 0.00     | 0.00   |

### FriAThanks

*FriAThanks* (After Thanksgiving Day)

|                | Value |
|----------------|-------|
| On Holiday     | 1     |
| Day After      | 0.2   |
| All other days | 0     |

### WkBeforeXMas

### WkAfterNewYear

*WkBeforeXMas*(If day is weekday before Christmas Day) *WkAfterNewYear*(If day is weekday after New Year)

|                | Value if Weekday |
|----------------|------------------|
| December 18    | 0.14             |
| December 19    | 0.29             |
| December 20    | 0.43             |
| December 21    | 0.57             |
| December 22    | 0.71             |
| December 23    | 0.86             |
| December 24    | 1                |
| All other days | 0                |

|                | Value |
|----------------|-------|
| January 1      | 1.14  |
| January 2      | 1.00  |
| January 3      | 0.86  |
| January 4      | 0.71  |
| January 5      | 0.57  |
| January 6      | 0.43  |
| January 7      | 0.29  |
| January 8      | 0.14  |
| All other days | 0     |

### XMasEve

*XmasEve* (Christmas Eve)

|                | Value by Day of Week |         |           |          |        |          |        |
|----------------|----------------------|---------|-----------|----------|--------|----------|--------|
|                | Monday               | Tuesday | Wednesday | Thursday | Friday | Saturday | Sunday |
| December 24    | 1.00                 | 1.00    | 0.80      | 0.67     | 1.00   | 0.50     | 0.33   |
| All other days | 0.00                 | 0.00    | 0.00      | 0.00     | 0.00   | 0.00     | 0.00   |

### XMasDay

XMasDay (Christmas Day)

|                | Value by Day of Week |         |           |          |        |          |        |
|----------------|----------------------|---------|-----------|----------|--------|----------|--------|
|                | Monday               | Tuesday | Wednesday | Thursday | Friday | Saturday | Sunday |
| December 25    | 1.00                 | 1.00    | 1.00      | 1.00     | 1.00   | 0.50     | 0.50   |
| All other days | 0.00                 | 0.00    | 0.00      | 0.00     | 0.00   | 0.00     | 0.00   |

### NYEve

NYEve (New Year's Eve)

|                | Value by Day of Week |         |           |          |        |          |        |
|----------------|----------------------|---------|-----------|----------|--------|----------|--------|
|                | Monday               | Tuesday | Wednesday | Thursday | Friday | Saturday | Sunday |
| December 31    | 0.8                  | 0.8     | 0.8       | 0.8      | 1.0    | 0.4      | 0.4    |
| All other days | 0.0                  | 0.0     | 0.0       | 0.0      | 0.0    | 0.0      | 0.0    |

### NYDay

NYDay (New Year's Day)

|                | Value by Day of Week |         |           |          |        |          |        |
|----------------|----------------------|---------|-----------|----------|--------|----------|--------|
|                | Monday               | Tuesday | Wednesday | Thursday | Friday | Saturday | Sunday |
| January 1      | 1.0                  | 1.0     | 1.0       | 1.0      | 1.0    | 0.5      | 0.4    |
| All other days | 0.0                  | 0.0     | 0.0       | 0.0      | 0.0    | 0.0      | 0.0    |

### WkDayBeforeHol WkDayAfterHol

WkDayBeforeHol (weekday before Holiday)

|                    | Value (if Weekday) |
|--------------------|--------------------|
| Day Before Holiday | 1.00               |
| All other days     | 0.00               |

WkDayAfterHol (weekday after Holiday)

|                   | Value (if Weekday) |
|-------------------|--------------------|
| Day After Holiday | 1.00               |
| All other days    | 0.00               |

Monthly Walk variables are graduated variables that start at 1 on the first day of the month and increase by 1 each day until the last day of the month to capture any potential inter-month trends.

|         |         |         |         |         |         |
|---------|---------|---------|---------|---------|---------|
| JanWalk | FebWalk | MarWalk | AprWalk | MayWalk | JunWalk |
| JulWalk | AugWalk | SepWalk | OctWalk | NovWalk | DecWalk |

## Zonal End-Use Variable Calibration

The Energy Information Administration's (EIA) 2022 Annual Energy Outlook Reference Case is the starting point for data on residential end-uses. Residential end-uses fall into categories, which are then grouped according to weather and non-weather sensitive use types (i.e. Heating, Cooling, and Other). These categories are expressed as saturation rates (% of customers), efficiency metrics (use per year or efficiency term like Seasonal Energy Efficiency Ratio), and intensities (kWh per customer per year). Categories and groupings are as follows:

- Heating
  - Electric furnace and resistant room space heaters
  - Heat pump space heating
  - Ground-source heat pump space heating
  - Secondary heating
  - Furnace fans
- Cooling
  - Central air conditioning
  - Heat pump space cooling
  - Ground-source heat pump space cooling
  - Room air conditioners
- Other
  - Electric water heating
  - Electric cooking
  - Refrigerator
  - Second refrigerator
  - Freezer
  - Dishwasher
  - Electric clothes washer
  - Electric clothes dryer
  - TV sets
  - Lighting
  - Miscellaneous electric appliances

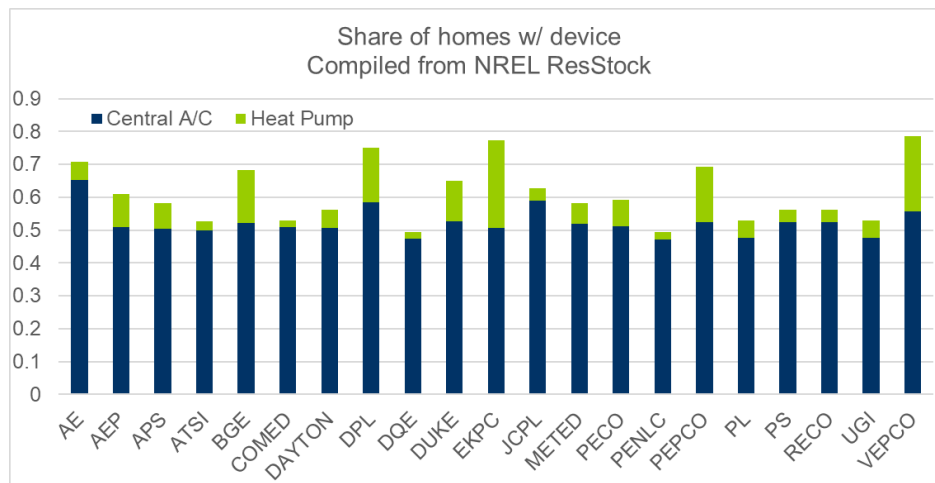
PJM receives this data at the Census division level through membership in Itron's Energy Forecasting Group. PJM then supplements this with two pieces of information:

- Zonal saturation and intensity data from NREL ResStock<sup>13</sup>
- Zonal saturation estimates from:

<sup>13</sup> <https://resstock.nrel.gov/>

- American Electric Power – all appliance categories through 2021
- Allegheny Power – all appliance categories through 2016
- American Transmission Systems, Inc. – all appliance categories through 2016
- Commonwealth Edison – all appliance categories for 2019
- Duke Energy Ohio and Kentucky – all appliance categories through 2014
- East Kentucky Power Cooperative – Heat Pumps for Heating and Cooling, Electric Furnaces, Secondary Heating (Room Heating), Central A/C, Room Air Conditioners, and Water Heaters through 2013
- Jersey Central Power & Light – all appliance categories through 2016
- Metropolitan Edison – all appliance categories through 2016
- Pennsylvania Electric – all appliance categories through 2016
- Dominion Virginia Power – Heat Pumps for Cooling, Central A/C and Room Air Conditioners through 2014

Data from NREL ResStock is used to calibrate zones for 2018 to help provide granularity across PJM. Zones are mapped to counties, and then PJM uses the ResStock database to provide customized data at the zonal level on appliance saturations, appliance intensities, and average home sizes<sup>14</sup>. The below chart displays some of the information gleaned from this exercise on central cooling.

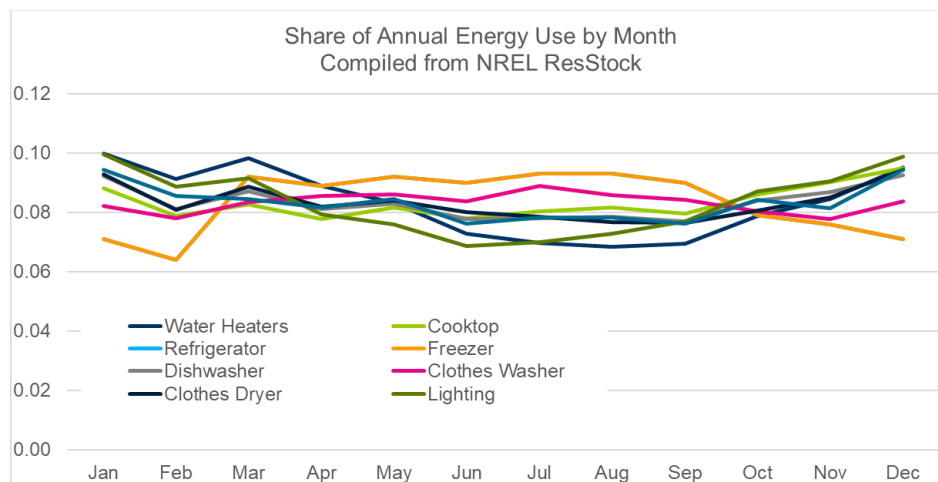


Resulting data is then aligned with zonal-supplied historical appliance saturation rates. Zones are subsequently assigned to Census Divisions for driving the forecasts. This process allows the forecast to be influenced by the historical relative mix of appliances. The below table shows the mapping of Zones to Census Divisions.

<sup>14</sup> In the case of RECO and UGI, this exercise yielded an insufficient sample size according to guidelines laid out by NREL for using their data. PS and PL were used, respectively, in this case.

| <b>Zone</b> | <b>Census Division</b> |
|-------------|------------------------|
| AE          | Middle Atlantic        |
| AEP         | East North Central     |
| APS         | South Atlantic         |
| ATSI        | East North Central     |
| BGE         | South Atlantic         |
| COMED       | East North Central     |
| DAYTON      | East North Central     |
| DPL         | South Atlantic         |
| DQE         | Middle Atlantic        |
| DUKE        | East North Central     |
| EKPC        | East South Central     |
| JCPL        | Middle Atlantic        |
| METED       | Middle Atlantic        |
| PECO        | Middle Atlantic        |
| PENLC       | Middle Atlantic        |
| PEPCO       | Middle Atlantic        |
| PL          | Middle Atlantic        |
| PS          | Middle Atlantic        |
| RECO        | Middle Atlantic        |
| UGI         | Middle Atlantic        |
| VEPCO       | South Atlantic         |

Finally, monthly non-weather sensitive shapes are calculated from the NREL ResStock data as well. These are used to shape the end-use intensity variables used in the monthly Residential Average Use model. These can be seen below.



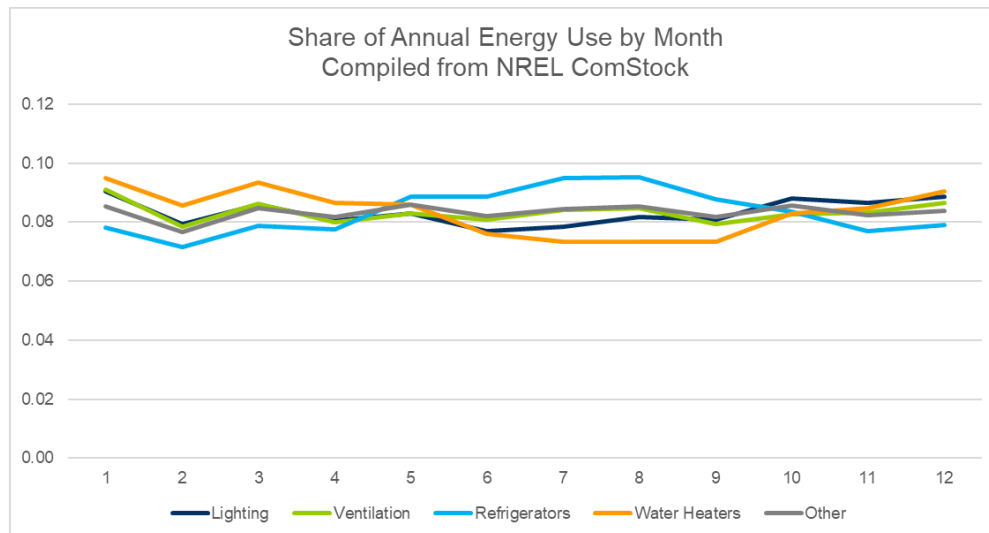
## Commercial

The EIA's 2022 Annual Energy Outlook Reference Case is the starting point for data on commercial end-uses. Commercial end-uses fall into categories, which are then grouped according to weather and non-weather sensitive

use types (i.e., Heating, Cooling, and Other). These categories are expressed as intensities (kWh per square foot per year). These categories and groupings are as follows:

- Heating
- Cooling
- Other
  - Ventilation
  - Water Heating
  - Cooking
  - Refrigeration
  - Lighting
  - Office Equipment
  - Miscellaneous

PJM receives this data at the Census Division level through membership in Itron's Energy Forecasting Group, and zones are assigned to Census Divisions using the same mapping as used for Residential end-uses. Like with Residential, NREL has also developed ComStock<sup>15</sup>. Monthly non-weather sensitive shapes are calculated from the NREL ComStock data. These are used to shape the end-use intensity variables used in the monthly Commercial Use model. These can be seen below.



## Economics Zonal Geographic Assignment

Economic variables come from Moody's Analytics and geographical areas are assigned to zones per the table below.

<sup>15</sup> <https://comstock.nrel.gov/>

| Zone  | Metro Area Name(s) or State                                                                                                                                                                                                                                                                                            |
|-------|------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| AE    | Atlantic City-Hammononton NJ, Ocean City NJ, Vineland-Bridgeton NJ                                                                                                                                                                                                                                                     |
| AEP   | Elkhart-Goshen IN, Fort Wayne IN, Muncie IN, South Bend-Mishawaka IN-MI, Niles-Benton Harbor MI, Canton-Massillon OH, Columbus OH, Lima OH, Kingsport-Bristol TN, Blacksburg-Christiansburg-Radford, VA, Lynchburg VA, Roanoke VA, Beckley, WV, Charleston WV, Huntington-Ashland WV-KY-OH, Weirton-Steubenville WV-OH |
| APS   | Cumberland MD-WV, Hagerstown-Martinsburg MD-WV, Chambersburg-Waynesboro PA, State College PA, Winchester VA-WV, Morgantown WV, Parkersburg-Vienna WV                                                                                                                                                                   |
| ATSI  | Akron OH, Cleveland-Elyria OH, Mansfield OH, Springfield OH, Toledo OH, Youngstown-Warren-Boardman OH-PA, Pittsburgh PA                                                                                                                                                                                                |
| BGE   | Baltimore-Columbia-Towson MD                                                                                                                                                                                                                                                                                           |
| COMED | Chicago-Naperville-Arlington Heights IL, Elgin IL, Kankakee IL, Lake County-Kenosha County IL-WI, Rockford IL                                                                                                                                                                                                          |
| DAY   | Dayton OH                                                                                                                                                                                                                                                                                                              |
| DEOK  | Cincinnati OH-KY-IN                                                                                                                                                                                                                                                                                                    |
| DLCO  | Pittsburgh PA                                                                                                                                                                                                                                                                                                          |
| DOM   | Virginia                                                                                                                                                                                                                                                                                                               |
| DPL   | Dover DE, Wilmington DE-MD-NJ, Salisbury MD-DE                                                                                                                                                                                                                                                                         |
| EKPC  | Cincinnati OH-KY-IN, Louisville/Jefferson County KY-IN, Elizabethtown-Fort Knox KY, Bowling Green KY, Lexington-Fayette KY, Huntington-Ashland WV-KY-OH                                                                                                                                                                |
| JCPL  | Camden NJ, Newark NJ-PA, Trenton NJ                                                                                                                                                                                                                                                                                    |
| METED | Allentown-Bethlehem-Easton PA-NJ, East Stroudsburg PA, Gettysburg PA, Lebanon PA, Reading PA, York-Hanover PA,                                                                                                                                                                                                         |
| PECO  | Montgomery County-Bucks County-Chester County PA, Philadelphia PA                                                                                                                                                                                                                                                      |
| PENLC | Altoona PA, Erie PA, Johnstown PA                                                                                                                                                                                                                                                                                      |
| PEPCO | Washington D.C., California-Lexington Park MD                                                                                                                                                                                                                                                                          |
| PL    | Allentown-Bethlehem-Easton PA, Bloomsburg-Berwick PA, East Stroudsburg PA, Harrisburg-Carlisle PA, Lancaster PA, Scranton-Wilkes-Barre-Hazleton PA, Williamsport PA                                                                                                                                                    |
| PS    | Camden NJ, Newark NJ-PA, Trenton NJ                                                                                                                                                                                                                                                                                    |
| RECO  | Newark NJ-PA                                                                                                                                                                                                                                                                                                           |
| UGI   | Scranton-Wilkes-Barre-Hazleton PA                                                                                                                                                                                                                                                                                      |