Searching for Industrial Load Shapes to Improve Load Forecasting Model

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Abstract: As more end uses transition to using electric power, the demand on our electrical grid will shift. To effectively prepare and expand the capabilities of the grid, we need to improve our load modeling tools. We, at the Grid Integration Systems and Mobility team at SLAC National Accelerator Laboratory, have already prepared forecasts for the residential and commercial sectors of our grid; however, we have not prepared the same analysis for industrial or agricultural sectors. In this work, I will describe my progress toward finding appropriate datasets we can use to effectively model future electricity demands from the industrial and agricultural sector. All datasets are publicly available, and data exploration was performed in Python using marimo (Agrawal & Scolnick). So far, we have not found any appropriate data sets. Once we do, we will be able to integrate the data into our code and model future grid demand.

INTRODUCTION

Electrification is the shift to powering end uses from electricity rather than fossil fuels or other fuels. Though electricity may be generated from fossil fuels, end-uses that are electrified get power from the electric grid, and the fuel that generates electricity does not matter. Some common examples of end-uses becoming electrified are cars, other vehicles, and stoves. Electrification may ultimately lead to a more sustainable future[1]; however current grid infrastructure needs to be improved to fully electrify the US. If grid infrastructure is unable to handle an increased demand, then there will be more blackouts and unreliability[2].

To improve grid reliability, we need to understand what the demand for electricity will look like in the future. We can predict demand using electric load forecasting. Using a webapp under development by the Grid Integration Systems and Mobility (GISMo) team at SLAC National Accelerator Laboratory[3], we can create an electrification forecast and predict load shapes by year. Currently this app works with residential and commercial buildings, but we need to figure out how other sectors will affect demand as well. According to the Energy Information Association (EIA), residential and commercial buildings use 29% of the US energy supply, while industry alone uses 35% of the US energy supply (**Figure 1**).[4,5] Given how large a share of energy the industrial sector uses, it is necessary to understand how this sector uses energy to adequately plan for future electrification.

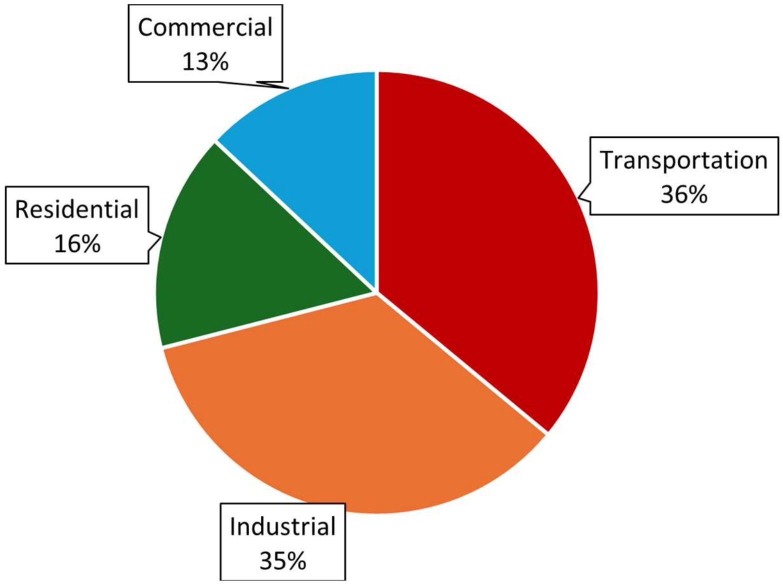

Figure 1. Energy use by sector according to the EIA

In this work, I will describe the process of finding data that can predict the energy usage and electrification of the industrial sector. Industrial load data is difficult to find, and information needs to be combined between data sets to have a clear picture of industrial energy use. Finally, I will describe how this data has been integrated into a prototype of GISMo's advanced load modeling app.

METHODOLOGY

The primary source of energy consumption data is from the Energy Information Association's (EIA) open data browser. The EIA open data browser contains a diverse array of statistics including total energy consumption over a year, electricity generation by different fuels per state, and consumption of different fuels per state. Within the open data browser, four different categories were used: annual electricity generation by state in all industries, annual industrial consumption of natural gas by state, annual industrial consumption of coal by state, and annual industrial consumption of petroleum by state.[6]

For coal consumption data, all data was pulled from EIA using an API link and key. From there, the consumption values were converted from short tons to trillion btu. Additionally, the first year's energy value was removed from the dataset to align its data with those of the other datasets.

Natural gas data was also pulled from the EIA using an API link and key. From there, the energy consumption data was converted from million cubic feet to trillion btu. No other conversions were performed.

For petroleum consumption data, the full dataset without a filter for industrial consumption was pulled from the EIA using an API link and key. The filter for industrial consumption was left out because the filter was broken on the open data browser. Instead, the data was filtered in python to include only industrial consumption values. From there, all petroleum consumption values were converted from thousand gallons to trillion btu using specific conversions for each petroleum type. Afterwards, all the consumption values for all petroleum consumption types were summed per year to provide total petroleum use in a year.

For electricity generation, the data was pulled from EIA using an API link and key. Electricity generation data was pulled for all industries for coal, natural gas, and petroleum fuels. No unit conversion was performed. To get percentages of fuels used for electricity generation, the electricity generation amount was divided by the total amount of a specific fuel consumed for a year.

End use load shapes for industry were sourced from the Electric Power Research Institute's (EPRI) Load Shape Library 8.0. The load shapes were already normalized, so a ratio was used to scale the load shapes based on annual energy usage in an industry.[7]

For this analysis, the load shapes for different end uses in industry were assumed to be identical across industries. Though this may not reflect reality, the lack of available load shape data meant that an industry specific analysis would be very challenging, and general load shapes would need to be used for initial analysis.

Data browsing and processing was performed using marimo notebooks.[8] Marimo provides lots of UI features such as text boxes, dropdown menus, and interactive which allow for easy data browsing and searching.

RESULTS & DISCUSSION

EIA Open Data

From the EIA Open Data Browser, we were able to collect fossil fuel consumption data by state for the industrial sector. Since petroleum data was only available on the annual level, all data has been collected with an annual resolution. Obviously, this is still far away from the hourly resolution we would want for the app, but it's a good starting point. The other limitation with this data was the availability of data past 2020. While natural gas data is available to 2024, coal consumption and petroleum consumption are limited to 2020 and earlier.

For states where data is available, most industrial sectors use predominantly natural gas. Between 2013-2020, natural gas usage has stayed relatively constant, if not increased in usage in the industrial sector. Coal usage tends to be the second highest, but for many states has decreased between 2013-2020. Petroleum usage in the industrial sector is the lowest and has stayed relatively constant across all states. The output for California is shown in **Figure 2**.

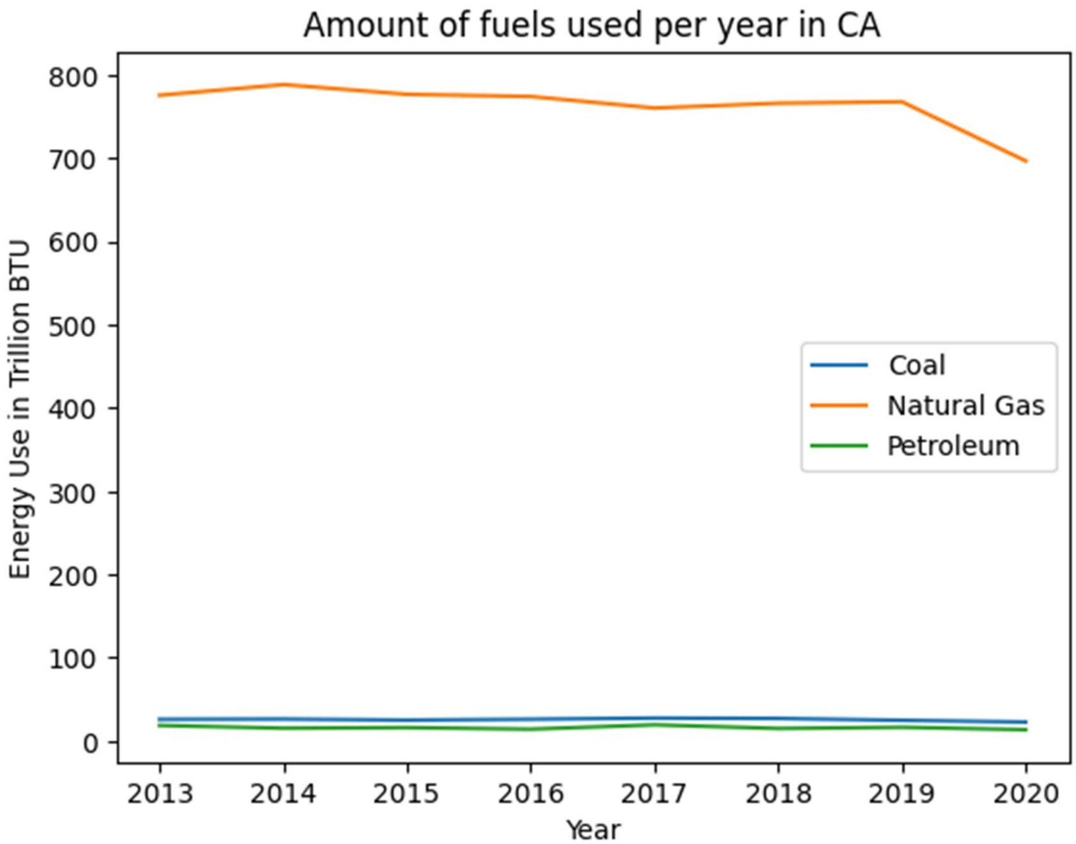

Figure 2. Fossil fuel usage by the CA industrial sector for 2013 through 2020.

Though the EIA open data does not divide fuel consumption by industry type, the trends shown suggest that fossil fuel consumption has remained constant. Using data from the MECS survey, which is divided by industry type, it may be possible to guess at the fuel distribution per industry per state. If we have hourly load shapes, we can use the assumption that fuel consumption has remained constant and divide the loadshape into fractions based on the percentage of different fuel consumption. This would allow us to estimate the supply of energy that would be added to the electric grid.

EPRI Load Shapes

For hourly load shapes for the industrial sector, we looked at the EPRI Load Shape Library. The library contains load shapes for 4 different end uses available by region and an “other” category available for only all regions, not for specific regions. Across different regions, load shapes for the same end use tend to be consistent, so for our prototype, we can start with end use load shapes for one region. Since data was not readily available from EPRI and the load shapes had to be transcribed, we started with just load shapes for CA and NV. The load shape for machine drives on an average weekday during peak season is shown in **Figure 3**. Most weekday load shapes are similar to what is shown in **Figure 3**, though the values at the beginning and ends of the day vary between end use.

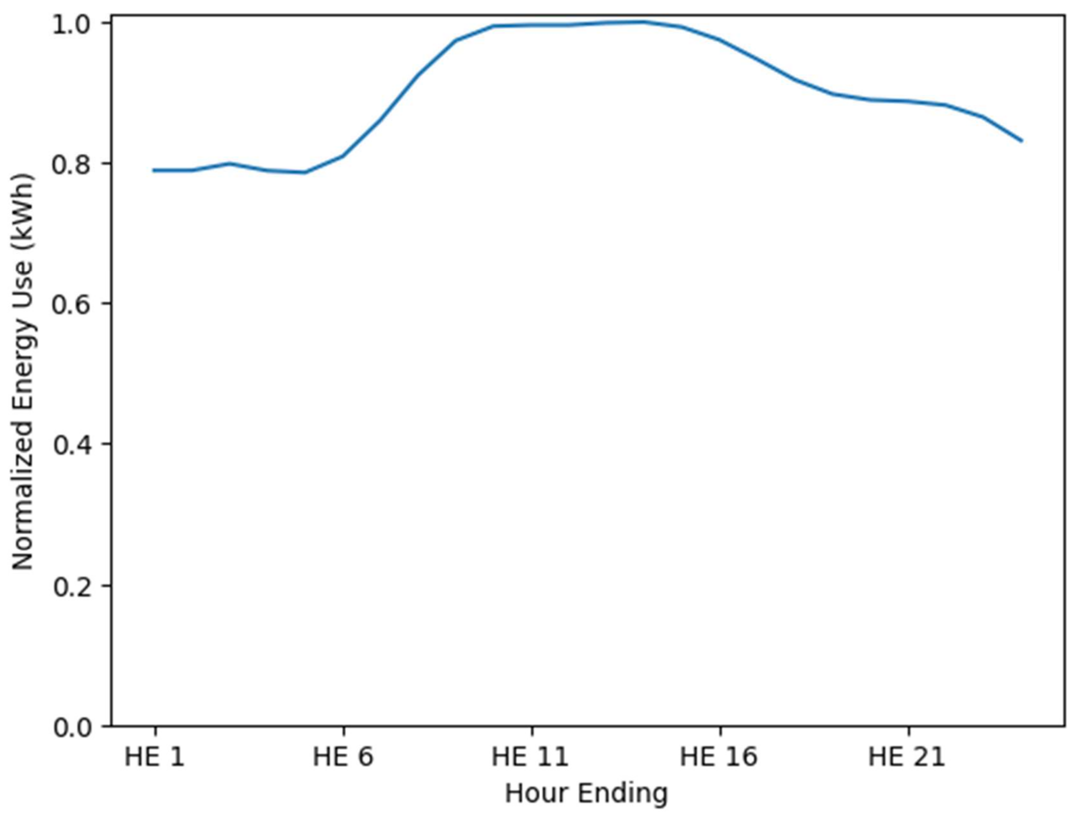

Figure 3. Sample load shape for machine drives in the industrial sectors of CA and NV during an average weekday in peak season.

The load shapes available from EPRI are normalized and can be scaled to fit different industries based on what we know from the EIA about relative fuel consumption per state per industry type. The main piece of information missing is the distribution of fuels across end uses for different industries. For example, we don't know that all end uses require the same amount of energy, and we don't know if all industry types distribute their energy the same way for different end uses. Data centers may not use a lot of energy for process heating while oil refineries do. More investigation would be required to figure out how industries divide their energy to create more accurate load shapes.

Other Databases

As far as we can tell, there are no other data sources that tell us energy consumption for the industrial sector. Lawrence Berkeley National Laboratory has some information about data sources, though many of their sources are not available or do not contain the information we want.

PGE has some data regarding electricity consumption across the industrial sector, but this data has a couple of problems. First, for an electrification analysis, we need to know energy consumption from other fuel types besides electricity. PGE only has electricity data for the industrial sector. Additionally, the data publicly available has a monthly resolution, which is okay but not hourly like we want. Finally, several load shapes for different industries are flat at 0 kWh and spike only for a month or two (**Figure 4**). This is likely because industries may need to pull from the grid when their own generation is not enough to supply their own needs, and the PGE meter data for this reason does not reflect the true electricity usage.

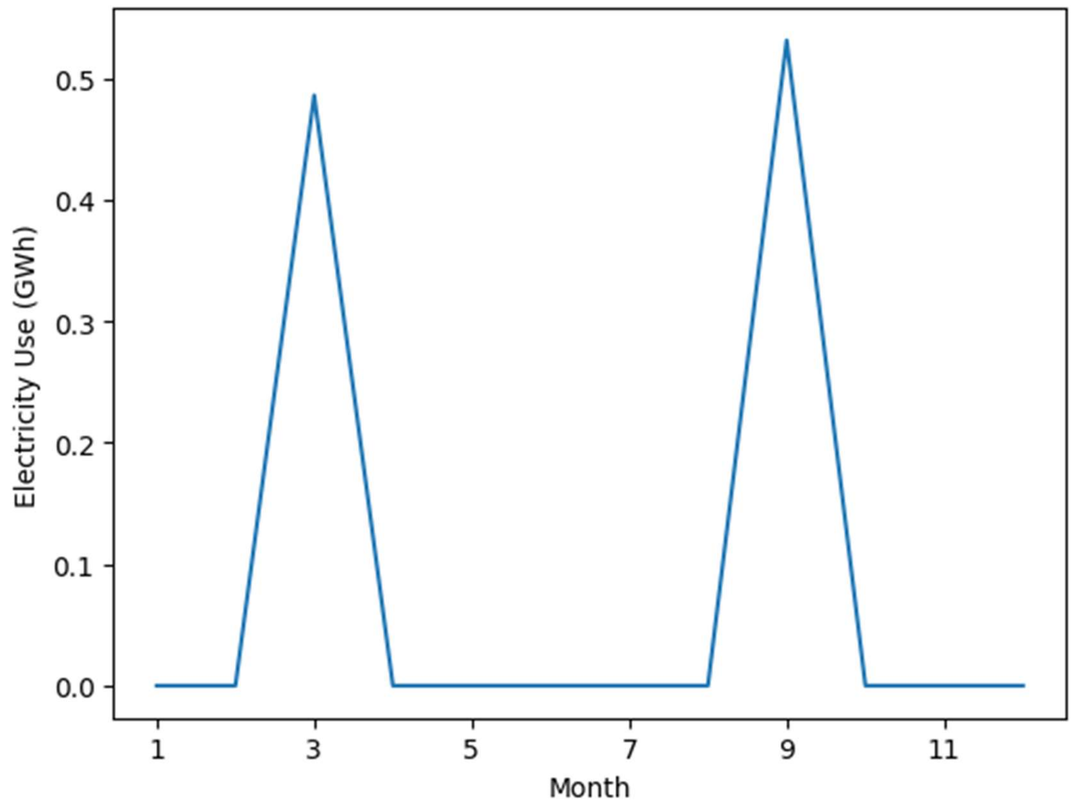

Figure 4. Sample loadshape for electricity usage (in GWh) in the industrial sector of Lathrop, CA

Electrification App

Using the loadshape data from EPRI, we created a prototype app which includes industrial load shape data. Sample outputs for the electrification potential plot and the load shapes with and without electrification are shown in **Figures 5 & 6**. Currently, the load shapes from EPRI are not scaled with the data from the EIA. This should be easy to accomplish once the percentage of energy consumption for each end use is known. Most of the features translate well between Resstock[9] and Comstock[10] data from NREL and EPRI data, however since the EPRI load shapes are more limited in what they say about industrial energy consumption, there are less options for how to analyze the load shape data. For example, the load shapes from EPRI can only be looked at during peak or off-peak seasons, while NREL data can be analyzed by month, season, or annually.

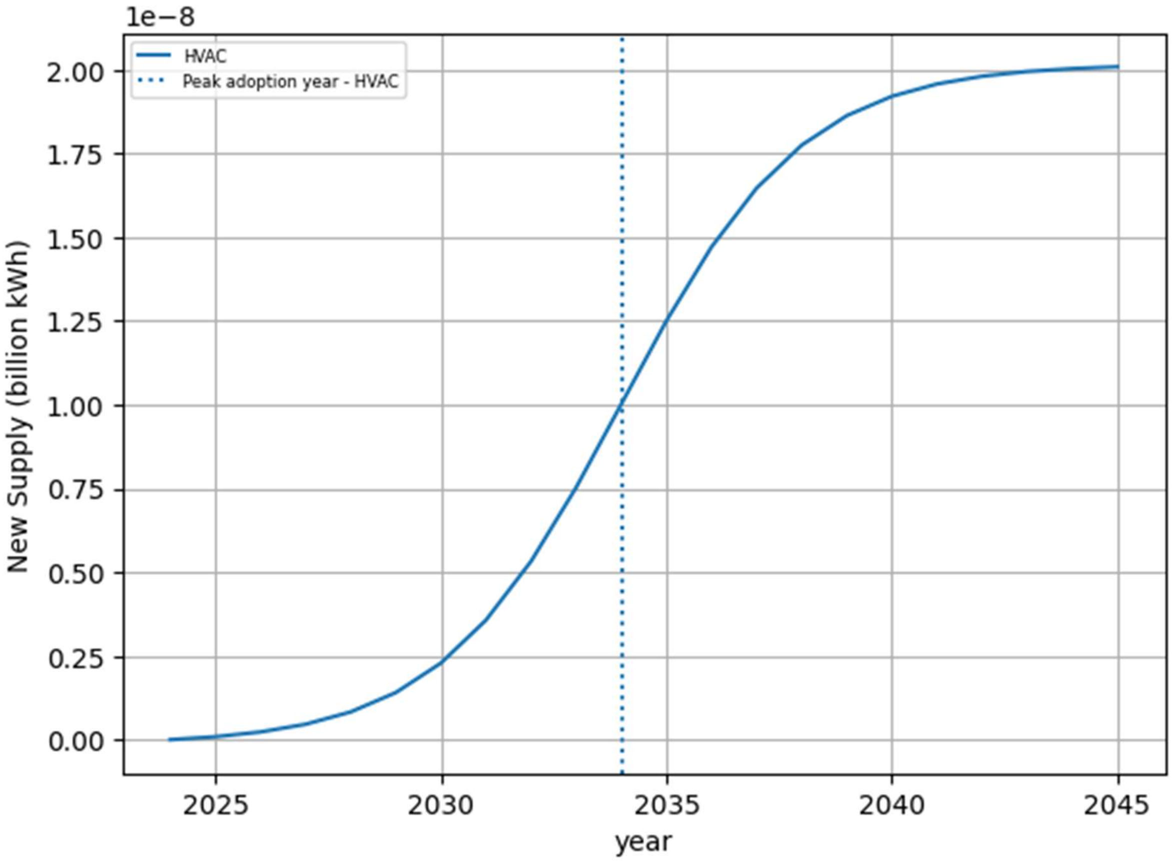

Figure 5. Sample Electrification Potential curve for the HVAC end use

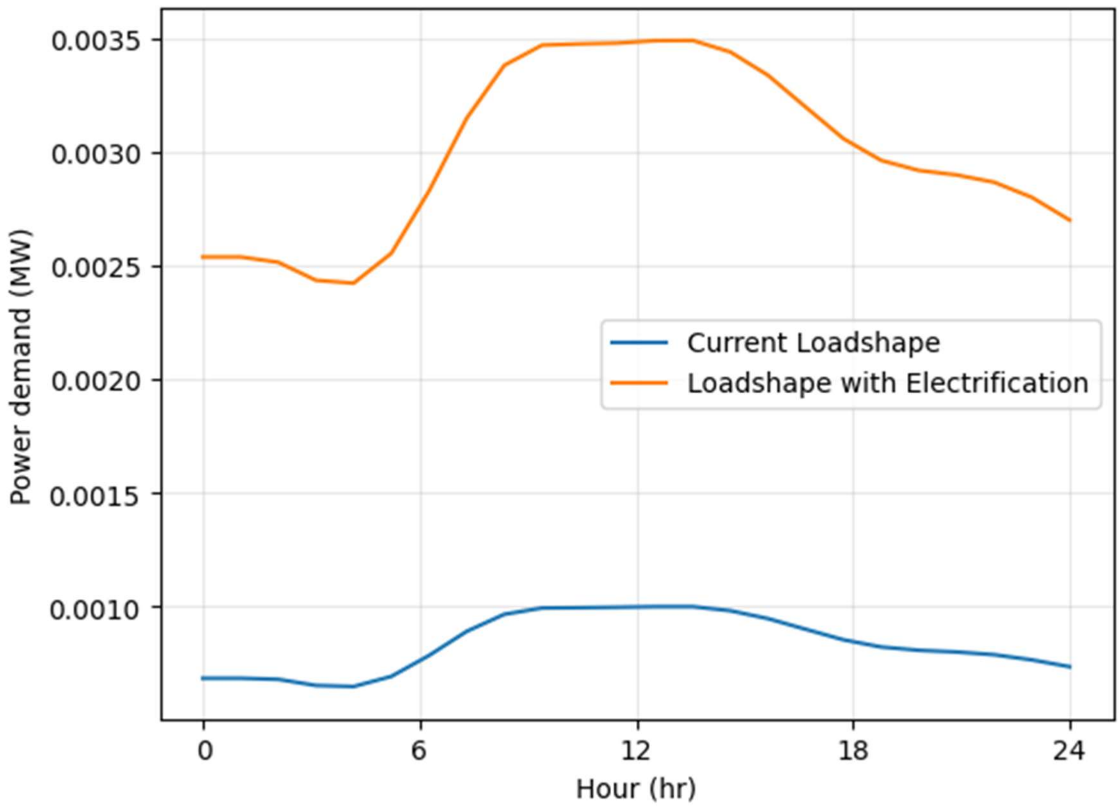

Figure 6. Sample HVAC load shapes for an industrial building with and without electrification.

CONCLUSION

Given the data we have found and some of the assumptions we can make, we are close to predicting the new supply of electricity onto the grid when the industrial sector electrifies. The main data we need to find is about how different industries distribute their energy consumption across different end uses. However, the load shapes we have found have allowed us to integrate industrial data into the existing web app, though more work is needed to integrate analysis features which are present for residential and commercial sector analyses. Future work will include figuring out the actual values of end use load shapes for different industries and data validation to assure the simulated load shapes from EPRI match reality. Once this work is completed, we can expand our grid reliability for all.

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