



# Non-destructive field measurements of moisture in building constructions- Possibilities and experiences

PhD-candidate Lars Gullbrekken,  
NTNU, Faculty of Engineering,  
Department of Civil and Environmental Engineering  
and Researcher at SINTEF



# Content

- Background and theory
- Building defects
- Moisture measurements
- Experiences (wood moisture measurements)
- Possibilities
- Summary



# Why field measurements of moisture in building constructions?

## 1. Avoid building defect

Control of moisture content of materials and constructions during a building construction process, typically when receiving materials and before installation of vapour tight layers.

## 2. Examination of buildings and building defects

Part of investigation during conditions surveys of buildings and building defects caused by moisture and water.

## 3. Research and development

As a supplement in research and development of moisture calculations, laboratory measurements and new building constructions

# ➔ Why non destructive?

Existing building constructions  
Monitoring of existing building  
What is destructive?



Illustration: <https://www.amazon.com/Wagner-MMC220-Extended-Range-Moisture/dp/B000063X19>

# Moisture in building constructions

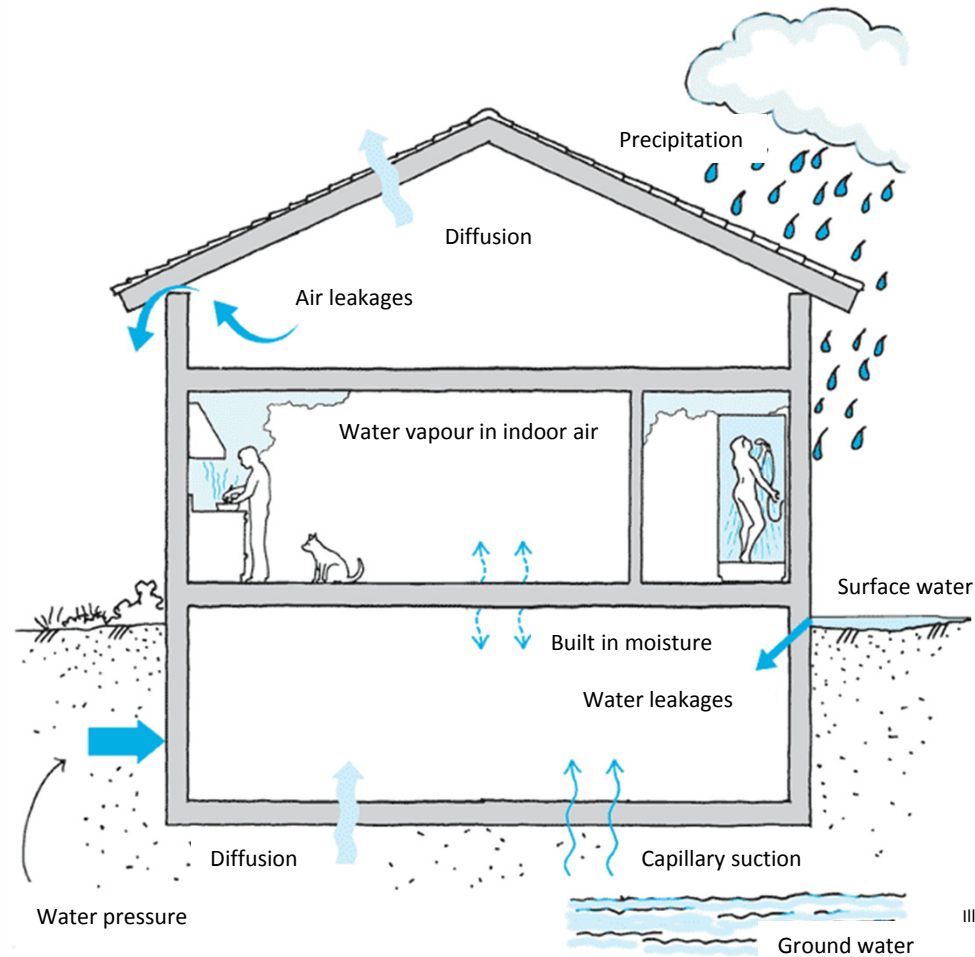


Illustration: Byggforskserien 421.132 Fukt i bygninger. Teorigrunnlag

# Moisture in air

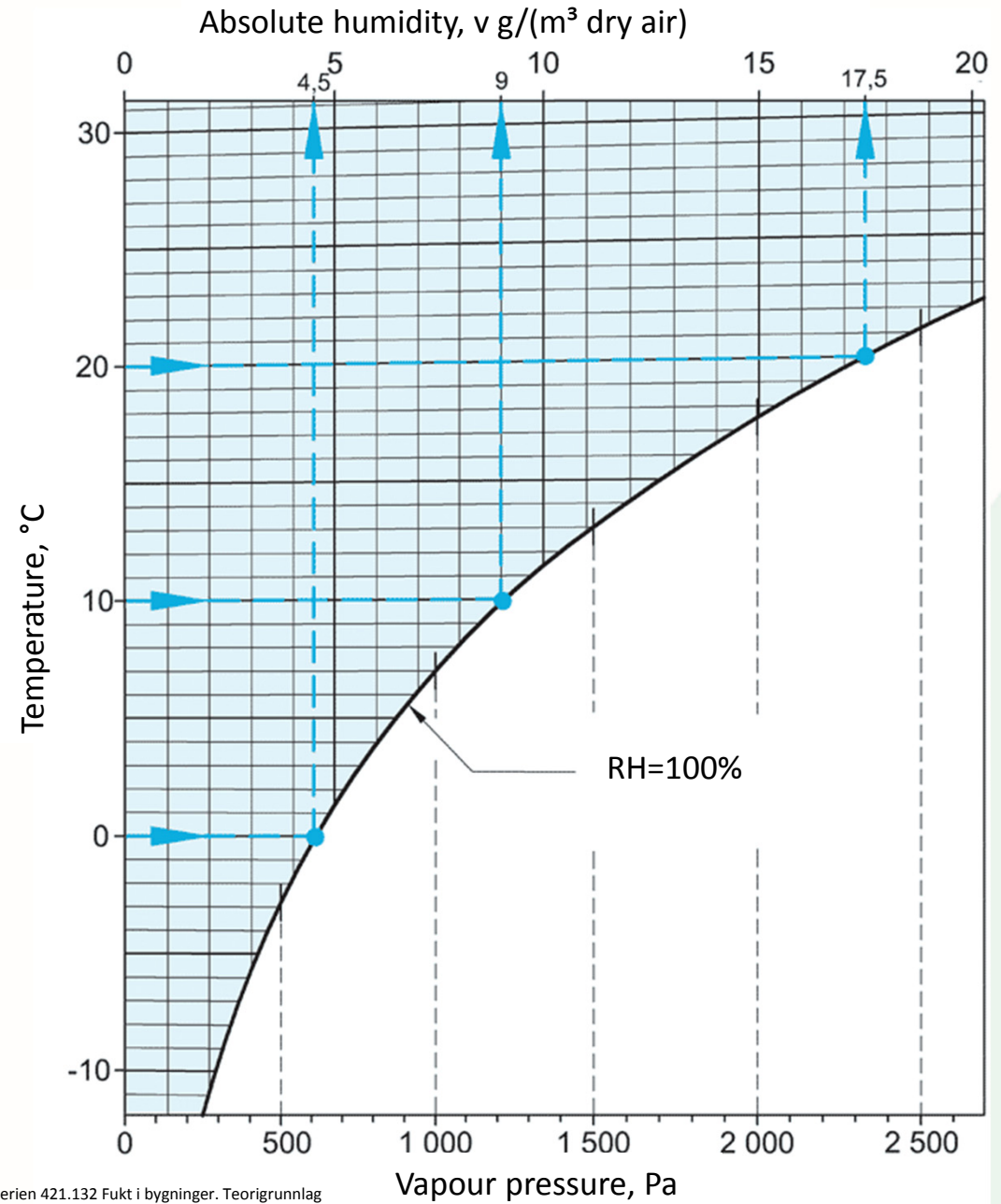


Illustration: Byggforskserien 421.132 Fukt i bygninger. Teorigrunnlag



# Moisture in building materials

Hygroscopic range 0-98 % RH  
Capillary area  
Saturated area

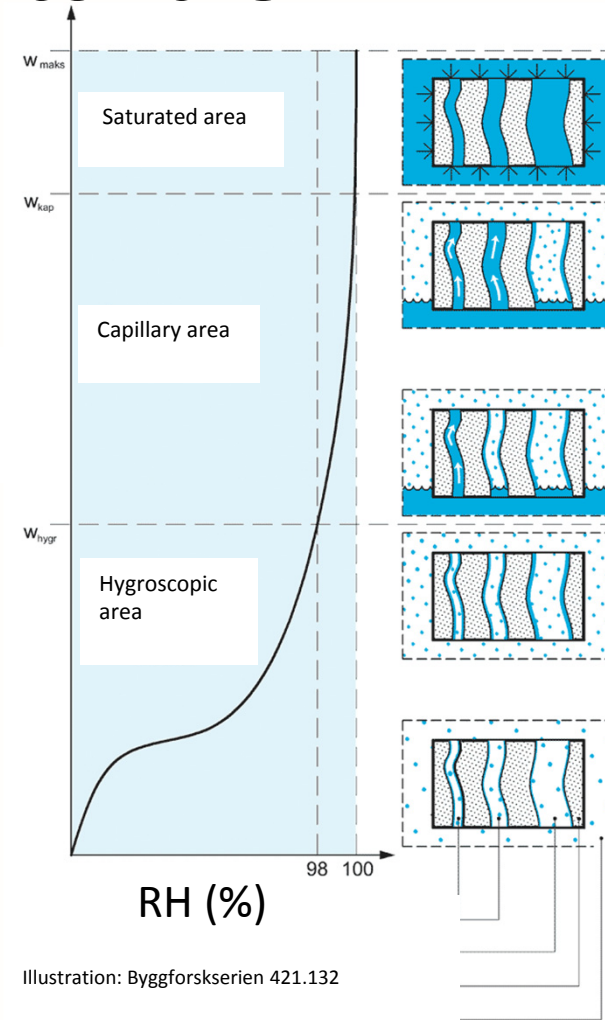


Illustration: Byggforskserien 421.132

# ➔ Sorption isotherms

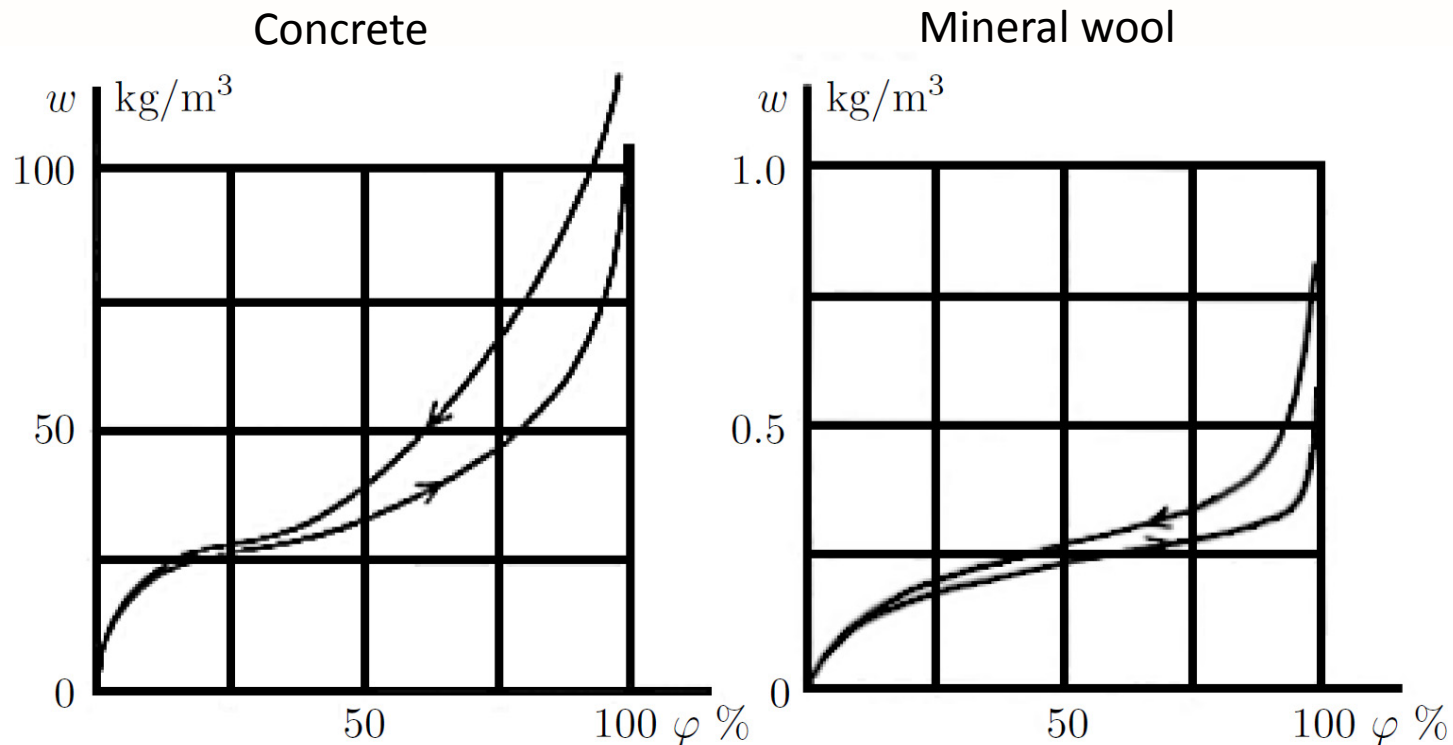


Illustration: Lars Erik Nevander and Bengt Elmarsson.(1994) *Fukthandbok: praktik och teori (Moisture handbook: practice and theory, in Swedish)*. Svensk byggtjänst, Solna, Sverige.





# Building constructions and moisture

SINTEF Building Defects Archive consisting of more than 2000 reports

Overview of typical defects and causes

76 % of the cases are caused by moisture

Moisture measurements are highly relevant

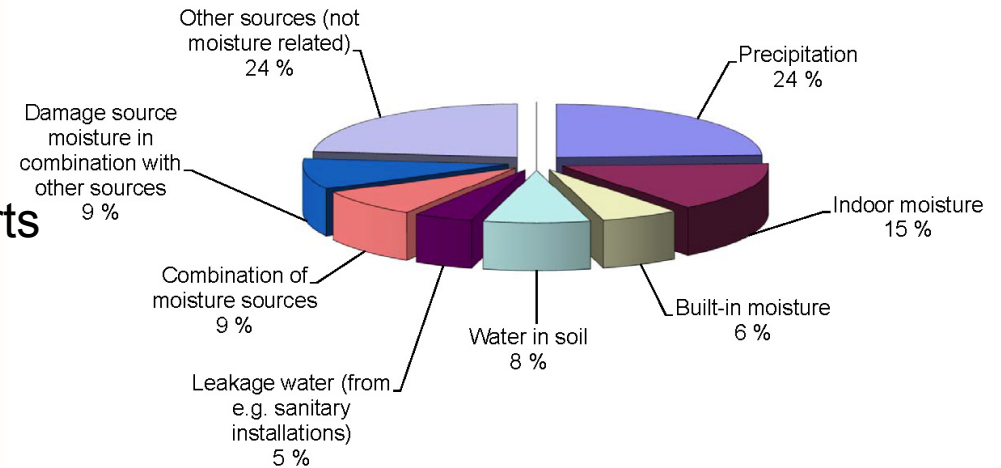


Illustration: Lisø, K.R., Kvannd, T. and Thue, J.V. (2006) Learning from experience – an analysis of process induced building defects in Norway, 3rd International Building Physics/Science Conference, Montreal, Canada, August 27-31

# Building defects

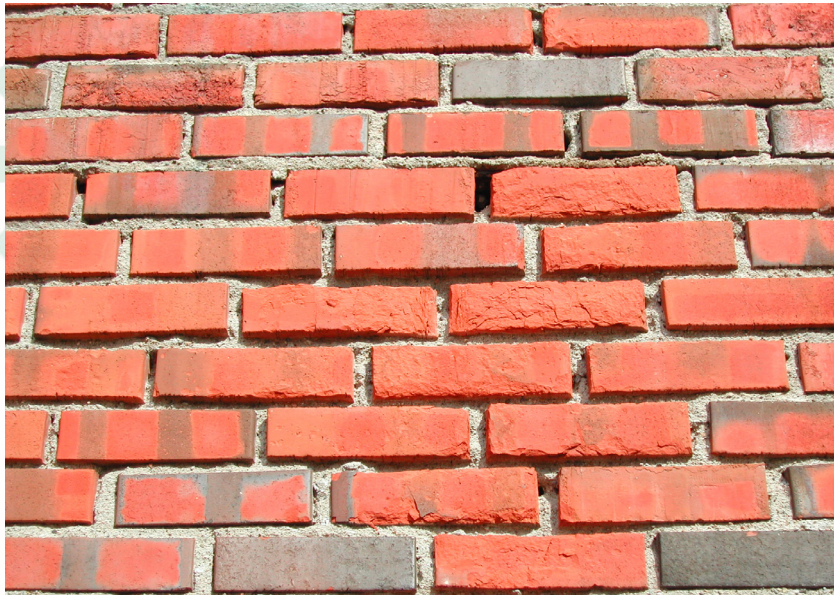


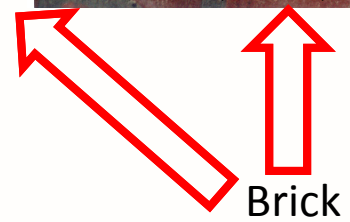
Photo: Kvanđe T., Lisø K.R., Waldum A. (2002) Rehabilitering av tak og teglfasader. NBI



Photo: Kvanđe T., Lisø K.R., Waldum A. (2002) Rehabilitering av tak og teglfasader. NBI



Photo: T. Kvanđe



Brick



# Building defects



Flooring



Source: S.Geving

## Building defects



Photo: Petter N. Hansen



Photo: SINTEF Building and Infrastructure



## Moisture measurements

Relative humidity (inside the pores of the materials)

Absolute moisture content (weight-%, volume-%)

Single measurement

Continuous measurements



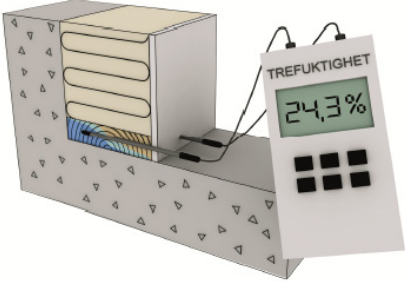
**Fuktmåling i bygninger**  
Instrumenter og metoder

**Byggforskserien**  
Byggedetaljer – september 2015

**474.531**

**0 Generelt**

**01 Innhold**  
Denne anvisningen behandler måling av fukt i bygninger. Anvisningen beskriver aktuelle instrumenttyper og metoder for å kartlegge eller måle fukt i materialer og konstruksjoner.  
Anvisningen angir ikke detaljerte krav til fuktinnhold. En innføring i teorigrunnet for fukt i bygninger er gitt i Byggedetaljer 421.132 *Fukt i bygninger. Teorigrunnlag*. Byggedetaljer 474.533 *Byggfukt. Uttørring og forebyggende tiltak* omhandler tiltak mot byggfukt i nye bygningskonstruksjoner. En mer omfattende behandling av fuktteori og -måling er gitt i håndboka *Fukt i bygninger* [751]. Anvisningen henvender seg til de som utfører fuktmålinger i bygninger og til bestillere og mottagere av fuktundersøkelser.



**Fig. 441 d**  
Eksempel på trefuktmåling med ekstra lange elektroder i forbored hull i en bunnsvill i en kjellerterverveg

# ➔ Relative humidity

Air cavities and insulation materials

Porous materials

Concrete, masonry

Destructive?

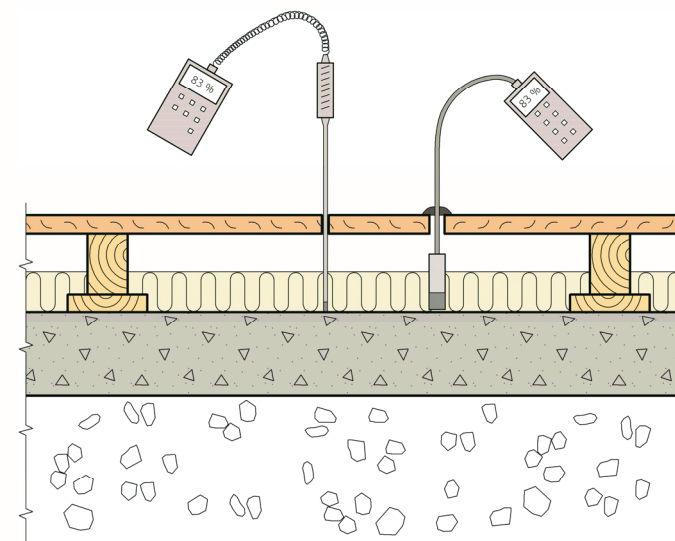


Illustration: Geving S. Fuktskader Årsaker, utredning og tiltak. SINTEF Byggforsk

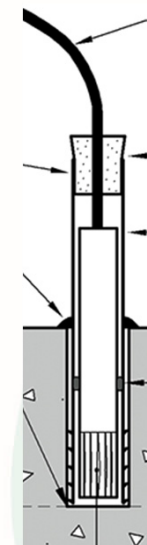
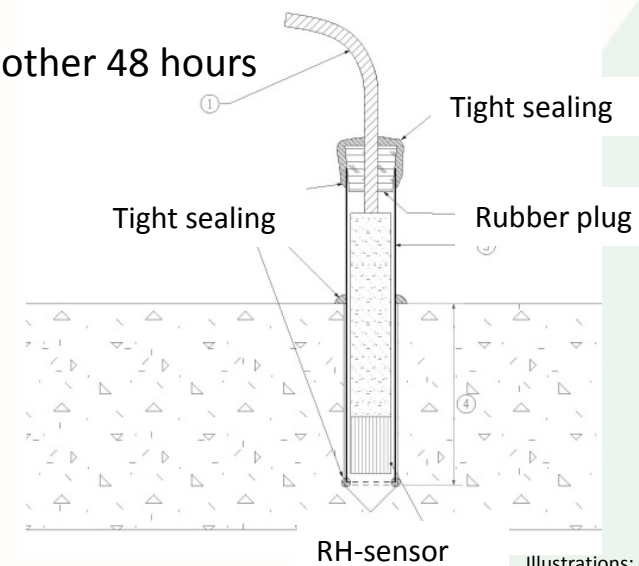
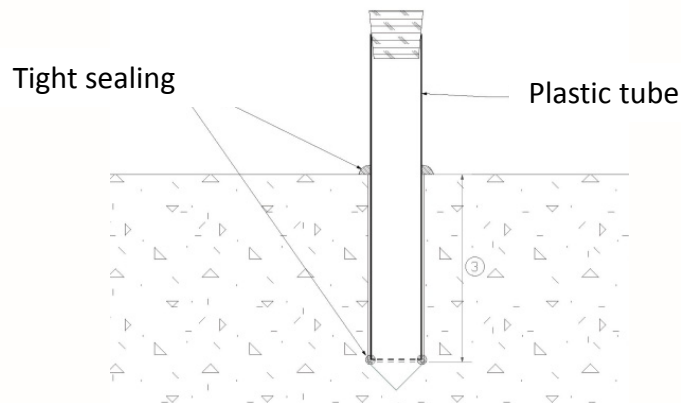


Illustration: Byggforskserien 474.531

# Relative humidity -Fresh cast concrete

### NS3511 Measurement of relative humidity in concrete

- 1) Drilling
- 2) Control the depth
- 3) Vacuum suction of the hole
- 4) Installation of plastic tube
- 5) Airtightness measurement
- 6) Rubber plug is installed in the plastic tube
- 7) After 3 days RH sensor can be installed. Wait for another 48 hours



Illustrations: NS 3512



# ➔ Drying and weighing

NS-EN 13183-1:2002  
Reference method  
High accuracy  
Long measuring period  
Destructive

$$\omega = \frac{m_1 - m_0}{m_0} \cdot 100$$

$m_1$  mass before drying

$m_0$  mass dry test slice



Illustration:www.norrona.net





# → Capacitance method

Application: Surface measurements, bathrooms, detecting water leakages, wooden boards

- Physical contact with the material
- Only surface measurement
- No moisture gradient
- Non-destructive

NS-EN 13183-3 Moisture content in a piece of sawn timber Part 3: Estimation by capacitance method



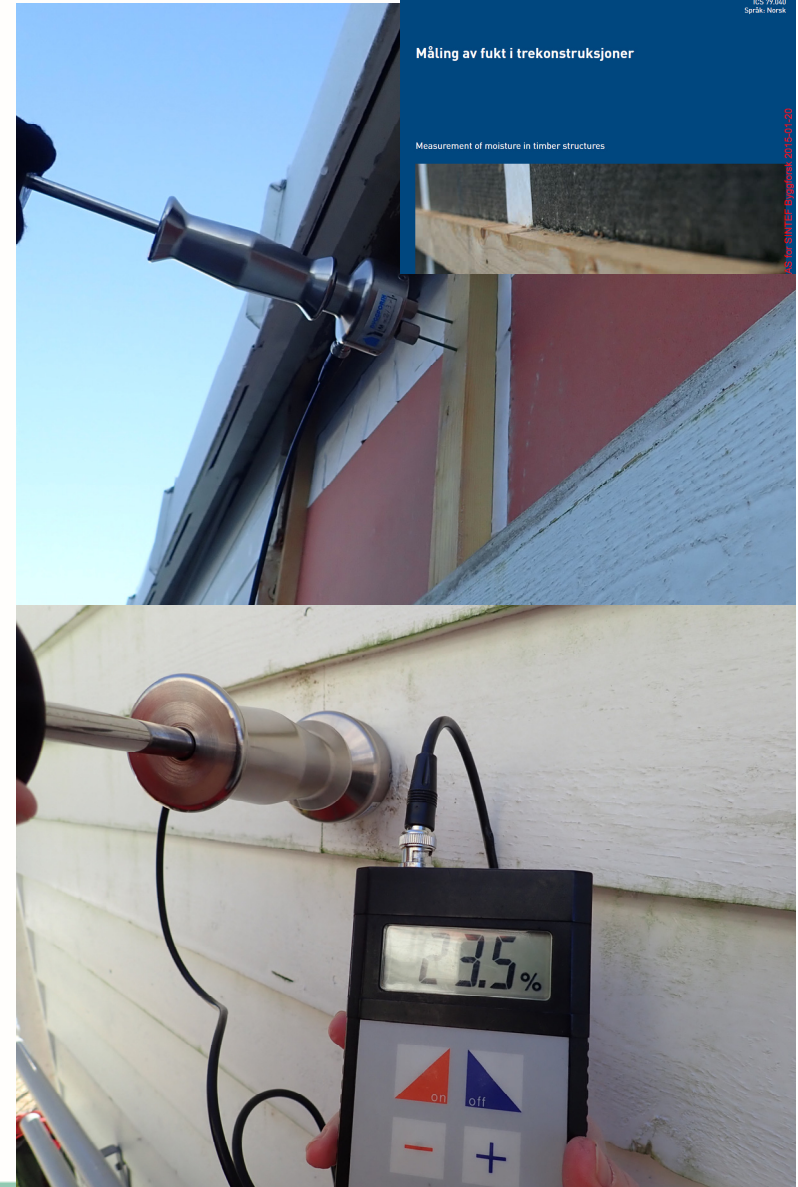
Picture: <https://verktoy24.no/elektroverktoy/slik-brukes-fuktmaleren-riktig/>

# ➔ Electrical resistance

**NS-EN 13183-2** Moisture content of a piece of sawn timber Part 2: Estimation by electrical resistance method

**NS 3512** Measurement of moisture in timber constructions

- Measuring range (8-28 weight-%)
- Temperature dependent; electrical resistance decreases by increasing temperature
- Uncertainty of 10 % associated with such measurements.
- Calibration to applied material
- Non-destructive



# ➔ Electrical resistance Challenging wood products

## Products with glue

- Plywood
- Wood fibre boards
- Glulam
- Cross laminated timber (CLT)

## Products with salts

- Impregnated wood

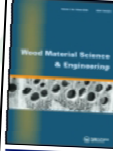


Illustration: <http://www.semproff.no/product/kryssfiner-poppel-22x2440x1220-bbcc/>



Illustration: [https://www.rakentaja.fi/artikkelit/11281/aanta\\_vaimentava\\_asennuslevy.htm](https://www.rakentaja.fi/artikkelit/11281/aanta_vaimentava_asennuslevy.htm)

# Recent studies Nordic climate



**Wood Material Science & Engineering**  
Taylor & Francis  
ISSN: 1748-0272 (Print) 1748-0280 (Online) Journal homepage: <http://www.tandfonline.com/loi/swoo20>


**Moisture conditions in well-insulated wood-frame walls. Simulations, laboratory measurements and field measurements**

Lars Gullbrekken, Stig Geving, Berit Time, Inger Andresen & Jonas Holme

**METHODS AND INSTRUMENTATION FOR MEASURING MOISTURE IN BUILDING STRUCTURES**

Jukka Voutilainen

Dissertation for the degree of Doctor of Science in Technology to be presented with due permission of the Department of Electrical Engineering, for public examination and debate in Auditorium S2 at Helsinki University of Technology (Espoo, Finland) on the 18th of March, 2005, at 12 noon.



**LUND UNIVERSITY**

**Moisture Safety in Wood Frame Buildings - Blind evaluation of the hygrothermal calculation tool WUFI using field measurements and determination of factors affecting the moisture safety**

Mundt Petersen, Solof



Judith Thomsen • Anna Svensson • Lars Gullbrekken

**SINTEF NOTAT** 13

**Evaluering av ni passivhusboliger på Rossåsen ved Sandnes**  
EBLE - EVALUERING AV BOLIGER MED LAVT ENERGIBEHOV, DELRAPPORT 1

**Moisture Convection Performance of External Walls and Roofs**


TARGO KALAMEES\* AND JAREK KURNITSKI  
Department of Energy Technology, Helsinki University of Technology  
PO Box 4100, FIN-02015 HUT, Finland  
(Received 20 July 2009)



Available online at [www.sciencedirect.com](http://www.sciencedirect.com)

**ScienceDirect**

Energy Procedia 78 (2015) 1455 – 1460



6th International Building Physics Conference, IBPC 2015

Laboratory investigations of moisture conditions in wood frame walls with wood fiber insulation

Stig Geving<sup>a\*</sup>, Erik Lunde<sup>a</sup>, Jonas Holme<sup>b</sup>

<sup>a</sup>Norwegian University of Science and Technology, NO-7491 Trondheim, Norway  
<sup>b</sup>SINTEF Building and Infrastructure, NO-7465 Trondheim, Norway



## Monitoring moisture content in constructions

The system has to fulfill some requirements:

- Not damage the construction, disturb as little as possible
- Consistent accuracy
- Enable mounting on or inside the construction
- Digital logging of results at equal time intervals (e.g. one hour)
- Climate data (room temperature, RH, material temperature)
- Electricity (batteries or plug in)
- Reliable at different climates

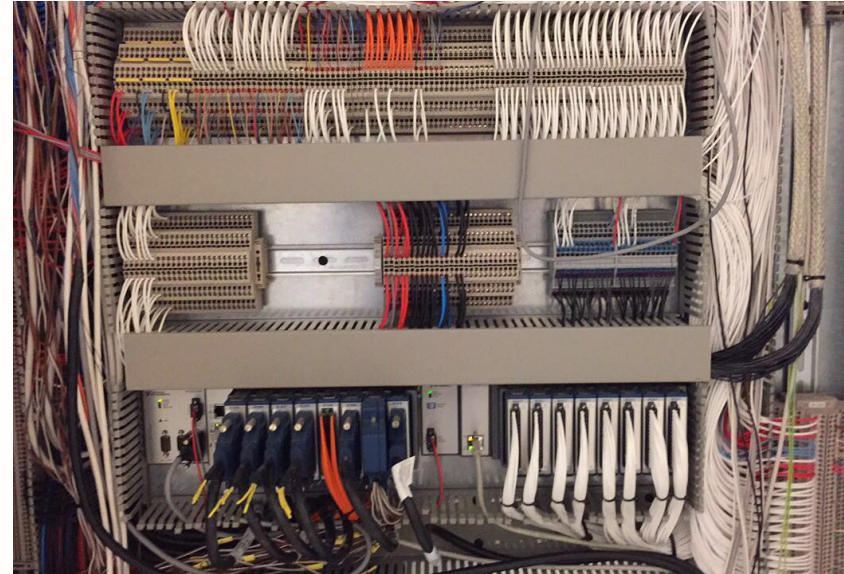


Illustration: [www.finiserra.no](http://www.finiserra.no)

# ➔ Continuous long term measurements



Illustrations: [www.finisterra.no/produktkategori/fukt](http://www.finisterra.no/produktkategori/fukt)



# ➔ Position of sensors

## Where?

- Critical location
- Bottom sill, double bottom sills
- Insulated/ non-insulated electrodes

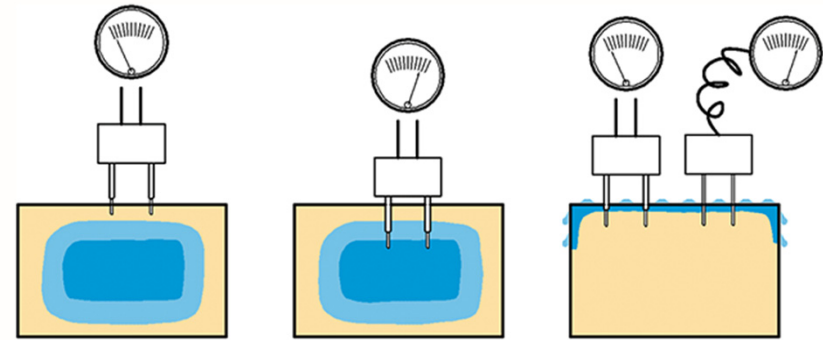
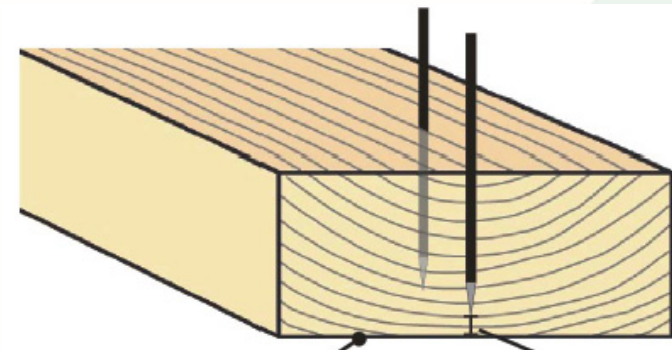


Illustration: Byggforskserien 474.531 Fuktmåling i bygninger. Instrumenter og metoder



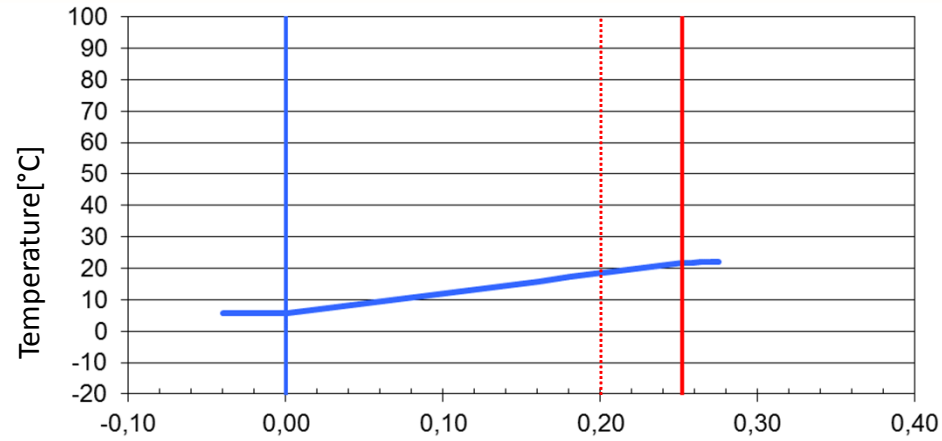
Critical location 5 mm

Illustration: NS 3512

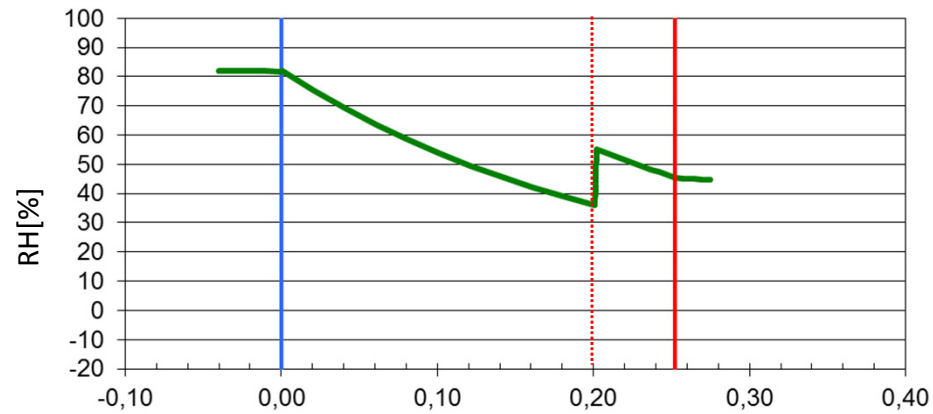
# Experiences



Outdoor  
7 °C



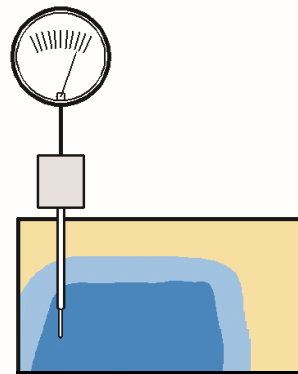
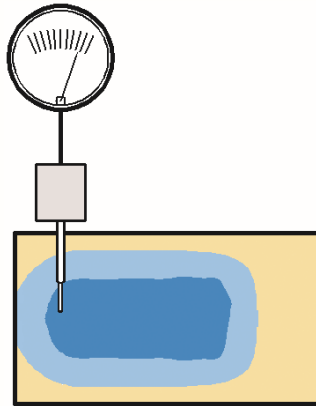
Indoor  
22 °C



Source: S. Uvsløkk



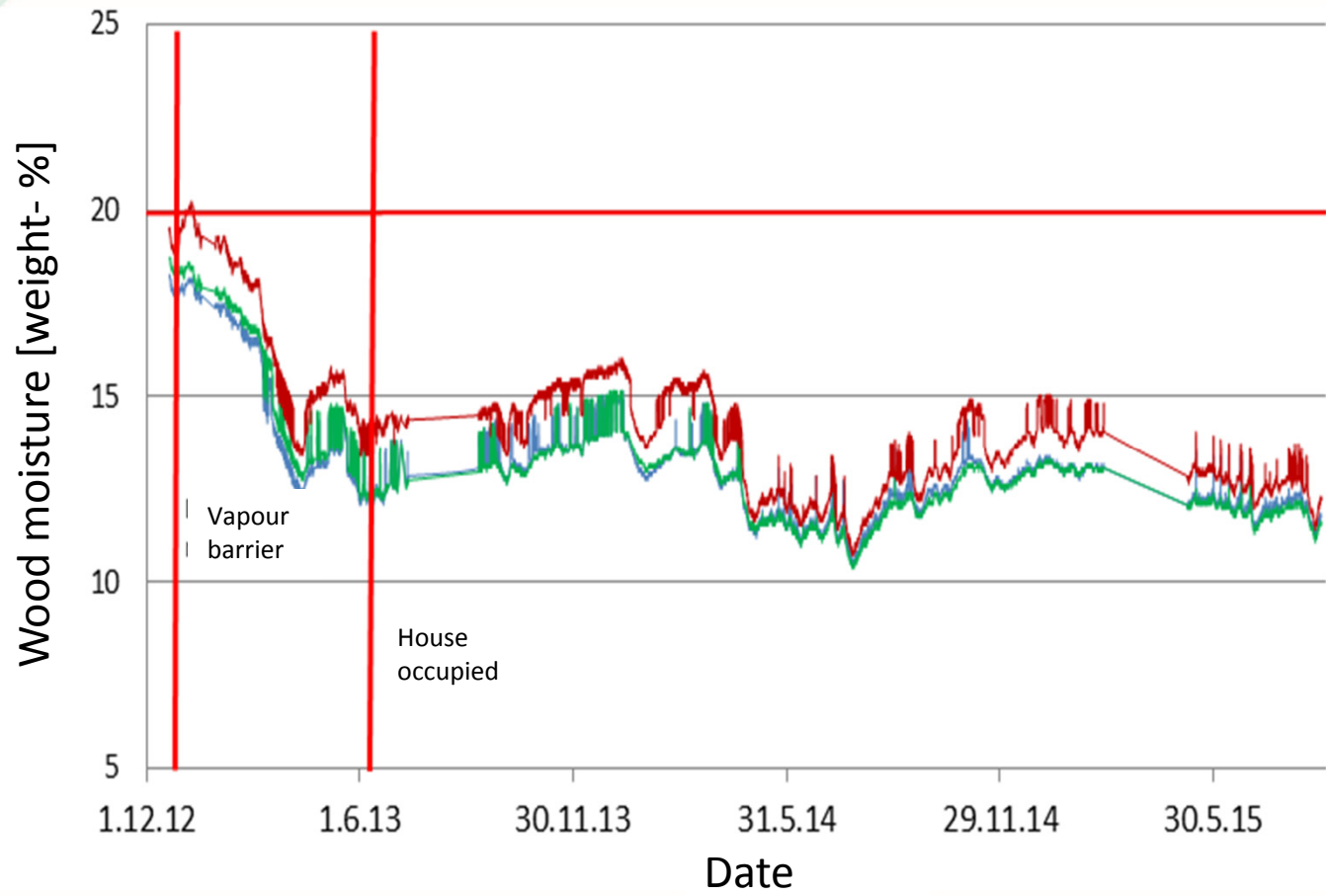
# ➔ Practical example



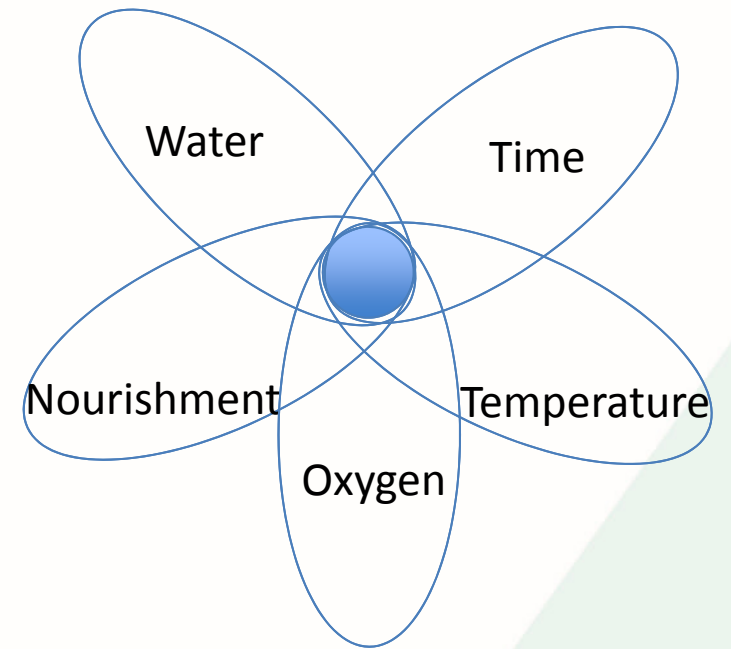
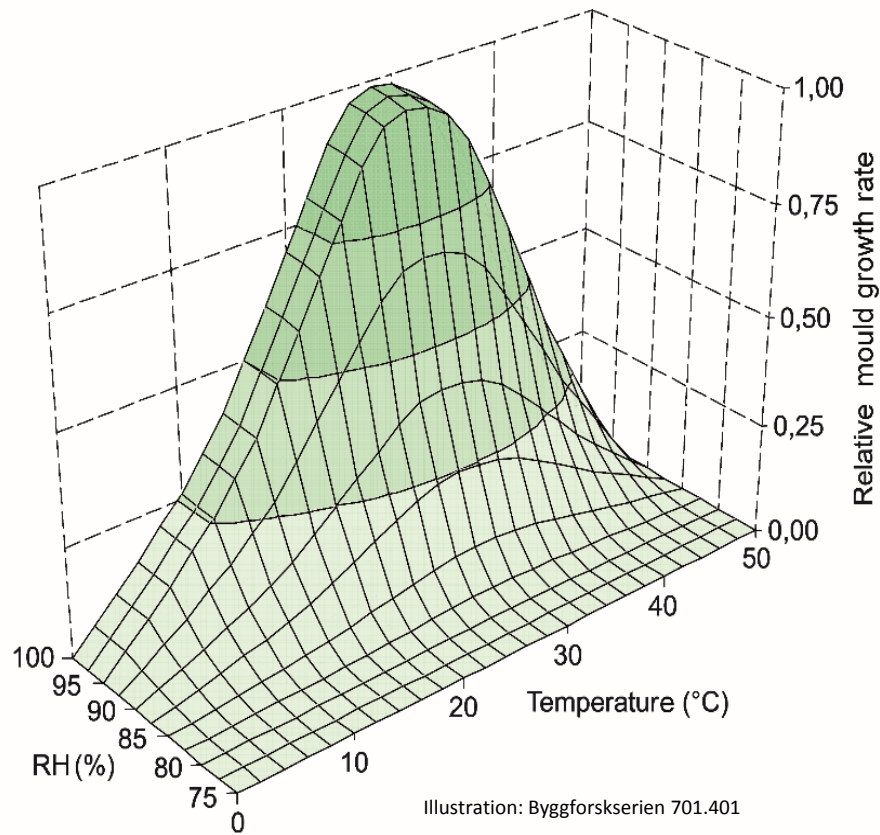
Illustrations: Remy-Eik Nikolaysen, SINTEF



# Experiences



# ➔ Mould growth





## Critical moisture level

### Norwegian building legislation (TEK17) § 13-9.

Groundwater, overflow, rainfall, drinking water and humidity should not penetrate and cause moisture damage, mould formation or other hygienic problems.

### Guidance document § 13-9

- 1) Keep building materials dry during storage, transport and constructions
- 2) Materials, products and building parts must endure the anticipated moisture strains without affecting the indoor environment negatively

**Documented solution: Byggforskserien 523.255 Timber frame constructions. Insulation and tightening:**

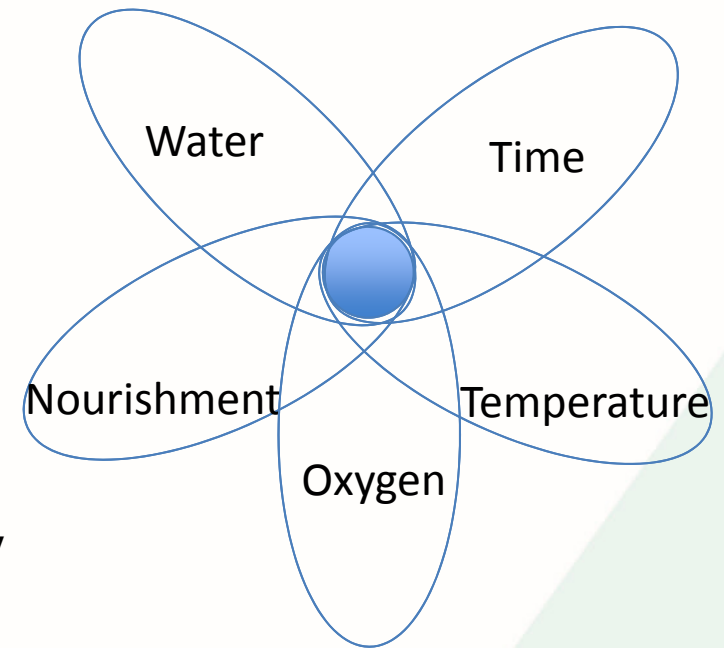
**20 weight-%**



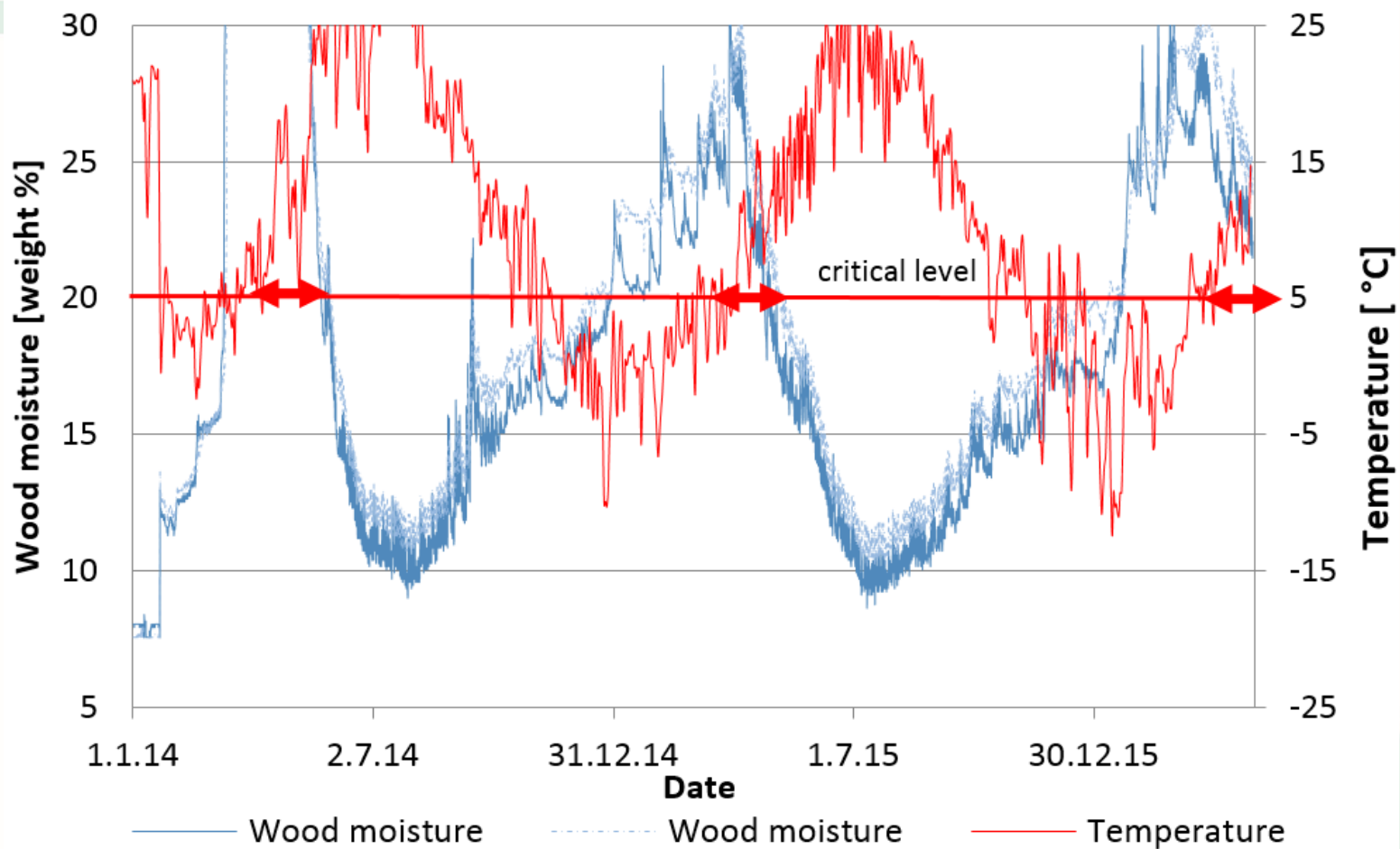
# Mould growth criterias

"Rule of thumb":

- Larger wood moisture content than 20 weight-% (corresponds to a relative humidity level of 80 % at 20 °C)
- Temperature (minimum 5 °C)
- Time for growth to start (minimum four weeks)

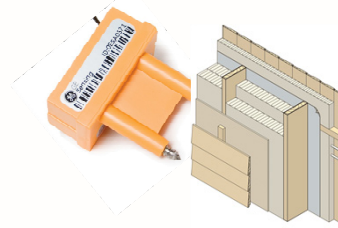


# Experiences



# → Challenges of field measurements

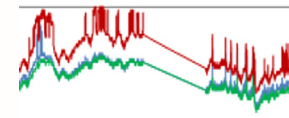
- Effect of introducing measuring sensor
- Communication between the sensors and the logging unit
- Missing data
- Measurements in wood products
- Corrosion of the electrodes



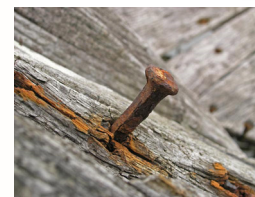
Source: Byggforskserien 523.255



Source: <https://elhandel.no/>



Source: <http://www.greenspec.co.uk/>



# → Future possibilities

- Cheaper and simpler hardware
- Online sensors
- Possibility to monitor moisture conditions in walls and roofs in order to notify if problems occur
- Monitor possible leakages in bathrooms; install monitoring units on the membrane at the drain



Illustration: netonnet.no



# ➔ Future possibilities

- Integration of sensors into the Operation Administration and Management (OAM)-systems
- BIM integration

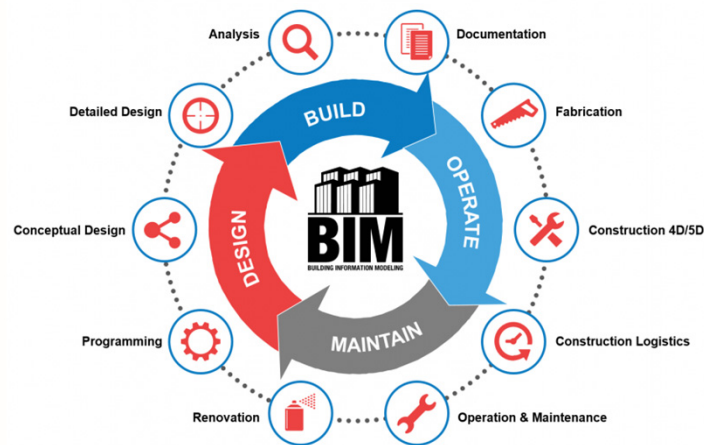






Illustration: <https://www.realserve.com.au>

## Summary

Measurement method	Materials	Use	Limitations	Destructive?
Capacitance 	Porous materials	Search for areas with increased moisture values	Only surface No moisture gradients	Non-destructive
Electrical resistance 	Wood	Absolute moisture content	Electrodes must penetrate the wood Calibration curves is needed	Non-destructive Destructive
RH 	Porous materials	RH inside material or air cavity	Holes must be drilled Calibration Takes time	Non-destructive Destructive
Drying and weighing 	Porous materials	Absolute moisture content High accuracy	Samples must be taken from the construction	Destructive

Source: Byggforskserien 474.531



Thank you for the attention

PhD-candidate Lars Gullbrekken



Picture: Anne J. Gullbrekken