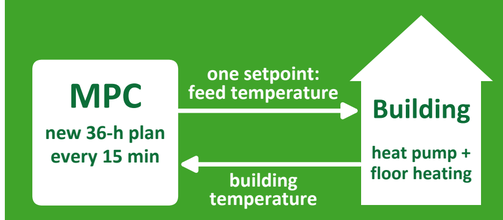
Building as Storage: Predictive Temperature Control for Single-Family Homes





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AT A GLANCE

Two heating curves (factory-set or hand-tuned) and two MPC settings (comfort band ±0.5 K or ±1.5 K), each without and with 10 kWp PV: eight cases, one simulated year each (Graz, 2025).

–10 / –34 %
net electricity costs with 10 kWp PV (MPC ±0.5 / ±1.5 K vs tuned curve)

4–18 %
less heat-pump electricity consumption than the tuned / factory curve (MPC ±0.5 K, no PV)

88 vs 78 %
of occupied heating hours in comfort class A, ISO 7730 (MPC ±0.5 K vs tuned curve, no PV)

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1 Motivation

Most new single-family homes pair a heat pump with floor heating. A rule-based **heating curve** maps the outdoor temperature to the feed temperature. It **does not plan ahead**: the building's thermal mass stays unused.

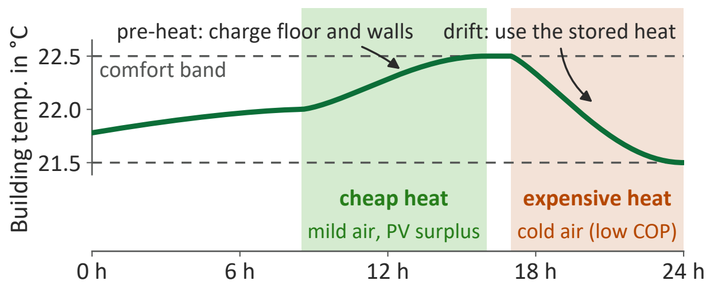
Question
What can a model predictive controller (MPC) gain from the building's thermal mass in **net costs**, **electricity consumption** and **comfort**?

2 Predictive control: heat when heat is cheap

The idea: store heat in the building itself: pre-heat its mass while heat is cheap, let the building temperature drift back within a **comfort band** around the building setpoint while heat is expensive (figure). Every 15 minutes the MPC re-plans 36 h ahead and sets **one value**: the feed-temperature setpoint.

What makes heat cheap: the heat pump's **COP** (coefficient of performance) is the heat per kWh of electricity. It depends on the **outdoor temperature**, the **load level** and the feed temperature: the first two matter about equally, the third can be left out, as floor heating keeps the feed at 30–40 °C, where its effect is about three times smaller than the other two.

How outdoor temperature and load level are considered: the outdoor temperature a priori in the cost function (**price of heat** = electricity purchase price / COP forecast at 35 °C feed and full load; with photovoltaic (PV) surplus the feed-in price, i.e. the missed opportunity costs), and the load level in the MPC's heat-source model, which is more efficient at part load than at full load.



Illustrative day (schematic, not a simulation result).

- **MPC model:** three-state, one-zone building dynamics (air, floor, wall); state, parameters and internal gains **estimated online** (unscented Kalman filter).
- **Comfort:** the building may drift within the comfort band, leaving it is penalized; pumps and safety functions stay rule-based.

3 Simulation study

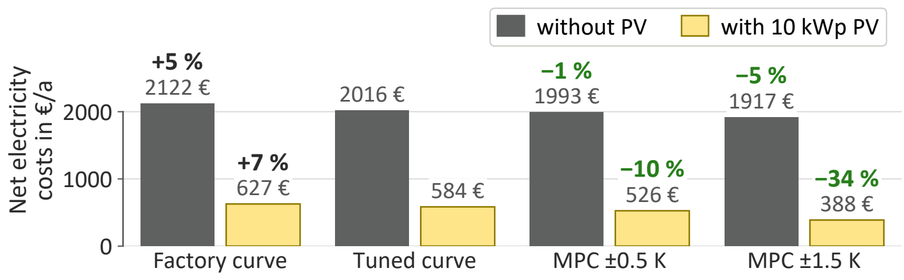
Eight cases: two heating curves, at the **factory** setting or **hand-tuned** to the building (real homes lie in between), and the MPC with a comfort band of **±0.5 K** or **±1.5 K** around a 22 °C setpoint, each without and with 10 kWp PV. Comfort is judged by ISO 7730 **class A** (building at 22 ± 1 °C): ±0.5 K stays inside class A with margin for model errors, ±1.5 K shows the effect of a wider band.

The building
Heavy construction: heat loss 156 W/K, heat capacity 60 MJ/K, design load 5.3 kW; 120 m² floor heating, one thermal zone. Optional 10 kWp PV; flat electricity tariff: 31.2 ct/kWh purchase, 6.8 ct/kWh feed-in.

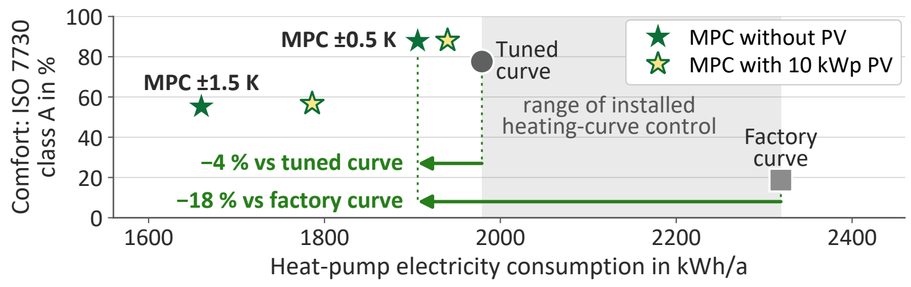
Heat pump and hydraulics
8.3 kW_{th} air-to-water heat pump, modulating down to 2.1 kW_{th}, COP 2.0–7.3 from the datasheet; 100 L hydraulic separator, no buffer tank; space heating only, no domestic hot water.

Boundary data and schedules
Graz weather 2025; solar gains per facade; heat and electricity from 4 occupants and appliances (4500 kWh/a, stochastic profile); building setpoint 22 °C with vacation setback (18 °C).

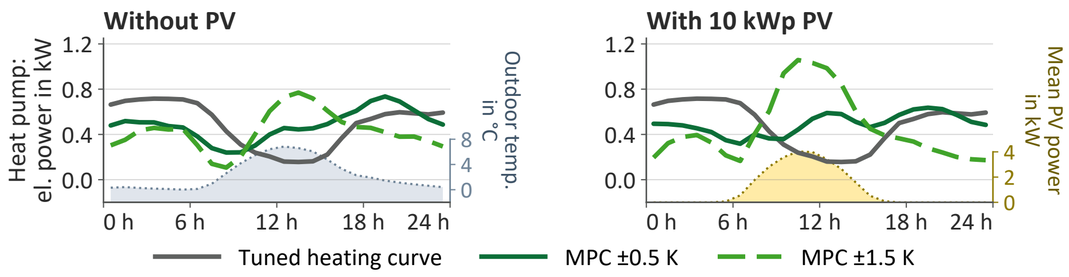
4 Results



Net electricity costs of all eight cases (household load and PV export included). The MPC's advantage **grows with PV**: without PV the MPC (±0.5 / ±1.5 K) costs 1 / 5 % less than the tuned curve; with PV it costs 10 / 34 % less than the tuned curve and 16 / 38 % less than the factory curve.



Comfort vs heat-pump electricity consumption (heating days only). MPC ±0.5 K: 4 / 18 % less than the tuned / factory curve at better comfort (88 vs 78 % of occupied hours in class A); ±1.5 K: 16 % less at 55 %. With PV (yellow stars) ±1.5 K uses 8 % **more** for equal comfort: minimizing costs, it buys cheap surplus power even at a lower COP (see below).



Daily profile of heat-pump electricity consumption (heating-season hourly means).

Without PV, heat is cheapest in the mild midday hours (best COP), but a warmer building loses more heat: pre-heating too far **eats its own saving**. With PV, surplus and mild hours coincide, a **far bigger price gap**, so a large shift pays, most with ±1.5 K. It costs **compressor starts**: MPC 488–798 per year, tuned curve 212 — far below the ∼2500 manufacturers recommend for full compressor life.

5 Conclusions

- **Net electricity costs:** –1 / –5 % without PV, –10 / –34 % with PV (±0.5 / ±1.5 K vs tuned curve): the gain is largest with PV.
- **Electricity consumption:** 4–18 % less than the heating curves, i.e. MPC worthwhile even with a flat electricity tariff.
- **Comfort:** 88 vs 78 % in class A (MPC ±0.5 K vs tuned curve).
- **Commissioning:** model estimated online, no hand-tuning required.

6 Limitations and outlook

- **Perfect forecast assumed:** with real PV forecasts (clouds) the savings will be somewhat lower; still to be quantified.
- **One simulated building:** the ranking of the controllers should be confirmed for other building types.
- **Next steps:** variable tariffs, consideration of domestic hot water and a field test in a real building.

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