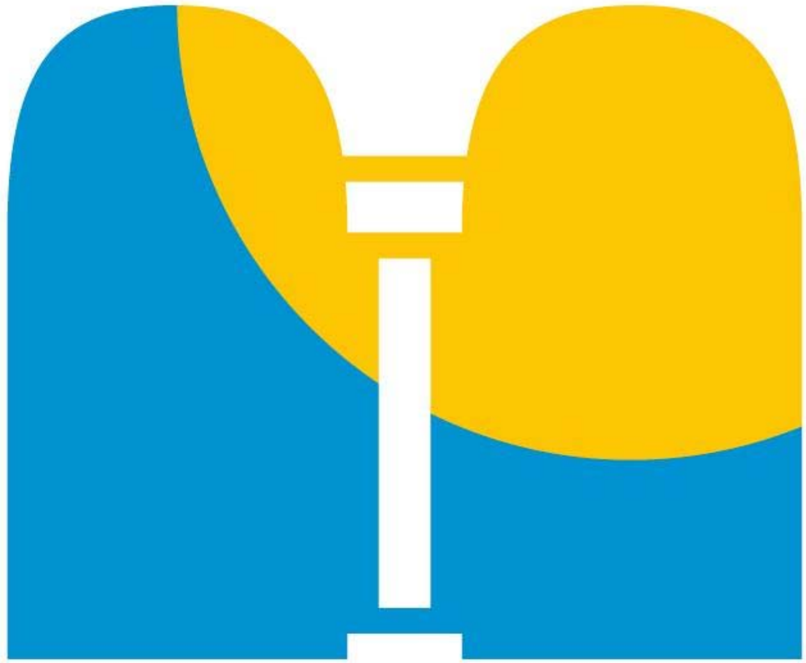

D8.9 Educational Material for University Studies

Sustainable Refurbishing of Historic Buildings and Relevant Building Physical Aspects based on

Case Study 5:
Secondary School Hötting
Innsbruck, Austria

The research leading to these results has received funding from the European Community's Seventh Framework Programme (FP7/2007-2013) under grant agreement n° 260162

Guiding principle

Presentation 1
Author: Rainer Pfluger, Gerald Gaigg, Kai Längle
Partner: University of Innsbruck (UIBK)
University course: Nachhaltige Gebäudesanierung ("Sustainable Renovation" for Students in "Masterstudium Domotronik")
Date: 16.01.2013
Place: Innsbruck, University of Innsbruck, SR-Container 5
Title of the lesson: “Sustainable Renovation of Buildings - Lessons learnt from 3ENCULT-Case Study CS5”
Description of the contents: Within the university course "Sustainable renovation", students learn refurbishing strategies and how to include energy efficiency. The course "Nachhaltige Gebäudesanierung" is about refurbishing in general (not only on listed buildings and cultural heritage), however the training material elaborated within 3ENCULT has it's special focus on that. The content includes some introduction in terms of basic building physical issues as well as the principles of conservation. The school building CS5 (NMS Hötting) was used to demonstrate how to find well adapted solutions for a specific building, based on detailed building diagnosis and measuring results for comfort and air quality parameters.
Name of the file: WP8_D8.9_20131007_UIBK-Presentation 1

Content Overview

Basic principles

- Conservation principles
- Building physical principles

Case study example 3ENCULT CS5

- Building **diagnosis** and **comfort** measurements
- Minimal invasive **insulation**
- **Prevention of condensation** Optimization of **heating control**
- Development of new **ventilation concept**
- Enhanced **daylight autonomy** by daylight redirection
- Improved **artificial lighting using LED**
- Highly efficient **acoustic absorbers**

Conservation Principles

Introduction

- "Historic structures constitute a large percentage of the building stock in Europe and a valuable asset for residential, public, representative cultural and touristic use. Although usually legally treated as exceptional cases and thus excepted from energy legislation, energy efficiency is a good chance to support the future use of historic buildings. Through smart implementation of high quality energy efficiency solutions in many cases a notable reduction in the energy demand of historic buildings is achievable. However, working on historic buildings requires sensitive approaches."

Source: D3.3 Introduction
(Christoph Franzen (IDK), Torben Dahl (KA), Ola Wedebrunn (KA), Franziska Haas (TUD))

Conservation Principles

The Basic Principles of Cultural Heritage Preservation

- Preservation of the building
- Retaining the historic character
- Maintaining the structure

Any intervention has avoid or minimize the

- Impact on substance (material)
- Impact on image

If changes are not avoidable, the interventions should guarantee the reversibility

Conservation Principles

Basic questions to be answerd before any intervention in historic buildings

- What kind of, which amount and where is **destructive work** on the building needed for that implementation?
- What is the **change of the actual appearance**?
- What is the change in terms of **the historic use and architectural idea**?
- What are the consequences for the **total building climate**?
- How is made sure, that the new climate situation does **not risk the building material or the interior?**

Source: D3.3 Introduction
(Christoph Franzen (IDK), Torben Dahl (KA), Ola Wedebrunn (KA), Franziska Haas (TUD))

Cultural Heritage:
EIA, SEA and SUIT

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Wind tunnel, Hispano-Suiza, Bois Colombes: 1937-1999
Historic monument

Source: Gerald Gaigg, case study group CS5

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Cultural Heritage:
EIA, SEA and SUIT

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Soufflerie Hispano-Szuiza, Bois Colombes: 1937-1999
Historic monument

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Conservation Principles

Further Reading

- **D2.1** Report on demand analysis and historic building classification
- **D2.2** Position Paper on criteria regarding the assessment of energy efficiency measures regarding their compatibility with conservation issues
- **D2.5** Report on Methodology and Checklist

Source: D3.3 Introduction
(Christoph Franzen (IDK), Torben Dahl (KA), Ola Wedebrunn (KA), Franziska Haas (TUD))

Energy Efficiency - Basic Principles

- Reduction of **transmission losses**
- Reduction of **ventilation losses**
- Avoiding of **thermal bridges, condensation** and **mold**
- Passive solutions: **Building envelope** and **thermal inertia**
- Active solutions: Energy efficient **heating, cooling** and **building services**

Source: D3.3

CS 5 NMS Hötting
Located in Innsbruck, Austria

CS 5 NMS Hötting
Situation before Intervention

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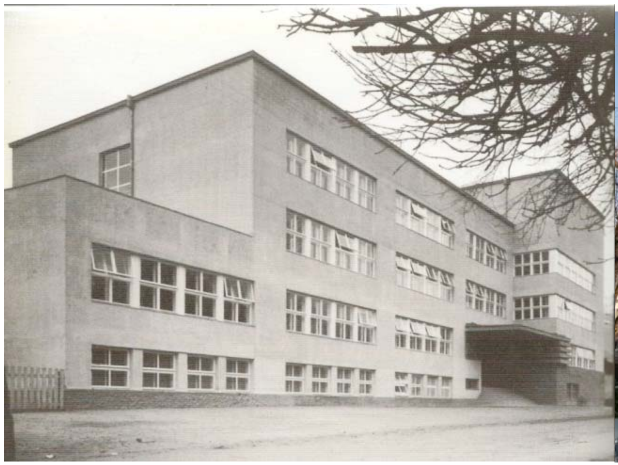
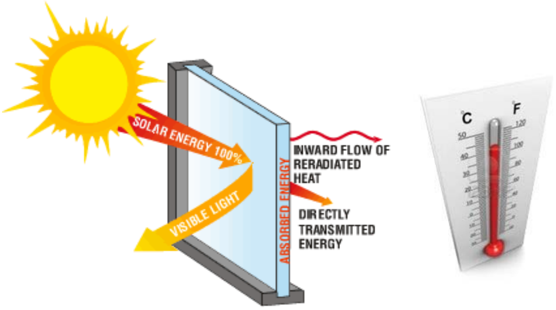
- **Construction in 1929/30**, architects Franz Baumann & Theodor Prachensky
- One of the most **important examples** of early modern architecture in Tyrol (Peter Behrens style), listed!
- **Annex from 1950** at the northeast part of the building
- Still in use as **school for pupil** at the age of 10 up to 15



Problematic issues of CS 5 NMS Hötting

Problems, which had to be solved:

- High **heating** energy demand ± **130 kWh/(m²a)**



- **Summer overheating** problems due to large unshaded glazing areas

- **Air quality** problems and low **thermal comfort**
  draft risk and low surface temperatures in winter

Cultural Heritage: EIA, SEA and SUIT

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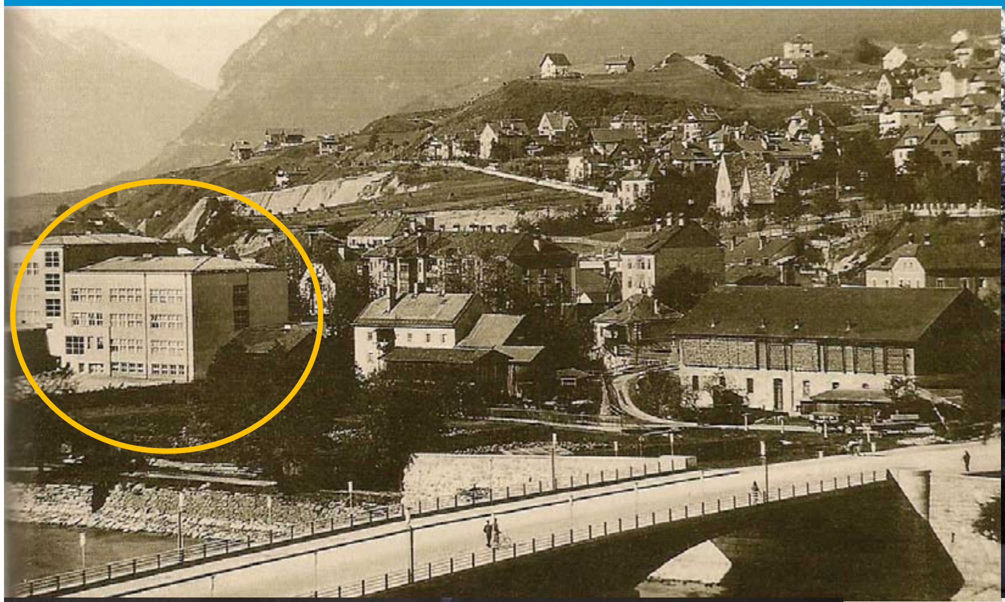

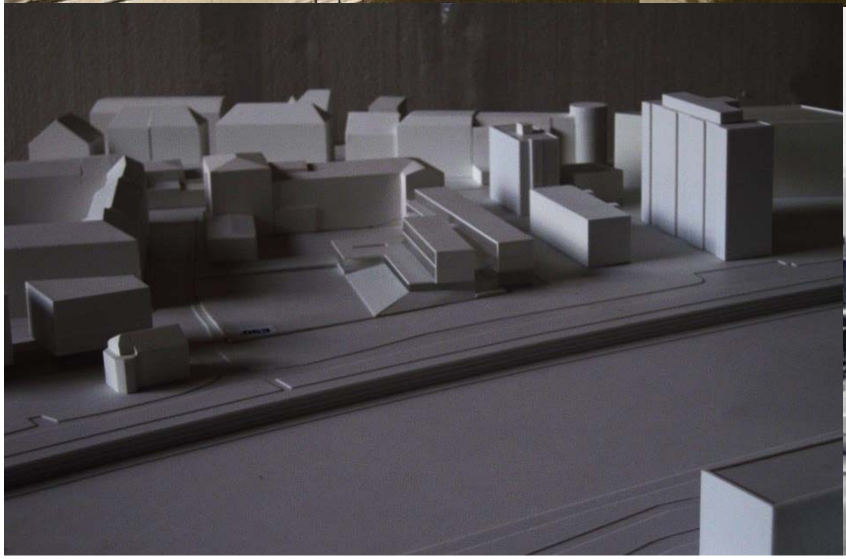

CS 5 NMS Hötting
Before and after Intervention

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CS 5 NMS Hötting
Building Diagnosis

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Why building diagnosis?

- Documentation of damages and risk of damages of the building construction
- Lack of comfort
- Information for decisions on future interventions

What kind of building diagnosis?

- Thermal, visual and acoustic comfort, indoor air quality
- Thermal bridges
- Material tests (plaster, screed, concrete, iron)

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CS 5 NMS Hötting
Monitoring Related to User Comfort

Thermal comfort

- Draft risk (air velocity)
- Temperature (radiation and air temperature)
- Relative humidity
- Open/close Status of windows and doors

Visual comfort

- Artificial light situation
- Daylight situation

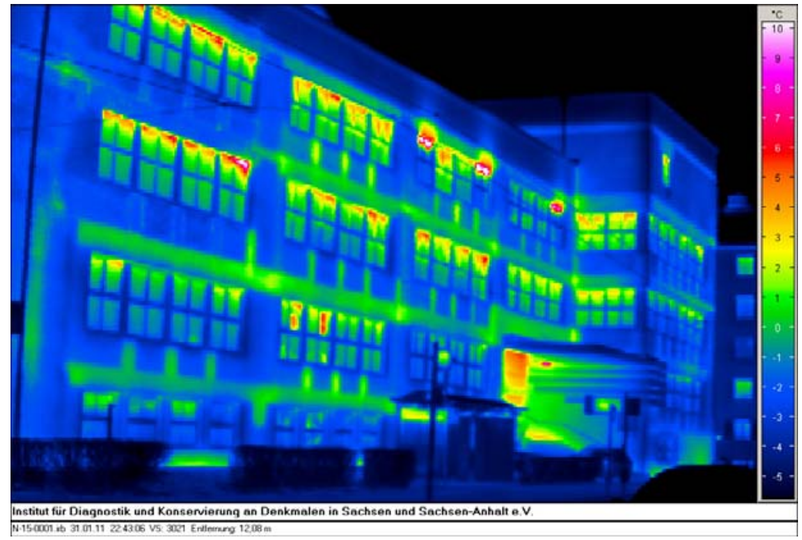
Indoor air quality

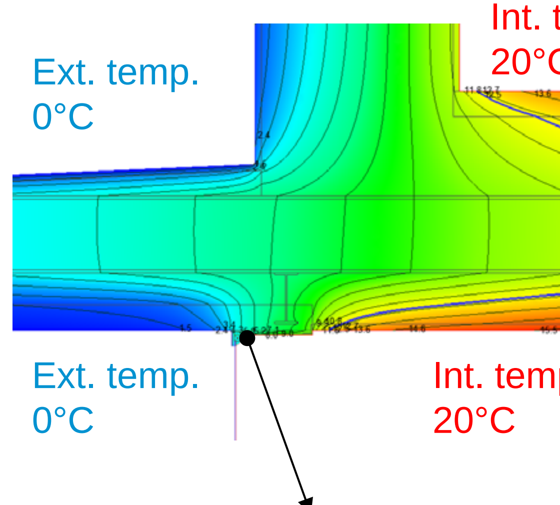
- high ventilation heat losses because of long-term windows ventilation even in winter

CS 5 NMS Hötting
Analysis of Energy Demand

Analyze → Building model

- **Building survey** and adaption of old plans
- **Infrared thermography**
- **Air-tightness-test**
- Analysis of actual **ventilation situation**
- Monitoring of **artificial light consumption**
- **Thermal bridge calculations**
- Calculation of **annual heat demand** by PHPP
- Calculations of **refurbishment variants**

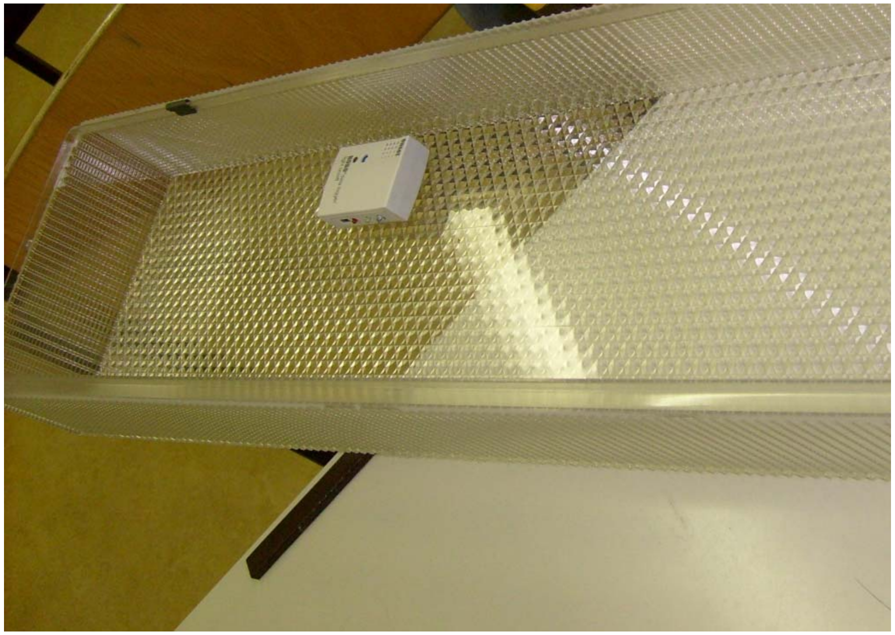




CS 5 NMS Hötting
Analysis of Energy Demand

Energy consumption of the electric lighting

-> Percentage of the artificial lights is monitored by on/off logger which are mounted at the luminaires



Thermal Comfort

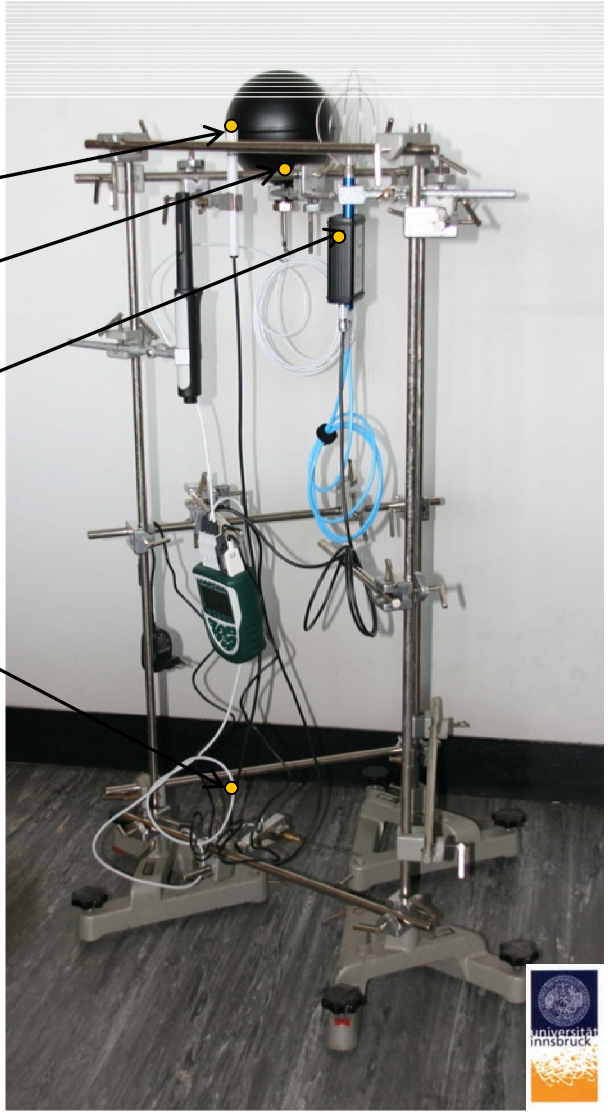
3 Sensors at the same height (1m above floor level):

- Combined humidity and temperature sensor
- Globe thermometer for radiative temperature
- Thermoanemometer for indoor air velocity (draft risk, turbulence of air)

1 NTC – sensor for temperature 10 cm above floor level

All sensors are logged by the Almemo logger 2590-4S

-> Calculation of the PMV and the PPD values



Window Ventialtion

The indoor climate is influenced by the users and their manual ventilation behavior.

-> therefore open/close loggers with reed contacts are mounted at the windows.

Indoor Air Quality IAQ

Measurement of the indoor air CO2 concentration at the same altitude (1m above floor level)

-> the occupancy of the rooms is important for both measurements: indoor air quality and thermal comfort

Classification (DIN EN 13779)	Description	CO_2-concentration above external concentration [ppm]
IDA 1	high indoor air quality	< 400
IDA 2	mean indoor air quality	400 - 600
IDA 3	moderate indoor air quality	600 -1000
IDA 4	low indoor air quality	> 1000

Occupancy

Occupancy of the classrooms

Klasse 1a - 011	St	Mo	Di	Mi	Do	Fr		
	1	■	■	■	■	■	07:45	08:35
	2	■	■	■	■	■	08:40	09:30
	3	■	■	■	■	■	09:35	10:25
	4	■	■	■	■	■	10:40	11:30
	5	■			■	■	11:35	12:25
	6				■		12:30	13:20
	7		■				14:30	15:20
	8		■				15:20	16:10
	9		■				16:20	17:10
	10						17:10	18:00

Klasse 1b - 010	St	Mo	Di	Mi	Do	Fr		
	1	■	■	■	■	■	07:45	08:35
	2	■	■	■	■	■	08:40	09:30
	3	■	■	■	■	■	09:35	10:25
	4	■	■	■	■	■	10:40	11:30
	5				■	■	11:35	12:25
	6				■		12:30	13:20
	7						14:30	15:20
	8						15:20	16:10
	9						16:20	17:10
	10						17:10	18:00

Klasse 2a - 114	St	Mo	Di	Mi	Do	Fr		
	1	■	■	■	■	■	07:45	08:35
	2	■	■	■	■	■	08:40	09:30
	3	■	■	■	■	■	09:35	10:25
	4		■	■		■	10:40	11:30
	5			■		■	11:35	12:25
	6	■					12:30	13:20
	7						14:30	15:20
	8						15:20	16:10
	9			■			16:20	17:10
	10			■			17:10	18:00

Klasse 3a - 201	St	Mo	Di	Mi	Do	Fr		
	1		■		■		07:45	08:35
	2	■	■	■		■	08:40	09:30
	3	■	■	■			09:35	10:25
	4	■		■	■	■	10:40	11:30
	5	■	■	■	■		11:35	12:25
	6		■				12:30	13:20
	7						14:30	15:20
	8						15:20	16:10
	9	■	■				16:20	17:10
	10	■	■				17:10	18:00

Klasse 3bi - 111	St	Mo	Di	Mi	Do	Fr		
	1		■	■	■	■	07:45	08:35
	2	■	■	■		■	08:40	09:30
	3	■	■	■		■	09:35	10:25
	4	■			■	■	10:40	11:30
	5	■	■	■	■		11:35	12:25
	6	■		■			12:30	13:20
	7						14:30	15:20
	8			■			15:20	16:10
	9			■	■		16:20	17:10
	10				■		17:10	18:00

Klasse 3c - 214	St	Mo	Di	Mi	Do	Fr		
	1		■	■	■	■	07:45	08:35
	2	■	■	■		■	08:40	09:30
	3	■	■	■		■	09:35	10:25
	4	■	■	■	■	■	10:40	11:30
	5	■	■	■	■		11:35	12:25
	6			■			12:30	13:20
	7						14:30	15:20
	8	■					15:20	16:10
	9	■					16:20	17:10
	10						17:10	18:00

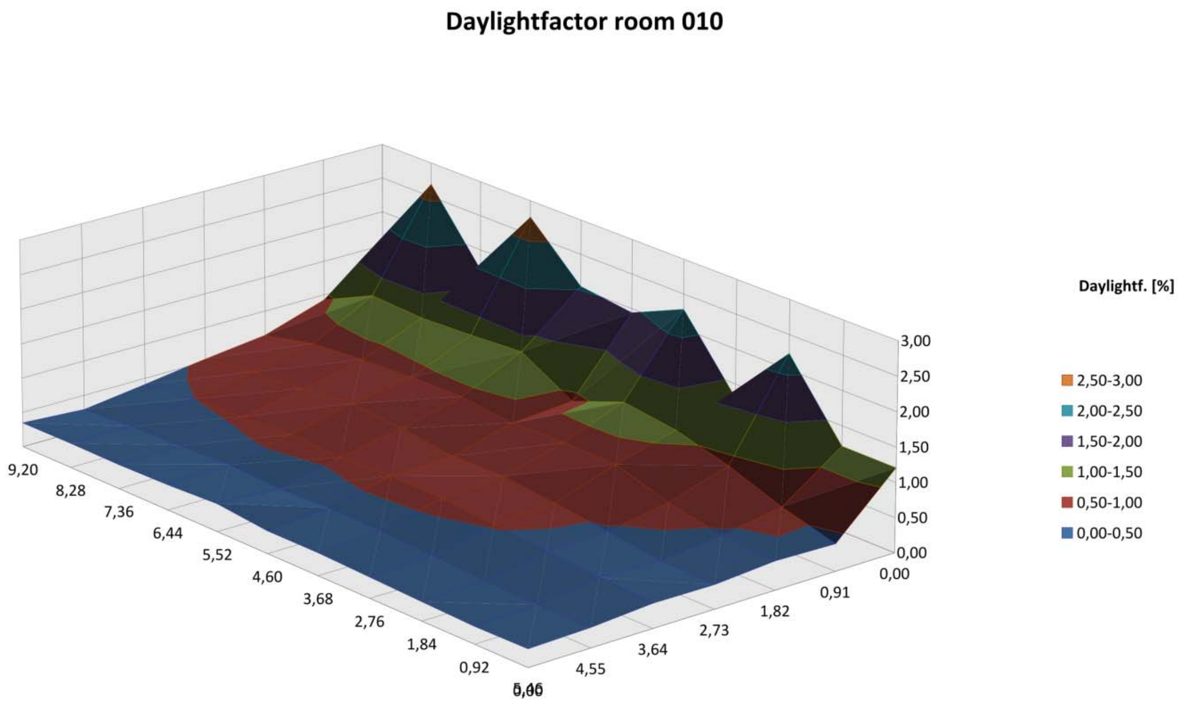
Daylight Measurement

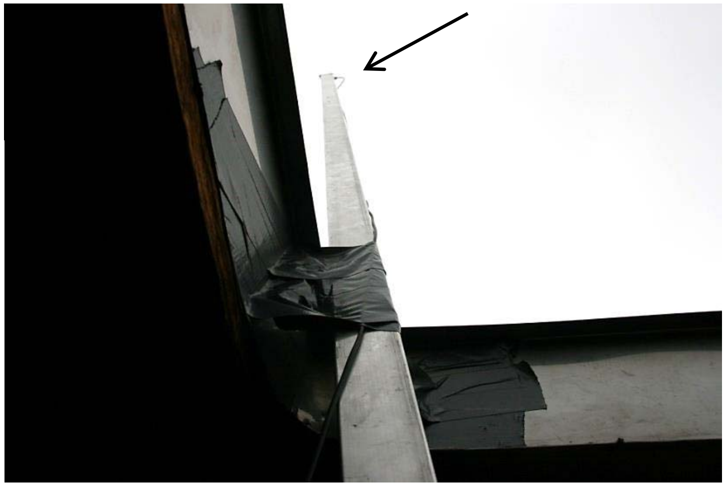
Method 1: -> Measurement of the illuminance at the height of the working plane in a grid of ca. 90*90cm inside the room

-> Measurement of the illuminance at a unobstructed point (at the roof) at the same time

-> Calculation of the daylight factor

Daylight Measurement





Daylight Measurement

Method 2 -> Measurement of the illuminace in- and outside, measuring of the luminace and taking pictures with a digital camera at the same time

-> Creation of a HDR-file out of the pictures

-> Definition of the luminace at one spot

-> Calculation of the factor


cd/m2
48.722
43.594
38.465
33.336
28.208
23.079
17.950
12.821
7.693
2.564

Glare

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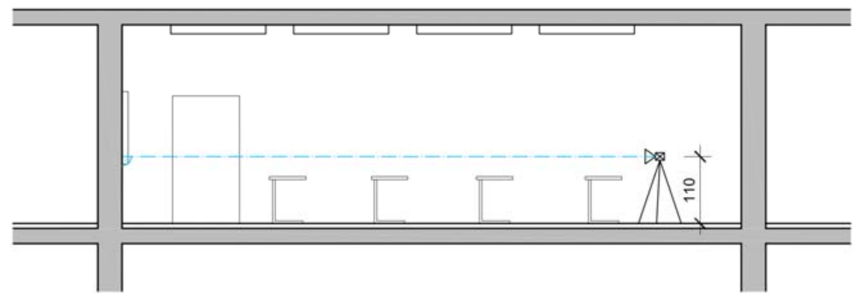
-> Taking 5 pictures with a calibrated digital camera in defined directions

-> Creation of a HDR-picture out of these pictures (WEB-HDR)

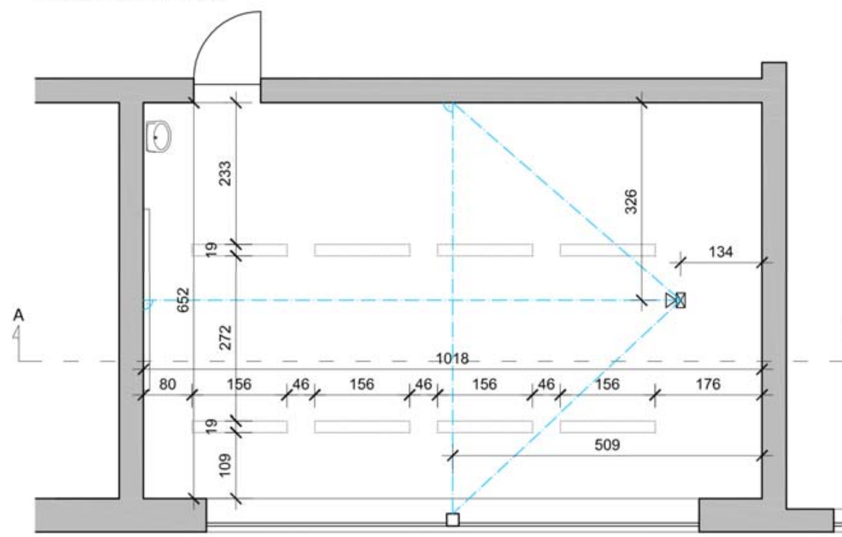
-> readout of the luminance and definition of the areas with glare risks

Glaremeasuring in room 213

Section A-A, scale 1:100



Floor plan, scale 1:100



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Possible Reduction of Heat Demand

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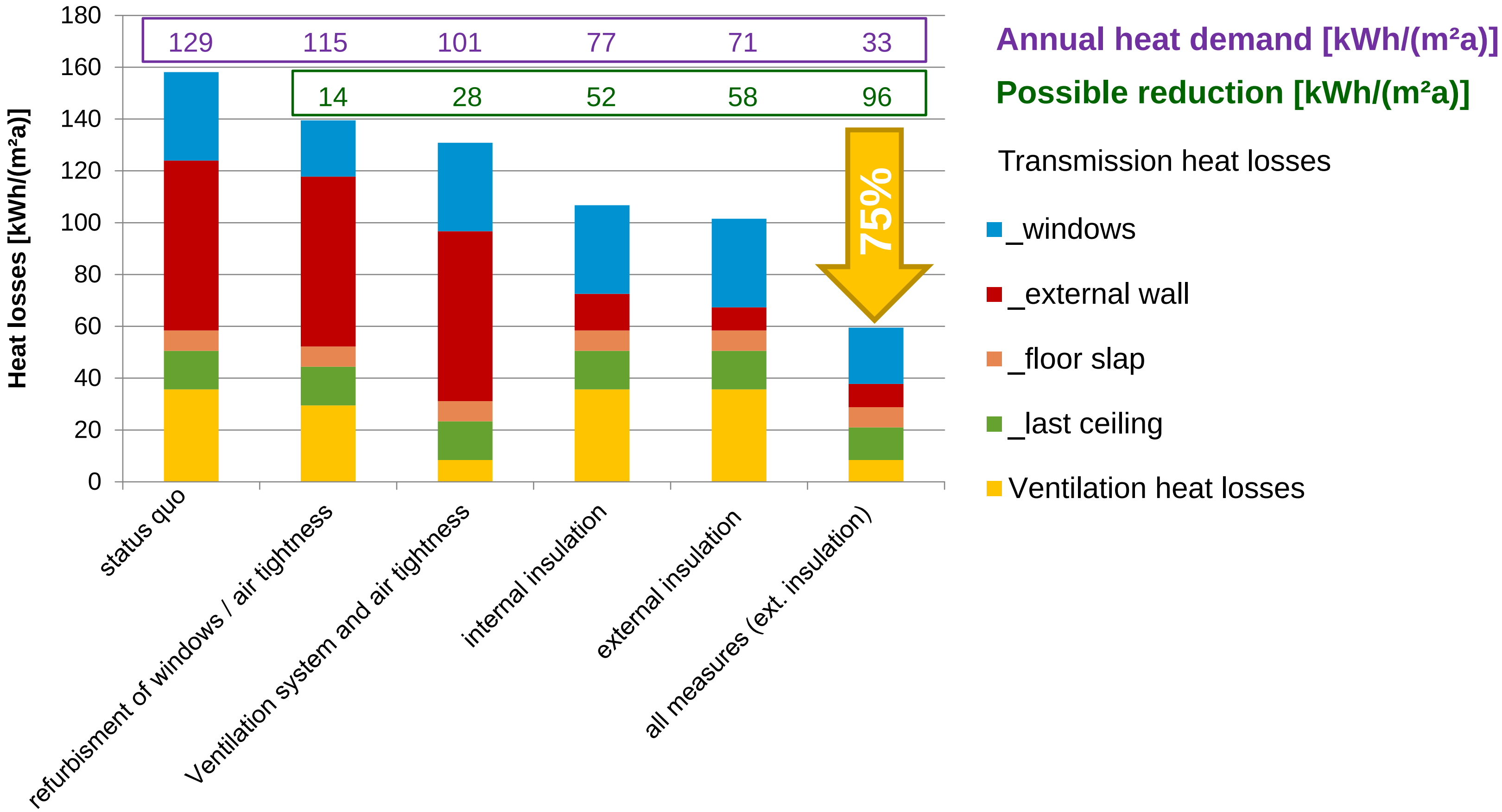

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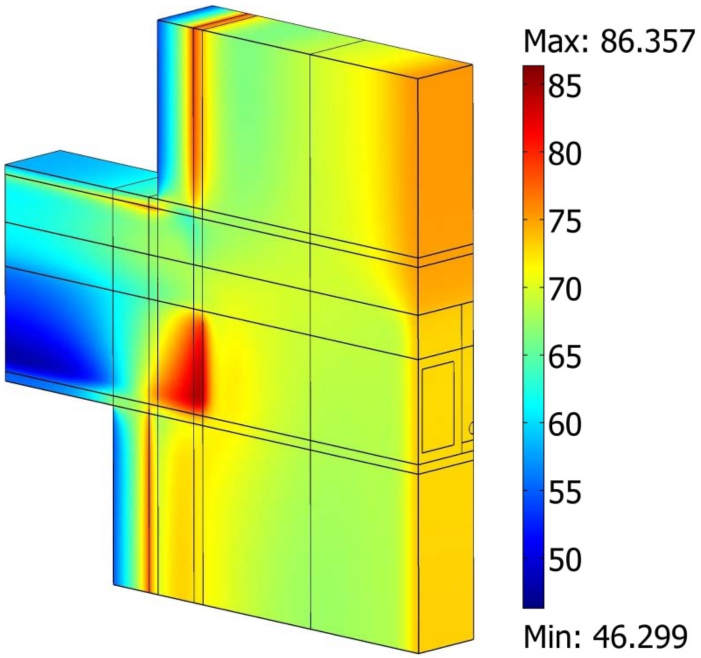
Energy Efficient Solutions

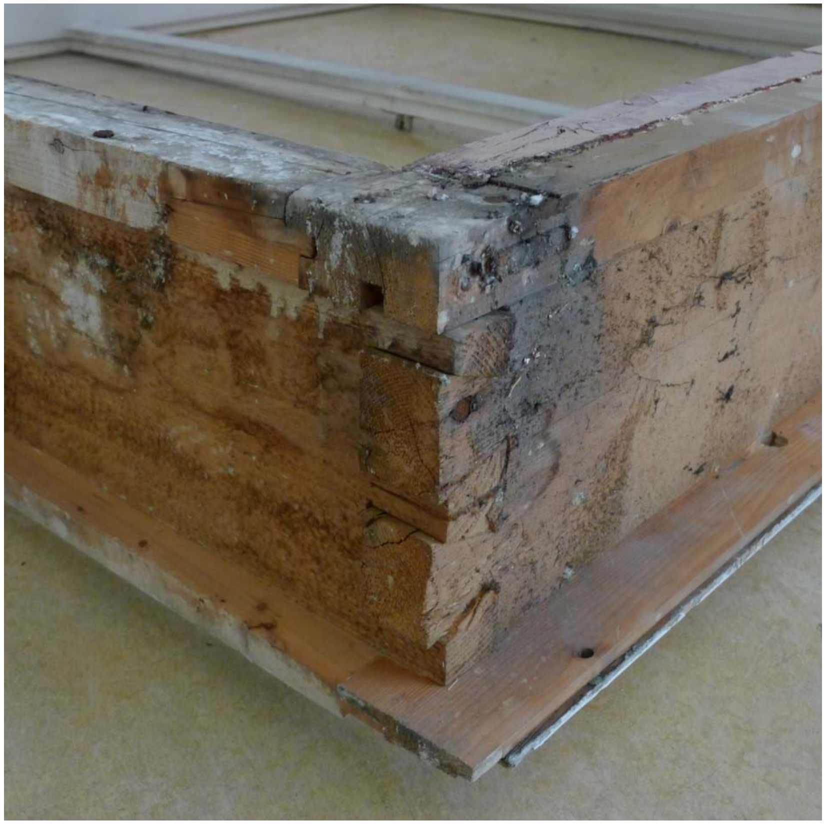
- Development of new **ventilation concept** Prevention of condensation at **beam end** of the concrete brick ceiling (internal insulation)
- Enhanced **daylight autonomy** by daylight redirection
- Improved **artificial lighting using LED**
- Optimization of **heating control**
- Minimal invasive **external insulation**
- Different variants of **internal insulation**
- Highly efficient **acoustic absorbers**

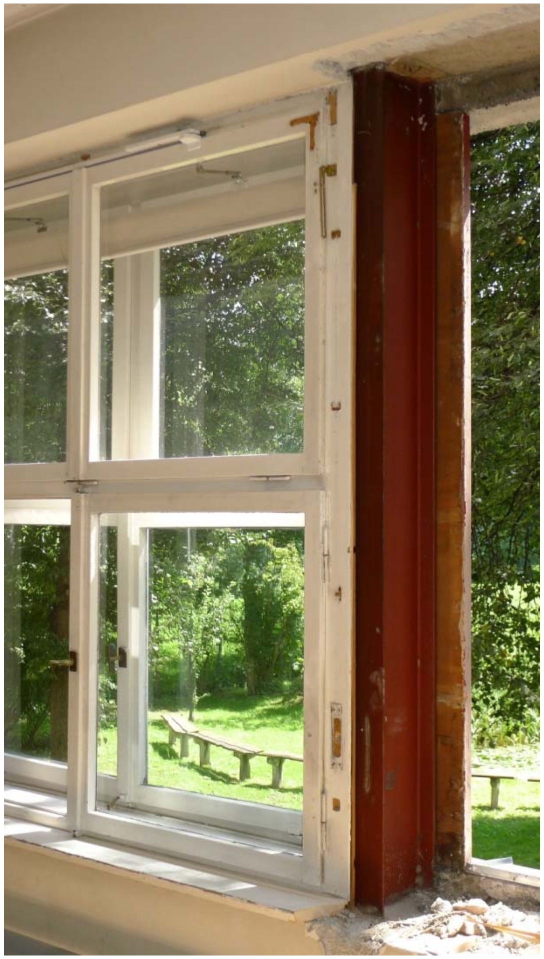


Relative humidity [%] at beam end

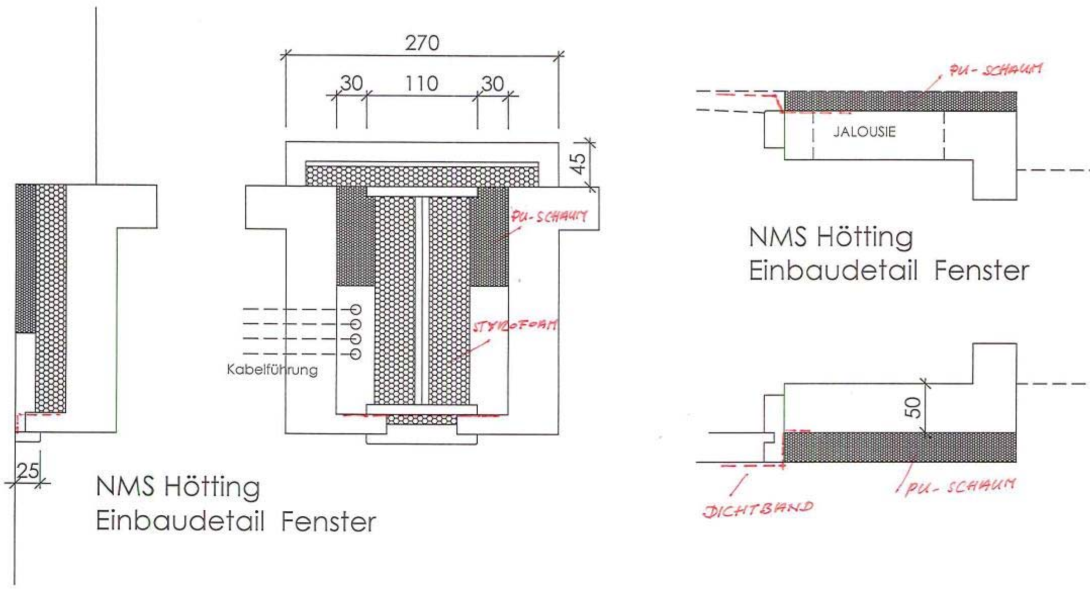
CS 5 NMS Hötting
Interventions on Windows

Box-type windows





CS 5 NMS Hötting
Interventions on Windows



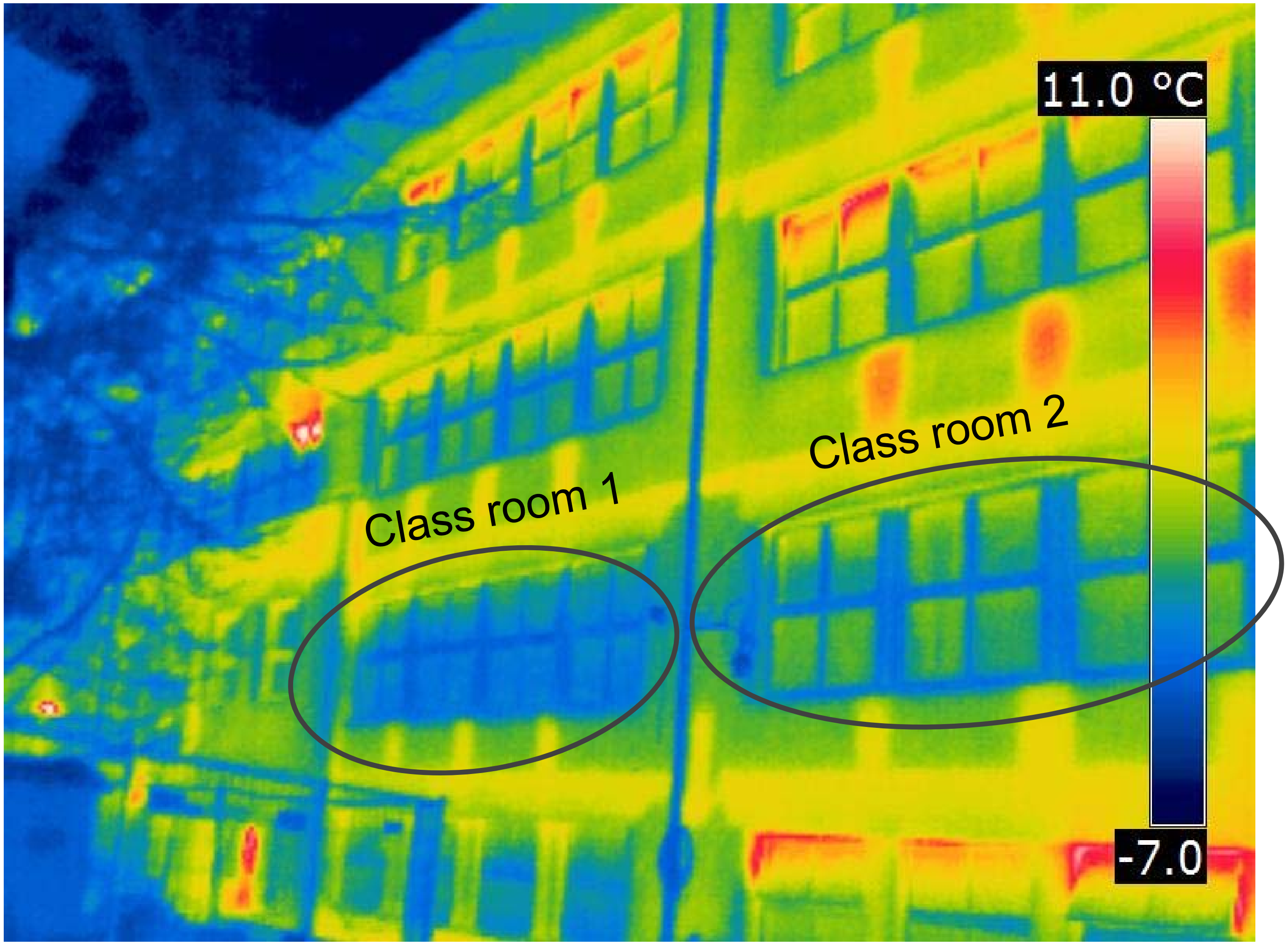
Box-type windows improvements:

Classroom 1

mounting: airtightness, thermal bridges
heatflux: double glazing

Uw 1,1 W/m²K (before Uw 2,8 W/m²K)

IR-Thermography after intervention (prototype classrooms)



3ENCULT CS5, Höttinger School

CS 5 NMS Hötting
Interventions on exterior wall

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Interior insulation: Remmers IQ Therm 80

Reversibel (loam glue)
Thermal conductivity **0,033 W/mK, capillaryactive***

***PUR-foamboards with capillaryactive calcium silicate - wicks**

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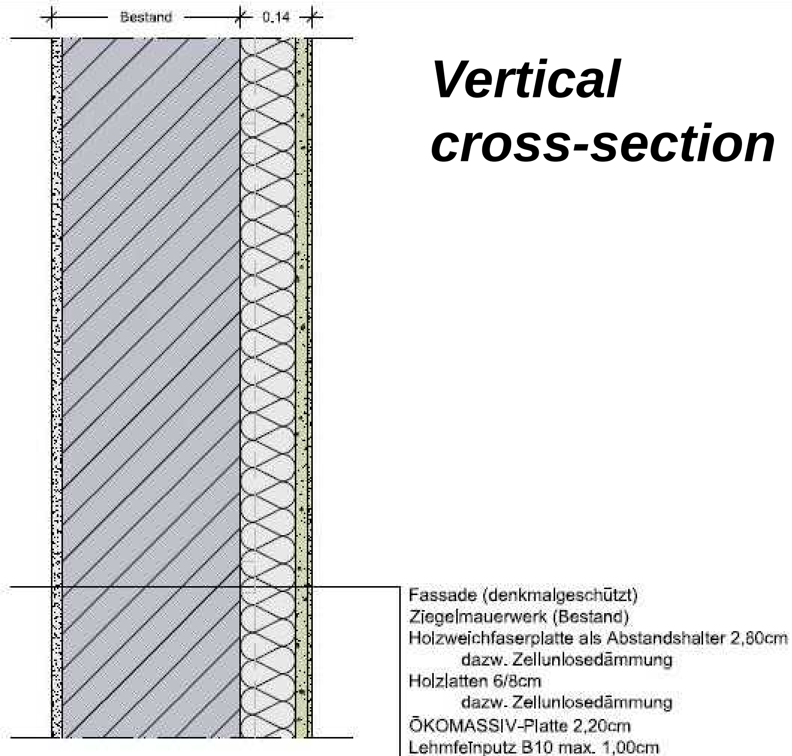
CS 5 NMS Hötting
Interventions on exterior wall

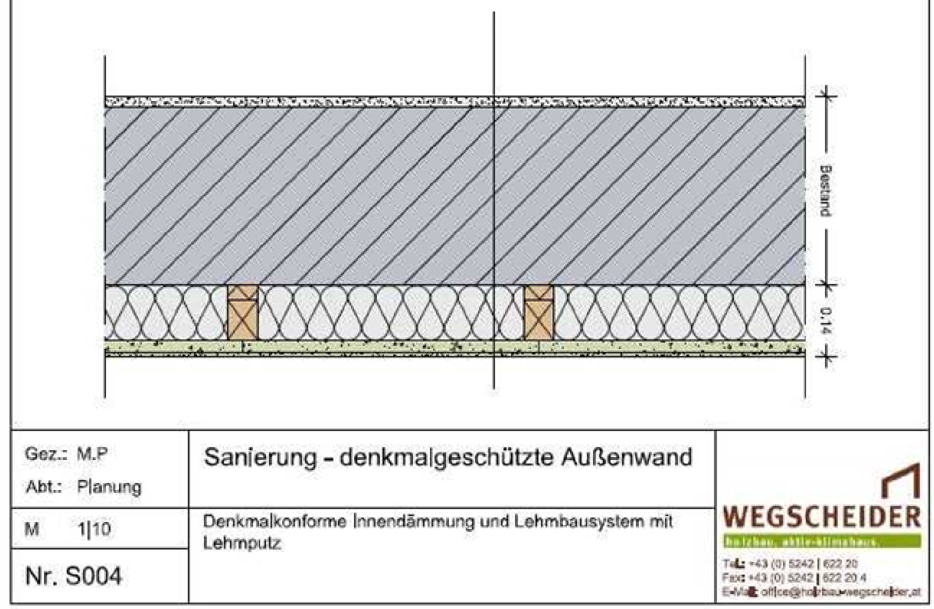
Interior insulation: Wegscheider Holzbau / Isocell

Reversibel : wooden frame construction, loam plaster, cellulose
Thermal conductivity: **0,04 W/mK, , capillaryactiv** cellulose

Vertical cross-section



Horizontal cross-section



CS 5 NMS Hötting
Interventions on exterior wall

Interior insulation: Wegscheider Holzbau / Isocell

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Interventions heating distibution

Radiators: heating water temperature actually up to 85°C

Target: lowering temperature to a level of 45°C integrating RE (solar thermal collectors)

Central system with direct vertical supply air ducts

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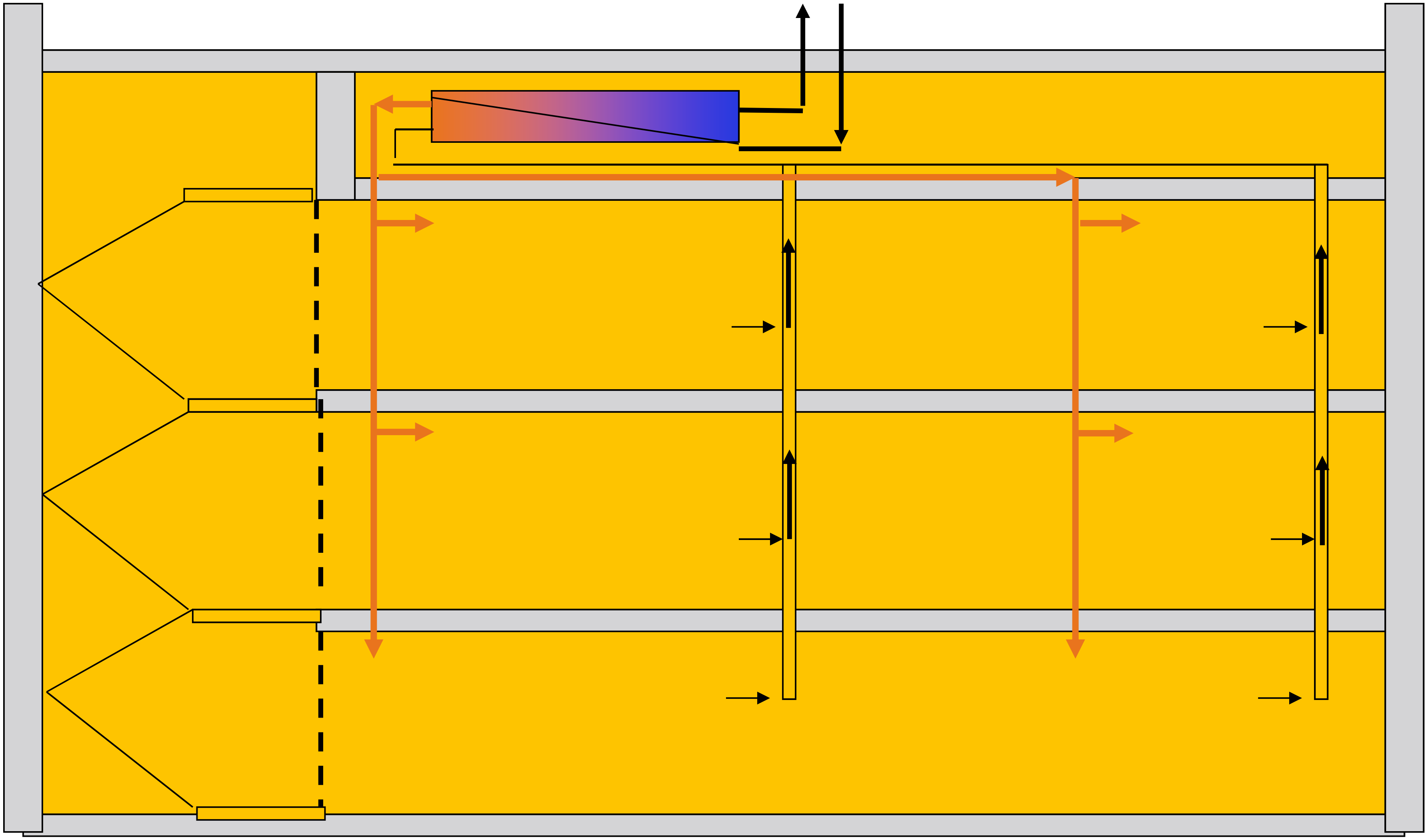

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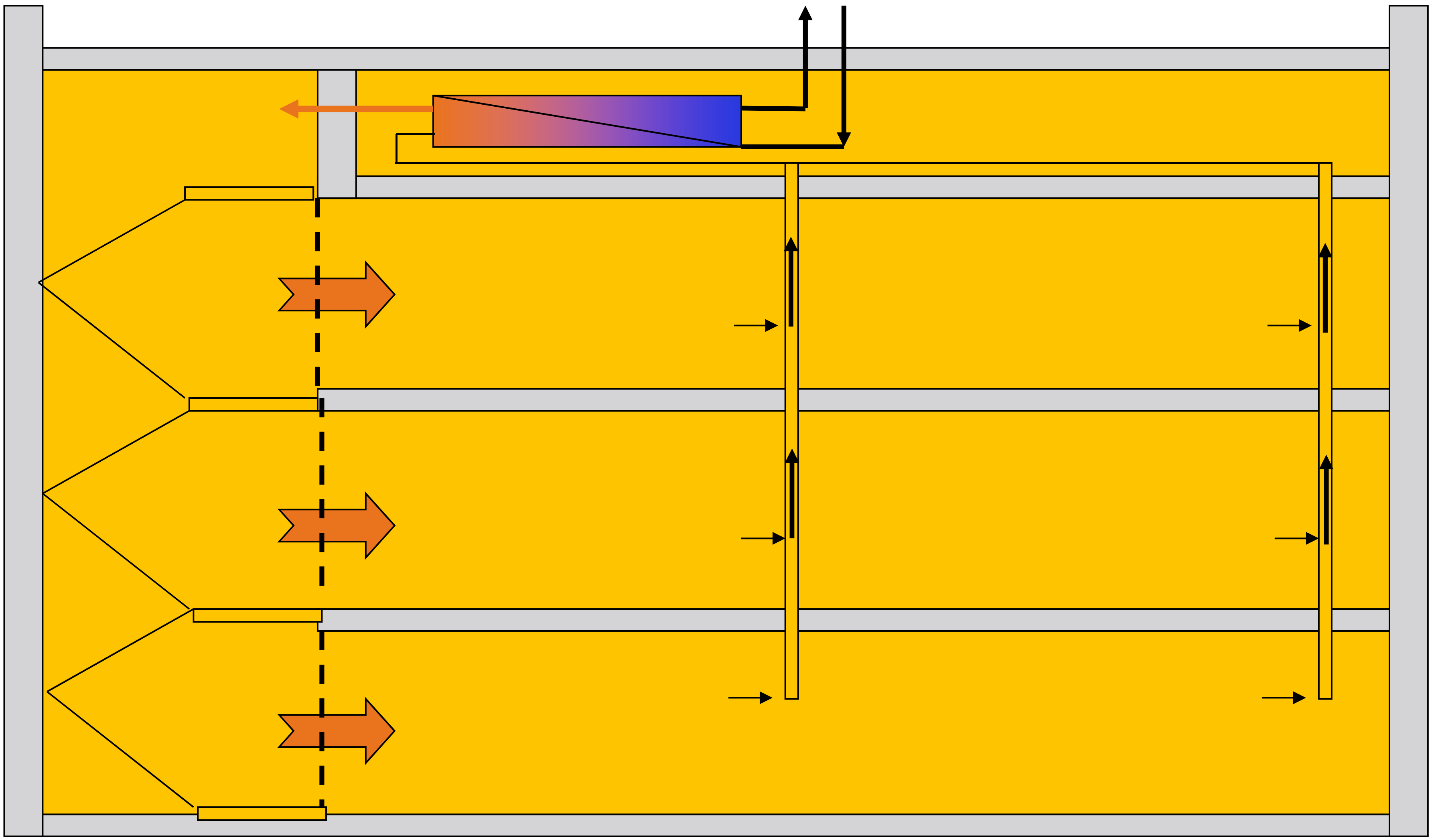
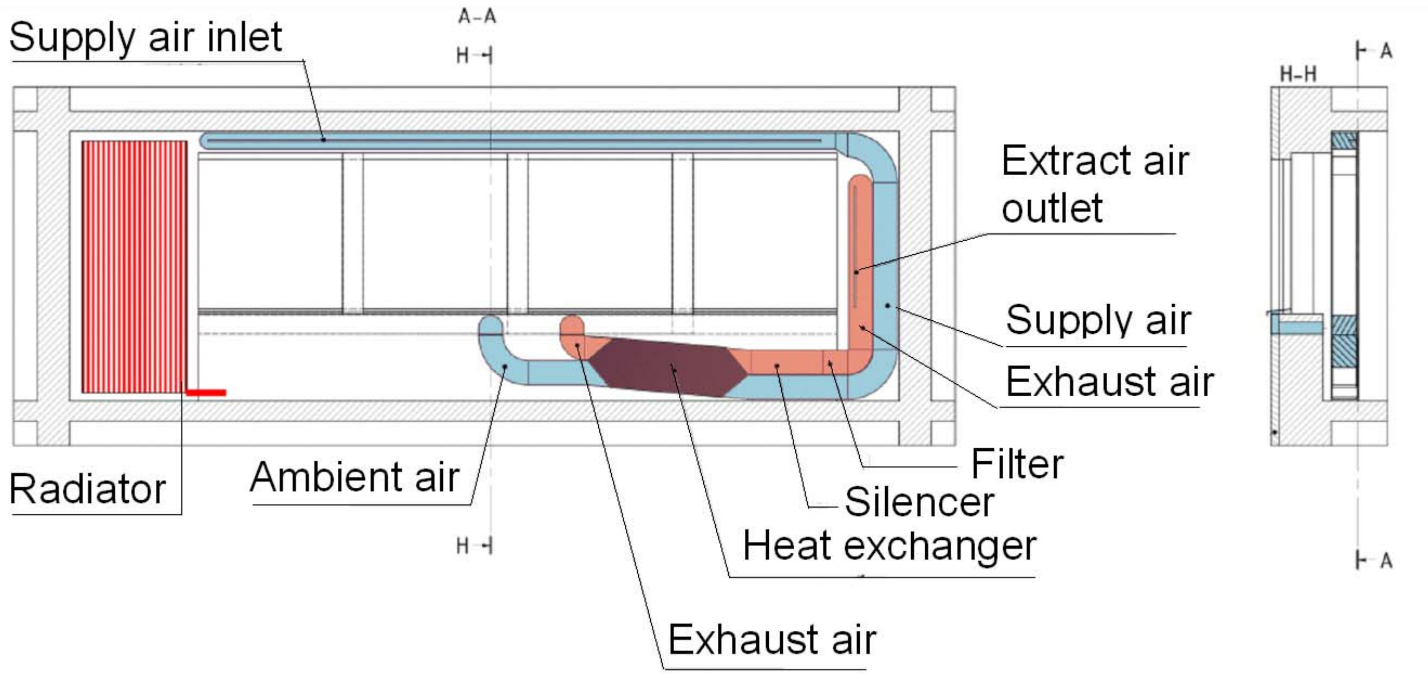
Principle of Active Overflow in school buildings

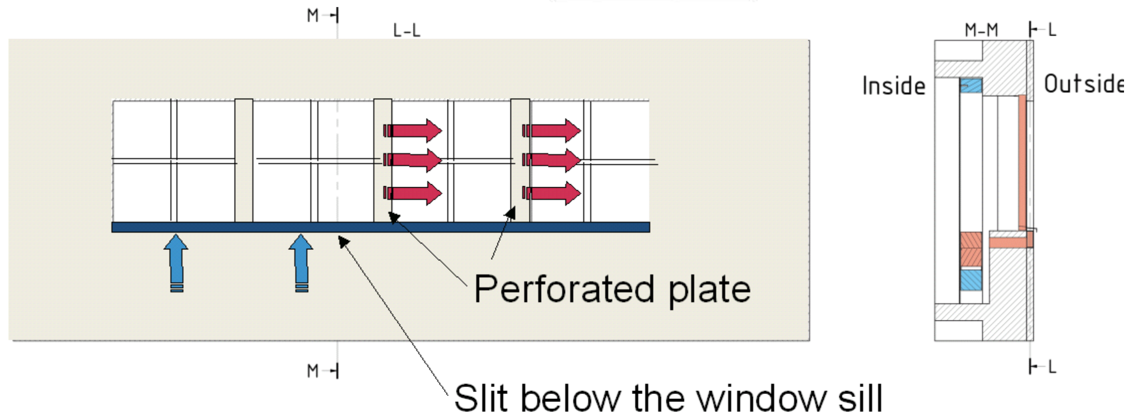


Pros and Cons of Active Overflow

- \+ Minimized duct network
- \+ Low impact for historic buildings
- \+ Easy control system
- − Mixed air in corridors
- − Fire protection doors have to be cept open

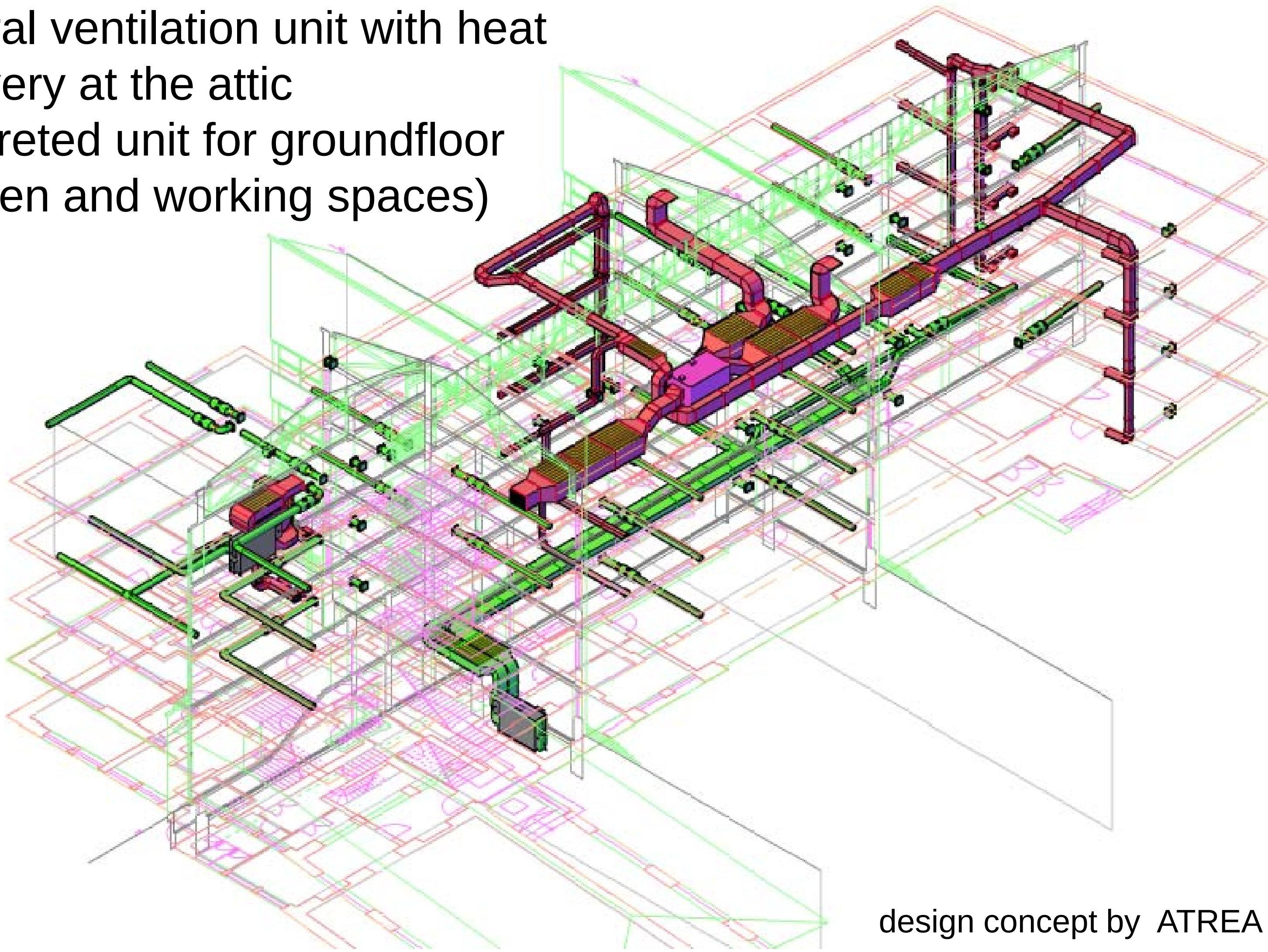
Decentralized wall integrated ventilation system





CS 5 NMS Hötting
Central Ventilation System

Central ventilation unit with heat recovery at the attic
Separeted unit for groundfloor (kitchen and working spaces)



design concept by ATREA

CS 5 NMS Hötting

Two prototype classrooms

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Horizontal Air Flow (via corridor)

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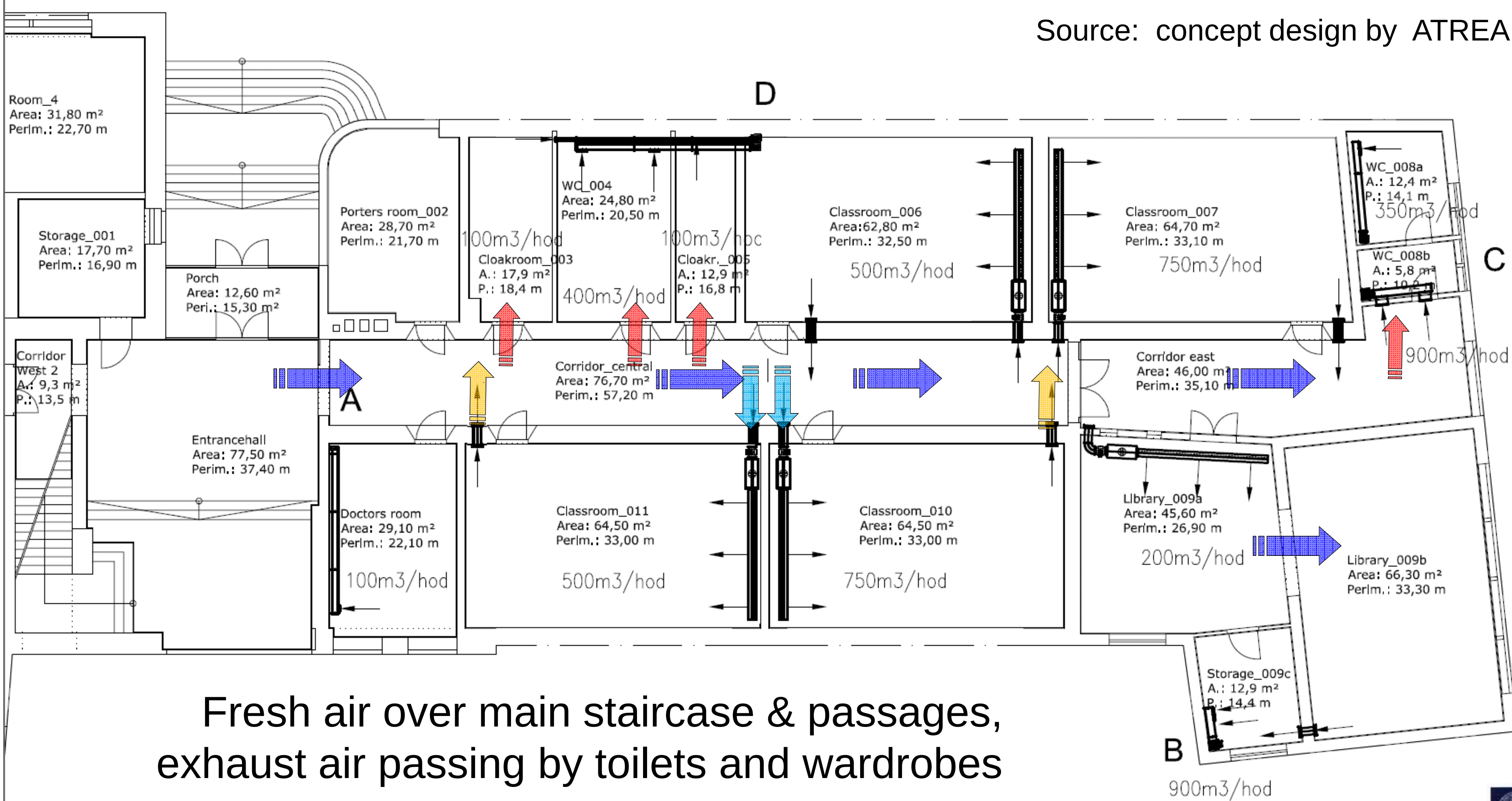
Source: concept design by ATREA



Fresh air over main staircase & passages,
exhaust air passing by toilets and wardrobes

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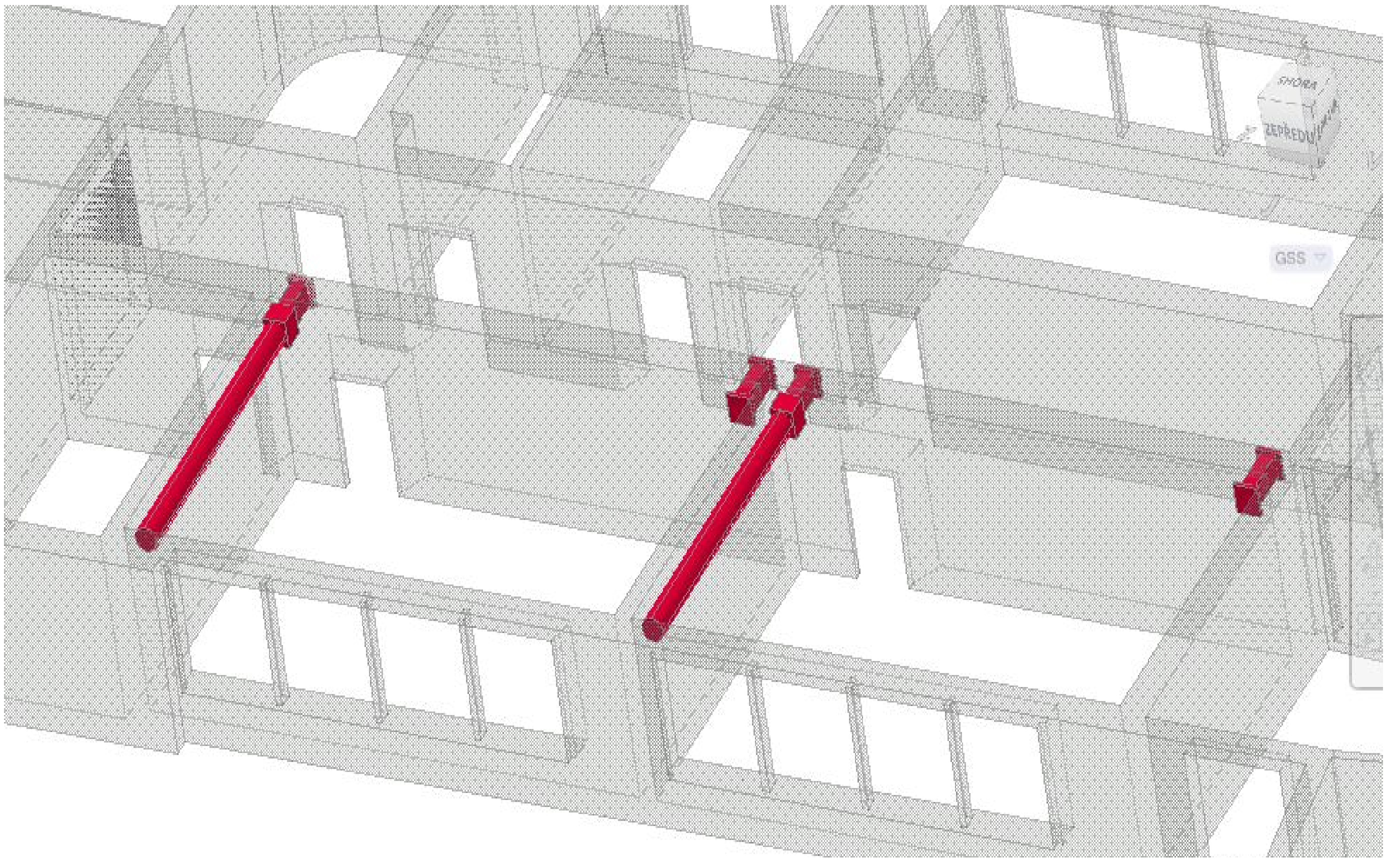
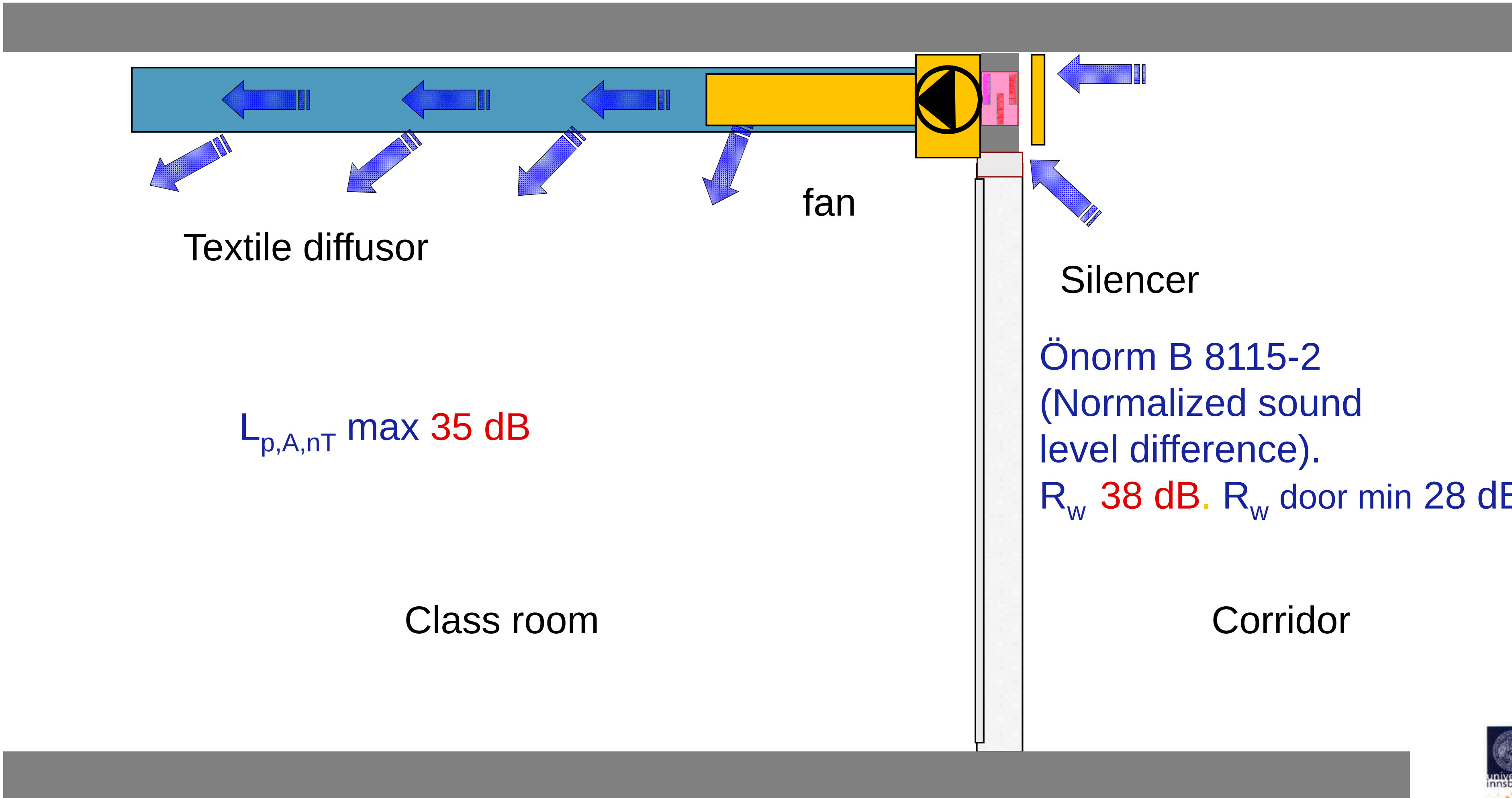
Two prototype classrooms



CS 5 NMS Hötting
Ventilation: Active Overflow



Önorm B 8115-2 (Normalized sound level difference).

R_w 38 dB. R_w door min 28 dB

$L_{p,A,nT}$ max 35 dB

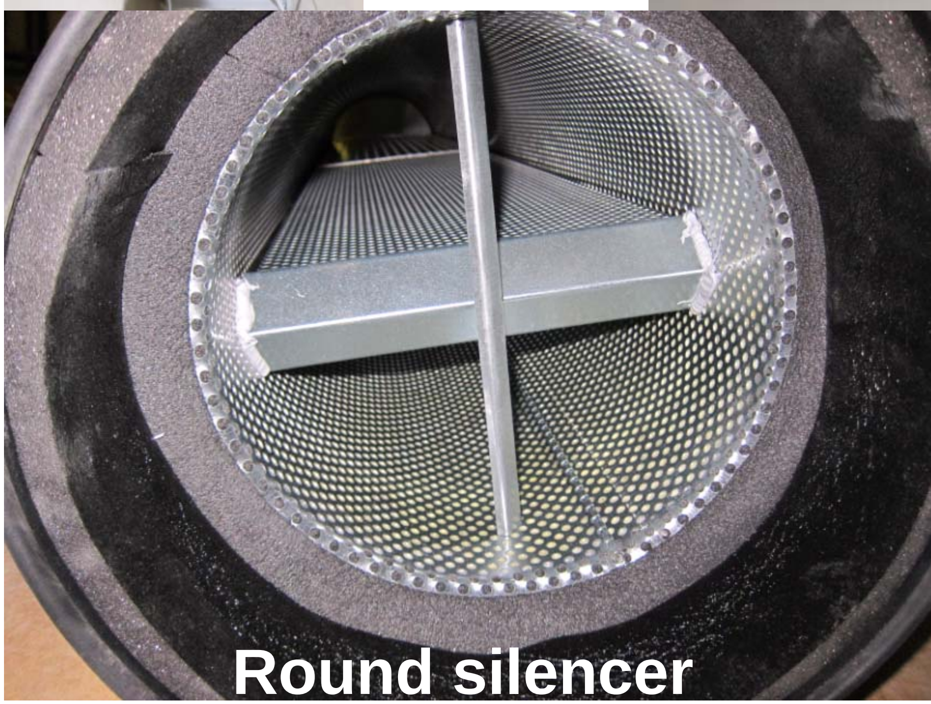
CS 5 NMS Hötting

Wall breakthrough for the silencer

CS 5 NMS Hötting
Active Overflow elements

CS 5 NMS Hötting

Active Overflow elements

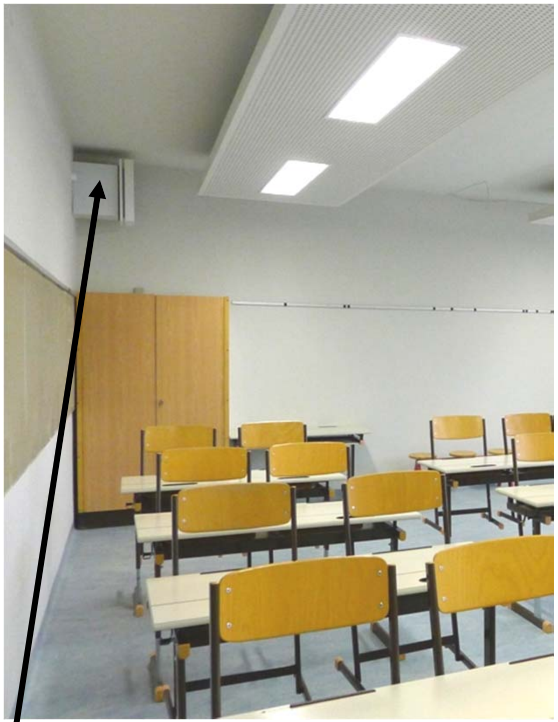


Round silencer

Fan box

CS 5 NMS Hötting
Passive overflow element with silencer





Passive overflow element with silencer

Sound absorber plate

Textile diffusor
(Prihoda, CZ)

Laser perforation

Flow visualisation

Snemometer measurement of air flow velocity

(Source: Prihoda, CZ)

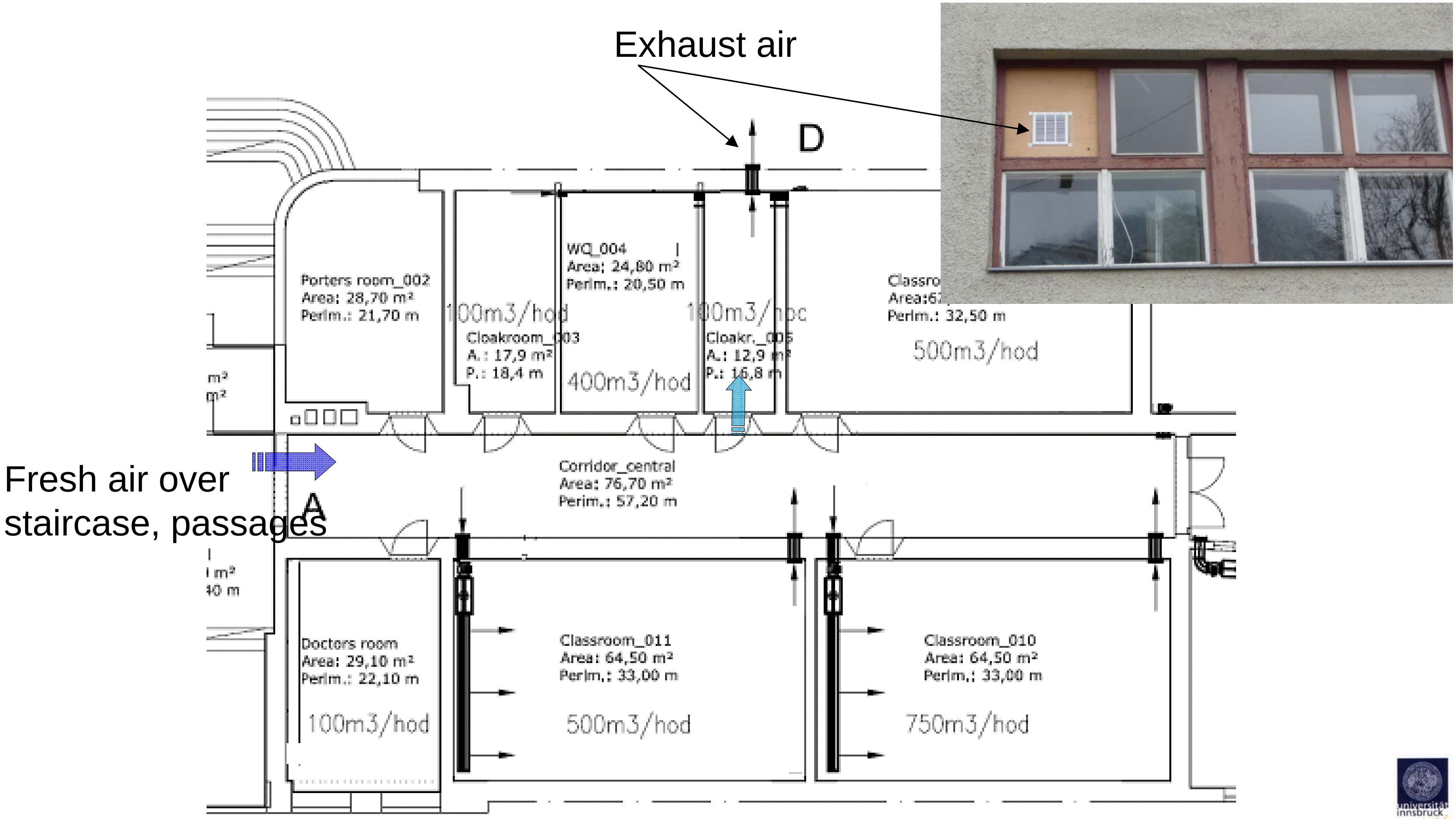
Mounting of textile diffusor

Finished ventilation system: Supply air through textile hose

Function of textile hose:

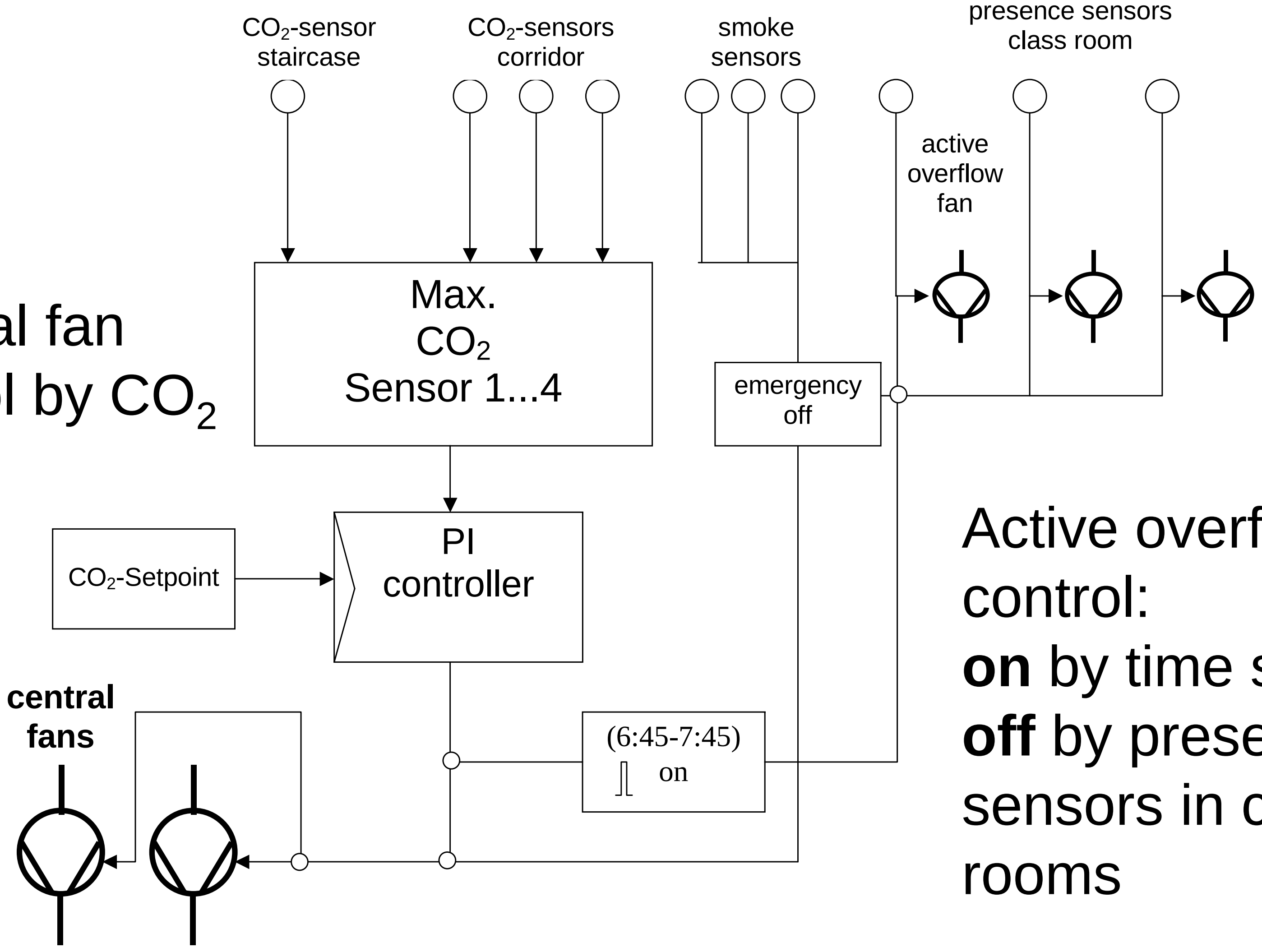
- distribution of air evenly
- covering of silencer
- reduced maintenance

CS 5 NMS Hötting
Test Setup: Exhaust Air Fan



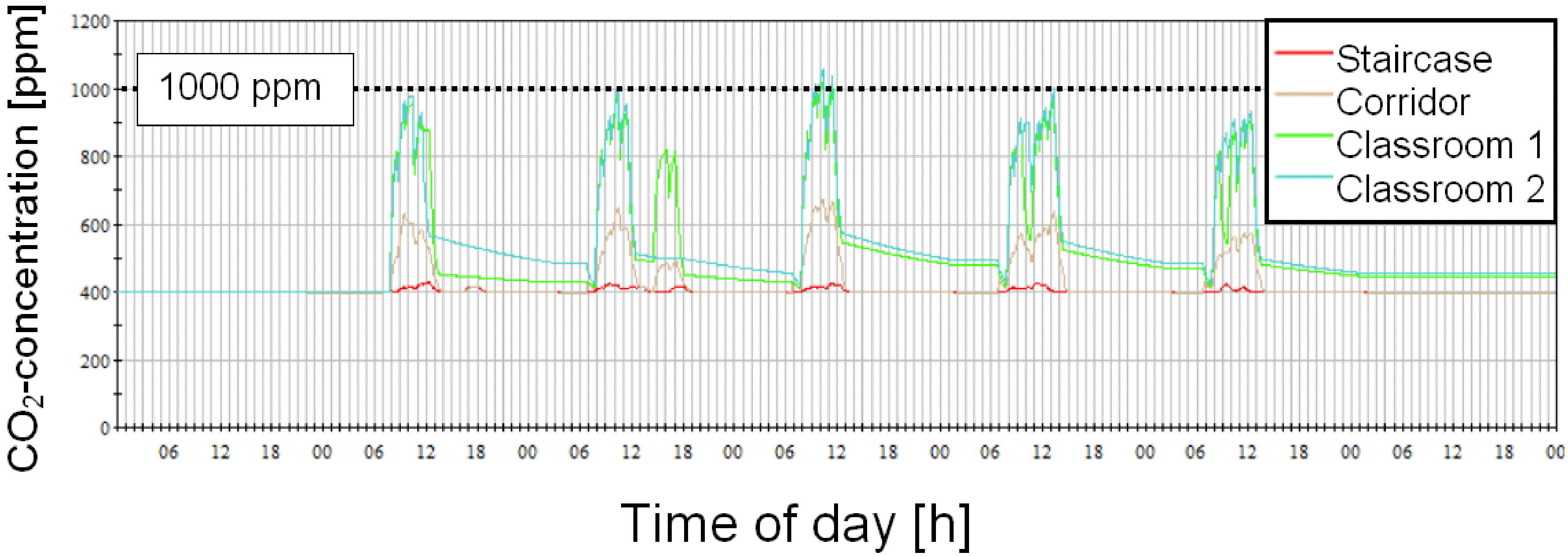
Control of central and active overflow fans

Central fan control by CO_2



Active overflow fan control:
on by time schedule
off by presence sensors in class rooms

CO_2-Simulation Results
(CONTAM-Simulation)



Measurement of CO_2-concentration at different positions and levels in the class room and corridor

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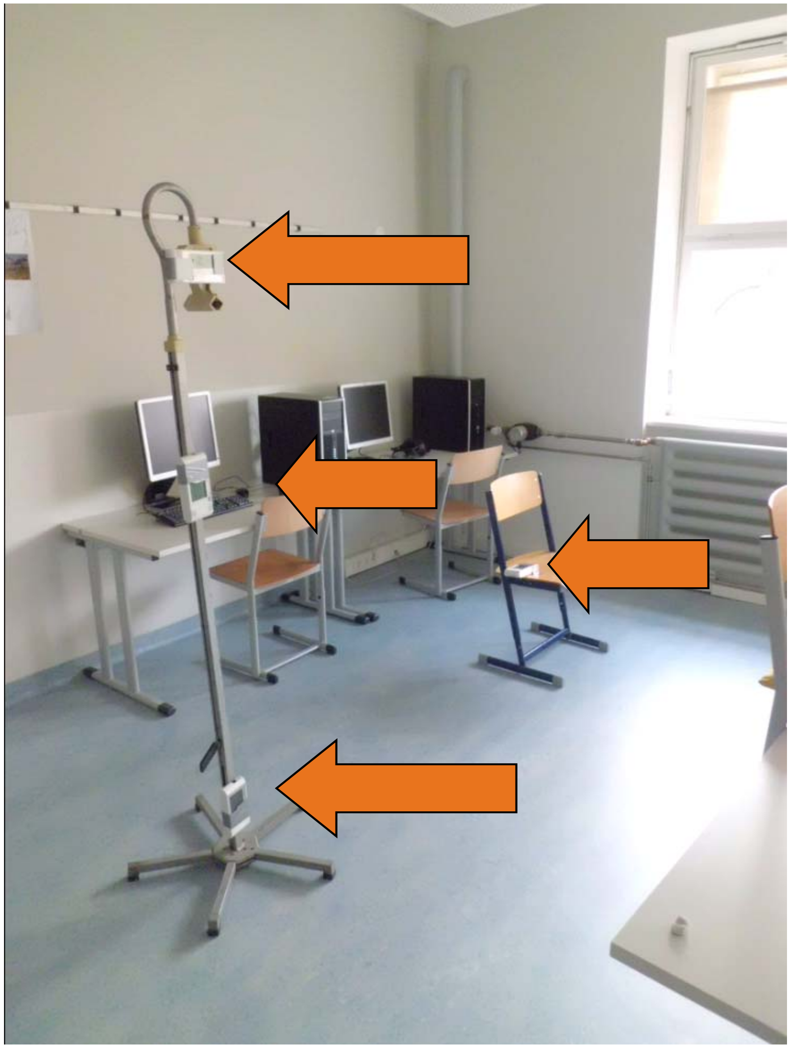

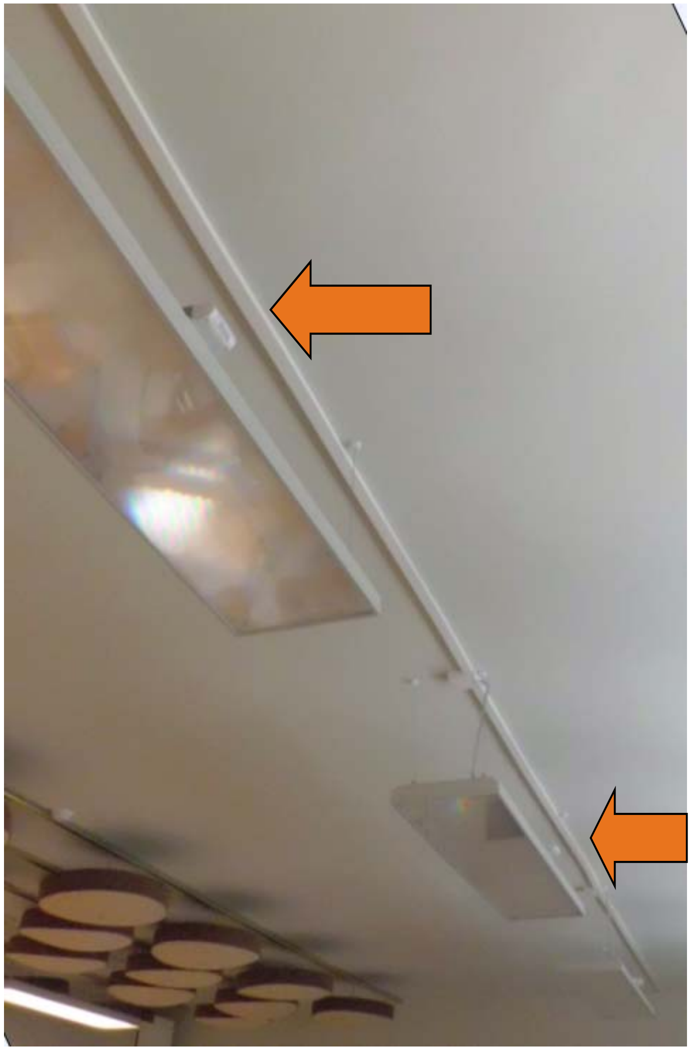

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Sensor Positions for CO_2-Concentration Measurement

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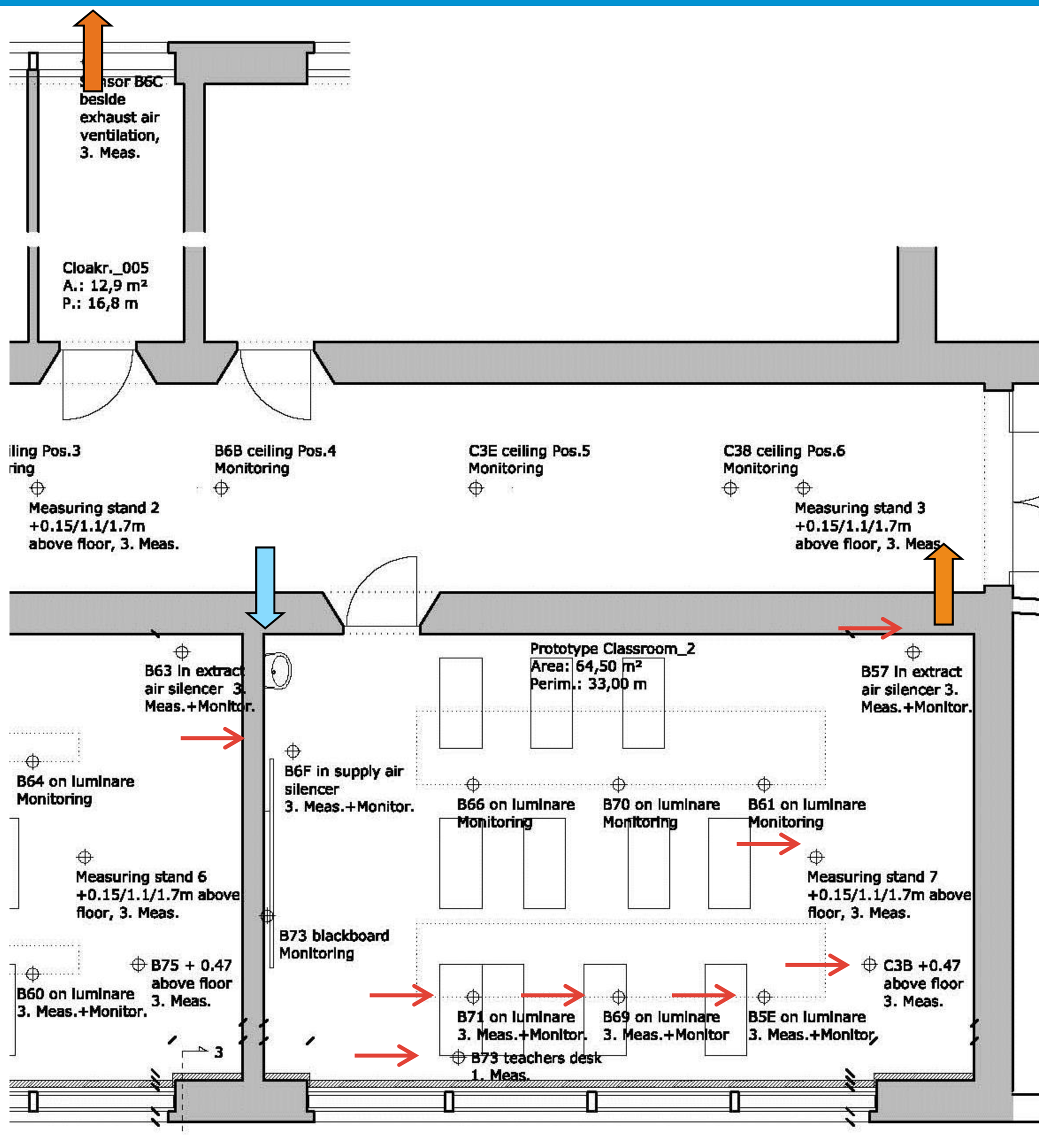

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Evaluation: Measurement of CO_2-Concentration

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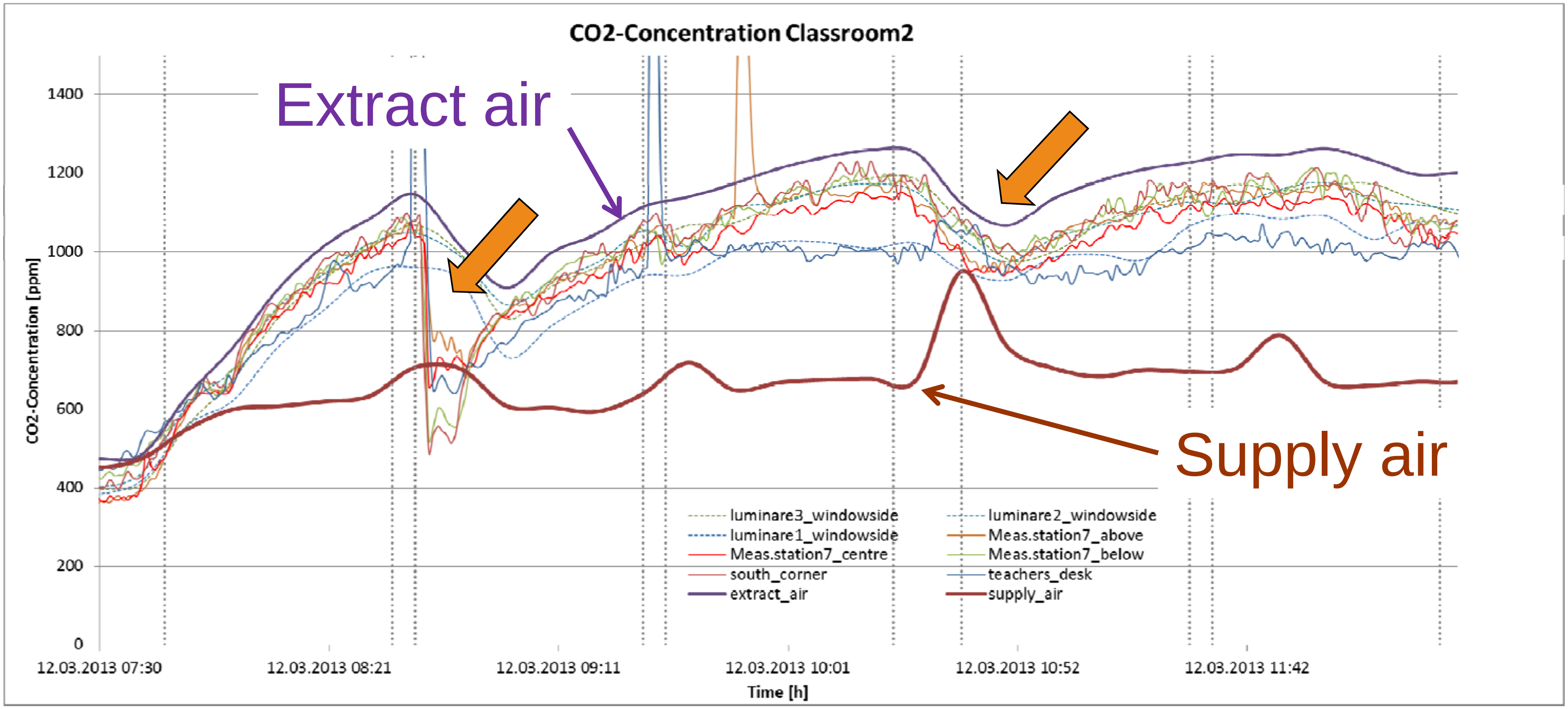
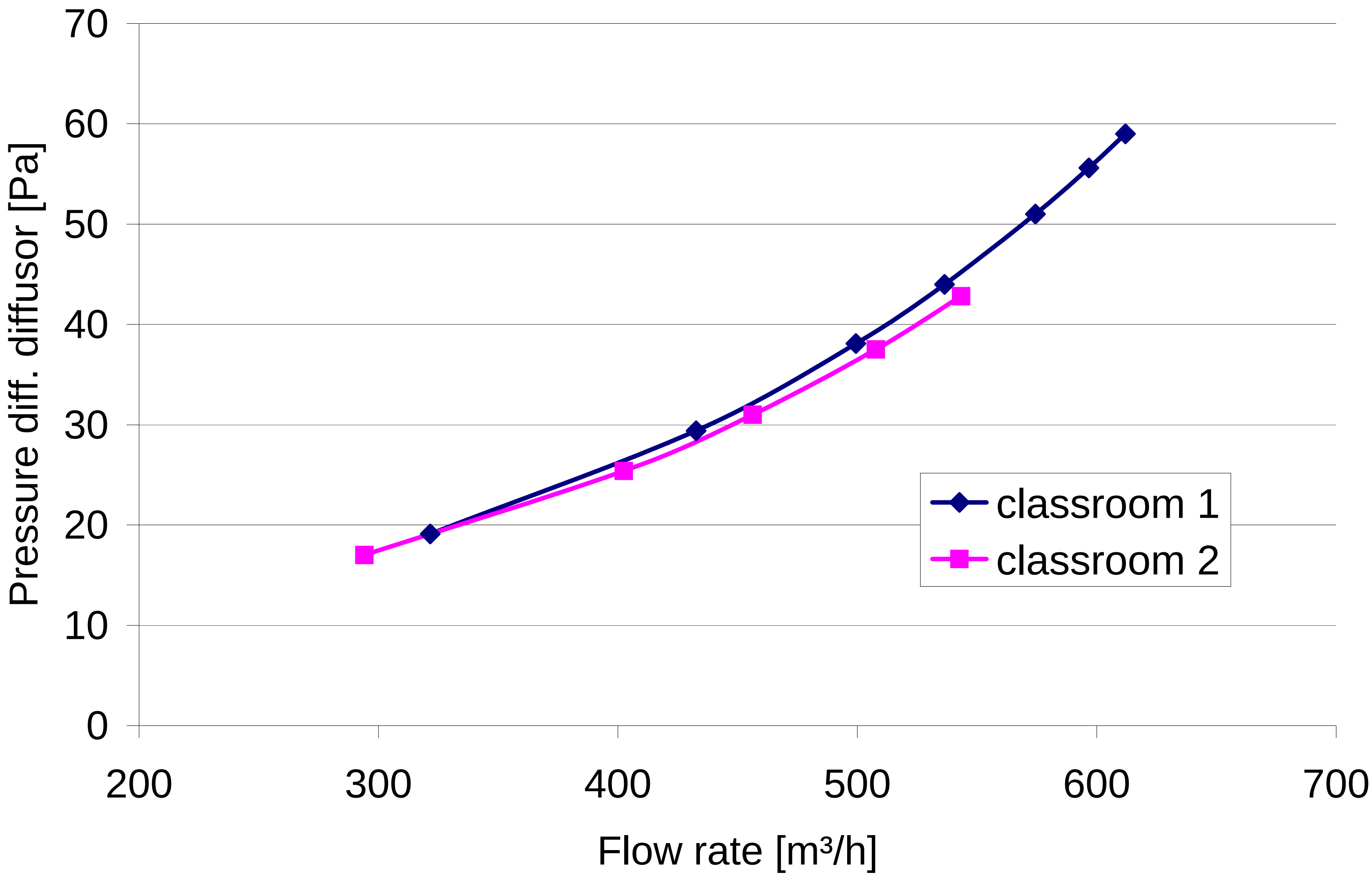
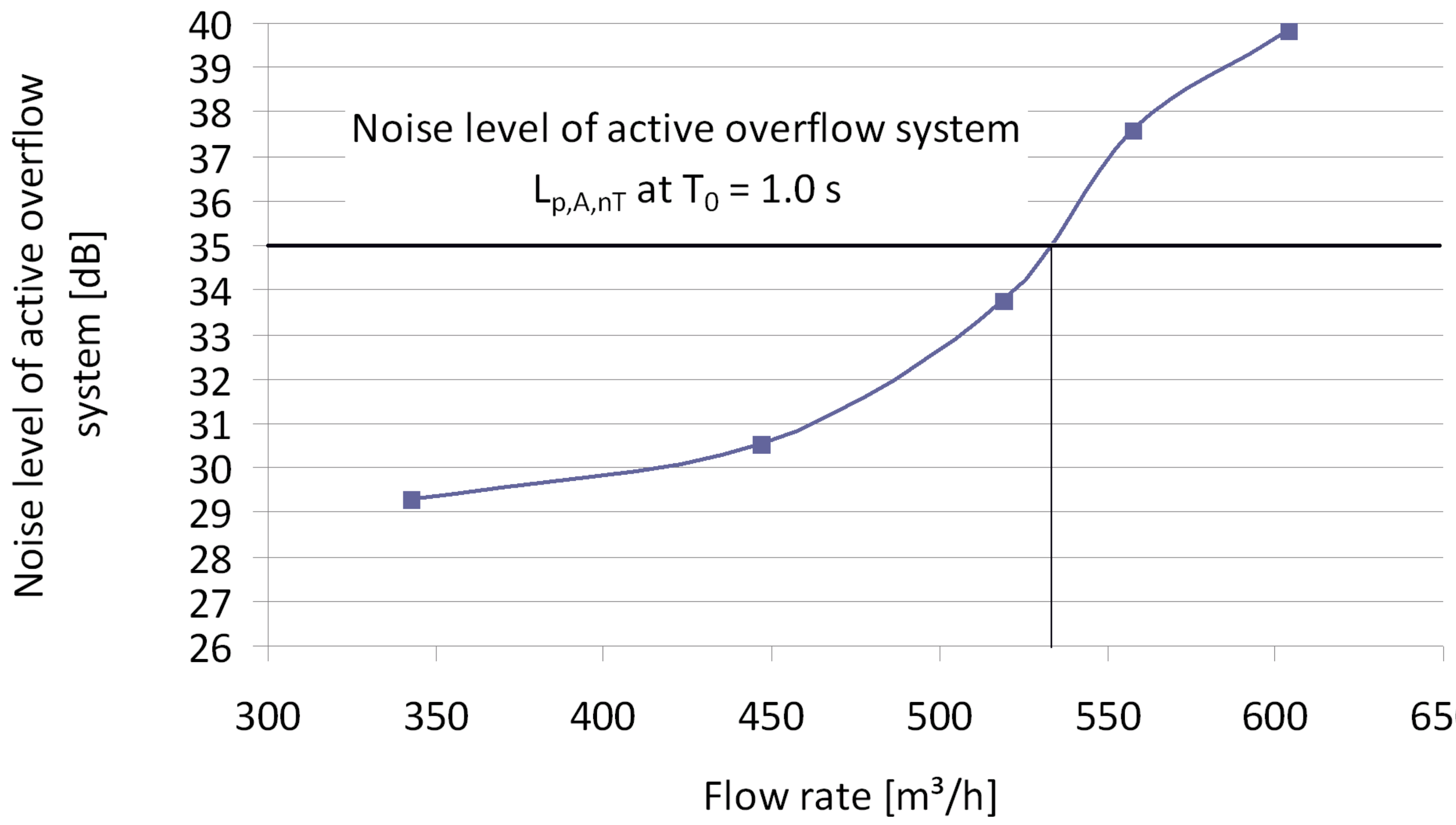


- 2 windows opened for about 8 minutes (left arrow)
- Pupils are not in classroom the first 15 minutes of the lesson (right arrow)

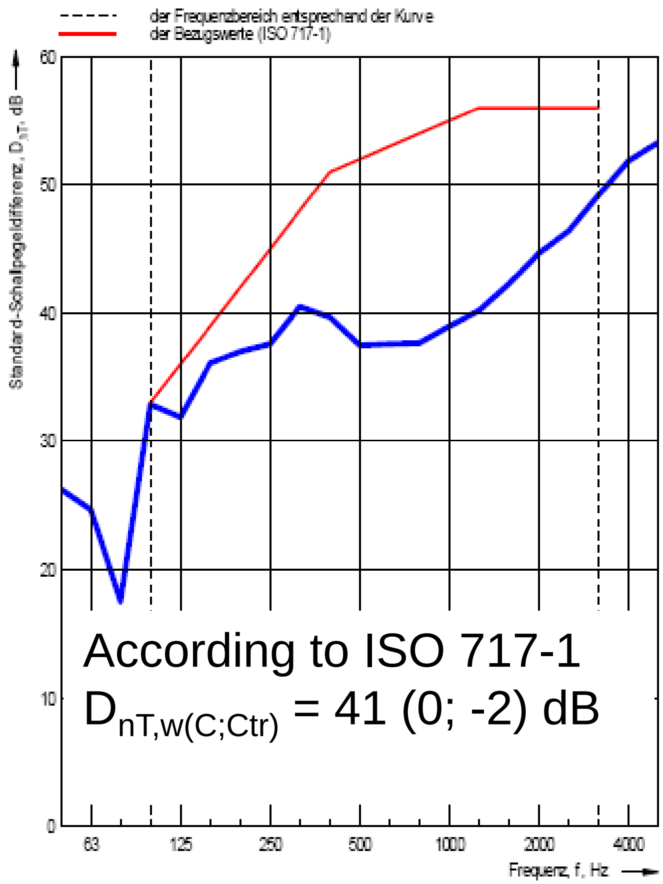
Measured Pressure Drop at the Textile Diffusors



Results of noise-level measurem. as function of the flow rate



Measured normalized sound level difference with airtight doors



According to ISO 717-1

$D_{nT,w(C;Ctr)}$ = 41 (0; -2) dB

class room 1: 41 dB

class room 2: 42 dB

Result: The quality of the protection for airborn sound transmission according to ÖISS was achieved

Summary - Ventilation

- Three solutions for minimal invasive ventilation systems (decentral, central vertical and active overflow)
- Active overflow ventilations for school building realized (prototype by ATREA) and measured
- Good sound protection from class room to corridor (41 dB)
- High electric efficiency (0,09 Wh/m³)
- On/Off control by time schedule and presence sensors
- Draft free supply air inlet by textile diffusors

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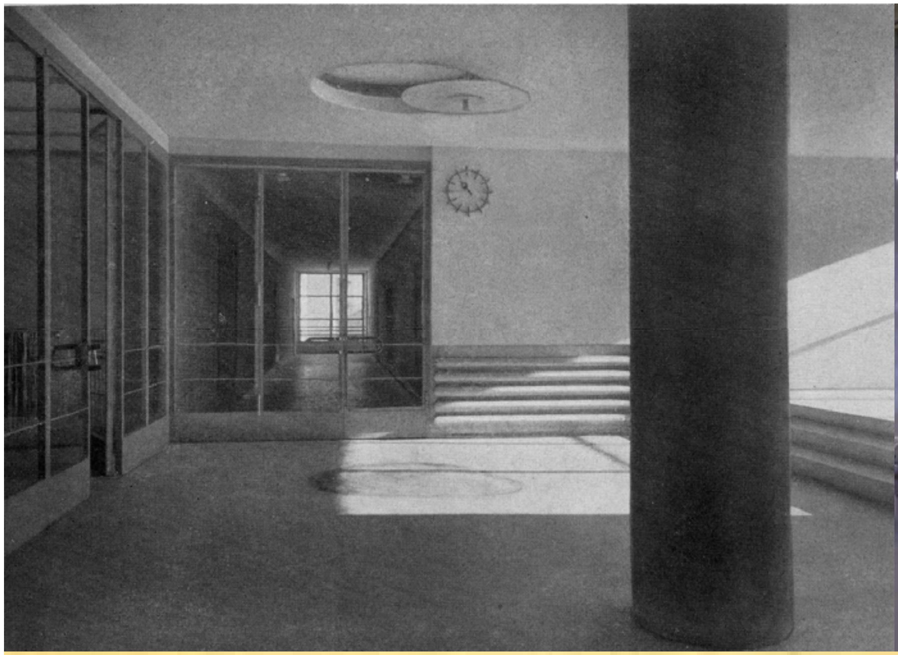
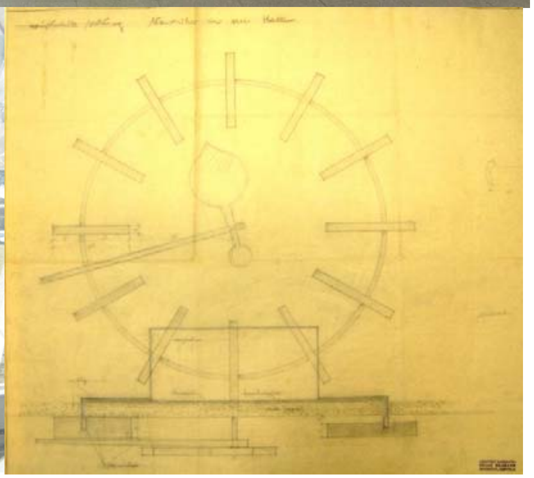
Cultural Values and Architecture







Details and daylight

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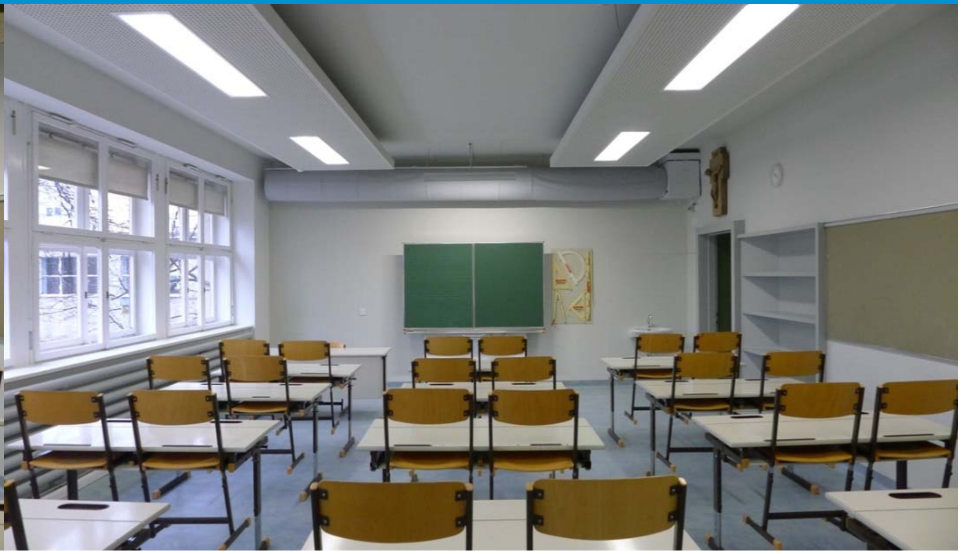
Artificial Light



Classroom 1:

- LED -lighting
- Automatc dynamic artificial and daylight control
- High-end solution (colour temperature control)

Classroom 2:

- Artificial light by fluorescent lamp
- Energy efficient day light dependant control
- Light integrated in sound absorber

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Artificial Light

Classroom 1:

- Control element

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Artificial Light Before Intervention

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Before Intervention

Classroom 1

	Window	Wall
Surface area	64,5	64,5
Occupied time in monitoring period [h]	826	826
Operation time per year[h]	513,68	528,43
Electric power consumption [W]	266,8	266,8
Elektric energy [kWh]	137,05	140,99
Energy consumption [kWh/m²a]	**4,31**	

Classroom 2

	Window	Wall
Surface area	64,5	64,5
Occupied time in monitoring period [h]	678,5	678,5
Operation time per year[h]	650,2	654,35
Electric power consumption [W]	266,8	266,8
Elektric energy [kWh]	173,47	174,58
Energy consumption [kWh/m²a]	**5,40**	

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Artificial Light after Intervention

After Intervention

Classroom 1

Lights:	Window	Wall
Surface area	64,5	64,5
Occupied time in monitoring period [h]	826	826
Operation time per year[h]	513,68	528,43
Electric power consumption [W]	279,5	279,5
Saving by daylight dependent control	0,52	0,74
Electric energy[kWh]	102,89	125,02
Energy consumption [kWh/m²a]	3,53	

Classroom 2

Lights:	Window	Wall
Surface area	64,5	64,5
Occupied time in monitoring period [h]	678,5	678,5
Operation time per year[h]	650,2	654,35
Electric power consumption [W]	282	282
Saving by daylight dependent control	0,52	0,74
Electric energy[kWh]	111,73	145,48
Energy consumption [kWh/m²a]	3,98	

Comparison of consumption before and after Intervention

Classroom 1

Energy consumption old [kWh/m²a]	**4,31**
Energy consumption new [kWh/m²a]	**3,53**

18 %

Classroom 2

Energy consumption old [kWh/m²a]	**5,4**
Energy consumption new [kWh/m²a]	**3,98**

26 %

CS 5 Daylight

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Day light redirection

Shading

Type E 80 LD

Classroom 1:

- Combined system for day light redirection and shading

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Acknowledgement and Partners

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Projectpartners:

3ENCULT (project coordination EURAC, Bozen, IT)

- **building physics, measurements:** Uni Innsbruck, Uni Stuttgart, Cartif, PHI
- **thermography:** IDK Institut für Diagnostik und Konservierung an Denkmalen
- **daylight/shading:** Bartenbach Lichtlabor
- **PV:** Soliker
- **interior insulation:** Remmers
- **ventilation:** Atrea

Others

- **artificial lighting:** Zumtobel, Tridonic
- **daylight/shading:** Warema
- **interior insulation:** Holzbau Wegscheider, Isocell
- **acoustic absorbers:** Organoid Technologies
- **cultural heritage authority:** BDA

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