Technische Hochschule Ingolstadt
Institut für neue Energie-Systeme

Flexibility Potential by Decoupling Building Mass and Room Temperature

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Agenda

1. Introduction and Research Motivation

- Using thermally activated building systems as storage capacity
- Introduction to the research Project optLWP

2. Description of the Reference use-case

- Multi-layer thermally activated building systems
- Setup of the developed building model

3. Simulation Results

- Verfication of static and dynamic behaviour
- Evaluation of the building‘s cool down behaviour

4. Conclusion and Outlook

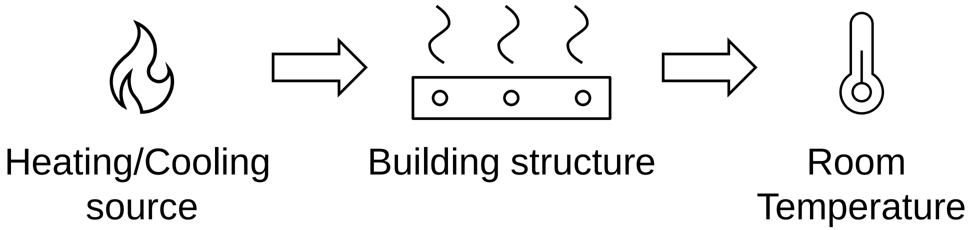
1. Introduction and Research Motivation

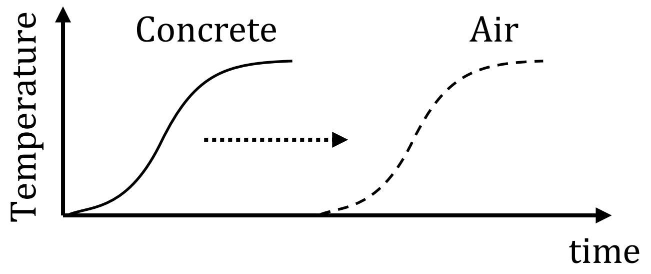
<u>Thermally activated building system (TABS) as storage capacity:</u>

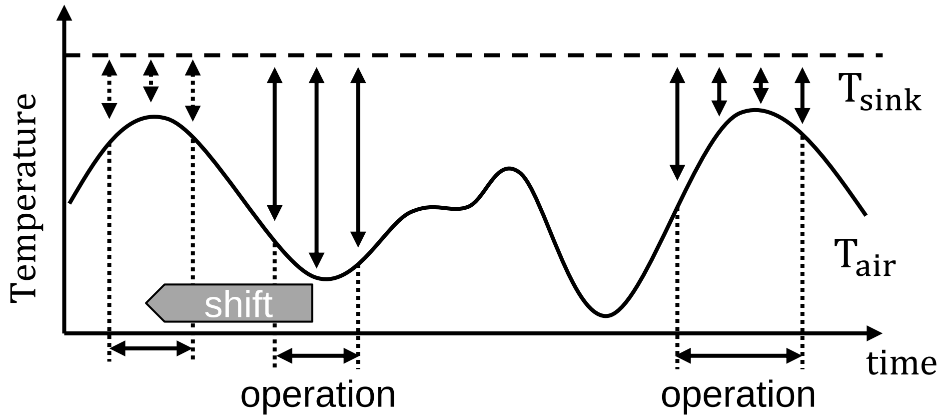
- Heat transfer from building mass to room temperature takes time
- Offers flexibility for the operation of the heating system
- In literature studies have been done in terms of:
  - Increase self consumption
  - React on dynamic price signals
  - Perform peak shaving
- **Limitation/Restriction:** Thermal comfort of the occupants

<u>Research project optLWP:</u>

- Investigate the benefits of using **thermal building mass** to improve the operation of **an Air-Source Heat Pump**
- Two benefits:
  - Varying ambient air temperature
  - Low supply temperatures needed to charge TABS

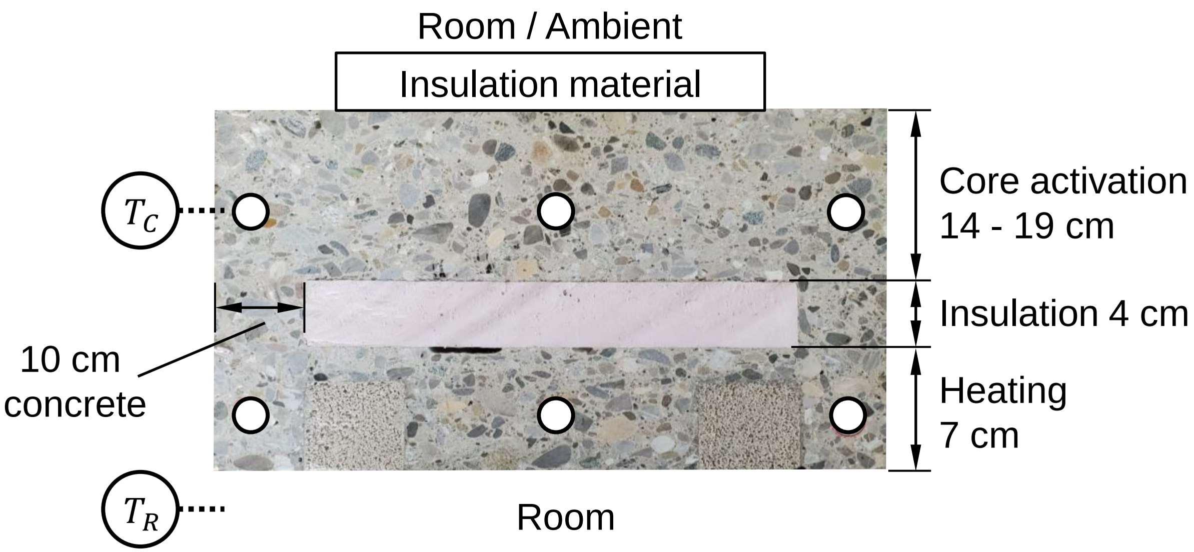






2. Description of the Reference Use-Case

Multi-Layer TABS concept & Research Question



During construction:

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- Decouples indoor and concrete temperature
- Increases the response time of the room temperature
- Enables active discharging of the concrete core

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- Additional grey energies (insulation, add. concrete / pipes, …)
- Acitve discharging requires auxiliary energy (pump electricity) and special hydraulic setup

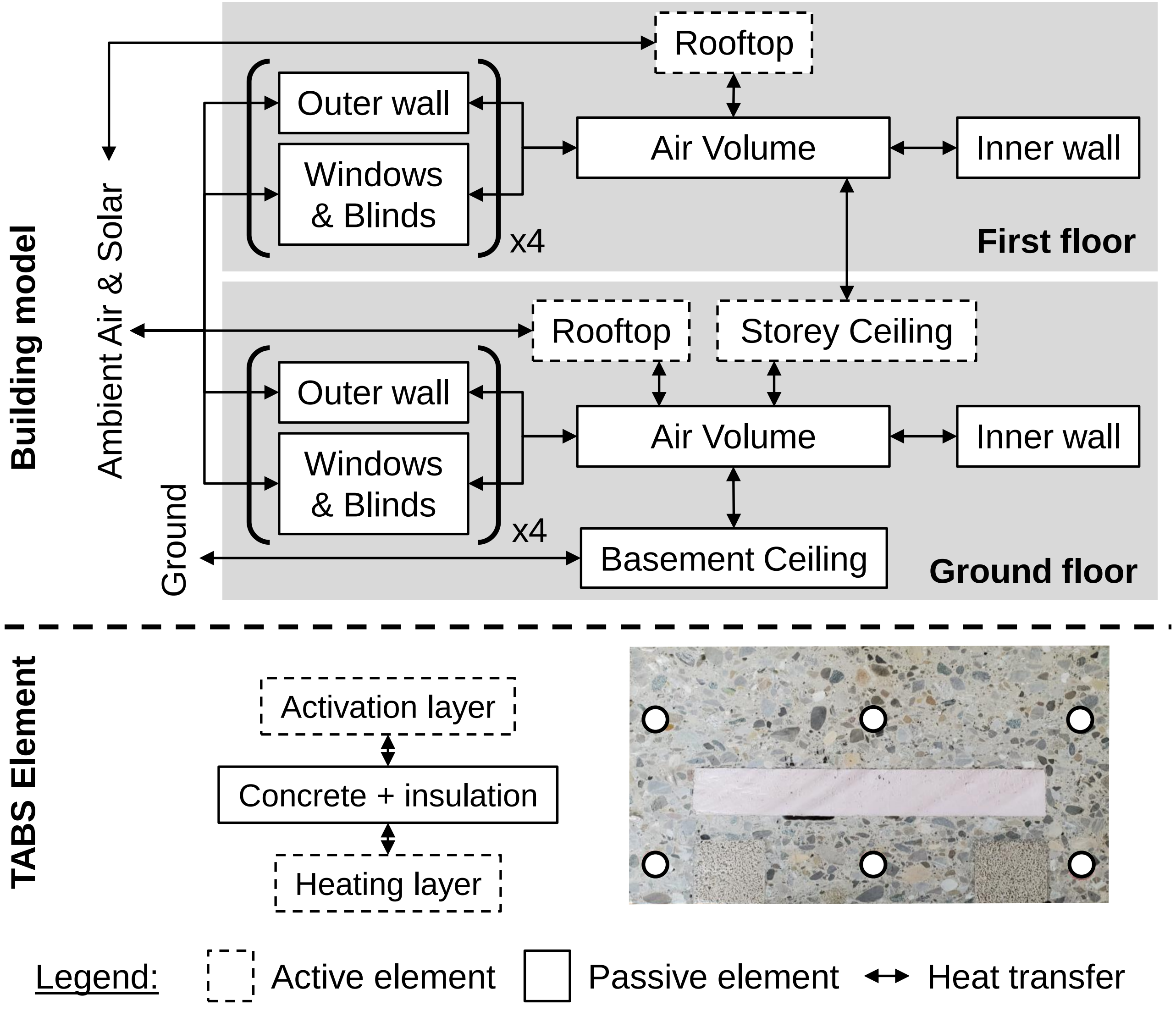
? Can the benefits of a multi-layer TABS concept compensate for or outweigh its disadvantages?

2. Description of the Reference Use-Case

Setup of the dynamic building simulation

<u>Building model</u>

- Simulation Environment: MATLAB/Simulink & CARNOT Toolbox (physical RC-model)
- Two thermal zones (one for each floor)
  - dynamic room temperature calculation based on radiation and convective heat transfer with adjacent surfaces
- Wall models (outer & inner wall, rooftop, ceiling)
  - 1D mutli-layer model (cp, lambda values according to planning documents)
  - Concrete + insulation layer: merging two parallel resistors
- Unheated basement → constant ground temperature ($18°C$)



3. Simulation Results

Verification of the static and dynamic behavior

Static behavior

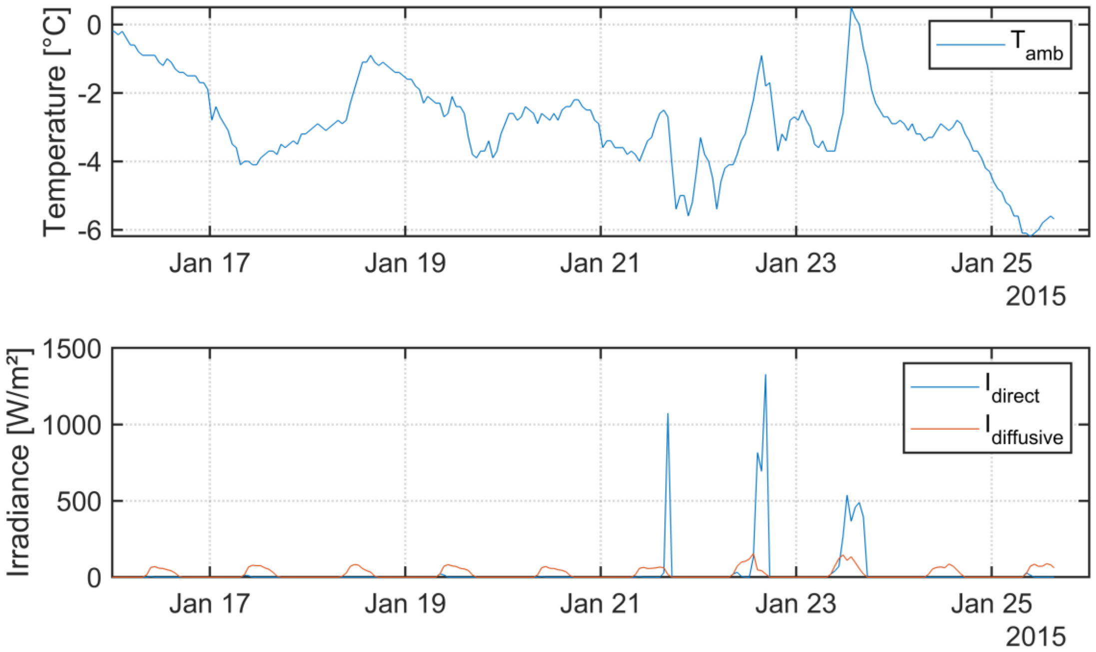
- Set-up according to DIN EN ISO 6946
- U-values match with planning documents: $\leq 0.8\%$ max. deviation

Dynamic behavior

- Investigate active charging and passive discharging process
- Compare it to results of literature [1]
  - Procedure in accordance to investigations of Fraunhofer IBP (good exchange within IEA ES Task 43):

1. Charge until 22 °C room temperature (Ground and First floor respectively)
2. Measure the duration until the room temperature drops below defined temperature limits (for the first time)

Weather data (Source: German Weather Service)
Location: Ingolstadt, Germany



[1] H. Sinnesbichler, M. Kersken, „Thermische Energiespeicher: Windheizung 2.0: Entwicklung von zentralen Hochtemperatur- und Bauteil-Langzeit-Speichern für Windheizung 2.0 Wohngebäude", Fraunhofer-Institut für Bauphysik IBP, 2023.

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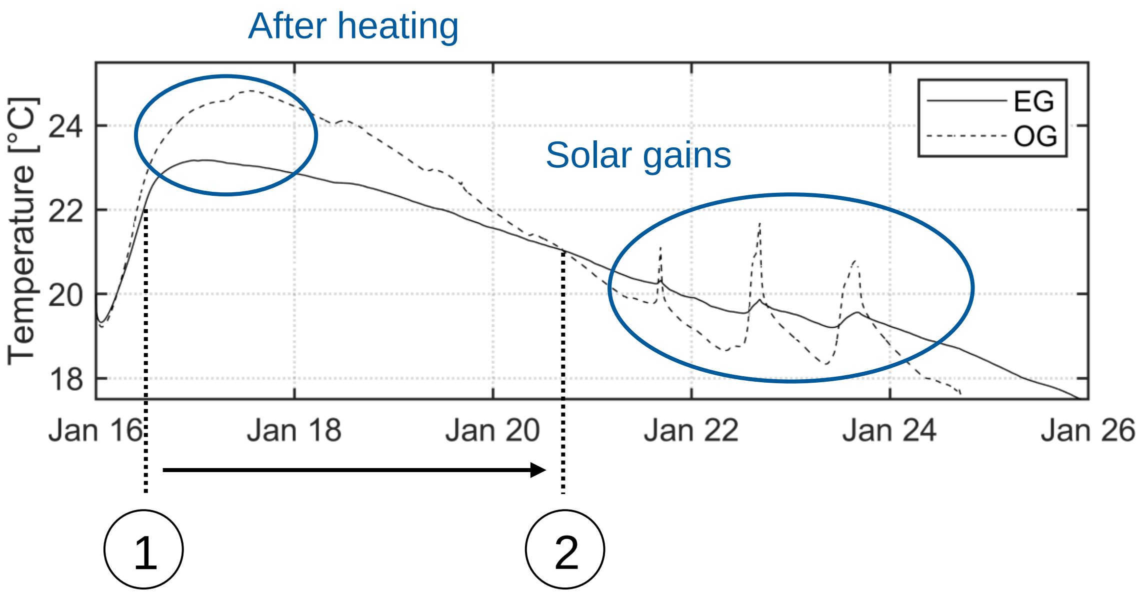
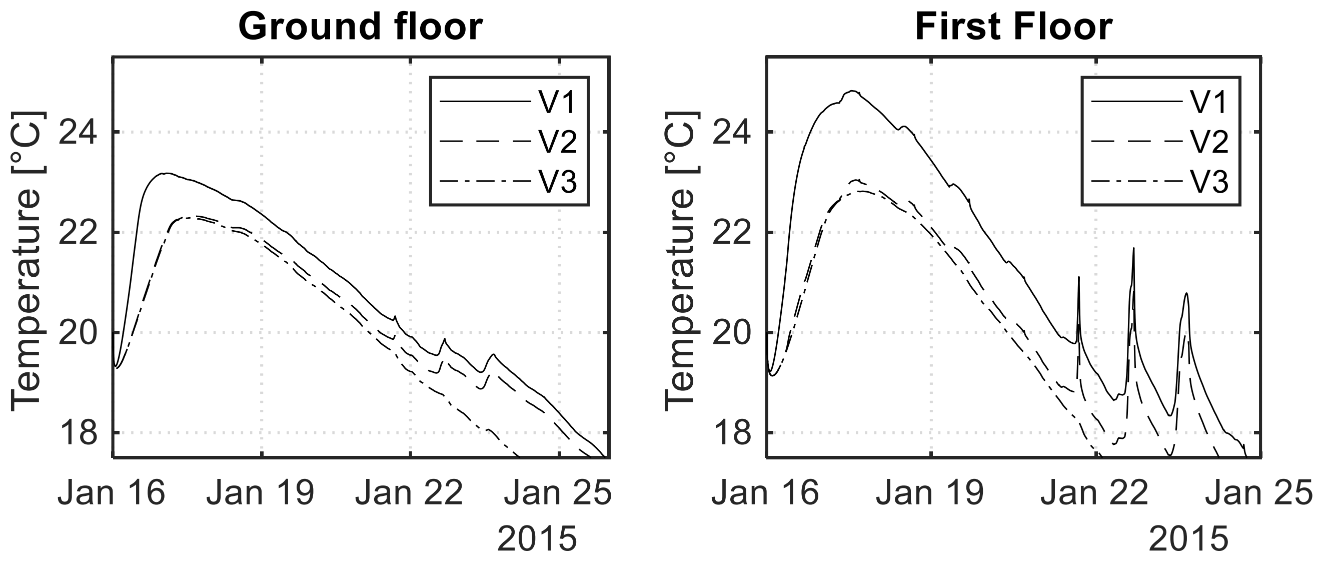


	Ground floor	First Floor	Literature study [1]
Charging time	12 h	10 h	7 h
21 °C	103 h	103 h	117 h
20 °C	129 h	117 h	158 h
19 °C	187 h	137 h	202 h
18 °C	213 h	191 h	-

3. Simulation Results

First Parameter Variation (Charging process)

	Volume-Flow (per heating-cycle)	Supply Temperature	Sunshade
V1	3 l/min	54 °C	0 %
V2	2 l/min	40 °C	0 %
V3	2 l/min	40 °C	100 %



V1	**Ground floor**	**First Floor**
Charging time	12 h	10 h
21 °C	103 h	103 h
20 °C	129 h	117 h
19 °C	187 h	137 h
18 °C	213 h	191 h

V2 & V3	**Ground Floor**	**First Floor**
Charging time	26 - 27 h	23 - 24 h
21 °C	68 - 74 h	64 - 70 h
20 °C	97 - 103 h	81 - 90 h
19 °C	123 - 147 h	98 - 104 h
18 °C	157 - 192 h	114 - 125 h

4. Conclusion & Outlook

- A dynamic Building model has been set up
  - Main capacities of the monitored reference building included
  - 1D-model of the multi-layer TABS concept used
- Heat losses of the building envelope are in accordance with the planning documentation
- Dynamic behaviour is expected to be reasonable based on a qualitative comparison with study from literature

Insights:

- Passive discharge of the multi-layer TABS can bridge times of 100h (thermal comfort will reduce the capacity further)
- After heating effects and solar gains can violate the thermal comfort boundaries and increase the storage losses (predictive controller incl. weather forecasts can be advantageous)

Next Steps:

- Modelling of relevant heat bridges & comparison of simulation and monitoring data
- Implement (predictive) controller to manage charging/discharging TABS & stay within thermal comfort boundaries
- Perform annual simulations to evaluate the extra flexibility of a multi-layer TABS concept by comparing with a typical TABS

Thank you for your attention!

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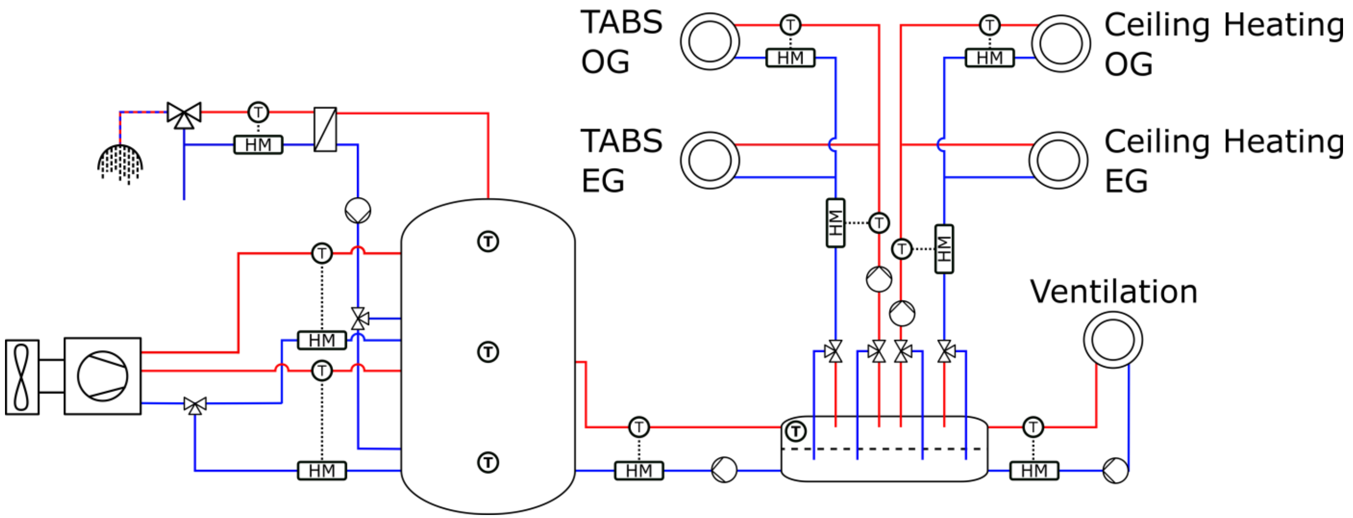
BACKUP

2. Research Project optLWP - Field Test

Monitored Reference Building



Reference Building:

- Located in Germany, Bavaria
- Constructed in 2017
- Living Area of 255 m²

Focus on an **energy efficient building operation**

- Ventilation system with heat recovery
- PV-System on the rooftop
- High insulation standard: H_T = 0.19 W/(m²K)
- Annual Final Energy Demand (DIN V 18599): 5.1 kWh/(m²a)
- Automated building operation using KNX → Included in the monitoring