# Climate adaptation of pitched wooden roofs

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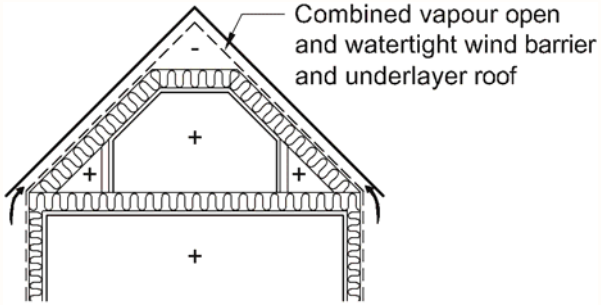
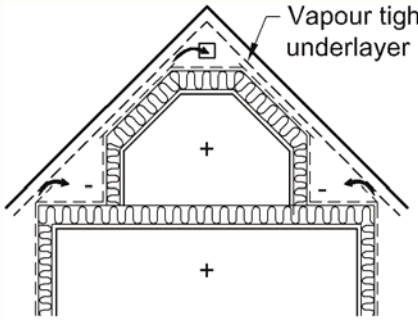
Department of Civil and Environmental Engineering
and Researcher at SINTEF

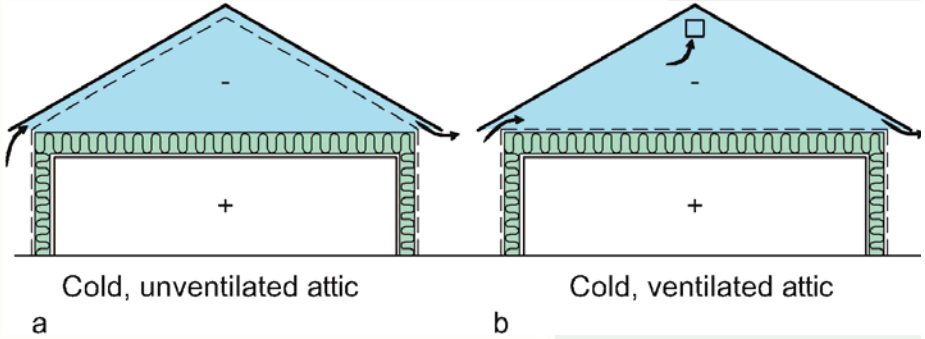
KLIMA2050

# Norwegian tradition of wooden roofs

Okstad hageby. Photo: Tore Kvande




Illustrations: Byggforskserien



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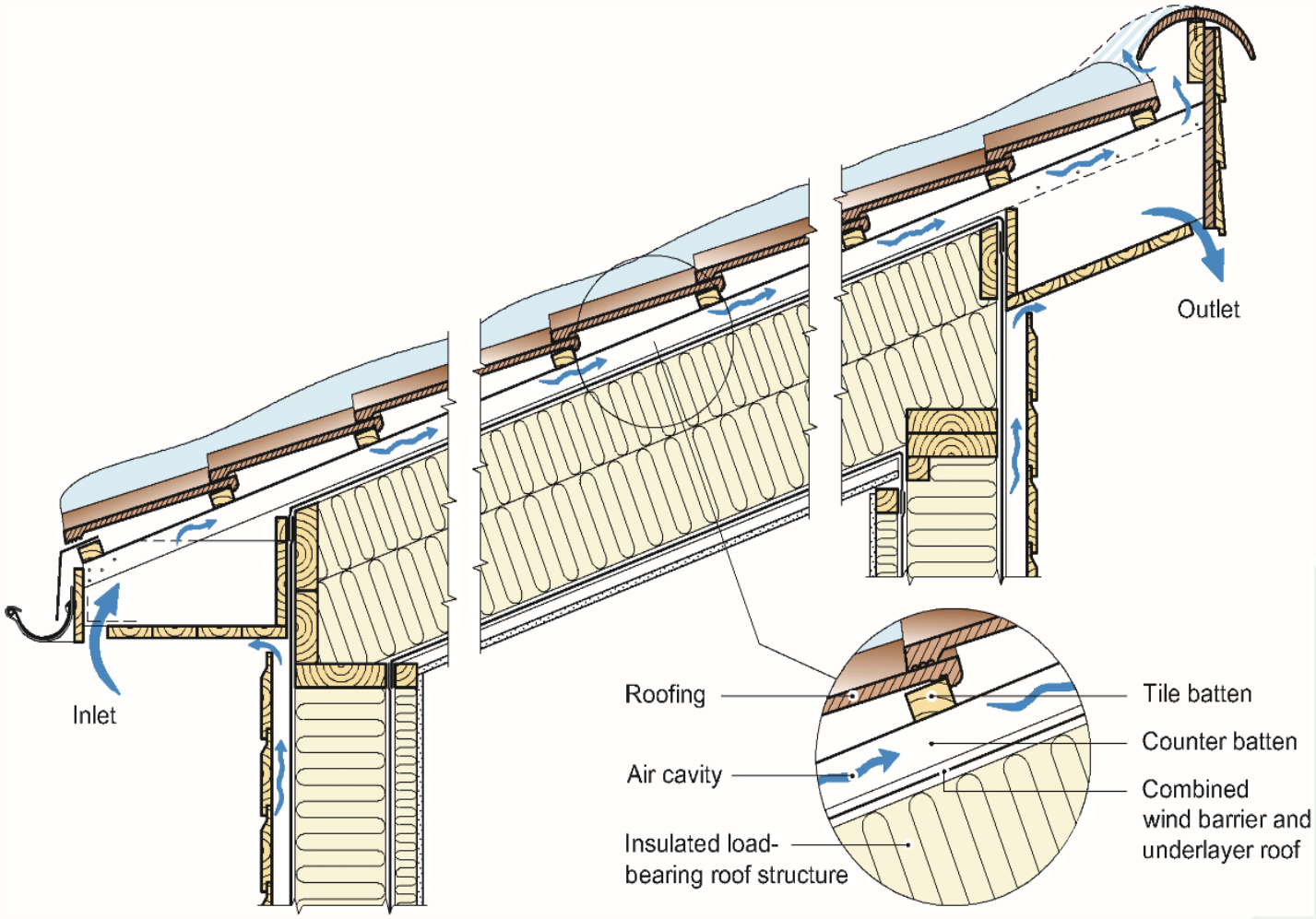
# Ventilated pitched wooden roofs



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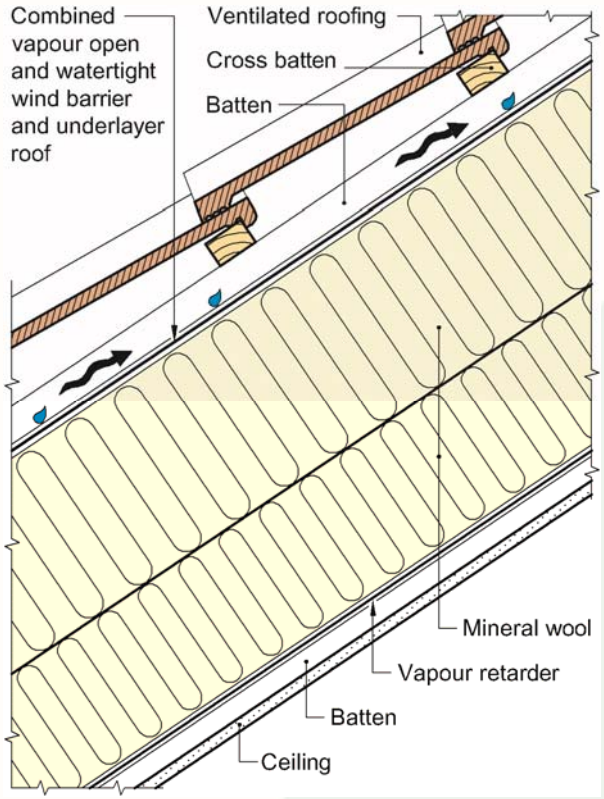
# Why ventilate roofs?

The basic principles for roofing ventilation is to transport:

1) moisture from the roof and thus prevent moisture damages
2) heat and thus prevent unwanted melting of snow and icing at the eaves



# Large ventilated wooden roofs - increased risks

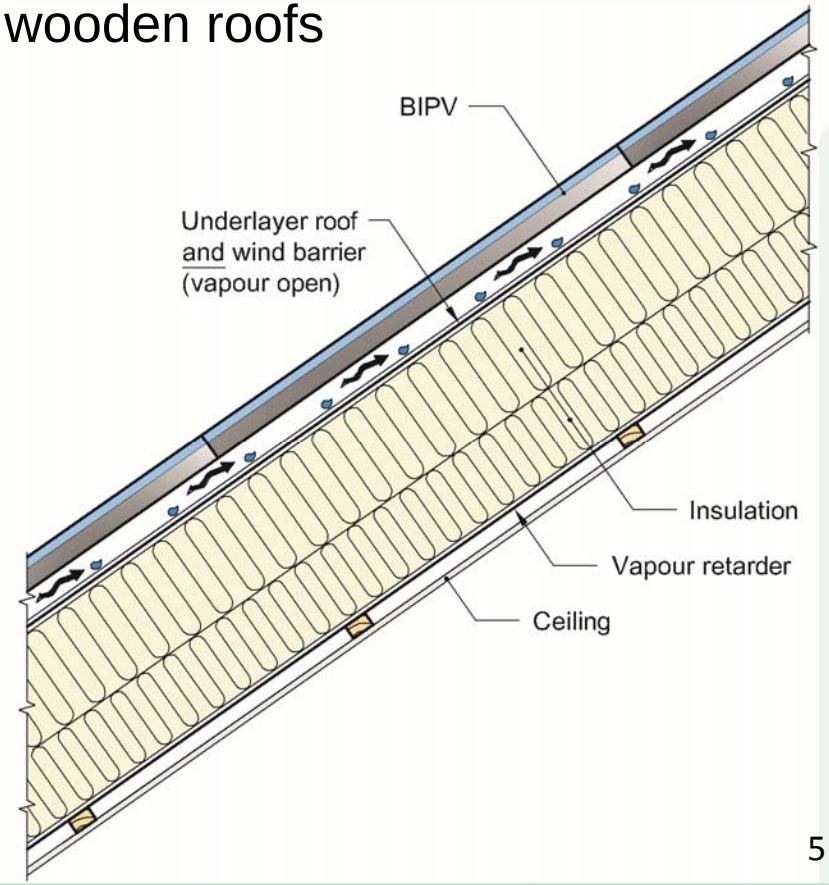
Increased interest in large, low slope wooden roofs

Lacking guidelines

Increased precipitation

Increased insulation thickness

Use of BIPV

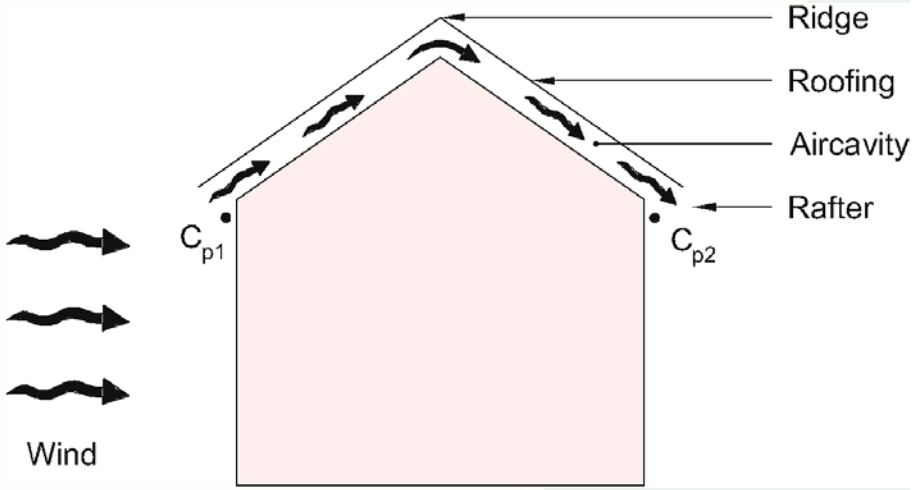


# Climate adaptation of wooden roofs

Main task:

1. Increase knowledge about moisture safety and air flow through the air cavity of pitched wooden roofs.

2. Form a basis for development of design guidelines for large low-pitched wooden roofs



# Research questions

1) What are the building physical challenges related to pitched wooden roofs and introduction of BIPV in the Nordic climate?

2) How is the thermal transmittance and the related moisture risk affected by natural convection in highly insulated timber frame structures?

3) How can the complex driving forces and resistances of ventilated pitched roofs be simplified for the design of an air cavity of long, low-pitched roofs?

# Structure of the work

Part 1 Motivation, current state and future challenges
(Papers 1 and 2)

Part 2 Increased insulation, moisture-resilient constructions
(Paper 3)

Part 3 Ventilating guidelines, knowledge base
(Papers 4, 5, 6 and 7)

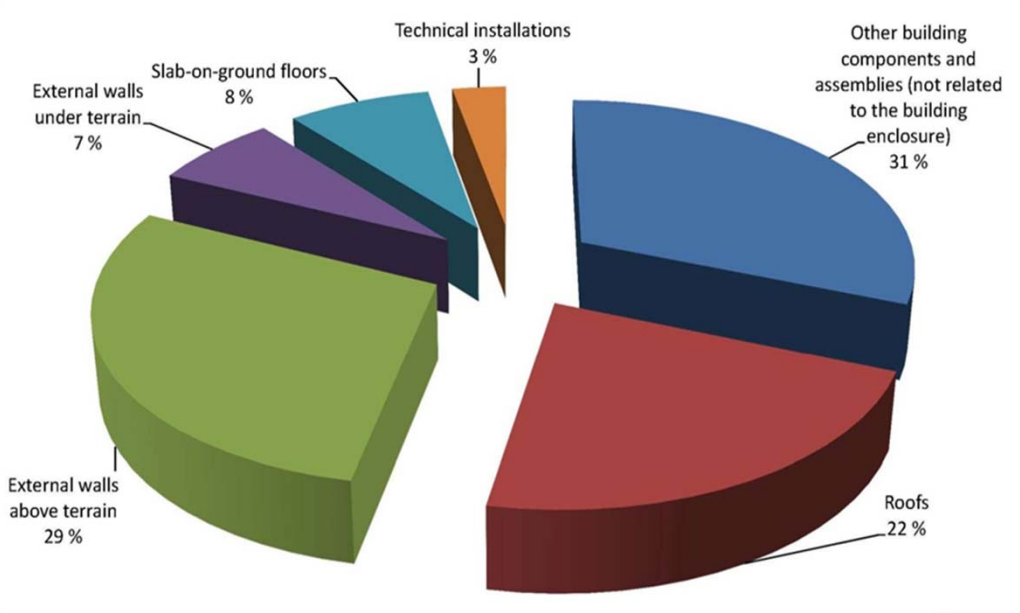
# Methods

Part 1 Scoping litterature review
SINTEF Building Defects Archive

Part 2 Scoping litterature review
Laboratory measurements (Hot-Box)

Part 3 Scoping litterature review
Field measurement (ZEB Test Cell Laboratory and Tyholt test house)
Laboratory measurements (Air cavity model)
Numerical analysis (COMSOL, Analytical calculation model)

# Building defects




A large part located to roofs

SINTEF Building defects archive consisting of more than 2000 reports

Overview of typical defects and causes

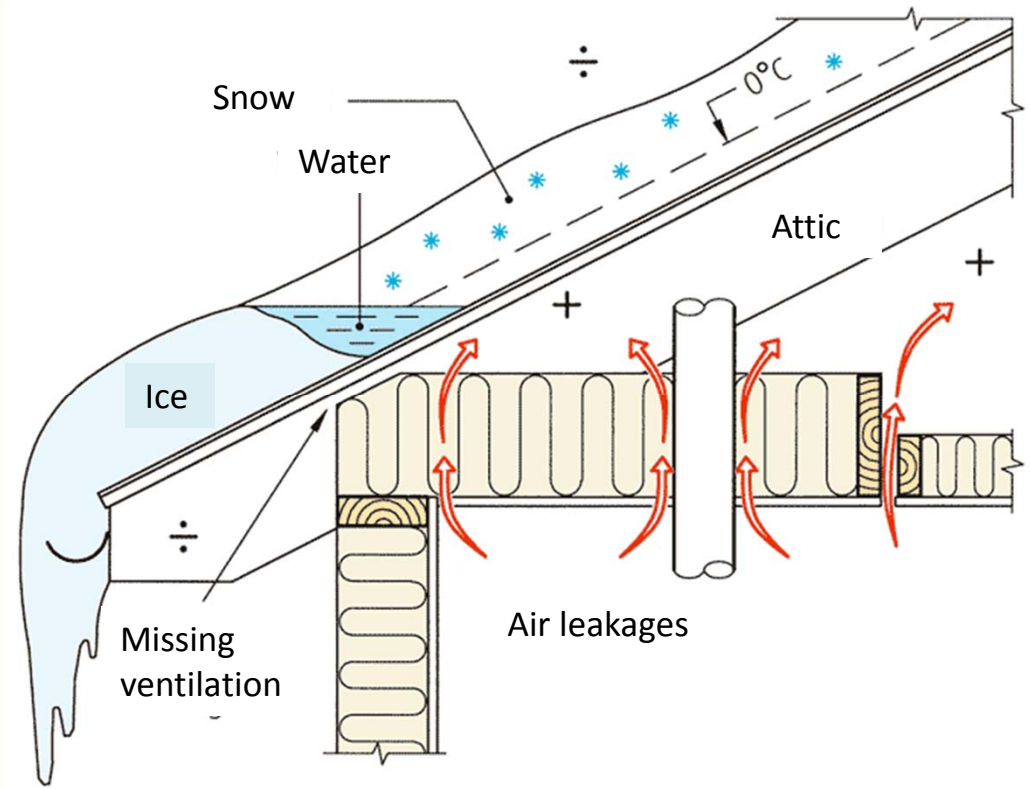
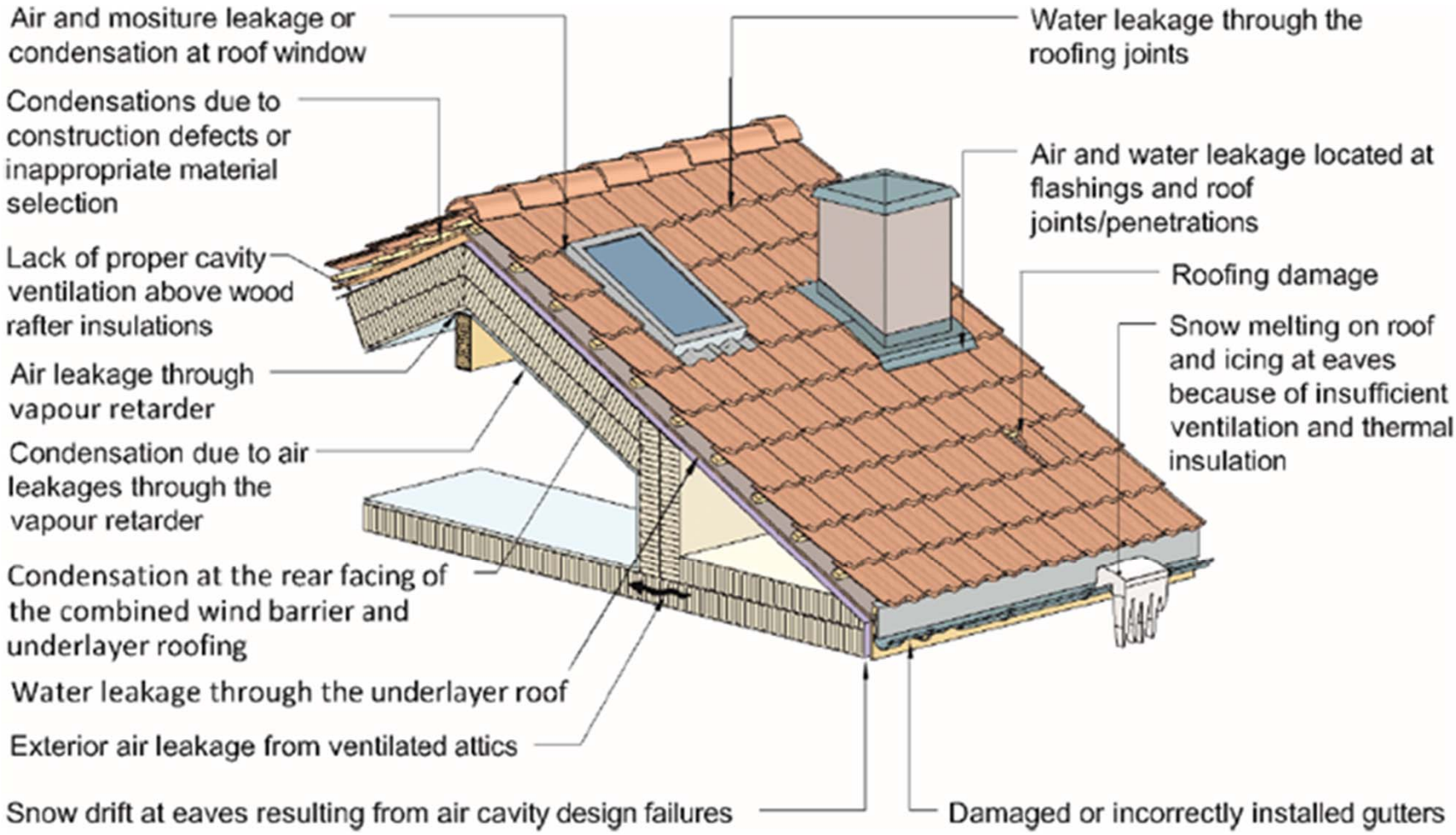



Illustration: Byggforskserien 725.117


Air and mositure leakage or condensation at roof window
Condensations due to construction defects or inappropriate material selection
Lack of proper cavity ventilation above wood rafter insulations
Air leakage through vapour retarder
Condensation due to air leakages through the vapour retarder
Condensation at the rear facing of the combined wind barrier and underlayer roofing
Water leakage through the underlayer roof
Exterior air leakage from ventilated attics
Snow drift at eaves resulting from air cavity design failures
Water leakage through the roofing joints
Air and water leakage located at flashings and roof joints/penetrations
Roofing damage
Snow melting on roof and icing at eaves because of insufficient ventilation and thermal insulation
Damaged or incorrectly installed gutters

# Part 1-2

Available online at www.sciencedirect.com
ScienceDirect
Energy Procedia 78 (2015) 1962 – 1967
Energy Procedia

6th International Building Physics Conference, IBPC 2015

## Roof-integrated PV in Nordic climate - Building physical challenges

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[b]SINTEF Building and infrastructure, Trondheim,




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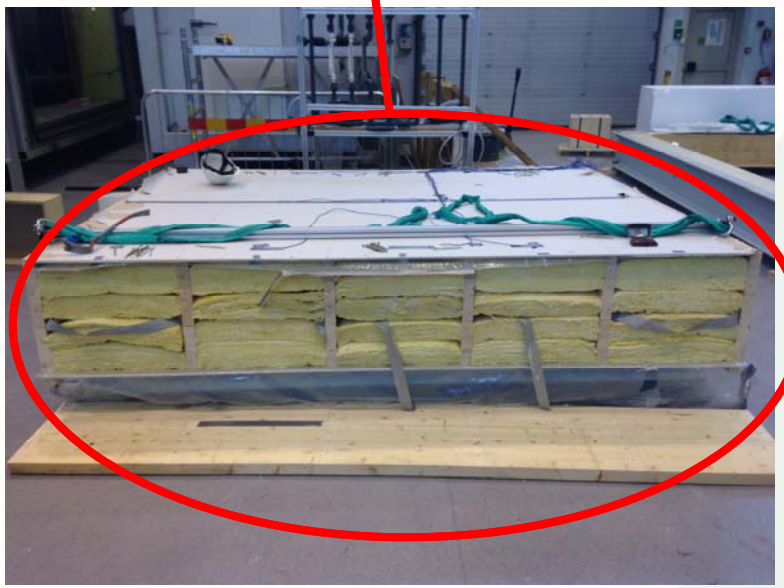
Part 2

# Highly insulated wooden roofs

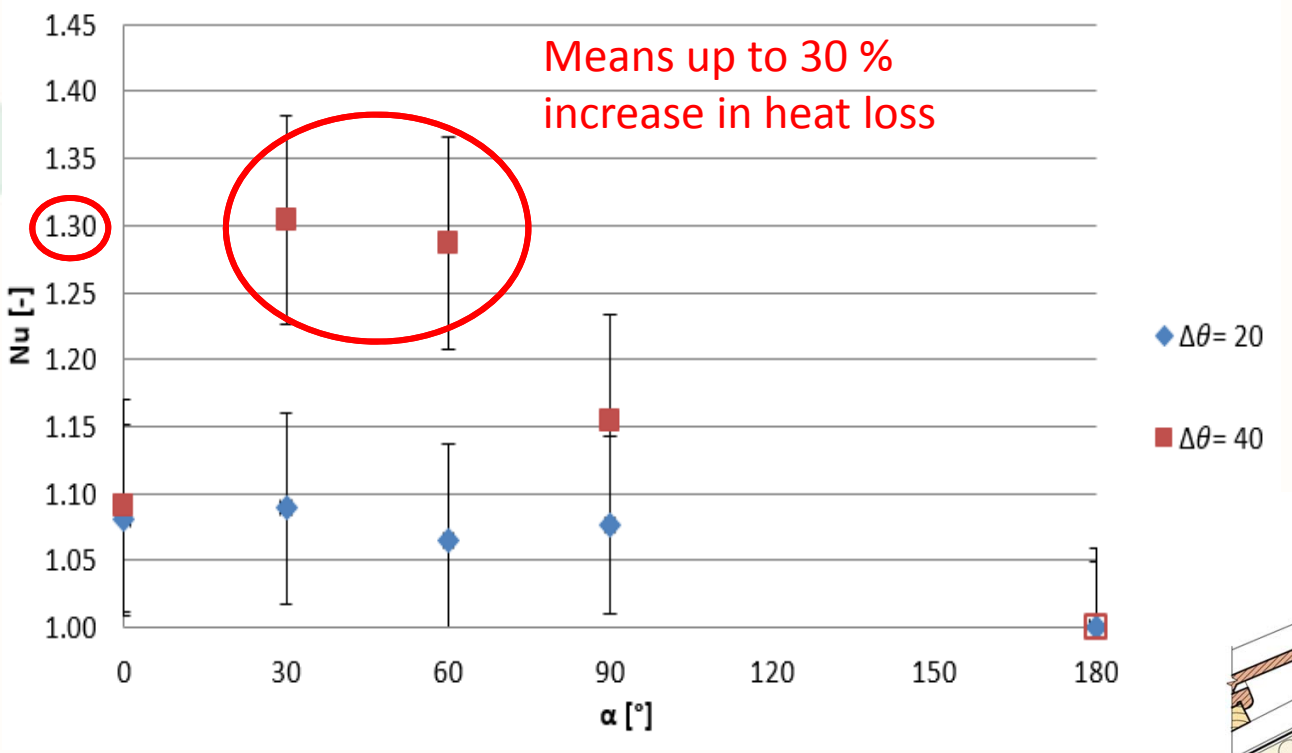
Risk of increased heat transfer (i.e energy use) and redistribution of moisture (i.e potential moisture problem)

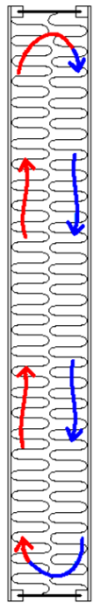
Thick wood frame structures

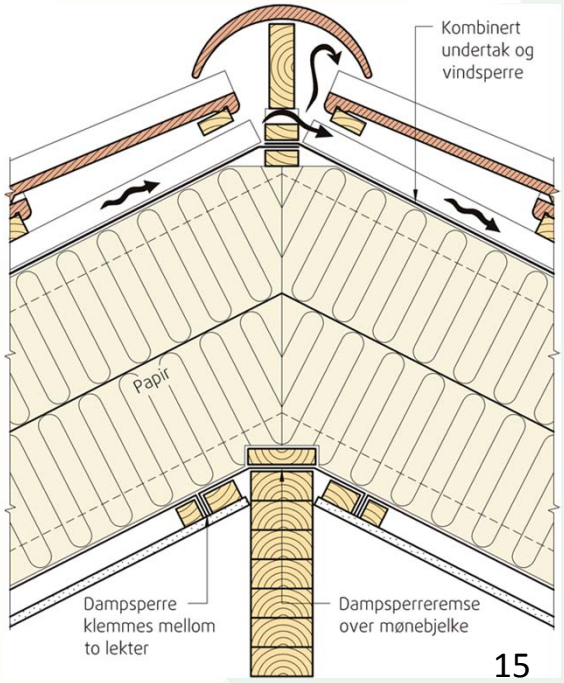
Angle of inclination



**Part 2**






Heat transfer affected by:

Temperature difference across structure

Angle of inclination



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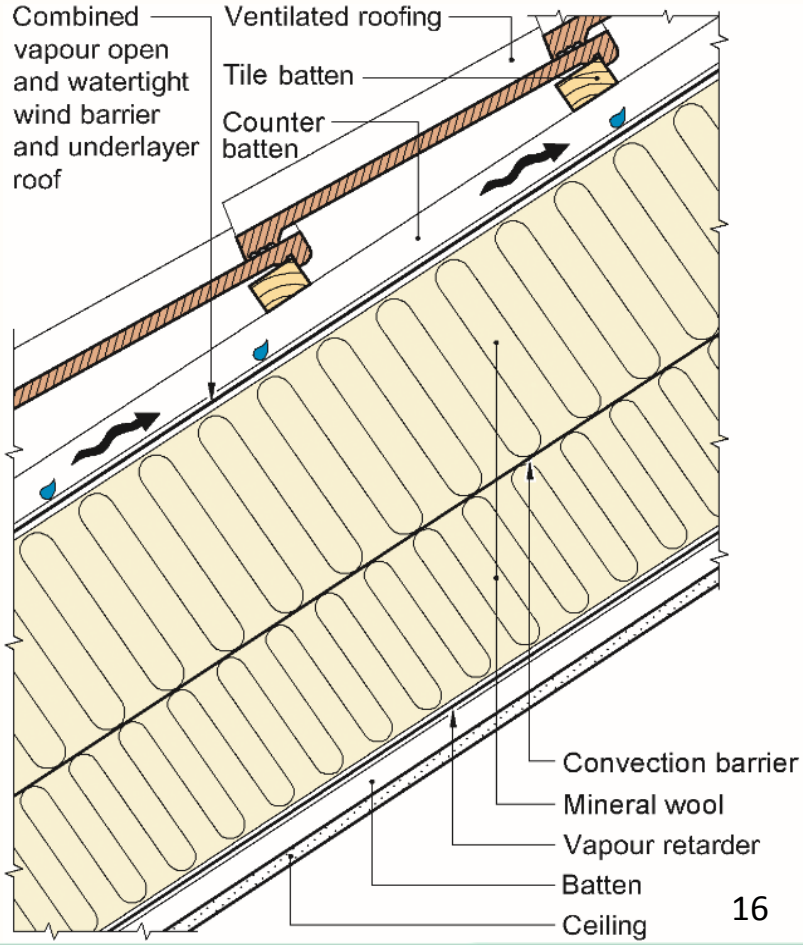
Part 2

# Recommendation for achieving full effect of the thermal insulation:

Install a convection barrier if the insulation thickness > 200 mm

Using mineral wool battens with paper on one face is sufficient



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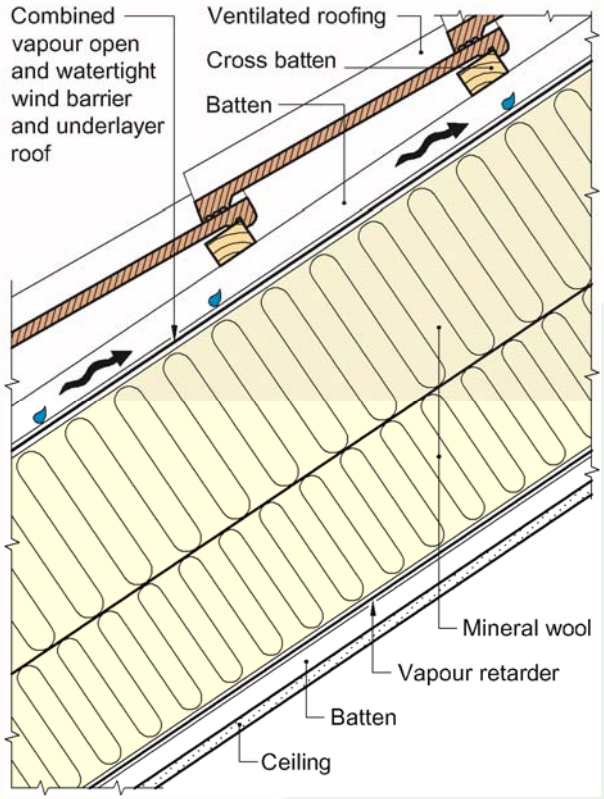
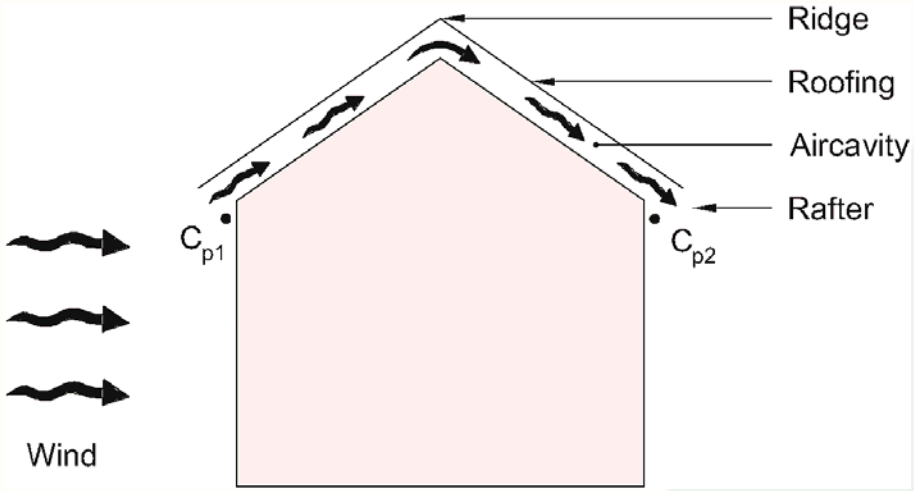


# Roof ventilation

The ventilation of the cavity is given by:

Driving forces: wind and temperature differences (natural convection)

Pressure losses



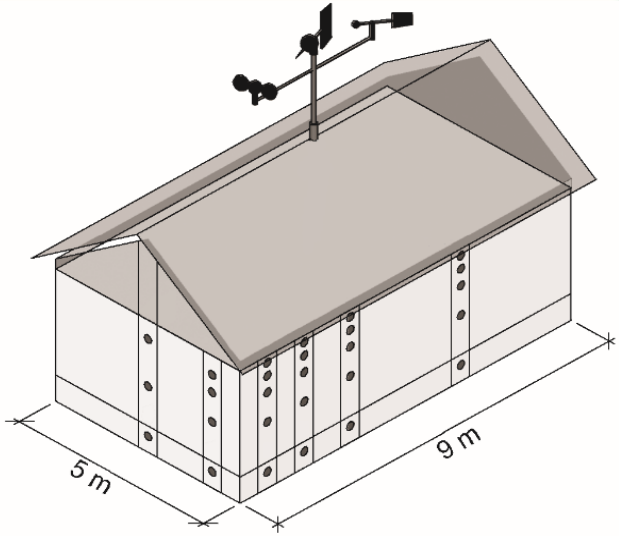
# Driving forces - wind

Measurements performed by Sivert Uvsløkk in 1985!

Wind pressure measurements performed on a rotating test house situated at Tyholt

We found; New wind pressure coefficients for building facade helping us in our calculations of wind driven ventilation


Picture by Sivert Uvsløkk, SINTEF




Wind pressure measuring on the exterior surface of the cladding

**Part 3-1**

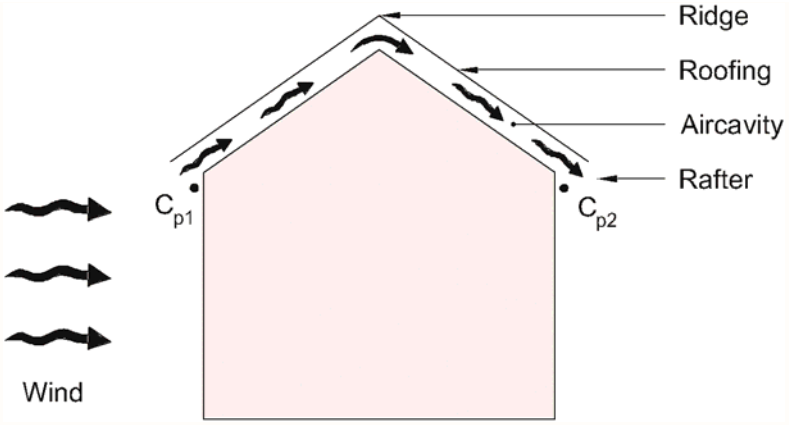




Photo: http://www.reeve.com/Weather/weather_station_installation.htm



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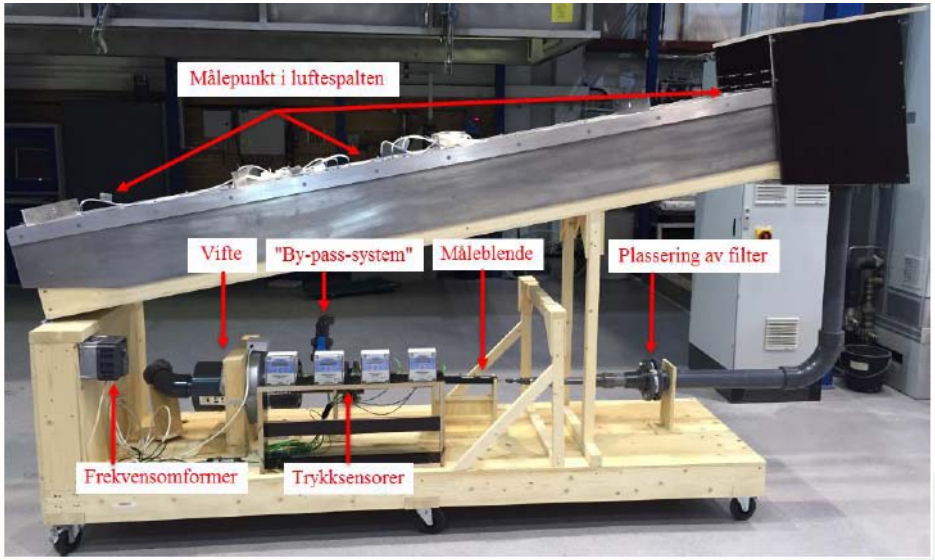
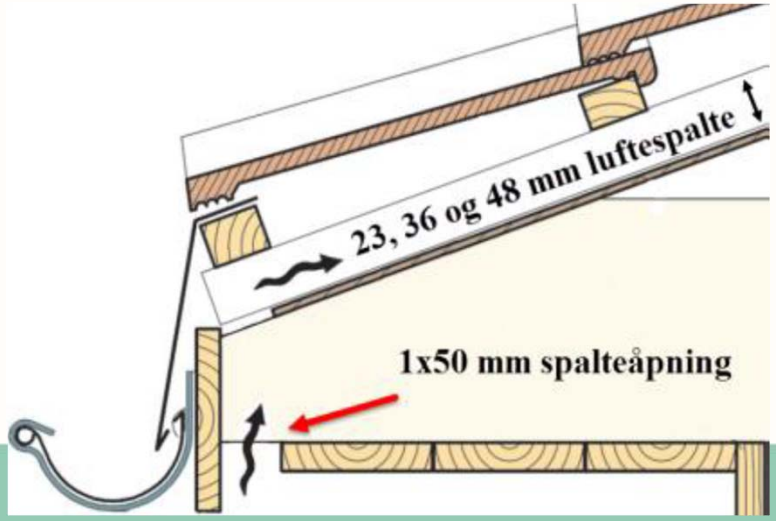
Part 3-2

# Air flow inside the air cavity in a roof

Laboratory investigation to investigate pressure losses







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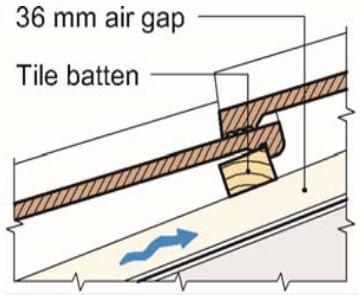
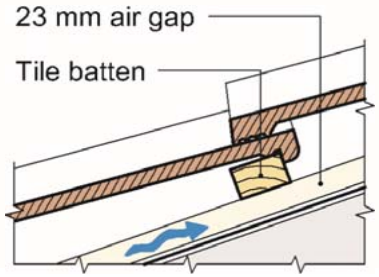
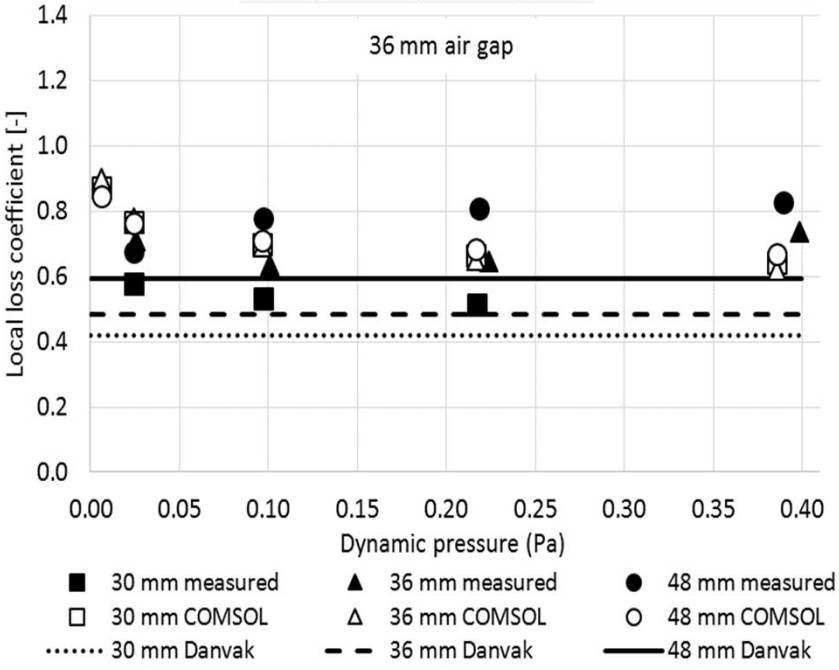
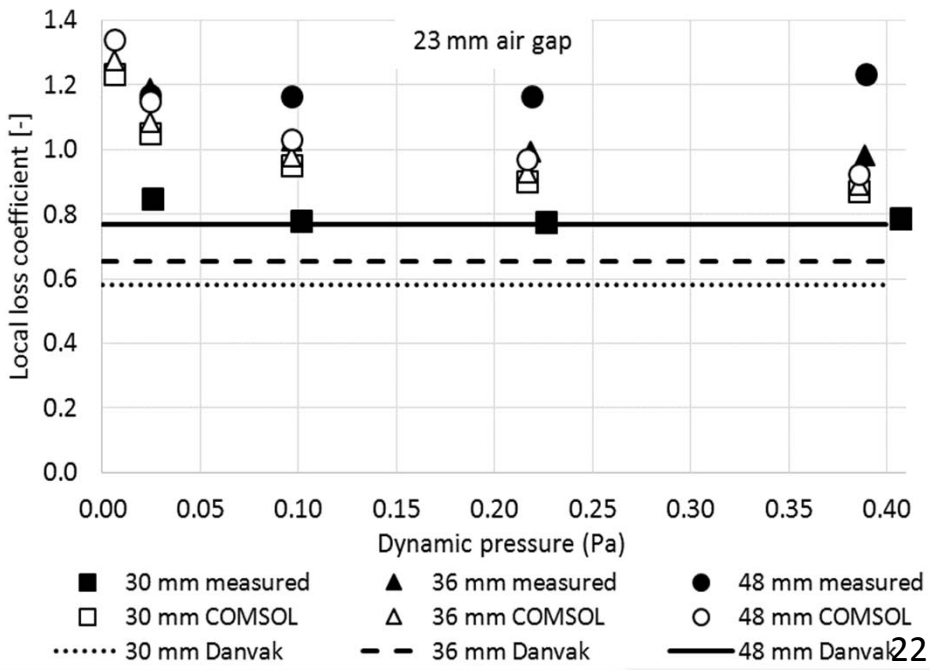
Part 3-2

# Local loss coefficient tile battens



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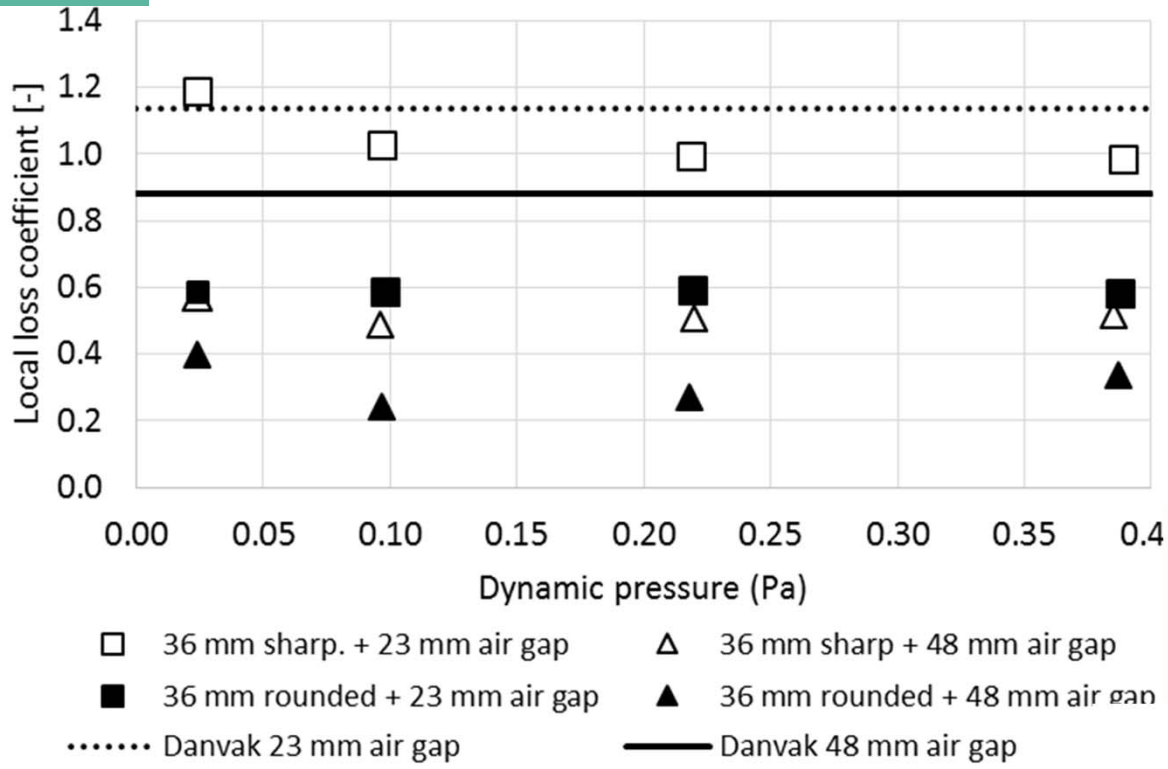
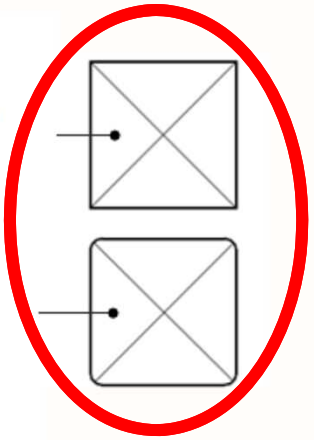
## Part 3-2

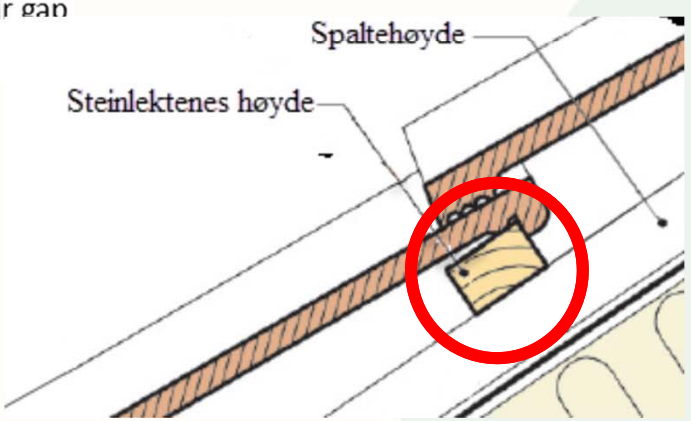



Sharp-edged tile batten

Round-edged tile batten

r = 3 mm



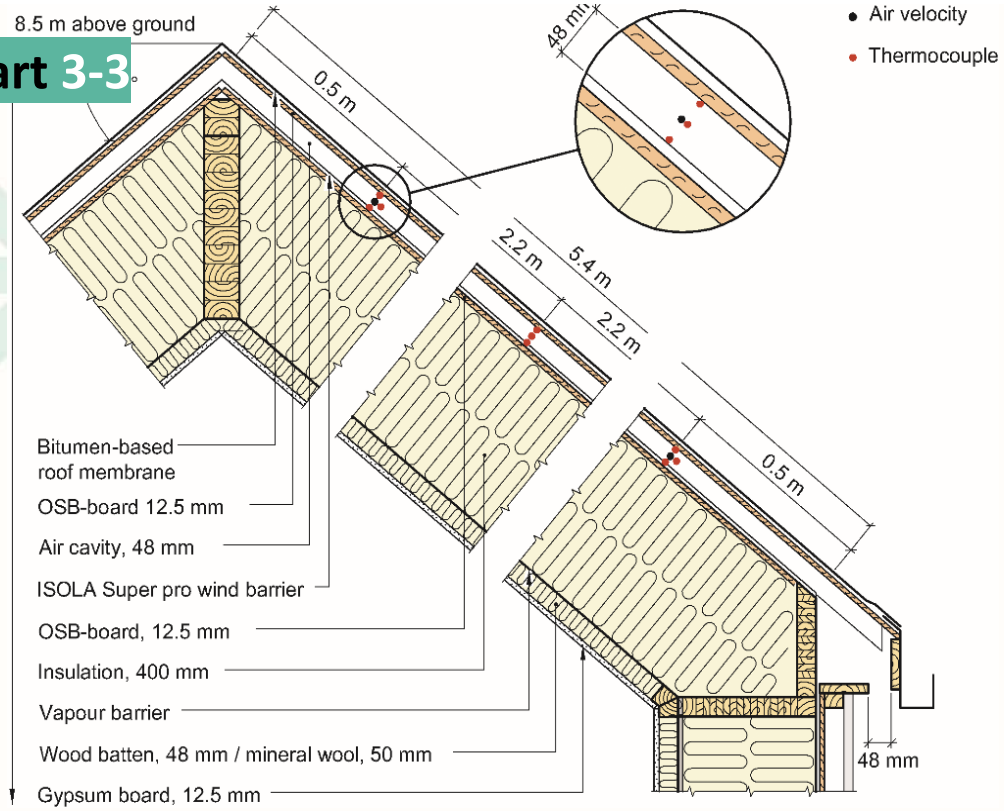


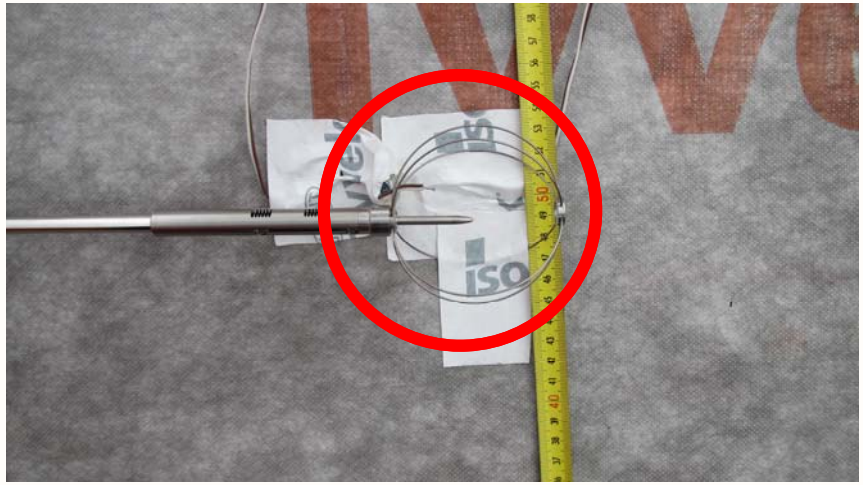
# Field experiments - performance of roofs

ZEB Test Cell Laboratory

Located at NTNU campus-Trondheim

## Part 3-3





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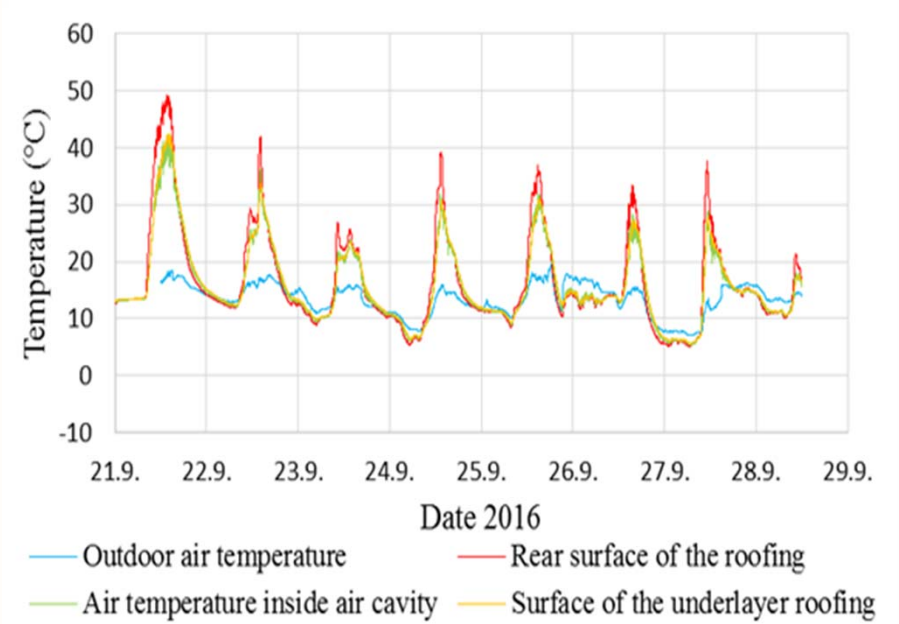
Part 3-3

# Temperature conditions of the roof




| | Lower surface of roofing | | | Top surface of the underlayer roofing | | |
|---|---|---|---|---|---|---|
| Period | Share of period with temp. lower than outdoor air temp. | Largest temperature difference below ambient temperature | Maximum temperature | Share of period with temp. lower than outdoor air temp. | Largest temperature difference below ambient temperature | Maximum temperature |
| 22.3–31.3 | 51 % | 5 °C | 36 °C | 50 % | 5 °C | 28 °C |
| 3.7–15.7 | 14 % | 3 °C | 60 °C | 5 % | 3 °C | 57 °C |
| 21.9–29.9 | 56 % | 11 °C | 49 °C | 55 % | 9 °C | 47 °C |



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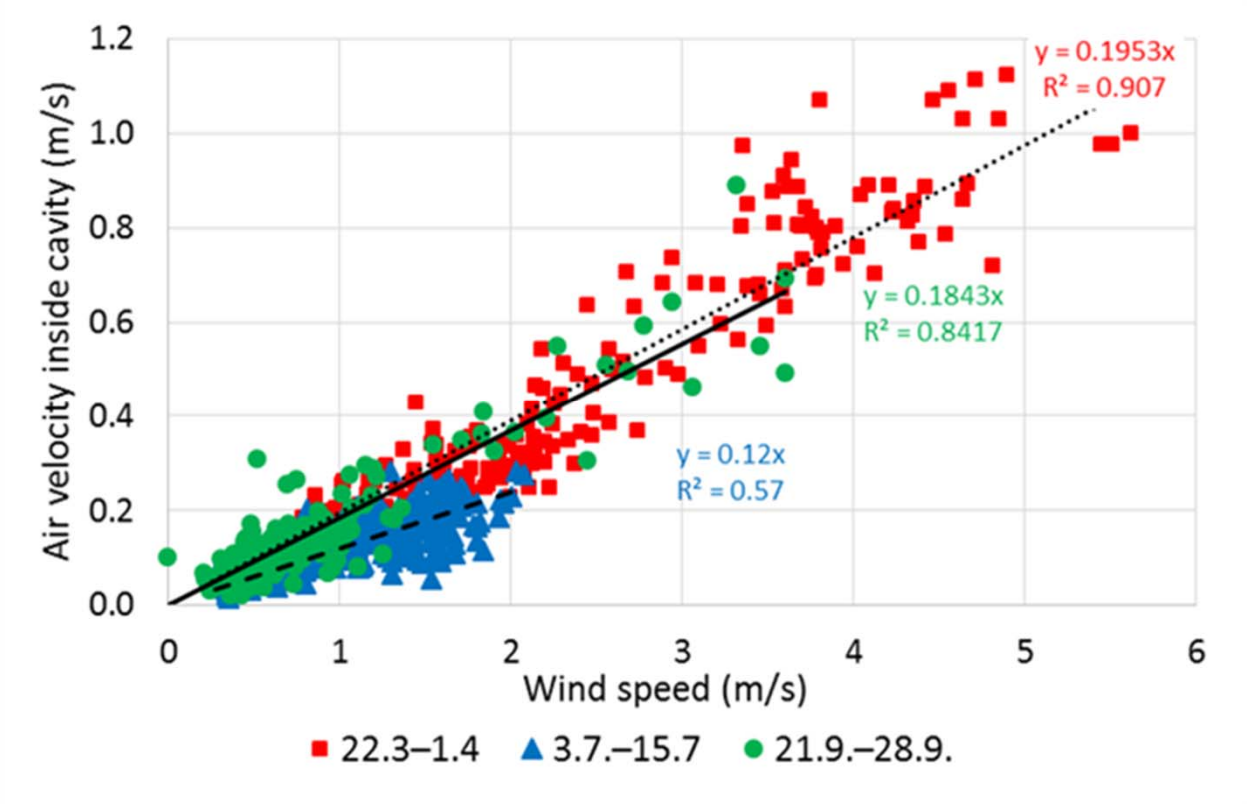
# Air velocity measurements

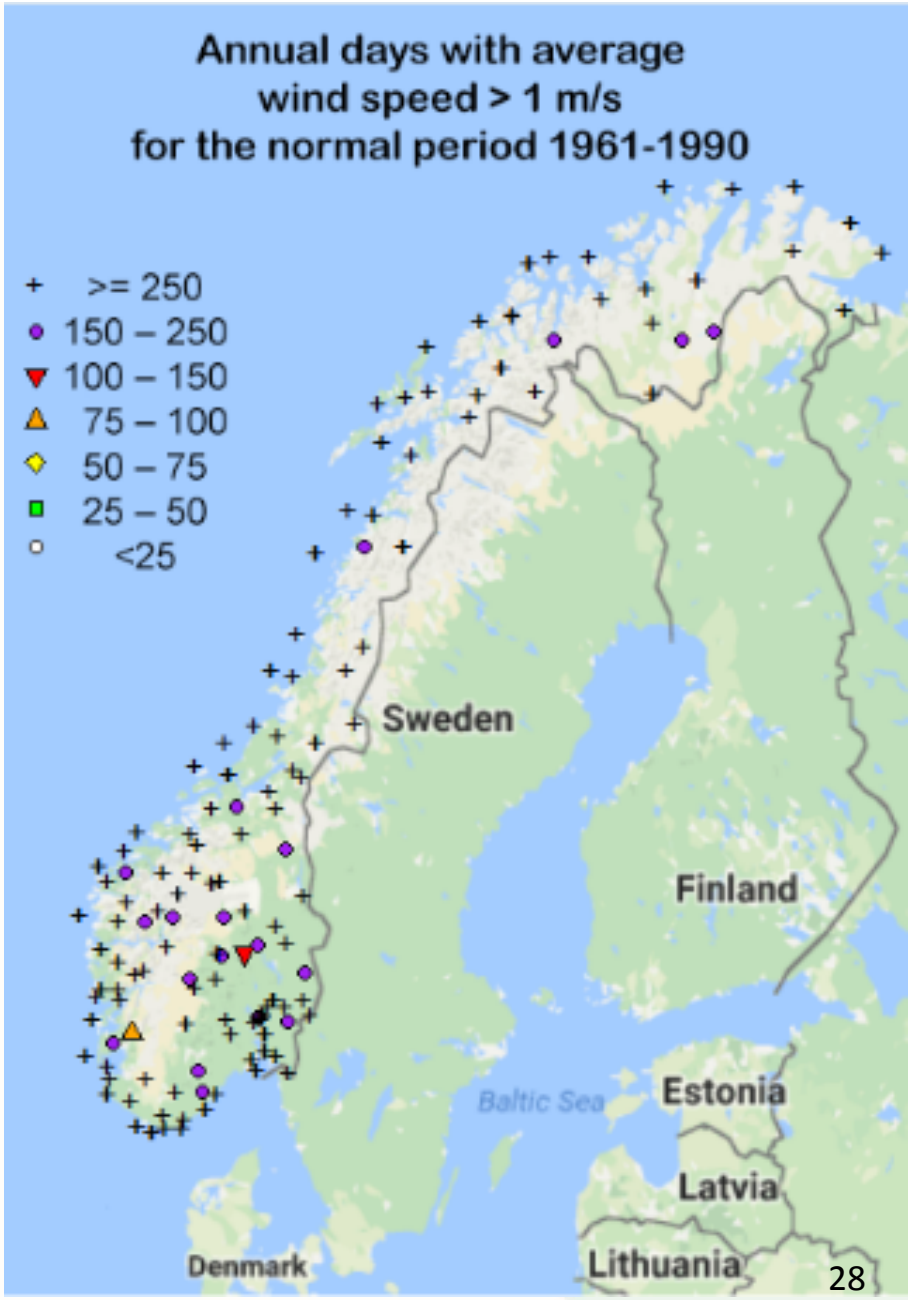


Part 3-4

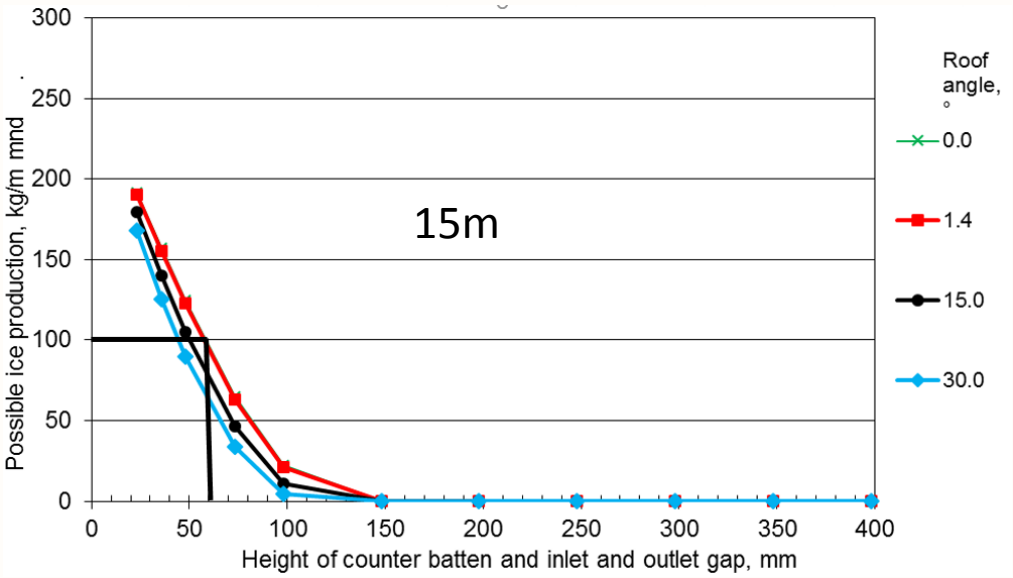
# Air cavity design guidelines

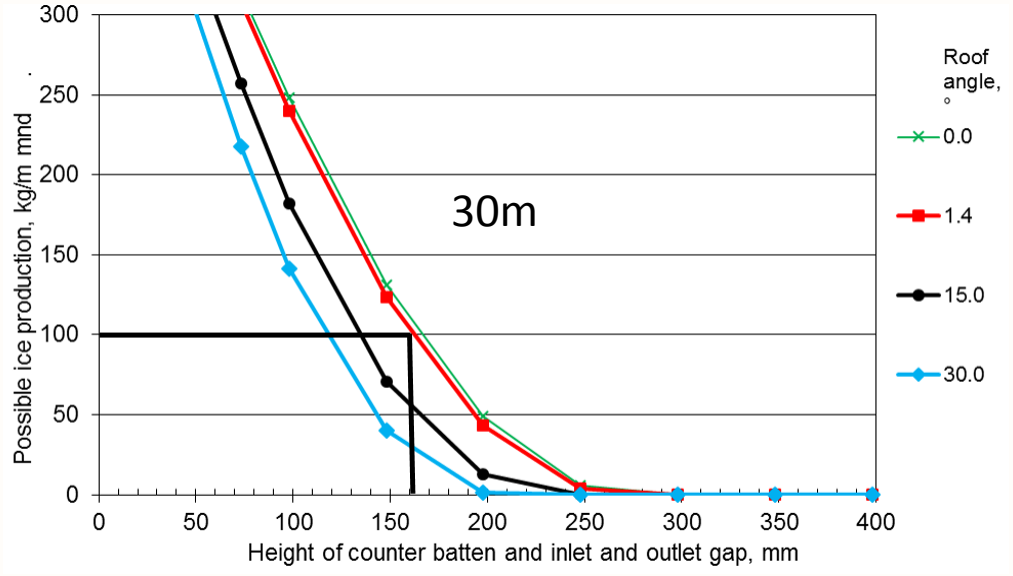
Input values of the existing roof ventilation model of Uvsløkk has been further improved.

Ventilation guidelines of longer roofs has been included.



**Part 3-4**



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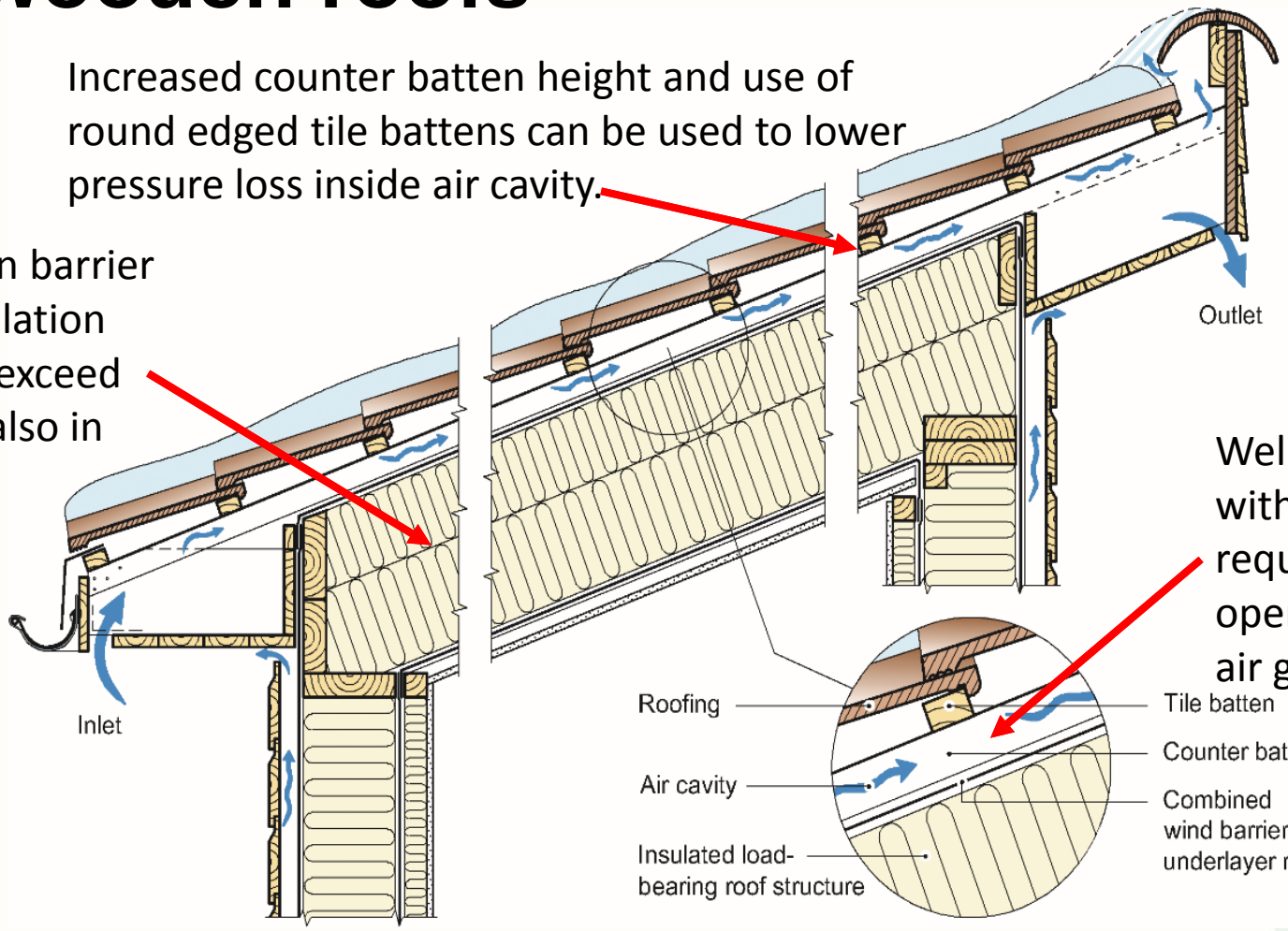
# New guidelines for risk reduction of wooden roofs

Increased counter batten height and use of round edged tile battens can be used to lower pressure loss inside air cavity.

Convection barrier when insulation thickness exceed 200 mm, also in roofs.

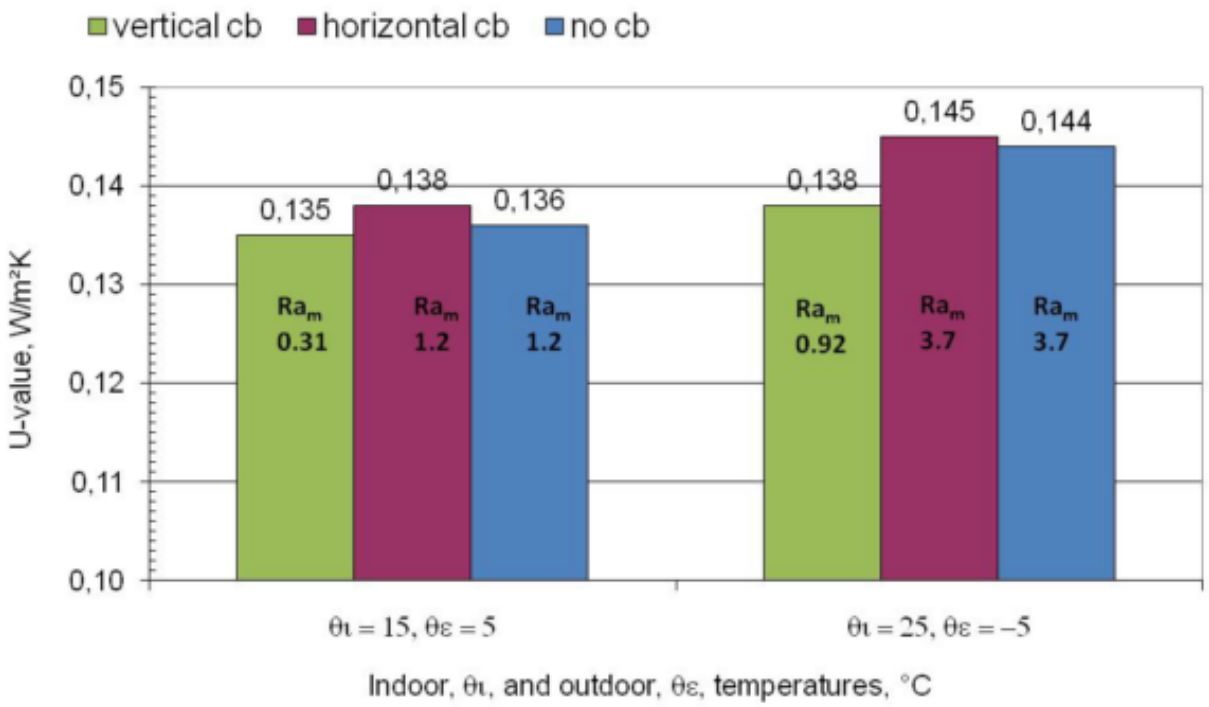


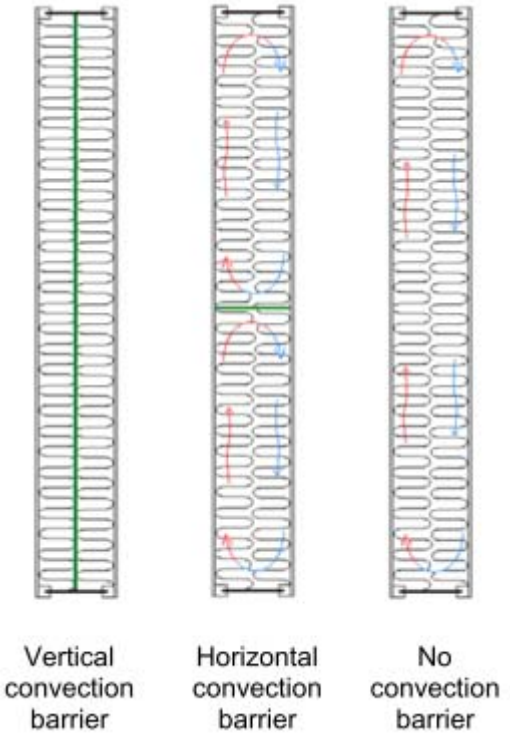

Well insulated roof with length of 30 m requires a 160 mm opening through the air gap system.

# Thank you for the attention

PhD-candidate Lars Gullbrekken.

E-mail: lars.gullbrekken@sintef.no




Uvsløkk et al (2010)

# U-value at 40 °C temperature difference to the right