Energy Consumption Forecasting & Anomaly Detection

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Executive Summary

This project analyzed historical household energy consumption to identify trends, detect seasonality, forecast future usage, and flag anomalous days. Multiple models were compared, and an interactive Tableau dashboard was created for visualization and business insights.

Project Overview

Understand consumption patterns, forecast future demand, detect anomalies, and assist operational planning through data-driven insights.

Data Description

- **Source:** UCI Machine Learning Repository - Household Power Consumption Dataset
- **Granularity:** Minute-level readings aggregated to daily
- **Key Variables:**
  - Date
  - Global_active_power (kW, minute-averaged)
  - voltage
  - sub-metering values

Data Preprocessing

- Handled missing values by dropping them as only 1.25% missing values present
- Generated time features for modeling
- Calculated Daily Demand (kW) considering peaks of `Global_active_power`
- Aggregated data to daily totals to get Daily Electricity Consumption (kWh)

Exploratory Data Analysis (EDA)

- Original Time series plot to explore trends and seasonality
- Observed strong monthly and moderate yearly seasonality

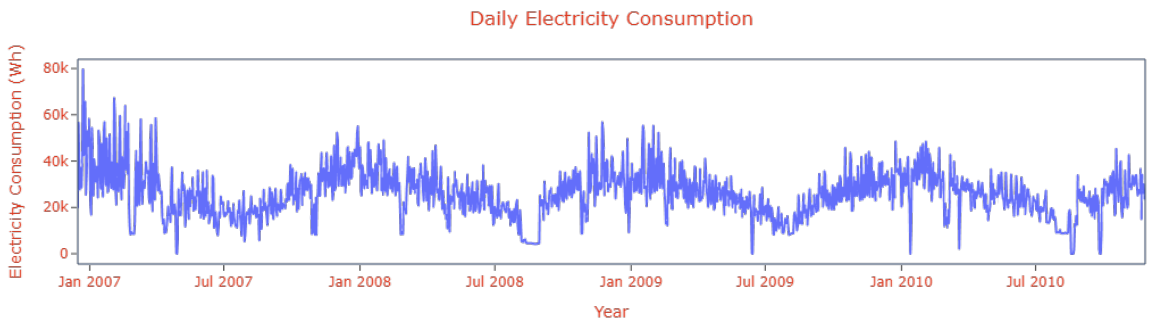

Figure 1: Daily Electricity Consumption

- Spotted Higher consumption in winter (Jan–Feb and Nov-Dec) Lower in summer (Jun–Aug)
- Noticed Monthly cyclic pattern

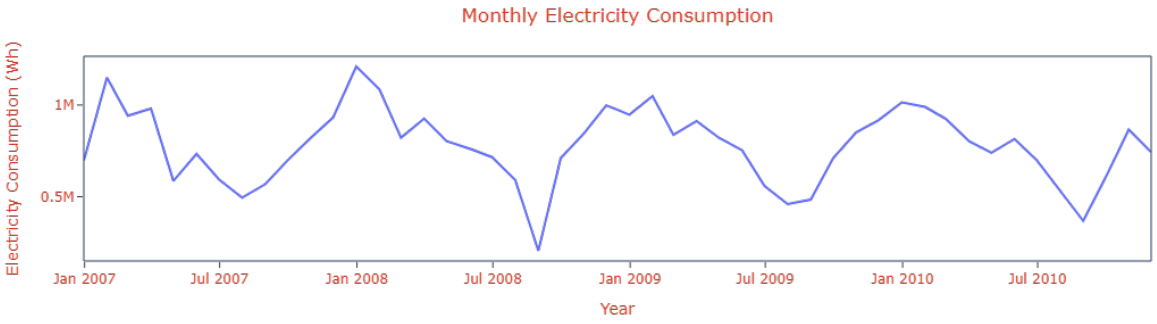

Figure 2: Monthly Electricity Consumption

- Residuals post SARIMAX-modeling showed no patterns, indicating good seasonality capture

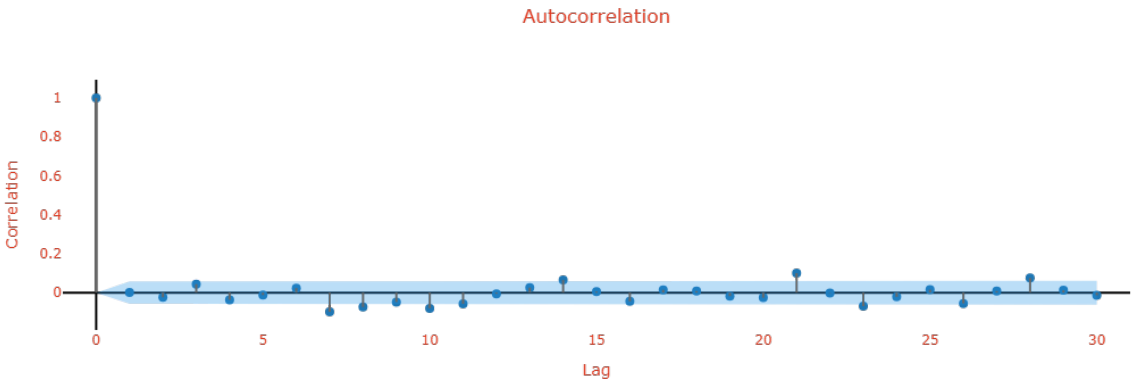

Figure 3: SARIMAX Fitted Residual ACF

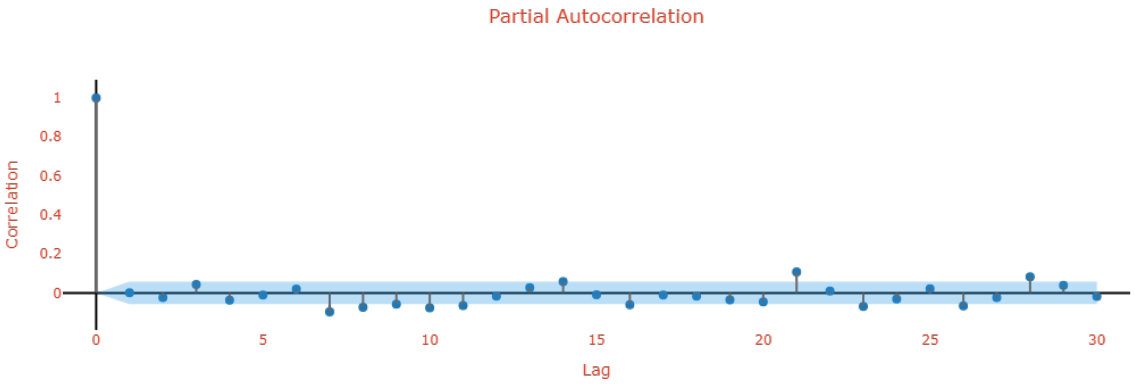

Figure 4: SARIMAX Fitted Residual PACF

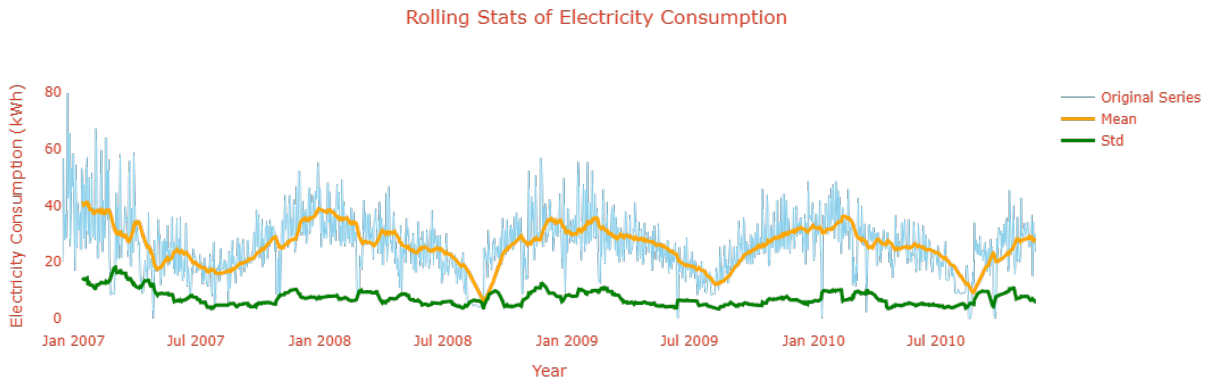

Figure 5: Rolling Statistics of the Series

Visualizations

- Daily demand & consumption time series

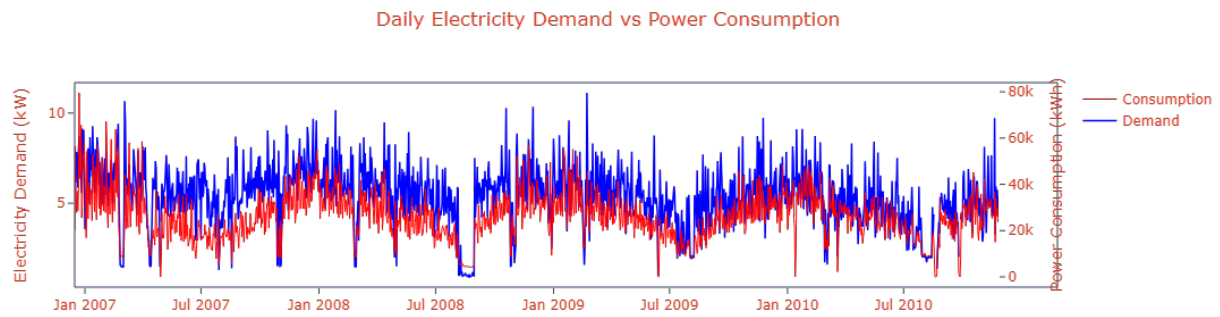

Figure 6: Daily Demand vs Power Consumption

- Decomposition Result: Level, Trend, Seasonality, Noise

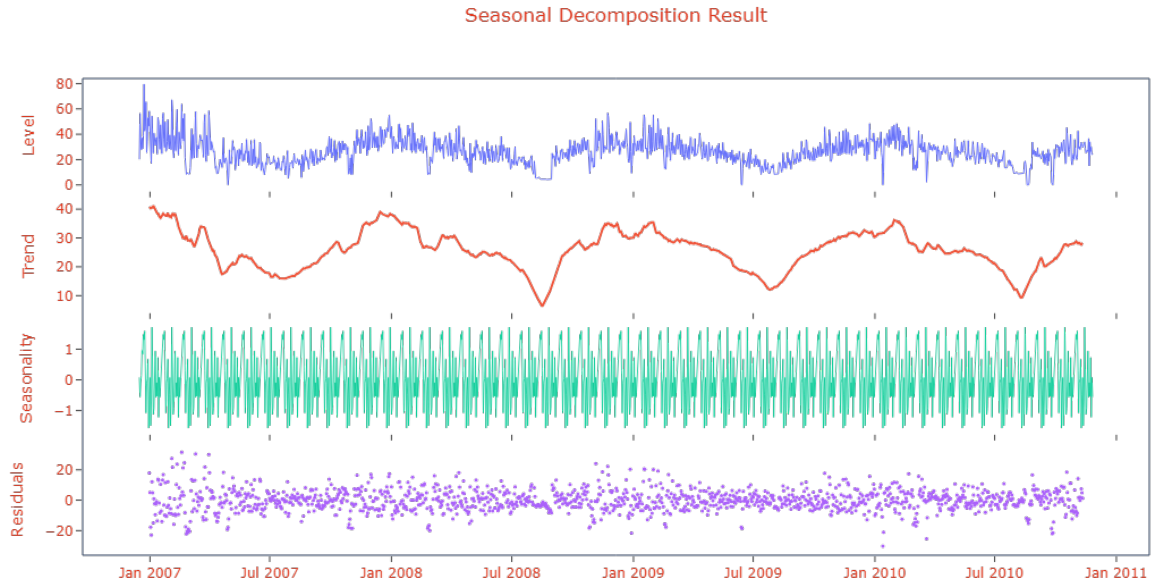

Figure 7: Seasonal Decomposition Result

- Anomaly Detection graph

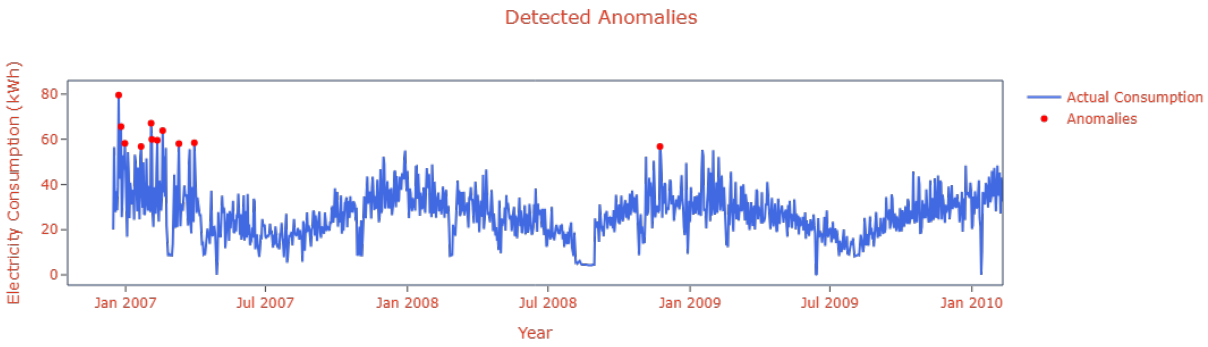

Figure 8: Anomaly Detection

- SARIMAX Forecast vs Actual Electricity Consumption

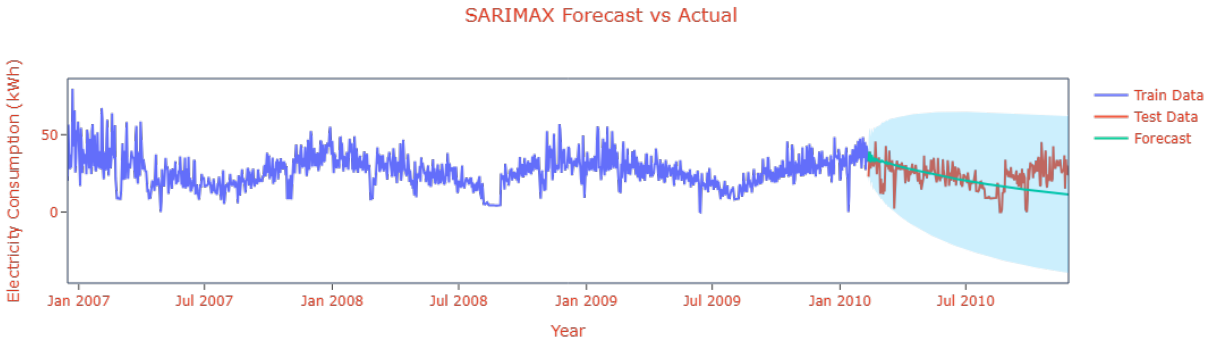

Figure 9: SARIMAX Forecast

- Prophet Forecast vs Actual Electricity Consumption

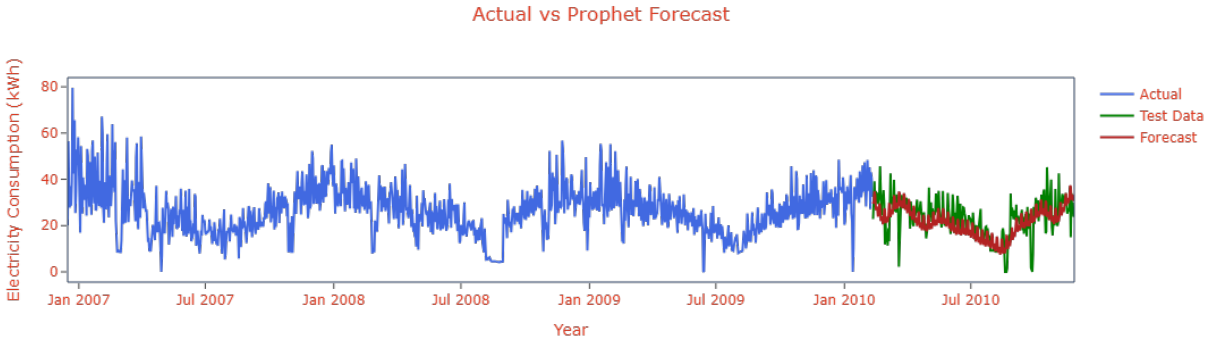

Figure 10: Prophet Forecast

Time Series Forecasting

SARIMAX

- Best model: (8, 0, 0)(1, 0, 1, 30)
- Forecasted daily consumption for one year

Prophet

- Detected yearly and monthly seasonality automatically
- Faster and more accurate with minimal tuning

Model Performance

Metric	SARIMAX	Prophet
MAE	22.13	8.41
MAPE	61177632153903.80	1835243223510714.25
MSE	555.24	107.37
RMSE	23.56	10.36

Insight: Prophet consistently outperformed SARIMAX on all metrics.

Anomaly Detection

- Used Z-Score method on residuals
- $|Z| > 3$ flagged as anomalies
- Example anomalous dates:
  - 2006-12-23
  - 2006-12-26
  - 2007-02-03

Key Insights

- **Peak Usage Trends:** Higher demand in winter, lower in summer
- **Seasonal Dependencies:** Yearly and monthly seasonality confirmed
- **Abnormal Demand Days:** Several flagged via anomaly detection

Dashboard & Interactive Visualization

- Developed in Tableau
- Time series plots, model metrics, anomaly visuals
- Interactive parameter for toggling SARIMAX/Prophet forecasts

Tableau Dashboard Link

Actionable Recommendations

- Adjust energy planning for high-demand months
- Investigate flagged anomalous days
- Adopt Prophet for operational forecasting
- Periodically review anomaly patterns for wastage/faults detection

Conclusion

Forecasting and anomaly detection improve operational efficiency, energy-saving strategies, and capacity planning. Prophet proved ideal for this problem.

Limitations & Future Scope

- Based on daily aggregates — future work could explore minute/hourly data
- External variables (weather, holidays) could improve models
- Try advanced anomaly detection (Isolation Forest, LSTM)