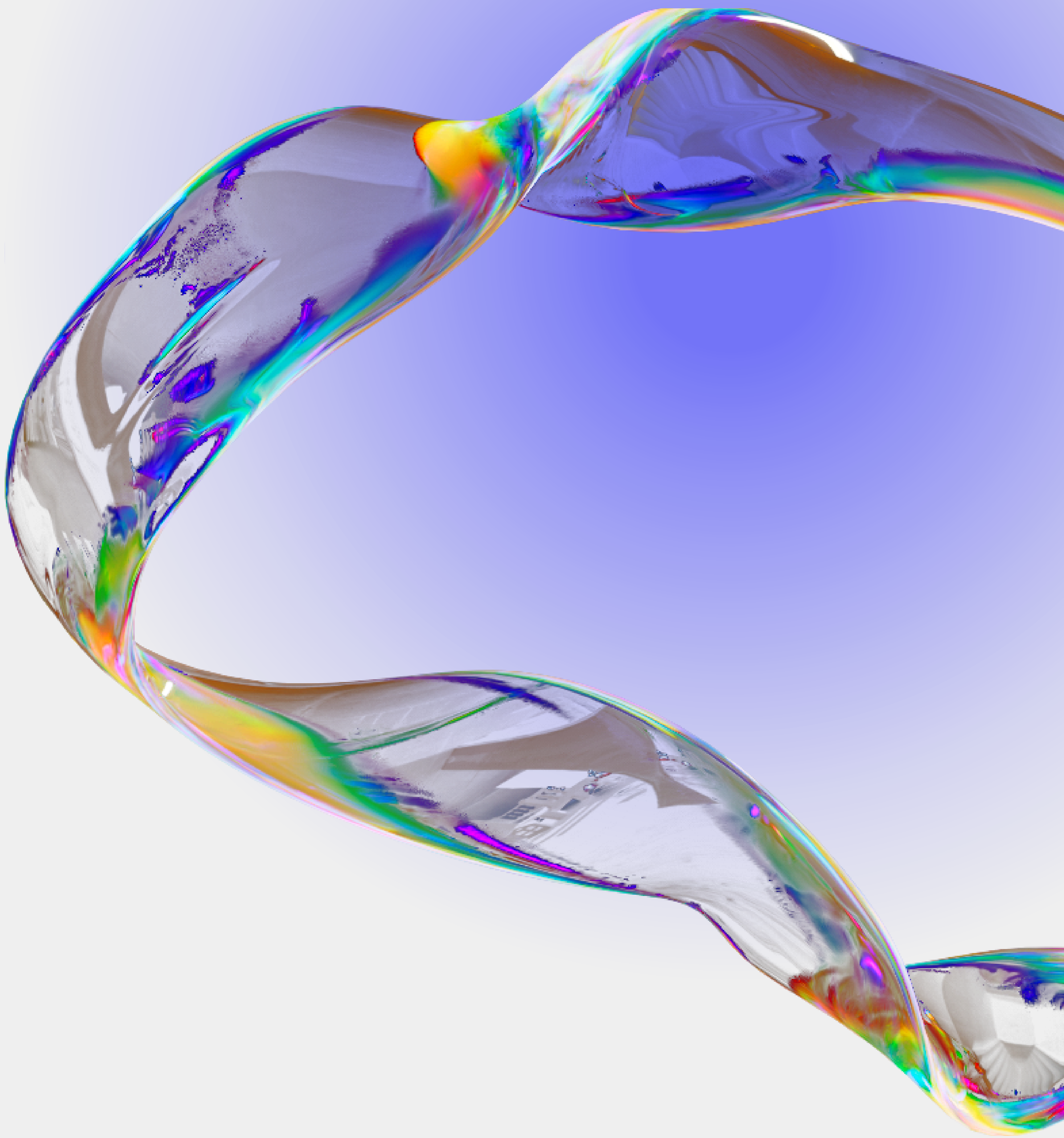
IE MBD SEPT 2023 - Capstone Project - July 2024

Electritect

Revolutionizing energy management with AI



MEET THE BIG DATA TEAM

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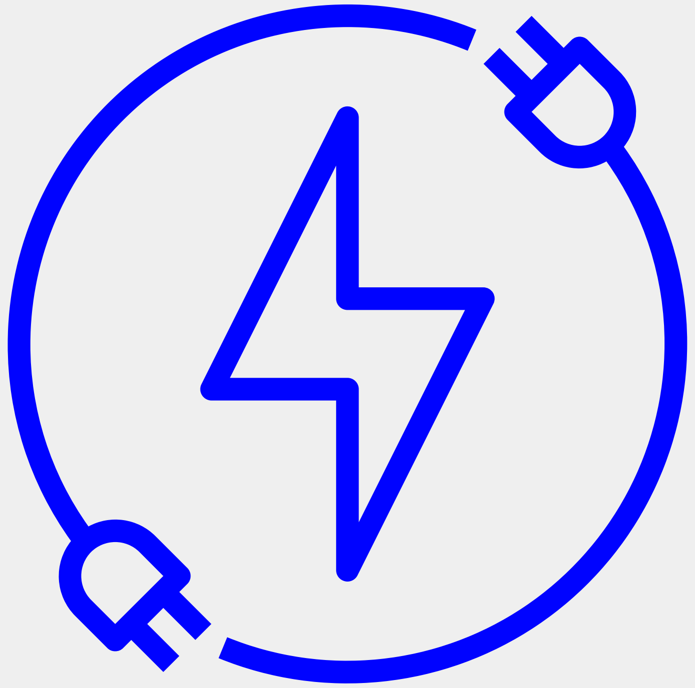
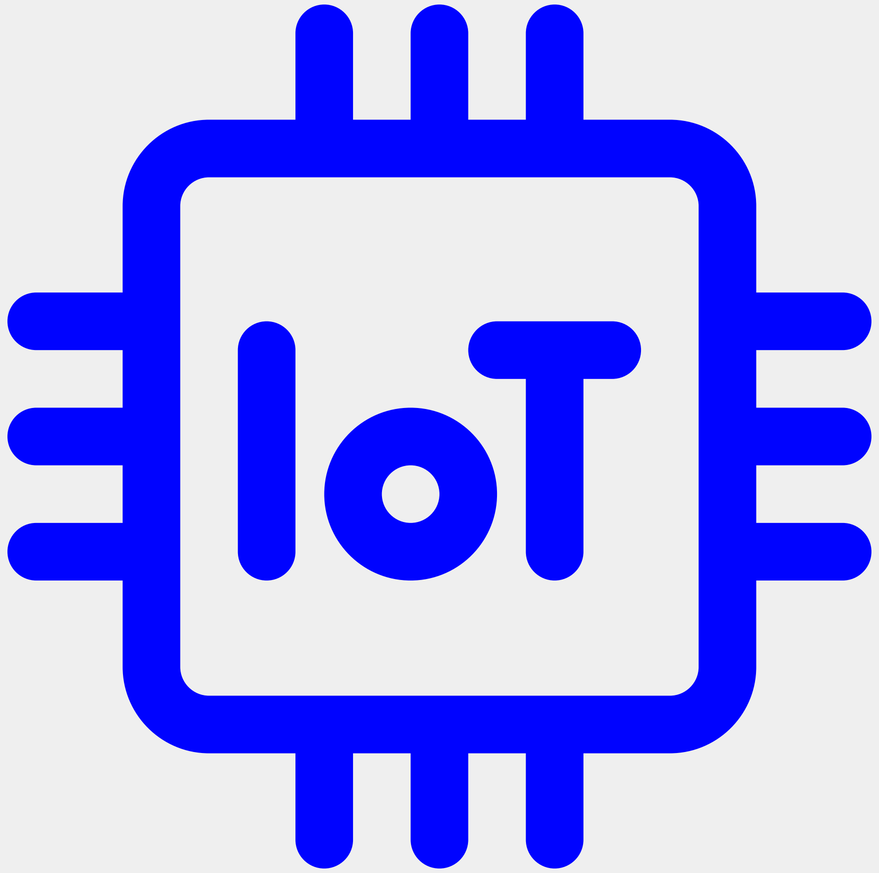
Agenda

Energy optimization is critical due to fluctuating costs and environmental regulations



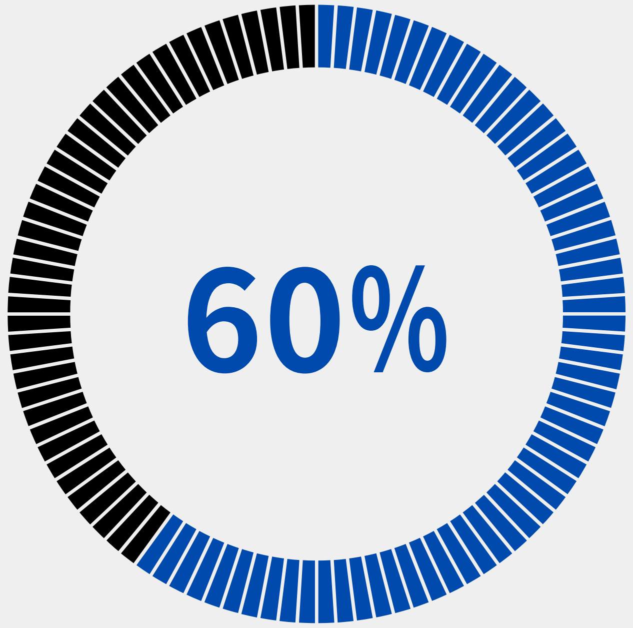
Electricity is an **essential commodity**

Industrial companies face **high energy consumption**



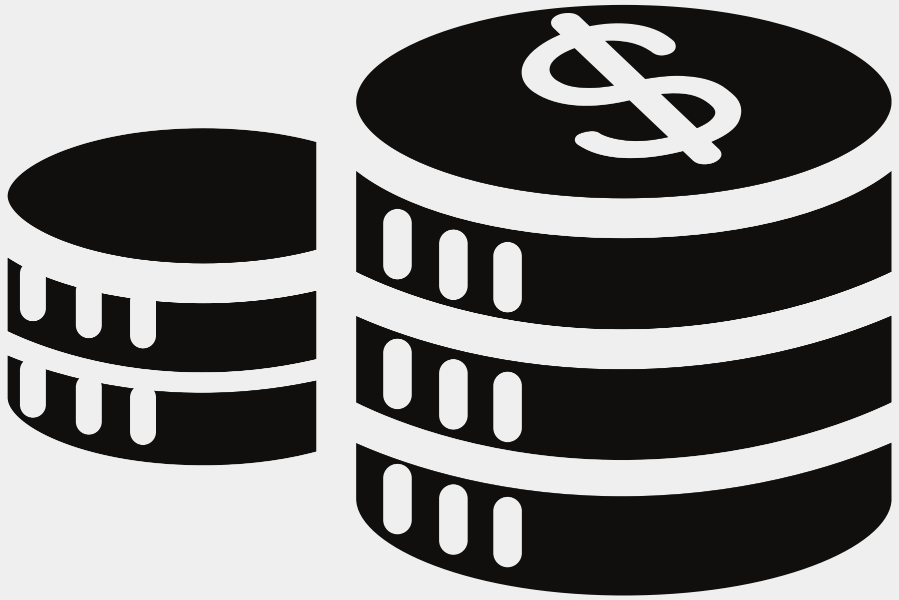
IoT technology in **monitoring**, control, customization, and prediction in industrial settings.

Current Landscape



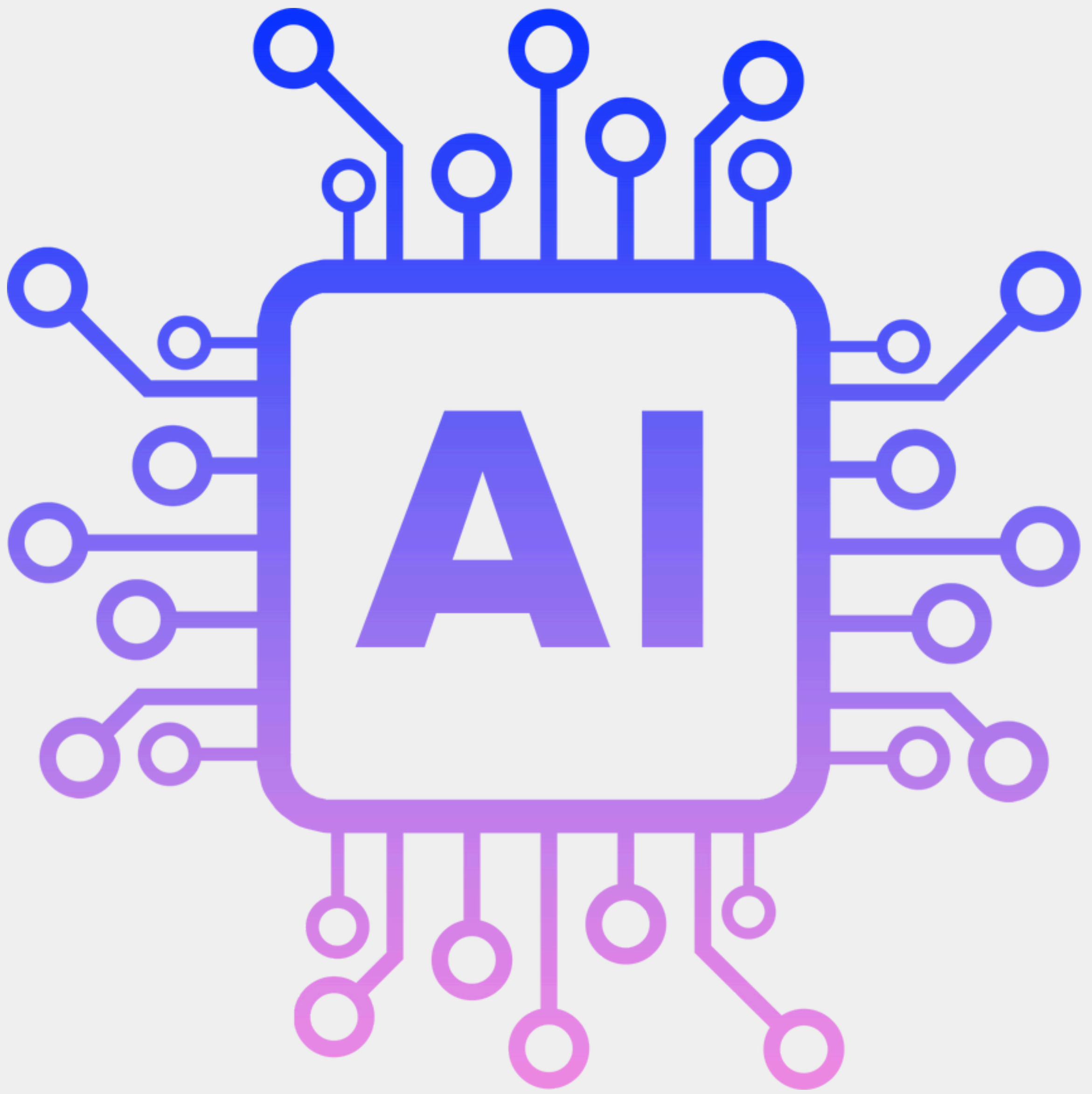
Large corporations account for **60% of total industrial energy usage.**

Compliance with regulations like the **EU's Green Deal** is crucial for sustainability and reputation



Energy expenses can constitute up to **30% of operational costs.**

What is Electritect?



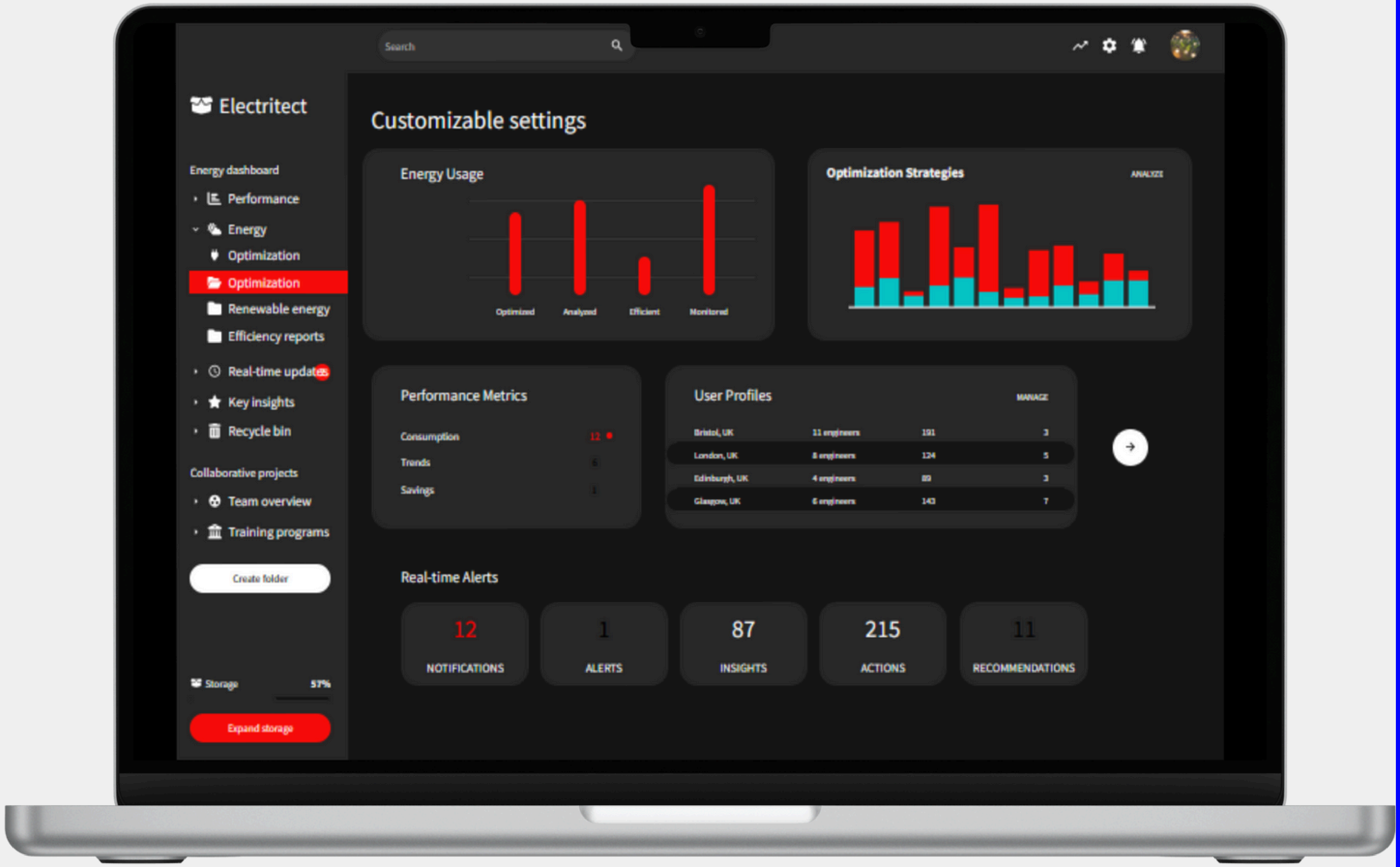
AI-powered Software-as-a-Service for large corporations to optimize their energy usage

What is Electritect?

I. Reducing Operating Costs

II. Enhanced Environmental Sustainability

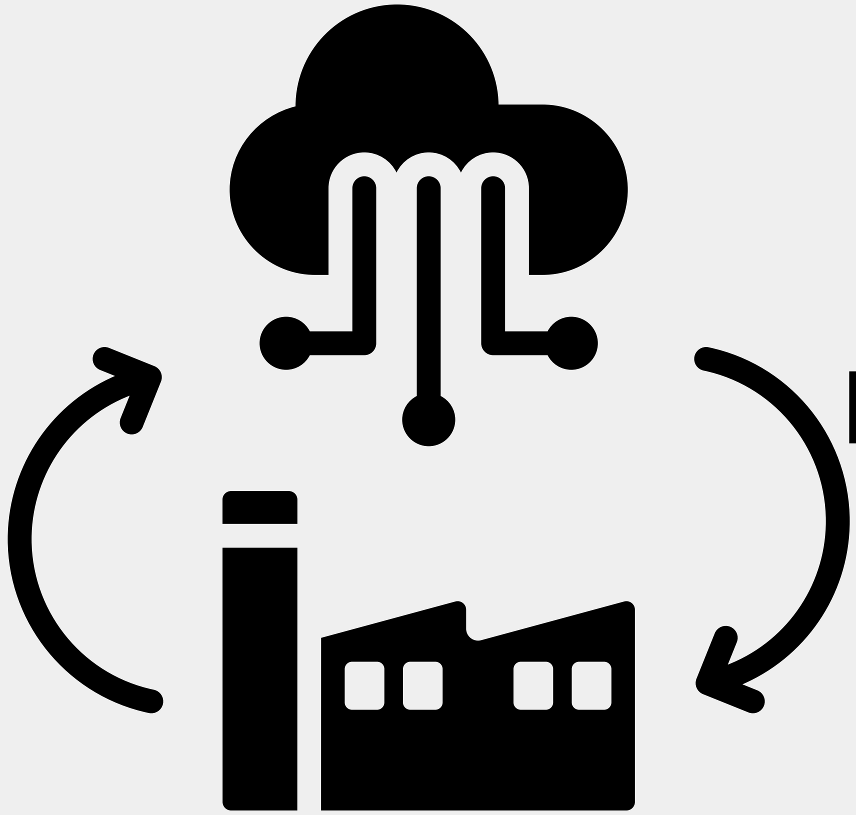
III. Compliance with Regulations



How can we achieve this?

IoT data as technical advantage

EDA + Coding



Optimization of the energy usage

Industry facilities

Goals & Needs

Industrial datasets showcase

Real energy dataset from 3 industrial sites in EU

A dataset containing real data related to energy consumption from 3 industrial sites in EU

Dataset

IndustrialSites.zip

i-NERGY GEM-GREEN

Energenius website

Reasons

- **Size**: Medium to Big Industry
- Building **Operational Data**
- **Indoor** environmental **measurements**
- **Sub-sectors** within the same industry **would showcase scalability** in our business solution
- **EU Industry**, which is our target market

Optimization Algorithm

Solver is based on
Pyomo

I Objective Function

II Decision Variables & Parameters

III Constraint Equations

IV Bounds

V Forecasting

I. Objective Function

Cornerstone of our optimization model

$$Cost = \sum_{h} \sum_{i}^{N} P_h \times E_{i,h}$$

P_h Hourly energy price ($ / kWh)

$E_{i,h}$ Energy consumed per sector at a given time (kWh)

II. Decision Variables & Parameters

- **Decision Variables:** under our control.
- **Parameters:** we do not have any control over them neither by choice nor by nature.

Decision Variables	Parameters
Temp. Set Point	Outdoor Temperature
# Active Lights	Outdoor Humidity
# Active Printers	Energy Price

III. Constraint Equations

- Links **decision variables** and **parameters** to the **objective function**
- Practical and adhere to real-world limitations

$$E_i = a_i + \sum_{k}^{K} b_k DV_k + \sum_{j}^{J} c_j Params_j$$

Chiller Group	**Compressor**
Data Center	**Office Space**
Production	**Ultrasonic Testing Apparatus (UTA)**

IV. Bounds

Defines how the math should behave to simulate real-world scenarios

- Temperature Set Point between 18 °C and 25 °C
- Printers Active During the Data
- More Active Data Center Hardware during peak hours
- Energy consumption cannot be below zero

V. Tomorrow's Parameter Values

- Future savings can be achieved utilizing forecasting techniques for our parameters
- **OMIE:** hourly day ahead energy prices
- **Visual Crossing API:** tomorrow's weather
- **Forecasting:**
  - SARIMA(p,d,q)(P,D,Q)*s*
  - Random Forest Regressor transformed with sinusoidal features
  - ARIMA(5,1,0)
  - ARIMA(8,1,0)

Timeline:

July 1st, 2022
00:00h

15-minute
granularity

June 30th, 2023
23:45h

Variables

Energy (kWh), **Power** (kW), **Power Factor** (real), **Temperature** (°C), **Flow Rate** (m^3/h), **Preassure** (bar), **Quantity** (m^3)

Format

Unique Sector in 3 different format: **Active Energy, Power Factor and Active Power**.

+

"Global Variables" (e.g. General Electric Active Energy)

Nulls

Industry 1 & 3 ≈ 0.3%
Industry 2 =10%

Solution → **"Forward Fill"**

Outliers

Relationship Encountered

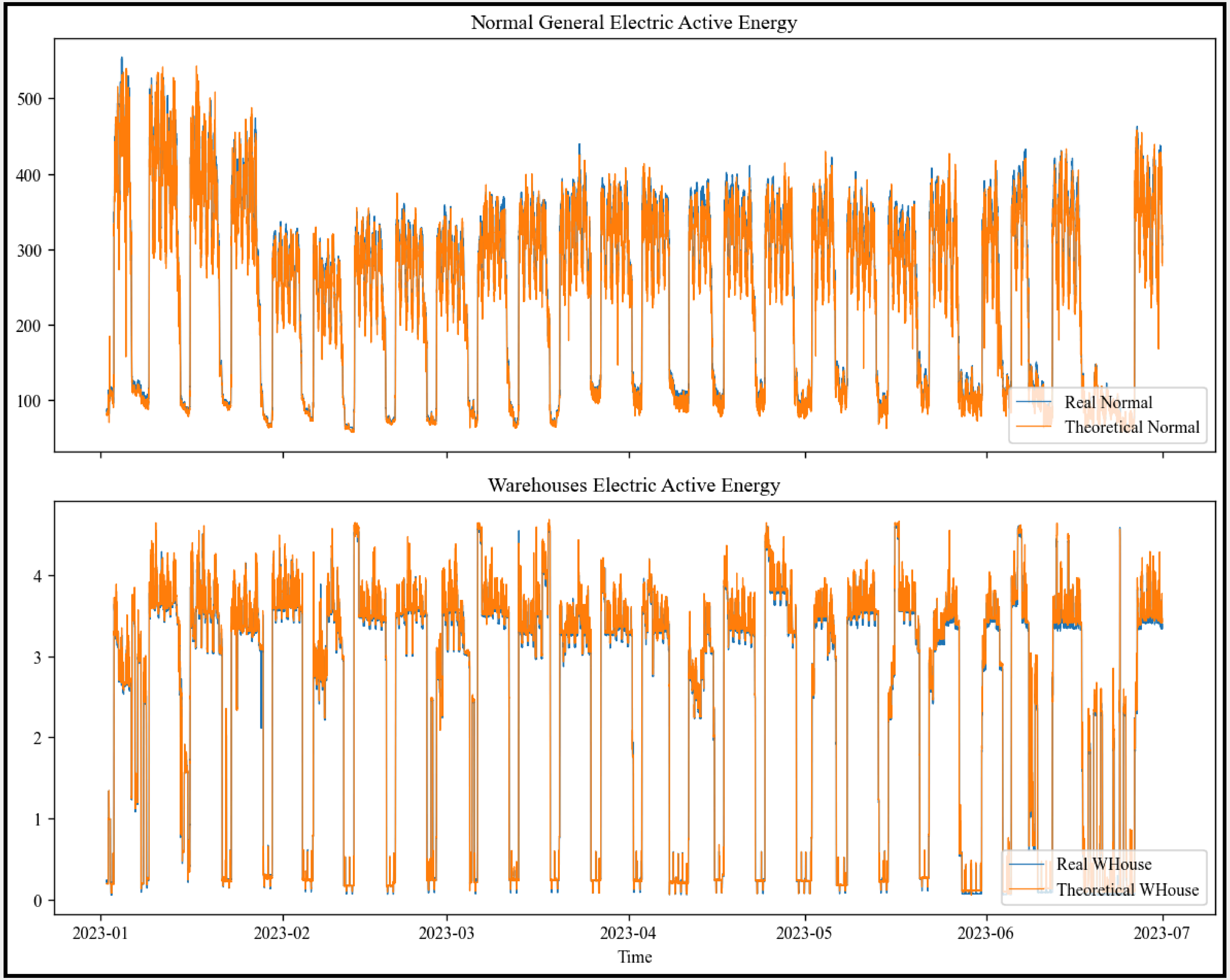
I. Monitored *vs* Theoretical Energy

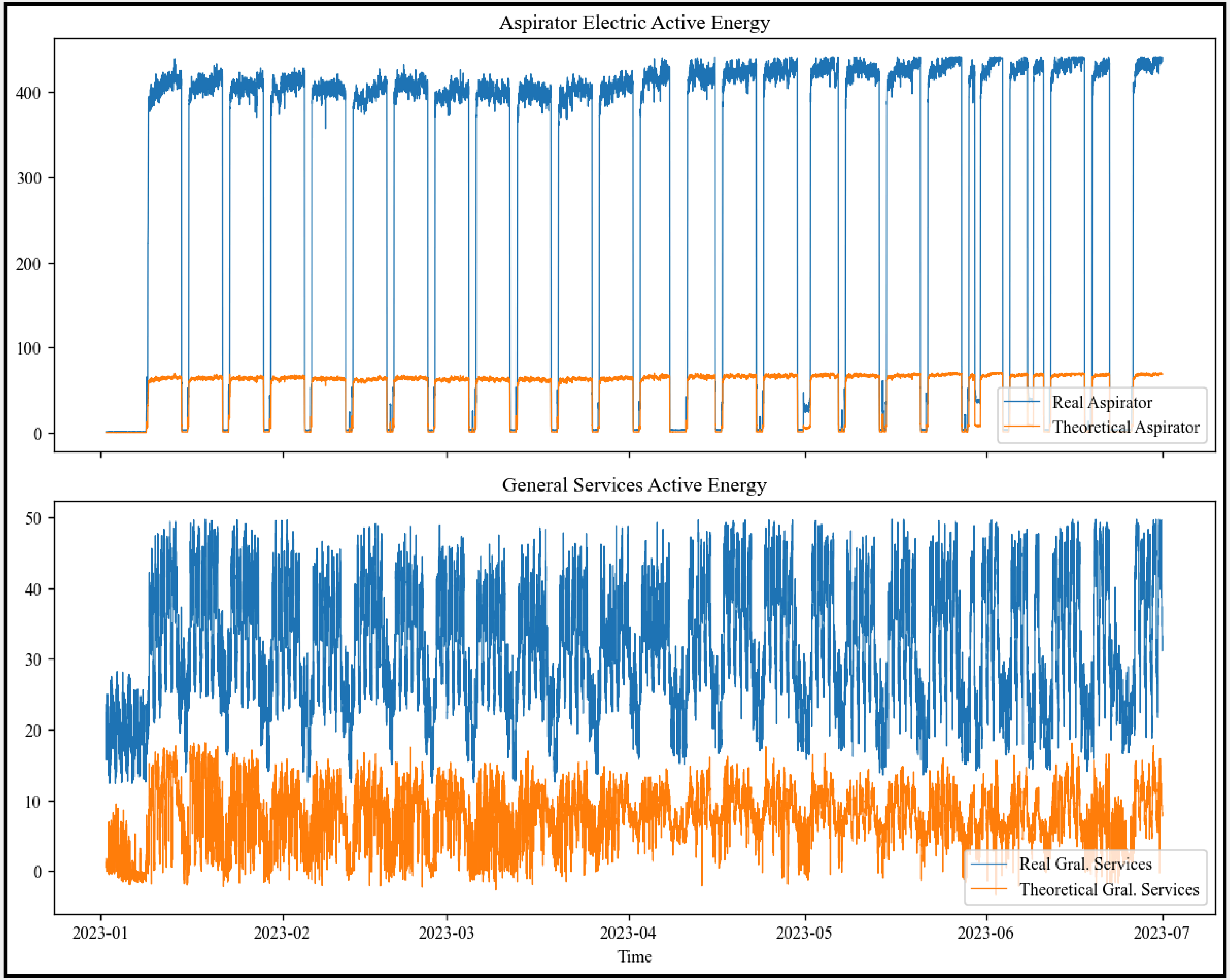
Active Energy

Active Power

Power Factor

$$Energy = Power \times 0.25 \times PowerFactor$$


Normal General Electric Active Energy
Real Normal
Theoretical Normal
100
200
300
400
500
Warehouses Electric Active Energy
Real WHouse
Theoretical WHouse
0
1
2
3
4
2023-01
2023-02
2023-03
2023-04
2023-05
2023-06
2023-07
Time



Aspirator Electric Active Energy
400
300
200
100
0
Real Aspirator
Theoretical Aspirator
General Services Active Energy
50
40
30
20
10
0
Real Gral. Services
Theoretical Gral. Services
2023-01
2023-02
2023-03
2023-04
2023-05
2023-06
2023-07
Time

16

Exploratory Data Analysis

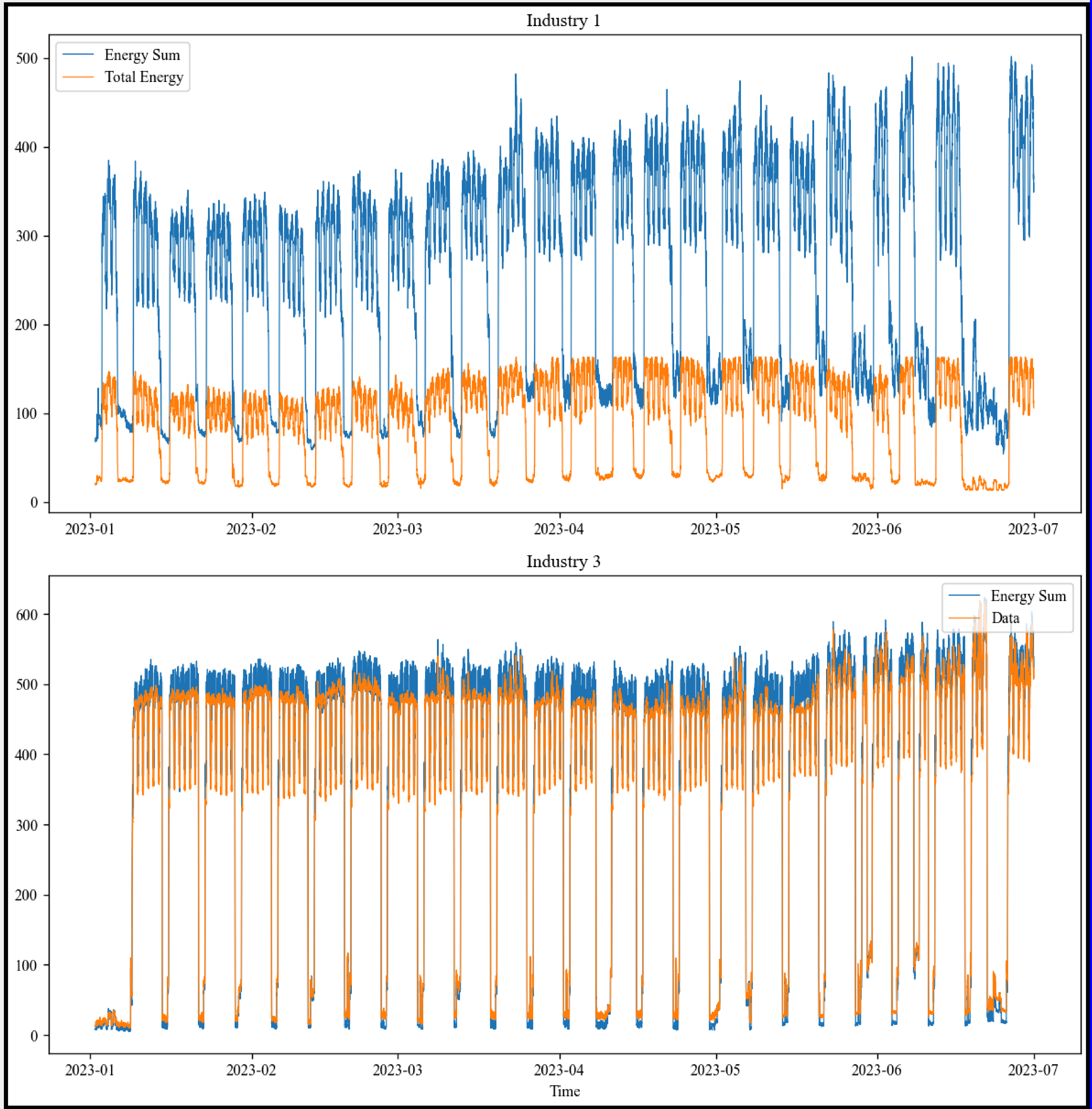
Relationship Encountered

II. Aggregation of Active Energies

$$\sum_{i}^{N} E_i$$

=?

Gen.Elec.Energy



Relationship Encountered

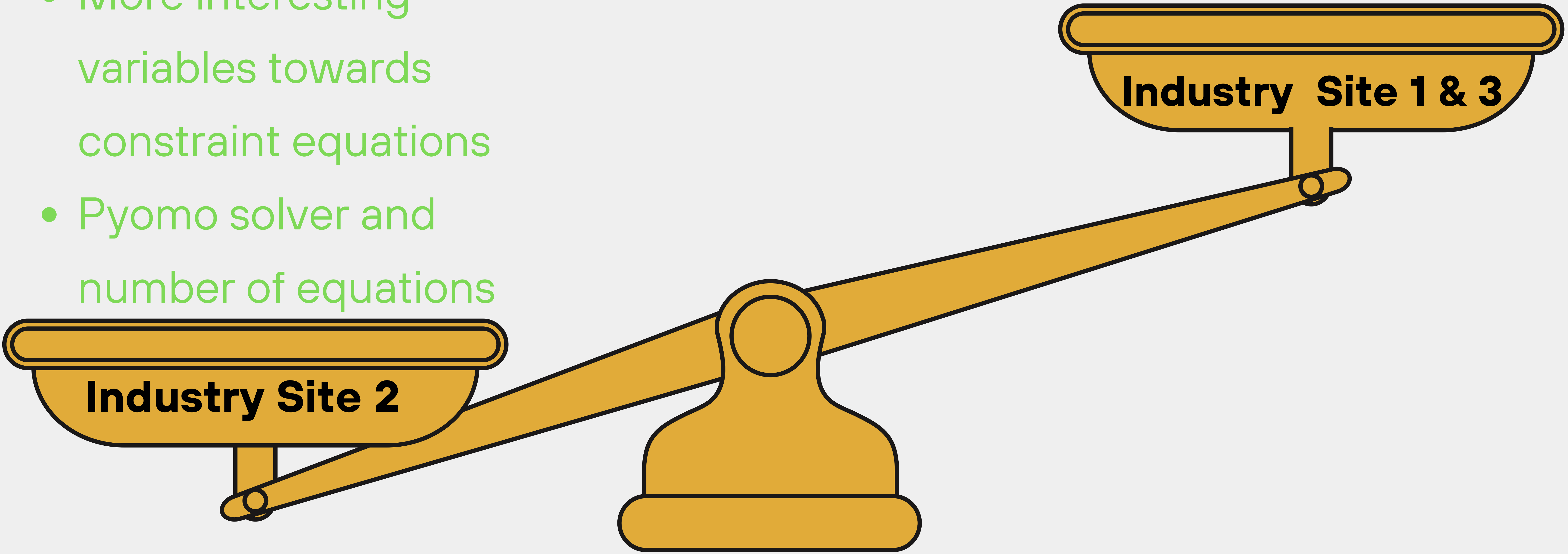
III. Hourly Aggregation

- By aggregating 15-minute interval data into hourly data, the size of the dataset was reduced by a factor of four.
- When relating the variables to other parameters or decision variables. Frequently presented as hourly data.

A new processed dataset …

- 10% of null values
- More interesting variables towards constraint equations
- Pyomo solver and number of equations

- 0.3% of null values



Updated Variables

Industial Site

Production
Chiller
UTA
Compressor
Offices
Data Center

- **Active Energy & Power** (kWh)
- **Power Factor**
- **Apparent Power** (kVA)

External Inputs

- **Seasonality**
- **Environmental Conditions**
- **Pricing**

Synthesized Data

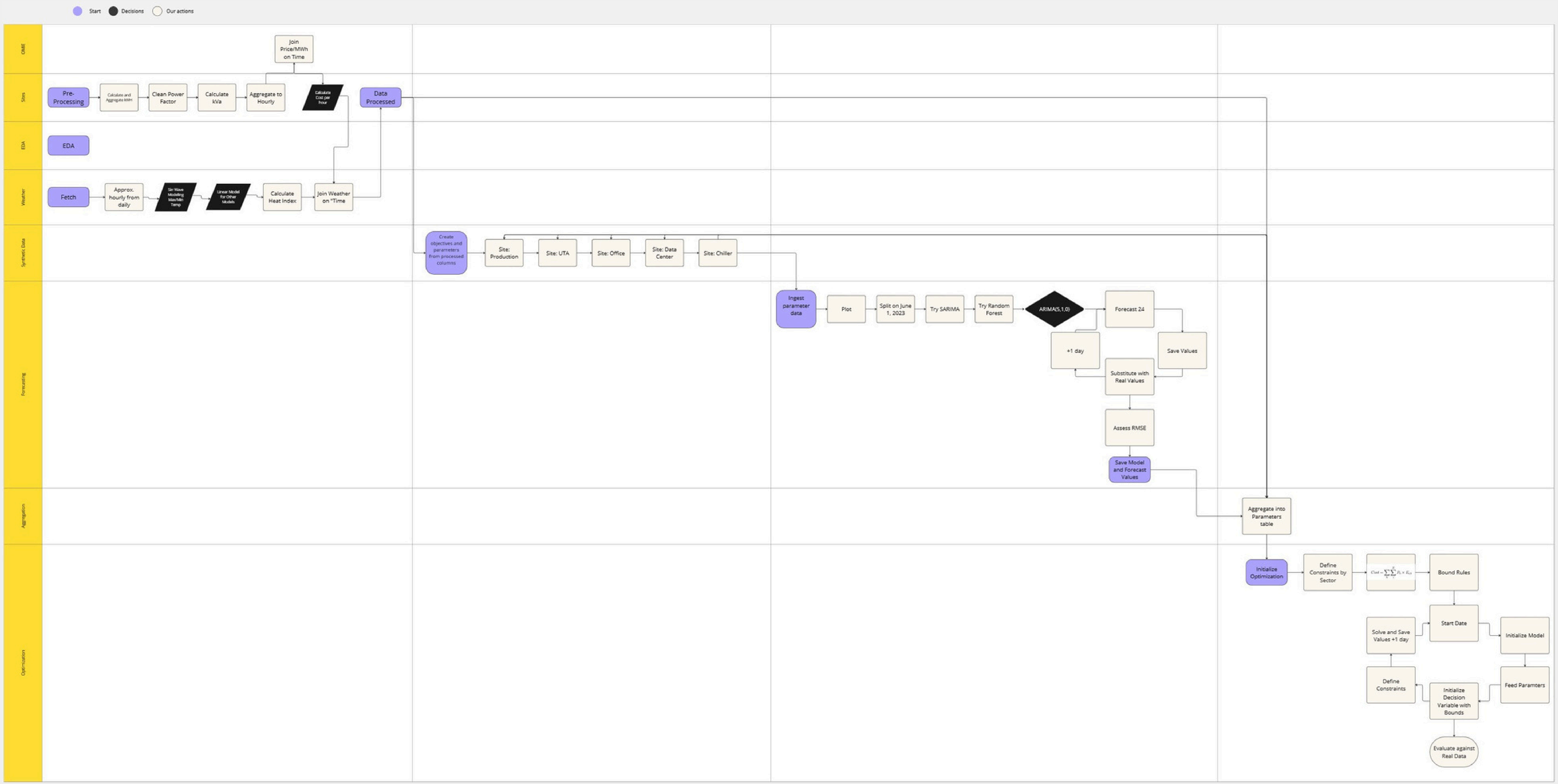
Updated Variables

Synthesized Data

Data Center	Chiller	Production	UTA	Office
Number of Active Servers	Temperature Set Point	Number of Workers	Operational Presence	Number of Active Light Bulbs
Number of Active PoE Network Swithces	Number of Active Chillers	Power Used to Charge Transport Vehicles	Fabric in Chamber	Number of Active Wall Plugs
Number of Active non-PoE Network Switches		Production Schedule	Testing Schedule	Number of Active Computers
Number of Active HDDs		Maintenance Status	Workload	Number of Active Printers
Number of Active SSDs		Volume Prediction Waste	Standby Power Down	Number of Active Coffe Machines

...Process Workflow...

[Open Link Here]



Results

With the new processed dataset, and understanding how each feature takes action, it is time to run the optimization algorithm.

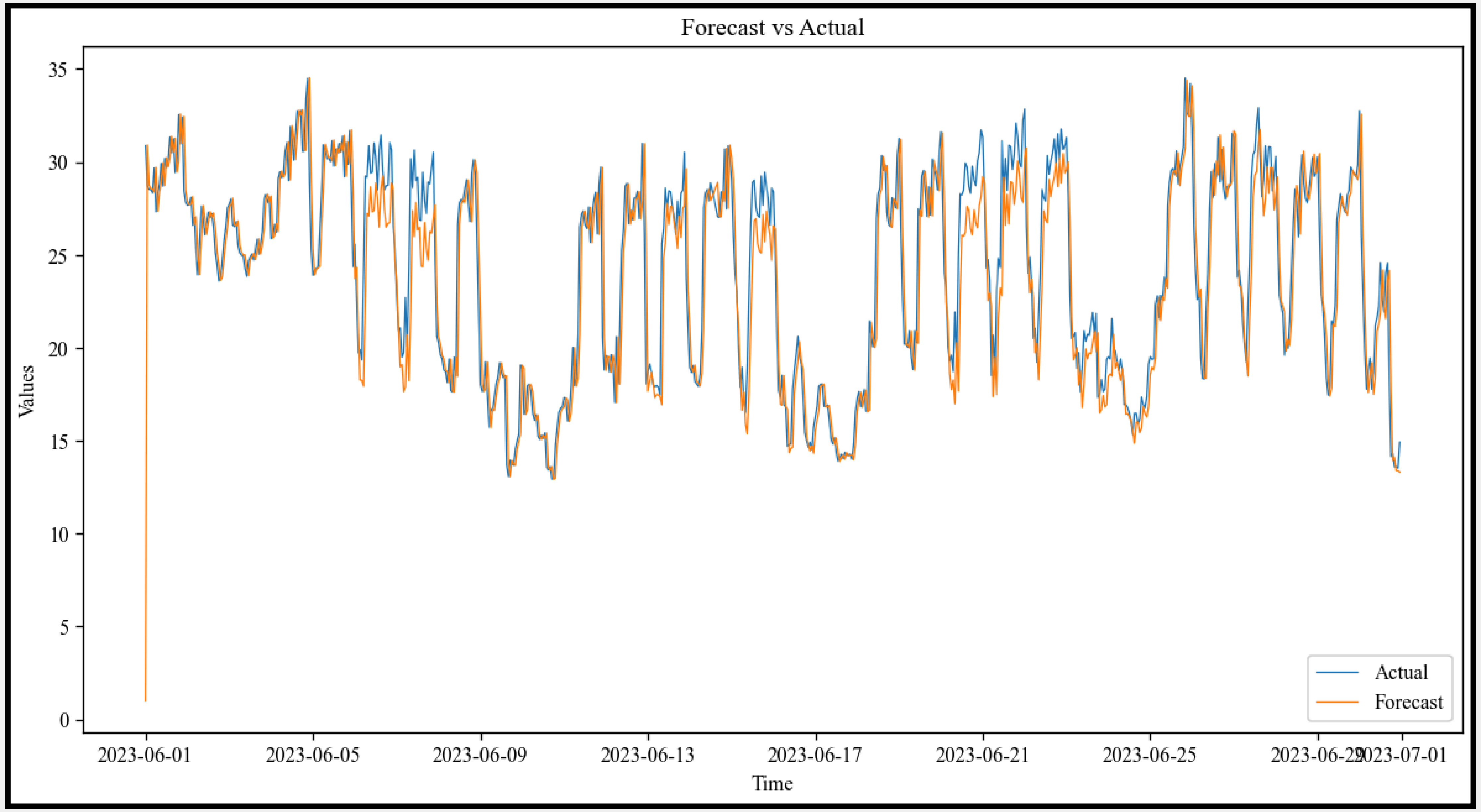
1. The definitive **constraint equations** are inputed to PYOMO.
2. Each with a combination of decision variables and parameters with their bounds and **forecasting**.
3. And finally, the potential **financial savings** are obtained.

I. Constraint Equations

Data Center	$DC = \epsilon 1 \cdot S + \epsilon 2 \cdot (NS - P) + \epsilon 3 \cdot (NS - NP) + \epsilon 4 \cdot HD + \epsilon 5 \cdot SSDs$
Chiller	$C = \beta 0 + \beta 1 \cdot HISPD + \beta 2 \cdot EAP + \beta 3 \cdot NAC$
Production	$P = \alpha 0 + \alpha 1 \cdot PTV + \alpha 2 \cdot PS + \alpha 3 \cdot MS + \alpha 4 \cdot VPW + \alpha 5 \cdot NW$
UTA	$UTA = \gamma 0 + \gamma 1 \cdot OP + \gamma 2 \cdot FC + \gamma 3 \cdot TS + \gamma 4 \cdot W + \gamma 5 \cdot SPD$
Office	$OFF = \delta 0 + \delta 1 \cdot LA + \delta 2 \cdot AWP + \delta 3 \cdot AC + \delta 4 \cdot AP + \delta 5 \cdot ACM$

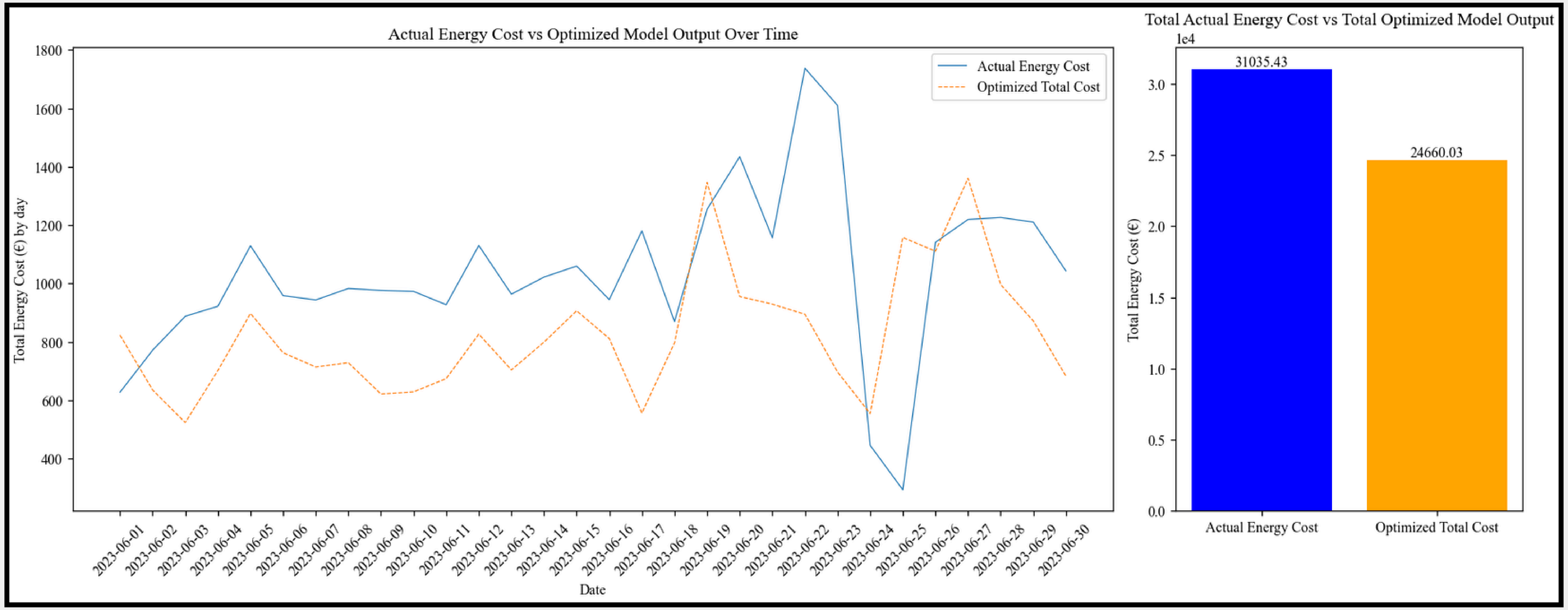
II. Forecasting

The parameters for the optimization were set using historical data analyzed with the **ARIMA(5,1,0)** model.



III. Financial Savings

The optimizer outputs a value of **24,660.03€** while the ground truth had a value of **31,035.43€**. Therefore, with a difference value of 6,375.40€, the optimizer resulted in savings by **20.5%**.



Conclusions

Key Achievements:
- Effective data cleaning and integration with external information
- The optimizer proved effective

Challenges & Outcomes:
- Dataset Limitations
- Variable Representation
- Issues with continuous empty periods and outliers

Despite challenges, Electritect achieved above-average outcomes, demonstrating exceptional capabilities

Further Improvement

Real-World Data Priority

Cloud-Based Forecasting

IoT Partnership Exploration

Standardized Implementation Processes

Advanced Optimization Techniques

10% Further Cost Reduction

Thank You

Let´s change energy together!