Outage Response in Microgrids using Demand Side Management

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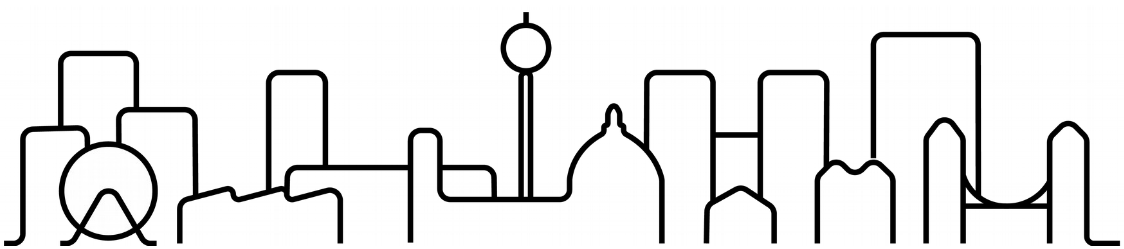

Project IRENE at a glance

- Program Call: JPI Urban Europe
- Duration: 30 months
- Overall costs: 1 400 000 €

Overall goal: Enable a highly robust and highly available power supply for smart city scenarios

Activities

- Analyse security and disaster threats on the power grids of cities
- **Investigate the use of demand side management in power outage situations**
- Develop tools that help city planners and distribution system operators to guide the planning/deployment of Smart Grid functions

Overview

Reliability of power supply is increasingly threatened due to natural catastrophes and cyber attacks

- Simulation of a microgrid with smart components
  - Components are able to switch off interruptible demand
- Calculate grid quality metric: „grid autonomy factor“

Architecture Overview

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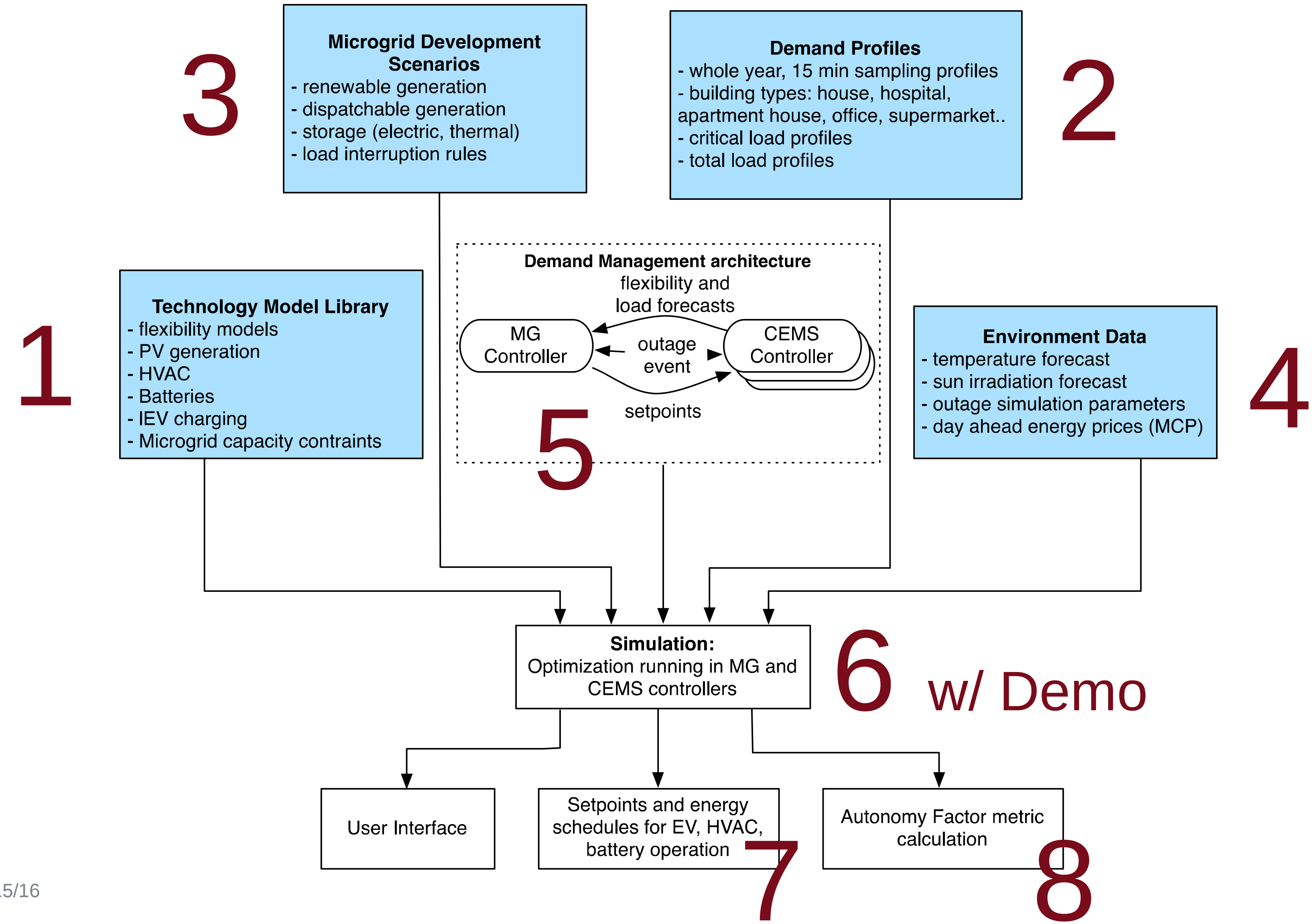
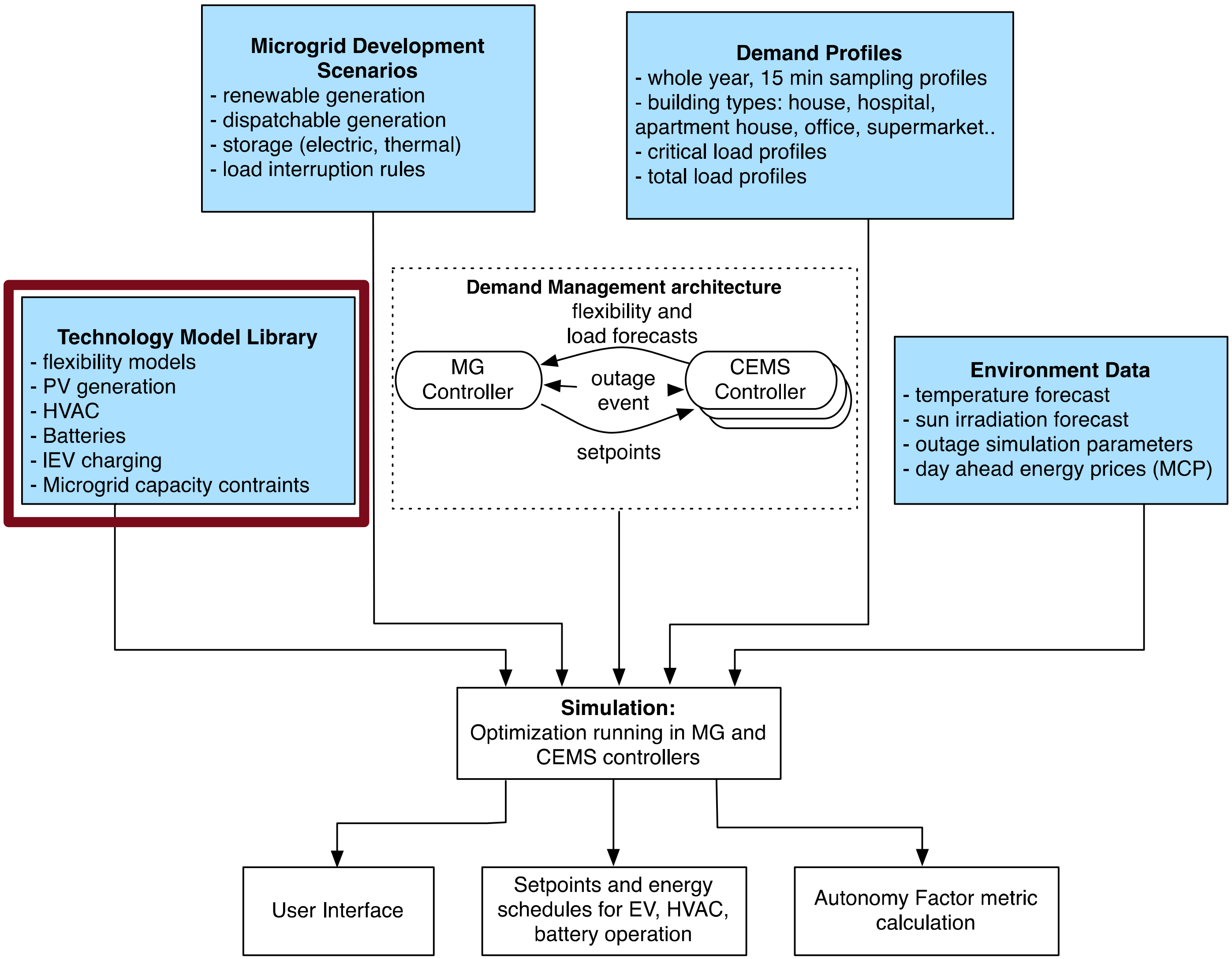


Simulation Concept



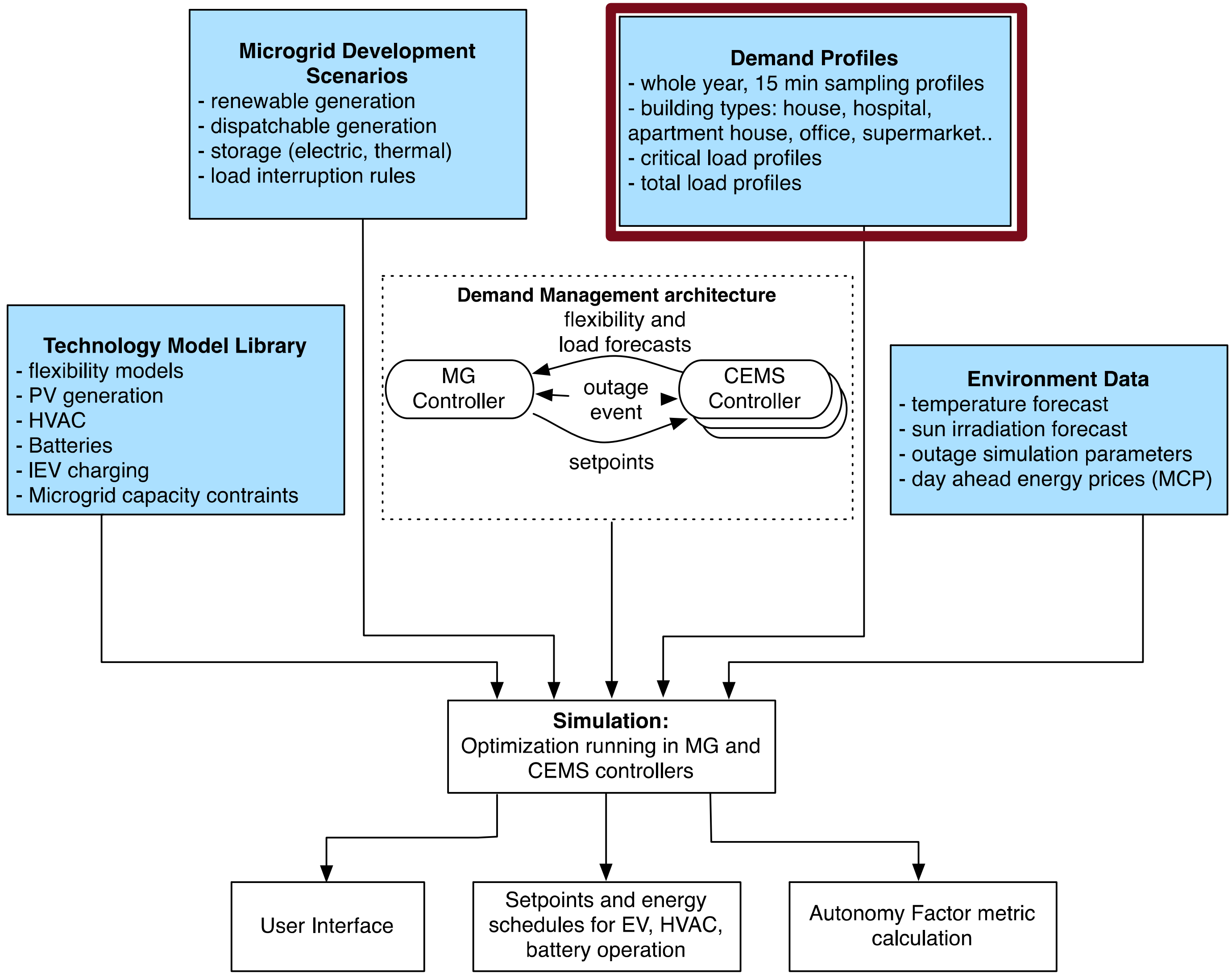
Technology Model Library

The model implements

- different technological components
  HVAC, PV power generation, energy storage (battery), …
  - Physically, these components would have to be able to communicate/receive commands from the CEMS.

- A standard model of physics for heating/cooling
  Sun radiation, ventilation loss, …

Simulation Concept



Demand Profiles

For simulating real life behaviour, we use demand profiles.

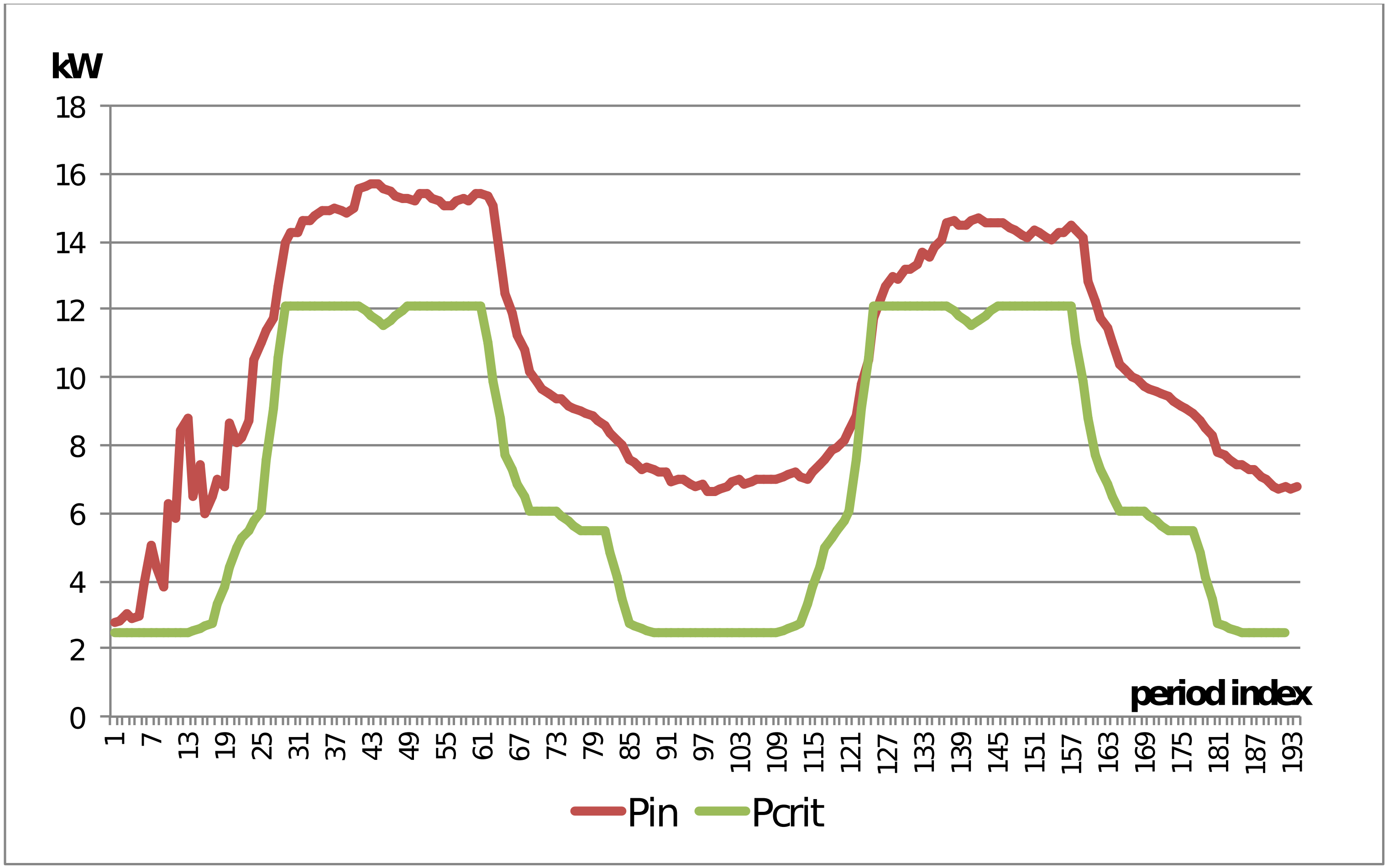
- Demand is split into critical and interruptable loads
- Adapting profile configuration requires a lot of fine tuning

Profiles include:

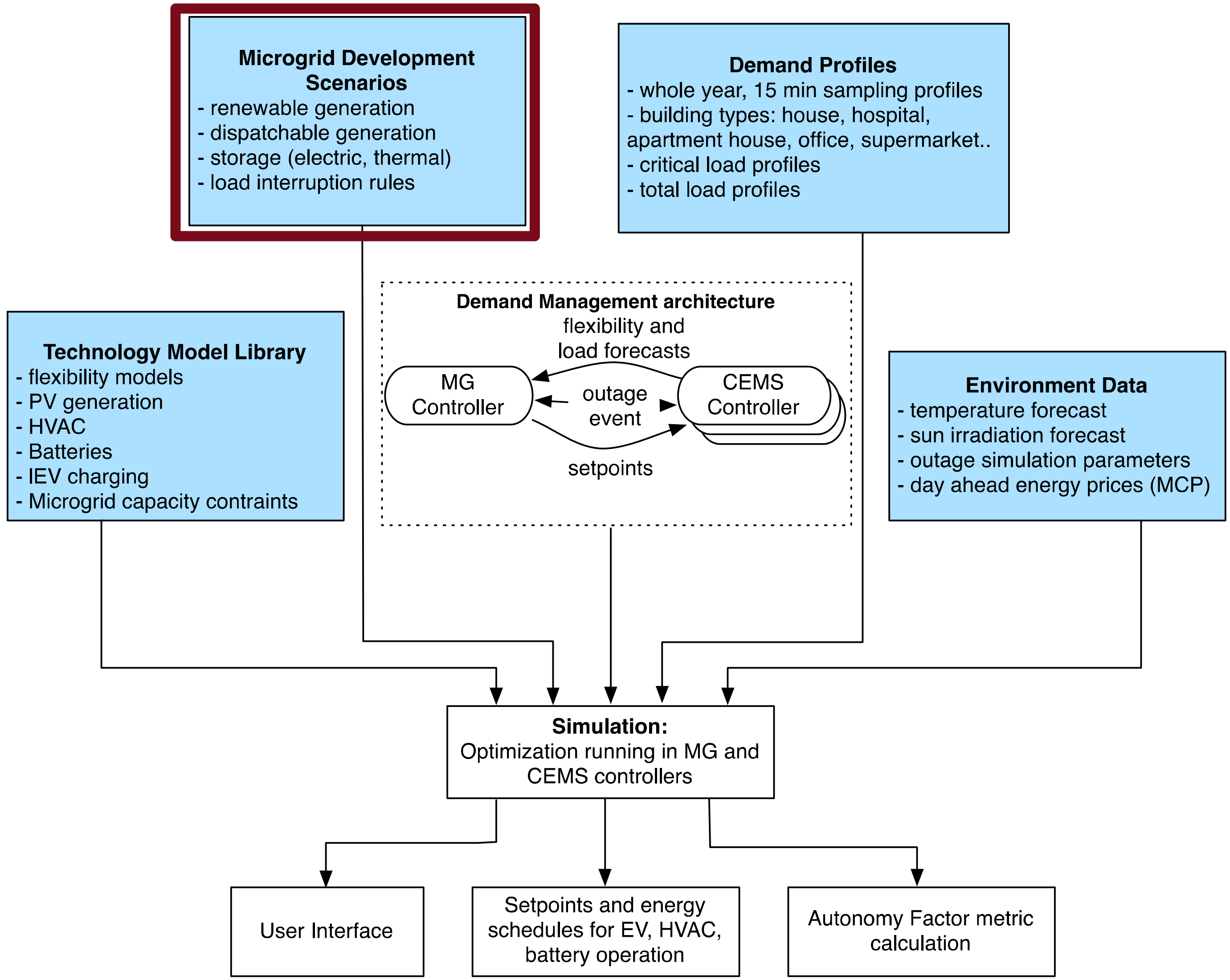
- Residential House
- Apartment Building
- Office
- Hospital & Outpatient Clinic
- Supermarket
- ...

Demand Profile Example

- Office Building (HVAC classified as not critical)



Outage Respone



Outage Scenarios

Scenario: An outage, such as a failure of one of the power plants, reduces the supplied power to the MG

Response: reduce the demand accordingly using a (emergency) demand response program.

Scenario: An outage strongly reduces or completely cuts off the supplied power, causing the microgrid to disconnect (islanding mode).

Response: Use demand response plus dispatchable generation such that the critical demand can be satisfied.

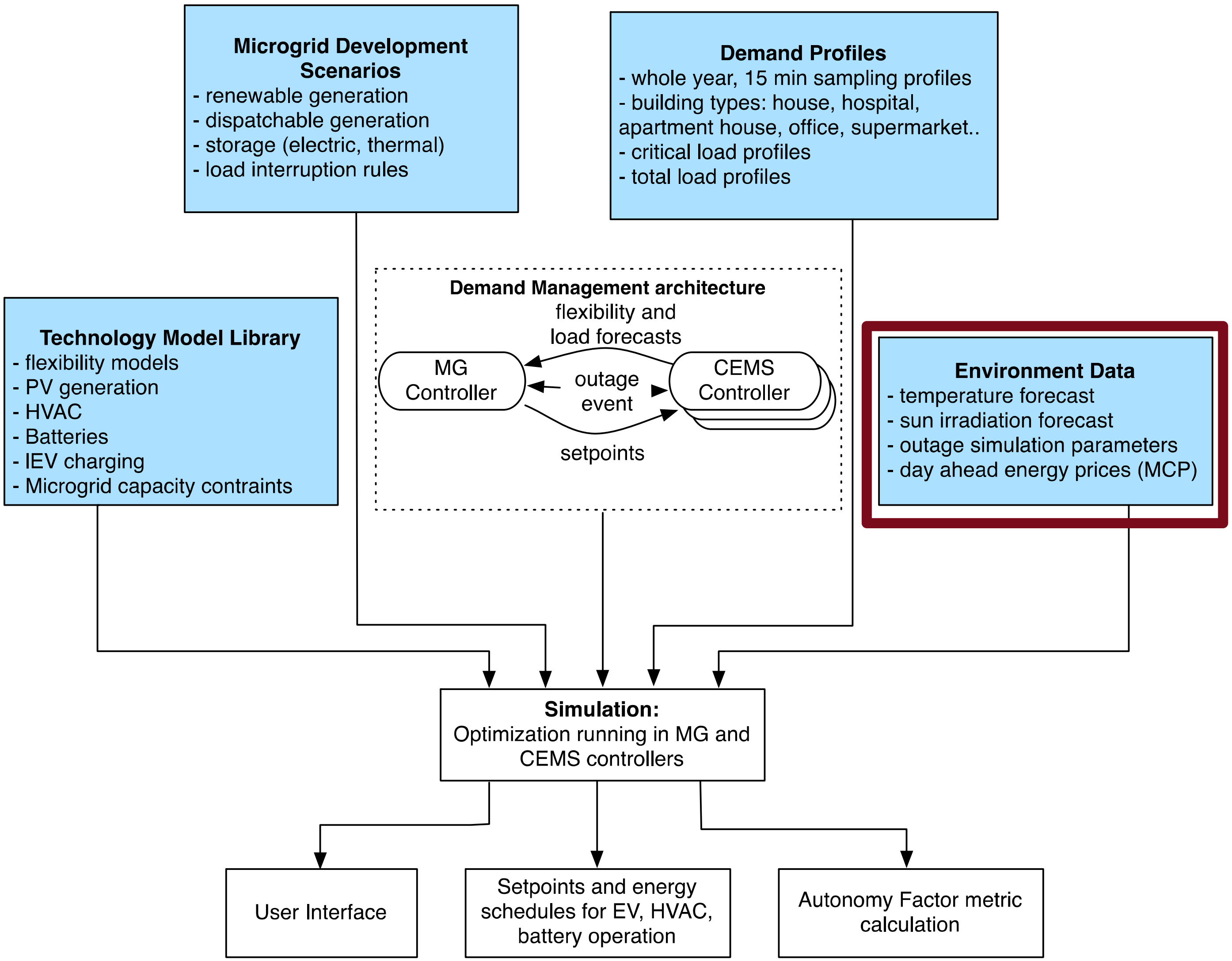
Approach:

Simulate both the normal operation and the outage response on medium time scale (minutes). Perform Demand Management both in normal and in outage state

The Outage mode

- Only Critical loads are satisfied
- No economic terms in the objective function, keep the strict balance between supply and demand
- outage policy rules are activated, e.g.
  - More flexible HVAC loads
  - EV charging would be discontinued

Simulation Concept

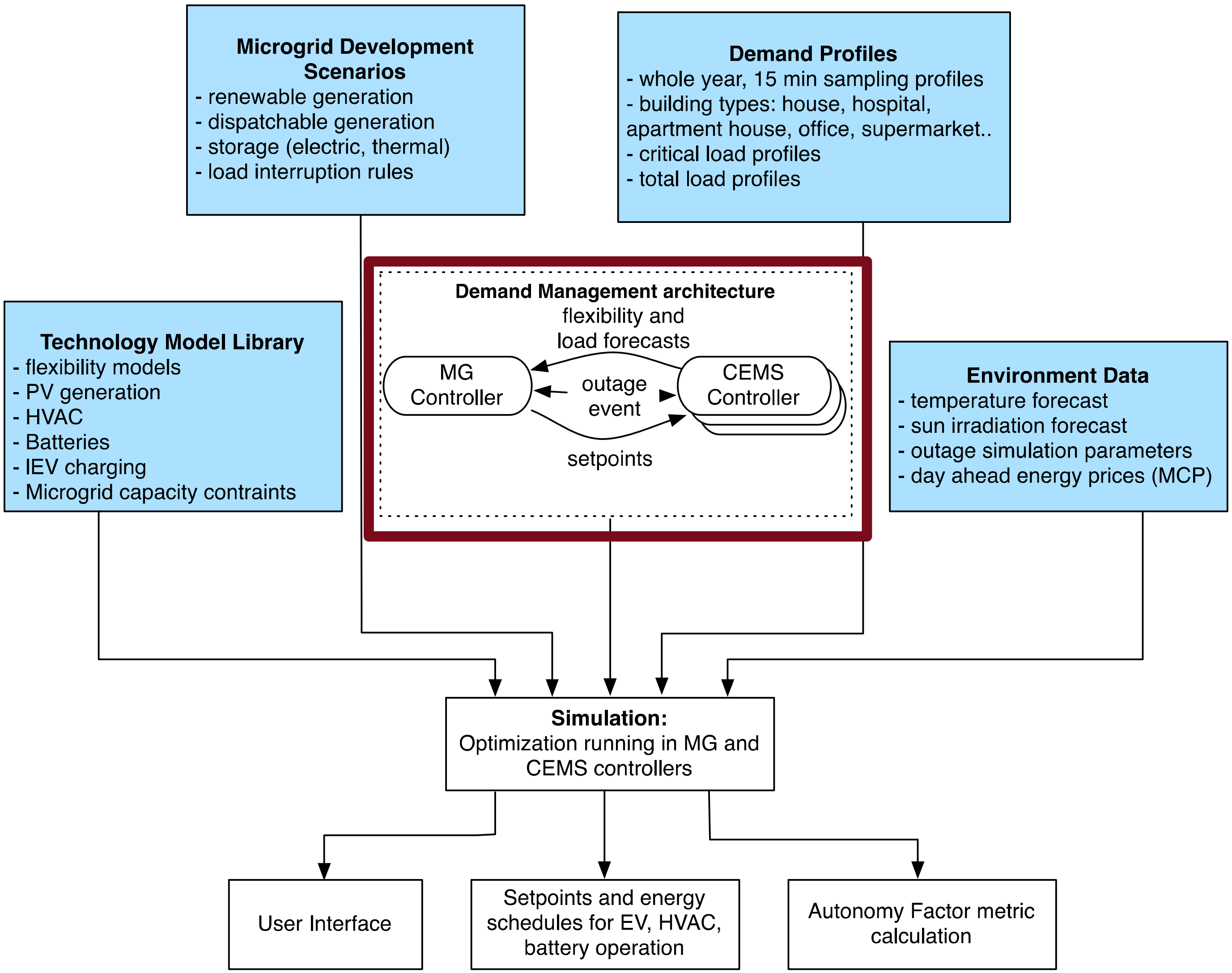


Environmental Influence Simulation

- Temperature
- Solar Radiation

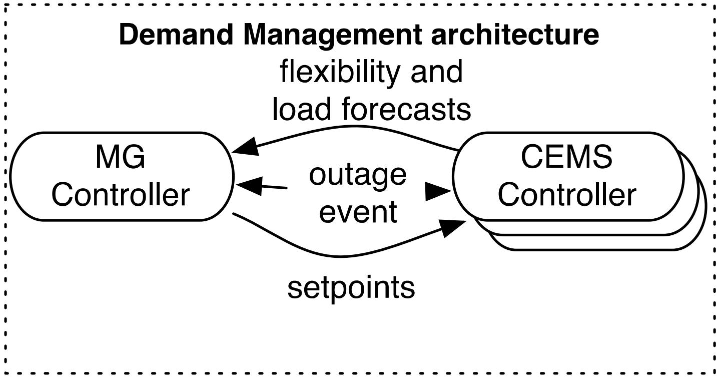
- Day-ahead energy prices

Simulation Concept



Control architecture

- Control loop (every 15 sim-min)
- Model prediction (6 sim-hours time horizon)



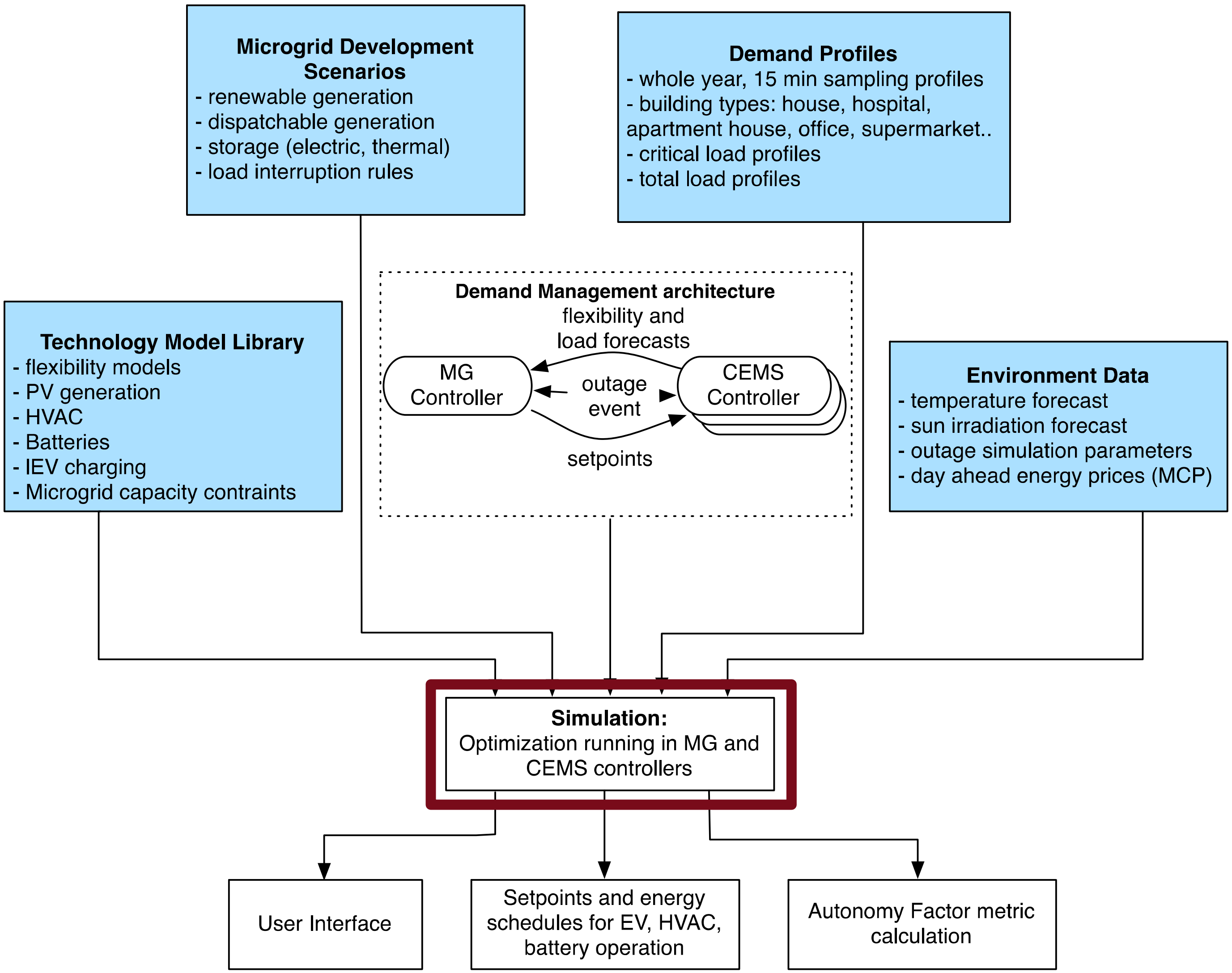
Mixed integer program, objective:

- follow the set points received from the MG controller,
- maximize the generated PV active power
- Maximize profit by charging the battery when the energy price is low.

Output:

- active power consumption plan P^{in}_j of the building
- control actions for HVAC; EV, PV, Battery.

Simulation Concept

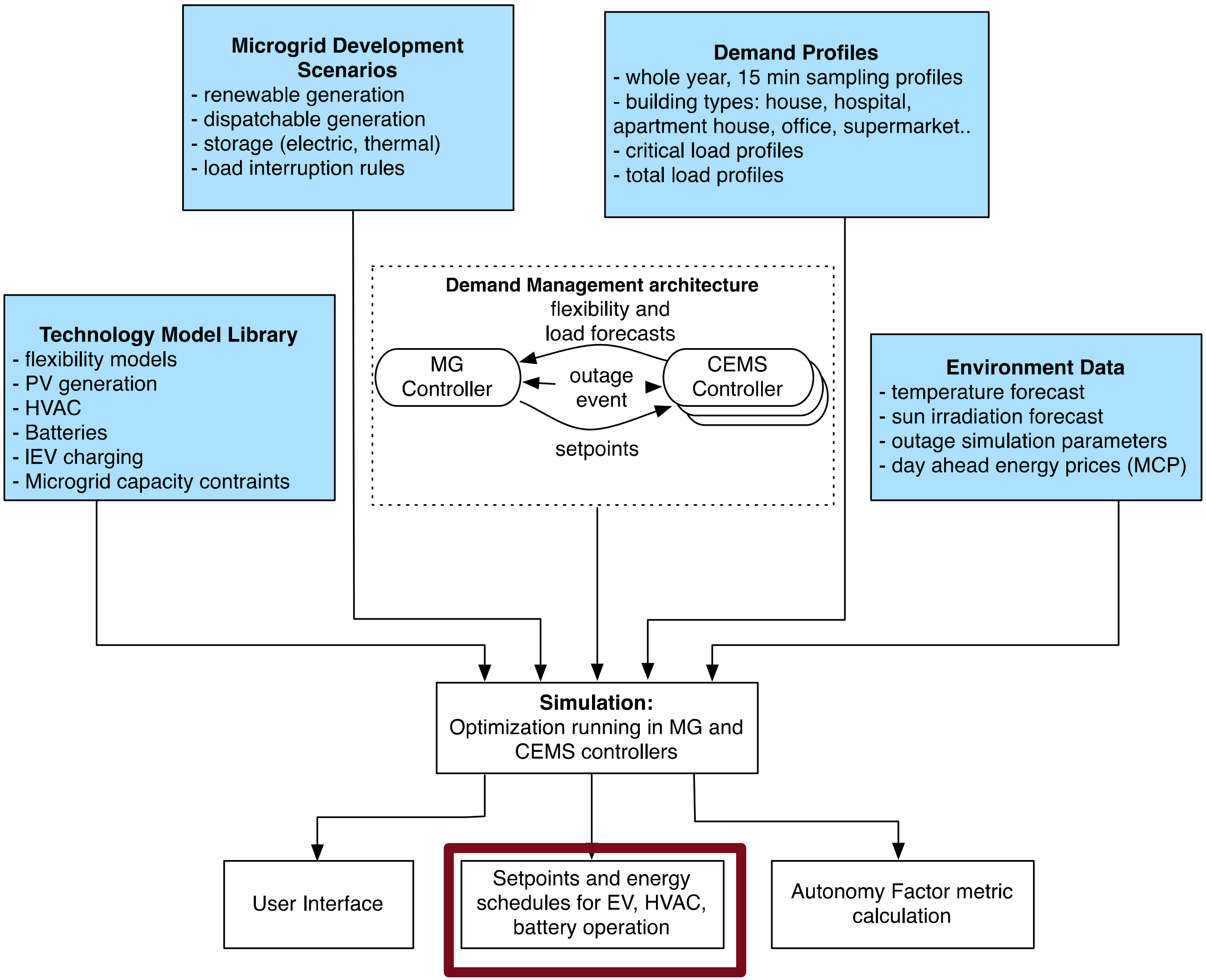


DEMO

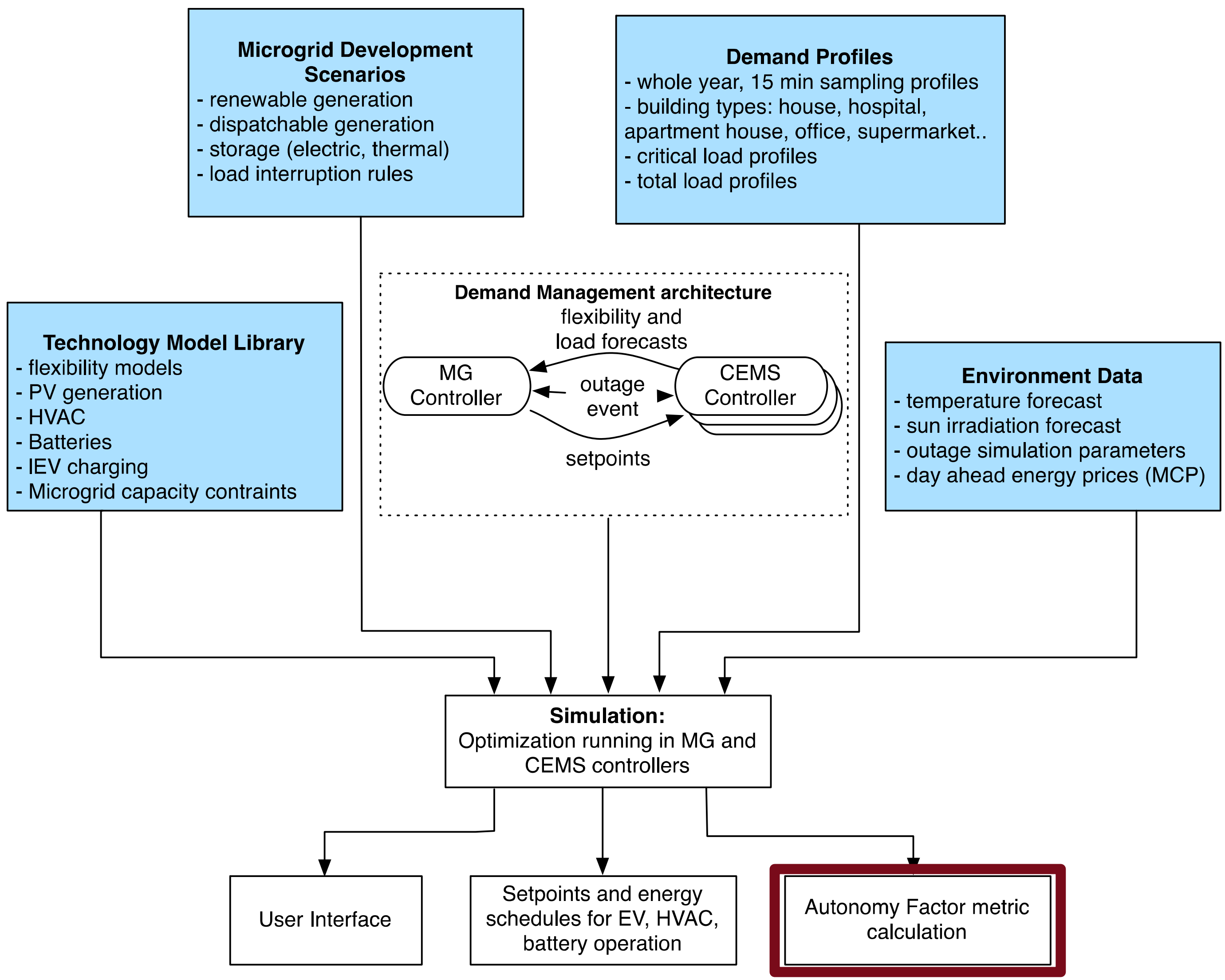
- Simulation Start Time: July 5, 12:00
- Outage: July 6, 9:00 to July 6, 22:00

  Max. power input from main grid reduced from 250kW to 120kW
- 25 residential houses
  - 13 electric cars charging in 1-2 intervals per day
  - 7 kW air conditioning AC (summer month)
  - 5 kWp PV generation in every house
  - Battery 5-10kWh
- 8 small offices
  - Up to 30 zones 0.5 kW AC cooling
  - PV 8 kWp
- 4 midrise apartment blocks
  - Up to 30 zones 0.5 kW AC cooling
- 100kW battery

Simulation Output



Autonomy Factor



Autonomy Factor

The Autonomy Factor describes how well a grid can cope with an outage in a specific scenario (with implemented DSM).

- The higher the factor, the more autonomous the MG is

Input parameters:

- Amount of storage in the batteries after the outage
- PV area in the grid
- Outage duration

$$\alpha = 1 - \frac{E_{in}^{o}}{D^{n}} = 1 - \frac{E_{in}^{o}}{E_{in}^{n} + E_{RES}}$$

Scenario	E_{in}^{n} MWh	E_{in}^{o} MWh	E_{RES}^{n} MWh	α
Baseline	4.675	2.46	1.15	0.58
NoPV (offices)	5.11	2.90	0.71	0.50
LessStorage	4.77	2.40	1.04	0.58
6hOutage	1.23	0.55	0.47	0.67
24hOutage-120kW	4.675	2.39	1.15	0.54
6hOutage-120kW	1.23	0.59	0.47	0.65

Concluding Remarks

- Bottom-up approach for improving response to outage: the level selected is that of Microgrid.

- Microgrids can lower their maximum load and their maximum excessive power generation by using flexible loads.

- Intelligent microgrids can react to an outage with a) islanding b) with a reduction of their load.

- The production required for emergency is less expensive and can be planned accordingly.

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