D 6.2 Documentation of each study case CS1 Public Weigh House, Bolzano (Italy) Delivered at M42

EUROPEAN COMMISSION

DG Research and Innovation

Seventh Framework Programme

Theme [EeB.ENV.2010.3.2.4-1]

[Compatible solutions for improving the energy efficiency of historic buildings in urban areas]

Collaborative Project – GRANT AGREEMENT No. 260162

Technical References

Project Acronym	3ENCULT
Project Title	Efficient ENergy for EU Cultural Heritage
Project Coordinator	Alexandra Troi EURAC research, Viale Druso 1, 39100 Bolzano/Italy Alexandra.troi@eurac.edu
Project Duration	1 October 2010 – 31 March 2014 (42 Months)

Deliverable No.	D6.2
Dissemination Level	PU
Work Package	WP 6 “Case studies & Transferability”
Lead beneficiary	P09 “TUD”
Contributing beneficiary(ies)	P10 “COBO”, P01 “EURAC”
Author(s)	Dagmar Exner
Co-author(s)	Francesca Roberti, Alexandra Troi, Elena Lucchi, Tiziano Caprioli, Roberto Lollini
Date	31st March 2014
File Name	WP6_D6.2_20140331_Documentation of case study 1

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0 Documentation of CS1: The Public Weigh House

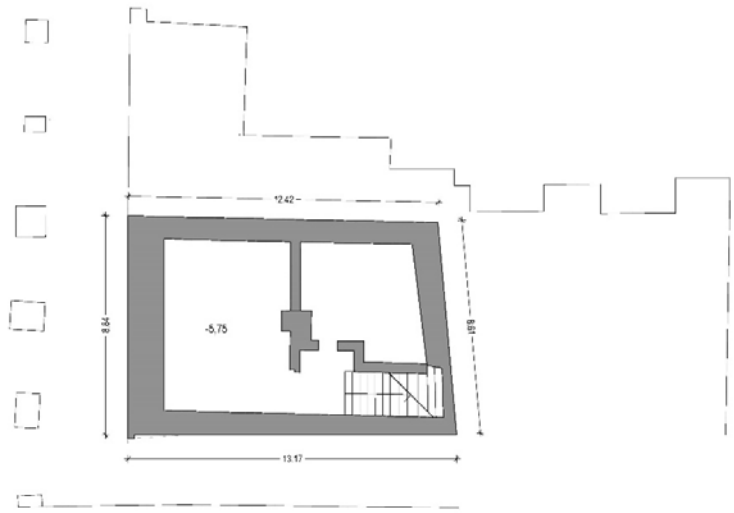
0.1 General Information

Location

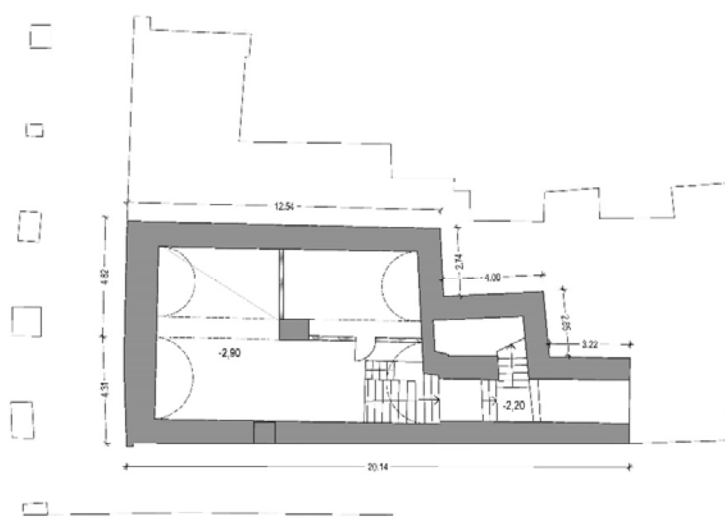
Name and location of building	Public Weigh House, Waaggasse 1, I-39100 Bozen Cadastral number: Bp. 269/1, 269/2 Altitude: 269,72 m (above sea level) Heating days: 183 days Heating degree days: 2791 HDD
Previous/other locality names	Waaghaus Bozen, Casa della Pesa Bolzano
Ownership	Stiftung Südtiroler Sparkasse, Talfergasse 18, I-39100 Bozen
Local legislation	The building is a representative example of the building stock of the middle age in the historic city Centre of Bolzano. It is qualified as building of historical and architectonic interest in the Urban Building Regulation Code and therefore admits only respectful interventions of renovation and maintenance.

Protection status	**Protection status:** Based on the national Italian law, the "Codice dei beni culturali e del paesaggio" (Decreto legislativo 22 gennaio 2004, n.42), buildings are protected by decision of the provincial government. The protection status is registered in the land register. Any change of the appearance of the building has to be approved by the local Authority for Cultural Heritage. **Registration in the index of listed building of South Tyrol:** BLR-LAB 4981 of 25/07/1977 **Category:** Urban residential building
Heritage administration	The subject in charge of the object is the local Authority for Cultural Heritage: Amt für Denkmalpflege, Armando-Diaz-Straße 8, I-39100 Bozen, phone: +39 0471 411900
Responsible Planner/ Architect	For the planned refurbishment project, so far no architect has been assigned.
Local case study team	The LCS-Team of CS1 – the Public Weigh House of Bolzano is consisting of the following partners: · Case study leader: EURACresearch · Building owner: Stiftung Südtiroler Sparkasse (foundation) · Conservator: director of the local state office for historical monuments · Architect/Project planner: to be involved after the selection through competition
Name and company of surveyor	Dagmar Exner, Francesca Roberti, Alexandra Troi, (EURACresearch); Franziska Haas, (University of Dresden)

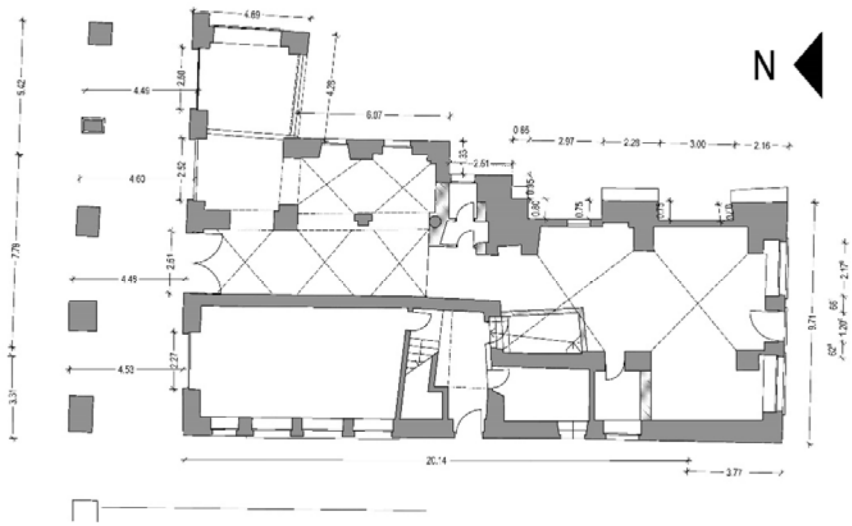
General description incl. building problems



GROUNDPLAN_SECOND BASEMENT



GROUNDPLAN_FIRST BASEMENT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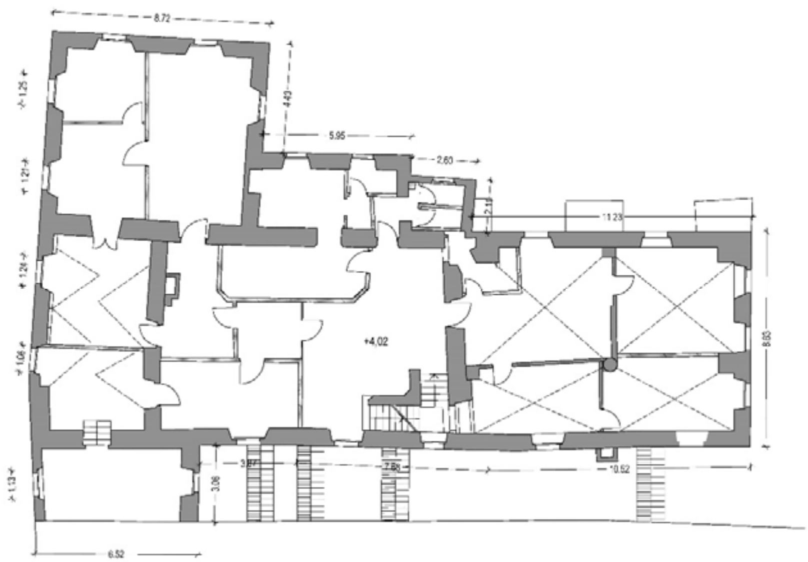
GROUNDPLAN_GROUND FLOOR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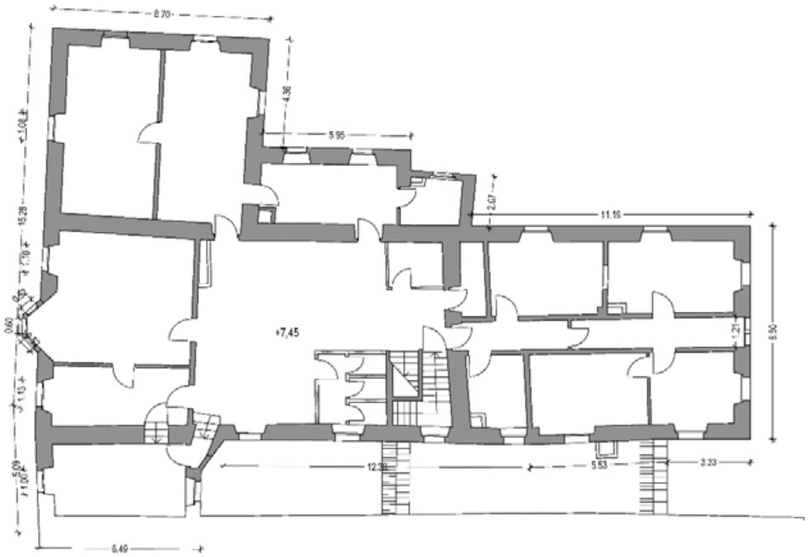
GROUNDPLAN_FIRST FLOOR



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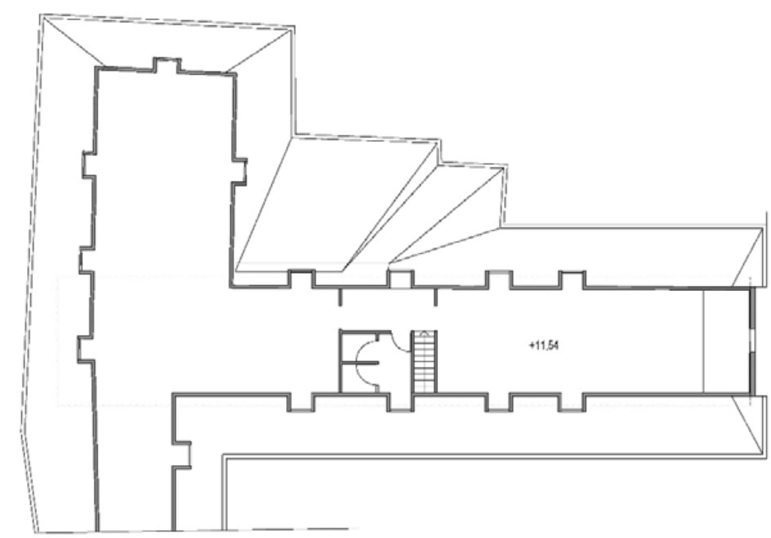
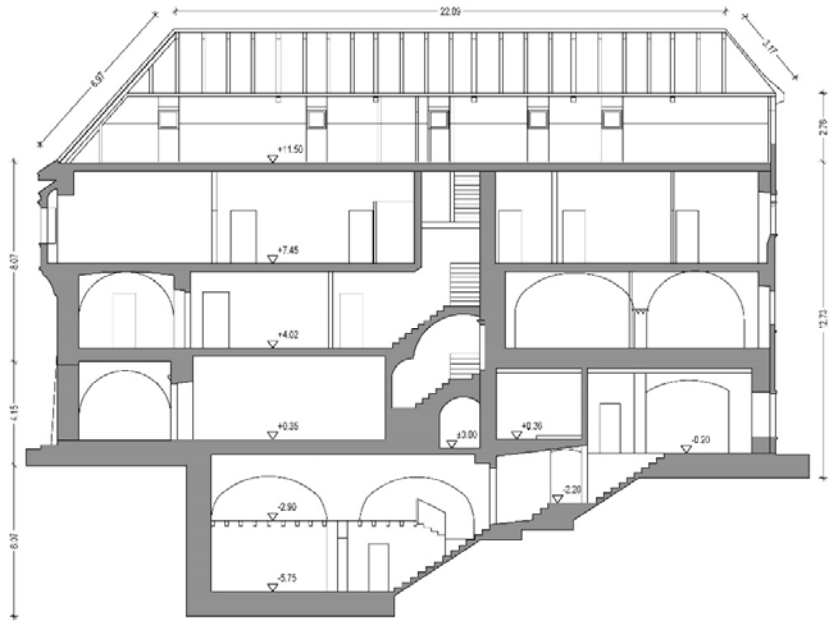
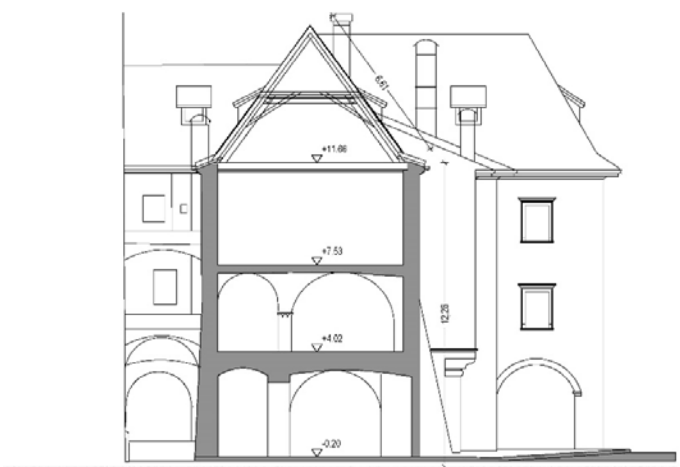


GROUNDPLAN_TOP FLOOR



LONGITUDINAL SECTION



CROSS SECTION

Date of construction	12th century: first phase of construction
Architect/Artist/other persons	The architect of the building and/or its extensions is not known, as well as no artist for the mural paintings inside the building. Fresco of the town scales on the arch above the small connecting street are from Albert Stolz.
Architectural style	Medieval arcade building („Laubenhaus“)
Typology of building	Urban residential building
Original objective	Seat of the Public Weigh House (Waaghaus) up until 1780
present use	Currently the building is completely uninhabited, before it was used for shopping area and bar on ground floor, for storage of goods in the basement floors and for apartments in the upper floors.
expected use in the future	Ground floor remains shops; upper floors for cultural purpose. After complete architectural and energy refurbishment, the building should become “house of photography”.
Construction materials	Construction in natural stone and lime mortar with lime plaster, wooden ceilings and wooden roof construction.
Construction method	Massive construction in natural stone (vaults), wooden roof construction
Short description of building	The Public Weigh House is placed in the historic city Centre of Bolzano. It is part of the “Portici Street”, which was built in the end of the 12th century. It represents a composition of street market with arcade houses and a central grain trade (“piazza del grano” – grain square), typical for that time. The building of the Weigh House, originally in Romanesque style was reconstructed at the end of 16th century. Until 1780 it was the seat of the so-called “Fronwaage”, a public, officially calibrated town scales. The building consists of 3 full storey, a top floor and two basement floors. The main part has the dimensions: 8,95 x 23,98 m. On the east and west side of the building there are subsequent extensions: on the west side a bridge to the neighbour building on the first, second and top floor with the dimensions of: 3,72 x 6,48 m. On the east side the extension has the dimensions 7,20 x 8,72 m. On the north side of the building there is an arcade gangway on the ground floor.
Number of Axes	Two axes
Shape of roof	Hipped roof
Internal access	Access to the areas on ground floor: directly from the square or from the Portici street. For most parts of the ground floor, there is no connection to the upper floors. Access to the upper floors: laterally access from the passageway on the west side

Status quo	At the moment (2014) the building is completely uninhabited. Ground floor was recently used for shops until 2011; at the moment only some windows on ground floor are used for show cases and one corner on ground floor is used for shop. The upper storeys, before used for apartments, are not inhabited since about 10/15 years. Condition of building: Not renovated. Refurbishment planning: The building owner plans to renovate the building during the next years. In summer/autumn 2012 an ideas competition was carried out to define the future utilization concept of the Weighhouse as a “House of Photography" – selection of winner project on the 22nd November 2012. The winner project foresees the following room functions: o Ground floor: Reception, shop, café o Basement: digital gallery for citizens, old photographic studio o First floor: temporary exhibition o Second floor: atelier of city photographer, apartment caretaker, permanent exhibition “Tyrol yesterday and today” o Top floor: Auditorium, bibliotheca, administration · Still it is not clear, if the winner will design and realize the refurbishment project
Overall conservation status	Not renovated. Upper floors not inhabited since about 15 years. The building is in a correlative condition considering that it is not in use for so many years: • Partially problems with humidity and mould growth • flaking of paint layers • partially damaged, not well-closing, leaking windows • outdated electrical and heating system • pollution of façades, windows and window sill through pigeon droppings.
Actual European energy standard	No available standards for historical buildings.
building problems with regards humidity	High relative humidity in basement floors (mould grow risk), mould grow risk on weak parts of the envelope like window reveals. Traces of mould grow at e.g. the inner surfaces of the bay and on the inner side of the southern wall of the “bridge”. Humidity in inner walls of the top floor and ceiling of the 2nd floor/top floor due to probably a pipe burst.
building problems with regards salts	Probably salts in wall of the entrance area (-> not verified and analysed)

Planned activities within the project	
Diagnosis	• Precise measurement of stratigraphy of construction elements of the thermal envelope - drawing of detail sections with correct dimensions

	• Thermography: first (02/2011) with unheated building and second (02/2012) with in parts heated building, combined with Blower Door measurement
	• Evaluation of Blower Door Test: measurement without and with top floor (over- and underpressure)
	• Measurement of heat transmission of construction elements of the thermal envelope
	• Determination of a “test room” on the first floor of the building for the installation and testing of prototypes and solutions:
	  • Opening of four wooden ceiling beam ends in the “test room”: 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
	  • Analysis of material sample (core drill hole: diameter 5 cm/length 30 cm) from exterior wall of “test room” by Remmers: water absorption coefficient, porosity, density -> material sample send to TUD for further analysis for the Delphin database
	  • Analysis of material parameters (from further material samples from wooden beams and filling between wooden beams) through TUD for the Delphin database
	• Radiation measurements:
	  • Shadow diagram for the east and south façade of the Weigh House
	  • Radiation on the east and south façade at the ground level: Global horizontal irradiance [W/m2], Direct normal irradiance [W/m2], Diffuse horizontal irradiance [W/m2], Global tilted irradiance [W/m2], time step: 15 min, data from the satellite (provided by the company Geomodel)
	  • Radiation on the central position of the building, ground level: Global horizontal irradiance [W/m2], Direct normal irradiance [W/m2], Diffuse horizontal irradiance [W/m2], Global tilted irradiance [W/m2], time step: 15 min, data from the satellite (provided by the company Geomodel)
	• Specialists for buildings history are analyzing the whole building structure -> more knowledge on heritage value of single construction elements
	• Documentation of the building in the DIS database

Planned solutions	• Proposal of passive solutions
	  • Insulation of roof
	  • Insulation of baseplate

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Insulation of ceiling “Portici”
Higher airtightness
Substitution of a major per of the windows
Controlled ventilation with heat recovery
Solar collector under roof tiles (in comb. with heat pump)

Semester project of students of LAB (Lighting Academy Bartenbach):

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

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<tr><td>Development/Implementation of products</td><td>

Internal insulation: Installation of IQ-Therm 8 cm in one “test room” (1st floor)

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

Window prototype: Development of first energy efficient window prototype (coupled window):

Development of a window prototype based on the individual demands of the case study: adaption of the “passive house” window to the special conditions of the historic building.
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

Development of second energy efficient window prototype (coupled window)

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	• Bring forward and improve existing window prototype (coupled window) to a applicable state • Installation of window prototype in summer to show it during the EWCHP in September in Bolzano • Development of an energy efficient prototype for a typical box-type window for historic buildings of Bolzano from the turn of the century
Monitoring system	• Installation of monitoring system: • Indoor climate of all rooms (temperature and relative humidity) • Surface temperatures on constructional critical points of the thermal envelope, as external corner, window, window reveal • Air streams • Outdoor climate (temperature and relative humidity) • Historical surfaces: near field climate, surface temperatures • Measures for a more realistic situation in the uninhabited building • Temporary installation of electric heaters in 8 rooms of the building (01/2012) • Opening of window shutters • Possible installation of mobile humidifier in the "test room" (planned) • Aims: Acquisition of energy demand, realistic situation for measurements like: thermography, monitoring of the before and after situation (e. g. in the "test room") -> comparison of energy consumption and comfort conditions • Detailed monitoring of one existing window and the new prototype window (both part of the same east oriented façade and on first floor) in terms of: • Surface temperature: interior surface wall near window, window reveal, interior surface inner glass layer, interior surface outer glass layer, exterior surface wall (vis-à-vis the interior surface temperature), interior surface breast • Relative humidity: window reveal, between window layers • Air flow in the center of the two window sashes
Simulation	• PHPP calculation of as-is-state and calculation with proposed passive solutions • "Test room": Simulation of joint/installation details (with and without internal insulation) in DELPHIN at some significant points: Floor (beam ends), Ceiling (beam ends), comparison and evaluation of 2 thicknesses of

	the insulation (5 and 8 cm with as-is-state), connection window/internal insulation, endpoint internal insulation at parapet height (room 2nd floor).
	• Simulation of energy consumptions and comfort conditions in Energyplus, comparison between the models in Eplus and PHPP results
	• "Test room – south-west façade": 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
	  • Optimization strategy: Building envelope and night summer ventilation optimization, minimizing energy consumption and discomfort, solution sets for building envelope and ventilation system
	• Simulation of different ventilation strategies, as well as simulation of a hybrid ventilation system which exploits the temperature of the cellar for cooling

Transfer to urban scale concept	The experiences gained in the attendance of the case study, the proposed refurbishment concept and the technological solutions were tested regarding their transferability to other buildings. This evaluation of transferability of solutions was evolved on two scales: - **On Urban scale**, investigating the energy potential and defining the possible energy refurbishment interventions for a wide spread medieval building type in the historic city center of Bolzano (Italy), the "Portici". - **On Building scale**, supporting the implementation planning phase of the enhancement of energy efficiency of a historic Villa from the middle of the 19th century, near Lake Como (Italy) The transferability study is reported in detail within the deliverable "6.4 Transferability study"
Others	• Conclusion of documentation of the building in the „Raumbuch" database

0.2 Building Assessment

Cultural Value (Specific valuable aspects)	
Architectural historical value	The building is a representative example of the architecture of the middle age building stock in the historic city centre of Bolzano. Typical local mediaeval massive construction method in natural stones (vaults in the cellars, on ground floor and on first floor) covered with lime plaster. The façade shows the construction history of the building and allows the beholder to perceive the evolvement of the building all over the years: on the south side, the façade has a baroque appearance, while on the east side we see the Romanesque masonry. "Gable-fronted construction with hipped roof. On the east side exposed brickwork, rectangular windows with stone framework. Towards the square, double arched windows with mural painting from the 16th century, which represent the armorial bearings of Austria, South Tyrol and the city of Bolzano. Painted pilasters at the corners. Stone-framed "Rechtecktur" with arms cartouche, crucifixion fresco, early 16th century. On the west side passage with sustaining arches. Mural painting with town scales from Albert Stolz." (Source: Local Authority for Cultural Heritage Bolzano; http://www.provinz.bz.it/denkmalpflege/themen/1071.asp?status=detail&id=13851)
Cultural historic value	From its beginning until 1780 the building was seat of the so-called "Fronwaage", the public, officially calibrated town scales. Like the buildings of the "Portici" street, the building has had the traditional distribution of room functions: Every building consists of ground floor and usually three upper full storeys, characteristically up to three basement floors and an originally non-inhabited top floor. The ground floor was and is used for shop area. The cellars served to store the goods. On the upper floors there was living space: more representative and larger rooms towards the "Portici Street" and rooms with less importance in the central and back part of the building. From the original core of the building we can see e.g. in the cellars and on the east façade of the building the typical execution of Romanesque brickwork with its typical execution of mortar joints for that time. The Spanish tiles ("Mönch und Nonne") of the saddle roof are historic tiles. They are handcraft manufactured in a unique way. The roof scape of the whole historic city center has a homogeneous appearance.
Context value	The building of Romanesque origins and the adjacent grain square formed the oldest part of the episcopal town. Here once stood the castle of the prince bishops of Trento, which were destroyed by Mainhard II of Tyrol, and the church of St. Andrew (Hl. Andreas), which was partially demolished in 1785.

	The building is furthermore surrounded by the "Portici", which were built as well in the end of the 12th century. As typical for this medieval building type, the "Portici" houses are lined up continuously along the road axis, with narrow facades to the street. This original urban system with its constant structure is still perfectly recognizable today and represents a for mediaeval times typical composition of street market with continuous arcades throughout the street front and a central square, where earlier the grain trade was held ("piazza del grano" – grain square). Still today, the "Portici" street is the most important shopping promenade of the city centre of Bolzano.
Social value	Through its appearance, its history and its central position in the historic city centre, the building has a strong symbolic value and is a major resource of identification for the citizens and an important touristic attraction.
Constraints conditions/ limits and prescriptions arising from Area Regulations	Based on the national Italian law, the "Codice dei beni culturali e del paesaggio" (Decreto legislativo 22 gennaio 2004, n.42), the building is protected by decision of the provincial government. The appearance of the building should not be changed. Any change of the appearance of the building has to be approved by the State Office for Preservation. The law does generally not give precise indications about the type of renovation admitted for buildings of historical and architectural interest. Every planned intervention has to be valuated for the individual case. Reversible solutions instead on irreversible solutions are preferable.
Limits and prescription determined by the owner	The planned use of the building as "House of Photography" requires a new access concept (including possibly a second staircase and an elevator). The winner project of the idea competition foresees furthermore in some parts larger rooms, a central stair from 2nd to top floor and the complete use of top floor and the two basement floors. The new use determines a controlled temperature and relative humidity (possibly new ventilation strategies).
Preservation concept	The main concept is to preserve the original integrity of every architectonic, artistic and decorative element of the building. "The building has evolved over the ages to what it is now. The layers of paint, the appearance of the historic plaster, the uneven surfaces and edges allows us to perceive the history of the building, they make the biography of the house readable. From conservators point of view the inner surfaces of a building are like the skin of a human being. They have to be preserved for historic and handcraft reasons. Wall paintings in connection with historic plaster are the most valuable surfaces. In case of the Public Weigh House, we have traces of wall paintings from baroque era and from the early modern times and frescos in the bay room. The majority of the mural paintings is covered by paint layers and only partially visible. In these cases, the conservator would have to decide and analyse room by room, fresco by fresco whether an exposure is feasible and useful from preservation point of view. The

	vaulted ceilings, as well as the historic inner plasters are of historic value and therefore worth for preservation." (Source: Director of the Local Authority for Cultural Heritage Bolzano)

Documentation	
diagrams/drawings	• Weigh House_cadastral map excerpt.jpg • WP6_CS1_20110201_P01_WeighHouseBalanceBoundary • WP6_CS1_20110215_P01_WeighHouseTreatedFloorArea • WP6_CS1_20110215_Project plans_as-is-state • WP6_CS1_20120320_Project plans with construction phases • WP6_CS1_20120320_Project plans_areas for PHPP • WP6_CS1_20121110_Detail sections_test room • WP6_CS1_20130316_Detail sections_thermal envelope
expertises/reports/deliverables	• RicercaStratigrafica-FacciateExterne.pdf • RicercaStratigrafica-FacciateInterne.pdf • 2011-12-22_WP6_Interventions Waaghaus.docx • 20130515_Weigh House_Portici_traditional passive strategies.pdf • Studienarbeit zum Waaghaus der TUD.pdf • WP2_task2.5_20110907_P03_IR-Waaghaus-first2011 • WP2_task2.5_20120505_P03_IR-Waaghaus-second2012second2012 • WP5_D5.2_21040106_ANDRE_New_heritage-compatible_window • WP6_D6.1_20110927_P09_Implemention plan and monitoring scheme • WP6_D6.4_20140228_P01_transferability study • WP7_D7.5_20140228_P04_Evaluation of the monitoring and PHPP data • WP7_D7.6_20140225_P03_ConservationCompatibility
files/correspondence	• Minutes of "Workshop on windows", 26th August 2011: WP6_20110830_P01_Workshop windows meeting minutes • Feedback of the conservator regarding the first window prototype 28th February 2012 (in German):

	WP6_20120228_P01_Feedback conservator first window prototype • Minutes of "Workshop on windows", 09th April 2013 (in German): WP6_20130412_P01_Workshop windows meeting minutes • Feedback of the conservator regarding the drawings of the second window prototype 13th June 2013 (in German): WP6_20130613_P01_Feedback conservator drawings second window prototype
photographs/images	• Q:\6_Projects\201010_EU_FP7_3ENCULT\6_Internal_Data_Calculations\WP6\CS1 Waaghaus\04_Fotos
publications/press	• Public Weigh House, Bozen/Bolzano (Italy) - 3encult case study http://www.youtube.com/watch?v=dXnClA5eLv0 • Restore history teaser - 3encult case studies #1 & #3 http://www.youtube.com/watch?v=GT0O1-315aE • TV and radio transmissions with regard to conservation compatible energy retrofit of historic buildings in occasion of the EWCHP 2013: Interviews with D. Exner and A. Troi, as well as EURAC's President W. Stuflesser and video scenes taken at the Waaghaus: "Energieeffizent restaurieren im Waaghaus" http://www.sdf.bz.it/Mediathek/%28video%29/15779 • A. Troi, R. Lollini, D. Exner, "Application of a holistic approach for realising energy efficiency in historic buildings respecting his heritage value", AR&PA Biennial of Heritage Restoration and Management, Valladolid, May 2012 • A. Troi, R. Lollini, D. Exner, Poster "Case Study 1: Public Weigh House Bolzano, Italy", AR&PA Biennial of Heritage Restoration and Management, Valladolid, May 2012 • P. Baldracchi, "Conservazione ed efficienza energetica negli edifici storici. Un caso studio del progetto 3EnCult", Convegno: Conservazione e riqualificazione energetica degli edifici storici, Energy Days 2012, Bologna, May 2012 • Freundorfer, F.: „Passivhausfenster der Energieeffizienzklasse A in denkmalgeschützten Gebäuden. Passt das zusammen?", International Passive House Conference, Hannover, April 2012 • EWCHP, the 3rd European Workshop on Cultural Heritage Preservation, Bolzano, September 2013: o short overview of CS1 (Public Weigh House) in the plenum before discussion in front of the posters ("3encult Case Study 1: test room", "3encult Case Study 2: Simulation of "passive" energy retrofitting solutions"

	- Training Workshop: Comprehensive diagnosis and multidisciplinary approach for conservation compatible energy retrofit (3ENCULT). Chaired by Francesca Roberti, Dagmar Exner and Tiziano Caprioli - Training Workshop: Energy efficiency of windows in historic context (3ENCULT) Chaired by Dagmar Exner and Franz Freundorfer - Study tour Waaghaus • D. Exner, R. Lollini, F. Roberti, A. Troi, “Sviluppo di un approccio metodologico per la riqualificazione degli edifici storici: la Casa della Pesa di Bolzano, caso studio all’interno del progetto EU FP7 3encult”, contribution to the book case studies of energy retrofitting of historic building, editor Politecnico of Milan • D. Exner, E. Lucchi: “Learning from the past: the recovery and the optimization of the original energy behaviour of “Portici” Houses in Bolzano”, AICARR, 49th International Conference, Rome, February 2014 • F. Roberti, D. Exner, U. F. Oberegger, A. Gasparella: “Energy diagnosis of a historic building and building simulation”, AICARR, 49th International Conference, Rome, February 2014 • D. Exner, E. Lucchi, A. Troi, F. Freundorfer, M. André, W. Kolfer Engl: “ Energy efficiency of windows in historic buildings”, 18th International Passive House Conference, Aachen, April 2014 • Press release regarding the agreement between municipality and building owner (definition of future cultural use), 31st July 2009: http://www.gemeinde.bozen.it/stampa_context.jsp?area=19&ID_LINK=426&page=4198 • Interview with the architect of the winner project of the ideas competition to define the future utilization concept of the Weigh House as a “House of Photography" (Arch. Wolfgang Piller), 19th December 2012: http://franzmagazine.com/2012/12/19/ein-haus-der-fotografie-fur-bozen-und-sudtirol/ • Minutes of the on-site inspection for the ideas competition, Bolzano, 31st July 2012: http://www.athena-x.it/FILES/SPK/11/10011567_PROTOKOLLKOLLOQUIUM.PDF

0.3 Detailed description

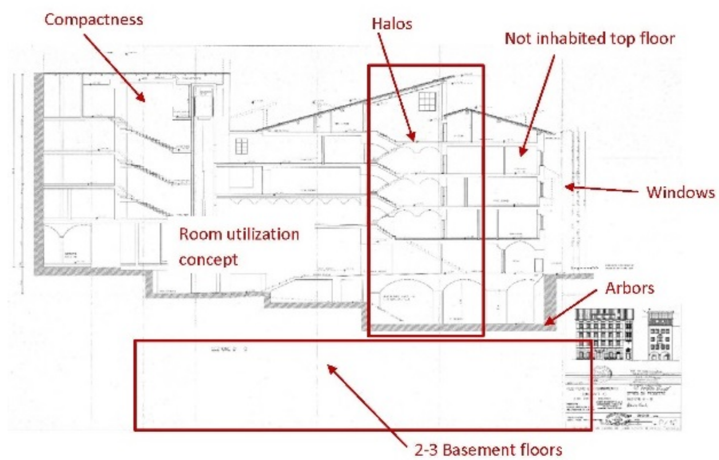
0.3.1 Urban Context and Local climate data

Urban Context	
	Cadastral map excerpt/site plan 
	
Relation with neighbouring buildings	The Public Weigh House is part of the “Portici” of Bolzano, but it is separated from the continuous structure of arcade houses on both long sides through a narrow alley. East and south façade look toward a little square, while the north façade is directed to the tight historic shopping street. The west façade faces the passage between Weigh House and the neighbour building (casa Zimmermann), with which the building is connected on first and second floor through a “bridge”.

Quarter/town/surrounding	The building of Romanesque origins is placed in the historic city centre of Bolzano. It is part of the "Portici di Bolzano", which were built at the end of the 12th century and once formed the nucleus of the town. The oldest settlement consists of a road axis along which the constructions of the "Portici" houses are built on both sides, on narrow and long properties, arranged rectangular to the street. The widespread medieval building type is a house with narrow facades to the street, lined up continuously along the road axis. A characterizing aspect of the "Portici" of Bolzano is the continuous arcade/walkway throughout the street front. It is noteworthy, moreover, the intensive use of land, which led to a complete use of the property for the construction, not only in width but also in depth - the typical arcade house is four steps wide (not quite 4 meters), 50 meters deep and structured by atriums into a front, middle and rear house. Through this situation and the serial repetition of this type of building a constant structure has been formed, that is interrupted by a system of atriums for the supply of air and light to the interior spaces. This original, urban system is still perfectly recognizable today. Every building consists of ground floor and usually three upper full storeys, up to three basement floors and an originally non-inhabited top floor. The ground floor was and is used as shopping area. The cellar served to store the goods, while on the upper floors the living space was situated.
location/orientation/ accessibility	The building lies in the zone with "limited access". That means that site vehicles can access the building only with permission in restricted periods of the day. Between 10.30 and 13.30 a. m. as well as between 4.00 and 7.00 p. m. no access is allowed. Because of the tight access roads only vehicles with limited dimension are able to pass.
Development plans	In 1990 a recovery plan for the old town has been elaborated, in order to regain the, in part, sub-standard dwellings as living space for the citizens: - definition of "ensembles to be conserved" - 87 ensembles were defined - The building is a representative example of the building stock of the middle age in the historic city Centre of Bolzano
Certificates/reports/regulations on energy efficiency	At a national level, there is not direct mandatory cooperation between the energy management and the heritage management. The local superintendence for cultural heritage has to evaluate each intervention on historic listed buildings. Only after the approval of the local superintendence is possible to do a retrofit action. Listed buildings are not subjected to any energy standards (DPR 59/09 art1). However, some regional legislations are trying to improve this cooperation trough mandatory energy certification for retrofit interventions on existing and historic buildings. In the region Alto-Adige/Südtirol, the KlimaHaus agency developed the certification KlimaHaus R. This certification

	defines the minimum energy standards to achieve after the retrofit starting from the existing building.
Historical context (see also D6.4)	The building of Romanesque and the adjacent grain square formed the oldest part of the episcopal town. Here once stood the castle of the prince bishops of Trento, which were destroyed by Mainhard II of Tyrol, and the church of St. Andrew (Hl. Andreas), which was partially demolished in 1785. The building is furthermore surrounded by the "Portici", which were built as well in the end of the 12th century. The masonry of the "Portici" houses – at least in the lower parts – is often from the founding period, the 12th and 13th century. This area with the tight parcels was very probably surrounded by this first city wall. As an indication rests of the city wall at a late medieval extension can be determined on the backside of the northern houses. The original Romanesque arcade houses in Bolzano (12th century) consisted at most of one floor and an upstream stone vault (in front of). The ground floor had to be built in stone, the first floor could be built also in timber framework. After several large fires however also this had to be vaulted. The structural shape of the houses of today, especially in the arcades, goes generally back to the late 16th century or the first half of the 17th century. During this time there was generally an intense construction activity. However, several buildings were destroyed by bombing during the 2nd world war. That is why in some places there are reconstructed houses in the sense of the original appearance. The "Via dei Portici" passes 300 m from east to west. Since the founding of Bolzano in the 13th century, the city walls were added around the center and thus formed the nucleus of the town. The oldest settlement consists of this road axis along which the constructions of the Portici are built on both sides, on narrow and long properties, arranged rectangular to the street. The widespread medieval building type, which is also present here, is a house with narrow facades to the street, lined up continuously along the road axis. A characterizing aspect of the "Portici" of Bolzano is the continuous arcade along the street front. It is noteworthy, moreover, the intensive use of land, which led to a complete use of the property for the construction, not only in width but also in depth (see excerpt from the cadastral map below). Through this situation and the serial repetition of this type of building has been formed a constant structure, that is interrupted by a system of patios for the supply of air and light to the interior spaces. This original, urban system is still perfectly recognizable today. In the arcades the limited space forced to very narrow facades, which are often only three, sometimes only two windows wide, but extend in depth and include regularly two, sometimes even three halos. The typical arcade house is four steps wide (not quite 4 meters), 50 meters deep and structured by halos into a front, middle and rear house. The houses are constructed close together, gaps of about 30 cm were used for the static of the Romanesque stone wall. To pass from the Portici street to the back side of the buildings in the parallel street (Via Dr. Streiter)

	the line of houses throughout its whole length is 3-4 times interrupted by a passage, sometimes only on the level of the ground floor (see picture below). Lying rectangular to the street, which passes from east to west, the buildings are north-south oriented, thus every building has a north and south façade. The eaves side of the saddle roof is oriented towards the street. Every building consists of ground floor and usually three upper full storeys, up to 3 basement floor and an originally non-inhabited top floor. The ground floor was and is used for shop area. The cellar served to store the goods. On the upper floors there was living space: more representative and larger rooms towards the Portici Street and rooms with less importance in the central and back part of the building (see also use pattern). Like in case of the Public Weigh House all full storeys of the “Portici” houses and the cellar are built in masonry of natural stones and lime mortar. Exterior walls have a thickness of about 60 to 80 cm. All walls (except on basement level) are plastered with lime plaster. Ceilings of the upper floors are built in wooden beams with wooden casing and filling material in between. The underside of the ceiling is plastered with lime plaster. The floor construction consists of a wooden substructure and wooden boards. Especially on ground floor and basement floor the ceilings are vaulted. The construction of the saddle roof is made in timber rafters with wooden casing and roof tiles (monk and nun) on it. The original window used in the Portici is mainly a wooden box-type window from the late baroque era. It consists of two window layers, each with two single-glazed window sashes and a skylight. This type of window however has been replaced in many cases by a window with double glazing. For shading and darkening usually a wooden window shutter is used.
  	
Key figures as e.g. % of historic buildings, renovation rate	- More than 20% of the buildings in Bolzano were built before 1919, a total of 37% before the last war - Heating of these buildings: more than 40 kt CO_2 (0.4 t CO2 per person and year)

	- As member of the Climate Alliance, the city of Bolzano is engaged in reducing its CO_2 emissions of 8.5 t/person. -> The energetic refurbishment of the building stock is the most important measure to reach "climate neutrality" of the town.
Necessary data for PHPP calculation available: Monthly mean averages of temperatures and solar radiation?	Yes, from the PHPP database (S-Europe, [IT] – Trentino-Bolzano)
Particular architectural solutions according to the local climate	
	In the following particular architectural solutions according to the locale climate with regards the "Portici" buildings are reported. Some of this architectural characteristics count also for the Public Weigh House: **Proportions "Portici" buildings – S/V ratio** The surface-to-volume ratio has a decisive influence on the heating demand of a building. This ratio is disproportionately low in these arcade houses, build tight together in one row. Assuming an arcade house with a width of 4 m, a depth of 50 m and a height of 4 full storeys the S/V factor results in about 0,11 m^2/m^3 (without considering the halos). A lower S/V ratio means a smaller heat-transferring surface for the same volume of the building. To compensate transmission heat losses through the thermal envelope less energy per m^3 is therefore necessary. Large multifamily houses have a smaller S/V ratio than freestanding single-family houses, for example. In comparison with typical values for single-family houses with a S/V ration of 0,8 to 1,0 m^2/m^3 or large compact buildings as multi-family houses with values up to 0,2 m^2/m^3 the arcade houses are real compact buildings. Therefore, transmission heat losses are comparatively low in this kind of buildings.

Example of typical proportions: Old Town Hall, Via Portici no. 30

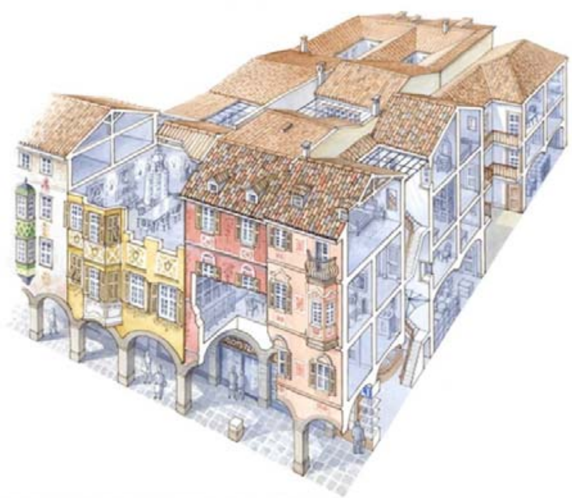
Atriums

As mentioned above the depth of nearly every arcade house is interrupted by two or three patios. In these atriums the staircases and open passageways are situated. Above the basement of the front building lies the vault store that originally always occupied the whole width of the house and where in most cases only later a narrow hallway with its own door was separated.

The patios have two functions: on one hand they provide the spaces lying inside the building with daylight on the other hand they ensure the removal of hot air from the inside of the building during the summer months and supply the internal rooms with fresh air.

The stairwells or atriums are vaulted on roof height to protect the inside of the courtyard from direct rain. Usually however the vault is open to the side of the wind incidence (south direction), to ensure some cooling at high summer temperatures.


Left: view of the openings of halos: all openings are oriented in the direction of south. Right: patio of the house Via Portici no. 39 (Haus der Südtiroler Werkstätten)

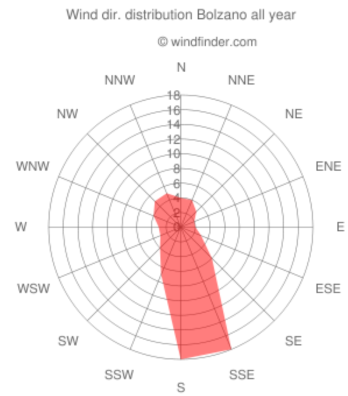
	Cellars Towards the street the arcade houses have up to three basement storeys, on the backside of the building there is just one. The basement storeys are like an extension of the shop on ground floor level. They were used as magazine to store goods. The cellar walls are built in masonry of natural stone and lime mortar – not plastered. The foundations are founded directly on the soil. The basement floor consists of tamped earth. Because of its contact to the surrounding soil and its depth of 6 meters and more the internal climate of the cellar stores is quite independent from the external climate (see also monitoring results).
	  Cellar of Mercantile building, Via Portici no. 39
	 **Room organization/Use pattern upper floors** In the (usually three) upper floors of the main house (towards the Via Portici) there are "better" dwellings and more important rooms, against the atrium, next to the vaulted and round-arched open courtyard, the kitchen and secondary rooms, against the alley (backside of the building) the rooms. The middle and the rear house include below cellar and magazines, above more simple and in the center section mostly quite dark dwellings [11]. The distribution of room functions shows that they are positioned according to its occupancy and frequency of use: rooms with less need of daylight and rooms with less frequency of use, for

	example bathrooms or kitchens are located in the inner part of the building, around the patios. Rooms of more importance and higher occupancy like living rooms or dining rooms are located towards the Portici street. Originally the top floor was not used. The not-inhabited space originally worked like a thermal buffer.
	Windows: In some rare cases there is still the original type of window of the late baroque period installed, which later (up to 1940) was also used for typical farmhouses in the alpine space. The bay of the building on the left side demonstrates the usual function of this kind of box-type window: in wintertime you can fit a second glazed window on the outer side, while in summertime it can be replaced by a window shutter. On the right photo we can see the north façade of a Portici building, from the late baroque period. Since it is the north side the outer windows were not changed in the summer period. The type on the right side is typical for the region around Vienna. It is called the “Wiener Kastenfenster” (Vienna box-type window). A characteristic of this window is that the outer layer is flush with the surface of the outside walls and the window sashes open to the outside. In former times in wintertime the space between the two windows was used like a vitrine and decorated with moss (maybe also to improve airtightness) or figures in wood etc.
	  Characteristic box-type window from the late baroque period
	Arcades: The type of “Portici” of Bolzano form covered sidewalks, which on ground floor level have the purpose to allow the way from house to house, protected from weather and also in times of war. Together with the basement they form an extension of the premises for purchase and sale. This type of arcade building was here in Bolzano but also in other cities and in the village mostly used by traders and craftsmen. On one hand, these corridors serve for easy transportation of goods and provide a well-protected space for sale booths, for example for food. On the other hand, also in case of bad weather different handicraft products could be processed, dried and exhibited. In addition, customers could easily walk from store to store and negotiate and buy undisturbed. This kind of use is preserved until today, in most cases, the shops under the arcades have the same

	function as in the time of their construction – complemented by numerous cafés and restaurants that offer a comfortable stay.
Overshadowing	As described above, the building lies in the historic city center of Bolzano and therefore in a high-density area. All facades, above all the north and west façade, but also in parts the east and south façade are overshadowed by the surrounding buildings. As they have a similar height, their overshadowing effect on the roof is not that high. The roof overshadowing is more effected by the mountains surrounding the city of Bolzano (see map). (See also shadow diagram of east and south façade of the building.)  Source map: https://www.google.it/maps/@46.4927821,11.2829372,11z/data=!5m1!1e4?hl=it
Description of nearby areas for organizing the on-site retrofit works	The building lies in the zone with “limited access”. That means that site vehicles can access the building only with permission in restricted periods of the day. Between 10.30 and 13.30 a. m. as well as between 4.00 and 7.00 p. m. no access is allowed. Only between 6.00 and 9.30 a. m. vehicles can access the building without any permission. Because of the tight access roads, only vehicles with limited dimension are able to pass.
Use of building/building part during the retrofit works?	In case of retrofit work, the building will not be ins use.

Local climate date	
Climate description	The region South Tyrol is located in the north of Italy in the eastern Alps, south of the main chain. The climate is mild and dry. Bolzano, the state capital, lies at an altitude of about 250 m a.s.l. The average air temperature is 12,3°C. Due to its location in the basin of a deep valley the city is affected also by high temperatures and heat waves during the summer months. The surrounding mountain ranges with a significant height prevent South Tyrol from balancing currents from the north and moisture from the south. This results in a distinctive continental climate with relatively strong seasonal fluctuations, but also daily fluctuations in temperature, which are clearly visible, especially

	in summer. Bolzano records for example during summer a daily mean temperature fluctuation of about 12°C, while in winter it is more moderate with 8°C. Bolzano stands out significantly also from the Italy wide temperature statistics: in the summer the state capital is often the hottest city in the entire national territory, in winter it is often the coldest provincial capital of Italy. The average daily maximum temperature in summer is 27-29°C; the average overnight lowest values in winter month are -1 to -5°C. In Bolzano the number of tropical nights, were the minimum temperature remains above 20°C, has increased significantly over the last 20 years. Until 1995, Bolzano had only from 0 to 5 tropical nights per years, for 2010 the measurements showed 20 tropical nights.  Source picture: http://www.montagna.tv/cms/?p=9806
Climate zone	E
Climate area	Temperate continental climate/humid continental climate
Degree days	2791 (HDD)
Coordinates:	Lat 46°50´´0´ - Long 11°35´´5´
Altitude	269,72 m (above sea level)
Average wind speed	1.6 - 3.3 m/s

Prevailing wind direction	 Source: www.windfinder.com

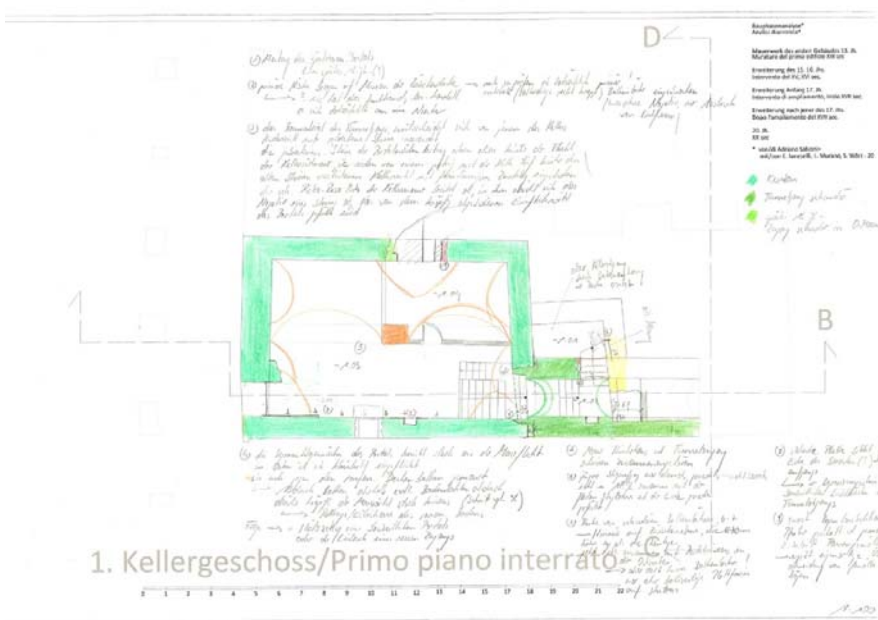
Building plan showing the north

Winter climate data		Summer climate data	
Winter design temperature	-15° C	Temperature: dry/wet bulb	Dry bulb: 21°C (average of July, the hottest month) 35° (max. hourly dry bulb July)
HR max (Nov.-Dec.)	100% (EnergyPlus weather data)	HR	100% (max.) Average HR: 15/04-15/10: 71,41% Media HR: 15/10 – 15/04: 71,30%

<table>
<tr><td>Heating day per year</td><td>212 days</td><td>Daily temperature range</td><td>July: 16°-27°
June 14°-24°
August 15°-26°
September 12°-24°</td></tr>
<tr><td colspan="2">Available data for the project</td><td colspan="2">Meteonorm, monitored data</td></tr>
<tr><td colspan="2">Reference statistic data from “common database” (e.g. Meteonorm)</td><td colspan="2">Reference data – static system
PHPP
Reference data – dynamic system
EnergyPlus database (Source dati EnegyPlus: Italian climatic data collection "Gianni De Giorgio" (IGDG))</td></tr>
<tr><td colspan="2">Data measured from local weather station</td><td colspan="2">yes</td></tr>
<tr><td colspan="2">Measured climate data</td><td colspan="2">On-site measurement of temperature and relative humidity: sensors fixed on the underside of the eaves of the dormers (on north and on south side).</td></tr>
</table>

0.3.2 Report on history of the building

History of the building	
Use of building over time	Until 1780 the building was seat of the so-called "Fronwaage, a public, officially calibrated town scales. This town scales is depicted on a fresco on the arch above the small connecting street between "Portici" street and "piazza del grano" (grain square). The following history of the use of the building has not sufficiently analyzed so far. It can be assumed with high probability that even after completion of the work of the "town scales" the rooms were used for commercial purposes. In the first half of the 20th century, the building was converted into a dwelling house and only the ground floor was further used for business. Especially after the 2nd world war the interior rooms have been given new dimensions, there have been installed some partitions to create more dwelling units. Since the 90th of the last century, the house was uninhabited and vacant. In 2009 it was sold by the city of Bolzano to the Foundation Cassa di Risparmio. The purchase agreement states that the property from the 1st to the 3rd floor and in the second basement floor must be used for cultural purposes for 20 years.

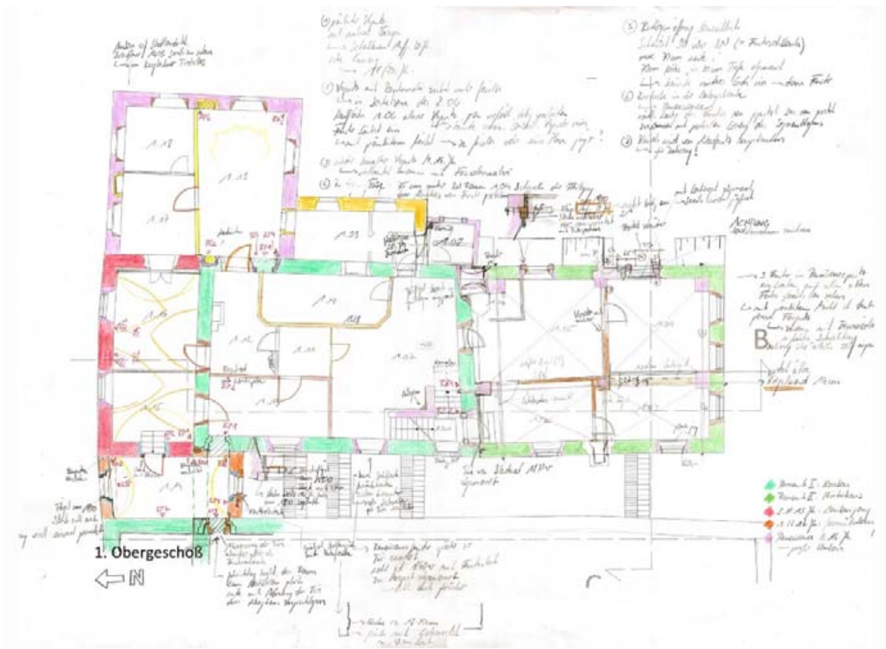


Ground plan with construction phases: first basement:

Blue-green: core building

Middle-green: subway, tunnel

Bright-green: late 13th century: access secondary



Ground plan with construction phases: first floor:

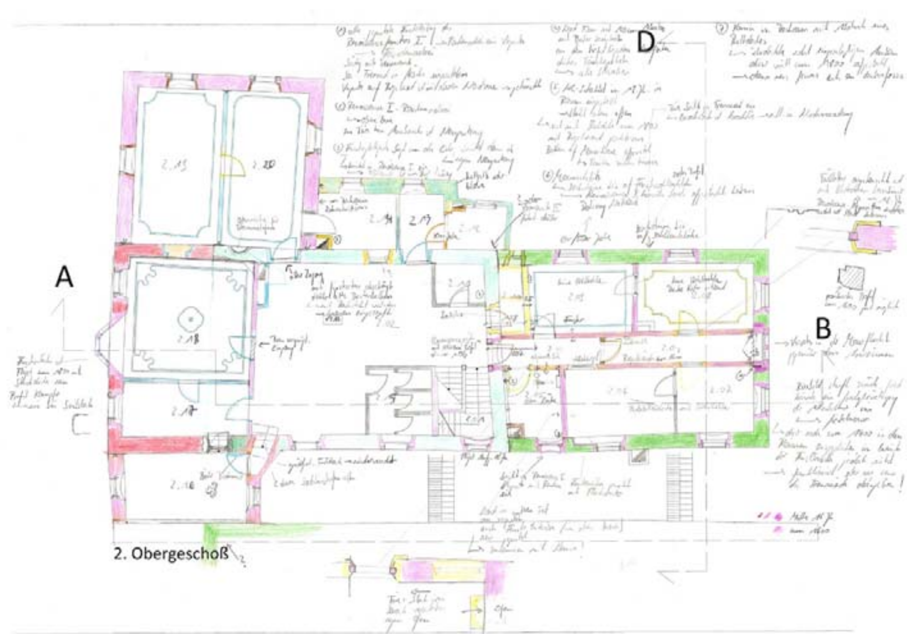
Blue-green: Romanesque period I: core building

Middle-green: Romanesque period II: rear house

Red: 2nd half of 15th century: arcades

Orange: 1st half of 16th century: passage over alley

Violet: Renaissance end of 16th century: major reconstruction



Ground plan with construction phases: second floor: Middle-green: Romanesque period II: rear house Red: 2nd half of 15th century: arcades Bright violet: around 1600 Dark violet: middle of 16th century Grey: last century	
Construction phases	
First phase of construction: 12th century	The central part of the building towards the „Portici“ and the rear building, as well as the two basement floors are of Romanesque origins (12th century).
Second phase of construction: 2nd half of 15th century	Only afterwards, during the 2nd half of 15th century, the continuous walkway (the arcades), typical for the “Portici” street were added on the north side.
Third phase of construction: first half of 16th century	To connect the building to the neighbour building on the west side during the first half of 16th century a bridge over the narrow alley was built.
Fourth phase of construction: end of the 16th century	Towards the end of the 16th century, the building has undergone a major intervention, which included e. g. the unification of window openings and extensions on the east and west side (over bridge) of the building as well as subdivision of south building part on 2nd floor with interior walls.
Fifth phase of construction: last century	Several inside partition walls were added during the last century.

0.3.3 Building consistency

Building consistency	
Description state of the building	The building is in a good general condition. It shows no obvious particular structural problems. The building shows typical defects for a building that has not been inhabited and maintained on the upper floor for about 15 years: partially damaged, leaking windows, contamination by pigeons above all on some window sills, etc. Because of the high relative humidity in basement floors, there is a high risk of mould grow on the open wooden construction of the basement ceilings. This also applies to few weak points of the thermal envelope. In some point there are already traces of mould grow e.g. on the thin walls of the jutty and on the southern exterior wall of the bridge. The roof construction seems to be in a good state, as it has been renewed during the 80th, when the top floor was partially refurbished to use it as an apartment.
Description construction method	All full storeys and the cellar are built in masonry of natural stones with lime mortar joints. The masonry is constructed as a “Schichtmauerwerk” (layer masonry): horizontal layers with continuous horizontal joints out of “Bachsteine” (stones from the near river Talvera) in granite not worked. Exterior walls have a thickness of about 60 to 80 cm. All walls (except on basement level) are plastered with lime plaster. The ceilings of the ground floor are vaulted, the ceilings of the upper floors are built in wooden beams with wooden casing and filling material in between. The underside of the ceiling is plastered with lime plaster. Especially on ground and basement floor, the ceilings are vaulted. The building has a purlin roof with wooden rafters and wooden casing, roofing cardboard (bitumen) on the wooden casing and above it roof cladding with monk and nun roof tiles. The building materials are typical for an urban mediaeval building of the area, using construction material from the surroundings (nearby river, forests).
Description shape	T-shaped freestanding building
Description of facades and roof	The stonework is covered in most parts on both sides with historic lime plaster and painting, partially also wall paintings and frescoes. In some parts of the exterior surface, we have facing brickwork; the windows are framed with a profiled sandstone from baroque era. The façade shows the construction history of the building: on the south side, the façade has a baroque appearance. We have the frescos, which represent the armorial bearings of Austria, South Tyrol and the city of Bolzano. On the east side, we see the Romanesque masonry with the typical execution of the mortar joints for that time.



Number of floors above ground	3 fully stories + top floor
Number of basement floors	2
Covered area	347 m²
Numbers of rooms	65
Heated/cooled surface	843,5 m² (Treated floor area)
Net air volume for press. Test	2033 m³

Occupancy rate (number of inhabitants/users)	At the moment the building is empty and not inhabited

Occupancy time (h/week, d/month)	At the moment the building is empty and not inhabited
Target energy demand heating/cooling	The target energy demand of heating is factor 2-4 (compared with the as-is-state heating demand).

Building Services (as- is-state)	
Heating system	Originally, the building was heated with several carbon ovens in some areas of the building. In the last years of use, the building was heated with radiators, supplied by a gas-fired boiler in the basement stores. Since the time the building is not inhabited anymore, the heating system has been switched off.
Plant room	So far there have been no separated plant room. The heating system (the boiler) is installed on the landing of the cellar stairs.
Electrical System	Outdated electrical system, not in use.
Ventilation System	There is no controlled ventilation system installed. Rooms were ventilated manually through opening the windows.
Cooling System	No cooling system.
Wastewater disposal	No waste water disposal
Renewable Energy	No renewable energies are used
Artificial Lighting	1 lamp in each room
Use of Daylight	Daylight comes through the windows. The top floor is lightened through the dormer windows.
DHW production	There is no centralized hot water production and hot water tank. DHW is produced with decentralized electrical flow heaters.
Chimney/ducts	Due to the traditional heating system, there are eight chimney in the building. Most of the chimneys are located on the second floor and only a few of them are present on the first floor. On the ground floor, in the inspected rooms no chimneys were found. This stresses the fact that the ground floor was used as a shop, while the upper floors as apartments.

Building Potential	
Potential for energetic use	- thermal mass of thick walls in natural stone in combination with natural night ventilation - use of existing chimneys as “solar chimneys” - exploitation of the constant climate in the cellars (see below) - collector under the roof tiles - collector in the soil of the basement
Subterranean floors and basements and the possibility of air exchange with upper floors/roof	Possibly exploitation of the constant climate of the two basement floors: Because of its contact to the surrounding soil and its depth of about 6 meters the internal climate of the cellar stores is relatively constant and quite independent from the external climate. During the day in summer it remains about 10 Kelvin colder than in the rooms upstairs on the 1st floor, while during the winter the basement temperatures remain higher and more constant as in the upper rooms (see also monitoring results). This temperature difference could be exploited through the application of a hybrid ventilation system.
Possible heat exchange with the surrounding ground	There is no access to the surrounding ground and therefore no heat exchange possible, except the area of the basement floor (at a level of – 6 m), which consists of tamped earth, as the foundations are founded directly on the soil.
Possible use of energy sources on the building or from nearby, possible application of “smart grids”	
Short description/overview on space available for building services/combustible/installations	
Possibility of installation of geothermal collectors (dimension)	
Possibility of de-/central ventilation system (available space/wiring etc.)	
Transferability of (energetic) refurbishment solutions to other buildings	The experiences gained in the attendance of the case study, the proposed refurbishment concept and the technological solutions were tested regarding their transferability to other buildings. This evaluation of transferability of solutions was evolved on two scales: - **On Urban scale**, investigating the energy potential and defining the possible energy refurbishment interventions for a wide spread medieval building type in the historic city center of Bolzano (Italy), the “Portici”.

	- **On Building scale**, supporting the implementation planning phase of the enhancement of energy efficiency of a historic Villa from the middle of the 19th century, near Lake Como (Italy) The transferability study is reported in detail within the deliverable "6.4 Transferability study"

0.3.4 Building Energy consumption

Energy bills	No energy bills were available
Documentation of former energy audits	No documentation of former energy audits were available
Measured energy consumption as-is-state	The energy consumption could not be measured, as during the phase of pre-intervention analysis the building was not inhabited.

As there were no data on consumption available (from the time when the building still was in use), a prediction of the energy behavior of the building can be made only through the calculation of the energy demand or the dynamic simulation of the as-is-state of the building.

0.4 Constraint condition and protection

Constraint condition and protection: internal and external surfaces/walls	
	
Actual state:	External walls and most internal partitions are of natural stones with lime mortar joints. The stonework is covered in most parts on both sides with historic lime plaster and painting, partially also wall paintings and frescoes. In some parts of the exterior surface, we have facing brickwork; the windows are framed with a profiled sandstone from baroque era. In various rooms, there are stuccoed or vaulted ceilings.
Assessment of the conservator:	The façade shows us the construction history of the building: on the south side, the façade has a baroque appearance. We have the frescos, which represent the armorial bearings of Austria, South Tyrol and the city of Bolzano. On the east side, we see the Romanesque masonry with the typical execution of the mortar joints for that time. All over the whole building, we have historic plaster, which are of historic value and therefore worth for preservation. The historic plaster, the frescos, the sandstone frames around the windows, the original proportions of the façade should remain perceivable and therefore not be covered.
Possible interventions:	To improve the thermal behavior of the external walls, the (temporary) installation of internal insulation is only possible in carefully selected parts of the building, from conservator's point of view. In general: the covering of surfaces has to be decided individually room by room. Internal insulation should be in any case removable and should not leave any trace on the existing walls. The original layers of paint (even if they are not historic), the appearance of the historic plaster, the uneven surfaces and edges should be preserved for historic

	and handicraft reason. The same counts for surfaces with wall paintings, even if the majority of mural painting is covered by paint layers and only partially visible, they are the most valuable surfaces and should be maintained as they are. The delicate original proportions of the rooms and above all the symmetry of stuccoed ceiling should not be changed by installation of internal insulation. Usual approach of renovation of inner side of the wall in similar cases: Uncover the last useful layer (that still has to be determined) and paint this layer with whitewash. Problems of internal insulation from conservation point of view: covering of historic surfaces in a way that they are no more visible and “perceivable”, changing symmetry of stuccoed ceiling. The Existing wooden pavement should be conserved.

Constraint condition and protection: roof

Actual state:	Saddle roof with wooden rafters and wooden casing, roofing cardboard (bitumen) on the wooden casing and above it roof cladding with tiles (Spanish tile roof). In the current state, the roof construction is partially insulated with a layer of mineral wool of 8 cm to the inside, in between the wooden rafters. The insulation is covered on the below side by a gypsum plasterboard.
Assessment of the conservator:	From conservator’s point of view, the roof has to be preserved in his actual form for two main reasons: (i) The

	Spanish tiles ("Mönch und Nonne") of the saddle roof are historic tiles. They have a value from conservators point of view because they ´re handcraft manufactured in a unique way. (ii) The homogeneous appearance of the roof scape of the whole historic city centre has to be kept. To assess the roofs not only the visibility is crucial but also the uniformity. Apart from that, the visibility of the roof areas can´t be evaluated standing besides the building and looking to the roof; it must be considered that the whole roof scape of the historic city centre of Bolzano is ascertainable, looking from the surrounding mountains. Not only the appearance of the roofage has to be kept, also the lower side of the roof (down spout) can´t be changed by f. e. rising the roof covering, in case of putting insulation of the roof above the rafters. The profile and the proportions of the roof-edge should be preserved.
Possible interventions:	To improve the thermal behavior of the roof, an insulation from inside is thinkable (insulation in between and below the rafters).

Constraint condition and protection: windows	
 	
Actual state:	The major part of the original windows was replaced by box-type windows in the 1950s/60s, just a few original windows are from the late baroque era with thin wooden profiles and single glazing (e.g. in the jutty on the north façade). The unified window size dating from the 16th is typical for baroque era, also profiled sandstone frames date from this era. For shading and darkening, wooden window shutters are used. The showcases on ground floor are single or double glazing from the last century with mostly thin metal profile frames, partially integrated in the plaster. The windows in the roof dormers are standard industrial insulation windows from the 1990s.
Assessment of the conservator:	The box-type windows, the showcases and the windows in the roof dormers are not of historic value, while the few original windows should be maintained.

Possible interventions:	Since the box-type windows of the 1950s/60s are not of historic value, they could and should be replaced reproducing the appearance of a historic window, the outer window being placed right behind the existing historic stone frame and positioned and installed in the reveal in a similar way. The late baroque original windows should be preserved and repaired – and possibly be enhanced from energetic point of view. The showcases on ground floor and the windows in the roof dormers could also be replaced.

Constraint condition and protection: installations work	
Assessment of the conservator:	- For installation work use as much as possible existing wholes, inspection chambers and chimneys - For the installation of ventilation channels the existing chimneys can be used - For horizontal distribution of installation cables and tubes existing space in the floors and ceilings should be used - In case if there have to be stemmed slots and apertures for vertical distribution of cables and tubes, it has to be analysed and decided individually if it is possible because of mural paintings - If possible, the vertical distribution of cables and tubes should be avoided: floor sockets should be inserted or cables should be laid on-wall. - In case of existing holes or apertures in the exterior wall, it has to be decided individually if they can be closed according to their position and original function. - If there is no need to use existing holes in the building structure or if they don´t have a relevant function, they can be closed. The closure of holes has to be documented during the process of construction.

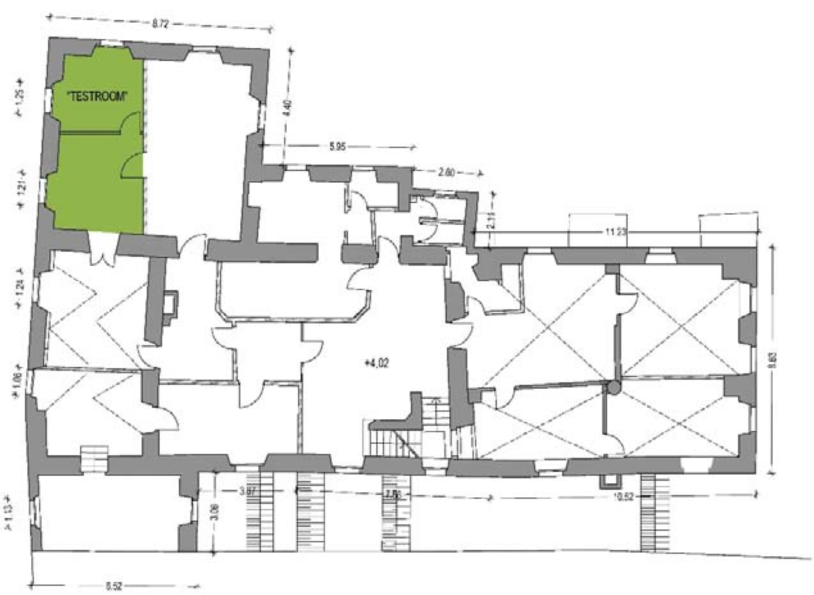
Constraint condition and protection	
Description of building safety with regards statics/structural problems - compliance with local regulations	-
Certificates/reports/regulations on statics	-
Description of building safety with regards dangerous materials (to remove)-Compliance with local regulations	-
Certificates/reports/regulations on dangerous materials	-
Description of building safety with regards fire protection - compliance with local regulations	-
Certificates/reports/regulations on fire protection	-
Description of building safety with regards seismic safety - compliance with local regulations	-
Certificates/reports/regulations on seismic safety	-
Description of building safety with regards noise protection - compliance with local regulations	-
Certificates/reports/regulations on noise protection	-

0.5 Selected area of intervention

0.5.1 Functional area: "Test room", 1st floor

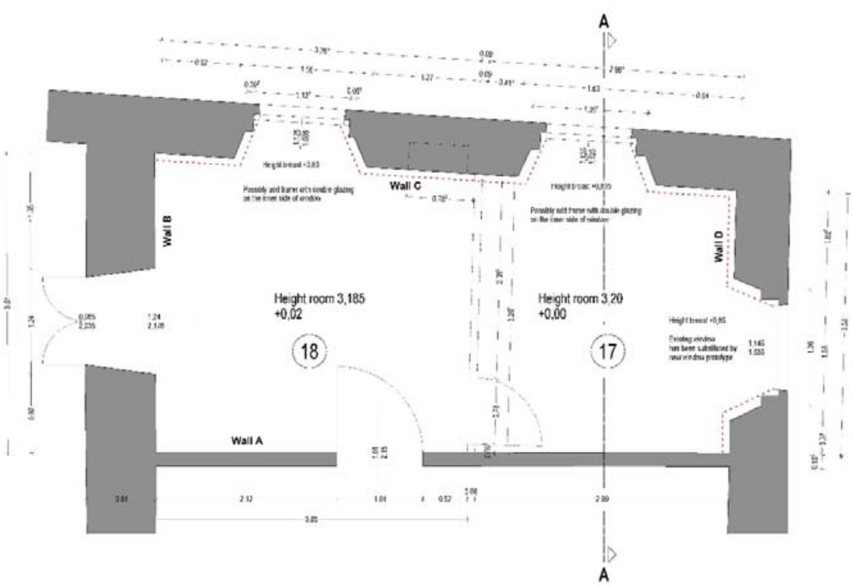
Functional area consistency	
Description	Determination of a "test room" on the first floor of the building for the implementation and testing of prototypes and solutions.
Number of rooms	1
Heritage aspects	The test room is a secondary room in the extension dating back to the renaissance (end of 16th century) on the northeast side of the building. The room has been chosen in accordance with the conservator. The restorer has proved the absence of historical mural paintings on covered paint layers at some points of the surface. In addition, the building historian confirmed that there are no painted surfaces of heritage value. The installation of internal insulation would be there for possible. As on all surfaces of the exterior wall we have historic plaster, the internal insulation should be in any case removable without leaving any trace on the existing walls. All windows of the "test area" are box-type windows from the 1950th/60th and could be replaced reproducing the appearance of a historic window. The existing wooden pavement should be conserved.

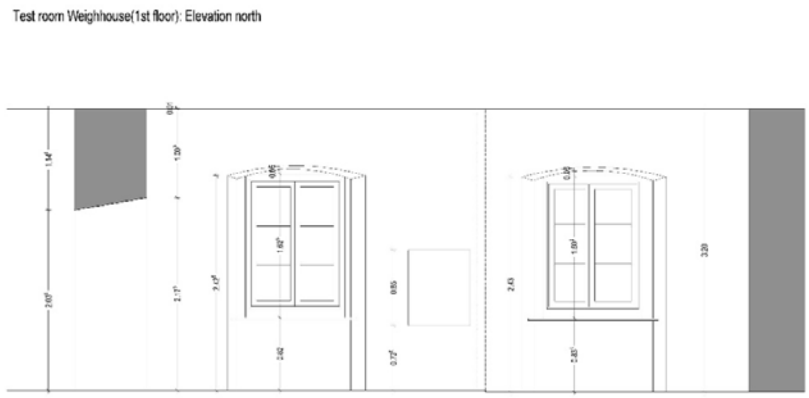




GROUNDPLAN_FIRST FLOOR

Test room Weighhouse (1st floor): Ground plan





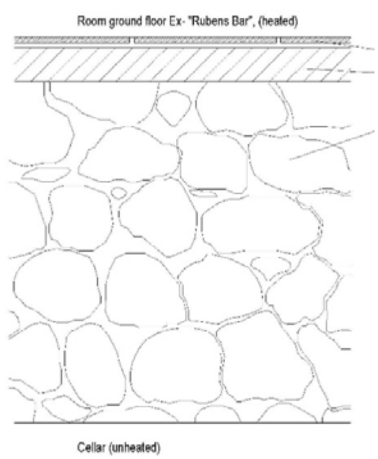
Height interpolated average net (m):	3,20 m
Surface area (Gross/Net) heated (mq):	Net surface area: 22,3 m²
Volume (gross/net) heated (mc):	71,36 m³
Opening to the public (from/to; hours /day; temperature set-up):	The room is not in use/inhabited
Hours of working (from/to, hours/ day; temperature set-up):	During the monitoring phase, the test room will be heated up. During the winter period, the temperature and humidity will be controlled and kept at a static max. level for the whole day.
Hours of air conditioning (from/to; hours/day; temperature set-up)	No air conditioning
Comments	-

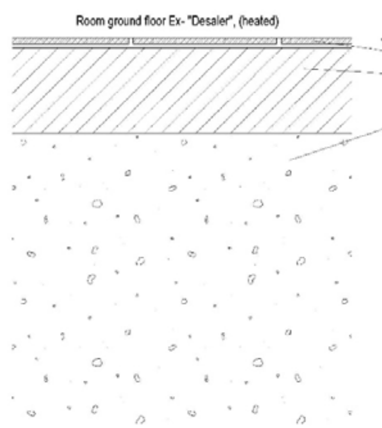
1 Report on status pre-intervention

1.1 Analysis of architectural elements

1.1.1 Thermal envelop

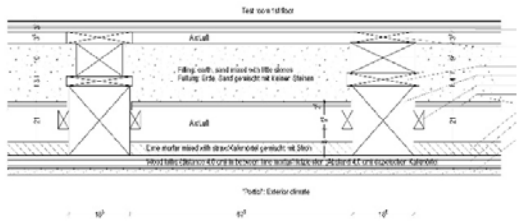
Analysis of Building envelope - bottom:

General description	
Description	The below side of the thermal envelope is divided into two areas with different constructions: the basement ceiling and the baseplate on soil.
Archaeological aspects	no
Total dimension	270,6 m²
Surface area part 1	**Basement ceiling (= floor slab towards first basement)**
  	
Dimension	148,30 m²
U-value (calculated)	0,907 W/(m²K)
Construction	

	Material layer	**[W/(mK)]**	**[mm]**
	Ceramic tiles Floating floor Natural stones/lime mortar	1,00 1,40 0,85	18 60 600
Surface area part 2	**Baseplate on soil**		
Dimension	122,30 m²		
U-value (calculated)	3,308 W/(m²K)		
Construction			
	Material layer	**[W/(mK)]**	**[mm]**
	Ceramic tiles Floating floor	1,00 1,40	18 160

Surface area part 3	**Ceiling over “Portici”**
Dimension	94,80 m²
U-value (measured)	0,434 W/(m²K)
Construction	

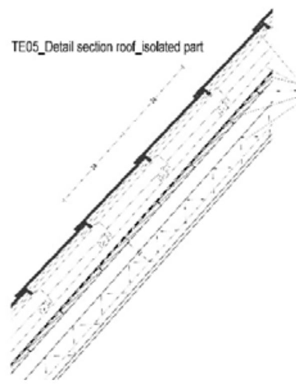


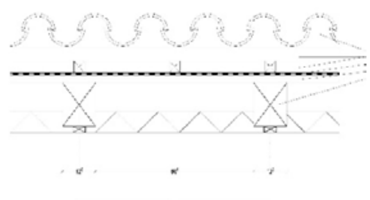


Material layer	**[W/(mK)]**	**[mm]**
Filling/wooden beams (21,5%)	2,10/0,13	178
Dead floor/wooden beams	0,13	26
Air layer/wooden beams (21,5%)	0,05/0,13	96
Lime mortar	0,82	40
Lime mortar/wood latts (33,3%)	0,82/0,13	40
Lime plaster	0,82	20

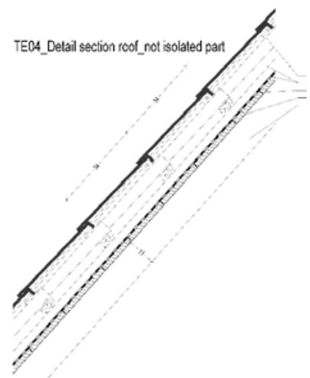
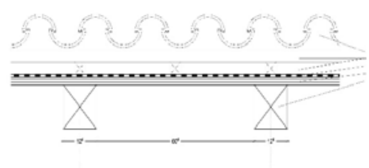
Analysis of building envelope - top:

General description	
Surface area part 1	Roof (isolated part)
Dimension	82,3 m²
U-value	1,487 W/(m²K)
Construction	



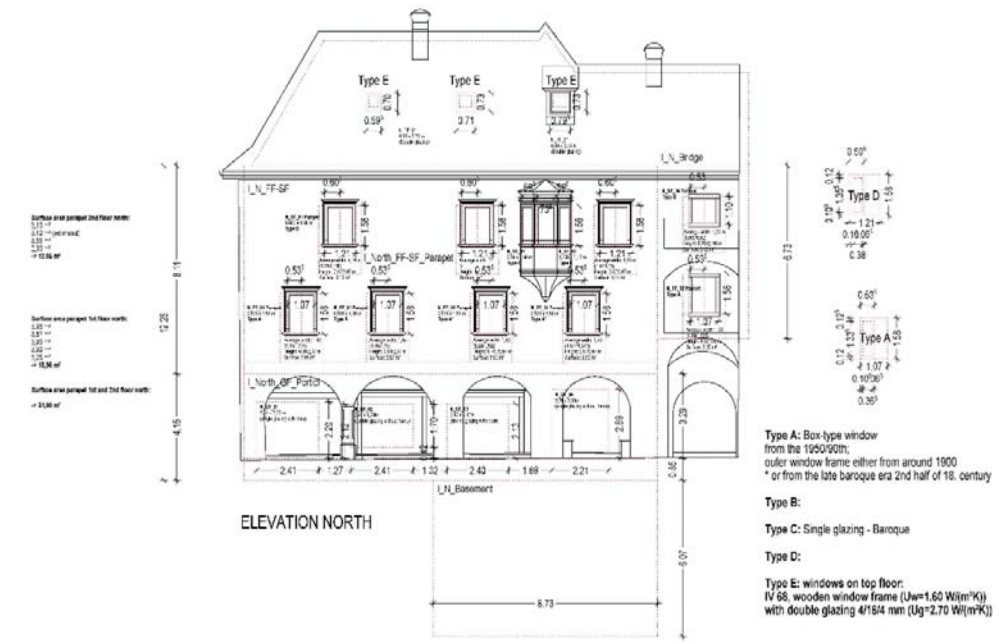


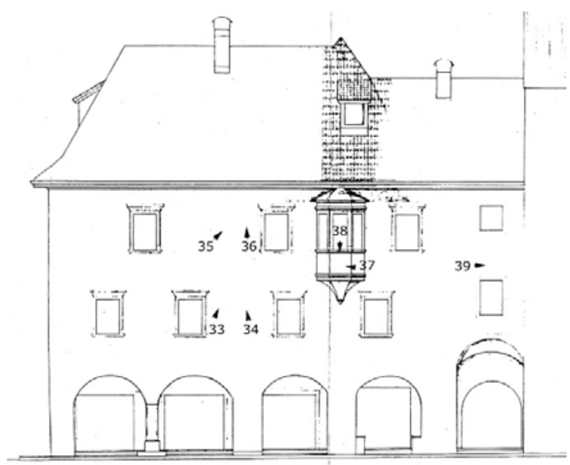
Material layer	W/(mK)]	[mm]
Bituminous sheeting	0,145	0,006
Boards in spruce	0,13	0,02
Mineral wool (lambda & thickness adapted)	0,073	0,02
Gypsum plaster board	0,2	0,0125

Surface area part 2	Roof (not isolated part)
	
U-value	2,983 W/(m²K)
Construction	
	

Material layer	W/(mK)]	[mm]
Bituminous sheeting	0,145	0,006
Boards in spruce	0,13	0,02

Exterior walls/facades:

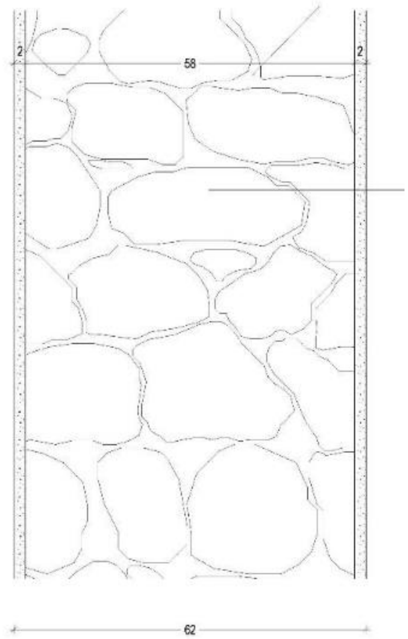


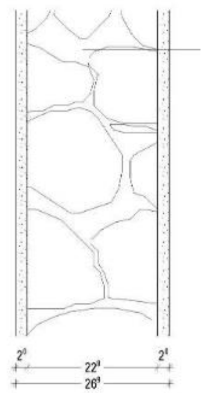



EURAC
ELEVATION EAST
3encult
Public Weigh House, Bozen/Bolzano (Italy)_As-is-state 1:100


EURAC
ELEVATION SOUTH
Public Weigh House, Bozen/Bolzano (Italy)_As-is-state 1:100

Type of facade	Punctuated facade
Balcony	No balcony
Eaves	Profiled and plastered down spout.
Conservation state of the façade: humidity or other visible stain/deterioration on walls	No visible deterioration on walls except some little obvious crack in the painting layers on the below side of the façade.
Openings/holes usable for wiring or pipes (e.g. 10cm diameter)	No openings
Membranes (waterproofing/breather/vapour control layer) applied	No membranes applied
Surface area part 1	Exterior walls
	External walls have a thickness from about 55 to 75 cm; depending on the construction phase of the building part (see also plans with wall thicknesses).
Dimension	922,1 m²
U-Value (measured)	1,12 W/(m²K)

<table>
<tr><td rowspan="5">Construction</td><td colspan="3">
</td></tr>
<tr><td>Material layer</td><td>[W/(mK)]</td><td>[mm]</td></tr>
<tr><td>Exterior lime plaster</td><td>0,82</td><td>0,02</td></tr>
<tr><td>Natural stone/lime mortar (cond. adapted)</td><td>0,855</td><td>0,58</td></tr>
<tr><td>Interior lime plaster</td><td>0,82</td><td>0,02</td></tr>
<tr><td>Surface area part 2</td><td colspan="3">Area of parapets under window</td></tr>
<tr><td></td><td colspan="3">The parts of the wall below the window are less thick. Parapets have a thickness from about 25 to 45 cm; depending on the construction phase of the building part (see also plans with wall thicknesses). The construction of the parapets does not differ from the rest of the walls; the original wall was narrowed during the restoration of the building at the end of 16th century.</td></tr>
<tr><td>Dimension</td><td colspan="3">34,5 m²</td></tr>
<tr><td>U-value (measured)</td><td colspan="3">1,92 W/(m²K)</td></tr>
</table>

Construction			
	Material layer	**[W/(mK)]**	**[mm]**
	Exterior lime plaster	0,82	0,02
	Natural stone/lime mortar (cond. adapted)	0,855	0,22
	Interior lime plaster	0,82	0,02

1.2 Structural analysis and assessment of moisture

1.2.1 U-value determination

For selected points of the thermal envelope, heat flux measurements were carried out to determinate the thermal transmittance, using a heat flow-meter measurement (HFM) applied directly in situ. The selected points are indicated in the project plans below (figure 1.1). To provide a stable average of the U-value (Baker, 2008 and 2011), which takes into account the thermal inertia of the stonewalls, instead of 72 h (as foreseen in the standard), the monitoring period was chosen to be 90-120 h, related to the thickness of constructive detail.

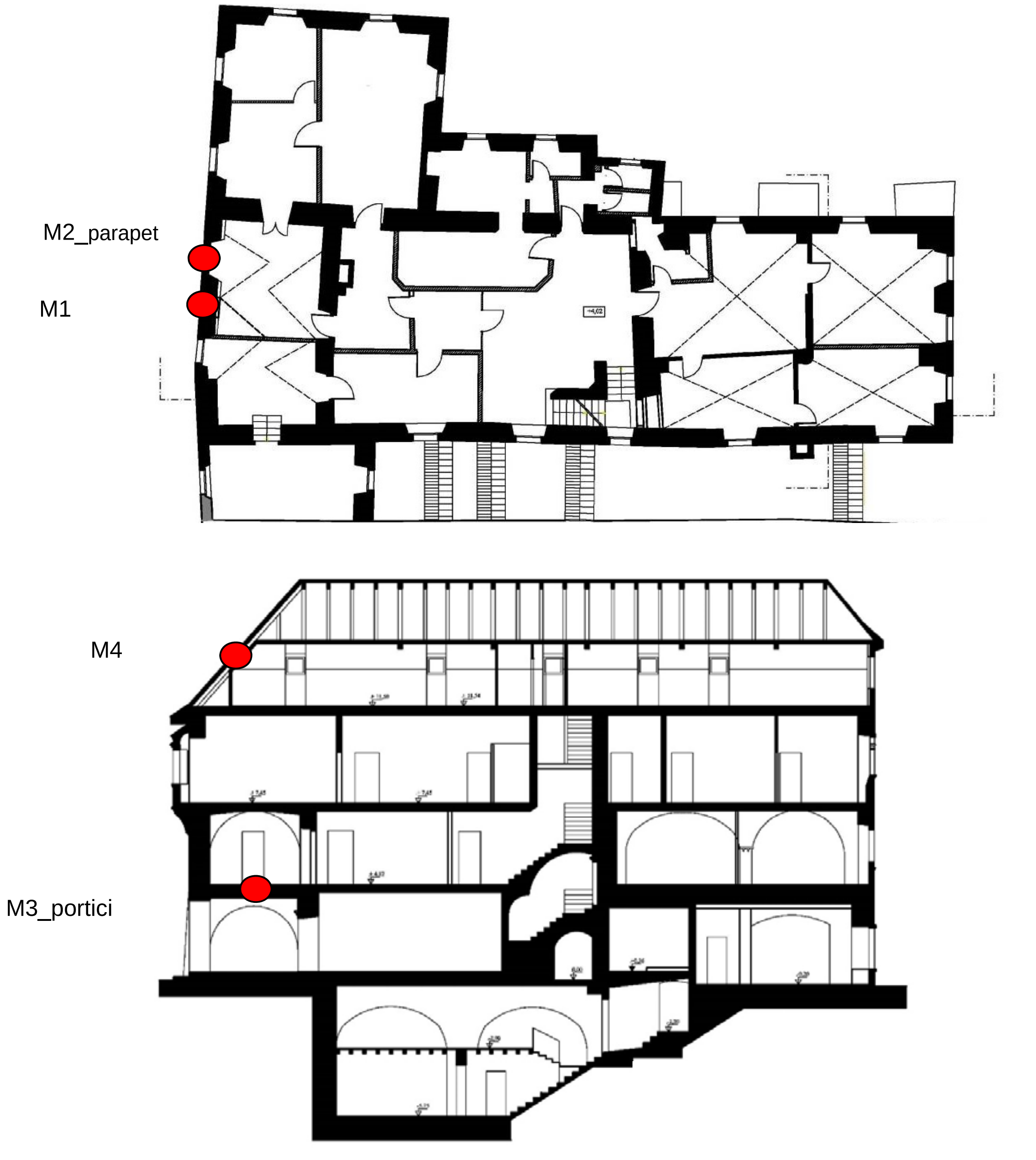


Figure 1: Points of measurement exterior wall, roof and ceilings

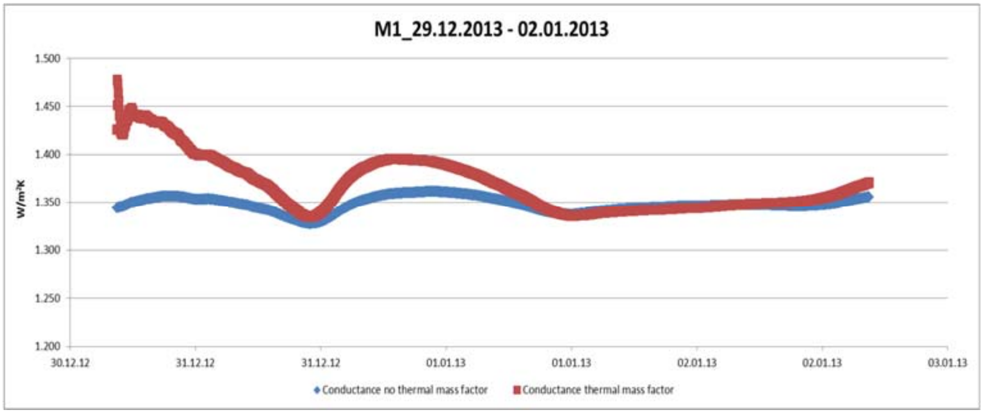
We calculated the thermal conductance of the components with the average method, the duration of the test depends on the material. The following picture shows the points of measurements. We performed the test on the exterior wall north-oriented in order to avoid direct solar radiation on the temperature sensor on the exterior surface. We did an IR thermography to be sure that there were no thermal bridges located in the points of measurements. As required by the standard, we positioned the plate on the surface where the temperatures were more stable, in our case the interior. We heated the room with an electrical heater in order to have a minimum temperature difference of 10°C, as required by the standard. We measured the thermal flux every two minutes and then we calculated the conductance using the average method that means calculating the mean value of all the previous calculations for each time-step until the measurement reached the stability.

Exterior walls

We measured the conductance of the exterior wall on the north side and on the east side in two different periods. We considered the external wall as a heavy element and therefore we analysed the results with and without the storage effect (see paragraph 7.2 ISO 9869). The difference between the two is less than 5% (max value established by the legislation).

ID building component	M1
Type	Exterior wall in natural stones
Construction/material layers	See above under: "Analysis of architectural elements" – "Facades"

<table>
<tr><td>Heat flux measurement</td><td colspan="4">M1</td></tr>
<tr><td>Period of building up the study area</td><td colspan="4">Renaissance 16th century</td></tr>
<tr><td rowspan="7"></td><td>Measure point</td><td colspan="3">First floor, room 18, exterior wall north side</td></tr>
<tr><td>Exposure</td><td colspan="3">North</td></tr>
<tr><td>Type</td><td colspan="3">Solid exterior wall in natural stones</td></tr>
<tr><td>Using area</td><td colspan="3">Residential zone (main room)</td></tr>
<tr><td>Measure period</td><td>Duration</td><td>Conductance not corrected</td><td>Conductance corrected with thermal mass factor</td></tr>
<tr><td>29.12.2012-02.01.2013</td><td>96 h</td><td>1,355 W/m²K</td><td>1,371 W/m²K</td></tr>
<tr><td>23.01.2012-28.01-2012</td><td>120 h</td><td>1,375 W/m²K</td><td>1,399 W/m²K</td></tr>
</table>

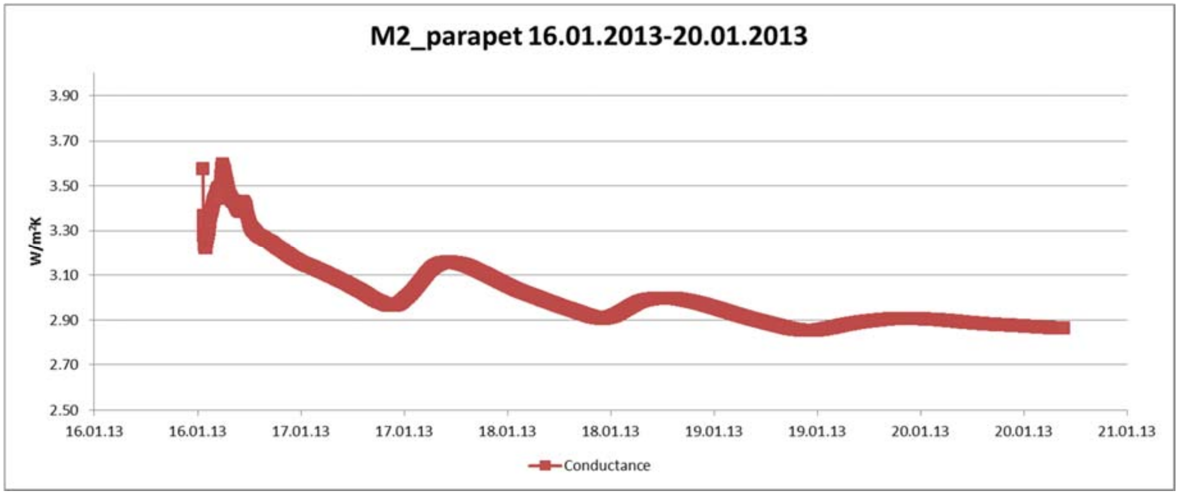


Exterior wall – parapet

We measured the conductance of the parapet position under the window, considering it as a heavy element.

ID building component	M2_parapet
Type	Exterior wall in natural stones
Construction/material layers	See above under: "Analysis of architectural elements" – "Facades"

Heat flux measurement	**M2_parapet**		
Period of building up the study area	**Renaissance 16th century**		
	**Measure point**	First floor, room 18, exterior wall north side	
	Exposure	North	
	Type	Solid exterior wall in natural stones	
	Using area	Residential zone (main room)	
	Measure period	**Duration**	**Conductance not corrected**
	16.01.2013-20.01.2013	96 h	2,864 W/m²K



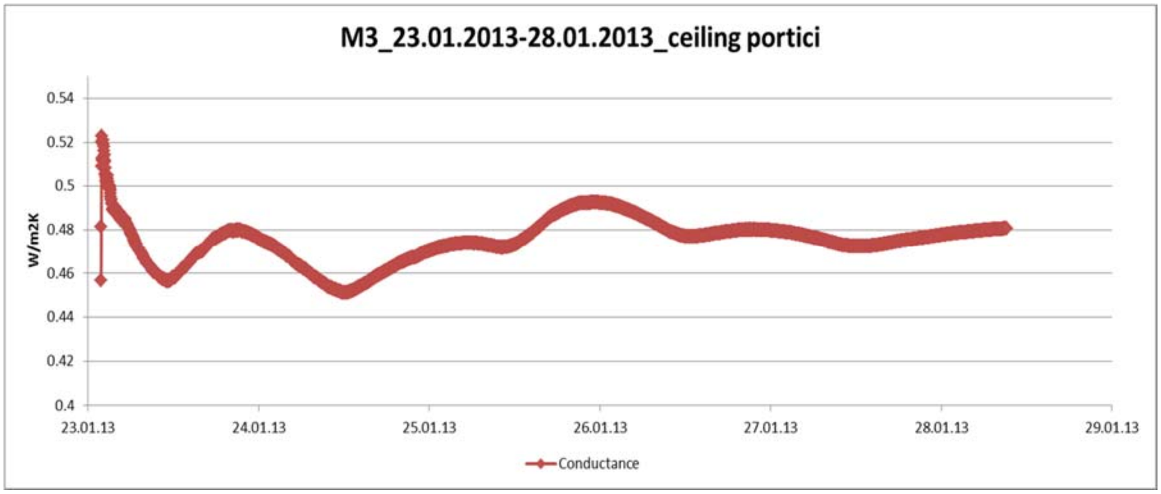
Ceiling over “Portici”

We measured the conductance of the ceiling above the portici, considering it as a heavy element.

ID building component	TE03
Type	Ceiling over outdoor area in wooden beams with filling in earth, sand and little stones. Outer side covered with lime plaster. Floor in wooden boards
Construction/material layers	See above under: “Analysis of architectural elements” – “Roofs”

<table>
<tr><td>Heat flux measurement</td><td colspan="3">M3</td></tr>
<tr><td>Period of building up the study area</td><td colspan="3">Renaissance 16th century</td></tr>
<tr><td rowspan="2"></td><td>Measure point</td><td colspan="2">First floor, room 18, floor (ceiling over “Portici”)</td></tr>
<tr><td>Type</td><td colspan="2">Ceiling over outdoor area in wooden beams with filling in earth, sand and little stones. Outer side covered with lime plaster. Floor in wooden boards.</td></tr>
<tr><td rowspan="2"></td><td>Using area</td><td colspan="2">Residential zone (main room)</td></tr>
<tr><td>Measure period</td><td>Duration</td><td>Conductance not corrected</td></tr>
</table>

	23.01.2013-28.01.2013	120 h	0,480 W/m²K



Results table

Element	Measure period	Duration	Conductance
Exterior wall	29.12.2012 – 02.01.2013	96 h	1,371 W/m²K

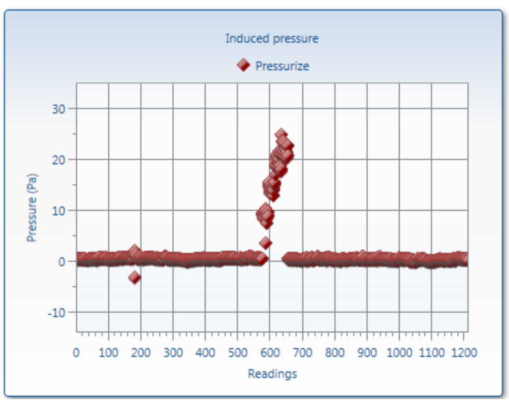
1.2.2 Determination of air tightness

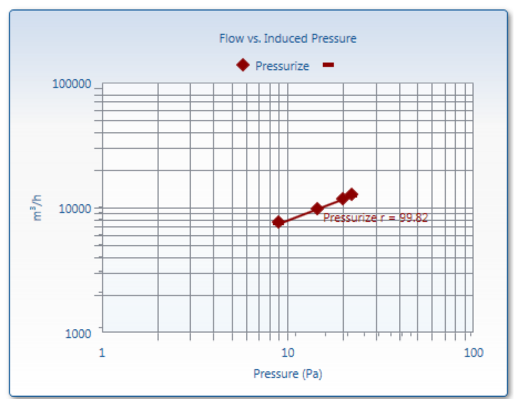
Results for the complete building

The blower door tests for the whole building were carried once considering the top floor and once excluding it. The fan was positioned on the outside door to create the pressure difference. The main difficult was to reach high levels of difference pressure, it was not possible to have more than 28 Pa. This caused an uncertainty in the measurements, especially carrying the test with overpressure in the building. For this reason after the test on the whole building we did the test also in some rooms, were we reached a difference pressure of 50 Pa (value established into the European and American legislation) without any problems. The results are similar for the measurements with and without the top floor: the air changes in an hour at a difference of pressure of 50 Pa are estimated to be in the range from 9,4 to 9,9 ac/h.

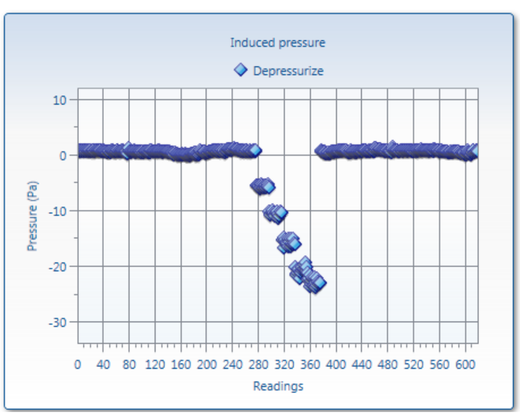
Total building with top floor results				

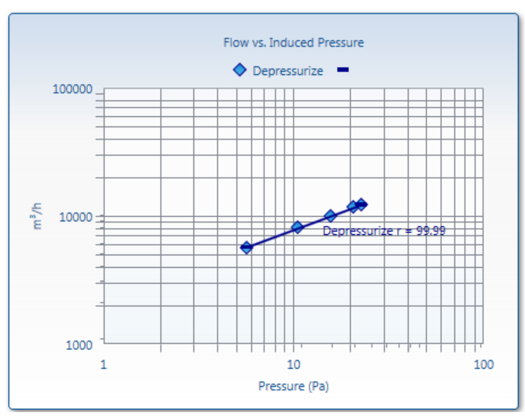
Total building with top floor overpressure	Enclosure volume [m³]	2033	Air change rate @ 50 Pa (EN)	9,86 (+-12,8%)



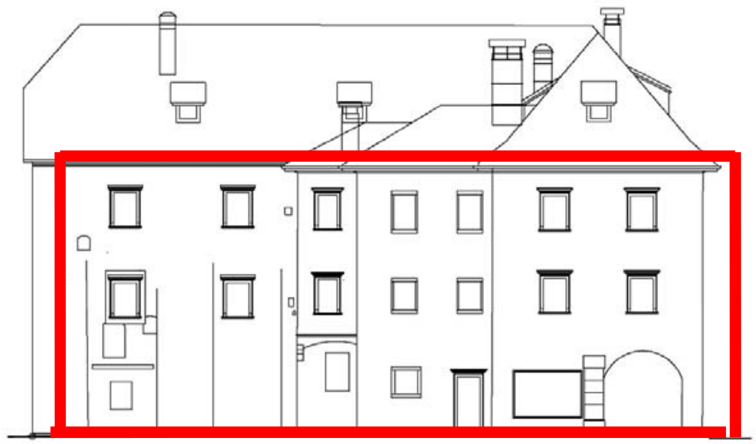


Total building with top floor underpressure	Enclosure volume [m³]	2033	Air change rate @ 50 Pa (EN)	9,38 (+-2,1%)

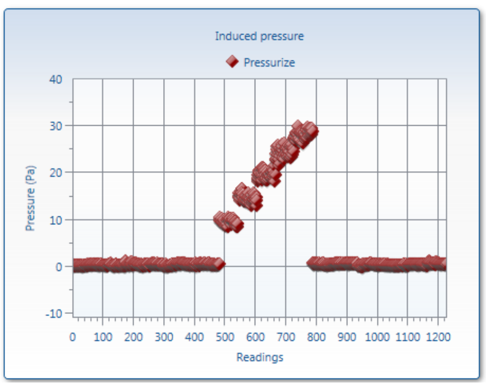


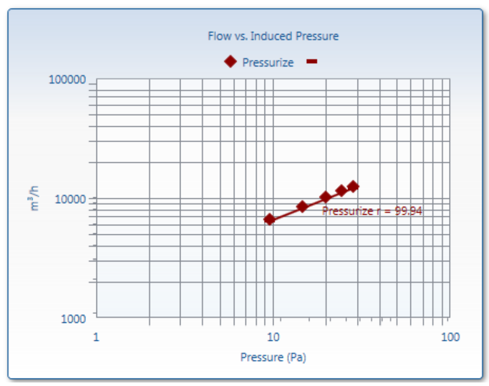


Total building without top floor results

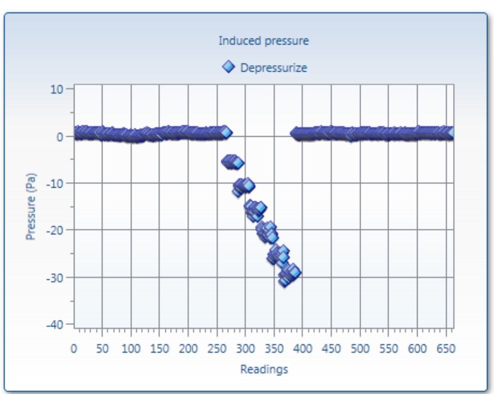


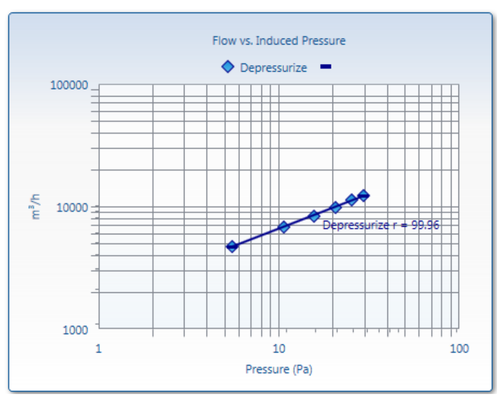
Total building without top floor overpressure	Enclosure volume [m³]	1747	Air change rate @ 50 Pa (EN)	9,915 (+-4%)





Total building without top floor underpressure	Enclosure volume [m³]	1747	Air change rate @ 50 Pa (EN)	9,51 (+-3%)





Results for single rooms

We carried the test on some rooms on the second floor positioned on the south part. As a first step, we used the gas tracer to check where the air infiltrations were localized. We created a pressure difference of 50 Pa with the fan, and we blew the gas inside the room. We saw that the gas overflew mainly through the windows and through some cracks on the interior wall. Therefore, we measured the air velocity inside the room, near the windows and near the cracks to check the differences.

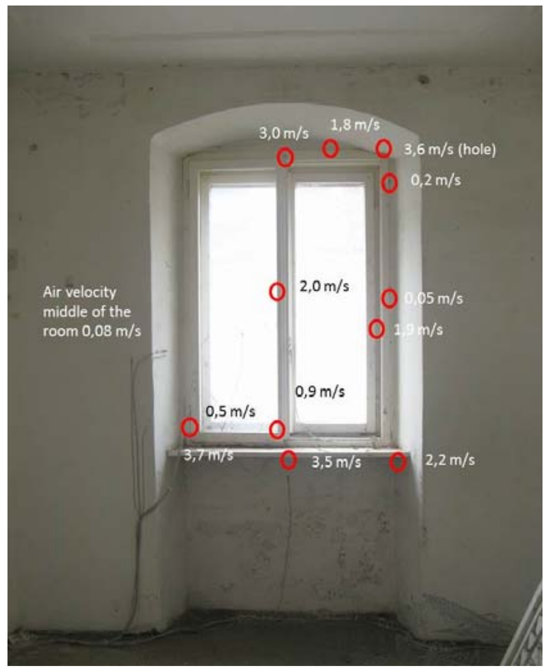


Figure 2 and Figure 1: Gas through the windows, air velocity near the window

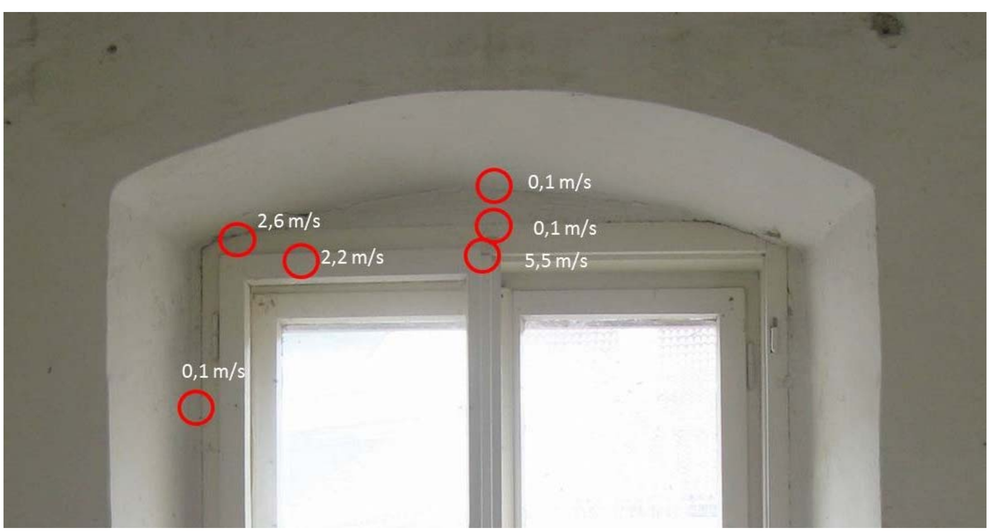


Figure 2: Air velocity near the window - details

Figure 3: Sealed cracks on the interior wall

After the gas tracing, we sealed the cracks on the interior wall in order to have only the air losses through the windows. At the end, we were able to measure the infiltration rate caused by the windows. The results of the blower door test in the rooms are reported in the following tables.

Room 51	
Enclosure volume [m³]	38,65
Floor area [m²]	9,99
Enclosure area [m²]	67,57

GROUNDPLAN_SECOND FLOOR

Equivalent Leakage Area [cm² @ 10 Pa]	268,08 (+-2,1%)
Effective Leakage Area [cm² @ 4 Pa]	159,68 (+-1,3%)
Intercept Cl [m³ / h Pa^n]	62,028
Intercept Cenv [m³ / h Pa^n]	62,15
Slope, n	0,6394
Air change rate @ 50 Pa (ASTM)	18,15 (+-2,7%)
Air change rate @ 50 Pa (EN)	18,30 (+-4,4%)

We did the same procedure for the other rooms on the floor

Room 45	
Enclosure volume [m³]	52,61
Floor area [m²]	13,81
Enclosure area [m²]	84,64

GROUNDPLAN_SECOND FLOOR

Equivalent Leakage Area [cm² @ 10 Pa]	113,23 (+-2,2%)
Effective Leakage Area [cm² @ 4 Pa]	59,032 (+-3,8%)
Intercept Cl [m³ / h Paⁿ]	20,70
Intercept Cenv [m³ / h Paⁿ]	20,713
Slope, n	0,6837
Air change rate @ 50 Pa (ASTM)	6,00 (+-1,5%)
Air change rate @ 50 Pa (EN)	6,01 (+-3,0%)

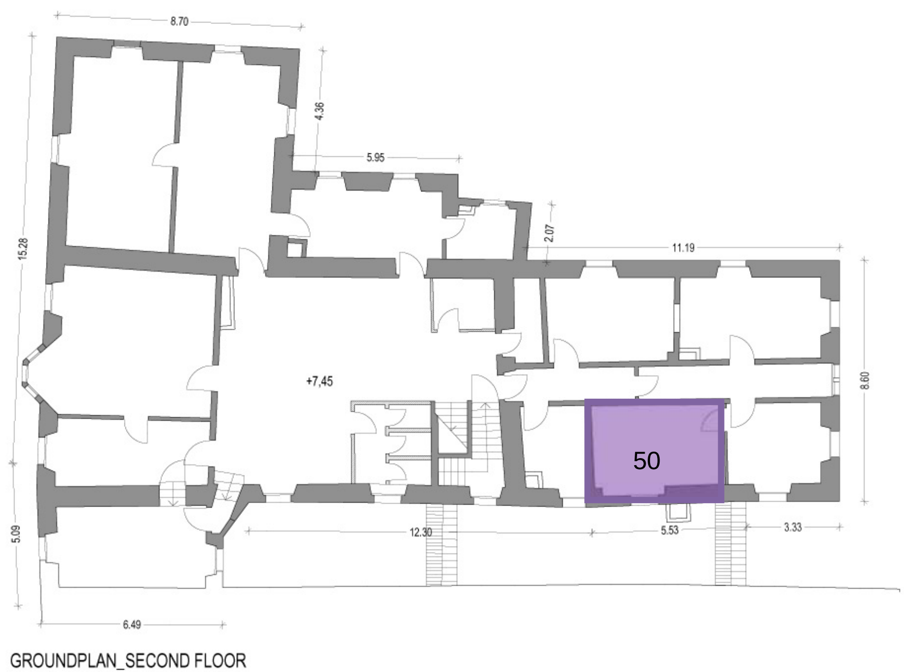
Room 46	
Enclosure volume [m³]	46,05
Floor area [m²]	14,89
Enclosure area [m²]	77,37

GROUNDPLAN_SECOND FLOOR

Equivalent Leakage Area [cm² @ 10 Pa]	284,84 (+-0,5%)
Effective Leakage Area [cm² @ 4 Pa]	155,16 (+-0,8%)
Intercept Cl [m^3 / h Pa^n]	67,25
Intercept Cenv [m^3 / h Pa^n]	67,071
Slope, n	0,5987
Air change rate @ 50 Pa (ASTM)	15,10 (+-0,3%)
Air change rate @ 50 Pa (EN)	15,15 (+-6,3%)

Room 50

Room 50	
Enclosure volume [m³]	54,86
Floor area [m²]	14,12
Enclosure area [m²]	86,08



Equivalent Leakage Area [cm² @ 10 Pa]	186,79 (+-1,3%)
Effective Leakage Area [cm² @ 4 Pa]	100,97 (+-2,1%)
Intercept Cl [m^3 / h Pa^n]	36,25
Intercept Cenv [m^3 / h Pa^n]	36,18
Slope, n	0,6545
Air change rate @ 50 Pa (ASTM)	8,43 (+-0,8%)
Air change rate @ 50 Pa (EN)	8,54 (+-1,8%)

room 49

Room 49	
Enclosure volume [m³]	25,40
Floor area [m²]	6,98
Enclosure area [m²]	54,70

Equivalent Leakage Area [cm² @ 10 Pa]	58,32 (+-0,8%)
Effective Leakage Area [cm² @ 4 Pa]	29,29 (+-1,3%)
Intercept Cl [m^3 / h Pa^n]	10,85
Intercept Cenv [m^3 / h Pa^n]	10,801
Slope, n	0,6839
Air change rate @ 50 Pa (ASTM)	6,47 (+-0,5%)
Air change rate @ 50 Pa (EN)	6,175 (+-3,0%)

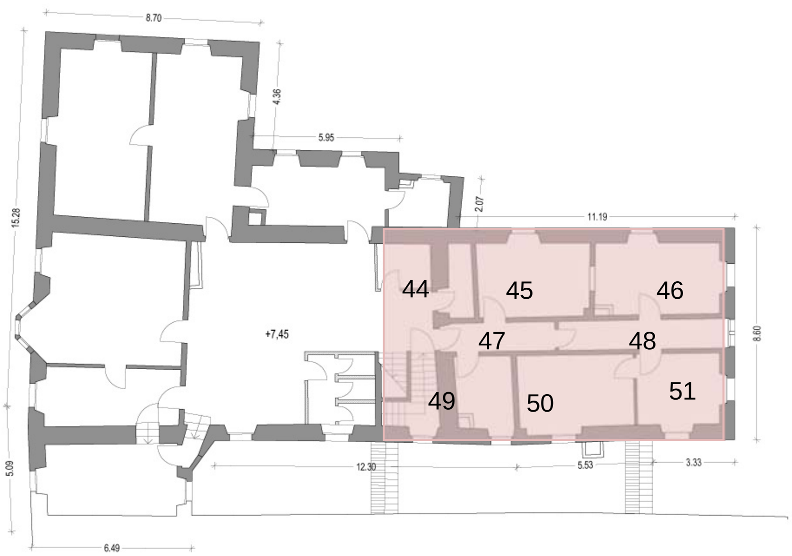
Room 46-48-51

Room 46-48-51	
Enclosure volume [m³]	114,78
Floor area [m²]	32,88
Enclosure area [m²]	169,24

Equivalent Leakage Area [cm² @ 10 Pa]	664,56 (+-6,1%)
Effective Leakage Area [cm² @ 4 Pa]	371,24 (+-10,1%)
Intercept CI [m^3 / h Pa^n]	133,0
Intercept Cenv [m^3 / h Pa^n]	132,10
Slope, n	0,6227
Air change rate @ 50 Pa (ASTM)	13,60 (+-3,9%)
Air change rate @ 50 Pa (EN)	13,15 (+-0,9%)

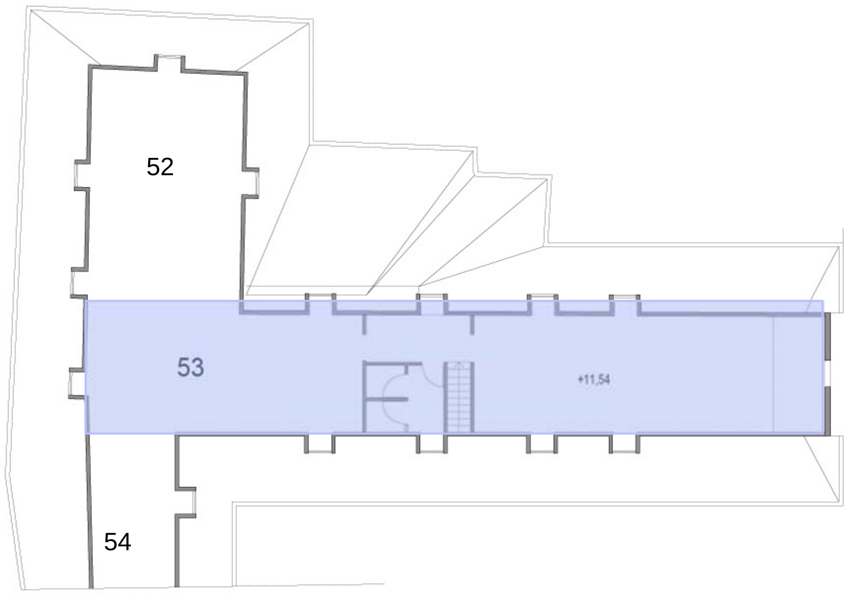
Room from 45 to 51

Enclosure volume [m³]	266,57
Floor area [m²]	72,78
Enclosure area [m²]	266,57



Equivalent Leakage Area [cm² @ 10 Pa]	803,27 (+-1,6%)
Effective Leakage Area [cm² @ 4 Pa]	432,6 (+-2,7%)
Intercept Cl [m³ / h Paⁿ]	158,0
Intercept Cenv [m³ / h Paⁿ]	157,19
Slope, n	0,6535
Air change rate @ 50 Pa (ASTM)	7,5 (+-1%)
Air change rate @ 50 Pa (EN)	7,6 (+-2,9%)

Room 53_Top floor

Enclosure volume [m³]	249,82
 GROUNDPLAN_TOP FLOOR	
Equivalent Leakage Area [cm² @ 10 Pa]	304,5 (+-1,8%)
Effective Leakage Area [cm² @ 4 Pa]	168,0 (+-4,6%)
Intercept Cl [m^3 / h Pa^n]	450,50
Intercept Cenv [m^3 / h Pa^n]	444,45
Slope, n	0,5991
Air change rate @ 50 Pa (ASTM)	18,70 (+-0,9%)
Air change rate @ 50 Pa (EN)	18,55 (+-2,7%)

1.2.3 IR-Thermography

Thermography with partially heated building on 2nd February 2011

The thermography was conducted when the building was only partially heated (on ground floor where the shops were still located at that time). The room temperature in the main part of the building ranged from 9 to 12°C. Air temperature outside was about 1°C. The IRT-investigation in passive procedure does visualize below the historic plaster the more or less regular, rounded boulder stone masonry. All facades are built with this homogeneous construction, except one the material change on top floor of the south façade (wooden frame construction with filling). Moreover, historic arc structures in the masonry are retraced.

Results of the IRT investigation are given as pictures. In the following, some significant IR-images are shown. For each IR-image a photo is given to improve orientation. All pictures of the whole tour of investigation are reported in WP2_task2.5_20110907_IR-Waaghaus_first2011.doc.

Eastern facade

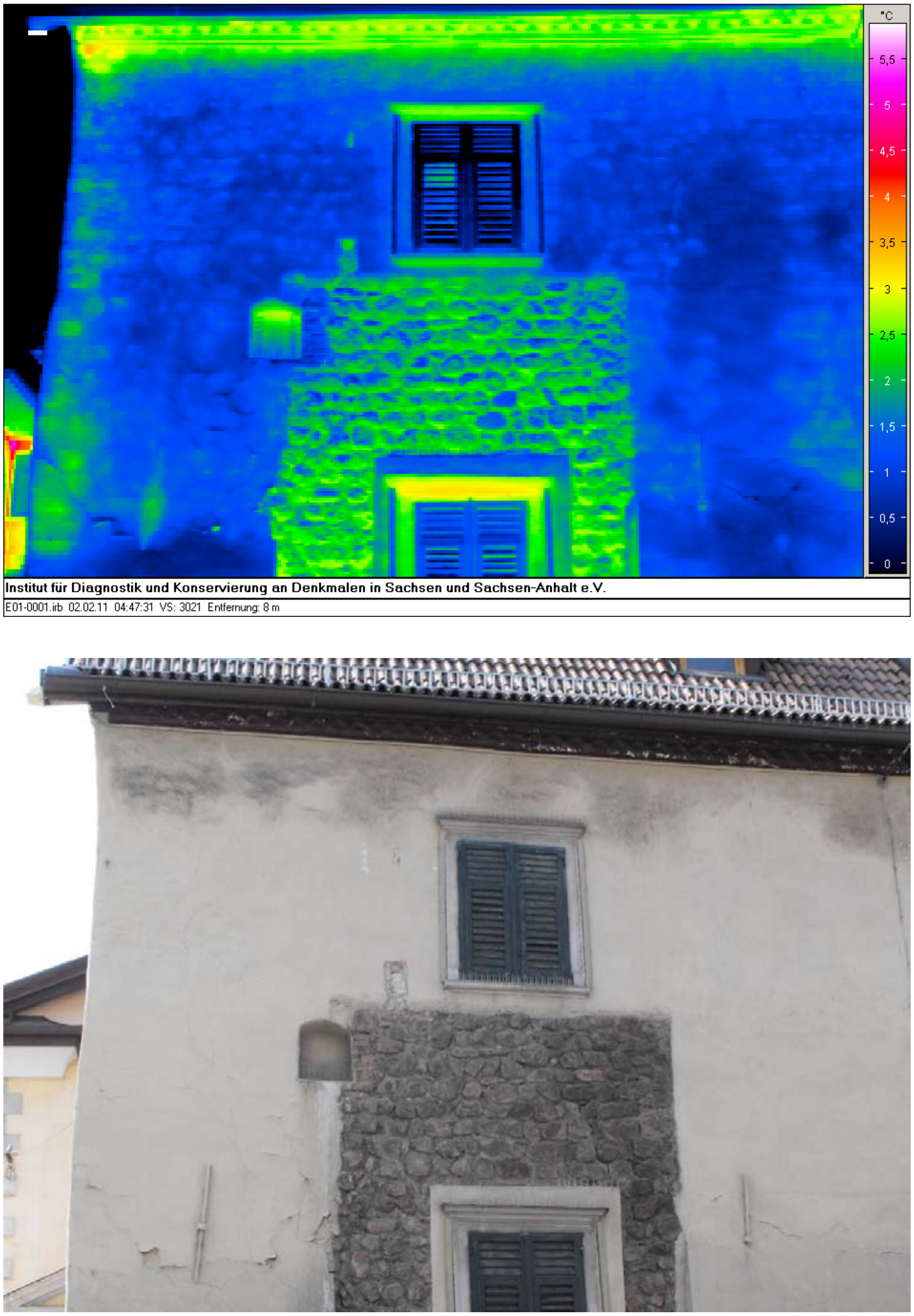


Figure 4: Eastern façade: additional information on masonry structure also behind plastered areas

Figure 5: Eastern façade: information on masonry structure on completely plastered areas, arc construction

Southern facade

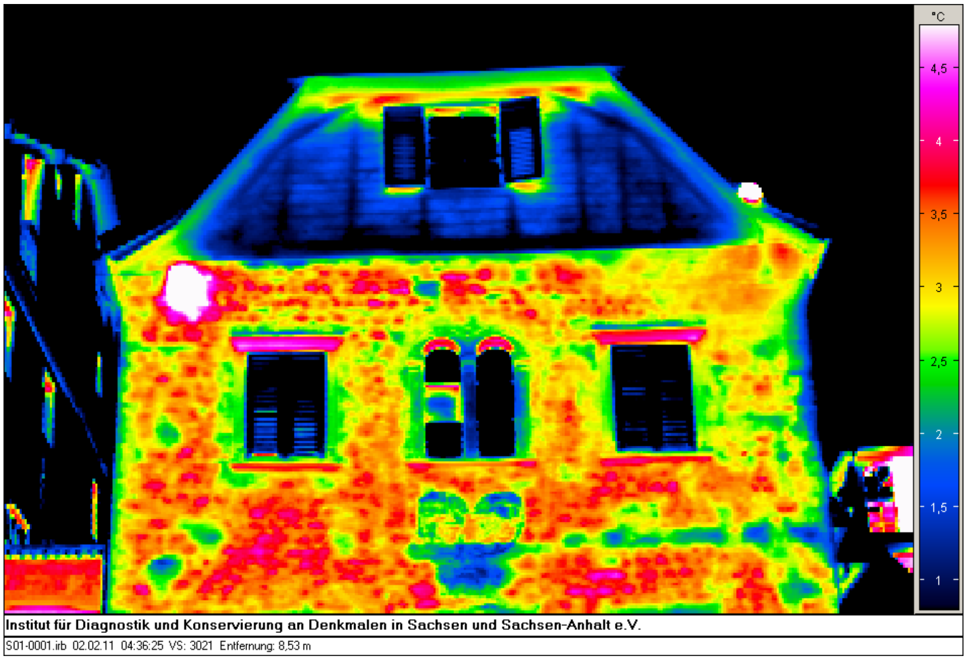


Figure 6: Southern façade: information on masonry structure in plastered areas, arc construction, attic

1.2.1 Physical and mechanical properties of elements

Where it was possible, the single layers of construction elements of the thermal envelope were measured precisely in terms of dimensions.

Several wooden beam-ends in the ceiling of first and second floor were opened to be able to do visual diagnosis on their exact position, their bearing in the exterior wall and on their condition (see figure …). Furthermore, number, position and dimensions of chimneys that could be used for ventilation were identified.

Figure 9: Opening of wooden beam ends

Figure 10: core drill hole from exterior wall

Additionally several material samples were taken: a core drill hole, painting and plaster samples from the exterior wall and material samples from the wooden beams and the filling of the ceiling, in order to analyse the material characteristics such as density, specific heat capacity as well as thermal conductivity, the water absorption coefficient and porosity (see figure 10 and table below).

	TUD	Remmers	TUD	TUD	TUD	Remmers			Remmers
	Gross density	**Gross density**	**Specific heat capacity**	**Thermal conductivity**	**Water absorption coefficient**	**Water absorption coefficient**			**Porosity**
	kg/m^3	kg/m^3	J/kgK	W/mK	kg/m^2s05	kg/m^2h05			[vol. %]
						1h	24h	acc. to DIN	
Exterior plaster	1567.80	1880.00	1000.00	0.7	0.1757			2.5	1
Interior plaster	1797.00	1930.00	850.00	0.87	0.87			1.6	1
Wooden beam (spruce - along grain)	528.30		2000.00	0.12	0.0582				
Wooden beam (spruce - across grain)	528.30		2000.00	0.13	0.0582				

Natural stone	2452.91		702.156	2.95	0.086				
Sand filling	2650.00		1050.00	2.1	0				
Natural stone grey		2620.00				0.1	0.1	0.1	2
Natural stone red		2540.00				1.1	0.4	0.9	2
Lime mortar		1860.00				5.0			1

Table: Measured material parameters

1.2.1 Physical and mechanical properties of elements

On-site lux measurements, obtained in a static way (at a single point in time), confirmed a punctual daylight factor in different rooms lower than 2.0%, which would be the minimum value to guarantee an acceptable supply of daylight. The daylight Factor is a ratio that represents the amount of illumination available indoors relative to the illumination present outdoors under an overcast sky. It determines the quantitative characteristics of daylight in a particular room, in order to verify if it has sufficient daylight. Especially in west, north and east oriented rooms there is a lack of daylight entering (see fig. 11), caused by the massive shading through the tight neighboring buildings. Notable is also the strong decrease of daylight towards the inside of the building. Throughout the building the type of window opening varies, the reveals are deep with few possibilities of changes/interventions.

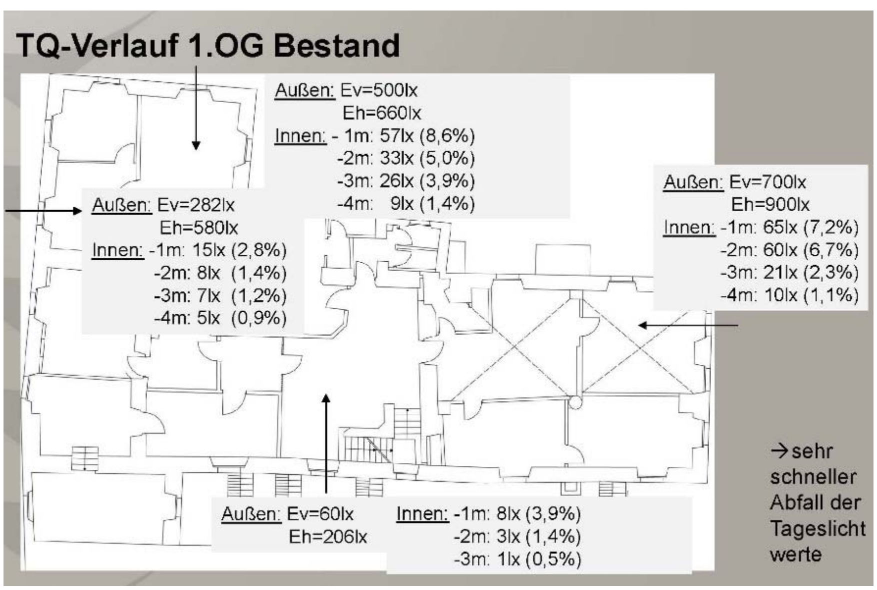


Figure 11: Gradual reduction of the daylight coefficient in north, east, south and west oriented room on the first floor of the building

1.3 Hygrothermal and environmental monitoring

This chapter contains the results from the environmental monitoring. The used monitoring system, is described in detail in Annex 2.

1.3.1 Monitoring results temperatures

The results of the temperatures are reported floor by floor. For the position of the sensors see the maps of the floors in annex I.

Basement

Table I and **Table II** show the results for the internal air temperature and for the surface temperatures on the basement floors. Figure 12 shows the yearly temperatures during 2012, Figure 13: shows the temperatures during July. The average difference between the outdoor and indoor temperature on the underground floor basement -2 is 6.2°C during summer and 4.9°C during winter; the average difference between the outdoor and the indoor temperature on the underground floor basement -1 is 4.44°C during summer and 5.22°C during winter. The basement floors have quite constant hourly temperatures, as graphically shown also in Figure 13 and 14. The most important reasons are the absence of solar radiation on the surfaces and the big thickness of the walls.

Basement-2					
Internal Air Temperature/ ATC 1162					
Minimum °C	Maximum °C	Average °C	0,25 Quantile °C	0,5 Quantile °C	0,75 Quantile °C
7,24 (17.01.2012)	19,28 (26.08.2012)	14,45	12,067	15,07	17,51
Surface Temperature/ ST 12					
7,311 (17.01.2012)	18,64 (26.08.2012)	13,95	11,59	14,53	17,07

Table I Basement-2 temperatures

Basement-1					
Internal Air Temperature/ ATC 1189					
Minimum °C	Maximum °C	Average °C	0,25 Quantile °C	0,5 Quantile °C	0,75 Quantile °C
6,44 (17.01.2012)	22,24 (21.08.2012)	14,96	11,36	15,25	18,84
Surface Temperature/ ST 33					
6,90 (17.01.2012)	22,03 (26.08.2012)	14,98	11,18	15,28	18,85

Table II Basement -1 temperatures

The following data were missing during 2012 and were all interpolated with linear interpolation

ATC 1162 AH1162, ST12 17/01 from 10 to 12; ATC 1189 AH1189 ST33 17/01 from 10 to 12;

ATC 1188 AH1188 17/01 from 10 to 12 ; ATC AH 1178 1174 1176 1155 17/01 from 10 to 12;

1189 1162 25/03 3:00. During the day 31/10 all the sensors data were missing and therefore not considered.

(legend line)	Outdoor Temperature
(legend line)	ATC 1189 -1Basement_Internal_Air_Temperature
(legend line)	ST 33 -1_Basement_Surface_Temperature
(legend line)	ATC 1162 -2 Basement_Air_Temperature
(legend line)	ST 12_-2 Basement_Surface Temperature

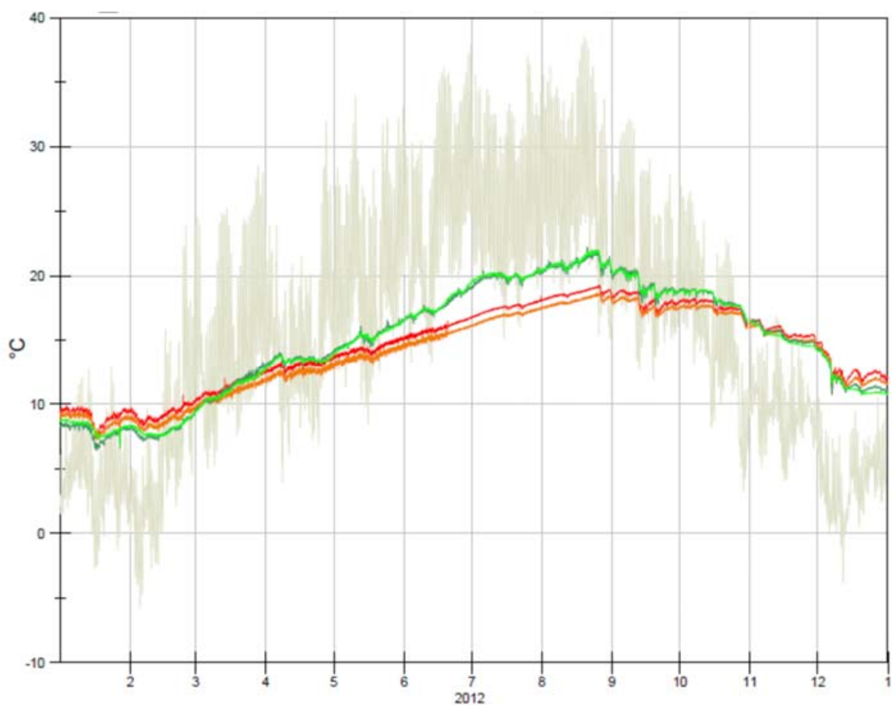


Figure 12: Basement floors yearly temperatures

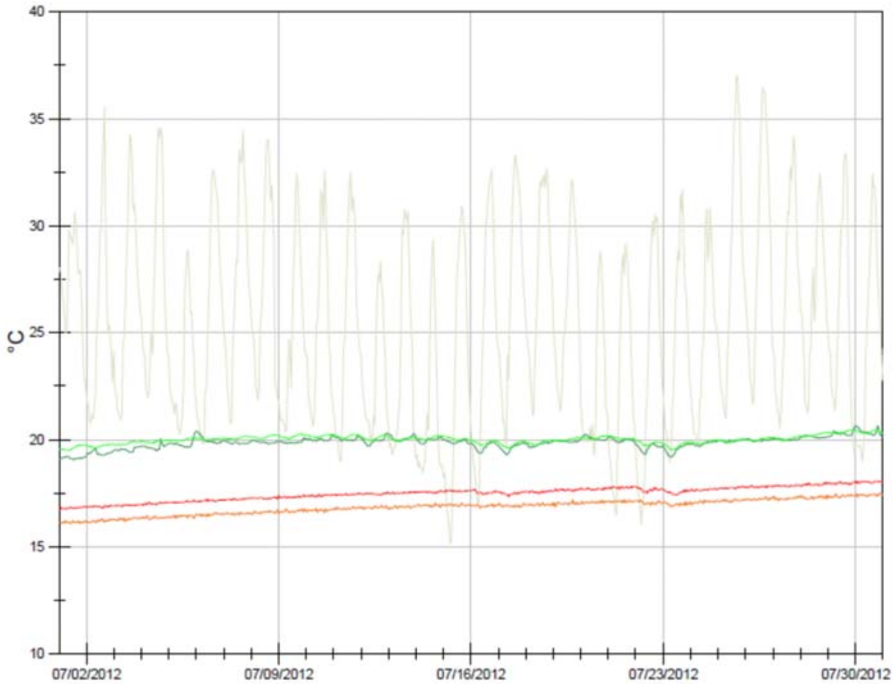


Figure 13: July Temperature

Table IV shows the difference between the surface and the air temperature during July 2012. The mean difference is of about 0,62°C for the basement -2 and of 0,14°C for the basement-1. The difference is higher than in the other floors (see Table III).

Table III Temperature difference

Basement -2 Mean Difference ST 12 and AT 1162	Basement -1 Mean Difference ST 33 and AT 1180
0,62°C	0,14°C

Table IV Difference between the surface and the air temperature in the basement floors

Figure 14: July shows the temperatures during one typical summer week in July. It is shown that the temperatures are constant during the whole period.

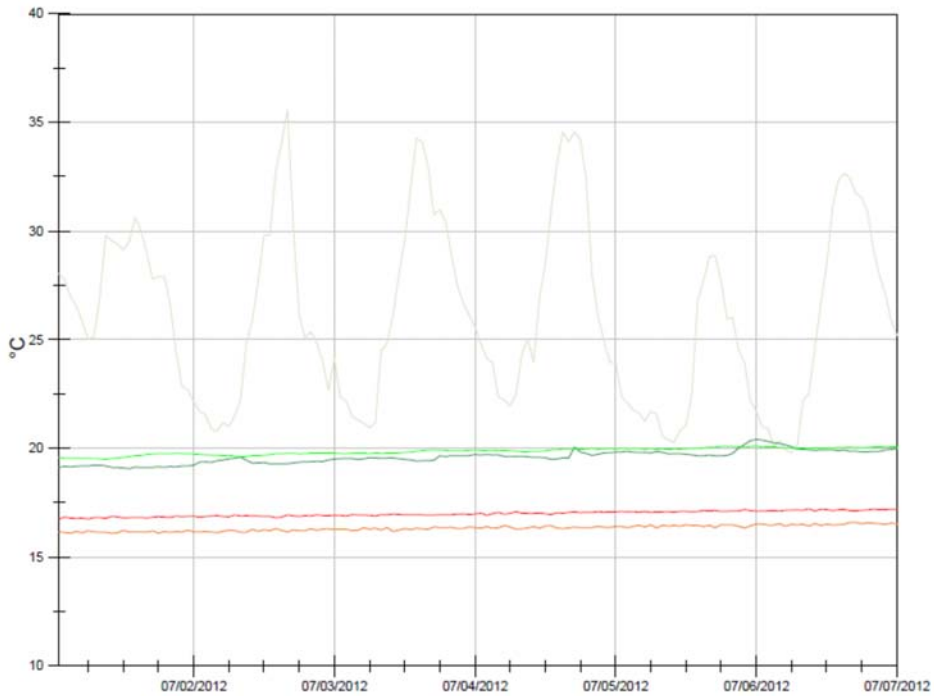


Figure 14: July_week Temperature

First floor

Table V show the temperatures of the monitored rooms on the second floor, divided by orientation. The rooms on the first floor were electrically heated and therefore they have the highest temperatures during April, when the heaters were still turned on and the outside temperatures were over 20°C. During summer the internal temperatures reached the 30°C, one reason of this high value is that there was not any shading systems on the windows. The interior hourly temperatures are quite constant during the day thanks to the big thermal inertia of the 60 cm stone walls, the variation during the hottest day in the summer 2012 (20.08.2012) is of 0.8°C, from 28.62 at 09:00 to 29.43 at 17:00, while the exterior temperature has a difference of 13,68°C, from 24,7°C at 07:00 to 38,38° C at 17:00 (see Figure 17: and Figure 18:).

The following data were missing during 2012 and were all interpolated with linear interpolation:

ATC 1177, ST46, ATC 1314 the 17th January from 10:00 to 12:00; ATC 1177, ST46, ATC 1314 from 28th February 12:00 to 27th March 01:00; ATC 1314 26th January from 16:00 to 18:00 and 27th January at 11:00; ATC 1155, ST46, ATC 1164 28th February 12:00 and 27th March 01:00.

The data of sensor ST45 were missing from 10 December 12:00 to 31 December 24:00 and therefore they were not considered.

First floor SOUTH					
Internal Air Temperature_ ATC 1155					
Minimum °C	Maximum °C	Average °C	0,25 Quantile °C	0,5 Quantile °C	0,75 Quantile °C
6,00	39,39 (03.04.2012)	24,08	21,21	24,84	28,29
Near Window Temperature_ATC 1164					
6,10	35,72 (03.04.2012)	22,96	19,90	23,31	27,74
Surface Temperature_ST 45					
6,25	38,01 (03.04.2012)	23,59	21,01	24,28	28,13

Table V First floor south oriented rooms temperatures

First floor EAST					
Internal Air Temperature_ ATC 1177					
Minimum °C	Maximum °C	Mean °C	0,25 Quantile °C	0,5 Quantile °C	0,75 Quantile °C
5,12	36,39 (04.04.2012)	22,32	19,25	23,91	27,30
Near Window Temperature_ATC 1314					
3,52	32,49 (04.04.2012)	20,35	16,79	21,01	25,80
Surface Temperature_ST 46					
4,96	33,22 (04.04.2012)	21,43	17,75	21,89	26,52

Table VI First floor east oriented rooms temperatures

Outdoor Temperature
AHC 1155 F1_South_Air_Temperature
ATC 1177 F1_East_Air_Temperature
ATC 1164 F1_South_ Near Window _Temperature
ATC 1314 F1_East Near Window_Temperature
ST 45 F1_South_Surface_Temperature
ATC 1314 F1_East Near Window_Temperature
ST 46_ F1_East_Surface_Temperature

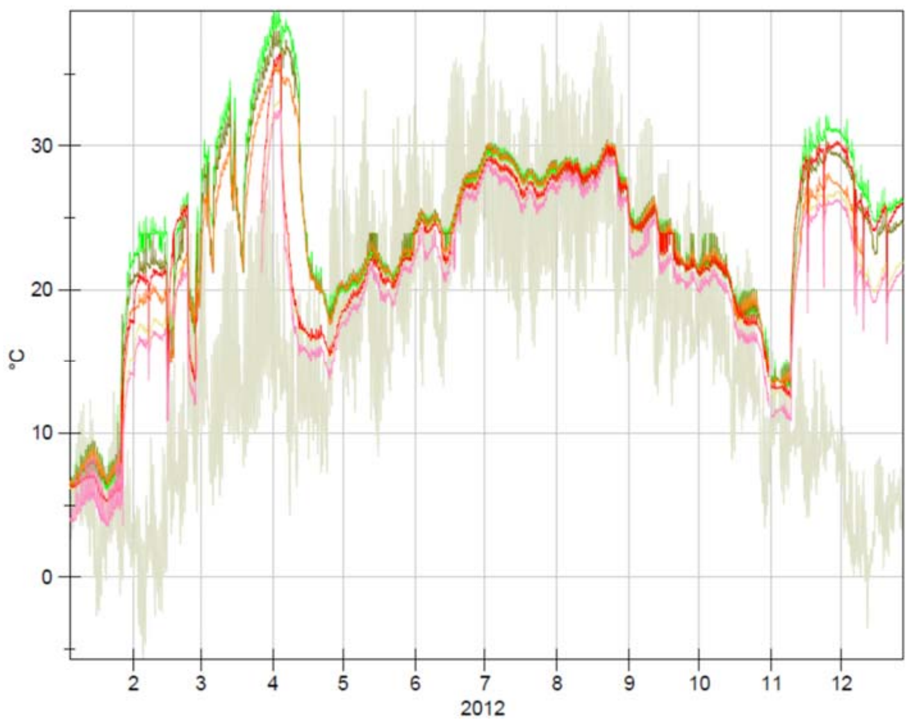


Figure 15: Yearly Temperature on the first floor

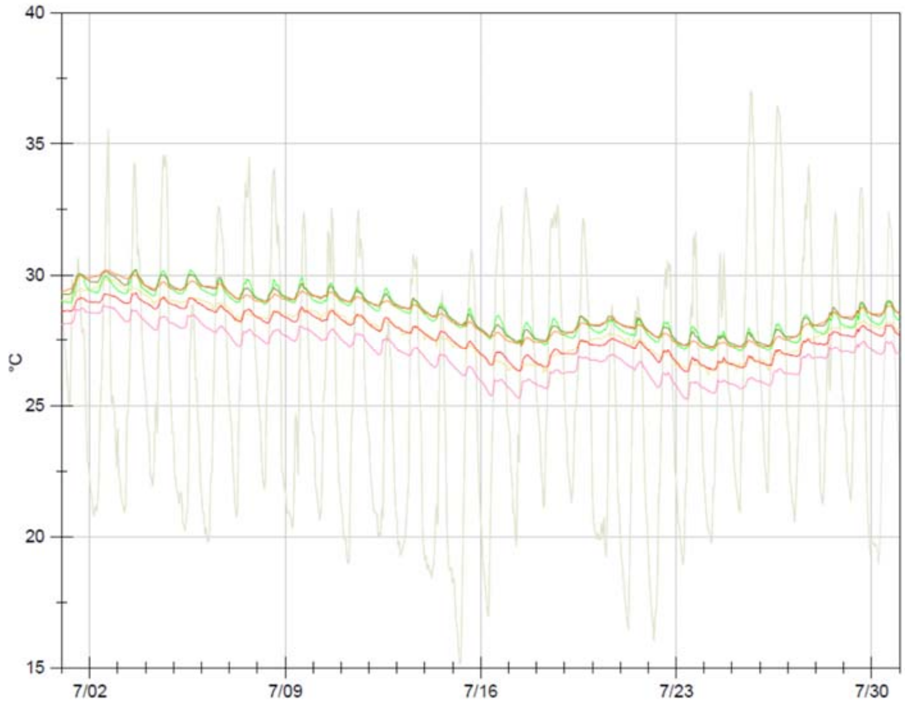


Figure 16: July temperature on the first floor

Table VII shows the difference between the surface and the air temperature during July 2012. The mean differences are low, especially on the first floor south oriented, where it is of about 0,01°C.

F1 Mean Difference ST 45 and AT 1155	F1 Mean Difference ST 46 and AT 1177
0,01°C	0,1°C

Table VII Difference between the surface and the air temperature on the first floor

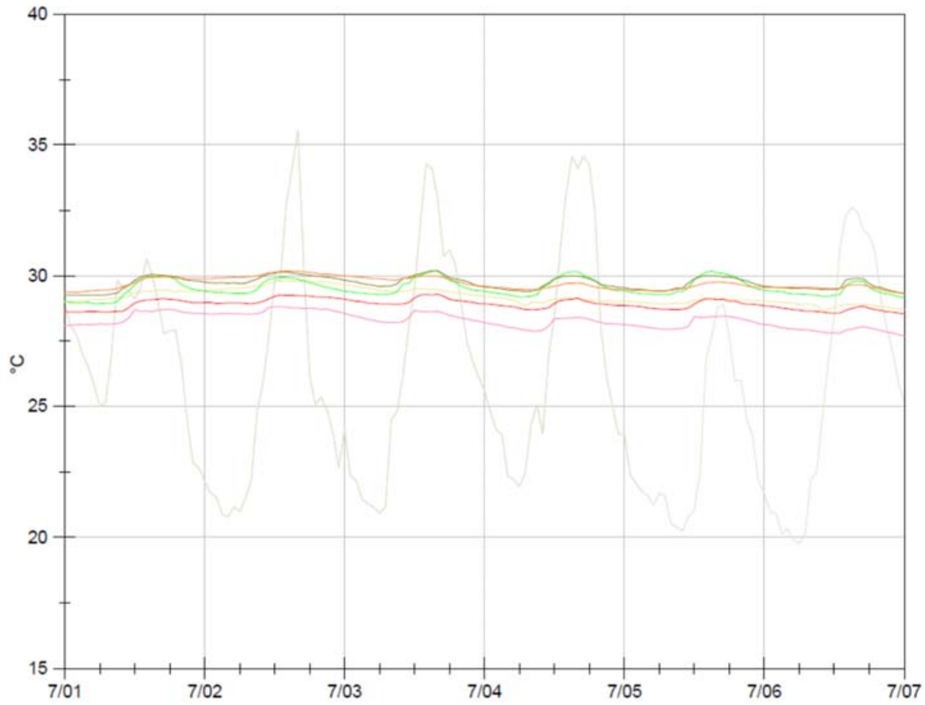


Figure 17: July_week temperature on the first floor

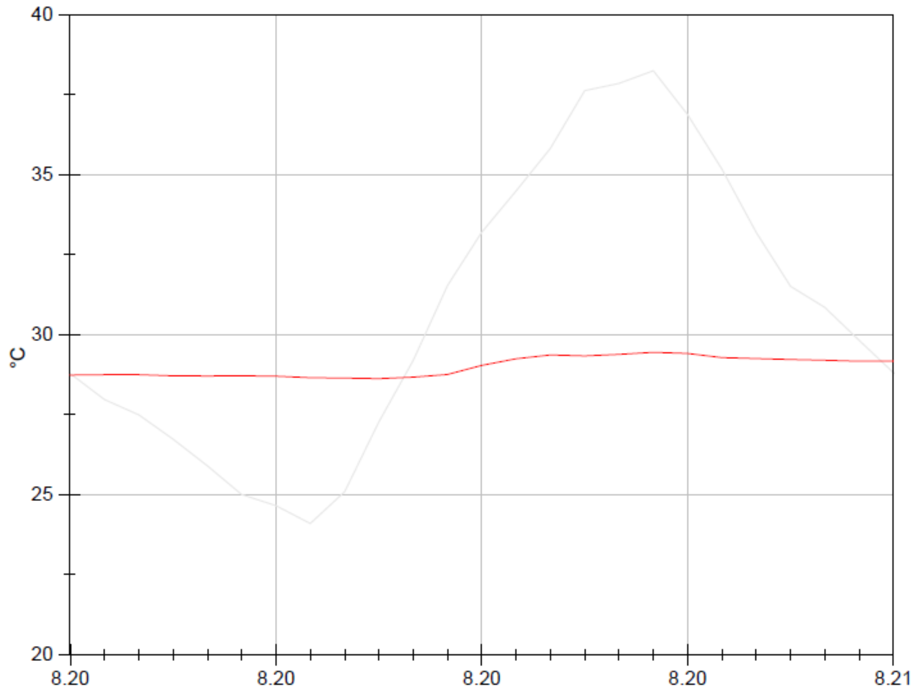


Figure 18: Temperatures during the hottest day 20.08.2012 on the first floor

Second floor

Table VIII and **Table IX** show the temperatures of the air, the surfaces and near the windows in the south and east oriented rooms. As for the first floor, the rooms on the second floor were electrically heated and therefore they have the highest temperatures during April. During summer the internal temperatures are higher than the ones on the first floor, because of the higher exposition to the sun radiation. As on the first floor, there was not any shading systems on the windows. Also in this case, the temperatures are constant during the day (see Figures) thanks to the big inertia of the thick stone exterior walls.

Second floor SOUTH					
Internal Air Temperature_ ATC 1163					
Minimum °C	Maximum °C	Mean °C	0,25 Quantile °C	0,5 Quantile °C	0,75 Quantile °C
4,87 (21.01.2012)	35,85 (01.04.2012)	23,00	20,01	23,94	28,05
Near Window Temperature_ATC 1156					
4,12 (21.01.2012)	32,46 (01.04.2012)	21,41	18,21	22,20	26,21
Surface Temperature_ST 20					
4,23 (21.01.2012)	32,13 (01.04.2012)	21,36	17,97	22,27	26,13

Table VIII Second floor south oriented rooms temperatures

Second floor East					
Internal Air Temperature_ ATC 1184					
Minimum °C	Maximum °C	Average °C	0,25 Quantile °C	0,5 Quantile °C	0,75 Quantile °C
5,32 (21.01.2012)	34,41 (01.04.2012)	22,13	18,51	22,54	27,23
Surface Temperature_ST 34					
4,32 (21.01.2012)	30,84 (01.04.2012)	20,36	16,88	21,25	25,37

Table IX Second floor east oriented rooms temperatures

Outdoor Temperature
ATC 1163 F2_South_Air_Temperature
ATC 1184 F2_East_Air_Temperature

ST 20 F2_South_Surface_Temperature
ST 34_ F2_East_Surface_Temperature
ATC 1156 F2_South_Near Window _Temperature

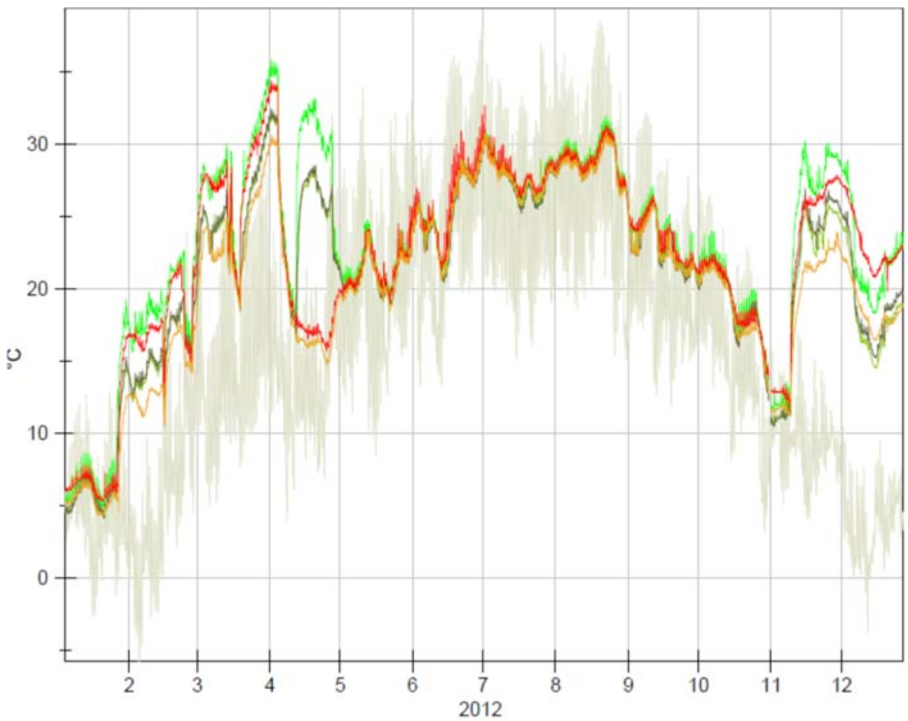


Figure 19: Yearly Temperature

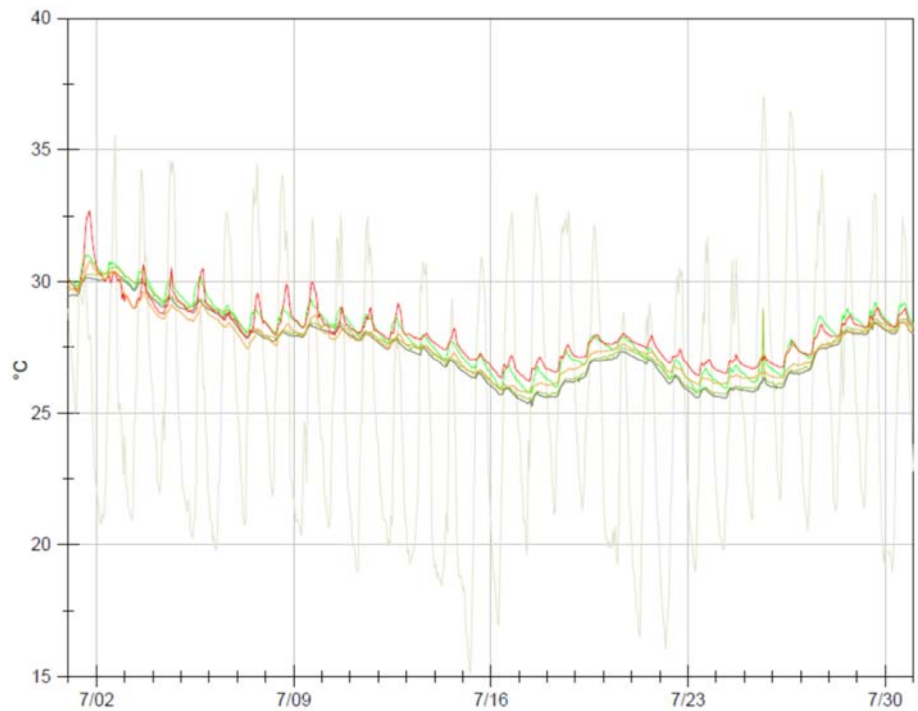


Figure 20: Figure 7 July Temperature

F2 Mean Difference ST 20 and AT 1163	**F2 Mean Difference ST 34 and ST 1184**
0,3°C	**0,44°C**

Table X Difference between the surface and the air temperature on the second floor

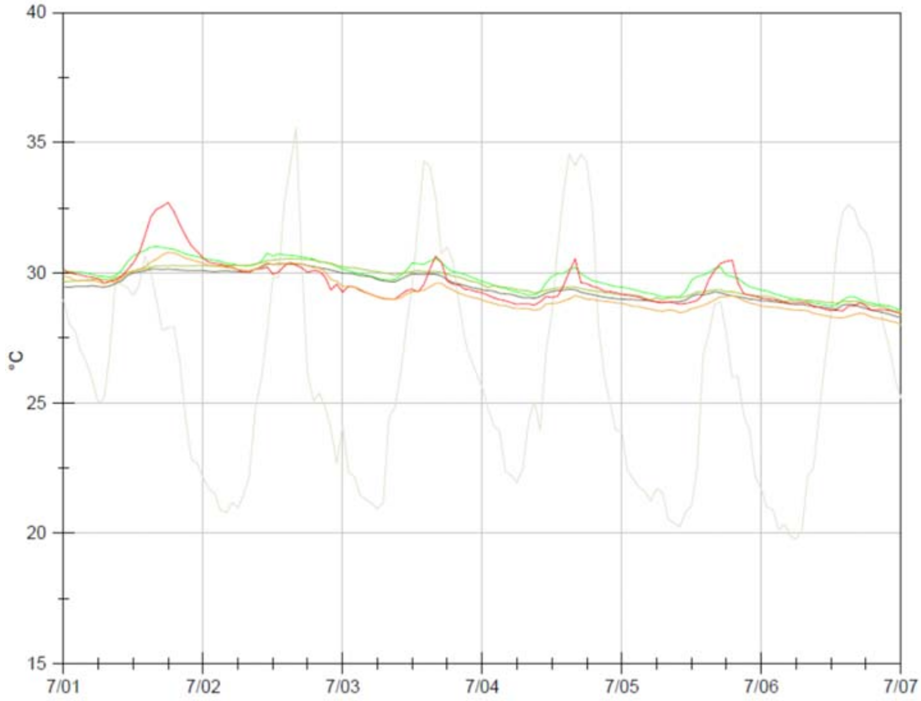


Figure 21: July week temperature

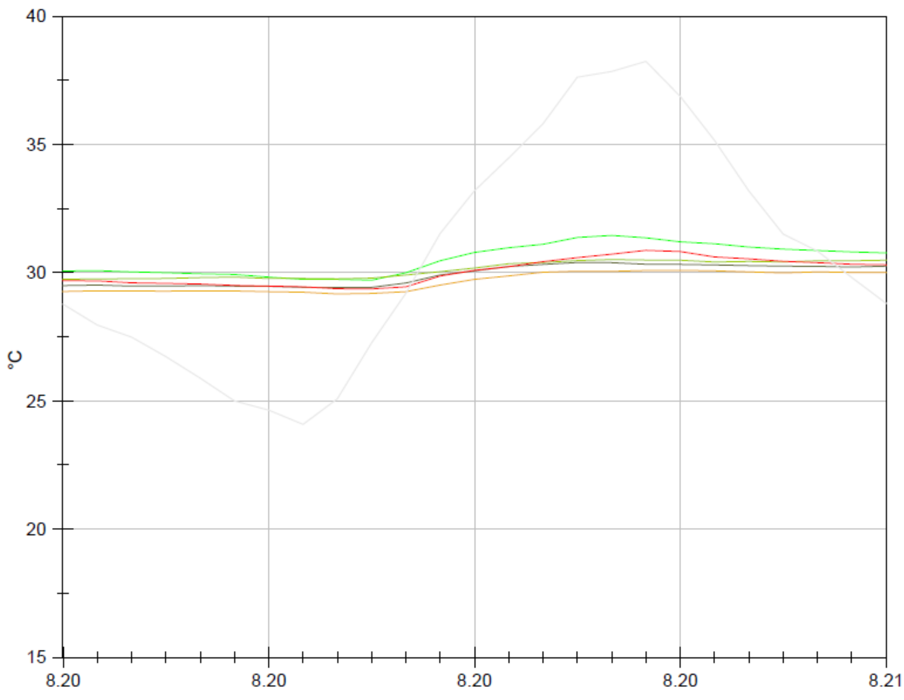


Figure 22: Temperatures during the hottest day 20.08.2012 on the second floor

Top floor

Table XI and **Table XII** show the temperatures of the air, the surfaces and near the windows in the south and north parts of the top floor. The rooms on the top floor were not heated during winter, therefore the minimum inside temperature are lower than on the other floors (see Figure) reaching the 0,9°C on the 05.02.2012. On the contrary of the other floors, the top floor has wooden roof and wooden exterior walls. These materials with low thermal capacity are responsible of the high fluctuations of inside hourly temperatures, especially during the summer. The variation during the hottest day in the summer 2012 (20.08.2012) is of 5.7°C, from 28.94 °C at 11:00 to 34.64 °C at 18:00, while the exterior temperature has a difference of 13,68°C, from 24,7°C at 07:00 to 38,38° C at 17:00 (see Figure).

Top floor SOUTH					
Internal Air Temperature_ ATC 1186					
Minimum °C	Maximum °C	Mean °C	0,25 Quantile °C	0,5 Quantile °C	0,75 Quantile °C
0,90 (05.02.2012)	34,65 (20.08.2012)	17,30	10,60	18,29	24,24
Surface Temperature_ST 16					
0,78 (05.02.2012)	34,34 (20.08.2012)	17,20	10,58	10,09	23,66

Table XI Top floor south oriented rooms temperatures

Top floor NORTH					
Internal Air Temperature_ ATC 1183					
Minimum °C	Maximum °C	Average °C	0,25 Quantile °C	0,5 Quantile °C	0,75 Quantile °C
1,29 (06.02.2012)	33,95 (01.07.2012)	17,41	10,49	18,17	24,59
Surface Temperature_ST 50					
0,844 (06.02.2012)	33,40 (01.07.2012)	17,05	10,23	17,73	24,20

Table XII Top floor north oriented rooms temperatures

Outdoor Temperature
ATC 1183 TF_North_Air_Temperature
ATC 1186 TF_South_Air_Temperature
ST 50 TF_North_Surface_Temperature

ST 16_South_Surface_Temperature

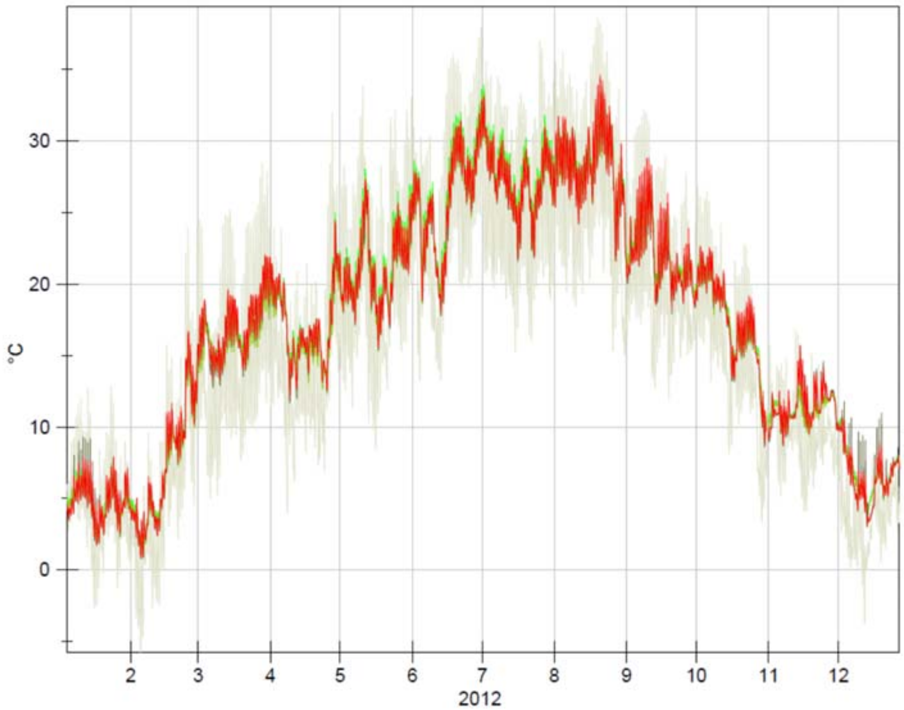


Figure 23: Yearly temperature on the top floor

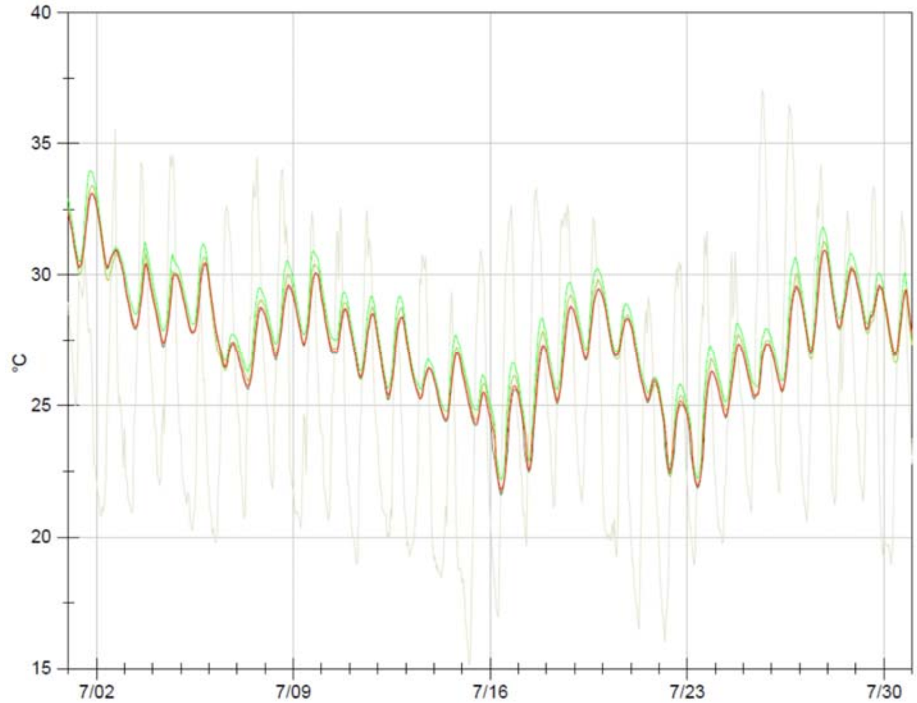


Figure 24: July Temperature on the top floor

TF Mean Difference ST 50 and AT 1183	TF Mean Difference ST 16 and AT 1186
0,4°C	0,06°C

Table XIII Difference between the surface and the air temperature on the top floor

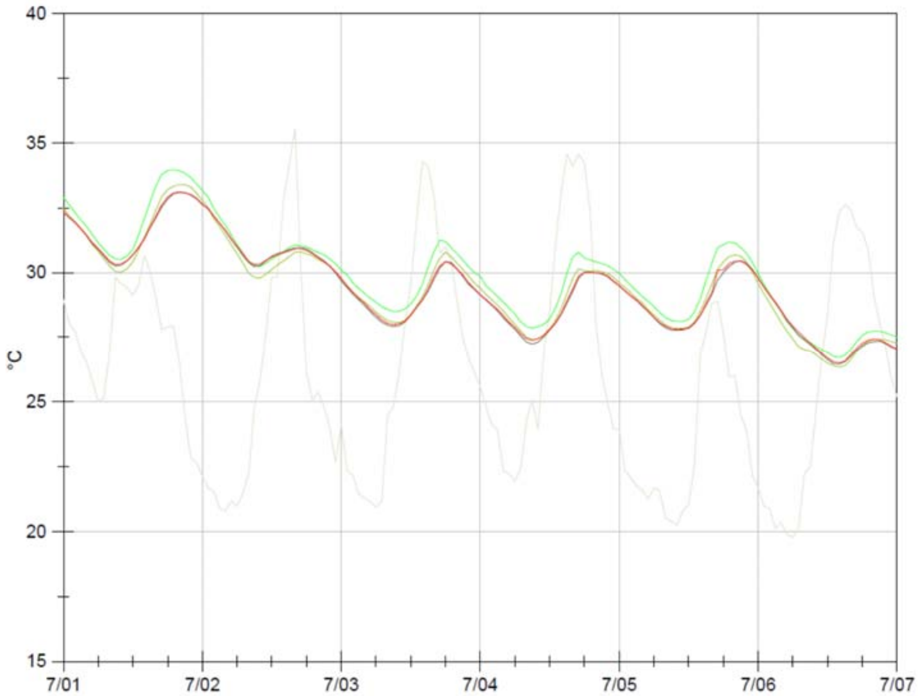


Figure 25: Week Temperature on the top floor

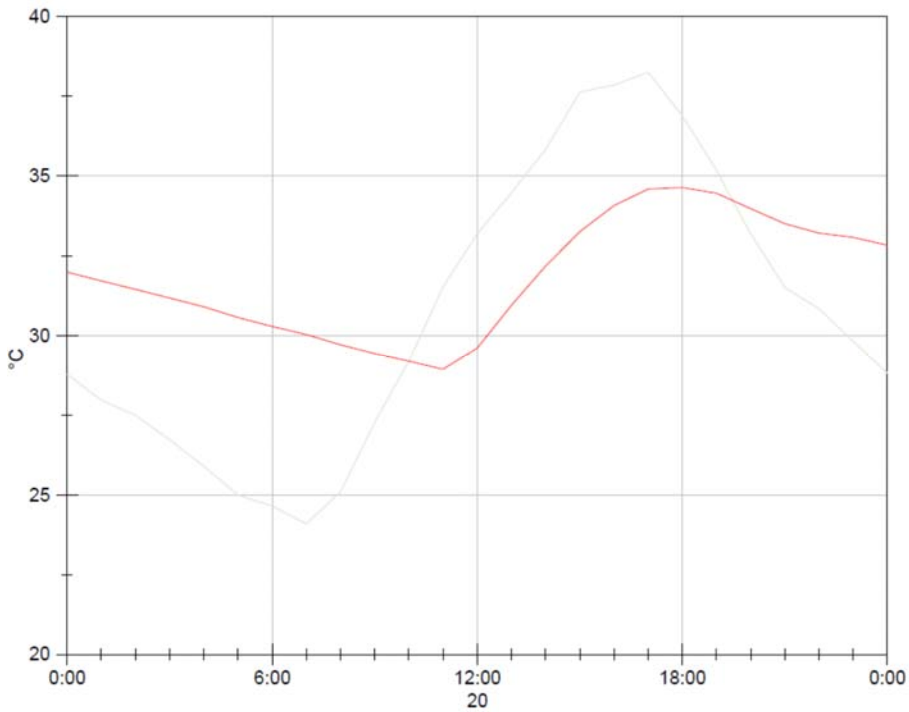


Figure 26: Temperatures on the top floor during the hottest day 20.08.2012

1.3.2 Monitoring results humidity

All floors

Figure 27 shows the internal air humidity on the monitored rooms an all the floors. The basement has the highest relative humidity both during summer and winter mainly because of the absence of ventilation or heating system. The rooms on the first and second floor have the lowest humidity during winter when the electric heaters are turned on.

External_ Air_Humidity
AHC 1162-2 Basement_Air_Humidity
AHC 1188 GF_ Staircase_Air_Humidity
AHC 1177 _F1_ East_Air_Humidity
AHC 1184 _F2_ East_Air_Humidity
AHC 1183 TF_North_ Air_Humidity

The following data were not available, and therefore they were not considered: AH1177 01 March 00:00 to 27 March 00:00.

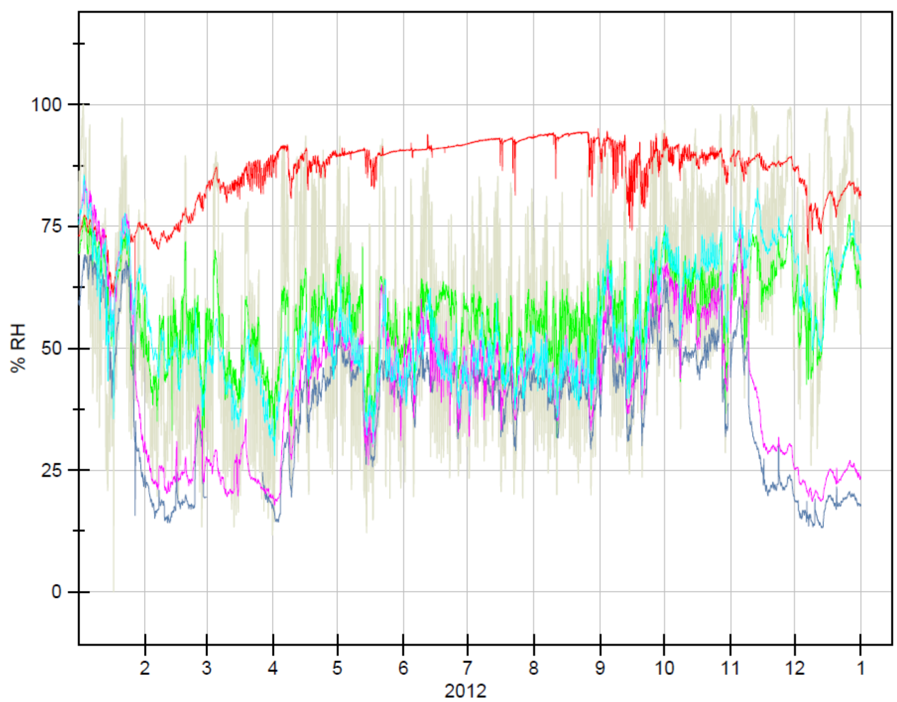


Figure 27: Yearly humidity all floors

1.4 Results derived from the application of PHPP

The heating energy demand for the building (as-is-state, including top floor), calculated with the software PHPP (Passive House Planning Package) is **225 kWh/m²h**. Looking at the energy balance of the building and respectively at the distribution of heat losses over the thermal envelope, we can see, that the low thermal resistance of the exterior walls causes with 38% most of the heat losses. Followed by the ventilation heat losses (19%) and the windows (16%). 22% of the transmission heat is lost over the isolated part of the roof, the walls and ceilings towards the unheated part of the roof and the ceiling of the walkway. The rest is caused by the baseplate towards the soil and the unheated cellar as well as the entrance doors (5%).

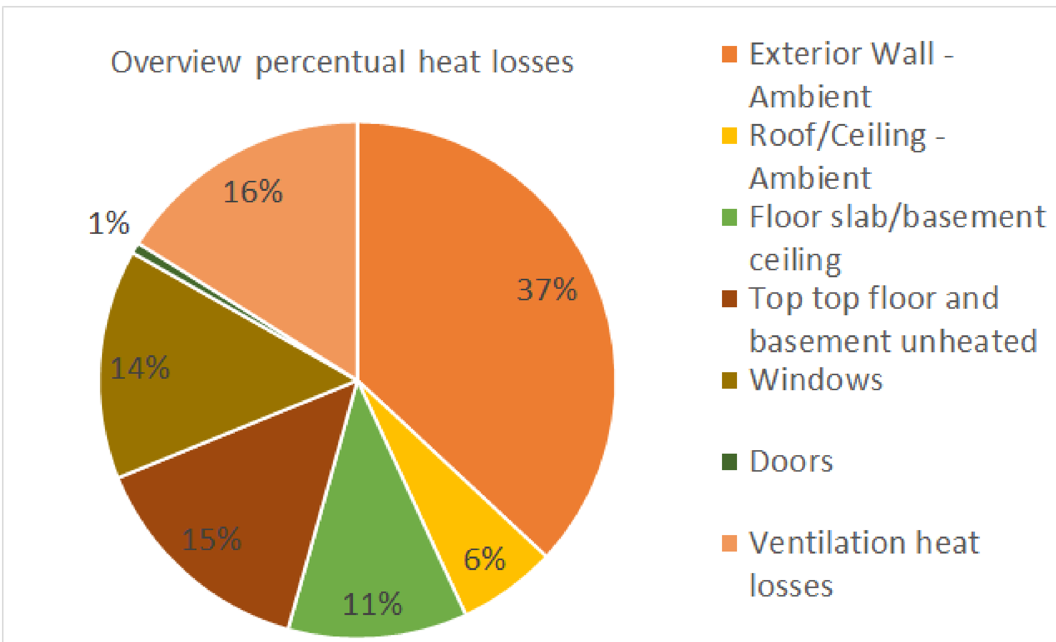


Figure 28: Energy balance of the building: distribution of heat losses over the thermal envelope

1.5 Overall rating

As conclusion of the pre-intervention analysis and a base for the refurbishment planning the following problems were identified:

- high transmission heat losses through opaque parts of the thermal envelope and through windows
- high infiltrations respectively uncontrolled ventilation heat losses mainly caused by not tight/leaking windows
- slight overheating in summer, mainly in the south part and on top floor
- lack of daylight, particularly in north, east and west oriented room (towards tight neighboring buildings)
- high relative humidity in basement floors (mold grow risk)
- condensation and mold grow risk in window reveals and weak points of the thermal envelope (putty)

2 Design

2.1 Simulation

The calculation of the heating energy demand shows that it is possible to reduce the energy demand for heating to 50% considering the proposed refurbishment interventions.

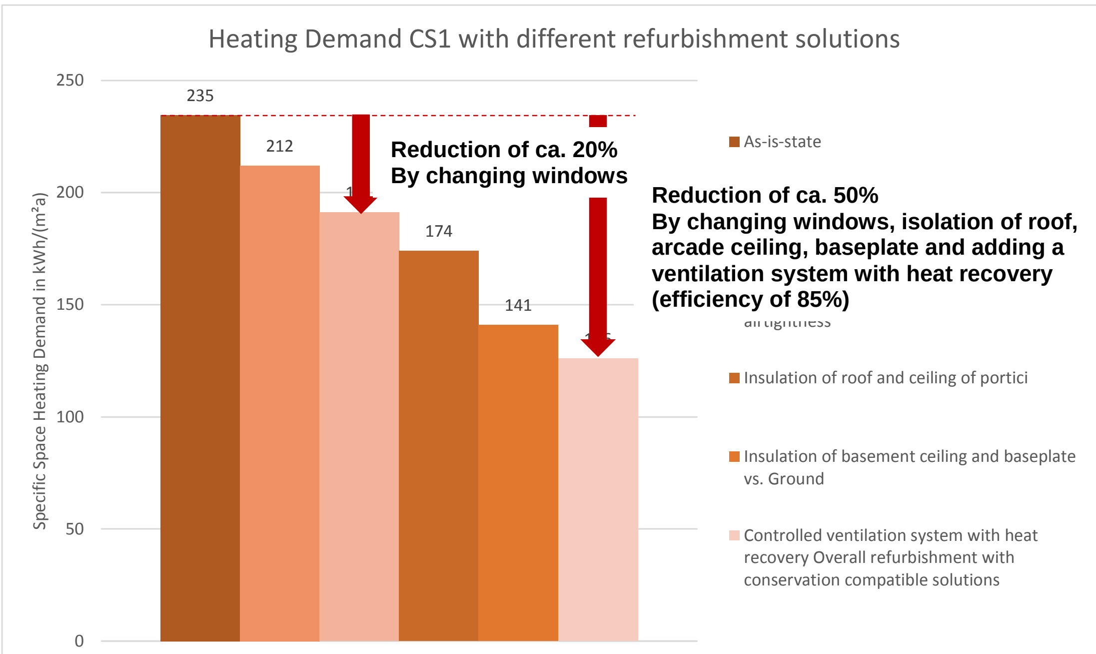


Figure 29: Heating energy demand of Public Weigh House: Reduction of 20% by enhancing the windows, reduction of 50% implementing all heritage compatible interventions

2.2 Planned solutions

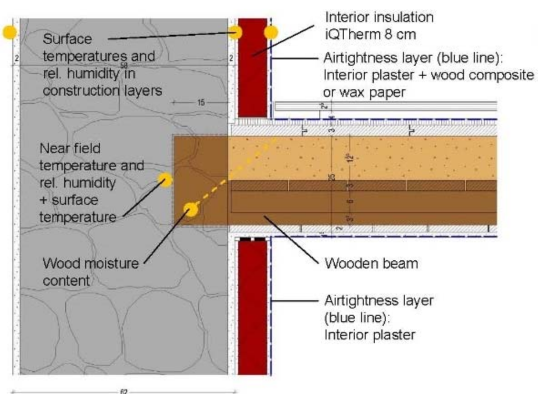
2.2.1 Solution package

Based on the comprehensive study a retrofit concept was proposed, improving energy performance and environmental comfort while simultaneously maintaining the architectural and artistic value of the building. The local case study team concentrated on passive architectonical solutions that are independent from the building use, as the specific use for the single rooms was still not committed.

INSULATION OF OPAQUE PARTS OF THE BUILDING

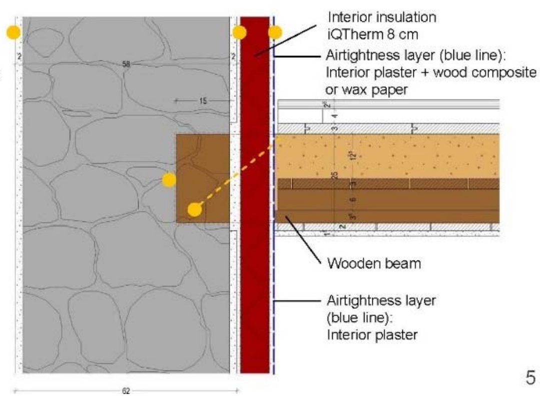
- **Insulation of walls:** As stated before, the historic plaster should stay the outermost visible layer. Only a reversible internal insulation in some rare, carefully selected, parts of the building is possible.
- In case of the installation of internal insulation, inevitable thermal bridges are remaining in the area where the outer wall is connected to internal construction elements (interior walls and ceilings). The particular difficulty regarding the application of interior insulation in the Weigh House is that the interior floors are built with wooden beams. In case of installation of an insulation, temperatures on the surface (and on the inside) of the original structure are lowered, the wooden beams are then in a cold area, with the risk of condensation at the heads of the beams. It is therefore important to prevent warm moist indoor air, through an "airtight" layer, from flowing to the inside of the structure. It is crucial to "study well the thermal bridge" and to solve the "airtight" connection between internal insulation and wooden beams
- The internal insulation system was realized in a representative “test room” using the capillary active insulation (IQTherm λ = 0,026 W/mK). To realize the reversibility of the insulation layer, the panels are fixed with a clay-based glue, which allows the removal of the insulation also after their installation.
- For the Public Weigh House therefor two possible solutions have been developed, that are transferable to similar wall/ceiling connections. Both executions have been studied with the software Delphin, a simulation program for the coupled heat and moisture transport: one case with an “interrupted” insulation and another case with the “continued” insulation (see scheme).

Version I: „interrupted” insulation



- Continuous airtight layer: internal plaster connected on the upside of the ceiling with airtight horizontal wooden composite through flexible airtight adhesive tape. Downside of the ceiling: Between insulation panel and existing ceiling plaster: compression tape. Continuous airtight layer is here the internal plaster (wall and ceiling)
- Advantages: minimum impact to the ceiling construction, less work
- Disadvantages: thermal bridge in the area of the ceiling, airtightness layer may be interrupted at the transition to the next room (interior door).

Version II: „continued” insulation



- Continuous airtight layer: internal plaster, which have to be connected with a flexible airtight material all around the wooden beam. In case of cracks in the wooden beam, that pass through the airtight layer, they have to be closed (e. g. by gluing of wooden dowels)
- Advantages: less heat losses, continuous airtight layer
- Disadvantages: connection wooden beams/internal insulation, higher impact on ceiling construction

Table: Scheme of wall/ceiling connection with internal insulation

REPLACEMENT/ENHANCEMENT OF WINDOWS AND BUILDING AIRTIGHTNESS (see also chapter 2.2.2)

- The rare original windows from the late baroque are energetically enhanced with an additional second window layer, while the windows from the 1950s should be replaced with new windows, which fit better the historic context. In a tight collaboration of local case study team, window developer and conservator a high energy efficient heritage compatible window with passive house standard was developed (see also chapter 2.2.2).
- Replacing the windows means at the same time a large reduction of infiltration, improving the “airtightness” of the building. In the existing building infiltrations cause a large part of the heating energy demand. With the “air leakage test” it was verified, that (the not well maintained) windows cause a main part of the ventilation heat losses.
- Taking into account the window energy balance (losses minus gains) the net losses can be reduced by 70% (double glazing vs. original window) or respectively 80% (triple glazing). Looking at the total energy balance of the whole building with 14% of window area and walls in natural stones, the exchange of windows can reduce the demand by up to 20%: 10% due to thermal performance increase, 10% due to airtightness improvement (need for indoor air quality considered, without heat recovery).
- U-values existing (box-type) window: Ug = ca. 2,8 W/m²K; Uf = ca. 2,5 W/m²K; Psi installation (without parapet) = 0,238 W/mK; Psi installation (with parapet) = 0,194 W/mK; g-Value = 0,77
- U-values new window after intervention: Ug = ca. 0,57 W/m²K; Uf = ca. 0,97 W/m²K; Psi installation (without parapet) = 0,164 W/mK; Psi installation (with parapet) = 0,124 W/mK; g-Value = 0,44

INSULATION OF ROOF OR OF CEILING OF THE UPPERMOST FLOOR/INSULATION OF SLAB TOWARDS WALKWAY/ARCADES

- Current state of the roof: the top floor is in parts inhabited/heated, the roof is isolated from the inside with a system of 8 cm rock wool covered with plasterboard. In the actual situation the insulation does not fulfil its purpose: it is in parts displaced and there is no “airtightness” layer foreseen.
- **Insulation of saddle roof:** 25 cm of insulation (lambda 0,042), 11 cm between rafters, 14 cm from below.
- U-value existing roof: isolated part of the roof: 1,384 W/m²K (transmittance measured on site); not isolated part of the roof: 2,606 W/m²K
- U-value roof after intervention: 0,171 W/m²K
- Current state of the ceiling over the arcades: Inserted floor ceiling in wooden beams with wooden casing and filling material of sand, earth and little stones in between. The underside of the ceiling is plastered with lime plaster. The floor construction consists of a wooden substructure and wooden boards.
- **Insulation of ceiling over the arcades:** substitution of existing filling material between the beam with insulation (lambda 0,042) of about 18 cm, additionally one continuous layer of 3 cm (lambda 0,042) on the wooden beams
- U-value existing ceiling: 0,437 W/m²K (transmittance measured on site)
- U-value ceiling after intervention: 0,173 W/m²K

INSULATION OF BASEPLATE ON GROUND AND OF BASEMENT CEILING

- Current state of the baseplate on ground: the baseplate on ground is probably a slab in concrete, floor covering in ceramic tiles

- **Insulation of baseplate:** 12 cm of perlite in the pavement structure (thermal bridges caused by interior walls!); (lambda 0,05 W/m²K)
  - U-value existing baseplate: 2,664 W/m²K (transmittance measured on site)
  - U-value baseplate after intervention: 0,36 W/m²K

- Current state of the basement ceiling: the basement ceiling is a vaulted ceiling of natural stones with lime mortar joints, floor covering also in ceramic tiles
- **Insulation of basement ceiling:** 12 cm of perlite in the pavement structure (thermal bridges caused by interior walls!); (lambda 0,05 W/m²K)
  - U-value existing basement ceiling: 1,028 W/m²K (transmittance measured on site)
  - U-value basement ceiling after intervention: 0,297 W/m²K

INSTALLATION OF A CONTROLLED VENTILATION SYSTEM WITH HEAT RECOVERY

- Installation of a controlled ventilation system with heat recovery (efficiency 85%) to decrease the ventilation heat losses. Installation outside the thermal envelope in the basement floor.

2.2.2 Development of an energy efficient heritage compatible window

As mentioned above, the major part of the original windows are not of historic value from conservator's point of view and should be replaced, reproducing the appearance of a historic window. For the development of such a new window the aim was to (i) build a highly energy efficient window with Passive House quality and (ii) a window that answers to the heritage demands of the building.

The heritage value of the windows and development of a holistic façade concept

Before starting with the enhancement of existing windows, a holistic façade concept for the whole building has to be elaborated in tight collaboration with the conservator. This overall window concept is based on a detailed acquisition and evaluation of every single window during an (interdisciplinary) on-site inspection, describing window typology, state of conservation, construction, materials, installation, surrounding framing (profiled stone frame etc.), type of window sash, glazing, wood joints, fittings and additional equipment such as window shutters etc. From the façade concept emerges which (part of) windows and additional equipment must be retained and which parts can be replaced, as well as the position of the original/new window or respectively the position of an additional new second window layer and how to treat the surrounding framing (reveals, profiled stone frame).

When developing the façade concept, it is crucial to consider not only the thermal performance of the window itself, but also the connection window-wall and the energy balance of the whole building – in order to optimize the heat losses and, most importantly, to assure sufficient internal surface temperatures to avoid condensation and mould growth.

Approach in case of the Public Weigh House:

A first workshop with window developer and producer, building physicist, architect and conservator, helped to understand the aesthetic, visual, formal and functional needs of the new window, before starting with the development of a first concept. It was important to know typical characteristics of local historic windows and relevant recurrent problems in connection with energy refurbishment of protected windows (see figures 30-35). From conservator´s point of view, two aspects of the original appearance of (local) historic windows should be adopted to the new window: (i) the original proportion between glass area and sash bars and window frame and (ii) the optic appearance of original historic glazing.

Figure 30-35: Originally, the wooden frames, impost and sash bars were very fragile and thin, possibly moulded (fig. 30-32), while the optic of the typical replacements is much broader (simple application of the IV68 standard, fig.33-35).

Exchanging historic single glazing with double-glazing changes the look to the façade because of different reflection and mirroring, caused by (i) convex or concave deformation of the glass pane through expansion and contraction of gas between the two glass layers, (ii) different surface finish of flat modern float glazing compared with traditional mouth-blown historic glazing and (iii) more regular reflection if subdivisions are not any more glass-dividing (and thus not causing different glass inclination)

In an expert workshop the overall window concept for the whole building was developed: for some rare original windows from the late baroque era, it was decided to possibly enhance them from energetic point of view with an additional second window layer, while the windows from the 1950s should be replaced with new windows, which fit better the historic context.

As there were no drawings from the original historic window available, the new window was based on a “classic” (coupled) window in terms of function, division and proportion, two sashes with two sash bars each. The developed concept separates the demands and functions into two layers: one outer layer for the reproduction of the original historic window and an inner layer for high energy efficiency. In this way, it is possible to obtain the same appearance like the original historic window from outside in terms of frame dimensions, sash bars and mirroring by taking a single glazing, without any negative effect on the energy efficiency. This outer layer takes over the weather tightness. The passive house window with triple glazing is integrated in a second additional inner layer, taking over the airtightness. By rotating the frame cross section 90 degrees and by moving the centre of rotation of the fitting, a smaller frame than the conventional solution was achieved (see figures 36 above). It is positioned in a way that its frame is not visible from the outside. Following to this approach, both box-type and a coupled window are executable (see figures 36 below). Additionally, it allows also preserving the original old window and just adding the second energy efficient layer (on the inside or also on the outside).

On the installed prototype of the coupled window version the conservator evaluated if heritage demands have been fulfilled: the appearance of the outer single glazing and the optic of the inner triple glazing, the proportions, subdivision and frame thickness and the evaluation of the concept of “division of functions” as well as colour and profiling. Based on this feedback the prototype was developed further. Since in the meanwhile a building historian had discovered traces of cut out imposts (in some rare cases where the outer sashes the of box-type window from the 1950s/60s where installed in an original baroque frame), the new prototype was also built with a horizontal impost and four window sashes (2 above, 2 below). As model served the still existing window with impost in the jutty. The use of the very thin triple glazing (2/8/2/8/2), with the thickness of a double glazing, made it possible that the frame proportion became even more fragile and the optic from inside becomes very similar to a double glazing (see figure 37).

The application of the concept and the execution of the window prototype profited from the flexibility, experience and know-how of the small traditional window producer, which is able to tailor his facilities to the production of this individual adapted windows.

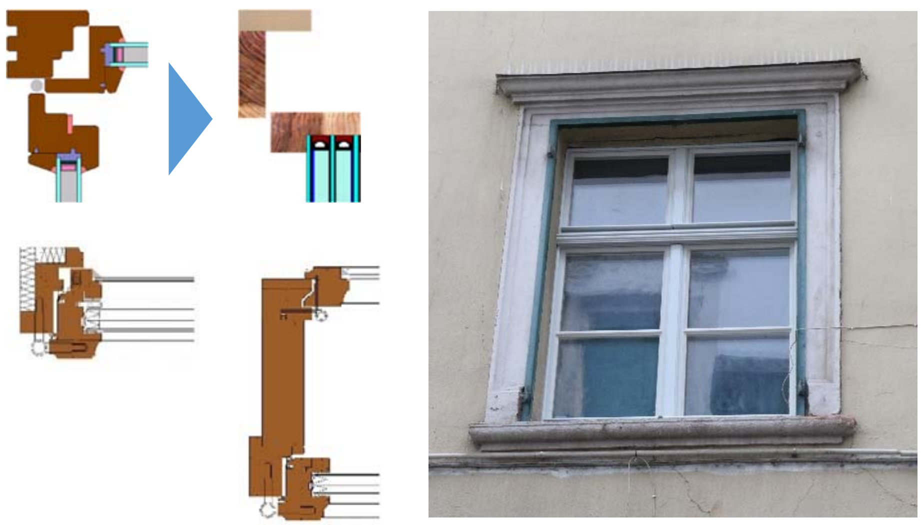


Figure 36-37: rotation of the frame cross section by 90 degrees (fig. 36 above) to achieve a smaller frame; separation of functions into two layers: “historic” window outside, integration of passive house window inside (fig. 36 below), last prototype installed in the Weigh House (fig. 37).

With regard to the window-wall connection, since in the major part of the case study, no application of internal insulation is possible, the junction was optimized by studying the existing reveal on-site and inserting all around the window an insulation layer of 4-6 cm. This helped two improve the psi-values and thereby to rise the surface temperatures in the critical points to required values (see figures 38-39).

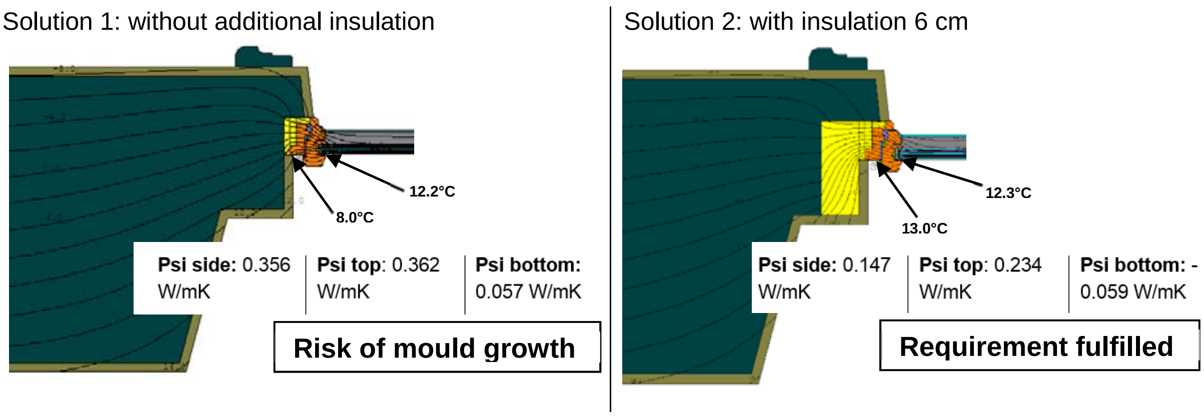


Figure 38-39: comparison of two window connections – with and without additional insulation

The entire transmission heat losses caused by the original windows are 31.100 kWh/a. With the installation of the developed window (with triple glazing) a reduction of 21.000 kWh/a can be achieved. Taking into account the window energy balance (losses minus gains) the net losses can be reduced by 70% (double glazing vs. original window) or respectively 80% (triple glazing). Looking at the total energy balance of the whole building with 14% of window area and walls in natural stones, the exchange of windows can reduce the demand by up to 20%: 10% due to thermal performance increase, 10% due to airtightness improvement (need for indoor air quality considered, without heat recovery).

Flexibility of the developed smartwin window concept

The flexibility of the developed window system allows the integration of an original historic window. In case of the three baroque windows in the jutty, it is important to maintain the interior view; the additional layer should be added therefore on the outside. For these windows the following solution was developed: removing the existing wooden frame outside, which served for the fixing of the window shutters. Instead of those, provide a second window layer, which takes over the energy efficient function (concept of the composite window prototype “the other way round”). The outer wing can be opened to the outside; it can be executed without the horizontal impost (only one sash). For the other remaining three original windows, instead it was decided to apply the second layer on the inside.

Elaborated approach for the energy retrofit of historic windows

An adequate enhancement of windows in historic building requires a tight collaboration between architect, window developer and producer and conservator from a very early planning stage on. The multidisciplinary team should follow the following approach:

Step	Measure	Content/scope
1.	**On-site inspection** **(with conservator)**	Documentation of every single existing window, evaluation of the heritage value of the window and its components, definition of an overall façade/window concept
2.	**Multidisciplinary workshop**	Definition of aesthetic, visual, formal and functional needs of the enhanced window.

		Definition of window details such as proportions, material, profiling and finish with the help of detail drawings.
3.	**Calculation of window connection**	Study and optimization of window/wall joint, both for minimization of heat losses at the connection and assurance of minimum internal surface temperatures and a minimum air exchange to avoid condensation and mould growth
4.	**Calculation of building energy balance**	Building energy balance: evaluation of different window technologies (e.g. different glazing solutions), taking into account reachable airtightness level and installation variants (window/wall joint) on building level.
5.	**On-site inspection (with conservator)/ multidisciplinary workshop**	Building and installing of first prototype – evaluation of conservator, possibly improvement, further adaptation

Conclusions

A significant energetic enhancement of historic windows is possible, while maintaining the historic value of the building and the window, thanks to the developed smartwin window concept. The flexible system is adaptable to the single individual case: Be it in case of improvement of an existing window by inserting of a new window layer or be it in case of the exchange of an existing window. Prerequisites are however: (i) the tight collaboration of planer, window developer and conservator from an early planning stage on; that (ii) with a sensitive approach adapt the developed window concept to the individual case and take (iii) into account not only the window performance, but also the impact of the installation to the whole building. Furthermore, there is the need to find window manufactures that have the necessary handicraft skills and facilities to produce smartwin historic windows.

2.3 Transfer to urban scale concept

One study within 3encult regarded the possibility of transferring the results obtained during the project and especially in the present case study to other historic buildings. The study is reported in detail in deliverable “D6.4 Transferability study”.

In case of a single monumental building, it is possible to realize profound pre-intervention analysis on a high level of detail, which on urban scale would not be feasible. By precise measurements and analysis of the case study Weigh House it was possible to better understand the characteristics and intervention needs of a certain building type. This allowed us to do diagnosis and to find the right solutions also on urban level for the surrounding buildings by visual inspections, without the use of sophisticated measurement tools and within a shorter time. In a second case, we were able to transfer the solutions for construction details that have been already addressed in case of the Weigh House to another building typology.

The evaluation of transferability of solutions was evolved on two scales:

- **On Urban scale**, investigating the energy potential and defining the possible energy refurbishment interventions for a wide spread medieval building type in the historic city center of Bolzano (Italy), the “Portici”.

- **On Building scale**, supporting the implementation planning phase of the enhancement of energy efficiency of a historic Villa from the middle of the 19th century, near Lake Como (Italy)

In the first case, within the project 3encult, a group of students from the University of Dresden carried out a documentation of this special typology of building, which is characteristic for the original nucleus of the city of Bolzano. Through questionnaires and project plans data on the existing building, the building envelope, the building use and the building energy consumption were collected for several selected buildings of the Via Portici. Complementary an on-site inspection was carried out. This study has been deepened and completed by a team from EURAC by analyzing the energy potential and the intervention needs of this building typology and by assessing the possible implementation of refurbishment solutions exemplary for one “Portici” building.

In the second case the experiences, gained within 3encult regarding the heritage compatible energy retrofit of historic buildings, the development and implementation of technologies and refurbishment solutions within a multidisciplinary design progress, were introduced into the refurbishment design process of a historic north Italian Villa. During four common workshops among the 3encult partner and Bolzano case study leader EURAC and the responsible building owner, architect and energy planner, design steps were discussed and verified and detail connections were evaluated.

3 Implementation (in the test room)

For the implementation of refurbishment solutions two particular innovative components were developed. As in this special case a part of windows, which were not of heritage value, should be replaced, the case study team developed, in collaboration with the local heritage office and the project partners, an energy efficient heritage compatible window prototype (see chapter 2.2.2). A solution for the reversibility of the internal insulation was developed and tested on-site, as well as two solutions for the installation of internal insulation in connection with wooden beam ceilings.

4 Summery and conclusion

From the attendance the Public Weigh House of Bolzano the following main conclusions can be drawn:

- To include all stakeholder in the design process of the energy retrofit of the historic building.
- For each energy retrofit of a historic building the multidisciplinary exchange between all stakeholders starts with the comprehensive diagnosis of the status quo, supports the development of solutions and selection of the most appropriate one, and does not end before an integrated monitoring and control is in operation, which verifies and guarantees performance
- Comprehensive diagnosis of the status quo include: Pre-intervention analysis such as analysis of historic evolution, investigation of building construction and determination of heritage value of the single construction elements
- Energy performance assessment includes the analysis of physical and mechanical properties of the elements of the thermal envelope, airtightness and infiltration causes, daylight potential, environmental monitoring, assessment of heating energy demand and distribution of heat losses, identification of intervention needs
- Development of a heritage compatible refurbishment concept – an interaction of different passive and active solutions. If needed: development of new products/technologies or respectively adaption of existing products tailored to the individual demands of the historic building. Prerequisites for the development of solutions are:
    - The tight collaboration of planer, developer and conservator from an early planning stage on, that with a sensitive approach, adapt the developed component/concept to the individual case as well as take into account not only the element performance, but also the impact of the installation to the whole building.
    - Starting with the analysis of the traditional (architectural) energy solution of the building in connection with the climate and the use of the building. The recovery of the original energy concept (in combination with new technologies) might allow an energetic and comfort enhancement without compromising the heritage value.

5 Annex 1 - PHPP calculation for status pre-intervention

Passive House verification

Building:	Public Weighhouse Bozen_Version II (including top floor, excluding basement)
Street:	Waaggasse 1
Postcode / City:	39100 Bozen
Country:	Italy
Building type:	Residential and commercial building_As-is-state
Climate:	[IT] - Trentino-Bolzano — Altitude of building site (in [m] above sea level): -
Home owner / Client:	Stiftung Südtiroler Sparkasse
Street:	Talfergasse 18
Postcode/City:	39100 Bozen
Architecture:	EURAC_Institute for renewable energies_Dagmar Exner
Street:	Drususallee 1
Postcode / City:	39100 Bozen
Mechanical system:	
Street:	
Postcode / City:	

Year of construction:	1250		Interior temperature winter:	20.0	°C	Enclosed volume V_e m³:	
No. of dwelling units:	7		Interior temperature summer:	25.0	°C	Mechanical cooling:	
No. of occupants:	24.1		Internal heat sources winter:	2.1	W/m²		
Spec. capacity:	132	Wh/K per m² TFA	Ditto summer:	2.1	W/m²		

Specific building demands with reference to the treated floor area

				Requirements	Fulfilled?*
	Treated floor area	843.5	m²		
Space heating	Heating demand	225	kWh/(m²a)	15 kWh/(m²a)	no
	Heating load	97	W/m²	10 W/m²	no
Space cooling	Overall specif. space cooling demand		kWh/(m²a)	-	-
	Cooling load		W/m²	-	-
	Frequency of overheating (> 25 °C)	5.2	%	-	-
Primary energy	Heating, cooling, dehumidification, DHW, auxiliary electricity, lighting, electrical appliances	323	kWh/(m²a)	120 kWh/(m²a)	no
	DHW, space heating and auxiliary electricity	276	kWh/(m²a)	-	-
	Specific primary energy reduction through solar electricity		kWh/(m²a)	-	-
Airtightness	Pressurization test result n_{50}	10.1	1/h	0.6 1/h	no

* empty field: data missing; '-': no requirement

Passive House?	no

We confirm that the values given herein have been determined following the PHPP methodology and based on the characteristic values of the building. The PHPP calculations are attached to this application.

	PHPP Version 8.4
Name:	**Registration number PHPP:**
Surname:	**Issued on:**
Company:	**Signature:**

6 Annex 1 - PHPP calculation for status after (hypothetical) interventions

Passive House verification

Building:	Public Weighhouse Bozen_Version II (including top floor, excluding basement)
Street:	Waaggasse 1
Postcode / City:	39100 Bozen
Country:	Italy
Building type:	Residential and commercial building_As-is-state
Climate:	[IT] - Trentino-Bolzano — Altitude of building site (in [m] above sea level): –
Home owner / Client:	Stiftung Südtiroler Sparkasse
Street:	Talfergasse 18
Postcode/City:	39100 Bozen
Architecture:	EURAC_Institute for renewable energies_Dagmar Exner
Street:	Drususallee 1
Postcode / City:	39100 Bozen
Mechanical system:	
Street:	
Postcode / City:	

Year of construction:	1250		Interior temperature winter:	20.0	°C	Enclosed volume V_e m³:	
No. of dwelling units:	7		Interior temperature summer:	25.0	°C	Mechanical cooling:	
No. of occupants:	24.1		Internal heat sources winter:	2.1	W/m²		
Spec. capacity:	132	Wh/K per m² TFA	Ditto summer:	2.1	W/m²		

Specific building demands with reference to the treated floor area

				Requirements	Fulfilled?*
	Treated floor area	843.5	m²		
Space heating	Heating demand	103	kWh/(m²a)	15 kWh/(m²a)	no
	Heating load	43	W/m²	10 W/m²	no
Space cooling	Overall specif. space cooling demand		kWh/(m²a)	-	-
	Cooling load		W/m²	-	-
	Frequency of overheating (> 25 °C)	9.6	%	-	-
Primary energy	Heating, cooling, dehumidification, DHW, auxiliary electricity, lighting, electrical appliances	186	kWh/(m²a)	120 kWh/(m²a)	no
	DHW, space heating and auxiliary electricity	140	kWh/(m²a)	-	-
	Specific primary energy reduction through solar electricity		kWh/(m²a)	-	-
Airtightness	Pressurization test result n_{50}	1.0	1/h	0.6 1/h	no

* empty field: data missing; '-': no requirement

Passive House?	**no**

We confirm that the values given herein have been determined following the PHPP methodology and based on the characteristic values of the building. The PHPP calculations are attached to this application.

PHPP Version 8.4

Name:	**Registration number PHPP:**
Surname:	**Issued on:**
Company:	**Signature:**

7 Annex 2 - Description of the monitoring system

7.1 Monitoring Concept

A monitoring system is required in order to assess the thermal behavior of a building. In the case of the Waaghaus, the variables to be measured are the interior climate conditions and the outdoor climate. The energy consumptions could not be evaluated because there is no a heating or cooling system installed.

Indoor climate

The monitoring system measures the indoor air temperature and humidity of some rooms, the surface temperatures and humidity of some surfaces of the external walls and the humidity and temperatures of many critical points such as corners and window reveals. The position of the sensors permits to monitor the thermal behavior on the different floors and in different orientations.

Outdoor climate

The outdoor climate is monitored with two couples of temperatures and humidity sensors located on the top floor north and south exposed. The outdoor climate sensors are necessary to compare the interior conditions with the exterior ones.

Comfort /Utilization	**Outdoor climate**	**Historical surfaces**
Inside air temperature AT and humidity RH of some rooms	Outdoor temperature, outdoor relative humidity	Near field climate, surface temperatures on walls (ST); Surface temperature and humidity (ST, SRH) on constructional critical points of the thermal envelope as: external corners, windows, window reveals

Table XIV Monitoring scheme

7.2 Monitoring system

Sensors

The humidity and temperature sensors collect the data every minute.

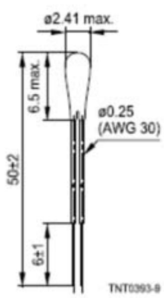
The temperatures are measured with a NTC (*Negative Temperature Coefficient*) thermistors (Epcos_B57863 S863). The accuracy is about +-0,2 K

Applications
- Heating systems
- Industrial electronics
- Automotive electronics

Features
- Uni curve sensor
- Fast response
- High temperature accuracy between 0 °C and 70 °C
- Excellent long-term stability
- Epoxy resin encapsulation
- PTFE-insulated leads of silver-plated nickel wire, AWG 30
- UL approval (E69802)

Delivery mode
Bulk

Dimensional drawing



Dimensions in mm
Approx. weight 60 mg

General technical data

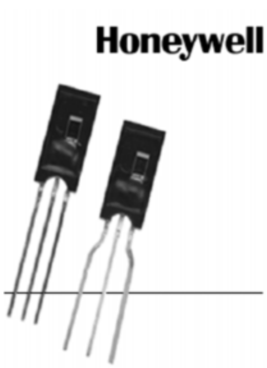
Climatic category	(IEC 60068-1)		55/155/56	
Max. power	(at 25 °C)	P_{25}	60	mW
Temperature tolerance	(0 ... 70 °C)	ΔT	±0.2, ±0.5	K
Rated temperature		T_R	25	°C
Dissipation factor	(in air)	δ_{th}	approx. 1.5	mW/K
Thermal cooling time constant	(in air)	τ_c	approx. 15	s
Heat capacity		C_{th}	approx. 22.5	mJ/K

Electrical specification and ordering codes

R_{25} Ω	No. of R/T characteristic	$B_{25/100}$ K	Ordering code
3 k	8016	3988	B57863S0302+040
5 k	8016	3988	B57863S0502+040
10 k	8016	3988	B57863S0103+040
30 k	8018	3964	B57863S0303+040

+ = Temperature tolerance
F = ±0.2 K
G = ±0.5 K

The humidity are measured with a capacity sensor Honeywell HIH-4000 Series. The accuracy is about +-3,5 % RH



FEATURES

- Molded thermoset plastic housing
- Near linear voltage output vs % RH
- Laser trimmed interchangeability
- Low power design
- Enhanced accuracy
- Fast response time
- Stable, low drift performance
- Chemically resistant

POTENTIAL APPLICATIONS

- Refrigeration equipment
- HVAC (Heating, Ventilation and Air Conditioning) equipment
- Medical equipment
- Drying
- Metrology
- Battery-powered systems
- OEM assemblies

Automation system

Bus-based measurement systems are used to measure the actual condition of the building. The measured on field data are collected on site installed central computer by using the same data structure. The central computer is located on the first floor of the building.

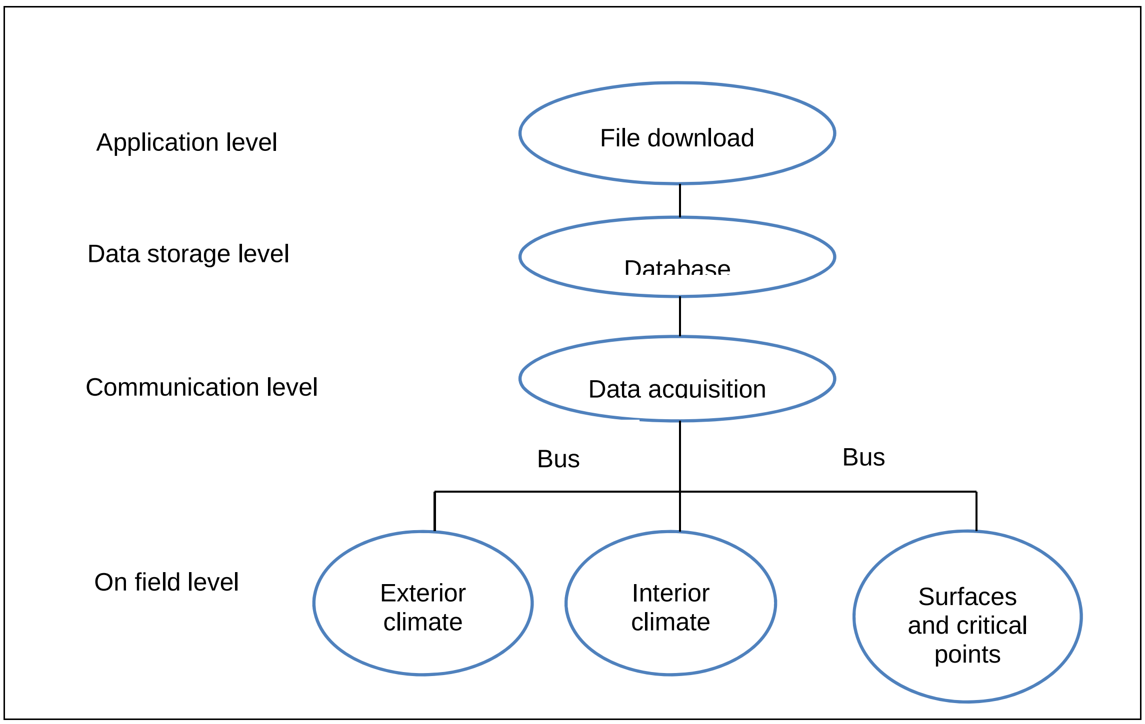
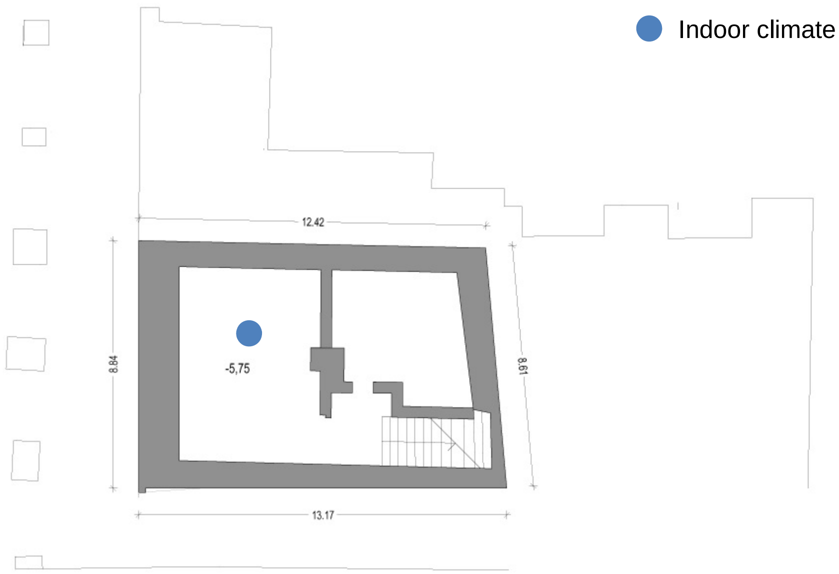


Table XV Hierarchy of the automation system

7.3 Monitoring layout/plans

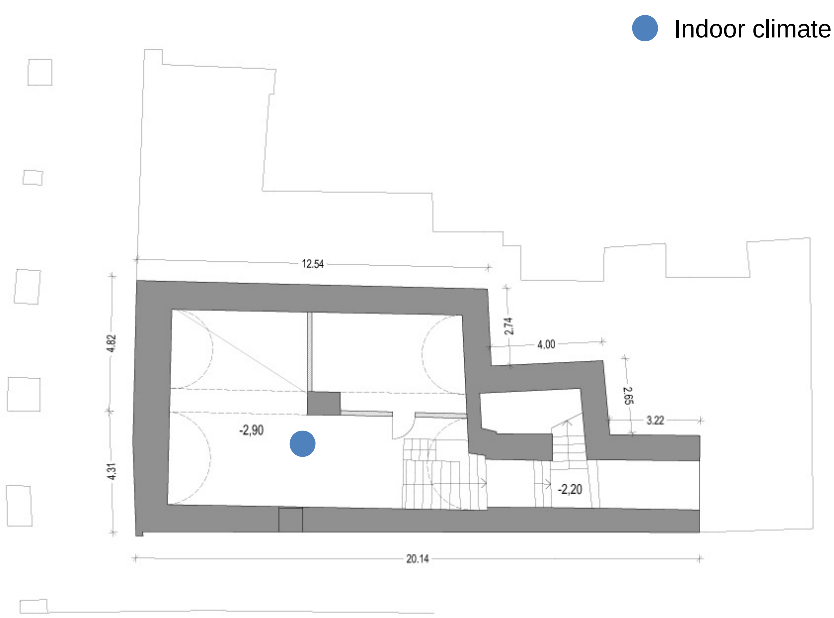
The sensors are installed on the different floors of the building and on different orientations (see annex I for the monitoring detailed plans and list). Some rooms are equipped with electrical heaters during the winter period.

Second basement:



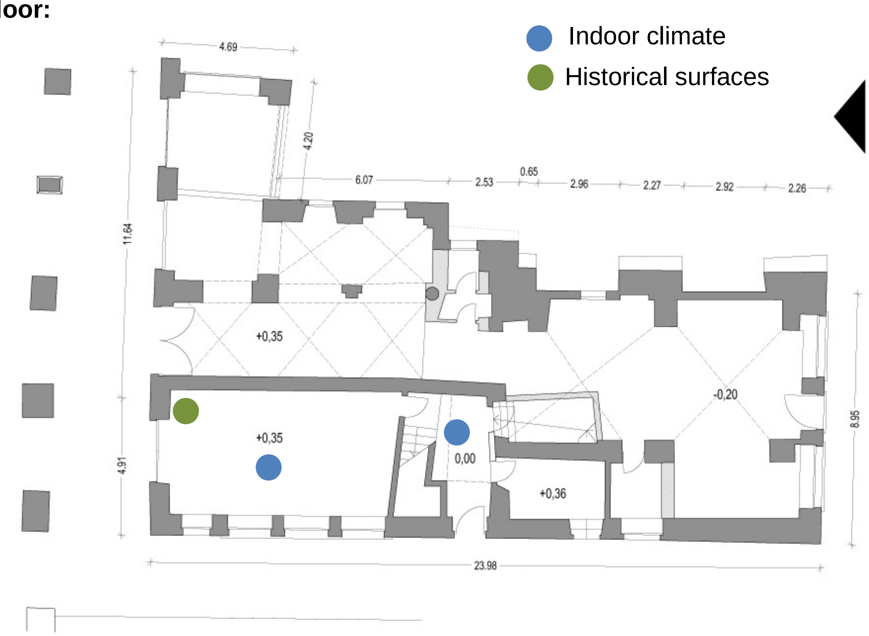
GROUNDPLAN_SECOND BASEMENT

First basement



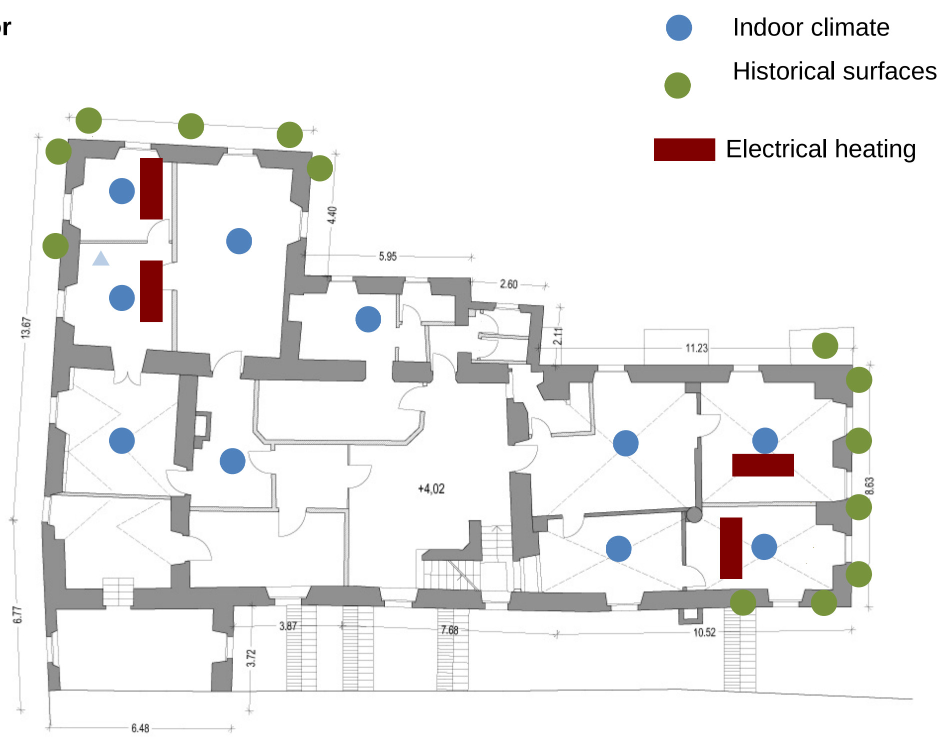
GROUNDPLAN_FIRST BASEMENT

Ground floor:



GROUNDPLAN_GROUND FLOOR

First floor

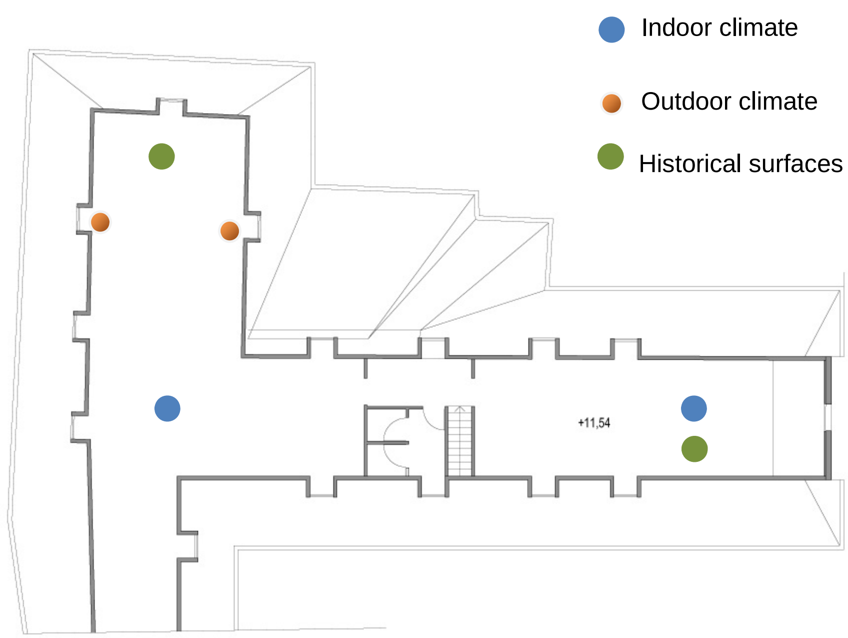


GROUNDPLAN_FIRST FLOOR

Second floor:

GROUNDPLAN_SECOND FLOOR

Top floor:



GROUNDPLAN_TOP FLOOR

7.4 Thermal transmittance of the exterior walls

The thermal conductance of a wall quantifies the thermal flux exchanged between the inside and the exterior surface. It is therefore one essential parameter to analyse the thermal behaviour of a building. The thermal transmittance (U-value) or the thermal conductance is the most important parameter for describing the thermal performance of building elements, and subsequently, the overall energy performance of a building. Normally, the walls constitute the largest surface of the opaque envelope. For this reason, the study focuses on the analysis of the thermal transmittance of walls.

In the Waaghaus we measured the thermal conductance of the exterior wall, of the parapet under the windows, of the ceiling over Portici, of the roof in the insulated part.

7.4.1 Heat flux instruments

The thermal performance of walls has been measured using the heat flow-meter measurement (HFM), a Non Destructive Testing (NDT) that permits to determine the thermal transmission properties of the opaque envelope directly in situ. The instrument is composed by a data-logger equipped with two or more temperature sensors (transducers) and one heat flux plate for measuring and registering the internal and external temperature and the heat flows through the walls. The temperatures sensors are usually thermocouple, positioned face to face on the exterior and interior surfaces. For the experimental measurements, one traditional data-logger have been used. The characteristics of the instrument are illustrated in Table 1.

Table 1: Characteristics of the heat flow measurements instruments

Characteristics	**Instrument 1 (no wireless)**
Number of temperature sensors	2 sensors: internal and external
Dimension of heat flux plate (mm)	500x500x6 mm
Substrate	Teflon

For the measure, an adjunctive ambient temperature sensor has been used to verify the stability of air temperature and to measure the U-value or the total thermal resistance.

The ISO 9869:1994 “Thermal insulation – Building elements – In-situ measurement of thermal resistance and thermal transmittance” describes how to measure the conductance of a wall using the heat flux meter. The measurements have been carried out according to the International standard on a representative part of the whole element.

The appropriate location has been investigated by thermography in accordance with standard (IS0 6781, 1983). The standard requires to have stable temperatures particularly on the side where the HFM is installed, in order to reduce the duration of the test.

For this reason we carried the measurements during the winter season in the heated rooms. HFM has been conducted preferably on the north-facing walls for avoiding the influence of direct solar radiation. In each case, the outer surface of the element was protected from rain, snow and direct solar radiation. Also, sensor locations have been chosen to avoid probable thermal bridges, influences of windows, plants, natural and artificial ventilation.

The difference between the values every 24h is always less than 5%. The accuracy of the measurements is estimated by the ISO 9869 between 14% and 28%.

The sensors, normally, have been located about half-way between window and corner, and floor and ceiling. Internal sensors have been mounted for minimizing the influence of solar radiation, heat sources, users, etc. It has be positioned protected from the sun radiation, in the Waaghaus it was positioned on the inside surface of the wall.

The monitoring period was chosen to provide a stable average of the U-value (Baker, 2008 and 2011) which takes into account the thermal inertia of the walls. The increase of the length of the monitoring period in the walls with high thickness improves the final results. The 72 hours of monitoring period recommended by the standard (ISO 9869, 1994) is insufficient for the historical walls. For this reason, in order to improve the reliability of the results, the test has been conducted continuously for 90-120 hours, with a climatic stability. In the walls with a thickness from 100 to 160 cm, the test has been conducted continuously for 180-220 hours.

Figure 8 Heat flow meter

Figure 9 Data logger for data acquisition

7.5 Blower door test and gas tracing

One of the most important parameter influencing the heat exchange are the air infiltrations from the outside into the inside of the building. Therefore, to calculate the energy balance within the simulation model, the right air volume that enters through the building envelope has to be measured. The standard UNI EN 13289 “Determinazione della permeabilità all’aria degli edifici” and the ASTM E779- 10 Standard test method for determining air leakage rate by fan pressurization” and ASM 1827- 11“Standard test methods for determining airtightness of buildings using an orifice blower door” describe how to quantify the infiltration rate with a fan that creates a pressure difference between the interior and the exterior. In the case of the “Waaghaus”, we measured the infiltration rate of the whole building and of some rooms. We used a fan positioned either on the outside door of the building or on the door of the rooms. We closed up all the possible holes in the envelope, checking the tightness of the rooms with a gas tracer. The main difficult to obtain reliable results was to reach a stability in low pressure differences and to reach a high level of difference pressure while testing the whole building. This is a typical problem in the test of a historic building because of the poor airtightness of the envelope. For this reason many attempts were done, using overpressure or under pressure and checking the uncertainty of the measurements.

7.5.1 Blower door test instruments

The Blower Door Instrument is composed by a fan to create the pressure difference between the inside and the outside, a gauge to measure the pressure difference and to elaborate the results; an airtight, wooden framework where the fan is positioned. At first, the baseline pressure difference between the inside and the outside has to be measured. Then the fan blows the air inside or outside the building and creates a pressure difference with 10 Pa steps until the difference pressure reaches the 50 Pas. The gauge measures the air rate to blow inside the building in order to keep the pressure difference. The main results are the curve of pressure, the air changes at 50 Pa and the Effective Leakage Area.

7.5.2 Gas tracing instruments

The gas tracer equipment is composed by a gas tracer to check where the infiltration is localize and an anemometer to measure the air speed localized in the critical points. The gas tracer test could be performed during the blower door test or during the standard conditions of use of the building.

Figure 10 Fan

Figure 11 Gas from the gas tracer

Figure 12 Anemometer

Figure 13 Gauge for data elaboration

7.5.3 Infrared thermography

Infrared thermography is a non-destructive investigation technique, which is becoming more frequently employed in civil and architectural inspections, in the diagnostic phase, in preventive maintenance or to verify the outcome of interventions. On historic structures, it allows investigating details of construction, damage and material decay. In order to obtain more detailed information IRT can be used with other NDT techniques (e.g. ultrasound, radar, etc.). Applications of infrared thermography to the field of Cultural Heritage diagnostic are not limited to the identification of heat losses in building envelope, instead they may be also used to enable localisation of voids and other irregularities in the near surface region, location of plaster delaminations, detection of moisture in the near surface region etc. Masonry and especially historic masonry has a very inhomogeneous structure containing several different materials (brick, stone, mortar, plaster, wood, metal etc.) with different thermal properties; in these cases thermography is a very reliable method to assess the following testing problems in the surface near region: detection of plaster and tile delaminations, location of mounting parts behind plaster, characterisation of masonry layout behind plaster, location of empty joints, detection of moisture, location of delaminations of strengthening materials (e.g. composite materials patches or stripes).

Technical equipment

For IRT-investigation of Waaghaus Bozen a Varioscan 3021ST (JENOPTIK Laser Optik Systeme GmbH) came into use. The camera works with Stirling cooled detector in a thermal resolution of ±0.03 K in the spectral range 8-12 µm. Its geometrical resolution is 1.5 mrad. A rechargeable Li-Ion battery allows liberated working in and outside the building. The camera was PC-controlled via IRBIS control 2.2 SW. Data examination was by IRBIS2.2 professional. For the image output the temperature scaling was always arranged that way, that the important information is visible best. This should be taken into account when doing direct comparison between two pictures.

7.6 Monitoring system after intervention

7.6.1 General description

Cs6 has a 3 measurement section, In each measurement section are measured the indoor climate (temperature, relative humidity), the surface temperatures (inside and outside), the heat flux (inside) and measured on the cold side of the internal insulation, the temperature and relative humidity.

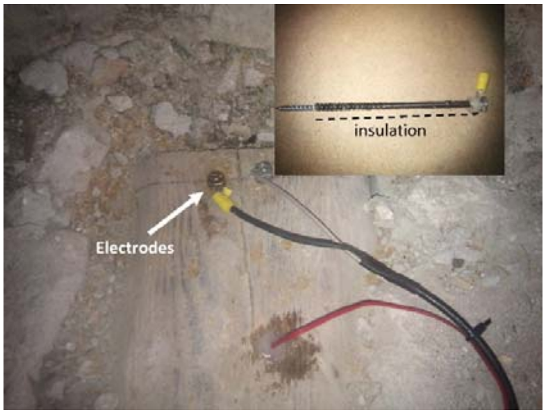
7.6.2 Measurement of humidity in wooden beam ends (test room)

Moisture is one of the most influencing factor of the wood decay [1]. It is well known that the moisture content (MC) of the wood can be measured by measuring the wood electrical resistance [2]. The electrical resistance varies exponentially with a linear variation of the MC. The challenging aspects of this measurements are twofold: the wide range of resistance to be measured (from 104 to 108 Ohm); the long term monitoring reliability requires a good measurement stability even in harsh conditions (dust, high air humidity, wood swelling and shrinking while keeping good mechanical contact between the electrodes and the inner wood).

The monitoring system used was an off-the-shelf data logger, the Material Moisture Gigamodule from Scanntronik Mugrauer GmbH, Zorneding, Germany. It is of the same family of an extensively tested system [4] that can measure a large range of resistance (from 10 KOhm to 100 GOhm) on up to eight different channels. It is provided with a software (SoftFox) that can convert the resistance data into MC values by using built-in selectable characteristic curves (of spruce wood in this case). The measuring principle was based on the discharge-time measurement method that consists in measuring the discharging time of a capacitor through the material tested. The data were collected using the Thermofox data logger from Scanntronik. The Gigamodule data logger was connected to the Thermofox data logger. The latter was also made to acquire two temperature sensors in order to correct the MC measurements (via the SoftFox sotware) [3].

The electrodes were prepared and installed by EURAC. They consisted of 160 mm long metal screws of 4 mm diameter. The screws were coated with insulating tape except the screw head and the last 10 mm of the tips. Each channel was made up by two wires of a BNC cable, each wire connected to a screw head and electrically insulated from the timber. The pair of screws was screwed at a distance of 30 mm in 5 mm-diameter holes drilled down to a depth of 150mm at an angle of about 45 degrees in order to reach the timber head (without drilling through).

Eight measuring points were chosen thus using all the available channels. The acquisition rate was set to 30 min which correspond of an autonomy of the batteries of about 120 days.



[1] Brischke C, Rapp AO, Bayerbach R. Decay influencing factors: A basis for service life prediction of wood and wood-based products. Wood Material Science and Engineering 2007;1(3&4):91-107.

[2] Stamm AJ. The electrical resistance of wood as a measure of its moisture content. Industrial & Engineering Chemistry Research 1927;19(9):1021-25.

[3] Du QP, Geissen A, Noack D. The effect of temperature on the electrical resistance of wood. Holz als Roh- und Werkstoff 1991;49:305-11.

[4] Brischke C, Rapp AO, Bayerbach R. Measurement system for long-term recording of wood moisture content with internal conductively glued electrodes

7.6.3 IR-Thermography: Airtightness of first window prototype

The pictures above show the air tightness of the existing box-type window from the fifties/sixties of the last century compared with the airtightness of the first window prototype implemented in the test room.

The IR-images where taken while the fan of the blower door instruments (see also chapter 7.5.1) generated under pressure in the room. Air leakages are made visible in this way through cold air that comes in from outside.

Fig. 1 Existing window

Fig. 2 New window prototype

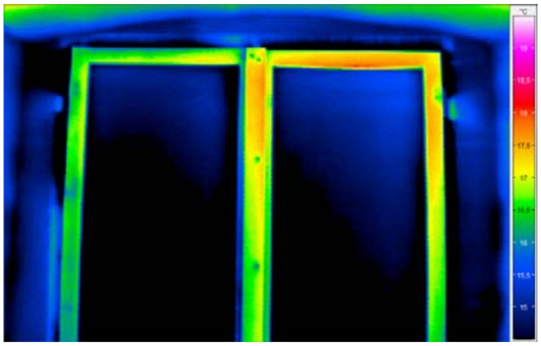


Fig. 3 Temperature distribution at the start of experiment

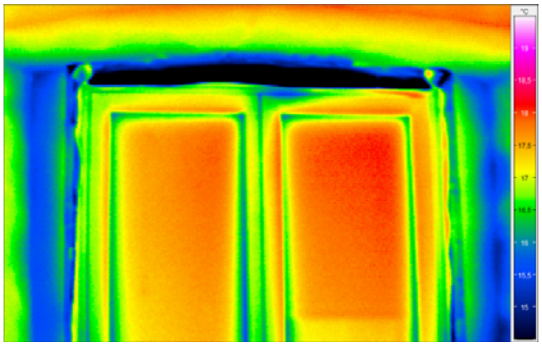


Fig. 4 Temperature distribution at the start of experiment

Fig. 5 First picture of difference mode

Fig. 6 First picture of difference mode

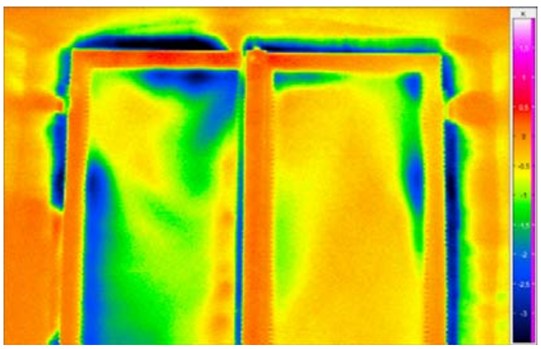


Fig. 7 After 6 minutes, difference mode, compare able scaling to Fig. 9

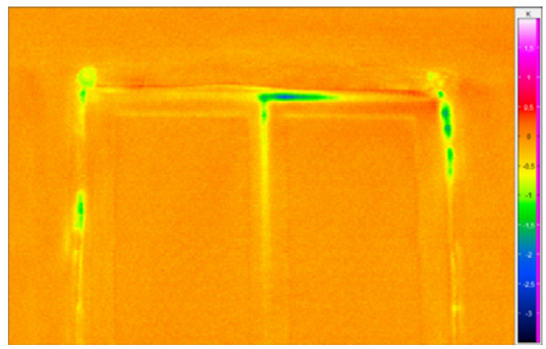


Fig. 8 After 6 minutes, difference mode, compare able scaling to Fehler! Verweisquelle konnte nicht gefunden werden.

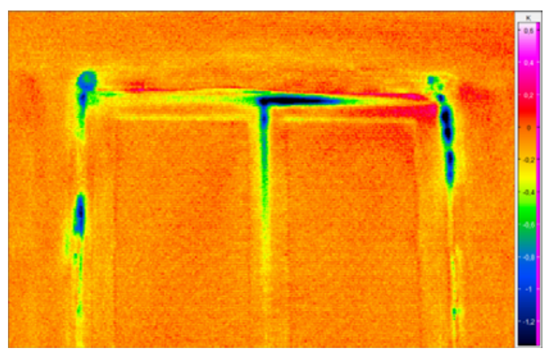


Fig. 9 After 6 minutes, new scaling

8 Annex 3 - Case Study organisation

8.1 Local Case Study Teams (LCS teams)

The LCS-Team of the Public Weigh House of Bolzano is composed by the following partners:

Scientific lead	EURACresearch	
	Institute for Renewable Energy	
	Via Luis-Zuegg 11	
	I-39100 Bolzano	
	Alexandra Troi	+39 0471 055602
	Alexandra.Troi@eurac.edu	
	Dagmar Exner	+39 0471 055655
	Dagmar.Exner@eurac.edu	
Conservation support	Local state office for historical monuments	
	Via Armando Diaz 8	
	I-39100 Bolzano	
	Dr. Waltraud Kofler Engl	+39 0471 411910
	Waltraud.Kofler@provinz.bz.it	
Building owner	Fondazione Cassa di Risparmio (foundation)	
	Via Talvera 18	
	I-39100 Bolzano	
	Dr. Andreas Überbacher	
	Ueberbacher@stiftungsparkasse.it	
	Haidy Berger	+39 0471 316017
	Berger@stiftungsparkasse.it	
Architect/Project planner	to be involved after the selection through competition	

8.2 LCST formalisation

8.2.1 First cooperation agreement (in German)

Original text of the first agreement between EURAC and CS Owner (WP6_20110822_Agreement EURAC and CS Owner):

Kooperationvereinbarung

zwischen

1. **Europäische Akademie Bozen/Accademia Europea Bolzano (EURAC)**, Drususallee 1, 39100 Bozen, vertreten durch den Dr. Werner Stuflesser, Präsident
2. **Stiftung Südtiroler Sparkasse**, Talfergasse 18, 39100 Bozen, vertreten durch den Präsidenten RA Dr. Gerhard Brandstätter

1. Gegenstand und Ziel

Partei 1 EURAC ist Koordinator des EU-Projektes „3ENCULT“, welches im 7. Forschungsrahmen-programm gefördert wird (EC-Grant Agreement number: 260162). Im Projekt „3ENCULT – Efficient Energy for EU Cultural Heritage“ (im folgenden: das Projekt) werden passive und aktive Lösungen zur denkmalgerechten energetischen Sanierung von historischen Gebäuden entwickelt, wobei sowohl marktverfügbare Produkte berücksichtigt als auch neue von den beteiligten KMU entwickelt werden. Ziel ist es, die Kluft zwischen Denkmalpflege und Klimaschutz durch die Zusammenarbeit im interdisziplinären Team zu überbrücken. Anhand von acht begleitenden Fallstudien wird die Machbarkeit der vorgeschlagenen Lösungen aufgezeigt und überprüft. Die dortigen lokalen Akteure (Besitzer, Architekten, Denkmalpflege, …) werden über die so genannten „Local Case Study Teams“ ins Forschungsprojekt integriert.

Partei 2 Stiftung Südtiroler Sparkasse ist Eigentümerin des “Waaghaus” (BP. 269/1 KG Bozen 613 E.Zl. 1169 II, Waaggasse 1-3, Lauben 19, 39100 Bozen) und hat sich in der Absichtserklärung vom 29.10.2009 dazu bereit erklärt, das „Waaghaus“ als Fallstudie für das oben genannte Projekt zur Verfügung zu stellen.

Diese Absichtserklärung schließt jeweils für den Projektzeitraum ein: (i) Zugang zur Dokumentation und zu Daten zum Waaghaus, (ii) Einbezug eines Projektvertreters in die projektrelevanten Phasen der Sanierungsplanung und (iii) Ermöglichung der Anbringung wissenschaftlicher Beobachtungssysteme und Gewährung der erforderlichen Zugangsrechte.

Mit dem vorliegenden Kooperationsvertrag legen die Parteien die Rechte und Pflichten in Bezug auf das Objekt der Fallstudie „Waaghaus“ fest, insbesondere die Festlegung des Zeitplans, die Zugangsrechte zum Gebäude und Haftungsfragen.

2. Aufgaben und Verantwortlichkeiten

Alle Parteien verpflichten sich, ihre vertraglichen Pflichten fristgerecht und nach Treu und Glaube zu erfüllen.

Die Parteien treffen sich in unregelmäßigen Abständen zum Informationsaustausch und zur Koordination der Tätigkeiten. Die Treffen werden von der EURAC einberufen und organisiert. Unabhängig vom Vertragsverhältnis EURAC/Stiftung kann die EURAC zu den Treffen sowie zur Umsetzung ihres Projektvorhabens weitere Partner einbeziehen, wobei der Ansprechpartner für die Stiftung jedoch immer die EURAC bleibt.

Im Speziellen haben die Parteien die folgenden Aufgaben und Verantwortlichkeiten:

Partei 1 EURAC

EURAC ist verantwortlich für die Koordination aller im Rahmen des Projektes 3ENCULT durchgeführten Maßnahmen und Messungen am Waaghaus. Diese werden durch die EURAC selbst, durch 3ENCULT-Projektpartner oder von der EURAC beauftragte Dritte durchgeführt und umfassen:

- Diagnose (nicht destruktiv) des Ist-Zustands durch IR-Thermographie (innen und außen), Blower-Door-Messung, Wärmeflussmessung und ähnliches - sowohl eigene Messungen als auch Koordination der Messungen von Partnern oder externen Dritten. Zum Zweck der IR-Thermographie und Wärmeflussmessung muss das Gebäude (oder Teile davon) temperiert werden.
- Diagnose (destruktiv) des Ist-Zustands in geringem Ausmaß: Kleine Probennahmen von Materialien, Bohrung in Wänden zur Bestimmung von Materialdaten (in Abstimmung mit Stiftung und Denkmalpflege, wenn gewünscht unter Hinzuziehen eines Restaurators)
- Monitoring von Variablen bezüglich
  (a) Behaglichkeit,
  (b) Energieverbrauch und
  (c) Denkmalpflege (Kondensation u.ä.);
  z.B. Temperaturen (Luft und Oberflächen, innen und außen, u. U. auch in verschiedenen Wandschichten und im Dachaufbau), relative Feuchtigkeit, Wärmestrom, CO_2 (im genutzten Zustand), Belichtung, Wärmemengenzähler, Stromzähler; wenn möglich Installation einer kleinen Wetterstation auf dem Dach.
  Installation zum Teil mit Kabeln, zum Teil wireless. Die Datenübertragung kann über Modem oder über Internet erfolgen.
- Umsetzung von Energieeinsparungsmaßnahmen (im kleinen Maßstab, also z.B. Testflächen oder eine Wand eines Raumes) mit neu entwickelten Produkten (z.B. Installation von einzelnen Fenster-Prototypen, Anbringen von Innendämmung an der Außenwand; Auswahl der Flächen in Abstimmung mit der Stiftung und dem Denkmalamt.) Sämtliche Veränderungen oder sonstige Maßnahmen an der Liegenschaft, welche die Denkmalvinkulierung des Hauses betreffen, müssen auf jeden Fall mit dem Eigentümer sowie dem Landesdenkmalamt abgestimmt bzw. von diesen genehmigt werden.
- Programmierung und Bereitstellung eines BMS System (Building Management System – Software und Hardware für Zentrale - nicht Hardware für Peripherie)

EURAC wird im Rahmen des Forschungsprojektes die folgenden Berechnungen und Simulationen durchführen, deren Ergebnisse der Stiftung Südtiroler Sparkasse (ebenso wie die Ergebnisse der oben beschriebenen Untersuchungen) kostenlos zur Verfügung gestellt werden, wobei die Nutzungsrechte jedoch bei der EURAC und deren Projektpartnern bleiben:

- Statische Berechnung des Energiebedarfs (mit PHPP, i.e. PassivHausProjektierungsPaket) im Ist-Zustand und verschiedener Sanierungsvarianten
- Dynamische Berechnung des Energieverbrauchs (mit EnergyPlus/Designbuilder oder ähnlichem)
- Evaluierung von möglichen Maßnahmen aus energetischer Sicht und im Hinblick auf Behaglichkeit und bauphysikalische Eignung (Vermeidung von Kondensation etc.)
- Berechnung und Bewertung von Problemstellen (z.B. Kältebrücken, Undichtigkeiten, …)

- Nach Auswahl und Bestimmung des Planungsteams durch den Eigentümer wird die EURAC die Eingabe- und Ausführungsplanungsphase in Form eines integrierten Planungsprozesses begleiten. Der „integrierte Planungsprozess“ sieht vor, das Projekt von einem frühen Planungsstadium an (Vorprojekt, bzw. Eingabeprojekt) mit Simulationen und Evaluierung verschiedener Ausführungsmöglichkeiten unter Berücksichtigung der Parameter, die die Energiebilanz, die Wohngesundheit und den Wohnkomfort beeinflussen, zu begleiten. Parallel dazu, werden die verschiedenen Lösungen in Bezug auf ihre Wirtschaftlichkeit verglichen. Die Ergebnisse der Simulationen werden bei ca. 4 regelmäßigen Workshops unter den Entscheidungsträgern des Projekts (LCS-Team) ausgetauscht und mit dem Planungsstand der einzelnen Fachplaner abgestimmt. Sie fließen so, jedoch für den Baubeginn nicht vinkulierend, in den Planungsprozess mit ein.

Die EURAC hat hier bereits Erfahrung mit der Begleitung der Projektierung verschiedener Firmensitze in Südtirol.

EURAC verpflichtet sich, jeden Besuch im Waaghaus, sei es allein oder in Begleitung eines 3ENCULT Projektpartners, der Stiftung Südtiroler Sparkasse im Vorfeld mitzuteilen und zwar mit mindestens einem

- Vorlauf von zwei Tagen, im Falle eines reinen Besuchs ohne Maßnahmen und Eingriffe
- Vorlauf von 14 Tagen und unter Mitteilung der technischen Details, im Falle eines Besuchs mit Maßnahmen und Eingriffen

Die Stiftung kann den Zugang nur verwehren, sollten zum vorgeschlagenen Termin dringende Arbeiten am Gebäude durchgeführt werden und unter Vorschlag eines Ausweichtermins innerhalb der nächsten 7 Tage.

Die EURAC verpflichtet sich dazu, alle kommunikationstechnischen Angelegenheiten (z.B. Pressekonferenzen u.Ä.), die im Waaghaus selbst stattfinden, vorher mit der Stiftung abzusprechen.

Partei 2 Stiftung Südtiroler Sparkasse

Die Stiftung Südtiroler Sparkasse gewährt der EURAC für die Durchführung der in diesem Abkommen beschriebenen Tätigkeiten freien Zugang zum “Waaghaus” (BP. 269/1 KG Bozen 613 E.Zl. 1169 II, Waaggasse 1-3, Lauben 19, 39100 Bozen). Dieser Zugang ist während der gesamten Laufzeit diese Vertrags an Werktagen und bei Bedarf auch während Feiertagen gewährleistet. Der EURAC wird für die Laufzeit der Fallstudie ein Schlüssel für das Gebäude ausgehändigt.

Wie schon in der Absichtserklärung vom 29.10.2009 beschrieben und jeweils für die Projektdauer

- gewährt die Stiftung Südtiroler Sparkasse der EURAC Zugang zur Dokumentation und zu Daten zum Waaghaus, soweit diese vorhanden und für die Umsetzung der in diesem Abkommen und im EC-Grant Agreement beschriebenen Tätigkeiten nötig sind,
- bezieht einen Projektvertreter der EURAC in die projektrelevanten Phasen der Sanierungsplanung ein,
- und ermöglicht der Anbringung eines wissenschaftlichen Beobachtungssystems
- sorgt die Stiftung Südtiroler Sparkasse dafür, dass in der Projektausschreibung festgehalten wird, dass die EURAC das Projekt im Rahmen der vorhergehenden Vereinbarung begleitet.

Zum Zwecke des Betriebs des wissenschaftlichen Beobachtungssystems und der gezielten Teilbeheizung des Gebäudes für wissenschaftliche Zwecke (Anschlussleistung geschätzt 3 kW, Betrieb jeweils für zeitlich beschränkte Dauer) stellt die Stiftung Sparkasse einen Stromanschluss zur Verfügung.

Um die Erfassung realistischer Daten sicherzustellen, verpflichtet sich die Stiftung Sparkasse die im Moment geschlossenen Fensterläden am gesamten Gebäude zu öffnen.

Für die Anpassung des Beobachtungssystem an den sanierten Zustand kann sich die EURAC bzw. der zuständige 3ENCULT-Partner in die im Rahmen der Sanierung getätigten Maßnahmen einklinken (z.B. Nutzung von Kabelschächten, etc.) sofern dies ohne weiteren baulichen oder finanziellen Mehraufwand möglich ist.

Außerdem stimmt die Stiftung der Installation von Prototypen (z.B. Fenster o.ä.) nach Klärung und Lösung der technischen Details und unter der Bedingung, dass für die Stiftung keine zusätzlichen Kosten anfallen, zu.

Die Stiftung Südtiroler Sparkasse benennt eine Kontaktperson für die Klärung technischer Fragen, evtl. Begleitung bei Lokalaugenscheinen, Zugang zu Dokumentation und Daten, sowie zur Teilnahme an den für den integrierten Planungsprozess vorgesehenen Workshops und Meetings des LCS-Teams.

3. Finanzierung

Partei 1 EURAC trägt die Kosten für ihre unter Art. 2 beschriebenen Tätigkeiten. Entwickelte Lösungsvorschläge für die energetische Sanierung des Fallstudien-Gebäudes können seitens des Eigentümers auf eigene Rechnung umgesetzt werden. Im Falle, dass der Gebäudeeigentümer sich für die Umsetzung der vorgeschlagenen Maßnahmen entscheidet, liegen alle Kosten, welche über die reine Installation eines Prototypen hinaus gehen, beim Gebäudeeigentümer.

Partei 2 Stiftung Südtiroler Sparkasse trägt für die Laufzeit der Fallstudie die von der EURAC verursachten Stromkosten mit einem Höchstbetrag von Euro 500,00.- monatlich.

Darüber hinaus anfallende direkte Kosten für die Umsetzung der in diesem Abkommen unter Art. 2 beschriebenen Maßnahmen trägt die EURAC.

4. Zeitplan

- Frühjahr 2011 – Bestimmung der Nutzung des Gebäudes (gemäß Kaufvorvertrag der Stiftung mit der Gemeinde Bozen ist die Zustimmung der Gemeinde erforderlich)
- April 2011 - Installation des Monitoringsystems
- Sommer 2011 – Abschluss der grundlegenden Diagnose und Berechnung des Energieverbrauchs IST-Zustand
- Sommer 2011 – Ausschreibung der Sanierung
- ab Sommer 2011 – Entwicklung von Lösungsvorschlägen
- ab Sommer 2011 - Begleitung der Eingabe- und Ausführungsplanungsphase in Form eines integrierten Planungsprozesses
- Herbst/Winter 2011 – Montage von Prototypen
- Sommer 2013 – Anpassung des Monitoringsystems an den sanierten Zustand
- Frühjahr 2014 – Abschluss des EU-Projektes

Dieser Zeitplan wird im gegenseitigen Einvernehmen während der Projektlaufzeit weiter detailliert und ggf. angepasst. Weder die EURAC noch die Stiftung können für Verzögerungen an der Fallstudie, welche durch das Verzögerungen im Gesamtprojekt 3ENCULT oder der Sanierungsarbeiten verursacht werden, belangt werden.

5. Haftung

Die Eurac hat eine Haftpflichtversicherung gegen Dritte und Arbeitnehmer mit Deckungssumme € 5 Mio. pro Schaden / Jahr abgeschlossen. Diese Haftpflichtversicherung deckt die gesetzlichen Haftpflichtansprüche Dritter und Arbeitnehmer, vorbehaltlich den bekannten Ausschlüssen der Polizze.

Die EURAC verpflichtet sich, zu überprüfen, dass die einzelnen Projektpartner eine Haftpflichtversicherung abgeschlossen haben. Die Projektpartner können nicht direkt von der EURAC versichert werden.

6. Obliegenheiten hinsichtlich der Sicherheit und Gesundheit am Arbeitsplatz

Was die Sicherheit und Gesundheit am Arbeitsplatz anlangt, ist die Stiftung Südtiroler Sparkasse weiterhin verpflichtet, EURAC hinsichtlich der spezifischen und interferierenden Risiken zu informieren, die im Umfeld, in welchem man die Tätigkeit ausübt, bestehen, mit besonderem Bezug auf den derzeitigen Zustand der verschiedenen Teile des Gebäudes.

In ihrer Eigenschaft als Koordinator wird EURAC diese Informationen sämtlichen Angestellten weitergeben, die aus verschiedenen Gründen im Rahmen des Projektes und für die gesamte Dauer desselben Zugang zum Gebäude haben.

EURAC wird sich im Sinne des Art. 26 der gesetzesvertr. Verordnung n. 81/2008 mit den Arbeitergebern aller Angestellten, die mit der Durchführung der vorgesehenen Tätigkeiten beauftragt sind, an der Realisierung sämtlicher Maßnahmen zur Vorsorge und zum Schutz vor interferierenden Risiken am Arbeitsplatz beteiligen, die auf die im Vertrag behandelte Tätigkeit Einfluss nehmen. Gleichfalls wird EURAC sich an der Koordinierung der Maßnahmen zur Vorsorge und zum Schutz vor interferierenden Risiken beteiligen, denen das Personal, das Zutritt zum Gebäude hat, ausgesetzt ist; dies auch zum Zweck der Beseitigung der Risiken im Zusammenhang mit Interferenzen zwischen dem betroffenen Personal.

EURAC übernimmt zudem die Kooperation und Koordinierung mittels Erstellung eines einzigen Dokuments zur Risikobewertung (welches Dokument ggf. von der Stiftung Südtiroler Sparkasse erstellt wird), in welchem sämtliche Maßnahmen aufgezeigt sind, die zur Beseitigung oder, falls dies nicht möglich, zur Minimierung der Interferenzrisiken im Sinne des Art. 26 der gesetzesvertr. Verordnung 81/2008 gesetzt wurden, vorbehaltlich der Aufnahme von Arbeiten durch die Stiftung oder von Dritten an 3Encult nicht Beteiligten im Auftrag der Stiftung (in welchem Fall die Stiftung oder ein von ihr zu Beauftragender für die Sicherheitskoordination in der Planungs- und Ausführungsphase sowie für alle anderen Obliegenheiten u.a. im Zusammenhang mit GvD 81/2008 Sorge trägt).

Dieses Dokument ist stets auf den neuesten Stand zu halten und ist, nach Unterzeichnung von Seiten aller Arbeitsgeber, die an der Durchführung der vorgesehenen Tätigkeiten beteiligt sind, vor Beginn der einzelnen Tätigkeiten zur Information und Kenntnisnahme an die Stiftung Südtiroler Sparkasse zu schicken.

7. **Confidentiality**

Alle Informationen in welcher Form oder Art der Übertragung auch immer (einschließlich aber nicht beschränkt auf Dokumente, Vorträge, geschäftliche Informationen, Wissen), die von der EURAC oder einem der 3ENCULT-Partner im Zusammenhang mit dem 3ENCULT Projekt kommuniziert wird, sind als vertraulich zu behandeln, auch wenn sie nicht ausdrücklich als vertraulich gekennzeichnet sind. Die Stiftung Südtiroler Sparkasse verpflichtet sich diese Informationen nicht an Dritte weiterzugeben und sie nicht für andere Zwecke als die in diesem Vertrag beschriebenen zu verwenden.

8. Materielle und geistige Eigentumsrechte

Die einzelnen Komponenten (Monitoringsystem, Prototypen), bleiben nach Abschluss des Projektes im Eigentum der Partei oder des 3ENCULT-Partners, welcher sie gekauft und die Installation begleitet hat. Die Partei/der Partner kann vorgenannte Eigentumsrechte an den Gebäudeeigentümer (die Stiftung Südtiroler Sparkasse) kostenlos abtreten.

Geistige Eigentumsrechte der Einzelteile bleiben beim ursprünglichen Eigentümer.

Das Recht, nach Abschluss des Projekts/Vertrags die Daten des Monitoring zu erheben und zu nutzen, geht an die EURAC. Die Stiftung Südtiroler Sparkasse gewährt hierfür angemessene Zugangsrechte. Dieses Nutzungsrecht ist unentgeltlich.

Bezüglich sonstiger Eigentumsrechte gilt das Consortium Agreement zum EU-Projekt.

9. Anwendbares Recht/Gerichtsstand

Auf diesen Vertrag ist das italienische Recht anwendbar. Der Gerichtsstand ist Bozen.

10. Beginn und Ende

Der Vertrag läuft rückwirkend ab 1.10.2010 nach Unterzeichnung durch alle Parteien und endet mit der Akzeptierung des Abschlussberichts für das 3ENCULT Projekt durch die EU-Kommission, spätestens jedoch vierundzwanzig Monate nach Abschluss der Umbauarbeiten seitens der Stiftung Südtiroler Sparkasse.

11. Allgemeines

Mündliche Absprachen zum Kooperationsvertrag existieren nicht. Änderungen des vorliegenden Vertrages bedürfen der schriftlichen Form.

12. Liste der Kontaktpersonen

EURAC

- Dr. Ing. Alexandra Troi, Projekt-Koordinatorin
  alexandra.troi@eurac.edu, tel. 0471 055602, mob. 338 7149464
- Dipl. Ing. Dagmar Exner, Projekt-Mitarbeiterin
  dagmar.exner@eurac.edu, tel. 0471 055655

Stiftung Südtiroler Sparkasse

- Dr. Andreas Überbacher, Direktor
  ueberbacher@stiftungsparkasse.it, tel. 0471 316000
- Dr. Sylvia Amonn, Projekt-Mitarbeiterin
  amonn@stiftungsparkasse.it, tel. 0471 316016

Dieser Vertrag ist in zweifacher Ausfertigung erstellt und unterschrieben.

Bozen, am 19. Juli 2011

EUROPÄISCHE AKADEMIE STIFTUNG SÜDTIROLER
SPARKASSE

DER PRÄSIDENT DER PRÄSIDENT
Dr. Werner Stuflesser RA Dr. Gerhard Brandstätter

Anhang:

EC-Grant Agreement mit Annex I and II

Consortium Agreement zum 3ENCULT Projekt

8.2.2 Second cooperation agreement (in German)

Original text of the second agreement between EURAC and CS Owner (WP6_20140310_Agreement EURAC and CS Owner):

Vereinbarung

zwischen

der Europäischen Akademie Bozen (EURAC), in Person des gesetzlichen Vertreters und Präsidenten Dr. Werner Stuflesser, mit Sitz in 39100 Bozen, Drususallee 1, und

der Stiftung Südtiroler Sparkasse, in Person des gesetzlichen Vertreters und Präsidenten RA Dr. Gerhard Brandstätter, mit Sitz in 39100 Bozen, Talfergasse 18.

Vorausgeschickt, dass

- die Stiftung Südtiroler Sparkasse Eigentümerin des "Waaghaus" (BP. 269/1 KG Bozen 613 E.Zl. 1169 II, Waaggasse 1-3, Lauben 19, 39100 Bozen) ist;
- die obgenannten Parteien am 19.07.2011 eine Kooperationsvereinbarung für die Durchführung des EU-Projektes „3ENCULT", welches im 7. Forschungsrahmenprogramm gefördert wird (EC-Grant Agreement number: 260162), abgeschlossen haben;
- das EU-Projekt „3ENCULT" mit dem 31. März 2014 abgeschlossen wird;
- im Zuge des EU-Projektes „3ENCULT"im Waaghaus, in einem in Abstimmung mit dem Denkmalamt ausgewählten Raum an der Nord-Ost-Seite im ersten Obergeschoss des Gebäudes, unter anderem folgende Arbeiten durchgeführt und abgeschlossen wurden:

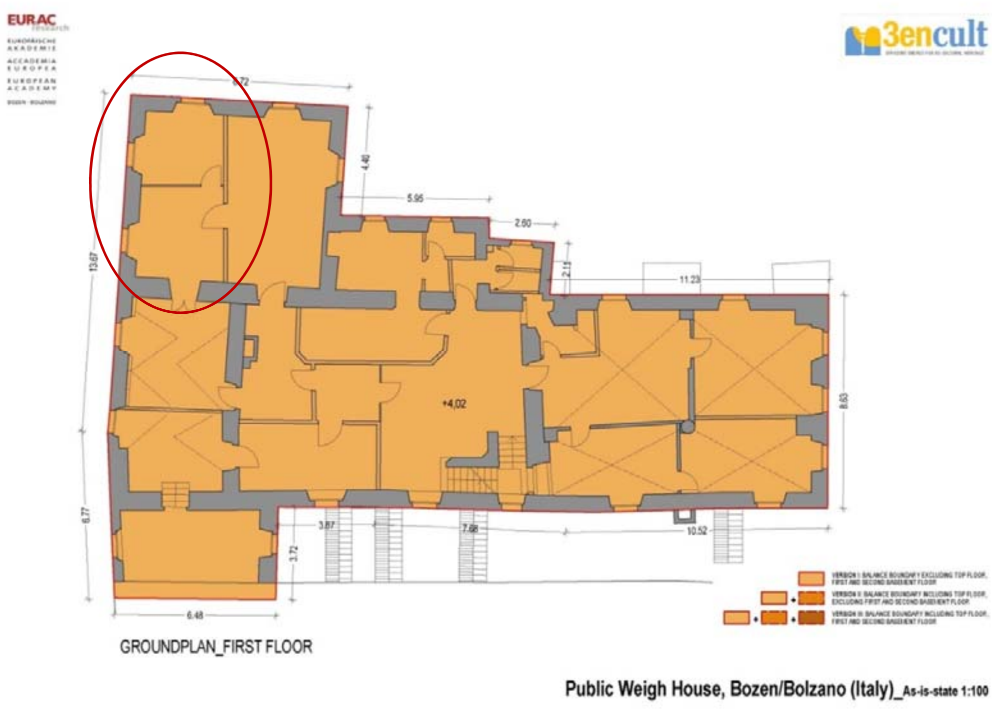


Abb. 1: Grundriss 1. Obergeschoss Waaghaus mit Kennzeichnung des „Testraums"

- sämtliche vorbereitende Arbeiten zur Installation der Innendämmung wie Entfernung der Trockenbauwand, Abkratzen der Oberflächen, Deckenschlitz etc.;

    - Dämmung der Decke über den Lauben (Boden des Testraums) sowie Installation einer luftdichten Schicht aus OSB-Platten;
    - vollständige Installation des Systems zur Messung der Holzfeuchte in den Balkenköpfen;
    - die teilweise Installation von Temperatur- und Feuchtigkeitssensoren in den Bauteilschichten und auf den Oberflächen;
    - Einbau eines Fensterprototyps im Testraum, sowie eines zweiten Prototyps im Raum daneben (Südseite). Bei den anderen beiden Fenstern wurde eine fixe Zweifachverglasung in die bestehenden Kastenfenster eingebaut.
- folgende im EU-Projekt vorgesehene Arbeiten nicht durchgeführt werden konnten:
    - Kartierung der Hohlstellen zwischen Wand und Innenputz samt Hinterfüllung durch einen Restaurator;
    - Einbau der im EU-Project „3Encult“ entwickelten Innendämmung iQTherm an den Außenwänden, samt vorher anzubringenden Ausgleichsputz und Innenputz
    - Während und nach Einbau der Innendämmung: Einbau und Wiedereinbau von Temperatur- und Feuchtigkeitssensoren in den Bauteilschichten und auf den Oberflächen;
- die EURAC daran interessiert ist, die noch ausstehenden Arbeiten fertigzustellen und anschließend den Testraum für zwei weitere Winter (bis ca. April 2016) zu überwachen;
- die Stiftung Südtiroler Sparkasse beabsichtigt, das Waaghaus demnächst zu sanieren;
- die EURAC diesen Sanierungsprozess nicht beeinträchtigen will;
- die Stiftung Südtiroler Sparkasse durch die noch durchzuführenden Arbeiten jedenfalls einen vollständig energetisch sanierten Raum erhält.

All dies vorausgeschickt vereinbaren die beiden obgenannten Parteien wie folgt:

1) Die Prämissen bilden integrierenden Bestandteil dieser Vereinbarung.
2) Die am 19.07.2011 abgeschlossene Kooperationsvereinbarung gilt als aufgelöst.
3) Die EURAC verpflichtet sich, jeden Besuch im Waaghaus, sei es allein oder in Begleitung eines 3ENCULT Projektpartners, der Stiftung Südtiroler Sparkasse im Vorfeld mitzuteilen und zwar mit mindestens einem Vorlauf von zwei Tagen, im Falle eines reinen Besuchs ohne Maßnahmen und Eingriffe bzw. einem Vorlauf von 14 Tagen und unter Mitteilung der technischen Details, im Falle eines Besuchs mit Maßnahmen und Eingriffen.

   Die Stiftung kann den Zugang nur verwehren, sollten zum vorgeschlagenen Termin dringende Arbeiten am Gebäude durchgeführt werden und unter Vorschlag eines Ausweichtermins innerhalb der nächsten 7 Tage.

   Die EURAC verpflichtet sich dazu, alle kommunikationstechnischen Angelegenheiten (z.B. Pressekonferenzen u.Ä.), die im Waaghaus selbst stattfinden, vorher mit der Stiftung abzusprechen.

4) Die Stiftung Südtiroler Sparkasse autorisiert die EURAC nachstehende Arbeiten im Testraum des Waaghauses, welche bis zum 31.12.2014 realisiert werden, durchzuführen:
    a. Kartierung der Hohlstellen zwischen Wand und Innenputz samt Hinterfüllung durch einen Restaurator;
    b. Einbau der im EU-Project „3Encult“ entwickelten Innendämmung iQTherm an den Außenwänden, samt vorher anzubringenden Ausgleichsputz und Innenputz
    c. Während und nach Einbau der Innendämmung: Einbau und Wiedereinbau von Temperatur- und Feuchtigkeitssensoren in den Bauteilschichten und auf den Oberflächen;
5) Zudem ist die Stiftung Südtiroler Sparkasse damit einverstanden, dass die angebrachte Innendämmung für zwei Winter, also bis ca. Mitte April 2016, im Testraum belassen wird und dass die EURAC für denselben Zeitraum die Messungen mit den eingebauten Temperatur- und Feuchtigkeitssensoren, insbesondere jedoch die Messung der Holzfeuchte in den Balkonköpfen, durchführen darf.
6) Die Parteien sind sich darüber einig, dass die vorgesehenen Messungen eine eventuelle Sanierung des Waaghauses nicht beeinträchtigen sollten. Bei einer eventuellen Sanierung wird jedenfalls die Stiftung Südtiroler Sparkasse die EURAC in den diesbezüglichen Sanierungsprozess miteinbeziehen, sodass die vorgesehenen Messungen auch währen der Sanierung bestmöglich aufrechterhalten bleiben.
7) Für eine eventuelle Sanierung gelten zwischen den Parteien folgende Richtlinien als vereinbart:
    a. Das Messsystem für Holzfeuchte in den Balkenköpfen ist bis auf den Verteilerkasten vollständig in der Konstruktion integriert. Aus diesem Grund wird davon ausgegangen, dass dieses Messsystem auch während eventueller Sanierungsarbeiten weiterlaufen kann. Sollte dennoch eine Unterbrechung der Messungen notwendig werden, so soll diese Unterbrechung in den Sommermonaten und über einen Zeitraum von nicht mehr als 14 Kalendertagen erfolgen.
    b. Sollten während den Sanierungsarbeiten im „Testraum“ Leitungen innerhalb der Wände verlegt werden, so soll darauf geachtet werden, dass diese Leitungen nicht in den Außenwänden verlegt werden. Sollte es sich nicht vermeiden lassen, dass solche Leitungen auch in den Außenwänden verlegt werden, so soll jedenfalls sichergestellt werden, dass die Installationsarbeiten das Innendämmsystem als auch das Messsystem nicht in ihrer Funktion beeinträchtigen.
    c. Das Messsystem für die Temperatur und Luftfeuchte in den Bauteilschichten ist größtenteils an der Innenoberfläche in Sicht installiert. Während einer eventuellen Sanierungsphase müssten diese Sensoren voraussichtlich abgedeckt und gegebenenfalls einige Zeit abgenommen werden. Während der Ausführungsplanung sollte zusammen mit der EURAC entschieden werden, welche dieser Sensoren nach der Sanierung weiterhin ausgelesen werden und wie diese während der Sanierungsphase eingebaut bzw. in die Konstruktion integriert werden können. Die Abnahme und der Wiedereinbau der Sensoren sollten in den Sommermonaten und über einen Zeitraum von nicht mehr als 14 Kalendertagen erfolgen.

d. Während und nach den Sanierungsarbeiten sollte sichergestellt sein, dass die Funktion des Innendämmsystems nicht beeinträchtigt wird. Somit sollte die Innenoberfläche des Testraumes nicht mit dampfdichten Anstrichen, sondern ausschließlich mit Wandfarben mit hoher Wasserdampfdiffusionsfähigkeit überdeckt werden. Zudem sollten keine Einbauten oder Installationen (Kabelschächte) die Funktionsweise der Innendämmung beeinträchtigen.
e. Im Zuge des EU-Projektes „3ENCULT“ wurde der Zwischenraum zwischen den Balken der Holzbalkendecke über den darunterliegenden Lauben gedämmt. Darüber wurde mit OSB-Platten eine luftdichte Ebene eingebaut. Aus bauphysikalischen Gründen ist es wichtig, dass die luftdichte Ebene nicht beschädigt wird. Somit sollten eventuelle Kabel- oder Rohrleitungen ausschließlich in der Ebene über der luftdichten Schicht geführt werden. Sollte dies nicht möglich sein so sollte gewährleistet werden, dass nach Installation dieser Kabel- oder Rohrleitungen die luftdichte Ebene nachträglich wieder luftdicht geschlossen werden.
f. Sollten die Fenster des Testraumes während der Sanierungsphase durch neue Fenster ersetzt werden, so sollte gewährleistet werden, dass die Innendämmung an den Anschlüssen zu den neuen Fenstern entsprechend den anerkannten Regeln der Technik angepasst werden.

8) Die Parteien verpflichten sich zur Einhaltung dieser Richtlinien im Falle von eventuellen Sanierungsarbeiten, mit Ausnahme von objektiver und begründeter Unmöglichkeit.
9) Die Kosten für ihre unter Art. 2 beschriebenen Arbeiten trägt die EURAC. Die Kosten eventueller Sanierungsarbeiten trägt ausschließlich die Stiftung Südtiroler Sparkasse.
10) Die Stromkosten für die Temperatur- und Feuchtigkeitsmessung trägt bis zu einem Höchstbetrag von € 50,00 monatlich die Stiftung Südtiroler Sparkasse.
11) Die EURAC verpflichtet sich, die bestehende Haftpflichtversicherung für das Projekt „3ENCULT“ mit denselben Bedingungen für die Dauer dieser Vereinbarung zu verlängern.
12) Die Stiftung Südtiroler Sparkasse verpflichtet sich die EURAC hinsichtlich der spezifischen und interferierenden Risiken, welche im Waaghaus bestehen, mittels dem Dokument zu Risikobewertung gemäß Art. 26 des GvD 81/2008 zu informieren. Das Dokument zu Risikobewertung muss stetig aktualisiert werden.
13) Die EURAC verpflichtet sich ihrerseits, diese Informationen Ihren Mitarbeitern sowie anderen interessierten Personen, die aus verschiedenen Gründen im Rahmen dieser Vereinbarung Zugang zum Gebäude haben, weiterzugeben.
14) Alle Informationen, in welcher Form oder Art der Übertragung auch immer (einschließlich aber nicht beschränkt auf Dokumente, Vorträge, geschäftliche Informationen, Wissen), die von den Vertragspartner im Zusammenhang dieser Vereinbarung kommuniziert werden, sind als vertraulich zu behandeln, auch wenn sie nicht ausdrücklich als solches gekennzeichnet sind. Die Stiftung Südtiroler Sparkasse verpflichtet sich diese Informationen nicht an Dritte weiterzugeben und sie nicht für andere Zwecke als die in dieser Vereinbarung beschriebenen zu verwenden.

15) Die einzelnen Komponenten (Monitoringsystem, Prototypen), bleiben nach Abschluss des Projektes im Eigentum der Partei, welche sie gekauft und die Installation begleitet hat. Die Partei kann vorgenannte Eigentumsrechte an die Stiftung Südtiroler Sparkasse kostenlos abtreten. In diesem Fall bleibt das geistige Eigentumsrecht der Einzelteile jedenfalls beim ursprünglichen Eigentümer.
16) Die gegenständliche Vereinbarung unterliegt italienischem Recht. Gerichtsstand ist Bozen.
17) Mündliche Absprachen zur gegenständlichen Vereinbarung existieren nicht. Änderungen der vorliegenden Vereinbarung bedürfen zu ihrer Gültigkeit der schriftlichen Form.

Bozen, am ___________________

Für die EURAC	Für die Stiftung Südtiroler Sparkasse
Dr. Werner Stuflesser	RA Dr. Gerhard Brandstätter
Präsident	Präsident

8.3 LCST meetings

- Minutes of "Workshop on windows", 26th August 2011: WP6_20110830_P01_Workshop windows meeting minutes
- Feedback of the conservator regarding the first window prototype 28th February 2012 (in German): WP6_20120228_P01_Feedback conservator first window prototype
- Minutes of "Workshop on windows", 09th April 2013 (in German): WP6_20130412_P01_Workshop windows meeting minutes
- Feedback of the conservator regarding the drawings of the second window prototype 13th June 2013 (in German): WP6_20130613_P01_Feedback conservator drawings second window prototype
-

8.3.1 Minutes of first "Workshop on windows", 26th August 2011

Participants List:

1	EURAC	Troi	Alexandra
1	EURAC	Lollini	Roberto
1	EURAC	Baldracchi	Paolo
1	EURAC	Exner	Dagmar
1	Amt für Denkmalpflege	Kofler-Engl	Waltraud
1	Amt für Denkmalpflege	Ausserhofer	Klaus
2	KA	Dahl	Torben
4	UIBK	Pfluger	Rainer
4	UIBK	Längle	Kai
5	ARUP	Orlandi	Matteo
8	BLL	Pohl	Wilfried
8	BLL	Weitlaner	Robert
8	BLL	Reim	Sarah
8	BLL	Atz	Edwin
9	TUD	Haas	Franziska
10	COBO	Tutino	Francesco
11	PHI	Krick	Benjamin
13	UNIBO	Colla	Camilla
17	ANDRE	Andre	Mathilde
17	ANDRE	Freundorfer	Franz

All presentations during the workshop and the meeting minutes have been uploaded on the teamsite in the following folders:

3encult Teamsite > Shared Documents > WP3 > Task 3.2.4 Windows > 20110826 Workshop on windows > Presentations

And:

3encult Teamsite > Shared Documents > WP5 > Task 5.2 New heritage-compatible window > 20110826 Workshop on windows > Presentations

Friday 26th August 2011

Location: historic city centre Bolzano, EURAC research Bolzano (Seminar 1-3)

Address: Vialle Druso 1, 39100 Bolzano, ITALY

Topic 1. Visit of some typical protected windows in the historic city center of Bolzano

Mrs Kofler-Engl, director of conservation office South Tyrol and member of the Local Case Study Team from CS1 Public Weigh House Bolzano, shows typical historic windows, some examples of refurbished windows and explains relevant recurrent problems in connection with energy refurbishment of protected windows.

Landhaus Bozen

Window type: Box-type window in varnished spruce from the 19th century.

Actual state: Existing window was refurbished in 2008: The single glass of the inner window was replaced by double glazing. To maintain the historic appearance the glass of the outer window remained the existing one. The windows on the outer side were caulked with a profiled joint in the rabbet of the lower side. In the office rooms also the inner windows were tightened with profiled joint all around the rabbet.

Problems:

1. Airtightness: Some windows are not airtight. The collaborators in the office are disturbed by cold air and draft in the winter season coming in through the closed windows.
2. Weather tightness: Although the profiled joint on the outer window, it is not rain proof.
3. Condition of weatherboard: coating is blistering from the weatherboard, humidity enters into the wood.
4. Varnish does not fit to putty: also here the coating is blistering from the putty, humidity and water enters the space behind the putty and comes into the window construction.


Possible reason and solutions discussed:

1. The reason for not airtight windows is that geometry of window frame is changing during the year according to climate. The adjustment of the old hinge is often not feasible as they are not flexible. To proof the airtightness in a fast way and to find non airtightness points on the window frame, Franz shows us the “paper-test”: A sheet of paper has to be put between the fixed and the movable window frame (in the rabbet – while the window is closed), if you can pull it away easily, the point is not airtight. A solution for airtightness in case of historic window frames could be a flexible geometric profiled joint. If it is possible to adjust the fittings, it is recommendable. In case that we replace a historic window and build a new one, the choice of the wood has to be done very carefully by an expert in order to obtain frames which keep the form as much as possible.
2. Also in case of missing weather tightness the reason is that geometry of window frame is changing during the year according to climate. Furthermore the profiled joint in some points is not fixed very well. The profiled joint on the lower part of the window is interrupted between the two window sashes. Also here a solution could be a flexible geometric profiled joint. To bridge the gap of the profiled joint between the two window sashes there are solutions already on the market, where a little extension of the profiled joint is added before closing the windows.
3. The condition of the weatherboard is mainly a maintenance problem. As the weatherboard is exposed to weathering it has to be replaced or at least to be sanded and varnished from time to time. For the weatherboard it is recommendable to choose a resistant type of wood like for example oak.
4. To coat the putty nowadays often we use acrylic paint, which chemically does not connect well with the material of the putty. To solve this problem it is recommendable to use a linseed oil, like it was used in the past, as base coat. Moreover it is important to let dry out the putty well, before painting it.

Generally we note that above every window there was a roller shutter box. It was not clear if it has been insulated. Problems of an existing roller shutter box can be: missing airtightness, thermal bridge in winter (missing insulation) and summer season (missing thermal mass), and acoustic problems.

Furthermore it is mentioned that it is hard to find a handcraft man which is really experienced with the old materials he needs to work with in case of refurbishment of historic windows like e.g. fixing the putty.

Municipality and building in Bindergasse/Via dei Bottai

Mrs Kofler-Engl shows the different appearance of a historic window with original glazing (photo above, on the left: Municipality) and of a refurbished window with double glazing (photo above, on the right: building angle Bindergasse/Via dei Bottai – Lauben/Portici). The optic appearance seems to be quite different because of the different mirroring.

The reason is that expansion and contraction of gas between the two glass layers of double glazing cause a convex or concave deformation of the glass pane and therefore a different mirroring. From the conservator`s point of view the original appearance should not be changed!


Above you can see another building example with original glazed windows (on the left: building Bindergasse/Via dei Bottai) and of a building with refurbished windows with double glazing (on the right: building Bindergasse/Via dei Bottai).


Also the glazing of the old and new part of the “Landhaus” shows the same optic appearance: photo on the left side above: old part with original glazing; photo on the right side: new part with double glazing.

Building in Bindergasse/Via dei Bottai and Lauben/Portici

The two buildings show a characteristic window of the late baroque period. Later (up to 1940) it was also used for typical farmhouses in the alpine space. The bay of the building on the left side demonstrates the usual function of this kind of window: in wintertime you can fit a second glazed window on the outer side, while in summertime it can be replaced by a window shutter. On the right photo we can see the north façade of a building, which is part of the Lauben/Portici of Bolzano, from the late baroque period. Since it is the north side the outer windows were not changed in the summer period. The type on the right side is typical for the region around Vienna. It is called the “Wiener Kastenfenster” (Vienna box-type window). A characteristic of this window is that the outer layer is flush with the surface of the outside walls and the window sashes open to the outside.

Mrs. Kofler-Engl explains that in wintertime the space between the two windows was used like a vitrine and decorated with moss (maybe also to improve airtightness) or figures in wood etc.

Corner House Lauben/Portici – Kornplatz/Piazza del Grano

In case when there is no available information on the original historic windows, usually the existing window is replaced by a new industrial manufactured window like we can see in this example (left above photo: two window sashes, right above photo: one window sash). The corner house shows a classic solution for South Tyrol for this case. The problem from the conservator's point of view is the optic: the proportion between glass area and sash bars/frame and the appearance of the double glazing.

Building Kornplatz/Piazza del Grano

Here Mrs Kofler-Engl explains the reproduction of a historic window with an overhead light. Originally the impost was much moulded and constructed in a very fragile and thin way, while the optic of the reproduction is much broader.

CS 1: Public Weigh House

Actual state: The main part of the existing structure is from the early middle age, several extensions and reconstruction where made in the last centuries. The window size is typical for baroque era. All original windows were replaced by different new window types during the last century. The main parts are box-type windows from the 50s/60s of the last century (see also pictures below: existing window from inside and outside). All of these windows are not of historic value from the conservator's point of view. This means that all windows should be replaced by a reproduction of a historic window. As there are no documents or information available on the type of the original historic window, the conservator proposes to base the new window on a "classic" window in terms of function, division and proportion. Mrs. Kofler-Engl recommends a window with two sashes with two sash bars each sash. It could be a box-type window, a coupled window or an insulating glass window. In case of a box-type window, the layer of the outer window layer should be placed behind the existing stone frame and the deepness of the box should be similar to the actual windows from the 50s/60s. It should be positioned and installed in the reveal in a similar way.

Possible interventions: Installation of a prototype, replacement of window during planned refurbishment

Topic 2. Presentation case studies, needed interventions (EURAC – Seminar 1-3)

The present case studies Case Study nr. 1, 2, 4 and 5 were already presented the day before at the workshop on lighting at Bartenbach Lichtlabor. Therefore we skip this point to have more time for the workshop. Only **case study nr. 3, Palazzina della Viola** which has not been presented the day before is presented by **Camilla Colla**.

CS3: Palazzina della Viola

Actual state: The refurbishment of the building start in 12/10 and the works will be finished in 03/12. There are several different existing window types: Glass panes with metal framework between stone columns on east, south and west side. Smaller wood frame windows mainly on the north façade. A particularity of the building is that windows cover an area of 45% of the total surface of the facades. For the shading curtains on the inside of the windows are used.

The north side of the building have quite simple, but not historic (protected) wooden windows. They could be modified or replaced.

Problems: During the summer period the space behind the window warms up. This will be a problem particularly in the future after the refurbishment when these spaces will be used for office spaces. The windows are not supposed to be weather tight so they will need some maintenance. The windows are protected and they cannot be replaced or modified.

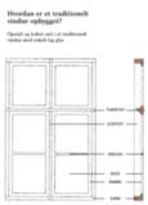
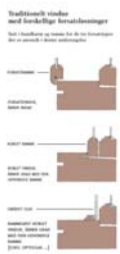
Possible interventions: All windows will be refurbished with low-e film; they should be maintained with a whole building approach, also foreseeing the enhancement of mechanical and thermal features as well as possible shading system. It would be possible to install a prototype during the refurbishment process on the north side.

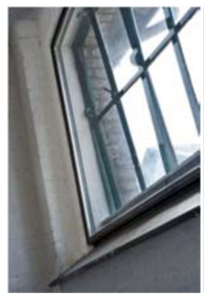
Topic 3. Energy efficient on-site refurbishment of a protected window

In most historic buildings a replacement of windows should be avoided to keep and protect the original window of historic value. In this case there should be solutions to refurbish the window on-site.

Torben Dahl presents examples of energy-efficient on-site refurbishment of protected windows. He points out that energy refurbishment of windows in general depends on architectural and cultural values like architectural style in terms of form, proportion, surface, glasses reflection etc. It depends further on function, technique in terms of materials and craftsmanship and on the weathering. Moreover it is influenced by the climate context and building physics as 3ENCULT eight case studies demonstrate: temperature, humidity and vapour pressure and related dew point and condensation. He shows different examples of refurbished windows. In most cases the historic window is kept in the original way and a second window layer is added on the inner side of the reveal. He shows different executions:

- Different materials of additional window frame: in rolled and welded steel profiles, aluminium profiles and wooden frame with energy glass
- Different position and fastening: fixed directly on the frame of the original window, in window reveal or on the inner side of the external wall
- Single glass additional pane fastened on the inside of the original wooden frame window




Finally he explains the solution in Case study no. 4, the Fortress Material Court Yard Copenhagen.

Topic 4. Introduction development of an energy efficient window prototype

Presentation Rainer Pfluger (UIBK): Historic windows – Project "Haus der Zukunft"

Rainer Pfluger from the University of Innsbruck gives an overview on the development of windows in the past and on energy refurbishment solutions for historic windows.

Over the last centuries different window types were developed and applied. Rainer Pfluger gives an overview of the different window types and its referring U-values:

Window type	Period of application	U_w-Value
Metal frame	1920 - today	Ca. 4,6 W/m²K
Countersash window	1910 - 1980	Ca. 3,0 W/m²K
Box type window	1850 - 1940	Ca. 2,2 – 2,5 W/m²K
Single glazing with additional ext. window	1820 - 1900	Ca. 2,3 2,9 W/m²K
Single glazing	…… - 1850	Ca. 3,5 – 5,0 W/m²K

2002 a special standard window with double glazing (called "Sonder-Iso-Fenster-D") was developed for historic buildings in Germany by the association "Glas-Fenster-Fassade Baden Württemberg". It has a minimum frame width of 56 mm with a slim double glazing (3-6-4) with an U_g-value of 1,5 W/m²K and an U_W-Value of 2,1 W/m²K (with sash bars).

On the base of design elements of historic windows in terms of dimensions, position and number of sash bars (partition), frame thickness and sash dimensions, as well as glazing reflections by different tilt angles (in case of sash bars) the partners from a "Haus der Zukunft" project developed a new window for historic buildings with double glazing.

The thin frame of this window contains a slim double glazing (4-10-4) with coating and krypton gas filling. The glazing is sealed with an acrylic joint. The spacer of double glazing is a thermally decoupled glass spacer; its colour can be adjusted to the frame so that the double glazing is not recognizable or less conspicuous. There are two window types available: either the single window type with an U_W-Value of 1,5 W/m²K or the box-type window with an U_W-Value of 1,1 W/m²K.


"Haus der Zukunft": left side: single window; right side: box type window

Presentation Benjamin Krick (PHI): Passive house comfort and hygiene criteria. Passive house windows in historic buildings.

Benjamin Krick from the PHI gives an introduction about passive house comfort and hygiene criteria and passive house windows in historic buildings, focusing in particular on heating conditions.

One primary criterion for indoor comfort is the minimum temperature of inner surfaces: For reasons of comfort this passive house criteria limits the minimum average temperature of a building component´s surface. The minimum surface temperature can deviate from average operative room temperature by a maximum of **4,2 K**. A greater difference can lead to drafts from cold air falling and to radiant heat loss. This determines a maximum thermal transmittance coefficient for building components, which depends on external climate.

He shows a map of Europe with the max. U-values that correspond to the maximum deviation. For a passive house window in Frankfurt for example it means that it has to have a triple glazing and it has to have an U-value of 0,85 W/(m²K), while in Rome a double glazing with an U-value of 1,35 W/(m²K) would be sufficient.

Another important criterion is the maximum water activity. For reasons of hygiene, this criterion limits the minimum temperature of inner surfaces. Water activity greater than 0,80 can lead to mould growth, the minimum temperature of inner surfaces has to be higher than 12,6 °C, when RH is 50%.

All parts (up to all points) of the window surface must fulfil these requirements. The coldest point of a window is the glass edge. Therefore it is crucial which kind of material is used (depending on the climate) for the spacer.

Benjamin Krick shows window solutions that fit to both above mentioned criteria for the climate of Rome, Frankfurt, Warsaw and Moscow. Furthermore he shows some examples of suitable frames. Recently there is a trend notable that window developers try to keep the frame dimensions smaller. The reason is not only an aesthetic one: From the energetic point of view the frame is the weak part of the window in comparison to the glass (U-value glass: 0,40 – 0,70 W/(m²K); U-value frame: 0,67 – 0,80 W/(m²K)). So there is the attempt to minimize the frame-area to decrease heat losses but also to raise solar gains through the bigger glass area.

Benjamin Krick underlines that it is a fundamental issue in which way the window is installed in the exterior wall in order to fulfil the above mentioned passive house criteria. Therefore it is recommendable to analyse the installation detail of the window with a tool for the calculation of thermal bridges. If possible the window should be installed in the insulation layer.

Finally he shows three examples of thermally enhanced window in historic buildings:

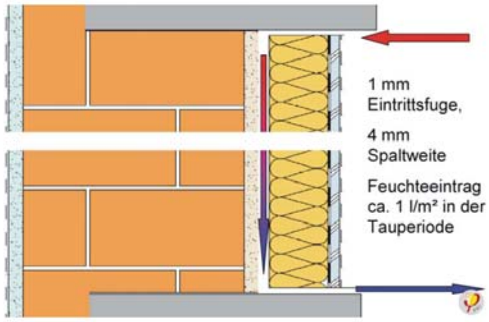
- New double windows with exterior and interior insulation: modernization of a historic monument in Görlitz, Germany (Cornad et al. 2008, Häupl et al. 2007)
- Hohenzollernhöfe, Ludwigshafen, Germany: Modernization of a protected housing complex in an architectural ensemble using new triple glazed windows (Zaman 2010)
- Brewery Restaurant with Hotel: Reconstruction of a Historical Monument in Autenried. Refurbished old windows added by new windows on the inside (Endhardt 2011)

Presentation Franz Freundorfer (Andre): Passive House windows and monuments. They are a bad match?

Franz Freundorfer from Fa. Andre speaks about passive house windows and monuments. He asks the question: are they a bad match?

First he points out the importance of windows as an element of the thermal building envelope from the energy point of view. Compared with all components of the end energy consumption of our households the space heating is 51%. If we look at how the consumption is distributed on the envelope elements we can see that windows account for 22% (frame 12%; glass 10%).

The answer to this issue is the retrofitting and the enhancement or exchange of old windows to energy efficient windows. In the recent history two main mistakes occurred: the raising of airtightness without raising the air exchange/ventilation at the same time and exchanging of windows without enhance the thermal insulation of the opaque part of the envelope at the same time. This led to a high risk of mould growth because of higher condensation risk (water activity) in combination with less ventilation. A solution of this problem is to raise the temperature of the opaque part of the envelope by insulation. In most cases in historic buildings it is not possible to insulate the exterior wall from the outer side so that in many cases interior insulation seems to be the best solution. Franz Freundorfer underlines to pay attention on the airtightness in case of interior insulation (see picture below).



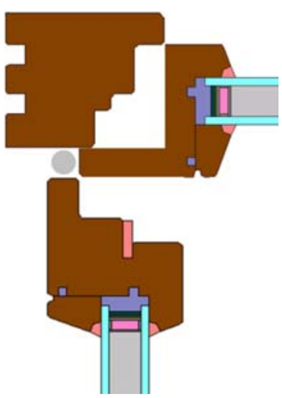
Presentation Franz Freundorfer (Andre): Window prototype solutions and materials

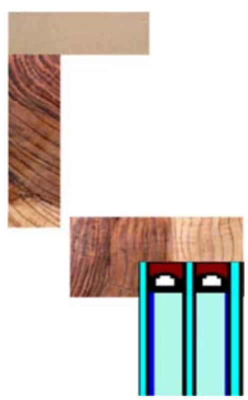
Before all participants start to work on window refurbishment solutions in different groups, Franz Freundorfer presents his first ideas for the development of an energy efficient prototype for case study nr. 1, the Public Weigh House of Bolzano and shows some possible materials and construction technologies.

Starting with the development of an energy efficient window prototype, he followed two main aims:

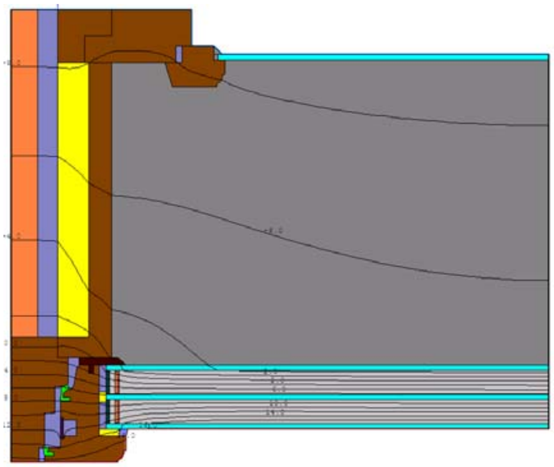
1. Original historic appearance of the replaced window from outside
2. Integration of a suitable passive house window

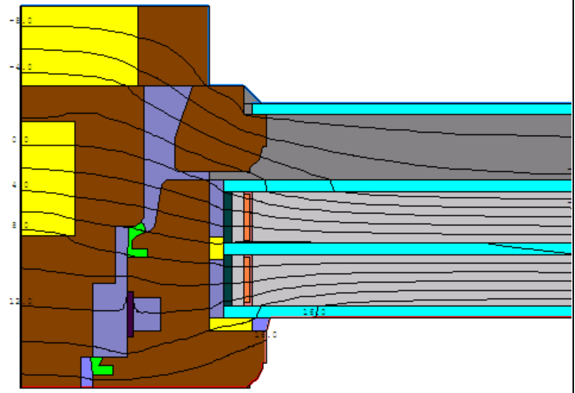
To answer to this aims his idea was to separate the demands and functions into two layers: one outer layer for the reproduction of the original historic window and an inner layer for the integration of a passive house window. In this way it is possible to obtain the same appearance like the original historic window from outside in terms of frame dimensions, sash bars and mirroring by taking a single glazing, without any negative effect on the energy efficiency. This outer layer takes over the weather tightness.
The passive house window is integrated in a second additional inner layer. By rotating the frame cross section 90 degrees and by moving the center of rotation of the fitting he accomplishes a smaller frame than the conventional solution (see picture below).





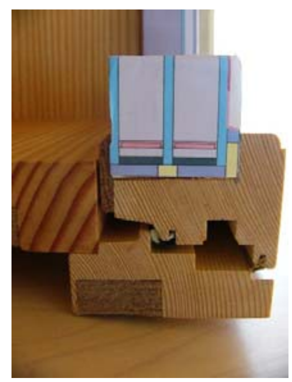
According to his approach both window types are possible: a box-type window or a coupled window (see picture below).





The inner layer fulfils the airtightness. It is positioned in a way that its frame is not visible from the outside.

Some pictures of the new window prototype, developed by Franz Freundorfer:



Franz Freundorfer presents two innovations in the glass sector, that can be useful for the development of an energy efficient window prototype:

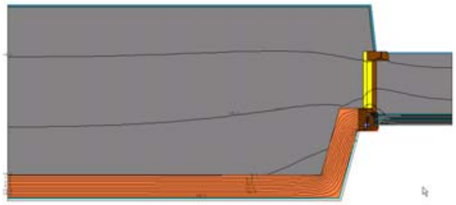
Vacuum glazing (Pilkington):
It consists of an outer pane of low-emissivity glass and an inner pane of clear float with vacuum in the interspace. This allows a very thin profile so it can be used in thin frames.
Disadvantage: For durability of the vacuum between the two glazing it is produced with a metal spacer which is an enormous thermal bridges particularly when we have little glass dimensions, as we have especially in historic buildings.

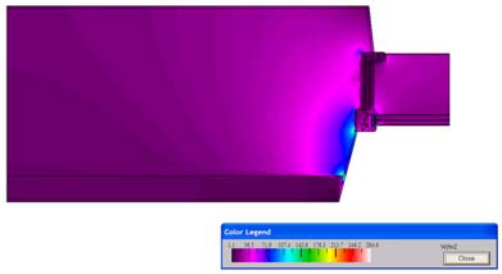
Thermal pre-tensioned thin window glass (Lisec):
It is a very thin single glazing of 2 mm. So for a triple glazing of 2-8-2-8-2 it means a total thickness of 22 mm instead of usually 28 mm. The company offers also a pane with the appearance of a historic single glazing. Franz Freundorfer asked for information about spectral data and a sample with historic appearance four month ago, but he did not get any material so far.

Franz Freundorfer underlines that every window solution should be evaluated and checked with a two-dimensional heat-transfer modeling software, like e.g. therm (free downloadable at

http://windows.lbl.gov/software/therm/therm.html), to assess the U-value of the frame, the psi-value and the surface temperatures.
To weight different window solutions from the energy point of view for the whole building it is useful to use PHPP.

Finally he shows different variants of installation of a box-type window in a 200 years old protected building with the connected psi-values and resulting heat losses. In the following table you can see an evaluation of a variant with (left side) and without (right side). The two variants show high differences.





Variant with insulation on reveal Psi-value window = 0,054 W/mK Losses fitting = 1.043 kWh/a Or 3 kWh/m²a	**Variant without insulation on reveal** Psi-value window = 0,512 W/mK Losses fitting = 10.117 kWh/a Or 23 kWh/m²a

Topic 5. Workshop: development windows prototype

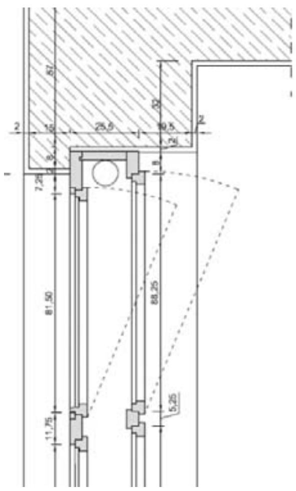
According to the present case studies the workshop participants divide into four groups:

- **Group 1:** Case study nr. 5: Monumental School – Innsbruck (Austria)
- **Group 2:** Case study nr. 1: Public Weigh House – Bolzano (Italy)
- **Group 3:** Case study nr. 3: Palazzina della Viola - Bologna (Italy)
- **Group 4:** Case study nr. 4: The Material Court of the Fortress, Copenhagen (Denmark)

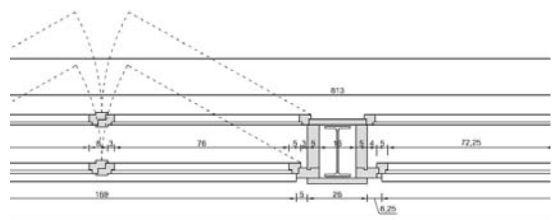
For one hour the participants discuss demands and possible solutions for the different case studies windows within the groups. In the end the results are presented.
Group 1: Possible solution for monumental school in Innsbruck (Austria):

First Kai Längle from the university of Innsbruck had explained demands and problems to resolve at the Innsbruck case study. The window type he presents is a four sash box-type window with single glazing. The distance between the two glass layers is ca. 16,5 cm. One problem is the occurring glare in different classrooms. Kai Längle proposes a blind with broad lamellas (max. possible broadness) installed in the space between the two glass layers. In case when the lamellas are in horizontal position there is a high distance between every lamella, which allows a better transparence and a better view from the classroom to the outside.
Another problem to solve is that actually it´s difficult to clean the outer sashes from the outside, above all the upper sashes, as the inner and the outer window can be only tilted (see vertical section below).

Box-type window Monumental School – Innsbruck (Austria)



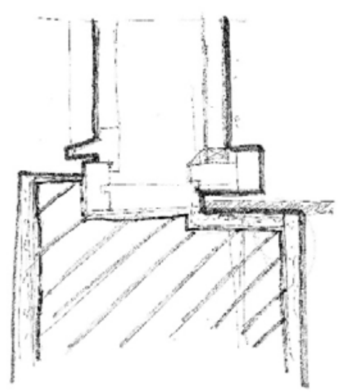
Vertical section



Horizontal section

Presented results: the group discussed first on how they can solve the shading problem (?). To solve the problem of maintenance and cleaning of the outer layer of the two above sashes they proposed to change the fittings into horizontal tilt-and-turn fittings. In this case it would be possible to turn the outside of the window to the inside of the room to clean it. There are sufficient solutions on the market as they are often used for roof-lights.

Outside:
The thick line shows the weather-tightness



Inside:
The thick line shows the airtightness

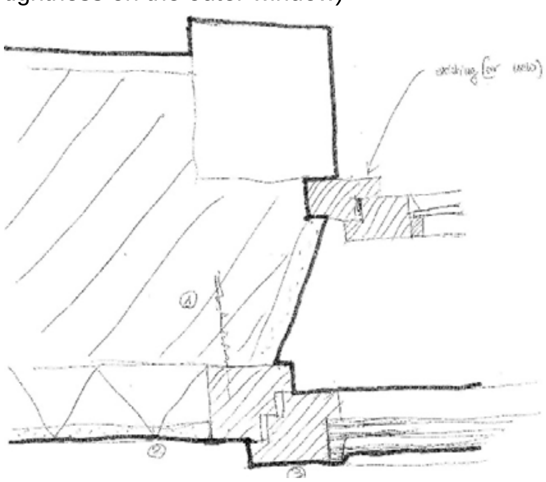
For the energetic refurbishment of the window they propose to change the single glazing of the inner windows into a double glazing by keeping the original window frame but by adapting a wood ledge on the inner side of the window (see vertical section above).

Group 2: Possible solution for Public Weigh House Bolzano (Italy)

The group presented a solution, which could work either when the existing historic window remains or when the existing window is replaced by a reproduction of a historic window (with sash bars). In both cases an energy efficient triple glazed window (without sash bars) is installed separately on the inner surface of the outside wall (see sketch below: horizontal section).

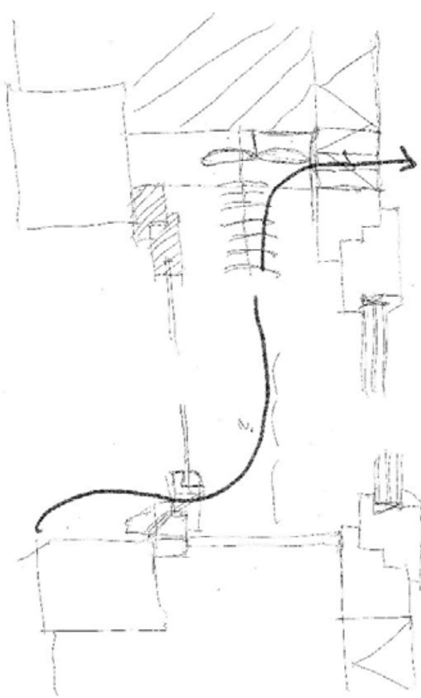
The group tried to find solutions that exploit the space between the windows in a better way. They foresee the installation of the shading device within this space. Furthermore they discussed how “controlled” ventilation could be possible to avoid ventilation heat losses. One solution could be to make openings on the upper part of the inner frame and the lower part of the outer frame and to foresee a little ventilator in the interspace. Winter case: the air in the interspace warms up by solar gains. When a certain temperature is achieved the ventilator is switched on and the wholes open in a way that the preheated air comes into the room. Summer case: in summer the air behind the dropped down blinds remains cooler and it can be ventilated into the room when a certain temperature occurs (see sketch: vertical section).

Outside:
The thick line shows the rain-tightness
(although it might be better to position the weather-tightness on the outer window)



Inside:
The thick line shows the airtightness

Horizontal section



Vertical section

Example of industrial product: http://www.vetroventilato.it/uk/applicazioni/

Advantages:

1. The new inner window can be fixed on the existing wall in an easy way
2. In case of inside insulation the window can be connected airtight to the insulation and can be integrated proper into the insulation layer

3. The window itself could be a standard industrial production of a passive house window with a thin frame (new generation of A-class passive house window).
4. This solution does not cover as much space of the reveal like a box-type window would do. This increases the daylighting because the plastered reveal can reflect more light.
5. The “controlled” ventilation could not only help to prevent ventilation heat losses but also to ventilate the room when there is no ventilation system available and there is the risk of too low air exchange because of airtightness.

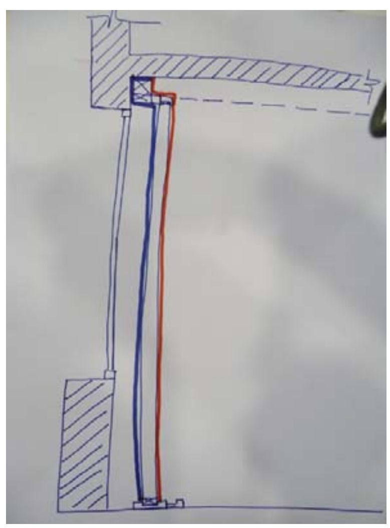
Critics/disadvantages:

1. Through the installation of an additional window on the inner surface the heavy and strong appearance of the thick walls is lost.
2. As the inner window decreases the dimensions of the window opening by covering the ridge of the window reveal parts of daylighting are lost.
3. Openings/Ventilation: The effort to keep the foreseen openings airtight is too high in comparison to the energy benefit

Group 3: Case study nr. 3: Palazzina della Viola - Bologna (Italy)

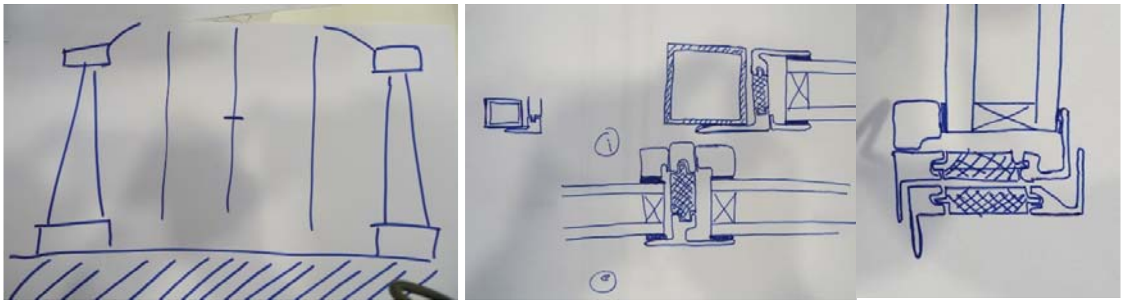
The Group concentrated on the glass panes with metal framework between stone columns on the east, south and west side. As this window should not be modified and there is no reveal inside, they proposed a second additional layer on the inner side with sliding windows.
This second skin would be fastened on the floor and guided in the upper part to allow this sliding. The possibility to open the internal skin, would allow fulfilling air-exchange requirements. Attention should be paid to the decorated wooden ceiling. In this way should be also possible to put some shading system in the air gap between the existing external skin and the new one.

Outside:
The blue line shows the weather tightness



Vertical section

Inside:
The red line shows the airtightness



Left image: schematically prospect of glass panes with metal framework between stone columns. Middle and right image: detail sketches

Advantages:

1. Better performance both from energy and indoor comfort point of view.

Critics/disadvantages:

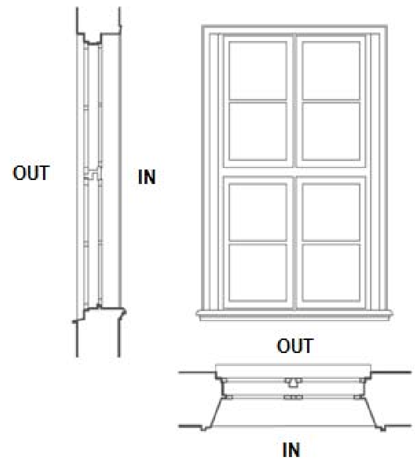
1. Costs for the second skin
2. Airtightness achievable with sliding windows
3. Loss of space inside (but the rest will be more confortable)

Palazzo D'Accursio case study was also analyzed. In this case there is no big constrains stated it will be possible also to replace the windows. At the moment there are two windows one in front of the other, but could be replaced with one performing window installed at outer part (removing the internal window). Solar control inside to protect fresco on the wall should be foreseen. There is also the possibility to use ledge for electric cabling for two purposes: lighting system, automatic opening of part of the window for natural ventilation: the retrofit concept foresees the use of window area both for lighting and air-exchange.

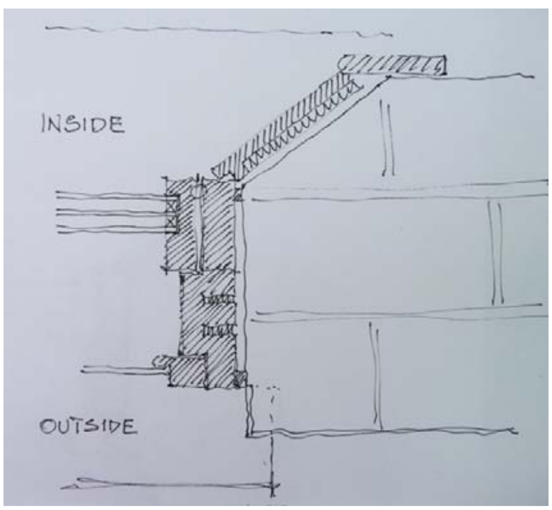
No further solution idea was developed for this case study.

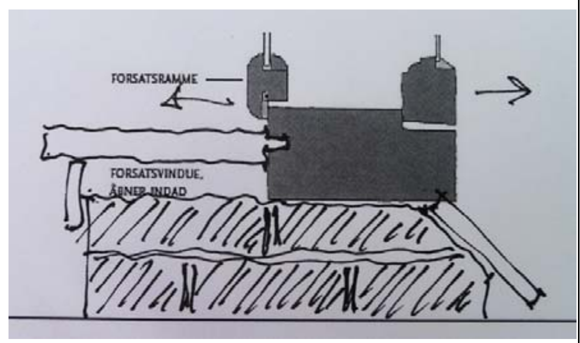
Group 4: Case study nr. 4: The Material Court of the Fortress, Copenhagen (Denmark)

The group started from the original design of the window and tried to respect the original dimensions of the window frame. The exterior pane has been kept with a single glass while the interior pane has been replaced with a triple glass.
Since the wall cannot be insulated neither inside nor outside, some insulation has been placed in the frame of the box in order to minimize the thermal bridge of the connection with the wall. The original box frame is really thick therefore there is enough space to design a new box frame able to accommodate the triple glass pane and also some insulation layer.
The interior edges of the window frame are also insulated with an insulation panel installed behind the wooden board that covers the interior wall (see the sketch horizontal section).



Original window design

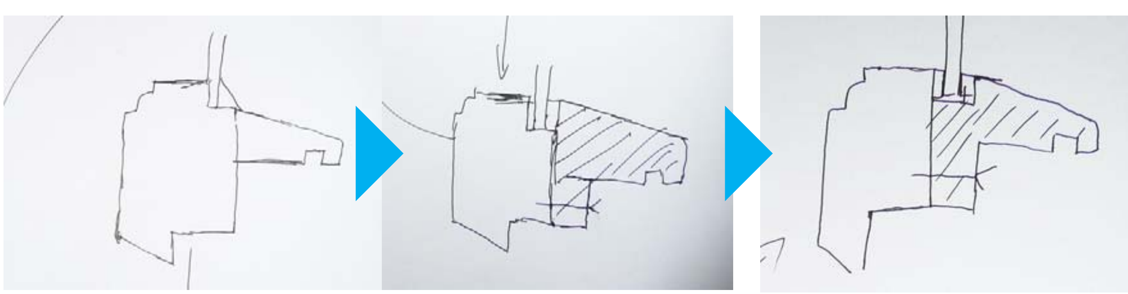




Horizonal section

Vertical section

Finally Benjamin Krick presents his solution for a weatherboard, developed during the workshop discussions. It is easy to replace since it is fixed with screws in the rabbet.



The sketches above show the development process of the weatherboard.

Topic 6. Summary and conclusions
Development of window prototype for Public Weigh House Bolzano: The feedback from the conservator´s side on the before presented window prototype from Franz Freundorfer was that the appearance is still too "heavy". If the proposed solution remains a box-type window the layer of the outer window should be placed behind the existing stone frame and the deepness of the box should be similar to the actual windows from the $50^s/60^s$. It should be placed and installed in the reveal in a similar way. Starting from the so far developed solution with triple glazing it should be checked if a double glazing would be sufficient for Bolzano. This will be a question of comparison of energy savings and efforts. During the further development the installation situation on-site has to be taken into account as in the Public Weigh House no internal insulation is possible. On the base of his so far developed prototype and on the base of the input of this workshop Franz Freundorfer will go ahead with the development of a window prototype for Case study 1. His work will be supported by Ms Kofler-Engl, who will follow the development with feedback from the conservator´s side. EURAC will support his work with any needed technical input like detailed drawings of the existing situation. **General conclusions:** In general every case study responsible should go ahead with finding and studying an energy efficient refurbishment solution for the windows of his case study in terms of analysing results with simulation tools (therm, energy plus etc.). In every case the relative partners from PHI and Andre are available to support their development and planning. The aim is to present to the building owner a feasible solution and to quantify the achievable energy saving. Moreover the results will be published within the project. For technical terms you can have a look on the following glossary: **Glossary:** http://visual.merriam-webster.com/house/elements-house/window.php

8.3.2 Feedback of the conservator regarding the first window prototype 28th February

Comment by Dr. Kofler Engl (Director of the Heritage Office of South Tyrol) regarding the first window prototype, developed in the framework of the research project 3Encult:

28.02.2012

Single glazing outer window sash:

- The optic of the single glazing seems to be "over the top". It does not correspond to the appearance of a historic glass. From the outside, to highly irregular reflection, from the inside to strong irregularities.
- The Heritage Office has not yet found a satisfactory type of glazing that would come closest to the historic glass. It can therefore not make any recommendation for the outer glazing.
- A single glazing in conventional float glass is preferable to the glass used now.

Proportions / Subdivision / Frame thickness:

- Overall positive impression of frame and sash bar thickness
- Also the subdivision and the proportions are suitable

Evaluation of the concept of “division of functions":

- The division of functions in **historic window sash** (outer sash) and **energy efficient sash** (inner sash) does not correspond to the function and execution of a coupled window. A classic coupled window at first would be closed all around the joint of the two superposed sashes - both sashes plus the composite structure would have an energy function - and would secondly be openable and therefore easier to clean. It is not clear why the outer layer has no energetic function, but only an optical function - this appears “dishonest".
- Triple glazing is highly questionable for Bolzano/South Tyrol climate. The conservation office does usually not approve triple glazing in a listed building. The black spacer attracts attention negatively, particularly because it is at the same level with the surrounding edge of the wooden frame.
- Maybe you could make a double glazing in the inner sashes and in the outer sashes remains the single glazing, but by closing the joint around the two window sashes and creating a composite, the whole “package " would have an energetic function or at least the energy efficiency of the inner double glazing would be improved through the outer sash.
- Overall, a double glazing with interior and exterior glued on sash bars would still be preferable in comparison to this actual solution.

Colour / Profiling:

- Colour inside is suitable
- Probably the outside colour will have to be adapted (after refurbishment) after the determination of the façade paint. Now it is too bright or the contrast a bit too strong compared with the paint of the exterior façade.
- The profile on the inside of the inner sash ("Glass Bar") should not be rounded off in the corners, but it should be made angular.

Overall summary:
The prototype as it is installed now in the Weigh House would not be taken as a substitute for the existing windows.

8.3.3 Minutes of second "Workshop on windows", 09th April 2013

1. **Elaboration of a window/façade concept for the Public Weigh House:**

Except some few original windows from the late baroque era, the existing box-type window of the Public Weigh House (which are mostly from the 1950th/60th) should be replaced through by a new coupled window. Franz Freundorfer, the window developer, therefor develops further the already existing coupled window prototype. The dimensions and proportions of the new composite window should refer to the original baroque window, from which in some rare cases there is still an outer window frame with a horizontal impost, which was cut out.

In that cases, where it is a late baroque original window, it should be preserved and repaired and possibly be enhanced from energetic point of view by an additional second window layer.

Worth preserving original windows from the late baroque era:

- The three window in the bay on 2nd floor on the north side
- Possibly the one sash window on 2nd floor on the west side
- Possibly the window in the staircase on 2nd floor on the west side
- Possibly the two sash window in the toilet on 1st floor on the east side (where the window sash and frame are baroque, but the fitting from the early 20th century

Figure 4.14: Photo from the Weigh House from 1958: On first floor, you can see the original baroque window with the horizontal impost

2. Recommendations for the further development of the composite window prototype for the Public Weigh House:

- The proportions and dimensions of the new composite window should correspond to those of the baroque window. Like the original baroque window, it should have a horizontal impost and four window sashes (2 above, 2 below). As a template for that, and for the position of the impost, the existing baroque window in the Weigh House is used (see measures in the sketch). The two lower sashes should have each a sash bar. The window sashes on the inner side should not flush with the window frame.
- Based on these windows´ dimensions, Franz Freundorfer develops a drawing, which is then discussed with the conservator. Based on his drawing and suggestions, questions regarding the shape and appearance of the weatherboard, type of sash bars, selection of fittings etc. are clarified. The colour of the window must be determined before the production (possibly based on colour samples taken from the original window by the historian Mr Mittermair).
- From energetic and conservation point of view it is still to clarify the definitive version of the glazing (evaluation double and triple glazing).
- When replacing the windows it must be assumed that the window reveal and inner (and outer) surface of the exterior wall for conservation reason cannot be insulated. Therefore, it must be guaranteed an adequate room ventilation (removal of moisture) in order that through the increased air tightness of the windows no condensation problems arise at the cold surface of the exterior wall. The chosen building physics concept should not only work for a “museum of photography” (planned use of the Weigh House in the future), but also in case of a change of the use of the building.
- The new prototype should be installed in the Weigh House until the EWCHP in September 2013.

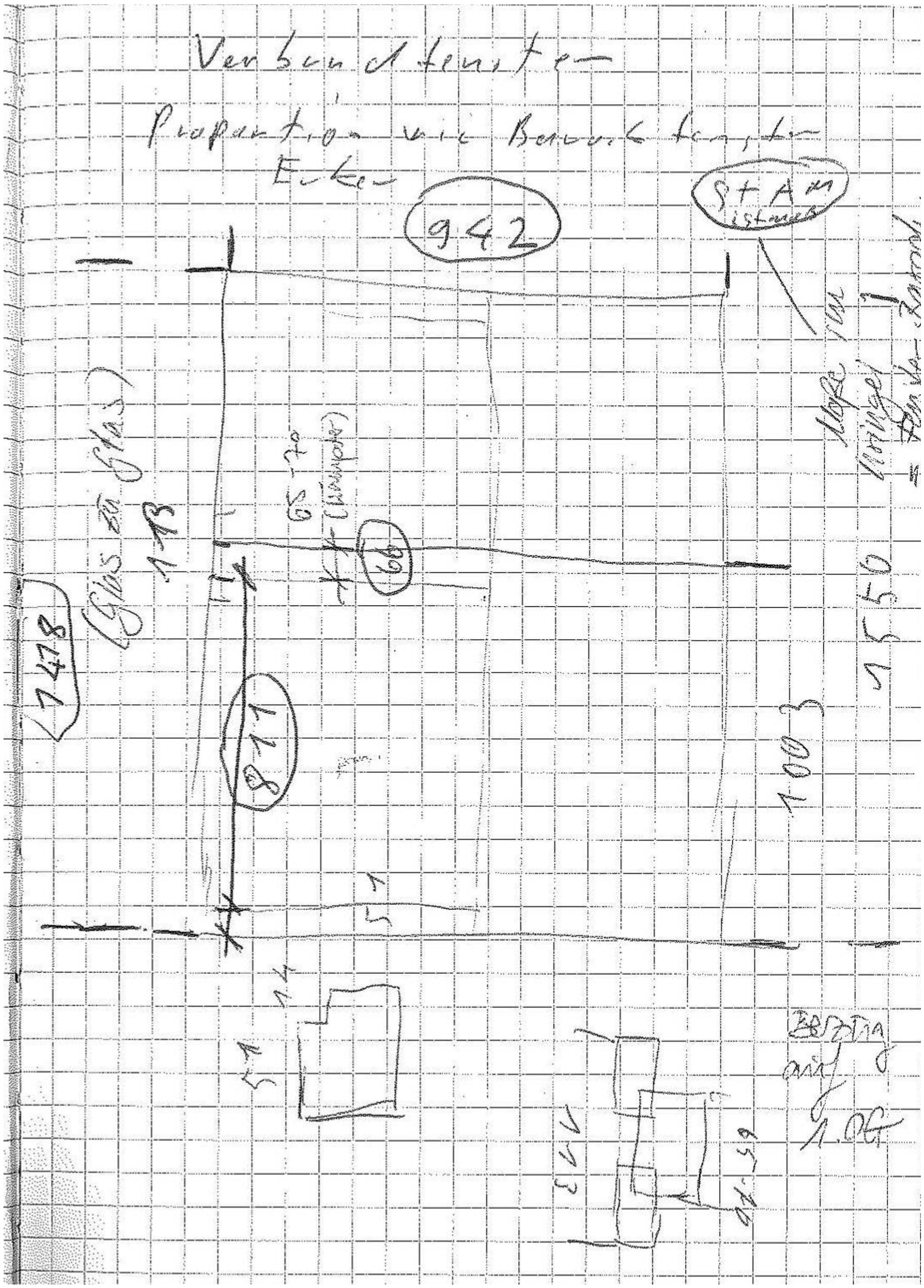


Figure 4.15: External dimensions of the window and position and dimensions of the horizontal impost at the bay window and at the baroque window frame on the first floor (in the loops).

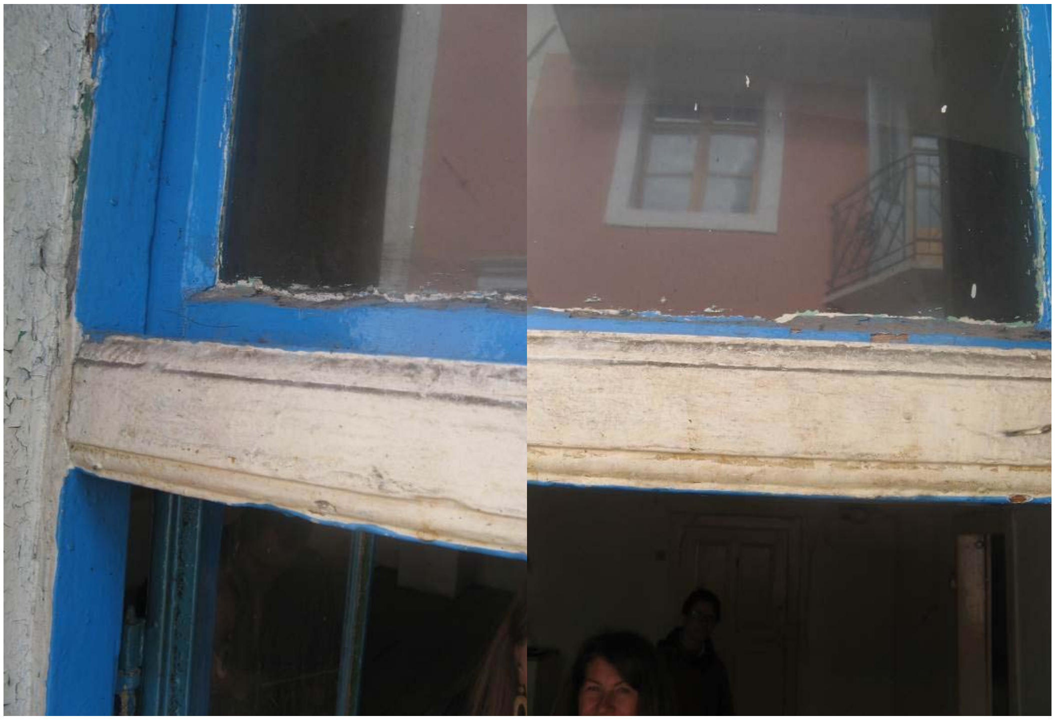


Figure 4.16: Shape of the impost at the bay window on second floor

3. Development of an energy-efficient solution for the original baroque windows

- The three windows of the bay should be preserved, they should be restored and repaired and improved from energetic point of view by an additional window layer.
- Solution: removing the existing wooden frame outside, which serves for the fixing of the window shutters. Instead of the wooden frame outside provide a second window layer, which takes over the energy efficient function (concept of the composite window prototype “upside down”). The outer wing can be opened to the outside; it can be executed without the horizontal impost (only one sash).
- The refurbishment solution for the bay windows should serve as an example for an individual case, which means a case where the original window should be preserved and where a solution for energetic improvement must be found individually. The solution should be developed in terms of drawings and heat-transfer calculations (in THERM) to the extent that they are executable. There will be no prototype built for this case.

Figure 4.17: Bay window on second floor (from outside and from inside)

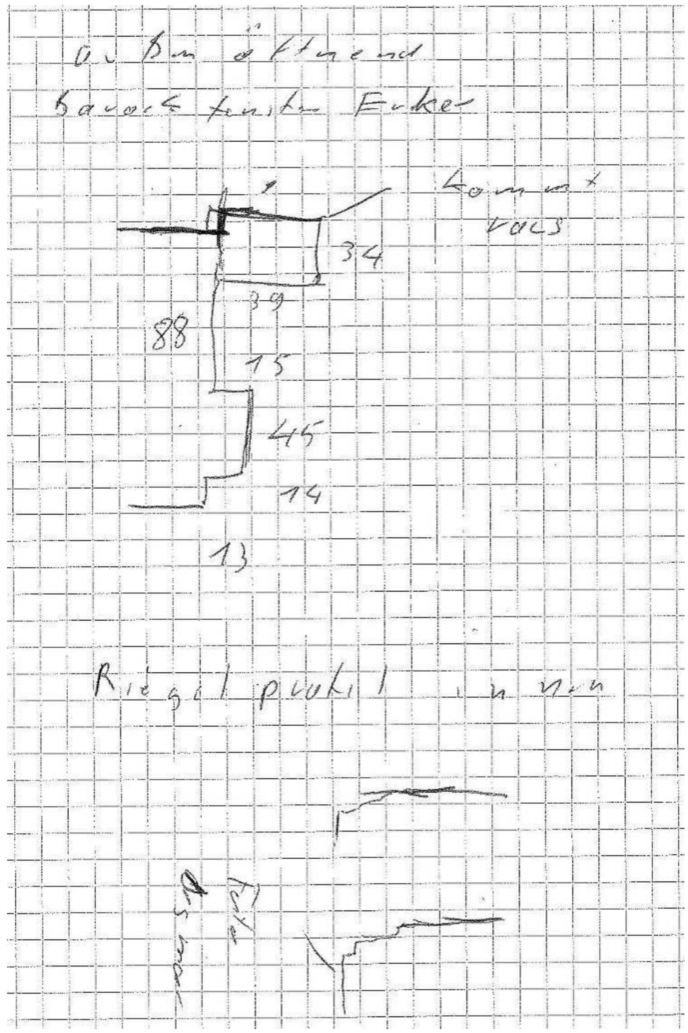


Figure 4.18: Dimensions of the bay window: window frame, exterior reveals and wooden frame on the outer side for fixing the window shutters

4. Development of an high energy efficient prototype for a box-type window typical for Bolzano from the turn of the last century (1900)

- For the development of an energy-efficient box-type window a box-type window from the turn of the century typical for Bolzano is used as a model
- Appearance, proportions, dimensions and division of the prototype should correspond to those of the model. As template window, the windows from the “Aufschnaiter Middle School” (Leonardo da Vinci Road 13) are selected. The window sashes be able to open inwards.
- The external dimensions (length * width) and the position of the horizontal impost are measured on-site by the case study responsible, the remaining dimensions/proportions assumes the window developer from the photo.
- The prototype is expected to be produced (in coordination with the company Andre) by the company Kranz. It will not be installed, but can be presented “free-standing” at seminars and fairs.

Figure 4.19: Box-type window of the "Aufschnaiter Middle School" in Bolzano

8.3.4 Feedback of the conservator regarding the drawings of the second window prototype 13th June 2013

Summary of the comment by Dr. Kofler Engl (Director of the Heritage Office of South Tyrol) regarding the drawings (see below) of the second window prototype, developed in the framework of the research project 3Encult, plus decisions between the case study responsible and the window developer:

13.06.2013

General decisions between the case study responsible and the window developer:

- Comparison of the energetic parameters of the window with two glazing solutions: once with double glazing and once with triple glazing: comparison of the Uw-value, the g-value (total) and the Psi values (installation and glass edge) and the light transmittance (Tau value).
- Comparison of energy savings (taking into account the transmission heat losses, solar gains and daylight potential) when using double and triple glazing at the example Public Weigh House (and possibly at the example "Aufschnaiter School"). Comparison of the costs.
- For the single glazing outside ("Restauro leicht") there is no g-value and Tau-value available by the manufacturer. For the measurement of these parameters, the expert for daylighting and artificial lighting will be contacted and involved.

- The case study responsible will do the comparison of the energy balance implementing the two glass types.
- For determination of the Psi-value the case study responsible will elaborate different detail sketches of the window connection (with the outer wall): one with internal insulation (iQTherm) and one without internal insulation. Franz Freundorfer will then determine the Psi-values with THERM.
- Based on several rooms the case study responsible will simulate and compare the use of daylight for both glass type applications.
- The prototype will be realized with the two glazing solutions inside: use of a double glazing (22 mm) in two window sashes (below and above) and use of the triple glazing (2/8/2/8/2) in the other two window sashes. The aim is to be able to compare the two solutions on-site from optic point of view.
- Selection of one window in the building that will be replaced by the window prototype and control of the dimensions (clear dimension window opening outside + depth “Mauerfalz”) -> Case study responsible
- In the new drawing, all dimensions that have to be controlled on-site by the case study responsible are marked in colour.

Comment of the conservator with regard the coupled window for the Public Weigh House:

- Colour of frame and sashes (outside): specification of the conservator is a “light grey”. Frame and sashes (inside): in an “off-white”. The specification of the colour of the glass edge seal is that its colour must correspond to the colour of the frame. Since there is only a limited selection of colours for the glass edge seal, the colour of the frame and sashes will be adapted to that of the glass edge seal. Normally for the definition of the window colour, a study of the façade colour is carried out (exposing the original paint layers and determining which layer is taken), in which the façade and window colour is specified.
- Colour of the silicone joints: should also correspond to colour of the respective frame
- Type of window handle: same as on the drawing. The size of the handle is suitable, the “Schild” should me smaller. As material brass shouldn´t be used.
- Single glazing outside: “Restauro leicht”
- Triple glazing inside: still questionable from aesthetical and functional point of view
- Type of wood: local timber: pine or larch. Since the wood is varnished spruce is more recommendable.
- Profiling inside and outside: like in the drawing
- Weatherboard: Production of the weather board on the above and below window sashes in timber (“overlap” at the joint of the two window sashes in metal) -> see drawing
- Horizontal impost: the design of the impost has to be revised. The impost should be a “T-piece” with a profile on the outer side -> see drawing

- Sash bars: the width of the sash bars seems a bit narrow. Please compare the design of the sash bars with that of the first window prototype – the width of the sash bars was suitable in that case. -> The window expert will study a solution where the sash bars are “interrupted” by the glazing.

Box-type window Aufschnaiter Middle School:

- Control of the dimensions/position of the impost corresponds to the original historic window. It is accepted.
- Colour of frame and sashes (inside and outside): specification of the conservator is a “light grey”. The specification of the colour of the glass edge seal is that its colour correspond to the colour of the frame. Since there is only a limited selection of colours for the glass edge seal, the colour of the frame and sashes will be adapted to that of the glass edge seal
- Colour of the silicone joints: should also correspond to colour of the respective frame
- Type of window handle: same as on the drawing. The size of the handle and of the “Schild” is suitable. As material brass shouldn´t be used.
- Single glazing outside: “Restauro leicht”
- Triple glazing inside: still questionable from aesthetical and functional point of view
- Type of wood: local timber: pine or larch. Since the wood is varnished spruce is more recommendable.
- Profiling inside and outside: like in the drawing

- Design of the upper window: rebating inside and on the above side tiling to inside
- Weatherboard: Production of the weatherboard on the upper and below window sashes in timber (“overlap” at the joint of the two window sashes in metal) -> see drawing
- Horizontal impost: the design of the impost has to be revised. The impost corresponds to that of the original window (see photo) -> see drawing
- Sash bars: provide sash bars also on the inner window sashes, as in the original window (see photo). Glue sash bars on the inner and outer side of the inner window sash.

- Also this prototype will be realized with the two glazing solutions inside: use of a double glazing (22 mm) in two window sashes (below and above) and use of the triple glazing (2/8/2/8/2) in the other two window sashes. The aim is to be able to compare the two solutions on-site from optic point of view.
- In the new drawing, all dimensions that have to be controlled on-site by the case study responsible are marked in colour.

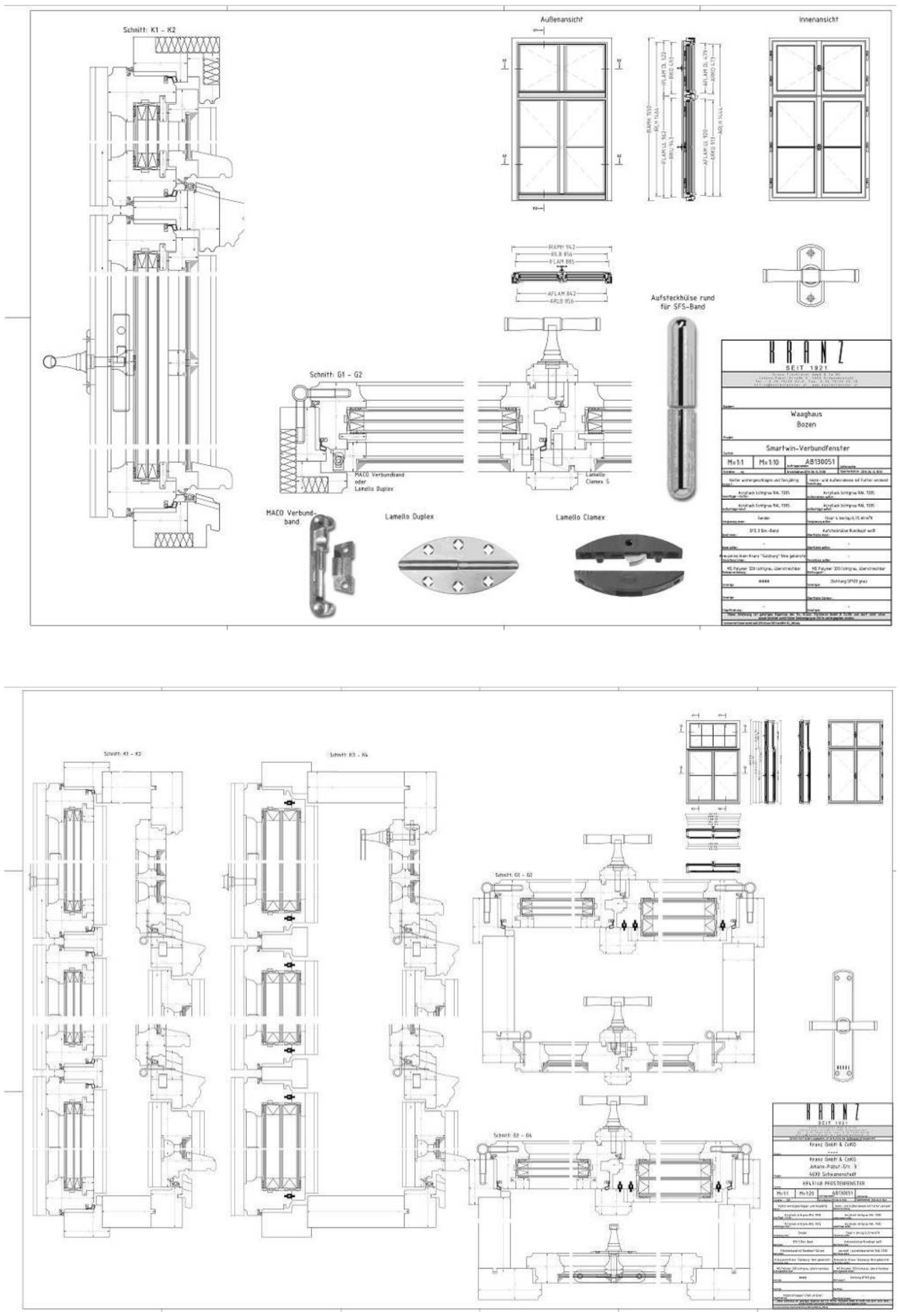


Figure 4.20: Drawings of the second window prototype for the Public Weigh House (above) and the prototype for a typical box-type window of Bolzano (below)