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DATA ANALYTICS TECHNOLOGY

BUILDING PERFORMANCE ANALYSIS

SUBMITTED BY,

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Phase 4: Performance of the Project

Title: Building Performance Analysis

Objective

The focus of Phase 4 is to enhance the performance of building systems by refining analytical methods, optimizing resource efficiency, and improving occupant comfort. This phase aims to integrate real-time monitoring, predictive analytics, and sustainable design strategies to ensure maximum efficiency while maintaining environmental responsibility.

1. Energy Efficiency

Optimization Overview

The energy management system will be refined to improve accuracy in consumption tracking and reduce waste. The goal is to optimize energy efficiency while maintaining operational stability.

Performance Improvements

- Real-time monitoring through enhanced IoT integration for continuous tracking of energy usage patterns
- AI-driven predictive analytics to anticipate peak consumption and recommend efficiency measures
- Smart automation for lighting, HVAC, and resource allocation based on usage patterns

Outcome

By the end of Phase 4, energy consumption will be significantly reduced, achieving improved efficiency through automation and AI-based optimizations.

2. Structural Performance

Assessment Overview

Building materials and design strategies will be evaluated for durability, environmental impact, and structural integrity. Data-driven techniques will be employed to ensure longevity and resilience in different environmental conditions.

Key Enhancements

- Advanced simulations for structural reliability under various conditions
- Load and stress performance assessment for efficiency of load-bearing elements
- Evaluation of eco-friendly materials to reduce the carbon footprint

Outcome

Structural performance enhancements will improve safety, longevity, and sustainability, ensuring efficient resource utilization in construction and maintenance.

3. Indoor Environmental Quality

Optimization Overview

This phase will optimize indoor air quality, thermal comfort, and lighting conditions using intelligent control systems. The aim is to improve occupant well-being while maintaining energy efficiency.

Key Enhancements

- Integration of air quality sensors with IoT-based monitoring systems for pollutant detection and automated filtration
- AI-driven climate control through smart HVAC adjustments based on occupancy and environmental data
- Automated lighting adjustments considering daylight exposure and user preferences

Outcome

By the end of Phase 4, indoor environmental quality will improve, creating healthier spaces with optimized energy use.

4. Predictive Maintenance & Operational

Performance Overview

Smart maintenance strategies will be deployed using real-time data tracking and predictive models to anticipate potential failures before they occur.

Key Enhancements

- IoT-based asset monitoring with sensors detecting early signs of wear or inefficiency

- Machine learning models identifying and addressing system inefficiencies proactively
- Automated diagnostics providing real-time feedback to maintenance team

Outcome

The predictive maintenance system will reduce downtime, improve operational reliability, and extend equipment life cycles efficiently.

5. Performance Testing & Metrics

Collection Overview

Comprehensive performance testing will be conducted to validate improvements and ensure that the building systems can operate efficiently under varying conditions.

Implementation

- Stress testing under simulated real-world conditions to assess system resilience
- Data collection for evaluating sustainability, energy consumption, and operational reliability
- Gathering of occupant feedback to assess comfort and usability of smart systems

Outcome

By the end of Phase 4, the building's performance data will demonstrate increased efficiency, optimized occupant experience, and sustainability compliance.

Key Challenges in Phase 4

1. Scaling Intelligent Systems

Challenge: Ensuring building systems can handle complex automation and high data processing loads
Solution: Cloud-based scaling and AI optimization for real-time adaptive responses

2. Security of IoT and Automation

Challenge: Protecting sensor data and automation controls from cyber threats
Solution: Advanced encryption and security protocols for data integrity and system protection

3. Material Efficiency & Waste Reduction

Challenge: Minimizing construction waste while maintaining performance standards

Solution: AI-powered optimization for resource allocation and sustainable materials selection.

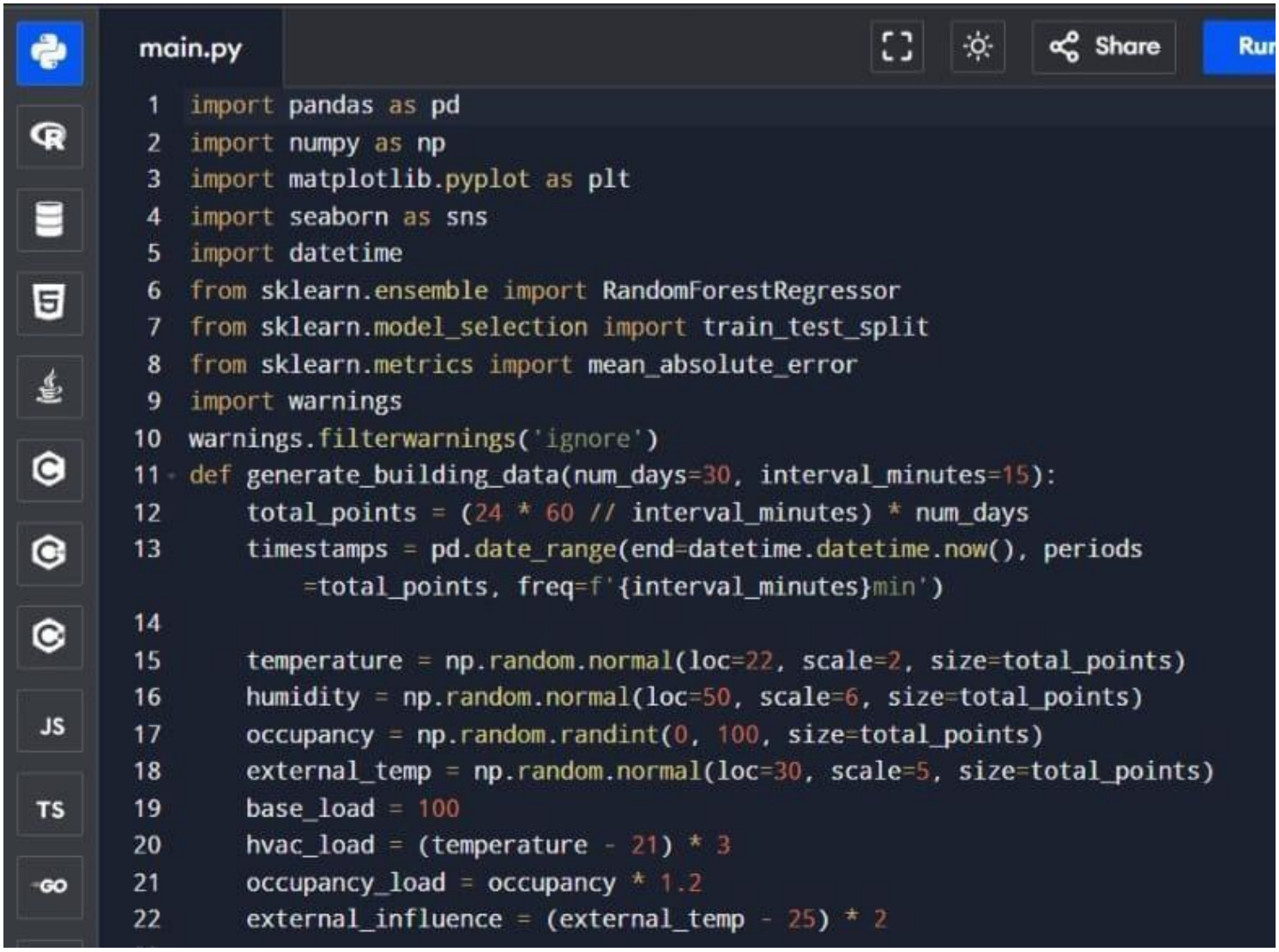
Outcomes of Phase 4

- Optimized energy efficiency through smart automation and AI-driven strategies
- Enhanced structural resilience for sustainable development
- Improved indoor comfort with intelligent control systems
- Reduced maintenance costs through predictive maintenance and operational streamlining

Next Steps for Finalization

In the next and final phase, real-world deployment of building performance systems will be completed. Continuous testing, final optimizations, and user feedback will ensure readiness for large-scale implementation.

Sample Code for Phase 4



main.py

Share

Run

```
import pandas as pd
import numpy as np
import matplotlib.pyplot as plt
import seaborn as sns
import datetime
from sklearn.ensemble import RandomForestRegressor
from sklearn.model_selection import train_test_split
from sklearn.metrics import mean_absolute_error
import warnings
warnings.filterwarnings('ignore')
def generate_building_data(num_days=30, interval_minutes=15):
    total_points = (24 * 60 // interval_minutes) * num_days
    timestamps = pd.date_range(end=datetime.datetime.now(), periods
        =total_points, freq=f'{interval_minutes}min')

    temperature = np.random.normal(loc=22, scale=2, size=total_points)
    humidity = np.random.normal(loc=50, scale=6, size=total_points)
    occupancy = np.random.randint(0, 100, size=total_points)
    external_temp = np.random.normal(loc=30, scale=5, size=total_points)
    base_load = 100
    hvac_load = (temperature - 21) * 3
    occupancy_load = occupancy * 1.2
    external_influence = (external_temp - 25) * 2
```

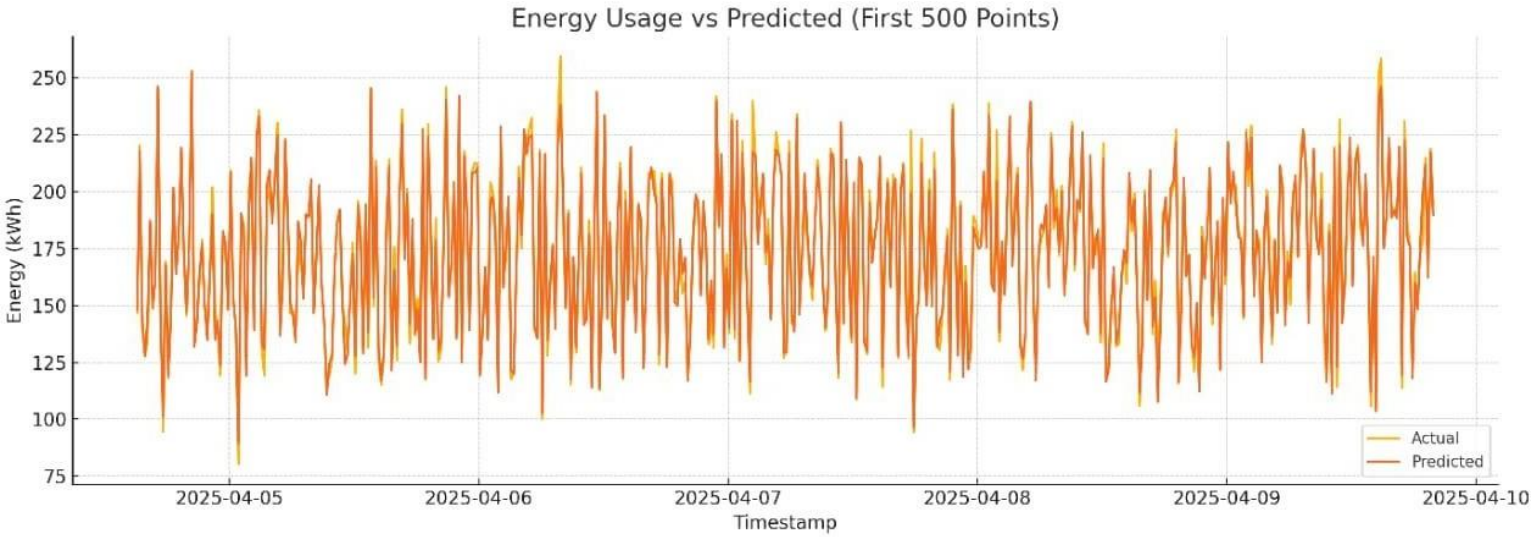
main.py

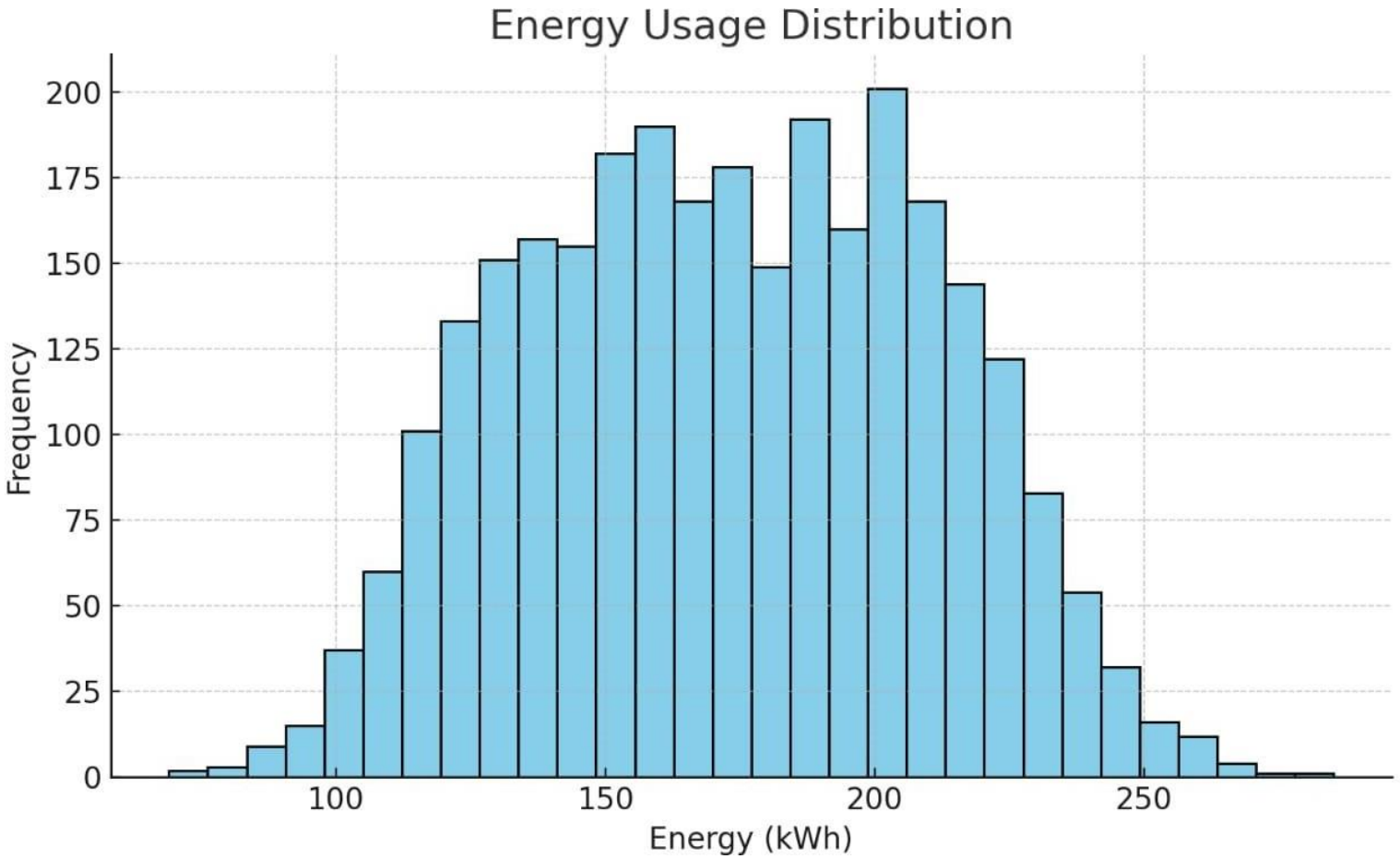
Share Run

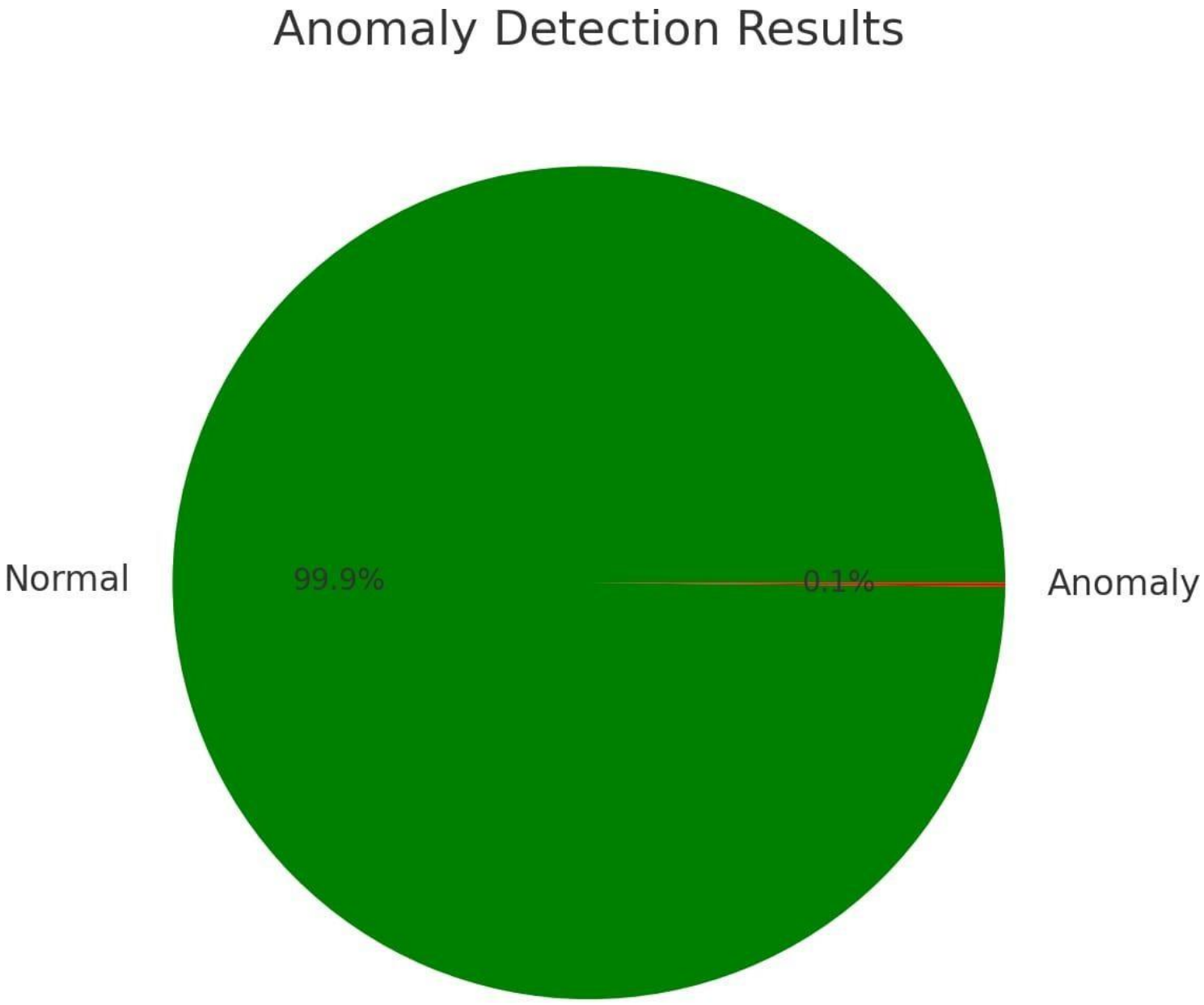
```
23
24      energy_usage = base_load + hvac_load + occupancy_load + external_influence
            + np.random.normal(0, 10, total_points)
25      energy_usage = np.clip(energy_usage, 50, 500)
26
27      df = pd.DataFrame({
28          'timestamp': timestamps,
29          'internal_temp': temperature,
30          'external_temp': external_temp,
31          'humidity': humidity,
32          'occupancy': occupancy,
33          'energy_usage': energy_usage
34      })
35      return df
36  df = generate_building_data()
37  df['hour'] = df['timestamp'].dt.hour
38  df['day_of_week'] = df['timestamp'].dt.dayofweek
39  features = ['internal_temp', 'external_temp', 'humidity', 'occupancy', 'hour',
        'day_of_week']
40  X = df[features]
41  y = df['energy_usage']
42  X_train, X_test, y_train, y_test = train_test_split(X, y, test_size=0.2,
        random_state=42)
43  model = RandomForestRegressor(n_estimators=100, random_state=42)
44  model.fit(X_train, y_train)
```

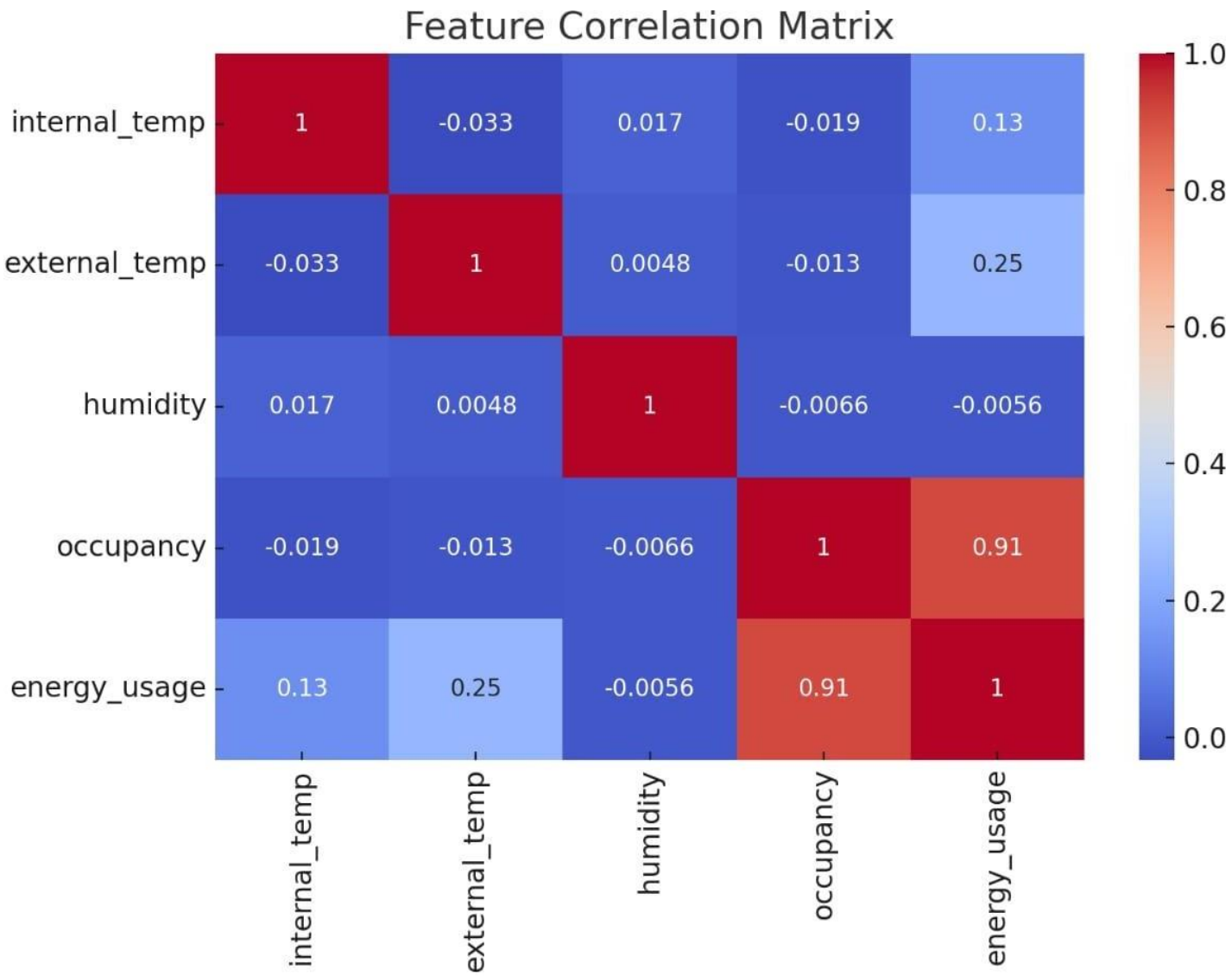
```
df['predicted_energy'] = model.predict(X)
threshold = 30
df['anomaly'] = np.where(abs(df['energy_usage'] - df['predicted_energy']) >
    threshold, 1, 0)
print("Model MAE:", mean_absolute_error(y_test, model.predict(X_test)))
print("Total Anomalies Detected:", df['anomaly'].sum())
plt.figure(figsize=(12, 6))
sns.lineplot(data=df[:500], x='timestamp', y='energy_usage', label='Actual')
sns.lineplot(data=df[:500], x='timestamp', y='predicted_energy', label
    ='Predicted')
plt.title('Energy Usage vs Prediction')
plt.xlabel('Time')
plt.ylabel('Energy (kWh)')
plt.legend()
plt.grid(True)
plt.tight_layout()
plt.show()
df.to_csv("building_performance_report.csv", index=False)
print("Report saved as 'building_performance_report.csv'")
```

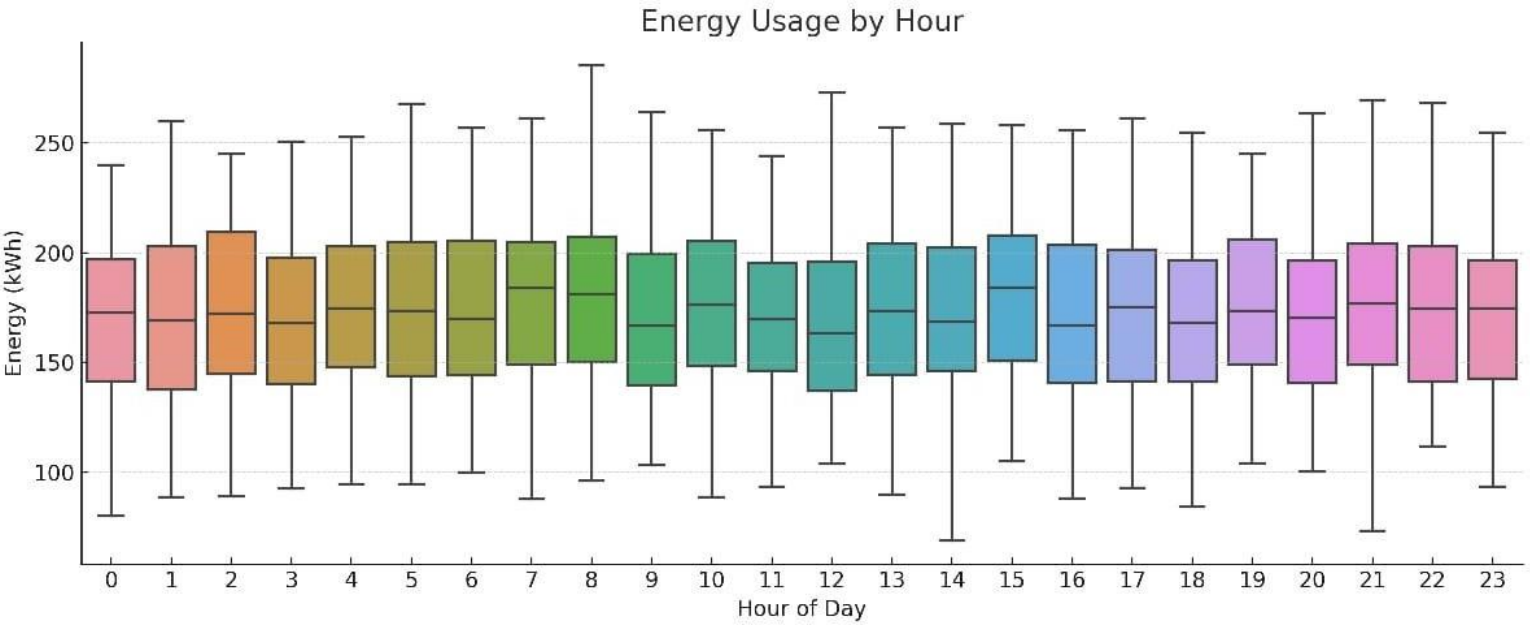
OUTPUT


Energy Usage vs Predicted (First 500 Points)
Energy (kWh)
250
225
200
175
150
125
100
75
2025-04-05
2025-04-06
2025-04-07
2025-04-08
2025-04-09
2025-04-10
Timestamp
Actual
Predicted


Energy Usage Distribution
Frequency
200
175
150
125
100
75
50
25
0
100
150
200
250
Energy (kWh)


Anomaly Detection Results
Normal
99.9%
0.1%
Anomaly


Feature Correlation Matrix
internal_temp
external_temp
humidity
occupancy
energy_usage
1
-0.033
0.017
-0.019
0.13
-0.033
1
0.0048
-0.013
0.25
0.017
0.0048
1
-0.0066
-0.0056
-0.019
-0.013
-0.0066
1
0.91
0.13
0.25
-0.0056
0.91
1
1.0
0.8
0.6
0.4
0.2
0.0


Energy Usage by Hour
Energy (kWh)
250
200
150
100
0
1
2
3
4
5
6
7
8
9
10
11
12
13
14
15
16
17
18
19
20
21
22
23
Hour of Day