Energie und Umwelt – Meine Idee für morgen
Model Predictive Control Strategies for Power to Heat of Buildings
Motivation

- **EU Green Deal**
  - first climate neutral continent by 2050
  - target: net-zero greenhouse gas emissions (GHE)
  - more than 75% of GHE result from energy production and use
  - building sector: 40% of consumed energy

- **Demand for research in energy and buildings**
  - buildings’ energy demand: mostly heat
  - energy-efficient heat generation: heat pump
  - possibility for intelligent sector coupling (Power to Heat “P2H”) and control strategies

- **Heat pumps can benefit the power grid**
  - stabilize the power grid frequency by following a power demand signal (match electricity generation)
  - importance for grid stabilization: ongoing integration of volatile, renewable energy sources (wind, solar)
  - service quality depends on heat pump’s available capacity to store energy

- **Utilize buildings as thermal energy storage**
  - cost-efficient alternative to typical storages like water tanks or batteries
  - identification of this usually unused capacity: dynamic thermal building model
**Model**

- **Lumped Capacitance Model**

\[
C_i \frac{dT_i}{dt} = \sum_j \dot{Q}_{i,j} + \sum_k \dot{Q}_{i,k} \]

\[
\dot{Q}_{i,k} = \frac{T_k - T_i}{R_{i,k}}
\]

- **State-Space notation of LTI system**

\[
\dot{x}(t) = A x(t) + B u(t) + B_{x_m} z_m(t)
\]

\[
y(t) = C x(t)
\]

\[
x(0) = x_0
\]

\[
u = \dot{Q}_{hp}
\]

\[
z_m = [\dot{q}_{sun}, \dot{Q}_{internal}, T_{amb}, T_{ground}]^T
\]

\[
y = T_{air}
\]

\[
x = [T_{air}, T_{interior}, T_{walls, out}, T_{walls, in}, T_{roof, out}, T_{roof, in}, T_{floor, out}, T_{floor, in}, T_{ground}]^T
\]
Control

- **Model Predictive Control**
  - minimize the input $u$ in a cost functional $l$
  - cost factors $w_1, w_2, w_3, w_4$ weigh up the various optimization goals:
    - follow reference temperature signal $y_r$
    - reduce energy consumption $u$
    - reduce energy costs ($p$: energy price function)
    - follow reference power signal $u_r$

$$\min_{u(t)} \sum_{k=t}^{N-1} l(k, y(k|t), u(k|t))$$

$$x(k+1|t) = Ax(k|t) + Bu(k|t) + B_{zm} z_m(k|t)$$

$$y(k|t) = Cx(k|t)$$

$$l(k, y, u) = w_1(y_t - y)^T(y_t - y) + w_2 u^T u + w_3 p(k)^T u + w_4 (u_r - u)^T (u_r - u)$$
Literature


