Experimental and numerical investigations to compare the thermal performance of infrared reflecting insulation and mineral wool

Matthias Kersken, Almuth Schade

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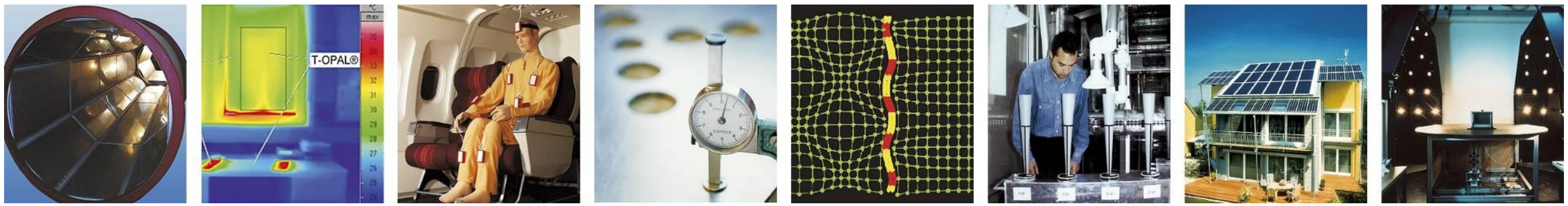
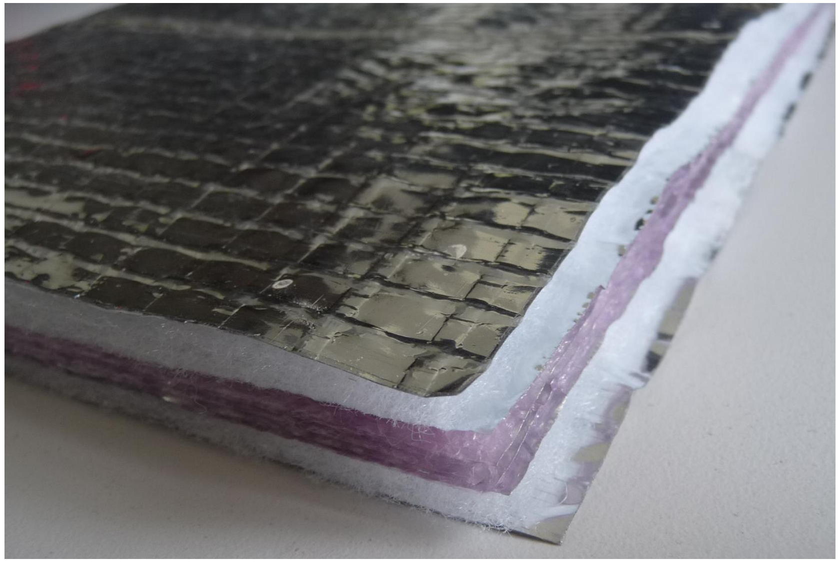
Auf Wissen bauen



Fraunhofer
IBP

Insulation Materials

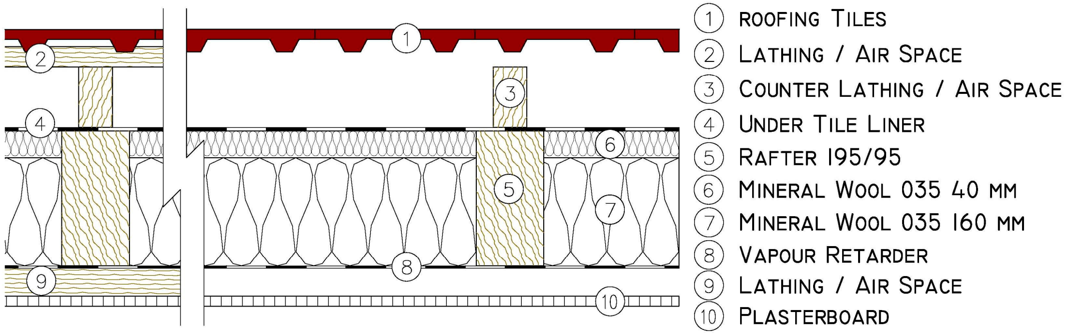
Mineral **W**ool (MW)	Infrared - **R**eflective **I**nsulation (RI)
	
R = 5.7 m²K/W	**R* = 5.7 m²K/W**

thermal resistance mineral wool = thermal resistance IR reflective insulation ?

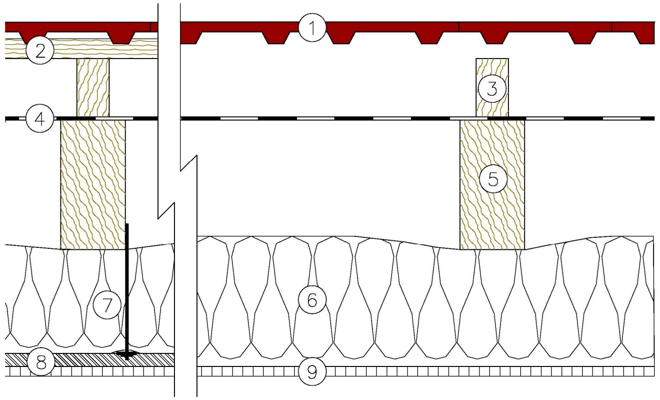
Experimental Buildings

view from south west

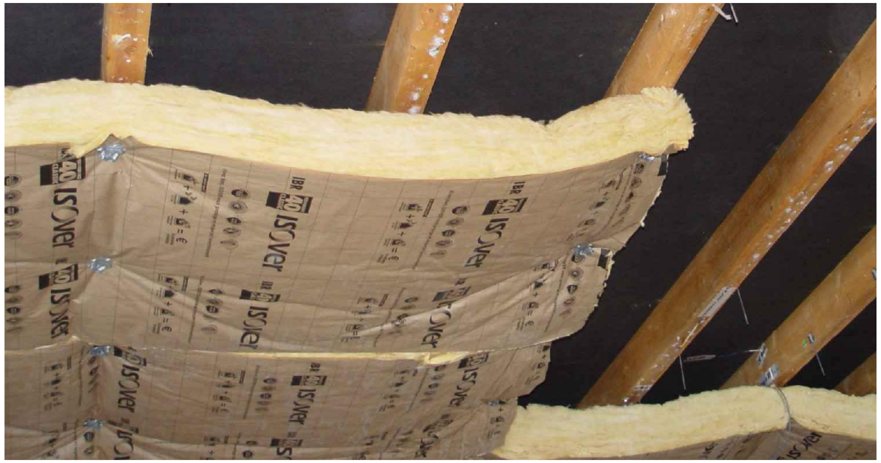
Mineral Wool Roof System 1



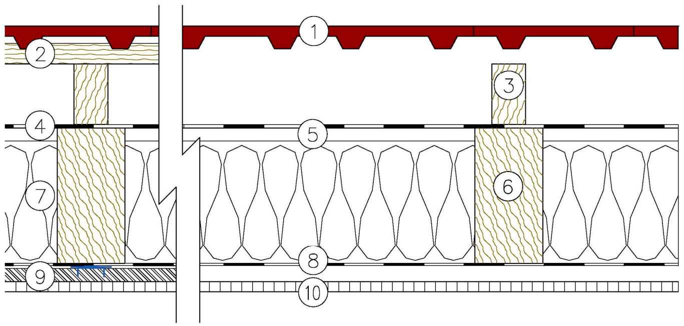
Mineral Wool Roof System 2



1. Roofing Tiles
2. Lathing / Air Space
3. Counter Lathing / Air Space
4. Under Tile Liner
5. Rafter 195/95
   Ventilated Air Space
6. Mineral Wool 040 200mm
7. Anchor Bar
8. Aluminium Profile
9. Plasterboard



Mineral Wool Roof System 3



1. Roofing Tiles
2. Lathing / Air Space
3. Counter Lathing / Air Space
4. Under Tile Liner
5. Ventilated Air Space 15 mm
6. Rafter 95/195
7. Mineral Wool 035 180 mm
8. Vapour Retarder
9. Aluminium Profile
10. Plasterboard

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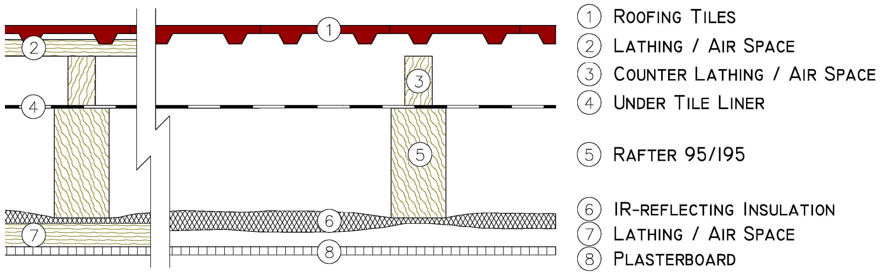
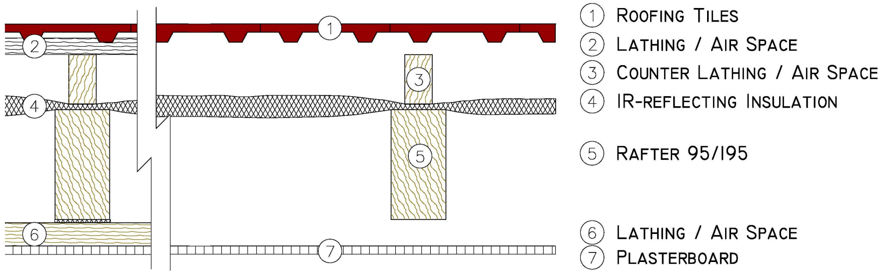
Different IR-reflecitve Insulation Roof Systems

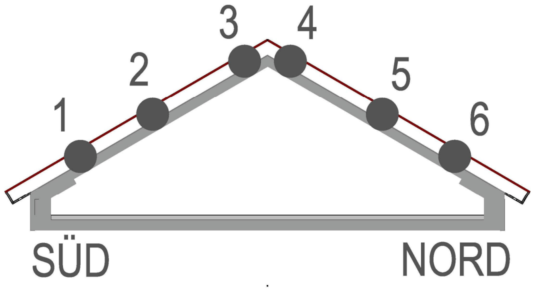
RI 1

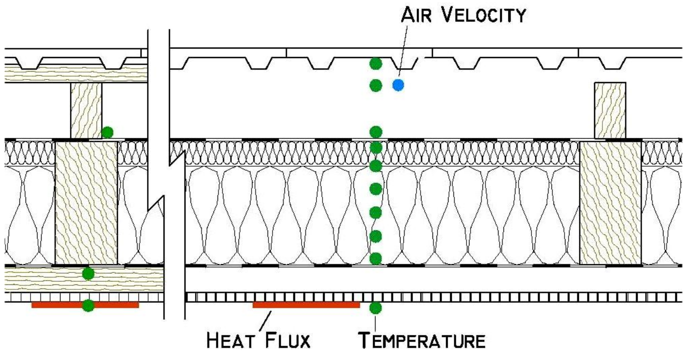


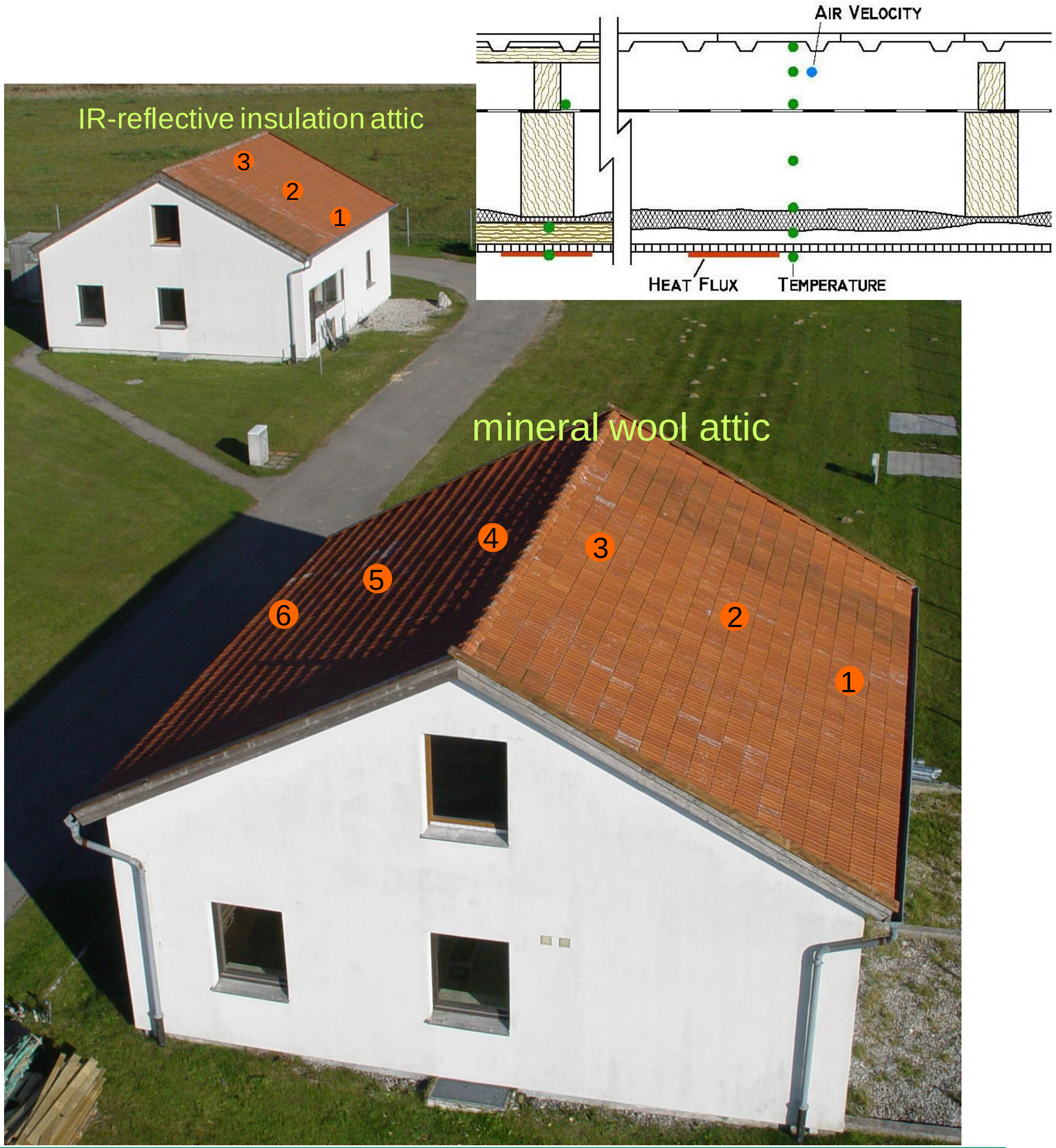
RI 2



Measurement System

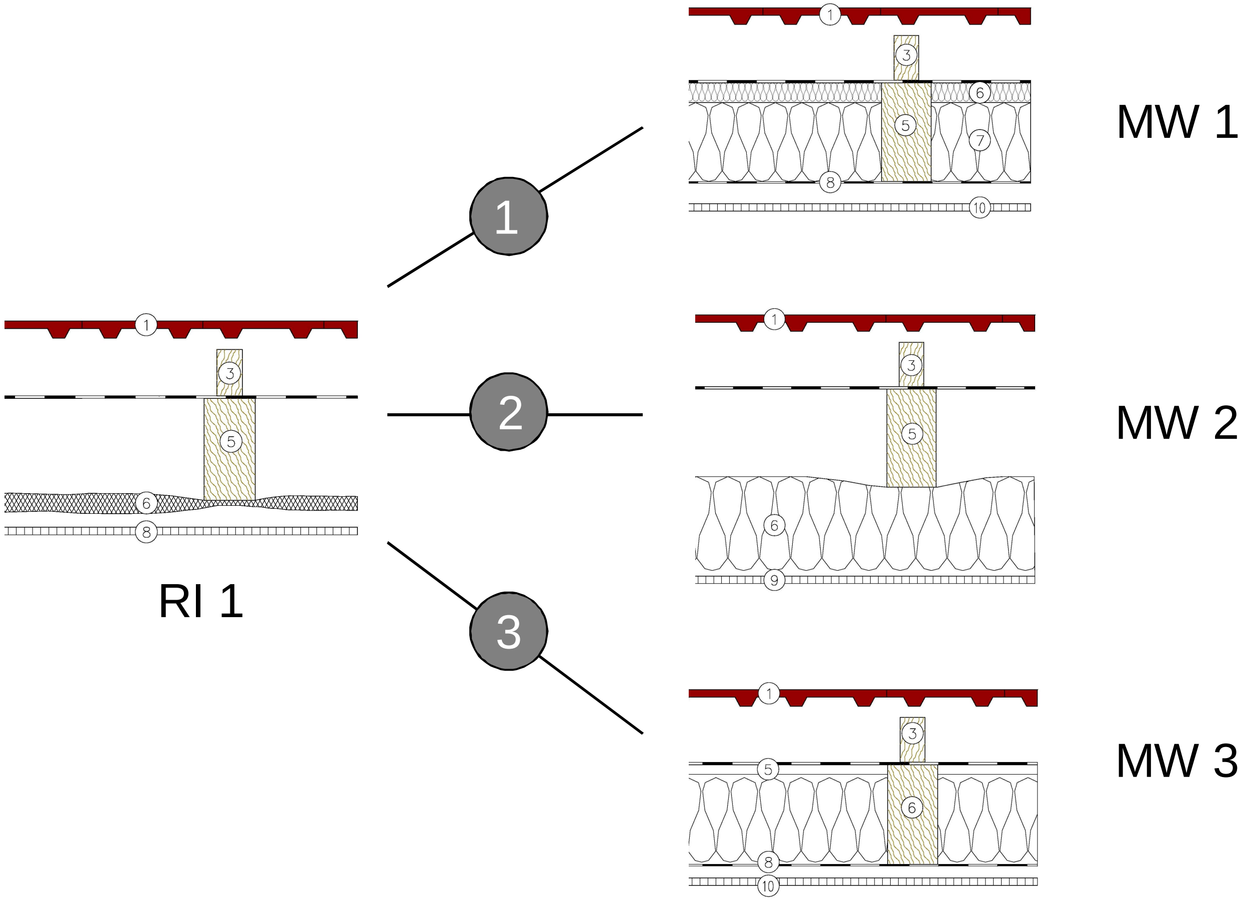






Examination Winter 2007 / 2008

3 measurement periods comparing different roof systems



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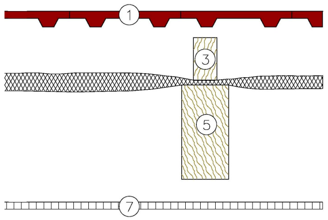
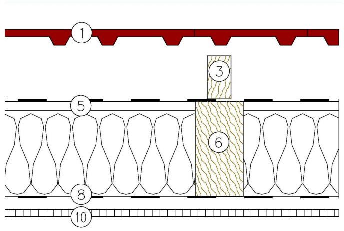
Examination Winter 2008 / 2009



RI 2



MW 3

1. **$n_{50} < 1\ h^{-1}$** high air tightness

2. **$n_{50} \approx 3\ h^{-1}$** design limit acc. EnEV (german energy saving regulations) for natural ventilated buildings

3. **$n_{50} \approx 10\ h^{-1}$** not air tight

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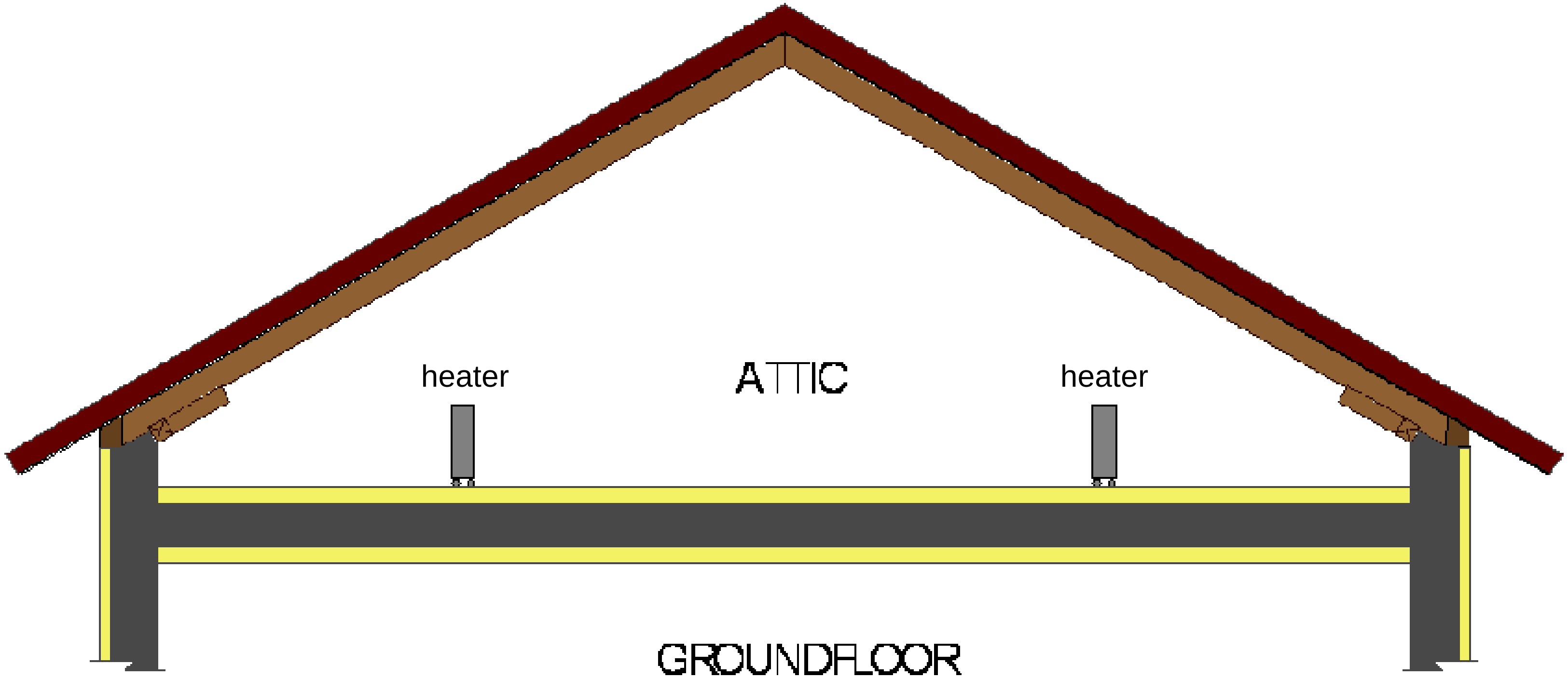
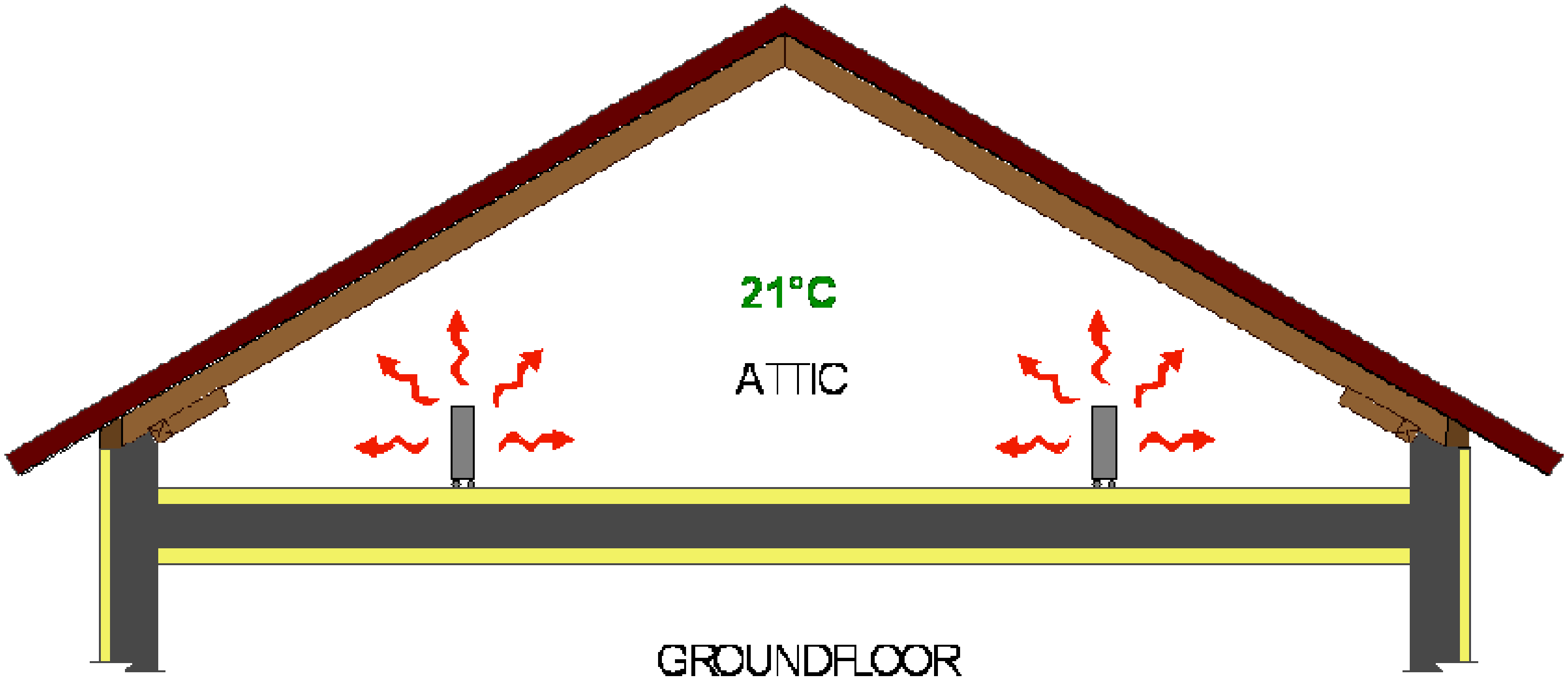
Winter Investigations

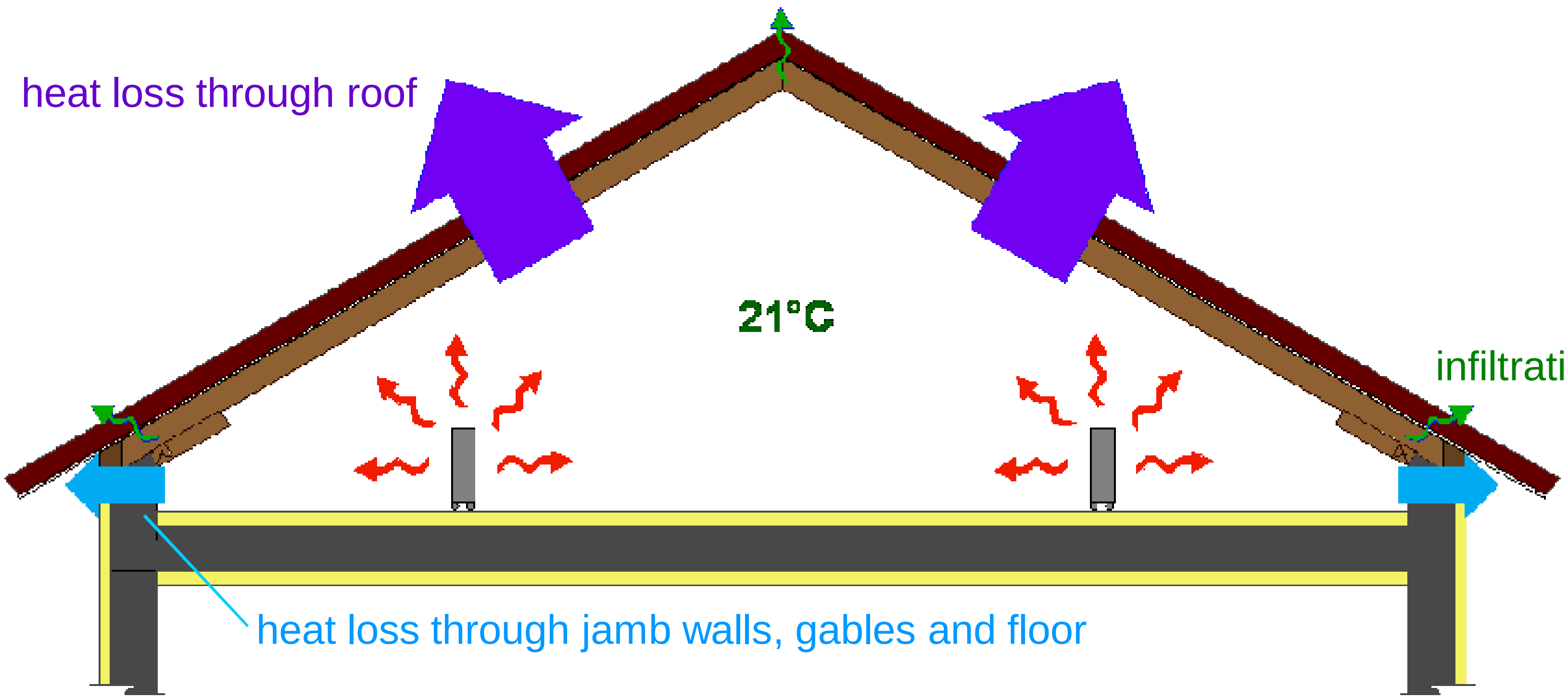


es

Energy Balance (winter): heat sources



Energy Balance (winter): heat losses



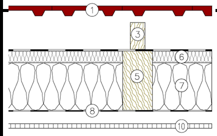
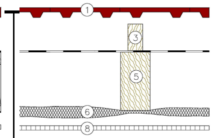
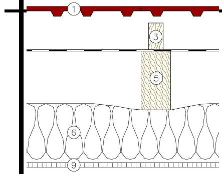
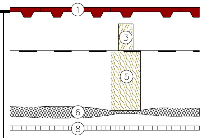
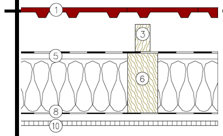
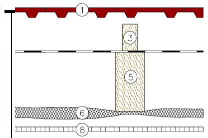
→ heat loss through the roof :

energy consumption (radiators)

– transmission heat losses of envelopes (other than roof)

– infiltration heat losses

Energy balance winter 2007 / 2008

Winter 2007/2008 **Energy balance of the 3 measurement periods**	**11.12.2007–21.1.2008** **(41 days – 984 h)**		**19.2.2008–6.3.2008** **(17 days – 408 h)**		**22.3.2008–30.4.2008** **(17 days – 408 h)**	
Climatic boundary conditions (mean values): External temperature / Global radiation / Wind speed	-2.0 °C 46 W/m² 2.1 m/s		-4.9 °C 108 W/m² 3.9 m/s		-5.4 °C 162 W/m² 3.0 m/s	
	 **MW 1**	 **RI 1**	 **MW 2**	 **RI 1**	 **MW 3**	 **RI 1**
Heat losses envelope areas besides the roof (calculated by measured heat flows)	172 kWh	184 kWh	47 kWh	57 kWh	108 kWh	121 kWh
Infiltration heat losses (acc. EN 832 [2] determined by tracer gas measurement)	33 kWh	45 kWh	33 kWh	17 kWh	50 kWh	23 kWh
Energy consumption (measured)	617 kWh	1264 kWh	195 kWh	369 kWh	439 kWh	806 kWh
	100 %	**205 %**	**100 %**	**189 %**	**100 %**	**184 %**
Heat losses through the roof (determined by energy balance)	412 kWh	1035 kWh	115 kWh	295 kWh	281 kWh	662 kWh
	100 %	**251 %**	**100 %**	**257 %**	**100 %**	**236 %**

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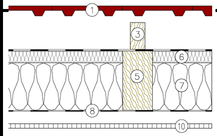
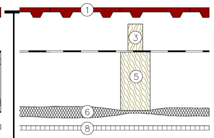
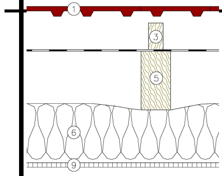
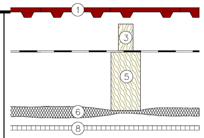
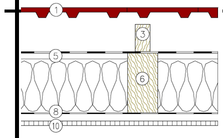
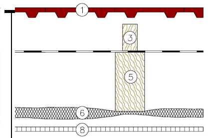
	 **MW 1**	 **RI 1**	 **MW 2**	 **RI 1**	 **MW 3**	 **RI 1**
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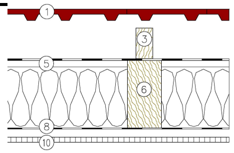
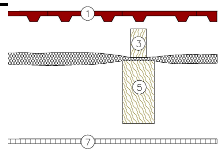
Energy balance winter 2008 / 2009

Winter 2008/2009 **Energy balance of the 3 measurement periods**	**$n_{50} \simeq 0.7\ h^{-1}$** 48 days – 1152 h		**$n_{50} \simeq 3\ h^{-1}$** 36 days – 864 h		**$n_{50} \simeq 10\ h^{-1}$** 44 days – 1056 h	
Climatic boundary conditions (mean values): External temperature Global radiation Wind speed	-2.2 °C 44 W/m² 2.1 m/s		-1.0 °C 84 W/m² 3.6 m/s		-8.6 °C 199 W/m² 2.8 m/s	
 **MW 3**  **RI 2**	**MW 3**	**RI 2**	**MW 3**	**RI 2**	**MW 3**	**RI 2**
Heat losses envelope areas besides the roof (calculated by measured heat flows)	200 kWh	205 kWh	160 kWh	138 kWh	82 kWh	70 kWh
Infiltration heat losses (acc. EN 832 [2] determined by tracer gas measurement)	116 kWh	128 kWh	174 kWh	146 kWh	large fluctuations due to very low air tightness	
Energy consumption (measured)	790 kWh	1787 kWh	642 kWh	1336 kWh	426 kWh	852 kWh
	100 %	**226 %**	**100 %**	**208 %**	**100 %**	**200 %**
Heat losses through the roof (determined by energy balance respectively for $n_{50} \simeq 10\ h^{-1}$ determined by measured heat flow)	474 kWh	1454 kWh	308 kWh	1052 kWh	205 kWh	687 kWh
	100 %	**307 %**	**100 %**	**342 %**	**100 %**	**335 %**

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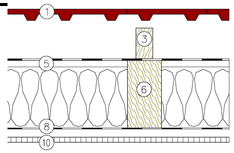
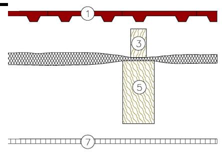
 **MW 3**  **RI 2**	**MW 3**	**RI 2**	**MW 3**	**RI 2**	**MW 3**	**RI 2**
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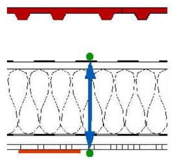
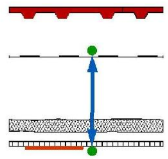
Thermal Resistance (R-Value)

material	mineral wool MW	infrared reflecting insulation RI
thermal resistance R [m²K/W]	5.69	1.00
method	hot plate method installation: horizontal	hotbox method installation: vertical
emissivity [-]	not determined	0.05

Laboratory Values

roof system		mineral wool MW 	IR-reflecting insulation RI 
thermal resistance R [m²K/W]	acc. ISO 6946 using laboratory values	6,0	2,1

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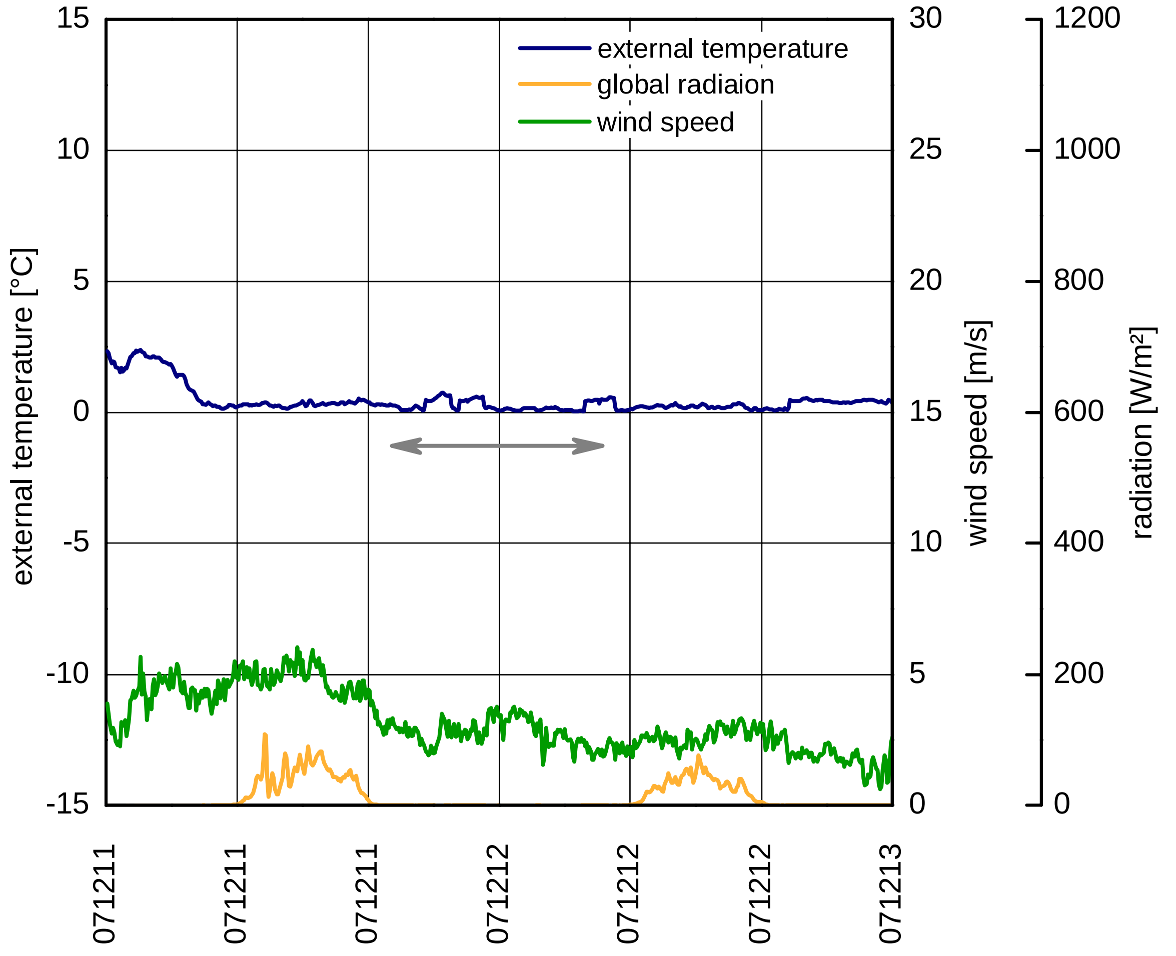
Thermal Resistance (R-Value)

weather conditions
11 to 12 December 2007



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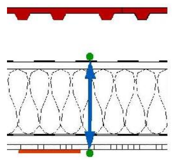
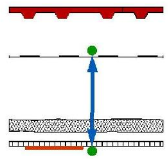
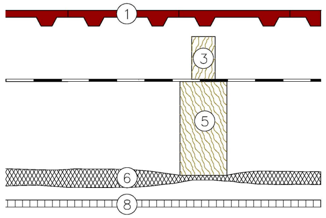
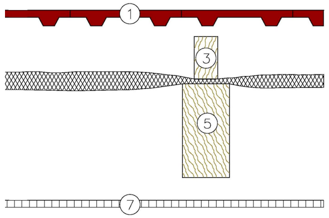
roof system		mineral wool MW 	IR-reflecting insulation RI 
thermal resistance R [m²K/W]	acc. ISO 6946 using laboratory values	**6,0**	**2,1**
in-situ thermal resistance R_{insitu} [m²K/W]	determined by measurement data	**6,4**	**2,0**

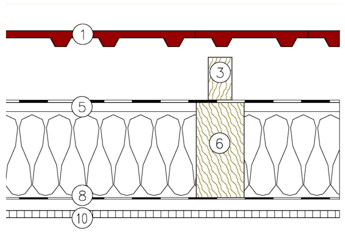
Examination Summer 2008

RI 1



RI 2





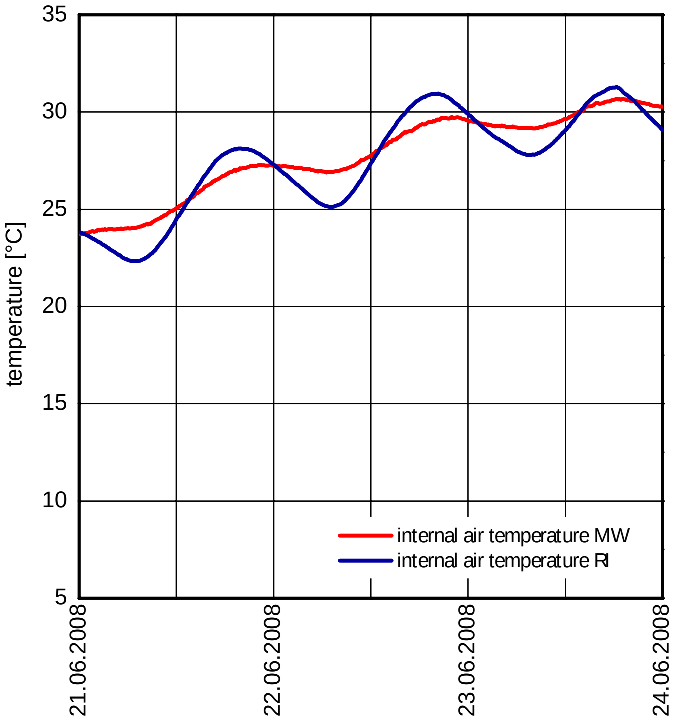
MW 3

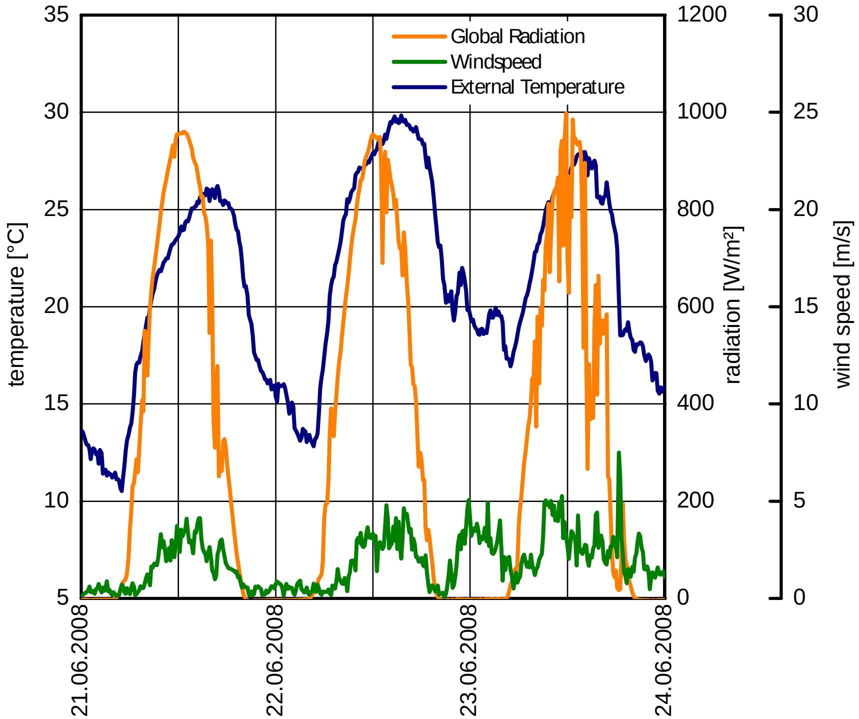
Summer tests varying the following parameters:

- with or without cooling
- with or without ventilation
- simulated window
- internal heat gains

Summer 2008

investigation with internal heat gains, without cooling or ventilation:





Summer 2008

evaluation by means of the total energy consumption is not reasonable

→ dynamic calculations

Dynamic Calculations: Validation

measurment peroid		winter 1	winter 2	summer 1	summer 2
date		**11.12.2007 – 19.1.2008**	**22.3.2008 – 30.4.2008**	**10.6.2008 – 20.6.2008**	**21.6.2008 – 25.6.2008**
days	[d]	39	29	10	5

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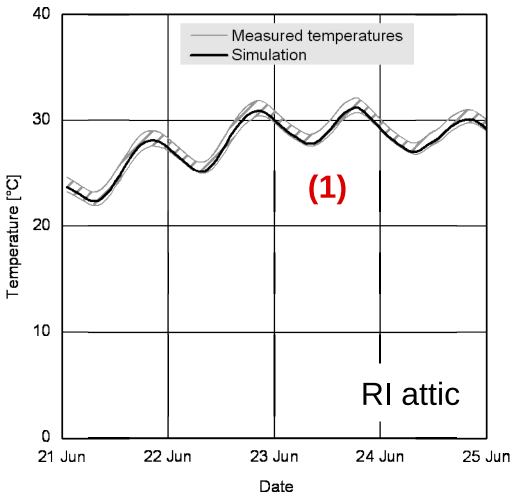
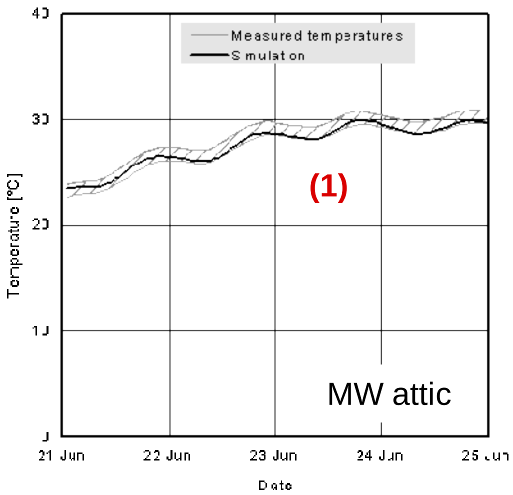
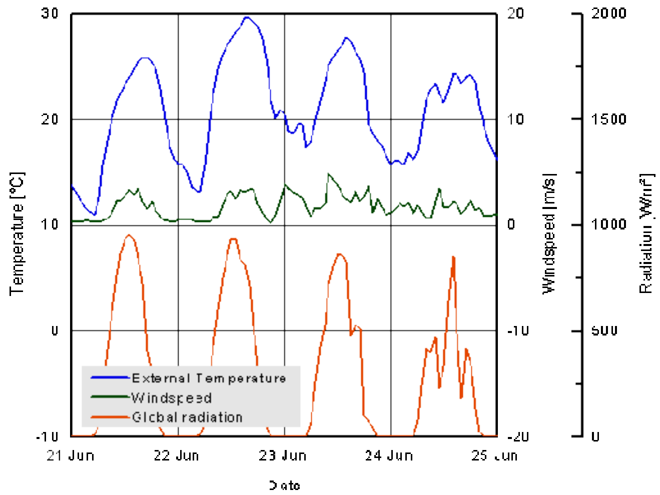
days	[d]	39	29	10	5
parameter for comparision of measurement and simation		heat consumption		room temperature	
difference MW attic	[%]	8.4	5.9	room temperature simulation in the range of all 5 measured values of room temperature **(1)**	
difference RI attic	[%]	1.9	4.1		







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Dynamic Calculations: different boundary conditions

- climate data of different places
- infiltration
- internal heat gains
- orientation
- fenestration
- ventilation
- cooling

Summary and conclusions

- heat losses trough the RI-roof are more than twice as much than through the MW-roof
- high radiation reduces the energy consumption more in the RI-attic than in the MW-attic

  → the thermal resistance of examined IR-reflective insulation is much lower than the thermal resistance of 18 to 20 cm mineral wool

- reducing the air tightness of both attics to the same, lower level does not change the ratio of energy conumption between both attics considerably during a whole measurement period

Summary and conclusions

- high wind impact may decrease the thermal resistance of mineral wool

  → air tight installation of mineral wool to avoid air flow through insulation is recommended

- in situ measurement is influenced by prevailing weather conditions and other boundary conditions

  → thermal parameters should not be determined by in situ testing only

- in situ thermal resistance confirm thermal resistance determined by common laboratory testing

  → common laboratory testing is also valid for IR reflective insulation