Reinforcement learning for microgrid management

ULiège

- Delta project
- Liège
- April 2019

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Welcome to Liège

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Agenda

- Review of the previous release
- Towards evolving environments
- Additional features & future work

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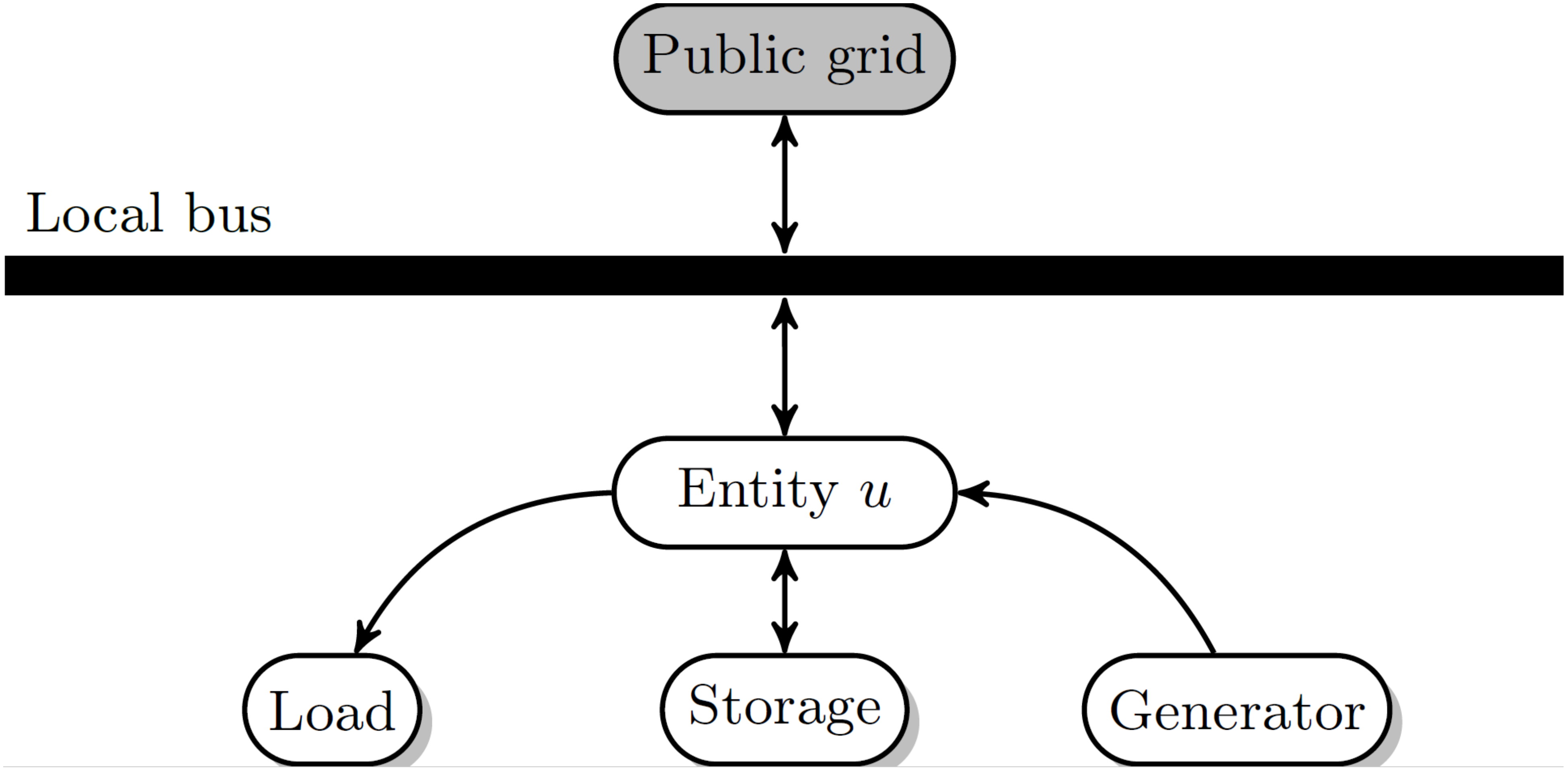
Previously...

A microgrid is made of loads, generation, storage, a network, a connection to the grid



Le projet MeryGrid

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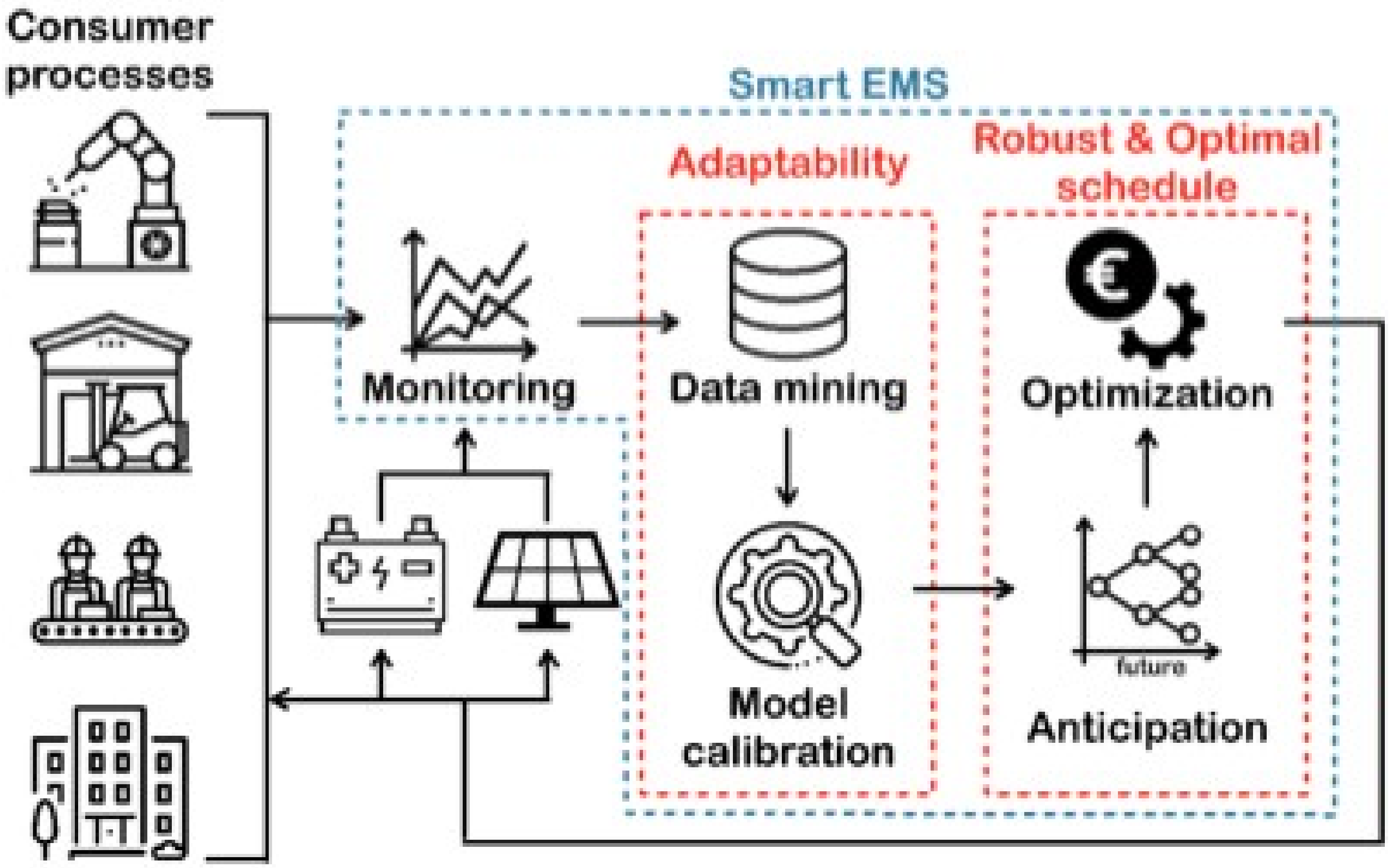
Avec le soutien du gouvernement Wallon, en collaboration avec Nethys, CE+T, Sirris, MeryTherm, la SPI

A **smart** microgrid energy management system …



- exploits data to make the microgrid flexible, robust, and extract the maximum of value!
- has a community management feature

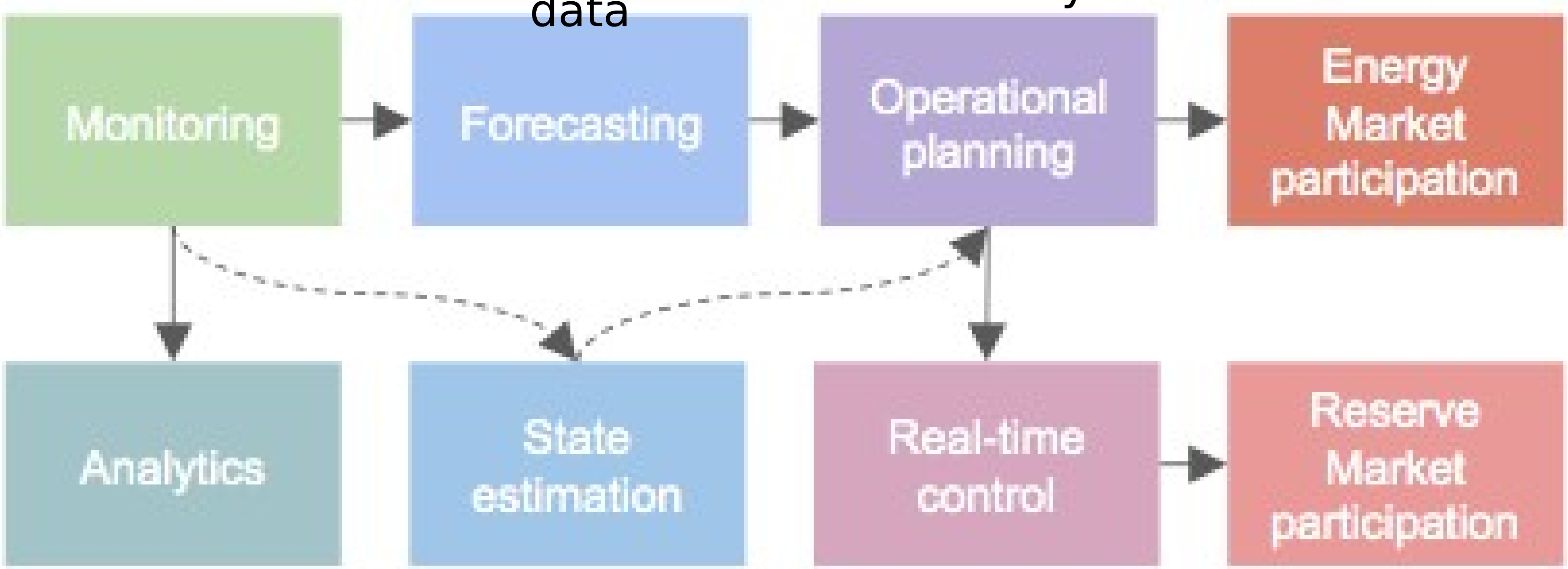
Functional modules that exploit data

Pull and store data

Forecast consumption and production using past data

Take decisions for next day

Participate actively in energy markets



Present data, decisions and results

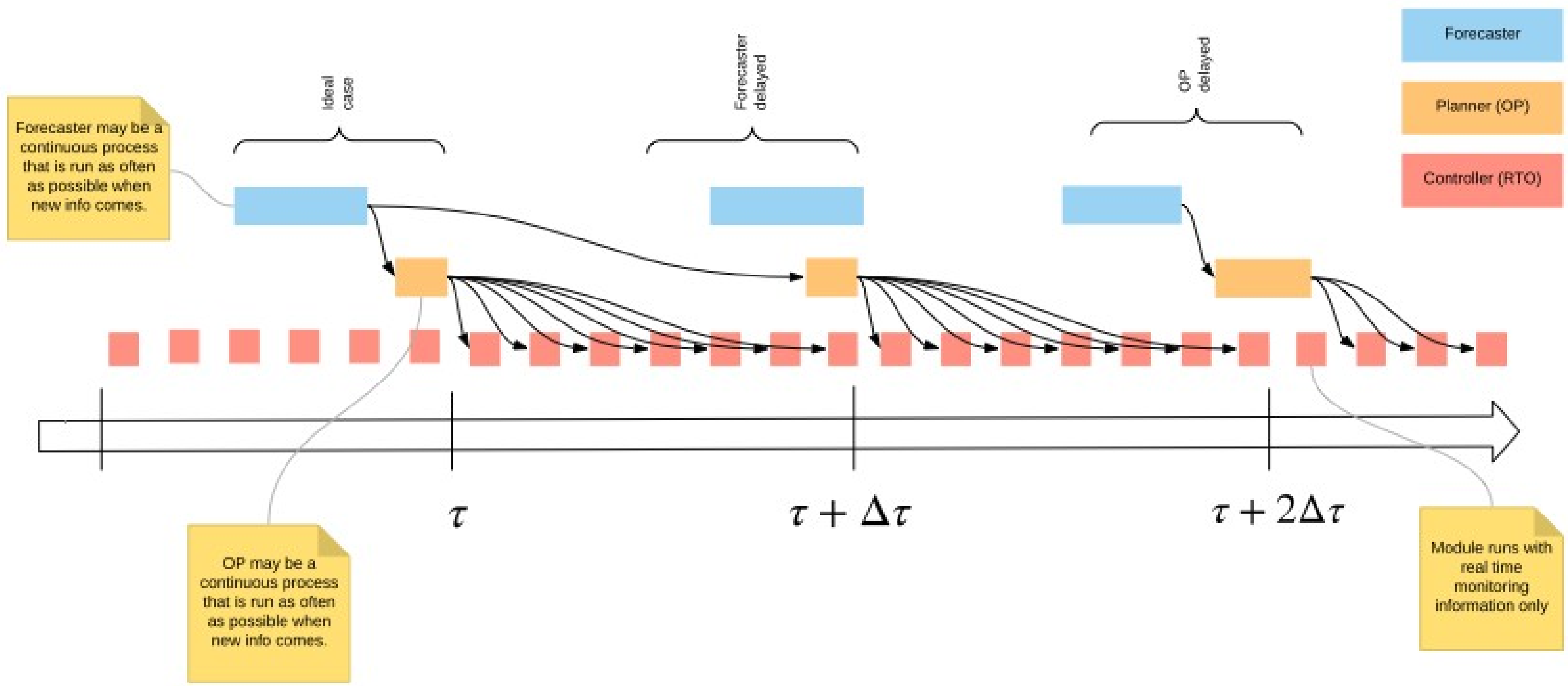
Calibrate models using data

Take decisions for next seconds

Participate actively in reserve markets

Arrows indicate a dependency between functional modules, not a flow of information!

EMS scheduling - Illustration of information exchange between computation modules depending on their run time.



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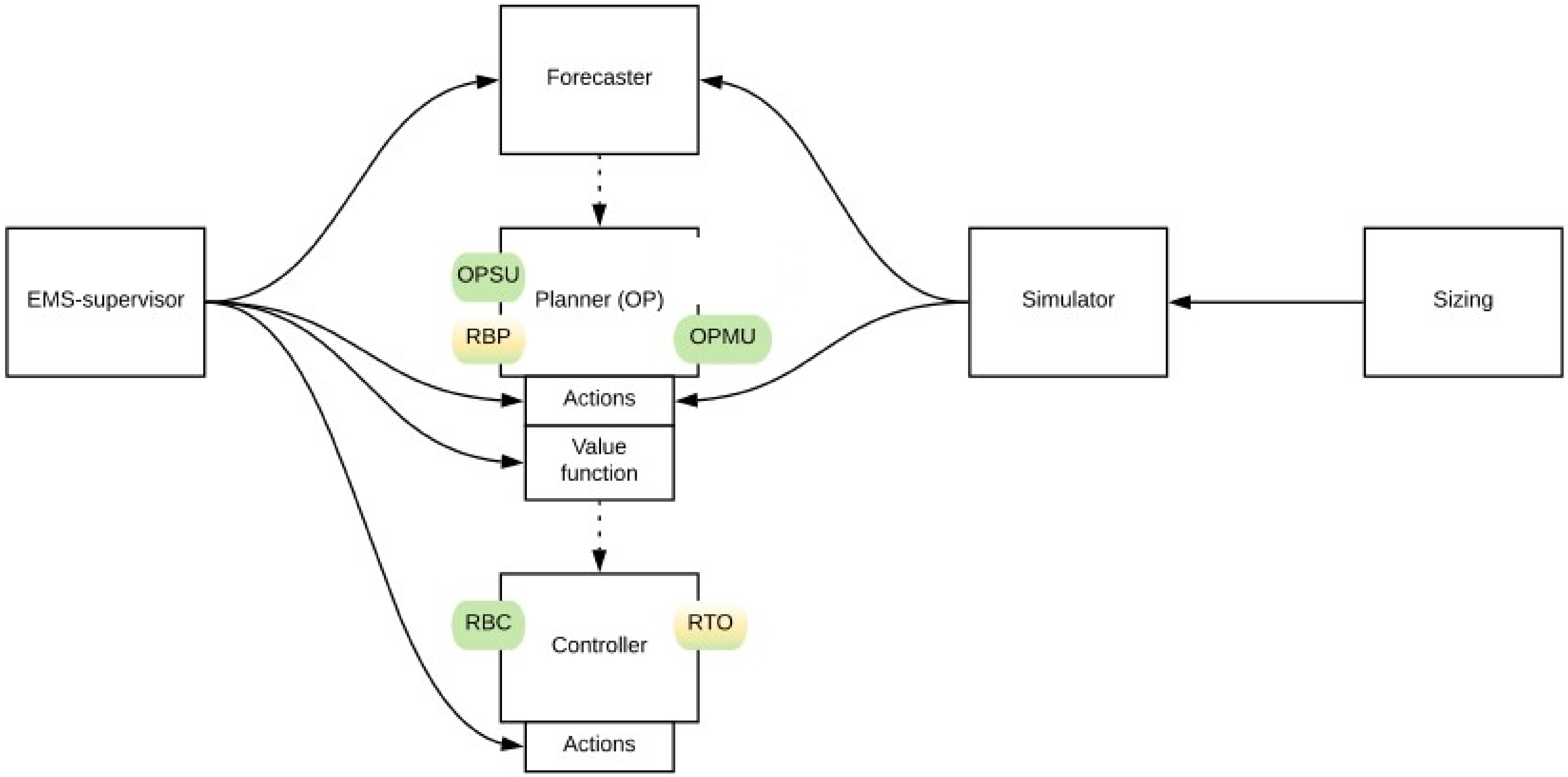
Interactions entre modules de calcul, EMS-supervisor, simulateur et outil de dimensionnement



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Problem Statement

Goal: off-grid Microgrid management

Control actions:

- Storages
- Generation

Continuous and high dimensional space

Reduce the action space to:

- on/off decisions for the generators
- idle/charge/discharge decisions for the storages

Define meta-actions

Challenging due to the components dynamics

Test case

Storage decisions: idle/charge/discharge

Meta-actions:

- Charge if there is excess
- Discharge if there is deficit
- Generator covers the rest at a cost
- Curtail the excess otherwise

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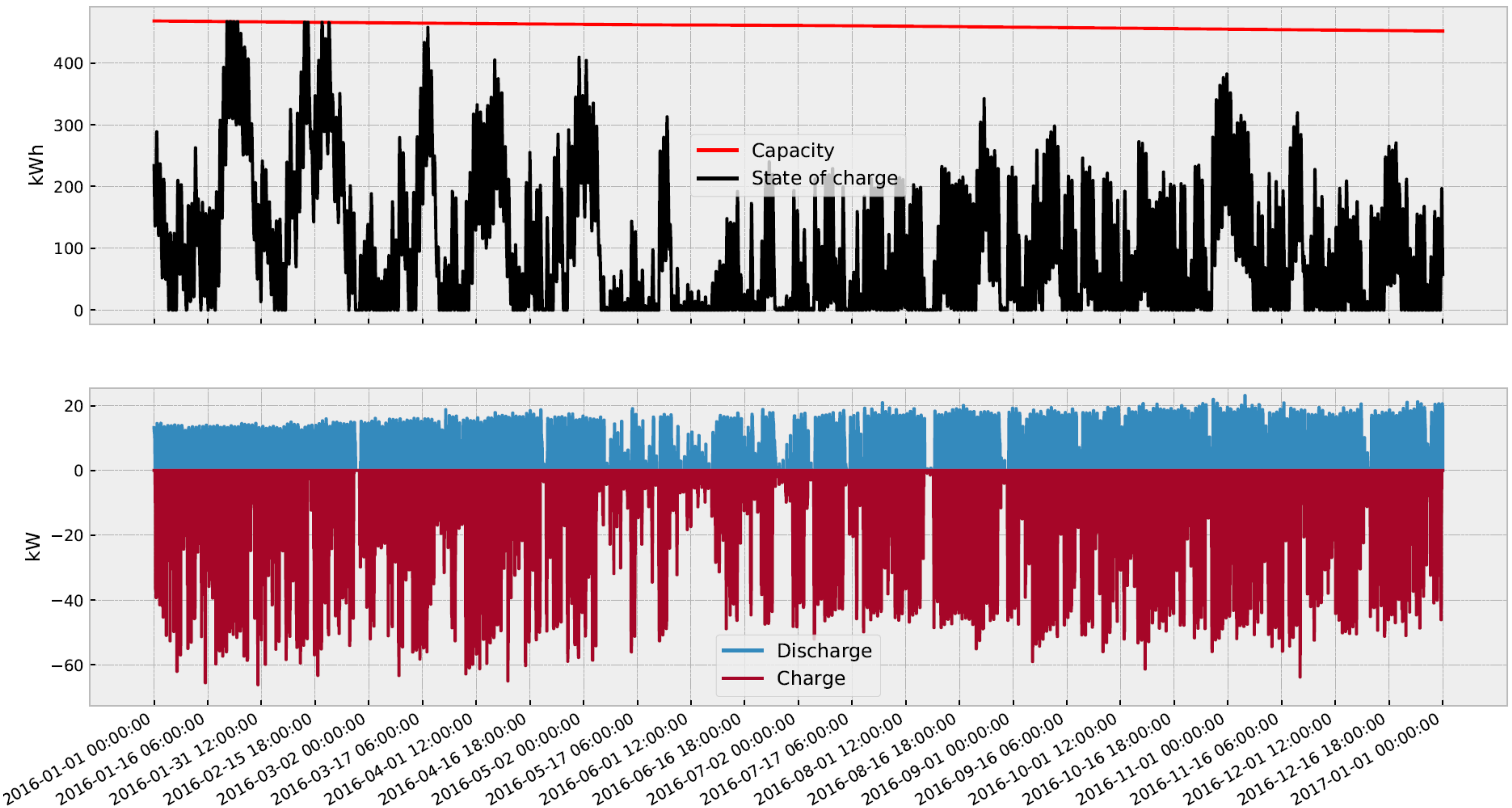
Towards an evolving microgrid

Storage system

Decreasing storage capacity:

- Degradations due to cycling
- Capacity is a linear function the number of cycles
- Each storage system has different degradation properties (user-specified)

Storage system



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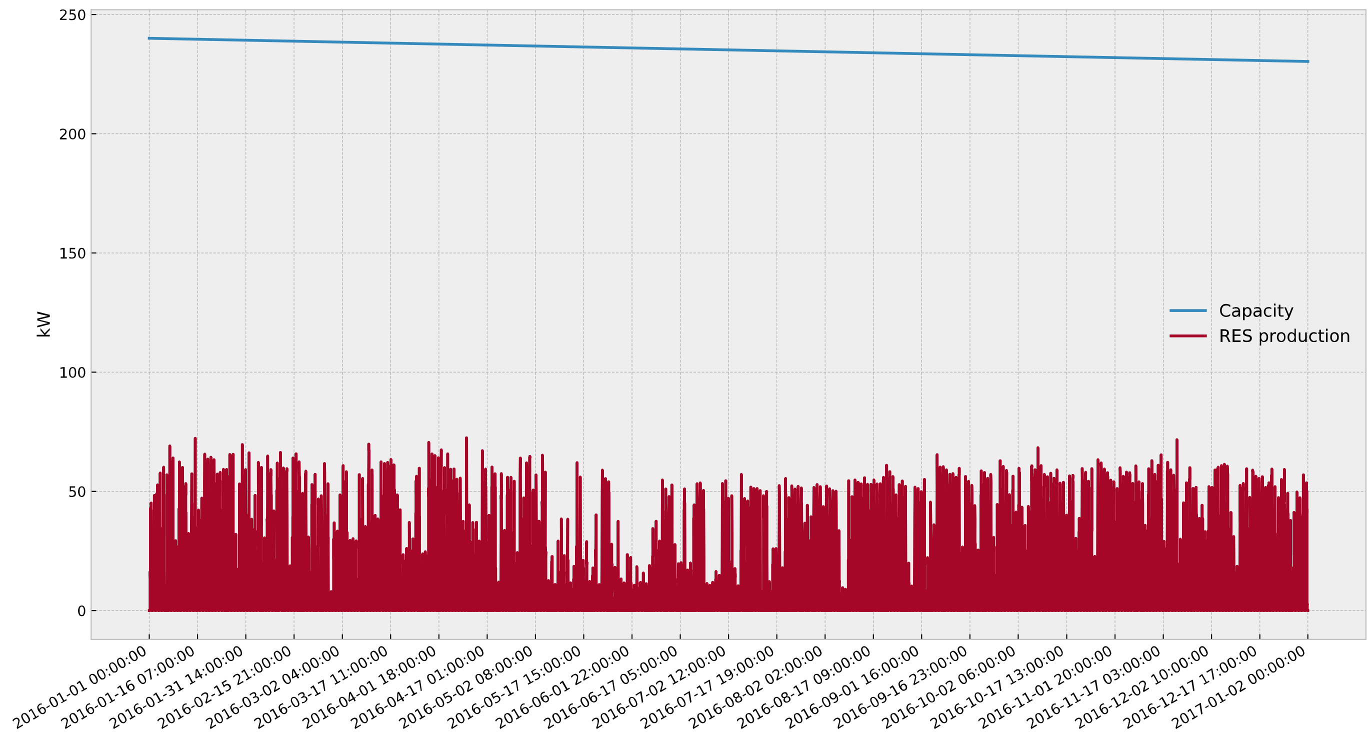
RES Generation

Decreasing generation capacity:

- Degradations due to aging of materials/improper maintenance
- Capacity reaches a user-defined level at the end of ea



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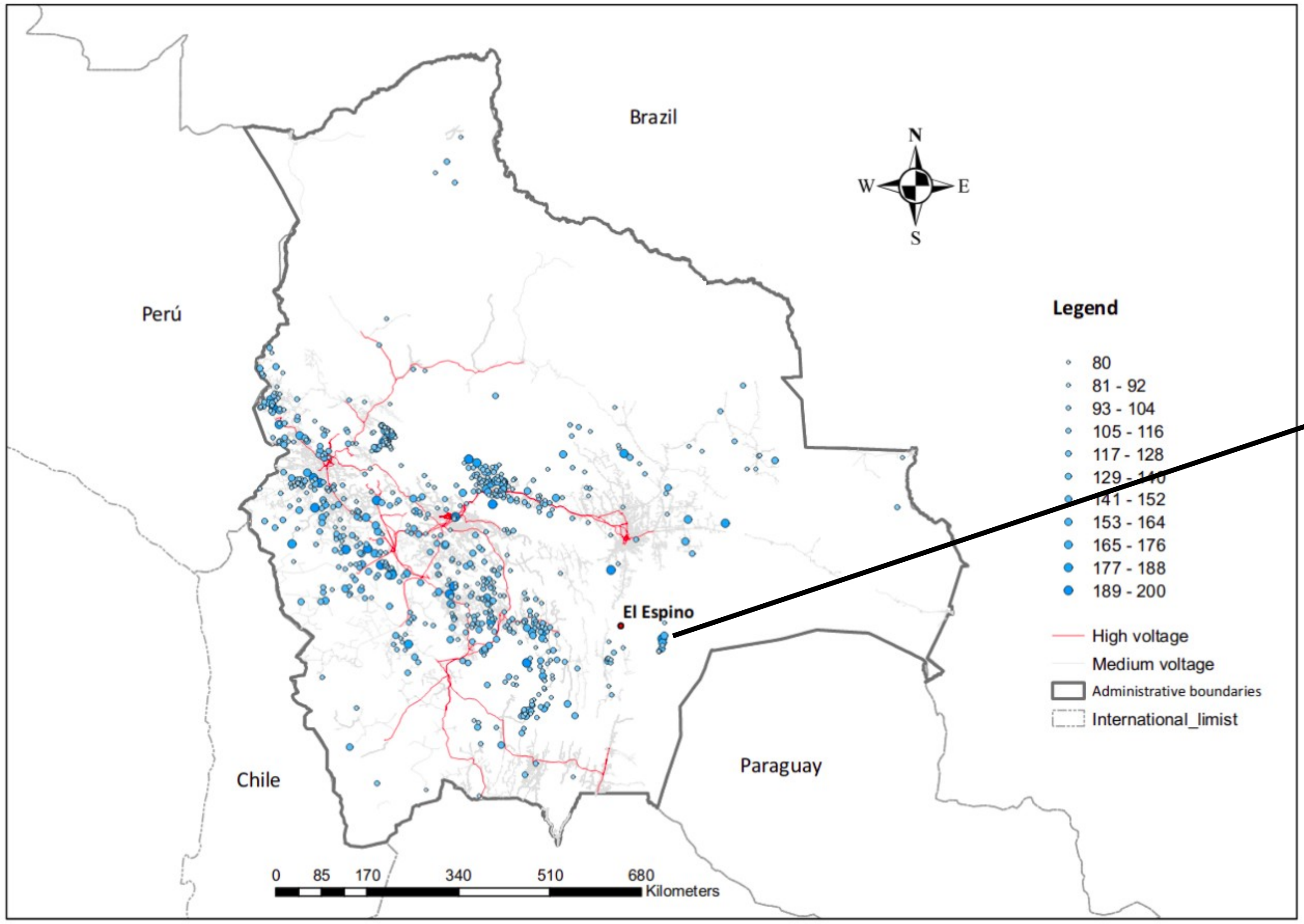
Consumption

Consider the case of a real isolated microgrid:

- Located in Bolivia
- In a place where people did not have electricity before
- Progressively people will connect

El Espino microgrid



- Guarani village
- Electrified village with a hybrid system PV/Diesel and storage
- 125 households
- 1 school
- 1 hospital

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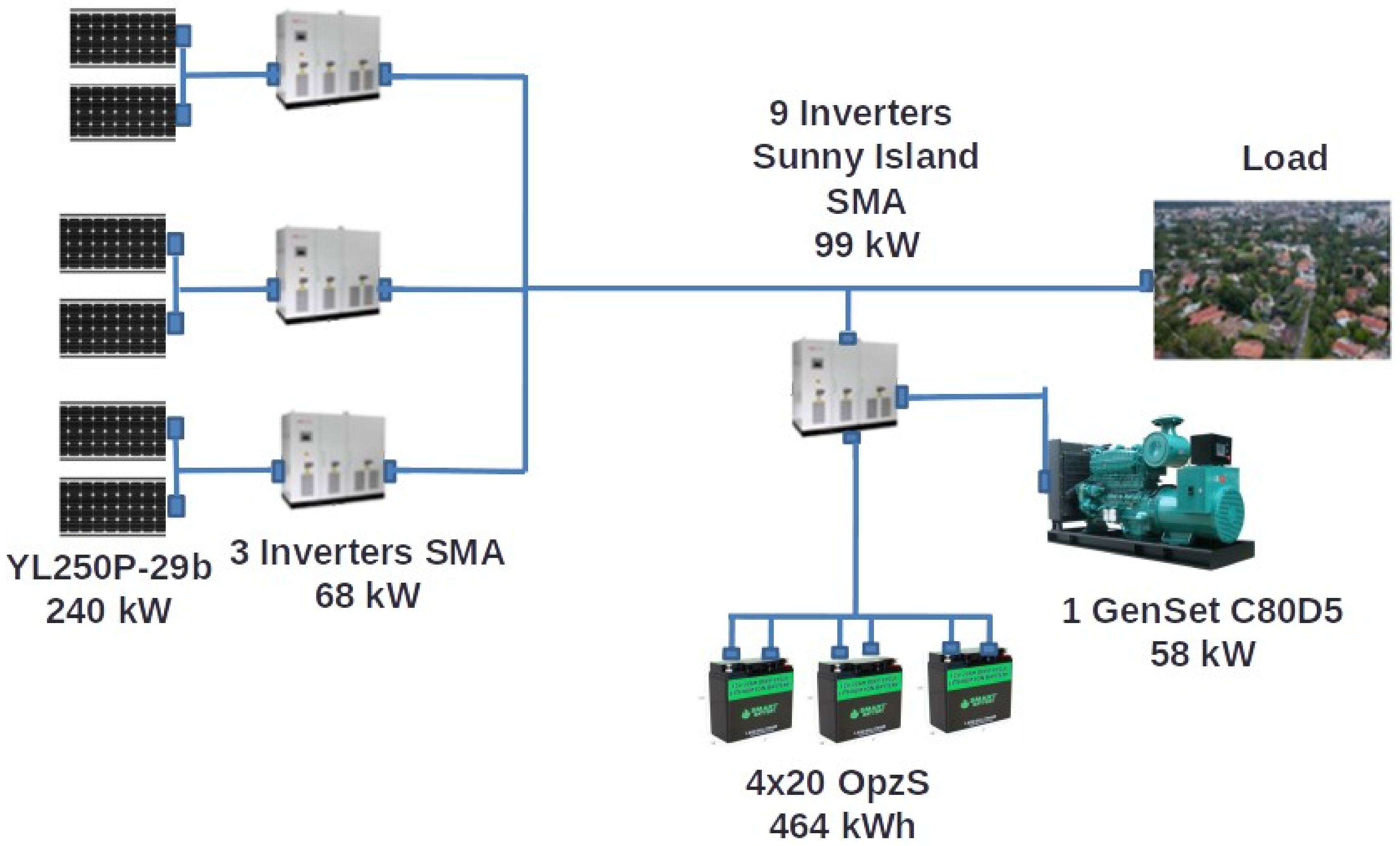
Microgrid Lay-out



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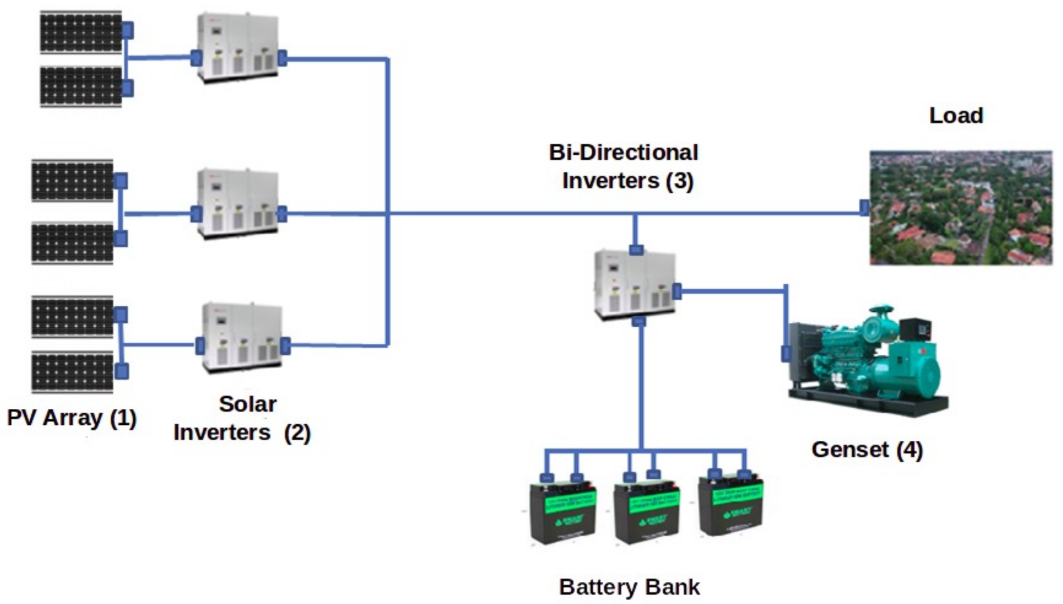
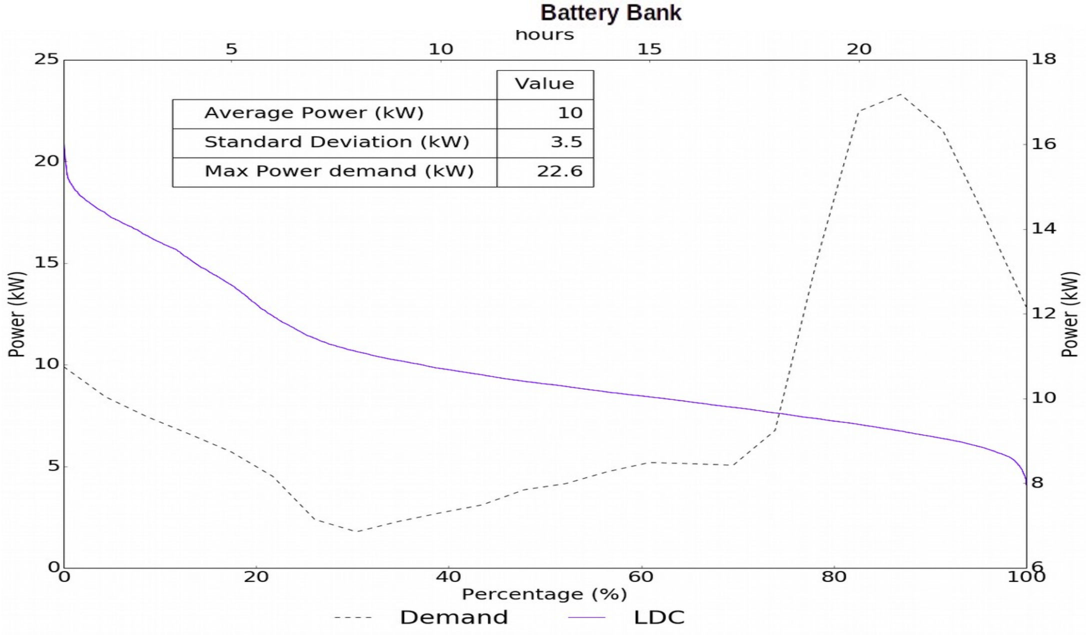
Available Data





Recollection Point	Data collected
PV array (1)	Module temperature (^oC)
Solar inverter (2)	PV power (W)
Bi-directional inverter (3)	Battery bank power (W)
	Genset power (W)
Genset (4)	Diesel consumption (L)
Meteorological station	Ambient temperature(^oC)
	Radiation (W/m^2)

- Collected data that cover more than a year
- Resolution of 5 minutes
- New data will be available soon

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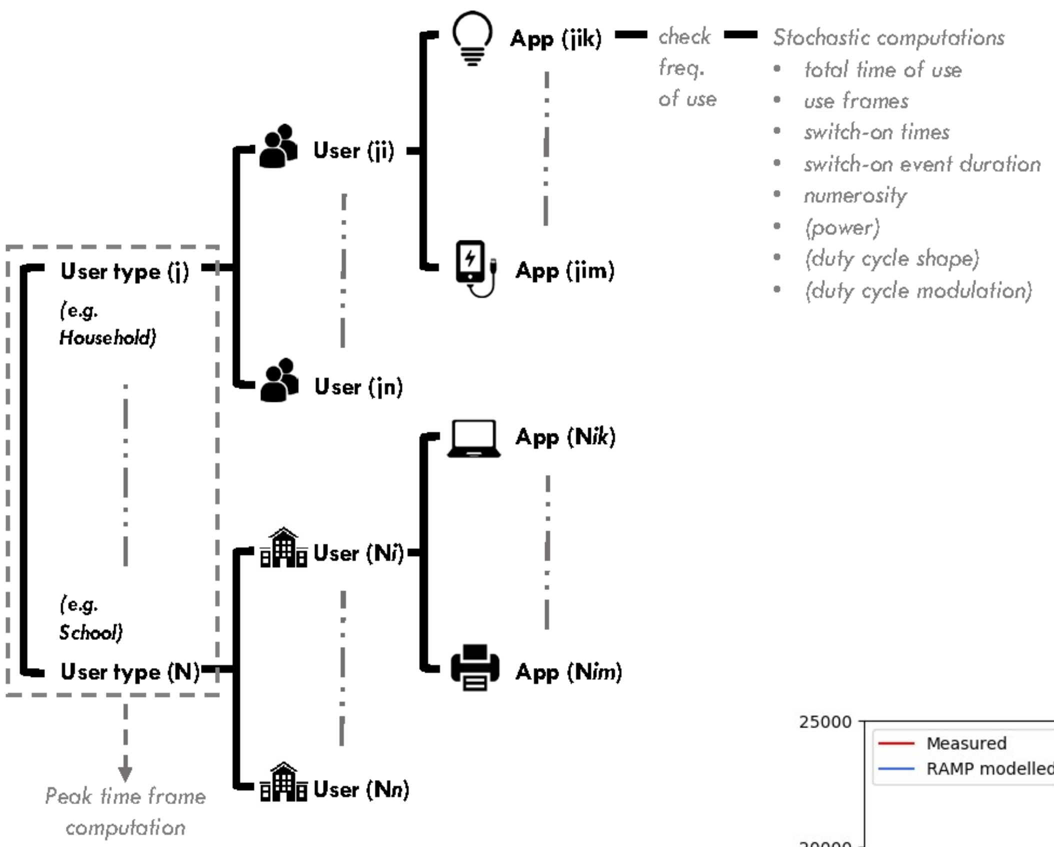
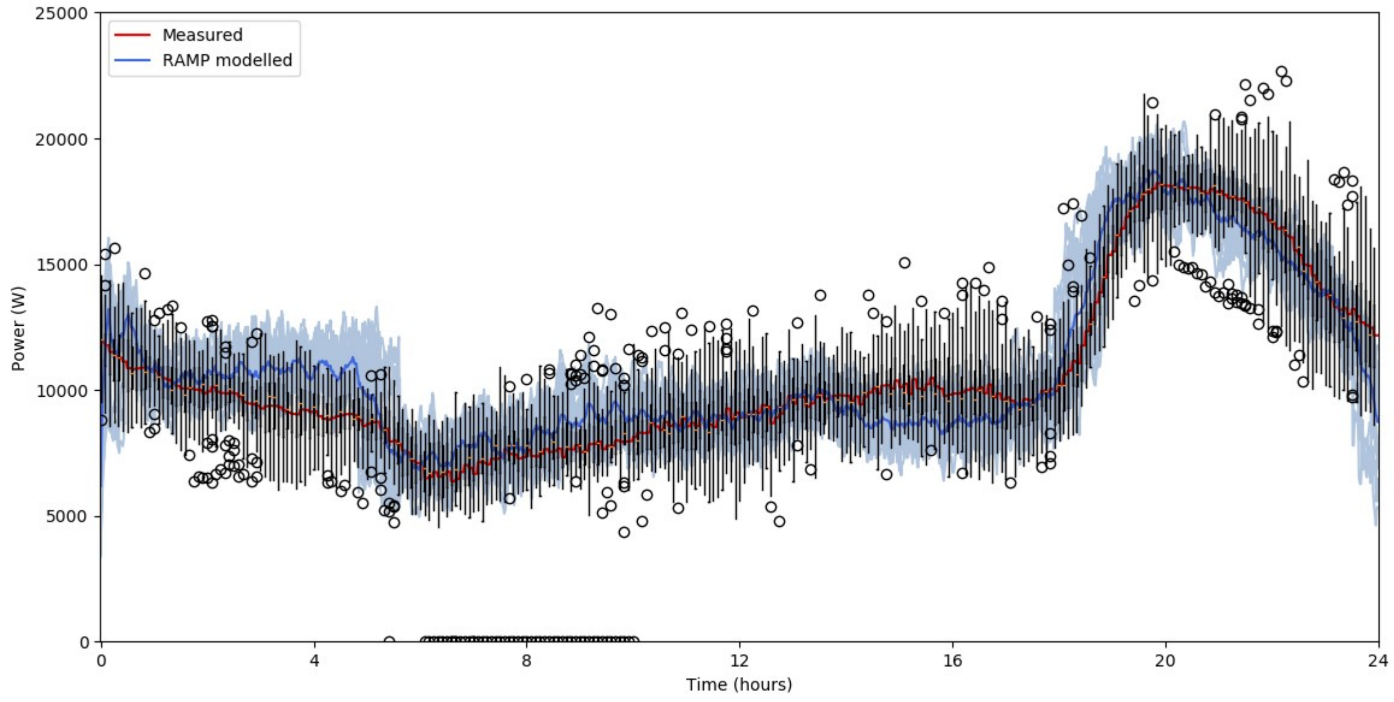
Validated Stochastic Demand Model (RAMP)



- After a survey the population was classified based on several criteria
- Construct a fundamental demand model that considers:
  - Vegetative growth of consumption.
  - Behavioral changes of people.
  - Addition of new services or industries.
  - New unplanned connections of villages.
- Demand model is validated using historical data



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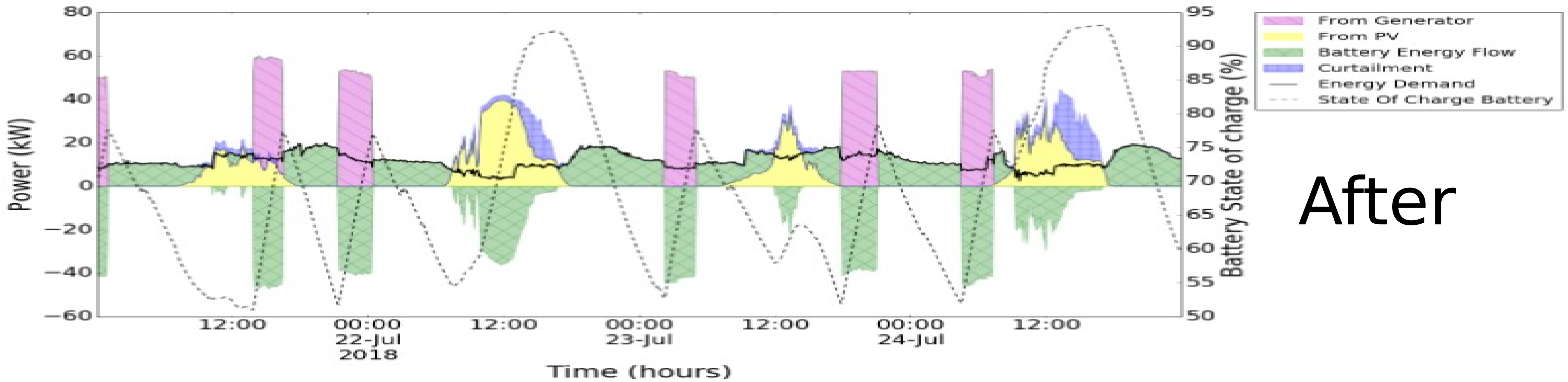
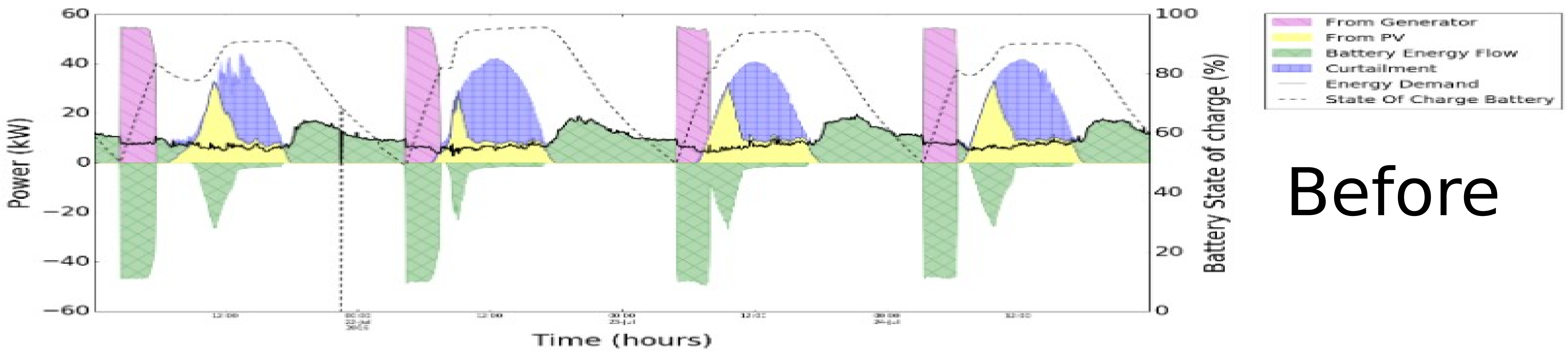
Example of demand evolution: un-planned 4.5 kW water pump



After



Before

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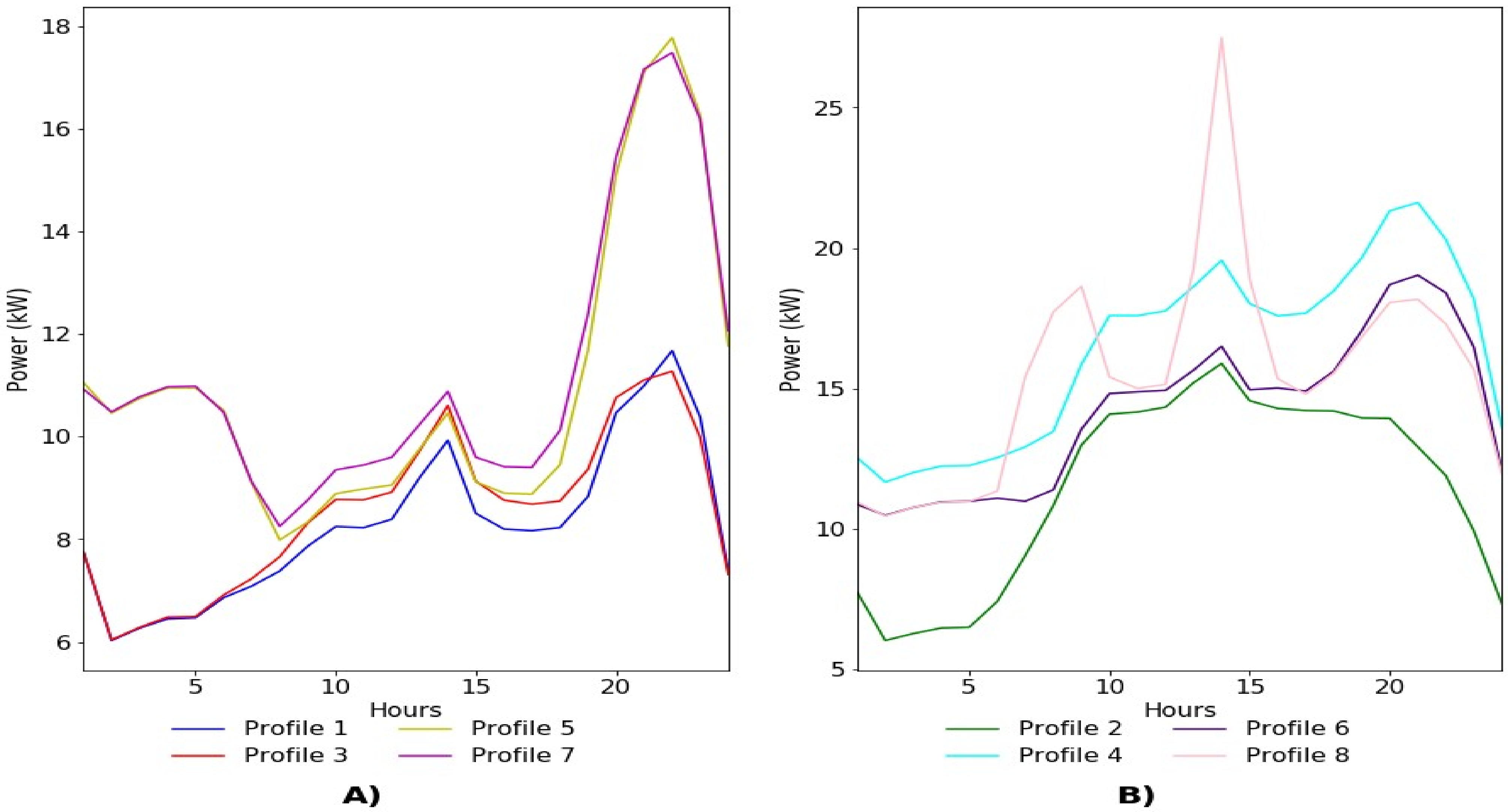
Example of demand evolution:Change in cooking behavior



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Demand explanation

- 1. Base scenario (Profile 1): accounting only for basic (i.e. no e-cooking) domestic appliances. No public services are considered;
- 2. Low Penetration of Simple Task e-Cooking (Profile 2) : only the higher income households make use of e-cooking and only to fulfil the simplest tasks, such as boiling water for preparing tea or mate. No public services are considered;
- 3. High Penetration of Simple Task e-Cooking(Profile 3) : all the households make use of e-cooking but only to fulfil the simpler tasks, such as boiling water for preparing tea or mate. No public services are considered;
- 4. High Class e-Cooking (Profile 4): only the higher income households use e-cooking at its full potential (i.e. preparing all the meals with such technology), while the rest of the households use e-cooking only to boil water for tea. No public services are considered;
- 5. Basic Energy Profile + Public Services (Profile 5) : specifically, public services include a school, a hospital, a church and a public lighting system;
- 6. Low Penetration of Simple Task e-Cooking + Public Services (Profile 6)
- 7. High Penetration of Simple Task e-Cooking + Public Services (Profile 7);
- 8. High Class e-Cooking + Public Services (Profile 8)

Additional features

Multiple objectives

The simulator can output separately:

- Fuel cost (€)
- Lost load (kWh)
- RES curtailment (kWh)
- Battery degradation (cycles)

(User can specify whether to return total cost or individual objectives)

Benchmarks for comparison

Consider:

- Heuristic agent (rule-based)
- Random agent
- Optimization agent (to be implemented)

Other features

- User can provide set of days for testing and training
- Plots xticks are fixed

Future work

- Include forecasts as part of the state using:
  - the validated consumption model (RAMP)
  - tools created by the Uliège team for RES forecasting
- Alternatively provide the features that would be used for forecasting
- Benchmark ‘optimization agent’
- Enrich ‘decision framework’, add actions, etc.
- Glad to hear your suggestions!

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Contact

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Discussion

- Add uncertainty - forecasts
- Hierarchical control
- Add actions
  - storage system of same type -> just change capacity
  - genset -> really a new action
  - New PV –> change input
- Common repository
- Common benchmarks – evaluation protocol

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