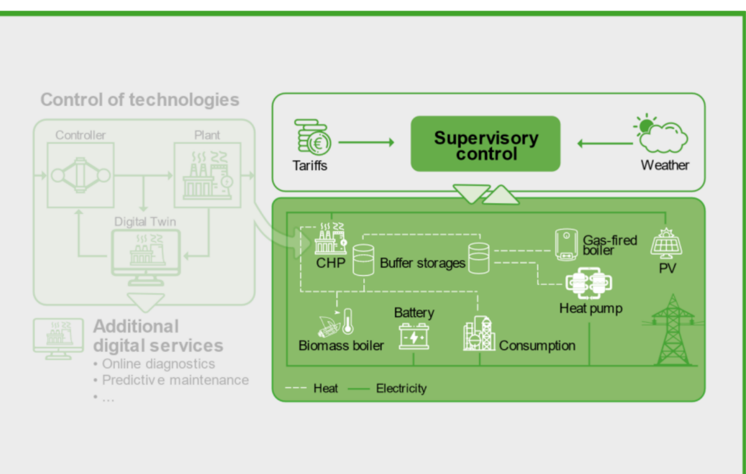

Predictive Building Energy Management with User Feedback in the Loop

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Area 2.2
Automation and Control

Motivation

Buildings consume 30% of the world's final energy and contribute 19% to indirect emissions, see [1]. Air-conditioned offices have a high energy footprint. Retrofitting buildings with predictive controllers, so called energy management systems (EMS) can lower energy demand and increase comfort by considering future weather. Infrastructure and user feedback are challenges in achieving these goals.

Energy Management System

Optimization-based energy management systems (EMS) are a high-level control approach for energy systems like district heating networks [2]. A descriptive model and objective function are required to solve an optimization problem and apply the resulting schedule in a receding horizon fashion. EMS for buildings require **a simplified model of each thermal zone**, and the objective function includes costs for heating and cooling, and a comfort model. **Feedback from users** is necessary since thermal comfort varies among individuals.

Building Model

For the model of the thermal zones, a **grey-box approach** is used

$$\frac{dT_z}{dt} = k_{w,z}(T_w - T_z) + k_{slab,z}(T_{slab} - T_z) + \boldsymbol{k}_{sol}^T \boldsymbol{I}_g + d \quad (1a)$$

$$\frac{dT_w}{dt} = k_{z,floor}(T_z - T_w) + k_{amb,w}(T_{amb} - T_w) \quad (1b)$$

$$\frac{dT_{slab}}{dt} = k_{z,slab}(T_z - T_{slab}) + k_h(T_{feed} - T_{slab})u_h + k_c(T_{feed} - T_{slab})u_c \quad (1c)$$

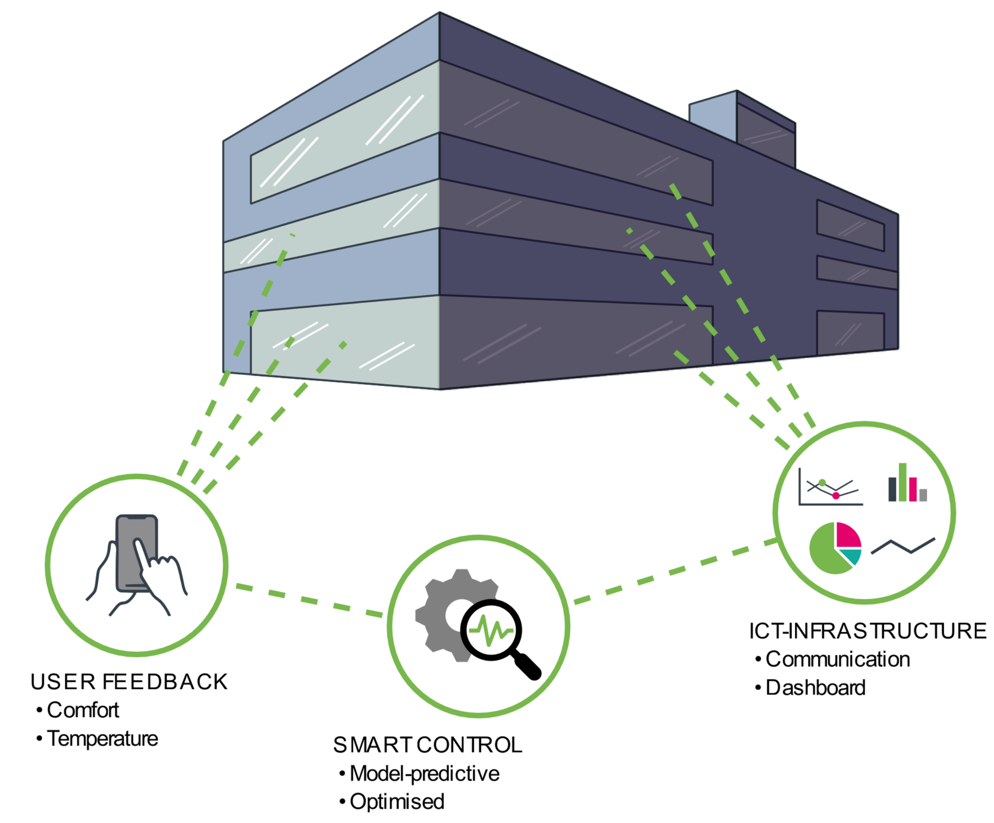
where T_z, T_w and T_{slab} is the temperature of the zone, the wall and the concrete slab, respectively. As external influences the ambient temperature, solar radiation and internal loads are considered. An **unscented Kalman filter (UKF)** handles the simultaneous state and parameter estimation.

User Feedback Integration

A model-based approach is used for incorporating the user feedback in the EMS. A comfort model is calibrated, based on the actual users. For this, a simple **web-based feedback system**, with a five-point Likert scale (“much too cold”, “too cold”, “pleasant”, “too warm” “much too warm”), is used. The feedback is viewed as measurements from the internal comfort model, and an UKF updates its parameters.

Case Study

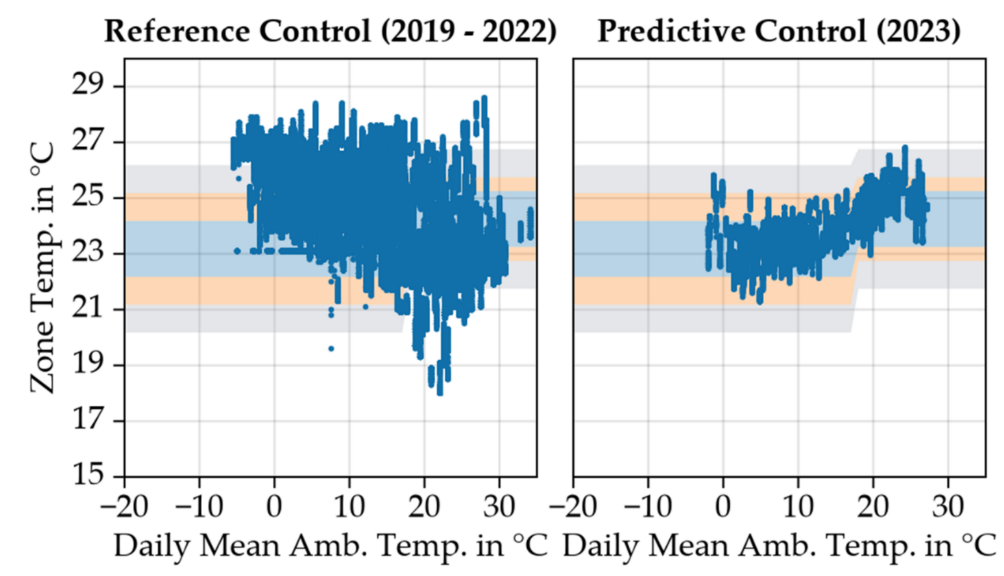
As a case study an **office building at the INNOVATION DISTRICT Infeld**[3] is considered. Each floor is actuated with only one valve and the temperature measurements from only one sensor per floor are collected.



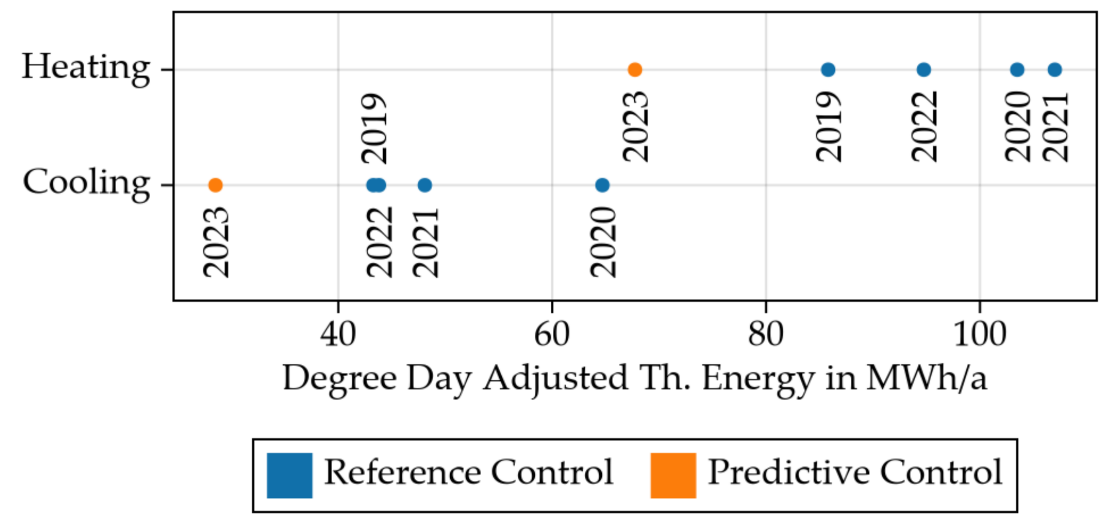
Schematic view of the building energy management system for Inffeldgasse 21b. The main components are the EMS, the user feedback integration and the ICT-infrastructure.

Results

The control scheme is running since 2023. Operation of the system for one year yielded significant results compared to conventional control. **Thermal comfort was improved by 12%** and **thermal energy consumption for heating and cooling was reduced by about 35 %.**



Zone temperature of the first floor for the new control scheme and a reference timespan (2019 - 2022) with the old control scheme (2023).



Comparison of the thermal energy for heating and cooling for the new control scheme (2023) and a reference timespan with the old control scheme (2019-2022). The values are adjusted for the different numbers of degree days. This ensures that years with different environmental conditions are comparable.

Conclusion

- A predictive control scheme for thermal control of buildings was implemented and its performance demonstrated in a **long-term validation.**
- Model-based handling of user feedback ensures that the wellbeing of the users is considered explicitly in the control scheme.
- Thermal comfort was improved by 12% and thermal energy consumption for heating and cooling was reduced by about 35 %.

Literature

1 IEA, “Buildings,” 2022. [Online]. Available: https://www.iea.org/reports/buildings.
2 V. Kaisermayer, J. Binder, D. Muschick, G. Beck, W. Rosegger, M. Horn, M. Gölles, J. Kelz and I. Leusbrock, “Smart control of interconnected district heating networks on the example of “100% Renewable District Heating Leibnitz”,” Smart Energy, vol. 6, 5 2022.
3 https://www.tugraz.at/tu-graz/universitaet/klimaneutrale-tu-graz/innovation-district-inffeld

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