

Jahutuse ruumiseadmed

18.03.2014 EKVÜ

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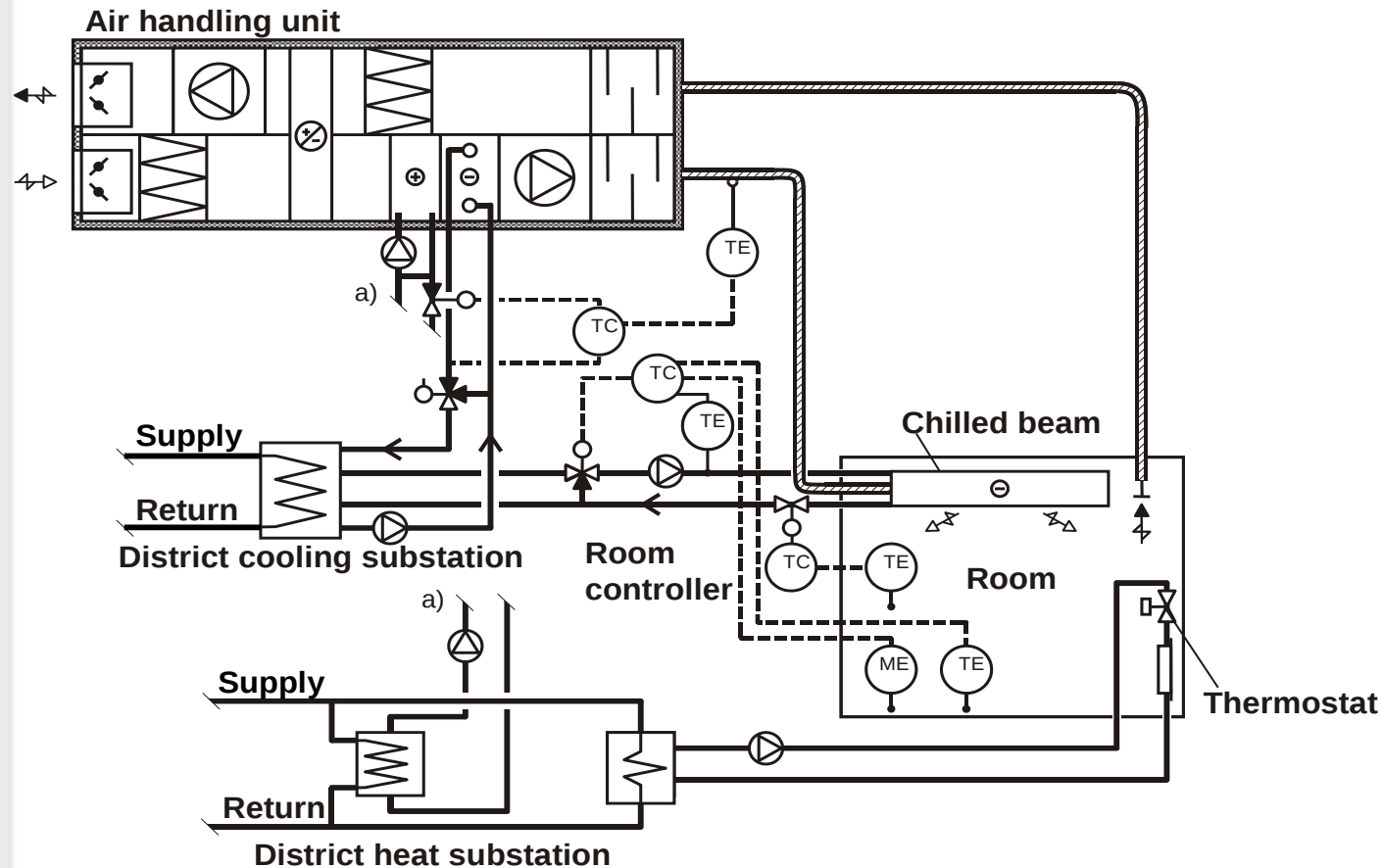
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Chilled beams performance measurements: YIT Turku, 6906 m², 34 000 m³, 180/270 occupants





AC system with mechanical supply and exhaust ventilation and chilled beams



- district heating and district cooling
- active chilled beam units/ room temperature controllers
- constant pressure CAV ventilation in offices of **3 L/s per floor m²**
- attendance and temperature sensors in meeting rooms



Typical chilled beam layout (3rd floor)



- Supply air temperature is extract air temperature compensated and has been set between 17 to 22 °C.
- The building is divided into five ventilation zones with its own central air handling unit



V, T



V

146
v, T

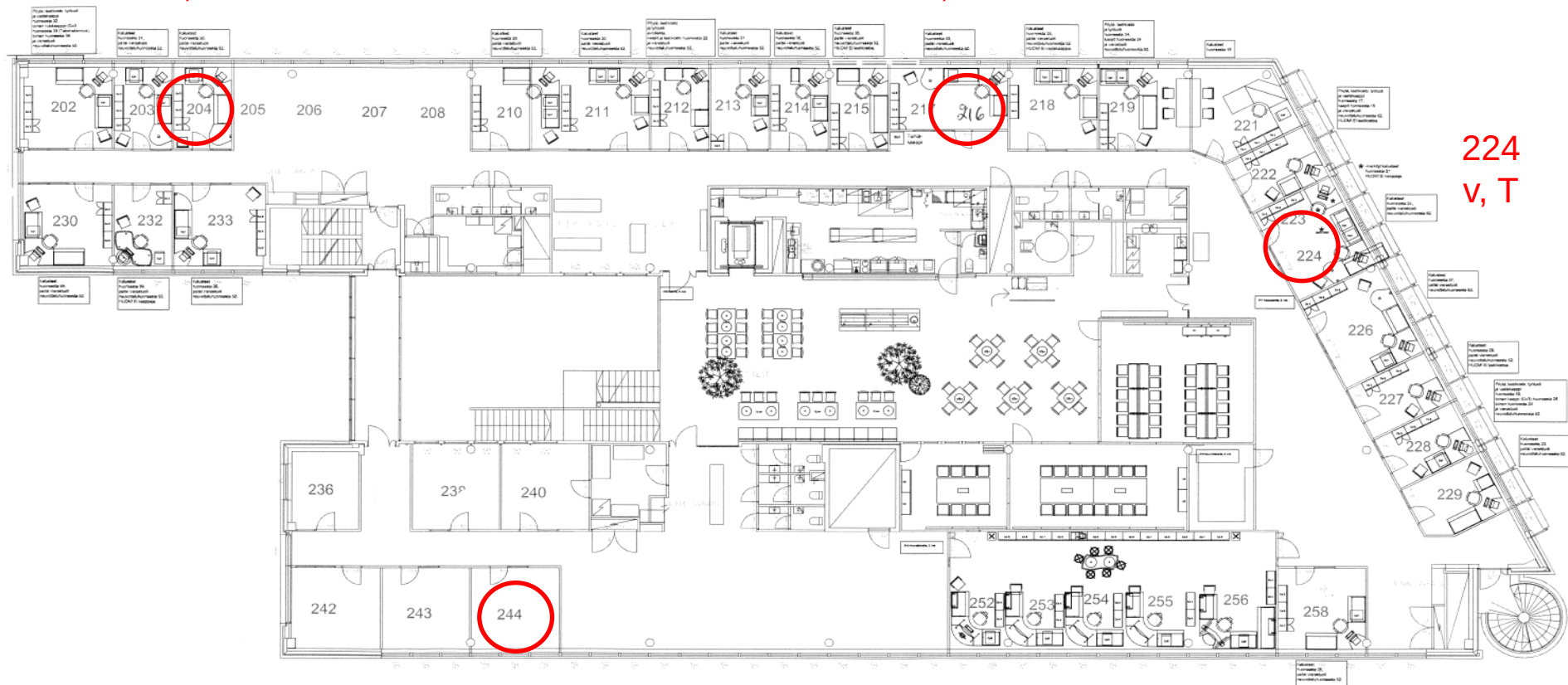
measurement points and parameters (red circles)



Measured rooms: First floor

204
v, T

204
v, T



224
v, T

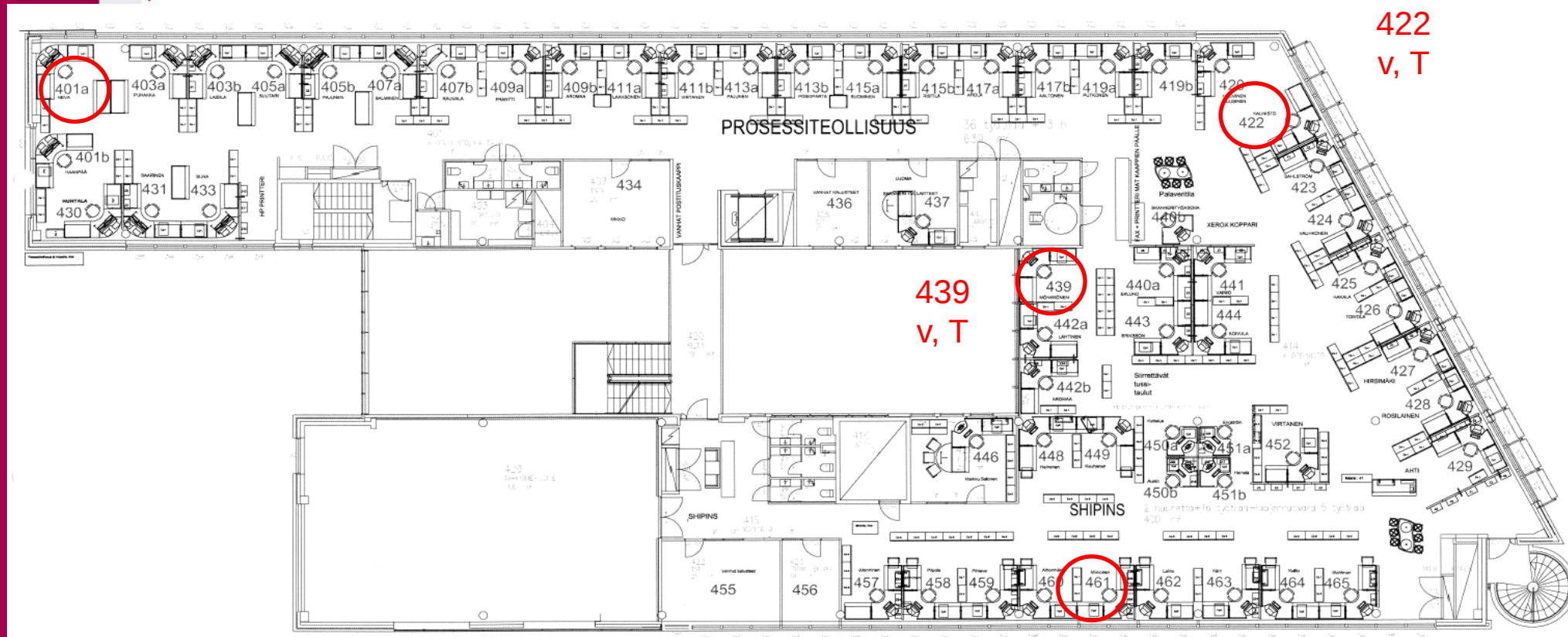
244
v, T



Measured rooms: Third floor

401
v, T

422
v, T



439
v, T

461
v, T



Air velocity measurements – draft rate (ISO 7726) – local thermal discomfort





Air velocity, draft rate and PPD – a spring day (EN ISO 7730)

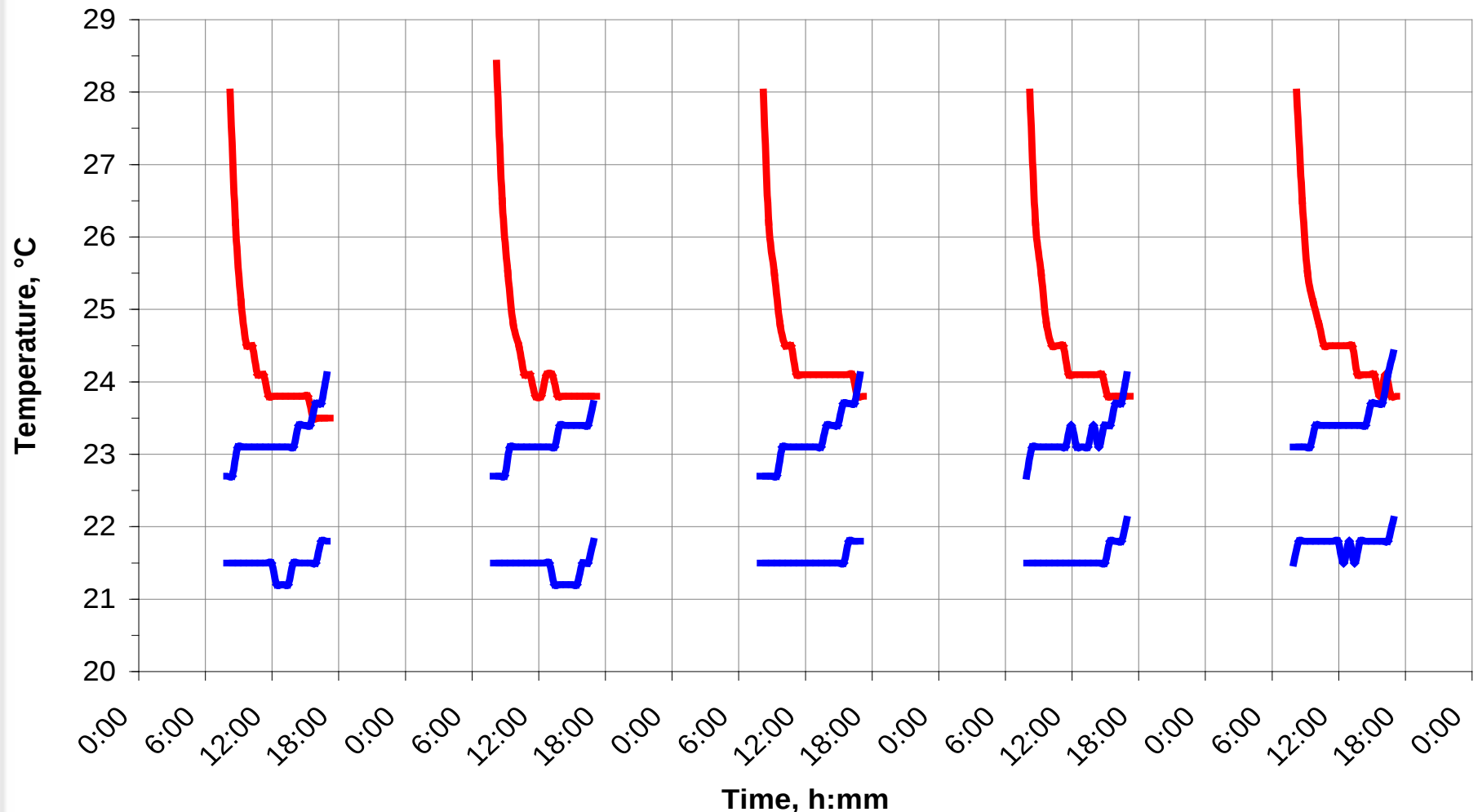
YIT Turku 26.3.2008	102	124M	146M	149M	204M	216M	224	244M	401M	422	439	461M
0,1 m												
Air Velocity [m/s]	-	0.02	0.13	0.04	0.04	0.02	0.01	0.02	0.03	0.04	0.03	0.03
Air Temperature [°C]	-	21.3	20.6	21.9	22.4	21.7	21.3	22.2	22.3	22.6	22.8	22.6
Turbulence Intensity [%]	-	62	20	56	37	65	95	69	45	53	61	40
Draught Rate [%]	-	0	11	0	0	0	0	0	0	0	0	0
0,6 m												
Operative Temperature [°C]	-	20.6	20.6	22.0	22.5	21.6	21.1	22.0	22.4	22.6	22.6	22.5
PMV	-	-	-	-	-	-	-	-	-	-	-	-
PPD [%]	-	-	-	-	-	-	-	-	-	-	-	-
1,1 m												
Air Velocity [m/s]	-	0.10	0.06	0.01	0.07	0.05	0.03	0.06	0.14	0.02	0.02	0.01
Air Temperature [°C]	-	20.9	20.9	22.4	22.6	22.2	21.6	22.1	22.3	22.7	23.0	22.8
Turbulence Intensity [%]	-	19	36	120	37	38	63	33	35	75	74	202
Draught Rate [%]	-	8	2	0	3	0	0	2	12	0	0	0
-	-											
1,7 m												
Air Velocity [m/s]	-	0.10	0.06	0.01	0.05	0.07	0.04	-	0.13	0.01	0.04	0.03
Air Temperature [°C]	-	21.1	20.9	22.4	22.8	22.1	21.7	-	22.4	22.7	22.9	22.9
Turbulence Intensity	-	28	38	125	40	28	57	-	36	105	59	83
Draught Rate	-	8	2	0	0	3	0	-	11	0	0	0

[illegible]



Daily temperature fluctuations

YIT Turku, 26.5.08–31.5.08, office hours (8–17)



- Daily temperature fluctuations during one week: a room with highest (AHU operation time problem), typical and smallest fluctuation
- Highest temperature indicates AHU operation time problem



Assessment according to EN 15251

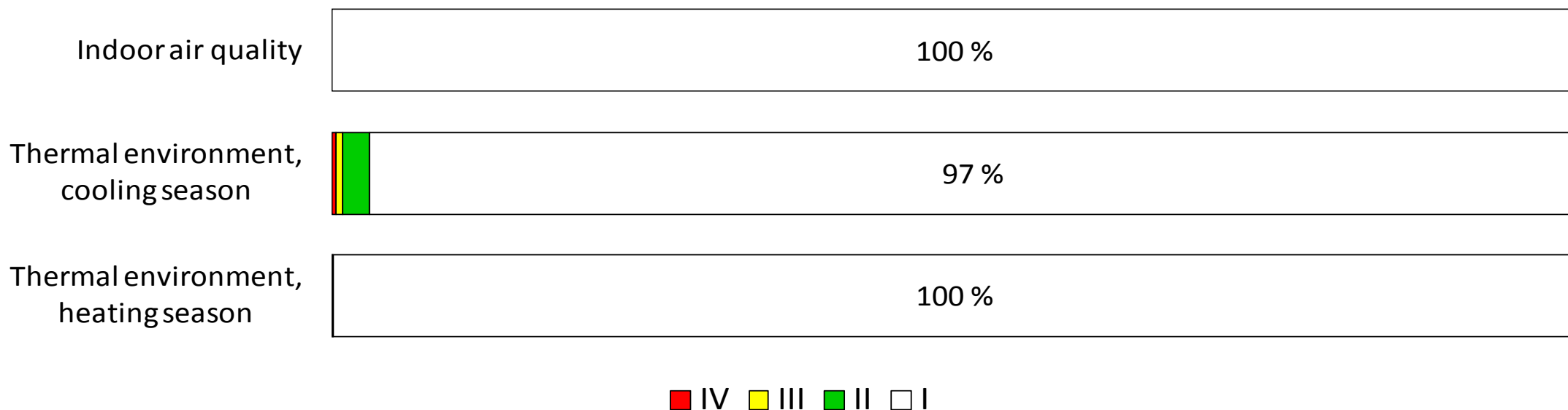
- Foot-print of thermal comfort based on measured temperatures and velocities (more data is needed)
- Foot-print of IAQ based on ventilation rate

Percentage	5	7	68	20
Thermal Environment	IV	III	II	I
Percentage	7	7	76	10
Indoor Quality Air	IV	III	II	I

an example from EN 15251



Foot-print of thermal comfort and IAQ



- Foot-print of general thermal comfort based on measured temperatures (weighted with area) and a foot-print of IAQ based on ventilation rate
- Room temperatures remained between 23.5 °C and 25.5 °C (category I, EN15251, CR 1752) for 97 % of occupied hours for cooling season.
- In heating season temperature was between 21.0 °C and 23.5 °C (category I) in occupied hours for the full measurement period. Daily temperature fluctuations were typically around 1.0 °C to 1.5 °C in the occupied hours during heating season.



Occupant assessment of performance

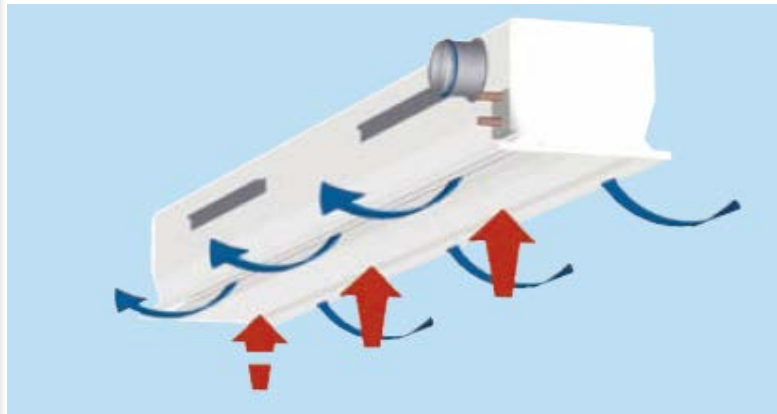
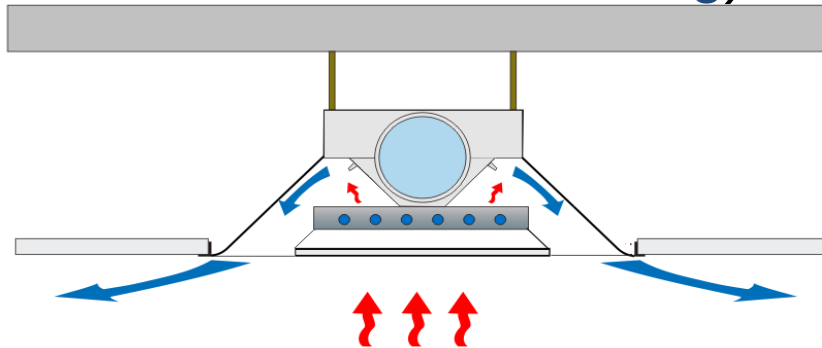
	SUMMER, %	WINTER, %
People finding the overall indoor environment acceptable	86	91
People finding the thermal environment acceptable	73	76
People finding the indoor air quality acceptable	82	90
People finding the acoustical environment acceptable	59	57
People finding the lighting acceptable	95	95

- Survey response: satisfaction with environment based on occupants responses
- Most of office workstations were in landscape offices without personal workstation temperature control and modest sound insulation typical to landscape offices. This has resulted with low satisfaction with acoustical environment.

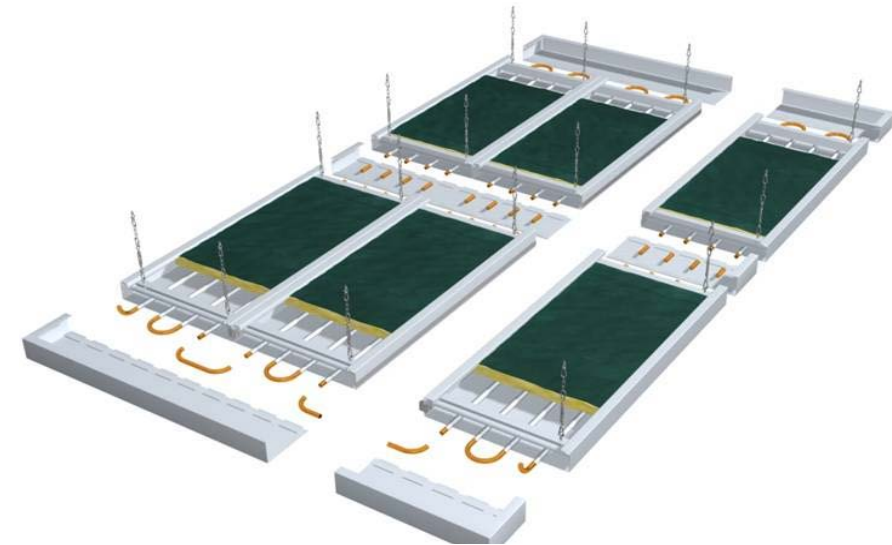


High temperature (15-17°C) room conditioning solutions

1. Chilled beams (water radiators for heating)



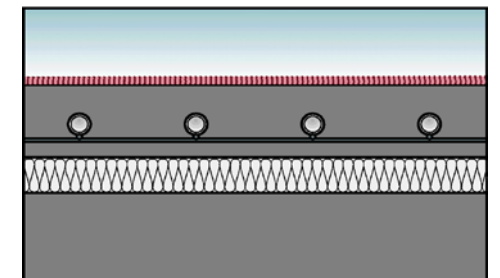
2. Ceiling panels



3. Floor cooling and heating

Simulated cases (in addition to ref. case):

- demand controlled ventilation
- night ventilation
- operative temperature control
- glazed facade





System sizing

Parameters for chilled beam and water radiators

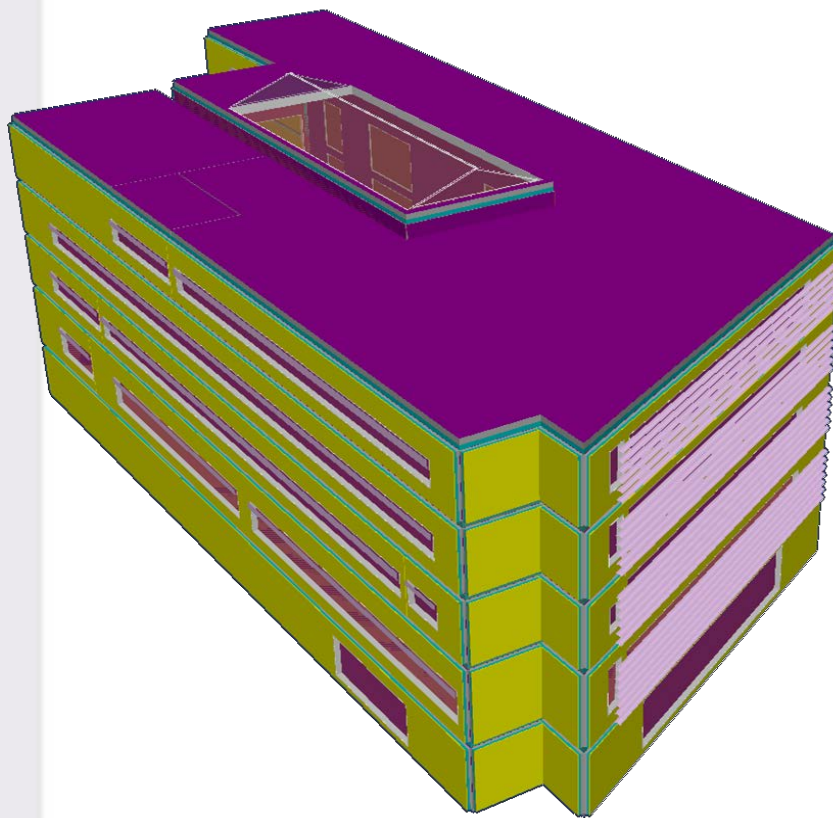
	Active chilled beam		Water radiator
Power at design air flow	40 W/Floor-m2	Maximum power	50 W/Floor-m2
Power at zero air flow	4 W/Floor-m2	Height	0.3 m
dT(coolant-zone air) at max power	8.5 K	Air temp. at maximum power	21 °C
dT(coolant) at max power	3.5 K	Supply temp. at maximum power	70 °C
Controller	PI	Return temp. at maximum power	40 °C
Width of beam	3.6 m	N, exponent of power curves	1.28
		Controller	Proportional

Parameters for floor heating and cooling

	Cooling	Heating
Design power	40 W/m ²	50 W/m ²
Design temperature difference	5 K	10 K
Controller	Thermostat or PI	
Depth under floor surface	0.04 m	

Parameters for ceiling panel

	Cooling
Design power	40 W/floor-m ²
dT(coolant-zone air) at design power	8.5
dT(coolant) at design power	3 K
Controller	Thermostat or PI
Backside insulation	40 mm



IDA-ICE simulation model

Weather data of Helsinki

Modern office building

District cooling and heating

Set points:

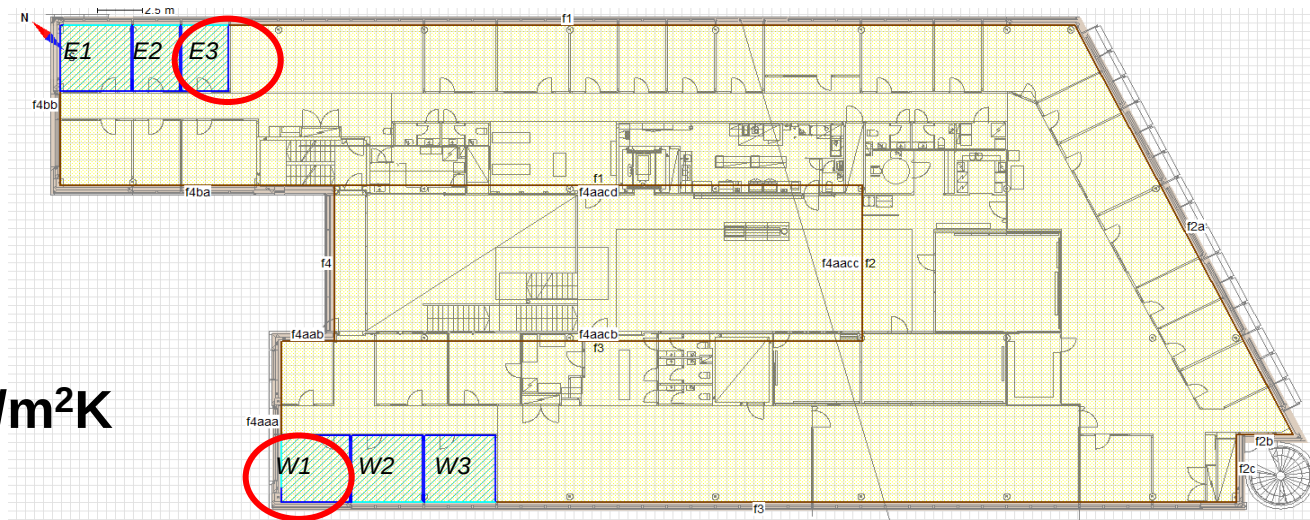
heating 21 °C

cooling 25 °C

U-values:
external wall 0.22 W/m²K
windows 1.2 W/m²K

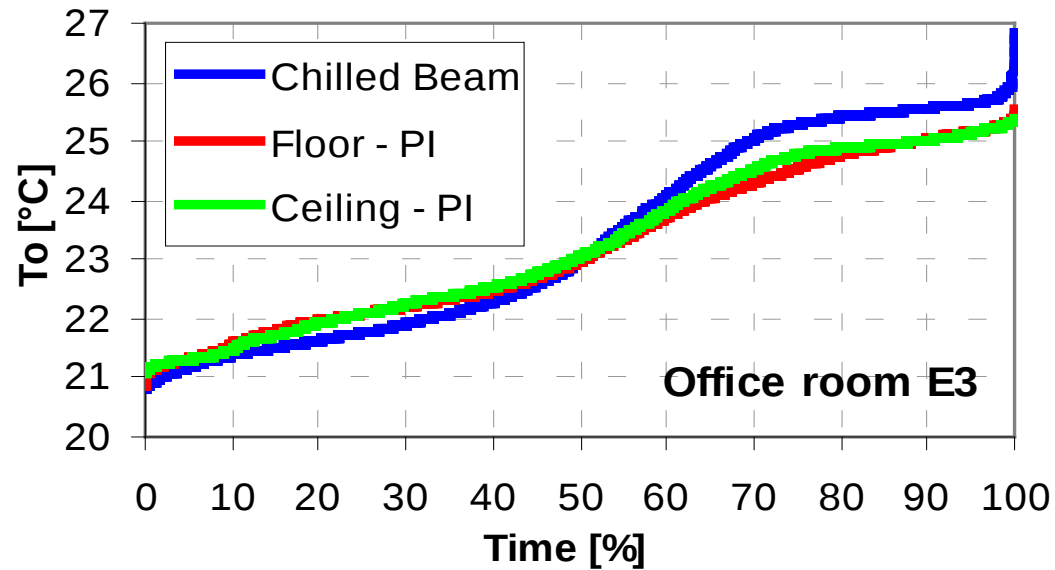
Heat recovery efficiency 80%

Supply (outdoor) and extract airflow rate
2 dm³/s,m²

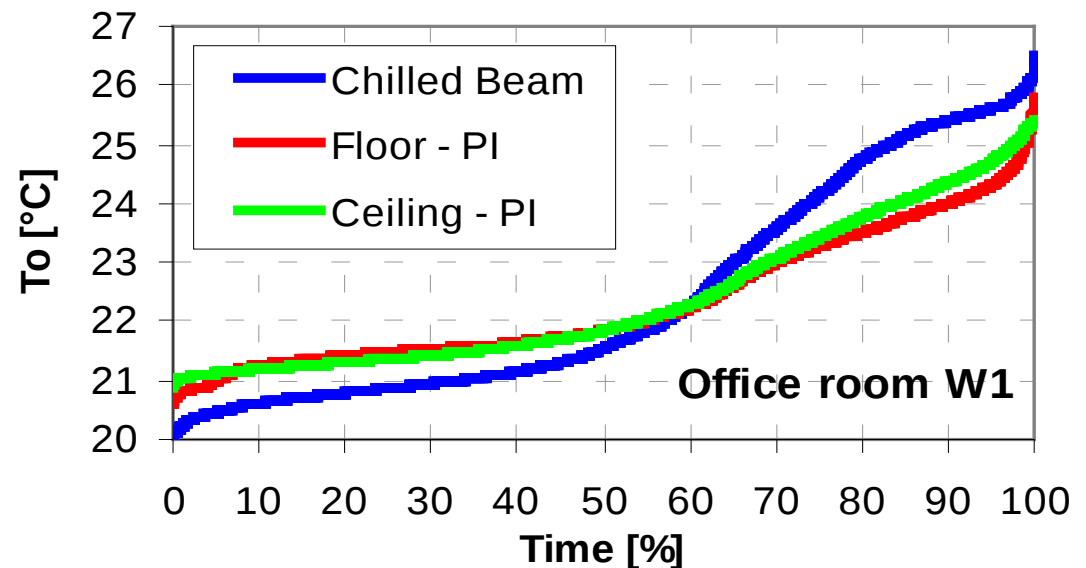




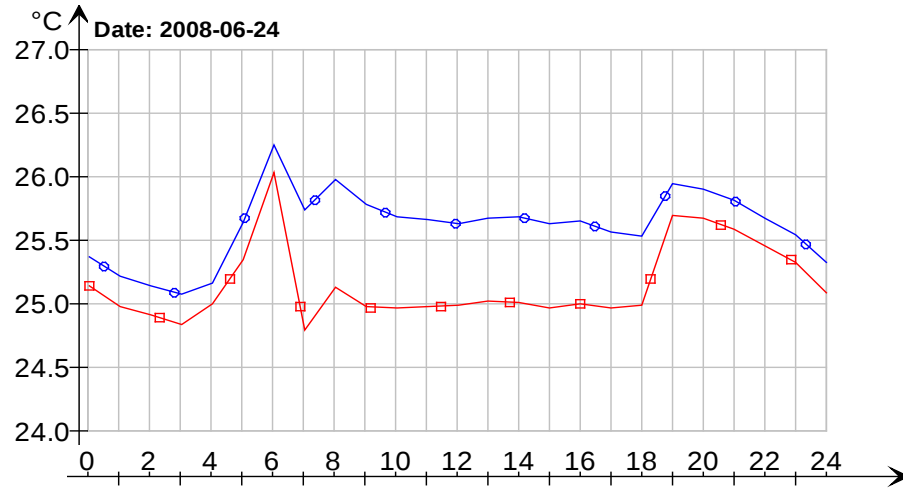
Operative temperature in reference cases



See the difference between convective (chilled beam) and radiative (ceiling and floor) cooling with typical air temperature control

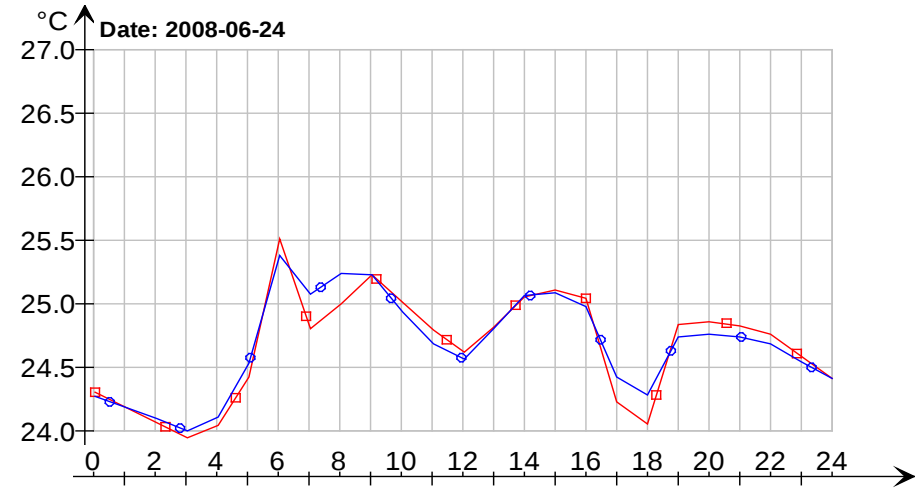


Reference cases: operative temperature vs. indoor air temperature



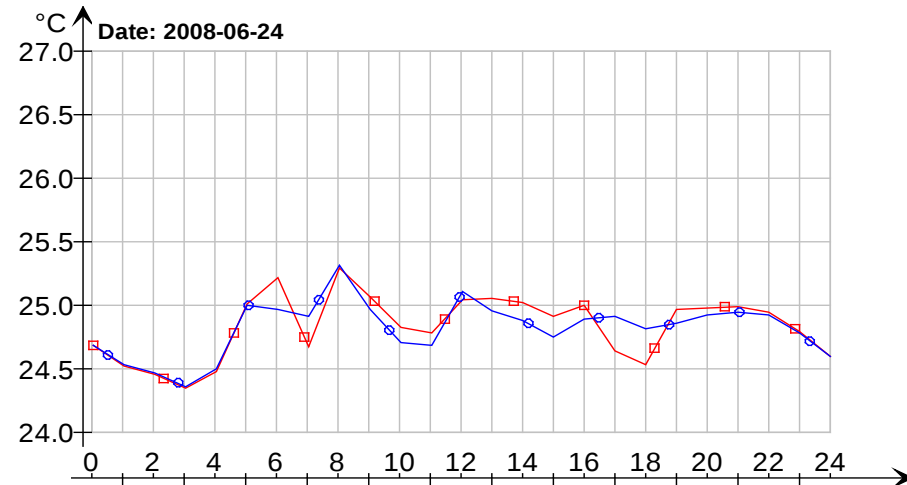
—□— Mean air temperature, Deg-C
—○— Operative temperature 1, Deg-C

Chilled beam



—□— Mean air temperature, Deg-C
—○— Operative temperature 1, Deg-C

Floor - PI



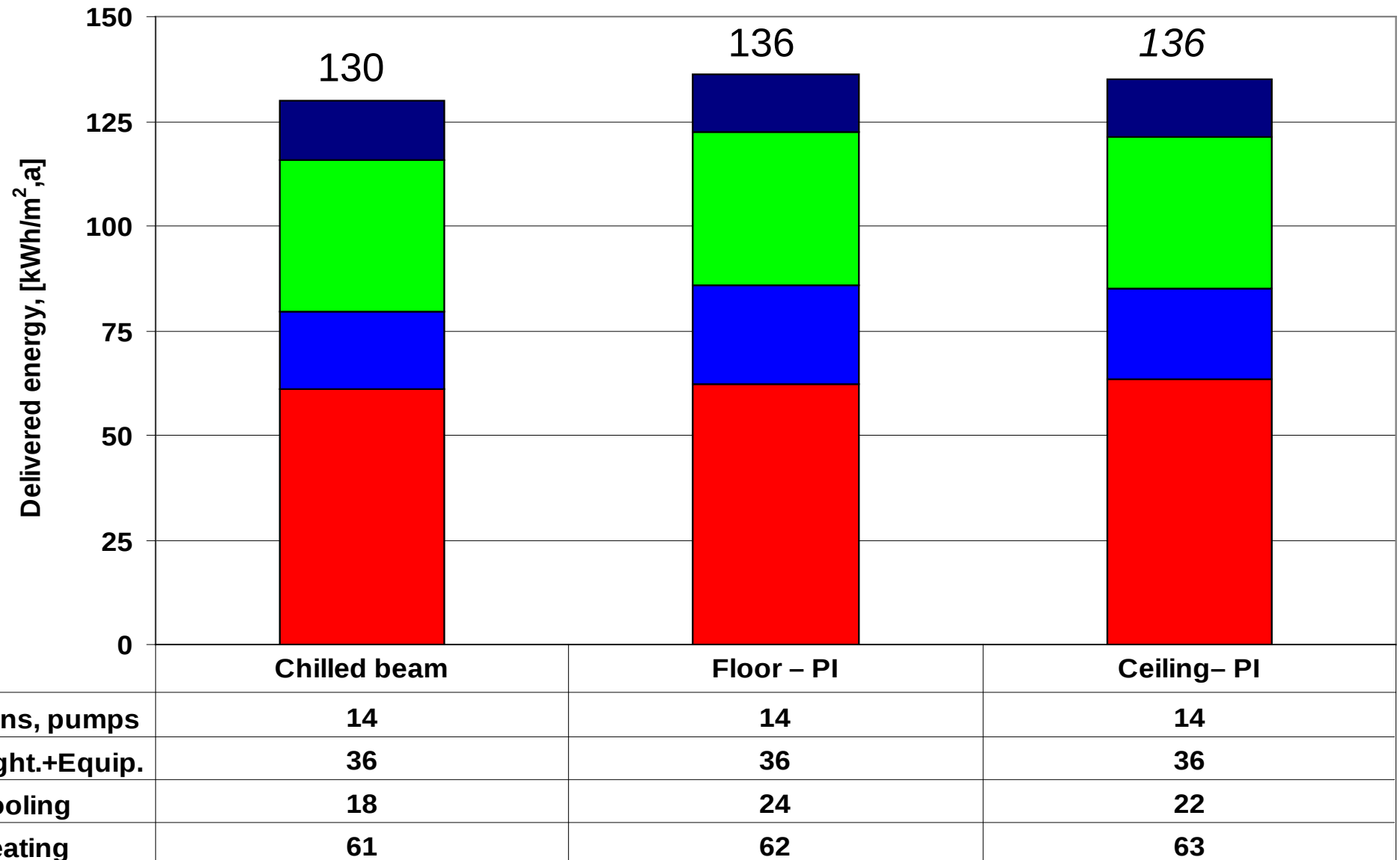
—□— Mean air temperature, Deg-C
—○— Operative temperature 1, Deg-C

Ceiling - PI



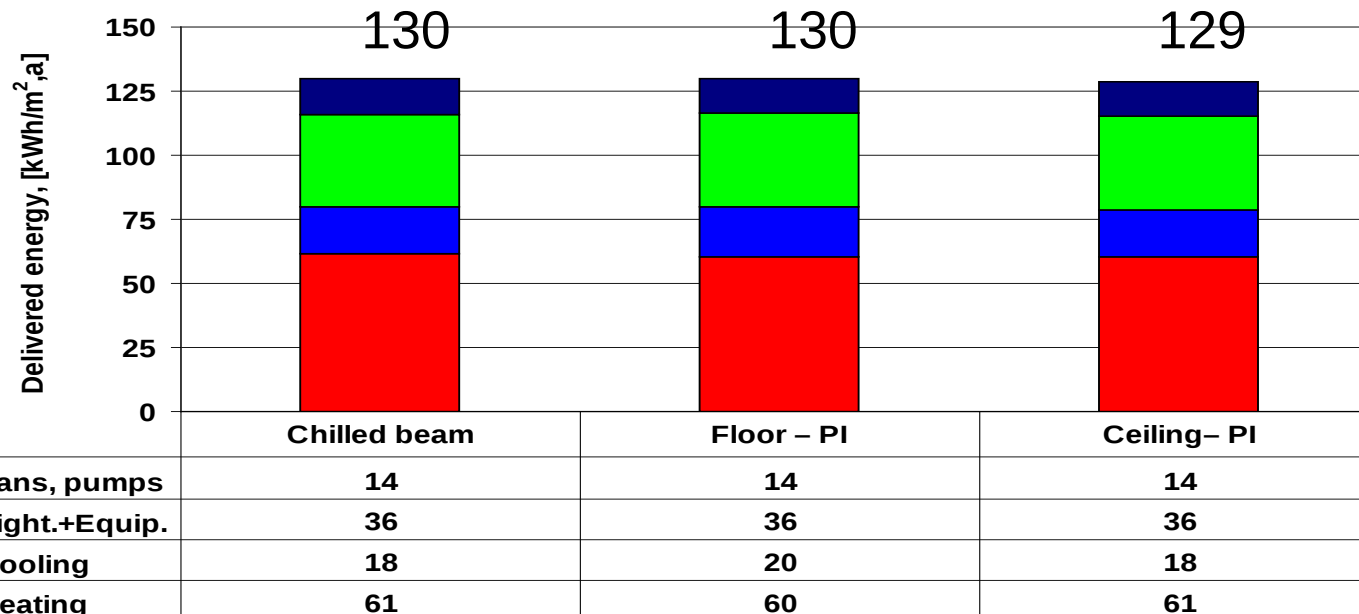
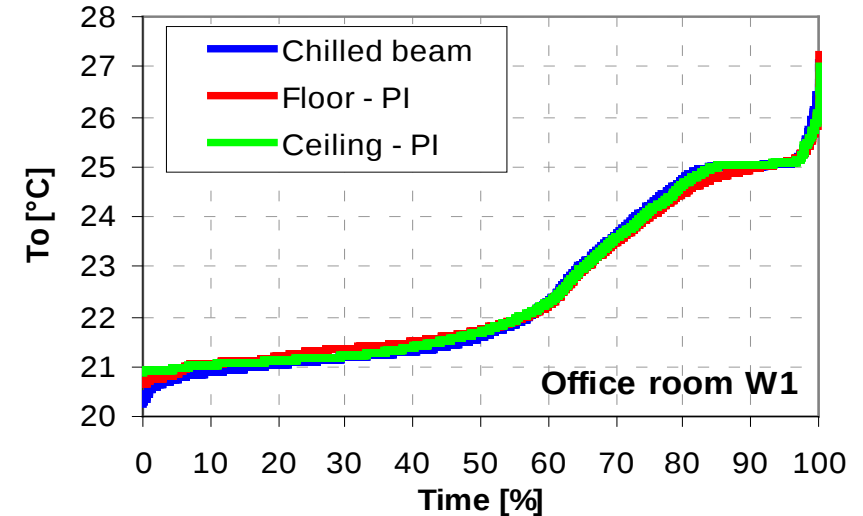
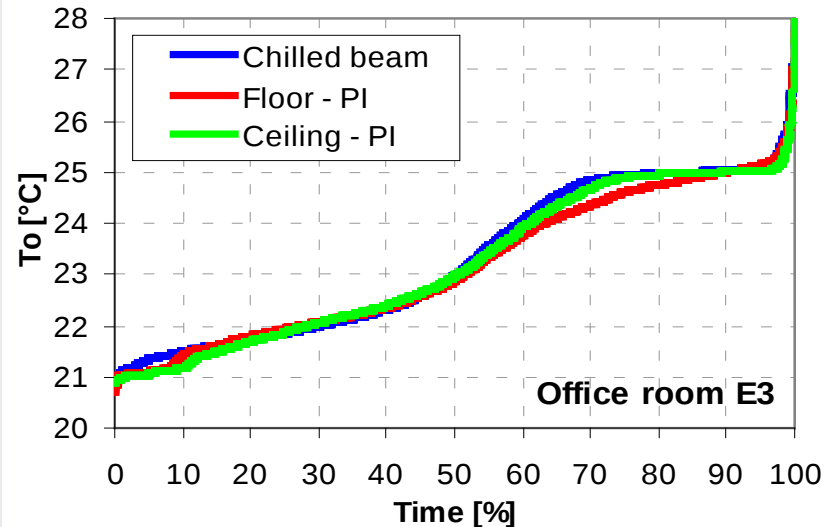
Delivered energy (kWh / m² a) in reference cases

(Cooling: delivered cooling energy, COP=1)





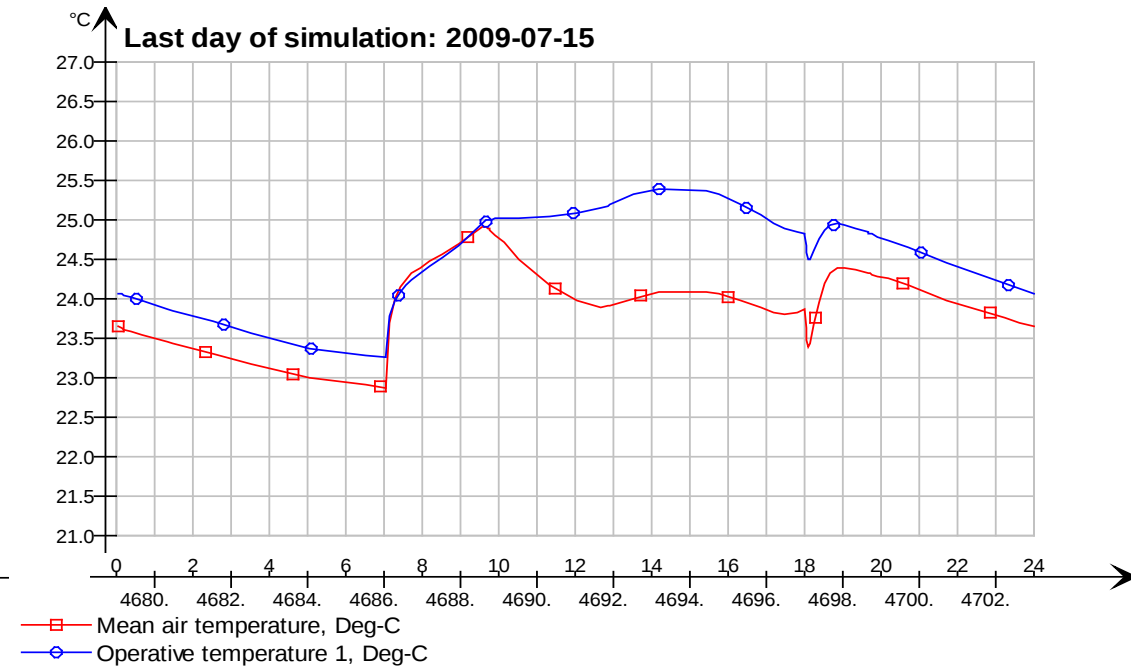
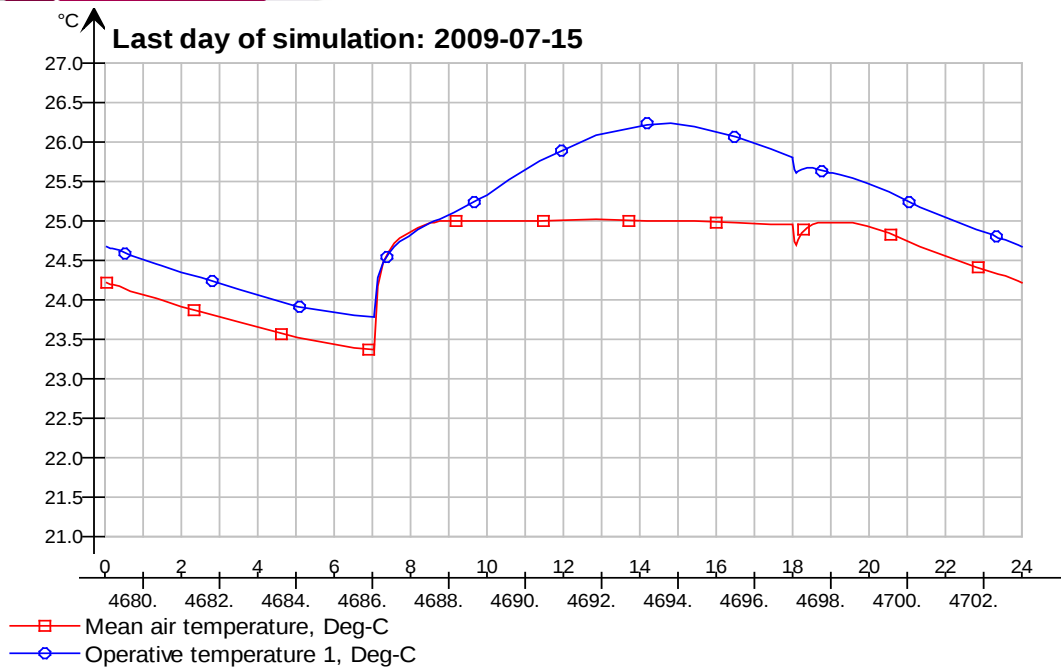
Operative temperature control and 12 h chiller operation time (24 h in ref. cases)





High loads / glazed facade / 60 W/m^2

Chilled beams



Air temperature control

- Temperature difference up to $1,5^{\circ}\text{C}$

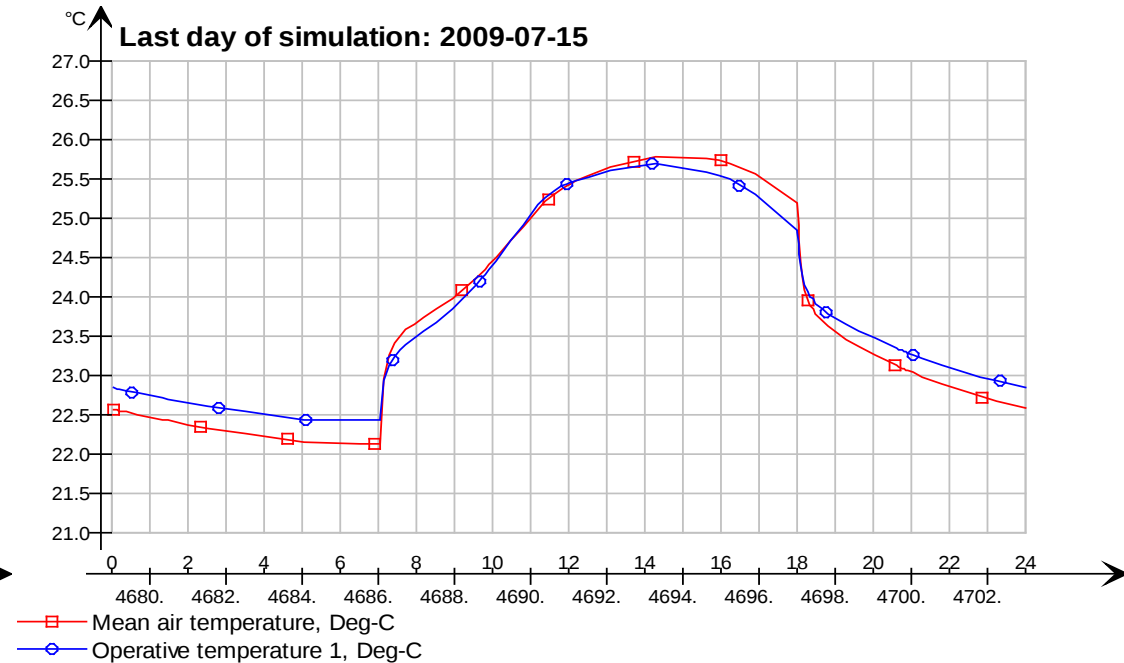
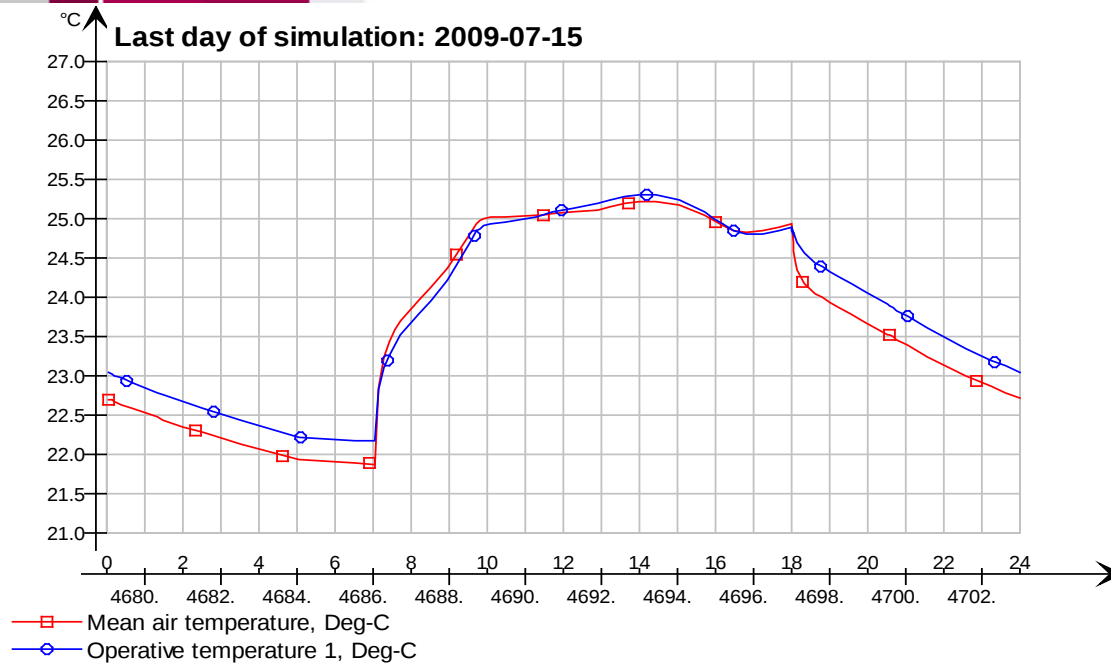
Operative temperature control





High loads / glazed facade / 60 W/m^2

Ceiling and floor cooling



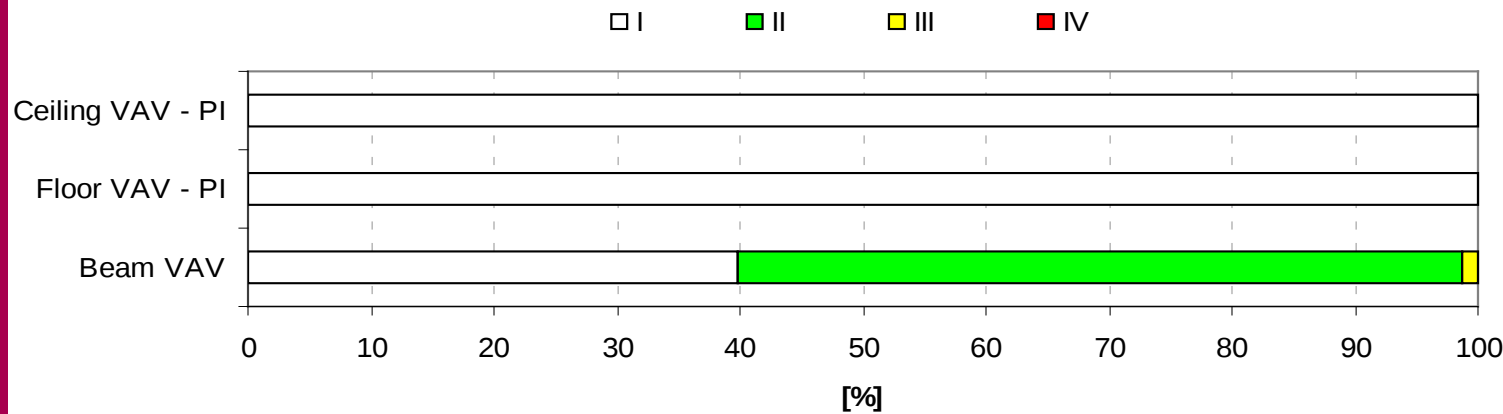
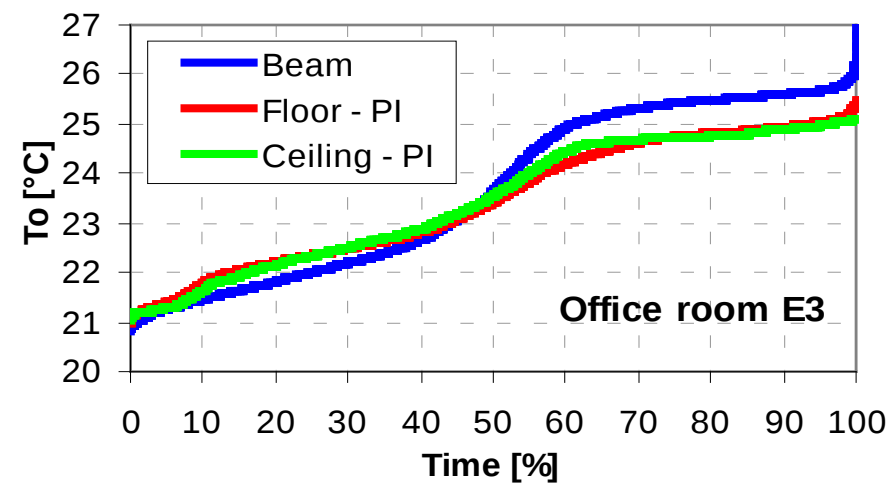
Ceiling cooling

- No significant difference between air and operative temperature control
- Slower response of floor heating

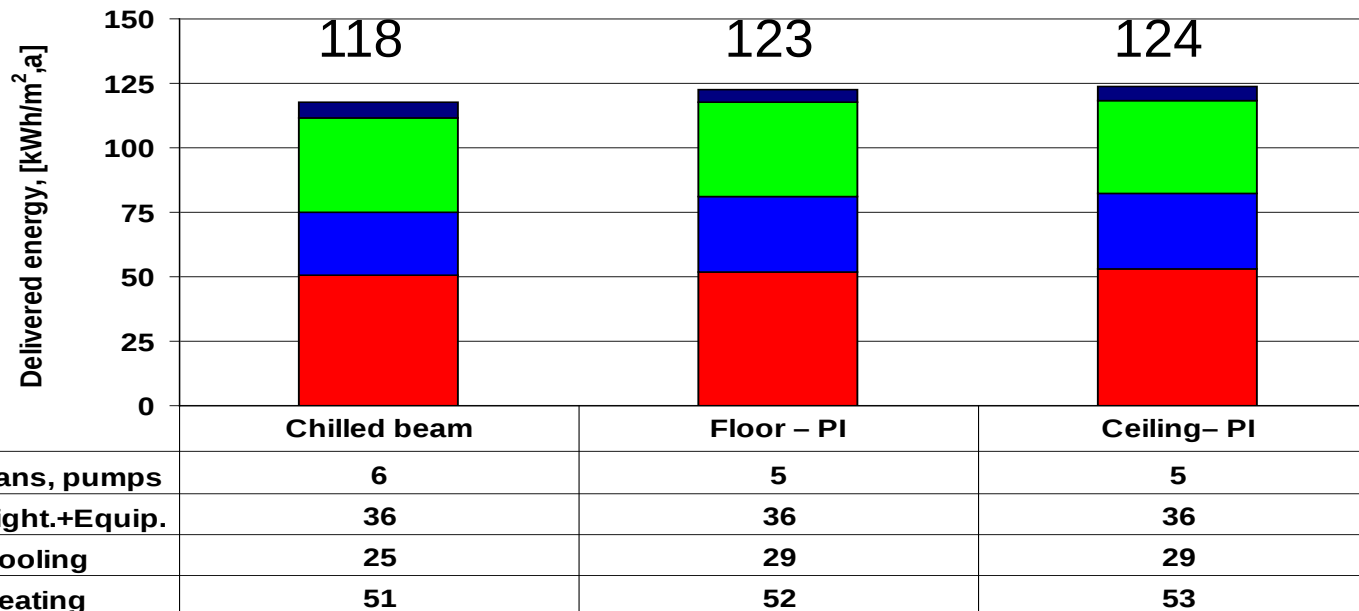
Floor cooling



Demand controlled ventilation (DCV)

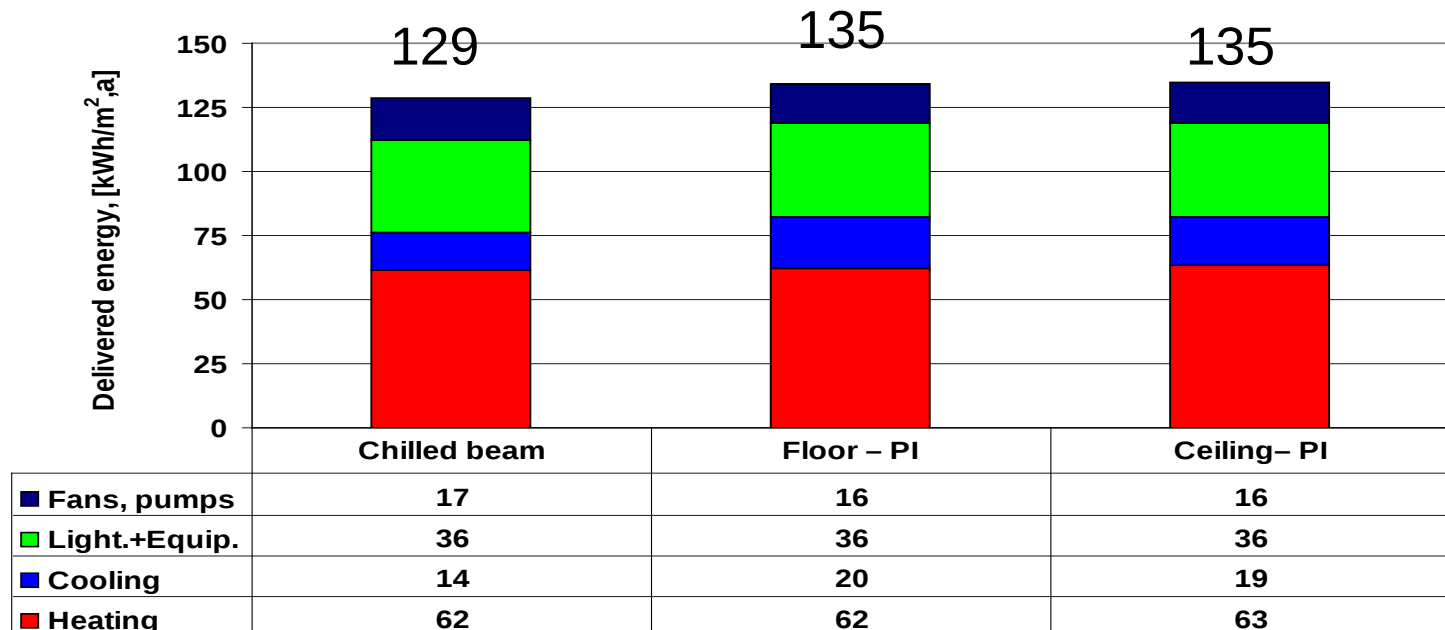
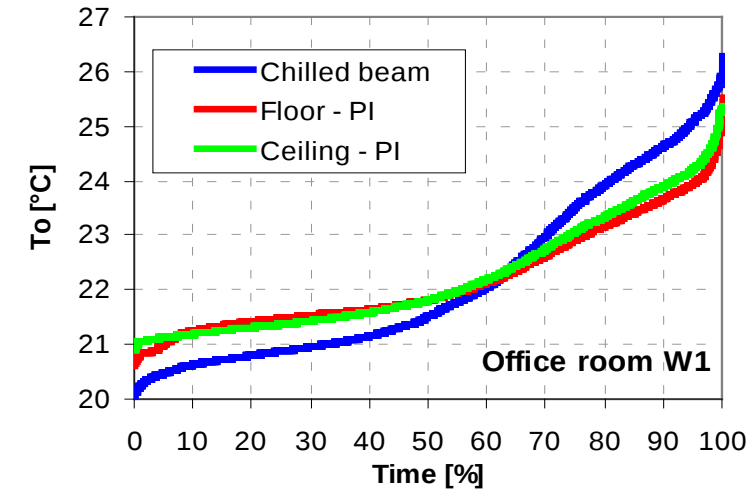
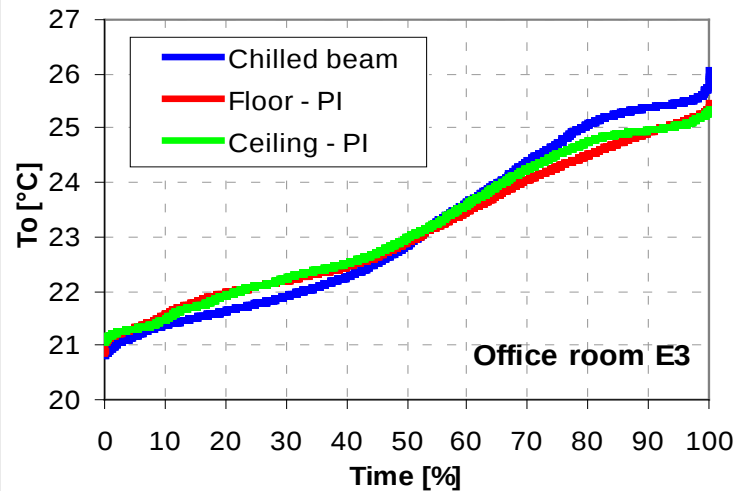


Thermal comfort footprint for cooling season (EN 15251:2007)





Night ventilation: no energy saving as increased fan energy compensated savings in cooling energy





Järeldused

Maximum cooling powers (air+water)

	Chilled beams				Floor cooling				Ceiling panels			
	CAV	DCV	NV	Oper.	CAV	DCV	NV	Oper.	CAV	VAV	NV	Oper.
Peak power, W/m^2	56	54	48	64	60	52	53	93	48	49	43	70

Põrand (TABS):

- TABS ei hoia energiat kokku, tasub kasutada, kui on tasuta vabajahutusenergiat
- sama efekt passiivjahutustaladega ja jahutuslaega, õhu liikumise kiirus S1

Aktiivsed jahutustalad

- Efektiivsed koos radiaatoritega
- Õhu liikumise kiirus S2, S1 raske saavutada

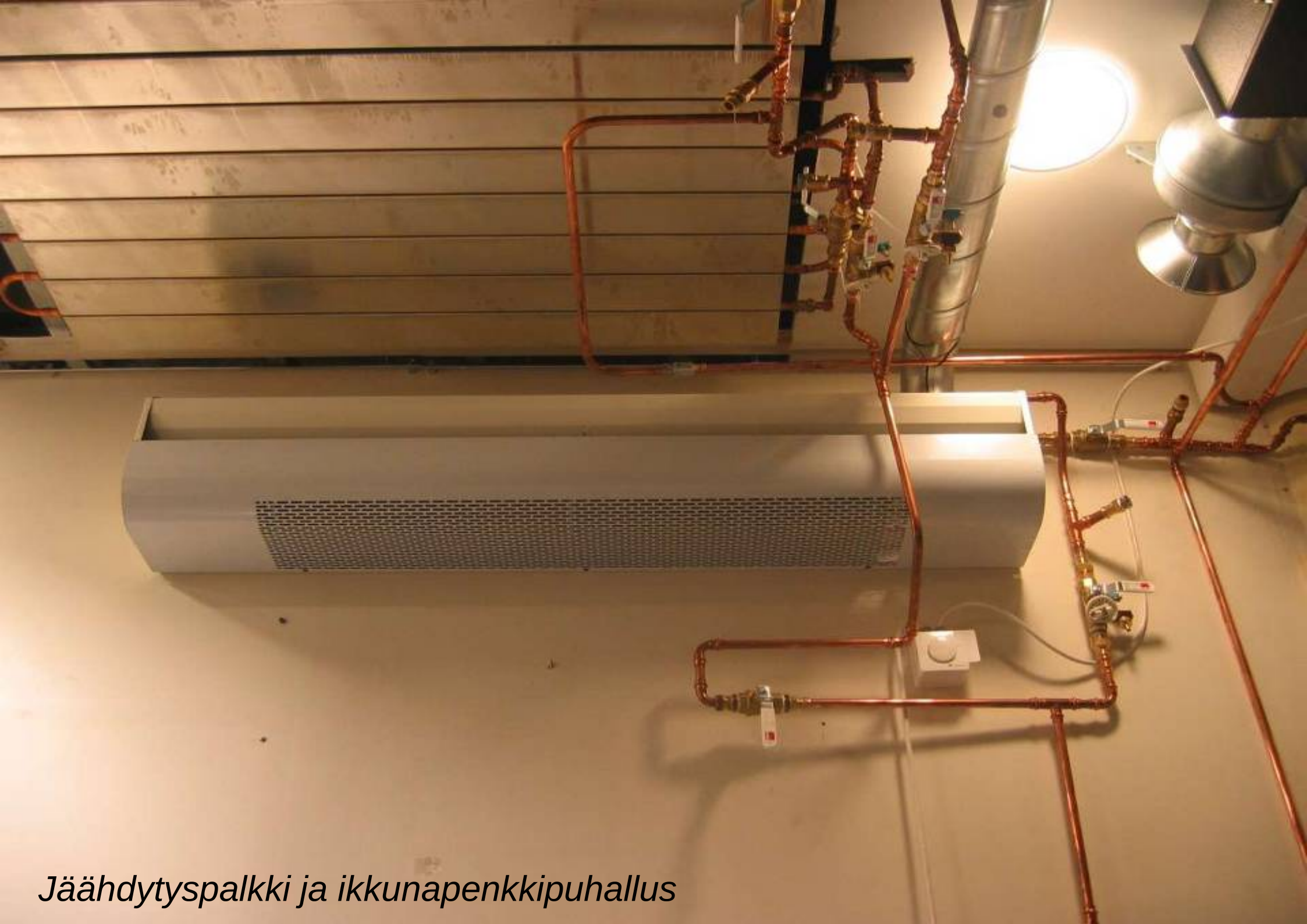
Laepaneel/jahutuslagi

- Võimaldab loobuda radiaatorküttest, tõmbusevaba – S1
- Nõuab väga head fassaadi, nurgaruumides võib vajada radiaatoreid



Näide üledimensioneeritud jahutustala ja laepaneeli mõõtmistest

- Jahutusvajadus 50 W/m^2



Jäähdytyspalkki ja ikkunapenkkipuhallus



Jäähdytyspalkki ja ikkunapenkkipuhallus

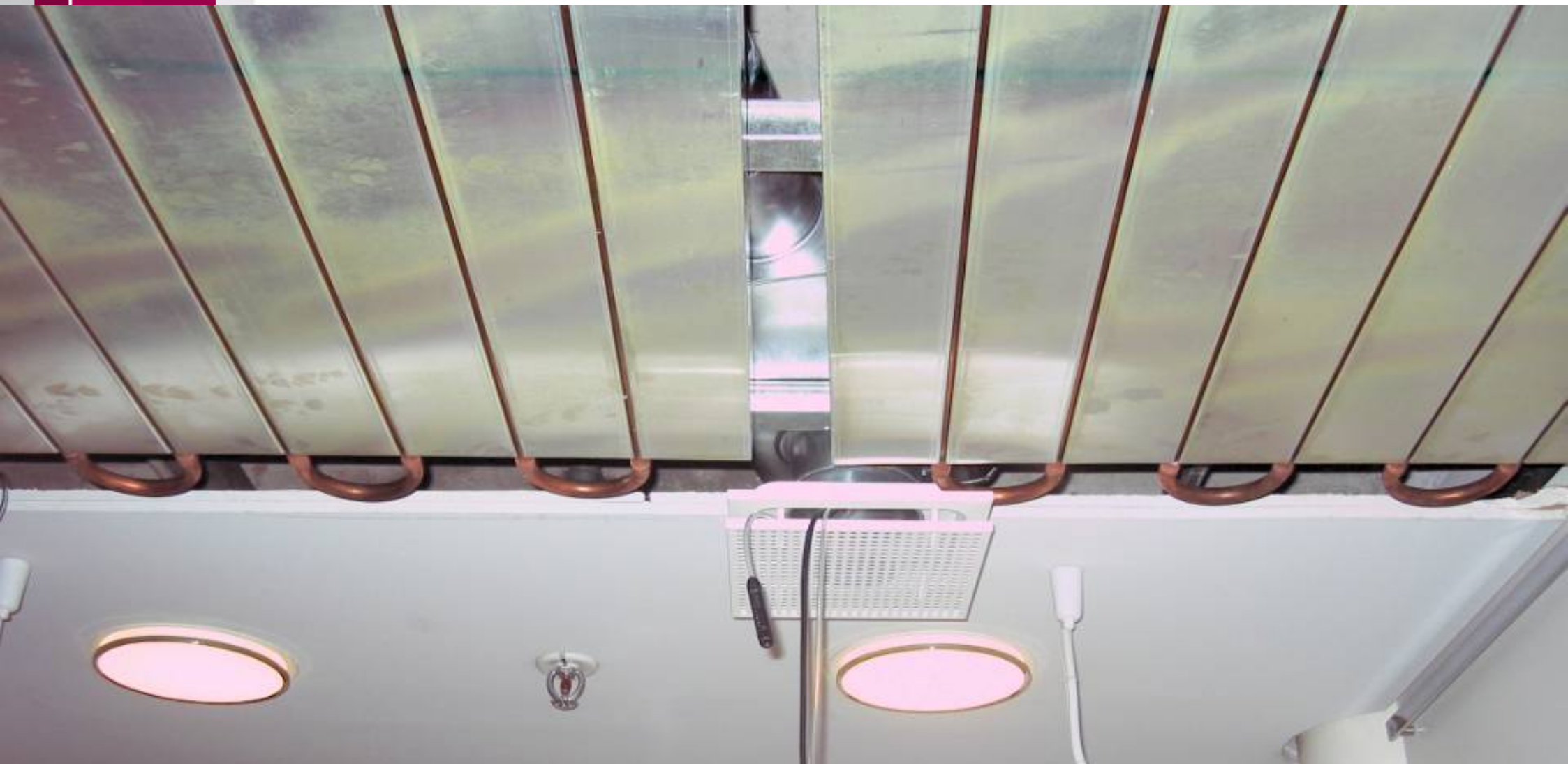


Jäähdytyskatto ja rakohajotin





Jäähdytyskatto ja kattohajotin





Mittaus tilanne

Huoneilman lämpötila 26 – 28°C
Tuloilman lämpötila 21 – 23°C
Jäähdytysteho (ilma+vesi) 300 – 530 W

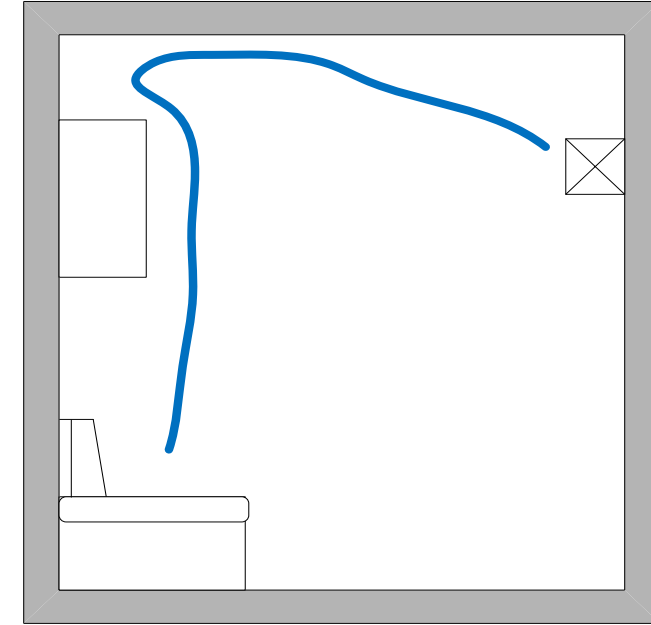
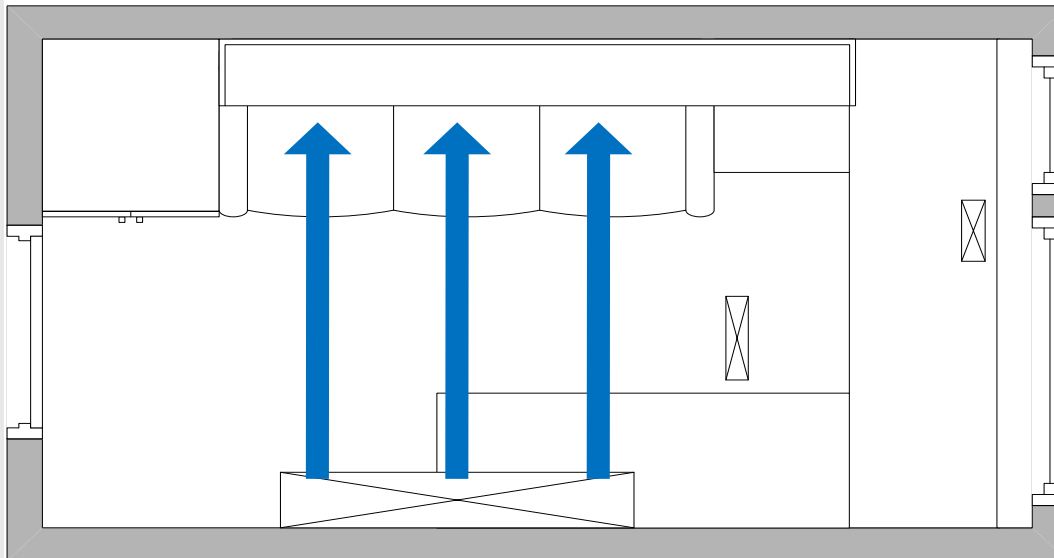
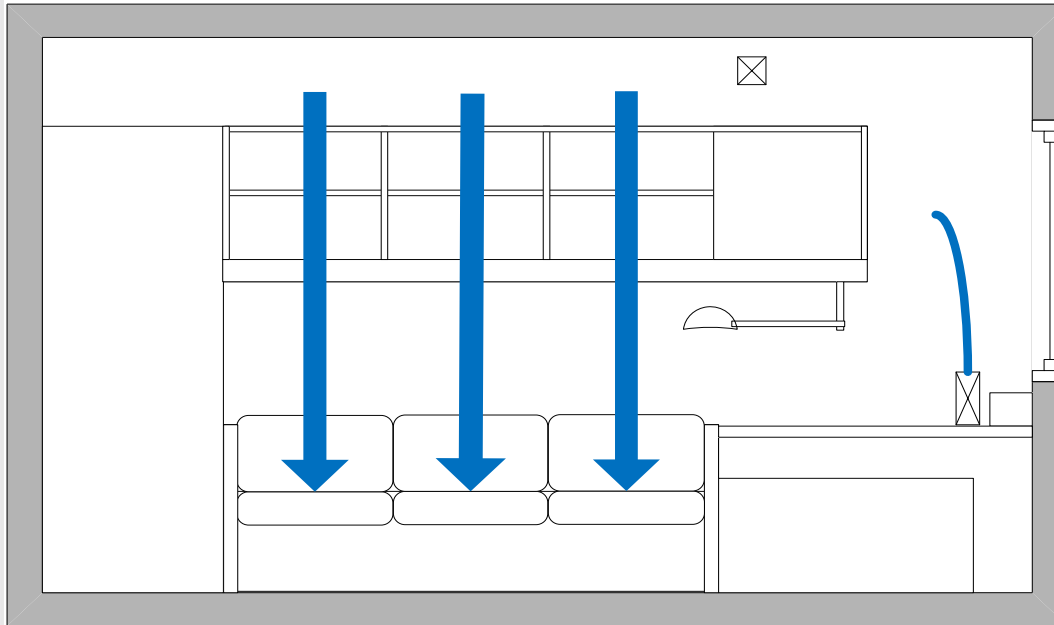
Sisäiset lämpökuormat henkilön,
PC:n ja television kuvaamiseksi

	Sähköteho W
pöydällä ikkunan edessä	139
työpöydän edessä	73
paneeli seinällä	180
paneeli pöydällä	100
Mittauskannettava	38
Yhteensä	530

Lisäksi nykyinen valaistus n. 10 W/m²



Jäähdytyspalkki ja ikkunapenkkipuhallus (1 / 3)



Vetoa sohvalla!

varauksin S2

Jäähdytyspalkki ja ikkunapenkkipuhallus (2 / 3)



Lämpötilat mittausten aikana

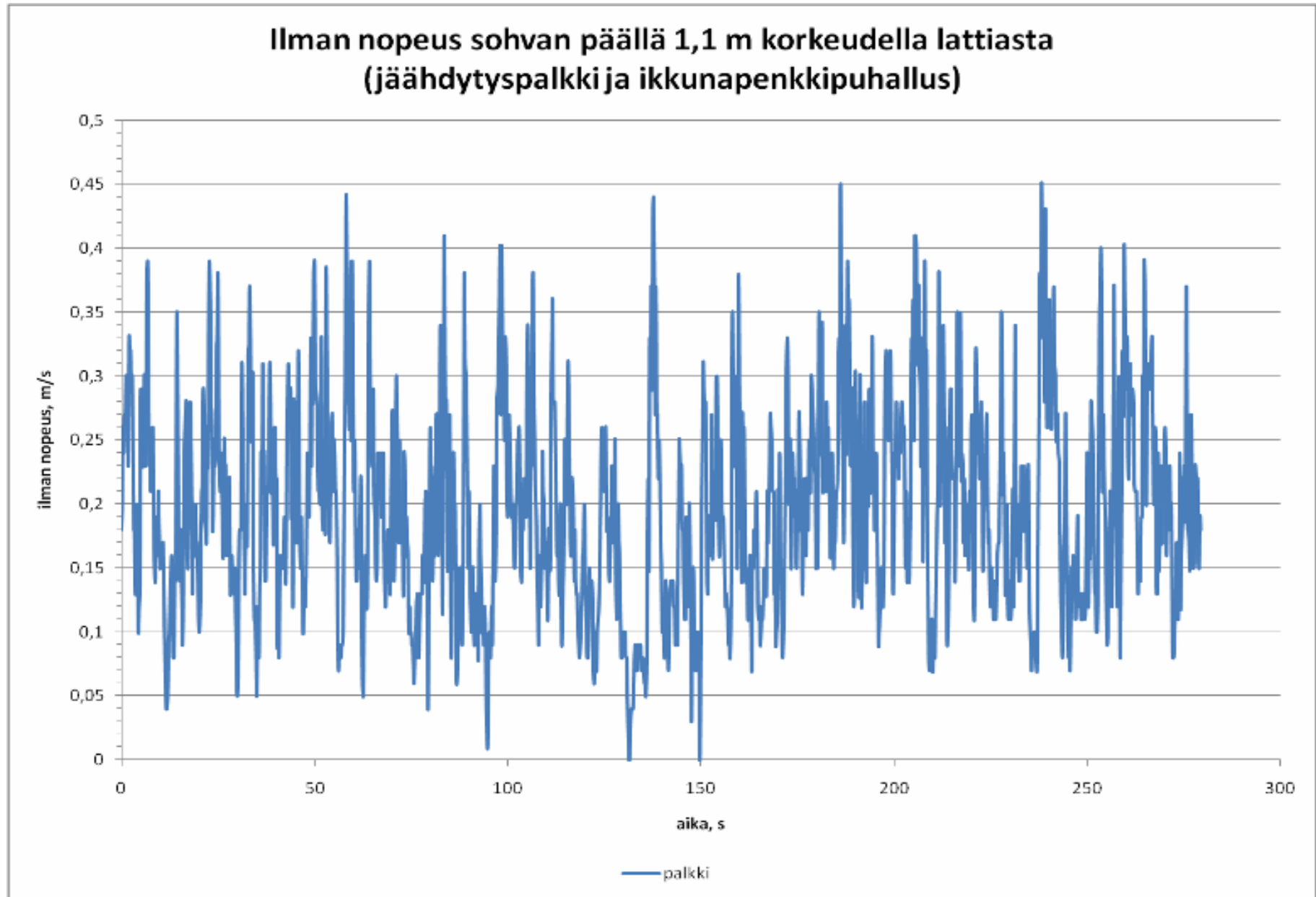
	°C
huoneilma	28,5
ilma palkille	21,0
ilma palkilta	19,9
tuloilma	22,7
vesi palkille	18,4
vesi palkilta	18,8

tuloilmalla tuotu jäähdytysteho	180 W
palkin jäähdytysteho (taulukko)	350 W



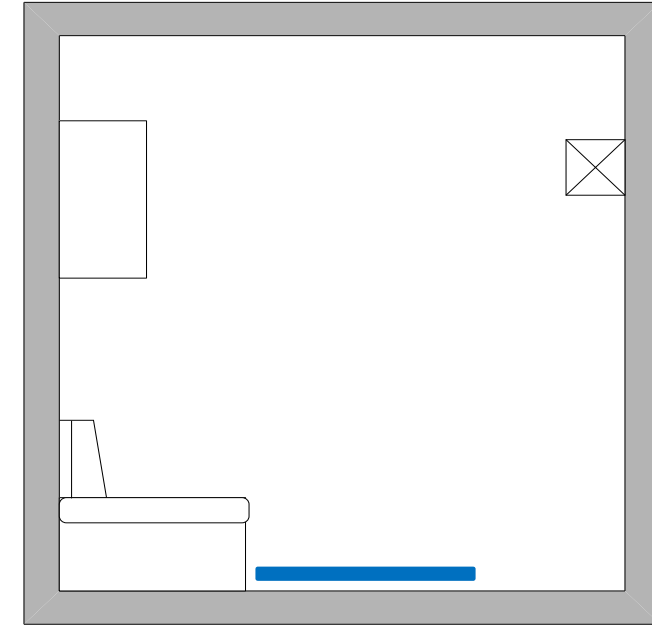
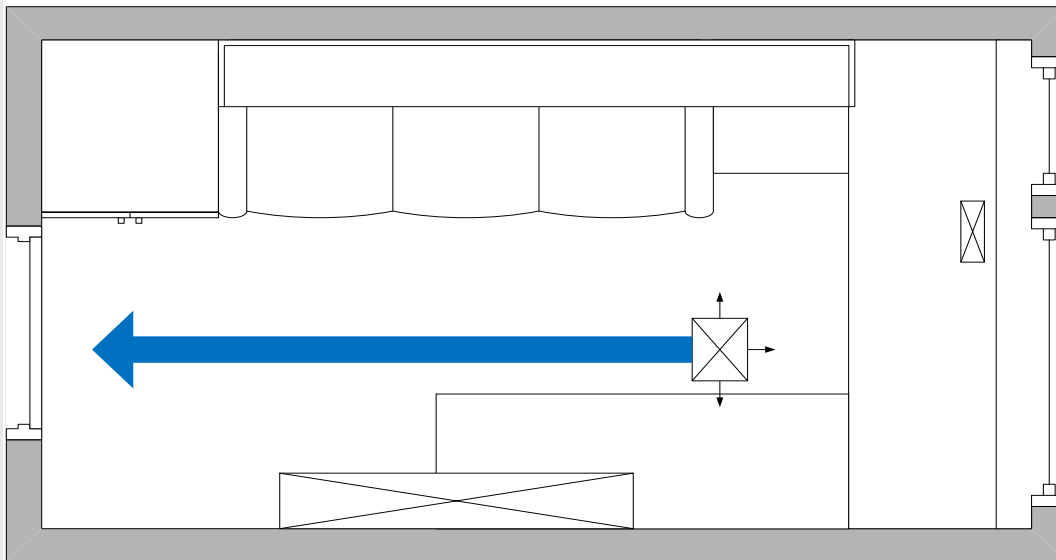
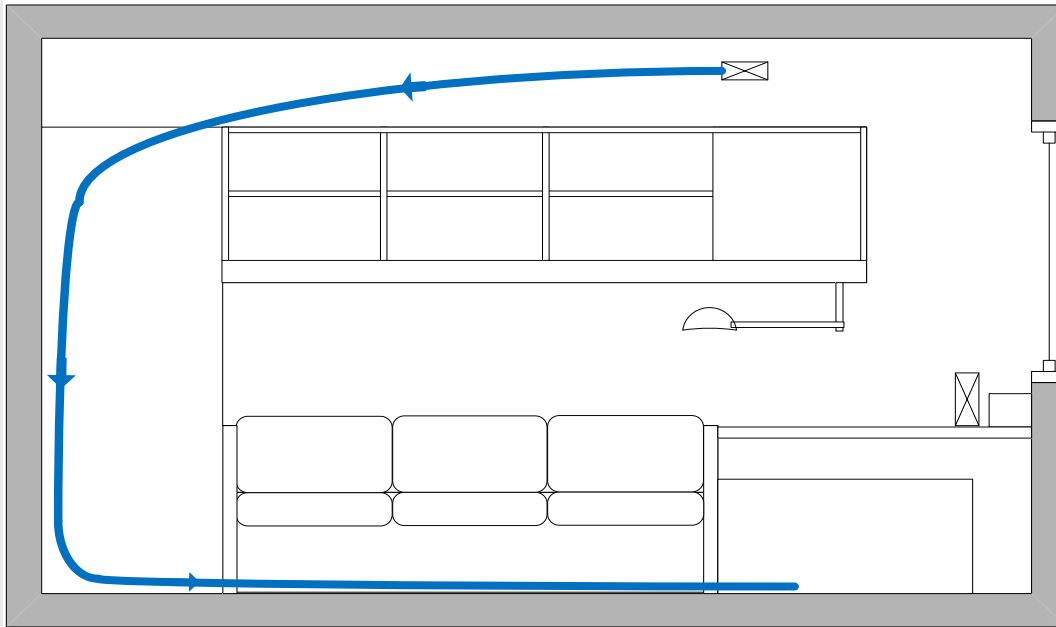
Jäähdytyspalkki ja ikkunapenkkipuhallus (3 / 3)

- 0,23 m/s + suuri nopeuden vaihtelu
- Suuri vetoriski vaikka täyttää S2 vaatimuksen (0,25 m/s)





Jäähdytyskatto ja rakohajotin (1 / 4)



*Vähäistä nilkkavetoa
sohvan edessä*

S2

Jäähdytyskatto ja rakohajotin (2 / 4)

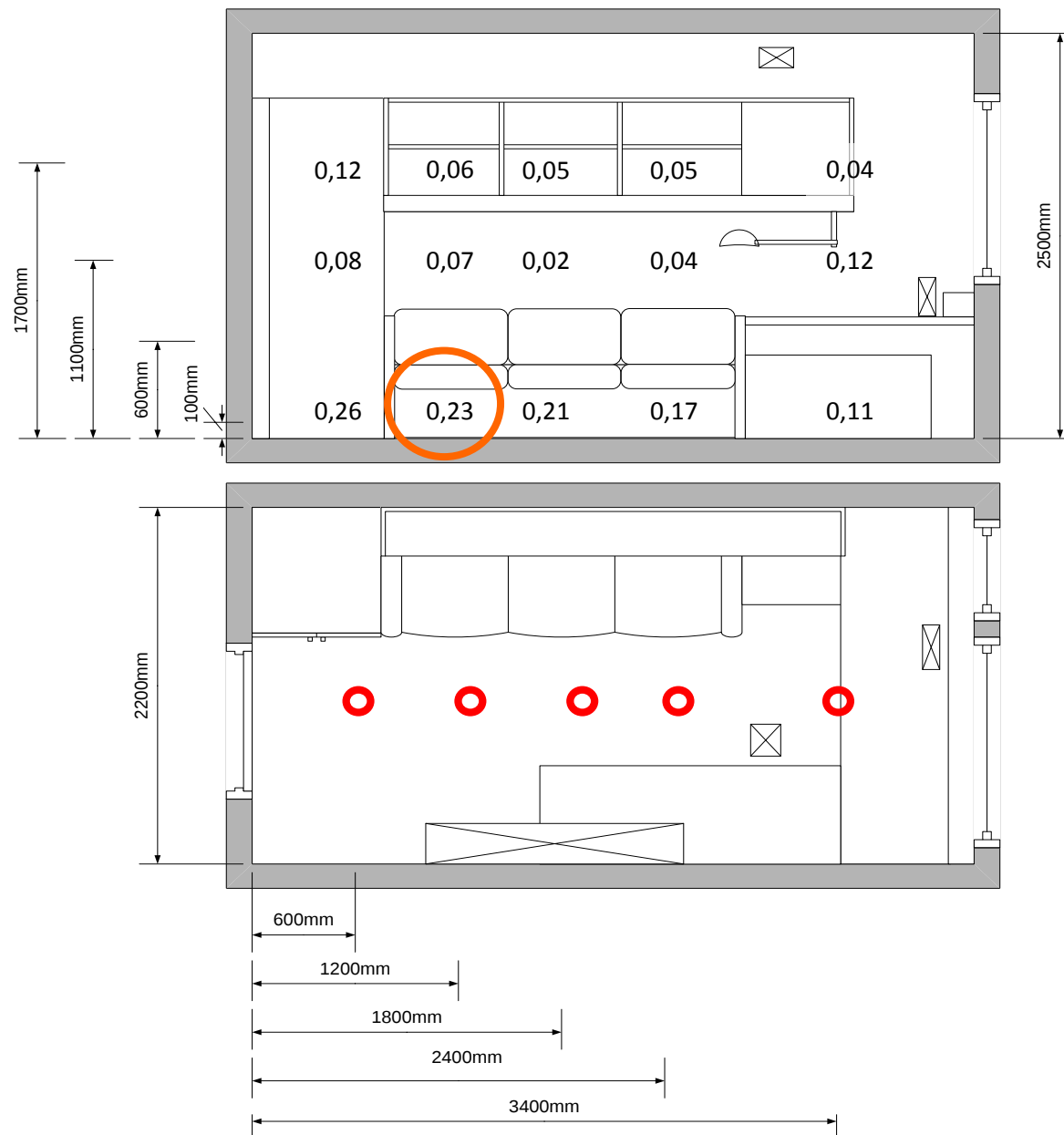


Lämpötilat mittausten aikana

	°C
huoneilma	26,7
tuloilma	22,1
vesi kattoon	19,0
vesi katosta	19,7

tuloilmalla tuotu jäähdytysteho	110 W
katon jäähdytysteho (taulukkoarvo)	150 W
katon jäähdytysteho (vesivirrasta mitattu)	270 W

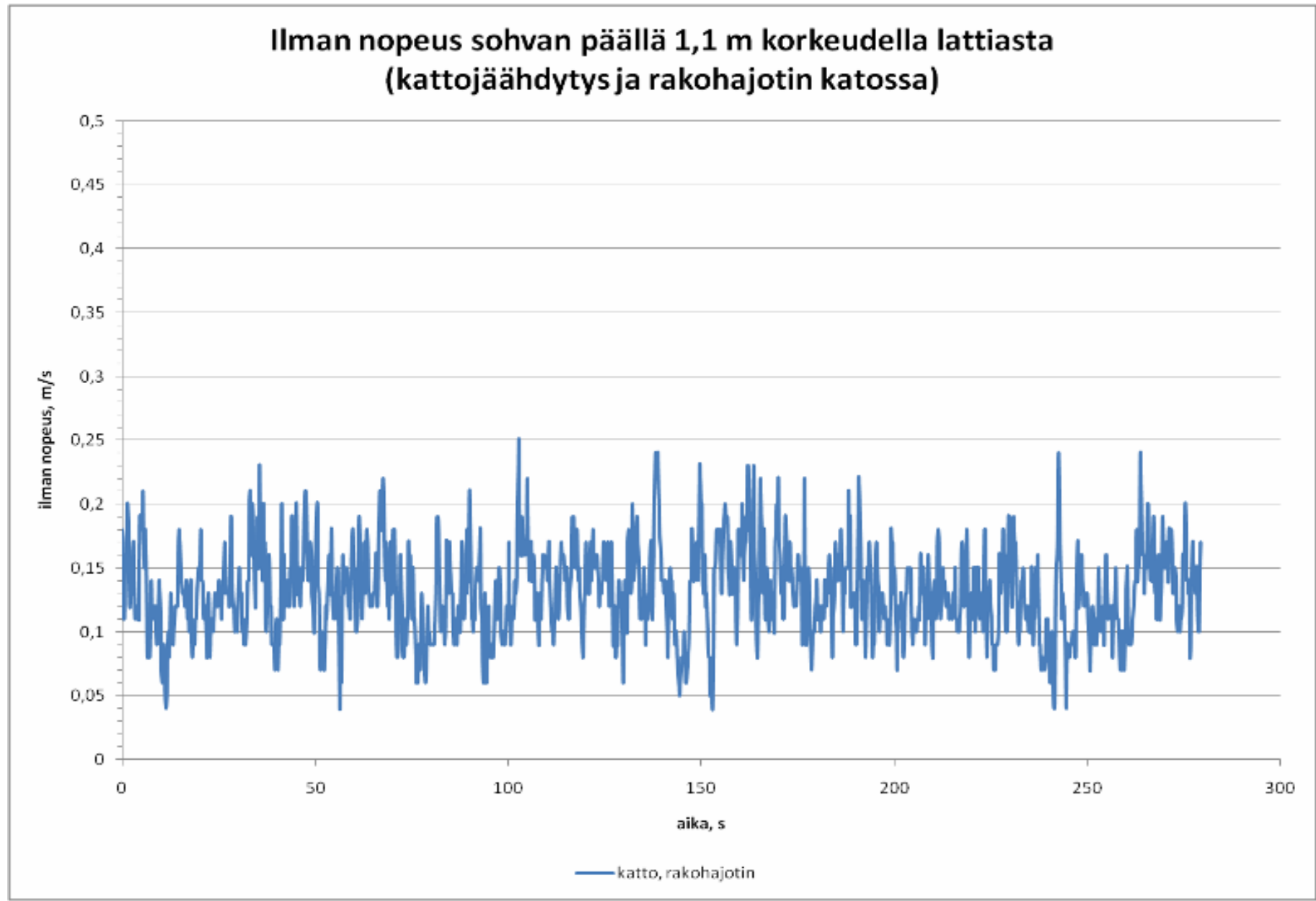
Jäähdytyskatto ja rakohajotin (3 / 4)



Jäähdytyskatto ja rakohajotin (4 / 4)

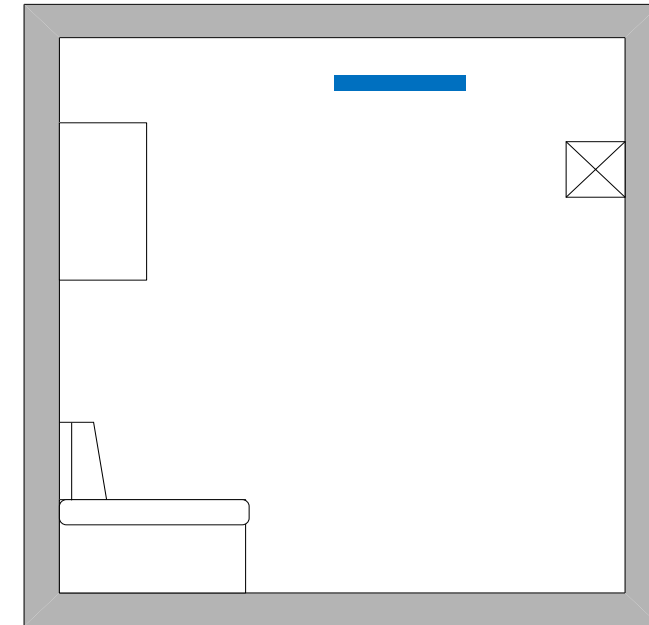
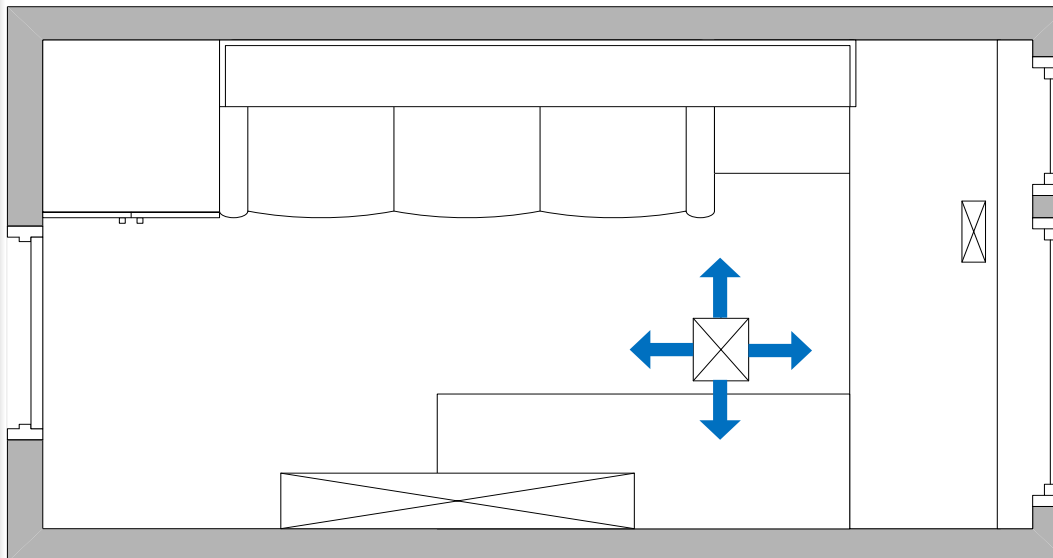
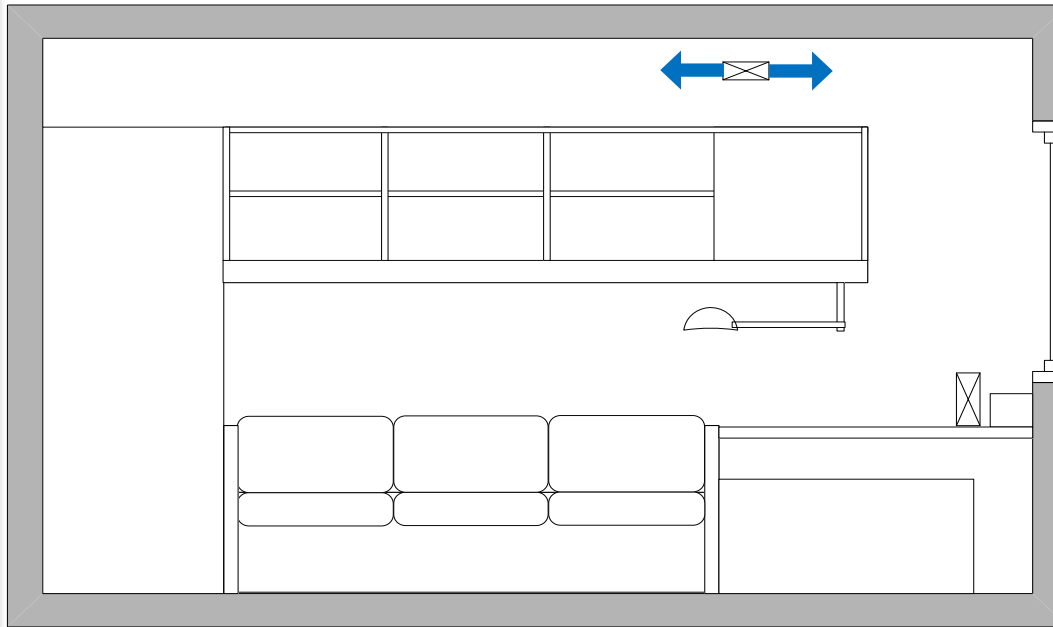


- Veturiski olemassa vaikka nilkan kohdalla voidaan hyväksyä noin 1,5 kertainen nopeus niskaan verrattuna





Jäähdytyskatto ja kattohajotin (1 / 3)



Täysin vedoton

S1

Jäähdytyskatto ja kattohajotin (2 / 3)



Lämpötilat mittausten aikana

	°C
huoneilma	25,1
tuloilma	21,2
vesi kattoon	18,8
vesi katosta	18,9

tuloilmalla tuotu jäähdytysteho	95 W
katon jäähdytysteho (taulukkoarvo)	130 W
katon jäähdytystehon taulukkoarvo huonelämpötilalla 28,5 °C	210 W

Jäähdytyskatto ja kattohajotin (3 / 3)



- Täysin vedoton kaikissa mittauspisteissä, $<0,1$ m/s
- S1-ratkaisu

