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#SESAAU2020

Smart Energy Systems ERA-Net

Enabling smart control by optimally managing the State of Charge of district heating networks

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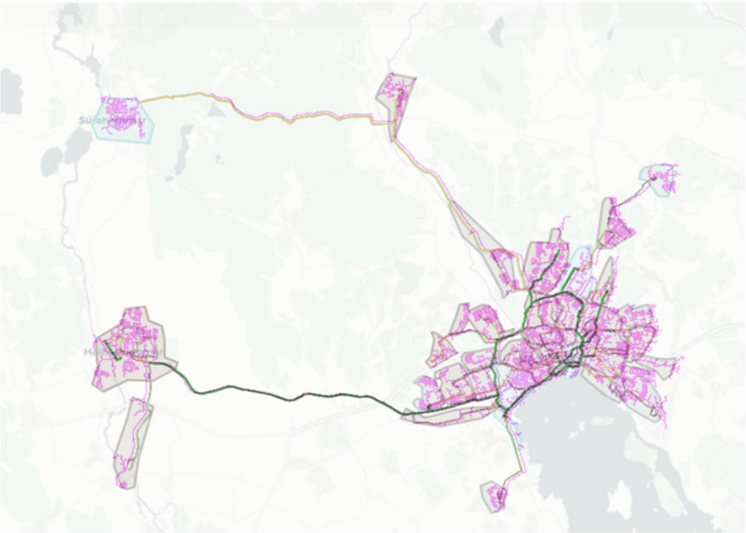
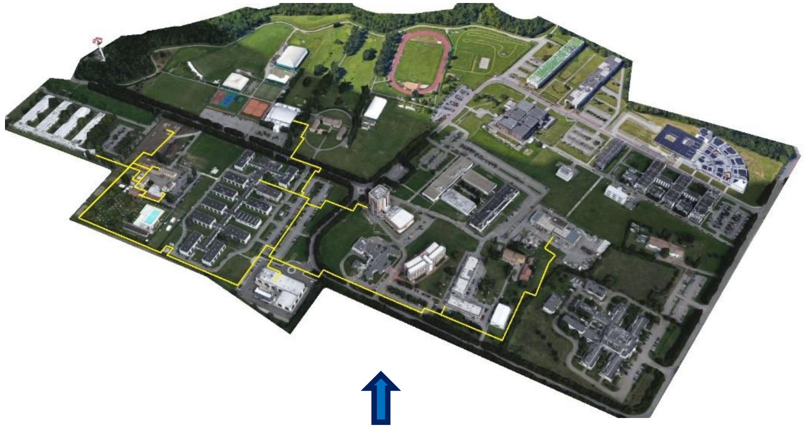
All heat distribution networks have to be **controlled** in a more intelligent way





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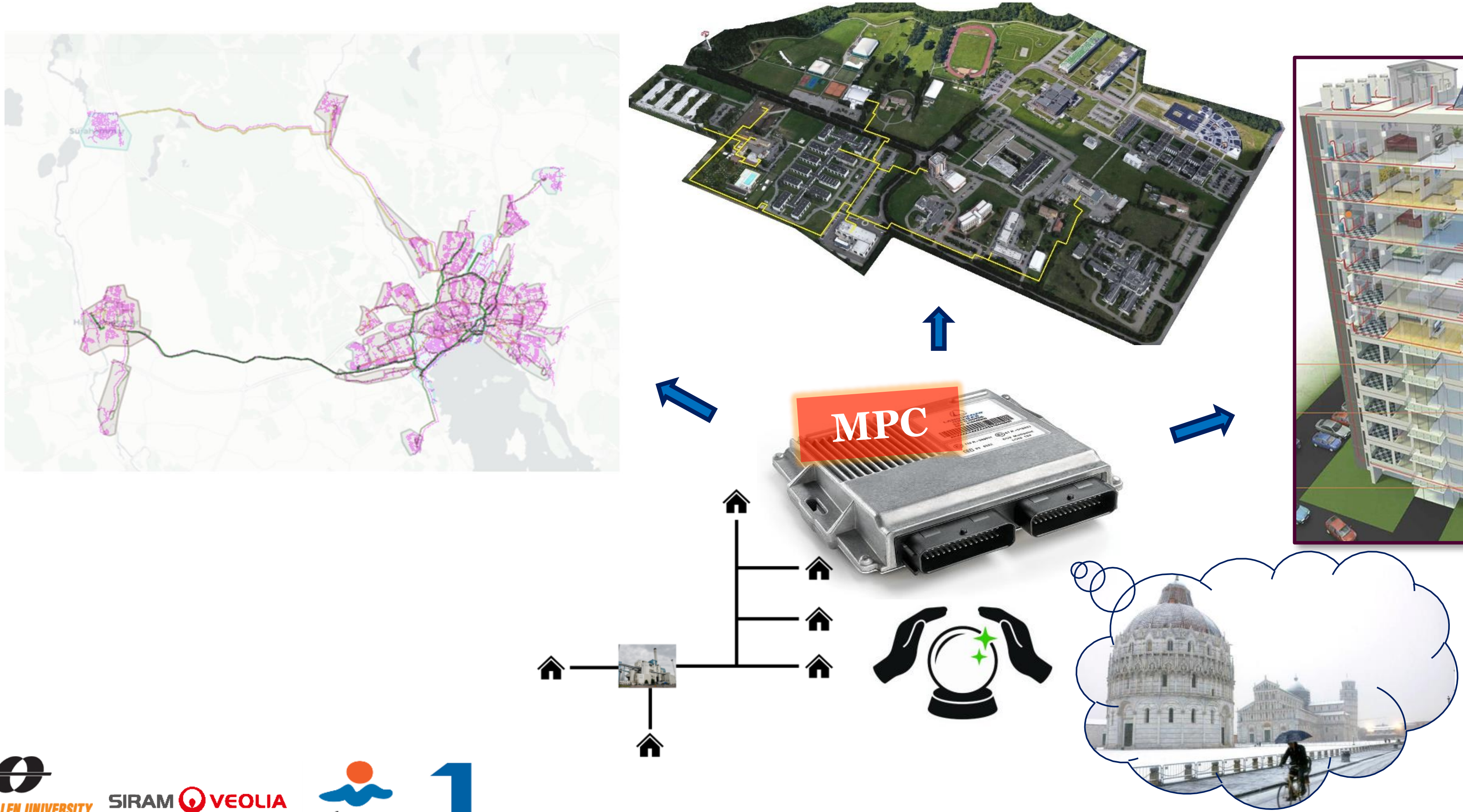
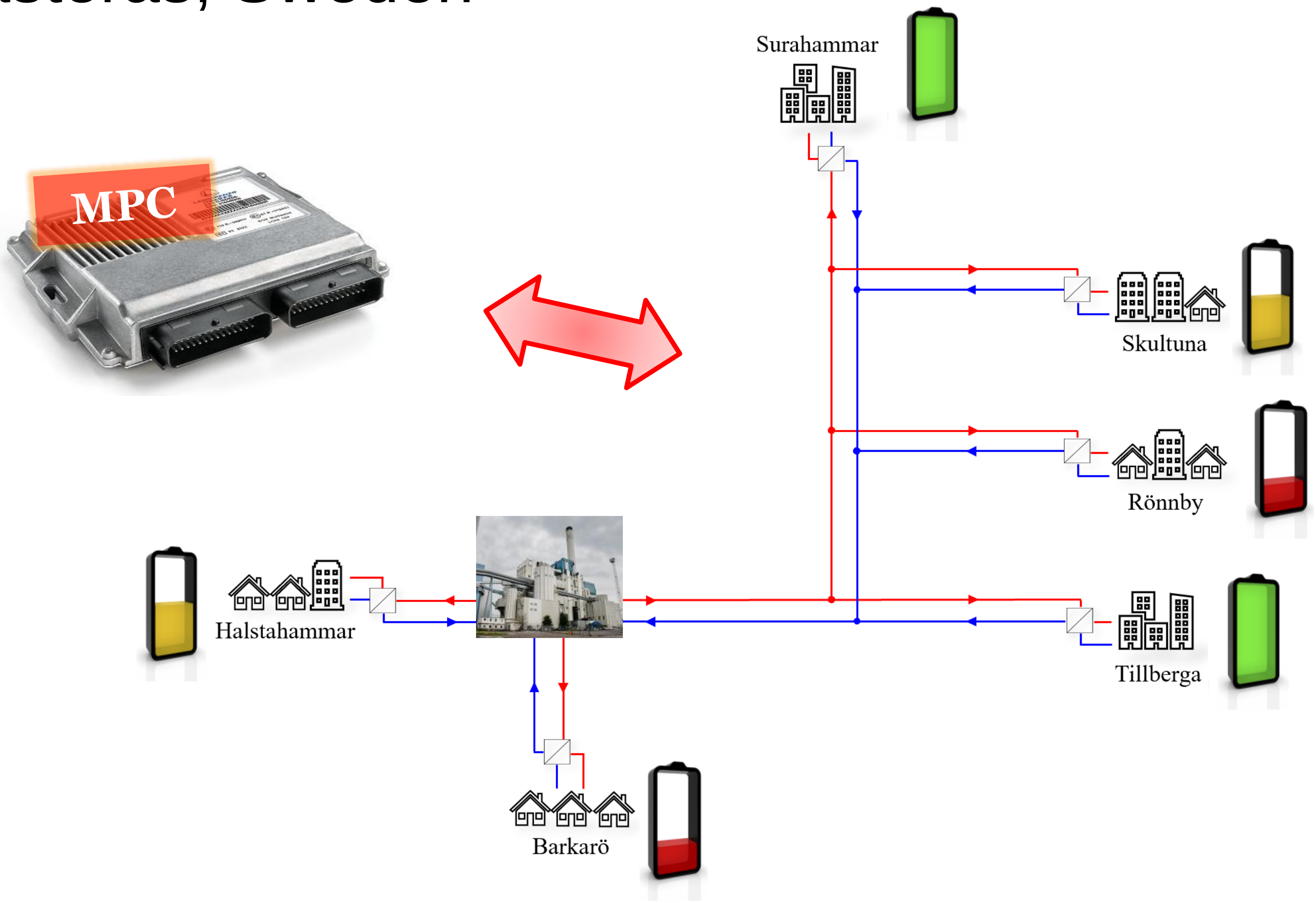
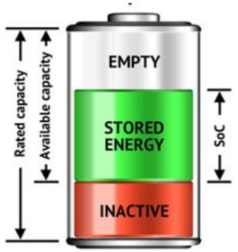
Model Predictive Control is an effective solution, but it is challenging to implement at **large-scale**



The scope of this work is to develop a **scalable MPC** for the network of Västerås, Sweden



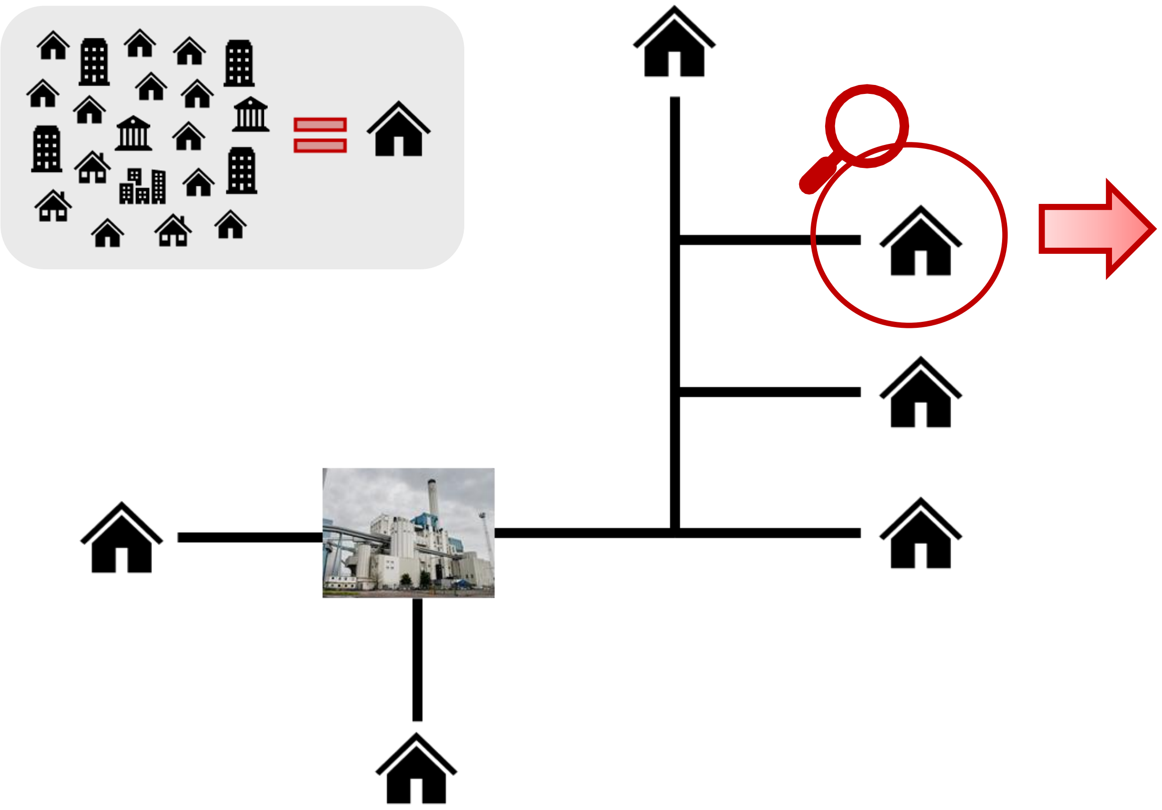
- Exploit **heat capacity** of connected end-users as **thermal storage**

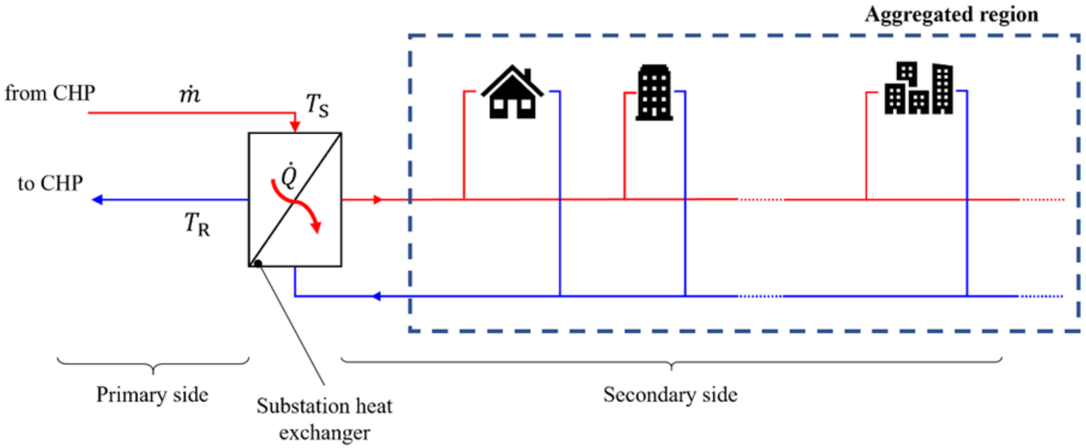


- Achieve thermal **peak shaving**

- Reduce **distribution temperature**

Each region is considered as an **aggregated consumer** with equivalent properties



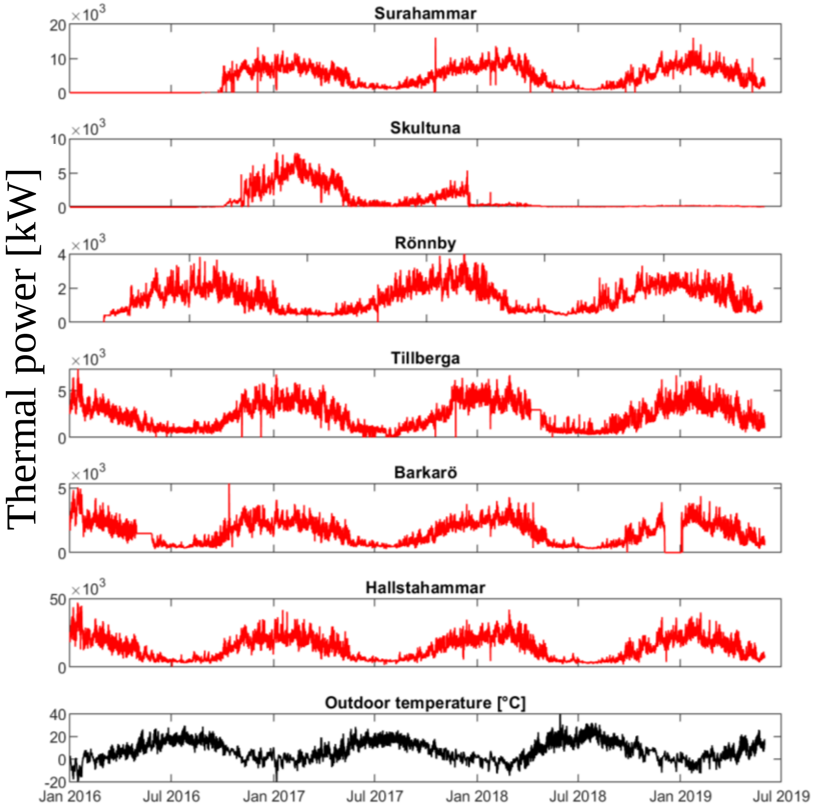


$$\boxed{\dot{Q} = \dot{m}\, c\, (T_S - T_R)}$$

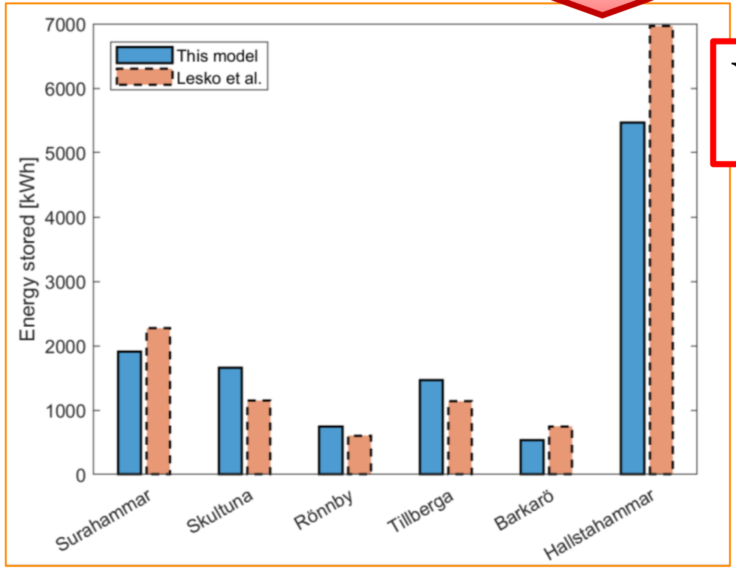
Available from:

- historical data
- forecasting techniques

A scale-free **model** of the aggregated region is developed and validated, considering properties such as **heat capacity**



$$\frac{dT}{dt} = -\underbrace{\frac{U}{C}(T - T_{\text{outside}})}_{\textbf{HEAT LOSS}} + \underbrace{\frac{1}{C}\dot{Q}}_{\textbf{HEAT SUPPLY}}$$



Validated with data from the literature and simulations

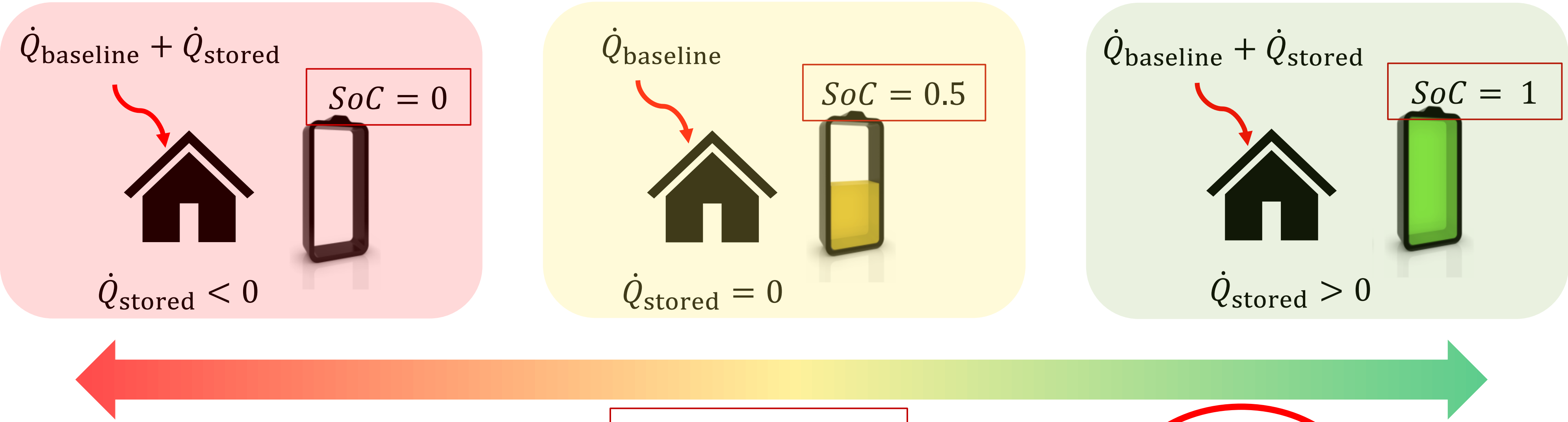
doi: 10.20944/preprints202006.0320.v1

The model is used to build the region **State of Charge** (SoC)

Assumptions:

- **Baseline load** keeps thermal comfort
- Indoor **temperature deviations** of 0.5 °C are acceptable to the consumers

$\Delta T_{\text{stored,max}} = 0.5\ °C$ ⟺ $\boldsymbol{SoC} = \dfrac{\boldsymbol{C}\ \Delta T_{\text{stored,max}} + Q_{\text{stored}}}{2\ \boldsymbol{C}\ \Delta T_{\text{stored,max}}}$



$\boldsymbol{0 < SoC < 1}$
by regulating $\boldsymbol{\dot{Q}}$

A **two-stage optimization algorithm** regulates the SoC of all regions to optimize the network management

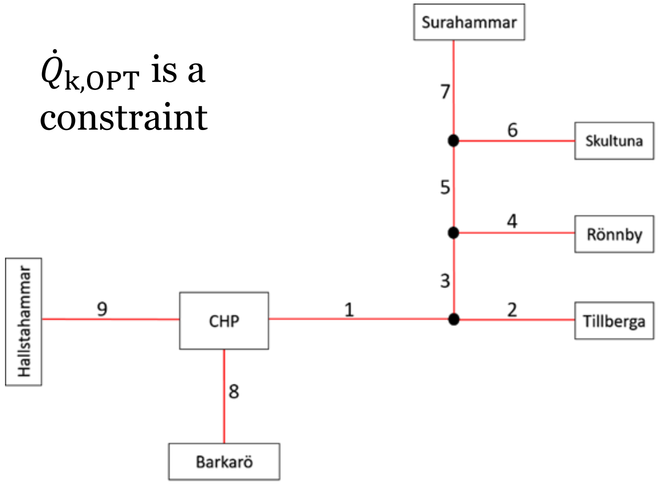
Stage 1. Optimize heat supplied to each region $\xrightarrow{\dot{Q}_{\mathrm{k,OPT}}}$ **Stage 2.** Optimize network operating parameters $\xrightarrow[T_{\mathrm{S,OPT}}]{\dot{m}_{\mathrm{k,OPT}}}$ Obtain optimal **control action**

State Input Disturbance

$$\begin{cases} SoC_{\mathrm{k+1}} = SoC_{\mathrm{k}} + \underbrace{\dfrac{(\dot{Q}_{\mathrm{k}} - \dot{Q}_{\mathrm{baseline,k}})\Delta t}{2C\Delta T_{\mathrm{max}}}}_{\text{HEAT SUPPLY}} - \underbrace{\dfrac{U\Delta t}{C}\left(SoC_{\mathrm{k}} - \dfrac{1}{2}\right)}_{\text{HEAT LOSS}} \\ 0 \leq SoC_{\mathrm{k}} \leq 1 \\ \dot{Q}_{\mathrm{k}} \geq 0 \end{cases}$$

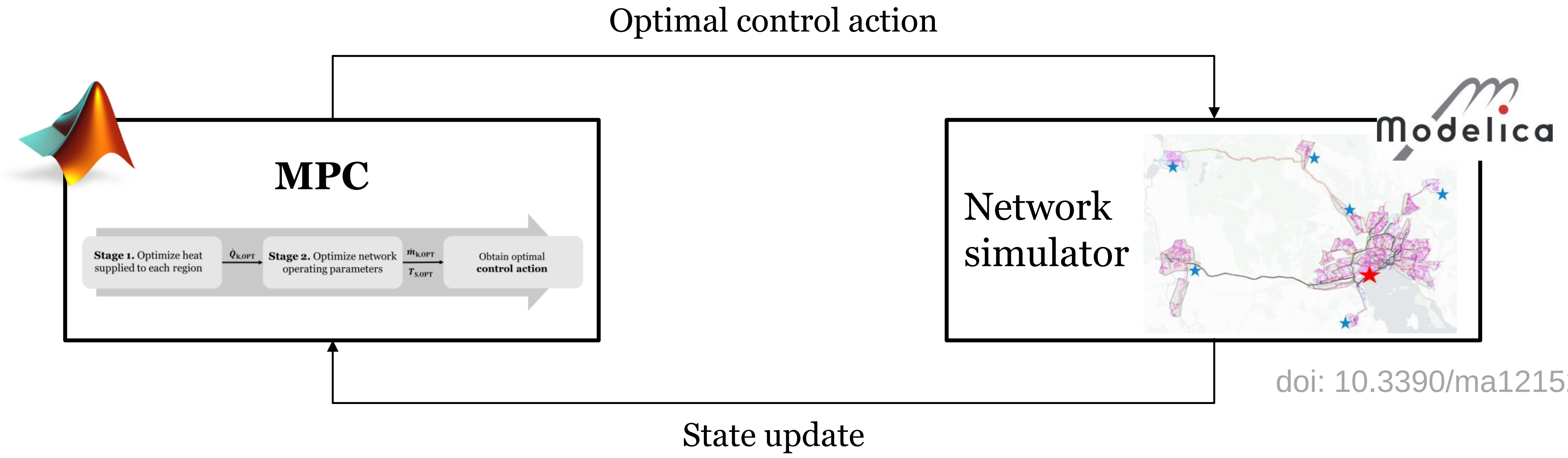
Minimize variations of $\dot{\boldsymbol{Q}}_{\mathbf{k}}$

$\dot{Q}_{\mathrm{k,OPT}}$ is a constraint



Minimize $\boldsymbol{T}_{\mathbf{S}}$ and pumping costs

The procedure is embedded in an **MPC**, tested on a detailed dynamic simulator of the Västerås network



doi: 10.3390/ma12152465

1 week simulation

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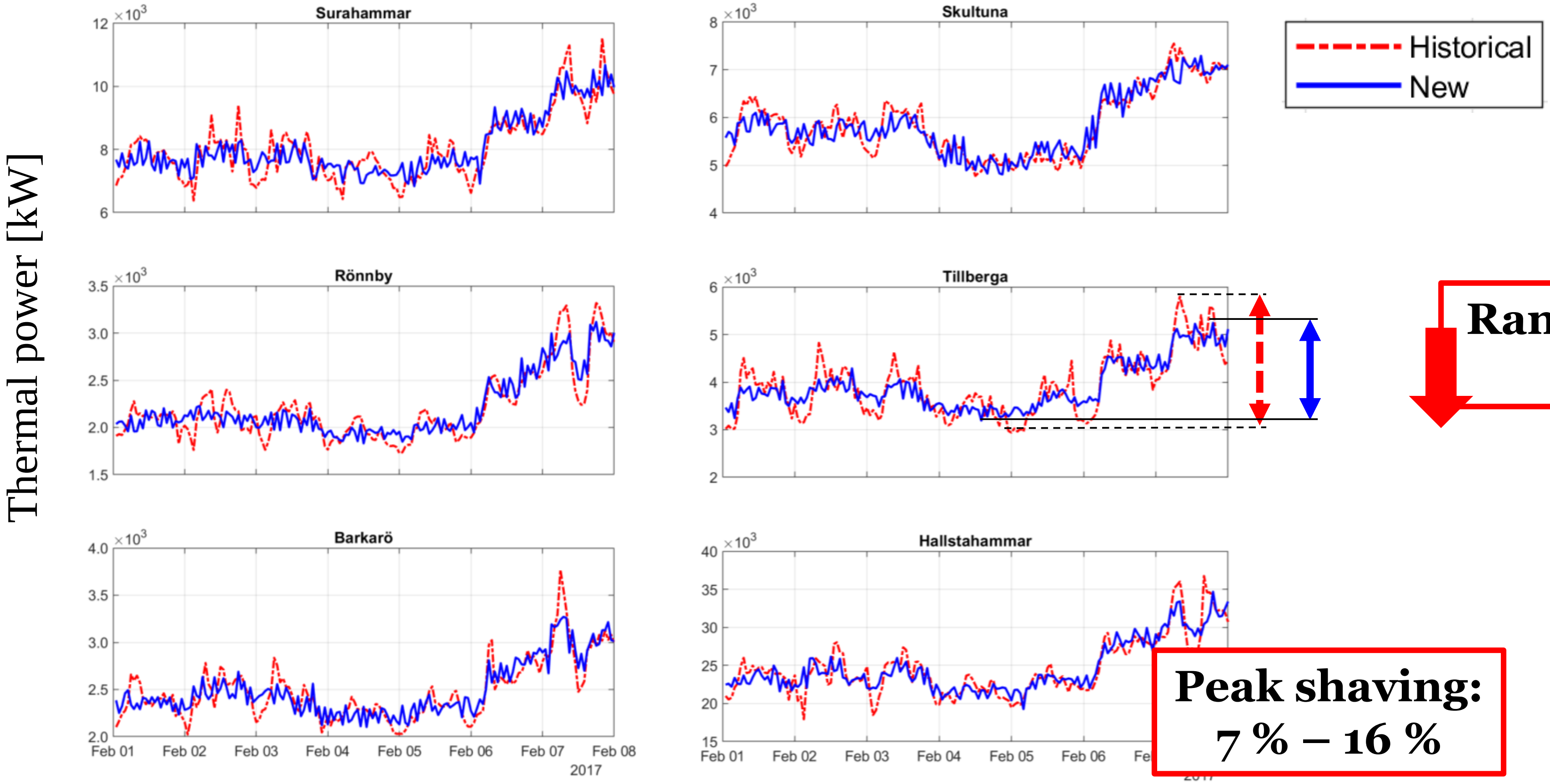
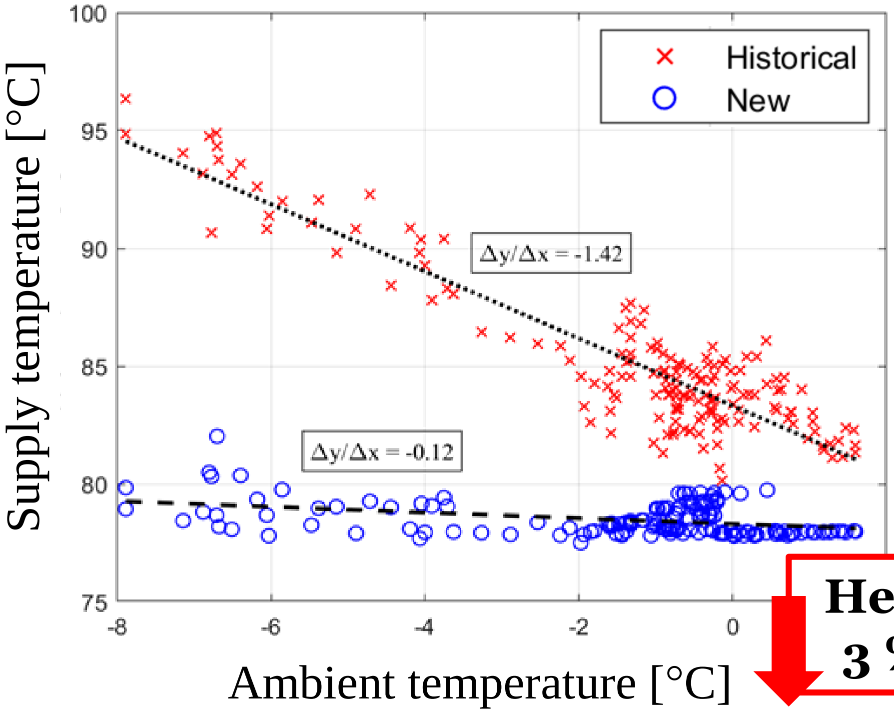
The results show that the controller achieves considerable **peak shaving** and reductions in distribution temperature and mass flow rate



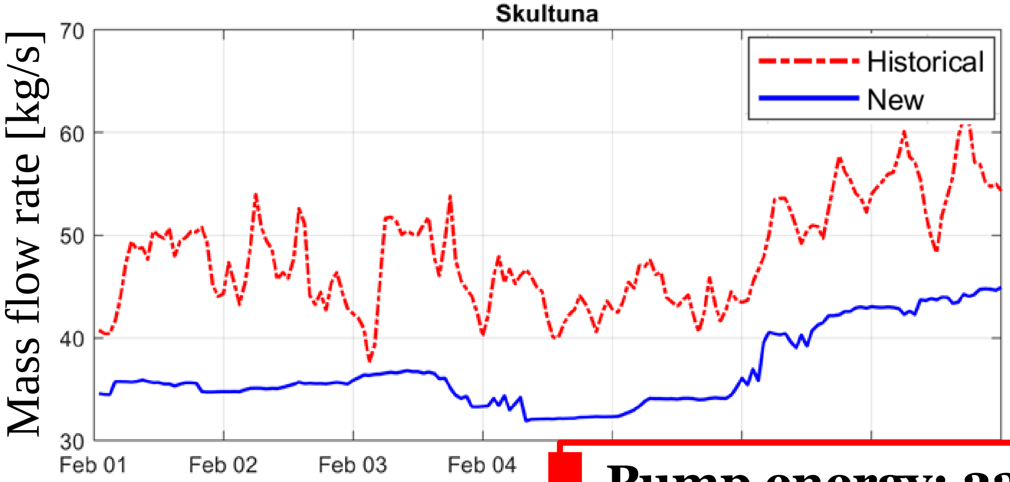
Range of variation:
10 % – 33 %

Peak shaving:
7 % – 16 %

The results show that the controller achieves considerable peak shaving and reductions in **distribution temperature** and **mass flow rate**



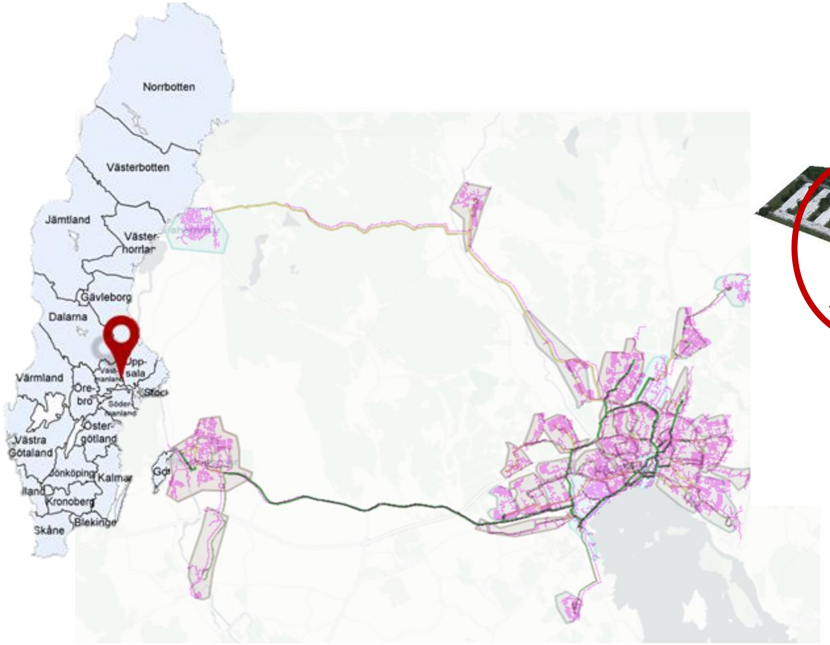
Heat losses: 3 % – 20 %

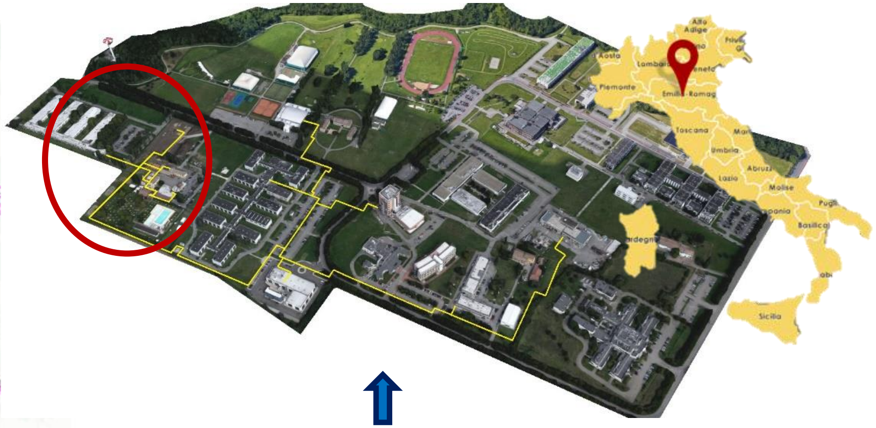


Pump energy: 23 %

Within the project, the controller will be prototyped and tested in the real case

doi: 10.1016/j.energy.2020.118054





Technical synthesis:
scale-free controller applicable to all types of heating networks

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Thank you for your attention!

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