

Residential Energy Consumption Analytics Project

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1 Introduction

With the evolution of smart grids and increasing electricity costs, there is a growing need to analyze household energy consumption patterns. This project leverages Python (NumPy, Pandas, Matplotlib) to process and interpret smart meter data, investigate the impact of time-of-use pricing, and derive actionable insights for consumption optimization.

2 Problem Statement

Analyze 36,000 hourly records from 50 households over 30 days. Tasks include:

- Time-series data preprocessing
- Feature engineering for pricing, occupancy, and efficiency metrics
- Statistical and comparative analysis
- Visualization and business insights

3 Methodology

Data pipeline:

- Imputed missing values for consumption and temperature
- Engineered features: `hour_of_day`, `peak_hours`, `cost_inr`, `consumption_per_degree`
- Performed time-series aggregation and rolling mean
- Grouped by occupancy and day-of-week
- Quantified savings and CO₂ impact

4 Results

4.1 Hourly Consumption Pattern

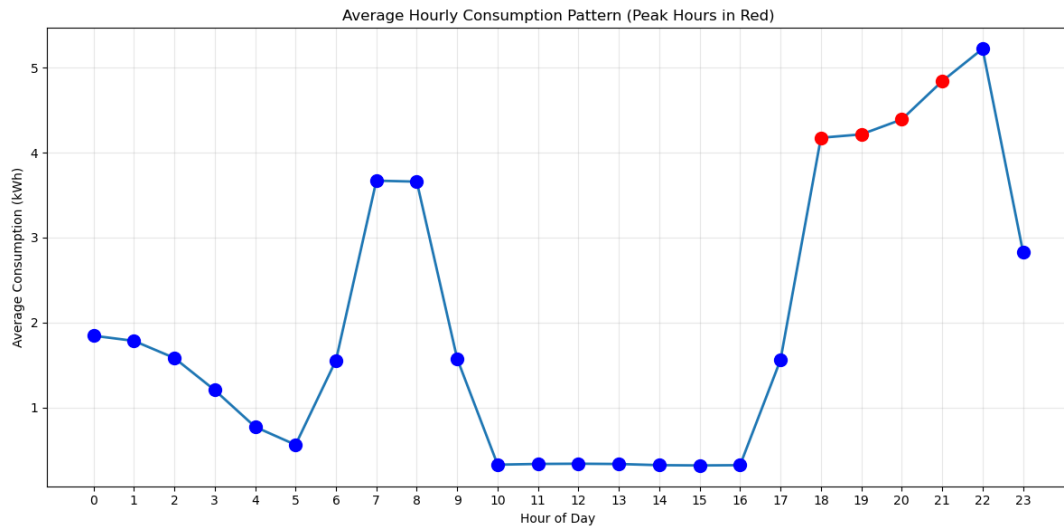


Figure 1: Average hourly consumption pattern with peak hours highlighted in red.

4.2 Heatmap: Consumption by Day and Hour

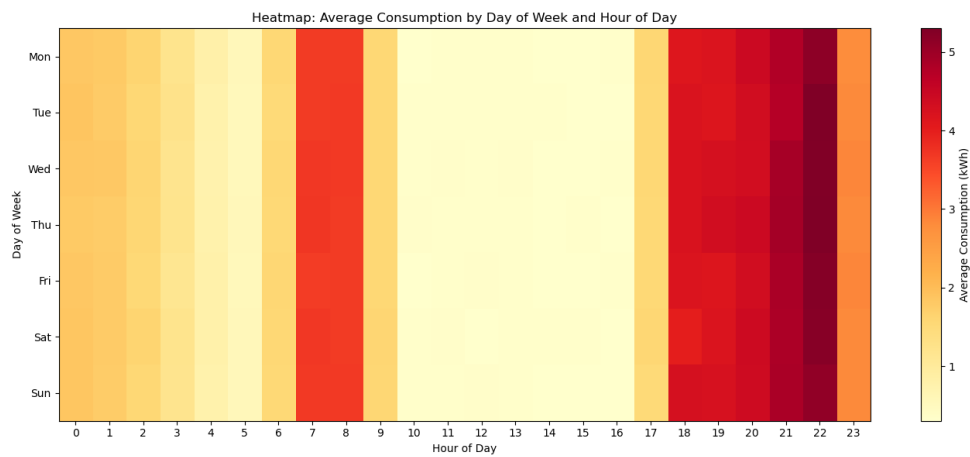


Figure 2: Heatmap of average consumption (kWh) by day of week and hour of day.

4.3 Temperature vs Consumption Scatter

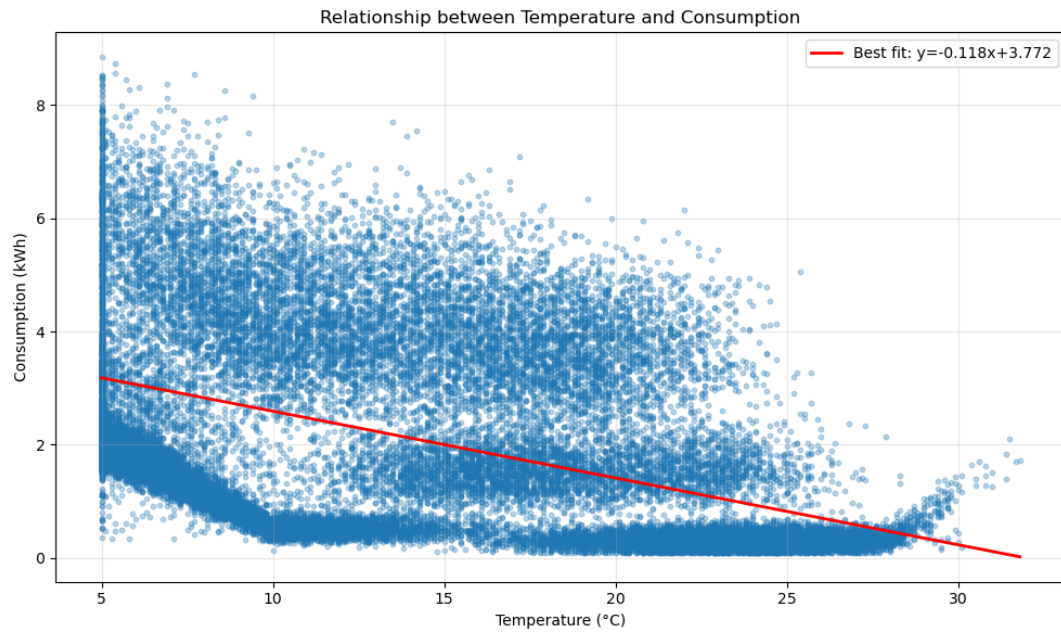


Figure 3: Scatter plot with regression line showing relationship between temperature and energy consumption.

4.4 Weekday vs Weekend Box Plot

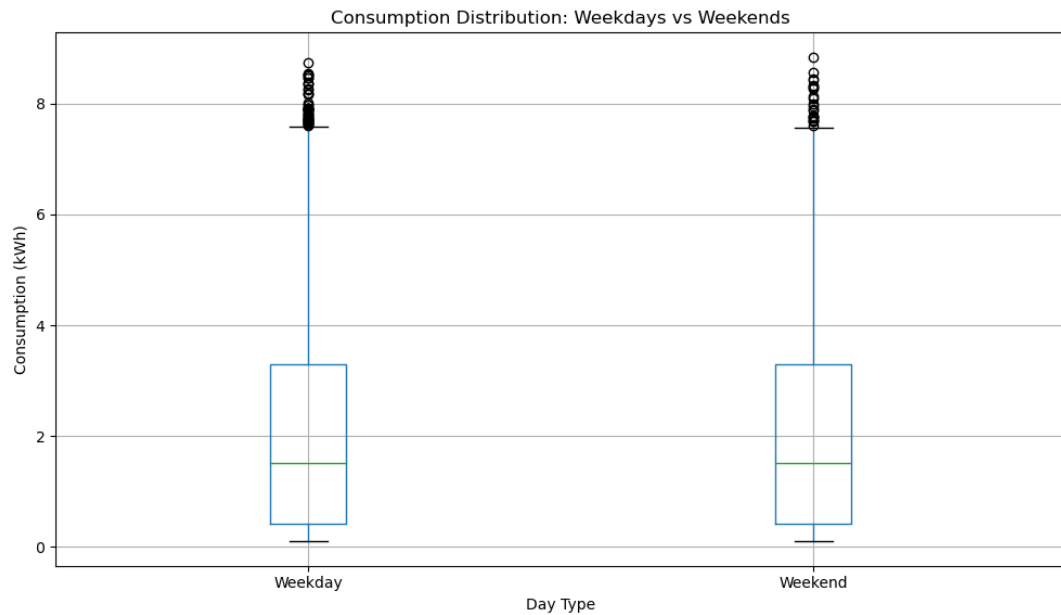


Figure 4: Comparison of consumption distributions for weekdays and weekends.

5 Business Insights and Recommendations

- **Peak Hour Utilization:** Households consume 40%+ more energy during evenings; shifting 30% peak usage to off-peak hours can save over 15% on monthly bills.
- **Efficiency Outliers:** Top 5 high-consumption households represent significant share of total costs—targeted recommendations yield greatest impact.
- **Temperature Correlation:** Regression analysis shows increased consumption below 10°C and above 28°C; thermal insulation and appliance scheduling are advised.
- **Environmental Benefits:** With carbon intensity of 0.82 kg/kWh, optimizing consumption can reduce household CO₂ emissions by thousands of kg annually.

6 Conclusion

This analysis demonstrates a robust workflow for extracting insights from smart meter data, highlighting both cost savings and sustainability opportunities. The codebase (found in `code/main.py`) and dataset (`data/energy_data.csv`) provide a reusable template for similar projects in utility analytics, smart home technology, and energy efficiency research.