AMBASSADOR project

Simurex 2015, IBPSA

Peter Pflaum, Schneider Electric

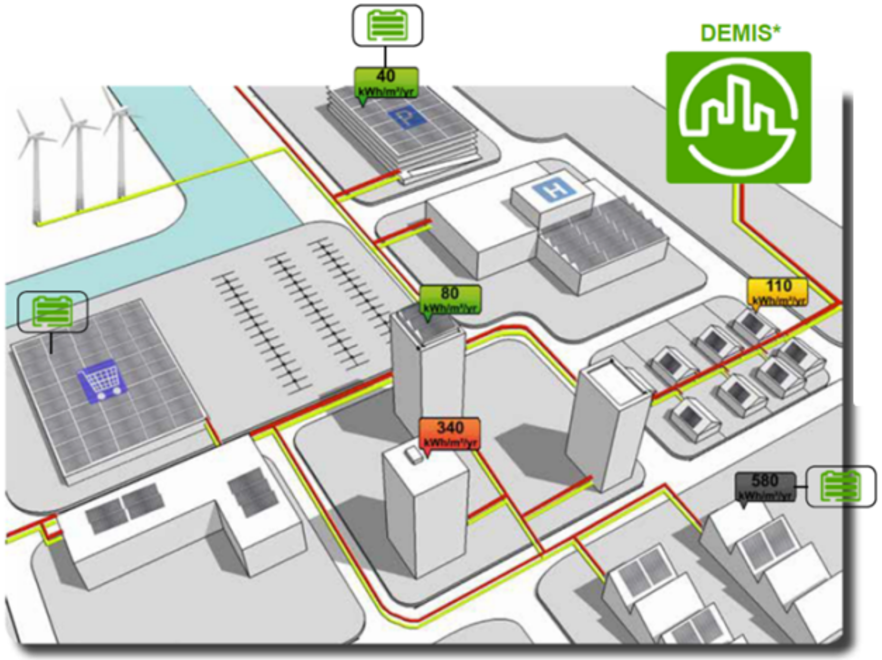
AMBASSADOR objectives

Energy flow management at district level for electrical and hot/cold water networks

Define the optimal energy flows answering to a specific mission assigned to the district

Typical missions

- Optimize net cost of energy
- Minimize CO2 footprint
- Mitigate energy outages impact



* DEMIS : District Energy Management Information System
hot water network
electric grid

Key developments

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- Distributed optimization framework to…
  - Coordinate the behavior of a **large** number of district actors in an optimal way
- Develop a District Simulation Platform (DSP) to…
  - Annual simulations of complete districts
  - Host and validate the optimization algorithms
  - Evaluate potentials
- Deploy validated algorithms on test sites (software-in-the-loop)

Distributed optimization approach

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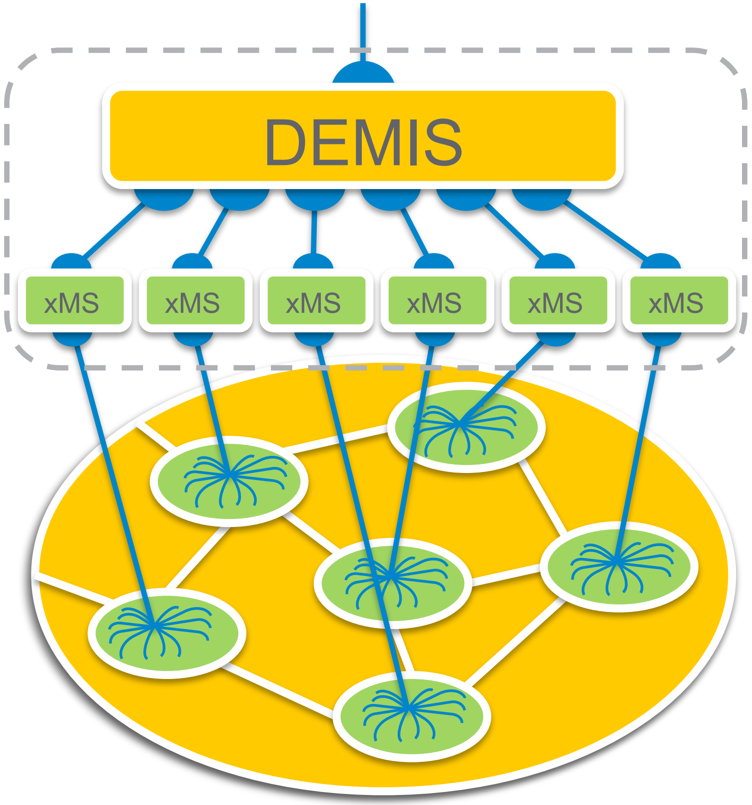
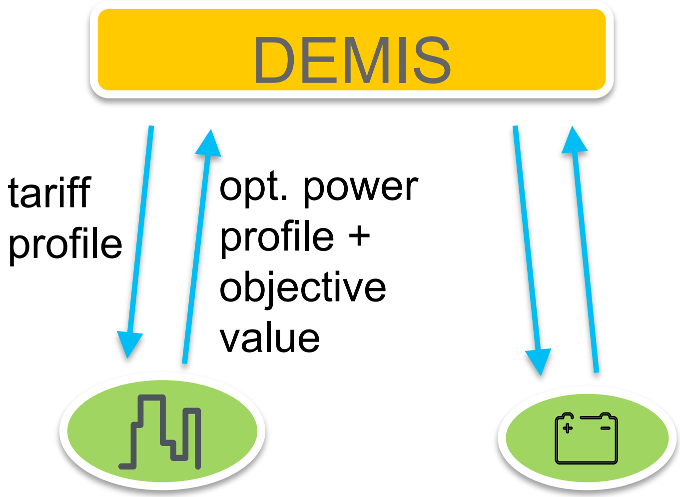
Distributed MPC approach



- **Why distributed MPC?**
  - Scalability
  - Modularity
  - Robustness
  - Privacy!
- **Principle**
  - xMS solve local optimization problems
  - DEMIS influences the local controllers in such a way that the **global objective** is achieved

Distributed MPC approach

- Information exchange:



- Optimization objectives:
  - Minimize the cost of energy
  - Fulfill the actors' missions (comfort in buildings,...)
  - Respect district power limitation **(coupling constraint!)**
  - Enhance auto-consumption **(coupling objective!)**

Exemplary results (power limitation)

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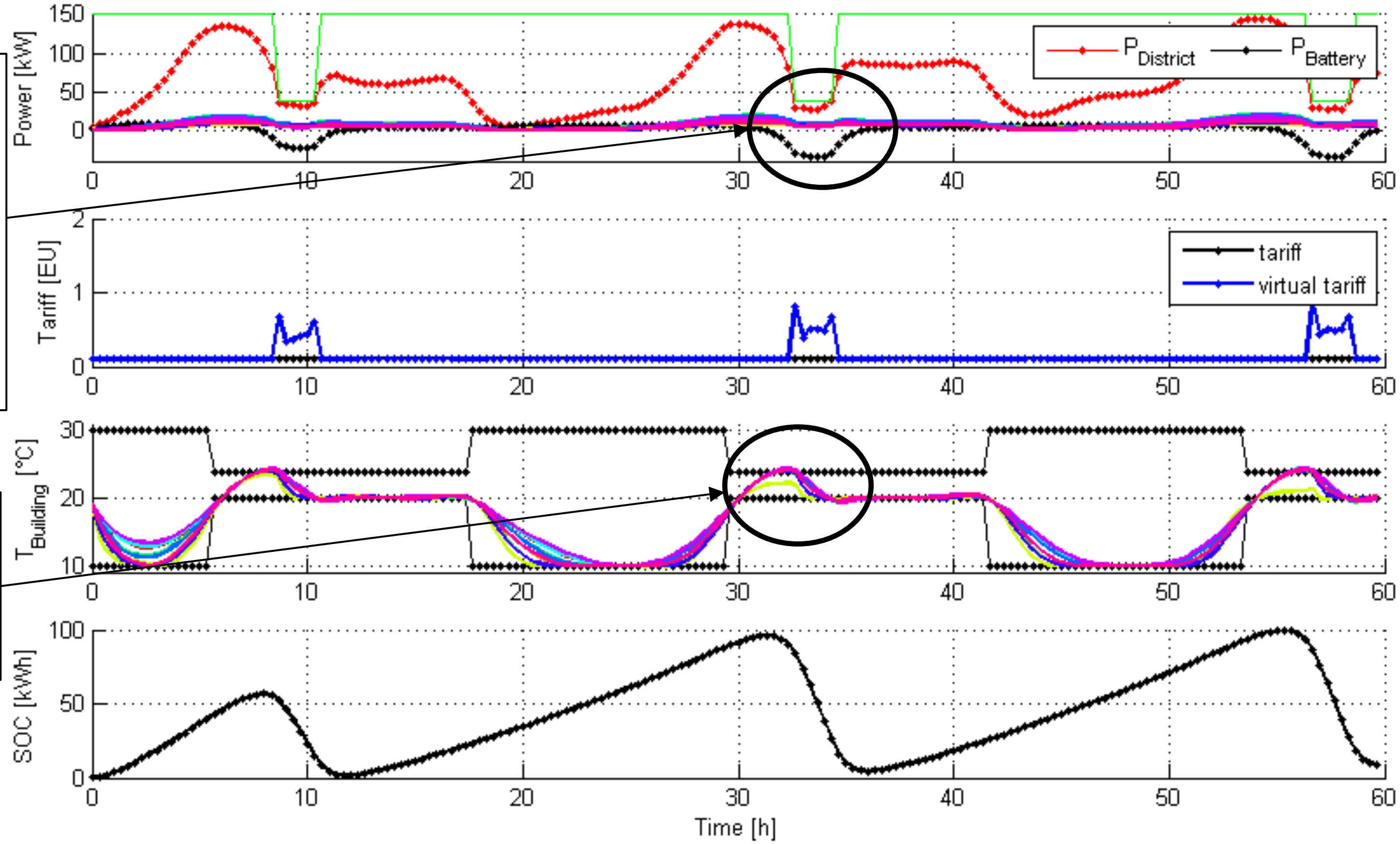
Battery supplies power during reduction period

Buildings use their inertia



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District Simulation Platform

Simulation Platform:

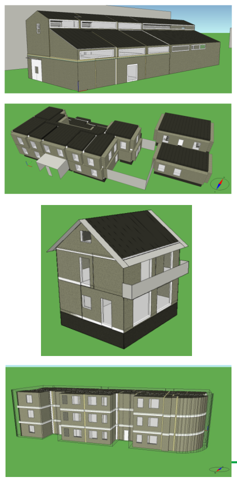
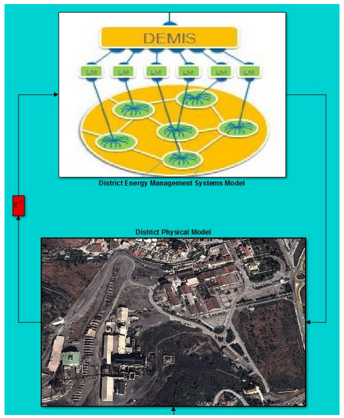
CEA, Schneider Electric

Features for district simulation platform

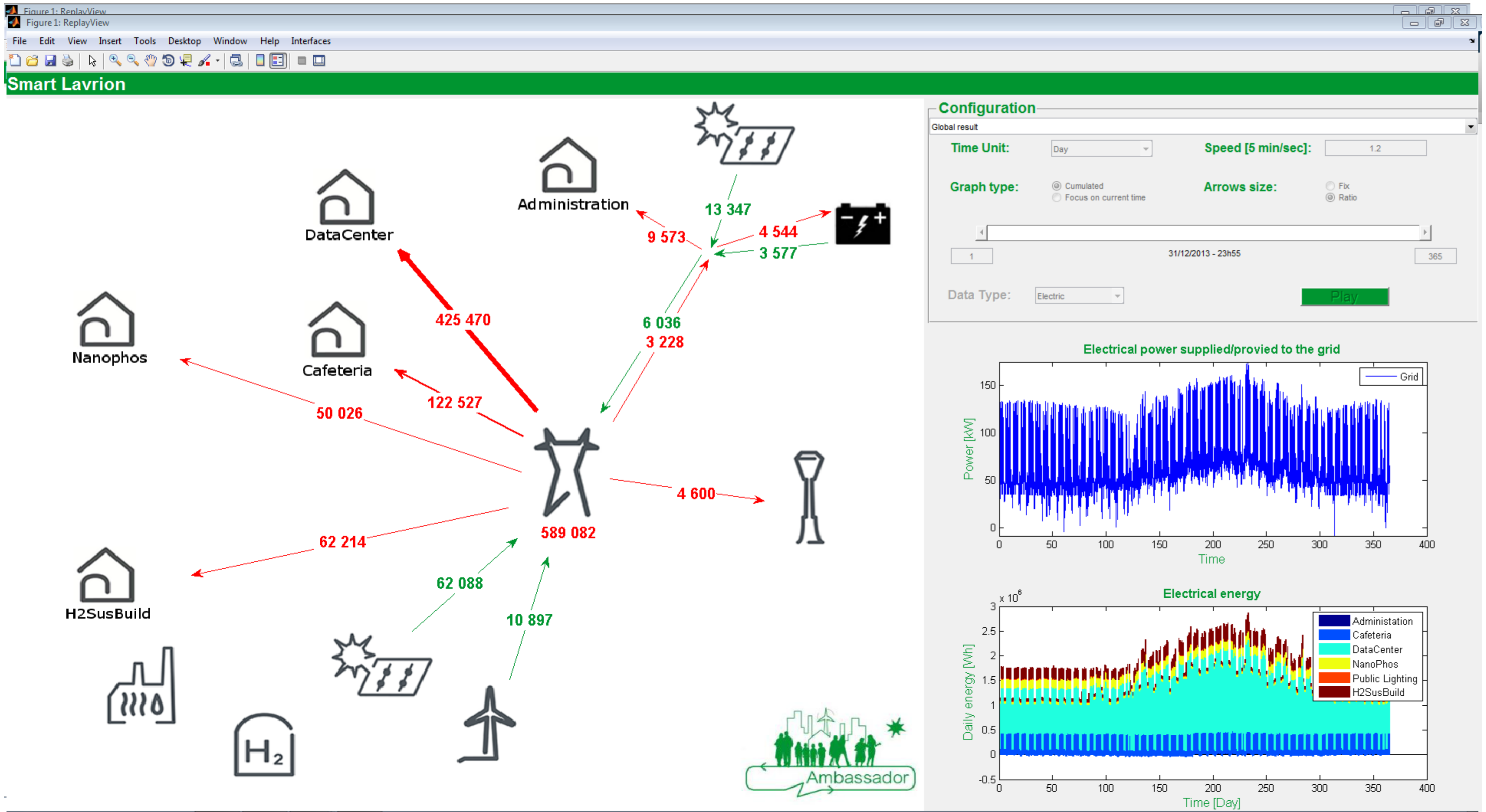
- Configurable model with evolutive models/libraries. ☺
- Electric/water distribution networks. ☹
- Stochastic occupancy/load. ☹
- Simulation time target: full year in few hours (>x1000). ☺ → 😐
- Optimization algorithm coupling. ☺
- Use real data to replace some simulation input. ☺
- Post-treatment and analysis (GUI). ☺

From detailled building models to reduced models in DSP and optimization

Automatic Process

IDA-ICE model	Data exported to MATLAB	Building Identification	Model generated for the DSP	Integration in the DSP	Simulation in the DSP
	Extraction of IDA-ICE data with MATLAB script	Identify models in MATLAB	Generate Sfunction (Simulink) file of the models for the DSP		Simulate over one year with reduced models in a few minutes

Postreatment : KPI, graphical display, sensitive analysis, …



Test sites

Simulation Platform:

CEA, Schneider Electric

Demonstration sites

BedZed - Sutton
United Kingdom

LTPC - Athens
Greece

Ines – Chambery
France

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Questions?

Backup – Optimization

Optimization objectives

- Minimize the sum of the sub-systems' objectives while taking into account some objectives on district level

- Local objectives:
  - Minimize the cost of the consumed energy
  - Fulfill the sub-systems mission (comfort in buildings,...)

- District objectives:
  - Respect global limitation on the power consumption
  - Enhance auto-consumption

Dual decomposition method

- Centralized problem:

$$\underset{\{\mathbf{x}_l,\mathbf{r}_l\}_{l\in S}}{\text{Minimize}} \sum_{l\in S} J_l(\mathbf{x}_l,\mathbf{r}_l)$$

$$\sum_{l\in S} \mathbf{r}_l \leq \mathbf{R}_{lim}$$

  - Build Lagrangian:

$$\mathscr{L}(\mathbf{x}_l,\mathbf{r}_l,\lambda) = \sum_{l\in S} J_l(\mathbf{x}_l,\mathbf{r}_l) + \lambda \cdot (\sum_{l\in S} \mathbf{r}_l - \mathbf{R}_{lim})$$

  - Decomposability:

$$\mathscr{L}(\mathbf{x}_l,\mathbf{r}_l,\lambda) = \sum_{l\in S} \boxed{[J_l(\mathbf{x}_l,\mathbf{r}_l) + \lambda \cdot \mathbf{r}_l]} - \lambda \cdot \mathbf{R}_{lim}$$

- Dual problem:

$$\underset{\lambda}{\text{Maximize}} \left[\inf_{\{\mathbf{x}_l,\mathbf{r}_l\}} \mathscr{L}(\mathbf{x}_l,\mathbf{r}_l,\lambda) \right]$$

$$\text{Subject to: } \lambda \geq 0$$

  - Maximization problem over the dual variable λ

Solving the optimization

- Control update period: 15 minutes
- Prediction horizon: 24 hours
- Iterative scheme: 10-30 iterations

- At each iteration:
  - The sub-systems solve their local problems in parallel and send their predicted power consumption and objective value to the DEMIS
  - The DEMIS aggregates the total power consumption and updates the energy tariff (λ) for the next iteration

Unified interface « eNode »

- Exchange between DEMIS and eNodes:
  - DEMIS → eNode: tariff profile
  - eNode → DEMIS: opt. power profile + cost value
- No knowledge of the sub-systems at DEMIS level

Backup – Optimization results

Some results (power limitation)

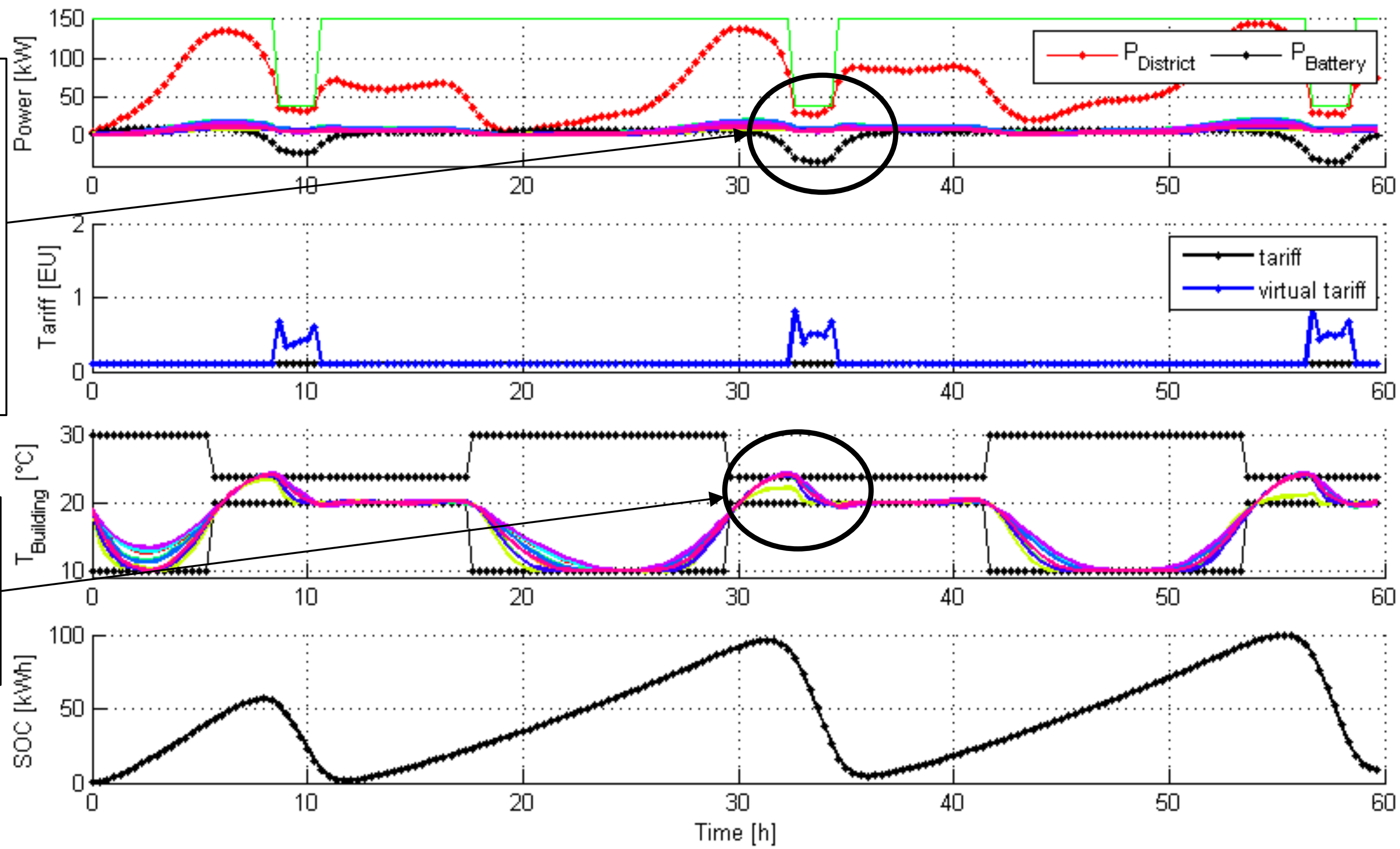
- District:
  - 10 buildings
  - 1 battery

- Use case:
  - Utility asks for consumption reduction of 2 hours
  - 3 day simulation in closed-loop

Exemplary results (power limitation)

Battery supplies power during reduction period

Buildings use their inertia



Some results (auto-consumption)

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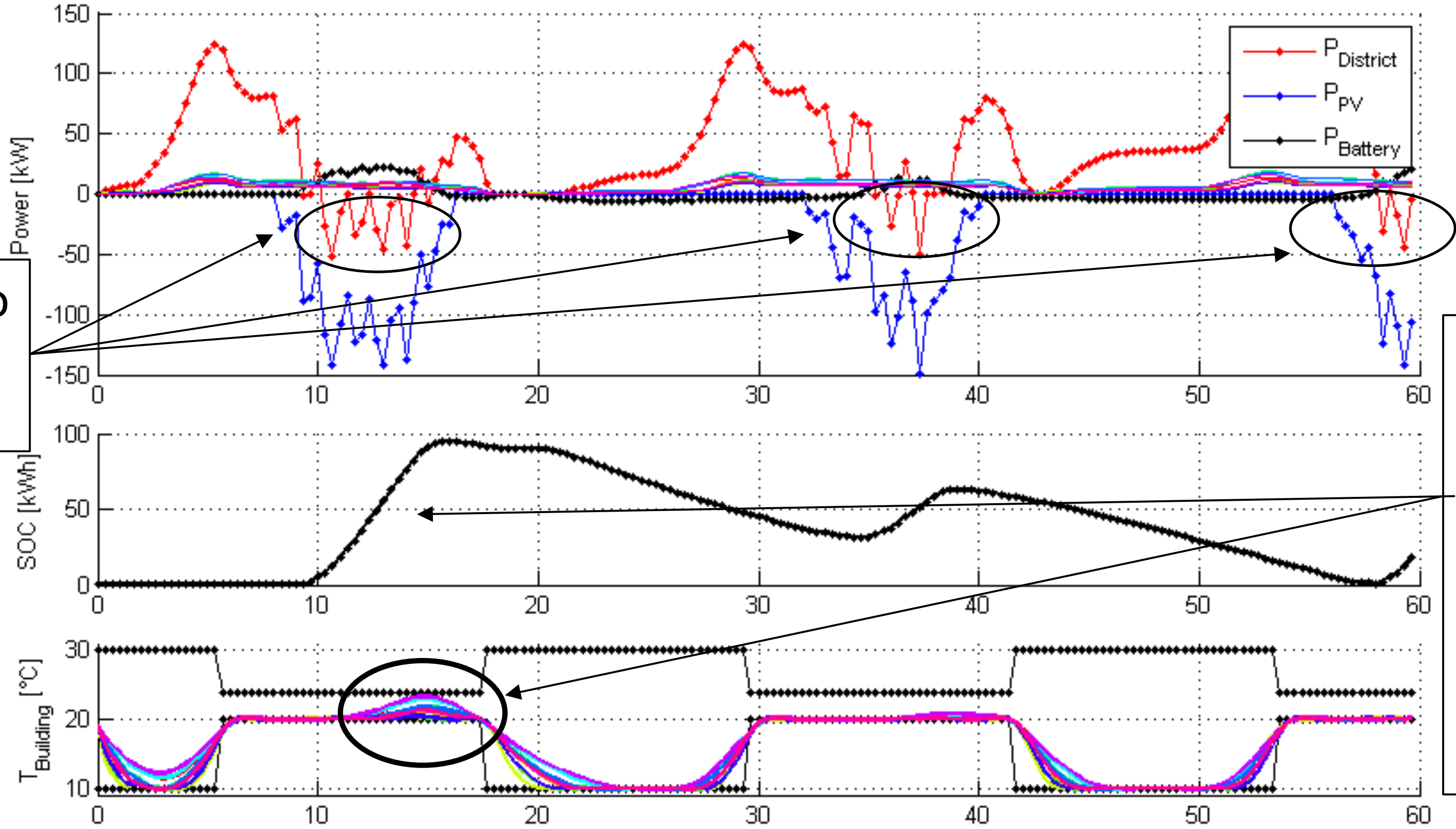
Energy to grid:
155 kWh



Battery & Buildings anticipate to consume locally produced energy

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