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PLUG-AND-USE RENOVATION WITH ADAPTABLE LIGHTWEIGHT SYSTEMS

D8.1 Product requirement Report

Version: 1.0

	Name	Date
Prepared by	ITeC (Jose Lucas and Diana Romeu), with input from NTUA, SPF, BGTeC	28/04/2023
Reviewed by WP leader	Diana Romeu (ITeC)	30/05/2023
Reviewed and edited by	Project coordinator (M. Founti)	31/05/2023
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Terms, definitions and abbreviated terms

GA	Grant agreement
eWHC	External Wall Heating and Cooling unit
eAHC	External Air Heating and Cooling unit

1. Executive summary (ITeC)

The deliverable *D8.1 Product requirement,* due in month 32 (end May 2023), presents the results of the Task T8.1 Environmental, Cost and Social Assessment of PnU kits. This deliverable is public.

After the completion of the testing and optimisation of the PnU kit prototypes in WP4 and the final design of the PnU kits for the real demonstration buildings by incorporating the suggestions, recommendations and optimisation results of WP4 and using the drawings, calculations (PA, ZRS, AMS) and performance simulations and testing (SPF, NTUA, IREC) that validate the final design for each demo building done in WP2, in this task we review the characteristics of each kit in order to comply with the regulations of each country.

The main objective of the subtask T8.1.2 “Product requirements” is to identify the technical, regulatory, market and marketing requirements for the specification of the benchmark methodologies for product validation. For this purpose, an analysis of the final configurations of each kit has been done and the validation of the compliance for each country has been reviewed.

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2. Introduction

2.1 Project Description

The deliverable *D8.1 Product requirement of PnU kits*, due in M32, presents the results of part of the task T8.1 "Environmental, Cost and Social impact Assessment of PnU kits". This task started in M19 and is due to finish in M42. There are two deliverables resulting from this task; the first one is the current document that has to be submitted in M32 of the project.

After the completion of the testing and optimisation of the PnU kit prototypes in WP4 and the final design of the PnU kits for the real demonstration buildings by incorporating the suggestions, recommendations and optimisation results of WP4 and using the drawings, calculations (PA, ZRS, AMS) and performance simulations and testing (SPF, NTUA, IREC) that validate the final design for each demo building done in WP2, in this task we review the characteristics of each kit in order to comply with the regulations of each country.

The task is led by ITeC. The following partners are involved: ZRS, NTUA and IREC. This deliverable is public.

2.2 Relation with other WPs

Inputs: This deliverable is based on deliverable *Final stage complete design of PnU kits (M25),* and the results of tasks mainly from WP2 that advanced since the mentioned deliverable D2.7:*, Task 2.2 Façade panel technologies selection (M9-M15), Task 2.3 Ventilation system selection (M10-M22), Task 2.4 Heating and cooling technology selection (M10-M22) and Task 2.5 Energy systems integration (harvesting & storage) – PLURAL toolbox (M10-M22)* that define the materials and technologies to be integrated in the PnU kits. Also, there are inputs from the WP4: *D4.5 PnU Testing, where the characteristics of each kit has been tested, WP1 where the first approximation of the compliance with the regulations of each country was done, especially in D1.1 Requirements: Context of application, building classification, used consideration – Definition of requirements and constraints and D1.2 Technical and market codes, national and European certification frameworks*.

Outputs: The outcome of this deliverable is an important input for: a) T7.7 Technical viability assessment of PLURAL solutions M35-M48, b) T8.4 Business Case analysis and assessment M25-M42.

This deliverable is not related to any milestone.

2.3 Objectives

Task T8.1 "Environmental, Cost and Social impact Assessment of PnU kits", has two different objectives and for this reason the task has been divided in two subtasks:

- Subtask 8.1.1 that relates to the Life Cycle Assessment, Life Cycle Cost, and Social Assessment of all the PnU kits.
- Subtask 8.1.2 that deals with the product requirements of each PnU kit.

The main objective of the subtask T8.1.2 “Product requirement” is to identify the technical, regulatory, market and marketing requirements for the specification of the benchmark methodologies for product validation. For this purpose, an analysis of the final configurations of each kit has been done and the validation of the compliance with the requirements of each country has been reviewed. The four characteristics for the compliance that had been analysed are:

- Thermal compliance
- Hygrothermal compliance
- Fire compliance
- Acoustic compliance

For each kit, all the configurations have been analysed to ensure that all the final products comply with the specific regulations of each target country. In some of the characteristics not only the design of each kit is necessary to verify the compliance, but also the configuration of the building that has to be renovated with these kits. Therefore, the analysis of the existing building has been another of the objectives of this deliverable.

2.4 Document structure

The first chapter of this document defines the main administrative characteristics of this deliverable, establishes the status of the real demo cases, with the main characteristics and the configuration of each building, and defines the final design of each PnU kit.

Following the introductory chapter in section 2, D8.1 is dived into 4 main parts, each dedicated to one of the four characteristics that have been analysed. In each section of Chapter 3, the analysis for each PnU kits is developed in different subsections.

The four characteristics that had been reviewed, the analyses and compliance for each kit, each configuration of each kit and each country are described in the following subsections:

- Subsection 3.1: Thermal compliance
- Subsection 3.2: Hygrothermal compliance
- Subsection 3.3: Fire compliance
- Subsection 3.4: Acoustic compliance

Each of these subsections is then further sub-divided into 3 main parts. The first part (X.X.1) is dedicated to the compliance of the SmartWall with the Greek regulations.

The second part (X.X.2) is dedicated to the compliance of the DENVELOPSComfort with the Spanish regulations. The third section (X.X.3) is dedicated to the compliance of the ConExWall with the Czech Republic regulations.

The main conclusions are described in chapter 4.

2.5 Real demonstration cases

The three demonstration buildings of the PLURAL project are a) a double residential house located in a natural environment in Kasava, Czech Republic, b) a multifamily residential block forming part of a dense urban structure in Terrassa-Barcelona, Spain and c) a shelter for homeless or low waged families, self-standing and located in Voula municipality, Athens, Greece. The demo buildings' basic characteristics and the approach for implementation are summarized in the table below (Table 1).

TABLE 1 SUMMARY OF CHARACTERISTICS OF THE PLURAL THREE REAL DEMO CASES

Real demo cases	Czech demo (CZ)	Spanish demo (ES)	Greek demo (GR)
Location	Kašava, Prague	Terrassa, Barcelona	Voula, Athens
Year of construction	1962	2008	1971
Climate	Continental Warm-humid	Mediterranean–mild summer	Mediterranean–hot summer
Typology	Multiple- double dwelling house	Block of residential dwellings	Block of residential dwellings
Urban setting	Self-standing in natural environment	Within an urban block	Self-standing in urban environment
PLURAL solutions	ConExWall with eWHC concept. • Gas boiler heat source replaced by Heat Pump • Facade panels with air handling and heating/ cooling system /installation • Windows • New control system, monitoring • Integration of BIPV system and/or solar thermal for DHW	Denvelops Comfort with eAHC units. The Al frame eAHC kit will integrate: • Insulation • PV panels • Ventilation units • Innovative windows • Folding blinds	"SmartWalls" including: • Innovative windows, • Fan coil, • PV panels, • Solar panels, • Heat pumps, • Control Toolbox, • Multifunctional coatings.
Other renovation	No (other building only, could be used for comparison)	Yes, renovation before the PLURAL renovation in 2021, to the 2006 standard	Yes, renovation before the PLURAL renovation, started in 2020
Approach	Renovate and update to the contemporary needs, adapt volume given the unfavourable conditions of the current structure and the potential of the system. Renovate ground floor and first floor and their complete thermal envelope.	Follow up on the previous innovation. Improve the building by intervening partially, with the aim to affect positively the whole building. Reach nZEB standard in the apartments which are affected by the PLURAL renovation only.	Refurbish and upgrade each apartment with recyclable and eco-friendly materials. Upgrade all energy systems in order to reduce energy consumption.

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Czech demo site (Kašava) characteristics:

FIGURE 2.5-1 CZECH DEMO SITE

The construction system of the building is the longitudinal walls. The walls are from burnt bricks. The roof structure is hipped with two dormers. The supporting structure of the roof is a purlin system with wooden elements - rafters. The sheet metal is used as roofing. The main construction data of the building can be summarized as following:

- Façade 01: The load-bearing walls: bricks full of burnt 500 mm incl. plaster (i.e., 450 mm solid fired brick).
- Façade 02: The side walls of the dormer: bricks 350 mm (i.e., 300 mm solid fired brick).
- The internal partitions: brick 180 mm (i.e., 150 mm solid fired brick).
- The horizontal load-bearing structure: ceramic cavity panels (Hurdis) with the slag embankment and subsequent concrete as a spreading layer.
    - Ceiling between the stories: 390-400 mm.
    - Ceiling to the attic: 300 mm insulated by 60 mm thick mineral wool.
    - Ceiling of the cellars: 390-400 mm insulated by the 50 mm polystyrene.
- Openings:
    - Windows: plastic windows with insulating double glazing (2013).
    - Exterior door: solid plastic.
- Roof: sheet metal.
- Floor finishing: ceramic tiles or wooden parquet.
- Internal finishing: plasters.
- External finishing: cementitious plasters.
- Wall's insulation: none.

The configuration of the existing exterior wall (layers from inside to outside) is described in more detail below. Taking into consideration the U-values and energy simulations performed in deliverable D7.1, two main outer walls are considered in the existing building with different layer configuration.

TABLE 2 CZECH REPUBLIC FAÇADE 01 LAYERS

Façade 01				
Layers of construction composition	**D [m]**	**Lambda [W/(m.K)**	**c [J/(kg.K)]**	**ρ [kg/m³]**
Lime plaster	0.025	0.87	840	1600
Burnt bricks	0.450	0.80	900	1700
Lime-cement plaster	0.025	0.99	790	2000
				U-value = 1.321 W/(m².K)

TABLE 3 CZECH REPUBLIC FAÇADE 02 LAYERS

Façade 02				
Layers of construction composition	**D [m]**	**Lambda [W/(m.K)**	**c [J/(kg.K)]**	**ρ [kg/m³]**
Lime plaster	0.025	0.87	840	1600
Burnt bricks	0.300	0.80	900	1700
Lime-cement plaster	0.025	0.99	790	2000
				U-value = 1.719 W/(m².K)

Spanish demo site (Terrassa) characteristics:

FIGURE 2.5-2 SPANISH DEMO SITE

The current situation of the construction systems in the PLURAL block (Block A), referring to the initial project of 2006 and before the AHC and PLURAL refurbishments. The main construction data can be summarized as following:

Structure:

- Foundations: reinforced concrete pad foundation with strap beam.
- Underground levels: reinforced concrete screen walls.
- Vertical structure: reinforced concrete pillars.
- Floors: reinforced concrete waffle slab.
- Roof: reinforced concrete sloped slab.
- Balconies: 1st & 2nd floor, in reinforced concrete.

Envelope:

- Roof: Sloped roof covered with ceramic tiles and insulation covering a concrete waffle slab.
- Terraces: 6 individual roof-terraces between east and west façade, on the 3rd floor. Solved as a flat roof with ceramic floor (inverted solution with a waterproof layer protected by the insulation).
- External walls (East and west facades): 2 layers masonry façade with non-ventilated air-chamber but insulated (inside; perforated brick, outside; hollow brick).
- External finishing: In Ground floor of eats façade stone cladding. The rest is plaster and acrylic paint.
- Balconies: 4 individual balconies in west façade (courtyard façade). Just in 1st & 2nd floors.
- Openings: Aluminium frame balconies and windows in both facades, with double glass (4/6/4) and manual roller shutters on the top part. Timber frame skylights on the roof. In addition, metallic main door entrance to the building.

Inside de Building:

- Internal walls: masonry perforated brick.
- Internal finishing: plasters; usual acrylic coating.

The configuration of the existing exterior wall (layers from inside to outside) is described in more detail below.

TABLE 4 SPANISH FAÇADE LAYERS

Façade				
Layers of construction composition	**D [m]**	**Lambda [W/(m.K)**	**c [J/(kg.K)]**	**ρ [kg/m³]**
Gypsum render	0.015	0.30	1000	750
Hollow brick	0.080	0.50	1000	1020
Enclosed air	0.055	0.26	1010	1
EPS Insulation	0.050	0.0375	1200	30
Perforated brick	0.150	0.991	1000	2170
Cement render	0.020	0.55	1000	1125
				U-value = 0.473 W/(m².K)

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Greek demo site (Voula) characteristics:


FIGURE 2.5-3 GREEK DEMO SITE

The building was constructed in 1971 in two stages; initially the basement, the ground floor and the first floor (Initial Building Permit) and in a second stage was added second floor (Supplementary Building Permit). The main construction data of the building can be summarized as following:

- Foundations: reinforced concrete.
- Structural frame for all floors.
- Floors: reinforced concrete.
- Balconies: continuous 3-side balconies to ground floor, 1st & 2nd floors.
- External walls: masonry (brick).
- External finishing: cement rendering / cementitious plaster; usual exterior acrylic paint.
- Internal walls: masonry brick.
- Internal finishing: cementitious plasters; usual acrylic coating.
- Openings:
    - Aluminium windows and doors at the basement and ground floor and in the two bathrooms of the 1st floor (replaced and renovated at 2020).
    - wood windows and doors at the 1st & 2nd floor.
- Exterior doors: Wood.
- Roof: reinforced concrete.
- Wall's insulation: none.
- Slab's insulation: none.
- Roof insulation: covered with geotextile painted with epoxy zinc paint (water penetration protection only).

The configuration of the existing exterior wall (layers from inside to outside) is described in more detail below.

TABLE 5 GREEK FAÇADE LAYERS

Façade				
Layers of construction composition	**D [m]**	**Lambda [W/(m.K)**	**c [J/(kg.K)]**	**ρ [kg/m^3]**
Rendering/plastering	0.020	0.57	1000	1150
Brick	0.090	0.56	1000	930
Enclosed air	0.050	0.29	1010	1
Brick	0.090	0.56	1000	930
Rendering/plastering	0.020	0.87	840	1600
				U-value = 2.440 W/(m^2.K)

2.6 SmartWall properties

In this section the SmartWall (used in Vari-Voula-Vouliagmeni, VVV version) characteristics are listed for the following thermal, hydrothermal, fire and acoustic compliance. The "Berlin" version of the SmartWall (wooden frame with bio-based materials) has not been evaluated because it is being used in a "virtual demonstration" and compliance with regulations is not necessary.

TABLE 6 SMARTWALL CHARACTERISTICS

Characteristic	
Dimensions	1200 mm (length) 2500 mm (height)
Installation	Internal side of an existing wall
Frame	Structural steel (hollow rectangular section, HRS) with section 50x30mm and 1.8mm thick
Space between frames	160mm (insulated)
Insulation	Mineral wool
Layers	• Gypsum board: 12.5mm. • Structural steel frame. • Mineral wool (frame gaps): 160mm. • Mineral wool with aluminium foil: 30mm. • Vacuum insulation panel (VIP): 20mm (only if fan-coil exists in the solution).

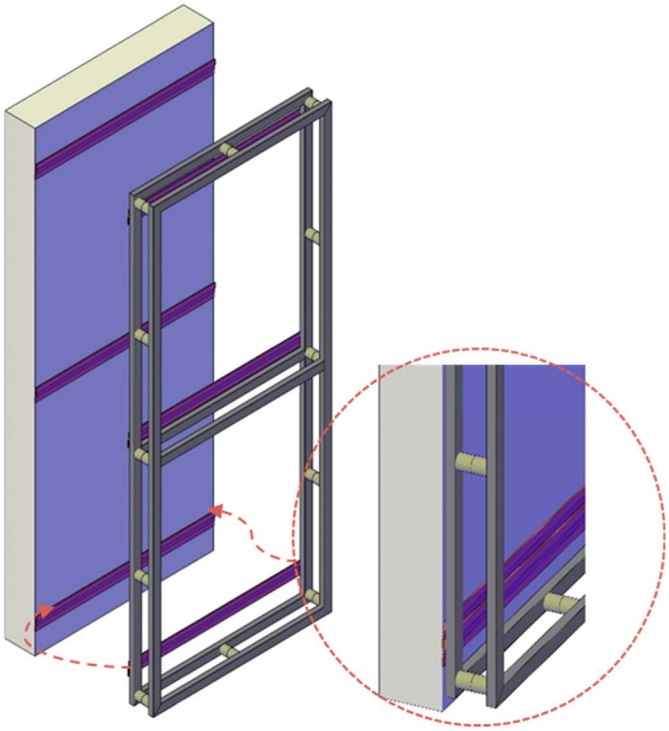
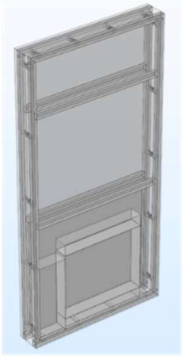
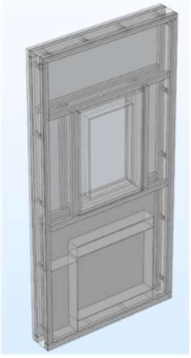


FIGURE 2.6-1 SMARTWALL LAYERS

SmartWall configurations and U-values are extracted from the deliverable "D4.5 - PnU kit prototype property and performance characterisation". These characteristics will be used, together with the existing external wall, for the compliance checking with the different regulations (thermal, hygrothermal, fire and noise).

TABLE 7 SMARTWALL TYPES

Type	Simulated geometries	Contents	U values
A		The module does not contain a fan-coil or window (Blank Type)	**$U_{eq,SW}$** 0.23 W/(m2K) **$U_{eq,opWall}$** 0.23 W/(m2K)

B		The module contains a window, but it does not contain any fan-coil	**$U_{eq,SW}$** 0.46 W/(m2K) **$U_{eq,opWall}$** 0.28 W/(m2K)
C		The module contains a fan-coil but it does not contain any window	**$U_{eq,SW}$** 0.25 W/(m2K) **$U_{eq,opWall}$** 0.25 W/(m2K)
D		The module contains both a fan-coil and a window	**$U_{eq,SW}$** 0.48 W/(m2K) **$U_{eq,opWall}$** 0.31 W/(m2K)

2.7 DENVELOPS Comfort/eAHC properties

In this section the DENVELOPS Comfort/eAHC (used in Terrassa) characteristics are listed for the thermal, hydrothermal, fire and acoustic compliance.

TABLE 8 DENVELOPS COMFORT CHARACTERISTICS

Characteristic	
Dimensions	2000 mm (length) 2700 mm (height)
Installation	External side of an existing wall
Frame	Steel frame
Air Handling Unit (AHU) dimensions	600 mm (length) 1500 mm (height)
Insulation	Mineral fibers
Layers	• Mineral fibres insulation (anchored to external wall): 140mm. • Ventilated steel frame. • Air Handling Unit (AHU): (only if unit exists in the solution). • DENVELOPS tile.

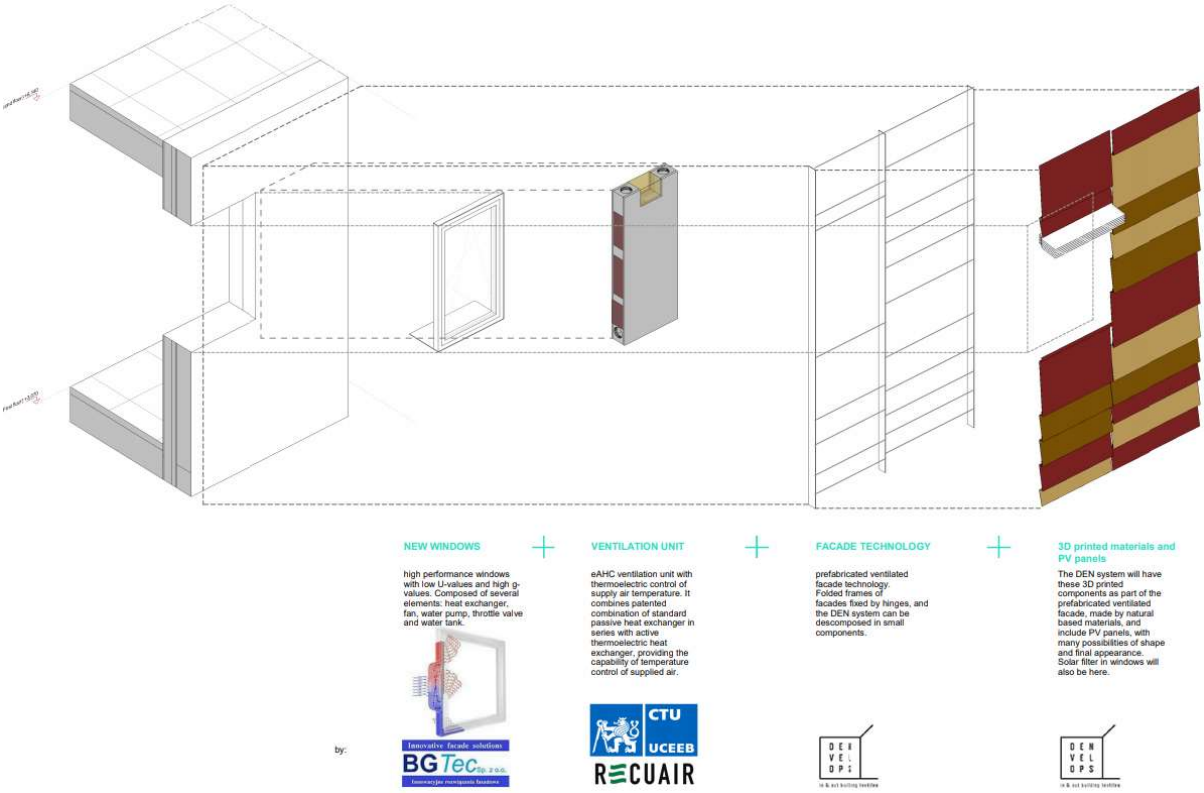
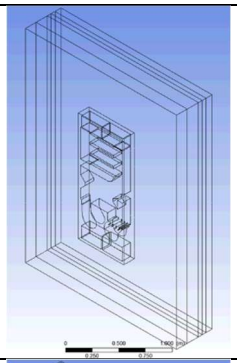
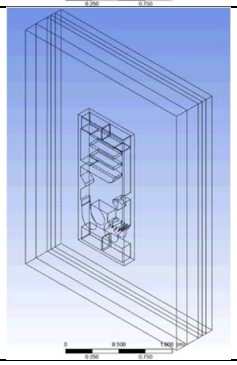


FIGURE 2.7-1 DENVELOPS COMFORT LAYERS

DENVELOPS Comfort configurations and U-values are extracted from deliverable "D4.5 - PnU kit prototype property and performance characterisation". These characteristics will be used, together with the existing external wall, for the compliance checking with the different regulations (thermal, hygrothermal, fire and noise).

TABLE 9 DENVELOPS COMFORT TYPES

Type	Simulated geometries	Contents	U values
A		The module contains anchoring system, but it does not contain an AHU (Blank Type)	**U-value** 0.195

B		The module contains an Air-Handling Unit (AHU) (off), as well as anchoring system	**U-value** 0.231
C		The module contains an AHU (in operation), as well as anchoring system	**U-value** 0.188

2.8 ConExWall/eWHC properties

In this section ConExWall/eWHC (used in Kasava) characteristics are listed for the following thermal, hydrothermal, fire and acoustic compliance.

TABLE 10 CONEXWALL CHARACTERISTICS

Characteristic	
Dimensions	7035 mm (length) 3400 mm (height)
Installation	External side of an existing wall
Frame	Timber frame with vertical studs with section 120x60mm
Space between frames	650-750mm (insulated)
Insulation	Glass wool and wood insulation

Layers	• Wood fibre board with embodied heating pipes: 20mm. • Glass wool insulation (ISOVER Akustik TP1): 60mm. • OSB board: 15mm. • Timber frame and studs. • Glass wool insulation (gaps): 120mm. • Hard wood insulation (anchored to frame): 50mm. • Ventilated timber frame: 40mm. • Wooden cladding (profiholz): 20mm.

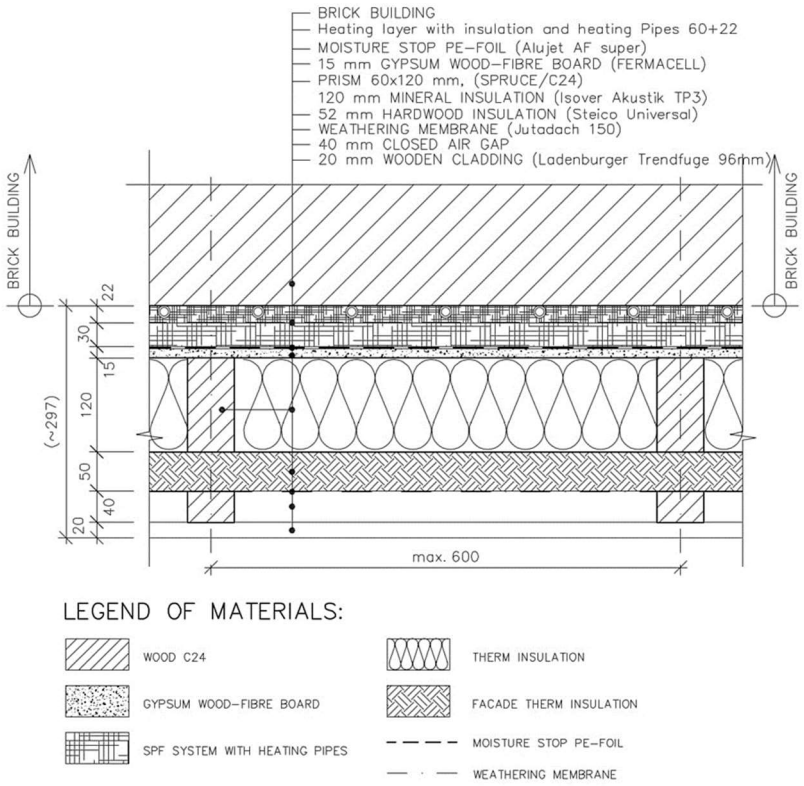
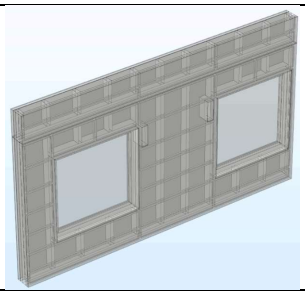


FIGURE 2.8-1 CONEXWALL LAYERS

ConExWall configurations and U-values are extracted from the deliverable "D4.5 - PnU kit prototype property and performance characterisation". These characteristics will be used, together with the existing external wall, for the compliance checking with the different regulations (thermal, hygrothermal, fire and noise). Only those configurations used in Kasava's demo building will be taken into consideration.

TABLE 11 CONEXWALL TYPES

Type	Simulated geometries	Contents	U values
A		Area away from windows, ventilation units and anchoring system	$U_{eq,opeWHC,noVent}$ 0.17
B		The module excluding windows	$U_{eq,opeWHC}$ 0.27
C		The module including windows	$U_{eq,eWHC}$ 0.40

3. Market requirements

3.1 Building physics - Thermal compliance

3.1.1 Greece

The compliance of the SmartWall with the Greek regulations is evaluated and checked in this section. Special attention is paid to the climatic conditions of the demonstration building of this project without forgetting the possible replicability of this solution in other areas of the country.

The following scenarios specify the thermal characteristics for the existing wall in Voula's demo building and the different configurations of SmartWall PnU installed.

Scenario 1: PnU does not contain a fan-coil or window.

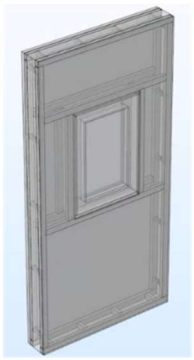
TABLE 12 SMARTWALL SCENARIO 1

Blank Type (no window, no fan-coil)					
	**Layers of construction composition**	**D [m]**	**Lambda [W/(m.K)**	**c [J/(kg.K)]**	**ρ [kg/m³]**
	Rendering/plastering	0.020	0.87	840	1600
	Brick	0.090	0.56	1000	930
	Enclosed air	0.050	0.29	1010	1
	Brick	0.090	0.56	1000	930
	Rendering/plastering	0.020	0.57	1000	1150
	SmartWall (Type A)	U-value = 0.23 W/(m2.K)			
	Total façade U-value (existing + PnU) = 0.204 W/(m².K)				

Scenario 2: PnU contains window but does not contain a fan-coil.

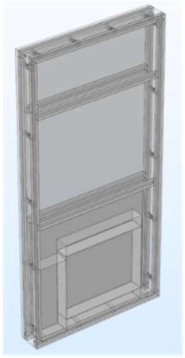
TABLE 13 SMARTWALL SCENARIO 2

PnU with window (no fan-coil)					
	Layers of construction composition	**D [m]**	**Lambda [W/(m.K)**	**c [J/(kg.K)]**	**ρ [kg/m³]**
	Rendering/plastering	0.020	0.87	840	1600
	Brick	0.090	0.56	1000	930

	Enclosed air	0.050	0.29	1010	1
	Brick	0.090	0.56	1000	930
	Rendering/plastering	0.020	0.57	1000	1150
	SmartWall (Type B)	U-value = 0.28 W/(m2.K)			
	Total façade U-value (existing + PnU) = 0.242 W/(m².K)				

Scenario 3: PnU contains a fan-coil but does not contain a window.

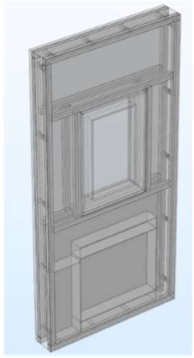
TABLE 14 SMARTWALL SCENARIO 3

PnU with fan-coil (no window)					
	**Layers of construction composition**	**D [m]**	**Lambda [W/(m.K)**	**c [J/(kg.K)]**	**ρ [kg/m³]**
	Rendering/plastering	0.020	0.87	840	1600
	Brick	0.090	0.56	1000	930
	Enclosed air	0.050	0.29	1010	1
	Brick	0.090	0.56	1000	930
	Rendering/plastering	0.020	0.57	1000	1150
	SmartWall (Type C)	U-value = 0.25 W/(m2.K)			
	Total façade U-value (existing + PnU) = 0.220 W/(m².K)				

Scenario 4: PnU with all its elements, fan-coil and window.

TABLE 15 SMARTWALL SCENARIO 4

Complete PnU with window and fan-coil					
	Layers of construction composition	**D [m]**	**Lambda [W/(m.K)**	**c [J/(kg.K)]**	**ρ [kg/m³]**
	Rendering/plastering	0.020	0.87	840	1600
	Brick	0.090	0.56	1000	930

	Enclosed air	0.050	0.29	1010	1
	Brick	0.090	0.56	1000	930
	Rendering/plastering	0.020	0.57	1000	1150
	SmartWall (Type D)	U-value = 0.31 W/(m2.K)			
	Total façade U-value (existing + PnU) = 0.265 W/(m^2.K)				

For **Voula's windows solution**, a PVC frame has been chosen with double glazing and roller shutters. The glazing layers are two laminated glasses (one of which has a low-e coating) and 12 mm gap that separates the two different glass panes.

As a result, the PVC frame achieves a thermal transmittance of 1.3 W/(m^2·K) and the double glazing with an estimated thermal transmittance value of 1.6 W/(m^2·K). The mean value for the whole **window would be 1.45 W/(m^2·K)**.

The thermal transmittance, U-value [in W/(m2K)] is the most common indicator for the thermal performance of the building envelope elements. The U-value of a wall represents the amount of heat per square meter that is transmitted through the element when the temperature difference between external and internal environments is 1^{o}C. The mean thermal transmittance value (U_m) of each building envelope element must be calculated according to the Greek Building regulation, "Regulation on the Energy Performance of Buildings – KENAK". The U_m has to be lower or equal to the maximum permitted values provided by KENAK. Table 16 and Table 17 provide the maximum permitted values of building envelope elements for new constructions and deep renovation existing buildings, respectively.

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TABLE 16: MAXIMUM PERMITTED VALUES OF THE THERMAL TRANSMITTANCE OF BUILDING ENVELOPE ELEMENTS PER CLIMATE ZONE IN CASE OF NEW BUILDING.

Building element	Maximum permitted U-value			
	Zone A	Zone B	Zone C	Zone D
External horizontal or tilted surface in contact with the outside air (roof)	0.45	0.40	0.35	0.30
External wall in contact with the outside air	**0.55**	**0.45**	**0.40**	**0.35**
Floor in contact with the outside air	0.45	0.40	0.35	0.30
Horizontal or tilted roof in contact with closed or unheated space	1.10	0.80	0.65	0.60
Wall in contact with closed or unheated space	1.30	0.90	0.70	0.65
Floor in contact with closed or unheated space	1.10	0.80	0.65	0.60
Horizontal or tilted roof in contact with the ground	1.10	0.80	0.65	0.60
Wall in contact with the ground	1.30	0.90	0.70	0.65
Floor in contact with the ground	1.10	0.80	0.65	0.60
Opening frame in contact with the outside air	**2.80**	**2.60**	**2.40**	**2.20**
Opening frame without glass in contact with the outside air	2.80	2.60	2.40	2.20
Glass building facade non or partly opening in contact with the outside air	2.10	1.90	1.75	1.70
Opening frame in contact with unheated space	5.00	4.60	4.30	4.00
Opening frame without glass in contact with unheated space	5.00	4.60	4.30	4.00
Glass building facade non or partly opening in contact with unheated space	5.00	3.40	3.00	2.80

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TABLE 17: MAXIMUM PERMITTED VALUES OF THE THERMAL TRANSMITTANCE OF BUILDING ENVELOPE ELEMENTS PER CLIMATE ZONE IN CASE OF DEEP RENOVATION OF EXISTING BUILDING.

Building element	Maximum permitted U-value			
	Zone A	Zone B	Zone C	Zone D
External horizontal or tilted surface in contact with the outside air (roof)	0.50	0.45	0.40	0.35
External wall in contact with the outside air	**0.60**	**0.50**	**0.45**	**0.40**
Floor in contact with the outside air	0.50	0.45	0.40	0.35
Horizontal or tilted roof in contact with closed or unheated space	1.20	0.90	0.75	0.70
Wall in contact with closed or unheated space	1.50	1.00	0.80	0.70
Floor in contact with closed or unheated space	1.20	0.90	0.75	0.70
Horizontal or tilted roof in contact with the ground	1.20	0.90	0.75	0.70
Wall in contact with the ground	1.50	1.00	0.80	0.70
Floor in contact with the ground	1.20	0.90	0.75	0.70
Opening frame in contact with the outside air	**3.20**	**3.00**	**2.80**	**2.60**
Opening frame without glass in contact with the outside air	3.20	3.00	2.80	2.60
Glass building facade non or partly opening in contact with the outside air	2.20	2.00	1.80	1.80
Opening frame in contact with unheated space	5.70	5.20	4.80	4.40
Opening frame without glass in contact with unheated space	5.70	5.20	4.80	4.40
Glass building facade non or partly opening in contact with unheated space	4.00	3.60	3.10	2.90

According to the results of the thermal transmittance we can conclude that:

- Façades for the Greek demo site in Voula (Climate Zone C) including all SmartWall configurations (Blank type, PnU with window (no fan-coil), PnU with fan-coil (no window) and Complete PnU with window and fan-coil) are **IN COMPLIANCE** with the thermal regulations stated above.
- Same existing façade and SmartWall configurations would be in **COMPLIANCE** with ALL climate zones in Greece for new buildings and renovation constructions.

This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No 958218

3.1.2 Spain

Compliance with Spanish regulations for DENVELOPS Comfort /eAHC is evaluated and checked in this section. Special attention is paid to the climatic conditions of the demonstrative building of this project without forgetting the possible replicability of this solution in other areas of the country.

The following scenarios specify the thermal characteristics for the existing wall in Terrassa's demo building and the different configurations of DENVELOPS Comfort or eAHC PnU installed.

Scenario 1: PnU does not contain an AHU or anchoring system (Blank Type).

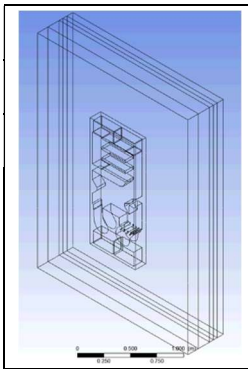
TABLE 18 DENVELOPS COMFORT SCENARIO 1

Blank Type (no AHU)					
	Layers of construction composition	**D [m]**	**Lambda [W/(m.K)**	**c [J/(kg.K)]**	**ρ [kg/m³]**
	Gypsum render	0.015	0.30	1000	750
	Hollow brick	0.080	0.50	1000	1020
	Enclosed air	0.055	0.26	1010	1
	EPS Insulation	0.050	0.0375	1200	30
	Perforated brick	0.150	0.991	1000	2170
	Cement render	0.020	0.55	1000	1125
	DENVELOPS Comfort	U-value = 0.195 W/(m2.K)			
	U-value = 0.141 W/(m².K)				

Scenario 2: PnU contains anchoring system and AHU (switched off).

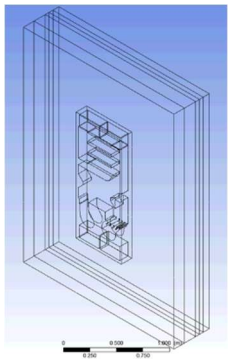
TABLE 19 DENVELOPS COMFORT SCENARIO 2

PnU with AHU (off)					
	Layers of construction composition	**D [m]**	**Lambda [W/(m.K)**	**c [J/(kg.K)]**	**ρ [kg/m³]**
	Gypsum render	0.015	0.30	1000	750
	Hollow brick	0.080	0.50	1000	1020
	Enclosed air	0.055	0.26	1010	1
	EPS Insulation	0.050	0.0375	1200	30

	Perforated brick	0.150	0.991	1000	2170
	Cement render	0.020	0.55	1000	1125
	DENVELOPS Comfort	U-value = 0.231 W/(m2.K)			
	U-value = 0.159 W/(m^2.K)				

Scenario 3: PnU contains anchoring system and AHU (switched on).

TABLE 20 DENVELOPS COMFORT SCENARIO 3

PnU with AHU (in operation)					
	**Layers of construction composition**	**D [m]**	**Lambda [W/(m.K)**	**c [J/(kg.K)]**	**ρ [kg/m^3]**
	Gypsum render	0.015	0.30	1000	750
	Hollow brick	0.080	0.50	1000	1020
	Enclosed air	0.055	0.26	1010	1
	EPS Insulation	0.050	0.0375	1200	30
	Perforated brick	0.150	0.991	1000	2170
	Cement render	0.020	0.55	1000	1125
	DENVELOPS Comfort	U-value = 0.188 W/(m2.K)			
	U-value = 0.138 W/(m^2.K)				

For **Terrassa's windows solution**, an aluminium frame has been chosen with double glazing with improved acoustic and thermal characteristics. The glazing layers are two laminated glasses with 20 mm Argon gap that separates the two glass panes

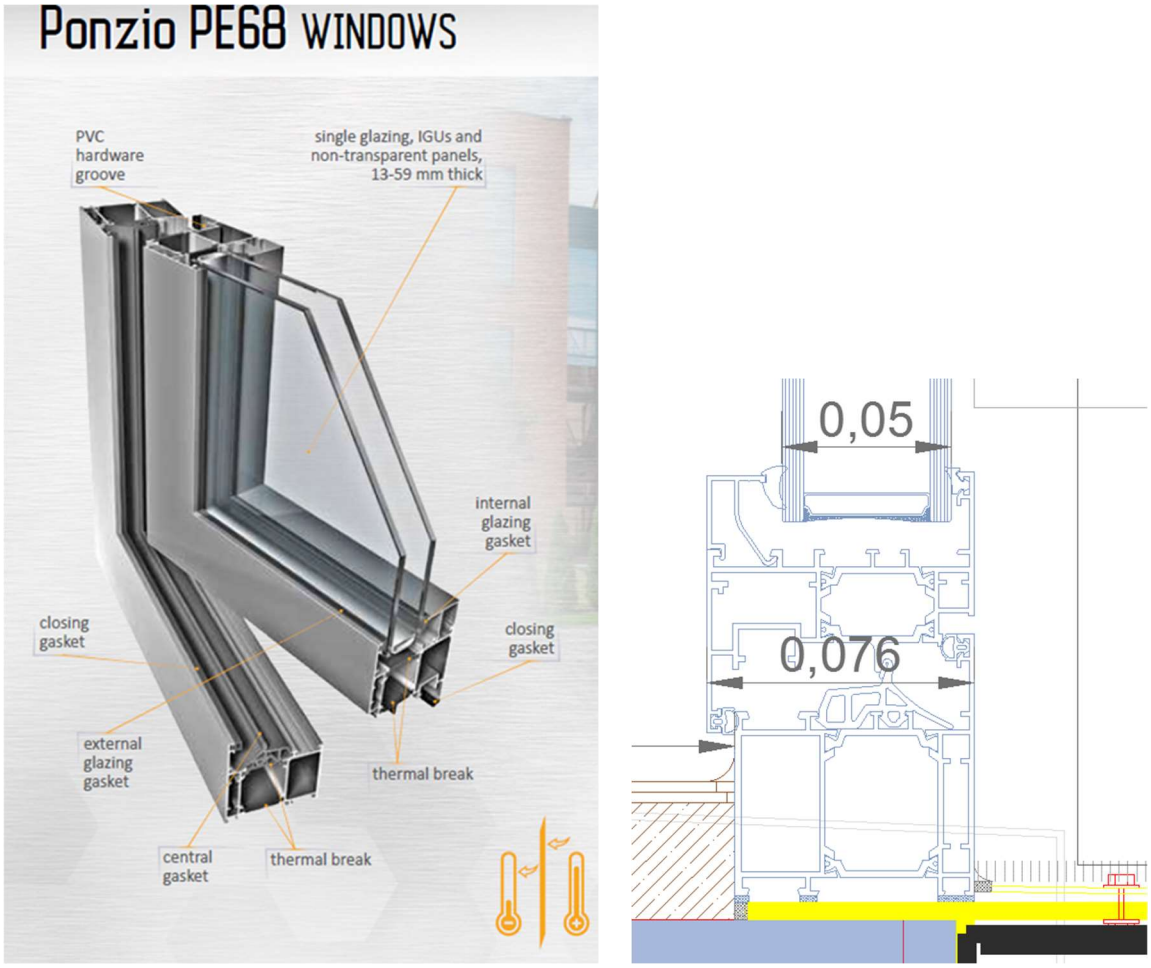


FIGURE 3.1-1 WINDOW SOLUTION FOR TERRASSA DEMO

As a result, the aluminum frame achieves a thermal transmittance of 1.8 W/(m^2·K) and the double glazing a thermal transmittance of 1 W/(m^2·K). The mean value for the whole **window would be 1.4 W/(m^2·K)**.

The "Documento Básico HE Ahorro de energía. HE1. Condiciones para el control de la demanda energética" (Basic Document HE Energy savings. HE1. Conditions for energy demand control) sets a thermal transmittance (U-value) for each element belonging to the thermal envelope that shall not exceed the limit value (U_{lim}) from the following table:

TABLE 21 LIMIT VALUES OF THERMAL TRANSMITTANCE, U_{LIM} [W/M^{2}K]

Building element	Max U – Value [W/m^2·K] Climate Zone					
	α	A	B	C*	D	E
Walls and floors in contact with outside air	0.80	0.70	0.56	0.49	0.41	0.37

Roofs in contact with the outside air	0.55	0.55	0.44	0.4	0.35	0.33
Walls, floors and roofs in contact with non-habitable areas or with the ground Partition walls or interior partitions belonging to the thermal envelope	0.90	0.80	0.75	0.70	0.65	0.59
Openings (frame assembly, glass and, where appropriate, roller shutter box)	3.2	2.7	2.3	2.1	1.8	1.8
Doors with a semi-transparent surface of 50% or less	5.7					

***** Spanish demo site climate zone.

In the case of reforms, the limit value (U_{lim}) above will only apply to those elements of the thermal envelope:

a) that are replaced, incorporated, or substantially modified;
b) that their interior or exterior conditions are modified as a result of the intervention, when these imply an increase in the energy needs of the building.

Likewise, in reforms, the values of the table may be exceeded when the global heat transfer coefficient (K) obtained considering the final thermal transmittance of the affected elements does not exceed that obtained by applying the values of the table.

According to the results of the thermal transmittance we can conclude that:

- Façades for the Spanish demo site in Terrassa (Climate Zone C) including all DENVELOPS comfort wall configurations (Blank type, PnU with AHU (off) and PnU with AHU (in operation)) are **IN COMPLIANCE** with the thermal regulations stated above.
- Same existing façade and DENVELOPS comfort wall configurations would be in **COMPLIANCE** with ALL climate zones in Spain for new building and renovation constructions.

This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No 958218

3.1.3 Czech Republic

Compliance with Czech regulations for ConExWall or eWHC is evaluated and checked in this section. Special attention will be paid to the climatic conditions of the demonstrative building of this project without forgetting the possible replicability of this solution in other areas of the country.

The following scenarios specify the thermal characteristics for the existing wall in Kašava's demo building and the different configurations of ConExWall or eWHC PnU installed.

Scenario 1: PnU does not contain a ventilation system or a window, installed in exterior wall type "Façade 01".

TABLE 22 CONEXWALL SCENARIO 1

Blank Type (no windows, no ventilation system) in Façade 01					
	Layers of construction composition	**D [m]**	**Lambda [W/(m.K)**	**c [J/(kg.K)]**	**ρ [kg/m³]**
	Lime plaster	0.025	0.87	840	1600
	Burnt bricks	0.450	0.80	900	1700
	Lime-cement plaster	0.025	0.99	790	2000
	ConExWall	U-value = 0.17 W/(m2.K)			
	U-value = 0.154 W/(m².K)				

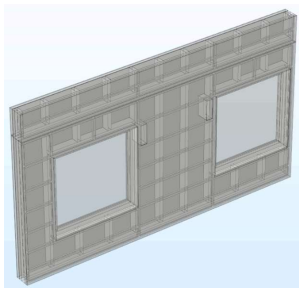
Scenario 2: PnU contains a ventilation system but does not contain a window, installed in exterior wall type "Façade 01".

TABLE 23 CONEXWALL SCENARIO 2

PnU with ventilation system (no windows) in Façade 01					
	Layers of construction composition	**D [m]**	**Lambda [W/(m.K)**	**c [J/(kg.K)]**	**ρ [kg/m³]**
	Lime plaster	0.025	0.87	840	1600
	Burnt bricks	0.450	0.80	900	1700
	Lime-cement plaster	0.025	0.99	790	2000
	ConExWall	U-value = 0.27 W/(m2.K)			
	U-value = 0.231 W/(m².K)				

Scenario 3: PnU with all its elements, ventilation system and window, installed in exterior wall type "Façade 01".

TABLE 24 CONEXWALL SCENARIO 3

Complete PnU with window and ventilation system in Façade 01					
	**Layers of construction composition**	**D [m]**	**Lambda [W/(m.K)**	**c [J/(kg.K)]**	**ρ [kg/m³]**
	Lime plaster	0.025	0.87	840	1600
	Burnt bricks	0.450	0.80	900	1700
	Lime-cement plaster	0.025	0.99	790	2000
	ConExWall	U-value = 0.40 W/(m2.K)			
	U-value = 0.321 W/(m².K)				

Scenario 4: PnU does not contain a ventilation system or a window, installed in exterior wall type "Façade 02".

TABLE 25 CONEXWALL SCENARIO 4

Blank Type (no windows, no ventilation system) in Façade 02					
	Layers of construction composition	**D [m]**	**Lambda [W/(m.K)**	**c [J/(kg.K)]**	**ρ [kg/m³]**
	Lime plaster	0.025	0.87	840	1600
	Burnt bricks	0.300	0.80	900	1700
	Lime-cement plaster	0.025	0.99	790	2000
	ConExWall	U-value = 0.17 W/(m2.K)			
	U-value = 0.158 W/(m².K)				

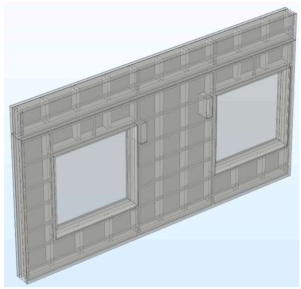
Scenario 5: PnU contains a ventilation system but does not contain a window, installed in exterior wall type "Façade 02".

TABLE 26 CONEXWALL SCENARIO 5

PnU with ventilation system (no windows) in Façade 02					
	Layers of construction composition	**D [m]**	**Lambda [W/(m.K)**	**c [J/(kg.K)]**	**ρ [kg/m³]**
	Lime plaster	0.025	0.87	840	1600
	Burnt bricks	0.300	0.80	900	1700
	Lime-cement plaster	0.025	0.99	790	2000
	ConExWall	U-value = 0.27 W/(m2.K)			
	U-value = 0.242 W/(m².K)				

Scenario 6: PnU with all its elements, ventilation system and window, installed in exterior wall type "Façade 02".

TABLE 27 CONEXWALL SCENARIO 6

Complete PnU with window and ventilation system in Façade 02					
	**Layers of construction composition**	**D [m]**	**Lambda [W/(m.K)**	**c [J/(kg.K)]**	**ρ [kg/m³]**
	Lime plaster	0.025	0.87	840	1600
	Burnt bricks	0.300	0.80	900	1700
	Lime-cement plaster	0.025	0.99	790	2000
	ConExWall	U-value = 0.40 W/(m2.K)			
					U-value = 0.341 W/(m².K)

For **Kašava's windows solution**, a finger jointed wooden frame has been chosen with triple glazing and internal Venetian blinds. The glazing layers are conformed by a laminated glass for each end and a single glass as a medium layer. A 16 mm Argon chamber separates the different glasses in the section.

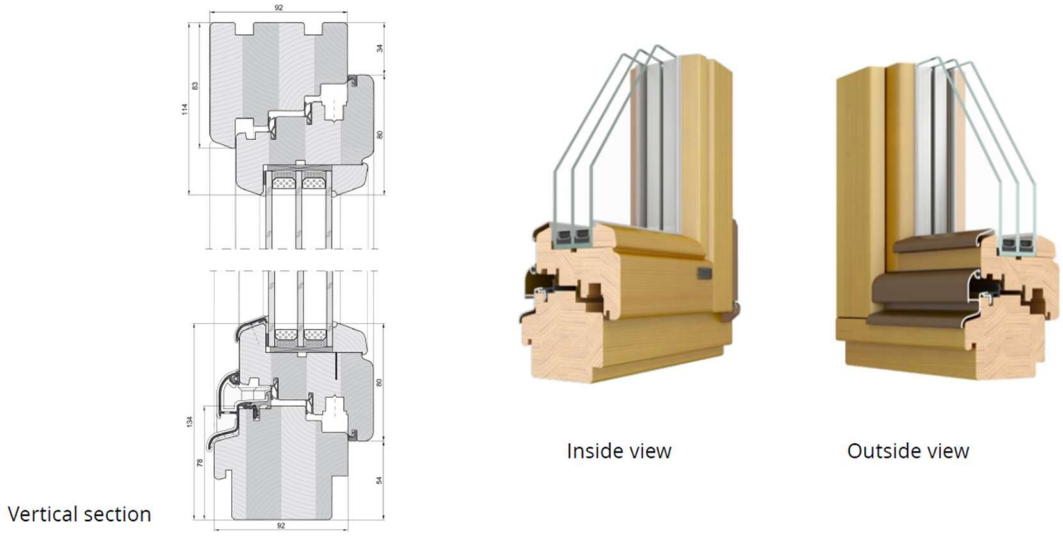


FIGURE 3.1-2 WINDOW SOLUTION FOR KASAVA DEMO

As a result, the wooden frame achieves a thermal transmittance of 1.1 W/(m²·K) and the triple glazing a thermal transmittance of 0.5 W/(m²·K). The mean value for the whole **window would be 0.8 W/(m²·K)**.

The ČSN 73 0540 (73 0540) Tepelná ochrana budov, části 1 až 4 specifies the thermal technical requirements for the design and verification of buildings with the required state of the indoor environmental during their use.

The thermal transmittance (U-values) defined by CSN 73 0540-2:2011 are the following:

TABLE 28 CZECH REPUBLIC THERMAL TRANSMITTANCE

	Required	Recommended	Recommended for passive buildings
Outside wall	**0.3**	**0.2 lightweight 0.25 heavyweight**	**0.12 to 0.18**
Roof (over 45°)	0.3	0.2	0.12 to 0.18
Roof (up to 45°)	0.24	0.16	0.1 to 0.15
Floor on terrain	0.45	0.3	0.15 to 0.22
Window	1.5	1.2	0.6 to 0.8
Door	1.7	1.2	0.9

According to the results of the thermal transmittance we can conclude that:

- Façades Type 01 and Type 02 for the Czech demo site in Kašava including ConExWall configurations: Blank type and PnU with ventilation system (no windows), are **IN COMPLIANCE** with the thermal regulations stated above.
- Façades Type 01 and Type 02 for the Czech demo site in Kašava including ConExWall configuration: Complete PnU with window and ventilation system, are **IN COMPLIANCE** with the thermal regulations stated above. Windows are assessed separately for a Complete PnU compliance and we can conclude that the solution proposed is not only compliant but also between the recommended values for passive buildings.
- Façades Type 01 and Type 02 for the Czech demo site in Kašava including ConExWall configuration: Blank type, can be considered in **COMPLIANCE** with passive building recommendations.

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3.2 Building physics - Hygrothermal compliance

3.2.1 Greece

Space Hydrometry W/N [gr/m^3] is calculated through the fraction of the water vapor production in a space W [gr/hr], to the volume of air exchange of the space N [m^3/hr]. Hellenic Organization for Standardization (ELOT) proposes regulations about hydrothermal compliance in buildings. Specifically, ELOT 1415, categorizes the buildings into four main categories, in terms of their hydrothermal compliance, provided that the regulations about air exchange in thermal zones of buildings are observed:

- Low Hydrometry buildings (W/N≤2.5gr/m^3): Office buildings with poor efficient energy systems, full-day schools, residential buildings with poor efficient mechanical ventilation systems.
- Medium Hydrometry buildings (2.5≤W/N≤5.0gr/m^3): Not overpopulated residential buildings.
- High Hydrometry buildings (5.0≤W/N≤7.5gr/m^3): Moderate ventilated, overpopulated residential buildings and some industrial buildings as well.
- Extremely high Hydrometry buildings (W/N≥5gr/m^3): Industrial buildings, where high relative humidity is needed, buildings with common spaces and closed swimming pools.

For the optimum design of buildings indoor comfort conditions, energy systems are installed so as to monitor and control the relative humidity. In small buildings and apartments, heat pumps, and A/C split units control the relative humidity only during the cooling operation. Based on the Regulation on the Energy Performance of Buildings (KENAK), Relative humidity and Temperature values for buildings' indoor comfort conditions are shown in Table 29.

TABLE 29: SPECIFIED TEMPERATURE AND RELATIVE HUMIDITY FOR BUILDING'S INDOOR CONDITIONS

Building Typology/ Thermal Zones	Temperature [°C]		Relative Humidity [%]	
	Heating Season	Cooling Season	Heating Season	Cooling Season
Single/Multi Family house	20	26	40	45
Hotel (Whole season)	20	26	35	45
Hotel (Summer season)	20	26	35	45
Hotel (Winter season)	20	26	35	45
Hotel Room	20	26	40	45
Hotel Social Space	20	26	35	40
Restaurant	20	26	35	50
Patisserie	20	26	35	50
Night club/ Music Hall	20	26	35	50

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Theatre/ Cinema	20	26	35	50
Concert Hall	20	26	35	50
Showyard/ Museum	20	23	35	50
Conference room/ Court of Justice	20	26	35	45
Bank	20	26	35	45
Multimedia centre	20	26	35	50
Sports Hall/ Swimming Pool	18	25	35	45
Corridors/ Public Spaces	18	26	35	50
Public Bathrooms	22	26	40	50
Kindergarten	20	26	35	45
Primary/Secondary School	20	26	35	45
University	20	26	35	45
Music Academy	20	26	35	45
Hospital	22	26	35	50
Patient room	22	25	35	50
Surgical Room	18	20	35	55
Out-patient room	20	26	35	50
Waiting Room	20	26	35	50
Health Care Centre	22	26	35	50
Mental health Clinic/Institution for people with disabilities/ Care homes for elderly people	22	26	40	45
Early Childhood Centre	20	26	40	45

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Prison	20	26	40	45
Police Station	20	26	35	45
Shopping Mall	19	25	35	45
Pharmacy	20	26	35	45
Barber shop	20	262	35	45
Office	20	26	35	45
Library	20	26	35	50

With the previous data we can check the compliance of the SmartWall PnU and make sure that there's not interstitial condensation.

According to the layer structure defined in sections 2.6 and 3.1.1 and the calculations made with the software eCondensa2 we can conclude that:

- Façades for the Greek demo site in Voula including Blank type and PnU with window (no fan-coil) Smart Wall configurations are **IN COMPLIANCE** and do **NOT** have interstitial condensation.

TABLE 30 SMARTWALL TYPE A AND B HYGROTHERMAL COMPLIANCE

Layer		Vapor pressure (Pa)	Saturation vapor pressure (Pa)	Accumulated condensation (kg/m2)
SmartWall (Type A and B)	Gypsum board	826,392	1143,08	0
	Mineral wool	826,392	1957,705	0
	Gypsum board	826,392	1967,601	0
	Mineral wool with aluminium foil	1051,628	2167,964	0
Existing façade	Rendering/plastering	1051,628	2252,22	0
	Brick	1051,628	2299,154	0
	Enclosed air	1051,628	2307,142	0
	Brick	826,392	1143,08	0
	Rendering/plastering	826,392	1957,705	0

This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No 958218

- Façades for the Greek demo site in Voula including PnU with fan-coil (no window) and Complete PnU with window and fan-coil Smart Wall configurations are **IN COMPLIANCE** and do **NOT** have interstitial condensation.

TABLE 31 SMARTWALL TYPE C AND D HYGROTHERMAL COMPLIANCE

Layer		Vapor pressure (Pa)	Saturation vapor pressure (Pa)	Accumulated condensation (kg/m2)
SmartWall (Type C and D)	Gypsum board	826,392	1161,045	0
	Fan-coil	1051,467	1161,243	0
	Vacuum insulation panel (VIP)	1051,467	1397,233	0
	Enclosed air	1051,467	1459,777	0
	Gypsum board	1051,467	1479,82	0
	Mineral wool with aluminium foil	1051,628	1918,332	0
Existing façade	Rendering/plastering	1051,628	1926,135	0
	Brick	1051,628	2034,577	0
	Enclosed air	1051,628	2121,453	0
	Brick	1051,628	2239,429	0
	Rendering/plastering	1051,628	2259,853	0

3.2.2 Spain

To calculate condensation, the average monthly values of the town where the building is located are taken as outdoor temperatures and outdoor relative humidity.

In the case of localities that are not provincial capitals and that do not have verified climatic records, it can be assumed that the outside temperature is equal to that of the corresponding provincial capital minus 1 ºC for every 100 m difference in height between both locations. The relative humidity for these localities is calculated assuming that their absolute humidity is equal to that of their provincial capital.

An indoor ambient temperature equal to 20 ºC is taken for the month of January.

If the indoor relative humidity data is available and it remains constant, for example due to an air conditioning system, this data can be used in the calculation by adding 0.05 as a safety margin.

In the absence of more precise data, it is possible to take, for all the months of the year, an indoor temperature equal to 20 ºC and a relative humidity of the indoor environment depending on the hygrometry class of the space:

a) hygrometry class 5, corresponding to spaces in which a large production of humidity is expected, such as laundries, restaurants and swimming pools: 70%
b) hygrometry class 4, corresponding to spaces in which a high production of humidity is expected, such as kitchens, sports halls, collective showers or others for similar use: 62%
c) hygrometry class 3 or lower, corresponding to spaces in which a high production of humidity is not expected, such as offices, shops, storage areas and all spaces in buildings for residential use: 55%

With the previous data we can check the compliance of the DENVELOPS comfort PnU and make sure that there's not interstitial condensation.

According to the layer structure defined in sections 2.7 and 3.1.2 and the calculations made with the software eCondensa2 we can conclude that:

- Façades for the Spanish demo site in Terrassa including Blank Type (no AHU) DENVELOPS comfort wall configuration is **IN COMPLIANCE** and do **NOT** have important interstitial condensation. The quantity of evaporated condensation is superior to the accumulated condensation stated below.

TABLE 32 DENVELOPS COMFORT TYPE A HYGROTHERMAL COMPLIANCE

Layer		Vapor pressure (Pa)	Saturation vapor pressure (Pa)	Accumulated condensation (kg/m2)
DENVELOPS comfort (Type A)	Aluminium cladding	1137,116	1137,116	0,0107
	Air chamber	1137,215	1149,235	0
	Weathering membrane	1149,338	1149,338	0,0194
	Mineral fibres insulation	1154,736	1873,932	0
Existing façade	Cement render	1162,016	1876,963	0
	Perforated brick	1216,567	1929,762	0
	EPS Insulation	1253,005	2216,161	0
	Enclosed air	1253,36	2256,613	0
	Hollow brick	1282,446	2299,873	0
	Gypsum render	1285,323	2306,079	0

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- Façades for the Spanish demo site in Terrassa including PnU with AHU (off) and PnU with AHU (in operation) DENVELOPS comfort wall configurations are **IN COMPLIANCE** and do **NOT** have important interstitial condensation. The quantity of evaporated condensation is superior to the accumulated condensation stated below.

TABLE 33 DENVELOPS COMFORT TYPE B AND C HYGROTHERMAL COMPLIANCE

Layer		Vapor pressure (Pa)	Saturation vapor pressure (Pa)	Accumulated condensation (kg/m2)
DENVELOPS comfort (Type B and C)	Aluminium cladding	838,748	1147,277	0
	Air chamber	838,748	1184,16	0
	Weathering membrane	838,748	1184,475	0
	Air Heating Unit (AHU)	1184,715	1184,715	0,0209
Existing façade	Cement render	1189,683	1190,492	0
	Perforated brick	1231,8	1299,301	0
	EPS Insulation	1258,123	1991,641	0
	Enclosed air	1258,123	2103,695	0
	Hollow brick	1280,936	2227,517	0
	Gypsum render	1285,323	2245,62	0

Insultation used in DENVELOPS comfort is designed to be able to be wet without losing its technical characteristics.

3.2.3 Czech Republic

With the previous data we can check the compliance of the ConExWall PnU and make sure that there's not interstitial condensation.

According to the layer structure defined in sections 2.8 and 3.1.3 and the calculations made with the software eCondensa2 we can conclude that:

- Façade Type 01 for the Czech demo site in Kašava including all ConExWall configurations (Blank type, PnU with ventilation system (no windows) and Complete PnU with window and ventilation system), are **IN COMPLIANCE** and do **NOT** have interstitial condensation.

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TABLE 34 CONEXWALL FAÇADE TYPE 01 HYGROTHERMAL COMPLIANCE

Layer		Vapor pressure (Pa)	Saturation vapor pressure (Pa)	Accumulated condensation (kg/m2)
ConExWall (Type A, B and C)	Wood cladding	764,732	938,742	0
	Ventilated air chamber	765,543	948,595	0
	Hard wood insulation	846,587	1059,68	0
	Mineral insulation	856,312	1810,908	0
	Gypsum wood fiber board	861,175	1825,518	0
	Moisture stop PE-foil	958,427	1825,714	0
	Heating layer with insulation and heating pipes	990,845	2265,062	0
Existing façade 01	Lime-cement plaster	1003,002	2272,527	0
	Burnt bricks (45 cm)	1039,471	2289,231	0
	Lime plaster	1051,628	2297,806	0

- Façade Type 02 for the Czech demo site in Kašava including all ConExWall configurations (Blank type, PnU with ventilation system (no windows) and Complete PnU with window and ventilation system), are **IN COMPLIANCE** and do **NOT** have interstitial condensation.

TABLE 35 CONEXWALL FAÇADE TYPE 01 HYGROTHERMAL COMPLIANCE

Layer		Vapor pressure (Pa)	Saturation vapor pressure (Pa)	Accumulated condensation (kg/m2)
ConExWall (Type A, B and C)	Wood cladding	766,015	938,808	0
	Ventilated air chamber	766,858	948,688	0
	Hard wood insulation	851,109	1060,104	0
	Mineral insulation	861,219	1814,179	0
	Gypsum wood fiber board	866,275	1828,853	0
	Moisture stop PE-foil	967,376	1829,049	0
	Heating layer with insulation and heating pipes	1001,077	2270,422	0
Existing façade 02	Lime-cement plaster	1013,715	2277,922	0
	Burnt bricks (30 cm)	1038,99	2289,101	0
	Lime plaster	1051,628	2297,699	0

3.3 Fire compliance

3.3.1 Greece

The Regulation for the fire protection of buildings lays down the requirements and the measures to be taken in buildings, in order to:

a) protect the lives and health of the persons therein, in case of fire;

b) prevent the fire spreading from where it originally started to the rest of the building;

c) prevent the fire spreading where it originally started to adjacent buildings and other nearby areas;

d) protect the buildings themselves and their contents.

The application of the Regulation on the fire protection of buildings is obligatory:

- for buildings or parts of buildings constructed after its entry into force, when their uses fall in one of the categories mentioned in Table 36;
- for functionally independent additions to existing buildings;
- for buildings or parts of buildings that fell under the scope of Chapter A of formerly applicable Presidential Decree 71/88 (Greek Government Gazette 32 A) and had not been the object of a fire protection analysis, according to the provisions of said Presidential Decree, in case there is a change in their use after the entry into force of this Regulation, in whole or in part, and/or in case a functionally dependent addition is installed to them;
- for buildings pre-existing the entry into force of Presidential Decree 71/88, in case there is a complete change of their use after the entry into force of this Regulation on the fire protection of buildings;
- for functionally dependent additions that serve a main use in buildings constructed before the entry into force of Chapter A of Presidential Decree 71/88, if they are larger than 50% of the total surface of the main use areas of the existing building and at the same time their surface is over 300 m^2;
- for substations of the Greek Public Power Cooperation (PPC) constructed after the entry into force of this Regulation, where PPC is responsible for the correct application of the Regulation in its properties.

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TABLE 36 CLASSIFICATION OF BUILDINGS ACCORDING TO THEIR USE UNDER THE BUILDING REGULATION

USE CATEGORIES		DESCRIPTION
A	RESIDENCE	buildings of three or more apartments, detached houses, semi-detached houses, shared houses
B	TEMPORARY ACCOMODATION	hotels, hostels, boarding institutions and dormitories for persons > 6 years old
C	PUBLIC ASSEMBLAGE	assemblage of at least 50 persons, conference rooms, large teaching rooms, exhibition areas, museums, concert halls, court rooms, temples, sports events areas, theatres, cinemas, restaurants, pastry shops, cafés, entertainment halls, multi-use halls, passenger waiting areas, banks ≥ 70 m^2
D	EDUCATION	teaching of 6-49 persons, compulsory education buildings, private tuition centres, kindergartens
E	HEALTH AND SOCIAL WELFARE	buildings intended for preventive, diagnostic and treatment purposes, for providing sleep and physical hygiene of infants, such as hospitals, clinics, regional medical practices, health stations, health centres, mental health clinics, facilities for people with disabilities, facilities for people suffering from chronic diseases, homes for the elderly, crèches <5* years, nurseries, medical practices
F	PENITENTIARY	buildings intended for detention, incarceration or serving of a sentence, detention cells, youth detention centres, prisons
G	COMMERCE	shopping malls, markets and supermarkets, shops, pharmacies, barber's shops, hair salons, gyms, small shops, clothes and shoes repair shops
H	OFFICES	public service offices, local government offices, libraries, business offices, freelancer offices, banks of a gross surface < 70 m^2
I	INDUSTRY - SMALL CRAFTS INDUSTRY	industries, small crafts industries, workshops, preparation areas, services with electromechanical equipment such as factories, oil refineries, energy production stations, car repair shops, dyeing workshops, carpenter's workshops, laboratories for research and educational purposes, food preparation areas, dry cleaning services, ironing services, laundry services, autonomous computer centres
J	STORAGE	general storage rooms, agricultural storage rooms, harbour depots, museum warehouses, shop storage rooms, stables, ox-stalls, pig-stalls, chicken rearing facilities
K	PARKING SPACE AND PETROL STATIONS	buildings intended for the parking of two-, three- and four-wheel vehicles or petrol stations or car washes

** The Ministerial Decision 3046/89 refers to children younger than 6 years of age, whereas compulsory education now starts at the age of five.*

In all other cases where a fire protection analysis is required for existing buildings, the relevant Provisions on firefighting apply, in their current version.

The aforementioned conditions do not apply to buildings that have been designated as monuments or as traditional or protected buildings by the responsible Ministries, and whose uses define the fire protection requirements according to the relevant Provision on firefighting, with the possibility of derogations through the enforcement of additional compensatory fire protection measures by the responsible fire department, if this is necessary in order to protect the special elements on which their designation as protected buildings is based. The aforementioned reasons are included in a technical report prepared by the responsible engineer, which is submitted to the fire department after having been approved by the Ministry responsible for the designation of the building.

Special provisions related to the installation of active fire protection means for specific categories of buildings or uses apply in addition to the requirements of Fire Regulation.

In case of buildings that fall under categories (C) Public assemblage, (J) Industry - Small crafts industry and (K) Storage of article 4 of this Regulation, and that are of large scale and have a particular form and function, and to which the full application of the provisions on passive fire protection included in the general and specific articles of this Regulation has proved impossible, a passive fire protection analysis can be prepared, by way of derogation, increasing the passive and active means of fire protection in such a way that an equivalent degree of fire safety of the building and safety of the public is guaranteed.

This analysis shall be approved by a five-member committee comprising of specialist scientists and representatives of the public and private sector, after a relevant reasoned proposal has been submitted by the entity that is responsible for the functionality of the building. The application of the said derogation to the specific building as well as the establishment of the committee are subject to a common decision by the Minister of Environment and Energy and other responsible Ministers, after a reasoned proposal has been submitted by the responsible Department of the Ministry of Environment and Energy.

The scope of this Regulation is shown in Table 37.

TABLE 37 SCOPE OF REGULATIONS ON FIRE PROTECTION

REGULATIONS ON FIRE PROTECTION	SCOPE	CLARIFICATIONS - OBSERVATIONS	
Regulation on the fire protection of buildings	New buildings	Buildings or parts of buildings constructed under a building permit for which an application is submitted after the entry into force of this Regulation	
	Functionally independent additions to existing buildings	Treated as new buildings due to their autonomy	
	Existing buildings built after 17/2/1989	Change of use or addition to buildings that have been the object of analysis according to P.D. 71/88	
	Hotels built before 17/3/1988		
	Buildings built before 17/2/1989 (except hotels)	Complete change of use	Additions to existing buildings covering >50% of the plot that have a surface >300 m^2
Firefighting provisions - Measures	Buildings built before 17/2/1989 (except hotels)	According to their use	
	Monuments, protected buildings, traditional buildings	According to their use and with the possibility for derogations	

3.3.1.1 Structural fire protection

The fire protection specifications of construction products and building elements are divided in two basic categories, according to their respective specifications:

TABLE 38 REQUIREMENTS ON THE DEGREE OF FIRE RESISTANCE PER BUILDING USE

MINIMUM ALLOWED DEGREES OF FIRE RESISTANCE								
Category	Use	Subcategory	Minimum degree of fire resistance (in minutes)					
			Underground storeys		Above ground storeys			
			height >10 metres*	height <10 metres*	up to 2 storeys and <5 metres (highest floor level)	between 3 and 6 storeys and < 15 metres*	between 7 and 10 storeys and < 27 metres*	>27 metres
A	**Residence**		90	60	30	60	90	120
B	**Temporary accommodation**		90	60	30	60	90	120
C	**Public assemblage areas**		120	90	60	90	120	180
D	**Education**		90	60	30	60	90	120
E	**Health & social welfare**		120	90	60	90	120	180
F	**Penitentiary**		120	90	60	90	120	180
G	**Commerce**		120	90	60	90	120	180
H	**Offices**		90	60	30	60	90	120
I	**Industry - Small crafts industry****	I1	120	90	60	90	120	
		I2	180	120	90	120	180	
		I3	240	180	90	180	240	
J	**Storage**	I1	120	90	90	120	180	
		I2	240	180	120	180	240	
		I3	240		180	240		
K	**Parking areas & petrol stations**	K_1, K_2 open	-	-	30	60	90	
		K_1, K_2, K_3, closed and K_4	120	90	60	90	120	180

** The level of the floor of the lowest storey for underground storeys or the highest storey for above ground storeys that are above the evacuation storey.*

1. The behaviour in relation to **"reaction to fire"** applies to construction products, such as interior finishings, which are expected to be directly exposed to the fire during its early phases. In that case, the basic fire protection aim is to contain the spread of the fire and smoke, as well as to prevent or delay flashover. Annex A contains additional information on the way that construction products are classified in the Euroclass system and on fire reaction tests.

2. The behaviour in relation to **"fire resistance"** applies to load bearing and non-load bearing building elements, as well as separating elements of fire compartments, which are expected to be exposed to fire during the phase of fully developed fire that comes after flashover. In that case, the main fire protection aim is to contain the fire in the area (or building) where it started, as well as to prevent structural failures. Additional information on ways to determine the degree of fire resistance of building elements and on fire resistance tests may be found in Annex B.

Requirements on the degree of fire resistance

The fire resistance requirements apply to load bearing elements of the building in order to ensure that it won't collapse, the fire protected escape routes for the secure evacuation of the building's users and the envelopes of the fire compartments of the building, in order to contain the fire inside the building (see Annex B).

The minimum degree of fire resistance for each building use and in relation to its height is presented in

MINIMUM ALLOWED DEGREES OF FIRE RESISTANCE								
Category	Use	Subcategory	Minimum degree of fire resistance (in minutes)					
			Underground storeys		Above ground storeys			
			height >10 metres*	height <10 metres*	up to 2 storeys and <5 metres (highest floor level)	between 3 and 6 storeys and < 15 metres*	between 7 and 10 storeys and < 27 metres*	>27 metres
A	**Residence**		90	60	30	60	90	120
B	**Temporary accommodation**		90	60	30	60	90	120
C	**Public assemblage areas**		120	90	60	90	120	180
D	**Education**		90	60	30	60	90	120

E	**Health & social welfare**		120	90	60	90	120	180
F	**Penitentiary**		120	90	60	90	120	180
G	**Commerce**		120	90	60	90	120	180
H	**Offices**		90	60	30	60	90	120
I	**Industry - Small crafts industry****	I1	120	90	60	90	120	
		I2	180	120	90	120	180	
		I3	240	180	90	180	240	
J	**Storage**	I1	120	90	90	120	180	
		I2	240	180	120	180	240	
		I3	240		180	240		
K	**Parking areas & petrol stations**	K1, K2 open	-	-	30	60	90	
		K1, K2, K3, closed and K4	120	90	60	90	120	180

** The level of the floor of the lowest storey for underground storeys or the highest storey for above ground storeys that are above the evacuation storey.*

TABLE 38.

In case there is an automatic water based fire extinguishing system (sprinkler) in the fire compartment, the degree of fire resistance may be reduced by 60 minutes, but in no case can it be less than 60 minutes.

The degree of fire resistance of a building element is defined according to the fire resistance tests as described in the EN 13501 standard and concerns many criteria/performance, that are presented in Annex D. However, the term fire resistance usually refers to meeting the following three criteria: load bearing capacity (R), integrity (E) and heat resistance (I).

In some cases, it is not necessary for building elements, depending on their location and the building's use, size and estimated risk, to meet all three criteria/performance, but may instead meet one or more of these or, additionally, one or several of the remaining criteria.

The necessary fire resistance criteria/performance that must be met by building elements are defined in Table 39.

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TABLE 39 MINIMUM NECESSARY PERFORMANCE IN TERMS OF DEGREE OF FIRE RESISTANCE OF BUILDING ELEMENTS

Building elements	Minimum criteria - performance
Load bearing masonry (indoor and outdoor)	R, E, I
Outdoor non load bearing masonry	E, I
Load bearing vertical elements (supporting elements, walls, frame assemblies, etc.)	R
Fire resistant doors, windows and window panes	E, I
Outdoor non load bearing masonry and walls of fire protected routes	E, I
Separating building elements of storeys – fire seals (plates & beams)	R, E, I
Walls of stairways	E, I
Load bearing elements of stairways	R
Self supporting roof coverings (panels, etc.)	R, E, I

Fire reaction requirements

Fire reaction requirements apply to construction products (internal finishings, floor coatings, duct thermal insulation, electric cables) that may be directly exposed to fire and aim at reducing the speed of fire spreading and the speed of smoke and flaming particles and droplets production (see Annex A). The minimum fire reaction requirements for internal finishings, per category of use, are shown in Table 40.

SmartWall and Smart Window PnU kits fire testing classification

The fire performance analysis focused on the SmartWall and Smart Window PnU kits and were carried out in the NTUA facilities. Two different SmartWall types were examined: the first one (Type A), serving as a “blank type”, was a simple configuration, constructed by the metal frame, gypsum plasterboards and rockwool. The second type (Type C) corresponded to a SmartWall module, with the addition of a Toolbox and a fan-coil unit. The two SmartWall prototypes were classified as B-s1, d0, while the Smart Window was classified as C-s3,d0. More information regarding the fire testing procedure can be found in “D4.5: PnU kit prototype property and performance characterization”.

TABLE 40 MINIMUM FIRE REACTION REQUIREMENTS FOR INTERNAL FINISHINGS AND FLOORS PER USE CATEGORY

Use category		Walls and ceilings				Interstitial spaces and ceilings	Floors	
		Fire protected escape routes	General				Fire protected escape routes	Unprotected escape routes
Residences		B-s1,d0	Areas >10 m^2	Areas <10 m^2	Unprotected escape routes	C-s1,d0	B_{FL}-s2	D_{FL}-s2
			C-s2,d2	D-s2,d2	C-s1,d1			
Temporary accommodation		B-s1,d0	Rooms <15 m^2	Rooms >15 m^2	Unprotected escape routes	C-s1,d0	B_{FL}-s2	C_{FL}-s2
			D-s2,d2	C-s2,d2	C-s1,d1			
Public assemblage areas		B-s1,d0	Areas <30 m^2	Areas >30 m^2	Unprotected escape routes	C-s1,d0	B_{FL}-s2	C_{FL}-s2
			D-s2,d2	C-s1,d1	C-s1,d1			
Education		B-s1,d0	Rooms < 40 m^2	Rooms > 40 m^2	Unprotected escape routes	C-s1,d0	B_{FL}-s2	C_{FL}-s2
			D-s2,d2	C-s1,d1	C-s1,d1			
Health & social welfare		B-s1,d0	Unprotected escape routes			B-s1,d0,	B_{FL}-s1	C_{FL}-s1
			C-s1,d1					
Penitentiary		B-s1,d0	C-s1,d1			C-s1,d0	B_{FL}-s2	C_{FL}-s2
Commerce		B-s1,d0	Areas >10 m^2	Areas <10 m^2	Unprotected escape routes	C-s1,d0	B_{FL}-s2	C_{FL}-s2
			C-s1,d1	D-s1,d1	C-s1,d1			
Offices		B-s1,d0	Areas <30 m^2	Areas >30 m^2	Unprotected escape routes	C-s1,d0	B_{FL}-s2	C_{FL}-s2
			D-s2,d1	C-s2,d1	C-s1,d1			
Industry - Small crafts industry	**Z1-Z2**	B-s1,d0	Areas >10 m^2	Areas <10 m^2	Unprotected escape routes	C-s1,d0	B_{FL}-s2	C_{FL}-s2
			C-s1,d1	D-s1,d1	C-s1,d1			
	Z3	B-s1,d0	Areas >10 m^2	Areas <10 m^2	Unprotected escape routes		$A2_{FL}$-s2	B_{FL}-s2
			B-s1,d1	C-s1,d1	B-s1,d1			
Storage	**Z1-Z2**	B-s1,d0	Areas >10 m^2	Areas <10 m^2	Unprotected escape routes	C-s1,d0	B_{FL}l-s2	C_{FL}-s2
			C-s1,d1	D-s1,d1	C-s1,d1			
	Z3	B-s1,d0	Areas >10 m^2	Areas <10 m^2	Unprotected escape routes		$A2_{FL}$-s2	B_{FL}-s2
			B-s1,d1	C-s1,d1	B-s1,d1			
Parking areas & petrol stations		B-s1,d0	Areas >10 m^2	Areas <10 m^2	Unprotected escape routes	C-s1,d0	B_{FL}-s2	C_{FL}-s2
			C-s1,d1	D-s1,d1	C-s1,d1			

3.3.2 Spain

At National level, there are three main regulatory documents ruling the fire safety in buildings:

- Basic Document for the Safety in case of fire DB-SI (Spanish Technical Building Code - CTE) [*Documento Básico DB-SI Seguridad en caso de incendios (Código Técnico de la Edificación - CTE*)].
- Fire Safety Regulation in Industrial Buildings [*Reglamento de seguridad contra incendios en los establecimientos industriales – RSCIEI*)].
- Regulation on fire-fighting installations [*Reglamento de instalaciones de protección contra incendios – RIPCI*)].

As for the DENVELOPS Comfort PnU Kit, only the first of the above-listed regulatory document applies.

The main purpose of the CTE DB-SI is to reduce to acceptable levels the risks for building users to suffer harm in the event of fire. The document establishes the requirements, rules, and procedures to fulfill the Basic Demands (see below) and achieve a minimum level of quality that ensures fire safety. Six Basic Demands (SI) are established as follows:

- SI1: Limitation of indoor fire spread.
- SI2: Limitation of external fire spread.
- SI3: Building occupants' egress.
- SI4: Fire protection installations.
- SI5: Firefighter's intervention.
- SI6: Structural resistance to fire.

Considering the intended use of DENVELOPS Comfort PnU Kit as a constructive element (i.e., ventilated cladding system installed onto an existing external wall), the Basic Demand of application in CTE is SI2 *Limitation of external fire spread*.

It is also relevant to note that, in the case of renovation of an existing building (without change in the building use or occupancy), as it is the main purpose of DENVELOPS Comfort PnU Kit, the CTE DB-SI requirements shall apply to the building elements subject to reform, provided that it results in a better alignment of the safety conditions with the provisions in CTE DB-SI. Consideration of the requirements in CTE DB-SI should be based on the principle of proportionality between the renovation scope and the degree of improvement in the safety conditions in case of fire. In no case will the building renovation result in a decrease of the safety conditions of the previously existing building.

Prescriptive regulatory requirements in CTE DB-SI2 *Limitation of external fire spread* are established on façade elements based on two essential characteristics:

- Resistance to fire.

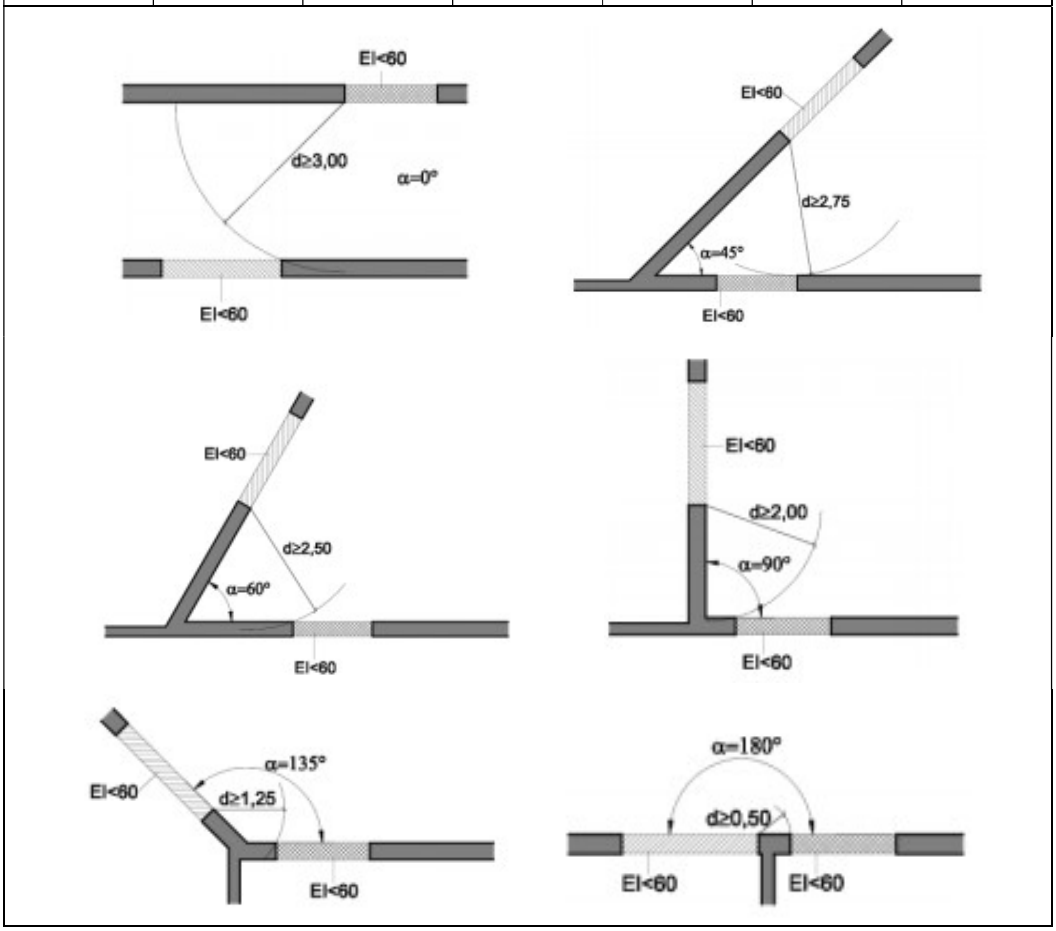
- Reaction to fire.

Regarding the resistance to fire, the main requirements on façade elements are described as follows:

1. To avoid horizontal fire spread, the distance to adjacent building elements from parts of the façade which have a resistance to fire less than EI 60 will be in accordance with the next table and figures, depending on the angle between buildings.

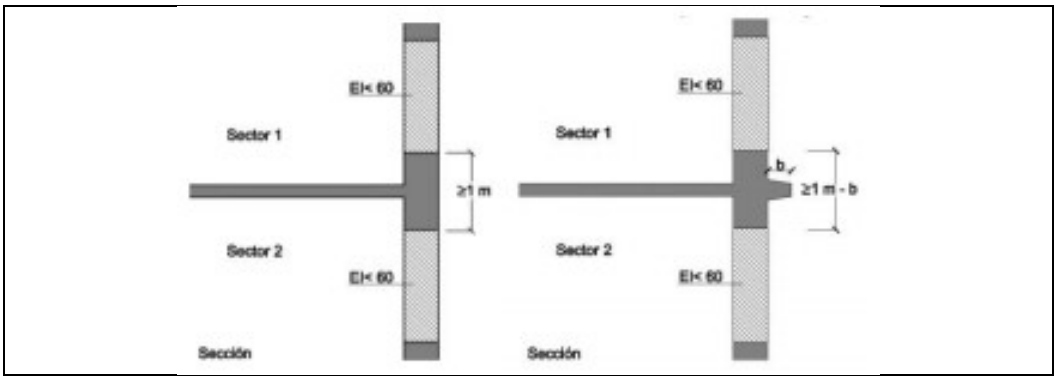
TABLE 41 MINIMUM DISTANCE BETWEEN ELEMENTS WITH EI<60 (SPANISH FIRE SAFETY REGULATION)

α	0°	45°	60°	90°	135°	180°
d (m)	3,00	2,75	2,50	2,00	1,25	0,50



2. To avoid vertical fire spread, the façade element (as a whole) will have a minimum resistance to fire EI 60 in a zone of at least 1m of vertical distance between fire compartments (i.e.: in general, between floors).

   Note: the 1 m vertical distance between façade parts less than EI 60 can be proportionally reduced if a horizontal wing is considered (as shown in the figure below, at the right).



SCHEMATIC OF MINIMUM VERTICAL DISTANCE BETWEEN ELEMENTS WITH EI<60 (SPANISH FIRE SAFETY REGULATION)

Technical justification of DENVELOPS Comfort PnU Kit installed in Terrassa demo case in relation to the resistance to fire requirements

In relation to the above-described resistance to fire requirements established in CTE DB-SI2 to avoid horizontal and vertical fire spread at the façade, they were already met by the previously existing external wall. The addition of the DENVELOPS Comfort PnU Kit (external wall cladding) does not adversely affect the resistance to fire performance and, therefore, the global façade solution still complies with the regulatory requirements. However, the pipework of the ventilation air handling unit pipework integrated in the DENVELOPS Comfort cladding system penetrates the existing wall and, in such points, the resistance to fire of the wall must be reinstated by the installation of an intumescent fire sealing collar. This requirement applies in the case that the pipe penetration is located within the prescribed 1-meter EI 60 distance, which is not the case in the Terrassa demo site. Nevertheless, the intumescent fire sealing collar can be installed as an extra safety measure.

According to the CTE DB-SI2 provisions, the resistance to fire performance of the intumescent collar is technically justified by its own product certification or, at least, by the relevant test according to EN 1366-3 and classification according to EN 13501-2. The selected intumescent collar has a resistance to fire classification EI 60 when sealing a PVC pipe of external diameter 100 mm and pipe wall thickness 3 mm, passing through a masonry wall.

Therefore, the installation of DENVELOPS Comfort PnU Kit in Terrassa demo site **COMPLIES** with the applicable resistance to fire requirements (EI 60 for the external wall as a whole).

Regarding the reaction to fire, the main requirements are described as follows:

1. The reaction to fire of the façade constructive elements which amount more than 10 % of the total façade area will be:
   - D-s3,d0 in façades with a height up to 10 m.
   - C-s3,d0 in façades with a height up to 18 m.
   - B-s3,d0 in façades higher than 18 m.

   The field of application of the reaction to fire classification shall consider the end-use constructive system including the inner layers of the façade element if not protected by a EI 30 external layer.

2. The insulation layer installed in the gap of ventilated façades will have the following reaction to fire:
   - D-s3,d0 in façades with a height up to 10 m.
   - B-s3,d0 in façades with a height up to 28 m.
   - A2-s3,d0 in façades higher than 28 m.

   Vertical fire spread through the gap in the ventilated façade shall be avoided at the floors level. Fire stopping barriers (at least E30) can be considered to that end.

3. In façades with a height up to 18 m where the lower part is accessible to the general public, the reaction to fire of the façade constructive elements, as well as of the elements in the gap of a ventilated façade, will be at least B-s3,d0 up to a height of 3,5 m from the lower edge.

<u>Technical justification of DENVELOPS Comfort PnU Kit installed in Terrassa demo case in relation to the reaction to fire requirements</u>

The technical justification of the DENVELOPS Comfort PnU Kit compliance is made by the assessment of the reaction to fire individual classification of its components (according to the European Assessment Document EAD 090062-01-0404 *Kits for external wall claddings mechanically fixed*, harmonised technical specification for CE marking under Construction Products Regulation UE 305/2011).

- Steel cladding tiles and steel substructure are class A1 according to Commission Decision 96/603/EC, as amended.
- Mineral wool insulation (ECOVENT 034) is class A1 as given in the manufacturer's Declaration of Performance (DoP Nº) ES0001-087 (es) 20201214 according to EN 13162 (harmonised product standard for CE marking).
- PV modules (SI-ESF-M-BIPV-CT-M156-14) are mainly made from non-combustible materials (tempered glass layers and monocrystalline PV cells) and are class A1 according to Commission Decision 96/603/EC, as amended. Moreover, tested in accordance with the reference international standard UL 790 *Standard Test Methods for Fire Tests of Roof Coverings (Building Integrated Photovoltaics – BIPV products only)*,

the PV modules obtained a Class A: best rating that can be achieved according to UL 790, which describes the ability of the modules to resist external fire as "effective against severe fire exposure".

- Window: reaction to fire is not a relevant characteristic for façade windows according to EN 14351-1 (harmonised product standard for CE marking) and, therefore, it is not part of the assessment.
- Ventilation air handling unit: reaction to fire is not a relevant characteristic according to the applicable European legislation (EMC Directive 2014/30/EU and Ecodesign Directive 2009/125/EC). The reaction to fire Euroclasses system established in EN 13501-1 does not apply to the ventilation unit under Regulation UE 305/2011. Therefore, it is not part of the assessment.

Therefore, by the assessment of the worst-case of the individual components that integrate DENVELOPS Comfort PnU Kit, it can be stated that DENVELOPS Comfort PnU Kit installed in Terrassa demo site **COMPLIES** with the applicable reaction to fire requirements.

Additional considerations

Local regulations do not pose any specific, additional requirement beyond CTE DB-SI2 provisions, regarding fire safety.

Finally, as a general consideration, the CTE DB-S2I does not establish any requirement on Façade fire performance (large-scale testing for façade constructive systems), as it occurs in several European countries (see next table).

TABLE 42 METHODS APPLIED IN EU MEMBER STATES FOR ASSESSING THE FIRE PERFORMANCE OF FACADES

Country	Assessment method
Austria	ÖNORM B 3800-5
Czech Republic	ČSN ISO 13785-1
Denmark, Sweden, Norway	SP Fire 105
Finland	SP Fire 105, BS 8414
France	LEPIR 2
Germany	DIN 4102-20 Complementary reaction-to-fire test for claddings of exterior walls, Technical regulation A 2.2.1.5
Hungary	MSZ 14800-6:2009 Fire resistance tests. Part 6: Fire propagation test for building façades
Ireland	BS 8414 (BR 135)
Poland	PN-B-02867:2013
Switzerland, Liechtenstein	DIN 4102-20, ÖNorm B 3800-5 Prüfbestimmung für Aussenwandbekleidungssysteme

Therefore, although not necessary for the technical justification of the DENVELOPS Comfort PnU Kit compliance with the regulatory requirements in CTE DB-SI for the Terrassa demo case, the determination of the façade fire performance might be an added value for a future kit certification, facilitating the product marketing across European countries.

3.3.3 Czech Republic

According to the information provided by the partner, the original RDR solution –that has been further developed in the design of the PLURAL PnU kit– is certified to comply with the relevant fire regulations, and the design adjustments introduced to adapt the solution do not affect such a compliance.

The ConExWall PnU kit is installed in 3 different ways:

- Basic type is installation as external insulation complex on external wall. In this case external walls are constructed from non-combustible materials – typically concrete, bricks, stones (with a reaction to fire class A1 in according to Commission Decision 96/603/EC, as amended).

Fire regulations require structural elements to have a specific fire resistance. However, in this case ConExWall is not load-bearing constructive element and therefore no requirement applies.

The ConExWall has only influence on fire risk area which defines the minimum distance from neighbouring buildings. Dimensions of fire risk area depend on the specific layers' composition, the characteristics of the external layer (e.g., plaster, wood cladding) and the windows dimensions. Dimensions of fire risk area are individually calculated for each specific case according to fire safety codes. In the case of Kasava demo site the neighbouring buildings are sufficiently far away to meet the distance requirements.

- Installation ConExWall as loadbearing external walls in last storey requires a specific fire resistance performance or protection of the structural elements, which is achieved by installing an internal fire-rated lining made of gypsum plasterboards or gypsum fibre-reinforced plasterboards, which provides the required resistance to fire protection (e.g., standard Fermacell or Knauf fire separating partitions already tested according to EN 1364-1 and classified according to EN 13501-2).

Influence on fire risk area is individually calculated as in first case.

- Installation ConExWall as a roof element requires a specific fire resistance performance or protection of the structural elements, which is achieved by installing an internal fire-rated ceiling made of gypsum plasterboards or gypsum fibre-reinforced plasterboards, which provides the required resistance to fire protection (e.g., standard Fermacell or Knauf fire-protective ceilings already tested according to EN 1364-2 and classified according to EN 13501-2).

3.4 Acoustic compliance

3.4.1 Greece

The buildings have to be designed and constructed in such a way as to protect the occupants from all forms of noise. Acceptable acoustic comfort has to be ensured, taking the necessary building sound insulation and sound protection measures. The parameters and the categories of acoustic comfort are defined in Greek Building Regulation.

3.4.1.1 Acoustic comfort parameters

The acoustic comfort of a building is its ability to protect the occupants from extraneous noises and provide a suitable acoustic environment for accommodation. The acoustic comfort is determined by a set of parameters regarding the sound insulation and sound protection of the space:

- airborne sound, produced in neighbouring spaces
- the impact sound, produced in neighbouring areas
- the airborne sound, produced by shared or private facilities of the same building
- airborne sound, produced by external sources

The definitions of the acoustic comfort parameters, R_w, R'_w, $L_{n,w}$, L_{pA} are shown in Table 43.

TABLE 43: ACOUSTIC COMFORT PARAMETERS

	Acoustic comfort parameter				Measured			
	Name	Symbol	Units	Standard	Name	Symbol	Units	Standard
Airborne sound	Weighted sound reduction index	R_w	dB	461.1	Sound reduction index	R	dB	370.3
	Weighted apparent sound reduction index	R_w	dB	461.1	Apparent sound reduction index	R’	dB	370.4
Impact sound	Weighted normalized sound pressure level of impact sound	$L_{n,w}$	dB	461.2	Normalized sound pressure level of impact sound	L'_n	dB	370.7 370.8
Airborne sound, produced by external sources	Hourly equivalent A - sound level	$L_{Aeq,h}$	dB (A)	230	A - sound level	L_{pA}	dB (A)	230
Airborne sound, produced by shared or private facilities	A - sound level	L_{pA}	dB (A)	229	A - sound level	L_{pA}	dB (A)	229

3.4.1.2 Acoustic comfort categories

The new buildings are classified into the following categories of acoustic comfort categories:

a. Class A: High acoustic comfort
b. Class B: Normal acoustic comfort
c. Class C: Low acoustic comfort

All new buildings have to meet at least the requirements of acoustic comfort class B.

3.4.1.3 Sound insulation - sound protection criteria

The criteria of sound insulation - sound protection are the limit values of the acoustic comfort parameters for each type of sound insulation – sound protection and each class of acoustic comfort. The requirements for all types of buildings are expressed by 9 criteria, summarized in Table 44 and Table 45. During the design of buildings, the relationship between R_w and R'_w has to be taken into account, according to Table 46.

TABLE 44: SOUND INSULATION - SOUND PROTECTION CRITERIA. CLASS A - HIGH ACOUSTIC COMFORT.

Building	Sound insulation from neighboring (main or auxiliary use) spaces and public spaces		Sound insulation of residence from other main use		Sound insulation from		Sound insulation among the spaces of the same residence	Sound insulation of main space from facility spaces	
					External sources	Facility sound			
	1	2	3	4	5	6	7	8	9
	R'_w	$L'_{n,w}$	R'_w	$L'_{n,w}$	$L_{Aeq,h}$	L_{pA}	R'_w	R'_w	$L'_{n,w}$
	dB	dB	dB	dB	dB	dB	dB	dB	dB
Residential building	54	55	-	-	30	25	48	60	45
Offices	52	60	58	52	35	30	-	55	55
Education	57	58	58	52	30	25	-	60	45
Health	57	55	58	52	30	25	-	60	45
Industry	65	40	62	47	(25)	(25)	-	(65)	(40)

TABLE 45: SOUND INSULATION - SOUND PROTECTION CRITERIA. CLASS B - NORMAL ACOUSTIC COMFORT.

Building	Sound insulation from neighboring (main or auxiliary use) spaces and public spaces		Sound insulation of residence from other main use		Sound insulation from		Sound insulation among the spaces of the same residence	Sound insulation of main space from facility spaces	
					External sources	Facility sound			
	1	2	3	4	5	6	7	8	9
	R'_w	$L'_{n,w}$	R'_w	$L'_{n,w}$	$L_{Aeq,h}$	L_{pA}	R'_w	R'_w	$L'_{n,w}$
	dB	dB	dB	dB	dB	dB	dB	dB	dB
Residential building	50	60	-	-	35	30	42	55	50
Offices	40	65	52	55	40	35	-	53	60
Education	50	65	55	55	35	30	-	55	50
Health	50	60	55	55	35	30	-	53	50
Industry	60	45	60	48	(25)	(25)	-	(62)	(45)

TABLE 46: RELATION BETWEEN R_W AND R'_W.

R'_w [dB]	R_w [dB]
up to42	$R'_w + 0$
43 – 48	$R'_w + 2$
48 – 52	$R'_w + 3$
53 – 55	$R'_w + 4$
56 – 60	$R'_w + 6$

According to deliverable “D2.7 Final stage complete design of PnU kits” it was decided by VVV Municipality not to include a ventilation system in the final PnU solution, in order not to complicate the system. SmartWall PnU kits either contain commercial and certified to noise elements and/or their acoustic performance has already been evaluated in the frame of the Task 4.1.

Regarding the commercial elements, the following table summarizes the technical characteristics of the slim type FWXM10ATV3 fan-coils by DAIKIN fitted internally in the SmartWall solution.

Sound power level		FWXM10ATV3
Min.	dBA	35
Med.	dBA	45
Max.	dBA	53

This sound power level values fall into the standard noise levels of other indoor domestic heating and cooling systems and will not affect neighbourhood noise levels, so we can consider that the system used by the SmartWall solution is **IN COMPLIANCE** with the Greek regulation.

We can also state that the same solution would be **IN COMPLIANCE** with the Spanish and Czech acoustic regulations.

3.4.2 Spain

The following table summarizes the results of the Full-scale model measurements in the building acoustic laboratory. The full-scale model was used to measure the emitted sound pressure level during the real operation of the unit (unit equipped with the silencer boxes, with the real mounting on the façade). For the tested volume flow rates, values from 23.3 to 43.4 dB(A) were measured. The values are about 2.5 dB(A) higher than the ones measured on the sample unit in the Anechoic acoustic laboratory (free acoustic field, direct acoustic field only). Such difference between both experiments is acceptable. This small difference defines that mounting of the unit does not deteriorate the acoustic comfort in the indoor environment. The structural noise propagation caused by transfer of the unit vibrations through the anchorage to the solid façade was negligible.

The night operation of the eAHC unit is possible with the maximum volume flow rate of 35 m^3/hod. In this operation mode the unit generates sound pressure level below 25 dB, meeting the night noise limits L_{AMAX} = 25 dB.

Voltage [V]		Flow rate [m^3/hod]		Sound pressure level corrected by A filter at a distance 1 m [dB]			
				INTERIOR (Summary Supply and Extract + structural noise from mounting the unit on the façade	**Acoustic laboratory (free filed, only direct acoustic field) – sources measured separately, without negative effect from structural mounting of the unit on the façade**		
Supply	**Extract**	**Supply**	**Extract**		**Supply**	**Extract**	**Summary**
4.1	4.62	35	35	23.3	14.5	19.8	20.9
7.05	7.73	75	75	35.3	25.1	32.2	33.0
10	10	115	100	43.4	-	-	

RESULTS OF THE FULL-SCALE MODEL MEASUREMENT, COMPARISON OF THE REAL AND LABORATORY ACOUSTIC MEASUREMENT

According to the results of the laboratory tests and the sound pressure parameters given by the manufacturer we can conclude that:

- Based on laboratory tests, the eAHC unit **COMPLIES** with the sound pressure limit values for a volume flow rate of 35 m^3/hod. This unit does **NOT COMPLY** when providing a volume flow rate of 75 m^3/hod or greater.

3.4.3 Czech Republic

The measurement of acoustic parameters was performed in the CVUT laboratory and a comparison with the values stated by the manufacturer and the hygienic limit values. The measurement was performed only with the Helty Flow 40 unit, as the Helty Flow 70 unit was not available at the time of the measurement. The following table show the sound pressure values specified by the manufacturer and the measured values.

TABLE 47 SOUND PRESSURE LEVEL OF HELTY FLOW 40

	Technical list parameters		Laboratory measurement		Sound pressure level limit according to No. 272/2011 Coll. [dB]	
Level of fan speed	**Air flow rate [m^3/h]**	**Pressure level in technical list [dB]**	**Pressure level $L_{pA,1m}$ [dB]**	**Tonal component in the spectrum according to No. 272/2011 Coll. [Hz]**	**Day**	**Night**
1	8.1	15	20.5	200, 250	35	25
2	14.4	20.9	26.0	Almost for 315		
3	22.0	26.3	33.3	No		
4	38.0	34.5	41.6	630		
turbo	42.1	-	43.7	630		

Based on the measurements of unit Helty Flow 40, the measurement showed a difference of approximately 6 dB between the measured values and the values given by the manufacturer. We can assume that a similar difference will be found for the unit Helty Flow 70. The values from the manufacturer´s data sheet is given in Table 48 Sound pressure level of Helty Flow 70.

TABLE 48 SOUND PRESSURE LEVEL OF HELTY FLOW 70

	Technical list parameters		Sound pressure level limit according to No. 272/2011 Coll. [dB]	
Level of fan speed	**Air flow rate [m^3/h]**	**Pressure level in technical list [dB]**	**Day**	**Night**
1	20	24.3	35	25
2	40	28.1		
3	55	31.8		
4	70	35.2		
turbo	85	-		

According to the results of the laboratory tests and the sound pressure parameters given by the manufacturer we can conclude that:

- Based on laboratory tests, Helty Flow 40 unit **COMPLIES** with the sound pressure limit values for day operation in mode 1 to 3 and for night operation only in mode 1. This unit does **NOT COMPLY** when using mode 4 or turbo during the day and modes 2 to turbo during the night.
- Based on manufacturer's data, Helty Flow 40 unit **COMPLIES** with the sound pressure limit values for day operation in mode 1 to 4 and for night operation only in mode 1 or 2. This unit does **NOT COMPLY** when using turbo mode during the day and modes 3 to turbo during the night.
- Based on manufacturer's data, Helty Flow 70 unit **COMPLIES** with the sound pressure limit values for day operation in mode 1 to 3 and for night operation only in mode 1. This unit does **NOT COMPLY** when using mode 4 or turbo during the day and modes 2 to turbo during the night. However, as mentioned above, it can be assumed that the real values of the sound pressure level will be higher than specified by the manufacturer.

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4. Conclusions

The current deliverable (D8.1 "Product requirement") analyses the final PnU characteristics and assesses their compliance with the regulations and standards applicable in each country of the real demo sites (Greece, Spain and Czech Republic). The analysis is divided into 4 main characteristics:

- Thermal characteristics: making sure the PnU complies with its U-values the national regulation for the respective demo sites.
- Hydrothermal characteristics: making sure that the whole solution (existing exterior and PnU installed) does not present condensation.
- Fire resistance/reaction characteristics: ensure that national regulations for fire protection are met.
- Acoustic characteristics: making sure the different units do not exceed the regulatory levels of noise allowed in each demo site location.

Smart Wall in Vari-Voula-Vouliagmeni (Greece)

Thermal: All SmartWall configurations (Blank type, PnU with window (no fan-coil), PnU with fan-coil (no window) and Complete PnU with window and fan-coil) are **IN COMPLIANCE** with the Greek thermal regulations. Same existing façade and Smart Wall configurations would be in **COMPLIANCE** with ALL climate zones in Greece, Spain and Czech Republic.

Hydrothermal: All Smart Wall configurations (Blank type, PnU with window (no fan-coil), PnU with fan-coil (no window) and Complete PnU with window and fan-coil) are **IN COMPLIANCE** and do **NOT** have interstitial condensation. Same existing façade and Smart Wall configurations would be in **COMPLIANCE** in Spain and Czech Republic.

Fire: All Smart Wall configurations (Blank type, PnU with window (no fan-coil), PnU with fan-coil (no window) and Complete PnU with window and fan-coil) were classified as B-s1, d0 and so they are **IN COMPLIANCE** with the Greek fire regulations.

Acoustic: Sound power level values fall into the standard noise levels of other indoor domestic heating and cooling systems and will not affect neighbourhood noise levels, so we can consider that the system used by the SmartWall solution is **IN COMPLIANCE** with the Greek regulation. Same solution would be **IN COMPLIANCE** with the Spanish and Czech acoustic regulations.

It should be added that the SmartWalls have been designed to comply with the Greek seismic regulations.

DENVELOPS Comfort/eAHC in Terrassa (Spain)

Thermal: All DENVELOPS Comfort wall configurations (Blank type, PnU with AHU (off) and PnU with AHU (in operation)) are **IN COMPLIANCE** with the Spanish thermal regulations. Same existing façade

and DENVELOPS Comfort wall configurations would be in **COMPLIANCE** with ALL climate zones in Greece, Spain and Czech Republic.

Hydrothermal: All DENVELOPS Comfort wall configurations (Blank type, PnU with AHU (off) and PnU with AHU (in operation)) are **IN COMPLIANCE** and do **NOT** have interstitial condensation. Insultation used in DENVELOPS comfort is designed to be able to be wet without losing its technical characteristics. Same existing façade and DENVELOPS Comfort configurations would be in **COMPLIANCE** in Spain and Czech Republic.

Fire: The worst-case assessment of the individual components that integrate DENVELOPS Comfort PnU Kit states that DENVELOPS Comfort PnU Kit **COMPLIES** with the Spanish reaction and resistance to fire requirements.

Acoustic: The eAHC unit **COMPLIES** with the sound pressure limit values in Greece, Spain and Czech Republic for a volume flow rate of 35 m^3/hod. This unit does **NOT COMPLY** when providing a volume flow rate of 75 m^3/hod or greater.

ConExWall/eWHC in Kašava (Czech Republic)

Thermal: ConExWall wall configurations (Blank type and PnU with ventilation system (no windows)) are **IN COMPLIANCE** with the Czech thermal regulations. Configuration "Complete PnU with window and ventilation system" is **IN COMPLIANCE** (needed a separate analysis for the windows) due to its declared values as a whole didn't match with the regulations. Windows are in compliance with the regulation (values recommended for passive buildings).

Same existing façade and ConExWall wall configurations would be in **COMPLIANCE** with ALL climate zones in Greece, Spain and Czech Republic.

Hydrothermal: All ConExWall wall configurations (Blank type, PnU with ventilation system (no windows) and Complete PnU with window and ventilation system) are **IN COMPLIANCE** and do **NOT** have interstitial condensation. Same existing façade and ConExWall configurations would be in **COMPLIANCE** in Spain and Czech Republic.

Fire: All ConExWall wall configurations MEET THE REQUIREMENTS in Czech Republic regulations regarding reaction to fire, as stated in the available certification, and regarding the resistance to fire performance of the structural elements due to the fire protective solutions. Requirements on fire risk area are also fulfilled in the case of Kasava demo site due to the distance of the neighbouring buildings.

Acoustic: The ventilation unit Helty Flow 40 unit **COMPLIES** with the sound pressure limit values in Greece, Spain and Czech Republic for day operation in mode 1 to 3 and for night operation only in mode

1. This unit does **NOT COMPLY** when using mode 4 or turbo during the day and modes 2 to turbo during the night.

The ventilation unit Helty Flow 70 unit **COMPLIES** with the sound pressure limit values in Greece, Spain and Czech Republic for day operation in mode 1 to 3 and for night operation only in mode 1. This unit does **NOT COMPLY** when using mode 4 or turbo during the day and modes 2 to turbo during the night.

Thermally and hydrothermally, all solutions comply with all regulations under study and grants the possibility to apply these solutions in other countries of the EU. Regarding fire resistance and reaction further analysis per country should be performed to state the same conclusions than the previous characteristics. Overall, the acoustic compliance will depend on the flow rate and speed mode for each ventilation unit. All units in the lowest flow rate and speed mode are consistently in compliance with all the requirements from the different countries under study.

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