Building Science Summit New Zealand

Hartwig M. Künzel

Climate Specific Moisture Control Design

Fraunhofer
IBP

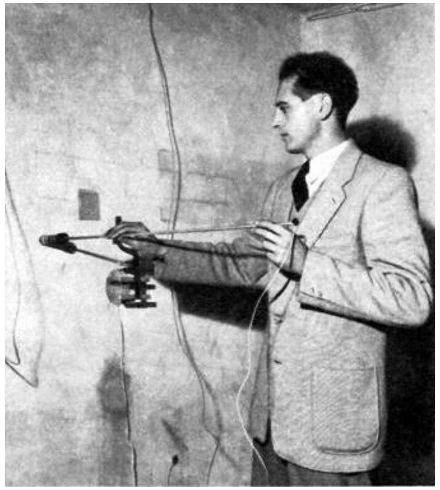
Building Science Summit

Ensuring Healthy and Comfortable Indoor Conditions and Durable Structures Through Climate Specific Moisture Control Design

Hartwig M. Künzel

Introduction

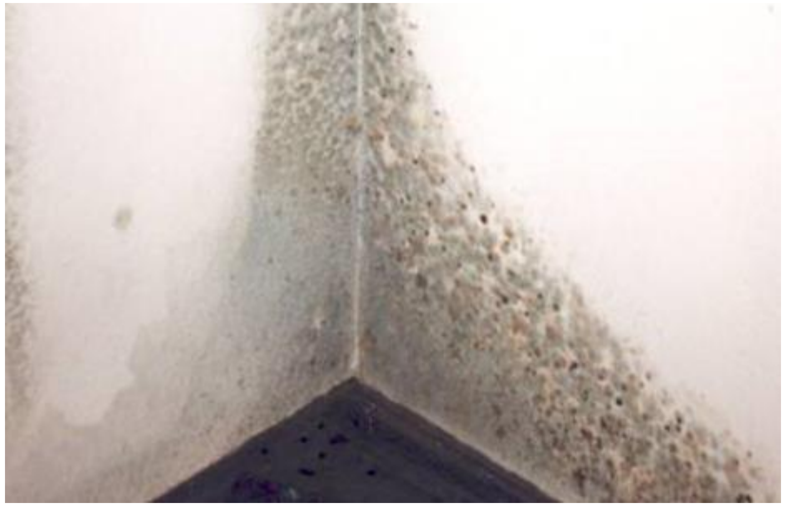
Fraunhofer IBP field test site



>70 years of field tests to investigate long-term building performance & durability

Introduction

Mould growth on indoor surfaces



Mould in a bathroom and at the window joint

Mould behind the couch of a living room

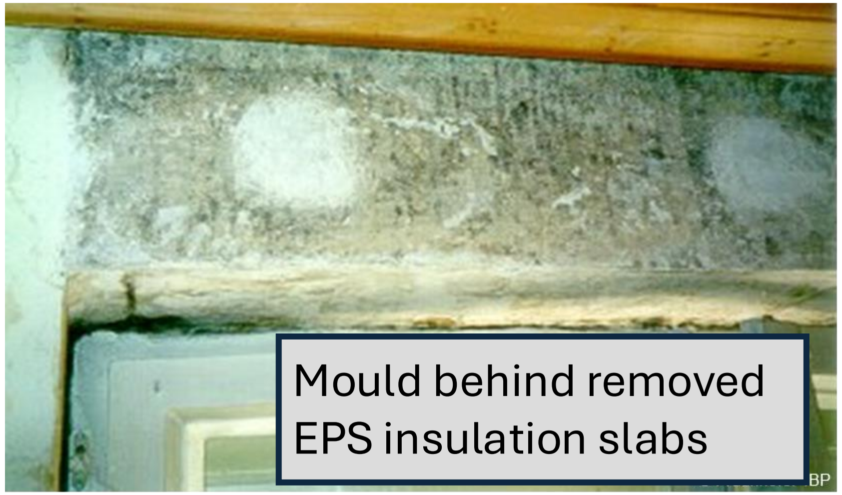
Mould grows on cold surfaces of poorly insulated envelope assemblies

► Prevention by **heated** and **well insulated** buildings (warm indoor surfaces)

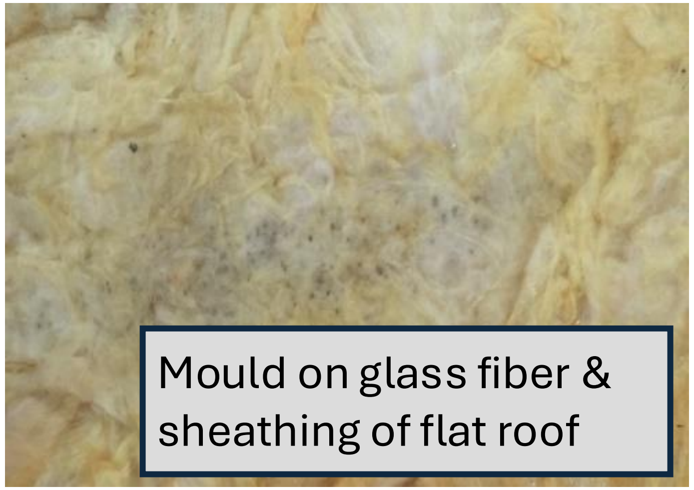
Introduction

Hidden (invisible) mould growth within the building envelope

Mould on the backside of cathedral ceiling sheathing



Mould behind removed EPS insulation slabs



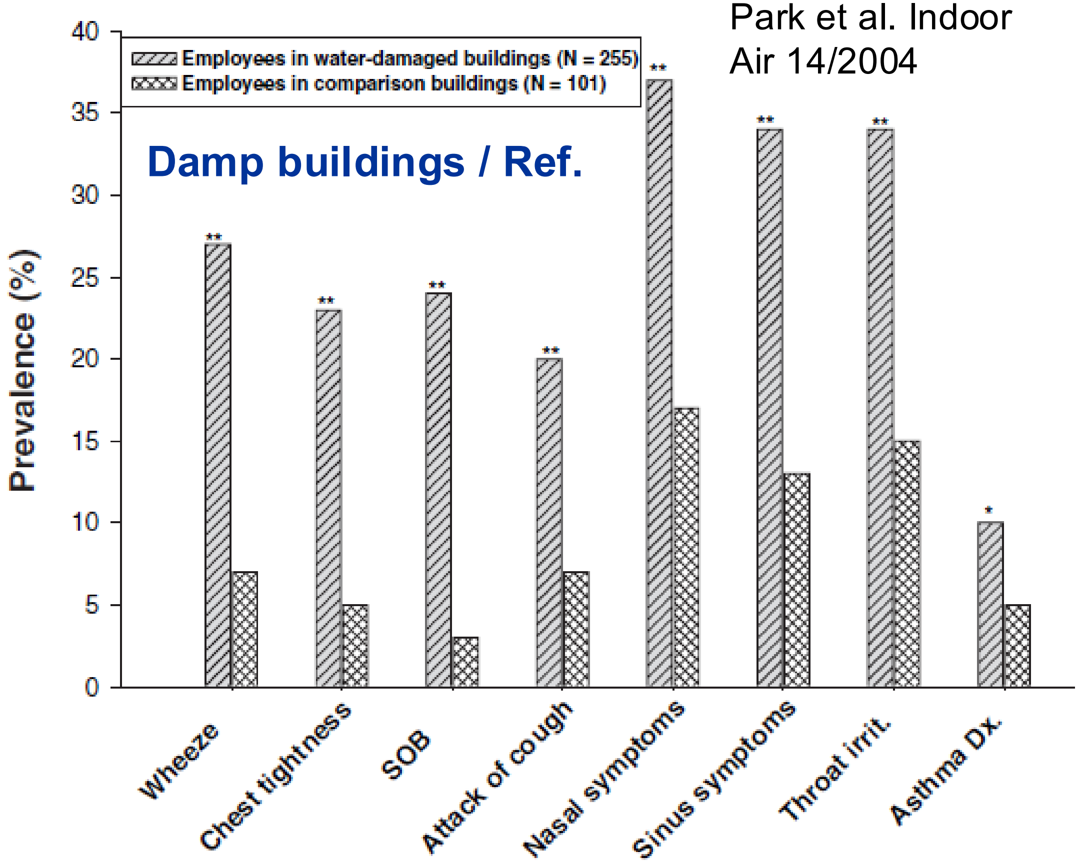
Mould on glass fiber & sheathing of flat roof

Mould behind vinyl wallpaper in Florida

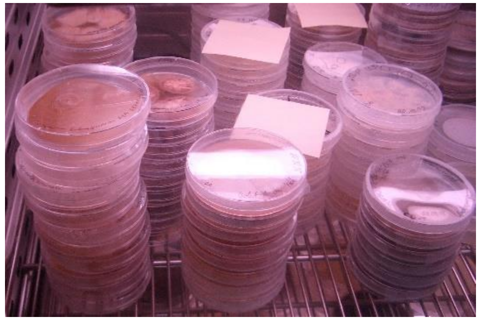
© Joe Lstiburek

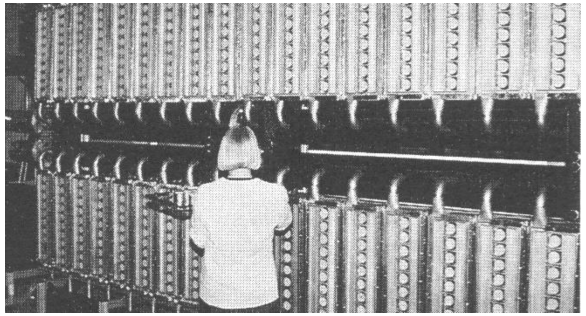
Introduction

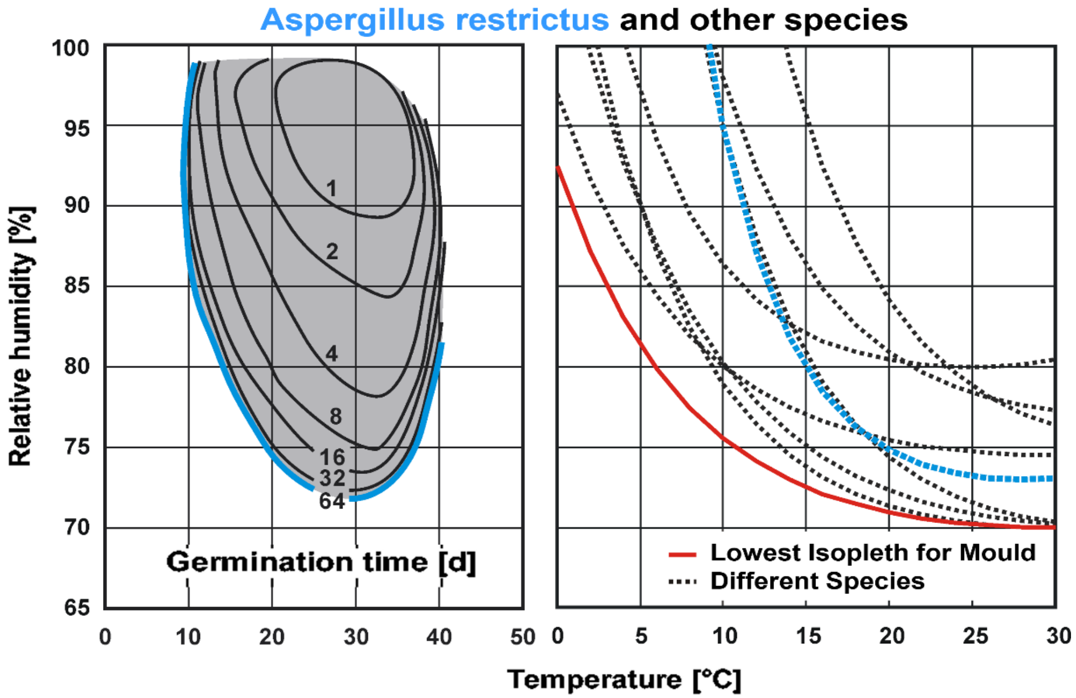
Damp buildings cause health problems



Park et al. Indoor Air 14/2004





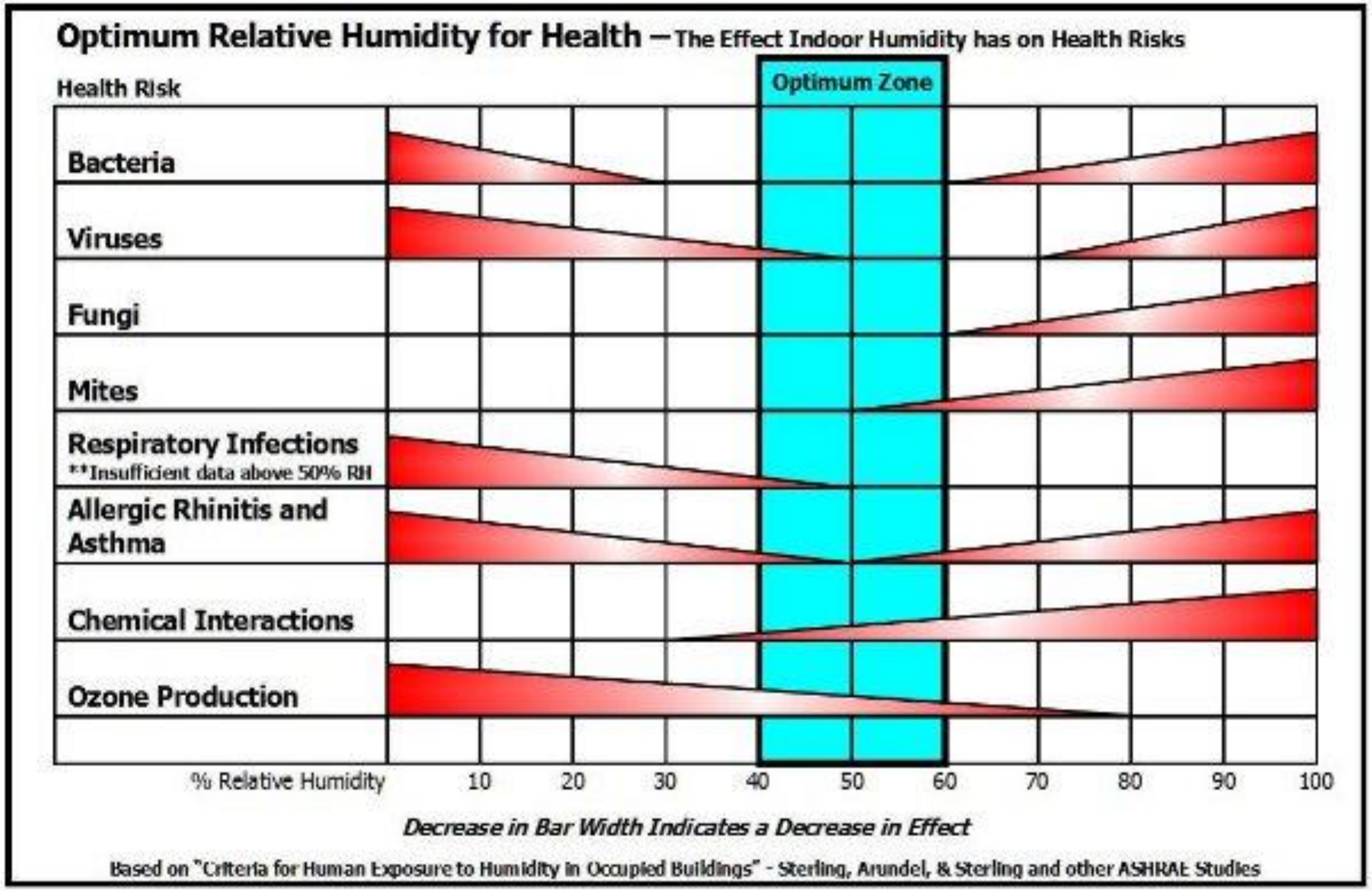


Germany: Hygienic minimum for wall insulation R = 1.2 m²K/W

The risk of mould growth can be predicted based on transient temperature and humidity conditions

Introduction

Safeguarding a healthy indoor environment – Key-factor: Indoor relative humidity



ASHRAE: ideal indoor humidity range:

40 ≤ RH ≤ 60%

RH < 40%

Infectious droplets evaporate and release germs into the air

RH > 60%

Mold may grow on colder surfaces and other small insects find better living conditions

Moisture buffering interior lining materials help to keep indoor RH in the ideal range

Introduction

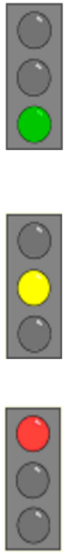
energies

MDPI

Article

Navigating Energy Efficiency and Mould Risk in Australian Low-Rise Homes: A Comparative Analysis of Nine External Wall Systems in Southeast Australia

Liqun Guan [1,*], Mark Dewsbury [1], Louise Wallis [1] and Hartwig Kuenzel [2]



MI	Mold 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
4	visual coverage >10%
5	coverage more than 50%
6	complete coverage, 100%

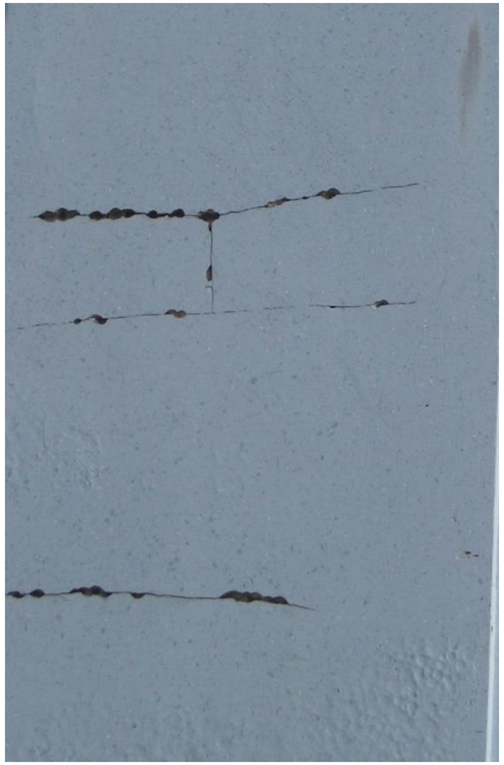
5. Conclusions

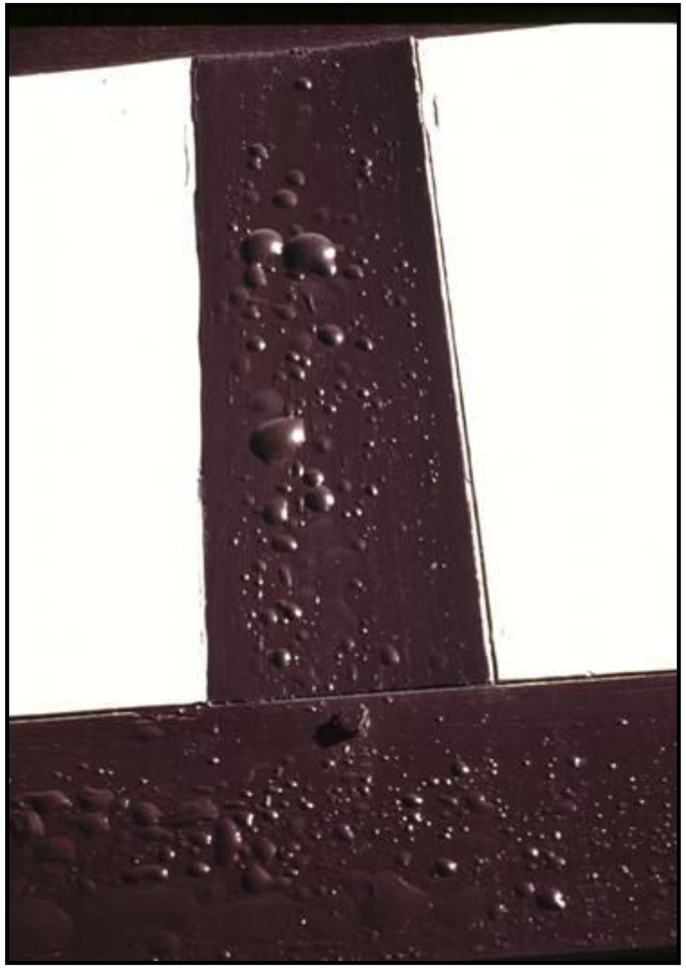
The primary focus of this research was to understand if ‘code compliant’ timber-framed external walls systems commonly constructed in southeastern Australia.

The first stage of the research demonstrated that **most 6- and 7-Star code compliant external wall systems had predicted mould index values > 3.0.** Cooler climates were found to be particularly vulnerable, with MI values remaining elevated even with the introduction of more permeable membranes as prescribed by the NCC 2022 standards.

Introduction

Damage and degradation are not “green” and damp buildings are unhealthy



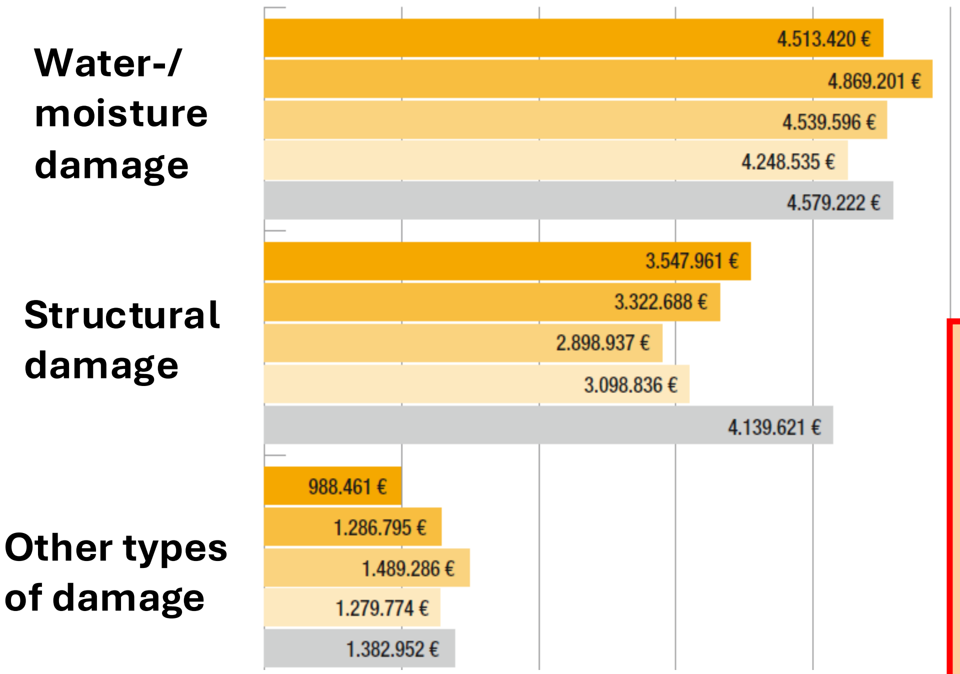


There are many types and causes of moisture damage

Introduction

Building damage report based on data from the German insurance company VHV

Repair costs for various types of construction damage, 2016 - 2020



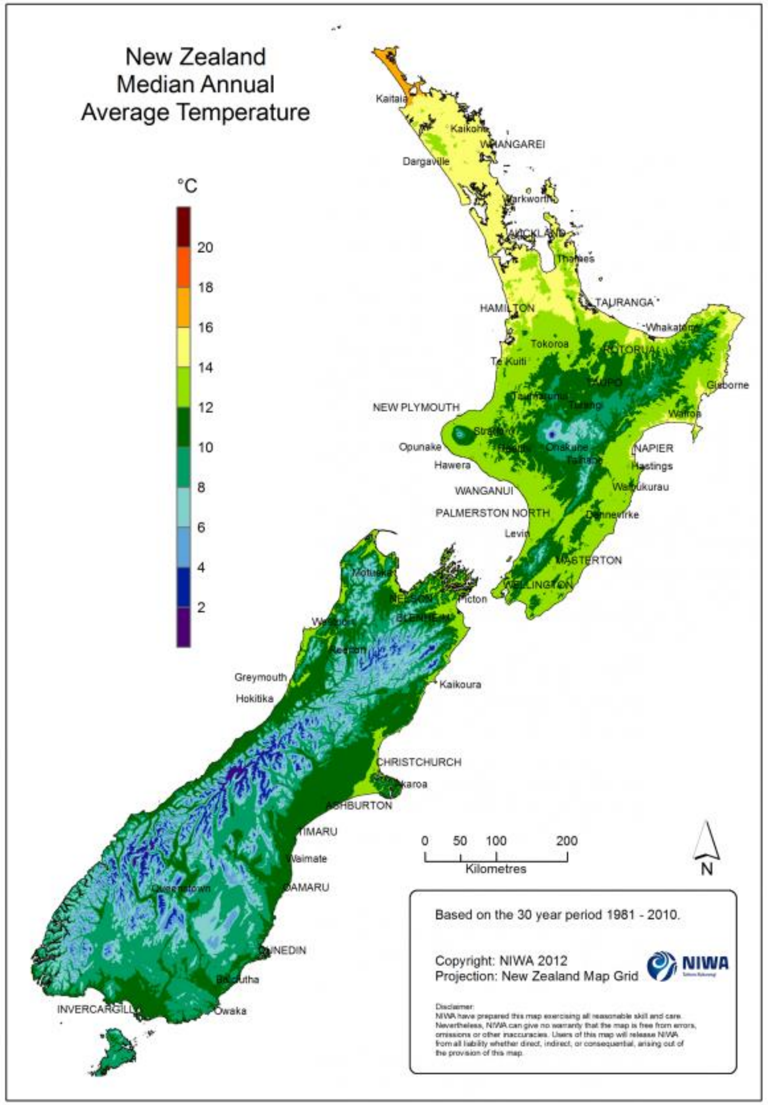
Moisture related damage is the most frequent and expensive problem in Germany

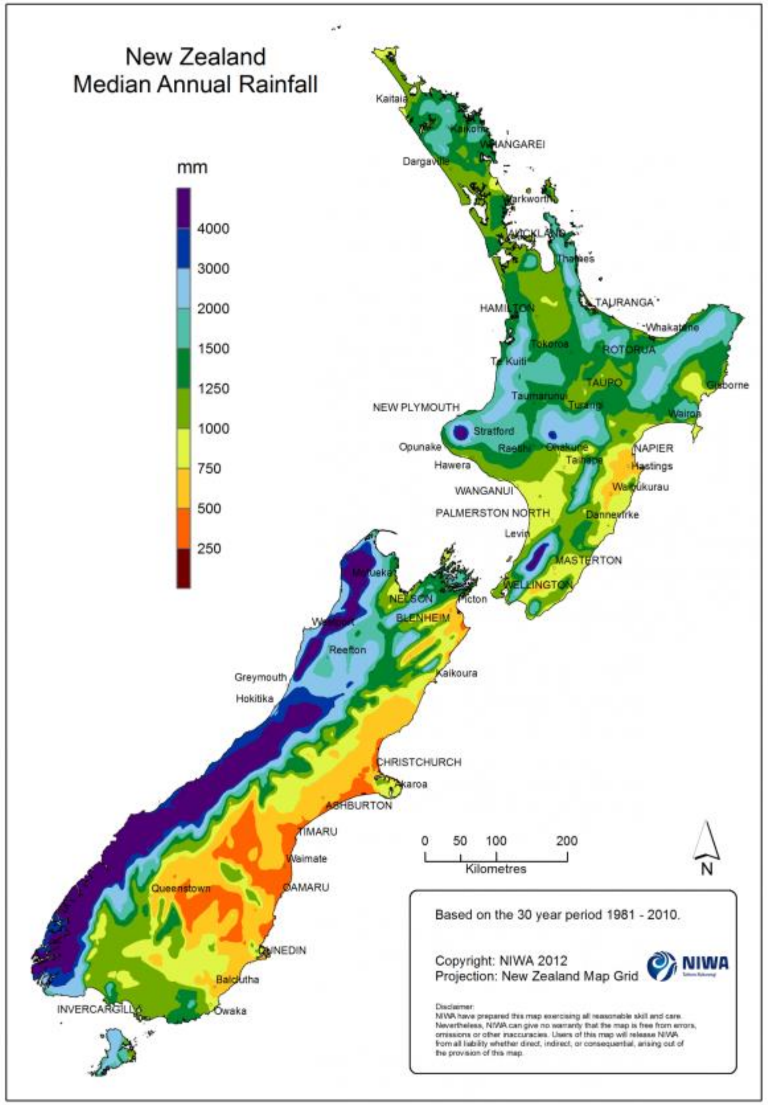
Our own research shows:

Energy efficient buildings are more at risk!

- More insulation ► more condensation & less drying
- Lower AC running time ► higher indoor air humidity in cooling climates

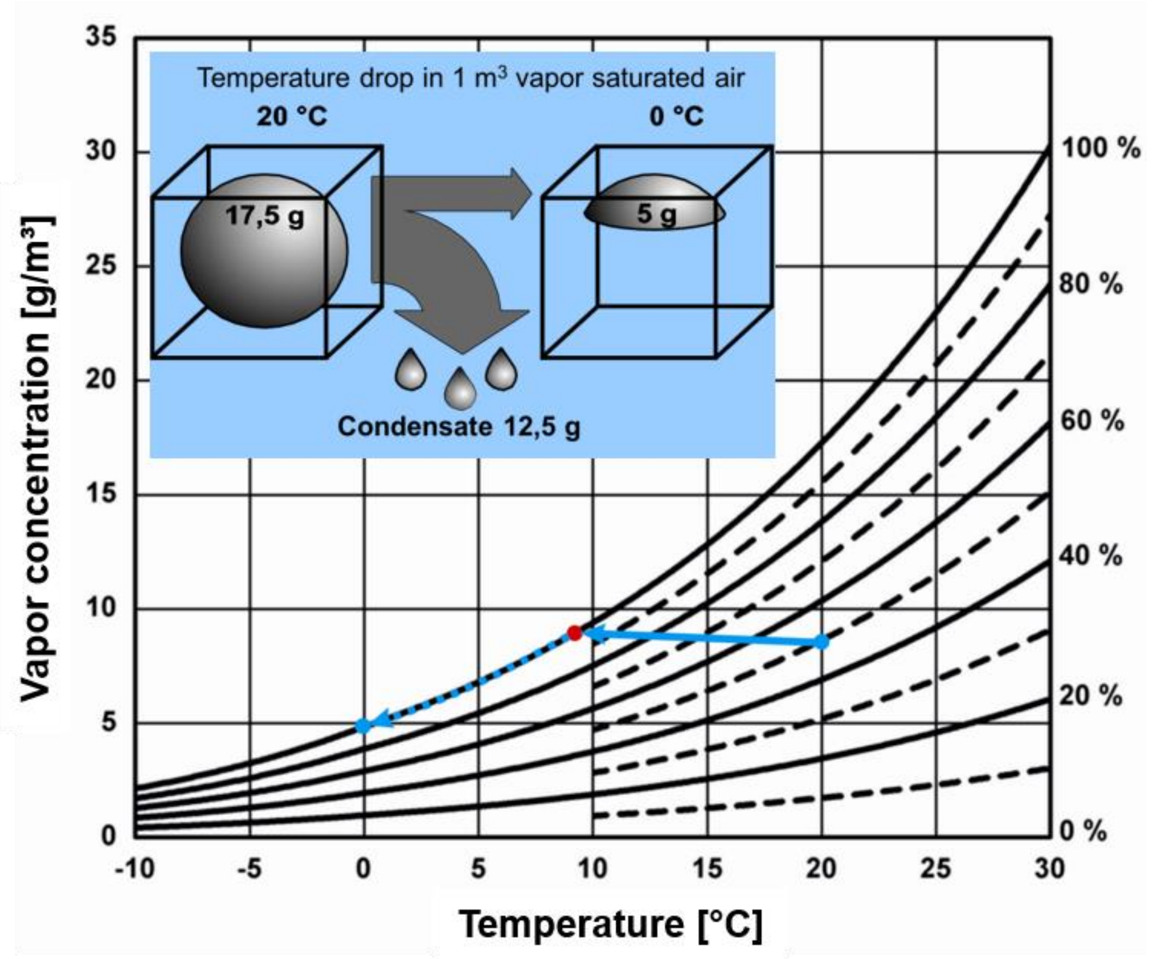
Climate conditions in New Zealand – average temperature and rainfall

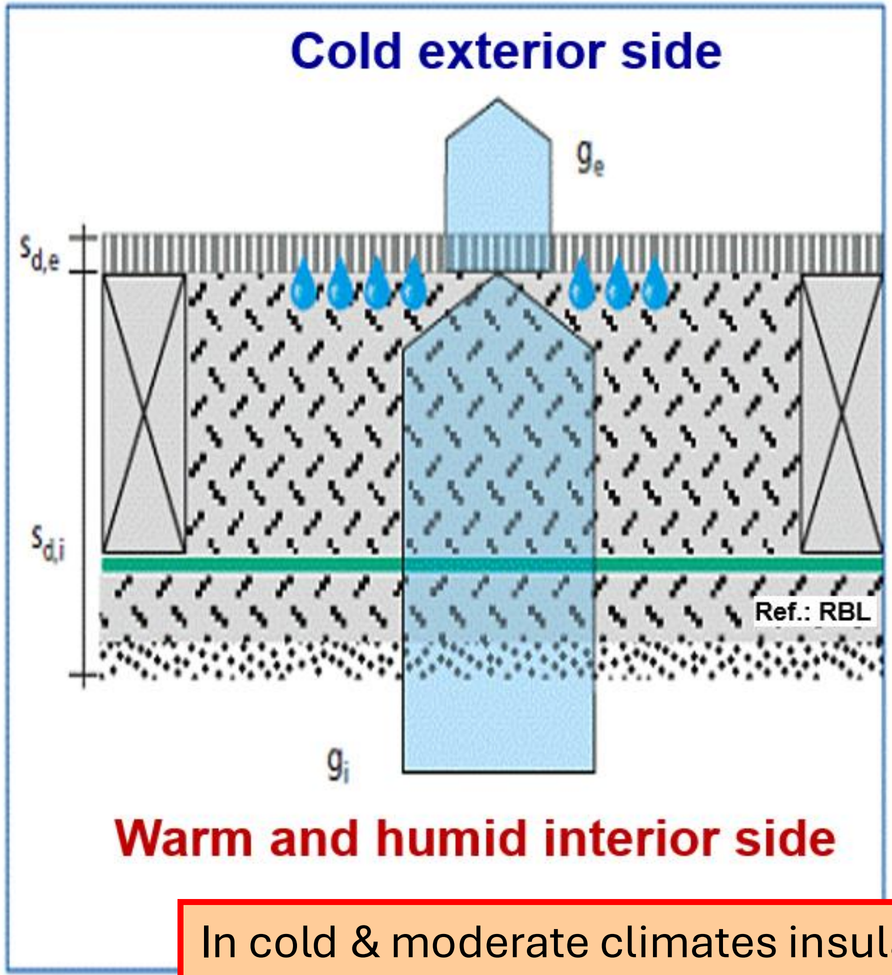




Adding insulation for healthy and energy efficient buildings

Condensation may occur at cold surfaces



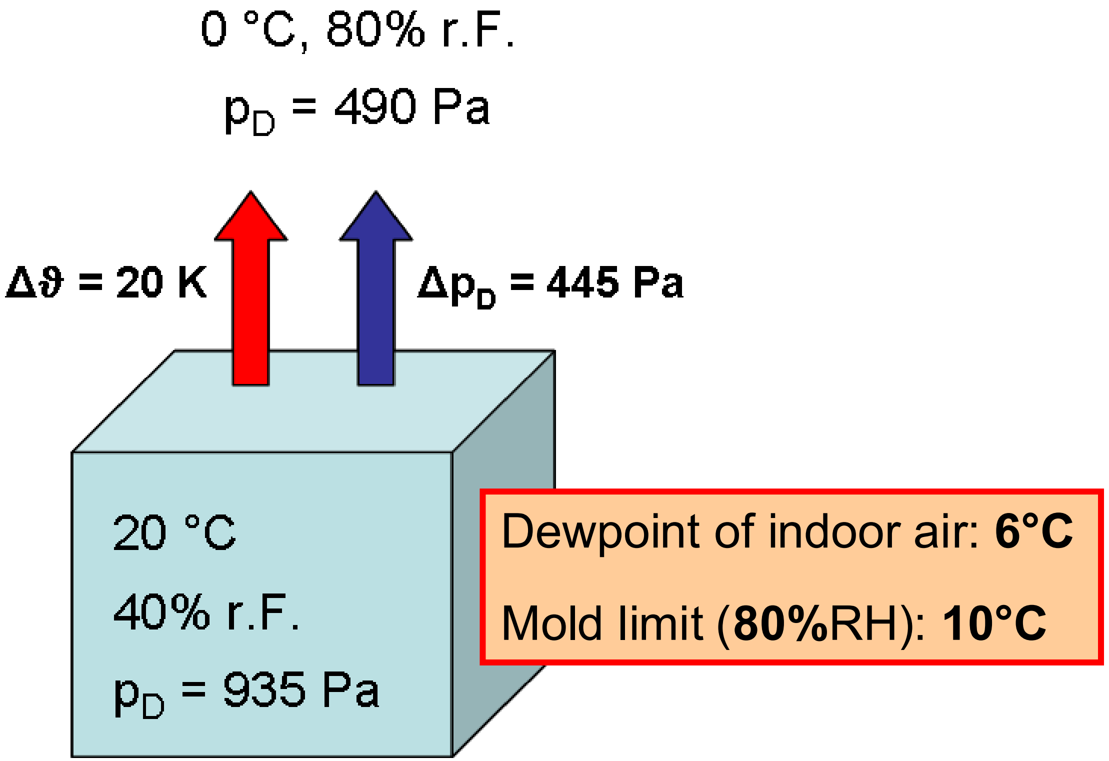


In cold & moderate climates insulated timber structures of **heated** buildings require interior vapour control layers

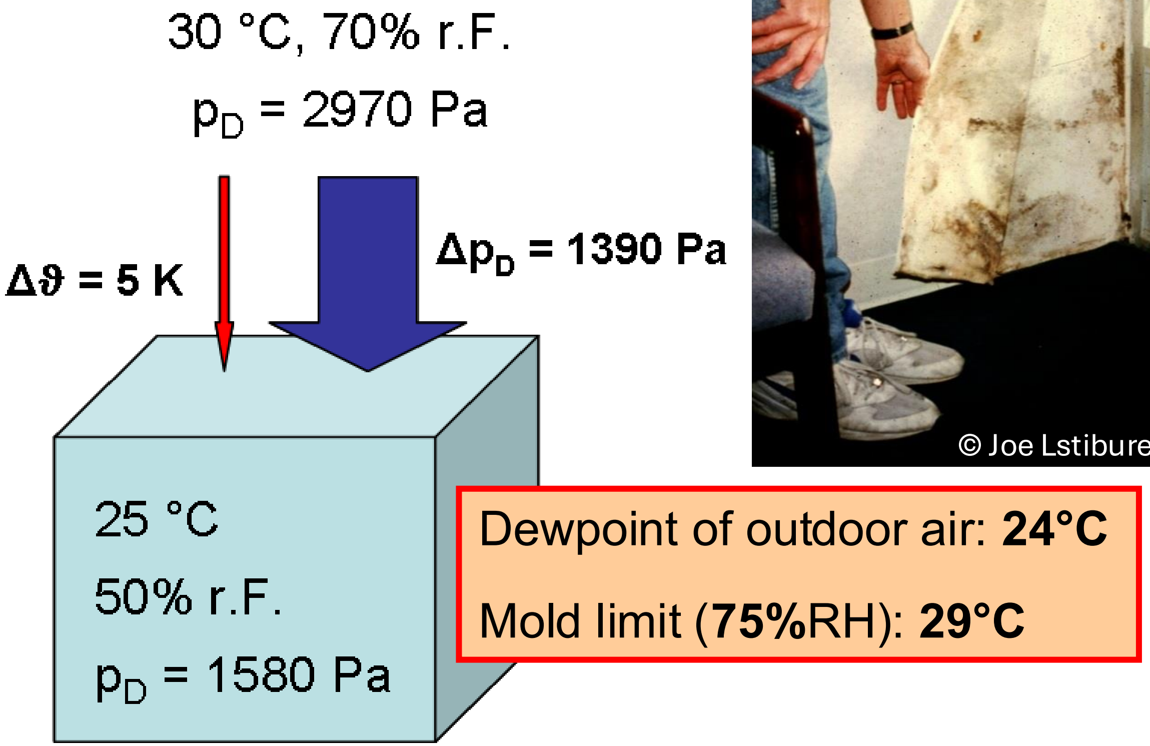
Adding insulation for healthy and energy-efficient buildings

Climate dependent vapor diffusion from warm to cold

Heating climate: outdoor temp. 0 °C



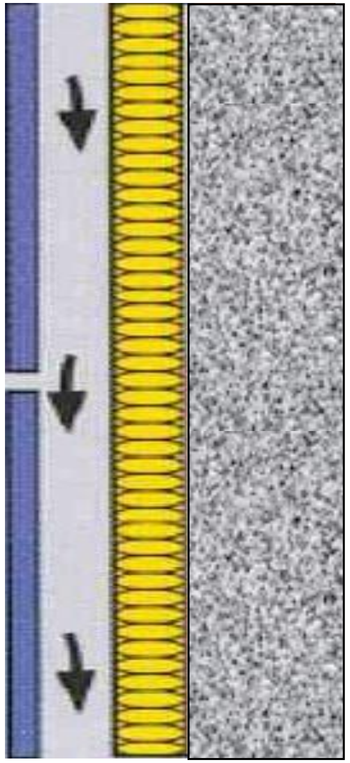
Cooling climate: outdoor temp. 30 °C



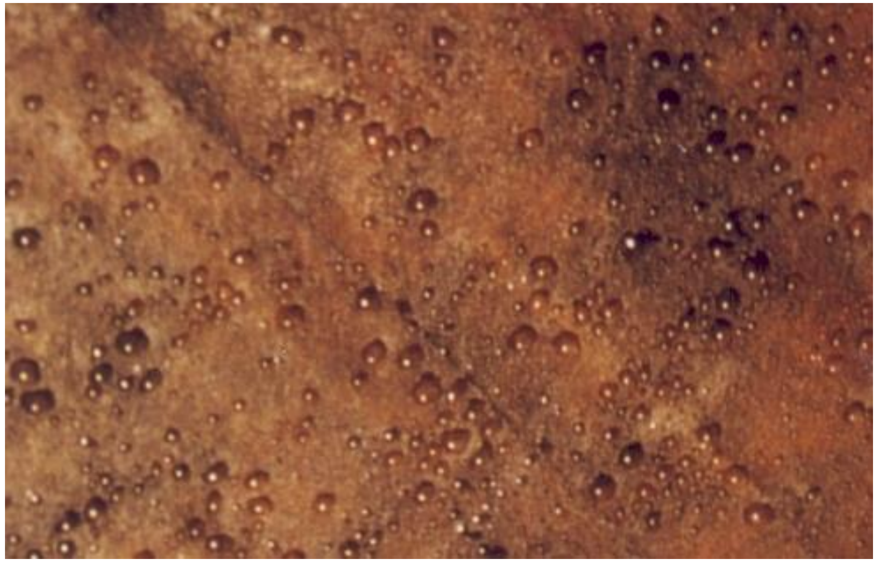
Vapour retarder should be placed at the side with the highest vapor pressure

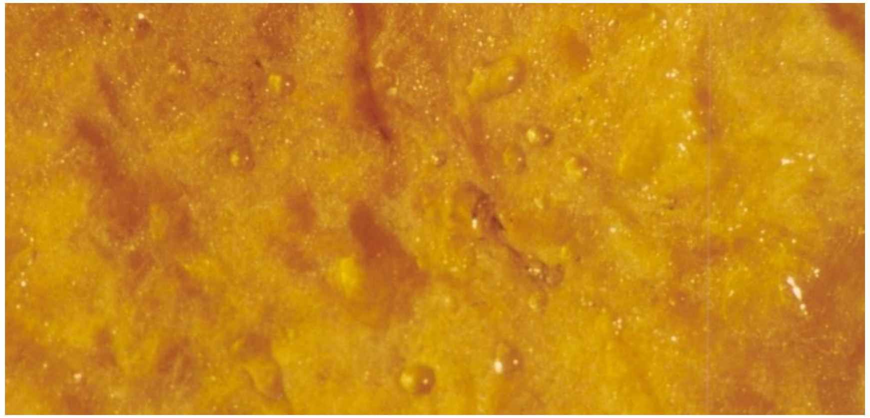
Consequences of building envelope insulation

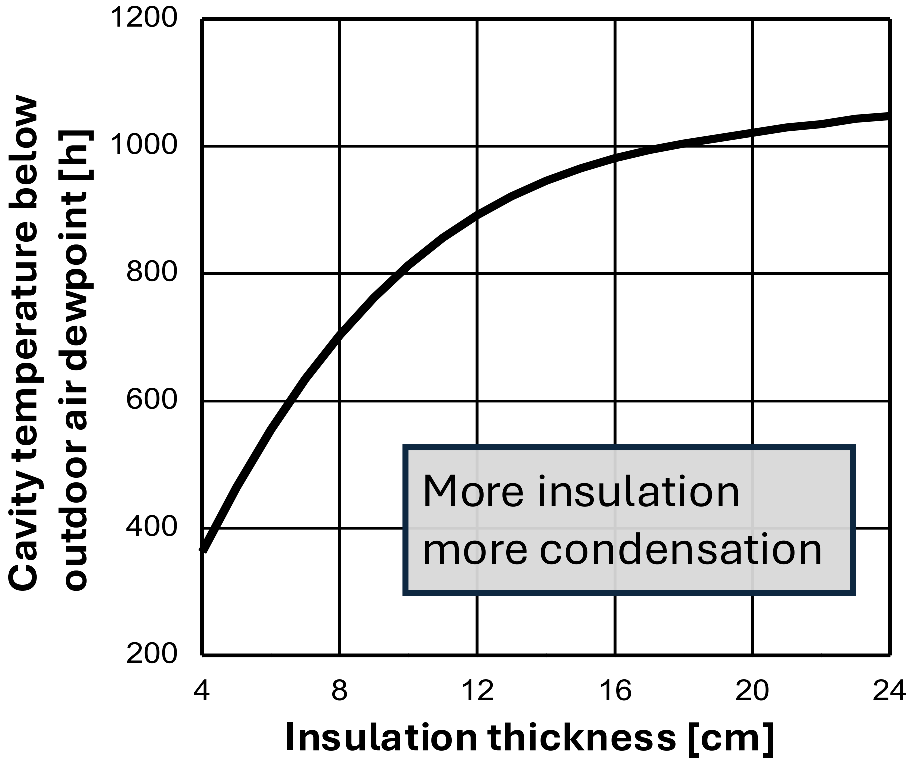
Insulation is a game changer for the building envelope



Night-time condensation in ventilated cavity





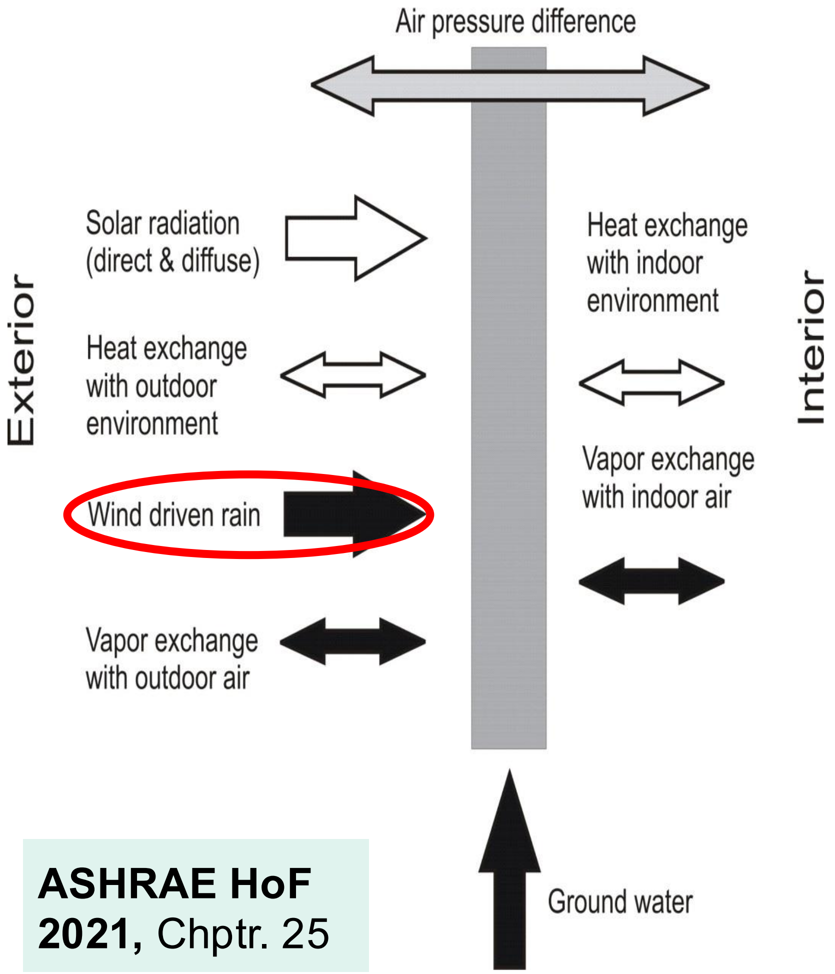


Thermal insulation raises interior surface temp. which prevents condensation & mould

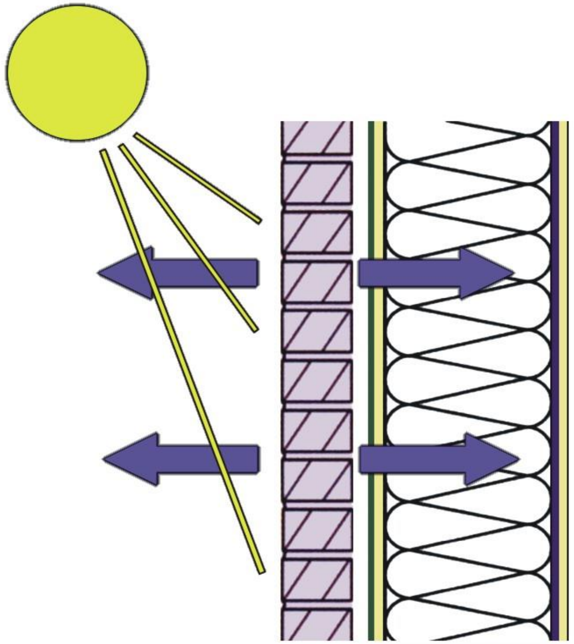
The exterior surface temp. may drop below the outdoor dewpoint causing condensation

Consequences of rainwater absorption

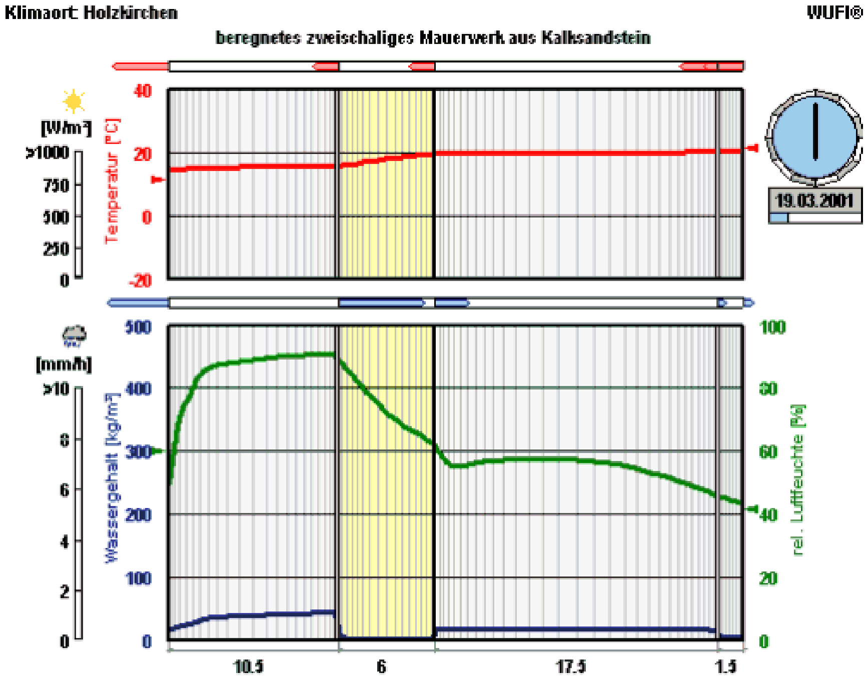
Driving rain on masonry or brick veneer will be absorbed and may degrade the wall



ASHRAE HoF 2021, Chptr. 25



Solar vapour drive may harm the interior of the assembly



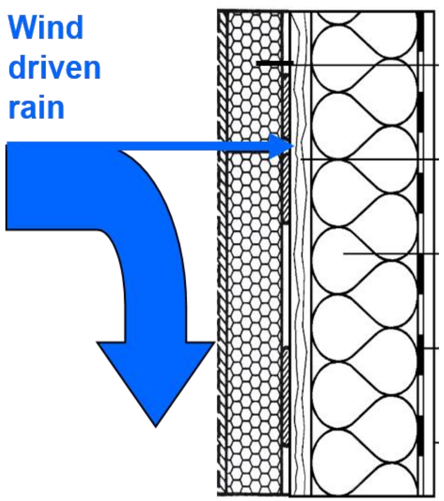
Masonry cavity wall with MW insulation exposed to natural weather including driving rain

Indoors: 20°C / 40% RHg

Consequences of rainwater penetration

Risk of damage due to driving rain leakage

1990s: damaged stud walls with EIFS in North America, later also in Sweden
Reason: water penetration at window joints and other wall connections



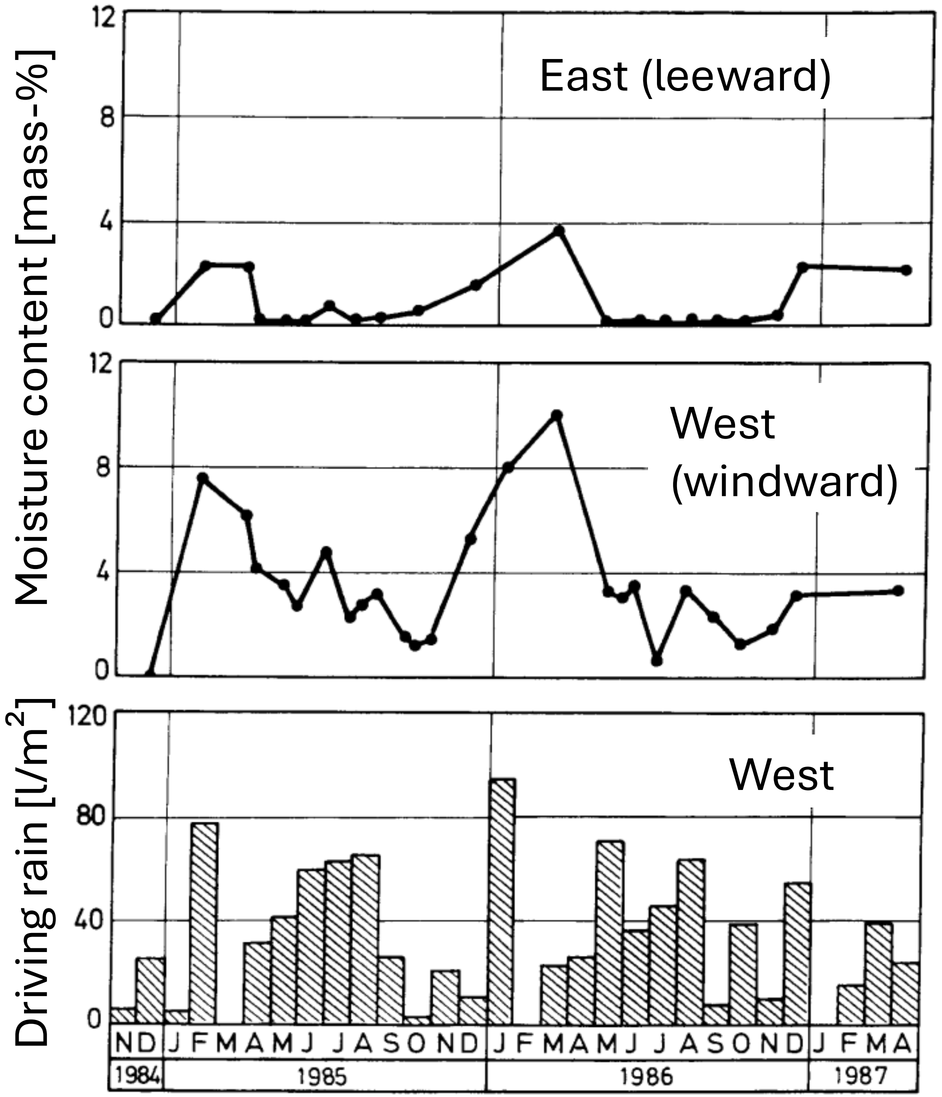
Rainwater entry behind the insulation must be dealt with!

External Wall Insulation Systems on timber structures require a technical approval in Germany

Probing of wall with rendered EPS as external insulation system (IBP field test)

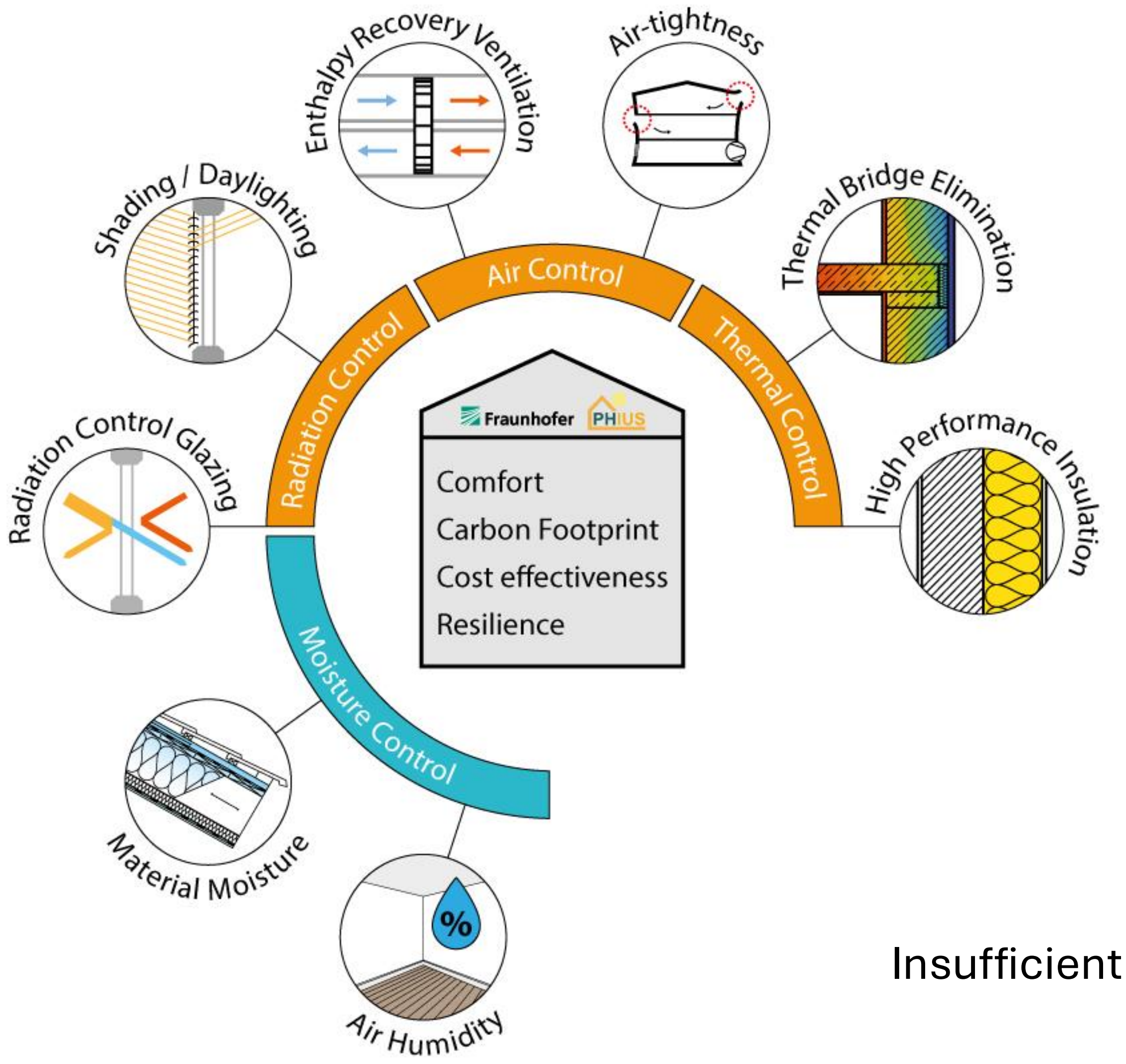
Consequences of rainwater penetration

Exposure of mineral wool to natural weather
behind open-joint cladding

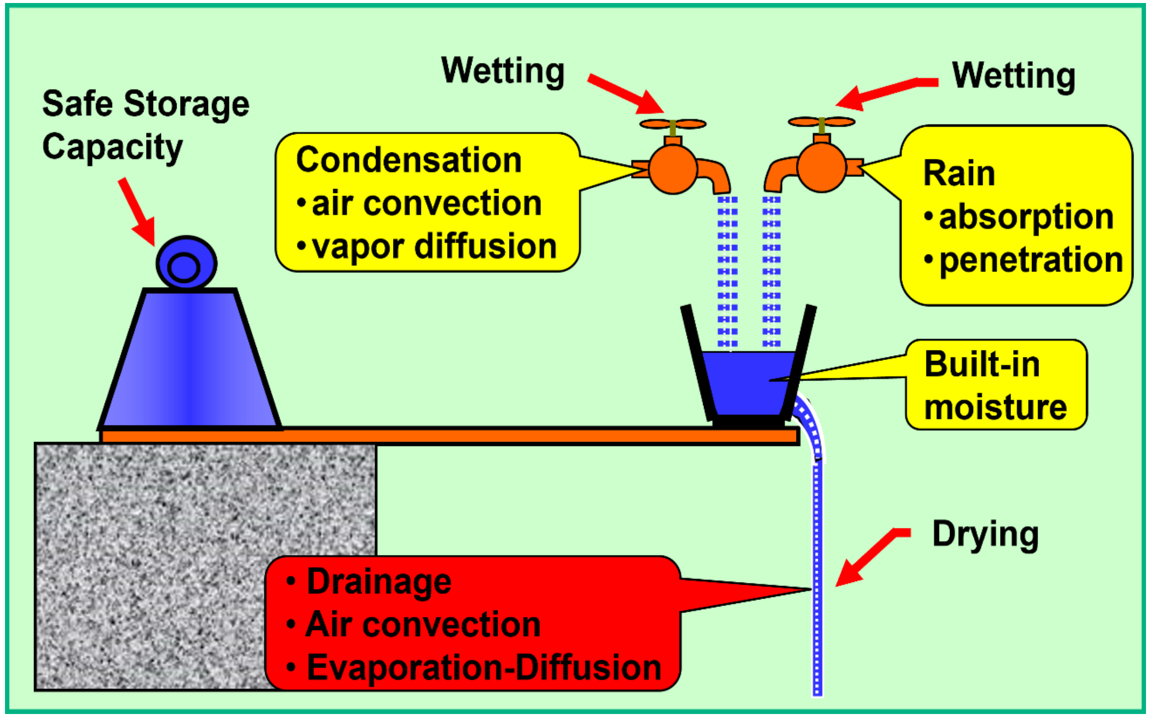


Field tests have proven the moisture resistance of hydrophobic mineral wool insulation under severe exposure conditions

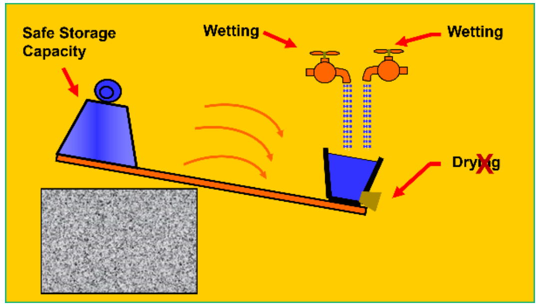
Integrated Building Design



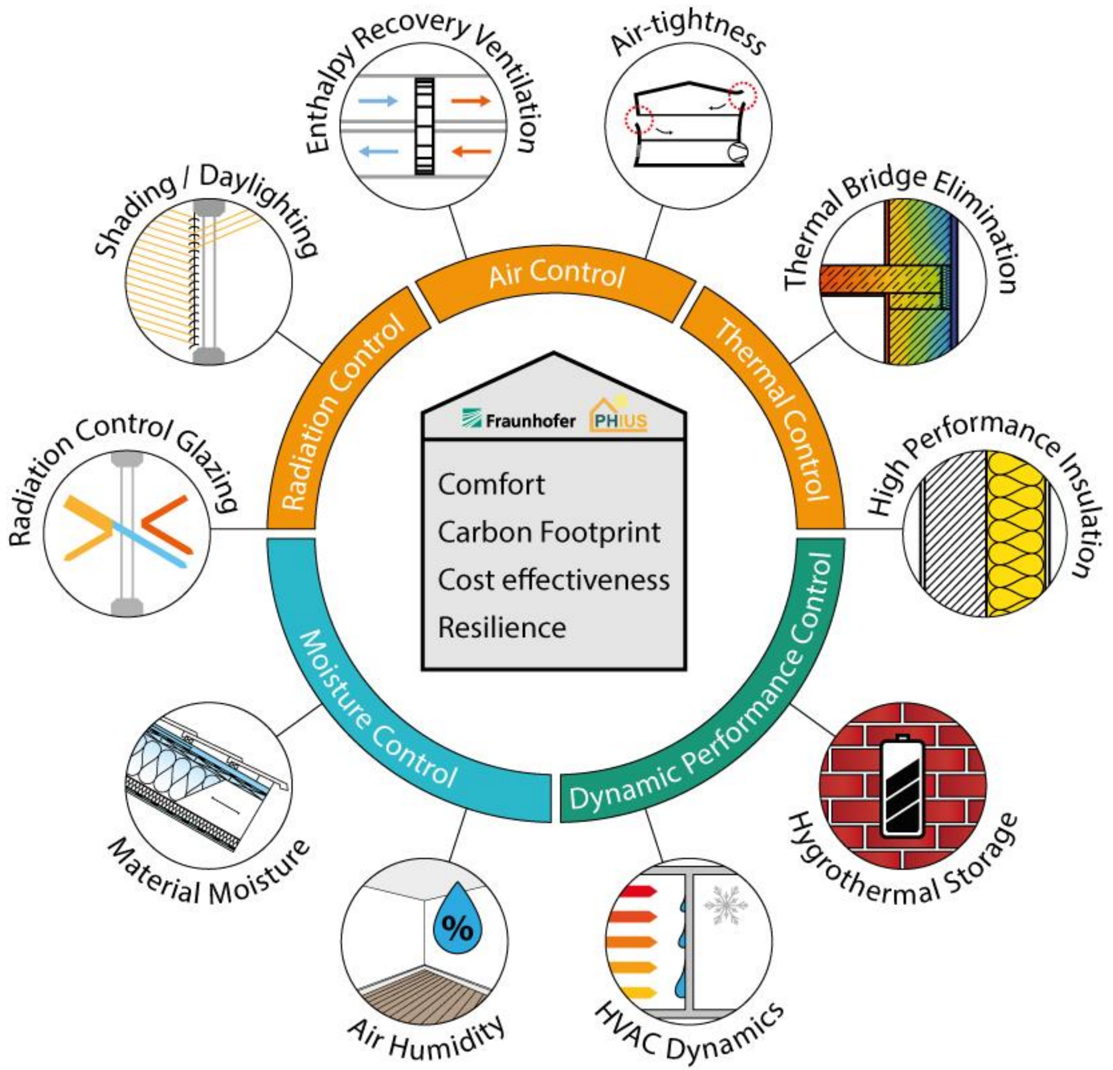
Damage or unhealthy conditions may result if **moisture control** is not part of the design process



Insufficient drainage or drying potential ►



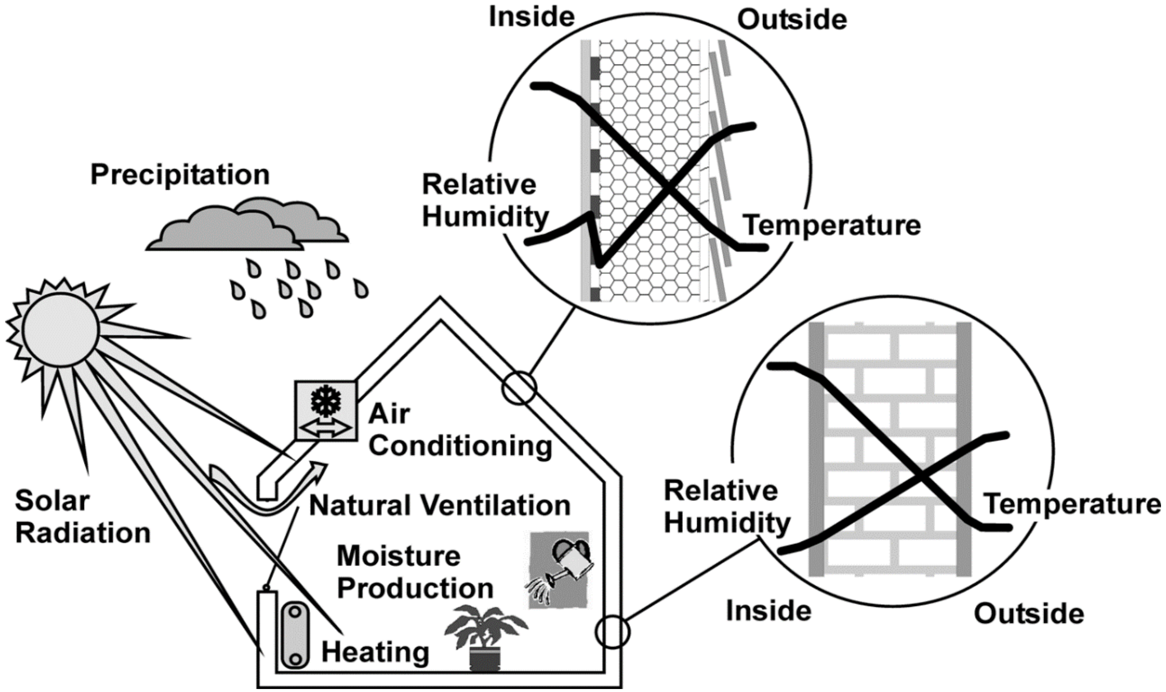
Integrated Building Design



Damage or unhealthy conditions may result if **moisture control** is not part of the design process

Outdoor conditions and building operation may vary significantly (dynamic behavior)

► Impact of heat and moisture storage on indoor climate conditions **(hygrothermal inertia)**

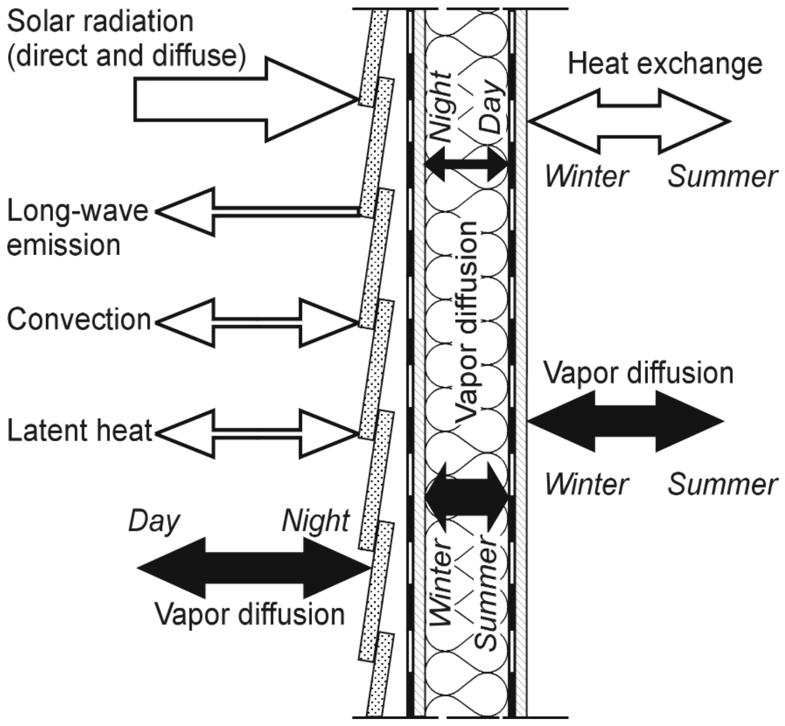


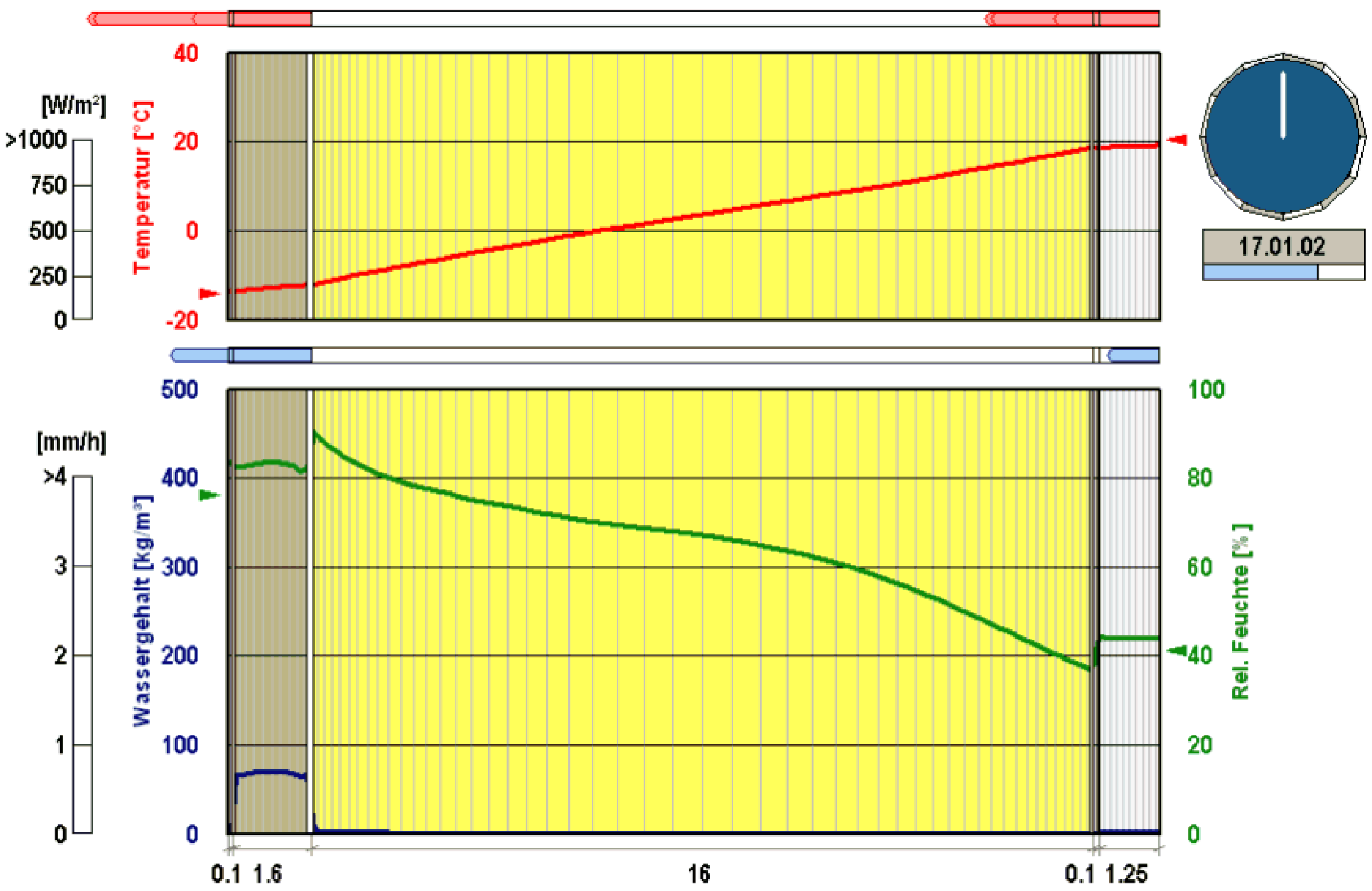
Calculating the moisture balance of envelope assemblies

Dynamic hygrothermal simulation according to internationally established standards

Evaluating the moisture balance of envelope assemblies

Resulting temperature and humidity conditions in insulated stud walls



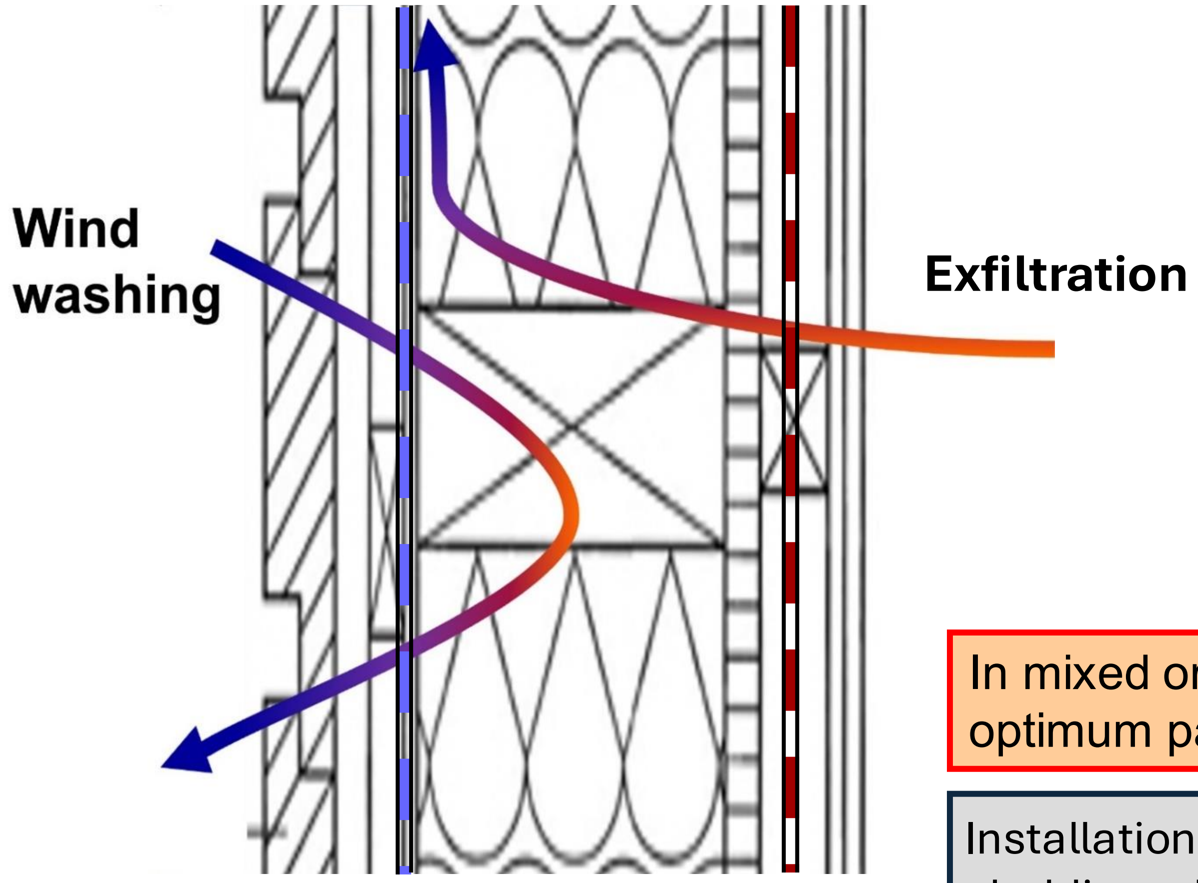


Light-weight assembly exposed to natural weather in winter.

Indoors: 20°C / 40% RH

Climate specific moisture and airflow control layers

Balancing indoor and outdoor vapour diffusion fluxes to keep light-weight assemblies dry



Wind and water resistive barrier (WB/WRB)

- In cold climates, the WB/WRB should be vapour open
- In hot and humid climates, the WB/WRB should be vapour retarding

Vapour control and air barrier (VC/AB)

- In cold climates, the VC/AB should be vapour retarding
- In hot and humid climates, the VC/AB should be vapour permeable

In mixed or moderate climates, there are no general rules, and the optimum parameters for WB/WRB and VC/AB must be calculated

Installation flaws and rainwater absorption in case of reservoir cladding add further moisture sources to the equation

Climate specific moisture and airflow control layers

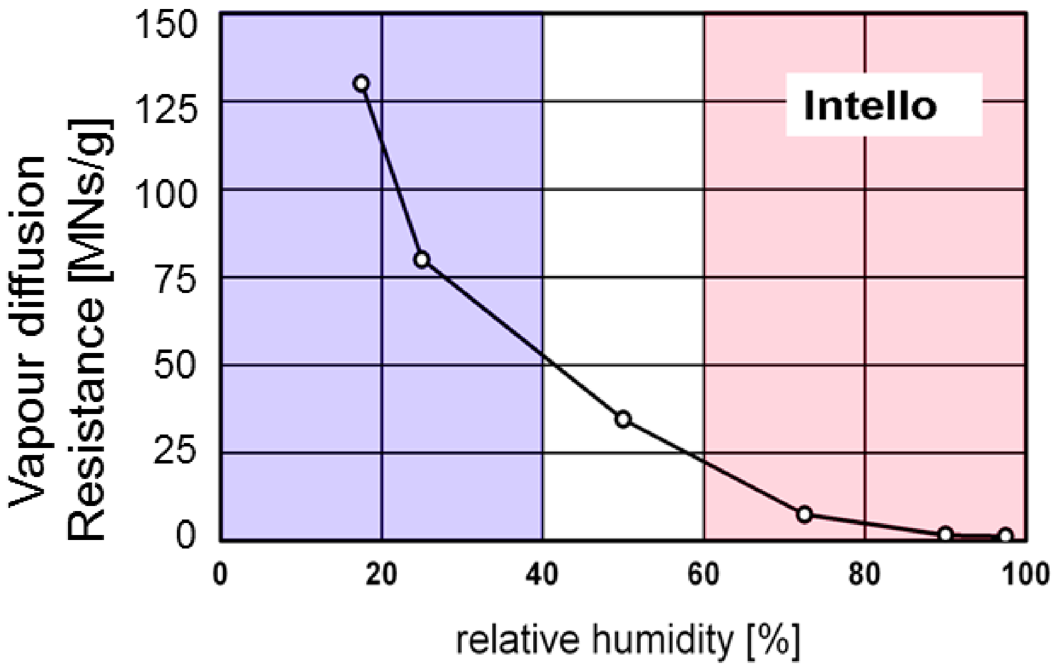
Definition of vapour retarder

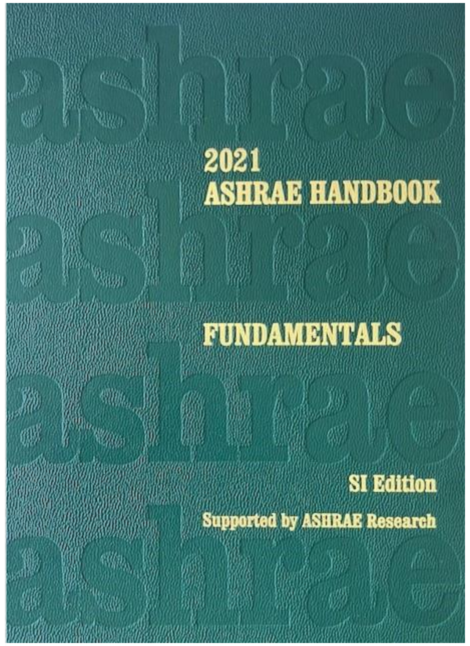
Water Vapour Retarders
The main characteristic of a vapour retarder is low vapour permeance.
Vapour retarders are completely ineffective **without airflow control**. A single layer may serve both purposes
The type of system depends on the climate zone, building usage and moisture sources

"Smart" vapour retarders allow substantial summer drying while functioning as effective retarders during the cold season ►►►

The Int. Construction Code lists three water vapor retarder classes:
- Class I: 0.1 perm or less
- Class II: > 0.1 perm ≤ 1.0 perm
- Class III: > 1.0 perm ≤ 10 perm
- (Class IV: > 10 perm)

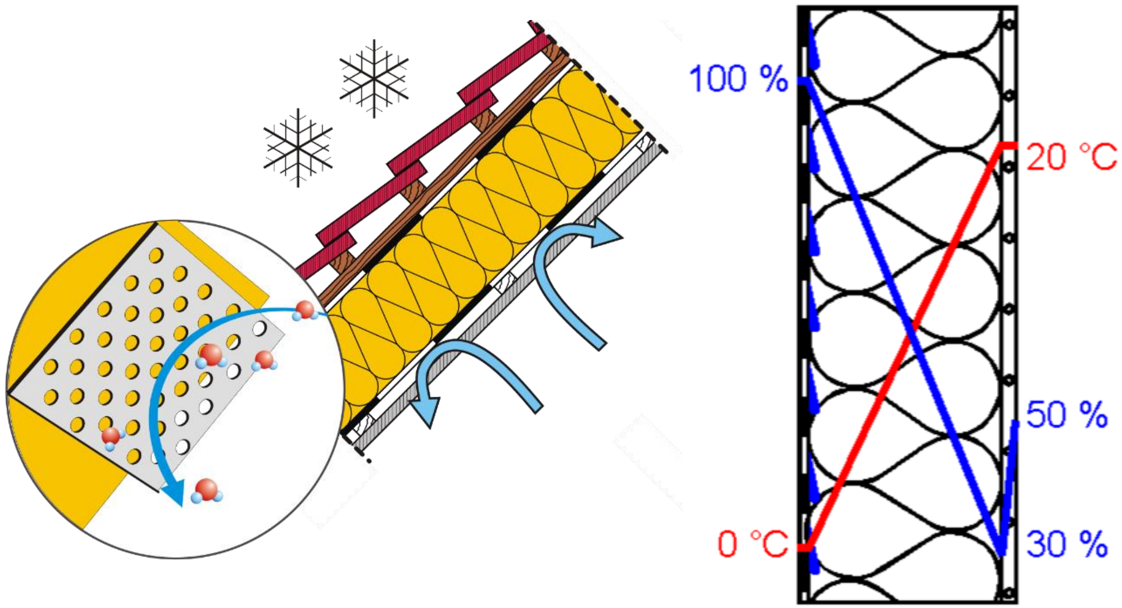
The designer determines the appropriate type of water vapor

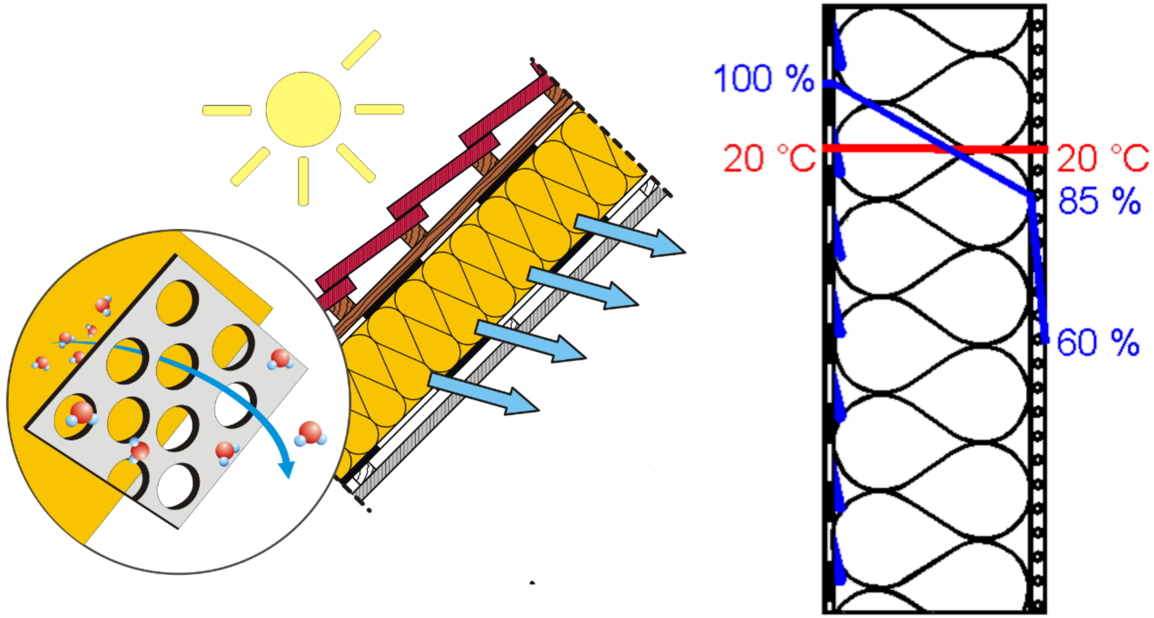




Climate specific moisture and airflow control layers

Working principle of smart vapour retarders (SVR)





In winter, indoor RH is low and RH at the backside of the retarder is even lower

SVR molecular pores (and permeance) are small

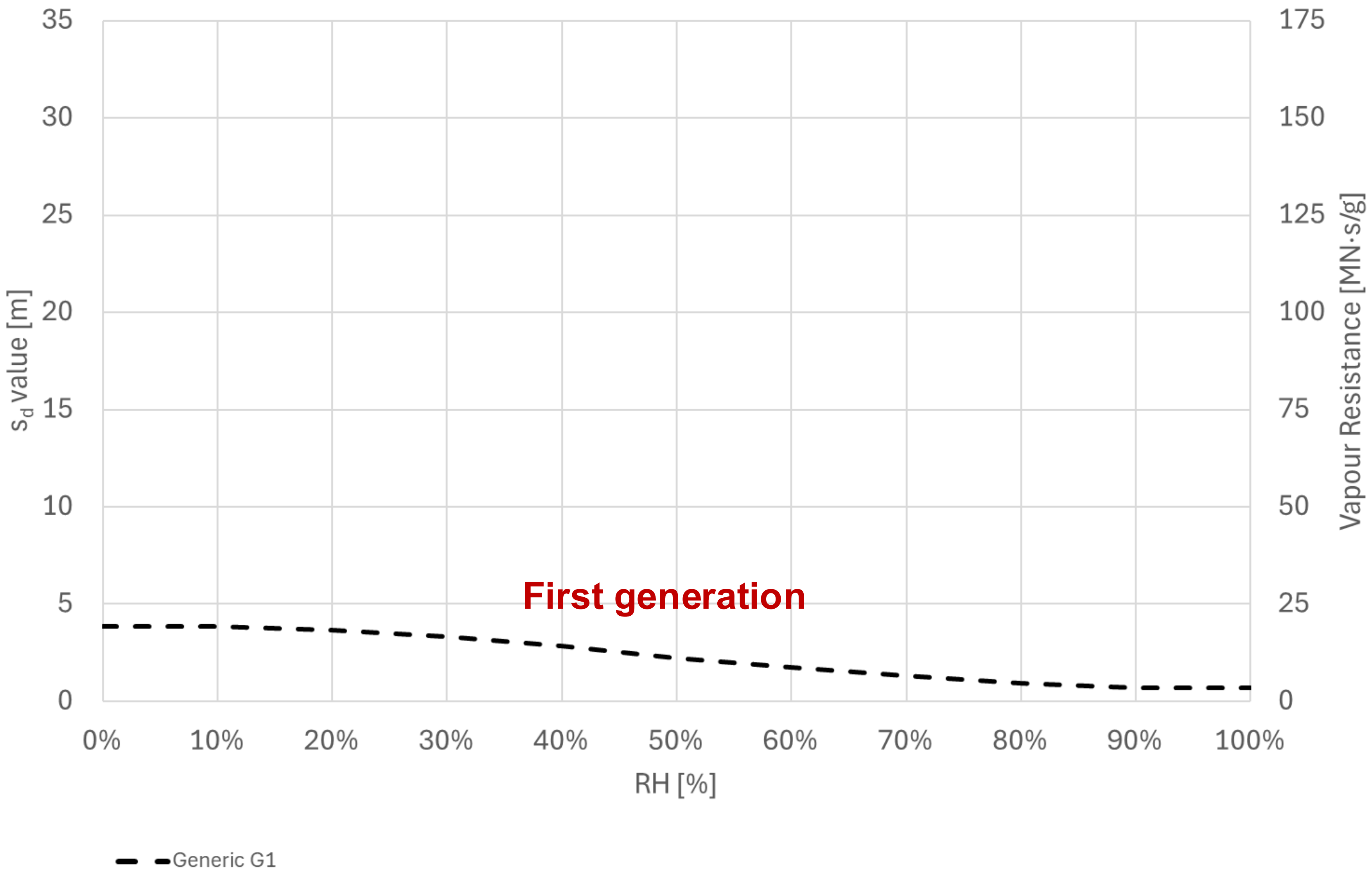
In summer, indoor RH is higher and RH at the backside of the retarder even more

SVR molecular pores (and permeance) widen

The size of molecular pores is in the range of water-molecules (0.3 nm). They are impermeable to air.

Climate specific moisture and airflow control layers

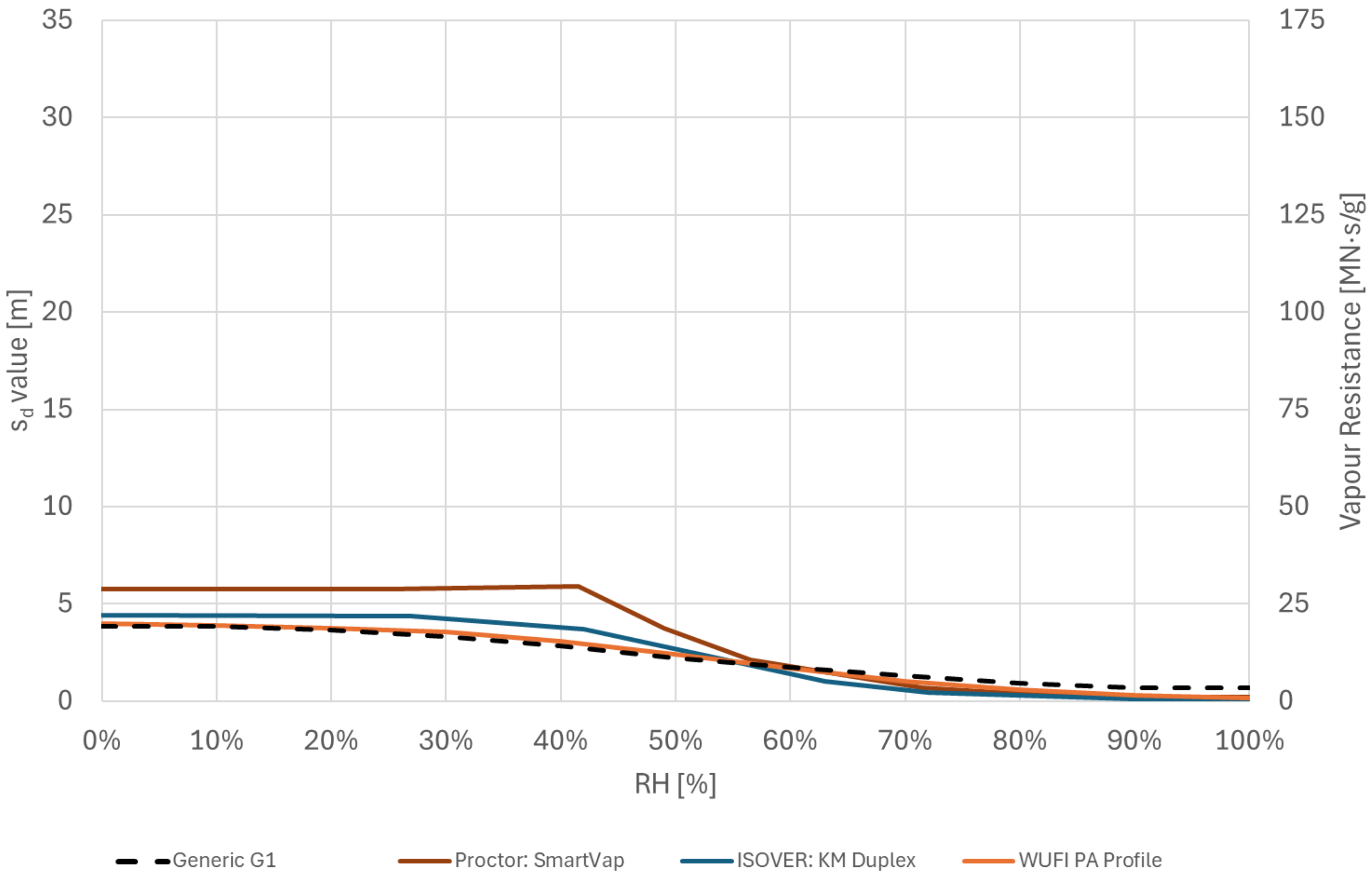
Next generation of smart vapour retarders (SVR)



First generation SVR have been crucial to meet the challenges of well-insulated light-weight envelope assemblies by providing sufficient drying potential

Climate specific moisture and airflow control layers

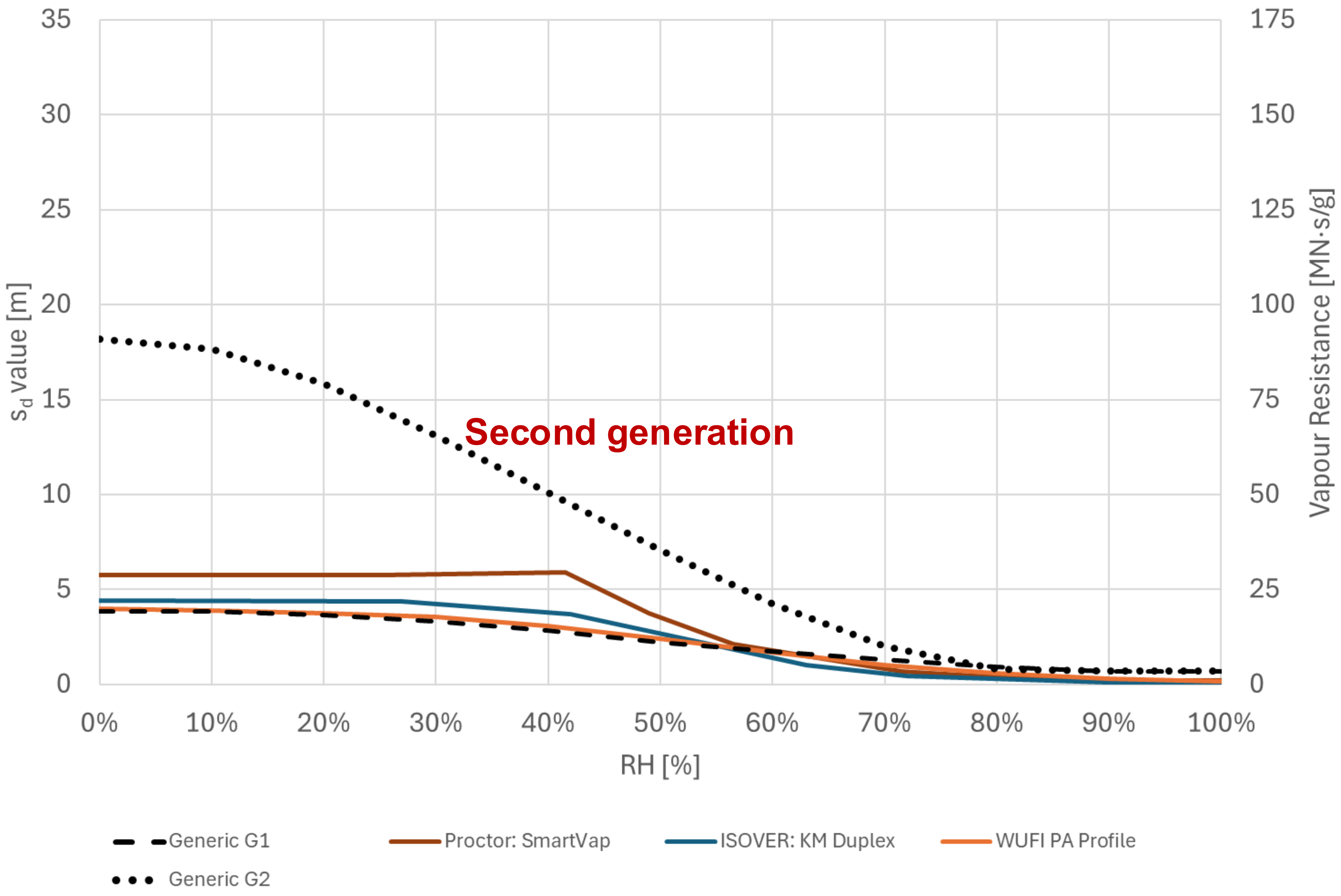
Next generation of smart vapour retarders (SVR)



First generation SVR have been crucial to meet the challenges of well-insulated light-weight envelope assemblies by providing sufficient drying potential

Climate specific moisture and airflow control layers

Next generation of smart vapour retarders (SVR)

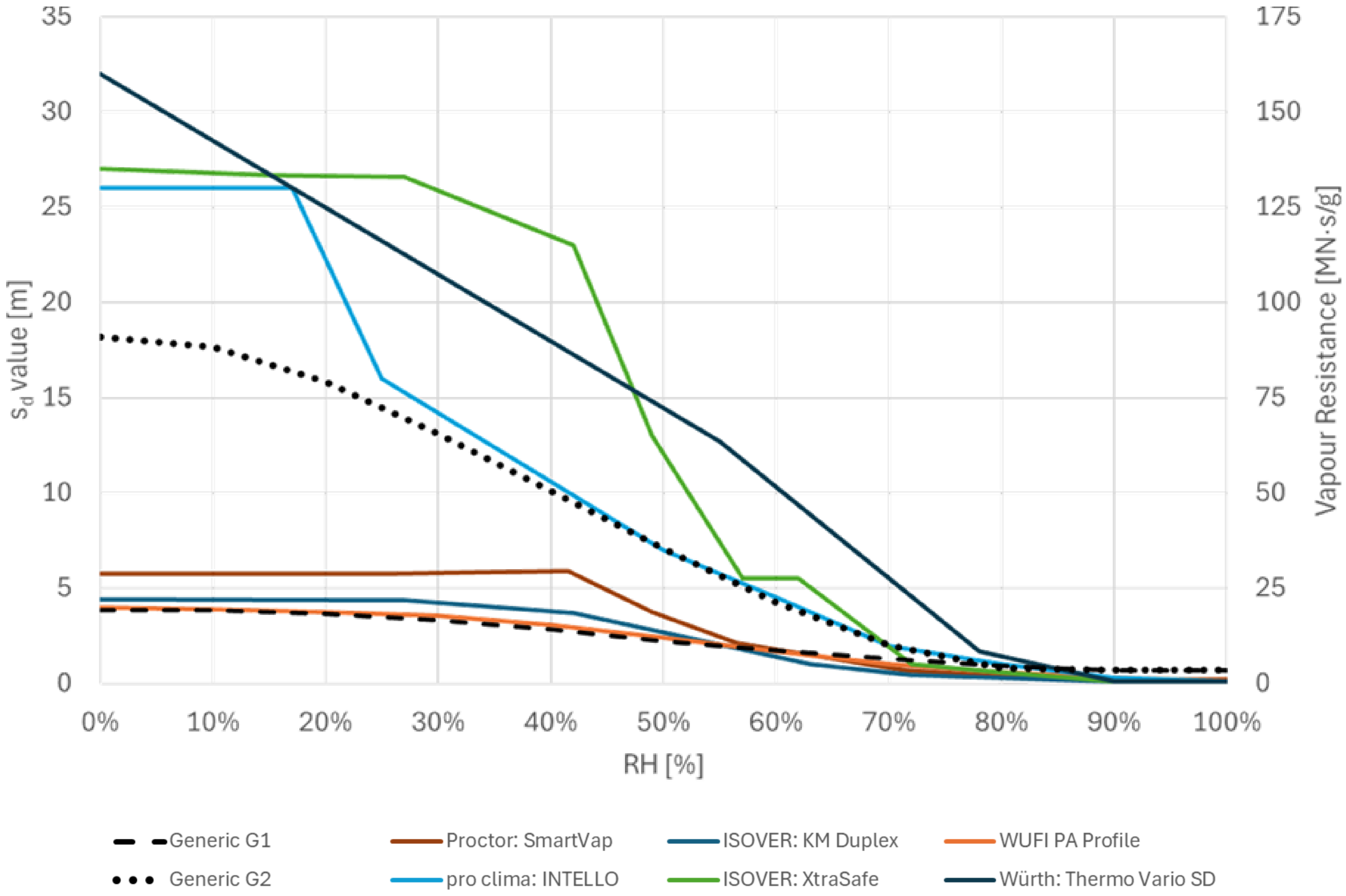


First generation SVR have been crucial to meet the challenges of well-insulated light-weight envelope assemblies by providing sufficient drying potential

Second gen. SVR proved to be superior in many applications and helped to reduce the risks of moisture susceptible constructions

Climate specific moisture and airflow control layers

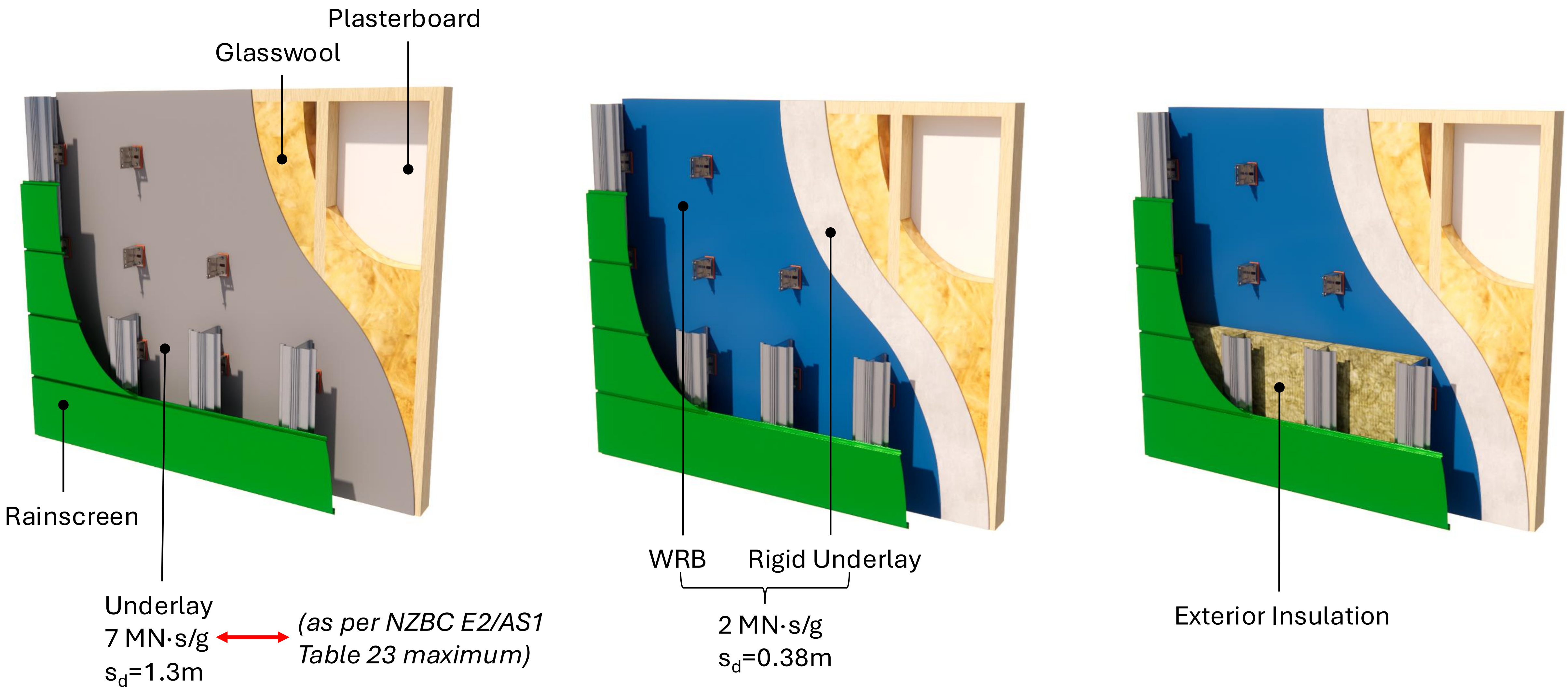
Next generation of smart vapour retarders (SVR)



First generation SVR have been crucial to meet the challenges of well-insulated light-weight envelope assemblies by providing sufficient drying potential

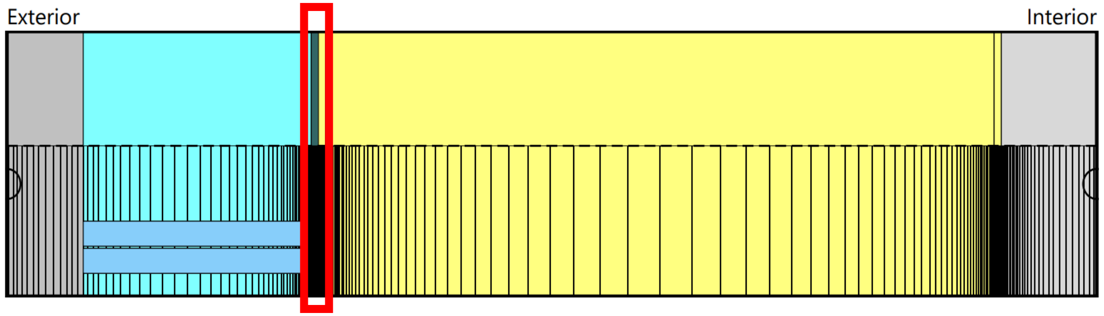
Second gen. SVR proved to be superior in many applications and helped to reduce the risks of moisture susceptible constructions

Case study: Stud walls in New Zealand



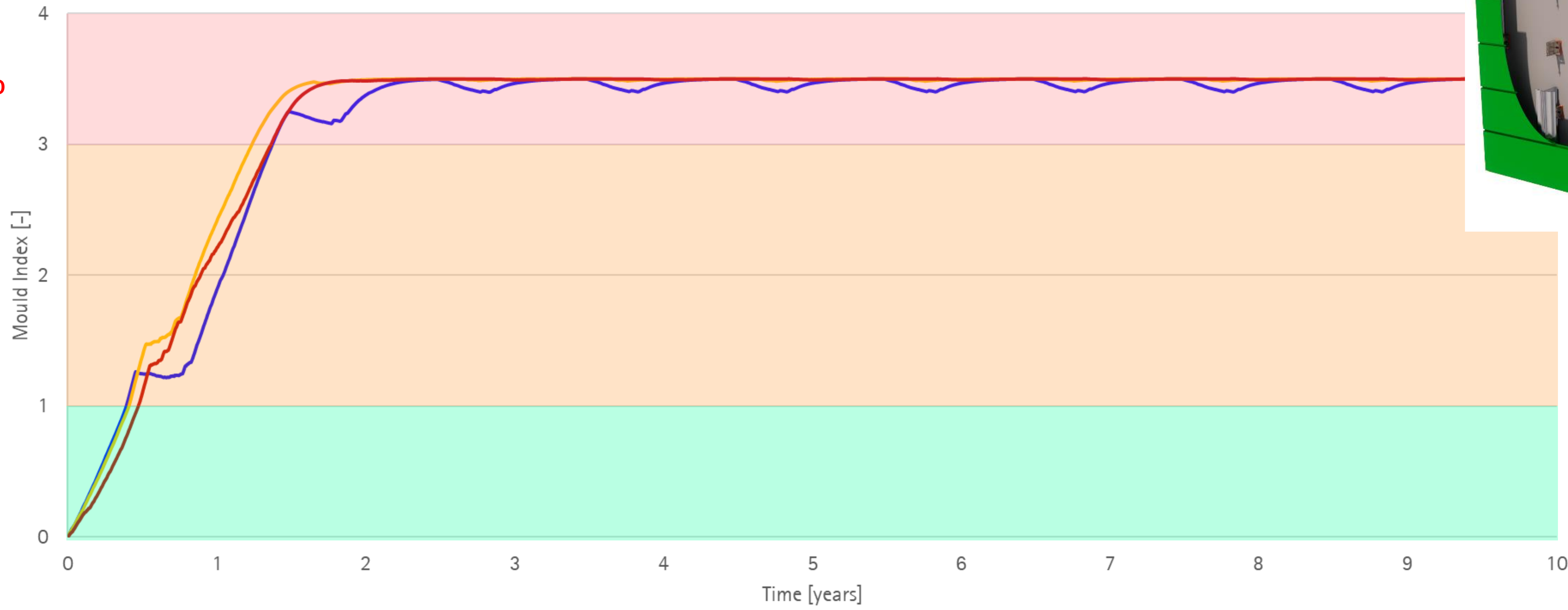
Indoor conditions - Auckland

Case 1: 7 MN·s/g underlay as per NZBC

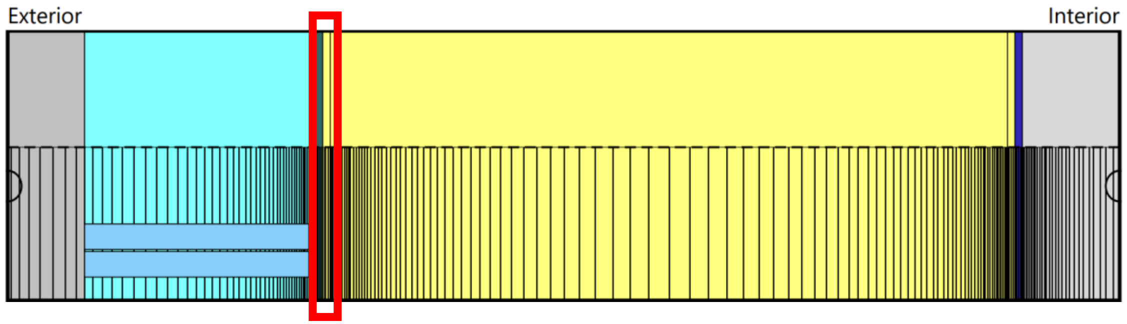


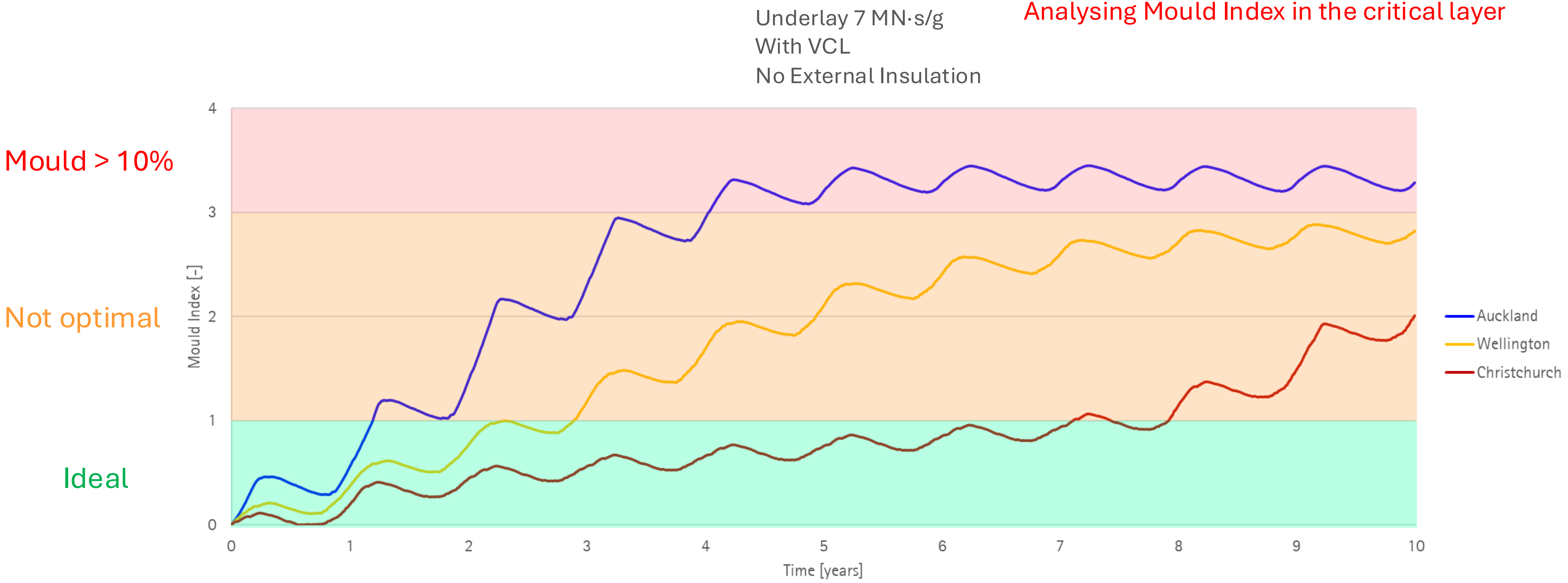
Analysing Mould Index in the critical layer

Underlay 7 MN·s/g
No VCL
No External Insulation



Case 2: 7 MN·s/g underlay with airtightness and vapor control layer



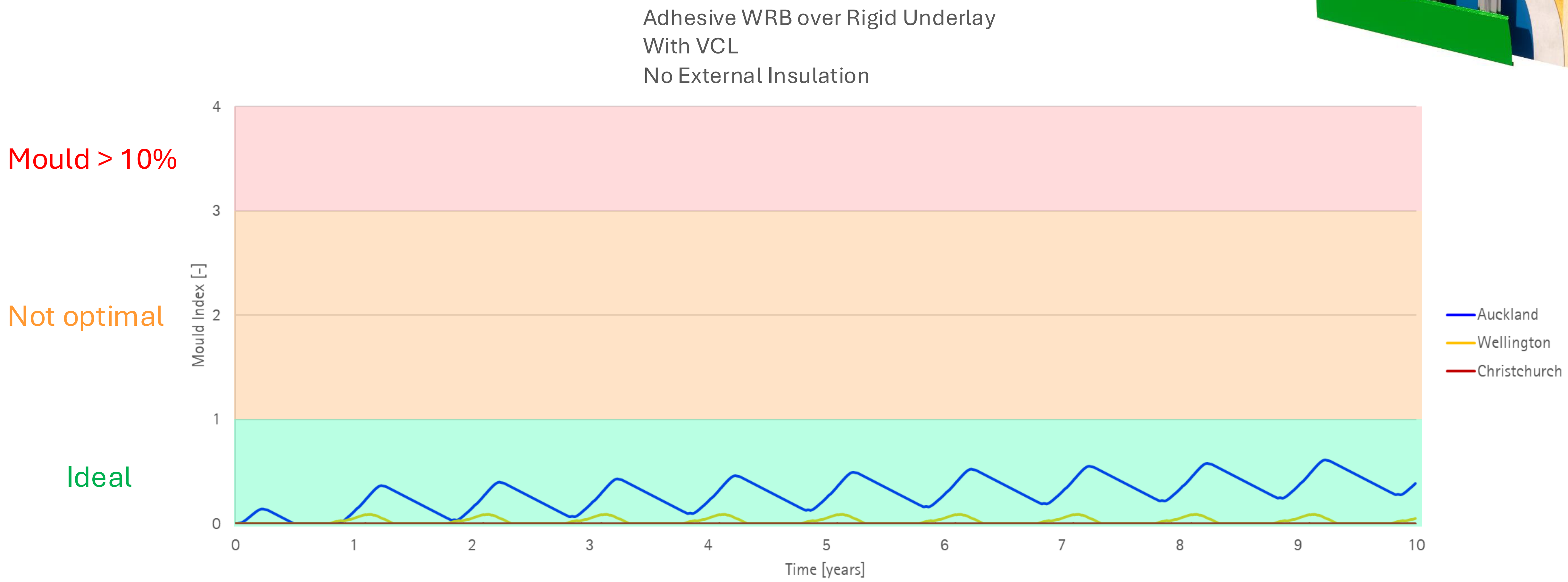


Case 3: Higher vapour permeability Adhesive WRB over rigid underlay with airtightness and vapor control layer

WRB + Rigid Underlay

2 MN·s/g

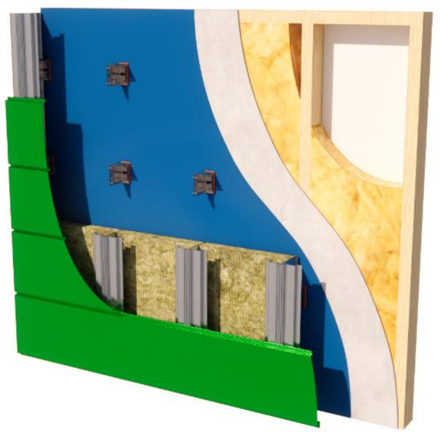
s_d=0.38m

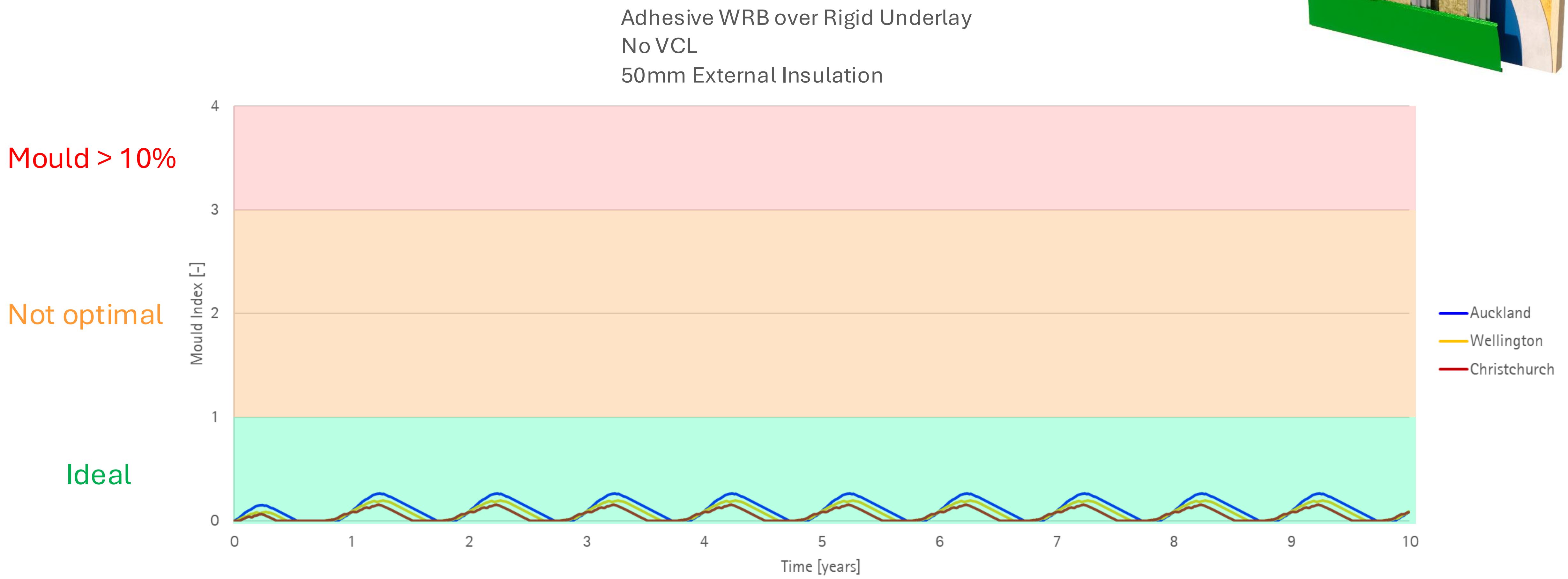


Case 4: Adhesive WRB over rigid underlay with 50mm exterior insulation

WRB Rigid Underlay

2 MN·s/g
s_d=0.38m





Case Summary

Case	Auckland	Wellington	Christchurch
Case 1: 7 MN·s/g underlay as per NZBC	> 3	> 3	> 3
Case 2: 7 MN·s/g underlay with airtightness and vapour control layer	> 3	Not Optimal	Not Optimal
Case 3: Higher vapour permeability Adhesive WRB over rigid underlay with airtightness and vapor control layer	✓	✓	✓
Case 4: Adhesive WRB over rigid underlay with 50mm exterior insulation	✓	✓	✓

Summary: Hygrothermal Passive Building Design and Innovation

Healthy and durable Passive Buildings require sound moisture control design:

- Envelope assemblies must have a high drying potential and should be moisture tolerant to avoid interstitial condensation, **mould growth** and moisture related **damage** or degradation.
- Indoor air quality and humidity must be managed by a combination of energy efficient HVAC and sensible building operation

Hygrothermal building design tools can help to:

- Design moisture tolerant assemblies for all climate zones and indoor conditions
- Define the set-points and limit conditions to keep the structure and the inhabitants safe
- Predict the building performance under future conditions (e.g. climate change)
- Analyze the cause of building damage and calculate the service life of constructions
- Assess and select suitable vapour control layers for healthy and durable design

Fraunhofer IBP

Thank you for your attention!

Hartwig M. Künzel

(www.building-physics.com)

Building Science Summit New Zealand

Shaping the Future of Building Performance & Sustainability