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Analysis and Predictive Modeling of Energy Consumption

Explainability AI

Introduction and Project Context

In a global context characterized by climate change and the imperative of energy transition, companies today face significant challenges in reducing their environmental impact while optimizing their energy resource management. This project specifically addresses this challenge by providing an in-depth and predictive analysis of an enterprise's energy consumption data to identify operational levers for optimizing energy use.

Phase 1: Data Collection and Preparation

The first phase of the project involved collecting and preparing two distinct datasets. The first dataset comprises energy consumption records from a corporate building, including meteorological parameters such as external temperature and humidity. The key variables identified for analysis are precise timestamps, energy consumption, and meteorological parameters (temperature, humidity). Several treatments were conducted to ensure data quality, including interpolation of missing values, temporal standardization, and the creation of specific temporal variables, such as periods of high and low consumption. The second, more detailed dataset originates from sensors installed directly on household appliances within the company, enabling more granular analysis of equipment-specific consumption. This dataset includes timestamps, precise appliance designation, and specific energy usage. Outlier removal and temporal segmentation by appliance were performed to facilitate subsequent analyses.

Phase 2: Exploratory Analysis and Modeling Analysis

The first dataset reveals an average daily consumption of approximately 145 kWh, with distinct peaks identified between 7-9 am and 6-10 pm, typically corresponding to morning and evening routines. Temporal visualization of consumption patterns confirmed these trends, and histograms demonstrated a clearly bimodal distribution. Additionally, a significant negative correlation with external temperature was observed, underscoring the importance of weather conditions in energy consumption. Two predictive models were applied to these data: linear regression, predicting energy consumption based on meteorological variables, and temporal clustering to automatically identify critical consumption periods. The second dataset facilitated more detailed analysis at the appliance level. For instance, refrigerator and freezer consumption remained stable at around 0.15 kWh on average, whereas heating exhibited significant peaks during winter, reaching up to 2.8 kWh per hour. Appliance-specific temporal charts clearly illustrated these trends, particularly highlighting a marked increase during winter. The Prophet predictive model, applied to this data, effectively identified seasonal patterns, with precise daily and seasonal peaks. However, limitations emerged, particularly in predicting consumption during exceptional events (holidays, public holidays), necessitating supplementary models or specific adjustments.

Phase 3: Synthesis, Visualization, and Recommendations

Integrating the two datasets confirmed a direct correlation between overall consumption peaks and simultaneous use of specific appliances (heating, lighting, household appliances), thus validating the project's initial hypotheses. These findings enabled several operational optimization recommendations, including intelligent scheduling of high-energy-consuming appliances during off-peak hours, employee awareness initiatives for rational equipment usage during peak times, and improvements in thermal insulation of buildings to mitigate external temperature effects.

Conclusion

This study accurately identified trends and causes of energy consumption peaks within the company and proposed relevant predictive models to effectively anticipate and manage future consumption. The recommendations provided are designed to support sustainable operational improvements.