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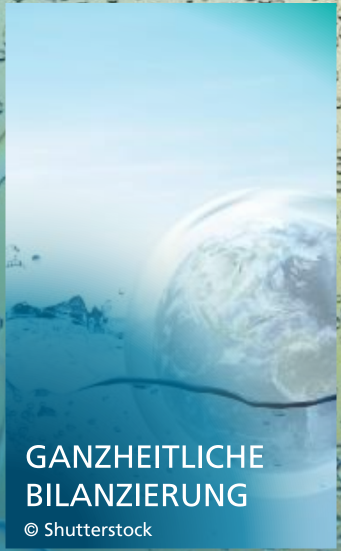






Finnish Building Physics Conference, Tampere October 2025

# Customized hygrothermal design for resilient and durable buildings

Daniel Zirkelbach

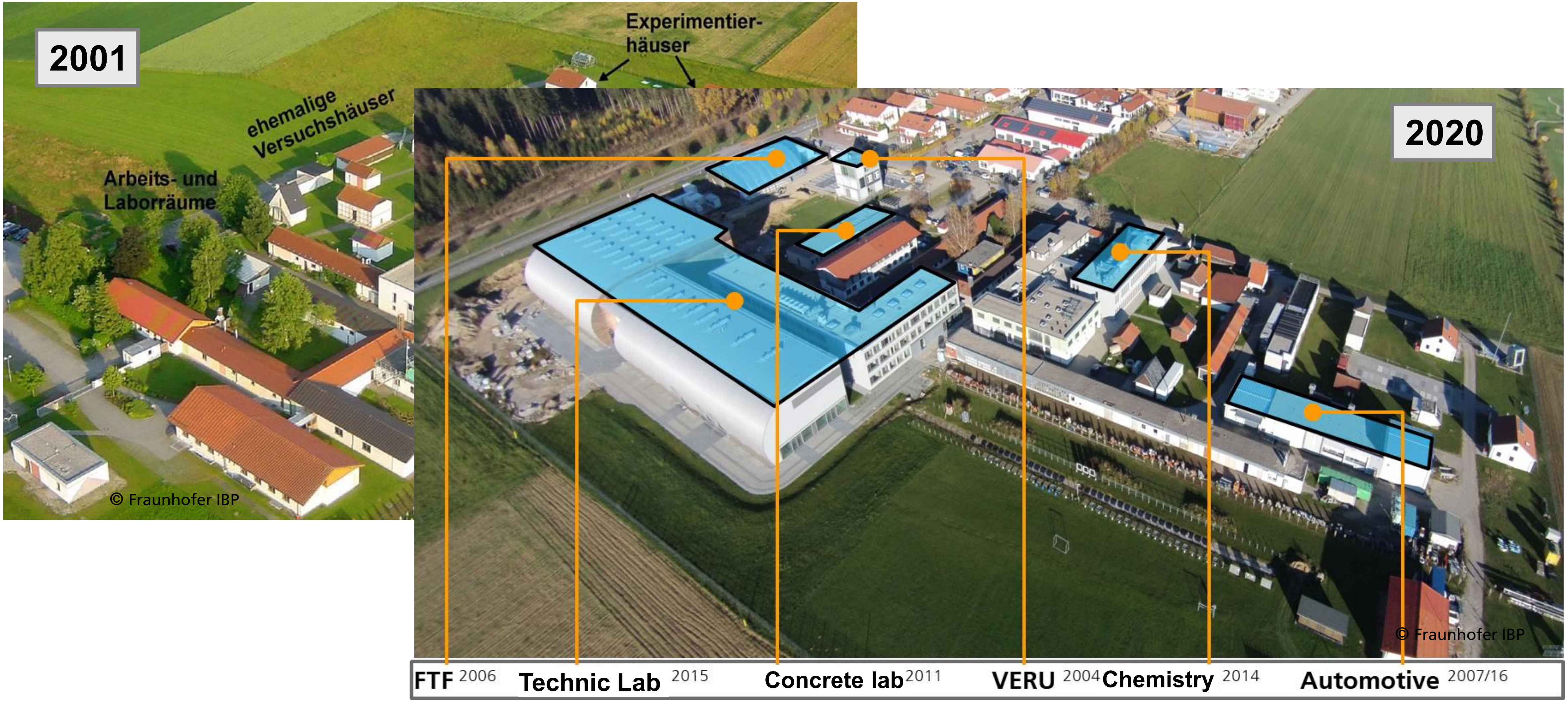
# Introduction


**IBP** Field test site 1951

**Dew water formation and mould risk on (poorly insulated) interior surfaces**

**Founded in 1951 to examine the hygienic performance of different wall and roof constructions under critical climate conditions on a plateau in front of the Alps.**

# Introduction



# Introduction





**Dew water formation and mould / algae risk on well insulated exterior surfaces**

**Better insulation levels solve moisture problems on the inside -**
**But create new risks on the exterior side!**

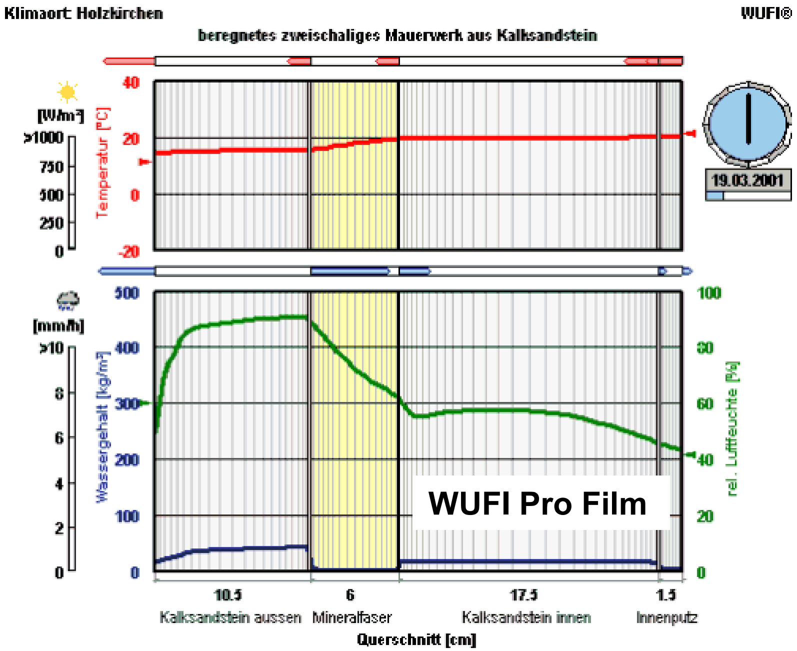
# Introduction

**Hygrothermal performance analysis considering heat, air and moisture transfer is often based on the triplet of field, lab and simulation studies to consider all influencing factors in real life!**

**Field test**


**Lab test, climate simulation**

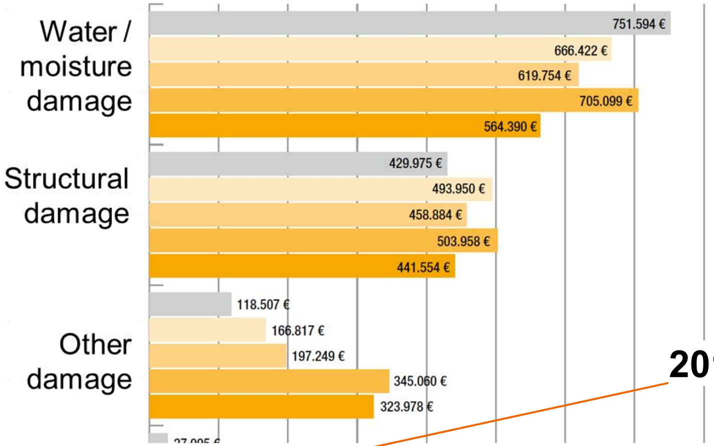
**Computer simulation**

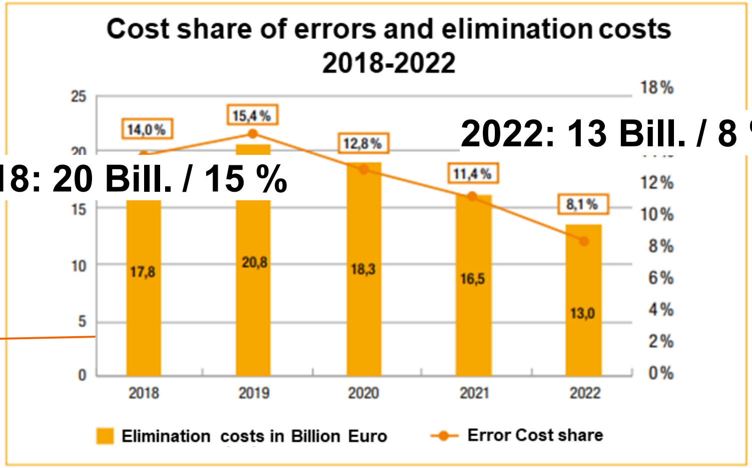


# Introduction

- **Building damages in Germany 8-15 % of turnover in the building sector!**
- **Moisture causes highest costs for repair: in total 4,5 – 6 Billion Euros per year!**
- **Strong increase over two decades from around 4 Bill. Euros in 1995 to over 20 Euros in 2019.**

**VHV Building Damage Report for Building Construction in Germany 2023/24**




**2018: 20 Bill. / 15 %**

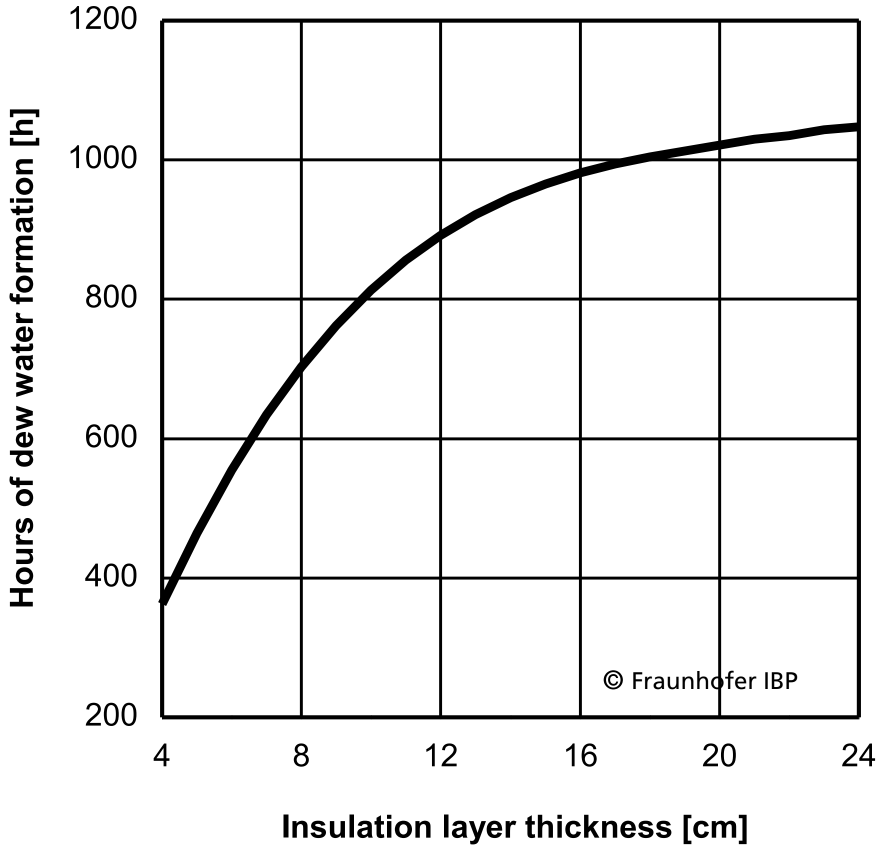
**2022: 13 Bill. / 8 %**

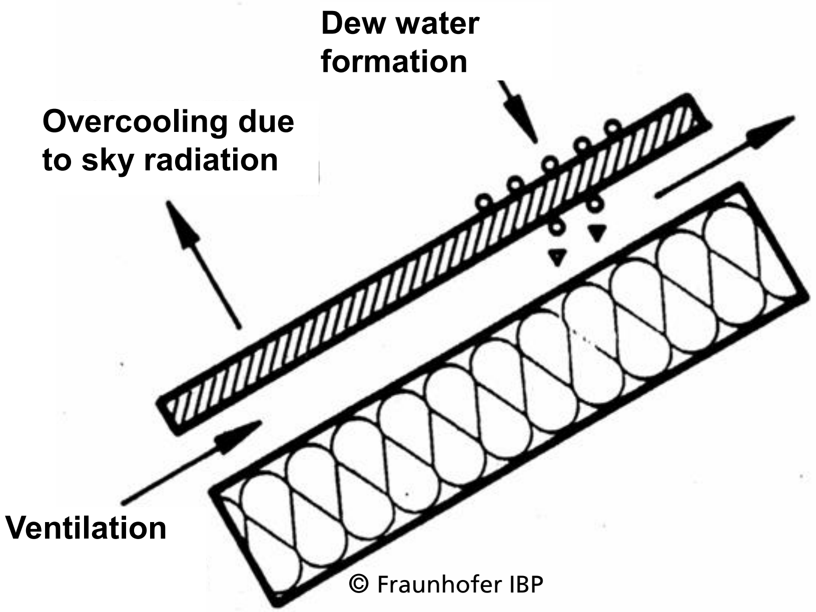
**1995: ~ 4 Billion or 5 %**

**In 2014 and 2018 the requirements for hygrothermal design in DIN 4108 were reviewed and clearly improved…**

# Correlation between Energy savings and moisture problems

## Example: Roof ventilation – from moisture sink to moisture source (?!)



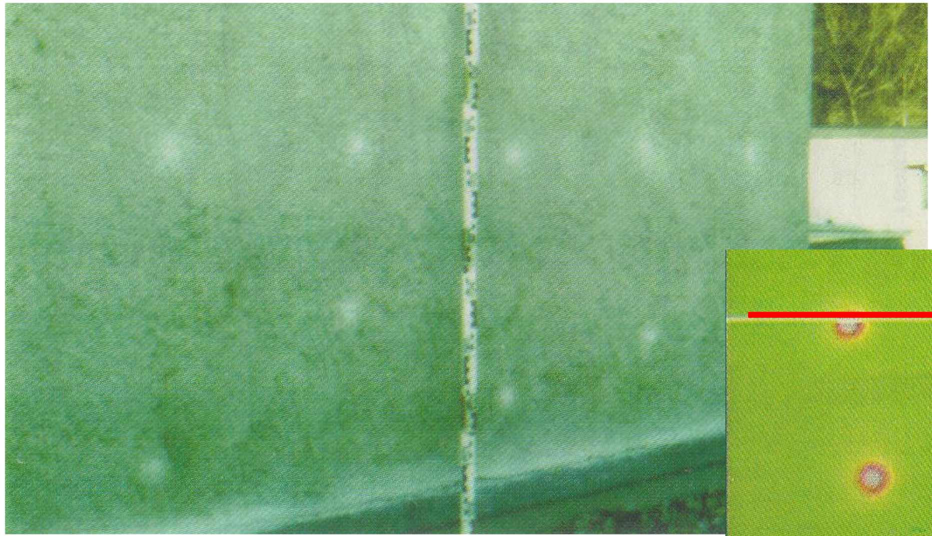

**Better insulation leads to lower temperatures on the outside of building components.**

**Without insulation: drying effect is dominant!**
**With insulation: increasingly frequent humidification!**

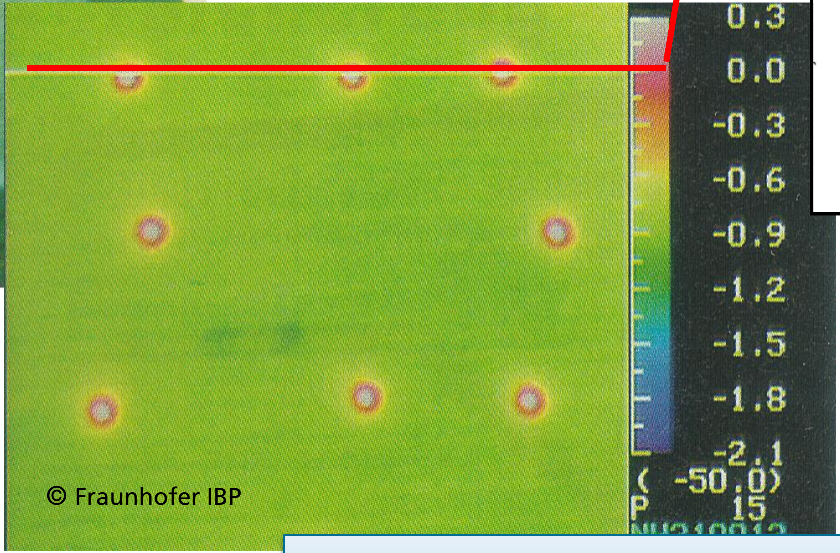
**Cold air in warm construction: drying!**
**Warm air in cold construction: humidification!**

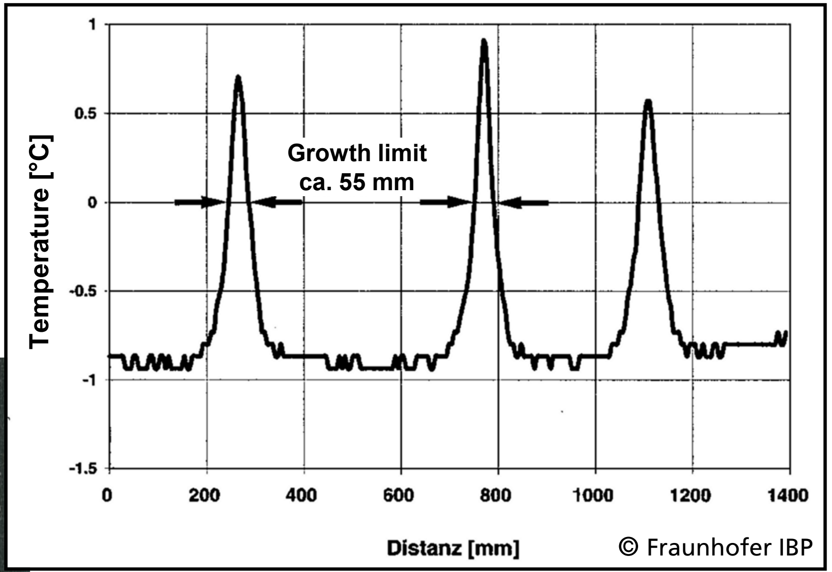
# Correlation between Energy savings and moisture problems

## Example: Algae growth on EIFS surface



Overcooling by sky radiation



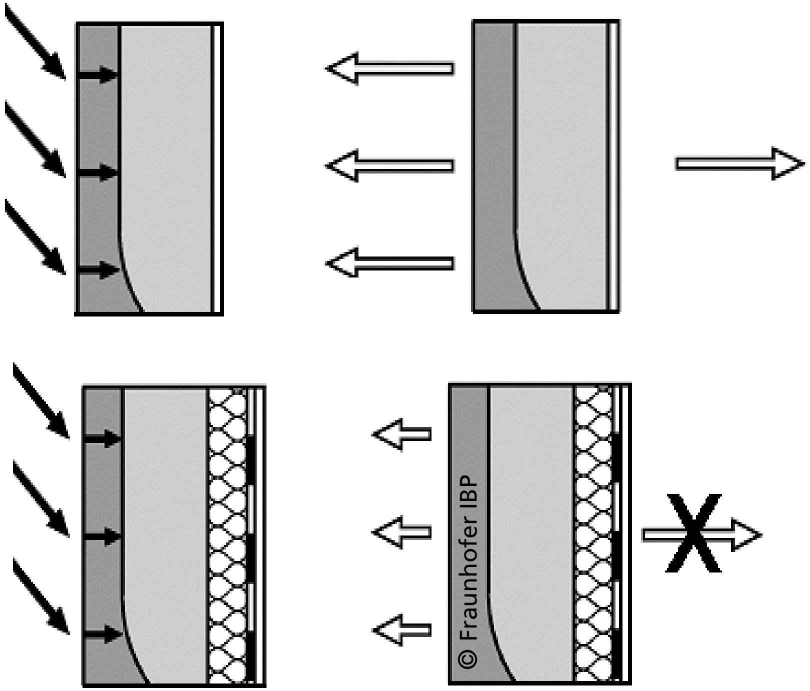




Thermal bridge and higher thermal inertia of the fasteners.

**Well-insulated Facades become and remain colder ⇨ more humidification, less drying.**

# Correlation between Energy savings and moisture problems

## Example: Frost damage after installation of interior insulation

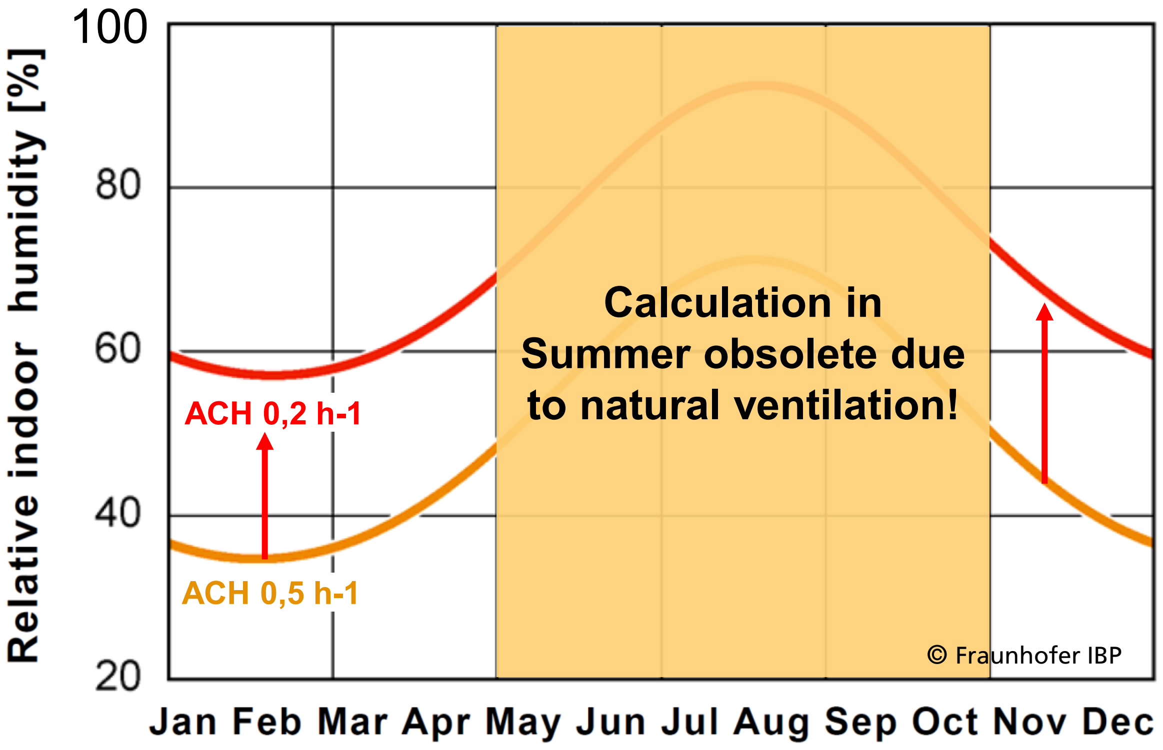

**Without interior insulation:**
**Equilibrium between humidification by rain and drying (wall is warm).**

**With interior insulation:**
**Same amount of rain leads to damage, drying is reduced (wall is cold)**

**Interior insulation saves "drying energy" and leads in this case to frost damage!**

# Correlation between Energy savings and moisture problems

## Example: Indoor air humidity level depending on the air change rate




**Indoor air RH in case of air change rates of 0,5 $h^{-1}$ and of 0,2 $h^{-1}$.**

**Typical moisture production rate of 1.0 $g/m^3h$ Temp: 20 - 22 °C.**

**Increases of RH by approx. 20 % RH in wintertime**

**Better airtightness increases RH level and vapor pressor in the indoor climate**

# Correlation between moisture problems and Energy savings

**Moisture protection in times of energy saving buildings and sustainability**

**Good insulation avoids dew water and mould growth on the interior surfaces!**

**However, energy saving measures move the problems further to the outside and increase in sum the moisture damage risks for two main reasons:**

1. **Better insulation means lower temperatures and worse drying of the exterior layers!**
2. **Better air tightness of the envelope means higher moisture levels and more humidification of the components by vapor diffusion.**

**The better the energy saving level, the more important is an adequate moisture protection by limitation of moisture ingress (vapor retarder, rain water protection) and facilitating drying (vapor permeable layers)!**

**Renewable materials are particularly moisture sensitive and exacerbate the challenge!**

# Hygrothermal evaluation methods with rising complexity

## Deemed-to-satisfy constructions

### Proven by:

- Longterm practice experience
- Glaser / Dew-Point calculations
- Hygrothermal simulations

Examples for deemed-to-satisfy wall and roof constructions in DIN 4108-3 and DIN 68800

DIN 4108 Teil 3

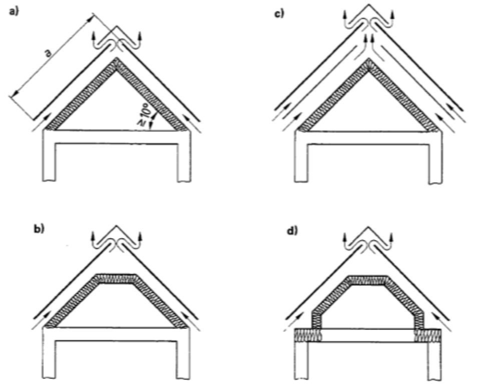
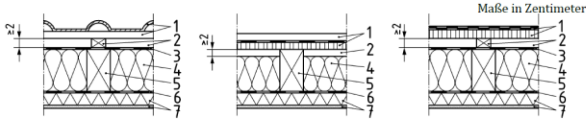



Bild 1 Beispiele für belüftete Dächer mit einer Dachneigung ≥10° (schematisiert)

DIN 4108-3:2024-03

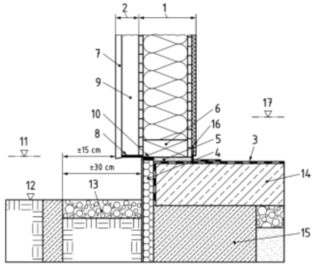
Maße in Zentimeter




**Legende**

1 Dachdeckung auf Traglattung (belüftete Dachdeckung), oder Dachdeckung auf Schalung (nicht belüftete Dachdeckung), oder Dachabdichtung auf Schalung
2 belüftete Luftschicht, ggf. Konterlattenebene
3 regensichernde Zusatzmaßnahme, Unterdeckbahn
4 Zwischensparrendämmung
5 Sparren
6 Schicht zur Begrenzung des Diffusionsstroms (ggf. auch Luftdichtheitsschicht)
7 raumseitige Bekleidung mit Unterkonstruktion, ggf. inkl. Dämmung

**Bild 1 — Grundkonstruktionen und Konstruktionsprinzipien für Dächer mit belüfteten Dachdeckungen oder belüfteten Luftschichten bei Dachneigungen ≥ 5°**

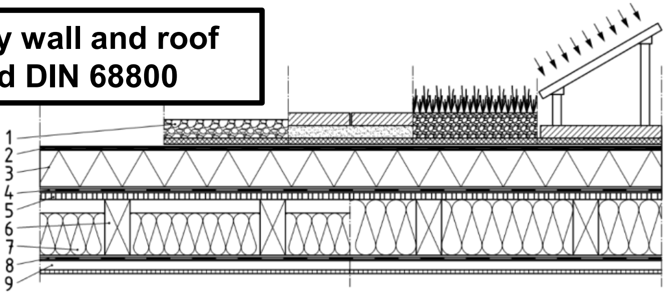



**Legende**

1 Wandkonstruktion variabel (Holztafelbau, Holzskelettbau, Massivholzbau usw.)
2 vorgehängte belüftetete oder hinterlüftete Fassade
3 Abdichtung nach DIN 18533 (alle Teile)
4 Perimeterdämmung bzw. für Spritzwasser und Erdeinbindung geeignete Dämmung nach DIN 4108-10 jeweils mit Sockelputz
5 Untermörtelung
6 Holzschwelle (Gebrauchsklasse GK 0)
7 Fassade
8 Kleintierschutz
9 Luftraum
10 Fugenabdichtung, z. B. Fugendichtband
11 Unterkante Schwelle im Endzustand min. 15 cm über GOK
12 Gelände-Oberkante Fertigmaß (GOK)
13 Kiesbett
14 Bodenplatte
15 Fundament
16 luftdichter Anschluss Wand-Betonbauteil (Bodenplatte/Keller)
17 Oberkante fertiger Fußboden (OFF)

**Bild A.11 — Außenwand-Fußpunkt mit Schwelle außerhalb Spritzwasserbereich mit vorgehängter belüfteter oder hinterlüfteter Fassade**

**5.3.4.2.11 Nicht belüftete Dächer mit Dachabdichtung bei Gebäudehöhen ≤ 10 m nach Bild 14**




**Legende**

1 Dachbelag (z. B. Kies, Plattenbelag, Begrünung, Solaranlagen)
2 Dachabdichtung ($s_d \geq 100$ m)
3 Aufdach-/Aufsparrendämmung i.d.R. druckfest
4 Diffusionssperrende Schicht ($s_d \geq 100$ m)
5 Schalung (Vollholz und Holzwerkstoffe)
6 Tragkonstruktion (Holzbalken)
7 Wärmedämmung im Gefach (Tragebene), höchstens 50 % des Gesamtwärmedurchlasswiderstandes
8 Luftdichtheitsschicht mit variablem $s_d$-Wert nach Tabelle 4
9 raumseitige Bekleidung mit Unterkonstruktion

Bei Aufbauten ohne Dachbelag kann nur unter Verwendung einer Dachabdichtung mit kurzwelliger Strahlungsabsorptionszahl ≥ 0,9 (z. B. schwarze Abdichtung) bei Gebäudehöhen ≤ 8 m die Wärmedämmung im Gefach (Tragebene) auf höchstens 60 % des Gesamtwärmedurchlasswiderstandes erhöht werden.

ANMERKUNG Bei diffusionsdichten Dämmelementen mit einem $s_d$-Wert ≥ 1 500 m können die Schichten 2 und 4 niedrigere $s_d$-Werte aufweisen.

**Bild 14 — Nicht belüftete Dächer mit Dachabdichtung und Wärmedämmung in der Tragebene (zwischen den Holzbalken) und auf der Tragebene (Aufdachdämmung) bei Gebäudehöhen ≤ 10 m**

**Easy to handle – just choice of assemblies which fit with the requirements**

**Only valid for similar climatic conditions and operations!**





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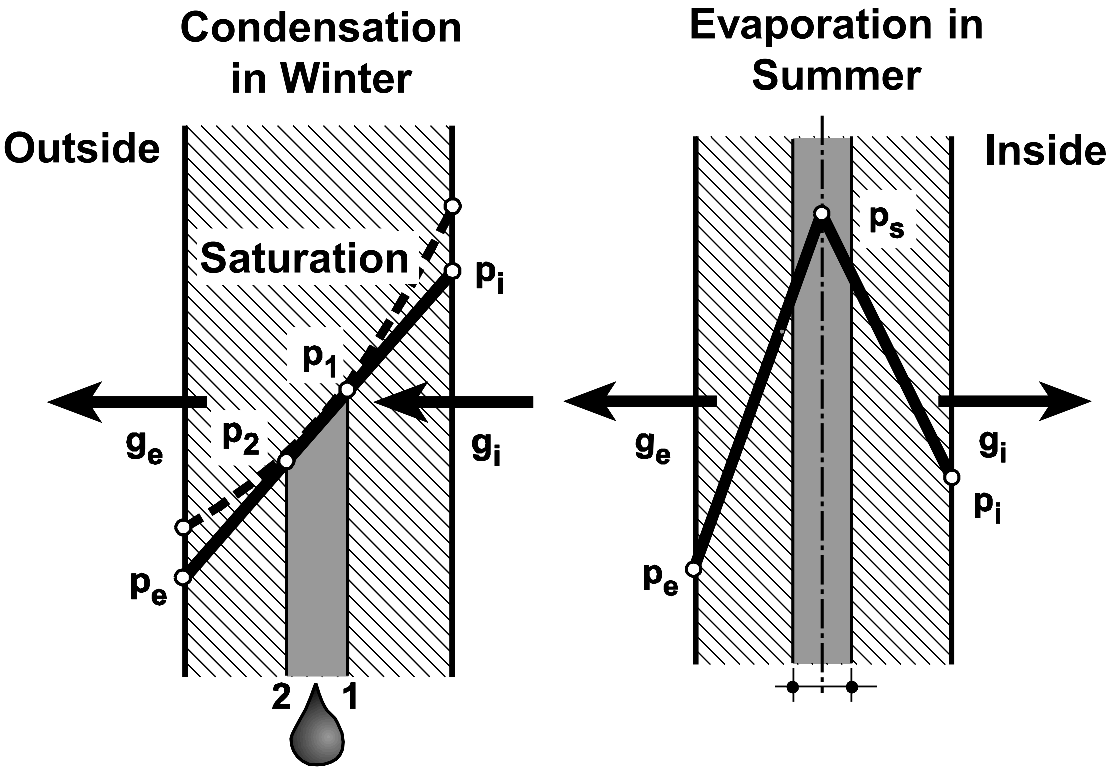
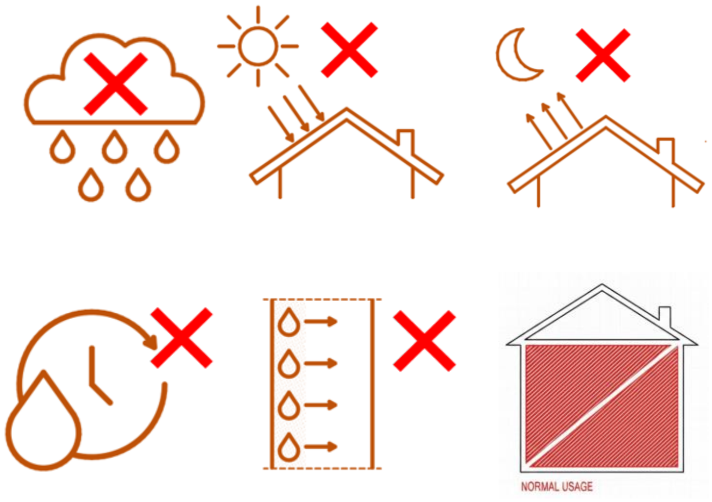
# Hygrothermal evaluation methods with rising complexity

## Glaser or Dew-Point calculations



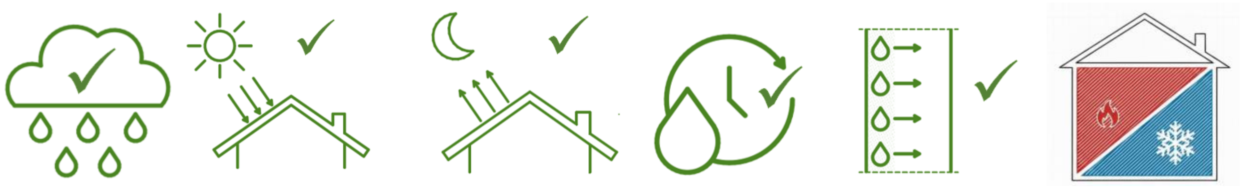

**Simple mathematical or graphical solution of the water vapor transport balance!**

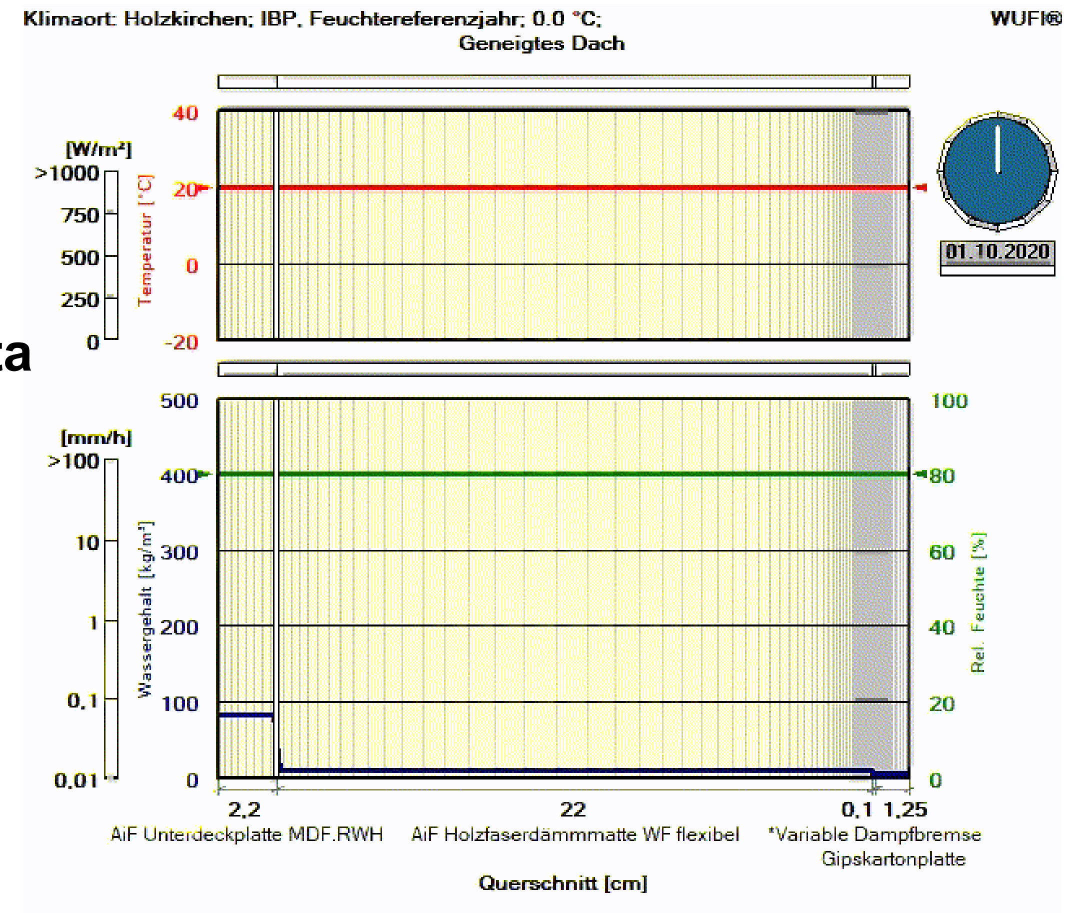
**Many influences are missing - only valid for intended climate conditions and operation**

# Hygrothermal evaluation methods with rising complexity

## Hygrothermal simulations

- **State of the art and recommended in many standards like EN 15026, DIN 4108, ASHRAE 160 etc.**
- **Consider the relevant climate and material data**
- **Able to handle imperfections ventilation, shading, green roofs etc.**






**Most detailed method based on physical models and real climate data**

**Challenge: Availability of climate and material, correct choice of input data, interpretation of results**





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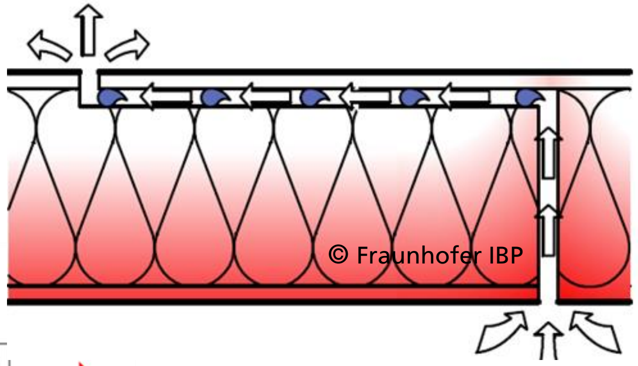
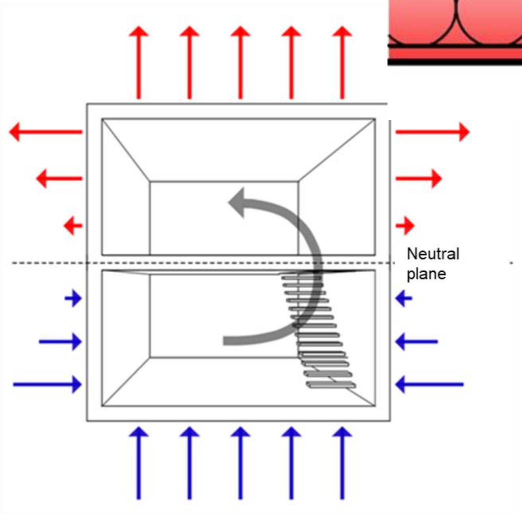
# Hygrothermal evaluation methods with rising complexity

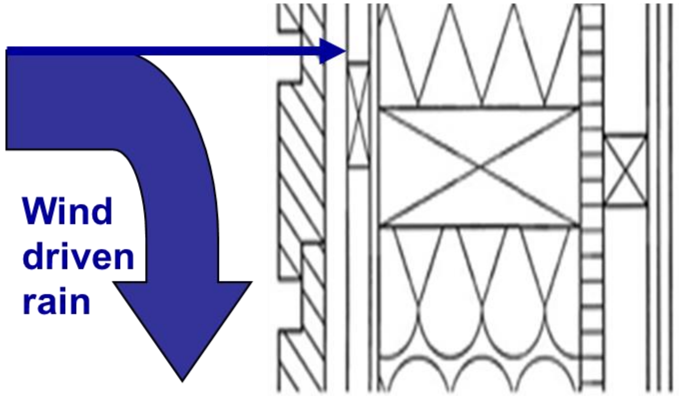
## Hygrothermal simulations

**DIN 68800: Air infiltration in case of wooden walls and roofs**



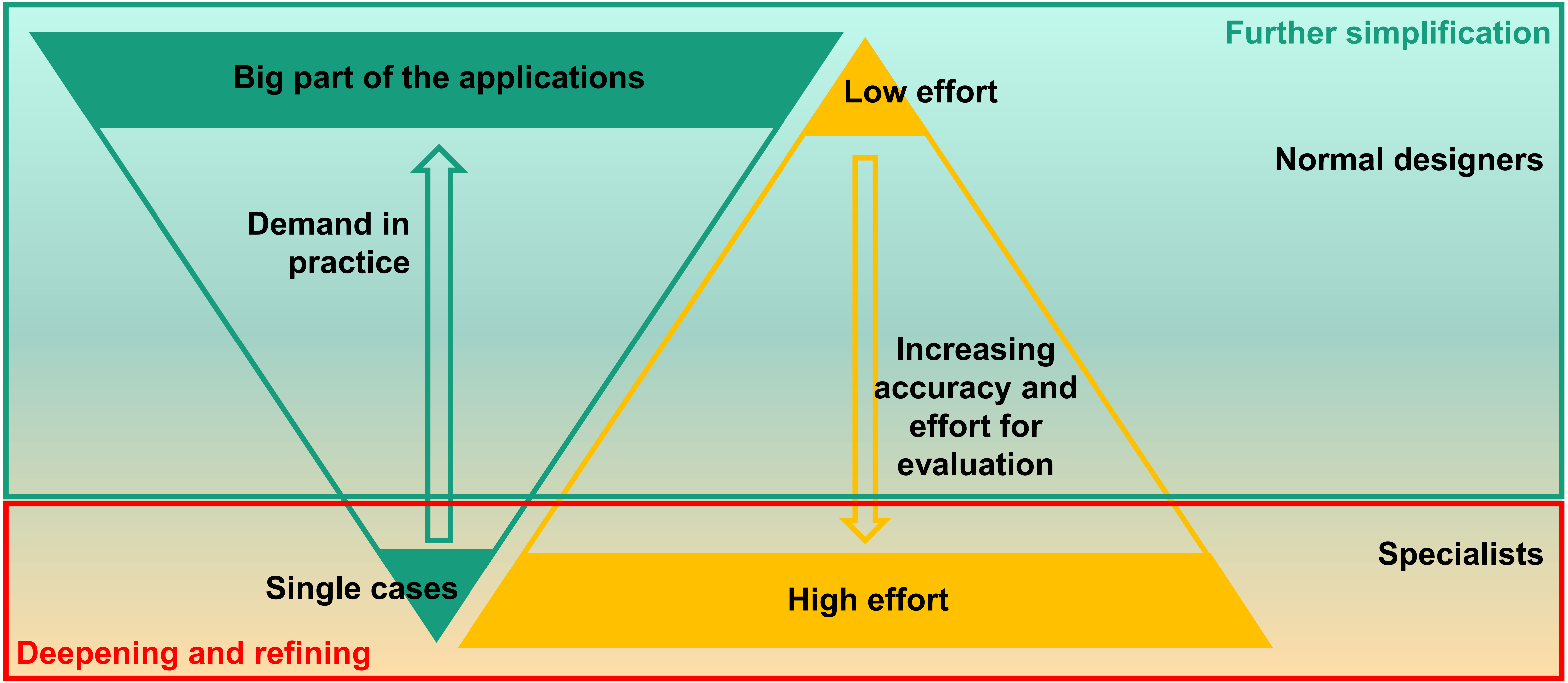




**ASHRAE 160 / EN 15026: rain water leakages in case of EIFS or Cladding systems**




**Safety Features for typical imperfections avoid constructions with insufficient drying potential**

# Project NaVe (Fraunhofer IBP und TU Dresden): Improved Evaluation Criteria for Hygrothermal Simulation Results



# Project NaVe (Fraunhofer IBP und TU Dresden): Improved Evaluation Criteria for Hygrothermal Simulation Results

- Hygrothermal Performance
- Condensation water limits to prevent run-off
- Mould Growth
- Fungal Decay
- Corrosion prediction

**Level 1**

Simple limits, proven in practice, high safety but often too conservative

↓

**Level 2**

e.g. limit curves of Temp and RH, Already closer to real conditions

↓

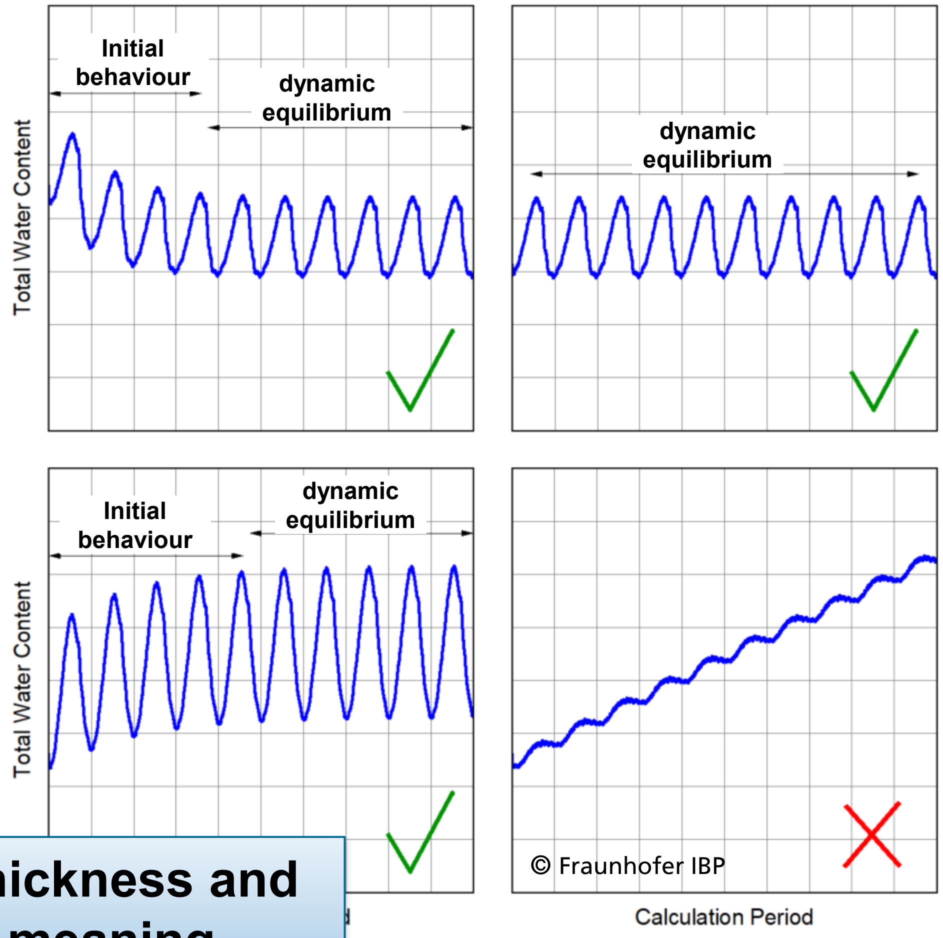
**Level 3**

e.g. transient damage prediction models as post-processors
⇨ account for the duration of exposure

# Evaluation criteria on different accuracy levels – Moisture performance

## Moisture content of the whole assembly

- **Decrease**: Component dries
- **No change to last year**: dynamic equilibrium is reached
- **Short-term increase also OK**!!: humidity level in dynamic equilibrium is higher than the assumed initial moisture;
- **Long-term increase**: permanent moisture accumulation in the construction (higher wetting than drying – may be acceptable at low levels if no critical moisture conditions are reached during lifetime)




**Qualitative assessment – level depends on thickness and sorption capacity of the materials but has no meaning.**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# Evaluation criteria on different accuracy levels – Interstitial condensation

## Little and contradictory information in international standards

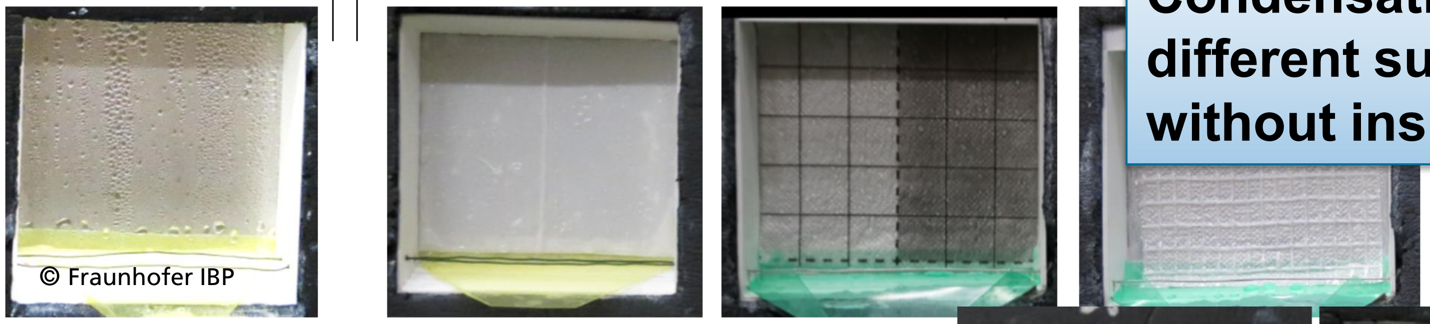
| Maximum amount of condenstion to avoid running off | |
|---|---|
| **DIN EN ISO 13788: interfaces** | |
| General limit value | ≤ 200 g/m² |
| **DIN 4108-3: interfaces** | |
| Impermeable surfaces | ≤ 1000 g/m² |
| Absorbing surfaces | ≤ 500 g/m² |
| **BSI 5250: Impermeable surfaces without insulation** | |
| General limit for fine mist | < 30 g/m² |
| Vertical surfaces | < 30 – 50 g/m² |
| 45° slope | < 70 g/m² |
| 23° slope | < 150 g/m² |
| Horizontal surfaces | ≤ 250 g/m² |

**What can be used? Obviously further investigations necessary!**

# Interstitial condensation

## New investigations in Nave

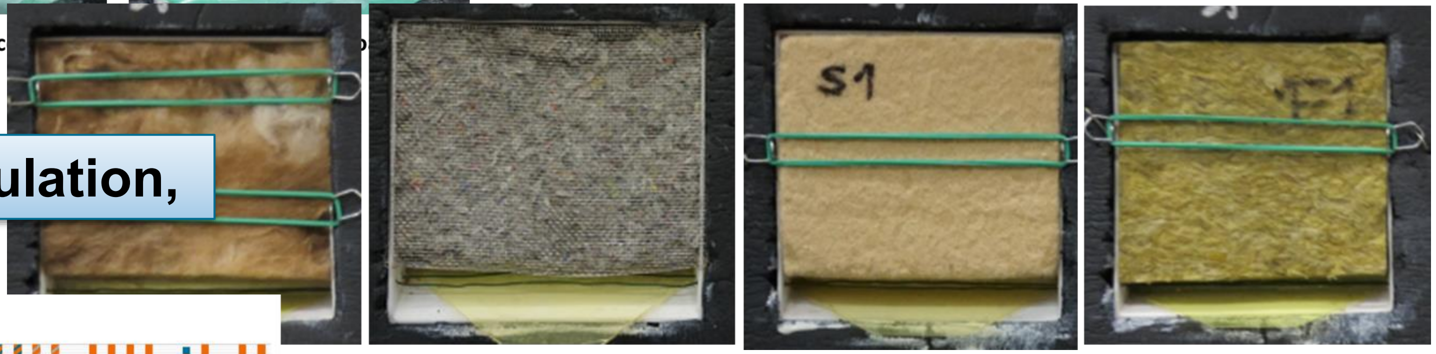
hydrophilic | hydrophobic

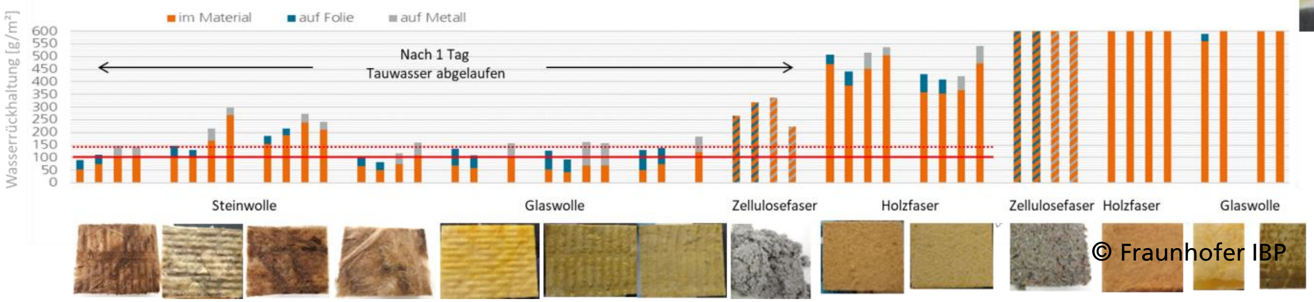



Metal | PE film (smooth) | PE film with fleec

**Condensation on different surfaces without insulation**


**… and with insulation,**



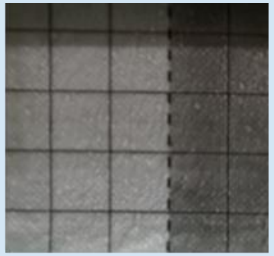

**… to measure the retained condensation water amounts dep. on surface and insulation type**

# Interstitial condensation

## Level 1: General limits independent on material types

| | |
|---|---|
| **Without insulation** | **50 g/m²** |
| **With insulation** | **100 g/m²** |

## Level 2: dependent on surface type



| Interface situation | hydrophobic smooth | hydrophilic | hydrophobic, fine structured | hydrophobic coarse struct. |
|---|---|---|---|---|
| Exemplary material | **PE film** | **metal plate** | **PE film w. fleece** | **film with mesh** |
| Dew water retention **without insulation** [g/m²] (factor **b**) | **50** | **100** | **100** | **150** |
| Dew water retention **with insulation** [g/m²] | **100** | **150** | **150** | **200** |





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# Interstitial condensation

## Level 3: Individual influence of inclination and moisture storage / liquid transport of the insulation!

Specific retention capacity considers
minimum retention, insulation properties, interface type and inclination:

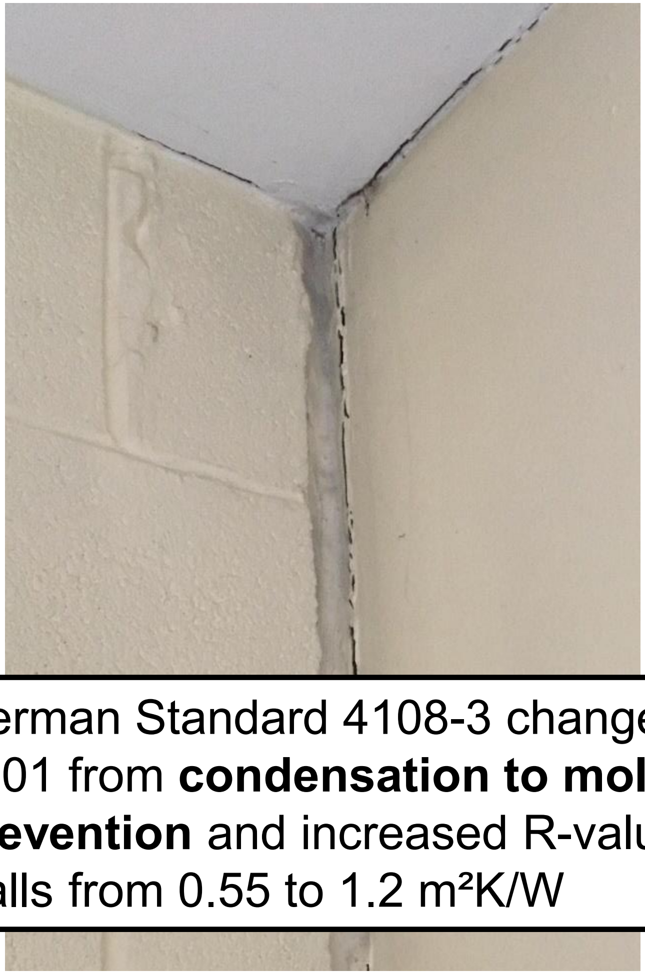
Retention capacity [g/m²] = 100 + 20 [m·g/kg] * $u_{80}$ [kg/m³] + b + c

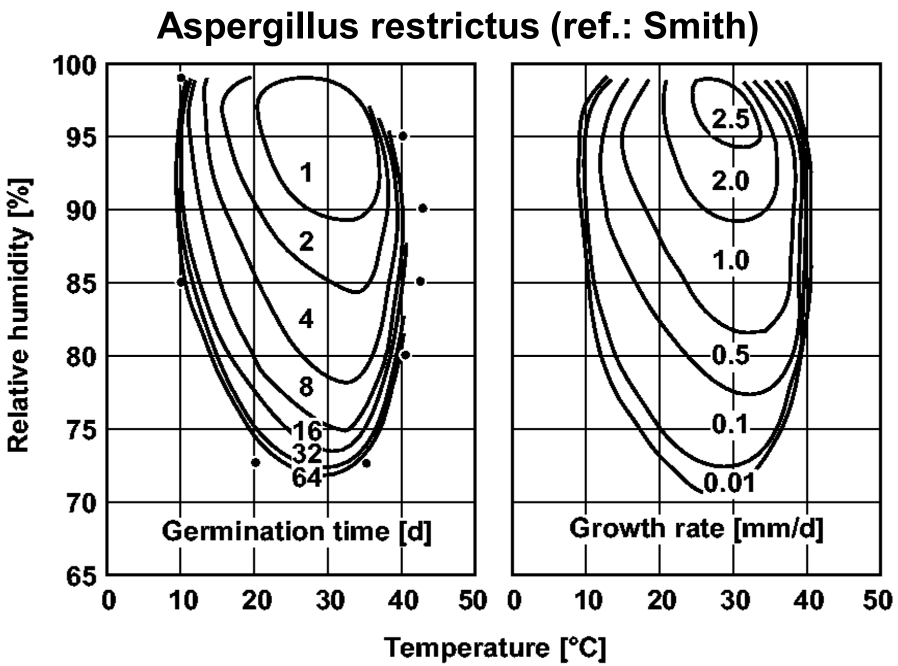
with:
- $u_{80}$: sorption capacity of the fibre insulation at 80 % RH
- b: influence of the interface material type acc. table
- c: influence of inclination acc. table

| Interface type | b [g/m²] |
|---|---|
| Unknown | 0 |
| Hydrophilic smooth or hydrophobic fine structured | 50 |
| Coarse structured | 100 |

| Inclination (α) | c [g/m²] |
|---|---|
| α ≤ 5° | 250 |
| 5° < α ≤ 10° | 200 |
| 10° < α ≤ 15° | 50 |
| 15° < α ≤ 90° | 0 |

# Mould growth






German Standard 4108-3 changed in 2001 from **condensation to mold prevention** and increased R-value for walls from 0.55 to 1.2 m²K/W

**Mould can start to grow at 75% RH at 25°C and at 80% RH around 10 °C**





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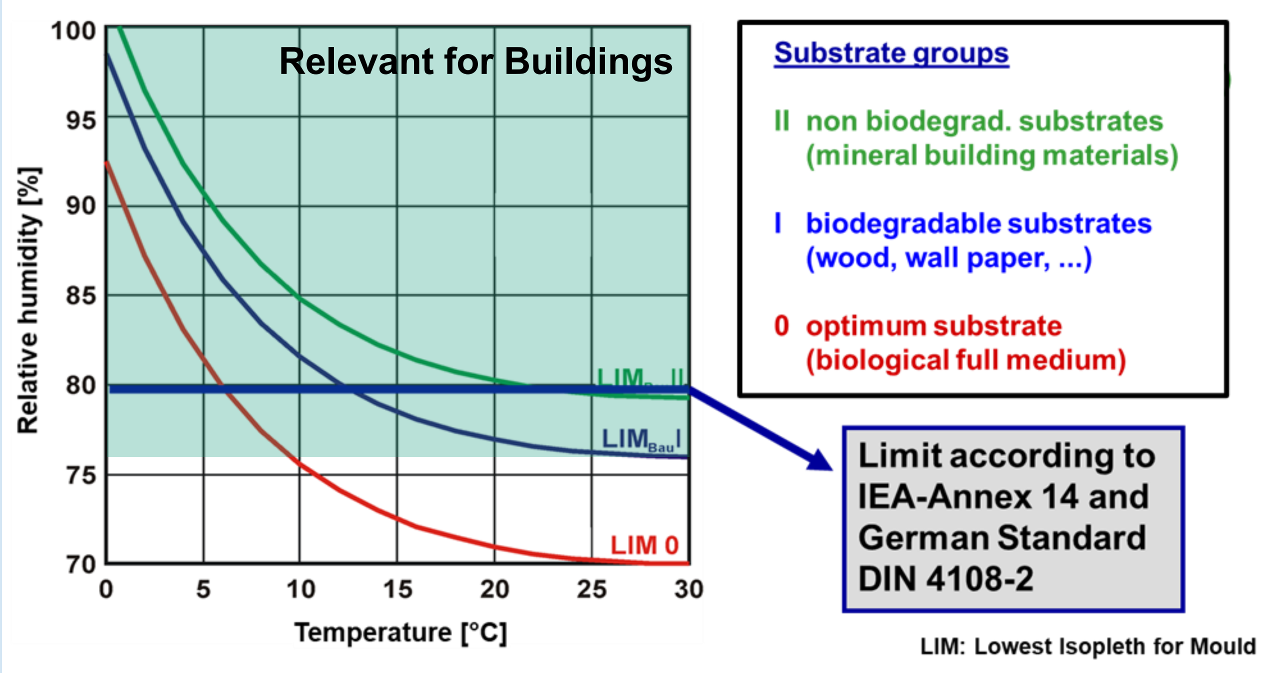
# Mould growth

## Level 1: Steady state limit (only moisture)

80 % RH at temperatures > 12,6 C - deals with winter mould growth.

## Level 2: Dependency on temperature and substrate quality (limit curves)




**More accurate for summer and winter!**

**No time influence - short-term loads can lead to failure in theory, while harmless in practice**





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# Mould growth

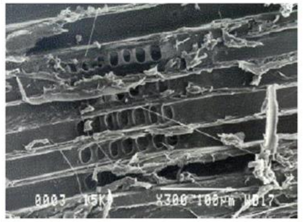
## Level 3 Transient models
## WUFI FinMould / Bio

**Include time effects and come very close to reality – application requires knowledge and experience**

### FinMould / Viitanen

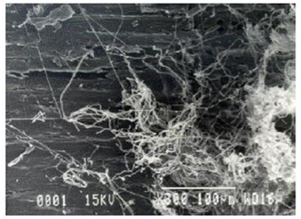
Mathematical / Empirical Model

Result: Mould growth prediction as Mould Index MI with intuitive scale



**Mould Index 1**

**starting growth, visible only by microscope**



**Mould Index 4-5**

**Growth visible also to the naked eye (here microscope) covering 10-50 % of the surface**

**Mould Index MI**

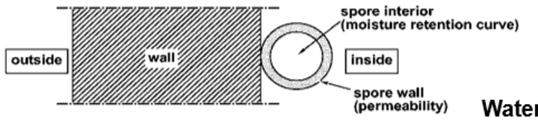
- 0 = no growth
- 1 = some growth (microscopy)
- 2 = moderate growth (microscopy) (coverage > 10 %)
- 3 = some growth (visually detected)
- 4 = visual coverage > 10 %
- 5 = coverage > 50 %
- 6 = tight coverage 100 %

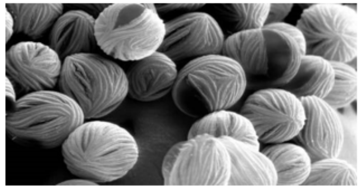
### Biohygrothermal IBP Model

Physical / Empirical Model

Calculation of the moisture content in a model spore and comparison to empirical limit conditions which allow germination and growth of mould.

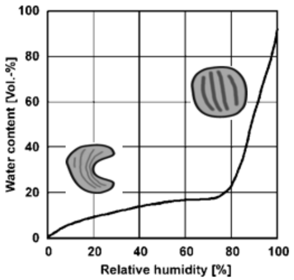
**model spore**



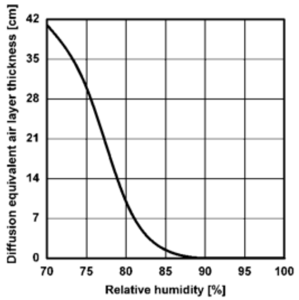



**Model spore properties**

**Water retention**




**Vapor permeability**




**Simple input and evaluation schemes are necessary to enable safe application in practice! Both models originally evaluated for interior surfaces!**



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# Mould growth

## Transient models – Evaluation Schemes

### WTA Guideline 6-3 (2024) Evaluation with Mould Index (MI)

| Exposure situation | | |
|---|---|---|
| Interior surface / direct contact to the indoor air | Outside airtightness layer/ no direct contact to the indoor air | Contact with users / inhabitants excluded |
| Evaluation Period too short (< 1 year) ⇨ Evaluation not possible or not meaningful | | |
| MI < 1: no or just starting invi-sible growth acceptable in indoor spaces (plants) | MI < 2 : no or only invisible growth, recognizable only by microscope | MI < 3: growth starts to become just visible to the naked eye |
| 1 ≤ MI < 2: invisible growth, recognizable only by microscope | 2 ≤ MI < 3: growth starts to become visible to the naked eye | MI ≥ 3: growth is visible to the naked eye and starts covering the surface |
| MI ≥ 2: growth starts to become just visible to the naked eye | MI ≥ 3: growth is visible to the naked eye and starts covering the surface | Individual evaluation – currently not defined |



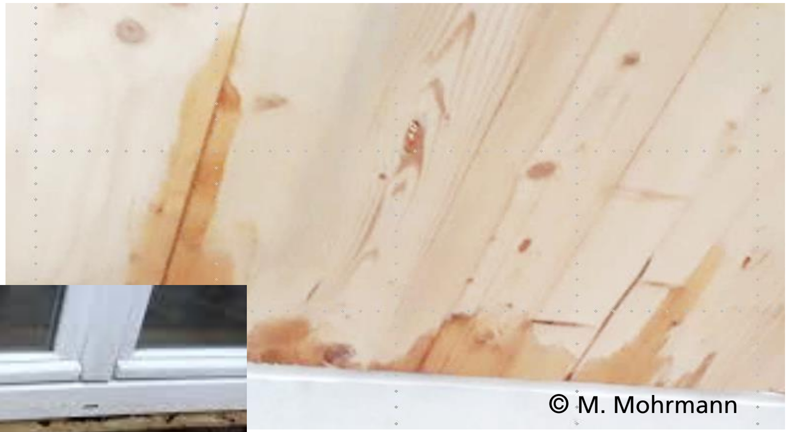
**ASHRAE 160: generally OK if MI < 3**

# Fungal decay of wood and natural materials

## Wood and wood fibre material must be protected from high moisture contents! But - what is adequately?

**In real live, moisture cannot completely and always be avoided in building components**

- **moisture ingress during construction**
- **moisture peaks in winter on the cold side of the insulation**
- **Air and rainwater leakages**



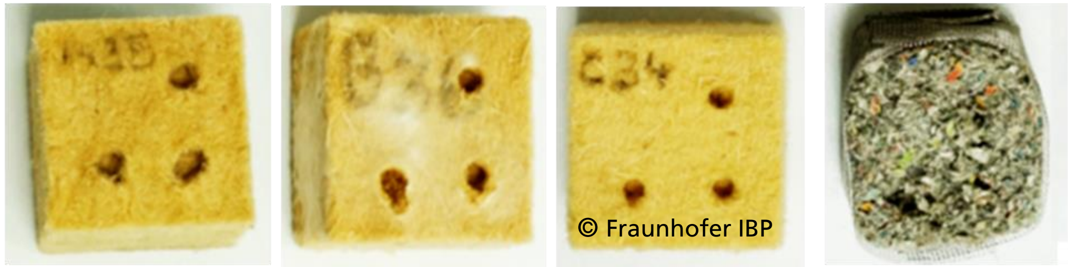


**How can such moisture impact be reliably evaluated to avoid both unnecessary measures on the one hand and damages on the other!**

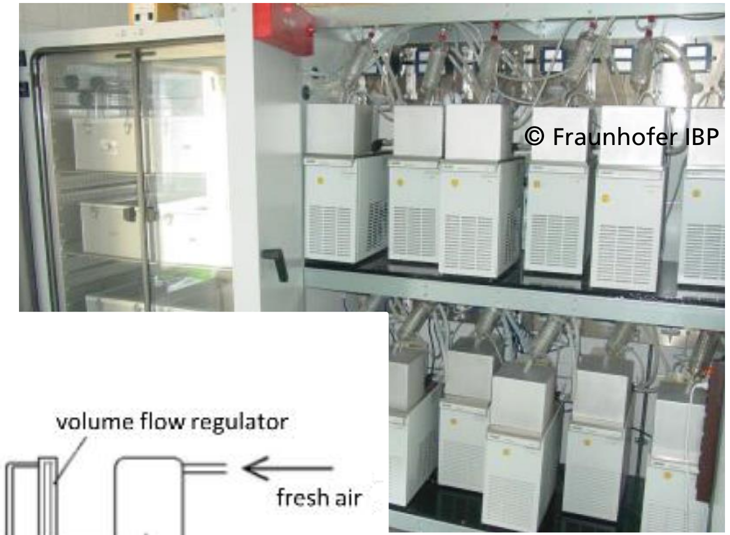
# Fungal decay of wood and natural materials

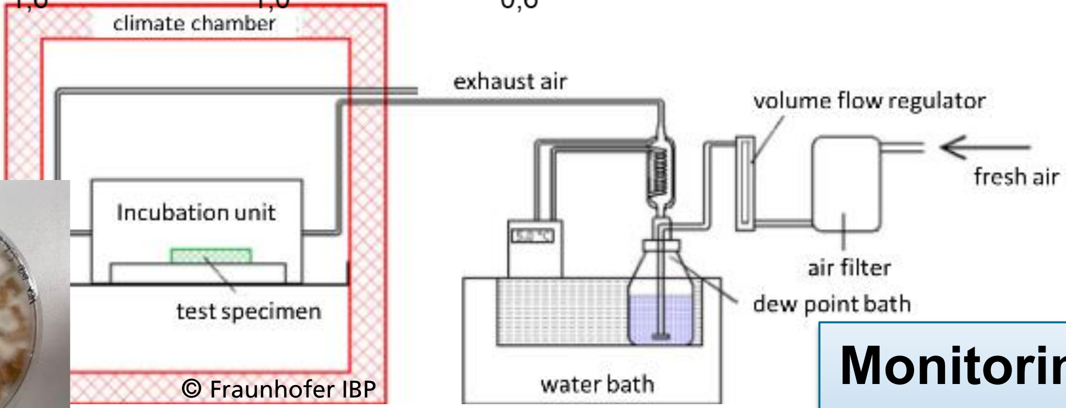
## Decay model based on lab tests on activity of decay fungi

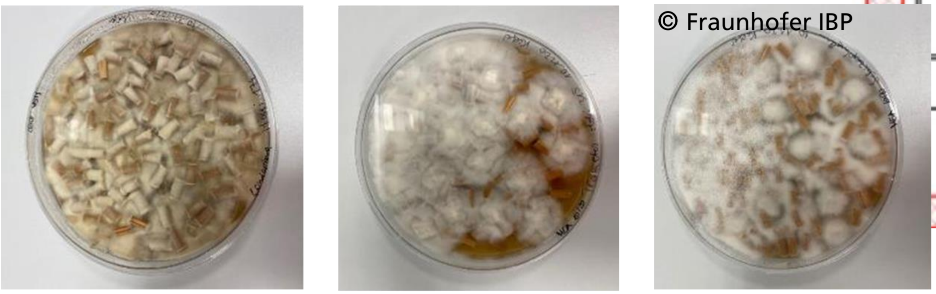
**After 11 months incubation at 10 °C, 97%RH**




Mass Loss [M.-%]
0,3 1,6 1,0 0,6



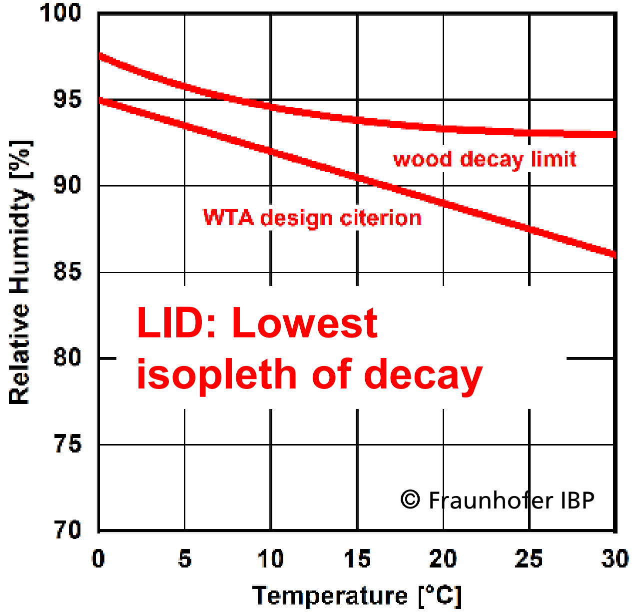



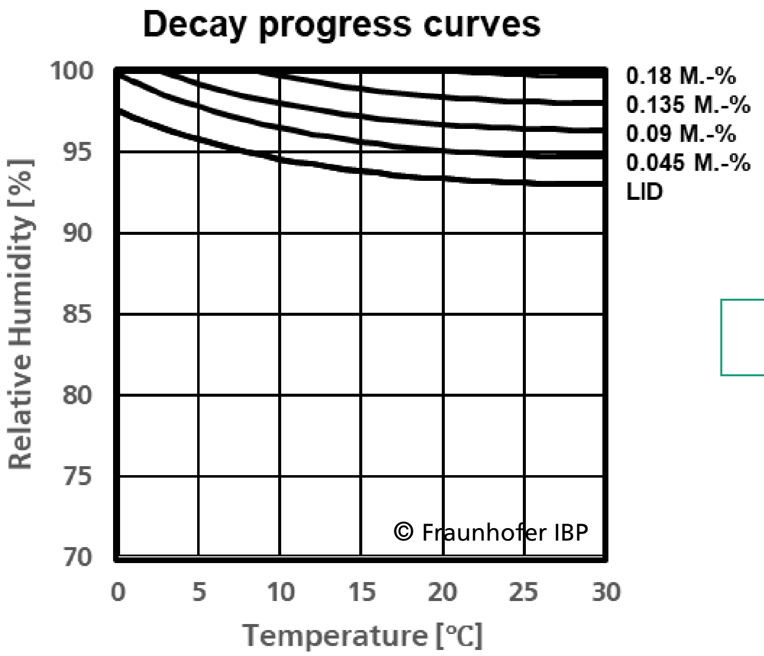

*Coniophora puteana* *Trametes versicolor* *Schizophyllum commune*

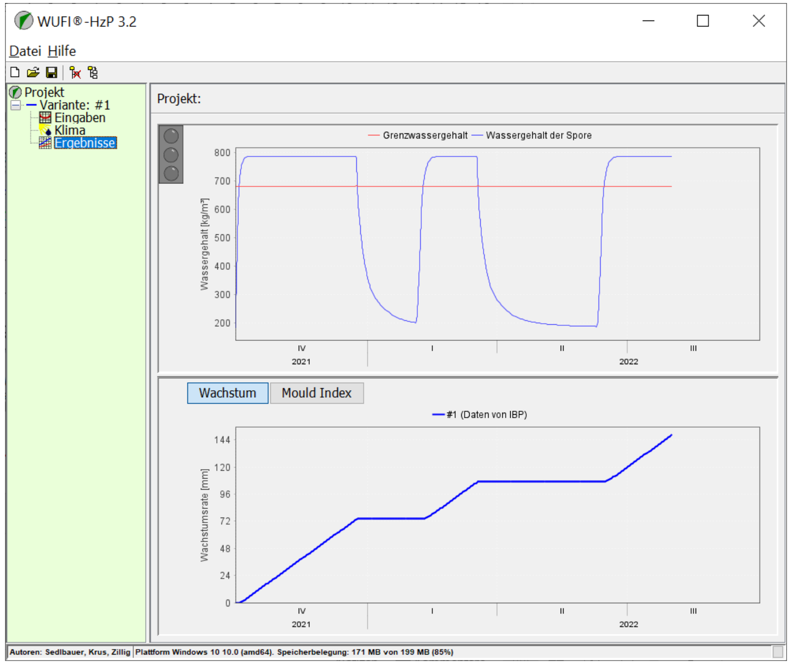
**Monitoring by optical observation and mass loss measurement**

# Fungal decay of wood and natural materials

## Implementation into a decay prediction postprocessor




**Initiation phase based on investigations from Viitanen[1] / new results fit well with this approach**

**Result: Wood decay in % by mass (relative) or in grams (absolute) can be predicted over time**

[1] Viitanen, H. (1997). Modelling the time factor in the development of brown rot decay in pine and spruce sapwood: The effect of critical humidity and temperature conditions. *Holzforschung*, *51*(2), 99-106 https://doi.org/10.1515/hfsg.1997.51.2.99

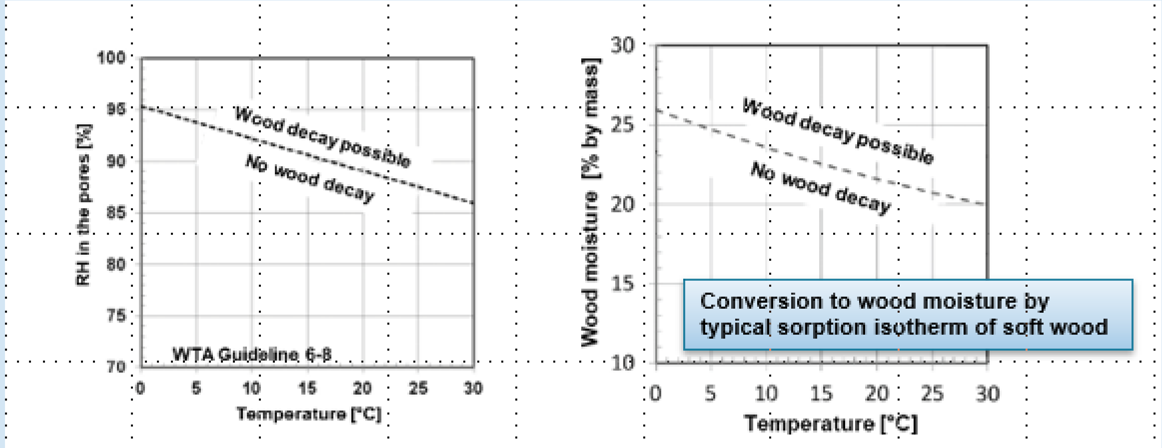
# Fungal decay of wood and natural materials

## Level 1: General moisture limit

**Only moisture: mostly used limit value is <u>20 % by mass</u> for solid wood as explicit decay-risk threshold**
(e.g. ASTM D245 1920, DIN 68800 1956, EN 335)

**Well established for standard design purposes. Ensures particularly high safety reserves**

## Level 2: Moisture and Temperature: limit curve RH over Temperature for solid wood according to WTA Guideline 6-8 (wooden constructions)




**Proven effective and safe for 10 years - represents a good alternative**

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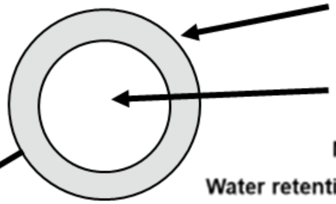
# Fungal decay of wood and natural materials

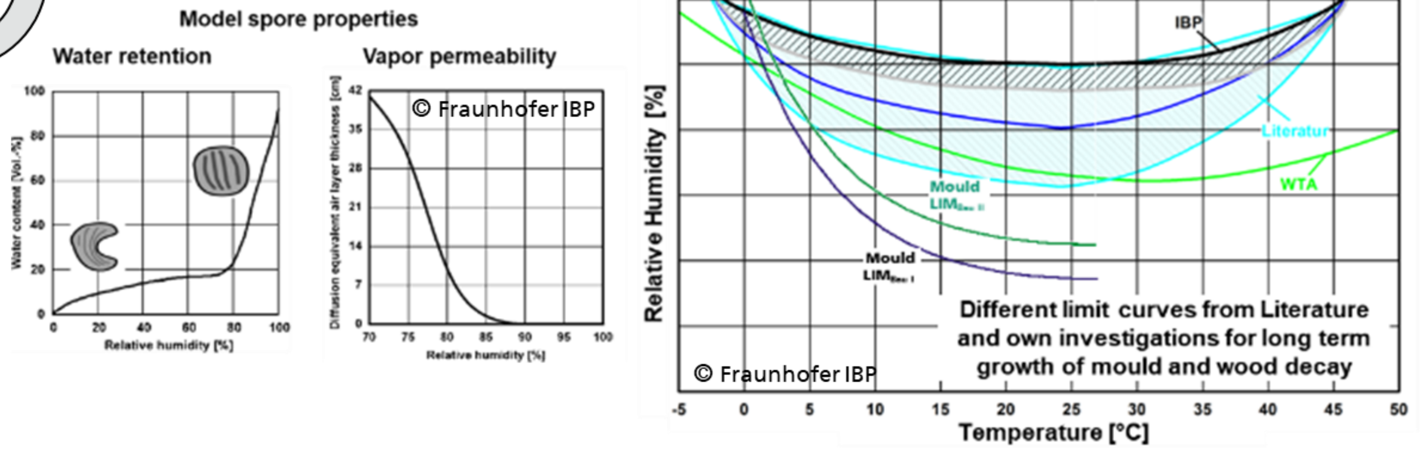
## Level 3: Transient prediction model WUFI Decay

**Include time effects and come very close to reality**



### Moisture level of spore / decay fungi in the material

- Spore / mycelium envelopes' diffusion resistance delays moisture absorption and drying
- Moisture level in the the spore required for growth

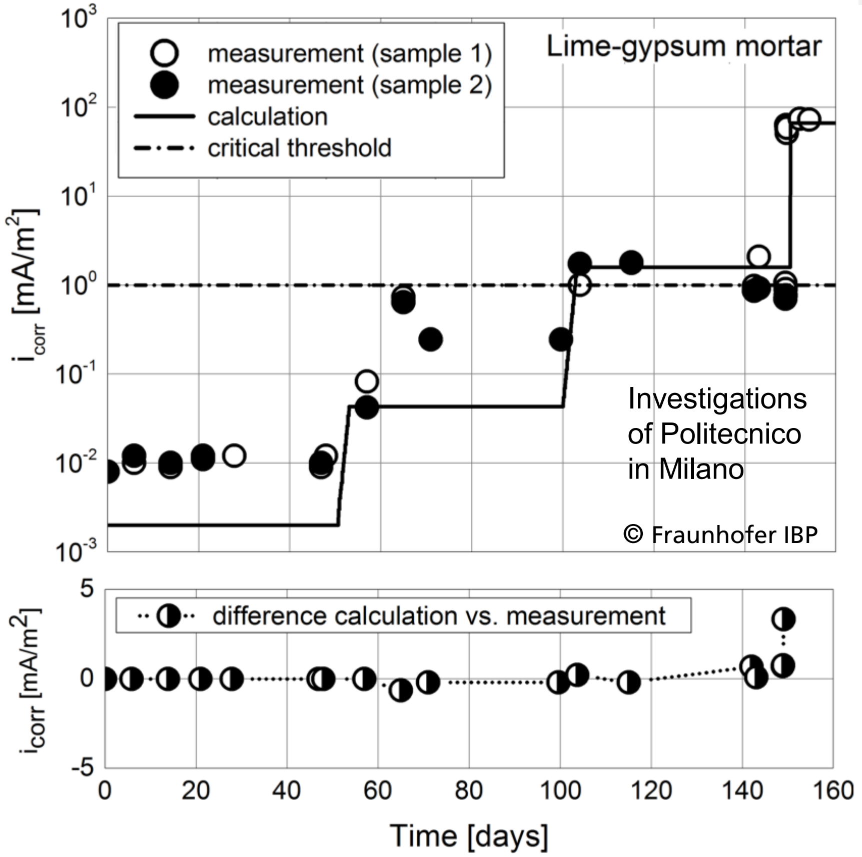


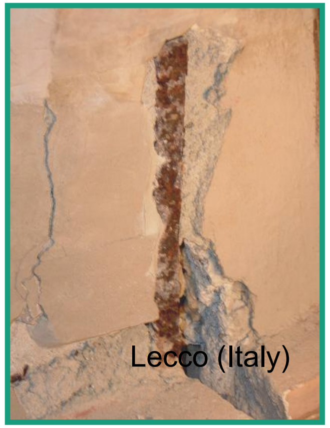

**Currently for solid wood and material that are at least as resistant. Resistivity classification for natural / wooden materials desirable!**

# Corrosion of Metal in Mineral embeddings

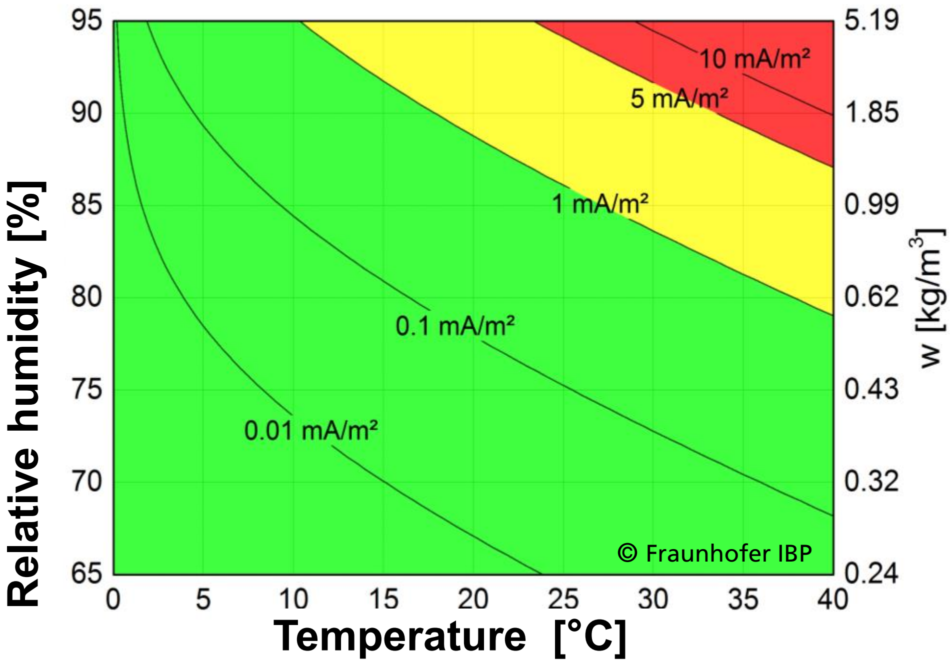
## Measurements and model in heritage materials

Corrosion rates of steal in mortar as function of temp. & RH








**First model was developed together with Polytecnico di Milano for corrosion in heritage buildings / materials**





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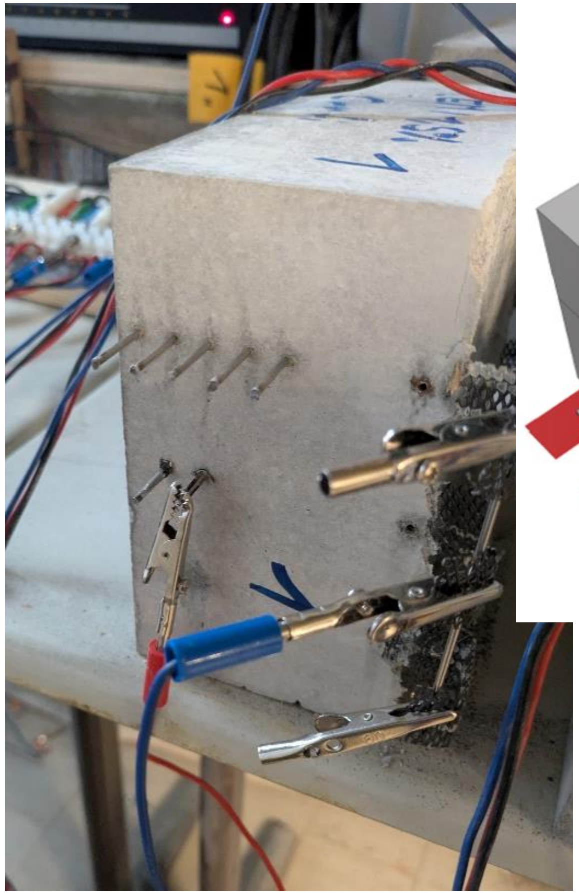
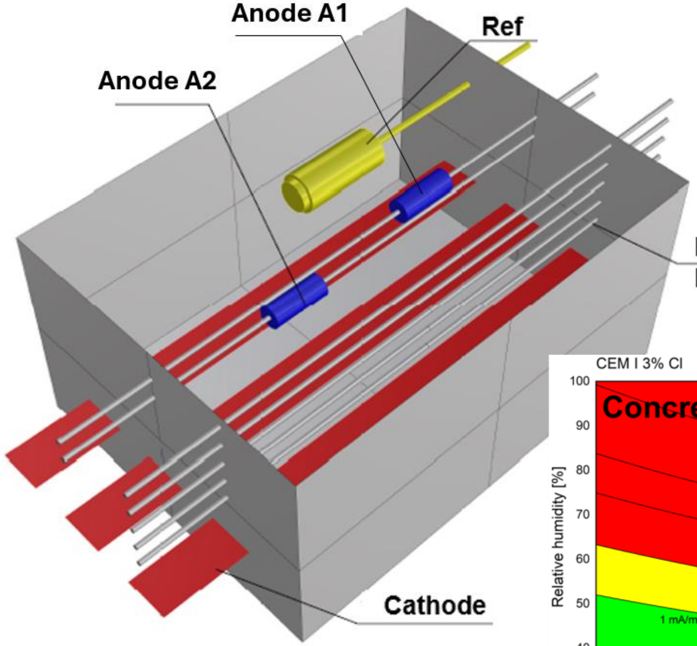
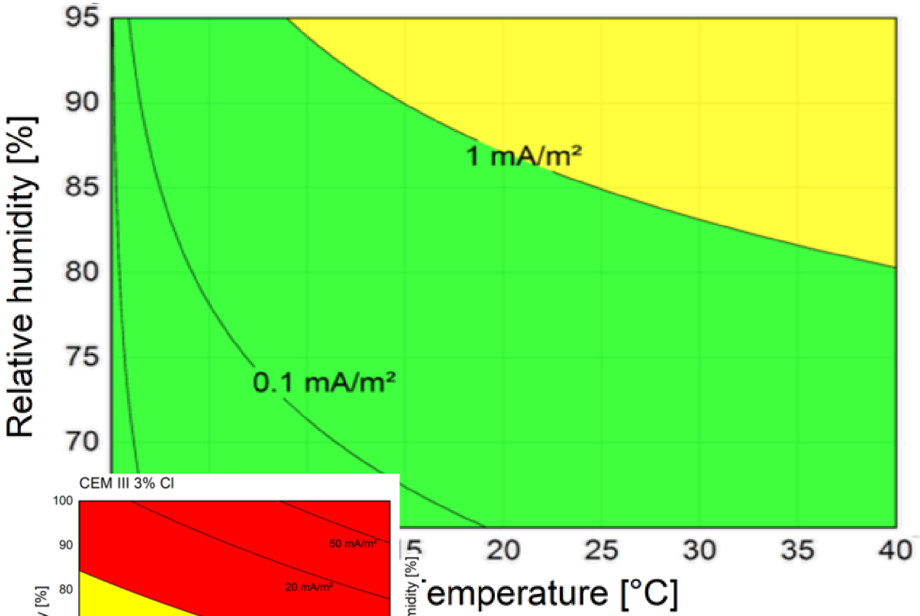
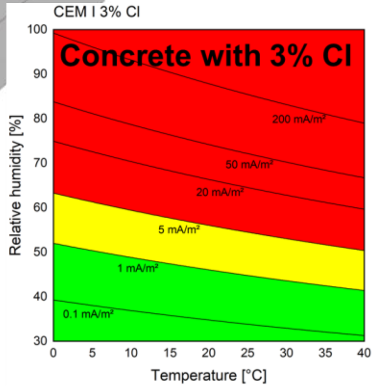
# Corrosion of Metal in Mineral embeddings

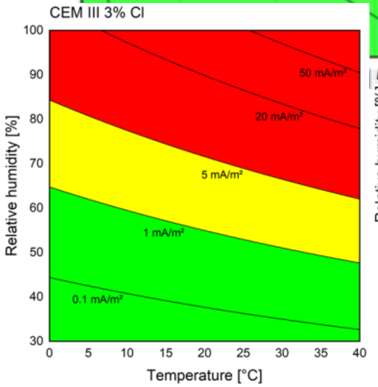
## Measurements and model in concrete





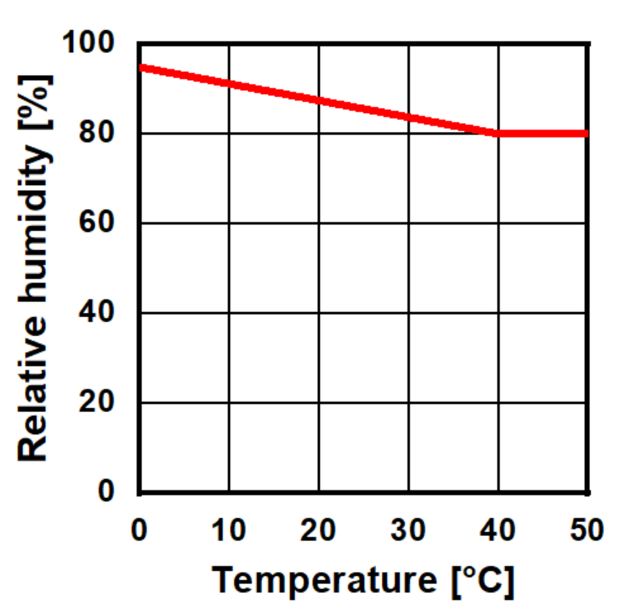

**Model for concrete developed in projects NaVe and CRUFI (last together with Munich University for Applied Sciences – ongoing research for Concretes with chlorides)**

# Corrosion of Metal in Mineral embeddings

## Level 1: General RH limit acc. to ISO 13788

< 80% RH for carbonated concrete
< 60% RH for non-cementitious embedding materials

## Level 2: Temperatur and RH according to NaVe project

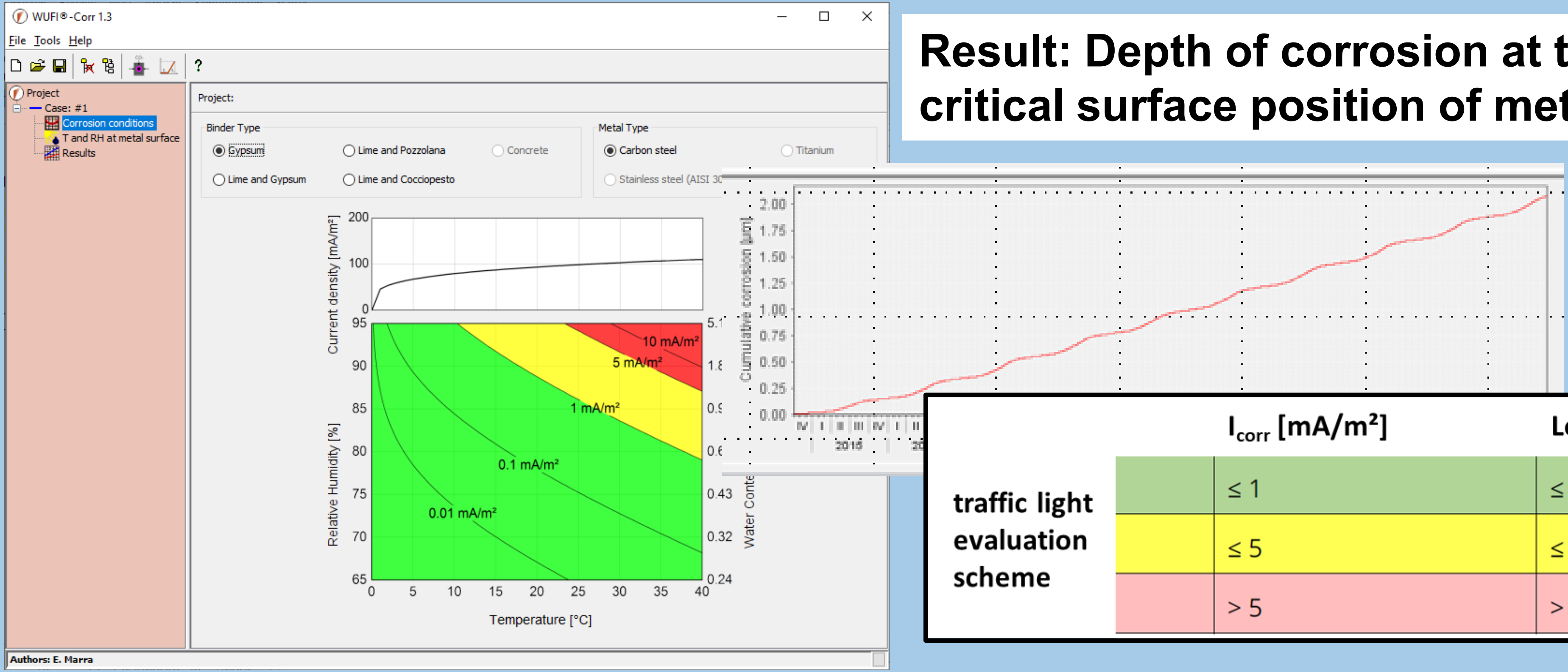



$$f(\vartheta) = \begin{cases} -0{,}375\vartheta + 95, & 0°C < \vartheta < 40°C \\ 80 & \vartheta \geq 40°C \end{cases} \quad [\%]$$

**80 % RH only relevant at high temperatures. Below 40 °C The RH can rise up to 95 % at 0 °C**

# Corrosion of Metal in Mineral embeddings

## Level 3: Transient prediction model WUFI Corr




**Result: Depth of corrosion at the critical surface position of metal**

| | $I_{corr}$ [mA/m²] | Loss [µm/25years] |
|---|---|---|
| traffic light evaluation scheme | ≤ 1 | ≤ 30 µm |
| | ≤ 5 | ≤ 150 µm |
| | > 5 | > 150 µm |

**Well verified for heritage embedding materials, good for carbonated concrete, further improvement and extension e.g. for concrete with chlorides ongoing.**

# Summary - How to reduce the damages?

**Moisture protection in times of energy savings requires:**

- **Adequate protection against humidification**
  - Rainwater protection renders / WRB
  - Airtight lightweight components
  - Adequate vapor retarders
  - Prefer dry materials for construction
- **Good drying potential**
  - Vapor permeable WRB
  - Moderate or variable VR (if tight outside)
  - Avoid bright exterior surfaces

**Rule: As vapor retarding as necessary and as vapor permeable as possible.**

# Summary - Better ways into practice?

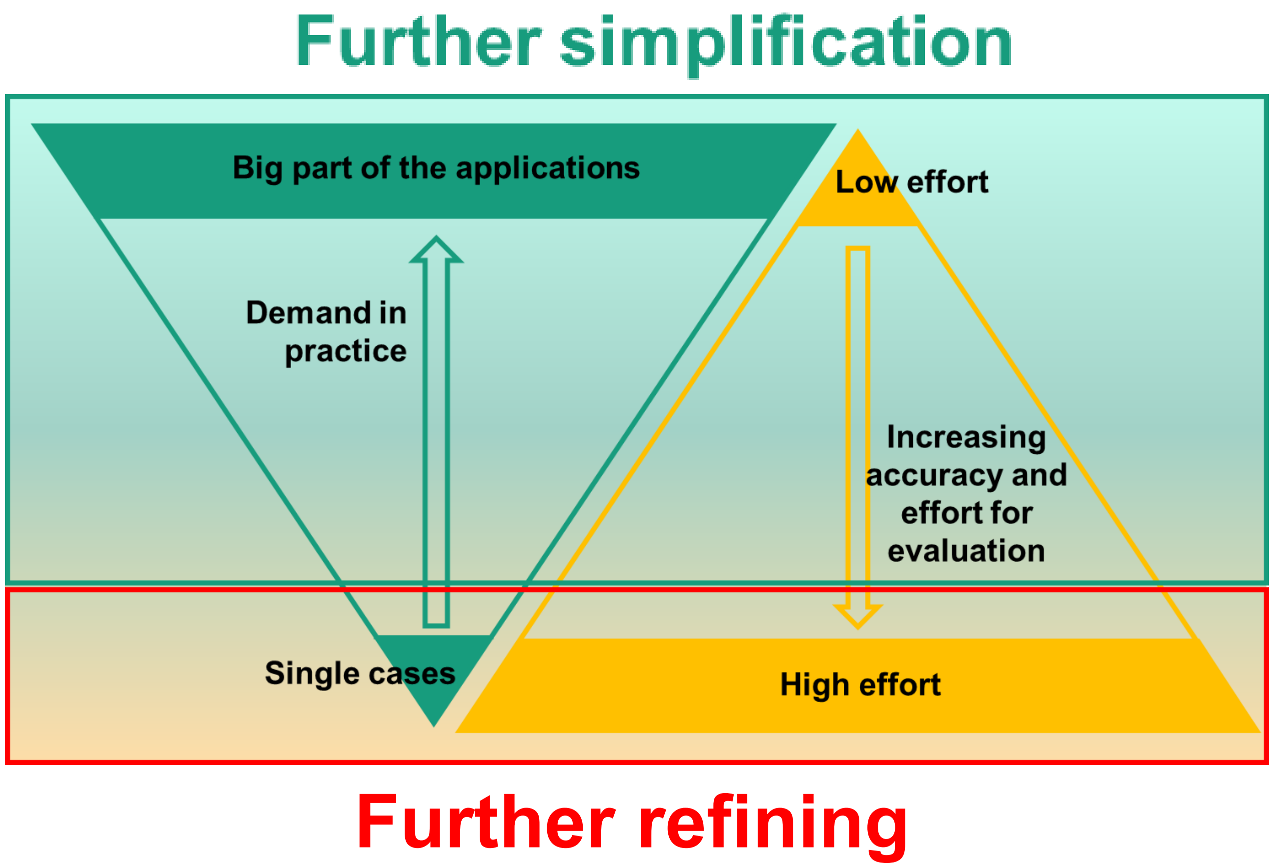
**High damage costs require higher effort for hygrothermal design of reliable and robust constructions. Early consideration of moisture reduces risks and costs!**

- **Well-established constructions in standards and guidelines!**
- **Clear modeling and evaluation proceedings for practitioners!**
- **Harmonization of criteria instead of national evaluation of physical results!**
- **More intern. collaboration helps to create consistent standards and practice guidelines.**

**Normal designers should be enabled to perform and evaluate hygrothermal simulation results on a basis level.**

**They need to decide whether the design is OK (≥ 90 % of the cases) or whether more experienced planners need to be involved (< 10 %)**

# Perspective




**We need to do both!**

**Moisture evaluation is still a niche topic -
the damages are not!!**

**Good simplification often more challenging than refinement!**

**And: reaches broader practice!**

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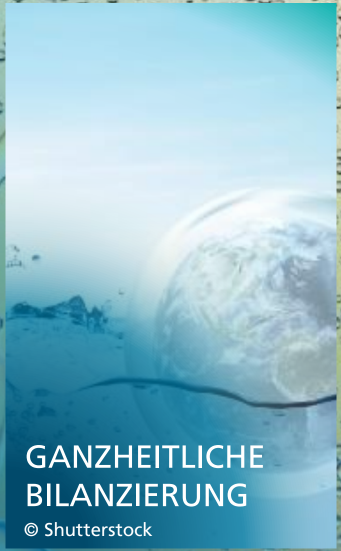





Finnish Building Physics Conference, Tampere October 2025

# Thank for your Attention!

Daniel Zirkelbach

# Addendum

**Total water content, and water content in single layers:**

In dynamic equilibrium status or decreasing
normally not permanently increasing (exception, if unproblematic over whole service live)

**Mold growth on interior surfaces:**

Level 1: < 80 % RH
Level 2: < material specific LIM curve
Level 3: transient evaluation with WUFI® FinMould or WUFI® Bio

**Moisture content in wood or natural materials/insulations:**

Level 1: < 20 % by mass (solid wood) bzw. 18 % by mass (load bearing wooden materials), whole layer
Level 2: limit curve acc. to WTA-6-8 (solid wood), critical 10 mm area
Level 3: transient evaluation WUFI® Decay (available soon)

**Corrosion of metal elements in mineral embedding materials:**

Level 1: < 80 % r.F.
Level 2: limit curve according to project NaVe between **< 95 % RH > 0 °C** and **< 80 % TH at ≥ 40 °C**
Level 3: transient evaluation with WUFI® Corr

# Addendum

**Impact of moisture content on thermal performance**

All building materials: U values are normally related to the equilibrium moisture content of the materials at 80 % RH (critical in-situ moisture level). In case of higher moisture contents, especially in the heating period, a correction may be necessary. This can be done for example by the help of the postprocessor “Transient U value”.

Moisture resistant insulation materials: Moisture contents up to approx. 2 % by volume or 20 kg/m³ are normally unproblematic and already considered by the declared λ value of the product. Higher moisture levels should be avoided or the influence on the λ value should be considered adequately.

Natural fibre or moisture sensitive insulation materials need to remain below the resp. limit values to avoid degradation / decay of the materials. These limits are mostly below the ones relevant for an increase of the thermal conductivity and thus the decisive ones.

**Condensation inside the construction (on interfaces or in fibre insulations)**

| | | |
|---|---|---|
| | smooth hydrophobic boundary layer material: | < 50 g/m² |
| without insulation | fine structured hydrophobic or hydrophilic boundary layer material: | < 100 g/m² |
| | coarse structured hydrophobic boundary layer material | < 150 g/m² |

With fibre insulation in direct contact with the boundary layer, the limits can be increased by at least 50 g/m².

**Dew water on exterior or interior surfaces**

On water impermeable surfaces, the condensation should be limited to 50 g/m² to avoid water runoff! However, to prevent mould / algae growth, lower limits must be kept on average (see mould growth).

# Addendum

## Frost risk / interior insulated walls

High moisture content at temperatures below 0 °C poses a risk of frost damage. In areas where such conditions occur, frost-resistant materials (exterior plasters, frost-resistant facing bricks, etc.) should normally be used.

WTA-6-4 specifies that for non-frost-resistant materials that may be exposed to frost conditions after interior insulation has been installed, a moisture content of 30 % (related to the maximum water content) may only be exceeded if the air in the pores remains below 95 % RH. Under these conditions, even non-resistant materials will not suffer frost damage.

Wood or gypsum-containing materials should not be used or remain in areas, where the humidity levels in exceeds 95% RH for long periods of time.

## Moisture content in Masonry

The U-value is based on the thermal conductivity at 80% relative humidity in the pore air of the materials. If this value is exceeded on average over a longer period of time, the thermal insulation properties would need to be corrected. However, high moisture content not only increases thermal conductivity but also results in additional heat losses through evaporative cooling. It also increases the risk of algae and fungal growth.

It is therefore a good idea to avoid long term moisture contents above 90% RH in the pores of the materials as far as possible, e.g., by improving the rainwater protection level.

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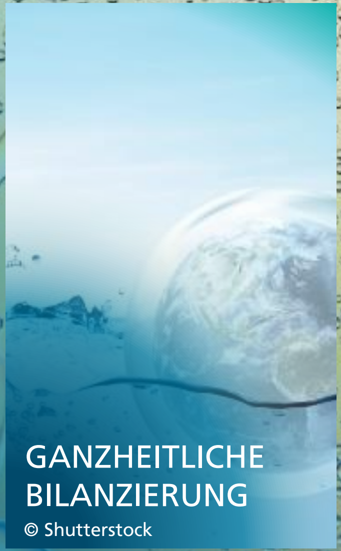





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