MODELLING FLEXIBILITY OPTIONS IN AGENT BASED MODELS

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Agenda

1. Introduction
2. Lightning Talks
3. World Café
4. Interactive Summary

INATECH
INSTITUT FÜR NACHHALTIGE TECHNISCHE SYSTEME

IISM
INSTITUTE OF INFORMATION SYSTEMS AND MARKETING

Fraunhofer IEG

Fraunhofer ISI

ASSUME toolbox

PROJECT AIM:

- Provide a fully modular architecture with easy adaptable and interchangeable main components
- Combine energy markets modeling and deep reinforcement learning

REINFORCEMENT LEARNING ALLOWS:

- Testing out new market designs
- Evaluation of market misuse or power exertion
- Influence of participation in parallel markets on agent’s behavior

ASSUME – Who?

IISM
INSTITUTE OF INFORMATION SYSTEMS AND MARKETING

- Benchmarking of DRL in electricity market modelling
- Explainable AI and interpretation of individual strategies for actors on the market using DRL
- DRL for multi-market bidding in electricity systems

FH AACHEN
UNIVERSITY OF APPLIED SCIENCES

- Comparability of different market designs
- Feature parity to existing market simulations
- Investigation of new market designs

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- Modelling strategic bidding on interrelated markets
- Investigation of Redispatch
- Implementing distribution grids and local energy markets

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ISI

- Modeling the demand side agents for emerging technologies
- Investigate market behavior of PtX plants
- Assess demand response measures to promote the market diffusion of flexible resources

Fraunhofer
IEG

- Modelling Electricity Infrastructure using PyPSA
- Modelling Sector Coupling Scenarios
- Market integration of Sector Coupling technologies

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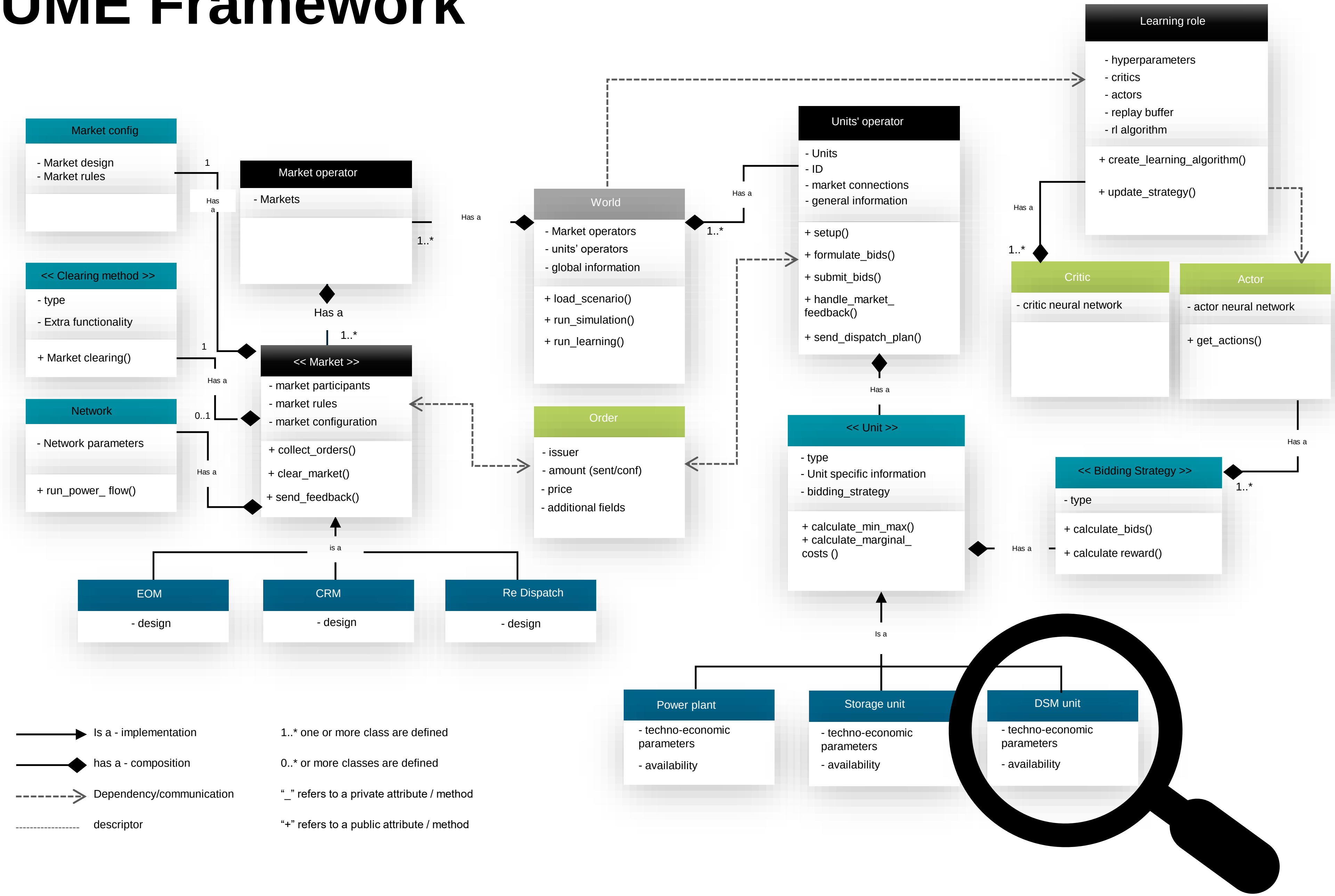
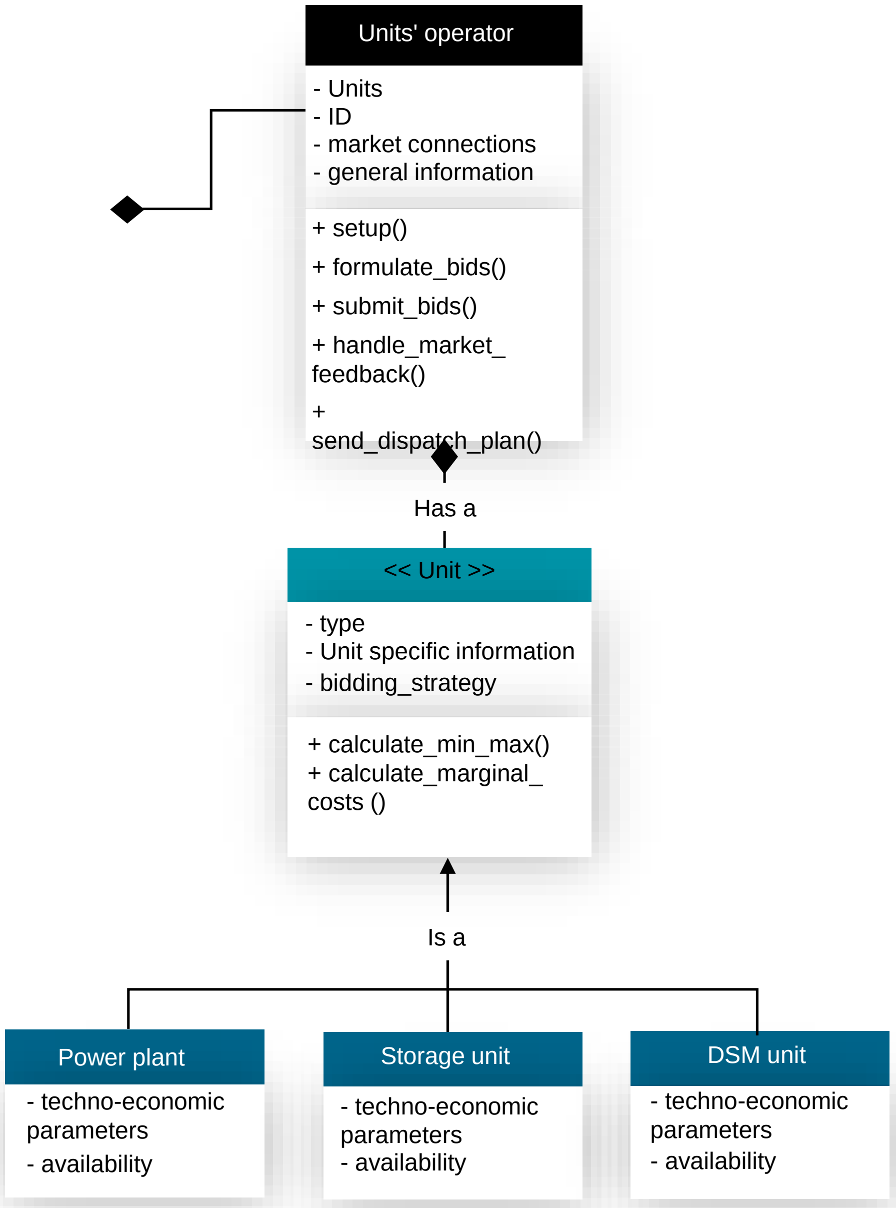
- Testing feasibility of DRL in electricity market modeling
- Investigation of individual strategies for actors on the market using DRL
- Testing different market design choices

ASSUME Framework





ASSUME

1. Supply side Units
2. Utility scale storages, Hydro-Pump storages
3. Demand Side Units
   i. Demand Side Management

CRI

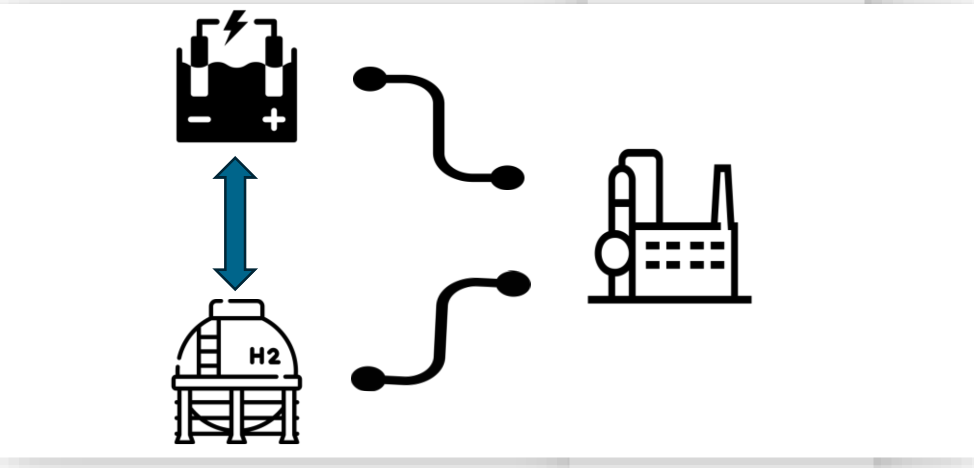
ASSUME

Units' operator

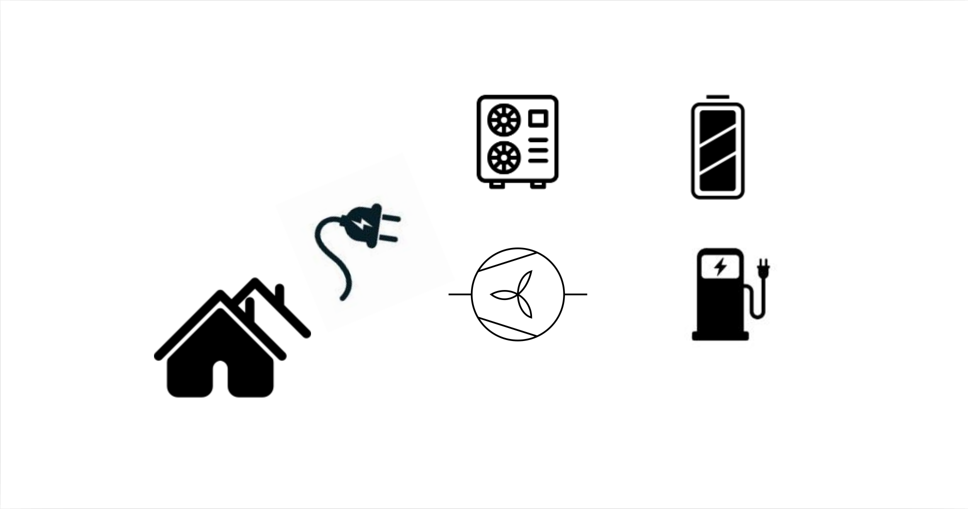
- Units
- ID
- market connections
- general information

+ setup()
+ formulate_bids()

Industrial Plant



Building



Is a

Power plant
- techno-economic parameters
- availability

Storage unit
- techno-economic parameters
- availability

DSM unit
- techno-economic parameters
- availability

CRI

Types of Demand-Side Flexibility Options in ASSUME

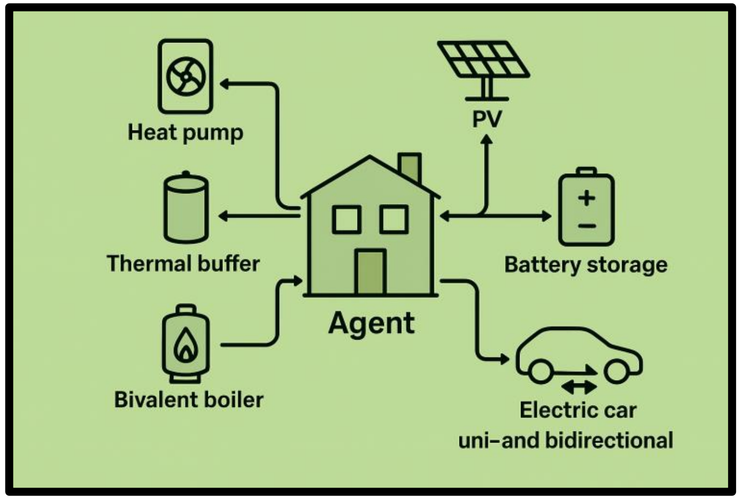
Small loads	Large loads

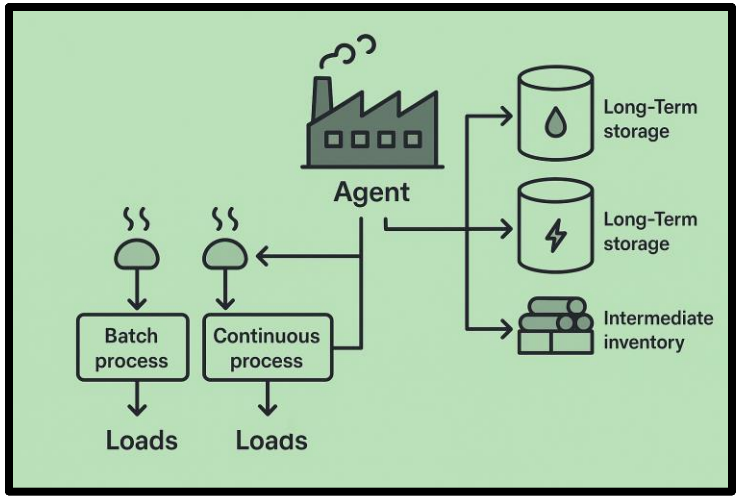
Small loads

- ❑ Thermal loads
  - Heat pump
  - Bivalent boilers
  - HVAC
- ❑ Electrical load
  - Electric Vehicle
  - PV
  - Inflexible load
- ❑ Buffers
  - Thermal buffer storage
  - Battery storage

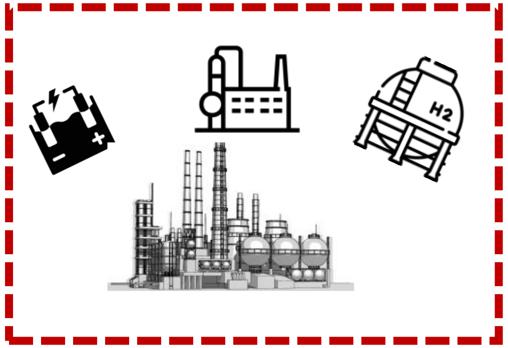
Large loads

- ❑ Thermal loads
  - Clinker production
  - Direct Reduction
  - Furnaces
  - Drying
  - Pulp prodution
- ❑ Electrical load
  - Grinding
  - Arc Furnace
  - Hydrogen production
  - CCS
  - Bus Depots
  - Inflexible load
- ❑ Short and Long Term storages
  - Thermal (Daily/ Seasonal)
  - Hydrogen (Daily/ Seasonal)
  - Intermediate inventory





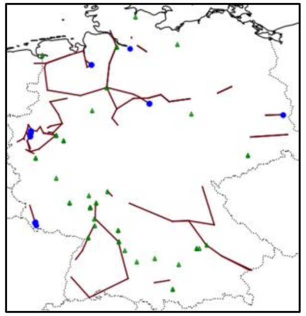
Setup of Characteristics and Behaviour in ASSUME



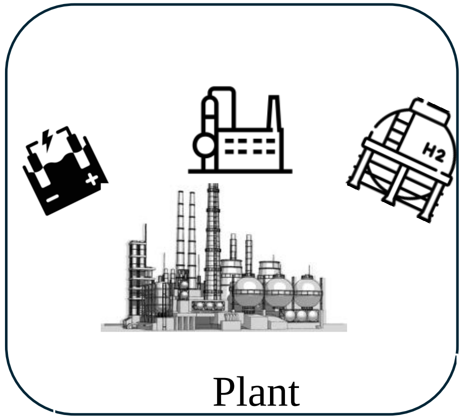
Use Case : Marketing Flexibility

Day Ahead

Redispatch



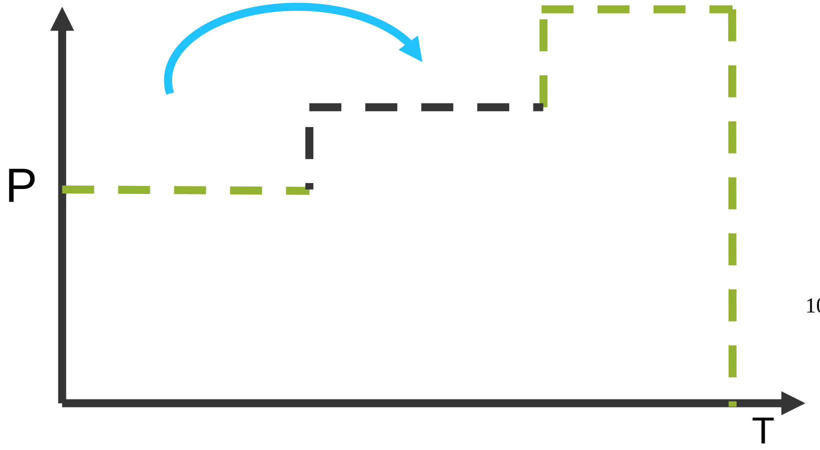
Unit Operator



Bidding strategy

Bidding Volume	MW
Bidding Price	€/MWh

Accepted OR Rejected



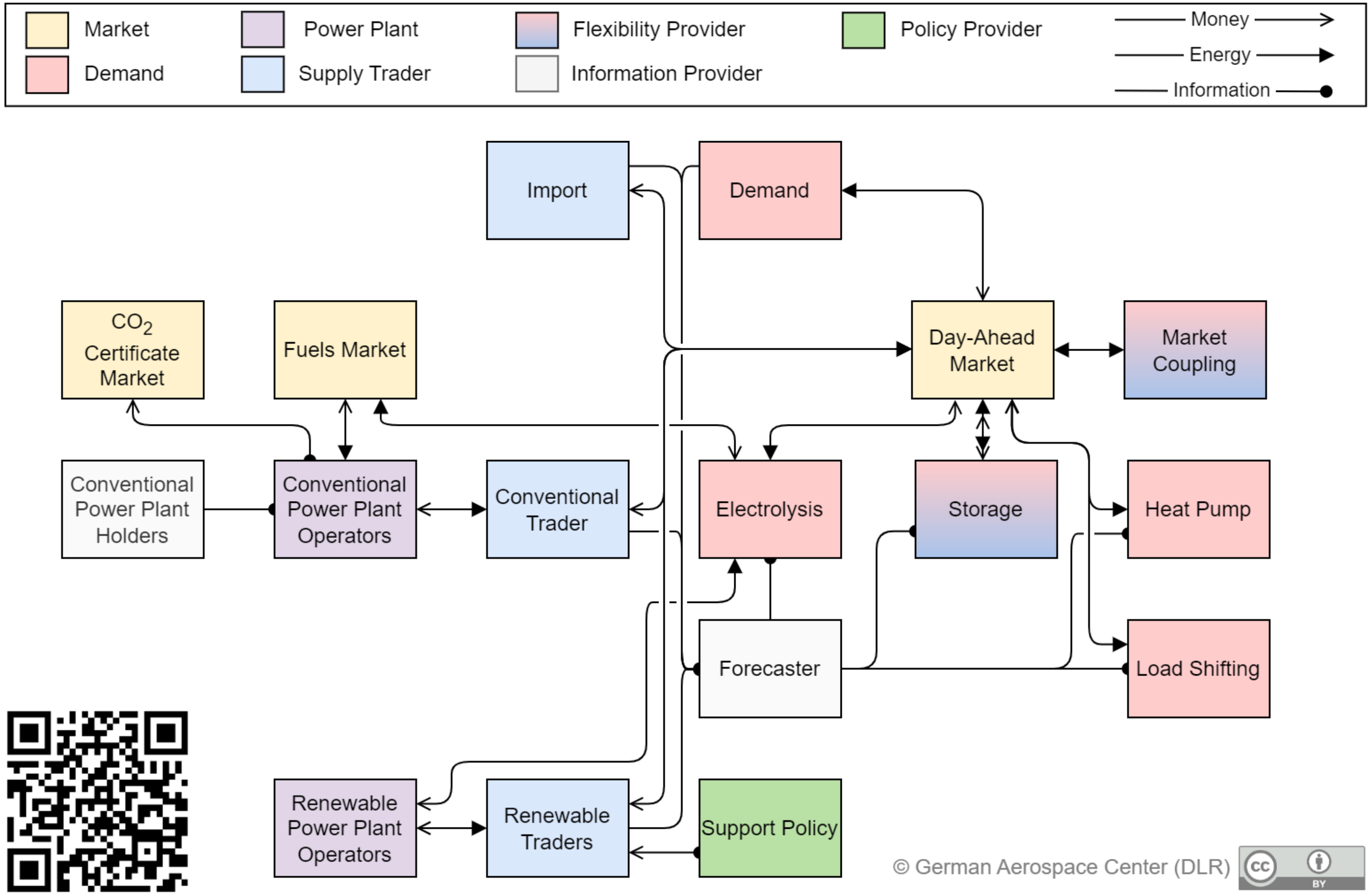
FLEXIBILITY OPTION MODELLING IN AMIRIS

Christoph Schimeczek, Felix Nitsch, Evelyn Sperber, Johannes Kochems

AMIRIS

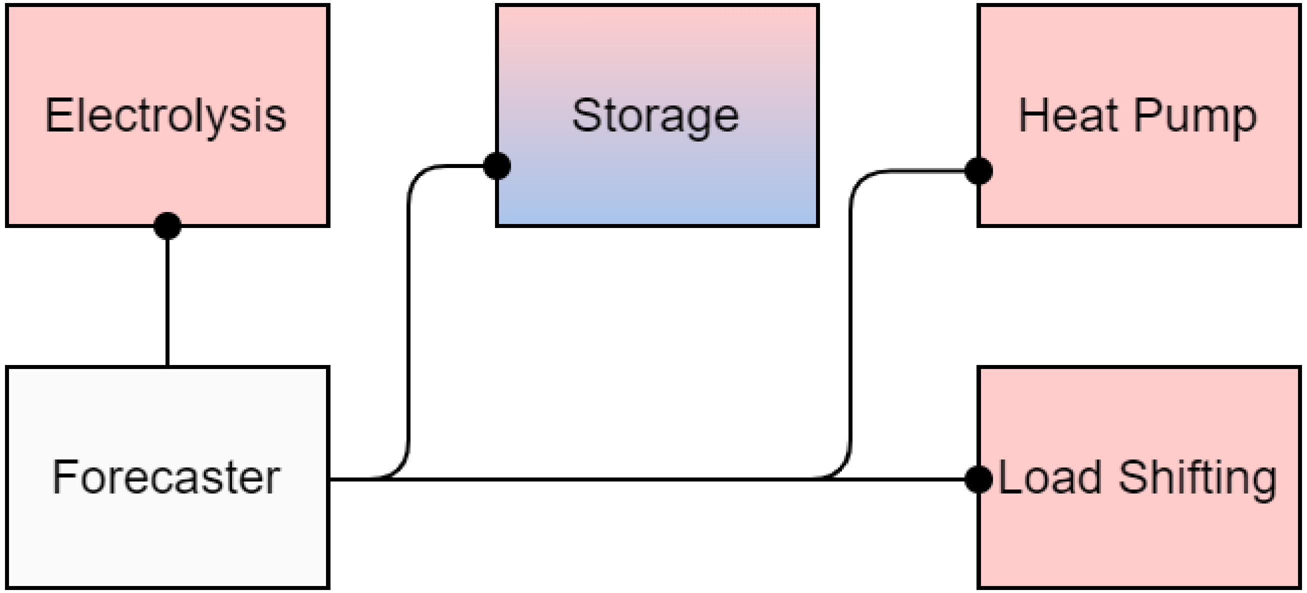
Agent-Based Market Model for the Investigation of Renewable and Integrated Energy Systems

- Simulate trading and operation
- Model business-oriented behaviour
- Temporal resolution: ≤ hourly
- Spatial resolution: market zone(s)

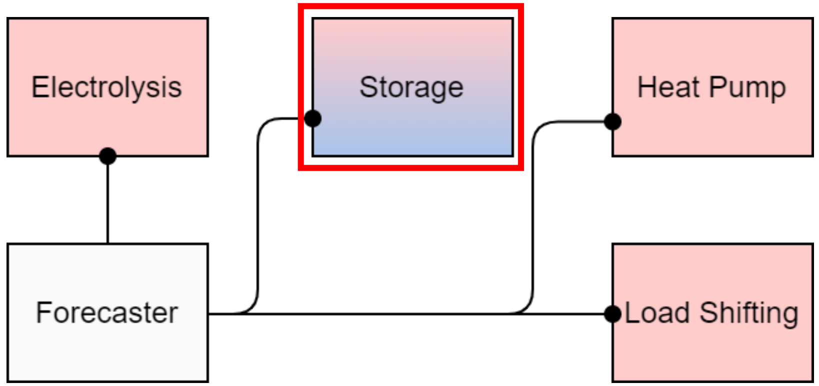


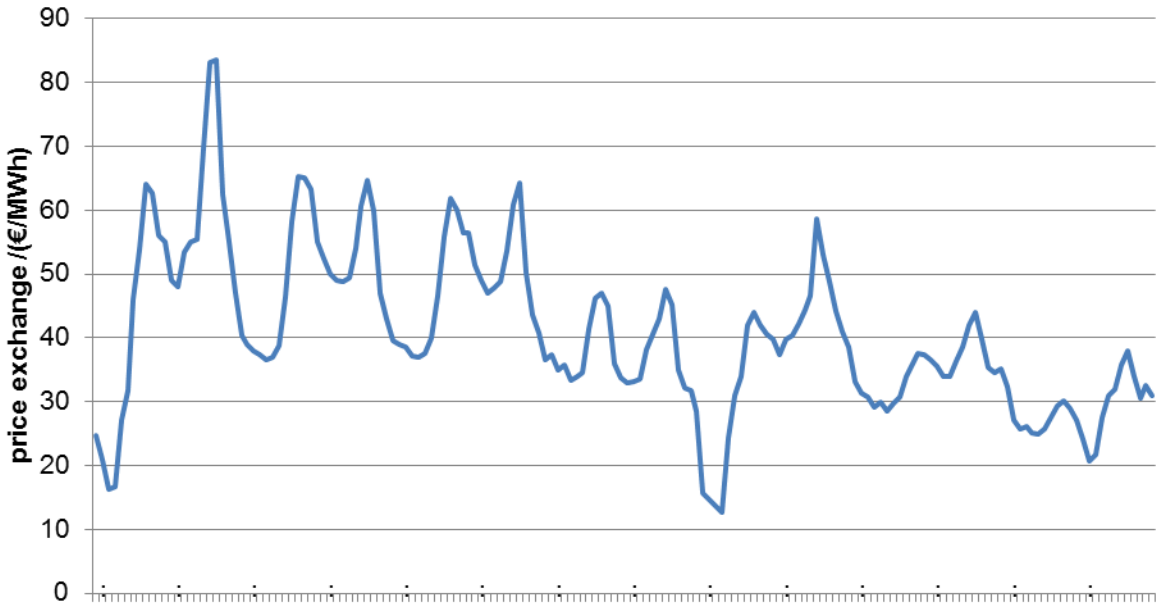
Federal Ministry for Economic Affairs and Climate Action
Federal Ministry of Education and Research
Bundesministerium für Umwelt, Naturschutz, nukleare Sicherheit und Verbraucherschutz
This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No 864276

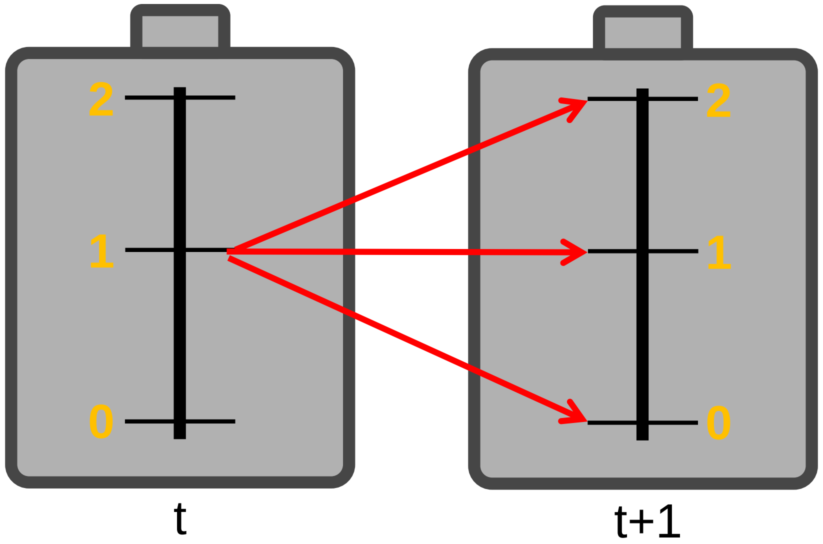
Flexibilities



Electricity Storage





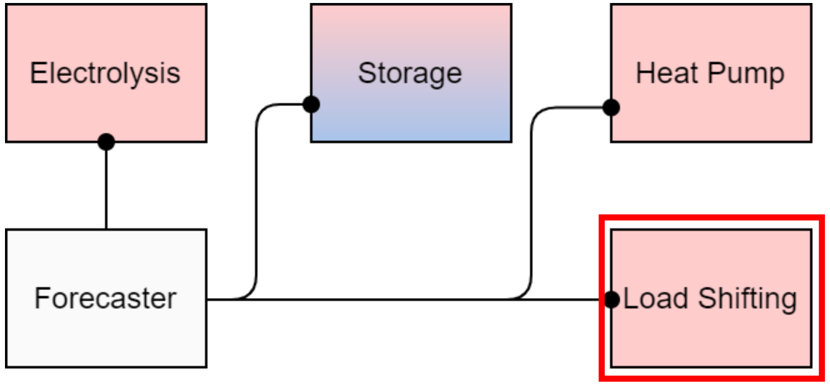


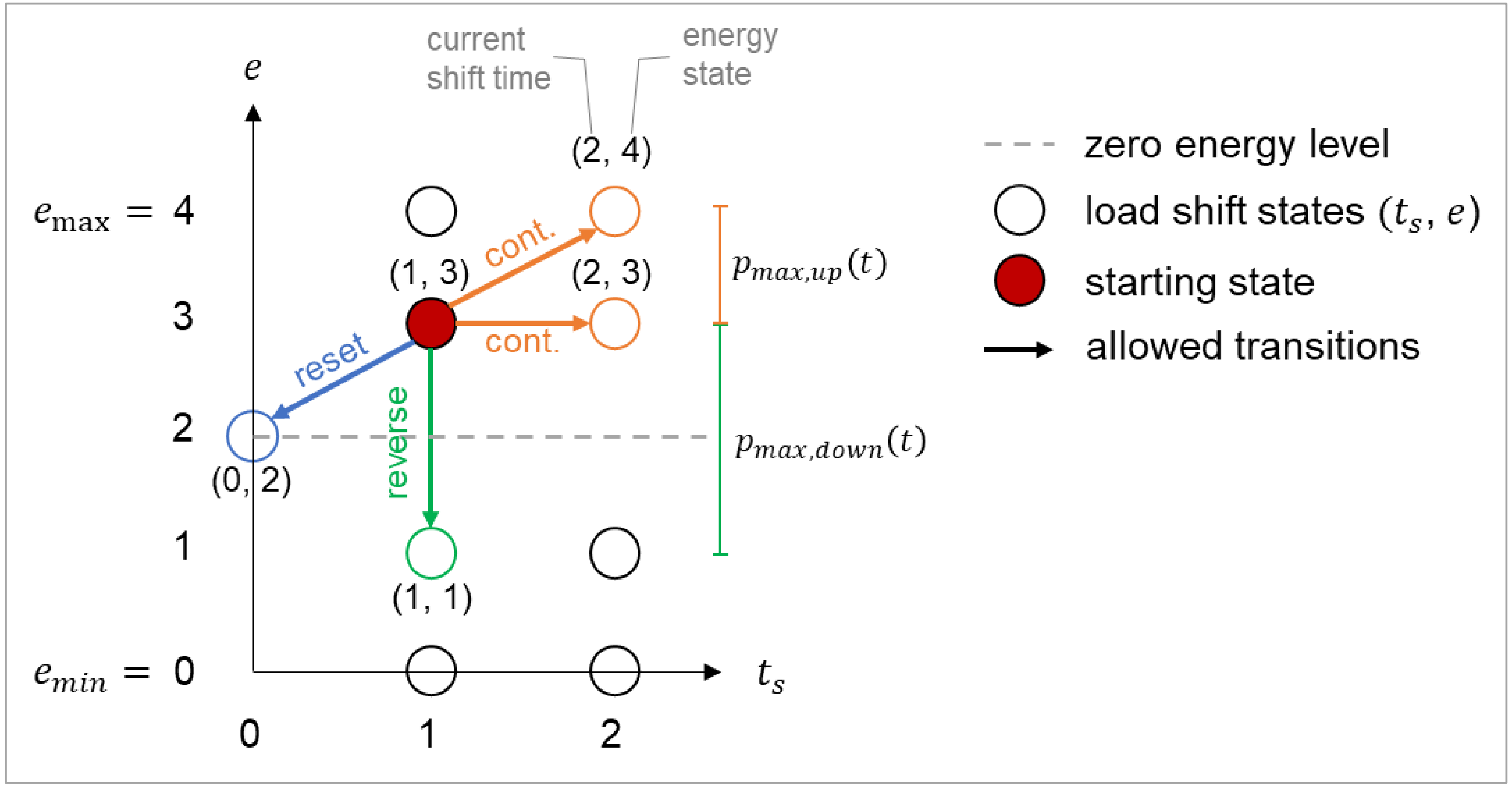
Method
Dynamic programming

Targets
Profit maximisation, system cost minimisation

Considerations
- Max power, max capacity
- (Own price impact)

Load Shifting
Dynamic Programming





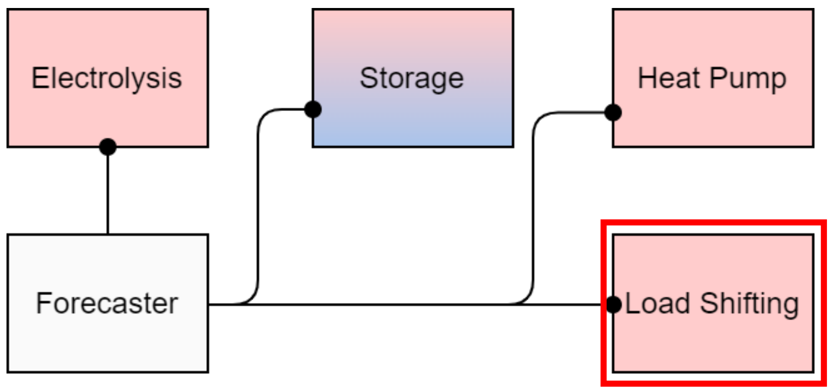
Method
Dynamic programming

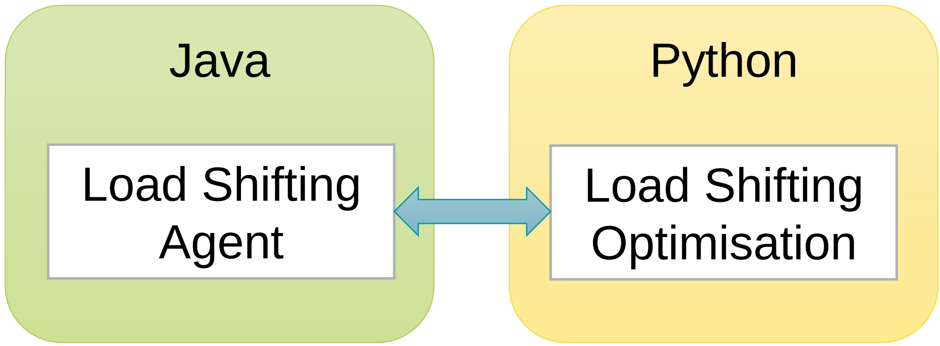
Targets
Dispatch cost minimisation

Considerations
- Max power, max capacity,
- Max shifting time,
- Own price impact

Load Shifting

External Optimisation

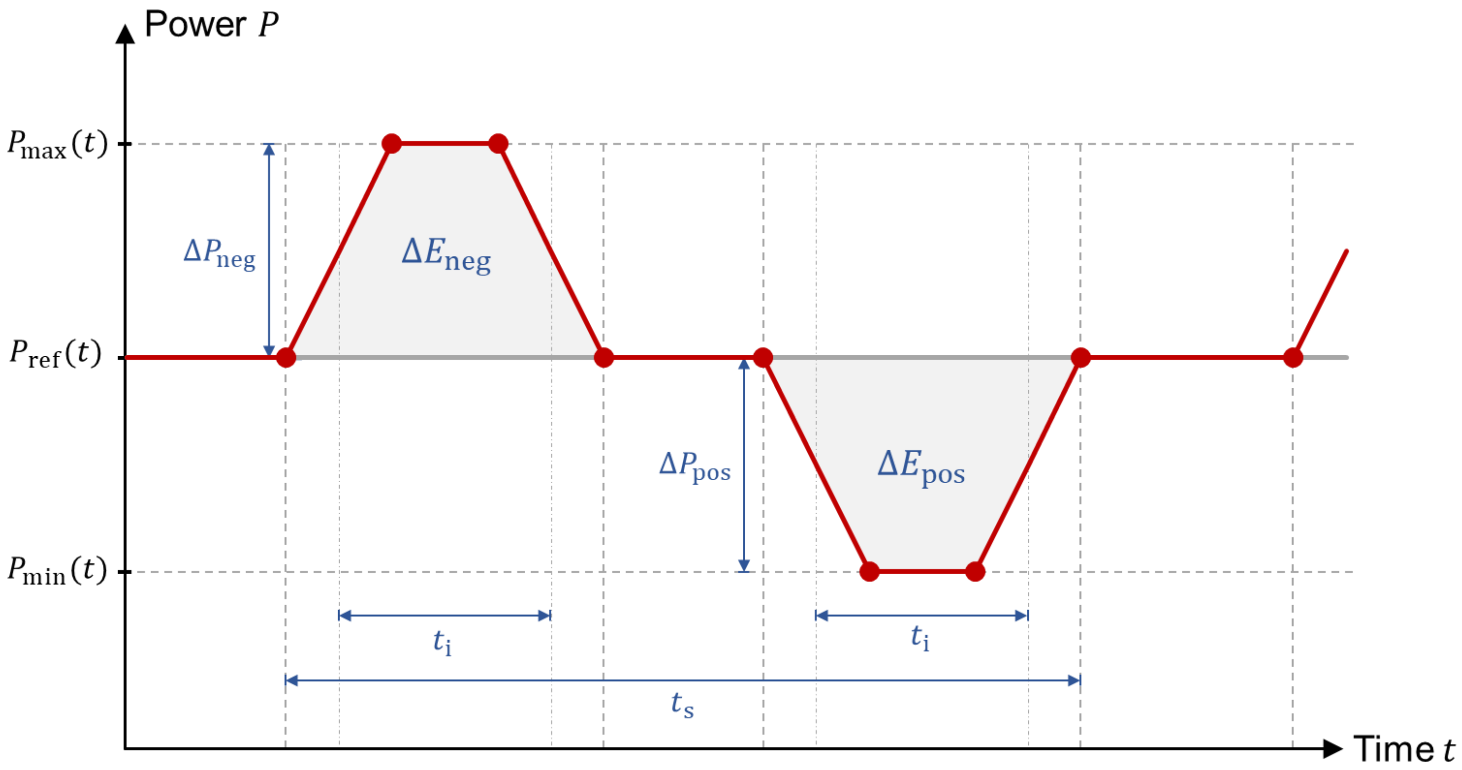




Method
Linear optimisation (pyomo)

Targets
Dispatch cost minimisation

Considerations
- Max power, max capacity
- Max shifting time, peak capacity
- Own price impact



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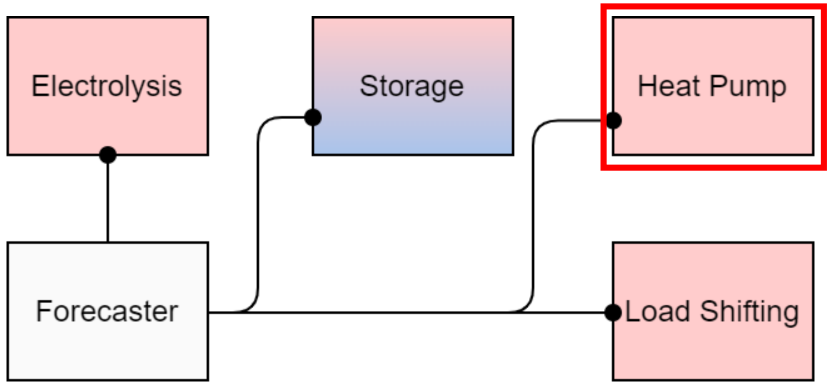
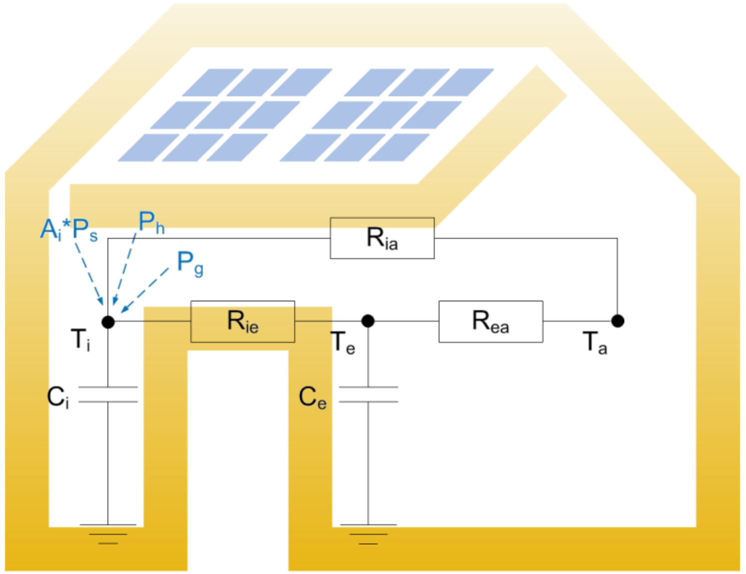
Heat Pump
Dynamic Programming

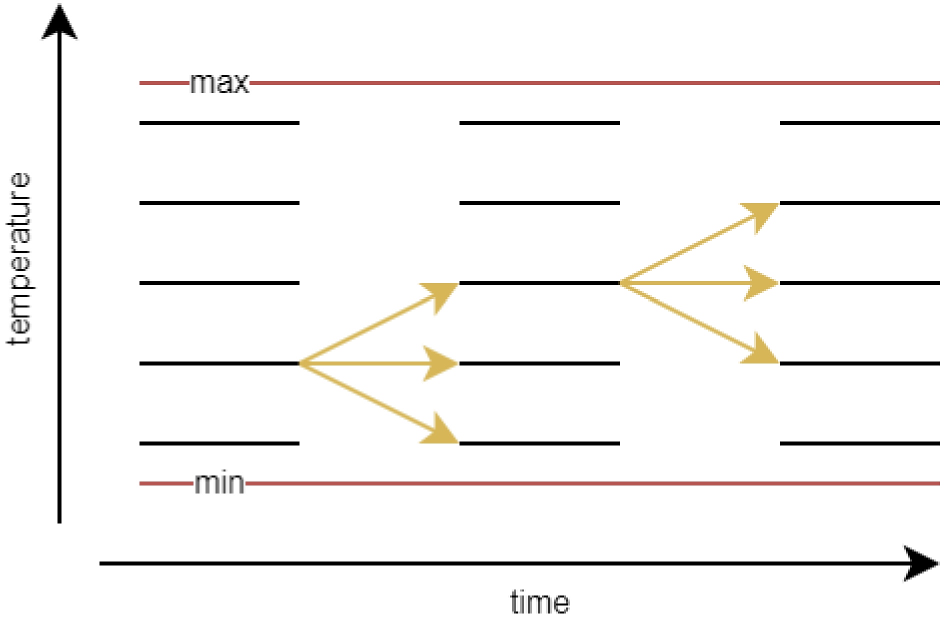


Method
Heating Model, Dynamic programming

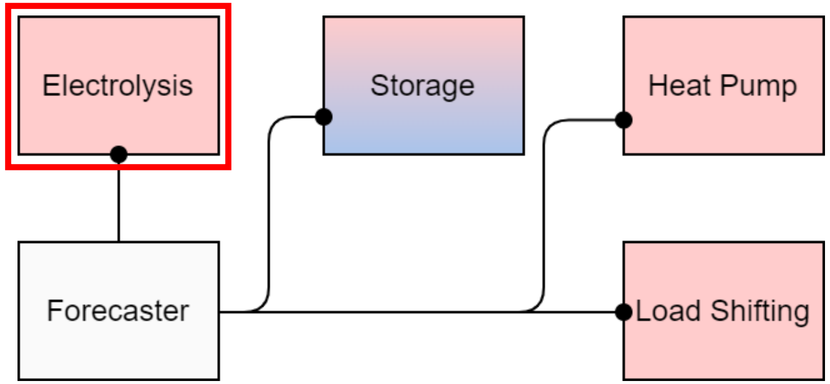
Targets
Consumer cost minimisation

Considerations
- Max power
- Min/Max room + external temperature
- Own price impact





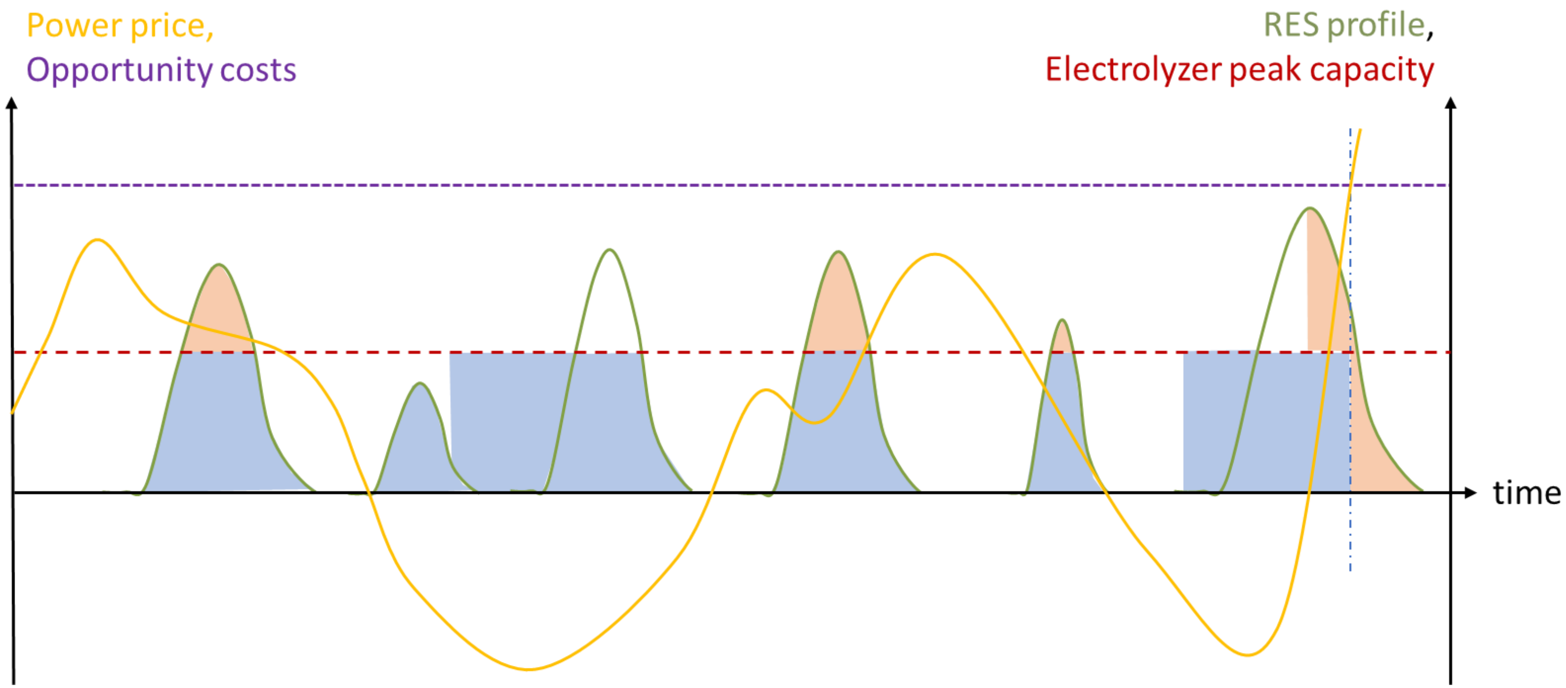
Electrolysis



Method
Own algorithm

Targets
Minimise H2 cost, maximise profits

Considerations
- Max power
- (Production targets)
- (PPA cost & profile)
- (Own price impact)



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Flexibility in PowerACE

Tim Signer, Thorsten Weiskopf, Jonathan Stelzer,
01.04.2025

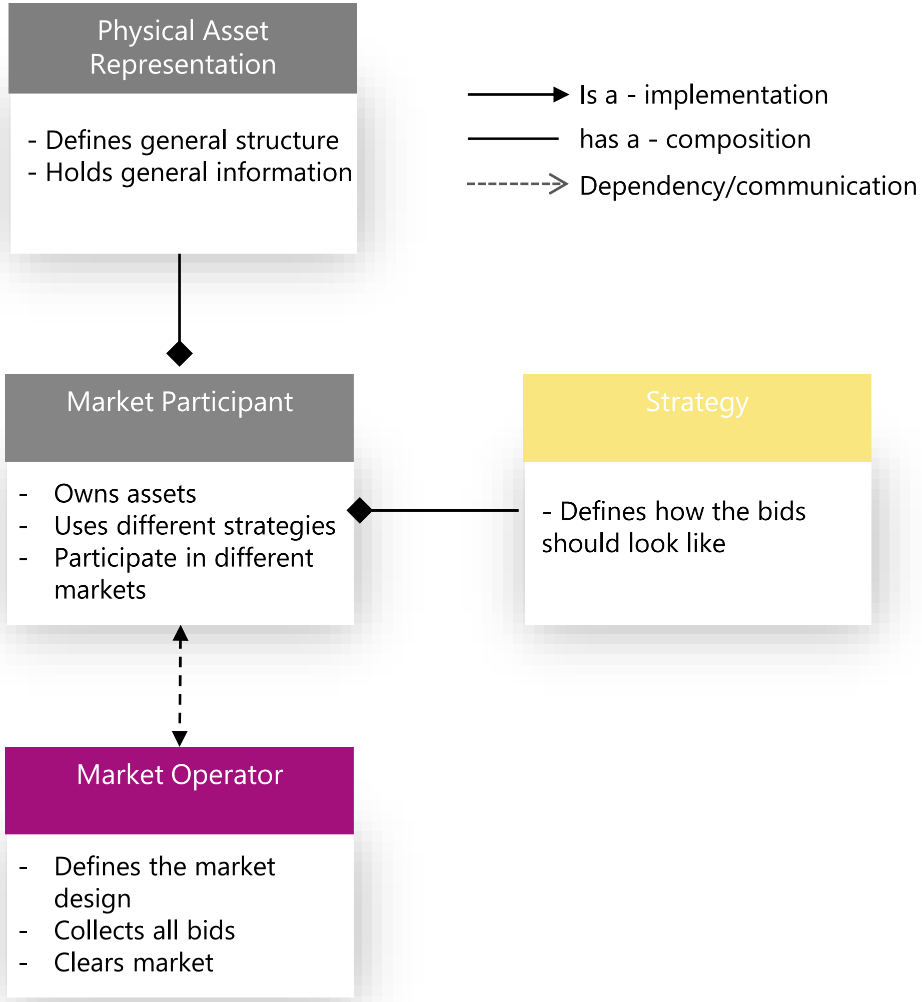
PowerACE - Simplified Day Ahead Scheme

Characteristics

- Core: European Day-Ahead Markets
- Long-term (2050) at hourly resolution (8760 h/a)
- Simulation of a spot market:
  - coupling of the national markets to maximize welfare
- Short-term decision: Dispatch
- Long-term: Investment

History

- Developed in 2005 in cooperation with the Chair for Information Economics and Fraunhofer ISI
- Later Extension:
  - Market Coupling
  - Capacity remuneration mechanism
  - Investment



Flexibility in PowerACE

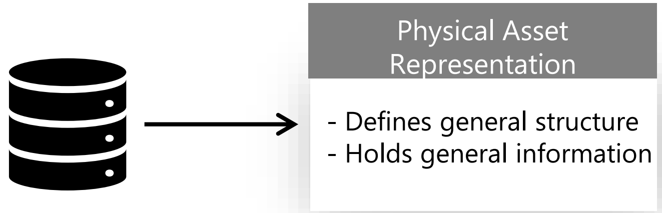
Flexibility can be categorized in:

- Storages
- Load-shifting (demand or supply)

Key parameters for flexibility are:

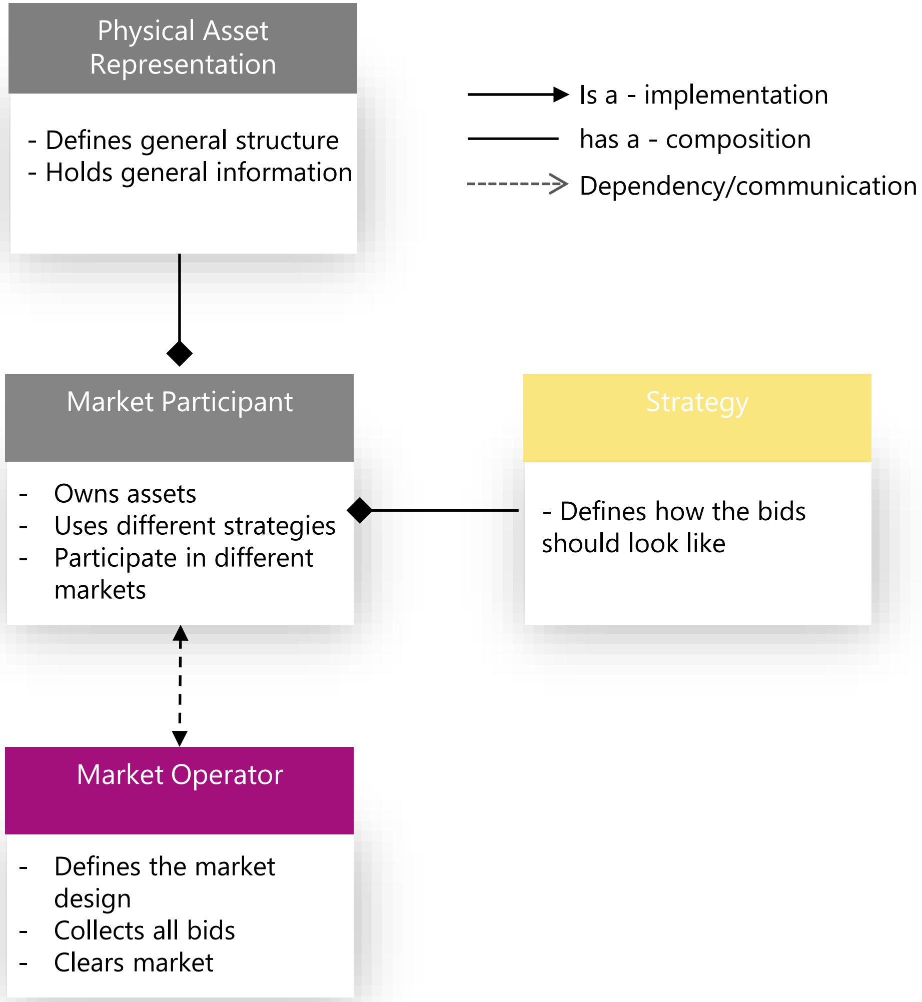
- SOC, power, discharge, availability, …
- Demand, availability, power, …

➢ Store information in flexibility profiles in database



Idea: General structure of flexibility.

Easy integration of new flex-technologies



World Café
Overview

3 Groups, 3 Discussion Boards, 15 minutes per board

Large-scale Flexibility

Small-scale Flexibility

Marketing Strategies

22 participants

RESULTS

Shown items have 3 votes or more

Results

Large-scale Flexibility: (Pumped) Hydro Storage, Industrial Load-Shifting, Large Batteries, …

How should flexibility be represented in ABM? Which kind of agents and decision paradigms to consider?

Uncertainties (Trade patterns, production plant reshuffling)	7
Grid congestion	6
Detailled technical characteristics (lead time, time dependencies, heterogeneity)	5
Risk appetite	3

Vote total: 31

What signals (price, CO_2, market forecasts,…) are critical for flexibility agent decision making?

Policy signals	10
Price Signals: Network charges	5
Price Signals: Energy component (clearing price)	3

Vote total: 20

Which (cross-sectoral) technologies can contribute?

Electrolyser	6
Data centers	6
Heat storage (e.g. molten salt)	3

Vote total: 22

Results

Heat Pumps, Electric Vehicles, Household Battery Storage, Household Load Shifting, …

Small-Scale Flexibility What gaps / uncertainties exist in representing small-scale flexibility?

Consumer behaviour (automatic control / manual control / weather)	6
Tariff structures	6
Grid impact	5
Real flexibility potential	4

Vote total: 26

Which (cross-sectoral) technologies can contribute?

EV (public: fixed-price / private)	7
Business / commercial (warehouse / office)	4
Data centers	3

Vote total: 22

Which aspects of flexibility options are underrepresented / poorly modelled in existing ABM?

Uncertainty	8
Habits, attitudes, bias, risk aversion, opinion, social pressure	8
Price impact of flexibilities	6
Level of automation during usage / investment behaviour modelled different from usage	6
Non-economical rationals / decisions	5
Grid impact	5
Seasonal pattern of availability; context: (e.g. holiday)	3

Vote total: 43

Results

Futures – Day-Ahead – Intraday – Balancing – Local Energy

How does marketing of demand-/supply-side flexibility and storages differ?

Non-market flexibility (e.g. households reacting to price signals / weather)	3

Vote total: 11

How to consider grid constraints?

Dynamic grid charges	4

Vote total: 9

How to deal with simultaneity effects / avalanches?

This is an important question	5

Vote total: 7

How to model sector-integrated markets (e.g. gas, power, heat hydrogen,…)?

Use model coupling, consider data availability, model availability	5
This is an important question	3

Vote total: 9

Which agents to model that have complex marketing strategies?

“““Irrational“““ participants (multi-criteria decision, attitudes, risk-avers strategies)	13

Vote total: 13

SCREENSHOTS

Large-Scale Flexibilities

Which (cross-sectoral) technologies can contribute?

Energy & Industrial plants
Intensive
- ↳ heat pumps
- ↳ heat storage (Molten salt)
- ↳ Waste heat
- ↳ H.
- -> Electrolyser
  - ↳ DRI
- -> Boiler
- -> CCS
- -> EAF
- -> Pumped storages
- -> DATA Centres
- -> H_2 Caverns
- -> Copper & Aluminum
- -> Utility scale batteries
- -> Clinker production
- -> Cooling pumps.
- -> Ammonia production
- -> Methanol crackers
- -> Cross cutting tech.
- -> Gas Caverns

What signals (price, CO_2, network congestion, market forecasts, ...) are critical for flexibility agents' decision-making processes?

- -> Price Signal
  - ↳ Network charges
  - ↳ Energy component (clearing price)
  - ↳ Incentives for Cong. Manag.
  - ↳ Imbalance prices
- -> Connection charges
- -> Over head cost
- -> Policy Signals
  - ↳ RNFBO targets
- -> ~~Clearing prices~~
- -> Emission prices (GHG)
- -> Fiscal supports

How should flexibility be represented in ABM Models (which kind of agents, decision paradigms)?

- -> Explicit spatial representation
- -> Detailed technical characteristics
  - ↳ lead time
  - ↳ time dependencies

  } hetrogenity.
- -> Integrated process
- -> Power & Energy.
- -> Aggregation of flex load
- -> Prosuming
- -> Consideration of power plants
- -> Definition of Industrial hubs.
- -> Grid Congestion.
- -> Coordinated decision making
- -> Demand response contracts
- -> Data centre: Job scheduling.
- -> Uncertainties
  - ↳ Trade pattern
  - ↳ production plant (reshuffling)
- -> Risk appetite
- -> Degradation factor
- -> Dynamic efficiencies.

Small-Scale Flexibilities

Which (cross-sectoral) technologies can contribute?

- EV
  - public (fixed-price)
  - private
- Thermal-Storage
- ~~Heat~~ pumps
- Two-way flexibility
- Electric Radiator
- PV
- Household Battery
- Battery standalone (small-scale)
- load-shifting in household
- lighting commercial / public
- load shedding
- data centers
- public transport
- behavioral change (price-driven)
- direct load control
- businesse / commercial
  - warehouse
  - office

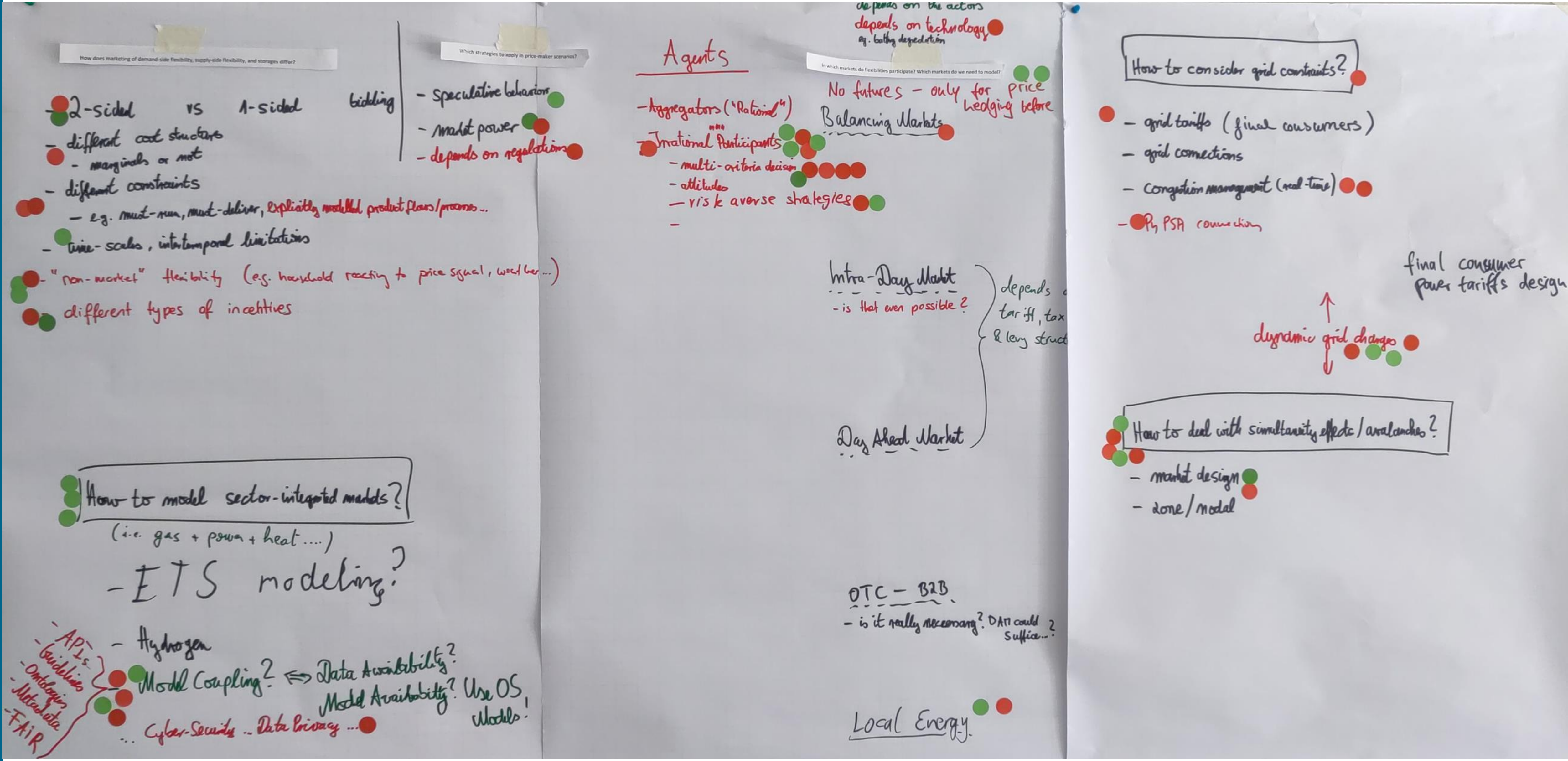
Which gaps or uncertainties exist in modelling small-scale flexibility?

- Unit combination
- Optimization
  - household
  - community
- Consumer Behavior
  - automatic control
  - manual control
  - weather
- Different control strategies
- Different objectives of diff. roles (TSO, DSO, Aggregator)
- Real flexibility potential
- cost / benefit structure
- Tarif structures
- Grid impact
- regulatory framework (TFS dattle taxation)
- adoption / rate

Which aspects of small-scale flexibility options are currently underrepresented or poorly modelled in existing ABM?

- Technology interplay
- non-economically rationale decision
- Technologies missing
- Multi-/sequential markets
- price impact of flex
- grid impact
- heterogeneous behavior of agents
- feedback-loops between models
- temporal/spatial resolution
- bilevel/portfolio optimization
- uncertainty
- habits, attitudes, bias, risk aversion, opinion, social pressure ...
- political rational
- time constraint of consumers
- level of automation during usage \ investment decision
- reliability of flexibility usage modelled different from
- seasonal pattern in availability
  - ↳ content (holiday, ..
- regional difference in trust

29


How does marketing of demand-side flexibility, supply-side flexibility, and storages differ?
2-sided vs 1-sided bidding
- different cost structures
- marginals or not
- different constraints
- e.g. must-run, must-deliver, explicitly modelled product flows/processes...
- time-scales, intertemporal limitations
- "non-market" flexibility (e.g. household reacting to price signal, weather...)
- different types of incentives
Which strategies to apply in price-maker scenarios?
- speculative behavior
- market power
- depends on regulations
How to model sector-integrated models?
(i.e. gas + power + heat ....)
- ETS modeling?
- Hydrogen
Model Coupling? ⇔ Data Availability?
Model Availability? Use OS Models!
Cyber-Security .. Data Privacy ...
APIs
Guidelines
Ontologies
Metadata
FAIR
Agents
- Aggregators ("Rational")
- Irrational Participants
- multi-criteria decision
- attitudes
- risk averse strategies
depends on the actors
depends on technology
eg. battery degradation
In which markets do flexibilities participate? Which markets do we need to model?
No futures - only for price hedging before
Balancing Markets
Intra-Day Market
- is that even possible?
depends on tariff, tax & levy structure
Day Ahead Market
OTC - B2B
- is it really necessary? DAM could suffice...?
Local Energy
How to consider grid constraints?
- grid tariffs (final consumers)
- grid connections
- congestion management (real-time)
- PV PSA connection
final consumer power tariffs design
dynamic grid charges
How to deal with simultaneity effects / avalanches?
- market design
- zone / nodal