A heuristic indicator-based heat pump control algorithm

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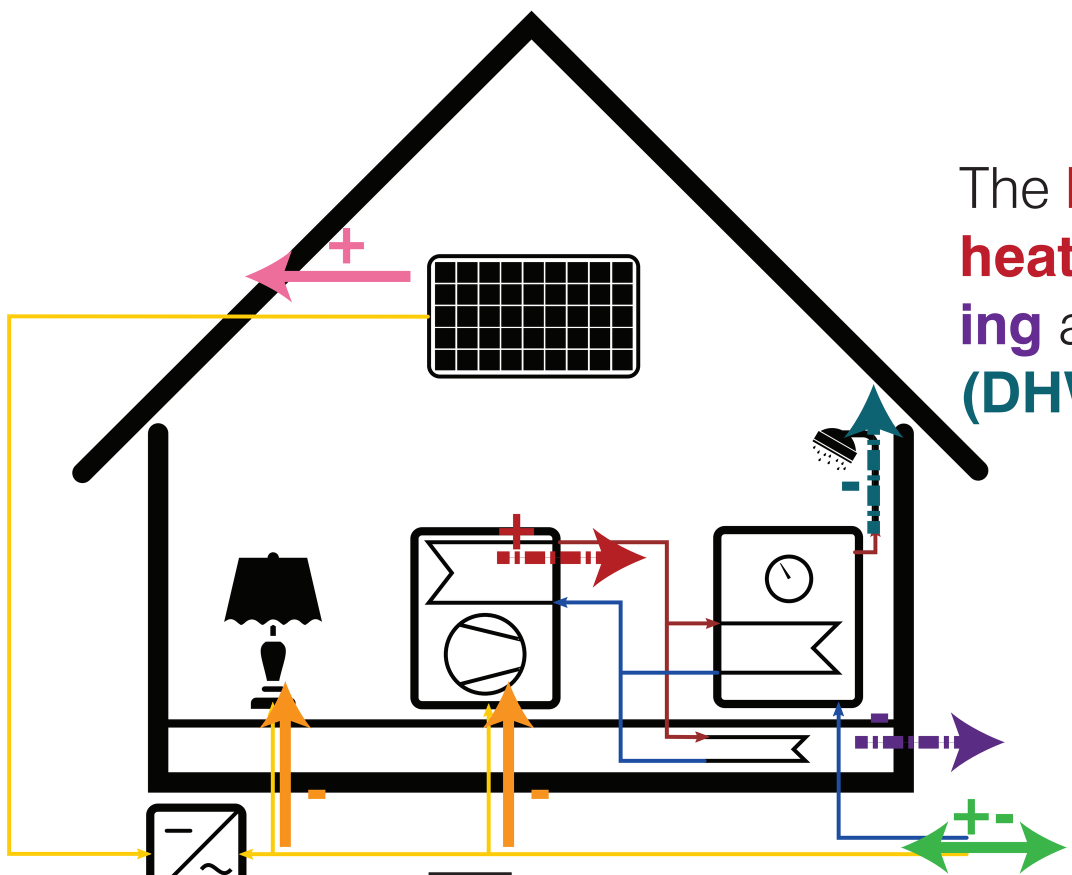
Motivation

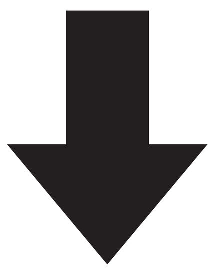
Simple and efficient control algorithms are required to enable the electrification of the building heating system and the integration of **photovoltaic (PV)**. The complexity of modern control algorithms for energy management applications might be detrimental to the rapid deployment of **smart heat pumps** and PV systems. Hence there is a need for **easily implementable** control algorithms. Our **heuristic control algorithm (HCA)** is a novel, simple and efficient heat pump control algorithm dedicated to optimizing the operating cost under PV generation. The algorithm aims to optimize an indicator that relates the variation of the operational cost due to a given action (like increasing the energy fed to a heat pump) and the heat production gain.

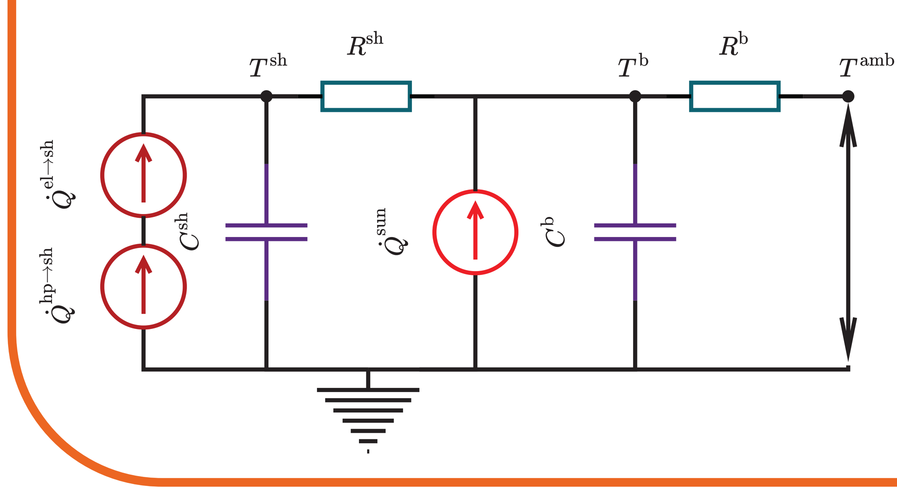
System modeling

The **PV array** and **grid** fulfill the **electric demand**.



The **heat pump** and **electric heater** fulfill the **space heating** and **domestic hot water (DHW)** demand.



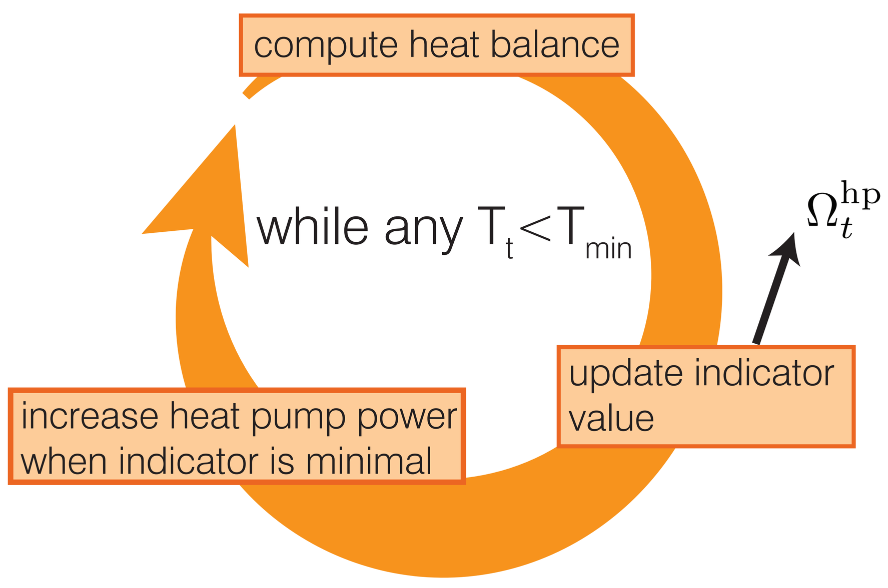


Thermal model as an electrically equivalent circuit, where the heat pump and electric heater are the **heat sources**, the **resistances** model the heat transfers and **capacitance** correspond to the thermal inertia. It also includes **solar gains**. A similar circuit is used for the DHW tank.

Algorithm

The HCA is a simple state machine performing three subsequent actions in a loop:

1) perform heat balance over the time horizon.
2) calculate the indicator values over the time horizon
3) choose the action that minimizes the indicator



If the heat pump is at max power, use electric heater.

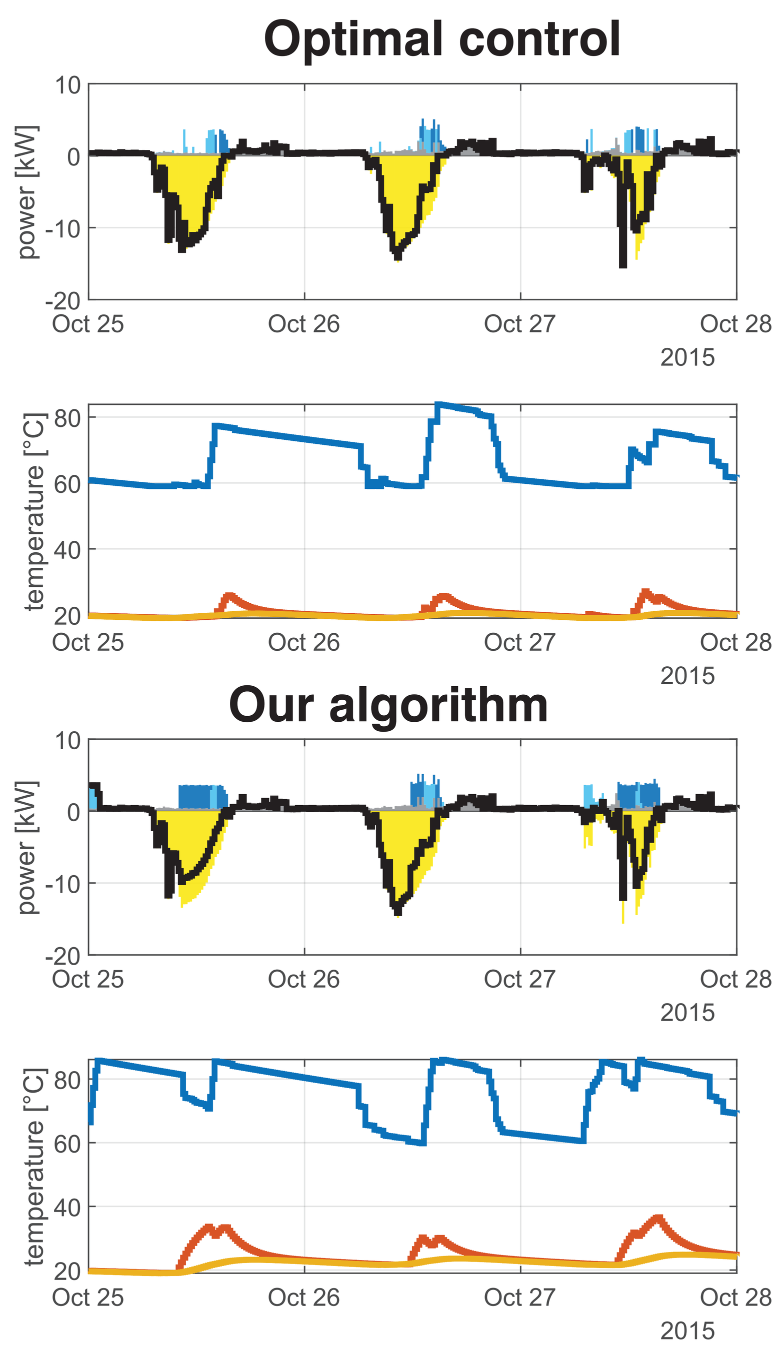
$$OPEX_t = OPEX_t^{\text{grid}} + OPEX_t^{\text{hp}}$$
$$OPEX_t^{\text{grid}} = \left(P_t^{\text{imp}} \cdot c_t^{\text{imp}} - P_t^{\text{exp}} \cdot c_t^{\text{texp}}\right) \cdot TS_t$$
$$OPEX_t^{\text{hp}} = c^{\text{start}} \cdot S_t + c^{\text{run}} \cdot R_t \cdot \text{TS}_t$$

$$\Omega_t^{\text{hp}} = \frac{\Delta OPEX_t}{\Delta Q_t}$$

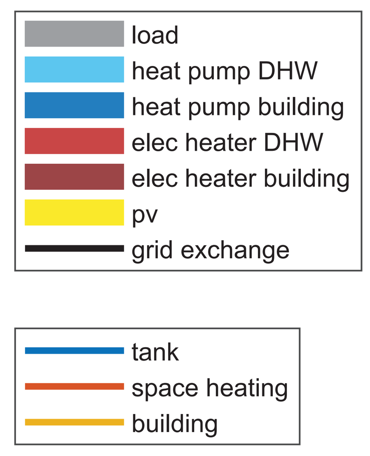
$$Q_t^{\text{hp}}(P_t^{\text{hp}}) = P_t^{\text{hp}} \cdot COP_t(P_t^{\text{hp}}) \cdot TS_t$$

The indicator relates the operating cost variation and the heat gain for a given increase of heat pump power

Qualitative comparison with optimal control



The benchmark consists of 15 representative buildings (split into three categories: single-family, multi-family, and non-residential buildings). For each building, the HCA is executed for 4 representative weeks (only 3 days are represented here as an example) and compared to optimal control.



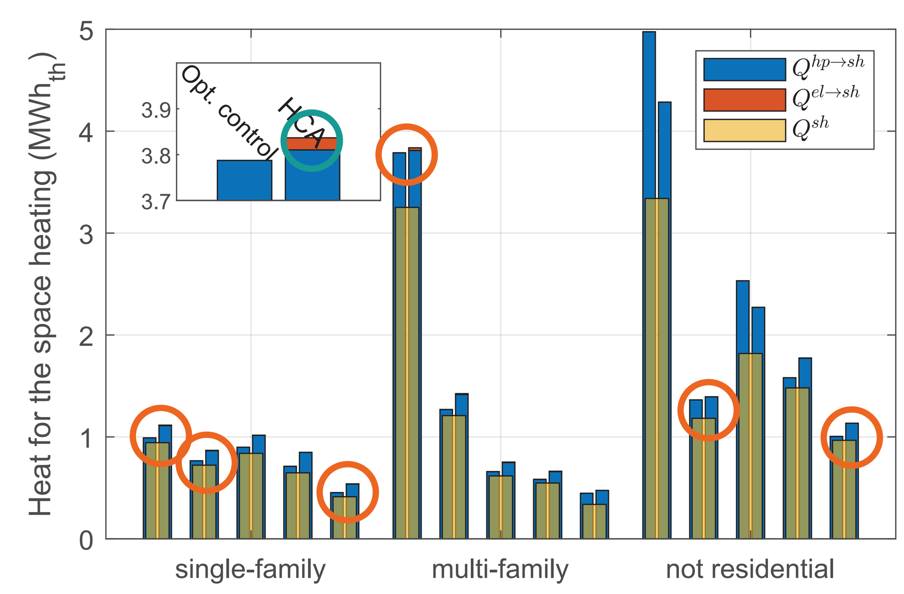
Compared to optimal control, the HCA follows a very close trajectory.

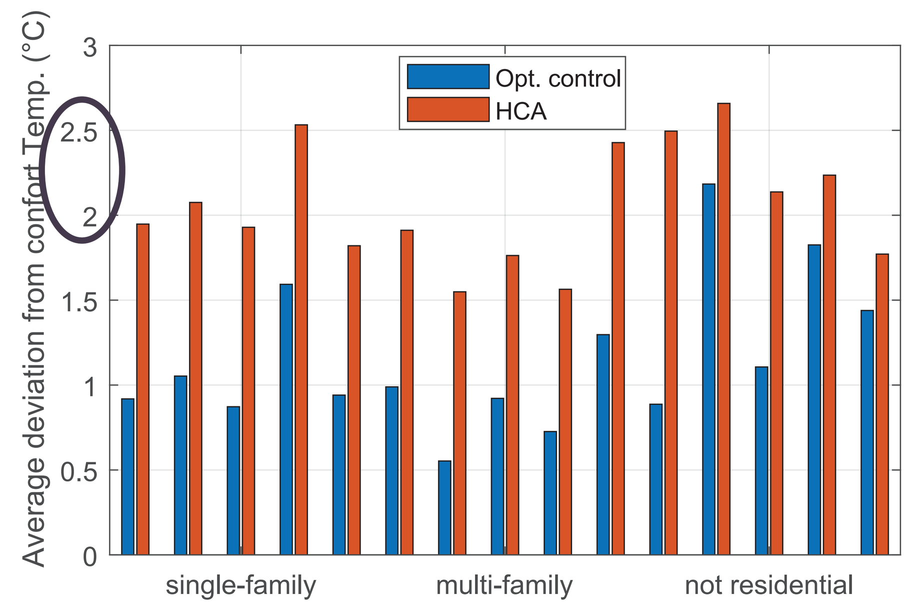
Quantitative comparison with optimal control

- **Heat generations** are very similar.
- The **electric heater** only generates a very insignificant fraction.
- **Temperature deviations** are significantly different but stay below 2.5°C.
- HCA achieves similar ***OPEX*** to optimal control.

average *OPEX* (CHF/day)

	MILP	HCA	Δ
single-family	-4.27	-4.06	0.21
multi-family	0.65	1.43	0.77
non-residential	-6.90	-6.79	0.11





Conclusion

Our heuristic control algorithm (HCA) for heat pump and PV system presents performance close to optimal control under a perfect forecast assumption. On average, the additional costs (with respect to optimal control) are below 1 CHF/day for single-family, multi-family, and non-residential buildings. The temperature deviations are mostly driven by the solar gain. Most differences between the optimal control and HCA are linked to the fact that the HCA considers the heat pump running and switching costs (which the MILP formulation of the optimal control does not).

In summary, this algorithm is efficient and simple enough to be implemented in any heat pump microcontroller.