# From Models to Data: Smarter Predictive Control in Buildings

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## Introduction

Buildings are major energy consumers, with heating systems playing a significant role. Traditional control strategies often rely on fixed rules or detailed physical models, which can be complex, costly to develop, and inflexible in real-world applications.

Data-driven predictive control offers an alternative. Instead of explicitly modeling system dynamics, this approach uses historical input-output data—structured as Hankel matrices—to forecast future behavior. This method is grounded in the fundamental lemma of behavioral systems theory [1], which shows that, under controllability and sufficient excitation, future trajectories can be expressed as combinations of past data [2].

Emerging research further suggests that additional energy savings can be achieved by accounting for occupant behavior and preferences directly. Rather than treating occupants as disturbances, a shift toward occupant-centric control emphasizes personalized comfort and adaptive energy use.

Figure 1: NEST, Dübendorf Switzerland. Vision wood residential living lab.

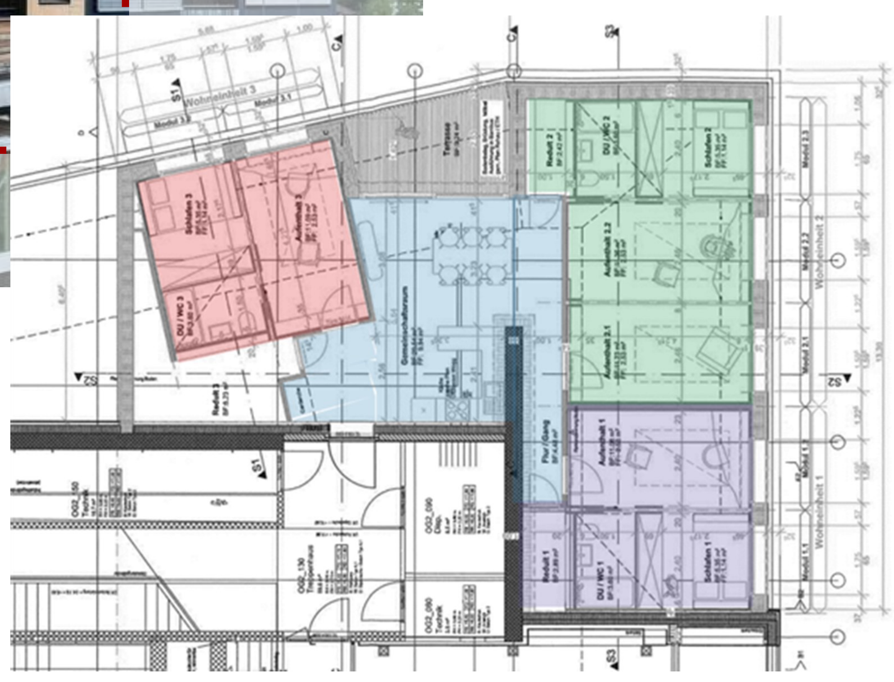

Figure 2: Floor plan of vision wood.

$$\min_{u,x,y} \sum_{k=0}^{N-1} \left(\|y_k - r_{t+k}\|_Q^2 + \|u_k\|_R^2\right)$$

Subject to
$$\begin{aligned} & x_{k+1} = Ax_k + Bu_k, \forall k \in \{0, \dots, N-1\}, \\ & y_k = Cx_k + Du_k, \forall k \in \{0, \dots, N-1\}, \\ & x_0 = \hat{x}(t), \\ & A_{ineq} y_k \leq b_{ineq}, \\ & A_{eq} y_k = b_{eq}, \\ & lb \leq u_k \leq up \end{aligned}$$

MPC

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$$\min_{u,y} \sum_{k=0}^{N-1} \left(\|u_k\|_R^2 + \|y_k - r_{t+k} + C\|_Q^2 + \|g\|_{\lambda_g} + \|u_{k+1} - u_k\|_{y_{regu}}\right)$$

Subject to
$$\begin{pmatrix} U_p \\ Y_p \\ U_f \\ Y_f \end{pmatrix} g = \begin{pmatrix} u_{ini} \\ y_{ini} \\ u \\ y \end{pmatrix}$$

$$lb \leq u_k \leq up$$

SM-MPC

## Methodology

The two control strategies were implemented in a single-zone building simulation with internal heat gains and occupancy-driven setpoint changes.

- MPC used a third order RC-model identified from data.
- SM-MPC was built using input-output data directly, structured as Hankel matrices, with no explicit system model.

Both controllers ran with a 24-hour horizon and 1-hour steps, minimizing heating demand while keeping indoor temperature within comfort bounds.

Constraints and cost functions were kept consistent for fair comparison.

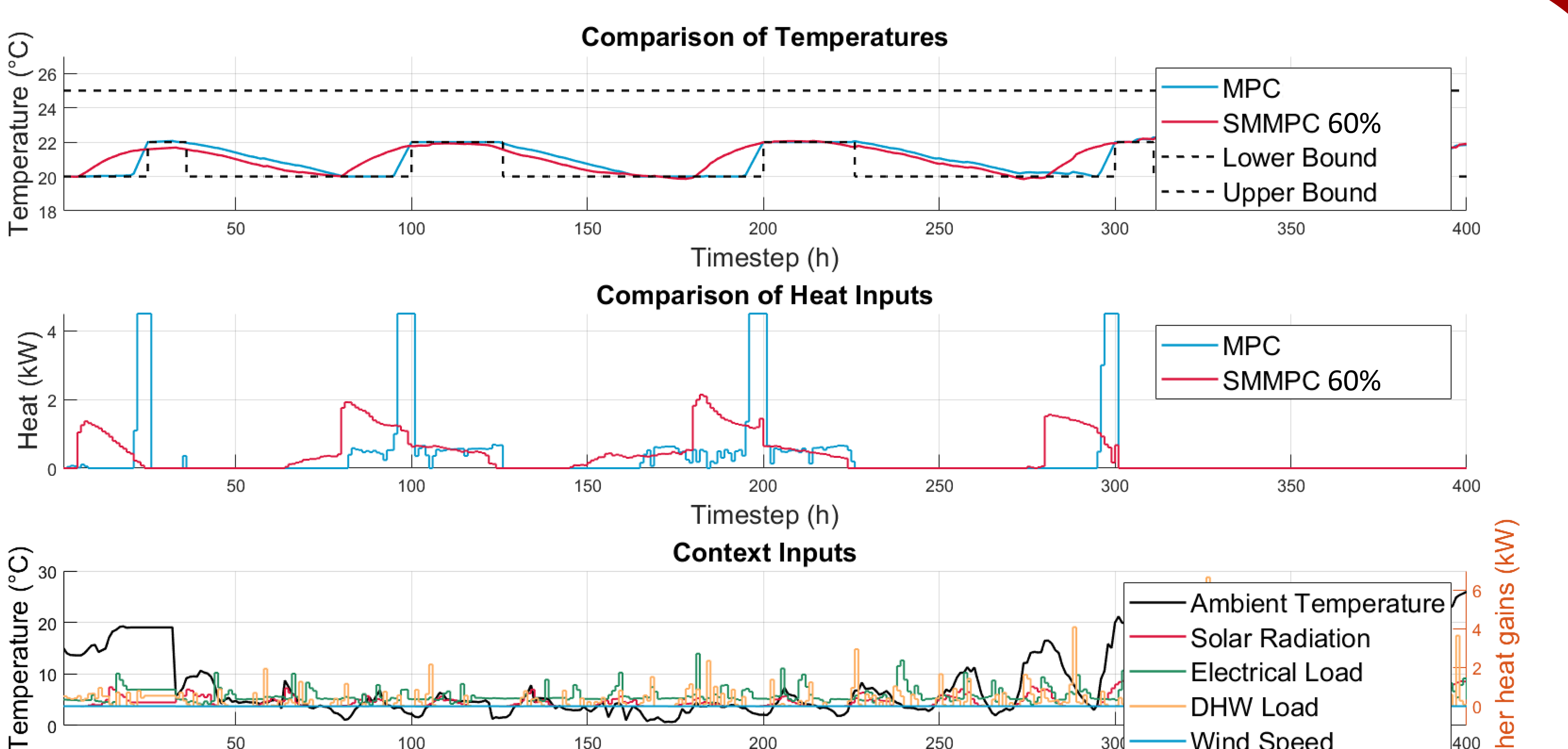


Figure 3: Results from the simulation study.

| Control solution | Total heat consumption | Degree hours | Occurences below |
|---|---|---|---|
| MPC | 132,96 kWh | 0 | 1,75% |
| SM-MPC confidence 95% | 155,44 kWh | 0,03 | 0,75% |
| SM-MPC confidence 60% | 138,83 kWh | 10,81 | 18,45% |

## Conclusion

| | MPC | SM-MPC |
|---|---|---|
| 👍 | + Well-established method<br>+ Intuitive with physical insight<br>+ Predictive capability based on known dynamics | + No need for detailed system model<br>+ Fast deployment<br>+ Naturally handles varying system behavior |
| 👎 | - Requires accurate system modeling<br>- Time-consuming model development<br>- Sensitive to model mismatch | - Requires quality data<br>- May struggle with extrapolation |


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MARIE CURIE ACTIONS


[1] J. C. Willems, P. Rapisarda, I. Markovsky, and B. L. M. De Moor, "A note on persistency of excitation," *Systems & Control Letters*, vol. 54, no. 4, pp. 325–329, Apr. 2005, doi: 10.1016/j.sysconle.2004.09.003.

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