Risk of performance failure in new low energy buildings and retrofitted building envelopes

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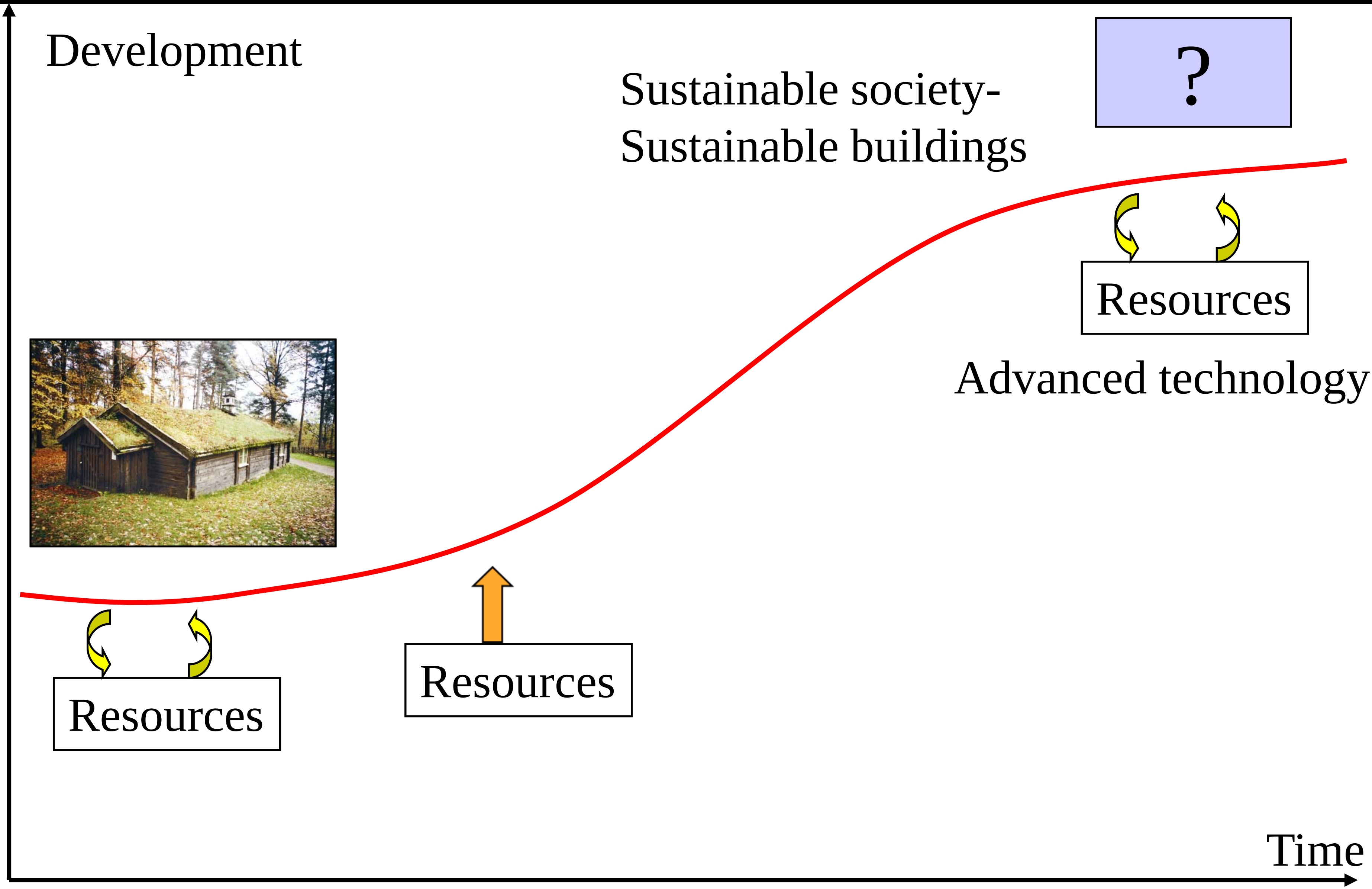
Outline of presentation

- Need for energy efficiency improvements - sustainability
- Changed building design – new risks
- Building performances
- Old mistakes… why do we forget (or ignore)
- Example: Walls, ventilated roof, cold attics
- Mould risk in building envelopes
- Probabilistic approach- Reliability assessment!
- Screening of possible problems with new low energy buildings


Development
Sustainable society-
Sustainable buildings
?
Resources
Advanced technology
Resources
Resources
Time

Old and new buildings!
Trends: Retrofitting and passive houses

Potential energy saving (according to the IEA)
of 20-60% in residential space heating and conditioning

In Sweden:
Upgrading to new low energy building performance;
-37 TWh
To today's building standard
-15 TWh

The top-level performances:

- Indoor air quality
- Thermal comfort

The demands from the society:

- Energy <--- Too much in focus?
- Durability

Sublevel performances:

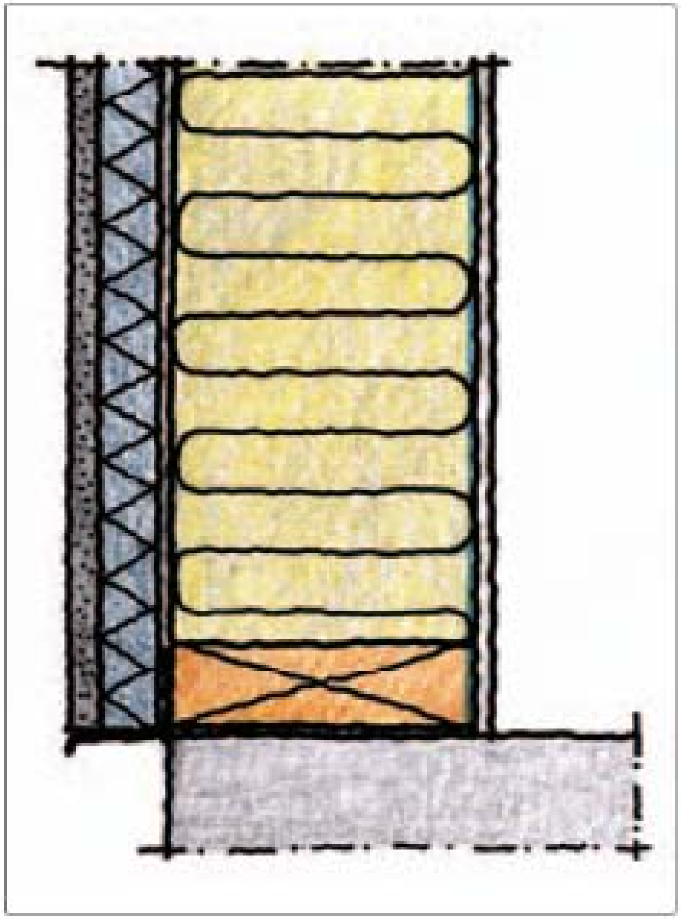
- Thermal protection
- Wind protection
- Rain protection
- Moisture safety
- Air tightness
- Frost safety

…

Moisture sources
A threat to the buildings

- Precipitation
- Moisture in air
- Ground moisture
- Construction damp
- (Leakage)

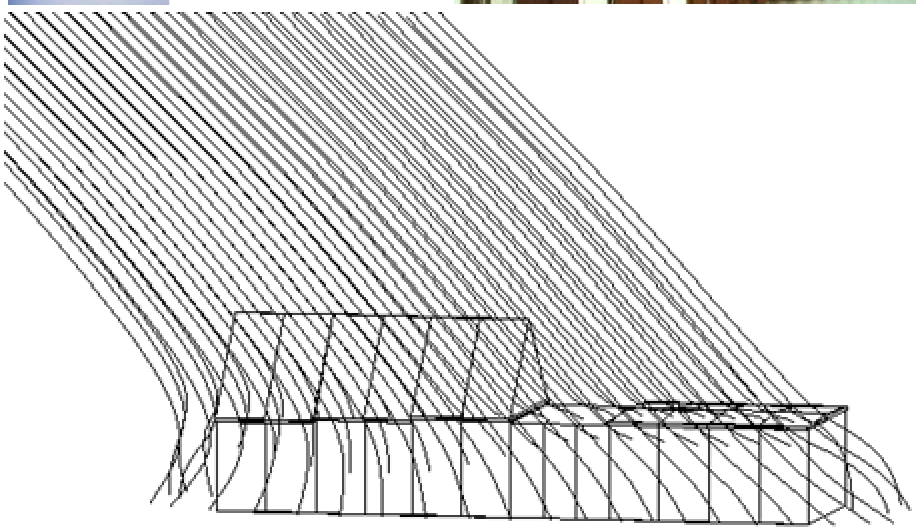
Problems with facades in Sweden
- external insulation sometimes a problem



Exterior surface of gypsum board

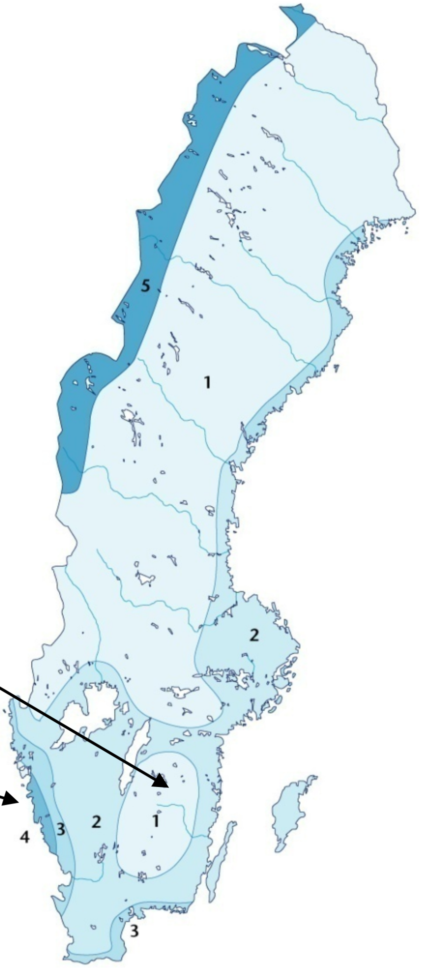
German experiences are positive – Stone houses/mineral based walls

Driving rain



Driving rain – how much hits a wall?

Zone	Year	Day (kg/m^2)
1	150	30
2	300	45
3	450	55
4	550	70
5	100-400	Lok.variation



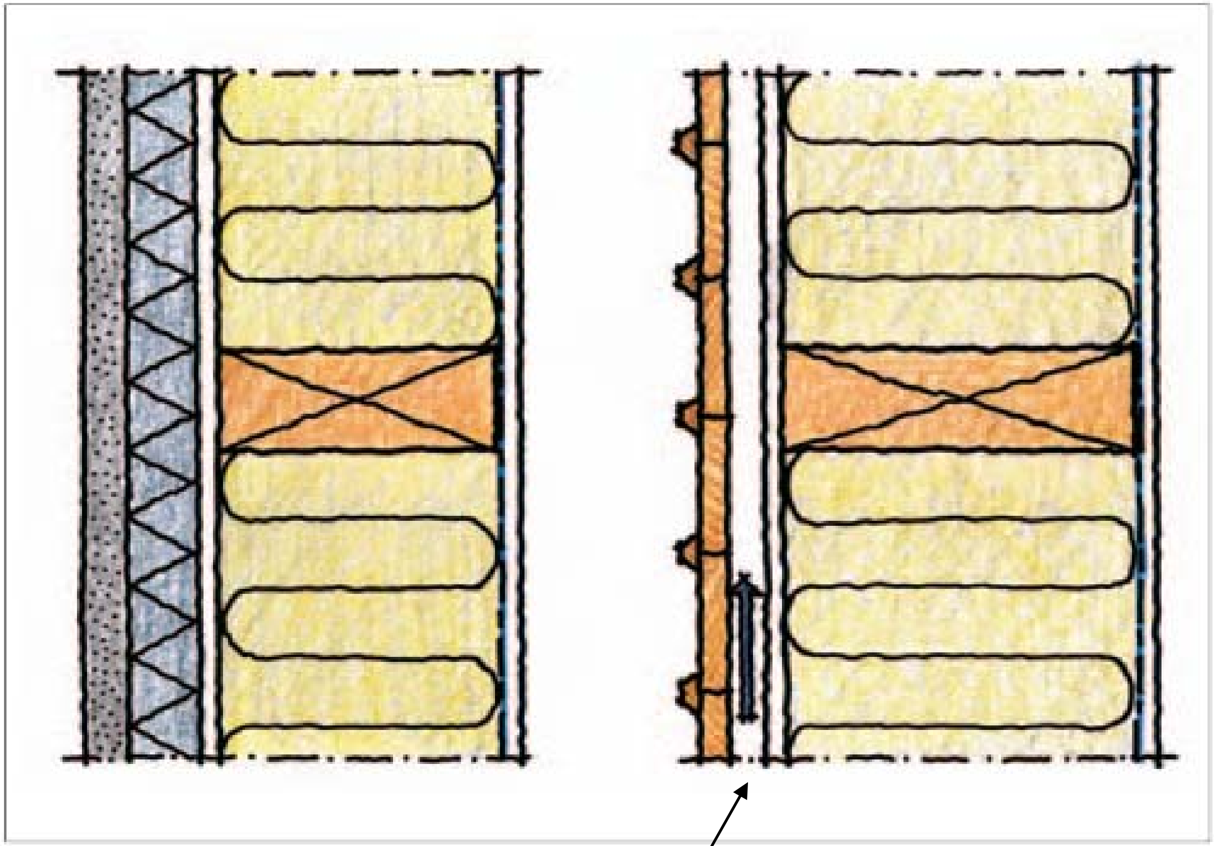
Fritt slagregn i utsatt läge

Construction damp:

Already their at the start

Ex. Wood 20 kg/m^3, Concrete 0-115 kg/m^3

Lightweight concrete 80-180 kg/m^3

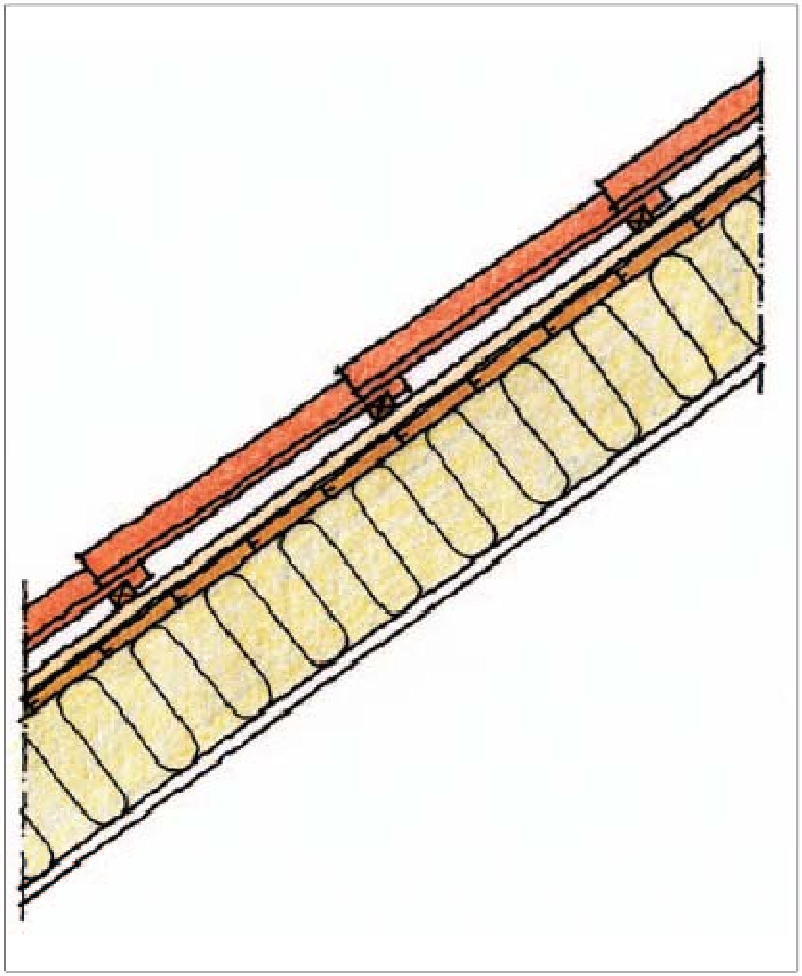


Traditional ventilated cavity –
more robust for timber-framed constructions!

But is ventilation always good?

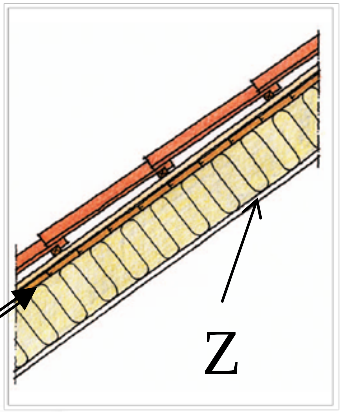
No risk?

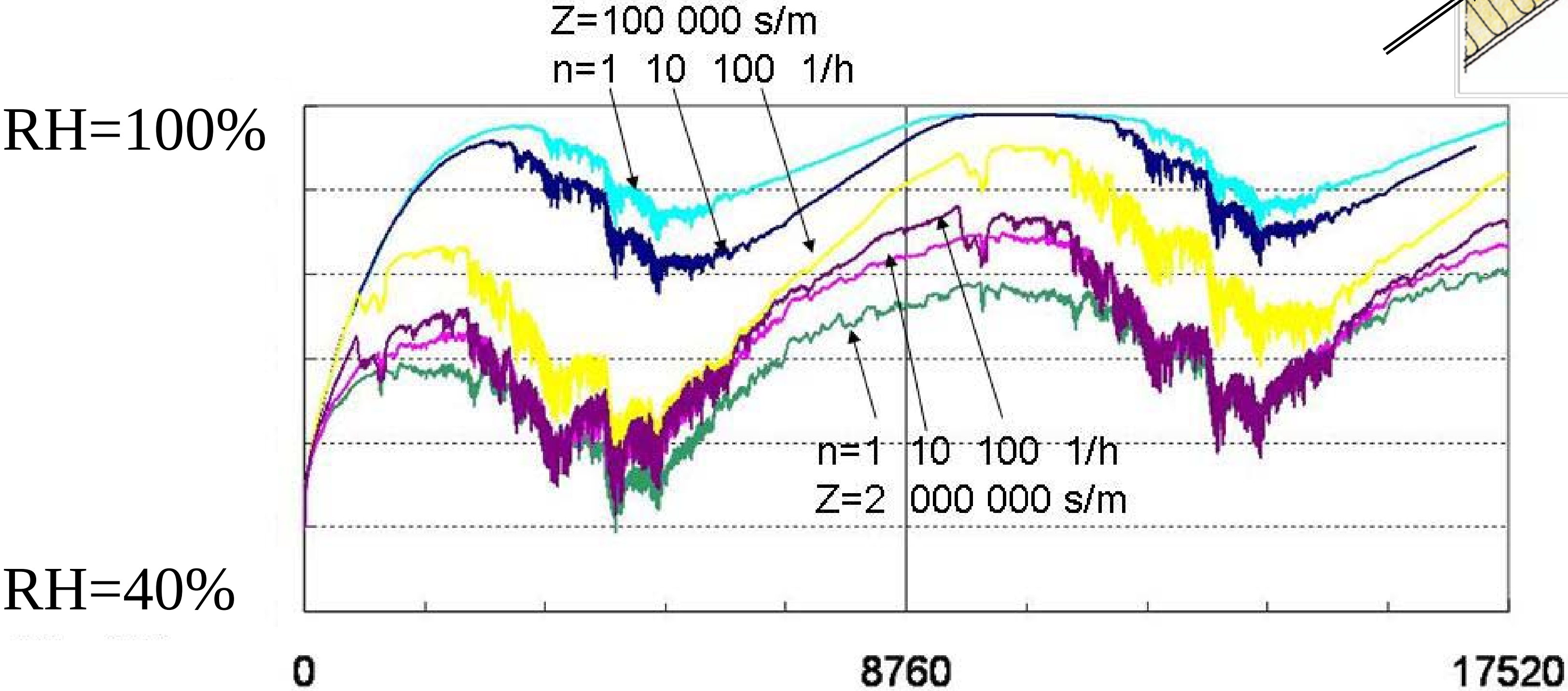
Ventilated cavity in thermally insulated roofs



Example from:

5 cm ventilated air cavity





1:st of Jan 1 year hours since start

Mould growth in cold attics

Problems!

At least 60% (maybe up to 84%) of the existing buildings

in the area around Gothenburg have mould growth in their attics!

In Sweden: Approx 2 million buildings, 73 +/-7 % have cold attics

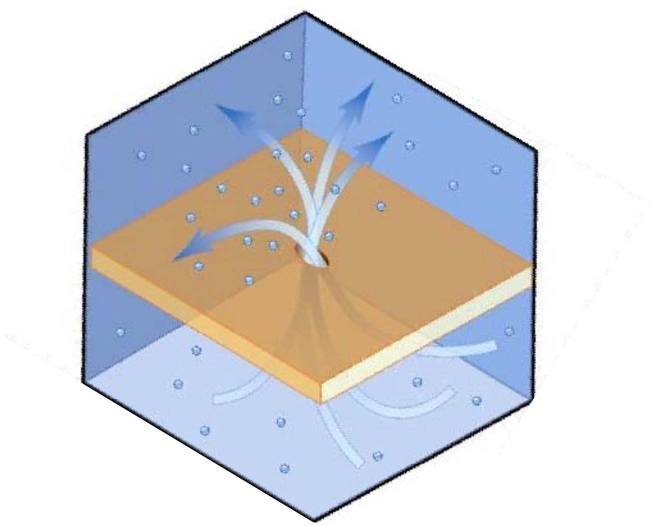
Correct ventilation?

- Construction damp → Requires ventilation
- Moisture entering from occupied space → Requires ventilation
- Vapor in outdoor air → Minimize the ventilation

Difficult to design!

- An air tight attic floor should be achieved – but is difficult to guarantee

- Ventilation system, heating system, moisture production and external climate influences the performance.

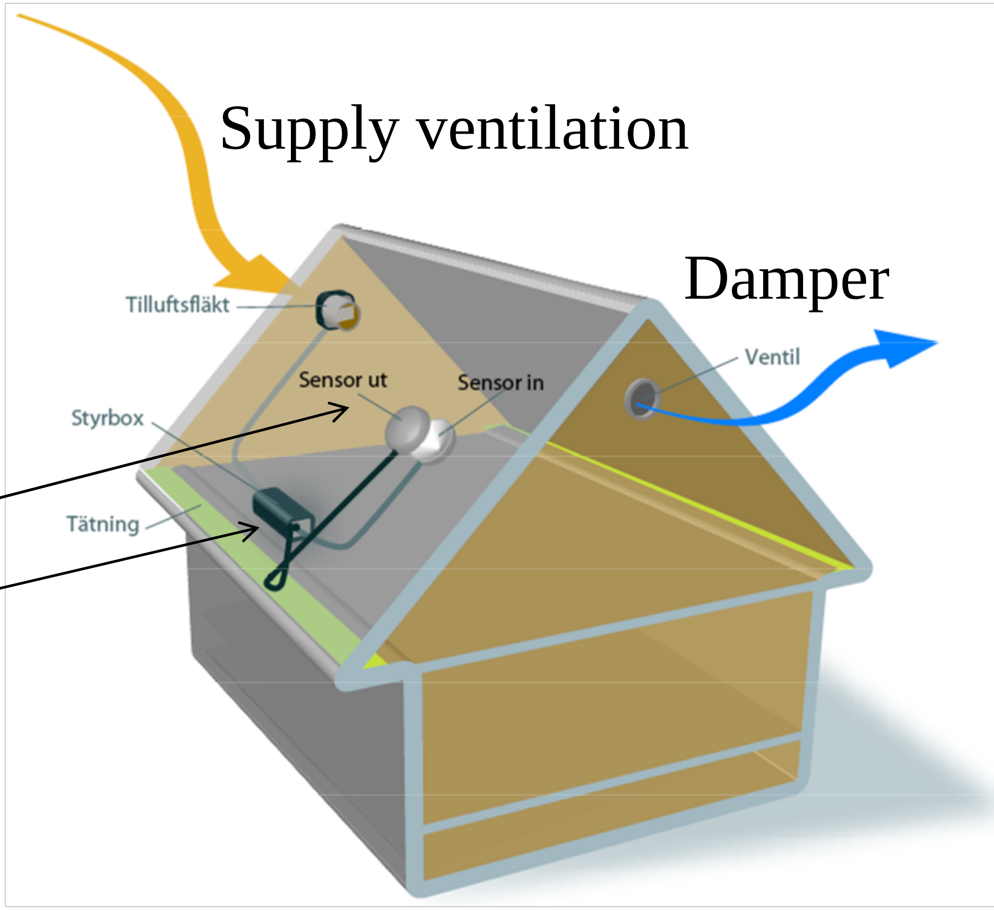


One innovative solution!

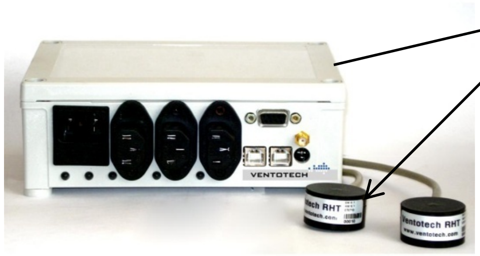
Controlled ventilation of the attic

An active ventilation that;

- Match the ventilation rate to the demand at the present situation
- Uses the natural variations of the weather
- Best effect when attic is as air tight as possible



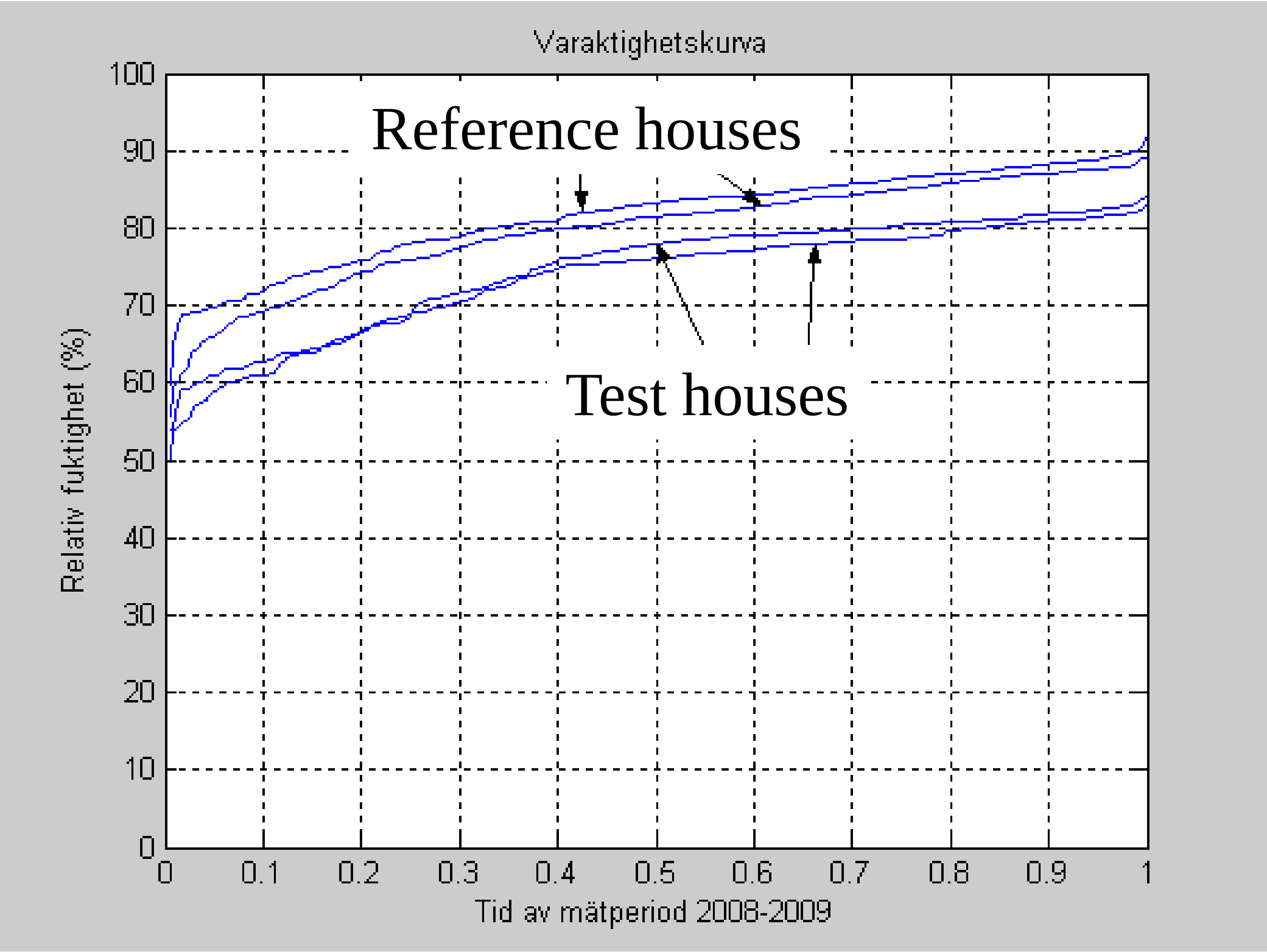
Sensors



Field tests:

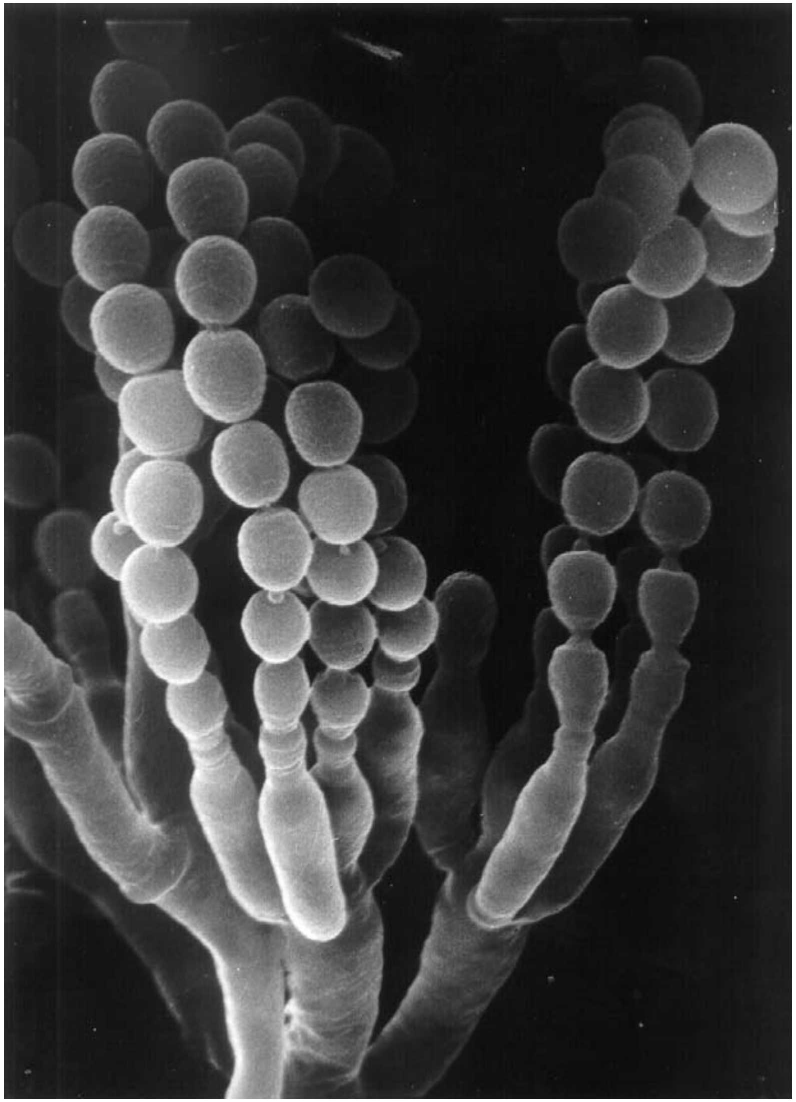
RH-Duration curves; Test and reference houses, winter 2008-2009

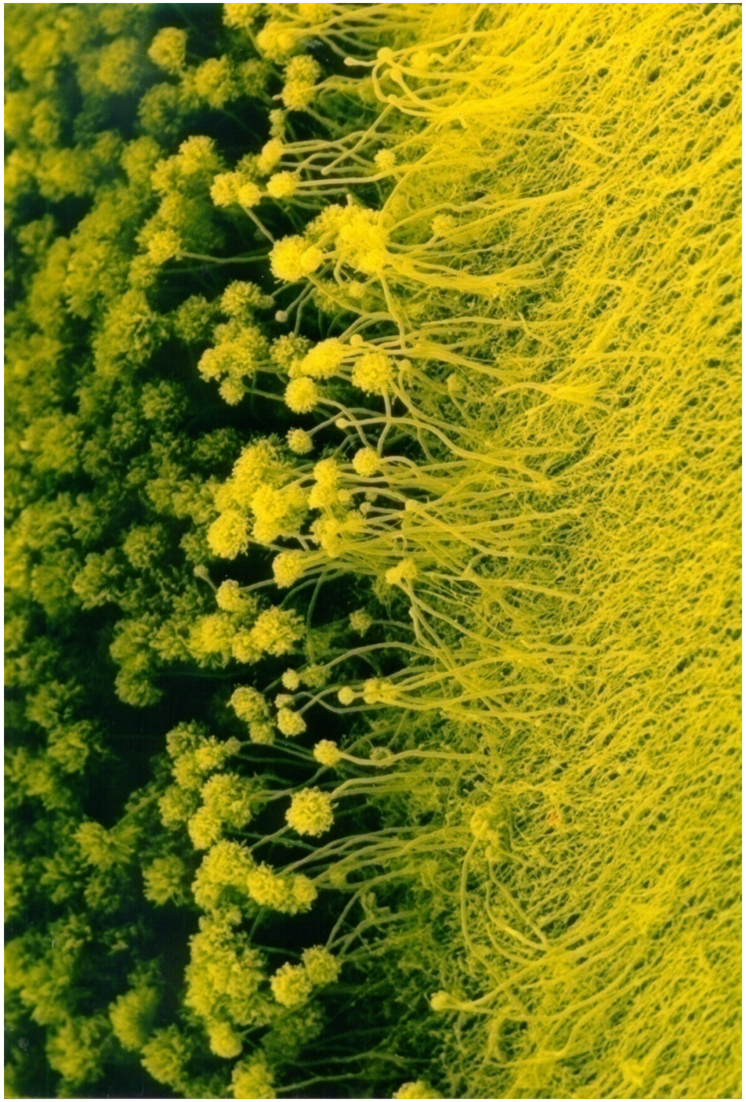
RH (%)



Fraction of time below certain RH

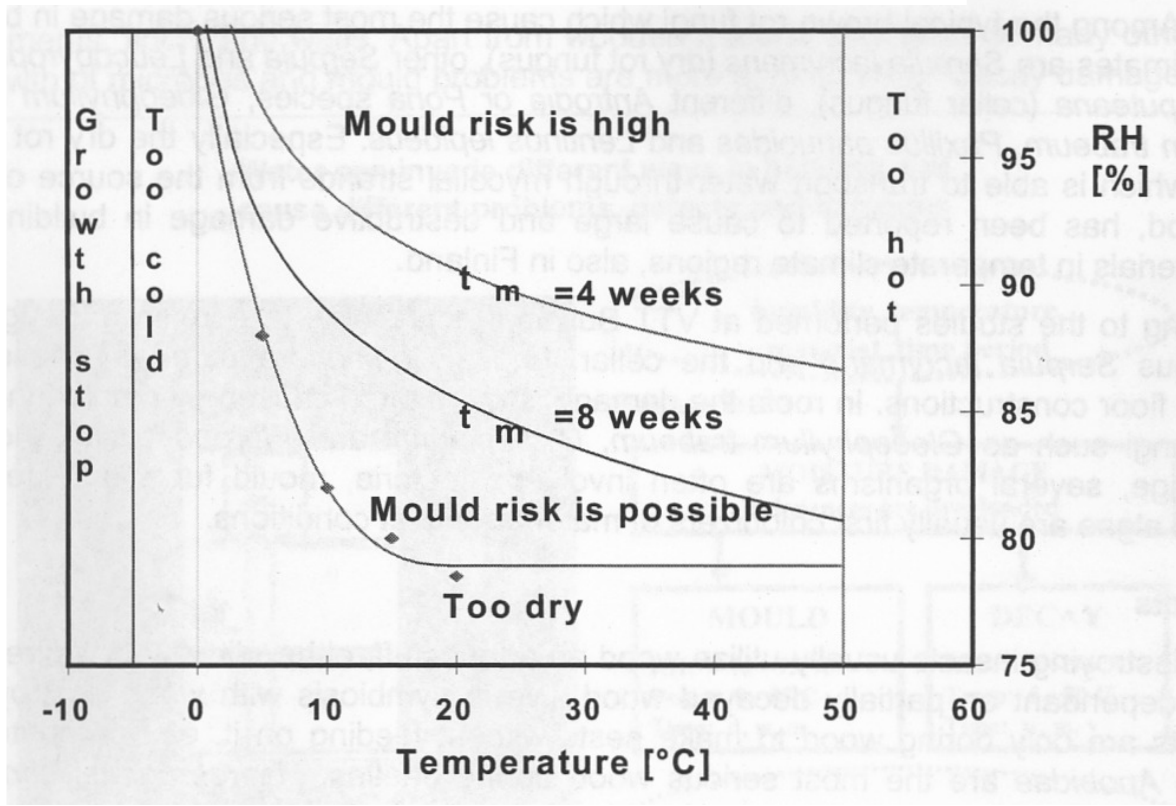
Mould risk?





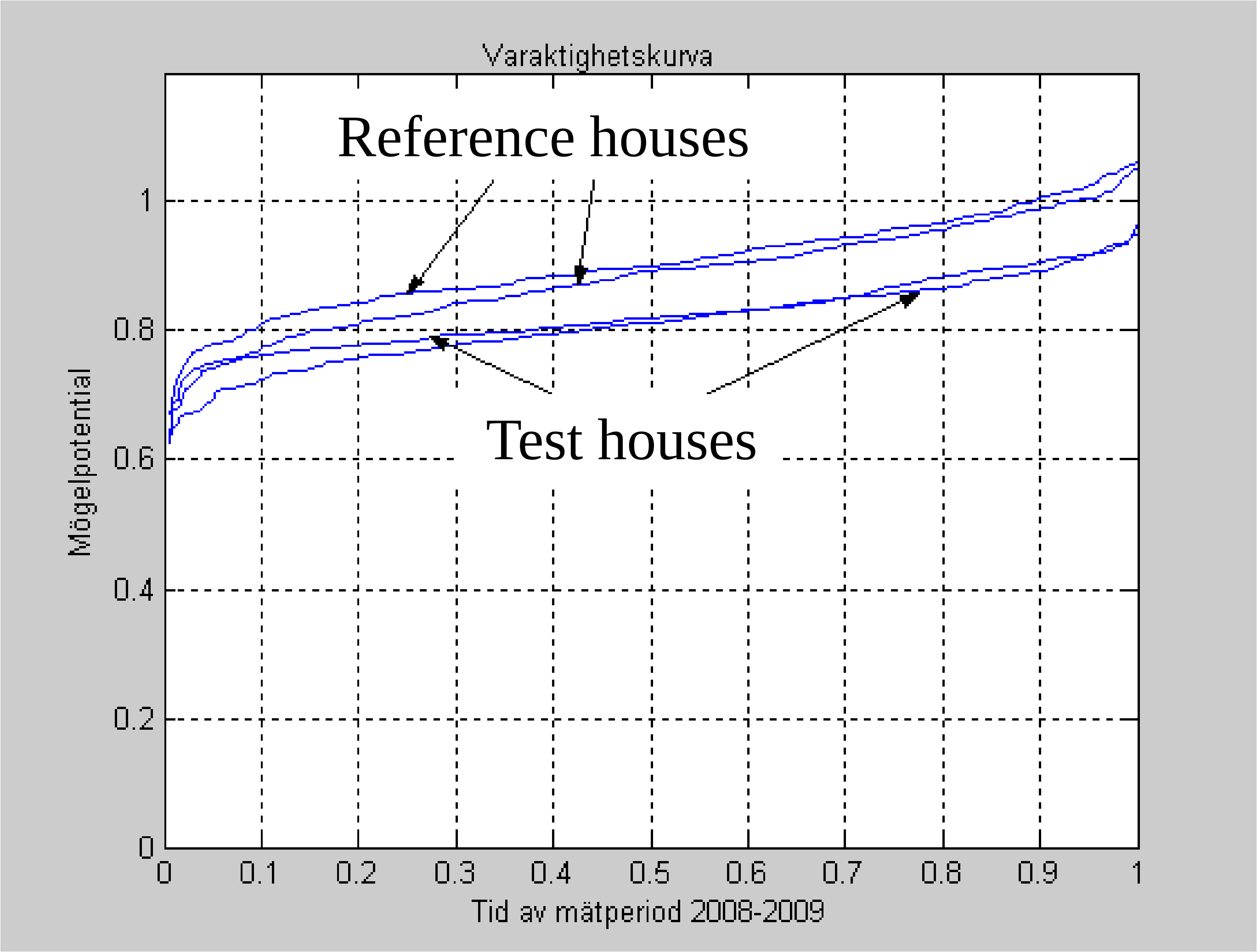
Index	Growth rate	
0	No growth	Spores not activated
1	Some growth detected only with microscopy	Initial stages of hyphae growth
2	Moderate growth detected with microscopy	Coverage more than 10 %
3	Some growth detected visually	New spores produced
4	Clear visually detected growth	Coverage more than 10 %
5	Plenty of visually detected growth	Coverage more than 50 %
6	Very heavy and tight growth	Coverage around 100 %

Mould index, (Viitanen)

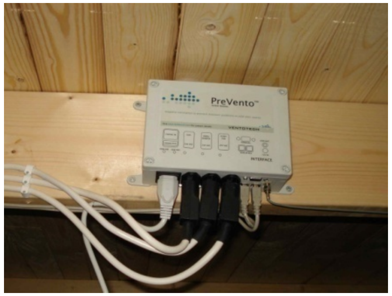


Mould growth potential
-Duration curves; Test and reference houses, winter 2008-2009

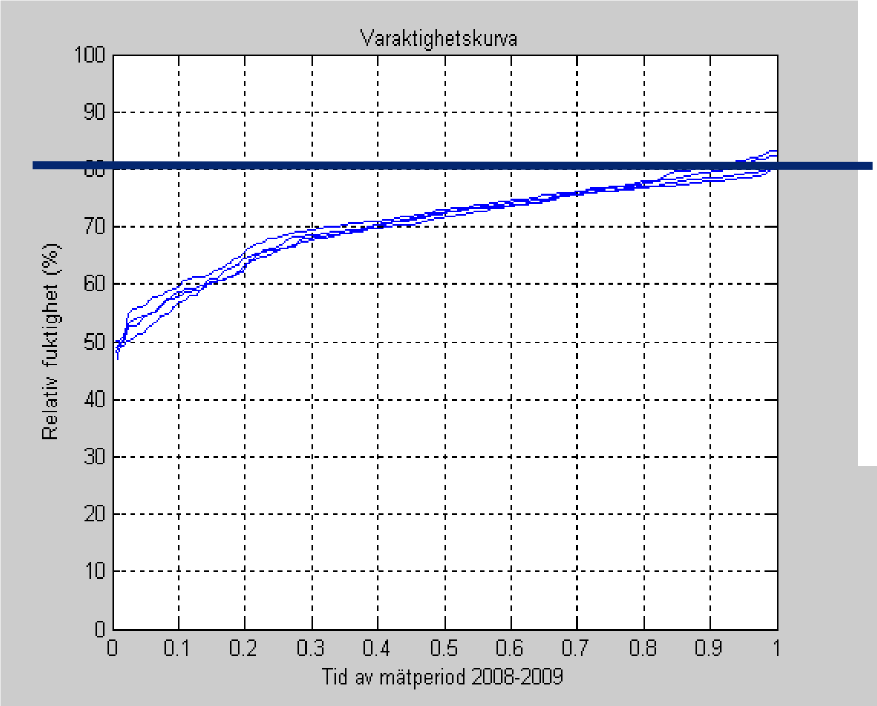
$RH/RH_{critical}$



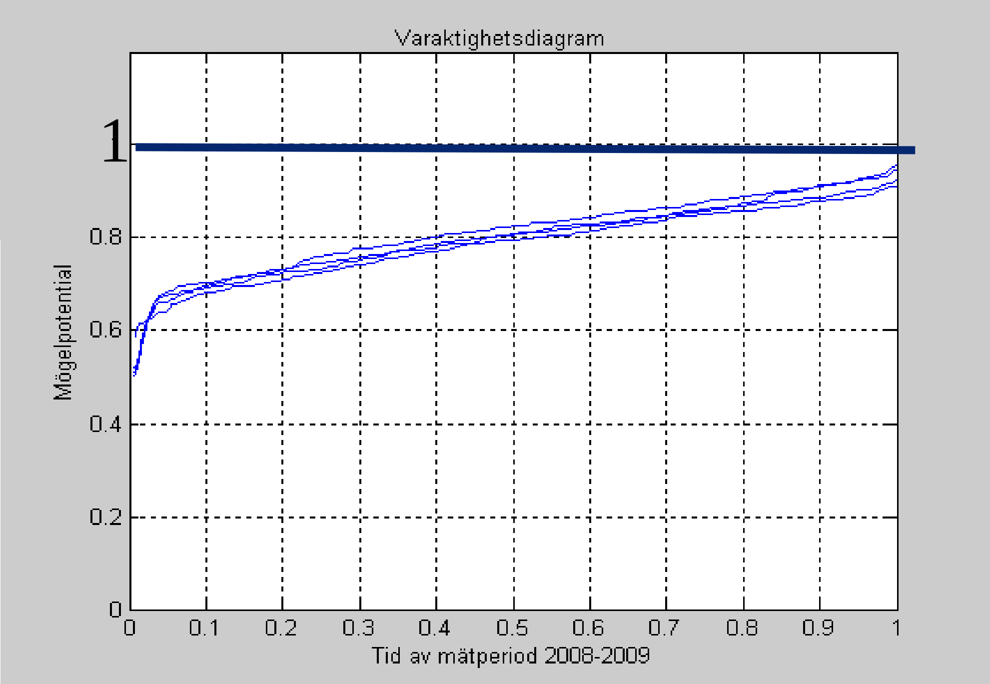
Largest passive house in Sweden (Hamnhuset) Göteborg



RH



RH/RH$_{critical}$



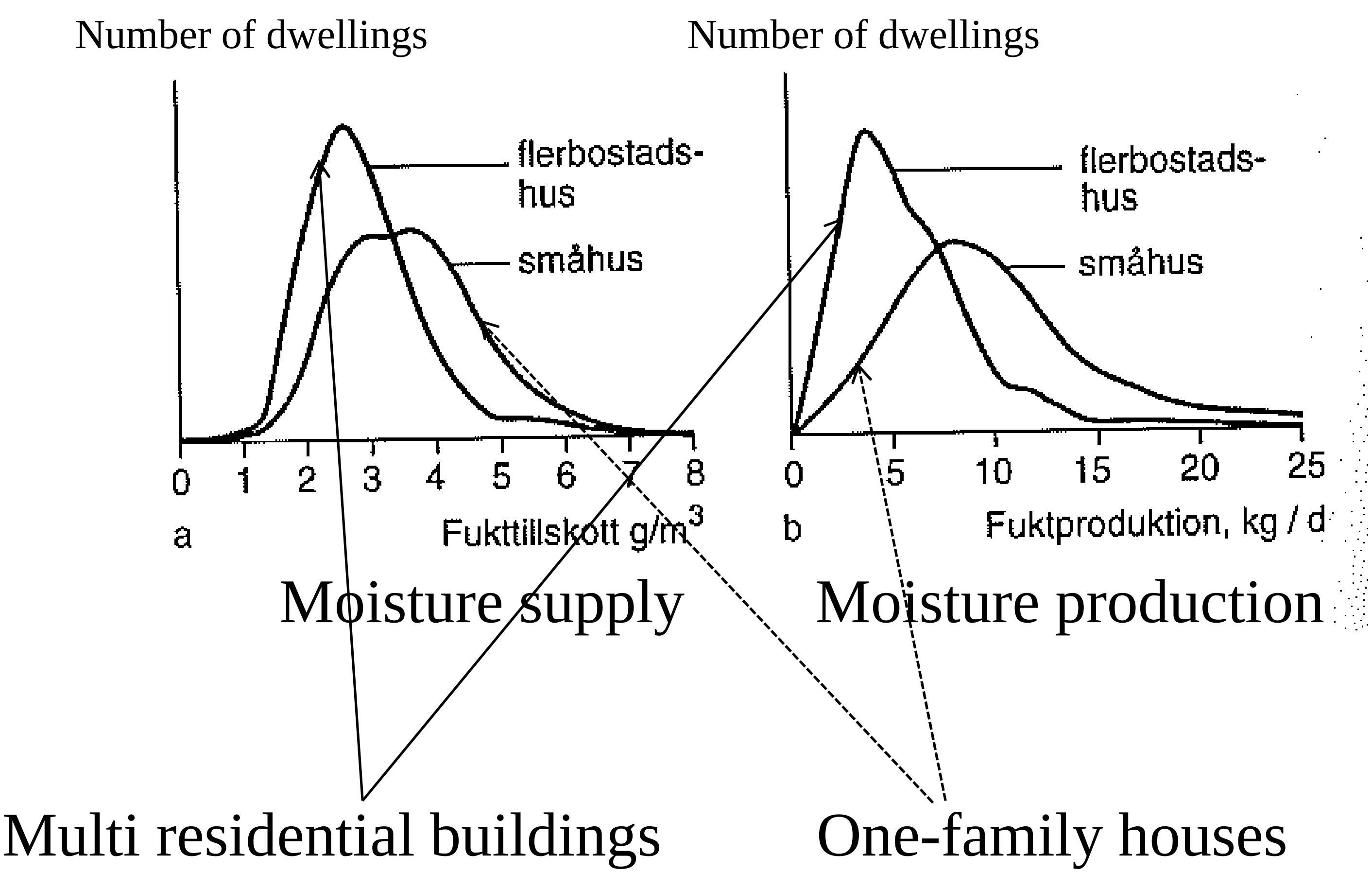
Indoor moisture supply

Moisture production

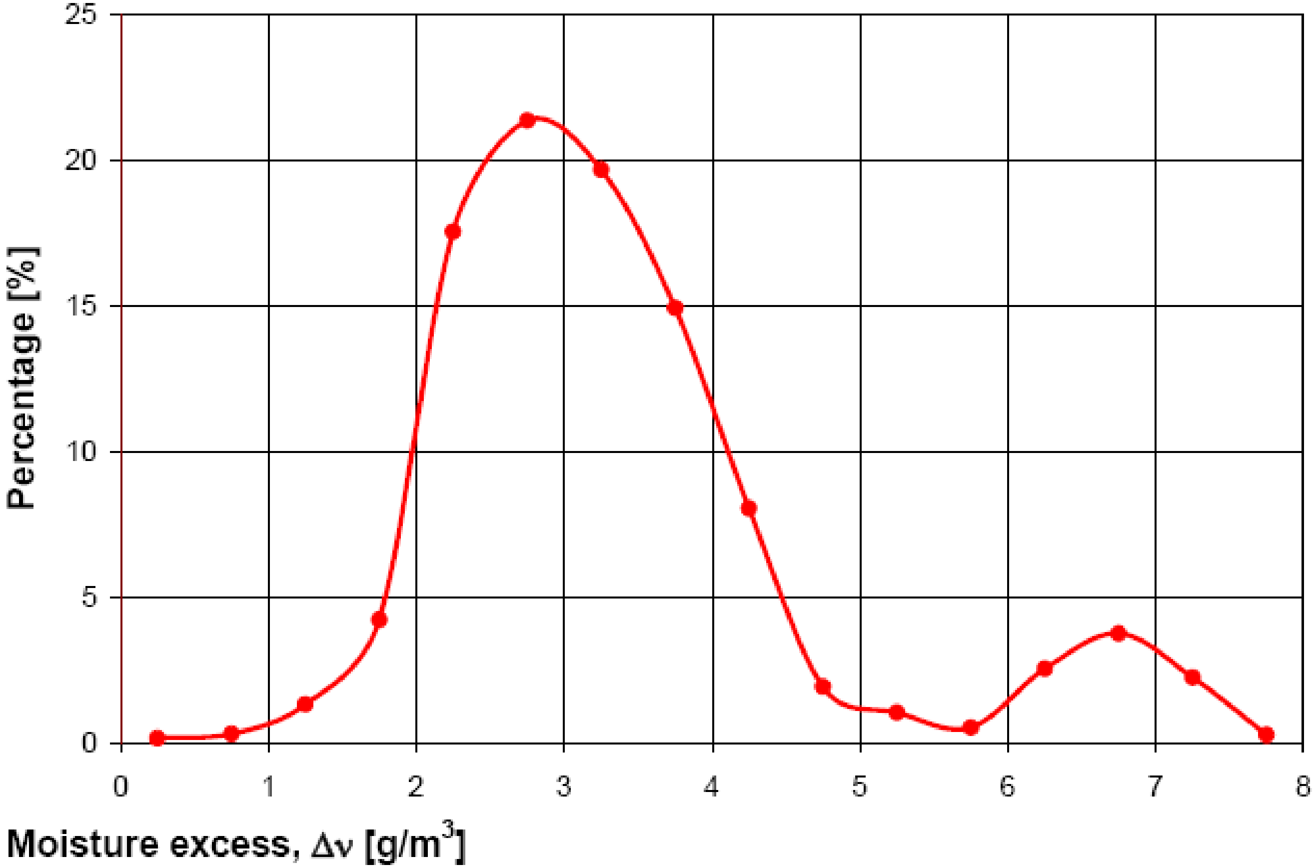
Higher ventilation rates – smaller moisture supply!

The level of the interior moisture supply can be important! But how big is it?

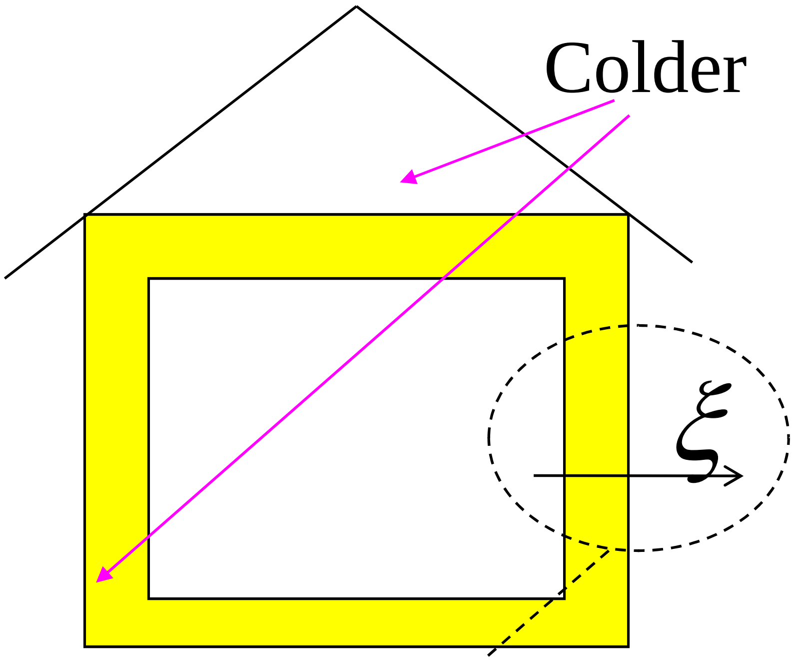
Field study of 2000 Swedish dwellings

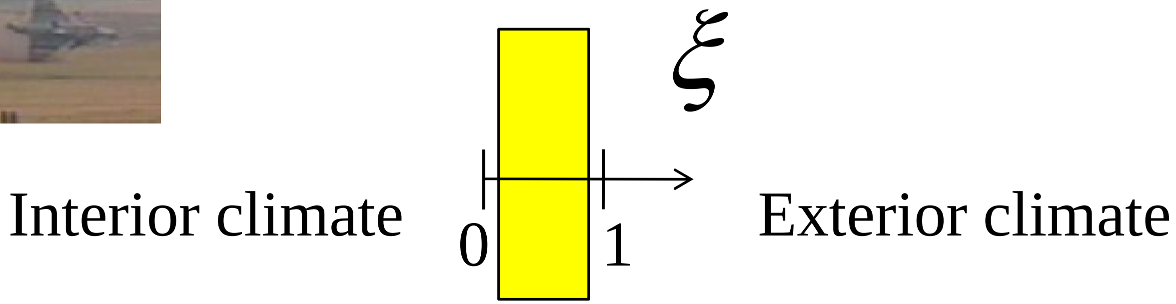


Measured indoor moisture supply in 13 Estonian departments during a winter period.

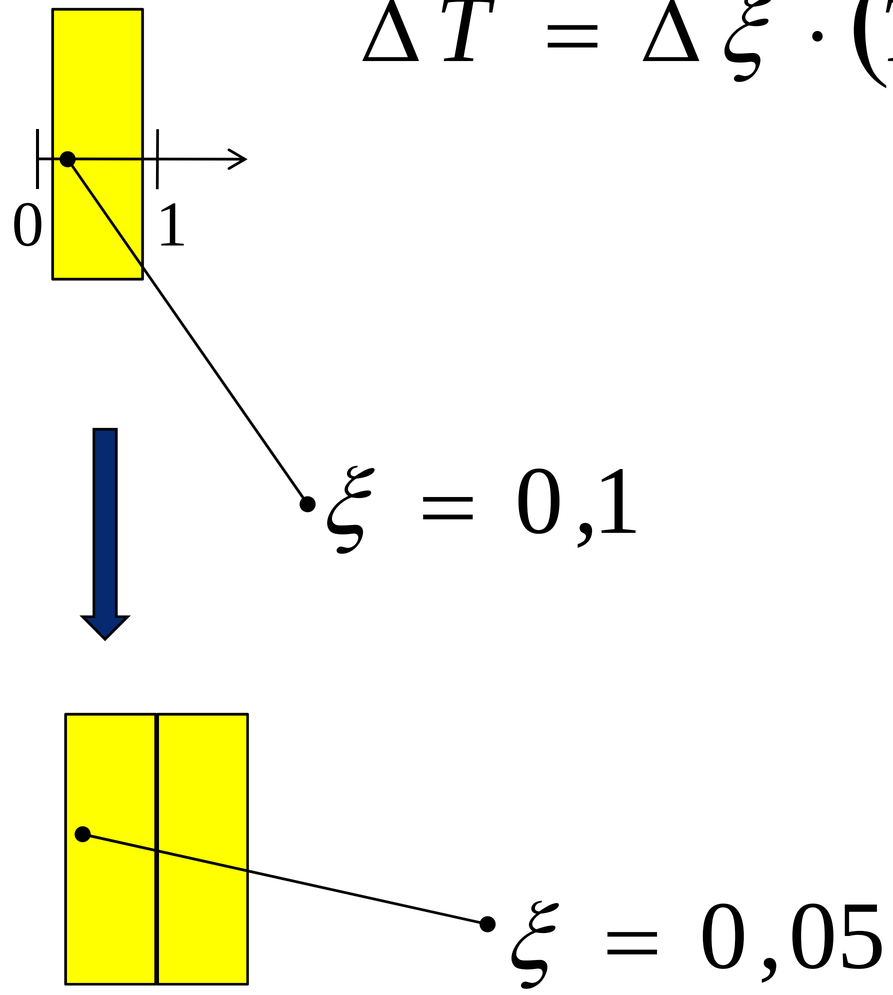


Energy efficient
Building envelopes
-
More
sensitive
structures -
"the JAS-effect"





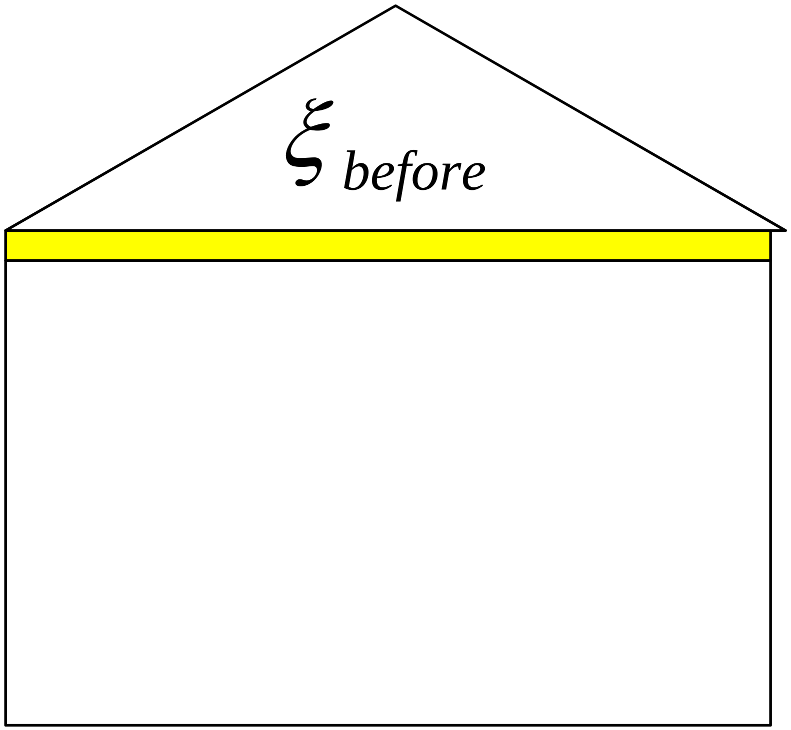
$$\Delta T = \Delta \xi \cdot (T_i - T_e)$$

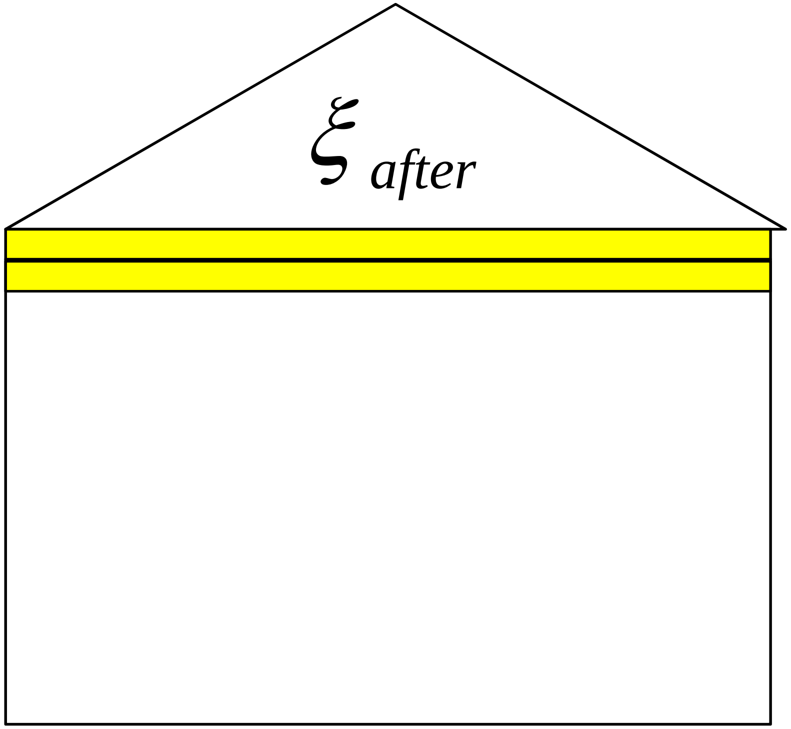


Same point
but more insulation
on the inside

It becomes colder

Retrofitting measure - More attic floor insulation:




ξ_{after}

Simplified analysis based on monthly average values
for the temperatures and indoor moisture supply (in structure)

$$T = T_e + \xi \cdot (T_i - T_e)$$

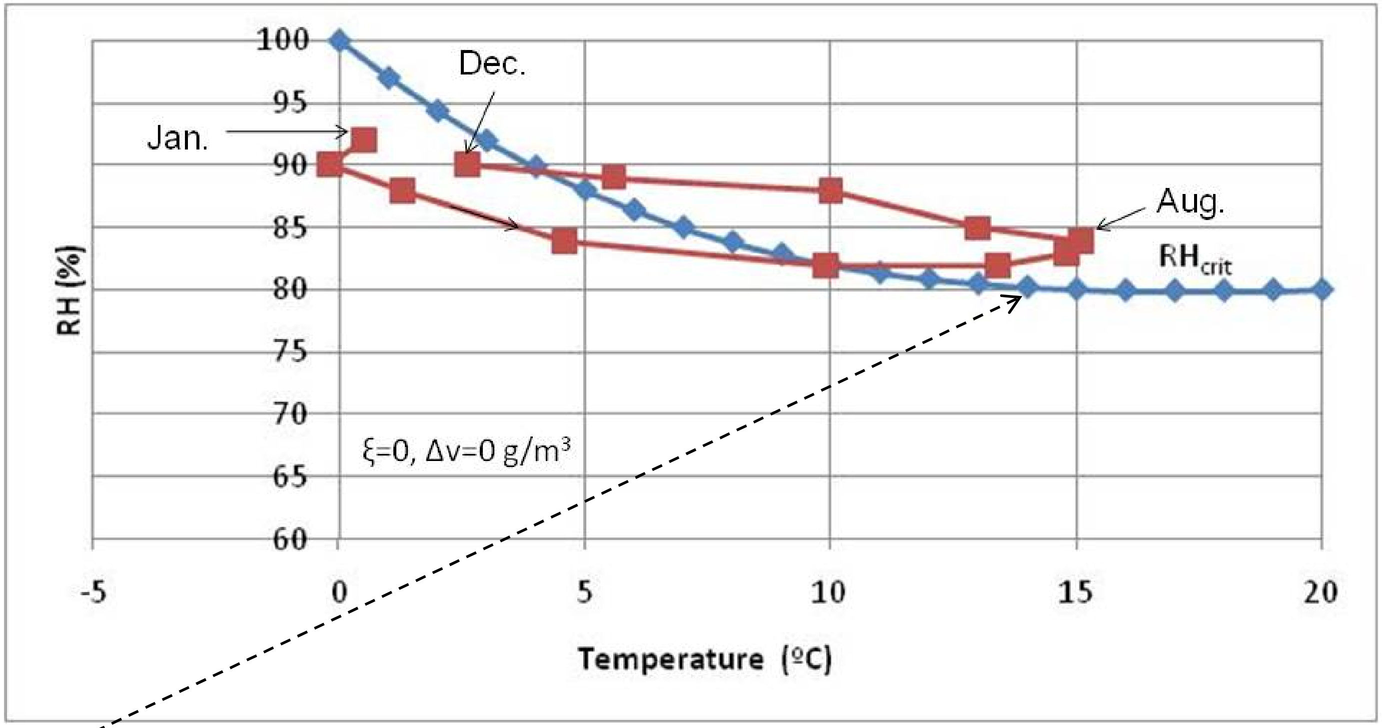
$$RH = \frac{v_e + \Delta v}{v_s(T_e + \xi \cdot (T_i - T_e))}$$

$\xi \downarrow$	$RH \uparrow$
$\Delta v \uparrow$	$RH \uparrow$

<u>Case:</u>

$\xi = 0$

$\Delta v = 0$

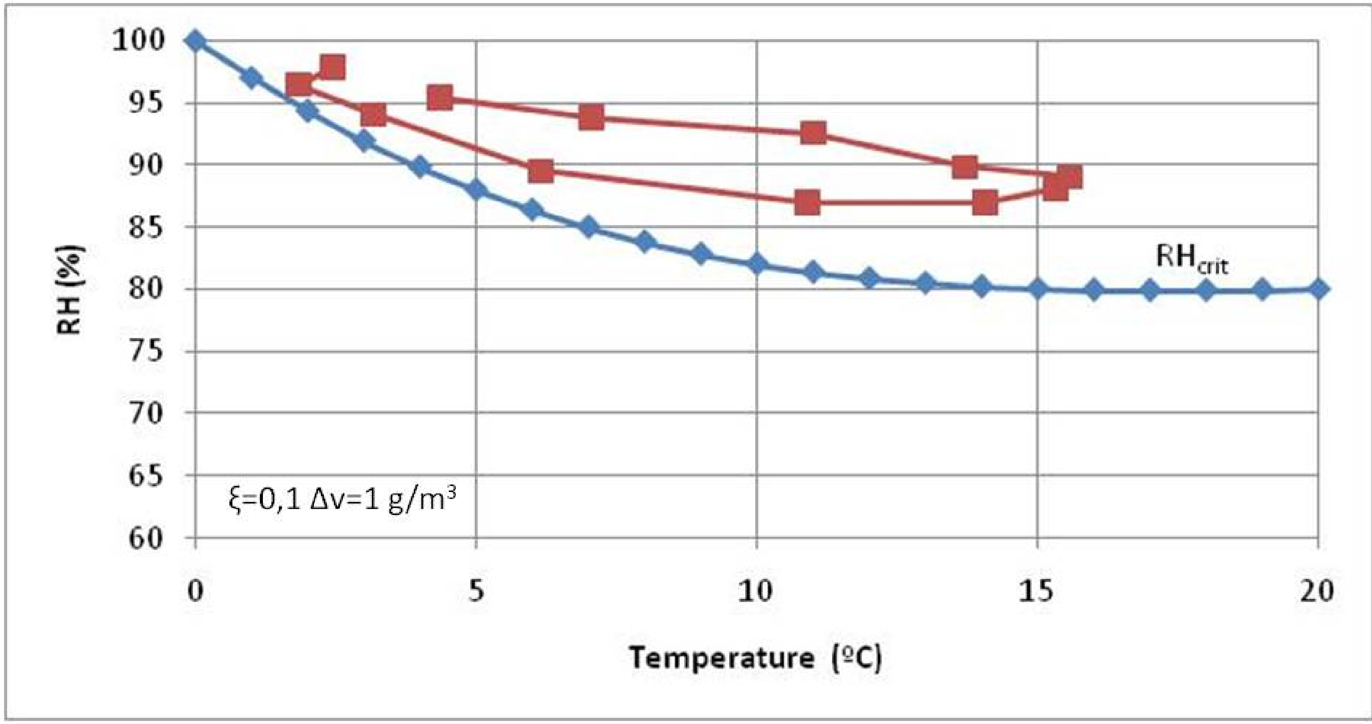


Göteborg climate
Comparison with critical RH (for mould growth)

Case:

$\xi = 0{,}1$

$\Delta v = 1\,\text{g/m}^3$

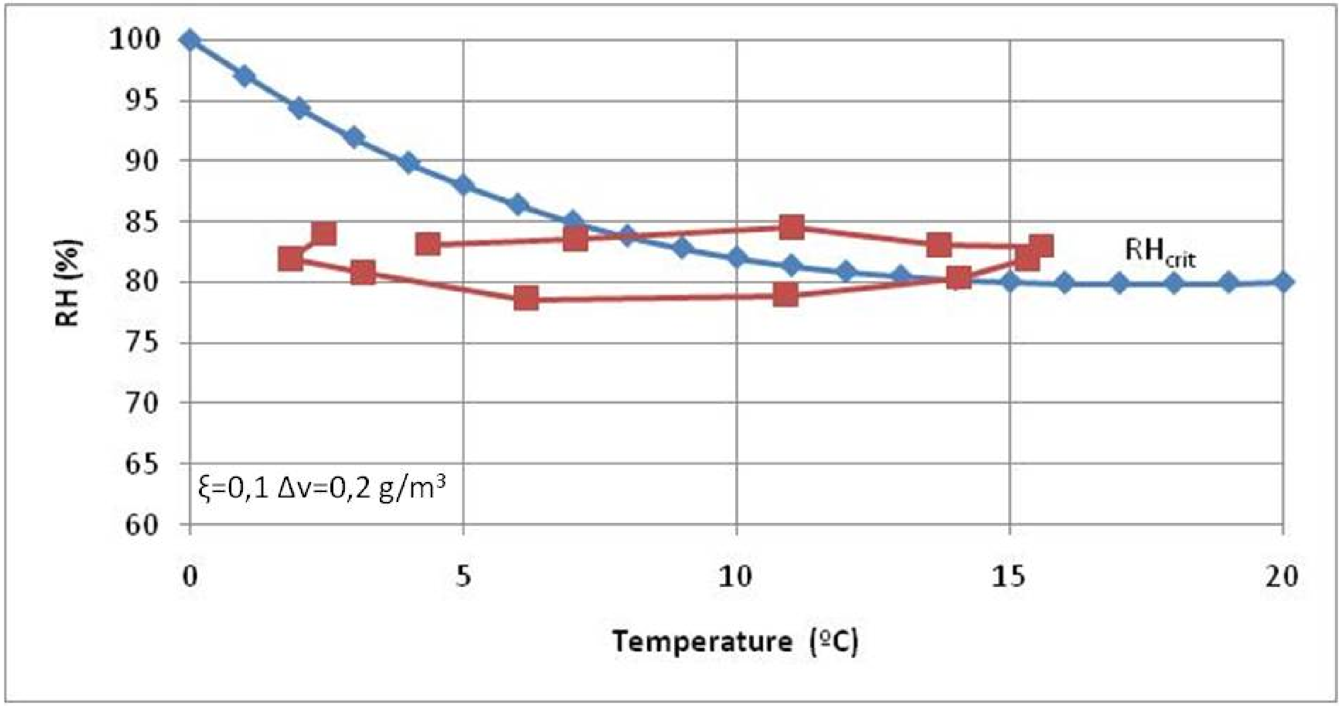


Moisture supply:
Depends on
moisture production,
ventilation rate
and transport processes of moisture
into the building
envelope

Case:

$\xi = 0{,}1$

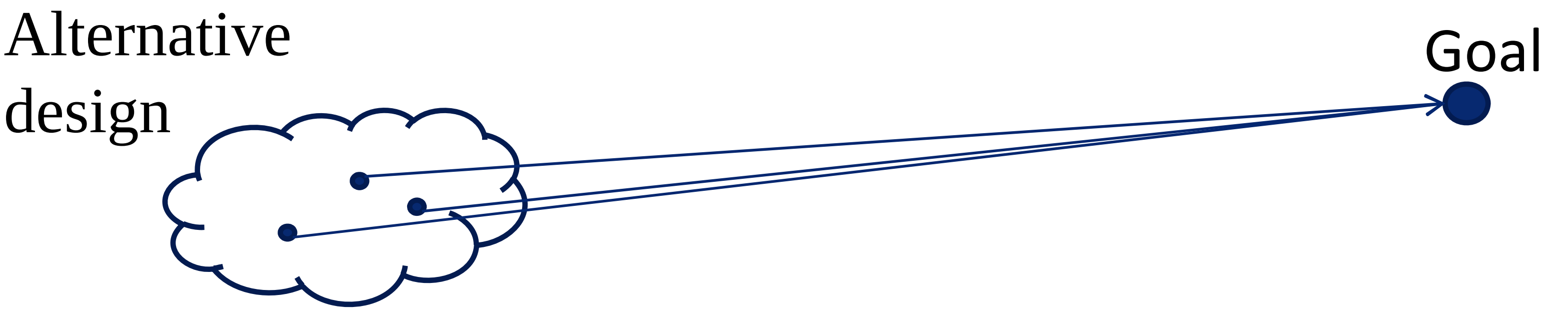
$\Delta v = 0{,}2 \text{ g/m}^3$



Difficult to design for 100% safety!

We can not double the thickness of the beam
-as in structural engineering!

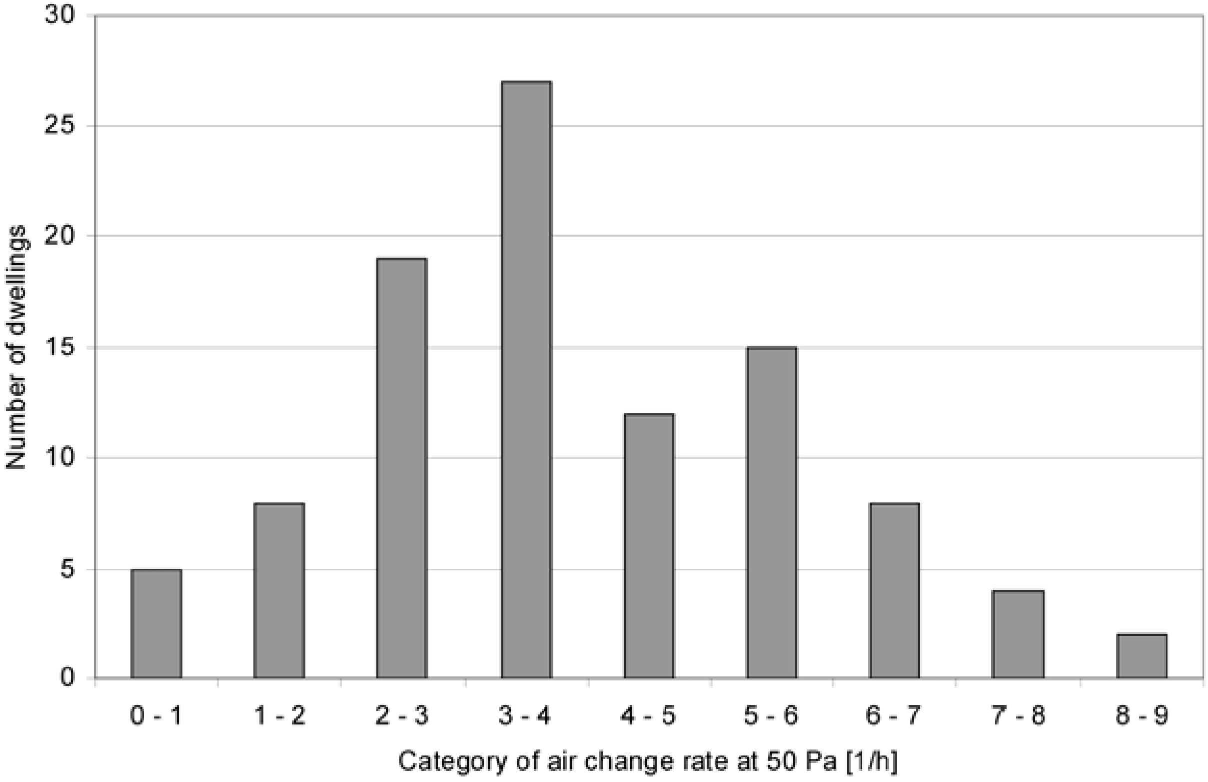
Deterministic approach



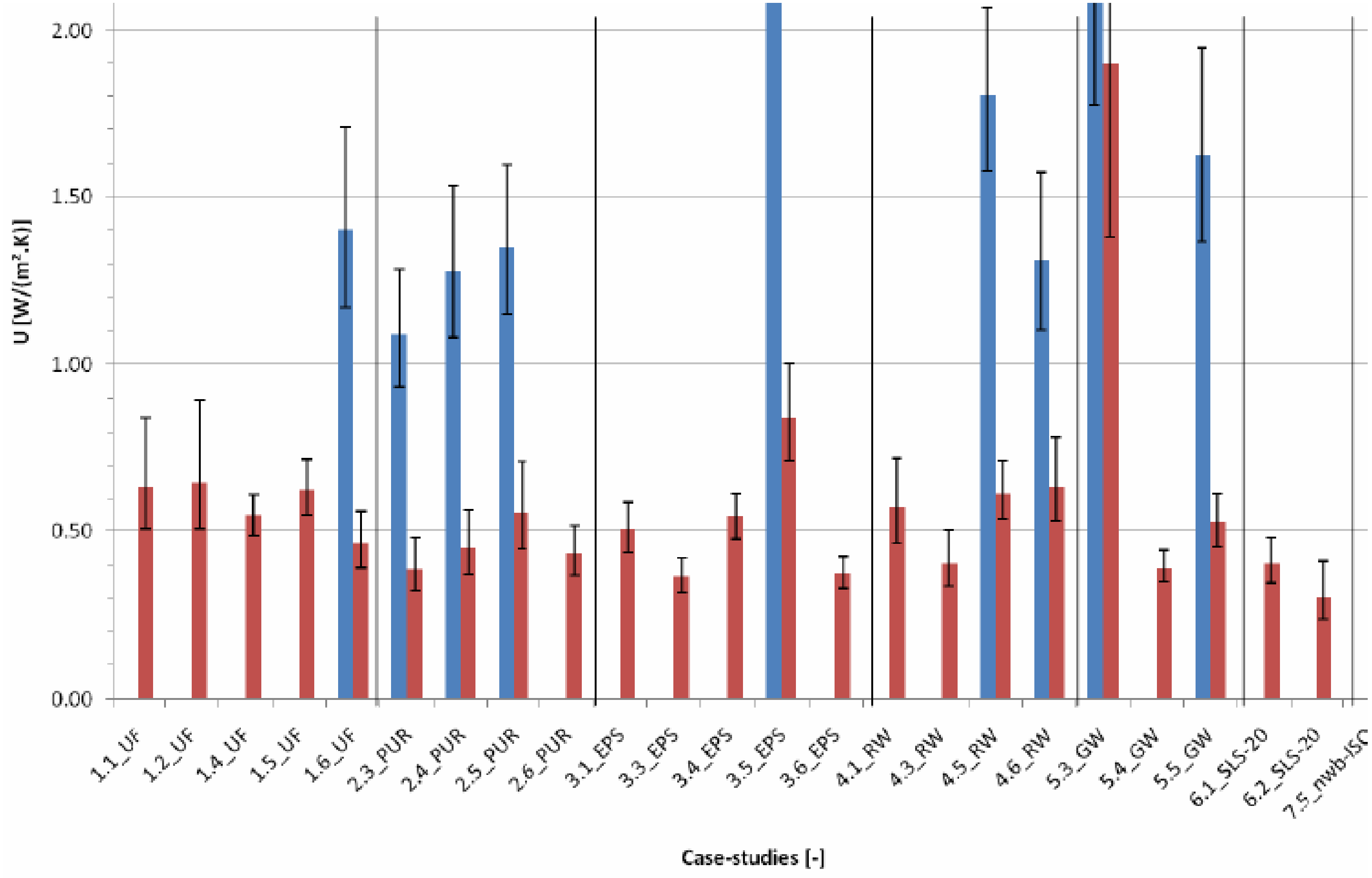
(Except if we accept poor energy efficiency!)

We must design as safe as possible –
accounting for the all uncertainties and for what might can happen!

Air tightness at 50 Pa of 100 timber-framed Finnish buildings

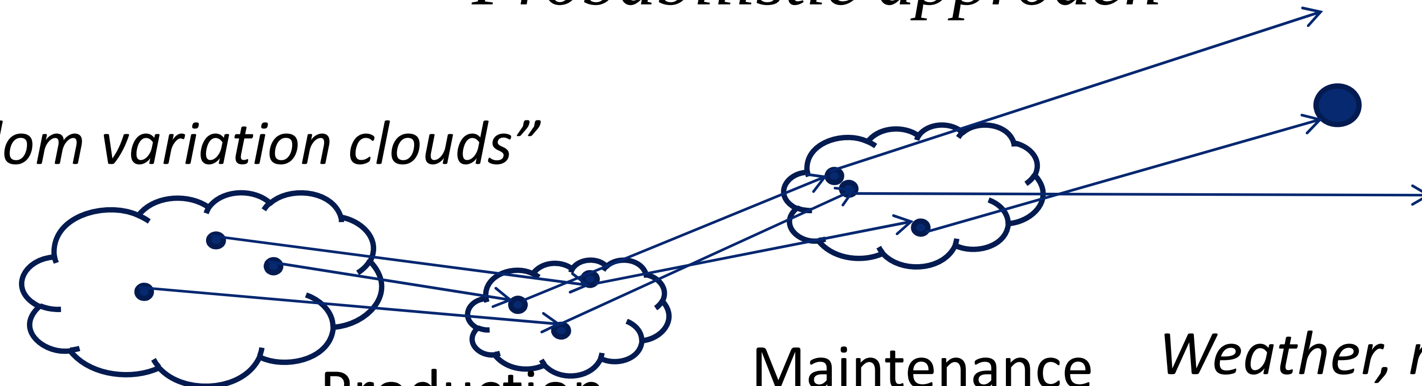


Measured U-values of a number of Belgian cavity walls. Blue before retrofitting, red: after insulation retrofitting



Probabilistic approach

"Random variation clouds"



Production

Maintenance
operation

Weather, material properties, exposure to spores, human behavior,…

Examples of
random variations in:

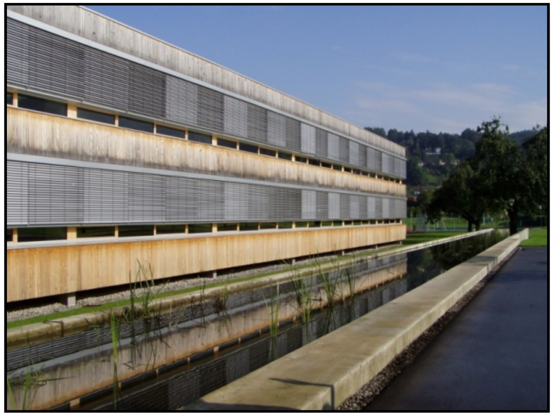
Indoor moisture sources, internal gains airing, aging of material, cracks in façades,…

Workmanship initial conditions of material,…

Wil, Switzerland

Dornbirn, Voralberg, Austria

School i Klaus, Voralberg, Austria

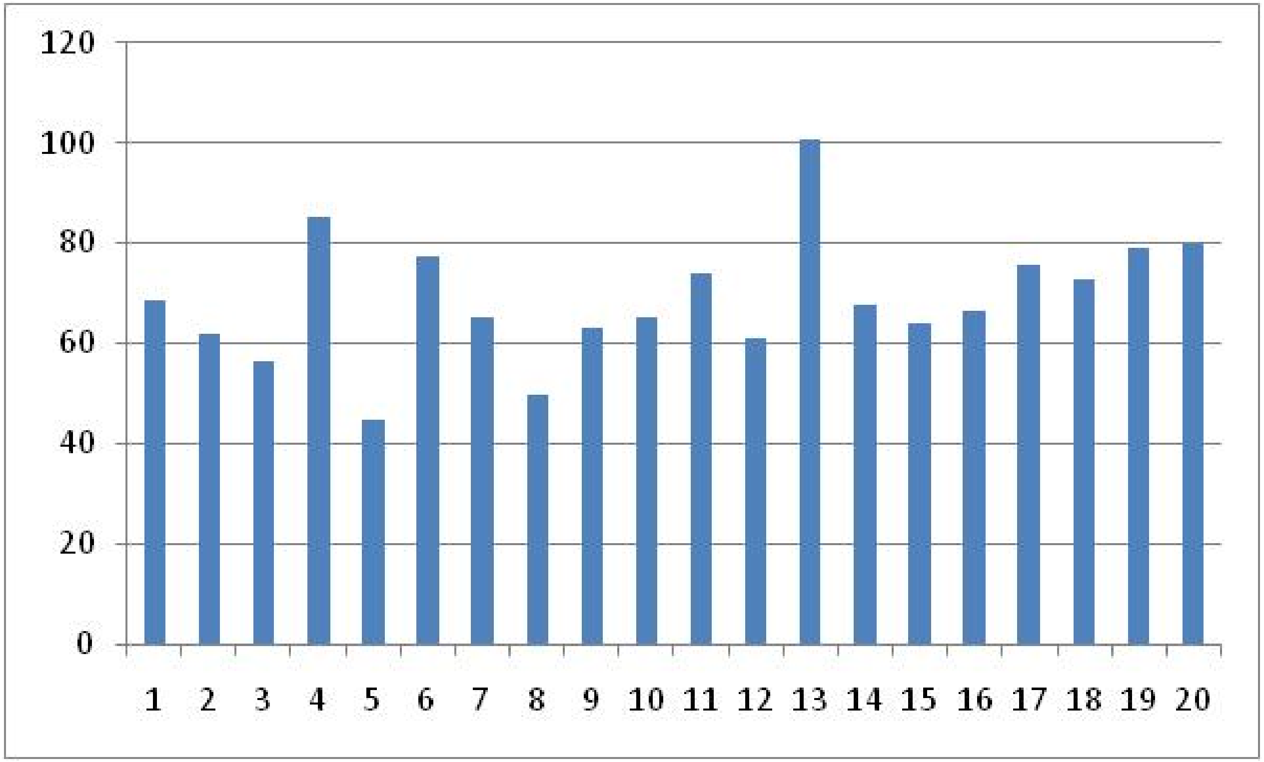


Wil, Switzerland

Lindås – South of Göteborg

From 2001

kWh/m²

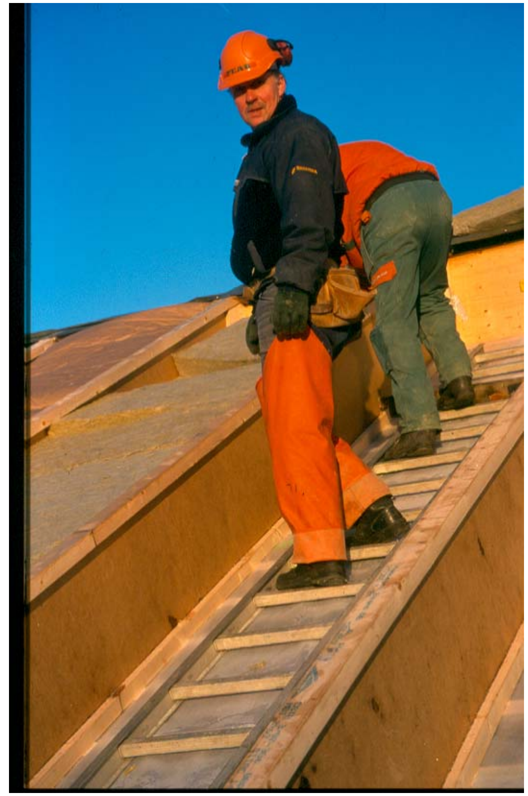


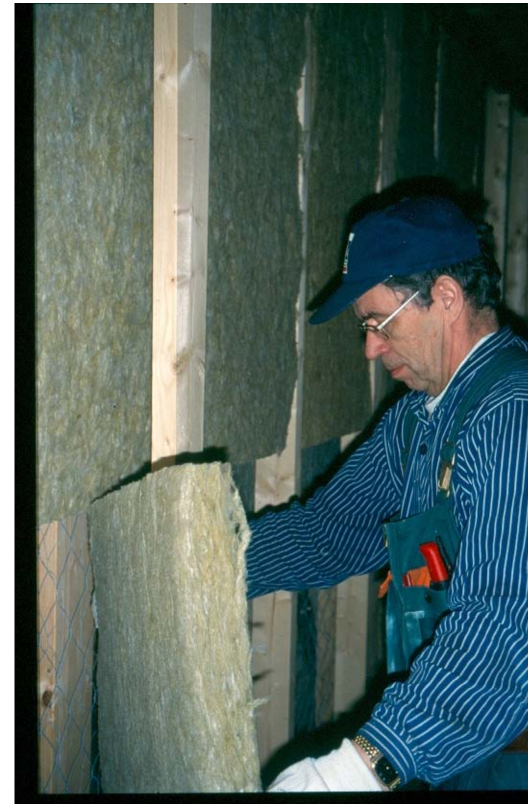
How difficult is it-
To minimize the use of energy in buildings?

▪Well-insulated building envelope-thick insulation

- Energy efficient windows
- Air tight building envelope
- Sufficient ventilation with heat recovery
- Utilization of internal gains and solar radiation
- Warm water – by solar panels
- Well-regulated and working appliances
- ‘Correct behaviour’

Good workmanship!





Screening of possible problems with passive houses

SP-report, Sikander et al 2009

Moisture safety

Air exchange rates and demand driven ventilation
Reduced ventilation rates during certain periods
-Higher indoor moisture supplies
-Degradation of indoor air quality

Kitchen fans with no exhaust air (Recirculation of filtered air)
-Increase the indoor moisture supply and
-Insufficient filtering capacity -poor indoor air quality
-During cooking -peaks in temperature

Air quality of the mechanically supplied air

Good air filters that are exchanged with new ones on a regular basis

Supply air - both the ventilation and heating demand satisfied
-insufficient heating or overheating.
(central heating or heat exchange device- common supply air temperature)

High supply air temperatures
-Insufficient mixing of air
-“Burnt dust” smell

Air ducts located in building envelope - excess heat losses.

Thermal comfort

Too high indoor temperature can occur during the summer periods
(Design and orientation of windows, activity of air heat exchanger altered, sufficient airing or forced mechanical ventilation, use of shading devices)

Thermal comfort in zones close to windows-cold periods?

Sound environment

Reduced transmission of noise/surroundings-discomfort?
Other sources of noise - more irritating. (requirement on mechanical systems)

Light environment

Reduced transmission of daylight to the interior
Thick walls – windows - influence the interior light environment.
Low-energy light sources – influence on occupants ?

Air tightness

Good air tightness over time?

Frost heave

Increasing risk of frost heave
(use of perimeter insulation)

Future internal heat gains

The internal gains might be lower!

Durability of energy efficiency

Durability of U-value of windows and the thermal insulations?
How well is energy efficiency maintained in connection to retrofitting measures?
How well are building services, solar collectors, solar cells working - long term basis?
How robust are the technical solutions?
How well are the maintenance kept?

The behavior of the users

It is difficult to determine the energy demand of a building during the design phase, especially for a given building or apartment.

The user's attitudes and expectations

The buildings require maintenance and service - satisfied and accepted by the users?
Are the expectations by the users reasonable and taken into account?
(e.g. comfortable walking bare-footed and naked in the building during winter)

Susceptibility for climate change

Future weather: Temperature, solar radiation, wind, humidity and precipitation
-Moisture safety, thermal comfort and energy demand.
Is the air tightness, solar shading, … still sufficient and acceptable?

…But we still need to move forward!

Better design, production, operation, maintenance

Better building process!

Risk assessment!

Thanks!