ElectroCap Pitch Deck

SMART GRID OPTIMIZATION
V2G SYSTEM AND BLOCKCHAIN TRANSITIONS

Smart Grid Optimization through V2G System and Blockchain Transactions

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TÉCNICO LISBOA

Team

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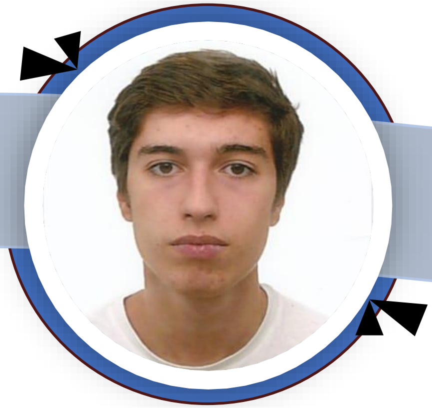

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Advisors and Mentors

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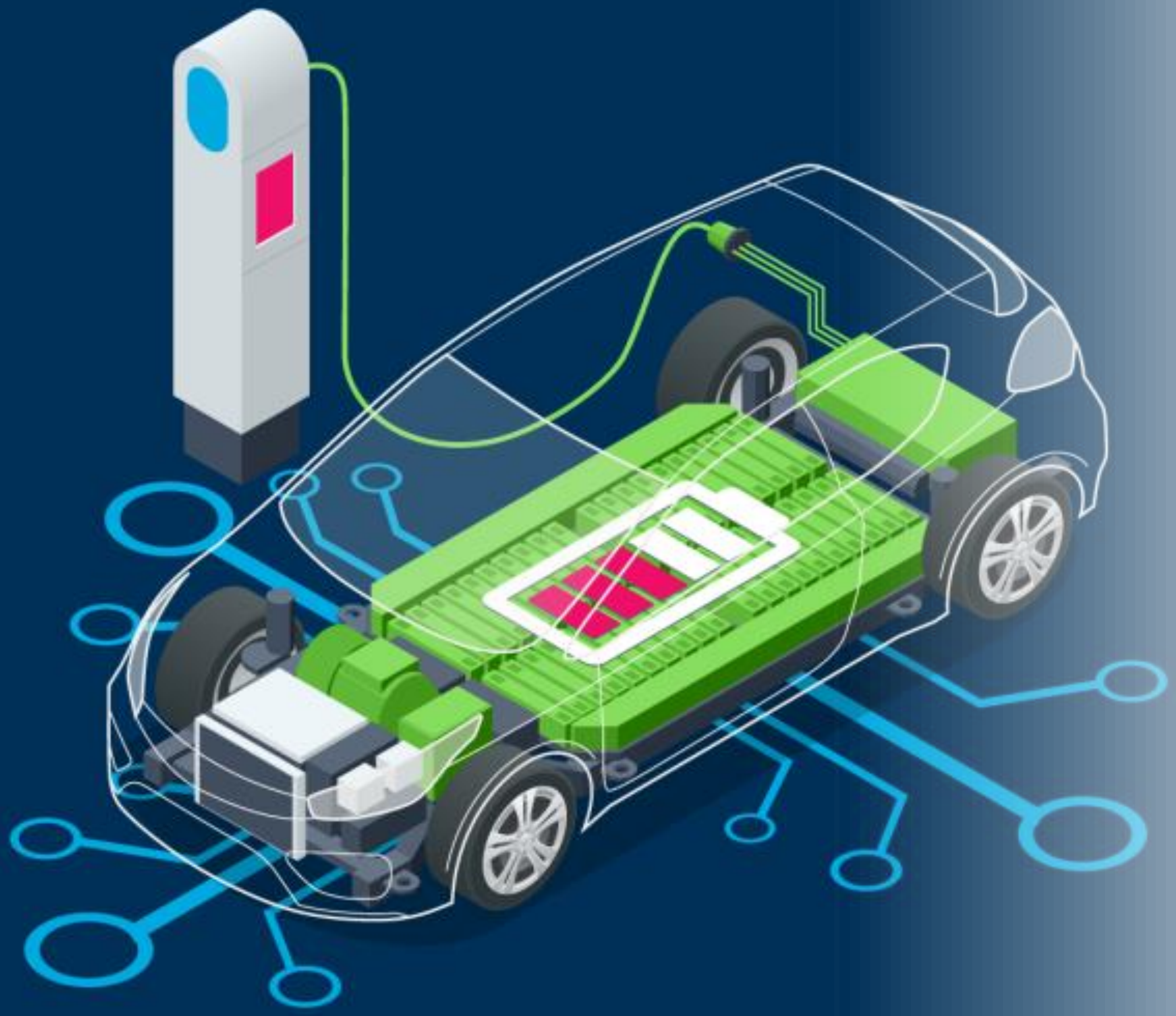


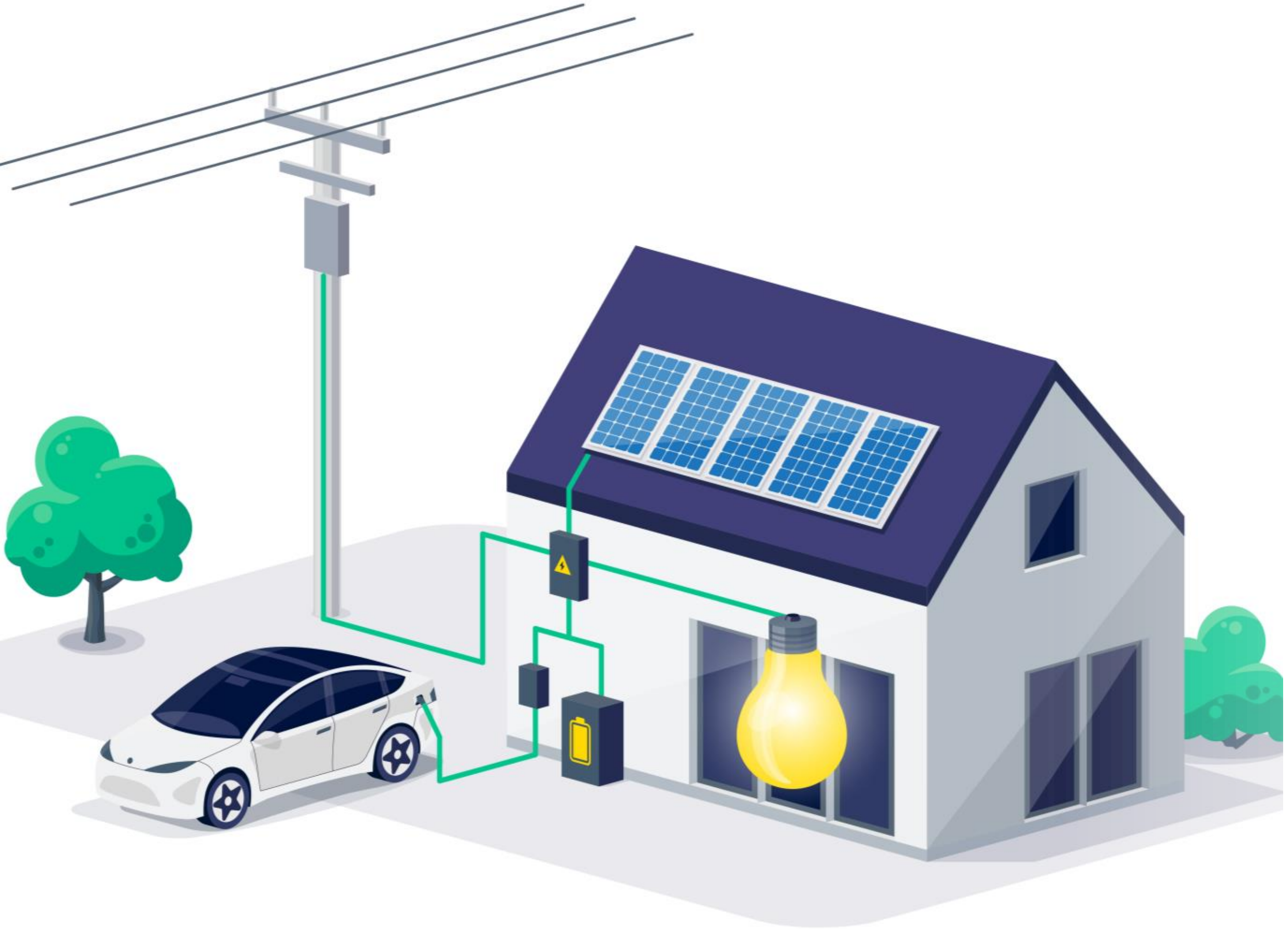
Problem definition

- Challenges in maintaining load stability
- Intermittent nature of Renewable Energy Sources (RES)
- Lack of optimization for grids with mixed generation sources
- Need for decentralized energy storage solutions
- Challenges posed by the increasing adoption of electric vehicles (EVs)
- The absence of a charging management strategy: additional demand, power grid congestion, and energy import costs
- Potential for EVs to assist in balancing the grid
- Issues with traditional energy market transactions

Solution beneficiaries

- Citizens and businesses reliant on the power grid
- Energy market participants
- Electric vehicle owners
- Energy producers
- Grid operators: Distribution System Operator (DSO) and Transmission System Operator (TSO)

Technological solution



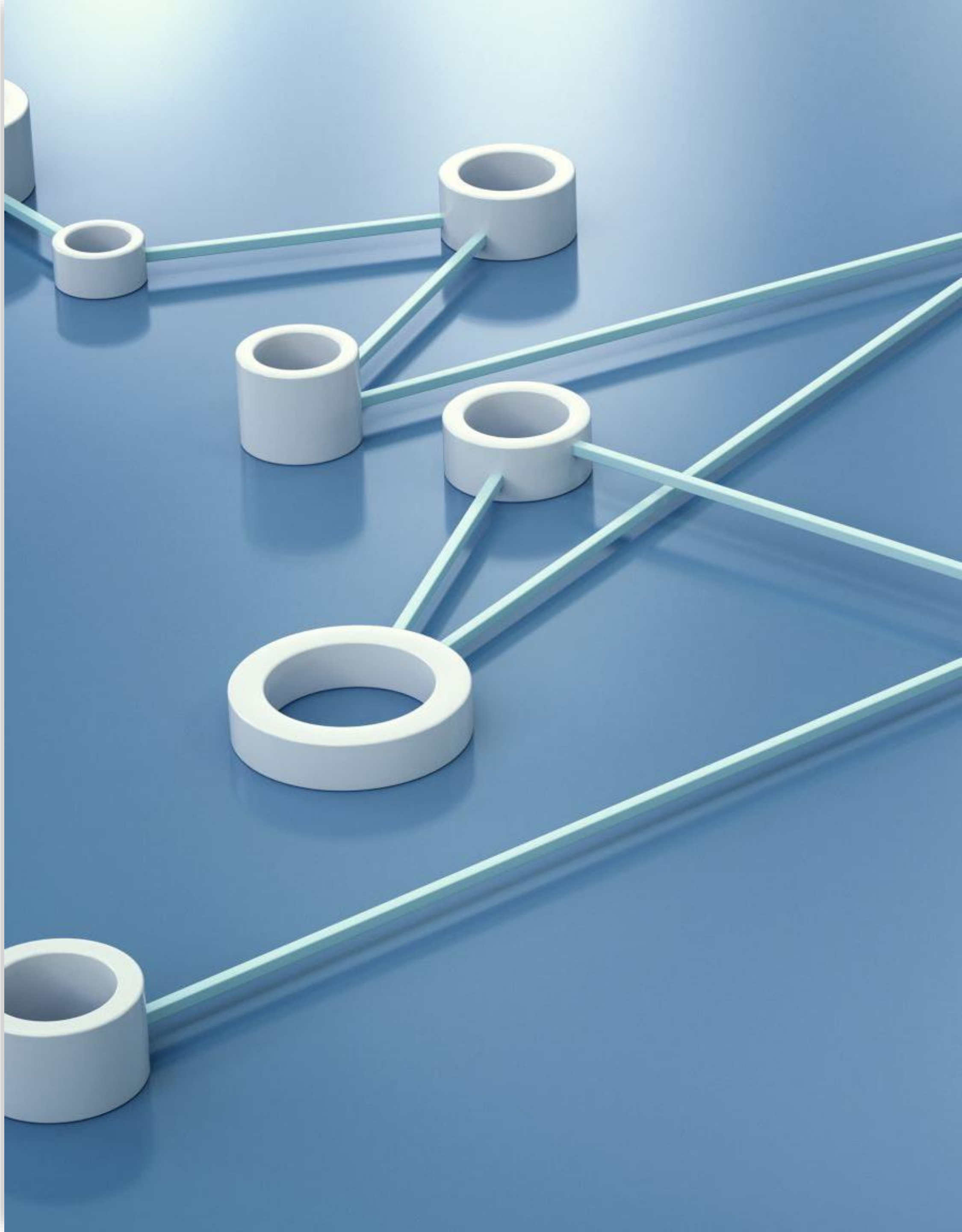
- Predictive Machine Learning models:
  - Energy Consumption Forecast
  - Renewable Energy Production Forecast
  - Dynamic Market Price Forecast
- Blockchain Transactions
- Machine Learning algorithms for optimizing grid flexibility and load distribution
- Real-time Adaptation to Energy Demand: more responsive and efficient energy distribution system
- Market dynamics and algorithms for profit maximization

Competitors and previous work

Competitors	**Synop, POCITYF, EnerNoc (EnelX), AMS, Siemens**
Previous work	These companies are developing solutions for optimizing energy management, integrating renewable sources, smart grid technologies, microgrid solutions and enhancing grid flexibility.

Solution requirements

- The prediction models should be capable of giving accurate information about the energy market to correctly calculate the user's gains
- The monetary transactions need to be fast, secure and trustworthy
- Different energy usage profiles need to be created to satisfy a wide range of users
- Limits to the energy transactions between the vehicles and the grid need to be established in order to reduce the impact on the vehicle's battery lifetime and daily life of the user



Technical challenges

- Ensuring the quality of the data used to train the ML models, and consequently the quality of the models themselves
- Integration of the prediction models into existent infrastructure
- Volatility of the energy market and how exceptional cases might influence the final users
- Implementing a system that correctly reflects the user's needs
- Immutable smart contract security vulnerabilities
- Gas optimization for cost-efficient smart contract execution
- Legal and regulatory compliance challenges in decentralized smart contracts

Testing and validation metrics

- Impact on the Load Profile
- Total energy exchanged with the grid
- Peak Load Reduction and Peak Load Shifting
- Load Flattening
- Total monetary value exchanged
- EV owner's monetary gains
- Scalability (how does the model respond to different numbers of connected EVs)
- Transaction security
- Prediction accuracy

Project Organization

Part A: Machine Learning and Statistics

The focus of this section is in the analysis of data and the creation of Machine Learning (ML) models to predict energy and market dynamics, and determine optimal transaction time.

Part B: Blockchain Transactions

This section is about creating conditions for secure and verifiable transactions.

Part C: Mock-Up Construction

This part deals with creating a mock-up to visually present our project. It will also include an interface that allows the user to input their requirements and simulate their energy usage and monetary gain.

Part D: Website and Marketing

Creation of the Website, promotional video and updating the blog.

Division of labor (1)

Diogo Faneco	Duarte Santos	Gonçalo Teixeira
Blockchain transactions / Interactive Mock-up Creation	**Machine Learning Development**	**Website and Marketing Development**
Smart Contracts Development	Data Set research and Statistical Analysis – energy market price	Website development
Legal Conditions Documentation	Development of ML model - energy market price	Project Presentation Video
Transaction Security Testing	Statistical Analysis Documentation	Scientific Poster Development
Modeling a Representative Model of the Project (Mockup - 3D modeling)	Technical Documentation (ML model)	Interactive Data Integration with Website

Division of labor (1)

Diogo Faneco	Duarte Santos	Gonçalo Teixeira
Blockchain transactions / Interactive Mock-up Creation	**Machine Learning Development**	**Website and Marketing Development**
Mockup Microcontroller Programming	Ideal Transaction Forecast – code implementation (KPIs, data output, and presentation)	Real Transaction Management – code implementation (KPIs, data output, and presentation)
Data Integration with Mockup Presentation (3)	Technical Documentation (code implementation)	Technical Documentation (code implementation)
Mockup Technical Documentation (4)	Data Integration with Mockup Presentation (3)	Integration of Predictive Data Into the Website (1)

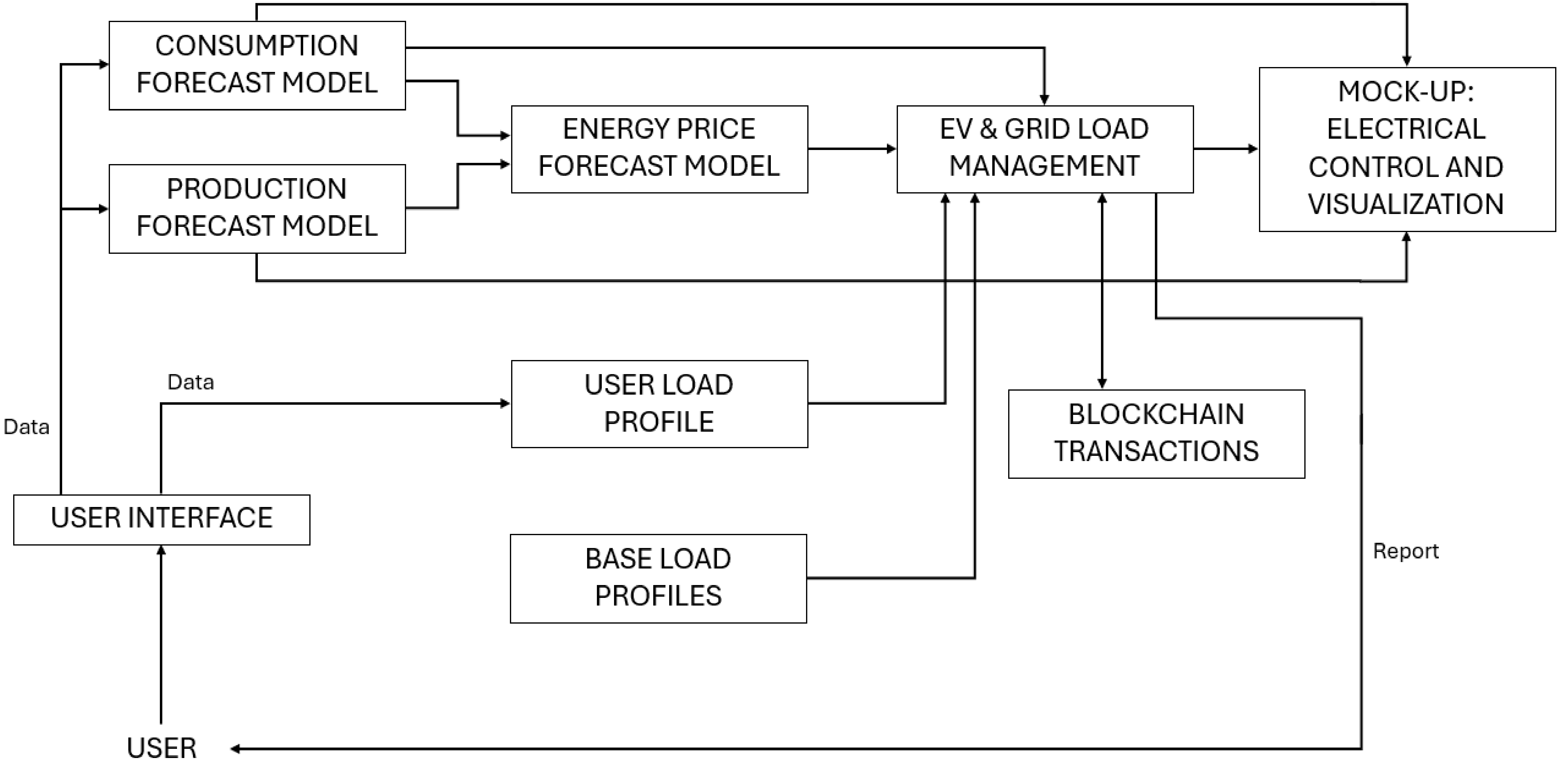
Division of labor (2)

José Correia	Rafael Rodrigues	Samuel Figueiredo
Blockchain transactions / Interactive Mock-up Creation	**Machine Learning Development**	**Machine Learning Development**
Smart Contract Interaction with Python Code	Data Set research and Statistical Analysis – energy consumption	Data Set research and Statistical Analysis – energy production
Technical Documentation	Development of ML model - energy consumption	Development of ML model - energy production
Analysis and Processing of Transaction Results	Statistical Analysis Documentation	Statistical Analysis Documentation
Mockup Electrical Assembly	Technical Documentation (ML model)	Technical Documentation (ML model)

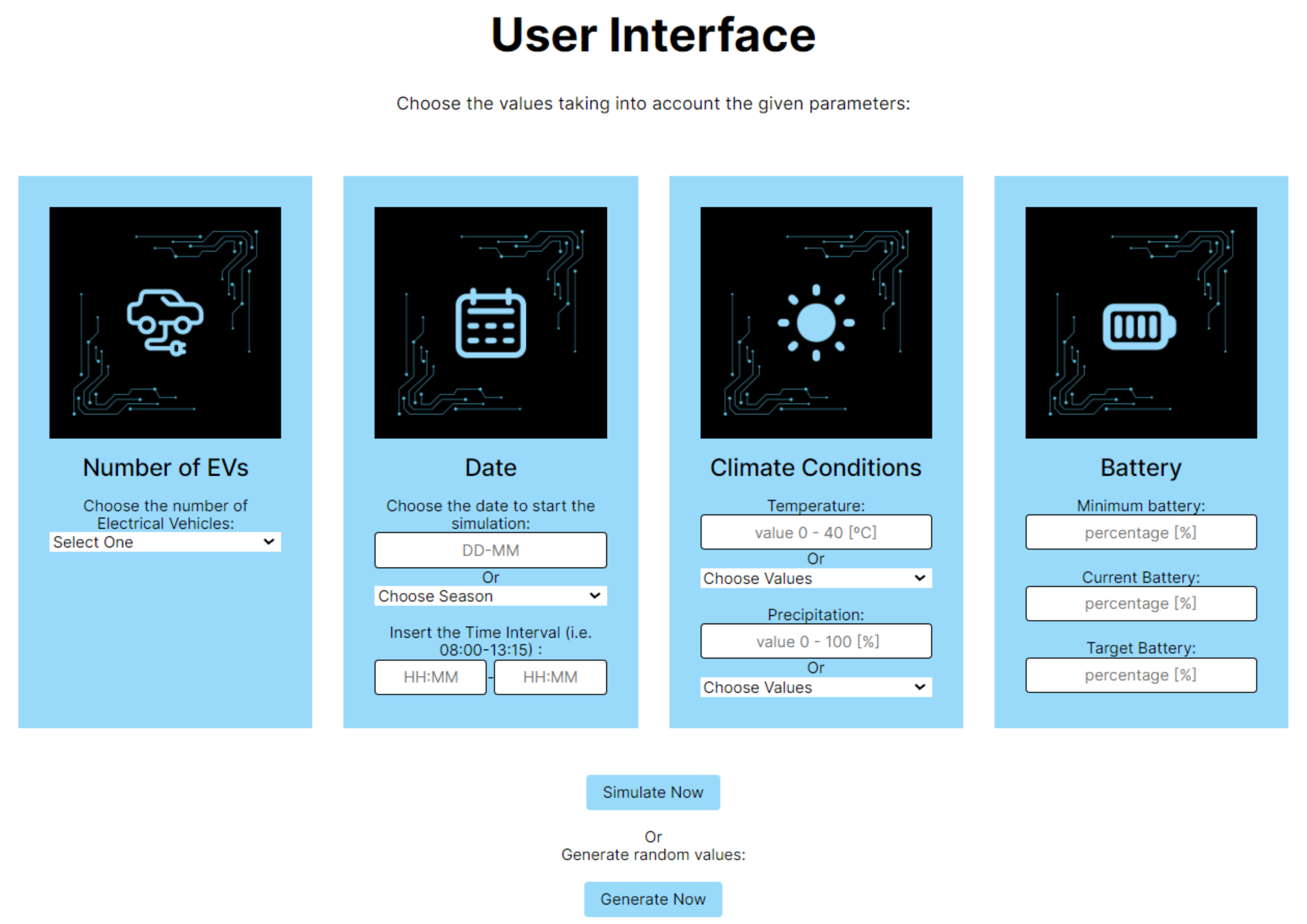
Division of labor (2)

José Correia	Rafael Rodrigues	Samuel Figueiredo
Blockchain transactions / Interactive Mock-up Creation	**Machine Learning Development**	**Machine Learning Development**
Blockchain Transactions Integration (2)	Real Transaction Management – code implementation (real load and transaction)	Ideal Transaction Forecast – code implementation (identification of key transactions)
Mockup Technical Documentation (4)	Technical Documentation (code implementation)	Technical Documentation (code implementation)
	Integration of Predictive Data Into the Website (1)	Blockchain Transactions Integration (2)

BLOCK DIAGRAM



User Interface



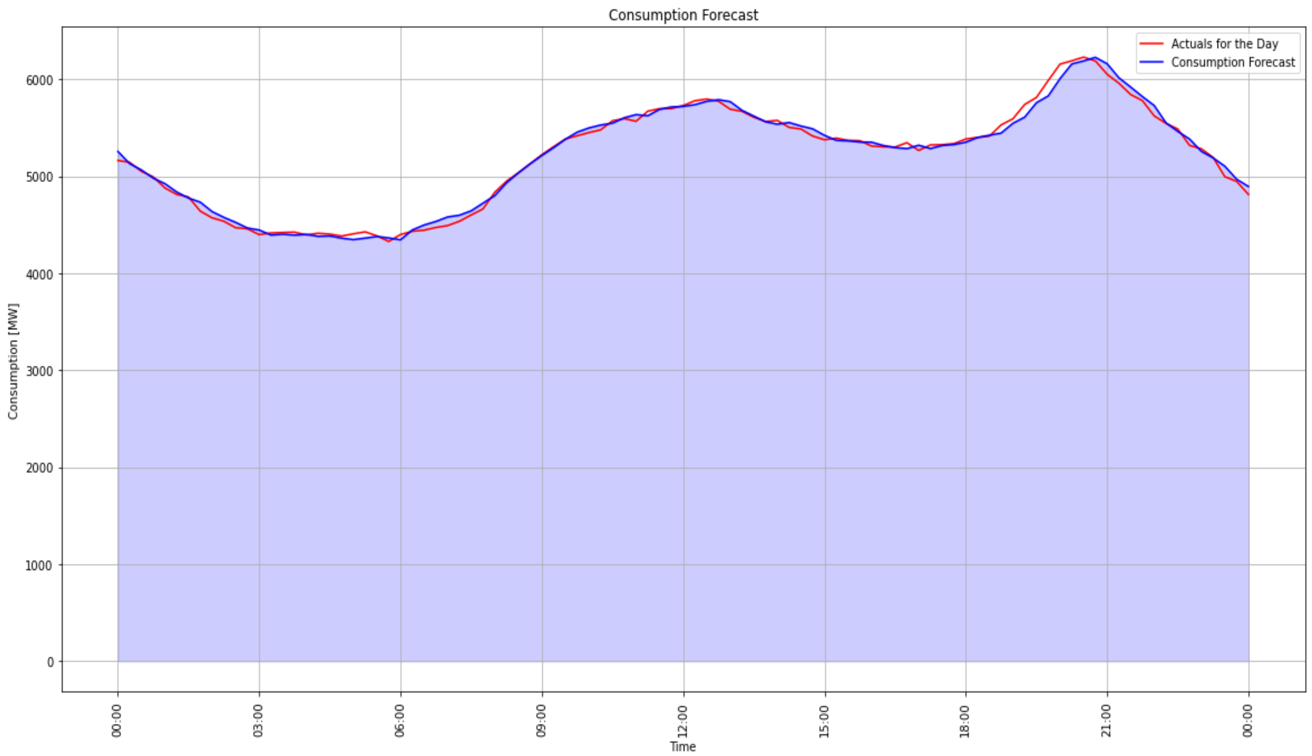
Achieved Results - ML Energy Consumption Model

The model can generate predictions on the amount of energy consumed in Portugal per intervals of 15 minutes for a given day of the year or a specific time period

LSTM (Long Short-Term Memory) neural networks

After statistical study, the model was trained with a large database that follows a coherent trend, from 2011 to 2023, to provide accurate predictions

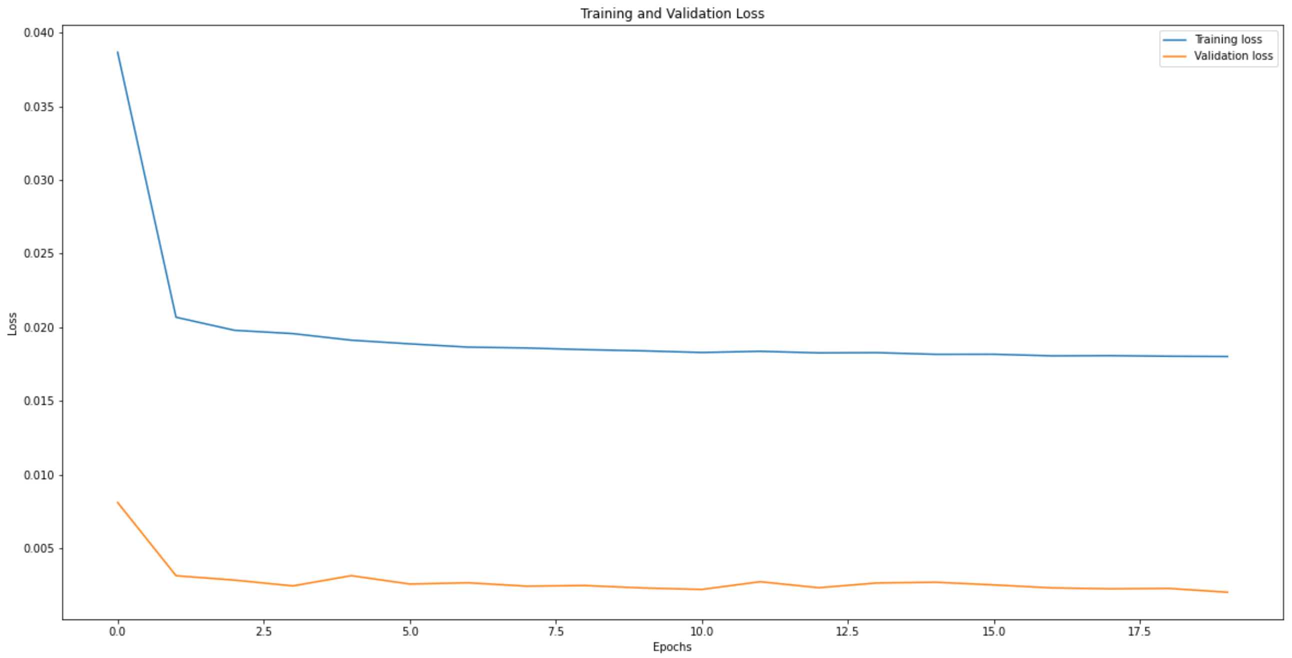
Forecasts energy consumption based on historical data, weather conditions and time context



Actual and predicted consumption – 01/04/2023

Model Metrics and Evaluation

- Training Loss:
  - Measure of how well the model is fitting the data during training.
  - Used during the optimization process
  - It decreases as the model becomes more accurate at the task being trained
- Validation Loss:
  - Measure of how well the model is generalizing to data not seen during training
- Optimization Strategy:
  - Improving model accuracy through reinforcement of weekly and annual periodicity



Training and Validation Loss

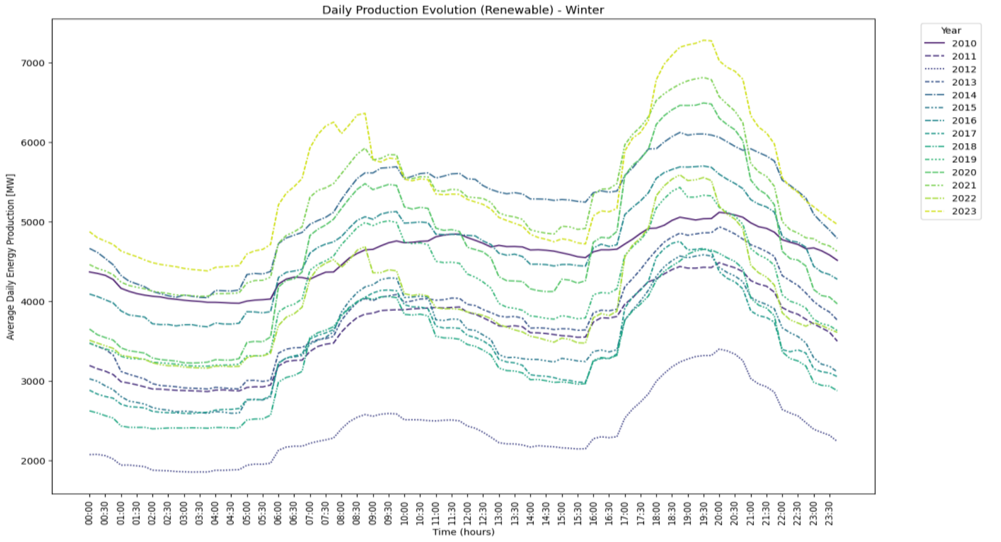
Achieved Results - ML Energy Production Model

The model can generate predictions on the amount of energy generated in Portugal per intervals of 15 minutes for a given day of the year or a specific time period on multiple sources of energy generation (Solar, Wind, Natural Gas, etc)

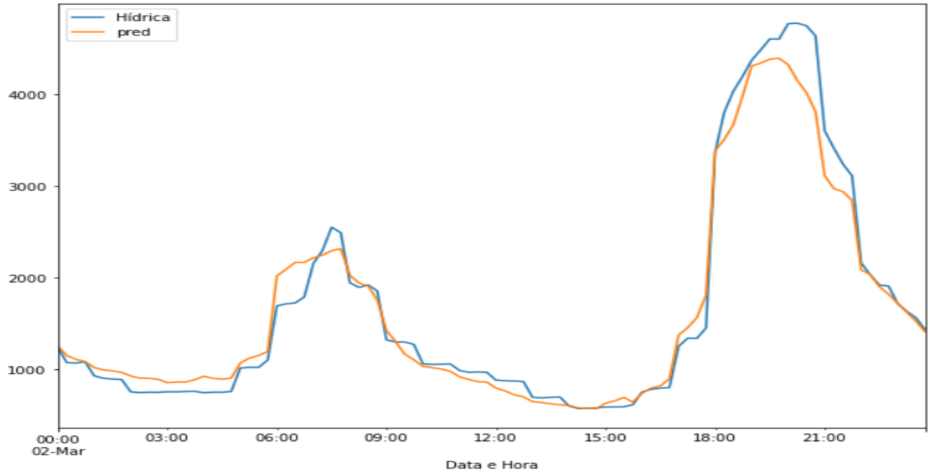
RFS (Random Forest Regression)

Training data taken from 2023 in order to give more accurate predictions. (Using older data would not give an accurate depiction of the current energy generation in Portugal due to the great changes that occured in this sector in the last decade)

The model uses information on meteorologic data and other variables like day of the week and if it's a holiday to further tweak the results



Example of evolution of daily production of renewable energy (Winter) from 2010 to 2023



Example comparison between real data (blue) and prediction (orange) for energy generated by hydro in a specific day

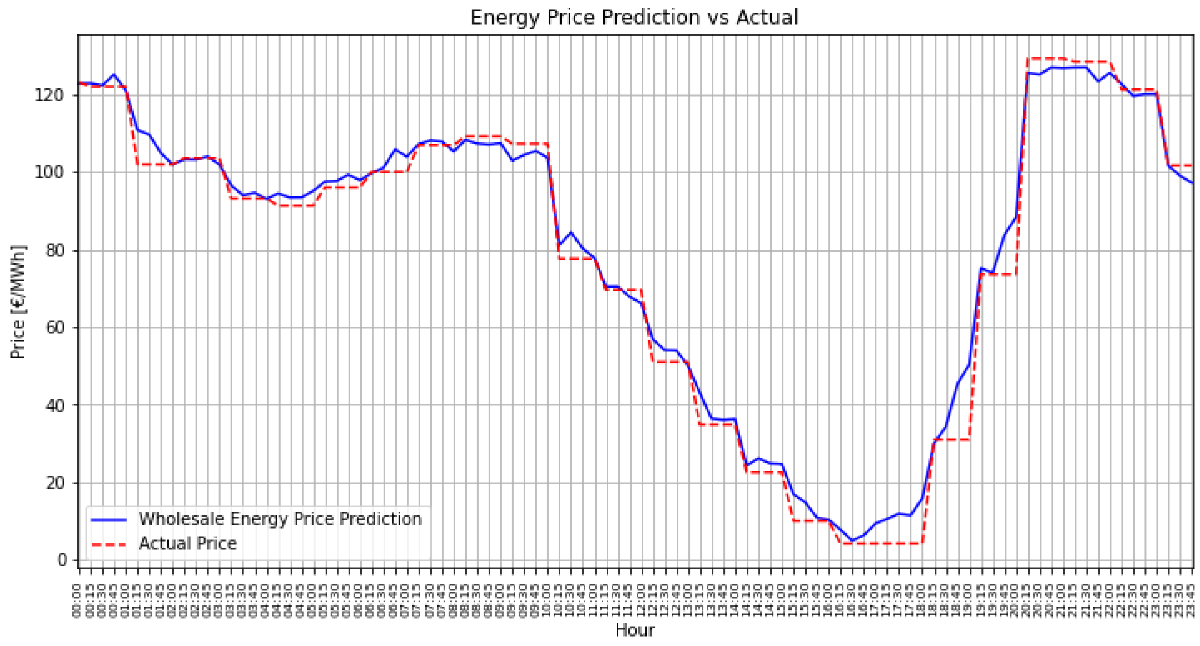
Achieved Results - ML Energy Price Model

The model can generate predictions on the wholesale enrgy market price in Portugal per intervals of 15 minutes for a given production and consumption data.

The model was trained with the Random Forest Regressor model using a database from 2015 to 2023 in order to provide accurate predictions, This extensive database enhances the robustness of the model.

The model uses information about the production and consumption combined with energy price data to allow for futher tweaking of the results (data sources: REN, OMIE).

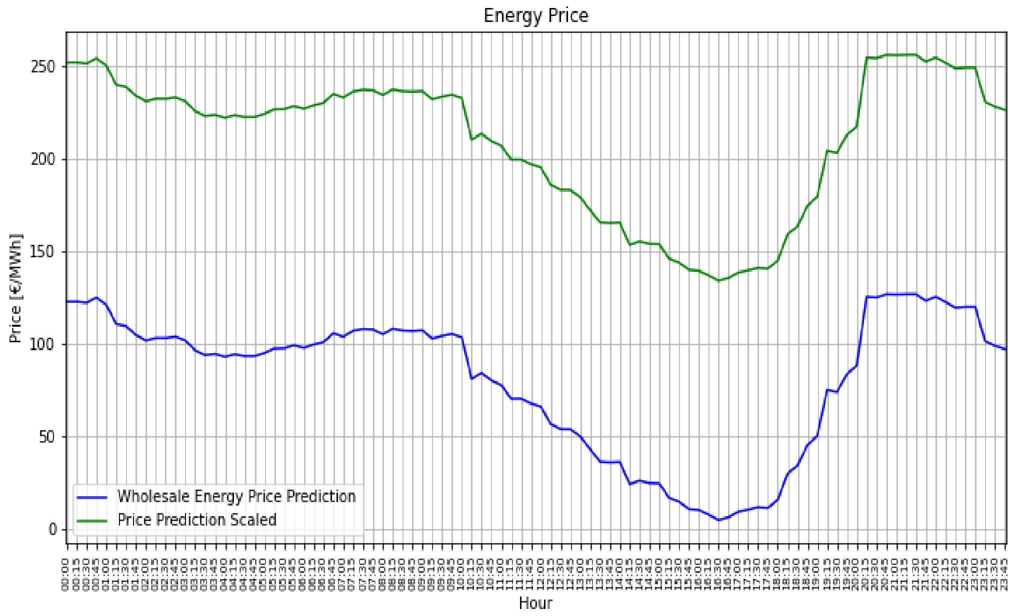
To test the model, a forecast was made for the wholesale energy market price for 04/2023, calculating the Mean Absolute Error (MAE) and Coefficient of Determination (R^2) on the results obtained on each day. The average MAE value was 3.552, and the average R^2 value was 0.958, suggesting that the model is performing well.



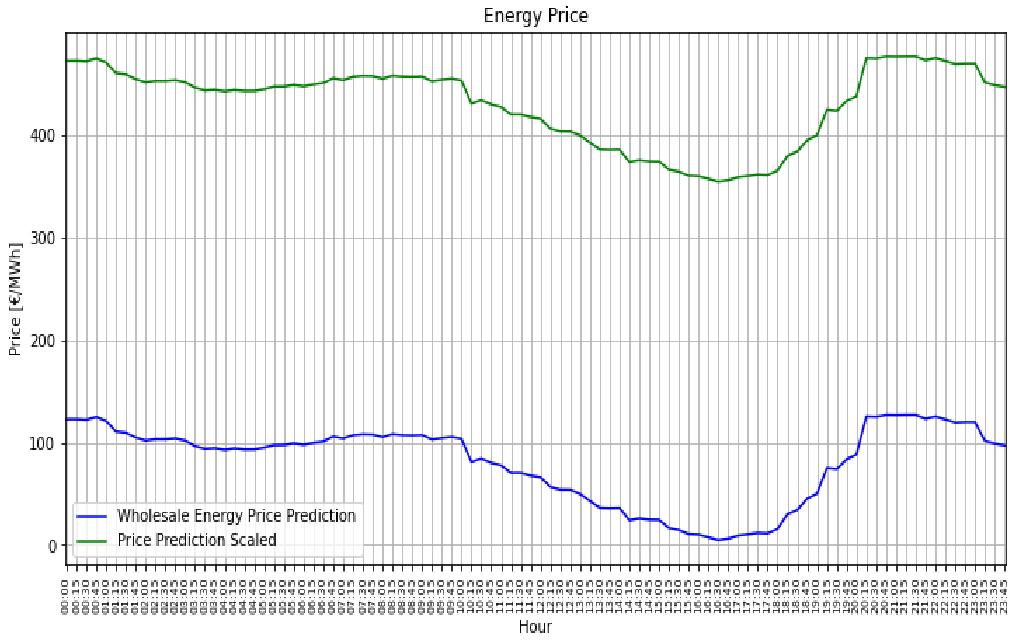
Actual and predicted wholesale energy price (€/MW) – 22/04/2023

Achieved Results - ML Energy Price Model

The model predicts wholesale energy market prices. However, to make predictions more relevant, it scales them to match the average prices consumers encounter. The scaling process incorporates reference values of energy price [€/MWh] for a residential and work profile.



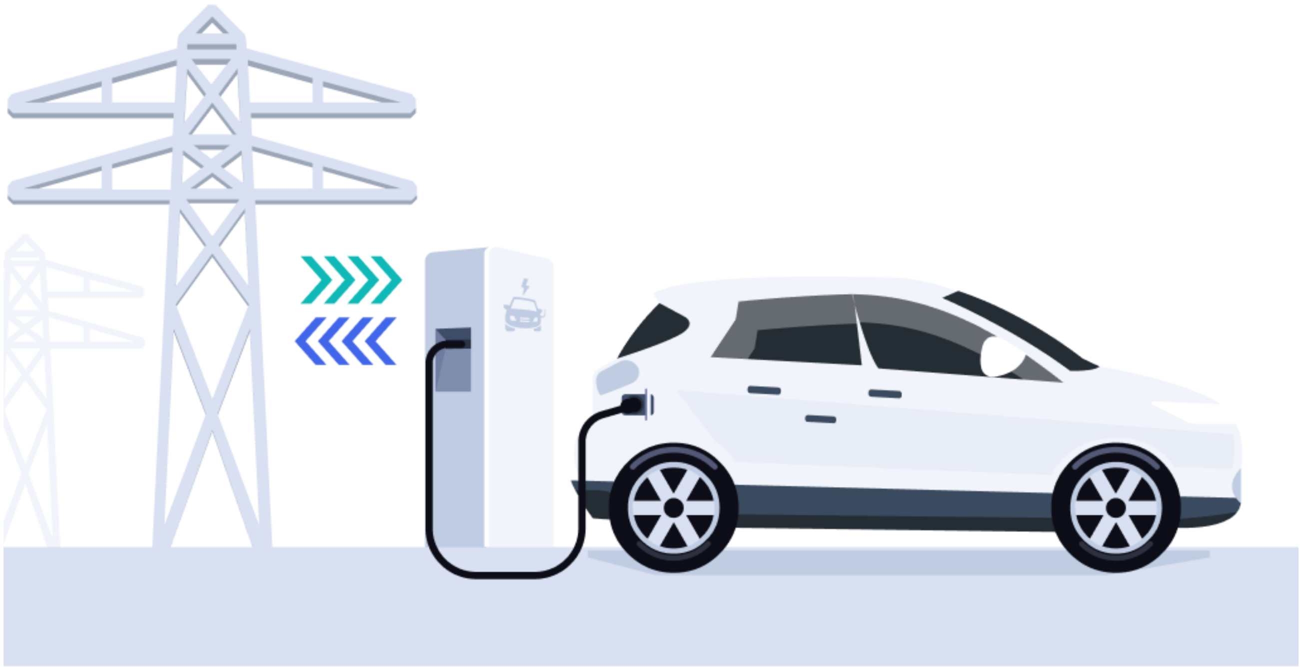
Predicted energy price for residential profile (€/MWh) – 22/04/2023



Predicted energy price for work profile (€/MWh) – 22/04/2023

Research: The Potential of V2G Technology

- 1. Investigation into V2G Technology
    - V2G Technology Overview
    - V2G Services and Advantages
- 2. Main Actors and System Architecture
- 3. Challenges and Decarbonization
- 4. Analysis of Charging Profiles
- 5. Comprehensive Examination of V2G Impact
    - Consumption Patterns Analysis
    - Assessment of Load Management Flexibility
    - Prediction of EV Penetration Effect (2025 to 2040)
    - Understanding Grid Implications
    - Quantification of Key Performance Indicators



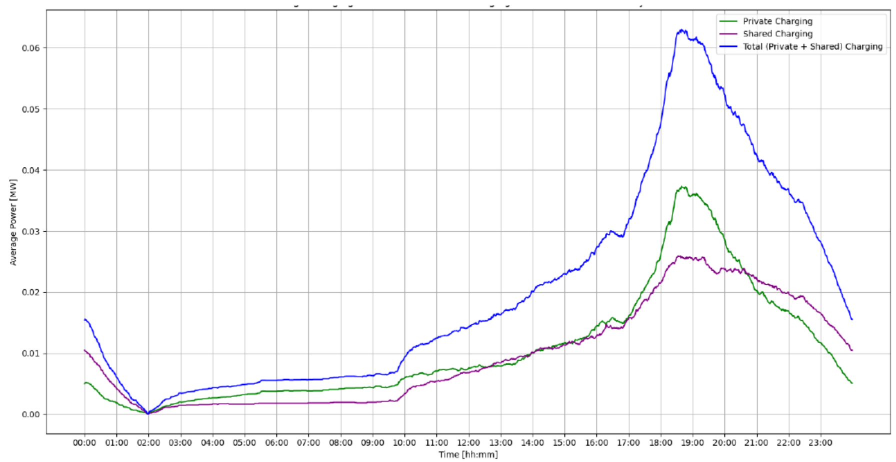
Load Profiles

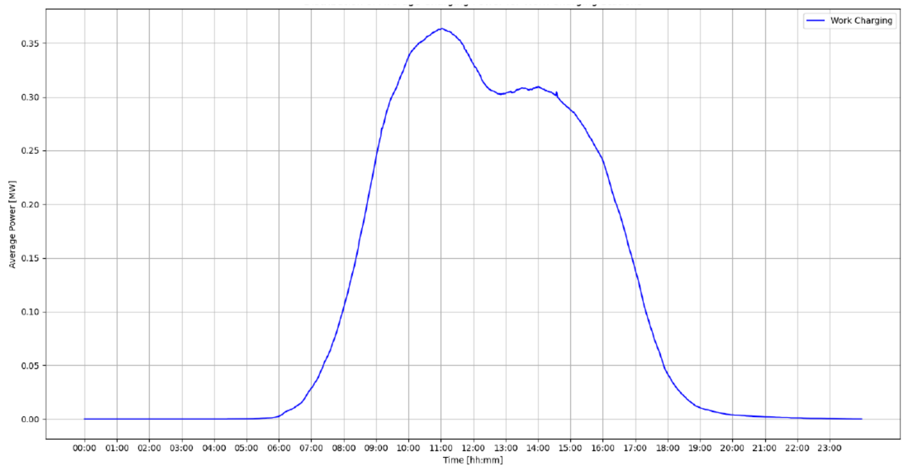
Residential Charging Stations

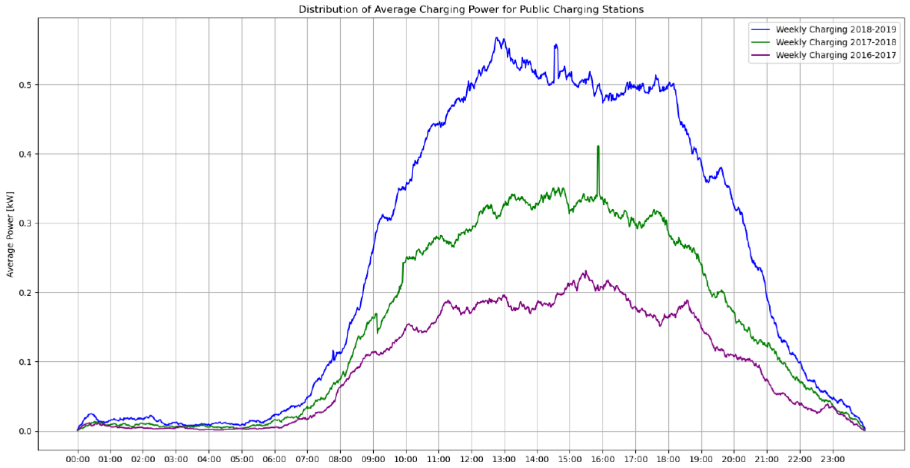
Workplace Charging Stations

Public Charging Stations

Scalable load profiles depending on the number of EVs in the national fleet and installed power at charging stations



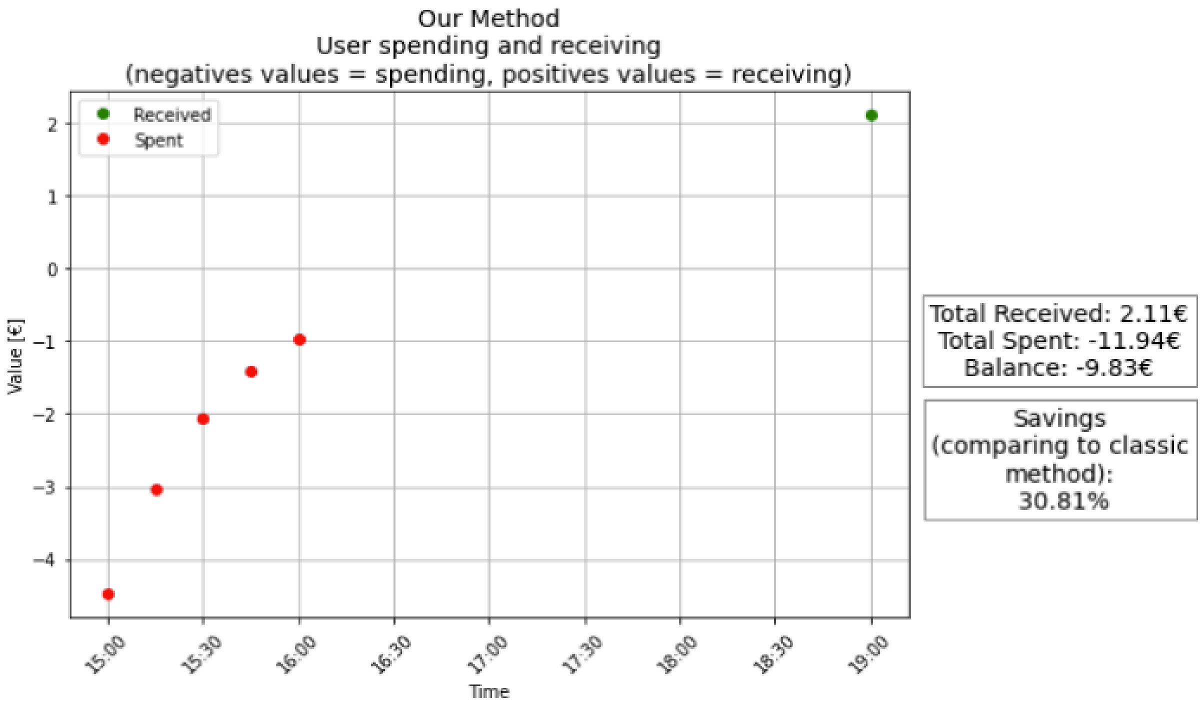


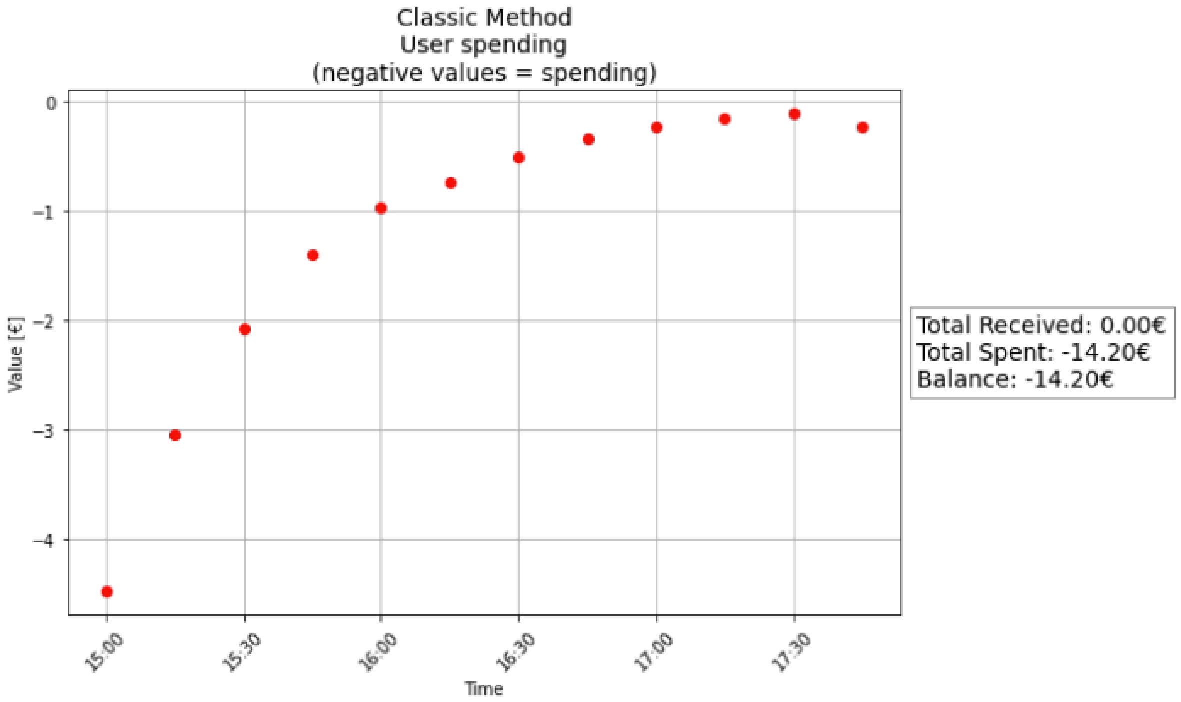


Ideal Transactions

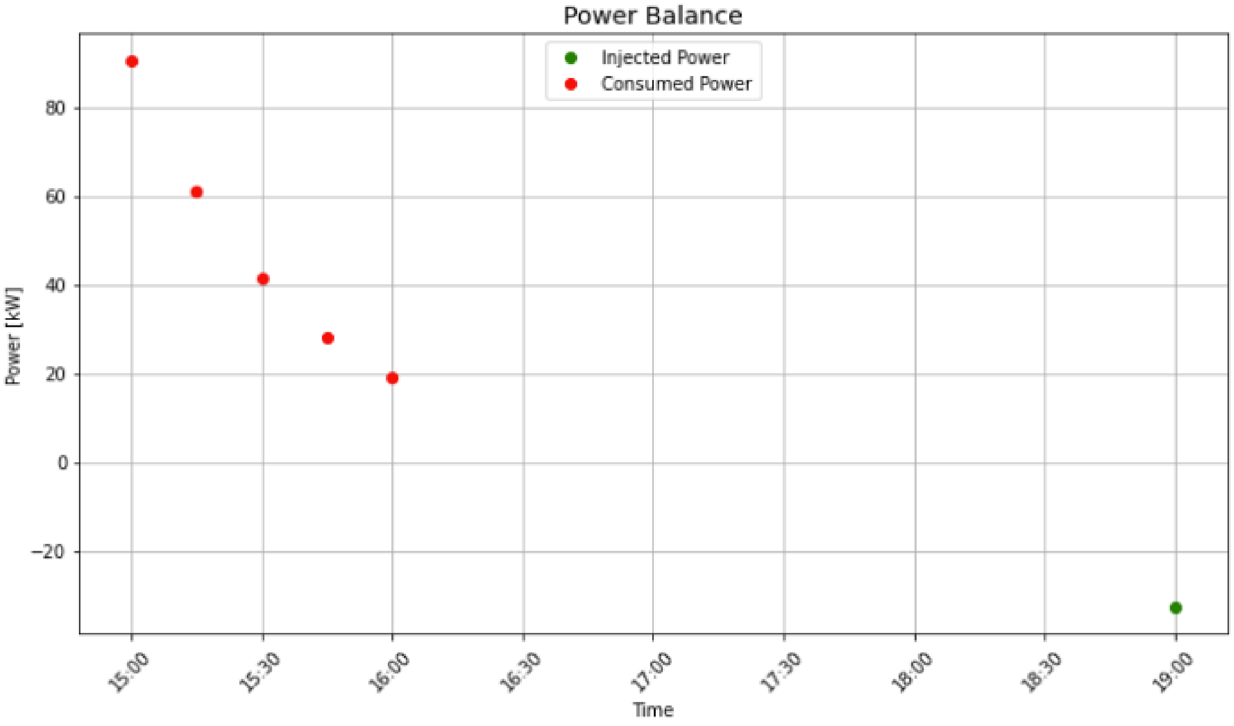
- Adjusts charging intervals using Vehicle-to-Grid (V2G) technology.
- Uses predictive modeling and real-time data for efficient charging.
- Maintains battery charge within specified limits to extend life.
- Optimizes charging to reduce energy costs.
- Maximizes use of renewable energy sources.
- Schedules charging to balance grid demand and reduce peak loads.
- Enhances reliability and efficiency of the energy distribution network.
- Adapts to changing conditions for optimal battery management and grid stability.

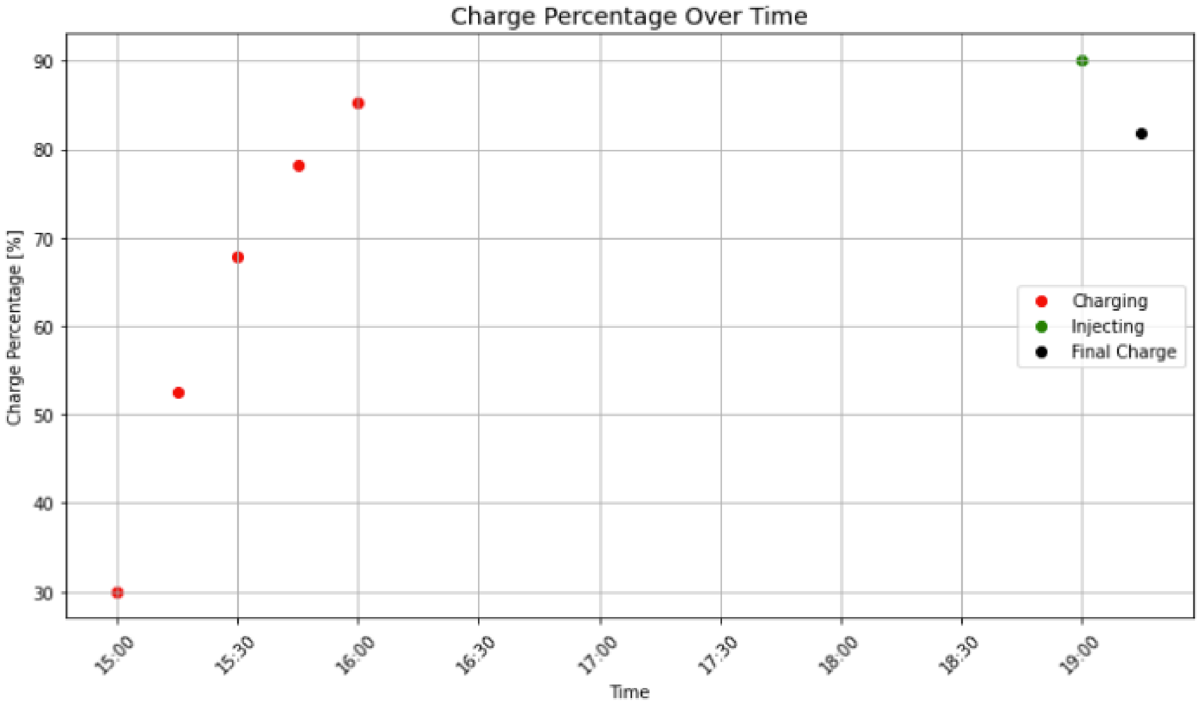
Ideal Transactions - Results





Ideal Transactions - Results





Ideal Transactions - Impact

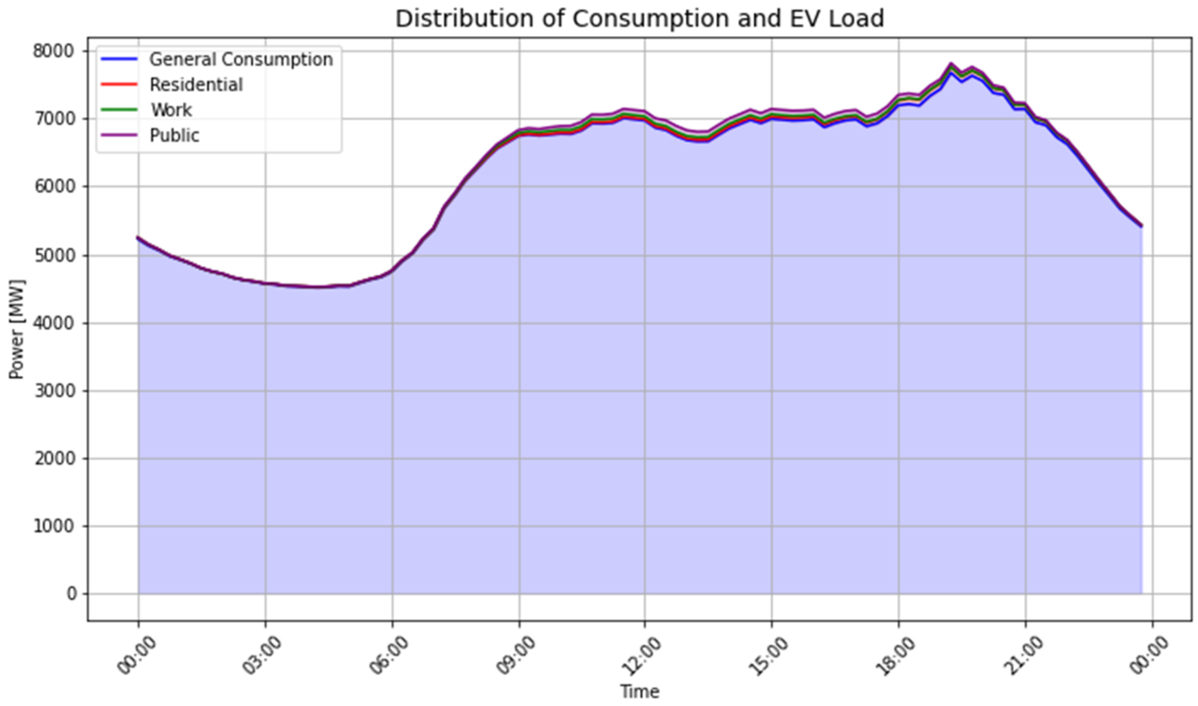


Figure 3. Before load management algorithm

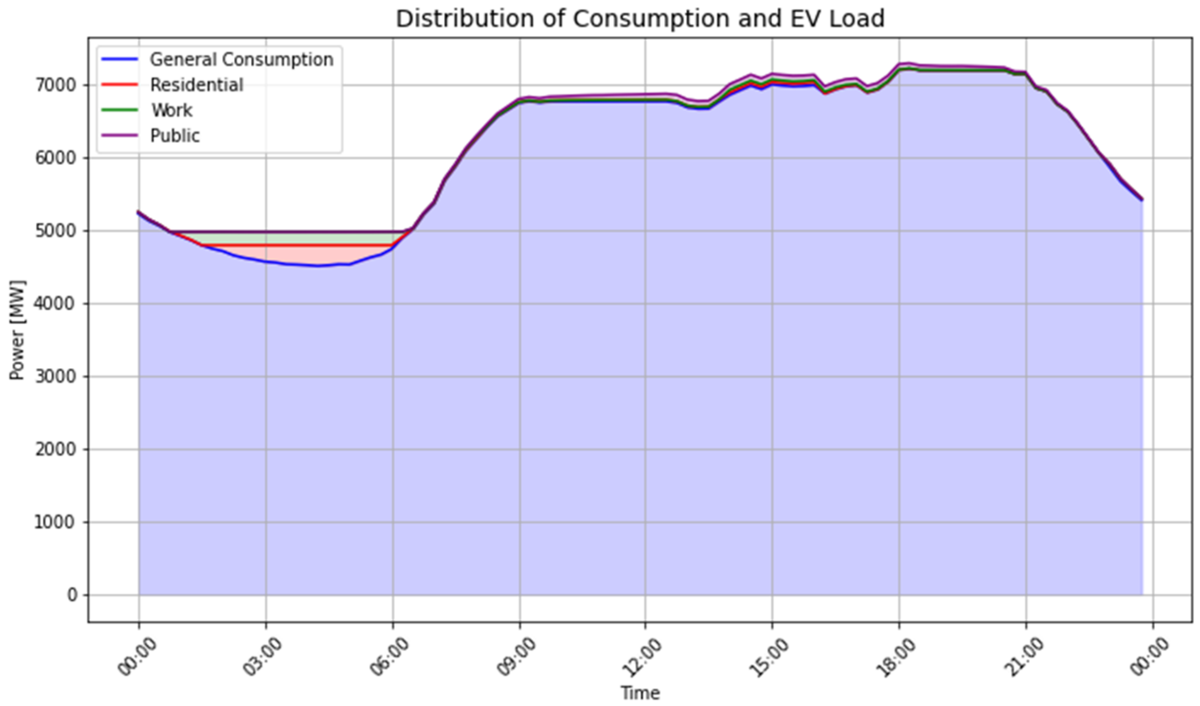
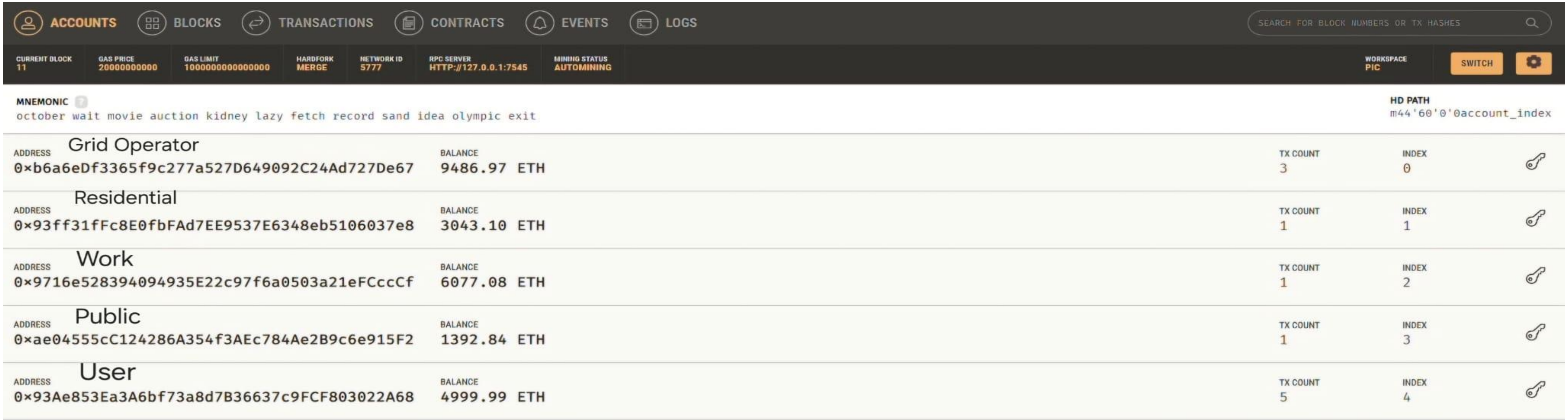


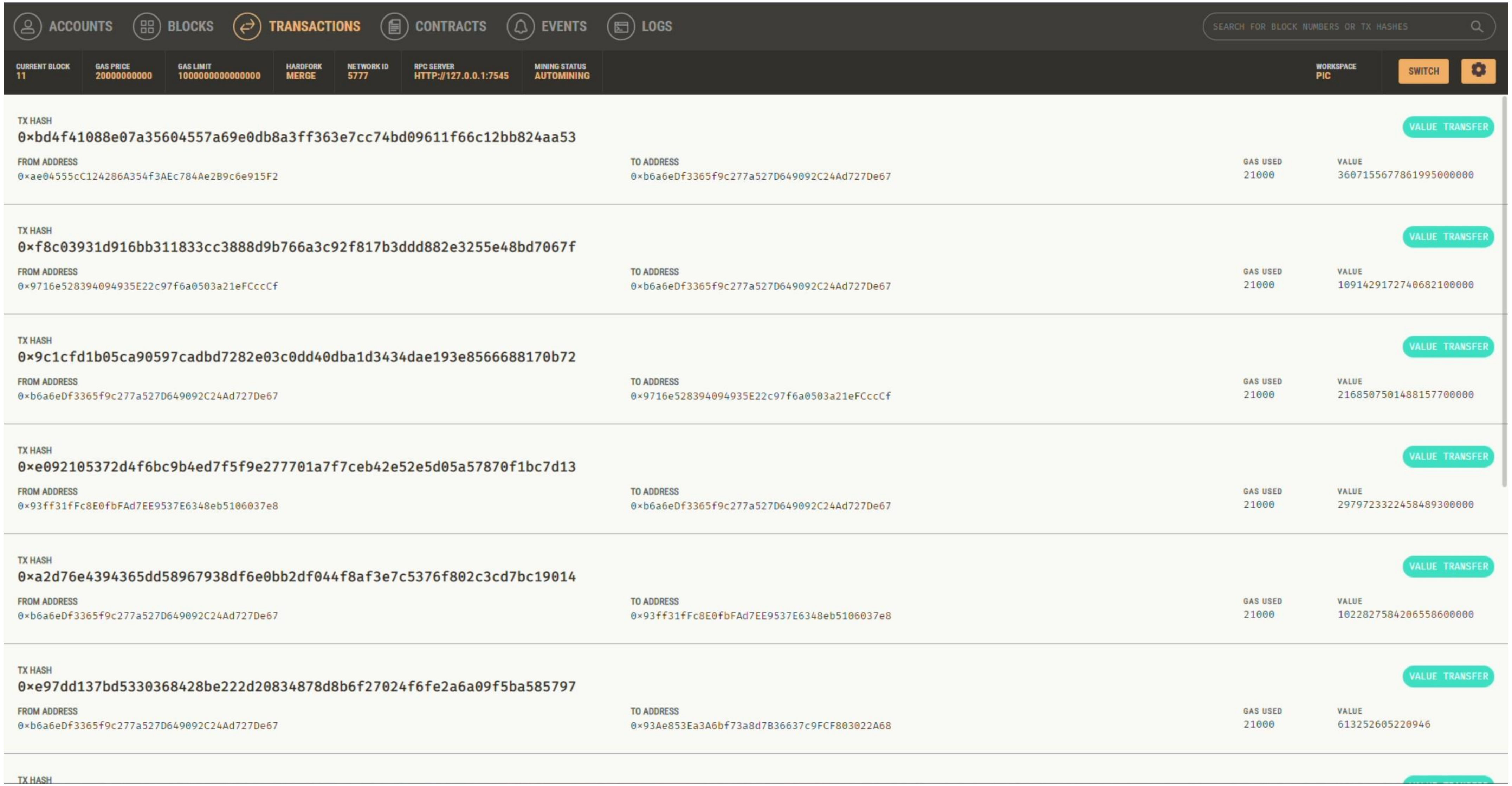
Figure 4. After load management algorithm

Achieved Results - Blockchain Transactions



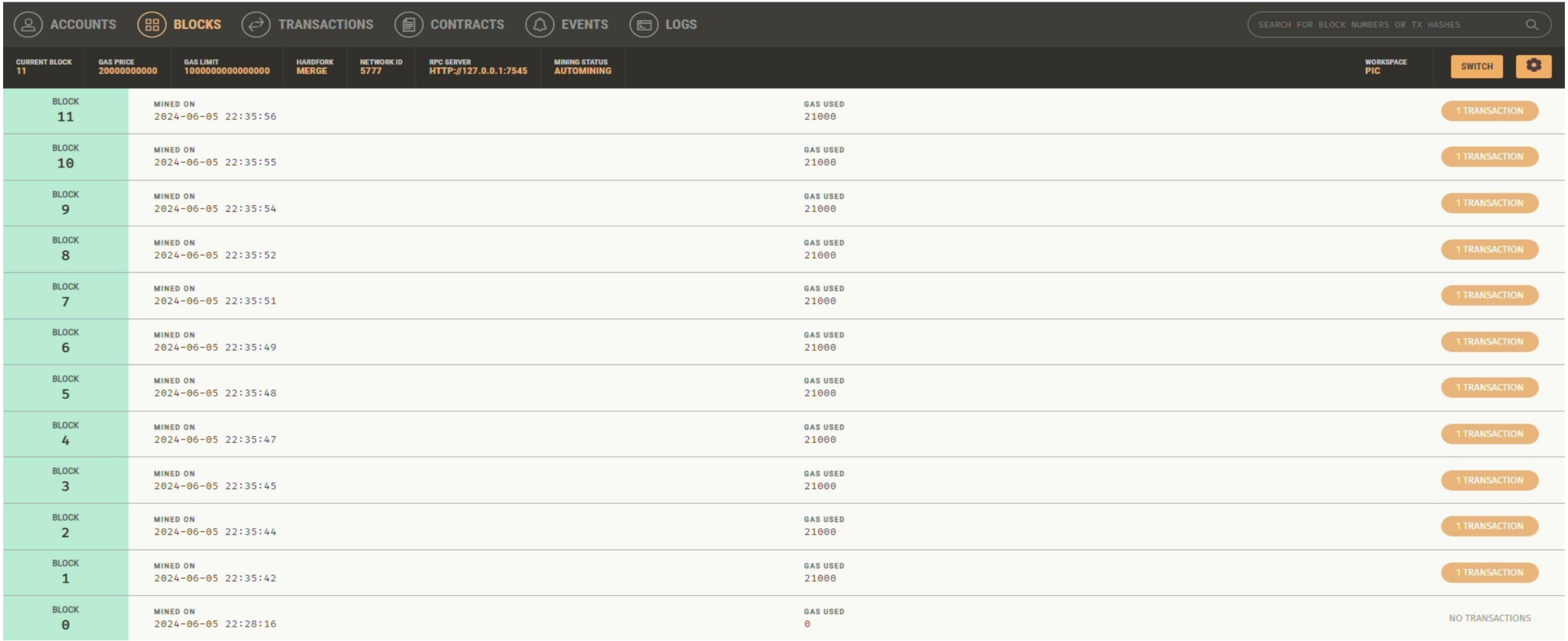
Fictional virtual wallets on Ganache

Achieved Results - Blockchain Transactions



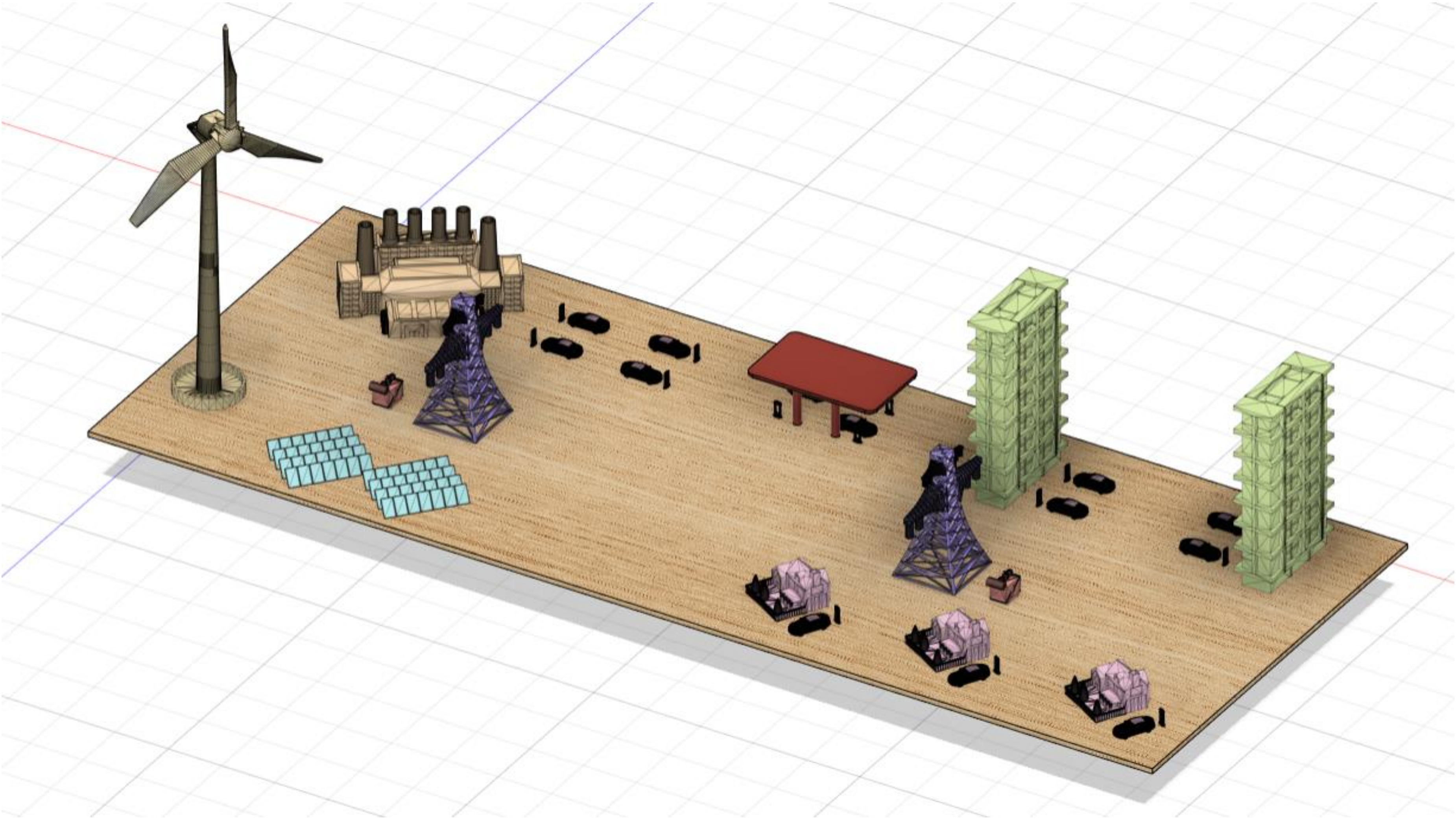
Transactions record

Achieved Results - Blockchain Transactions



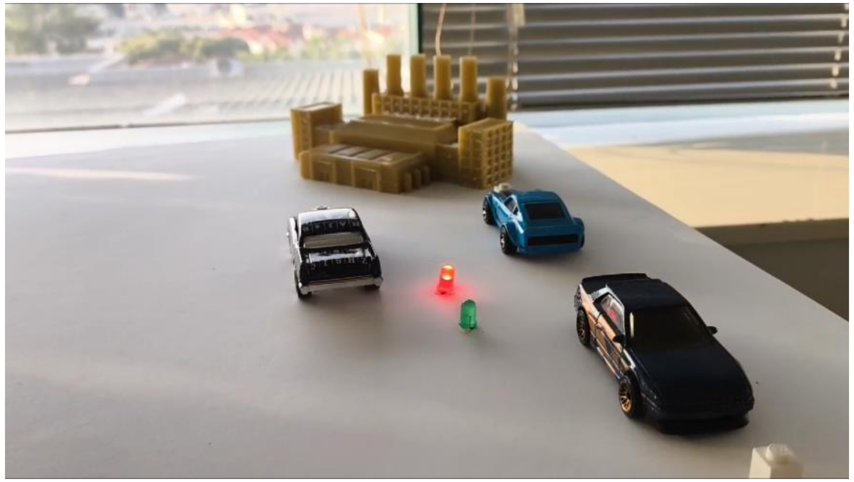
Blockchain

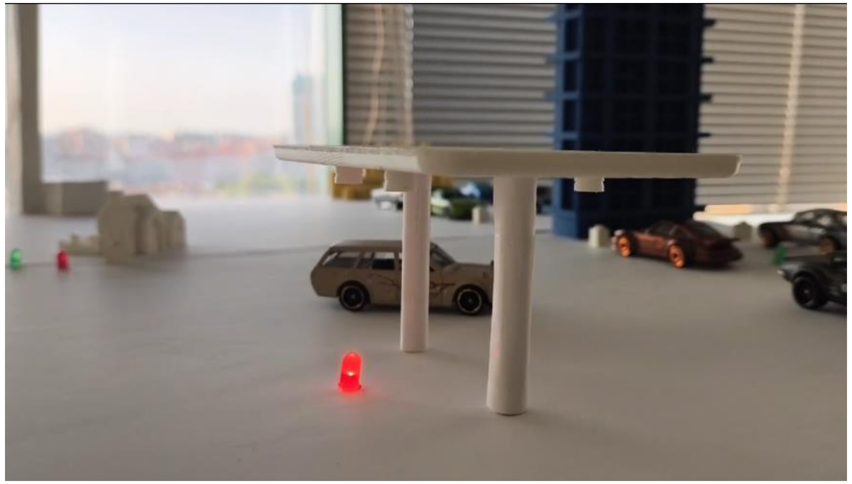
Achieved Results - Prototype Presentation



Mockup simulation

Achieved Results - Prototype Presentation

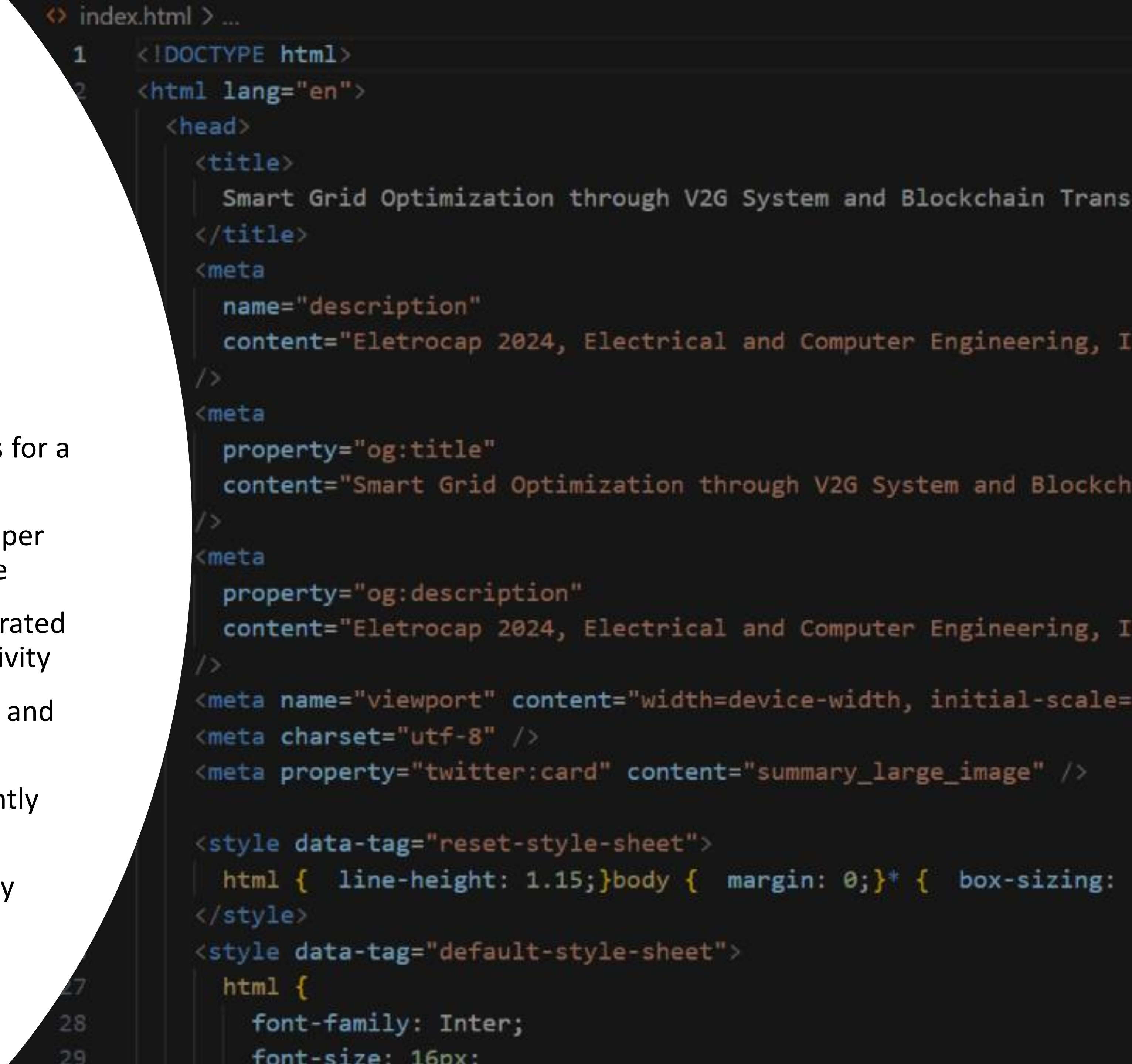




Mockup Presentation

Achieved Results - Site & Marketing

- Developed a functional website as per project requirements
- Ensured compatibility across devices and browsers for a consistent user experience
- Successfully published the website online with proper hosting configuration for stability and performance
- Integrated a blog for updated content and incorporated visual effects for enhanced aesthetics and interactivity
- Integrated visual effects to enhance the aesthetics and interactivity of the site
- Utilized CSS, JavaScript, and frameworks to efficiently implement desired effects
- Conducted thorough testing to ensure functionality across scenarios



Challenges faced by the team

- Defining requirements for the prototype
- Selecting the appropriate data for model training
- Finding suitable datasets
- Complexity of implementation

Contribution of each team member (1)

Diogo Faneco	Duarte Santos	Gonçalo Teixeira
Blockchain transactions / Interactive Mock-up Creation	**Development of Machine Learning Model /Ideal Transactions Algorithm**	**Website and Marketing Development**
Smart Contracts Development	Energy price data analysis	Blog Maintenance
Legal Conditions Documentation	ML model for energy price	User Interface Development
Transaction Security Testing	Ideal Transactions Management Algorithm	Website improvements and addition of features
Analysis and Processing of Transaction Results	User Interface Development	Poster and Video Development

Contribution of each team member (1)

Diogo Faneco	Duarte Santos	Gonçalo Teixeira
Blockchain transactions / Interactive Mock-up Creation	**Development of Machine Learning Model**	**Website and Marketing Development**
Modeling a Representative Model of the Project (Mockup - 3D modeling)	Blockchain Transactions Integration	
Blockchain Transactions Integration (2)	Data Integration with Mockup Presentation	
	Technical Documentation (code implementation)	

Contribution of each team member (2)

José Correia	Rafael Rodrigues	Samuel Figueiredo
Blockchain transactions / Interactive Mock-up Creation	**Development of ML Model / Scientific Research**	**Development of Machine Learning Model /Ideal Transactions Algorithm**
Implementation Documentation	Energy consumption data analysis	Energy production data analysis
Mockup Electrical Assembly	ML model for energy consumption	ML model for energy production
Mockup Microcontroller Programming	Development of load profiles	Ideal Transactions Management Algorithm
Data Integration with Mockup Presentation	Scientific research: The Potential of V2G Technology	Data Integration with Mockup Presentation

Contribution of each team member (2)

José Correia	Rafael Rodrigues	Samuel Figueiredo
Blockchain transactions / Interactive Mock-up Creation	**Development of ML Model / Scientific Research**	**Development of Machine Learning Model /Ideal Transactions Algorithm**
Technical Documentation (code implementation)	Impact Analysis on Power Curve	Blockchain Transactions Integration
	Technical Documentation (code implementation)	Technical Documentation (code implementation)

Vídeo Demonstração

https://drive.google.com/file/d/1lIxI9gIOx-L1yBhjn-3-uDgCeWIVOgGB/view?usp=sharing

Conclusion

The innovative approach to smart grid optimization through Vehicle-to-Grid (V2G) technology and blockchain transactions addresses critical challenges in the energy sector.

By leveraging predictive machine learning models, we have developed robust solutions for energy consumption and production forecasting, dynamic market price prediction, and real-time energy distribution adaptation.

Our blockchain implementation ensures secure and efficient transactions, while our comprehensive mock-up and user interface demonstrate practical applications and user benefits.

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For more information or any questions scan the QR code below and visit our website