REPORT
DELIVERABLE 2.7

D2.7_Description of a whole house renovation system certification concept (Task 2.6)

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CONTACT

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INTRODUCTION

EnerPHit is an international high efficiency standard for building retrofits, based on Passive House principles for renovation components. The EnerPHit standard offers immense benefits. These include significantly increased supply and crisis security and improved residential health and domestic value creation. The low heating load relieves the grid in the sustainable supply structure of the future.

A building that fulfils the EnerPHit criteria as defined by the Passive House Institute can be certified by an accredited Passive House certifiers, and will, after the certification, receive a seal as Certified EnerPHit Retrofit:

EnerPHit seal

Climate zone according to PHPP	Heating	Cooling
	Max. heating demand	Max. cooling + dehumidification demand
	[kWh/(m²a)]	[kWh/(m²a)]
Arctic	35	equal to Passive House requirement
Cold	30	
Cool-temperate	25	
Warm-temperate	20	
Warm	15	
Hot	-	
Very hot	-	

EnerPHit Energy Demand Criteria

For deep renovation projects, it is not always possible to achieve a low energy demand as required by the Passive House Standard. Due to challenges for thermal bridges, airtightness, compactness or solar aperture of the existing building, the building´s energy efficiency cannot be improved to Passive House Standard. Furthermore, the impact of these problems that cannot be solved in a renovation project with reasonable measures, differs with the climatic challenges. The EnerPHit standard has foreseen for this fact by describing climate zone dependent criteria for EnerPHit retrofits. The fulfilment of this criteria can be achieved by fulfilling the energy demand requirements, as shown in the diagram above. The other certification path follows the component method, where minimum component qualities for the building components have to be met.

These minimum component ambitions for EnerPHit retrofits, which follow the component requirement certification method, are derived from the climate-zone dependent criteria for Certified Passive House Components and are described in the table below:

Climate zone according to PHPP	Opaque envelope[1] against...				Windows (including exterior doors)					Ventilation	
	...ground	...ambient air			Overall[4]			Glazing[5]	Solar load[6]		
	Insu-lation	Exterior insulation	Interior in sulation[2]	Exterior paint[3]	Max. heat transfer coefficient ($U_{D/W,installed}$)			Solar heat gain coefficient (g-value)	Max. specific solar load during cooling period	Min. heat reco-very rate[7]	Min. hu-midity re-covery rate[8]
	Max. heat transfer coefficient (U-value)			Cool colours							
	[W/(m²K)]			-	[W/(m²K)]			-	[kWh/m²a]	%	
Arctic	Deter-mined in PHPP from project specific heating and cooling degree days against ground.	0.09	0.25	-	0.45	0.50	0.60	U_g - g*0.7 ≤ 0	100	80%	-
Cold		0.12	0.30	-	0.65	0.70	0.80	U_g - g*1.0 ≤ 0		80%	-
Cool-temperate		0.15	0.35	-	0.85	1.00	1.10	U_g - g*1.6 ≤ 0		75%	-
Warm-temperate		0.30	0.50	-	1.05	1.10	1.20	U_g - g*2.8 ≤ -1		75%	-
Warm		0.50	0.75	-	1.25	1.30	1.40	-		-	-
Hot		0.50	0.75	Yes	1.25	1.30	1.40	-		-	60 % (humid climate)
Very hot		0.25	0.45	Yes	1.05	1.10	1.20	-		-	60 % (humid climate)

EnerPHit component requirements for PHI climate zones @ PHI

CERTIFIED PASSIVE HOUSE COMPONENTS

As a rule, Certified Passive House Components are two to three times more efficient than the corresponding commonly used products. This high level of efficiency is critical to not only achieving the Passive House Standard, but also climate neutrality of the building stock.

However, for building professionals or other stakeholders it is often very difficult to assess the energy-efficiency, durability and the necessary energy parameters of a component, as the available standard parameters are frequently unrealistic or are not accurate enough. Reliable project planning using manufacturers' information alone is thereby often not possible.

As an independent authority, the Passive House Institute tests and certifies products in respect of their suitability for use in Passive House or EnerPHit projects. Products that carry the Certified Passive House Component seal have been tested according to uniform criteria; they are comparable in terms of their specific values, and are of excellent quality regarding energy efficiency. Their use facilitates the designer's task to assure high energy performance and contributes significantly to ensuring the faultless functioning of the resultant Passive House building, EnerPHit renovation, or other nearly Zero Energy Building (nZEB) or Zero Emission Building (ZEB) approaches. All these high performance Buildings require high quality components: highly insulating window frames and insulation levels, highly efficient ventilation units, thermal bridge free connection details, glazing that allows solar gains, compact heat pump units or air-tightness. Certified Passive House suitable products allow users to verify and compare the relevant parameters of the respective products.

For the certification of such building components, practice-oriented, easily verifiable and clearly identifiable criteria has been developed by the Passive House Institute, which must be met by Passive House suitable products. These criteria are based on two categories:

- health and living comfort ("comfort criteria")
- the energy balance in practice ("energy criteria")

It is the objective of the Passive House Institute to base the standard of these requirements on the physically or physiologically verifiable, objectively determinable criteria (e.g. maximum radiation temperature difference of 5 K between the half spaces, derived from ISO7730). Additional efficiency categories have been introduced (e.g. for Passive House windows) where this alone is not sufficient for formulating the criteria. All criteria can be expressed by using measurable quantities and tested by using established methods. The specific values of the respective products which are relevant for the energy balance, as well as those for determining comfort, have been given in the certificate. These can thus be entered directly into the PHPP.

Criteria for Certified Passive House Components is available for 3 main component categories:

- Transparent building envelope
- Opaque building envelope
- Building services

The quality requirements are based of component certification process, which is offered to any manufacturer providing those products. For certified products those key parameters are published, so anybody can apply for the information needed for design, planning, and tendering:

- Quality assurance for planners of high-performance and Passive House buildings
- Presentation in Passive House Institute component database
- Increased market visibility and product recognition
- Independently tested and certified
- Use of Certified Passive House Component seal
- Announcement to Passive House stakeholders in monthly newsletters

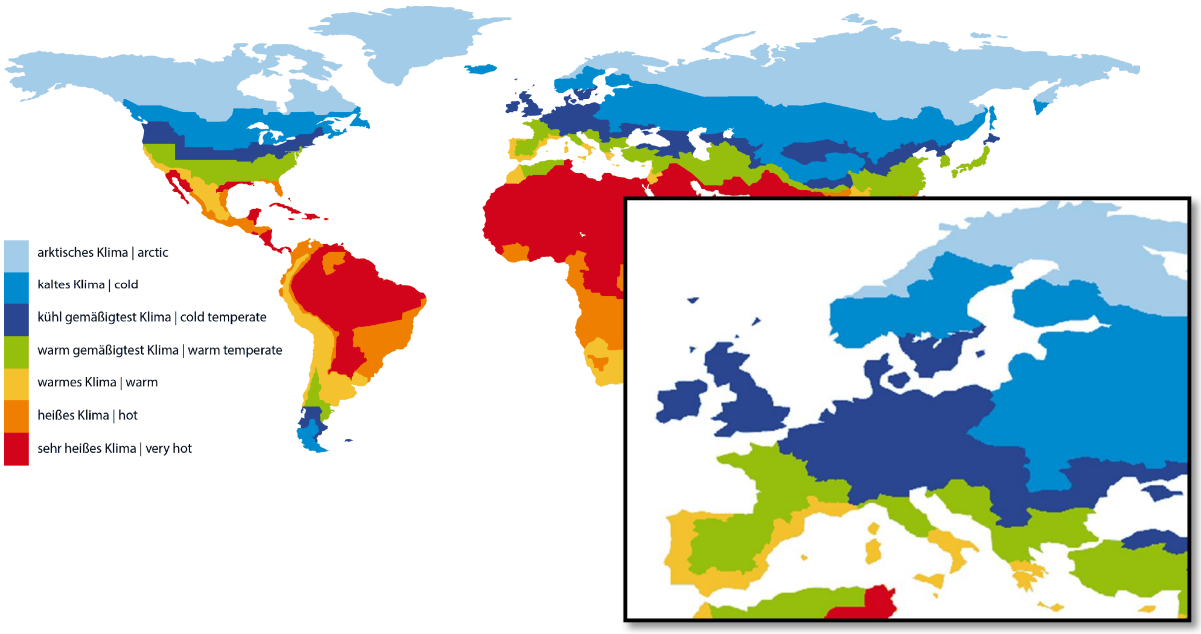
ASSIGNMENT OF CLIMATE ZONES (REGIONS WITH IDENTICAL REQUIREMENTS)

The requirements of the PH or EnerPHit standard for the overall efficiency of the building are essentially defined by the heat losses via the building envelope to the surroundings. Milder climates therefore require less thermal insulation of the building, which is directly reflected in the required U-values of the building envelope components. However, the values mentioned for the various climatic zones usually are significantly more ambitious than the legal minimum standards currently in force in the respective regions. Furthermore, the actual qualities of the existing building stock is usually significantly worse. In this respect, the EnerPHit standard represents a significant improvement in the energy efficiency of buildings worldwide.

Where possible, Certified Passive House Component criteria has been specified for different climate zones, that have been defined by the Passive House Institute. The climate zone is assigned based on the location of the manufacturer's headquarters, or any other facility where the manufacturer conducts its operations. The nearest PHPP climate data set will be used;

further climate data sets can be requested from PHI where this is uncertain, e.g. in regions with wide variations in altitude. The certification criteria and a certificate that is issued based on them are valid for the assigned climate zone and also for climates with lesser requirements, bearing in mind however that more economical solutions may be possible.

These climate zones are as follows:



Assignment of regions with identical component requirements @ PHI

The seven climate zones defined by the Passive House Institute range from arctic to very hot climate. As can be seen, the climate regions relevant for Europe are mainly the cool-temperate and warm-temperate, with some cold regions in Northern Europe and warm regions in the Mediterranean areas. These climate zones are described with the following component certification seals and indicate the suitability for a certain component for this climate region with identical component requirements:

Component seals according to PHI climate zones @ PHI

The criteria for Certified Passive House Components can be found here:

https://passiv.de/en/03_certification/01_certification_components/02_certification_criteria/02_certification_criteria.htm

WHOLE HOUSE RENOVATION SYSTEMS

The outPHit project explores and supports streamlined deep renovation processes, such as prefabricated renovation elements (e.g. insulated wall panels) or one-stop-shop models for conventional retrofits. In such fast renovation approaches, changes to the energy efficiency properties of the components or connection details during on-site construction works are or may not be possible any more. This fact demonstrates the importance to provide reliable renovation systems to the renovation market, with well-designed and quality assured renovation packages that can be applied easily to most of typical renovation projects and will still achieve the projects ambitions to reach highest building efficiency after the renovation.

Through a certification process of such renovation systems, the quality of the system, the overall component performance, but also including critical points such as thermal bridges, airtightness or ventilation heat recovery, can be assured to fulfil the ambitions required for deep renovation projects, such as EnerPHit retrofits. Furthermore, through the examination by the certification process, specific performance values of the renovation systems are determined and made available, by transparently describing U-Values, thermal bridge coefficients or ventilation heat recovery efficiency within the certificate so these values can reliably be used for the energy efficiency planning of the renovation projects. By additionally offering approved descriptions of the airtightness concept and further information about the systems, stakeholders applying such renovation concepts have a better basis to select a renovation system.

ENERGY EFFICIENCY REQUIREMENTS

The goal of this whole hose renovation system requirements would be to enable renovation projects to reliably achieve the EnerPHit standard for renovation projects of typical building typologies, if the system can be applied completely to the existing building. The energy efficiency requirements for whole house renovation systems is thereby derived from the component requirements described for the different component categories, which also match the EnerPHit component requirements. Thereby, buildings renovated with such a whole house renovation system would be able to meet the criteria of EnerPHit retrofits certified by the component method in many cases, if all building elements (walls, roof, floor, windows and ventilation system) have been renovated in component qualities as described by this preliminary criteria.

However it is important to understand, that the average specific component quality, or better, the average U-Values, of windows or opaque components do considerably depend upon the geometry of the building elements. Thereby the average values calculated by PHPP may be slightly better or worse than the U-Values determined for the components for standard geometries in the certification. On the other side, the U-value requirements for the opaque building envelope to the ground may differ from the requirement described by the certification criteria, based on the assessment of the project specific heating or cooling degree days against the ground determined in PHPP, based on the floor slab or basement ceiling geometry of the specific project. In both cases, the renovation project cannot automatically fulfill the EnerPHit certification by following the component method, even if the standard component U-values of the renovation components fulfil the requirements.

COMPLETE BUILDING RENOVATION APPROACH

Whole House Renovation Systems must be able to provide all the renovation elements for the renovation of the complete building envelope and the implementation of an efficient ventilation concept with heat recovery! In addition to these renovation elements, the Whole House Renovation systems consists of several obligatory and optional extension:

1. Certified Deep Renovation Components:
- Roof insulation
- Wall insulation
- Floor slab / basement ceiling insulation
- Window / Door replacement
- Ventilation with heat recovery implementation

These renovation components are required for a whole house renovation system. The component qualities are derived from the Certified Passive House Components criteria for each component category. The component qualities must be provided in form of detail drawings / descriptions / data sheets and will be approved by the certification process

2. Obligatory additional descriptions / information:
- Thermal bridge free connection details
- Dummy building test calculation
- Airtightness concept description
- Embodied energy information for all building envelope components
- User manual and inhabitant introduction

These concepts must be delivered in form of detail drawings / descriptions / data sheets and will be approved by the certification process.

3. Optional system features / options
- Step-by-Step retrofit connection concept
- RES implementation (PV or Solar thermal)
- Maintenance services
- Efficiency design (PHPP calculation) or funding application services
- Quality assurance services

It is optional to offer these concepts / services as part of the whole house renovation system package. The concepts must be delivered in form of detail drawings / descriptions / data sheets / certificates and will be approved by the certification process.

WHOLE HOUSE RENOVATION SYSTEM PACKAGE

The whole house renovation system package consists of these obligatory and optional elements:

Certified Deep Renovation Components


Roof


Wall

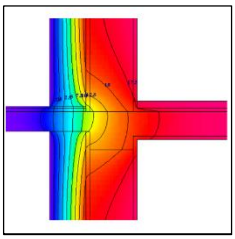

Floor


Windows


Ventilation

+

Obligatory additional descriptions / information


Thermal Bridges


Dummy project


Airtightness


Embodied Energy

User Manual

+

Optional system features / options


SBS concepts


RES systems


Maintenance


Efficiency design


QA services

=

Whole House Renovation System

BOUNDARY ASSUMPTIONS

1. Existing building Quality Assumptions

The component quality of the existing building may also be relevant for the quality of the renovation components. Thereby a typical solid construction is chosen:

- 24cm brick wall with plaster on both sides, U-Value = 1,40 W/(m²K)
- 15cm concrete basement ceiling, U-Value = 1,00 W/(m²K)
- 15cm concrete ceilings
- 15cm concrete flat roof ceiling, insulated 8cm, U-Value = 0,45 W/(m²K)
- 16cm wooden rafters pitched roof, insulated 8cm, U-Value = 0,40 W/(m²K)

Any renovation components and connection details have to be tested under the assumption of these existing construction elements

2. U-value calculation of windows and window installation

U-values for windows are determined for vertical windows with a test size of 1,23*1,48 m. In addition to DIN EN ISO 10077-1, the thermal bridges for the window installation have to be considered in the U-value calculation of the installed window $U_{w,inst}$, as defined in the Passive House component Certification criteria for transparent components.

3. Ventilation system air flow rates and efficiency of ventilation distribution

The implementation of a ventilation system with sufficient heat recovery efficiency is an energy performance requirement for the whole house renovation system. However, ventilation concepts greatly differ in distribution concepts or air flow rates. To foresee for the average minimum and maximum use cases in either small or very big residential units, the ventilation units used within the whole house renovation system should thereby cover typical ranges of air flow rates:

- Small residential unit / 50 -150 m² / 60 – 120 m³/h
- Big residential units / 150 - 250 m² / 120 – 240 m³/h

Furthermore, ventilation systems may be installed inside or outside the thermal envelope. The specific heat loss coefficients of the insulated ventilation ducts, either ODA and EHA ducts within the thermal envelope, or SUP and ETA ducts outside the building envelope, have to be declared and approved by the certification.

4. Ventilation system options

For the implementation of the ventilation system, various options may be possible. To be able to select the most adequate solutions, the ventilation concept will be categorised into these options:

- Centralised ventilation concept
- De-centralised ventilation concept
- Conventional ventilation distribution concept
- Façade integrated ventilation distribution concept

Component requirements of whole house renovation systems

1. Arctic climate

- U-value opaque exterior building component	≤ 0,09 W/(m²K)
- U-value opaque building component to the ground:	≤ 0,15 W/(m²K)
- Absence of thermal bridges:	≤ 0,01 W/(mK)
- Hygiene criterion:	$f_{Rsi\ @\ 0,25\ m^2K/W}$ ≤ 0,80
- U-value of the installed window	≤ 0,45 W/(m²K)
- Solar heat gain coefficient (g-value):	U_g-g*0,7 ≤ 0
- Heat recovery efficiency of the ventilation system:	≥ 80 %

2. Cold climate

- U-value opaque exterior building component	≤ 0,12 W/(m²K)
- U-value opaque building component to the ground:	≤ 0,20 W/(m²K)
- Absence of thermal bridges:	≤ 0,01 W/(mK)
- Hygiene criterion:	$f_{Rsi\ @\ 0,25\ m^2K/W}$ ≤ 0,75
- U-value of the installed window	≤ 0,65 W/(m²K)
- Solar heat gain coefficient (g-value):	U_g-g*1,0 ≤ 0
- Heat recovery efficiency of the ventilation system:	≥ 80 %

3. Cool temperate climate

- U-value opaque exterior building component	≤ 0,15 W/(m²K)
- U-value opaque building component to the ground:	≤ 0,25 W/(m²K)
- Absence of thermal bridges:	≤ 0,01 W/(mK)
- Hygiene criterion:	$f_{Rsi\ @\ 0,25\ m^2K/W}$ ≤ 0,70
- U-value of the installed window	≤ 0,85 W/(m²K)
- Solar heat gain coefficient (g-value):	U_g-g*1,6 ≤ 0
- Heat recovery efficiency of the ventilation system:	≥ 75 %

4. Warm temperate climate

- U-value opaque exterior building component	≤ 0,30 W/(m²K)
- U-value opaque building component to the ground:	≤ 0,50 W/(m²K)
- Absence of thermal bridges:	≤ 0,01 W/(mK)
- Hygiene criterion:	$f_{Rsi\ @\ 0,25\ m^2K/W}$ ≤ 0,65
- U-value of the installed window	≤ 1,05 W/(m²K)
- Solar heat gain coefficient (g-value):	U_g-g*2,8 ≤ 0
- Heat recovery efficiency of the ventilation system:	≥ 75 %

5. Warm Climate

- U-value opaque exterior building component	≤ 0,50 W/(m²K)
- U-value opaque building component to the ground:	≤ 0,83 W/(m²K)
- Absence of thermal bridges:	≤ 0,01 W/(mK)
- Hygiene criterion:	$f_{Rsi\ @\ 0,25\ m^2K/W}$ ≤ 0,55
- U-value of the installed window	≤ 1,25 W/(m²K)
- Solar heat gain coefficient (g-value):	-
- Heat recovery efficiency of the ventilation system:	-

OBLIGATORY ADDITIONAL DESCRIPTIONS / INFORMATION:

1. Thermal bridge free connection details

One of the more crucial aspects of this whole house renovation system certification is the thermal bridge free design of the renovation systems. As required for any climate region, the thermal bridge coefficients of all connection details have to be thermal bridge free, with Psi ≤ 0,01 W/(mK). However, for complicated connection details exemptions have to be made, as long as the connections still fulfil the hygienic requirements of the EnerPHit certification, to avoid mould or condensation risk. Usually, this occurs to inner wall edges which result in a Psi-Value that is not thermal bridge free. Thereby geometric thermal bridges, where the insulation thickness around the junction is consistent, but the calculation methodology results in a Psi-value of > 0.010 W/(mK), are exempt from this criterion.

Furthermore, in renovation projects, where penetrations of the thermal envelope cannot be avoided in case of balcony slabs or perimeter connections between insulated basement ceiling and external wall insulation, the thermal bridges can also exceed the Psi-value- requirement of > 0.010 W/(mK), as long as the hygiene criterion is fulfilled. In the particular case of prefabricated façade or roof modules it may occur, that the timber frame elements to stabilise the prefab panels become too dominant and result thermal bridges in special connections, that also exceed a Psi-value of > 0.010 W/(mK). For such cases, exemptions can also be made by the certifier, as long as the connection details with their specific thermal bridge coefficients are declared in the certification document.

The overall performance of the system will then be tested with the dummy building test, in order to ensure, that system specific impact of thermal bridges can be considered.

2. Dummy Reference building Test

The energy efficiency performance of all components of the building envelope will thereby be tested against a reference dummy building approach. This building will be of a typical end-of-terrace house building typology, 2 storey buildings strictly south orientated, and have the following specifications for the building envelope geometry:

- two roof variants: pitched roof with 30 degrees inclination and flat roof
- unheated basement with external access stairs
- the north and south façade both have 1 wall recess each, depth 1m
- the south façade has a balcony over the recessed part of the façade
- windows with moderate dimensions, smaller than 1,23m*1,48m, except for balcony and terrace doors and entrance door

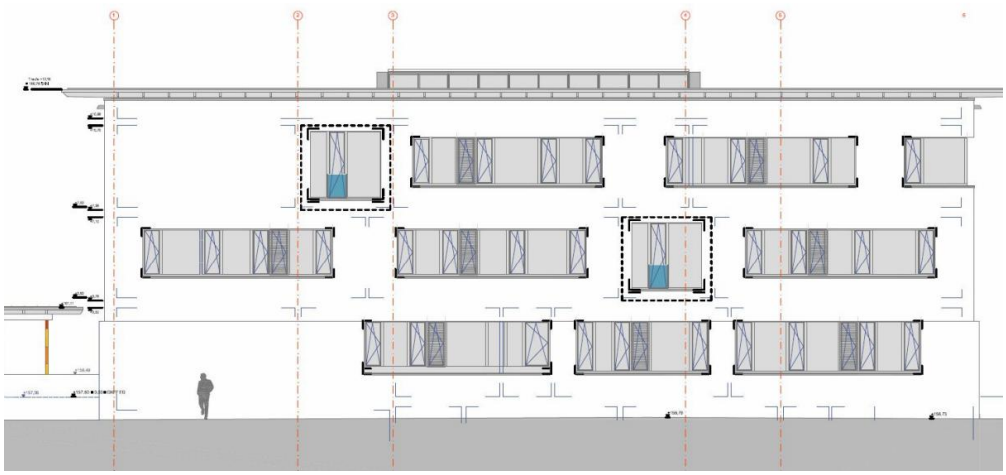
A building with such specifications offers various challenges to a renovation system:

- roof connection details for either pitched roof eaves or flat roof with parapet
- connection between insulated basement ceiling to external wall insulation
- 2 recesses mean 2 inner wall corners which will not be thermal bridge free
- Smaller dimensions of wall areas mean a increased share of timber frame elements in timber construction concepts like prefab or semi-prefab systems, which is a challenge for the thermal bridge free connection requirement

- The balcony slab penetrates the new thermal envelope; a connection detail that cannot be solved thermal bridge free
- Due to the smaller windows, the average U-value of the windows is higher than the U-value of the standard window

The certification for a whole house renovation system will only be awarded if the average U-values of all building envelope elements fulfils the component criteria described below:

- the opaque exterior building elements walls and roofs
- the basement ceiling and
- the windows and French windows



Example façade anchor certification with a reference facade @ PHI

3. Airtightness concept between elements and connections to existing building

A professional quality standard of airtightness must be ensured for the renovation to achieve the airtightness requirement of the EnerPHit renovation standard: The airtightness of the renovated building must not exceed a pressure test result of n50 = 1,0 1/h. This should be verified by detail representation, text descriptions of the creation of the airtight layer, the materials used for this and a general description of the overall system. The graphical representation should be such that the layers and connections of the membranes and sealing materials to the walls and windows frames are recognisable. All connection details must be planned and executed in a permanently airtight manner. The airtight layers must be clearly identified in the submitted documents (e.g. outlined in red ink).

If the ventilation distribution is planned façade integrated within the whole house renovation concept, the thermal bridge coefficients of these ducts have to be determined and approved by the certification. Condensation risk on ventilation ducts foreseen in façade integrated boxes must be avoided.

4. Embodied Energy information

In addition to the energy efficiency performance specifics of the renovation elements like roof, wall or windows, these renovation components have been produced through the investment of manufacturing energy. In order to enable building professionals to assess the impact of the embodied energy within the materials of the whole house renovation system and compare it to the energy savings expected by the renovation measures.

Thereby, the manufacturing energy of any building envelope component of the whole house renovation system must be declared in kWh/m². This declaration is informative only, but supports stakeholders to quicker understand the quality of the renovation systems in terms of embodied energy. By using the embodied energy evaluation tool developed within the outPHit project, building professionals can even assess the amount of energy used for the production of the renovation of the specific project and compare it to the amount of energy saved by the retrofit.

5. User manual and inhabitant introduction

Obligatory part of the whole house renovation project will be a short user introduction into the energy efficiency specifics of the renovated building, and an explanation of the features and maintenance requirements of the mechanical equipment like ventilation units or heat pumps.

Furthermore, a user manual for the renovated building has to be provided that enables the inhabitants to operate the highly efficient building adequately. A template for such a user manual must be approved by the certification process.

OPTIONAL SYSTEM FEATURES / OPTIONS:

Deep renovation projects applying such whole house renovation systems can reach the EnerPHit standard or at least come quite close to it and thereby consume very little energy for heating or cooling. This will enable the renovated buildings to considerably contribute to the transformation of a climate neutral building stock.

However, further features of whole house renovation systems may be interesting to the potential clients, beyond the mere energy efficiency performance specifics of the building envelope and the ventilation concept. The certification process for whole house renovation projects thereby should be able to inform about such options additionally:

1. Step-by-Step retrofit connection concept ☒

In many renovation projects, recent retrofit activities have already replaced an old component with a new one, for example windows in moderate quality only, so that these components will have to be replaced in the future. Also budget considerations may lead to renovation activities that do not lead to a one-shot-retrofit of all building components, but to a step-by-step renovation, either component by component, or building section by building section.

The whole house renovation systems, that offer step-by-step connection concepts, can be labelled as step-by-step renovation systems. The connection details describing the intermediate connection details will then also be checked and calculated, the thermal bridge coefficients of the intermediate connections will be added to the documentation.

2. RES Implementation ☒

The whole house renovation system renovation include the installation of renewable energies as BIPV or solar thermal systems. In this case, the additional heat losses caused by the support structure for the PV or solar thermal panels on either roofs or facades have to be determined during the certification.

The additional heat losses potentially caused by the sub-structure of RES implementation have to be declared as U-value supplement in W/(m²K) to the regular U-values of the roof or wall components of the renovation system.

3. Maintenance services ☒

If the provider of the whole house renovation system offers maintenance options for the technical equipment implemented by the renovation, for example ventilation units, compact ventilation units or heat pumps, this can be declared and presented as optional service by the provider.

Maintenance options can also be offered for transparent building envelope components like windows or doors, which may need to be adjusted every few years to guarantee reliable airtightness qualities.

4. Efficiency design and funding application ☒

The provider of the whole house renovation system can also offer the energy efficiency calculation for the renovation project with the Passive House Planning Package. The Passive House Planning Package (PHPP) is an affordable energy balance tool ideal for high performance building standards with extremely accurate result and the verification tool for Passive House projects and EnerPHit retrofits.

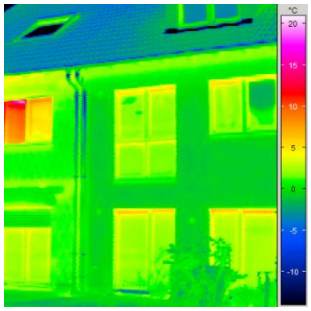
When offering the whole house renovation, the provider can include the energy efficiency design of the project with PHPP as optional service, if a Certified Passive House Designer works in the company who is qualified to carry out such PHPP calculations.

Furthermore, In case of funding applications, a qualified or accredited energy expert may be required to submit the funding application documents Application for funding. The provider of the whole house renovation system can offer accredited funding expert

5. Quality assurance services ☒

The provider may also offer quality assurance services for the renovation projects. These services will also be listed as optional services to the whole house renovation system:

- blower door tests – to be executed by an external expert
- leakage search – to be executed by an external expert
- thermal imaging
- ventilation adjustment



To be accepted for the EnerPHit certification, quality assurance services like blower-door-tests and leakage search can only be conducted by external experts.

REFERENCES:

Criteria for opaque Certified Passive House Components:
https://passiv.de/downloads/03_certification_criteria_construction_systems_en.pdf

Criteria for transparent Certified Passive House Components:
https://passiv.de/downloads/03_certification_criteria_transparent_components_en.pdf

Criteria for Certified Passive House Ventilation systems:
https://passiv.de/downloads/03_Reqs_and_testing_procedures_ventilation_en.pdf

Building certification criteria:
https://passiv.de/downloads/03_building_criteria_en.pdf

PICTURES / GRAFIC MATERIALS:

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