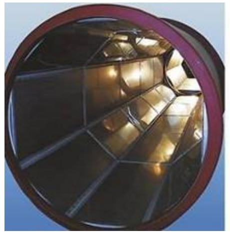
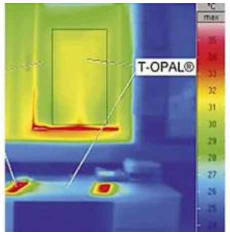


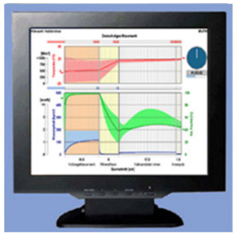
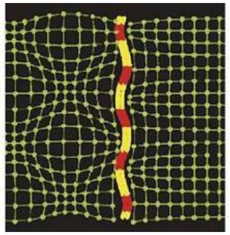


WUFI® Guideline

Evaluation of the dew water runoff risk in hydrophobic fiber insulation materials

Date: October 2024

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Content

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Basics – Glaser method

The international standard EN ISO 13788 [1] as well as for example the German standard DIN 4108-3 [2] provide **steady-state** assessment methods („Glaser“) for the condensation risk in building assemblies.

A construction is approved, if

1. no condensation occurs at all, or
2. the amount of condensation remains below the limit values and can dry out completely within a year.

The steady-state diffusion methods have some simplifications, like:

- Constant boundary conditions for temperature and rel. humidity (summer, winter or monthly averages - without rain and radiation)
- No moisture dependencies of the material parameters (e.g. the thermal conductivity)
- No built-in moisture
- Moisture buffering effects are neglected.

Basics – Assessment by hygrothermal simulation with WUFI®

WUFI® tankes into account the moisture storage capacity (sorption isotherm) of building materials. The moisture storage function describes the correlation between the water content in the material and the relative humidity of the environment.

In the hygroscopic range up to around 95 % RH, the water molecules are absorbed in increasing numbers onto the inner surfaces of the pores.

In the capillary water range between 95 % RH and 100 % RH, liquid water is already present in the pores, but is „bound“ in the pores by the capillary forces.

A risk of dew water runoff is therefore only possible when 100 % RH is reached and the amount of the condensate is above the amount that can be retained (adhered) at the surfaces.

Basics – Assessment by hygrothermal simulation with WUFI®

With fiber insulation materials, it is hardly possible to clearly distinguish between the capillary water range and the supersaturation range. In such materials, when water contents near free saturation are reached, the water runoff is also hindered by the flow resistance of the surface and fiber structure and not only by the actual capillary forces.

Within the NaVe [3] project, a measurement method was developed in which the effective dew water retention is determined independently of the exact causes, capillary forces or flow resistance. The amount of dew water simulated by WUFI® on the surface or at the interface between the insulation material and the neighboring material can be evaluated on this basis regarding the runoff risk.

The measured limit water content at the interface is a mixture of the amount of moisture that is bound by sorption forces in the insulation material, the water which is retained by the fiber structure and the part which is retained on the surface of the vapor barrier or the roofing membrane. If the limit water content is exceeded, the dew water starts to run off.

Limit values of condensate amount in standards

DIN EN ISO 13788: 2012 (steady state calculation)	
Maximum amount of condensate in order to prevent a runoff of liquid water from watertight surfaces.	< 200 g/m²
DIN 4108-3: 2024 (steady state calculation)	
Maximum amount of condensate per area (general)	< 1000 g/m²
At layer interfaces with a non-capillary absorbent layer	< 500 g/m²
BSI 5250: 2011 (British Standard)	
Fine mist, no dropping of liquid water	< 30 g/m²
Drop formation and draining on vertical surfaces	< 30 – 50 g/m²
Drop formation and draining on inclined surfaces	51 – 250 g/m² 70 g/m² for inclination of 45° 150 g/m² for inclination of 23°
Prevention of the formation of big drops on horizontal surfaces which can drainage	≤ 250 g/m²

Limit value for wall by NaVe project [3]

Measurement of the retention capacity at the interface between the fiber insulation material and the non-absorbent material surface of walls [3]

- Measurement of the dew water retention capacity at the vertical interfaces between the fiber insulations (14 materials) and the non absorbent surface materials (4 types)
- The minimum measured retention capacity was **100 g/m²**.
- The amount of moisture retained in the insulation material correlates with its sorption capacity at 80 % RH as well as with the hydrophobicity and roughness of the adjacent surface material.
- The material-specific retention capacity can be determined using the following equation based on the minimum retention capacity, the material surcharge and the surface surcharge:

$$\textbf{Retention capacity} = 100\ [g/m^2] + 20\ [m{\cdot}g/kg] * u_{80}\ [kg/m^3] + b\ [g/m^2]$$

u_{80}: sorption moisture content of the fiber insulation material at 80 % RH
b: surface factor, depends on the properties of the adjacent surface according to the table below

Property of surface	b [g/m²]
unknown or smooth and hydrophobic	0
smooth, hydrophilic / finely structured, hydrophobic	50
roughly structured	100

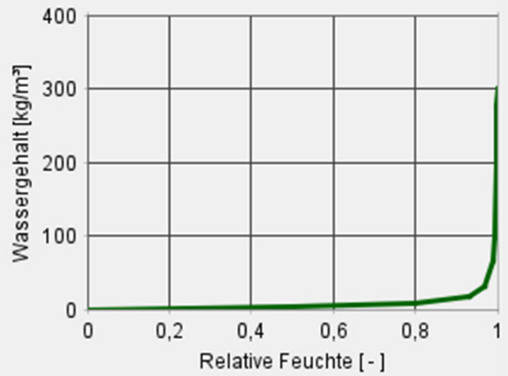
Limit value for wall by NaVe project [3]

Note on material surcharge:

material surcharge = 20 [m·g/kg] * u_{80} [kg/m³]
(u_{80}: sorption moisture content at 80 % RH)

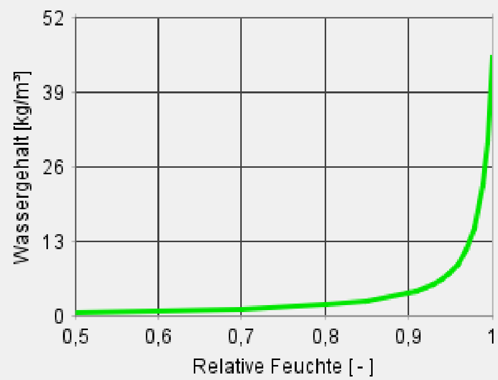
In case of a measured moisture storage function (dark green curve, black values), u_{80} can be taken from the table.

Nr.	R.F. [-]	Wassergehalt [kg/m³]
1	0	0
2	0,5	4
3	0,65	5
4	0,8	9
5	0,93	17,5
6	0,97	30
7	0,99	65,53
8	0,995	98,8
9	0,999	193,29
10	0,9995	228,16
11	0,9999	276,38
12	1	300



If an internal moisture storage function (light green curve and values) is used, no material-specific surcharge is applied.

Nr.	R.F. [-]	Wasserge... [kg/m³]
1	0	0
2	0,5	0,461
3	0,6	0,687
4	0,7	1,06
5	0,8	1,79
6	0,85	2,49
7	0,9	3,83
8	0,91	4,26
9	0,92	4,78
10	0,93	5,43
11	0,94	6,27
12	0,95	7,38
13	0,96	8,94
14	0,97	11,3



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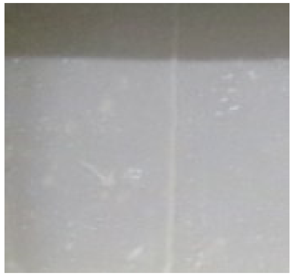
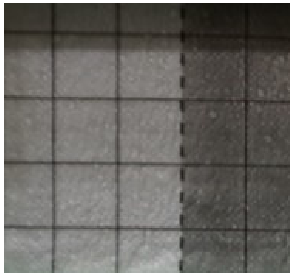
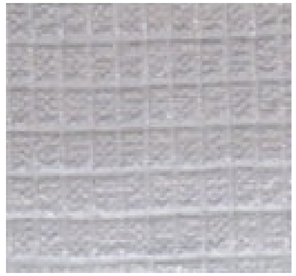
Limit value for wall by NaVe project [3]

Surface property examples:



Property	hydrophobic, smooth	hydrophilic	hydrophobic, finely structured	hydrophobic, roughly structured
Example material	PE-film	metal plate	film laminated on fleece	film reinforced with fabric
Retention capacity without insulation material [g/m²]	50	100	100	150
Additional retention capacity (surcharge **b**) for contact with insulation material [g/m²]	0	50	50	100

Limit value for roof and wall (by [3] and [4])

Measurement of the dew water retention capacity on PE spunbonded fleece depending on the slope [4]

The following slope-depending limit values can be derived from [4]:

Slope (α)	Limit value
$\alpha = 0°$	400 g/m²
$0° < \alpha \leq 5°$	350 g/m²
$5° < \alpha \leq 10°$	300 g/m²
$10° < \alpha \leq 15°$	150 g/m²
$15° < \alpha \leq 90°$	100 g/m²

The minimum value of 100 g/m² measured at 90 ° corresponds to the value measured in NaVe [3] for fiber insulation on a smooth hydrophobic surface. Thus, the PE spunbonded fleece corresponds to a smooth surface in direct contact with a fiber insulation.

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Limit values - overview

Overview of the material and slope dependent limit values

<table>
<tr><th>Slope (α)</th><th>Minimum limit value</th><th>Material surcharge</th><th colspan="2">Surface surcharge</th></tr>
<tr><td>$\alpha = 0°$</td><td>400 g/m^2</td><td rowspan="4">For measured moisture storage function:
$\mathbf{20}\ [\mathrm{m \cdot g/kg}] * \mathbf{u_{80}}\ [\mathrm{kg/m^3}]$

No surcharge for internal moisture storage function.</td><td colspan="2" rowspan="4">No surcharge</td></tr>
<tr><td>$0° < \alpha \leq 5°$</td><td>350 g/m^2</td></tr>
<tr><td>$5° < \alpha \leq 10°$</td><td>300 g/m^2</td></tr>
<tr><td>$10° < \alpha \leq 15°$</td><td>150 g/m^2</td></tr>
<tr><td rowspan="3">$15° < \alpha \leq 90°$</td><td rowspan="3">100 g/m^2</td><td rowspan="3"></td><td>unknown or smooth + hydrophobic</td><td>0 g/m^2</td></tr>
<tr><td>smooth + hydrophilic or finely structured + hydrophobic</td><td>50 g/m^2</td></tr>
<tr><td>roughly structured</td><td>100 g/m^2</td></tr>
</table>

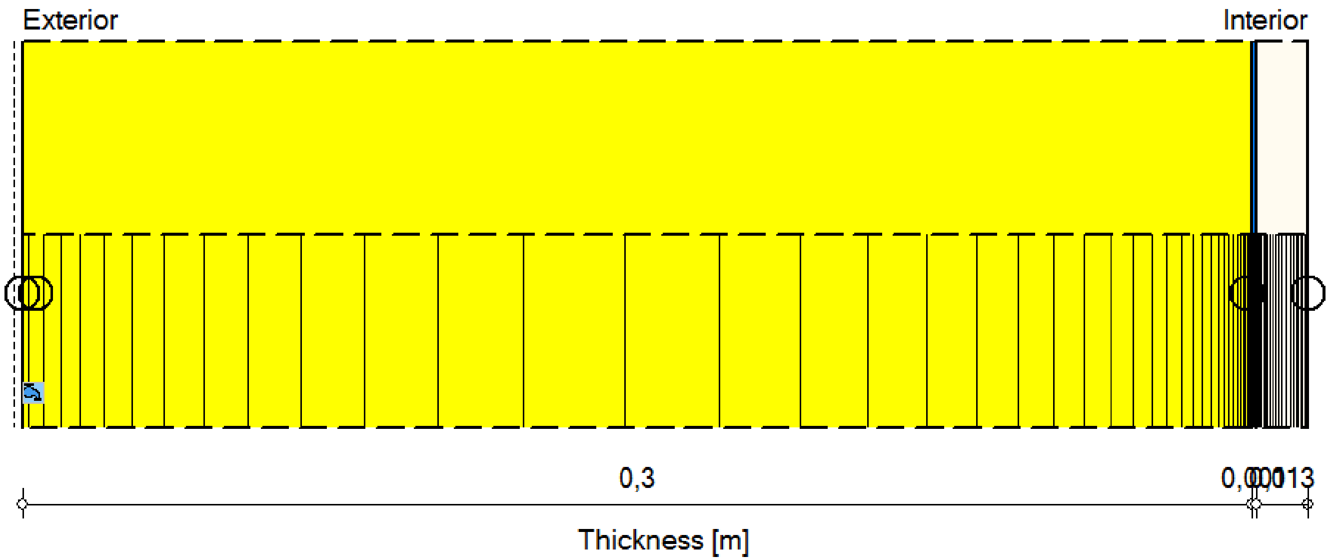
Surcharges are only considered <u>if the respective slope-dependent **minimum limit value** is exceeded in the simulation.</u>

Procedure in WUFI®

Evaluation of the dew water runoff risk in hydrophobic fiber insulations:

1. Determination of the dew water amount in the critical 10 mm in the insulation.
   - Identification of the condensation area in WUFI® Animation 1D (relative humidity reaches 100 %) and Evaluation in WUFI® Graph
   - Or separation of the critical 10 mm before the (re) calculation and evaluation of the water content in this layer.
2. Comparison of the water content with the limit values
   - If the water content remains below the slope-dependent minimum limit value (slide 11), no runoff of condensate can occur.
   - If the water content is higher, the acceptable amount can be increased: by the "material surcharge" in case of sorptive materials or / and in case of steeper slopes (> 15 ° incl. walls) by the “surface surcharge”.
   - If also these limits are exceeded, runoff cannot be excluded.

Example – flat roof



- Monitor positions

- Heat/Moisture source/sink positions

Materials:

- *Mineral wool (thermal conductivity.: 0,04 W/mK)	0,3 m
- vapour retarder **(sd=2 m)**	0,001 m
- *Gypsum board	0,013 m

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Example – flat roof

Boundary condition

Location:	Holzkirchen
Orientation:	North
Inclination:	5°
Short wave absorptivity α:	0.8 (dark)
Long wave emissivity ε:	0.9
Roofing membrane:	s_d = 300 m (surface s_d-value)
Rain absorption:	no / (switched off)

Indoor climate	according to EN 15026 with high moisture load
Initial condition:	20 °C and 80 % RH
Start of the evaluation:	1st of October

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Convective moisture source flat roof

The German wood protection standard DIN 68800-2 [5] requires the consideration of an additional moisture source due to air infiltration and proposes two possibilities to consider:

1. A fixed amount of additional dew water for steady state dew point calculations (Glaser)

2. A transient model for the air infiltration for hygrothermal simulations (like IBP infiltration model which is directly implemented in WUFI®)

steady state	transient
Additional drying potential required – 100 or 250 g/m^2a per Winter	Calculation of the hourly condensation by a transient model [6]

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Convective moisture source flat roof

As the hygrothermal simulation is a transient process, the IBP air infiltration model [6] is used with the following boundary conditions.

The following are used for the example:

- Heated & connected indoor air space height: 5 m
- Air tightness level: B (q_{50} = 3 m³/m²h)
- Source area: outer 5 mm of the insulation

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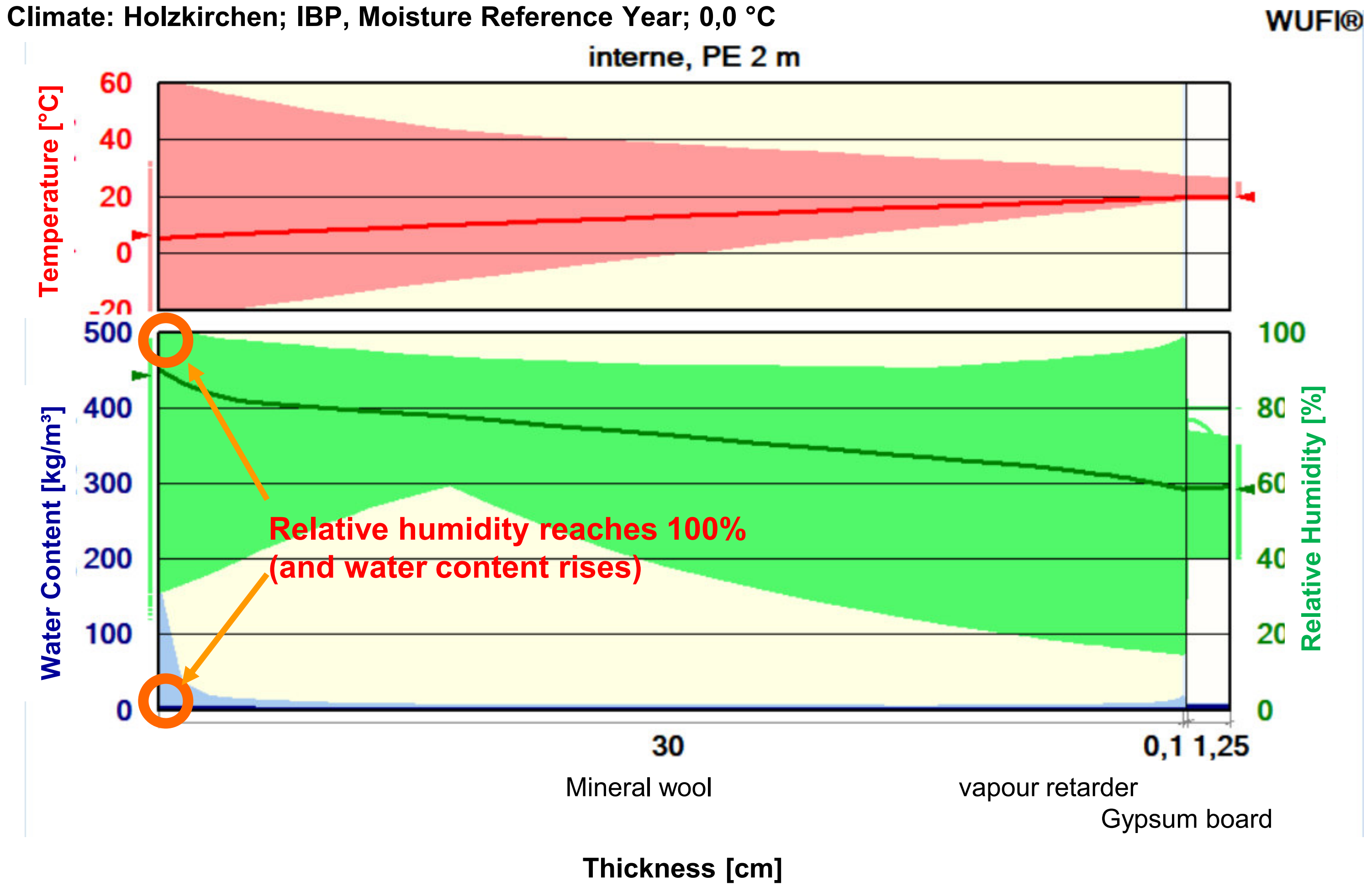
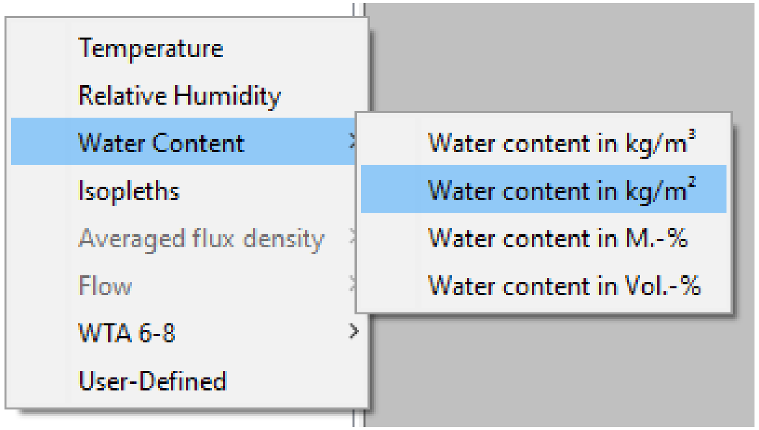
Example – flat roof: WUFI® Animation 1D

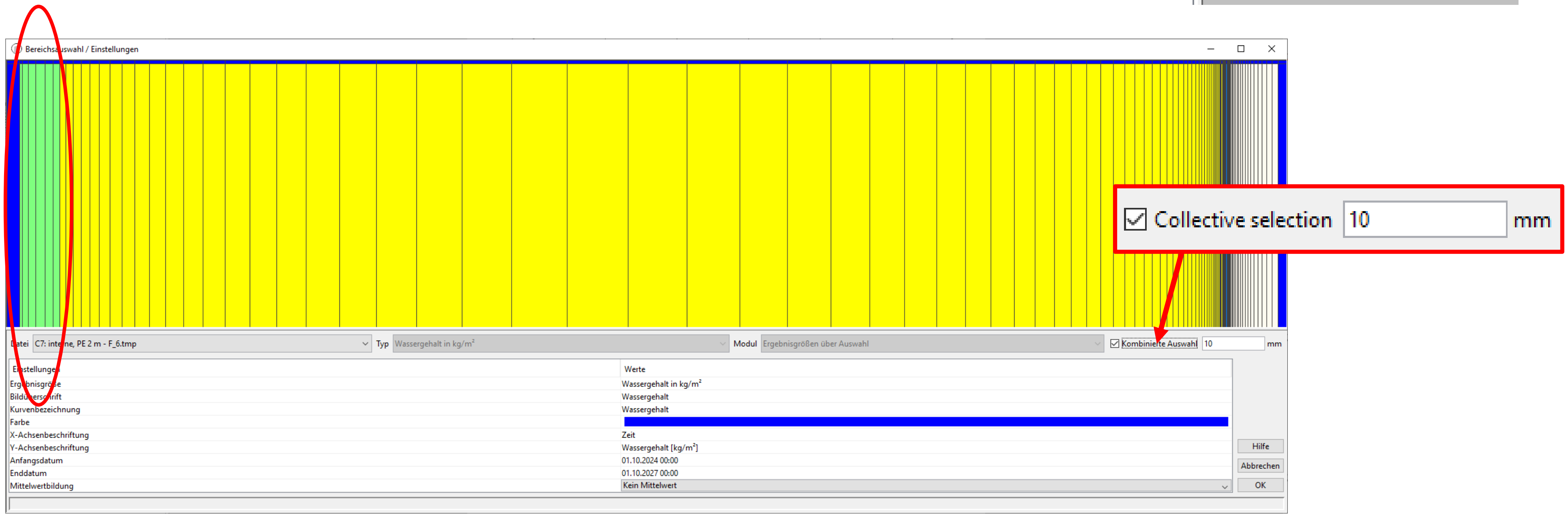


Example – flat roof: Evaluaion with WUFI® Graph

In WUFI® Graph:

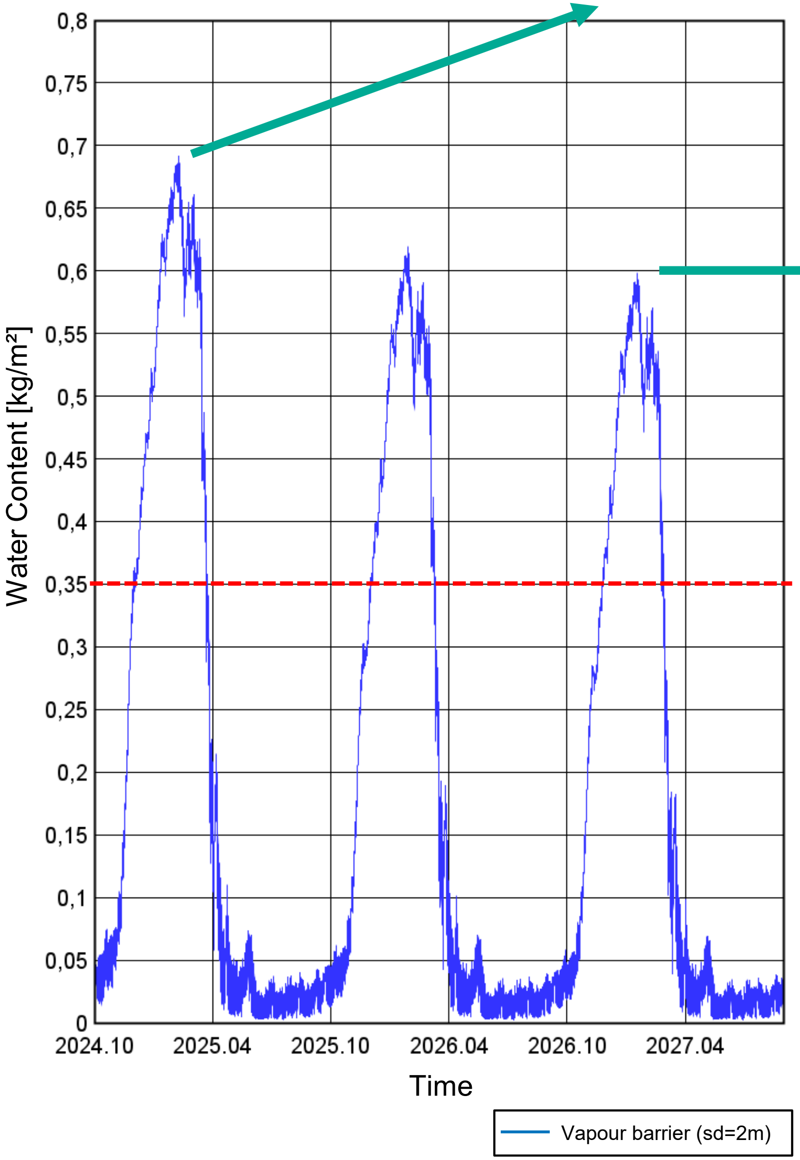
1. Click „Water content in kg/m²“
2. Select outermost 10 mm of the insulation





Example – flat roof: Evaluaion with WUFI® Graph

Maximum water content (incl. built-in moisture)
0,69 kg/m² = 690 g/m²



Maximum water content
(dynamic equilibrium)
0,6 kg/m² = 600 g/m²

Limit value for the inclination of 5 ° (350 g/m²)

(No material surcharge, as no measured storage function is available for the mineral fiber used; the limit value could be increased further when using a product with a measured storage function.
No surface surcharge for the inclination of 5°.)

Amount exceeds the limit – runoff cannot be excluded!

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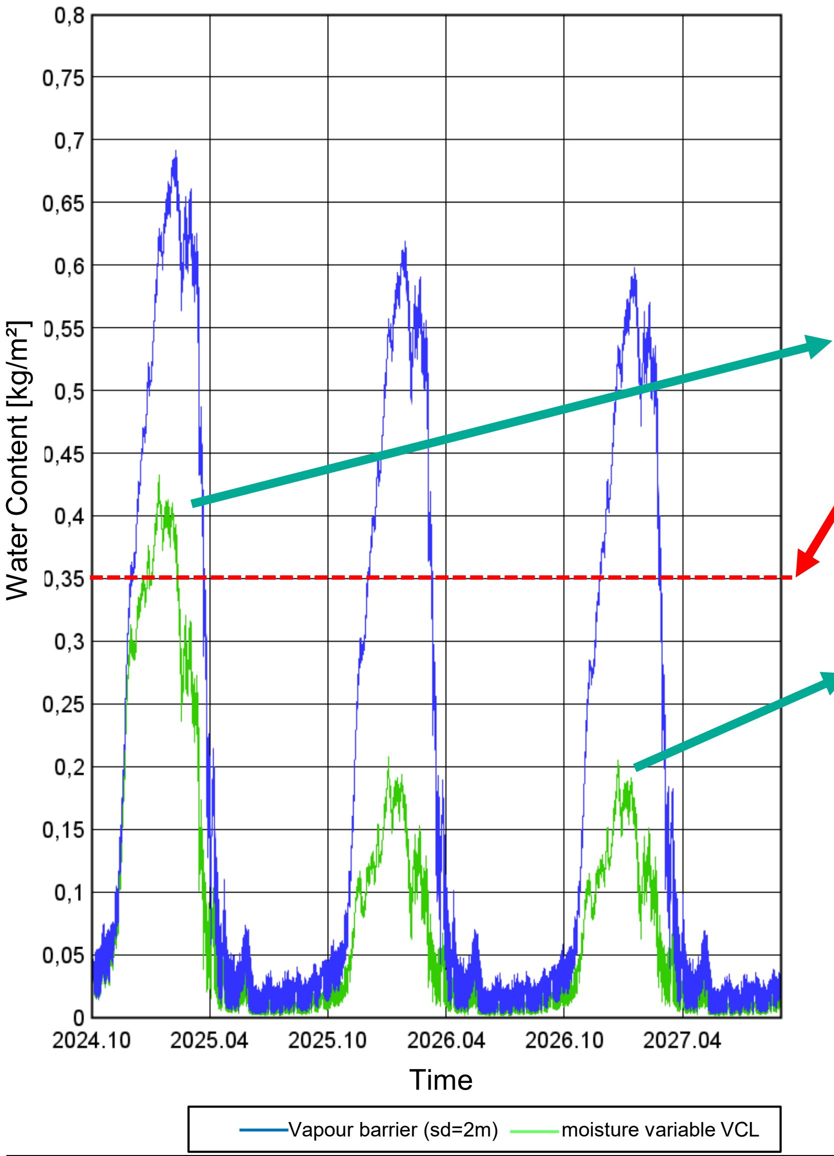
Example – flat roof: Evaluaion with WUFI® Graph



Improvement: replace the constant vapor retarder (s_d = 2 m) by a variable membrane (here with s_d: 0.04 - 27 m)

Maximum water content (incl. built-in moisture) 0,42 kg/m² = 420 g/m²

Limit value for the inclination of 5 ° (350 g/m²)

Maximum water content (dynamic equilibrium) 0,2 kg/m² = 200 g/m²

- ✓ **OK – no condensate runoff from year 2**

Note: In the first year, the limit value is exceeded and approx. 80 g/m² of condensation water could run off. This quantity depends largely on the assumed initial moisture content - whether such an excess really occurs and can be accepted must be checked on a case-by-case basis.

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Literature

[1] 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, Mai 2013.

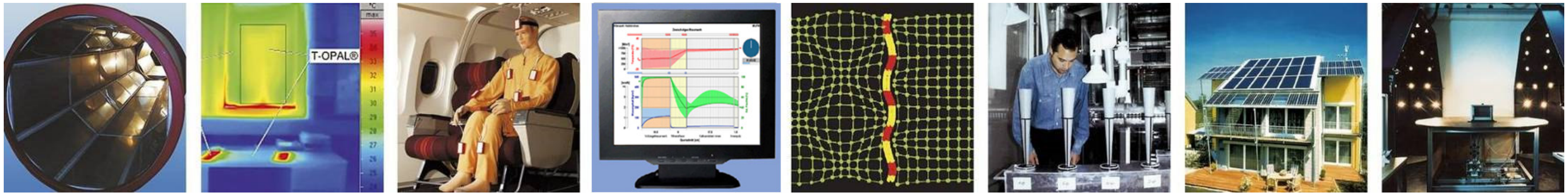
[2] DIN 4108-3: Thermal protection and energy economy in buildings – Part 3: Protection against moisture subject to climate conditions – requirements and directions for design and construction. Beuth Verlag, March 2024.

[3] Erarbeitung wissenschaftlich begründeter Bewertungskriterien und Implementierung eines Nachweisverfahrens für die schadenfreie energetische Bestandssanierung und Neubauplanung (NaVe). Forschungsbericht EnOB: Energieoptimierte Gebäude und Quartiere - dezentrale und solare Energieversorgung Auftrag des Bundesministeriums für Wirtschaft und Energie (BMWi), Förderkennzeichen:03ET1649 A/B, 2023.

[4] Janssens, A.: Reliable control of interstitial condensation in lightweight roof systems. Dissertation, Heverlee 1998. ISBN 90-5682-148-2

[5] DIN 68800-2: Holzschutz – Teil 2: Vorbeugende bauliche Maßnahmen im Hochbau. Beuth Verlag, Februar 2022.

[6] 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.



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