1

Summary. To avoid too low humidity consider:

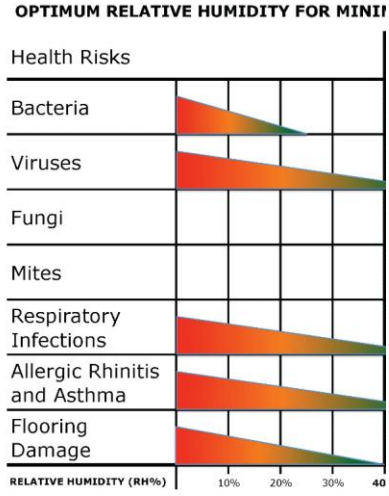
Action	Potential effect	Limitations / challenges
Hygroscopic materials	Limited	Only short-term variation
Decreasing indoor temperature	Limited	User comfort and preferences
Adding sources	Limited	Indoor air quality
Reducing ventilation	Moderate	Indoor air quality
Recovering moisture	Moderate – large	Hygiene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

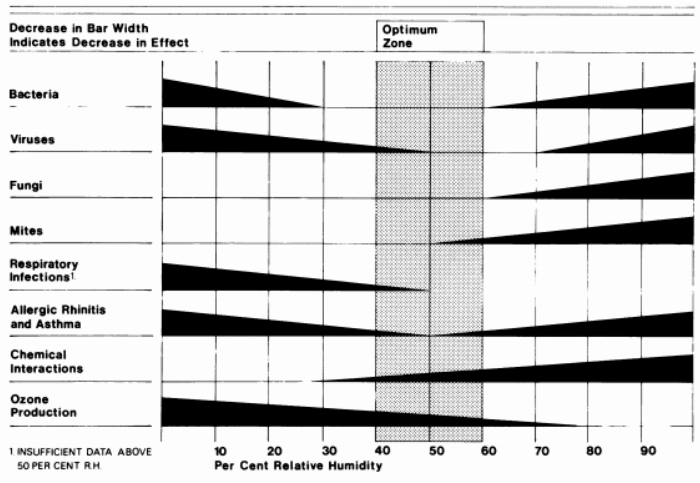
2

SINTEF

2

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





Source: Arundel A, Sterling E, Biggin J, et al - Indirect Health Effects of Relative Humidity in Indoo

FIGURE 1. Optimum relative humidity range for minimizing adverse health effects.

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

SINTEF

3

Arundel & al. reexamined

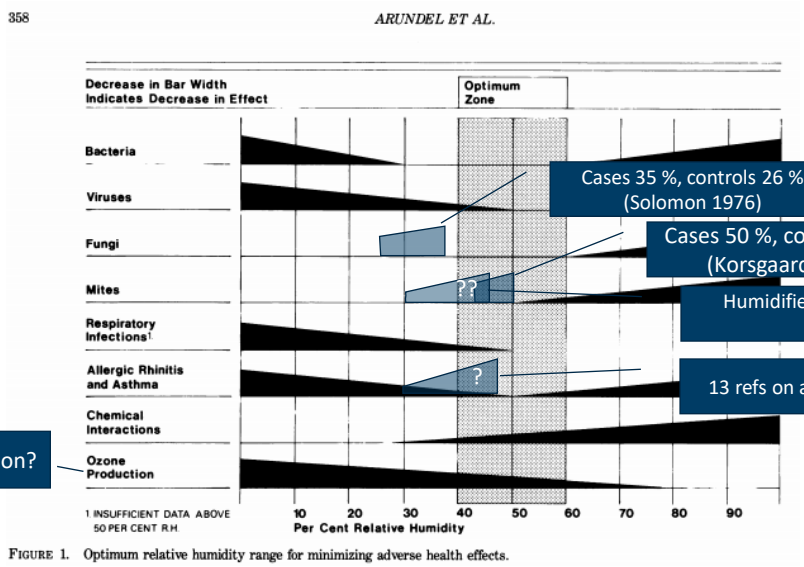


FIGURE 1. Optimum relative humidity range for minimizing adverse health effects.

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

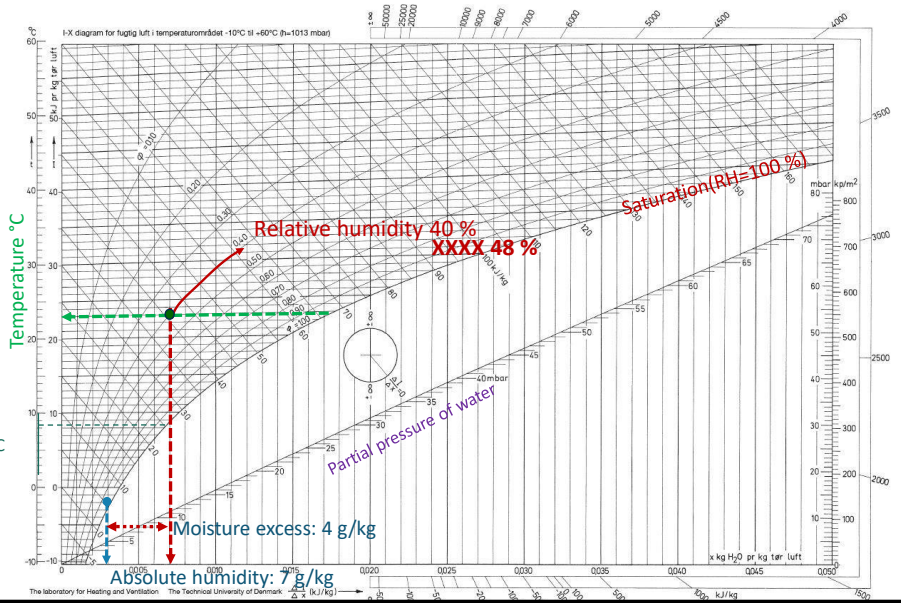
Production?

SINTEF

4

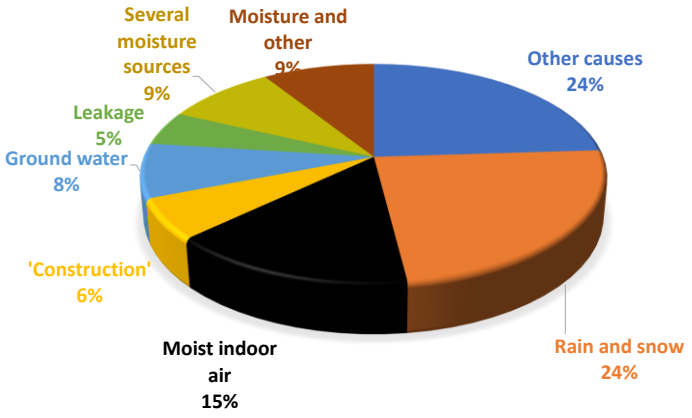
4

Relative and absolute moisture, moisture excess, dewpont



SINTEF

Causes of building damage -Norway



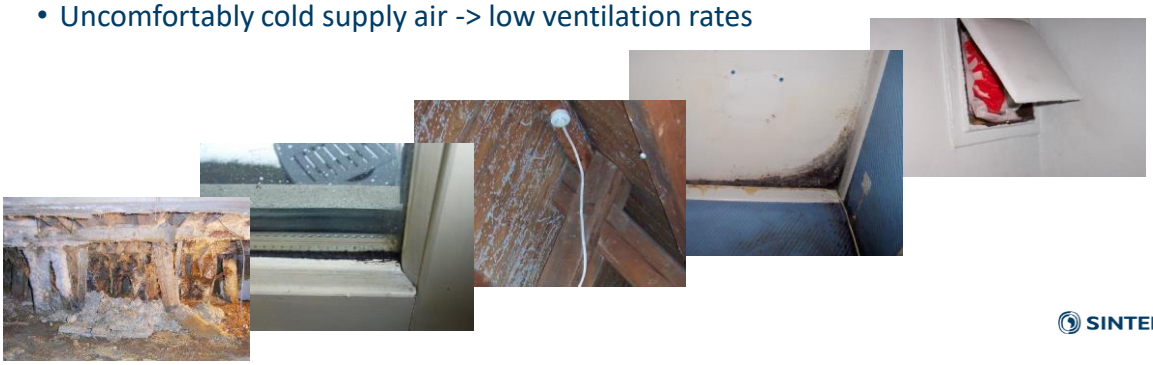
Data source: SINTEF archives 1993-2002.
Bias **towards** large buildings, non-trivial cases, costly repairs.
Bias **against** single houshold dwellings, "water damage".

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

SINTEF

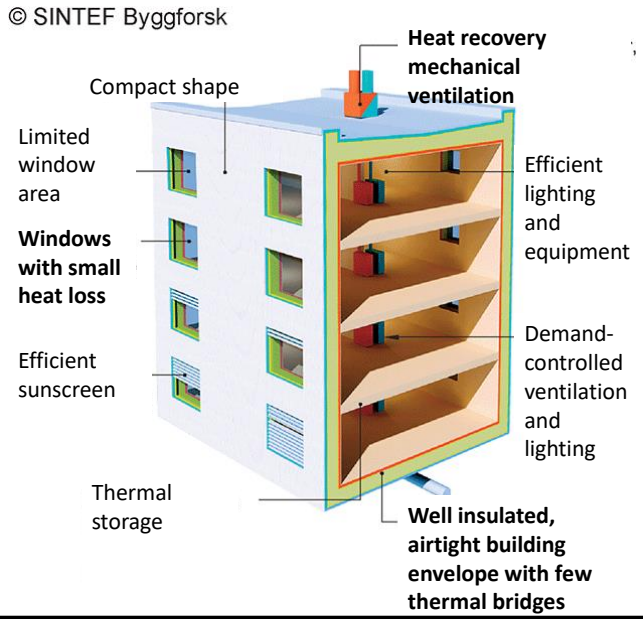
Existing buildings are vulnerable to high humidity:

- 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

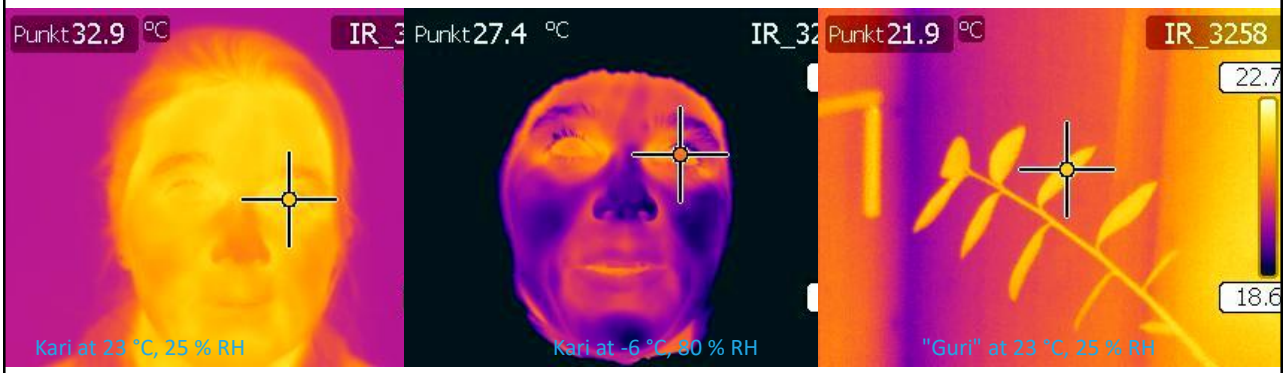


SINTEF

Newer buildings less vulnerable to high humidity:

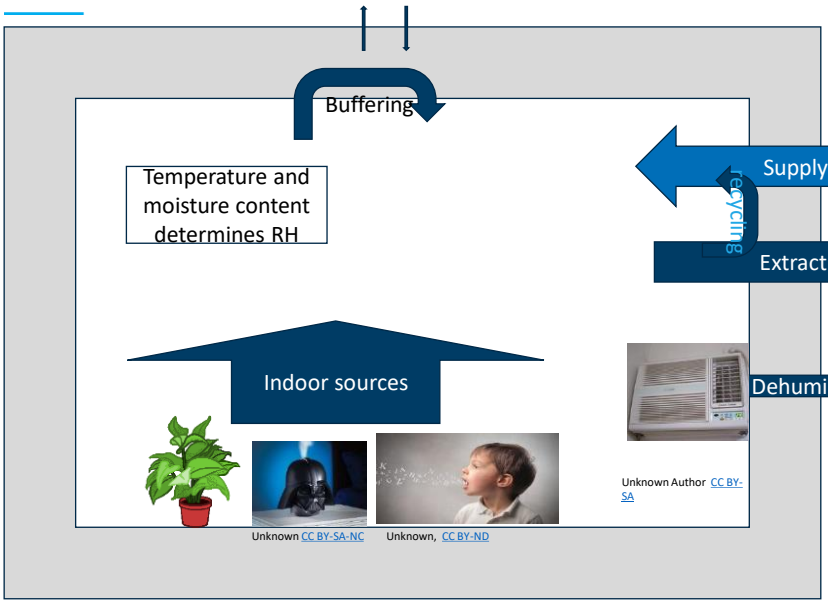


You are not a plant: Relative humidity is not the only important humidity for health and comfort



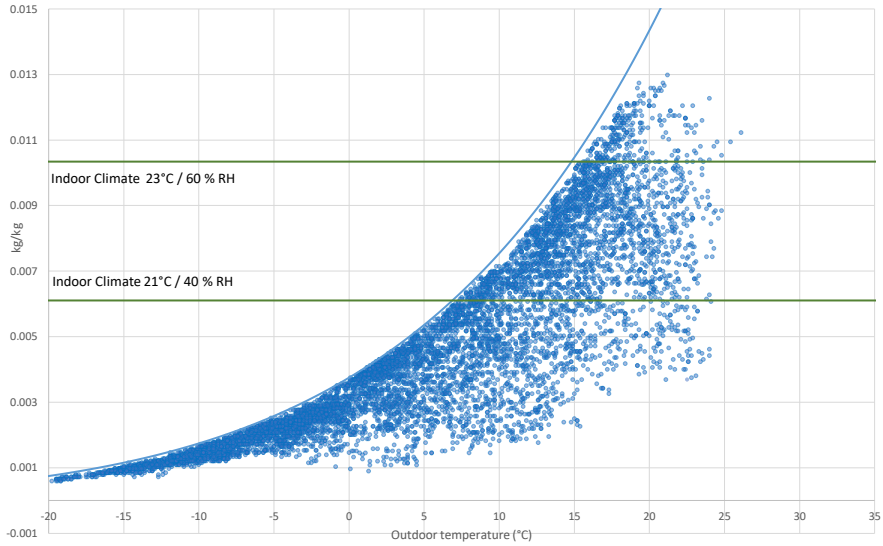
SINTEF

What determines indoor humidity?



SINTEF

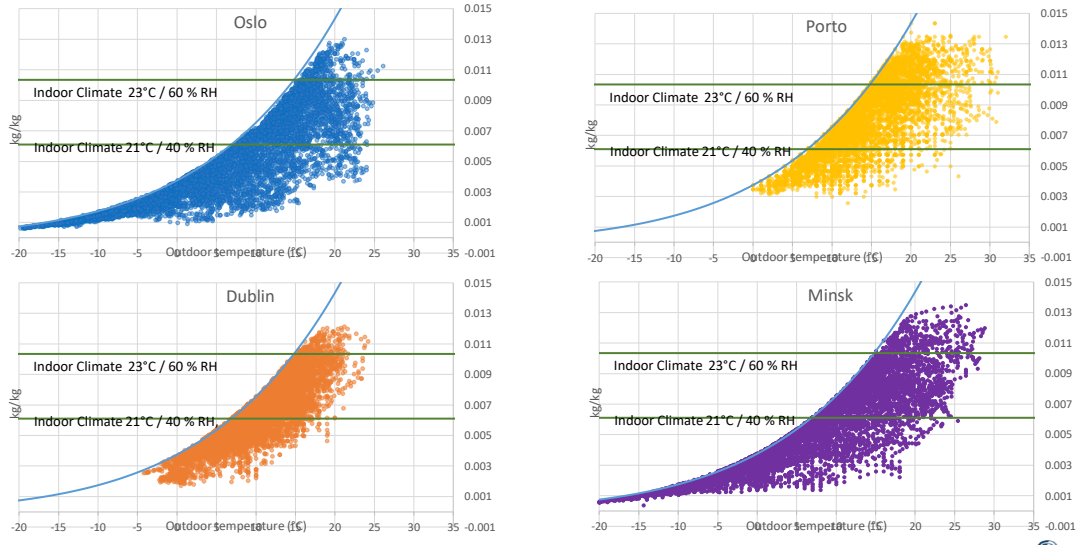
Moisture content of outdoor air – Oslo



SINTEF

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

Moisture content of outdoor air



SINTEF

Dublin, Minsk and Port climate data from Energy Plus data (ASHRAE)

What can we do about (too) low humidity

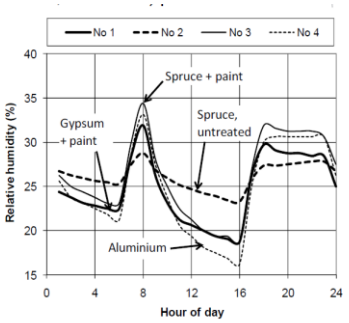
- Buffering — Reduces variation only
- Reduce temperature — Increases relative humidity only
- Reduce ventilation rates
- Add moisture — Increased absolute and relative humidity
  - Plants, drying clothes, showering, cooking…
  - Room humidifier / airconditioner
  - Supply air humidification
- Recover moisture
- Compensating actions — Does not change humidity

SINTEF

Moisture buffering

Photo CC0 Public domain via Piqsels.com

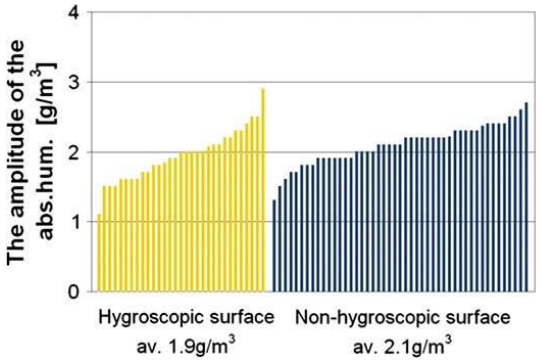
Effect of materials on diurnal RH variation - laboratory

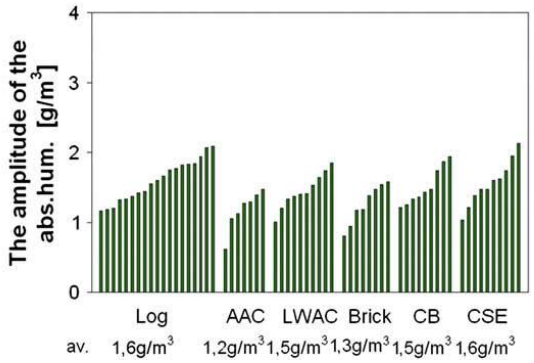


Geving, S. and J. Holme. 2012. Mean and diurnal indoor air humidity loads in residental buildings. Journal of Building Physics 35(4) 392-421.

SINTEF

Moisture buffering: field studies





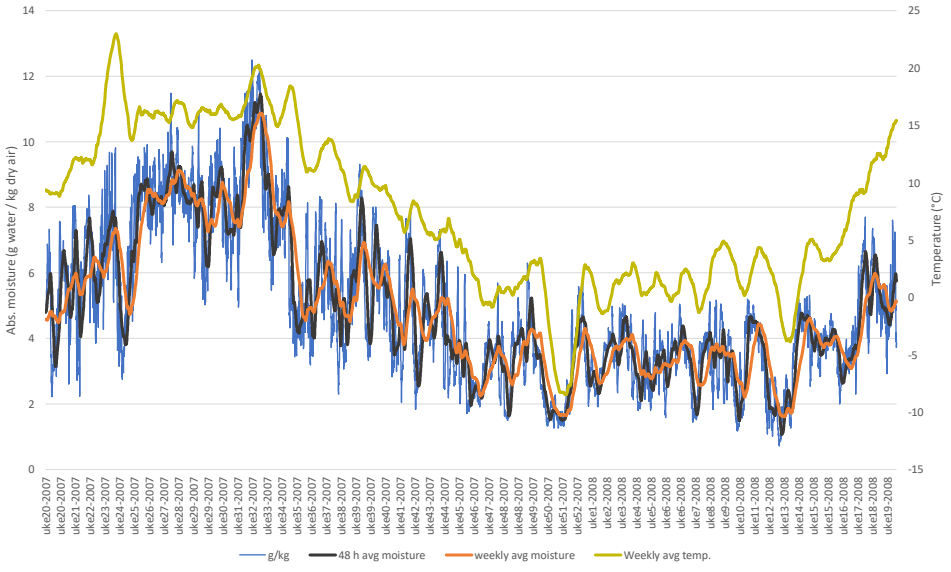
Both figs from (Kalamees, et al. 2009)

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.

SINTEF

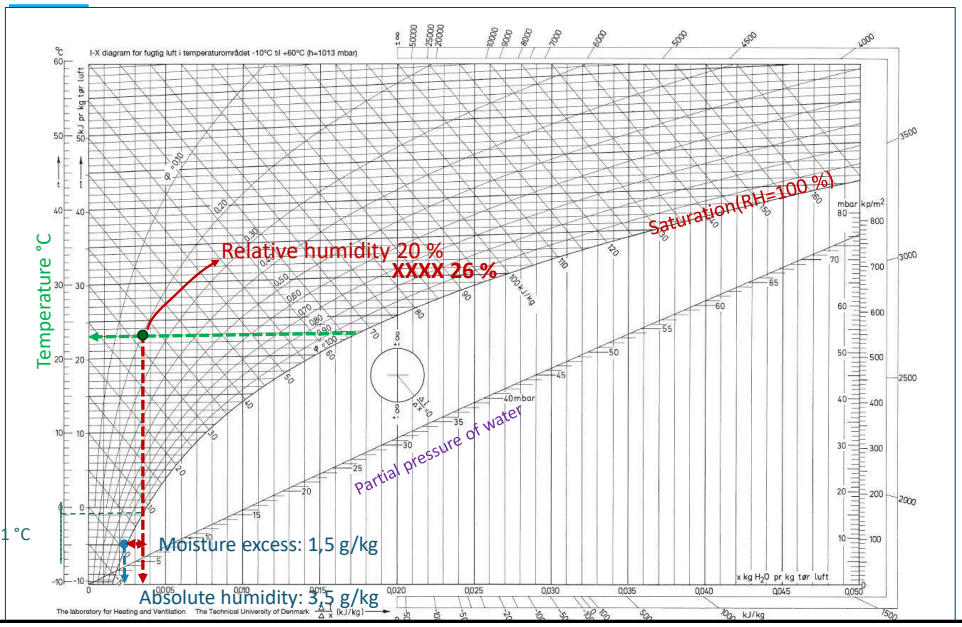
TO

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



SINTEF

Reducing indoor temperature –low RH



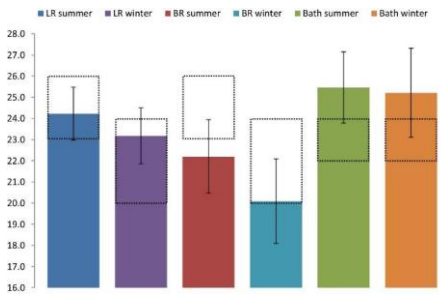
17

SINTEF

17

Reducing indoor temperatures?

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



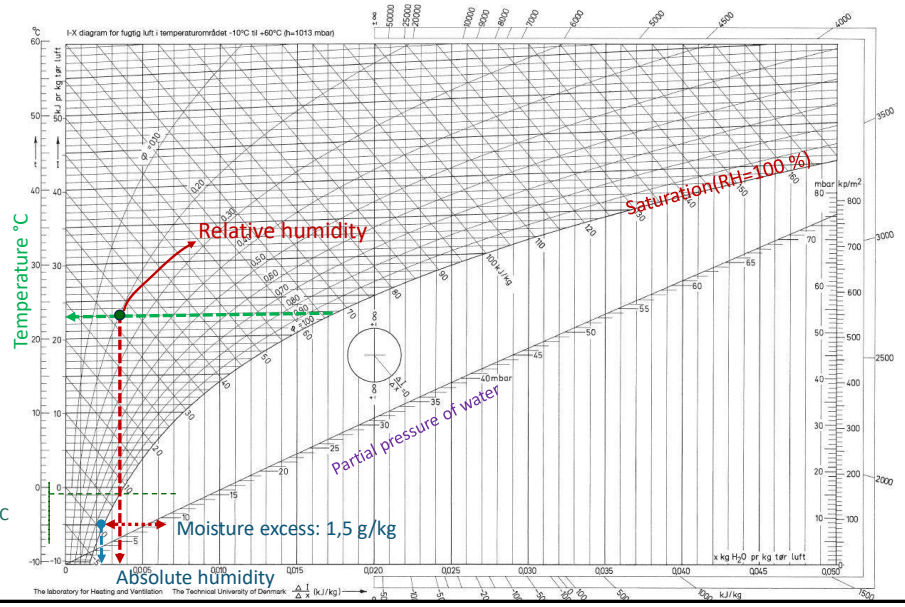
18

SINTEF

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

18

Increasing moisture excess



SINTEF

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

SINTEF

Ventilation and respiration

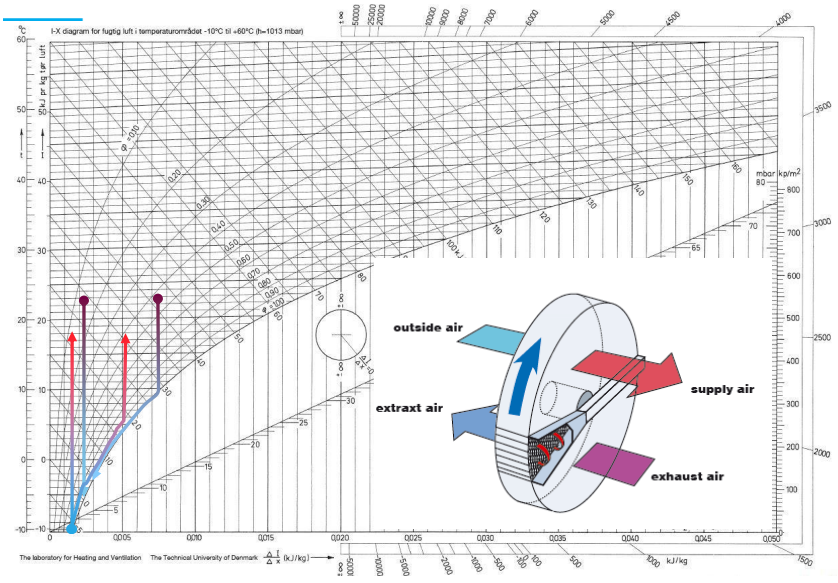
I adult at 23 °C, 1 met, 1 clo

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

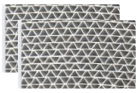
Target 1000 ppm CO_2 : 26 m³ / hour per person
Added moisture 1,5-2,3 g / m³

SINTEF

Moisture recovery



Ikke-hygroskopisk rotor



SINTEF

Increase excess: adding sources

Shower 3kg /h

Tree 2-4 kg /h

SINTEF

Add or remove indoor sources

- Drying of clothes
- Greenery
- Extract at source (shower, cooker, combustion)
- Humidifyer
- Dehumidifier / Air-conditioning

SINTEF

"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)

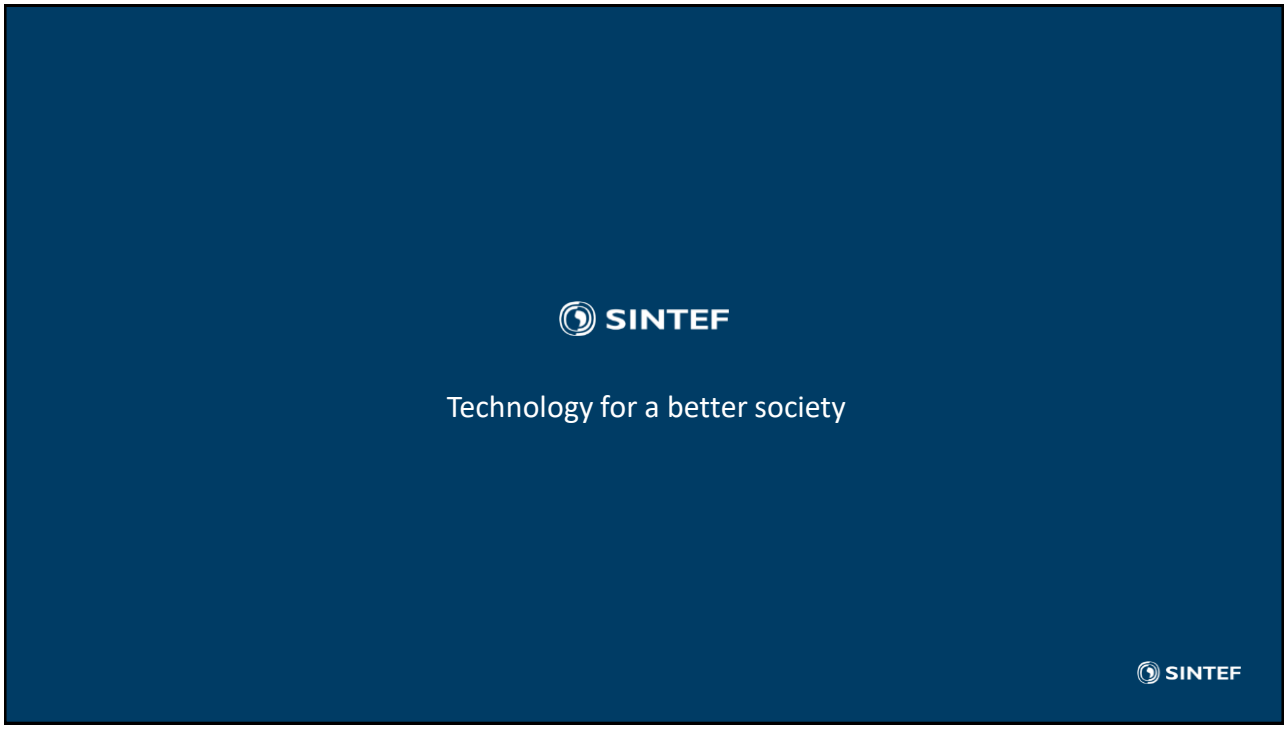
SINTEF

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
Recovering moisture	Moderate – large	Stay tuned...
Humidification	Large	Energy, hygiene
All above:		Condensation risks!

SINTEF



27

	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	

28

Questions

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

SINTEF

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?

SINTEF

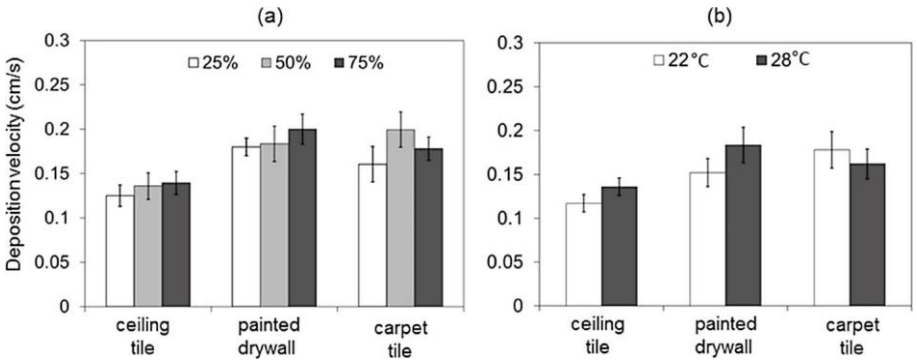
Asthma recommendations

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

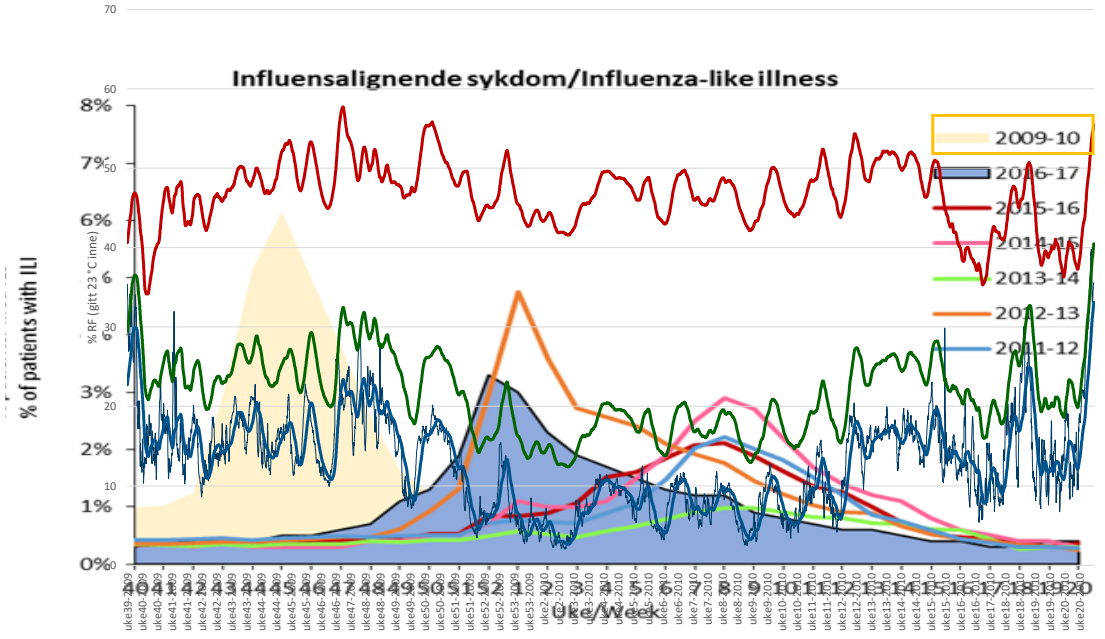
- Catalytic degradation of ozone less efficient at high RH. (Namdari, Lee et al. 2019)
- There is no certain conclusion about the impact of relative humidity (RH) on ozone surface removal. According to the previous studies, the impact of humidity on ozone surface removal generally depended on the nature of the material surface. (Shen and Gao 2018)

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



SINTEF

34

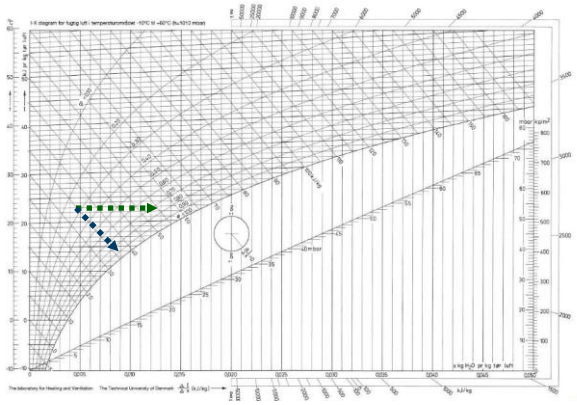


Influensadata: FHI

SINTEF

39

Tiltak: befuktning



Forstøvning

Fordampning

Fig: Qviller klimaprodukter, Stadler Form

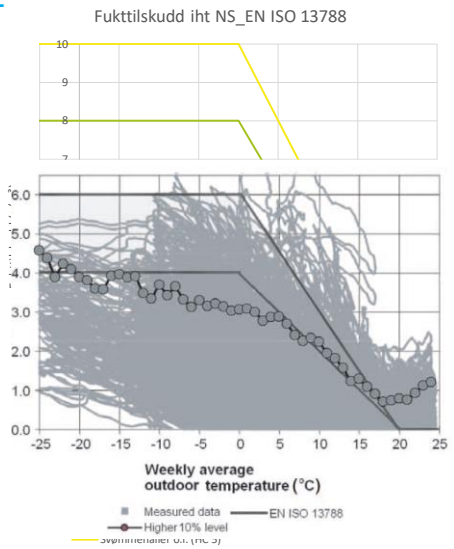
SINTEF

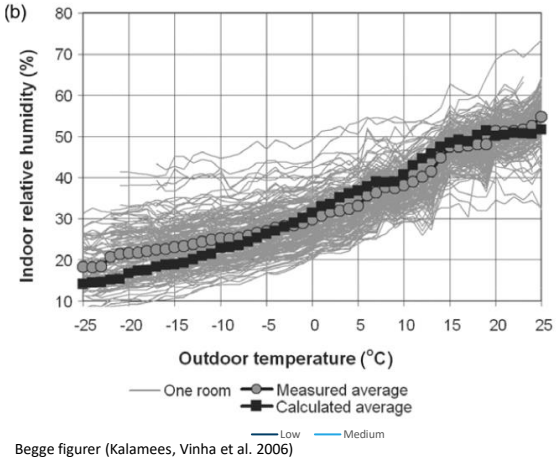
Befuktning

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

SINTEF

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

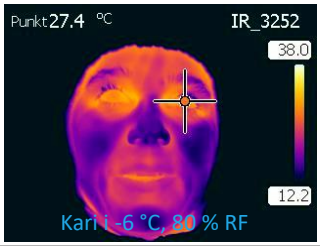
SINTEF

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]



SINTEF

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