

daylighting.de



**Task 47 Workshop: Renovation of Non-Residential Buildings towards Sustainable Solutions, Sydney 05.04.13**

## **Lighting standards in renovated buildings**

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# Lighting retrofit in selected classrooms of Königin-Luise-Schule, Berlin

This lighting renovation was part of a research project of TU-Berlin, IBUS and Charité with Trilux.



- **Energy efficient lighting**

- Energy efficient fixtures, additional blackboard lighting



ambient lighting  
4 x Trilux 5041 (RPX-L/35/49/80 EDD),  
equipped with: 1 x 35 W T16  
and dimmable electronic ballast.



blackboard lighting  
2 x Trilux 5041 (RAV-L/35/49/80 E)  
equipped with: 1 x 80 W T16  
and electronic ballast.

- **Light for better learning**

- Possibility to shift color temperature to bluish and to increase lighting level beyond standard requirements, additional blackboard lighting



4 x Trilux Valuco active,  
equipped with: 1 x 35 W T16 for ambient  
lighting and 2 x 49 W T16 for activating  
light, dimmable electronic ballast.



blackboard lighting  
2 x Trilux 5041 (RAV-L/35/49/80 E)  
equipped with: 1 x 80 W T16  
and electronic ballast.

» daylight responsive controls and occupancy sensors for ambient lighting.

# Classroom 120: Energy efficient lighting



Classroom 120 before renovation



Classroom 120 after renovation



The calculation according to DIN V 18599-4 :2011-12 includes no method for lighting on a vertical plane.

# Classroom 120: Energy efficient lighting

profile of usage: classroom (schools)

		after renovation			before	Reference
		total	blackboard	working plane	working plane	EnEV 2009
<b>installed power density</b>	$p_j$	<b>9,9 W/m<sup>2</sup></b>	<b>5,3 W/m<sup>2</sup></b>	<b>4,7 W/m<sup>2</sup></b>	<b>13,8 W/m<sup>2</sup></b>	<b>9,2 W/m<sup>2</sup></b>
expenditure figure for electric lighting system	$e_{l,K}$	-	-	1,53	4,53	3,15
gross window area	$A_{RB}$	6,23 m <sup>2</sup>	6,23 m <sup>2</sup>	6,23 m <sup>2</sup>	6,23 m <sup>2</sup>	6,23 m <sup>2</sup>
area of daylighting zone	$A_{TL}$	29,87 m <sup>2</sup>	29,87 m <sup>2</sup>	29,87 m <sup>2</sup>	29,87 m <sup>2</sup>	29,87 m <sup>2</sup>
area of electric lighting zone	$A_{KTL}$	2,51 m <sup>2</sup>	2,51 m <sup>2</sup>	2,51 m <sup>2</sup>	2,51 m <sup>2</sup>	2,51 m <sup>2</sup>
<b>daylight factor for structure</b>	$D_{Rb}$	<b>3,4%</b>	<b>3,4%</b>	<b>3,4%</b>	<b>3,4%</b>	<b>3,4%</b>
<b>classification of daylight level</b>	-	<b>poor</b>	<b>poor</b>	<b>poor</b>	<b>poor</b>	<b>poor</b>
factor daylight contribution (without shading)	$C_{TL,Vers,SNA}$	0,70	0,70	0,70	0,70	0,67
factor daylight contribution (with shading)	$C_{TL,Vers,SA}$	0,15	0,15	0,15	0,15	0,15
<b>factor daylight contribution over all</b>	$C_{TL,Vers}$	<b>0,59</b>	<b>0,59</b>	<b>0,59</b>	<b>0,59</b>	<b>0,56</b>
<b>factor of daylight responsive controls</b>	$C_{TL,Kon}$	<b>0,63</b>	<b>0,5</b>	<b>0,781</b>	<b>0,5</b>	<b>0,5</b>
reduction factor for daylighting	$F_{TL}$	0,63	0,71	0,54	0,71	0,72
expenditure figure daylight	$e_{l,TL,Kon}$	-	-	1,26	1,59	1,54
<b>factor of occupancy responsive controls</b>	$C_{prä,Kon}$	<b>0,71</b>	<b>0,50</b>	<b>0,95</b>	<b>0,50</b>	<b>0,50</b>
reduction factor for occupancy	$F_{Prä}$	0,82	0,88	0,76	0,88	0,88
expenditure figure - occupancy	$e_{l,Präs,Kon}$	1,10	1,17	1,02	1,17	1,17
<b>reduction factor for maintenance</b>	$F_{KL}$	<b>0,95</b>	<b>1,00</b>	<b>0,90</b>	<b>1,00</b>	<b>0,90</b>
expenditure figure - maintenance	$e_{l,Präs,Kon}$	1,06	1,11	1,00	1,11	1,00
eff. operation time in daylighting zone (day)	$t_{eff,Tag,TL}$	701 h	863 h	518 h	863 h	790 h
eff. operation time (night)	$t_{eff,Nacht}$	2 h	2 h	1 h	2 h	2 h
eff. operation time in el. lighting zone (day)	$t_{eff,KTL}$	1099 h	1223 h	959 h	1223 h	1101 h
final energy use of building zone	$Q_{l,b,j}$	235 kWh/a	152 kWh/a	84 kWh/a	400 kWh/a	243 kWh/a
<b>specific final energy use per squaremeter</b>	$Q_{l,b,n}$	<b>6,5 kWh/m<sup>2</sup>a</b>	<b>4,2 kWh/m<sup>2</sup>a</b>	<b>2,3 kWh/m<sup>2</sup>a</b>	<b>11,1 kWh/m<sup>2</sup>a</b>	<b>6,8 kWh/m<sup>2</sup>a</b>
expenditure figure for lighting	$e_l$	-	-	1,96	9,34	5,66

# Classroom 14: Light for better learning



Classroom 14 before renovation



Classroom 14 after renovation



# Classroom 14: Light for better learning

profile of usage: classroom (schools)		after renovation			before	Reference
		total	blackboard	working plane	working plane	EnEV 2009
<b>installed power density</b>	$p_j$	<b>23,2 W/m<sup>2</sup></b>	<b>5,3 W/m<sup>2</sup></b>	<b>18,0 W/m<sup>2</sup></b>	<b>8,7 W/m<sup>2</sup></b>	<b>9,2 W/m<sup>2</sup></b>
expenditure figure for electric lighting system	$e_{l,K}$	-	-	5,54	2,68	3,15
gross window area	$A_{RB}$	5,95 m <sup>2</sup>	5,95 m <sup>2</sup>	5,95 m <sup>2</sup>	5,95 m <sup>2</sup>	5,95 m <sup>2</sup>
area of daylighting zone	$A_{TL}$	30,44 m <sup>2</sup>	30,44 m <sup>2</sup>	30,44 m <sup>2</sup>	30,44 m <sup>2</sup>	30,44 m <sup>2</sup>
area of electric lighting zone	$A_{KTL}$	1,77 m <sup>2</sup>	1,77 m <sup>2</sup>	1,77 m <sup>2</sup>	1,77 m <sup>2</sup>	1,77 m <sup>2</sup>
<b>daylight factor for structure</b>	$D_{Rb}$	<b>2,4%</b>	<b>2,4%</b>	<b>2,4%</b>	<b>2,4%</b>	<b>2,4%</b>
<b>classification of daylight level</b>	-	<b>poor</b>	<b>poor</b>	<b>poor</b>	<b>poor</b>	<b>poor</b>
factor daylight contribution (without shading)	$C_{TL,Vers,SNA}$	0,55	0,55	0,55	0,55	0,52
factor daylight contribution (with shading)	$C_{TL,Vers,SA}$	0,15	0,15	0,15	0,15	0,15
<b>factor daylight contribution over all</b>	$C_{TL,Vers}$	<b>0,47</b>	<b>0,47</b>	<b>0,47</b>	<b>0,47</b>	<b>0,44</b>
<b>factor of daylight responsive controls</b>	$C_{TL,Kon}$	<b>0,72</b>	<b>0,5</b>	<b>0,78</b>	<b>0,5</b>	<b>0,5</b>
reduction factor for daylighting	$F_{TL}$	0,66	0,77	0,63	0,77	0,78
expenditure figure daylight	$e_{l,TL,Kon}$	-	-	1,17	1,40	1,36
<b>factor of occupancy responsive controls</b>	$C_{prä,Kon}$	<b>0,85</b>	<b>0,50</b>	<b>0,95</b>	<b>0,50</b>	<b>0,50</b>
reduction factor for occupancy	$F_{Prä}$	0,79	0,88	0,76	0,88	0,88
expenditure figure - occupancy	$e_{l,Präs,Kon}$	1,05	1,17	1,02	1,17	1,17
<b>reduction factor for maintenance</b>	$F_{KL}$	<b>0,92</b>	<b>1,00</b>	<b>0,90</b>	<b>1,00</b>	<b>0,90</b>
expenditure figure - maintenance	$e_{l,Präs,Kon}$	1,03	1,11	1,00	1,11	1,00
eff. operation time in daylighting zone (day)	$t_{eff,Tag,TL}$	683 h	937 h	608 h	937 h	856 h
eff. operation time (night)	$t_{eff,Nacht}$	1 h	2 h	1 h	2 h	2 h
eff. operation time in el. lighting zone (day)	$t_{eff,KTL}$	1019 h	1223 h	959 h	1223 h	1101 h
final energy use of building zone	$Q_{l,b,j}$	526 kWh/a	162 kWh/a	364 kWh/a	267 kWh/a	258 kWh/a
<b>specific final energy use per squaremeter</b>	$Q_{l,b,n}$	<b>14,7 kWh/m<sup>2</sup>a</b>	<b>4,5 kWh/m<sup>2</sup>a</b>	<b>10,2 kWh/m<sup>2</sup>a</b>	<b>7,5 kWh/m<sup>2</sup>a</b>	<b>7,2 kWh/m<sup>2</sup>a</b>
expenditure figure for lighting	$e_l$	-	-	6,61	4,86	5,00

# New Gallery, Kassel



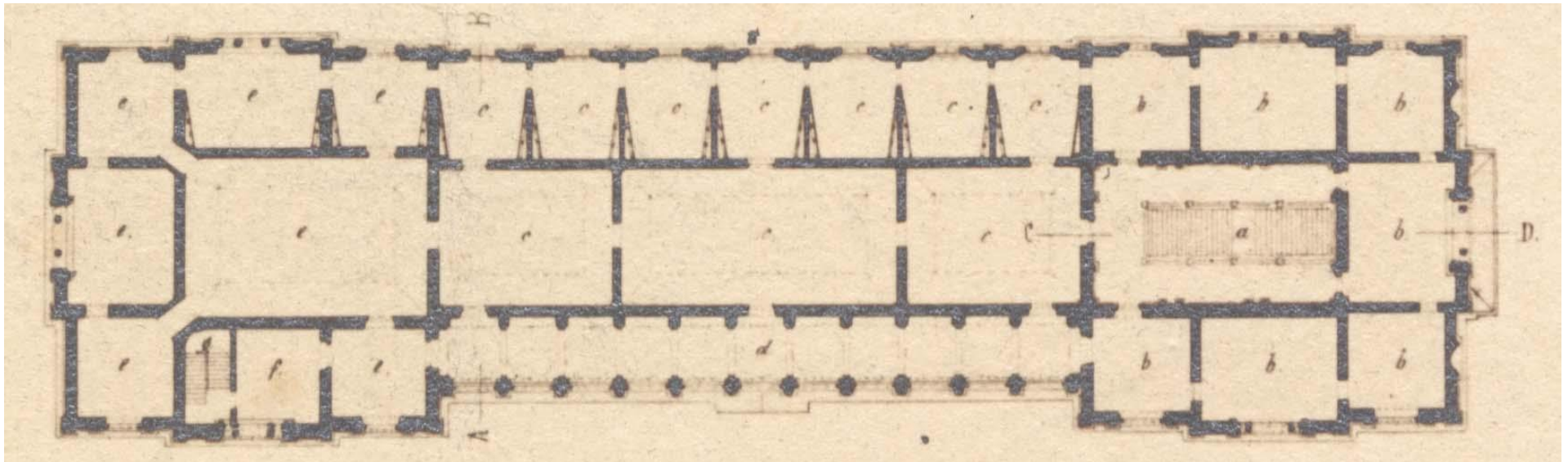
View from North West before renovation



East façade after renovation



South façade after renovation



Floor plan of exhibition level (Heinrich von Dehn-Rotfelser ca. 1870 (Source: Wikipedia))

1870: Design by Heinrich von Dehn-Rotfelser; 1877: Opening; 1943: Bomb damages; 1962-1976: Reconstruction and reopening; 2007-2011: renovation designed by Staab-Architekten, Berlin, lighting consultant: Licht Kunst Licht with Roman Jakobiak / daylighting.de



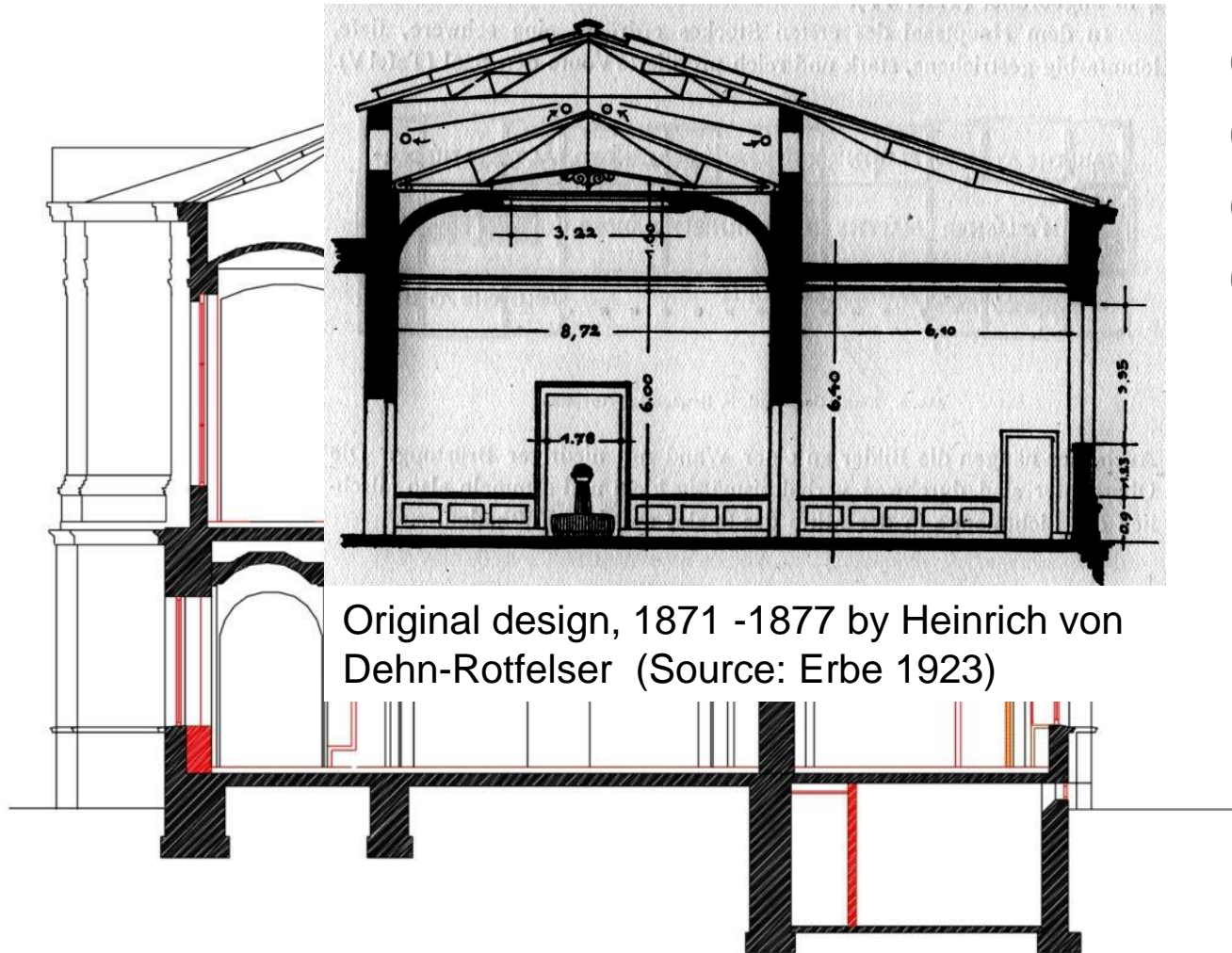
**New Gallery, hall with rooflight before refurbishment**





# New Gallery, planning refurbishment

- ① Prismatic glazing
- ② Roller blinds
- ③ Electric lighting
- ④ Double glazing
- ⑤ Scattering plastic

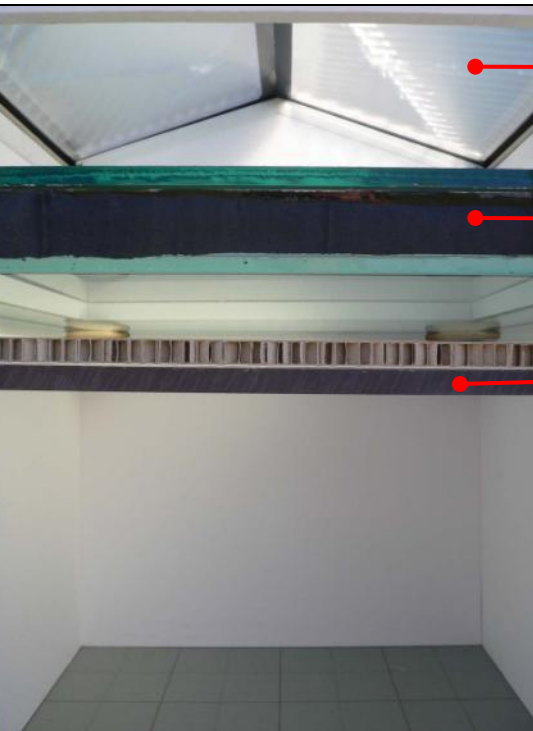


Original design, 1871 -1877 by Heinrich von Dehn-Rotfelser (Source: Erbe 1923)

New design, 2007 - 2011 by Staab-Architekten (Source: Staab-Architekten)



# New Gallery, planning refurbishment



● Prismatic glazing

● Double glazing

● Scattering plastic





## New Gallery during construction





## New Gallery after refurbishment



IEA-Task 47 Workshop, Sydney, Australia

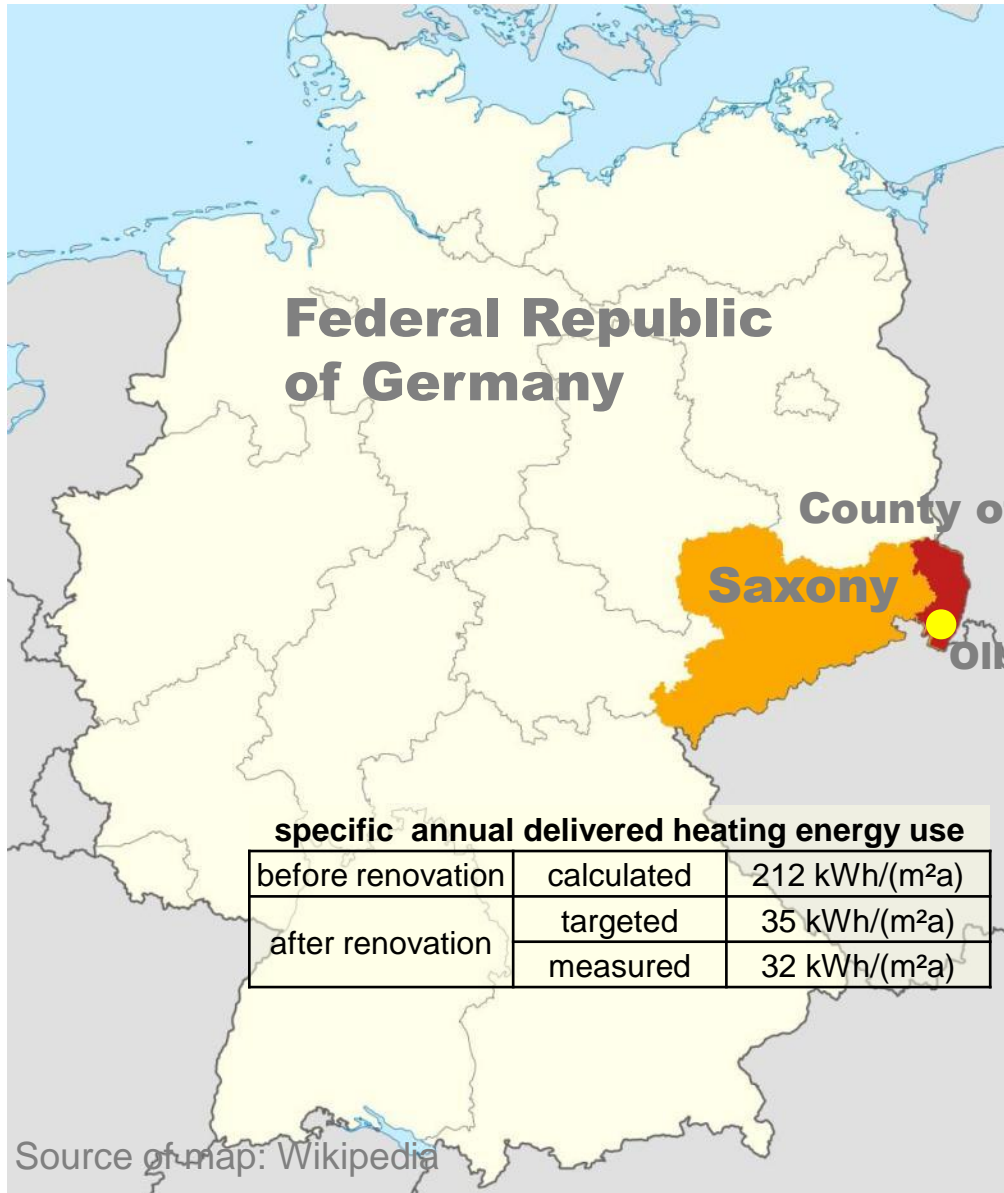
# Renovation of the Friedrich-Fröbel-School in Olbersdorf



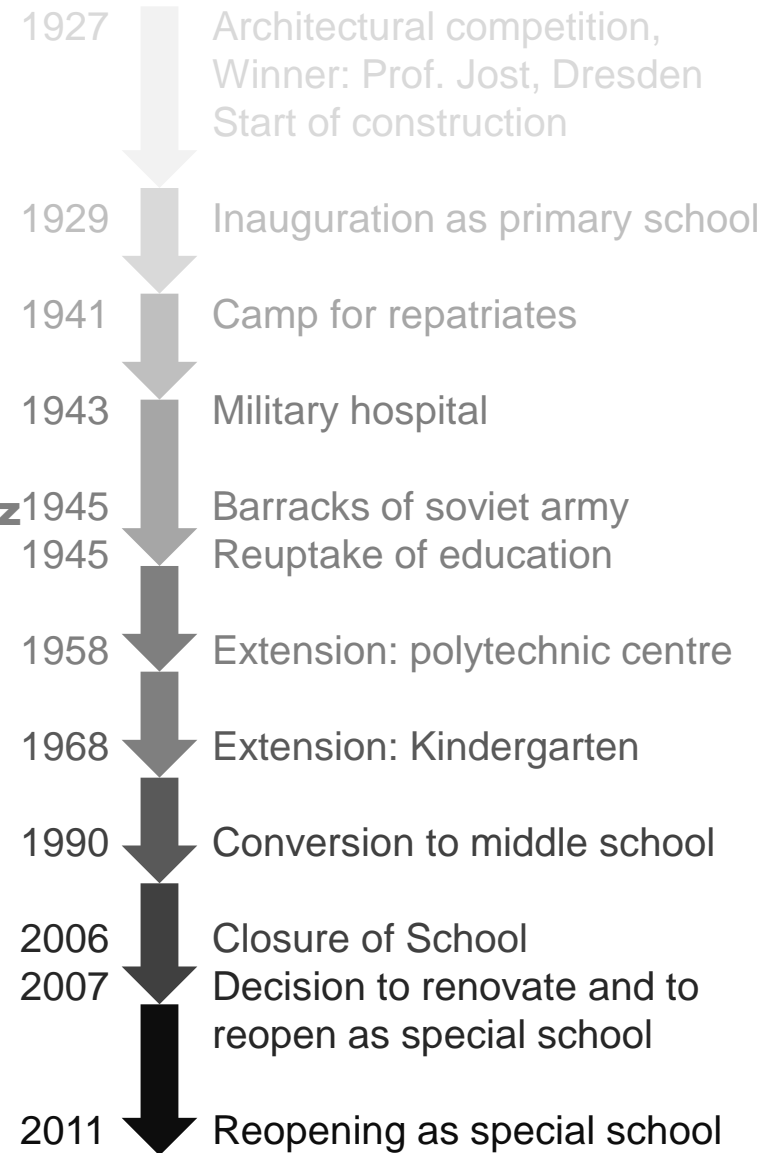
Involved Institutions	
Client	Landkreis Görlitz
Leader of Research Project	HS Zittau/Görlitz, Fakultät Bauwesen, Lehrgebiet Bauklimatik, Prof. Dr. Bolsius
Subcontractor for Lighting	TU-Dresden, Fakultät Architektur, Institut für Bauklimatik
Subcontractor of Subcontractor for Lighting	Roman Jakobiak (Werkvertrag)
Projektbegleitung	Projektträger Jülich
Architect	AIZ - Architektur- und Ingenieurbüro für Hoch- und Tiefbau Zittau GmbH
Electrical engineering	ILM - Ickrath Land Messner, Ingenieurbüro für Elektroenergieanlagen



# Location of Olbersdorf



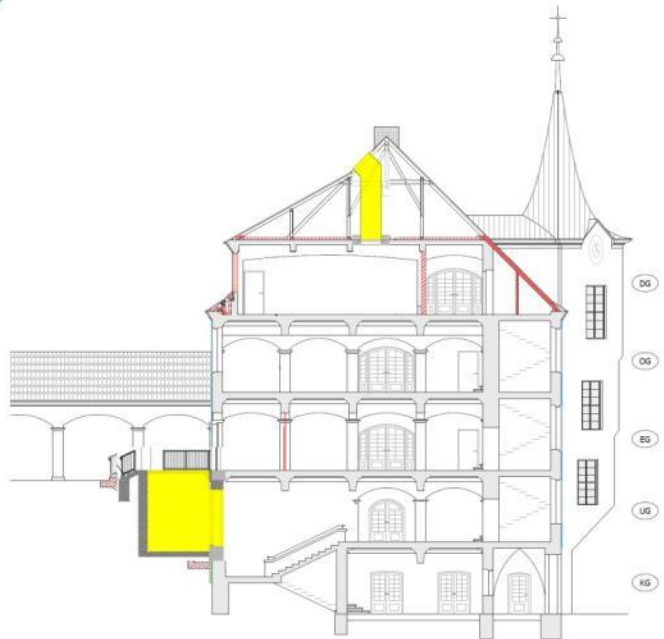
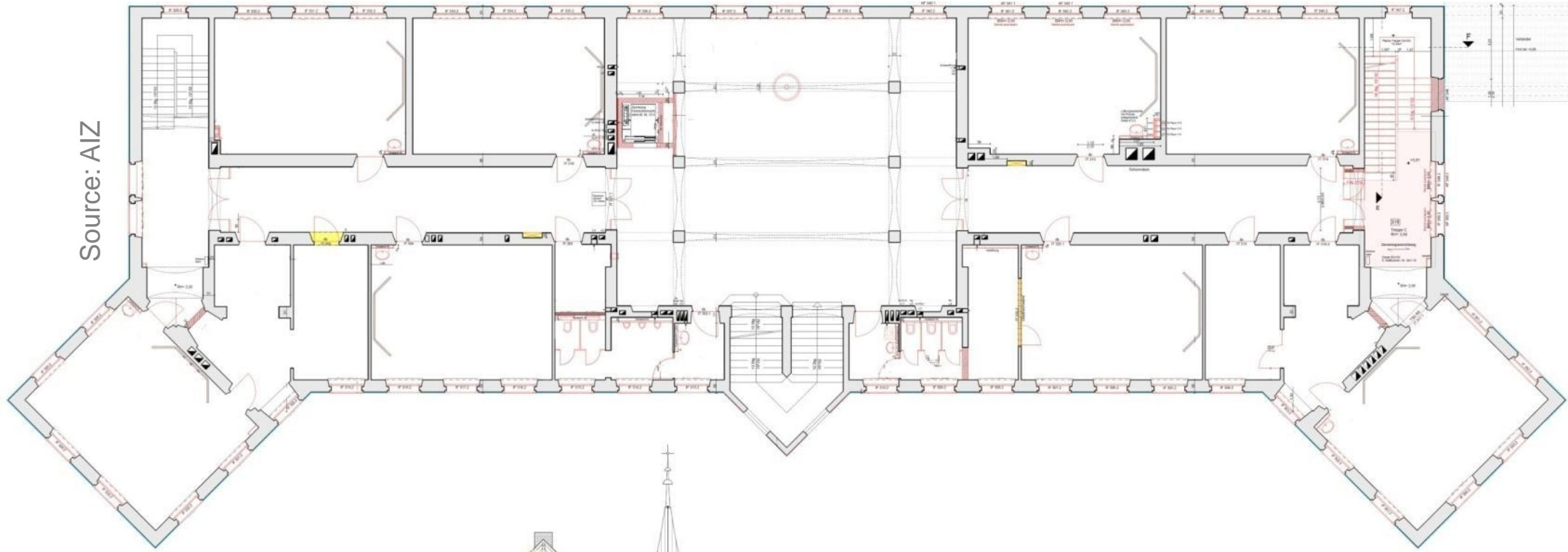
# Timeline of school



# 2<sup>nd</sup> floor plan and cross section

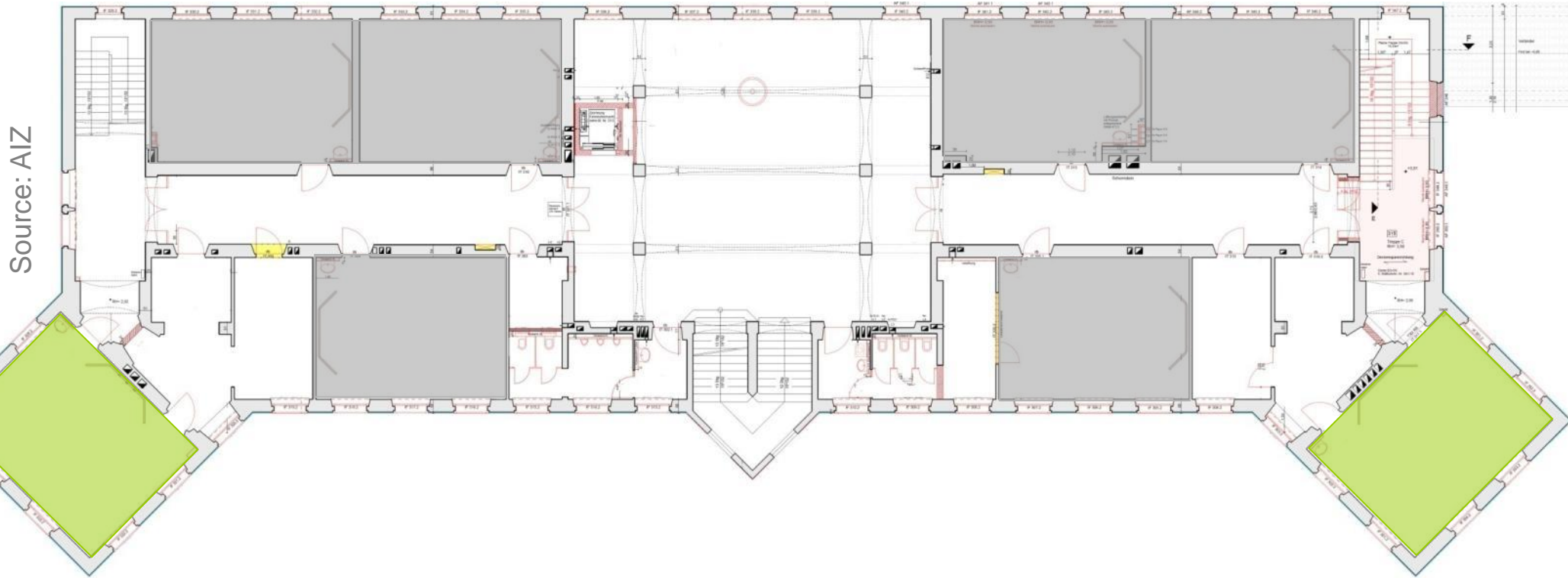


Source: AIZ





# Daylight level before renovation



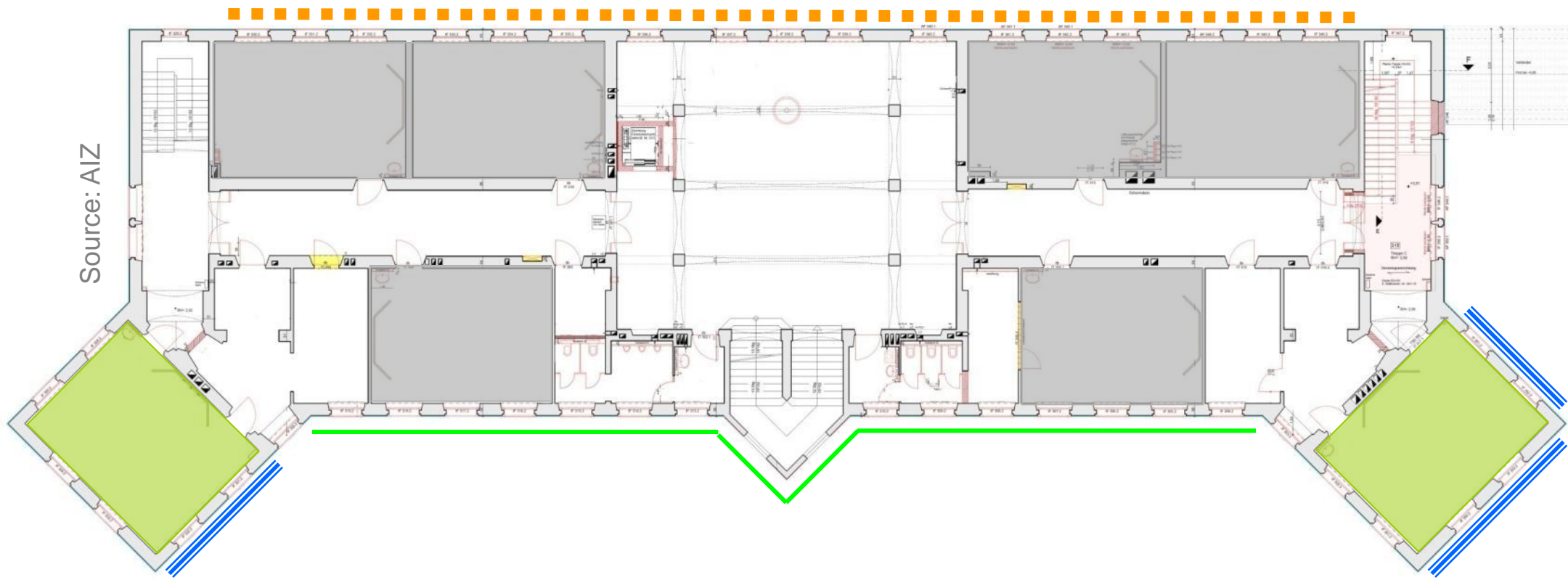
low daylight level (window to floor area ratio = 17%, DF 1,3%)



adequate daylight level (window to floor area ratio = 32 %, DF 2,4%)

# Glazing of double windows

Source: AIZ



Interior: double low-E, exterior: single white glass



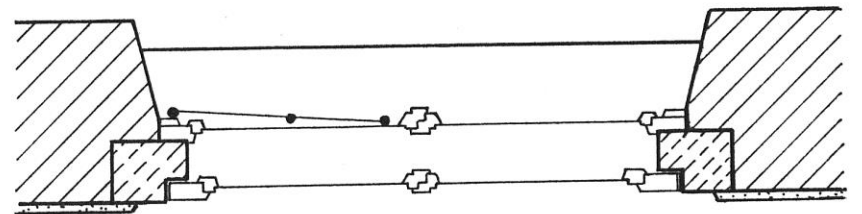
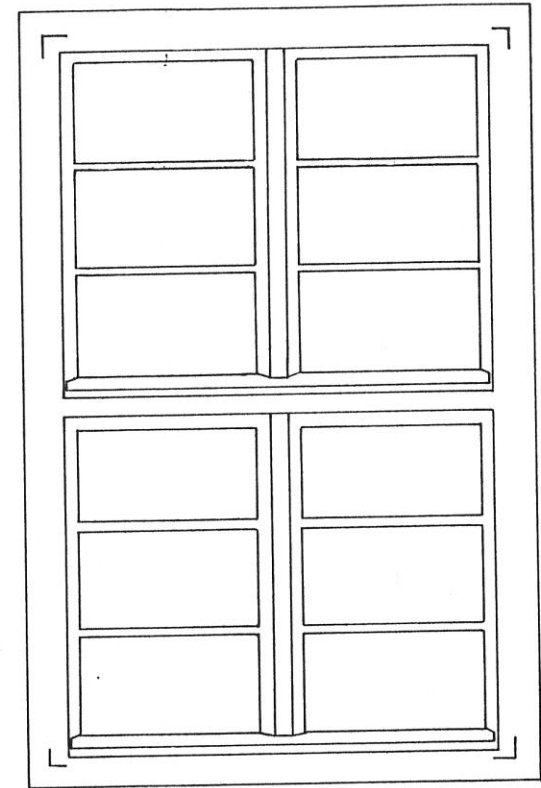
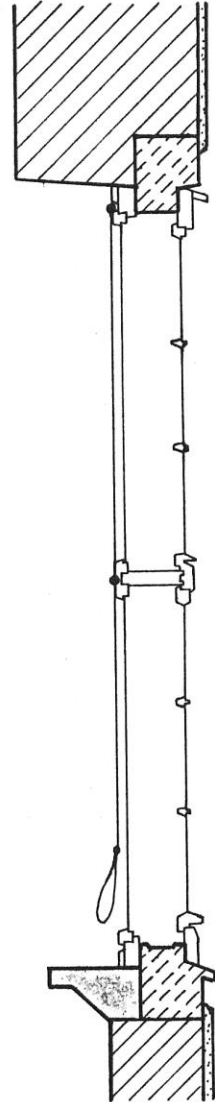
Interior: double low-E , exterior: Electrochromic glazing



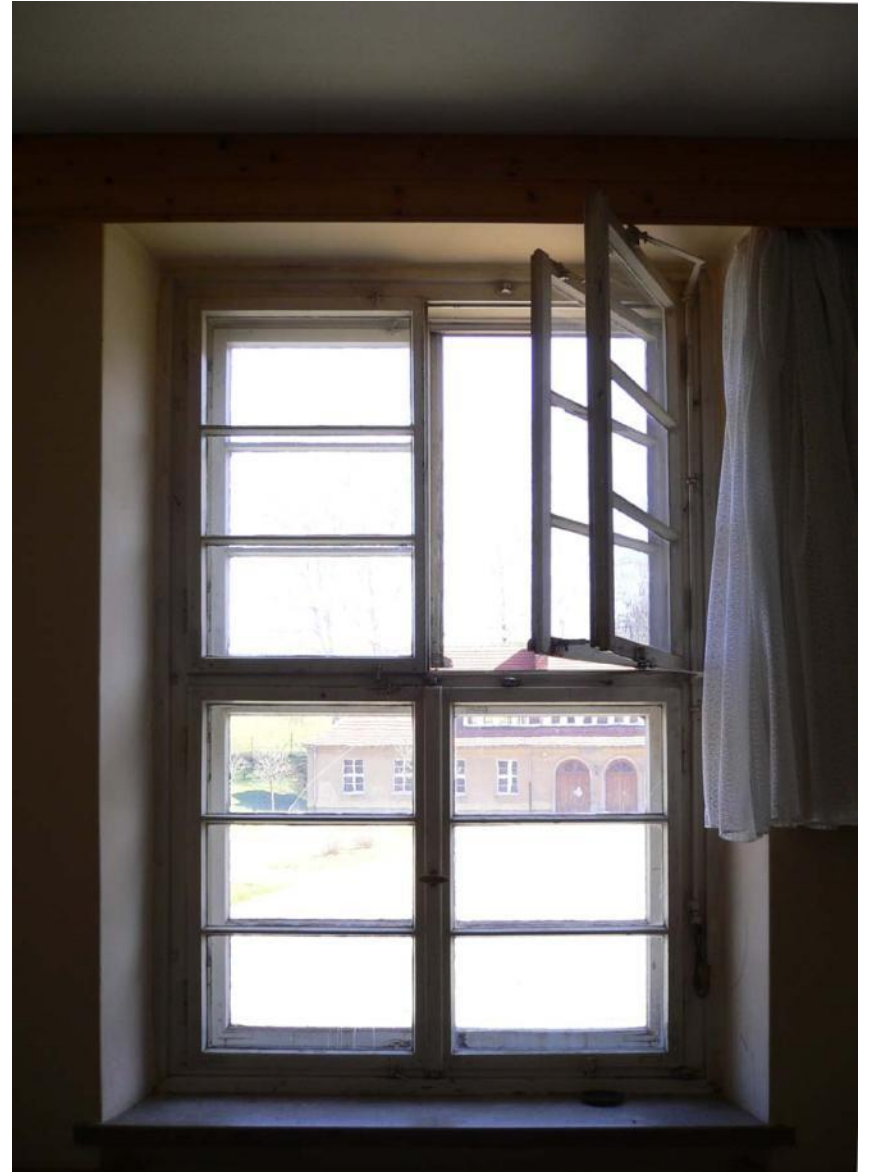
windows already had been changed before renovation (double low-E)



# Window, old, mock-up a



## Window, old and new





# mock up with different glazing and daylighting systems



exterior upper window: daylight  
redirecting glass "Okasolar W";  
exterior lower window: electrochromic  
glazing; interior window: double low-E

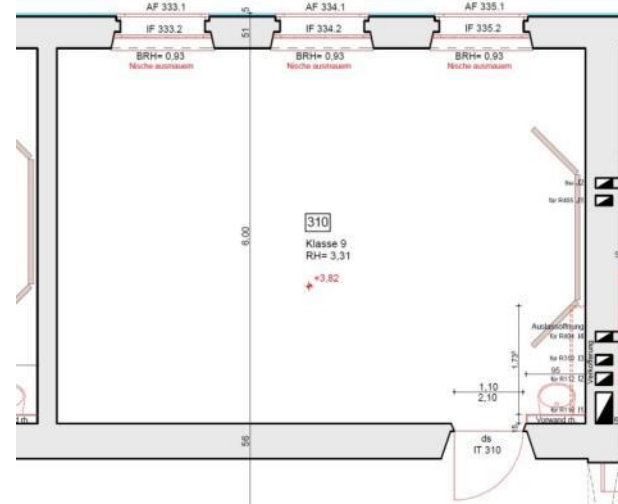


exterior and interior glazing:  
double low-E;  
shading system: Blinds: Warema  
Genius E 50 (white)



exterior and interior glazing:  
double low-E;  
shading system: Blinds: Warema  
Genius C/E 50 (mirrored aluminum)

# standard classroom – metrics on window system



Southeast orientation,  
glazing:  
interior: double low-E ,  
exterior: single white  
shading: blinds in double-  
window

	before renovation	after renovation
area of classroom	50,76 m <sup>2</sup>	50,76 m <sup>2</sup>
opening area (gross)	8,70 m <sup>2</sup>	8,70 m <sup>2</sup>
opening to floor area ratio	17%	17%
reduction factor of frame	0,60	0,55
glazing area	5,24 m <sup>2</sup>	4,79 m <sup>2</sup>
glazed to floor area ratio	10%	9%
visible transmission of glazing	0,84	0,76

-9%

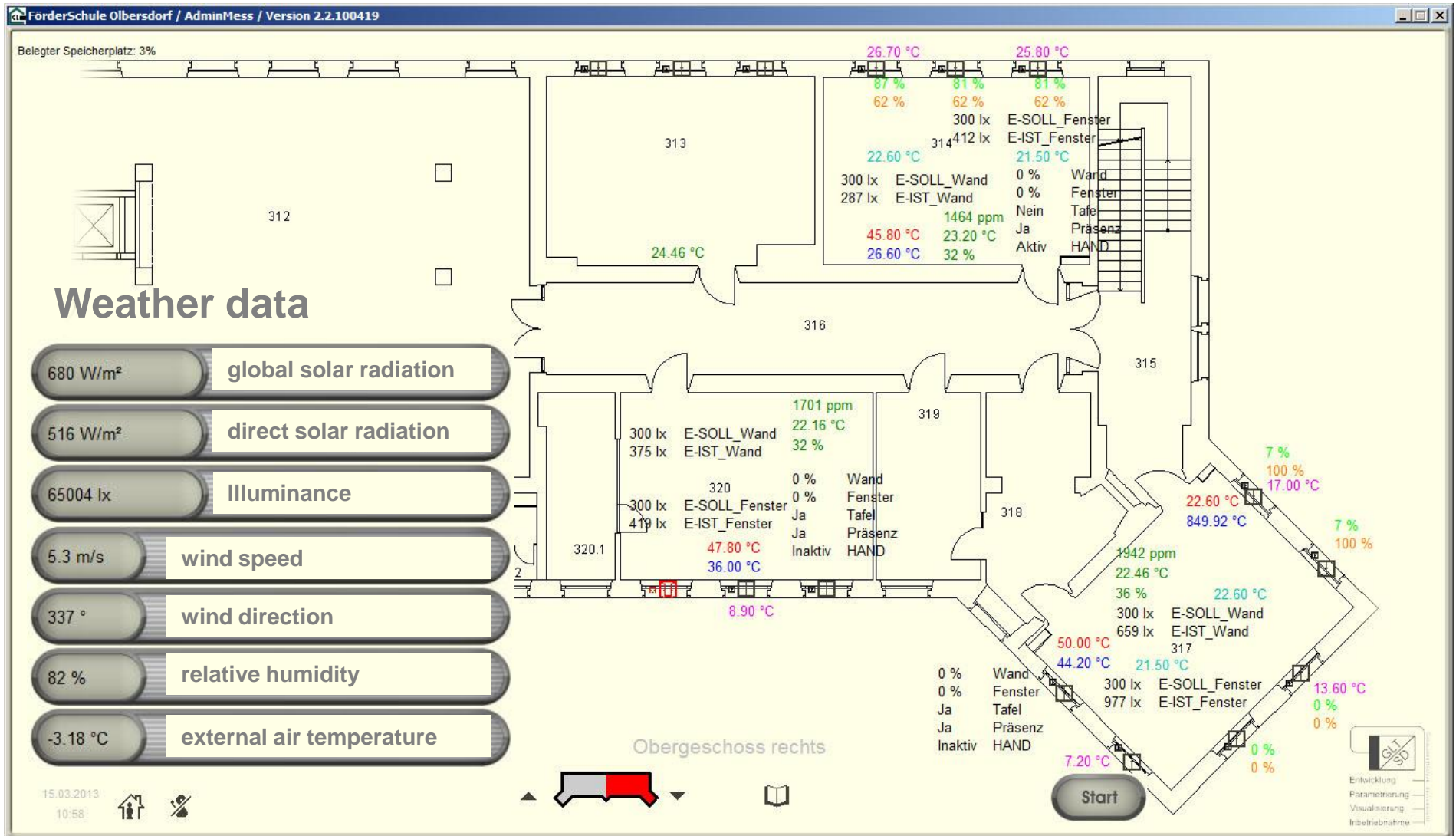
-10%

Metrics on Window-System before and after renovation

	before renovation	after renovation
Center	1,3%	1,4%
Reference point left side (half depth, 1 m from left sidewall)	1,1%	0,9%
Reference point right side (half depth, 1 m from right sidewall)	0,9%	0,8%

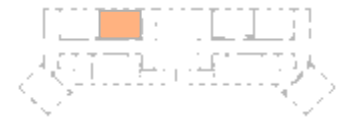


# Screen dump of monitoring system on 15<sup>th</sup> of March, 2013 10:58



monitoring of 549 data points in the lighting scan

# standard classroom – interior view



	window (point 2)	middle (point 3)	corridor (point 4)
relative usable lighting contribution (spring / fall*, 9. am – 2 pm, base: 300 lx)	99,5%	92,4%	85,2%
relative period of use (spring / fall*, 9. am – 2 pm, base: 300 lx)	96,4%	71,7%	62,7%
cylindric / horizontal illuminance	66,2%	87,5%	100,9%

\*) monitoring was performed from 20.10.2011 until 25.10.2011 and from 11.02.2012 until 16.02.2012.



# standard classroom – control system

light switch;  
location: next to entrance.

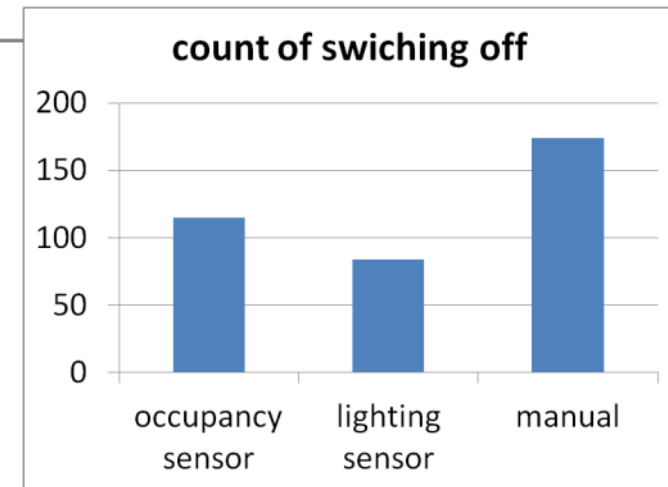
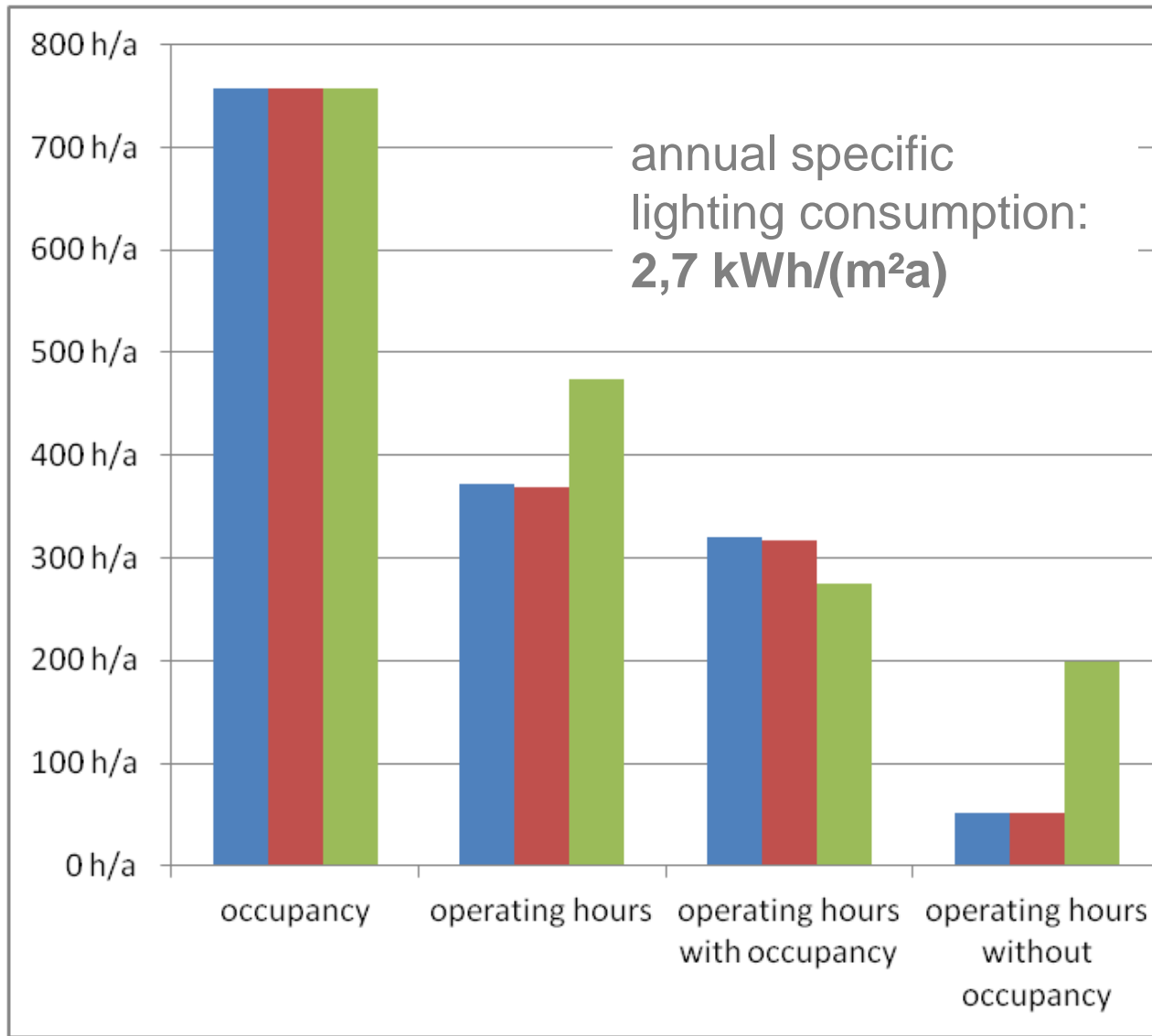
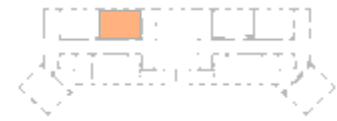


Activation of room-lighting:  
daylighting systems and electric lighting systems are adjusted in order to safeguard the set-point-illuminance.  
In case of direct sunlight automated louver-blinds prevent from glare.

Control panel for teacher;  
location: next to blackboard  
secured by keyswitch.



# occupancy & operating hours of electric lighting

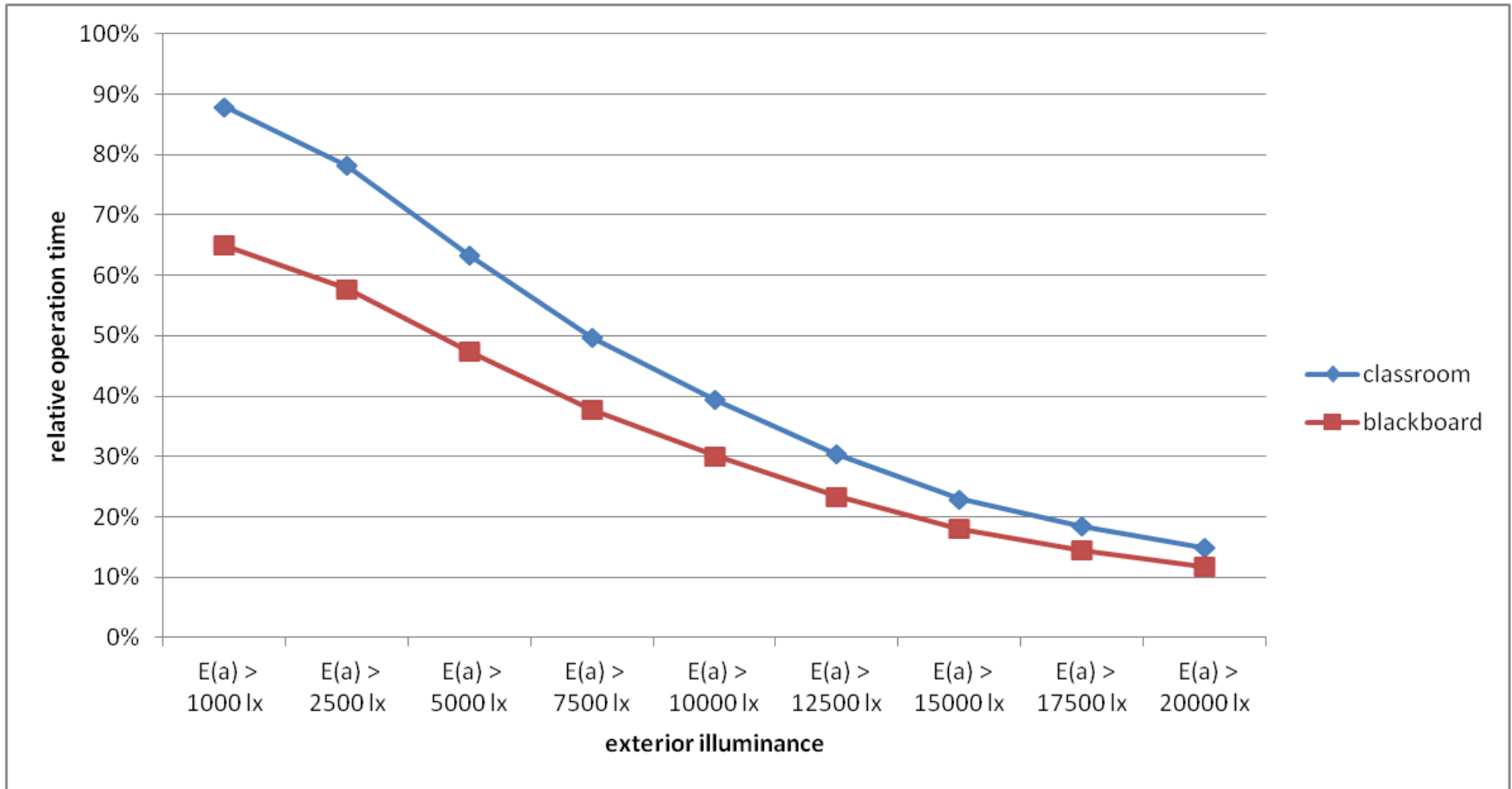
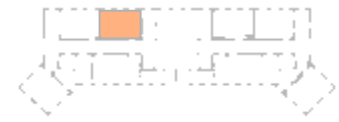


- 314\_wall
- 314\_window
- 314\_blackboard

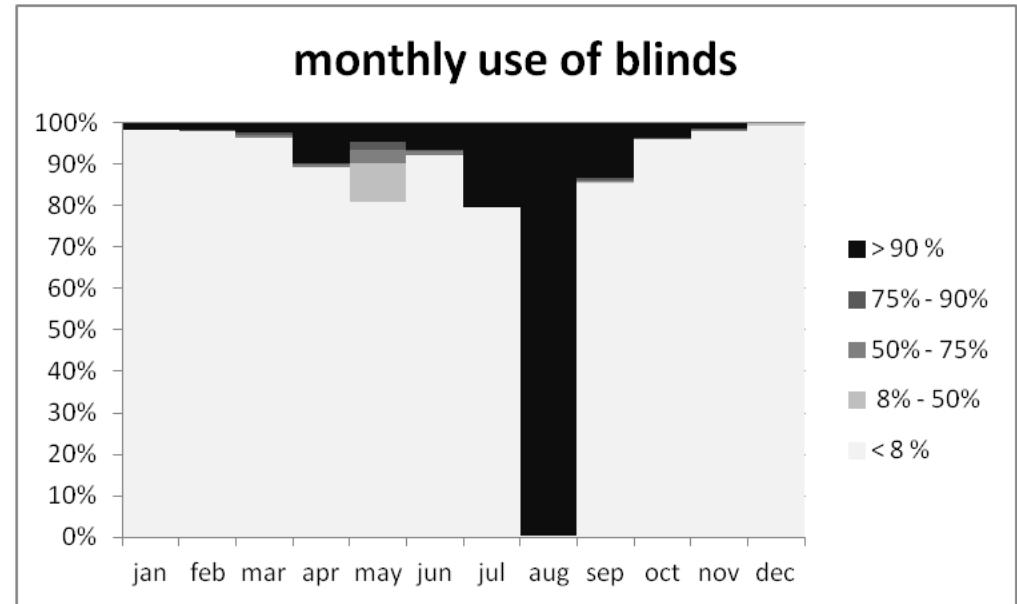
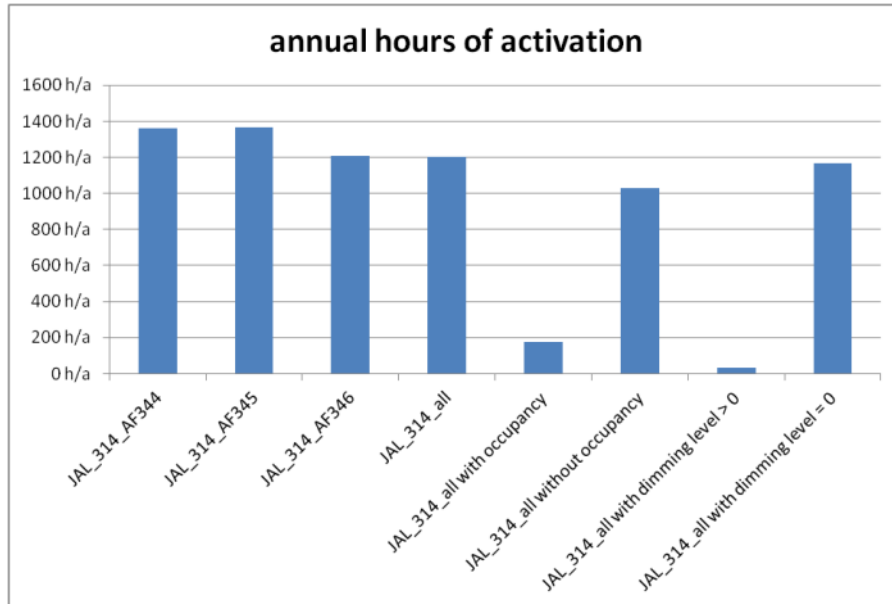
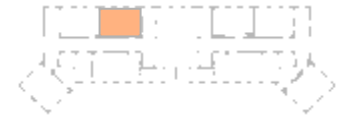
specific final annual energy lighting energy use calculated with adjusted profile of usage according to DIN V 18599-4:  
 after renovation: **2,73 kWh/(m²a)**  
 before renovation: **10,95 kWh/(m²a)**



# daylight & operating hours of electric lighting



# Shading systems – Blinds (Southeast-facing)

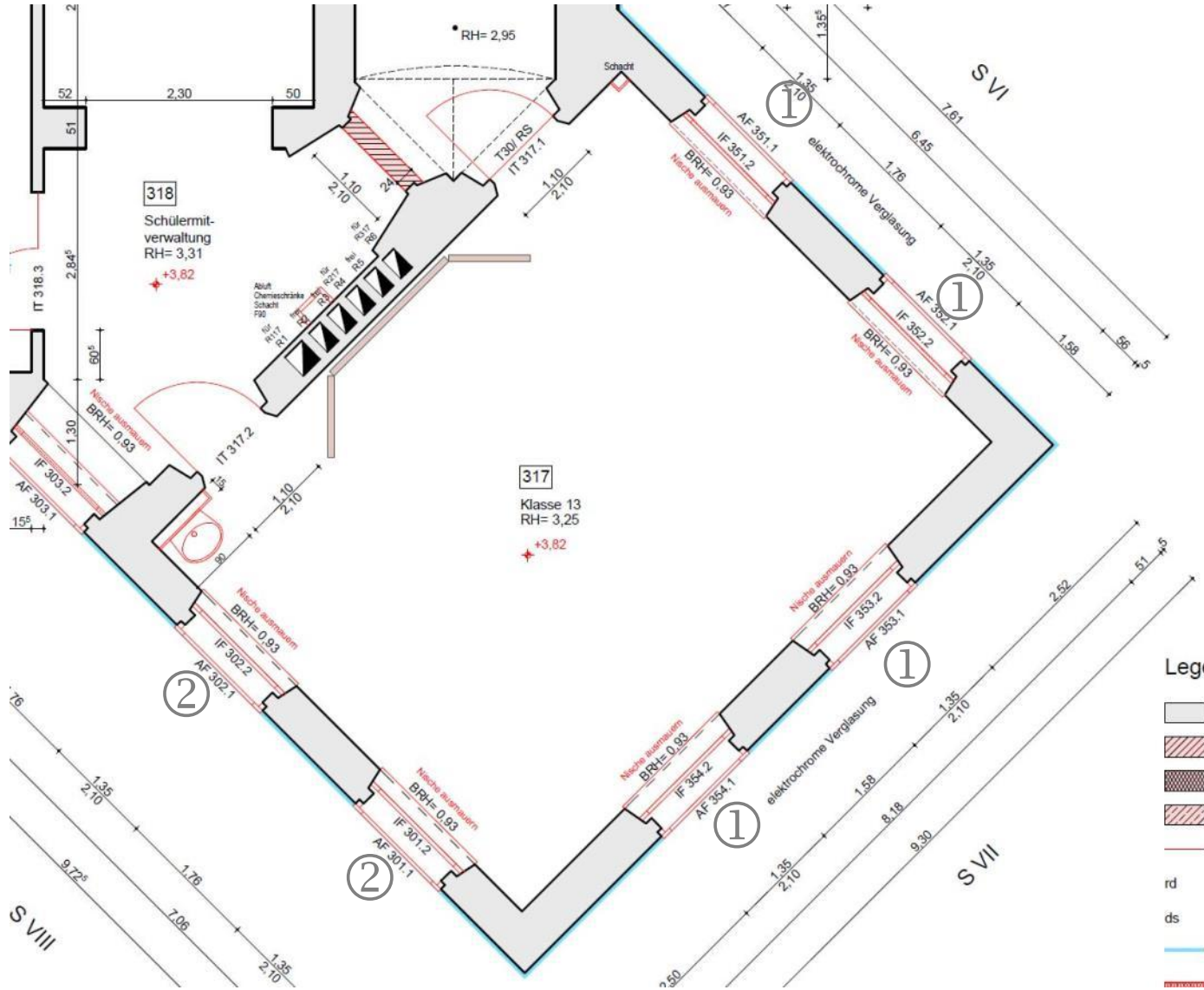


monthly relative period of relative extension of blinds  
 (<8%: recessed; >90 blinds completely cover the window)



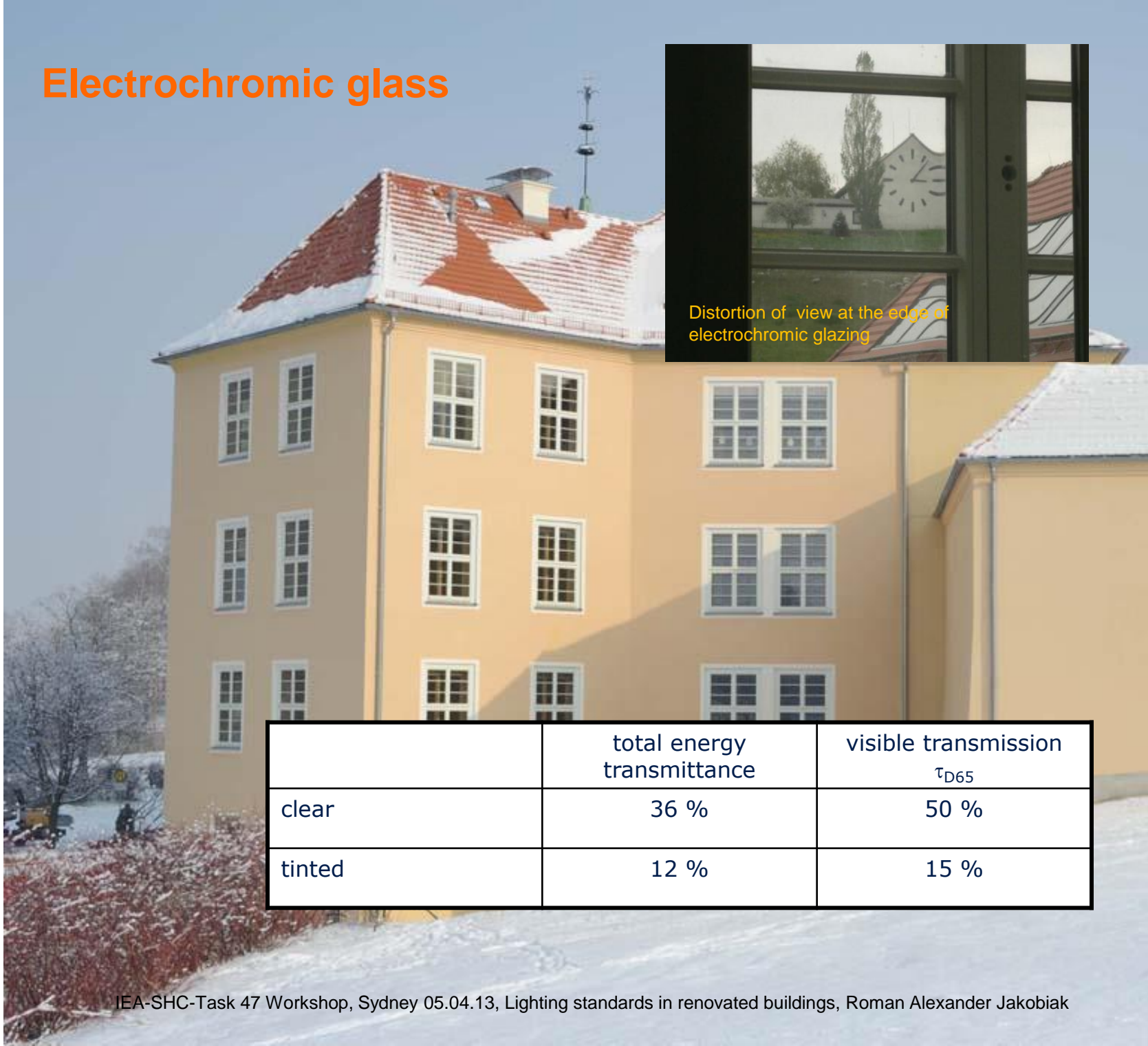
# floor plan of classroom with three facades

Source: AIZ



- ① South and West:  
glazing:  
interior: double low-E ,  
exterior: electrochromic  
  
shading: blinds in double-  
window
- ② North:  
glazing:  
interior: double low-E ,  
exterior: single white  
  
shading: none

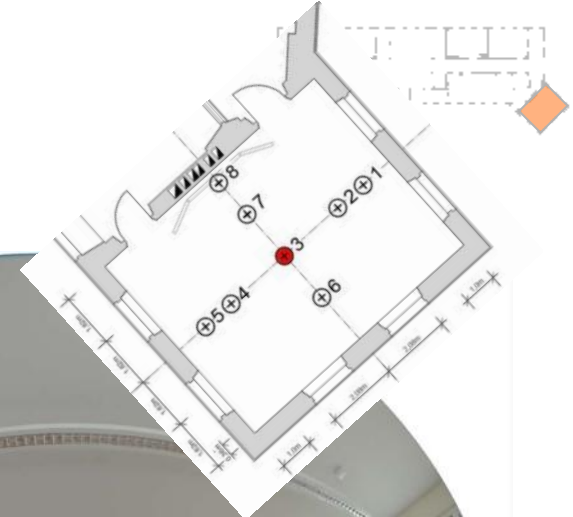
# Electrochromic glass



	total energy transmittance	visible transmission $\tau_{D65}$
clear	36 %	50 %
tinted	12 %	15 %

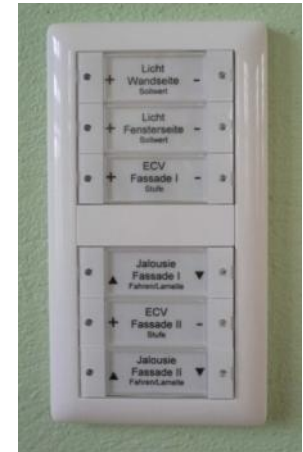
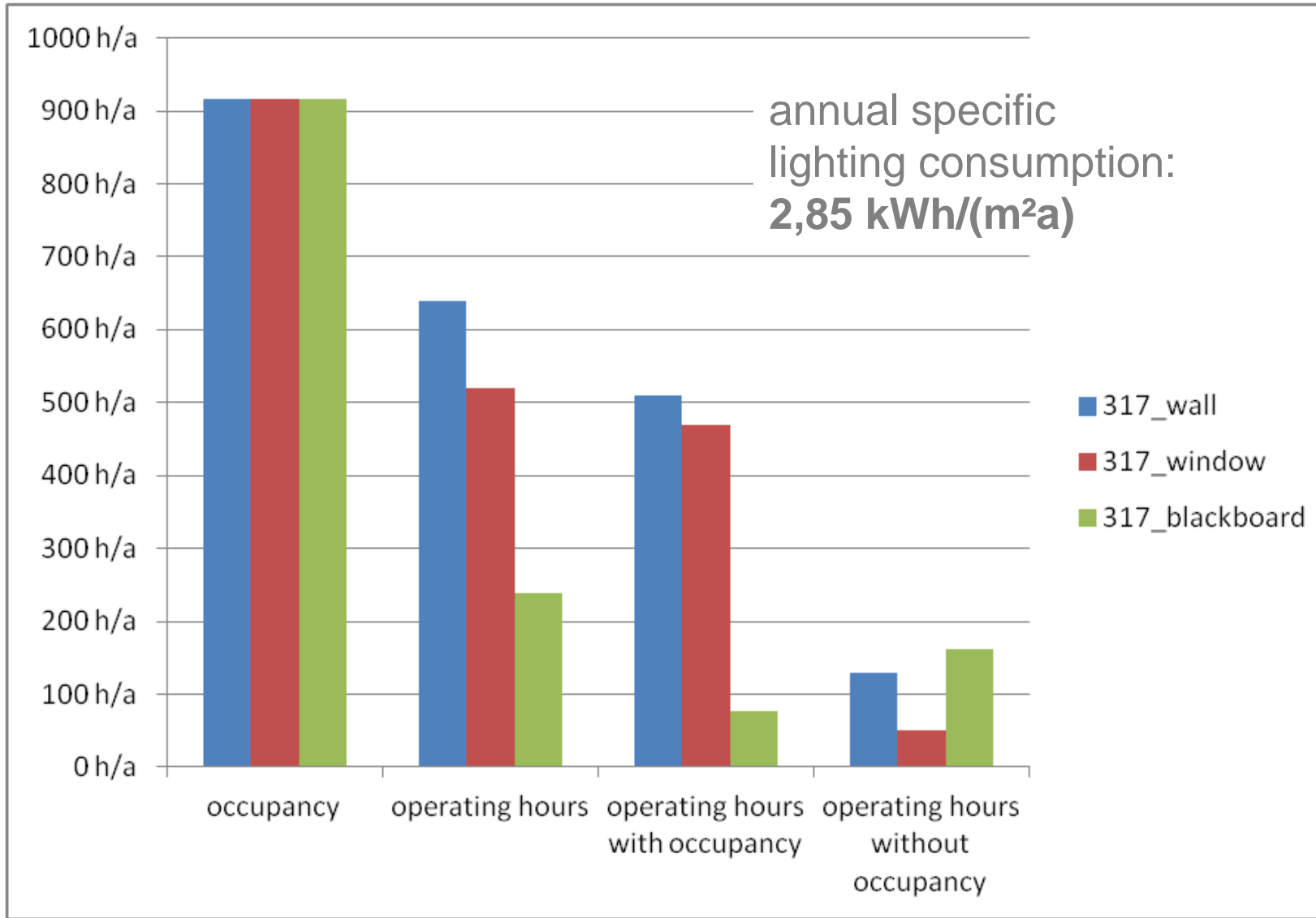


# Classroom with three facades



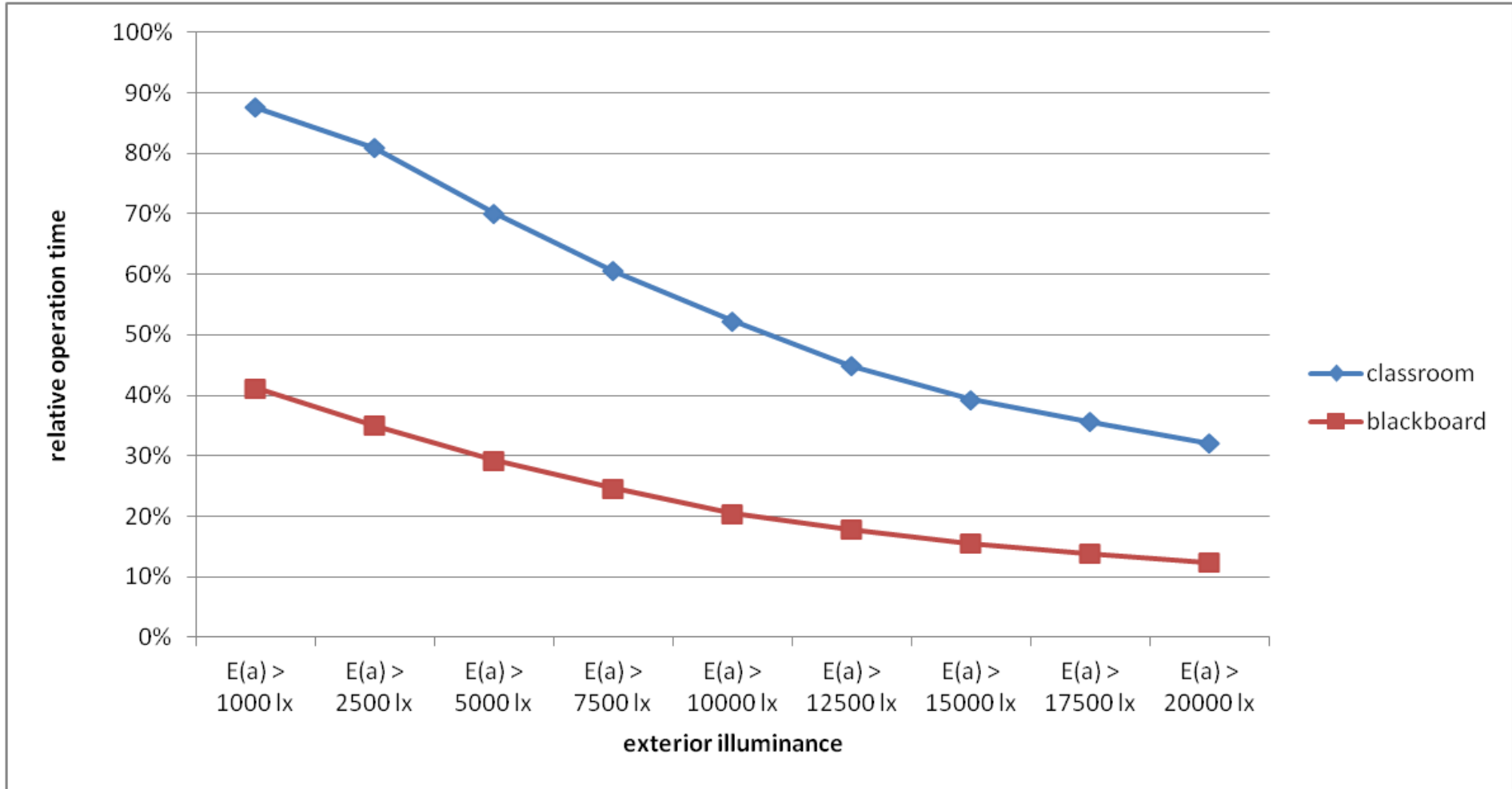
	summer	spring / fall	winter
relative usable lighting contribution (9. am – 2 pm, base: 300 lx)	99%	93%	82%
relative period of use (9. am – 2 pm, base: 300 lx)	93%	74%	61%
cylindric / horizontal illuminance	100%	98%	106%

# occupancy & operating hours of electric lighting

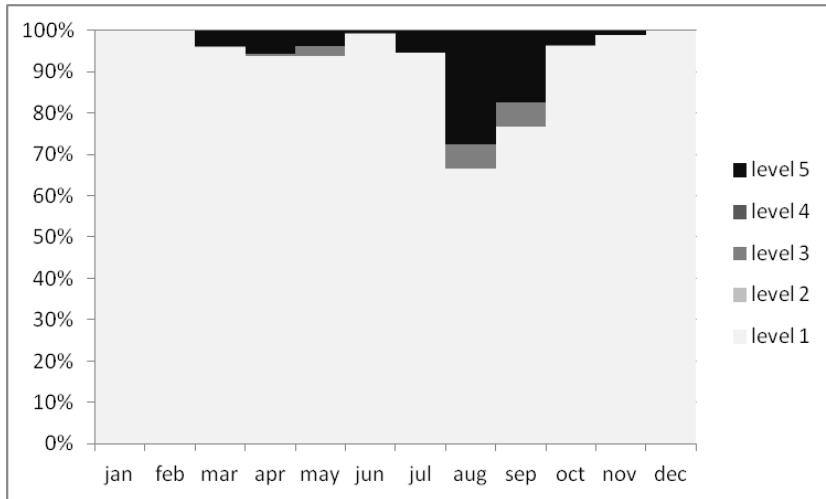




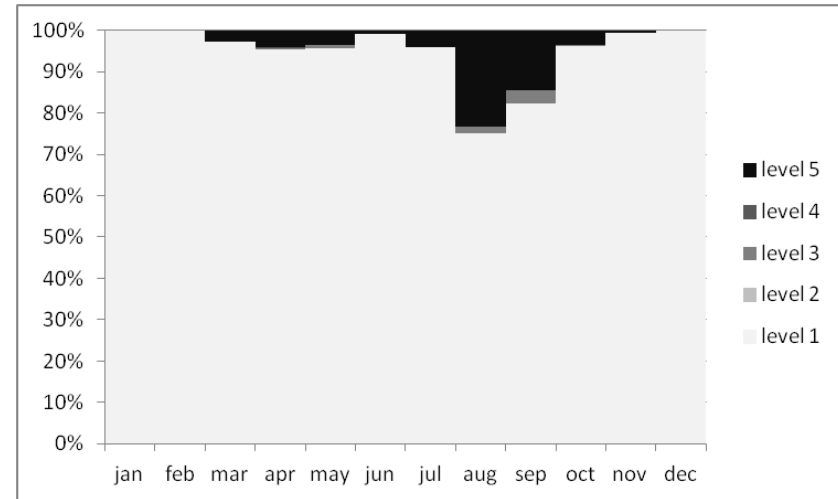
# daylight & operating hours of electric lighting



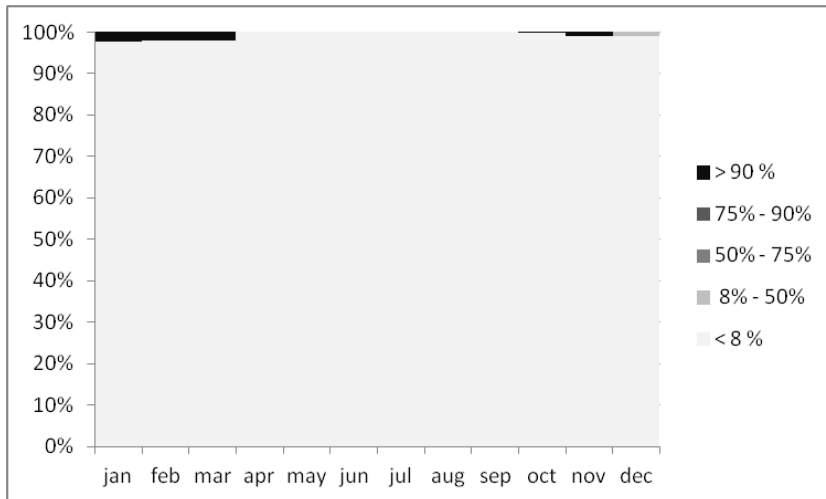
# Shading systems



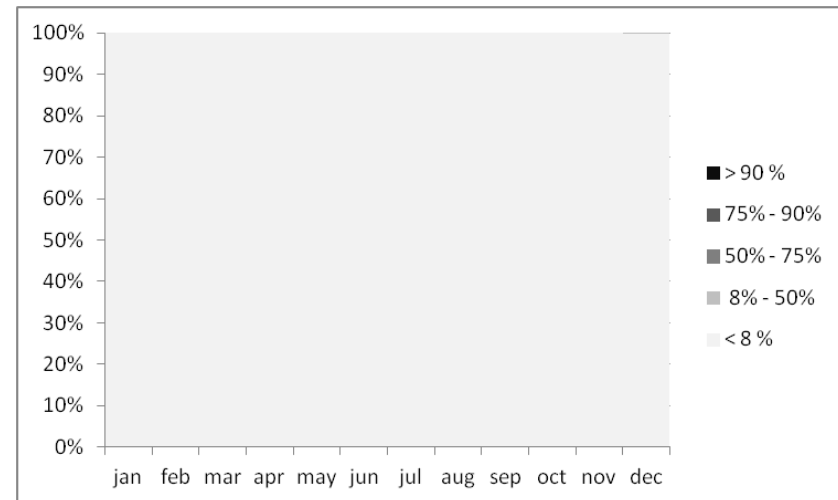
EC-Glass – South facing  
(automated + manual override)



EC-Glass – West facing  
(automated + manual override)



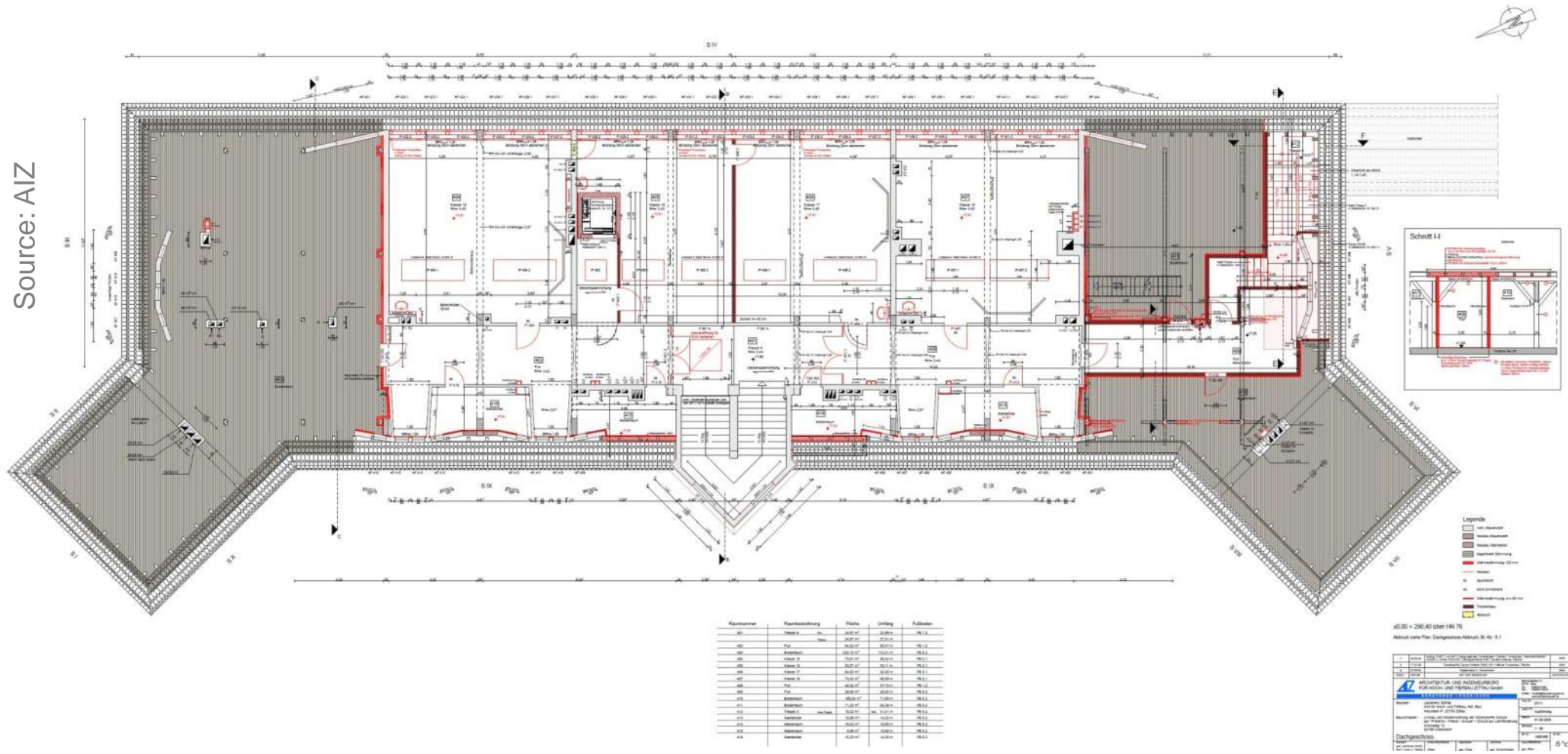
Blinds – South facing  
(operated manually)



Blinds – West facing  
(operated manually)

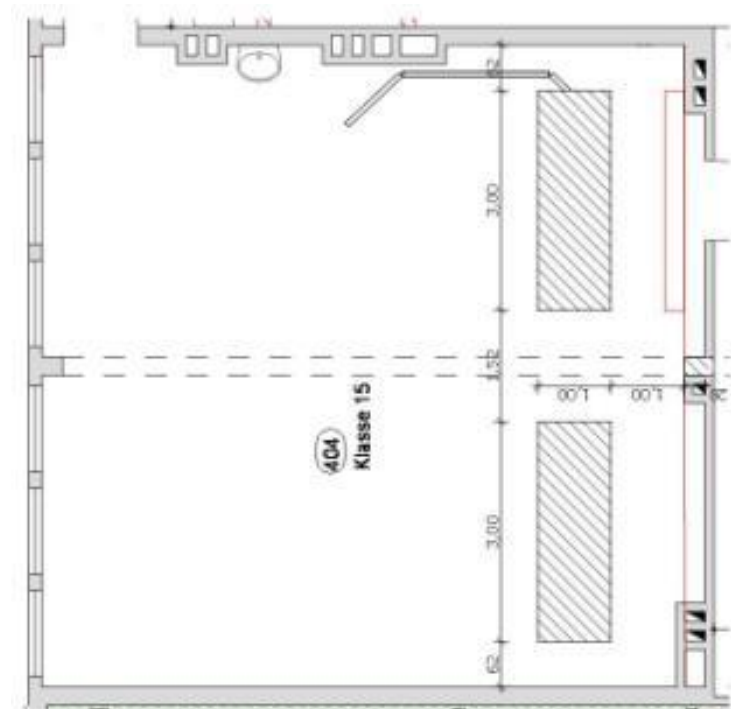
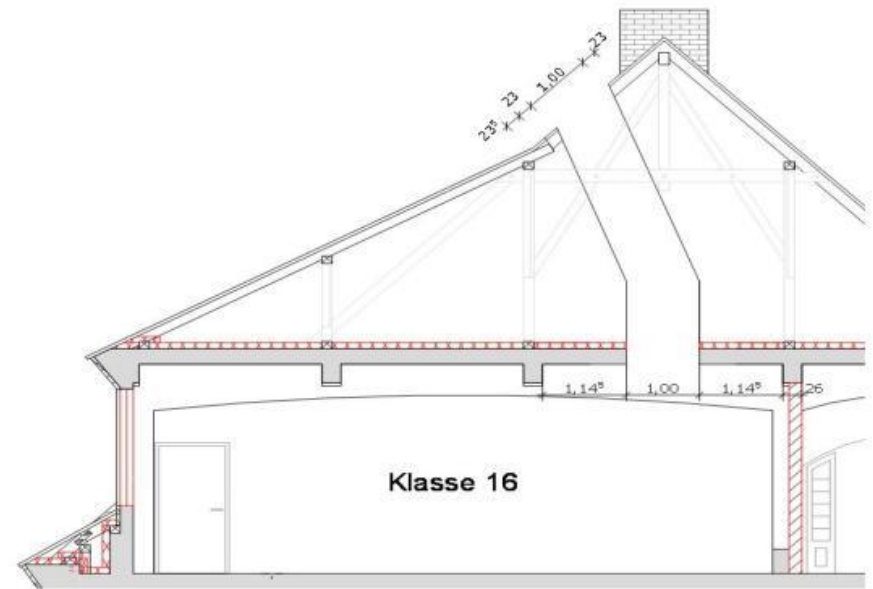
# Floor plan of the attic

Source: AIZ

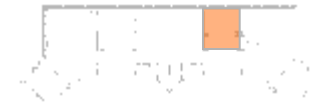
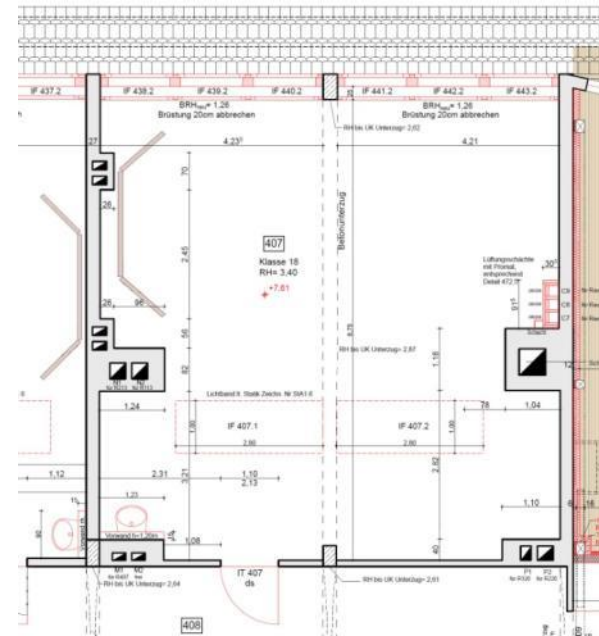




# new rooflight



# Classroom in the attic

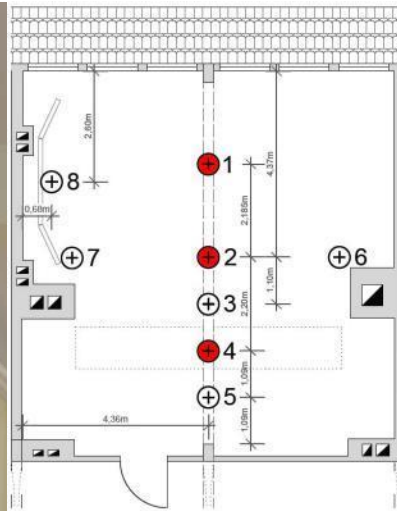
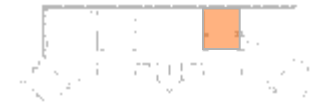


	before renovation	after renovation
area of classroom	75 m <sup>2</sup>	75 m <sup>2</sup>
opening area (gross)	8,03 m <sup>2</sup>	17,32 m <sup>2</sup>
opening to floor area ratio	11%	23%
glazing area	5,08 m <sup>2</sup>	11,09 m <sup>2</sup>
glazed to floor area ratio	7%	15%

Metrics on Window-System before and after renovation

	before renovation	after renovation
middle axis, distance from window: 2,26 m	2,5%	1,2%
center of room	1,3%	1,1%
middle axis, distance from window: 6,77 m	0,6%	1,7%

# Classroom in upper storey



Snow on rooflights

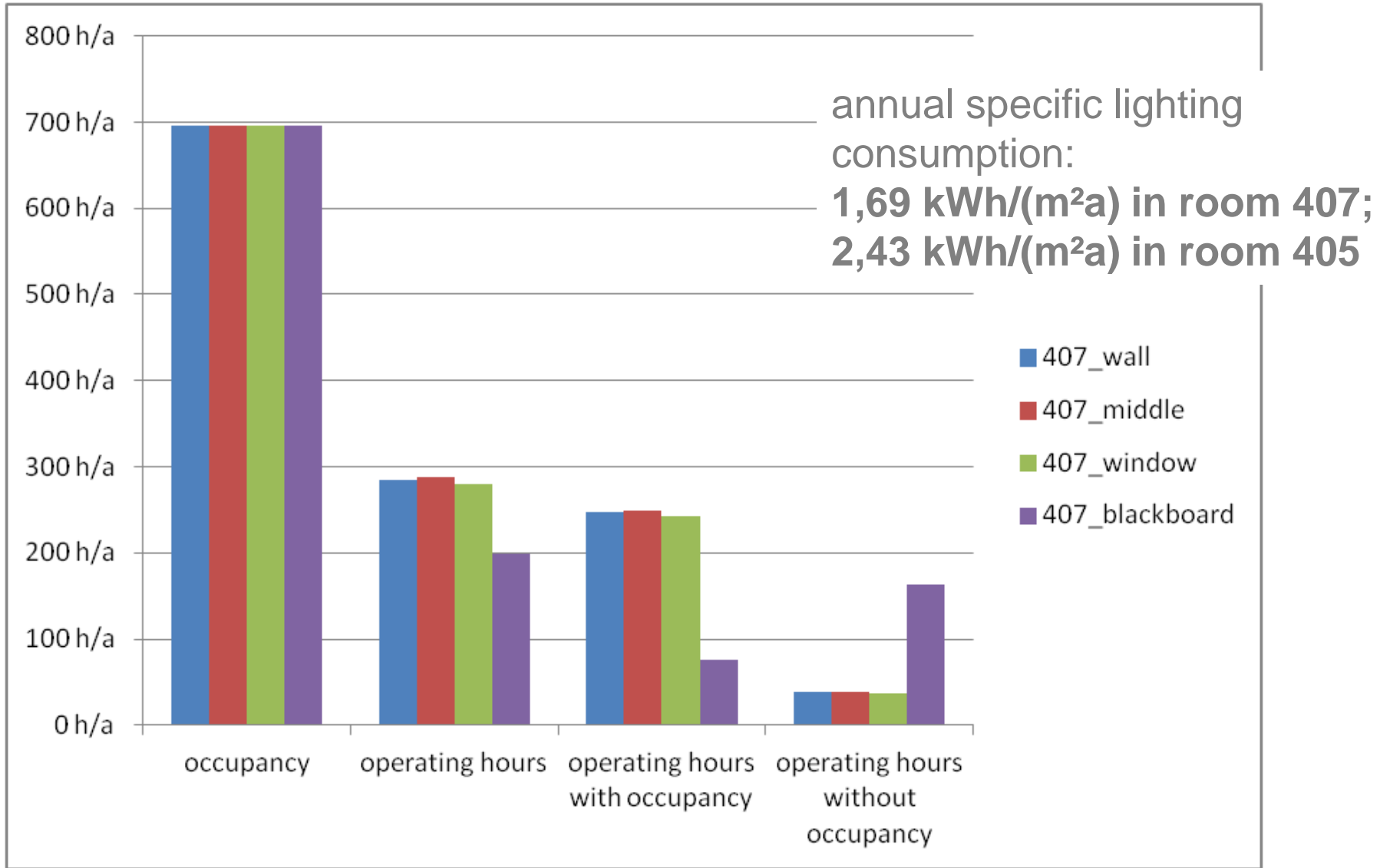
EC-glass



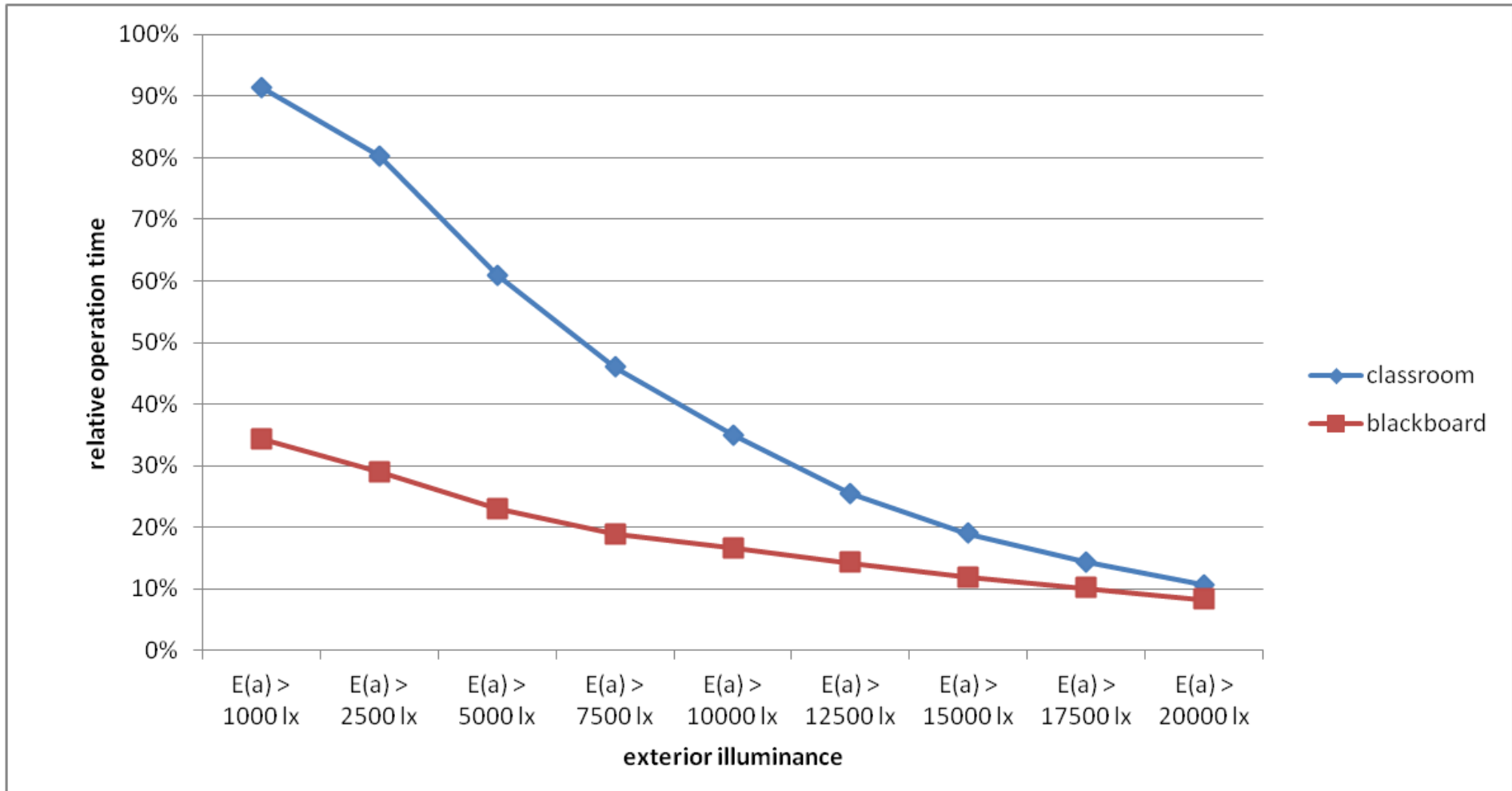
		corridor (point 4)	middle (point 2)	window (point 1)
relative usable lighting contribution (9. am – 2 pm, base: 300 lx)	summer	92%	80%	79%
	spring	94%	91%	88%
	winter	40%	33%	37%
relative period of use (9. am – 2 pm, base: 300 lx)	summer	74%	53%	50%
	spring	86%	78%	73%
	winter	8%	8%	10%
cylindric / horizontal illuminance	summer	34%	66%	65%
	spring	39%	59%	78%
	winter	48%	75%	75%



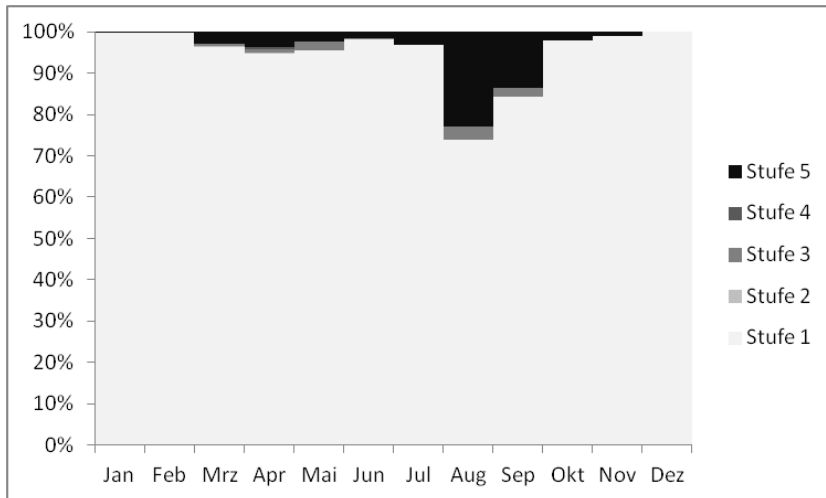
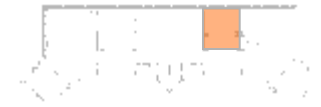
# occupancy & operating hours of electric lighting



# daylight & operating hours of electric lighting



# Shading systems



EC-Glass – Southeast facing  
(automated + manual override)



Blinds – Southeast facing  
(operated manually)



# Olbersdorf special school, sports hall before refurbishment

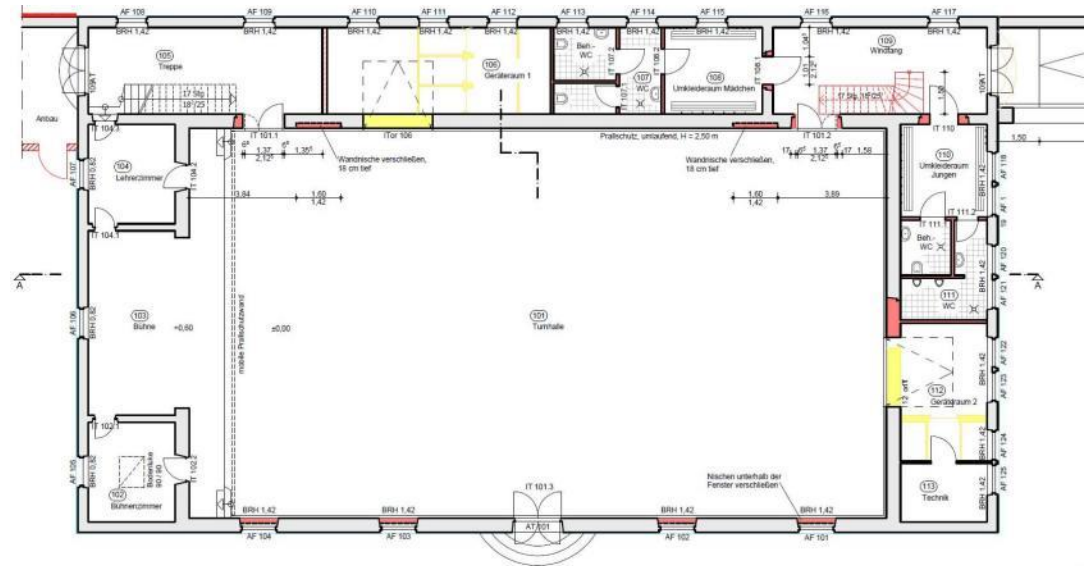




## Sports hall – construction of new rooflight



# Sports hall



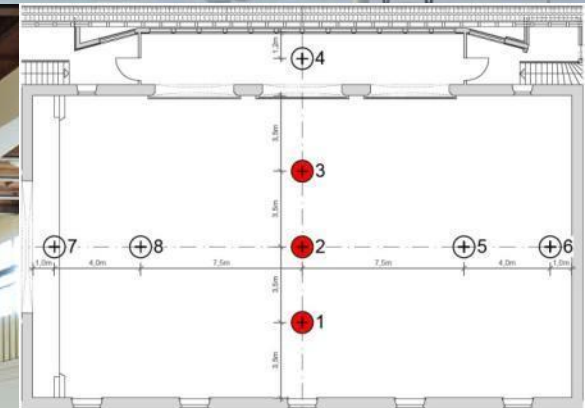
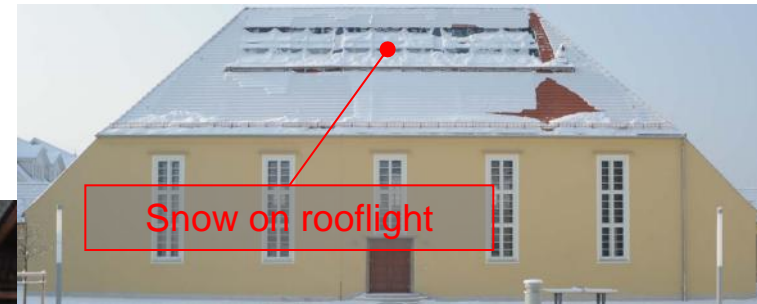
	before renovation	after renovation
floor area	350 m <sup>2</sup>	350 m <sup>2</sup>
opening area (gross)	39,3 m <sup>3</sup>	80,2 m <sup>2</sup>
opening to floor area ratio	11%	23%
glazing area	21,17 m <sup>2</sup>	58,02 m <sup>2</sup>
glazed to floor area ratio	6%	17%

Metrics on Window-System before and after renovation

	before renovation	after renovation
middle axis, window area	1,0%	2,7%
center of room	0,7%	3,1%
middle axis, rear side	0,3%	2,0%

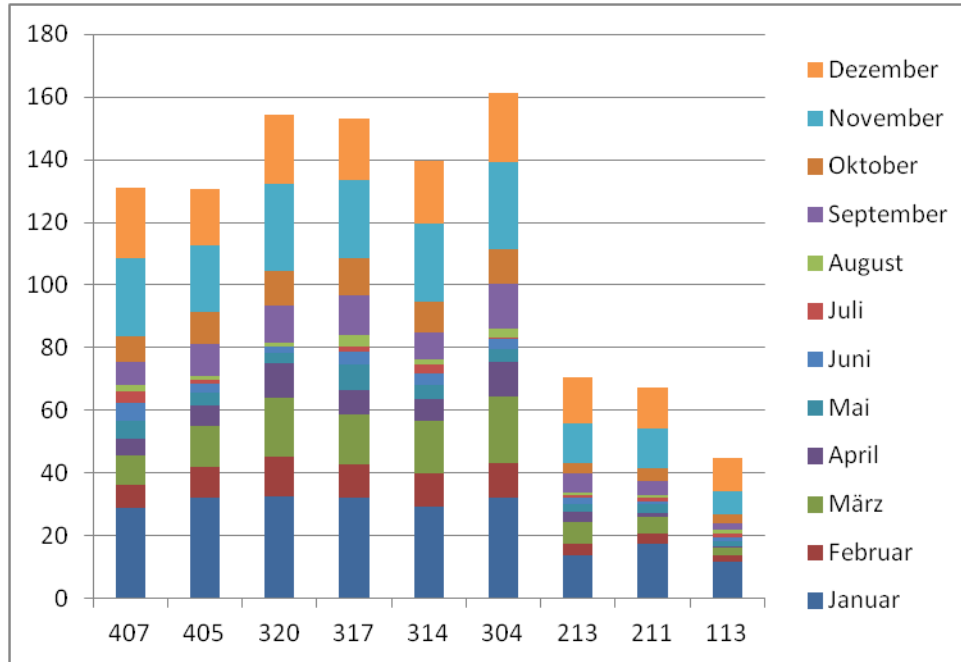


# Sports hall with new rooflight

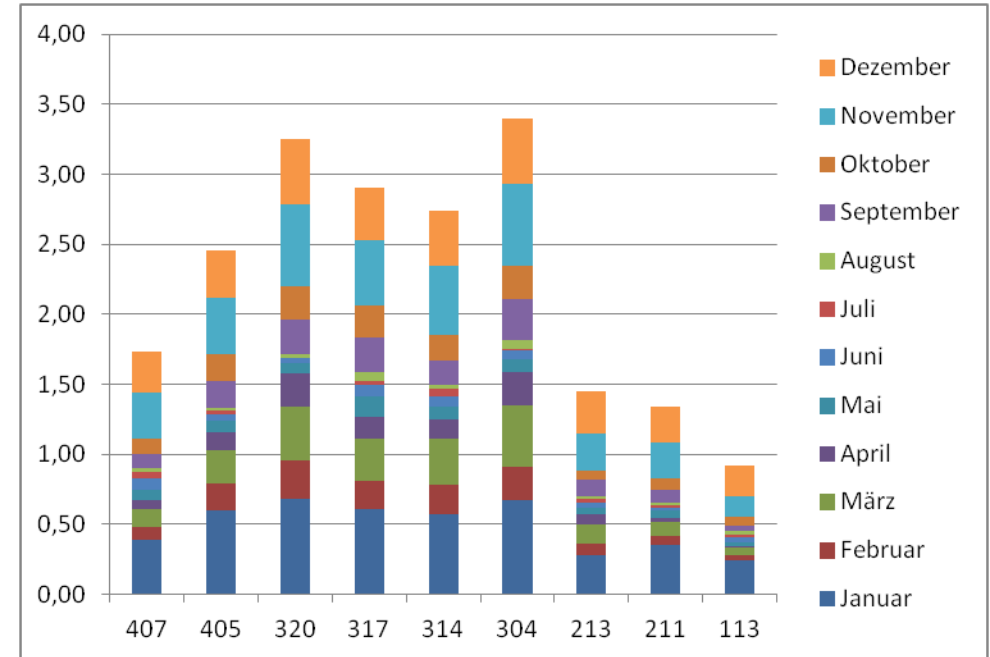


		window (point 1)	middle (point 2)	next to gallery (point 3)
relative usable lighting contribution (9. am – 2 pm, base: 300 lx)	summer	100%	100%	99%
	spring	96%	97%	91%
	winter	55%	60%	42%
relative period of use (9. am – 2 pm, base: 300 lx)	summer	98%	98%	97%
	spring	79%	85%	68%
	winter	12%	18%	3%
cylindric / horizontal illuminance	summer	42%	42%	49%
	spring	48%	47%	51%
	winter	40%	40%	46%

# classrooms, lighting energy consumption



lighting energy consumption in classrooms in the first year of operation [kWh]



Specific lighting energy consumption in classrooms in the first year of operation [kWh/m²]



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**T h a n k   Y o u   !**

**Task 47 Workshop: Renovation of Non-Residential Buildings towards Sustainable Solutions, Sydney 05.04.13**

**Lighting standards in renovated buildings**

**Roman Alexander Jakobiak  
office@daylighting.de**

