D4.7

Tailored concepts for energy efficient refurbishing of buildings and smart districts

SINFONIA

"Smart INitiative of cities Fully cOmmitted to iNvest In Advanced large-scaled energy solutions"

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Publishable executive summary

As part of the Sinfonia Work Package 4, detailed information on different important topics for highly energy efficient refurbishment were collected for this Deliverable to help you to take the right decision "how to do it best" in your very own refurbishment project.

The information and advice within these guidelines are directly linked to some of the already realized and implemented best practice solutions. The guidelines focus on building thermal envelope for efficient refurbishment, building services engineering, household electricity and standardization of energy refurbishment.

In order to speed up the planning process and to reduce the costs and time needed for thermal bridge and condensation calculations, the Passive House Institute and CasaClima developed in the frame of the Sinfonia Project the Thermal Bridge Catalogue (Annex A), the Condensation Tool (Annex B) and the CasaClima refurbishment guidelines (Annex C).

TABLE OF CONTENTS

SINFONIA; "Smart INitiative of cities Fully cOmmitted to iNvest In Advanced large-scaled energy solutions" has received funding from the European Union's Seventh Programme for research, technological development and demonstration.

TABLE OF FIGUTES

1. INTRODUCTION

As part of the Sinfonia Work Package 4, detailed information on different important topics for highly energy efficient refurbishment were collected for this Deliverable to help you to take the right decision "how to do it best" in your very own refurbishment project.

The information and advice within these guidelines are directly linked to some of the already realized and implemented best practice solutions. The guidelines focus on building thermal envelope for efficient refurbishment, building services engineering, household electricity and standardization of energy refurbishment - districtPH. The detailed description of prefabricated timber framed façade, innovative and smart integration of ventilation and electric energy efficiency are aslo included.

In order to speed up the planning process and to reduce the costs and time needed for thermal bridge and condensation calculations, the Passive House Institute and CasaClima developed in the frame of the Sinfonia Project the Thermal Bridge Catalogue (Annex A), the Condensation Tool (Annex B) and the CasaClima refurbishment guidelines (Annex C).

2. THERMAL ENVELOPE

2.1 THERMAL ENVELOPE BY PHI

The calculation of an energy balance is required for all buildings in the Passive House planning phase. To calculate the thermal heat losses through the envelope, the U-value is the commonly used concept, being an easy to handle and straightforward method. Thermal bridge effects, defined by the Ψ-value (linear) and the Χ-value (punctiform), occur for every building due to geometric effects (e.g. corners) or penetrations (e.g. balconies). One of the Passive House principles is "thermal bridge free-design". As a result, thermal bridges due to penetrations and connections, which cause interruptions to the thermal envelope, need to be avoided. However, this principle cannot always be applied in practice and in cases such as retrofits or projects in seismic areas, different solutions must be found.

There are many factors to determine which thermal bridges have to be considered in detail and whether they can be estimated from tables or must be calculated individually. Since the Ψ-value changes according to the insulation thickness of a specific detail when the insulation thickness is varied, several calculations can be necessary.

In order to speed up the Passive House planning process and to reduce the costs and time needed for thermal bridge calculations, the Passive House Institute evaluated approximately 1.200 thermal bridges, varying a number of parameters that affect both the Ψ-value and the f_{Rsi} factor, relevant for hygiene and comfort reasons. The outcome is a catalogue of Ψ-values and f_{Rsi} factors for the different cases, which can be used to determine a value for a particular detail or to estimate the value of a similar case. The Thermal bridge catalogue can be found in Annex A of this Deliverable.

2.1.1 CONNECTION DETAILS EXAMINED - ARCHITECTURAL DETAILS

Two different solid wall construction systems were chosen for evaluation in all of the Passive House climate zones (Zones 1-7), according to the international EnerPHit criteria [1]. The two solid wall construction systems are:

A brick wall construction of 240 mm thickness and λ = 0.42 W/(mK), as typically found in European building stock. The uninsulated wall shows a U-value of about 1.30 W/(m²K).

A concrete wall construction of 120 mm thickness and λ = 2.10 W/(mK), as very often found in developing countries. The uninsulated wall shows a U-value of about 4.00 W/(m²K).

Connection details were calculated for insulation thicknesses increasing in 25 mm steps (roughly 1 inch), starting with 0 mm of insulation (the existing building wall) up to 400 mm of insulation.

The graduations in insulation thickness were applied to both construction types (brick wall and concrete wall). The lambda value of the insulation was also varied and λ = 0.025 W/(mK), λ = 0.035

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W/(mK) and λ = 0.045 W/(mK) were used for the study to allow a quick estimation of the Ψ-value of the connection.

The following connections were studied:

- External wall – outer corner (EWEC01)
- External wall – inner corner (EWIC01)
- Roof ridge (roof inclination 45°) (RORI01)
- Roof eaves (roof inclination 30°,45°,60°) (ROEA01)
- Balcony (BALC01)
- Porch roof (BALC02)
- Roof parapet (FRRP01)
- External wall - ceiling (EWCE01)
- Window bottom (WIBO)
- Floor slab – external wall (FSEW01)
- Basement ceiling – external wall (BCEW01)

The scope of this study only includes improvements which do not modify the underlying nature of the wall structure. Retrofits or new buildings in seismic areas require solutions such as thermal breaks in the wall structure, but these cannot be practically applied. In these situations, the most practical solution is to apply flanking insulation to reduce the thermal bridge effect caused by the penetrations in the insulation layer e.g. a balcony. In non-seismic areas thermal breaks should be considered as solutions to reach the "thermal bridge free-design" goal.

FIGURE 2-1: FLOOR PLAN OF A TYPICAL BUILDING

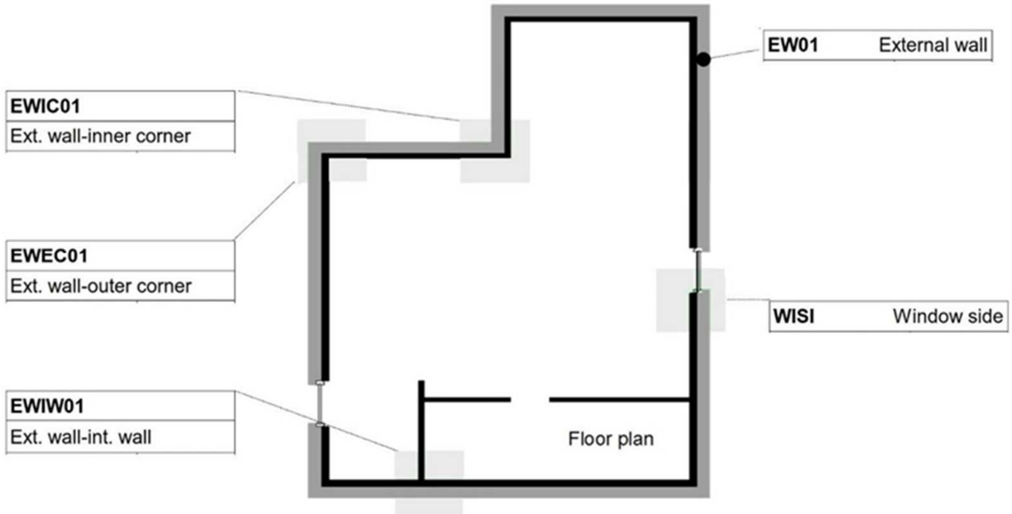

FIGURE 2-2: LONGITUDINAL SECTION OF A TYPICAL BUILDING

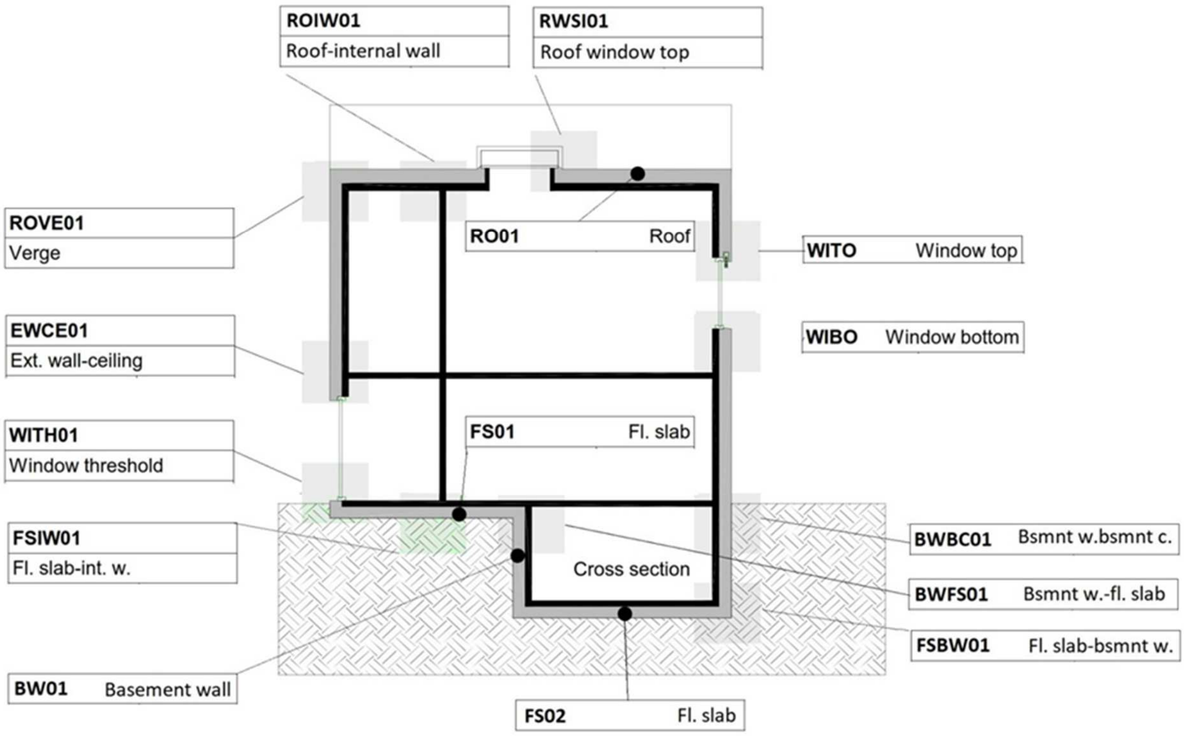

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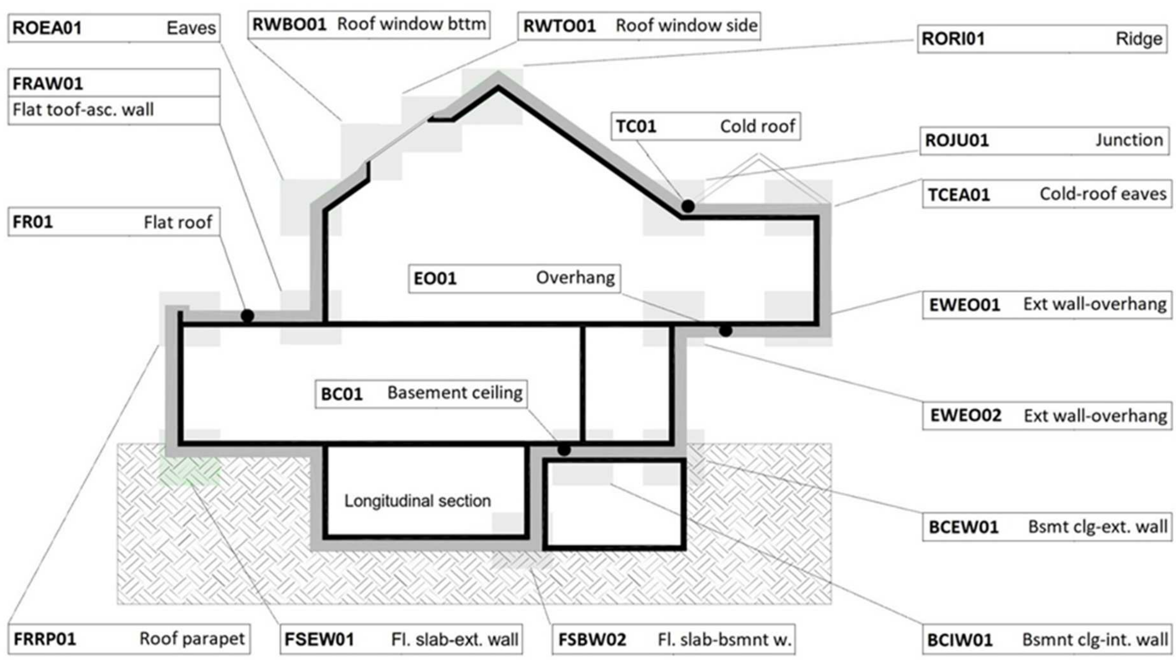
FIGURE 2-3: ASSIGNMENT OF THE REGIONS WITH IDENTICAL REQUIREMENTS, BASED ON STUDIES OF PHI



Figures 2-1, 2-2 and 2-3 display floor plan, cross section and longitudinal section showing the typical connections in a building and the codes assigned in the "Criteria and Algorithms for Certified Passive House Components: Opaque construction systems" [2].

2.1.2 ENERGY, HYGIENE AND EFFICIENCY PARAMETERS

The connections were evaluated to determine two parameters:

- Ψ-value, for an energy evaluation of the detail;
- f_{Rsi} factor, for a hygiene and efficiency evaluation of the detail.

2.1.3 ENERGY EVALUATION

The Ψ-value is a means to evaluate the linear heat losses that occur through the connection caused by a thermal bridge effect. In a Passive House, the aim is to reach $\Psi \leq 0.01$ W/(mK), which means "thermal bridge free design". However, there is no limit for the Ψ-value that would prevent the building being defined as a Passive House. The Ψ-value must be taken into account when calculating the total transmission losses through the envelope, because it will have an influence on the overall energy balance.

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2.1.4 HYGIENE AND EFFICIENCY EVALUATION

For each connection, the minimum surface temperature was calculated as well. The results are displayed through the f_{Rsi} factor, which is determined as follows:

f_{Rsi} =(θsi-θe)/(θi-θe)

where θsi is the minimum interior surface temperature, θe is the minimum outside temperature (assumed to be -10°C) and θi is the interior temperature (assumed to be 20°C). The θsi is calculated considering Rsi = 0.25 (m²K)/W as the internal surface resistance.

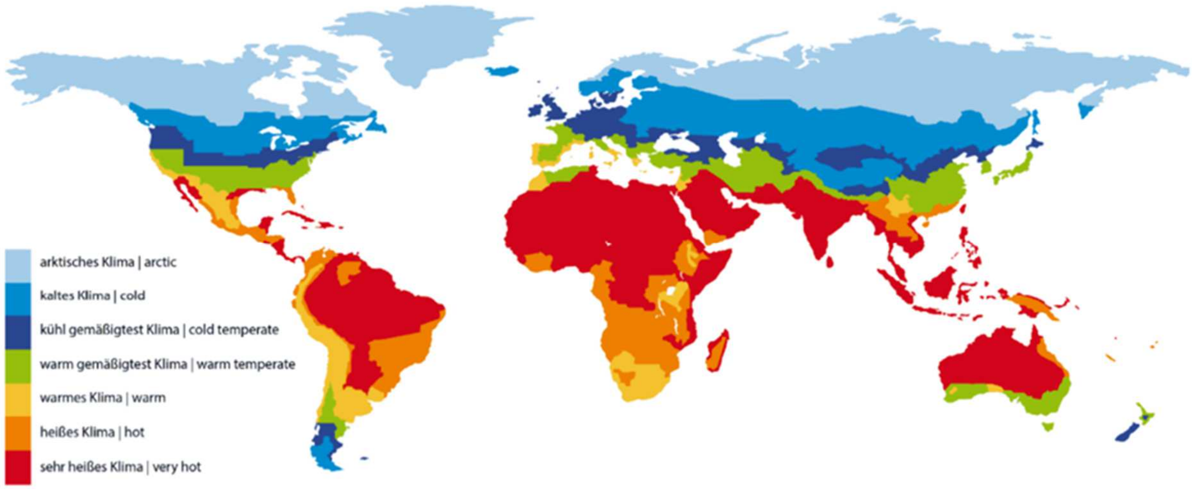
The f_{Rsi} factor is the parameter chosen to easily identify the risk of mould growth and condensation.

A hygiene and an efficiency criterion were established for each climate zone. The hygiene criterion identifies the minimum f_{Rsi} factor that a component can tolerate in relation to the risk of mould growth. The efficiency criterion establishes the minimum f_{Rsi} factor that needs to be reached to ensure thermal comfort. Fanger's theory [3] explains that one of the causes of thermal discomfort is radiant temperature asymmetry in the room. The Passive House standard is defined to reach comfort class A [4]. These temperature limits are translated into f_{Rsi} limits for opaque components in the efficiency criterion.

The f_{Rsi} factor limits in each climate zone for the hygiene and efficiency criterion according to the "Criteria and Algorithms for Certified Passive House Components: Opaque construction systems" [2] are as follows:

No	Climate Zone	Hygiene Criterion $f_{Rsi\ 0.25\ (m^2K)/W}$	Efficiency Criterion $f_{Rsi\ 0.25\ (m^2K)/W}$
01	Artic	0.80	0.90
02	Cold	0.75	0.88
03	Cold-Temperate	0.70	0.86
04	Warm-Temperate	0.65	0.82
05	Warm	0.55	0.74
06	Hot	-	0.74
07	Very Hot	-	0.82

FIGURE 2-4: ASSIGNMENT OF THE REGIONS WITH IDENTICAL REQUIREMENTS, BASED ON STUDIES OF PHI



2.1.5 RESULTS

The results of this study (Ψ-values and f_{Rsi} factors) are summarized in graphs. The graphs are displayed on sheets. One sheet was created for each detailed connection.

The catalogue sheets are structured as follows:

1. Detail drawing

The analysed connection is reported with specifications about the materials of the assemblies and the boundary conditions assigned to the internal and external surfaces for the thermal bridge calculation (temperature [°C] and surface resistance [W/(mK)]). The figure reported in this section of the catalogue sheet shows the connection geometry when a 200 mm insulation layer is applied.

2. Heat flow analysis

The connection is shown with a colour infrared diagram. The outside temperature is indicated in blue (-10 °C) and the internal temperature in red (20 °C). A scale is reported to easily identify the relation between each colour and the temperature in the component (-25 to 25°C).

The point on the interior surface with the lowest temperature is marked in the diagram. The value of the minimum temperature depends on the thickness of the insulation layer in the assembly.

3. Ψ-value graph

The graph reports the results of all the thermal bridge simulations for the detail. The insulation thickness applied to the components is on the x-axis. The Ψ-value results are on the y-axis.

The Ψ-values were calculated for different insulation thicknesses (from 0 mm to 400 mm) and for three different insulation conductivities (0.025 W/(mK), 0.035 W/(mK), 0.045 W/(mK)). The results are displayed in three curves on the graph.

When the detail can be improved through the addition of flanking insulation, the results of the simulations are displayed with a yellow curve. In these cases the details were simulated considering a flanking insulation layer with varying insulation thicknesses (0-400 mm). The insulation conductivity for the flanking insulation is assumed to be 0.035 W/(mK).

4. Ψ-value optimization

When detail optimization is possible, a drawing showing how to apply the additional insulation is shown. Notice that thermal bridges created by a geometric effect cannot be improved. The optimal thickness of the flanking insulation is chosen according to the studies in "Protokollband" Nr.16 and Nr.24 [5].

5. Thermal bridge characteristics

Each connection is identified through a code, as in the "Criteria and Algorithms for Certified Passive House Components: Opaque construction systems".

Thermal bridges can be classified as geometric (caused by a change in the shape of a component), structural (when there is a discontinuity in the material used), and mixed (when both geometric and structural discontinuities are present). For each connection, information about the category to which the connection belongs is reported.

With reference to the classifications reported in PHPP, the thermal bridges are identified as follows:

A) interior against ambient air;

B) interior against the ground or basement;

P) thermal bridge at the perimeter against the ground.

This classification is important for the calculation of the heat losses caused by the thermal bridge. In fact, different categories will lead to different degree-days (Gt [kWh/a]) to be taken into account in the final transmission heat losses balance.

6. f_{Rsi} factor graph

The graph reports the results of the f_{Rsi} factor, calculated with the previously shown formula. The insulation thickness applied to the components is on the x-axis. The f_{Rsi} factor results are on the y-axis. The f_{Rsi} factor was calculated using the minimum internal surface temperature determined in each case.

The simulations were calculated for three different insulation conductivities (0.025 W/(mK), 0.035 W/(mK), 0.045 W/(mK)) and displayed through three different curves.

When the detail can be optimized through the addition of flanking insulation, the results of the simulations are displayed with a yellow curve. The insulation conductivity for the case is assumed to be 0.035 W/(mK).

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The graph also shows an orange area, which represents the hygiene criterion, and a yellow area, which represents the efficiency criterion. When a point of the curve lays in one of these areas, it means that the corresponding criterion is fulfilled. Fulfilling the efficiency criterion implies fulfilling the hygiene criterion as well.

7. Table

The table summarizes the main results for each climate zone. The limit U-value of the component is defined by the EnerPHit criteria, as previously explained. This translates into a certain insulation thickness, if the components (e.g. wall) are defined similarly to those used in this research (240 mm brick wall, 0.42 W/(mK); 120 mm concrete wall, 2.1 W/(mK)). The main element influencing the U-value of the component will be the insulation layer. Therefore, the results of this study can be used also to estimate the Ψ-value and f_{Rsi} factor of details with construction systems similar to the ones studied here. However, it is highly recommended to apply a safety margin to the values.

For each connection in which the wall component is characterized by a limit U-value, the Ψ-value and the f_{Rsi} factor are reported. The f_{Rsi} factor limit values to fulfil the hygiene and efficiency criterion are reported in the table as well.

2.1.6 REFERENCES

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[3] Fanger, P. Ole, “Thermal Comfort: Analysis and applications in environmental engineering”, 1970.

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2.2 CONDENSATION ASSESSMENT: EXCEL TOOL BASED ON ISO 13788 BY PHI

The *Passive House condensation tool* is the new tool developed by Passive House Institute Darmstadt, in the commonly used Excel format *.xlsx.

This tool is based on the International Standard ISO 13788:2012 and provides simplified calculation methods that enable calculation of:

- The hygrothermal performance of building components and building elements;
- Internal surface temperature to avoid critical surface humidity;
- Temperature and vapour pressure inside the component to estimate interstitial condensation.

The moisture transfer theory is complex and requires information that is typically hard to gather; the theory requires highly specific knowledge of hygrothermal calculation.

The most common values available for the building materials are not sufficient for describing the moisture transfer process accurately. The designer needs more data e.g. moisture and capillarity function, moisture content of the material, inclination of the component, short and long-wave radiations, hourly climate data etc., to obtain more precise and complete results.

This method brings more reliable results for lightweight and airtight components that do not contain materials with a large water storage capacity.

This method (Glaser Method) and this tool are based on simplified calculations. Users should note that where a component is not verified following this methodology, it could in theory be verified using different and more detailled methods e.g. dynamic calculations according to EN 15026.

The method is an assessment rather than an accurate prediction tool.

The ISO 13788:2012 is a monthly calculation and does not take into account:

- The variation of thermal conductivity, heat transport and other moisture content and temperature properties;
- Capillary suction, sorption coefficient, liquid transfer and moisture capacity of materials;
- Three- or two-dimensional moisture transport;
- Air leakages through the various layers of the component;
- External climate conditions as solar radiation, rainfall, wind exposure;
- Air, rising damp, rain or underground infiltrations;
- Gravity;
- Moisture transport other than vapour diffusion;

Passive House condensation tool is composed by three worksheets:

1. **Instructions:** It contains the general information and the necessary instructions about how to use the tool.
2. **Climate:** there are the options to define the exterior and interior climates to use for the verification.
3. **Assembly:** In this worksheet the designer inserts the structure, materials and hygrothermal data of the component to verify.

The Manual of *Passive House condensation tool* can be found in Annex B of this Deliverable.

2.2.1 SINFONIA - SILLBLOCK (SANIERUNG), INNSBRUCK - VERIFICATION

This tool has been used for checking the refurbished external wall of Sillblock SINFONIA project in Innsbruck, a residential building with 34 appartments.

The existing wall was composed by brick (thickness 51 cm) and interior and exterior plaster, for a total thickness of 55 cm. The refurbishment project was established in 22 cm of grey EPS, the correct intervention to obtain the predicted energy saving and thermal comfort.

The boundary conditions for this verification were as follows:

- Exterior climate: Innsbruck monthly mean values from PHPP dataset (lowest temp. -2,1°C in December, highest temp. 18,1°C);
- Interior climate: monthly mean values of temperature and relative humidity as predicted in PHPP calculation and for the summer period, the exterior relative humidity as interior relative humidity.

FIGURE 2-5: BOUNDARY CONDITIONS FOR VERIFICATION

Exterior Climate — Location: 1 - PHPP

1 - PHPP	1	2	3	4	5	6	7	8	9	10	11	12
	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Exterior temperature [°C]	-1,9	0,6	5,3	10,1	15,2	17,2	18,1	17,8	14,4	9,2	4,3	-2,1
Exterior rel. humidity [%]	88,2%	78,4%	74,3%	63,1%	56,8%	67,3%	72,6%	70,2%	75,4%	72,9%	82,6%	90,4%

Interior Climate — Location: 2 - Air conditioned building

2 - Air conditioned building	1	2	3	4	5	6	7	8	9	10	11	12
	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Interior temperature [°C]	22,0	22,0	22,0	22,0	22,0	22,0	22,0	22,0	22,4	22,8	23,1	22,0
Interior rel. humidity [%]	36,0%	37,6%	43,9%	48,9%	57,5%	67,3%	72,6%	70,2%	68,3%	51,8%	44,9%	36,2%
Condensation [°C]	6,26	6,88	9,16	10,77	13,22	15,66	16,85	16,32	16,25	12,41	10,54	6,32
Mold growth [°C]	9,54	10,17	12,52	14,17	16,69	19,19	20,42	19,87	19,80	15,85	13,93	9,60
f_{Rsi} min [-]	0,48	0,45	0,43	0,34	0,22	0,42	0,59	0,49	0,68	0,49	0,51	0,49

The results shown in Figure 2-6 below, confirms that any condensation occurs during the year.

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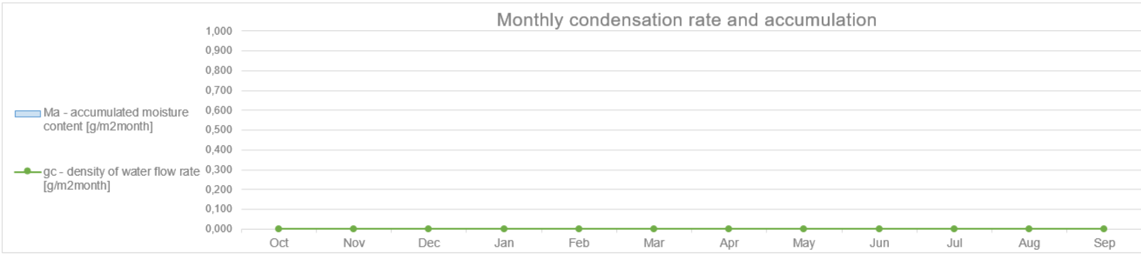
FIGURE 2-6: OUTPUT FROM PHI CONDENSATION TOOL – MONTHLY CONDENSATION RATE

Monthly Condensation rate and accumulation



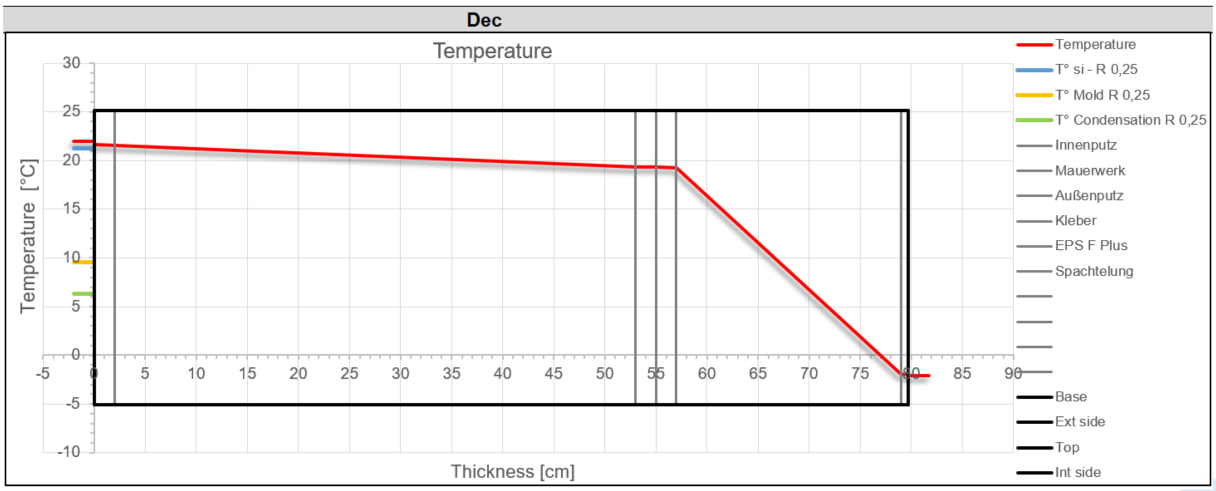
	10	11	12	1	2	3	4	5	6	7	8	9
Days	31	30	31	31	28	31	30	31	30	31	31	30
Months	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep
gc - density of water flow rate [g/m²month]	**0,000**	**0,000**	**0,000**	**0,000**	**0,000**	**0,000**	**0,000**	**0,000**	**0,000**	**0,000**	**0,000**	**0,000**
Ma - accumulated moisture content [g/m²month]	**0,000**	**0,000**	**0,000**	**0,000**	**0,000**	**0,000**	**0,000**	**0,000**	**0,000**	**0,000**	**0,000**	**0,000**
Interfaces with condensation	0	0	0	0	0	0	0	0	0	0	0	0
Verification												

The interior surface temperatures for mold growth and condensation are always above the critical threshold as shown in the picture below even in the coldest month (December).

The red line describes the temperature along the layers from the interior side (left) to external side (right) using the air temperature as boundary conditions. The blue line represents the mark of the component interior surface temperature, calculated by using 0,25 m^2K/W as interior thermal resistance as described in ISO 13788. At interior side, yellow and green lines represent, the temperature where mold growth and condensation appear. It is clear that having the blue line above the 20°C, the mold growth and condensation will not appear.

The blue line get us another important information regarding the interior comfort i.e the surface temperature is very close to the interior air temperature (red line), ensuring the absence of discomfort given by asymmetrical radiant surfaces.

FIGURE 2-7: OUTPUT FROM PHI CONDENSATION TOOL – TEMPERATURE PROFILE WITHIN THE LAYERS



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2.2.2 REFERENCES

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2.3 PREFABRICATED TIMBER FRAMED FAÇADE SYSTEMS BY UIBK

Written by UIBK: Le Levé, Clemens; Badergruber, Thomas; Kraler, Anton; Flach, Michael

2.3.1 PREFABRICATED TIMBER FRAMED FAÇADE SYSTEM

The thermal refurbishment of the building stock is one of the most fundamental challenges of sustainable urban development. Particularly the use of natural and local materials gets an increasing relevance, regarding the embodied energy. Systematised solutions for thermal refurbishment with prefabricated and integrated façade systems such as the E.T. (ecological timber framed) façade system and the Sherpa EFcon façade system connector are developed at the Unit of Timber Engineering of the University of Innsbruck.

The renovation by using prefabricated and integrated façade systems represents an interesting alternative to ETICS (external thermal insulation composite systems) and consists of several advantages, as the high precision in prefabrication and assembly off-site or the short construction time on-site. Also the possibility to integrate windows, insulation, ventilation and solar modules into the façade elements and the fact that no scaffolding is needed illustrate further benefits of this renovation method. The main fields of application are especially schools and multi-storey residential buildings, where large scaled and repetitive elements are used. The concept of this renovation method is well described in the research project TES EnergyFaçade [1] and several objects in Germany, Austria and Switzerland were already refurbished using this renovation method.

FIGURE 2-8: PREFABRICATED FAÇADE ELEMENT FOR THE THERMAL RENOVATION OF A FARMHOUSE IN TRINS [2,3]

Photo Source: Flach, M; Eibl, R.

The importance of the use of natural renewable materials increases, regarding the embodied energy and the use of local resources. But concerning economic aspects, their use can only be competitive, if short assembly time and a maximum in precision through integrated prefabrication are ensured. Therefore the logistics have to be coordinated in regard to working steps as digital building survey, planning of the façade elements with integrated HVACR, computer controlled joinery, prefabrication and mounting of the façade elements on the existing building.

Experiences made in project Sinfonia and Expert Workshops show that there are still facts which lead to decisions of building promoters to use ETICS instead. The main reasons are costs and business as usual on one side, but also the lack of systematised solutions for different applications on the other side. Therefore the Unit of Timber Engineering of the University of Innsbruck is developing systematised solutions for refurbishments with prefabricated timber framed façade elements.

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2.3.2 THE E.T. FAÇADE SYSTEM

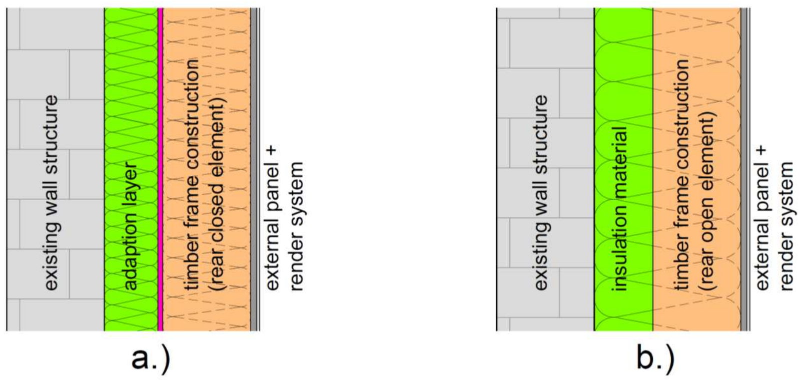
Conventionally the cladding of prefabricated façade systems consists of a ventilated façade. To reduce costs of the prefabricated façade system the E.T. façade system [4] is developed, where the amount of layers and the amount of work on-site is reduced to a minimum. It can be entirely prefabricated, including the external render system, allows a fast assembly on-site and its fire behaviour is classified. The reduction of costs plays an essential role and is provided by

- scalability and replicability
- holistic prefabrication
- reduction of layers
- simple structure
- systematised joint details
- systematised fixation possibilities
- fast and easy assembly
- classified fire behaviour
- disassembly and exchange
- easy recycling

THE E.T. FAÇADE SYSTEM CONSISTS OF TIMBER FRAMED ELEMENTS WITH A NON-REAR-VENTILATED EXTERNAL RENDER-BASEBOARD AND AN EXTERNAL RENDER SYSTEM AND IS ENTIRELY PREFABRICATED. TWO TYPICAL WALL STRUCTURES OF THE FAÇADE SYSTEM ARE SHOWN IN

Figure 2-9, a rear-closed (a) and a rear-open element (b).

FIGURE 2-9: TYPICAL WALL STRUCTURES OF THE E.T. FAÇADE SYSTEM, (A) REAR-CLOSED ELEMENT, (B) REAR-OPEN ELEMENT [4]



Source: Le Levé, C.

The adaption layer of the rear-closed element consists of a ductile insulation material, which is fixed on the rear panel in prefabrication or a blow-in insulation, which is filled on-site. The blowing-in procedure of the cellulose can be done storey-wise according to the mounting process or by the window sills and reveals. To reduce costs and layers and also for building physic reasons it is possible to omit the rear panel.

For an easy and fast mounting process special joint solutions are developed. These vertical and horizontal joints have to provide watertightness, transmission of loads, absorption of expansions and fire safety. In general the horizontal joint is placed in the area of the ceiling, but can also be placed corresponding to the building geometry and architectural wishes. The horizontal joint, which consists of a tongue and groove system, provides the transmission of horizontal loads between the upper and lower façade element. For fire safety reasons the joint is backed by an incombustible panel. An additional horizontal board provides a horizontal fire separation between the elements.

The watertightness is achieved by sliding joint profiles, which are developed for this application by using standard profiles and modified profiles. A watertight seal, stuck on the profiles ensure watertightness (Figure 2-10).

FIGURE 2-10: SAMPLE OF THE E.T. FAÇADE SYSTEM (LEFT) AND A HORIZONTAL JOINT DETAIL (RIGHT) [4]

Photo Source: Badergruber, T.; Le Levé, C.

2.3.3 FIRE SAFETY

The façade system consists of ecological and renewable but combustible materials. So the fire safety plays an important role. The Unit of Timber Engineering performed in collaboration with IBS (Institut für Brandschutztechnik und Sicherheitsforschung) in Linz several fire behaviour and fire resistance tests to proof the fire safety of the prefabricated façade system (Figure 2-11). The fire behaviour of

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the E.T. façade system is now classified and allows its application on buildings of class 4 and 5 up to a fire escape level of 22 m as a standardised system using renewable materials as wood and cellulose.

FIGURE 2-11: FIRE BEHAVIOUR AND FIRE RESISTANCE TESTS TO PROOF THE FIRE SAFETY OF PREFABRICATED FACADE ELEMENTS [4, 5]

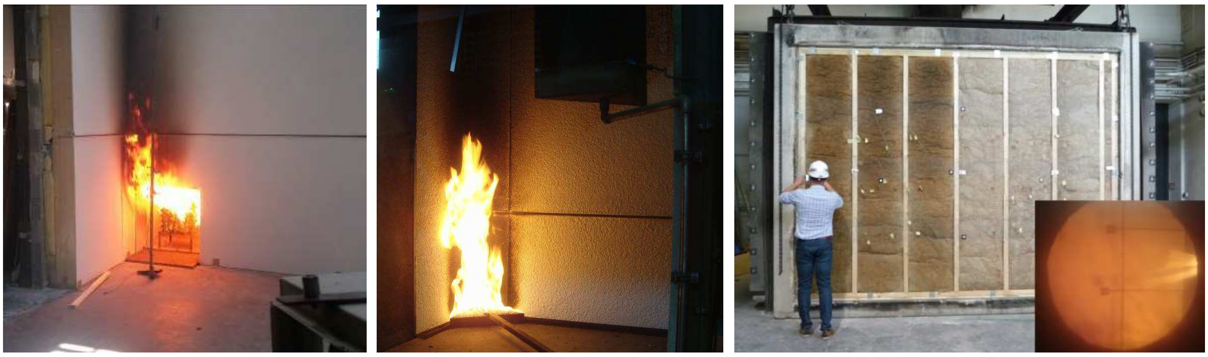

Photo Source: Badergruber, T.; Le Levé, C.

Further fire tests were performed with an adapted prefabricated façade system to show that prefabricated timber framed façade elements can also be implemented on high-rise buildings. In this case mineral wool was used as insulation material and the external layer of the timber frame construction consist of gypsum fibre boards. And the rear ventilated cladding system has to be approved for high-rise buildings [5].

Further information about fire tests and classification reports can be obtained at the Unit of Timber Engineering of the University of Innsbruck.

2.3.4 THE SHERPA EFCON FAÇADE SYSTEM CONNECTOR

The façade elements are self-supporting and can be mounted on the existing building in different ways. Depending on the building structure and materials the element might be storey wise hanging on the substructure or standing at the bottom or is storey wise standing. Building geometry plays an important role on the application of the façade elements. It influences the choice of the orientation (horizontally or vertically) as well as the possibilities of fixation. Especially the roof, the balcony, the openings of the building and the building foundation play a central criterion.

The “Sherpa EFcon” Façade-System-Connector is developed at the Unit of Timber Engineering of the University of Innsbruck to get a standardized and multifunctional mounting system (Figure 2-12) [3]. The company Vinzenz Harrer GmbH has recently included the connector in its product portfolio.

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FIGURE 2-12: THE SHERPA EFCON FAÇADE-SYSTEM-CONNECTOR [2, 3]

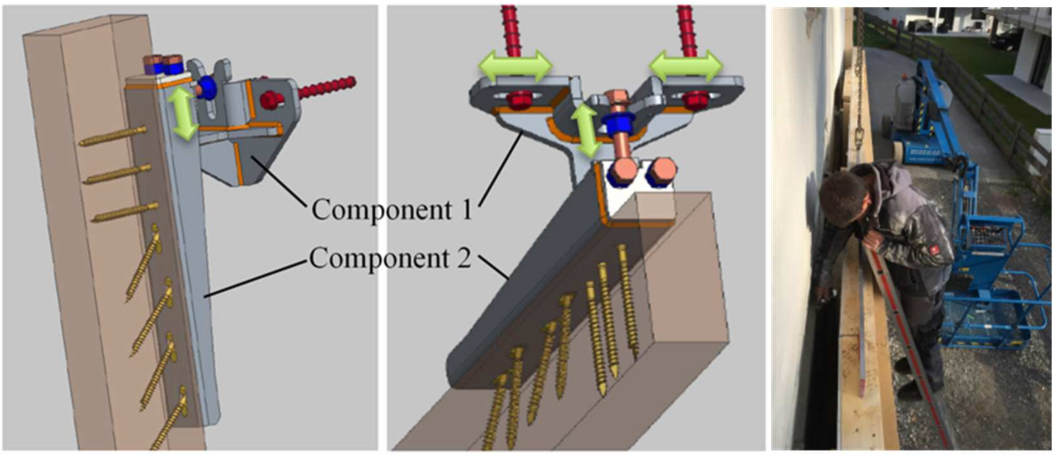

Photo Source: Le Levé, C.; Flach, M.

An important factor is the possibility to lead vertical and horizontal loads storey wise in the existing building, so that at the bottom no concentrated load introduction occurs. Thereby the application of prefabricated façade elements gets more flexible. A central role plays the accessibility of the connector during assembly. Its position on the upper part of the façade element and a detailed consideration of dimensions allow the handling from the top of the respective element (Figure 2-12, right). It is fixed on the reinforced concrete floor slab, pillars or masonry walls with concrete screws or injectable adhesive anchors. It is able to absorb tolerances in all three directions to compensate an uneven existing wall, inaccuracies in building survey or in prefabrication as well. The most essential requirements of the connector are listed in the following itemisation:

- Fast and easy assembly
- Absorption of tolerances in all directions
- Bearing of vertical and horizontal loads
- Accessibility
- For different building types and materials
- Multifunctional application
- Avoidance of thermal bridges
- Systematised solution leads to cost reduction

2.3.5 CONCLUSION

A standardised solution for thermal refurbishments with ecological prefabricated façade systems is developed in order to reduce the construction time, the disturbance of inhabitants and costs. For a wide range of application possibilities up to mid-rise buildings the fire behaviour of the E.T. façade system is classified. Thereby it is permitted to use variable products for external and internal panels,

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render systems or insulation, so it is not depending on individual producers. Further investigations on fire safety shall contribute to use prefabricated façade systems even on high-rise buildings.

The presented joint details allow the prefabrication of the entire façade element, even including the external render system and require no additional work on-site or scaffolding. In combination with the Sherpa EFcon Façade System Connector a fast and easy, modular construction system is ensured. The assembly on-site of the prefabricated, pre-rendered and integrated elements can be done in few days. An implemented refurbishment project, offered the opportunity to attempt, analyse and demonstrate the newest developments and to prove the user-friendly feasibility.

2.3.6 LITERATURE

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[2] Le Levé, C.; Badergruber, T.; Flach, M.: Ökologisch sanieren mit einem neuen Fassadensystem am Beispiel des Mayrhofs in Trins. In: Passivhaustagung 2018. München, 2018.
[3] Le Levé, C.; Badergruber, T.; Kraler, A.; Flach, M.: Neue Wege in der thermischen Fassadensanierung und ein Systemverbinder zur schnellen und einfachen Montage. In: Bauingenieur 93 (2018), Ausgabe 7/8-2018. Springer VDI Verlag, Düsseldorf 2018.
[4] Le Levé, C.; Badergruber, T.; Kraler, A.; Flach, M.: Ökologisches Sanieren mit verputzten, vorgefertigten Fassadenelementen in der Gebäudeklasse 5 mit mehr als 6 Vollgeschoßen. Endbericht, Innsbruck 2016.
[5] Le Levé, C.; Badergruber, T.; Kraler, A.; Flach, M.: Vorgefertigte Fassadensysteme in Holzbauweise bei einem Fluchtniveau von mehr als 22 m. Endbericht, Innsbruck 2018.

3. BUILDING SERVICES ENGINEERING

3.1 INNOVATIVE AND SMART INTEGRATION OF VENTILATION BY UIBK

Written by Rainer Pfluger, University of Innsbruck

3.1.1 FACADE INTEGRATION

Especially in case of refurbishment, any changes and construction within the dwellings should be reduced to a minimum for two reasons: The living space should not be reduced too much by the ventilation system (heat recovery unit and air ducts) and the integration should be as minimal invasive as possible in order to avoid disruption to the residents. Another advantage of façade integration is the minimization of the ductwork for outdoor air (ODA) and exhaust air (EHA).

Decentralised units (one per dwelling): How may heat recovery units be integrated in prefabricated facade elements and in assembling at the construction sites? Which design options may be offered for the intake of external air and the outgoing of exhaust air?

Centralized units (one heat recovery unit for several dwellings): How to install supply (SUP) and extract (ETA) air ducts in the external insulation system?

The following example shows the façade integration of the ducts in one of the SINFONIA buildings (NHT, IN22/23).

FIGURE 3-1: EXAMPLE OF FAÇADE INTEGRATION OF THE DUCTS

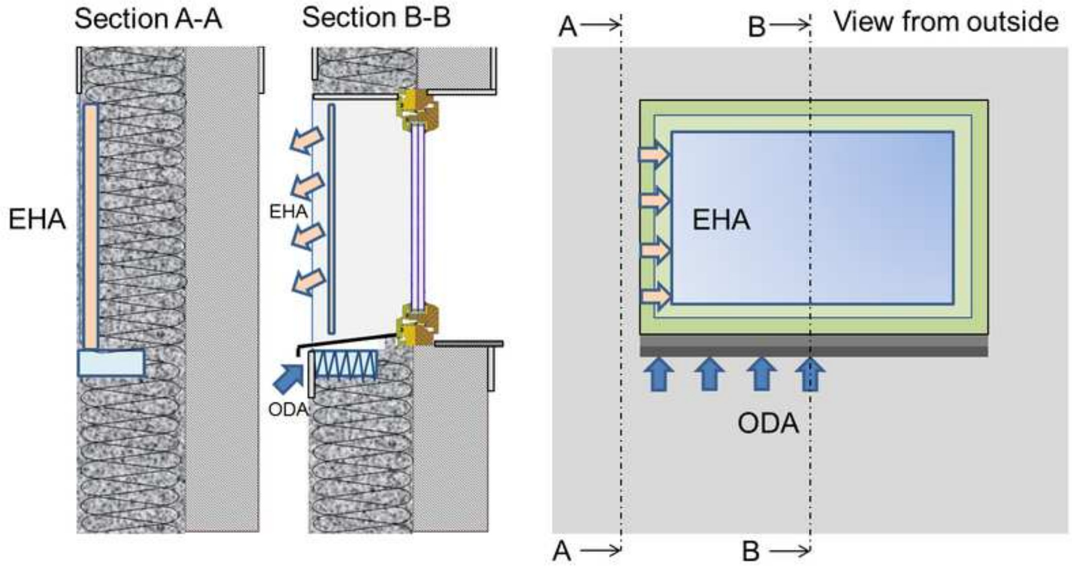
Photo Source: Malzer, H.

3.1.2 WINDOW INTEGRATION

Connection to and integration of heat recovery units and ventilation ducts close to window reveals, window lintels and parapets, in- and outlets through shadow gaps and slot diffusers.

The following design principle shows how the slot below the window sheet is used as outdoor air inlet. Compared to an air inlet via a grille, this solution is much better from architectural and design point of view. The exhaust air outlet is located at the window reveal. This slot diffuser should blow the air to the outside to avoid any condensation/freezing of the EHA-humidity at the window.

FIGURE 3-2: SLOT DIFFUSER



Source: Pfluger, R.

This principle was adopted by the Smartshell refurbishment solution of Franz Freundorfer, which was shown at the Passive House Conference Exhibition in 2017 (see next figure). In this case the open larch casing works as ventilation grill, the outdoor air is sucked through and is ducted to the horizontal air filter below the window sheet.

FIGURE 3-3: SMARTSHELL REFURBISHMENT SOLUTION

System: Smartshell, Photo Source: Pfluger, R.

3.1.3 SPACE-SAVING SYSTEMS FOR THE RETROFITTING OF SMALL HOUSING UNITS

Which opportunities can be offered for the post integration provided restricted space of given floor plans?

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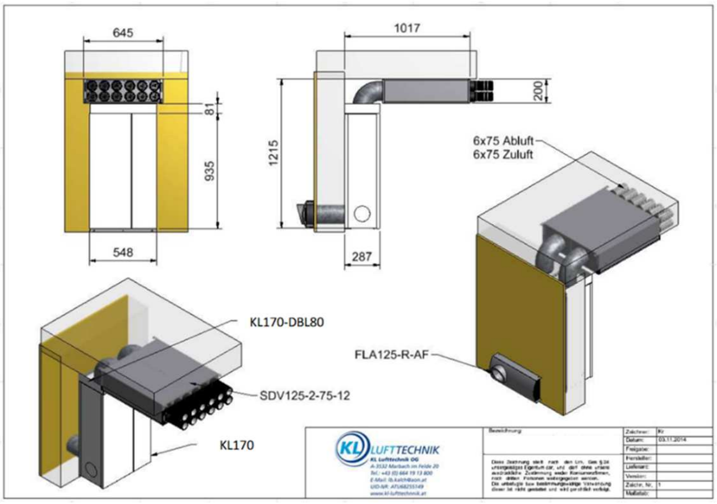
Since several years, new types of ventilation units especially suitable for post integration are on the market. Besides the wall integration, also the integration in the ceiling or floor is possible. In all of these cases, the geometry of the unit should be as flat as possible and the location of the air duct connections have to be at the narrow sides of the casing.

FIGURE 3-4: VENTILATION UNITS FOR POST INTEGRATION

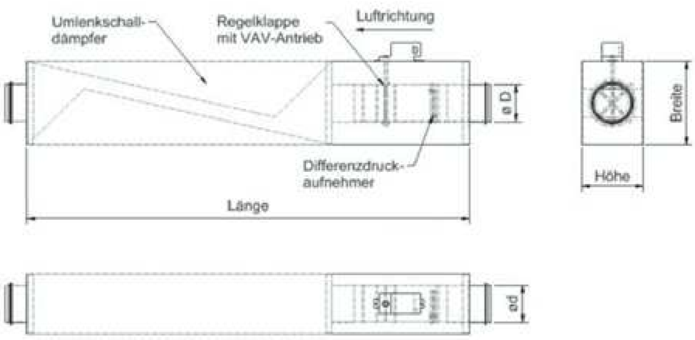


Source: KL Lufttechnik

As the post integration calls for flexibility, different options for the connections should be provided. Either this options are available as different models of the unit, ore inbuilt within the same model (non-used connectors to be closed).

Besides the heat recovery unit itself, also the air distribution boxes and silencers should be as flat as possible, if they should be integrated within the suspended ceiling. In case of centralized ventilation systems, each dwelling is equipped with two volume flow controllers. In order to save as much space as possible and to save installation costs at the same time, the combination of volume flow controller, silencer and air distribution box is a good solution (see next figure).

FIGURE 3-5: COMBINATION OF VOLUME FLOW CONTROLLER, SILENCER AND AIR DISTRIBUTION BOX



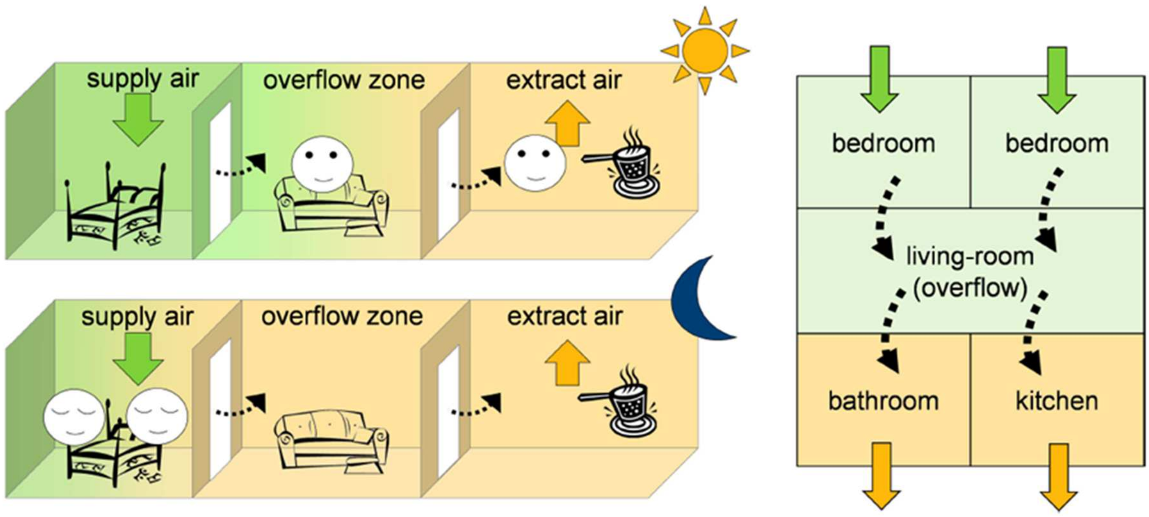
Source: Pichler Luft

Link to an implemented option

3.1.4 CASCADE VENTILATION (PASSIVE OVERFLOW)

Saving of supply air ducts and components through zoning of the floor plan in supply air, overflow and exhaust air zones: Normally the supply air zones are living rooms and bedrooms. The air is routed from this supply air zones via the overflow zone (e.g. corridor) to the exhaust air zone (e.g. kitchen, bathroom). This air routing principle is called cascade ventilation. Compared to a system with supply and extract air for each room, this principle already saves a lot of space and money. By means of the extended cascade ventilation, the supply air may be restricted to bedrooms. In this case, the living room is regarded as overflow zone as shown in the next graph.

FIGURE 3-6: PASSIVE OVERFLOW



Source: Sibille, E.

3.1.5 ACTIVE OVERFLOW

Active overflow may be useful especially for retrofitting because an even more extensive reduction of the duct network may be achieved. In order to do so, small fans are implemented to deliver air from corridors to bed- and living rooms.

In the following figure, the fan blows the air actively into the room, it returns to the corridor via a passive overflow. From building physical point of view (avoiding overpressure), the other way round is to be preferred.

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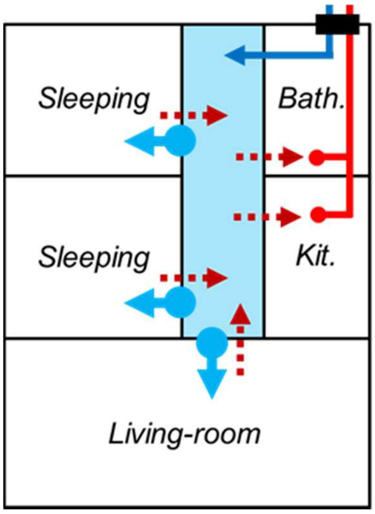
FIGURE 3-7: PASSIVE OVERFLOW



For refurbishing, several options of installation of this active overflow are available:

- Door leaf integration
- Doorframe integration
- Mounting above the door
- Mounting besides the door

The decision, which solution to choose depends on the cost and the intervention for the installation. The minimal intervention is to be done in case of door leaf integration. The disadvantage of this solution is the fact, that the fan unit is mounted in the moving part (problem for wiring, mechanical robustness etc.). The wall integration however requires higher construction effort.

3.2 HEATING AND DOMESTIC HOT WATER - BY UIBK, IIG HOUSEHOLD

3.2.1 HEATING ADAPTED TO DEEP RETROFIT

Deep retrofit of the building envelope reduces the heating energy demand by a factor of up to ten. At the same time, the heating load and consequently the size and power of the heat generator is reduced significantly, too.

3.2.2 DOMESTIC HOT WATER AND SEWAGE HEAT RECOVERY BY RAINER PFLUGER, UNIVERSITY OF INNSBRUCK

The energy balance of buildings after a deep retrofit shows that the relevance of the heat for domestic hot water (DHW) compared to the heating demand is high. In some cases of high efficient refurbishment, close to passive house standard, the heat demand for heating is even lower than the demand for DHW production and distribution in terms of the yearly energy demand. In general, there are four main saving potentials for DHW: Reduction of circulation pipe and storage tank losses as well as flow reduction and shower heat recovery.

3.2.2.1 REDUCTION OF CIRCULATION PIPE LOSSES

In multi-family homes, a circulation is necessary for DHW comfort, to avoid the latency for warm water drawing. For hygienic reasons, the temperature of this pipe has to be kept at 60 °C in order to avoid legionella growth. This pipe system has to be well insulated to avoid high DHW distribution losses. Especially in summertime this losses have negative impact on the avoiding of overheating, but even in wintertime, the heat from DHW-ducts is uncontrolled heat and should be reduced to a minimum. The following measures help to reduce these losses:

- Reduction of the duct length
- Insulation thickness double of the duct diameter
- Pipe in pipe circulation system

The reduction of operation time and temperature of the circulation loop is only in accordance with hygienic standards, if there is chlorine disinfection (e.g. by electro-chemical diaphragm-electrolysis) or UV disinfection.

3.2.2.2 REDUCTION OF THERMAL STORAGE TANK LOSSES

Beside the distribution losses (ducts), the storage losses are one of the mayor reasons for high DHW heat consumptions. First of all, it should be clarified if the tank volume can be reduced or even if the tank can be completely eliminated (instantaneous water heaters, tankless water heaters). If the tank cannot be avoided, it should be well insulated. The quality of the insulation depends on the material (thermal conductivity), thickness and avoidance of convection between insulation and storage tank wall. The insulation should cover all warm parts, especially the flanges and fittings.

3.2.2.3 FLOW LIMITER AND LOW-FLOW SHOWERHEADS

The highest effect in terms of efficiency is the reduction of the tapped DHW by the user (reduction of shower time etc.). A technical solution for reduction of the tapped amount of water is the flow limiter and the low-flow showerheads. Both result in a limitation of the rate of flow. The advantages of special low-flow showerheads are, that they intend to reduce the rate of flow with only a small loss of comfort. For practical reasons the saving potential is limited, further reduction is possible by application of heat recovery as described hereunder.

3.2.2.4 SHOWER HEAT RECOVERY

In addition to potential savings in the field of storage and distribution losses as well as the use of water-saving fixtures, the heat recovery from the waste water has proved to be a cost-effective solution. Drain water heat recovery can be used in different ways to reuse the heat of waste water. It can be used as heat source for heat pumps ore directly for preheating of DHW.

Specifically, the shower water heat recovery is a promising solution, based on the available amount of waste water and the hot water demand and waste heat supply occurring practically simultaneously (this is not the case for having a bath in a bath tub, because the water is drained later than it's tapped). Therefore the shower heat recovery is in some countries (especially in the Netherlands) already a widespread technology. Vertically arranged heat exchangers are the most efficient both in terms of costs and of heat recovery. The subsequent use in refurbishment raises the problem of the interference with the underlying housing unit. The heat exchanger should be mounted horizontally in this case, however, systems currently on the market are significantly less efficient. Attention has to be paid to both, a highly compact design with the ability to integrate into the shower tray as well as to the most simple and efficient cleaning.

An overview of both types of shower water heat recovery with certified values of heat recovery can be found here.

FIGURE 3-8: INSTALLATION OF DRAIN-WATER-HEAT-RECOVERY HEAT-EXCHANGED IN THE BATHROOM OF BEST NBR. 3

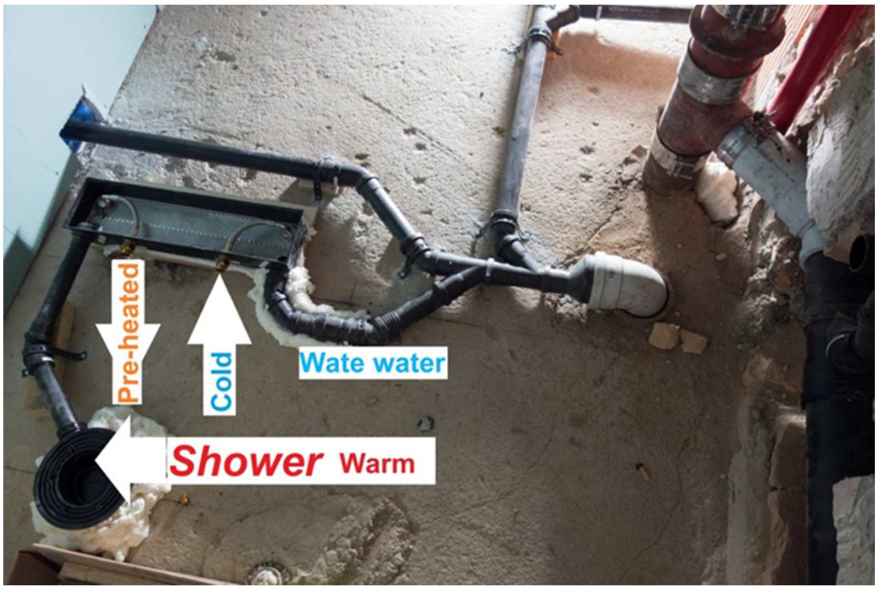


Photo Source: Pavel Sevela

Heat recovery system directly integrated in the shower tray, dynamic efficiency 36% measured according to PHI-criteria within a real field measurement test in a small dwelling in Innsbruck:

FIGURE 3-9: HEAT RECOVERY SYSTEM INTEGRATED IN THE SHOWER TRAY

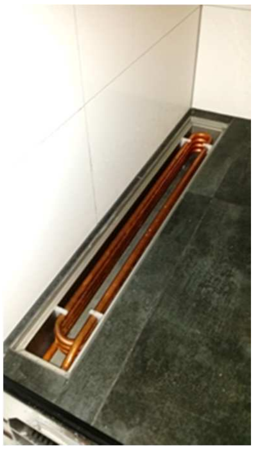


Photo Source: Pavel Sevela

Shower heat recovery allows to reduce the total useful heat demand for hot water by 25 to 35%. The efficiency achieved depends on the way of hydraulic connection:

The highest savings are achieved when the heat exchangers supply the cold and hot water connection of the shower.

If the heat exchanger is only connected to the hot water connection, high hot water temperatures noticeably reduce the degree of utilization.

If the heat exchanger is only connected to the cold water connection, scarcely any heat is recovered if the hot water temperature set-point is low.

4. HOUSEHOLD ELECTRICITY

4.1 ELECTRIC ENERGY EFFICIENCY BY IIG

4.1.1 SWITCH TO LED TECHNOLOGY

The switch to LED technology in each corridor and classroom allows for considerably reduced energy use. This means that in the summer months cooling is not necessary due to the reduced use of energy for lighting. Improved comfort is possible during periods of excessive heat in summer. Furthermore, the new LED technology is much better for visibility in each classroom. Consequential damage to the health of users (negative effects on eye health) due to poor quality lighting can thus be reduced. Greatly improved quality is achieved in the schools through the appropriate use of separate lighting for the blackboards.

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FIGURE 4-1: HIGHER ELECTRIC ENERGY EFFICIENCY THROUGH LED IN A CLASSROOM

Photo Source: Pfeifer, B.

4.1.2 CONNECTIVITY OF THE BUILDINGS AND REMOTE CONTROL

Connectivity of the buildings via KNX bus and remote control allows for significantly better energy management. Due to intelligent bus control technology, it is possible to optimise the building in case of overheating in summer and cooling down in winter. Furthermore, different sensors (wind, rain, sun etc.) enable intelligent intervention in the respective daily routine of the various users. Reprogramming of various scenarios can be carried out quickly. Different actual values (CO_2 content, temperature, air humidity) can be recorded by means of sensors in the classrooms. On this basis active intervention is possible with regard to shading or regulation of the ventilation system. This allows for a significantly better indoor climate in the classrooms.

4.1.3 USER BEHAVIOUR

In apartments, different types of usage behaviour can be documented. How often does ventilation take place? Air humidity in the apartments, room temperatures and usage of e.g. heating or daily hot water consumption. Various insights can be derived from these measurements which can then be taken into account in the future.

Measurement of the electricity consumption (5 - 15 minutes increments) makes it possible to analyse different consumption behaviours by means of the anonymously recorded electricity demand. This allows conclusions to be drawn regarding different models, e.g. the use of PV modules, or about how efficient shared heat generation facilities are. Among other things, hot water generation could possibly be changed to a different time of the day (from the current 22:00 p.m. to 06:00 a.m.).

5. STANDARDIZATION OF ENERGY REFURBISHMENT

5.1 ENERGY BALANCE OF A DISTRICT BY PHI

As part of the Sinfonia project, the Passive House Institute has developed a calculation programme to assess and optimise city districts in terms of their energy efficiency. districtPH calculates detailed energy balances for buildings within the neighbourhood. Heat or electricity production in the district, both centrally and in individual buildings, is considered in the total energy balance. It is also possible to account for public supply structures as well as public consumers.

The development was aiming at two major fields of interest:

- The energy balance of the district, including heat and electricity generators and grids, at a given point in time. Questions such as 'What is required to make the district zero-energy?', 'What would be an appropriate size for a seasonal heat storage?', 'How much energy will be exported from the district in a specific situation?' can be addressed.
- The interaction of current and future retrofits with supply structures. Possible projections include the total primary energy demand or the CO_2 emissions over several decades, depending on different scenarios for e.g. retrofit subsidies or district heating network installations. The probability of a refurbishment to a certain efficiency level can be defined, depending on factors like component age, time, subsidies, or existing efficiency level. The difficulties arising from the probabilistic nature of refurbishment rates were solved by implementing a Monte Carlo Simulation method.

FIGURE 5-1: DISTRICTPH LOGO

Source: Passive House Institute

5.1.1 BASIC STRUCTURE OF DISTRICTPH

For reasons of flexibility and transparency, districtPH was realised as an Excel spreadsheet. Building-related energy consumption and the effects of refurbishment measures play a central part. In addition, districtPH considers user-related energy consumptions in buildings. This is supplemented by street lighting and the energy consumption of trams and other electric vehicles. A district heating system and

the electricity grid, including short and long-term storages, can be represented. Estimation methods for the energy production from renewable sources were integrated.
For some purposes algorithms from the [PHPP] could conveniently be integrated, many other methods were developed from scratch. We assumed that the data acquisition would not be as accurate as when planning a new building. Design drawings will not be available, neither will exact component qualities, numbers of inhabitants, etc. Once accepted, this fact allows for entering the buildings in the district by assigning them to certain pre-defined building types from a typology. For the current version, due to the inhomogeneous availability of data, it was decided not to develop an import filter for GIS data, e.g. from CityGML.

One of the major goals in the development of districtPH is the prediction of how the district's energy demand evolves over time. Since future developments will always depend on many currently unknown parameters, the calculation results will have an unavoidable inaccuracy, which in turn justifies time-saving simplifications of the calculation methods themselves.

The first step in setting up an energy balance is to enter the buildings in the district. Each building is assigned to one of up to 30 building types, which can be either user-defined or chosen from the Episcope database ([Tabula 2018]). The buildings with their type, their positions and square meters of floor area can be entered. The building types already contain efficiency levels for all building components and the mechanical systems.
Excel can now calculate the energy balance of each building type with regard to heating, cooling, hot water, and electricity, and report the sum totals of e.g. delivered energy, CO_2 emissions, or source energy. The relevant results are saved, and the district moves on to the next year. Now, with a user-defined probability, a retrofit of the building components to a different efficiency level takes place, and the calculation process starts again.
In order to deal with the exponentially growing number of buildings from year to year, a Monte Carlo method was selected: The number of building types remains constant in every time step, with each building type having only one renovation status, determined by retrofit probabilities. The whole simulation is repeated several times, with different random numbers, until the average of all individual results for the required quantity has been determined with sufficient accuracy.

This core calculation process is supplemented by several additional tools:

- an import filter from the PHPP, for defining a building type from existing PHPP input data

- a variant management, allowing for a comparison of e.g. different supply structures
- an economics calculator, suitable to determine economically optimal renovation measures
- a climate data worksheet, where local climate data can be entered
- a set of worksheets for an hourly analysis of electricity and district heating networks

5.1.2 EXAMPLE APPLICATION FOR A DISTRICT IN THE NORTH OF DARMSTADT

In this section, a simple example will be laid out in order to illustrate potential uses of districtPH. This example was also used for the presentation of districtPH on the 22nd International Passive House Conference in Munich [Schnieders 2018].

A small district in the north of Darmstadt, Germany, was selected to be used as an example (Figure 5-2). The district covers an area of about 350 x 350 m. The railway line and the ring road on the western side are separated by a landscaped noise barrier approximately 20 m high.

In total, 63,000 m^2 of living area were included in the calculation. The district is primarily populated with terraced housing and 3 and 4 storey multi-family houses. The areas of the terraced house plots range from 200 to 400 m^2. For the most part, the district was developed between 1995 and 2005, and any older properties are only found on the eastern edge. There is a supermarket in the south of the district and a retirement home in the north-east corner of the area selected. A natural gas network has been laid in the district, but district heating is not yet available. In the model, it was assumed that the heating and hot water requirements of all the buildings would be covered by natural gas in 2018, the first year of the simulation.

FIGURE 5-2: SATELLITE PICTURE OF THE EXAMPLE DISTRICT

Source: Schnieders 2018

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5.1.2.1 DIFFERENT RETROFIT STRATEGIES

Using districtPH, the effects of average quality retrofits and of the possibly resulting lock-in-effect on the total CO_2 emissions were investigated. Simultaneously, the importance of the retrofit rate was examined.

The following 4 variants were considered:

A) Retrofitting the wall, roof, floor slab and windows to the current minimum legal standard required in Germany according to the EnEV (roof 0.24, basement ceiling 0.30, exterior wall 0.24, window 1.3 W/(m²K)), and only if the building component in question is being retrofitted anyway. Window ventilation as before.
B) Identical to A) but with the modernisation rate roughly doubled until 2028. This is realized by a shortened service life. We have therefore taken a realistic approach and assumed that primarily older building components will be modernised.
C) Retrofitting the wall, roof, floor slab and windows as cost effectively as possible. This generally means using components of Passive House quality. The retrofit however is carried out only at the end of the service life of the building component in question. This follows a step-by-step retrofit in accordance with an EnerPHit Retrofit Plan. Installing a mechanical ventilation system with a highly efficient heat recovery system and improvements to the airtightness to EnerPHit level, as well as replacing the windows.
D) The same as B) for the first 10 years, and thereafter, the same as C).

Figure 5-3 and Figure 5-4 illustrate the resultant CO_2 emissions for space heating and hot water production (the power consumption is initially not taken into consideration here). It should first be noted that even after 50 years, only moderate reductions in emissions were achieved in the variant A). If the rate – but not the quality – of modernisation is increased in the variant B), this initially reduces the CO_2 emissions to a significant degree. The economic cost of this would, however, probably be considerable as purely energetic modernisations, which are not incorporated in the regular maintenance cycle, tend not to be financially viable. Sufficient funding would therefore have to be available to bring forward retrofits that were not due until a later date. In addition, manufacturers and tradespeople would have to build up the required capacities (which would then have to be run down again). If, as assumed in the example, the funding were to come to an end after 10 years, then – as shown in Figure 5-3 – basically nothing more would be done in the following 10 years because all the building components (apart from the insulation level) would then be in relatively good condition. After this, further improvements would have to take place, so that in the long term the emissions are approximately equal to those in the variant A).

In variant C), the drop in emissions is initially very slow. This is partly due to the relatively new fabric of the buildings in the district used in the study. Subsequently, however, a strong, continuous and sustainable improvement can be seen.

Variant D) shows the outcome if this course of action is not taken until a later date, for example after 10 years of widespread intensive funding of broadly average quality. As in variant B), there is a longer pause after the end of the funding before the emissions resume a course similar to the variant C). However, the variant D) will not attain the final result of the systematic EnerPHit retrofit C) by the end of the 50-year financing period, whereby many opportunities will have been missed.

FIGURE 5-3: TIMELINE OF THE ANNUAL CO2 EMISSIONS IN 4 DIFFERENT SCENARIOS

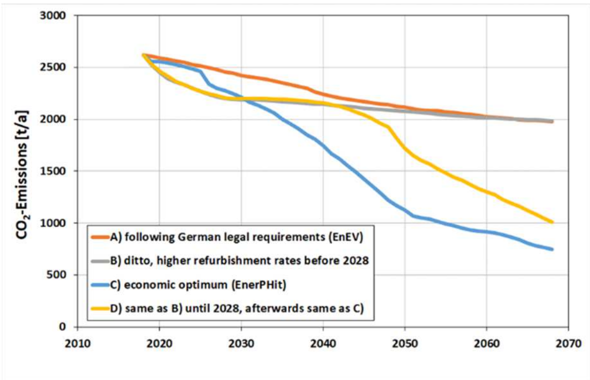
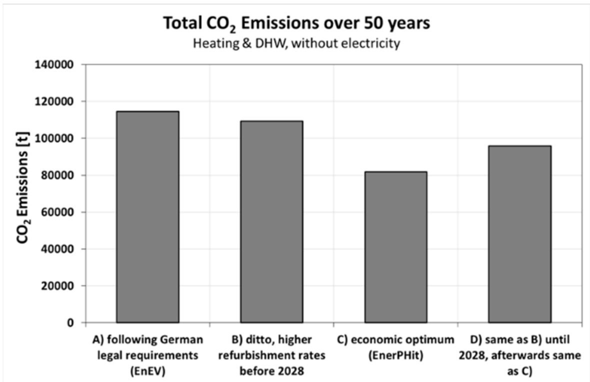


FIGURE 5-4: IN VIEW OF THE SUM TOTAL OVER 50 YEARS, THE LOWEST CO_2 EMISSIONS ARE ACHIEVED THROUGH CONSISTENT ENERPHIT RETROFITTING AS PART OF THE MAINTENANCE CIRCLE



Source: Schnieders 2018

On the basis of these findings, the following conclusions may be drawn: Substantial improvements to the fabric of the building which bring it to a sustainable level are crucial for reducing energy consumption in the building sector in the long term. In contrast, funding for average quality retrofits only provides short term improvements, before having a negative impact on the starting situation for any additional measures required.

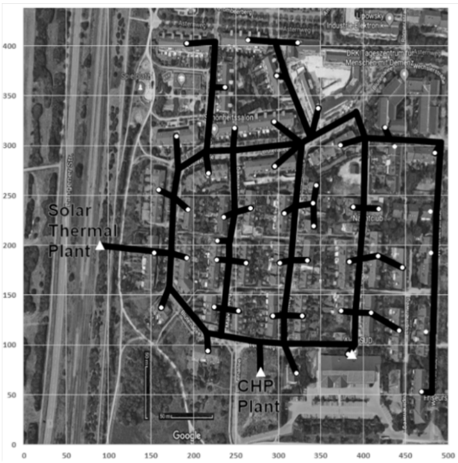
5.1.2.2 DISTRICT HEATING FOR DEEP RETROFITS

A second topic was the extent to which district heating is still worthwhile if the district is, in the long term, retrofitted to the EnerPHit level.

In the calculation, the area will now be provided with a district heating grid at usual operating temperatures (110 °C for winter and 80 °C for summer) (Figure 5-5). The heat is predominantly generated by a gas-driven CHP plant located near the supermarket with an overall efficiency of 85% (55% thermal and 30% electrical). The CHP plant is heat-driven and is designed to operate at a thermal output of 3.3 MW so that it generates approximately 3,000 full-load hours in the initial state of the district.

The heat supply is supplemented by a 2,000 m^2 solar thermal collector which can be installed on the railway line side of the landscaped noise barrier without incurring a significant adverse effect on its functionality. The collector is oriented towards the west and is inclined at an angle of 45°. It is supplemented by a storage device which operates during the day and enables the yields to be fully utilised even in summer.

FIGURE 5-5: SIMPLIFIED OVERVIEW OF THE DISTRICT HEATING GRID. IT WAS ASSUMED THAT EVERY RESIDENTIAL UNIT IN THE ROWS OF TERRACED HOUSING WOULD REQUIRE ITS OWN CONNECTION TO THE DISTRICT HEATING TRANSMISSION LINE.



Source: Schnieders 2018

The refrigeration units in supermarkets consume large amounts of electricity. In winter, the ideal use for the waste heat generated is to directly heat the supermarket. In summer, however, the waste heat can be used in the district heating network, but it must be passed through a heat pump to bring it to the corresponding temperature. A usable waste heat output of 57 kW was set during opening hours and 33 kW for other times.

At the starting point, the district heating grid incurred heat losses of 17% of the heat fed in. In summer, the solar thermal collector and supermarket approximately cover the heat losses of the network. Setting up a district heating grid would reduce the total CO_2 emissions of the district (for heating, hot water and all electricity consumers) from 5,100 to -2,100 t/a. The emissions are counted as negative due to the CO_2 credit for the surplus power. In Germany, renewable electricity is not replaced in the overall electricity mix (power grid operators prioritise purchasing electricity from renewable sources), instead it replaces the electricity which is generated by inefficient, coal-fired medium-load power

stations. The corresponding CO_2 factor amounts to 1,008 g/kWh. The gas CHP plant emits just 833 g per kWh of electricity, thereby simultaneously covering another portion of the thermal demand in the district.
The CO_2 emissions calculated in this way are clearly misleading, not only because higher losses from the district heating pipelines would further reduce the emissions in terms of numbers, but also because the displacement electricity mix will drastically change over the decades, the latter being the relevant timescale for buildings and building modernisations. Germany has undertaken to reduce greenhouse gas emissions by 80% to 95% compared with 1990 by as early as 2050. This can only be achieved if coal-fired power stations are largely phased out.

One possibility for a more meaningful basis of assessment, especially for long term developments, is the PER system (for details, please see [Feist 2014] and [PHPP]). It is based on a future energy supply generated entirely from renewable sources. It comprises a cost-effective mix of photovoltaic installations, wind energy and biomass, tailored to regional availability. Methane, which is generated in summer from renewable electricity and reconverted to electricity in combined cycle power stations in winter, is used to cover the winter gap. According to this system, electricity generated by photovoltaics or wind, for example, has a PER factor of 1. Methane generated from renewable energies (renewable power-to-gas) has a value of 1.75. Electricity generated by CHP plants is evaluated in the same way as electricity generated by combined cycle power stations. The PER demand of the buildings in the district can therefore be calculated – the more electricity the CHP plant supplies, the lower the PER factor of the district heating system.

The PER demand of all the buildings in the district amounts to 21,100 MWh/a in the initial state. The transition to district heating would reduce the PER demand, though only to 17,600 MWh/a.
If the complete fabric of the buildings in the district were brought up to the EnerPHit level, the PER demand would fall to 7,700 MWh/a if the gas boiler continued in operation, however it would only fall to 8,000 MWh/a if the district heating system were used. The district heating grid losses would increase to 38% of the heat fed in. The CHP plant would then be operated at only 1,200 full load hours per year. It can therefore be seen that the installation of a conventional district heating grid for the district investigated is not advisable, neither economically nor in terms of the cost of the energy supply. The heat fed in by the large solar thermal collector (11% contribution in the EnerPHit variant) and the supermarket's utilisation of waste heat (3%) does not affect this assessment. Heating by gas would also be questionable in a renewable energy system. As it takes considerable effort to produce gas from

renewable electricity, it is more beneficial to produce heating and hot water using efficient heat pumps: the PER demand then falls to 4,300 MWh/a. This outcome however cannot be applied universally, as CHP plants with greater electrical efficiency and in more densely populated districts can generate different results.

5.1.3 REFERENCES

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6. CASACLIMA REFURBISHMENT GUIDELINES

The CasaClima R method has been developed with the aim of ensuring a high level of quality in the renovation process of low energy buildings.

CasaClima R was established as a quality assurance protocol consisting of a careful check of both the project and the building site. Specific requirements for the building envelope and the building system were assessed.

The certification procedure and requirements were preliminary defined in 2013 by means of a pilot guideline, which allowed getting a first overview of the practicability of the quality assurance protocol in some renovation cases of single and two-family housing units.

In the framework of the EU-project SINFONIA, CasaClima tested the feasibility of the pilot certification tool CasaClima R on the large-scale refurbishments of the district of Bolzano. This was the first application of the pilot protocol to a large-scale refurbishment.

During the design and refurbishment phases of the demo buildings, a constant check and comparison of the applicability of the preliminary set certification requirements for building envelope and systems was carried out. The evaluation process focused on the characteristics of the real buildings, taking into account technical, urban, and procedural constraints. In some cases, the evaluation requirements and methodology had to be modified with the goal of working more properly on the real cases. A reduction of complexity and bureaucracy (for instance, the required documentation) resulted to be necessary in order to facilitate the access and use of this quality assurance procedure among the stakeholders.

Evaluation criteria	
Building envelope	Performances of building elements (construction layers, windows, doors, shading systems) Thermal bridges resolution Interstitial condensation evaluation Air tightness test
Building systems	Heating, cooling and hot water generation subsystem Distribution subsystem Emission subsystem Regulating and control subsystem Thermal storage subsystem Auxiliar electric devices Ventilation subsystem

TABLE 1, CASACLIMA R REQUIREMENTS, PILOT PROTOCOL

The improvement process led to significant adjustments of the pilot guidelines and the development of a thermal bridges catalogue, a supporting tool for technicians. At the end of the assessment process, the new “CasaClima refurbishment guidelines, 2017” were issued in both Italian and German languages.

FIGURE 6-1: CASACLIMA REFURBISHMENT GUIDELINES (ANNEX C)

6.1 CASACLIMA CERTIFICATION PROCESS

The CasaClima certification process consists of following phases:

1. Check of the requirements for the building envelope and for the building systems (detailed project and ProCasaClima calculation)
2. Audit on-site: during the construction phase, CasaClima appoints an auditor to carry out the planned inspections (audits). During the audit, the technical information required for the certification are collected by means of an audit protocol.
3. On-site measurement of the air tightness
4. Final control: at the end of the process a final control of the entire documentation and of the energy calculation are carried out. CasaClima acquires, either directly or through the auditor, the final updates and the data necessary for issuing the CasaClima certificate.

6.2 BUILDING ENVELOPE

In the framework of the Sinfonia project, CasaClima introduced a modification of the requirements for both the heating and the cooling demand. While in the old pilot guidelines the single values of transmittance of the envelope elements were considered and checked, in the new refurbishment guidelines these parameters were replaced by the assessment of the overall energy efficiency of the building after the renovation works. Following energy efficiency standards have been set for refurbished residential buildings:

Heating demand: $Q_h \leq 70$ kWh/m²a (CasaClima Class C)

Cooling demand: $Q_{c,sens} \leq 20$ kWh/m²a

In the event of documented constraints that could limit the possibility to reach these standards, an improvement of the efficiency of at least 50% compared to the energy efficiency value of the existing building (prior to refurbishment) is required.

6.2.1 ADDITIONAL REQUIREMENTS FOR THE BUILDING ENVELOPE ELEMENTS

Since the overheating during summer is a critical issue particularly in the warm climatic zone (A, B, C, D), supplementary requirements were set for external walls, roofs and floors subject to refurbishment and exposed to direct solar radiation.

CLIMATIC ZONE	PHASE SHIFT	DYNAMIC TRANSMITTANCE	ATTENUATION FACTOR (24h)
A, B, C, D	≥ 12 h	Y_{11} ≥ 2.0 W/m²K	≤ 0,30
E, F (≤ 4000 GG)	≥ 9 h	-	-
F (> 4000 GG)	-	-	-

TABLE 2, REQUIREMENTS FOR THE BUILDING ENVELOPE ELEMENTS

Moreover, in case of replacement of the glazed surfaces (windows), the windows must be equipped with a mobile or fixed screening system. With regard to shading systems, different requirements were set for mobile and fixed, integrated and not integrated shading systems.

6.2.2 AIR THIGHNESS REQUIREMENTS IN CASE OF PRESERVATION OF OLD ELEMENTS

In the case of maintenance of the existing doors, windows and mobile shading systems, the air tightness of these elements must be guaranteed, both for the connections and for the inspection openings. Windows must have a gasket on all sides, while doors must have a threshold on the fourth side (bottom). In cases of insufficient thermal insulation in the mobile shading box, it is recommended to improve the thermal insulation.

6.2.3 THERMAL BRIDGES

Thermal bridges are thermally weak areas of the building envelope where critical internal surface temperatures can be reached due to increased heat losses during the coldest season. Thermal bridges not only have to be introduced in the energy calculation to consider the heat losses, but their internal surface temperature must fulfil severe requirements. In heated rooms the internal surface temperature θsi, of structural elements subject to energy requalification, must be:

- θsi ≥ 17.0° C in case of apartments without controlled mechanical ventilation system
- θsi ≥ 12.6° C in case of apartments with controlled mechanical ventilation system ensuring an air exchange n≥0.3 Vol/h

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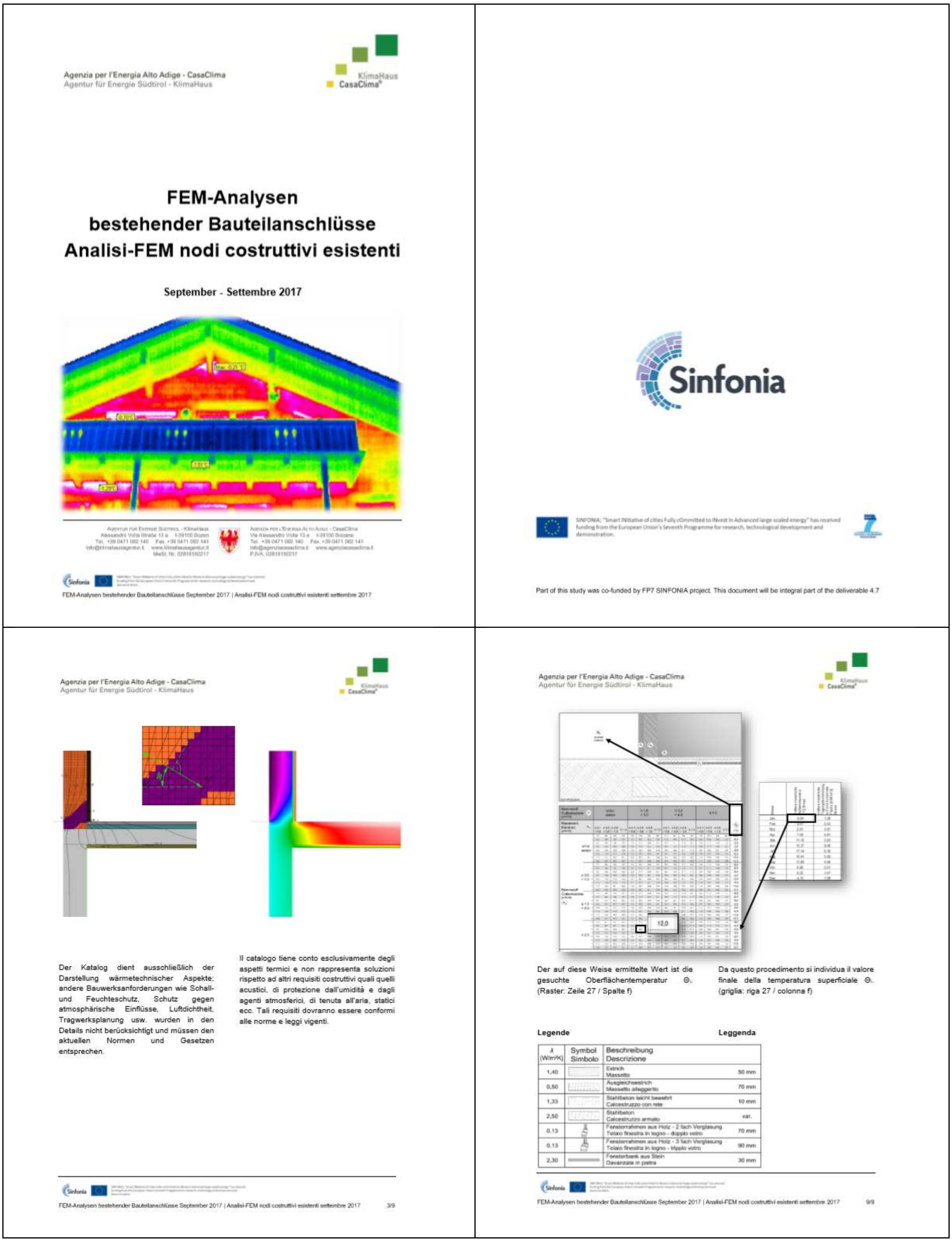
FIGURE 6-2: CASACLIMA THERMAL BRIDGES CATALOGUE (ANNEX C)



For the evaluation of surface temperatures of the building details, a two-dimensional calculation with finite elements (FEM) validated according to UNI EN ISO 10211 is generally required. Since the evaluation by means of a finite elements tool is usually a difficult task to carry out for technicians, in the framework of the Sinfonia project, a thermal bridges catalogue was developed by CasaClima for the Italian territory. The catalogue considers the most frequent thermal bridges that can be found in Italy in energetically refurbished buildings.

In the event of existing buildings where the presence of constraints do not allow reaching the minimum temperature, an active protection system can be installed. Following cases are possible:

- Active protection of thermal bridges with electric heated cable. In this case there must be a surface temperature sensor for regulating the switching on and off of the circuit and the nominal power of the heating cable must be ≤ 15 W/m
- Active protection of thermal bridges with hydronic system (radiant floor / wall)

6.2.4 INTERSTITIAL CONDENSATION

The hygrothermal behaviour of the elements of the thermal envelope must ensure compliance with the verification of interstitial condensation. Following construction elements of the thermal envelope must be checked:

- Structures subject to energy refurbishment with internal or cavity thermal insulation
- Unventilated, flat wooden roofs

The verification can be performed according to the UNI EN ISO 13788 or UNI EN 15026 standards. For the choice of the verification method it must be taken into account that the UNI EN ISO 13788 standard describes a simplified method for assessing the risk of interstitial condensation due to vapour diffusion. This method does not take into account some important physical phenomena such as:

- the variation of the properties of the materials according to the moisture content
- capillary rise and transport of liquid moisture inside the materials
- the movement of air in the components, through cracks or cavities
- the hygroscopic capacity of materials

If at least one of these phenomena is relevant or the verification according to the UNI EN ISO 13788 standard is not compliant, more advanced assessment methods can be considered in compliance with the UNI EN 15026 standard.

6.3 BUILDING SYSTEMS

The refurbishment guidelines contain a series of parameters that have to be respected for the building subsystem components to guarantee a minimum efficiency performance.

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Different requirements are applied in case of existing installations (the technical systems of the existing building or unit are not replaced) and in case of substitution of the technical systems (substantial or partial replacement). The performance of following subsystems must be verified:

- Heating, cooling, hot water generation subsystems
- Distribution subsystem
- Emission subsystem
- Regulating and control subsystem
- Thermal storage subsystem
- Auxiliary electric devices (pumps, fans…)
- Ventilation subsystem

Mandatory performance criteria are required for generation subsystem (generator efficiency), regulating subsystem, distribution subsystem (visible pipes insulation), storage subsystem and auxiliary electric devices. An appropriate adaptation of the heating and cooling regulating subsystem is always required, to ensure that the thermal energy supply complies with the new state of the energy demand in the housing units. In case of maintenance of the existing radiators, no mandatory requirements are required for the emission subsystem.

6.3.1 CONTROLLED MECHANICAL VENTILATION

CasaClima recommends the installation of a ventilation system with air exchange and heat recovery. Specific requirements are considered for different types of ventilation systems.

DUCTED	NON-DUCTED	
Centralized ventilation unit with a network of air ducts bringing and extracting the air in the housing units. The heat recovery system (HRS) is contained in the centralized machine	Small, non-ducted ventilation units. Fresh, filtered supply air and exhaust air are respectively introduced and extracted directly in the housing units.	
	Typ A	Typ B
	Machine with continuous air intake. Double channel, separate entry and exit airflow	Machine with discontinuous air supply. Single channel, unidirectional airflow

TABLE 3, DIFFERENT CONFIGURATIONS OF VENTILATION SYSTEMS

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In the cooler climate zones and in general in all those areas characterized by low external absolute humidity during the winter period, CasaClima recommends the use of regenerative heat exchanger, equipped with an efficient heat recovery both latent and sensitive.

In case of an existing ventilation system in a non-residential building, CasaClima requires the installation of a heat recovery unit with bypass. For ventilation systems equipped with a heat recovery unit, its operation and the proper insulation of all the existing accessible channels must be verified.

In case of new installation of a ducted ventilation system, a bypass on the heat recovery unit is recommended to operate in "free-cooling" during the cooling season when the outdoor air temperature is lower than the internal one.

In residential buildings, the fan must be equipped with at least 3 speeds, easily manageable by the user and the flow must be $q_{v,d} \leq 0.7\ q_{v,max}$, where $q_{v,max}$ is the maximum air flow rate of the appliance.

In case of new installation of a non-ducted ventilation system, there must be at least one appliance for each housing unit.

6.4 AIR TIGHTNESS OF THE BUILDING ENVELOPE

At the end of the renovation process, to obtain the CasaClima R certification the air tightness of the building/apartment must be verified. The air tightness of the building envelope is defined by the air change rate n_{50}, measured by means of a quick and non-invasive method, the blower door test (BDT). The limit value to obtain the CasaClima R certification is $n_{50,lim} \leq 3.0$ h (-1).

During the test, a qualitative check of the air tightness of the building thermal envelope must be carried out, to identify the significant air leakages.

The air tightness measure procedure and the report must comply with the criteria of the "*CasaClima directive for the execution of air tightness tests (blower door test)*".

6.5 CONSTRAINT CASES

In existing buildings, historical constraints, urban regulations, etc. may be an issue making it impossible to implement certain requirements of the directive, precluding the achievement of the certification. Cases of restrictions in existing buildings are:

- historical-architectural constraints
- urban planning restrictions (distances between buildings, etc.)
- hygienic-sanitary constraints due to internal heights, internal walk-on surfaces, etc.

- technical constraints due to provisions for the removal of architectural barriers, for compliance with current legislation on fire prevention, anti-seismic protection and more generally for compliance with national or local rules.

In special cases, where the non-achievement of a determined requirement or performance does not affect the final building quality, the intervention durability and the internal health conditions, CasaClima can evaluate to issue the certification.

6.6 CONCLUSION

In the refurbishment process of nearly zero energy buildings, a fitting quality assurance procedure is essential to guarantee a high level of quality of the renovation.

The CasaClima refurbishment guidelines issued in the framework of the Sinfonia project provide a procedure for a global energy refurbishment aimed at exploiting the potential of improvement of the existing buildings, reducing their energy needs and improving indoor comfort.

The experience of the Sinfonia project demonstrated that a protocol for refurbishment must differ from the quality assurance method used for a new construction: it has to be flexible in order to consider the existing constrains and be applicable both in the design and in the implementation phase.

The requirements and the methodology have to be set considering the particular characteristics of refurbishment. For instance, the initial state (building envelope and systems) has to be investigated for each single case, in order to determine the best, most cost-effective solution.

Moreover, a reduction of the complexity of the certification and of bureaucracy (for instance, the required documentation) is necessary to spread out the use of quality assurance procedures among the stakeholders in the building sector (designers, construction companies).

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Annex: DOCUMENT INFORMATION

SINFONIA DELIVERABLE FACT SHEET		
PROJECT START DATE	1 June 2014	
PROJECT DURATION	73 months	
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DOCUMENT		
DELIVERABLE NUMBER:	D4.7	
DELIVERABLE TITLE:	Tailored concepts for energy efficient refurbishing of buildings and smart districts	
DUE DATE OF DELIVERABLE:	30 April 2019	
ACTUAL SUBMISSION DATE:	3 June 2019	
EDITORS:		
AUTHORS:	UIBK - Clemens Le Levé, Thomas Badergruber, Anton Kraler, Michael Flach, Rainer Pfluger, Alexander Thür, IIG - Bernhard Pfeifer PHI - Jürgen Schnieders, Roberto Iannetti, Maria-Chiara Failla ACC – Martina Demattio	
REVIEWERS:	Laszlo Lepp	
PARTICIPATING BENEFICIARIES:	PASSIVE HOUSE INSTITUTE	
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WORK PACKAGE TITLE:	Integrated refurbishment processes coupling building, electricity grids and heat/cold networks	
WORK PACKAGE LEADER:	RISE	
WORK PACKAGE PARTICIPANTS:	RISE, IKB, NHT, UIBK, BOZ, EURAC, IPES, SEL SPA, CASA CLIMA, PHI, ALFA LAVAL CORPORATE, IIG,	
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