

DANVAK Temamøde 3. sept. 2019

Diffus ventilation

About me

Forskningfelt: indeklima, HVAC, energi, simuleringsmodeller

Associate Professor DTU Byg

-financed 50% by Saint-Gobain Nordic

Fortid: erhvervsPhD , rådgiver ALECTIA

Worked with diffuse ventilation since 2009

Formand for DANVAK Ventilationsgruppen

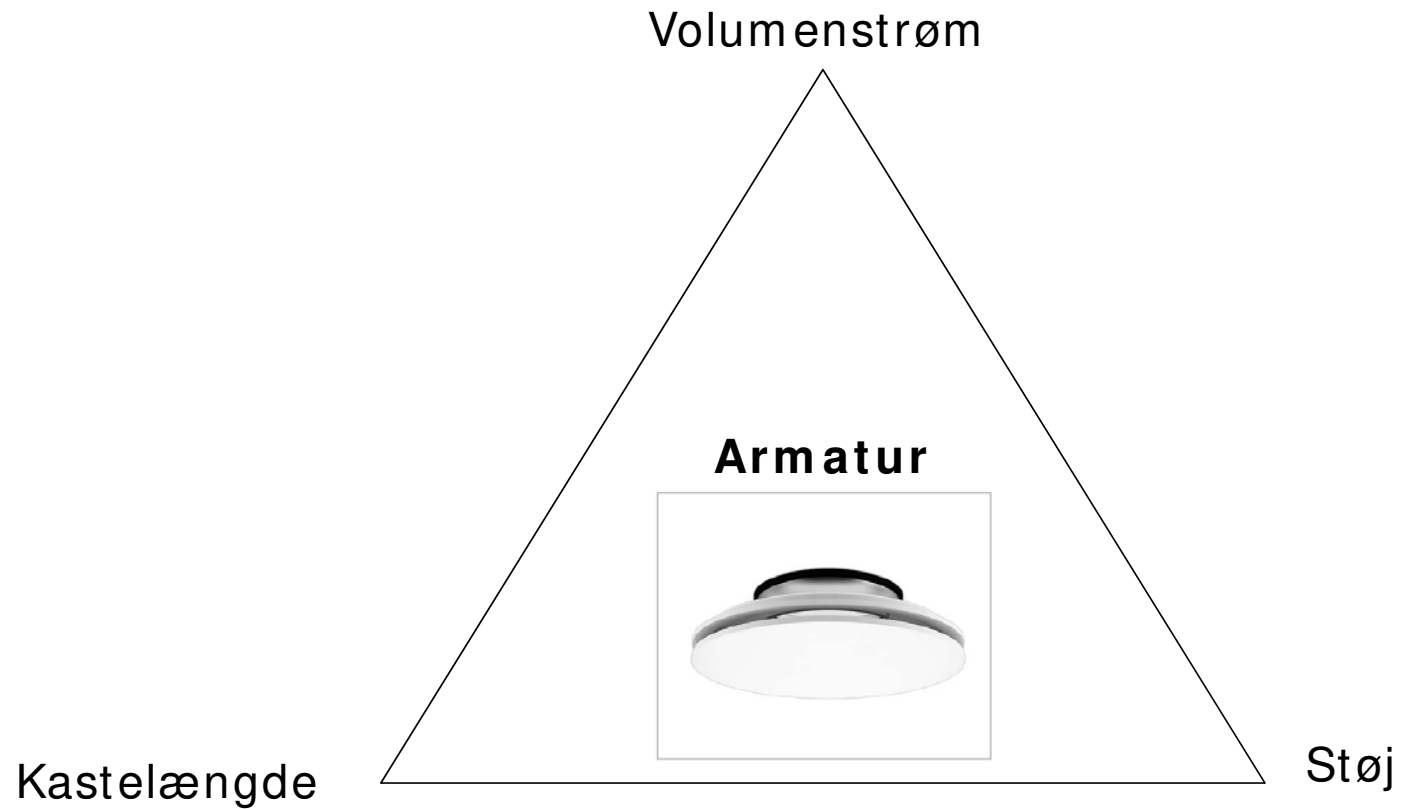


Emner

- Koncept
- Lufthastighed
- Temperaturgradient
- Ventilationseffektivitet
- Kølekapacitet
- Præstationer, Byens skole
- Opsummering

Baggrund

The ventilation dilemma triangle

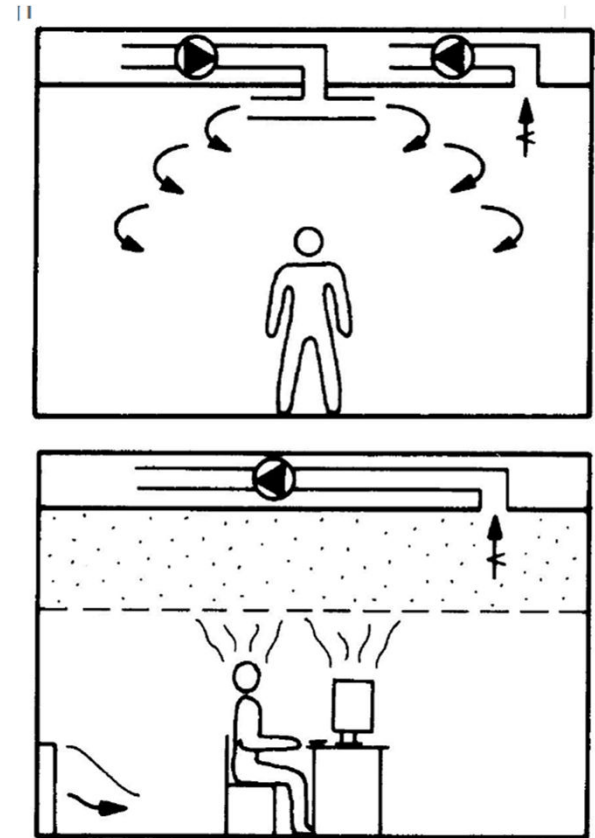


Høj-impuls

- Virkemåde: fortynding af forureninger ved opblanding med høj hastighed
- Issue: træk og støj fra indblæsningen

Lav-impuls

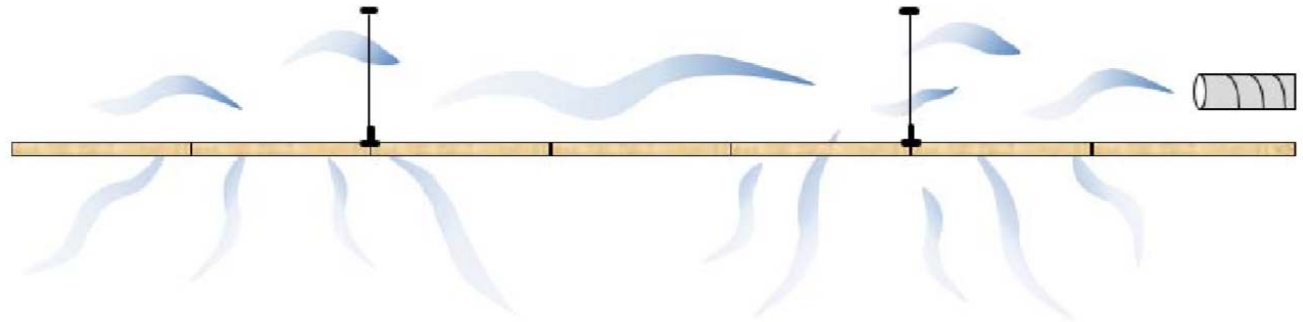
- Virkemåde: fortrænger gammel luft med frisk luft vha. temperaturlagdeling
- Issue: flexibilitet begrænset



Koncept

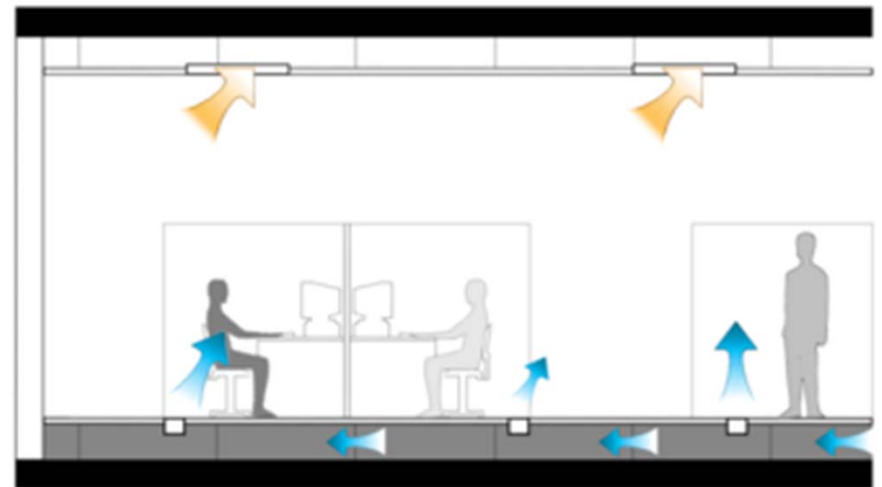
Diffus (lav-impuls)

- Virkemåde: opblanding ved lav hastighed
- Issue: nyt design paradigme

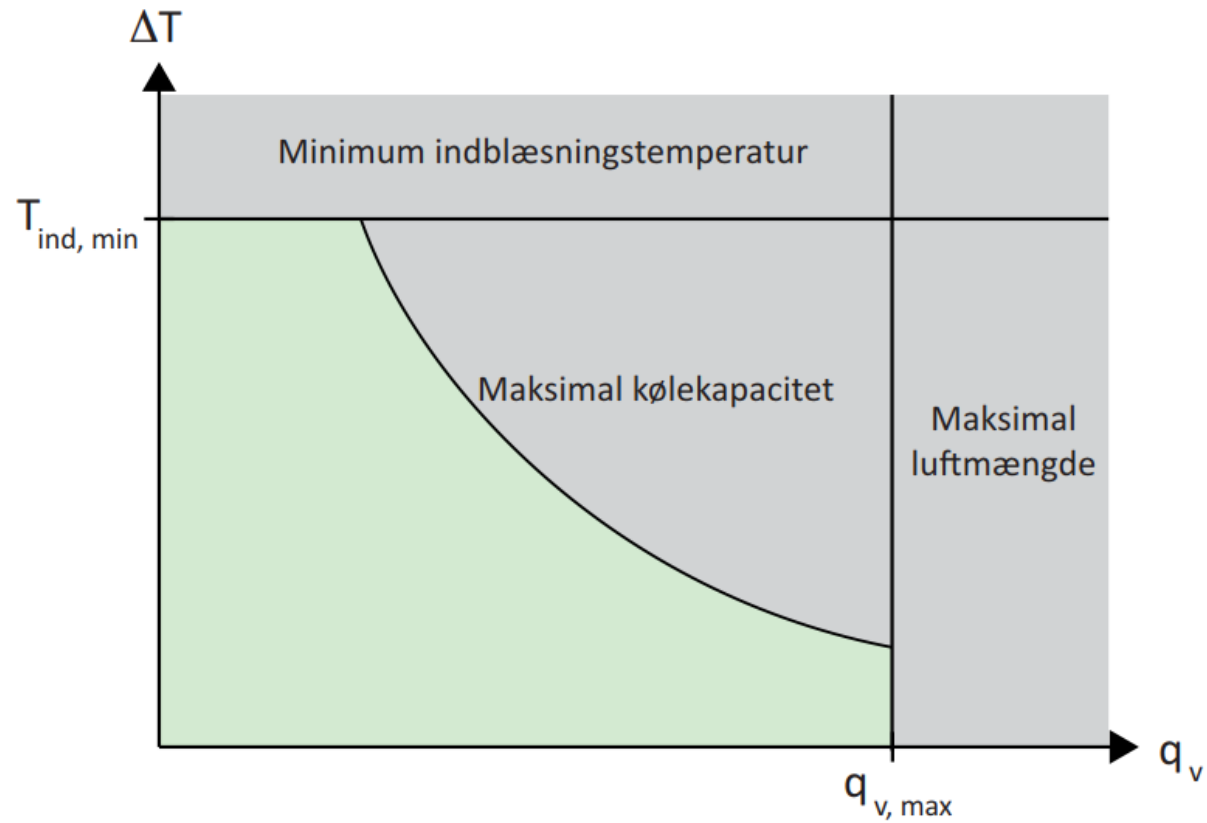


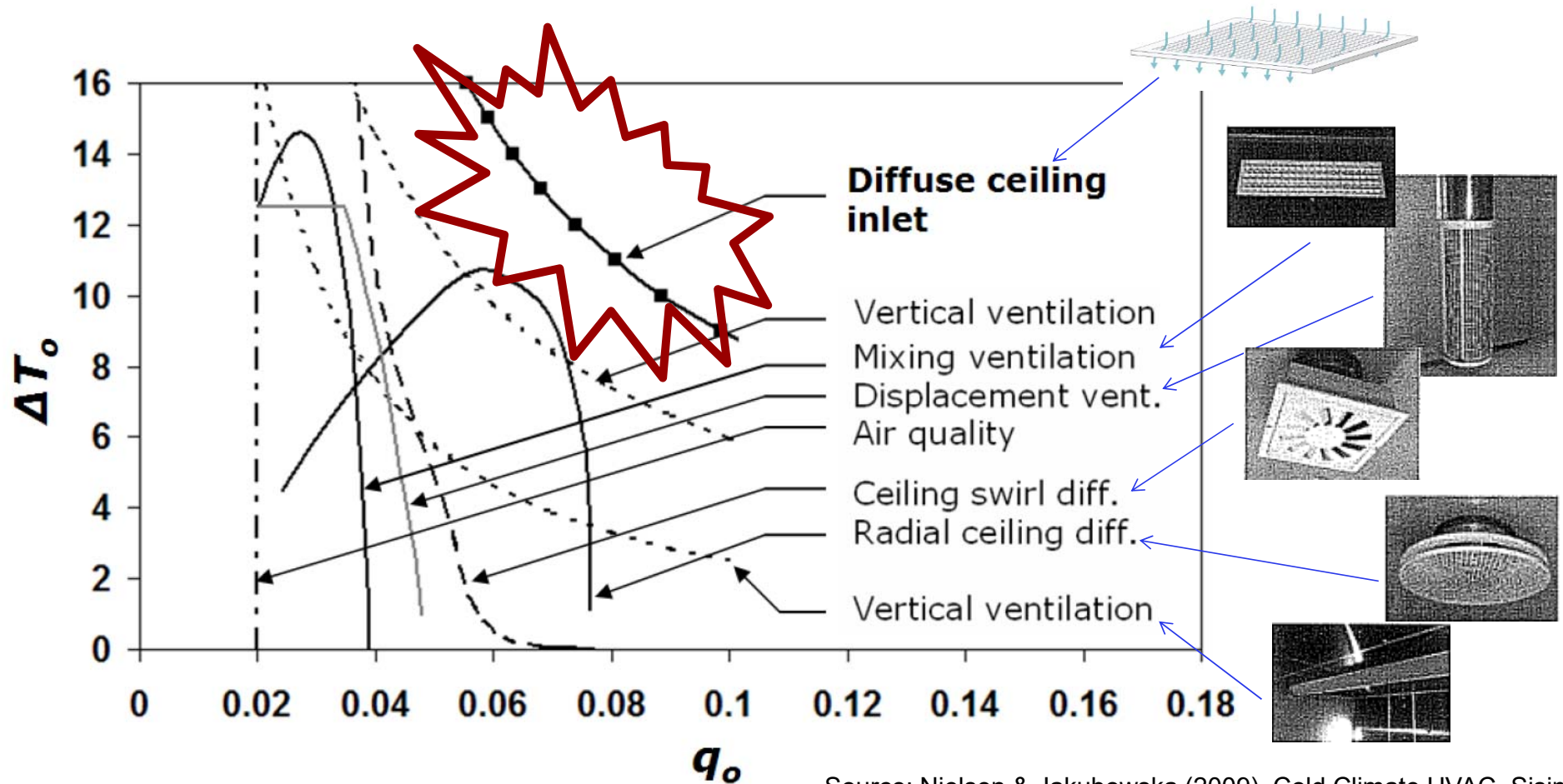
Virkemåde

- Nedhængte akustikloft anvendes til ventilation
- Ventilationsluften indblæses i hulrummet (plenum) over akustikpladerne
- Plenum virker som et trykkammer, som fordeler luften gennem loftet
- Omrøringen skabes vha. de konve lokalet
- Ventilationen skaber ikke sig selv t luftskifte
- Iøvrigt i familie med Underfloor Air



Design Chart



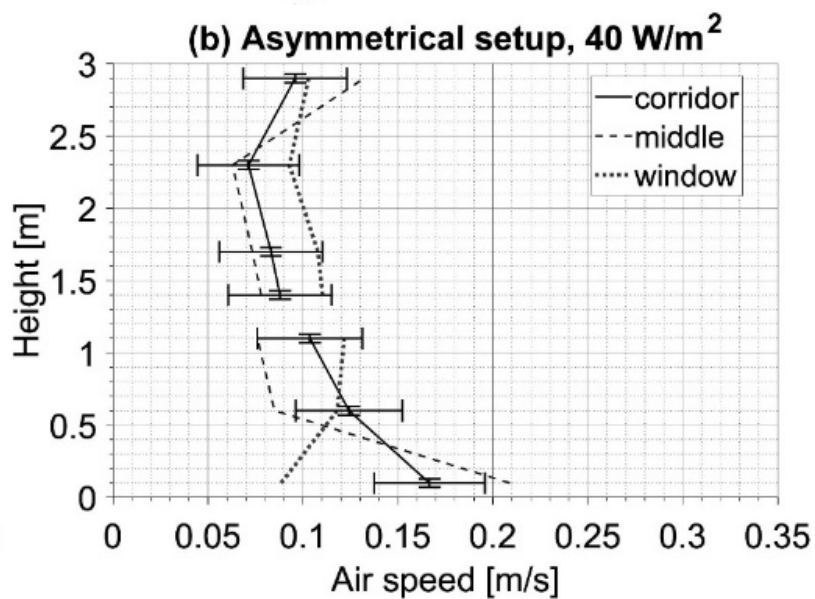
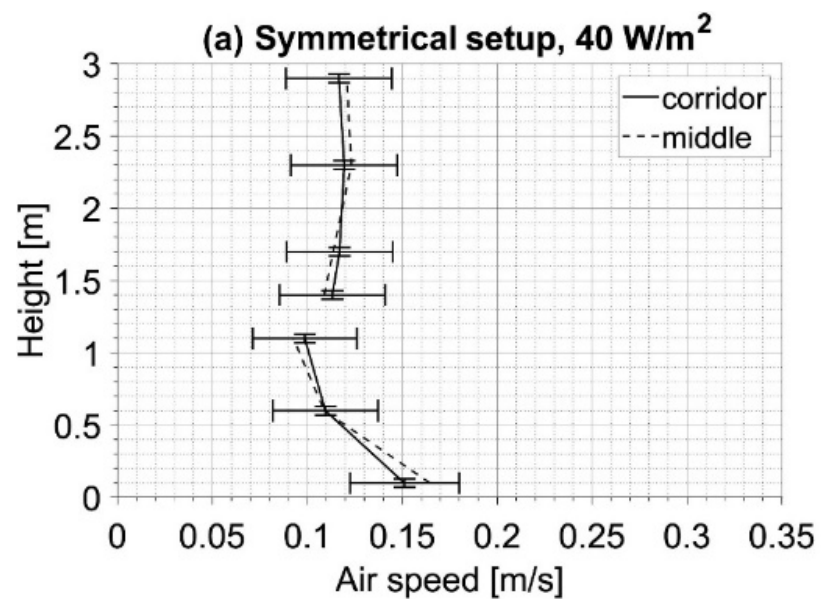
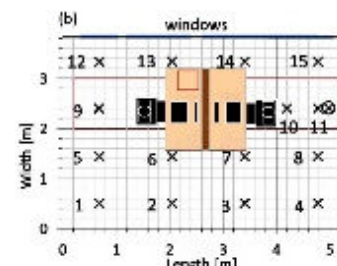
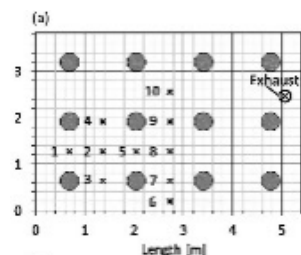


Source: Nielsen & Jakubowska (2009). Cold Climate HVAC, Sisimiut

Lufthastighed

Air speeds

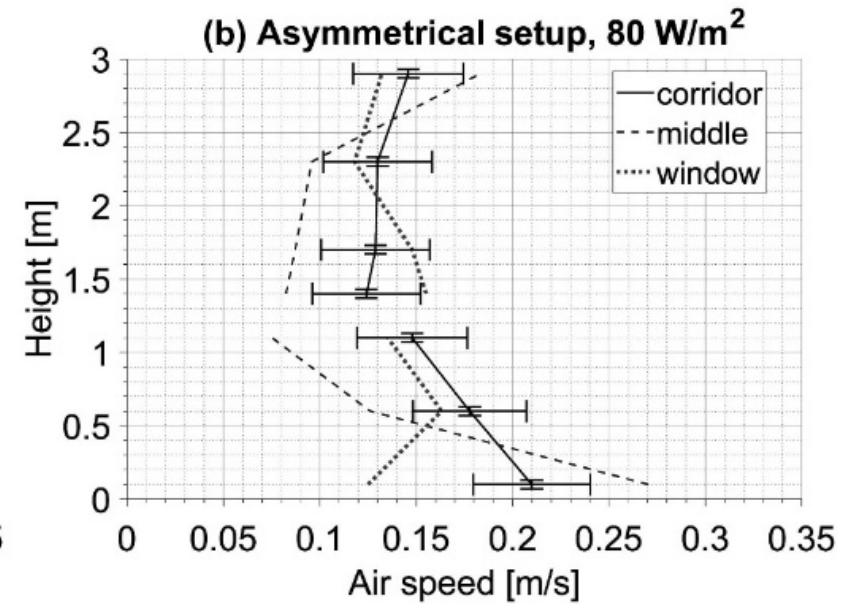
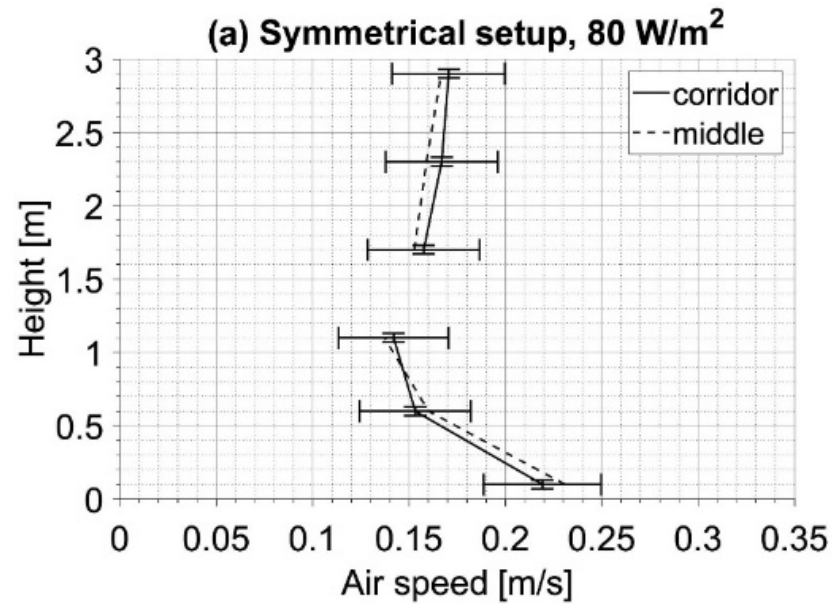
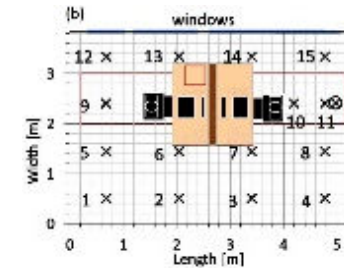
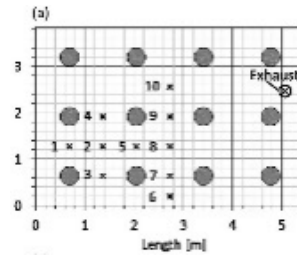
Lab tests



Source: S. Lestinen et al (2019). Building and Environment

Air speeds

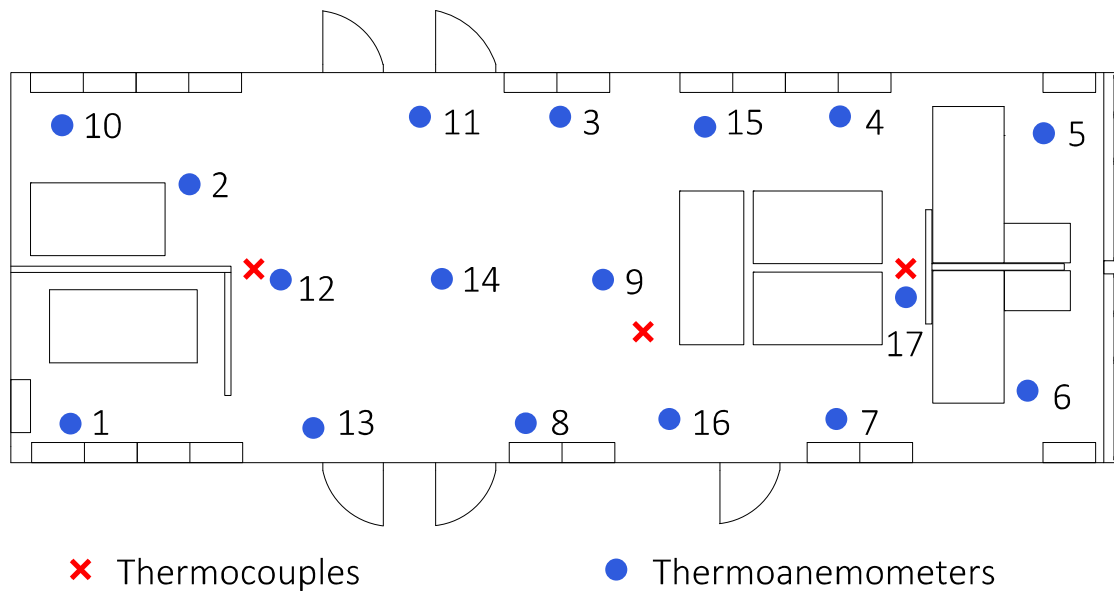
Lab tests



Source: S. Lestinen et al (2019). Building and Environment

Air speeds

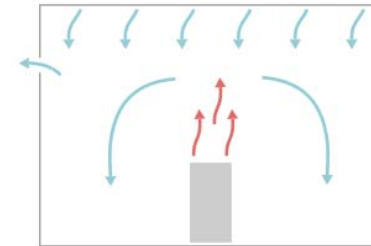
Field test



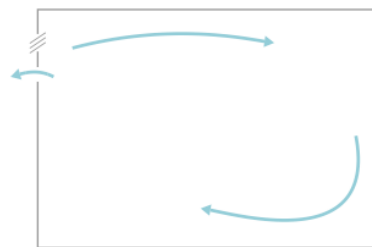
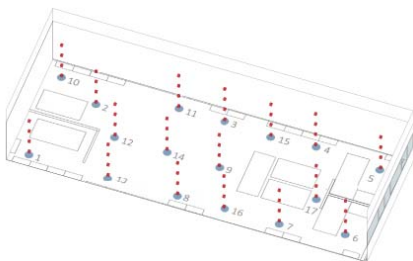
Direct comparison: Mixing vs diffuse

Air change rate 17.9 h⁻¹ from fan coils. Tinlet -6K

Position	Ankel	Lænd	Hoved	Under loft
1	Nej	Ja	Ja	Nej
2	Nej	Nej	Ja	Nej
3	Nej	Nej	Ja	Nej
4	Nej	Nej	Nej	Ja
5	Nej	Ja	Ja	Nej
6	Nej	Ja	Ja	Ja
7	Nej	Nej	Ja	Ja
8	Nej	Nej	Nej	Ja
9	Nej	Nej	Nej	Ja



Position	Ankel	Lænd	Hoved	Under loft
1	Nej	Nej	Nej	Nej
2	Nej	Nej	Nej	Ja
3	Nej	Nej	Nej	Nej
4	Nej	Nej	Nej	Nej
5	Nej	Nej	Nej	Ja
6	Nej	Nej	Nej	Nej
7	Nej	Nej	Nej	Nej
8	Nej	Nej	Nej	Ja
9	Nej	Nej	Nej	Ja
10	Nej	Nej	Nej	Nej
11	Nej	Nej	Nej	Nej
12	Nej	Nej	Nej	Nej
13	Nej	Ja	Nej	Nej
14	Nej	Nej	Nej	Ja
15	Nej	Nej	Nej	Nej
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17	Nej	Nej	Nej	Nej

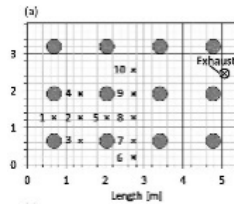


Source: D. Zukowska-Tejsen et al (2016). CLIMA, Aalborg

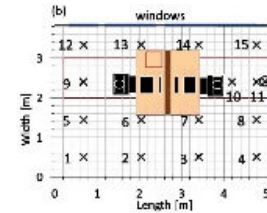
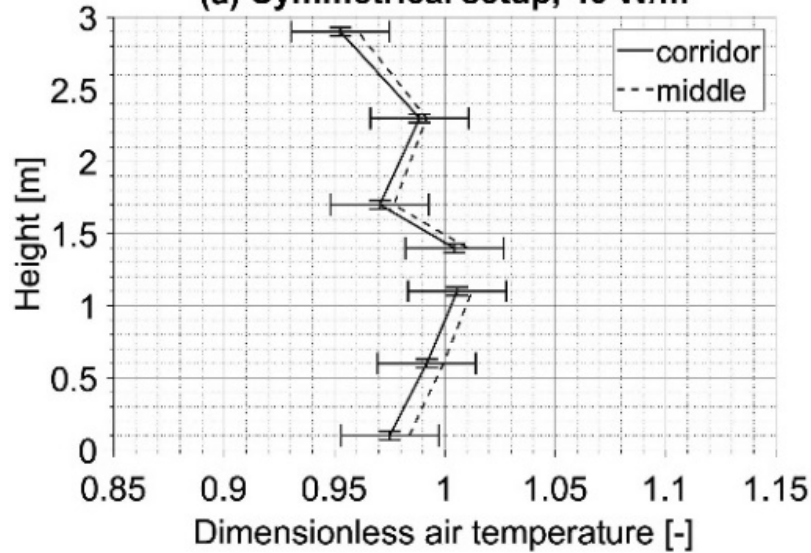
Temperaturgradient

Temperature gradient

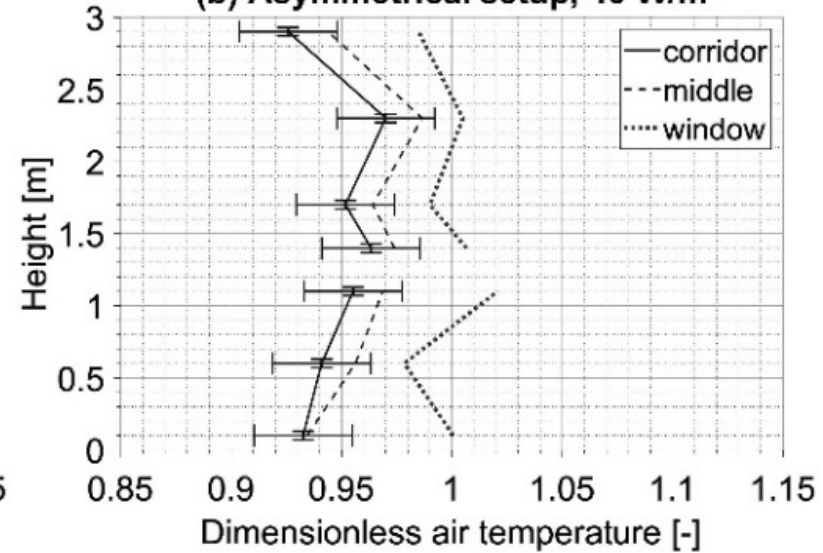
Lab tests



(a) Symmetrical setup, 40 W/m^2



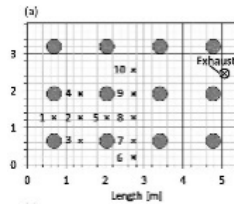
(b) Asymmetrical setup, 40 W/m^2



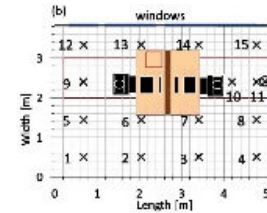
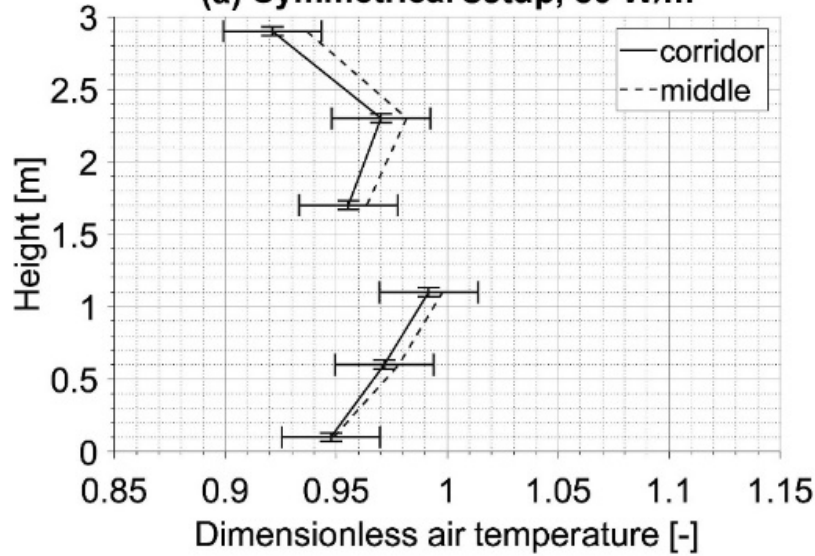
Source: S. Lestinen et al (2019). Building and Environment

Temperature gradient

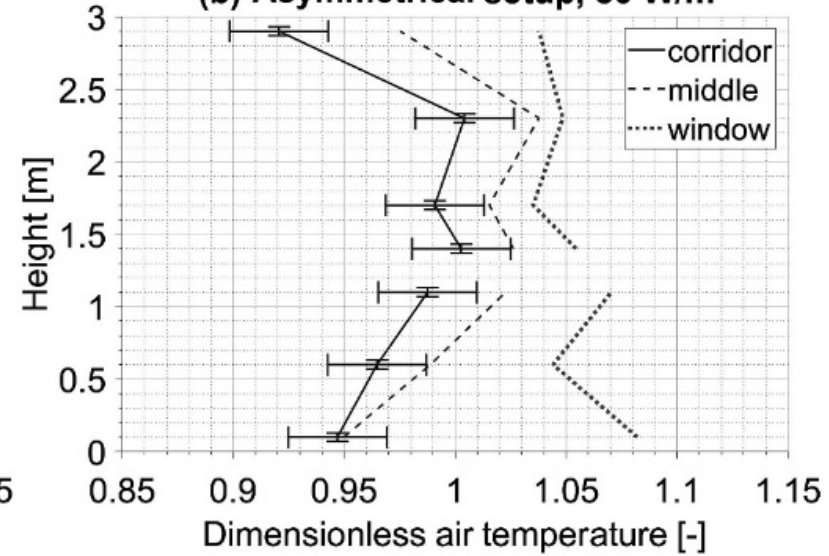
Lab tests



(a) Symmetrical setup, 80 W/m^2



(b) Asymmetrical setup, 80 W/m^2

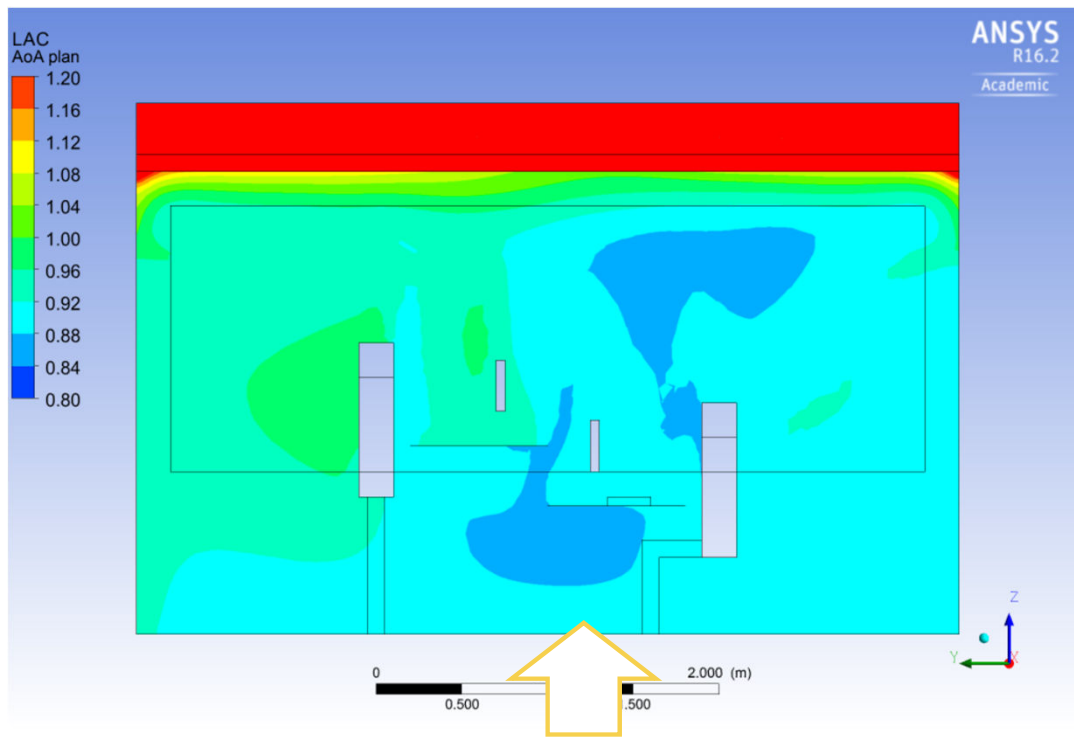


Source: S. Lestinen et al (2019). Building and Environment

Ventilations- effektivitet

Luftudskiftningseffektivitet

CFD study



Small range of values is good

TABLE 6.8: Air change efficiency in the two-person office

	$\Delta T = -4 \text{ K}$	$\Delta T = -8 \text{ K}$	$\Delta T = -12 \text{ K}$
0.5 l/s/m ²	47.65 %	48.66 %	49.54 %
1 l/s/m ²	49.29 %	50.80 %	50.22 %
2 l/s/m ²	51.22 %	50.16 %	46.74 %
4 l/s/m ²	49.11 %	49.55 %	50.18 %
8 l/s/m ²	52.37 %	50.01 %	50.76 %

50% is perfect mixing

Source: Hykkelbjerg (2016). M.Sc. DTU

Luftudskiftningseffektivitet

Forskellige scenarier

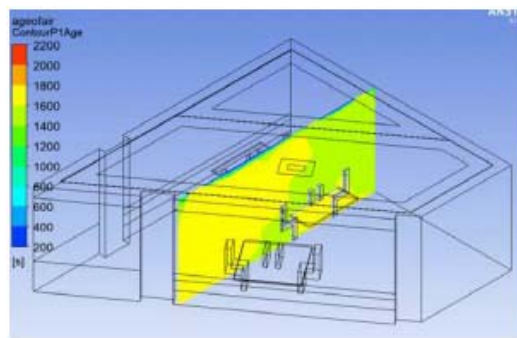


FIG 17. Age of air, scenario 1

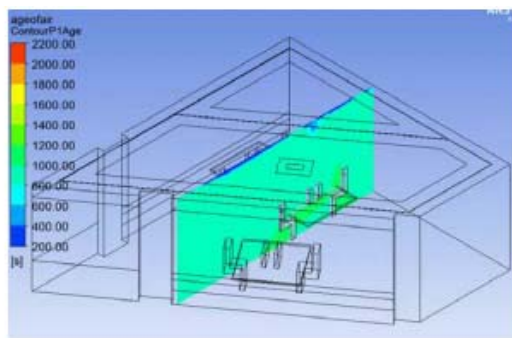


FIG 18. Age of air, scenario 4

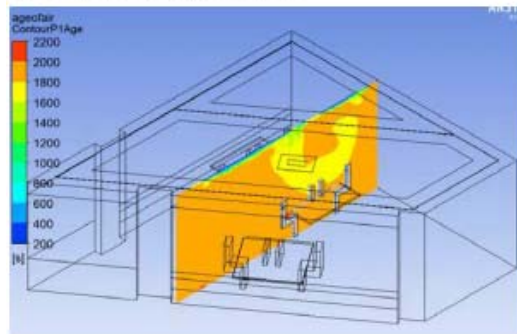


FIG 19. Age of air, scenario 2

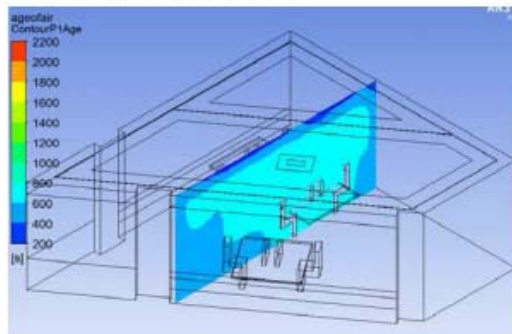
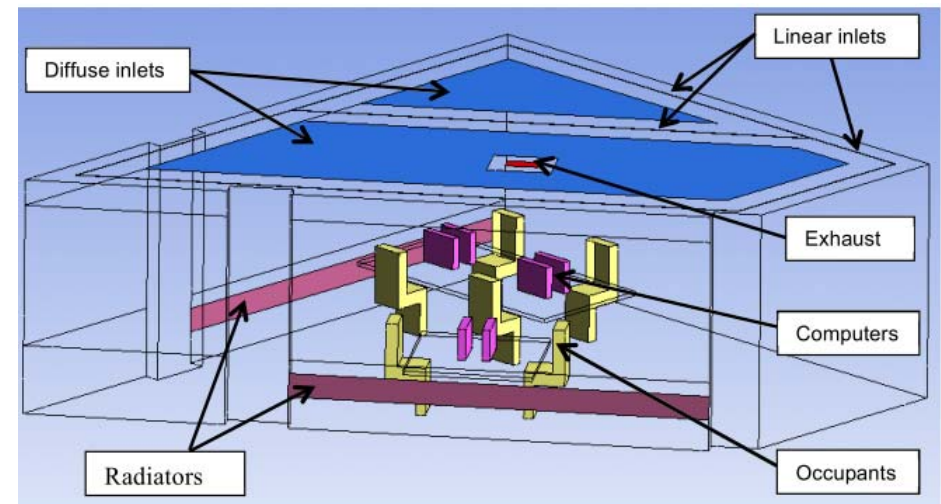


FIG 20. Age of air, scenario 5



Source: Hviid & Petersen (2014), NSB, Lund

Luftudskiftningseffektivitet

Forskellige scenarier

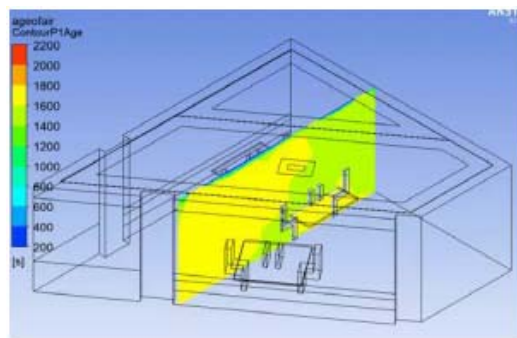


FIG 17. Age of air, scen

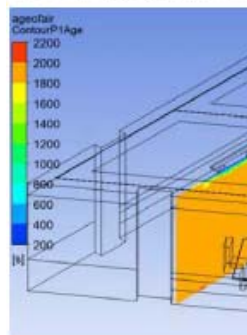
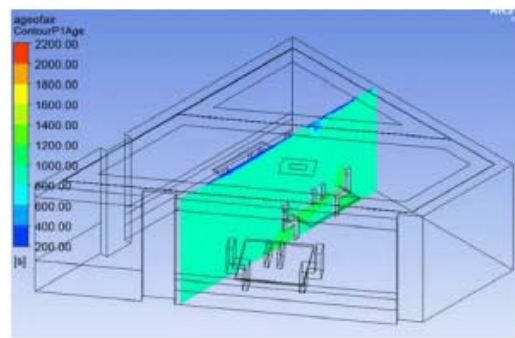


FIG 19. Age of air, scen

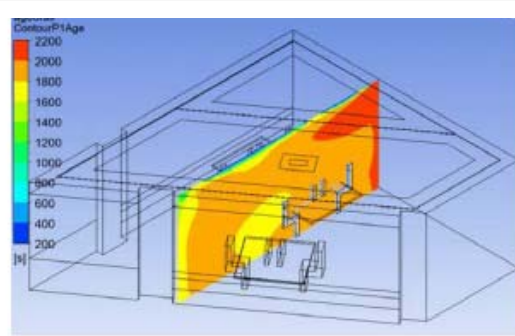
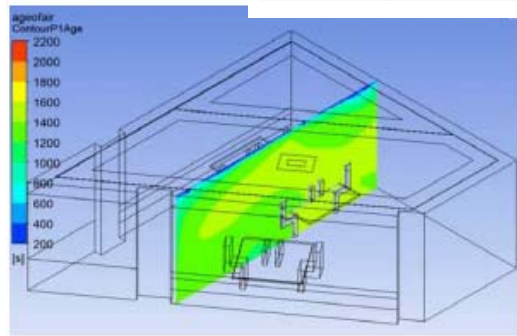


TABLE 2. Comparison of simulated air change efficiency with perfect mixing

Scen.	Description	Perfect mixing	CFD-results @ outlet	Deviation
1	Winter day, normal operation	1800 s	1640	-9 %
2	Winter morning, pre-conditioning	1800 s	1793	0 %
3	Winter morning, air-heating	1200 s	1220	2 %
4	Summer day, cooling by low supply air temp.	900 s	901	0 %
5	Summer day, cooling by high flow rate	600 s	576	-4 %
6	Summer night ventilation	1800 s	1755	-3 %

Linear inlets

Exhaust

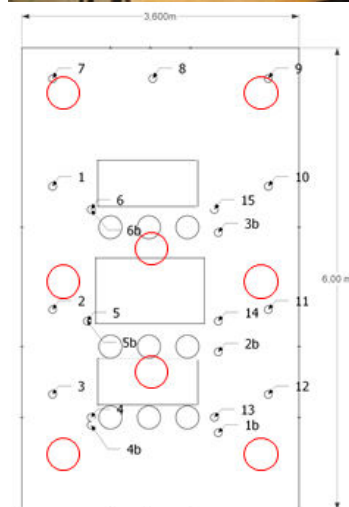
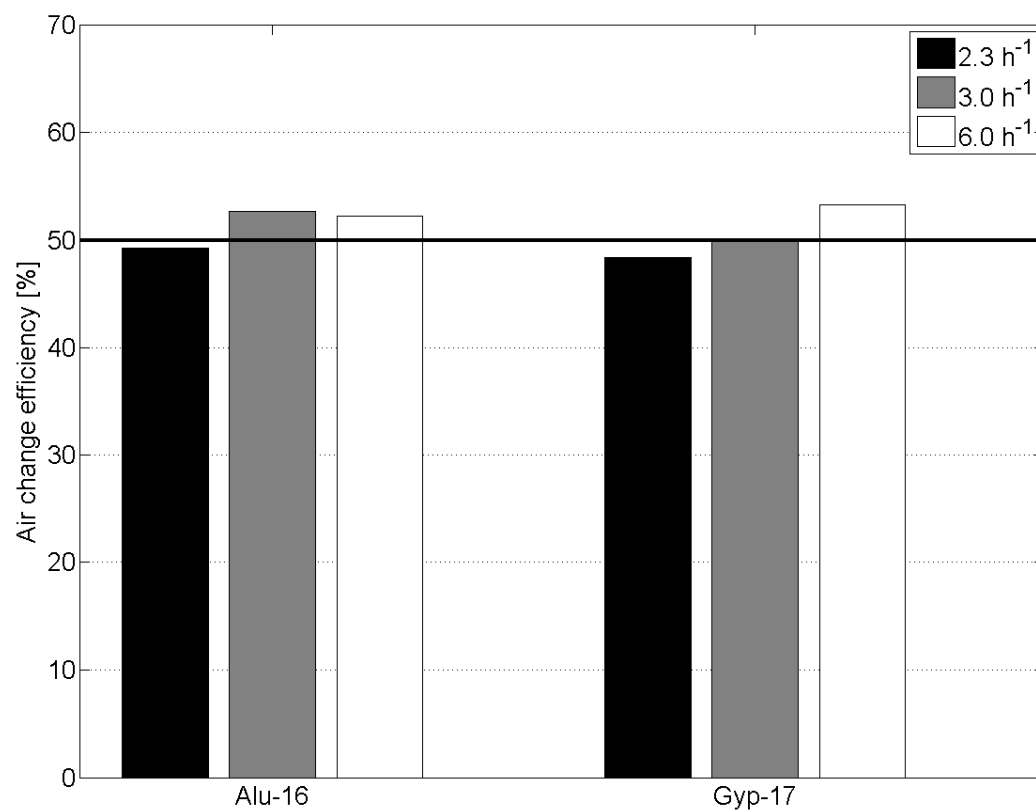
computers

ccupants

Source: Hviid & Petersen (2014), NSB, Lund

Ventilation efficiency

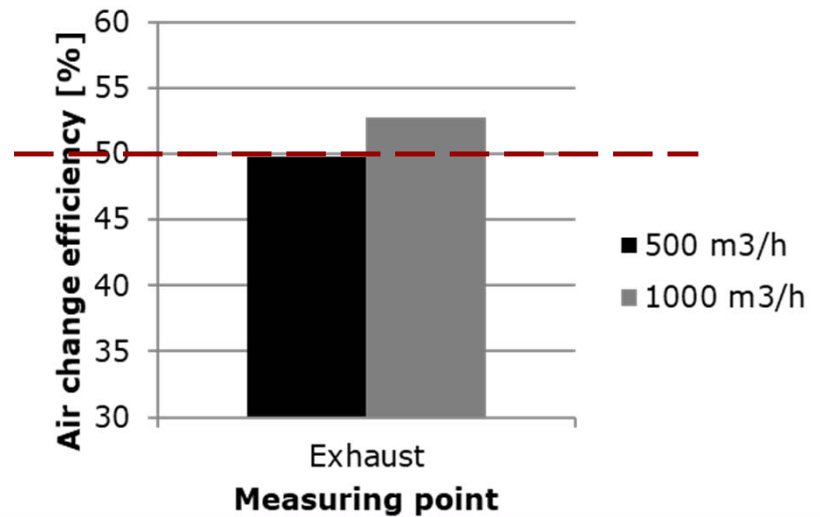
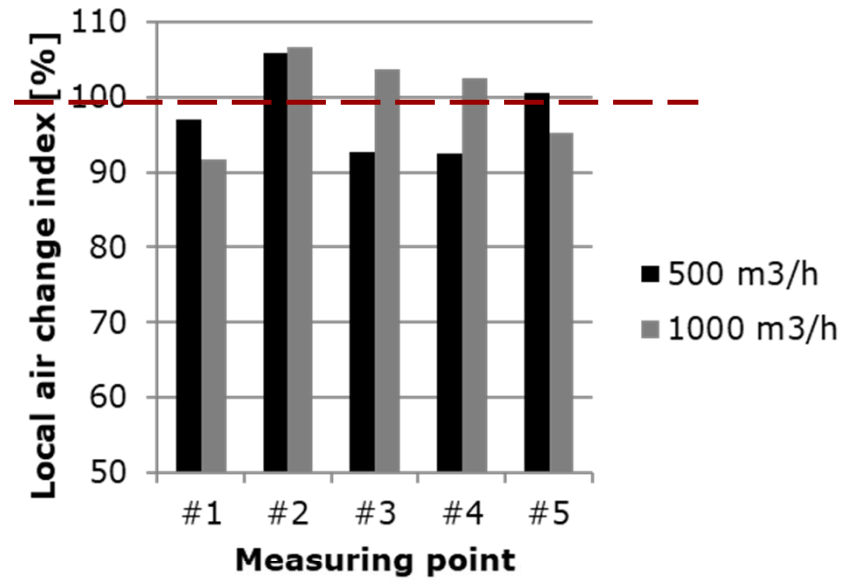
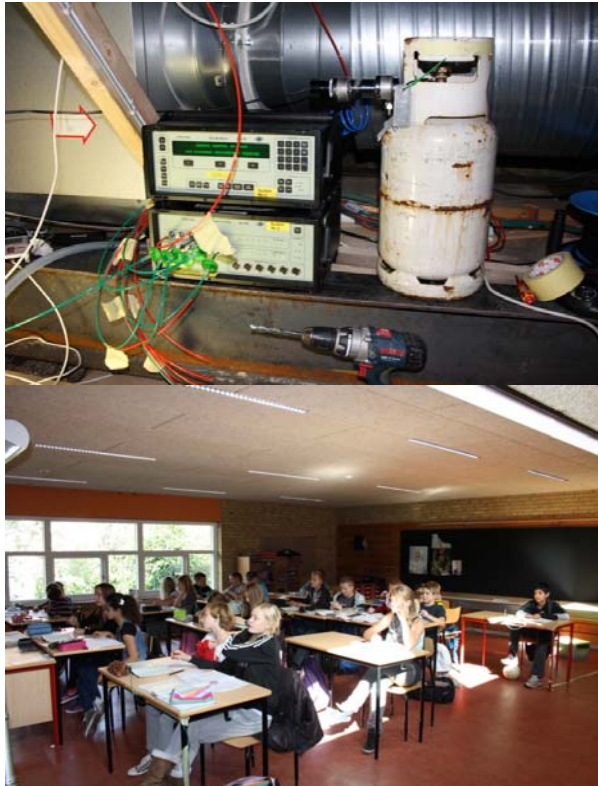
Lab test



Source: Hviid & Svendsen (2013). Energy and Buildings

Ventilation efficiency

Field test



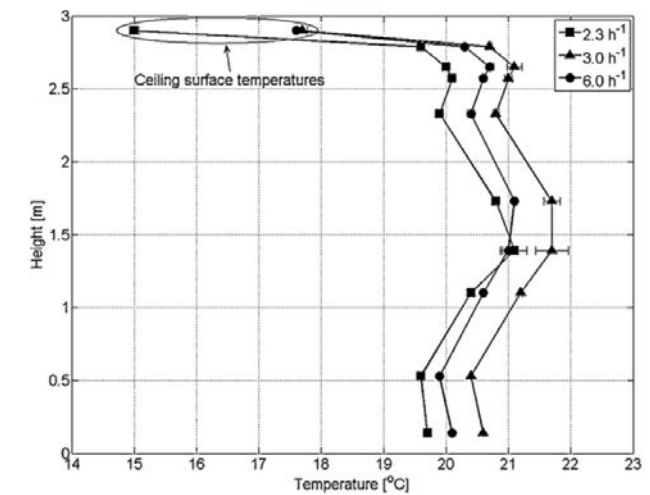
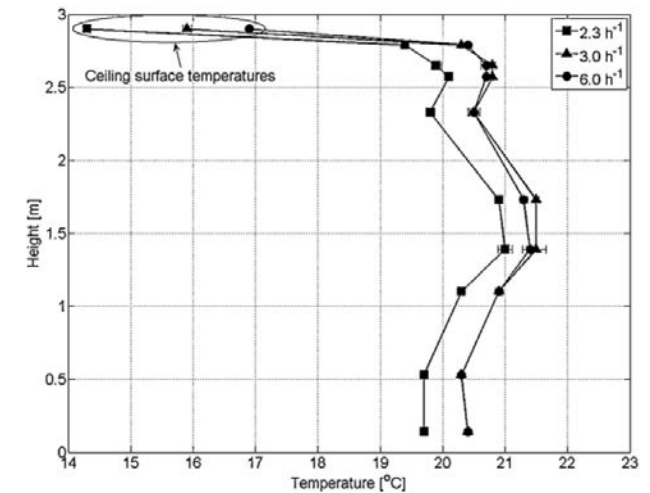
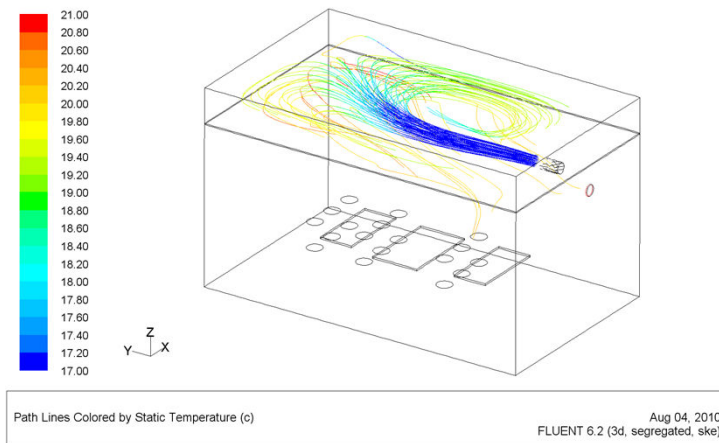
Source: Hviid & Terkildsen (2012). AIVC, Copenhagen

Kølekapacitet

Forvarmning i plenum

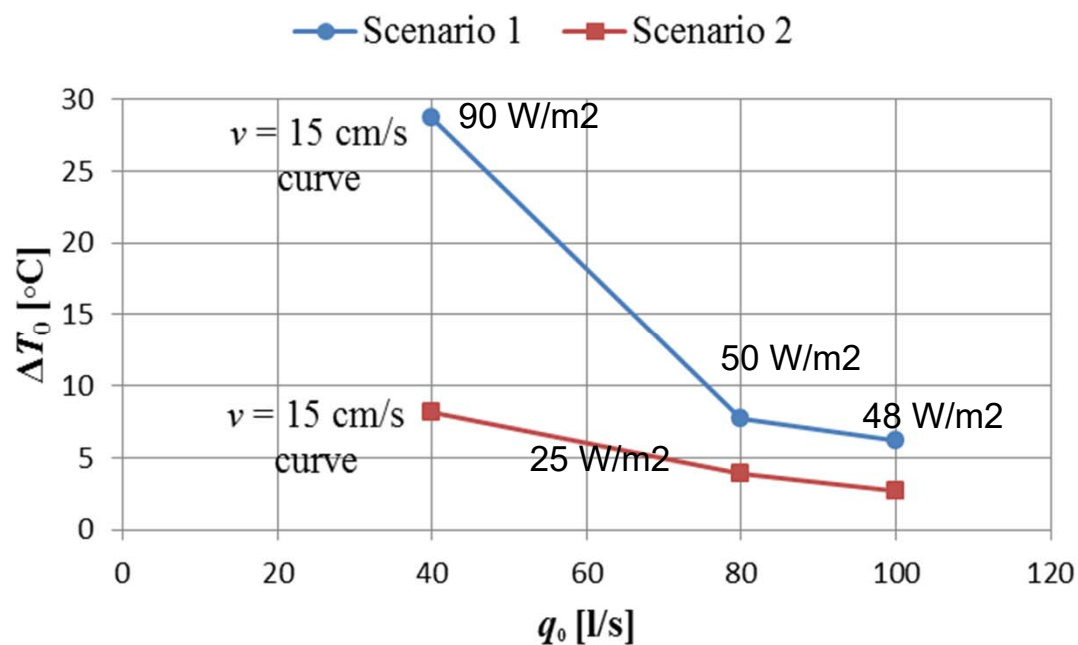
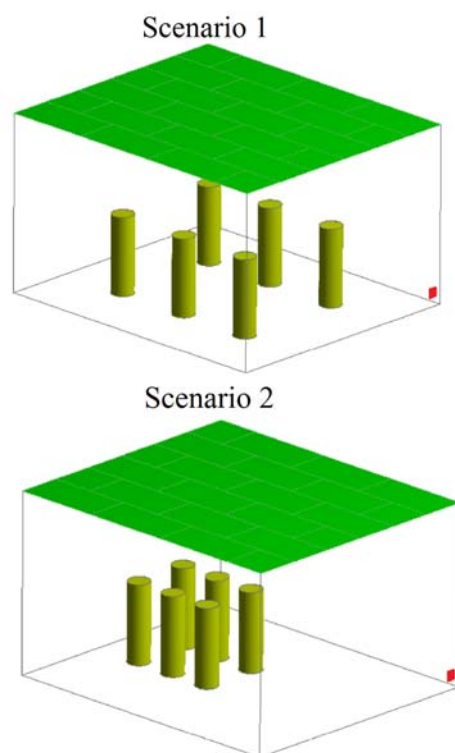
- Loftet afkøles oppefra - virker delvist som strålekøleloft

Luftskifte	T_{ind}	T_{beton}	$T_{loft,op}$	$T_{loft,ned}$
3.0h-1	3.2	14.4	14.0	17.7
6.0h-1	11.2	15.3	12.4	17.6



Source: Hviid & Svendsen (2013), Energy and Buildings

Kølekapacitet



Source: Rahnama, S., et al (2019). Evaluating the cooling capacity of diffuse ceiling ventilation system - Full-scale experimental study, CLIMA

Præstationer

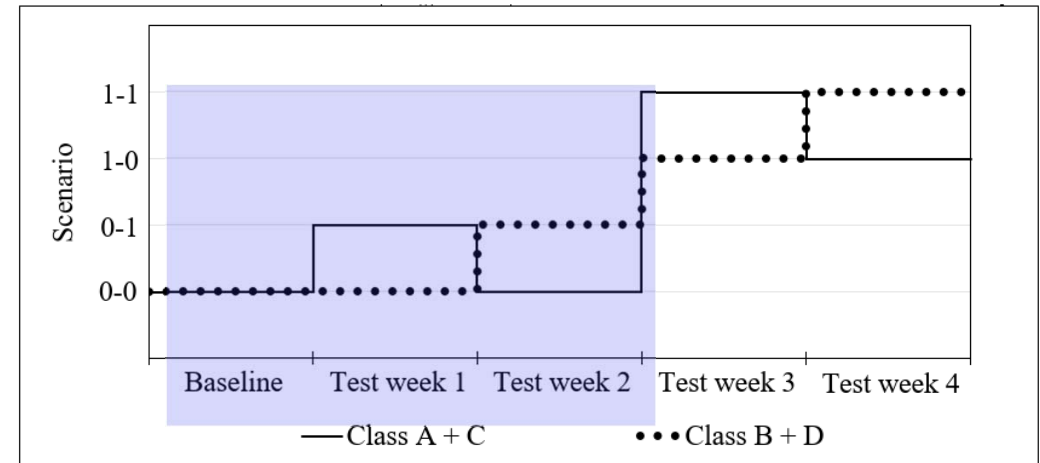
Byens skole – cognitive performance test

The effect of lighting and ventilation on cognitive performance



Four classes, 92 pupils, 24 tests

Combined ventilation rate and dynamic lightning level in cross-over test design.


$$\begin{array}{r} 690 \\ - 303 \\ \hline \end{array}$$

8 · 63

$$\begin{array}{r} 66 \\ - 33 \\ \hline \end{array}$$

The triangle is smaller than the circle



True False

[illegible]

Opmærksomhed

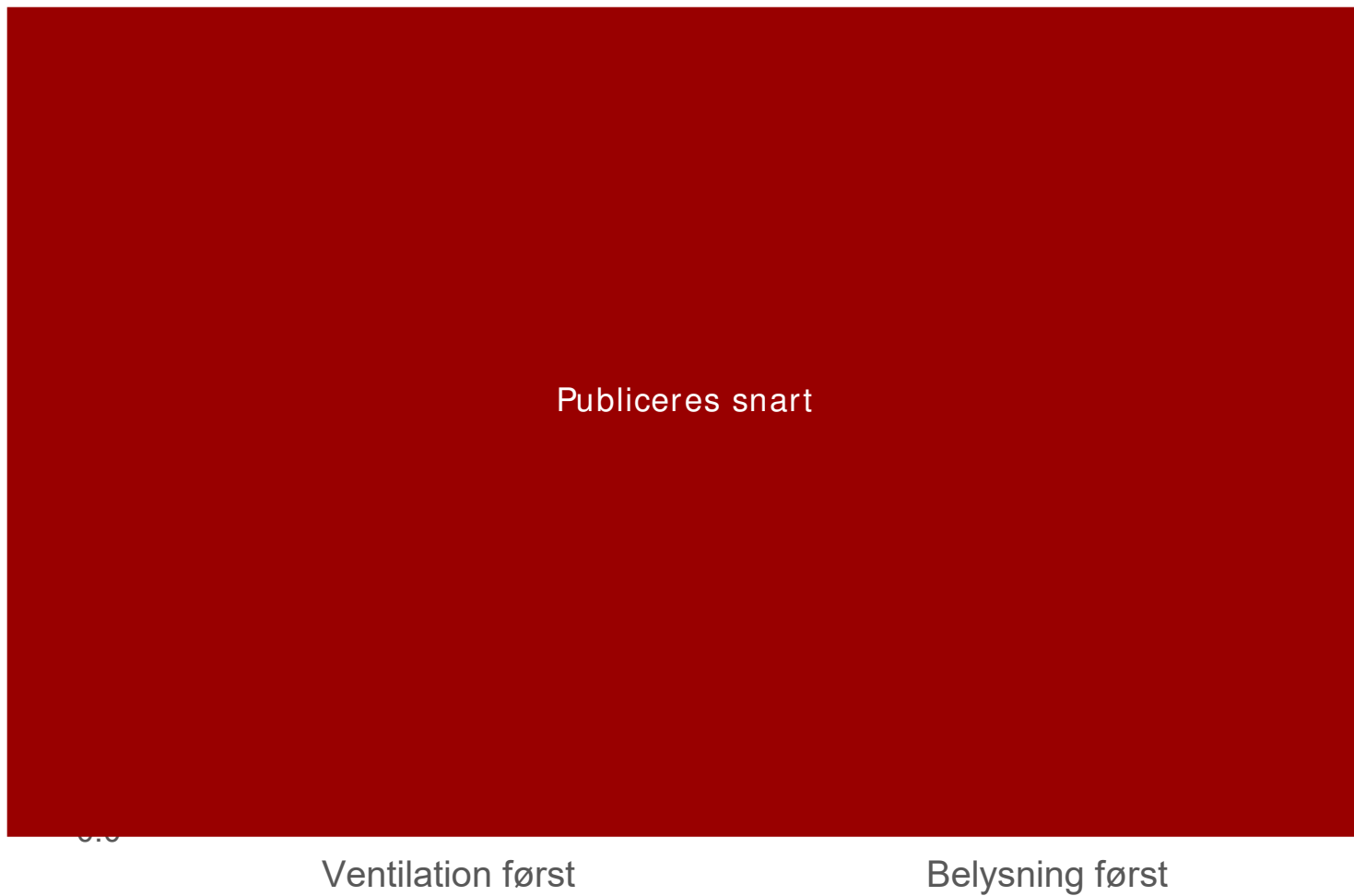
Publiceres snart

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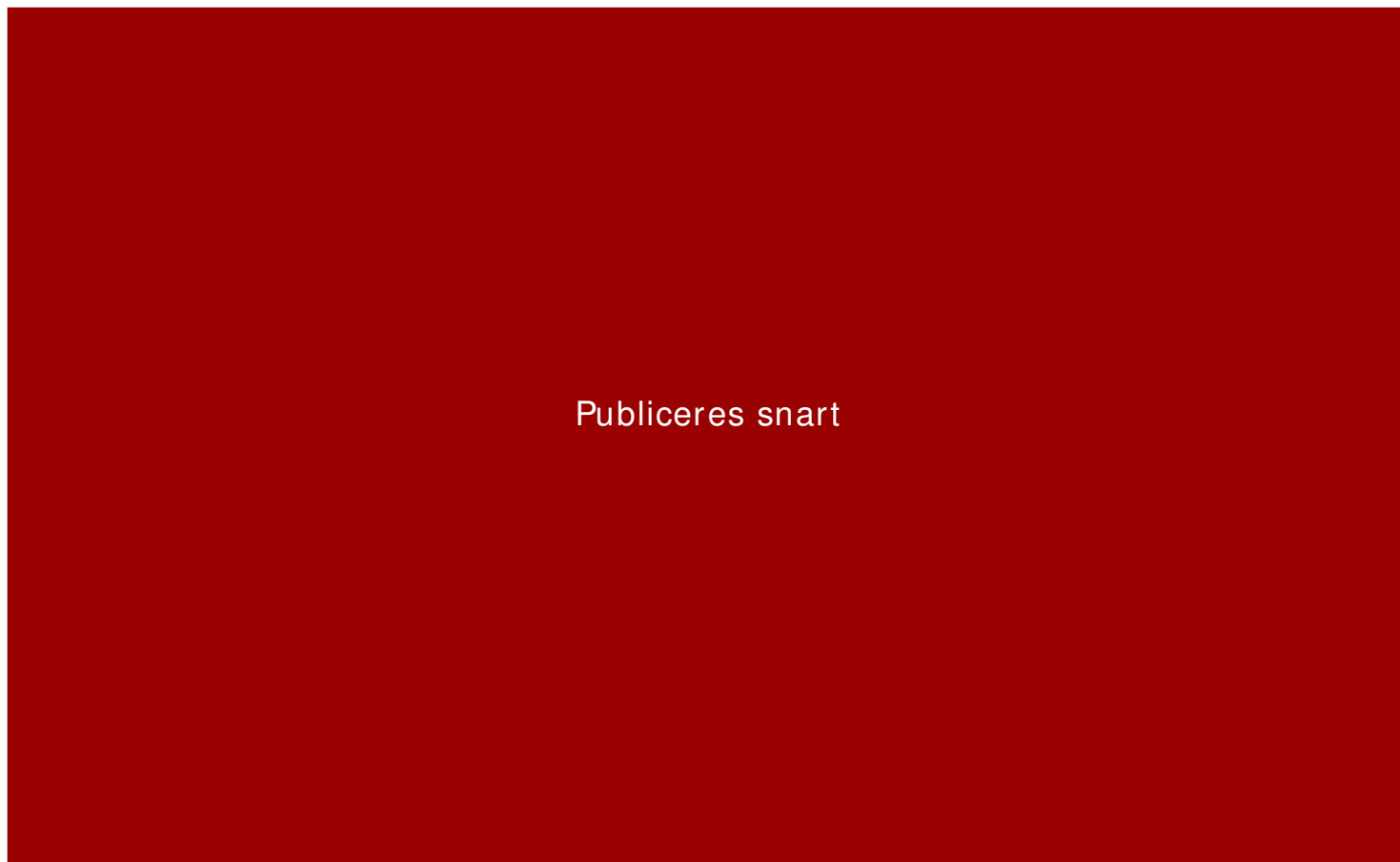
Ventilation først

Belysning først

Koncentration



Subtraktion/multiplikation



Publiceres snart

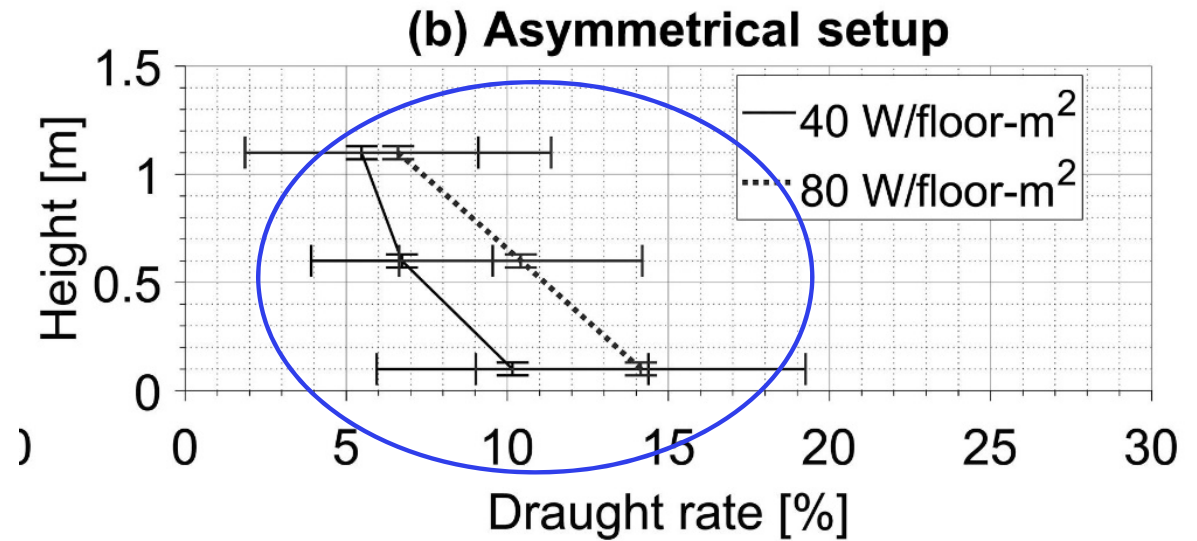
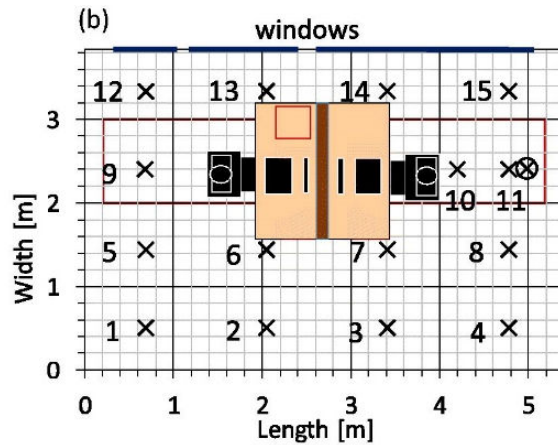
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Ventilation først

Belysning først

Opsummering

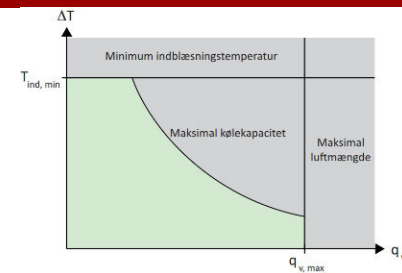
Slides to remember



Source: S. Lestinen et al
(2019)

Opsummering

Slides to remember



Intern design guide AereNmore

DTU

