A Baseline Lighting Retrofit: Measurements and User Experiences at Horsens Town Hall

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Building Description

The present Horsens Town Hall is a modern red-brick building with approximately 20,800 m^2 floor area across three main floors of administrative offices and a basement containing archives, a fitness center and technical installations.

It was designed by Danish architects Knud Blach Petersen, Niels Primdahl and Erich Weitling and completed in 1985.

It is located at the Town Hall Square (Rådhustorvet) just south of the old town hall and main pedestrian shopping street in Horsens.

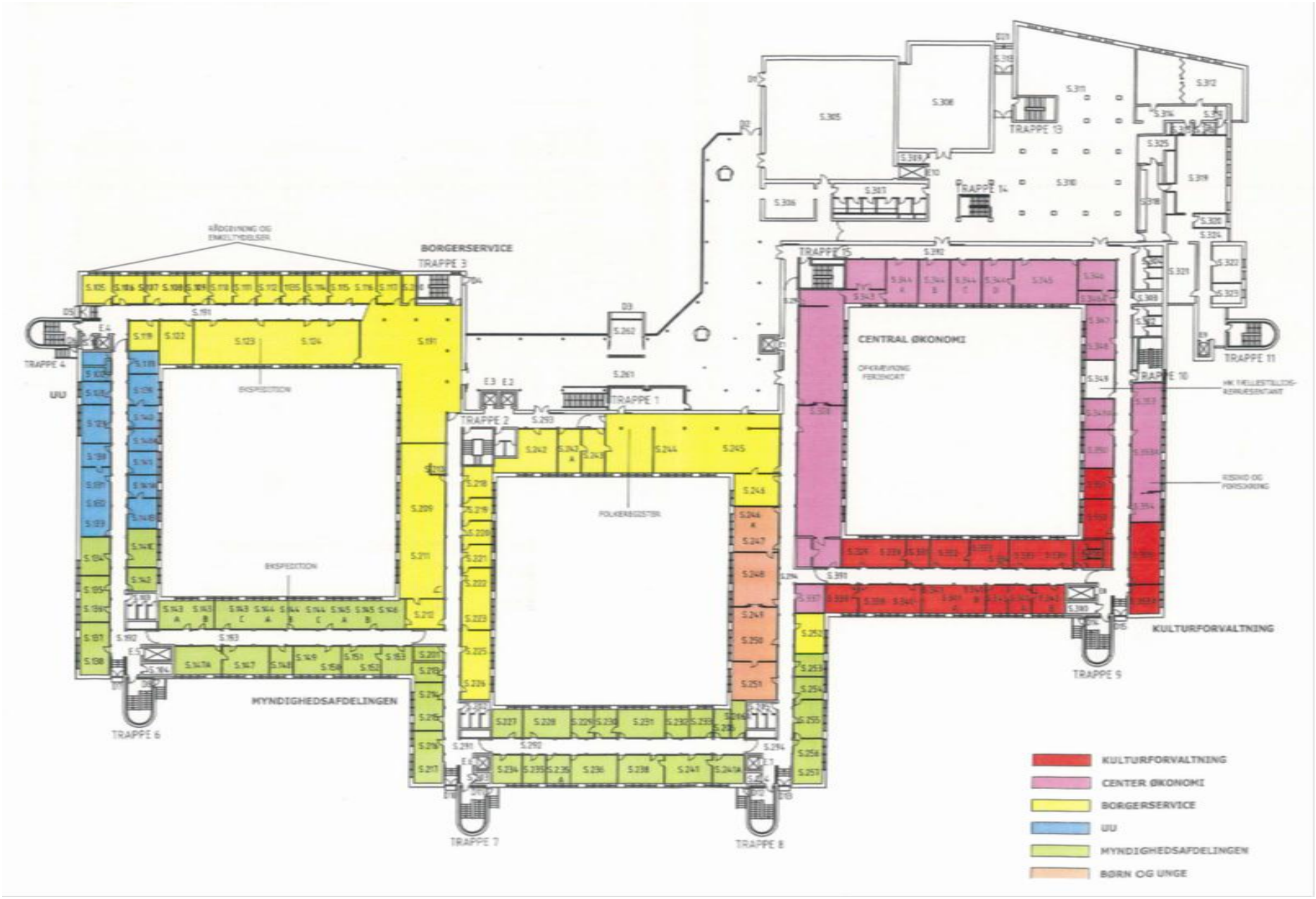
It consists of three main building blocks each surrounding a central courtyard, a glazed entrance lobby and an annex to the north-east containing the council chamber, event and meeting rooms, cafeteria and wedding room.

The main exterior facades and the facades facing into the courtyards have relatively low window bands in viewing height for seated employees with double glazing and integrated venetian blinds between the glazing layers. Some windows have additional interior fabric blinds for glare control.

Horsens has ca. 85,000 inhabitants


HØRSENS KOMMUNE

HØRSENS KOMMUNE


BORGERSERVICE
TRAPPE 3
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TRAPPE 1
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TRAPPE 6
TRAPPE 7
TRAPPE 8
TRAPPE 10
TRAPPE 11
TRAPPE 13
TRAPPE 14
TRAPPE 15
CENTRAL ØKONOMI
KULTURFORVALTNING
MYNDIGHEDSAFDELINGEN
EKSPEDITION
FOLKEREGISTER
KULTURFORVALTNING
CENTER ØKONOMI
BORGERSERVICE
UU
MYNDIGHEDSAFDELINGEN
BØRN OG UNGE

Wedding Room (l) and Cafeteria (r)


Mayor’s Office

Aims of Lighting Retrofit

Energy savings

- 40-50% lighting energy per year

Better working environment

- Improved well-being
- Higher concentration

Sustainable performance

- CO_2 reduction, less waste

Exchange of ca. 1600 luminaires in offices from fluorescent to LED panels

Exchange of additional ca. 1300 fluorescent lamps for LED lamps in hallways, foyer and service rooms

Aims of Case Study

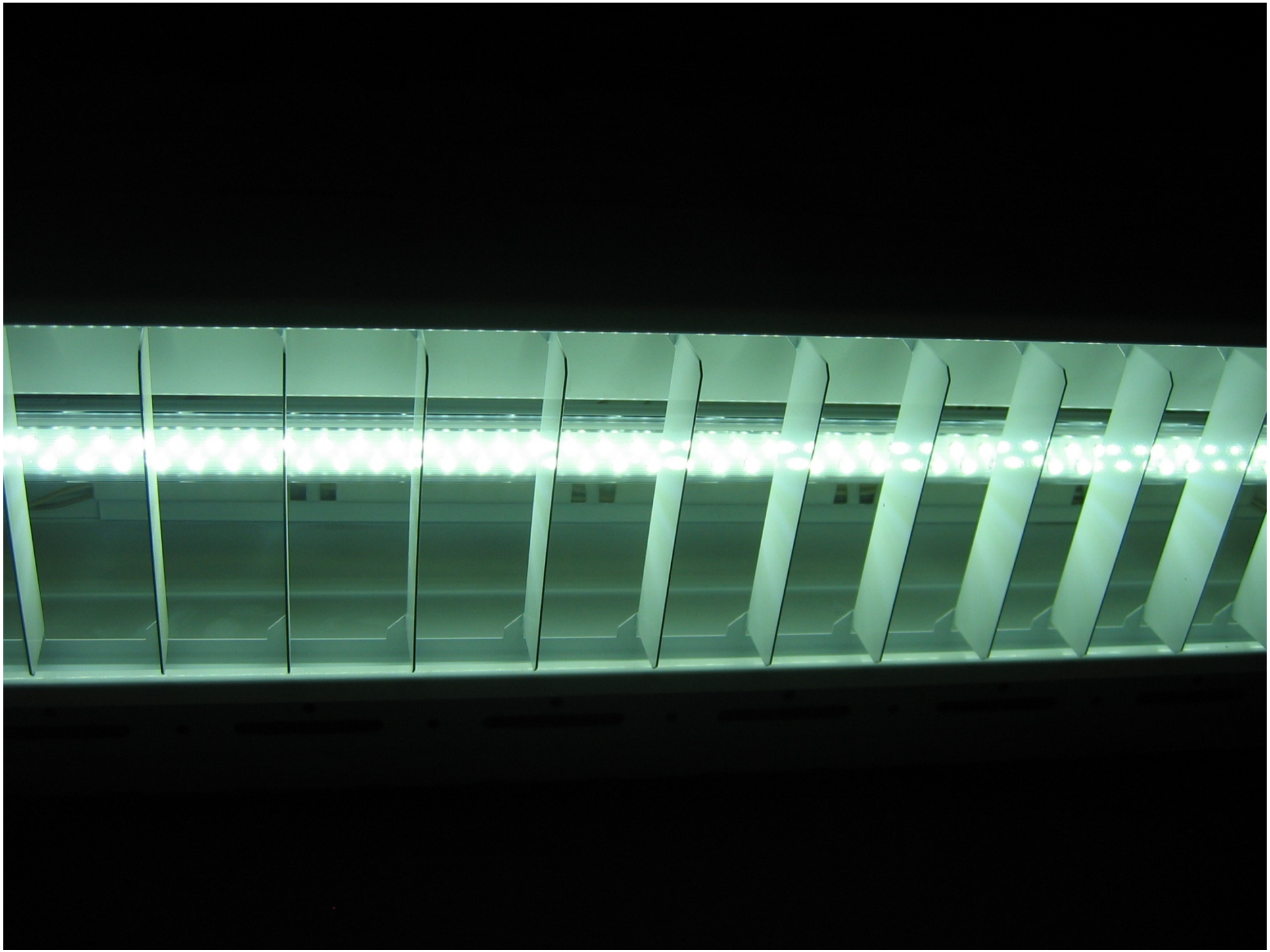
Gaining experience

- Is a budget (very basic) lighting retrofit useful?
  - How much improvement can be gained and where (occupant well-being, energy, sustainability)?
  - Are there negative or positive side-effects?
- Should other measures be considered?
  - Complete lighting re-design
  - Daylighting improvements
  - Occupancy-off sensors
  - Dimming
- What would such additional measures cost?


TESS


6000K


2700K




6000K
2700K


4200K


S.212
S.223
S.225
S.201
S.213
S.226
S.214
S.202
S.215
S.227
6000K
LED panels @ 6000K

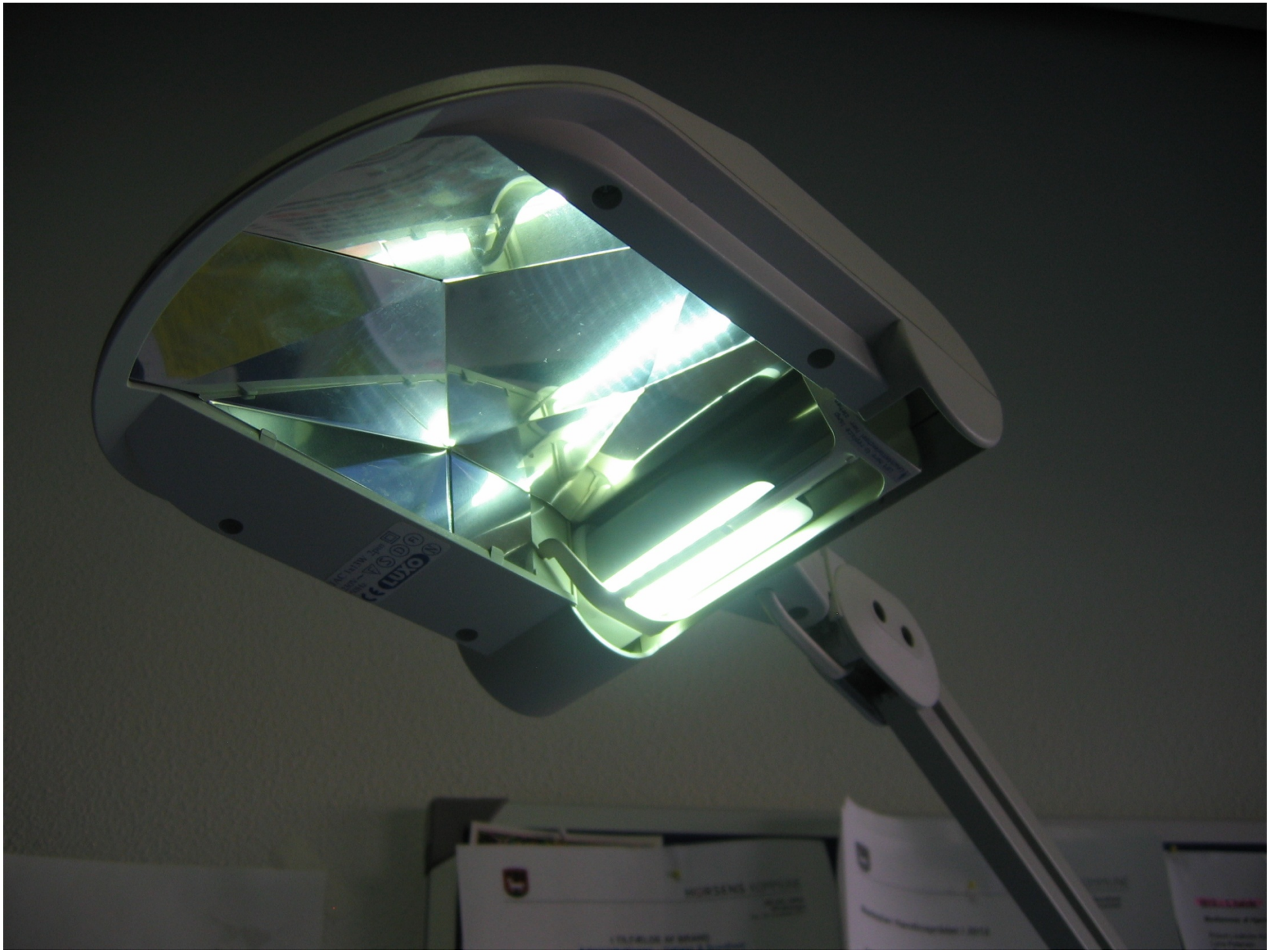

6000K


2700K

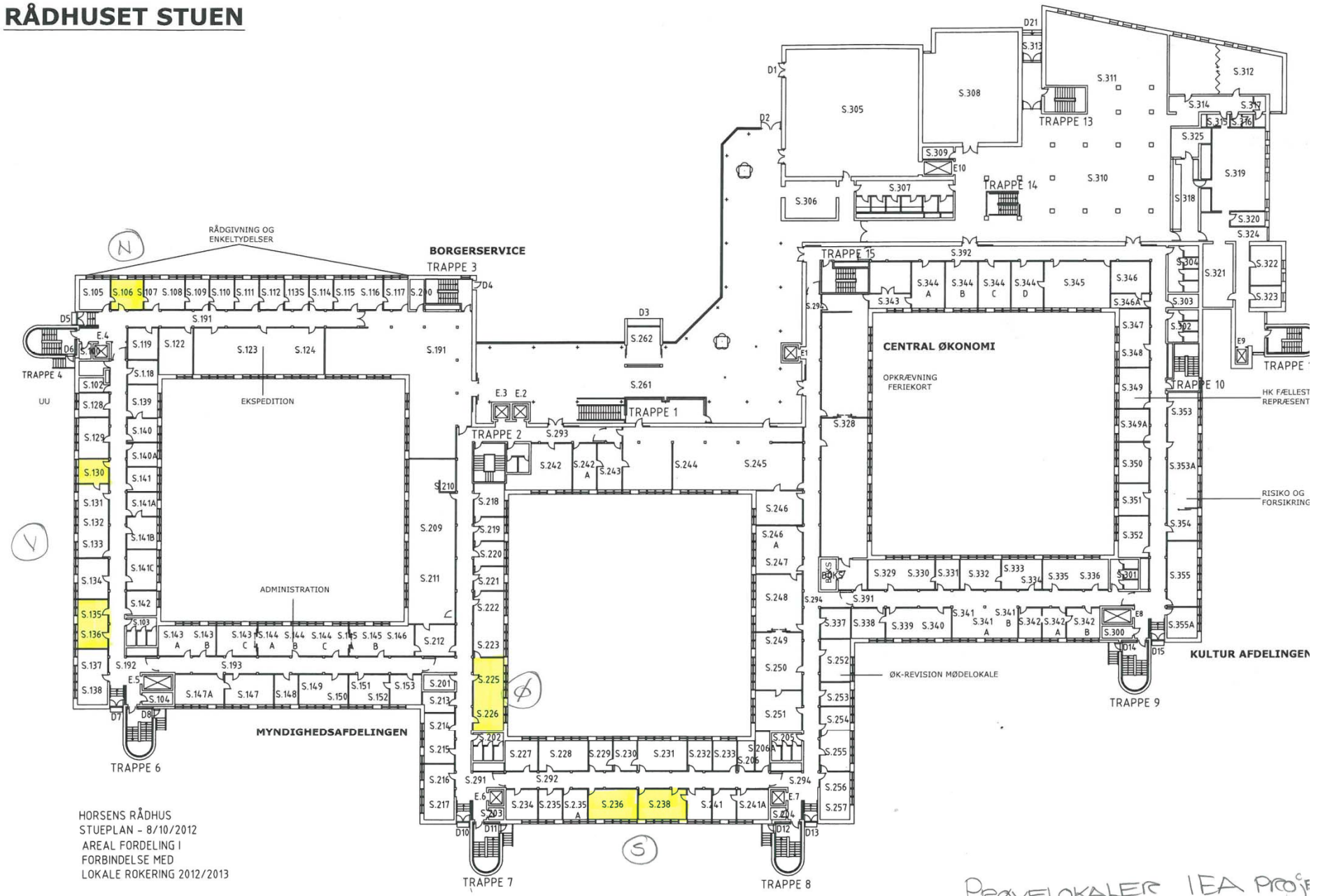

5500K


4200K


6000K



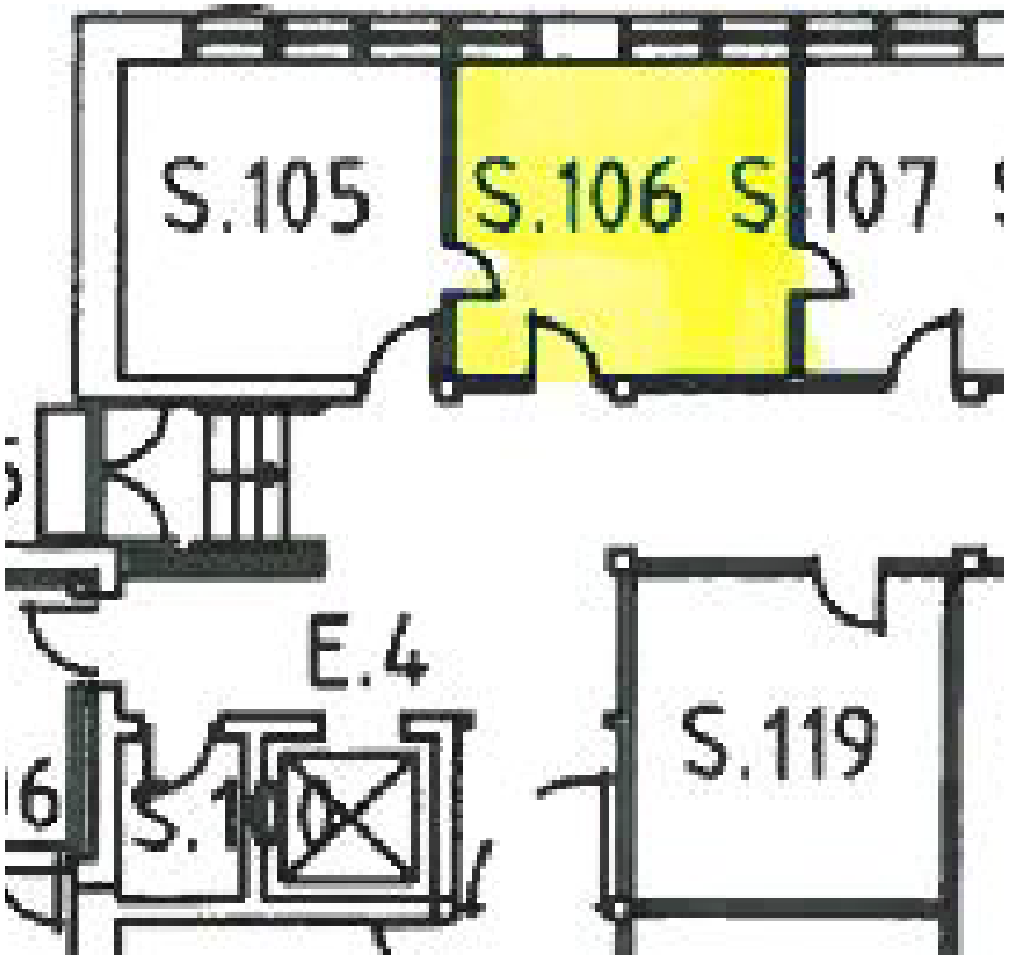
RÅDHUSET STUEN



HORSENS RÅDHUS
STUEPLAN - 8/10/2012
AREAL FORDELING I
FORBINDELSE MED
LOKALE ROKERING 2012/2013

PRØVELOKALER IEA PROJ
HORSENS RÅDHUS

Room S.106 (North)

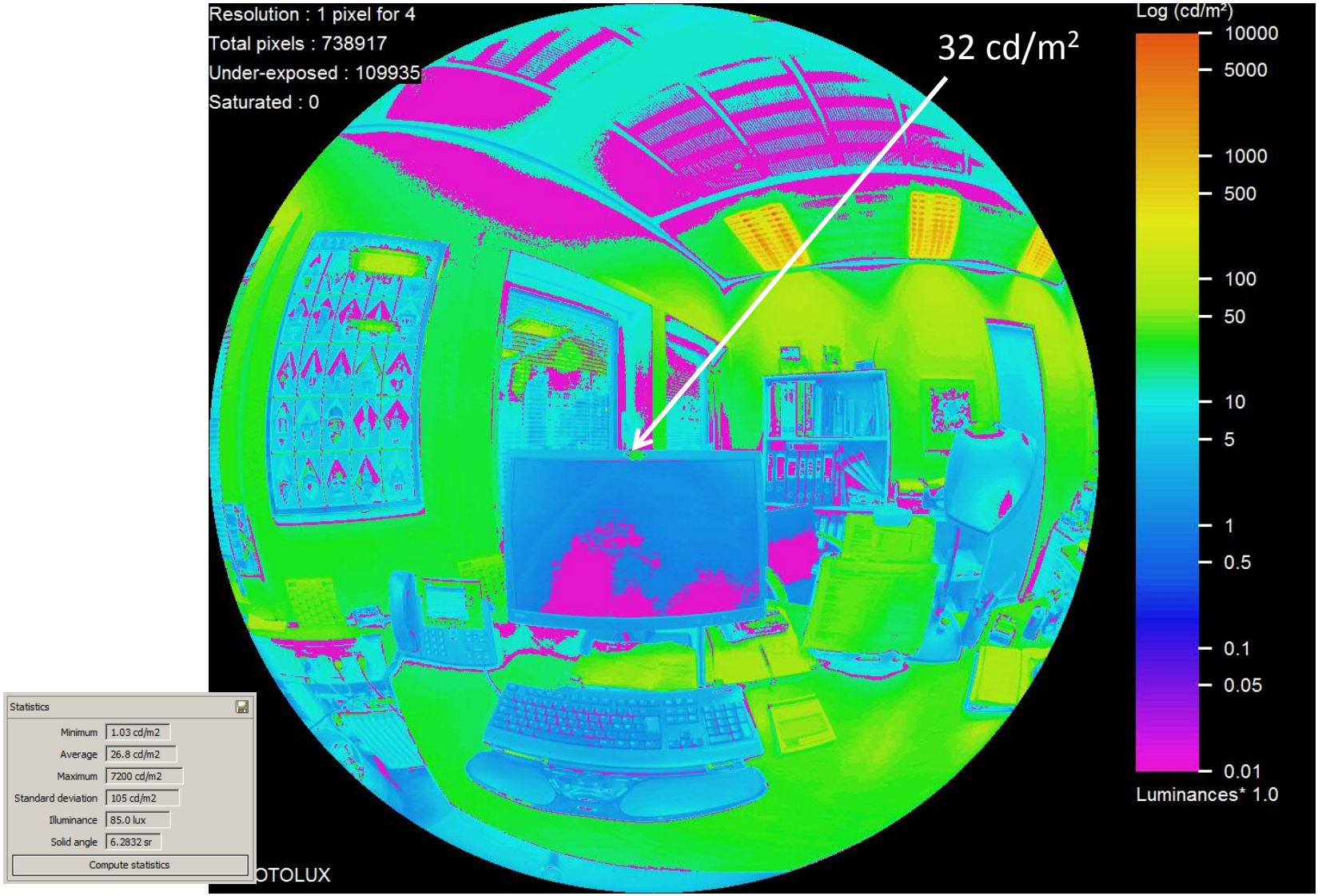


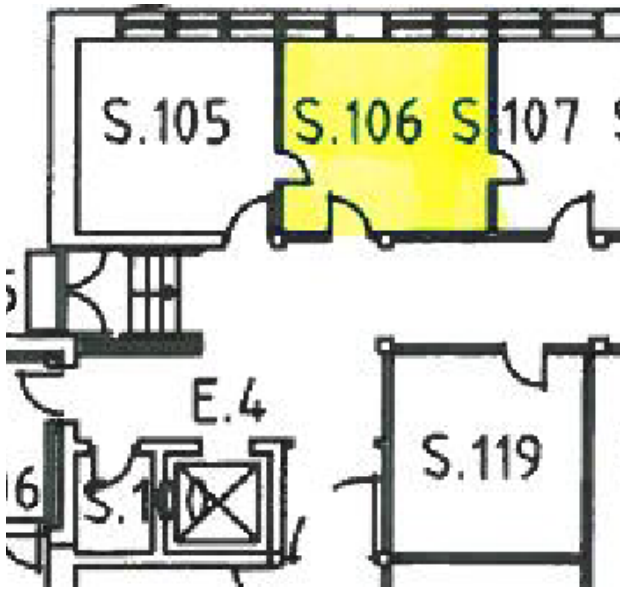

TOPPEN AF HORSENS
2012


32 cd/m²

Room S.106 (North)

6 x AEG Fluorescent Luminaires 2700K: $E_{h\ ave}$ = 350 Lux

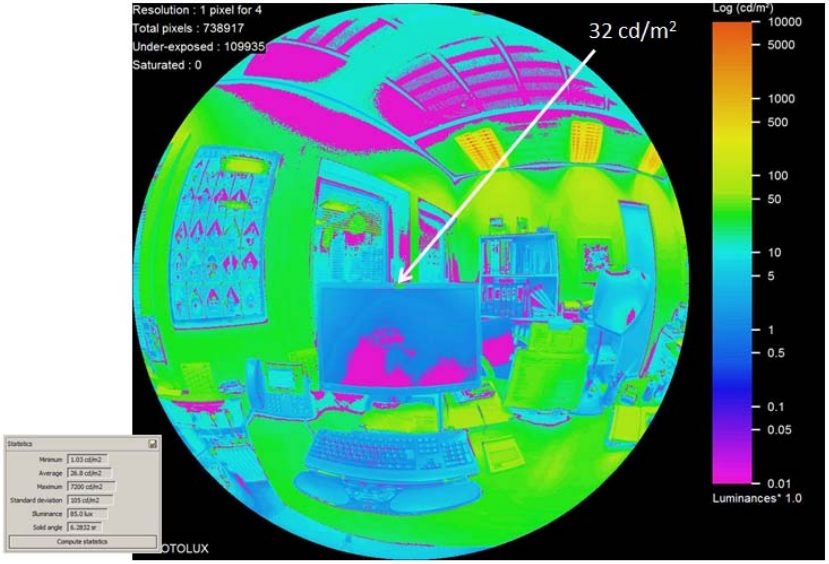




Single-person office was converted into meeting room

Room S.106 (North)

6 x AEG Fluorescent Luminaires 2700K: $E_{h\ ave}$ = 350 Lux



Example Daylighting Performance

Room 1.06 (North into Square)

- Does not reach 3%
- Drops below 2% at window

Room 1.36 (West into Park)

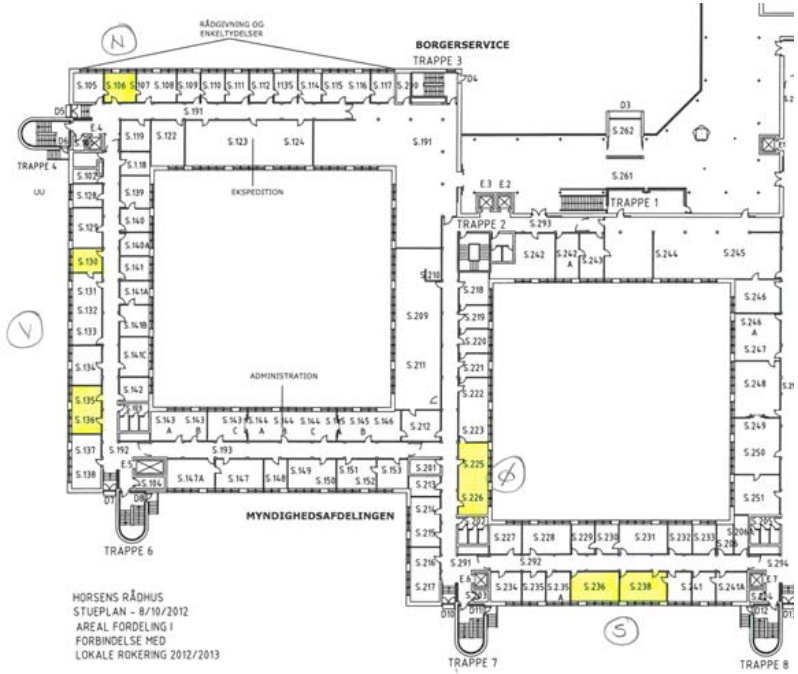
- Drops below 3% 1.0 m from window
- Drops below 2% 1.3 m from window

Room 2.25 (East into Courtyard)

- Drops below 3% 0.5 m from window
- Drops below 2% 0.8 m from window

Room 2.36 (South into Park)

- Drops below 3% 0.7 m from window
- Drops below 2% 0.9 m from window



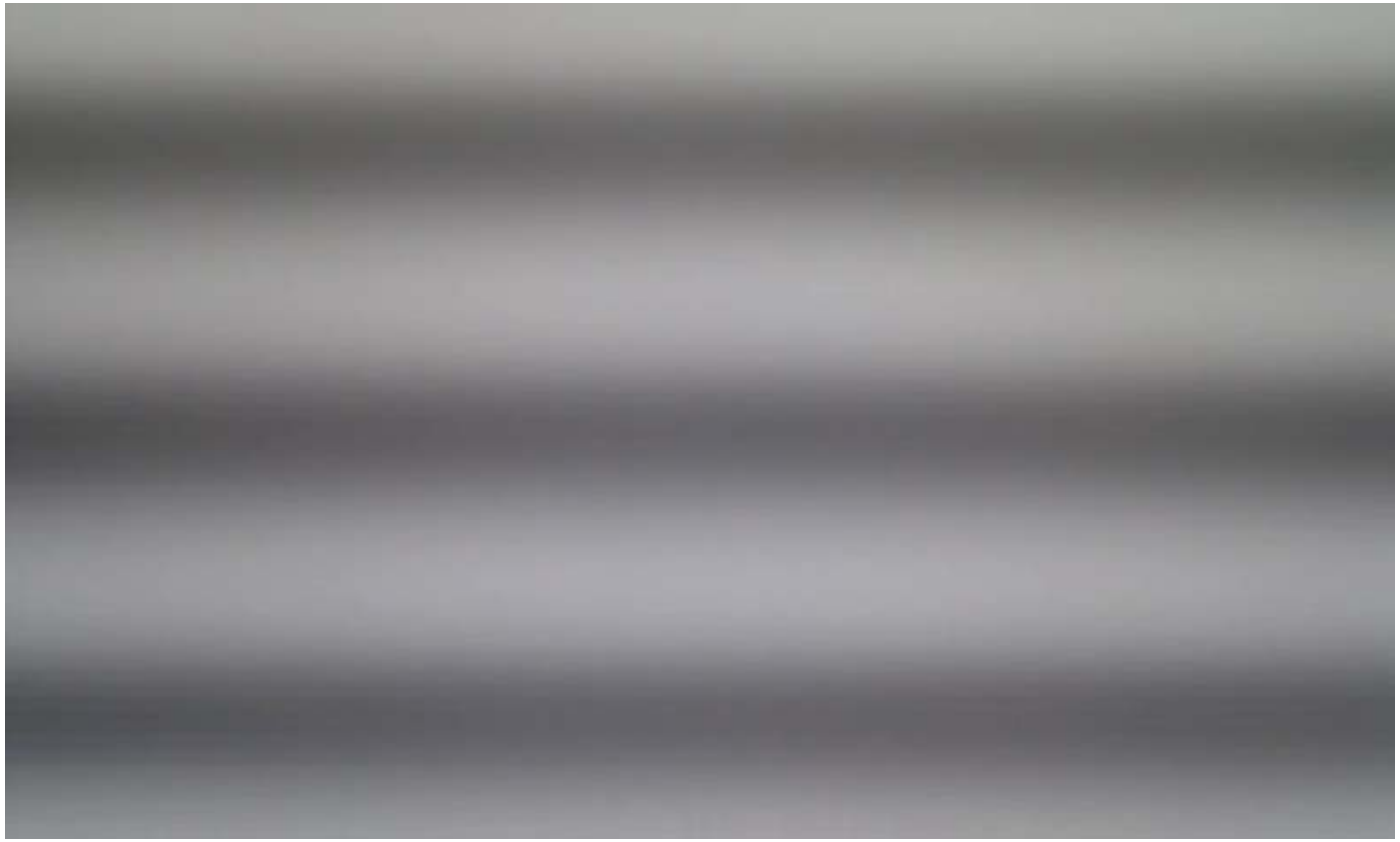
Observation

Venetian blinds between glazing layers appear to be rarely changed once set in a particular position

Points to Investigate

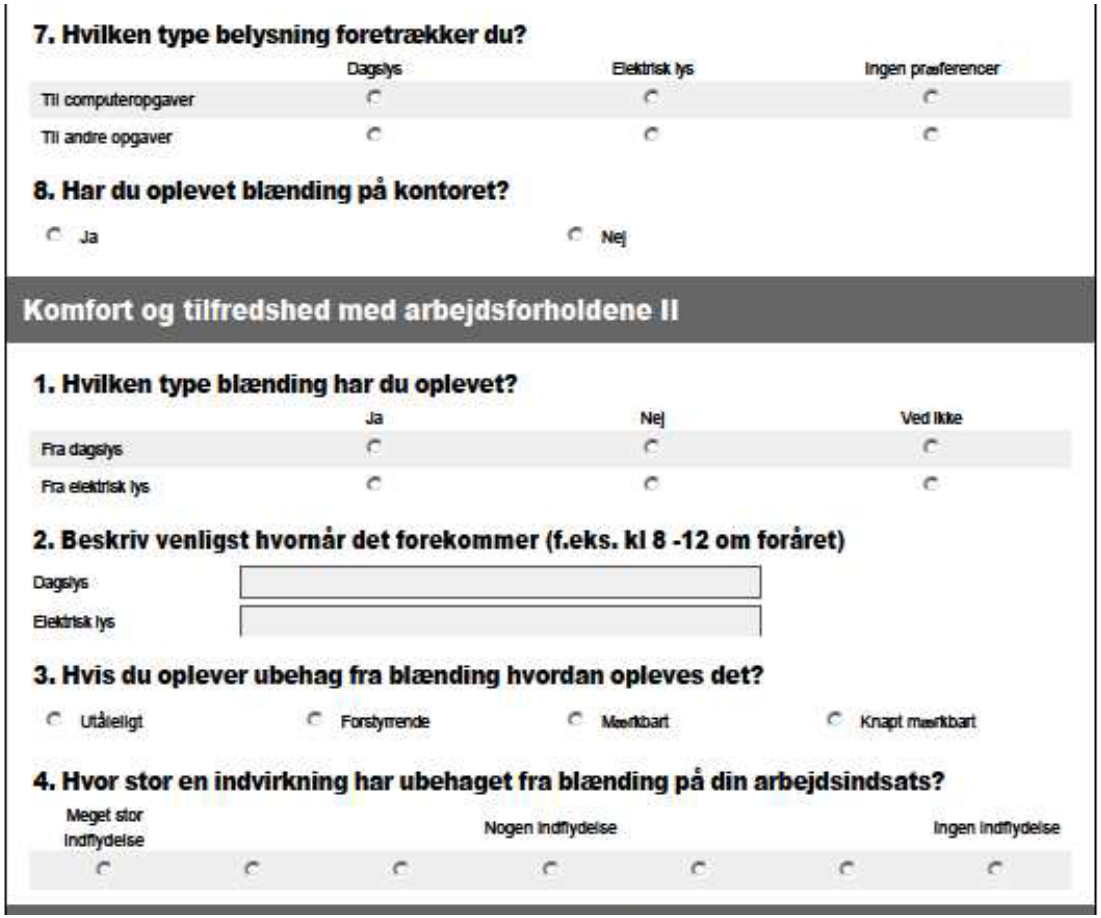
- User survey → lighting evaluation, well-being – difficult to get before and after evaluations as people have moved around and test offices have been changed
- Measurements of luminous environment original lighting (November), winter and summer solstice, spring and fall equinox
- Measurement of thermal environment (DB temperature and relative humidity)
- Lighting simulation →comparison with measured results
- Illuminance levels at desk height → significantly less (ca. 45%) with LED tubes in existing luminaires → daylight factor
- Luminous intensity → influence on brightness perception
- Distribution → luminous intensity distribution curves, patterns on wall
- Direction → very directional LED tube downlight, more diffuse fluorescent tubes, even more diffuse LED panels
- Potential discomfort glare from the various sources → UGR from LED panels high
- Luminance of luminaire aperture → high with LED panels
- Color → spectrum, correlated color temperature, influence on brightness perception and well-being
- Lamp flicker → noticeable with LED panels
- Energy use → luminous efficacy (lm/W) – power density (W/m^2)
- Occupancy and electric lighting use → initial assumption by City of Horsens was all lights on during opening hours – observations suggest different patterns

Flicker from LED Panels



Tests to determine flicker rate and flicker index as well as spectral composition

Web-Based User Survey Questionnaire



7. Hvilken type belysning foretrækker du?

	Dagslys	Elektrisk lys	Ingen præferencer
Til computeropgaver	○	○	○
Til andre opgaver	○	○	○

8. Har du oplevet blænding på kontoret?

○ Ja ○ Nej

Komfort og tilfredshed med arbejdsforholdene II

1. Hvilken type blænding har du oplevet?

	Ja	Nej	Ved ikke
Fra dagslys	○	○	○
Fra elektrisk lys	○	○	○

2. Beskriv venligst hvornår det forekommer (f.eks. kl 8 -12 om foråret)

Dagslys

Elektrisk lys

3. Hvis du oplever ubehag fra blænding hvordan opleves det?

○ Utåleligt ○ Forstyrrende ○ Mærkbart ○ Knapt mærkbart

4. Hvor stor en indvirkning har ubehaget fra blænding på din arbejdsindsats?

Meget stor indflydelse			Nogen indflydelse			Ingen indflydelse
○	○	○	○	○	○	○

Statistical significance will likely not be reached due to various factors
→staff moving to different offices, illness, office reconfiguration, very different responses to questions, etc.

42. Hvordan vil du bedømme niveauet af dagslyset på kontoret?

	For lyst			Godt			For mørkt	Ikke eksisterende	Rating Average
Lige nu	0,0% (0)	0,0% (0)	0,0% (0)	**50,0% (3)**	**50,0% (3)**	0,0% (0)	0,0% (0)	0,0% (0)	4,50
Generelt	0,0% (0)	0,0% (0)	0,0% (0)	**66,7% (4)**	33,3% (2)	0,0% (0)	0,0% (0)	0,0% (0)	4,33
								answered question	
								skipped question	

43. Hvordan vil du bedømme niveauet af det elektriske lys på kontoret?

	For lyst			Godt			For mørkt	Ikke eksisterende	Rating Average
Lige nu	16,7% (1)	0,0% (0)	0,0% (0)	**50,0% (3)**	33,3% (2)	0,0% (0)	0,0% (0)	0,0% (0)	3,83
Generelt	16,7% (1)	0,0% (0)	0,0% (0)	**50,0% (3)**	33,3% (2)	0,0% (0)	0,0% (0)	0,0% (0)	3,83
								answered question	
								skipped question	

44. Hvilken type belysning foretrækker du?

	Dagslys	Elektrisk lys	Ingen præferencer	Response Count
Til computeropgaver	33,3% (2)	33,3% (2)	33,3% (2)	6
Til andre opgaver	16,7% (1)	**50,0% (3)**	33,3% (2)	6
			answered question	6
			skipped question	0

45. Har du oplevet blænding på kontoret?

	Response Percent	Response Count
Ja	16,7%	1
Nej	**83,3%**	**5**
	answered question	**6**
	skipped question	**0**

46. Hvilken type blænding har du oplevet?

	Ja	Nej	Ved ikke	Response Count
Fra dagslys	**100,0% (1)**	0,0% (0)	0,0% (0)	1
Fra elektrisk lys	0,0% (0)	**100,0% (1)**	0,0% (0)	1
			answered question	**1**
			skipped question	**5**

47. Beskriv venligst hvornår det forekommer (f.eks. kl 8 -12 om foråret)

	Response Percent	Response Count
Dagslys	**100,0%**	**1**
Elektrisk lys	0,0%	0
	answered question	**1**
	skipped question	**5**

48. Hvis du oplever ubehag fra blænding hvordan opleves det?

	Response Percent	Response Count
Utåleligt	0,0%	0
Forstyrrende	100,0%	1
Mærkbart	0,0%	0
Knapt mærkbart	0,0%	0
answered question		1
skipped question		5

49. Hvor stor en indvirkning har ubehaget fra blænding på din arbejdsindsats?

	Meget stor indflydelse			Nogen indflydelse			Ingen indflydelse	Rating Average
	0,0% (0)	0,0% (0)	0,0% (0)	100,0% (1)	0,0% (0)	0,0% (0)	0,0% (0)	4,00
answered question								
skipped question								

50. Er din arbejdsplads generelt designet efter ergonomiske principper?

	Ja	Nej	Ved ikke	Response Count
Bordhøjde	66,7% (4)	33,3% (2)	0,0% (0)	6
Stol	66,7% (4)	33,3% (2)	0,0% (0)	6
Udstyr	50,0% (3)	50,0% (3)	0,0% (0)	6
answered question				6
skipped question				0

51. Har du mulighed for at ændre på positionerne eller højderne hvis du ønsker det?

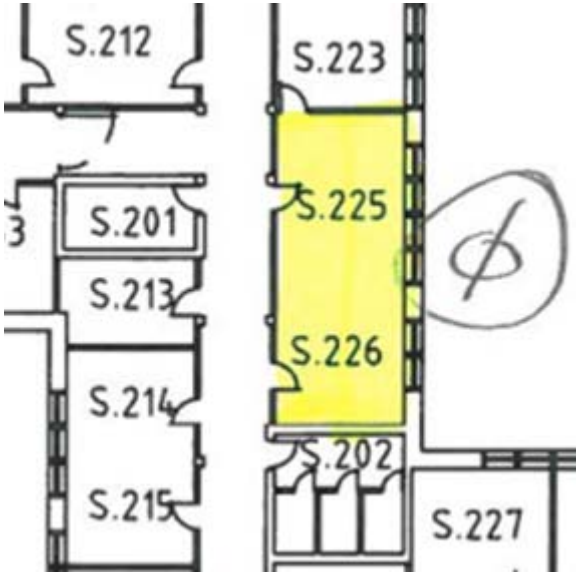
	Response Percent	Response Count
Ja	100,0%	6
Nej	0,0%	0
answered question		6
skipped question		0

52. Kan du frit ændre lysniveauet i dit kontor?

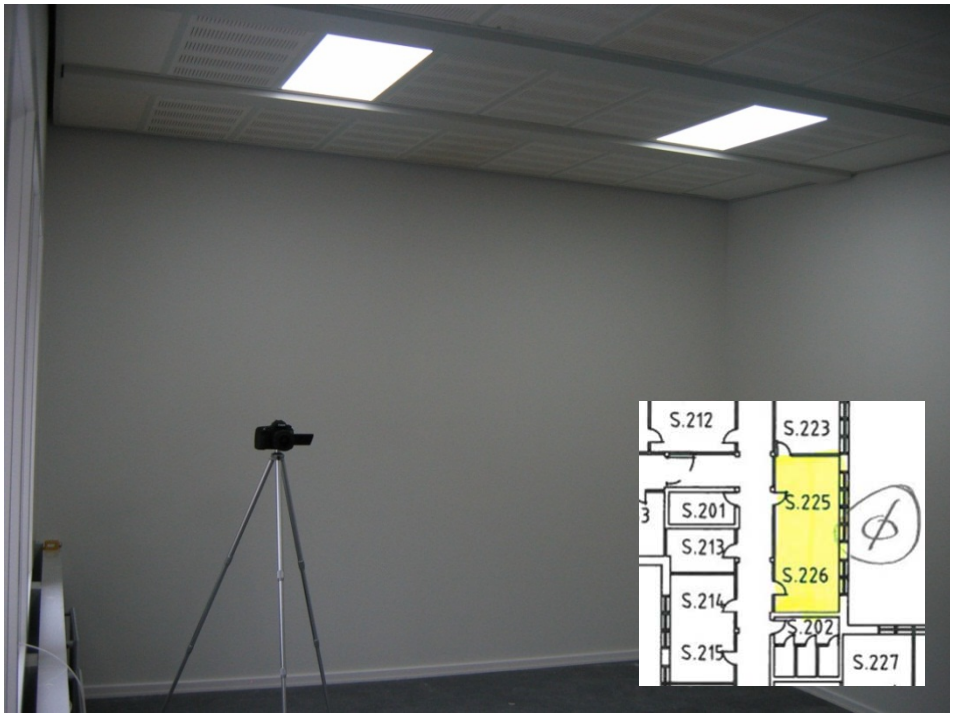
	Response Percent	Response Count
Ja	83,3%	5
Nej	16,7%	1
answered question		6
skipped question		0

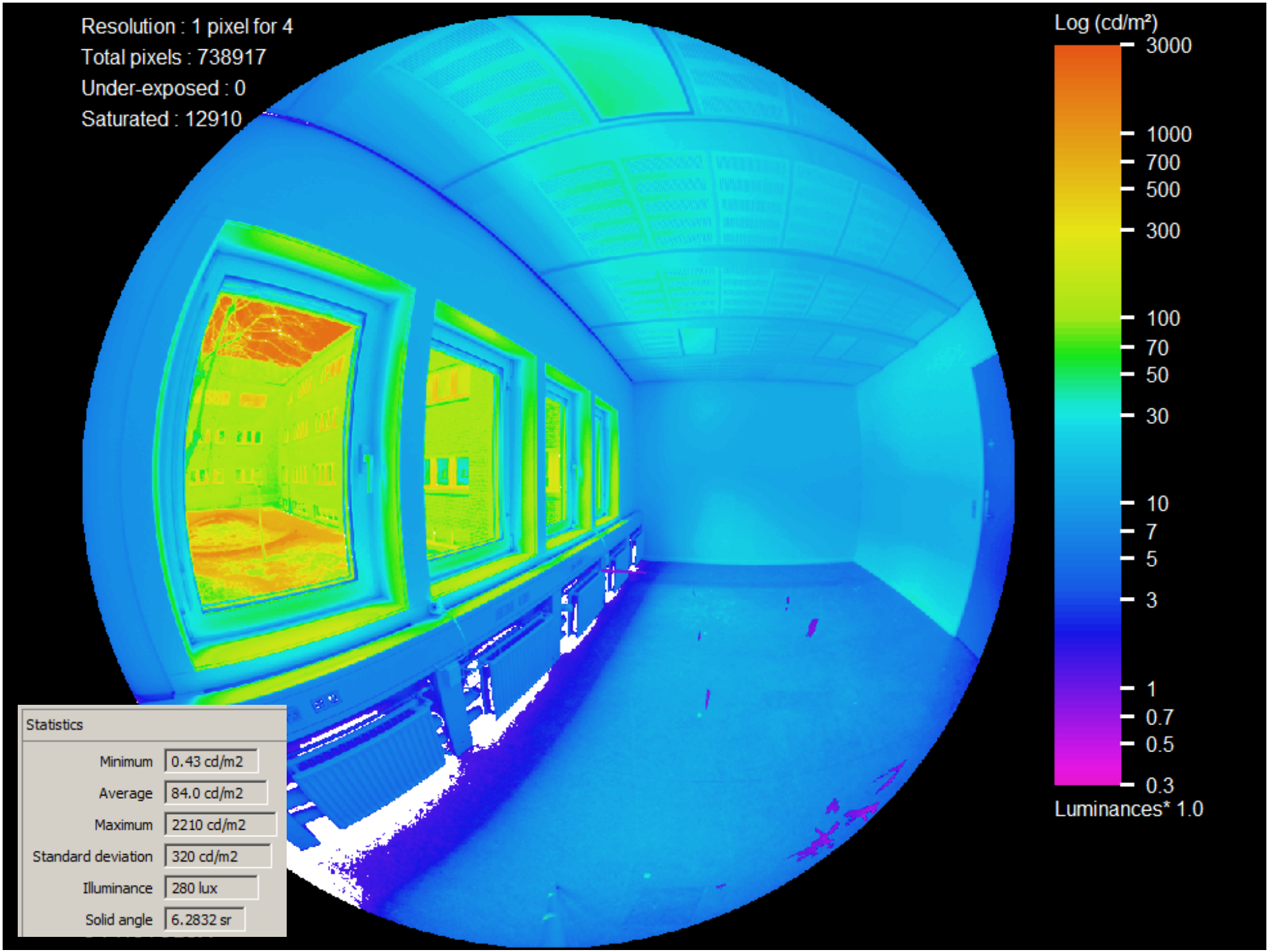
53. Hvilke muligheder har du for at ændre lysniveauet?

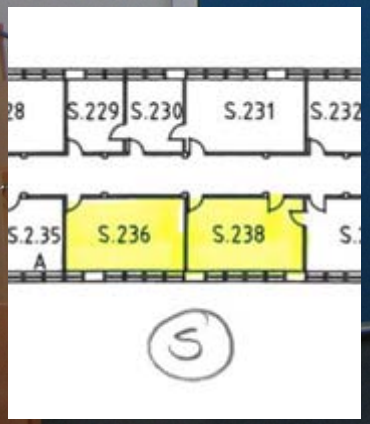
	Response Percent	Response Count
Tænd / sluk-knap	100,0%	5
Lysdæmper	20,0%	1
Skygge-enheder	20,0%	1
Lysstyringssystem	0,0%	0
Andet (angiv venligst)		2
answered question		5



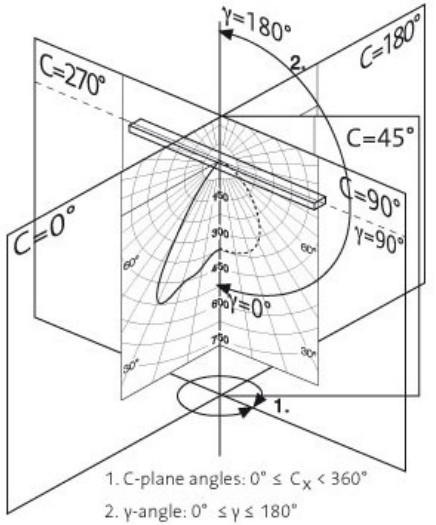
Office split into two (larger one is shown)


S.212
S.223
S.225
S.201
S.213
S.226
S.214
S.202
S.215
S.227

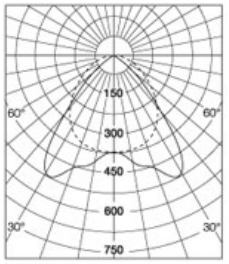

Resolution : 1 pixel for 4
Total pixels : 738917
Under-exposed : 0
Saturated : 12910
Log (cd/m²)
3000
1000
700
500
300
100
70
50
30
10
7
5
3
1
0.7
0.5
0.3
Luminances* 1.0
Statistics
Minimum 0.43 cd/m2
Average 84.0 cd/m2
Maximum 2210 cd/m2
Standard deviation 320 cd/m2
Illuminance 280 lux
Solid angle 6.2832 sr


28
S.229
S.230
S.231
S.232
S.2.35
A
S.236
S.238
S

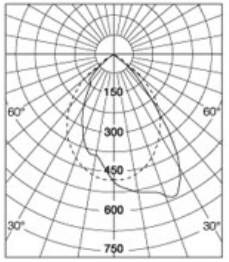
Lysmåling



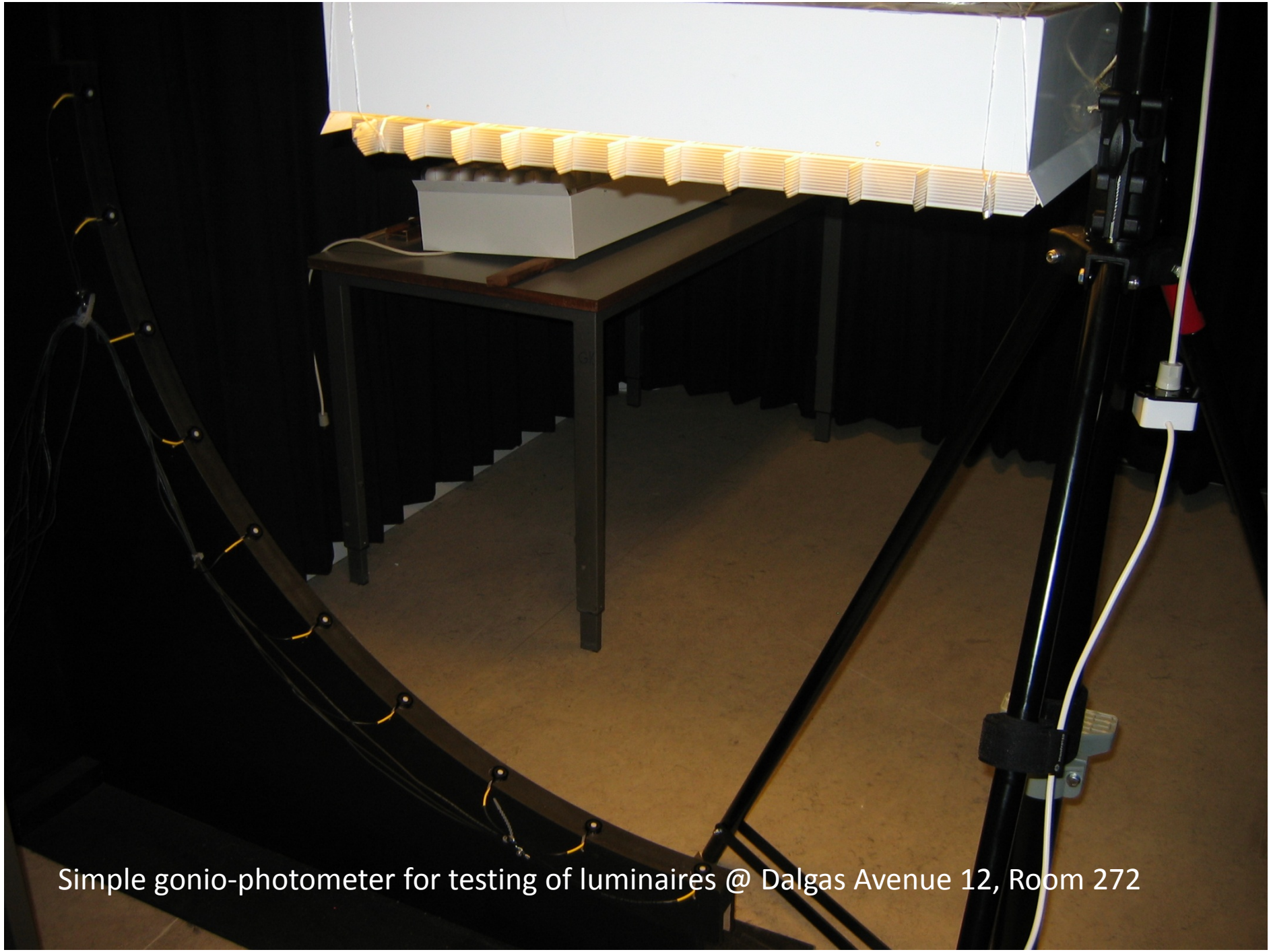
Lysfordelingskurve



Symmetrisk

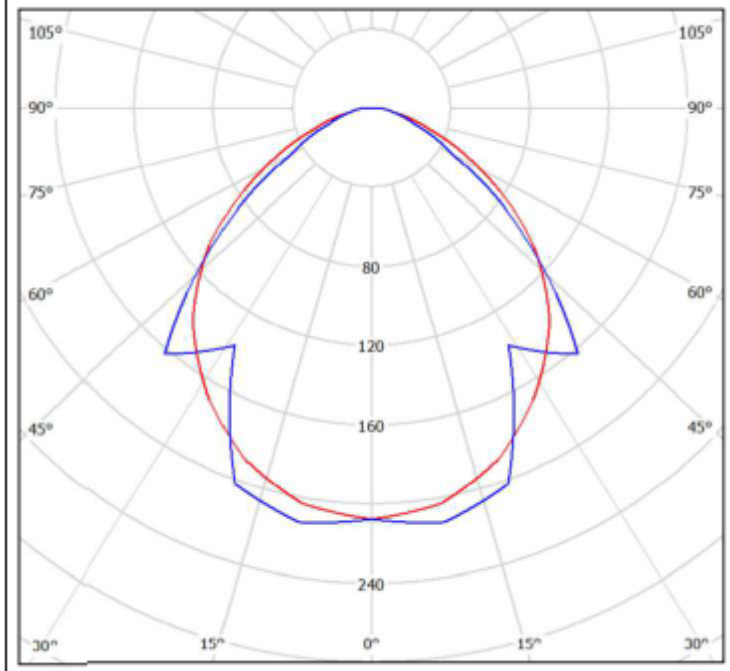


Asymmetrisk

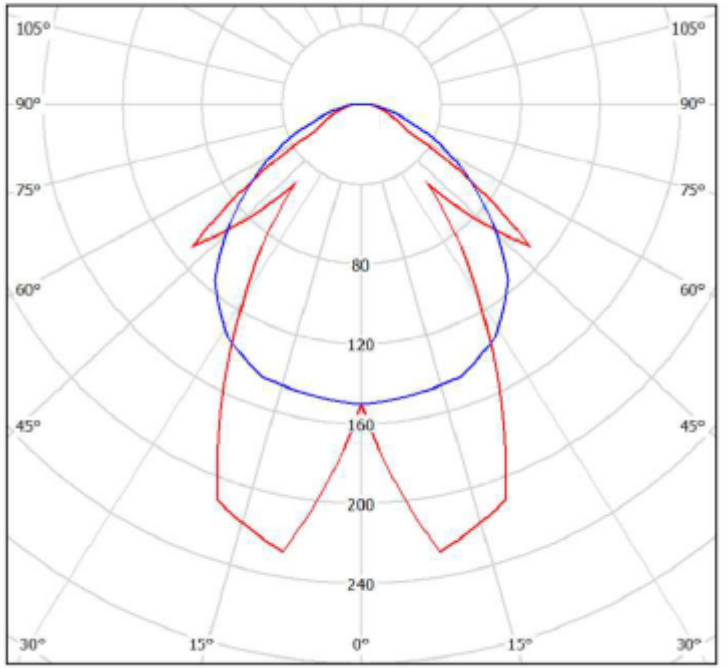


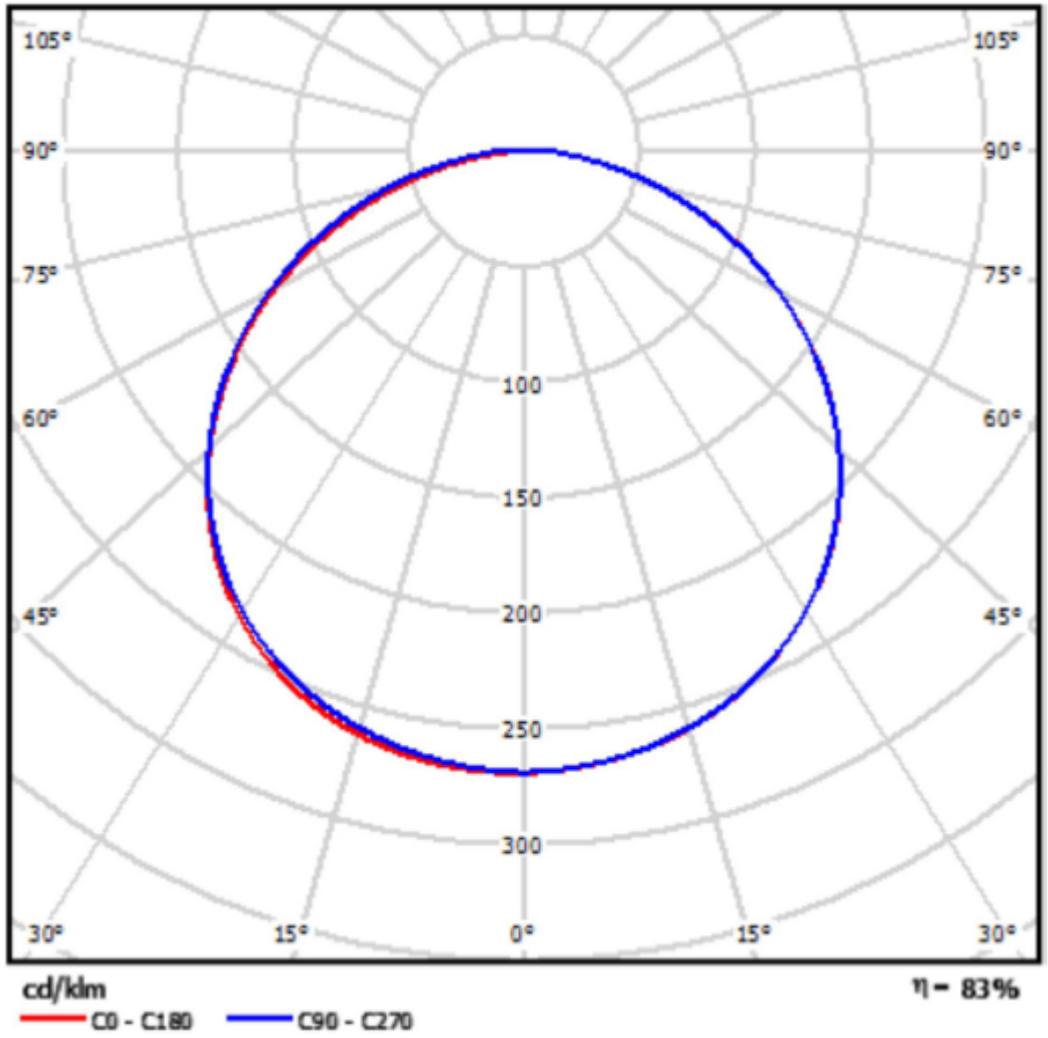
Simple gonio-photometer for testing of luminaires @ Dalgas Avenue 12, Room 272

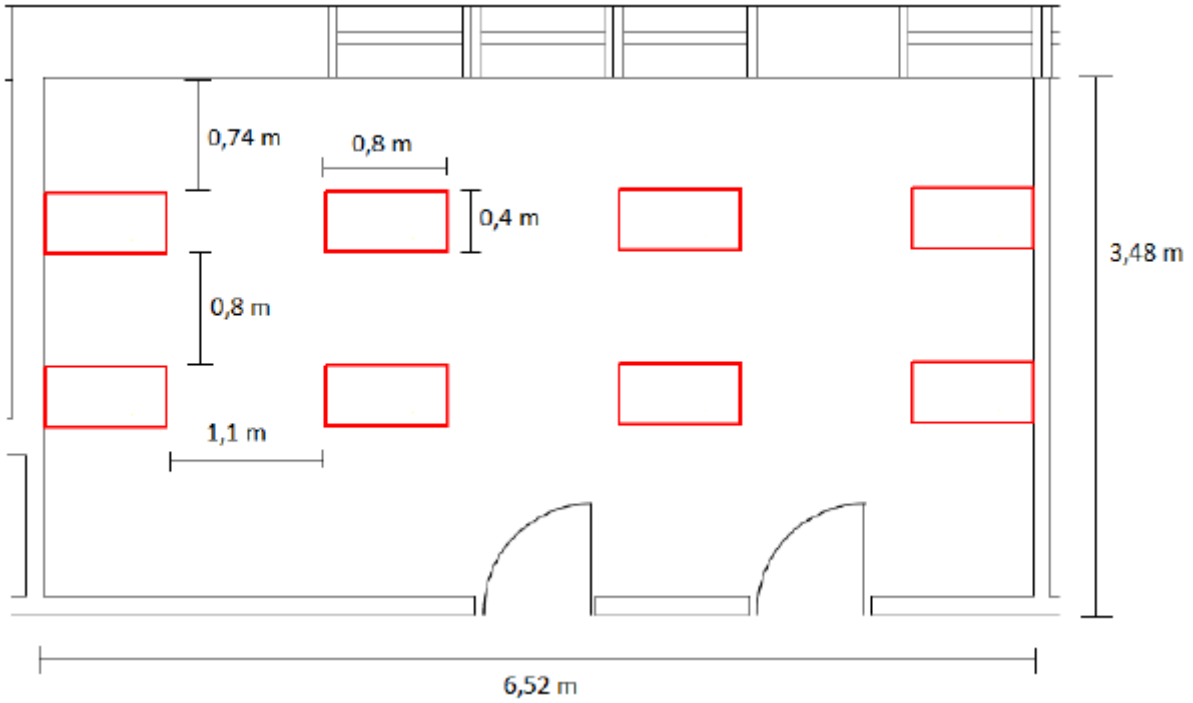
Lysstofrør



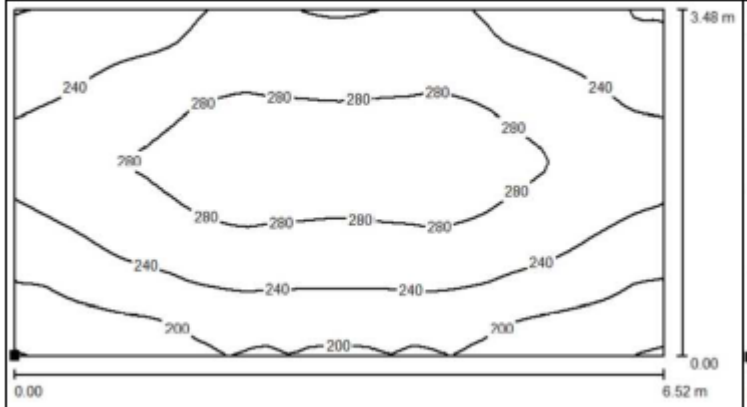
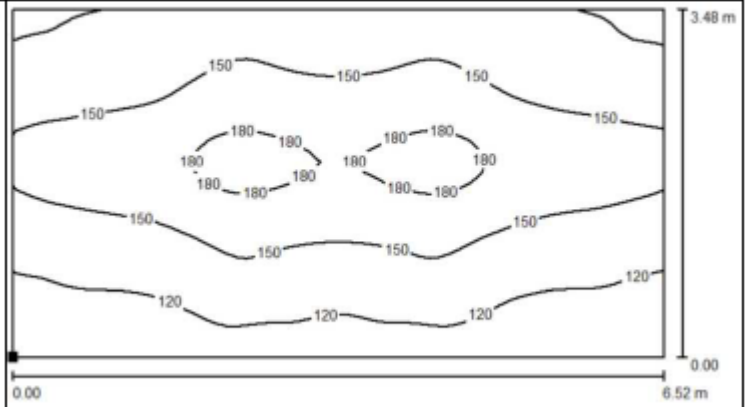
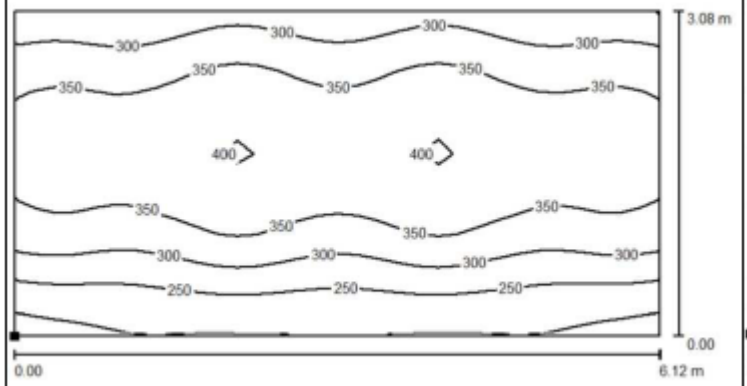
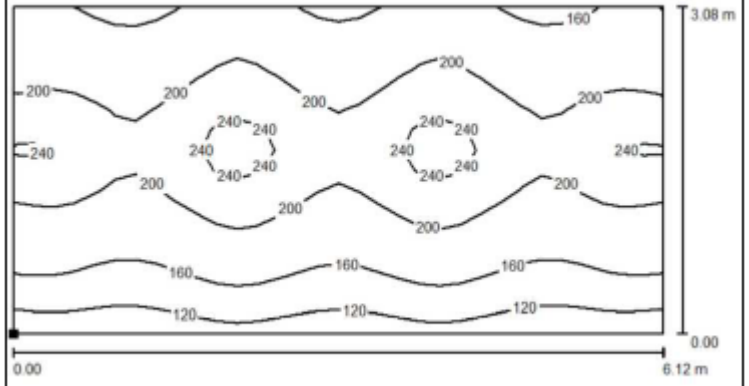
LED

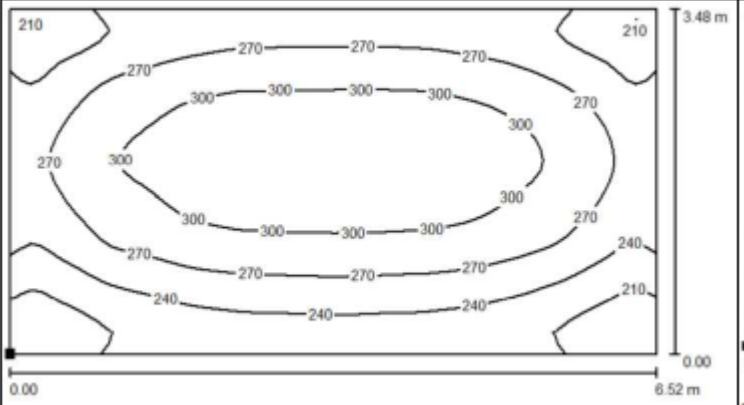
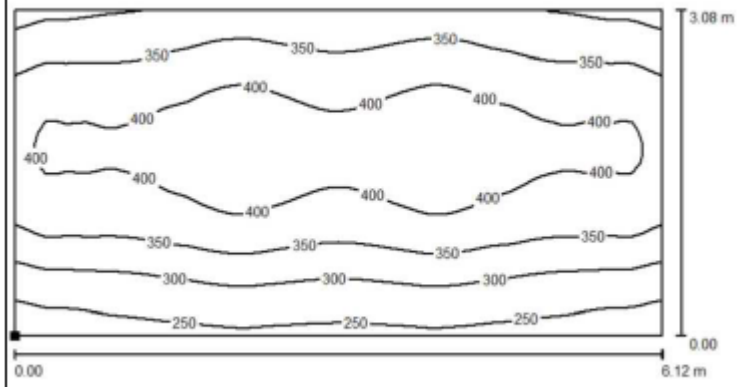


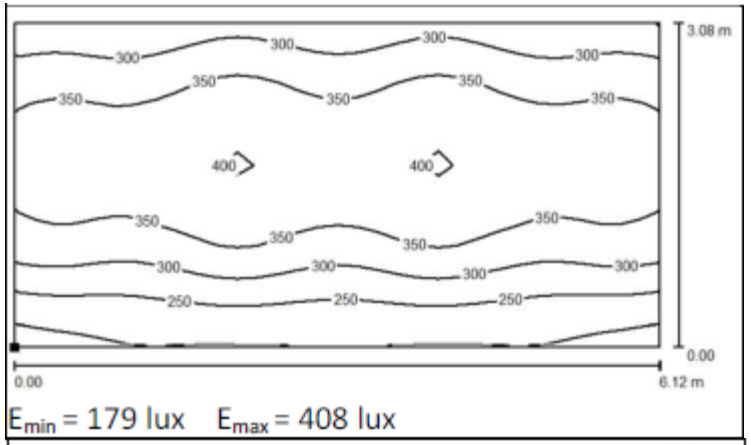

105°
105°
90°
90°
75°
75°
100
60°
60°
150
45°
200
45°
250
300
30°
15°
0°
15°
30°
cd/klm
η = 83%
C0 - C180
C90 - C270



Test office simulated with DIALux

Lysstofrør	LED
Gulvplan	
	
E_{min} = 158 lux E_{max} = 310 lux	E_{min} = 90 lux E_{max} = 192 lux
Plan i 0,85 m højde	
	
E_{min} = 179 lux E_{max} = 408 lux	E_{min} = 99 lux E_{max} = 264 lux

Gulvplan	Plan i 0,85 m højde
	
E_{min} = 178 lux E_{max} = 322 lux	E_{min} = 215 lux E_{max} = 433 lux



E_{min} = 179 lux E_{max} = 408 lux

E_{min} = 99 lux E_{max} = 264 lux

E_{min} = 215 lux E_{max} = 433 lux

DIALux Simulations

@ workplane height

Original fluorescent lamps and luminaires

LED tubes in existing luminaires

New LED panels

Suggestions from Industry Experts

- What else would you suggest we do as part of the case study?
- Do you have any experiences with similar lighting retrofits of which we should be aware?
- Do you know of any lighting retrofit projects which we might use for comparison?

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