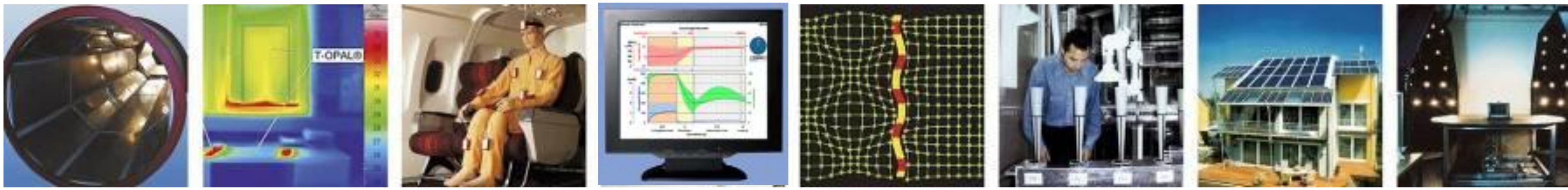
Buildings XI Conference – Workshop 2: Thermal Mass IV



Assessing Thermal and Moisture Control Benefits of PCM Components by Hygrothermal Simulation

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Fraunhofer IBP

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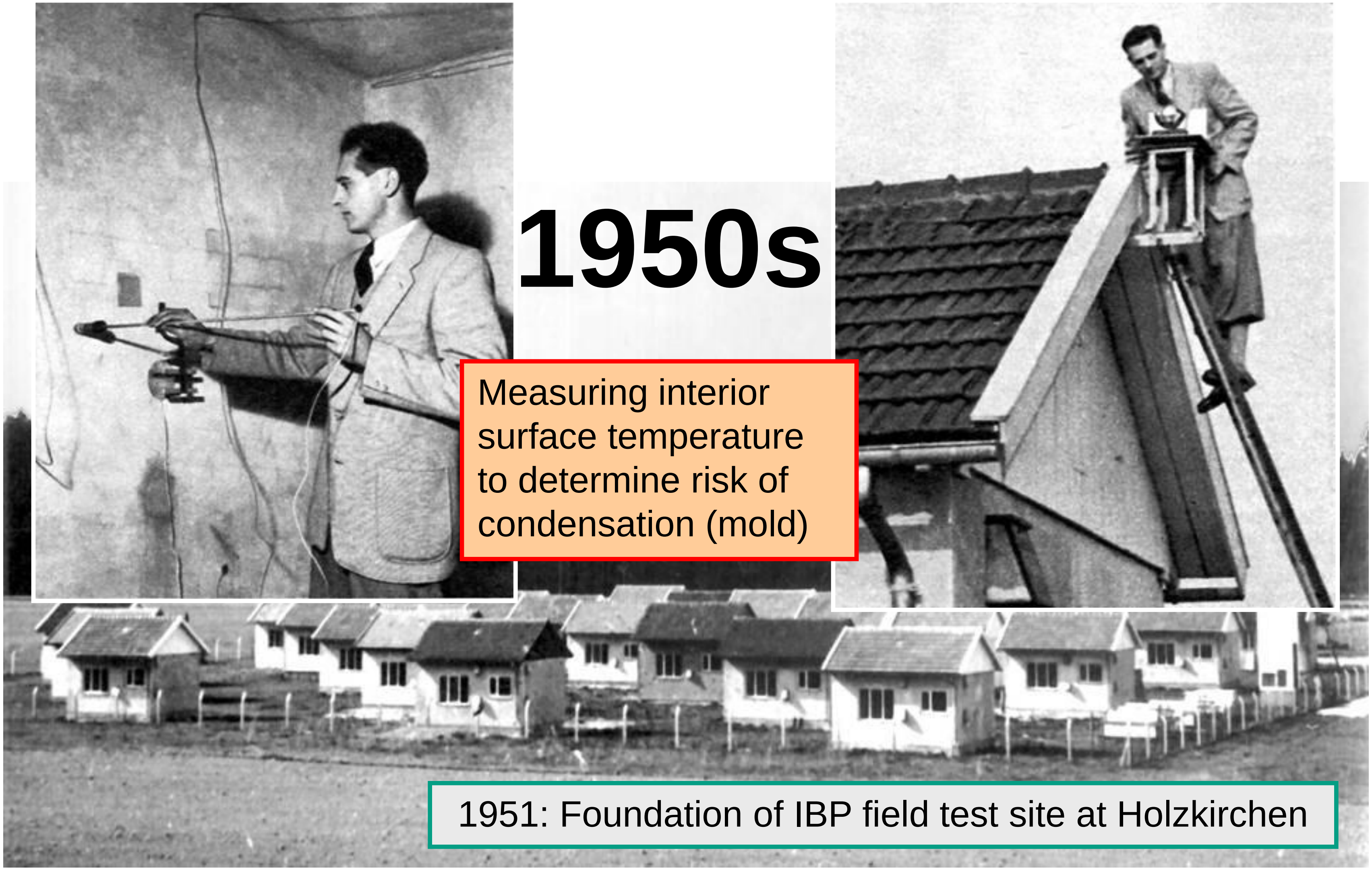
Introduction – Field Testing



1950s

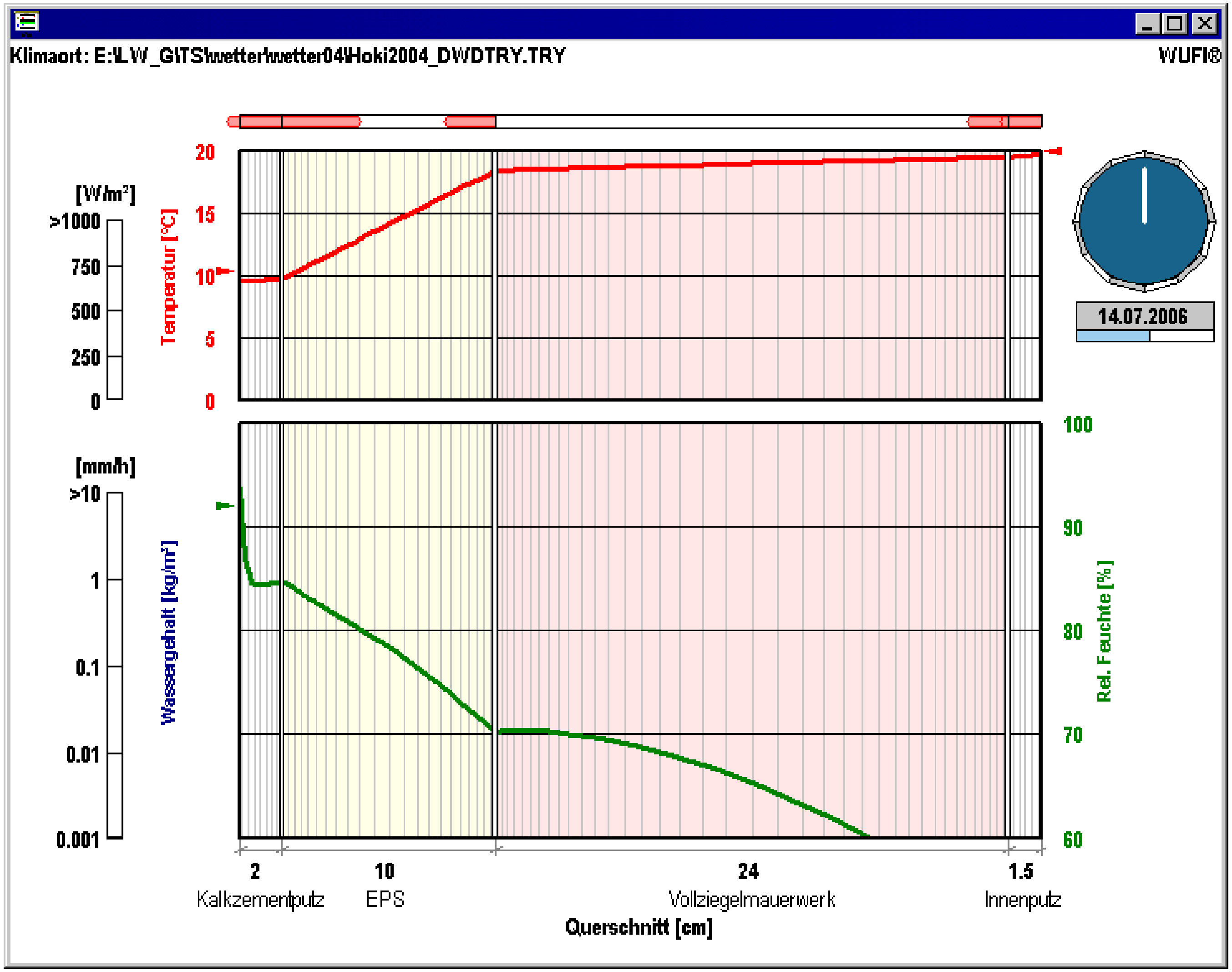
Measuring interior surface temperature to determine risk of condensation (mold)

1951: Foundation of IBP field test site at Holzkirchen

Introduction – Field Testing

Recording exterior surface temperature to determine risk of condensation (algae)

Introduction – Hygrothermal Simulation



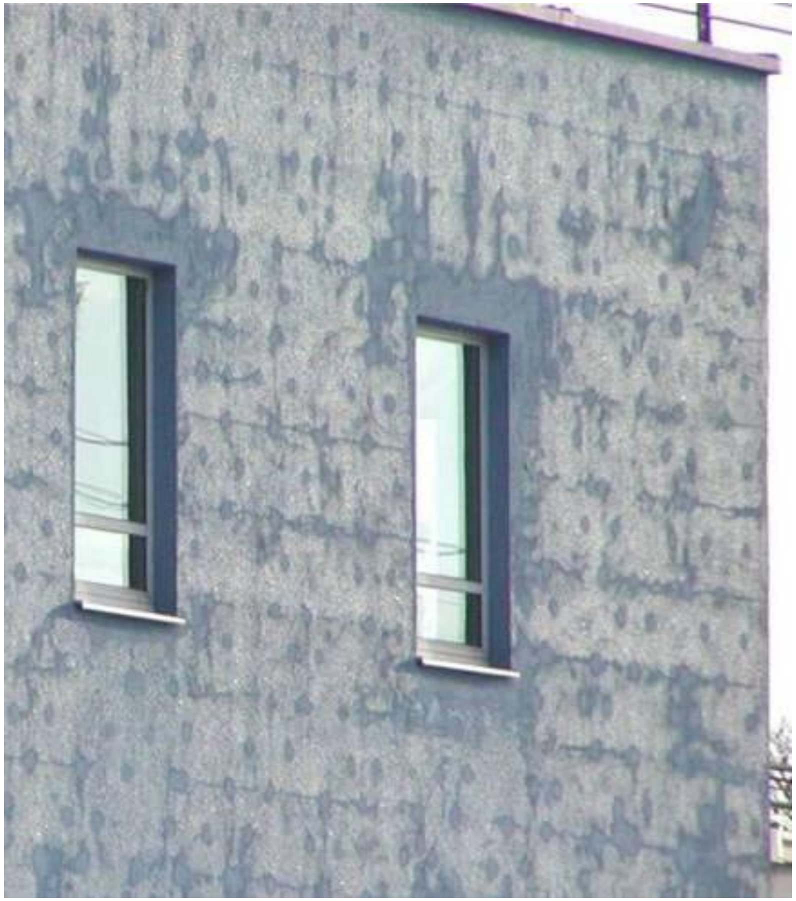
Hygrothermal building envelope simulation with detailed radiation balance

Façade Moisture Control

“Tiger” pattern caused by wind driven rain

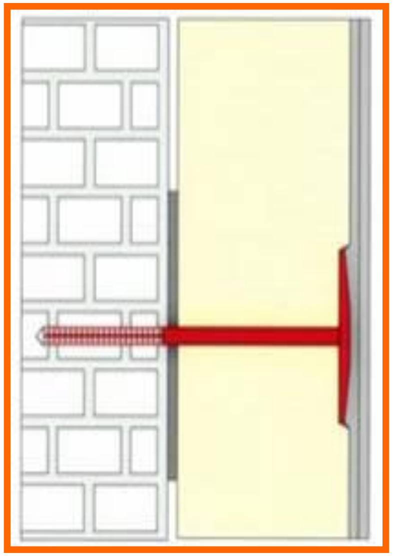
Façade Moisture Control

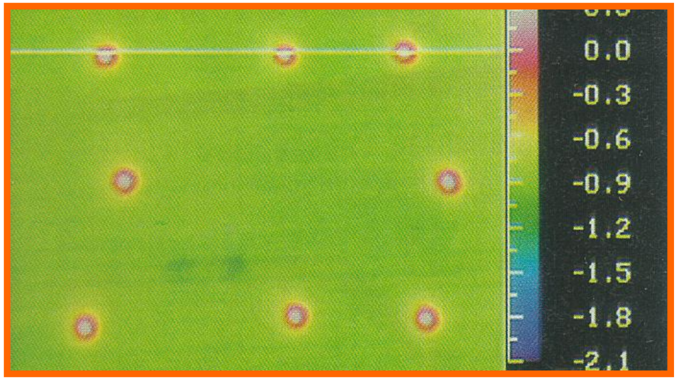
"Leopard" pattern caused by exterior condensation



Façade Moisture Control

Microbial growth on EIFS façades

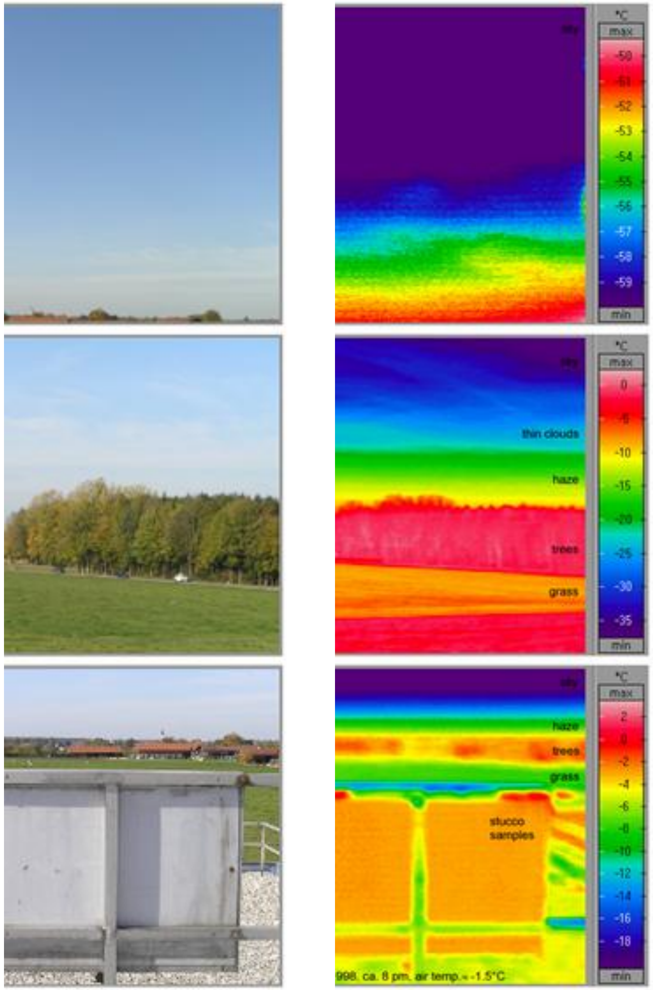




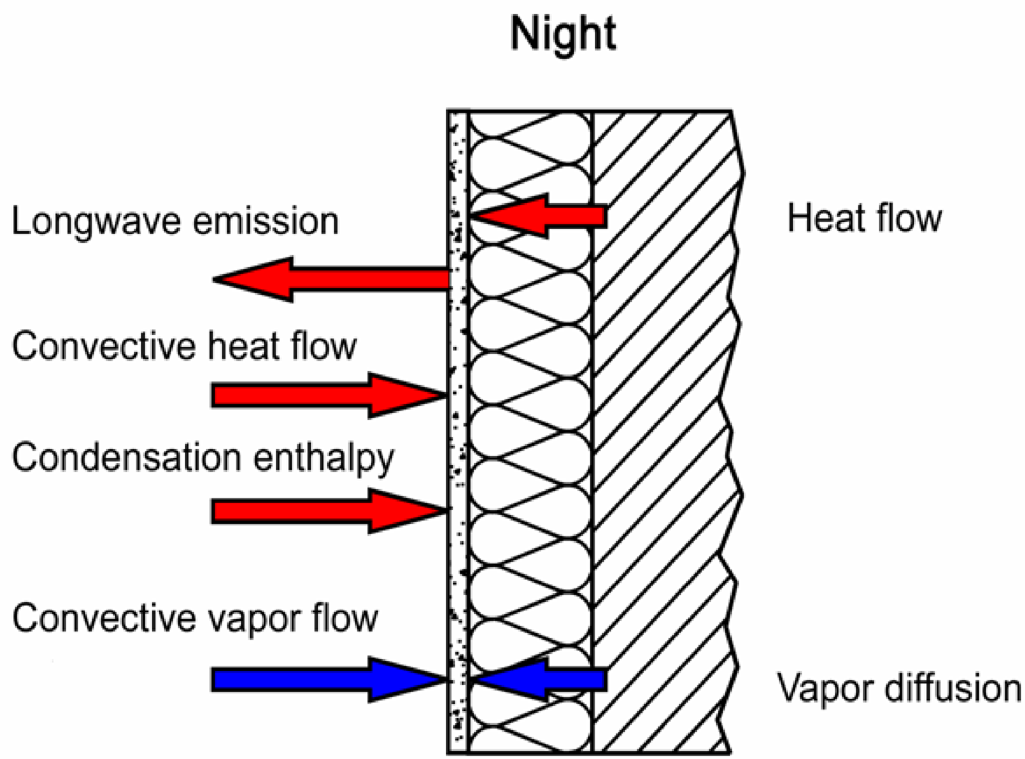
Fasteners act as thermal bridges and raise surface temp. above dewpoint

Façade Moisture Control

Day Night

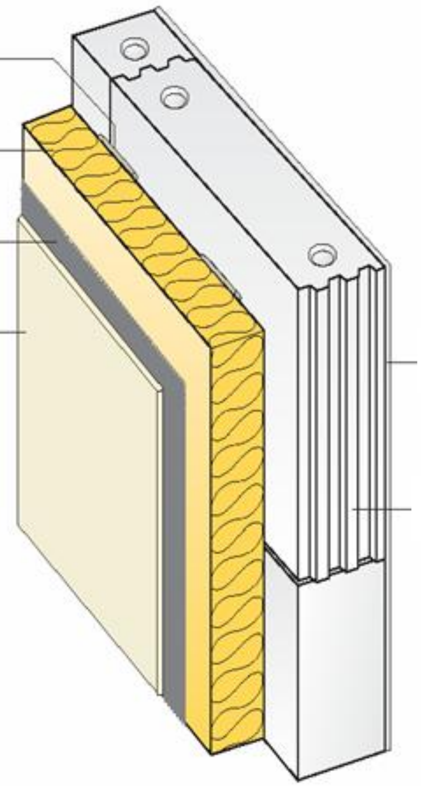


Hygrothermal transfer processes at the surface of an EIFS



Façade Moisture Control

Field tests comparing façade sections

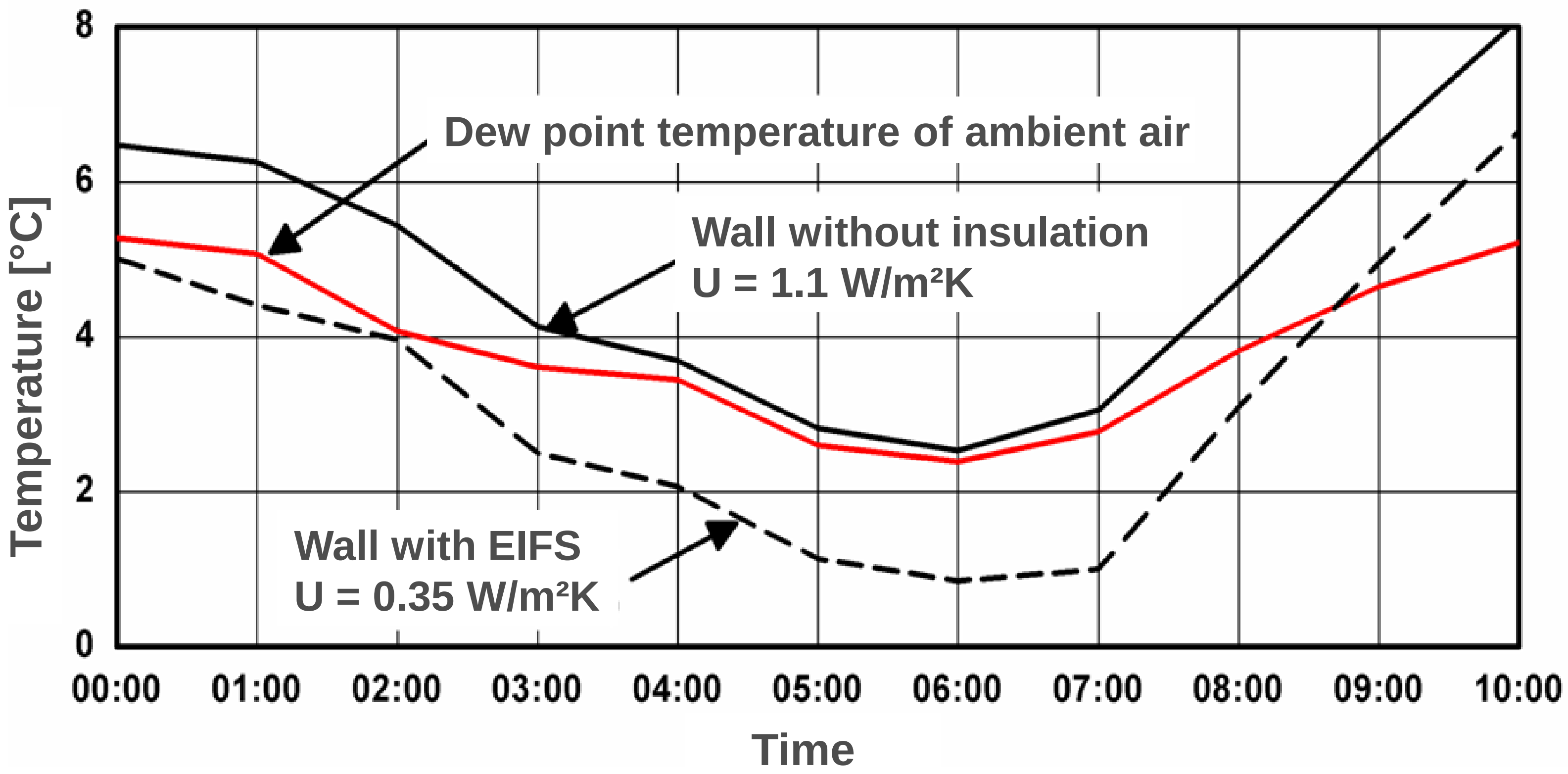


Test wall sections facing west

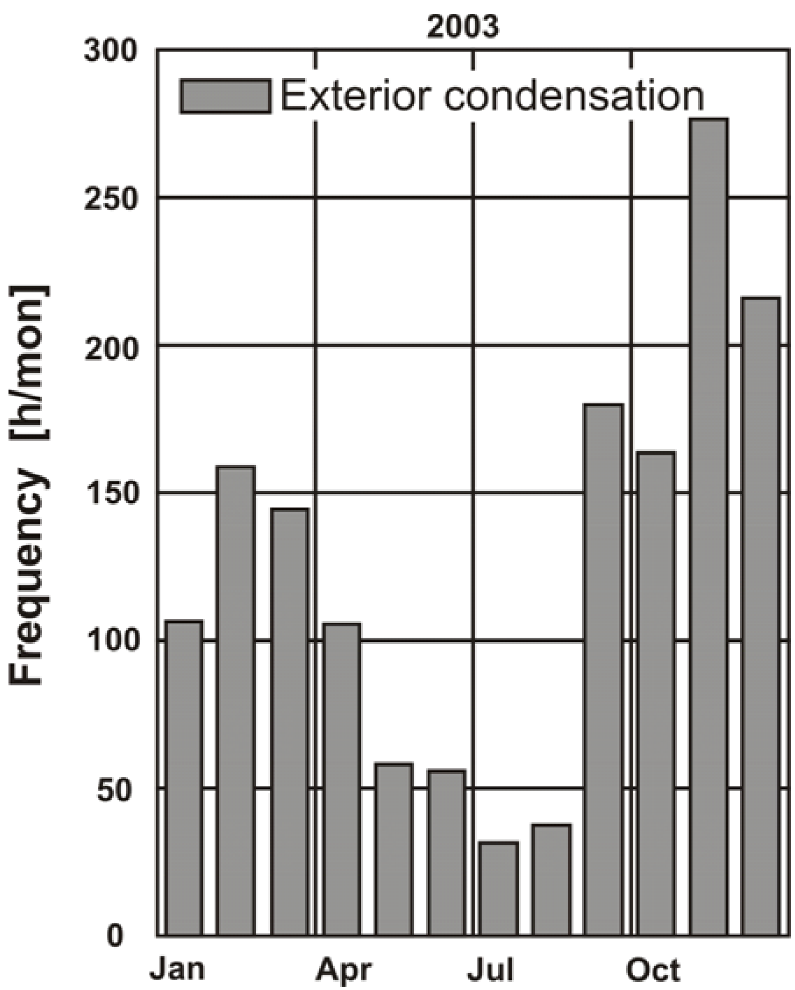
U = 0.3 W/m²K

Façade Moisture Control

Temperature recordings at field test site



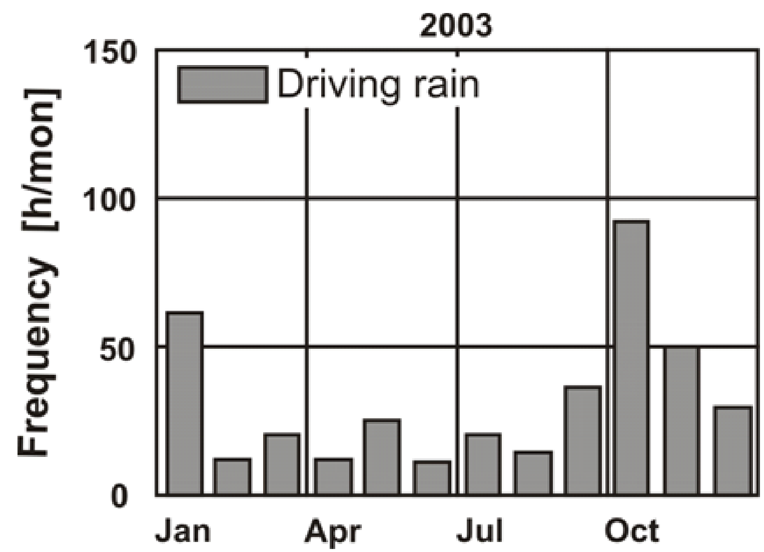
Frequency of load occurrence



Exterior condensation occurs more often than driving rain

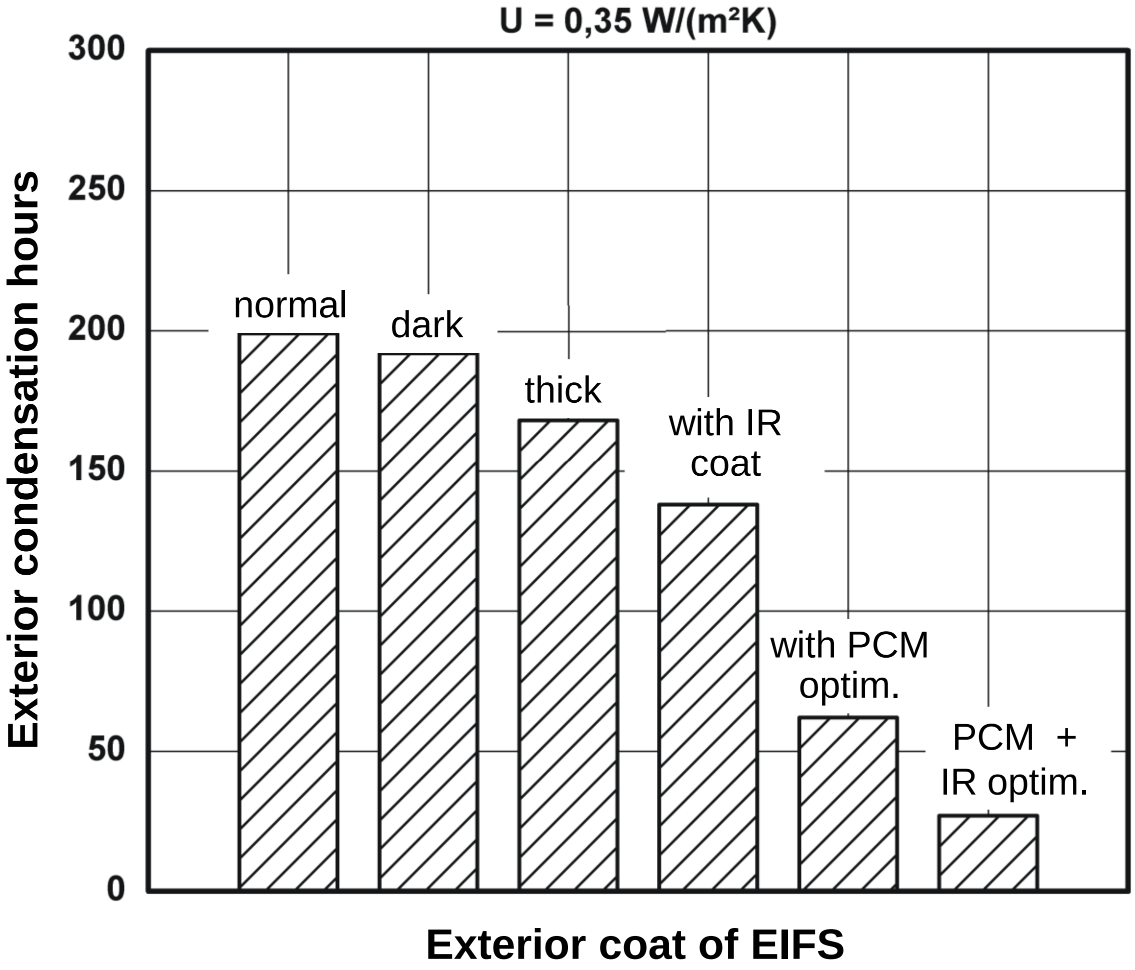
But

Amount of water from driving rain is approx. 10 times higher



Façade Moisture Control

Hygrothermal simulation results for masonry with 10 cm (4”) EIFS



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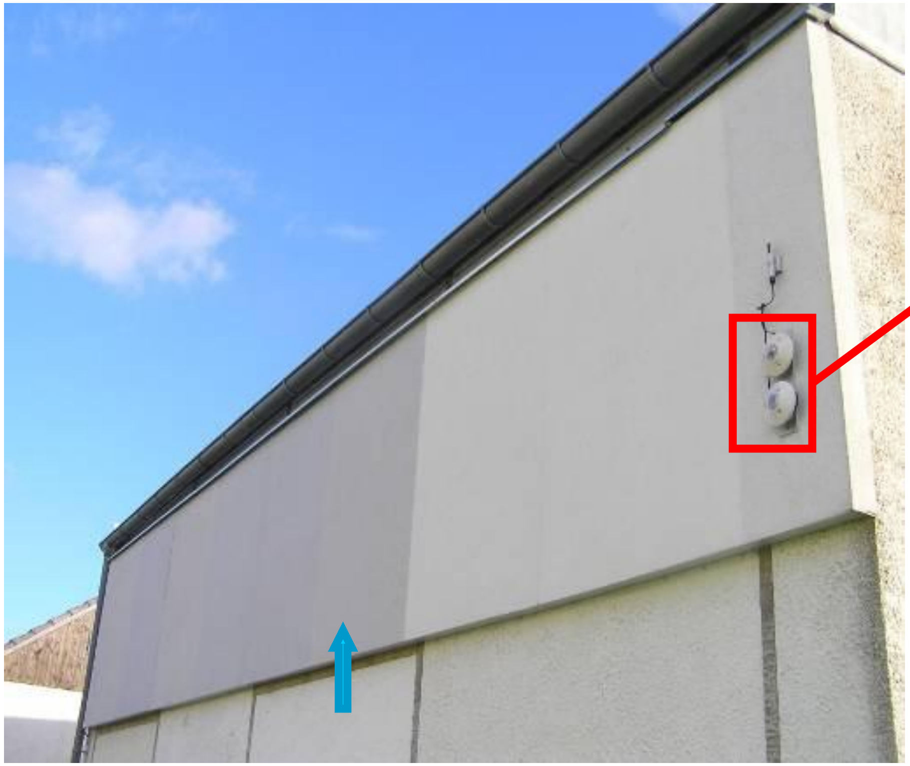
Façade Moisture Control

Field test



Solarimeter
(short wave
0.3 – 2.8 µm)

Pyrgeometer
(long wave
5 – 25 µm)

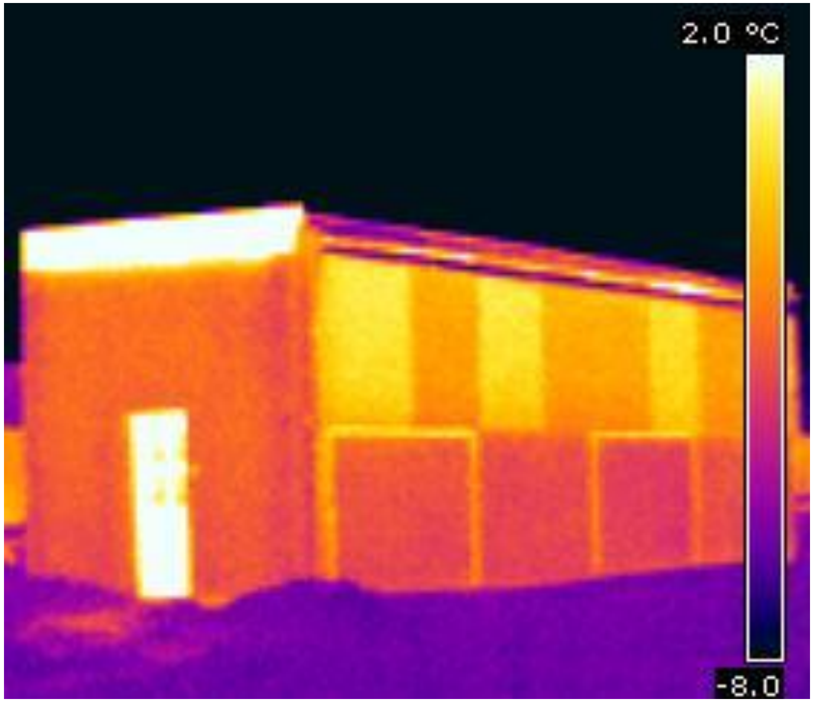
- Continuous recording of short and long wave incident radiation as well as stucco surface temperature

Brick wall with EIFS (10 cm EPS; 5 mm stucco)

Location: Holzkirchen

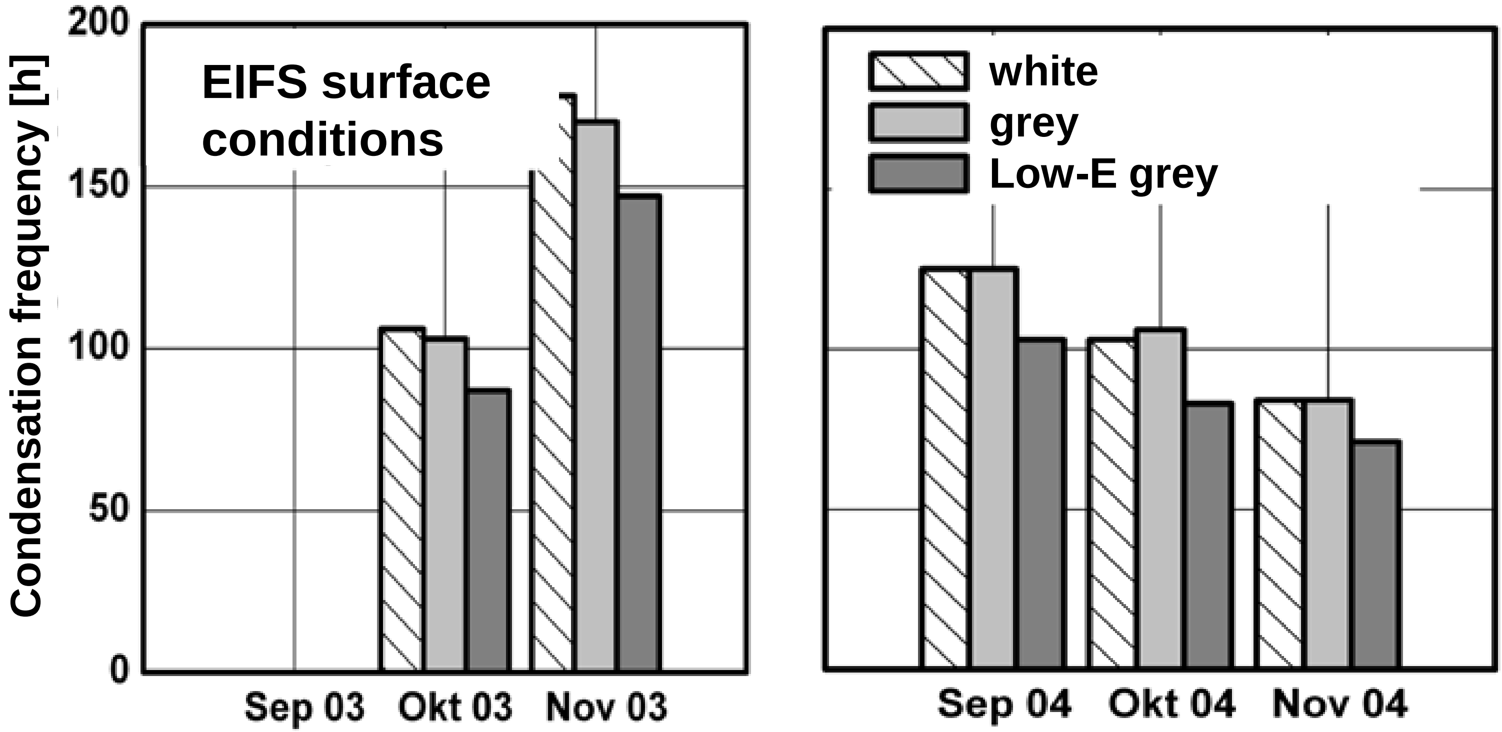
Orientation: North

Effect of low-E paint



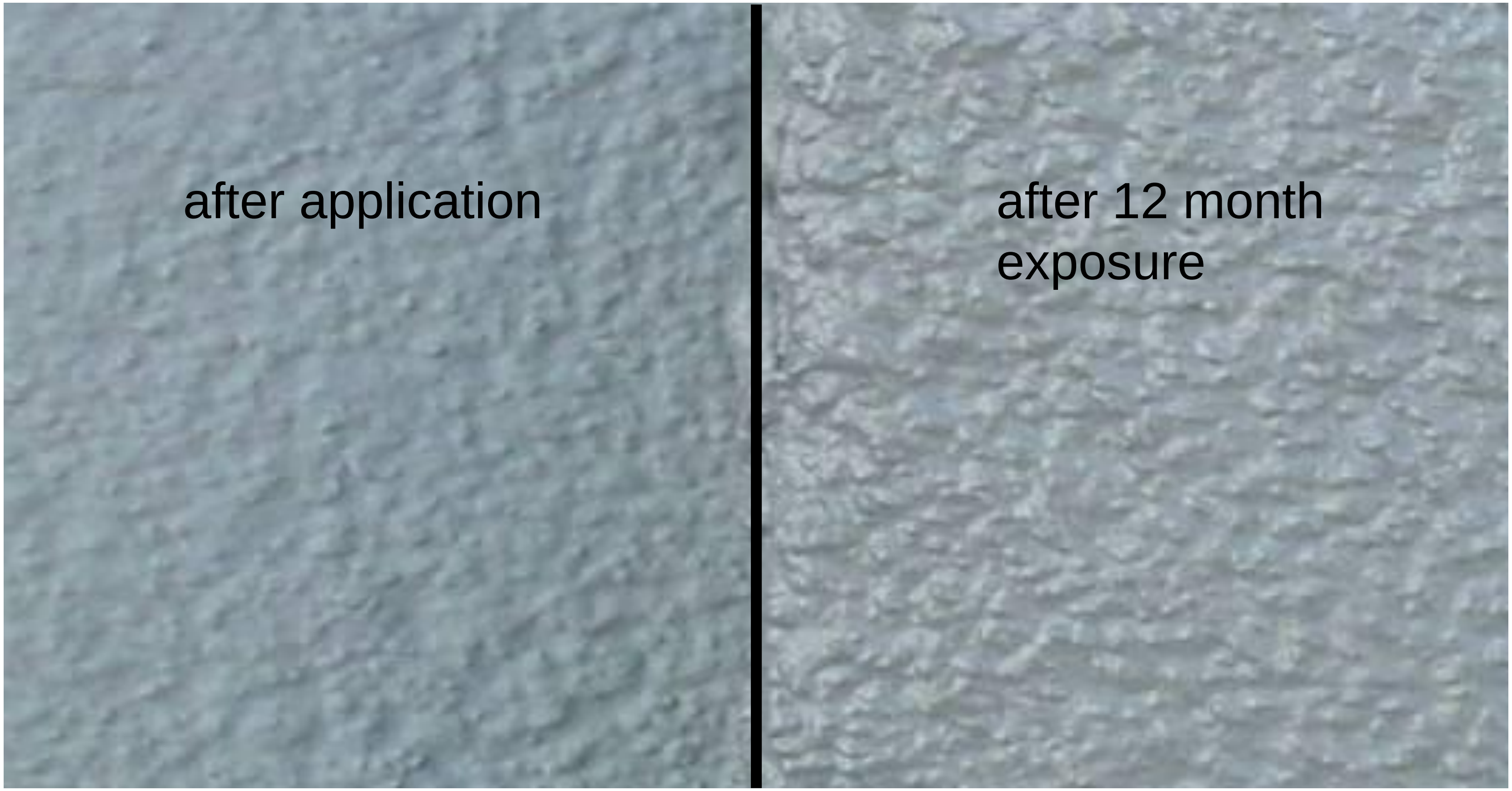
Façade Moisture Control

Field test results

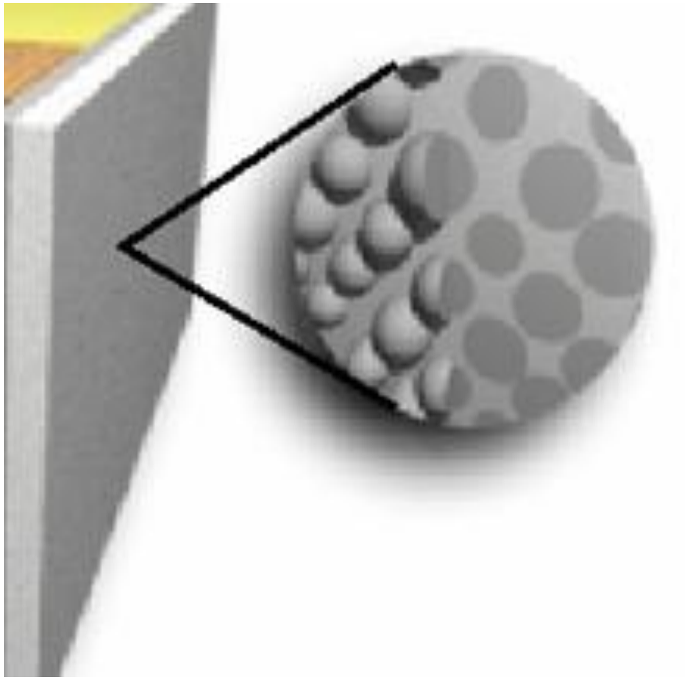


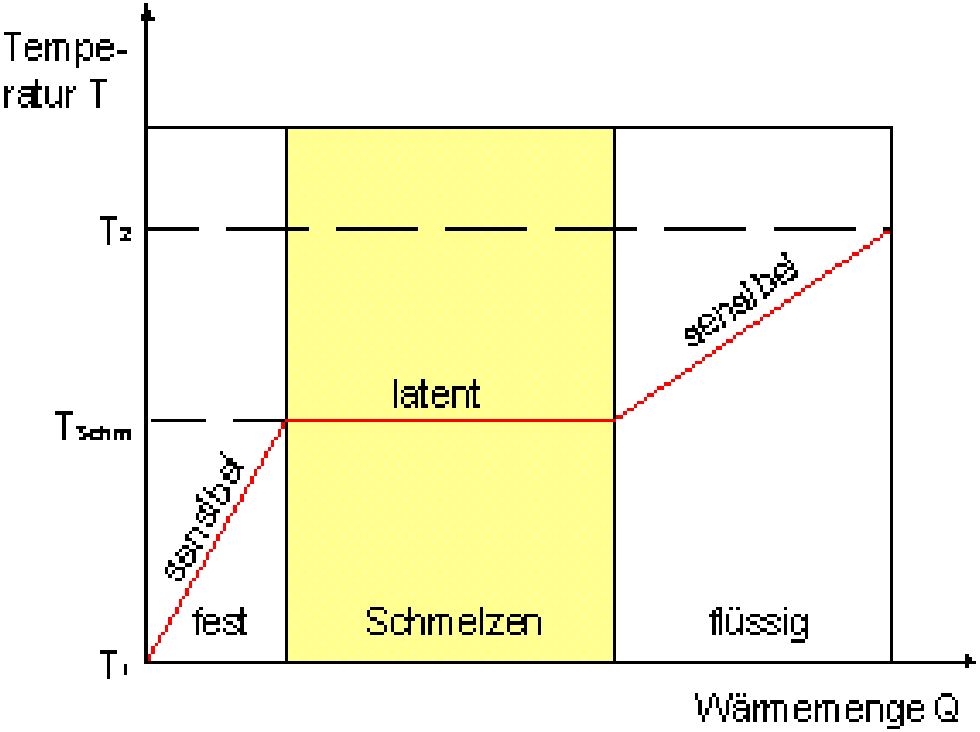
Long wave emissivity		Short wave absorptivity	
white:	0.95	white:	0.23
grey:	0.96	grey:	0.39
Low-E grey:	0.74	Low-E grey:	0.39

Durability of Low-E Paint



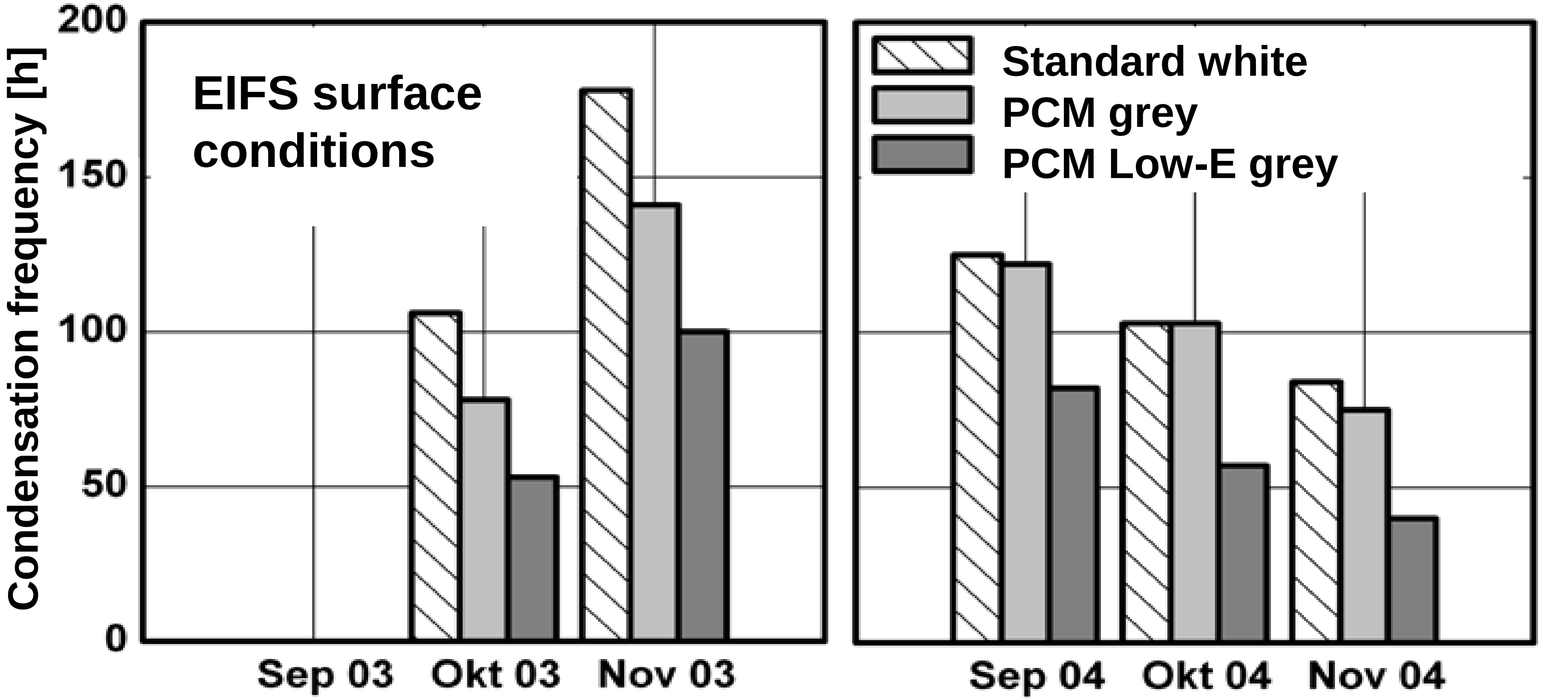
Stucco with phase change materials (PCM)





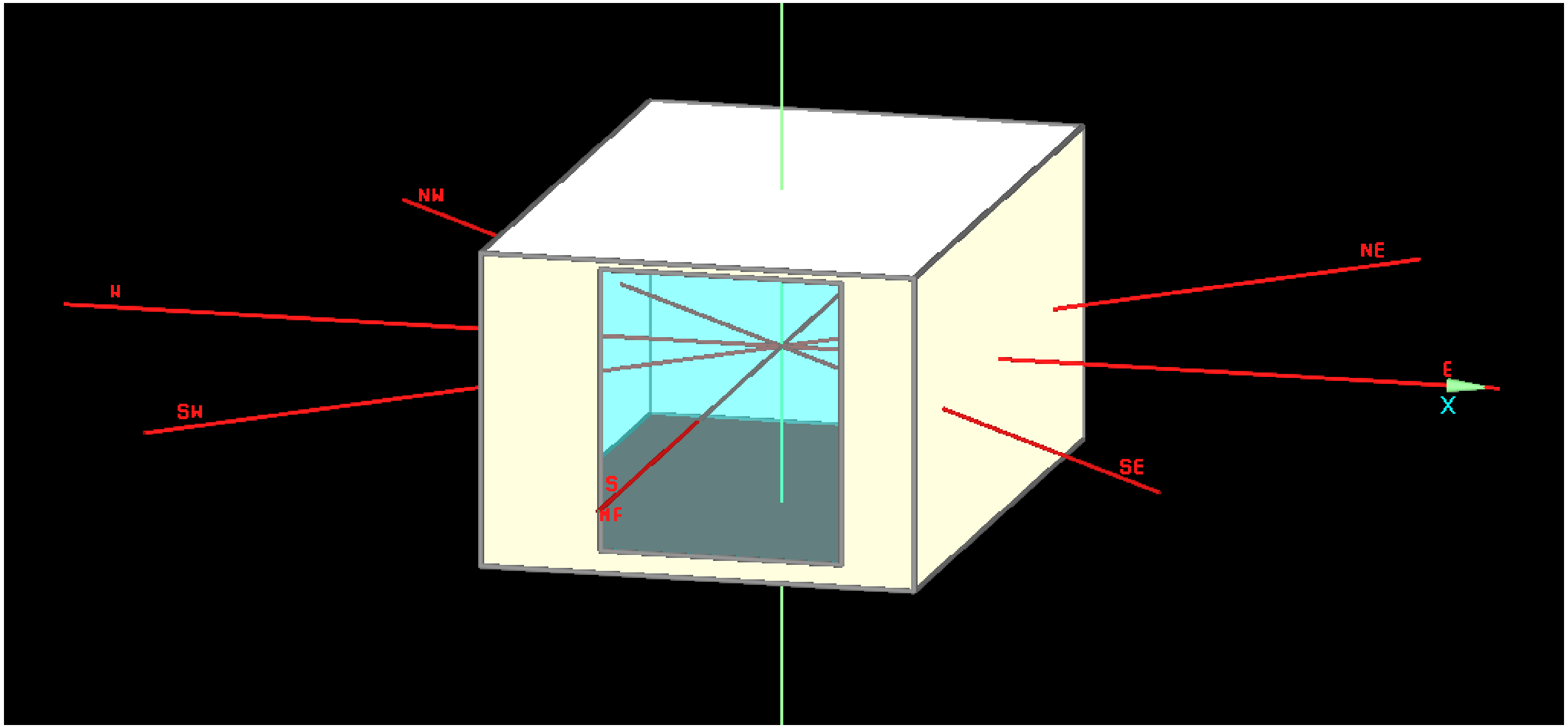
Façade Moisture Control

Field test results



<u>Monthly mean outdoor temperature</u>
October 2003: 5°C
October 2004: 10°C

Example case: Office with large window facing south
Hygrothermal building simulation



Energy Efficiency Benefits in Winter

Window Parameters

Main Parameters

U	[W/m2K]	1,5
Frame factor	[-]	0,7
SHGC hemispherical	[-]	0,53
Emissivity of external surface	[-]	0,2

SHGC detailed

Incident Angle [°]	SHGC [-]
0	0,6
60	0,51
80	0,21

Parameters

Reduction factor of solar radiation (b-value)	[-]	0,4
Thermal resistance supplement	[m²K/W]	0
Operation mode		Reduce overheating / Cooling

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Energy Efficiency Benefits in Winter

PCM characteristics

Name

Gypsum Board; PCM

Basic values

Bulk density [kg/m³]	800
Porosity [m³/m³]	0,65
Spec. heat capacity [J/kgK]	1200
Thermal conductivity [W/mK]	0,2
Water vapour diffusion resistance factor [-]	8

Additional Data

Typical Built-In Moisture [kg/m³]	8
Thermal Conductivity Supplement [%/M.-%]	8
Color	

Optional Data

- Moisture Storage Function
- Liquid Transport Coefficient, Suction
- Liquid Transport Coefficient, Redistribution
- Thermal Conductivity, moisture-dependent
- Thermal Conductivity, temperature-dependent
- Water vapour diffusion resistance factor, moisture-dependent
- Enthalpy, temperature-dependent (PCM)

No.	Temperature [°C]	Enthalpy [J/kg]
1	0	0
2	5	6000
3	11,25	13983
4	14,5	18838
5	17	23083
6	18	24943
7	19	27075

New

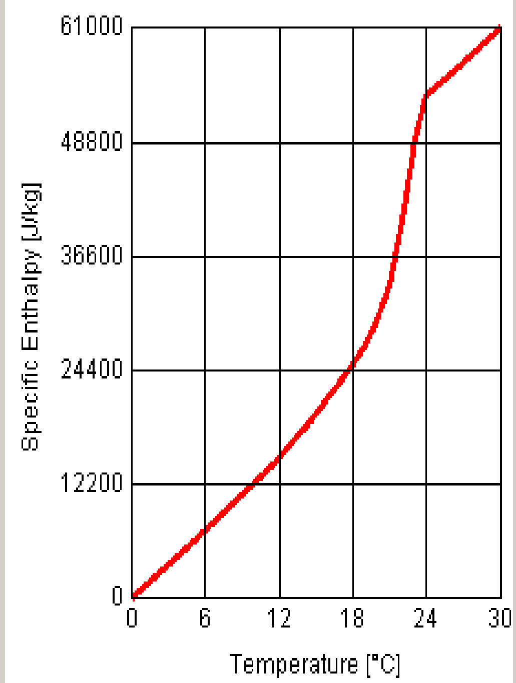
Delete

Copy

Insert

New/Insert:

after



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Light-weight external walls (without PCM)

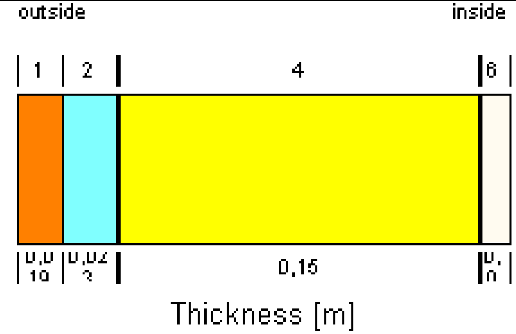
Assembly (Id.2): Lightweight timber framed wall

Homogenous layers

Thermal resistance: 4,17 m2K/W

Heat Transfer Coefficient(U-value): 0,23 W/m²K

Thickness: 0,2 m



Nr.	Material/Layer (from outside to inside)	ρ [kg/m3]	c [J/kg]	λ [W/mK]	Thickness [m]
1	Spruce, radial	455	1500	0,09	0,019
2	Air Layer 25 mm	1,3	1000	0,155	0,023
3	60 minute Building Paper	280	1500	12	0,001
4	Mineral Wool (heat cond.: 0,04 W/mK)	60	850	0,04	0,15
5	PE-Membrane 0,15 mm (sd = 70 m)	130	2200	2,2	0,001
6	Gypsum Board	850	850	0,2	0,012

Energy Efficiency Benefits in Winter

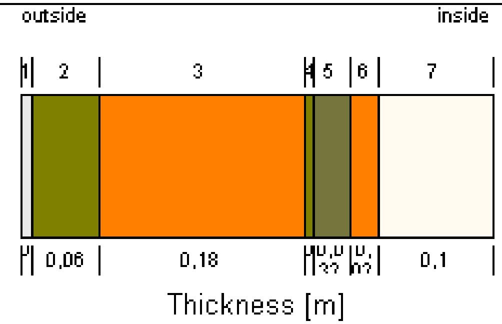
Floor assembly with PCM

Assembly (Id.3): jah_Bodenaufbau

Homogenous layers

Thermal resistance: 5,124 m2K/W

Heat Transfer Coefficient(U-value): 0,19 W/m²K

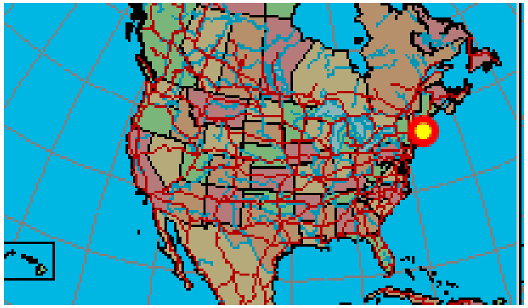


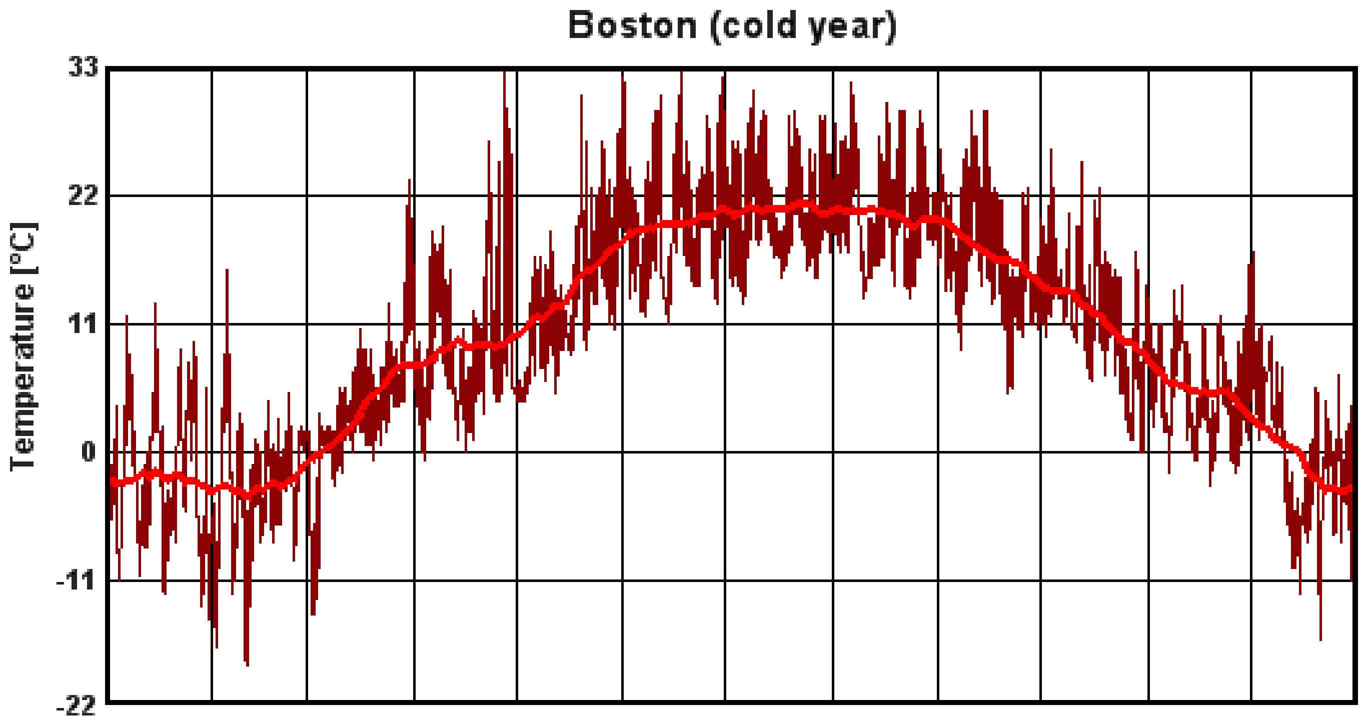
Thickness: 0,4 m

Nr.	Material/Layer (from outside to inside)	ρ [kg/m3]	c [J/kg]	λ [W/mK]	Thickness [m]
1	Gypsum-Fibreboard	1153	1200	0,32	0,01
2	Flax Insulation Board DP	38	1660	0,036	0,06
3	Softwood	400	1500	0,09	0,18
4	Felt	70	2500	0,04	0,008
5	Pearlite fill	165	850	0,06	0,032
6	Oriented Strand Board (density: 630 kg/m³)	630	1500	0,13	0,025
7	Gypsum Board; PCM_jah	800	1200	0,2	0,1

Energy Efficiency Benefits in Winter

Location and climate





Temperature [°C]:

Max. 32,8

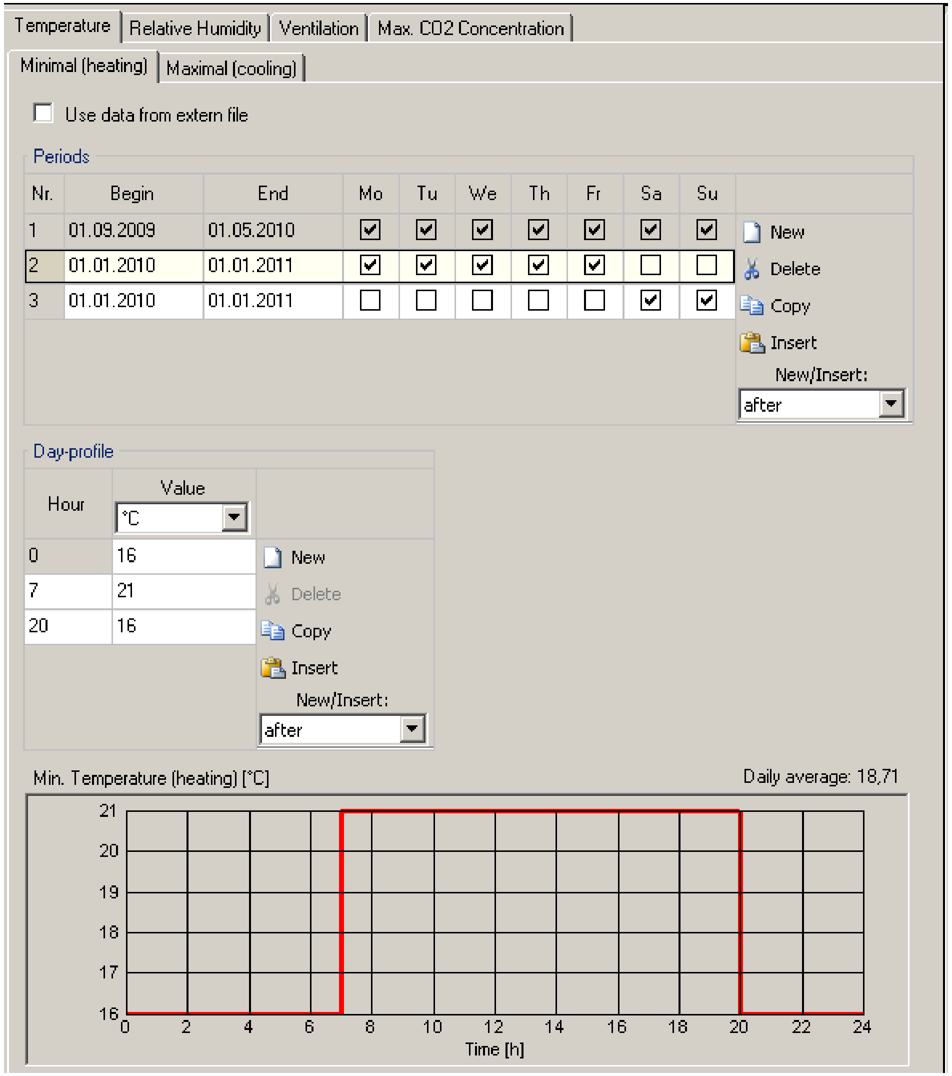
Mean. 9,69

Min. -20

Energy Efficiency Benefits in Winter

Temperature set-points with night-time and weekend set-backs

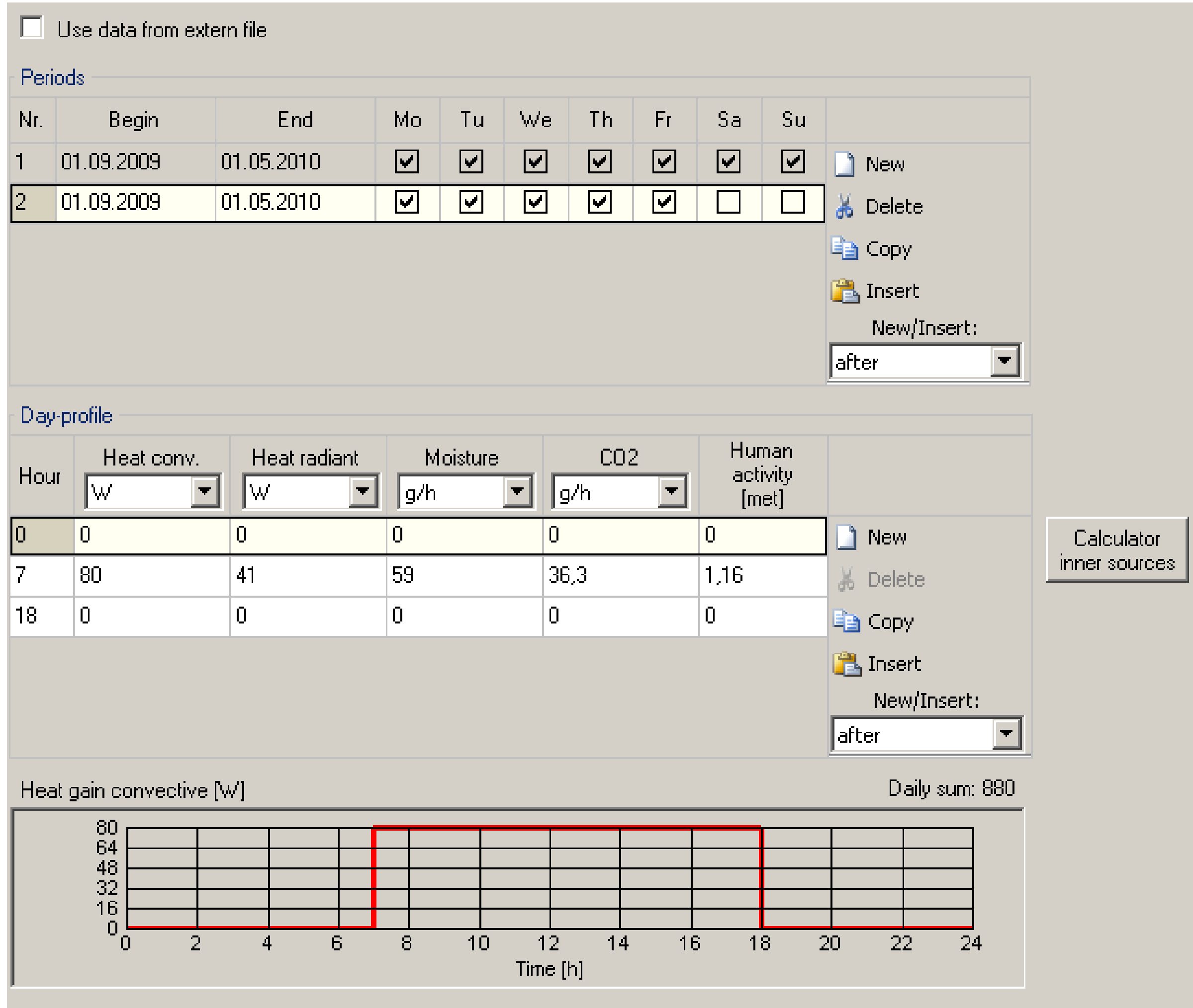
21°C / 16°C



Energy Efficiency Benefits in Winter

Internal heat and moisture sources

21°C / 16°C



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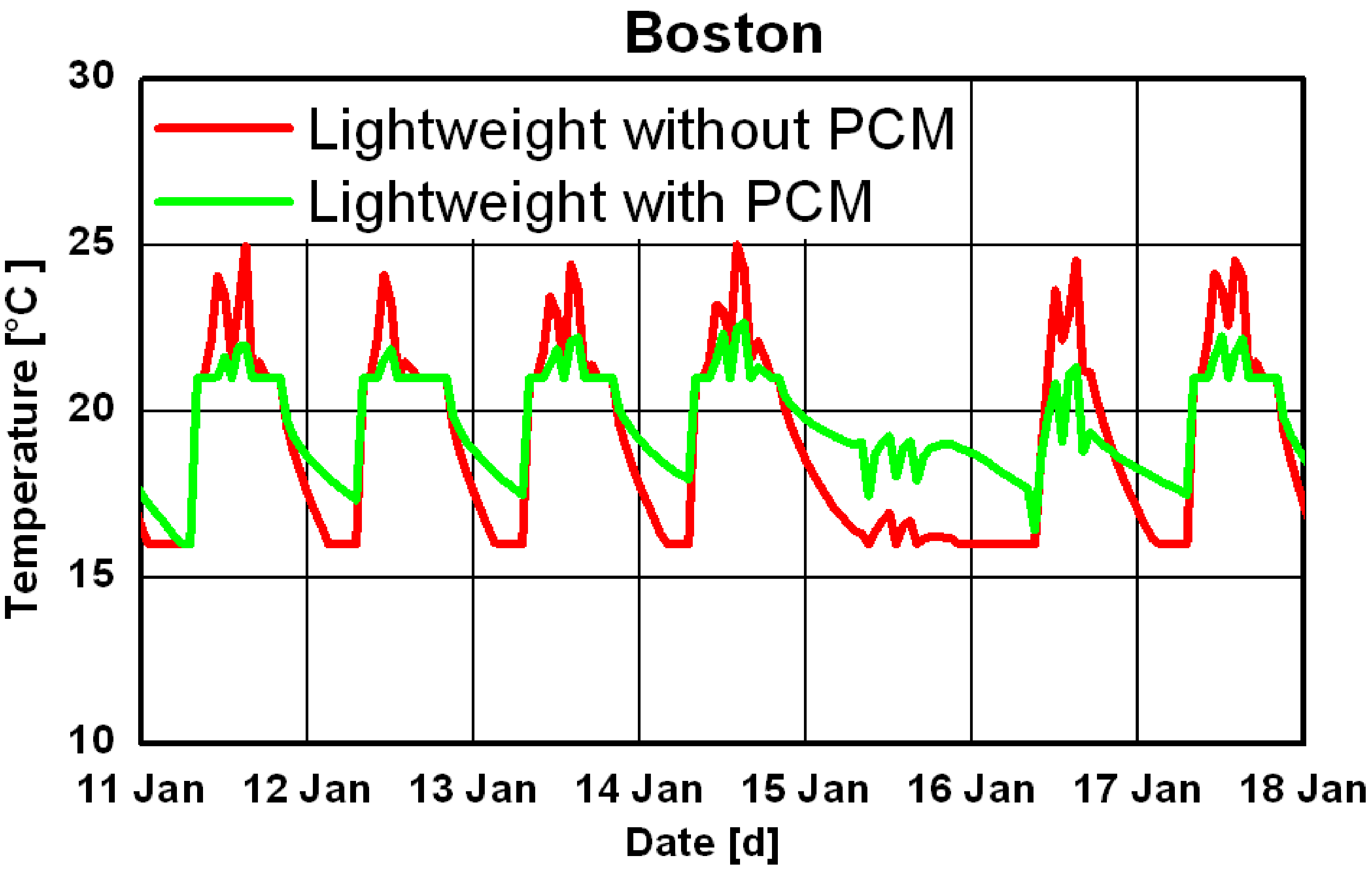
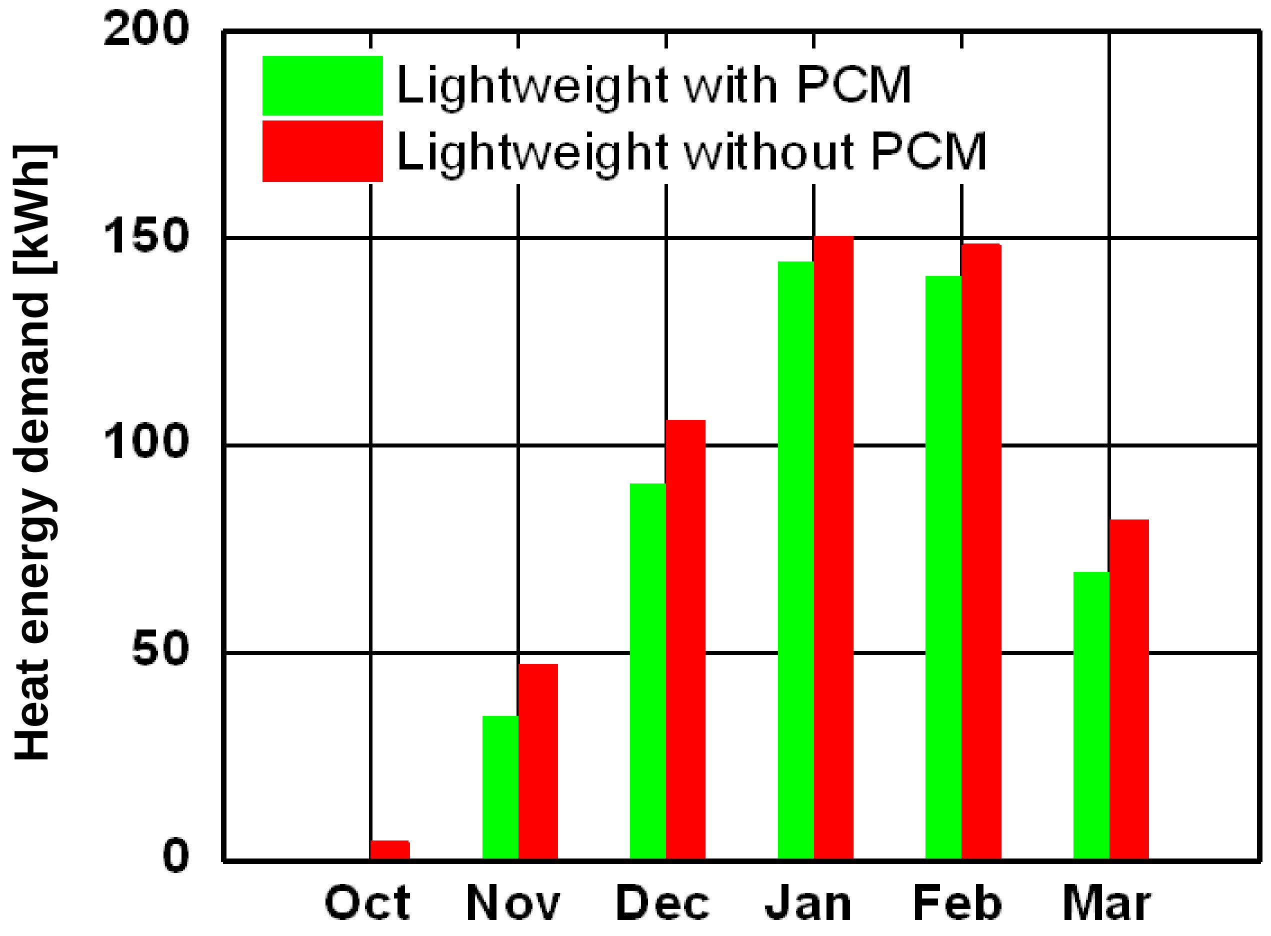
Energy Efficiency Benefits in Winter

Calculation results



Energy Efficiency Benefits in Winter

Calculation results



Energy Efficiency Benefits in Winter

Heavy-weight external walls

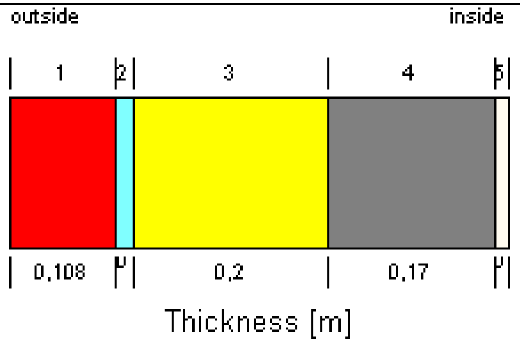
Assembly (Id.2): Masonry wall

Homogenous layers

Thermal resistance: 5,459 m2K/W

Heat Transfer Coefficient(U-value): 0,18 W/m²K

Thickness: 0,5 m



Nr.	Material/Layer (from outside to inside)	ρ [kg/m3]	c [J/kg]	λ [W/mK]	Thickness [m]
1	Solid Brick Masonry	1900	850	0,6	0,108
2	Air Layer 20 mm	1,3	1000	0,13	0,02
3	Mineral Wool (heat cond.: 0,04 W/mK)	60	850	0,04	0,2
4	Concrete, C35/45	2220	850	1,6	0,17
5	Cement Lime Plaster (stucco)	1900	850	0,8	0,015

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Energy Efficiency Benefits in Winter

Heavy-weight floor

-

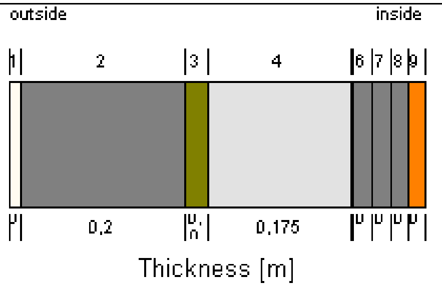
Assembly (Id.4): jah_Boden, massiv

Homogenous layers

Thermal resistance: 5,181 m2K/W

Heat Transfer Coefficient(U-value): 0,19 W/m²K

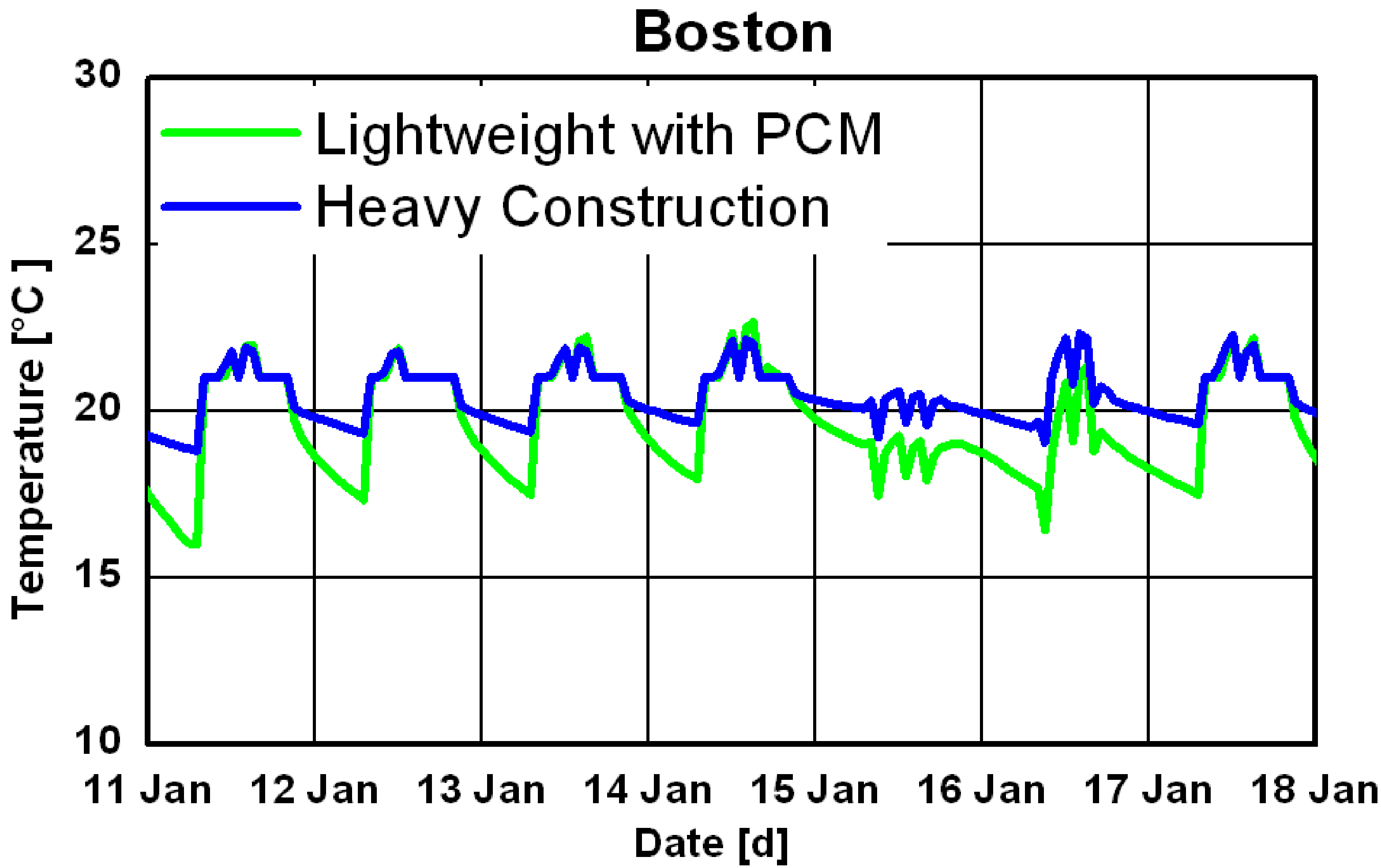
Thickness: 0,5 m



Nr.	Material/Layer (from outside to inside)	ρ [kg/m3]	c [J/kg]	λ [W/mK]	Thickness [m]
1	Interior Plaster (Gypsum Plaster)	850	850	0,2	0,015
2	Concrete, C12/15	2200	850	1,6	0,2
3	Wood-Fibre Insulation Board	155	2000	0,042	0,03
4	Mineral Insulation Board	115	850	0,043	0,175
5	PE-Membrane (Poly; 0.07 perm)	130	2300	2,3	0,001
6	Concrete Screed, bottom layer	1990	850	1,6	0,023
7	Concrete Screed, mid layer	1970	850	1,6	0,023
8	Concrete Screed, top layer	1890	850	1,6	0,023
9	Hardwood	650	1500	0,13	0,02

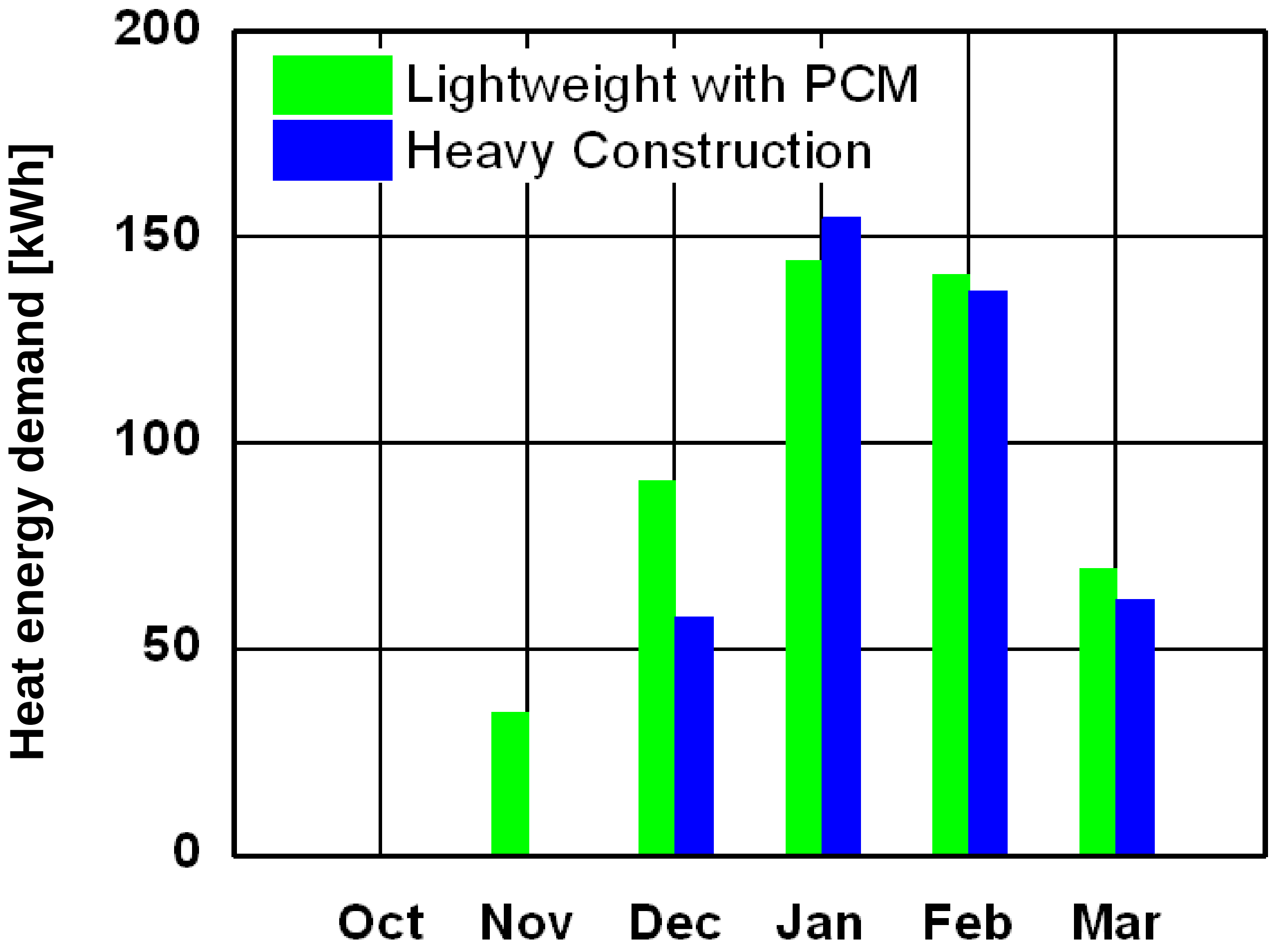
Energy Efficiency Benefits in Winter

Calculation results



Energy Efficiency Benefits in Winter

Calculation results



Conclusions and Outlook

PCM in stucco of EIFS may help to reduce night-time surface condensation if phase-change temperature range is adapted to local climate conditions

PCM may reduce the heating energy demand of light-weight buildings in winter by making better use of solar heat gains

For both applications a small hysteresis is not a problem. It could be even beneficial

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Conclusions and Outlook

Introducing PCM hysteresis into hygrothermal simulation models