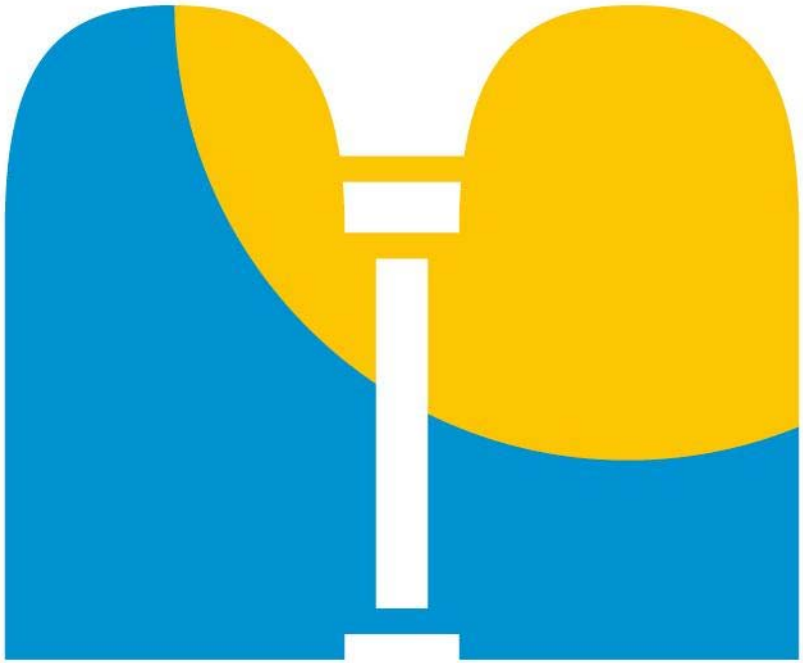

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EFFICIENT ENERGY FOR EU CULTURAL HERITAGE

Public Weigh House

Alexandra Troi, EURAC research

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

Location

- Bolzano, Italy
- Altitude: 269 m
- Heating days: 183
- Heating Degree Days: 2791 HDD
- Surrounded area: mountainous

- Historic city center of Bolzano
- Building is part of the “portici” of Bolzano
- East and south façade look toward a little square, while the north façade is directed to the tight historic shopping street (“portici”) of Bolzano

History use

Original objective	▪ Seat of the public weigh-house (Waaghaus) up until 1780
Current use	▪ Ground floor: shops ▪ 1st and 2nd floor: apartments ▪ 1st and 2nd basement: storage
Expected use in future	▪ Ground floor remains shop ▪ Upper floors for cultural purpose ideas: • museum of photography • regional cultural associations • “Künstlerbund” • Apartments for artists

Future use

Planning progress – use of building:

To define the use and the refurbishment project for the building, a two-stage competition will be carried out:

- Ideas competition for the **future use** of the Weighhouse
- Architecture competition for the **refurbishment project**

CS1: State of progress

Planning progress – use of building:

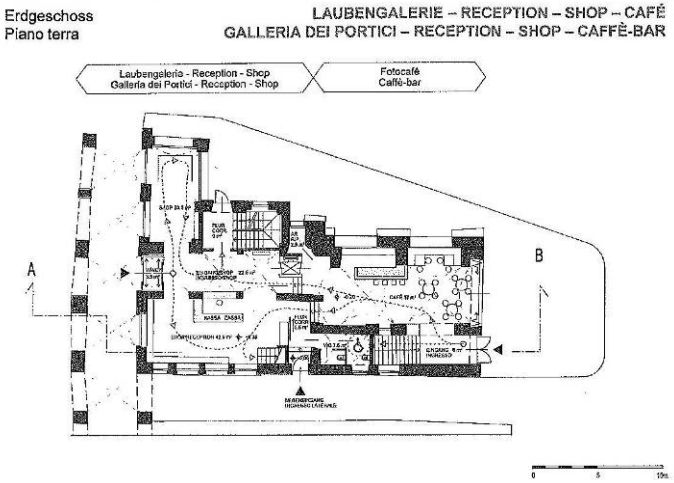
- Ideas competition to define the **future utilization concept** of the Weighhouse as a **“House of Photography"** -> published in May 2012, selection of 10 planners and start of competition phase: beginning of July, delivery of projects: yesterday, publication of decision: 22nd November
- -> besides utilization concept it was asked explicitly to exploit the energetic potential of the building

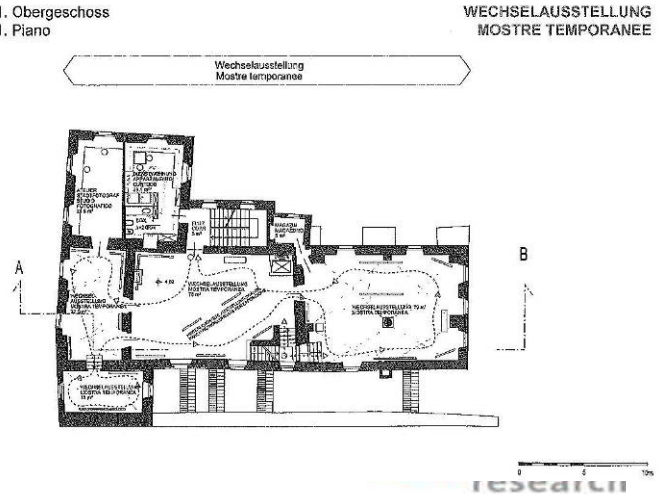
- The winner will project and realize the **refurbishment**

State of progress

Planning progress – use of building:

- Ideas competition to define the **future utilization concept** of the Weighhouse as a **“House of Photography"** -> selection of winner project 22nd November 2012:
- **Ground floor:** Reception, shop, café; **Basement:** digital gallery for citizens, old photographic studio
- **First floor:** temporary exhibition; **Second floor:** atelier of city photographer, apartment caretaker, permanent exhibition “Tyrol yesterday and today: ; **Top floor:** Auditorium, bibliotheca, administration
- Next steps still not clear: if the winner will project and realize the **refurbishment project**



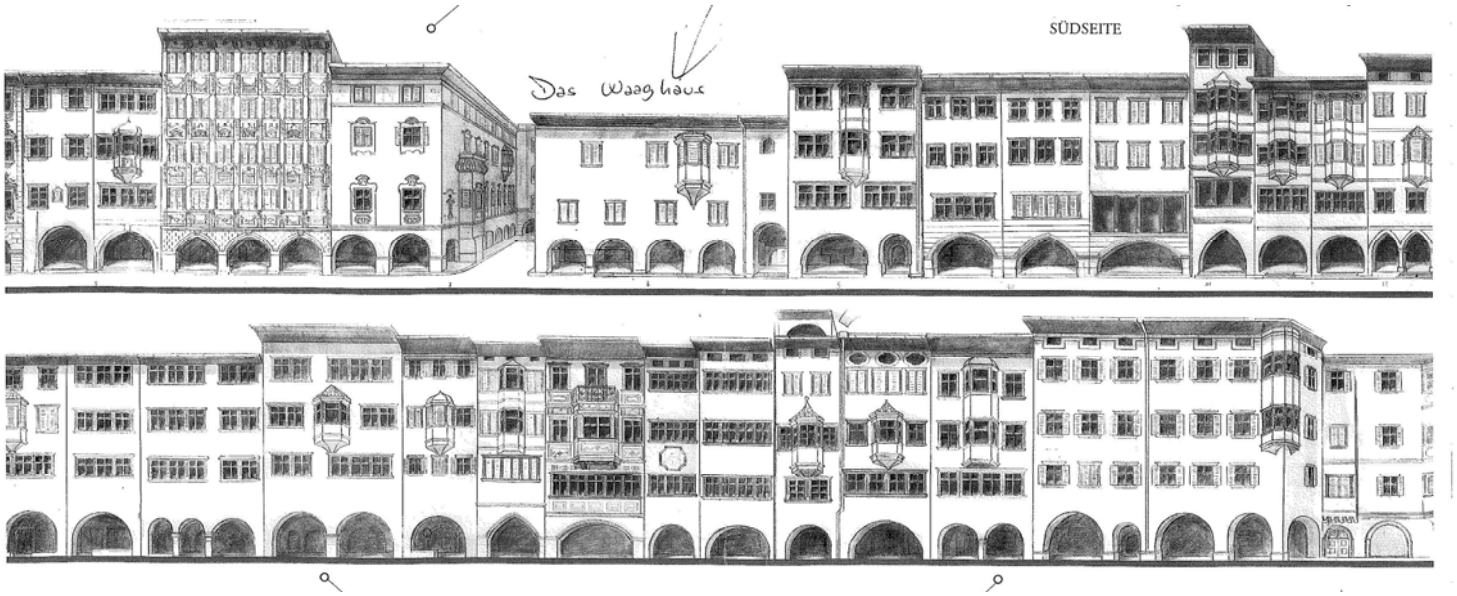


Diagnosis and pre-intervention status

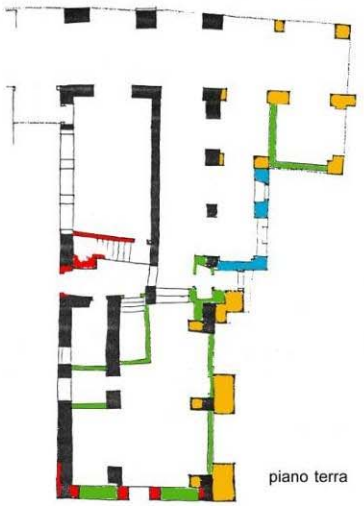
Dagmar Exner

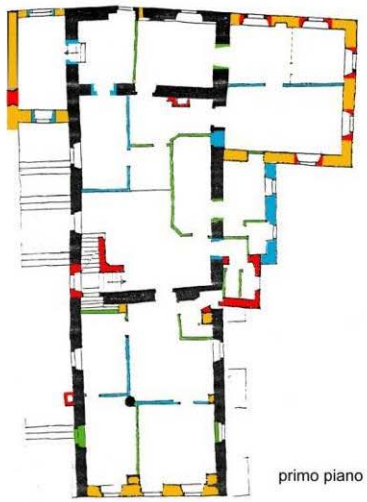
Architecture/ Construction

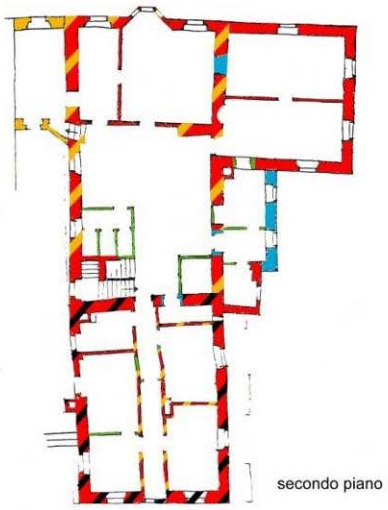
- Massive construction in natural stone (vaults)
- Wooden roof construction
- **Characteristics “Portici” of Bolzano:**
  - Ground floor: Walkway for the mercantile life, behind it vaults for the storage of goods, often several floors below ground level
  - On the upper floors: apartments often placed around an atrium

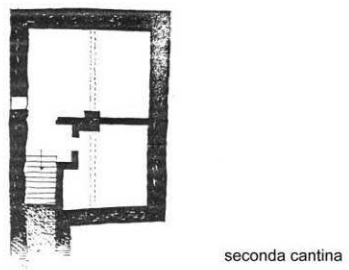


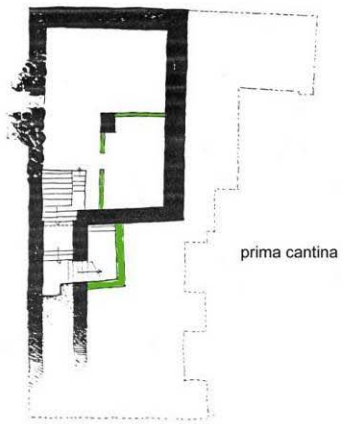
History construction











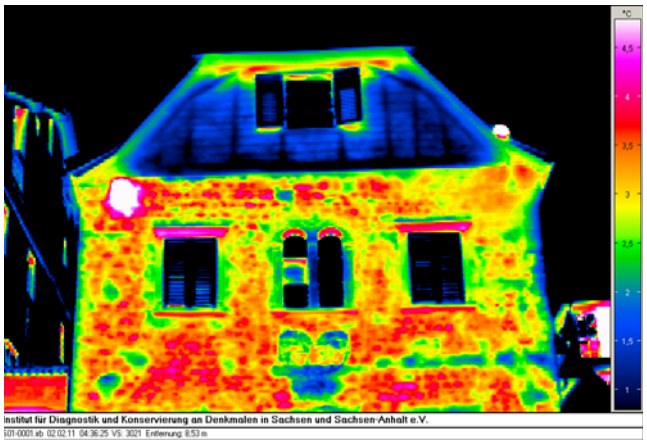
- Original building 13th century
- Intervention 15th and 16th century
- Extension (2nd floor) beginning 17th century
- After extension 17th century, during public ownership
- Inner walls from the last century

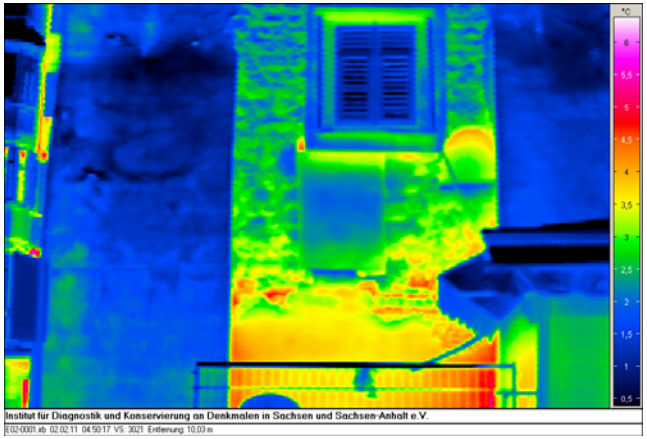
State of diagnosis preintervention

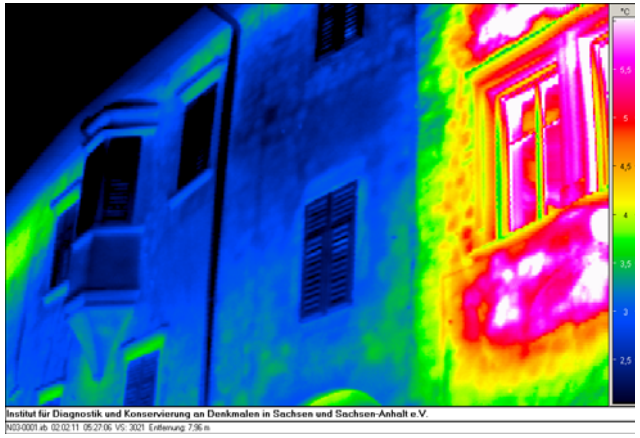
- **Calculations:**
  - PHPP As-is-state
  - EnergyPlus as-is-state
- **Measurements:**
  - Thermography
  - Blower Door Test
- **Documents:**
  - Report on stratigrafic analysis, diachronic analysis (Conservator: Adriano Salvoni 2006)
  - Project plans as-is-state (Architect: Dalla Bona 2006)

State of diagnosis preintervention

- **Calculations/Simulations**
  - PHPP: As-is-state
- **Measurements:**
  - Thermography (unheated building) by Christoph Franzen 02/11
- **Monitoring system:**
  - Installation 04/11 by TUDA – Update/extension 10/2011







State of diagnosis preintervention

- **Results specific space heat demand – As-is-state – for different pressurization test results (n50)**

(VERSION I: Balance boundary excluding top floor, first and second basement floor)

Specific space heat demand	Pressurization test result*
390 kWh/m²a	3,0 h^{-1}
417 kWh/m²a	11,5 h^{-1}
441 kW	
472 kW	

WHERE THESE RESULTS ARE COMING FROM? PLEASE SPECIFY

* „Eine Schweizer Untersuchung benennt für "Altbauten vom 17. Jh. bis 1870" einen Wertebereich der Messungen bei 50 Pa Prüfdruck von n50 = 11,5-29 je Stunde (Mittelwert 19 h-1).“ http://www.baufachinformation.de/denkmalpflege.jsp?md=2004077108843

Monitoring system

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Indoor climate

Surface temperatures on constructional critical points of the thermal envelope. As: external corner, window, window reveal

Air streams

Outdoor climate

Solar radiation, outdoor temperature, outdoor relative humidity

Historical surfaces

Near field climate, surface temperatures

Changing of form in laboratory and on-site

Air streams

EURAC research

Monitoring system

Monitoring As-is-state:
Selected rooms will be temperate and dependent on the results on historical surfaces (indoors) they will be also conditioned regarding the relative humidity
- Acquisition of energy consumption -

Interventions:
Selected rooms/surfaces: Interventions like:
- Installation of windows prototype
- Installation of interior insulation

Monitoring after interventions


Monitoring of window situation (as-is-state) Before intervention

Monitoring system

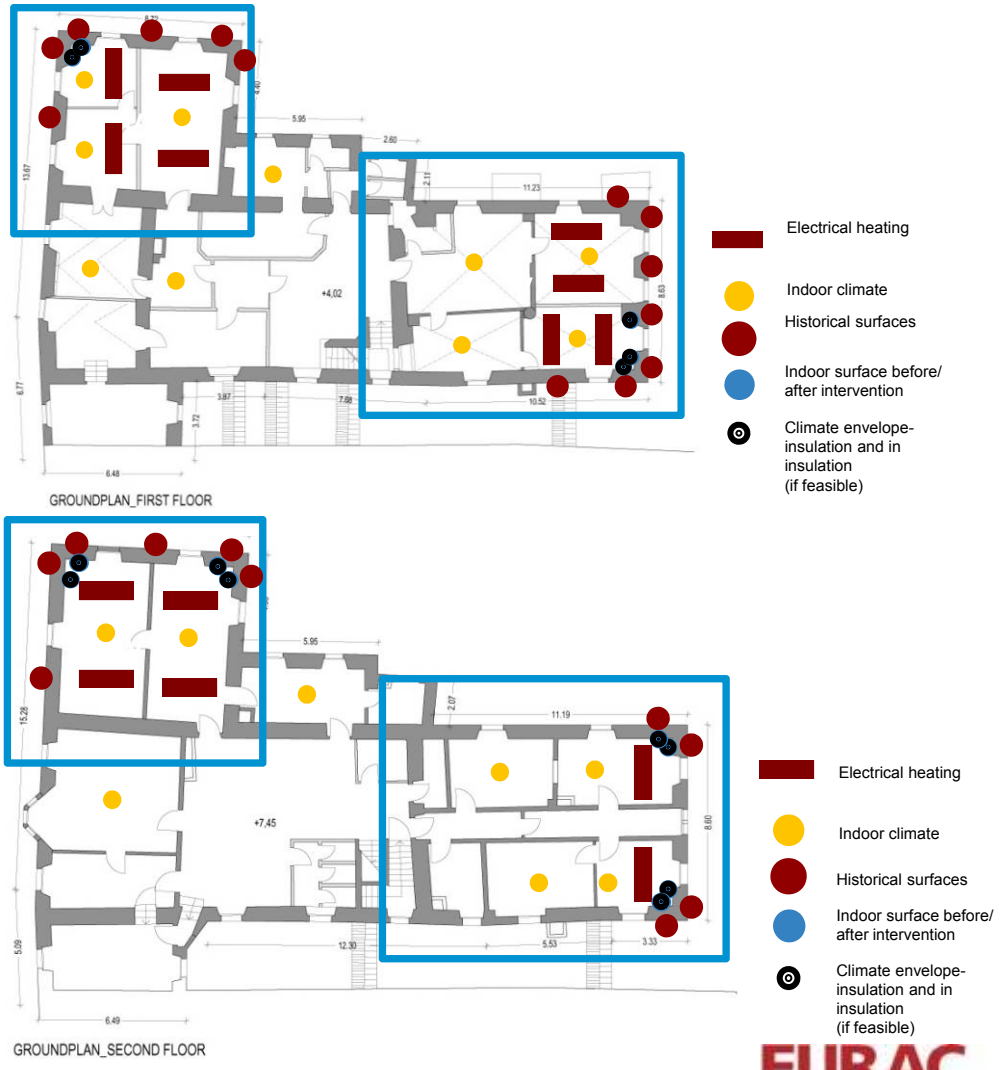
Monitoring energy consumption

Heating up with electrical heating

Mobile humidifier/dehumidifier

Comfort

Acquisition of energy demand



Monitoring layout: Second basement

GROUNDPLAN_SECOND BASEMENT

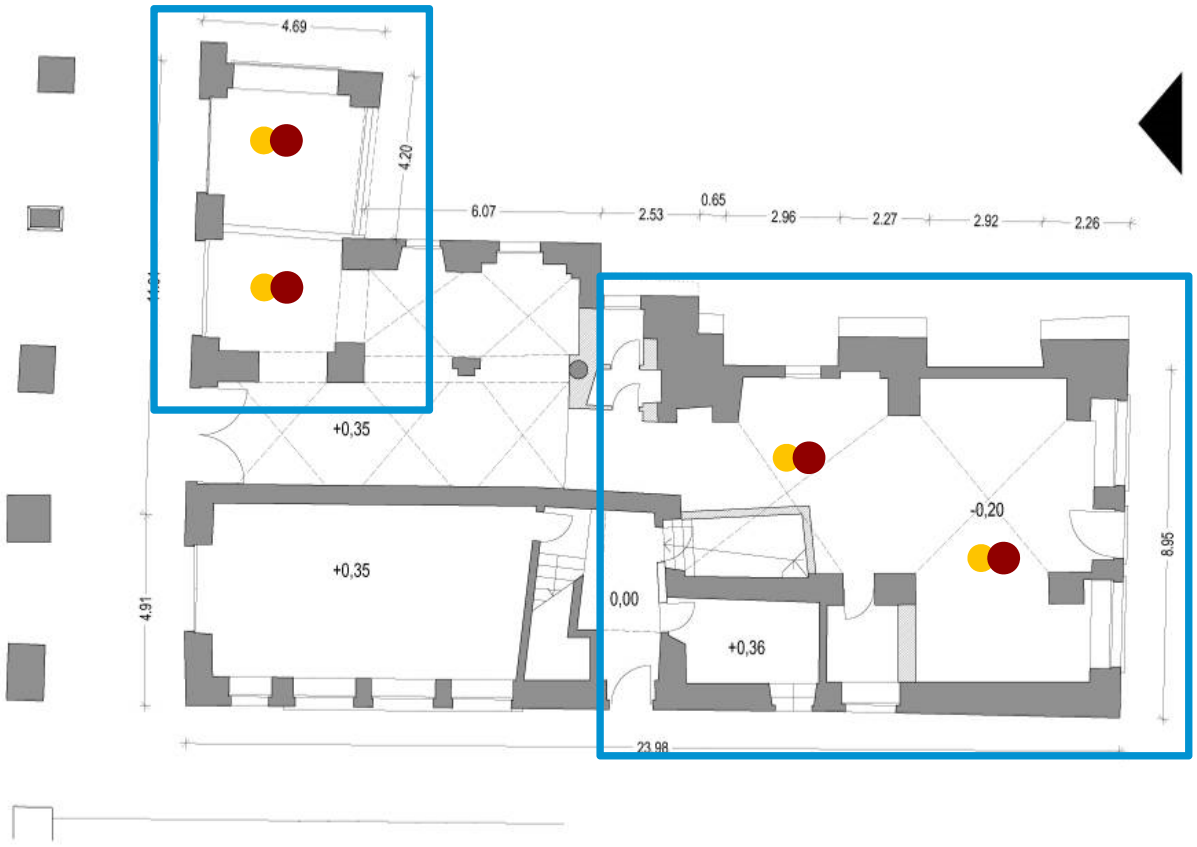
Indoor climate

Monitoring layout: First basement

GROUNDPLAN_FIRST BASEMENT

Indoor climate

Monitoring Layout : Ground Floor



GROUNDPLAN_GROUND FLOOR

Indoor climate

Historical surfaces

Monitoring layout: First floor

GROUNDPLAN_FIRST FLOOR

- Electrical heating
- Indoor climate
- Historical surfaces
- Indoor surface before/ after intervention
- Climate envelope- insulation and in insulation (if feasable)

Monitoring layout: Second floor

GROUNDPLAN_SECOND FLOOR

Electrical heating

Indoor climate

Historical surfaces

Indoor surface before/ after intervention

Climate envelope- insulation and in insulation (if feasable)

Monitoring layout: Top floor

GROUNDPLAN_TOP FLOOR

Indoor climate

Surface temperatures in roof construction

Monitoring system

Monitoring System

- Installation of **electric heaters** in 8 rooms of the building
- Extension monitoring system: mobile sensors
- Opening of window shutters

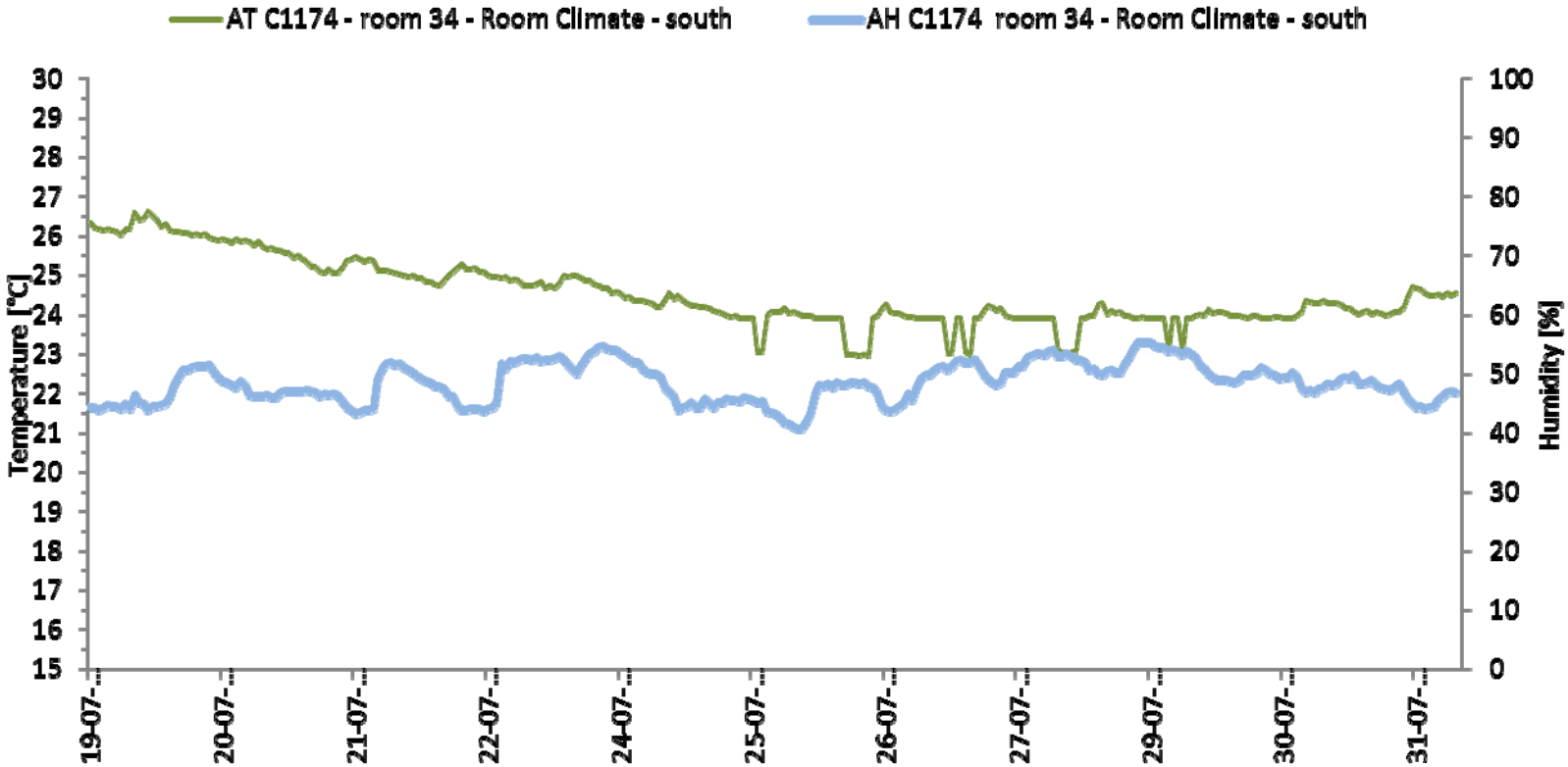
Aims:

- Acquisition of **energy demand**
- Realistic situation for measurements like: thermography, monitoring after interventions

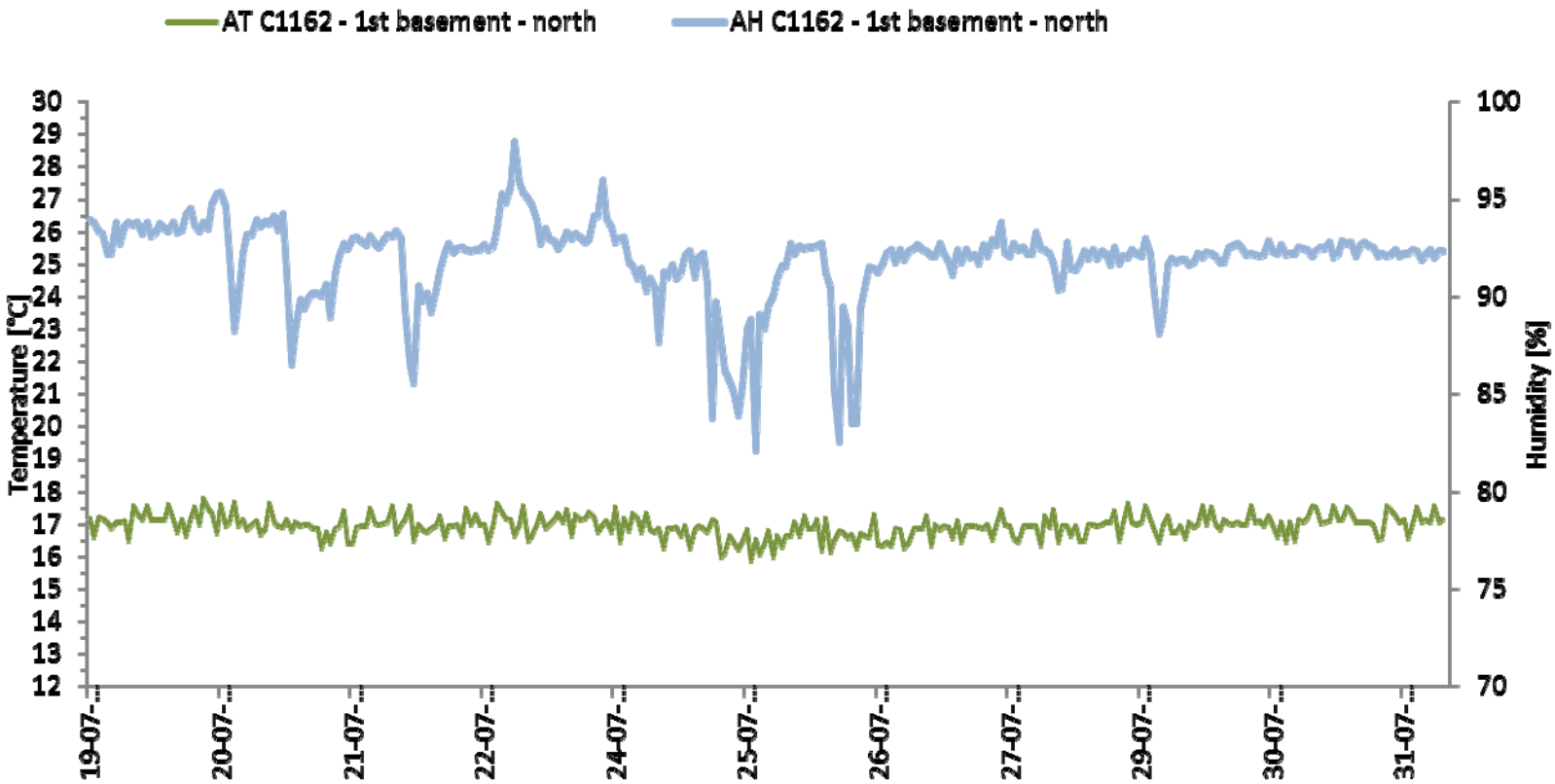
Monitoring of window situation (as-is-state) Before intervention

Example of environmental monitoring results

Inner surface temperature (10.03.2011- 15.12.2011) north wall heating with IQ-Therm interior insulation system,



Example of monitoring results



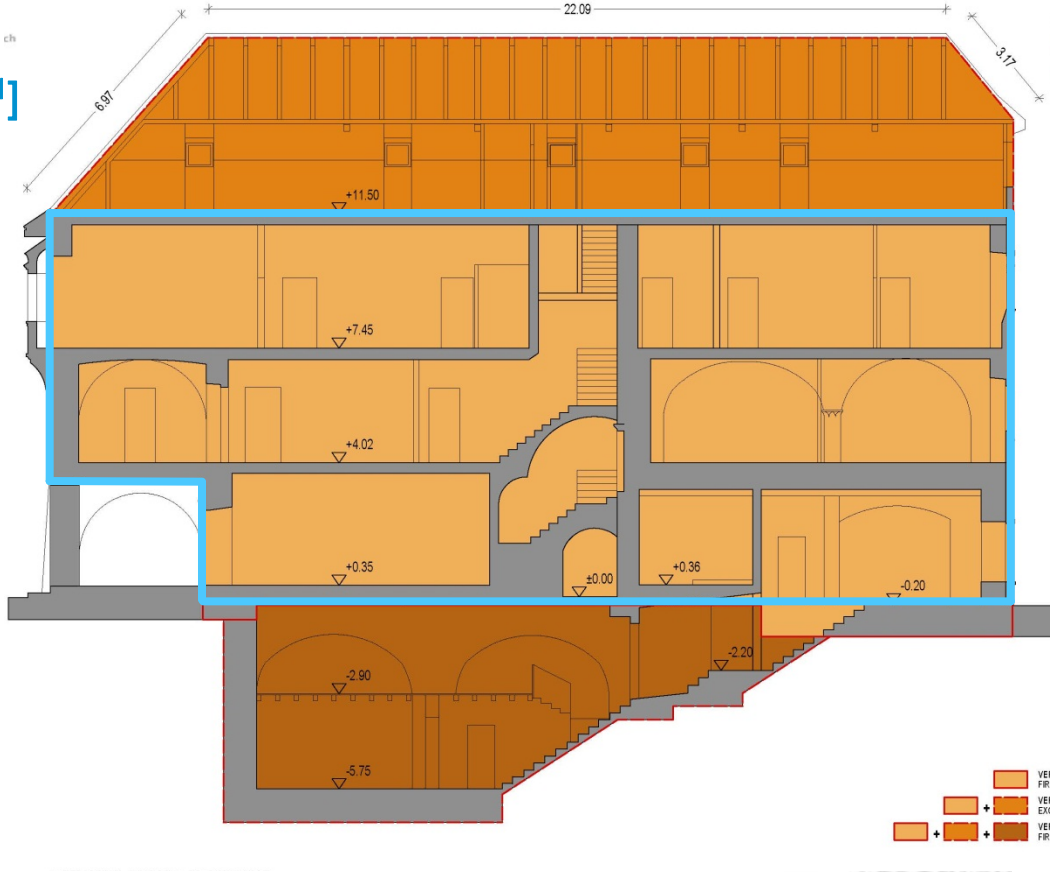
Inner surface temperature (10.03.2011- 15.12.2011) north wall heating with IQ-Therm interior insulation system,

Diagnosis pre-intervention

Evaluation of Blower Door Test:

Measurement without top floor (V_{Netto}= 1.780 m³)

Overpressure: n_{50} = 9,98 ± 0,04 % [h^{-1}]
Underpressure: n_{50} = 9,08 ± 0,02 % [h^{-1}]

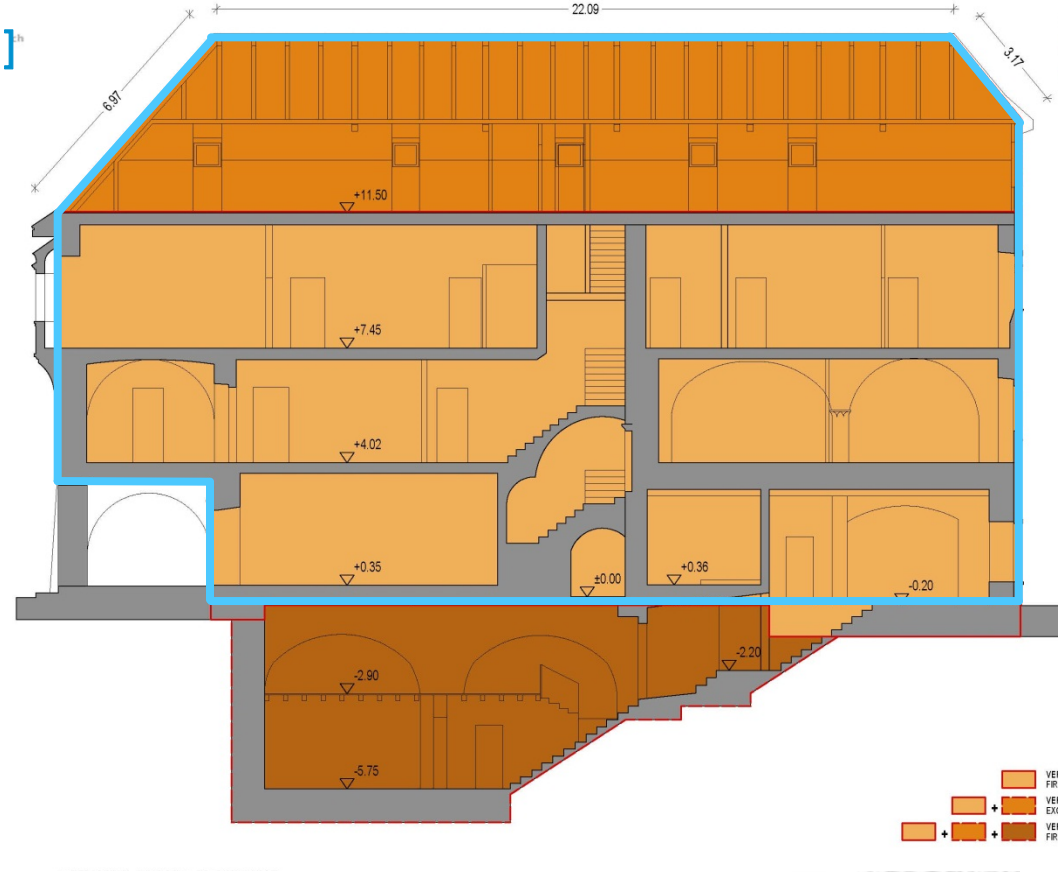


Diagnosis pre-intervention

Evaluation of Blower Door Test:

Measurement with top floor (V_{Netto}= 2.042,5 m³)

Overpressure: n_{50} = 10,05 ± 0,13 % [h^{-1}]
Underpressure: n_{50} = 9,1 ± 0,02 % [h^{-1}]



Diagnosis pre-intervention

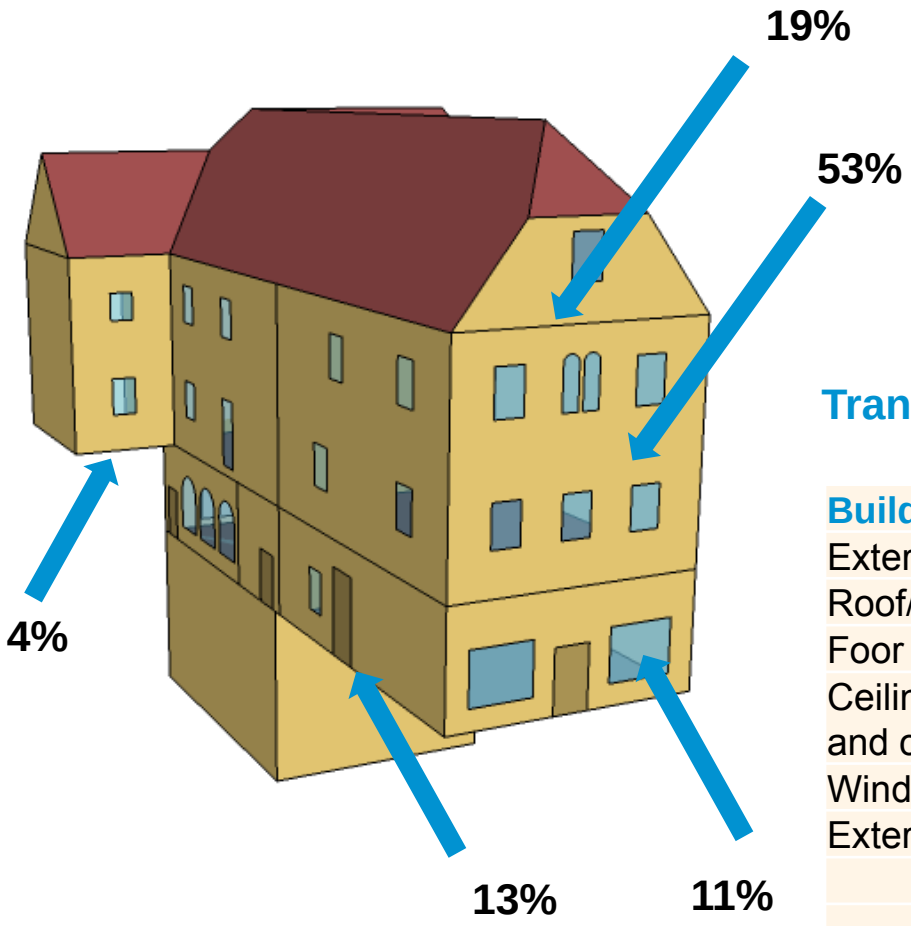
Further diagnosis

- Analysis of **material sample** (02/12) -> core drill hole (diameter 5 cm – length 30 cm) from exterior wall of “test room”, first floor: water absorption coefficient, porosity and density
- **Heat flux measurements** (02/12)
- **Second thermography** (02/12) with in parts heated building, combined with Blower Door

- **Opening of 2 wooden ceiling beam ends** in “test room”, first floor. 2 in the pavement – opening from above (ceiling ground floor/first floor) and 2 in the ceiling – opening from below and from above (ceiling first floor/second floor): visual diagnosis on position and state of beam ends




Diagnosis pre-intervention



Calculated annual specific heat demand of as-is-state (version I) with PHPP: 343 kWh/(m²a)

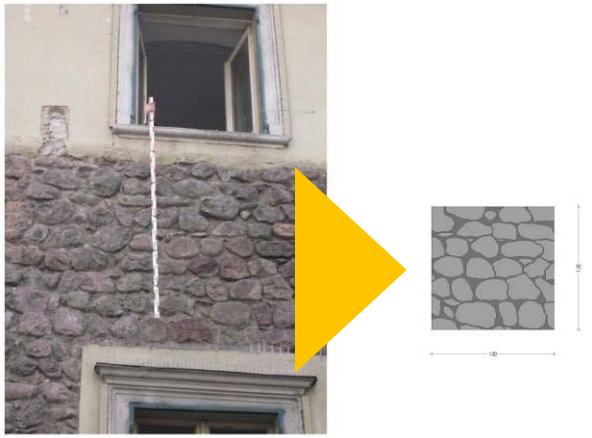
Transmission heat losses over external surfaces:

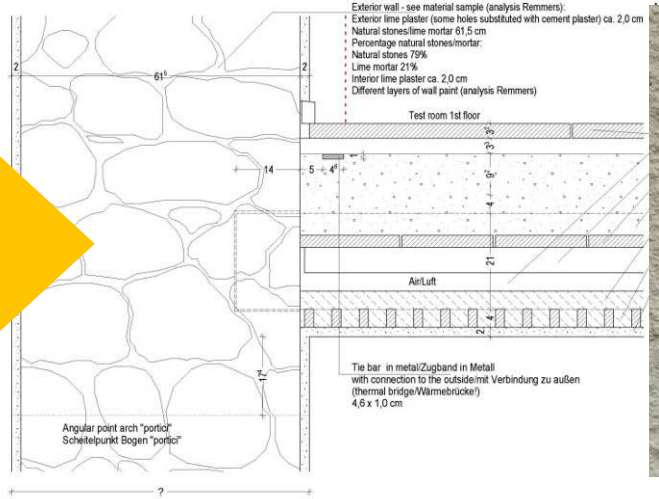
Building Element	m²	kWh/(m²a)	%
Exterior Wall - Ambient	968,41	157,45	52,53
Roof/Ceiling - Ambient	99,09	12,52	4,18
Foor slab/ basement ceiling	127,51	39,51	13,18
Ceiling 2nd floor to cold roof and ceiling basement	512,48	55,73	18,59
Windows	116,10	32,53	10,85
Exterior Door	9,89	1,98	0,66
		299,72	100

Diagnosis pre-intervention

Analysis of architectural elements

- Precise **measurement of stratigraphy** of construction elements -> drawing of detail sections with correct dimensions
- **Analysis of material parameters** (from material samples) through TUD for the Delphin database
- Documentation of the building in the DIS database





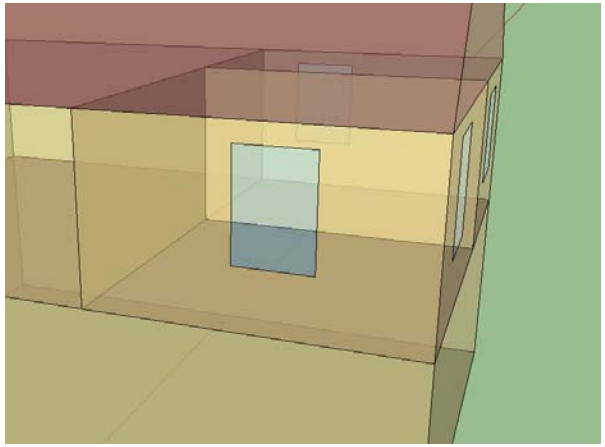
Diagnosis pre-intervention

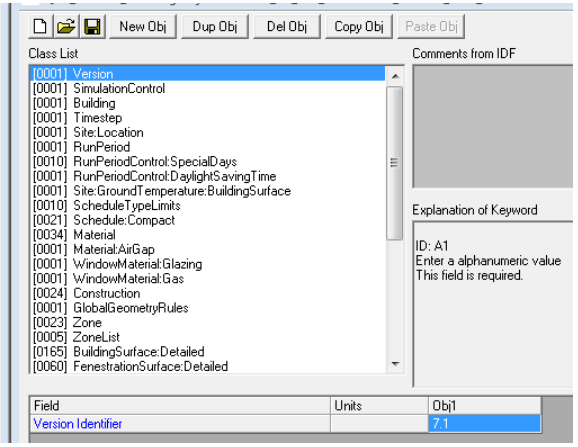
Eplus model of the whole building

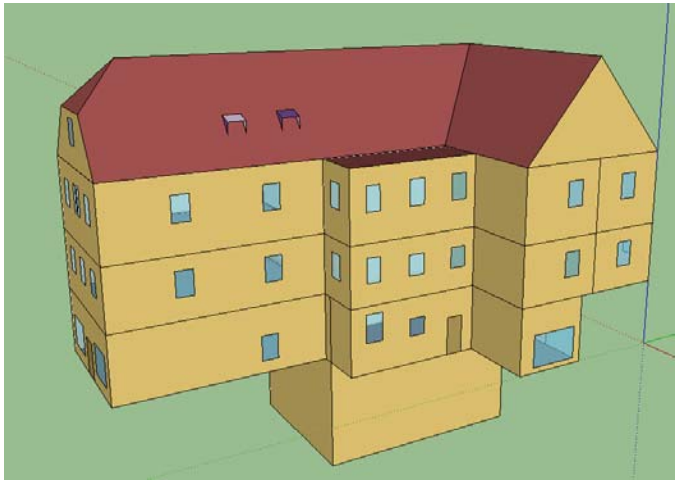
- Model with Energy plus for the calculations of energy consumptions and comfort conditions
- Comparison between the models with **Eplus and the PHPP results**

Test room model in Energy plus:

- **Validation of the model** through the comparison between the monitored and simulated surface temperatures of one test room in the as is state
- Simulation in a 3D space of the behaviour of the wall with the interior insulation to understand the influences on the thermal mass



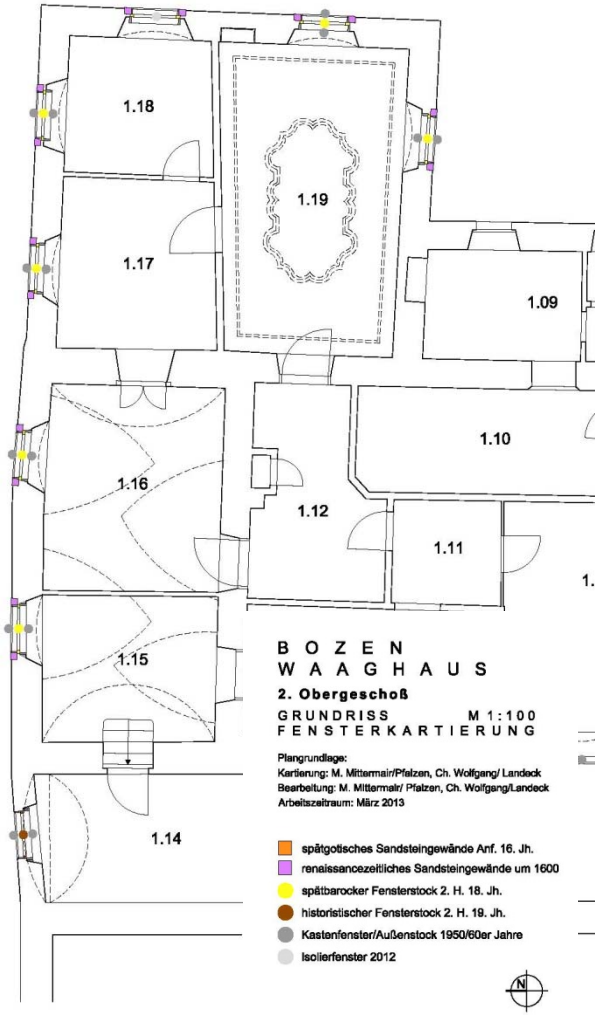




Diagnosis pre-intervention

Analysis of architectural elements

- Calibration of model: **measurement of heat transmission** of construction elements of the thermal envelope
- **Specialists for buildings history** are analysing the whole building structure -> more knowledge on heritage value of single construction elements
- Documentation of the building in the DIS database



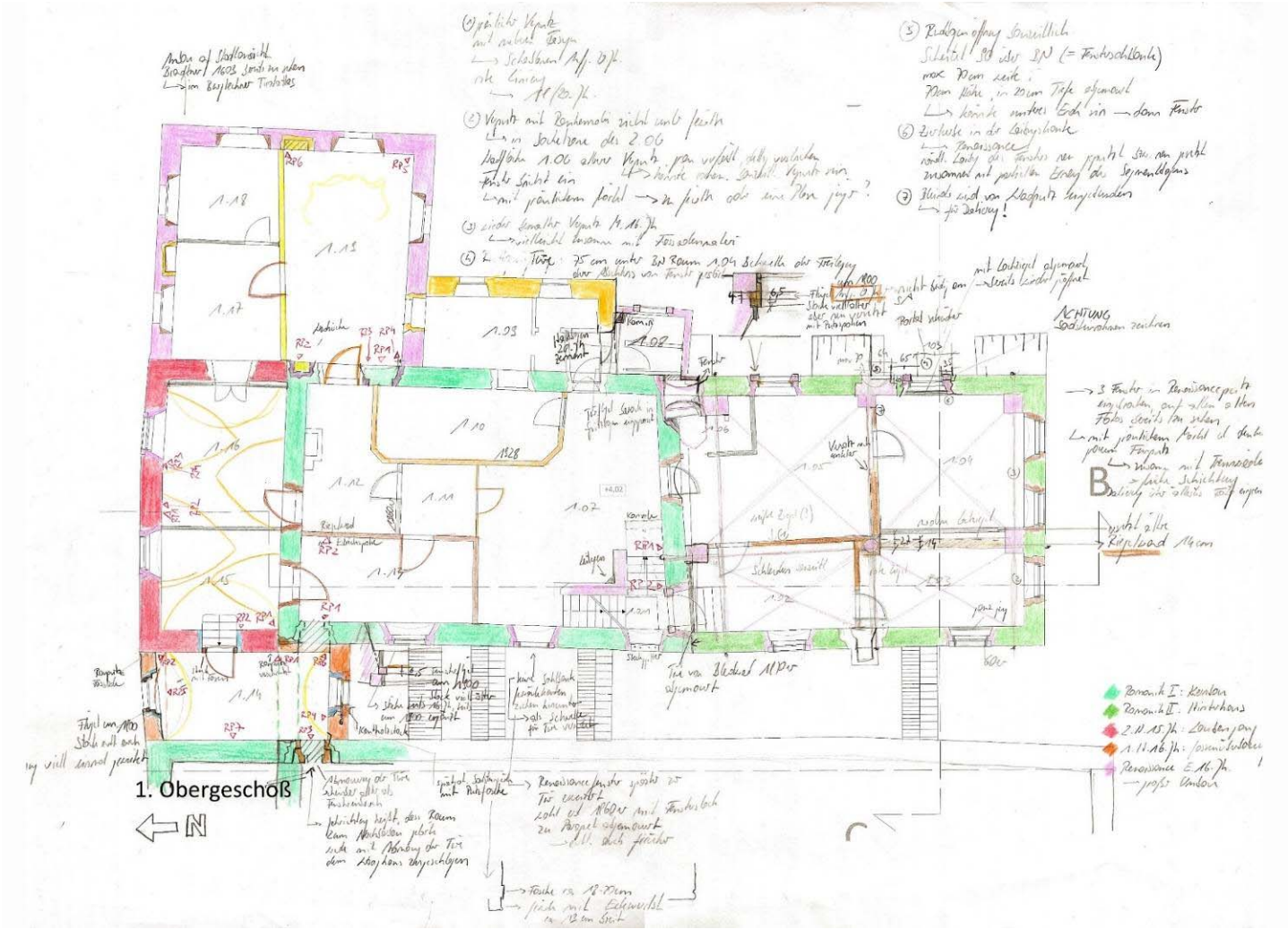
Diagnosis pre-intervention

New window situation:

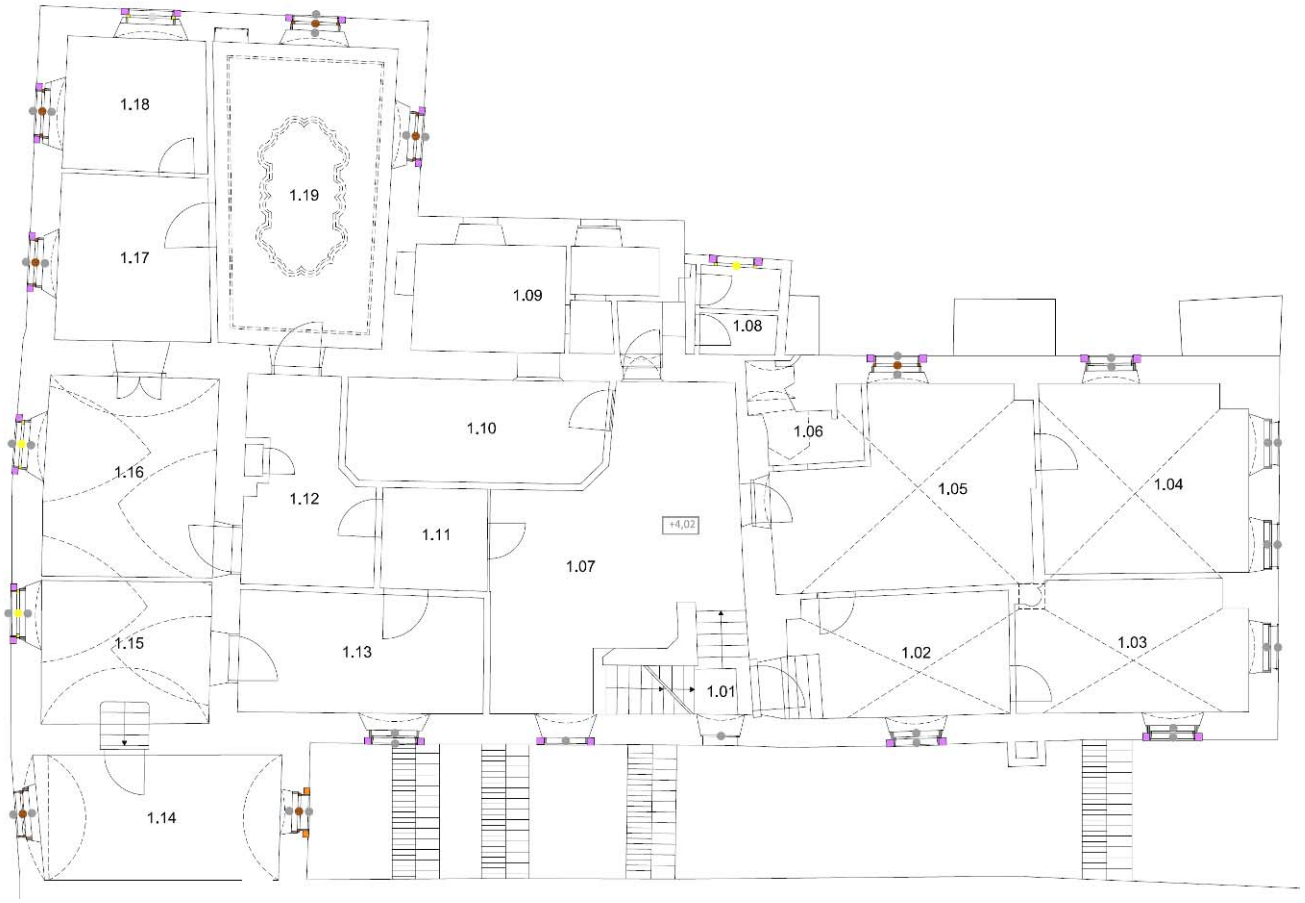
- **Outer window frame:** from baroque period 1750/1800, originally with impost
- **Outer window sashes:** around 1900
- **Inner window sashes** + box-type window frame: 1950th

- **Need of a consistent window/façade concept**
- **Development of a 2nd window prototype -> energy efficient box-type window**
- **Bring existing window prototype (coupled window) forward to a applicable state**

Diagnosis pre-intervention



Diagnosis pre-intervention



B O Z E N
W A A G H A U S

2. Obergeschoß

G R U N D R I S S M 1:100
F E N S T E R K A R T I E R U N G

Plangrundlage:
Kartierung: M. Mittermair/Pfalzen, Ch. Wolfgang/ Landeck
Bearbeitung: M. Mittermair/ Pfalzen, Ch. Wolfgang/Landeck
Arbeitszeitraum: März 2013

- spätgotisches Sandsteingewände Anf. 16. Jh.
- renaissancezeitliches Sandsteingewände um 1600
- spätbarocker Fensterstock 2. H. 18. Jh.
- historistischer Fensterstock um 1900
- Kastenfenster/Außenstock 1950/60er Jahre
- Isolierfenster 2012

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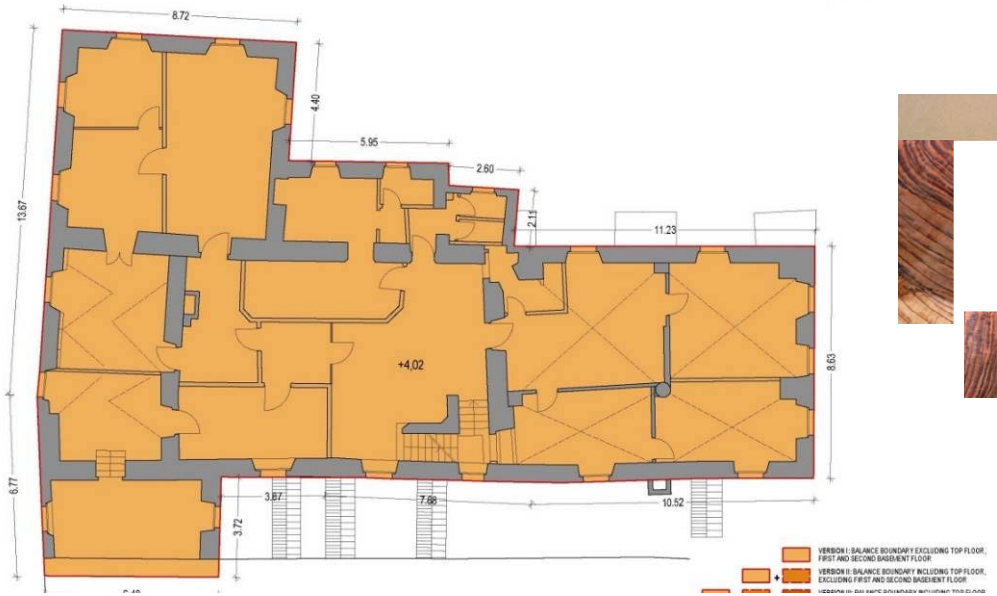
Prototypes
and support in design phase

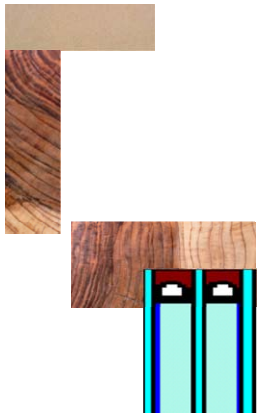
Planned Solutions/Interventions

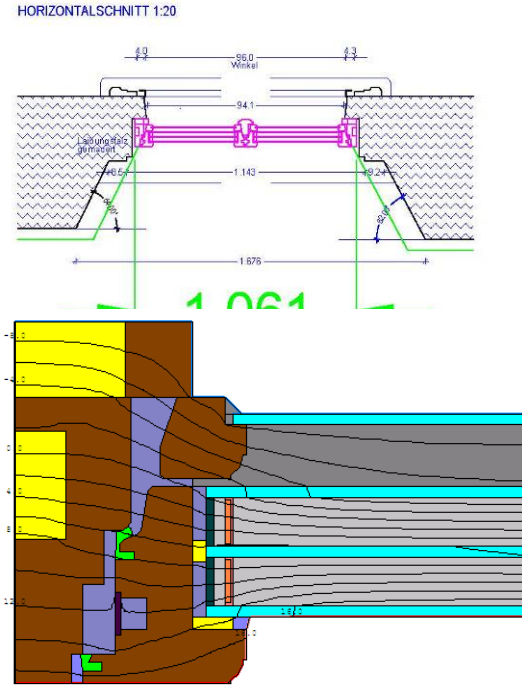
- **Development of Window prototype (developed by Franz Freundorfer and André)**

Aims:

- Based on the individual demands of the case study: **adaption of the "passive house"** window to the special conditions of the historic building
- Window solution should be applicable **for similar historic buildings**







Planned Solutions/Interventions

- **Installation of Window prototype**

Aims:

- Installation of **a coupled window prototype** in a “test room” with internal insulation. The room will be temporary heated up during the heating period.
- Visualize the developed prototype in the building context

- On-site testing of the prototype: **conservator evaluation**
- Monitoring of **before and after situation** in terms of surface temperatures and relative humidity

Planned Solutions/Interventions

- **Installation of internal insulation in one test room**

- **Installation of IQ-Therm** in a north-east oriented room on the first floor. The room will be temporary heated up during the heating period. Use of **clay glue** for fixing the insulation panels in a removable way

Aims:

- **Summer case/winter case:** Weighting of the influence of internal insulation on the "efficiency" of the thermal mass/energy consumption
- Observing and analysing **risk of condensation** in the layers under the internal insulation, the corners and beam ends



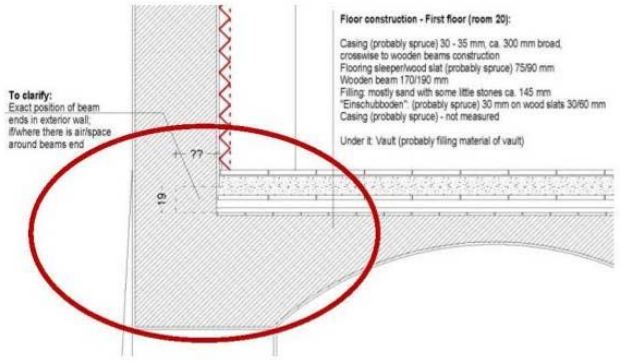
Planned Solutions/Interventions

- **Installation of internal insulation in one test room – actual state**

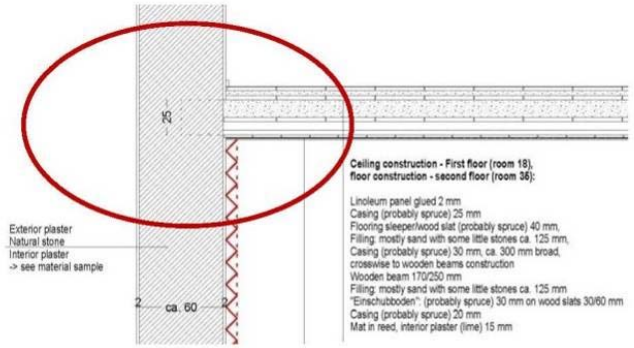
- Simulations of three points in Delphin by TUD:

- Window prototype/window reveal
- Floor (beam ends)
- Ceiling (beam ends)

Comparison of 2 thicknesses: 5 and 8 cm



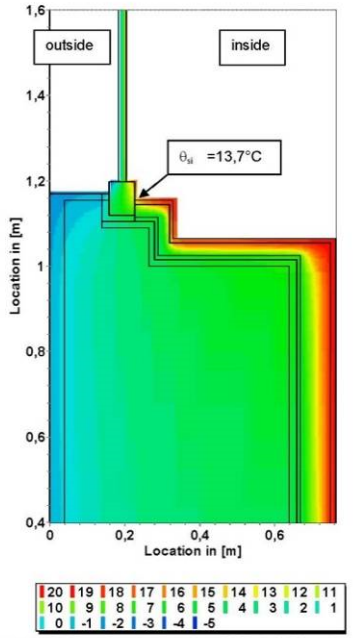
floor construction – first floor (room 20)



ceiling construction- first floor (room18)

1.5 Calculation under unsteady state conditions (real climate of Bolzano)

Outer wall thickness = 60 cm, insulated with 8 cm IQ -therm, window reveal insulated with 3 cm IQ Therm,
Distance between window rfigureet to the outer edge: ≥ 12.5 cm



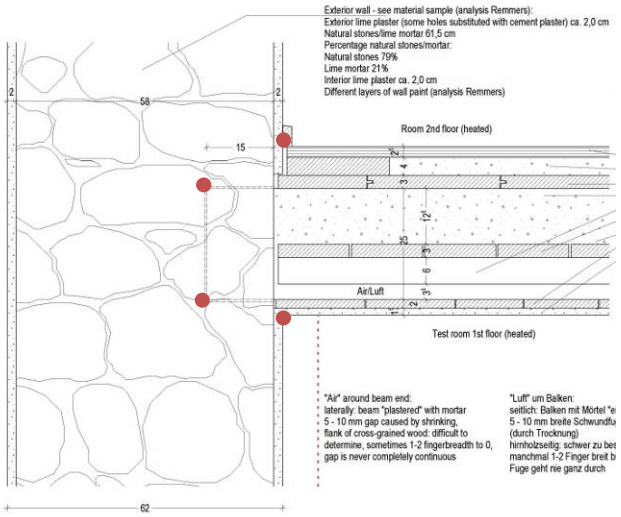
Temperature field, surface temperature [° C], OW 60 cm insulated with 8 cm IQ Therm, window reveal insulated with 3 cm IQ Therm
Boundary conditions: Bolzano outdoor climate,on January10th

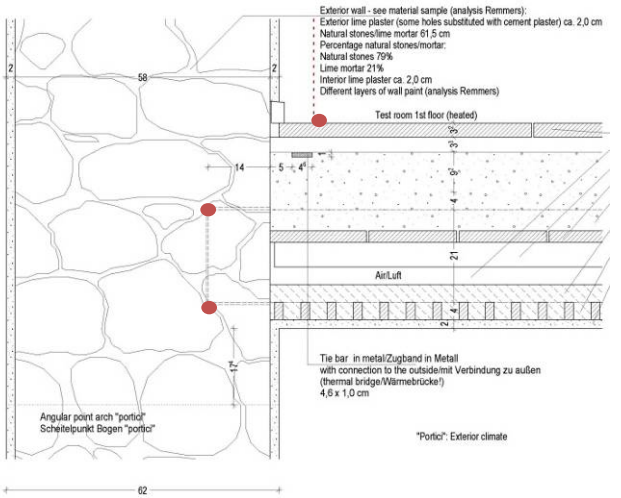
State of diagnosis pre intervention

Installation of internal insulation in one test room – actual state

Simulations in DELPHIN of **two significant points**:

- Floor (beam ends)
- Ceiling (beam ends)
- Comparison of 2 thicknesses: 5 and 8 cm with as-is-state

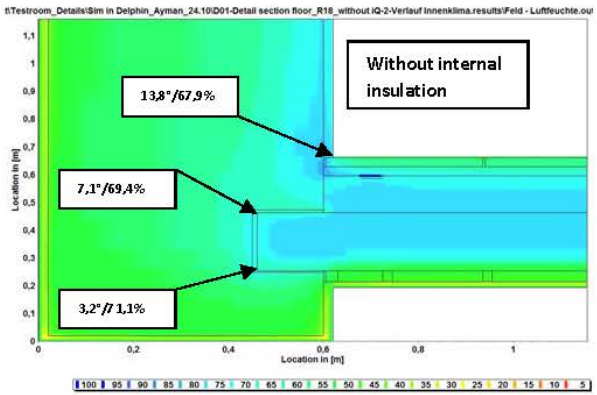


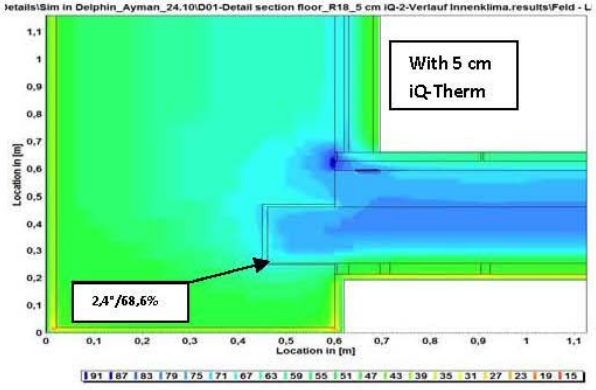


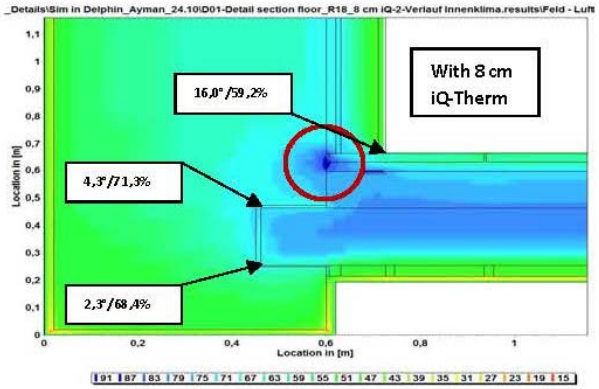
State of diagnosis pre intervention

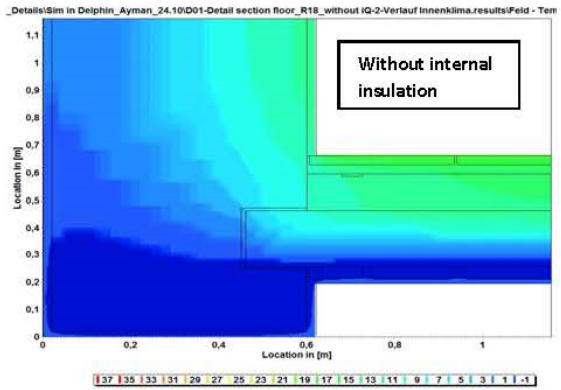
Simulation of beam ends floor (ceiling “portici”)

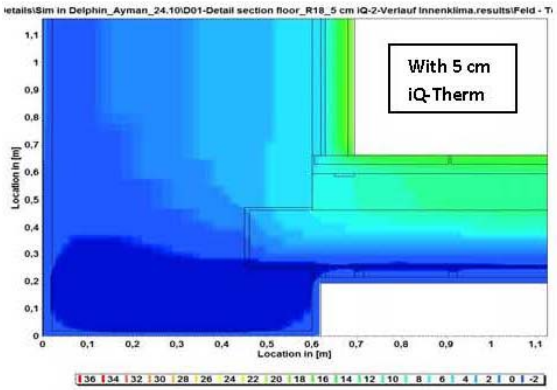
Comparison: relative **humidity and temperature** within the structure on a cold winter day (Winter 2nd/3rd year: 12th January)

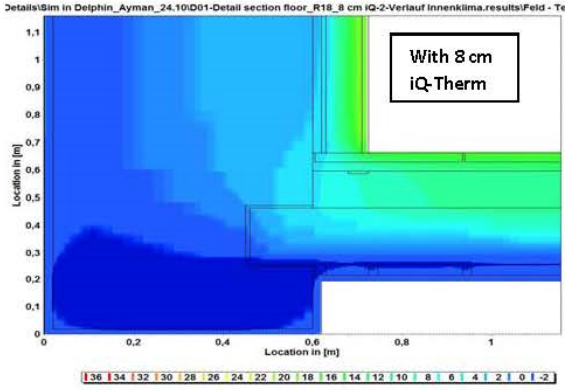








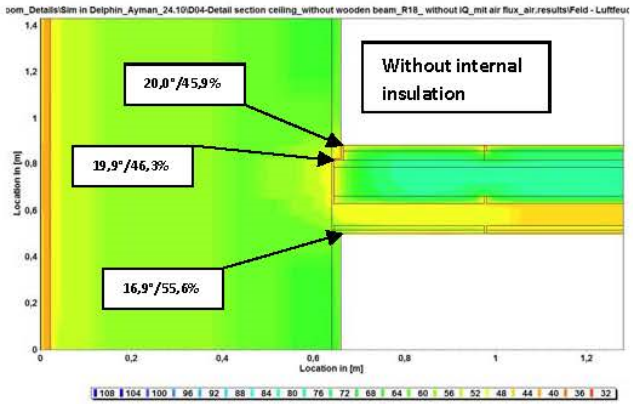


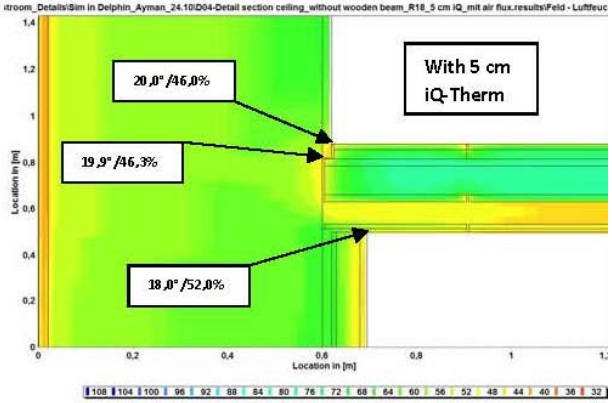


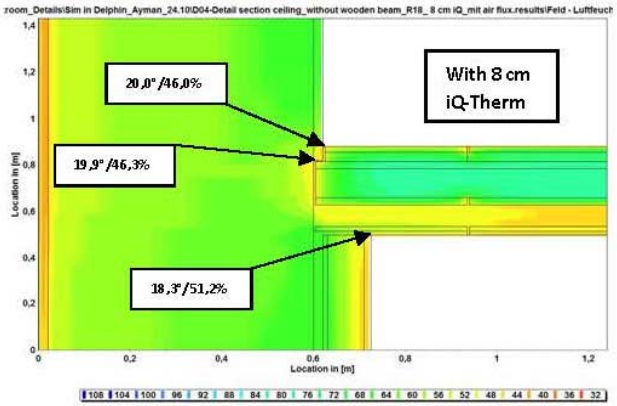
State of diagnosis pre intervention

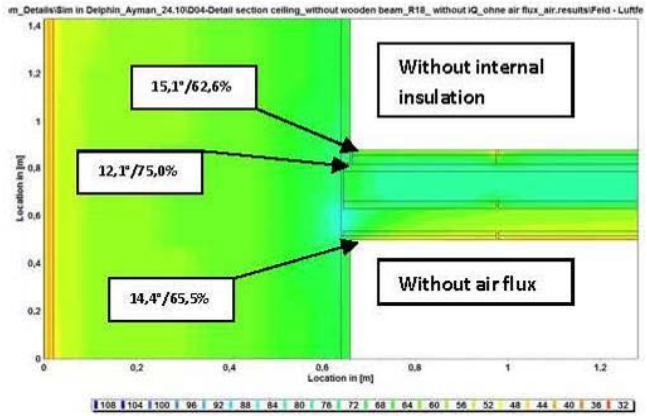
Simulation of beam ends ceiling -> with air flux and without

Comparison: relative **humidity and temperature** within the structure on a cold winter day (Winter 2nd/3rd year: 12th January)









Planned Solutions/Interventions

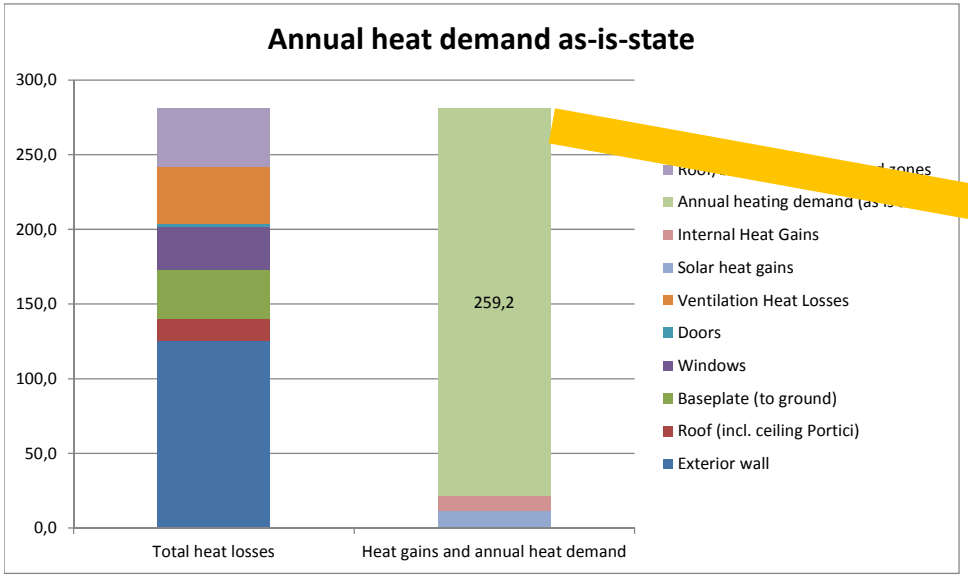
Proposal of passive solutions

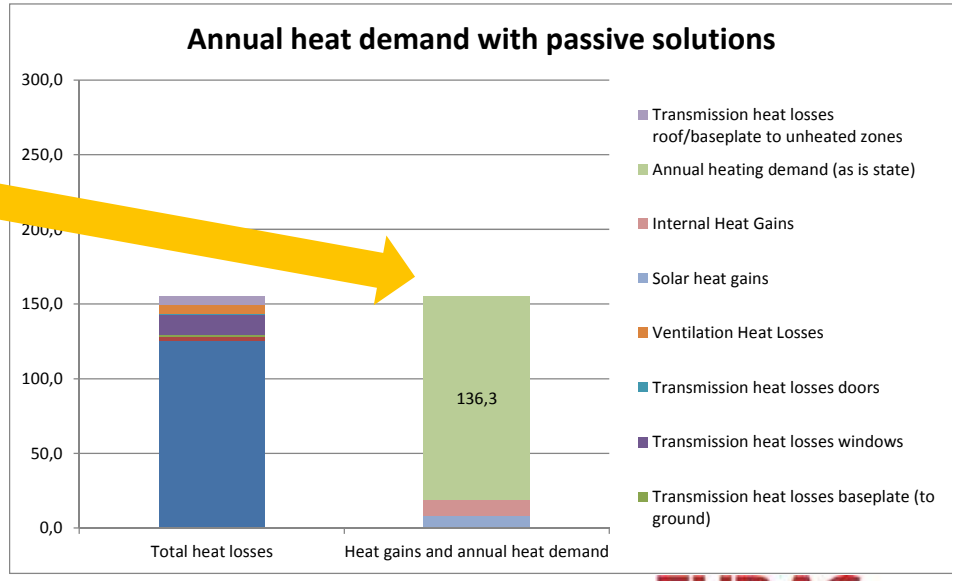
- **Insulation of roof**
- **Insulation of baseplate**
- **Insulation of ceiling portici**
- **Higher airtightness** (10,05 -> 1,5 h-1)
- **Substitution of windows** (2,5-2,9 ->1,2-1,4 double glazing)
- **Controlled ventilation with heat recovery** (85%)
- Solar collector under roof tiles (in comb. with heat pump)

Planned Solutions/Interventions

Annual heating demand 259 kWh/m²a -> 136 kWh/m²a

- Insulation of roof -> 244 kWh/m²a
- Insulation of baseplate/insulation of ceiling portici -> 188 kWh/m²a
- Higher airtightness/substitution of windows -> 150 kWh/m²a
- Constrolled ventilation with heat recovery (85%) -> 136 kWh/m²a



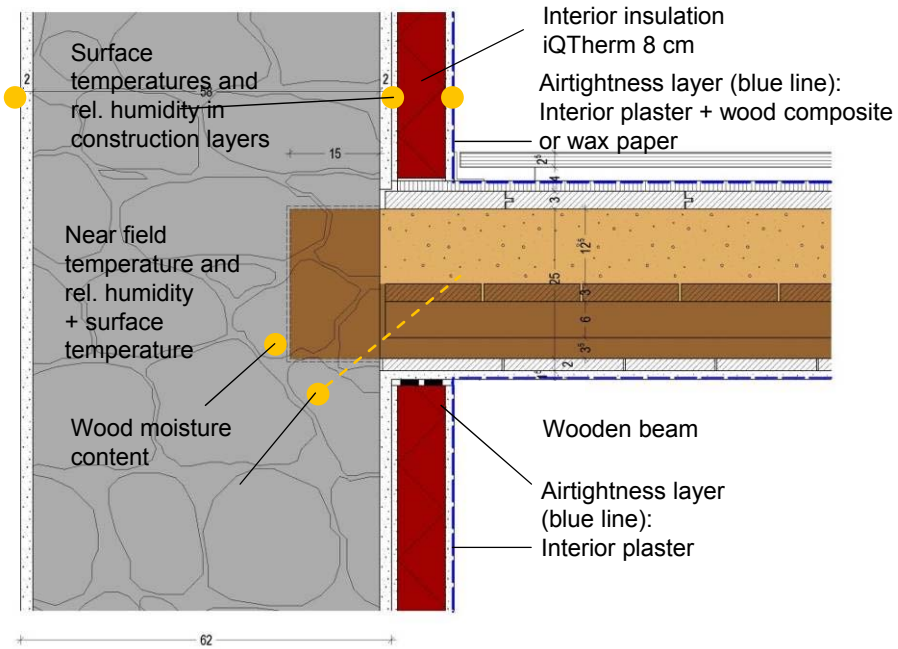


Retrofit design
Planned solutions

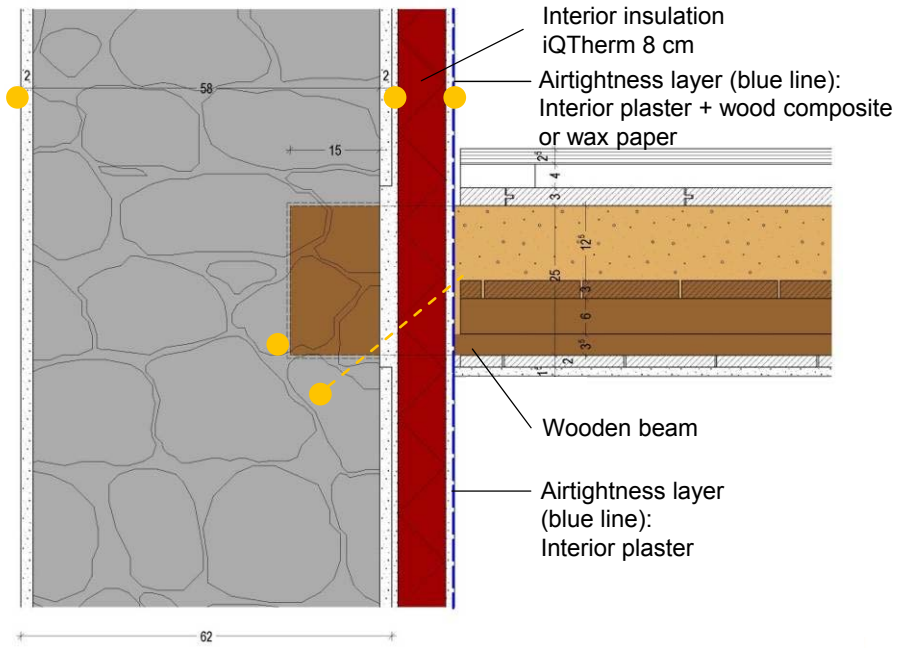
Installation of iQTherm 8 cm in test room (1st floor)

- **Wooden beams in ceiling:** implementation of two different connections
- **Monitoring and comparison of both solutions:** wood moisture content, temperature and rel. humidity

Version I: „interrupted" insulation

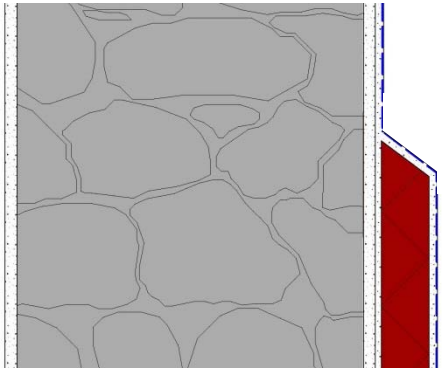


Version II: „continued" insulation

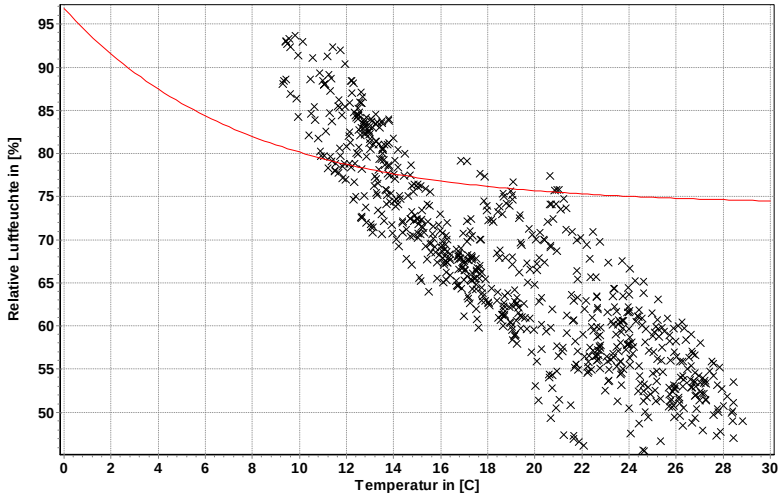


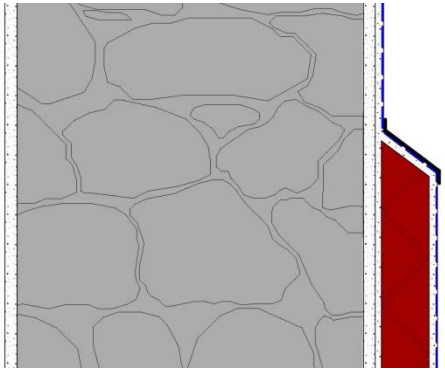
Retrofit design
Planned solutions

Detail: endpoint internal insulation at parapet height (room 2nd floor)

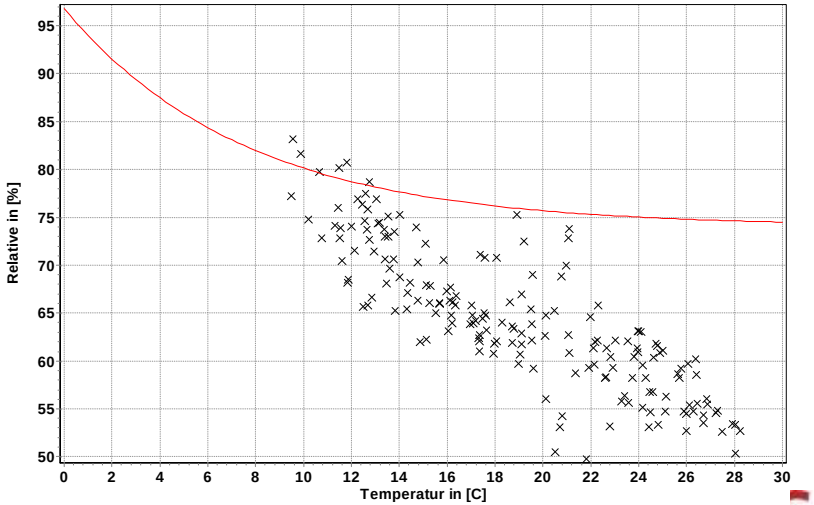


Without metal sheet





With metal sheet



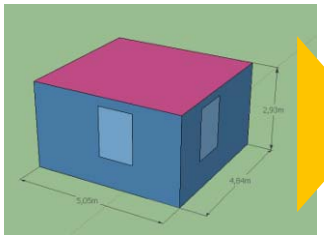
Retrofit design
Planned solutions

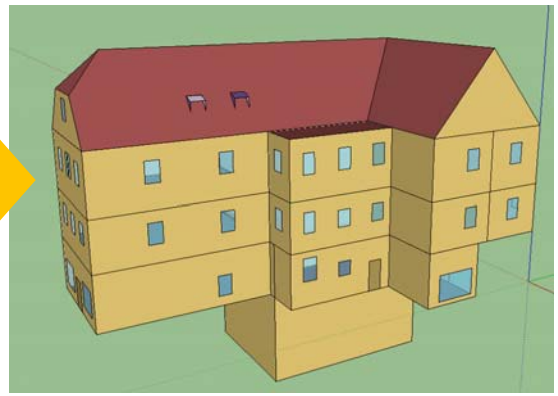
3encult
EFFICIENT ENERGY FOR EU CULTURAL HERITAGE

Energy efficiency solutions for the whole building:

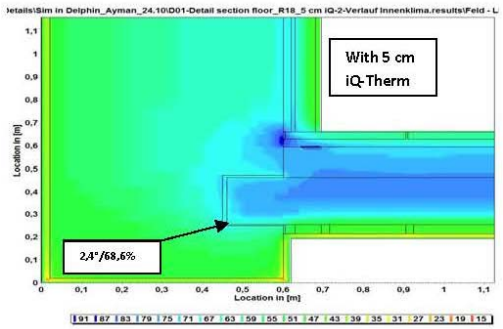
Optimization strategy

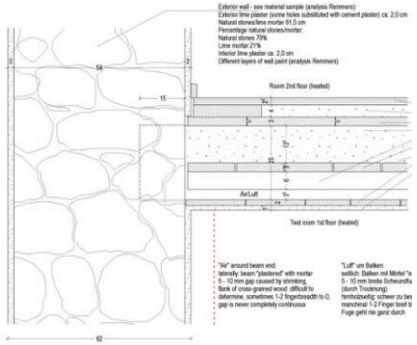
- Building envelope and night summer ventilation optimization
- **Minimizing** energy consumption and **discomfort**
- Solution sets for building envelope and ventilation system





Detail planning and technical feasibility of passive solutions

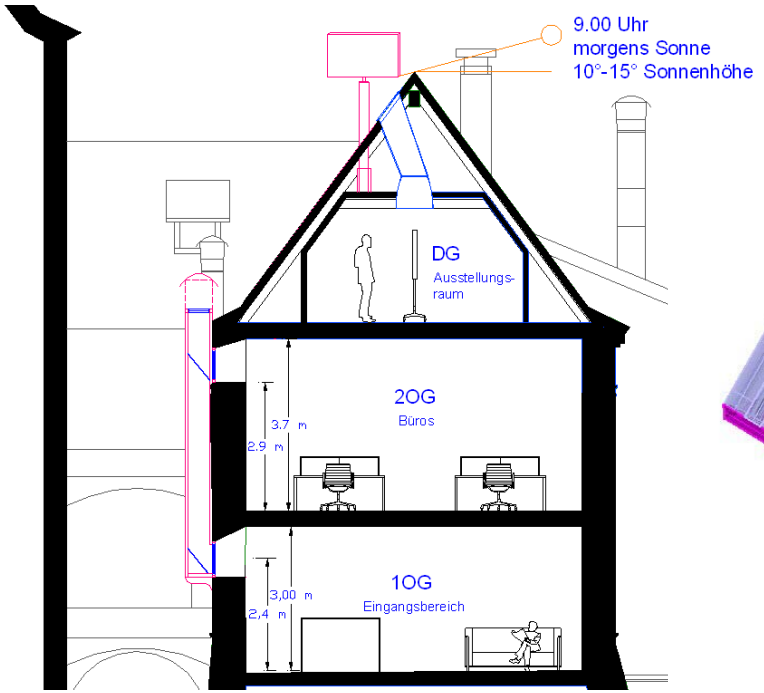


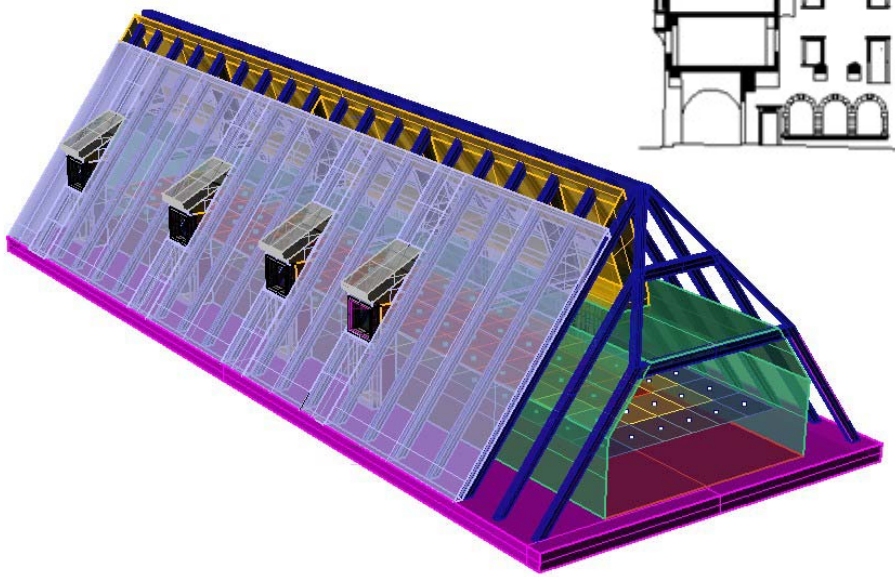


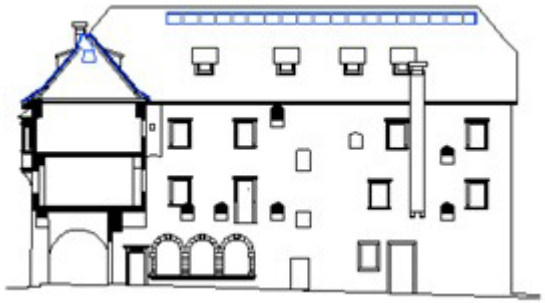
EURAC research

Planned Solutions/Interventions

- **Semester project on Weigh House of students of LAB (Lighting Academy Bartenbach)**
- Development of concepts for daylighting of the Waaghaus



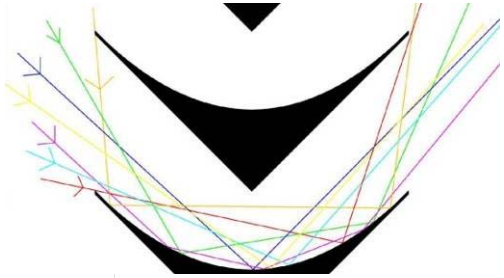


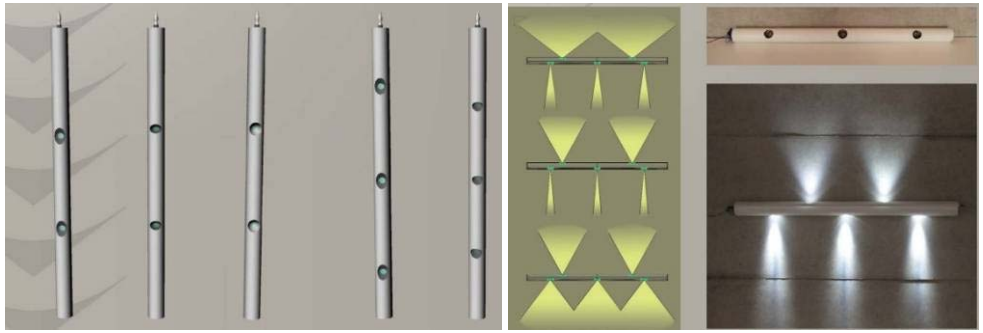


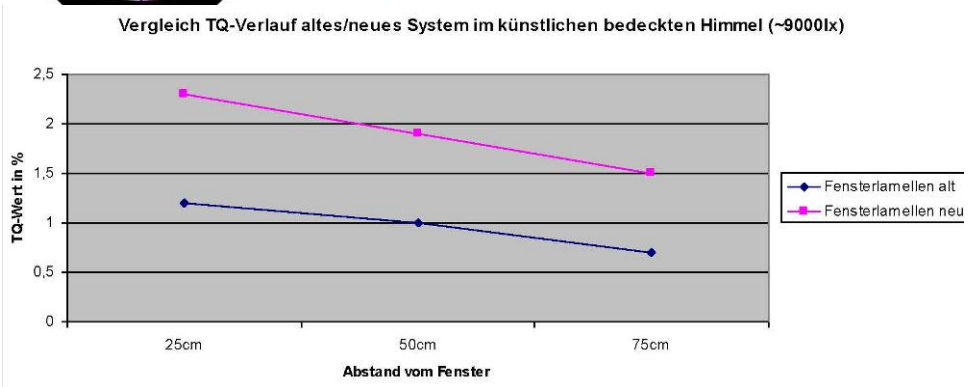
Planned Solutions/Interventions

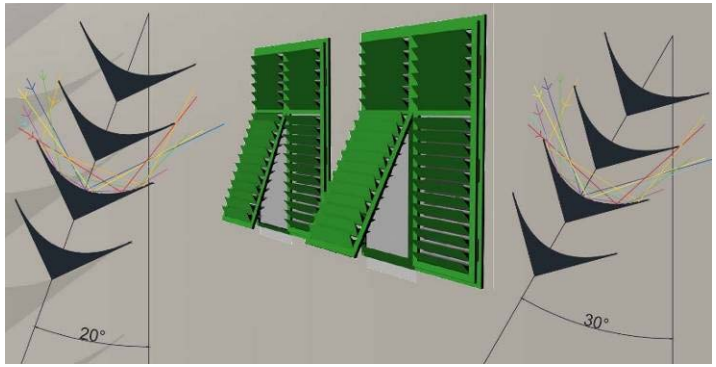
- **Semester project on Weigh House of students of LAB (Lighting Academy Bartenbach)**

- Development of concepts for daylighting and artificial lighting of the Waaghaus
- Development of an energy efficient artificial lighting system responding to the demands of a protected building





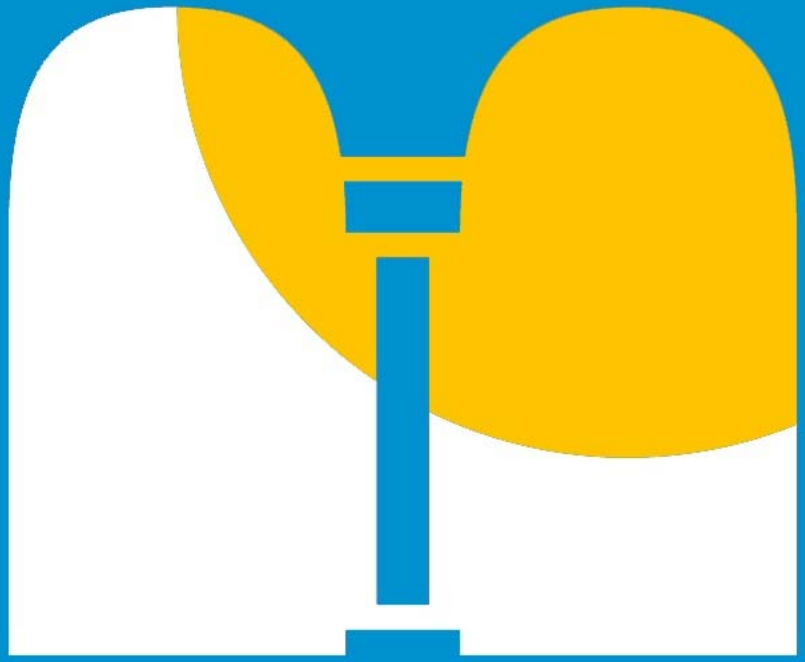




Planned Solutions/Interventions

- **Semester project on Weigh House of students of TUD "Masterstudiengang Denkmalpflege und Stadtentwicklung"**

- Documentation of **as-is-state of most of the "portici" – buildings**, regarding the following issues:
- Are there basement floors? How many basement floors?
- Roof areas
- Last refurbishment
- As-is state windows
- As-is state facades (historic plaster)
- Atriums
- Comfort of inhabitants



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