Modelling and Optimization of Seasonal Heat Storage

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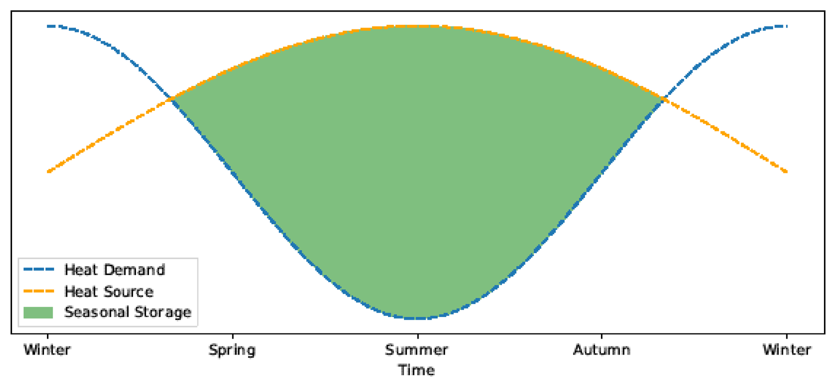
Introduction

- Heat accounts for half of the total energy demand.
- The seasonal mismatch between source and demand requires seasonal storage solutions.



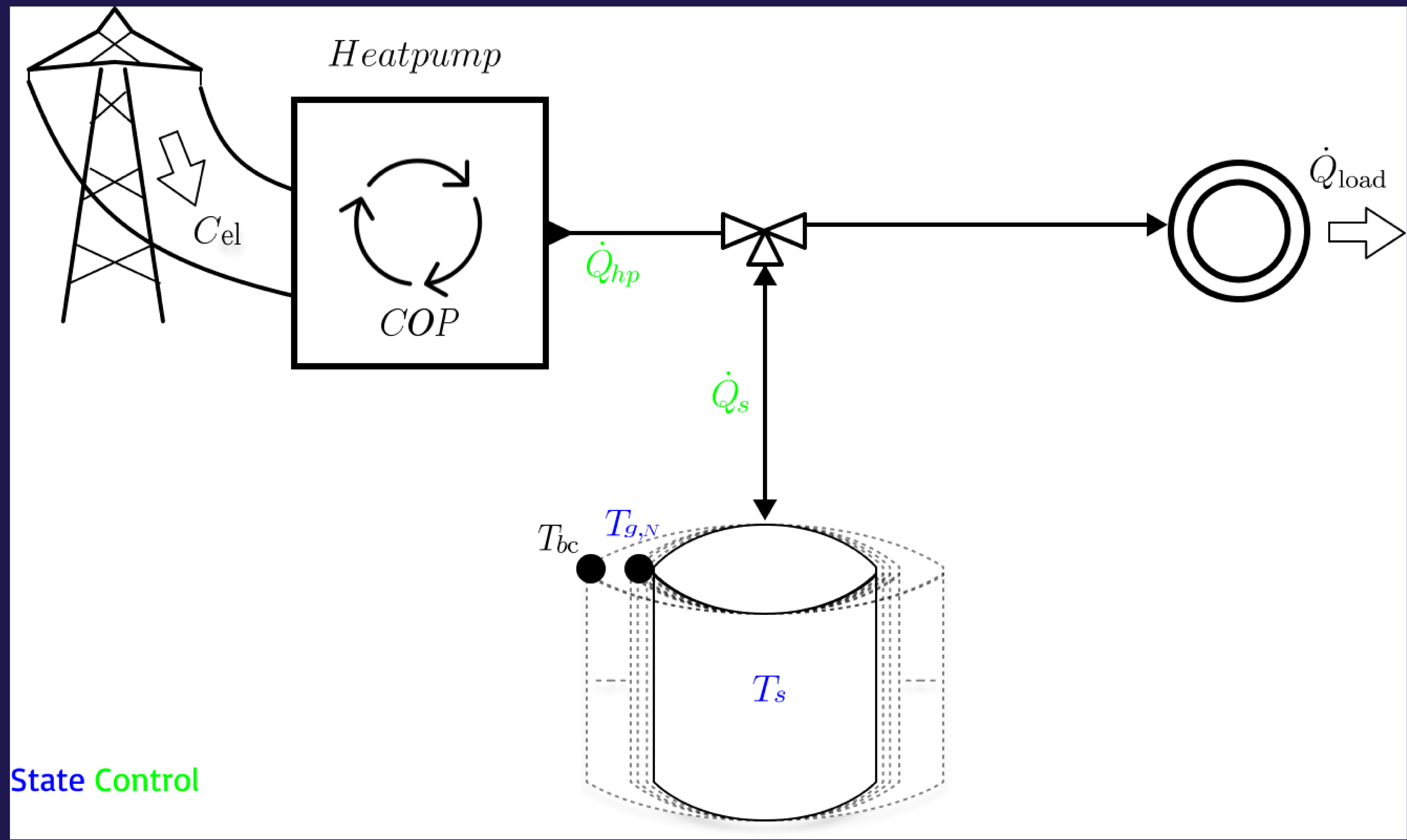
- Success stories abound in Denmark with pit storage.

Courtesy by Angelos Chatzidiakos, Ramboll

Idea

- **Heating demand**: 51 GWh/a for the new city town Dietenbach.
- Use *Seasonal Underground Heat Storage* to utilize excess renewable energy with large-scale heat pumps.

„Ohne **Wärmewende**, keine **Energiewende**" **Seasonal Heat Storage:** Key to decarbonize the heating system?



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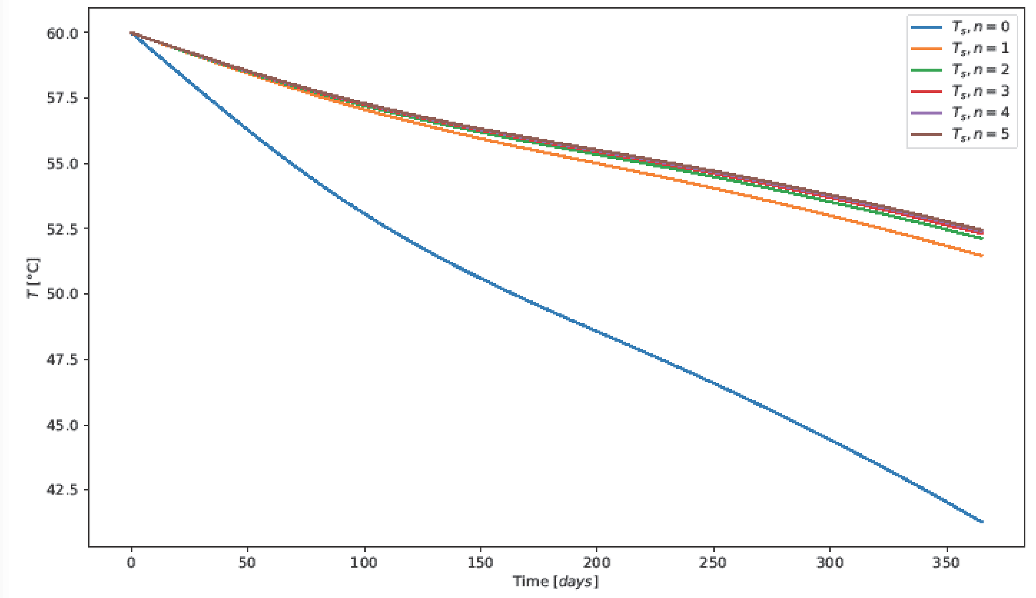
Storage Modelling

- Lumped approach – electric circuit analogy - for the storage and ground model.



- Use differentiable models for fast computation.

Optimization Problem

$$\min_{\substack{x_0,\dots,x_N,\\ u_0,\dots,u_{N-1}}} \sum_{k=0}^{N-1} u_{1,k} c_{\mathrm{el,k}}/\eta_{\mathrm{HP,k}} + (I_{\mathrm{HP}} u_{1,k}/\eta_{\mathrm{HP,k}} + V_{\mathrm{s}} I_{\mathrm{s}})$$

$$\begin{aligned} \text{s.t.}\quad & x_0 = \bar{x}_0, && \text{(initial conditions)} \\ & x_{k+1} = F_{rk4}(x_k, u_k, \alpha_{\mathrm{s}}), && \text{(system dynamics)} \\ & \dot{Q}_{\mathrm{load,k}} - (u_{1,k} - u_{0,k}) = 0, && \text{(Energy Balance)} \\ & x_{\min} \le x_k \le x_{\max}, && k = 0,\dots,N \\ & u_{\min} \le u_k \le u_{\max}, && k = 0,\dots,N-1 \end{aligned}$$

$\eta_{\mathrm{HP,k}}$: COP, $I_{\mathrm{s}} = 30\,\mathrm{EUR/m^3}$, $I_{\mathrm{HP}} = 0.25 \times 1.5\,\mathrm{EUR/W_{th}}$

Results

- η_s: 94.9%, V_s: 200,000 m^3
- Electricity Usage: 22 GWh
- Electricity Cost: 12.7 €/MWh