FIELD MEASUREMENTS OF MOISTURE IN COLD VENTILATED ATTICS WITH DIFFERENT TYPES OF INSULATION AND VAPOR BARRIERS

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PAPER 45

Why this project?

The DaLo project – vapor barrier in ventilated attics

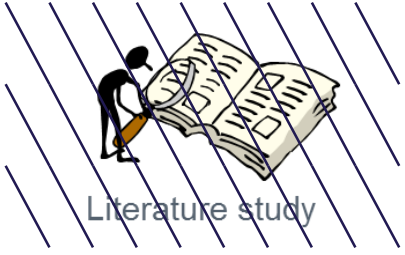
Background:

- Experience based recommendation from The Danish Building Research Institute (SBi):
  No tight vapor barrier $\Rightarrow$ Max 150 mm (6 inch) insulation in ceiling – independent of type of insulation material
- Some state the recommendation is way on the safe side
- Research based knowledge needed

Aim:

- To clarify under which conditions a water vapor barrier in ceilings under naturally ventilated attics is needed.

Main topics in the project

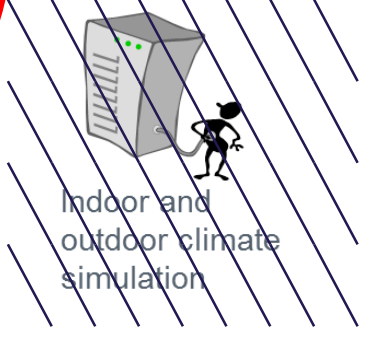


Literature study

Full size test building

Measurements in existing houses

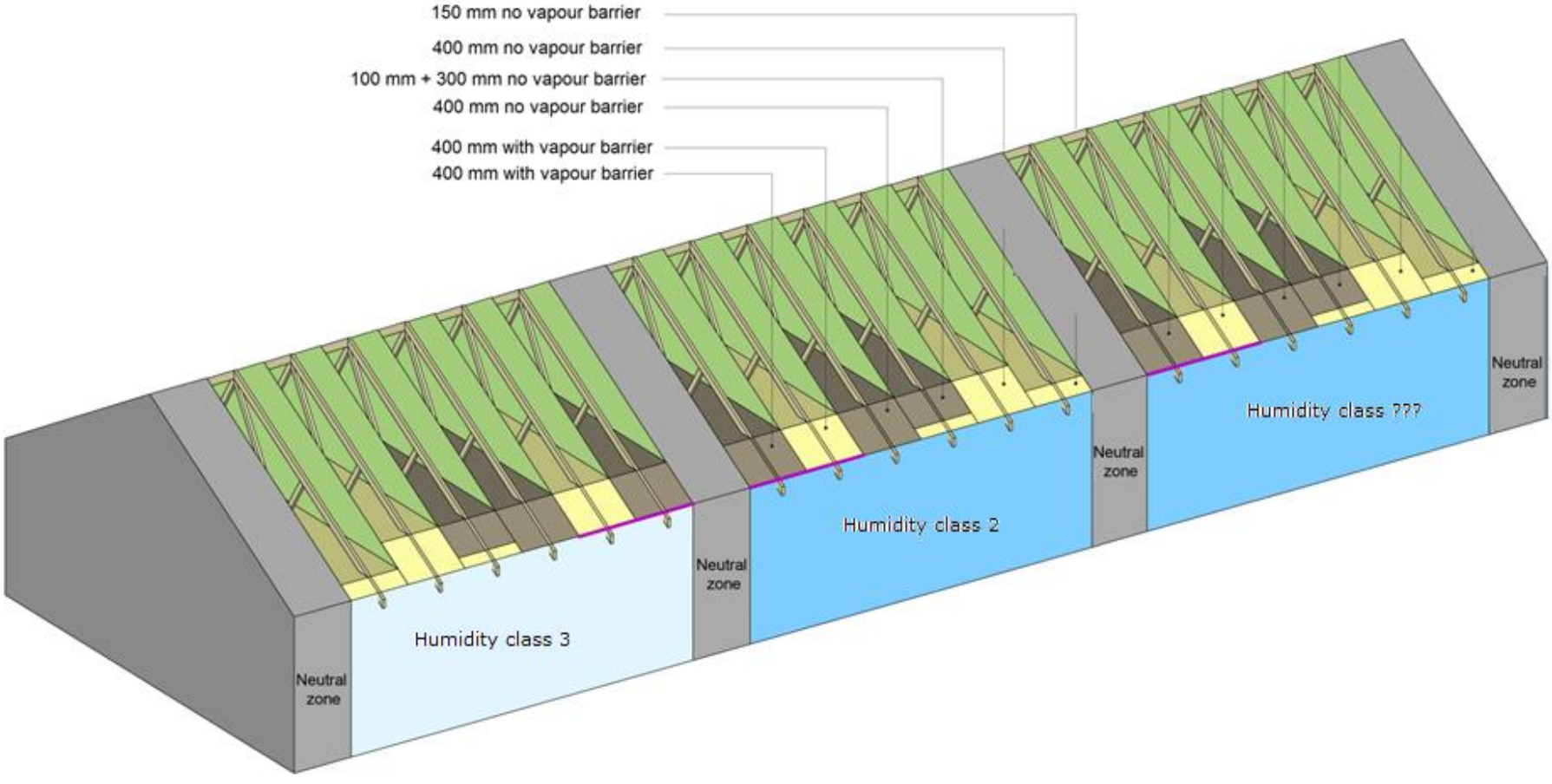
Simulations



Indoor and outdoor climate simulation

Full size test building

Full size test building



Differences in convection and diffusion

- Simple calculation for illustrating differences between convection and diffusion to attic under stationary conditions.
- Fixed parameters shown in Table 2.
- Variable parameters:
  - Insulation thickness
  - Attic air change rate
  - Indoor moisture level

Table 2. Parameters Used in the Examples

Parameter	Value	Unit	Value	Unit
Indoor temperature	20	°C	68	°F
Indoor RH	50	% rh	50	% rh
Outdoor temperature	0	°C	32	°F
Outdoor RH	90	% rh	90	% rh
Sd-value, vapor barrier	100	m	328	ft
Sd-value, 150 insulation	0.15	m	0.5	ft
Sd-value, 400 insulation	0.4	m	1.3	ft
Sd-value, plasterboard	0.1	m	0.3	ft
Crack in ceiling	0.0001	m^2	0.0011	ft^2
Approximated air pressure different over a ceiling	2.5	Pa	0.052	lbf/ft^2
Ceiling area	1	m^2	10.8	ft^2
Attic volume	1	m^3	35.3	ft^3

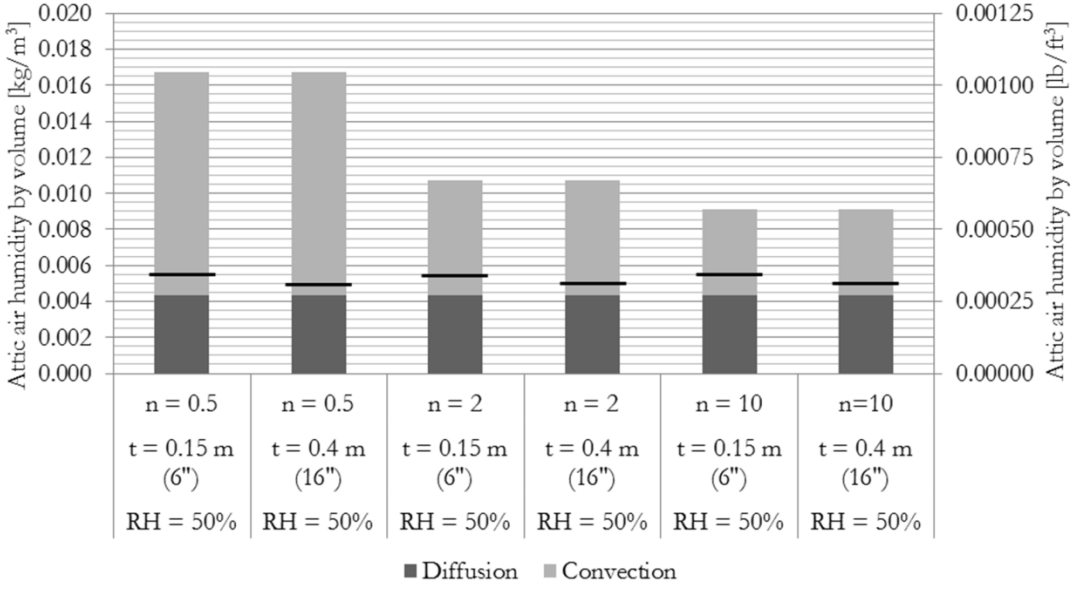
Figure 2 – Examples on the air change rate with fixed RH

No vapor barrier:

The total moisture excess to the attic by diffusion alone is near the threshold for condensation

If the air change rate is changed from 0.5 h^{-1} to 2.0 h^{-1} the amount of condensation is decreased.

Further increase will not eliminate the risk of condensation.



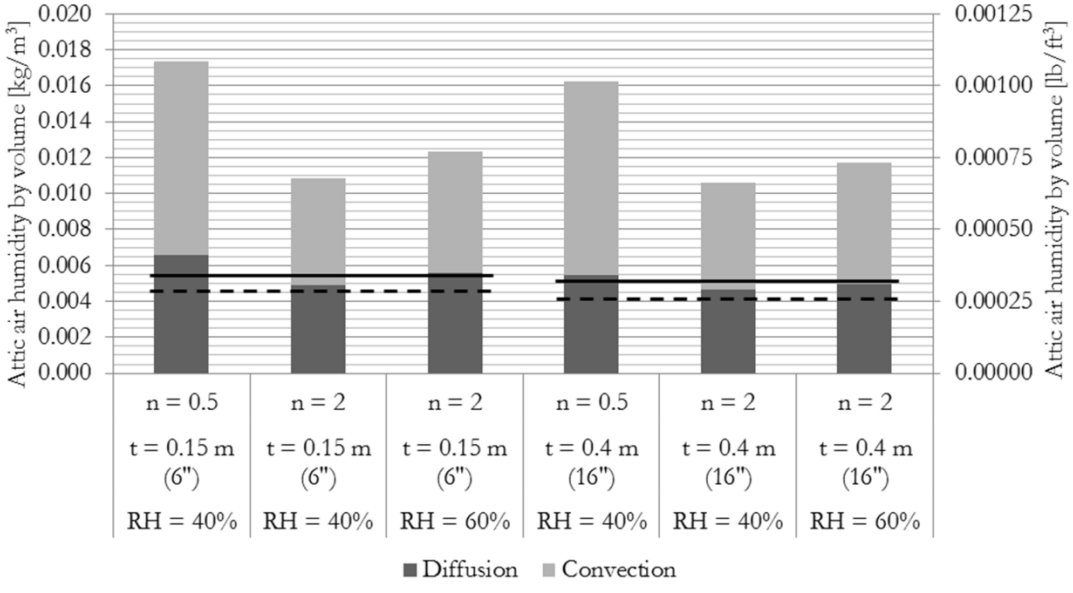
Solid black line threshold for condensation

Figure 3 – Examples with different RH

No vapor barrier:

The air change rate has a higher effect on the attic climate than the indoor climate

The amount of insulation has a influence on how close the moisture excess is to the threshold for condensation.



Solid black line threshold for condensation

Dotted line threshold for mold growth

Theoretic example

From the theoretic examples it can be noticed:

- The moisture contribution due to diffusion alone result in a moisture amount close to the threshold for condensation
- The total amount of insulation material change the temperature in the attics and consequently the threshold values
- How critical the moisture excess due to diffusion is depends on the ventilation rate and the insulation thickness

Simplifications:

- Glaser calculations
- Consequently e.g. no solar radiation, no hygroscopic effects etc.

Selection of parameters to be investigated

- The type of vapor barrier
- The orientation of the roof surface
- The amount of insulation
- The type of insulation

The attic ventilation rate (openings) has not been one of the selection parameter, although it is expected to have a high influence on the attic moisture level.

But it is good practice in Denmark that there is ventilation in these kind of attics. Furthermore, it is normally not difficult to establish sufficient ventilation openings.

Buildings

- At the moment there is installed sensors in 30 buildings.
- Around 5 additional houses is to be contacted.

Building year	Vapor barrier	Orientation of roof	Original insulation thickness [mm]	Type	Additional insulation thickness [mm]	Type	Total amount of insulation [mm]
2015	None	E/W	-	-	600	CL	600
1964	None	N/S	150	MW	200	CL	350
1935	None	-	50	MW	300	CL	350
1956	None	E/W	80	MW	170	MW	250
2004	PE-foil	N/S	250	MW	-	-	250
1979	PE-foil	N/S	200	MW	-	-	200
1996	PE-foil	N/S	150	MW	-	-	150
1998	PE-foil	NW/SE	250	MW	-	-	250
1970	PE-foil	E/W	200	MW	250	MW	450
1969	Alu-foil	N/S	100	MW	200	CL	300
1969	Alu-foil	N/S	100	MW	350	CL	450
1971	Alu-foil	N/S	100	MW	200	CL	300
5 X 1980	Alu-foil	E/W	100	MW	300	CL	400
5 X 1980	Alu-foil	N/S	100	MW	300	CL	400
1971	Alu-foil	N/S	100	MW	100	MW	200
1968	Alu-foil	N/S	200	MW	200	MW	400
1970	Alu-foil	N/S	100	MW	200	MW	300
1976	Alu-foil	N/S	100	MW	150	MW	250
1976	Alu-foil	N/S	100	MW	250	MW	350
1964	Alu-foil	N/S	100	MW	300	MW	400
1976	Alu-foil	E/W	100	MW	250	MW	350
1976	Alu-foil	E/W	100	MW	250	MW	350

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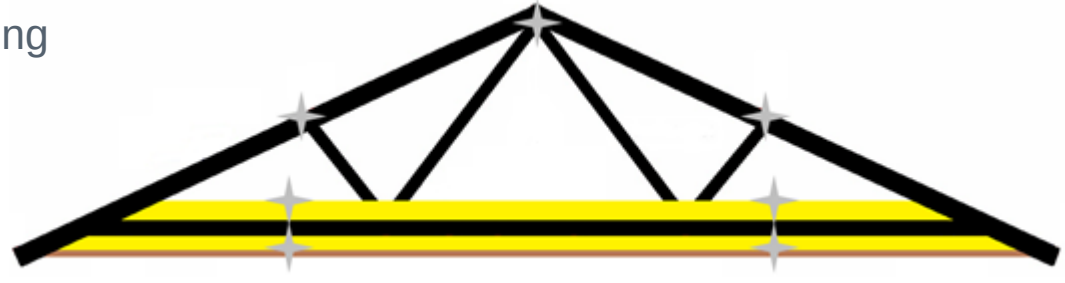
1996	PE-foil	N/S	150	MW	-	-	150
1998	PE-foil	NW/SE	250	MW	-	-	250
1969	Alu-foil	N/S	100	MW	200	CL	300
1969	Alu-foil	N/S	100	MW	350	CL	450
1971	Alu-foil	N/S	100	MW	200	CL	300
1971	Alu-foil	N/S	100	MW	100	MW	200

Unfortunately only 10 dwellings are presented in this paper because of complication in collecting data, and postponement of installing sensors.

Sensor positions and logging interval

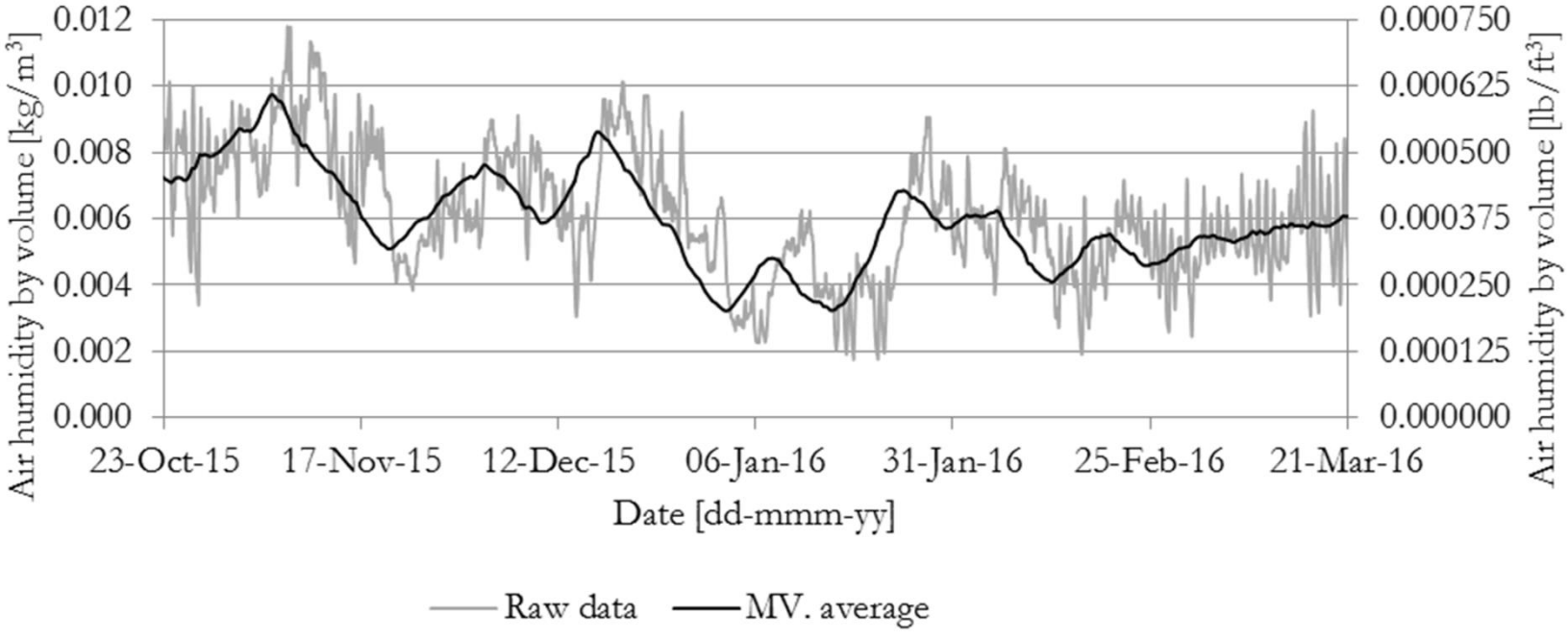
Sensors for measuring the temperature and the relative humidity is placed:

- At the ridge
- Near the roof underlay both orientation
- Above the insulation material
- Between the insulation and ceiling
- Between two types of insulation
- Indoor and outdoor



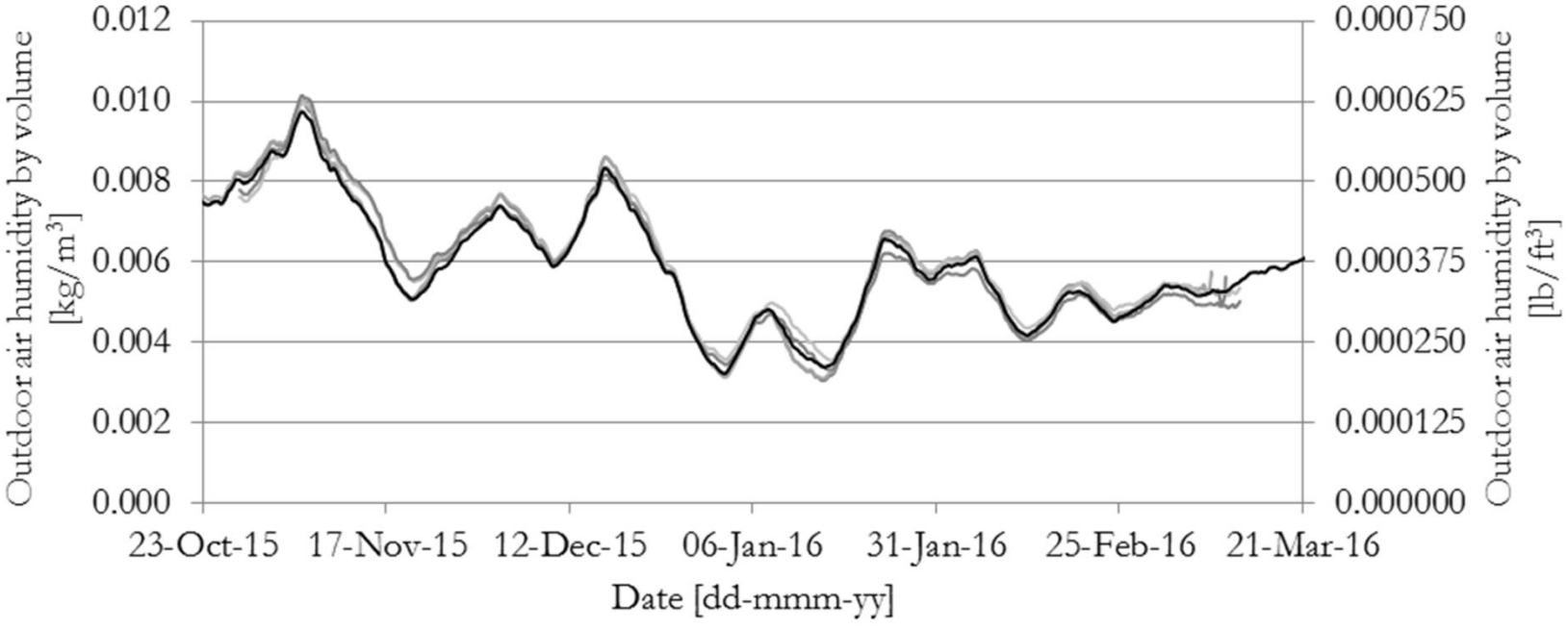
Logging interval every hour

Figure 5 – Raw data compared to moving average



Black line illustrate the calculation of moving average over a period of one week.

Figure 6 – Variation of outdoor climate



The black line represent the average between the five locations within 40-70 km (25-40 mi.).

Moisture excess to the indoor climate

- Illustration of the indoor humidity levels based on EN/ISO 13788 (2012).
- Danish dwellings is in generally considered in Level 2 or 3.

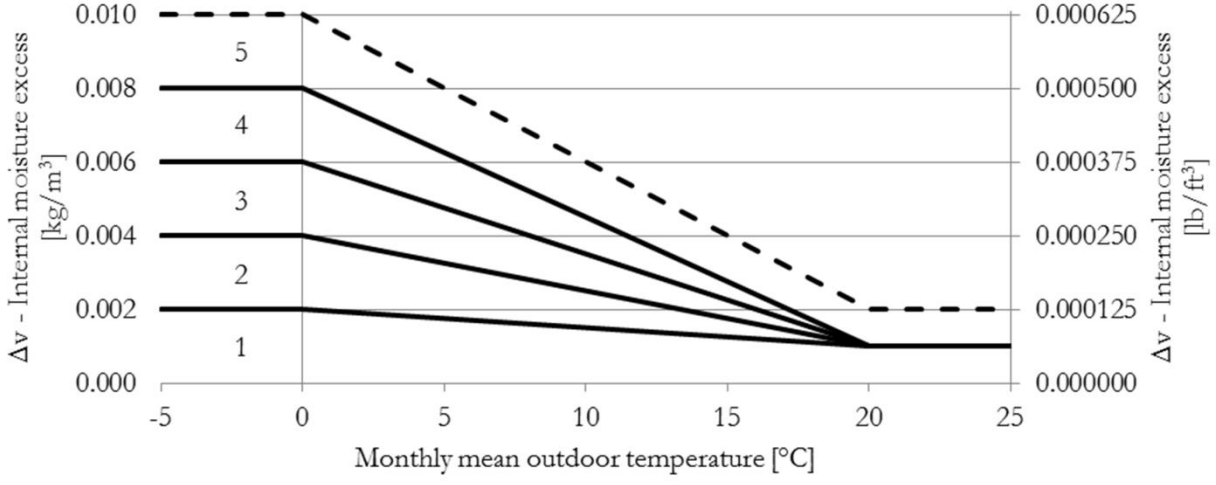
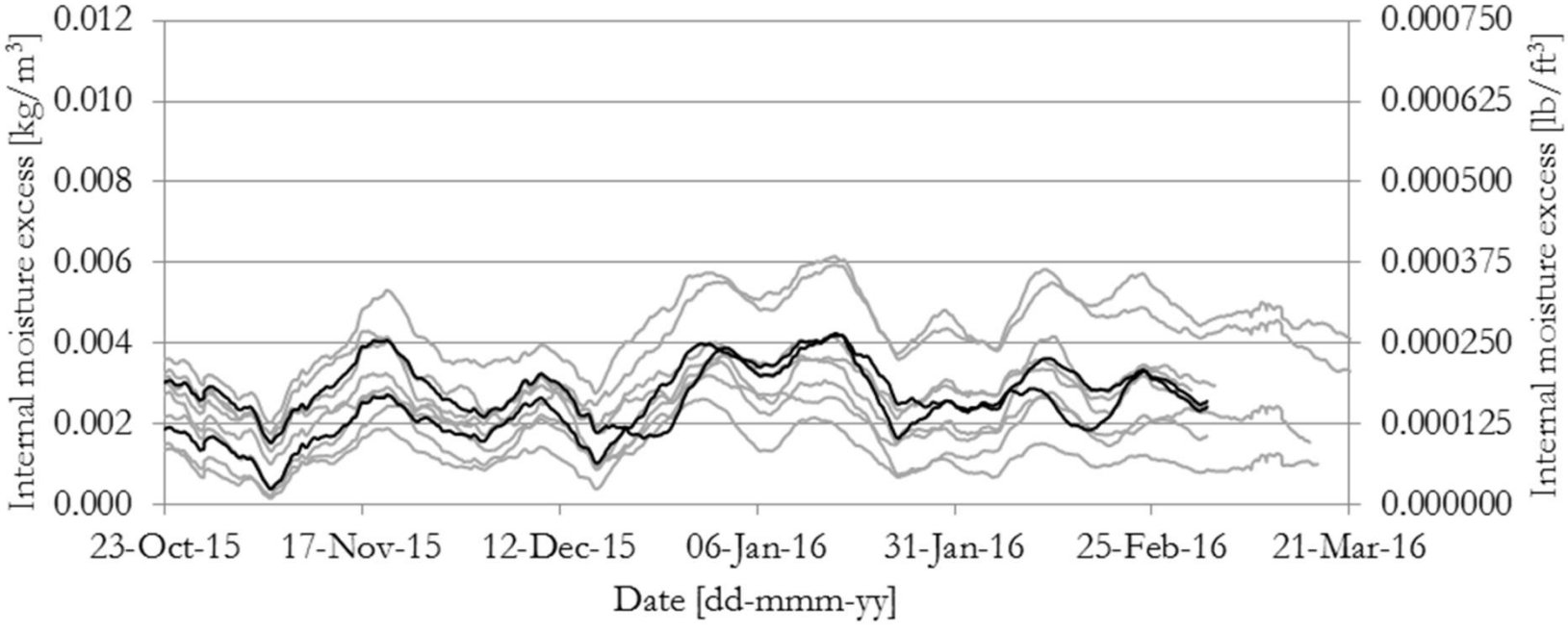
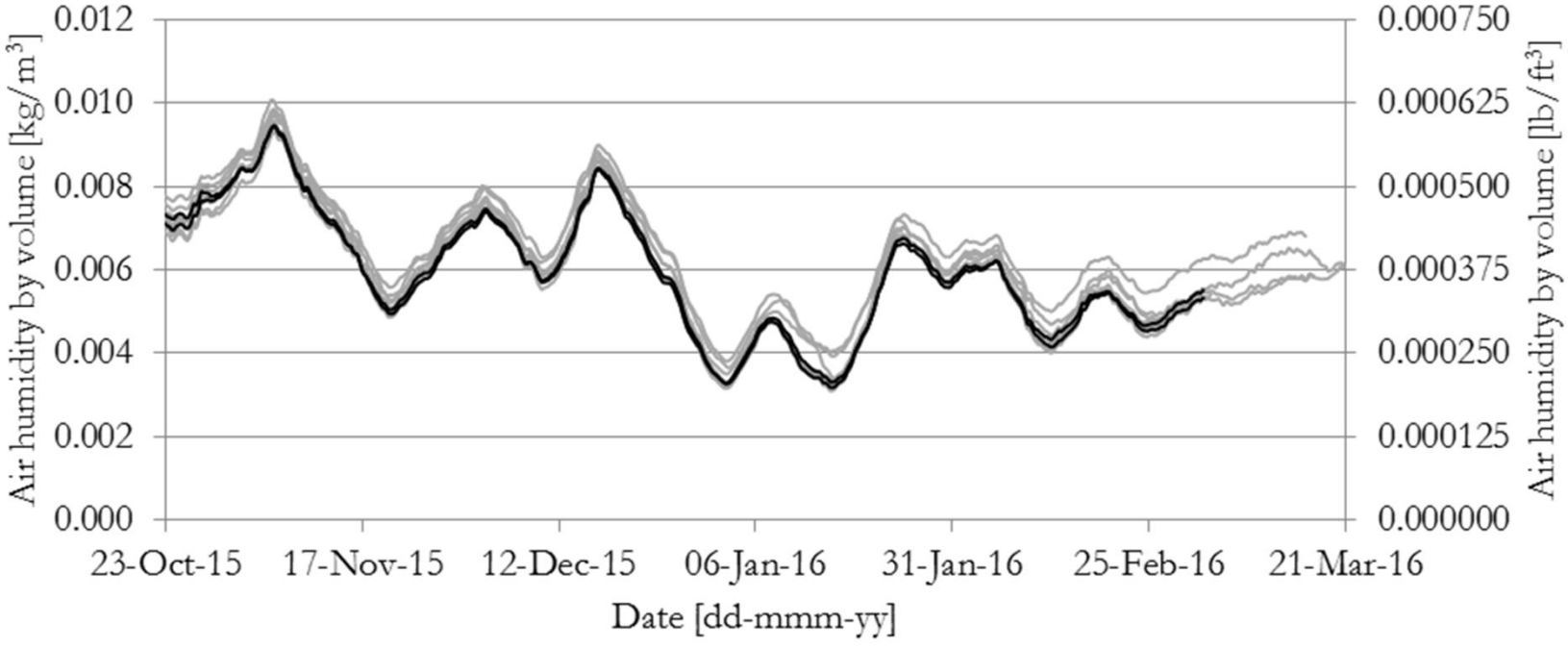


Figure 7 – Internal moisture excess



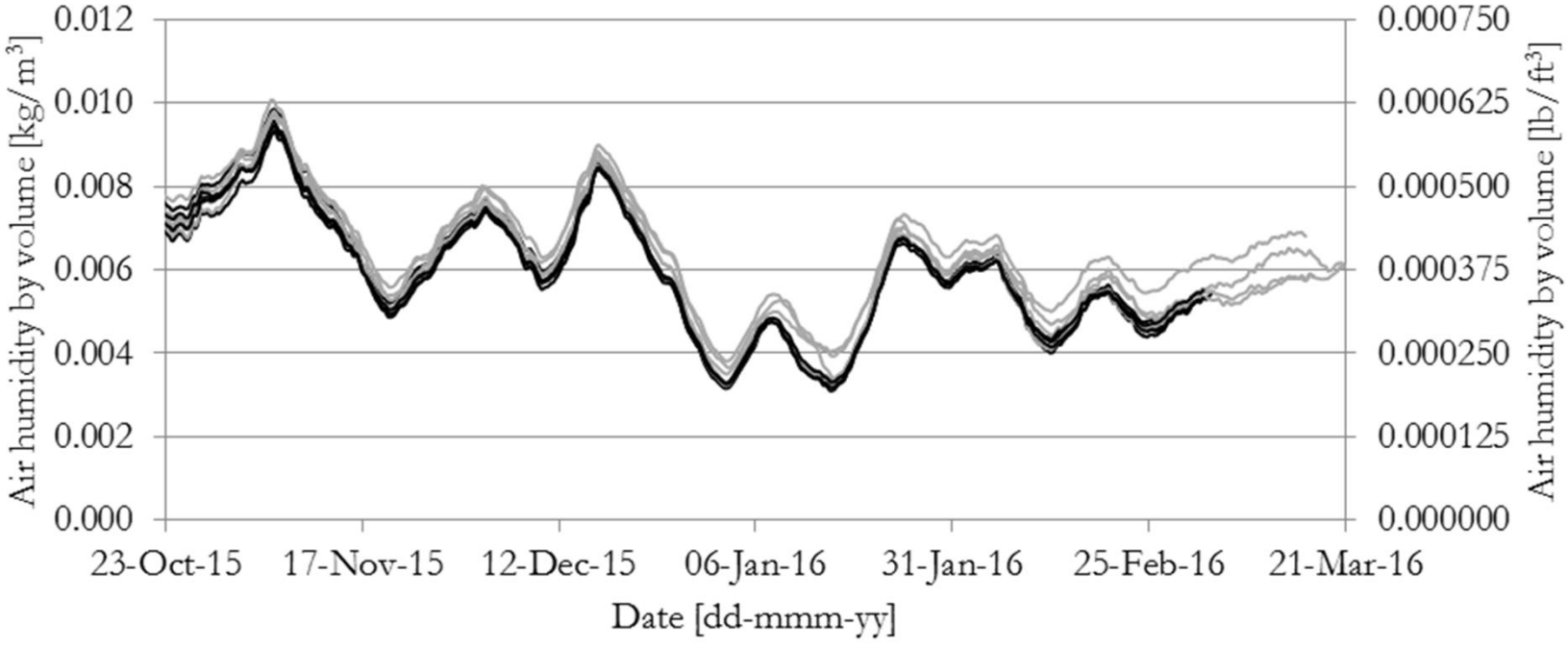
- Black lines is for buildings with no vapor barrier.
- Two dwellings has a sizeable indoor moisture production.

Figure 8 – Moisture level at ridge



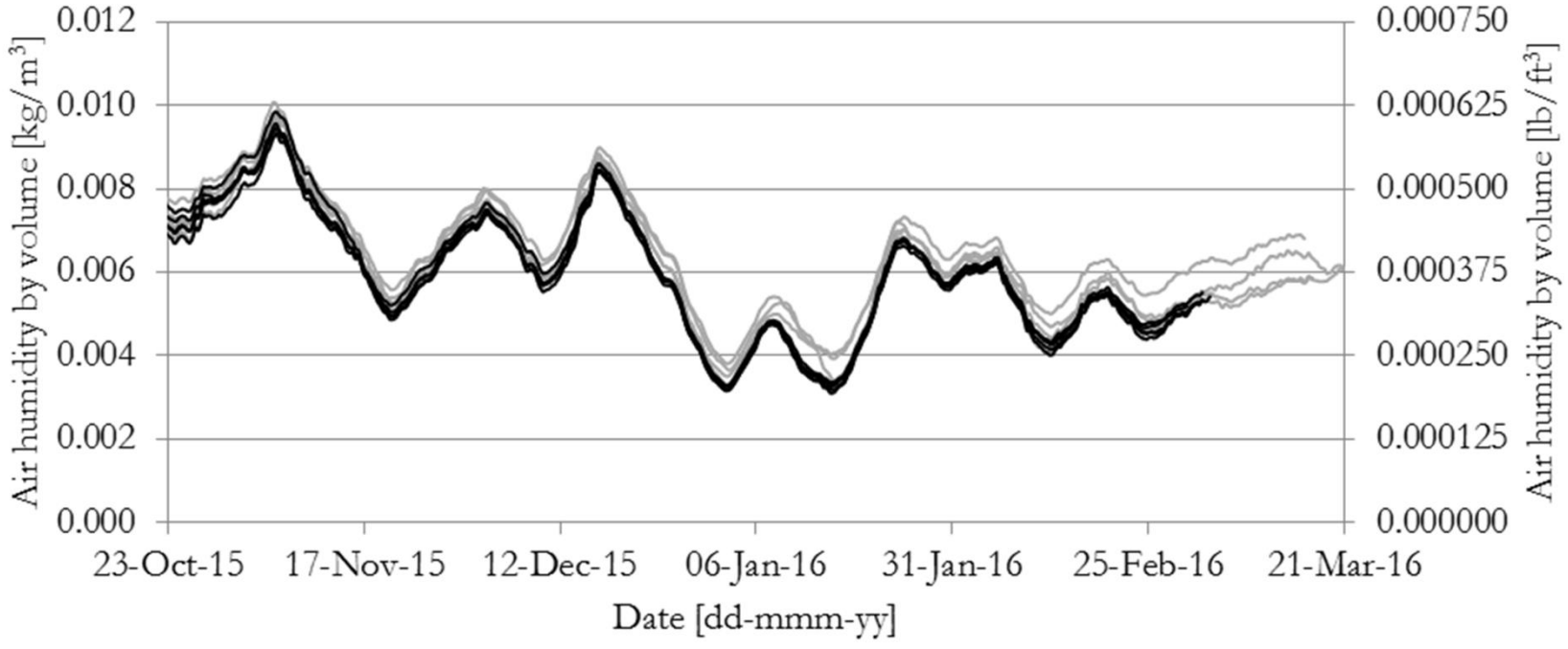
Black lines represent buildings where there is no vapor barrier.

Figure 9 – Moisture level at ridge



Black lines represent buildings where the insulation thickness is 300 mm (12 in.) or more.

Figure 10 – Moisture level at ridge



Black lines is buildings with insulation material based on cellulose where grey lines is with mineral wool based insulation material.

Figure 11 – Average moisture level compared with threshold values for mold growth

Average moisture levels

Grey line – Insulation < 300 mm (12 in.)

Black line – Insulation ≥ 300 mm(12 in.)

Threshold values for mold growth

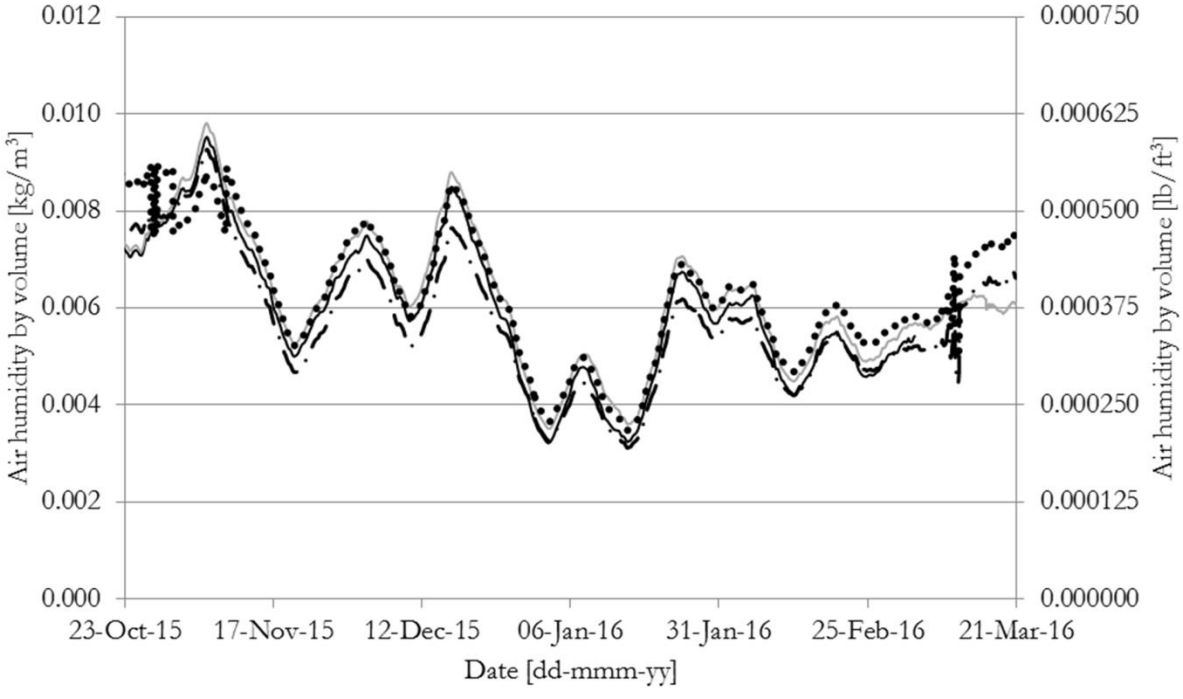
Broken line – 15°C (59°F) and 85% rh

Dotted line – 10°C (50°F) and 95% rh

Remarks

If the threshold “Broken line” is the real one, it would be expected to find moisture and mold damage when installing sensors.

But this is not the case so the threshold value must be higher, maybe like the dotted line.



Conclusion

- Theoretic examples illustrate how close the moisture level in attics due to diffusion alone is to a critical level for mold growth
- Unfortunately there have been some complications in collecting data from the original planed thirty dwellings
- Based on the remaining ten dwellings it is not possible to make a solid conclusion which can verify or refine the current recommendation.
- More measurements will come later
- The limited number of dwellings show a trend: The hygroscopic properties of the insulation material might have an essential impact on the moisture level in the attic, compared to the effect of either the vapor barrier or the amount of insulation material. But there is a coincidence between the amount of insulation and hygroscopic insulation
- The experimental set-up will show more

THANKS FOR YOUR ATTENTION

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