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Optimization of flexible electricity loads of a building cluster using distributed model predictive control

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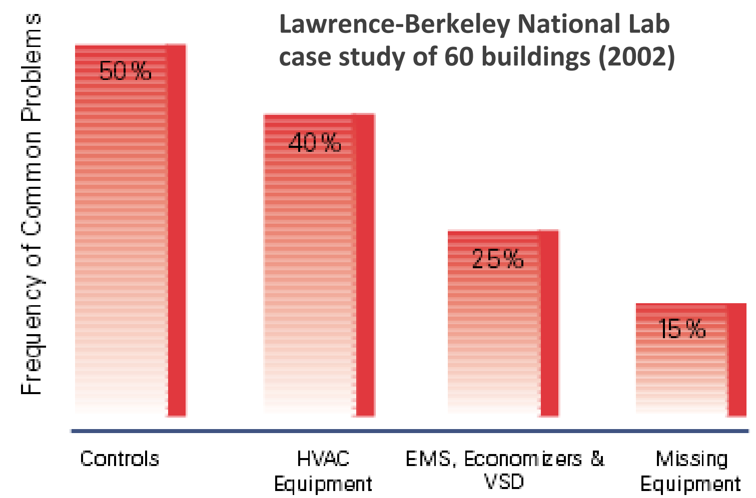
The BATTERIE project - Context

- For tertiary buildings, final electricity consumption ≥ 25% of the energy balance
- Increasing renewable electricity production → need more flexibility of electricity demand
- Possible improvement through better controls.



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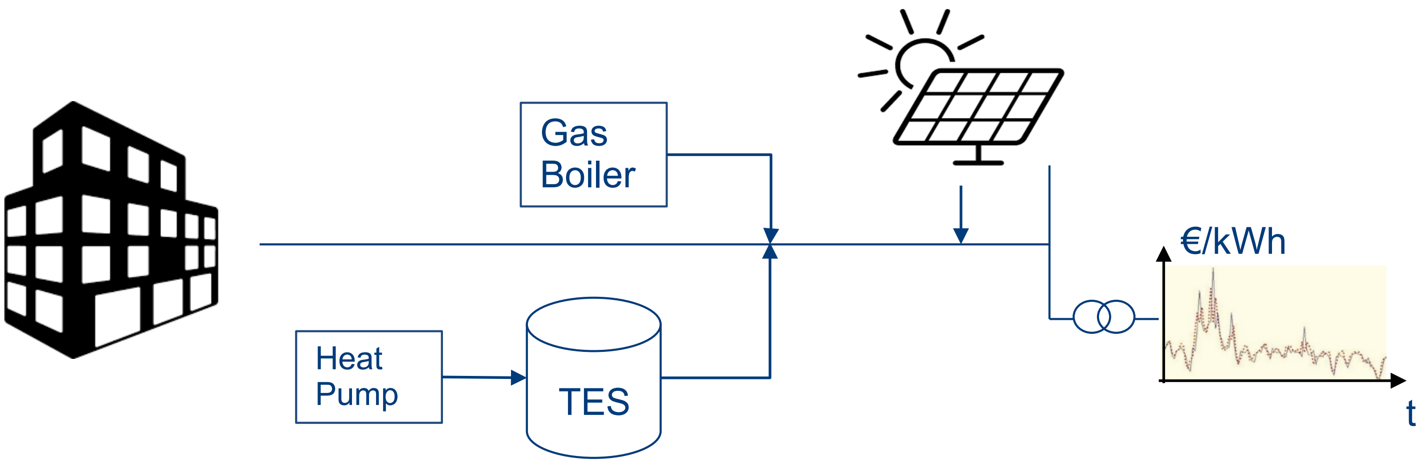
The BATTERIE project - Objective

- “Développement d'une interface pour les BATiments Tertiaires Efficaces intégrés au Réseau Electrique Intelligent”

- Development of an interface for smart control of tertiary buildings:
  - Reduction of building energy consumption through optimal control
  - Improvement of the flexibility of a group of buildings by collaborative control



Multiple objectives
Constraints
Dynamics
Time-varying inputs

Optimal Control

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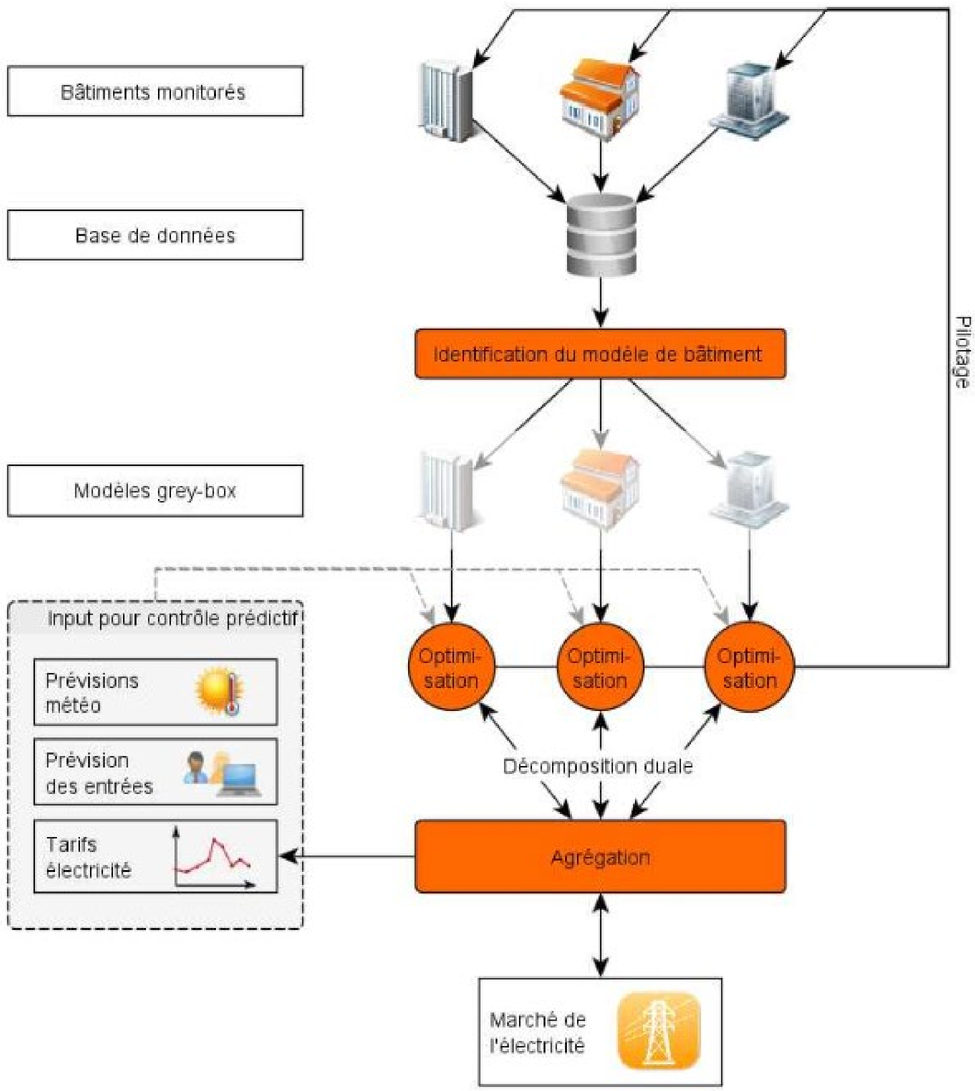

Block diagram of the developed Interface:

- Building monitoring, data mining
- Identification of building model
- Loads forecast and optimization of consumption
- Operation of flexible resources through optimization of HVAC control (MPC)
- Aggregation of flexibility at building stock level

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Study case - description

- **Test case: 4 buildings** with different heating systems and insulation levels: Radiators & K30, Radiators & K45, Floor heating & K30, Floor heating & K45.

- **Objective function**: minimizing thermal discomfort and energy costs for each building.

- **Global constraints**:
  - Scenario 1: Sum of the power of all buildings at each time step cannot exceed a given threshold (5000 W) (to prevent grid congestion when N houses are connected to the same power line).
  - Scenario 2: Minimum shared usage of PV.

- Modeled in **Modelica** and optimized via the **NLP solver IPOPT** (Interior Point OPTimizer).

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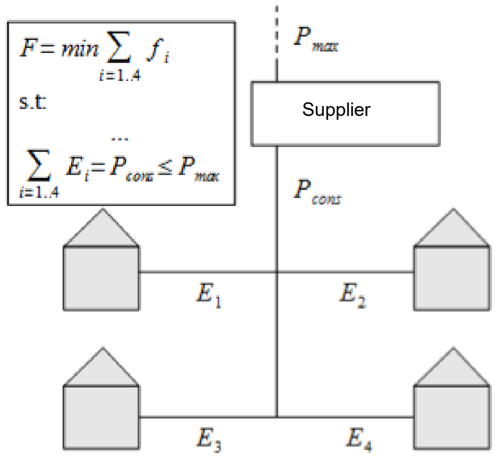
MPC methods

Centralized MPC

Global objective = min of individual objectives

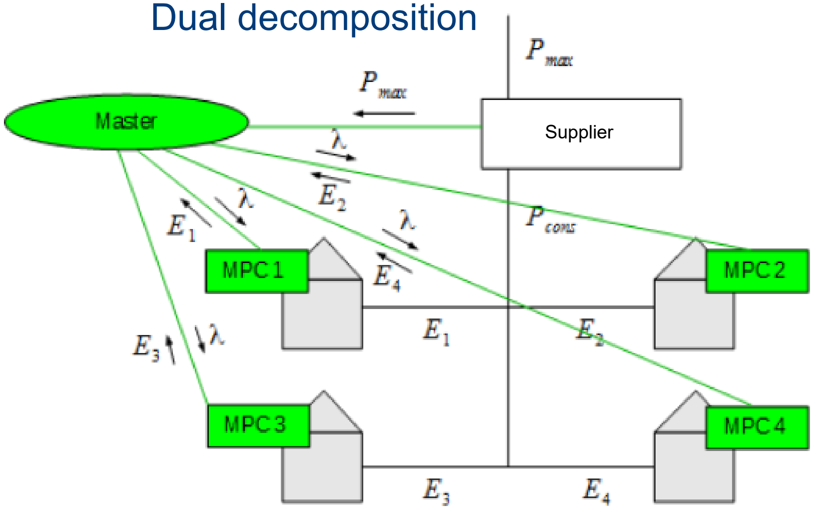
Global constraint



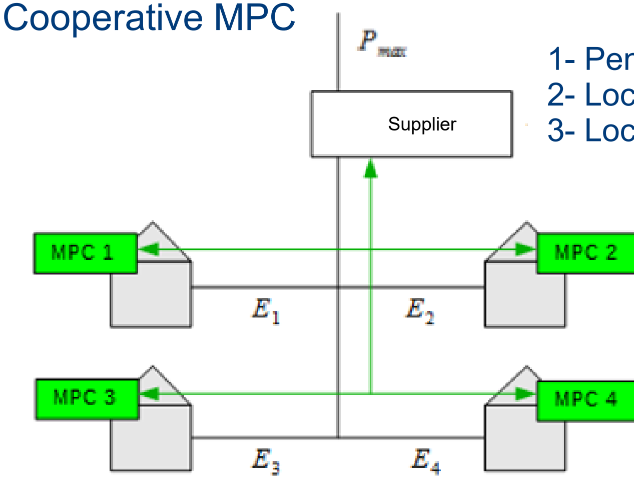
f_i local objective
E_i local energy consumption
λ shadow price for the use of the shared resource
P_{cons} total power consumption
P_{max} maximum load supported by a power grid line

Distributed MPC

Dual decomposition



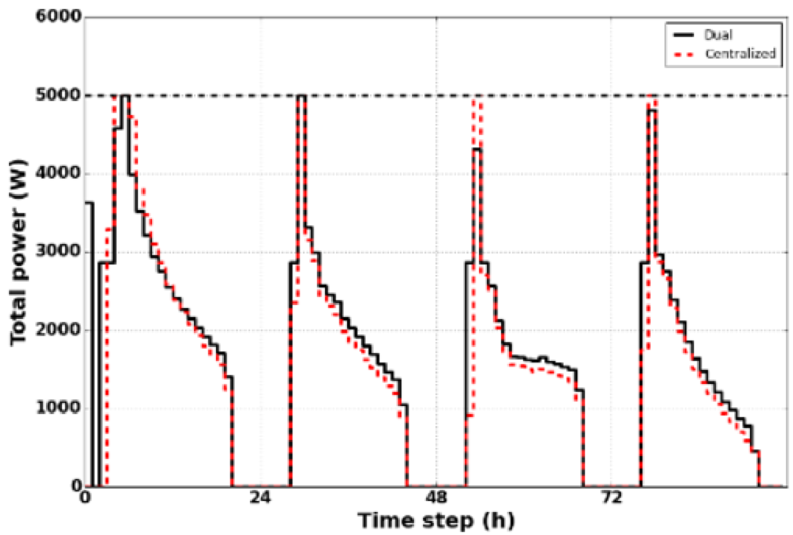
Cooperative MPC

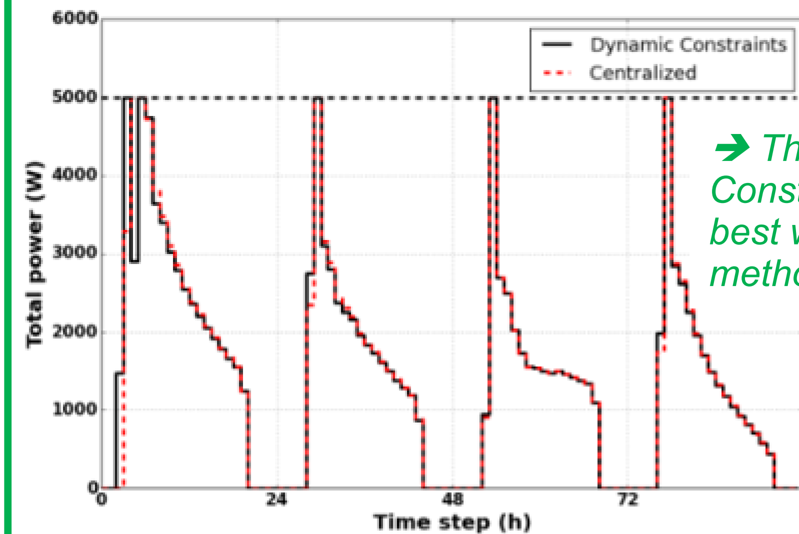


1- Penalty function
2- Local static constraints
3- Local dynamic constraints

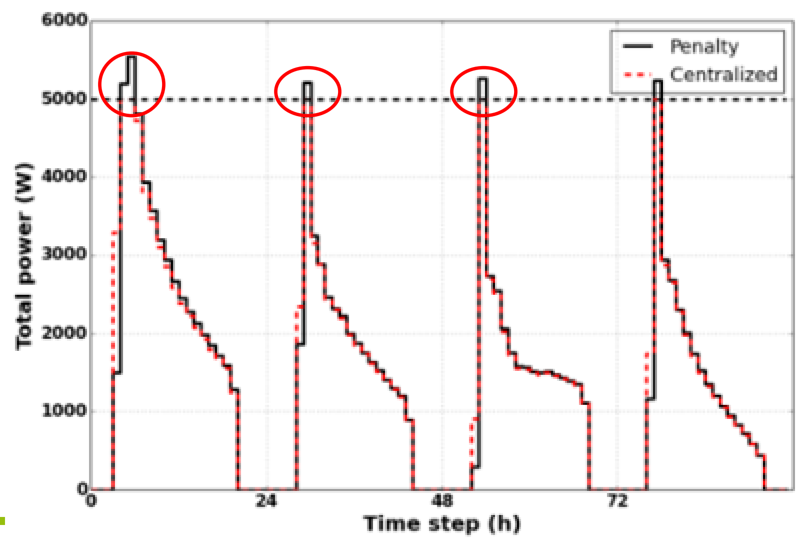
PRO

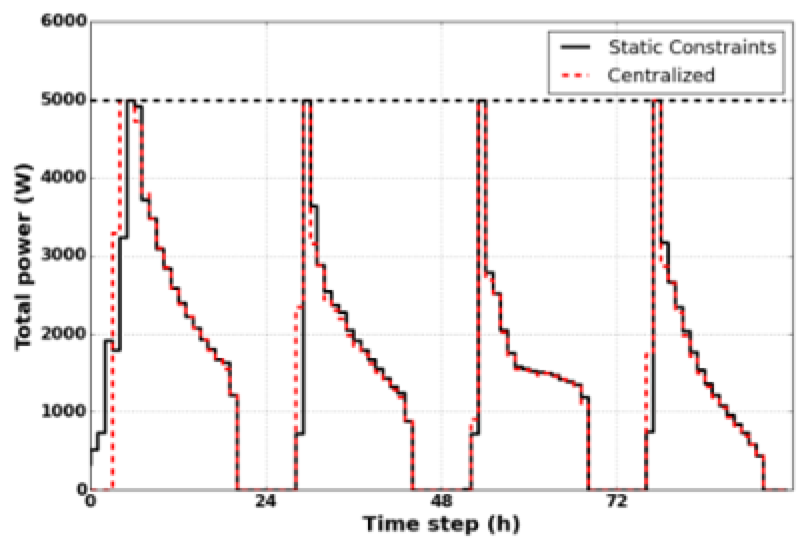
- **Comparison of total power usage**





➔ The Local Dynamic Constraints Method fits best with the centralized method.





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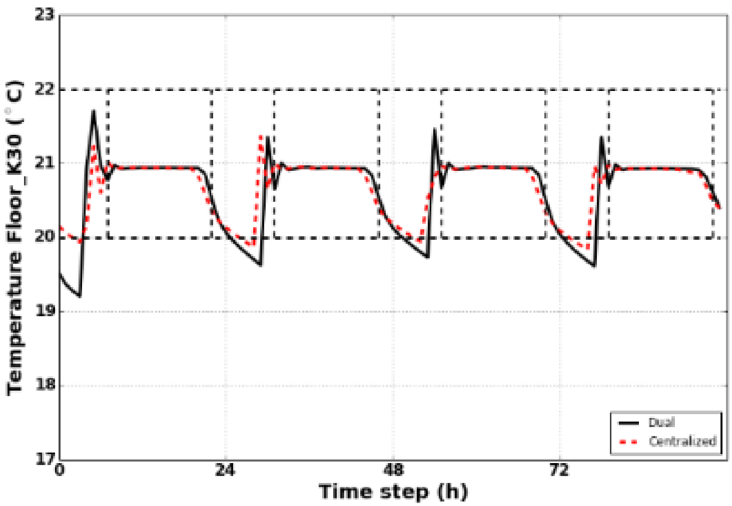
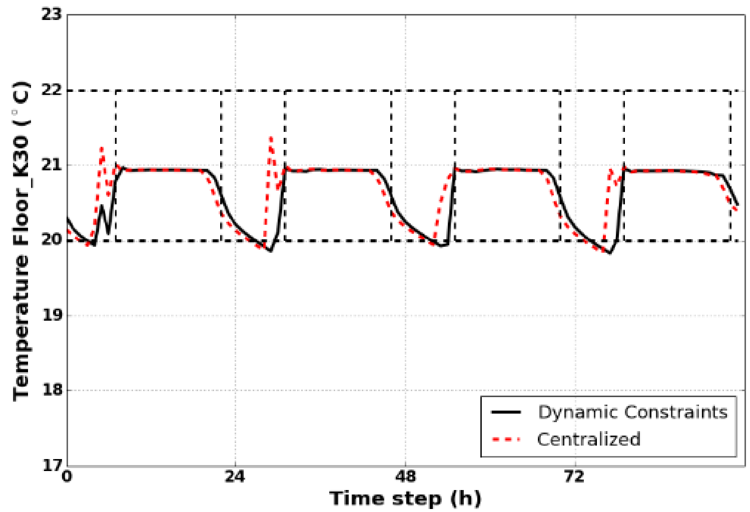
Scenario 1: Results
Centralized vs. Distributed MPC methods

- **Comparison of air zone temperature**





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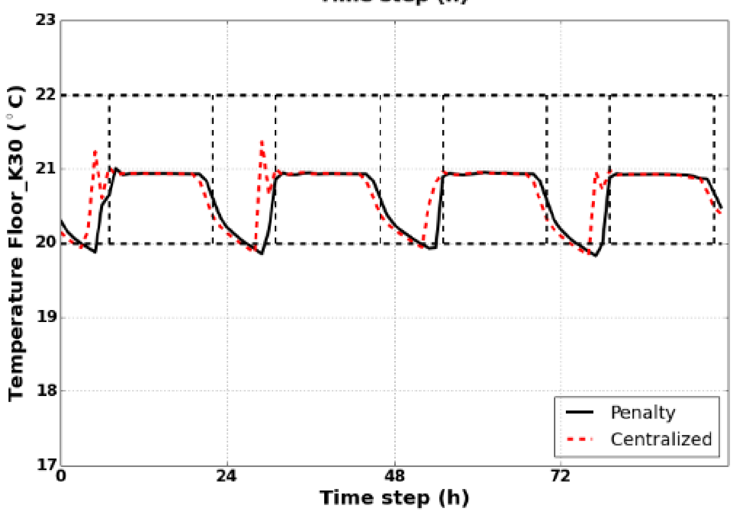

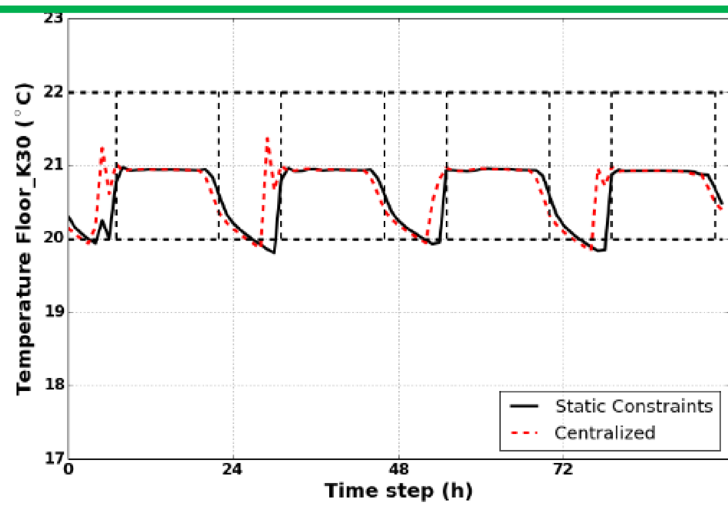

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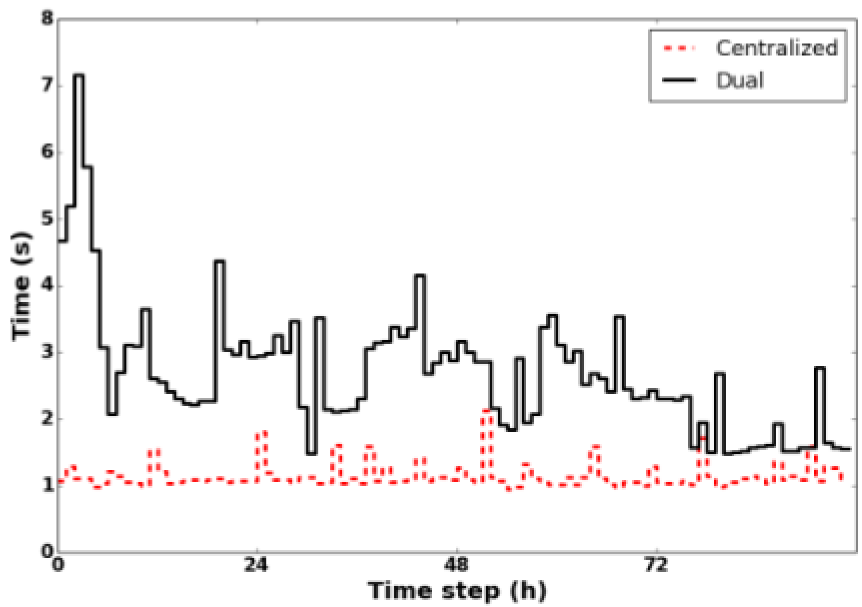
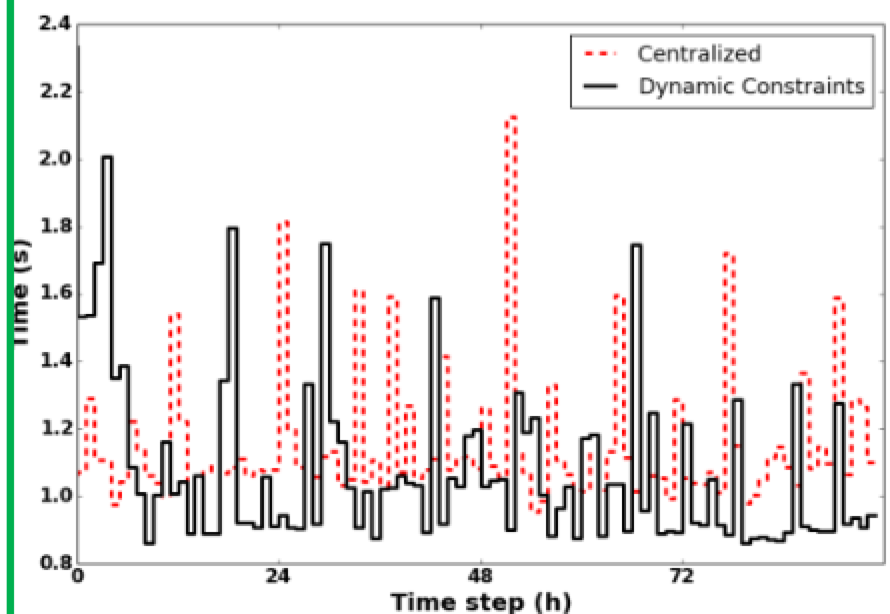
Scenario 1: Results
Centralized vs. Distributed MPC methods

- **Dual decomposition method vs Cooperative MPC (computational time for each time step)**





➔ The Local Dynamic Constraints is faster

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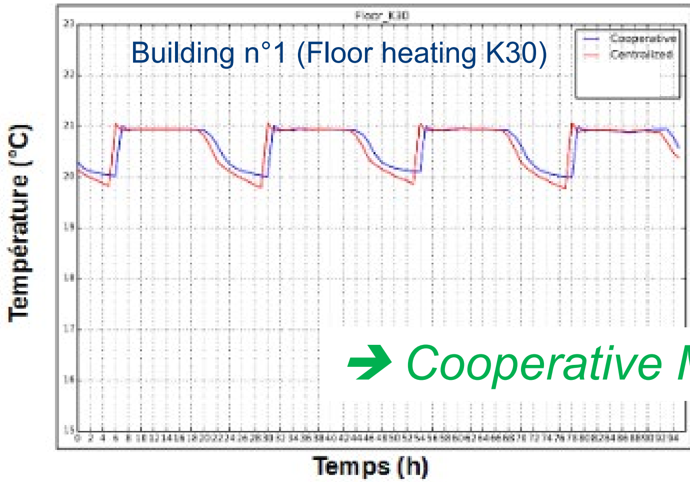
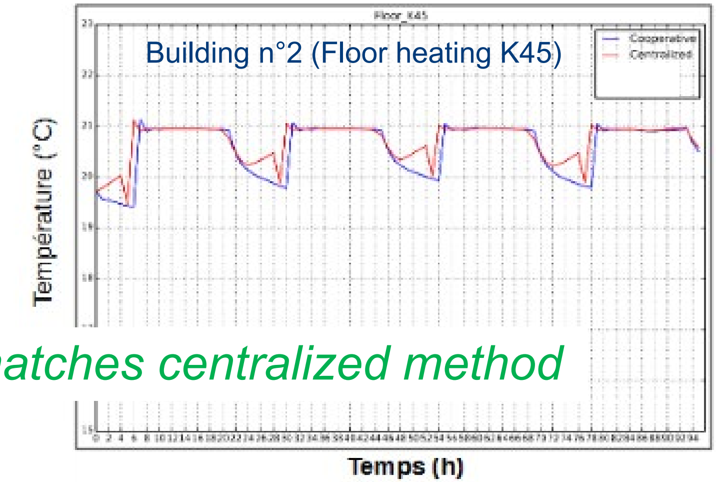
Scenario 2: Results
MPC methods comparison

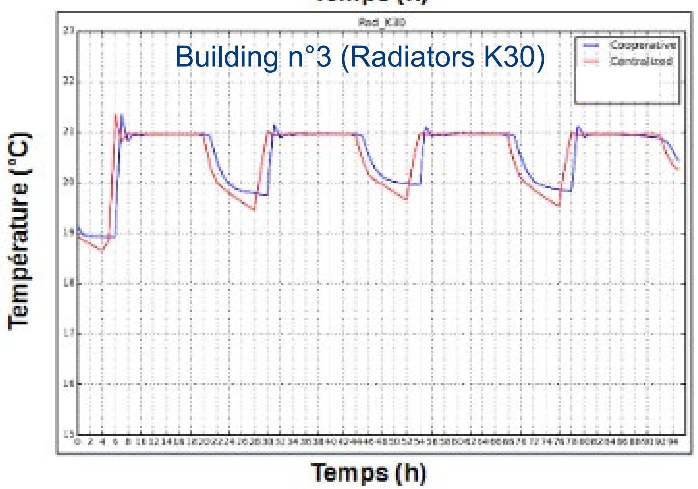
- **4 buildings – minimum shared PV power usage: Temperature profile**

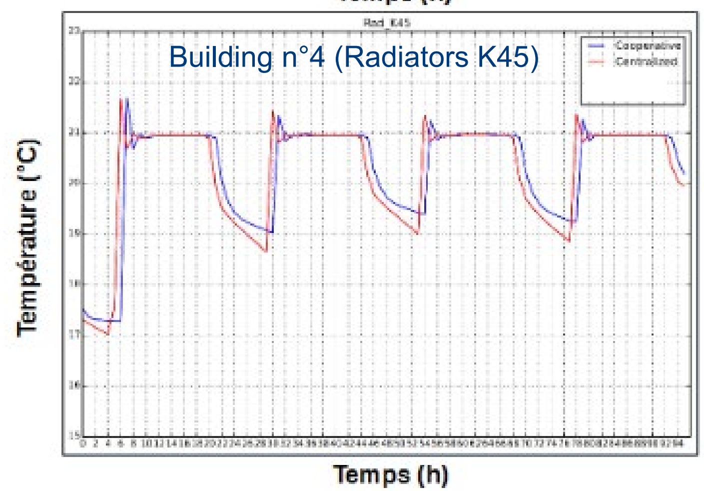
Cooperative
Centralized





➔ Cooperative MPC matches centralized method





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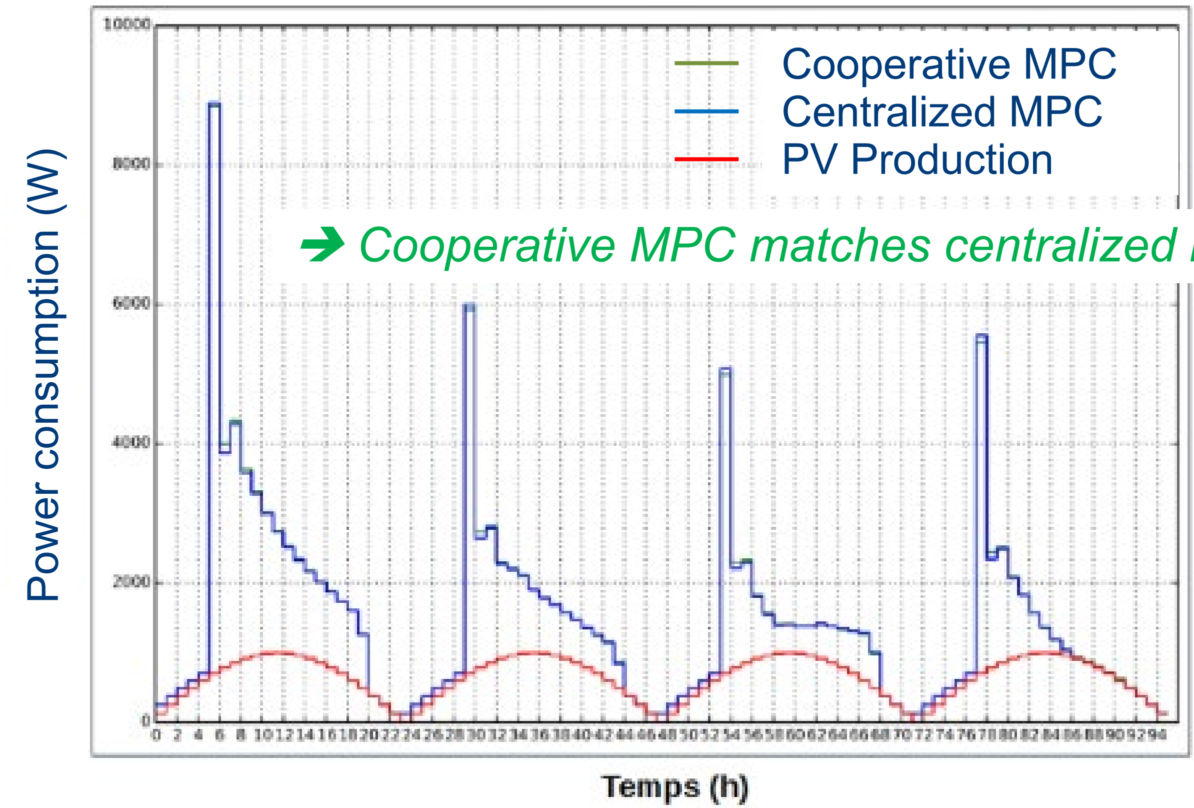
Scenario 2: Results
MPC methods comparison

- **4 buildings – minimum shared PV power usage: total power consumption**



➔ Cooperative MPC matches centralized method

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Conclusions

- The aim of Distributed MPC is to decompose a large optimization problem into smaller, easier to solve and manageable problems, leading to the same optimal solution.
- For this specific test case, the dynamic constraints method performs better than the dual decomposition method (accuracy and computational time).
- Different algorithms were implemented and tested on different use cases
  - The algorithms are robust with respect to global constraints
  - The applied methodology is working well and scalable.

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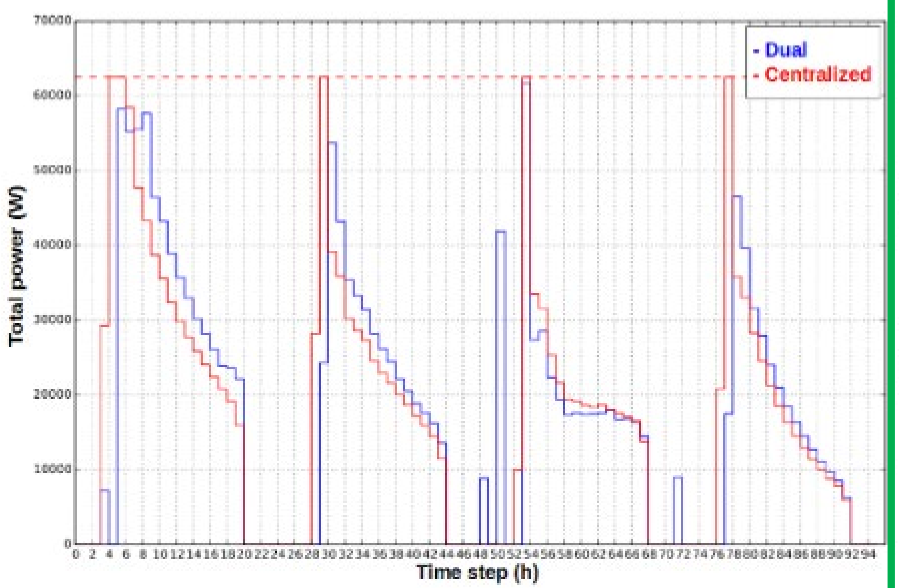
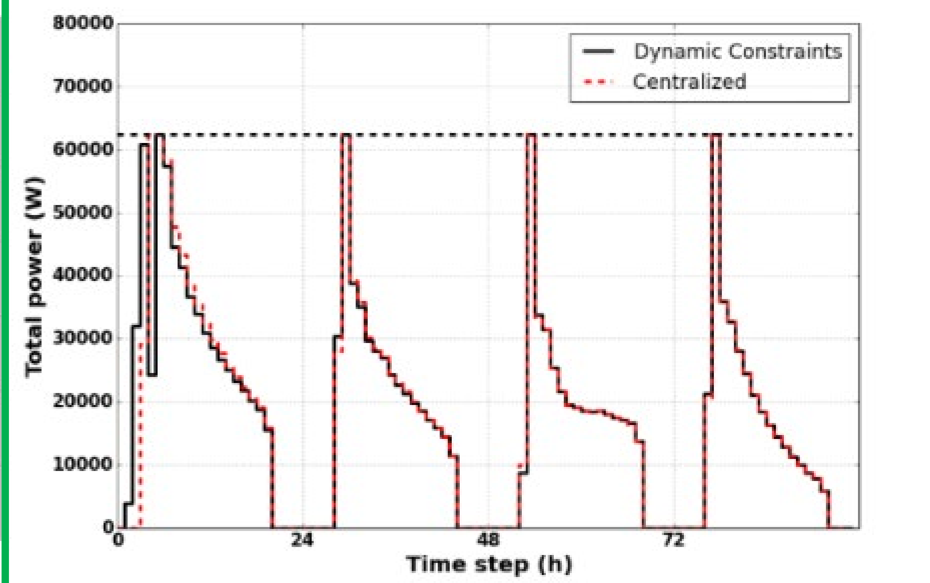
Thank you for your attention!

Scenario 1 (extended to 50 buildings): Results Centralized vs. Distributed MPC methods

- Test case extended to 50 buildings to test the scaling capabilities and robustness of the algorithms.
- Total power consumption of the 50 buildings for Distributed MPC and centralized MPC:





➔ *Cooperative MPC fits the best to the centralized method*

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