PREDICTING & MANAGING ENERGY DEMAND IN EXTREME HEAT CONDITIONS

A DATA-DRIVEN APPROACH FOR PREDICTING ENERGY USAGE & MANAGING PEAK DEMAND

TEAM MEMBERS:
ABHINAV BHANDARI
MEGH KURLEKAR
SUMIT KHARCHE
YASH SINGH

DATE: 24TH APRIL 2025

BUSINESS PROBLEM & PROJECT GOAL

Business Problem

Hotter summers are increasing the risk of power outages across South Carolina and parts of North Carolina

The energy provider, eSC, needs to prepare for rising electricity usage — especially in July when air conditioning demand peaks.

Our Goal

To help eSC:

- **Forecast energy usage in July**, using historical data.
- **Understand the impact of hotter weather** on peak demand.
- **Recommend actionable strategies** to reduce the risk of blackouts — without building costly new infrastructure.

PROJECT OVERVIEW

OBJECTIVE:

TO PREDICT ENERGY USAGE IN EXTREME HEAT CONDITIONS AND PROVIDE ACTIONABLE STRATEGIES FOR MANAGING PEAK DEMAND.

APPROACH:

WE INTEGRATE WEATHER, ENERGY, AND HOUSE DATA TO BUILD PREDICTIVE MODELS, WITH A FOCUS ON OPTIMIZING ENERGY USAGE DURING THE HOTTEST MONTHS.

OUTCOME:

DATA-DRIVEN INSIGHTS THAT HELP REDUCE ENERGY CONSUMPTION AND MITIGATE THE RISK OF BLACKOUTS DURING EXTREME SUMMER HEAT.

STATIC HOUSE DATA:

INCLUDES HOUSE ATTRIBUTES SUCH AS APPLIANCE TYPES, HVAC SYSTEMS, AND HOUSE SIZE.

ENERGY USAGE DATA:

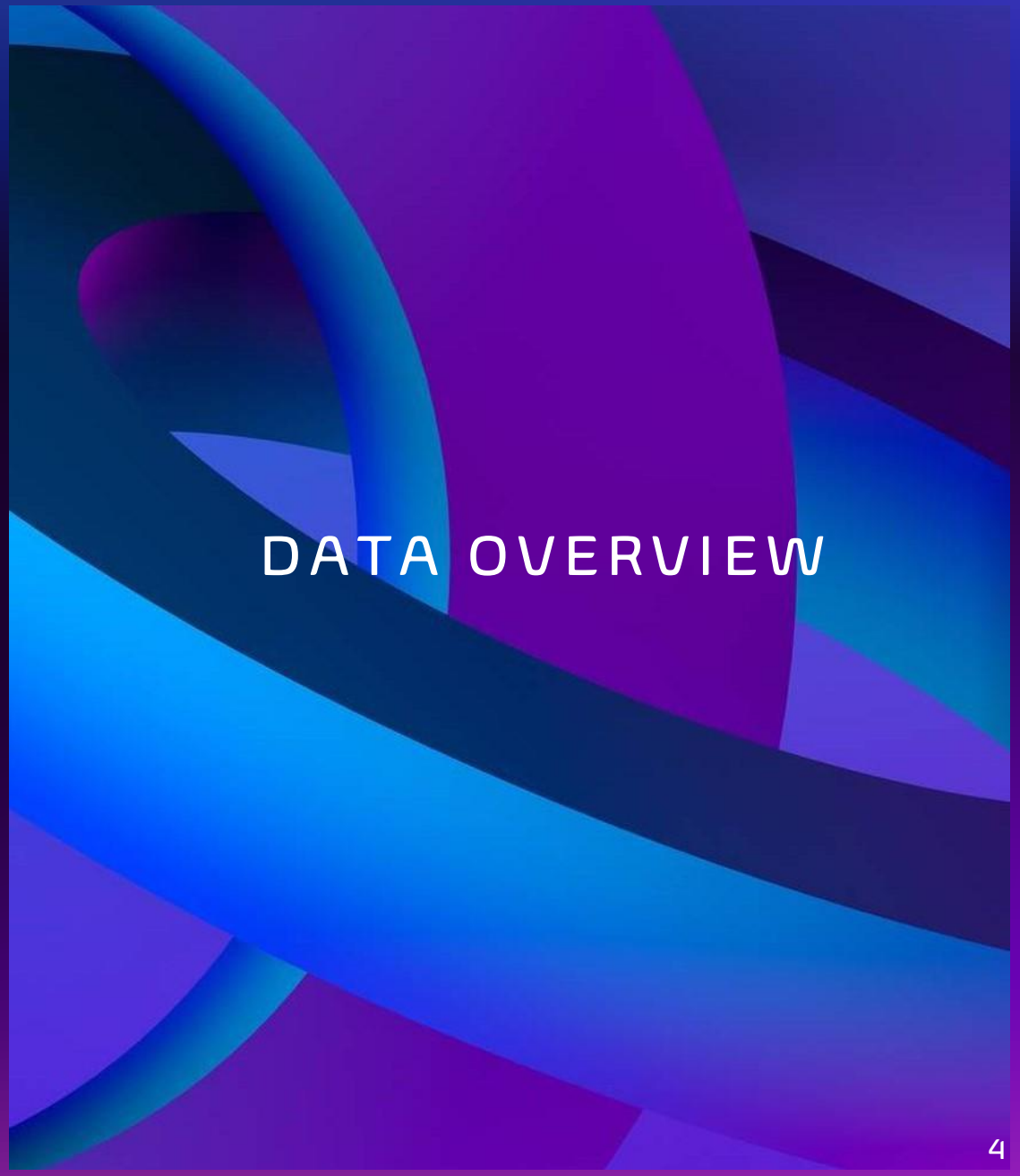
HOURLY ENERGY CONSUMPTION FOR 5,710 HOMES.

WEATHER DATA:

HOURLY WEATHER DATA, INCLUDING TEMPERATURE AND HUMIDITY FOR EACH COUNTY.

META DATA:

DESCRIPTIONS OF THE FIELDS IN THE DATASETS, INCLUDING HOUSE CHARACTERISTICS AND ENERGY USAGE TYPES.



DATA PREPARATION

DATA INGESTION:

MERGED WEATHER DATA BY COUNTY AND HOUSE DATA BY BUILDING ID.

CLEANING:

REMOVED MISSING DATA, STANDARDIZED FORMATS, AND HANDLED INCONSISTENCIES.

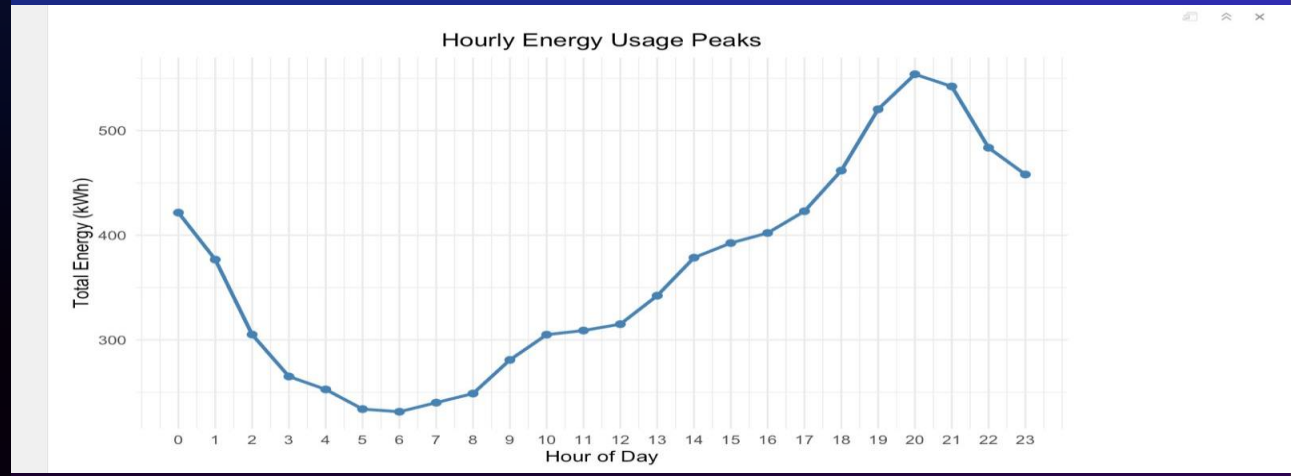
UNIFIED DATASET:

THE FINAL DATASET INCLUDES 12,607,680 OBSERVATIONS SPANNING JUNE TO AUGUST, READY FOR ANALYSIS.

EXPLORATORY DATA ANALYSIS (EDA)

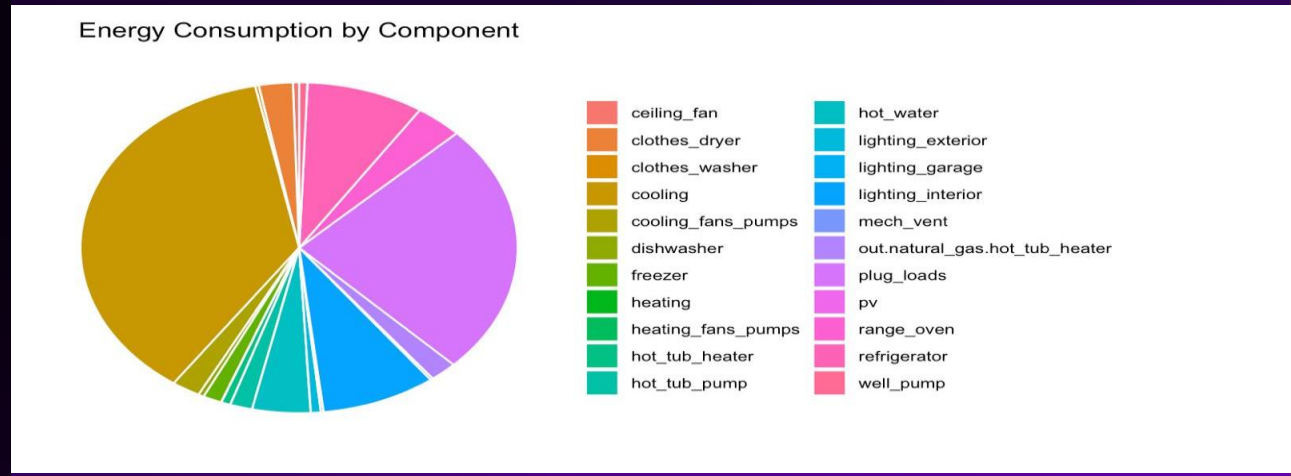
ENERGY USAGE PEAKS:

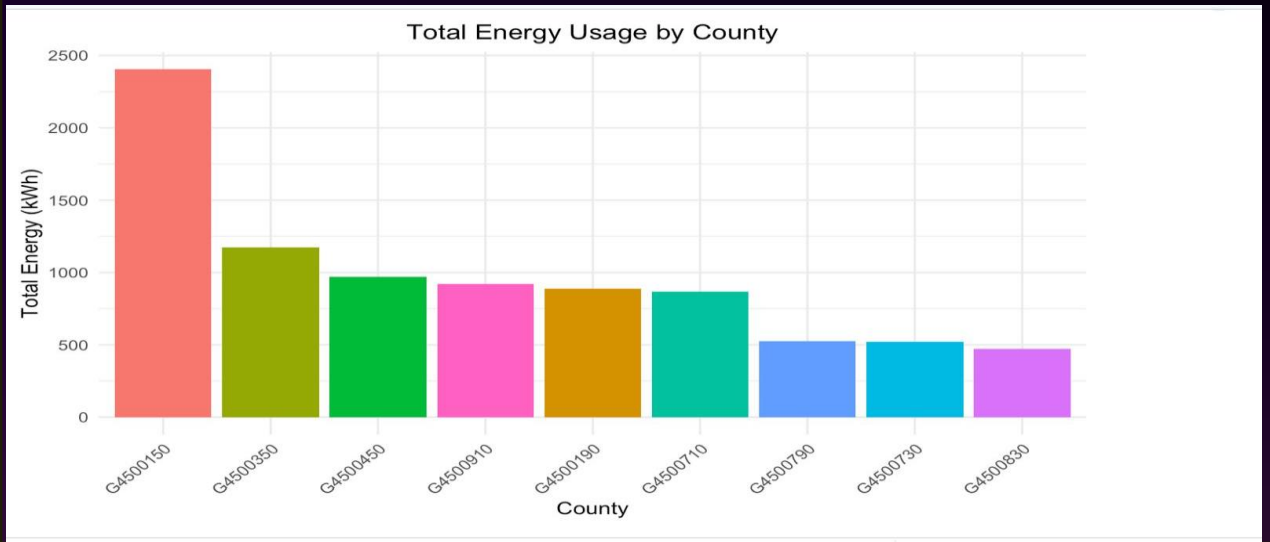
HIGHEST CONSUMPTION DURING AFTERNOONS AND EVENINGS.



KEY CONTRIBUTORS:

PLUG LOADS CONTRIBUTE THE MOST, FOLLOWED BY COOLING, LIGHTING, AND HEATING.





REGIONAL VARIATIONS:
URBAN AREAS EXPERIENCE HIGHER ENERGY USAGE DURING PEAK TIMES, WITH A SIGNIFICANT DIFFERENCE BETWEEN REGIONS.

PREDICTIVE MODELING

MODELS EXPLORED:

I. LINEAR REGRESSION: BASIC MODEL FOR ENERGY PREDICTION.

II. GRADIENT BOOSTING (XGBOOST): IMPROVED MODEL FOR BETTER ACCURACY.

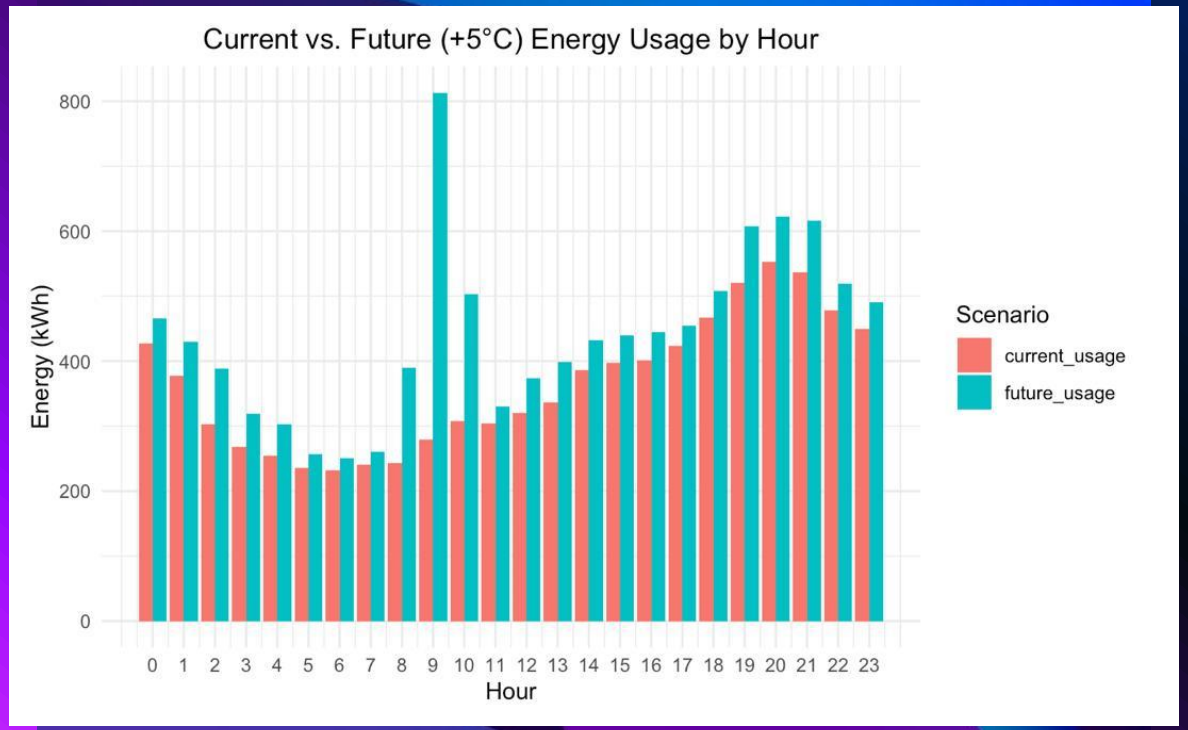
III. GENERALIZED ADDITIVE MODEL (GAM): BEST-PERFORMING MODEL FOR PREDICTING ENERGY USAGE.

MODEL INSIGHTS

Model	RMSE	R^2
Linear Regression	0.589	0.205
GAM (Best Model)	0.462	0.612
XGBoost	0.547	0.313

EVALUATION METRICS:

GENERALIZED ADDITIVE MODEL (GAM) PERFORMED BEST WITH THE HIGHEST R^2 OF 0.612 AND A LOW RMSE OF 0.462



FUTURE SCENARIOS

5ºC TEMPERATURE INCREASE:

PREDICTS ENERGY USAGE UNDER EXTREME HEAT CONDITIONS.

AVERAGE PEAK DEMAND INCREASE:

FROM 9:00 AM - 10:00 AM &
7:00 PM – 9:00 PM .

STRATEGIC RECOMMENDATION

I. **TIME-OF-USE PRICING**:
SHIFT ENERGY USE TO OFF-PEAK HOURS WITH DYNAMIC PRICING.
ENCOURAGE **NIGHT-TIME APPLIANCE USE**.

II. **SMART THERMOSTAT SUBSIDIES**:
OFFER SMART THERMOSTATS TO OPTIMIZE COOLING DURING PEAK HOURS.
PROMOTE **AUTOMATIC TEMPERATURE ADJUSTMENTS**.

III. **PUBLIC AWARENESS**:
EDUCATE CONSUMERS ON **LED USE**, **UNPLUGGING DEVICES**, AND **APPLIANCE EFFICIENCY**.

IV. **ENERGY-EFFICIENT APPLIANCES**:
INCENTIVIZE **ENERGY-EFFICIENT HVAC** AND **APPLIANCES** TO REDUCE OVERALL CONSUMPTION.

INTERACTIVE SHINY APPLICATION

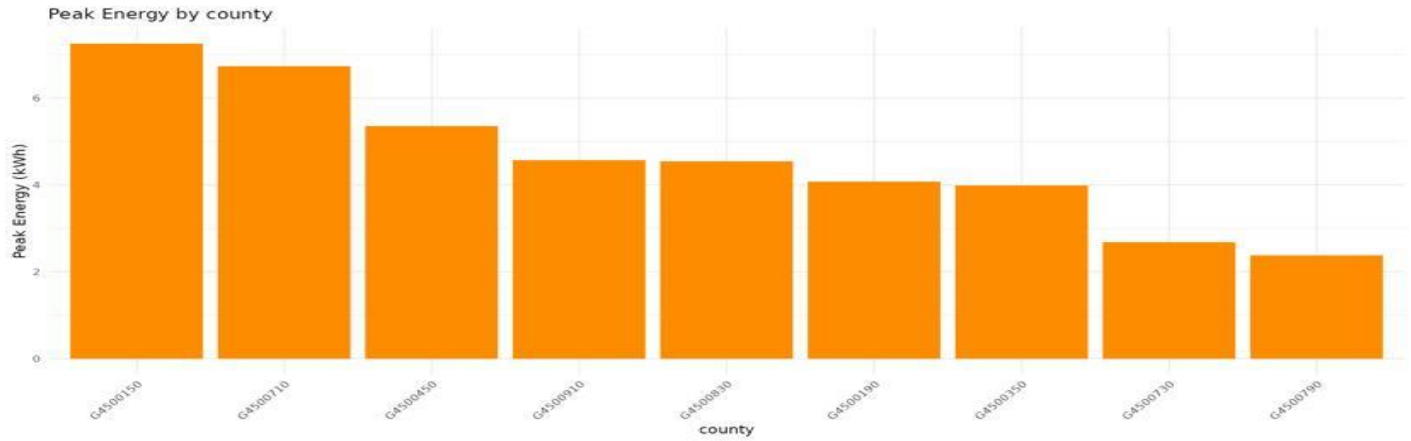
Energy Usage Explorer

Select date range:

2018-07-01 to 2018-07-31

Group peaks by:

County



group	peak_energy
G4500150	7.26
G4500710	6.73
G4500450	5.36
G4500910	4.57
G4500830	4.54
G4500190	4.08
G4500350	3.98
G4500730	2.68
G4500790	2.37

CHALLENGES & LEARNINGS

❑ **Data Inconsistency**

Overcame varied formats for robust analysis

❑ **Model Complexity**

Balanced accuracy with project understanding

❑ **Data Size Complexity**

Not able to run predictions with more fine-tuned parameters due to large and complex data size

❑ **Visualization Impact**

Key for stakeholder engagement and buy-in

CONCLUSION & NEXT STEPS

CONCLUSION:

- **GAM** IS THE BEST MODEL FOR PREDICTING **ENERGY USAGE** UNDER HEAT.
- **XGBOOST** PERFORMS WELL BUT **GAM** BALANCES **ACCURACY** AND **INTERPRETABILITY**.
- RECOMMENDATIONS WILL **REDUCE PEAK DEMAND** AND PREVENT BLACKOUTS.

NEXT STEPS:

- **REFINE MODEL**: IMPROVE **ACCURACY** AND INCLUDE MORE VARIABLES.
- **DEPLOY SHINY APP**: ENABLE **INTERACTIVE EXPLORATION** OF ENERGY DEMAND.
- **IMPLEMENT RECOMMENDATIONS**: ROLL OUT **PRICING** AND **SMART THERMOSTAT** PROGRAMS.
- **MONITOR & ADJUST**: TRACK PERFORMANCE AND **ADJUST STRATEGIES** AS NEEDED.

THANK YOU

Abhinav Bhandari | Megh Kurlekar | Sumit Kharche | Yash Singh