



Institut für Wärmetechnik

Technische Universität Graz

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Graz University of Technology

Analysis of the thermal behavior of historical box type windows for renovation concepts with CFD

Graz University of Technology

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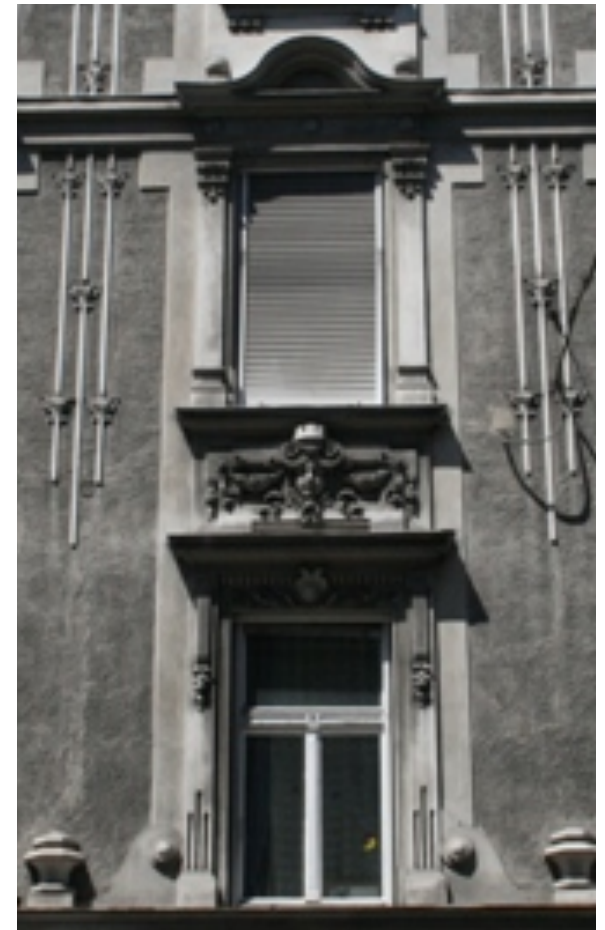
Ulrich Ruisinger



Introduction

Basic information

- Box Type Window (BTW), typical construction from early 19th to mid of 20th century
 - ca. 10 Mio. in Austria
 - ca. 100 Mio in Germany



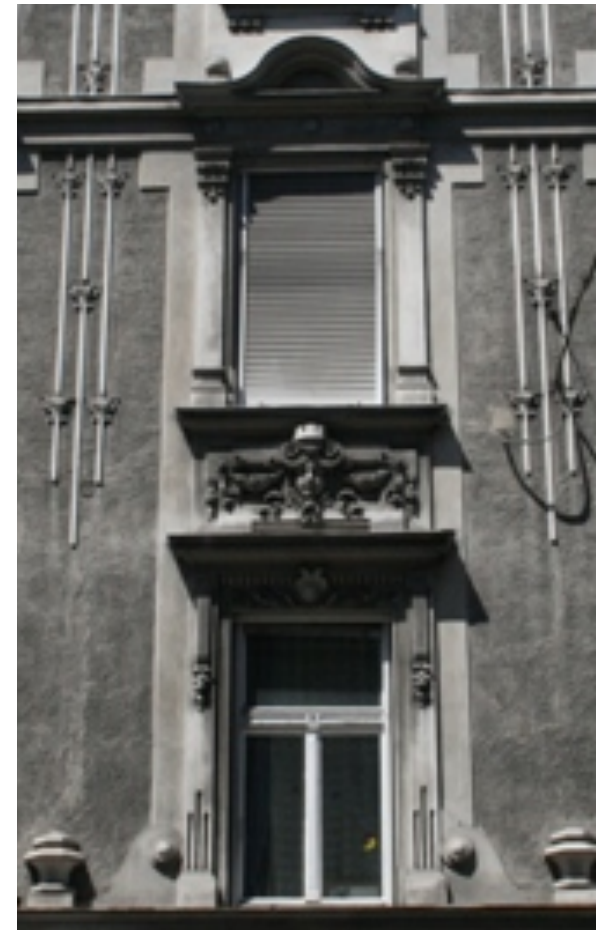
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- Better understanding of thermal behaviour as well as fluid dynamics inside the BTW
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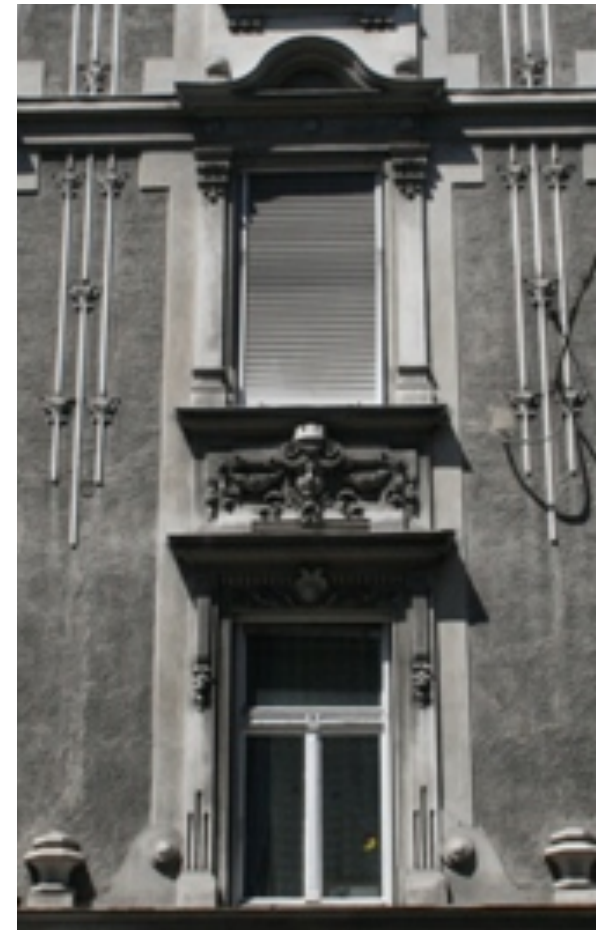
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Investigation methods

- In situ measurements
- **Computational Fluid Dynamics (CFD)**





Description of BTW

Double façade window

(1) Interior casement

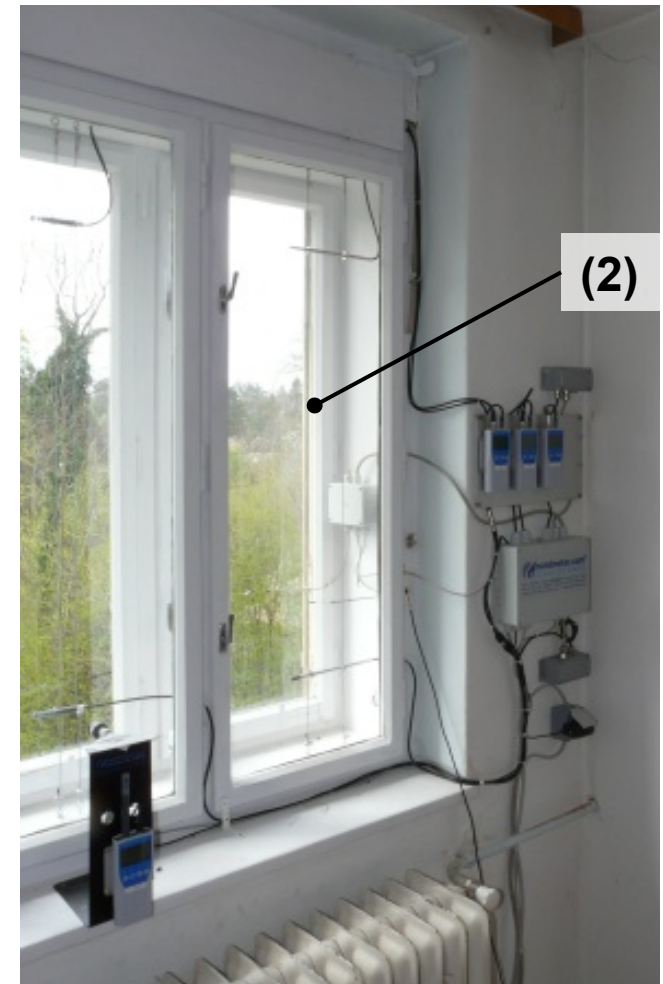




Description of BTW

Double façade window

- (1) Interior casement
- (2) Exterior casement





Description of BTW

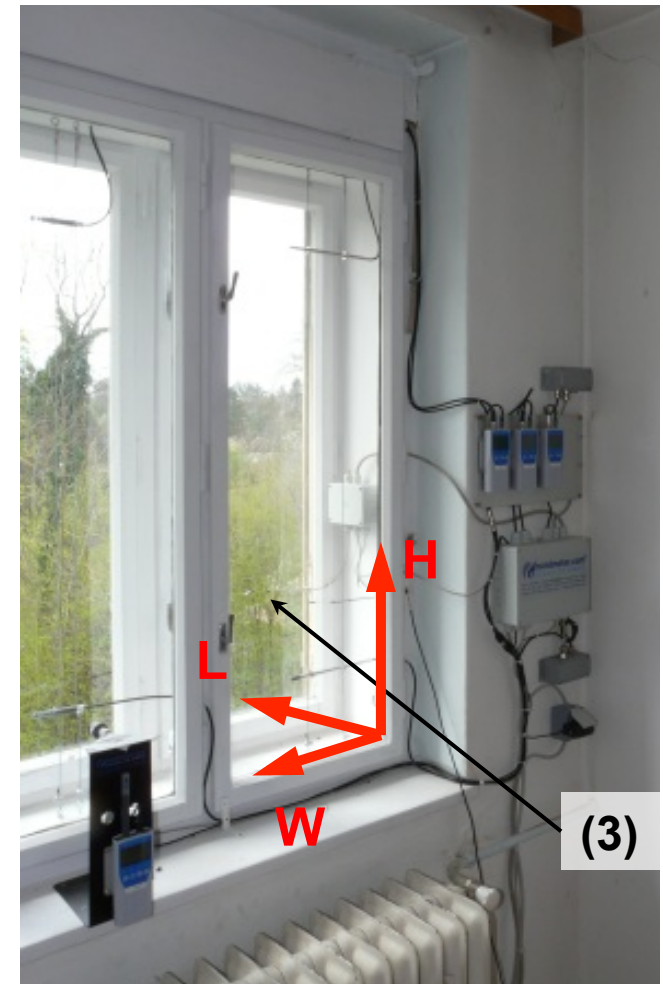
Double façade window

(1) Interior casement

(2) Exterior casement

(3) Air filled cavity

- Distance between casements about 150 and 200 [mm]
- Main dimensions are 1.63 x 1.76 x 0.28 [m] (W x H x L)





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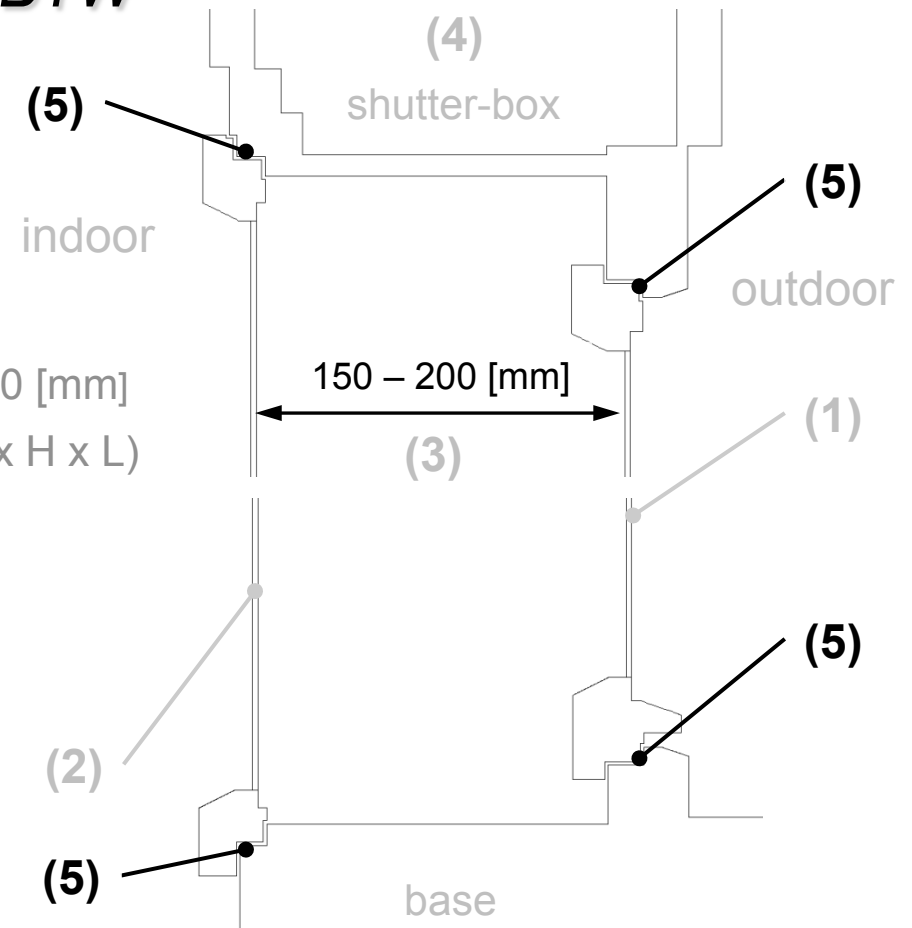
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- joint width about 0.5 to 5.0 [mm]





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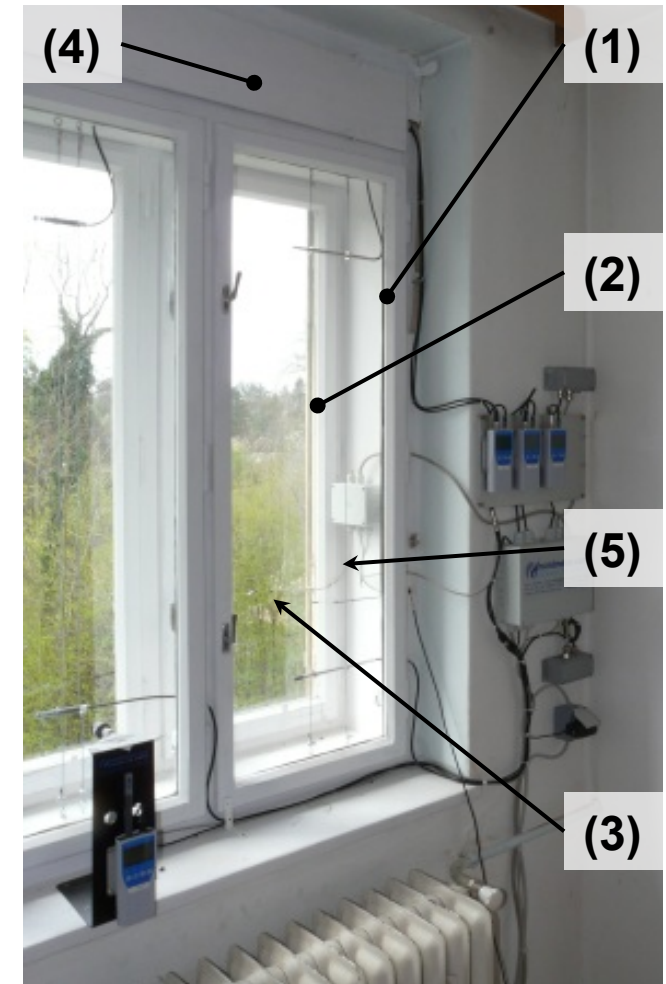
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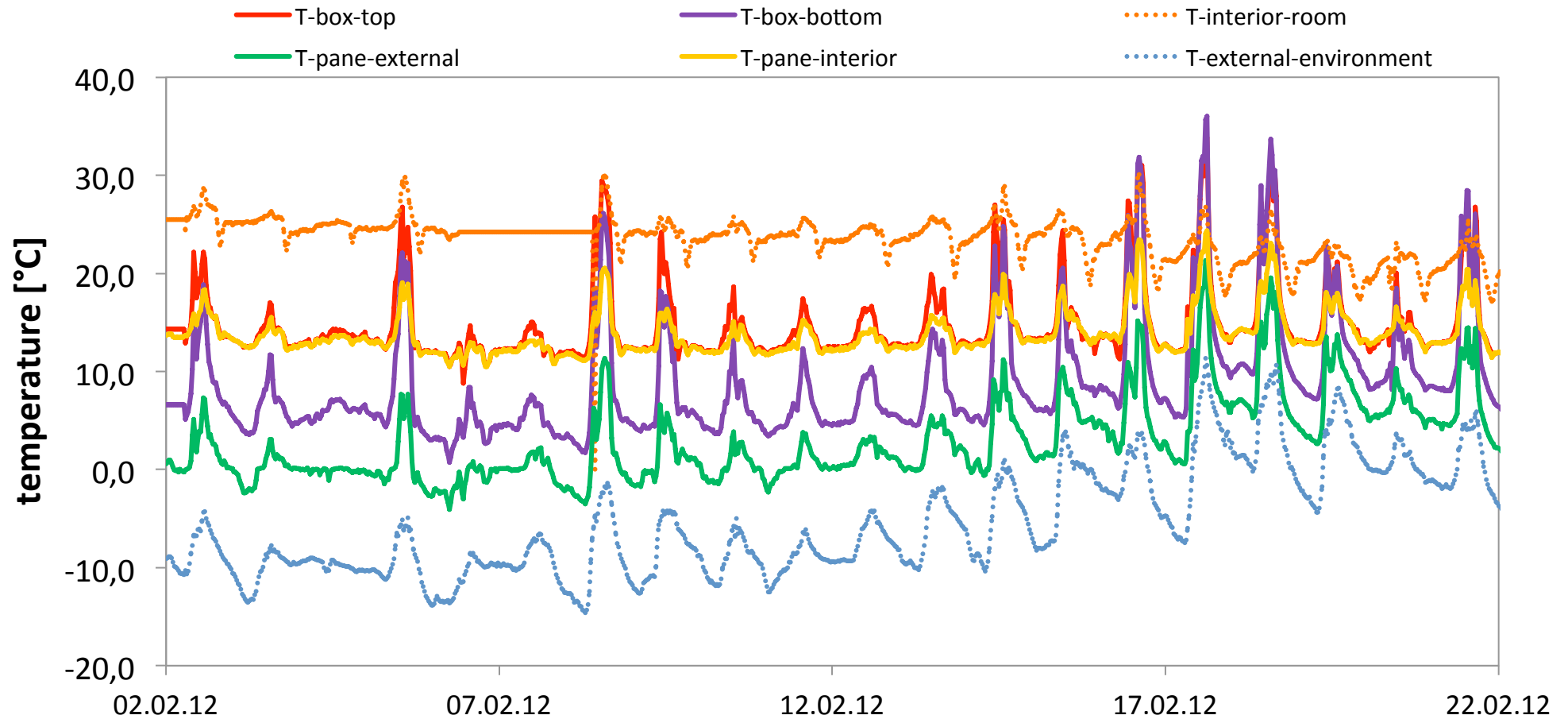
Functionality

- Joints allow natural air change
- Prevents damage of wooden parts by moisture



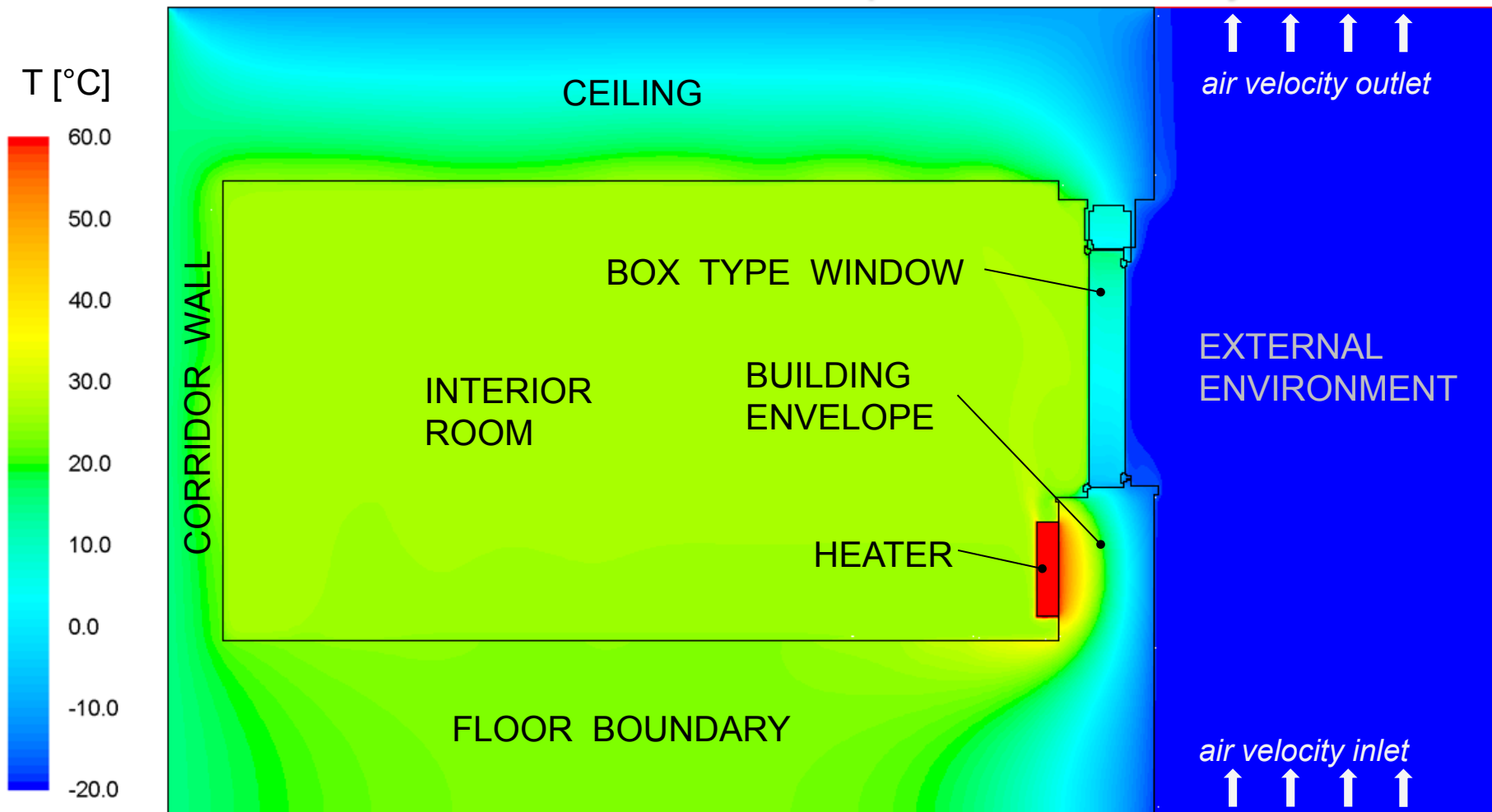


Measurement - results



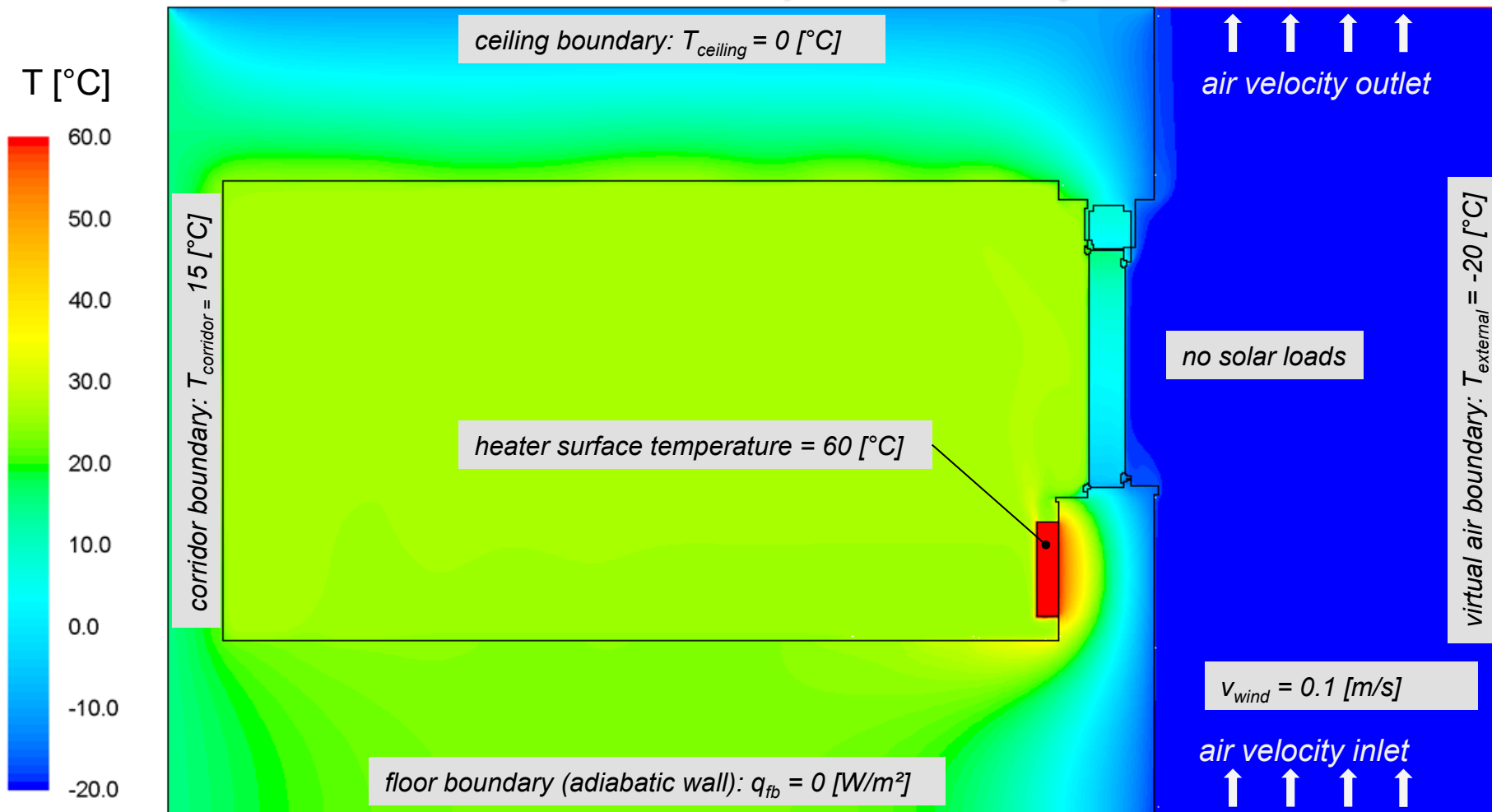


CFD - Simulation setup – 2D Geometry



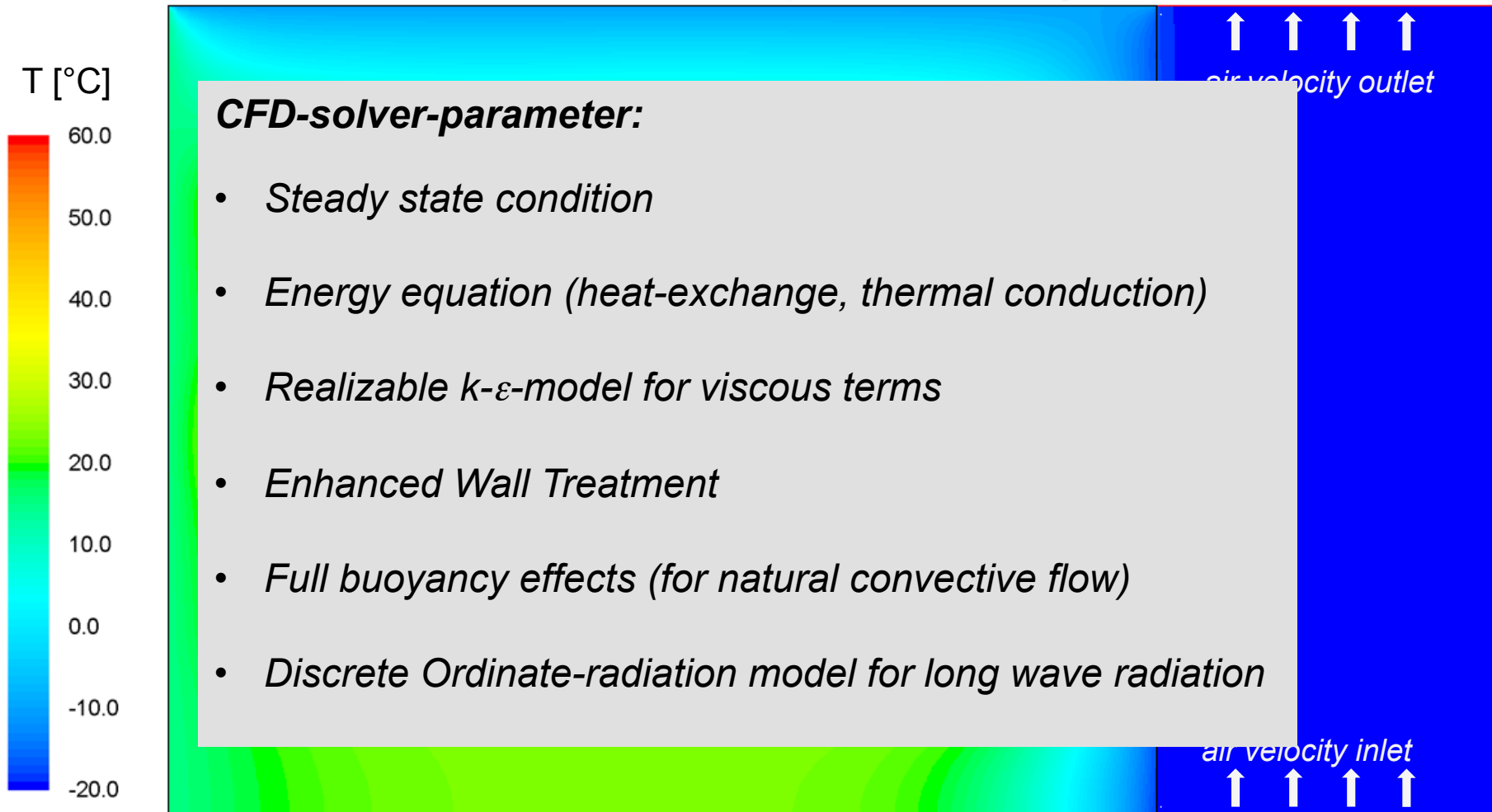


CFD - Simulation setup – Boundary Conditions



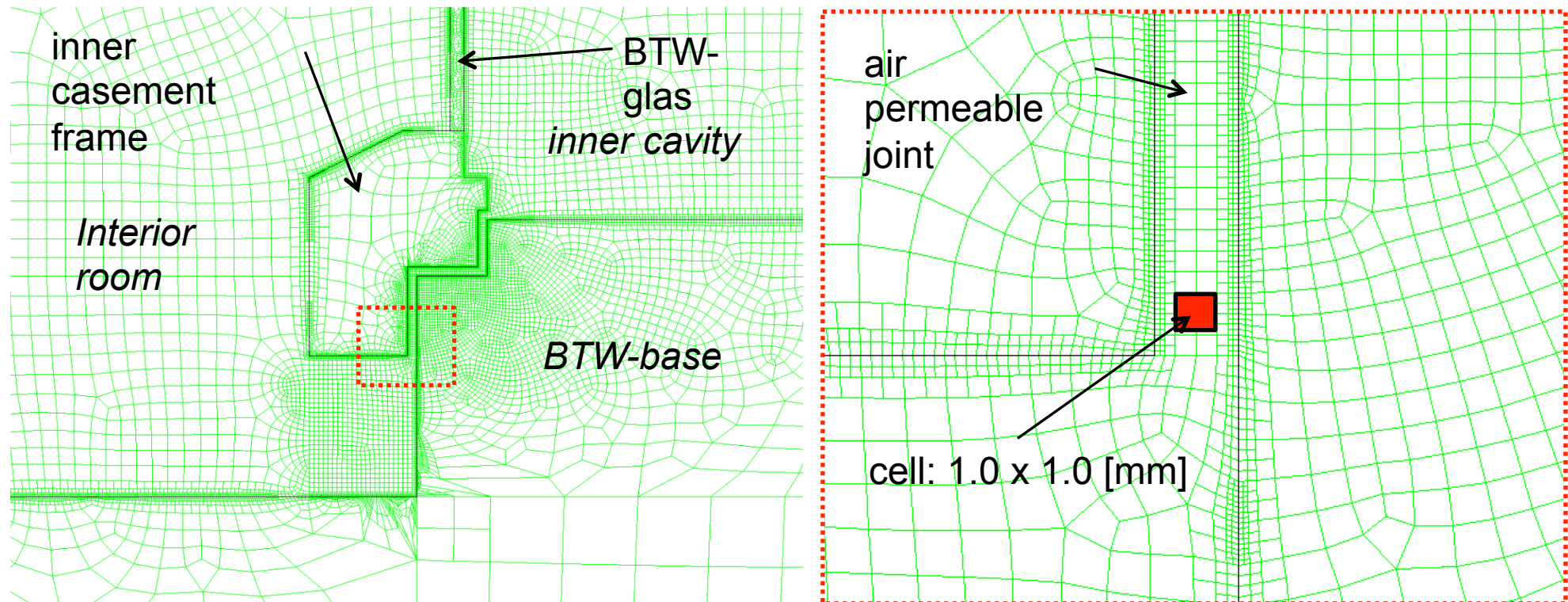


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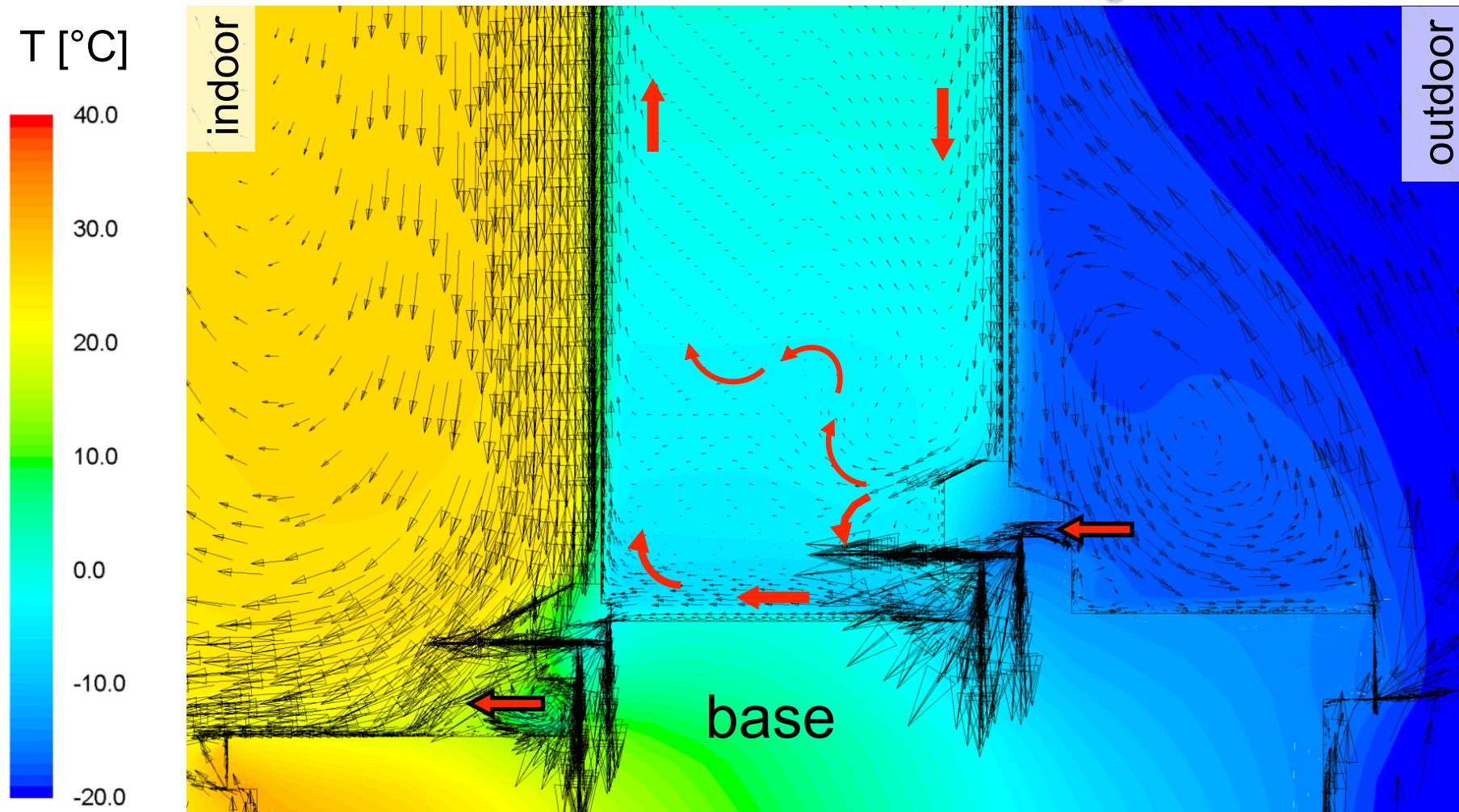


CFD - Simulation - mesh



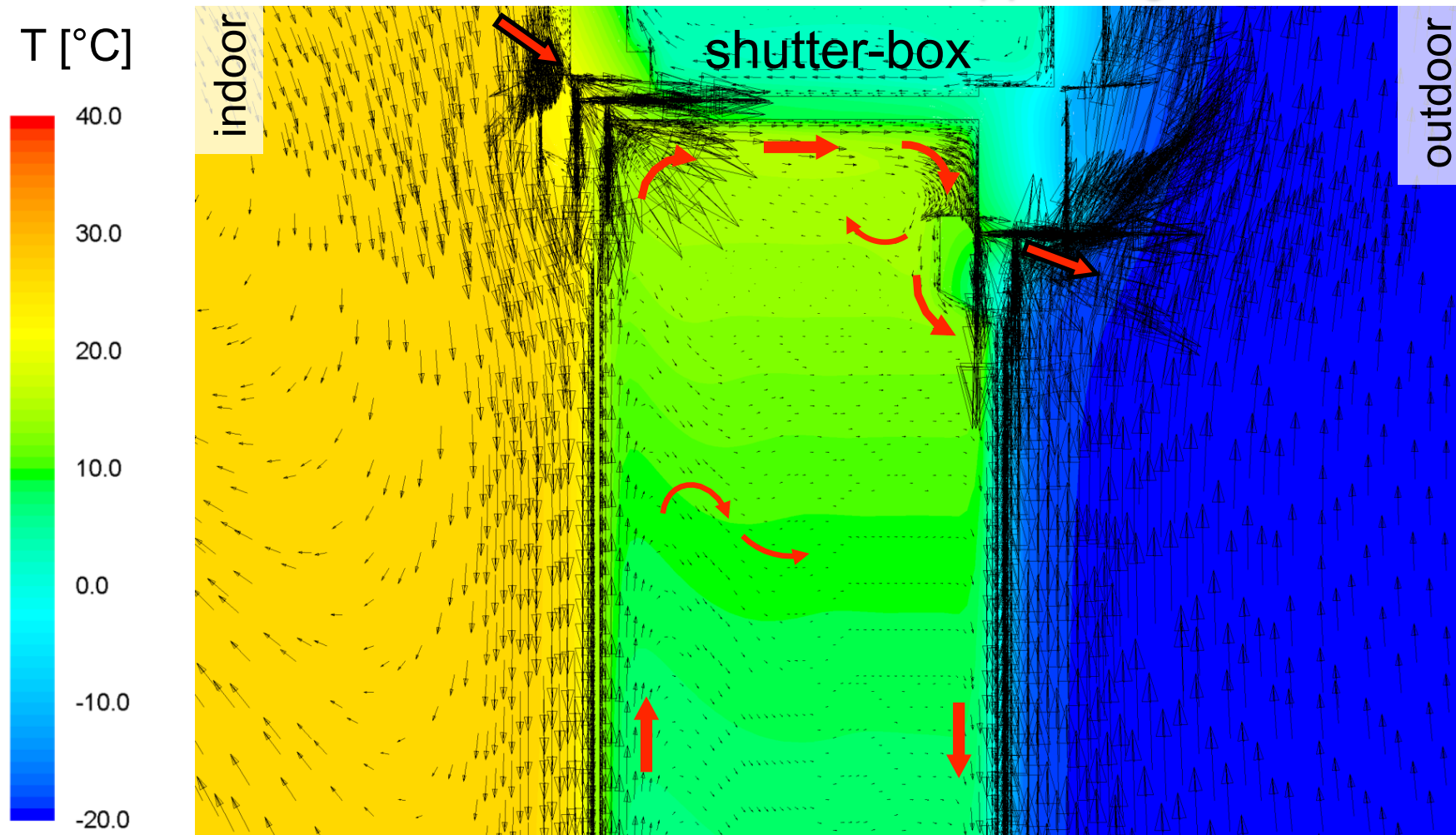


CFD – BTW refurbished – lower region





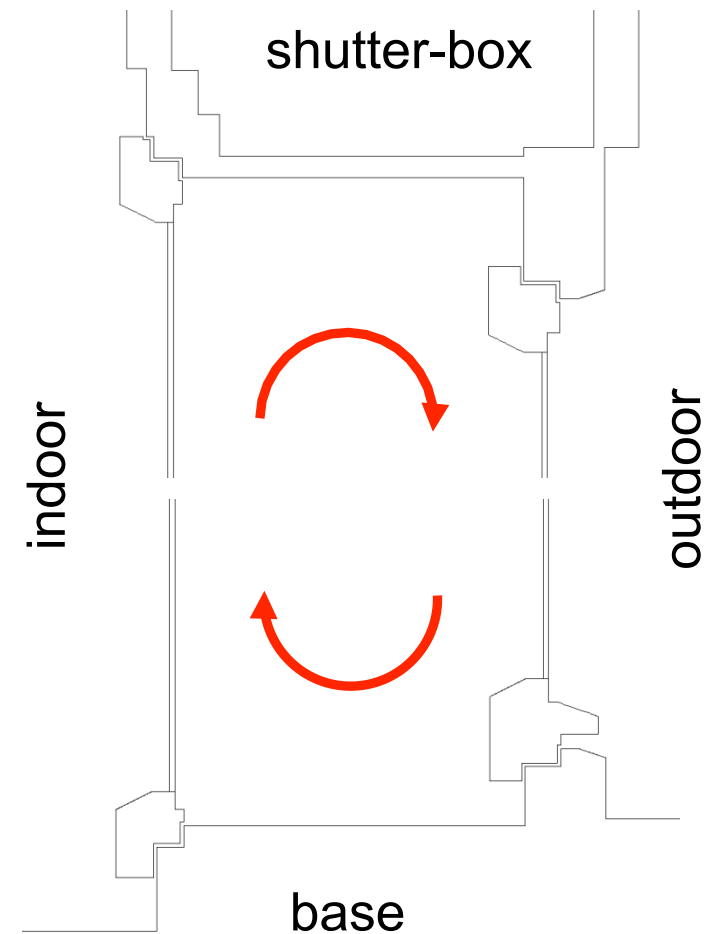
CFD – BTW refurbished – upper region





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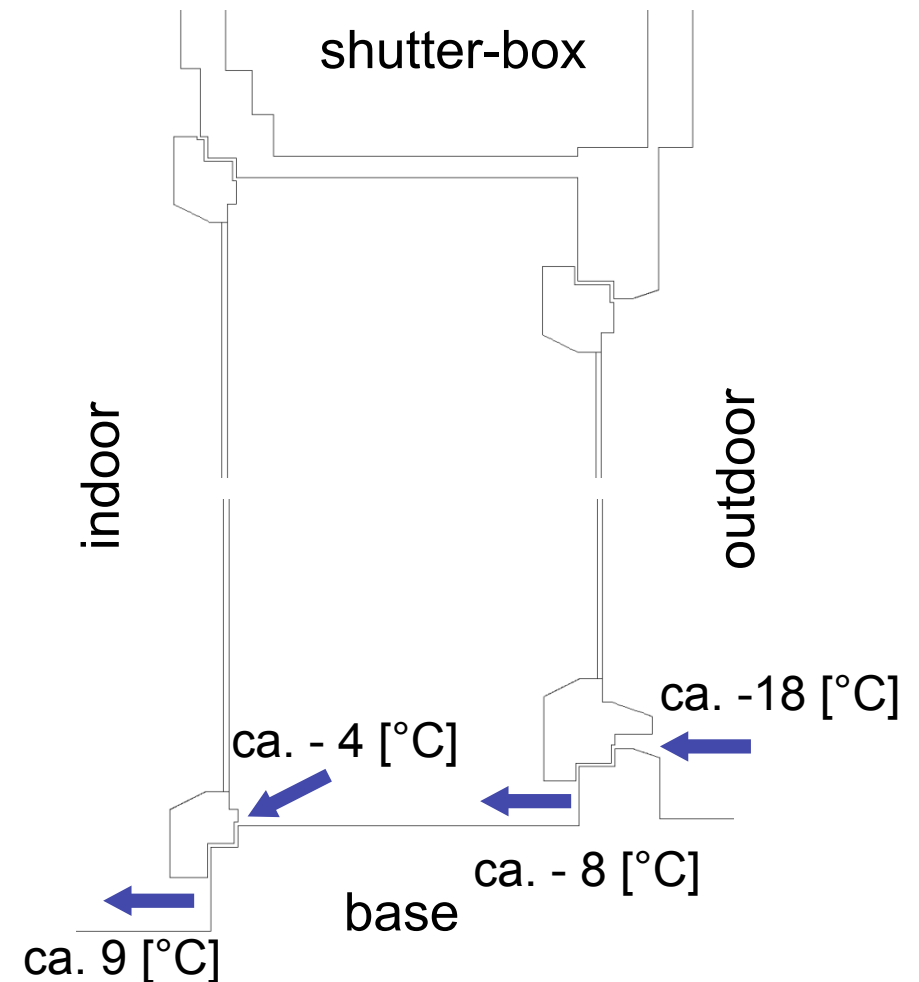
- Circulation of air inside the BTW cavity





CFD – BTW refurbished – upper region

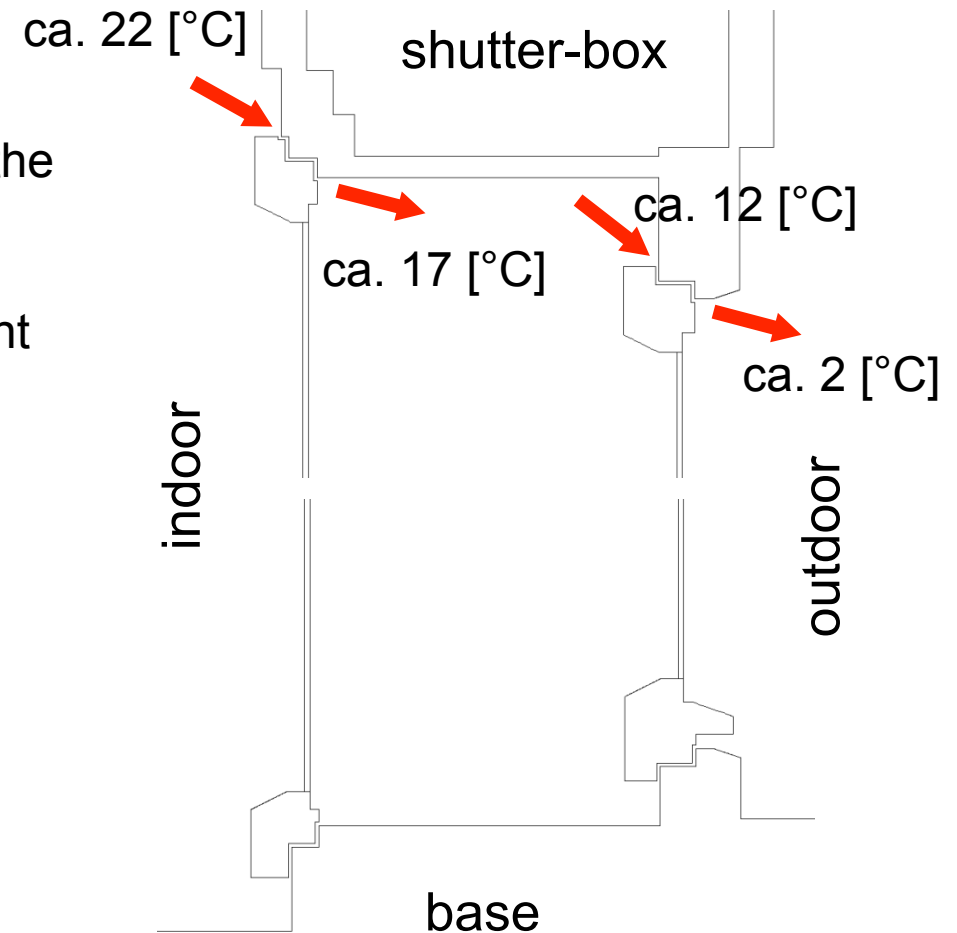
- Circulation of air inside the BTW cavity
- Cold air flows inside the cavity and also into the room





CFD – BTW refurbished – upper region

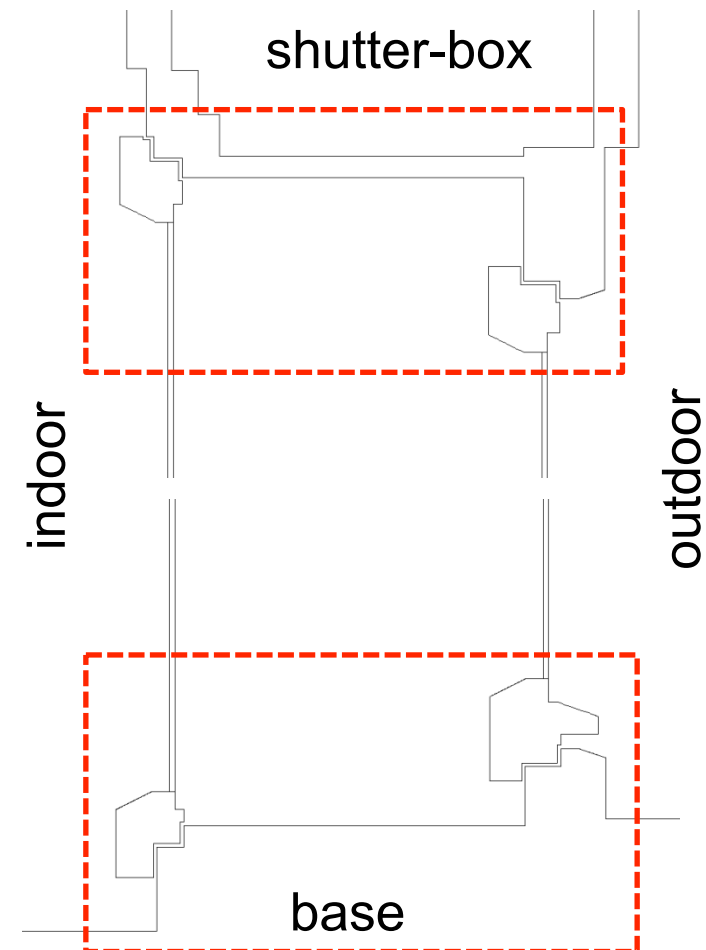
- Circulation of air inside the BTW cavity
- Cold air flows inside the cavity and also into the room
- Heated air got lost to the external environment





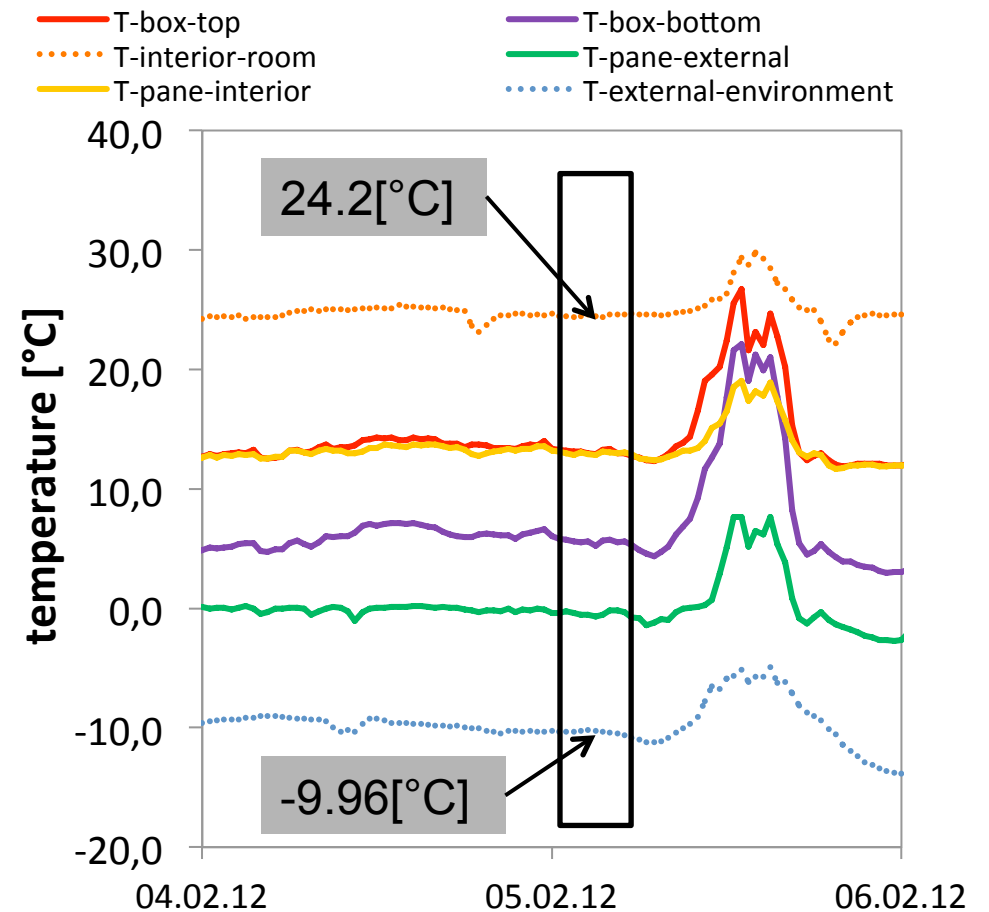
CFD – BTW refurbished – upper region

- Circulation of air inside the BTW cavity
- Cold air flows inside the cavity and also into the room
- Heated air got lost to the external environment
- Ventilation effects amplify the temperature stratification
- Turbulences occur in the region close to the air permeable joints





Boundary Conditions for comparison simulation and measurement





Measurement



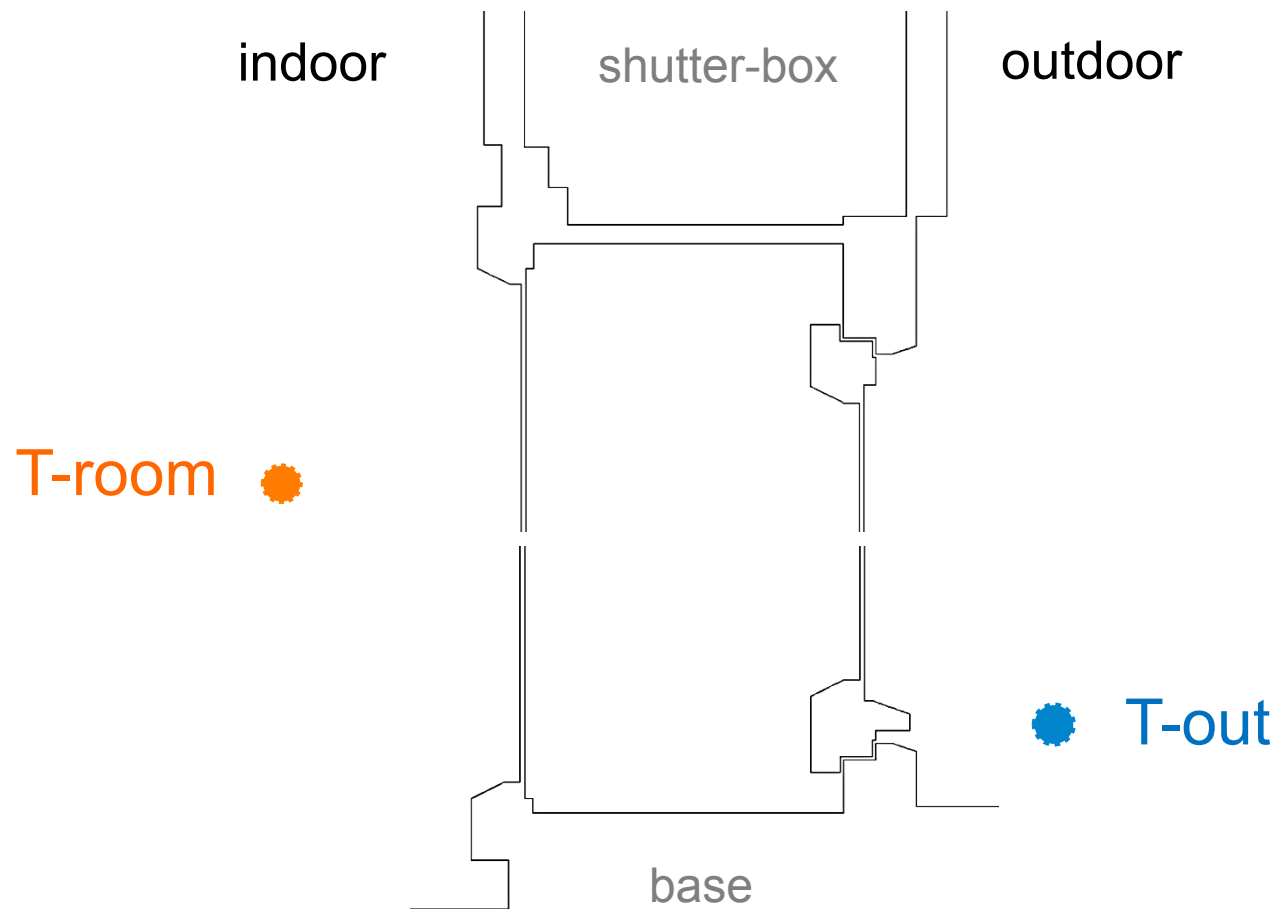
reference object of the research project “denkmalaktiv I”:
Schönbrunnngasse 30, 8034 Mariatrost in Graz, Austria,
a former mental home built in 1885, now a public kindergarten.

A.... BTW- refurbished B.... BTW-improved
(improvements: inner gasket frame, low-emission coating for
inner pane, thermal insulation for shutter-box)



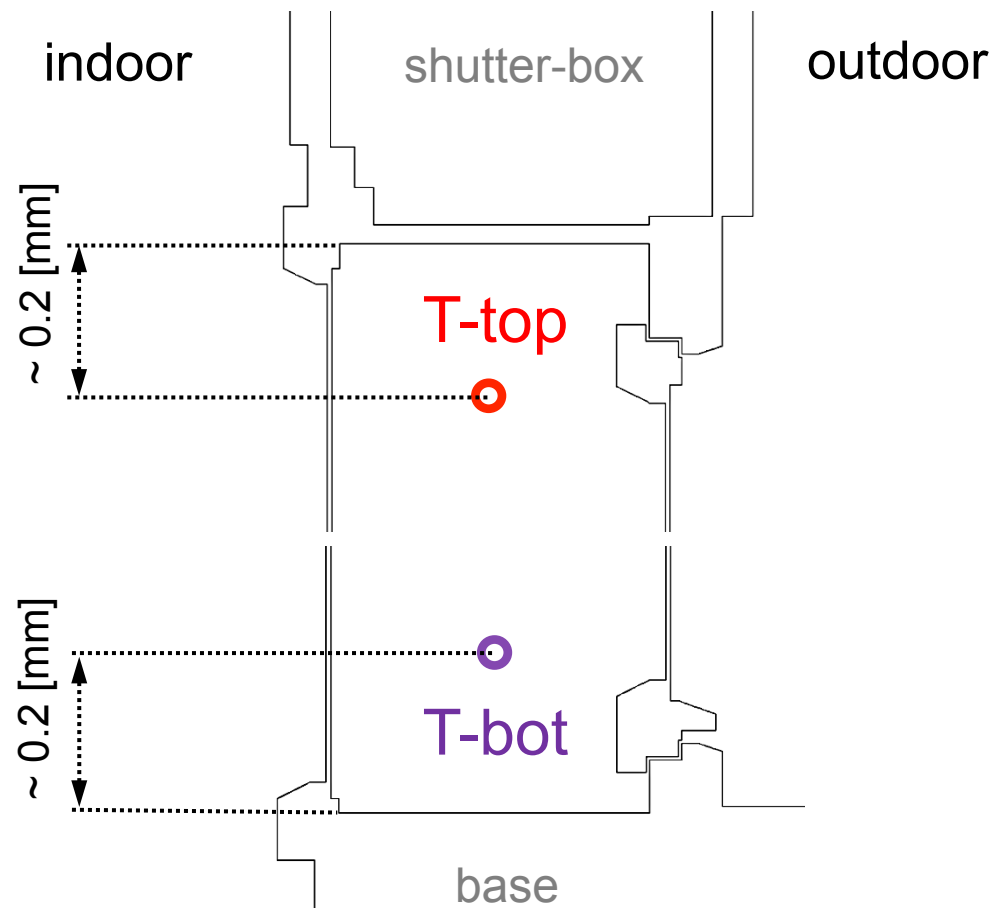


Measurement – temperature sensors



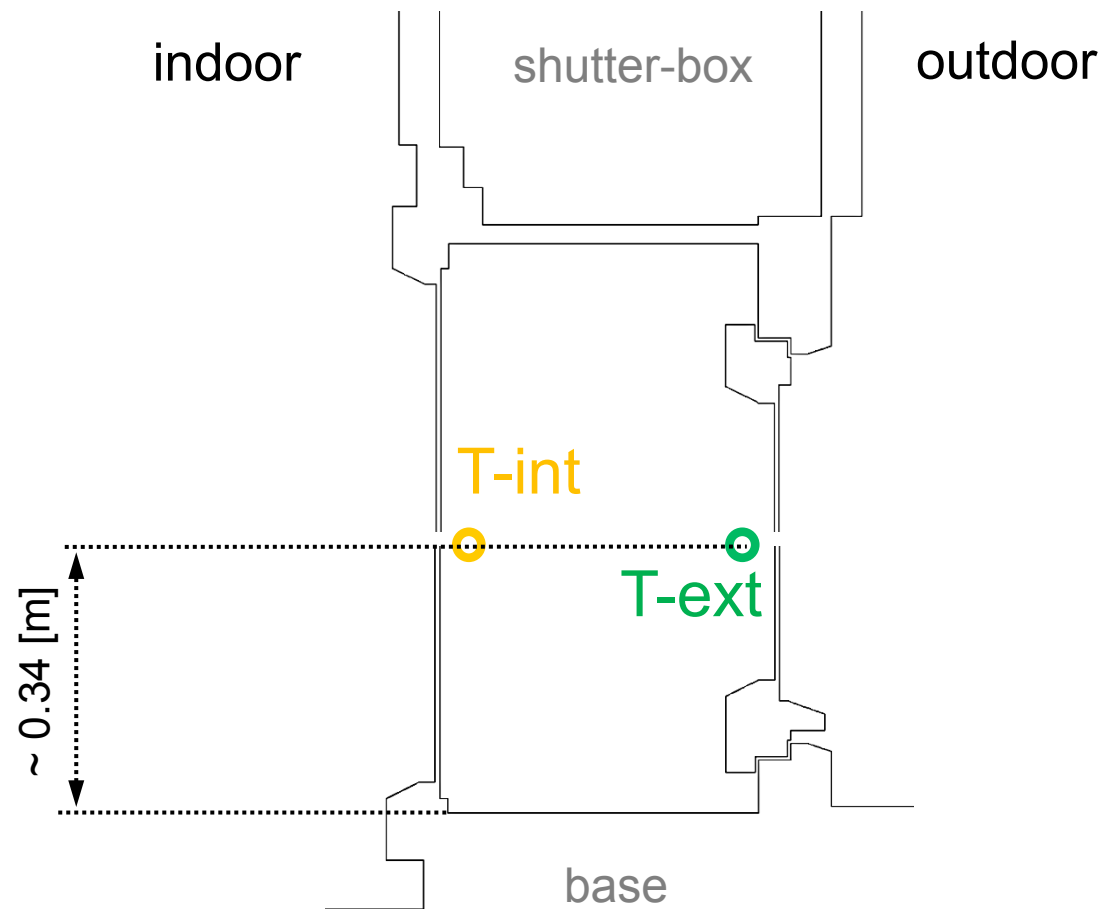


Measurement – temperature sensors



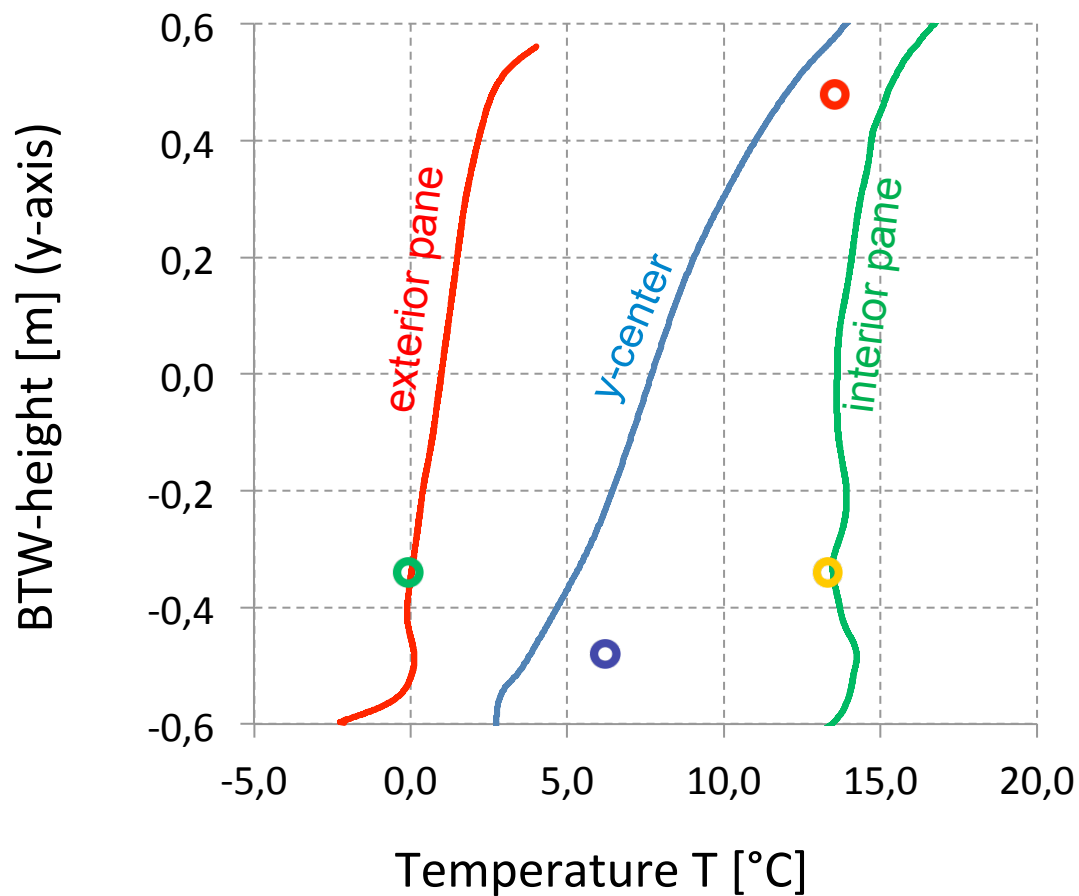


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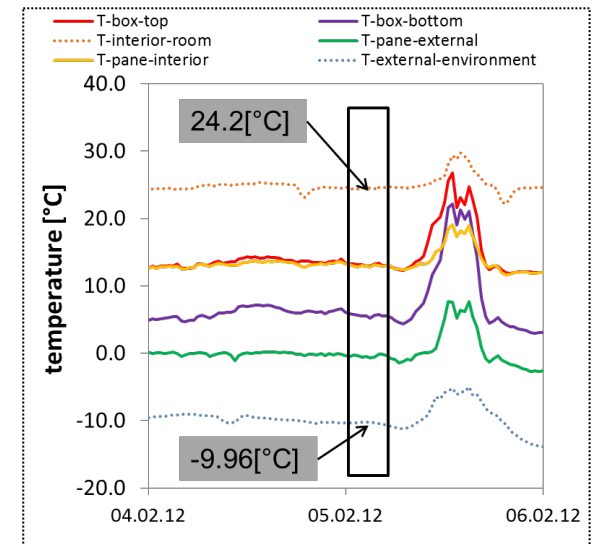




Comparison Measurement vs. Simulation

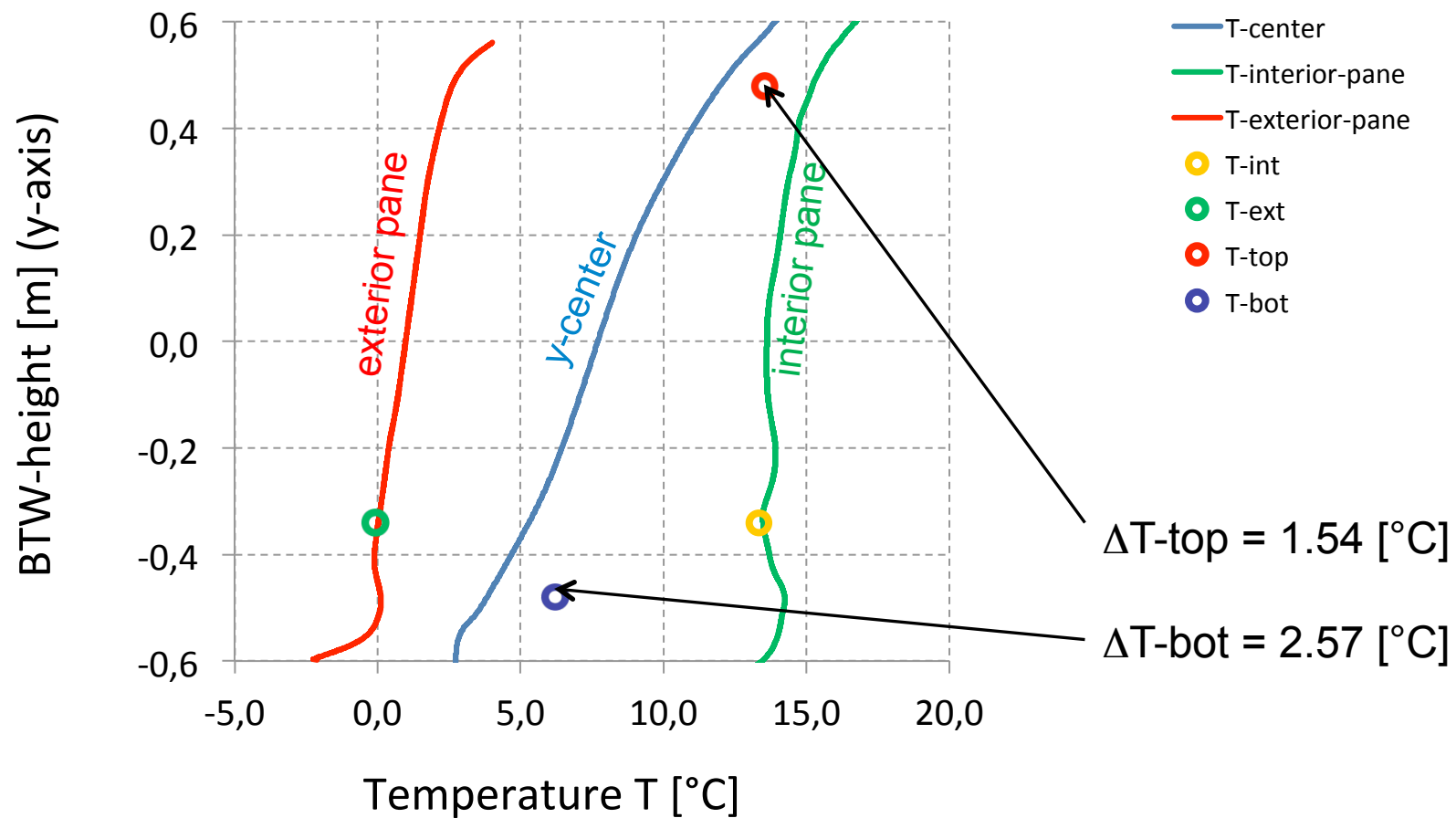


- T-center
- T-interior-pane
- T-exterior-pane
- T-int
- T-ext
- T-top
- T-bot



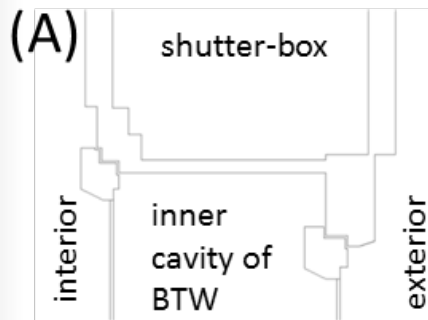


Comparison Measurement vs. Simulation





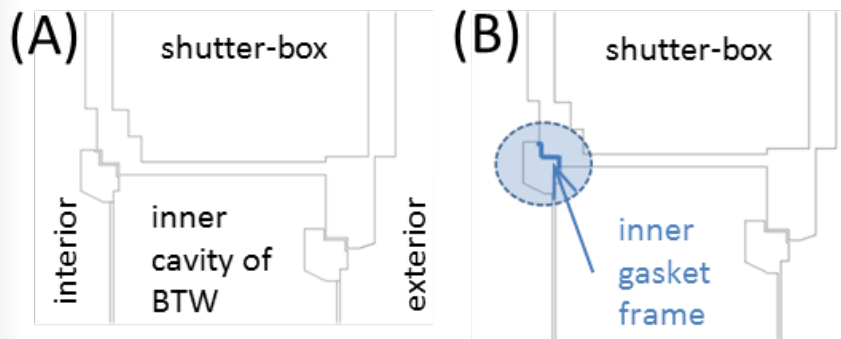
Renovation Concepts



A.... refurbished



Renovation Concepts

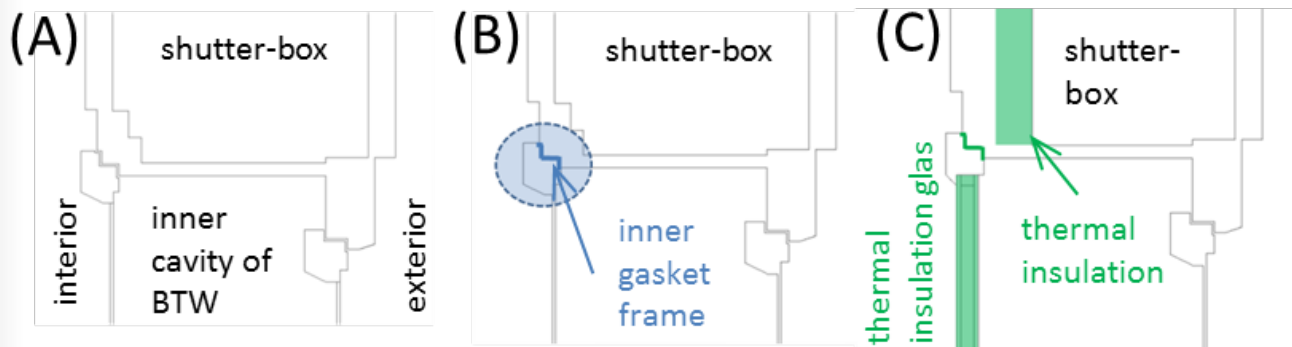


A.... refurbished

B.... inner gasket frame



Renovation Concepts



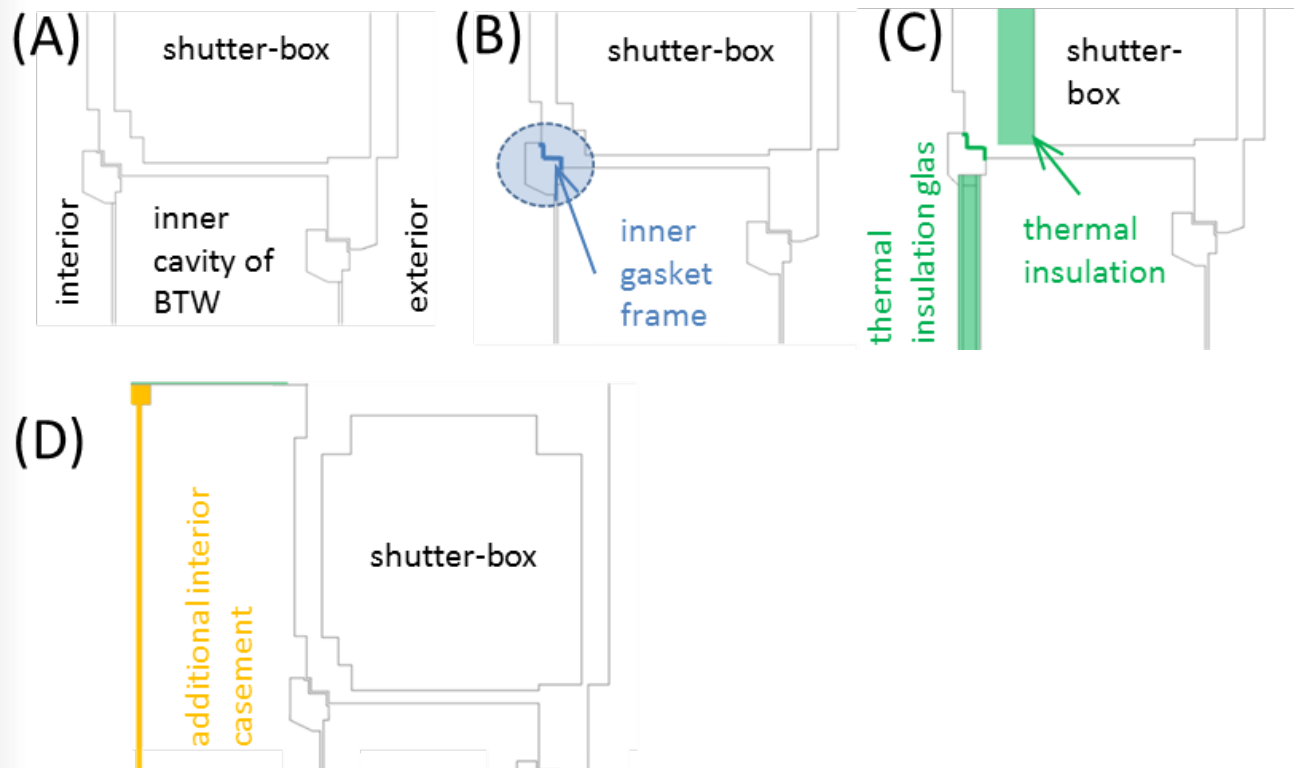
A.... refurbished

B.... inner gasket frame

C.... insulated glass inner casement and thermal insulation for shutter-box



Renovation Concepts



A.... refurbished

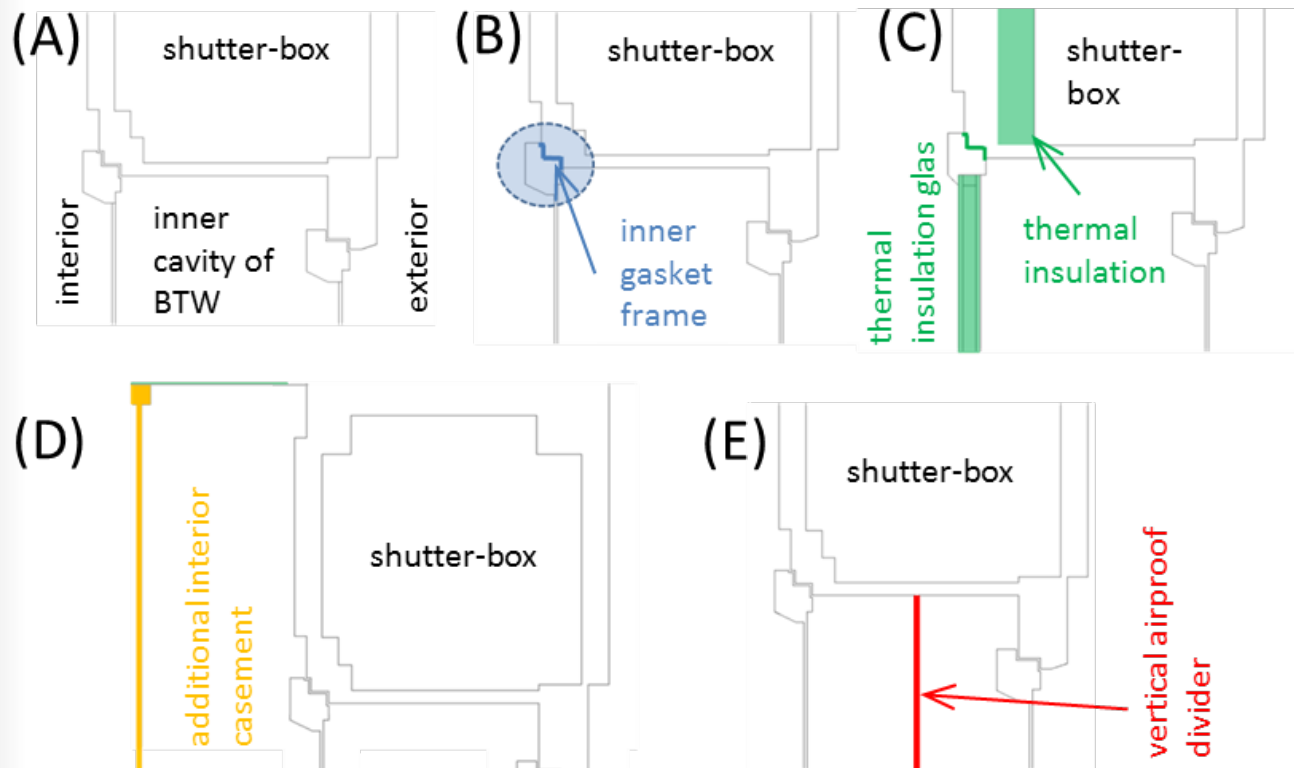
B.... inner gasket frame

C.... insulated glass inner casement and thermal insulation for shutter-box

D.... additional interior casement



Renovation Concepts



A.... refurbished

B.... inner gasket frame

C.... insulated glass inner casement and thermal insulation for shutter-box

D.... additional interior casement

E.... vertical airproof divider



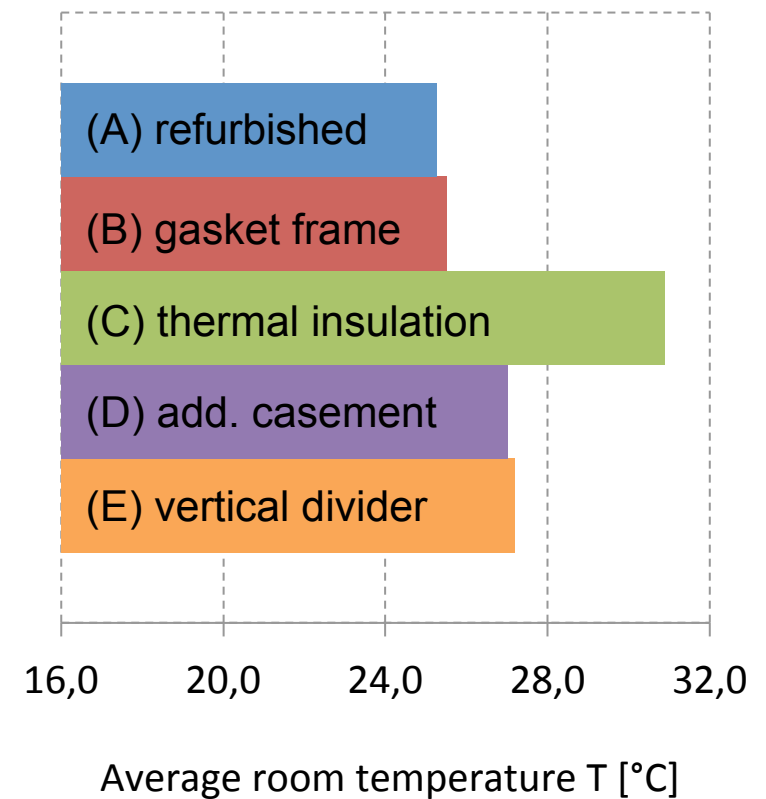
Comparison of the Renovation Concepts

- Average room temperature $T_{\text{average,BTW(i)}}$



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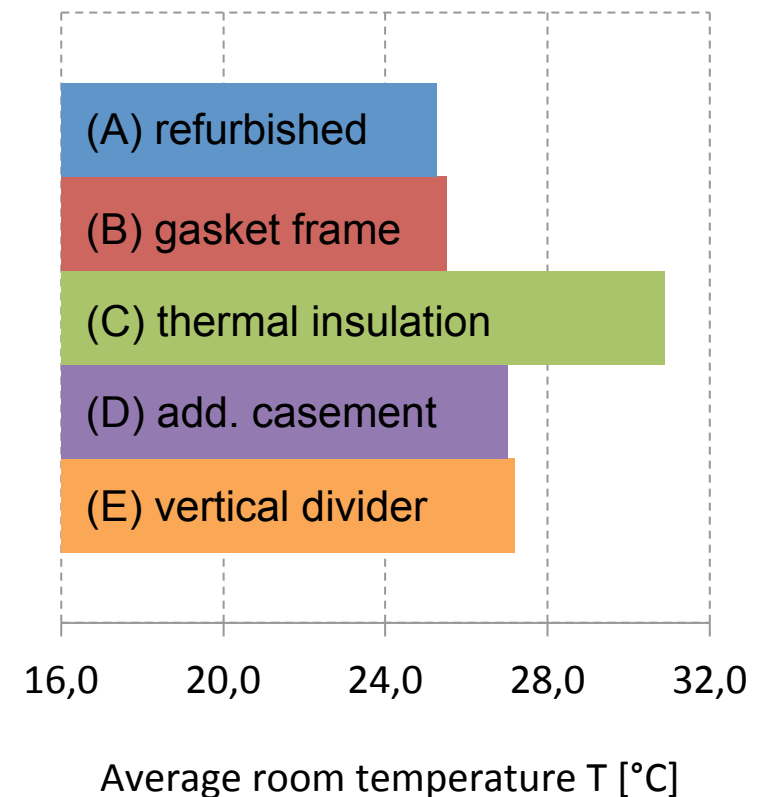




Comparison of the Renovation Concepts

- Average room temperature $T_{\text{average,BTW}(i)}$
- Rating = difference of average room temperature compared with (A) refurbished BTW

$$\text{rating}_{\text{BTW}(i)} = \frac{T_{\text{average,BTW}(i)} - T_{\text{average,BTW}(A)}}{T_{\text{average,BTW}(A)}} \cdot 100\%$$

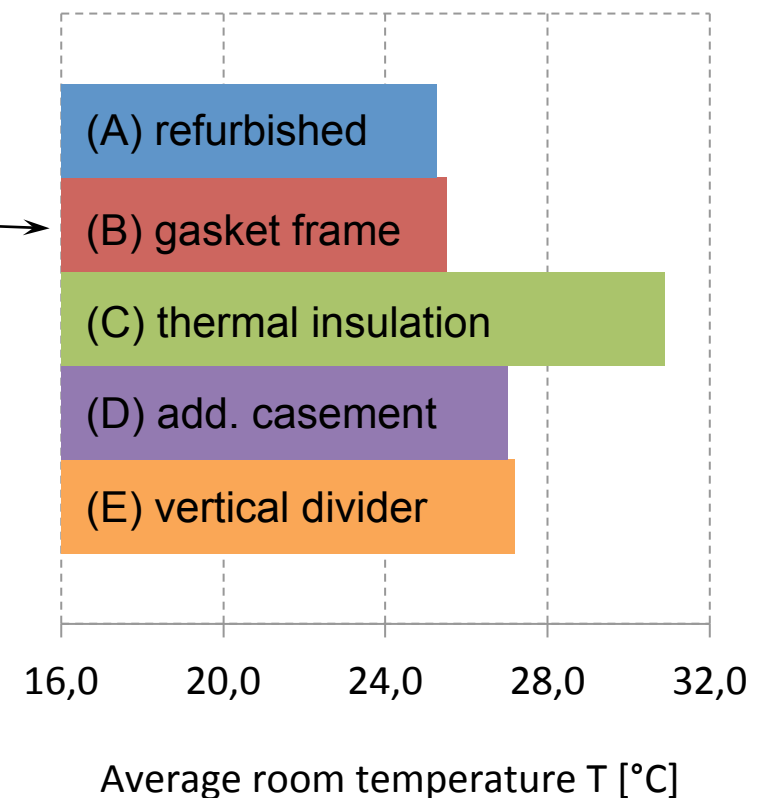




Comparison of the Renovation Concepts

- Average room temperature $T_{\text{average,BTW(i)}}$
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$$\text{rating}_{BTW(A)} = 1.24\%$$



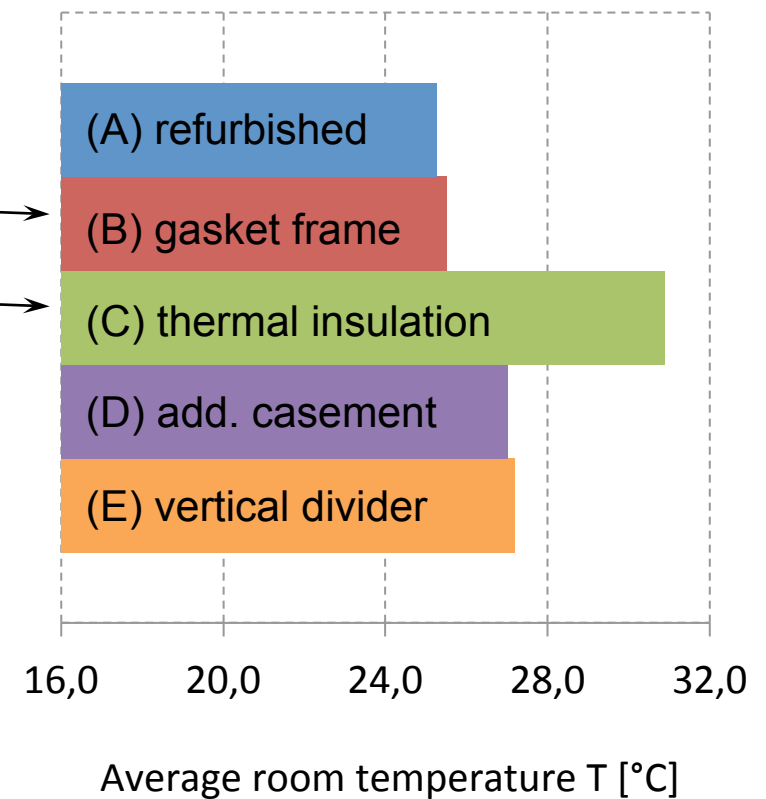


Comparison of the Renovation Concepts

- Average room temperature $T_{\text{average,BTW(i)}}$
- Rating = difference of average room temperature compared with (A) refurbished BTW

$$\text{rating}_{BTW(B)} = 1.24\%$$

$$\text{rating}_{BTW(C)} = 21.6\%$$





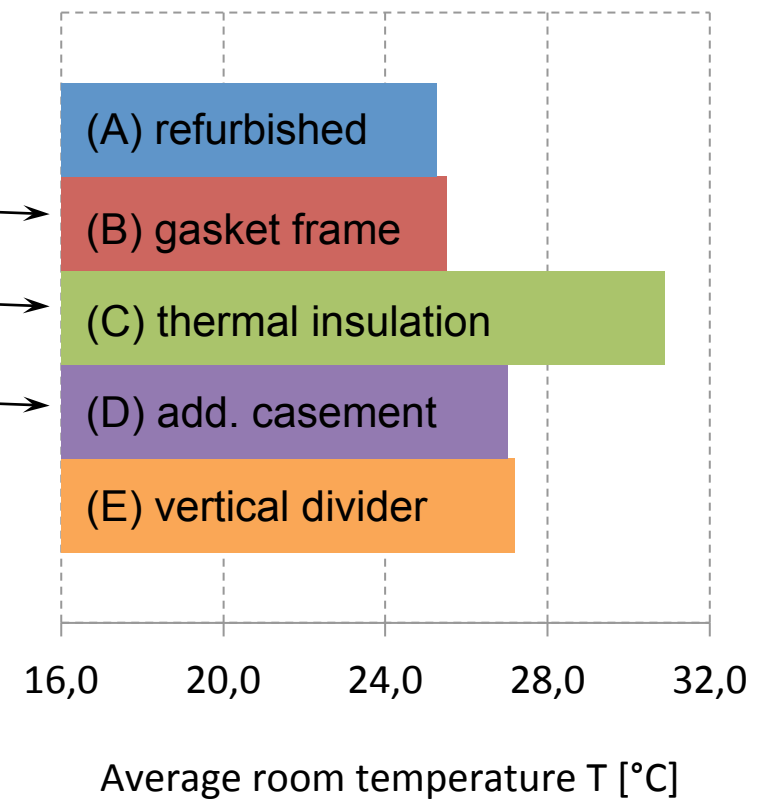
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$$\text{rating}_{BTW(B)} = 1.24\%$$

$$\text{rating}_{BTW(C)} = 21.6\%$$

$$\text{rating}_{BTW(D)} = 4.4\%$$





Comparison of the Renovation Concepts

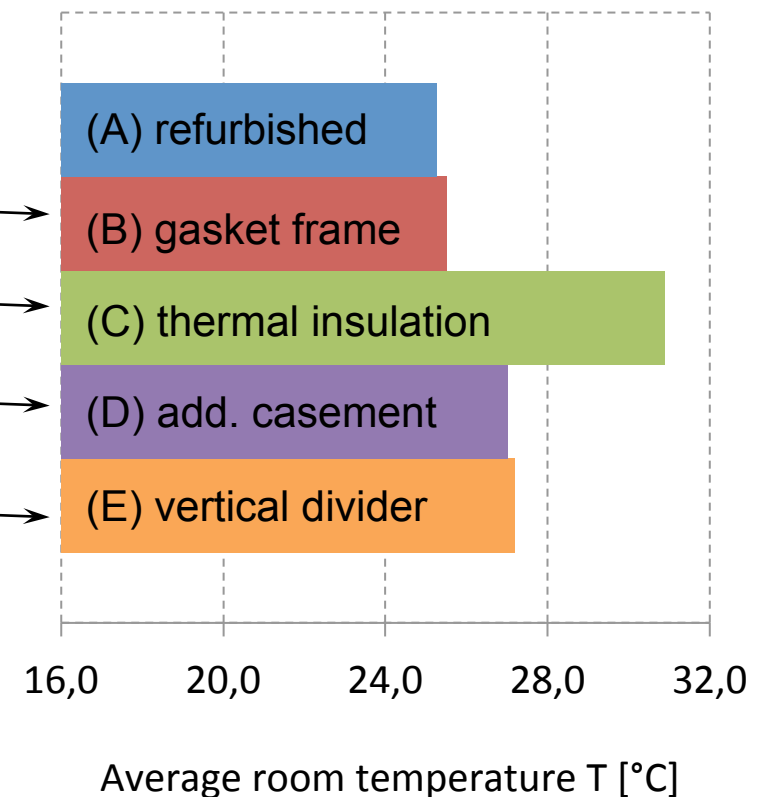
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$$\text{rating}_{BTW(D)} = 4.4\%$$

$$\text{rating}_{BTW(E)} = 6.9\%$$





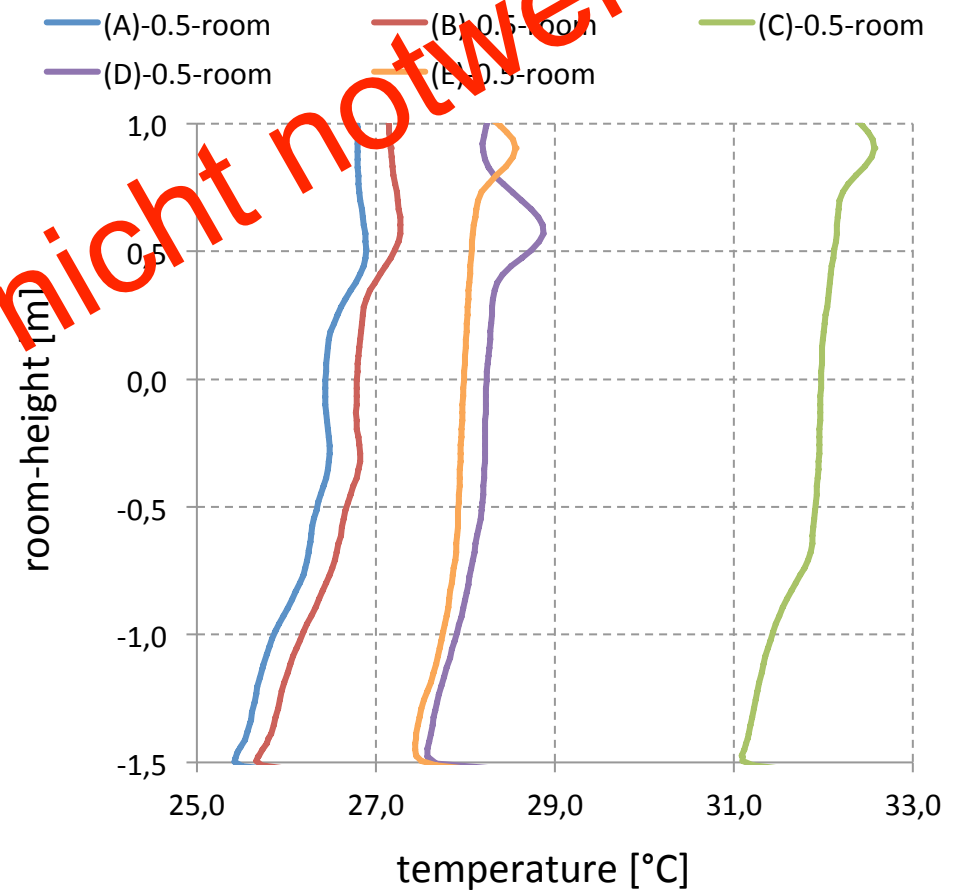
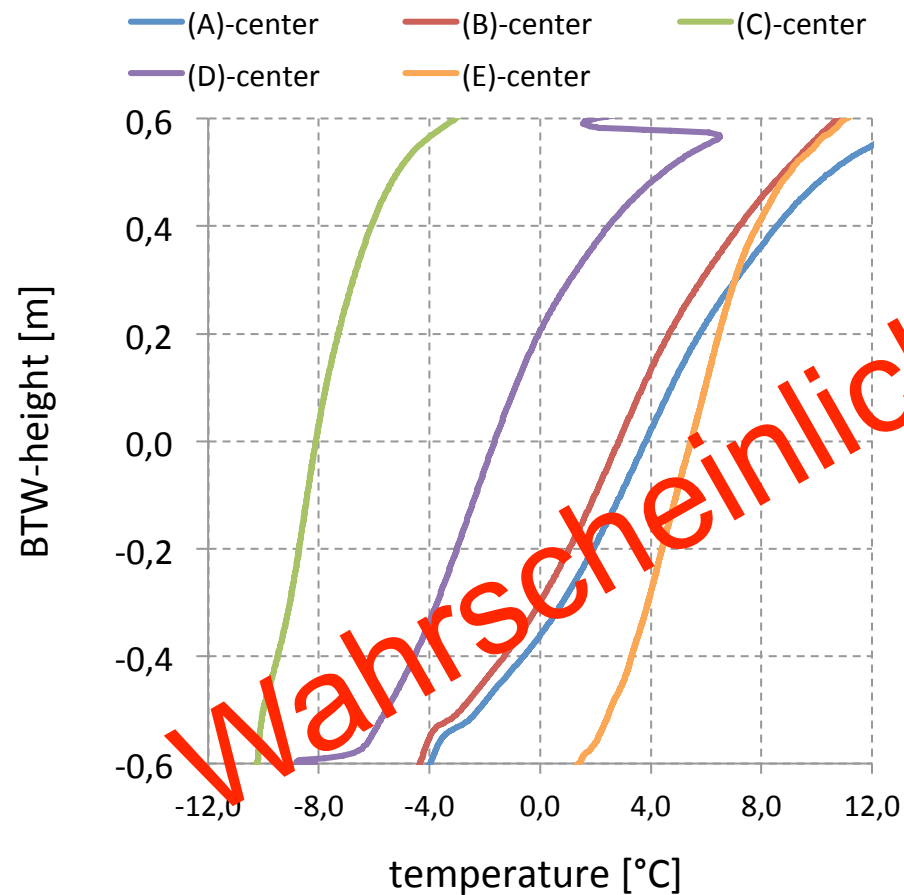
Comparison of the Renovation Concepts

- Average room temperature $T_{\text{average,BTW(i)}}$
- Rating = difference of average room temperature compared with (A) refurbished BTW
- U-value calculation
 - With CFD
 - Virtual test rig (2D-geometry)
 - Room temperature = 25 [°C]
 - External temperature = -20 [°C]

U-value [W/m ²]	BTW	Facade + BTW
(A) refurbished	1.73	1.38
(B) gasket frame	1.69	1.35
(C) thermal insulation	0.76	0.65
(D) add. casement	1.31	1.08
(E) Vertical divider	1.32	1.09



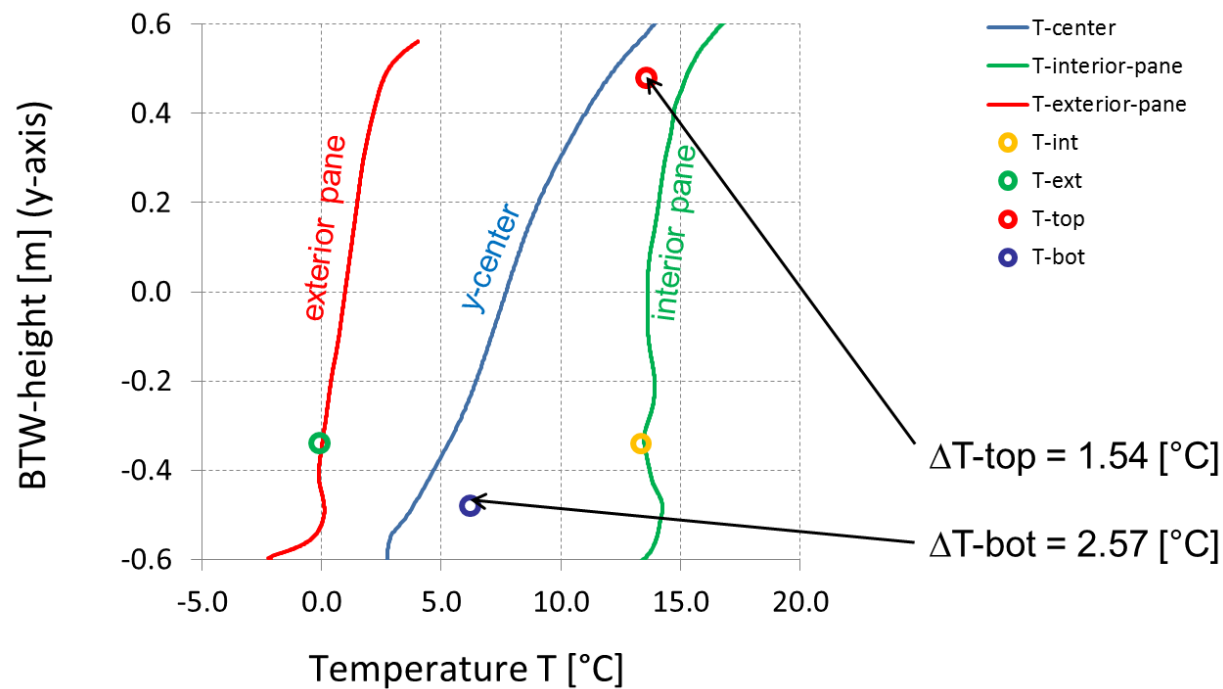
Simulation Results - Comparison of the Renovation Concepts





Conclusions and Outlook

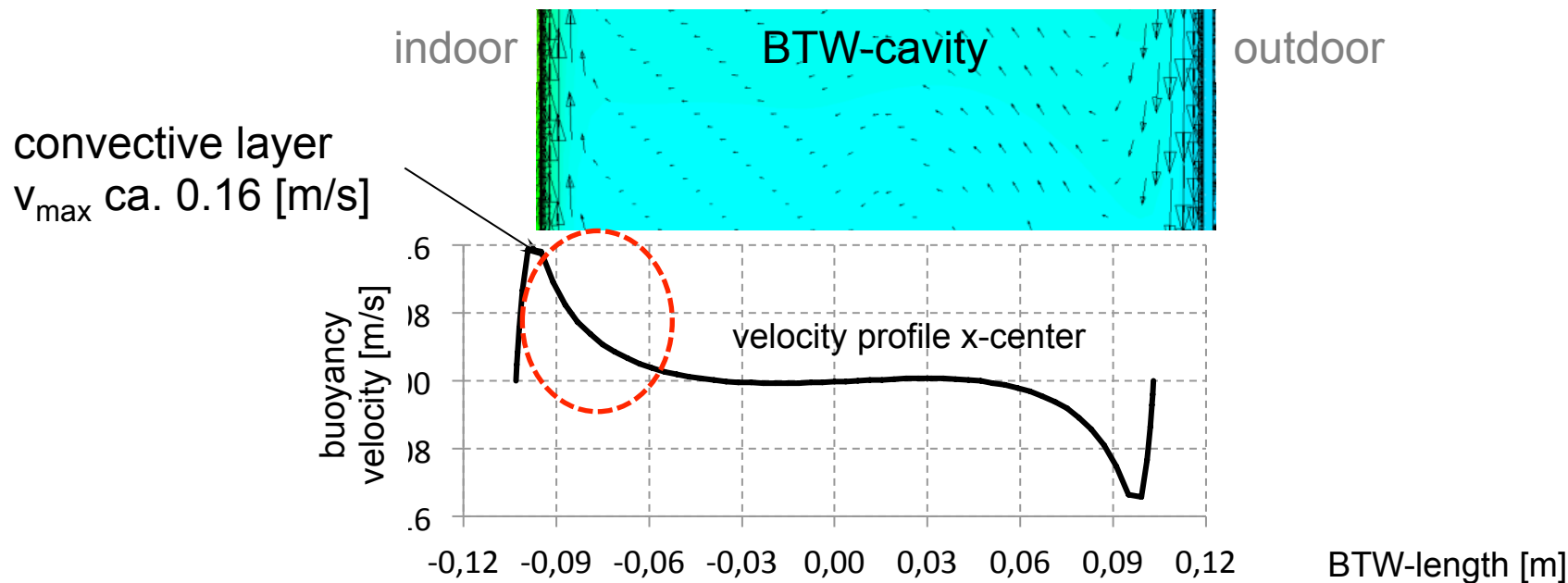
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 - Differences are explainable by the assumption of 2 [mm] gap width for the air permeable joints





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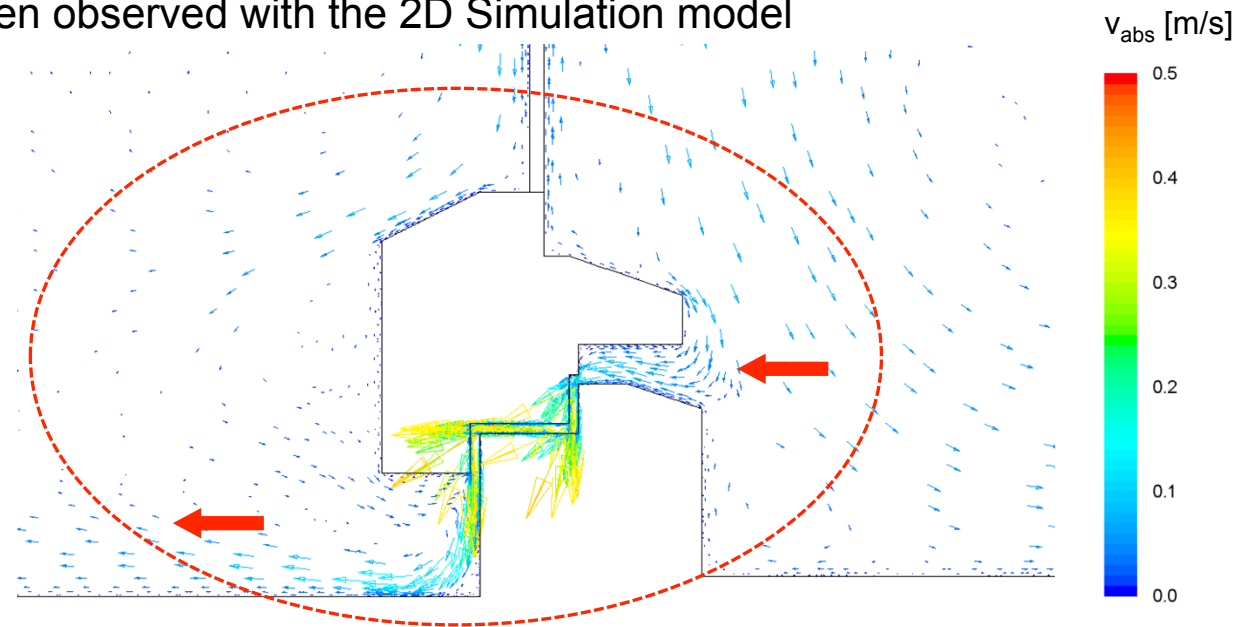
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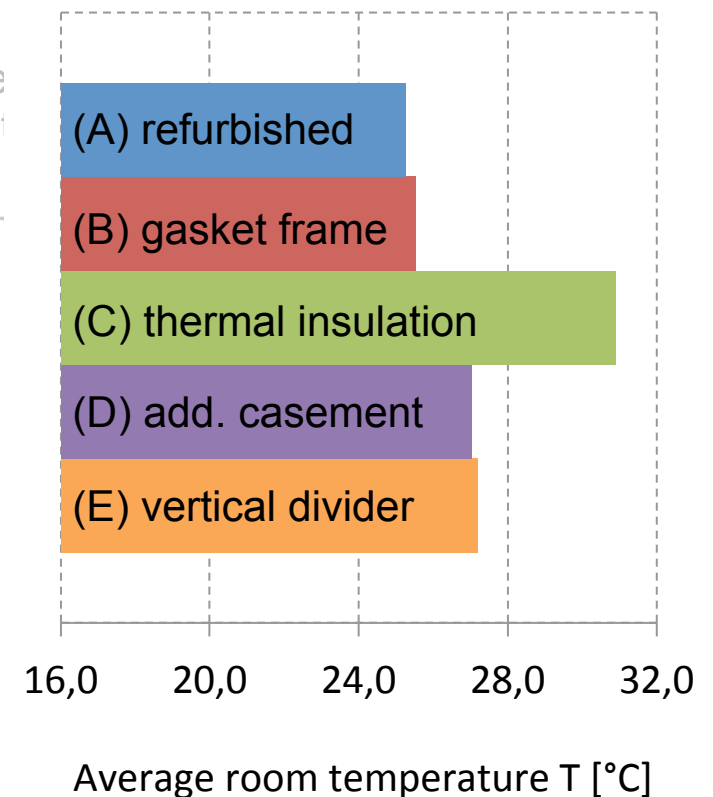
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 - Resulting temperature stratification
 - Effects of infiltration and ventilation





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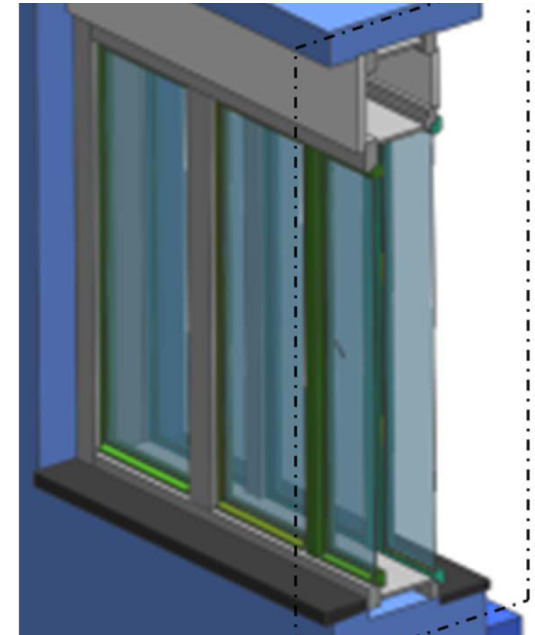
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- More detailed information on the flow characteristic as well as the influence of the vertical joints by use of 3D-BTW-geometry
- Analysis of transient behaviour
 - Thermal storage capacity of solid materials
 - Effects of solar radiation on solid materials the airflow



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*Thank you for your
attention*

