

ENERGY COMMUNITIES DIGITAL TWIN PLATFORM

Thesis Final Presentation

MSc Sustainable Energy Technology

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TABLE OF CONTENTS

- › **Research Objective**
- › **Methodology**
 - › *Multi-layered Energy Community Architecture*
 - › *Mosaik*
 - › *The Illuminator*
- › **Implementation**
 - › *Software architecture*
 - › *Layers*
 - › *Energy assets*
 - › *Controllers*
 - › *Agents*
 - › *Games*
- › **Application**
 - › *Study Case 1: Ownership Topology*
 - › *Study Case 2: Agents' Strategy*
 - › *Study Case 3: Control Strategy*
- › **Conclusions**

CONTEXT

- › Historical **transition** towards **Distributed Energy Resources**
- › **Digital Twins:** virtual replicas of **real-world systems** and **processes**
 - › enable **real-time monitoring** and **optimization**
 - › enhance **efficiency, sustainability** and **reliability**
 - › facilitate **data-driven decision-making**
- › **Energy Communities:** socio-technical **collaborative** entities formed for **energy management**
 - › Their operation is the result of the **interactions of numerous diverse domains**

RESEARCH OBJECTIVE

Realise a **holistic, multi-energy, flexible** and **modular Energy Communities Digital Twin (ECDT) platform** that supports the **comprehensive modelling, real-time simulation, and in-depth result analysis** of the complex **multi-layered** structure of ECs



METHODOLOGY

MULTI-LAYERED ENERGY COMMUNITY ARCHITECTURE



GAMES
AGENTS
CONTROL SYSTEMS
ENERGY ASSETS
ENVIRONMENT

INTERACTIONS
OWNERS
EMSS
DERs
DATA

MOSAİK

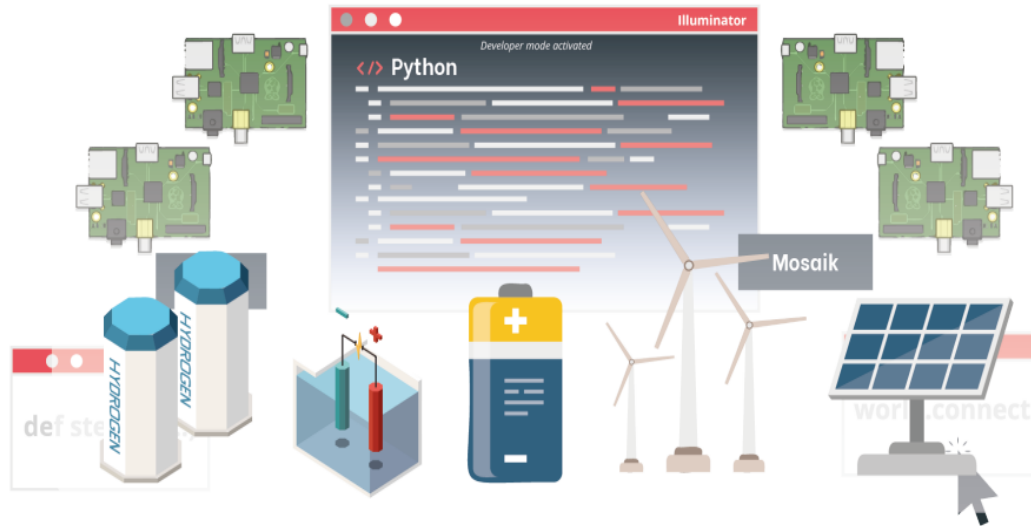
Smart Grid **co-simulation** framework



- › **Combine** existing simulators and models
- › **Distributed** computational units
- › **Large-scale** Smart Grid scenarios
- › **Simple** API
- › **Coordinated** Execution
- › **Real-time** operation

THE ILLUMINATOR

Development toolkit designed to **demonstrate** the working of renewable energy technologies, their system-level integration, and challenges and to **educate** students and communities

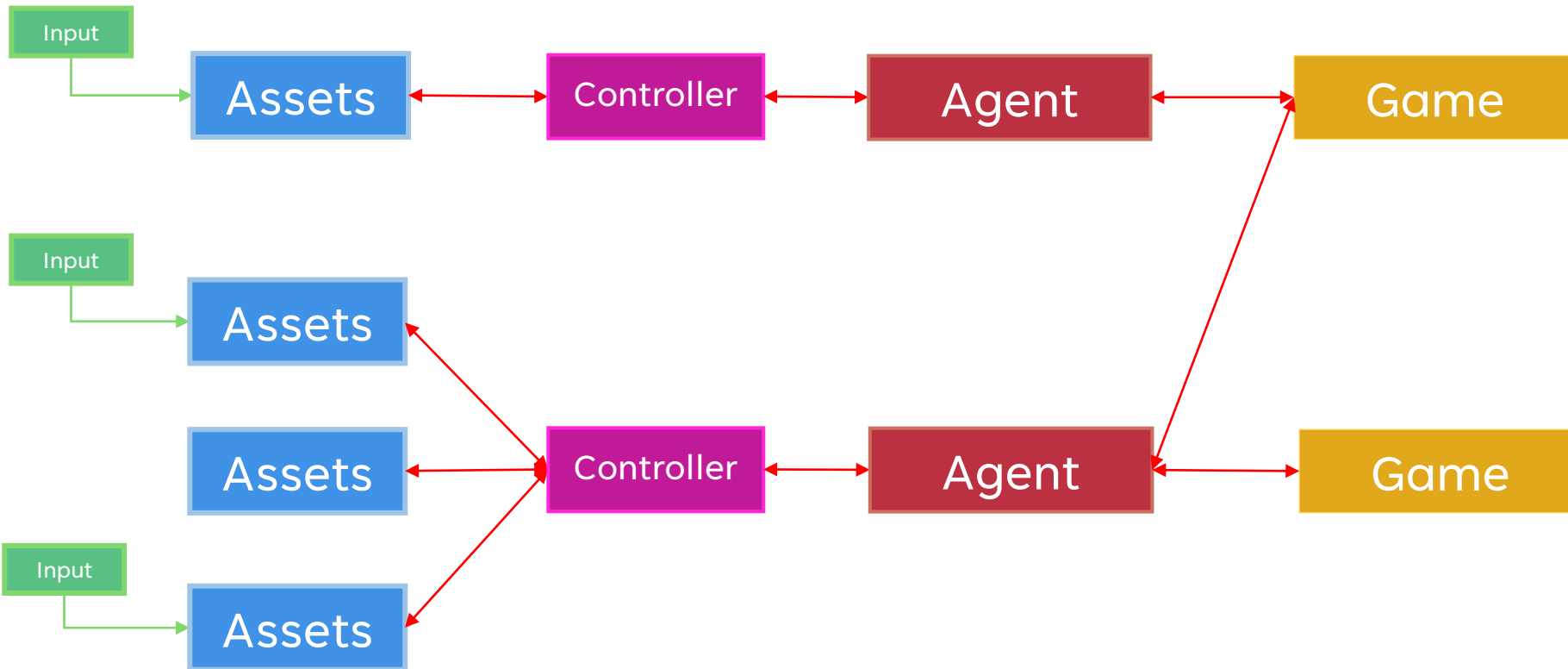


- › **Modularity, scalability and configurability**
- › **Tabletop approach**
- › **Easy to use**
- › **Default set of models**

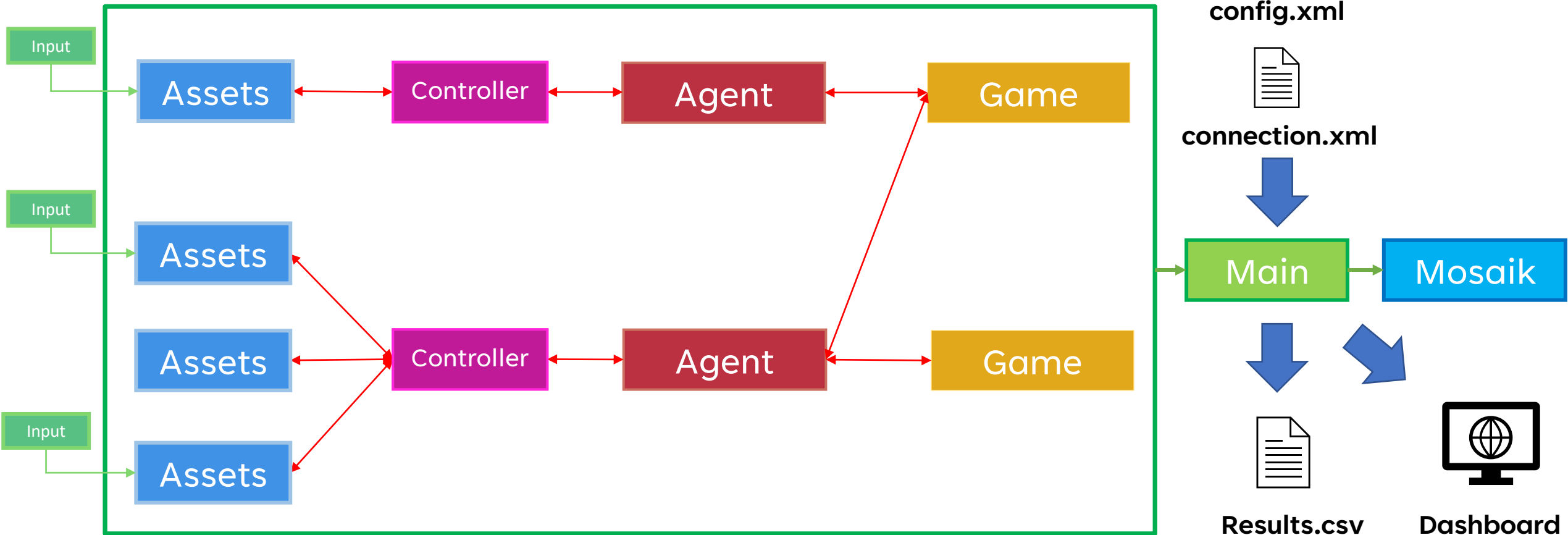


IMPLEMENTATION

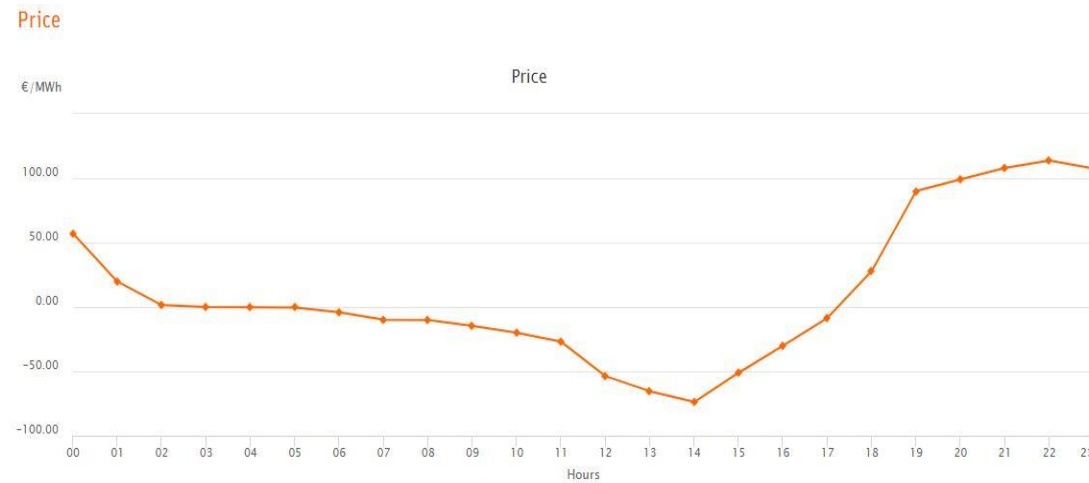
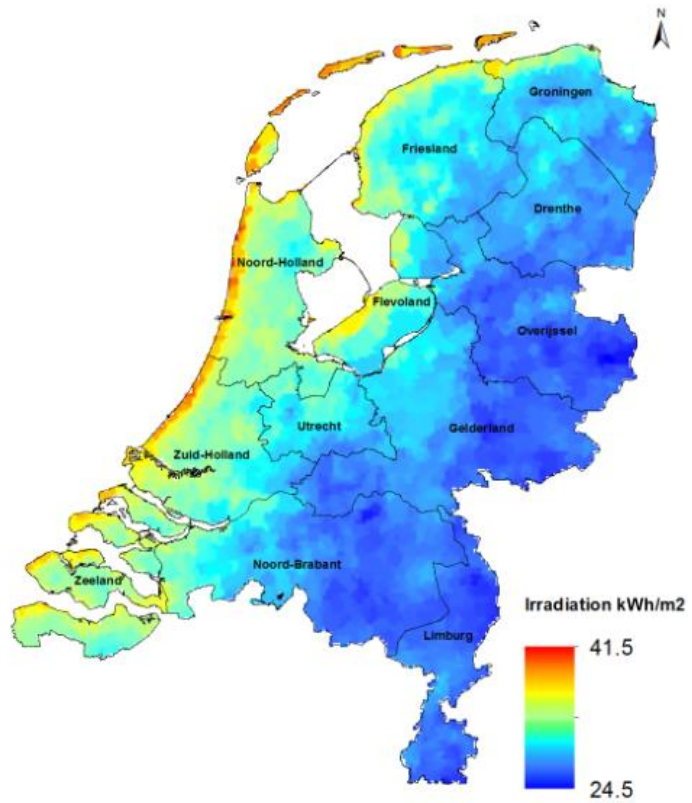
SOFTWARE ARCHITECTURE



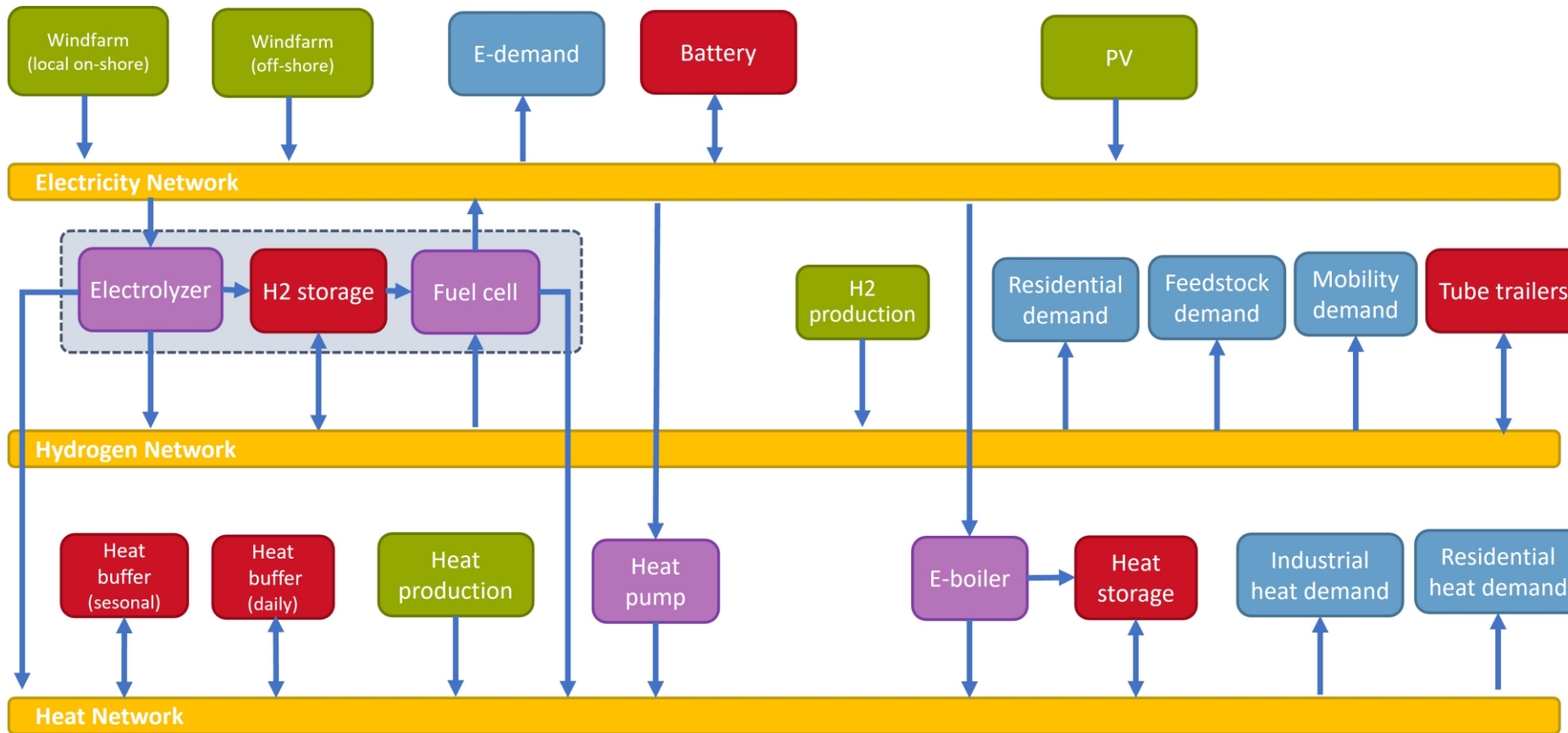
THE ARCHITECTURE



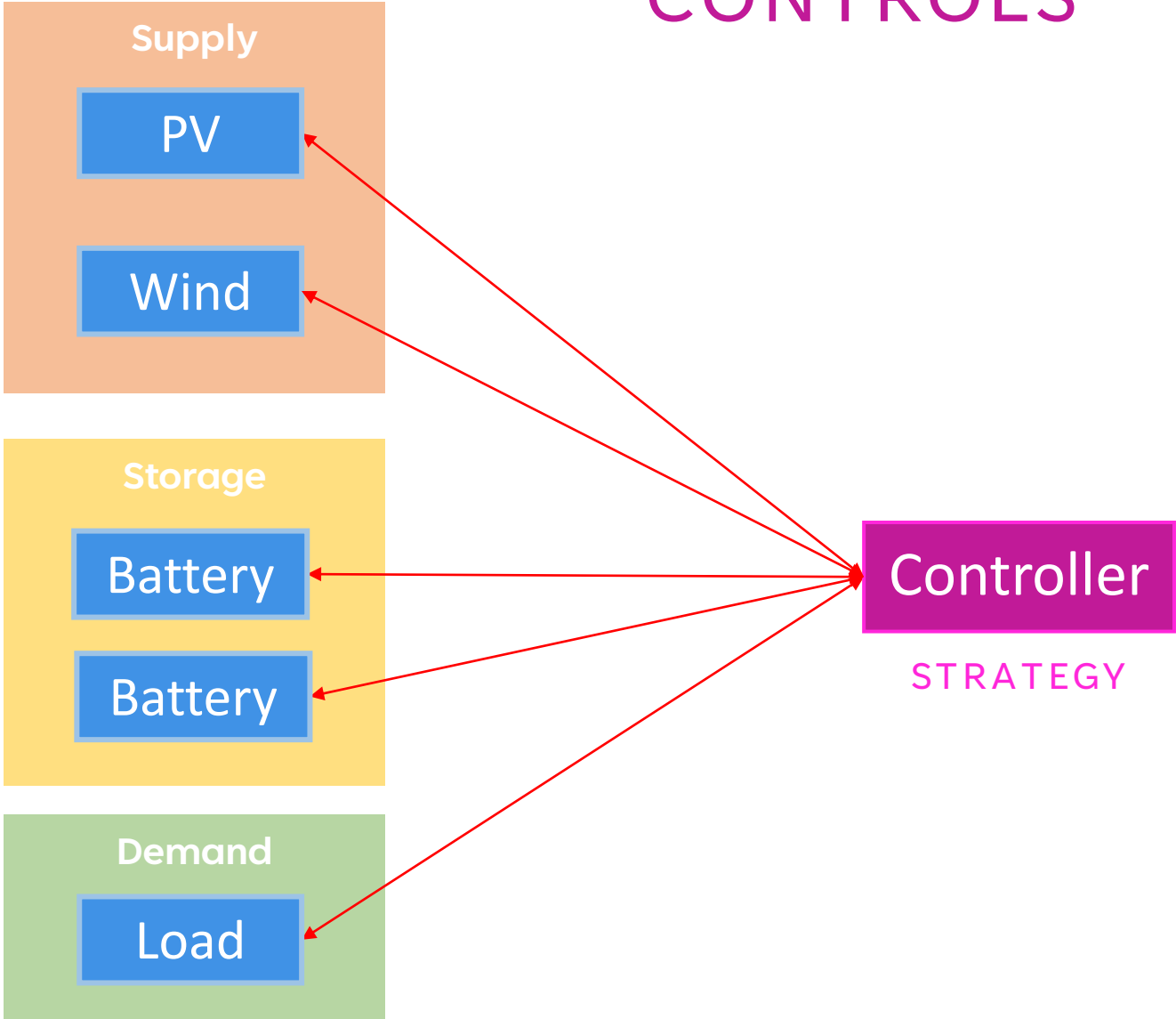
ENVIRONMENT



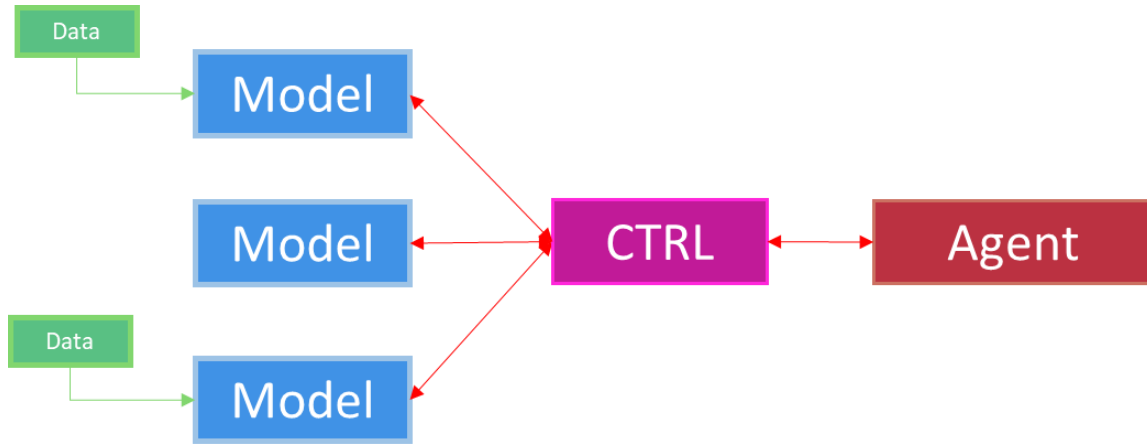
ENERGY ASSETS



CONTROLS



AGENTS



Beliefs

Agent's knowledge or understanding of the world

Desires

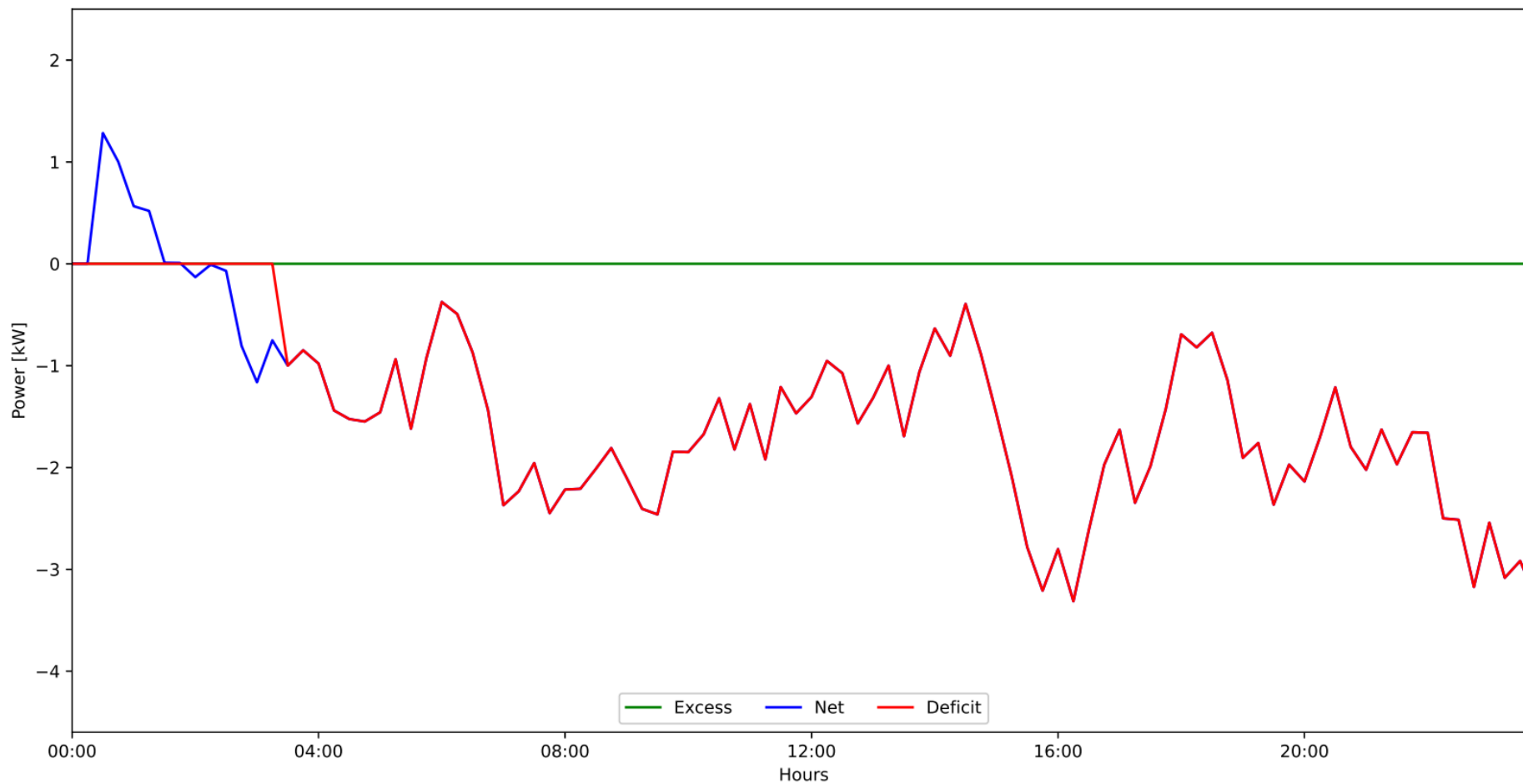
Agent's goals or objectives, based on beliefs

Intentions

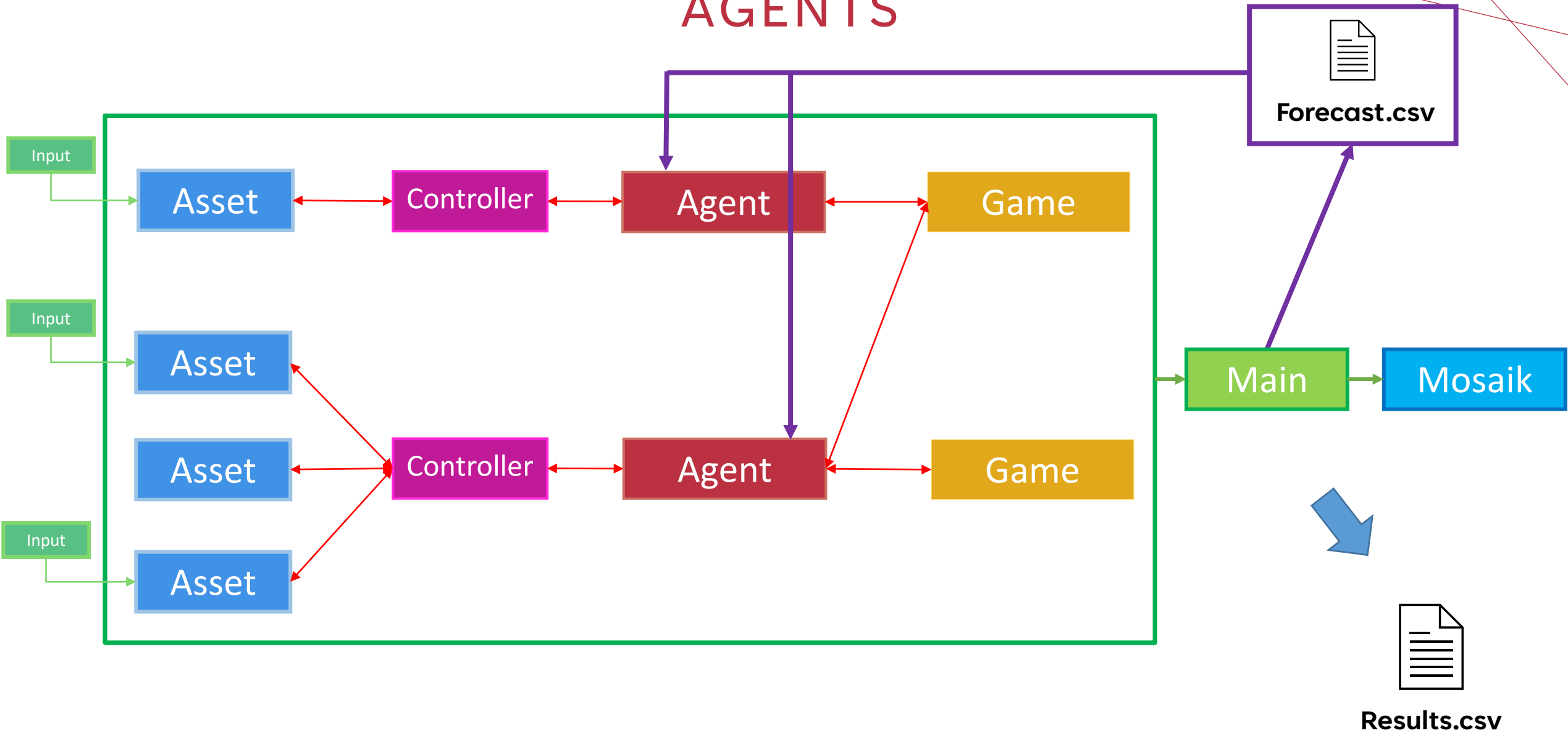
Agent's plans or actions to achieve its desires



AGENTS



AGENTS



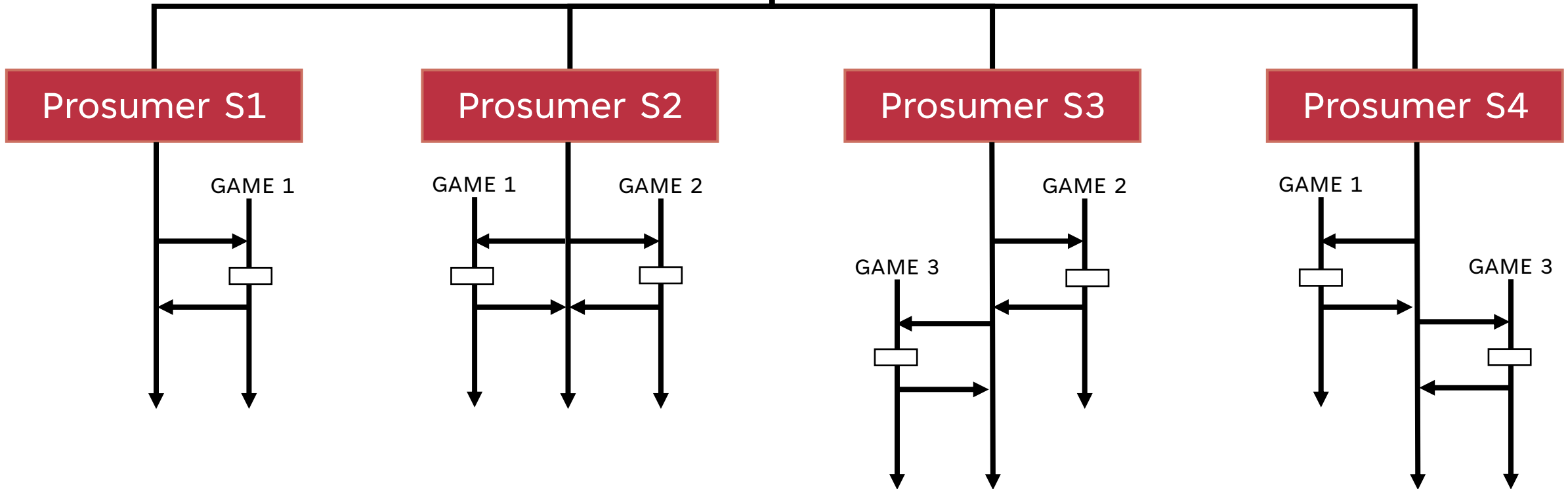
AGENTS

ABSTRACT
CLASS



METHODS:

- › INITIALIZE
- › PLAY GAME 1
- › PLAY GAME 2
- › PLAY GAME 3



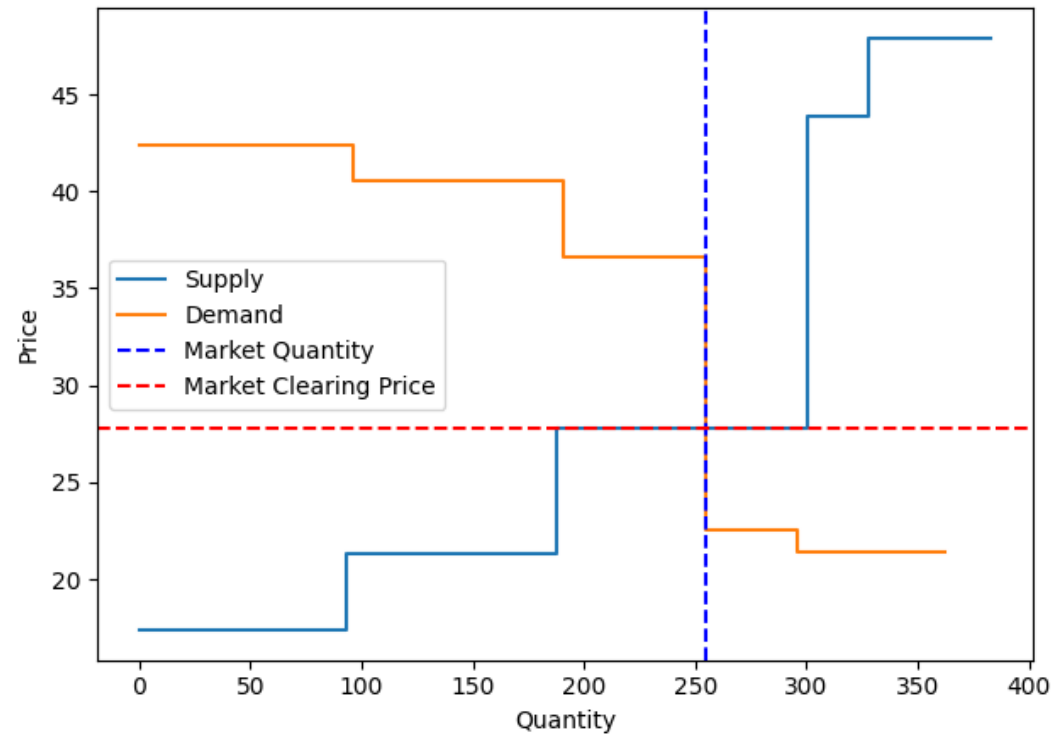
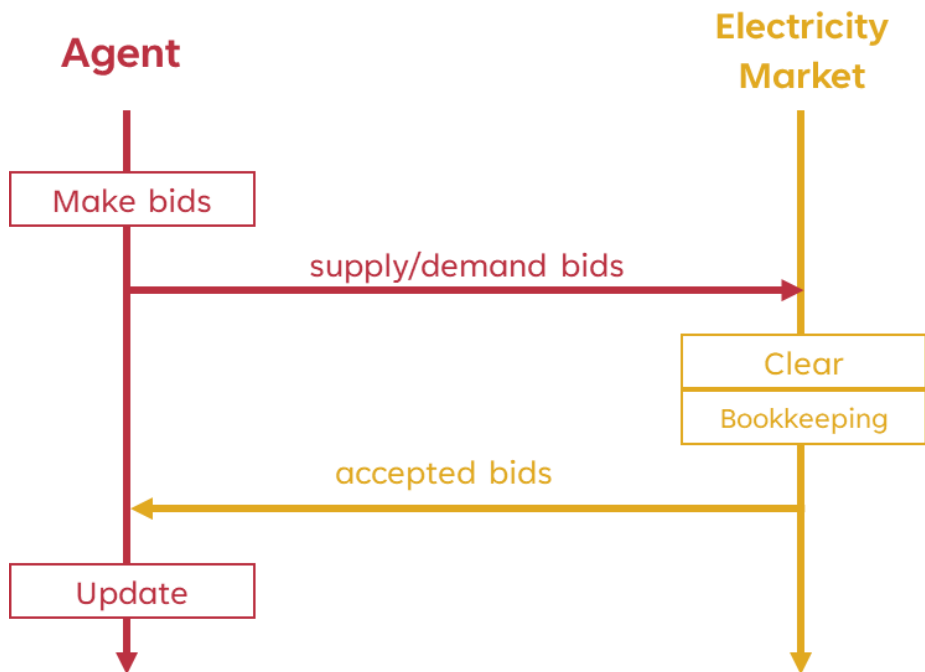
GAMES

Game	Type	Message	Metric
Electricity Market	Many to Many	Supply Bids Demand Bids	Financial
P2P Trading	One to One	Supply Offers Demand Requests	Enviromental
Real time Price	Many to One	Buy Sell	Financial



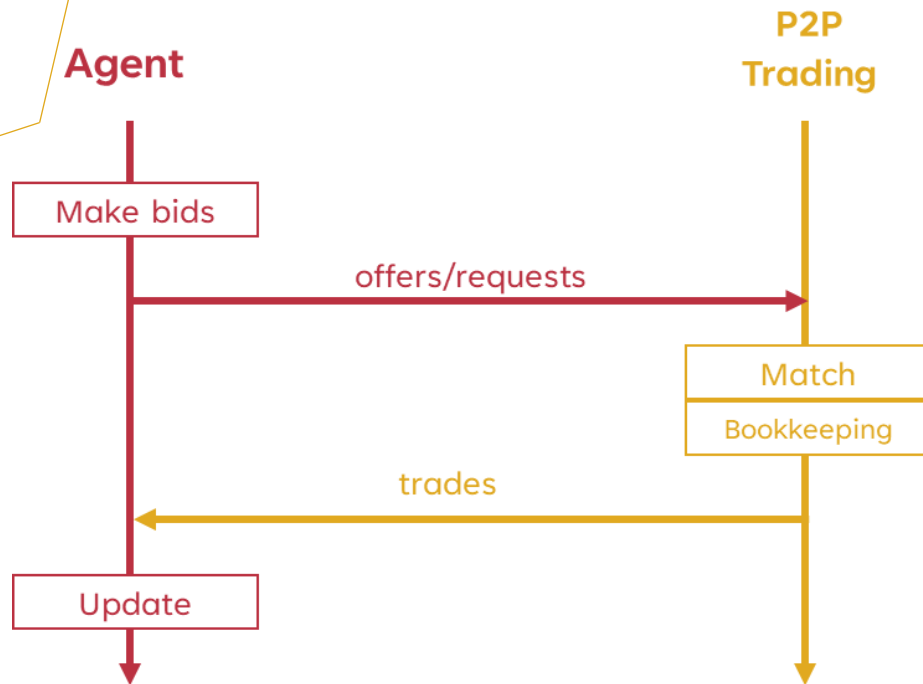
GAMES

ELECTRICITY MARKET

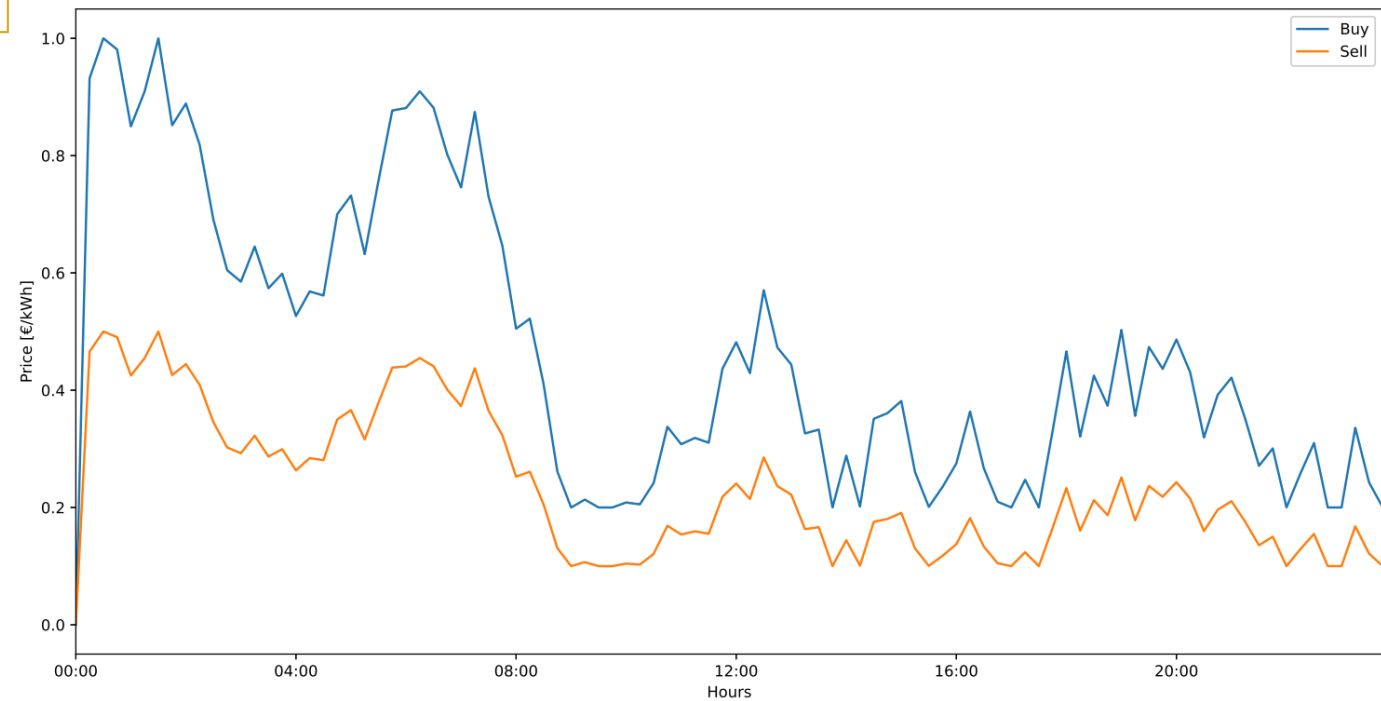


GAMES

P2P TRADING



GAMES RT PRICE



An abstract graphic consisting of several thin white lines that intersect to form a complex, multi-sided polygonal shape. The lines are white and stand out against the solid blue background. The shape is irregular and somewhat jagged, with several sharp angles and overlapping lines.

APPLICATIONS

APPLICATIONS

Degrees of Freedom

› Energy System Analysis

- › Realizing the DT of complex multi-energy ECs
- › Monitoring and controlling EC operations in real-time
- › Exploring optimal solutions for integrating energy assets in different ownership topologies
- › Forecast or back-test the behaviour of ECs in specific environmental conditions
- › Assessing the effects of control strategies on ECs operations

› Policy Analysis and Decision Support

- › Fostering transparent and collaborative decision-making processes in ECs
- › Analyzing the impact of different policy measures and regulatory frameworks on Ecs
- › Assessing the effects of decisions related to the change in the management of Ecs

› Game Theory and Behavioral Studies

- › Integrating MASs to capture stakeholders' behaviours and preferences
- › Studying strategic interactions and outcomes among stakeholders within ECs
- › Evaluating the effectiveness of energy trading schemes
- › Assessing the financial flows of ECs' members in real-world conditions
- › Exploring the possible factors influencing stakeholders' choices and cooperation patterns
- › Investigate the social acceptance within ECs and their inclusivity

› I. Environment Layer

- › **I-A.** Modify environmental/external conditions

› II. Energy Assets Layer

- › **II-A.** Modify parameters of assets
- › **II-B.** Modify assets set
- › **II-C.** Modify assets ownership

› III. Controls Layer

- › **III-A.** Modify control strategy

› IV. Agents Layer

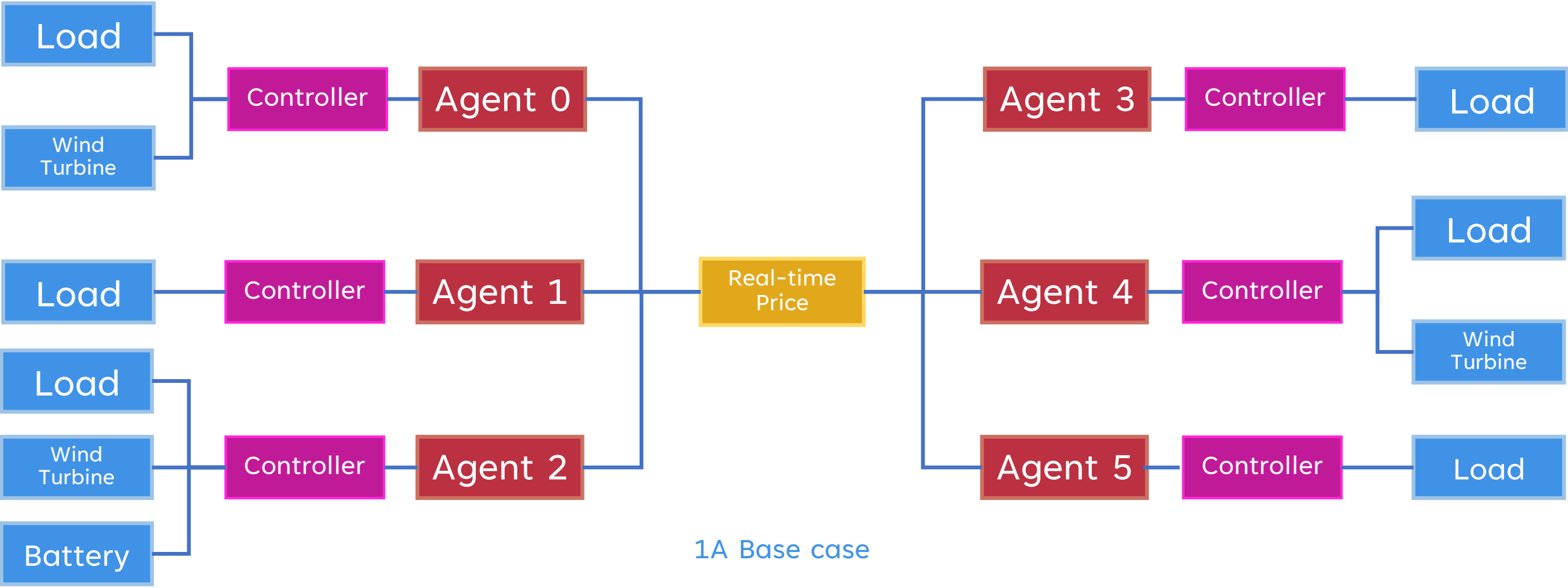
- › **IV-A.** Modify games participation
- › **IV-B.** Modify agents' strategy

› V. Games Layer

- › **V-A.** Modify games parameters
- › **V-B.** Modify games metrics

STUDY CASE 1

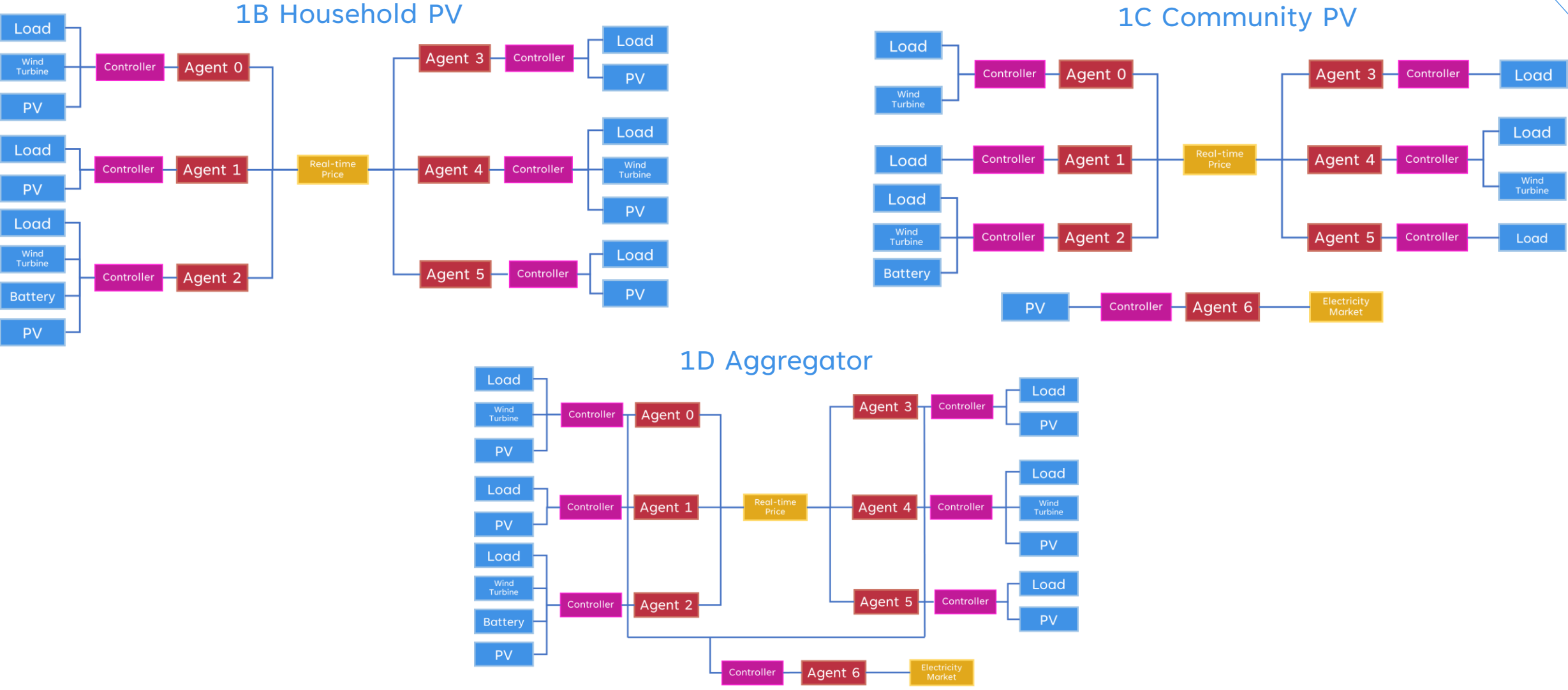
Ownership Topology



1A Base case

STUDY CASE 1

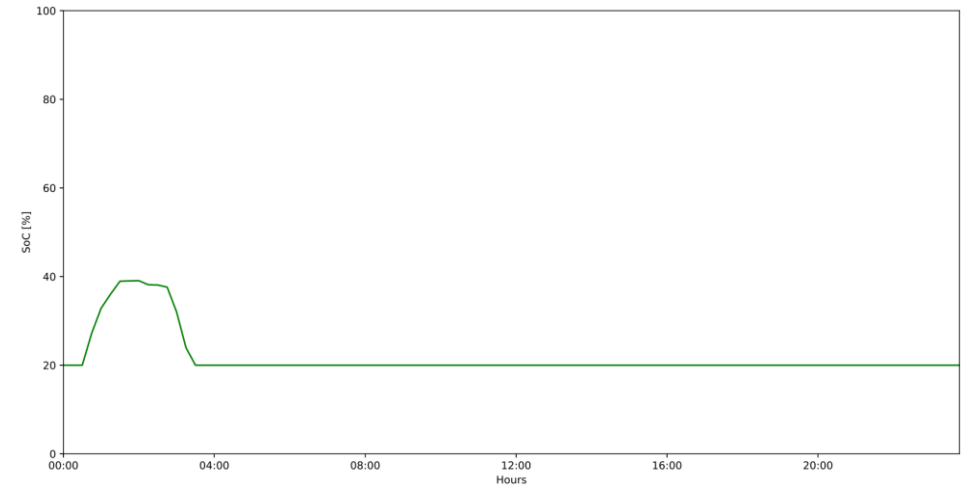
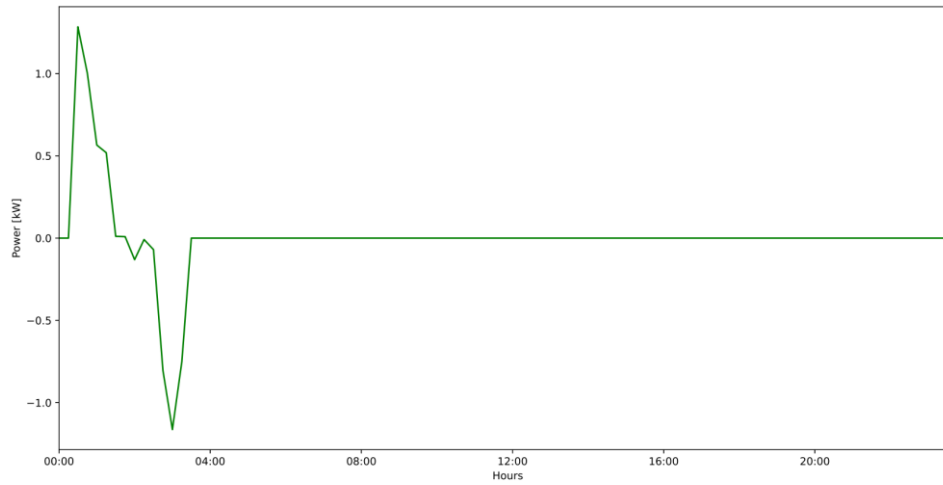
Ownership Topology



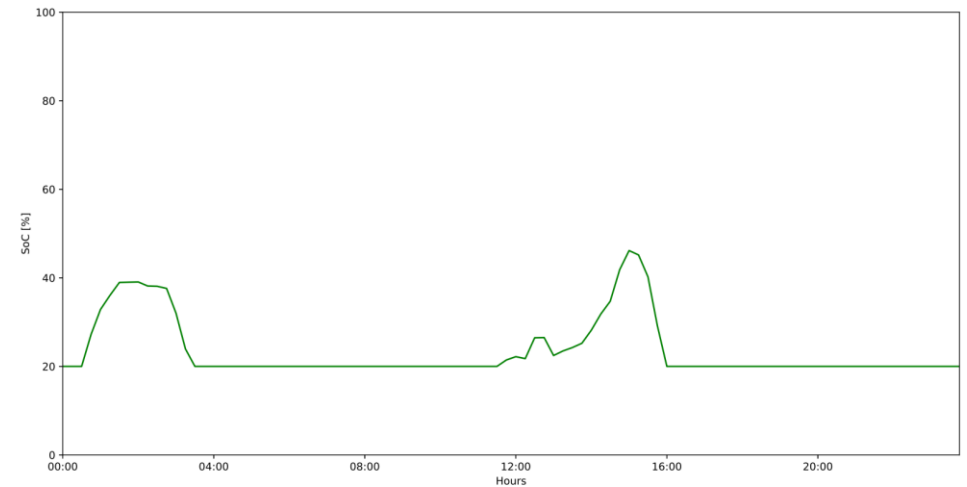
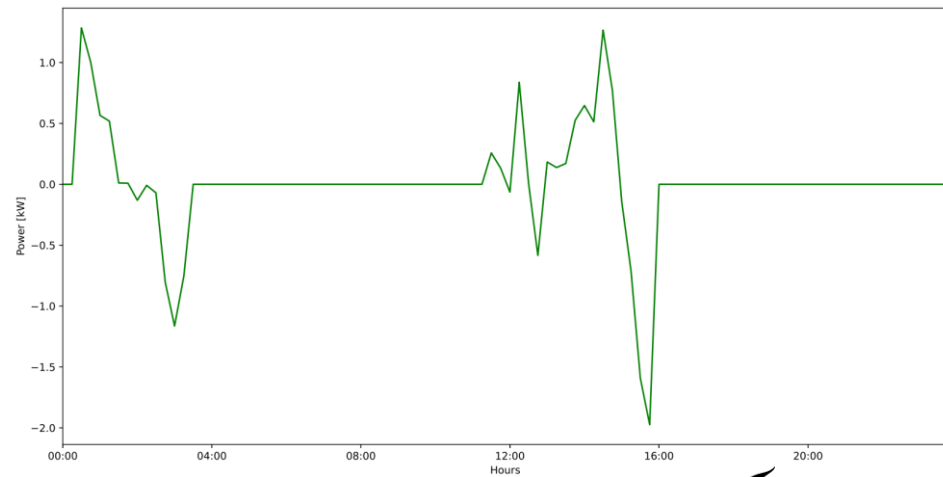
STUDY CASE 1

Ownership Topology

1A Base case

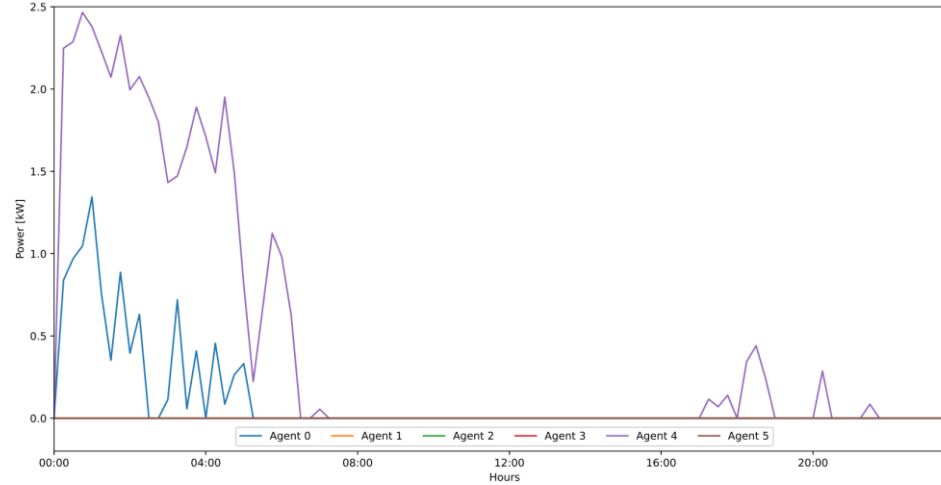
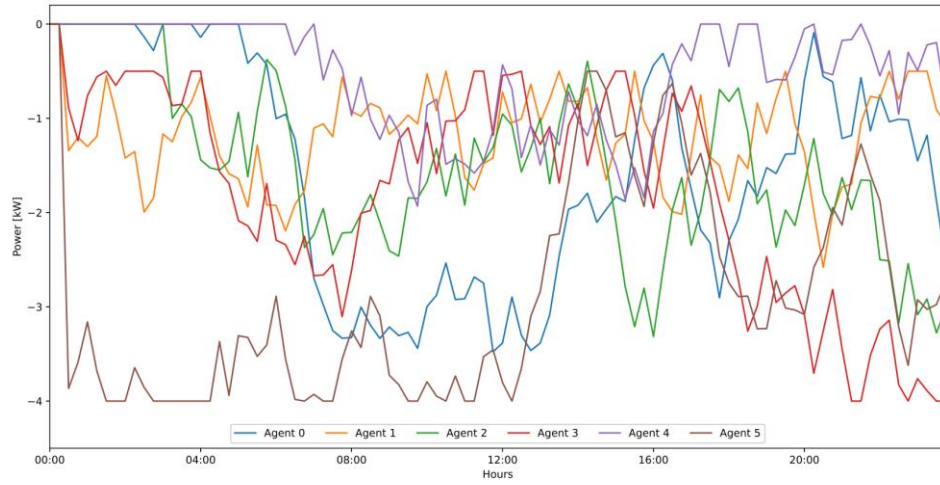


1B Household PV

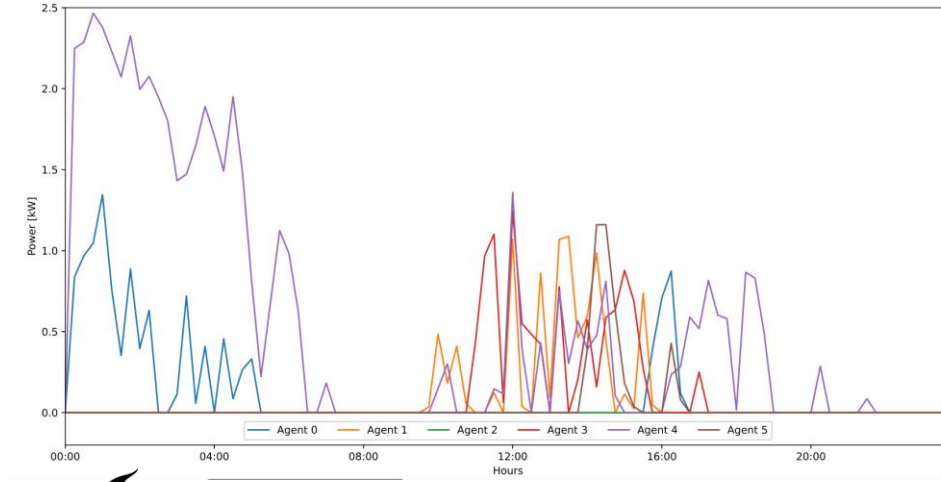
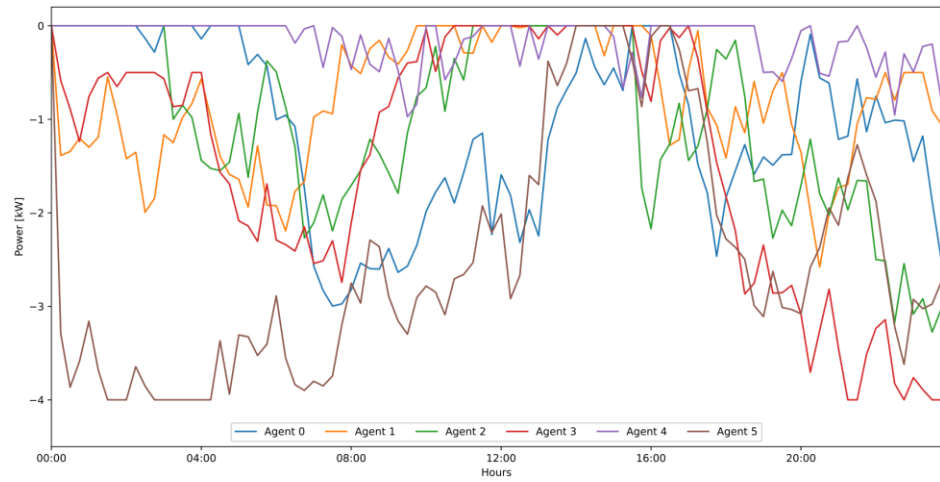


STUDY CASE 1

Ownership Topology



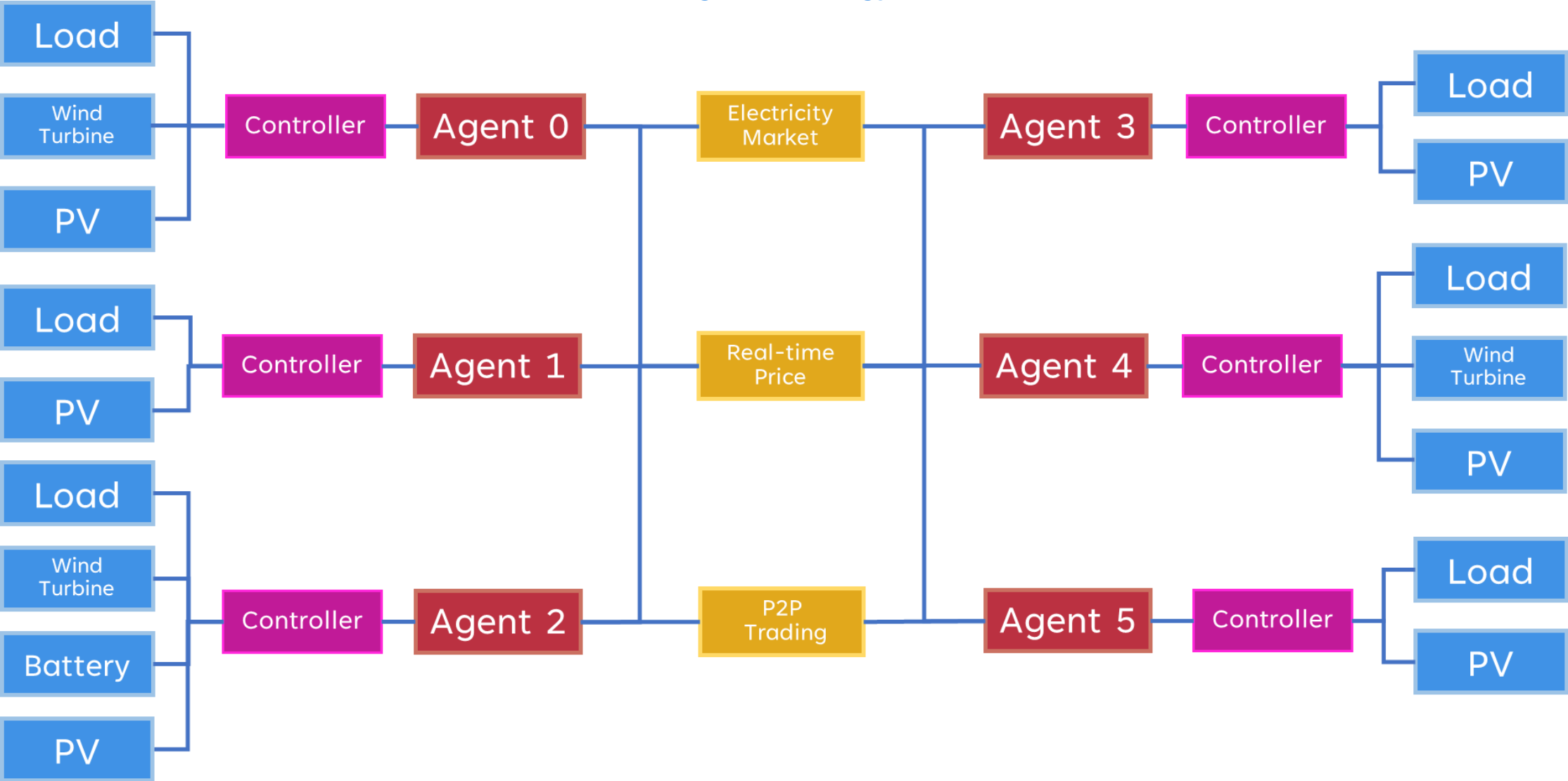
1A Base case



1B Household PV

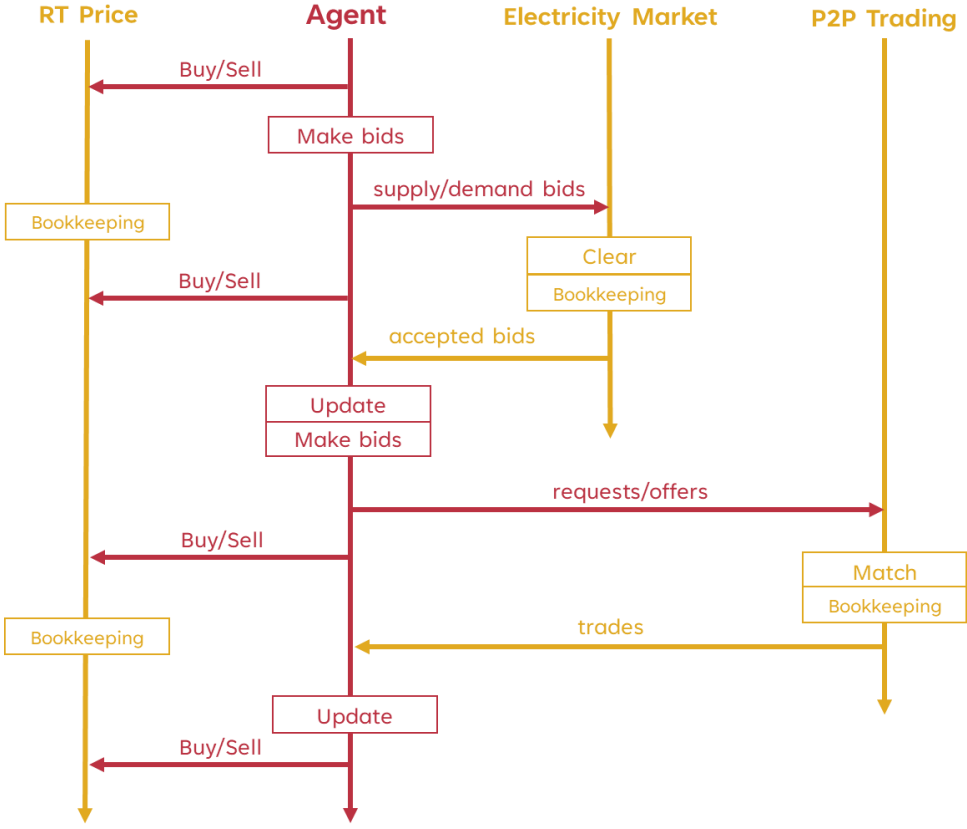
STUDY CASE 2

Agent Strategy

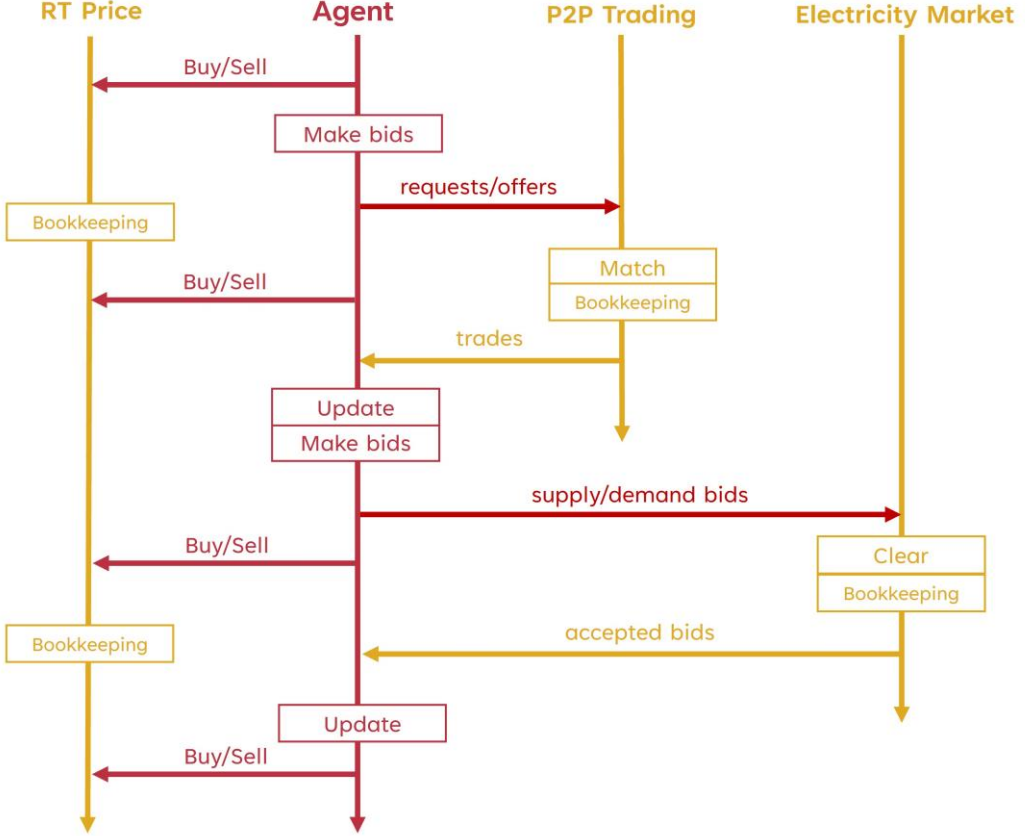


STUDY CASE 2

Agent Strategy



2A Strategy EM-P2P

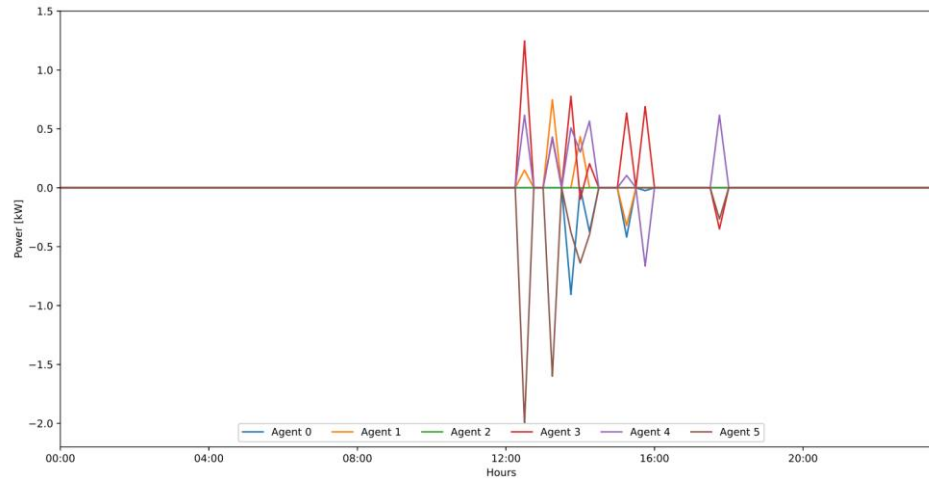


2B Strategy P2P-EM

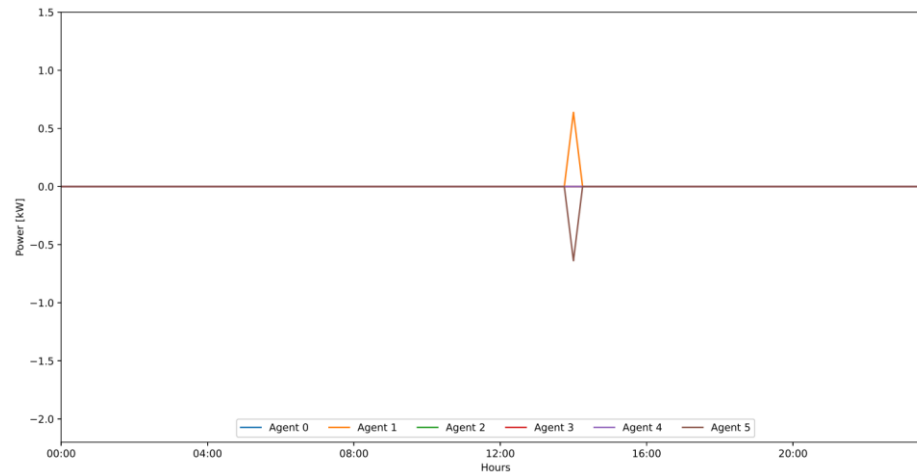
STUDY CASE 2

Agent Strategy

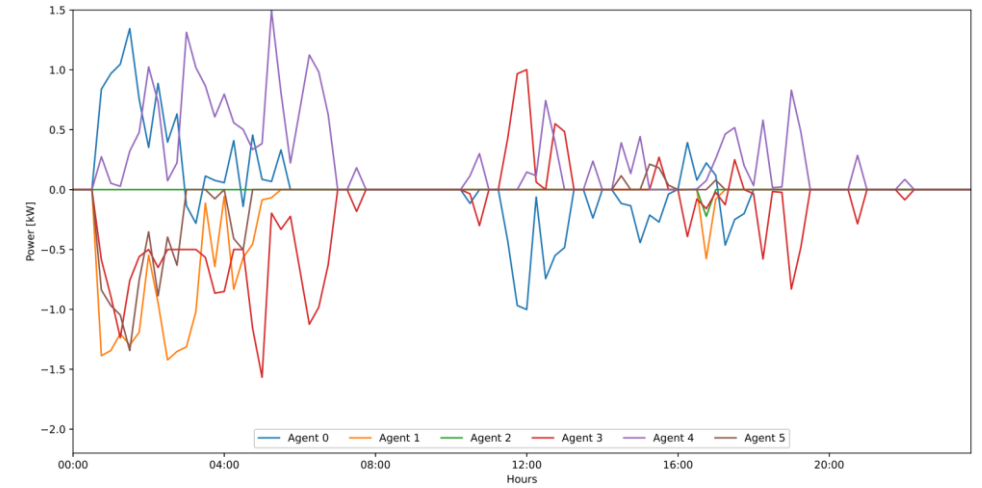
2A Strategy EM-P2P



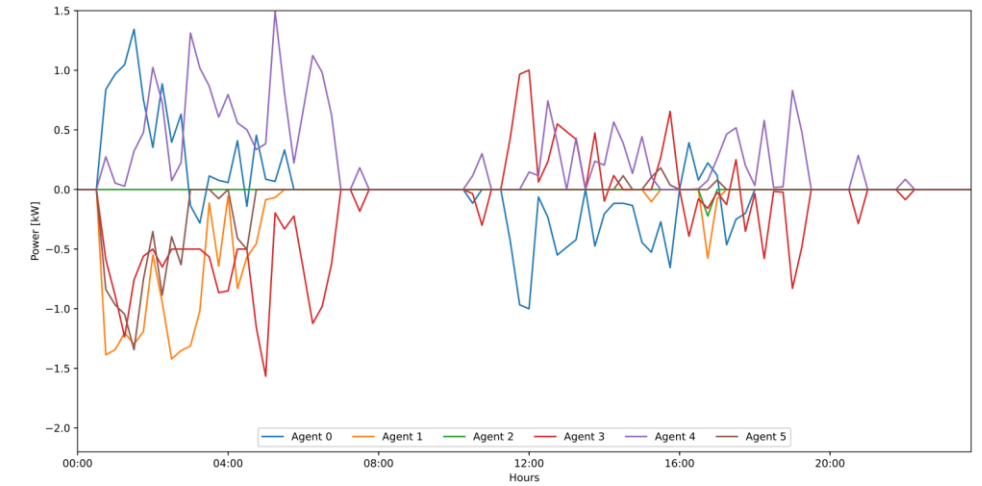
EM



2B Strategy P2P-EM

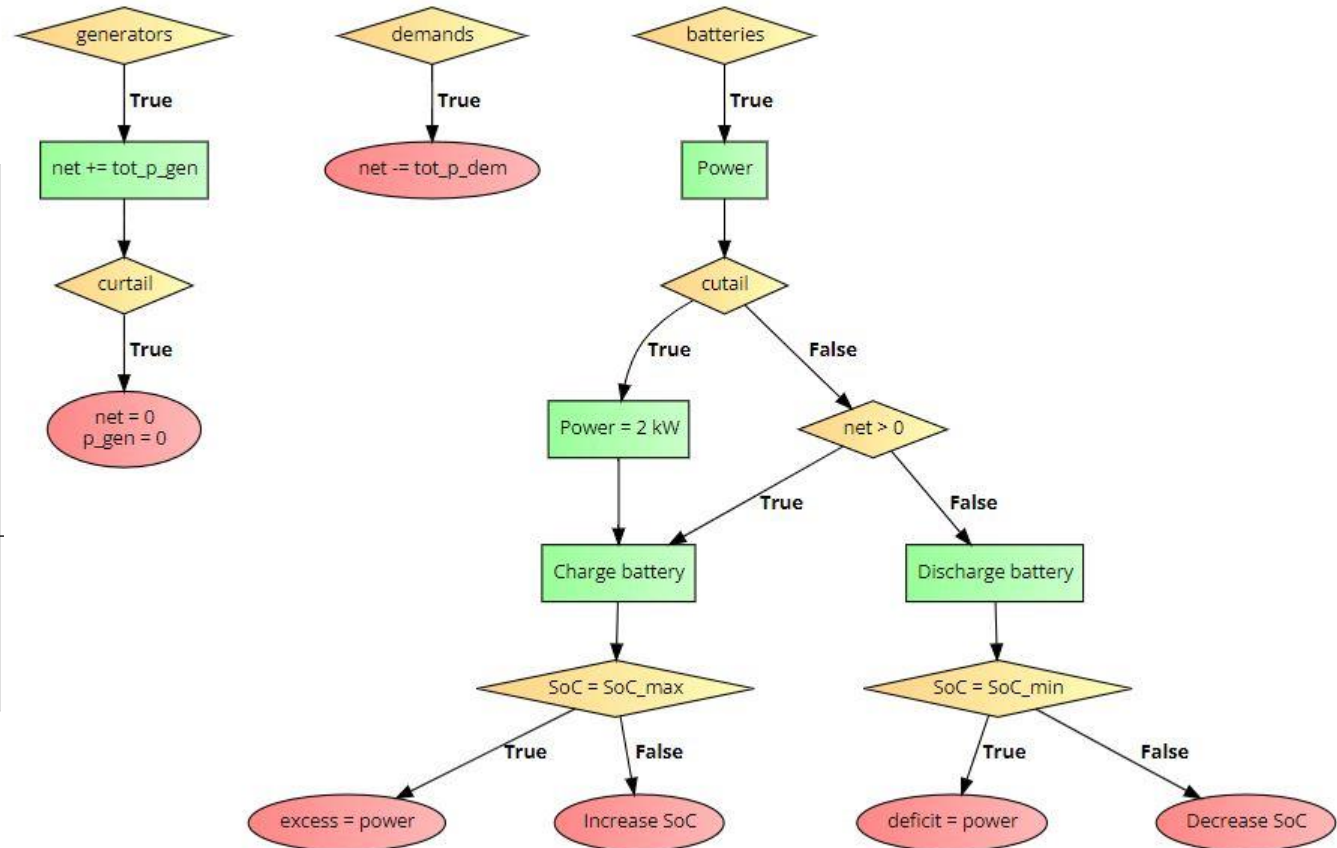
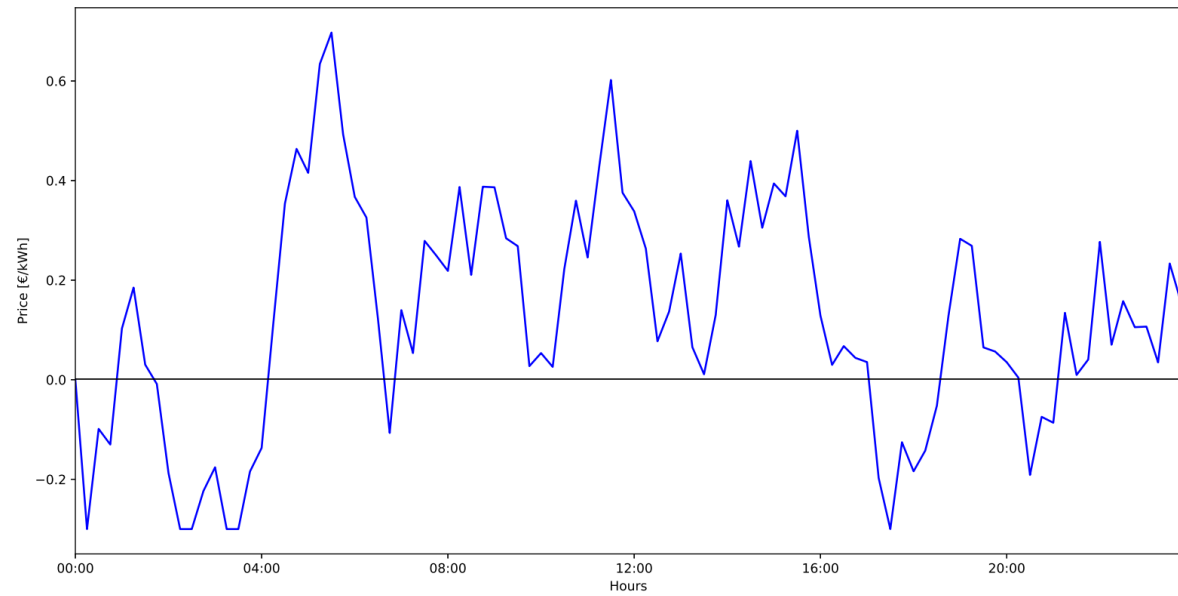


P2P



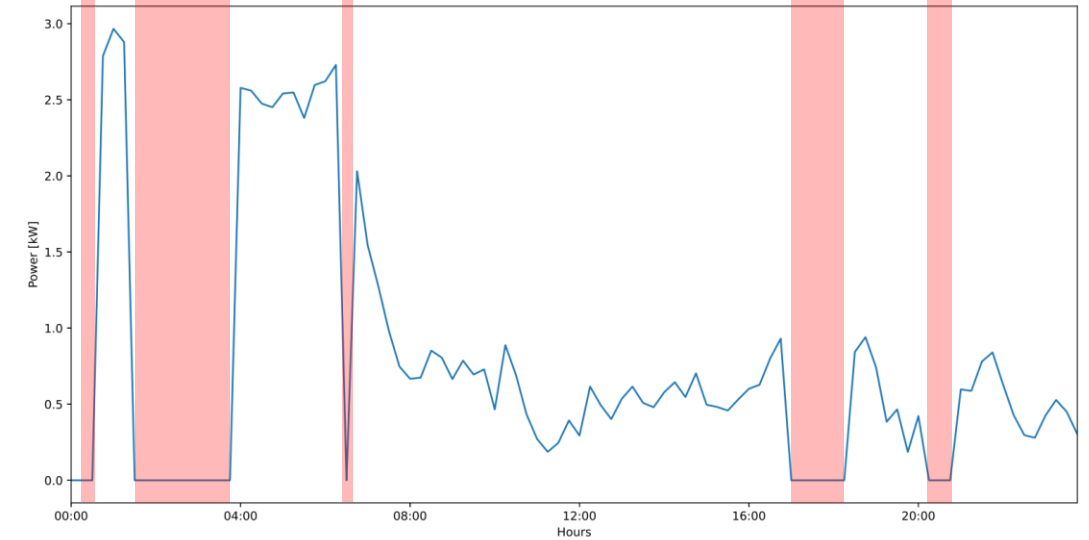
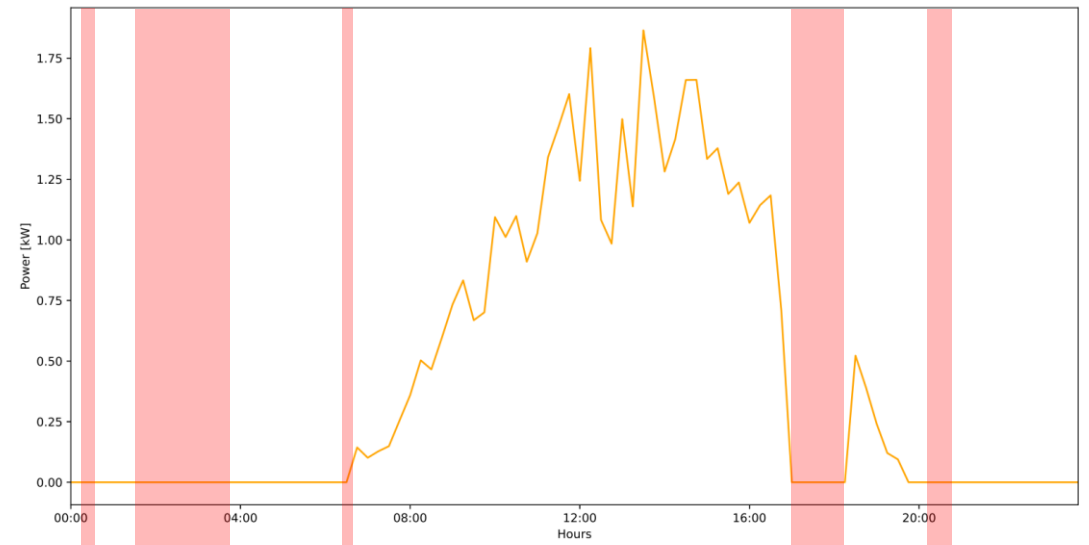
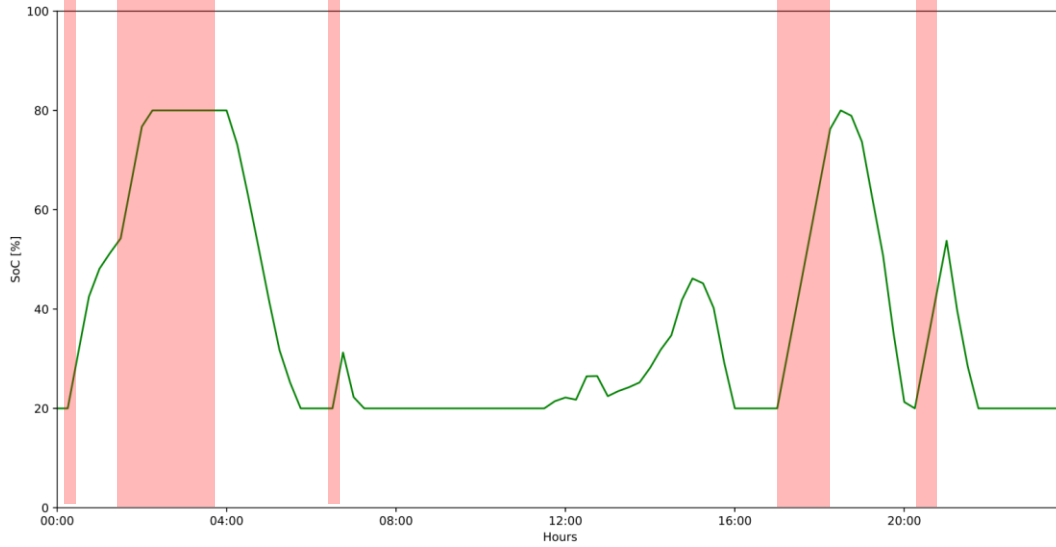
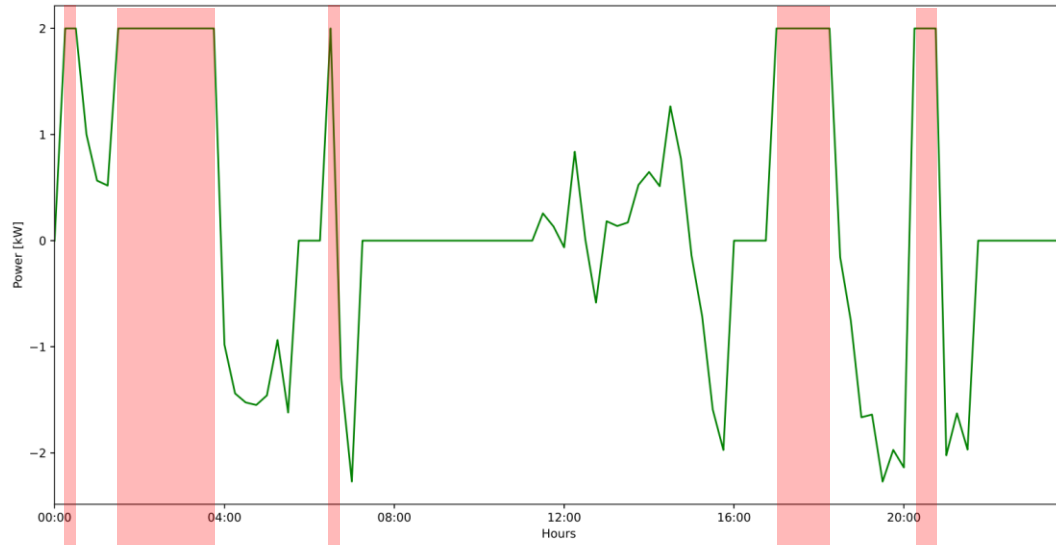
STUDY CASE 3

Control Strategy



STUDY CASE 3

Control Strategy



An abstract graphic consisting of several thin white lines that intersect to form a complex, multi-sided polygonal shape. The lines are white and stand out against the solid blue background. The shape is irregular and occupies the left side of the frame.

CONCLUSIONS

CONCLUSIONS

- › To design a **holistic, modular, and flexible** EC DT platform a **structural decomposition** of **ECs' architecture** shall be performed and a **powerful co-simulation virtual environment** shall be employed.
- › To comprehensively encompass the **diverse domains** and **complexities** of ECs, the EC DT platform shall be able to **reliably** and **extensively represent** the **physical dynamics**, the **agents' behaviours** and their **interactions**.
- › The EC DT platform's **comprehensive design** and **customizability** foster a **holistic approach** to ECs' analysis, allowing for the capture of **cross-layer effects**, thus unlocking a **deeper understanding** of these socio-technical systems.



THANK YOU :)

ABOUT ME

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