Introduction

Weather conditions have a significant impact on how households use electricity, influencing daily routines and energy demand patterns (Kang & Reiner, 2022). Understanding these effects is important for energy planning and efficiency strategies in Morocco. This study uses a dataset of electricity consumption in Morocco recorded at 10-minute intervals across three different zones. The data includes environmental factors such as temperature, humidity, wind speed, and solar radiation measures.

In this case study three questions was conducted to explore:

Is temperature correlated with electricity consumption?

This question examines whether there is a statistically significant relationship between temperature and electricity use across the recorded periods.

Do different zones have different electricity consumption in different seasons?

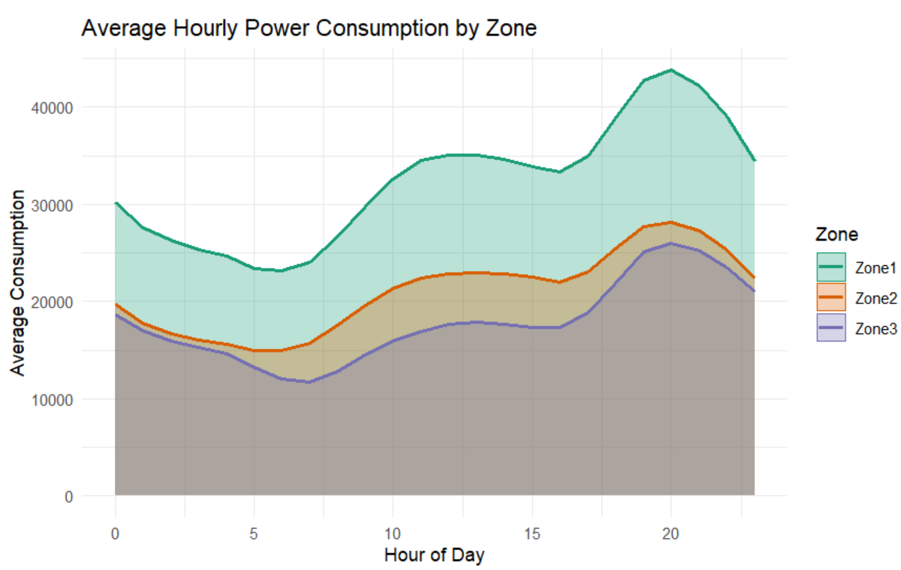
This question investigates whether electricity usage patterns vary across the three zones depending on the season of the year.

Does adding both solar radiations significantly improve the prediction of power consumption compared to using only temperature, humidity, and wind speed?

This question evaluates whether including solar radiation variables enhances model performance in predicting electricity usage.

Data Preparation and Exploration

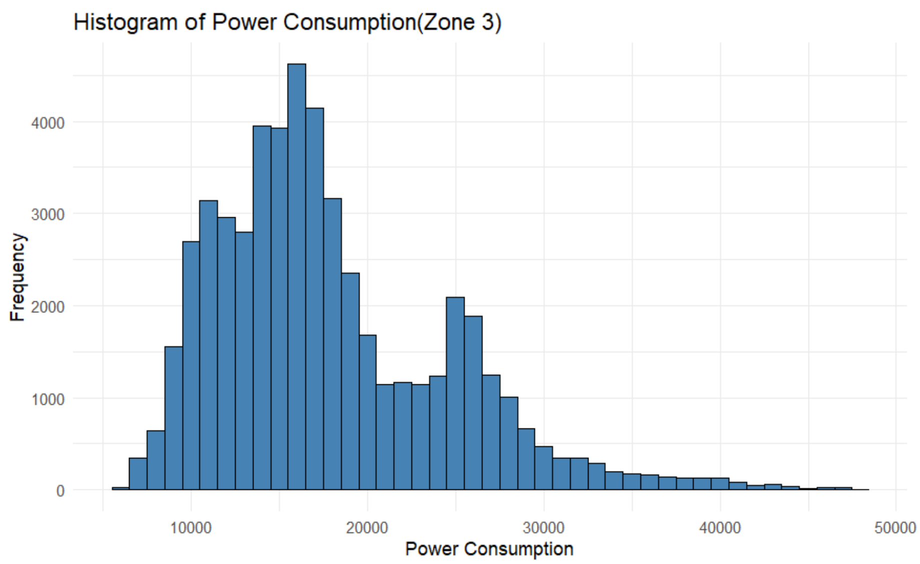
The dataset contains 52,416 observations measured at 10-minute intervals, with no missing values or anomalies detected. Therefore, no imputation or removal of rows was necessary. The variables' names were formatted as lower cases for standardization.



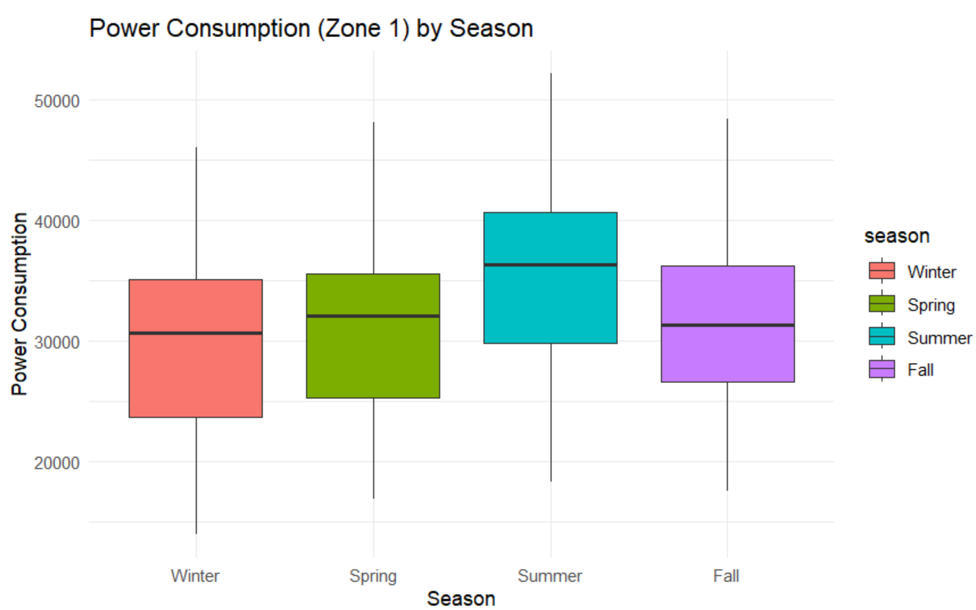
By time of day, the highest mean consumption occurred in the evening for all zones, with Zone 1 reaching 40,193.22 kWh (*SD* = 5,088.49), Zone 2 at 26,051.98 kWh (*SD* = 4,135.33), and Zone 3 at

23,792.01 kWh (*SD* = 6,753.12). The lowest means were recorded at night, particularly in Zone 3 (*M* = 15,790.86 kWh, *SD* = 4,922.84).

Histograms of power consumption in Zone 3 indicate a right-skewed distribution with a long tail toward higher values.



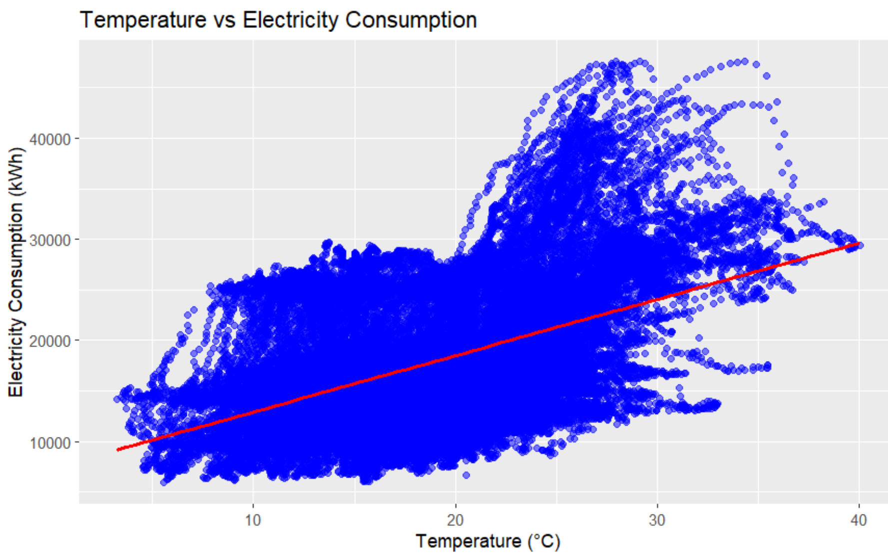
Boxplots illustrate seasonal differences in power consumption, with summer generally showing higher median values across zones.



Statistical Analysis

Question 1

The first research question aimed to determine whether temperature is correlated with electricity consumption in Morocco across three different zones. A Pearson's product–moment correlation test was conducted separately for each zone to examine the linear relationship between temperature (°C) and electricity consumption (kWh). This test was chosen because both variables are continuous and approximately normally distributed within the large sample. Scatter plots with fitted regression lines were also created to visualize the relationship.



The Temperature and Electricity Consumption in Zone 3

For Zone 1, there was a significant, moderate positive correlation between temperature and electricity consumption, $r(52{,}414) = .44$, 95% *CI* [.43, .45], $p < .001$. For Zone 2, there was a significant, moderate positive correlation, $r(52{,}414) = .38$, 95% *CI* [.38, .39], $p < .001$. For Zone 3, the correlation was also significant and moderate, $r(52{,}414) = .49$, 95% *CI* [.48, .50], $p < .001$
In Zone 1 and 3, higher temperatures were moderately associated with higher electricity consumption whereas it is weak in Zone 2.

Question 2

The second research question aimed to determine whether electricity consumption patterns differ across seasons and zones, and whether there is an interaction between these two factors. Before conducting the analysis, assumptions for a 2-way mixed ANOVA were reviewed. Given the large sample size, minor deviations from normality were not considered problematic. However, boxplot inspection revealed that more than 2% of the data points were statistical outliers. While these may represent genuine high-consumption periods, they were retained in the analysis. Potential seasonal effects can be revealed with further exploration.

A 2-way mixed ANOVA was conducted with season as a between-subject factor and zone as a within-subjects factor. A Huynh–Feldt correction was applied due to a violation of sphericity. There was a significant interaction between season and zone on power consumption, F (5.84, 7152.62) = 7344.33, $p < .001$. Pairwise comparisons with Bonferroni correction indicated that within each season, mean consumption differed significantly between all zones ($p < .001$).

For example, in winter, Zone 1 had the highest mean consumption (*M* = 30,340.83 kWh, *SD* = 6,903.11) compared to Zone 2 (*M* = 20,648.78, *SD* = 5,377.93) and Zone 3 (*M* = 15,357.90, *SD* = 5,005.77). In summer, Zone 1 consumption (*M* = 35,635.17, *SD* = 7,157.89) was also higher than Zone 2 (*M* = 23,185.38, *SD* = 5,182.44) and Zone 3 (*M* = 24,468.06, *SD* = 7,119.21). Across all seasons, Zone 3 generally had the lowest mean consumption, except in summer, where it slightly exceeded Zone 2.

Question 3

The third research question aimed to examine whether adding solar radiation variables improves the prediction of electricity consumption in Zone 1, beyond temperature, wind speed, and humidity. Before conducting the regression analyses, model assumptions were assessed. Although the normality of residuals assumption was violated, this is not uncommon with very large datasets, and the models were deemed robust to this deviation.

Two multiple linear regression models were estimated. The first model included temperature (°C), wind speed (m/s), and humidity (%) as predictors of electricity consumption in Zone 1 (kWh). The second model added general diffuse flows (W/m^2) as an additional predictor. Model comparison was conducted using an ANOVA test to assess improvement in model fit.
In the first model, temperature, wind speed, and humidity significantly predicted electricity consumption, $p < .001$. In the second model, which included general diffuse flows, the model remained significant, $p < .001$, and the coefficient (-1.73) for general diffuse flows was also statistically significant, $p < .001$.

An ANOVA comparing the two models indicated that adding general diffuse flows significantly improved the model fit, $F(1, 52{,}410) = 189.69$, $p < .001$. Although the increase in R^2 from .2044 to .2073 was small, the improvement was statistically significant, suggesting that general diffuse flows is a relevant predictor for power consumption in Zone 1.

Conclusion

This study investigated three key questions regarding electricity consumption in Morocco. First, temperature was found to be moderately and positively correlated with electricity use in all zones, with the strongest relationship observed in Zone 3 and the weakest in Zone 2. Second, a 2-way mixed ANOVA revealed a significant interaction between season and zone, indicating that seasonal effects on power usage vary across geographic areas. Zone 1 consistently recorded the highest consumption, while Zone 3 generally used the least, except in summer when it slightly exceeded Zone 2. Third, multiple regression analyses showed that temperature, wind speed, and humidity significantly predicted consumption in Zone 1, and that adding general diffuse flows—representing solar radiation—provided a small but statistically significant improvement in predictive accuracy.

Limitations

Although the dataset was large and comprehensive, certain limitations remain. The normality assumption for residuals was violated in regression analyses, though this is less critical with large samples. Outliers were present in more than 2% of cases, which may reflect genuine high-consumption events but could also influence statistical results. Additionally, the dataset was limited to environmental and time-related variables and did not include socioeconomic or behavioral factors that might also explain consumption patterns.

Future Research

Future work could involve controlled weather condition analyses—examining the effect of one environmental variable while holding other conditions constant. For example, assessing the influence of temperature on electricity consumption only when humidity, wind speed, and solar radiation are within a narrow, stable range. Such approaches would help isolate the true impact of each factor and reduce confounding effects from simultaneous changes in multiple weather variables. Further studies should also incorporate with household demographic and appliance usage data to better understand drivers of electricity consumption.

References

Kang, J., & Reiner, D. M. (2022). What is the effect of weather on household electricity consumption? Empirical evidence from Ireland. *Energy Economics, 111,* 106023. https://doi.org/10.1016/j.eneco.2022.106023