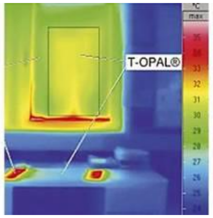
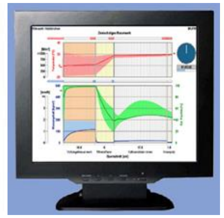
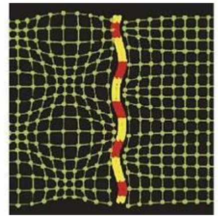




WUFI®

Guideline for Assessing the Risk of Mould Growth with WUFI®

Date: January 2024

Fraunhofer
IBP

Content

Basics: Mould Growth in and on Components

Mould growth in occupied dwellings has the following effects on the occupants, among others:

- Aesthetic concerns
- Hygienic concerns
- Potential health hazards due to the production and dissemination of harmful substances

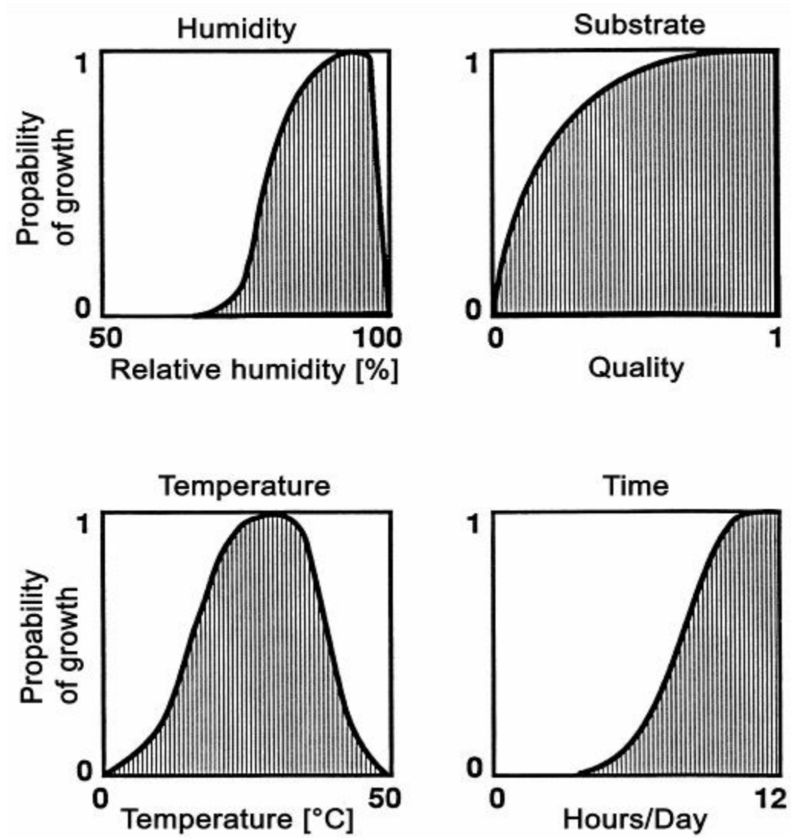
Basics: Factors Influencing Mould Growth

Influencing Factor	Reality	Consideration
Moisture	Most important influence	Can be influenced or determined by the planner through construction and material selection respectively through consideration of real usage. (These factors are also considered in WUFI® Bio)
Temperature	Strong influence	
Time	Strong influence	
Substrate	Nutrients from substrate and contaminated surfaces	
pH-value	Is influenced by the fungi themselves – difficult to predict	Mostly difficult to predict – should in doubt be considered favourable. (These factors cannot be considered in WUFI® Bio)
Light	Growth also possible without light	
Oxygen	Normally available	
Presence of spores	Normally available everywhere	
Surface roughness	Lighter contamination	
Biological interactions	unavoidable	

Basics: Factors Influencing Mould Growth

Growth requirements for mould:

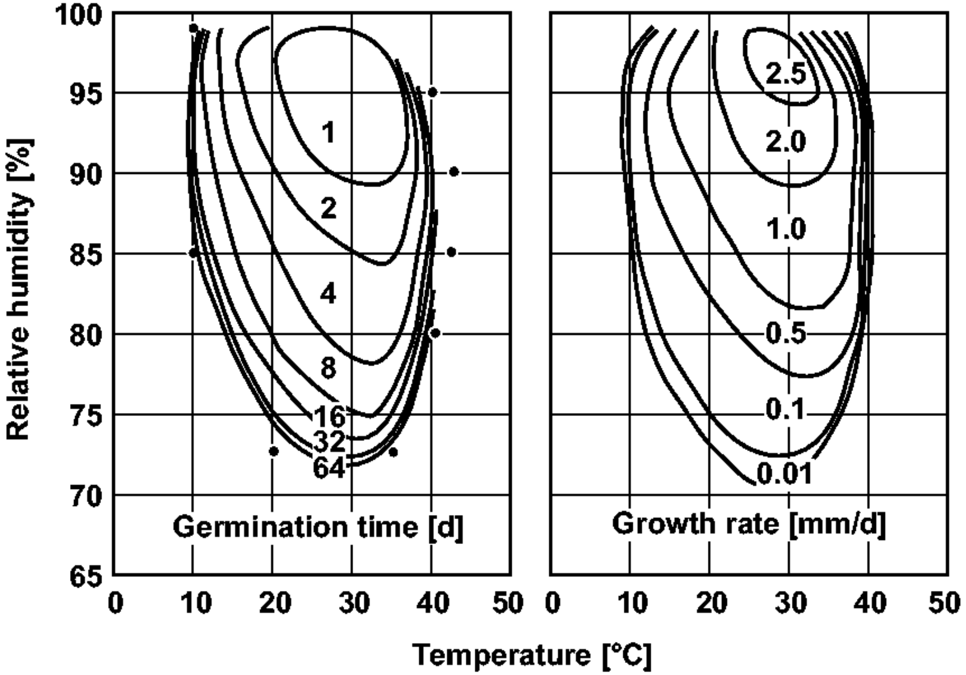
Reduction to the essential influencing factors temperature and humidity, their combined exposure time as well as the substrate quality.



WUFI® Bio: Evaluation of Isopleths

Germination and growth conditions of single mould species:

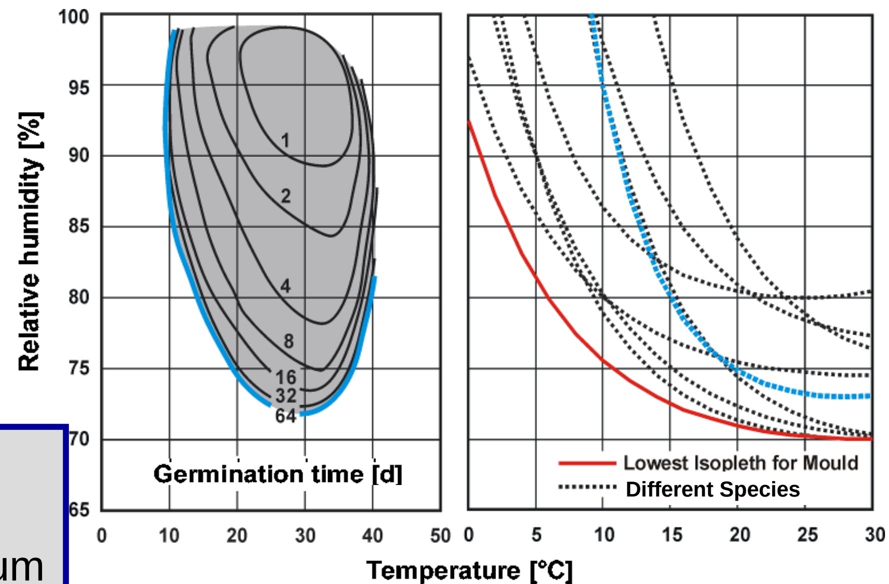
- Mould spores are exposed to different combinations of temperature and relative humidity, and the times needed for germination are plotted in a temperature-humidity diagram. The curves of equal germination time are called isopleths.
- Isopleth systems for germination time and growth rate of Aspergillus restrictus (Smith*):



Smith, S. L.; Hill, S. T.: Influence of temperature and water activity on germination and growth of *Aspergillus restrictus* and *Aspergillus versicolor*. Transactions of the British Mycological Society Vol. 79 (1982), H. 3, S. 558 - 560.

Combination of the lowest growth conditions to LIM-Curves:

- The lowest germination isopleth (left figure – blue curve) separates the diagram into the region where ambient conditions allow the spore to germinate and the region where germination is not possible.
- For all practical relevant mould species, the lowest germination isopleths are combined into one diagram (right figure) and then the lower envelope of this set of curves is defined as generic Lowest Isopleth for Mould growth (LIM, right figure – red curve)



Substrate:
Optimal
culture medium

WUFI® Bio: Evaluation of Isopleths

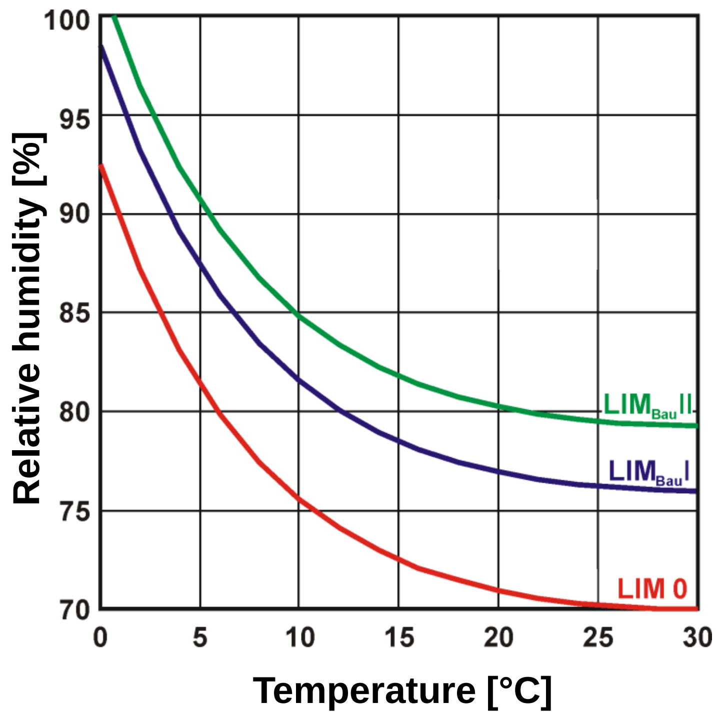
Adaption of the LIM-curves from optimum substrate to building materials:

- Experimental determination of the isopleth systems by cultivating the mould on a culture medium (biological full medium).
- In buildings generally only substrates with a lower nutrient supply are available → consideration of the nutrient quality by the use of two substrate classes for building materials:

II less bio-utilizable substrates (mineral building materials)

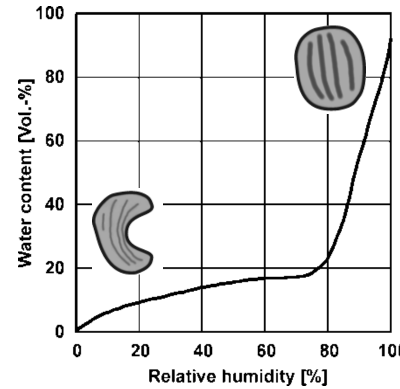
I bio-utilizable substrates (wall paper, wood, strongly contaminated surfaces)

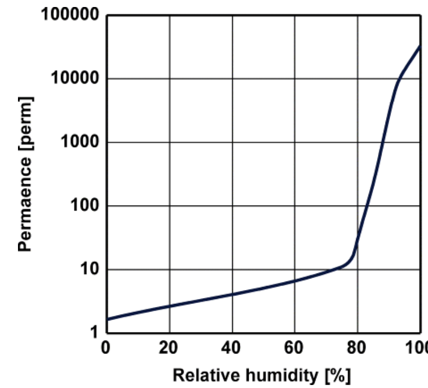
0 optimum substrate (biological full medium)

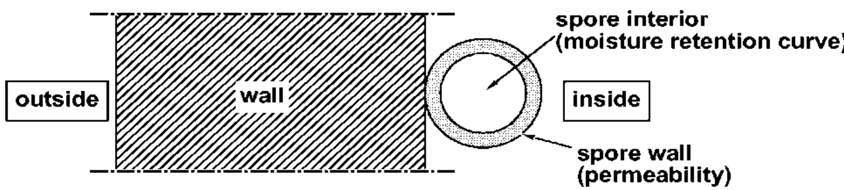


Calculation of a generic model spore:

- A mould spore has a certain osmotic potential which enables it to take up water from its environment
  → mathematically this potential can be described by a moisture storage function.
- The spore wall has a moisture-dependent diffusion resistance, which delays the moisture exchange with the environment.
- With changing ambient temperature and humidity the water content in the spore also changes
  → by reaching a certain critical water content, the spore germinates.







WUFI® Bio: Proceeding

1. Comparison of the calculated conditions with the LIM curves shows whether temperature and humidity combinations occur, in which long-term germination of the spore would be expected.
2. If so, evaluation of the position with WUFI® Bio and calculation of the temperature-dependent water content in the model spore.
3. If the limit water content is exceeded in the spore, the spore germinates and mycelium growth starts.
4. The expected growth is then given according to the growth isopleths and summed up.
5. The signal light helps to assess the risk.

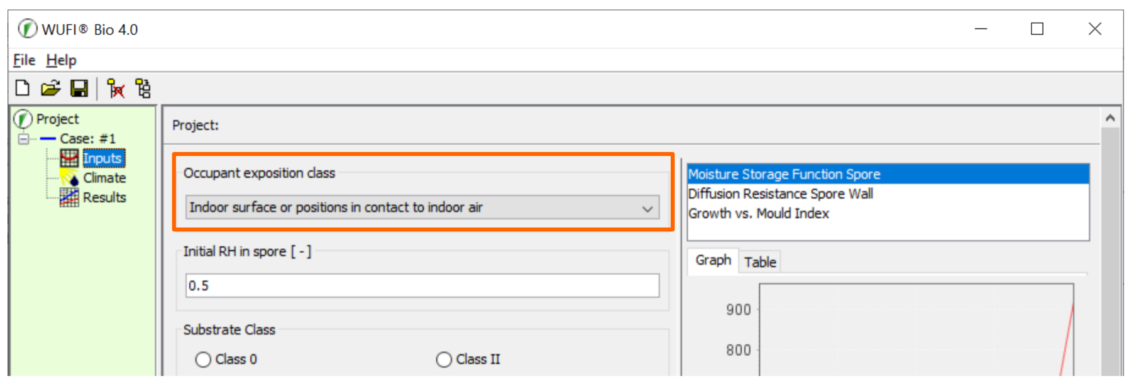
Download-Link: WUFI® Add-ons | WUFI (en)

WUFI® Bio: Notes and Limitations

- The biohygrothermal model is an assessment of the risk of mould growth, it is not necessarily a realistic simulation of the growth processes in all points.
- Usually, the predicted spore germination times may be shorter, or the growth rates may be higher than they are under real conditions (safe side)!
- It is assumed that mycelium growth stops when the moisture content in the spore falls below the critical water content, and instantly resumes when the critical water content is exceeded again.
- The biohygrothermal model is only applicable for interior surfaces. In the case of differing boundary conditions (for example in the construction or on exterior surfaces) it must be considered in individual cases, whether the model can be used. Maybe other effects can impede the growth: heating through solar radiation, disinfection through UV radiation or washing-off through rain. However, comparative evaluations can also be carried out at these positions.

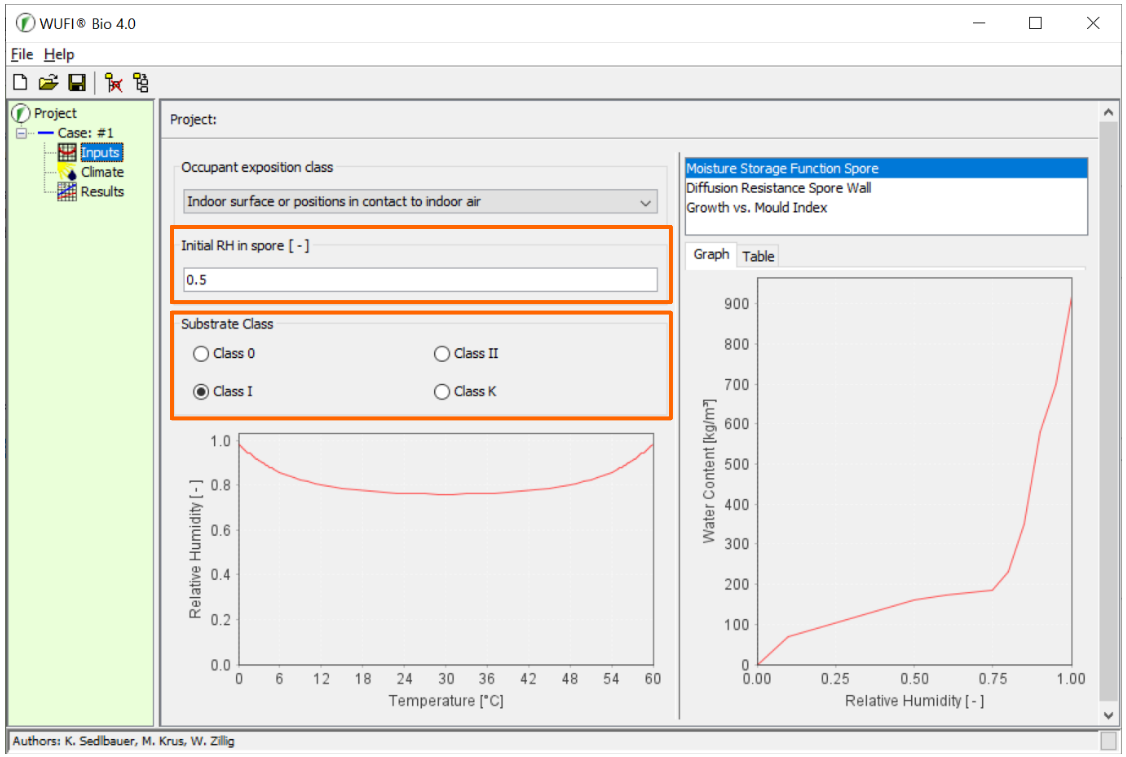
Input data:

- Specification of the occupant exposition class. This indicates the extent to which the user gets into contact with the evaluated position of the component (respectively with the mould or spore).
- Three classes are available:
  - Indoor surface or position in contact to indoor air
    (e.g. interior wall surface, installation layer, etc.)
  - Surface inside construction without direct contact to indoor air
    (e.g. unused roof space, outside ventilated cavity of a wall, etc.)
  - No impact on occupants expected
    (e.g. perimeter insulation, cavities in multi-layered, rendered masonry, etc.)



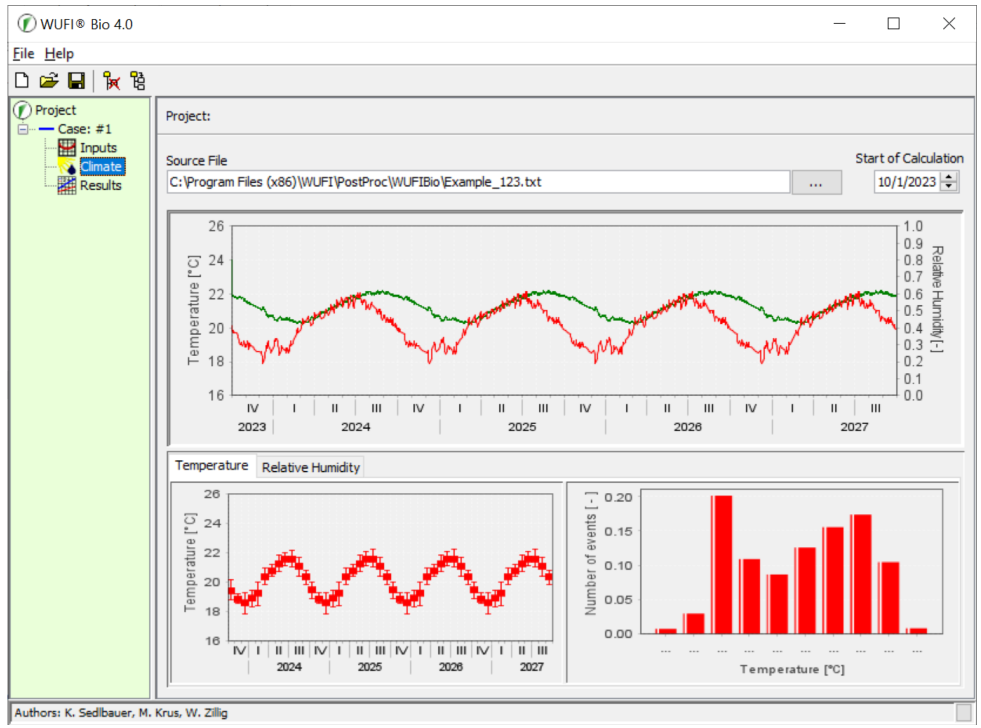
Input data:

- Specification of the initial humidity in the simulated spore. This only affects the early stages of the simulation. After a while, the water content in the spore will be dominated by the ambient conditions. (recommendation: 0.5)
- Selection of the substrate class:
  - Class 0
  - Class I
  - Class II
  - Class K
  (growth properties of species critical to health)



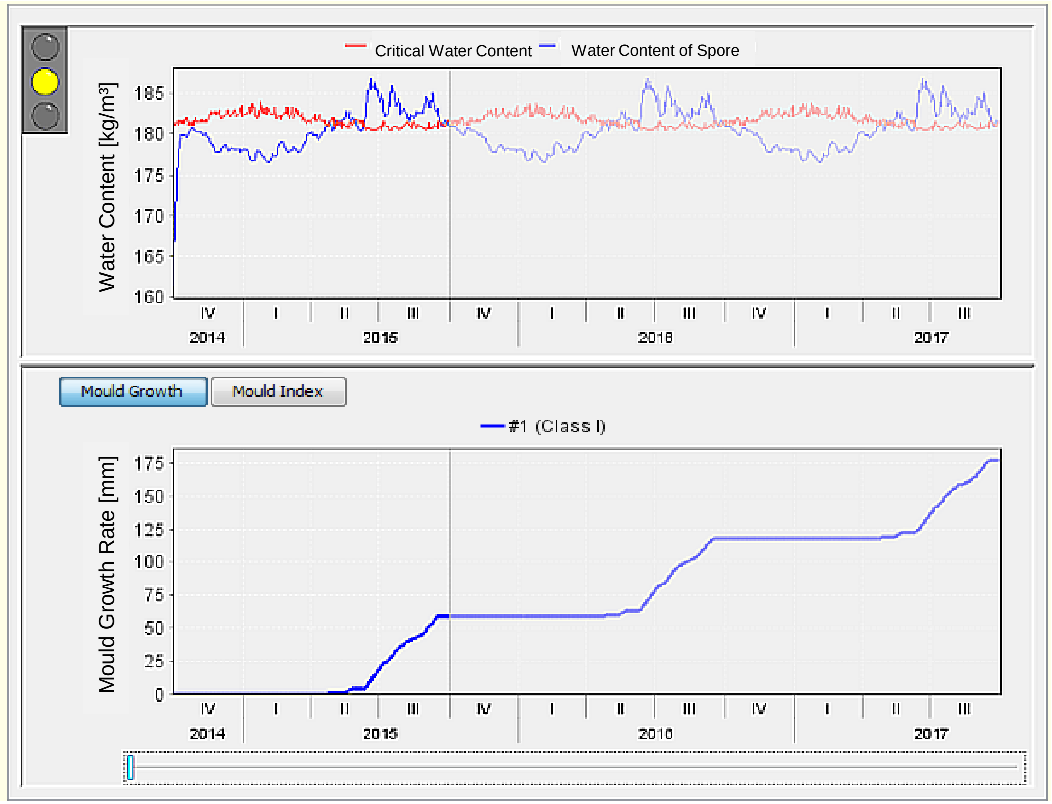
Input data:

- Specify the climatic conditions to which the model spore is exposed.
- If you have started WUFI® Bio directly out of WUFI® or Animation1D, the climate conditions will automatically be transferred to WUFI® Bio and displayed in this dialog.
  Note: If WUFI® Bio is started directly out of WUFI®, only the climate conditions of the interior surface are shown. To evaluate a different position, WUFI® Bio must be started from Animation1D. Here you can select any grid element.
- Otherwise, climate data can be imported manually (e.g. measurement data).



Evaluation of the results:

- Top diagram: calculated water content in the spore (blue) and the critical water content (red).
- Bottom diagram: mycelium growth (in mm) to be expected after germination.
- Growth rate:
  Describes by how many millimeters the edge of the infested area moves outward over time; the total growth is then the radius of a mould blotch (in a petri bowl).
- Alternatively:
  Result of the evaluation can be expressed in terms of the "mould index".



WUFI® Bio: Application

Evaluation of the results:

- The Viitanen model uses a six-level “Mould Index” describing the intensity and spread of the growth.
- Since the “Mould Index” can be interpreted more easily, WUFI® Bio's mould growth can automatically be translated into the “Mould Index”.

Index	Description
0	no growth
1	some growth visible under microscope
2	moderate growth visible under microscope, coverage more than 10%
3	some growth detected visually; thin hyphae found under microscope
4	visual coverage more than 10%
5	coverage more than 50%
6	tight coverage, 100%

WUFI® Bio: Application

Evaluation of the results:

- The signal light presents a general assessment of the mould growth risk.

	Occupant exposition class		
	Indoor surface or position in contact to indoor air	Surfaces inside constructions without direct contact to indoor air	No impact on occupants expected
Mould Growth *(g_m)*	< 129 mm/year	< 176 mm/year	< 239 mm/year
Mould-Index *(MI)*	≤ 1	≤ 2	≤ 3
Assessment	Usually acceptable.		
Mould Growth *(g_m)*	129 < g_m ≤ 176 mm/year	176 < g_m ≤ 239 mm/year	> 239 mm/year
Mould-Index *(MI)*	1 < *MI* ≤ 2	2 < *MI* ≤ 3	> 3
Assessment	Additional criteria or investigations are needed for assessing acceptability.		
Mould Growth *(g_m)*	> 176 mm/year	> 239 mm/year	
Mould-Index *(MI)*	> 2	> 3	
Assessment	Usually not acceptable.		
	Calculation period is less than 1 year. No assessment possible.		

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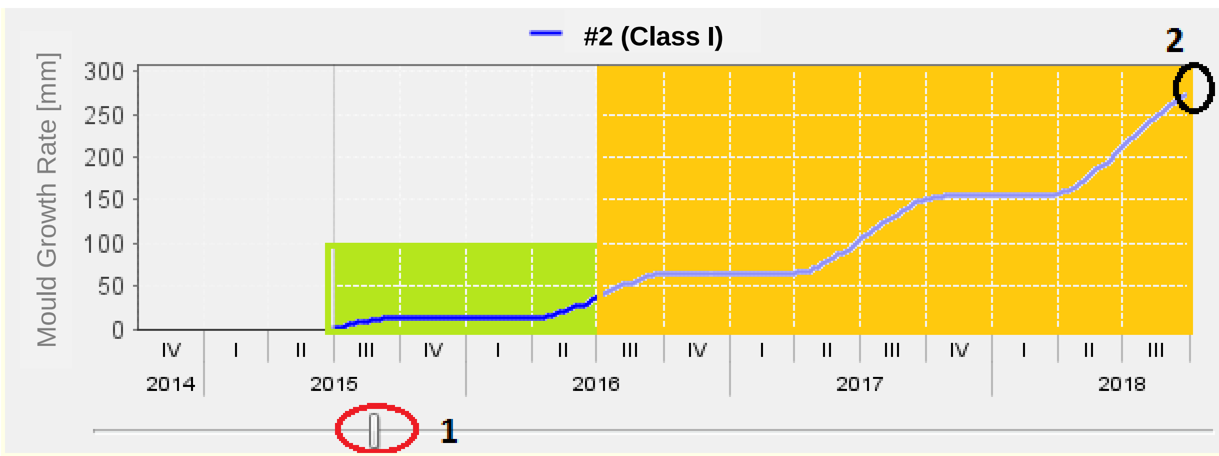
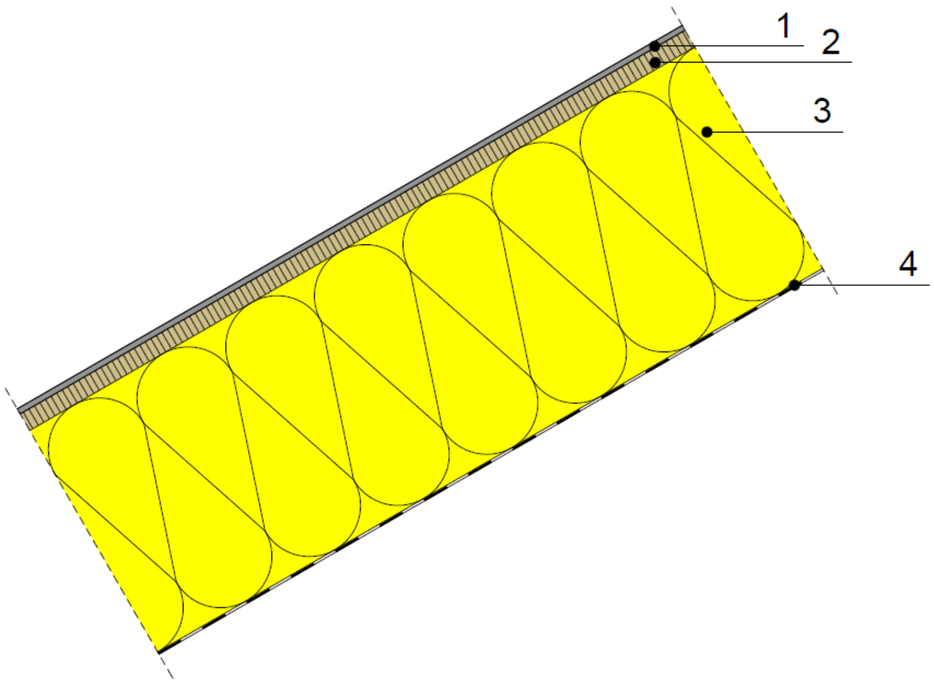
Evaluation of the results:

- The evaluation period is limited to only one year (green area). The slider (1) allows the user to shift the evaluation period within the calculation period.
- The growth in the following period (orange area) is a forecast based on the mycelium growth of the first year.
- If the evaluation period is changed using the slider (1), both the starting date of the mycelium growth assessment as well as the maximum growth at the end of the simulation period (2) change.



Examples: Problem Description

Using the example of a pitched roof with metal sheet and two different interior vapour retarders, the procedure for assessing mould risk is explained.



1 Metal roofing (zinc)
2 Wooden sheathing
3 Insulation
4 Vapour retarder

Note: It is assumed that the wooden sheathing has an increased initial moisture content!

Examples: Component Assembly

Assembly (from outside to inside):

- Zinc roofing (s_d = 50 m)
- Wooden sheathing (Softwood) 0.02 m
- Mineral Wool (heat cond.: 0.04 W/mK) 0.14 m
- Case 1: Kraft Paper (s_d = 3 m)
  Case 2: PA-Membrane (moisture-variable)

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Examples: Boundary Conditions

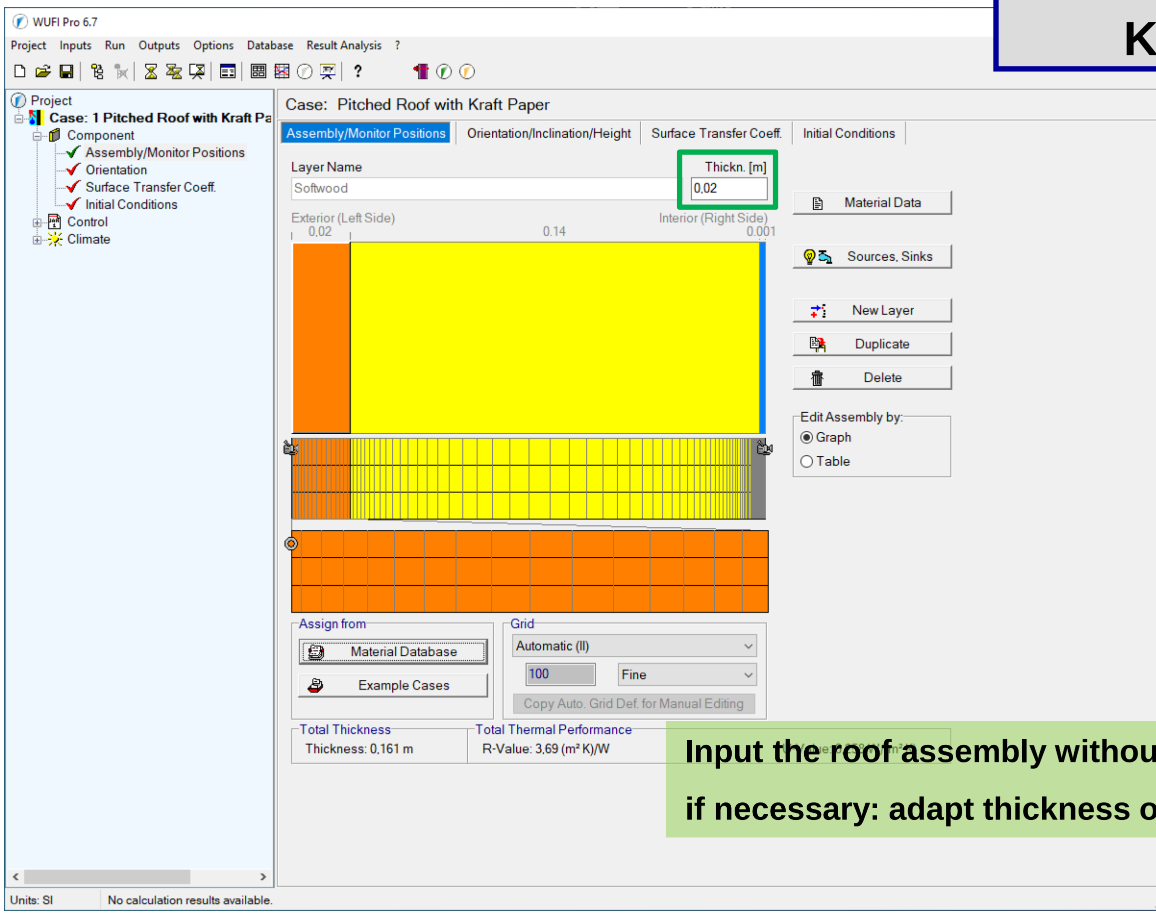
Boundary Conditions:

- Pitched roof (50° to the North)
- Zinc surface (a = 0.6; ε = 0.4)
- Outdoor Climate: Holzkirchen
- Indoor Climate: EN 15026 with medium moisture load +5%
- Air tightness of the der building envelope: q_{50} = 3 m³/m³h
- Stack height: 5 m
- Initial moisture in the wooden sheathing: 25 % by mass

Case 1: Component

__Input:__ Component - Assembly / Monitor Positions

**Case 1:
Kraft Paper**



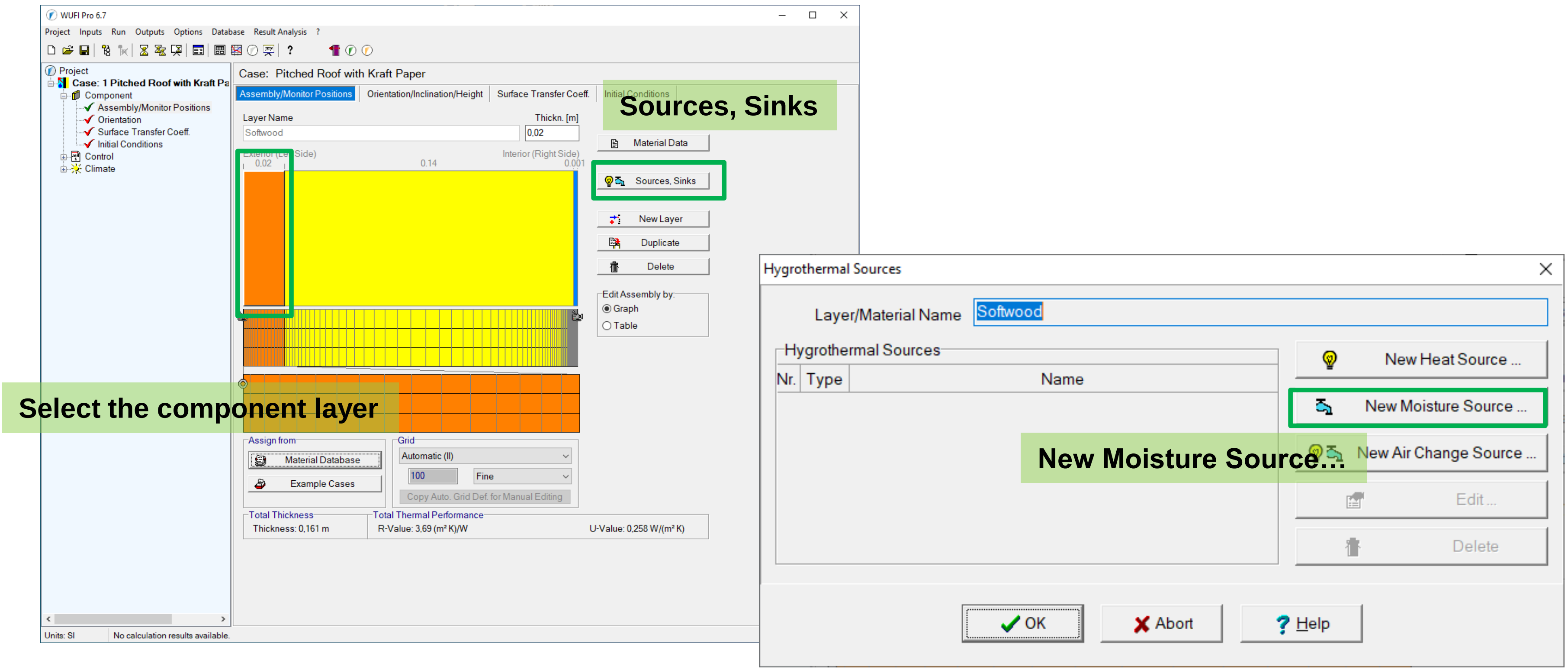
Input the roof assembly without metal sheet

if necessary: adapt thickness of the layers

Case 1: Consideration of infiltration moisture

__Input:__ Component - Assembly / Monitor Positions

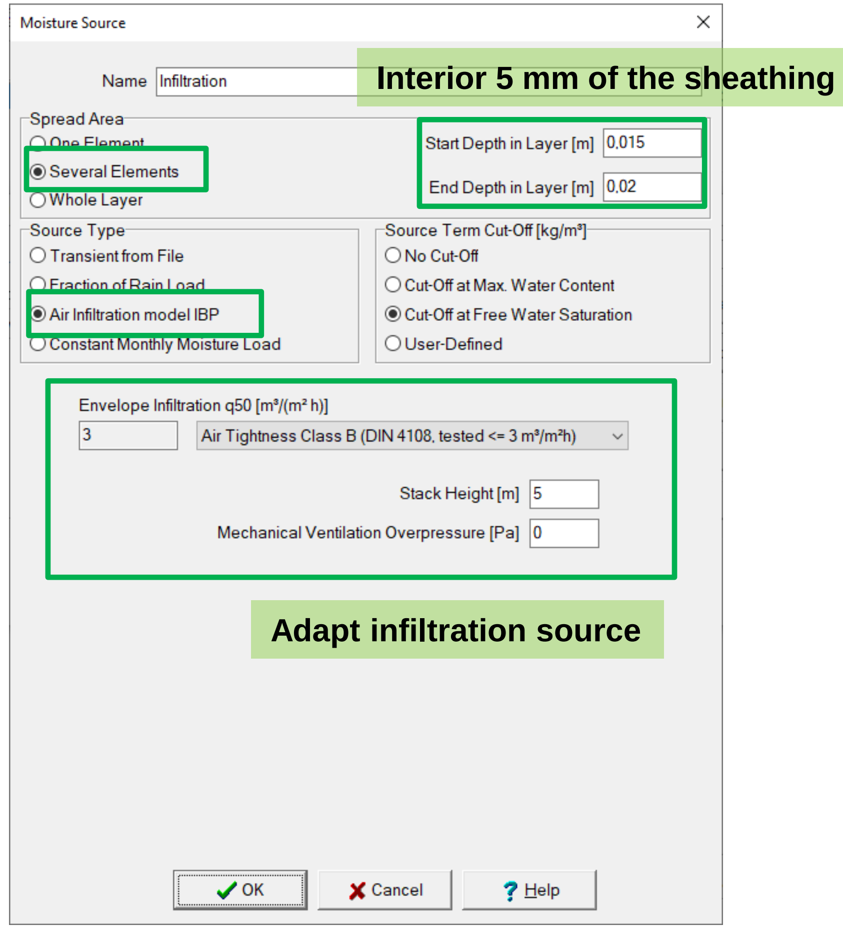
Consideration of the infiltration source in the sheathing according to EN 15026.



Case 1: Consideration of infiltration moisture

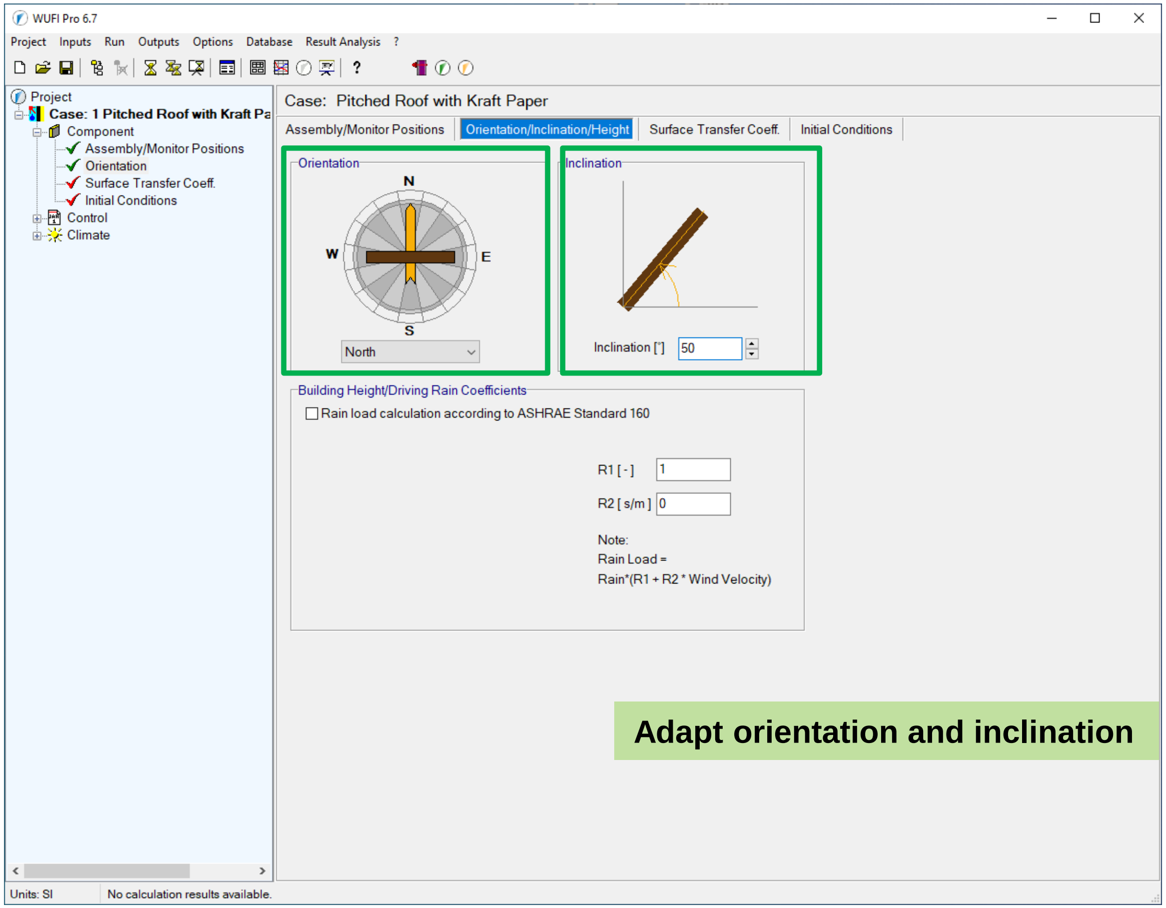
Input: Component - Assembly / Monitor Positions

Moisture source in the interior 5 mm of the sheathing.



Case 1: Inclination and Orientation of the Component

Input: Component - Orientation



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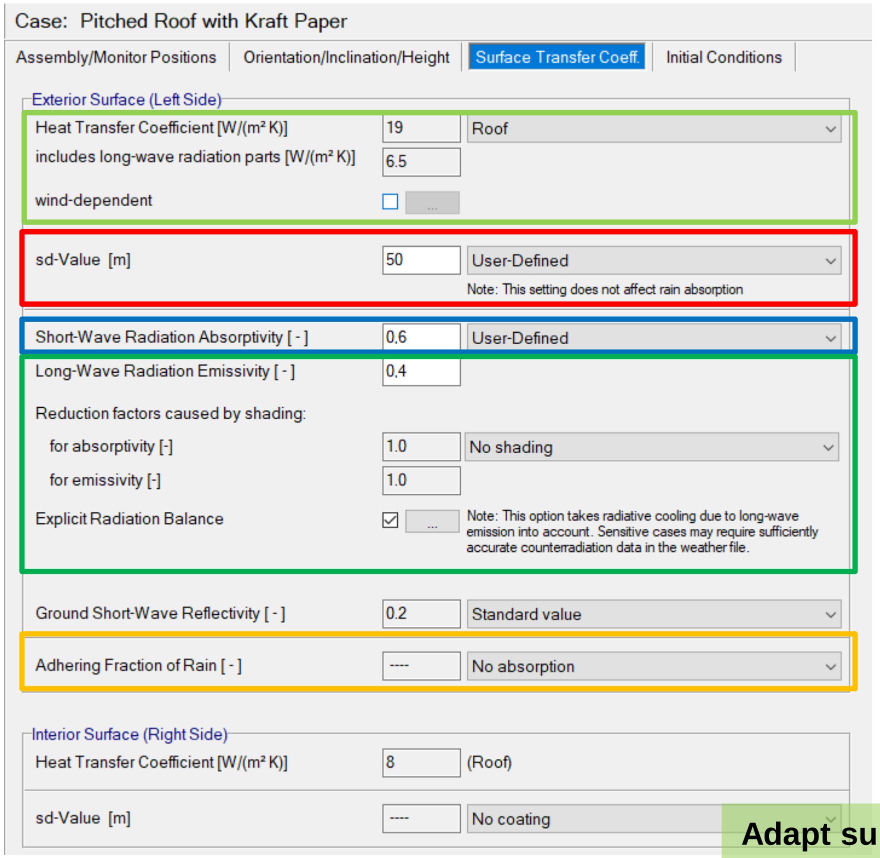
Case 1: Surface Transfer Coefficients

Input: Component – Surface Transfer Coeff.



Heat Transfer Coefficient for Roof = 19 W/m²K

s_d-value of the metal sheet = 50 m

Colouring of the metal sheet (a_e = 0.6)

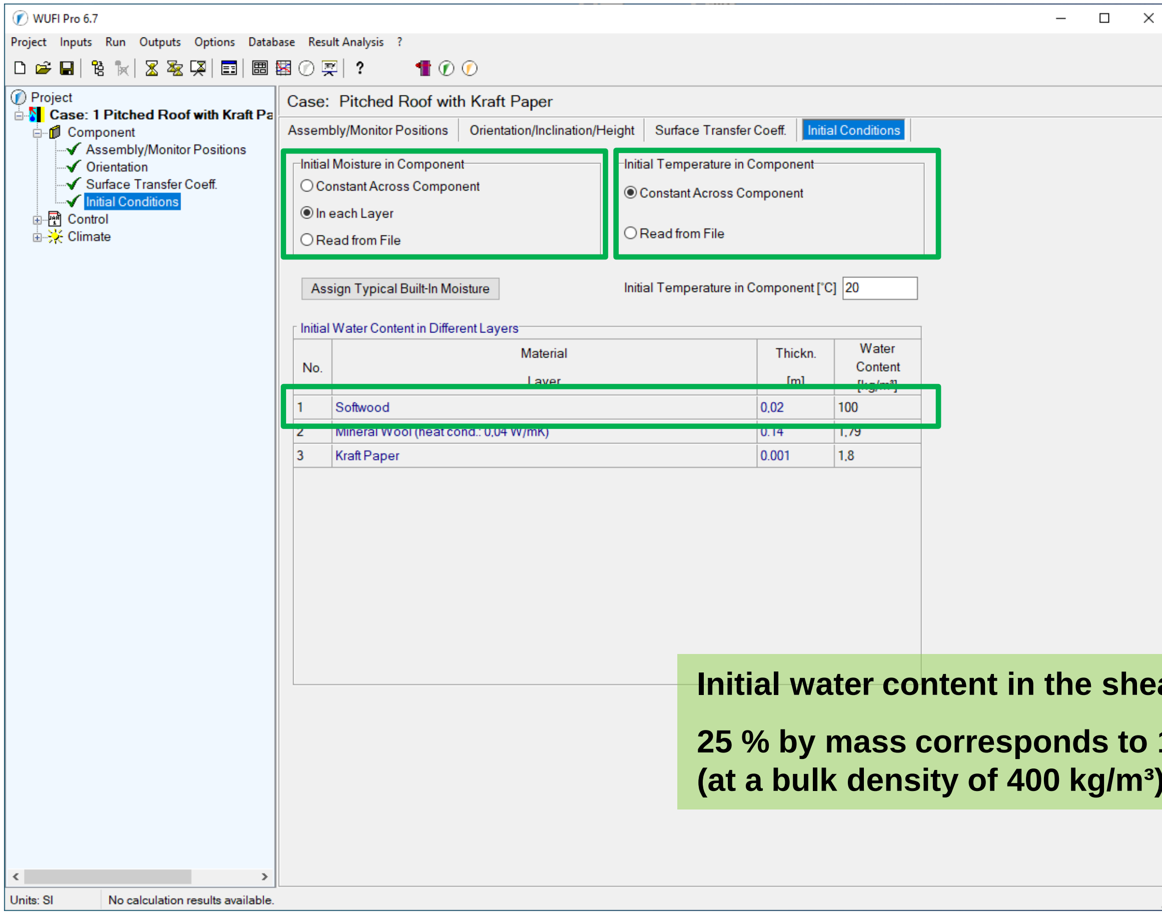
Switch on Explicit Radiation Balance (ε = 0.4)!

No absorption!

Adapt surface transfer coefficients!

Case 1: Initial Conditions

Input: Component – Initial Conditions



Initial water content in the sheathing:

25 % by mass corresponds to 100 kg/m³ (at a bulk density of 400 kg/m³)

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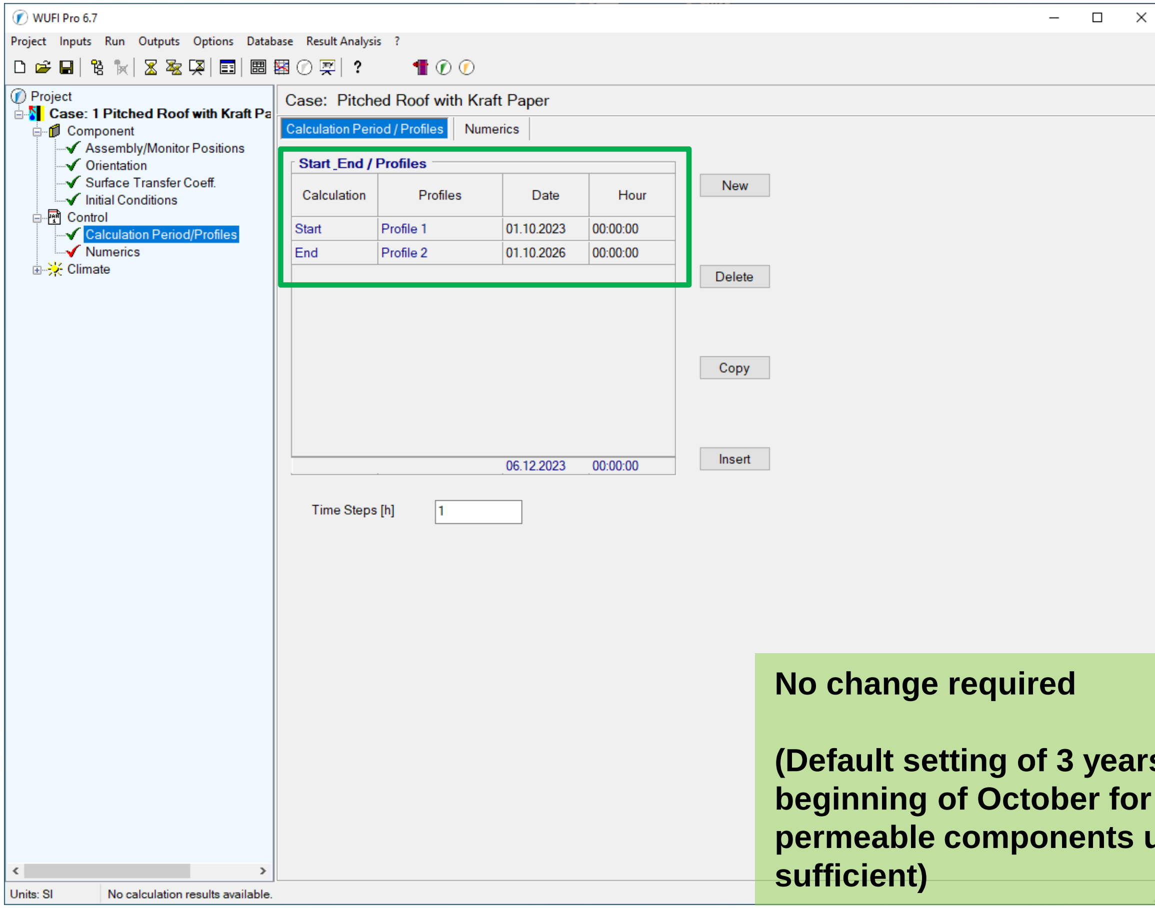
Case 1: Calculation Period

Input: Control – Calculation Period / Profiles

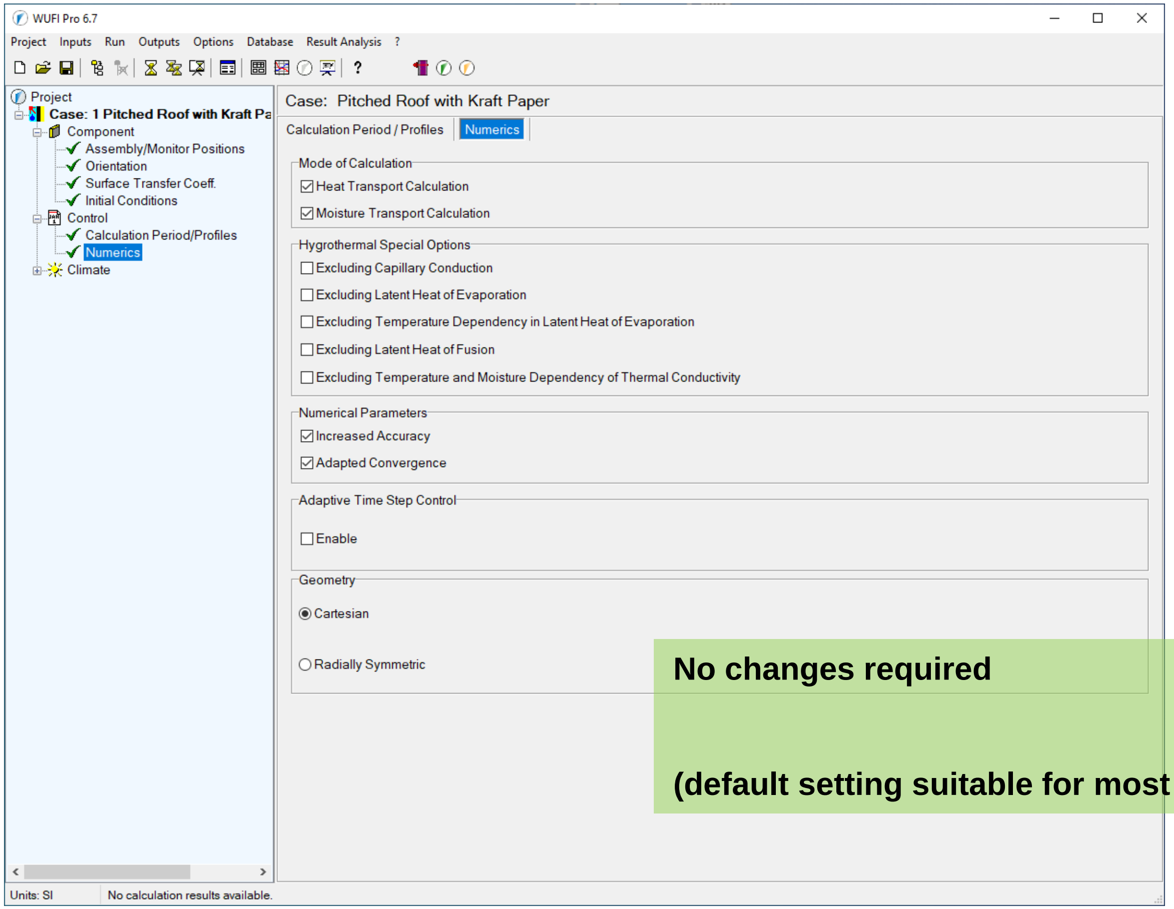


No change required

(Default setting of 3 years from the beginning of October for vapour-permeable components usually sufficient)

Case 1: Numerics

Input: Control – Numerics



No changes required

(default setting suitable for most questions)

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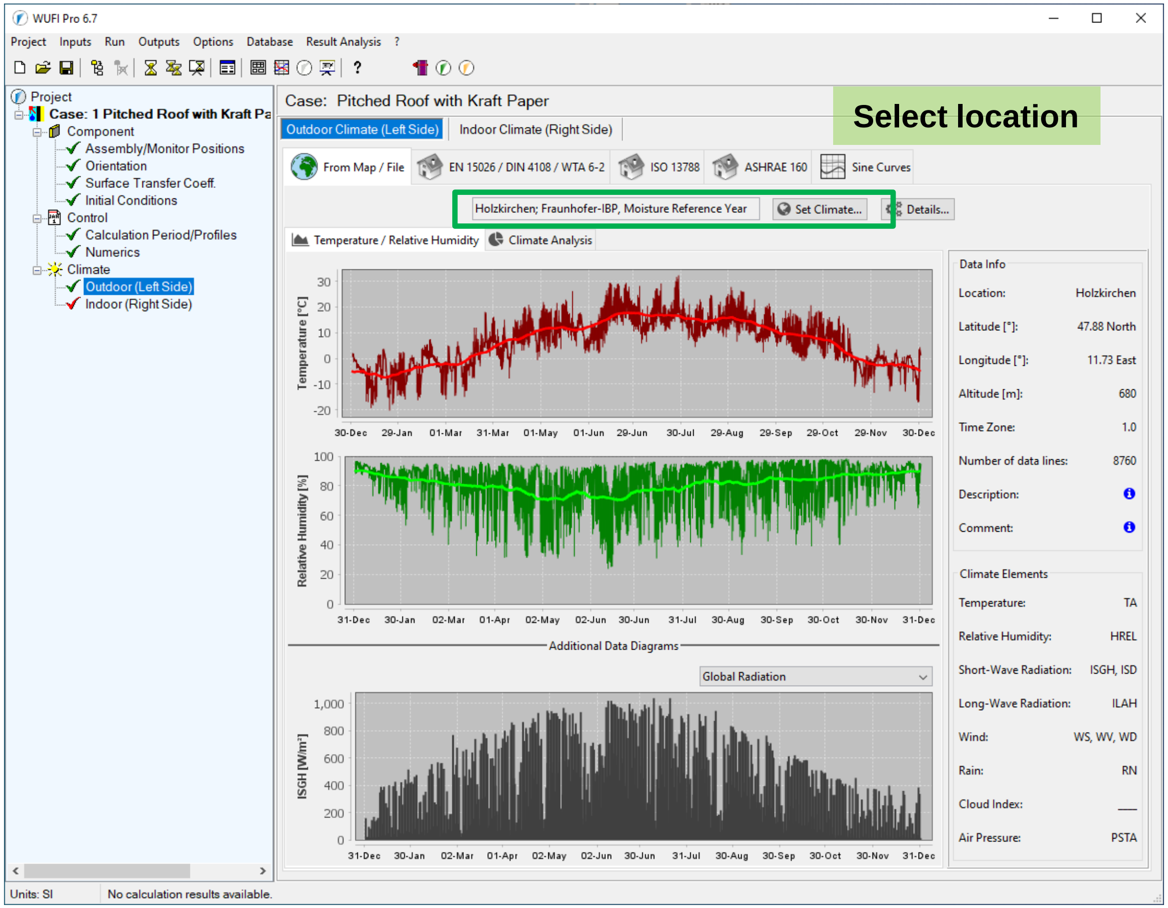
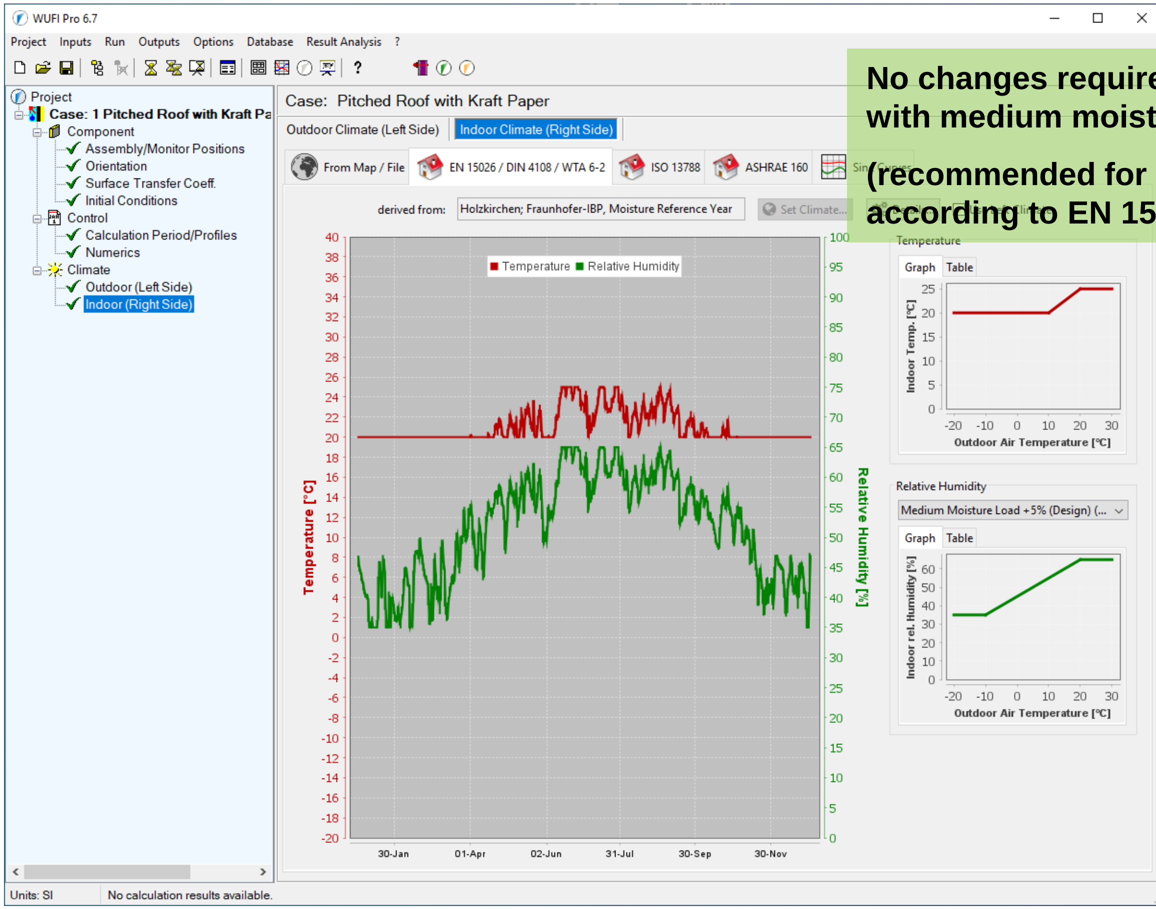
Case 1: Outdoor Climate

<u>Input:</u> Climate – Outdoor (Left Side)



Case 1: Indoor Climate

<u>Input:</u> Climate – Indoor (Right Side)

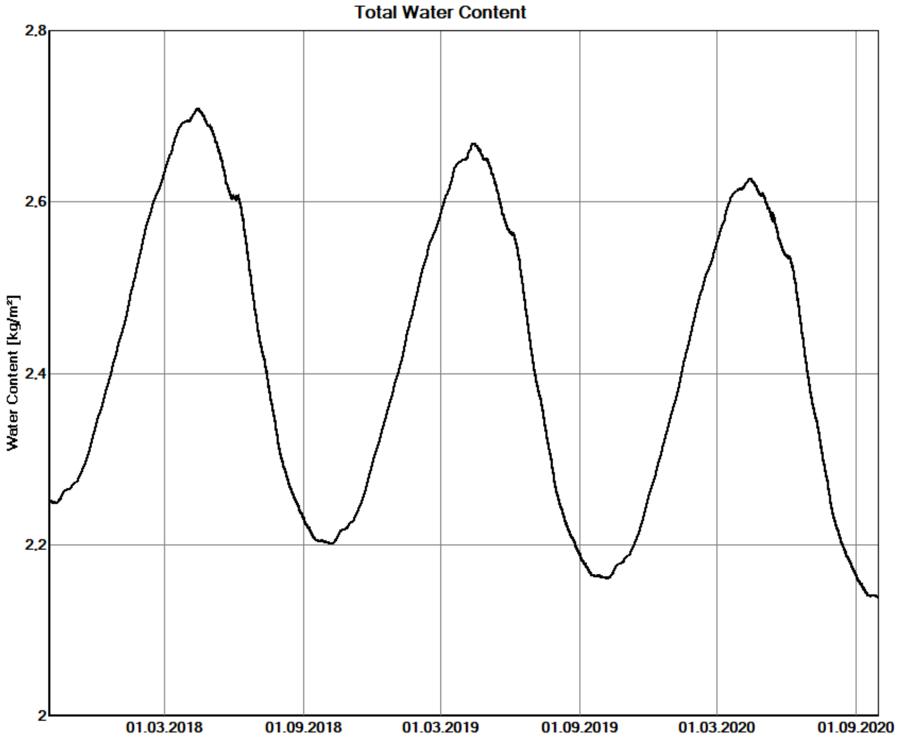


No changes required for indoor climate with medium moisture load +5%

(recommended for the design of components; according to EN 15026 and WTA 6-2)

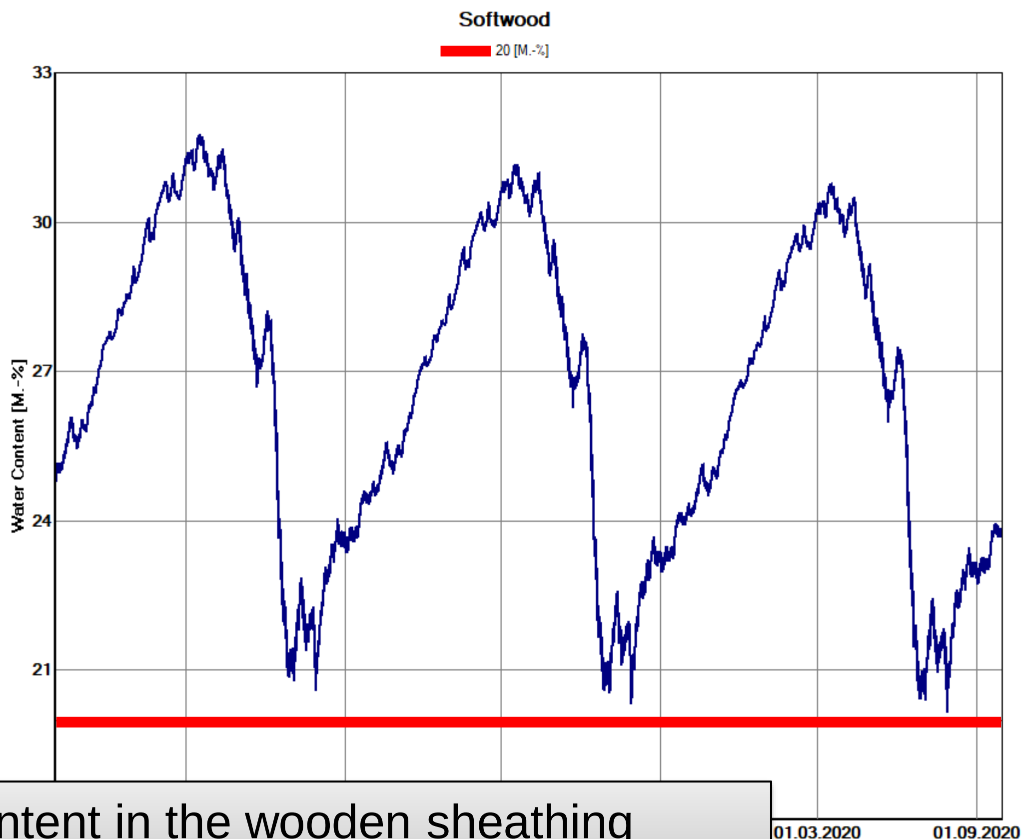
Case 1: Evaluation of the Total Water Content

<u>*Evaluation:*</u> Total water content



Case 1: Evaluation of the Wood Moisture in the Sheathing

Evaluation: Wood moisture in the sheathing
– according to German Standard DIN 68800

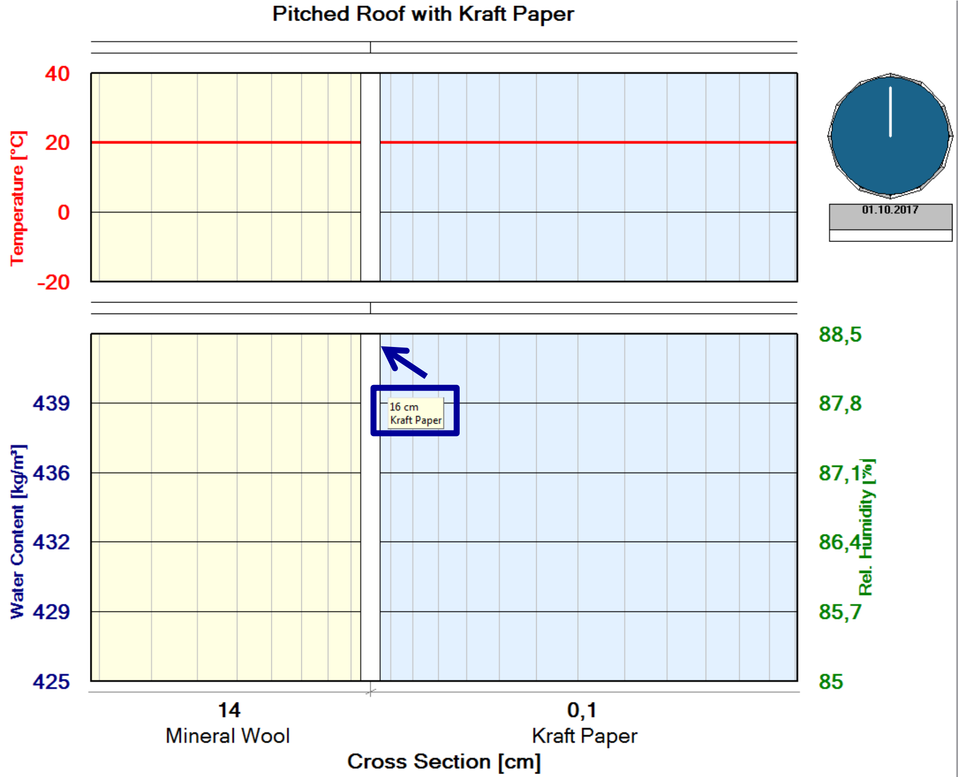


The water content in the wooden sheathing clearly exceeds the limit value of 20 % by mass!

Case 1: Evaluation of the moisture conditions at vapour retarder

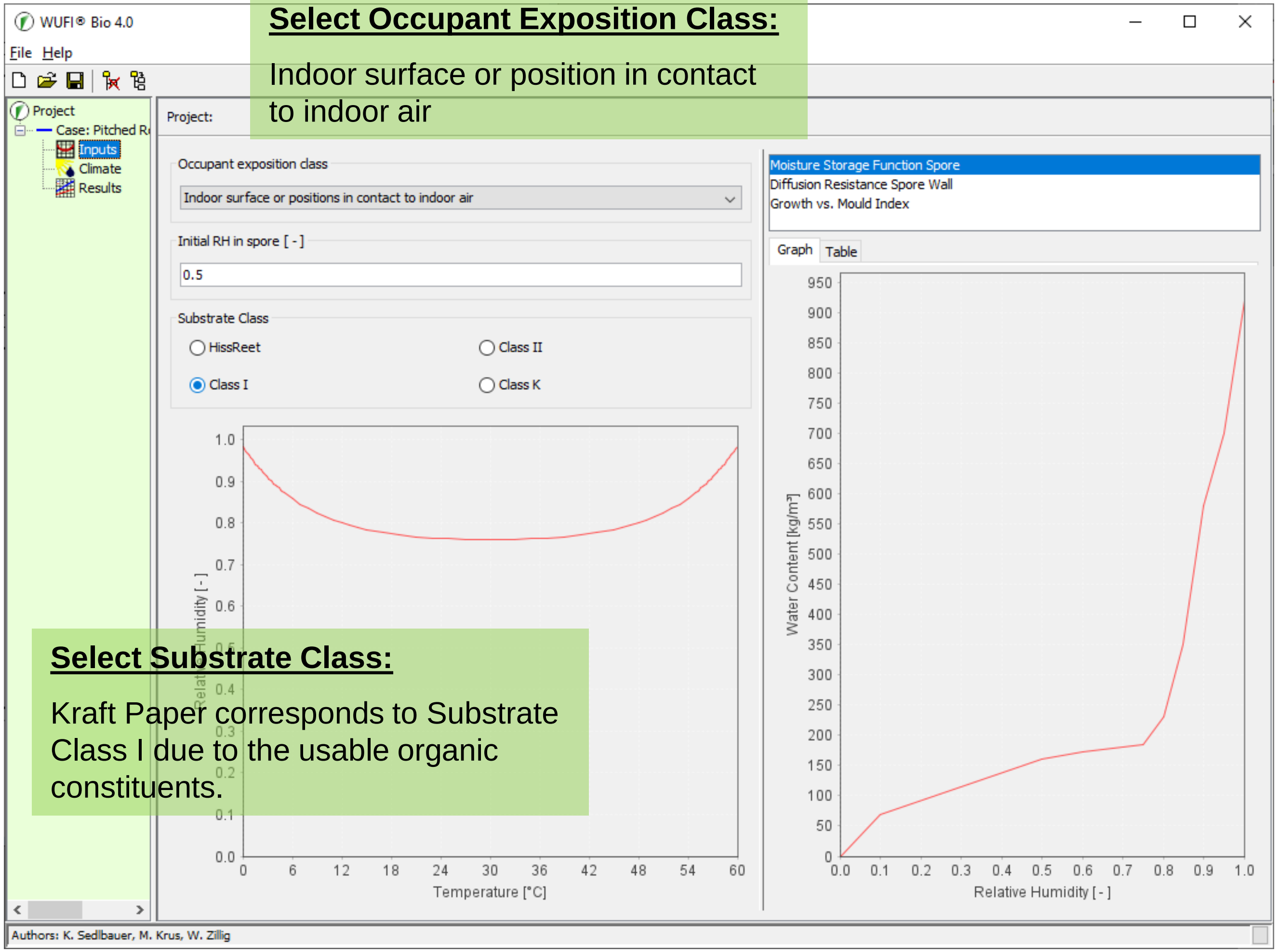
<u>Evaluation:</u> Mould risk behind the vapour retarder

- Open WUFI® Animation
- Zoom in the boundary layer mineral wool / vapour retarder
  (while pressing the left mouse button: pull a box from the upper left to the lower right)
- Press the WUFI® Bio-Button  in the taskbar and select the outermost element of the kraft paper.



Case 1: Settings in WUFI® Bio

Evaluation: Mould risk behind the vapour retarder



Select Occupant Exposition Class:

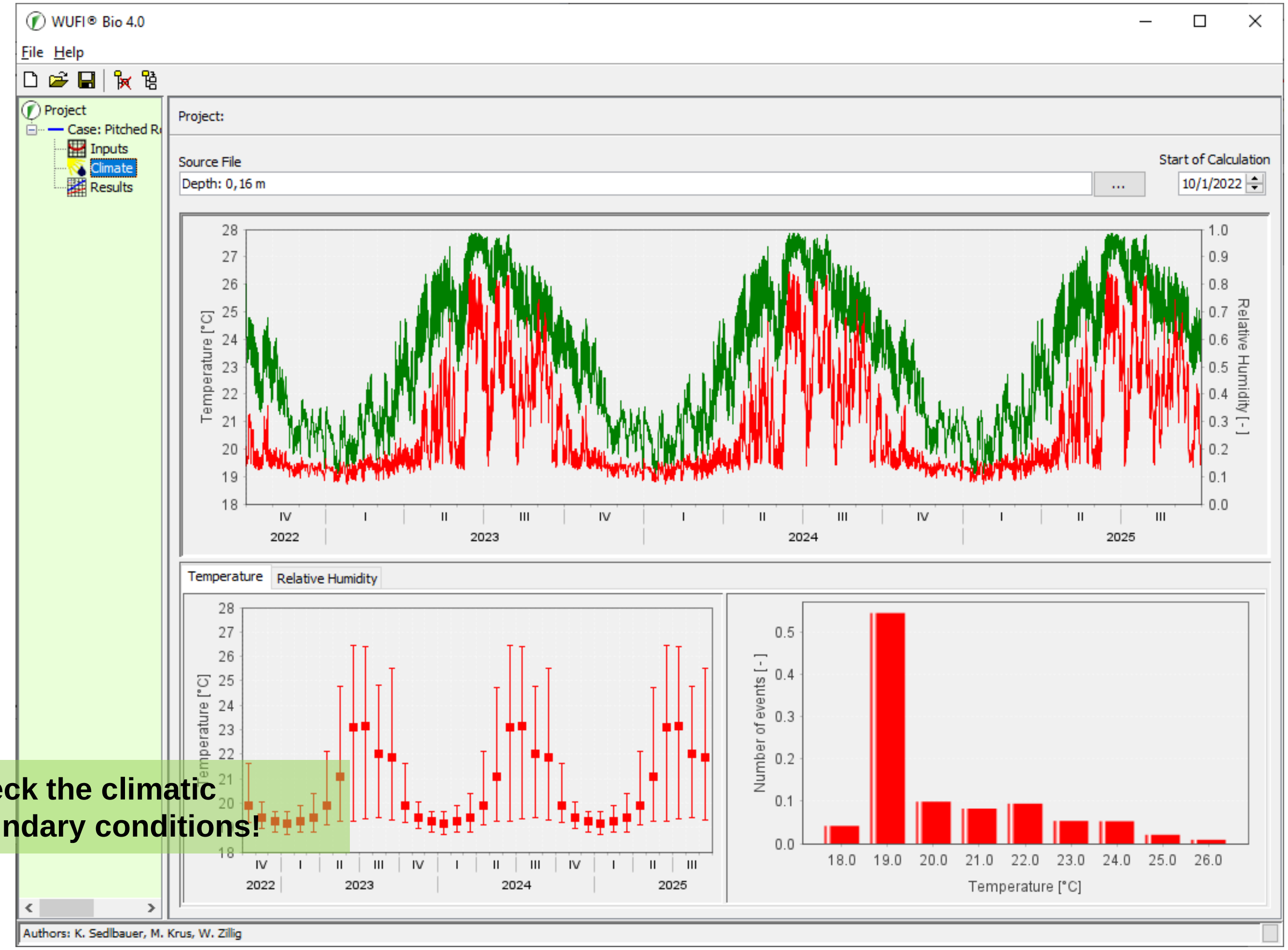
Indoor surface or position in contact to indoor air

Select Substrate Class:

Kraft Paper corresponds to Substrate Class I due to the usable organic constituents.

Case 1: Settings in WUFI® Bio

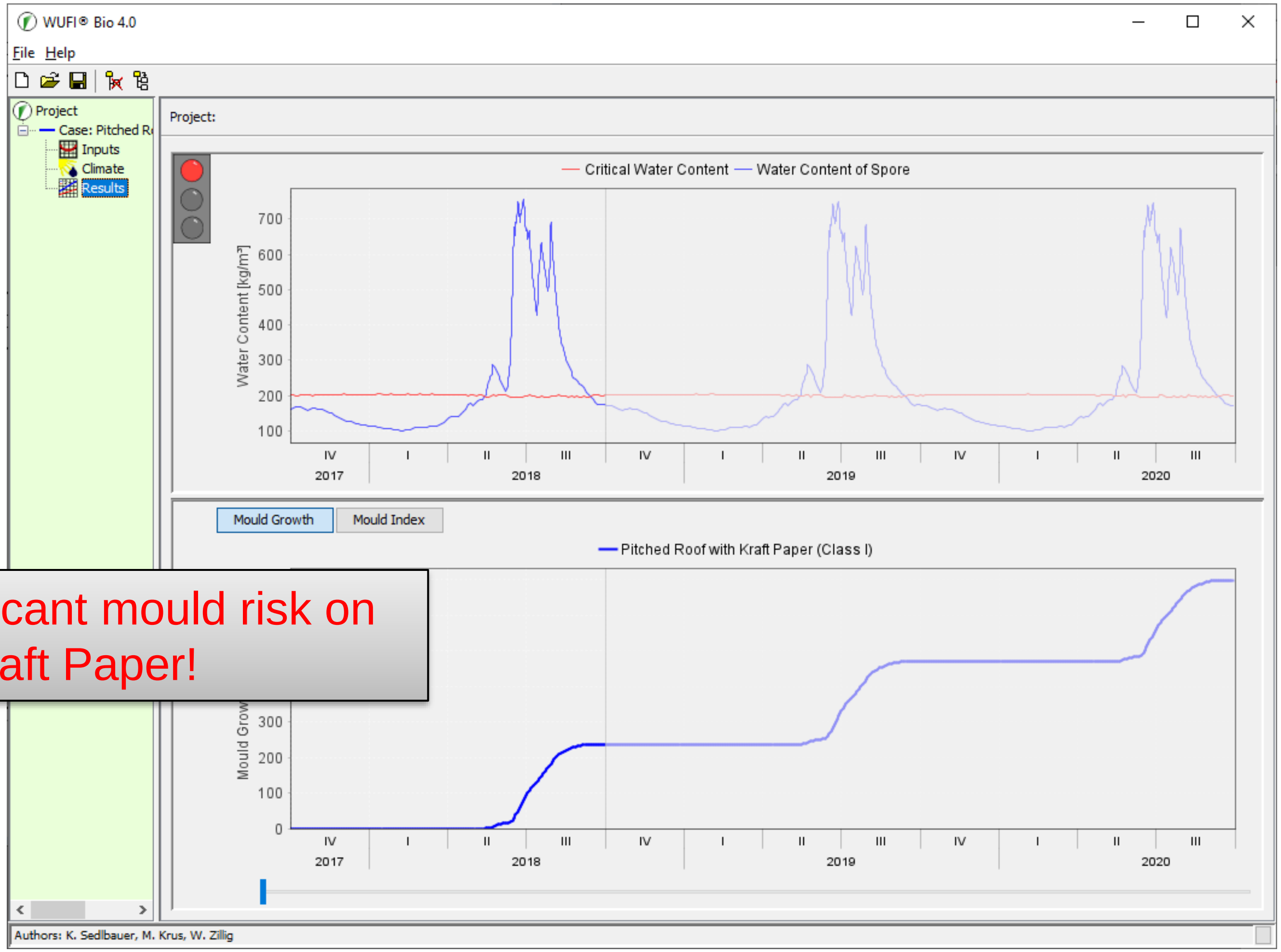
Evaluation: Mould risk behind the vapour retarder



Check the climatic boundary conditions!

Case 1: Evaluation with WUFI® Bio

__Evaluation:__ Mould risk behind the vapour retarder



Significant mould risk on the Kraft Paper!

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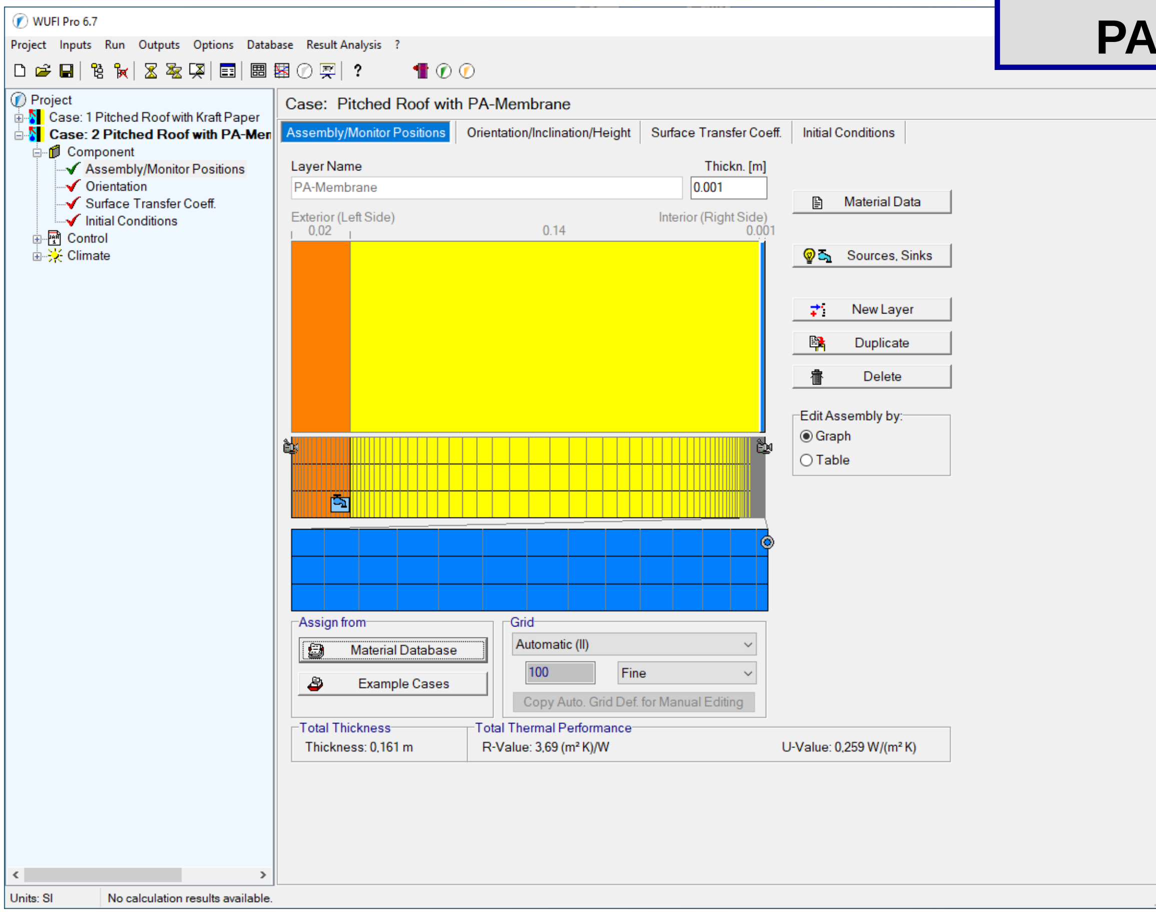
Case 2: Replacement of the Vapour Retarder

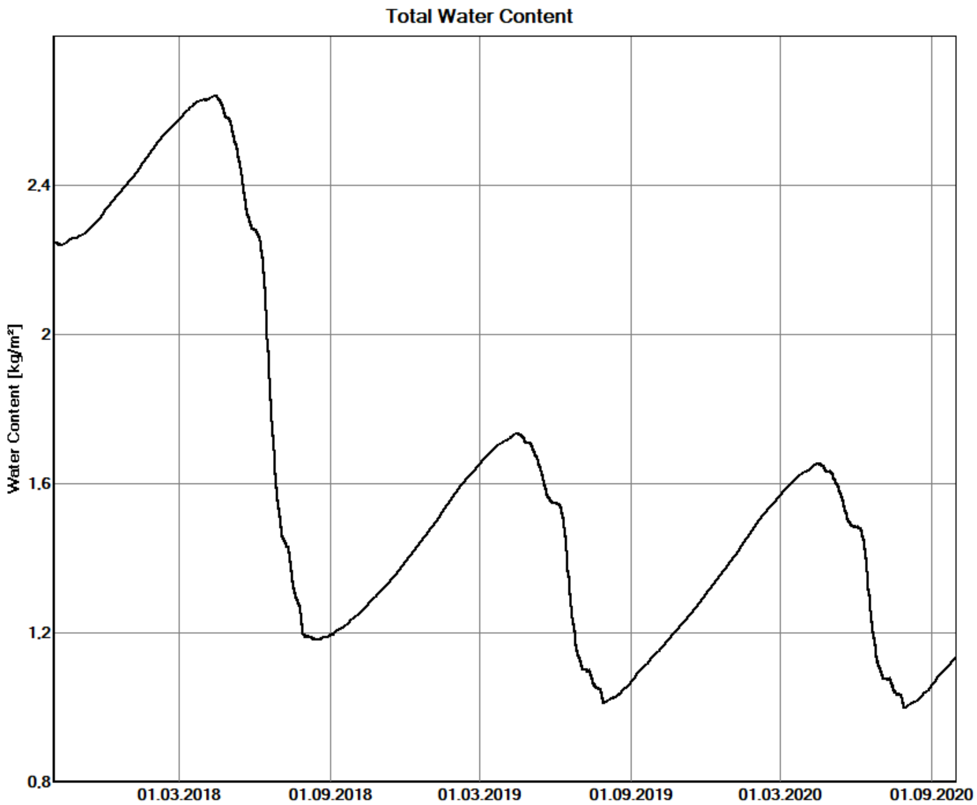
Input: Component - Assembly / Monitor Positions

Case 2:
PA-Membrane



Case 2: Evaluation of the Total Water Content

Evaluation: Total water content



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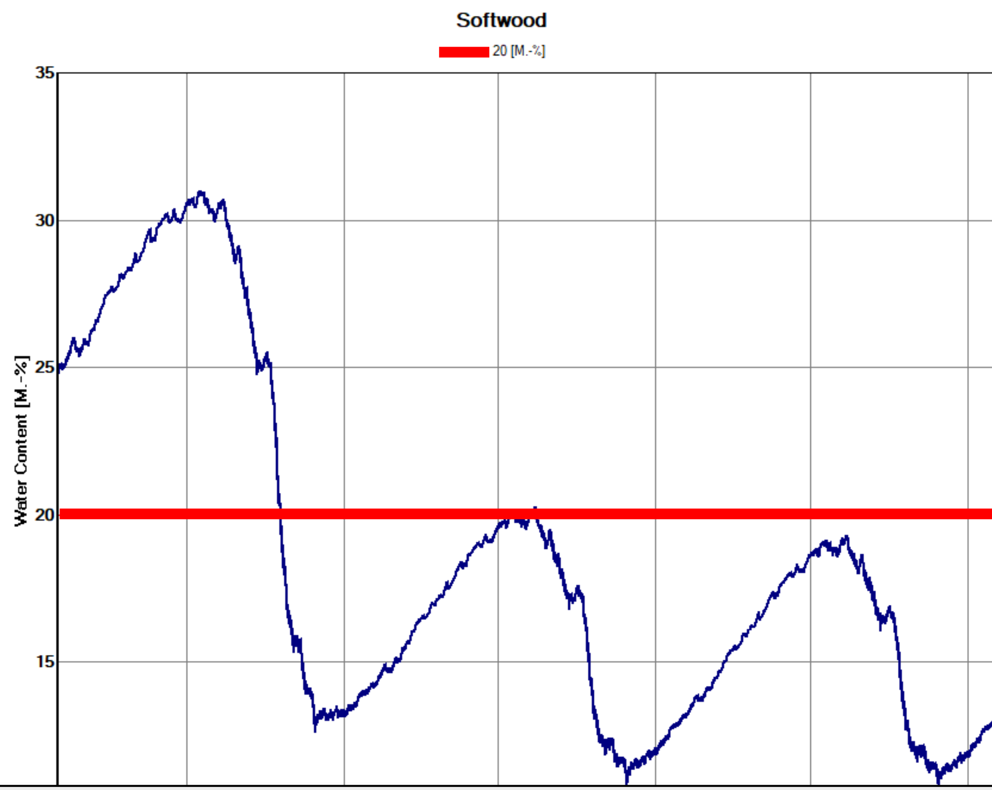
Case 2: Evaluation of the Wood Moisture in the Sheathing

Evaluation: Wood moisture in the sheathing
– according to German Standard DIN 68800



After the redistribution of the initial moisture in the first year, the water content in the wooden sheathing remains below the limit value of 20 % by mass!

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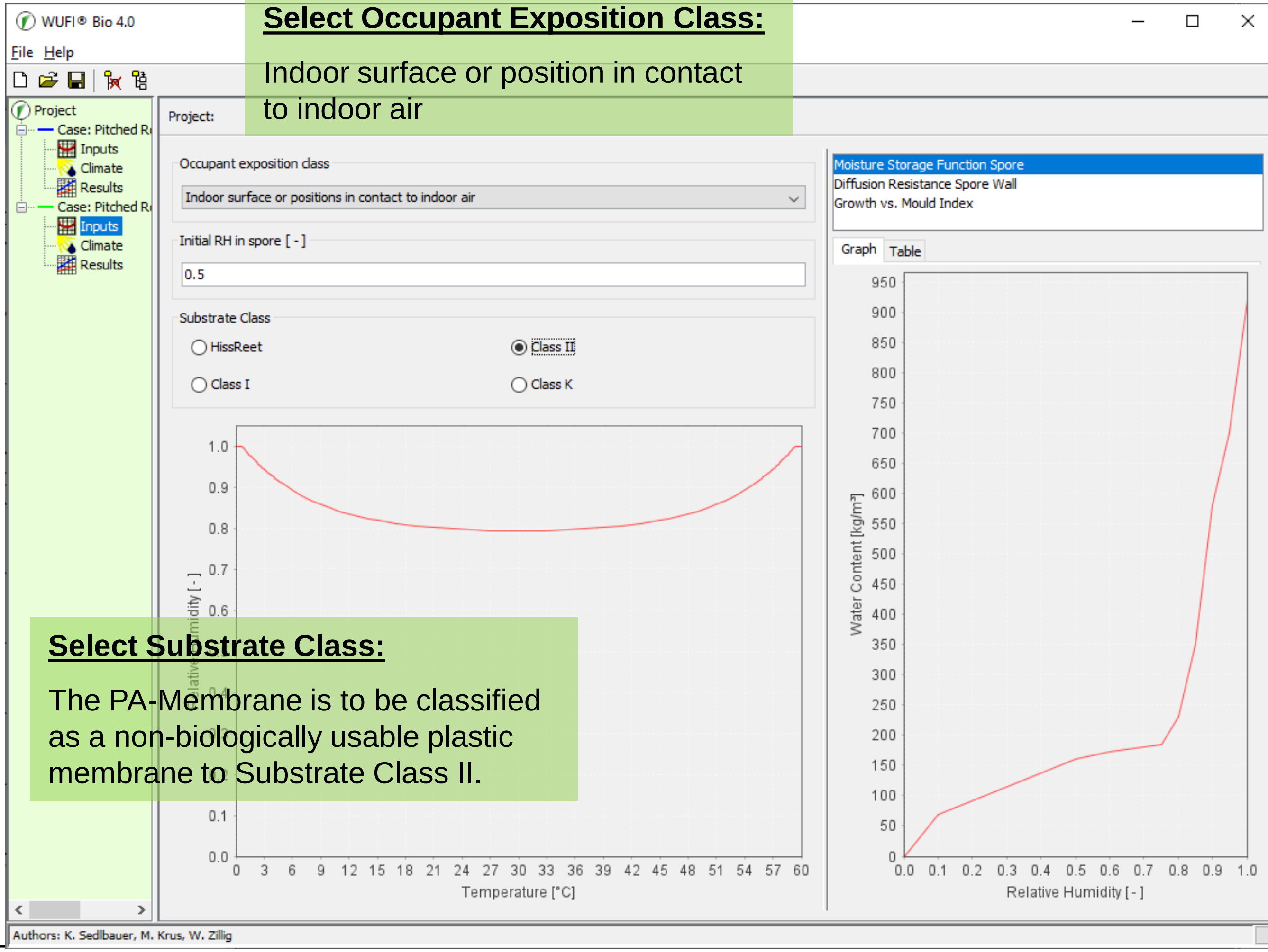
Case 2: Settings in WUFI® Bio

Evaluation: Mould risk behind the vapour retarder



Select Occupant Exposition Class:

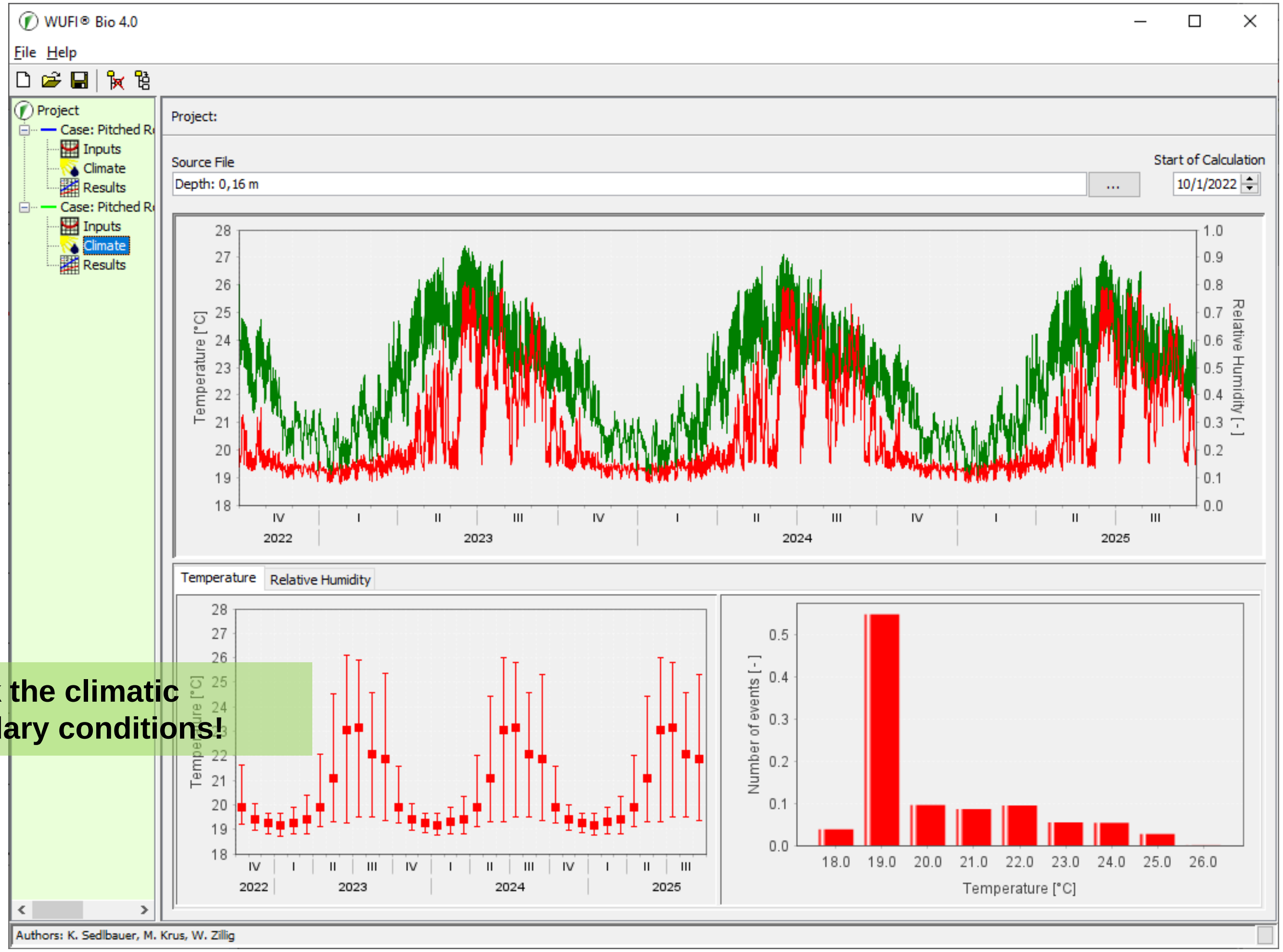
Indoor surface or position in contact to indoor air

Select Substrate Class:

The PA-Membrane is to be classified as a non-biologically usable plastic membrane to Substrate Class II.

Case 2: Settings in WUFI® Bio

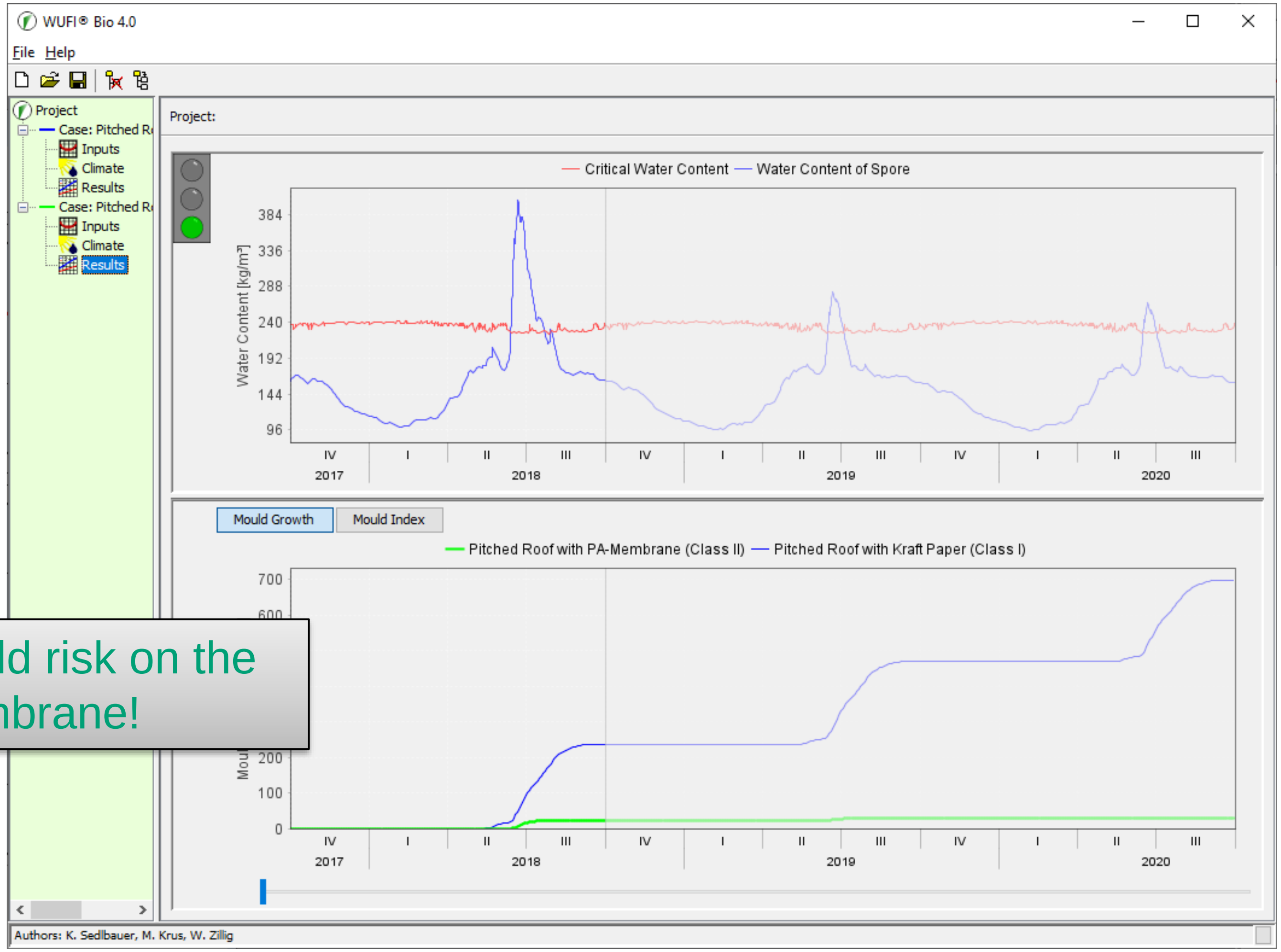
Evaluation: Mould risk behind the vapour retarder



Check the climatic boundary conditions!

Case 2: Settings in WUFI® Bio

Evaluation: Mould risk behind the vapour retarder



No mould risk on the PA-Membrane!