2020-NMBP-ST-IND-2018-2020-GA 958218

PLUG-AND-USE RENOVATION WITH ADAPTABLE LIGHTWEIGHT SYSTEMS

PLURAL

D6.4

Installation and in-situ validation methodologies

Version: 1.0

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

	Name	Date
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Distribution list

External		Internal	
European Commission	1x	Consortium partners	1x

Change log

Issue	Date	Remark / changes	Pages
0.1	10/05/2022	Defined document structure and adding information	All
0.2	01/02/2023	Input from contributors received	All
0.3	01/03//2023	First version by DEN	All
0.9	03/04/2023	Final version reviewed by technical manager	All
1.0	10/04/2023	Final version reviewed – edited by Project Coordinator-submitted	All

Disclaimer

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Terms, definitions, and abbreviated terms

F.Q.P.	Factory qualities procedures
PnU	Plug and Use (Acronym for the prefabricated façade kits developed in PLURAL)

1 Publishable summary

This report aims to present the in situ-installation methodologies of all the PLURAL PnU kits intended for installation at the three real demonstration buildings of PLURAL in Spain, Czech and Greece. The described in situ-installation methodologies are based on the knowledge and experience earned during the design, manufacturing, and prototyping phases of PLURAL PnU kits.

The installation methodologies were validated via tests executed during the PnU prototype manufacturing, and prior to their mass production at the manufacturers' plants, aiming to identify and correct installation errors and/or installation methodology inaccuracies, and/or defects that might occur either to the PnU kits or to the building envelope during their installation.

Furthermore, all actions described in the current report, were driven by the necessity to modify and adjust all installation methodologies in such a manner as to minimize occupants' disturbance, noise, dust and fumes generation in comparison to the traditional installation methods. Moving a step forward, alternative installation methodologies are proposed for each PLURAL PnU kit intended for installation at the virtual demo buildings.

2 Introduction

One of the most challenging aspects during the development of the installation methodology of each PnU kit is its proper implementation on the ongoing renovation plan as scheduled by the building owner. The PnU kits implementation to the *"as planned by the owners"* renovation activities is complex in technical terms and conditions, as well as in relation to their introduction as part of the *"traditional building"* renovation schedule.

By exploiting the results of the prototyping campaign described in D4.5 "PnU kit prototype property and performance characterization" (submitted M27), installation errors, defects, discrepancies, material and components mistreatment and technical omissions and/or mistakes were identified. They were used as a baseline by the manufacturers in order to develop a range of tests to be performed at their premises to ensure that the installation methodologies are complying with the National Regulations and Normatives.

In this sense, the manufacturers investigated and evaluated in their plants the proposed installation methodologies, focusing on:

a. safety on site.
b. environmental impact during installation e.g. dust, noise, fumes etc.
c. creation of the minimum possible disturbance to the building's occupants, during execution of works.

Furthermore, self-improving methodologies (6σ of LEAN methodology under the form of Quality Assurance Plan to be described in T6.3) were adopted, aiming to reduce not only the installation time and cost, but also to increase its in-situ application efficiency. As a result of this process, a series of interactive loops between the human involvement at every installation step and the necessary remedial actions during manufacturing are identified and developed. This procedure allowed the manufacturers to improve not only the installation methodology for their products but also their production line efficiency.

Almost the 17% of the mistakes/omissions[1] that might occur during a "traditional construction process" are related with the installation process. Therefore, implementation of LEAN processes to the PnU kits installation methodology can minimize installation errors, defects, and omissions.

The current deliverable D6.2 is the outcome of Task 6.2 "Assembly methodology and planning" (M18-M2630) and is prepared with the contribution of PnU and their component manufacturers (DEN, AMS, CVUT, BGTC, SPF, DAIK, RECUAIR, RDR). The results presented in D6.2 provide input to the majority of activities in WP7 "Real and virtual building demonstration. Pre-and post-renovation monitoring and assessment. Validation of PLURAL solutions activities". Additionally, they support

T8.3 "Business model for PLURAL solutions and PnU kit appraisal report " and T8.4 "Business Case analysis and assessment" by identifying the installation costs and time and by validating at least 50% reduction in comparison with the commercial products.

[1] https://www.researchgate.net/publication/320942738_Errors_Defects_and_Safety_Control_at_Construction_Stage

3 SmartWall – Installation Methodology

The SmartWall PnU kits will be installed at the Vary Voula Vouliagmeni – VVV demonstration site in Greece.

3.1 Design & installation requirements

3.1.1 Structural stability

When considering structural stability, the following loads have been taken into account **(and should be the base point by the designers of the facades in any future application)**:

- Dead weight
- Wind loads (wind uplift and wind pressure)
- Snow and ice
- Dynamic (shock) loads
- Special cases (seismic loads, signage)

Proof of the structural stability of the facade system, has been provided in a verifiable form in accordance with the state of the art and the applicable European Regulations in the *Deliverables D2.1 – Architectural & Structural Design of PnU kits* and *D2.7 –Final Stage Complete Design of PnU kits.*

The proof of structural stability, in particular, included the structural stability calculations for the substructure, the cladding and the anchoring and connecting or fastening components, as well as, earthquake simulations and live testing in NTUA premises.

Where necessary, the applicable special loads (impacts, relatively mild forms of vandalism such as balls being thrown on to it, etc.) were taken into account (more closely spaced substructure members) in areas where special stresses of this kind are to be expected.

3.1.2 Fire protection

Facades must comply with the applicable national requirements regarding fire protection. The planning of fire protection measures was investigated in *Deliverable D4.1 – Optimization of PnU kits – Main Components*. Several fire-tests were executed to verify SmartWall systems fire-protection, and they have been presented in *Deliverable D4.5 - PnU kit prototype property and performance characterization*.

3.1.3 Thermal insulation and protection from dampness

The thermal performance of PnU kits has been fully analyzed and presented in the *Deliverables D4.1 – Optimization of PnU kits – Main Components* and *D4.5 - PnU kit prototype property and performance characterization*.

In addition, SmartWall systems, in terms of its cladding and substructure, has been designed and constructed in such a way that any rainwater does not allow to penetrate behind SmartWall system and

any condensation is drained away to the exterior in a controlled manner.

3.1.4 Deformation

Due to the nature of SmartWall systems, minor deformation may occur, in particular, due to temperature fluctuations and changes in humidity, which at the time that this report is written is not possible to determine its existence or its effect to the SmartWall systems, as the installation of the systems in the demo building has not started yet.

Though in future, attention must be paid to the local temperature differences (ΔT) (usually within the -20° to+80°C range). Deformation must not cause individual parts of the SmartWall panel to become loose and must have no detrimental effect on the structural stability of the facade. Such effects can be avoided, for example, by the following:

- Division of the substructure and cladding into separate areas (e.g. height of each floor);
- The positioning and size of joints;
- Avoidance of forces of constraint during installation of the facade cladding and substructure through use of fixed and sliding points or other suitable measures Building expansion joints must be taken into account by the substructure and cladding and allowance made accordingly.

3.1.5 Tolerances

The surface of the facade cladding must be flat and even.

Any unevenness of the load-bearing surface must be taken into account right at the planning stage and evened out by the supporting substructure. The permissible degree of unevenness of the load-bearing surface or facade must be defined by a structural survey.

3.1.6 Air-tightness

Requirements regarding the airtightness of the external envelope of the building have been fulfilled by its design and construction. SmartWall systems contribute to the airtightness of the building at its installation extent.

3.1.7 Soundproofing

Requirements in terms of soundproofing were taken into account and presented in the *Deliverable D4.1 – Optimisation of PnU kits – Main Components*.

3.1.8 Lightning protection

Lightning protection requirements have been met at the design stage as presented in *Deliverables D2.1 – Architectural & Structural Design of PnU kits* and *D2.7 – Final Stage Complete Design of PnU kits* and SmartWall systems are fully compatible with the national and European regulations (no cover to any lighting points or openings at the façade).

3.1.9 European regulations

The standards applicable to SmartWall have been extensively analyzed In Deliverables *D1.1 - Requirements: Context of application, building classification, used consideration - Definition* of requirements and constraints and *D1.3 - Certification requirements accounting for occupant legal and privacy monitoring*. Briefly summarizing them:

3.1.9.1 Steel members & frame

At a European level, harmonized standards in terms of general action and design of steel structures apply to facade substructures.

This harmonized standard is applicable and is required in all CEN member states.

For steel substructures for rain screens/ventilated facades, the following European harmonized standards / codes are required:

- EN 1993-1-1:2005[2] Part 1: General actions
- EN 1993-1-6:2007[3] Part 1-6: Strength and stability of shell structures
- EN 1993-1-8:2005[4] Part 1-8: Design of joints
- EN 1993-1-10:2005[5] Part1-10: Material toughness and through-thickness properties
- EN 1993-1-3:2006[6] Part 1-3: General rules - Supplementary rules for cold-formed members and sheeting

3.1.9.2 Electromechanical equipment

The electric storage module is mainly covered by the following European regulations:

- Low Voltage Directive (LVD) 2014/35/EU[7] and
- Electromagnetic Compatibility (EMC) Directive 2004/108/EC[8]
- EN 14511:2022 + 14825:2022- Standards for Air conditioners all parts9
- BS EN 15879-1:2011[10] & BS EN 16147:2017[11] – Standards for heat pumps with electrical driven compressors

[2] https://eurocodes.jrc.ec.europa.eu/EN-Eurocodes/eurocode-3-design-steel-structures

[3] https://www.en-standard.eu/bs-en-1993-1-6-2007-a1-2017-eurocode-3-design-of-steel-structures-strength-and-stability-of-shell-structures/

[4] https://www.en-standard.eu/bs-en-1993-1-8-2005-eurocode-3-design-of-steel-structures-design-of-joints/

[5] https://www.en-standard.eu/bs-en-1993-1-10-2005-eurocode-3-design-of-steel-structures-material-toughness-and-through-thickness-properties/

[6] https://www.en-standard.eu/bs-en-1993-1-3-2006-eurocode-3-design-of-steel-structures-general-rules/

[7] https://eur-lex.europa.eu/legal-content/EN/TXT/?uri=CELEX:32014L0035

[8] https://eur-lex.europa.eu/legal-content/EN/ALL/?uri=celex%3A32004L0108

[9] https://www.en-standard.eu/en-14511-2022-14825-2022-standards-for-air-conditioners-all-parts/?gclid=CjwKCAjwp9qZBhBkEiwAsYFsbzdPUOvay-jiJ--Jni83uFzDIhU9GsynBRgfi3AGT5R3bbm7_fLuzxoCOS8QAvD_BwE

[10] https://www.en-standard.eu/bs-en-15879-1-2011-testing-and-rating-of-direct-exchange-ground-coupled-heat-pumps-with-electrically-driven-compressors-for-space-heating-and-or-cooling-direct-exchange-to-water-heat-pumps/

[11] https://www.en-standard.eu/bs-en-16147-2017-heat-pumps-with-electrically-driven-compressors-testing-performance-rating-and-requirements-for-marking-of-domestic-hot-water-units/

- EN 60335-1 - Household and similar electrical appliances - Safety - Part 1: General requirements[12]
- EN IEC 61215-1 - Terrestrial photovoltaic (PV) modules - Design qualification and type approval - Part 1: Test requirements[13]
- EN IEC 61730 - Photovoltaic (PV) module safety qualification - Part 1: Requirements for construction[14]
- BS EN 55014-1:2017 Electromagnetic compatibility. Requirements for household appliances, electric tools and similar apparatus - Emission[15]
- Directive 2006/66/EC Batteries & Accumulators[16]
- Hazardous substances Directive 2011/65/EU (RoHS)[17]
- Machinery Directive 2006/42/EC (MD)[18]

If a product is not covered by a European harmonized standard or code, it is necessary to have an ETA (European Technical Assessment) that is valid in all EOTA member states or a national approval for the applicable country (Example: For Germany: National Approval from the DIBt-German Technical Approval body).

3.1.10 SmartWall installation limitations

Despite the fact that SmartWall systems are flexible and versatile and is possible to be installed in a very wide range of buildings, there are some limitations which need to be carefully considered when designing the SmartWall systems. These limitations are mainly focused on:

- the height of the building and
- the size of SmartWall panel

They are analyzed and clearly presented in:

- *Deliverables D2.2 – Technologies and Materials selected for demo the demo sites* and *D2.1 – Architectural and Structural Design*
- Table *SmartWall Technologies' Compatibility Matrix included in Deliverable D2.2 – Technologies and Materials selected for demo the demo sites*

[12] https://www.en-standard.eu/bs-en-60335-1-2012-a15-2021-household-and-similar-electrical-appliances-safety-general-requirements/
[13] https://www.en-standard.eu/csn-en-61215-1-terrestrial-photovoltaic-pv-modules-design-qualification-and-type-approval-part-1-test-requirements/
[14] https://www.en-standard.eu/une-en-iec-61730-1-2019-photovoltaic-pv-module-safety-qualification-part-1-requirements-for-construction/
[15] https://www.en-standard.eu/bs-en-55014-1-2017-electromagnetic-compatibility-requirements-for-household-appliances-electric-tools-and-similar-apparatus-emission/?gclid=CjwKCAjwp9qZBhBkEiwAsYFsb_x8fSH4xk00Mjg387ikD2r1owgfqxuSAr7xzgBBkt3p3J1v1ALLUBoCuMcQAvD_BwE
[16] https://eur-lex.europa.eu/legal-content/EN/ALL/?uri=CELEX%3A32006L0066
[17] https://eur-lex.europa.eu/legal-content/en/TXT/?uri=CELEX:32011L0065
[18] https://eur-lex.europa.eu/legal-content/EN/ALL/?uri=celex:32006L0042

3.1.11 Applicable sub-substrates for SmartWall installation

Based on the limitations of the previous paragraph, the surfaces to which SmartWall panels can be anchored may consist of standardized materials (e.g. concrete, brick, steel, timber, etc.) or non-standardized materials. (Surface layers such as rendering, coatings or facings do not count as load-bearing materials).

The following are suitable base materials:

- Concrete in accordance with EN 206:2013+A2:2021[19]
- Bricks in accordance with EN 771-3:2011+A1:2015[20]
- Sand-lime block in accordance with EN 771-3:2011+A1:2015
- Aerated concrete in accordance with EN 771-3:2011+A1:2015
- Timber in accordance with CSN EN 14081-1[21]
- Composite lumber in accordance with UNE EN 14080:2013[22]
- Steel frame structures in accordance with DIN EN 1090 Part 1-5[23]
- Existing/unclassified masonry (load-bearing capacity must be verified by pull-out tests)
- Sandwich components (e.g. metal, concrete or lightweight concrete) may be considered suitable only after verification

3.2 SmartWall systems installation methodology at VVV demo building

3.2.1 Installation layout, requirements, and strategy

Figure 1 interprets the data of the Architectural Design of VVV demo building, as presented in *Deliverables:*

- *D2.1 – Architectural and Structural Design,*
- *D2.6 – First Stage Design of PnU kits and*
- The minor modifications occurred by the *WP4 Optimization of PnU Components, as* presented in *D2.7 – Final Stage Design of PnU kits*

[19] https://www.en-standard.eu/bs-en-206-2013-a2-2021-concrete-specification-performance-production-and-conformity/

[20] https://www.en-standard.eu/bs-en-771-3-2011-a1-2015-specification-for-masonry-units-aggregate-concrete-masonry-units-dense-and-lightweight-aggregates/

[21] https://www.en-standard.eu/csn-en-14081-1-timber-structures-strength-graded-structural-timber-with-rectangular-cross-section-part-1-general-requirements/

[22] https://www.en-standard.eu/une-en-14080-2013-timber-structures-glued-laminated-timber-and-glued-solid-timber-requirements/

[23] https://www.en-standard.eu/set-en-1090-part-1-5-standards-for-execution-of-steel-structures-and-aluminium-structural/

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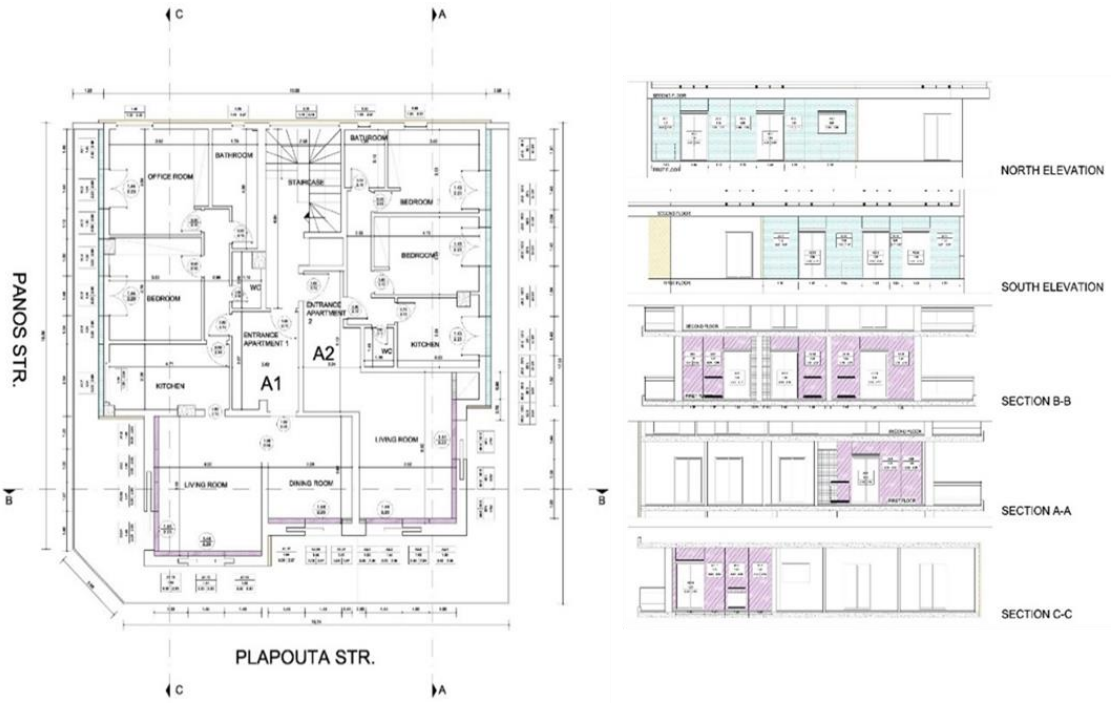

FIGURE 1: LAYOUT OF SMARTWALL INSTALLATION IN VVV DEMO BUILDING

There will be installed in total:

- 17 "SmartWall" panels in apartment A1 (7 exterior and 10 interior panels)
- 16 "SmartWall" panels in different dimensions in apartment A2 (9 exterior and 7 interior panels)

Table 1 interprets the outcome of the architectural design in terms of SmartWall panels' dimensions, type and layout per building's area that will be installed in the Greek demo site, while *Table 2* indicates on which SmartWall panels E/M components will be installed.

AREA	ID	TYPE	LENGTH (M)	WIDTH (M)	HEIGHT (M)	FLOOR DISTANCE (M)	OPENINGS
APARTMENT A1-OFFICE ROOM	A1.1	EXTERIOR	1,45	0,185	2,99	0	N/A
	A1.2	EXTERIOR	1,44	0,185	0,76	2,23	BALCONY DOOR
	A1.3	EXTERIOR	1,12	0,185	2,99	0	N/A
APARTMENT A1-BEDROOM	A1.4	EXTERIOR	1,36	0,185	2,99	0	N/A
	A1.5	EXTERIOR	1,44	0,185	0,76	2,23	BALCONY DOOR
	A1.6	EXTERIOR	1,04	0,185	2,99	0	N/A
APARTMENT A1-	A1.7	EXTERIOR	2,64	0,185	2,99	0	WINDOW

APARTMENT A1-LIVING ROOM	A1.8	INTERIOR	1,2	0,17	2,93	0	N/A
	A1.9	INTERIOR	1,2	0,17	2,93	0	N/A
	A1.10	INTERIOR	1,07	0,17	2,93	0	N/A
	A1.11	INTERIOR	1,46	0,17	0,7	2,23	BALCONY DOOR
	A1.12	INTERIOR	1,32	0,17	2,93	0	N/A
	A1.13	INTERIOR	1,44	0,17	0,7	2,23	BALCONY DOOR
	A1.14	INTERIOR	1,46	0,17	2,93	0	N/A
APARTMENT A1-DINING ROOM	A1.15	INTERIOR	1,44	0,17	2,97	0	N/A
	A1.16	INTERIOR	1,44	0,17	0,74	2,23	BALCONY DOOR
	A1.17	INTERIOR	0,41	0,17	2,97	0	N/A
APARTMENT A2-LIVING ROOM	A2.1	INTERIOR	0,26	0,17	2,96	0	N/A
	A2.2	INTERIOR	1,44	0,17	0,73	2,23	BALCONY DOOR
	A2.3	INTERIOR	1,06	0,17	2,96	0	N/A
	A2.4	INTERIOR	1,06	0,17	2,96	0	N/A
	A2.5	INTERIOR	1,09	0,17	2,96	0	N/A
	A2.6	INTERIOR	1,08	0,17	2,96	0	N/A
	A2.7	INTERIOR	1,44	0,17	0,73	2,23	BALCONY DOOR
	A2.8*	INTERIOR	0,76	0,17	2,96	0	N/A
	A2.9**	INTERIOR	0,98	0,17	2,96	0	N/A
APARTMENT A2-KITCHEN	A2.10	EXTERIOR	1,82	0,185	2,97	0	N/A
	A2.11	EXTERIOR	1,43	0,185	0,74	2,23	BALCONY DOOR
APARTMENT A2-BEDROOM 1	A2.12	EXTERIOR	1,84	0,185	2,97	0	N/A
	A2.13	EXTERIOR	1,43	0,185	0,74	2,23	BALCONY DOOR
	A2.14	EXTERIOR	0,64	0,185	2,97	0	N/A
APARTMENT A2-BEDROOM 2	A2.15	EXTERIOR	1,43	0,185	0,74	2,23	BALCONY DOOR
	A.2.16	EXTERIOR	1,55	0,185	2,97	0	N/A

TABLE 1: SMARTWALL PANELS DIMENSIONS

Area	Id	Type	Heating-Cooling	Ventilation	Smart Controls
Apartment A1-Office Room	A1.1	EXTERIOR	FWXM10ATV3	N/A	AMscope
	A1.2	EXTERIOR	N/A	OPENING'S FRAME	N/A
Apartment A1- Bedroom	A1.5	EXTERIOR	N/A	OPENING'S FRAME	N/A

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	A1.6	EXTERIOR	FWXM10ATV3	N/A	AMscope
Apartment A1- Kitchen	A1.7	EXTERIOR	FWXT15ATV3	OPENING'S FRAME	AMscope
Apartment A1-Living Room	A1.9	INTERIOR	FWXM10ATV3	N/A	AMscope
	A1.11	INTERIOR	N/A	OPENING'S FRAME	N/A
	A1.13	INTERIOR	N/A	OPENING'S FRAME	N/A
	A1.14	INTERIOR	FWXM10ATV3	N/A	AMscope
Apartment A1-Dining Room	A1.15	INTERIOR	FWXM10ATV3	N/A	AMscope
	A1.16	INTERIOR	N/A	OPENING'S FRAME	N/A
Apartment A2-Living Room	A2.2	INTERIOR	N/A	OPENING'S FRAME	N/A
	A2.3	INTERIOR	FWXM10ATV3	N/A	AMscope
	A2.7	INTERIOR	N/A	OPENING'S FRAME	N/A
	A2.8	INTERIOR	FWXM10ATV3	N/A	AMscope
Apartment A2- Kitchen	A2.10	EXTERIOR	FWXT15ATV3	N/A	AMscope
	A2.11	EXTERIOR	N/A	OPENING'S FRAME	N/A
Apartment A2-Bedroom 1	A2.12	EXTERIOR	FWXM10ATV3	N/A	AMscope
	A2.13	EXTERIOR	N/A	OPENING'S FRAME	N/A
Apartment A2-Bedroom 2	A2.15	EXTERIOR	N/A	OPENING'S FRAME	N/A
	A2.16	EXTERIOR	FWXM10ATV3	N/A	AMscope

TABLE 2: SMARTWALL PANELS WITH E/M COMPONENTS

All the relevant requirements to the installation of SmartWall systems in VVV demo building, have been fully analyzed and presented in *Deliverables D2.1 – Architectural & Structural Design of PnU kits* and *D2.7 – Final Stage Complete Design of PnU kits.*

In order to minimise the disturbance of the occupants in VVV demo building, it was decided to divide the installation of SmartWall systems in two (2) separate phases:

1. *Phase 1 - Installation of "auxiliary" to SmartWall systems*

   In this phase PVs, solar panels, heat pumps, and their pipework will be installed mainly in the roof of the building, which is "isolated" from the main living areas of the building, therefore, the disturbance to the occupants is limited (worker's access to the roof area via the staircase only).

2. *Phase 2 -Installation of SmartWall systems*

   In this stage is planned the installation of SmartWall panels inside and outside the apartments but also some "traditional" construction works, related to the auxiliary systems installation, such as:

- Plumbing works (main pipes of heating – cooling and DHW systems on the outside perimeter of the apartments) as per description of *Deliverable D2.4 – Heating and Cooling technologies selection*;
- Main power supply the PVs to the apartments (following the same route as the main pipework mentioned on the above and
- ETICS installation to the east façade of the building as per description of *Deliverable D2.6 – Final Stage design of PnU kits.*

There are several reasons that led to the division of SmartWall installation works in two different phases:

- The nature of renovation works and space limitation on working areas.

  Different kind of construction works will be executed in the same area. For example, in the roof must be installed:

  a. Roof insulation (VVV);
  b. Repairs on the balustrades (VVV);
  c. Exterior repairs and painting (VVV);
  d. TV & Wi-Fi cabling (VVV);
  e. PV panels (AMS);
  f. Solar panels (AMS);
  g. Heat pumps (AMS);
  h. Pipework (AMS).

  For this reason, the proposed works scheduling took into consideration not only the nature of works but also the space availability establishing a sequence of works that one task would not interfere to another.

- VVV Municipality contractual obligations, as occurring by the contract among them and the sub-contractor appointed for the 2nd Renovation Stage.

  As a result of the above paragraph (nature and space limitation) and due to the time clauses linked with financial penalties to the sub-contractor as these occurring by the contract signed with VVV Municipality, the sub-contractor requested as possible as minimum disturbance during the execution of the works by his side.

- Minimum disturbance of the occupants during renovation works

  The two previous reason serve one more purpose, to avoid overpopulation of working force in the building resulting to minimisation of occupant's disturbance.

  Furthermore, the majority of works will be executed outside the apartments, resulting to limited disturbance of the occupants, while when installing the internal SmartWall panels is expected to complete a room per working day, which will be isolated by the rest of the apartment in order to minimise the disturbance, will occur by its installation.

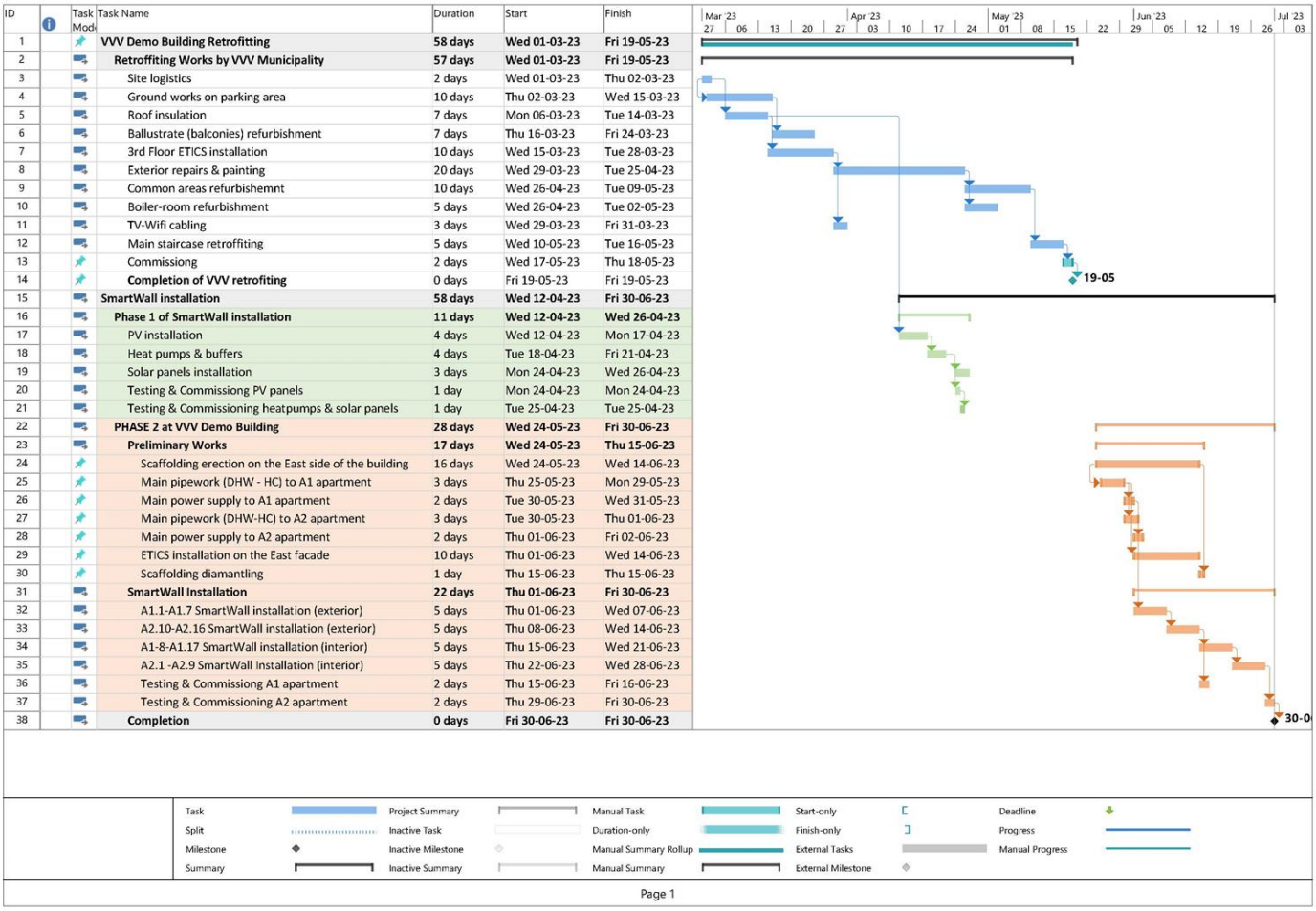
- The inelastic deadline for the installation of PLURAL PnU kits in VVV demo building

The timeframe for the installation of PnU kits in VVV's demo building according *T7.4 – Installation of PLURAL system in Athens*, is up to M34 (07.2023) in conjunction with the expected manufacturing completion of PnU kits (04.2023.

This inelastic condition, led to the adoption of a more compact and complex time schedule, requiring the co-existence of the VVV's appointed sub-contractor (for the 2nd Renovation Stage) and AMS (responsible for PLURAL systems installation).

Based on the above requirements, the overall renovation schedule is presented in the following illustration *(Figure 2), in* which is clearly visible the division of construction as:

- *2nd Stage Renovation Works* by VVV Municipality's subcontractor (blue bars)
- *Phase 1* of SmartWall installation (green bars)
- *Phase 2* of SmartWall installation (orange bars)



ID	Task Mode	Task Name	Duration	Start	Finish
1		**VVV Demo Building Retrofitting**	**58 days**	**Wed 01-03-23**	**Fri 19-05-23**
2		**Retroffiting Works by VVV Municipality**	**57 days**	**Wed 01-03-23**	**Fri 19-05-23**
3		Site logistics	2 days	Wed 01-03-23	Thu 02-03-23
4		Ground works on parking area	10 days	Thu 02-03-23	Wed 15-03-23
5		Roof insulation	7 days	Mon 06-03-23	Tue 14-03-23
6		Ballustrate (balconies) refurbishment	7 days	Thu 16-03-23	Fri 24-03-23
7		3rd Floor ETICS installation	10 days	Wed 15-03-23	Tue 28-03-23
8		Exterior repairs & painting	20 days	Wed 29-03-23	Tue 25-04-23
9		Common areas refurbishemnt	10 days	Wed 26-04-23	Tue 09-05-23
10		Boiler-room refurbishment	5 days	Wed 26-04-23	Tue 02-05-23
11		TV-Wifi cabling	3 days	Wed 29-03-23	Fri 31-03-23
12		Main staircase retroffiting	5 days	Wed 10-05-23	Tue 16-05-23
13		Commissiong	2 days	Wed 17-05-23	Thu 18-05-23
14		**Completion of VVV retrofiting**	0 days	Fri 19-05-23	Fri 19-05-23
15		**SmartWall installation**	**58 days**	**Wed 12-04-23**	**Fri 30-06-23**
16		**Phase 1 of SmartWall installation**	**11 days**	**Wed 12-04-23**	**Wed 26-04-23**
17		PV installation	4 days	Wed 12-04-23	Mon 17-04-23
18		Heat pumps & buffers	4 days	Tue 18-04-23	Fri 21-04-23
19		Solar panels installation	3 days	Mon 24-04-23	Wed 26-04-23
20		Testing & Commissiong PV panels	1 day	Mon 24-04-23	Mon 24-04-23
21		Testing & Commissioning heatpumps & solar panels	1 day	Tue 25-04-23	Tue 25-04-23
22		**PHASE 2 at VVV Demo Building**	**28 days**	**Wed 24-05-23**	**Fri 30-06-23**
23		**Preliminary Works**	**17 days**	**Wed 24-05-23**	**Thu 15-06-23**
24		Scaffolding erection on the East side of the building	16 days	Wed 24-05-23	Wed 14-06-23
25		Main pipework (DHW - HC) to A1 apartment	3 days	Thu 25-05-23	Mon 29-05-23
26		Main power supply to A1 apartment	2 days	Tue 30-05-23	Wed 31-05-23
27		Main pipework (DHW-HC) to A2 apartment	3 days	Tue 30-05-23	Thu 01-06-23
28		Main power supply to A2 apartment	2 days	Thu 01-06-23	Fri 02-06-23
29		ETICS installation on the East facade	10 days	Thu 01-06-23	Wed 14-06-23
30		Scaffolding diamantling	1 day	Thu 15-06-23	Thu 15-06-23
31		**SmartWall Installation**	**22 days**	**Thu 01-06-23**	**Fri 30-06-23**
32		A1.1-A1.7 SmartWall installation (exterior)	5 days	Thu 01-06-23	Wed 07-06-23
33		A2.10-A2.16 SmartWall installation (exterior)	5 days	Thu 08-06-23	Wed 14-06-23
34		A1-8-A1.17 SmartWall installation (interior)	5 days	Thu 15-06-23	Wed 21-06-23
35		A2.1 -A2.9 SmartWall Installation (interior)	5 days	Thu 22-06-23	Wed 28-06-23
36		Testing & Commissiong A1 apartment	2 days	Thu 15-06-23	Fri 16-06-23
37		Testing & Commissioning A2 apartment	2 days	Thu 29-06-23	Fri 30-06-23
38		**Completion**	**0 days**	**Fri 30-06-23**	**Fri 30-06-23**

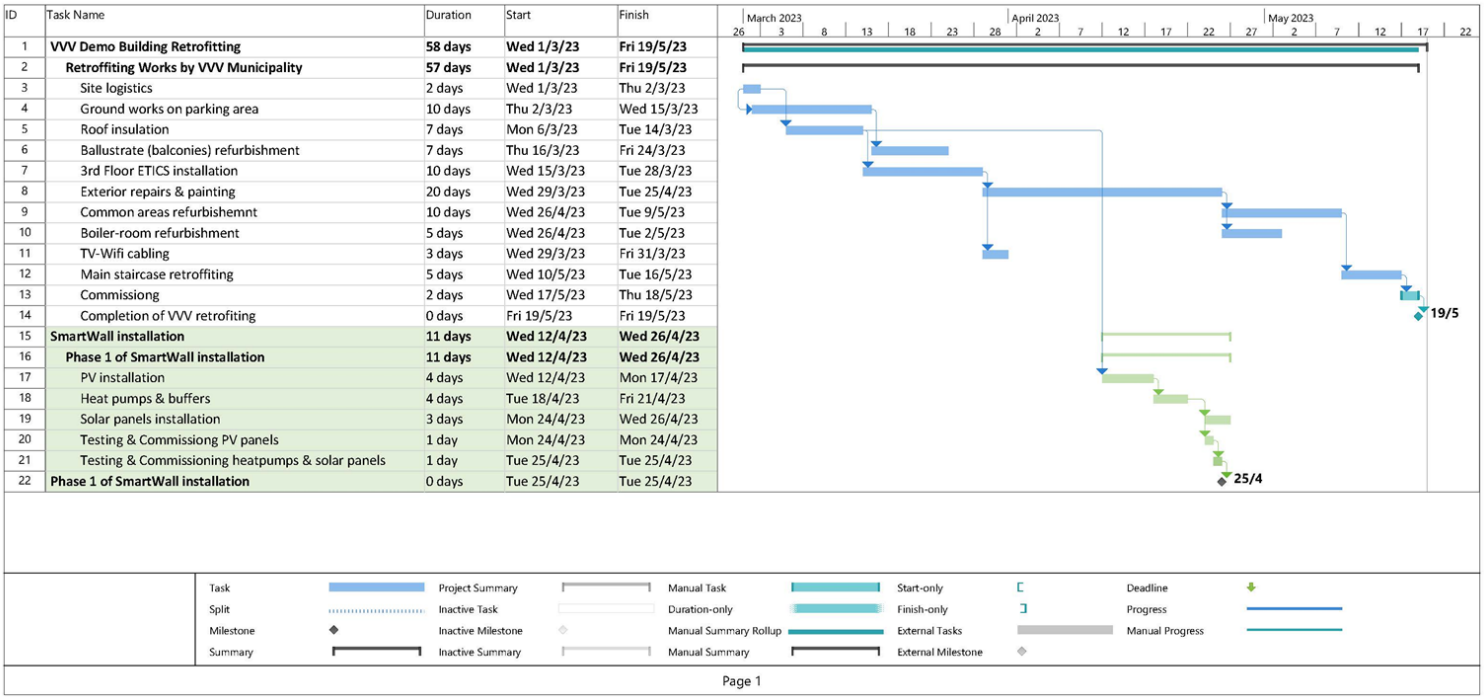
FIGURE 2: OVERALL CONSTRUCTION SCHEDULE FOR VVV RENOVATION

3.2.2 Phase 1 - Installation of "auxiliary" to SmartWall systems

The installation of the "auxiliary" to SmartWall systems has been scheduled to be executed during the time period in which VVV Municipality will execute the *2nd Stage Renovating Works,* as described in the *Deliverable D7.1 – Preliminary design.*

The time schedule in *Figure 3* illustrates the type and the expected duration of the related to SmartWall installation works during the *2nd Renovation Stage* and has been divided in two different sections:

- The first section (blue bars) is representing the works that will be executed by VVV Municipality during the *2nd Renovation stage*.
- The second section (green bars) is illustrating the works that will be executed by AMS and are related to SmartWall installation (installation of "auxiliary" systems).



ID	Task Name	Duration	Start	Finish
1	**VVV Demo Building Retrofitting**	**58 days**	**Wed 1/3/23**	**Fri 19/5/23**
2	**Retroffiting Works by VVV Municipality**	**57 days**	**Wed 1/3/23**	**Fri 19/5/23**
3	Site logistics	2 days	Wed 1/3/23	Thu 2/3/23
4	Ground works on parking area	10 days	Thu 2/3/23	Wed 15/3/23
5	Roof insulation	7 days	Mon 6/3/23	Tue 14/3/23
6	Ballustrate (balconies) refurbishment	7 days	Thu 16/3/23	Fri 24/3/23
7	3rd Floor ETICS installation	10 days	Wed 15/3/23	Tue 28/3/23
8	Exterior repairs & painting	20 days	Wed 29/3/23	Tue 25/4/23
9	Common areas refurbishemnt	10 days	Wed 26/4/23	Tue 9/5/23
10	Boiler-room refurbishment	5 days	Wed 26/4/23	Tue 2/5/23
11	TV-Wifi cabling	3 days	Wed 29/3/23	Fri 31/3/23
12	Main staircase retroffiting	5 days	Wed 10/5/23	Tue 16/5/23
13	Commissiong	2 days	Wed 17/5/23	Thu 18/5/23
14	Completion of VVV retrofiting	0 days	Fri 19/5/23	Fri 19/5/23
15	**SmartWall installation**	**11 days**	**Wed 12/4/23**	**Wed 26/4/23**
16	**Phase 1 of SmartWall installation**	**11 days**	**Wed 12/4/23**	**Wed 26/4/23**
17	PV installation	4 days	Wed 12/4/23	Mon 17/4/23
18	Heat pumps & buffers	4 days	Tue 18/4/23	Fri 21/4/23
19	Solar panels installation	3 days	Mon 24/4/23	Wed 26/4/23
20	Testing & Commissiong PV panels	1 day	Mon 24/4/23	Mon 24/4/23
21	Testing & Commissioning heatpumps & solar panels	1 day	Tue 25/4/23	Tue 25/4/23
22	**Phase 1 of SmartWall installation**	0 days	Tue 25/4/23	Tue 25/4/23

FIGURE 3: 2ND STAGE RENOVATION WORKS BY VVV MUNICIPALITY AND PHASE 1 - SMARTWALL'S "AUXILIARY" INSTALLATION

The *2nd Stage Renovating Works* by VVV Municipality have been very extensively presented and analysed in *D7.1 – Preliminary Design* and can be briefly summarised as following:

- Ground works in the parking area with duration ten (10) working days;
- Roof insulation with expected duration of seven (7) working days;
- Repairs on the existing balustrades in 2nd, 3rd floor and roof scheduled at seven (7) working days;
- ETICS installation at the 3rd floor, estimated to last ten (10) working days;
- Repairs and painting on the exterior envelope of the building for twenty (20) working days;

- Repairs, painting and refurbishment of the common areas with expected duration of ten (10) working days;
- Refurbishment of the existing boiler room for five (5) working days;
- TV and Wi-Fi (access points) cabling, estimated duration three (3) working days and
- Repairs at the main staircase of duration five (5) days.
- In total fifty five (55) working days

The works related to the *2nd Stage Renovation Works* are expected to start on the 01.03.2023 and planned to be completed at 19.05.2023, corresponding to eighty (80) calendar days or fifty eight (58) working days (as provided by VVV Municipality).

The nature of these works do not involve any tasks which might alter the planned time schedule or the renovation methodology, as they have been fully surveyed as presented in *Deliverable D7.1 – Preliminary Design*, they VVV's sub-contractor is fully aware of the building's condition and the extent of the works to be executed and do not include any "hidden" works that might occur during their execution.

Additionally, they considered to be "*traditional construction works*" constituting them very common and well established in the construction industry, therefore no drawbacks and/or bottlenecks during the construction of the particular works are not foreseen or expected apart delays due to material shortages or weather conditions.

The *"auxiliary" to SmartWall systems installation* works during this stage of the project, will be executed in parallel with the works of the *2nd Renovation Stage,* in such a manner that they do not interfere each other, and can be summarised as following:

- PV installation, including their supporting base, panels, inverters, batteries, switchboards and automations for both apartments, four (4) days and one (1) day for testing. In total five (5) working days.
- Heat pumps, including buffers, pipework, wiring and their automations for both apartments, five (5) working days.
- Solar panels including their supporting base, tanks, and their pipework for both apartments, three (3) working days.
- In total eleven (11) working days

Their construction methodology and sequence of works are fully described in detail at the *Technical Description Section* in the relevant design ANNEXES at the already submitted Deliverables:

- *D2.4 - Heating – cooling technology selection*: (referring to the heat pumps, pipework and automations)
- *D2.5 - Report with design and operational features of toolbox*: (referring to the PV and solar panels installation including their wiring and pipework)

Similarly to the aforementioned works of the *2nd Renovation Stage*, all works for the installation of *SmartWall's "auxiliary" systems* are executed exterior the building, and are new installations therefore no "hidden" tasks or actions can occur and their installation sequence and methodology is common in the construction industry. Therefore, is not expected any problems or delays to occur during the installation,

apart the weather conditions, as the materials have been already pre-ordered at the time that this report was written.

If any, will be confronted within the common construction practices and methods usually followed for such a kind of works.

3.2.3 Phase 2 - Installation of SmartWall systems

Phase 2 is dealing with the installation of the actual SmartWall systems in VVV demo building and has been divided in two (2) different *Stages*:

A. *Preliminary works*, dealing with all the supporting installations to the SmartWall systems and
B. The actual *installation of SmartWall panels* in to the building.

Figure 4 represents the overall time schedule of *Phase 2*, the activities involved, the sequence of work and the dependencies among the activities involved to SmartWall installation.

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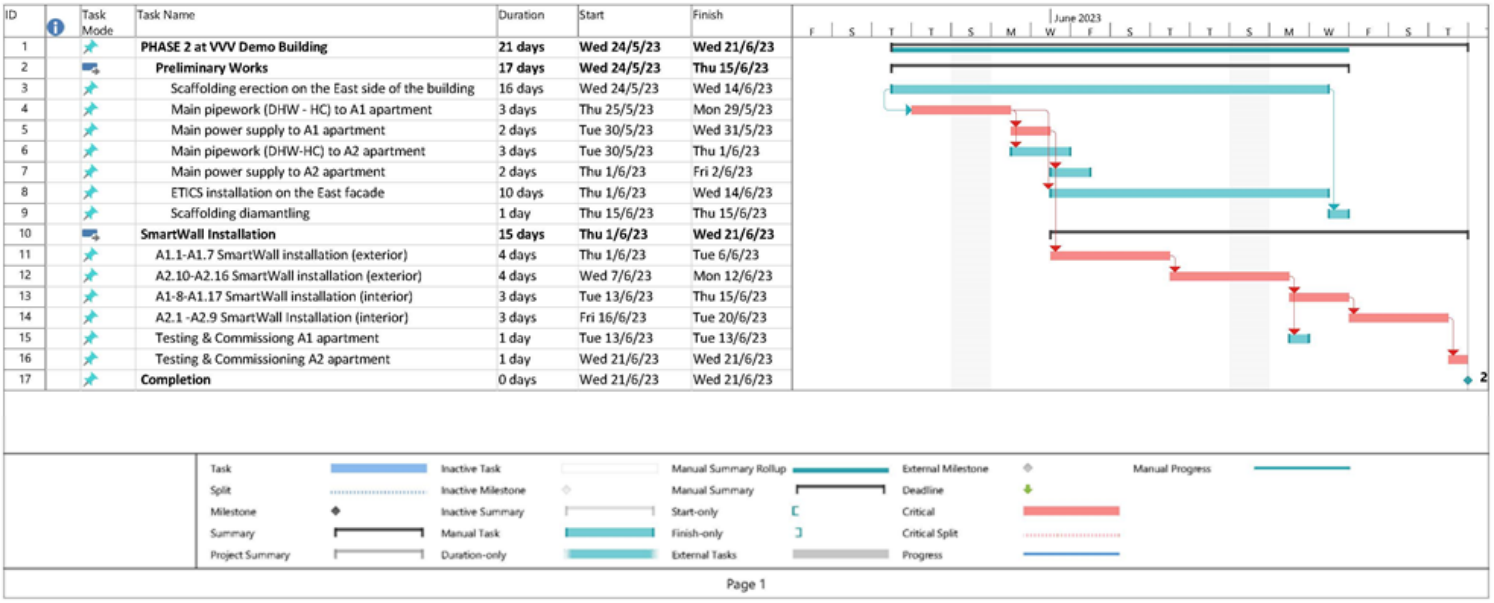


ID	Task Mode	Task Name	Duration	Start	Finish
1		**PHASE 2 at VVV Demo Building**	**21 days**	**Wed 24/5/23**	**Wed 21/6/23**
2		**Preliminary Works**	**17 days**	**Wed 24/5/23**	**Thu 15/6/23**
3		Scaffolding erection on the East side of the building	16 days	Wed 24/5/23	Wed 14/6/23
4		Main pipework (DHW - HC) to A1 apartment	3 days	Thu 25/5/23	Mon 29/5/23
5		Main power supply to A1 apartment	2 days	Tue 30/5/23	Wed 31/5/23
6		Main pipework (DHW-HC) to A2 apartment	3 days	Tue 30/5/23	Thu 1/6/23
7		Main power supply to A2 apartment	2 days	Thu 1/6/23	Fri 2/6/23
8		ETICS installation on the East facade	10 days	Thu 1/6/23	Wed 14/6/23
9		Scaffolding diamantling	1 day	Thu 15/6/23	Thu 15/6/23
10		**SmartWall Installation**	**15 days**	**Thu 1/6/23**	**Wed 21/6/23**
11		A1.1-A1.7 SmartWall installation (exterior)	4 days	Thu 1/6/23	Tue 6/6/23
12		A2.10-A2.16 SmartWall installation (exterior)	4 days	Wed 7/6/23	Mon 12/6/23
13		A1-8-A1.17 SmartWall installation (interior)	3 days	Tue 13/6/23	Thu 15/6/23
14		A2.1 -A2.9 SmartWall Installation (interior)	3 days	Fri 16/6/23	Tue 20/6/23
15		Testing & Commissiong A1 apartment	1 day	Tue 13/6/23	Tue 13/6/23
16		Testing & Commissioning A2 apartment	1 day	Wed 21/6/23	Wed 21/6/23
17		**Completion**	0 days	Wed 21/6/23	Wed 21/6/23

FIGURE 4: PHASE 2 – INSTALLATION OF SMARTWALL SYSTEMS

A more comprehensive analysis of the *Phase 2 i*s presented in the following paragraphs:

3.2.3.1 Stage A - Preliminary Works

Site logistics

Prior any works commencement, site logistics and welfare facilities for the workers will be organised and installed, in particular:

- an office container (to be also used as resting area);
- chemical toilets, and
- storage area.

will be installed at the assigned by VVV municipality area at the back side of the at the abandoned parking area of the building facing Plapouta St.

Safety training the will take place in this area prior any work commencement according the *Health & Safety Plan* and the Site Regulations, as have been presented and analysed in the *Deliverable D6.1 – Manufacturing Methodology of PnU kits.*

All components required for the installation of the auxiliary to SmartWall systems, e.g. solar and PV panels, heat pumps, pipes, fittings etc., will be gathered and stored at the designated storage area, and once fully gathered, then will be lifted to the roof with the aid of a crane – hoist where will be stored since their installation. The lifting operation is not expected to last more than two (2) hours and the expected disturbance to the occupants (if any) would be very limited as internal spaces of the building will not be used during the lifting operation.

Scaffolding erection on the East side of the building

Scaffolding will be erected on the overall east façade of the building according the provisions of:

- P.D. 778/1980 (O.G. 193 A-26.08.1980)[24]
- P.D. 1073 /1981 (O.G. 260 A-16.09.1981)[25]
- M.D. D.22/4193/2019 (O.G. 4607/B-13.12.2019)[26]

The estimated duration of scaffolding presence on site is sixteen (16) working days (24.05 – 15.06.2023) and will serve the following construction tasks:

- Main pipework for DHW - HC in both apartments.
- Main power supply (PV) for both apartments and
- ETICs installation on the east side of the building.

It is scheduled to be dismantled on the 15.06.2023 but, if necessary, it can be maintained in its position as long as is required as it does not affect the overall construction methodology and schedule.

[24] https://www.elinyae.gr/ethniki-nomothesia/pd-7781980-fek-193a-2681980
[25] https://www.elinyae.gr/ethniki-nomothesia/pd-10731981-fek-260a-1691981
[26] https://www.elinyae.gr/ethniki-nomothesia/ya-d2241932019-fek-4607b-13122019

Main pipework for DHW – HC to A1 apartment

This task involves the installation of the heat pump, solar panels, buffer tank, and the automations required for their smooth. Additionally, the necessary interconnecting the DHW and H-C systems pipework will be installed and the main supply to A1 apartment will be installed to the designated routes across the east façade of the building.

The construction methodology for the installation activities is presented and analysed in the Technical Sections of the relevant designs in Deliverables:

- *D2.4 - Heating – cooling technology selection*: (referring to the heat pumps, pipework and automations)
- *D2.5 - Report with design and operational features of toolbox*: (referring to the PV and solar panels installation including their wiring and pipework)

In addition, further information – instructions for the task's requirements, are available:

- All relevant Standards and Directives mentioned on the paragraph *1.1.9 - European Regulations* of the current report are applicable.
- Specific precautions during installation are presented in paragraphs *1.1.13 - HVAC systems* and *1.4.5 HVAC systems installation* of the current report.

The estimated duration of the task is three (3) working days (25.05-29.05.2023). It is considered to be critical (red bar in *Figure 4*) as it is a predecessor task for most of the activities involved to A1 renovation tasks and under specific conditions, as analyzed in paragraph *1.2.4 - Risk Assessment Plan,* can become highly critical to the overall renovation schedule of works in VVV demo building.

However, no further delays, risks, drawbacks are expected during its execution, since it is considered as a new job with no "hidden" tasks apart the weather conditions, manufacturing defaults and installation mistakes or omissions. If any, they will be confronted within the common construction practices and methods usually followed for such a kind of works.

Main power supply (PV) to A1 apartment

During this task all works related to energy storage for apartment A1 will be completed. More specifically the following will be installed:

- The PV solar panels in the roof of the building including their supporting system and their interconnections wiring;
- The inverter, batteries, all required automations and their wiring, in the storage house located in the of the roof area of the building, and
- Finally, they will be tested for their smooth and safe operation.

All aforementioned tasks are presented and analysed in the Technical Section of *D2.5 - Report with design and operational features of toolbox.* In addition to the aforementioned design requirements there are available further information related to the task activities, as following:

- All relevant Standards and Directives mentioned on the paragraph *1.1.9 - European Regulations* of the current report are applicable.

- Specific precautions during installation are presented in paragraphs *1.1.12 – PV panels* and *1.4.5 PV panels installation* of the current report.

Its estimated duration is two (2) working days (30.05-31.05.2023). It is considered to be critical as it is successor of the previous task "*ID 4 - Main pipework for DHW – HC to A1 apartment*" and predecessor to the remaining activities involved to A1 renovation tasks.

Similarly to the previous activity "*ID 4 - Main pipework for DHW – HC to A1 apartment*", under specific conditions, as analyzed in paragraph *1.2.4 - Risk Assessment Plan,* it can become highly critical to the overall renovation schedule of works in VVV demo building.

No delays, and/or risks, and/or drawbacks are expected of its execution, due to the nature of the activity as described on the previous paragraph, apart the weather conditions, manufacturing defaults and installation mistakes or omissions. In such a case they will be confronted with the usual construction techniques applicable to the installation of such systems.

Main pipework for DHW – HC to A2 apartment

Similar activity / conditions, as to the mentioned in paragraph *1.2.3.1.3 Main pipework for DWH – HC to A1 apartment* focusing on the installation of DHW – HC supply at A2 apartment.

It starts immediately after the completion of A1 installation at the 30.05.2023 and is completed at the 01.06.2023. Is not considered as a critical activity and under the circumstances presented in paragraph *1.2.4 - Risk Assessment Plan* can be shifted forward if needed to gain time in case of unforeseen delays.

Main power supply (PV) to A2 apartment

Similar activity / conditions as per tasks described in *1.2.3.1.4 Main power supply (PV) to A1 apartment* but referring to A2 installation of PV panels, batteries, inverters and automations.

It also starts at the completion of A1 installation 01.06.2023 and is completed at the 02.06.2023. Is also not considered to be as a critical activity and also under the circumstances presented in paragraph *1.2.4 - Risk Assessment Plan* can be shifted forward if needed to gain time in case of unforeseen delays.

ETICS installation on the East façade of the building

This activity involves the installation of ETICS in the façade of the building and the replacement of the existing windows facing the East façade of the building.

Additionally, as ETICS installation will cover the main pipework and power supply cables from the roof to A1 and A2 apartments, as presented in the previous paragraphs, must commence after the complete installation of "*ID 6 - Main pipework for DHW – HC to A2 apartment*" at 01.06.2023, while at the meantime and in order to gain valuable construction time, would be executed in parallel with the works of the activity "*ID 7 - Main power supply (PV) to A2 apartment*". This overlapping among the aforementioned activities is expected to last only for two (2) working days and is not considered as critical on the construction schedule, because of the different working areas of the installers (installers for the main PV power supply will be working on the roof area, while ETICS installers on the EAST façade).

It is expected to be completed within ten (10) working days at the 14.06.2023, is not part of the critical path of the construction schedule and according the analysis of paragraph *1.2.4 - Risk Assessment Plan*

cannot affect the overall construction schedule under any circumstances, even if there is significant delays up to 15 working days on "*ID 6 - Main pipework for DHW – HC to A2 apartment*" and "*ID 7 - Main power supply (PV) to A2 apartment*" which are considered as its predecessor activities.

Deliverables D2.1 – Architectural and Structural Design and *D2.6 – Final Stage design of PnU kits,* as well as the EOTA Installation Guide[27] for ETICS systems are providing all the relevant information and the installation details and methodology for the proper installation of ETICS system in VVV demo building.

ETICS installation is also considering as "*traditional construction method*" well familiarised by the installers, therefore, no delays, and/or risks, and/or drawbacks are expected of its execution due to the nature of the activity as described on the previous paragraphs, apart the weather conditions, manufacturing defaults and installation mistakes or omissions. In such a case, they will be confronted with the usual construction techniques applicable to the installation of such systems.

3.2.3.2 Stage B – SmartWall panels Installation

A1.1 – A1.7 SmartWall panels installation (exterior)

The task is focused on the activities related to the SmartWall panels installation and more specifically to the:

- Installation of the railing system which will be used as hanging system for the SmartWall panels;
- Positioning, leveling and securing on its final position of seven (7) each SmartWall panel;
- Connections for the heating – cooling pipework to four (4) SmartWall panels, with the main supply pipework;
- Interconnections of power cabling to four (4) SmartWall panels;
- Installation of windows glazing units to three (3) SmartWall panels and,
- Finally joints treatment and local repairs if necessary.

The task is expected to start at the completion of "*ID 5 – Main pipework for DHW – HC to A1 apartment"* at the 01.06.2023 and its expected duration is five (5) working days, to be completed on 06.06.2023.

The activities involved in the current task are considered as part of the critical path of the construction schedule. According to the analysis of paragraph *1.2.4 - Risk Assessment Plan,* they cannot affect the overall construction schedule under specific circumstances e.g. delays on installation by defaults, weather conditions etc. In such a case, any problems might occur will be confronted with the usual construction techniques available on a case-by-case condition.

The installation requirements / methodology / guidelines apart the analysis presented in the other paragraphs of the current report is well established and analyzed in *Deliverables D2.1 – Architectural and Structural Design* and *D2.6 – Final Stage design of PnU kits.*

[27] https://www.eota.eu/download?file=/2014/14-04-0083/for%20ojeu/ead%20040083-00-0404_ojeu2020.pdf

A2.8 – A2.17 SmartWall panels installation (exterior)

Similar activity / conditions / methodology as per activities described in paragraph *1.2.3.2.1 - A1.1 – A1.7 SmartWall panels installation (exterior*) of the current report but referring to the installation of six (6) exterior panels in A2 apartment which three (3) of them need to be connected to the main H-C pipework and main power supply.

The task is planned to last five (5) working days and it starts at the completion of task "*ID 11 – A1.1 – A1.7 SmartWall panels installation (exterior)"* at the 07.06.2023 and is completed at the 12.06.2023.

It is considered as a critical activity and under the circumstances presented in paragraph *1.2.4 - Risk Assessment Plan,* it can become highly critical to the overall renovation schedule of works in VVV demo building. Though, it can be shifted either forward (start earlier) or with task "*ID 13 - A1.10 – A1.16 SmartWall panels installation (interior)",* if necessary, to gain time in case of unforeseen delays or to complete the installation of A1 apartment earlier to minimise occupants disturbance during SmartWall installation.

A1.10 – A1.16 SmartWall panels installation (interior)

Similar activity / conditions / methodology as per activities described in *1.2.3.2.1 - A2.1 – A1.7 SmartWall panels installation (exterior)* but referring to the installation of six (6) interior panels in A2 apartment which two (2) of them need to be connected to the main H-C pipework and main power supply.

It starts at the completion of task "*ID 12 – A2.8 – A2.17 SmartWall panels installation (exterior)"* at the 15.06.2023 and is completed at the 21.06.2023 (five -5- working days).

It is considered to be as a critical activity but is also acting as a time buffer among the critical activities of the project because the amount of SmartWall panels need to be installed are only six (6) in two different rooms and the expectation target is to complete one (1) room per day. Though, as is the first activity dealing with the installation of interior panels, the allocation of more than the required time estimated that was necessary in order the workers to get familiarise with the interior SmartWall panels installation method and consequently verify it.

Under the circumstances presented in paragraph *1.2.4 - Risk Assessment Plan* can also become highly critical to the overall renovation schedule of works in VVV demo building.

A2.1 – A2.7 SmartWall panels installation (interior)

Similar activity / conditions / methodology as per tasks described in previous paragraph *1.2.3.2.3 A1.10 – A1.16 SmartWall panels installation (interior)* and Is focusing in the installation of seven (7) interior SmartWall panels in A2 apartment.

It starts at the completion of "*ID 13 – A1.10 – A1.16 SmartWall panels installation (interior)"* at 16.06.2023 and is completed at the 20.06.2023. Is also considered to be as a critical activity and under the circumstances presented in paragraph *1.2.4 - Risk Assessment Plan* can become highly critical to the overall renovation schedule of works in VVV demo building. Though, it can be shifted either forward (start

earlier) if necessary to gain time in case of unforeseen delays or to complete the installation of A2 apartment earlier to minimise occupants disturbance during SmartWall installation.

Testing and commissioning

Testing and commissioning is planned as the last activities of the construction schedule with an overall duration of two (2) working days and is divided in two subtasks:

a. *"ID 15 - Testing & commissioning for A1 apartment"* (13.06.2023) and
b. *"ID 16 - Testing & commissioning for A2 apartment"* (21.06.2023).

The reason of the division is that each subtask starts immediately after the completion of works in each apartment in order to minimize occupants' disturbance but also to provide a time buffer for remedial actions as per paragraph *1.2.4 - Risk Assessment Plan* of the current report.

The inspection actions / tests to all of its components to be performed by the installers, are briefly presented in paragraph *1.3.15 Testing & commissioning* of the current report while their detailed analysis is presented in the *Deliverables D4.5 - PnU kit prototype property and performance characterization* and *D6.3 - Quality Assurance Plan – manufacturing / assembly.*

3.2.4 Risk Assessment Plan on installation of SmartWall systems in VVV demo building

As part of the *6σ Methodology* which will be presented and analysed in *Deliverables D6.1 – Manufacturing methodology of PLURAL kits* and *D6.3 - Quality Assurance Plan – manufacturing /assembly,* in order to:

- anticipate any delays might occur during the installation of PLURAL PnU kits;
- determine which activities can become critical during installation process in case of delays;
- identify any looping actions might occur because of the possible delays, and
- beware of the consequences of possible delays on the overall time schedule, therefore being able to anticipate them,

several different installation scenarios have been developed and analysed.

The most representative and/or the most possible to happen scenarios are presented in the following paragraphs.

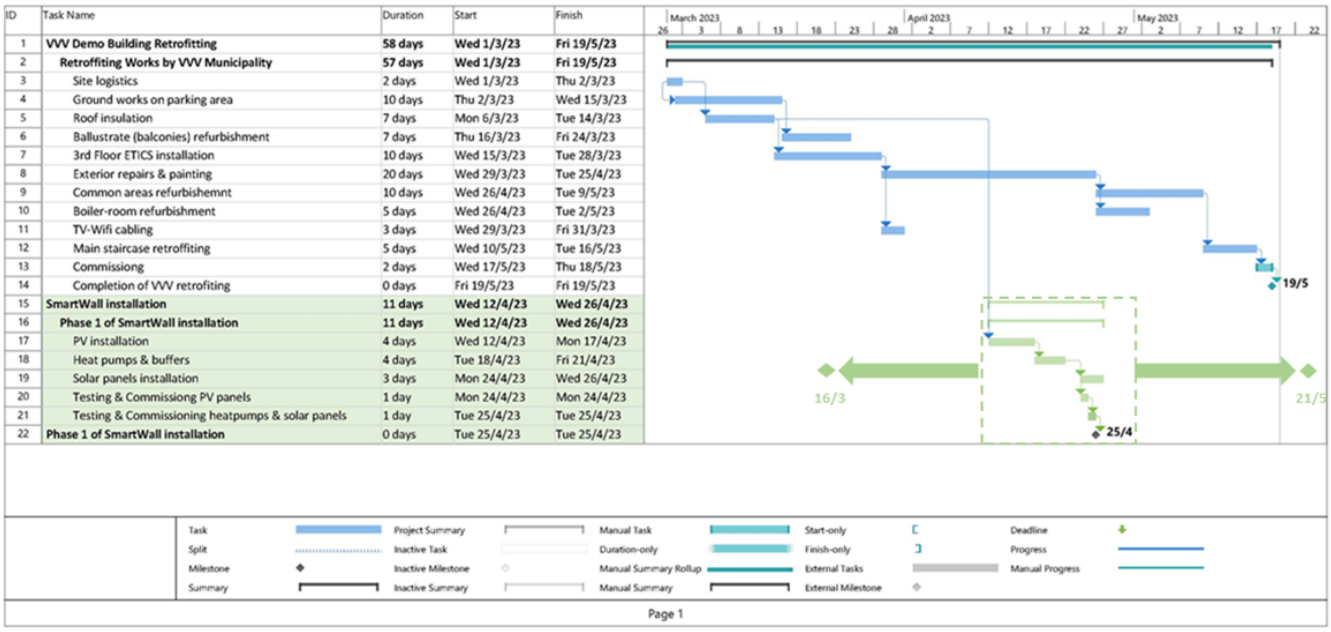
3.2.4.1 Delays on 2nd Renovation Stage Works by VVV's Municipality subcontractor

Assumptions

- VVV's subcontractor does not respects the installation schedule proposed (for any reason), and/or
- Delays occurring at the works of VVV's sub-contractor (by any reason), and/or
- These conditions affect the Preliminary Works for SmartWall commencement and/or installation schedule.

Outcome

- *Figure 5* analysis reveals a time buffer of fifty-two (52) calendar days allowing *Phase 1* of SmartWall installation to be completed prior Phase 2 commencement. This is analysed as following:
  a. Works commencement time buffer of twenty-five (25) calendar days, which allows the Preliminary works to start immediately after the completion of task "*ID 5 – Roof insulation Installation*", regardless the sequence or progress of the other works that VVV's subcontractor will execute, and
  b. Preliminary works for SmartWall installation can be completed at the 21.05.2023 (prior the commencement of *Phase 2* Works), indicating a time buffer of twenty-seven (27) calendar days.



ID	Task Name	Duration	Start	Finish
1	**VVV Demo Building Retrofitting**	**58 days**	**Wed 1/3/23**	**Fri 19/5/23**
2	**Retroffiting Works by VVV Municipality**	**57 days**	**Wed 1/3/23**	**Fri 19/5/23**
3	Site logistics	2 days	Wed 1/3/23	Thu 2/3/23
4	Ground works on parking area	10 days	Thu 2/3/23	Wed 15/3/23
5	Roof insulation	7 days	Mon 6/3/23	Tue 14/3/23
6	Ballustrate (balconies) refurbishment	7 days	Thu 16/3/23	Fri 24/3/23
7	3rd Floor ETICS installation	10 days	Wed 15/3/23	Tue 28/3/23
8	Exterior repairs & painting	20 days	Wed 29/3/23	Tue 25/4/23
9	Common areas refurbishemnt	10 days	Wed 26/4/23	Tue 9/5/23
10	Boiler-room refurbishment	5 days	Wed 26/4/23	Tue 2/5/23
11	TV-Wifi cabling	3 days	Wed 29/3/23	Fri 31/3/23
12	Main staircase retroffiting	5 days	Wed 10/5/23	Tue 16/5/23
13	Commissiong	2 days	Wed 17/5/23	Thu 18/5/23
14	Completion of VVV retrofiting	0 days	Fri 19/5/23	Fri 19/5/23
15	**SmartWall installation**	**11 days**	**Wed 12/4/23**	**Wed 26/4/23**
16	**Phase 1 of SmartWall installation**	**11 days**	**Wed 12/4/23**	**Wed 26/4/23**
17	PV installation	4 days	Wed 12/4/23	Mon 17/4/23
18	Heat pumps & buffers	4 days	Tue 18/4/23	Fri 21/4/23
19	Solar panels installation	3 days	Mon 24/4/23	Wed 26/4/23
20	Testing & Commissiong PV panels	1 day	Mon 24/4/23	Mon 24/4/23
21	Testing & Commissioning heatpumps & solar panels	1 day	Tue 25/4/23	Tue 25/4/23
22	**Phase 1 of SmartWall installation**	0 days	Tue 25/4/23	Tue 25/4/23

FIGURE 5: DELAYS ON 2ND STAGE RENOVATION WORKS

Conclusions

- No feasible risks and/or delays and/or looping actions due of delays among the installation works sequence influencing the installation works of *Phase 2* are expected due to the extensive time buffer occurred by the proposed planning of works in *Phase 1*.
- The critical activity on this scenario, is the "*ID 5 – Roof insulation Installation*", which in the worst-case scenario need to be completed up to 25.04.2023, with a lag of thirty six (36) calendar days of the "*as planned*" schedule.
- In the unlikely event of further delays than the "*ID 5 – Roof insulation Installation*" will affect *Phase 2* of SmartWall systems installation and will be anticipated at the time of occurrence by re-evaluating the overall construction schedule.

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

- From the above is clear that the "*Preliminary Works for SmartWall installation*" in *Phase 2,* are difficult to be affected by any delays might occur during the *2nd Stage Renovation Works*.
- If needed, time could be gained (up to 8 calendar days) either by VVV's Municipality sub-contractor or AMS technical team by working on the weekends.

3.2.4.2 Delays on SmartWall Installation +7 days (≈45% time increase)

Assumptions

- VVV's subcontractor respects deadline and completes as scheduled the *2nd Stage Renovation Works*;
- *Stage A - Preliminary Works for SmartWall installation* completed as per schedule;
- Seven (7) days delays occur during SmartWall installation which correspond to ≈45% increase of the scheduled installation time due to any reason (weather conditions, installation mistakes and/or omissions and/or remedial actions required) (*Figure 6*).

Outcome

- The *Stage A - Preliminary Works* schedule is not affected.
- The critical activities remain the same as in "*as planned*" time schedule with the most important activities those related to A1 apartment installation.
- The completion time is shifted at the 30.06.2023 (+9 days than "*as planned*" schedule due to weekends which are not considered as "working time").

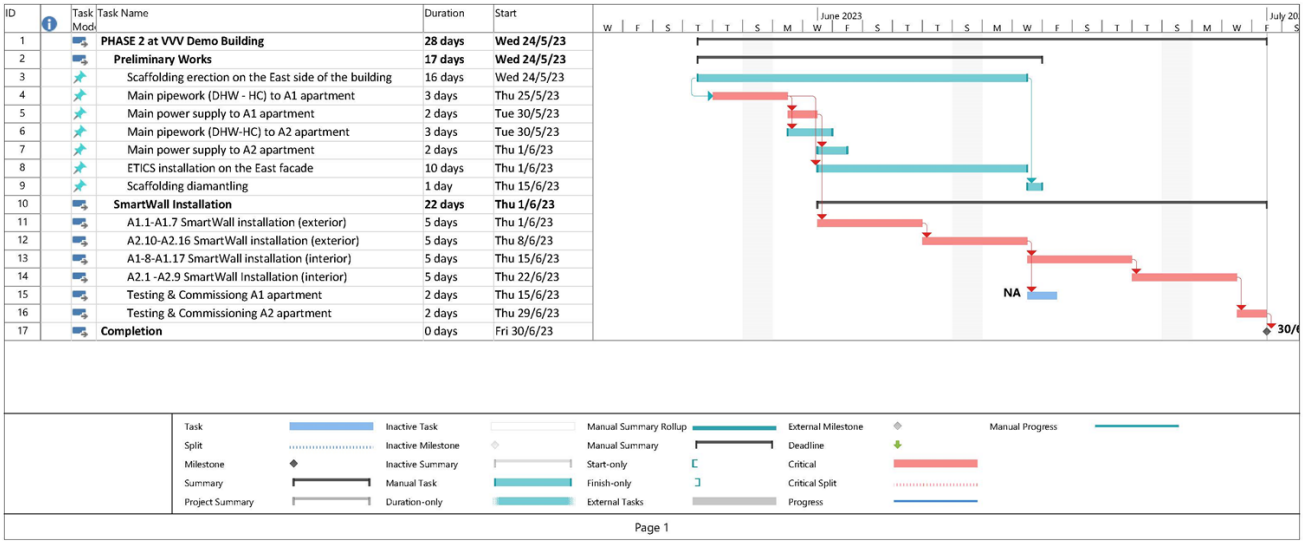


FIGURE 6: SMARTWALL INSTALLATION DELAYS +7 DAYS (≈45% TIME INCREASE)

Conclusions

- If the delay will occur during A1 apartment installation works some time (up to 3 days) could be gained by accelerating (bringing forward) the critical activities related to A2 apartment installation.
- If the delay will occur during A2 apartment installation works no working time can be gained.
- In any case, the delay of +7 working days does not really affect the completion of works in terms of DoA obligations as is completed earlier that the scheduled time (07.2023)
- If needed, time could be gained (up to 6 calendar days) by working on the weekends.

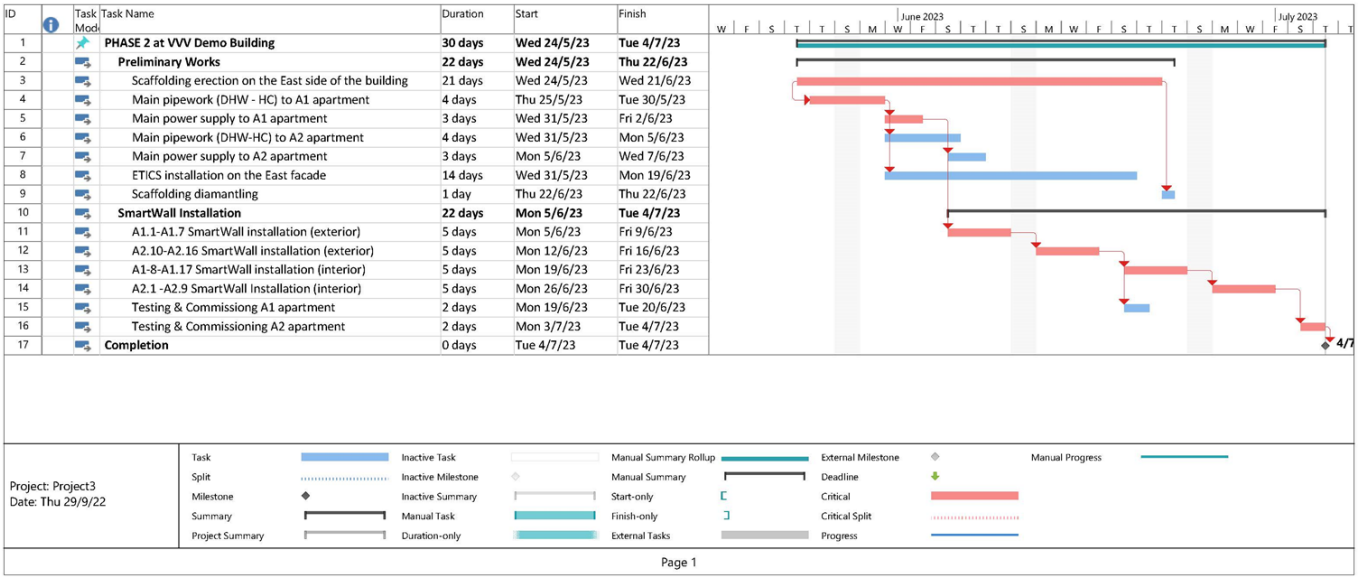
3.2.4.3 Overall delay of +12 days (≈55% time increase)

Assumptions

- VVV's subcontractor respects deadline and completes as scheduled the 2nd Stage Renovation Works;
- Five (5) working days delay on the Preliminary Works for SmartWall installation for any reason;
- Seven (7) days delays occur during SmartWall installation, which correspond, to ≈55% increase of the overall scheduled installation time due to any reason (weather conditions, installation mistakes and/or omissions and/or remedial actions required).

Outcome

- The Preliminary works schedule is not affected.
- The critical activities remain the same as in "as planned" time schedule
- The completion time is shifted at the 04.07.2023 (+12 days than "as planned" schedule due to weekends which are not considered as "working time")



ID	Task Mode	Task Name	Duration	Start	Finish
1		**PHASE 2 at VVV Demo Building**	**30 days**	**Wed 24/5/23**	**Tue 4/7/23**
2		**Preliminary Works**	**22 days**	**Wed 24/5/23**	**Thu 22/6/23**
3		Scaffolding erection on the East side of the building	21 days	Wed 24/5/23	Wed 21/6/23
4		Main pipework (DHW - HC) to A1 apartment	4 days	Thu 25/5/23	Tue 30/5/23
5		Main power supply to A1 apartment	3 days	Wed 31/5/23	Fri 2/6/23
6		Main pipework (DHW-HC) to A2 apartment	4 days	Wed 31/5/23	Mon 5/6/23
7		Main power supply to A2 apartment	3 days	Mon 5/6/23	Wed 7/6/23
8		ETICS installation on the East facade	14 days	Wed 31/5/23	Mon 19/6/23
9		Scaffolding diamantling	1 day	Thu 22/6/23	Thu 22/6/23
10		**SmartWall Installation**	**22 days**	**Mon 5/6/23**	**Tue 4/7/23**
11		A1.1-A1.7 SmartWall installation (exterior)	5 days	Mon 5/6/23	Fri 9/6/23
12		A2.10-A2.16 SmartWall installation (exterior)	5 days	Mon 12/6/23	Fri 16/6/23
13		A1-8-A1.17 SmartWall installation (interior)	5 days	Mon 19/6/23	Fri 23/6/23
14		A2.1 -A2.9 SmartWall Installation (interior)	5 days	Mon 26/6/23	Fri 30/6/23
15		Testing & Commissiong A1 apartment	2 days	Mon 19/6/23	Tue 20/6/23
16		Testing & Commissioning A2 apartment	2 days	Mon 3/7/23	Tue 4/7/23
17		**Completion**	0 days	Tue 4/7/23	Tue 4/7/23

FIGURE 7: OVERALL DELAY OF +12 DAYS (≈55% TIME INCREASE)

Conclusions

- If the delay will occur at "*Preliminary Works*" critical activities (works for A1 apartment installation) working time could be gained (up to 4 days) by working the weekends. If the delay will occur on the "Preliminary Works" non-critical activities the overall schedule is not affected.
- Furthermore, additional time (up to 3 days) as an alternative to weekend work time, could be gained by accelerating (bringing forward) the critical activities related to A2 apartment installation.
- If the delay will occur during A2 apartment installation works, no working time can be gained.
- In any case, the delay of +12 working days does not really affect the completion of works in terms of DoA obligations as is completed earlier that the scheduled time (07.2023)
- If needed, time could be gained (up to 6 calendar days) by working on the weekends.

3.3 General instructions for SmartWall panels* installation

* *Generic type, including fan-coil unit, mechanical ventilation on windows frame, PV panel with integrated power storage system, AMscope and active fire protection system.*

3.3.1 Safety instructions working with SmartWall panels

- Respect the applicable **Health and Safety Plan** as presented on the *Deliverable D6.1 – Manufacturing Methodology of PnU kits.*
- Wear appropriate, not loose-fitting work clothing. Avoid wearing rings, necklaces, watches or other type of jewelry and ornaments.
- Wear safety goggles and a dust mask when sawing, sanding, and milling.
- Wear ear protection for noisy processing (e.g. sawing).
- Provide continuous dust extraction during machining activities.
- Wear protective gloves during activities involving adhesives, solvents or other chemical products.
- Make sure that all electrical equipment are earthed.
- Remove adjusting spanners or wrenches before using any type of machine.
- Keep the workplace clean and tidy.
- Ensure that the work pieces are always stable and clamped before proceeding with processing.
- Respect the generally applicable instructions and measures concerning occupational safety and fire prevention.

3.3.2 General instructions

- Before processing, it is suggested to leave the panels in a well-supported ventilated position for a period of one (1) day per mm thickness allowing them to acclimatise, in order to prevent any distortion of the panels.

- Processing SmartWall panels by any means should be done only in the workshop and under normal climatic conditions.
- Ensure that surfaces are clean before laying the panels on them.
- Ensure that the room is well lit and provide adequate dust extraction to be able to view the panels correctly at all times while installing them (for interior installation only).
- Before processing, check the panels for any production defects.
- Beware of panels numbering to match with drawing's numbers and direction. Wrong positioning of SmartWall panels will result to improper installation (*Figure 7*).

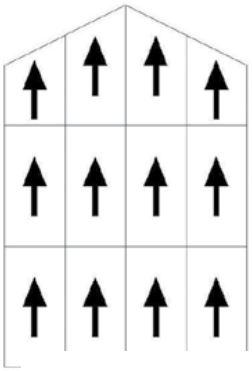


FIGURE 8: PANELS NUMBERING

3.3.3 Packaging – transportation

For transport, due to the nature of SmartWall panels, all panels should be stacked into each other in an offset pattern. Thus, packaging should require even number per item (*Figure 9*). It is suggested that delivery should be made on special wood pallets and wood packaging.

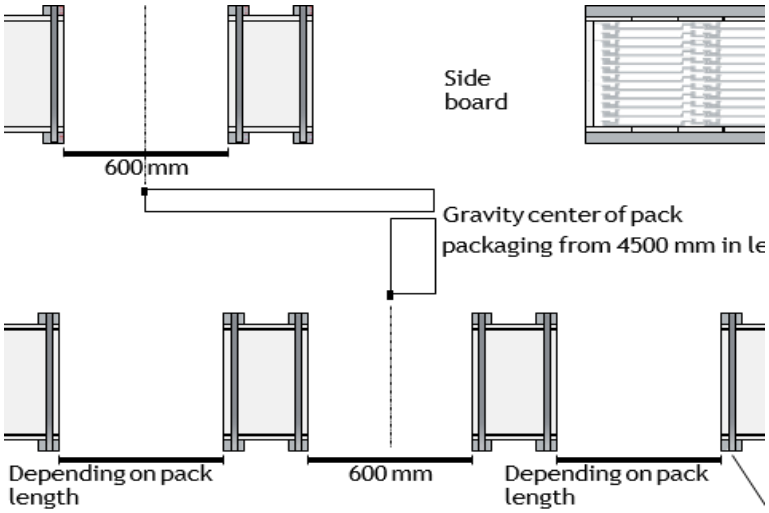


FIGURE 9: MEANS OF TRANSPORTATION

If a building contractor requires a weight limitation, then this should comply with the restrictions of offset system of packaging.

The element packs should be checked for completeness and any possible damage immediately after delivery to the construction site, and then the unloading report of the shipping company should be filled in.

3.3.4 Handling – unloading

SmartWall panels should be handled with care during transport, unloading, storage and installation in order to avoid damaging the edges and the decorative surfaces (*Figure 3*). Therefore, the following points should be observed:

- The panels should be stacked horizontally on a flat and sufficiently supporting pallet, to prevent distortion or damage. Between the pallet and the first panel, place a protective PE sheet as well as on top of the stack.
- Secure the panels to the pallet using steel or nylon straps, so that they cannot move and cause damage.

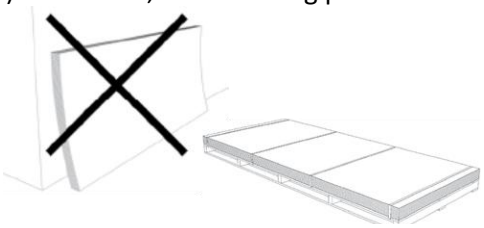


FIGURE 10: SMARTWALL PANELS STACKING METHOD

It should be ensured that all SmartWall panels are always held in vertical position (*Figure 11*) during removal from the pack as well as during lifting to the installation location.

Improper manipulation or transport in horizontal position results in bending and may lead to permanent wave formation on the visible surfaces.

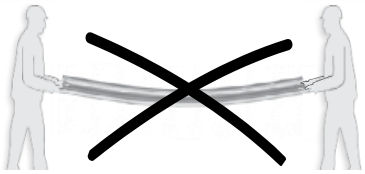


FIGURE 11: MEANS OF CARRYING

Façade elements with a length of up to 3 m are recommended in order to ensure manipulation without damage; above that length is not recommended due to its weight (*Figure 12*). Manipulation (unloading) of the packs should be performed with suitable lifting devices (spreader bars, if applicable) and slings (belts). The hoisting slings should always be fixed to the packing, but not to the product; deformation of the elements during the lifting procedure must be avoided.
When stacking the packs, it should be granted that the pallets are placed on top of each other in order to avoid dent marks at the facade elements.

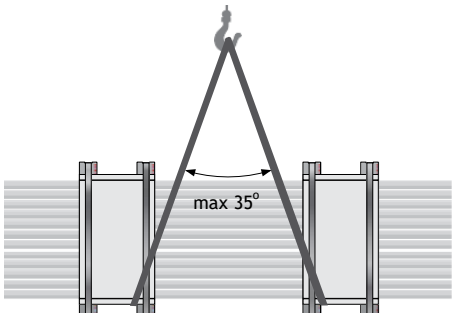


FIGURE 12: MEANS OF HOISTING

3.3.5 Storage

3.3.5.1 Temporary storage (outside)

- Cover SmartWall panels with polythene or tarpaulin to protect from climatic elements and also to avoid moisture ingress accumulating between the sheets (*Figure 13*).

- It is strongly recommended that the delivered material remains strapped on the pallet until needed.
- When the pallet is opened and material is used, at the end of the day, a polyethylene sheet should be placed over the top sheet and re-strapped, the whole stack of sheets should then be covered with polythene or waterproof tarpaulin, this being all the more important if the protective film has been removed.

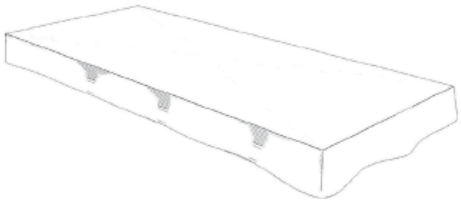


FIGURE 13: TEMPORARY MEANS OF STORAGE

- The pallet should be sited on a well-drained area, so as not to stand over wet or damp. Never position the pallet over open soil as these areas are of higher ambient humidity.
- If SmartWall panels have been prepared in a workshop, re-stack in the same manner that they were received from the factory.
- For SmartWall panels which have been pre-prepared in the workshop by affixing hanging brackets etc. or for panels which may have bowed through moisture absorption to one face, these can be positioned on hard wooden slats placed between the panels, with a maximum distance of 500mm. SmartWall Panels should be strapped when not being worked and covered in a ventilated way with polythene or tarpaulin.
- Storage at the construction site should be performed in such a way that elements are stored level and without any bending. Packs and/or elements stored outside should be protected by a rainproof and well-ventilated cover.
- Any penetration of water into the pack as well as formation of condensate within the packs must be avoid. Furthermore, storage should be performed with slight longitudinal inclination so that any possibly penetrating water may run off without problems. Interim storage of the facade elements for a longer period should be made at a dry and roof-protected location.

3.3.5.2 Interior storage

- It is advisable to store the façade panels in a closed warehouse under normal climatic conditions (advised temperature 10-30°C / humidity 40 to 65%).
- When warehousing, place the façade panels horizontally, together, on a sturdy, well supported and completely flat rack (*Figure 14*).
- Provide a PE sheet between the supporting rack and the first panel.
- Cover the top panel with a protective PE sheet and on top of this a larger panel that has sufficient mass to exert a downward pressure on the stack of the panels.

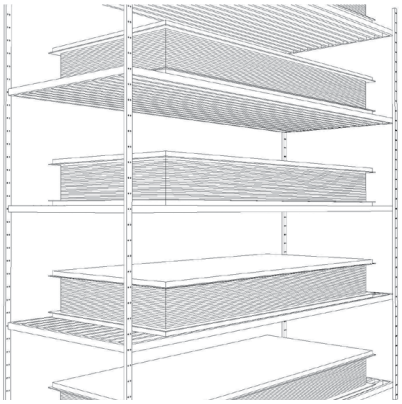


FIGURE 14: MEANS OF INSIDE STORAGE

3.3.6 Sawing, milling and grinding

Sawing, milling and grinding are prohibited (*Figure 15*).

SmartWall panels are ready made prefabricated elements that do not require further processing.

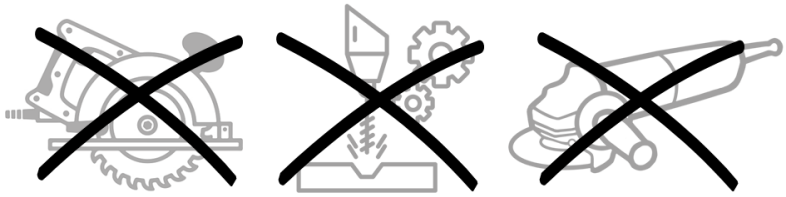


FIGURE 15: PROHIBITED PROCESSES

3.3.7 Drilling

While SmartWall panels usually do not require any holes to be opened in their surface in case that there is a necessity to perform a hole on to it the use of a high speed drilling machine is necessary to avoid chipping of the panel's finishing board.

Ideal are helicoidal drills with a drill point angled at 60° to 80° (instead of 120° for conventional metal drills) and with steep chip evacuation (so-called rapid inclination) and a wide channel. Hole saws may be used for large diameters but are not suggested to be opened, though if necessary and in order to prevent chipping, it is advisable to cover the board with masking tape in the area to be drilled.

3.3.8 Corners and joints

Depending on SmartWall's design, their corners can be open or closed (*Figure 16*) and the key points for both methods are:

- If corners are closed without any possibility of the joint opening and closing, the panel dimensions on either side of the corner may not exceed 300 mm. If they do exceed 300 mm, the corner has to be considered as fixed and the following dilatation gap should be twice the calculated width.
- Temperature and humidity do not affect the panel dimensions. Generally, a dilatation gap should be calculated as 0.15% of the length of the panel for the longitudinal direction and 0.3% of the width for the transversal direction.

  For the joints among panels, a minimum gap of 6 mm is required. This has not only a technical but also an aesthetical function. How smaller the joints, how more joint width differences will be visible. The most important issues regarding joints are:

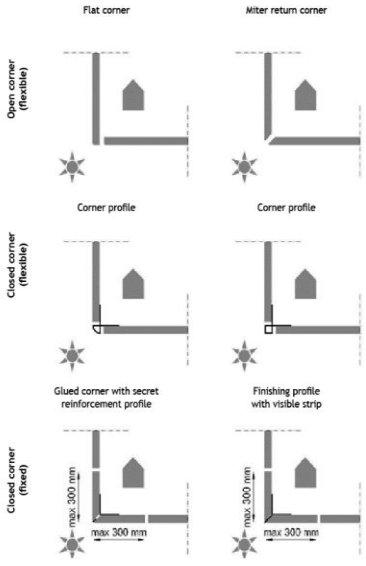


FIGURE 16: TYPE OF CORNERS

- If a profile (aluminium or plastic) is placed in the joint, spacing should be allowed on both sides of the profile equal to half the joint width (*Figure 17*).
- For aesthetic considerations, it is best to mask the joints, but also in order to prevent insects and vermin nesting behind the panels.
- At open joints, any potential rain or damp infiltration, can adversely affect the panel's integrity. Placing a vapour permeable moisture barrier can be a solution for this.
- Where air supply and extraction needs to be provided, the openings must be closed off with specially designed perforated screens and/or perforated profiles, in order to prevent access by vermin and insects behind the cladding.
- Optionally a drip edge profile could be used in order to prevent collecting and stagnating on the edge of the panel and also in order to avoid water infiltration behind the panel which could cause deterioration of the backing sub-construction.

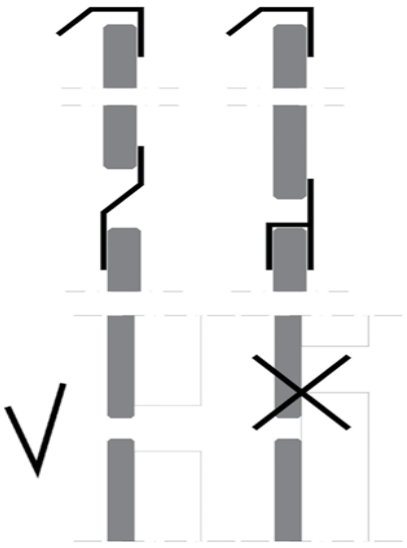


FIGURE 17: TYPE OF JOINTS

- Joints of the SmartWall panels do not need to coincide with the dilation joins of the sub-construction but can be offset to it, where their installation is more suitable.

3.3.9 Anchoring layout

Anchoring layout is **not** identical for each SmartWall panel, mainly because of:

- Depending on the SmartWall type, as presented in the *Deliverable D2.2 – Technologies and Materials selected for demo the demo sites* (blank type, or with openings, or multi type etc.);
- By this means, each panel is custom made, their dimensions varying and consequently its weight affecting the anchoring layout;
- Additionally, each substrate where SmartWall panels can be installed is not the same; different layout required for reinforced concrete and totally different for timber;
- The layout of E/M components into the SmartWall panels has a significant role to the selection of anchoring system, as limited accessibility to the anchors might be a constrain which needs to be override.Anchoring layout also depends on the anchoring system that SmartWall accommodates, as there two different

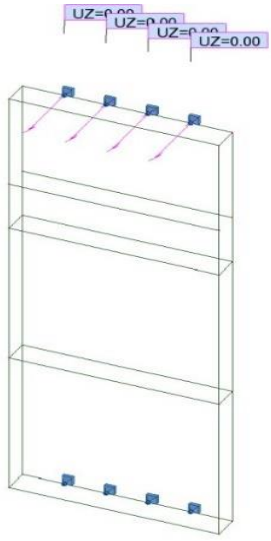


FIGURE 18: EXAMPLE OF STEEL BRACKETS ANCHORING LAYOUT

systems available, depending on the reasons mentioned on the above.

a. Fixed steel brackets (*Figure 18*), placed at the internal sub-frames upper and bottom beams @ 250mm c/c, suitable to accommodate from M6 to M12 mechanical of chemical anchors. This system is suggested for heavier panels <250kgr, or on panels that would be installed above the 2nd floor of the building and there is not a supporting slab to carry out the weight of the panel or
b. A "Z clip" system attached on both the SmartWall frame and the wall as per *Figure 19*. This system is suitable for lighter SmartWall panels >250kgr and to panels that can be supported by a slab capable to carry their weight.

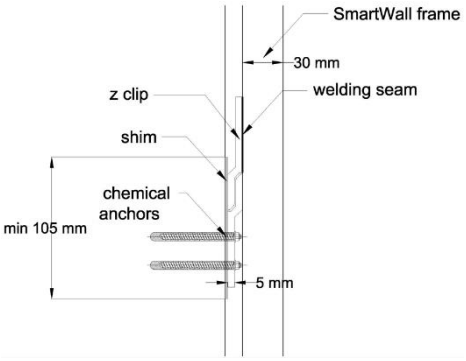


FIGURE 19: Z CLIP ANCHORING SYSTEM

In any case, the selection of the most appropriate anchoring layout can only be determined by the structural design, which will so provide the data for the anchoring properties (size, dimensions, span, and location on SmartWall panels).

3.3.10 Bracket fastening methods.

Bracket fasteners are the most suitable option to anchor SmartWall panels to load-bearing base materials.

The bracket fasteners must comply with national and/or European regulations or approval requirements and must also meet the manufacturer 's installation specifications. The applicable approval must cover the application for which these items are used, e.g. suitability for the demands of rain screen/ventilated facade installation. Where applicable, corrosion protection measures must also be implemented, and the compatibility of materials considered.

The load-bearing capacity of the bracket fastener must also be verified by carrying out on-the-spot pull-out tests in accordance with, e.g. ETAG 020 Annex B[28], ETAG 029 Annex B[29] or an equivalent test method.

Datasheets for each particular component suitable for SmartWall installation depending on the substrate that SmartWall systems will be installed, are presented in PLURAL's Repository of Materials developed in T4.1 – Optimisation of PnU kits – Main Components and has been uploaded in EMDESK portal).

However, its selection is always subject of the Structural Design, which will determine the type, and the characteristics of the anchoring system will be selected for the installation of SmartWall systems to each building.

[28] https://www.eota.eu/sites/default/files/uploads/ETAGs/etag-020-annex-b.pdf
[29] https://www.eota.eu/sites/default/files/uploads/ETAGs/etag-029-annex-b-april-2013.pdf

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

3.3.10.1 Anchoring on concrete and masonry

Mechanical or chemical anchors can be used depending on the substrate that SmartWall panels will be installed on it. The most typical (commercially commonly used) examples are presented in *Figure 20,* though there several other options as HALFEN anchoring systems[30], Eurofox systems[31] etc., which are not suggested due to their installation complexity.

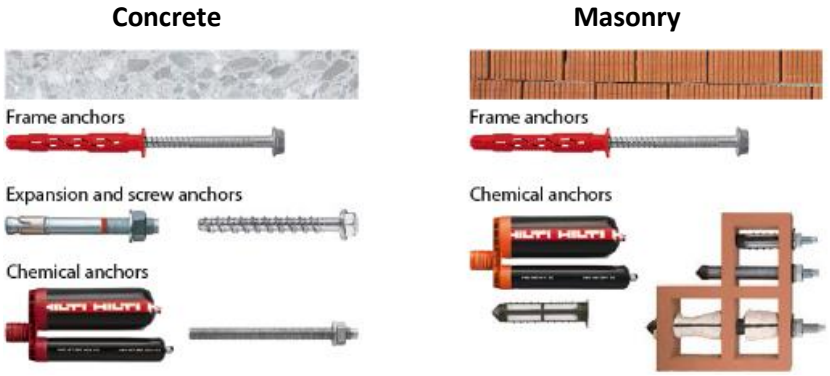


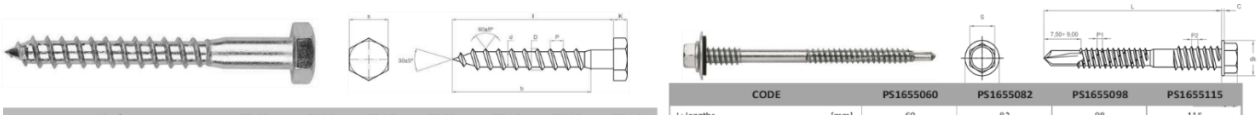
FIGURE 20: EXAMPLES OF ANCHORING SYSTEMS ACCORDING THE SUBSTRATE

3.3.10.2 Screw fastening on timber or steel

Before the right screw for fastening brackets can be selected, the properties of the material, i.e. the thickness of the timber or steel must be known.

As mentioned on the above the final selection of the screw's fastening type, their size and their particular characteristics will be identified and substantiated by the structural design of each SmartWall panel.

In *Figure 21* is presented an example type of screws suitable for most installations on timber (left) and steel frames (right).



Code		TB05	TB06	TB07	TB08	TB10	TB12	TB14
s: Head diameter	[mm]	8	10	12	13	17	19	22
D: Outer thread diameter	[mm]	5	6	7	8	10	12	14
d: Inner thread diameter	[mm]	3.5	4.2	4.9	5.6	7.0	9.0	10.5
p: Pitch	[mm]	2.2	2.6	3.2	3.5	4.5	5.0	5.5
k: Head thickness	[mm]	3.5	4.0	5.0	5.5	7.0	8.0	9.0
l: Screw length	[mm]	30 - 60	25 – 120	30 - 120	30 – 200	40 – 200	60 - 260	100

CODE		PS1655060	PS1655082	PS1655098	PS1655115
L: lengths	[mm]	60	82	98	115
d_k: head diameter	[mm]	10.50	10.50	10.50	10.50
C: washer head thickness	[mm]	1	1	1	1
P_1: thread ST 5.5	[mm]	1.8	1.8	1.8	1.8
P_2: thread ST 6.3	[mm]	1.8	1.8	1.8	1.8
S: spanner	[mm]	8	8	8	8
Drill hole capacity	[mm]	1.5 – 6.0	1.5 – 6.0	1.5 – 6.0	1.5 – 6.0
Thickness of sandwich panel to be fixed	[mm]	27 – 44	31 – 68	48 – 84	63 – 100

FIGURE 21: EXAMPLE TYPE OF SCREW SUITABLE FOR TIMBER (LEFT) & STEEL FRAMES (RIGHT)

[30] https://www.halfen.com/us/2524/product-ranges/construction/anchoring-systems/

[31] http://www.3dm.de/efox/

3.3.11 Connections among SmartWall panels

During tasks of *WP4 – Optimisation of PnU components – prototype – testing* several interlocking among SmartWall panels were investigated and the most suitable (depending on the customer's requirements, were presented in the *Deliverables D2.1 – Architectural and Structural Design* and *D2.6 – Final Stage design of PnU kits*. Briefly, were developed two (2) different types of interlocking system:

a. Flat type interconnection system (*Figure 22*)

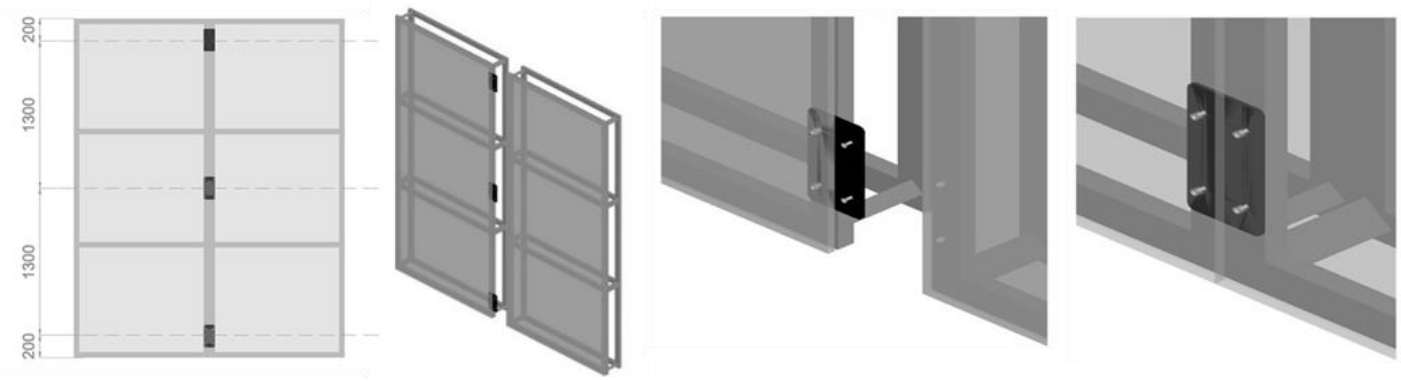


FIGURE 22: FLAT PLATE INTERCONNECTION SYSTEM

Suitable when there no need and/or request the customer (for aesthetic reasons) for joints among SmartWall panels (seamless paneling).

In this case, a metallic plate is installed on the front side of the SmartWall panel and is secured with stainless steel bolts at predrilled (during manufacturing) locations. The dimensions and properties of the interconnection metallic plate depend on the:

- Size of the panels;
- Weight of the panel and the
- Anchoring to the pre-existing wall method will be selected on the design stage.

b. Clip type interconnection system (*Figure 23*)

Suitable for all SmartWall applications regardless the restrictions mentioned on the above paragraph. It is preferred than the flat type interlocking system because:

- The clips are located in the side part of each SmartWall panel and are completely seamless.
- They are easier to be installed as no bolting is involved during the installation, only lifting of the panel for 30 mm and then descent it to secure in the clip.
- Allows undisturbed expansion by temperature variations of the SmartWall panel.

There are two (2) types of clip joints (*Figure 23*):

- Narrow type of clip joint allowing a gap among the panels up to 20mm and

- Wide type of clip joint allowing 40 mm gap among panel.

The gap among the joints is filled with mastic sealant while the thermal properties of the panels are not affected by the use of any of the type of clips as the internal insulator covers the area of the joint.

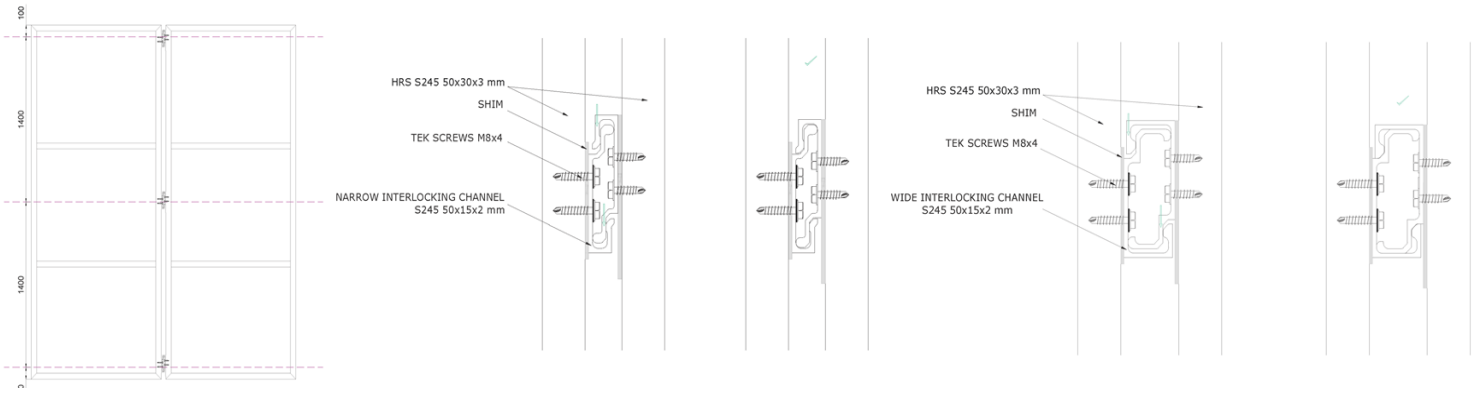


FIGURE 23: CLIPS TYPE INTERCONNECTION SYSTEM - NARROW CLIP (LEFT), WIDE CLIP (RIGHT)

3.3.12 PV panels

During installation of SmartWall systems in a building, PV panels are dismantled form the SmartWall panel for security reasons, while all the necessary wiring and components for their smooth and continuous operation are built in the SmartWall panels. Therefore, during the on-site installation, there are only two simple actions to be executed by the installer:

a. The PV panel to be attached on the pre-existing frame on the SmartWall panel (*Figure 24*) and
b. The connection of the power connectors of the PV panel to the waiting connector of the SmartWall system (*Figure 24*).

Moreover, the PV modules selected for SmartWall panels can be fixed on both the long and the short side of the module, using a minimum of four clamps. The selected modules are capable to withstand a downward force of up to 5400 Pa (550 kg/m^2).

In order to be re-attached on the SmartWall panel, there are eight (8) mounting holes (*Figure 25*). The PV module frame must

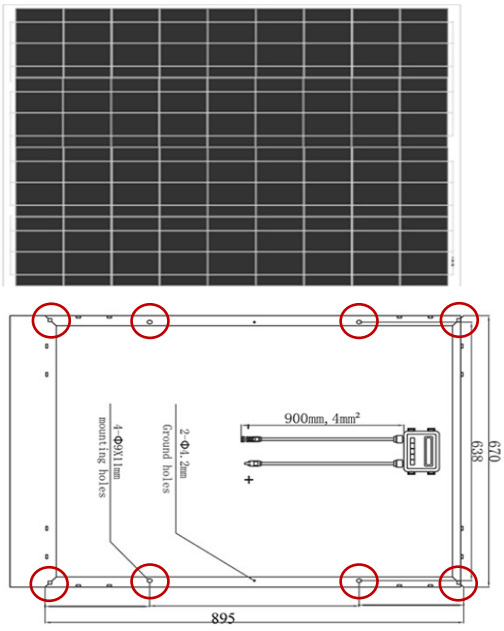


FIGURE 24: INSTALLATION HOLES OF PV PANELS

be attached to the mounting attached on the SmartWall panel rail by using the M8 corrosion-proof screws together with spring washers and flat washers in eight symmetrical locations on the PV module.

The applied torque should be big enough to fix it steadily. The reference torque value for M8 screw is 16~20N*m. The 4mm^2 cable connector should then be connected to the connector attached on the SmartWall panel and capacity must satisfy the maximum short-circuit of PV. The PV is then installed on the SmartWall panel.

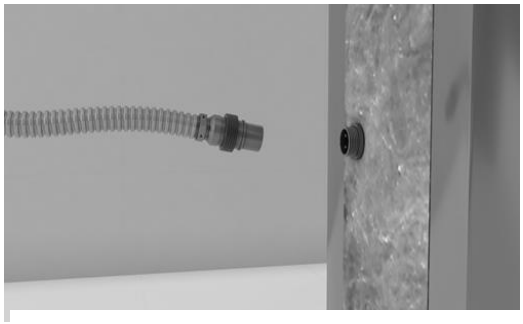


FIGURE 25: PV PANEL POWER CONNECTION TO THE SMARTWALL PANEL

The PV modules attached on SmartWall panels are qualified for application class A, which may be used in systems operating at greater than 50 V DC or 240 W. PV modules qualified for safety through this part of IEC 61730-1:2016[32] and IEC 61730-2:2016[33] and within this application class are considered to meet the requirements for safety class II. The temperature limit of cables is 85 °C and the temperature limit of connector is 105°C.

3.3.13 HVAC systems(Fan coil)*

Similarly, to the PV panels SmartWall's HVAC system is fully integrated within the SmartWall panel and the installation tasks required, are limited to:

a. Connect the push lock fittings of the main heating supply to the pre-existing to SmartWall fittings for the inlet and outlet of the fan coil (*Figure 26*), and
b. Turn on the isolation ball valves installed on the fan-coil's inlet and outlet pipes to allow water circulation in the fan-coil unit.

Both actions can be achieved by accessing the fan-coil unit via the access panel hatch located in front of it.

In addition, the pipe must have a certain fixed space to accommodate the thermal expansion and contraction of the pipe when go hot and cold water. Water inlet / outlet pipes and drainage pipes can be installed in the left of the fan coil (left-style) or in the right of the fan coil (right-style), depending on where the fan-coil's valves are located.

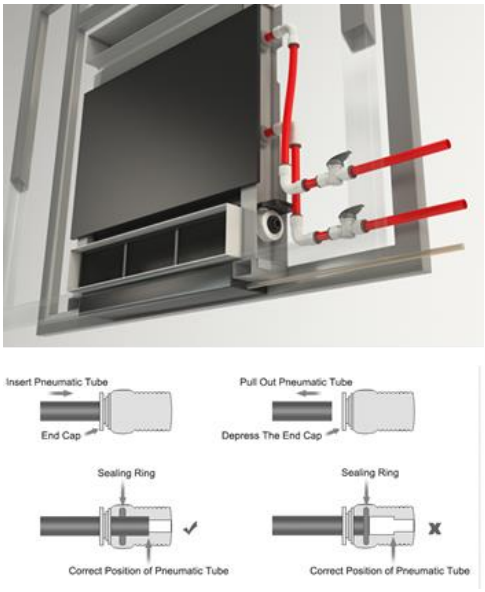


FIGURE 26: FAN-COIL CONNECTION TO SMARTWALL

[32] https://webstore.iec.ch/publication/25674

[33] https://webstore.iec.ch/preview/info_iec61730-2%7Bed2.0.RLV%7Den.pdf

All the main water pipe must have sufficient support to take the weight of pipe and water in it. Supply and return water pipe and the condensate pipe must be insulated to prevent dewing when cooling.

All electrical components and wiring required for the operation of the fan-coil unit are accommodated within the SmartWall panel, pre-checked and tested during manufacturing and are fully compatible with the provisions of European and national regulations.

3.3.14 Power connections

All electric components of SmartWall systems are fully integrated within it, pre-checked, tested and validated for their operation during manufacturing stage, therefore, no further actions apart its connection with of its main plug to a pre-existing wall plug in the building wall are required (*Figure 27*).

FIGURE 27: SMARTWALL PANEL CONNECTION TO THE BUILDING'S POWER GRID

Electrical connection of the SmartWall systems to the main power supply of the building is required only to those systems that include either fan coil unit and / or electrical ventilation and / or electrical roller blinds and / or AMscope.

The properties of the power supply (wire length, dimensions, power plug type and the exact location of the socket will be installed on the pre-existing wall) have been identified on the design stage and each SmartWall panel has been manufactured according the specific requirements of the wall will be installed on to.

All electrical equipment attached on the SmartWall systems comply with the provisions of the EU Directive 2014/35/EU[34].

3.3.15 Testing & Commissioning

A series of inspection actions / tests is required in order to complete the installation. It must be done to all components and be performed by the installers. The tests have been presented in detail in *Deliverables D4.5 - PnU kit prototype property and performance characterization* and *D6.3 - Quality Assurance Plan – manufacturing / assembly.*

Briefly, the inspection actions / tests that need to be performed on site after the installation of SmartWall systems are:

Visual tests

- Surface observation / defects on paint, cracks, flakes etc. identification;
- Sealant check defects on windows, sealant, sills, edges, bead.

IR thermography

[34] https://eur-lex.europa.eu/legal-content/EN/TXT/?uri=celex%3A32014L0035

- To window's / opening's joints and sill;
- To SmartWall panels' joints and interlocking system.

Mechanical tests

- Anchoring system (bottom and top hinges of the frame);
- Power outlet's condition e.g. firmly secured on the board, loose screws, etc.;
- PV panel mounting rail to be firmly secured on the frame;
- Window's frame to be securely attached on the frame;
- Window operation (open / close / tilt);
- Window's hinges;
- Blinds mechanical (without power supply) operation;
- Access panel locking system / unlocking system;
- AMscope casing to be firmly attached on the frame;
- Air pressure test for leakages on the fan-coil pipework.

Electrical tests

- Power inlet / outlet's voltage & current;
- Fan-coil voltage & current;
- Fan-coil control panel operation;
- PV panels voltage & current;
- Battery voltage & current;
- AMscope operation;
- Electrical operation of the roller blinds;
- Circuit breakers testing;
- Grounding testing, and
- Emergency cut-off mode.

3.4 Specific installation & safety requirements for SmartWall systems

The **Health & Safety Plan** as presented on the *Deliverable D6.1 – Manufacturing Methodology of PnU kits* refers in particular for the installation in the VVV demo building and covers all aspects in terms of Safety at Work according to the Greek Legislation (Law 3850/2010 O.G.A-84/2.06.2010)[35].

Though, some general precautions – instructions for the safe installation of the SmartWall panels, (applicable to all SmartWall installations and **NOT** only for the installation at the VVV demo building), should be taken into consideration for any future installation of SmartWall panels, as following:

[35] https://www.e-nomothesia.gr/kat-ergasia-koinonike-asphalise/n-3850-2010.html

3.4.1 Working on heights during installation of SmartWall panels

Where possible, when working at heightworkers should make sure the area below is cordoned off.

In all cases of working at height, ensure that:

- The equipment used is suitable for the job and is maintained and in good condition;
- Workers are competent and trained to use the equipment and carry out the job safely;
- All workers understand the job and the control measures in place to ensure their safety.

More complex installations may be accompanied by a detailed method statement for the activities will be performed.

A permit to work system (according the Local Authorities Regulations) might govern the nature and/or the duration of the work at height.

3.4.1.1 Ladders

Ladders are acceptable only for access or work of short duration. They should be:

- Erected at the correct angle (4 up to 1 out);
- Secured, preferably at the top, or footed;
- Positioned close to the work to avoid over-reaching;
- Protected at the base to stop vehicles or pedestrians bumping into them.

3.4.1.2 Stepladders

Stepladders should:

- Be spread to their full extent and locked off;
- Only have one person on the ladder at any one time;
- Be appropriate and of the correct grade for the intended use;
- Not have the top tread, tool shelf or rear of the steps used as a foot support.

3.4.1.3 Mobile elevated platforms

When using Mobile Elevated Work Platforms (MEWPs) the installers should:

- Wear a safety harnesses;
- Only use the platform on level, firm ground;
- Work with a trained operator at ground level;
- Only use the equipment with outriggers and stabilisers;
- Keep the platform within safe working limits and radius, taking account of wind speeds, beams, hanging obstructions and power cables.

3.4.1.4 Scaffolding

Scaffolds should be erected and periodically inspected by a competent person.

Where a person might fall two (2) metres or more, the scaffolding must be inspected by a competent person, a record maintained and further inspection at least weekly thereafter.

A tagging system is a useful way to inform workers that these inspections are taking place.

A risk assessment may find the need for more frequent inspections. They may also be required after bad weather and always after any modification

Additionally tower scaffolds should:

- Follow the manufactures guidelines to meet the correct height to base ratio;
- Have all casters firmly locked before use and never be moved while the tower is occupied;
- Have ladder access to the working platform;
- Never be used in strong winds or with broken, missing or incompatible parts.

3.4.2 SmartWall panel installation

They are described in chapter *1.2 – General guidelines for generic SmartWall panels installation* of the current report.

3.4.3 ETICS installation

Please refer to EOTA Installation Guide[36] for ETICS system installation guide.

3.4.4 PV panels installation

- Only use the equipment, connectors, wiring and support frames provided for SmartWall PV modules.
- Do not clean the modules with chemicals.
- Do not lift the PV module by grasping the module's junction box or electrical leads on its backside.
- Do not stand or step on the PV modules or place heavy objects onto it.
- Do not drop the PV module or allow objects to fall on the PV module.
- Do handle with care when move, transport and install the PV modules on SmartWall's designated position.
- Do not apply paint or adhesive to the PV module top surface.
- Do not use mirrors or other magnifiers to concentrate sunlight onto the PV modules.

[36] https://www.eota.eu/download?file=/2014/14-04-0083/for%20ojeu/ead%20040083-00-0404_ojeu2020.pdf

- Do not drill any other holes, than the pre-drilled on SmartWall's frame. This may reduce the frame mechanical strength and cause crack cells due to vibration.
- Do not break the anodized coating of the frame (except for grounding connection); this may cause corrosion of the frame.
- Do not handle panels in wet condition unless you have appropriate protection.
- Do not expose PV module to sunlight until installation to avoid unnecessary degradation.
- During transportation, please make sure there is no strenuous vibration on module.
- Check the electrical, grounding and mechanical connections every six months to verify that they are clean, secure, undamaged and free of corrosion.

Further information available in TRINA solar panels installation guides[37]

3.4.5 HVAC systems installation

3.4.5.1 Heat pump and fan-coil system

- Insulation must cover the entire line set length to avoid condensation and decreased efficiency. In addition, both pipes (i.e. supply and return) should be insulated separately to minimize heat transfer between them.
- Glue insulation joints to prevent condensation from dripping inside space.
- Protect the outdoor line set from insulation damage with rigid line hide and building code approved line set protection.
- Protect any remaining exposed line set with UV-resistant tape or other mechanical protection.
- Protect line set penetration through the building enclosure with rodent-proof insulation (e.g. with PVC sleeve and cap drilled to the size of the refrigerant lines, metal-wool stuffing, or similar).
- Correctly seal all penetrations through the shell of the home with insulating sealant/spray foam. As necessary, use gasket material to properly seal all penetrations.
- Make tubing connections using gasketed press/crimp designed for the refrigerant and tubing type.
- Follow the steps given below to perform good quality refrigerant line set work:
    a. Select suitable pipes and joints (i.e. pipes must be rated for the refrigerant pressure being used in the system);
    b. Ensure pipes are clean and moisture-free;
    c. Make bends properly and use proper bending tools to prevent kinking;
    d. Create flared joints properly;

[37] https://static.trinasolar.com/sites/default/files/PS-M-0434%20A%20Installation%20Manual%20of%20Standard%20Module_IEC_UL_2016_A.pdf

e. Ensure pipework is properly-supported or clipped to prevent sagging, excessive movement, or an unsightly installation 6. Insulate refrigerant pipework;

f. Position and connect the condensate drainage pipe properly.

- Keep the charge lines as short as possible.
- Leak test the pipework before charging, by partially opening, then closing the cylinder valve to pressurize the connecting pipework.
- Check for leaks using the bubble test solution.
- Wrap the indoor and through wall section of the drainage pipe in polyurethane foam insulation.
- Use smooth, hard PVC-U drainage pipe if drainage pipe runs laterally – flexible, ribbed drainage pipe can be used for vertical drainage.
- Where pipe traps are recommended by the manufacturer to reduce negative pressure, install in accordance with the manufacturer's specifications.

Further information available in DAIKIN ALTHERMA heat pumps installation guides[38]

3.4.5.2 Domestic hot water system

- The collectors should be installed as close in proximity as possible to the storage tank.
- The collectors should be mounted in an area with a full solar window.
- The collectors should be mounted with a minimum of 50mm air gap above the roof sheeting.
- The collectors should be mounted in parallel positioning.
- All roof penetrations should be sealed.
- Install collector array piping in a reverse-return configuration so that path lengths of collector supply and return are of approximately equal length.
- Install a freeze protection valve on the return line according to the diagram (optional).
- An air vent should be installed vertically on the highest point of the system.
- An air vent cup must remain loose for proper operation. The Air vent should be insulated
- The collector sensor should be mounted near the collector outlet.
- For best protection the freeze sensor should be mounted on the absorber in the center of the collector's array.
- Sensor wires should not be exposed to direct sunlight.
- Wire nuts connecting the sensors should be filled with silicon to prevent any moisture from penetration the sensor.
- All exterior pipe insulation should be protected from UV radiation and moisture. (Paint with exterior latex)

[38] https://www.daikin.eu/content/dam/document-library/installation-manuals/heat/air-to-water-heat-pump-low-temperature/EHVH-DV,DVG_4PEN499571-1B_2017_12_Installation%20manual_English.pdf

- Set the storage tank indoors close in proximity to 110V electrical outlets. Secure tank in event of an earthquake.
- Install a shut-off valve for the solar system so that the cold water supply is not interrupted.
- Install a T&P Relief Valve. The drain line should be discharged the to the outdoors no higher then 100mm above grade.
- Install the pump on the collectors feed line with the arrow pointing to the direction of flow. (To collectors)
- Install a thermosiphon prevention check-valve on the collectors return line.
- Install the tank sensor on the threaded stud located behind the cover plate of the bottom portion of the tank.
- Install the controller according to the installation instructions provided with the controller.

Further information available on Interplast solar water heaters installation guide[39]

3.4.6 Electric components / devices installation

- Power off.

  Make sure the power is off at the breaker before you start and use a voltage tester to verify that wires and/or electrical connections are completely dead before you start working on them. Make sure everyone in your home is aware that electrical work is going on. Tape the circuit breaker into the off position.
- Be careful what to be touched.

  Never touch plumbing or gas pipes while working with electricity they are often used to ground electrical systems.
- Use the right tools.

  Before any works commencement, make sure that there is a plan in place as to what outlets, switches and fixtures will be involved in the working tasks. Make sure all the appropriate tools are available, including but not limited to: needle nose pliers, wire cutters, cable & wire stripper, fish & colored tape, voltage tester, continuity tester, electric & right-angle drill.
- Include a junction boxes.

  Never splice wires together and conceal them within a wall without a junction box — an accessible junction box should always be used to join wires.
- Replace old wiring that shows signs of deterioration or fraying.
- Fix fuse and breaker problems (if any).
- Don’t overload devices and/or components and/or circuits.
- Make sure electrical equipment is properly connected, grounded and in good working order.

[39] https://www.interplast.gr/sites/default/files/technical_bulletin_-_solar_water_heaters_manual_final_eng.pdf

- Extension cords may not be used as permanent wiring and should be removed after temporary use for an activity or event.
- Surge suppressors with built-in circuit breakers may be used.
- High amperage equipment must be plugged directly into permanent wall receptacles.
- Do not allow access, use or alter any building's electrical service, including circuit breaker panels, unless the people are authorized to do so.
- Wet environments can increase the risk of an electrical shock.
- To prevent electrical hazards, always make sure equipment is properly grounded.
- Equipment with a grounding prong must be plugged into an extension cord with a ground; the grounding plug should not be removed from the equipment.

For the Greek demo building, refer to the Regulation of Interior Power Installations (K.E.H.E)[40]

For other countries than Greece, refer to National Regulations Guidelines of each country for further information.

3.4.7 Additional safety equipment

Additional equipment should only be considered as a last resort when no other means are reasonably practicable. These include:

- Nets;
- Airbags;
- Harnesses;
- Safety lines;
- Other fall restraint and arrest equipment.

They should only be used and erected by trained personnel and be tested and inspected regularly.

[40] https://www.elinyae.gr/ethniki-nomothesia/ya-f751816882004-fek-470b-532004

4 Hybridwall (eAHC) – Installation Methodology

4.1 Design & installation requirements

4.1.1 Structural stability

The Denvelops® System for facade cladding does not contribute to the stability of the building. The HybridWall will be installed at the Terrassa demo site in Spain.

The rear enclosure, supporting the Denvelops® coating, must obey the regulations attaining their own essential structural safety requirements, and in view of the actions and requests appropriate to the incorporation of the ventilated facade. Without considering other requirements, the next ones must be considered as standards: Dead weight, Wind loads (wind uplift and wind pressure), Snow and ice, Dynamic (shock) loads, Special cases (seismic loads, signage).

The Connection between the Load Points of the system and the existing support must be chosen considering that the extreme limit stresses or the limit values of durability are not exceeded during their lifetime.

Regarding to the PLURAL project, in *Deliverables D2.1 (Architectural & Structural Design of PnU kits)* and *D2.7 (Final Stage Complete Design of PnU kits)* specific calculation has been submitted to prove and accomplish the required regulations in Europe and Spanish laws.

4.1.2 Fire protection

The complete enclosure solution must be in accordance with the regulations that apply regarding Fire Safety in each country, in terms of fire stability, as well as in the reaction to fire of the materials that form the solution.

All the materials used in the solution were described in Deliverable 2.1, Section 5.2, and comply with the fire resistance requirements defined in the CTE-SI (Spanish technical building code). The values required for the external propagation will be justified in each project intended for the exterior or interior cladding materials and the interior surfaces of the ventilated facade chambers.

In *Deliverable D4.5 (PnU kit prototype property and performance characterization)* the fire resistance and protection of the HybridWall has been defined by demonstrating that all used components accomplish with the required regulations in Europe and Spain laws.

4.1.3 Thermal insulation and protection from dampness

The complete construction solution of the enclosure must satisfy the requirements of each executive project, regarding Energy Saving.

Regarding the calculation of the thermal transmittance of the system, the air chamber can be considered either a "highly ventilated air chamber" or not. It will depend on the density of the tiles and the type of designed joints between the tiles for each project.

In the first case, the total thermal resistance of the enclosure will be obtained by neglecting the thermal resistance of the air chamber. The other layers between the air chamber and the external environment will be obtained by including an outer surface resistance equivalent to calm air, equal to the inner surface resistance of the same element.

In the second case, which is the case developed for the Plural Project, the detailed solution has been designed to incorporate overlaps between the tiles. In *D4.5 - PnU kit prototype property and performance characterization* has been quantified the transmittance for the Hybrid wall solution considering the final designed solution.

In addition, the system has been designed to expulse any leakage of water or intern dampness that may generate, taking into special account the joints with the windows or with the unit ventilation pipes connection.

4.1.4 Deformation

The basic assembly, design, and anchoring type of the HybridWall solution aim to prevent such deformations due to changes in temperatures or wind loads that may cause damages to the façade.

Although such deformations or damage would not occur, it is assumed that the system is capable of absorbing them without problems. That is why all anchoring systems have been designed to move freely along the façade in case of heavy and/or non-standard conditions.

Even if such damages might occur, the problems could be avoided by installing more wind-resistance anchoring to the facades in order to reduce the stress of the system and its deformations.

4.1.5 Tolerances

Tolerances must be set up in every project according to its requirement. In the Denvelops case, and especially for the PLURAL project, tolerances depend on the following:

- Flat surface of the façade: It is not important since the system works as a double skin façade, which is hung from the top, and later attached to the wall with an anchoring system, which at the same time can absorb the irregularities of the façade in the case is not perfectly flat.
- Front elevation tolerances: Specific dimensions must be taken to determine the required tolerance to determine the dimensions of the frames and sequences of the Denvelops systems.

  Regarding the HybridWall solution, two types of tolerances must be contemplated:

  a. External frames and sequences tolerances: Depending on the height and width of the façade. Normally are defined between 8 and 12 mm, so that all frames' dimensions will be produced according to this.

  b. Windows' tolerances: It is a specific case for the sequences that must cover two windows (in different levels) at the same time. It is important to know if they are vertically aligned since the same sequence (with the windows) must be able to cover both of them at the same time. Regarding the Plural project, the finishing of the windows between the façade and the windows

has been done to absorb differences of 5 cm. In case this would not fit, the position of one of the existing window holes should be modified to accomplish the HybridWall requirements.

4.1.6 Air-tightness

The design of the HybridWall system and the specific construction details and solutions for its installation on the Demo building site have been done in order to accomplish the required airtightness for this type of solution and building uses.

4.1.7 Soundproofing

The soundproofing requirements were taken into consideration in deliverable *D4.1 - Optimized components for PnU kits*, related to the Optimization of PnU kits and its Main Components.

4.1.8 Lightning protection

In the Deliverables developed in tasks *D2.1 – Architectural & Structural Design of PnU kits* and *D2.7 – Final Stage Complete Design of PnU kits* the lightning protection was taken into consideration for the design of the HybridWall solution to accomplish the National and European regulations regarding to not cover to any lighting points or openings at the façade.

4.1.9 European regulations

As for the other Plural solutions developed within the project, all European regulations have been taken into consideration to be applicable for the HybridWall solution. These regulations were fully integrated and can be consulted in the *Deliverables D1.1 - Requirements: Context of application, building classification, used consideration - Definition of requirements and constraints* and *D1.3 - Certification requirements accounting for occupant legal and privacy monitoring.*

These regulations apply to both PLURAL solutions and have been briefly summarized in the following sections of this document: Section 3.1.9.1 Steel members & frame and section 3.1.9.2 Electromechanical equipment.

4.1.10 HybridWall limitations

The HybridWall solution has been designed to be applied in all types of building shapes and typologies. However, there are some limitations that will decrease the advantages of using the proposed solutions. These limitations can be summarized in the following ones:

- The structural resistance of the building slabs and walls.
- Random positioning of the windows.

All applicable limitations were analyzed in the Deliverable 2.2 *Technologies and Materials selected for demo the demo sites,* and *the Deliverable 2.1 Architectural and Structural Design.*

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

4.1.11 Applicable sub-substrates for HybridWall installation

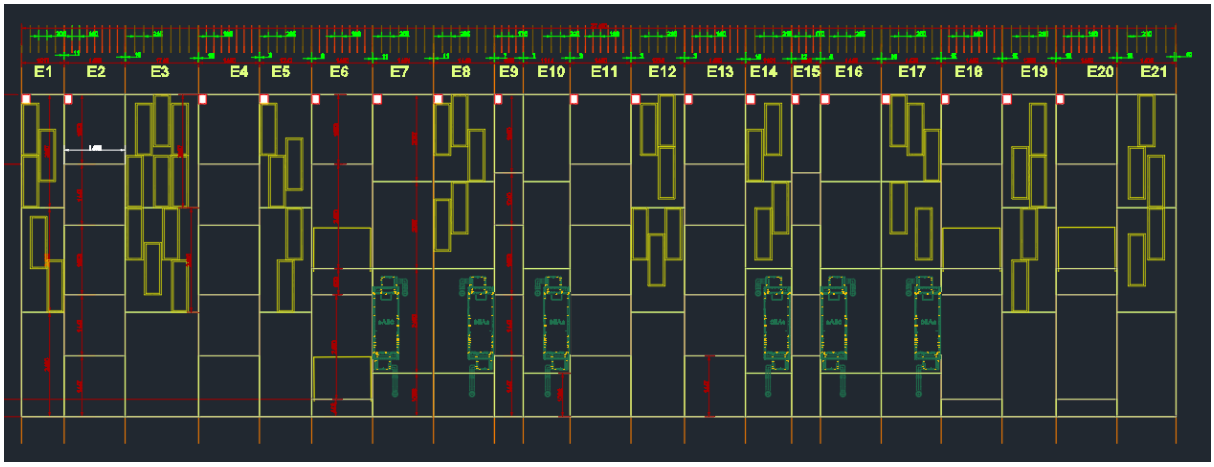
The range of sub-substrates where the HybridWall solution can be installed is very large, and most of them will always be possible to be used, if the sub-substrates' system have been constructed according the European regulations. Even with weak sub-substrates, there are reinforcement systems and strategies to reduce possible sub-substrate limitations.

Always according to the European regulations and following the necessary on-site evaluation of the materials and the structural system of the building, the aforementioned suitable base materials can be used for the HybridWall solution: Concrete, bricks, sand-lime block, aerated concrete, timber, composite lumber, steel frame structures, existing/unclassified masonry, and sandwich components.

4.2 HybridWall systems installation methodology at Terrassa demo building

4.2.1 Installation guideline, requirements and strategy

According to the Deliverable *2.7 Final Stage Design of the Panel Units Kits*, the Terrassa Demo building has been decomposed in 42 sequences, each of which will be hung from the top of the building. The sequences will be formed by 3 to 5 HybridWall frames.



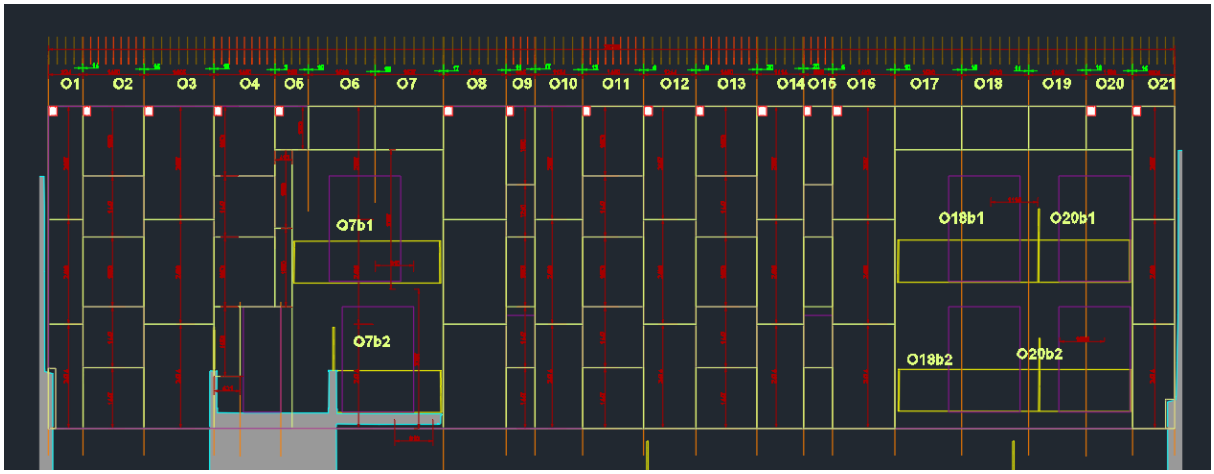


FIGURE 28: MODULAR DESIGN OF SEQUENCES AND THEIR FRAMES FOR THE EAST AND WEST FACADE

There will be installed in total:

- 21 "HybridWall" sequences of panels on the east façade, including 18 window frames, 6 UV frames (unit ventilation) and 18 frames with PV panels, and the rest correspond to insulated frames.
- 21 "HybridWall" sequences of panels on the west façade, including 12 window frames, and the rest corresponding to insulated frames.

Table 1 interprets the outcome of the architectural design in terms of HybridWall frames' dimensions, type and layout per building's area that will be installed in the Terrassa demo site.

FAÇADE	Height Frame 1	Louver & Window 1	Height Frame 2	Louver & Window 2	Height Frame 3	Height Frame 4	Total sequence Height[m]	Sequence Width [m]	NUM SEQ
East facade									
E1	2,687	0,000	2,480	0,000	2,480	0,000	7,647	1,017	1,00
E2	1,653	1,447	1,653	1,447	1,447	0,000	7,647	1,450	1,00
E3	2,687	0,000	2,480	0,000	2,480	0,000	7,647	1,748	1,00
E4	1,653	1,447	1,653	1,447	1,447	0,000	7,647	1,450	1,00
E5	2,687	0,000	2,480	0,000	2,480	0,000	7,647	1,242	1,00
E6	1,653	2,480	0,620	2,480	0,413	0,000	7,646	1,450	1,00
E7	2,067	0,000	2,067	0,000	2,480	1,033	7,647	1,421	1,00
E8	2,067	0,000	2,067	0,000	2,480	1,033	7,647	1,452	1,00
E9	2,067	1,240	1,447	1,447	1,447	0,000	7,648	0,730	1,00
E10	2,067	0,000	2,067	0,000	2,480	1,033	7,647	1,097	1,00
E11	1,653	1,447	1,653	1,447	1,447	0,000	7,647	1,450	1,00
E12	2,687	0,000	2,480	0,000	2,480	0,000	7,647	1,275	1,00
E13	1,653	1,447	1,653	1,447	1,447	0,000	7,647	1,450	1,00
E14	2,037	0,000	2,067	0,000	2,480	1,033	7,617	1,073	1,00
E15	2,067	1,240	1,447	1,447	1,447	0,000	7,648	0,730	1,00
E16	2,067	0,000	2,067	0,000	2,480	1,033	7,647	1,551	1,00
E17	2,067	0,000	2,067	0,000	2,480	1,033	7,647	1,304	1,00
E18	1,653	2,480	0,620	2,480	0,413	0,000	7,646	1,450	1,00
E19	2,687	0,000	2,480	0,000	2,480	0,000	7,647	1,286	1,00
E20	1,653	2,480	0,620	2,480	0,413	0,000	7,646	1,450	1,00
E21	2,687	0,000	2,480	0,000	2,480	0,000	7,647	1,405	1,00
West facade									
O1	2,687	0,000	2,480	0,000	2,480	0,000	7,647	0,824	1,00
O2	1,653	1,447	1,653	1,447	1,447	0,000	7,647	1,450	1,00
O3	2,687	0,000	2,480	0,000	2,480	0,000	7,647	1,666	1,00
O4	1,653	1,447	1,653	0,000	0,000	0,000	4,753	1,450	1,00
o4	0,000	0,000	0,000	0,000	2,523	0,000	2,687	0,545	0,00
O5	1,033	0,000	0,000	0,000	0,000	0,000	1,033	0,793	1,00
O5	1,860	0,000	1,860	0,000	0,000	0,000	3,720	0,397	0,00
O6	1,033	0,000	0,000	0,000	0,000	0,000	1,033	1,213	1,00
O7	1,033	0,000	0,000	0,000	0,000	0,000	1,033	1,995	1,00
O8	2,687	0,000	2,480	0,000	2,480	0,000	7,647	1,488	1,00
O9	2,067	1,240	1,860	1,240	1,240	0,000	7,647	0,725	1,00
O10	2,687	0,000	2,480	0,000	2,480	0,000	7,647	1,089	1,00
O11	1,653	1,447	1,653	1,447	1,447	0,000	7,647	1,450	1,00
O12	2,687	0,000	2,480	0,000	2,480	0,000	7,647	1,249	1,00
O13	1,653	1,447	1,653	1,447	1,447	0,000	7,647	1,450	1,00
O14	2,687	0,000	2,480	0,000	2,480	0,000	7,647	1,094	1,00
O15	2,067	1,240	1,860	1,240	1,240	0,000	7,647	0,730	1,00
O16	2,687	0,000	2,480	0,000	2,480	0,000	7,647	1,483	1,00
O17	1,033	0,000	0,000	0,000	0,000	0,000	1,033	1,586	1,00
O18	1,033	0,000	0,000	0,000	0,000	0,000	1,033	1,587	1,00
O19	1,033	0,000	0,000	0,000	0,000	0,000	1,033	1,369	1,00
O20	1,033	0,000	0,000	0,000	0,000	0,000	1,033	1,092	1,00
O21	2,687	0,000	2,480	0,000	2,480	0,000	7,647	1,006	1,00

TABLE 3: HYBRIDWALL PANELS DIMENSIONS AND COMPONENTS (GREEN CELLS ARE UNIT VENTILATION FRAMES)

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

In Deliverables *D2.1 Architectural & Structural Design of PnU kits* and *D2.7 Final Stage Complete Design of PnU kits,* were defined and presented the basic standards for the installation requirements.

Regarding to construction works, the installation of the system must be divided into 3 phases:

4.2.1.1 Phase 1 – Preparation of the building façade:

All the preparatory work effort is required to achieve the standard conditions which allow the installation of PnU HybridWall solution. In general, depending on the developed solution, this phase can be composed of the next construction works actions:

- Façade measurements to obtain real dimensions of all components, especially the position of the façade windows holes, and the position of the structural slabs of the building. In case of having to install ventilation units, it will be also required to obtain more measurements of the internal wall in order to know which of the elements like electrical boxes, water or gas pipes, heating radiators or whatever other type of installations exist.
- Construction works to prepare the façade for the panel's installation:
  a. Adjustments on the dimensions of the windows' holes in case of detecting tolerances between them (related with their vertical or horizontal alignment positions).
  b. Move the interior installations in case of an intersection with the holes for the unit ventilation connection.
  c. Drilling of the holes for the air pipes (appr. 100 mm hole) and the electrics to connect the unit ventilation to the interior of the façade.
  d. Install the interior finishing of the pipe –and its funnel at the wall- that will be located in the hole façade for the ventilation unit.
  e. Install Load Anchors and the "Cartelas" anchoring , which are another specific anchoring element, along the perimetral finishings of the windows and the façade.
  f. Install the electrical wiring which will be used to connect the PV inverters to the main electrics of the building.

Most of the aforementioned works can be executed from the outside of the façade, therefore no disturbance to the building occupants will occur. Only some of them will require the access to the interior:

- Movement of the interior installations only if required.
- Clean minor waste that can fall inside the façade during the drilling of the ventilation holes.

4.2.1.2 Phase 2 – Installation of the HybridWall PnU

This phase is dedicated to the hanging of the HybridWall. At this stage the following methodology is followed:

- Hang with the aid of a crane each “work sequence”: “Work sequences” arrive at the site divided by frames, and placed all together in the same pallet, in a vertical position. By using the crane, each frame must be elevated and positioned over the following one and connected to each other by 5 mm screws, washer, and nuts (two attachment per frame line or columns). Once the “work sequence” of the frame is linked, place the “work sequence” at the designated position of the building.

Notes:

a. The order of the installation “work sequences” is defined according to the requirements and characteristics of each project.
b. In case of PV tiles, they must be connected to each other before the “work sequence” installation.
c. In case of insulation panels: connect them with the adhesive joints after every frame linking.
d. After installing every “work sequence” install the wind anchors positioning them according to the installation plan.
e. Repeat the installation of all “work sequences” for the project.
f. Once all “work sequences” are installed then proceed to phase 3 of the installation, where the crane will be no longer required.

4.2.1.3 Phase 3 – Finishing the installation of the systems:

This phase consists of finishing the installation of all HybridWall construction works:

- Windows:
  a. From the interior side of the façade install the expansive multifunctional joints to the window perimeter.
  b. By using the extension of the window’s temporary anchors, move the window to the opening of the façade.
  c. Level the window and install the screws to connect the window to the façade opening.
  d. Add sound insulation joints.
  e. Finish the interior of the window with aluminium L finishing profiles.
  f. Remove the window temporary anchors.
  g. Install the external taping to protect the windows’ joints with the façade.
  h. Install the windows’ finishing pieces to the perimeter.

- Insulation:
  a. Take out the required tiles according to the installation plan and move the insulation to the wall until are both contacting. Use the insulation knife, by folding them to ensure the insulation remains in the required position.
  b. Install insulation fixing rosettes at the designated installation plan location.
  c. Take out the required tiles according to the installation plan and ensure that the joints of the insulation between “work sequences” are fitting well. Add adhesive tape on the joints.

d. Reinstall all the tiles that have been taken out.

- PV tiles:
  a. Take out the required tiles according to the installation plan to connect the PV cable and the inverters to the main wiring of the building.
  b. Reinstall all the tiles that have been taken out.

- Ventilation unit:
  a. Take out the required tiles according to the installation plan to have access to the ventilation units' anchors.
  b. Make the holes and install the unit by using the extension of the anchors.
  c. Take out the temporary anchors.
  d. Take out the required tiles according to the installation plan to have access to the unit ventilation pipes to connect the pipe which is already installed in the façade with the UV.
  e. Connect the electrical wires of the system with the interior façade junction box.

- Install in the façade the finishing pieces of the perimeter of the wall.

4.2.2 Time schedule for the HybridWall Terrassa Demo building

The installation at the demo building will start as soon as the tender for the installer is completed.

However, according to the number of workers and auxiliary equipment's the construction works can be executed in a limited time, therefore the total working hours required, depends on the installer's capacity to provide adequate number of workers and teams for the installation works execution.

To complete the installation variables the following table 4 indicate the time line of the required works for the completion of installation works.

Activity		Month 1				Month 2				Month 3			
	Work days	Week 1	Week 2	Week 3	Week 4	Week 1	Week 2	Week 3	Week 4	Week 1	Week 2	Week 3	Week 4
Implementation of works													
Construction fence and booths													
Assembly use of auxiliary means elevations													
Disassembly of auxiliary means													
Facade preparation													
Dismantle shutter boxes and Adjustment of windows holes	15	0,50	0,50	0,50	0,50	0,50	0,50						
Drill holes	2		0,40										
Install sate	10	1,00		1,00									
Install PV roof													
Install PV roof	20					1,00	1,00	1,00	1,00				
Assembly Denvelops Modules													
Install facade load anchoring	5		1,00										

Hanging Denvelops Sequences and install wind anchors	28			0,93	0,93	0,93	0,93	0,93	0,93				
Install windows	17			0,57	0,57	0,57	0,57	0,57	0,57				
Install perimetral facade finishing	2,4									0,48			
Install balconies	1,88					0,38							
Install PV tiles	5,73									0,38	0,38	0,38	
Install insulation	4,82			0,16	0,16	0,16	0,16	0,16	0,16				
Install unit ventilation	3,38					0,34	0,34						
Interior finishes													
Dismantle old windows and Finishing of interior windows holes	29					0,97	0,97	0,97	0,97	0,97	0,97		
Painting	2						0,07	0,07	0,07	0,07	0,07	0,07	
Install screens	2										0,13	0,13	0,13
Waste management													
Quality control and helps works													
Health and safety													
End of works													

TABLE 4. TIMETABLE FOR THE INSTALLATION PNU WORKS

4.2.2.1 Testing and commissioning

Testing and commissioning is planned as the last activities of the construction schedule with an overall duration of two (2) working days that will have to be agreed with the occupants of the building to disturb the least.

The inspection actions / tests for all its components which will be performed by the installers will be the next:

- Visual and functional test
  a. General aesthetic of the façade.
  b. Window finishes adjustments.
  c. Ventilation tiles for unit ventilation
  d. Façade finish perimeter.
  e. Louver movement.
- Mechanical tests
  a. Fixation tear-off test
  b. Window tightness test
  c. Facade tightness test
  d. Blower Door test.
  e. Statistic Check of 10% of load and wind anchors torque.
- PV system
  - The installation procedure will be completed by final check of the system functionality.

4.2.3 Risk Assessment Plan on installation of HybridWall systems in Terrassa demo building

According the description in Task 6.1 Manufacturing methodology of PLURAL PnU, regarding the installation scenarios plans, should be considered at the time this report is written that only the last of the scenarios can be fulfilled, as per Table 5 description.

By the data of Deliverables *D6.1 – Manufacturing methodology of PLURAL kits* and *Deliverable 6.3 - Quality Assurance Plan – manufacturing /assembly*, a large range of possible risk and critical activities, that could affect the installation provisional time of PLURAL PnU kits are indicated.

Specifically, for the installation methodology the following key points are important:

- Critical activities during installation that can produce delays, and how these delays will affect the operability of construction works.
- Improve and define alternative ways on the installation actions to reduce the installation time.

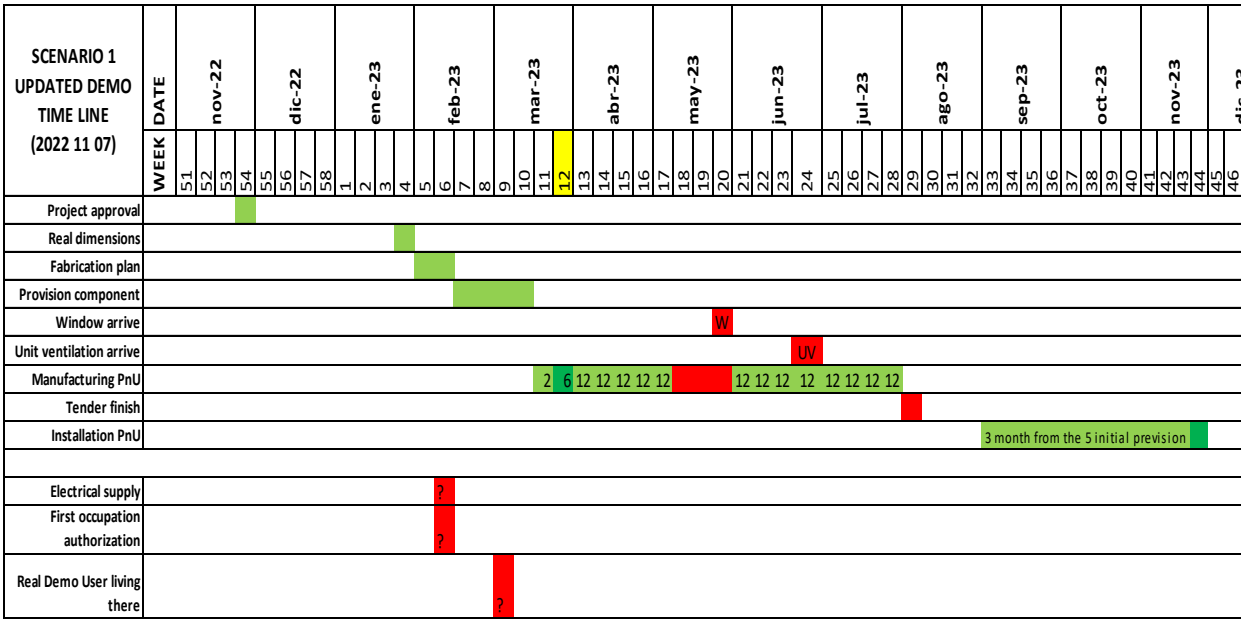


TABLE 5. PRODUCTION PLAN SCENARIO FROM TASK 6.1

According to both tables 4 (presented at the previous section) and table 5, the most representative and/or the most possible to happen scenario is presented in the following table.

TYPE OF POSSIBLE DELAY: DELAYS IN THE STARTING DAY OF THE WORKS		
Causes:	**Time delay:**	**Mitigation plan:**

The renovation demo project needs modifications to achieve the budgets of the PLURAL project	3 months.	Reduction of manufacturing PnU (2 months) Reduction of installation time by adding more team workers.
Delays to get the permission from the Municipality	2 months	
The Tender procedure terminates with no offers, so that a new tender must be executed	2 months	Reduce the project quantities to reduce the installation costs, and execute the project without tendering procedure.
Conclusions: • Up to 1- or 2-months delays: May 23 and August 23 are months with no working activity, which could be used to recuperate the delayed time. • Up to 3 moth delays: This 3rd month could be recuperated by trying to fabricate faster the PnU, or by trying to improve the installation time by increasing the working force.		

TYPE OF POSSIBLE DELAY: DELAYS DURING THE WORKS INSTALLATION		
Causes:	**Time delay:**	**Mitigation plan:**
Delays to get the permission from the Roads Department to install the crane on the road.	20 days	Reduction of installation time by adding more working force. Install the crane in another position out of the road
Installation works take longer from initial provision	7 days	
Problem to entry in the end-user apartments to execute the interior works	7 days	
Delay to PV installation due to delays on completion of the electrical works of the building.	10 days	Use an electrical generator to provide electricity on site.
Conclusions: • Up to 7-10 days delays could be easily recuperate by increasing the workforce. • Up to 20 delays could be easily recuperate by increasing workforce and auxiliary construction machinery (elevator, scaffolders etc.) • Since Denvelops is not the installer, the schedule for the installation works has been executed with long-term assumptions. It is a possibility that can be compressed about 2 weeks.		

4.3 General instructions for HybridWall installation system

The assembly of the HybridWall solutions will generally be done by following the next steps:

1. Setting out, general specifications.
2. Load Anchors Installation
3. Frames or Sequences Installation (made by hanging)
4. Wind anchors installation.
5. Windows installation (if applicable)
6. Insulation Installation (if applicable)
7. PV tiles installation (if applicable)
8. Unit ventilation (if applicable)
9. Finish general works.

4.3.1 General specifications

Denvelops®, may appoint an assembly director to the building site to train and help the professionals who will participate in the installation process.

However, the assembly of the system must be carried out by personnel specialized in installing metal facades using anti-corrosion fasteners.

The setting out of a Denvelops® system must consider the support flatness and the width and height of the façade. So prior the beginning of the installation a façade layout should be executed to exactly determine where all components need to be installed.

- Flatness: The wall will be set out by checking the polarimetry of the supports and confirm the that the planned anchors follow the required regulation foreseen in the project phase.
- Horizontal Layout: The horizontal layout will aim to mark all the vertical joints of the Frames or Sequences in the designated location of the installation. In case the total lengths are longer than expected, under the acceptance of the Facultative Direction, the Frames or Sequences can be spaced, or an additional column of tissue can be added either in situ or by means of a fabric produced in Denvelops plant. Otherwise, it would be necessary to disassemble one or several columns of a Frame or Sequence to achieve the alignment.
- Vertical Layout: For the vertical layout, the heights of the wall will be checked, and the location of the Load and Wind anchors Lines will be reframed. Finally, a plumb line will be marked serving as a reference to regulate the depth of the Load and Blocking anchors that will be installed in the subsequent phases.

Besides these initial instructions, other important factors must be considered:

- It is important, in case of installing stainless steel components, to use stainless steel tools that are clean and uncontaminated by the use on other types of steel or metals. Otherwise, spot stains of oxidation by contact may appear, which do not damage the components, but disfigure the product aesthetically.
- Construction manager and the crane will be responsible for the installation of Frames or Sequences in days of high winds.
- It is also important to note that the installation of each Frame or Sequence must be completed with the Load and Block Lines when are being fully installed (or if it is not possible, to install a

provisional system that serves for this purpose), otherwise, a sudden wind blow could cause a fabric damage.
- Load anchors are placed.
- Windows openings are clean and have been aligned.
- Pre-installation of the PV system has been done, and the cables to connect the PV are visible.
- Holes and electrical connections for the Ventilation unit have been completed.

4.3.2 Safety instructions working with HybridWall system.

The safety instructions for the HybridWall are the same as for the SmartWall:

- Respect the applicable **Health and Safety Plan** as presented on the *Deliverable D6.1 – Manufacturing Methodology of PnU kits.*
- Wear appropriate, not loose-fitting work clothing. Avoid wearing rings, necklaces, watches or other type of jewellery and ornaments.
- Wear safety helmet, goggles and a dust mask when doing the jobs (e.g. drilling façade, touch insulation, touch anchors).
- Wear ear protection for noisy processing (e.g. drilling).
- Provide continuous dust extraction during machining activities.
- Wear protective gloves during activities involving adhesives, dissolvents, or other chemical products.
- Make sure that all electrical equipment is earthed.
- Remove adjusting spanners or wrenches before using any type of machine.
- Keep the workplace clean and tidy.
- Ensure that the work pieces are always stable and clamped before proceeding with processing.
- Respect the generally applicable instructions and measures concerning occupational safety and fire prevention.
- Don't throw wastes and small metal pieces while doing the works.

4.3.3 Load anchors installation

The Load points will be positioned on center to center of the horizontal layout of the Frames, separated according to the defined boreholes of the Load Guides.

It is required to place and leave them leveled in depth and height, according to what was expected in the previous setting outs. Only after this step has been completed, the installation of the sequences can start.

The installation will be done by the wall fixing method (mechanical, chemical, or other) design indicated.

Note: In case of extraction test execution ensure that the wall's fixing methods accomplish with the test results.

4.3.4 Frames or sequences installation

Frames or Sequences installation is normally done by the aid of cranes.

However, in some cases where the weight of the fabrics is very small, their installation could be executed by using pulleys, ropes or even manually, under the assumption that mandatory personal and safety regulations are followed.

In both cases, the process to place a Frame or Sequence is:

1. Use the Load Guide that already comes preassembled with the fabric as a tool where to hook the hoist on the frame.
2. Take out the wood packaging and elevate each Frame or Sequence with delicacy until placing the Load Guide on its corresponding Load anchors.
   Note: In case that the "work sequence" arrives divided in frames, by the aid of the crane, assemble all frames by installing the hinges between them. Once the sequence is done, can be positioned over the Load anchors as point 2 explains.
3. Screw the Load Guide to the Load Points using the load torque defined by the design.
4. Release the crane from the Load Guide.
   Note: After the installation of every "work sequence" might be required to install the wind anchors before proceed to the next "work sequence". Consult the installation methodology to determine if is necessary or not.

To carry out these operations, a worker will be required at the base of the pallets to fix the crane to the Load Guide, and install the hinges to assemble the "work sequence". A crane operator and one or two operators (depending on the weight of the Sequences) will be required at the Load Anchors Points.

Apart from these steps, some other generic instructions must be accomplished when performing on this phase:

- It must be considered that Frames and Sequences of Frames are elements that are vulnerable on movements during their elevating process, therefore is always recommended that the crane cable accompanies the movement of the suspended weights.
- The installation of the fabric to the support plane must be slow to avoid collisions with the wall.
- In case of heavy winds or bad weather it is not recommended the installation of the "work sequences".
- Be aware not to hit the tiles to not damage them.
- While the assembled frames are elevating be aware to fit the insulation panels of the back side of them. That will make easier the installation of the insulation.
- In case of louver frames, or windows, be aware that are closed, secured, and cannot open suddenly while the crane is lifting them.
- In case of Ventilation unit frames be aware not to hit it during all process.

- To install the "work sequences" some tiles might have to be temporarily removed, use the installation plan to reinstall them in their correct position by taking care to respect the original colours patterns of the design.
- In case of PV tiles to be installed between different frames, consider installing and connecting them simultaneously with the installation of the hinges. It will be easier than doing it after in the façade installation.
- Dispose of the protection sheets and the packaging as per standard protocols.

4.3.5 Wind anchors installation

Installation of the Wind Anchors according to the installation drawings as following:

- The wind anchor is made by two parts, an L anchor shape part fixed to the wall and a cap which is attached on the vertical line of the L anchor shape. Ensure the attachment of the cap, secure the movement of the lines at the horizontal plan, but allow the lines move freely at the vertical axis.
- The installation will be done by the wall fixing method (mechanical, chemical, or other) that is indicated on the design.
- In case of screw extraction test ensure that the wall fixing methods complies with the test results.
- Be aware not to hit the tiles with the installation tools.
- In order to install the window anchors some tiles will have to be temporarily removed; consult the installation plan to reinstall them in their correct position taking care to respect the original colours patterns of the design.

4.3.6 Windows installation

In addition to the standard installation steps for windows installation described in paragraph 4.2.1.3 of the present deliverable, other generic instructions must be followed for the installation of the windows:

- HybridWall can be designed with many types of different windows systems. Before every installation consult Denvelops personal to define the correct procedure for each case
- Be aware to not hit the windows or the aluminium profiles with the installation tools.
- Never take the temporal anchors prior installation is completed or without having installed another temporary anchor system.
- Windows are considered a heavy load, therefore the presence of adequate personnel for its installation needs to be considered at least as follows: Two workers outside the façade to move the window, and another worker inside to finish the installation, to install the expansive joint filler and the anchor screws.
- Wait for the designated by the manufacturer time of the expansion joint to stabilise, before start using the window.
- Recover the temporal anchors and send back to Denvelops for their reuse in future installations.
- Dispose of the protection sheets and packaging as per standard protocols.

- To install the window and its perimetrical finishes some tiles will have to be temporarily removed; use the installation plan to reinstall them in the correct position taking care to respect the original colours patterns of the design.

4.3.7 Insulation installation

The standard installation steps described in paragraph 4.2.1.3 of the present deliverable. In addition to these steps, other generic instructions must be accomplished to install the insulation:

- The HybridWall system can be designed with many types of insulation, therefore before any installation consult Denvelops personal to define the correct procedure for each case.
- To fit the insulation layer the some tiles will have to be temporarily removed, use the installation plan to reinstall them in the correct position taking care to respect the original colours patterns of the design.
- In case of detecting a gap between the insulation and the wall, proceed to install additional insulation as per general instructions.
- Ensure that the joints between the panels are firmly tight. In case of holes, install more insulation and protect them with adhesive tape.
- Use certified materials for insulation accessories material (anchors or stick joints tape).
- Dispose of the protection sheets and packaging as per standard protocols.

4.3.8 Photovoltaics (PV) tiles

In addition to the standard installation steps described in paragraph 4.2.1.3 of the present deliverable, other generic instructions must be accomplished to install the PV tiles:

- The HybridWall can be designed with many types of different PV systems, therefore before any installation consult Denvelops personal to define the correct procedure for each case.
- Be aware to not hit the PV tiles with the installation tools.
- PYs are considered as heavy load, therefore the presence of adequate personnel for its installation needs to be considered.
- Dispose the protection sheets and packaging as per standard protocols.
- To install the PV tiles some tiles will have to be temporarily removed, use the installation plan to reinstall them in the correct position taking care to respect the original colours patterns of the design.

4.3.9 Ventilation units

The standard installation steps are described in paragraph 4.2.1.3 of the present deliverable. In addition to these steps other generic instructions must be accomplished to install the ventilation units:

- Be aware to not hit the UV panels with the installation tools.

- Ventilation units are considered as a heavy load, therefore the presence of adequate personnel for its installation needs to be respected.
- To install the ventilation units some tiles will have to be temporarily removed, use the installation plan to reinstall them in the correct position.
- Once installed check that the ventilation unit operates smoothly, ensuring that it does not produce vibrations to the HybridWall.
- Never remove temporary anchors prior the installation completion or without another temporary anchoring system installed.
- Ventilation units are considered a heavy load, therefore at least two workers are required to complete their installation.
- Recover the temporal anchors and send back to Denvelops for their reuse in future installations.
- Dispose of the protection sheets and packaging as per standard protocols.

4.3.10 Install of the façade's end-finishing parts

According to the installation plan install the façade's end-finishing parts by the following instructions:

- Do not hit the pieces with any of the installation tools.
- To install the façade's end-finishing parts some tiles will have to be temporarily removed, use the installation plan to reinstall them in the correct position taking care to respect the original colours patterns of the design.
- Follow the installation procedures in case of need to seal the joints between the wall and the end-finishing parts.
- Dispose of the protection sheets and packaging as per standard protocols.

4.3.11 Auxiliary installations

4.3.11.1 Placement of connectors

During the installation of a Denvelops® fabric or during its life-span it might be necessary to place or remove some connectors from the fabric.

It is a common practice that in the folding parts of the fabric are not placed some of the connectors in order to facilitate the folding of the fabric. In those cases, the fabric projects and indicates which connectors should be located go in each place. Denvelops® has designed a specific tool that facilitates this operation.

4.3.11.2 Equipment and assembly time

To facilitate the cost estimation of installing a Denvelops® fabric, the following information are attached below.

In all projects, Denvelops® will provide the total number of components to be installed on site and with the aid of the following table cost estimation could be extracted (Table 6).

Phase	Operators	Crane (optional)	Elevator (optional)	Minutes x unit
Setting Out	2		x	
Load Points	1		x	5
Blocking Load Points	1		x	5
Blocking Plates Installation	2		x	10
Frames o Sequences installation	4	x	x	20
Blocking Hinges	1		x	5
Blocking Connectors	1		x	5
System Connectors	1		x	2

TABLE 6 : TABLE EQUIPMENT / ASSEMBLY TIMES

4.3.11.3 Packaging – transportation

The “Frames or Sequences” are distributed in vertical position on wooden pallets stacked by floors, with the precaution of placing a foam-type protection material or wood beams along them to avoid contact of the materials of different hardness and to avoid damage by friction.

The components of the Frames can be assembled without removing the protective adhesive covering with which have been produced. In that case, it will be necessary to remove it once the system is installed.

The Frames or Sequences are strapped on wooden pallets for safety and stability reasons. The pallets will be shrink-wrapped with identifying labels of the product and the manufacturing company. The packages are delivered in pallets that will guarantee their integrity, both in transportation in vehicles, and in the loading and unloading operations.

The pallets will be placed in the truck so that they do not suffer displacement, which could cause damage during transportation.

The unloading of the material should be done as close as possible to the final position to avoid unnecessary hauling. To avoid deterioration of the surface by friction with sharp particles, Frames or Sequences, must be handled with care avoiding sliding, one on top of the other, lifting them one by one.

During both the unloading and handling, it must be avoided that the materials are hit or dropped.

Also, avoid leaving the materials in dusty places or outdoors to prevent them from getting dirty.

If a building contractor requires a weight limitation, then this should comply with the restrictions of offset system of packaging.

The element packs should be checked for completeness and any possible damage immediately after delivery to the construction site, and then the unloading report of the shipping company should be filled in.

All HybridWall panels should be ensured that they are always stored in a vertical position.
Stacking of pallets is not allowed for HybridWall. Use always auxiliary means of storage if needed.

4.3.11.4 Storage

The pallet arrives on site perfectly protected according to the project specifications, installation requirements and Denvelops specifications.

As normal protection for the pallets, products are protected with a film which prevents the HybridWall to get dirty or dusty before it is installed.

General instructions:

- Never take off the packaging prior to installation commencement.
- In case of a partially damaged protection cover check carefully the products for defects.
- Never store the pallets in dusty, or wet areas on site.

4.3.11.5 Sawing, milling, drilling and grinding.

Sawing, milling and grinding are prohibited (Figure 29: Prohibited Processes).

HybridWall panels are ready made prefabricated elements that do not require further processing.

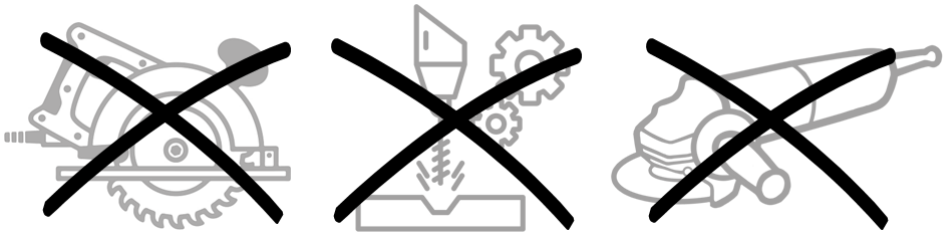


FIGURE 29: PROHIBITED PROCESSES

4.3.11.6 Corners and joints

For corner and joint details follow the installation plan detailed specifications. It is important, to ensure tight fitting between façade elements and the insulation layer. For this reason, Denvelops recommends the use of Insulation Stick Tape at the back surface of the façade elements.

4.3.11.7 Anchoring layout

The HybridWall solution can be installed in two different layout ways:

- Punctual Load anchors: By using punctual load anchors according to the modulation of the sequences.
- L shape profile: Sequences also can be installed along a large L profile with predrilled holes on its length to accommodate the Sequences Load guides.

According to the specific design of each façade, both of the systems can be applied.

Note: The components to be installed in every façade position will be defined in the installation plans and cannot be changed under any circumstances.

4.3.11.8 Bracket fastening methods.

Any type of bracket fastening method following the EU's regulations and specifications can be used for HybridWall's anchors panels installation.

This selection can be done by taking into consideration:

- Surface façade material;
- Structural elements of the building;
- Type and quantity of loads to be supported.

Denvelops recommend to do a screw load extraction test in order to confirm that the chosen selection complies with the design's specifications.

Datasheets for each particular component suitable for HybridWall installation depending on the substrate that HybridWall systems will be installed, are presented in PLURAL's Repository of Materials developed in T4.1 – Optimisation of PnU kits – Main Components and has been uploaded in EMDESK portal).

4.3.11.9 Testing & commissioning

After every HybridWall installation, a range of generic tests is mandatory to ensure the quality and safety of the installed system and its proper operability and functionality. The most important tasks to be performed are the same as those presented in para. 1.3.15 of the present deliverable, which are:

Visual tests

- Surface observation / defects on paint, cracks, flakes etc. identification.
- Sealant check defects on windows, sealant, sills, edges, bead.

IR thermography

- To the façade in general
- To window's / opening's joints and sill;

- To the unit ventilations.

Mechanical tests

- Anchoring system (bottom and top hinges of the frame). Statistic check of a percentage of installed screws or rivets.
- Window's frame to be securely attached on the frame.
- Window operation (open / close / tilt).
- Window's hinges.
- Louver operations (open / close)
- Blower-door test from inside the home to check the permeability of the new windows and unit ventilation seals.

Electrical tests

- UV voltage & current.
- PV panels voltage & current.
- Emergency cut-off mode.

4.4 Specific installation & safety requirements for HybridWall systems

On the *Deliverable D6.1 – Manufacturing Methodology of PnU kits, a* **Health & Safety Plan** was presented in relation of the Terrassa Demo building installation and defines all aspects of Safety at Work according to the Spanish Legislation.

It is obvious that every installation requires a specific design and organization especially for the safety of the installations, focused on the following:

4.4.1 Working on heights

Following the Safety at Work described in the Spanish legislation, all of the different type of ways to work on height must be treated with sensitive attention due to their risk. Denvelops recommend paying special attention to those that apply to the process, which are:

- Ladders
- Stepladders
- Mobile elevated platform

Whatever the system always must be ensured:

- Minimise the distance and consequences of a fall, by using the right type of equipment where the risk cannot be eliminated.
- Ensure workers can get safely to and from where they work at height and all workers understand

what job is to be done.

- Ensure workers have the required formation to work in heights, to manage the machinery in correct conditions, and mandatory insurance state payment.
- Mark the working areas with signs and marks.
- Ensure equipment is homologated, suitable, stable and strong enough for the job, maintained and checked regularly.
- Take precautions when working on or near fragile surfaces.
- Provide protection from falling objects.
- Dress the specific safety clothes and protection equipment.
- Consider the equipment or materials workers are carrying before working at height. Check the pictogram or label on the ladder for information.
- Don't overreach on ladders or stepladders.
- Don't rest a ladder against weak upper surfaces, eg glazing or plastic gutters
- Don't use ladders or stepladders for strenuous or heavy tasks, only use them for light work of short duration (a maximum of 30 minutes at a time)
- Don't let anyone who is not competent (who doesn't have the skills, knowledge and experience to do the job) work at height.

Note: It is not recommended the use of scaffolding to install the HybridWall.

4.4.2 HybridWall panels installation

As described in chapters 4.2 and 4.3 of this document.

4.4.3 PV panels installation

- Use Only Approved Materials – Each solar system is designed to use specific gauge wires and other materials Only use the equipment, connectors, wiring and support frames provided for HybridWall PV modules.
- Stop Working During Bad Weather – When working outside to install a solar PV system, make sure to stop work if it starts raining since the rain could increase the risk of shock or electrocution.
- Use Proper Safety Precautions when Working at Heights – If installing solar panels on a roof, make sure to follow standard safety protocols. This includes fall suppression equipment, ladder safety, and more.
- Use Electrical PPE – Whenever the PV system may be energized, everyone in the area should be wearing the appropriate personal protection equipment for electrical safety.
- When working with the wiring coming from a solar PV array, treat it with the same caution as a utility power line. De-energized all circuits before working on them. To ensure that they are de-energized, use a meter or circuit test device.

- Lock out the power on systems that can be locked out.
- Never disconnect PV module connectors or other associated PV wirings when they are energized. And make sure to use insulated tools when working with electricity.
- Solar panels should be covered with an opaque sheet when unpackaged, to prevent heat or energy buildup. Also, keep your photovoltaic solar panels covered with an opaque material during wiring to stop or prevent electricity production.
- Wear insulated gloves when working with solar panels as they may have an eclectic charge.
- Do not clean the modules with chemicals.
- Do not lift the PV module by grasping the module's junction box or electrical leads on its backside.
- Do not use mirrors or other magnifiers to concentrate sunlight onto the PV modules.
- Do not expose PV module to sunlight until installation to avoid unnecessary degradation.
- During transportation, make sure there is no strenuous vibration on the module.
- Check the electrical, grounding and mechanical connections every six months to verify that they are clean, secure, undamaged and free of corrosion.

Further information available in SOLAR INNOVA solar panels installation guides

4.4.4 Unit ventilation installation

- Align ventilation unit in vertical position along the façade surface.
- Check distance between ventilation back and building façade. Minimum is 5 mm, unit body should not be in contact with façade.
- Create four holes for ventilation unit anchors.
- Install the unit connecting each anchor to the façade using proper anchoring hardware for façade material (plugs, chemical plugs, or another).
- If an anchoring hole is close to a wall edge (e. g. beside a window) and stability of anchor in façade is not certain, then use auxiliary C profile for support of ventilation unit's anchors.
    - C profile allow variable positions of holes in façade for anchoring hardware.
    - Make two holes in façade per one C profile.
    - Fix the C profile in horizontal position to the façade.
    - Adjust ventilation unit anchors and connect each to C profile with a bolt.
- Connect upper air channel to air supply to the room and lower air channel to extract from the room.
- Make sure to remove the UV temporal anchor, and that it is returned to Denvelops facilities to be reused in other projects.
- Connect electric power cable and cable for indoor air sensor.
- Check the insulation is covering all spaces without leaving thermal bridges.

- Check that the filter boxs can be slide out and slide in freely without an obstacle removed (for future maintenance)
- Correctly seal all penetrations through the shell of the home with insulating sealant/spray foam. As necessary, use gasket material to properly seal all penetrations.
- Check UV don't produce noises and works.

4.4.5 Electric components / devices installation

Following the Safety at Work described in the Spanish legislation, the specific advice regarding the safety requirements to work with the electrical components of the Hybridwall are the same that have been described in 3.4.6 of the present deliverable.

For the Terrassa demo building, refer to the Low Voltage Electrotechnical Regulations (REBT).

4.4.6 Additional safety equipment

Additional equipment should only be considered as a last resort when no other means are reasonably practicable. These include:

- Nets;
- Airbags;
- Harnesses;
- Safety lines;
- Other fall restraint and arrest equipment.

They should only be used and assembled by trained personnel and be tested and inspected regularly.

The equipment has to be inspected regularly and only used in accordance of its purpose and guidelines. Health and safety site manager is responsible for safety construction works establishment and observing the HS plan during construction works.

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

5 ConExWall (eWHC) – Installation Methodology

5.1 Design & installation requirements

5.1.1 Structural stability

The ConExWall system for façade cladding does not contribute to the stability of the building. It will be installed at the Kasava demonstration site, Czech.

For structural stability check, the following loads have been taken into account.

- Permanent load (self-weight of the panel);
- Wind loads (wind suction and wind pressure);
- Snow load (ice);
- Pre-stress axial load (fixing).

In general, it is also necessary to consider other loads (if they are relevant for the given case):

- Dynamic loads (seismicity);
- Temperature load;
- Special loads (shock, vandalism, ...).

Proof of the structural stability of the façade system, has been provided in a verifiable form in accordance with the applicable European Regulations in the *Deliverables D2.1 – Architectural & Structural Design of PnU kits* and *D4.5 – PnU kit prototype property and performance characterisation.*

The proof of structural stability included the structural stability calculations for the substructure, the cladding and the anchoring and connecting or fastening components.

In general, it is not possible to specify the critical point of the system. In the Kasava case, the critical part of the construction of the façade system is anchoring to the brick wall. For example, in the case of a massive reinforced concrete structure, it can be assumed that one of the load-bearing elements of the panel will be a critical point.

5.1.2 Fire protection

Installation of ConExWall comprises 3 different cases listed below. In general, ConExWall does not include materials without fire tests (e.g. gypsum boards, insulation) or materials not classified in fire codes (e.g. wood). All structures can be individually calculated on each specific project. Explanation follows:

- Basic type is installation as external insulation complex on external wall. In this case external walls are constructed from non-flammable materials – typical concrete, bricks, stones. Fire regulations require load-bearing structure from materials with certain fire resistance. ConExWall is not load-bearing structure in this case. ConExWall has only influence on fire risk areas which limit neighboring buildings.

- The dimensions of fire risk area is various, it depends on specific layer composition, surface layer (e.g. plaster, wood cladding) and windows dimensions. The dimension of fire risk area is individually calculated according to fire protection codes for each specific case.
- Installation ConExWall as loadbearing external walls in last storey requires specific fire resistance. Fire resistance is achieved by using gypsum board / gypsum fibreboard plates from interior with existing fire tests (e.g. Fermacell[41], Knauf[42], ...). Influence on fire risk area is individually calculated as in first case.
- Installation ConExWall as roofs requires specific fire resistance. Fire resistance is achieved by using gypsum board / gypsum fibreboard plates from interior with existing fire tests (e.g. Fermacell, Knauf ..)

5.1.3 Thermal insulation and protection from dampness

The ConExWall solution applied on an existing building must ensures that individual structures and details satisfy the requirements of European and Czech national standards and regulations as far as thermal transmittances and moisture balance of a structure are concerned. Further, the overall thermal transmittance of the building envelope must contribute to sufficient energy savings. The U-values of the ConExWall elements are provided in the *Deliverable D2.7 – Final stage complete design of PnU kits*.

The panel connections design and implementation must ensure no possibility for atmospheric precipitation to penetrate into the panels' structures. The wall panels have a ventilated façade cladding which serves as a primary atmospheric barrier. The thermal insulation layer in contact with the ventilated air gap has hydrophobic treatment and/or is covered by a diffusion foil.

In the Czech climatic conditions, water vapour diffuses from the interior to the exterior. Therefore, in general, the water vapour barrier is designed as close as possible to the interior side of the panel to prevent excessive amount of vapour to penetrate the thermal insulation layers. The OSB layer right behind the heating layer serves as a water vapour barrier and therefore emphasis must be put to water vapour diffusion resistance factor of the OSB used. The existing wall, where retained, also serves as a significant water vapour barrier. The design was verified by calculations, presented in *Deliverable D2.7 Final stage complete design of PnU kits*.

Details and joints must be precisely designed, manufactured and on-site implemented to prevent water vapour or atmospheric precipitation to penetrate into the panel structure (e.g. details such as window-to-wall connection, ventilation unit-to-wall connection, panel-to-panel connections, etc.). Connection between panels will be treated by a rubber seal applied on the panel perimeter, and a vapour barrier foil applied on the panel perimeter having sufficient overlaps (both within the manufacturing process), so that the foils of the two adjoining panels can be connected together using Airstop Flex[43] adhesive tape.

[41] https://www.fermacell.co.uk/en , https://www.fermacell.co.uk/en/technical-documents

[42] https://www.knauf.co.uk/systems-and-products/products

[43] https://www.isocell.com/en/product/airstop-flex-kb

5.1.4 Deformation

Due to the nature of ConExWall system, minor deformation may occur, in particular, due to temperature fluctuations and changes in humidity.

Deformation caused by horizontal wind load and vertical load (own weight, snow) is taken into account in the static design of system elements. Horizontal deformation from wind load meets the L/400 limit. Deformation in the façade layer, caused by temperature load and changes in humidity, are solved by dividing the façade into individual dilatation parts with corresponding dilatation joints.

5.1.5 Tolerances

Tolerances must be set up in every project according to the requirements of the project.

The surface of the façade cladding must be flat and even. The required flatness of the existing façade is 20 mm. This inequality can be eliminated by rectification of the anchors. The anchors are designed for this. In the case of Kasava, this requirement is fulfilled. If the existing façade does not meet the required flatness, it must be prepared (sanding, finishing) before installation.

The overall dimensions of the existing building must be accurately measured and the panels manufactured with a tolerance of +0, -20mm. It is not recommended to shorten the manufactured panels. Negative tolerance values can be solved by adjusting expansion joints.

5.1.6 Airtightness

The airtightness issue largely overlaps with the water vapor tightness issue. Airtightness within the panel area is ensured by the high-quality OSB with high water vapour diffusion resistance factor. The existing wall, where retained, also serves as a significant airtight barrier.

For the panel joints, two protection measures will be applied. The first one is a rubber seal applied in double rows within the panel perimeter already within the manufacturing process (alternatively, a sealing foam can be applied on-site).

The second measure, for a case the tape's impairs during panel installation, on the perimeter of each panel a vapour barrier foil will be applied within the manufacturing, having sufficient overlaps so that the foils of the two adjoining panels can be connected using Airstop Flex[44] adhesive tape.

All the critical details, whether manufactured or implemented on-site (such as window-to-wall connection, ventilation unit-to-wall connection, panel connection, etc.) must be carefully treated and sealed to prevent any imperfections. Blower door test is recommended to verify the overall installation and detail implementation quality from the airtightness point of view, and locate imperfections, if any.

Another crucial point is to guarantee airtightness of the heating layer to ensure its high performance. Therefore, all the edges around the heating layer and to the installation channels will be sealed with an airtight foam.

[44] https://www.isocell.com/en/product/airstop-flex-kb

5.1.7 Soundproofing

The building, after ConExWall system installation, will meet all applicable standards for acoustics. In general, the ConExWall system is developed to be put on an existing wall. Usually, soundproofing of that existing wall is sufficient. In case of Kasava demo building, part of the building uses also ConExWall standalone panels (some walls in 2nd storey, and roofs) with no existing structure to be installed onto. The standalone panels design is based on common RDR structures and sample structures provided by materials producers, that are verified and satisfies soundproofing limits.

A local ventilation unit is designed for each room, equipped with high outside noise attenuation. The unit itself, however, emit certain acoustic noise which have to comply with national requirements while providing required amount of fresh air. In case of Kasava demo building, this is currently being resolved.

5.1.8 Lightning protection

External and internal lightning protection system will be designed by certified electrical engineer in compliance to valid Czech standards. The main standards valid in the protection against lightning is summarized in IEC 62305 standards namely in Czech legislation:

- ČSN EN 62305-1 Protection against lightning - Part 1: General principles
- ČSN EN 62305-2 Protection against lightning - Part 2: Risk management
- ČSN EN 62305-3 Protection against lightning - Part 3: Physical damage to structures and life hazard
- ČSN EN 62305-4 Protection against lightning - Part 4: Electrical and electronic systems within structures

These standards are valid for designing, installations, revisions and maintenance, and protection of buildings, equipment and persons against overvoltage.

5.1.9 European regulations

At a European level, harmonized standards in terms of general action and design of structures apply to façade substructures and façade panels. These harmonized standards are applicable and required in all CEN member states.

The detail analysis of the relevant standards to the ConExWall system is presented in Deliverables *D1.1 – Requirements: Context of application, building classification, used consideration – Definition of requirements and constraints*, and *D1.3 – Certification requirements accounting for occupant legal and privacy monitoring*.

Short summary for ConExWall system is concluded in the Table 7 and section 5.1.9.1.

Component	European legislation	Requirement for compliance
ConExWall heating and cooling system: heating pipes	CPR (EU) 305/2011	EN ISO 21003 as reference standard
ConExWall heating and cooling system: support for the pipes	CPR (EU) 305/2011	CE marking according to EN 13171
ConExWall heating and cooling system: flexible thermal insulation	CPR (EU) 305/2011	CE marking according to EN 13162
Timber Structure	CPR (EU) 305/2011	CE marking according to EN 14080 or EN 14250
Thermal insulation: wood fibre	CPR (EU) 305/2011	CE marking according to EN 13171
Vapour barrier	CPR (EU) 305/2011	CE marking according to EN 13984
Weathering membrane	CPR (EU) 305/2011	CE marking according to EN 13859-2
Reused metal cladding	CPR (EU) 305/2011	CE marking according to EN 14782
Wooden windows	CPR (EU) 305/2011	CE marking according to EN 14351-1
Stainless steel anchors	CPR (EU) 305/2011	CE marking according to EN 14592
Ventilation unit		
Sealants for joints	CPR (EU) 305/2011	CE marking according to EN 15651-1
Metal cladding (roof panels)	CPR (EU) 305/2011	CE marking according to EN 14782
PV modules (roof panels)		CE marking (declaration of conformity) according to:
	LVD 2014/35/EC	EN IEC 61215 and EN IEC 61730
	EMC Directive 2014/30/EU	EN 61000
	RoHS 2011/65/EU	EN 50581

TABLE 7: SHORT SUMMARY OF EUROPEAN REGULATIONS FOR CONEXWALL SYSTEM

5.1.9.1 Structural design

The analysis of elements will be calculated according to the European Standards – Eurocodes and Czech adjustment ČSN EN.

- Eurocode: Basis of structural design (ČSN EN 1990, ed.2, 02/2021)
- National Annex - Eurocode: Basis of structural design (ČSN EN 1990 NA, ed.A, 02/2021)
- Eurocode 1: Action on structures – Part 1-1: General actions – Densities, self-weight, imposed loads for buildings (ČSN EN 1991-1-1, 03/2004)
- National Annex - Eurocode 1: Action on structures – Part 1-1: General actions – Densities, self-weight, imposed loads for buildings (ČSN EN 1991-1-1 NA, ed.A, 06/2011)
- Eurocode 1: Actions on structures - Part 1-4: General actions - Wind loads (ČSN EN 1991-1-4, ed.2, 11/2020)
- National Annex - Eurocode 1: Actions on structures – Part 1-4: General actions - Wind loads (ČSN EN 1991-1-4, ed.A, 07/2013)

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

- Eurocode 3: Design of steel structures – Part 1-1: General rules and rules for buildings (ČSN EN 1993-1-1, ed.2, 07/2011)
- National Annex - Eurocode 3: Design of steel structures – Part 1-1: General rules and rules for buildings (ČSN EN 1993-1-1 NA ed.A, 06/2016)
- Eurocode 3: Design of steel structures – Part 1-8: Design of joints (ČSN EN 1993-1-8, ed.2, 11/2013)
- National Annex - Eurocode 3: Design of steel structures – Part 1-8: Design of joints (ČSN EN 1993-1-8 NA ed.A, 02/2012)
- Eurocode 5: Design of timber structures – Part 1-1: General – Common rules and rules for buildings (ČSN EN 1995-1-1, 12/2006)
- National Annex – Eurocode 5: Design of timber structures – Part 1-1: General - Common rules and rules for buildings (ČSN EN 1995-1-1 NA ed.A, 11/2011)

If a product is not covered by a European harmonized standard or code, it is necessary to have an ETA (European Technical Assessment) that is valid in all EOTA member states or a national approval for the applicable country.

5.1.10 ConExWall installation limitations

ConExWall system is flexible and versatile and is possible to be installed in a very wide range of buildings. There are some limitations which need to be carefully considered when designing the ConExWall systems. These limitations are mainly focused on:

- The height of the building
- The size of ConExWall panel
- Number, size and location of windows and doors
- Material of existing building (a brick or concrete wall system is considered suitable)
- Construction location (possibility of transport, possibility of crane arrival)

5.1.11 Applicable sub-substrates for ConExWall installation

Based on the limitations of the previous paragraph, the surfaces to which ConExWall panels can be anchored may consist of standardized materials (e.g. concrete, brick, steel, timber, etc.) or non-standardized materials. (Surface layers such as rendering, coatings or facings do not count as load-bearing materials).

The following are suitable base materials:

- Concrete in accordance with EN 206:2013+A2:2021
- Bricks in accordance with EN 771-3:2011+A1:2015
- Sand-lime block in accordance with EN 771-3:2011+A1:2015
- Aerated concrete in accordance with EN 771-3:2011+A1:2015

- Timber in accordance with ČSN EN 14081-1
- Steel frame structures in accordance with EN 1090
- Existing/unclassified masonry (load-bearing capacity must be verified by pull-out tests)
- Sandwich components (e.g. metal, concrete or lightweight concrete) may be considered suitable only after verification.

5.2 ConExWall systems installation methodology at Kasava demo building

5.2.1 Installation layout, requirements and strategy

5.2.1.1 Installation layout and strategy

Installation layout of the ConExWall panels on the Kasava demo building is shown in Figure 30. List of panels and their basic characteristics are provided in Table 8.

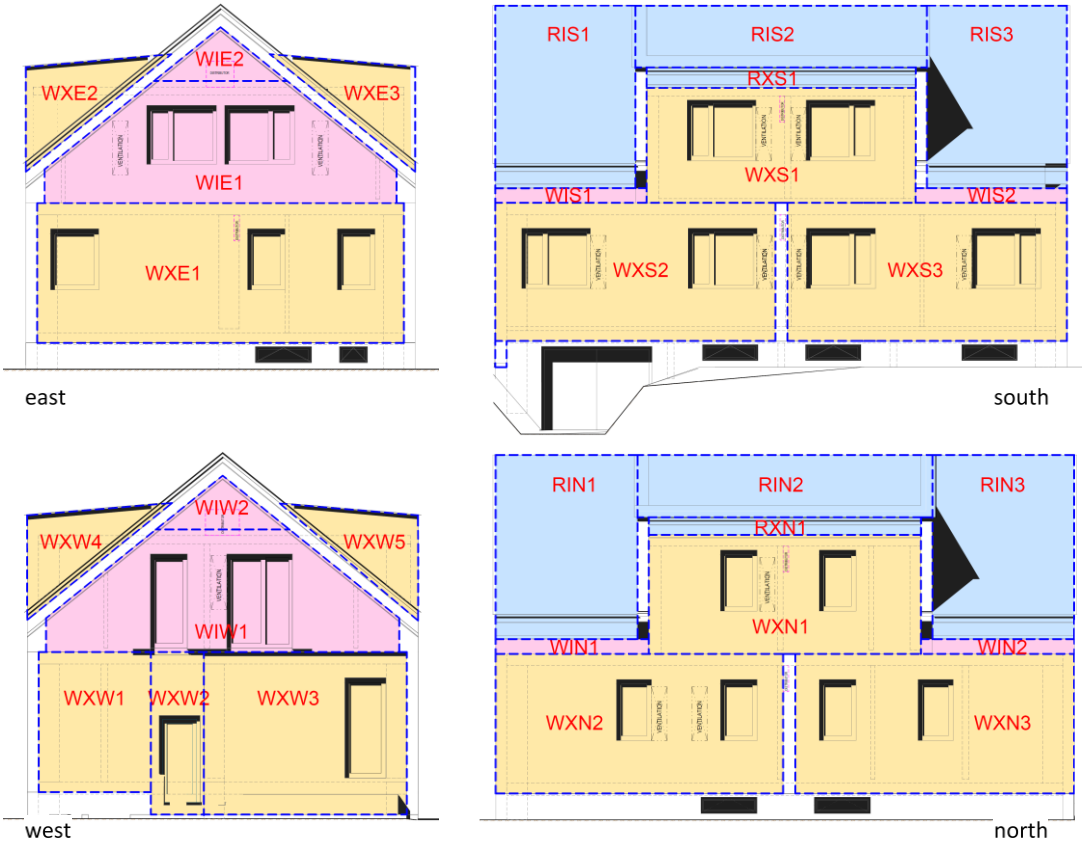


FIGURE 30: LAYOUT OF CONEXWALL INSTALLATION ON KASAVA DEMO BUILDING

ID	Type	Width [m]	Length [m]	Area [m²]	Vent. unit included [number]	Window Included [number]	Heating included [Y/N]
WXS1	Wall panel type 1	6.68	2.87	19.14	2	2	Y
WXS2	Wall panel type 1	6.96	3.43	23.87	2	2	Y
WXS3	Wall panel type 1	6.94	3.43	23.80	2	2	Y
WIS1	Wall panel type 2	3.76	0.83	3.12	-	-	-
WIS2	Wall panel type 2	3.76	0.83	3.12	-	-	-
WIW1	Wall panel type 2	8.62 to 3.26	0.83 to 3	20.04	1	2	Y
WIW2	Wall panel type 2	3.26 to 0	1.32 to 0	2.15	-	-	-
WXW1	Wall panel type 1	2.74	3.43	9.39	-	-	-
WXW2	Wall panel type 1	1.29	3.98	5.14	-	1	-
WXW3	Wall panel type 1	4.95	3.98	19.70	-	1	Y
WXW4	Wall panel type 1	3.57 to 0	2.57 to 0	4.59	-	-	-
WXW5	Wall panel type 1	3.57 to 0	2.57 to 0	4.59	-	-	-
WIE1	Wall panel type 2	8.62 to 3.26	0.83 to 3	20.04	2	2	Y
WIE2	Wall panel type 2	3.26 to 0	1.32 to 0	2.15	-	-	-
WXE1	Wall panel type 1	8.98	3.43	30.80	-	3	Y
WXE2	Wall panel type 1	3.57 to 0	2.57 to 0	4.59	-	-	-
WXE3	Wall panel type 1	3.57 to 0	2.57 to 0	4.59	-	-	-
WXN1	Wall panel type 1	6.68	2.93	19.54	1	2	Y
WXN2	Wall panel type 1	7.06	3.43	24.21	2	2	Y
WXN3	Wall panel type 1	6.83	3.43	23.43	-	2	Y
WIN1	Wall panel type 2	3.76	0.83	3.12	-	-	-
WIN2	Wall panel type 2	3.76	0.83	3.12	-	-	-
Total	**Wall panel type 1**			**217.36**			
	Wall panel type 2			**56.86**			

TABLE 8: LIST OF BASIC CHARACTERISTICS OF CONEXWALL WALL PANELS TO BE INSTALLED ON KASAVA DEMO BUILDING

ID	Type	Width [m]	Length [m]	Area [m²]	Vent. unit included [number]	Window Included [number]	Heating included [Y/N]
RIS1	Roof panel	3.76	6.14	23.06	-	-	-
RIS2	Roof panel	7.24	2.40	17.40	-	-	-
RIS3	Roof panel	3.76	6.14	23.06	-	-	-
RXS1	Roof panel	6.68	2.89	19.31	-	-	Y
RIN1	Roof panel	3.76	6.14	23.06	-	-	-
RIN2	Roof panel	7.24	2.40	17.40	-	-	-
RIN3	Roof panel	3.76	6.14	23.06	-	-	-
RXN1	Roof panel	6.68	2.89	19.31	-	-	-
Total	**Roof panel**			**165.64**			

TABLE 9: LIST OF BASIC CHARACTERISTICS OF CONEXWALL ROOF PANELS TO BE INSTALLED ON KASAVA DEMO BUILDING

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

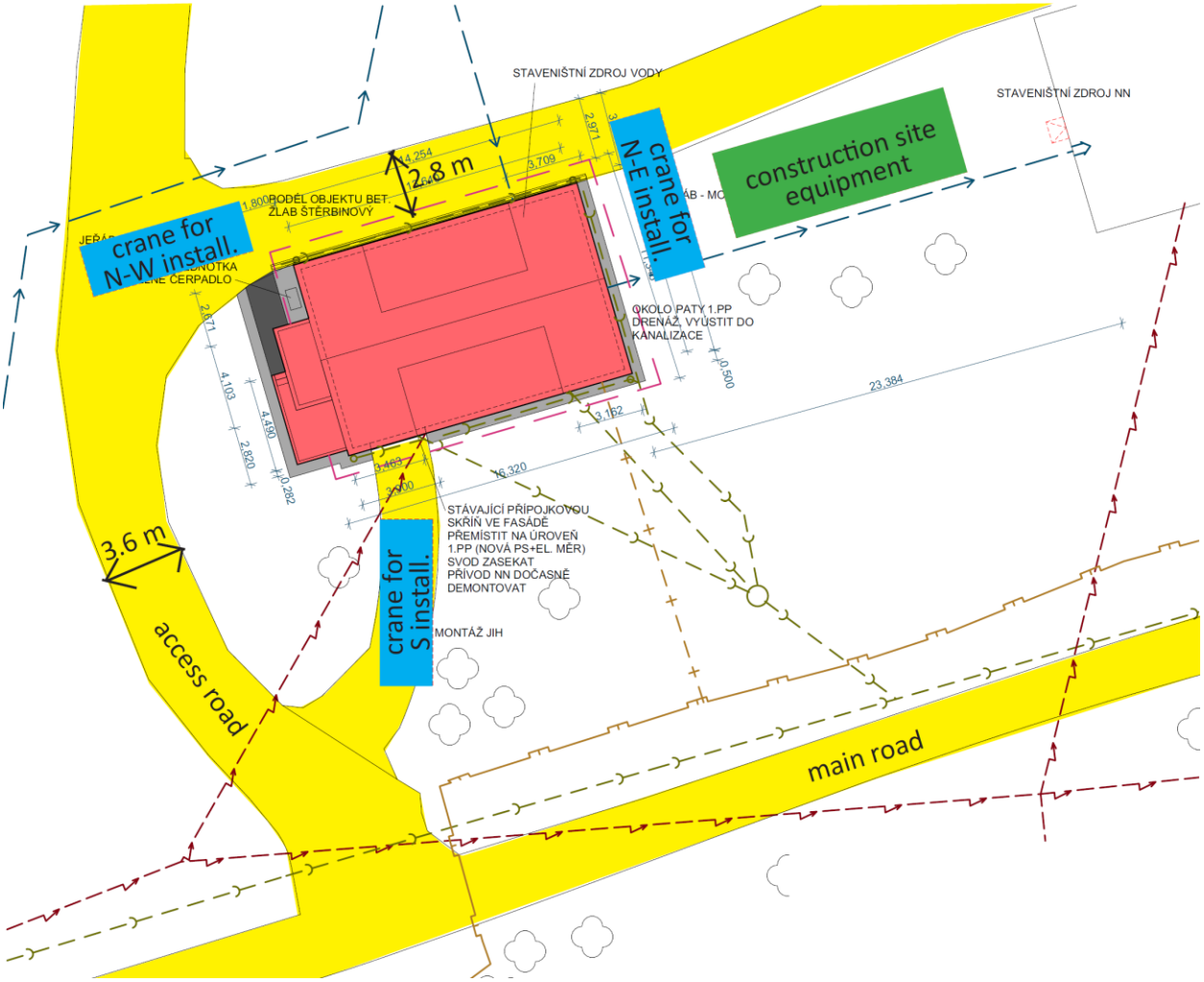


FIGURE 31: KASAVA DEMO BUILDING CONSTRUCTION SITE PLAN

Panels are intended to be installed using a small crane that is easy to rent and assesses the construction site easily. The crane will change its position during the installation works to span the whole construction site, see Figure 31. The site plan may subject to changes once the installer is selected, since the installer usually arranges the construction site plan based on his common practice and machines used.

All the manual works unreachable from the ground (fastening the panels to the anchors, sealing, pipes and wiring connections, channels completion, roofing, PV installation, etc.), are preferably performed from mobile elevating work platform. Only works which are not feasible from the elevating platform will be done using personal safety equipment (the roof panels will be equipped by anchoring points for working at heights) or with the assistance of other equipment/measures for working at heights. Final decision about what method will be used for particular works at heights will be made by the installer.

5.2.1.2 Time schedule for the ConExWall Kasava demo building

Overall preliminary construction schedule for Kasava demo building is presented in Figure 32. Final construction schedule is to be made by the installer.

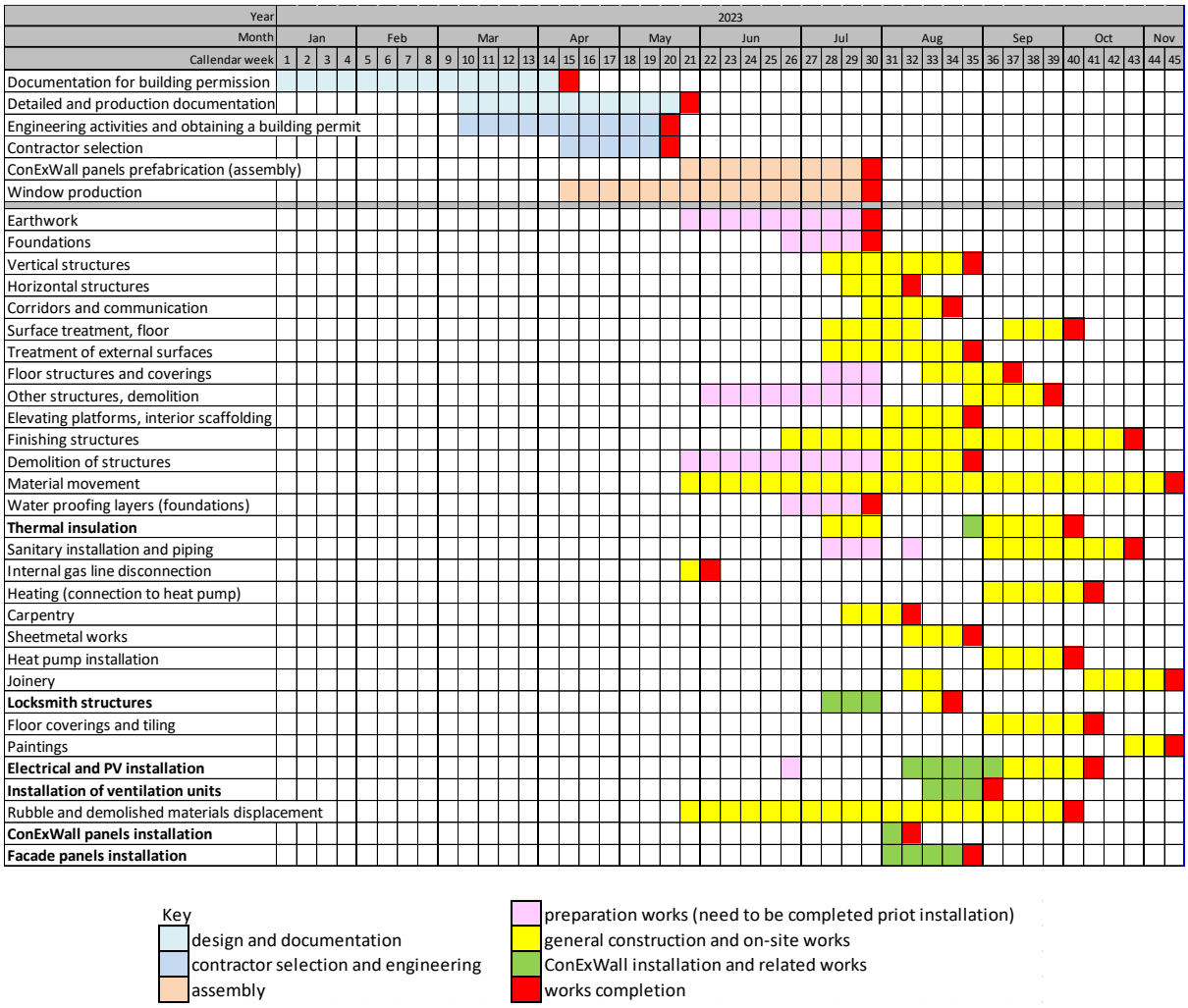


FIGURE 32: OVERALL CONSTRUCTION SCHEDULE FOR KASAVA RENOVATION

Compared to the preliminary schedule presented in the *Deliverable D6.1 Manufacturing methodology of PLURAL kits*, the process got some delay. There have arisen potential issues regarding ventilation unit parameters which showed not to comply with Czech regulations and had to be resolved. As a result, the project is going to be submitted for statements only at the beginning of March and building permit documentation is expected to be submitted in mid April (after obtaining the statements) and building permit received in mid May. Installer selection stage is scheduled to be finished by the date the building permit is received.

5.2.2 Phase 1 – Preparatory works

Once the building permit is received, preparatory construction works starts. Meanwhile, detailed and production documentation is finished and the assembly is scheduled into the production plan and materials and components are ordered.

There are some preparatory works that needs to be completed prior the ConExWall panels installation: earthworks and foundation adjustments, basement water proofing, demolition works, part of floor structures, part of sanitary installations and plumbing, and flattening and fixing of the existing wall outer surfaces (if needed).

5.2.3 Phase 2 – ConExWall panels installation

The installation processes described in the following section may subject to changes since the final and detailed workplan will be elaborated by the installer, once selected.

Anchors:

- ConExWall panel installation starts with anchors installation onto the existing walls. Once all the anchors are attached, installation of panels starts. For detailed information about process of anchor installation and tightening, in relation to panel installation sequence, see sections 5.3.9 and 5.3.10.

Panels:

- Panels for 1st storey are installed throughout the building perimeter. A small crane is used; therefore, it moves twice to span the building perimeter. For detailed information about sequence of anchor tightening in relation to panel installation, see sections 5.3.9 and 5.3.10.
- Panels for 2nd storey are installed throughout the building perimeter. For detailed information about sequence of anchor tightening in relation to panel installation, see sections 5.3.9 and 5.3.10.
- Ridge beam is installed and connected with the gable panel.
- Roof panels are installed.
- Dormers' side panels are installed.
- The zinc roofing is laid once all the roof panels are installed and rectified.

Sealing and panel connections:

- Once the panels are installed, windows are sealed to the openings in the existing walls using a water vapour barrier tapes pre-installed on the windows already from manufacturing.
- All the panel joints are sealed and/or taped (see sections 5.1.3, 5.1.6, 5.3.12.2).
- Space around anchors is sealed with airtight foam.
- Bottom edge of the heating layer of the first row of panels, as well as side of the panels within the installation channel, are sealed with an airtight foam to ensure heating layer airtightness.

E/M components installation:

- Ventilation units are installed into the shell imbedded within the assembly process and connected to electricity wiring included in the panel. See more in section 5.3.15.
- Electrical cables are pulled through plastic protecting tubes preinstalled in the panels during assembly phase, connected to the electrical components, to each other in the installation channels, and to the building interior wiring.
- Heating pipes coming from the panels are connected in the installation channels and passed through the existing building to interior, and connected to the indoor heat pump unit.
- After completion of zinc sheeting, rails for PV panels are installed and attached to the roofing folds with corresponding clips (see Figure 33 and Figure 34). The PV panels are subsequently fixed to the rails and cables are connected and lead to the installation channel. See more in section 5.2.5)
- Penetrations inside the installation channels are sealed and the channels are filled with thermal insulation, diffusion foil and enclosed.
- External heat pump unit is connected once all the panels and related works are completed.

Facade cladding:

- Once the panels installation is completed including all the components and connections, installation of façade cladding starts. The exact processed depend on the way and extent in which the façade cladding have been prefabricated (see *Deliverable D6.2 Assembly methodology for PnU kits*). The cladding is screwed into the laths on the exterior side of the installed panels.

5.2.4 Phase 3 – Finishing and other works

- After the wall panels installation, the follow-up works starts.
- Interior surface around the window opening in the existing wall will be cladded by a wooden prefabricated frame installed as a one peace and sealed/fixed to the existing wall.
- Construction works at Kasava demo building involve amount of processes not related to panels installation itself (extensive interior reconstruction, basement walls and ceiling thermal insulation, etc.). During ConExWall panels installation and related works, other construction works are in progress (as can be seen in Figure 32). The interior works do not interfere with panels installation at all.

5.2.5 PV panels installation details

Plural ConExWall system in Czech demo building will be installed on the older house. Due to the simulations of PV harvest and the local situation it has been decided at the very early stage of the project to install the PV system on the roof only and avoid expensive and less efficient PV part on the façade. The metal sheet roofing system was selected for Czech demonstration and thus corresponding PV installation system will be used. One of the available PV supporting rail system will be used which is available on the market.

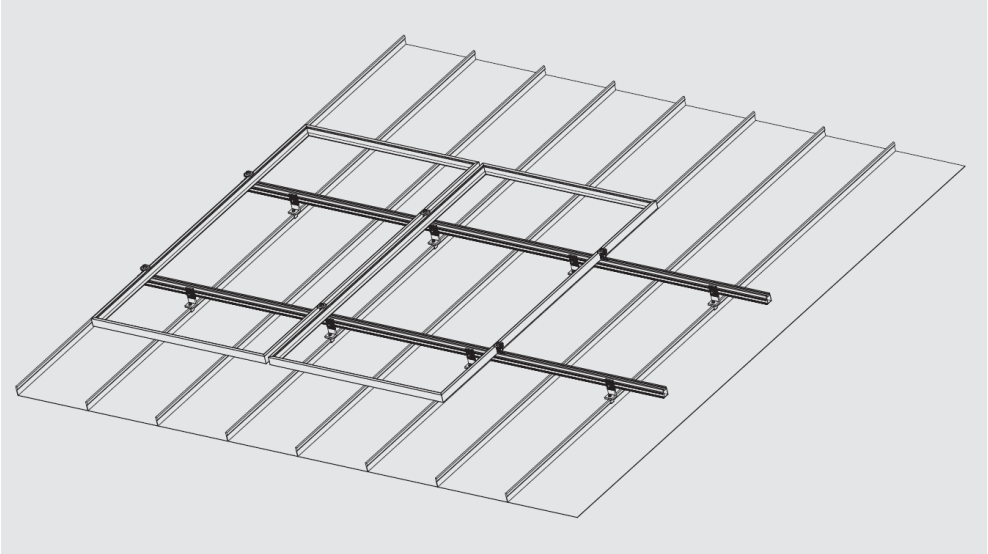


FIGURE 33: PV PANEL INSTALLATION ON THE ROOF FROM CORRUGATED METAL SHEET

MS Klik system[45] could be one of possible solutions to secure the installation rails on the metal roof with dedicated clips (see Figure 34). PV system in Czech demo is designed as 3-string system. In ideal situation all three strings are connected to separate MPPT tracker[46]. If only two are available then designed two side string could be connected together. The cables from each string are led to the side of the roof and into the façade installation channel from which they are led through the existing wall to the interior (location of the solar inverters). The cables from individual panel have to be connected according to the scheme of the proposed PV installation and according to the project documentation.

Image	Item No.	Description	Nm
	400254	S-5!® E-Mini	15 - 20
	400255	S-5!® Z-Mini	15 - 20
	400259	S-5!® S-Mini	15 - 20
	400252	S-5!® R-465	15 - 20

Image	Item No.	Description	Nm
	400289	S-5!® A-Mini	15 - 20
	400284 / 400288	S-5!® K-Grip Mini GXM10	15 - 20
	400284 / 400285	S-5!® K-Grip Mini GXM50	15 - 20
	400563	S-5!® R-465 Mini	15 - 20

Image	Item No.	Description	Nm
	400256	Kalzip FS	15
	400257	Rib-Roof R-465	20
	400258	Rib-Roof R-500	20

FIGURE 34: AVAILABLE CLIP SYSTEMS FOR METAL SHEET ROOFS

[45] https://www.twi.cz/files/pdf/sol-prislusenstvi/montazni-sady/ms-klik-v-srouby.pdf

[46] GoodWe 12DT, https://emea.goodwe.com/sdt-g2-series-three-phase-residential-solar-inverter

5.2.6 Risk Assessment Plan on installation of ConExWall systems in Kasava demo building

The ConExWall panel installation bears certain uncertainty in the installation time since some of the installation steps are specific and new for the workers. Further, certain installation methodology issues may have not been perfectly resolved during the design phase which may result in longer installation time than estimated.

Potential small delay need not to imperil the construction works completion date since ConExWall panels installation is not the last stage of the construction works and there are some works that can proceed meanwhile even if the panels installation is delayed. However, there are activities that are conditional on the panels installation completion (façade cladding, roofing, PV panels installation, interior finishing, technical system connection and testing, etc.); the panel installation delay should not reach more than a week to keep the scheduled commissioning date.

Detailed risk assessment plan on ConExWall system installation on Kasava demo building will be elaborated later, after the installer is selected by the tendering process and the final time schedule will be composed.

5.3 General instructions for ConExWall installation

Installation of the eWHC-ConExWall system, in general equipped with heating layer, ventilation units, and PV panels employs the following steps in general:

- On-site survey, models of the existing buildings according to the point cloud geometry obtained by the 3D scanning process, structural survey of the building envelope, general specifications;
- ConExWall design, individualized for given case, considering local conditions;
- Flattening the existing façade if it does not meet the required tolerances, and fixing the surface and other issues if needed/any;
- Penetrations through existing walls for future pipes/wiring passing to the house interior;
- Load bearing anchors installation;
- Wall panels installation and fastening;
- Roof panels installation;
- Joints and details sealing
- Roofing installation/finishing;
- PV panels installation;
- Ventilation unit installation;
- Pipes and cable connections;
- Installation channels insulation and covering;
- Facade cladding installation;
- General finishing and interior works.

5.3.1 Safety instructions working with ConExWall system

The most relevant safety instruction for the ConExWall system installation are as follows:

- Respect the applicable Health and Safety Plan as presented on the *Deliverable D6.1 – Manufacturing Methodology of PnU kits*, and the one elaborated for on-site installation phase.
- All workers are trained for the works they are doing and equipment they are using.
- Wear and shoe appropriate, not loose-fitting work clothing. Avoid wearing rings, necklaces, watches or other type of jewellery and ornaments.
- Wear reflective vests when high visibility of workers is of importance (machine operated works)
- Special safety measures and protective equipment has to be used for working at heights.
- Wear goggles and a dust mask when doing works of relevant exposure or risks (sawing, sanding, milling, drilling, etc.).
- Wear ear protection for noisy works (e.g. drilling).
- Provide continuous dust extraction during machining activities.
- Wear protective gloves during activities involving adhesives, dissolvents, or other chemical products.
- Make sure that all works on electrical equipment are performed by persons with professional electrician certification.
- Remove adjusting spanners or wrenches before using any type of machine.
- Keep the workplace clean and tidy.
- Ensure that the work pieces are always stable and clamped before proceeding with processing.
- Respect the generally applicable instructions and measures concerning occupational safety and fire prevention.
- Don't throw wastes and small metal pieces while doing the works.
- Respect any other safety instruction not described in here, that arise or are specified before or during the installation phase.

5.3.2 General instructions

ConExWall is a renovation system introducing certain technical and installation specifics compare to the common renovation practice. The professional who will participate in the ConExWall installation process should thus be trained in the system installation.

Anyway, the installation of the system must be carried out by personnel specialized or skilled in installing prefabricated components.

Precise on-site survey must precede the design of ConExWall system application – a detailed model of the existing building based on the point cloud geometry obtained by the 3D scanning process is recommended that identifies any surfaces' unevenness in advance. All those must be treated or flattened to fit the required tolerances before installation.

Structural survey of the existing building envelope and load bearing structures must be performed prior the design and installation to identify the quality and load bearing capacity of the structures. Existing

structures must satisfy sub-substrate requirements to be able to accommodate anchoring and carry the ConExWall panels.

Within the design phase, the transportation limitations and site operations (crane lifting capacity and position on site) must be considered and panel sizes conformed to those. Further, the panel joints and sealing thickness must be taken into consideration and the necessary tolerances incorporated into the manufactured panel sizes.

Further, the following factors shall also be considered:

- The stored panels must be protected against precipitation.
- The stored panels must be secured against falling (e.g. caused by wind load or a machine- or manpower accidents)
- Handling and installation of ConExWall panels by any means should only be done under normal climatic conditions. Precipitation during handling may cause impair of heating layers and thermal insulation layers function and cause dampness issues leading to gradual degradation of wooden elements.
- Surfaces must be clean before installing the panels on them.
- Site must be well lit to be able to view the panels well throughout the installation and anchoring, as well as during the sealing and other works.
- Before processing, check the panels for any production defects.
- Windows and door openings, as well as any holes in the existing walls must be clean and aligned.
- Beware of panels numbering to match with drawing's numbers and direction. Wrong positioning of ConExWall panels will result in improper installation. It is recommended to arrange the load/unload order with respect to the installation sequence to prevent mistakes.

5.3.3 Packaging – transportation

The panels are distributed preferably in vertical position on wooden pallets stacked by floors, with the precaution of placing a foam-type protection materials or woods to avoid contact between materials of different hardness and to avoid damage by friction. Roof panels, unless completed with roof sheeting, may be transported in horizontal position as well. The panel dimensions in relation to transportation limits affect the decision about horizontal/vertical position as well.

The panels are supplied strapped for stability on wooden pallets. The pallets will be shrink-wrapped with identifying labels of the product and the manufacturing company.

The packages are delivered in pallets that will guarantee the integrity, both in transportation in vehicles, and in the loading and unloading operations.

The pallets will be placed in the truck so that they do not suffer displacement, which could cause damage during transportation.

If a building installer requires a weight limitation, then this should be complied with the restrictions of offset system of packaging.

The element packs should be checked for completeness and any possible damage immediately after delivery to the construction site, and then the unloading report of the shipping company should be filled in.

All wall ConExWall panels should be ensured that they are always held in vertical position.

Suspension during handling is possible only in places designated by the manufacturer.

5.3.4 Handling – unloading

ConExWall panels should be handled with care during transport, loading/unloading, storage and installation in order to avoid damaging the edges and the surfaces. Therefore, the following points should be observed:

- Suspension during handling is possible only in places designated by the manufacturer.
- All wall ConExWall panels should be ensured that they are always held in vertical position. Roof panels may be handled in horizontal position, unless completed with roof sheeting. If the roof panels are completed with roof sheeting (even partly), handling in vertical position is only possible. Only for the purposes of installation itself, the panels are turned to a horizontal position at the in-process storage and installed.
- Manipulation (unloading) of the packs should be performed with suitable lifting devices (spreader bars, if applicable) and slings (belts). The hoisting slings should always be fixed to the packing, but not to the product; deformation of the elements during the lifting procedure must be avoided.
- The unloading of the materials should be done as close as possible to the final position to avoid unnecessary hauling. To avoid deterioration of the surface by friction with sharp particles, panels must be handled with care avoiding sliding, one on top of the other, lifting them one by one.
- During both the unloading and handling, it must be avoided that the materials are hit or dropped.
- Also avoid leaving the materials in dusty places or outdoors to prevent them getting dirty.
- Handling and installation of ConExWall panels by any means should only be done under normal climatic conditions (mainly avoid precipitation and wind).

5.3.5 Storage

The pallets arrive to the site perfectly protected according to the project specifications, installation requirements and specifications.

As normal protection pallets arrive protected with a film which prevents the panels to get dirty or dusty before it is installation.

Never store the pallets in too dusty, or wet, or bad weather conditions site.

Storage at the construction site should be performed in such a way that elements are stored in vertical position and without any bending. Roof panels may be stored in horizontal position as well, unless completed with roof sheeting. If the roof panels are completed with roof sheeting (even partly), storage in vertical position is only possible. Only for the purposes of installation itself, the panels are turned to a horizontal position at the in-process storage and installed.

Elements stored outside should be protected by a rainproof and well ventilated cover.

Any penetration of water into the pack as well as formation of condensate within the packs must be avoided. Furthermore, storage should be performed with slight longitudinal inclination so that any possibly penetrating water may run off without problems. Interim storage of the façade elements for a longer period should be made at a dry and roof-protected location.

5.3.6 Sawing, milling and grinding

Sawing, milling and grinding are prohibited (Figure 35).

ConExWall panels are ready made prefabricated elements that do not require further processing.

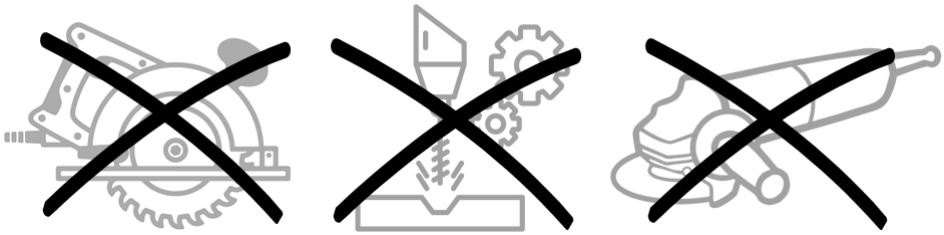


FIGURE 35: PROHIBITED PROCESSES

5.3.7 Drilling

ConExWall panels usually do not require to make any holes on site. If it is necessary to drill a hole in them, a high-speed drill must be used to avoid chipping the panel finish board.

Ideal are helicoidal drills with a drill point angled at 60° to 80° (instead of 120° for conventional metal drills) and with steep chip evacuation (so-called rapid inclination) and a wide channel.

In order to prevent chipping, it is advisable to cover the board with masking tape in the area to be drilled.

Any holes after drilling must be carefully sealed if exposed to external weather conditions or penetrating the airtight or water vapour tight layers.

5.3.8 Corners and joints

For corner and joint details follow the installation plan details. It is very important to ensure the tight fitting between the isolation layers.

For the joints among panels, a minimum gap of 6 mm is required. This has not only a technical but also an aesthetical function. The smaller the joints, the more joint width differences will be visible.

A joint between the panels is always assumed at the corner. The panel on one side goes all the way to the outer edge of the façade, and the perpendicular panel will be attached to the first. Vertical joints between panels are limited by production possibilities, transport possibilities and the design of the façade. The horizontal joints between the panels are preferably located at the level of the ceiling structures.

5.3.9 Anchoring layout and installation

The ConExWall system can be installed in two different layout ways:

- Local point anchors (for load-bearing base structure);
- L-profile: Panel can be installed along a large L-profile which already has the holes to fix it to the existing wall (construction).

According to the requirements of each project, both systems can be integrated.

Anchorage levels are:

- bottom of the façade;
- levels of ceiling structures;
- top of the façade;

Anchoring layout is not identical for each ConExWall panel, mainly because of:

- Each panel is custom made, their dimensions vary and consequently its weight affects the anchoring layout;
- Each sub-construction where panels can be installed is not the same; different layout are required for reinforced concrete and totally different for timber, masonry etc.;
- Each location is specified by different climatic load values.

In any case, the selection of the most appropriate anchoring layout can only be determined by the structural design, which will thus provide the data for the anchoring properties (size, dimensions, span, and location on ConExWall panels).

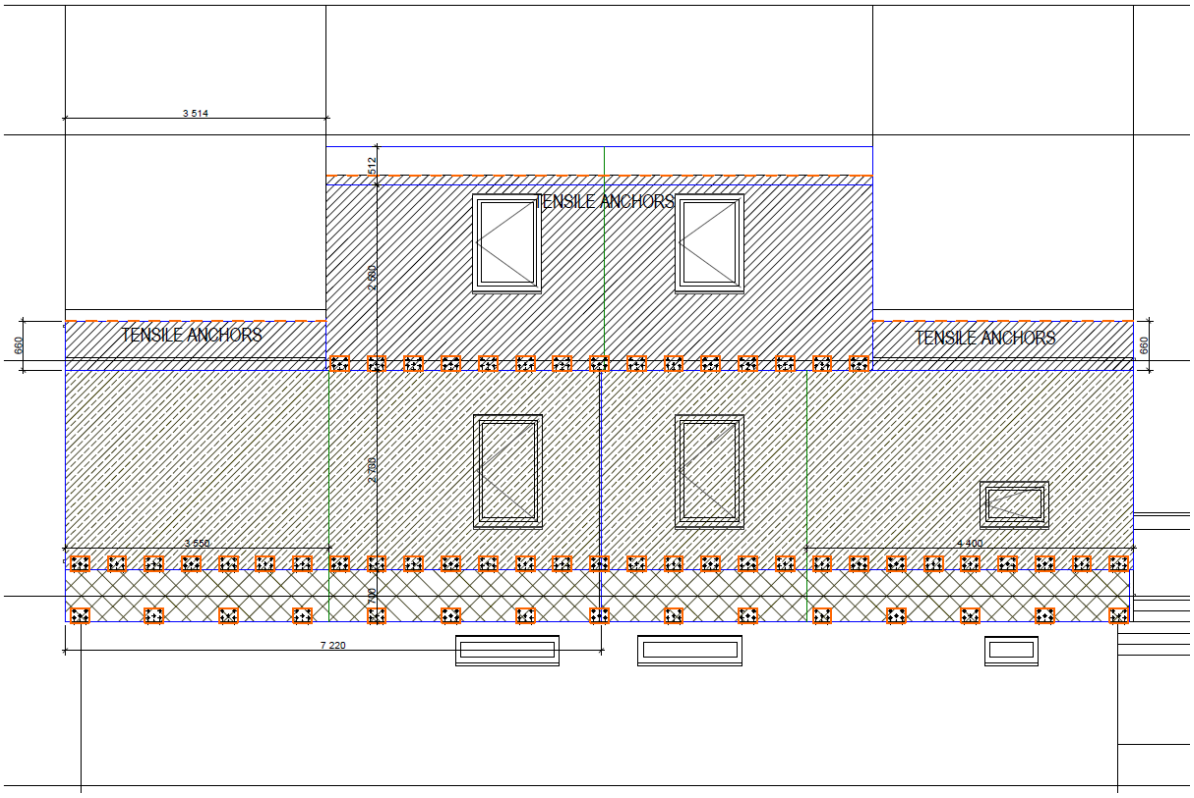


FIGURE 36: EXAMPLE – SCHEME OF THE LOCAL ANCHORS

5.3.10 Panels installation

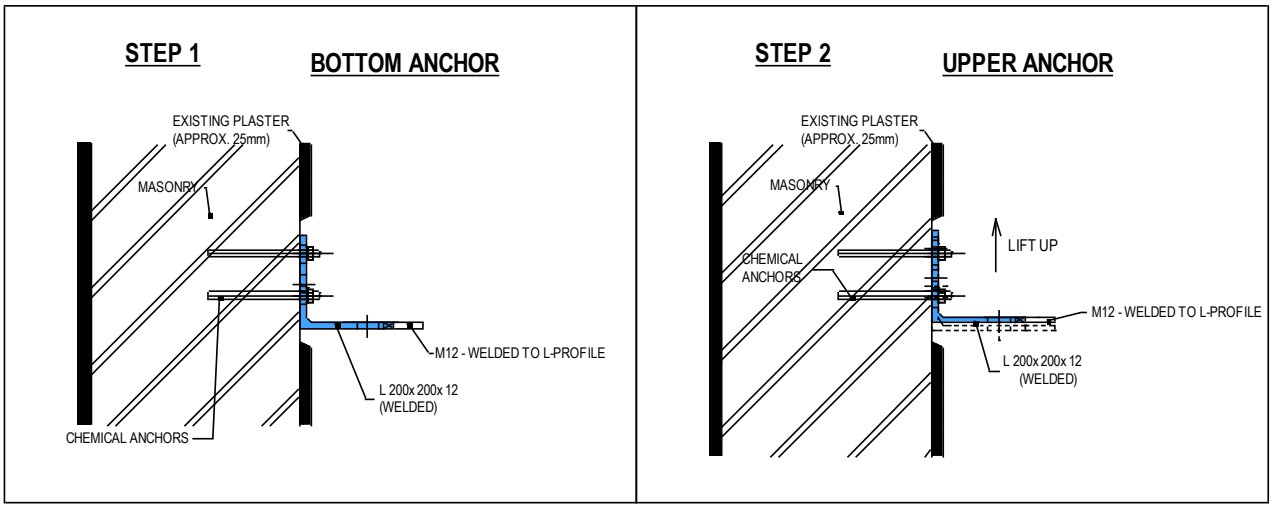
After accurate measurement and levelling of the façade surface, assembly will begin.

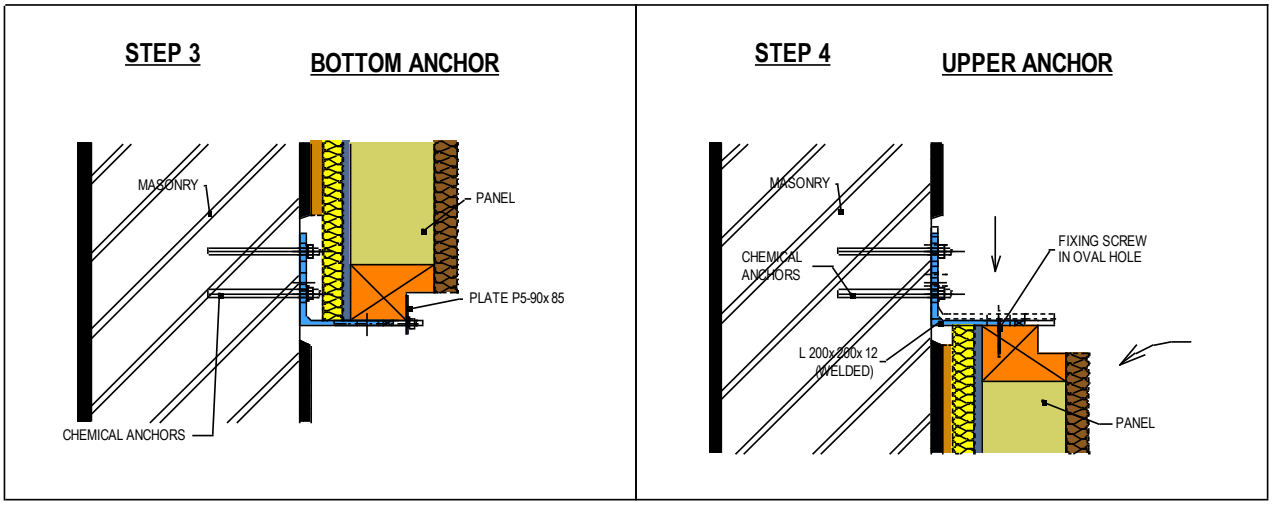
Steps are as follows (Figure 37):

1. The lower row of anchors (chemical anchors + L-profile) is installed and fixed. The position of the L-profile in the vertical direction must be aligned using the oval holes.
2. The upper row of anchors is installed. The chemical anchors are fixed and the L-profile is only temporarily fixed in the upper position. This creates space under the L-profile for inserting the panel.
3. The panel is placed on the lower anchor and fixed with plate P5 + nut. The panel will not yet be pulled into the final position.
4. In the upper anchor, the L-profile is lowered onto the panel and temporarily fixed from above using 2 screws with a diameter of 5 mm. The screws are not tightened – the panel can therefore move freely perpendicular to the façade within the range of the length of the oval hole ±20mm.
5. The upper panel is installed and fixed with plate P5 + nut. The panel will not yet be pulled into the final position.

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

6. After all the panels have been installed, the P5 sheets will be tightened and will press the panels to the existing wall. Their position is fixed from the front with 6x90mm screws.





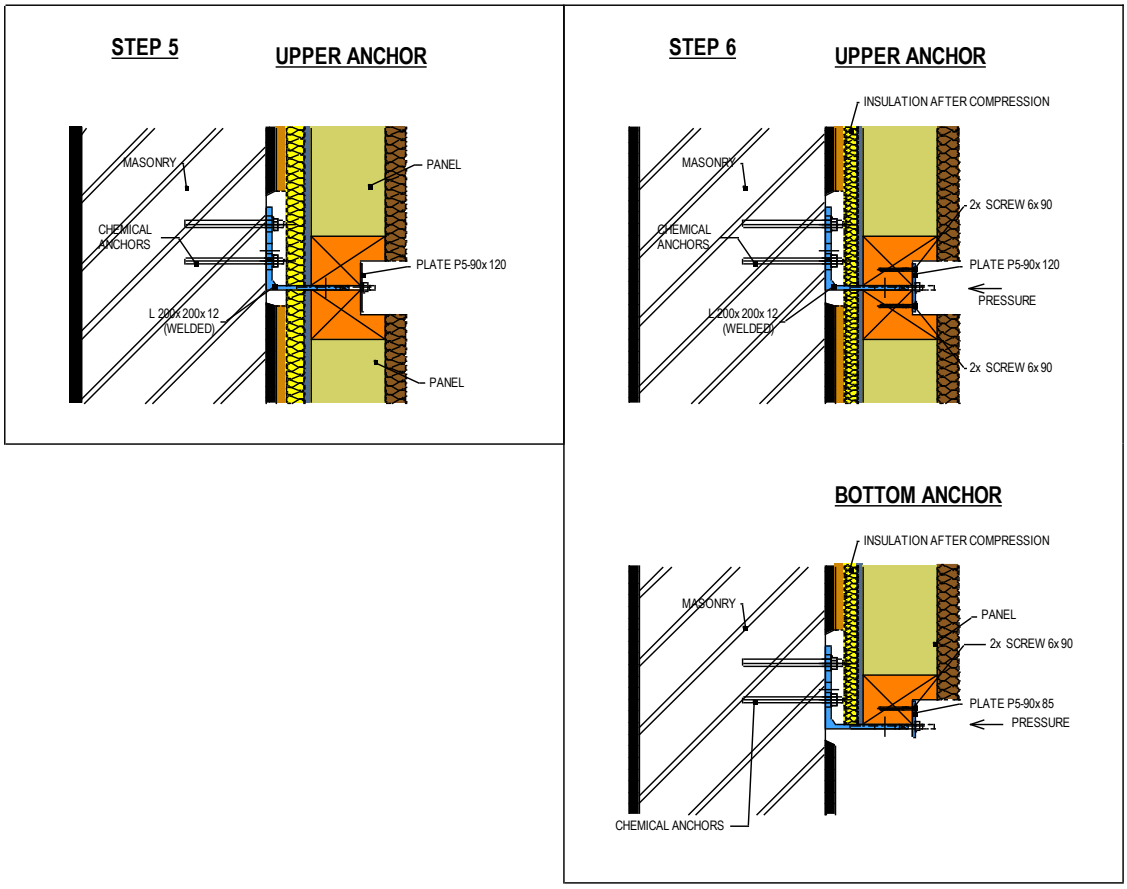


FIGURE 37: STEPS FOR PANELS INSTALLATION AND ANCHOR TIGHTENING

Panels installation is done by means of cranes. For fastening, sealing and other related works mobile elevating work platform will be preferably used. No exterior scaffolding is involved during panel installation.

5.3.11 Bracket fastening methods

Only systems homologated according to the EU regulations can be used for the installation of ConExWall panels.

This selection will be done according to the next items:

- Surface façade material
- Structural building system
- Loads to be supported

The bracket fasteners must comply with national and/or European regulations or approval requirements and must also meet the manufacturer's installation specifications. The applicable approval must cover the application for which these items are used, e.g. suitability for the demands of rain screen/ventilated façade installation. Where applicable, corrosion protection measures must also be implemented and the compatibility of materials taken into account. The load-bearing capacity of the bracket fastener must also be verified by carrying out on-the-spot pull-out tests.

5.3.12 Connections among ConExWall panels

From the airtight and water vapour diffusion point of view, the panel connections accommodate two protection measures as follows. Both together serves as a reliable solution.

- Rubber seal is applied in double rows on the panel perimeter within the manufacturing process (alternatively, a sealing foam can be applied on-site).
- On the perimeter of each panel a vapour barrier foil is applied within the manufacturing process, having sufficient overlaps so that the foils of the two adjoining panels can be connected using Airstop Flex[47] adhesive tape. This second measure is designed for a case the rubber seal impairs during panel installation.

5.3.12.1 Horizontal joints

Anchors are placed in the horizontal joint between the panels (Figure 38). Each row of anchors supports the panel above. The bottom panel does not load this anchor. The pressure plate P5 ensures that the outer surface of both panels is in one plane.

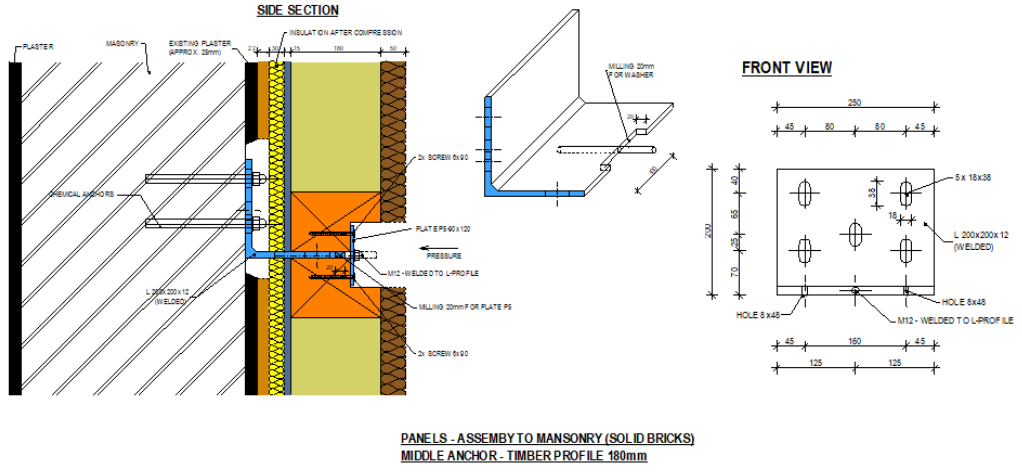


FIGURE 38: MIDDLE ANCHOR BETWEEN PANELS

[47] https://www.isocell.com/en/product/airstop-flex-kb

5.3.12.2 Vertical joints

The vertical joints between the panels must compensate for the effects of thermal expansion of the panels and the effects of changes in humidity. Therefore, they are considered as dilatative. To ensure the same position of the outer surface of the panels, the panels will be structurally connected with slant screws into pre-drilled holes (in the factory).

5.3.13 Insulation installation

The ConExWall system is based on prefabrication in maximum reasonable extent. However, the installation methodology introduces small amount of work that needs to be done on-site. One of them is filling the installation channels with thermal insulation. In the channels, pipes and cables are connected after panel installation and therefore must be reachable during the installation processes. Once the connections are completed and is sealed what is to be sealed, the channels have to be precisely filled with thermal insulation to avoid thermal bridges and completed with diffusion foil.

5.3.14 PV panels

The PV panel installation on ConExWall is possible on the vertical structures (façade integration) or preferably on roof panels. The façade integration is not demonstrated within the scope of ConExWall PLURAL project but generally integration to façade outer layer is also possible. If the installation of the PV panels is planned during the prefabrication procedure, special measures have to be taken to protect the fragile PV system during transportation and installation on-site.

PV installation on the façade elements

Even of the façade PV integration was not fully sorted out within the PLURAL ConExWall demonstration, the designed façade system does not rule out PV integration into the cladding layer of the façade.

PV installation on roof elements

The installation of the PV system could be done as one of the prefabricated steps, or on-site installation is also possible. Certified components have to be used for installation on the roof with respect to selected roof covering. It has to be pointed out that elements for various roof covering significantly differs for different type of roof covering.

Basic roof covering types:

- Corrugated metal sheets
- Asphalt shingles
- Rubber slate
- Clay or concrete tiles
- Cement-fibred tiles

Special elements are designed for every type of the covering and also roof covering manufacturers provide components specially designed for their roofing products.

- Only certified and trained person can do the works related to PV installation. Panels as source of energy generate voltage on the terminals or connectors. Special attention for works with electric devices, trained staff and certification of the installers needs to be checked prior the installation.
- Special safety measures and safety equipment has to be used for working at heights.
- Special care has to be taken during installation not to damage the fragile panels by tools or impact.
- Photovoltaic system documentation has to be available on-site and verified by authorized engineer.
- PV support rails could be installed on roof or façade elements during prefabrication and the PV panels can be installed later on on-site to avoid any damage during transport or roof element installation.
- The panels are carefully installed on the rails on-site or during prefabrication, using specified components. Cable management has to be applied in order not to damage the PV cables or connectors.
- The installed panels are connected according to the scheme in documentation and a series connection of the panels creates the PV string. Voltage on the string terminals can easily exceed 1000 V DC
- The string cables are led to roof junction box or are led to the area with solar inverter.

FIGURE 39: EXAMPLE OF PV SYSTEM USED FOR INSTALLATION ON METAL SHEETING (SOURCE: HTTP://RENUSOL.COM)

The roof elements of ConExWall system have no limitation in terms of the roof covering system used and corresponding PV system installation set. Possible mounting solutions compatible with ConExWall system are shown in Figure 40.

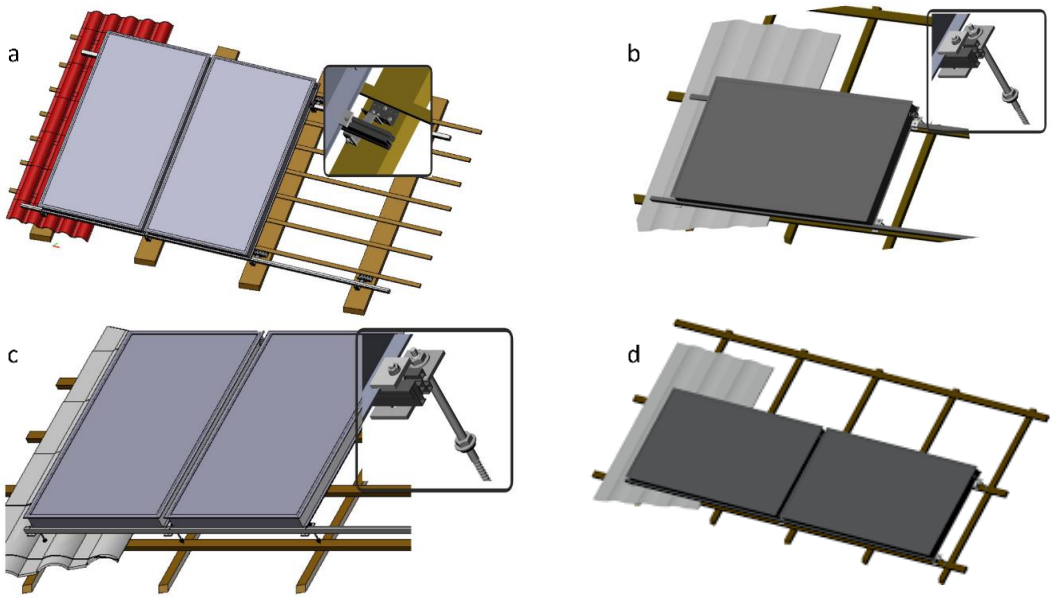


FIGURE 40: POSSIBLE PV MOUNTING SOLUTIONS COMPATIBLE WITH CONEXWALL SYSTEM – A) TILES, B) BOARD ROOFING, C) + D) METAL ROOFING) (SOURCE: HTTP://TWI.CZ)

5.3.15 HVAC systems

Panel contains local ventilation unit Helty Flow[48], or may contain any similar-system-based unit. Type and size of the unit depend on requirements given by building operation and project specifics. The unit is to be installed in rectangular hole in a building wall/panel in horizontal or vertical position. Outer connections to exterior pass through ConExWall panel and are covered by grills. Indoor side is covered by panel with unit's controller.

The installation does not require any ducting or other air channels, only connection to electric grid (included in the panel).

Helty unit is supposed to be installed in unit arrangement (case) made of thermal insulation, which is an accessory of ventilation unit (see Figure 41). The preparation for the installation of ventilation units Helty Flow is a process that is developed in three simple steps:

1. Making a rectangular hole in the wall according to the geometry required by the type of machine to be installed.

[48] https://www.heltyair.com/en/products/built-in-recessed-hrv/flow-70/

2. Installation of the arrangement (outer shell of the unit) in the wall (or already imbedded in the panel), including external vents and sealing the perimeter of the arrangement with flexible polyurethane foam or tape.
3. Insertion of the ventilation unit and connection to the power supply; positioning of the interior cover.

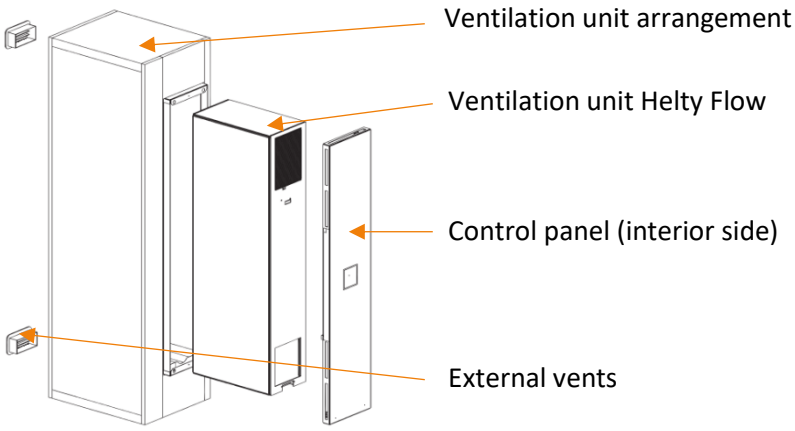


FIGURE 41: COMPONENTS OF HELTY VENTILATION UNIT ASSEMBLY

Location of ventilation unit should keep minimum distances 500 mm from neighbouring walls, 300 mm from ceiling and 700 mm from floor. Distances apply for vertical and horizontal position, see Figure 42.

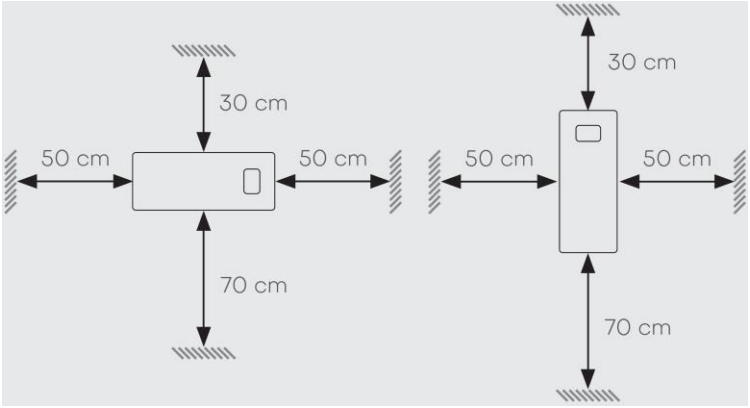


FIGURE 42: HELTY VENTILATION UNIT POSITIONING REQUIREMENTS[49] – MINIMUM DISTANCES OF FROM STRUCTURES

[49] source: https://f.hubspotusercontent20.net/hubfs/3795173/HELTY/schede%20tecniche%20Helty/Helty_Flow70_Flow100_scheda_2021.pdf

5.3.16 Power connections

The ventilation units Helty 70 are the only electrical device that are integrated directly in the wooden panels. All other electrical devices are mounted on the existing walls like IAQ sensors, or on the roof panel like PV system. The necessary electric cables are integrated in the wooden panels. All the cables must be led through the plastic conduit and if necessary, they must be connected in the junction boxes.

5.3.17 Testing & Commissioning

In order to complete the installation, a series of inspection actions/tests is required to all of the components to be performed by the installers:

Visual tests

- Checking the number and location of anchors before starting installation;
- Sealing the joints between the panels (preventing the ingress of moisture);
- Surface observation / defects on paint, cracks, flakes etc. identification;

Mechanical tests

- Checking the tightening of the anchors.

PV system

- The installation procedure will be completed by final check of the system functionality. The first check will be done after panels installation. This does not necessarily mean functional check because other components (circuit breakers, protections, inverters) might not be installed at the same time. The final functional check will be done when all the components are installed, and system completed. The administrative procedure and request for first parallel connection to grid has to be approved by distributor and required electrometer installed.

5.4 Specific installation & safety requirements for ConExWall systems

5.4.1 Working at heights during installation of ConExWall panels

During ConExWall panels installations, some of the works are not reachable from the ground. Usually an installer decides a way of how works in heights will be performed. Those comes into consideration:

- Mobile elevating work platforms.
- Use of collective or personal protective equipment for works at heights.
- Ladders.
- Stepladders.

Preferred solution is to use mobile elevating work platforms. If there are some works, for example at the roof, that are not feasible using an elevating platform, those will be done using protective equipment.

Roof panels have to be equipped with anchoring points designed for working at heights and roof revision purposes.

Regardless of what method is used, appropriate safety/protective equipment, well maintained, must be used and health and safety plan followed. Work must be done by people trained (certified) for works at heights (if required for given technique/measure used).

Scaffolding is not recommended for ConExWall system installation.

5.4.2 ConExWall panels installation

See sections 5.2 and 5.3.

5.4.3 ETICS installation

Although not incorporated within the Czech demo Kasava, the ConExWall system enables use of ETICS. The ETICS is to be applied within panel assembly phase. Technology of panel connections during installation on-site should be carefully considered within detailed design phase to minimize amount of on-site works while ensuring access to panel joints for the sake of sealing. Potential dilatation requirements should be considered in the design phase, where relevant, and carefully followed during installation to prevent cracks and damage of the ETICS surface layers during years following the installation.

5.4.4 PV panels installation

Installation & safety requirements related to PV panels installation depends on type of roofing, PV panel types and chosen installation method. General safety and installation requirements apply, considering corresponding methods. Increased safety measures must be adopted in case the PV panels are integrated within the panel assembly process to prevent their damage during transportation and handling.

5.4.5 HVAC systems installation

The ConExWall system contains the heating layer as an integral part of the assembled panels. The required heating performance must be calculated, taking into consideration mainly: local climatic conditions, building envelope geometry and parameters after ConExWall system application (heat loss, thermal mass, solar gains), building operation (internal heat gains, ventilation loss, temperature set points).

The surface of existing wall must be flat within the limits and panels installation must be carefully performed to ensure perfect contact of the heating layer with the existing building to avoid impair of heating performance due to installation defects that might lead to insufficient indoor climate in the end.

Further, the ConExWall system contains a ventilation unit. To ensure good performance and prevent unwanted heat loss due to reduced airtightness, the outer shell of the unit (case made of thermal insulation) should be carefully sealed after its installation to the panel/existing wall.

See more about HVAC components installation in sections 5.2 and 5.3.

5.4.6 Electric components / devices installation

- Power off.
  Make sure the power is off at the breaker before you start and use a voltage tester to verify that wires and/or electrical connections are completely without voltage before you start working on them. Make sure everyone in the house is aware that electrical work is going on. Tape the circuit breaker into the off position and put the warning sign over it.
- Be careful what to be touched.
  Never touch conductive parts if not necessary while working with electricity they are often grounded.
- Use the appropriate tools.
  Before any works commencement, make sure that there is a plan in place as to what outlets, switches and fixtures will be involved in the working tasks. Make sure all the appropriate tools are available, including but not limited to: needle nose pliers, wire cutters, cable & wire stripper, coloured tape, voltage tester, continuity tester, necessary electric devices.
- Include junction boxes.
  Never splice wires together and conceal them within a wall without a junction box — an accessible junction box should always be used to join wires.
- Replace old wiring that shows signs of deterioration or fraying.
- Fix fuse and breaker problems (if any).
- Don't overload devices and/or components and/or circuits.
- Make sure electrical equipment is properly connected, grounded and in good working order.
- Extension cords may not be used as permanent wiring and should be removed after temporary use for an activity or event.
- Surge suppressors with built-in circuit breakers may be used.
- High amperage equipment must be plugged directly into permanent wall sockets.
- Do not allow access, use or alter any building's electrical service, including circuit breaker panels, unless the people are authorized to do so.
- Wet environments can increase the risk of an electrical shock.
- To prevent electrical hazards, always make sure equipment is properly grounded.
- Equipment with a grounding pin must be plugged into an extension cord with a grounding pin.

For the Czech demo building, refer to the National technical standards and regulations, mainly:

- PV related: EN IEC 61215 and EN IEC 61730, EN 61000, EN 50581;
- Related to internal electrical installations: ČSN 33 2130 – Low-voltage electrical installations – Internal electric distribution lines
- Related to overvoltage/lightning protection: ČSN EN 62 305 Protection against lightning

5.4.7 Additional safety equipment

A need for the use of additional safety equipment may arise if specific work techniques need to be involved during the construction works. Those may consist of nets, airbags, safety lines, or other fall restraint and arrest equipment, or any other types of safety equipment, for example for electrician installation and other. Works that need any special safety equipment should only be performed by workers who are trained or certified for such work. The equipment has to be inspected regularly and only used in accordance of its purpose and guidelines.

6 Conclusions

Prior to the extraction of any conclusions, it must be underlined that installation processes and their guidelines are always the result of various processes that have been performed and evaluated in previous steps of the PnU kits design and manufacturing. Several tasks of PLURAL Project have contributed to allow the manufacturers to develop successful and sustainable installation methodologies, as described in the current report.

By seeing the big image of PLURAL project, all activities – tasks involved in *WP2 Selection of technologies – Integration – Design of PnU kits* established the framework of the PnU technologies and setup the targets and barriers for their installation in each demo building. The main challenge, emerging from WP2, for the manufacturers is to be able incorporate the PLURAL's PnU kits design to the "traditional building techniques" by adjusting the installation methods of PnU kits in such a manner as to incorporate them to the overall renovation schedule. Even though all three innovative PnU kits have been designed in WP2 with a different "philosophy – approach" to the "traditional renovation processes", the manufacturers developed a series of "generic" installation steps capable to be adopted to almost all traditional installation methodologies confronting the barriers occurred by the requirements and limitations of WP2.

Furthermore, the outcome of *D4.5 – PnU kits prototype properties and performance characterization, (*as result of all *WP4 - Optimization of PnU components – prototyping – testing* actions), identified and determined the mistakes, omissions, bottlenecks, and remedial actions that might be necessary to be performed during their installation. Via a series of tests (as described in D4.5), the manufacturers were able to redesign and/or adjust the PnU kits' critical elements, components and/or systems that might be possible sources of future installation errors.

Aiming to tackle the human installation mistakes that usually occur during new construction or renovation projects, an effort to implement the LEAN methodology during installation processes was performed. Gaining by the knowledge obtained in *T6.1 – Manufacturing process, T6.2 – Assembly methodology for PnU kits and T6.3 – Quality Assurance Plan,* the same looping interactive actions (check – install – test – correct – recheck) were identified and instructions were issued to facilitate future installers and professionals. In this sense, a series of installation instructions were developed for each PnU kit covering all aspects of their installation, as well as providing remedial solutions in case that mistakes and/or quality issues occur during their installation.

Even if one of the main targets of T6.2 was to minimize human mistakes and occupants' disturbance during the PnU kits installation, it has been necessary to use some of "traditional renovation installation methodologies" in some cases. For example, additional safety equipment and need of specific safety measures may arise, if some specific installation techniques need to be involved during the construction works. Those may consist of nets, airbags, safety lines, or other fall restraint and arrest equipment, or any other types of safety equipment. The adoption of such "traditional renovation methods" does not minimize or eliminate the installation guidelines provided in this report, but act as supplementary to ensure safety at work and mineralization of installation's environmental impact e.g. noise, dust, fumes generation, etc.

Apparently, this report does not claim that the described installation processes are the “nostrum” solutions for all renovation projects where PLURAL PnU kits can be applied. It must be kept in mind that the integration of the PLURAL PnU kits in every renovation project depends mainly on the requirements of the building and the owners, with their design playing the most significant role. Nevertheless, an extensive effort has been made in this public report (D6.2) to provide “generic” guidelines to the professionals and installers trying to cover all possible alternatives during the PLURAL PnU kits installation.

Moreover, this report was written based on the results obtained at the pilot plants of the manufacturers and does not take into consideration any future industrialization of the PnU kits. Under the prism of future industrialization, the components, systems, and/or manufacturing techniques will probably be modified and optimized, possibly resulting to adoption of different manufacturing processes and eventually installation guidelines.

NOTE: It has to be noted that due of the PUBLIC nature of the current deliverable sensitive information has not been included into it and will be presented in Deliverable D6.3 – Quality Assurance Plan.