AEP Electricity Forecast: Phase 1

Blue 5
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AEP Electricity Forecast: Phase 1

Overview

Deregulation in the energy industry allows consumers to choose suppliers, increasing market competition. Accurate demand forecasts help suppliers like AEP meet consumer needs and plan expenses. Our team forecasted AEP's hourly energy load for the Appalachian Power transmission zone from September 22, 2023, to October 4, 2023.

We developed an exponential smoothing model (ESM) and a seasonal auto-regressive integrated moving average (ARIMA) model. The ARIMA model had a 4.79% mean absolute percent error (MAPE) and 180.49-megawatt mean absolute error (MAE) on the validation data, outperforming the ESM's 5.93% MAPE and 226.61-megawatt MAE.

Although the ARIMA model performs best, it still has significant autocorrelation in the residuals. As new data becomes available, we recommend regularly reevaluating model performance and fine-tuning parameters to maintain optimal accuracy. In the future, we can incorporate multiple seasonality effects, include external data like temperature, and use the ARIMA model as a baseline comparison to enhance forecasting performance.

Methodology & Analysis

Data Used

We received hourly metered energy data from the AEP Appalachian Power transmission zone. Our model underwent training using data from January 1, 2016, to September 21, 2023, and was validated using data spanning September 22, 2023, to October 4, 2023. Because of daylight savings, the data included duplicate and missing observations in some hours, which we addressed by mean-imputing energy values for those observations.

Model Development

To forecast AEP's hourly energy load, we developed and tested a set of exponential smoothing and ARIMA models with daily seasonality. The best-performing exponential smoothing model included a multiplicative seasonal effect and no trend effect.

Before fitting the ARIMA model, we used a Canova-Hansen test to determine the nature of the seasonality effect. The test indicated that hourly transmission load followed a stochastic seasonal pattern. Therefore, we seasonally differenced the data before fitting the ARIMA model.

We examined autocorrelation plots to determine the number of lag terms to the ARIMA process. We detected significant seasonal effects in partial autocorrelations as far as 15 seasons back, but models with this many lags did not outperform simpler models. The best-performing ARIMA model was an ARIMA(2,0,0)(5,1,1) process, with two auto-regressive terms, five seasonal auto-regressive terms, and one seasonal moving average term fit to seasonally-differenced data. The alternative models we considered are listed in Appendix 1 and Appendix 2.

Model Evaluation

Table 1 displays the MAPE and MAE of our two models forecasted on the validation data. The ESM achieved a MAPE of 5.93% and an MAE of 226.61 megawatts, compared to the ARIMA model MAPE of 4.79% and MAE of 180.49 megawatts.

Table 1: Validation Accuracy Metrics for ESM and ARIMA Models

Model	MAPE	MAE (mw)
ESM (M, N, M)	5.93%	226.61
ARIMA(2, 0, 0)(5, 1, 1)[24]	4.79%	180.49

We tested the ARIMA model residuals using the Ljung-Box test, and we found that there was uncaptured autocorrelation in the residuals. However, more complex models did not substantially reduce the amount of uncaptured autocorrelation. Future models may need to incorporate external data and multiple seasonality effects to capture more non-random variation.

Results & Recommendations

We forecasted energy load from September 22, 2023, to October 4, 2023, and found that the ARIMA(2,0,0)(5,1,1) model produced the most accurate forecast. Figure 1 shows the actual energy usage versus the forecasted values.

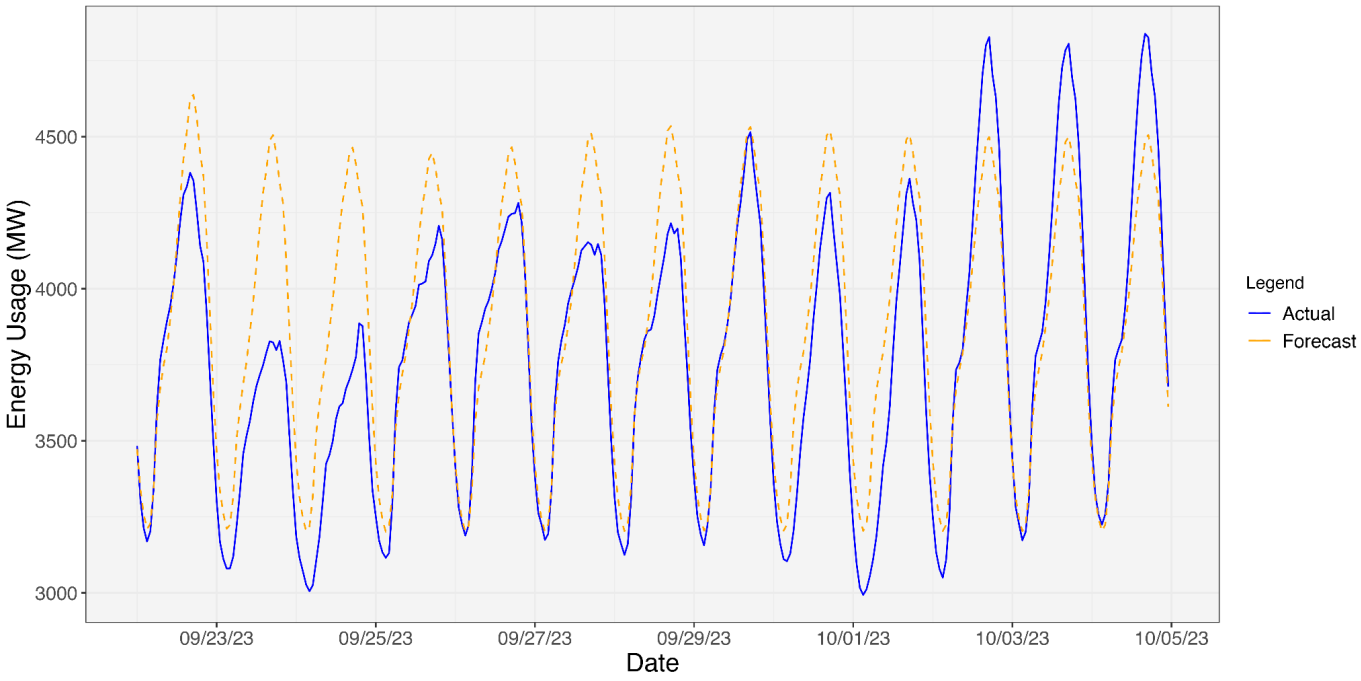

Figure 1: Actual vs. ARIMA-Forecasted Energy Usage, September 22 to October 4, 2023

Our model is expected to forecast energy load with about 4.79% mean absolute percent error over a two-week period. This forecast will allow the AEP to manage operational expenses and align its operations to meet customer demand.

The ARIMA model was our best-performing model, but there are still opportunities for improvement. Future models could incorporate outside variables such as temperature, holidays, or time of year to improve forecasting.

Conclusion

To forecast AEP's hourly energy load, we developed a multiplicative exponential smoothing model and a seasonal ARIMA(2,0,0)(5,1,1) model. The ARIMA model performed better than the ESM on the validation data, with a MAPE of 4.79% and an MAE of 180.49 megawatts. In the future, we may investigate external variables and multiple seasonality effects to capture the remaining autocorrelation structure in the series. However, this ARIMA model can be a baseline comparison for future models.

Appendix

Appendix 1

Table 2: Goodness-of-fit and AIC/BIC Metrics for Holt-Winters Exponential Smoothing Models

Model	MAPE	MAE	AIC	BIC
Additive Seasonality Without Trend	1.99%	86.10	1,390,662	1,390,909
Multiplicative Seasonality Without Trend	1.88%	82.52	1,388,151	1,388,397
Additive Seasonality With Trend	1.99%	86.11	1,390,658	1,390,932
Multiplicative Seasonality With Trend	1.89%	83.24	1,388,697	1,388,971

Appendix 2

Table 3: Goodness-of-fit and AIC/BIC Metrics for ARIMA Models

Model	MAPE	MAE	AIC	BIC
ARIMA(2, 0, 0)(2, 1, 2)[24]	0.85%	37.01	738,202	738,266
ARIMA(2, 0, 2)(2, 1, 2)[24]	0.85%	37.04	738,076	738,159
ARIMA(2, 0, 0)(5, 1, 1)[24]	0.84%	36.57	736,985	737,068
ARIMA(2, 0, 0)(5, 1, 0)[24]	0.87%	37.84	741,668	741,742
ARIMA(2, 0, 0)(2, 1, 0)[24]	0.93%	40.55	751,732	751,788
ARIMA(2, 0, 0)(2, 1, 0)[24]*	-	42.05	757,972	758,027

*model included monthly dummy variables

Sections & Structure

Overview

YC	Is the overview concise?
YC	Does it provide context about the business problem? <Content>
YC	Does it briefly address your team's work, quantifiable results, and recommendations? <Action>
YC	Does it offer audience-centered reasons for recommendations? <Context>

Body Sections

YC	Does the report body include information on methods, analysis, quantifiable results, and recommendations?
YC	Is content grouped into appropriate sections (*methodology*, *analysis*, *results*, *recommendations*)?

Conclusion

YC	Does the report have a conclusion?
YC	Does the conclusion sum up the report and emphasize relevant takeaways?

Structure

YC	Does each major section have a heading?
YC	Are sections, subsections, and paragraphs organized logically for easy navigation?

Visuals

Introduction, Discussion, and Captions

MK	Is each visual introduced in the text before it appears?
MK	Is each visual close to where it is introduced?
MK	Does each visual include a title with the following information: type (*table* or *figure*), number, and a descriptive caption?
	Is each visual discussed and interpreted in the text?
MK	Are figures and tables numbered separately?
MK	Are table captions above the table? Are figure captions below the figure?

Visual Design

MK	Do figures/tables use audience-friendly labels rather than variable names?
MK	Are the visuals easy to interpret?
MK	Are the visuals appropriately sized?
MK	Do tables appear on one page (*not split between 2 pages*)?
MK	Are legends and axis labels included for figures?
MK	Are numbers in tables right aligned?
MK	Are the visuals designed well (*ex*: *re-created in Word or Excel*, *not blurry or stretched*,…)?

Document Design

Title Page Design

CH	Does it include a descriptive title?
CH	Does it state the team name, team members' names, and the submission date?

Table of Contents Design

CH	Does it list all the major sections of the report with corresponding page numbers?
CH	Do the page numbers and sections in the Table of Contents match the report?

Document Design for Entire Report

CH	Is a standard typeface (*Calibri*, *Arial*, *etc.*) used?
CH	Is the size of the body text between 10-12 pt.?
CH	Are headings and subheadings used to organize information?
CH	Are distinctive text styles (*bold*, *italic*, *etc.*) used to distinguish between heading levels?
CH	Are text styles for headings used consistently (*ex*: *all level-one headings are bold*)?
CH	Are all paragraphs an appropriate length (*fewer than 12 lines*)?
CH	Is white space used to indicate paragraph breaks?
CH	Are bullet lists used for a series of items and numbered lists to show a hierarchy?

Writing Style and Mechanics

Spelling and Capitalization

JB	Are spelling errors located and corrected?
JB	Is spelling consistent throughout (*no switching between acceptable spellings*)?
JB	Is capitalization used appropriately (*proper nouns*, *etc*.)?
JB	Is capitalization of words consistent throughout the report?

Grammar and Punctuation

JB	Are verb tenses used appropriately?
JB	Are marks of punctuation used appropriately?
JB	Is subject-verb agreement used in every sentence?
JB	Is the grammar checker updated and are underlined grammar issues addressed?

Writing Style

JB	Are all sentences in the report easy for your audience to understand quickly?
JB	Are most sentences written in active voice?
JB	Are idioms and vague words eliminated from the report?
JB	Are acronyms introduced before being used?
JB	Are well-written topic sentences included at the beginning of each paragraph?
JB	Are lists parallel?
JB	Is the appropriate point of view used when addressing your audience or describing team actions?