

**WUFI**<sup>®</sup>

## **Guideline for the Calculation of Pitched Roofs**

**Date: December 2023** 



## Content

Introduction			
Notes of	on the Input		
_	Component Assembly	<u>slide 4</u>	
_	Moisture Sources	<u>slide 5</u>	
_	Orientation / Inclination	<u>slide 7</u>	
_	Surface Transfer Coefficients	<u>slide 8</u>	
_	Initial Conditions	slide 14	
_	Control	slide 15	
_	Climate	slide 16	
Notes	on the Evaluation		
_	Mineral Wool Insulation	slide 18	
_	Wood Fibre Insulation	slide 19	
_	Wooden Sheathing	slide 20	
Literatu	ıre	slide 24	
Examp	les: Pitched Roof with Mineral Wool and Wooden Sheathing	slide 25	
_	Assembly and Boundary Condition	slide 26	
_	Evaluation Matrix	slide 28	
_	Procedure for Input	slide 29	
_	Procedure for Evaluation	slide 39	



## Introduction

This guideline explains the procedure of the calculation and evaluation of pitched roofs with a vapour retarder applied on the whole interior surface.

In the first step all necessary input data and the evaluation criteria are described.

The procedure from input to evaluation is then explained using an example case.





### **Component - Assembly/Monitor Positions**

#### Roof Cladding with Tiles

The ventilated roof cladding is replaced in the simulation by effective transfer parameters, e. g. according to Kölsch [1]. So, this is not modelled for the simulation.

## Underlay / Weather Protection Membrane

The underlay / weather protection membrane is also not included in the calculation as a component layer but is taken into account as an  $s_d$ -value in the surface transfer parameters. This leads to practically identical results, but speeds up the calculation significantly compared to taking the roofing membrane into account in the component structure.

#### Underlying Roof Assembly

The underlying layers are to be entered according to the assembly in the cross section of the insulated cavity.



### **Component - Assembly/Monitor Positions**

Moisture Source - Infiltration (only needed for structures with wooden parts)

According to EN 15026 [7], the amount of moisture which enters the construction by convection depending on the air tightness of the envelop always needs to be assessed for wooden structures. In the simulation it is considered using the IBP infiltration model.

The moisture source must be placed at the position in the model where the condensation water will form in practice – usually this is below of the second airtight layer on the cold side of the component.

For roof constructions we recommend the following settings:

- with wooden sheathing: moisture source in the interior 5 mm of the wooden sheathing
- without wooden sheathing: moisture source in the exterior 5 mm of the insulation layer



#### **Component – Assembly/Monitor Positions**

Moisture Source - Infiltration (only needed for structures with wooden parts)

The source strength is automatically determined depending on the overpressure due to the building's thermal buoyancy (temperature difference between outside and inside as well as specified air space height), the indoor air humidity and the specified airtightness of the building envelope [3].

For more information on using the infiltration source in WUFI<sup>®</sup>, click here: <u>Guideline for Using the Air Infiltration Source in WUFI<sup>®</sup></u>



#### **Component - Orientation**

#### **Orientation**

The relevant orientation usually is North where the lowest radiation gains occur. Alternatively, the most unfavourable orientation of the building part can be used for specific projects.

#### Inclination

The inclination of the roof must be specified according to the planned roof inclination.



## Notes on the Input: Surface Transfer Coefficients

## **Component – Surface Transfer Coefficients**

Heat Transfer Coefficient on the exterior surface

The heat transfer coefficient is set according to the following tables (Kölsch [1]); the long-wave radiation parts of the heat transfer coefficients must be set to 0 W/m<sup>2</sup>K, as the radiation is calculated explicitly.

Usually "normal ventilated" can be assumed!

Strong ventilated	a <sub>k,e</sub> = 30 [W/m²K]
Normal ventilated	a <sub>k,e</sub> = 19 [W/m²K]
Low ventilated	a <sub>k,e</sub> = 13,5 [W/m²K]

 $a_{k,e}$ : convective heat transfer coefficient

Strong ventilated	Eaves open without any ventilation grid etc.	Ridge open with a low flow resistance	
Normal ventilated	Eaves openings with insect protection grid or eave comb	Ridge closed with ridge / arris role	
Low ventilated	Small openings at the eaves	Small openings at the ridge	No counter battens



#### **Component – Surface Transfer Coefficients**

s<sub>d</sub>-value on the exterior surface

The underlay / weather protection membrane is considered as  $s_d$ -value in the surface transfer parameters, instead of modelling it as a layer.

Underlay membranes with  $s_d$ -values of less than 0.1 m are offered on the market. As this value may increase due to dust and deposits, the  $s_d$ -value of the underlay membrane should be set at a minimum of 0.1 m in the calculation according to the note in the German Standard DIN 4108-3, Annex A [4].



## Notes on the Input: Surface Transfer Coefficients

## **Component – Surface Transfer Coefficients**

<u>s<sub>d</sub>-value on the exterior surface</u>

Note for constructions with absorbent underlay materials:

In the case of assemblies with exterior wooden sheathing, an additional  $s_d$ -value of 0.01 m must be applied to the external surface in order to avoid unrealistically high condensation on the substructure caused by the absence of roof tiles in the simulation.

For a more detailed explanation, see <u>Hygrothermal Simulation of</u> <u>ventilated pitched roofs with effective transfer parameters</u>, chapter 8.



## Notes on the Input: Surface Transfer Coefficients

## **Component – Surface Transfer Coefficients**

## Short-Wave Radiation Absorptivity

The short-wave radiation absorptivity should be selected depending on the colour of the roof tiles (examples below or in right table) and, if necessary, be reduced according to Kölsch [1] (table on next slide).

Red tiles	a = 0.67 – 0.78
Grey tiles	a ~ 0.85
Dark tiles	a = 0.9 – 0.94





## **Component – Surface Transfer Coefficients**

Short-Wave Radiation Absorptivity

The middle position can be used to evaluate typical conditions, especially if the coldest position (30 cm distance to the eaves opening) is still in the area of the roof overhang.

	Coldest position	Middle position	Warmest position
Strong ventilated	a <sub>e</sub> = a · 0.7	a <sub>e</sub> = a · 0.9	a <sub>e</sub> = a
Normal ventilated	a <sub>e</sub> = a · 0.7	a <sub>e</sub> = a · 0.9	a <sub>e</sub> = a
Low ventilated	a <sub>e</sub> = a · 0.75	a <sub>e</sub> = a · 0.9	a <sub>e</sub> = a

a<sub>e</sub>: effective coefficient of absorption



## **Component – Surface Transfer Coefficients**

## Long-Wave Radiation Emissivity

The long-wave radiation emissivity depends on the surface condition of the clay / concrete tiles and varies between 0.82 and 0.91.

Clay tile, high closs clazed	ε ~ 0.82
Clay tile, matt	ε ~ 0.84
Concrete tile, in general	$\epsilon = 0.9 - 0.91$

In order to take into account the (night-time) overcooling, the explicit radiation balance must always be switched on for roofs due to its large field of view to the sky.

## Adhering Fraction of Rain

The roofing is assumed to be waterproof, so the absorption of rainwater must be switched off.

Note: The setting for the  $s_d$ -value in the boundary condition only affects the diffusion behaviour of the surface and not the liquid water absorption.



#### **Component – Initial Conditions**

Initial Temperature and Moisture:

A constant initial relative humidity of 80 % and an initial temperature of 20 °C is recommended as a default setting.

If increased build-in moisture contents are known, these can be specified separately for the corresponding layer.



### Control

#### Calculation Period / Profiles:

It is recommended to start the calculation on October 1<sup>st</sup>, because the component usually moistens up further in the following winter months before drying to the inside possibly starts in spring. This start date is therefore usually an extra stressing of the component.

The calculation time depends on the time the construction needs to reach steady state conditions. Usually, a calculation time of 5 years is sufficient. In the case of diffusion-open building components, the calculation times tend to be shorter, in the case of diffusion-tight building components, the calculation times tend to be longer.

### Numerics:

For the numerical settings, default values can be used.



## Climate

## Outdoor Climate:

A climate appropriate for the location of the building should be used.

## For Germany:

The hygrothermal reference years (HRY), which were created for 11 locations in Germany as part of a research project [5], are useful here. These locations are representative for the respective climate region. For more information, please refer to the  $WUFI^{(R)}$  Help (F1)  $\rightarrow$  Topic: Hygrothermal Reference Years

The Holzkirchen location is considered critically representative for Germany for many application fields. However, especially when evaluating roofs, locations with less radiation may cause more unfavorable conditions.



## Climate

#### Indoor Climate:

By default, we recommend to use the indoor climate with medium moisture load + 5% for design purposes according to German Standard DIN 4103-3 Appendix D [4], EN 15026 [7] and WTA Guideline 6-2 [6].



## Notes on the Evaluation: Mineral Wool Insulation

#### Roofs with mineral wool insulation and underlay membrane

These assemblies do not have any moisture-sensitive materials in the standard cross-section (insulated cavity). Below the roofing felt, due to the higher diffusion resistance compared to the insulation, temporarily increased moisture or condensation may occur.

The amount of condensation occurring below the roofing felt is used for result evaluation. For this purpose, the maximum water content in [kg/m<sup>3</sup>] in the outer area of the mineral wool insulation is evaluated. A distinction is made here between insulation materials with an internal moisture storage function and those with a measured moisture storage function. For more detailed information, please refer to the <u>Guideline for assessing</u> condensation problems in hydrophobic material fiber.

As a general limit value, the condensation water quantity of 200 g/m<sup>2</sup> specified in EN ISO 13788 [8] is recommended (conversion required). Above this quantity, there is a risk of condensation running off.





## Notes on the Evaluation: Wood Fibre Insulation

### Roofs with wood fibre insulation and underlay membrane

For assemblies with wood fibre insulation between the rafters, an evaluation of the wood moisture in the wood fibre insulation is performed.



For this purpose, the wood moisture content is evaluated in [% by mass] in the outer centimeter of the wood-fiber insulation in the settled state. The settled stage has reached if the course of the water content does not change inbetween the years any longer.

For evaluation purposes, the general limit value of 18 % by mass from DIN 68800 [2] can be used, which may be exceeded by a maximum of 20 % by mass for up to three months a year. Alternatively, the manufacturer can guarantee the maximum moisture content for which his product can be used.



## Notes on the Evaluation: Wooden Sheathing

Roofs with insulation and wooden sheathing

For assemblies with exterior wooden sheathing, the insulation between the rafters (mineral wool or wood fibre) is evaluated according to <u>slide 18+19</u>.



For the evaluation of the wooden sheathing, the course of the wood moisture content in [% by mass] in the wooden sheathing in the settled state is used. The value of 20 % by mass for wood and 18 % by mass for wood-based materials specified in DIN 68800 [2] is recommended as the limit value. If this limits are kept, no further evaluation is necessary.

If the wood moisture exceeds the limit value according to DIN 68800 [2], an evaluation according to the WTA Guideline 6-8 [9] also can be carried out for solid wood. This allows a more precise evaluation considering the temperature and humidity conditions.



#### Roofs with insulation and wooden sheathing

Evaluation according to DIN 68800 [2]

Critical moisture conditions regarding damage to the wood can occur, if the moisture content limits of 20 % by mass for wood and 18 % by mass for wood-based materials are exceeded over a long period.

However, this limit value includes high safety margins and, in contrast to the WTA guideline 6-8 [9], no specifications are made for the evaluation area. In the case of thin wooden sheathings, the entire section of the sheathing shall be evaluated, otherwise the most critical 1 cm thick section should be used in accordance with the WTA evaluation.

If the wood moisture remains below the limit values (see above), no further evaluation is necessary.





## Notes on the Evaluation: Wooden Sheathing

Roofs with insulation and wooden sheathing

Evaluation according to WTA Guideline 6-8 [9]

If the limit value for wood of 20 % by mass according to DIN 68800 [2] is exceeded, also an evaluation according to the WTA 6-8 [9] can be carried out. Here, the evaluation of wood structures is carried out based on temperature-dependent limit values for the relative pore air humidity in a 1 cm thick layer at the critical position of the wood. This allows a more accurate and realistic evaluation.

Please note: This evaluation can not be used for wood-based materials, as other limit values for rotting processes may apply here.



## Notes on the Evaluation: Wooden Sheathing

Roofs with insulation and wooden sheathing

Limit curve for wood decay depending on temperature (x-axis) and relative humidity (y-axis) according to WTA 6-8 [9].

At conditions below the red limit line, wood decay is not possible in solid wood.





23

## Literature

- [1] Kölsch, Ph.: Hygrothermal simulation of ventilated pitched roofs with effective transfer parameters. 01/2017. (Guideline for the simulation of ventilated pitched roofs with effective transfer parameters)
- [2] DIN 68800-2: Holzschutz Teil 2: Vorbeugende bauliche Maßnahmen im Hochbau. Beuth Verlag, February 2022.
- [3] Zirkelbach, D.; Künzel, H.M.; Schafaczek, B. und Borsch-Laaks, R.: Dampfkonvektion wird berechenbar Instationäres Modell zur Berücksichtigung von konvektivem Feuchteeintrag bei der Simulation von Leichtbaukonstruktionen. Proceedings 30. AIVC Conference, Berlin 2009.
- [4] DIN 4108-3: Klimabedingter Feuchteschutz, Anforderungen, Berechnungsverfahren und Hinweise für Planung und Ausführung. Beuth Verlag, October 2018.
- [5] Research Report: Energieoptimiertes Bauen: Klima- und Oberflächenübergangsbedingungen für die hygrothermische Bauteilsimulation. IBP-Bericht HTB-021/2016. Durchgeführt im Auftrag vom Projektträger Jülich (PTJ UMW). July 2016.
- [6] WTA Guideline 6-2/E: Simulation of heat and moisture transfer. December 2014.
- [7] EN 15026: Hygrothermal performance of building components and building elements Assessment of moisture transfer by numerical simulation. Beuth Verlag, December 2023.
- [8] EN ISO 13788: Hygrothermal performance of building components and building elements Internal surface temperature to avoid critical surface humidity and interstitial condensation - Calculation methods. Beuth Verlag, May 2013.
- [9] WTA Guideline 6-8: Feuchtetechnische Bewertung von Holzbauteilen Vereinfachte Nachweise und Simulationen. August 2016.



## **Example: Pitched Roof with Mineral Wool and Wooden Sheathing**

Based on the example of a pitched roof with mineral wool insulation and wooden sheathing, the procedure for the input and the evaluation is described.



- 1 Roofing and Battens
- 2 Weather Protection Membrane
- 3 Wooden Sheathing
- 4 Insulation
- 5 Vapour Retarder
- 6 Installation Layer
- 7 Gypsum Board



#### Assembly (from outside to inside):

- Red Concrete Tiles
- Weather Protection Membrane ( $s_d = 0.01$  m)
- Wooden Sheathing (Softwood)
   0.025 m
- Mineral Wool (heat cond.: 0.04 W/mK)
   0.24 m
- Moisture-Variable Vapour Retarder (Intello Plus)
   0.001 m
- Air Layer
   0.02 m
- Gypsum Board
   0.0125 m



## **Boundary Conditions:**

- Pitched roof (30° to the North)
- Red concrete tiles (a = 0.67; ε = 0.9)
- Normal ventilated roof (middle position)
- Outdoor climate: Holzkirchen
- Indoor climate: medium moisture load + 5 % according to EN 15026
- Air tightness of the envelope:  $q_{50} = 3 \text{ m}^3/\text{m}^3\text{h}$
- Stack Height: 5 m



### Evaluation Matrix:

The following matrix shows the evaluation criteria relevant to this design.

	Criteria	
1) Numerics	Low balance differences?	
	Few or no convergence failures?	
2) Evaluation parameters	Total water content settled?	
	Amount of condensation in the insulation layer?	
	Risk of wood decay in the wooden sheathing? (limit values according to DIN 68800-3 or WTA 6-8)	



## Input: Component - Assembly / Monitor Positions

🕐 WUFI Pro 6.7	×			
Project Inputs Run Outputs Options Datab	base Result Analysis ?			
D 🚅 🖬 🐮 🗽 🛣 😼 🗐 📰	翻 ⑦ 戻 │ ?			
Project	Case: Pitched Roof			
Component	Assembly/Monitor Positions Orientation/Inclination/Height Surface Transfer Coeff. Initial Conditions			
Assembly/Monitor Positions	Layer Name Thickn. [m]			
<ul> <li>Surface Transfer Coeff.</li> <li>Initial Conditions</li> </ul>	Gypsum Board 0.0125			
Control	Exterior (Left Side) Interior (Right Side) 10.025 0.24 0.000.00.0125			
	👔 🖉 🖓 Sources, Sinks			
	t and the second s			
	📴 Duplicate			
	r Delete			
	Edit Assembly by:			
	e Graph €			
	Assign from			
	Automatic (II)			
	Example Cases			
	Copy Auto. Grid Der Enteraroof assembly without roofing tiles and			
	Total Thickness Thickness: 0299 m B-Value: 645 (m² K) W eather protection, membrane			
	Adjust layer thicknesses if necessary			
Units: SI No calculation results available.				



## **Example: Input - Infiltration Source**

Input: Component - Assembly / Monitor Positions

Infiltration source in the wooden sheathing according to EN 15026.

🕐 WUFI Pro 6.7			- 🗆 X		
Project Inputs Run Outputs Options Datab	base Result Analysis ?				
🗅 🛩 🖬   🗞 🔭   🛣 🧏 💷   📰	騷 ⊘ 栗│?   ¶ ⑦ ⑦				
Project inputs kui ouputs oputin para     B	Case: Pitched Roof Assembly/Monitor Positions Orientation/Inclination/Height Softwood Extension Case: Discharge Softwood Case: Discharge Softwood Case: Discharge Softwood Case: Control Cont	Initial Conditions             Material Data              Material Data	Bources, Sinks		×
	EditA	Edit Assembly by: Graph Table	Layer/Material Name Hygrothermal Sources Nr. Type	Softwood Name	😵 New Heat Source
Select compo	nent layer			New Moisture Source	New Moisture Source
	Assign from  Assign from  Material Database  Example Cases  Copy Auto Grid Def. for Manual Editing  Total Thickness  Total Thermal Performance				Edit
Units: SI No calculation results available.	Thickness: 0.299 m R-Value: 6,45 (m² K)/W U	J-Value: 0,151 W/(m² K)	[*	✓ OK X Abort ?	Help



Input: Component - Assembly / Monitor Positions

Moisture Source in the interior 5 mm of the wooden sheathing.

Moisture Source	×
Name Infiltration Source	Interior 5 mm of the sheathing
Spread Area One Element Several Elements Whole Layer Source Type Transient from File Fraction of Rain Load Air Infiltration model IBP Constant Montnly Moisture Load	Start Depth in Layer [m] 0.02 End Depth in Layer [m] 0.025 Source Term Cut-Off [kg/m³] O No Cut-Off O Cut-Off at Max. Water Content © Cut-Off at Free Water Saturation O User-Defined
Envelope Infiltration q50 [m³/(m² h)] 3 Air Tightness Class f	B (DIN 4108, tested <= 3 m³/m²h) v Stack Height [m] 5 ation Overpressure [Pa] 0
Adjus	st infiltration source
€ОК	X Cancel ? Help



## Input: Component - Orientation

🕐 WUFI Pro 6.7	- 0	×
Project Inputs Run Outputs Options Database Result Analysis ?		
다 🖆 🖬 😫 😿 🕱 🗐 📰 🖩 🖼 🔿 🛒 ? 📲 🕐 🕧		
Case: Pitched Roof (Act Case) Component Conserved and Conditions Control	and ir	n <mark>clin</mark> a



## Input: Component – Surface Transfer Coeff.

Exterior Surface (Left Side)		
Heat Transfer Coefficient [W/(m <sup>2</sup> K)]	19 User-Defined ~	Heat Transfer Coefficient
includes long-wave radiation parts [W/(m <sup>2</sup> K)]	0	für a normal ventilated roof = 19 W/m <sup>2</sup> K
wind-dependent		Note. long-wave radiation parts set to 0.
sd-Value [m]	0.01 User-Defined	s <sub>4</sub> -value of the weather protection membrane
	Note: This setting does not affect rain absorption	
Short-Wave Radiation Absorptivity [ - ]	0.603 User-Defined ~	Colouring of the roofing for middle position
Long-Wave Radiation Emissivity [ - ]	0.9	(a <sub>e</sub> = a ⋅ 0.9 = 0.67 ⋅ 0.9 = 0.603)
Reduction factors caused by shading:		
for absorptivity [-]	1.0 No shading ~	
for emissivity [-]	1.0	Use Explicit Radiation Balance ( $\epsilon = 0.9$ )!
Explicit Radiation Balance	Note: This option takes radiative cooling due to long-wave emission into account. Sensitive cases may require sufficiently accurate counterradiation data in the weather file.	No shading
Ground Short-Wave Reflectivity [ - ]	0.2 Standard value ~	
Adhering Fraction of Rain [ - ]	No absorption ~	No Rain Water Absorption!
Interior Surface (Pight Side)		
Heat Transfer Coefficient [W/(m <sup>2</sup> K)]	8,0 (User-Defined)	
	Adjust surfac	e transfer coefficients
sd-Value [m]	No coating	



## Input: Component – Initial Conditions

🕐 WUFI Pro 6.7						_		×
Project Inputs Run Outputs Options Data	oase Resi	ult Analysis ?						
□ ☞ ■ 陰 隊 🛛 🕿 寝 🗐 圖 圞 ② 栗 ? 📲 ⑦ ⑦								
Project     Case: 1 Pitched Roof (Act. Case)     Case: 1 Pitched Roof (Act. Case)     Component     ✓ Assembly/Monitor Positions     ✓ Orientation     ✓ Surface Transfer Coeff.     ✓ Initial Conditions     ① Control     ⑦ Columnate	Case: Assem	Pitched Roof      Diy/Monitor Positions     Orientation/Inclination/I  Moisture in Component  onstant Across Component  each Layer ead from File	Height Surface Transfer C Initial Temperature in Co Constant Across Com Read from File	oeff. Initia mponent	I Conditions			
	Initia	Relative Humidity [ - ]	Initial Temperature in Co	mponent [°C]	20			
	No.	Water Content in Different Layers Material Layer		Thickn. [m]	Water Content [kg/m³]			
	1	Softwood	(	0,025	60,0			
		Mineral Wool (heat cond.: 0,04 W/mK)	(	0.24	1,79			
	3	INTELLO PLUS (ETA)	(	0.001	6,7			
	4	Air Layer 20 mm	(	0.02	1,88			
	5	Gypsum Board	(	0.0125	6,3			
					No ch	nang	es r	equ
Units: 51 No calculation results available.								



## Input: Control – Calculation Period / Profiles

🕐 WUFI Pro 6.7								- 0	×
Project Inputs R	Run Outputs Options Datab	ase Result Analys	is ?						
D 🛩 🖬 😫	🗽 🛛 🏖 🖾 🗐 📰 🛙	8 🕜 🛒 ?	📲 🕐 🕐						
Project		Case: Pitch	ed Roof						
🖹 🎦 Case: 1 P	Pitched Roof (Act. Case)	Colculation Por		norice					
√ Ass	embly/Monitor Positions	Calculation Fer	Ind / Fromes Thur	nencs		-			
	ntation	Start_End /	Profiles						
✓ Suna ✓ Initia	al Conditions	Calculation	Profiles	Date	Hour	New			
	culation Period/Profiles	Start	Profile 1	01.10.2023	00:00:00				
Num	nerics	End	Profile 2	01.10.2028	00:00:00				
a-3K ciintate		L				Delete			
						Сору			
				04.07.2023	00:00:00	Insert			
		Time Steps	s [h] 1						
							Adjust c	alcula	ation <sub>j</sub>



## Input: Control – Numerics

Component     Conductivity     Component     Conductivity     Component     Conductivity     Component     Conductivity     Component	WI JEI Pro 6 7			_		×
Image: Section of the section of th	Project Inputs Run Outputs Options Datab	ase Result Analysis ?			-	
Project     Case: 1 Pitched Roof (Act Case)     Component     Case: A consendy/Monitor Positions     Control     Calculation Period (Profiles     Mode of Calculation     Mode of Calculatin     Mode of Calculatin     Mode of Calculation     M						
Case: Pitched Roof (Act Case) Concorrent Case: Pitched Roof Calculation Period/Profiles Calculation Calculation Calculation Case: Pitched Roof Calculation Calculation Case: Pitched Roof Calculation Calculation Calculation Case: Pitched Roof Calculation Calculation Case: Pitched Roof Calculation Case: Pitched Calculation Case: Pitched Calculation Calculation Case: Pitche						
Component Constant Conditions Control	Case: 1 Pitched Roof (Act. Case)	Case: Pitched Roof				
Assembly/Monitor Positions     Surface Transfer Coeft     Surface Transfer Coeft     Control	Component	Calculation Period / Profiles Numerics				
Surface Transfer Coeff.     Initial Conditions     Calculation Period/Profiles     Commerce     Calculation Period/Profiles     Climate     Clima	<ul> <li>Assembly/Monitor Positions</li> <li>Orientation</li> </ul>	Mode of Calculation				
Minial Conditions Control Cliculation Period/Profiles Climate Moisture Transport Calculation Hygrothermal Special Options Excluding Capillary Conduction Excluding Temperature Dependency in Latent Heat of Evaporation Excluding Temperature Dependency of Thermal Conductivity Numerical Parameters Increased Accuracy Adaptive Time Step Control Geometry Cartesian Radially Symmetric No changes require	Surface Transfer Coeff.	☑ Heat Transport Calculation				
Catculation Period/Profiles     Hygrothermal Special Options     Excluding Capillary Conduction     Excluding Temperature Dependency in Latent Heat of Evaporation     Excluding Temperature and Moisture Dependency of Thermal Conductivity      Numerical Parameters     Increased Accuracy     Adaptive Time Step Control     Enable     Geometry     Cartesian     Radially Symmetric      No changes require	Initial Conditions	Moisture Transport Calculation				
Implemental special oppoints         Bx://Uning Latent Heat of Evaporation         Excluding Latent Heat of Evaporation         Excluding Latent Heat of Fusion         Excluding Temperature Dependency in Latent Heat of Evaporation         Excluding Temperature and Moisture Dependency of Thermal Conductivity         Numerical Parameters         Increased Accuracy         Adapted Convergence         Adapted Convergence         Adapted Convergence         Cerementry         © Cartesian         Radially Symmetric    No changes required	Calculation Period/Profiles	- Hugrathormal Special Options				
Clinitate Clini	Numerics	Frygrothermal Special Options     Frygrothermal Special Options				
Cecularity callent reactor Exerptionation  Cecularity  Numerical Parameters  Adaptive Time Step Control  Cecularity  Cecularit						
Excluding Temperature Dependency in Latent Heal of Evaporation Excluding Latent Heat of Fusion Excluding Temperature and Moisture Dependency of Thermal Conductivity   Numerical Parameters   Increased Accuracy   Adapted Convergence     Adaptive Time Step Control   Enable     Geometry   © Cartesian   Radially Symmetric   No changes require						
☐ Excluding Latent Heat of Fusion ☐ Excluding Temperature and Moisture Dependency of Thermal Conductivity          Numerical Parameters         ☐ Increased Accuracy         ☑ Adapted Convergence         Adaptive Time Step Control         □ Enable         Geometry         ④ Cartesian         ○ Radially Symmetric						
		Excluding Latent Heat of Fusion				
Numerical Parameters Increased Accuracy Adapted Convergence Adaptive Time Step Control Enable Geometry • Cartesian <a href="https://www.communication.com">https://www.communication.com</a> No changes requint		Excluding Temperature and Moisture Dependency of Thermal Conductivity				
<ul> <li>☐ Increased Accuracy</li> <li>☐ Adapted Convergence</li> <li>Adaptive Time Step Control</li> <li>☐ Enable</li> <li>Geometry</li> <li>③ Cartesian</li> <li>○ Radially Symmetric</li> </ul> No changes required		Numerical Parameters				
Adapted Convergence Adaptive Time Step Control Enable Geometry  Cartesian Radially Symmetric No changes requin		⊡ Increased Accuracy				
Adaptive Time Step Control Enable Geomety  Cartesian  Radially Symmetric No changes requin		Adapted Convergence				
Adaptive Time Step Control Enable Geometry Cartesian Radially Symmetric No changes requin		Adaptive Time Orea Control				
Ceometry Cartesian C Radially Symmetric No changes requin		Adaptive Time Step Control				
Geometry  Cartesian  C Radially Symmetric  No changes requin		Enable				
Ceresian O Radially Symmetric No changes requin						
Cartesian     CRadially Symmetric     No changes require		Geometry				
○ Radially Symmetric No changes requir		Cartesian				
○ Radially Symmetric No changes requir						
No changes requir		◯ Radially Symmetric				
No changes requi						
			No cha	ange	es re	equi
Units: SI No calculation results available.	Units: SI No calculation results available.					



Input: Climate – Outdoor (Left Side)





#### Input: Climate – Indoor (Right Side)





## **Example: Evaluation – Numerics**

Eval	luation:	Numerics

Nata

For more information on the evaluation of the numerical quality, see "<u>Guideline for the Evaluation</u> and Assessment of hygrothermal Calculation Results".

indicate rather difficult	ate	04.07.202 1 min	,15 sec.
	n	01.10.2023	/ 01.10.2028
No. of Converge	nce Failures	1	14
Check for numeric	al quality		
Integral of fluxes,	left side (kl,dl)	[kg/m²]	0,0 -1,91
Integral of fluxes,	right side (kr,dr)	[kg/m²]	7E-8 -0.89
Balance 1		[kg/m²]	-0,33
Balance 2		[kg/m²]	-0,33
Water Content [kg	'(m²]		
	Start End	Min.	Max.
			16
Many convergence fai	lures, but balances OK!		40
Many convergence fai $\rightarrow$ if necessary recalc	lures, but balances OK! ulate with adaptive time step	control	40



### *Evaluation:* Numerics – with Adaptive Time Step Control

	Status of Last Calculation					×	
	Status of Calculation						
	Calculation: Time and Date				04.07.2023 10:18:04		
	Computing Time	1 min,	23 sec.				
	Begin / End of calculation	01.10.2023 / 01.10.2028					
	No. of Convergence Failures				0		
	Check for numerical quality						
	Integral of fluxes, left side (kl,dl)	[kg/m²]	0,0 -1,91				
	Integral of fluxes, right side (kr,dr)				7E-8 -0.9		
	Balance 1	[kg/m²]	-0,33				
	Balance 2	[kg/m²]	-0,33				
	Water Content [kg/m²]	Water Content [kg/m²]					
		Start	End	Min.	Max.		
	Total Water Content   2,05   1,74				2,45		
				_			
No convergence failures and no balance differences!					Max.	~	
	Calculation locked			Close	? <u>H</u> elp	,	



Evaluation: Total Water Content





*Evaluation:* Moisture Content in the Wooden Sheathing – according to German Standard DIN 68800





















## **Example: Evaluation – Wooden Sheathing**

# *Evaluation:* Moisture Content in the Wooden Sheathing – according to WTA 6-8



The relative pore air moisture in the interior centimetre of the sheathing doesn't exceed the limits according to WTA.

→ no damage by wood decay



## **Example: Evaluation – Amount of Condensation**

Evaluation: Amount of condensation in the mineral wool insulation

 $\rightarrow$  Evaluation of the water content in the outer centimetre of the insulation





## **Example: Evaluation – Amount of Condensation**

Evaluation: Amount of condensation in the mineral wool insulation

 $\rightarrow$  Evaluation of the water content in the outer centimetre of the insulation





## **Example: Evaluation – Amount of Condensation**

Evaluation: Amount of condensation in the mineral wool insulation

 $\rightarrow$  Evaluation of the water content in the outer centimetre of the insulation





#### Final Evaluation:

	Criteria	Evaluation
1) Numerics	Low balance differences?	$\checkmark$
	Few or no convergence failures?	$\checkmark$
2) Evaluation parameters	Total water content steady-state?	$\checkmark$
	Amount of condensation in the insulation layer?	$\checkmark$
	Risk of wood decay in the wooden sheathing? (limit values according to DIN 68800-3 or WTA 6-8)	$\checkmark$
		Construction

unproblematic from the moisture point of view!

