DISTRHEAT

Smart Energy Systems ERA-Net

Panel session “Smart district heating networks”

Optimal management of smart district heating networks

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1st December 2021

UNIVERSITÀ DI PARMA

MÄLARDALEN UNIVERSITY SWEDEN

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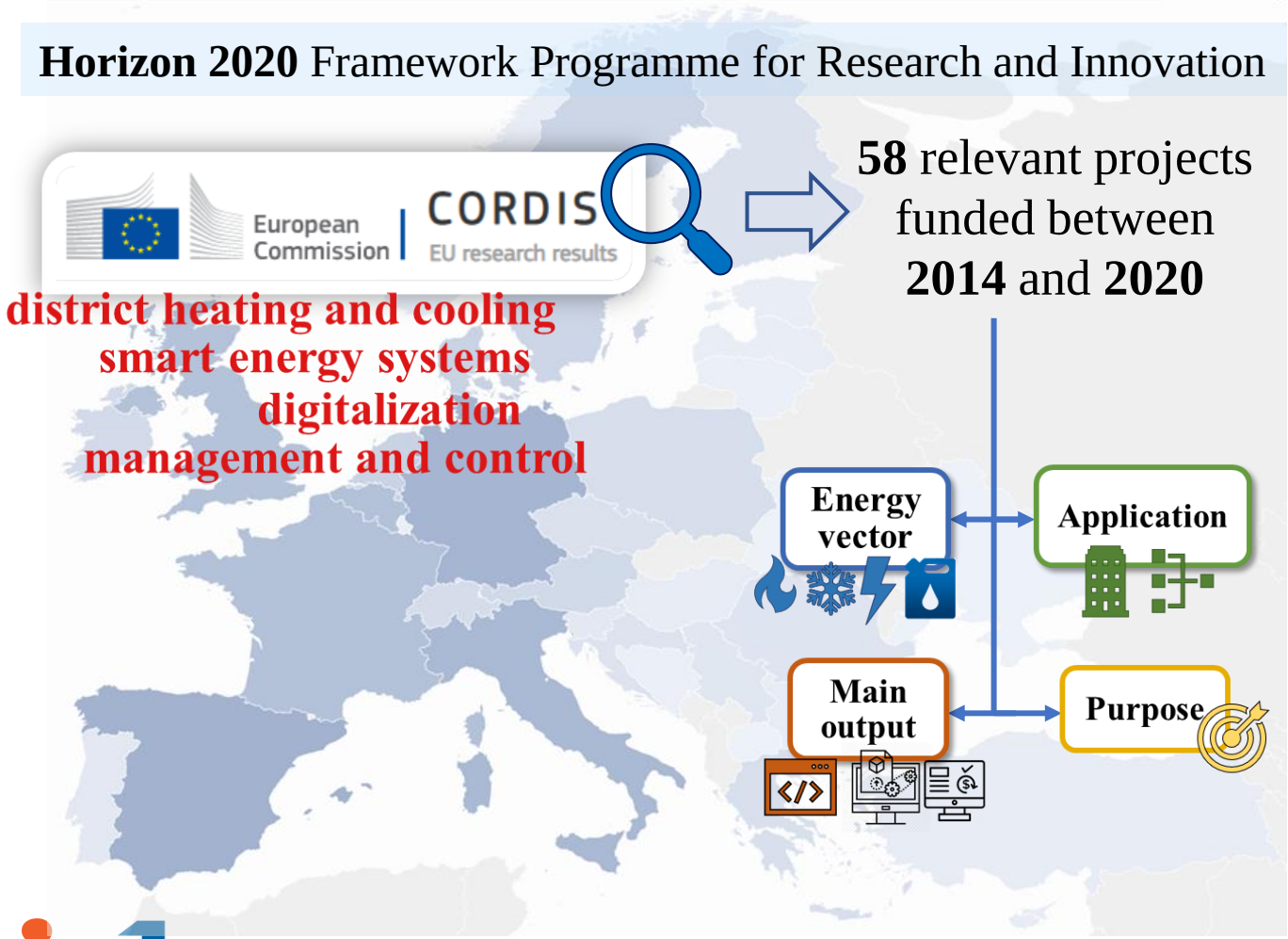
FIRST CONTROL

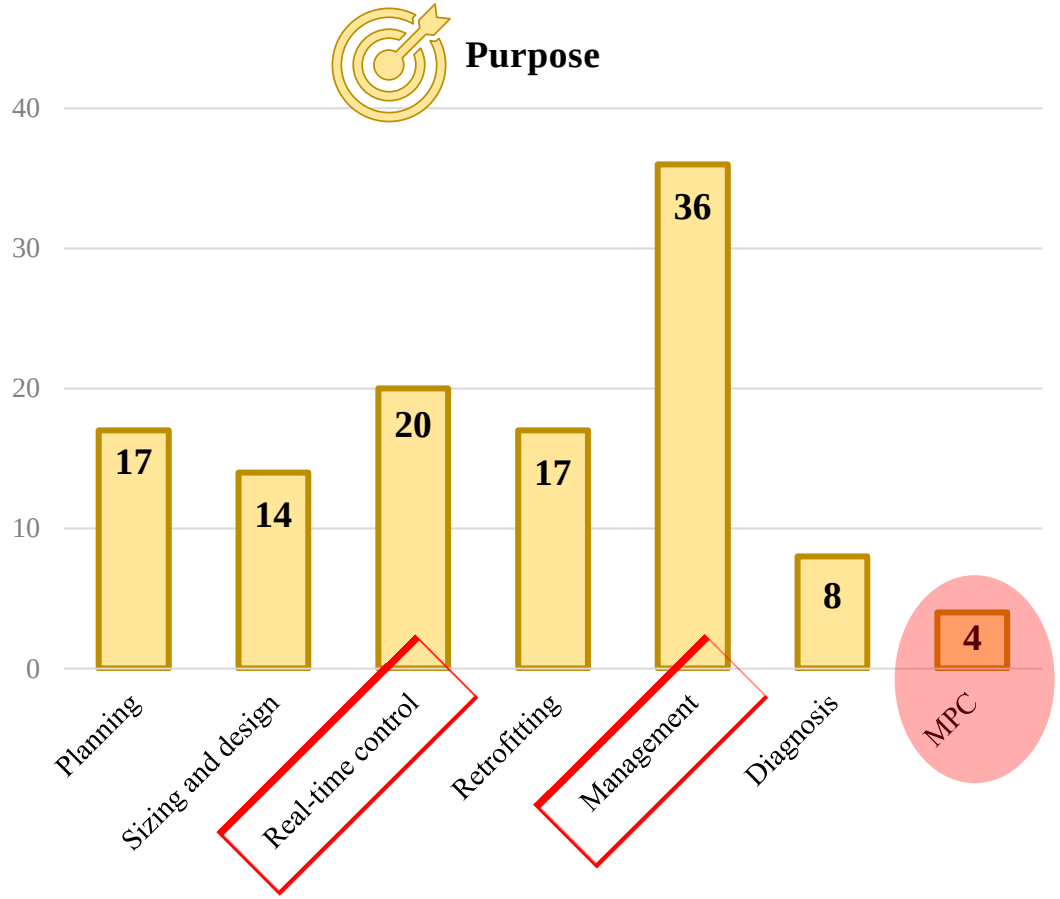
This project has received funding in the framework of the joint programming initiative ERA-Net Smart Energy Systems’ focus initiative Integrated, Regional Energy Systems, with support from the European Union’s Horizon 2020 research and innovation programme under grant agreement No 775970.

Performing a state-of-the-art review of H2020 projects on district heating networks as smart energy systems we found 58 projects



https://doi.org/10.3390/en13112835

Network management has been recognized as a hot topic, as was for real-time control, but only 4 projects dealt with predictive controllers



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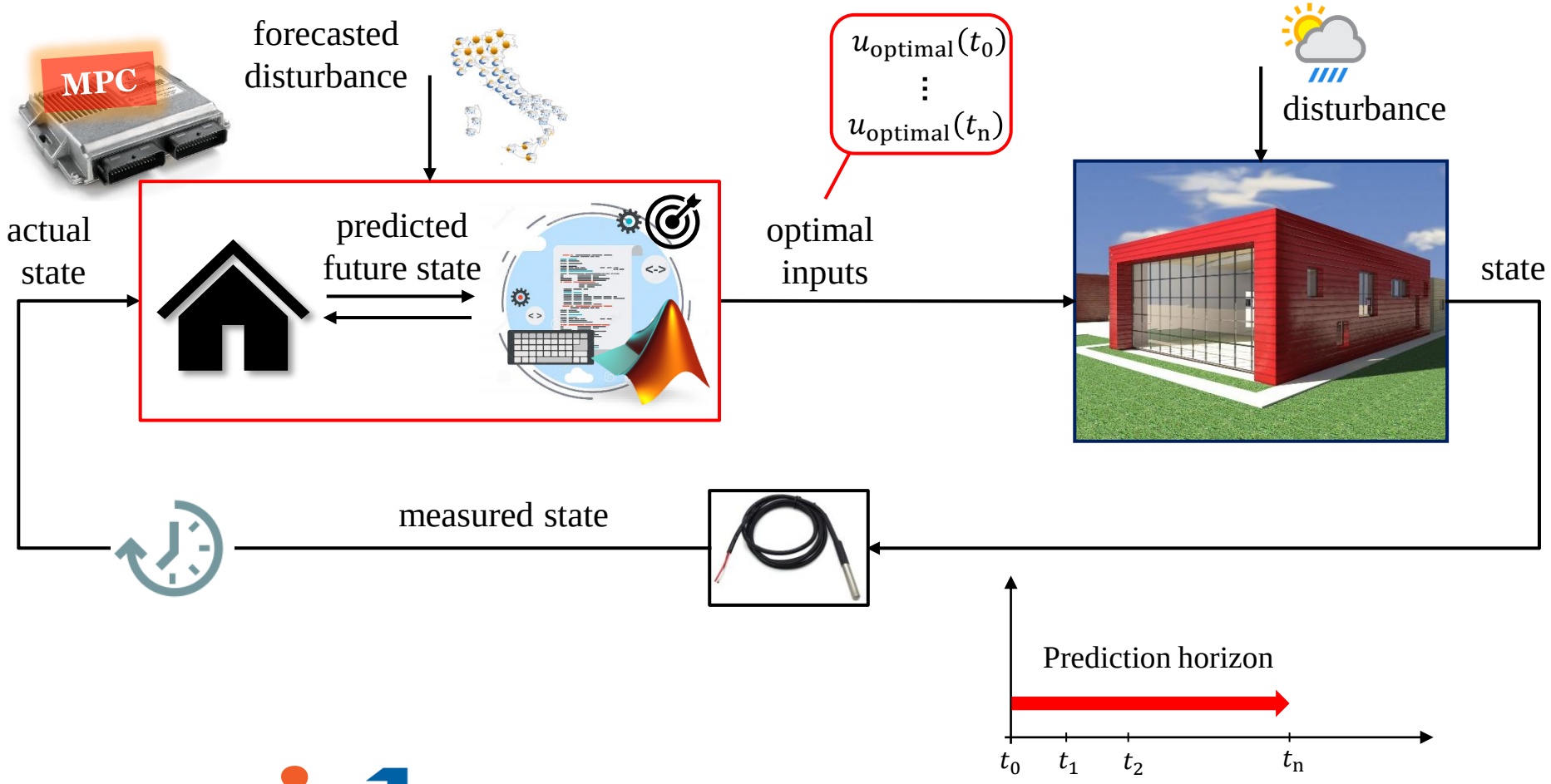
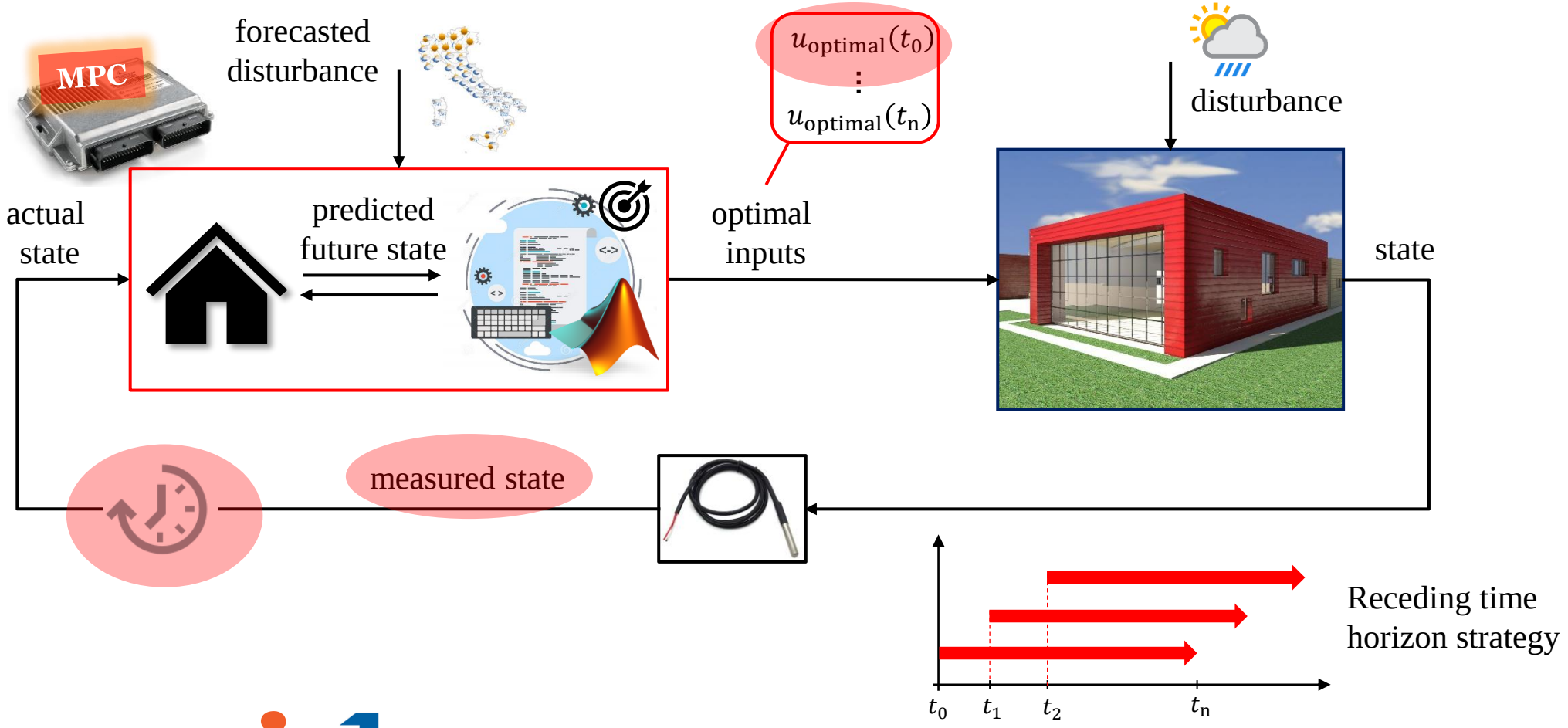
MPC uses a model to predict the future behavior of the system and calculates the control sequence through an optimization algorithm

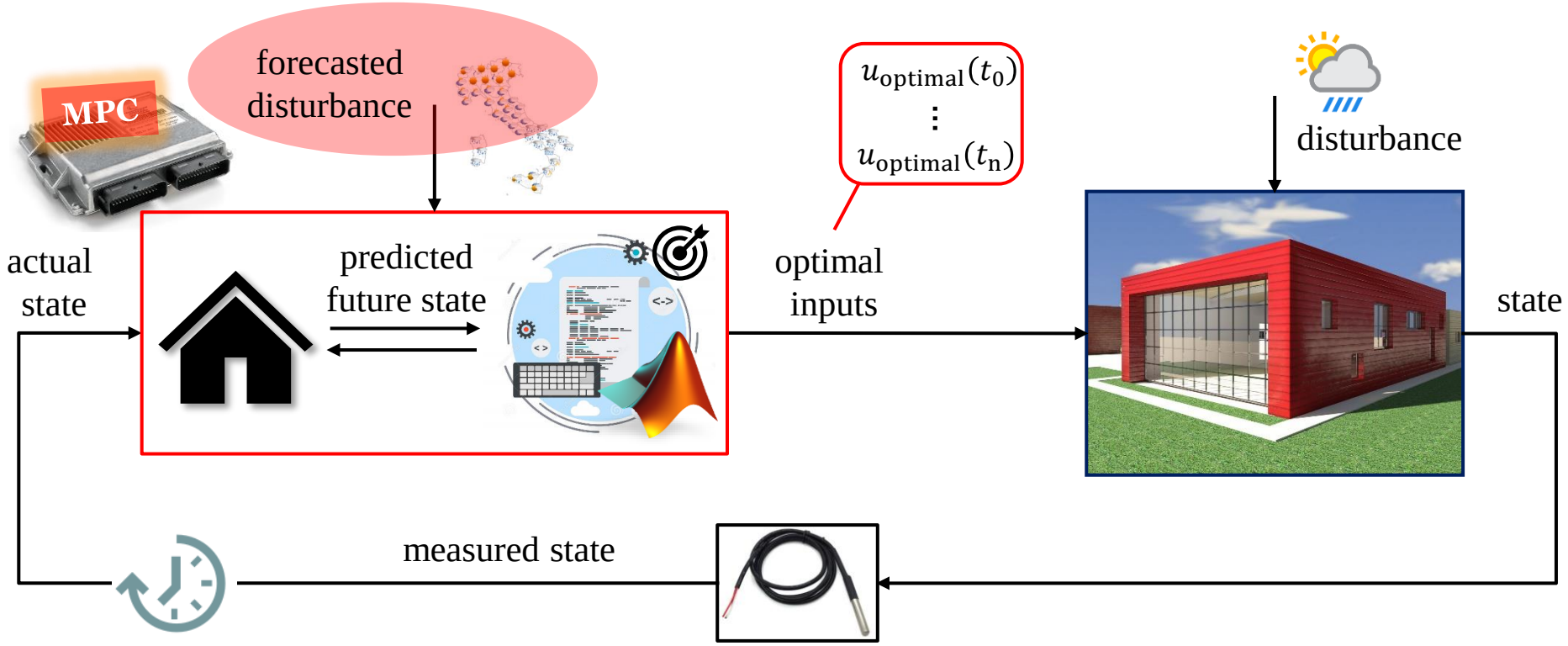


https://doi.org/10.1016/j.applthermaleng.2019.114558

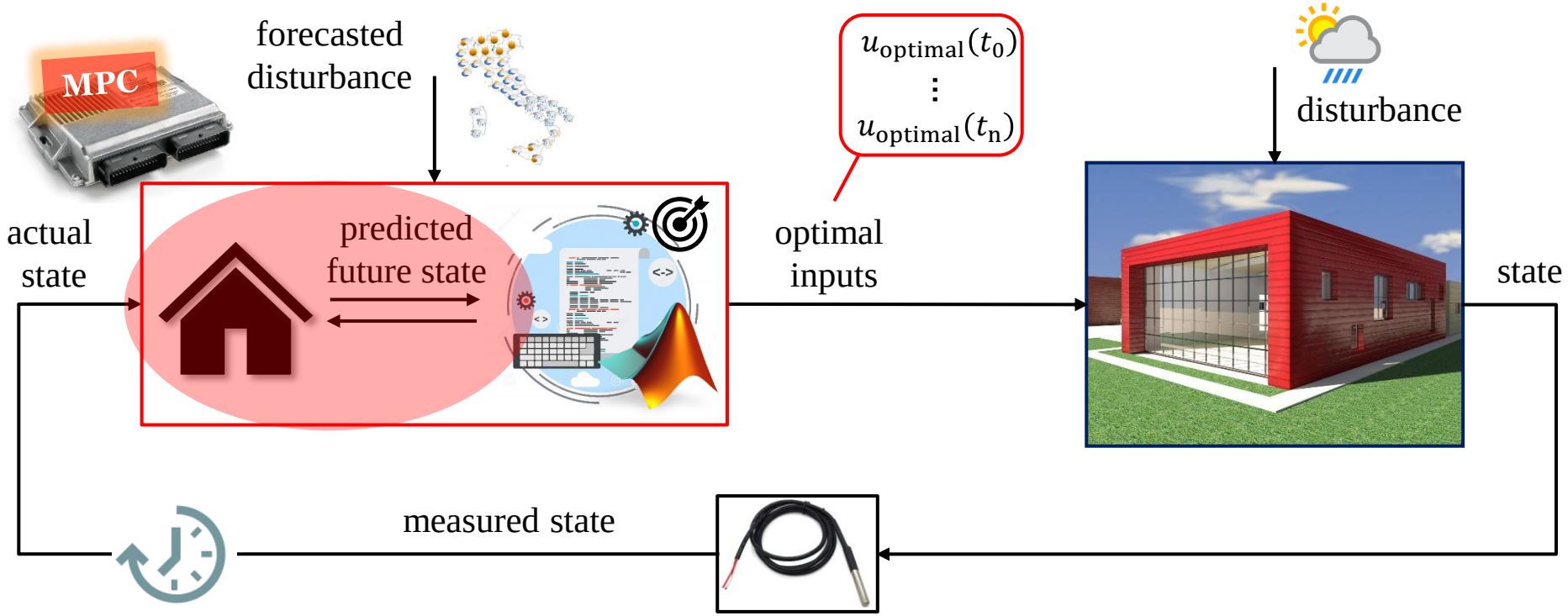
It applies the first step of the sequence, moves one timestep forward, updates its knowledge and restarts the procedure with a new horizon



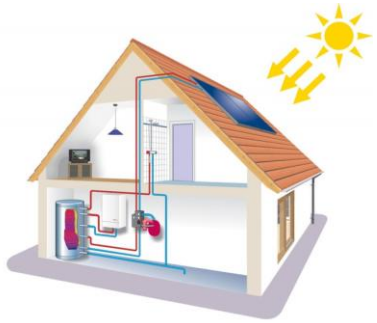
The success of this strategy relies on the “quality” of the forecast of the disturbances…

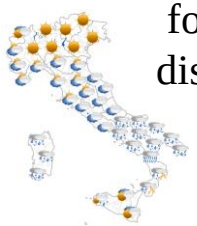


… and of the model, that on the other side must be as light as possible to be called many times by the optimization algorithm



A building can be represented with a simple RC-model that consider heat supplied, exchanged through walls and natural and forced ventilation





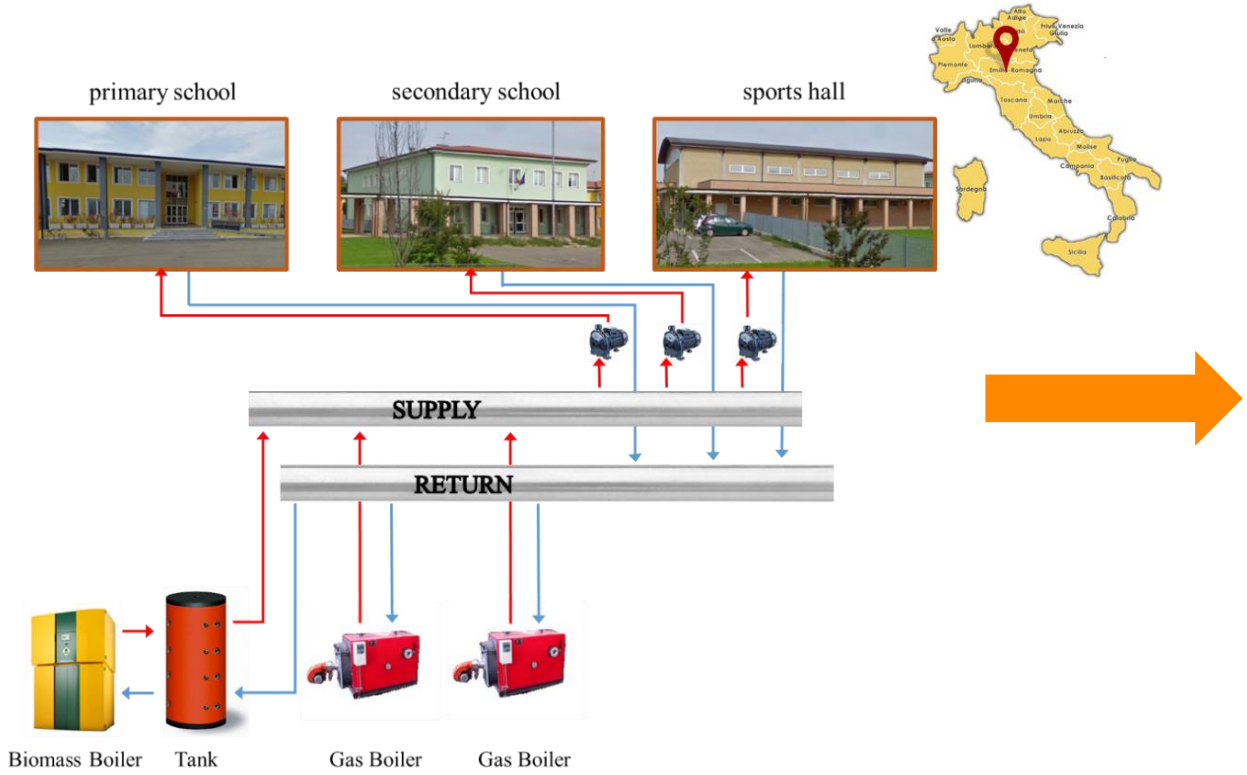
forecasted disturbance

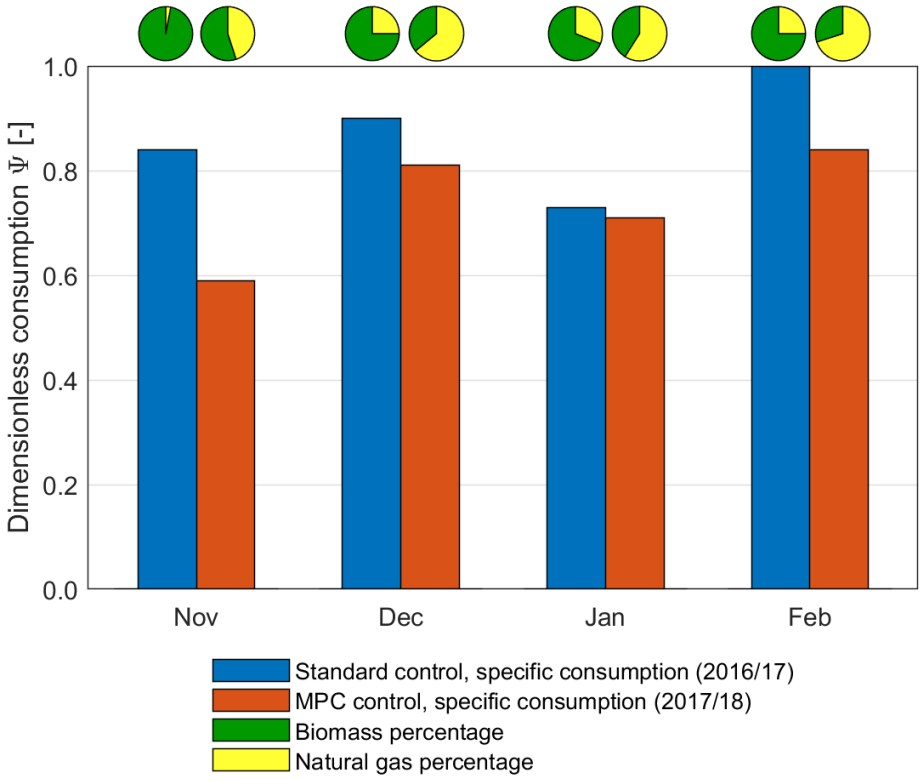
input

$$\frac{\Delta T_{\mathrm{b}}}{\Delta t} = -a\,(T_{\mathrm{b}} - T_{\mathrm{out}}) + b\,\dot{Q} - c\,(T_{\mathrm{b}} - T_{\mathrm{out}}) - d(T_{\mathrm{b}} - T_{\mathrm{air}})$$

https://doi.org/10.1016/j.energy.2020.118054

The application of MPC to the Podenzano heat distribution systems led to an average reduction of 13 % in energy consumption





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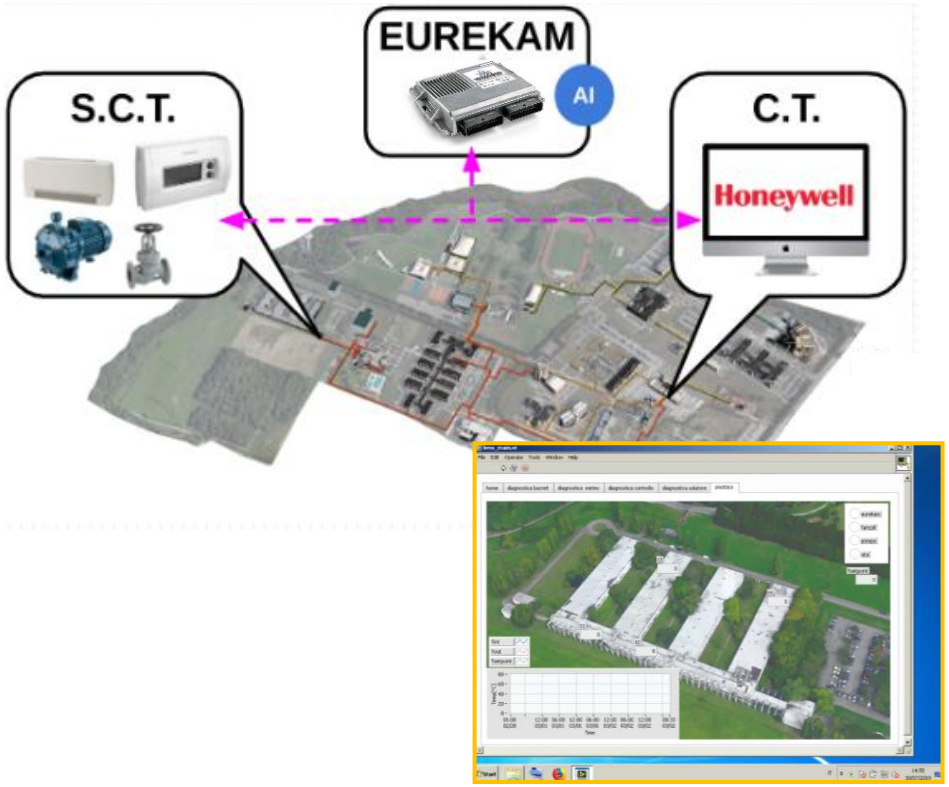
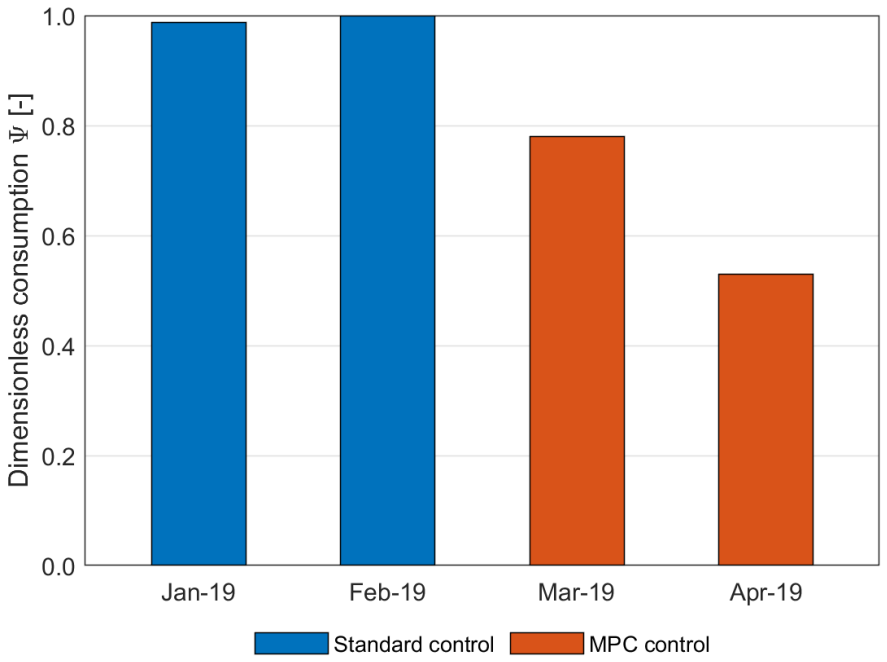
A second test on a branch of the network of our Campus in Parma showed a 34 % reduction and now this MPC is a product





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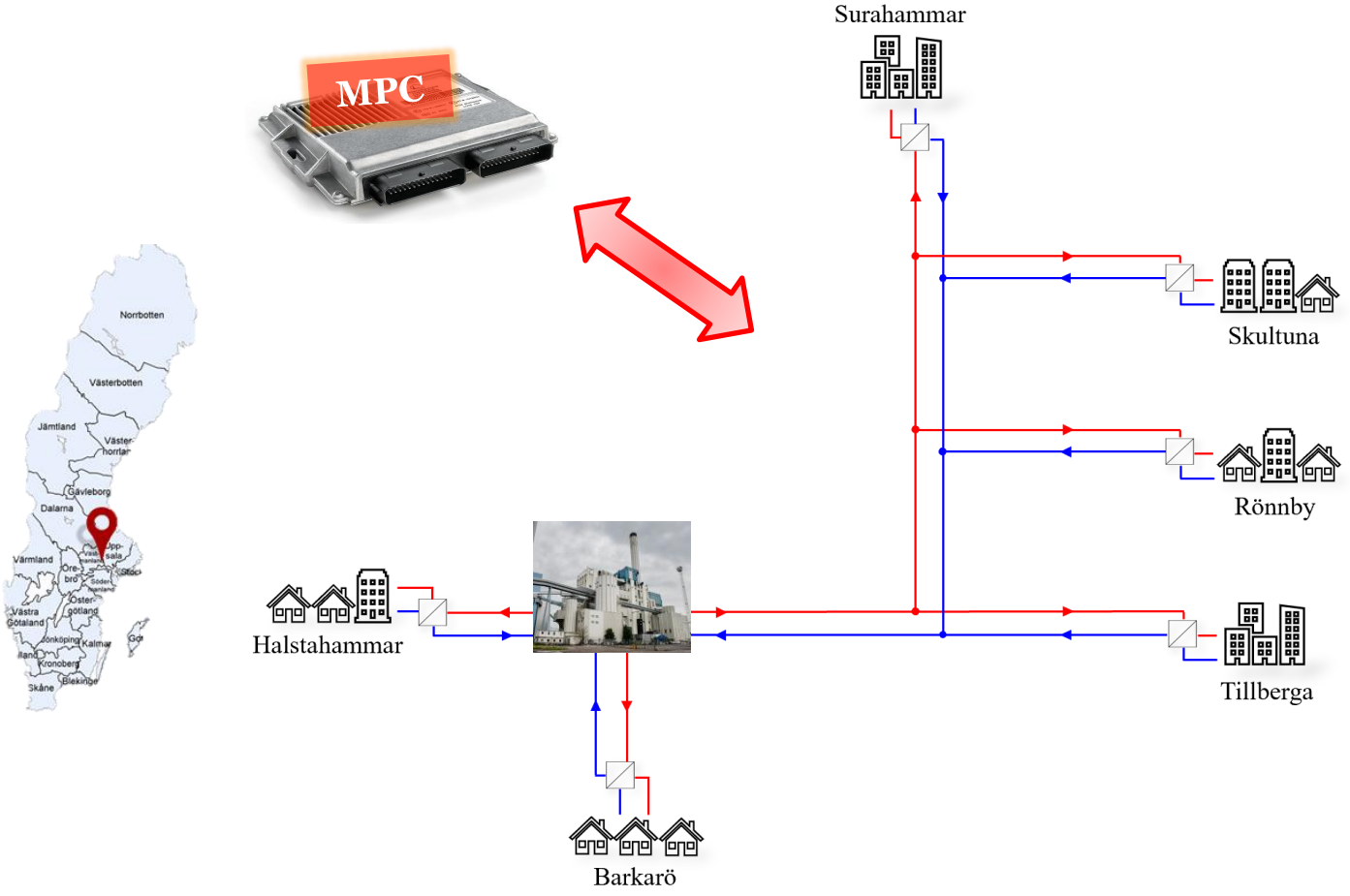
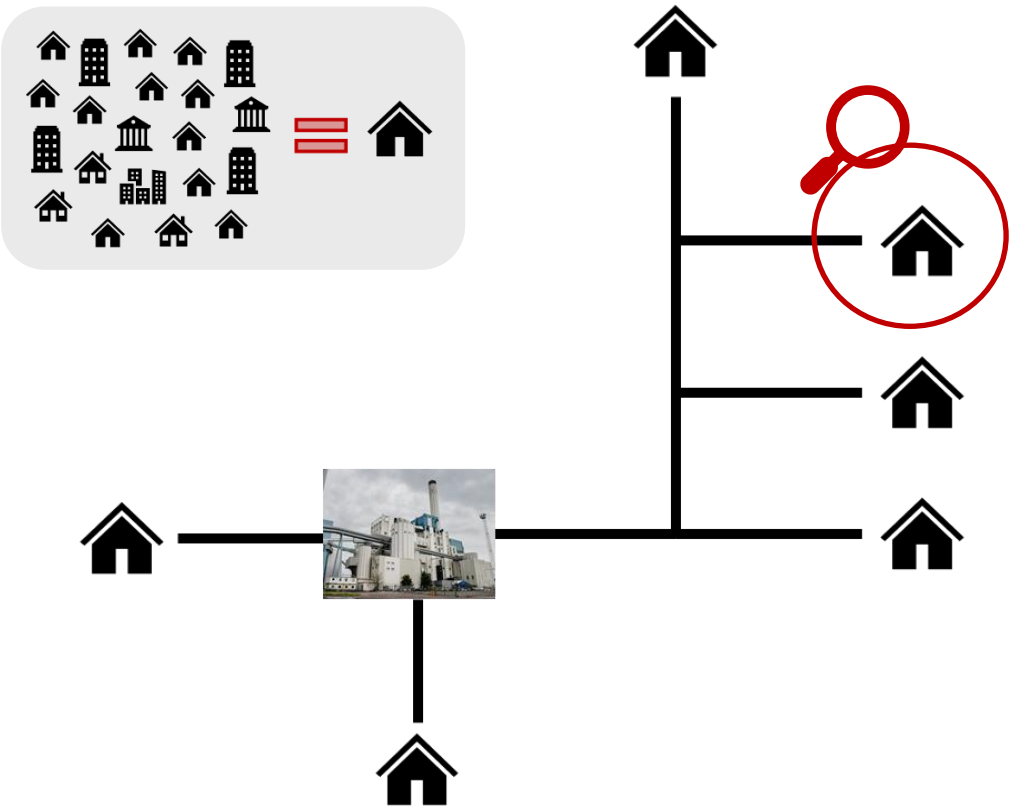
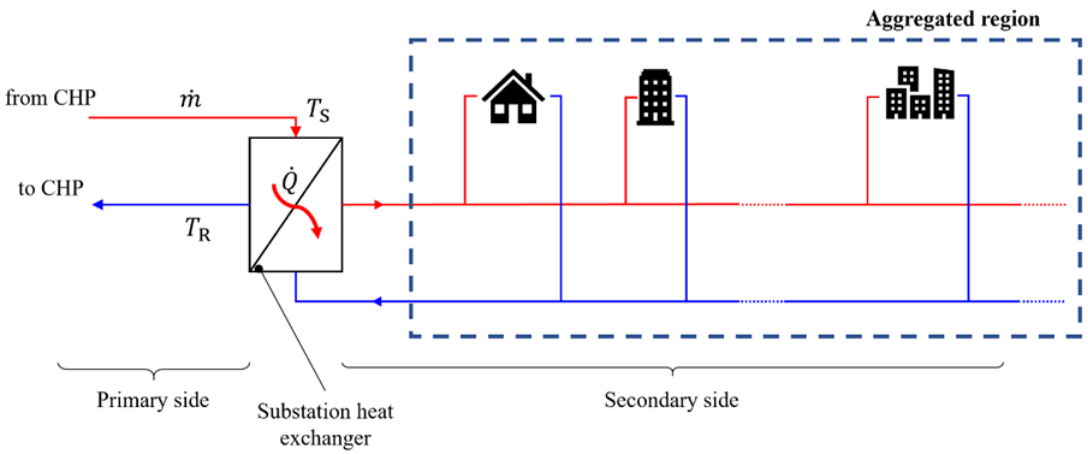
The approach can be scaled up to a city level: we evaluate it with the Västerås (Sweden) district heating network



https://doi.org/10.1016/j.applthermaleng.2021.117681

In this case we consider each neighborhood as an aggregated consumer with equivalent properties





$$\dot{Q} = \dot{m}\, c\, (T_S - T_R)$$

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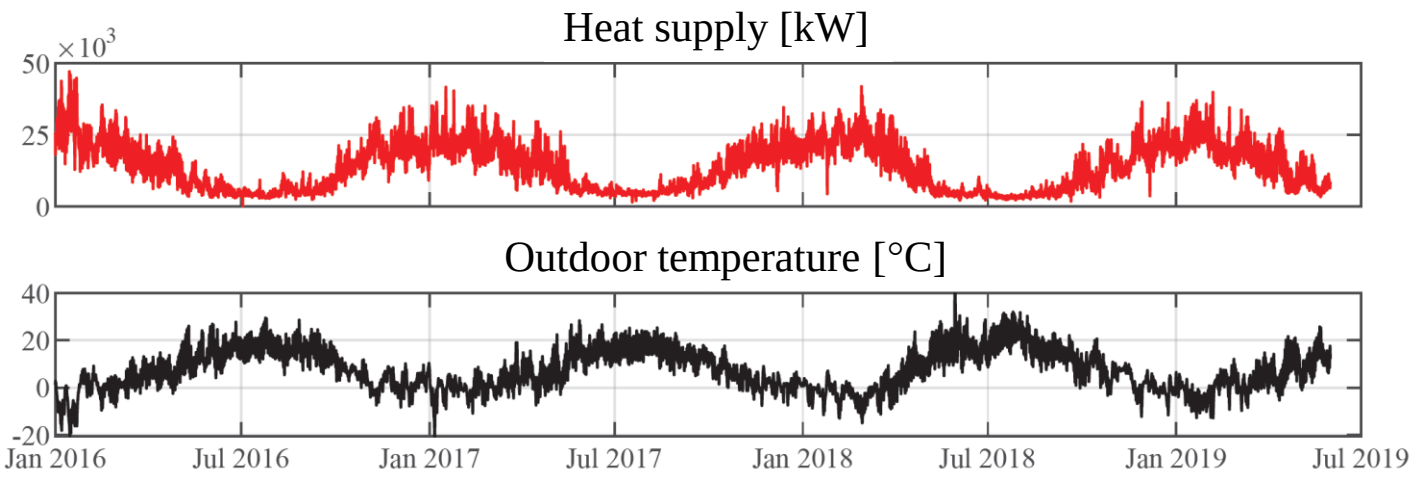
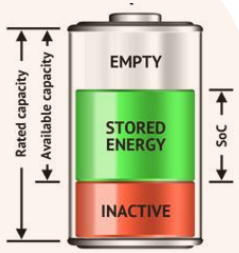
Model parameters for aggregated capacity and heat transfer can be identified starting from the historical data



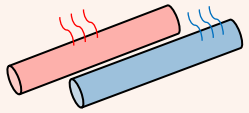
$$\frac{\Delta T}{\Delta t} = \underbrace{-\frac{U}{C}(T - T_{\text{outdoor}})}_{\text{heat loss}} + \underbrace{\frac{1}{C}\dot{Q}}_{\text{heat supply}}$$

- Exploit **heat capacity** of connected end-users as **thermal storage**



- Achieve thermal **peak shaving**

- Reduce **distribution temperature**



https://doi.org/10.1016/j.apenergy.2020.116286

MPC can be applied also to the production side of a district heating network: we are testing it on the Cona Hospital in the North of Italy

Goals

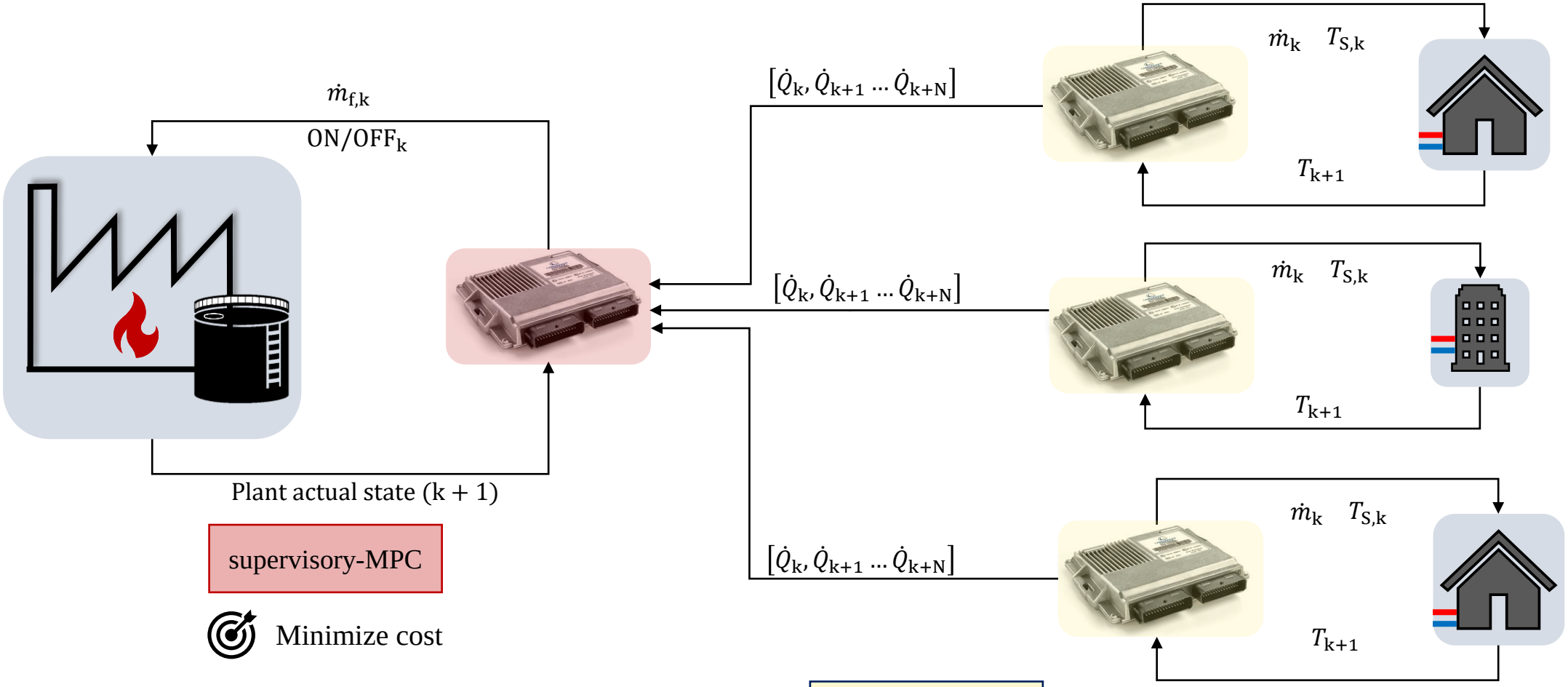
- Optimize both **energy distribution** and thermal station **management**
- Include **short-term** (daily) and **long-term** (yearly) factors and objectives

Application

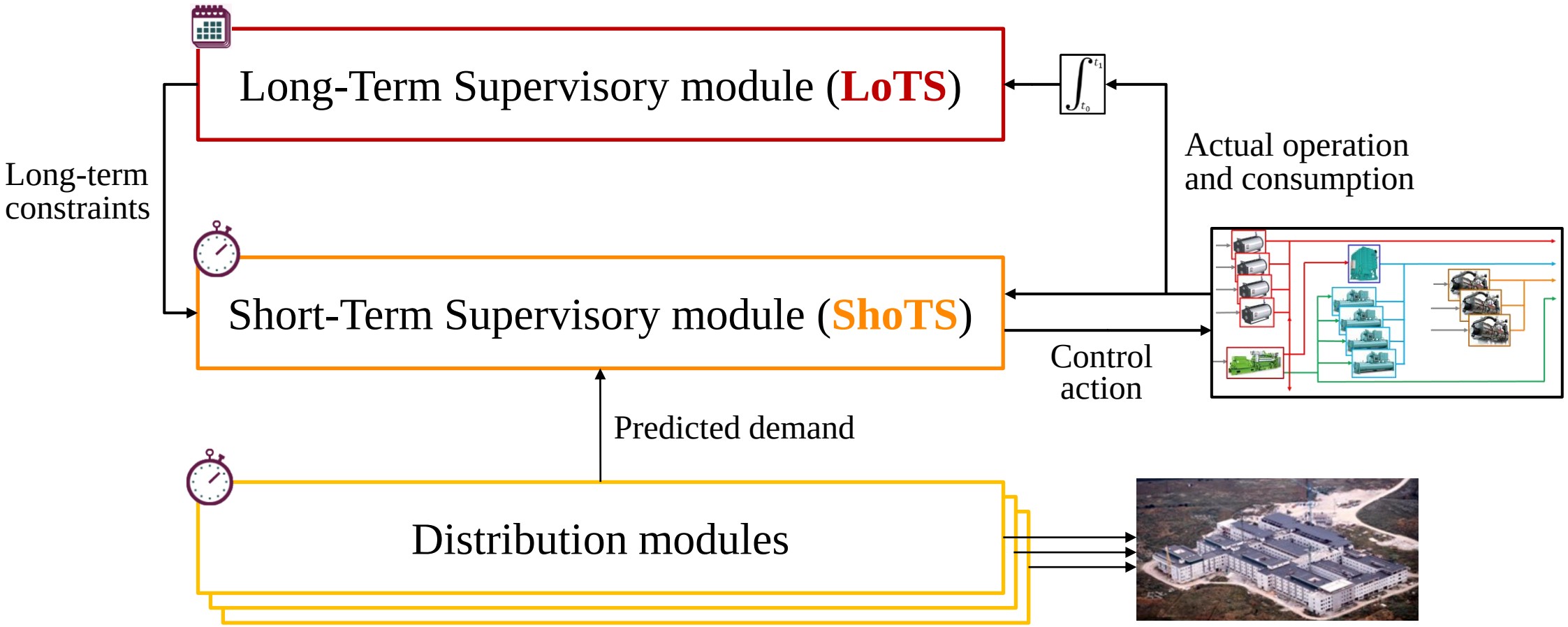
Cona Hospital

- Small-scale district heating and cooling
- Multi-energy conversion system

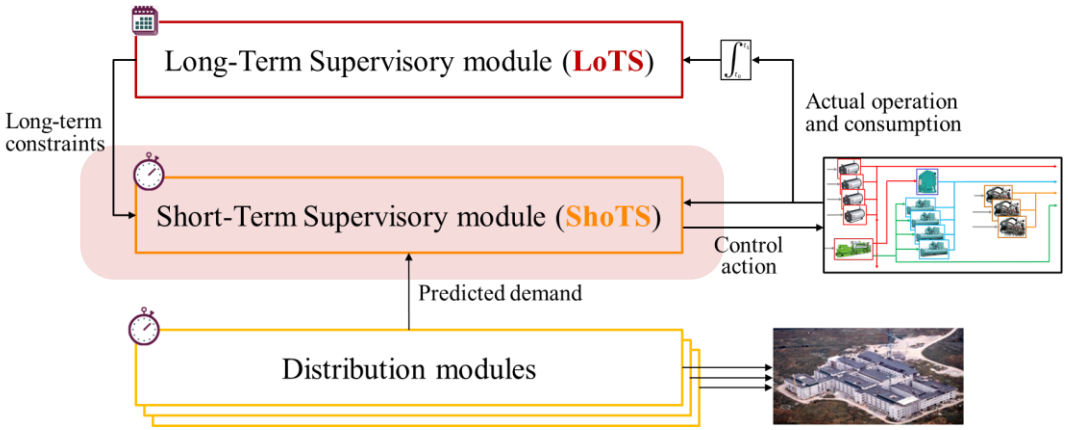
The structure is hierarchical multi-agent: several distribution-MPC manage the branches and define the forecast of the demand for the plant

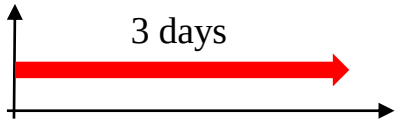


The supervisory-MPC operates on a double time-scale and defines the optimal management of the production plant



ShoTS module finds the optimal short-term operation of the plants by solving a high-detail unit commitment problem





Constraints

- Meet demand of all energy vectors
- Plant boundaries
- Operation ramps
- Minimum up-time and down-time
- Meet long-term constraints from **LoTS**

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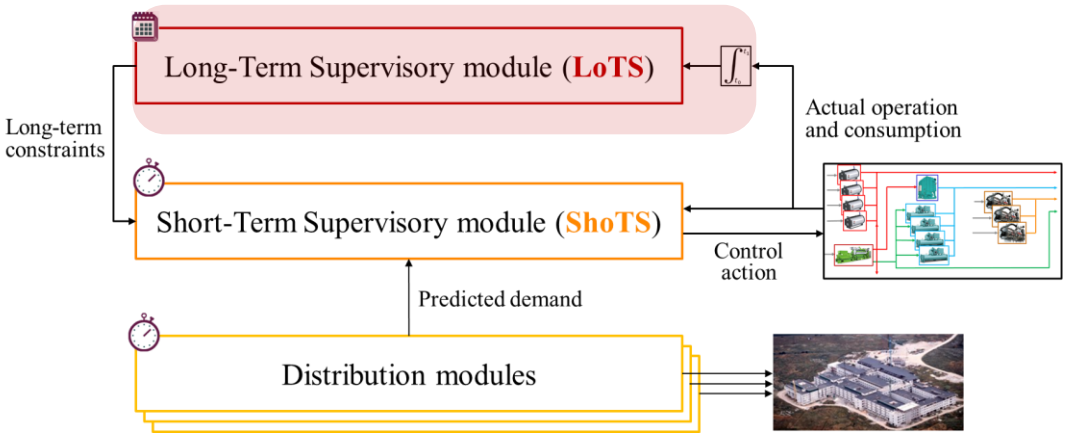
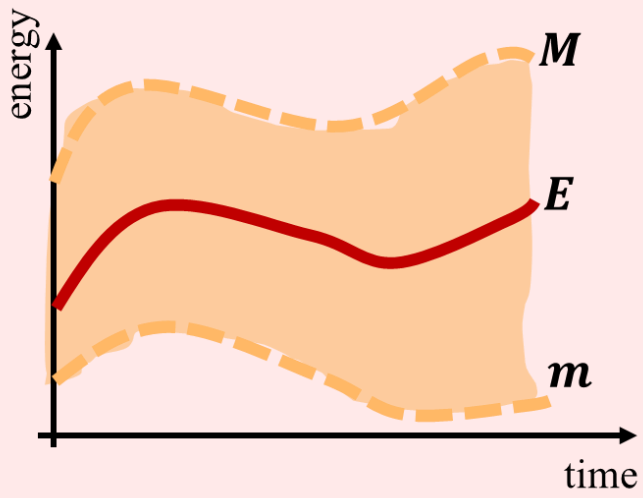
LoTS module defines the optimal yearly scheduling and provides the optimal bands of operation for the short-term module…



Control variables

- Daily energy to each plant
- Daily energy exchanged with grid
- Seasonal storage, if available

Optimal bands of operation



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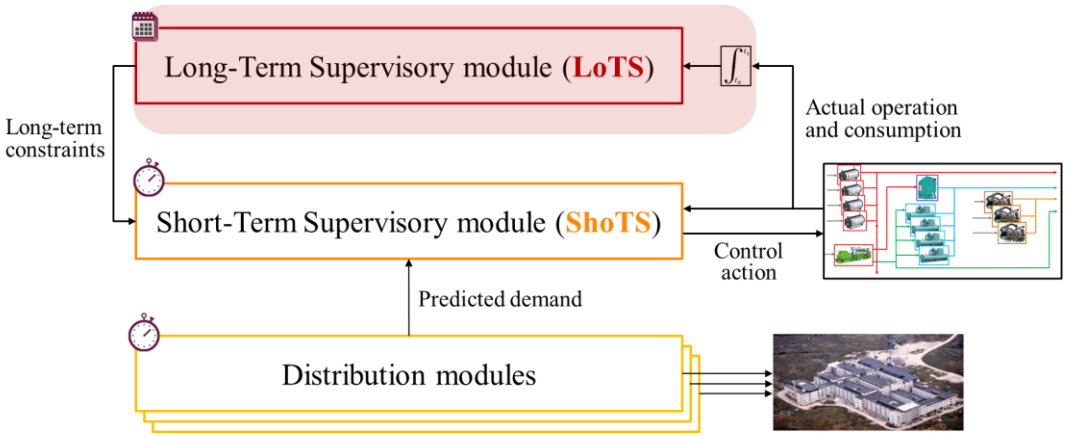
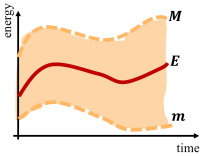
…that allows the plant to fulfil long-term requirements, such as efficiency constraints for the admission to incentives



Constraints

- Meet daily demands
- Regulation and contracts
- Maintenance schedule
- White certificates
- $PES > PES^*$
- $\eta_I > 0.75$

Update **cumulated** energy and fuel consumption $\int_{t_0}^{t_1}$ → Solve optimization problem → Create optimal bands for **ShoTS**



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Thank you for your attention!

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