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Webinar 6-13-19 May 2020

Urban Home Ventilation

	Date	Theme:
Webinar	6th May:	Kitchen ventilation
Webinar	13th May:	Ventilation requirements, trends and thermal comfort
Webinar	19th May:	Moisture control

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Urban Home Ventilation

Webinar 6-13-19 May 2020

Webinar 6 May

Theme 1:
Kitchen ventilation

15:00	Welcome Chair: Kari Thunshelle, SINTEF
15:05	Documentation of cooker hood performance, a laboratory prespective *Svein Ruud, RISE, Sweden*
15:25	Extract cooker hoods – possibilities and challenges *Haavard Augensen, Røros Metall, Norway*
15:40	Recirculationg cocker hoods – possibilities and challenges *Martin Oberhomburg/Reinhard Wiedenmann, BSGH, Germany*
15:55	Experiences from assessing in-situ effectiveness of cooker hoods *Iain Walker, LBNL, USA*
16:10 - 16:30	*Q&A poll* *Workshop discussion* *Moderator: Peter Schild, OsloMet*

Webinar 13 May

Theme 2:
Ventilation requirements, quality, and trends

15:00	Welcome Chair: Kari Thunshelle, SINTEF
15:05	Ventilation and IAQ in Nordic countries – Status, trends and opportunities *Kari Thunshelle, SINTEF, Norway*
15:25	A developer's perspective on urban home ventilation issues *Ole Petter Haugen, Selvaag Bolig, Norway*
15:45	nZEB temperature zoning – "Fresh" bedrooms and a warm living room *Laurent Georges, NTNU, Norway*
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Webinar 19 May

THEME 3:
Moisture control

15:00	Welcome Chair: 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*
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webinar
2020. 05.19

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

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webinar
2020. 05.19

Urban Home Ventilation

Part 3: Moisture control

- 15:00 | **Welcome**, *Kari Thunshelle, SINTEF*
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- 16:30 | **End of webinar**

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2020. 05.19

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)

webinar
2020. 05.19

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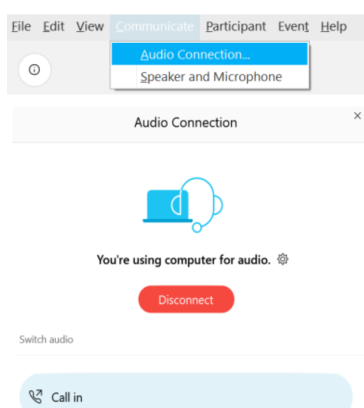
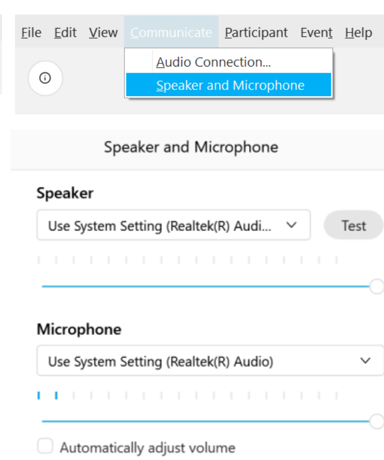
If you still can't hear, run a Speaker Audio Test to make sure the correct output is selected [To run the test, click on Communicate / Speaker and Microphone]





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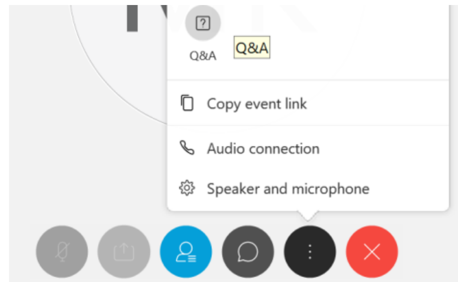
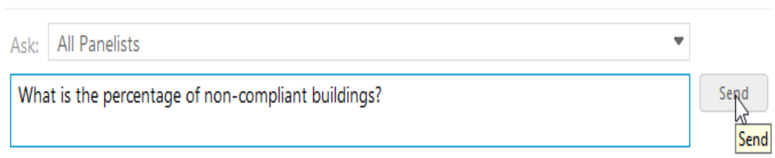
Locate the **Q&A box** **(NOT the Chat)**



Select **All Panelists** | Type your question | Click on Send



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Urban Home Ventilation

Webinar 6-13-19 May 2020

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.

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70 years
1950-2020

Technology for a better society

Kari.thunshelle@sintef.no

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Healthy Energy-efficient Urban Home Ventilation

https://www.sintef.no/projectweb/healthy-energy-efficient-urban-home-ventilation/

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70 years
1950-2020

Technology for a better society

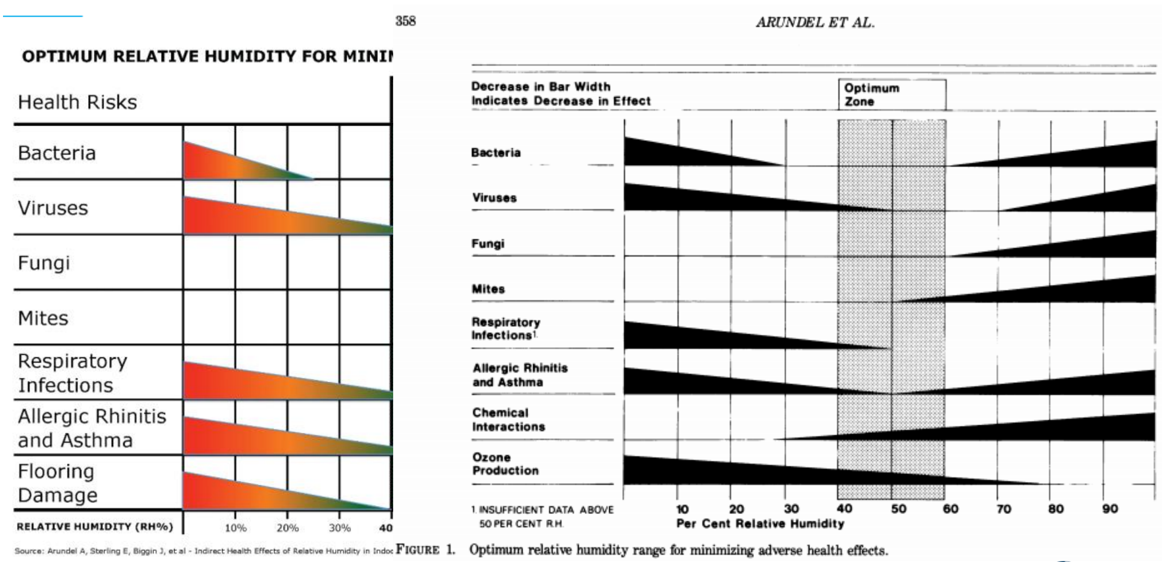
1

Summary. To avoid too low humidity consider:

Action	Potential effect	Limitations / challenges
Hygroscopic materials	Limited	Only short-term variation
Decreasing indoor temperature	Limited	User comfort and preferences
Adding sources	Limited	Indoor air quality
Reducing ventilation	Moderate	Indoor air quality
Recovering moisture	Moderate – large	Hygiene and technology, stay tuned...
Humidification	Large	Energy, hygiene
All above:		Condensation risks!

2

What do we mean by too high or too low indoor moisture?



https://www.humiditydevices.co.uk/blogs/about-floors/15508913-health-risks-of-adverse-relative-humidity

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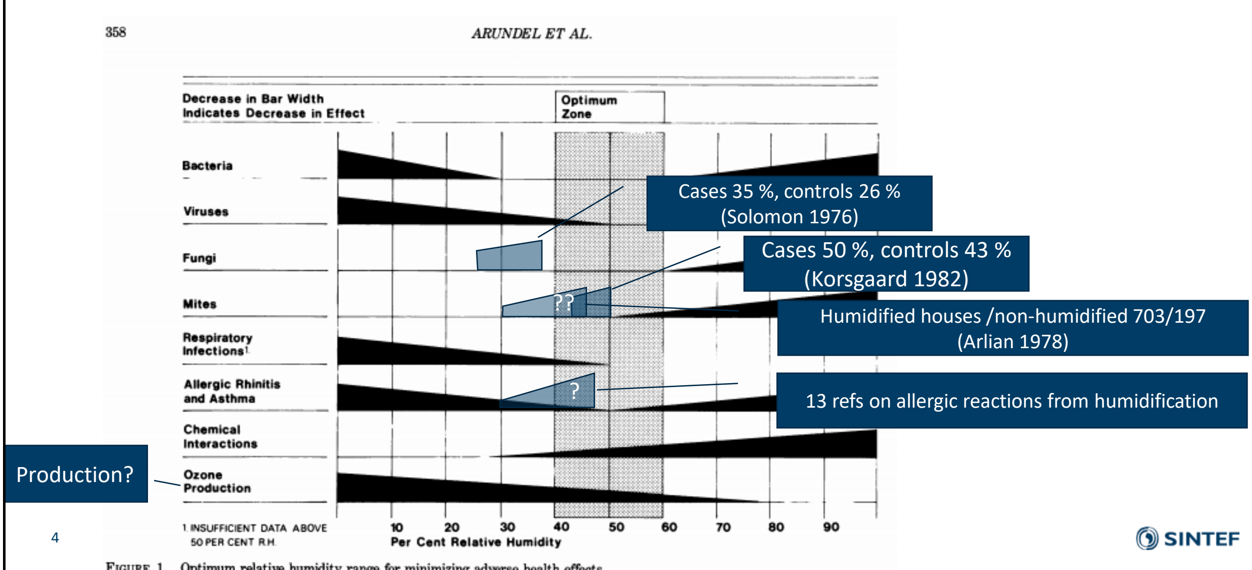
Arundel & al. reexamined



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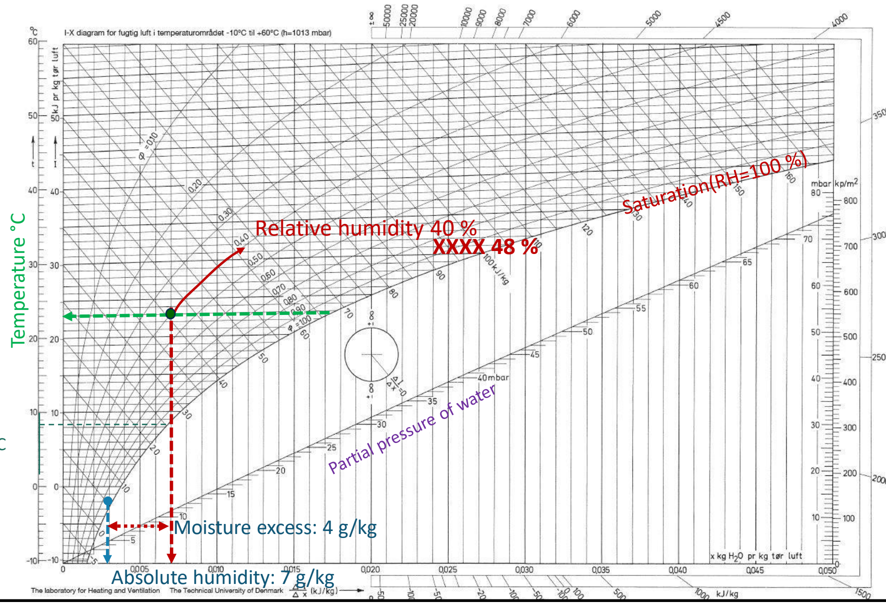
Relative and absolute moisture, moisture excess, dewpont



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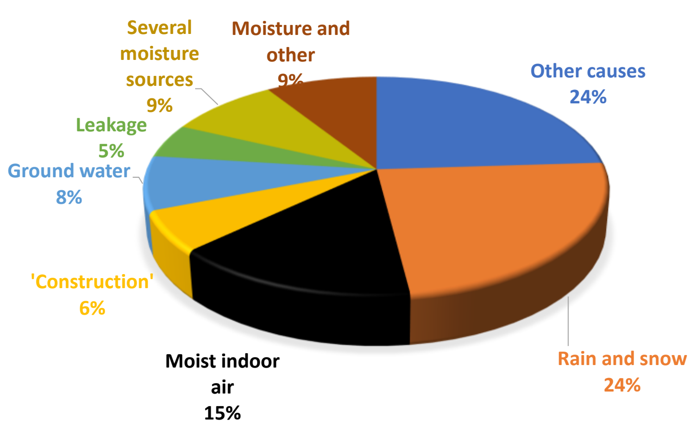
Causes of building damage -Norway



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

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Liso, K. R., T. Kvande and J. V. Thue (2006). "Learning from experience - an analysis of process induced building defects in Norway." Research in Building Physics and Building Engineering 2006: 425-432

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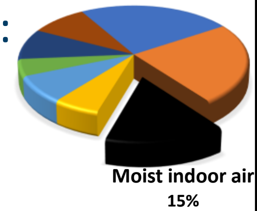
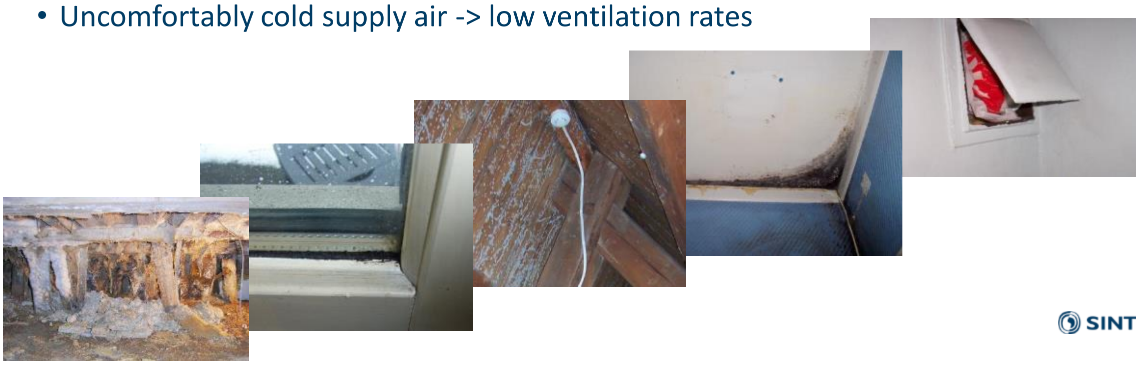
Existing buildings are vulnerable to high humidity:



- 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



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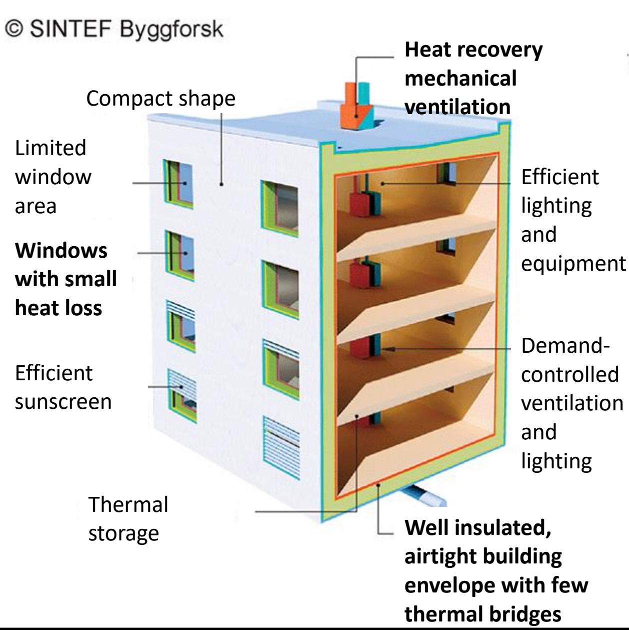
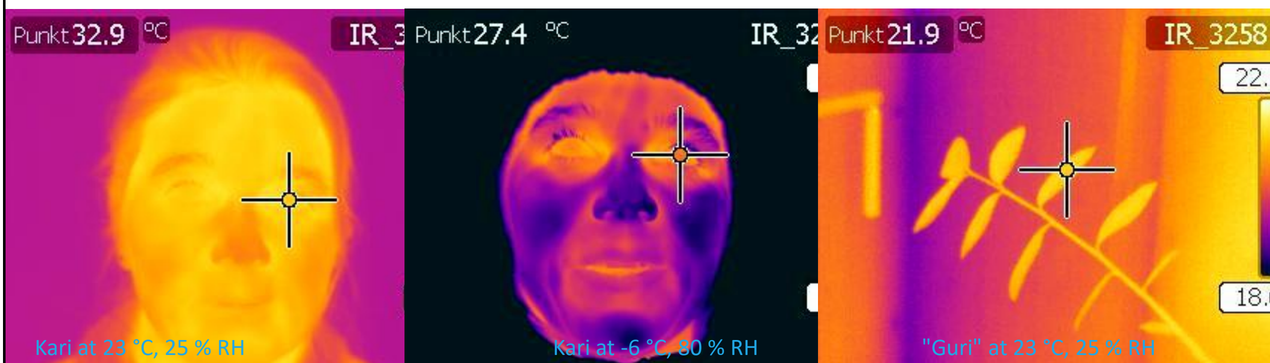
Newer buildings less vulnerable to high humidity:



Kravene til passivhus møter nå økende motstand blant ekspertene. Oslos første passivhus (bildet) stod nylig ferdig på Skøyen. Foto: Terje Pedersen, ANB

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



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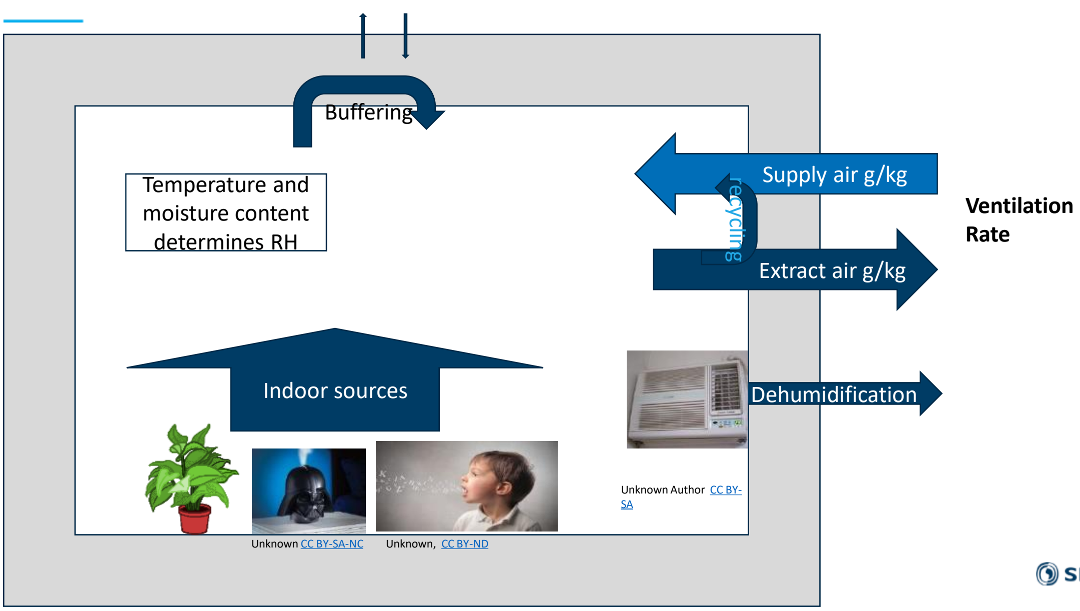
What determines indoor humidity?



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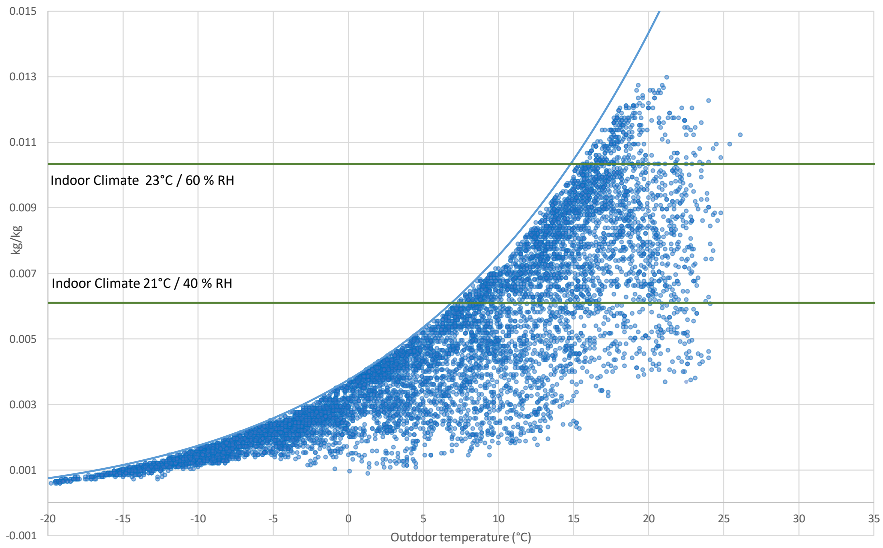
Moisture content of outdoor air – Oslo



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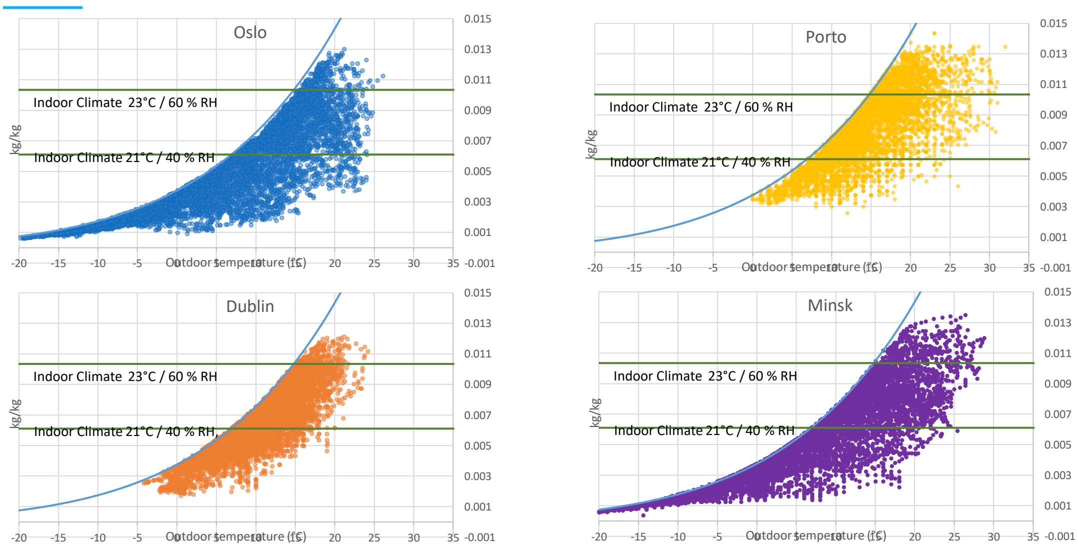
Observations from Blindern, 2010. Data from The Norwegian Meteorological Institute

Moisture content of outdoor air



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Dublin, Minsk and Port 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

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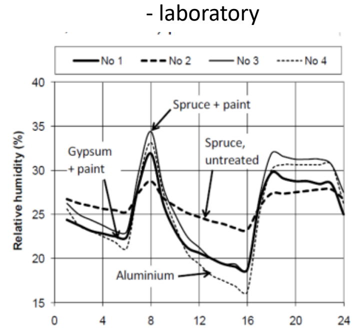
Moisture buffering

Photo CC0 Public domain via Piqsels.com

Effect of materials on diurnal RH variation - laboratory



Geving, S. and J. Holme. 2012. Mean and diurnal indoor air humidity loads in residental buildings. Journal of Building Physics 35(4) 392-421.

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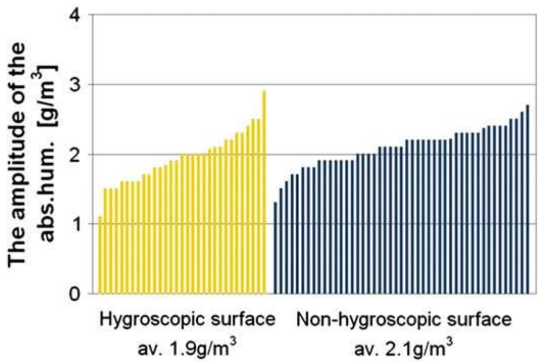
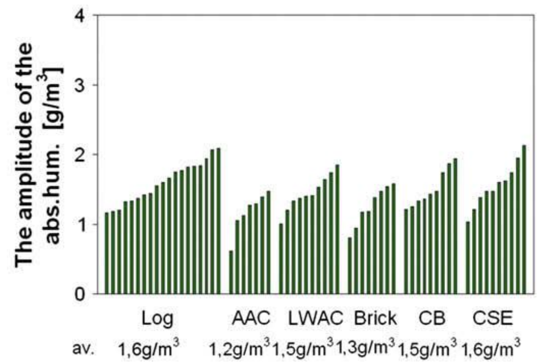
Moisture buffering: field studies





Both figs from (Kalamees, et al. 2009)

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Kalamees, T., M. Korpi, J. Vinha and J. Kurnitski (2009). "The effects of ventilation systems and building fabric on the stability of indoor temperature and humidity in Finnish detached houses." Building and Environment: 1643-1650.

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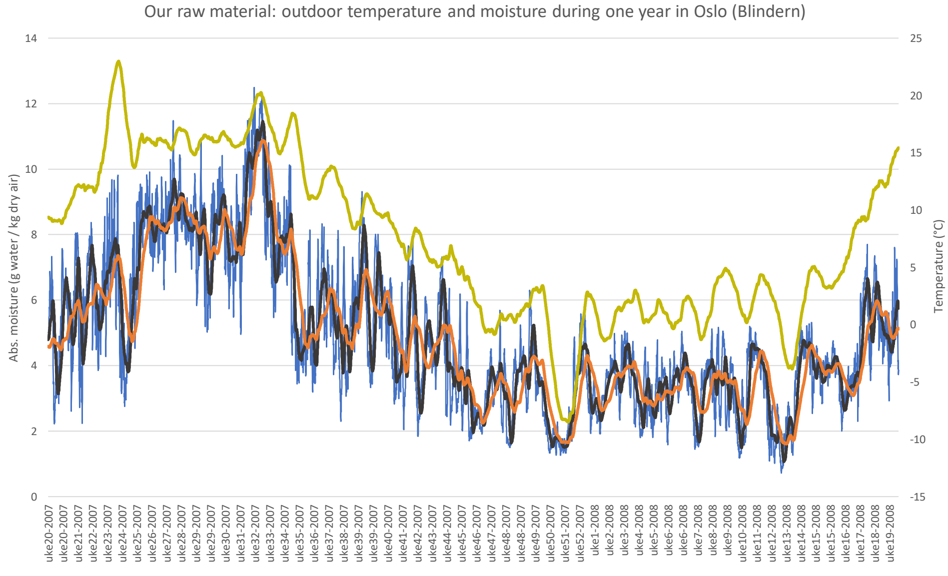
TO

Our raw material: outdoor temperature and moisture during one year in Oslo (Blindern)



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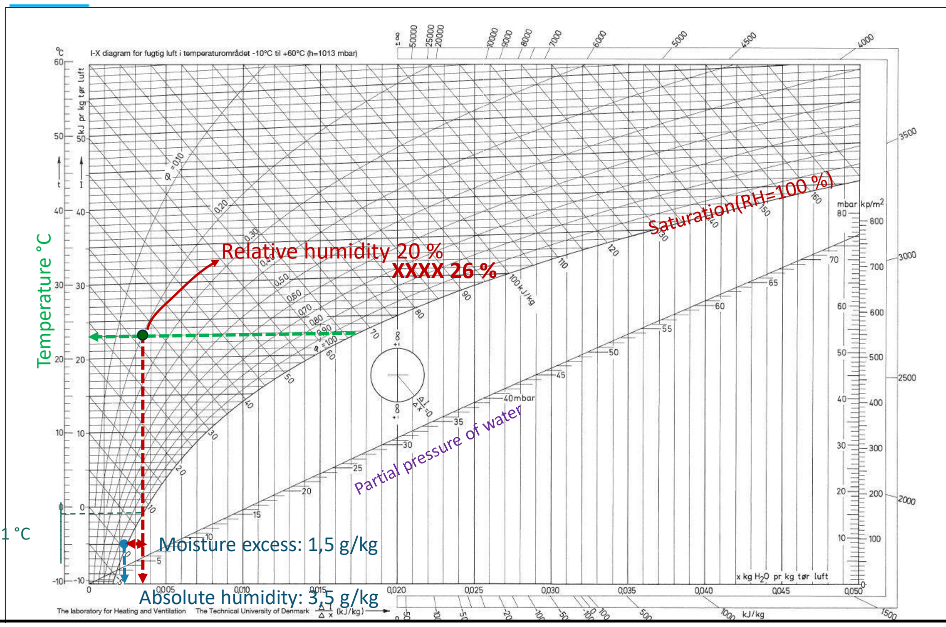
Reducing indoor temperature –low RH



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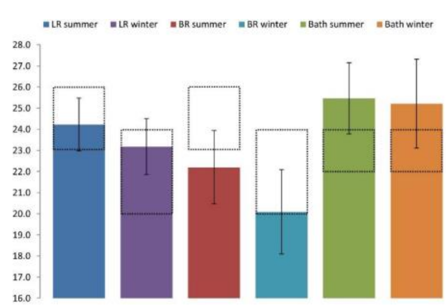
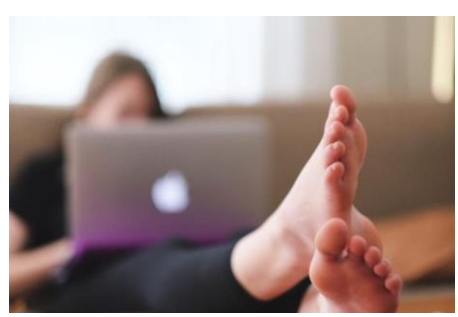
Reducing indoor temperatures?

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





Berge, M. and H. M. Mathisen (2016). "Perceived and measured indoor climate conditions in high-performance residential buildings." Energy and Buildings **127**: 1057-1073.

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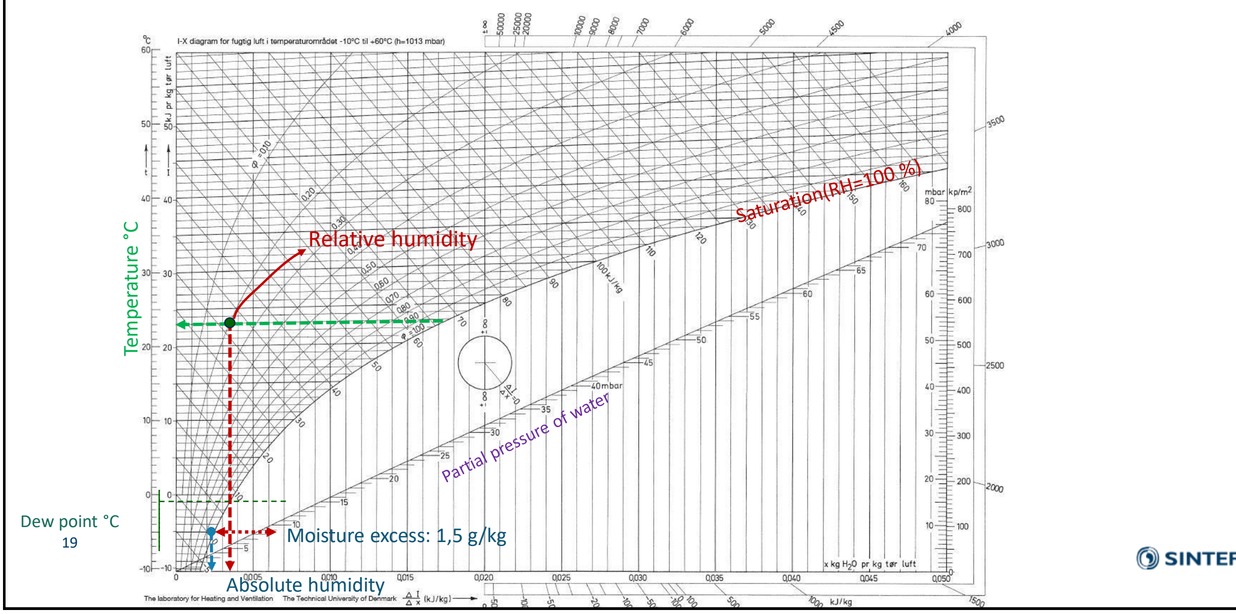
Increasing moisture excess



Increasing excess: reducing ventilation

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 Prillen CC BY-SA via Wikimedia Commons

Foto Pixabay, merket fri bruk

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Ventilation and respiration

I adult at 23 °C, 1 met, 1 clo

- 40-60 g water / hour
- 15 liters CO_2 /hour
- 1 olf

Target 1000 ppm CO_2 : 26 m³ / hour per person
Added moisture 1,5-2,3 g / m³

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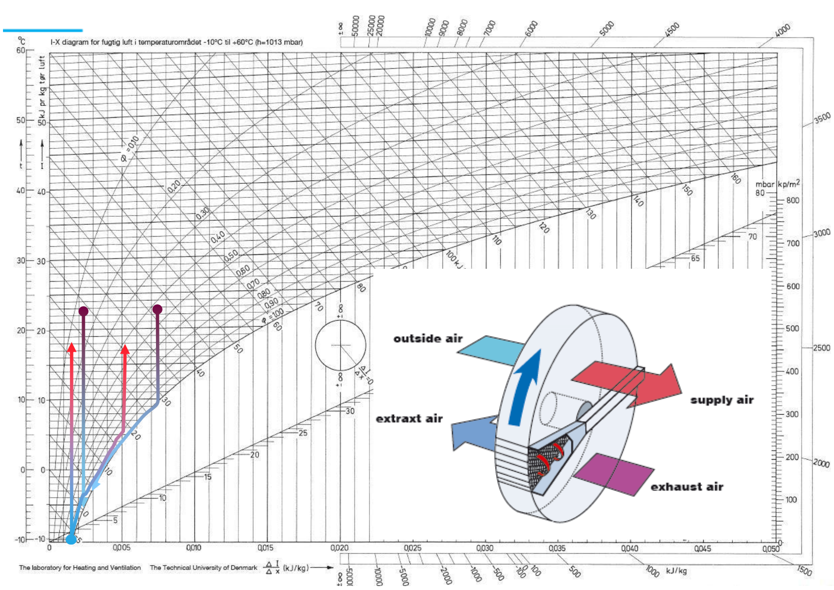
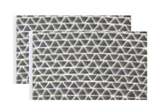
Moisture recovery



Ikke-hygroskopisk rotor



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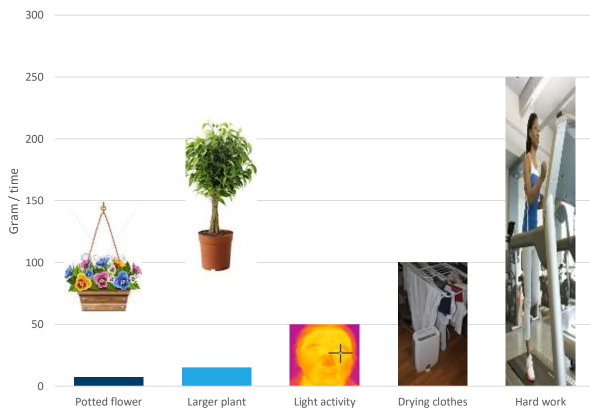
Increase excess: adding sources



Shower 3kg /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)

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Summary:

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

Action	Potential effect	Limitations / challenges
Hygroscopic materials	Limited	Only short-term variation
Decreasing temperature	Limited	User comfort and preferences
Adding sources	Limited	Indoor air quality
Reducing ventilation	Moderate	Indoor air quality
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Humidification	Large	Energy, hygiene
All above:		Condensation risks!

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

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Questions

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

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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?

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Asthma recommendations

Org	rec		
National Asthma Council Australia	30-50 %		
CDC	35-50 %	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.	
AAAAI	40-50 %		https://www.aaaai.org/conditions-and-treatments/library/allergy-library/humidifiers-and-indoor-allergies
US Housing and Urban Development	30-50%		https://www.hud.gov/sites/dfiles/HH/documents/Home%20Assessment%20Checklist%20English.pdf
British Lung Foundation		Avoid condensation	https://www.blf.org.uk/support-for-you/indoor-air-pollution/improving-air-quality
American Lung Association		To minimize the growth of dust mites, keep your home below 50 percent humidity.	https://www.lung.org/clean-air/at-home/indoor-air-pollutants/dust-mites
NAAF	20-40 % <60 %	Winter in heated rooms Summer	https://www.naaf.no/subsites/fersking---foreldre-og-barn/i-hjemmet/inneklima/luftfuktighet/
Astma allergi Danmark	35-60 %		

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)

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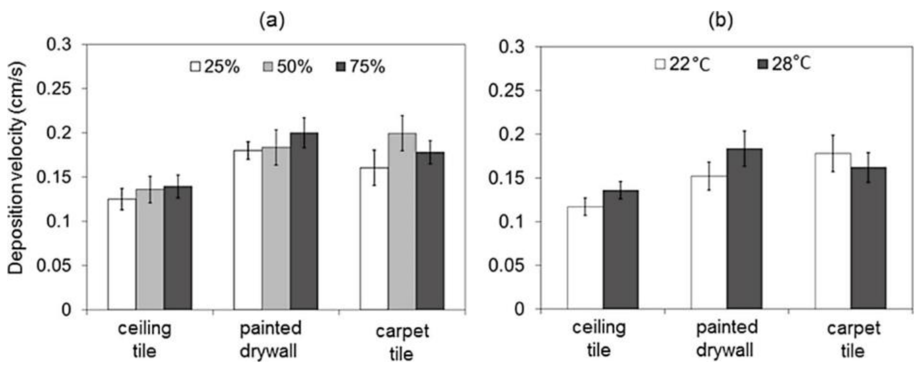
Influence of temperature and humidity on ozone-surface reactivity is moderate.(Rim, Gall et al. 2016)



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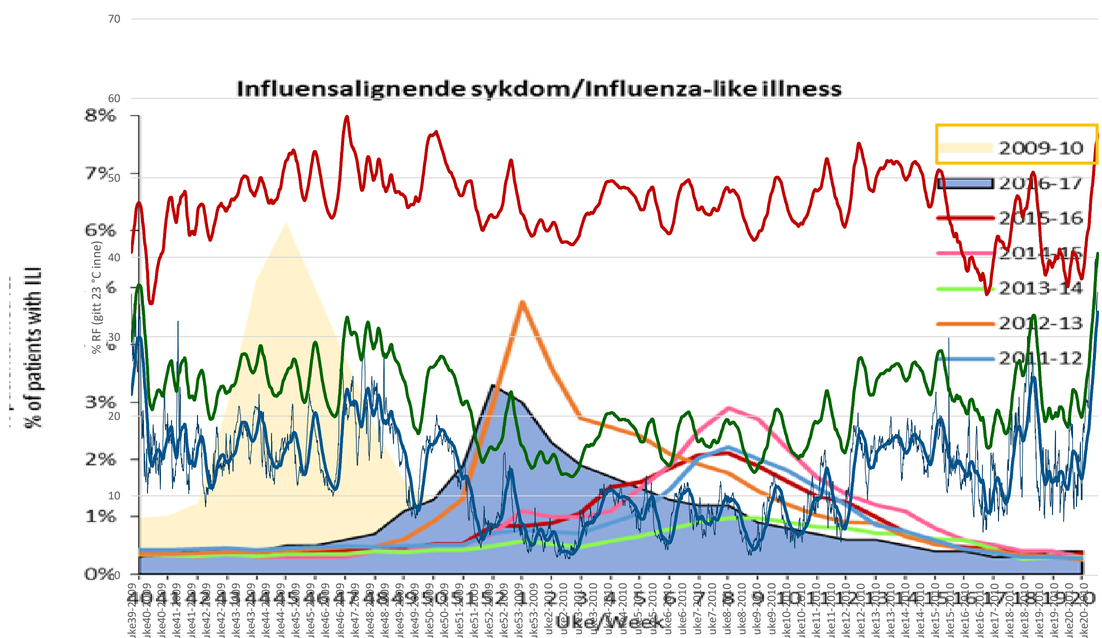

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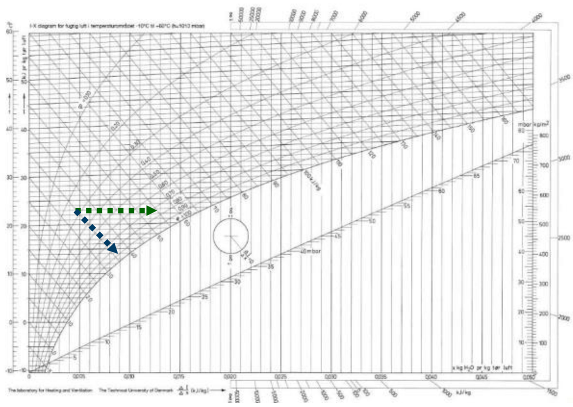
Tiltak: befuktning



Forstøvning

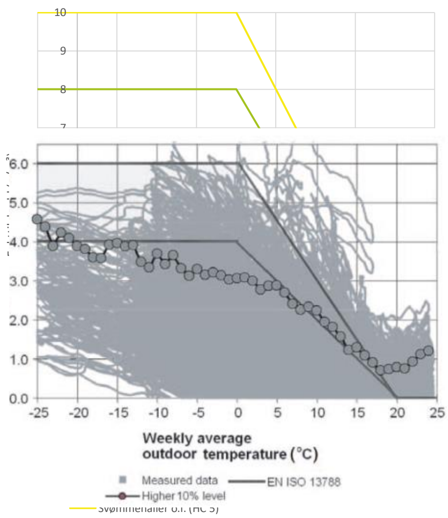
Fordampning

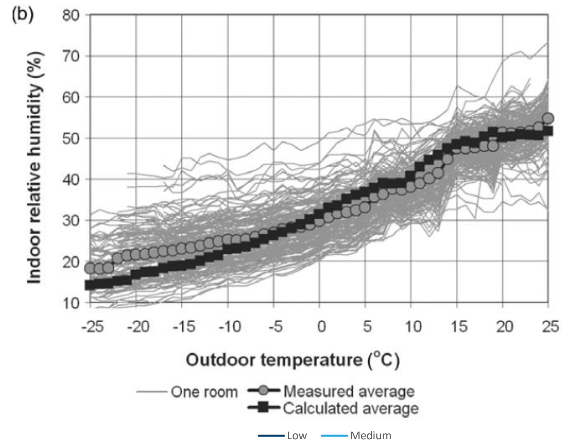
Fig: Qviller klimaprodukter, Stadler Form

Befuktning

- "Uendelig" kapasitet
- Kontrollerbart
- Energikrevende i oppvarmingssituasjon (2,4 kJ/g)
- Hygieniske utfordringer

Effekten av utetemperatur på RF og fukttilskudd





Begge figurer (Kalamees, Vinha et al. 2006)

SINTEF

Grunner til å være skeptisk (III)

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

"Bypass humidifier" http://www.eiowainspections.com

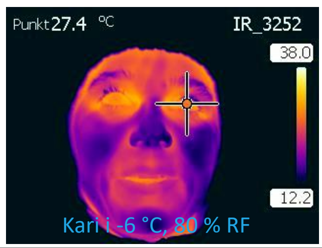
SINTEF

Grunner til å være skeptisk (IV):
Opplevd luftkvalitet påvirkes av temperatur og RF

	At 12:00 (Mean/median)			At 14:30 (Mean/median)		
	14 % RF N=14	24 % RF N=12	38 % RF N=12	14 % RF N=14	24 % RF N=12	38 % RF N=12
Dry air*	**1.67**/0.23	0.09/0	0.06/0	**1.95**/0.27	1.71/0	0.02/0
Stuffy air*	0.71/0	0.96/0	**3.48**/1.55	0.43/0	1.33/0	**3.22**/0.79
Unpleasant odor	0.07/0	1.40/0	1.43/0	0/0	1.72/0	2.34/0
Too cold	2.53/0	1.24/0	1.4/0	2.65/0.73	1.55/0	1.29/0
Too warm	0.34/0	0.61/0	3.32/2.12	0.56/0.08	0.94/0	1.47/0.03
Draught	1.54/0	0.64/0	0.07/0	1.86/0	1.44/0	0.17/0
Varying temperature	1.77/0	1.44/0	2.08/0	1.33/0	1.28/0	1.83/0
Heat from sun	0.18/0	0/0	0/0	0.11/0	0/0	0/0

Lind, Holøs & al. 2018

Foto Kjetil Ree (Own work) [CC BY-SA 3.0]



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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 kuldebroer (trykktest og termografer eksisterende bygninger)
  - Ha kontroll på trykkforhold
- Ta lav OG høy fuktighet på alvor

SINTEF

AIVC – SINTEF Community – OsloMet
Workshop 'Urban Home Ventilation' | 19th May 2020
Part 3: Moisture Control

Moisture buffering in modern timber constructions

Dimitrios Kraniotis

Dep. of Civil Engineering & Energy Technology
Oslo Metropolitan University - OsloMet
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OSLO METROPOLITAN UNIVERSITY
STORBYUNIVERSITETET

Norway: a country with long tradition in timber

Photo: Dagfinn Rasmussen, Riksantikvaren

Photo: Own archive

Photo: Own archive

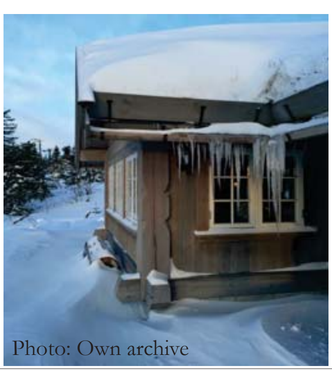
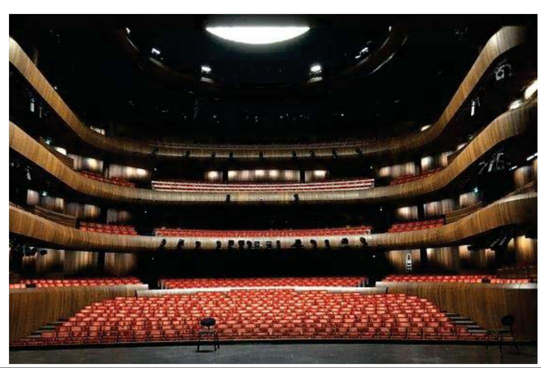
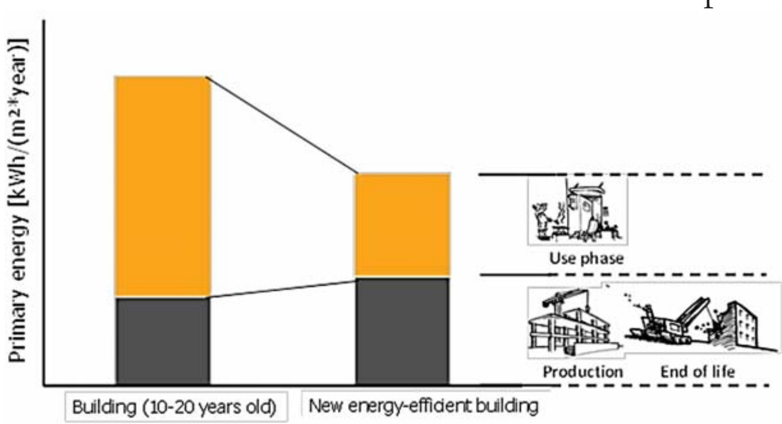


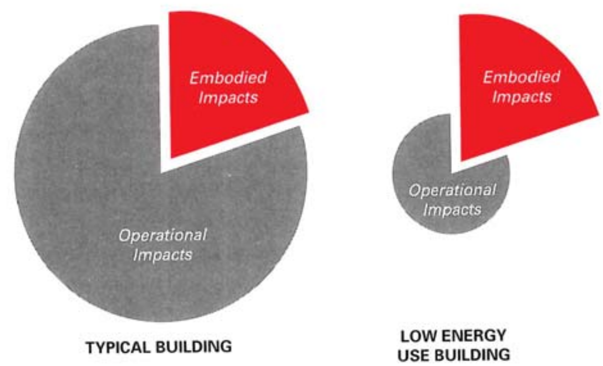
Photo: Own archive



Increased interest in use of engineered timber products

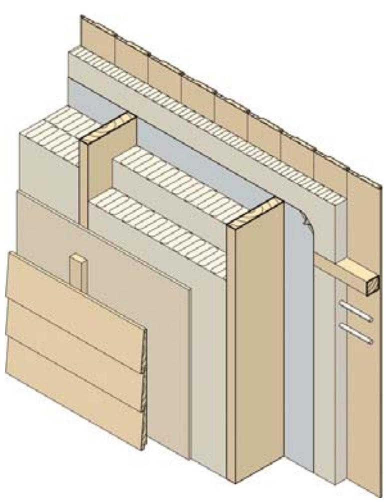
- Tradition is not the only reason
- Norway – Strict national framework for energy use in buildings →
  dramatic reduction of energy use for heating since 1990 (-69%) (NEA, 2018)
- Ensure high indoor environmental quality (IEQ)
- Efforts to decrease the carbon footprint from building materials





Kathrina Simonen, Life Cycle Assessment

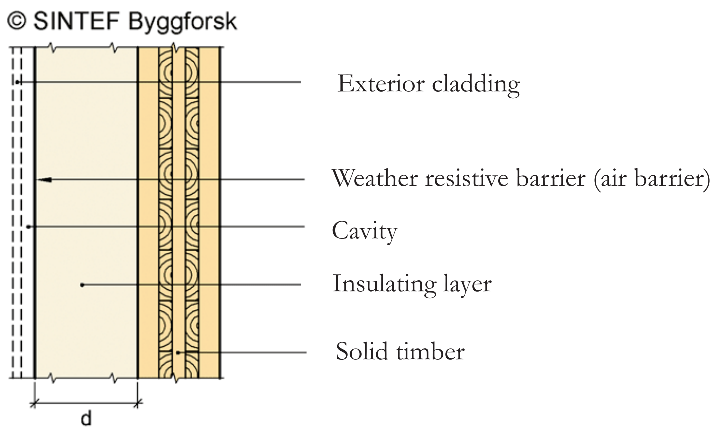
Typical light timber construction



SINTEF Community, Byggforskserien

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

Typical light timber construction



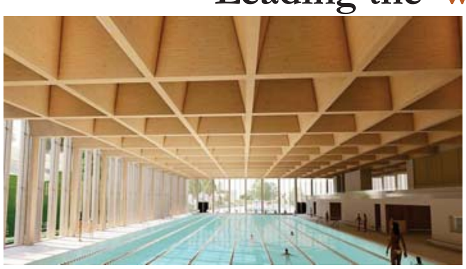
SINTEF Community, Byggforskserien

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

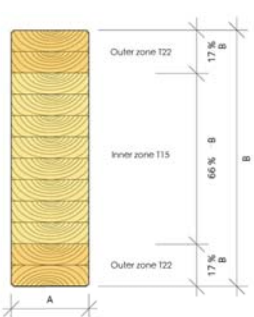
Modern timber constructions

Cross Laminated Timber (CLT)

Leading the 'woodification' of building industry



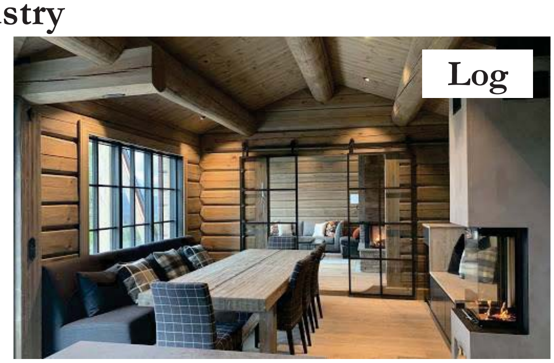
Asplan Viak, 'The new Tøyen Swimming Hall'



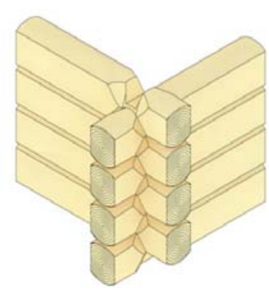
Glulam

Glulam from Swedish wood

Photo: Own archive



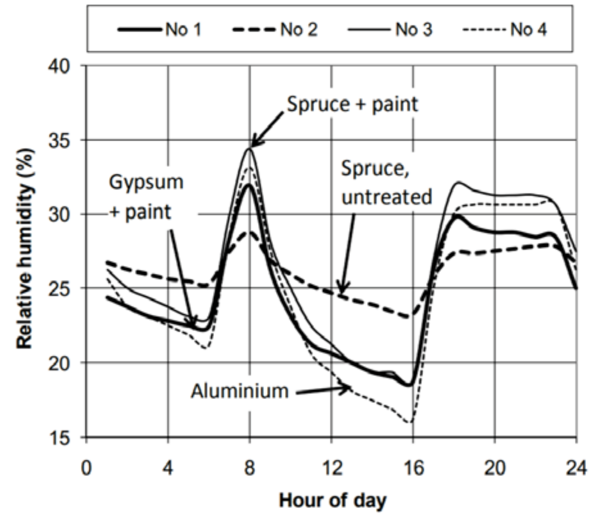
Laftekompaniet AS



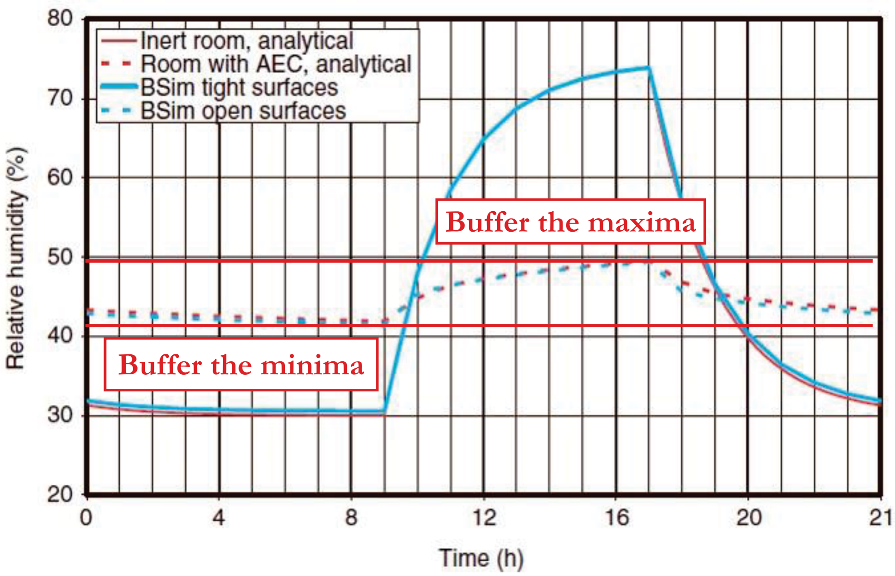
SINTEF Community, Byggforskserien

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/byg-r126.pdf

Moisture Buffer Value (MBV)

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
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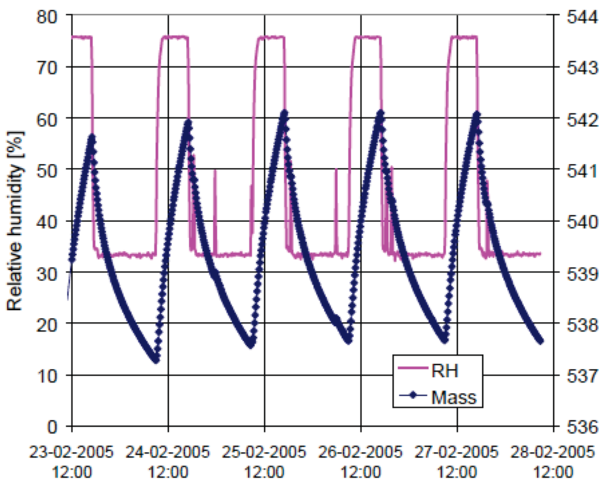
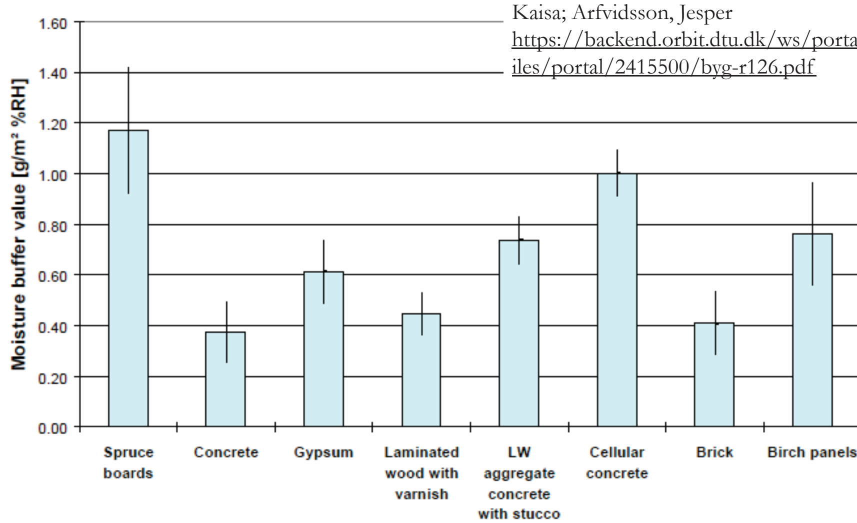




$$\text{Moisture Buffer Value: MBV} = \frac{\textit{moisture uptake}\ [g]}{\textit{change in RH}\ [\%] * \textit{hygroscopic surface}[m^2]}$$

Internal humidity loads according to ISO 13788

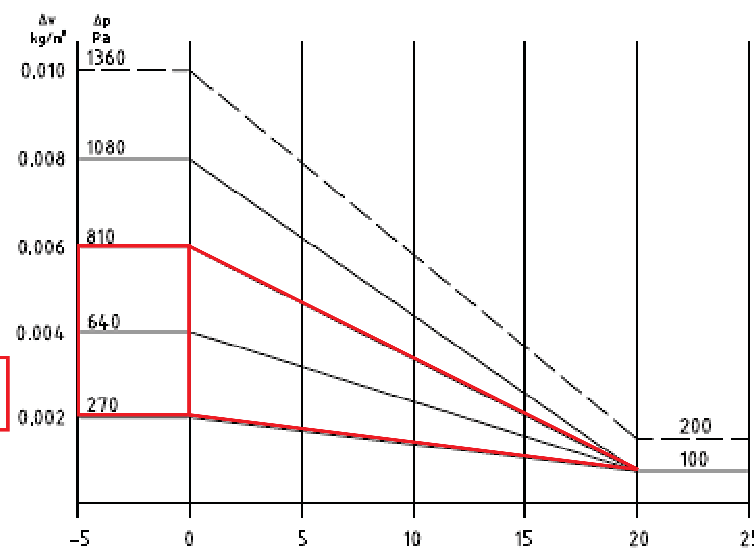
$v_i = v_e + \Delta v$

$\Delta v = G/V'$

G: moisture production indoors [g/h]

V': ventilation rate [m^3/h]

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



max Δv = 4 or 6 g/m^3

Moisture sources indoors

Branz.co.nz

Moisture buffering and ventilation strategies

Photo: inhabitat.com

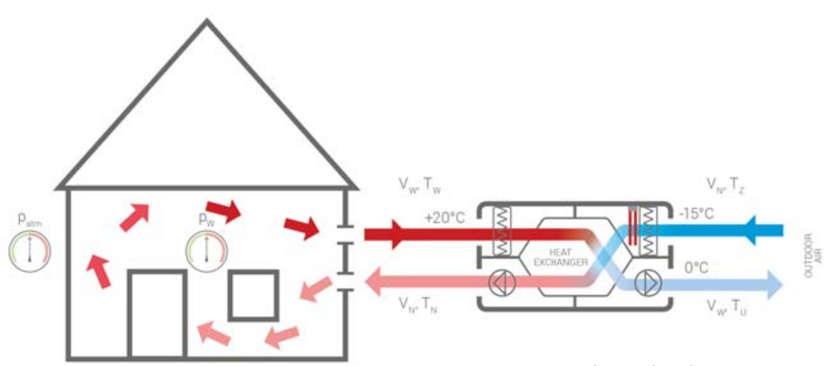


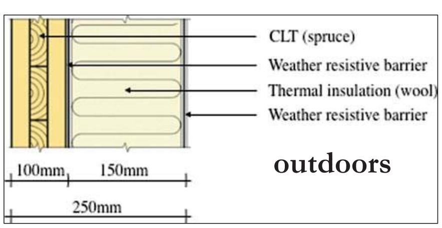
Photo: thesslagreen.com

Case study 1/4 - Field

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

Field test of moisture buffering capacity in CLT modules

Photo: Tormod Aurlien, NMBU



outdoors

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 m^3
- Exhaust ventilation V' = 0.5 ACH
- Moisture load G = 0.62 kg/h (in total 5.8 kg)

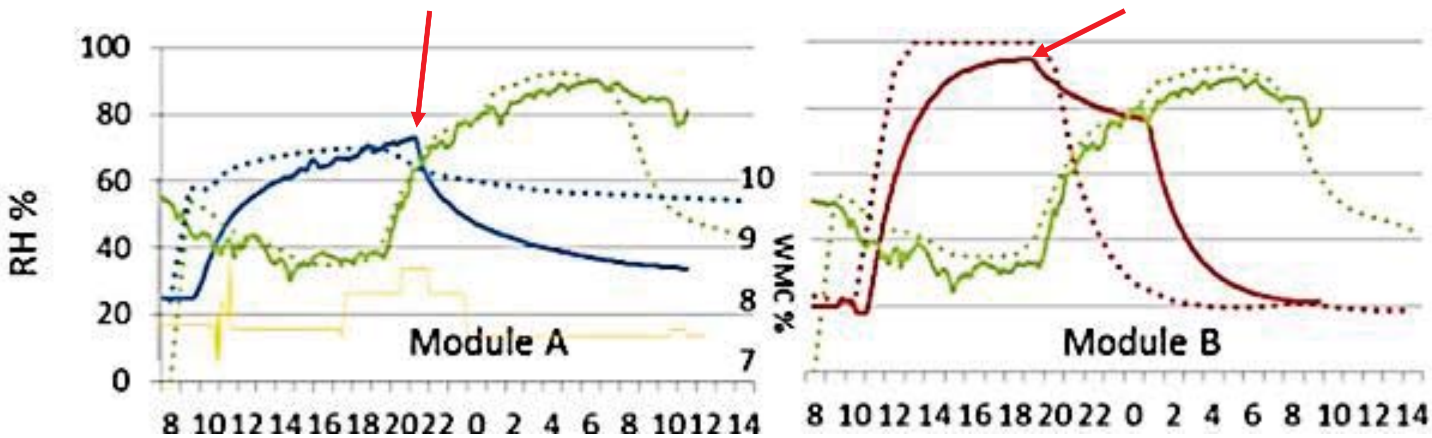
Very high load! (Δv > 20 g/m^3)

Moisture buffering, energy potential, and volatile organic compound emissions of wood exposed to indoor environments
K. Nore, A.Q. Nyrud, D. Kraniotis, K.R. Skulberg, F. Englund, T. Aurlien
https://www.tandfonline.com/doi/abs/10.1080/23744731.2017.1288503

Field test of moisture buffering in CLT modules

Exposed CLT
max $RH_i \approx 70\%$

non-hygroscopic
max $RH_i \approx 95\%$



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Case study 2/4 - Lab

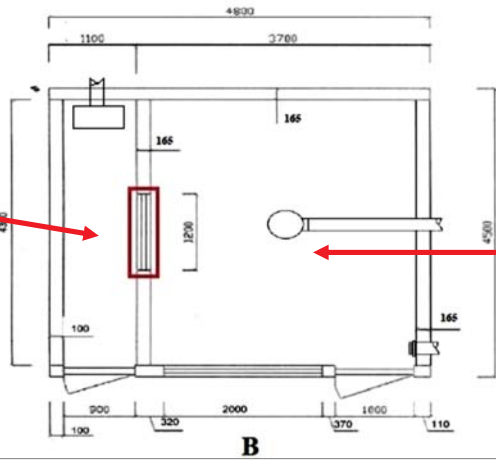
What is the moisture buffering performance of CLT under controlled operational conditions in the lab?

Moisture buffering capacity of a CLT element

- **Step 1**: determination of **MBV = 1.1 g/(%RH*m²)** – almost the same as reported in NordTest for wooden sample (softwood)

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

‘outdoors’
$\theta e \approx -8.5$ °C
$RH_e \approx 70\%$
$v_e = 1.7\ g/m^3$



‘indoors’
$\theta e \approx 21.5$ °C
$RH_{i,initial} \approx 20\%$
$V_{i,\ initial} = 3.5\ g/m^3$

Moisture buffering capacity of a CLT element

Three different scenarios of moisture load:

1. Moisture $load_{,8h}$ = **268.75 g/h**
   → **expected** increase of humidity indoors = 268.75/57.5 = **4.7 g/m³** ($RH_i \approx 45\%$)
   → **actual** increase of humidity indoors = **3.54 g/m³** ($RH_i \approx 40\%$)
   → corresponding **‘ventilative’ effect** of moisture buffering = **18.4 m³/h (total: 75.9 m³/h)**

2. Moisture $load_{,8h}$ = **312.5 g/h**
   → **expected** increase of humidity indoors = 312.5/57.5 = **5.4 g/m³** ($RH_i \approx 50\%$)
   → **actual** increase of humidity indoors = **3.7 g/m³** ($RH_i \approx 41\%$)
   → corresponding **‘ventilative’ effect** of moisture buffering = **27 m³/h (total: 84.5 m³/h)**

3. Moisture $load_{,8h}$ = **343.75 g/h**
   → **expected** increase of humidity indoors = 343.75/57.5 = **6 g/m³** ($RH_i \approx 60\%$)
   → **actual** increase of humidity indoors = **3.8 g/m³** ($RH_i \approx 45\%$)
   → corresponding **‘ventilative’ effect** of moisture buffering = **33 m³/h (total: 90.5 m³/h)**

Case study 3/4 - Field

Photo: Rumi Baumann
Design: Tron Meyer

What is the moisture buffering performance of CLT under fully operational conditions in-situ?

Ulsholtveien 31, housing units in exposed CLT

Photo: Are Carlsen
Design: Haugen/Zohar Arkitekter (HZA)

Norwegian Architecture Prize 2017
Wooden project of the year 2017

Ulsholtveien 31, housing units in exposed CLT

- Floor area of the tested appartment, **A = 56 m²**
- Volume, **V = 148 m³**
- Decentralised ventilation, **V' = 38 m³/h**, in each of the three rooms (2 units in the kitchen/living room (34.4 m²) and 1 unit in each of the two bedrooms (7.3 m² and 9.7 m²)
- Exhaust ventilation in the bathroom, **V' = 50 m³/h** when $RH_{i,bath}$ > 50% or for 15 minutes every 2 hours

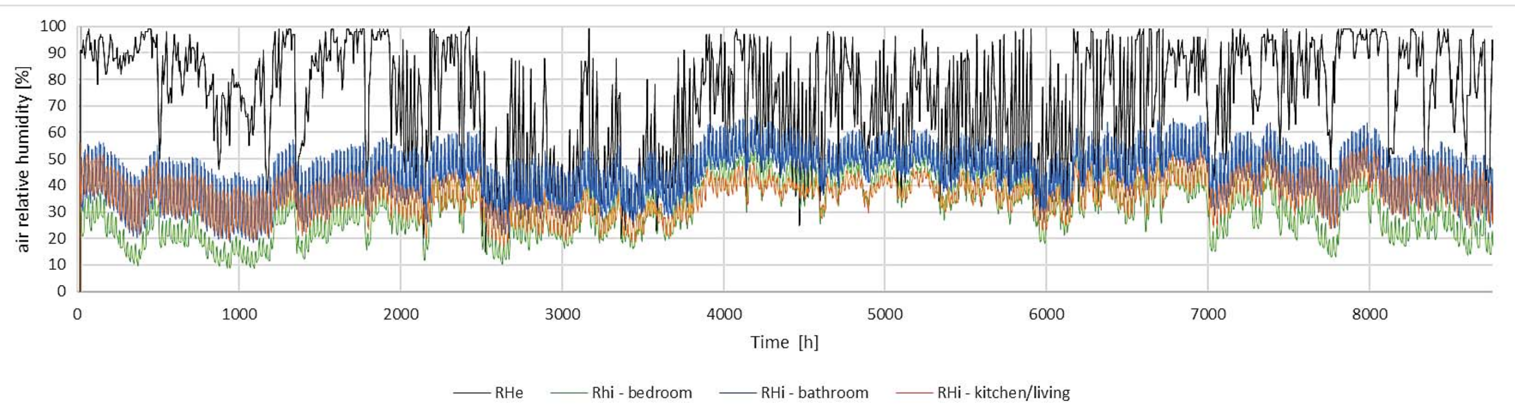
Photo: own archive

Photo: own archive

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

Interior finishing: cement board at the shower

Ulsholtveien 31, housing units in exposed CLT



Bedroom: 9% < RH_i < 54% (too high air temperature, i.e. $\theta_{i,bed}$ = 29 °C)

Bathroom: 18% < RH_i < 66% | water content in wood u = 8.1% - 11.7% < 15.4%

Kitchen/living room: 17% < RH_i < 55% | [CO_2]: usually below 1150 ppm, max = 1550 ppm

Case study 4/4 – Simulation


Photo: Rumi Baumann
Design: Tron Meyer

What is the RH indoors in case CLT is replaced by gypsum boards and tiles (bathroom)?

Numerical comparison between gypsum/tiles and CLT

	Bedroom CLT	Bedroom Gypsum board	Bathroom CLT + cement board	Bathroom Tiles	Kitchen/living room CLT	Kitchen/living room Gypsum board
RHi, min	9%	6% (-3%)	18%	9% (-9%)	17%	13% (-4%)
RHi, max	53%	58% (+5%)	66%	98% (+32%)	55%	63% (+8%)

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).

1

Three questions

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

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2

About/Not about

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

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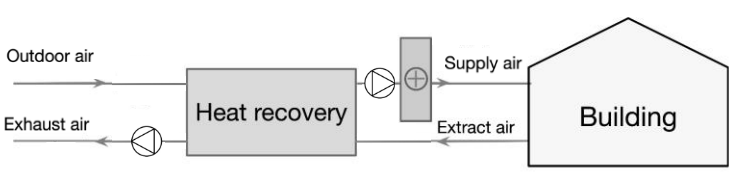
Moisture recovery

Moisture recovery rate = internal moisture excess × moisture recovery efficiency



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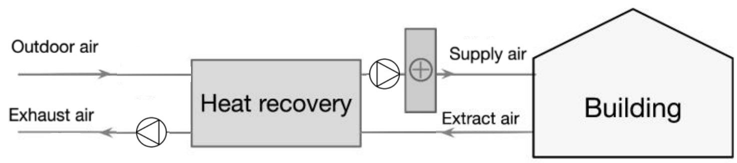
Moisture recovery

Moisture recovery rate = internal moisture excess × moisture recovery efficiency



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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

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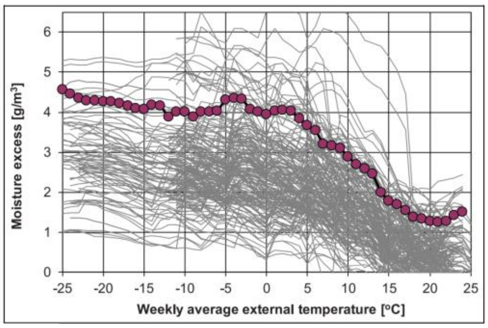
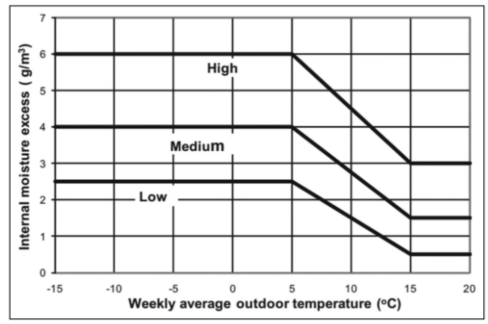
Internal moisture excess



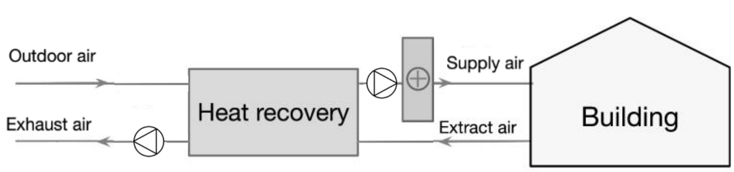
The weekly average moisture excess of 101 timber-framed single-family buildings as a function of weekly average outdoor air temperature. Each thin line represents one measured bedroom or living room. The dotted line represents the moisture excess curve on the higher 10% critical level (Kalamees et al., 2005, 2006; Vinha et al., 2005).



Proposed internal moisture excess design curves for residential buildings (based on 10% critical level; Geving and Holme, 2011).

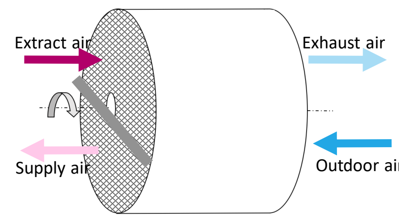
Moisture recovery

Moisture recovery rate = internal moisture excess × moisture recovery efficiency

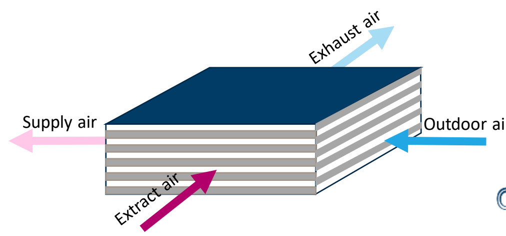


Two types of heat/energy recovery ventilator (HRV/ERV) usually applied in residential buildings

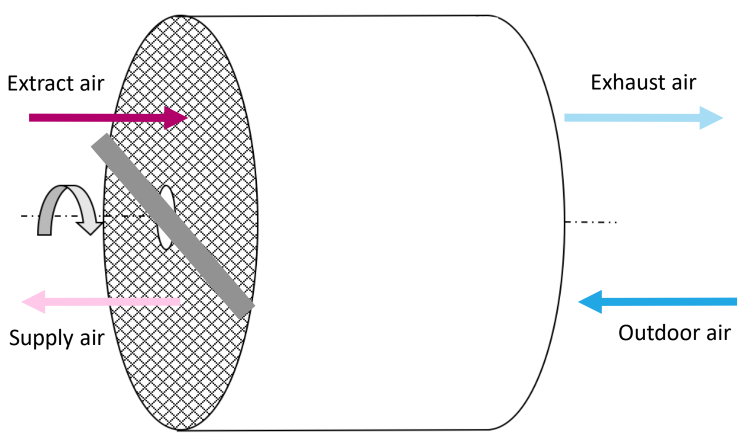
- Two types of air-to-air heat recovery
  - Regenerators
    - Heat wheel (HRV)
    - Enthalpy wheel (ERV)



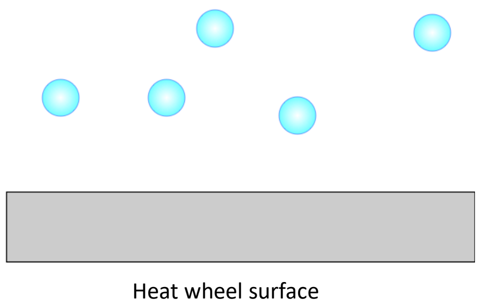
  - Recuperators
    - Plate heat exchanger (HRV)
    - Membrane energy exchanger (ERV)



Moisture transfer in heat and enthalpy wheels



Moisture transfer in heat wheel



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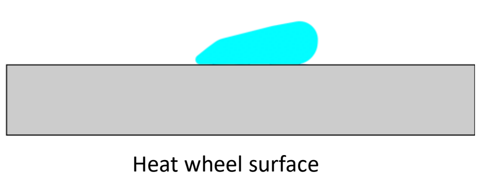
Moisture transfer in heat wheel



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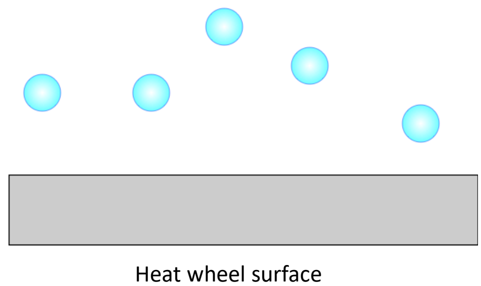
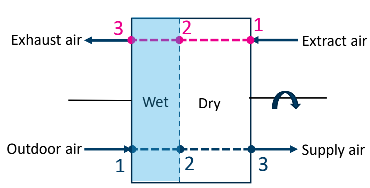
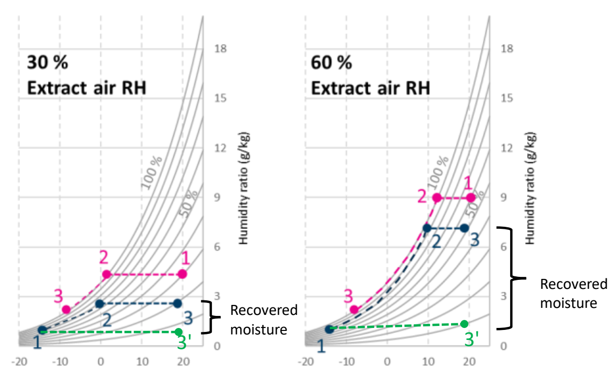
Moisture transfer in heat wheel

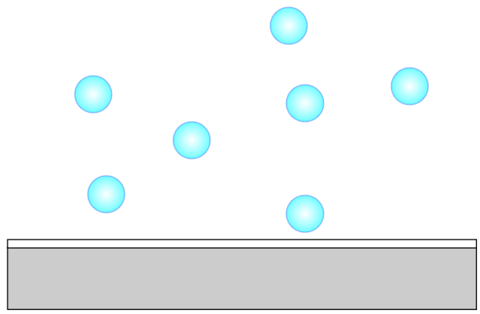


Heat wheel moisture transfer process for cold climate





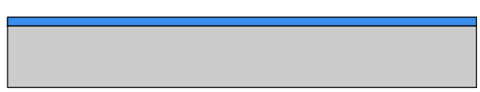
Moisture transfer in enthalpy wheel



Enthalpy wheel surface

15

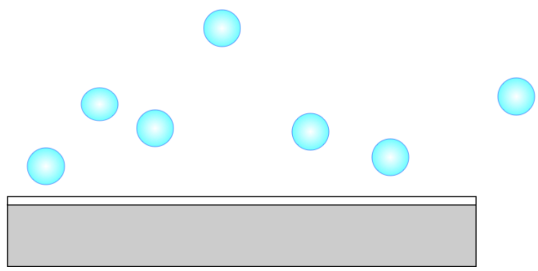
Moisture transfer in enthalpy wheel



Enthalpy wheel surface

16

Moisture transfer in enthalpy wheel



Enthalpy wheel surface

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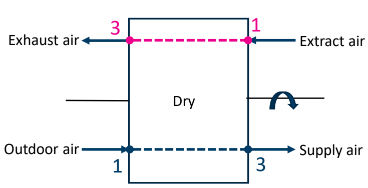
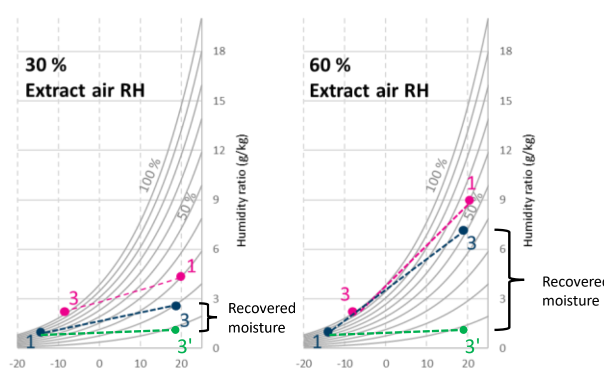
Enthalpy wheel moisture transfer process for cold climate





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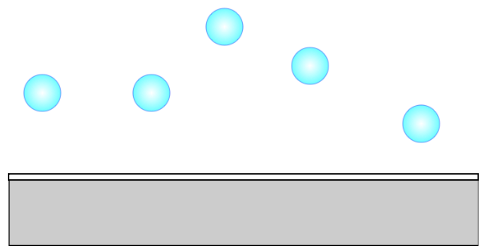
Moisture transfer in oxidized or fouled heat wheel



Oxidized or fouled surface

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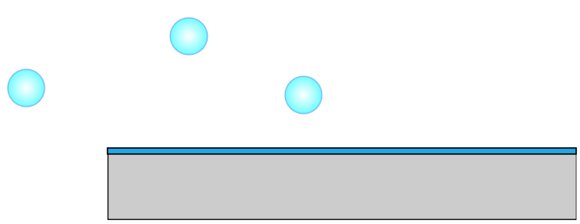
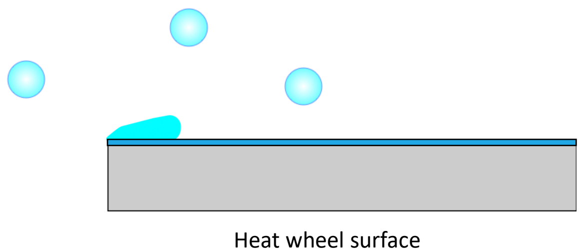
Moisture transfer in oxidized or fouled heat wheel



Heat wheel surface

20

Moisture transfer in oxidized or fouled heat wheel



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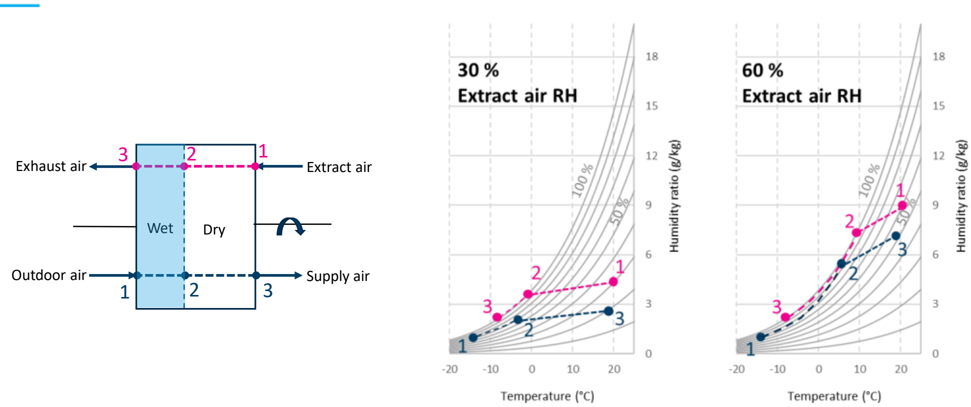
Oxidized or fouled heat wheel moisture transfer process for cold climate



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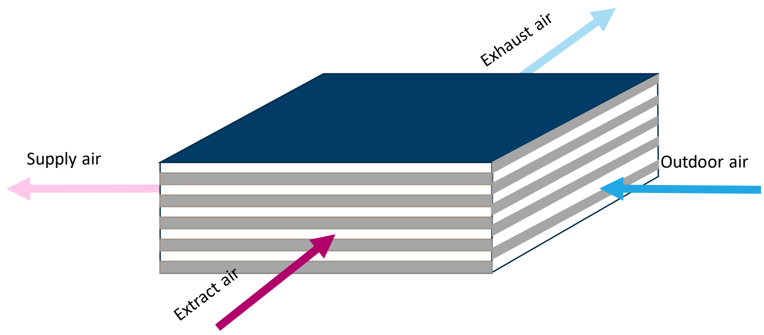
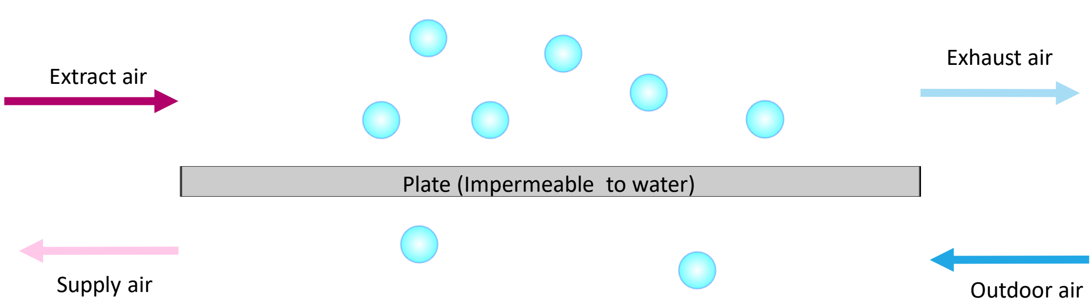
Moisture transfer in plate and membrane exchangers



23

Moisture transfer in plate heat exchanger



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Moisture transfer in plate heat exchanger

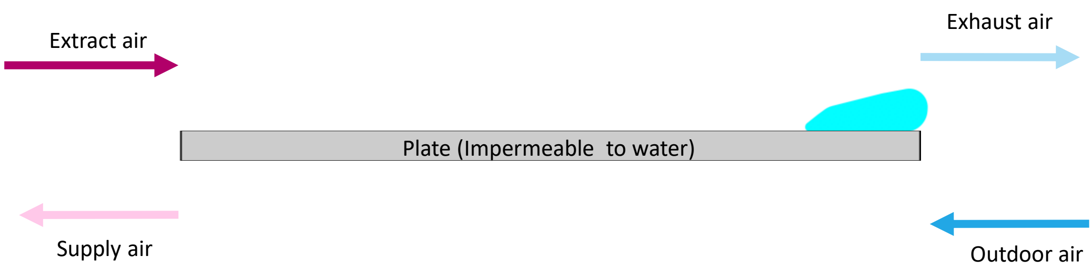

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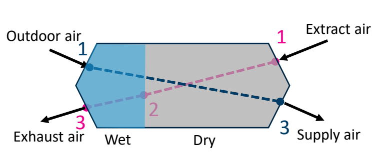
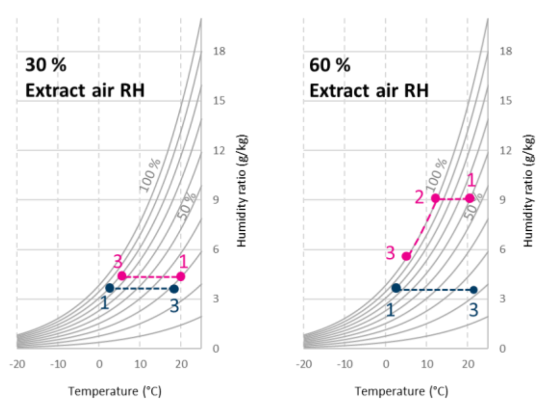
Plate heat exchanger moisture transfer process in HRV/ERV





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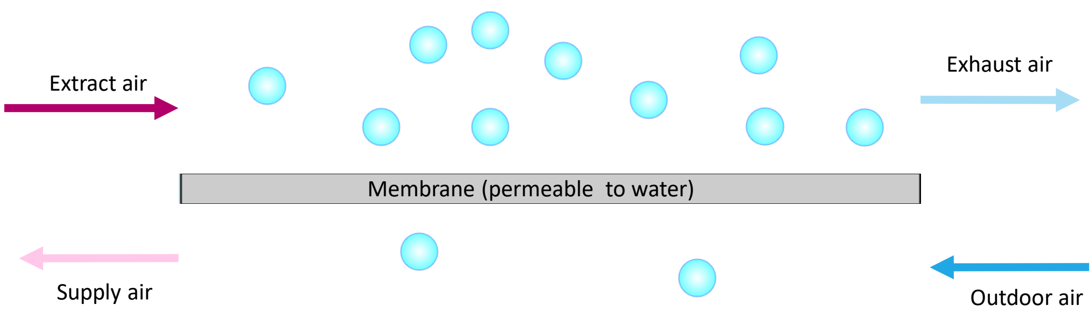
Moisture transfer in membrane energy exchangers



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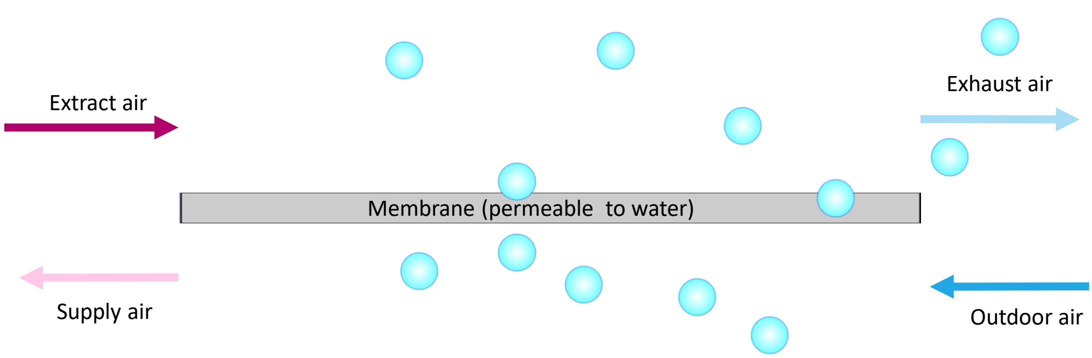
Moisture transfer in membrane energy exchangers



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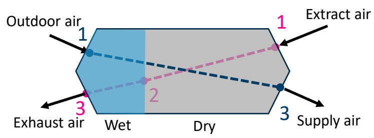
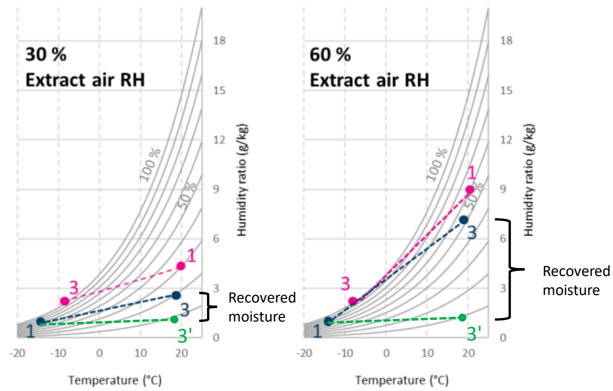
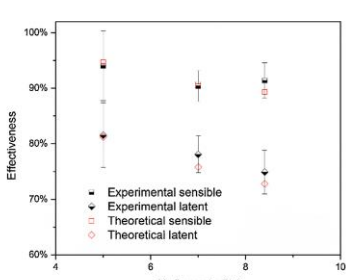
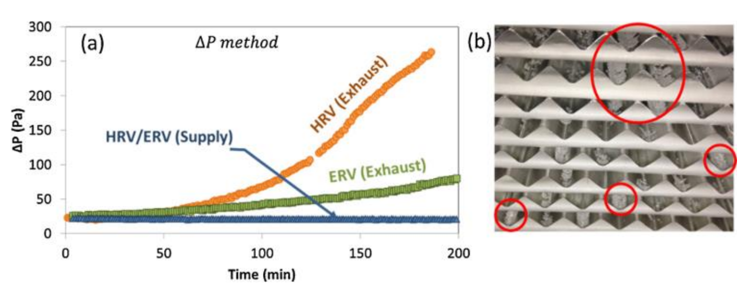
Membrane energy exchanger moisture transfer process





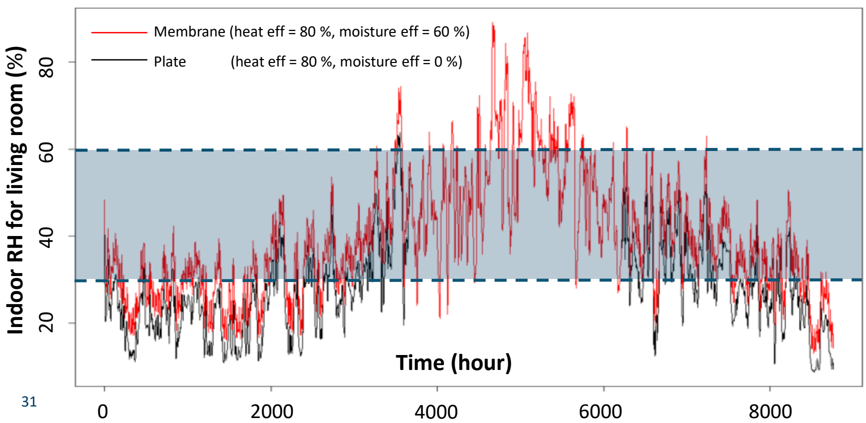
Performance of a quasi-counter flow membrane exchanger





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

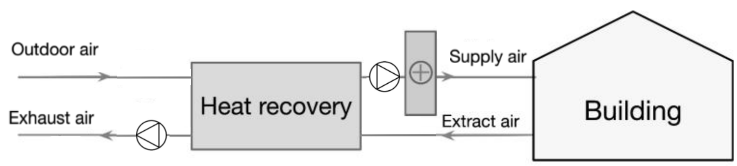
RH in range of 30-60 %
Plate heat exchanger:
3876 h, 44 % time of the year
Membrane exchanger:
5695 h, 65 % time of the year

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



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Acknowledgements

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Anneli Halfvardsson, Flexit

Daniel Nielsen, Flexit

Maria Justo Alonso, NTNU, SINTEF

Projects: EnergiBolig, Defreeze MEE Now, Healthy and Energy Efficient Urban Home Ventilation

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