PASSIV KLIMATISERING

NATURLIG/HYBRID ELLER MEKANISK VENTILATION

– JA TAKK, BEGGE DELE!

PER HEISELBERG
DEPARTMENT OF CIVIL ENGINEERING

AALBORG UNIVERSITY
DENMARK

NATURLIG KLIMATISERING ?

REDUKTION AF ENERGIFORBRUG TIL OPVARMNING

- Høste og udnytte solstråling
- Tilstrækkelig isolering og lufttæthed
- Varmeakkumulering og frigivelse (solvarme, overskudsvarme)

REDUKTION AF ENERGIFORBRUG TIL VENTILATION

- Vinduesudluftning
- Naturlig ventilation (evt. med varmegenvinding/forvarmning)

REDUKTION AF ENERGIFORBRUG TIL KØLING (OVERTEMPERATUR)

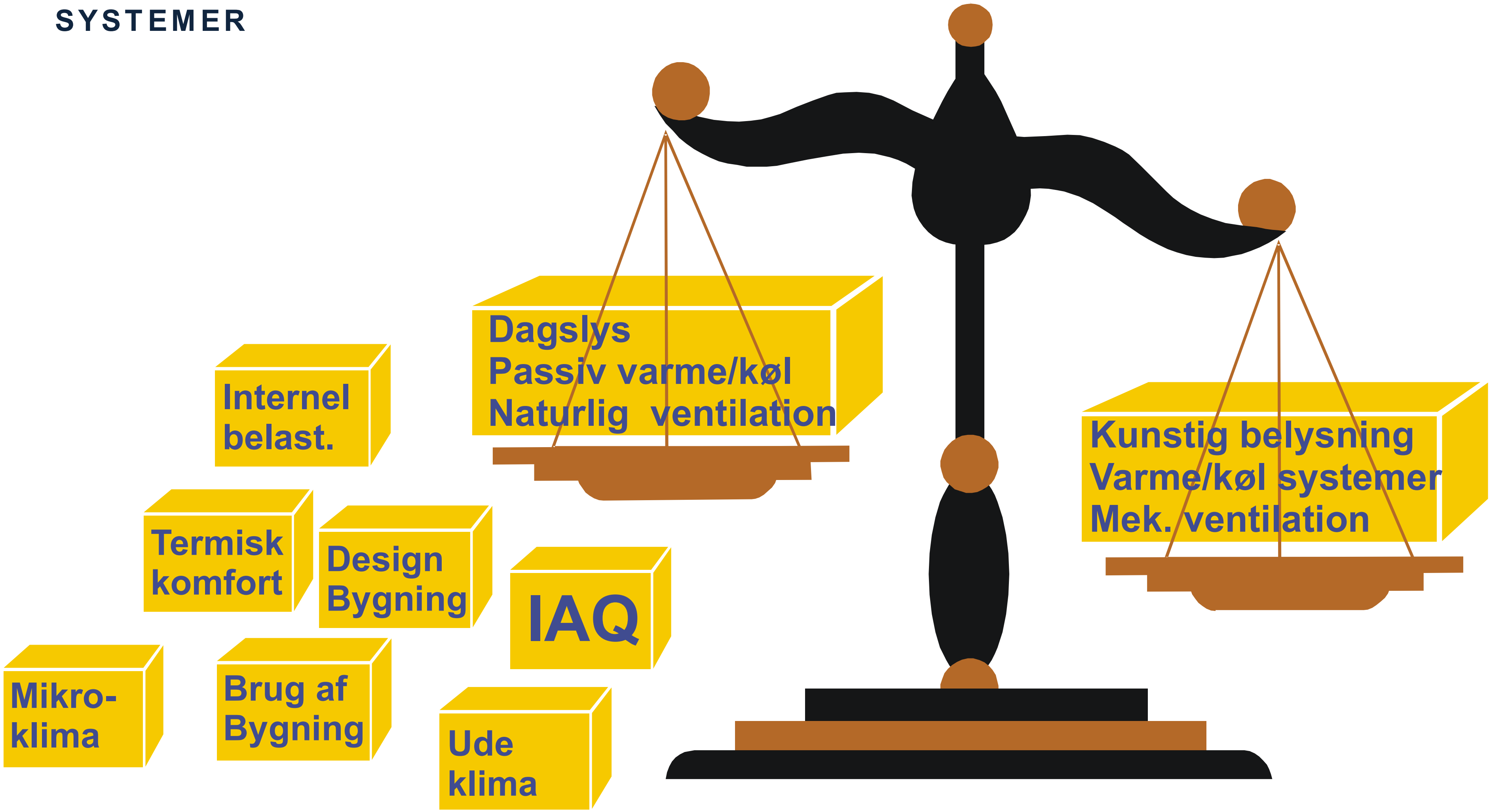
- Solafskærmning
- Vinduesudluftning og naturlig ventilation (”frikøling” med udeluft)
- Nattekøling med udnyttelse af termisk masse

REDUKTION AF ENERGIFORBRUG TIL BELYSNING

- Forbedret indtrængning og udnyttelse af dagslys
- Integration af solafskærmnings/dagslyssystemer

KLIMATISERING AF BYGNINGER

BALANCE OG INTEGRATION MELLEM PASSIVE OG MEKANISKE SYSTEMER



Building Facades

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BYGNINGS (GLAS) FACADERS FUNKTIONER

KONTROLLERER OG OPTIMERER ENERGITRANSPORTEN MELLEM BYGNING OG OMGIVELSER

KONTROLLERER OG OPTIMERER UDVEKSLING AF LUFT MELLEM BYGNING OG OMGIVELSER

KONTROLLERER OG OPTIMERER DAGSLYS OG SOLINDFALD

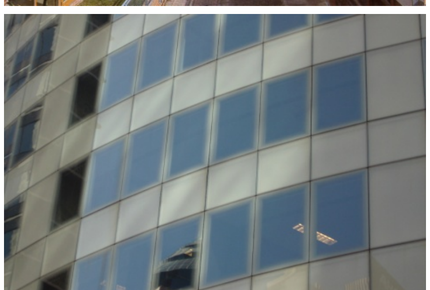
KONTROLLERER OG OPTIMERER ENERGILAGRING OG/ELLER UDJÆVNER VARMEBELASTNINGER I FACADE OG BYGNING

BYGNINGS (GLAS) FACADERS FUNKTIONER

INKLUDERER I FORHOLD TIL INDEKLIMA OG ENERGIFORHOLD:

- Begrænse varmetabet fra bygningen til det fri
- Begrænse infiltration og exfiltration mod det fri
- Udnytte solvarme, passivt og aktivt
- Beskytte mod solindfald, som vil resultere i kølebehov i bygningen
- Udnytte dagslys og regulere til aktuelt behov
- Tillade udsyn til omgivelserne
- Beskytte mod blænding, store kontraster og refleksioner i blanke overflader
- Bidrage til (naturlig) ventilation, manuelt eller automatisk reguleret
- Beskytte mod støj udefra

FACADENS FUNKTIONER



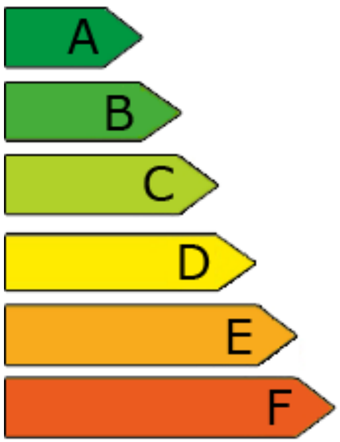
ER MODSÆTNINGSFYLDTE

- Dagslys – solafskærmning – udsyn
- Vinduesåbning – lydisolation
- Glasareal – varmebehov/kølebehov

MEDFØRER AT FACADEN IKKE KAN "DIMENSIONERES" MEN MÅ DESIGNES UD FRA EN OPTIMERINGSSTRATEGI

- Definition af vigtigste funktioner og funktionskrav
- Vægtning af funktionskrav efter aktuelle prioriteringer
- Vurdering af samspil med bygningens øvrige systemer (installationer og anlæg).

GLASFADADENS VARMEBALANCE, E_{REF}



www.eref.dk/

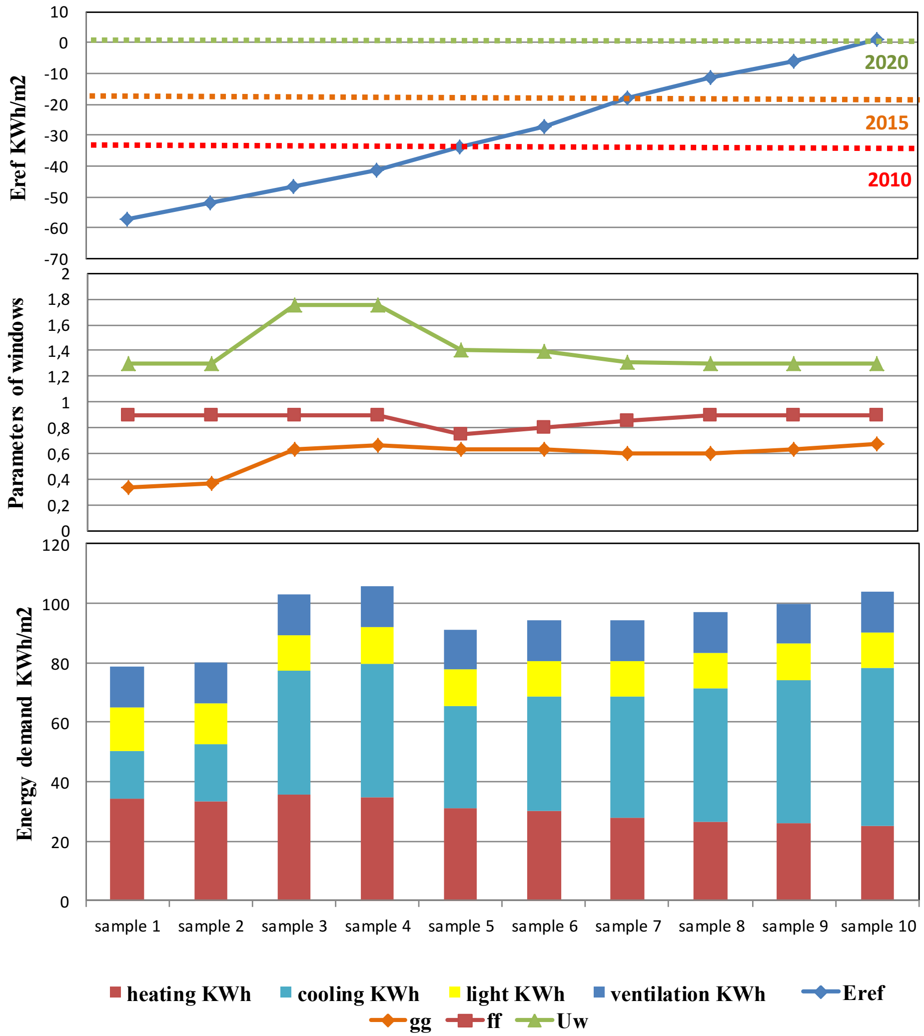
$$E_{ref} = 196{,}4 \cdot g_g \cdot f_f - 90{,}36 \cdot U_W \ [kWh/m^2]$$

2015: -17 kWh/m^2

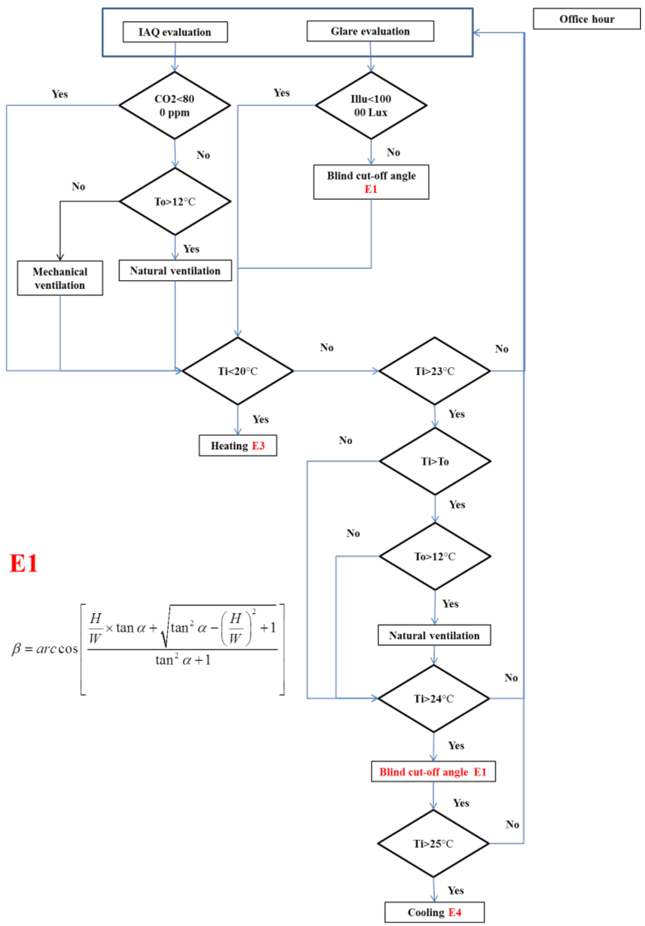
2020: 0 kWh/m^2

www.sophienberg.com

VINDUETS ENERGIBALANCE E$_{REF}$



DYNAMIC FACADE
CONTROL STRATEGY- OCCUPIED HOURS



E1

$$\beta = arc\cos\left[\frac{\frac{H}{W}\times\tan\alpha+\sqrt{\tan^2\alpha-\left(\frac{H}{W}\right)^2+1}}{\tan^2\alpha+1}\right]$$

Natural ventilation/CO2, T_o>12°C

Blind cut-off/glare

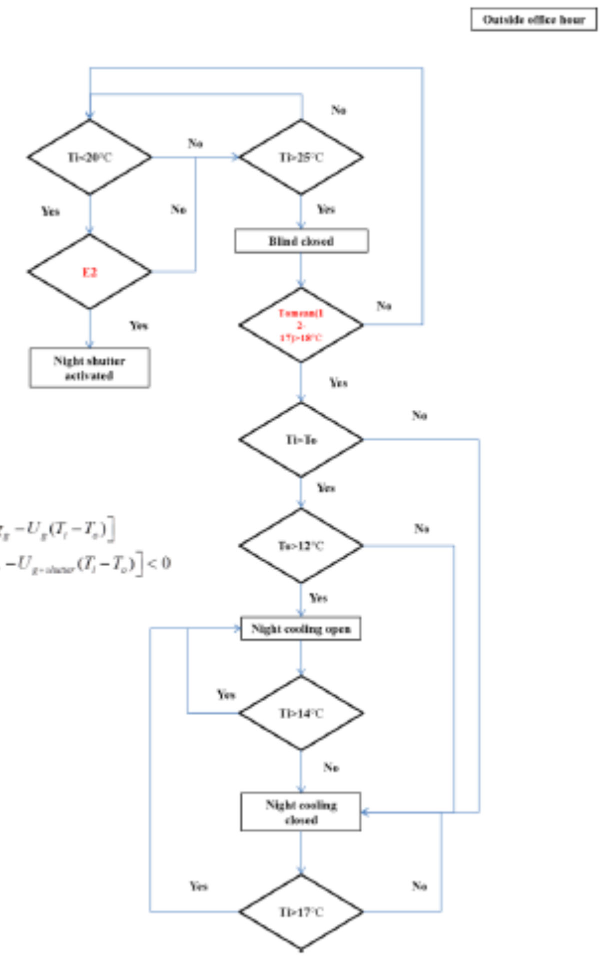
Natural ventilation/>23°C

Blind closed/>24°C

Heating/<20°C **Cooling/>25°C**

Source:: Liu, Wittchen & Heiselberg Applied Energy 2015

DYNAMIC FACADE
CONTROL STRATEGY- OUTSIDE OCCUPIED HOURS



E2

$$\phi_{facade} = \left[\phi_{sol} g_g - U_g (T_i - T_o)\right] - \left[\phi_{sol} g_{g+shutter} - U_{g+shutter}(T_i - T_o)\right] < 0$$

Night Shutter/<20°C

Blind Closed/>25°C

Night Cooling Open/T_o>18°C (12-17)

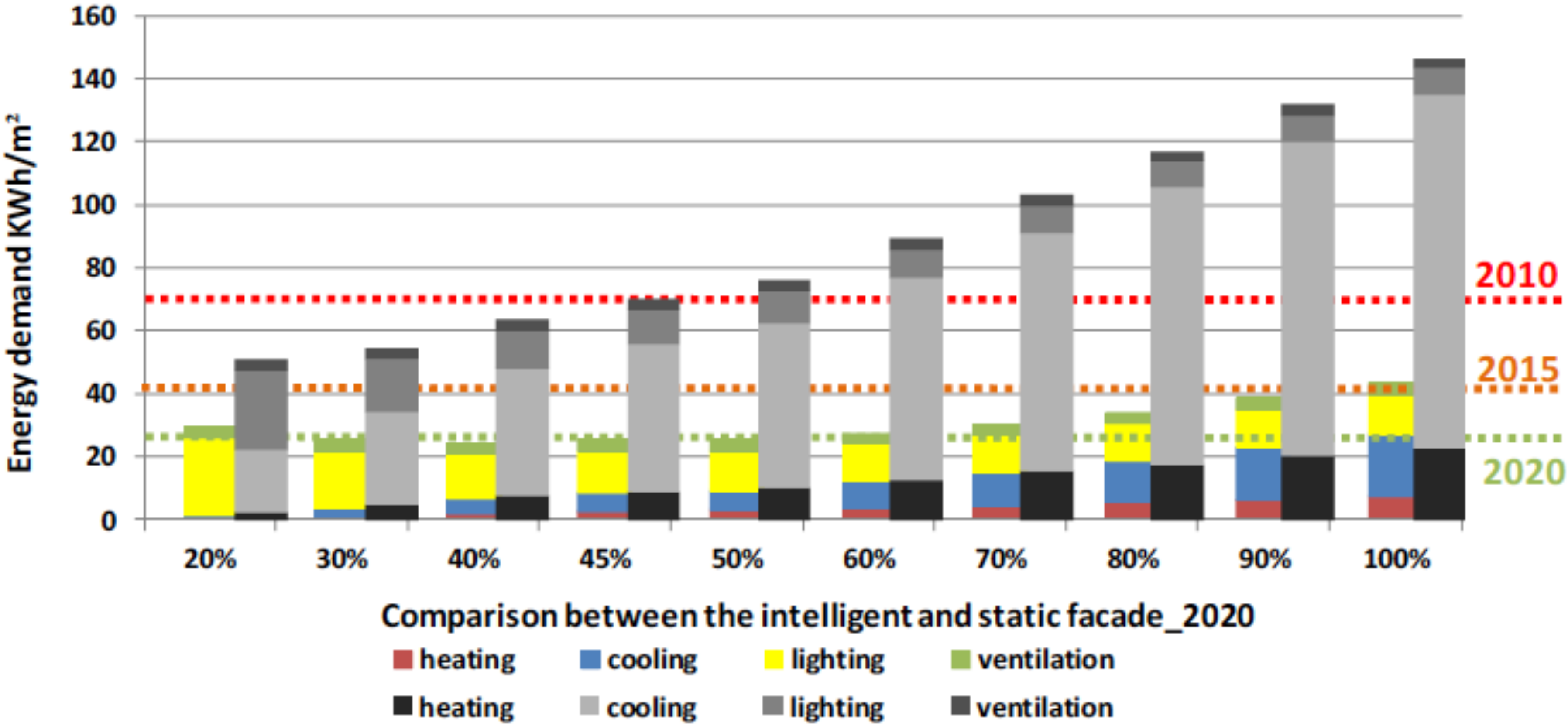
Night Cooling closed/<17°C

Heating/<20°C

Cooling/>25°C

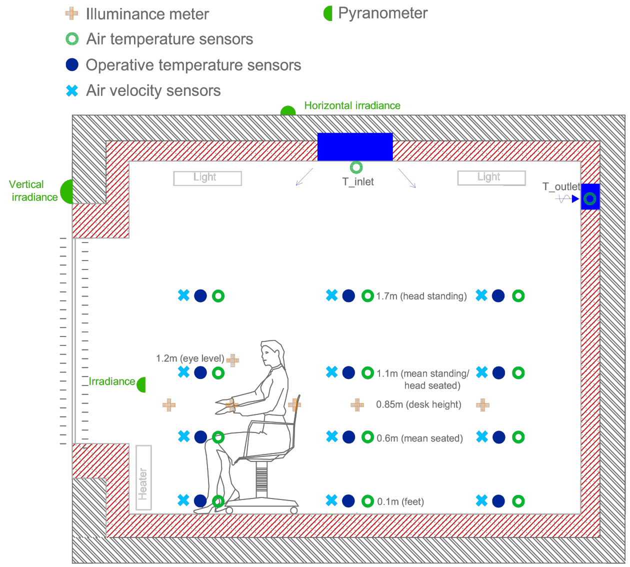
Source:: Liu, Wittchen & Heiselberg Applied Energy 2015

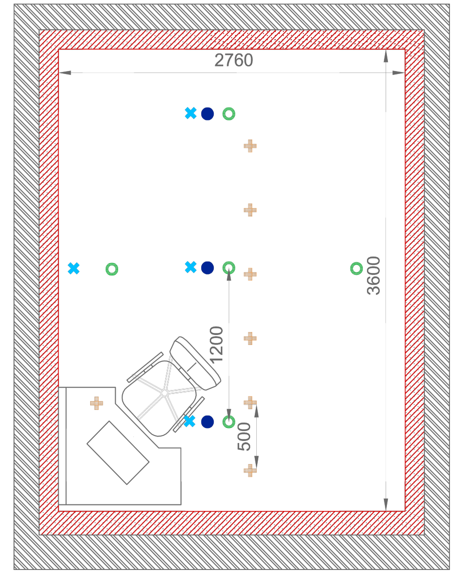
SAMMENLIGNING AF ENERGIFORBRUG FOR STATISK OG DYNAMISK FAÇADE VED FORSKELLIGE GLASPROCENTER

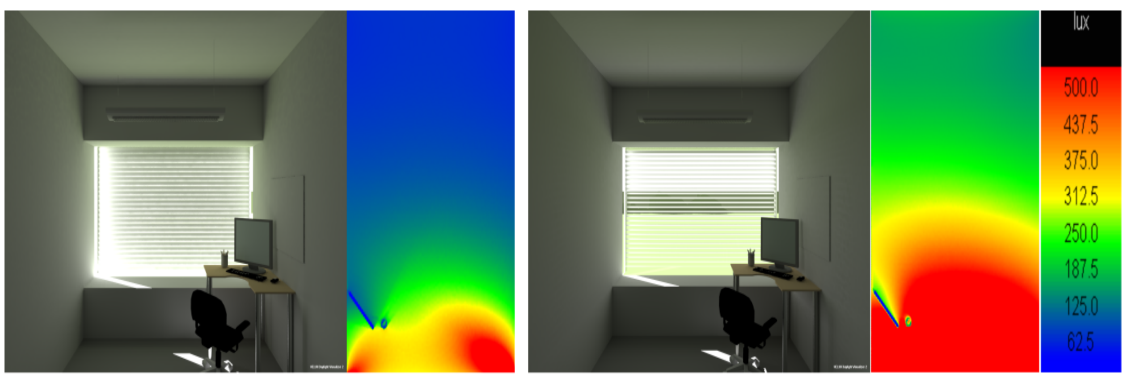


Source:: Liu, Wittchen & Heiselberg
Applied Energy 2015

BRUGERAFPRØVNING AF STYRINGSSTRATEGI FOR BLÆNDING



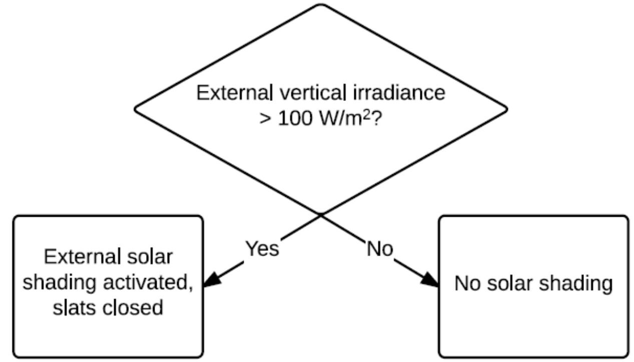




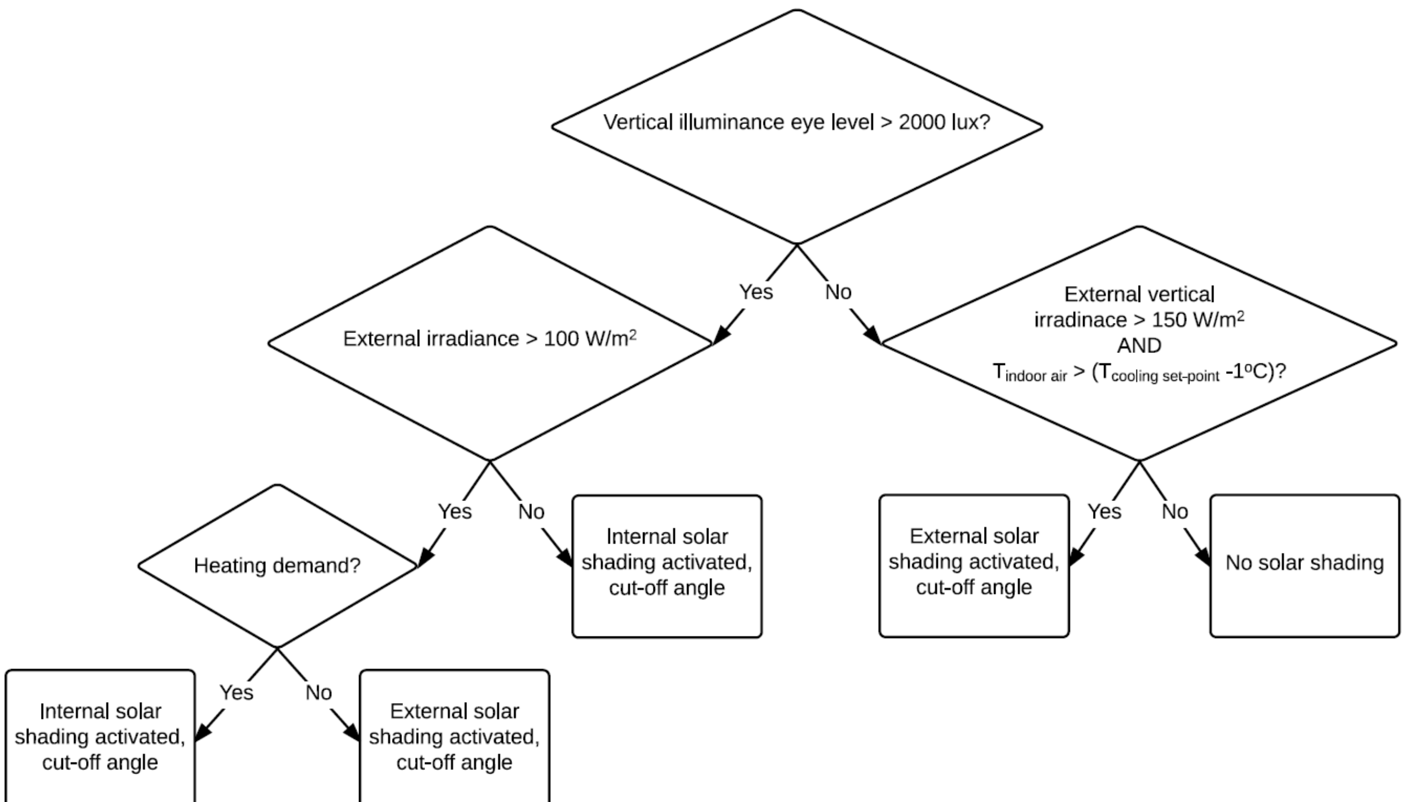
Source:: Karlsen, Heiselberg & Bryn
Solar Energy 2015

STYRINGS-STRATEGI

Simple solar shading control strategy:

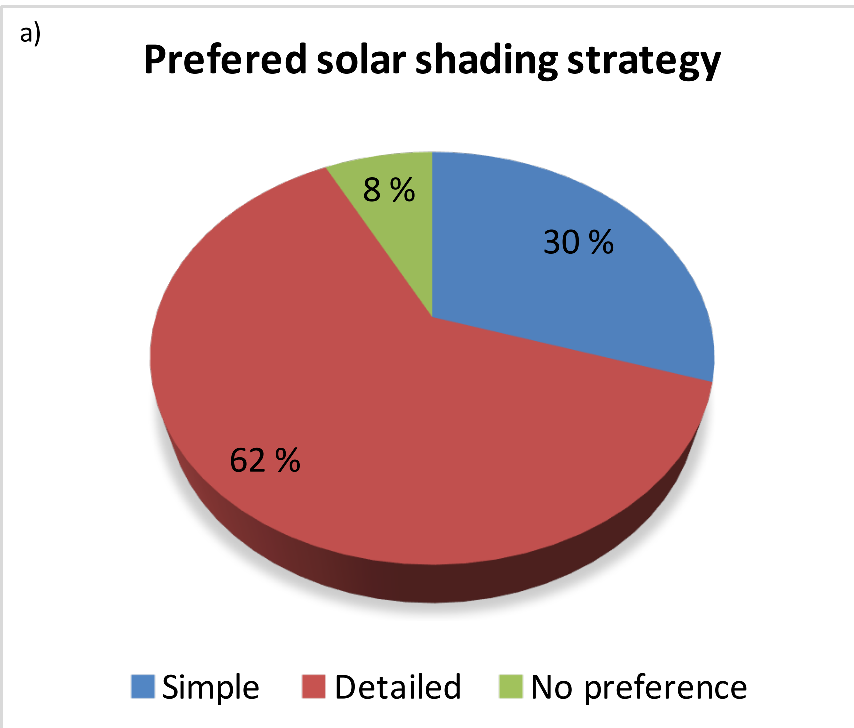


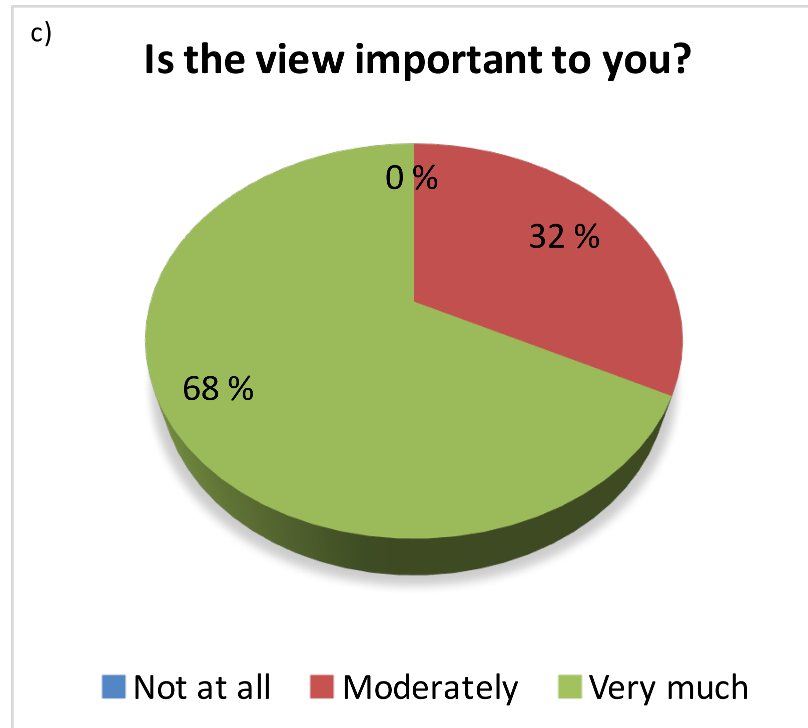
Detailed solar shading control strategy:



Source:: Karlsen, Heiselberg & Bryn
Solar Energy 2015

OCCUPANT SATISFACTION WITH TWO BLIND CONTROL STRATEGIES: SLATS CLOSED AND SLATS IN CUT-OFF POSITION

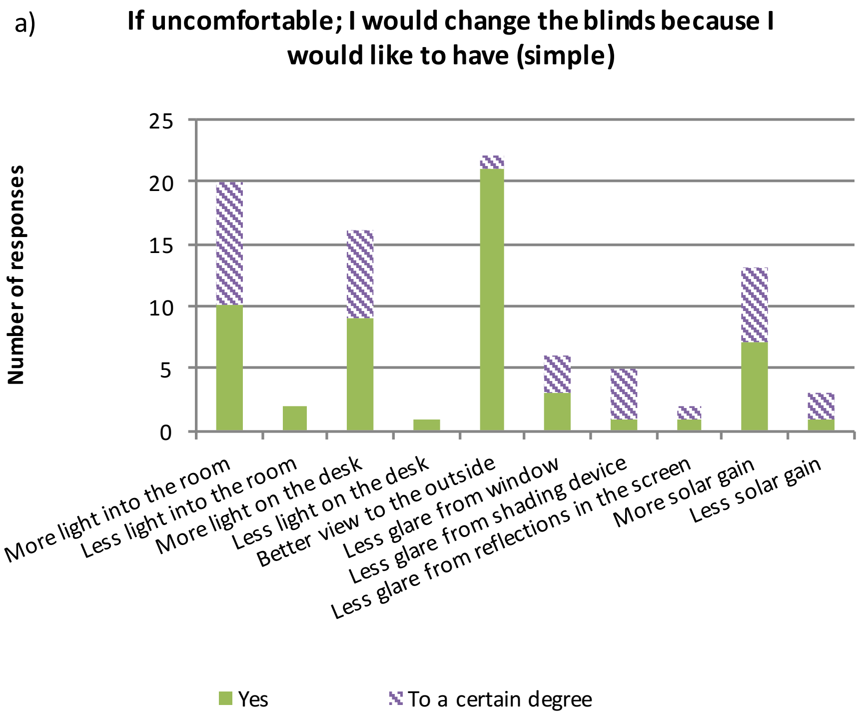




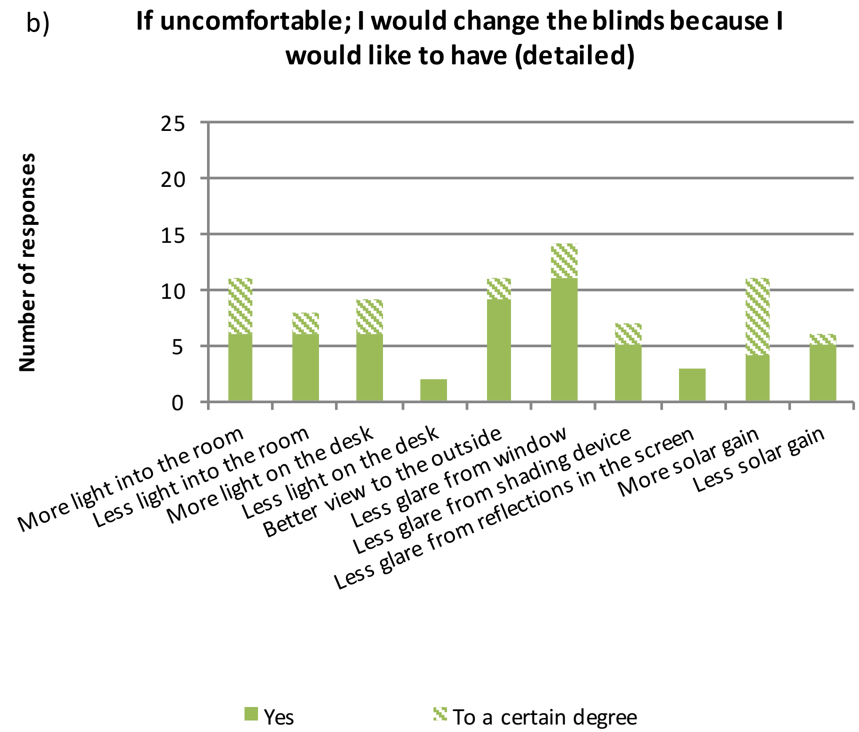
Source:: Karlsen, Heiselberg & Bryn
Solar Energy 2015

OCCUPANT SATISFACTION WITH TWO BLIND CONTROL STRATEGIES: SLATS CLOSED AND SLATS IN CUT-OFF POSITION

a)



b)



Source:: Karlsen, Heiselberg & Bryn
Solar Energy 2015

SUMMARY

IN NZEB OFFICES WITH HIGH INSULATION AND AIR TIGHTNESS LEVELS:

- The need for cooling is increasing and more efficient systems have to be developed to fulfill future energy requirements
- There will always be a cooling need during occupied hours even in the winter season
- Application of the free cooling potential of outdoor air is widely used in mechanical ventilation systems, but high air flow rates are needed also in winter because of draught risk leading to relatively high energy use for Air transport

POTENTIAL SOLUTIONS

- Increased use of natural/hybrid ventilation for cooling
- Distribution of cold air to rooms without creating discomfort
- Effective decentralized ventilation solutions

Energy use for ventilation

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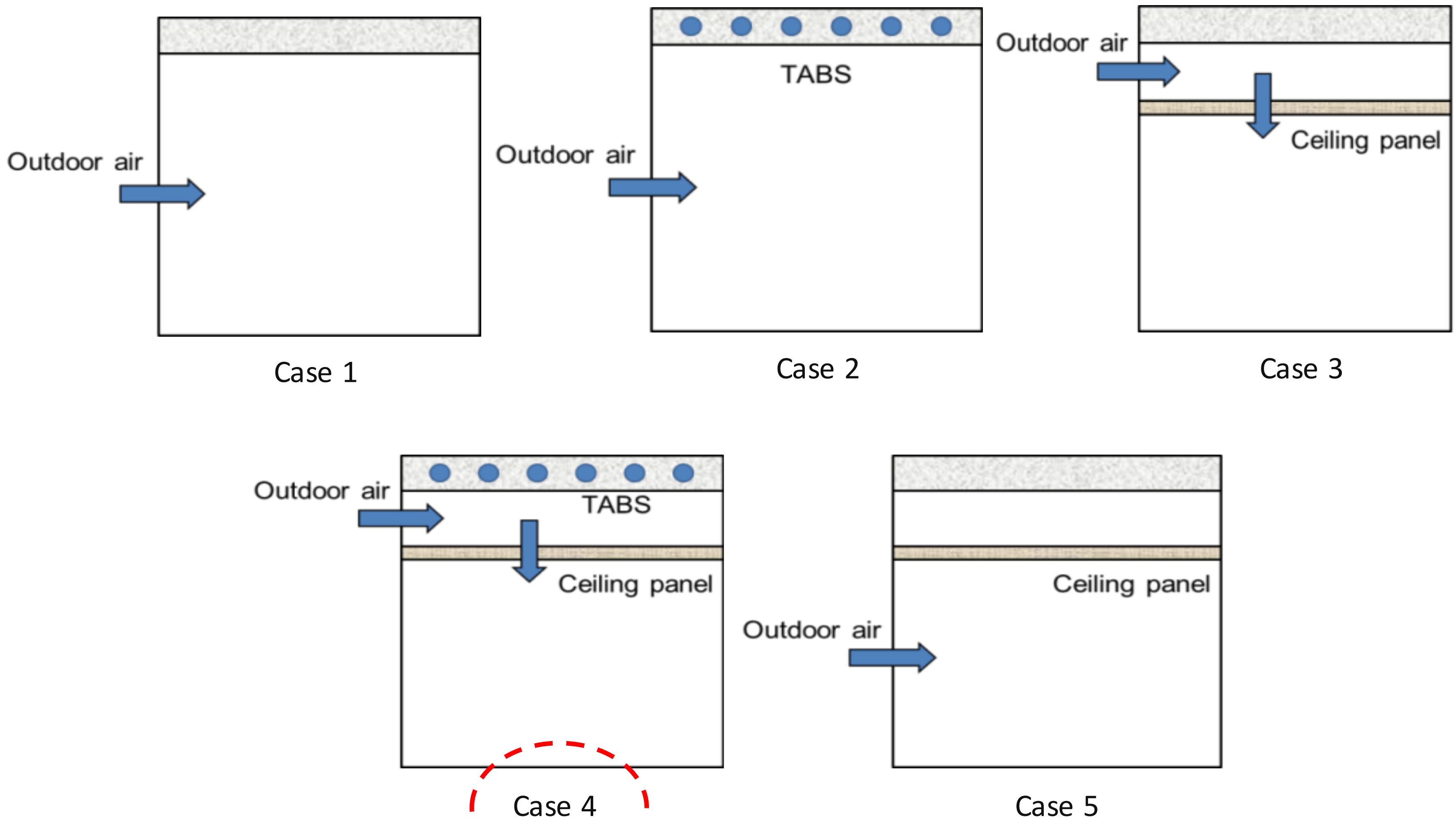
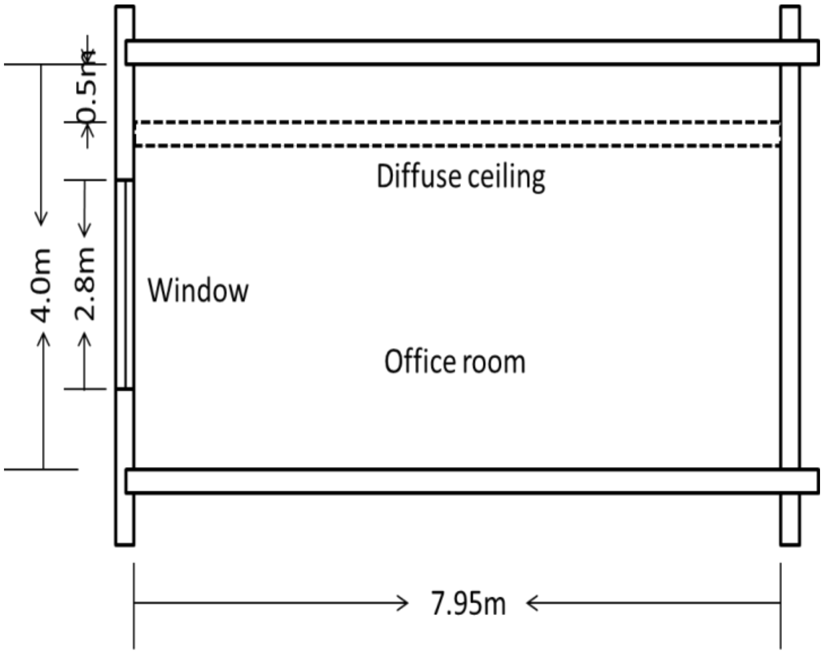
DENMARK

COMPARISON OF ENERGY USE FOR DIFFERENT VENTILATION SYSTEM SOLUTIONS

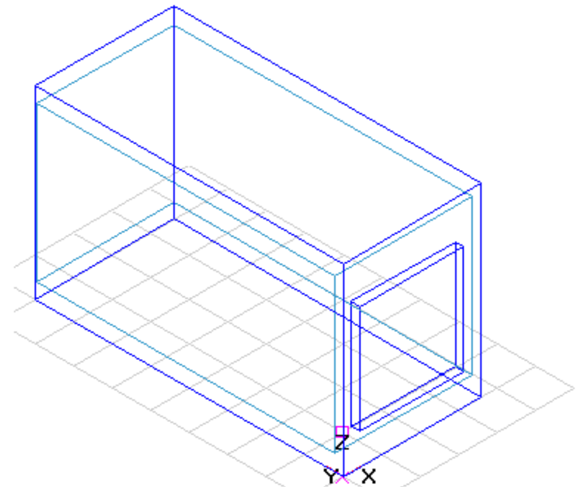


Source:: Yu, Heiselberg, Lei, Pomianowski & Zhang. Energy & Buildings, 2015

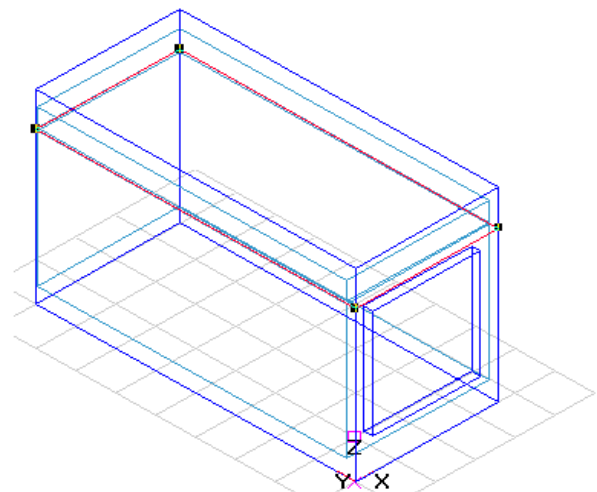
COMPARISON OF ENERGY USE FOR DIFFERENT VENTILATION SYSTEM SOLUTIONS



Room geometry



Without diffuse ceiling



With diffuse ceiling

Source:: Yu, Heiselberg, Lei, Pomianowski & Zhang. Energy & Buildings, 2015

COMPARISON OF ENERGY USE FOR DIFFERENT VENTILATION SYSTEM SOLUTIONS

PAREMETERS

- Building location: Copenhagen
- Orientation: South
- Occupied time: 9-17
- Ventilation system: Minimum ACH-1.1 h^{-1}, Heat recovery-0.75
- Infiltration rate : 0.15 h^{-1}
- Internal heat load: 30 W/㎡, including occupants, lighting, and equipment
- Shutter: Un-occupied time，when T_{op}<20 ℃, R=5 W/㎡·K
- Shading control: different controls in winter and summer

Source:: Yu, Heiselberg, Lei, Pomianowski & Zhang. Energy & Buildings, 2015

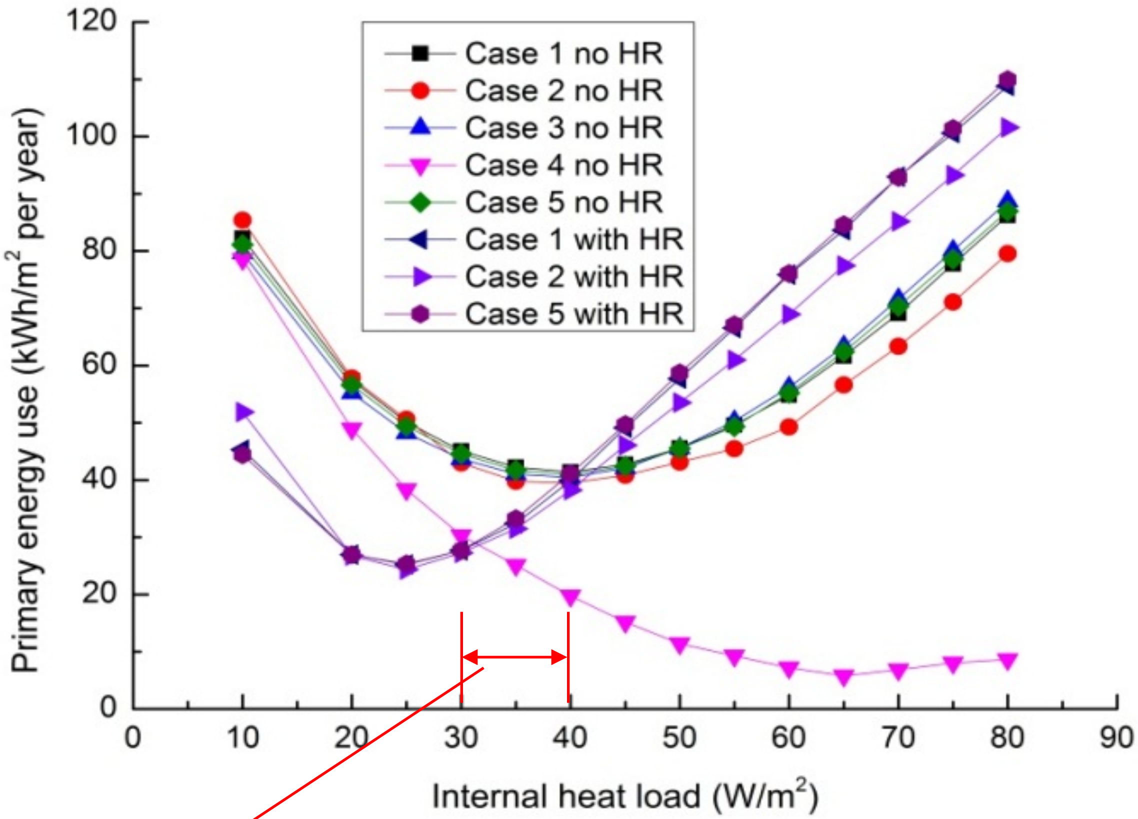
COMPARISON OF ENERGY USE FOR DIFFERENT VENTILATION SYSTEM SOLUTIONS

PRIMARY ENERGY CONVERSION FACTORS

	System conversion factor	Primary energy conversion factor
Air-based heating	0.8	1.0
Air-based cooling	3.0	2.5
Radiant heating	0.8	1.0
Radiant cooling	3.5	2.5
Mechanical ventilation	1.0	2.5

Source:: Yu, Heiselberg, Lei, Pomianowski & Zhang. Energy & Buildings, 2015

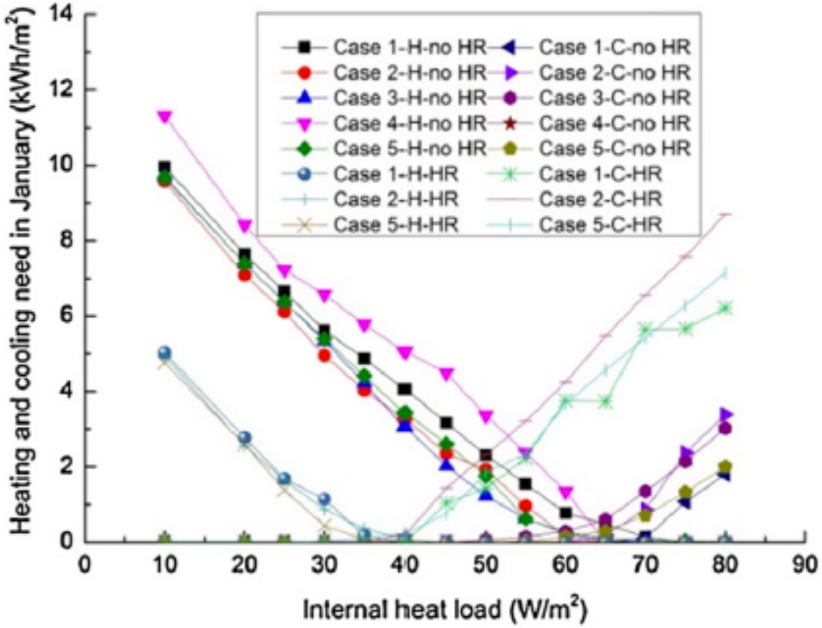
COMPARISON OF ENERGY USE FOR DIFFERENT VENTILATION SYSTEM SOLUTIONS



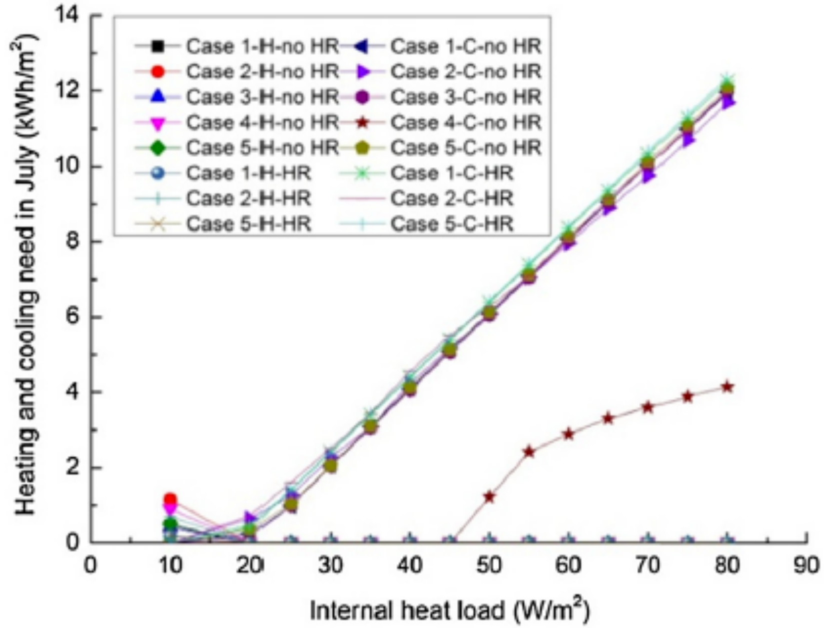
Maximum energy saving, 50%

Source:: Yu, Heiselberg, Lei, Pomianowski & Zhang. Energy & Buildings, 2015

COMPARISON OF ENERGY USE FOR DIFFERENT VENTILATION SYSTEM SOLUTIONS



(a) January



(g) July

Source:: Yu, Heiselberg, Lei, Pomianowski & Zhang. Energy & Buildings, 2015

SUMMARY

THE CHOICE OF THE MOST ENERGY EFFICIENT VENTILATION SYSTEM DEPENDS ON THE BUILDING HEAT LOAD

- Mechanical ventilation with heat recovery is most energy efficient for small heat loads and during winter
- Natural ventilation without heat recovery is most energy efficient at high heat loads and during summer.

FURTHER OPTIMIZATION CAN BE ACHIEVED USING A HYBRID SYSTEM. TYPICALLY OPERATION STRATEGY:

- Mechanical ventilation with heat recovery in the winter period (heating season) in occupied periods with cloudy conditions as well as outside occupied periods
- Natural ventilation in the winter period in occupied periods with sunny conditions as well as outside the heating season
- Night time ventilation and cooling during the summer period

Cold Air Supply through Diffuse Ceilings

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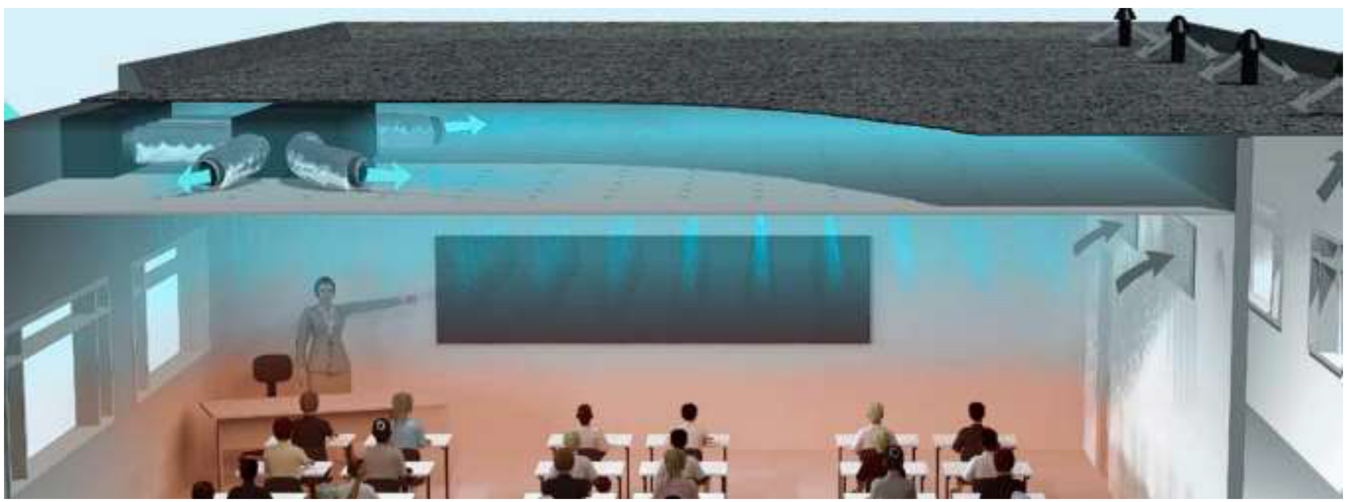
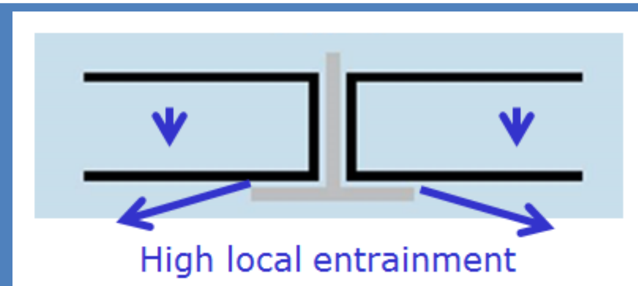
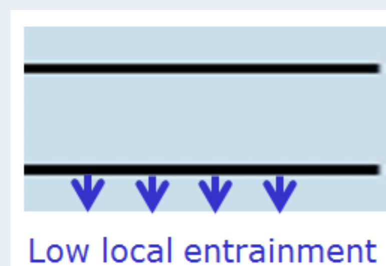
DENMARK

WHAT IS DIFFUSE CEILING VENTILATION

THE SPACE ABOVE A SUSPENDED CEILING IS USED AS A PLENUM AND FRESH AIR IS SUPPLIED TO THE OCCUPIED ZONE THROUGH PERFORATED SUSPENDED CEILING.

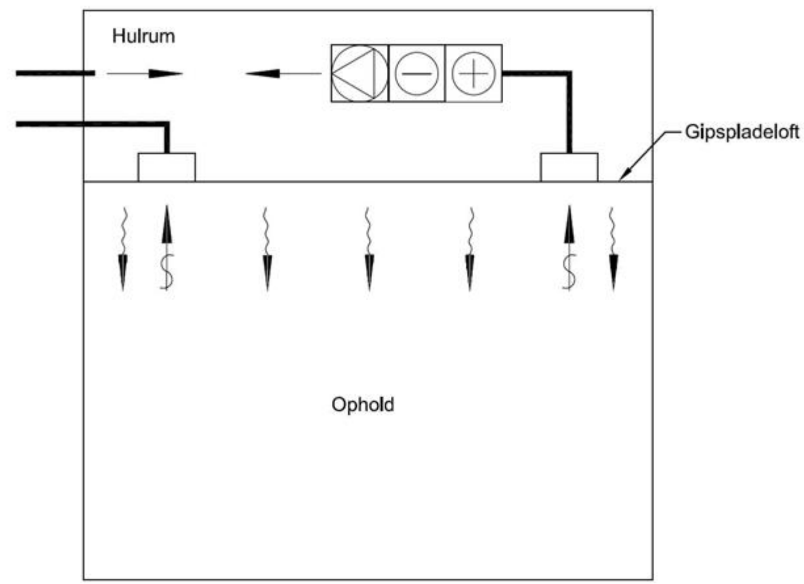


THE PRINCIPLE

Rockfon / Troldtekt ceiling	
Ecophon ceiling	
Fully diffuse ceiling	

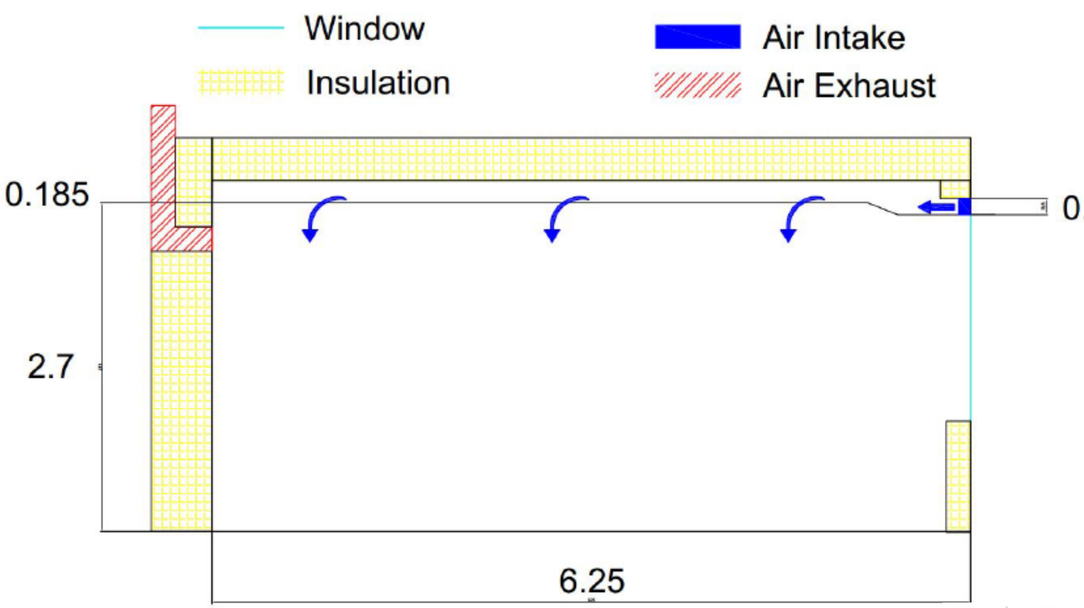
VENTILATIVE COOLING OFFICES IN COLD CLIMATE

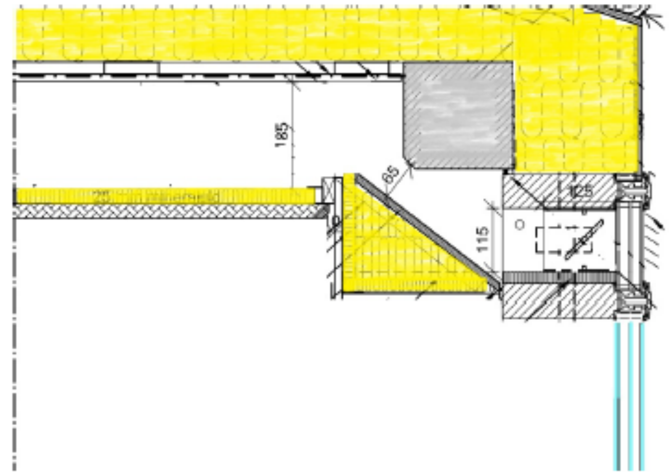
WIDEX/WESSBERG A/S

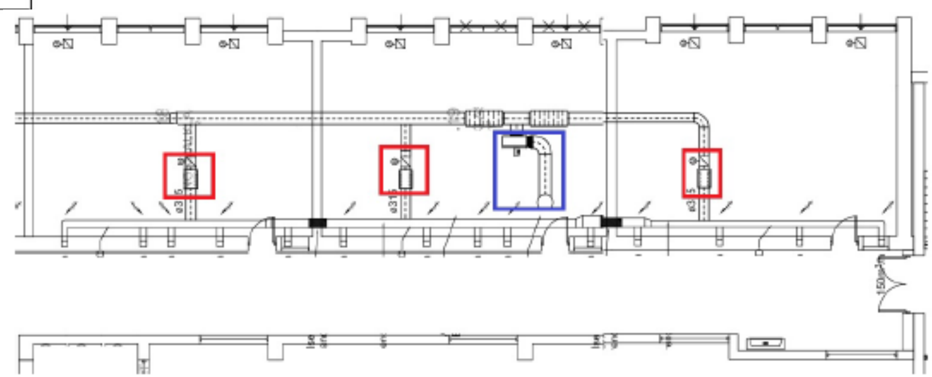


SOLBJERGSKOLEN SOUTHWEST OF ÅRHUS

SYSTEM PRINCIPLE

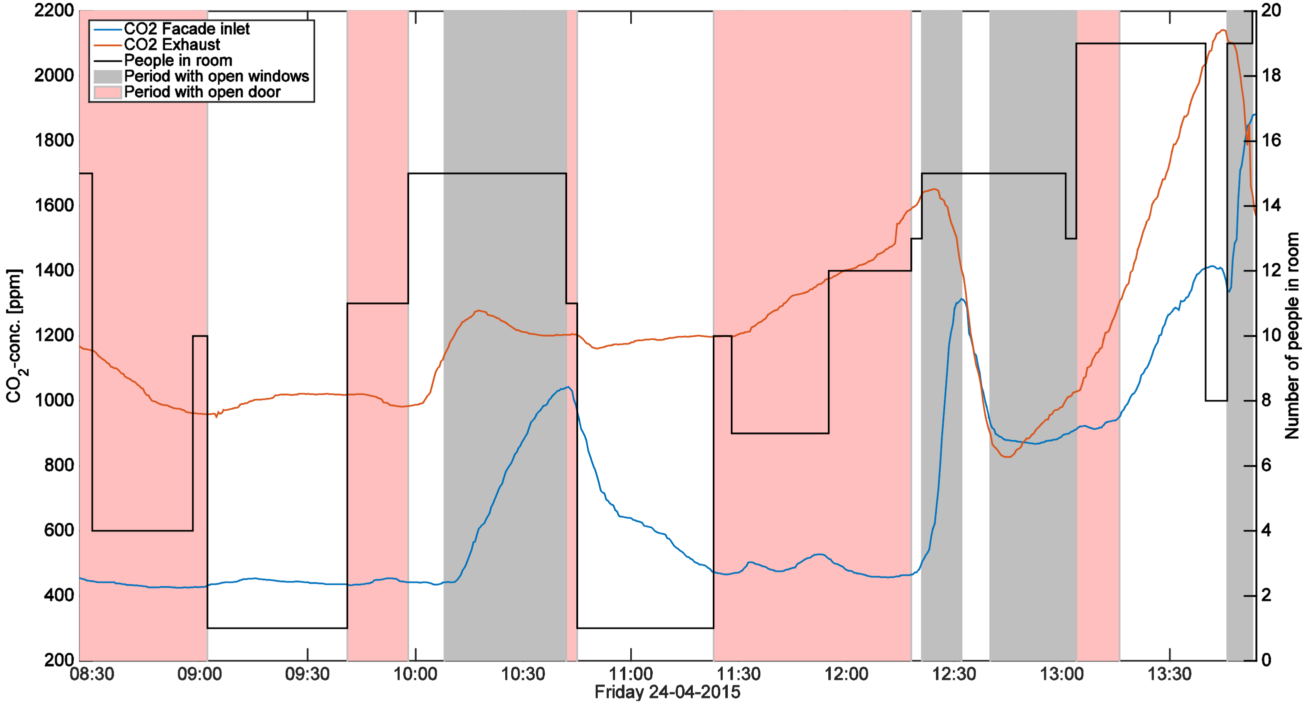






DRIFT PÅ EN NORMAL SKOLEDAG

BEHOVSTYRET MEKANISK VENTILATION, DER SLUKKES NÅR VINDUET ÅBNES



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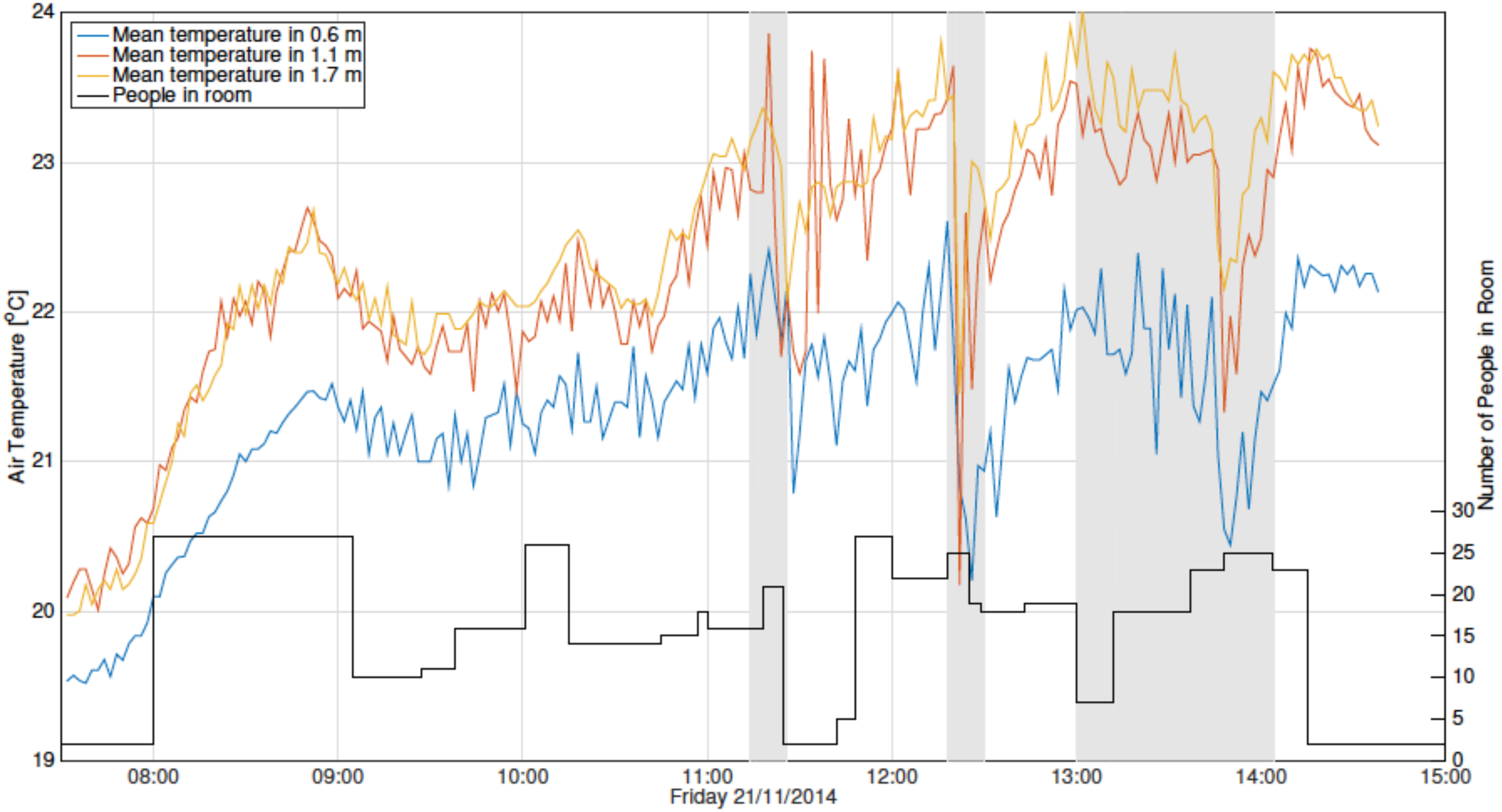
TEMPERATURE DISTRIBUTION ON TYPICAL DAY (OUTDOOR: 5-8^{O}C, N= 2-3H^{-1})



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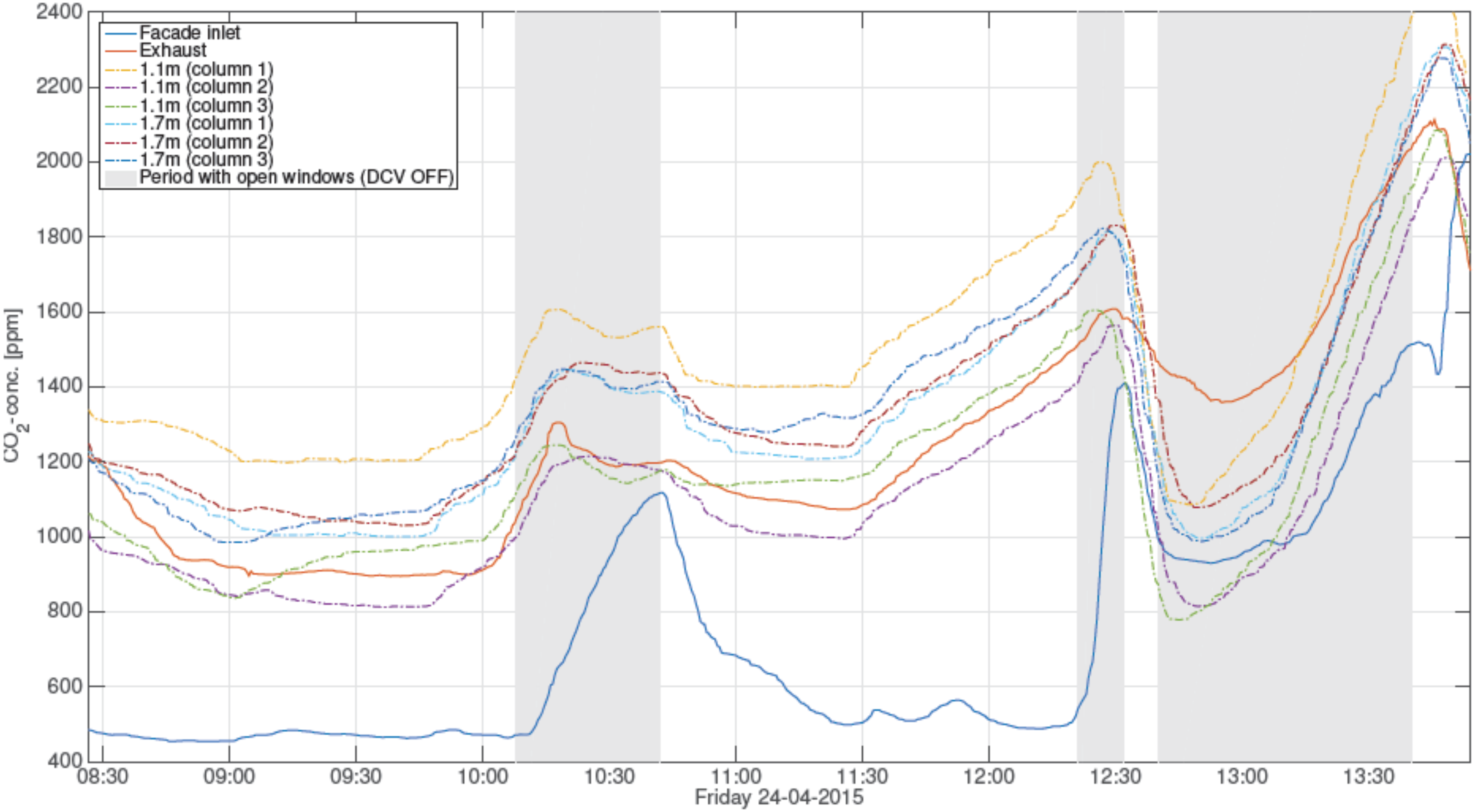
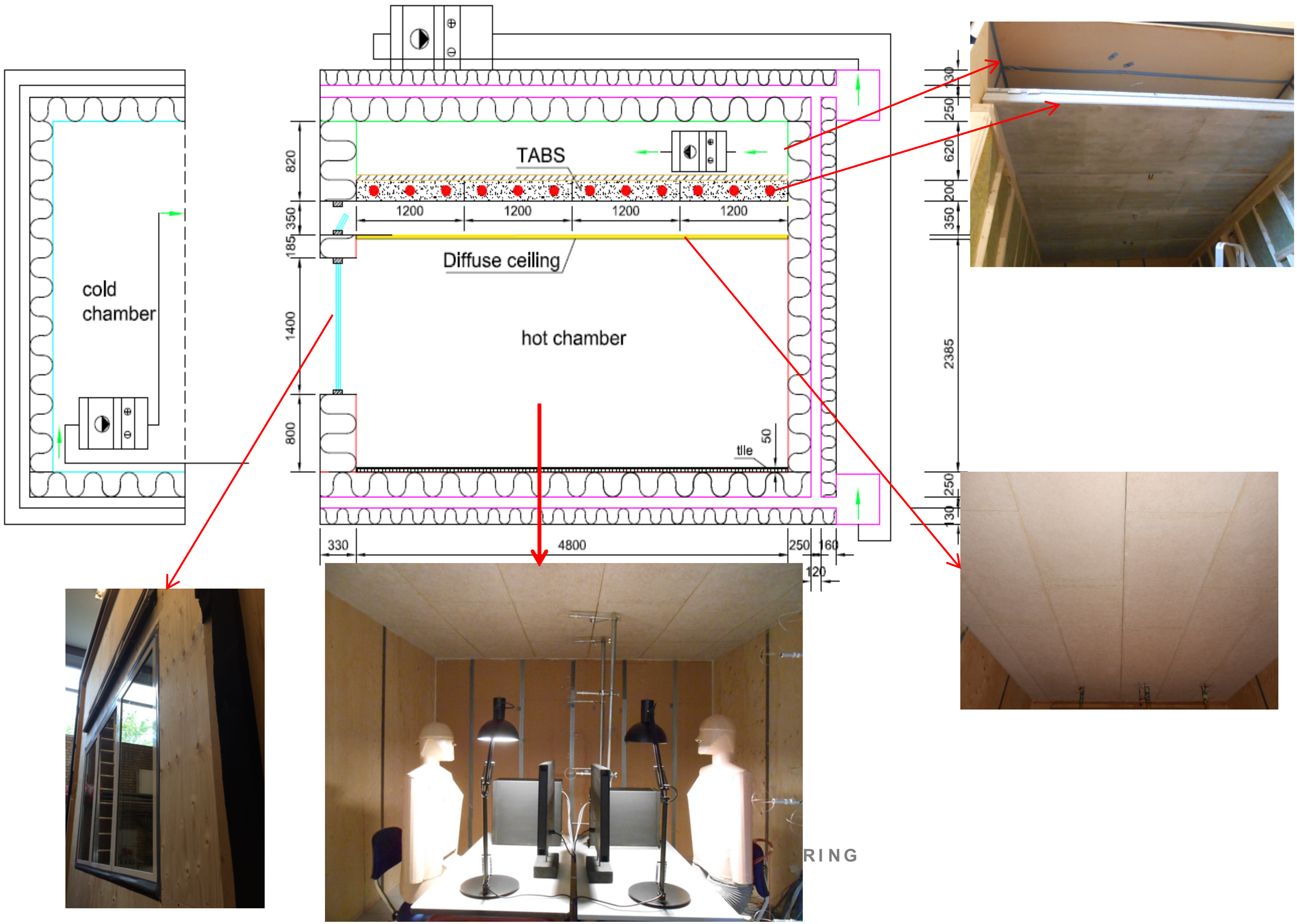
ROOM AIR VELOCITIES (OUTDOOR: 5-8^{O}C, N= 2-3H^{-1})

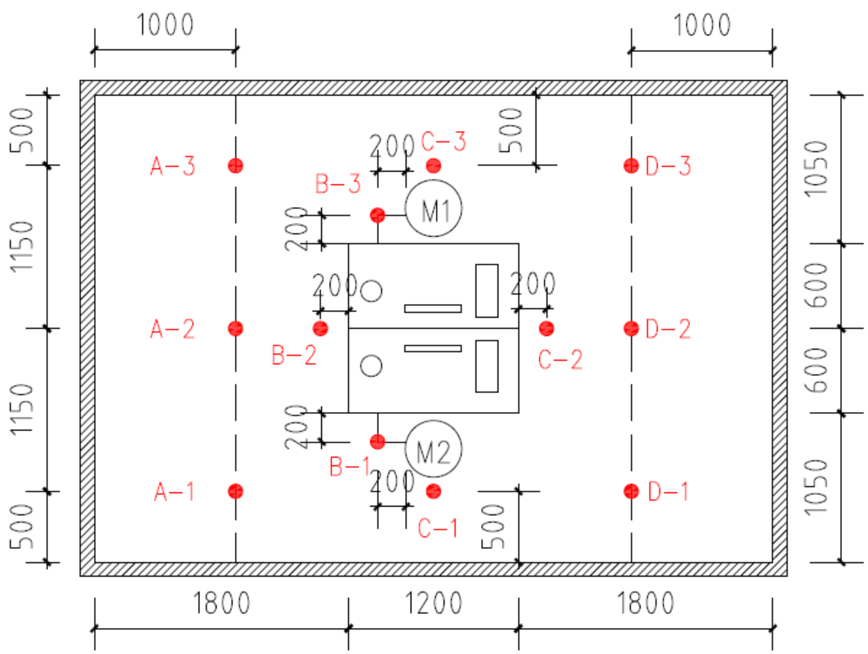
MÅLT CO_2 KONCENTRATION I KLASSEN

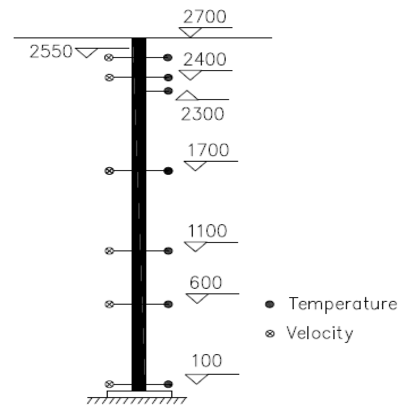


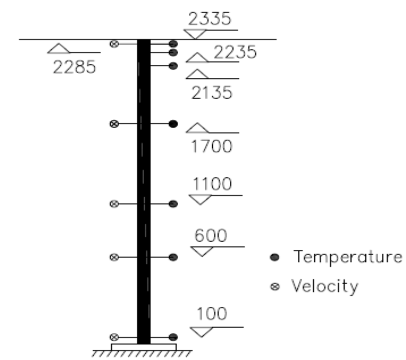
EXPERIMENTAL SET-UP IN THE LAB



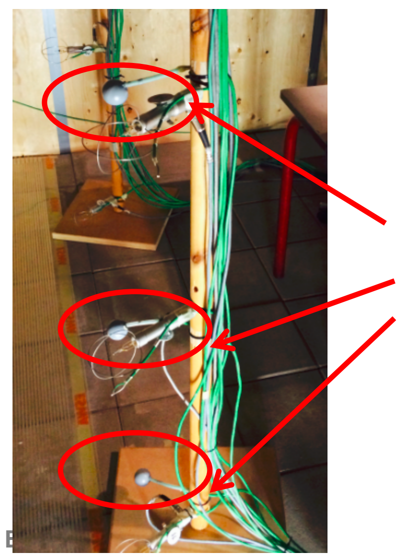
MEASUREMENT POINTS IN THE TEST ROOM







12 positions with 3 movable columns (Temperature and velocity)



Operative temperature

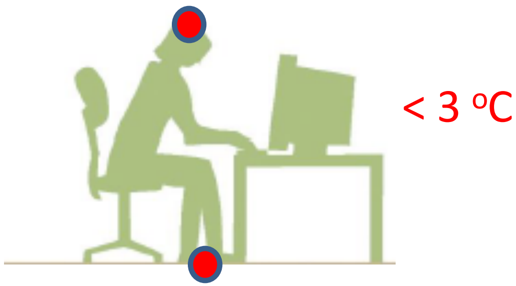
Source:: Zhang, Heiselberg, Pomianowski, Yu & Jensen. Energy & Buildings, 2015

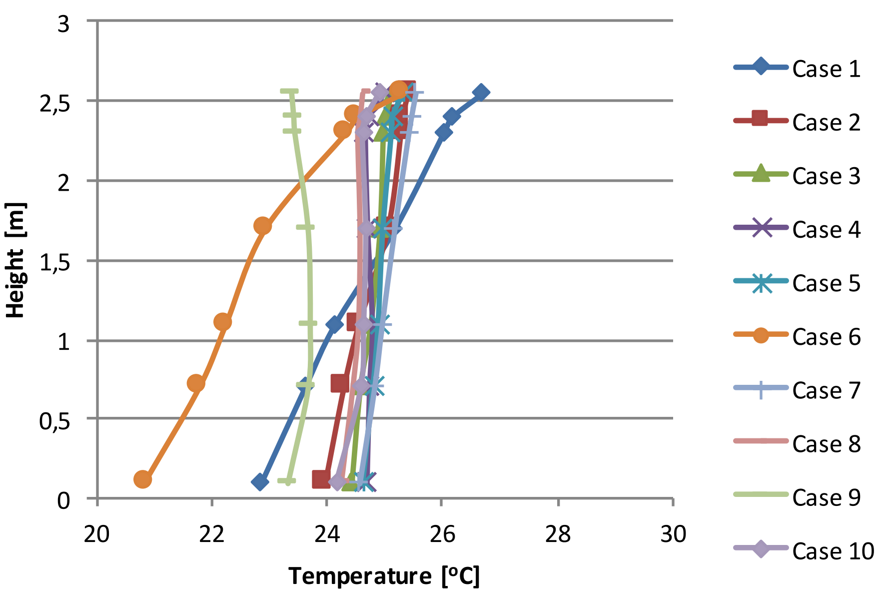
DESIGNED CASES

Heat load	Air change rate (h^{-1})	Natural ventilation ('-' means heat loss, '+' means heat gain)	TABS ('-' means heat loss, '+' means heat gain)	Outdoor temperature (°C)	Indoor temperature (°C)	Solar heat gain (W/m^2)	With diffuse ceiling	Without diffuse ceiling
30 W/㎡ (only internal heat gain)	2	-200%	+100%	-8	24	0	√	√
	2	-100%	0%	9	24	0	√	√
	2	-50%	-50%	15	24	0	√	√
	2	0%	-100%	24	24	0	√	√
	2	50%	-150%	32	24	0	√	√
60 W/㎡ (internal and solar heat gain)	4	-200%	+100%	-8	24	30	√	√
	4	-100%	0%	9	24	30	√	√
	4	-50%	-50%	15	24	30	√	√
	4	0%	-100%	24	24	30	√	√
	4	50%	-150%	32	24	30	√	√

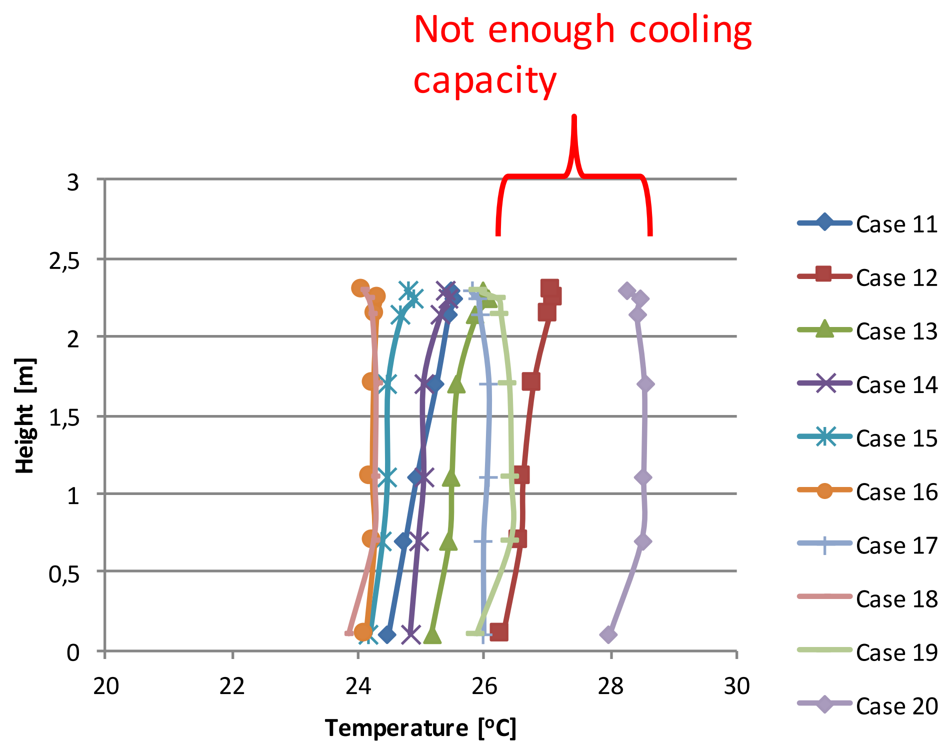
Source:: Zhang, Heiselberg, Pomianowski, Yu & Jensen. Energy & Buildings, 2015

VERTICAL TEMPERATURE GRADIENT





Without diffuse ceiling

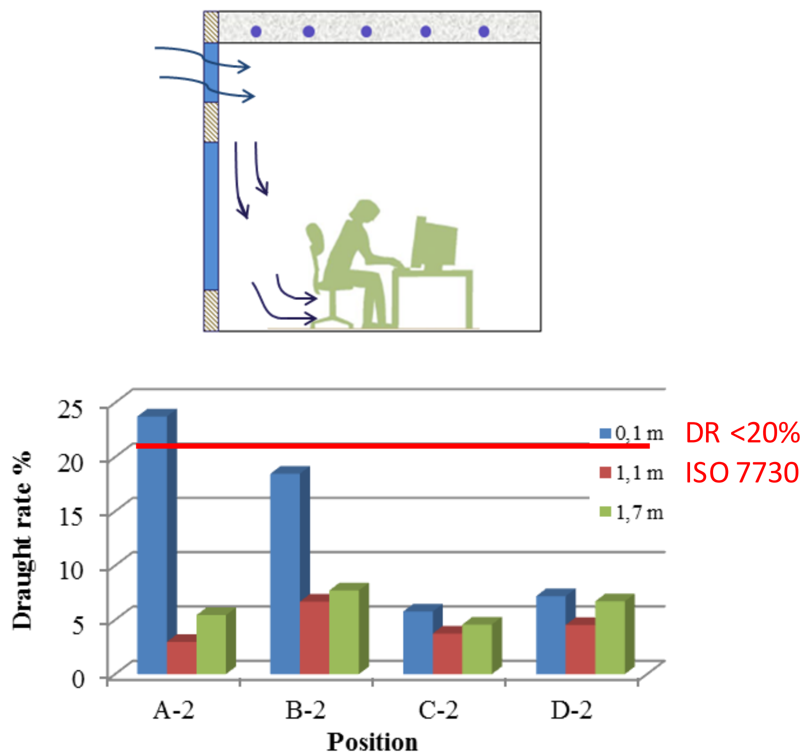


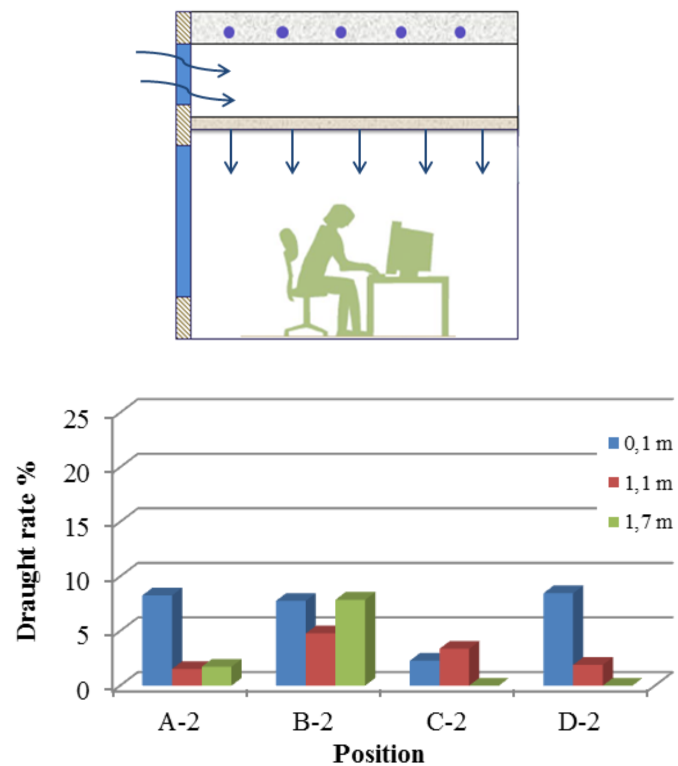
With diffuse ceiling

Source:: Zhang, Heiselberg, Pomianowski, Yu & Jensen. Energy & Buildings, 2015

DRAUGHT RISK

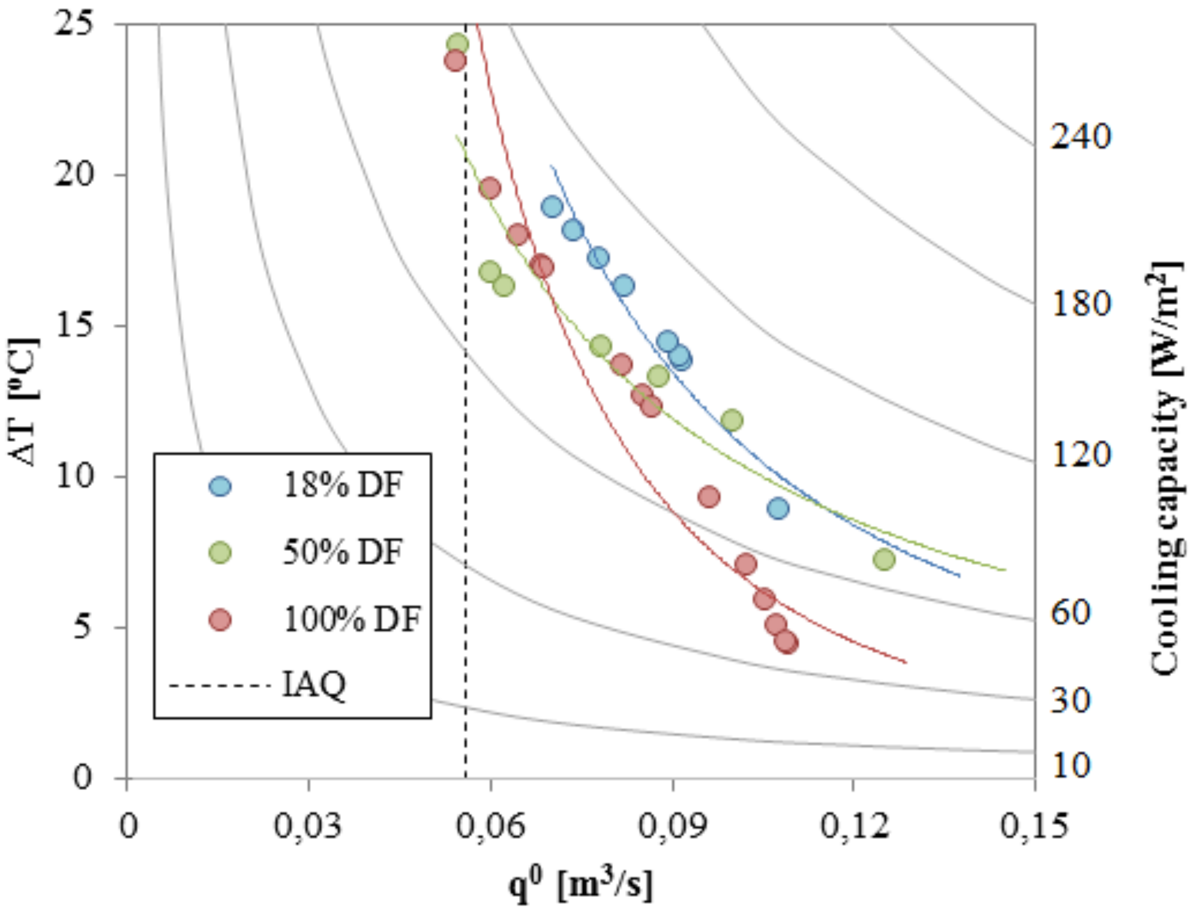
- Winter condition: Supply air temperature -8 ^{o}C, ACH =4





Source:: Zhang, Heiselberg, Pomianowski, Yu & Jensen. Energy & Buildings, 2015

DESIGN CHART FOR DIFFERENT DIFFUSE CEILING OPENING AREAS



Source:: Zhang, Kristensen, Jensen, Heiselberg, Jensen & Pomianowski, Energy & Buildings, 2016

SUMMARY

Low draught risk in the occupied zone, even when supplying air at temperatures below 0C^{o}

Air distribution and draught risk dependent on heat load location, ceiling height, area and location of supply.

Very low vertical temperature gradient in the room with diffuse celling supply

Low radiant temperature asymmetry and no clear radiation cooling potential of diffuse ceiling, due to low conductivity

Very low pressure drop across diffuse ceiling (less than 5 Pa)

Thanks for your attention

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