Urban Home Ventilation

Webinar 6-13-19 May 2020

Date	Theme:
Webinar 6th May: Kitchen ventilation
Webinar 13th May: Ventilation requirements, trends and thermal comfort
Webinar 19th May: Moisture control
Webinar on May 6th, 2020 (Urban Home Ventilation part 1: Kitchen Ventilation)
- More than 230 people attended
- Recordings now available at: https://www.aivc.org/resources/collection-publications/events-recordings

Webinar on May 13th, 2020 (Urban Home Ventilation part 2: Ventilation requirements, trends and thermal comfort)
- More than 300 people attended
- Recordings now available at: https://www.aivc.org/resources/collection-publications/events-recordings

Urban Home Ventilation
Part 3: Moisture control

- 15:00 | Welcome, Kari Thunshelle, SINTEF
- 15:05 | Strategies for avoiding too high or too low relative humidity in dwellings, Sverre Holøs, SINTEF, Norway
- 15:25 | Moisture buffering in modern timber constructions, Dimitrios Kraniotis, OsloMet, Norway
- 15:45 | Understanding moisture recovery in heat/energy recovery ventilation as the basis for new market solutions, Peng Liu, SINTEF, Norway
- 16:05 | Q&A poll & Workshop discussion, Peter Schild, OsloMet
- 16:30 | End of webinar

Disclaimer: The sole responsibility for the content of presentations and information given orally during AIVC webinars lies with the authors. It does not necessarily reflect the opinion of AIVC. Neither AIVC nor the authors are responsible for any use that may be made of information contained therein.
Urban Home Ventilation
Part 3: Moisture control

Speakers

Sverre Holøs (SINTEF, NO)
Dimitrios Kraniotis (OsloMet, NO)
Peng Liu (SINTEF, NO)

Moderators

Kari Thunshelle (SINEF, NO)
Peter Schild (OsloMet, NO)

Webinar management

Maria Kapsalaki (INIVE, BE)
Valérie Leprince (INIVE, BE)

If you can’t hear the webinar sound

Make sure that Audio Connection is on by clicking on Communicate / Audio Connection.

If you still can’t hear, run a Speaker Audio Test to make sure the correct output is selected [To run the test, click on Communicate / Speaker and Microphone]
How to ask questions during the webinar

Locate the Q&A box (NOT the Chat)

Select All Panelists | Type your question | Click on Send

NOTES:
• The webinar presentations will be recorded and published at http://aivc.org/resources/collection-publications/events-recordings within a couple of weeks, along with the presentation slides.
• Short Q&A Poll before workshop discussion
• After the end of the webinar you will be redirected to our post event survey. Your feedback is valuable so please take some minutes of your time to fill it in.

www.aivc.org
www.sintef.no
www.oslomet.no/
Urban Home Ventilation

Webinar 6-13-19 May 2020

<table>
<thead>
<tr>
<th>Webinar 6 May</th>
<th>Webinar 13 May</th>
<th>Webinar 19 May</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Theme 1:</strong> Kitchen ventilation</td>
<td><strong>Theme 2:</strong> Ventilation requirements, quality, and trends</td>
<td><strong>Theme 3:</strong> Moisture control</td>
</tr>
<tr>
<td>15:00 Welcome</td>
<td>15:00 Welcome</td>
<td>18:00 Welcome</td>
</tr>
<tr>
<td>15:05 Chair: Kari Thunshelle, SINTEF</td>
<td>15:05 Chair: Kari Thunshelle, SINTEF</td>
<td>15:05 Chair: Kari Thunshelle, SINTEF</td>
</tr>
<tr>
<td>15:05 Documentation of cooker hood performance, a laboratory prospective</td>
<td>15:05 Ventilation and IAQ in Nordic countries — Status, trends and opportunities</td>
<td>15:05 Strategies for avoiding too high or too low relative humidity in dwellings</td>
</tr>
<tr>
<td>Swen Rued, RISE, Sweden</td>
<td>Kari Thunshelle, SINTEF, Norway</td>
<td>Olly Wanggård, SINTEF, Norway</td>
</tr>
<tr>
<td>15:25 Extract cooker hoods — possibilities and challenges</td>
<td>15:25 A developer’s perspective on urban home ventilation issues</td>
<td>15:25 Moisture buffering in modern timber constructions</td>
</tr>
<tr>
<td>Hasvard Augusten, Roto Vet, Norway</td>
<td>Ole Petter Haugen, Selisqog Bolig, Norway</td>
<td>Dimitris Krokidis, OsloMet, Norway</td>
</tr>
<tr>
<td>15:45 Remodelling cooker hoods — possibilities and challenges</td>
<td>nZEB temperature zoning — “Fresh” bedrooms and a warm living room</td>
<td>Understanding moisture recovery in heat/energy recovery ventilation as the basis for new market solutions</td>
</tr>
<tr>
<td>Martin Olsenhjamborg, Reinhard Wiedermann, BRE, Germany</td>
<td>Laurent Georges, MIT, Norway</td>
<td>Feng Liu, SINTEF, Norway</td>
</tr>
<tr>
<td>15:55 Experiences from assessing in situ effectiveness of cooker hoods</td>
<td>Q&amp;A poll</td>
<td>Q&amp;A poll</td>
</tr>
<tr>
<td>Jan Eideil, LEML, USA</td>
<td>Workshop discussion</td>
<td>Workshop discussion</td>
</tr>
<tr>
<td>16:10 Q&amp;A poll</td>
<td>Moderator: Peter Schiold, OsloMet</td>
<td>Moderator: Peter Schiold, OsloMet</td>
</tr>
<tr>
<td>16:30 Workshop discussion</td>
<td>- 16:30</td>
<td>- 16:30</td>
</tr>
<tr>
<td>Moderator: Peter Schiold, OsloMet</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

The webinar presentations will be recorded and published at [http://aivc.org/resources/collection-publications/events-recordings](http://aivc.org/resources/collection-publications/events-recordings)
Webinar on May 6\textsuperscript{th}, 2020 (Urban Home Ventilation part 1: Kitchen Ventilation)
- More than 230 people attended
- Recordings now available at: https://www.aivc.org/resources/collection-publications/events-recordings

Webinar on May 13\textsuperscript{th}, 2020 (Urban Home Ventilation part 2: Ventilation requirements, trends and thermal comfort)
- More than 300 people attended
- Recordings now available at: https://www.aivc.org/resources/collection-publications/events-recordings

Healthy Energy-efficient Urban Home Ventilation

https://www.sintef.no/projectweb/healthy-energy-efficient-urban-home-ventilation/
Technology for a better society
## Summary. To avoid too low humidity consider:

<table>
<thead>
<tr>
<th>Action</th>
<th>Potential effect</th>
<th>Limitations / challenges</th>
</tr>
</thead>
<tbody>
<tr>
<td>Hygroscopic materials</td>
<td>Limited</td>
<td>Only short-term variation</td>
</tr>
<tr>
<td>Decreasing indoor temperature</td>
<td>Limited</td>
<td>User comfort and preferences</td>
</tr>
<tr>
<td>Adding sources</td>
<td>Limited</td>
<td>Indoor air quality</td>
</tr>
<tr>
<td>Reducing ventilation</td>
<td>Moderate</td>
<td>Indoor air quality</td>
</tr>
<tr>
<td>Recovering moisture</td>
<td>Moderate – large</td>
<td>Hygiene and technology, stay tuned...</td>
</tr>
<tr>
<td>Humidification</td>
<td>Large</td>
<td>Energy, hygiene</td>
</tr>
<tr>
<td>All above:</td>
<td></td>
<td>Condensation risks!</td>
</tr>
</tbody>
</table>
What do we mean by too high or too low indoor moisture?

Arundel & al. reexamined

Cases 35%, controls 26% (Solomon 1976)
Cases 50%, controls 43% (Korsgaard 1982)
Humidified houses / non-humidified 703/197 (Arlian 1978)
13 refs on allergic reactions from humidification
Relative and absolute moisture, moisture excess, dewpoint

Absolute humidity: 7 g/kg
Moisture excess: 4 g/kg
Relative humidity 40 %
Dew point 9 °C
Partial pressure of water

Causes of building damage - Norway

Data source: SINTEF archives 1993-2002. Bias towards large buildings, non-trivial cases, costly repairs. Bias against single household dwellings, "water damage".

Existing buildings are vulnerable to high humidity:

- Cold surfaces, including windows and thermal bridges
- Air leakages
- Cold area (crawl space, garage) ventilated by hot humid outdoor air
- Uncomfortably cold supply air -> low ventilation rates

Newer buildings less vulnerable to high humidity:

© SINTEF Byggforsk
You are not a plant: Relative humidity is not the only important humidity for health and comfort.

What determines indoor humidity?

- **Buffering**
  - Temperature and moisture content determines RH

- **Indoor sources**

- **Dehumidification**

  - Supply air g/kg

  - Extract air g/kg

  - Ventilation Rate
Moisture content of outdoor air – Oslo

Observations from Blindern, 2010. Data from The Norwegian Meteorological Institute

Moisture content of outdoor air

Dublin, Minsk and Porto climate data from Energy Plus data (ASHRAE)
What can we do about (too) low humidity

- Buffering
- Reduce temperature
- Reduce ventilation rates
- Add moisture
  - Plants, drying clothes, showering, cooking...
  - Room humidifier / airconditioner
  - Supply air humidification
- Recover moisture
- Compensating actions

Reduces variation only
Increases relative humidity only
Increased absolute and relative humidity
Does not change humidity

Moisture buffering

Effect of materials on diurnal RH variation - laboratory
Moisture buffering: field studies

Both figs from (Kalamees, et al. 2009)


Our raw material: outdoor temperature and moisture during one year in Oslo (Blindern)
Reducing indoor temperature – low RH

Absolute humidity: 3.5 g/kg
Moisture excess: 1.5 g/kg
Relative humidity 20%
Dew point -1°C

Reducing indoor temperatures?

• Generally controlled by inhabitants
• Energy-efficient homes: cheap and easy to heat
• Likely trend: increasing indoor temperatures

Increasing moisture excess

Indoor RH lowest normally coincides with
• Highly polluted outdoor air
• Freezing risk in heat exchanger
• Peak energy demand
• Spending most of the time indoors

Energi i Norge – Wikipedia. Foto Priljen CC BY-SA via Wikimedia Commons
Ventilation and respiration

- 40-60 g water / hour
- 15 liters CO₂ / hour
- 1 olf

Target 1000 ppm CO₂ : 26 m³ / hour per person
Added moisture 1,5-2,3 g / m³

Moisture recovery

Ikke-hygroskopisk rotor
Increase excess: adding sources

- Shower: 3 kg/h
- Tree: 2-4 kg/h

- Add or remove indoor sources
  - Drying of clothes
  - Greenery
  - Extract at source (shower, cooker, combustion)
  - Humidifyer
  - Dehumidifier / Air-conditioning
"Compensating actions"

Against low humidity
- Remove irritant sources (volatiles and particles)
- Drink
- Select appropriate materials
- Moisten eyes and airways?

Against high humidity
- Tighten envelope
- Remove thermal bridges
- (Use robust materials)

Summary:

An integrated approach including Indoor humidity as one parameter of indoor environmental quality, combining elements below

<table>
<thead>
<tr>
<th>Action</th>
<th>Potential effect</th>
<th>Limitations / challenges</th>
</tr>
</thead>
<tbody>
<tr>
<td>Hygroscopic materials</td>
<td>Limited</td>
<td>Only short-term variation</td>
</tr>
<tr>
<td>Decreasing temperature</td>
<td>Limited</td>
<td>User comfort and preferences</td>
</tr>
<tr>
<td>Adding sources</td>
<td>Limited</td>
<td>Indoor air quality</td>
</tr>
<tr>
<td>Reducing ventilation</td>
<td>Moderate</td>
<td>Indoor air quality</td>
</tr>
<tr>
<td>Recovering moisture</td>
<td>Moderate – large</td>
<td>Stay tuned...</td>
</tr>
<tr>
<td>Humidification</td>
<td>Large</td>
<td>Energy, hygiene</td>
</tr>
<tr>
<td>All above:</td>
<td></td>
<td>Condensation risks!</td>
</tr>
</tbody>
</table>
## Target

<table>
<thead>
<tr>
<th>Target</th>
<th>Practical recommendation</th>
<th>Significance</th>
</tr>
</thead>
<tbody>
<tr>
<td>Bacteria</td>
<td>Avoid growth and reduce dissemination of pathogens</td>
<td>Avoid condensation, keep humidifiers free of bacteria, low RH in heating season</td>
</tr>
<tr>
<td>Virus</td>
<td>Reduce dissemination of pathogens</td>
<td>Avoid extreme highs and lows. Some indications that medium RH may inactivate virus.</td>
</tr>
<tr>
<td>Fungi</td>
<td>Avoid mould growth on materials -&gt; RH &lt; 85% on organic materials</td>
<td>Avoid &quot;high&quot; moisture excess: Differs among buildings and climates. Higher in older buildings in cold or humid climates</td>
</tr>
<tr>
<td>Mites</td>
<td>Reduce population</td>
<td>&lt; 40% RH in bedroom in winter. Hard to achieve in warm climates</td>
</tr>
<tr>
<td>Respiratory infections</td>
<td>For influenza: avoid extreme drop in RH</td>
<td>?</td>
</tr>
<tr>
<td>Allergic rhinitis &amp; asthma</td>
<td>Reduce symptoms</td>
<td>Avoid extreme highs and lows. Individually high</td>
</tr>
<tr>
<td>Chemical interactions</td>
<td>?</td>
<td>?</td>
</tr>
<tr>
<td>Ozone production</td>
<td>?</td>
<td>?</td>
</tr>
<tr>
<td>Flooring damage</td>
<td>-</td>
<td>Select suitable material, avoid extremes. Flooring panels according to climatic zone</td>
</tr>
<tr>
<td>Dry eyes</td>
<td>Reduce symptoms</td>
<td>&gt; 40%, avoid extreme lows. Individually high</td>
</tr>
<tr>
<td>Skin symptoms</td>
<td>Reduce symptoms</td>
<td>Avoid extreme lows</td>
</tr>
<tr>
<td>Clogged nose</td>
<td>Reduce symptoms</td>
<td>Avoid extreme lows</td>
</tr>
<tr>
<td>Energy demand</td>
<td></td>
<td>Avoid unnecessary humidification</td>
</tr>
</tbody>
</table>
Questions

• Should humidity determine ventilation rate?
  • When is it too high?
  • When is it too low?

More questions

• How much of the day (week, year) are dwellings occupied?
• What is the distribution of ventilation rates, temperatures and moisture supply? Can the profiles be predicted by dwelling characteristics?
### Asthma recommendations

<table>
<thead>
<tr>
<th>Org</th>
<th>rec</th>
<th>Recommendation</th>
</tr>
</thead>
<tbody>
<tr>
<td>National Asthma Council Australia</td>
<td>30-50%</td>
<td>In hot, humid climates, you may need to use an air conditioner or a dehumidifier or both. Fix water leaks, which allow mold to grow behind walls and under floors.</td>
</tr>
<tr>
<td>CDC</td>
<td>35-50%</td>
<td></td>
</tr>
<tr>
<td>AAAAI</td>
<td>40-50%</td>
<td></td>
</tr>
<tr>
<td>US Housing and Urban Development</td>
<td>30-50%</td>
<td></td>
</tr>
<tr>
<td>British Lung Foundation</td>
<td></td>
<td>Avoid condensation</td>
</tr>
<tr>
<td>American Lung Association</td>
<td></td>
<td>To minimize the growth of dust mites, keep your home below 50 percent humidity.</td>
</tr>
<tr>
<td>NAFAF</td>
<td>20-40%</td>
<td>Winter in heated rooms</td>
</tr>
<tr>
<td>Astma allergi Danmark</td>
<td>35-60%</td>
<td>Summer</td>
</tr>
</tbody>
</table>

### Indoor chemistry including ozone

- Catalytic degradation of ozone less efficient at high RH. (Namdari, Lee et al. 2019)

- There is no certain conclusion about the impact of relative humidity (RH) on ozone surface removal. According to the previous studies, the impact of humidity on ozone surface removal generally depended on the nature of the material surface. (Shen and Gao 2018)
Influence of temperature and humidity on ozone-surface reactivity is moderate. (Rim, Gall et al. 2016)
Tiltak: befuktning

- "Uendelig" kapasitet
- Kontrollerbart
- Energikrevende i oppvarmingssituasjon (2,4 kl/g)
- Hygieniske utfordringer
Effekten av utetemperatur på RF og fukttilskudd

Fukttilskudd iht NS_EN ISO 13788

![Diagram of fufitkudd](image)

(b)

Indoor relative humidity (%)

![Diagram of indoor relative humidity](image)

Begge figurer (Kalamees, Vinha et al. 2006)

Grunner til å være skeptisk (III)

- Hygieniske utfordringer ved befuktere og gjenvinnere
  - Bakterievekst – *Legionella*
  - Sopp
  - Urenheter i vann
  - Desinfeksjonsmidler

Image: "Bypass humidifier" [http://www.eiowainspecions.com]
Grunner til å være skeptisk (IV):
Opplevd luftkvalitet påvirkes av temperatur og RF

<table>
<thead>
<tr>
<th></th>
<th>At 12:00 (Mean/median)</th>
<th>At 14:30 (Mean/median)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>14 % RF N=14</td>
<td>24 % RF N=12</td>
</tr>
<tr>
<td>Dry air*</td>
<td>1.67/0.50</td>
<td>0.98/0.00</td>
</tr>
<tr>
<td>Stuffy air*</td>
<td>0.19/0.01</td>
<td>1.40/0.00</td>
</tr>
<tr>
<td>Too cold</td>
<td>2.53/0.01</td>
<td>1.24/0.00</td>
</tr>
<tr>
<td>Too warm</td>
<td>0.34/0.00</td>
<td>0.61/0.00</td>
</tr>
<tr>
<td>Draught</td>
<td>1.54/0.00</td>
<td>0.64/0.00</td>
</tr>
<tr>
<td>Varying temperature</td>
<td>1.77/0.00</td>
<td>1.44/0.00</td>
</tr>
<tr>
<td>Heat from sun</td>
<td>0.18/0.00</td>
<td>0.00/0.00</td>
</tr>
</tbody>
</table>

Lind, Holøs & al. 2018

Så – hva gjør vi?

- Reduser unødvendig ventilasjon
  - Behovsstyring – tomme rom trenger lite luft
  - Lavemitterende materialer, innredning og inventar. Fjern kilder heller enn å tynne ut!
  - Fuktbufrende materialer i lett møblerte rom
- Unngå overtemperatur
- Styr (også) mot RF. Vurder og kontroller fuktgjenvinning
- Tilfør evt. ekstra fuktighet
- Reduser risiko for bygningsskader
  - Bygg tett og velisolert, uten kuldebøner (trykktest og termografer eksisterende bygninger)
  - Ha kontroll på trykkforhold
- Ta lav OG høy fuktighet på alvor
Moisture buffering in modern timber constructions

Dimitrios Kraniotis
Dep. of Civil Engineering & Energy Technology
Oslo Metropolitan University - OsloMet
dimkra@oslomet.no

Norway: a country with long tradition in timber

Photo: Dagfinn Rasmussen, Riksantikvaren
Photo: Own archive
Photo: Own archive
Photo: Own archive
**Increased interest in use of engineered timber products**

- Tradition is not the only reason
- Norway – Strict national framework for energy use in buildings → dramatic reduction of energy use for heating since 1990 (-69%) (NEA, 2018)
- Ensure high indoor environmental quality (IEQ)
- Efforts to decrease the carbon footprint from building materials

![Graph showing energy use comparison between typical building and energy-efficient building](oslomet.png)

**Typical light timber construction**

- Interior wooden cladding (softwood)
- Thin wooden boards, 12 – 14 mm
- Almost always painted

![Typical light timber construction diagram](oslomet.png)
Typical light timber construction

- Solid timber, exposed or covered by gypsum boards
- Thick wooden elements, 60 – 140 mm
- When exposed, treated with diffusion-open Osmo oil

Modern timber constructions

Cross Laminated Timber (CLT)
Leading the ‘woodification’ of building industry
Controlling the RH indoors

- DCV - Moisture control, e.g. max at 50%
- Humidification / Dehumidification
- Adjusting respectively the air temperature indoors
- **Moisture buffering** in hygroscopic surfaces indoors, building materials, furnitures etc.

Moisture buffering – What is it?

NordTest project

- Technical University of Denmark (DTU)
- Norwegian Building Research Institute (earlier NBI, nowadays SINTEF Community);
- Technical Research Centre of Finland (VTT);
- Lund University, Sweden (LTH);

Moisture buffering of building materials,
Rode, Carsten; Peuhkuri, Ruut Hannele;
Mortensen, Lone Hedegaard; Hansen, Kurt
Kielsgaard; Time, Berit; Gustavsen, Arild;
Ojanen, Tuomo; Ahonen, Jarkko; Svennberg,
Kaisa; Arfvidsson, Jesper
https://backend.orbit.dtu.dk/ws/portalfiles
/portal/2415500/bvg-e126.pdf
Moisture Buffer Value (MBV)

Moisture Buffer Value: \( MBV = \frac{\text{moisture uptake \[g\]}}{\text{change in RH \[\%\]} \times \text{hygroscopic surface \[m^2\]}} \)

Internal humidity loads according to ISO 13788

\[ v_i = v_e + \Delta v \]
\[ \Delta v = \frac{G}{V'} \]

- **G**: moisture production indoors \[g/h\]
- **V'**: ventilation rate \[m^3/h\]

<table>
<thead>
<tr>
<th>Humidity class</th>
<th>Building</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Unoccupied buildings, storage of dry goods</td>
</tr>
<tr>
<td>2</td>
<td>Offices, dwellings with normal occupancy and ventilation</td>
</tr>
<tr>
<td>3</td>
<td>Buildings with unknown occupancy</td>
</tr>
<tr>
<td>4</td>
<td>Sports halls, kitchens, canteens</td>
</tr>
<tr>
<td>5</td>
<td>Special buildings, e.g., laundry, brewery, swimming pool</td>
</tr>
</tbody>
</table>

\[ \max \Delta v = 4 \text{ or } 6 \text{ g/m}^3 \]
Moisture sources indoors

- Cooking
- Clothes washing
- Adult sleep
- Breathing/evaporation
- Uninflated gas heating
- Showers/boths
- Unwanted clothes drying
- Washing dishes

Moisture buffering and ventilation strategies

Photo: thesslagreen.com
Case study 1/4 - Field

What’s the behaviour of CLT under extreme moisture load?

Field test of moisture buffering capacity in CLT modules

**WEEE project** - Wood, Energy, Emissions, Experience
- Norwegian Institute of Wood Technology
- OsloMet (earlier HiOA)
- NMBU
- Norwegian Institute of Air Research

**Test modules:**
- Volume $V = 57 \text{ m}^3$
- Exhaust ventilation $V' = 0.5 \text{ ACH}$
- Moisture load $G = 0.62 \text{ kg/h}$ (in total 5.8 kg)
  
  **Very high load!** ($\Delta v > 20 \text{ g/m}^3$)

Moisture buffering, energy potential, and volatile organic compound emissions of wood exposed to indoor environments


[Link to source](https://www.tandfonline.com/doi/abs/10.1080/23744731.2017.1288503)
Field test of moisture buffering in CLT modules

Exposed CLT
max RH_i ≈ 70%

non-hygroscopic
max RH_i ≈ 95%

Moisture buffering, energy potential, and volatile organic compound emissions of wood exposed to indoor environments
https://www.tandfonline.com/doi/abs/10.1080/23744731.2017.1288503

Case study 2/4 - Lab

What is the moisture buffering performance of CLT under controlled operational conditions in the lab?
Moisture buffering capacity of a CLT element

- **Step 1**: determination of \( MBV = 1.1 \text{ g/}(%\text{RH}\cdot\text{m}^2) \) – almost the same as reported in NordTest for wooden sample (softwood)

- **Step 2**: investigation of moisture buffering capacity under ‘operational conditions’
  - \( V = 37 \text{ m}^3 \) | \( V' = 57.5 \text{ m}^3/\text{h} (= 1.55 \text{ ACH} = 3.82 \text{ m}^3/\text{h}\cdot\text{m}^2) \)

‘outdoors’
- \( \theta_e \approx -8.5 \, ^\circ\text{C} \)
- \( \text{RH}_e \approx 70\% \)
- \( v_e = 1.7 \text{ g/m}^3 \)

‘indoors’
- \( \theta_i \approx 21.5 \, ^\circ\text{C} \)
- \( \text{RH}_{i,\text{initial}} \approx 20\% \)
- \( V_{i,\text{initial}} = 3.5 \text{ g/m}^3 \)

Three different scenarios of moisture load:

1. Moisture load\(_{\text{sh}} = 268.75 \text{ g/h}\)
   - \( \text{expected} \) increase of humidity indoors = 268.75/57.5 = 4.7 g/m\(^3\) (RH\(_i \approx 45\%\))
   - \( \text{actual} \) increase of humidity indoors = 3.54 g/m\(^3\) (RH\(_i \approx 40\%\))
   - \( \text{corresponding ‘ventilative’ effect of moisture buffering} = 18.4 \text{ m}^3/\text{h} \) (total: 75.9 m\(^3\)/h)

2. Moisture load\(_{\text{sh}} = 312.5 \text{ g/h}\)
   - \( \text{expected} \) increase of humidity indoors = 312.5/57.5 = 5.4 g/m\(^3\) (RH\(_i \approx 50\%\))
   - \( \text{actual} \) increase of humidity indoors = 3.7 g/m\(^3\) (RH\(_i \approx 41\%\))
   - \( \text{corresponding ‘ventilative’ effect of moisture buffering} = 27 \text{ m}^3/\text{h} \) (total: 84.5 m\(^3\)/h)

3. Moisture load\(_{\text{sh}} = 343.75 \text{ g/h}\)
   - \( \text{expected} \) increase of humidity indoors = 343.75/57.5 = 6 g/m\(^3\) (RH\(_i \approx 60\%\))
   - \( \text{actual} \) increase of humidity indoors = 3.8 g/m\(^3\) (RH\(_i \approx 45\%\))
   - \( \text{corresponding ‘ventilative’ effect of moisture buffering} = 33 \text{ m}^3/\text{h} \) (total: 90.5 m\(^3\)/h)
What is the moisture buffering performance of CLT under fully operational conditions in-situ?

Ulsholtveien 31, housing units in exposed CLT

Norwegian Architecture Prize 2017
Wooden project of the year 2017
Ulsholtveien 31, housing units in exposed CLT

- Floor area of the tested apartment, $A = 56 \, \text{m}^2$
- Volume, $V = 148 \, \text{m}^3$
- Decentralised ventilation, $V' = 38 \, \text{m}^3/\text{h}$, in each of the three rooms (2 units in the kitchen/living room ($34.4 \, \text{m}^2$) and 1 unit in each of the two bedrooms ($7.3 \, \text{m}^2$ and $9.7 \, \text{m}^2$)
- Exhaust ventilation in the bathroom, $V' = 50 \, \text{m}^3/\text{h}$ when $\text{RH}_{\text{bath}} > 50\%$ or for 15 minutes every 2 hours

Interior finishing: exposed CLT, treated with diffusion open Osmo oil

Interior finishing: cement board at the shower

Bedroom: $9\% < \text{RH}_i < 54\%$ (too high air temperature, i.e. $\theta_{\text{i,bed}} = 29 \, ^\circ\text{C}$)

Bathroom: $18\% < \text{RH}_i < 66\%$ | water content in wood $u = 8.1\% - 11.7\% < 15.4\%$

Kitchen/living room: $17\% < \text{RH}_i < 55\%$ | $[\text{CO}_2]$: usually below 1150 ppm, max = 1550 ppm
What is the RH indoors in case CLT is replaced by gypsum boards and tiles (bathroom)?

Numerical comparison between gypsum/tiles and CLT

<table>
<thead>
<tr>
<th></th>
<th>Bedroom CLT</th>
<th>Bedroom Gypsum board</th>
<th>Bathroom CLT + cement board</th>
<th>Bathroom Tiles</th>
<th>Kitchen/living room CLT</th>
<th>Kitchen/living room Gypsum board</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>RHi, min</strong></td>
<td>9%</td>
<td>6% (-3%)</td>
<td>18%</td>
<td>9% (-9%)</td>
<td>17%</td>
<td>13% (-4%)</td>
</tr>
<tr>
<td><strong>RHi, max</strong></td>
<td>53%</td>
<td>58% (+5%)</td>
<td>66%</td>
<td>98% (+32%)</td>
<td>55%</td>
<td>63% (+8%)</td>
</tr>
</tbody>
</table>
Synopsis

- Under normal moisture loads, the corresponding ventilation effect (maxima of RH) of exposed wooden surfaces in residential buildings can be expected between 20% and 35% (lab investigation).
- In these conditions, the moisture content in CLT is not critical for mould growth, even when CLT exposed in bathrooms (affected by water vapour but not water) and being supported by low-level moisture control (field investigation).
- CLT manages contributes to keep maxima of RH indoors within accepted limits, i.e. < 60% (Category II) (field investigation).
- Overheating has negative consequences not only for the thermal environment but for moisture buffering capacity (minima of RH indoors) as well (field investigation).
- An equivalent apartment in gypsum boards and tiles, instead of CLT, would result to both lower and higher values of RH indoors (field investigation and simulation).

Thank you for your attention!
Three questions

• When does moisture recovery occur?
• What amount of moisture is recovered?
• Is moisture recovery needed?
About/Not about

- Cold period (heating season)
- Air-to-air heat/energy recovery
- Balanced mechanical ventilation
- Well-insulated and air-tight residential buildings

Moisture recovery

Moisture recovery rate = internal moisture excess \times \text{moisture recovery efficiency}
Moisture recovery

Moisture recovery rate = \text{internal moisture excess} \times \text{moisture recovery efficiency}

Internal moisture excess

Difference between indoor and outdoor humidity ratio

• Indoor moisture profile
  • Occupants, pets, plants
  • Bathing or showering, cooking, dish washing, laundry, drying, cleaning
  • Ventilation, building characteristics

• Outdoor moisture
  • Weather conditions
Internal moisture excess

The weekly average moisture excess of 191 timber-framed single-family buildings as a function of weekly average outdoor air temperature. Each thin line represents one measured bedroom or living room. The dotted line represents the moisture excess curve on the higher 10% critical level (Kulmala et al., 2005, 2006; Viinik et al., 2005).

Moisture recovery

Moisture recovery rate = internal moisture excess × moisture recovery efficiency
Two types of heat/energy recovery ventilator (HRV/ERV) usually applied in residential buildings

- Two types of air-to-air heat recovery
  - Regenerators
    - Heat wheel (HRV)
    - Enthalpy wheel (ERV)
  
- Recuperators
  - Plate heat exchanger (HRV)
  - Membrane energy exchanger (ERV)

Moisture transfer in heat and enthalpy wheels
Moisture transfer in heat wheel

Heat wheel surface

Moisture transfer in heat wheel

Heat wheel surface
Moisture transfer in heat wheel

Heat wheel surface

Heat wheel moisture transfer process for cold climate
Moisture transfer in enthalpy wheel

![Enthalpy wheel surface](image)

Moisture transfer in enthalpy wheel

![Enthalpy wheel surface](image)
Moisture transfer in enthalpy wheel

Enthalpy wheel moisture transfer process for cold climate
Moisture transfer in oxidized or fouled heat wheel

Oxidized or fouled surface

Moisture transfer in oxidized or fouled heat wheel

Heat wheel surface
Moisture transfer in oxidized or fouled heat wheel

Oxidized or fouled heat wheel moisture transfer process for cold climate
Moisture transfer in plate and membrane exchangers

Moisture transfer in plate heat exchanger
Moisture transfer in plate heat exchanger

Plate (Impermeable to water)

Extract air

Exhaust air

Supply air

Outdoor air

Plate heat exchanger moisture transfer process in HRV/ERV

Outdoor air

Extract air

Exhaust air

Supply air

Wet

Dry

30% Extract air RH

60% Extract air RH
Moisture transfer in membrane energy exchangers

Extract air

Membrane (permeable to water)

Supply air

Exhaust air

Outdoor air

Supply air

Outdoor air
Membrane energy exchanger moisture transfer process

Performance of a quasi-counter flow membrane exchanger
Impacts of membrane vs. plate heat exchanger on indoor RH

A single-family house (two adults and one child) in Oslo

- RH increase by 7% with using MEE compared to plate exchanger
- RH in range of 30-60%
  - Plate heat exchanger: 3876 h, 44% time of the year
  - Membrane exchanger: 5695 h, 65% time of the year

Three questions

- When does moisture recovery occur?
- What amount of moisture is recovered?
- Is moisture recovery needed?
Moisture recovery

Moisture recovery rate = internal moisture excess × moisture recovery efficiency

References

Peng Liu
Peng.Liu@sintef.no
SINTEF Community, Trondheim, Norway

Acknowledgements
Hans Martin Mathisen, NTNU
Anneli Halfvardsdson, Flexit
Daniel Nielsen, Flexit
Maria Justo Alonso, NTNU, SINTEF
Projects: EnergiBolig, Defreeze MEE Now, Healthy and Energy Efficient Urban Home Ventilation