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PLUG-AND-USE RENOVATION WITH ADAPTABLE LIGHTWEIGHT SYSTEMS

PLURAL

D6.1

Manufacturing methodology of PLURAL kits

Version: 1.0

	Name	Date
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Disclaimer

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Terms, definitions, and abbreviated terms

F.Q.P.	Factory Quality Procedure
HSP	Health and Safety Plan
PERT	Program Evaluation and Review Technique
PPE	Personal Protective Equipment
PuN	Panel Unit Kit
WS	Workstation

Publishable summary

Deliverable D6.1: Manufacturing methodology of PLURAL kits reports the work done under Task 6.1: Manufacturing methodology and planning and fulfills the WP6 objective to develop flexible and fully adaptable manufacturing processes based on the LEAN management system and the specifications of PnU kits.

As it is known, the PLURAL project develops three core hybrid prefabricated PnU kits: the SmartWall, the HybridWall and the ConEXWall. Each of them includes different materials and components, but the all serve deep renovation purposes and are fully prefabricated off-site.

The PnU kit manufacturing is based on the LEAN manufacturing methodology. The current report presents in detail the steps that have to be followed during the manufacturing stage in order to ensure compliance with the LEAN manufacturing principles. The LEAN manufacturing methodology is applied to:

- *Movement:* related to the workplace, movement of machines, ergonomics and movement of people.
- *Overproduction*: occurs when the continuous process is not stopped and stock is generated that the customer has not requested.
- *Waiting:* an inactive period does not add value, but it does generate an extra cost in the final price of the products.
- *Transportation:* occurs when there is unnecessary and continuous movement of materials.
- *Over-processing*: arises when there is an excess of unnecessary work or processes.
- *Correction:* arises from the need to correct a defective product.
- *Inventory:* storage requires good management and care so that it does not become obsolete.

The results reported in the current deliverable are extremely useful to remaining activities of WP6 and of WP8, such as:

a) Establish assembly processes (T6.2).
b) Define Factory Quality Procedures - F.Q.P (T.6.3).
c) Facilitate PLURAL kits installation methodology development (T 6.4).
d) Provide information and guidelines for the future industrialization of the PnU kits (T6.5).
e) Provide data for the Market Uptake and Exploitation in WP8.
f) Identify manufacturing costs and validate its cost reduction compared to the traditional manufacturing methods with similar functionalities (input to T.8.3 & T8.4).
g) Identify manufacturing time and validate its time reduction compared to the traditional manufacturing methods with similar functionalities
h) Provide basic data to LYSIS-MODEST and the LCA/LCC and KPIs (WP5 and WP8).

1 Introduction

1.1 Factory Quality Procedure (F.Q.P) Guidelines

Factory Quality Procedure (F.Q.P.) are essential to eliminate mistakes and errors that might occur during a product's cradle phase and secure the final product's value.

The core guideline is to design workflows and business processes towards best practices, to acquire the highest manufacturing quality levels, at every step of production/manufacturing process. The implemented practices to reach high quality results ensure that each step of the assembly process:

a) is linked to a particular final product or service and
b) is executed correctly and error-freely.

The ISO 9000 family[1] standards constitute indicative guideline for quality management, addressing various aspects of quality management and containing ISO 9001:2015[2] specifying *"Quality Management systems – Requirements"*. Some of the main benefits delivered by ISO 9001 are the reduction of operating cost, the increase of productivity, the application of constant development parameters for high quality actions etc.

There are a broad variety of quality assessment methods used for final product evaluation, like the LEAN methodology[3] developed by TOYOTA, the six sigma[4] established by Motorola, the Taguchi method[5], the X-bar chart assessment[6], etc.

1.2 The LEAN Methodology

The LEAN methodology is an evolution of the Toyota Production System that the Japanese automaker implemented following World War II to improve the efficiency and flexibility of its manufacturing[7]. Although the Lean management system started in manufacturing, today it is widely used for process improvement across the globe in every sector, manufacturing, including logistics and distribution, services, retail, healthcare, construction, maintenance, software development, and even higher education.

[1] https://www.iso.org/iso-9001-quality-management.html
[2] https://www.iso.org/standard/62085.html
[3] https://www.planview.com/resources/articles/lean-methodology/
[4] https://www.cio.com/article/227977/six-sigma-quality-management-methodology.html
[5] https://www.investopedia.com/terms/t/taguchi-method-of-quality-control.asp
[6] https://mmrjournal.biomedcentral.com/articles/10.1186/s40779-020-00238-8
[7] Ohno, Taiichi (1988). Toyota Production System: Beyond Large-Scale Production. CRC Press.

Two guiding concepts are the heart of the Lean methodology. An organization can not practice Lean without embracing them both.

a. *Respect for People*

LEAN methodology recognizes that the best ideas often come from people directly responsible for producing the product or providing the services. Therefore, a successful implementation of LEAN process, requires that the top-down management to give those people involved to the product or the customer, an equal voice. Furthermore, LEAN processes are demonstrating respect for people by giving them the tools and training they need to be successful. LEAN leaders take the time to ensure that everyone understands the techniques that the organization will use to implement, manage, and report on improvement work. In addition, they invest in training, software, and other necessary resources to achieve operational excellence[8].

b. *Continuous Improvement*

LEAN leaders believe that processes can constantly be improved, and that improvement is a daily activity that is the responsibility of everyone in the organization. The structure is applied with an improvement cycle such as PDSA (Plan, Do, Study, Act) or DMAIC (Define, Measure, Analyze, Improve, Control.) Often continuous improvement software is used to organize, measure, and report on Lean activities.

1.3 Five Core Principles of Lean methodology

Womack and Jones[9] laid out five core principles for the Lean methodology, giving leaders a framework under which to operate (*Figure 1*).

01. Define Value

Lean starts by understanding what value the customer ascribes to the offered product or services. The customer, not the producer, defines all value. The price is based on the customer's willingness to pay, which determines the maximum allowable cost to produce the product. The organization then focuses on eliminating waste to deliver what the customer wants with the highest possible margins.

[8] Plenert, G. 2007.Reinventing Lean: Introducing Lean Management into the Supply Chain. Oxford, U.K.

[9] *Womack, James P.; Jones, Daniel T. (2003),* Lean Thinking: Banish Waste And Create Wealth In Your Corporation, *Simon and Schuster*

02. Map Value Stream

The value stream represents the sum of the product's entire life-cycle from research and development through to the customer's use of the product. A deep understanding of the value stream is necessary to achieve maximum value and eliminate waste. Every process is examined to see what value it adds. Processes, features, and materials that don't add value are removed.

03. Create Flow

The value stream should flow seamlessly without interruption or delay. The LEAN method seeks to have every process entirely in sync with every other. A smooth process flow is one of the conditions necessary for just-in-time production.

FIGURE 1: PRINCIPLES OF LEAN METHODOLOGY

04. Establish Pull

In LEAN, pull means ensuring that nothing is made before it is needed. Instead of creating work based on a forecast and schedule, in a Lean organization, nothing is made until the internal or external customer orders it. This makes shorter delivery cycle times possible and increases flexibility. The most important aspect in this principle is to develop a solid way of communicating what is needed in each step of the value chain.

05. Pursuit Perfection

In line with the guiding concept of continuous improvement, Lean practitioners exercise a relentless pursuit of perfection. They dig deeper into the root causes of quality problems and waste, apply more rigorous measurements, and make incremental changes more effectively than their less successful competitors.

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2 SmartWall Manufacturing methodology

2.1 SmartWall manufacturing methodology

This report aims to exercise the LEAN methodology model for SmartWall manufacturing, while some of the involved to the process aspects are part of other PLURAL Deliverables, such as:

- Analysis of the *"Value"* principle will be performed in the *Deliverable D8.7 – Market Assessment*
- Associated to the products' manufacturing assembly process will be extensively presented on the *Deliverable D6.2 - Assembly methodology for PnU kits,* and
- The designated remedial actions related to the Quality Assurance Plan for each Working Station will be extensively presented in *Deliverable D6.3 - Quality Assurance Plan – manufacturing / assembly.*

By:

- implementing the other four (4) LEAN principles described in the above paragraph of the current report to a manufacturing process and by
- the outcome of *Deliverable "D4.4 PnU kit prototypes addressing the 3 demo building requirements"* and the F.Q.P guidelines indicated in its section *"6.6-Factory Quality Procedure (F.Q.P) Guidelines*",

the overall manufacturing methodology for SmartWall systems can be summarized as in the following chart (*Figure 2*), divided in **six (6)** different stages:

[1] ***Data Collection & Design*** where all data and requirements are gathered for the manufacturing process, e.g., site conditions, dimensions, requirements of the customer, auxiliary systems to be used such as PV's, solar panels, etc. as described in *Deliverable D7.1 Preliminary Design*;
[2] ***Production of 2d- 3d Drawings***, a stage where the gathered data from *Stage [1]* (corresponding to *WP2 - Selection of technologies – Integration – Design of PnU kits* performed actions*)* are interpreted into dimensional and quantitative manufacturing drawings with the highest accuracy possible;
[3] ***Production,*** the core of manufacturing assembly where the actual production / assembly of SmartWall systems is taking place (will be detailed described in *Deliverable D6.2 – Assembly Methodology of PnU kits*);
[4] ***Assessment and Testing,*** where the manufactured products are tested according to the Quality Assurance Plan developed by the manufacturer and will be detailed presented in *Deliverable D6.3 - Quality Assurance Plan – manufacturing / assembly;*
[5] ***Packing & Storage,*** where the produced storage is securely packed and stored to designated areas and conditions and finally
[6] ***Loading - Transportation on site,*** where appropriate means of transportation are chosen to deliver SmartWall systems on sites***.***

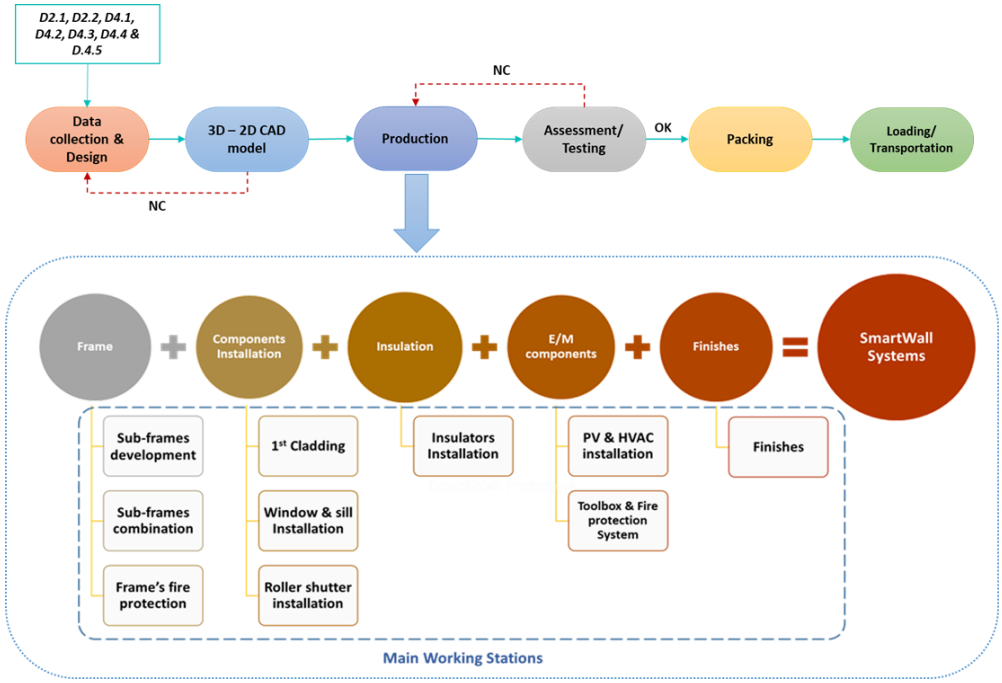


FIGURE 2: SMARTWALL MANUFACTURING METHODOLOGY

The schematic overview of the SmartWall manufacturing methodology is presented in *Figure 3,* where are illustrated the:

- Actions prior manufacturing procedure;
- Working stations and the activities performed to each one;
- Communication lines among working stations;
- Dependencies among the tasks of each working station;
- Sequence of actions;
- "*Cut off*" points of the production line, and
- Looping actions among tasks

aiming to optimize the:

- ***Overproduction (Unnecessary features*):** Overproduction and unnecessary features can lead to added costs like extra storage, wasted materials, and useless inventory.
- ***Inventory***: Inventory waste, waste from incomplete work, and mismanaged backlogs all incur unnecessary costs for storing inventory, transportation costs, and additional costs spent to complete work.
- ***Motion (Task switching)***: Motion waste is the unnecessary cost of internal motion by people or machines.
- ***Defects (Technical debt)***: Defects can result in costly repairs and a loss of materials. Technical debt can result in a loss of valuable time.

- ***Fragmented teams***: Fragmented teams can result in wasted costs due to miscommunication, unnecessary meetings, and lack of strong collaboration.

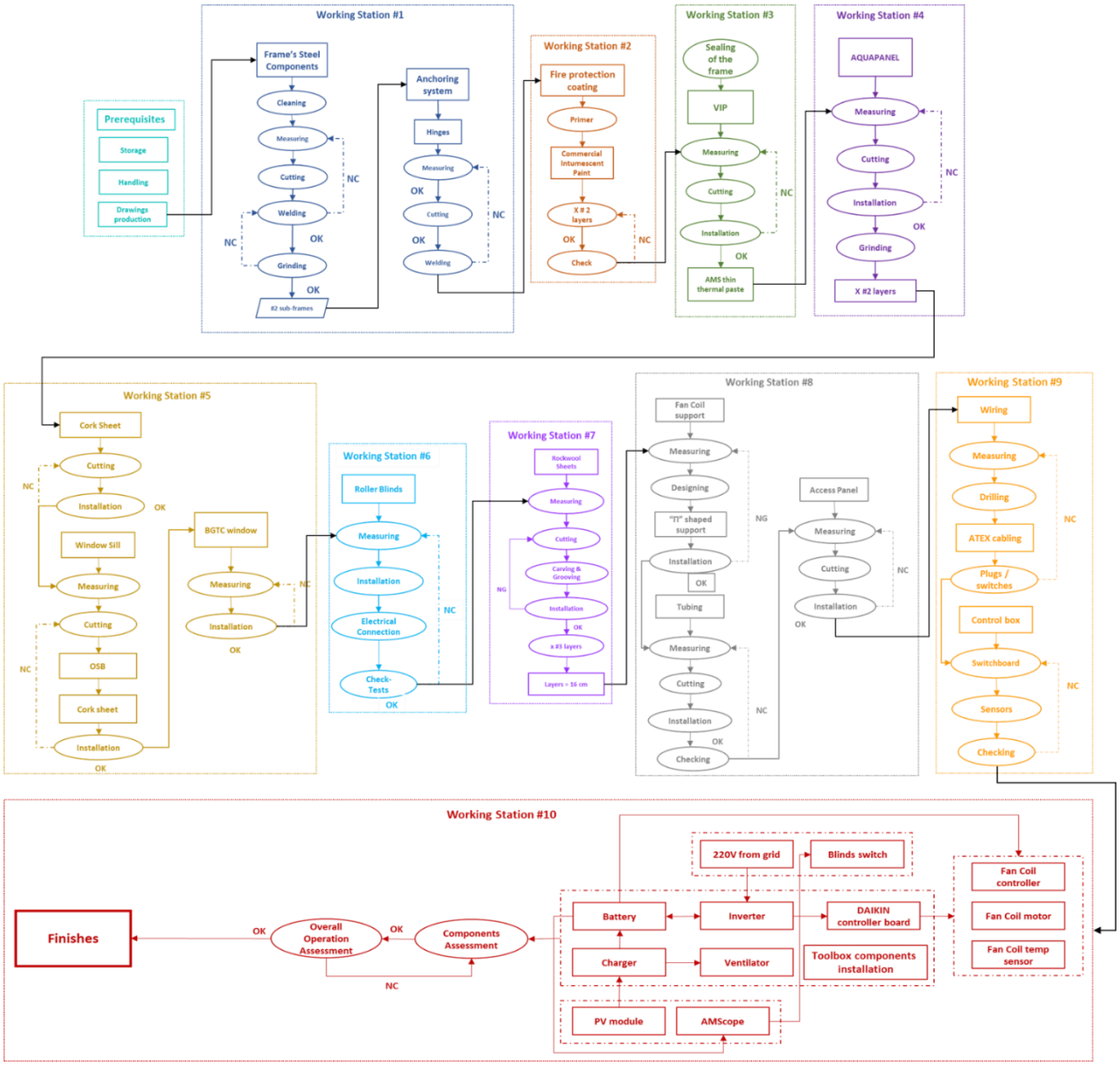


FIGURE 3: SCHEMATIC OVERVIEW OF SMARTWALL MANUFACTURING METHODOLOGY

2.2 Manufacturing methodology per Working Station

During the current F.Q.P. analysis a comprehensive assessment is performed, by employing the "*100% Inspection Method"* under the accreditations of ISO 9001:2015 & ISO 17020[10].

The "*100% inspection Method*" is an F.Q.P. process incorporating an in-depth approach to the manufacturing processes and the final product itself. The implementation of this method during the manufacturing of SmartWall systems, requires a variety of data as prerequisites, such as detailed design and drawings of the systems, but also detailed information and data related to the parts / components and properties will be used for their assembly. Both requirements have been fully fulfilled by the tasks of *WP2 - Selection of technologies – Integration – Design of PnU kits* and the *"PLURAL's repository of materials"* together with *D4.1 - "Optimized components for PnU kits"*.

As a result of the implementation of the proposed method, is the production of complex, high quality with added value products, challenging the necessity for every-single part / component / product inspection in very frequent manufacturing procedure steps. Furthermore, as the manufacturing process of SmartWall systems is a one-time-product manufacturing process, by evaluating the single component-parts which is performed almost automatically during the construction flow, leads to the conclusion that the implementation of the proposed methodology is the most appropriate solution for SmartWall systems.

From the above, is clear that by manufacturing SmartWall systems with the "*100% Inspection Method*" customized manufacturing and inspection processes are applied before and after every manufacturing phase and to each working station involved to the manufacturing process.

Prior to the actual manufacturing stage a range of prerequisites need to be met mainly associated with the smooth and safe operation of the manufacturing plant, but most important to ensure that all required data for the manufacturing stage such as design data, customers' requirements, specific design conditions, etc. are available.

In every working station a series of inspections e.g., safety, availability, condition of raw materials, etc., are conducted prior to any manufacturing work commencement. During PnU kits' manufacturing at working station level certain "cut-off" points indicate quality inspections and progressing to the next step or working station is feasible only when the inspection conditions are satisfied. The unsuccessful evaluation at every *"cut-off"* point, leads to designated actions, looping among them until the product will successfully meet the setup manufacturing standards.

[10] https://www.iso.org/standard/52994.html

2.2.1 *Manufacturing Stage #1 (Frame)*

Manufacturing Stage #1 is focused on SmartWall frame development production tasks and are executed at three (3) different working stations (WS), as *Figure 4* illustrates*:*

- **WS1:** is focused on the individual steel sub-frames production, including the handling, cut on size and welding of the steel components.
- **WS2:** the fire protection coatings (primer & intumescent paint) are applied to ensure fire protection to the overall frame, and
- **WS3:** is dealing with the sub-frames combination producing the final frame of the SmartWall system.

Figure 4 analyses the basic operational steps in each working station, their interoperability and interdependencies as well as, *the "cut-off"* points where the "*100% Inspection Method*" is applied and clearly indicates the looping actions among them which are marked with *NC* (Non-Complying) – *OK* markers.

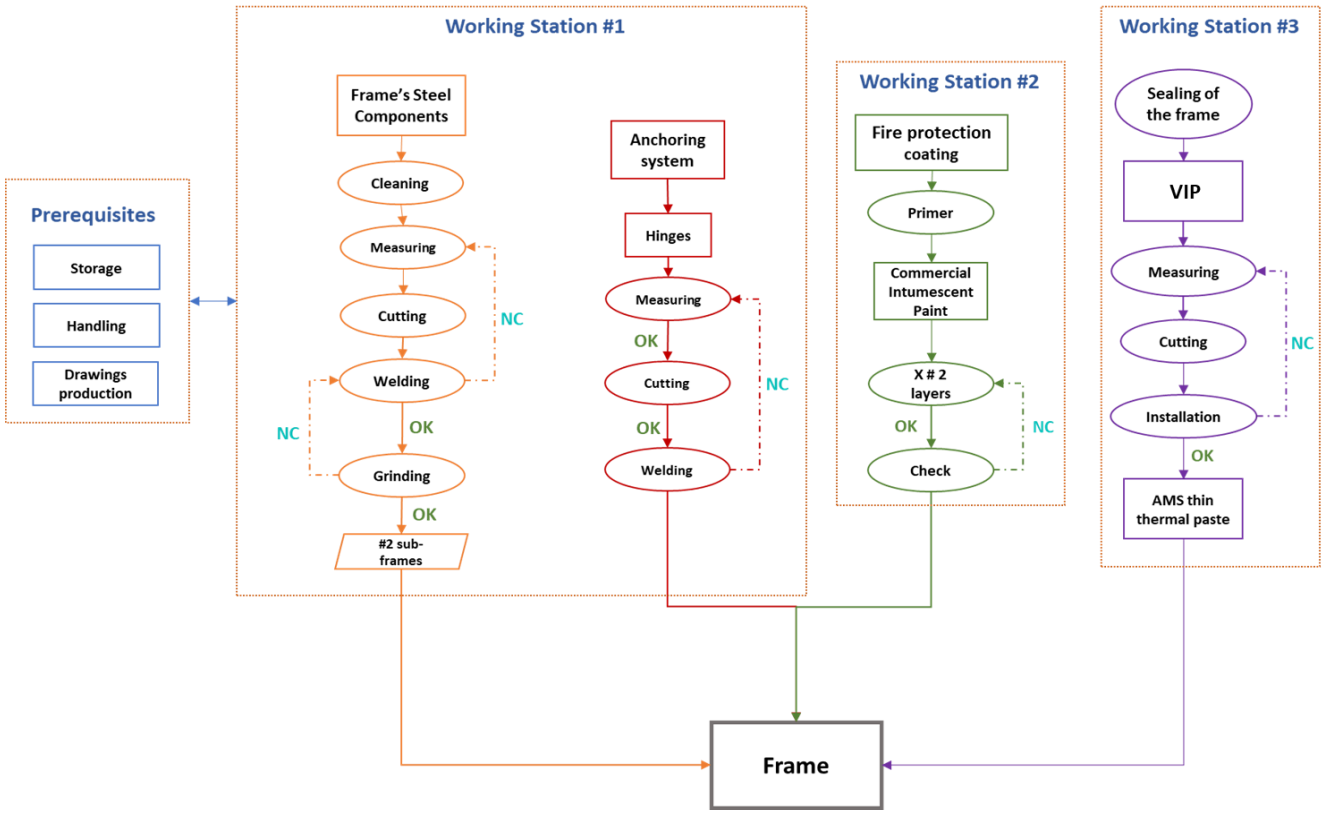


FIGURE 4: MANUFACTURING STAGE #1 STEPS PER WORKING STATION

Table 1 summarizes the designated procedures / steps / actions to be followed in each working station, while the remedial actions in case of failure will be extensively presented in *Deliverable D6.3 - Quality Assurance Plan – manufacturing / assembly.*

F.Q.P. *(per Manufacturing Stage)*	**Working Station**	**Actions**
Drawings inspection for mistakes & omissions	Prerequisites	a. Visual inspection of drawings to determine any drawing's omissions; b. CAD inspection to determine if drawings comply with requirements; c. CAD inspection to determine if dimensions are correct; d. CAD inspection to determine if auxiliary systems are complying with units to be produced; *e.* 3D CAD or BIM inspection to determine any discrepancies on design and/or components and/or materials.
Check availability of raw materials	Prerequisites	a. Check CAPEX system (storage software if any) in any for materials availability; b. Visual quantification of raw materials.
Raw materials quality check – handling – storage to the Working Stations	Prerequisites	a. Visual inspection to determine that the raw materials will be used would be of good quality, e.g., undamaged and without defects etc. b. Clean with appropriate means all materials to be used for manufacturing; c. Use appropriate handling equipment for their transportation to the designated working stations; d. Store them to the designated working stations as per manufacture instructions; *In case of failure at every point of the above follow instruction issued at the Remedial Action Plan as per Quality Assurance Plan*
Sub-frame members (cutting)	WS1	a. Prior any action rechecks members' dimensions on drawings and that are suitable for the purpose b. Use of the bench saw cutter as per H&S instructions c. Grind sharp and rough edges / surfaces as per Q.A.P. d. Drill heat breakers' holes as per drawings provided e. Grind any remaining steel chips on the drilled holes as per Q.A.P f. Check quality of the completed member as per Q.A.P.

Sub-frame members (welding)	WS1	a. Ensure welding edges are clear, clean and at the correct angles (45°) b. Use of MIG welding machine at the appropriate current and the welding wire complies with the specifications c. Use designated protective equipment as per H&S plan d. Grind remaining welding to ensure even surface as per Q.A.P e. Check quality of the completed sub-frame as per Q.A.P.
Auxiliary frame's members (anchoring system)	WS1	Same actions as per tasks *Sub-frame members – Cutting & Welding*
Coating application (primer & 2 layers of coating)	WS2	a. Use recommended means of sub-frame's transportation to the paint shop b. Ensure that surface is clear and clean. c. Ensure that coating's viscosity is as per manufacturer's specifications. Use of appropriate thinner if necessary. d. Ensure that air pressure at the air supply outlet is the recommended. e. Use air spraying gun for the application of the primer f. Use roll for the application of the intumescent paint g. Repeat actions a, b, c for each coating's layer application f. Check quality of the completed sub-frame prior application of each coating' layer as per Q.A.P.
Drying time among coating's layers application	WS2	a. Use recommended means of sub-frame's transportation from the paint shop to the drying area b. Ensure that drying area is free of dust c. Ensure that ventilation system in the drying area is fully operational d. Ensure applied coating's quality as per Q.A.P. prior moving sub-frame to next step e. Repeat tasks a, b, c & d for each layer of coating f. Use protective equipment as per H&S Plan
Heat breakers installation (interconnections among sub-frames)	WS3	a. Ensure sub-frames alignment b. Ensure proper fitting of the elastic pads to the sub-frame c. Tight the inserted bolts as per Q.A.P. d. Check bolts tightness with the aid of tensiometer e. Use protective equipment as per H&S Plan
Inspection	WS3	Follow inspection procedures as per Q.A.P. prior forwarding completed component to next manufacturing stage

TABLE 1 : MANUFACTURING TASKS. FOR STAGE #1 – FRAME

- Working Station WS1

Manufacturing Step: #1
Step Description: Steel frame manufacturing *(Figure 5)*
Tasks' description: As per *Table 1*

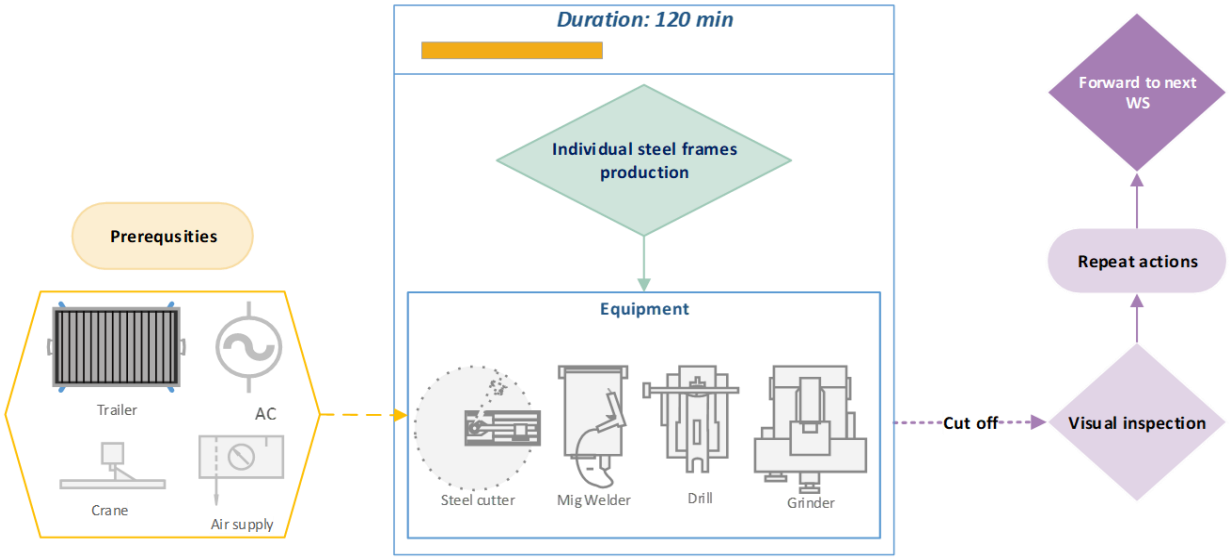


FIGURE 5: WS1 - SCHEMATIC FLOW CHART

Equipment: Steel cutting machine
Bench drilling machine
Mig welder
Portable steel grinder

Auxiliary equipment: Plant's crane
Carrying trailer
Hand tools
Sandpapers
Cleaning material – solvents, detergents etc.

Estimated task duration: 120 minutes (for #2 subframes of the generic type SmartWall systems L 1,200 x H 2,400 x W 170 mm)

Storage: At designated areas at the plant
Energy required Power supply 240V & 400V
Inspection / "cut off" points: Prior forwarding to next WS
Possible failures / risks: As per Q.A.P.

- Working Station WS2

Manufacturing Step: #2
Step Description: Frame's fire protection *(Figure 6)*
Tasks' description: As per *Table 1*

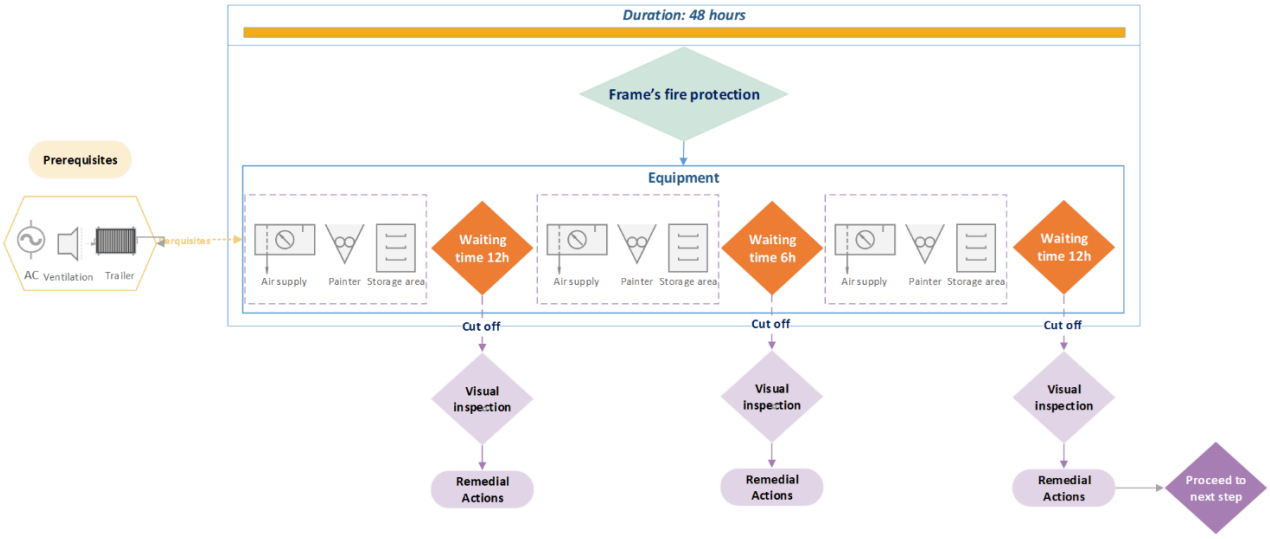


FIGURE 6: WS2 - SCHEMATIC FLOW CHART

Equipment: Air brush painter
Auxiliary equipment: Carrying trailer
Ventilation system
Hand tools
Paint brushes and rollers
Cleaning material – solvents, detergents etc.
Estimated task duration: 24 hours (for #2 sub-frames of the generic type SmartWall systems L 1,200 x H 2,400 x W 170 mm)) due to drying time
Storage: At designated areas at the plant
Energy required Power supply 240V
Inspection / "cut off" points: After each coating's layer application & prior forwarding to next WS
Possible failures / risks: As per Q.A.P.

- Working Station #3

Manufacturing Step: #3
Step Description: Sub-frames combination *(Figure 7)*
Tasks' description: As per *Table 1*

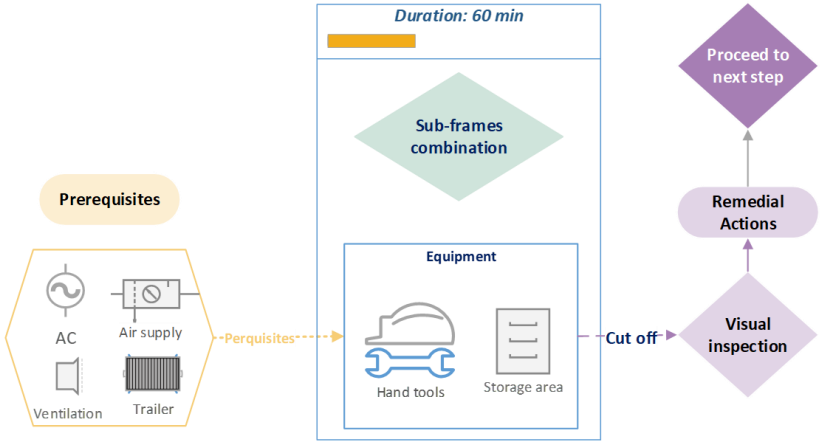


FIGURE 7: WS3 - SCHEMATIC FLOW CHART

Equipment:	Air powered screw/bolts driver Bolt's tensiometer
Auxiliary equipment:	Plant's crane Carrying trailer Air ventilation unit or vacuum unit Cleaning material – solvents, detergents etc.
Estimated task duration:	60 minutes (for #2 sub-frames of the generic type SmartWall systems L 1,200 x H 2,400 x W 170 mm)
Storage:	At designated areas at the plant
Energy required	Power supply 240V
Inspection / "cut off" points:	Prior forwarding to next WS
Possible failures / risks:	As per Q.A.P.

2.2.2 *Manufacturing Stage #2 (Components installation)*

Manufacturing Stage #2 is consisting by three (3) working stations (WS), as following (*Figure 8 & Table 2):*

- **WS4:** the external cladding is installed depending on customer's choice is cut on shape, firmly secured at the frame and prepared for the finishes application;
- **WS5:** is dealing with forming the openings, where the opening's sill and the opening's frame is attached at the frame and the ventilation units are secured on the frame of the opening (if any);
- **WS6:** is focused on the roller shutter installation at the SmartWall frame and its electrical connections (wiring only).

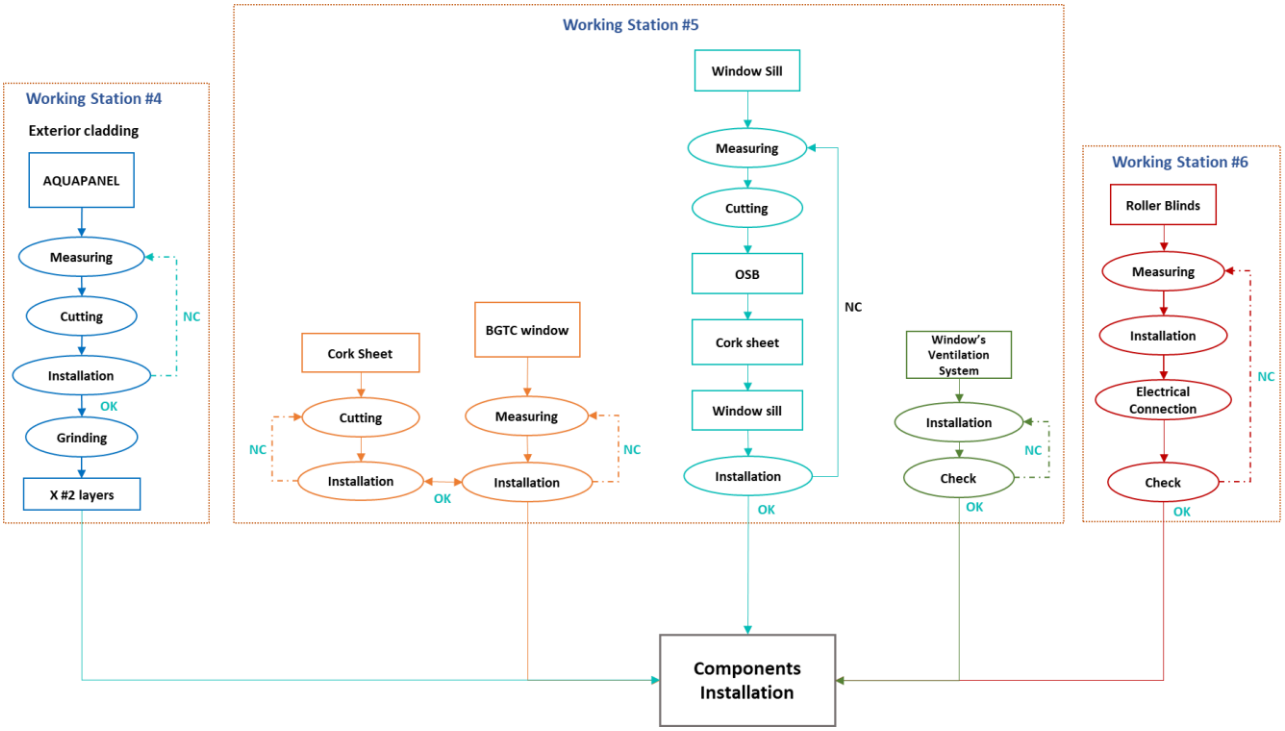


FIGURE 8: MANUFACTURING STAGE #2 STEPS PER WORKING STATION

F.Q.P. *(per Manufacturing Stage)*	Working Station	Actions
Check availability of raw materials	Prerequisites	As per *Table 1 "Check availability of raw materials"*
Raw materials quality check – handling – storage to the Working Stations	Prerequisites	As per *Table 1 "Raw materials quality check – handling – storage to the Working Stations"*
Exterior cladding installation* * *Cement-board installation* *Other type of exterior cladding materials requires alternative processes*	WS4	a. Prior any action re-check dimensions on drawings b. Use of the bench saw cutter as per H&S instructions to cut on shape both layers of the cladding material c. Install 1st layer cladding as per Q.A.P d. Ensure that securing bolts are firmly screwed e. Grind rough edges / surfaces as per Q.A.P. f. Install 2nd layer of cladding (if required) as per specifications. g. Grind rough edges of 2nd layer as per Q.A.P h. Install edge bead and firmly screw it on the panel. i. Apply putty on its edges as per specifications j. Check quality of the completed member as per Q.A.P. k. Use designated protective equipment as per H&S plan

Window's sill pre-installation* ** Marble sill installation* *Other type of sill materials requires alternative processes*	WS5	a. Ensure that both panel sub-frames are aligned and levelled b. Measure sill's support frame to match with dimensions on drawings. dimensions are c. Cut on size with the use of a circular saw the OSB panel on the dimensions required d. Smoothen OSB edges with a grinder and fix it with screws on the panel's sub-frames as per Q.A.P e. Cut on size with a cutter the insulation cork and attach it on the OSB panel. f. Secure it with nail stripes as per Q.A.P g. Apply on cork's surface the epoxy resin glue h. Use designated protective equipment as per H&S plan
Window's sill installation* ** Marble sill installation* *Other type of sill materials requires alternative processes*	WS5	a. Prior any action re-check dimensions on drawings b. Check sill's water –groove as per Q.A.P. c. Cut on size with a circular saw as per Q.A.P. d. Align sill on its supporting frame e. Secure screw with clumps on its frame as per Q.A.P f. Wait for 15 minutes the epoxy resin glue to fully dry and remove clamps g. Apply sealant mastic to the sill and frame edges as per Q.A.P. h. Use designated protective equipment as per H&S plan
Window's installation	WS5	a. Check window frame for defects as per Q.A.P b. Install cladding material to the interior limbs of the opening as per task *"1st cladding installation"* c. Align window's frame to the designated opening's position d. Secure it with screws as per Q.A.P e. Install screws coverings f. Attach window to its turning-tilting mechanism g. Seal with mastic sealant both sides of the frame h. Perform quality checks as per Q.A.P i. Use designated protective equipment as per H&S plan
Window's ventilation system installation	WS5	a. Check ventilation gaps on window's frame for blockages or misalignment b. Attach top and bottom ventilation covers c. Follow quality tests as per Q.A.P. d. Use protective equipment as per H&S Plan

Roller blinds installation	WS6	a. Install wiring as per Q.A.P b. Secure wiring tubs as per Q.A.P c. Ensure roller's blinds box alignment to the window d. Secure roller's blind box with the appropriate screws as per Q.A.P. e. Install side brackets on the internal limbs of the window frame f. Ensure proper alignment of roller blinds brackets g. Seal with mastic sealant around roller's blinds box h. Use protective equipment as per H&S Plan
Inspection	WS6	Follow inspection procedures as per Q.A.P. prior forwarding completed component to next manufacturing stage

TABLE 2: MANUFACTURING TASKS. FOR STAGE #2 – COMPONENTS INSTALLATION

- Working Station #4

Manufacturing Step: #4
Step Description: 1st cladding installation *(Figure 9)*
Tasks' description: As per *Table 2*

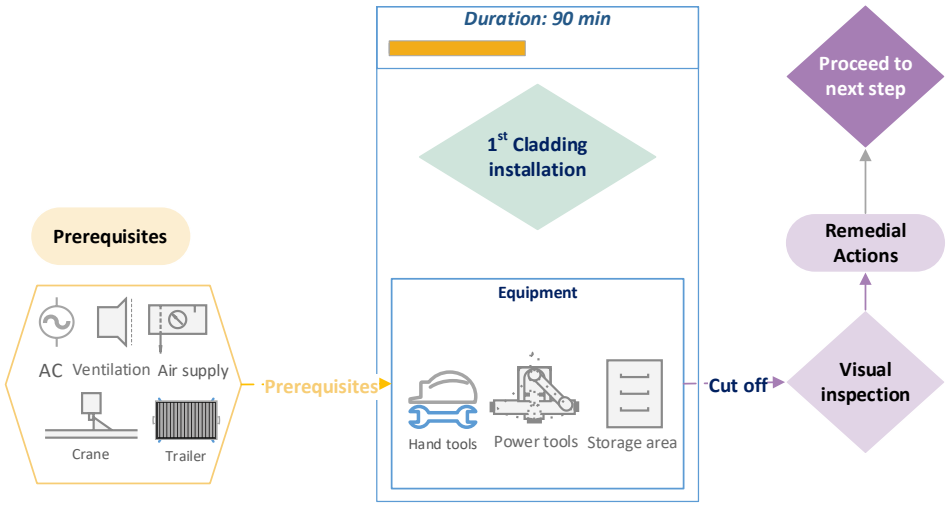


FIGURE 9: WS4 - SCHEMATIC FLOW CHART

Equipment: Air powered screw/bolts driver
Portable grinder
Cutters
Sandpapers

Auxiliary equipment: Plant's crane
Air ventilation unit or vacuum unit
Carrying trailer
Cleaning material – solvents, detergents etc.
Estimated task duration: 90 minutes (for generic type SmartWall systems frame L 1,200 x H 2,400 x W 170 mm)
Storage: At designated areas at the plant
Energy required Power supply 240V & 400V
Inspection / "cut off" points: Prior forwarding to next WS
Possible failures / risks: As per Q.A.P.

- Working Station #5

Manufacturing Step: #5
Step Description: Frame's openings treatment *(Figure 10)*
Tasks' description: As per *Table 2*

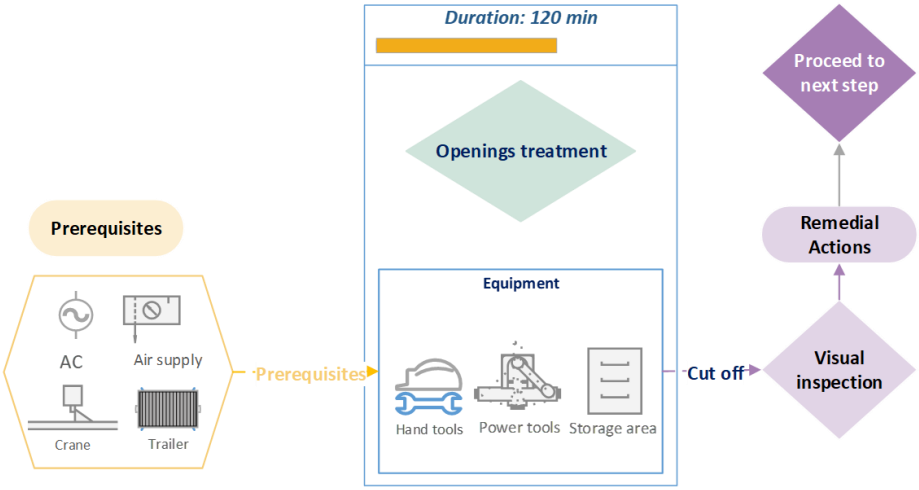


FIGURE 10: WS5 - SCHEMATIC FLOW CHART

Equipment: Air powered screw/bolts driver
Various hand tools
Auxiliary equipment: Plant's crane
Carrying trailer
Cleaning material – solvents, detergents etc.
Estimated task duration: 120 minutes (for generic type SmartWall systems frame L 1,200 x H 2,400 x W 170 mm)

Storage: At designated areas at the plant
Energy required Power supply 240V & 400V
Inspection / "cut off" points: Prior forwarding to next WS
Possible failures / risks: As per Q.A.P.

- Working Station #6

Manufacturing Step: #6
Step Description: Roller shutter installation *(Figure 11)*
Tasks' description: As per *Table 2*

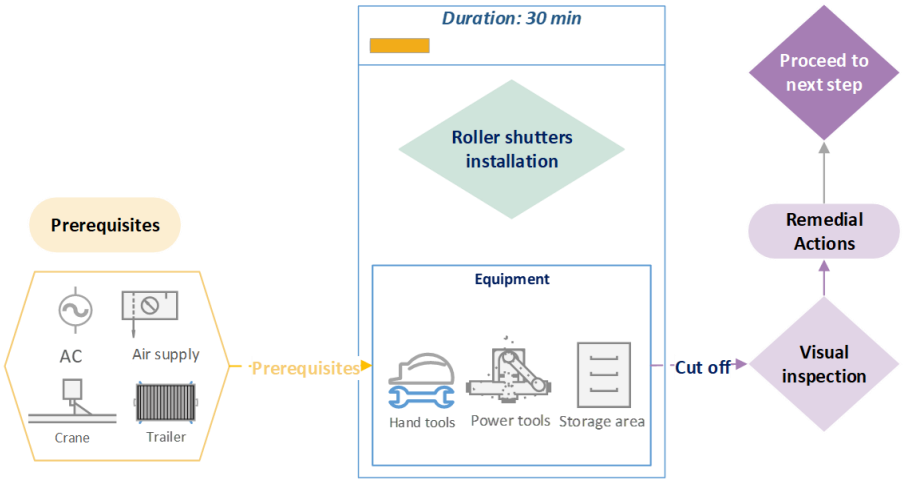


FIGURE 11: WS6 - SCHEMATIC FLOW CHART

Equipment: Air powered screw/bolts driver
Various hand tools
Auxiliary equipment: Plant's crane
Carrying trailer
Cleaning material – solvents, detergents etc.
Estimated task duration: 30 minutes (for generic type SmartWall systems frame L 1,200 x H 2,400 x W 170 mm)
Storage: At designated areas at the plant
Energy required Power supply 240V & 400V
Inspection / "cut off" points: Prior forwarding to next WS
Possible failures / risks: As per Q.A.P.

2.2.3 *Manufacturing Stage #3 (Insulators installation)*

Manufacturing Stage #3 is consisting by one (1) working station (WS), as following (*Figure 12 & Table 3):*

- **WS7:** the designated insulators are installed depending on customer's choice is cut on shape and secured at the panel

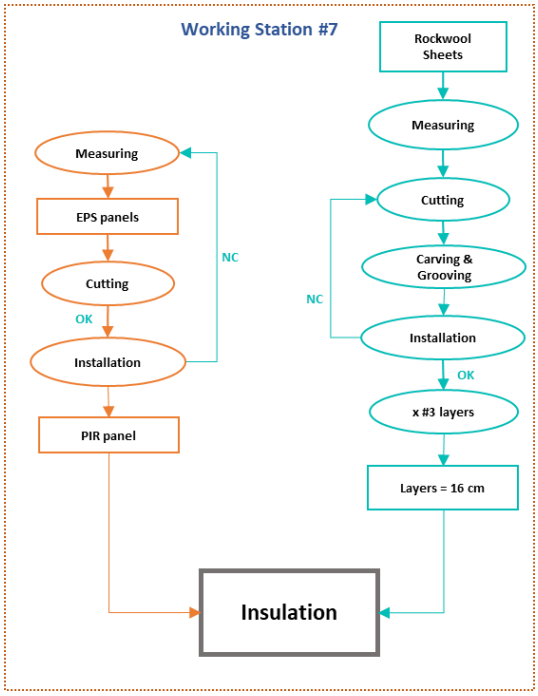


FIGURE 12: MANUFACTURING STAGE #3 STEPS PER WORKING STATION

F.Q.P. *(per Manufacturing Stage)*	Working Station	Actions
Check availability of raw materials	Prerequisites	As per *Table 1 "Check availability of raw materials"*
Raw materials quality check – handling – storage to the Working Stations	Prerequisites	As per *Table 1 "Raw materials quality check – handling – storage to the Working Stations"*
Fan-coil's insulator installation* * *VIP or EPS installation*	WS7	a. Prior any action re-check dimensions on drawings b. Install VIP panels beyond fan-coil location as per Q.A.P **or** c. Cut off with a cutter knife or with a thermal wire the EPS panels at the appropriate dimensions and install them beyond the fan coil location d. Secure them with brackets as per Q.A.P.

Rockwool installation (main insulator)	WS7	a. Follow steps as per previous task "fan coil insulator installation" b. Repeat them for each insulator's layer required as per Q.A.P. c. Use designated protective equipment as per H&S
Inspection	WS7	Follow inspection procedures as per Q.A.P. prior forwarding completed component to next manufacturing stage

TABLE 3: MANUFACTURING TASKS. FOR STAGE #3 – INSULATORS INSTALLATION

- Working Station #7

Manufacturing Step: #7
Step Description: Insulator installation *(Figure 13)*
Tasks' description: As per *Table 3*

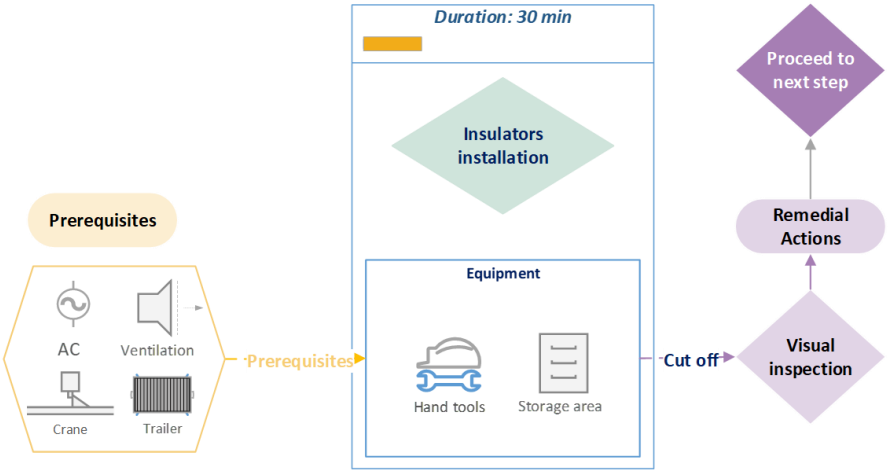


FIGURE 13: WS7 - SCHEMATIC FLOW CHART

Equipment: Various hand tools
Auxiliary equipment: Plant's crane
Carrying trailer
Ventilation

Estimated task duration:	30 minutes (for generic type SmartWall systems frame L 1,200 x H 2,400 x W 170 mm)
Storage:	At designated areas at the plant
Energy required	Power supply 240V & 400V
Inspection / "cut off" points:	Prior forwarding to next WS
Possible failures / risks:	As per Q.A.P.

2.2.4 *Manufacturing Stage #4 (E/M components installation)*

Manufacturing Stage #4 is consisting by two (2) working stations (WS), as following (*Figure 14 & Table 4):*

- **WS8:** is dealing with all necessary tasks related to the fan-coil installation at its position, its piping connections at the main tubes and with the installation of the fan-coil's access panel;
- **WS9:** the main control box is installed and the PV panel's frame, as well as the tubing and wiring for the electrical components, the external plugs, and switches and finally all the necessary sensors are installed on the appropriate locations at the SmartWall panel.

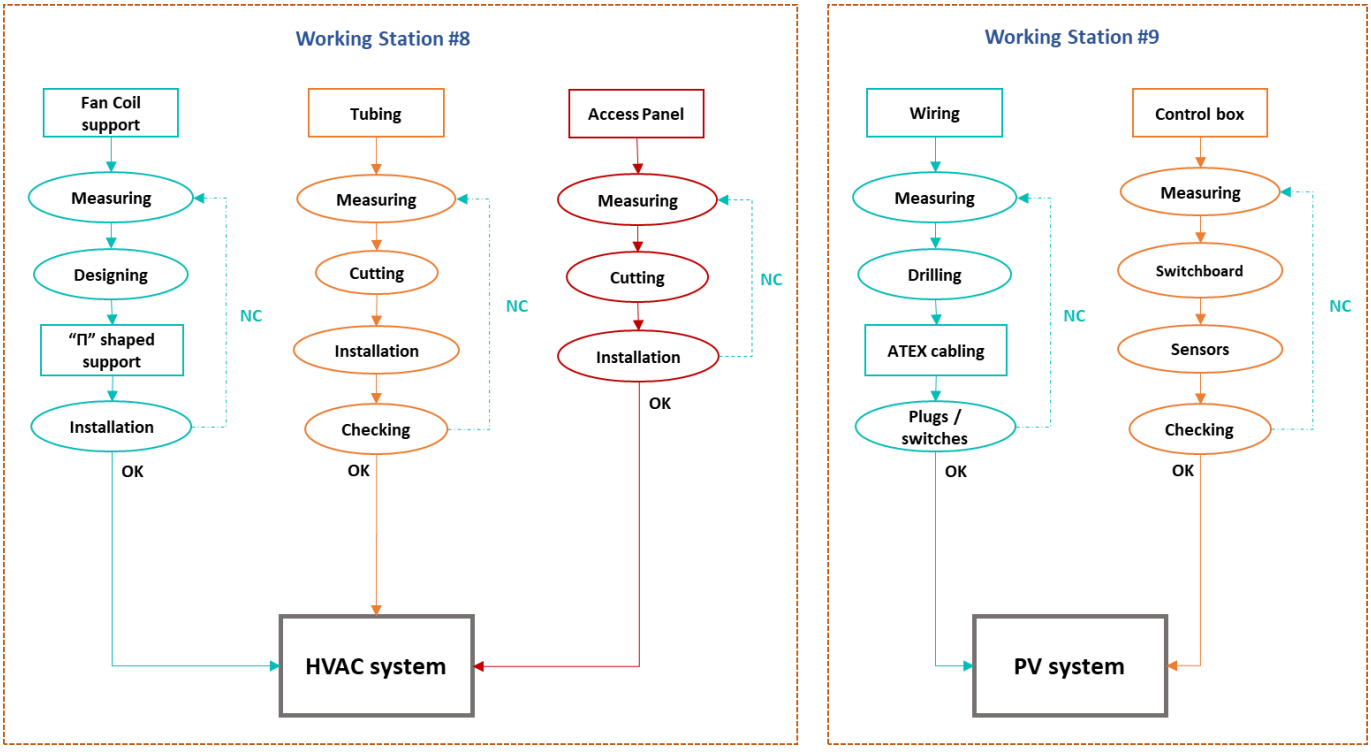


FIGURE 14: MANUFACTURING STAGE #4 STEPS PER WORKING STATION

F.Q.P. *(per Manufacturing Stage)*	Working Station	Actions
Check availability of raw materials	Prerequisites	As per *Table 1 "Check availability of raw materials"*
Raw materials quality check – handling – storage to the Working Stations	Prerequisites	As per *Table 1 "Raw materials quality check – handling – storage to the Working Stations"*
Fan-coil positioning	WS8	a. Inspect fan-coil's installation brackets for any defects b. Measure correct distance among anchoring holes of the fan-coil's supporting brackets and ensure accurate fitting with the Π shape support of the frame c. Drill holes on the Π shape of the frame as per Q.A.P requirements d. Install anti-vibration pads on the fan-coil's brackets e. Secure fan-coil with the appropriate screws to its supporting frame them with brackets as per Q.A.P. f. Use designated protective equipment as per H&S plan
Fan-coil piping & tubing	WS8	a. Install valves on the inlet and outlet of the fan-coil piping system as per Q.A.P requirements b. Ensure correct fitting of valves on the fan-coil c. Connect the flexible pipes to both inlet and outlet piping system including the push-lock fittings as per Q.A.P d. Install drainage pipe to the fan-coil's drainage tank, install push-lock fitting to it e. Ensure correct fitting of drainage pipe as per Q.A.P. f. Use designated protective equipment as per H&S plan
Fan-coil's access panel installation	WS8	a. Ensure panel's frame is suitable to provide access to the fan-coil installation; measure; check drawings b. Align access panel frame with the panel's sub-frame c. Level access panel's frame as per Q.A.P requirements d. Use self-drilling screws to secure panel frame to main panel as per Q.A.P requirements e. Install self-locking mechanism to the access panel frame as per Q.A.P. f. Install covering to the access panel as per task WS4 1st cladding installation g. Use designated protective equipment as per H&S plan h. Check for proper installation prior moving to next working station

PV panel installation* * *If is attached on the external frame of SmartWall*	WS9	a. Inspect PV panel's frame for any defects b. Measure correct distance among anchoring holes of the PV panel's frame supporting brackets and ensure accurate fitting to its designated interior support of SmartWall panel c. Drill holes to the PV panel's frame as per Q.A.P d. Secure PV panel frame to SmartWall panel's frame with self-drilling screws as per Q.A.P e. Install PV panel's frame brackets (supporting the PV panel itself) f. Use designated protective equipment as per H&S plan
Main control box installation	WS9	a. Inspect main control box for any defects b. Measure dimensions: ensure that all components can be installed into it as per Q.A.P requirements c. Ensure correct application of fire-protection coating by WS1 tasks d. Align and level it at the SmartWall frame e. Use self-drilling screws to secure it at the SmartWall frame as per Q.A.P. f. Drill appropriate size holes for wiring connections g. Install ATEX protective fittings to the connections' holes as per Q.A.P. h. Ensure control box covering's firmly installation i. Use designated protective equipment as per H&S plan
Wiring	WS9	a. Inspect tubing & wiring for any defects b. Measure dimensions; cut on size required c. Installation of ATEX tubing d. Installation of wires within ATEX tubing e. Installation of ATEX protective fittings to the connection boxes f. Check for short-circuits or connections breakage as per Q.A.P g. Use designated protective equipment as per H&S plan
Sensor' installation	WS9	a. Installation of thermal sensor to the fan-coil b. Installation of smoke detector to the control box c. Installation of thermal sensor to the control box d. Drill holes for the installation of BlazeCut system in the control box e. Check for short-circuits or connections breakage as per Q.A.P f. Use designated protective equipment as per H&S plan
Inspection	WS9	Follow inspection procedures as per Q.A.P. prior forwarding completed component to next manufacturing stage

TABLE 4: MANUFACTURING TASKS. FOR STAGE #4 – E/M COMPONENTS INSTALLATION

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

Working Station #8

Manufacturing Step: #8
Step Description: HVAC systems installation *(Figure 15)*
Tasks' description: As per *Table 4*

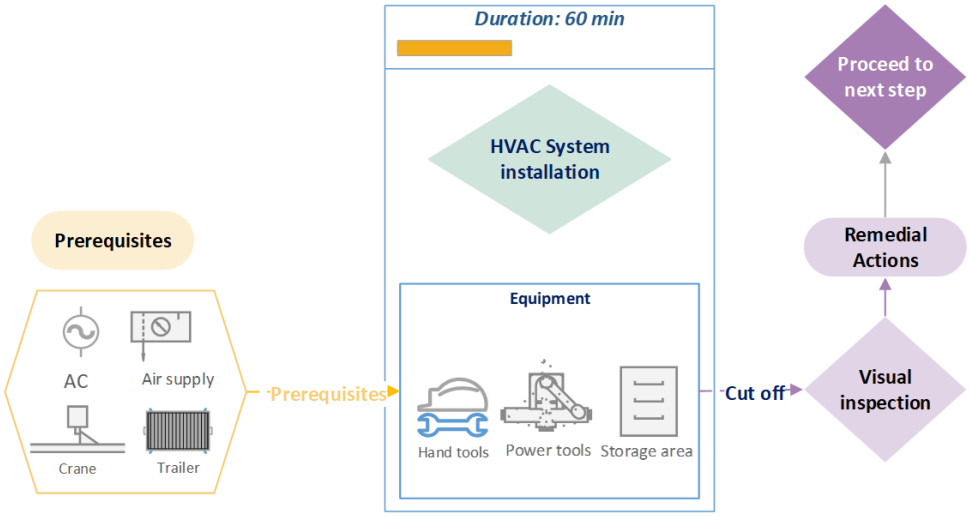


FIGURE 15: WS8 - SCHEMATIC FLOW CHART

Equipment: Various hand tools
Power tools
Auxiliary equipment: Plant's crane
Carrying trailer
Estimated task duration: 60 minutes
Storage: At designated areas at the plant
Energy required Power supply 240V & 400V
Inspection / "cut off" points: Prior forwarding to next WS
Possible failures / risks: As per Q.A.P.

- Working Station #9

Manufacturing Step: #9
Step Description: PV panels system installation *(Figure 16)*
Tasks' description: As per *Table 4*

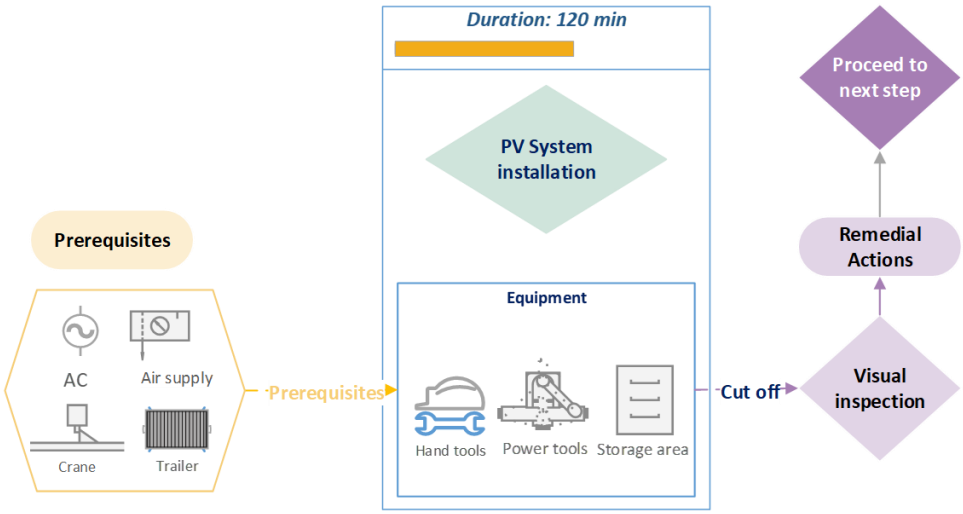


FIGURE 16: WS9 - SCHEMATIC FLOW CHART

Equipment:	Various hand tools Power tools
Auxiliary equipment:	Plant's crane Carrying trailer
Estimated task duration:	120 minutes
Storage:	At designated areas at the plant
Energy required	Power supply 240V & 400V
Inspection / "cut off" points:	Prior forwarding to next WS
Possible failures / risks:	As per Q.A.P.

2.2.5 *Manufacturing Stage #5 (Finishes installation)*

Manufacturing Stage #5 is consisting by one (1) working station (WS), as following (*Figure 17 & Table 5):*

- **WS10:** is finalizing SmartWall's manufacturing performing all actions to ensure its aesthetical and operational sustainability. It is the most complex WS therefore, is divided in several tasks:
  a. E/M components tasks;
  b. Testing and
  c. Remedial actions tasks.

Once completed SmartWall panels would be ready for packaging and storage at the designated areas of the manufacturing plant or transferred to the installation site.

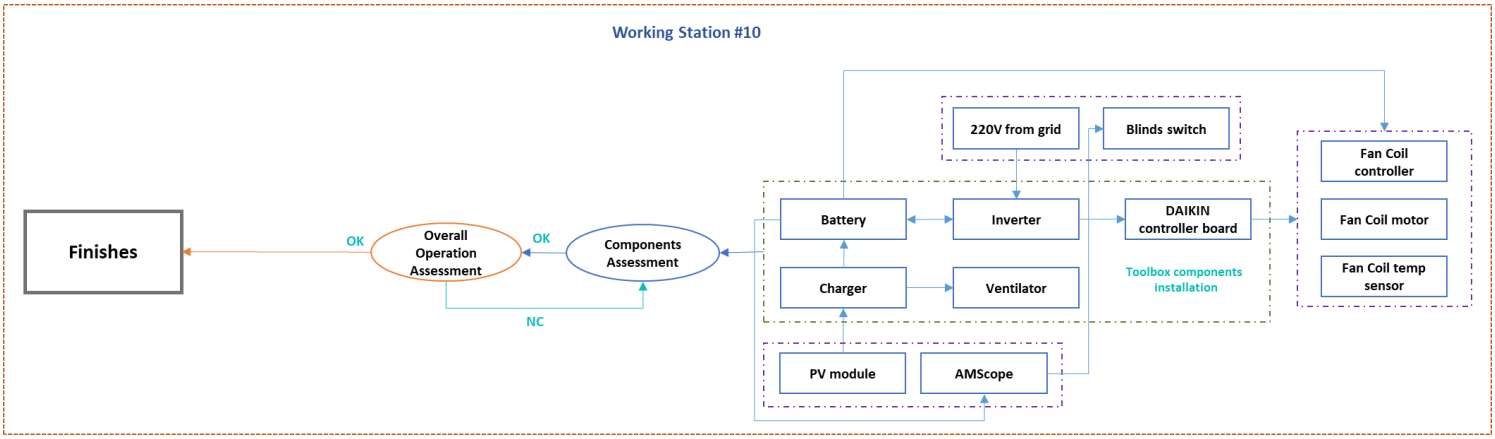


FIGURE 17: MANUFACTURING STAGE #5 STEPS PER WORKING STATION

F.Q.P. *(per Manufacturing Stage)*	Working Station	Actions
Check availability of raw materials	Prerequisites	As per *Table 1 "Check availability of raw materials"*
Raw materials quality check – handling – storage to the Working Stations	Prerequisites	As per *Table 1 "Raw materials quality check – handling – storage to the Working Stations"*
Electrical components installation completion	WS10	a. Installation of PV inverter, charger and battery as per Q.A.P requirements at the designated locations within control box. b. Installation of fan-coil's controller in the designated location within control box c. Installation of AMscope in the external side of SmartWall panel d. Use designated protective equipment as per H&S plan
Electrical Installation completion	WS10	a. Installation and wiring of the switchboard in the control box as per Q.A.P b. Installation and wiring of all external electrical components e.g. socket plugs, switches etc. c. Installation of PV panels electricity connectors d. Use designated protective equipment as per H&S plan
Mechanical components installation	WS10	a. Installation of BlazeCut fire suspension system b. Installation of blind rollers end stops c. Installation of blind rollers mechanical (auxiliary in case of power failure) system

Visual tests	WS10	*AS PER Q.A.P* a. Surface observation / defects on paint, cracks, flakes etc. identification b. Sealant check defects on windows, sealant, sills, edges, bead c. Gas pressure on fire suspension system.
Mechanical tests	WS10	*AS PER Q.A.P* a. Anchoring system (bottom and top hinges of the frame) b. Power outlet's condition e.g. firmly secured on the board, loose screws, etc. c. PV panel mounting rail to be firmly secured on the frame d. Window's frame to be securely attached on the frame e. Window operation (open / close / tilt) f. Window's hinges g. Blinds mechanical (without power supply) operation h. Access panel locking system / unlocking system i. AMscope casing to be firmly attached on the frame j. Toolbox cover to be firmly secured on its casing k. Leakages on the fan-coil pipework l. Battery to be secured in the toolbox
Electrical tests	WS10	*AS PER Q.A.P* a. Power inlet / outlet's voltage & current b. Fan-coil voltage & current c. Fan-coil control panel operation d. PV panels voltage & current e. Inverter operation f. Charger operation g. Battery voltage & current h. AMscope operation i. Electrical operation of the roller blinds j. Circuit breakers testing k. Grounding testing l. Emergency cut-off mode

TABLE 5: MANUFACTURING TASKS. FOR STAGE #5 – FINISHES INSTALLATION

- Working Station #10

Manufacturing Step: #10
Step Description: Finishes installation *(Figure 18)*
Tasks' description: As per *Table 5*
Equipment: Various hand tools
Power tools

Auxiliary equipment:	Plant's crane Carrying trailer Ventilation Testing equipment
Estimated task duration:	240 minutes
Storage:	At designated areas at the plant
Energy required	Power supply 240V & 400V
Inspection / "cut off" points:	Prior forwarding to packaging
Possible failures / risks:	As per Q.A.P.

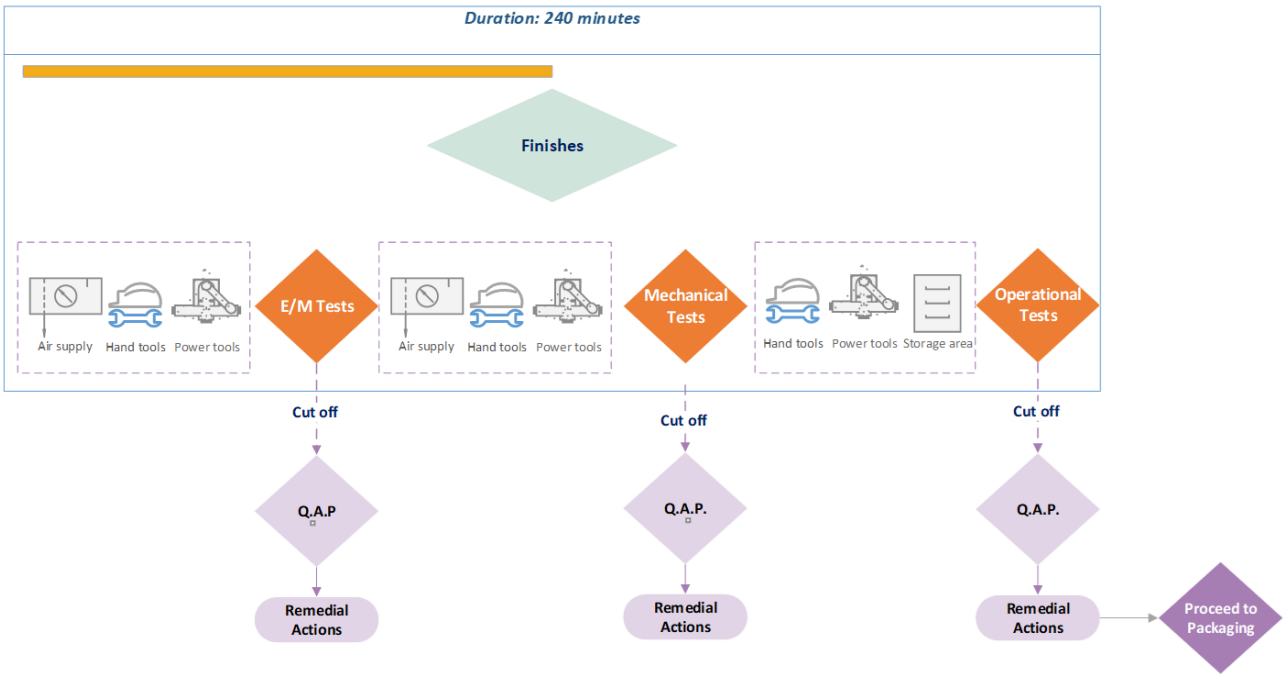


FIGURE 18: WS10 - SCHEMATIC FLOW CHART

2.3 PERT diagram

From the data evaluation extracted from the previous section it becomes obvious that when the "*100% inspection Method*" is applied during the manufacturing process, it is very difficult to identify the critical activities related to the PERT chart of the manufacturing process flow (*Figure 19*).

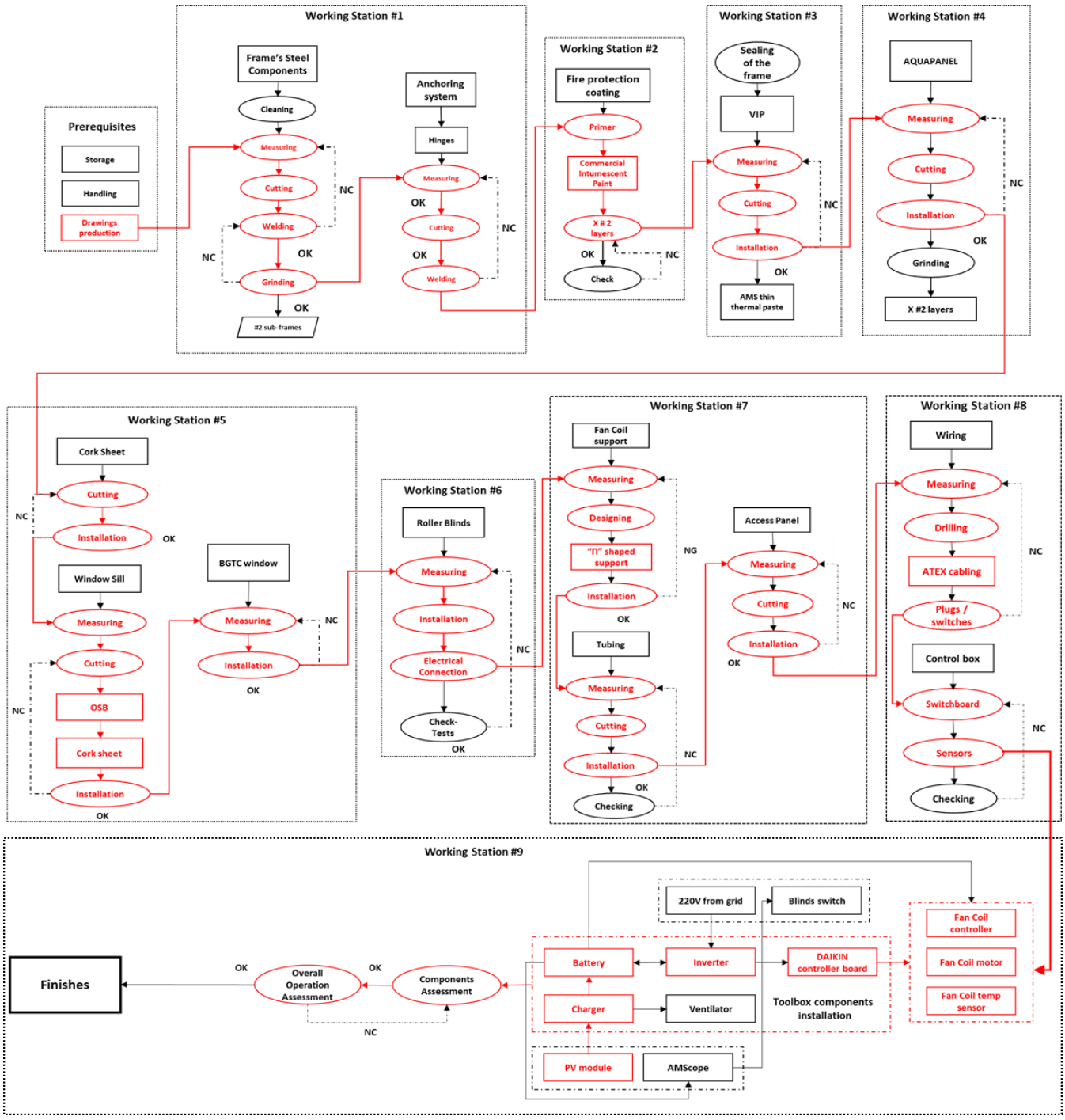


FIGURE 19: SMARTWALL PERT DIAGRAM & CRITICAL ACTIVITIES

The main reason is that the loops occurring among the steps where the "*100% inspection Method*" is applied are by their nature critical and any loop back action constitutes their entire predecessor critical to the overall process.

This condition is clearly illustrated in *Figure 19* where:

- If **no** *loop back* actions will occur during manufacturing (supposing that everything goes as per manufacturing standards) then the critical path activities are illustrated in Figure 19 with the red line reassuring the claim as described in the previous paragraphs that SmartWall production is one-time-product manufacturing process where the majority of the production tasks are considered to be critical;
- If *look back* actions **do exist,** then due to the delays in the production schema occurring **ALL** activities are considered as critical.

This is the main reason why the exact time duration prediction for each task at every working station is hard to be calculated and predicted. However, as the overall manufacturing is labour based, it is subject to good personnel training and familiarisation to the manufacturing processes to avoid loop back actions without compromising the final quality of the products.

Further details and the designated remedial actions related to the looping back actions for each WS will be extensively presented in *Deliverable D6.3 - Quality Assurance Plan – manufacturing / assembly*.

2.4 Production Plan scenarios

As described in the previous paragraph "PERT diagram, due to the nature of the production methodology it is extremely difficult to predict and develop a realistic production plan in a product that has never been manufactured in the past and several technical issues might be uncertain. Additionally, the fact that global shortages, especially in raw materials and electronic components and equipment, are more often noticeable in the local markets are leading manufacturing to develop three different Production Plan scenarios as illustrated in *Table 6* and *Figure 20*:

	Week 6	Week 7	Week 8	Week 9	Week10	Week 11	Week 12	Week 13
Planned Production	1.00	2.00	**Trial & Error**		3.00	4.00	4.00	4.00
Back-up Plan	-	-	1.00	2.00	**Trial & Error**		2.00	2.00
Delayed Start (+30 Days)	-	-	-	-	2.00	2.00	**Trial & Error**	
	Week 14	**Week 15**	**Week 16**	**Week 17**	**Week 18**	**Week 19**	**Week 20**	**Week 21**

Planned Production	4.00	4.00	4.00	4.00	-	-	-	-
Back-up Plan	2.00	3.00	4.00	4.00	4.00	4.00	4.00	2.00
Delayed Start (+30 Days)	2.00	4.00	4.00	4.00	4.00	4.00	4.00	4.00

TABLE 6 : PRODUCTION PLAN SCENARIOS

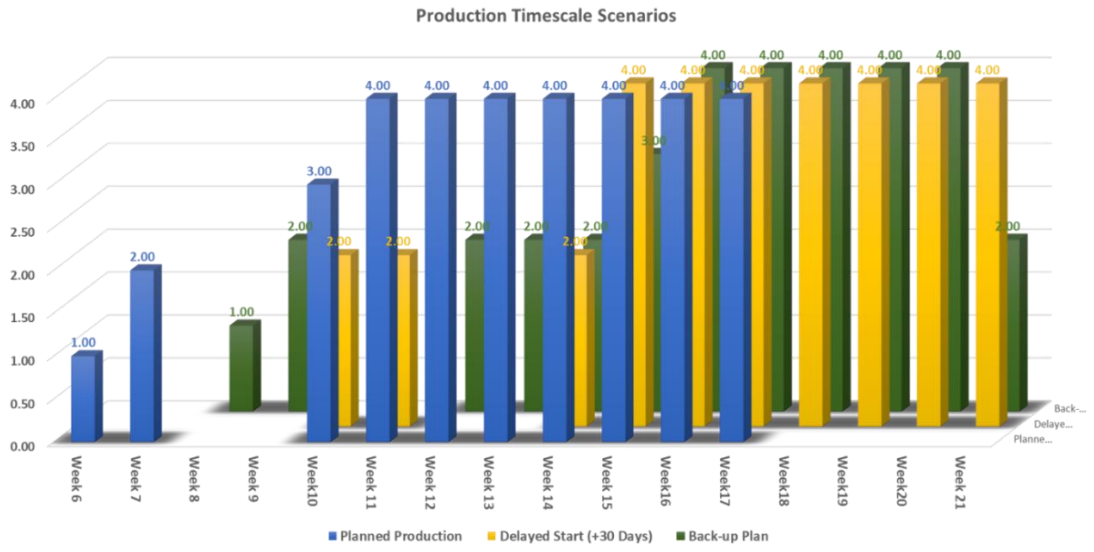


FIGURE 20: ILLUSTRATION OF PRODUCTION PLAN SCENARIOS

2.4.1 *Planned production*

This scenario assumes that everything will be executed as planned by the manufacturing team and raw materials will be available in the manufacturer's plant.

It starts on week 6/2023 (01.02.2023) and is completed on week 17/2023 (21.04.2023).

During the two first weeks (6/2023 & 7/2023) a limited number of panels will be produced, three (3) in total to identify mistakes, omissions, discrepancies, and technical details that might require further or specific treatment. A pause in the production, called as "*trial & error period*", will follow at the next two weeks (8/2023 & 9/2023) to apply any modifications on the production line and adjust technical issues might have been noticed within the two first weeks of the production.

The actual production will follow by week 10/2023 (27.02.2023). Taking into consideration the manufacturing capacity of the plant (in conjunction with its daily operation to produce its official products) is expected to produce four (4) SmartWall panels every week.

Based on the assumption that delivery date of the produced SmartWall panels on site, is inelastic due to scheduled installation tasks (week 24/2023), the transportation to Voula demo building of the produced SmartWall panels is scheduled between weeks 20/2023 to 22/2023 (08.05.2023 – 26.05.2023). This scheduling allows a time buffer of 2 weeks between end of production and transportation, which might be useful in case minor delays in normal production weeks will occur.

2.4.2 *Back-up plan*

This scenario is taking into consideration:

- Minor delays (two weeks) on purchasing raw materials, and/or
- Difficulties to adopt modifications, omissions, adjustment on the production line, and/or
- Difficulties on personnel familiarization with manufacturing techniques of SmartWall systems, and/or
- Inability of the manufacturing plant to proceed on initially scheduled time to the production of SmartWall panels due to delays on its ongoing production of its official products.

Additionally, this scenario also takes into consideration that the delivery date of SmartWall panels to Voula demo building is inelastic, therefore same transportation dates apply, as mentioned on the above, between weeks 22/2023 to 23/2023 (22.05.2023 – 02.06.2023).

According to this scenario, production starts at week 8/2023 (13.02.2023) adopting the same philosophy as on "*Planned Production*" scenario regarding the limited production on the beginning and the "*trial & error period*".

Furthermore, illustrates the difficulty of both personnel and production line to adopt either the modifications occurred by the "trial & error period" or the production techniques with limited production per weeks 12, 13, 14 & 15/2023, while fully capacity production starts in week 16/2023 (10.04.2023) and ends at week 21/2023 (20.05.2023).

2.4.3 *Delayed Start (+30 Days)*

Assuming that:

- There is a 30-day delay on delivery of raw materials due to the global shortages, and/or
- Minor difficulties to adopt modifications, omissions, adjustment on the production line, and/or
- Minor difficulties on personnel familiarization with manufacturing techniques of SmartWall systems, and
- Same conditions as in previous two scenarios regarding the delivery date of the panels in Voula's demo sit,

Limited scale production starts at week 10/2023 (27.02.2023) adopting the same philosophy related to "trial & error period" as in previous two scenarios, while the normal production commences on week 15/2023 (03.03.2023) and completed by the end of week 21/2023 (20.05.2023).

2.4.4 *Alternative Plans*

Any other delay might occur during production phase and has not been foreseen by the aforementioned scenarios will be confronted depending on its severity and impact to the ongoing production schedule at the time will occur. Some of the actions to confront possible delays are among other:

- Increase manpower for the production of the official products of the manufacturer;
- Increase manpower to be trained to SmartWall production acting as reserve personnel for future use, if needed;
- Place standing orders for materials purchasing with the option to be cancelled in case that will not be needed;
- Extent working swifts (either for the official products production or SmartWall systems);
- Extent working days (weekend work) either for the official products production or SmartWall systems);

Though, it must noticed that the mentioned on the above actions are only indicative and not all of them are applicable to all conditions might occur. The actions will be selected to remedy production in case of delays would be subject of the nature of delay, its severity and related cost.

2.5 AMS's Health & Safety Plan

The following paragraphs are briefly describing AMS's Health & Safety Plan (translated from the Greek language), as updated at 14.09.2022.

(The updated original AMS's Health & Safety Plan in Greek language (as per Greek Law 3850/2010 - O.G. A-84/ 2-06-2010 provisions) -has been uploaded in PLURAL's EMDESK portal EMDESK/Documents/07 Deliverable /WP6 _Manufacturing_DEN/D6.1/AMS_H&S_Plan)

2.5.1 *Traffic & Delivery Management*

Deliveries of materials will be organised to maximise the safety of all personnel.

The emergency services, e.g. fire appliances, ambulances, etc. will use the same access routes to the working areas. These routes, particularly the main access road, site operatives parking, and the main entrance to the site will be kept free from obstructions throughout the construction phase.

Production Manager will adhere to plant rules as follows:

- Traffic rules apply (No illegal parking, speed limit of 5 km/h)", and
- store materials as close to the working area as possible.

Materials will be ordered on a 'just in time' basis to minimise the amount of space needed on the plant.

Deliveries and collections will avoid peak times and therefore will be restricted to the hours of 10.00-15.00.

The crossing of the public roads in front of the plant and/or the parking spaces shall be visibly marked with road signs or markings. Workers should respect safety distances to any means of transportation vehicles. The roads must always be kept free, clean, secure against slipping, skidding.

Drivers are obliged to be aware and to observe the traffic speed limit, traffic signs and warning means inside the company's or on public roads. Personnel will not operate any vehicle without the necessary training and certification.

2.5.2 *Working at Height*

External works will include the blockwork, cladding, render, roof construction, installation of windows and rainwater goods etc. These works shall be performed from fixed scaffolding supplied and constructed by the designated contractor. When working from non-fixed systems the wind speed should be measured on a regular basis throughout the working day to ensure that systems are not being used outside of the limits set by the manufacturer. Any platform that you need to work off must be at least 600mm wide, which is 3 scaffold boards wide. Scaffold boards will need supporting by transoms or trestles at a minimum of 1200mm centres.

Internal works at a low level and so shall be performed utilising 'Hop Ups', aluminium towers or podium steps. If ladders or steps are required they are to be of Class One (Industrial) grade. Where works at higher levels are required the contractor will utilise mobile aluminium scaffolding towers constructed and certified trained operative. Where there is a significant risk of fall, a permit to work will be issued.

2.5.3 *Storage of Materials*

Inert materials such as blocks, timber and plasterboard will be stored at the general storage are of the plant and/or on-site. Hazardous materials such as chemical cleaners and petrol will be locked in the

designated area on plant and away from the common access area at the site, at the end of each working day.

Power tools will also be stored at the designated area at the plant and/or site at the end of each working day.

Materials will be located on the designated areas in the pant and/or the site and brought to the working area as required. Where practical the construction materials will be delivered directly to the working area to minimise the need for the manual handling of materials.

Materials will be stored in such a way that there is adequate working space to safely handle them manually or by machine. The storage of materials will be carefully controlled to ensure minimal risk to the work personnel, visitors and members of the public.

2.5.4 *Storage of Waste Materials*

Waste materials from the production process will be deposited in designated locations or in containers.

A licensed waste handler will manage the waste, and a record of waste transfer notes will be maintained on plant. Any hazardous waste will be marked as such and handled and disposed of in an appropriate manner.

2.5.5 *Manual Handling*

Whether the transport of materials to the work, care must be taken to minimize the inherent risks.

Deliveries shall be dropped as close to the working area as is possible and when there is a need to handle items long distance a suitable lifting aid (trolley etc.) should be used. Where manual handling cannot be avoided, heavy items shall be either broken down into smaller loads or handled as a group lift.

All risk assessments and method statements provided by the plant contractors must identify heavy items used and how they are to be handled.

Materials and equipment will generally be moved around the site to the place of work via, board carriers, pump trucks, pallet trucks or similar. Heavy items (structural steels) in the project area will be manoeuvred via the aid of genie lifts or similar.

2.5.6 *Live Services*

Before starting work any position at the plant all existing services shall be ascertained as far as possible, unless are necessary to work with them.

Extreme care will be taken, at all times, not to disturb any existing services. The Production Manager is to scrutinize all available plans along with the information provided by the Operating Companies responsible for their maintenance.

Any and all unidentified cables and pipes are to be treated as live until it is confirmed otherwise. If we are unsure at any time as to the location of any services, an investigation will take place to determine their whereabouts before the work commences using a cable detector. A qualified electrician will isolate and make safe any electrical works before commencing work. Telephone overhead cables are in close proximity, plant operators to be made aware.

2.5.7 *Use of and Contact with Power Tools*

The hazards are from contact with electrical conductors, contact with the revolving tools and power tools. The risk is high, and the operatives should be trained in the proper use of tools. The tools must be visually inspected before first use and receive a periodic test as required by the National Health and Safety Regulations.

Individual risk assessments contain information on exposure limits for vibrating tools such as drills and breakers. It is not anticipated that heavy duty vibration tools will be an issue on the plant, however, should any operatives suffer any form of numbness or pain associated with the use of vibrating tools they must take suitable breaks from use and the work activity should be shared.

2.5.8 *Control of Lifting Operations*

All plant and equipment brought onto the plant must be accompanied by all relevant certification and retained for the currency of the work operations.

Training certification for all equipment operators must also be produced and logged in the site appointed persons register. Lifting operations involving lifting equipment:

- Must be planned properly;
- Use people who are sufficiently competent;
- Supervised appropriately;
- Carried out in a safe manner

2.5.9 *Noise and Dust*

Noise Emissions generated as a result of the work shall be restricted to between 08.00hrs and 17.00hrs.

Works outside these hours are not permitted. In all cases, noise will be kept to a minimum with hearing protection used as deemed necessary in compliance with current regulations.

Personnel must continually assess the level of noise that operations are creating and implement measures that keep levels within acceptable limits, not only for workers on plant but for others who may be affected by the works. There will be a noise assessment detailing all tools found to be 85dB (A) and over available in the site health and safety folder.

Dust will be minimized by wetting down or extraction systems as applicable to the type of tool and activity being carried out where is permitted. Ventilations system should always be operational to minimize dust generation.

Good housekeeping principles will be followed and ensuring that no build up of waste materials/debris is allowed to occur. Appropriate respiratory protection will be available i.e., FFP2 & FFP3.

2.5.10 *Hot Works*

Without exception, all works that generate heat or sparks (abrasive cutting, welding, soldering) must be sanctioned by the Production Manager and/or the Safety Manager.

Additionally, fire extinguishers commensurate with the surrounding materials are provided in the designated areas. Production Manager and/or Safety Manager are to ensure the designated operative knows how the extinguisher works and what its limitations are.

2.5.11 *Spills*

All on plant water sources shall be regularly checked to ensure that they are not being left running and that they are not leaking.

Water sources shall be kept away from electrical systems when they are fitted on the plant and any spillages shall be cleaned up as soon as they are noted/generated. Spill kits will be made available in the plant and on-site to deal with any accidental spillage of chemicals.

2.5.12 *Exposure to UV Radiation*

The plant rules ‘Long trousers and shirt to be worn at all times’ will be enforced for the duration of working in it.

Workers will be advised of the dangers and health risks of working in the sun at induction via the Safety Manager. Personnel affected by sunscreen exposure to UV radiation (from the sun) will be advised to provide creams/lotions to their workforce with a sun protection factor (SPF) rating of 15 or more.

2.6 Safe Working Procedures during Production

2.6.1 *Method Statements and Risk Assessments*

Apart the internally operated method statements and/or risk assessments, contractors will be required to provide their own statements prior to them commencing work on the plant.

The Health & Safety folder will contain the significant risks assessments and method statements provided by the contractors that are generally applicable to the work being undertaken on this scheme, together with procedures and policies that should be followed. The Safety Manager will have highlighted known significant risks to the contractors via the design phase.

For high-risk activities, a site-specific method statement is required, which will be agreed before the work can commence. For routine plant and/or site operations, these site rules should be observed together with any relevant guidance issued by the Safety Manager.

2.6.2 *Personal Protective Equipment*

The following policy will be adopted:

- Safety footwear

  Protective footwear must be worn by all persons on plant at all times with the type and level of protection depending on the site conditions and the activities carried out e.g., anti-slip, (steel toe caps and steel sole plates are required as a minimum).

  Pilot plant visitors are not necessarily required to wear steel toe capped/plated boots; however, sensible footwear must be worn depending on site conditions.

- Dust masks

  Respiratory protection must be worn on the plant where is indicated on the risk assessments for the various activities. FFP3 masks must be worn when cutting, sanding, grinding silica based products or hardwoods.

  Additionally, and brushing up activities will require damping down wherever possible. The personnel must wear an FFP3 mask as the content of dust may contain a mixed variety of hazardous dusts such as premixing and or mixing during HDG production stage.

- Overalls

  Overalls must be worn on the plant as and when the work necessitates to provide body protection against hazardous substances, painting, moisture, contaminated ground etc.

- Safety goggles

At all times during production.

- hi-vis vests

  High Visibility Jackets must be always worn by all persons on site.

- appropriate gloves

  At all times during production.

- hard hats for head protection

  Hard hats must be worn on the plant at all times by all persons including visitors, delivery drivers, etc. regardless of apparently low risks.

  The Production Manager and/or the Site Supervisor will be responsible for enforcing the wearing of all necessary PPE.

2.6.3 *Safety signs*

Hazards identification and their signing is divided in two categories:

- Permanent signing (when there is a permanent condition that needs to be notified to the workers and other involved parties) and
- Circumstantial signing (when a condition occurs during or after an operation and requires further attention than the usual operation's procedures)

Permanent marking is achieved by signs or security color and is related to:

- Restriction (red or red & white color)
- Warning (yellow or yellow & black color)
- The obligation (blue or blue & white color)
- Identification and recognition of rescue aid & firefighting equipment (green or green & white color).

While occasional labeling refers to:

- Labeling of dangerous incidents (yellow or yellow & black color)
- Call people for a specific action (green or green & white color)
- Emergency removal (red or red & white color)
- Guidance for people handling and achieved through sound signals, wireless communication signals and gesture signals (blue or blue & white color)

2.6.4 *Emergency Procedures during Pilot Production*

In order to be prepared for any emergency event, the company will, when considered necessary,

plan for reasonably foreseeable incidents and prepare a written plan outlining procedures to be followed in such an event.

The company will, in consultation with workers and their representatives:

a) carry out a risk assessment to identify foreseeable major incidents for which emergency procedures would be required

b) establish procedures to be followed by employees in the event of an emergency situation, including:

I. raising the alarm;

II. means of escape;

III. assembly points and 'safe muster areas';

IV. summoning the emergency services;

V. evacuation of disabled persons;

VI. appoint persons to be responsible for specific procedures in the event of an emergency situation (including the shutting down of plant and making it safe before evacuating the area);

VII. fire wardens and fire marshals (as necessary);

VIII. persons responsible for emergency power supplies and lighting;

IX. first aiders;

c) provide a written version of the procedures to all personnel;

d) ensure that the plans cover out of hours working, weekend working and closures for holidays;

e) ensure there is an up to date call-out list for key personnel and that this is readily accessible;

f) keep all access routes for emergency services and all escape routes clear at all times;

g) reassess the emergency plan at regular intervals and update or alter it as necessary;

h) provide training in emergency procedures for all employees, plus specialist training for those with special responsibilities.

Most emergencies are unlikely if all risks at the workplace are adequately controlled. When devising the emergency plan the company will:

a) nominate personnel to be responsible for specific emergency actions and ensure that they are trained to deal with their responsibilities;

b) ensure that all employees without special responsibilities are aware of how to evacuate the area without delay;

- Reporting an Injury or Dangerous Occurrence

- Training
- Fire and Emergency Procedure

- Fire

2.6.4..1 Control Measures

- Site fire layout plans will be located around the plant indicating firefighting equipment and emergency escape routes.
- Hot Work involving the use of blow lamps, welding equipment soldering irons, abrasive wheels, etc., must obtain the Safety Manager permission to work operations commencing.
- Smoking is not allowed anywhere on the site.
- Rubbish is not to be burnt on site.
- Waste materials are to be placed in skips positioned the site compound.
- Fire routes are to be always maintained.
- Fire extinguishers, fire alarm and sprinklers systems to be promptly maintained by the authorized company.

High-risk fire areas such as hot work areas must have fire extinguishers within easy reach.

- CO2 – Black – Liquid, electrical
- Water – Red – Paper, wood, textiles, solids
- Foam – Cream – Liquid, wood, textiles, paper
- Powder – Blue – Liquid, electrical, wood, textiles, paper

The emergency alarm must be tested weekly and all workers to be notified of the alarm at induction. Please refer to the Emergency Plan for the location of fire extinguishers and alarms.

The assembly area is the open space outside the front entrance of the plant. The location of the assembly area is highlighted on the Emergency Plan.

2.6.4..2 Actions

The person discovering a hazardous situation which has resulted or may result in a fire or explosion will alert other personnel, and if the fire is small, and if safe to do so, attempt to extinguish it using the correct fire extinguisher. If the fire cannot be quickly or safely extinguished, or if there has been, or there is the potential for an explosion, ensure that all personnel move out of the area as quickly as possible.

Control over any hazardous situation will be exercised by the Production Manager and/or the Safety Manager, who will immediately upon being made aware of the situation raise the alarm using the site emergency alarm.

The plant's emergency alarm will be tested once per week. The safety Manager will direct all

personnel to the Assembly Area and ensure that the emergency services have been called.

The Safety Manager will go to the Assembly Area, check if any personnel are missing and be ready to receive and brief the emergency services giving the location of the emergency water supplies/hydrants and details of any missing personnel.

- Health

In the event of someone being taken ill or being injured as a result of an accident that requires medical attention, the IP should be taken to the nearest Hospital.

If the injury is serious or the person cannot be moved, then the Ambulance Service must be notified by calling 166 and giving as much information as possible as to the nature of the incident and location of the injured parties.

Carry out First Aid Treatment and keep them warm and comfortable.

DO NOT MOVE THEM.

Leave them for the Ambulance Crew who have the equipment and training to deal with such incidents.

Do not give them anything to eat or drink.

- Reporting accidents

All accidents and near misses, however, minor must be reported to the Principal Contractor and recorded in the site accident book kept by the Site Project Manager regardless of the severity of the incident.

Once the accident book sheet is completed it is to be detached and returned to Head Office where it will be securely held in the interests of confidentiality. The Production Manager must be immediately informed of any accident or dangerous occurrence on the plant or of ill health, which could be linked to production work.

All incidents and near misses must be recorded onto the Incident Report Form as soon as is reasonably practicable with a copy being submitted to head Office in order that an investigation can commence.

Near Miss – an unplanned event that did not result in injury, illness, or damage - but had the potential to do so e.g., materials falling close to someone's head.

Incident – A planned/wanted event that resulted in or had the potential to result in injury, damage, or loss. Injury, damage, or loss resulted or could have resulted from the activities of the planned/wanted event.

Accident – An undesirable or unfortunate happening that occurs unintentionally and results in injury

All reportable accidents are subject to the procedures detailed in Reporting of Injuries, Diseases and Dangerous Occurrences as per Law requirements:

- Death, major injury, and over 10-day injuries or disease - reported by the person's

employer.

- Death or an injury requiring hospital treatment of a person at the site not directly involved in the works - reported by the Safety Manager.
- Dangerous occurrences at the site reported by the Safety Manager.
- Accidents or dangerous occurrences during transport to or from the plant or in preparatory works at contractors' premises must be reported by that contractor - the Safety Manager should, however, be informed of such incidents.

- First aid

  The Principal Contractor will ensure that a trained and in date 'First Aider, 'Emergency First Aider / Appointed Person' 'is available on the plant at all times during production activities.

  A first aid box (20 persons) will be available on the plant.

  All instances requiring First Aid treatment are to be initiated via the Site First Aider / Appointed Person / Emergency First Aider.

  Where contractors have a dedicated and authorised First Aider, then treatment may be provided, and the Safety Manager informed accordingly.

  For the first aid arrangements are provided in the plant a short briefing will be given to all personnel on the first arrival at the plant.

  Nearest hospital A&E Department:
  Agia Olga,
  Agias Olgas 3, Nea Ionia,
  14233, Attika

2.6.5 *Welfare arrangements*

Welfare facilities will be provided and controlled by the Production Manager. They are for use at the plant by all authorized persons. These facilities are to be kept clean and tidy by those using them.

Location of welfare facilities: Welfare facilities are located in the production area close to the emergency exit of the service road of the plant.

Drinking water: Supply of wholesome drinking water is available direct from the mains. Cooled stored water equipment is provided in designated areas. A supply of cups will be made available where the water is not an upward jet.

Toilets: Two toilet block are provided in the production area .

Washing facilities:

- Clean hot and cold (warm) running water (running where reasonably practicable)

- Soap or other suitable means of cleaning
- Towels or other suitable means of drying
- Sufficient ventilation and lighting
- Sinks large enough to wash hands, face and forearms

Rest Facilities/making meals: Within the welfare unit two tablesa table, seating with backs, a means for heating water for drinks and for warming up food (kettle, microwave, gas/electric heating ring etc.) are provided.

Smoking rules: No smoking inside any welfare facilities. No smoking in any enclosed area. (roof + 50% walls). Smoking only in designated areas.

Cleaning arrangements: All personnel that use them must maintain all welfare facilities on the plant. Additional cleaning will be carried out as per weekly cleaning schedule of the company.

2.6.6 *Unforeseen Eventualities*

Procedures for dealing with unforeseen eventualities during project execution which result in substantial design changes and which might affect resources are as follows:

As soon as unforeseen eventuality arises, the person noticed the event will inform the Production Manager.

The health and safety issues arising from the eventuality are to be as soon as possible after the occurrence, together with proposals for dealing with them.

Details of the re-design and the health and safety implications are to be submitted for consideration and acceptance in due time before execution. Health & safety issues will be on the agenda of the progress meetings.

3 eAHC – HybridWall Manufacturing Methodology

3.1 Hybrid Wall manufacturing methodology

The basic requirements / principles / methodology setting up the framework for eAHC – HybridWall PnU kit development, were thoroughly presented and described in the following Deliverables of PLURAL Project:

- D2.1 – "Architectural and Structural design of PnU kits";
- D2.2 – "Technologies and materials selected for the demo sites";
- D2.7 – "Final stage complete design of PnU kits";
- D4.1 – "Optimized components of PnU kits";
- D4.2 – "Add-on technologies for PnU kits";
- D4.3 – "Pre-assembled toolbox with control system"
- D4.4– "PnU kit prototypes addressing the 3 demo-building requirements"

Furthermore, additional considerations had to be taken into account such as the:

a) Necessity to change the transportation system to the building site, due to the higher frames that will be needed in order to fit the demo building requirements. This change implies that the new maximum length of the frames to be manufactured to be 2.6m.
b) The window frame component has proven to be too expensive in relation to the performace offered.
c) The Ventilation Units to have the flexibility to be installed at any side of the window.
d) The access to the maintenance filters of the Ventilation Unit can be achieved with the installation of louvers in its shading position, resulting to redesigning of the overall movement possibilities of the louvers' lines in order to improve the users usability.
e) Management and treatment of the wates by the insulation material will be generated during production were a significant chalenge.

All the aforementioned considerations enforced several modifications to the original eAHC-HybridWall design, as presented in detail in the *task T.4.5 - PnU testing campaning*, and have been adopted in the manufacturing process which is described in the following chapters of the current report.

The Hybrid Wall (eAHC) overall manufacturying metholodogy, can be definied in the next 8 phases, as in the following chart (Figure 21):

- Phase 1: Detailed Design

- Phase 2: Components provision process
- Phase 3: Components storage
- Phase 4: Comopnentes production process
- Phase 5: Frame assembly process
- Phase 6: Frame storage
- Phase 7: Support (building) preparation (described in detail in Task 7.3)
- Phase 8: Installation process (described in detail in Task 7.3)

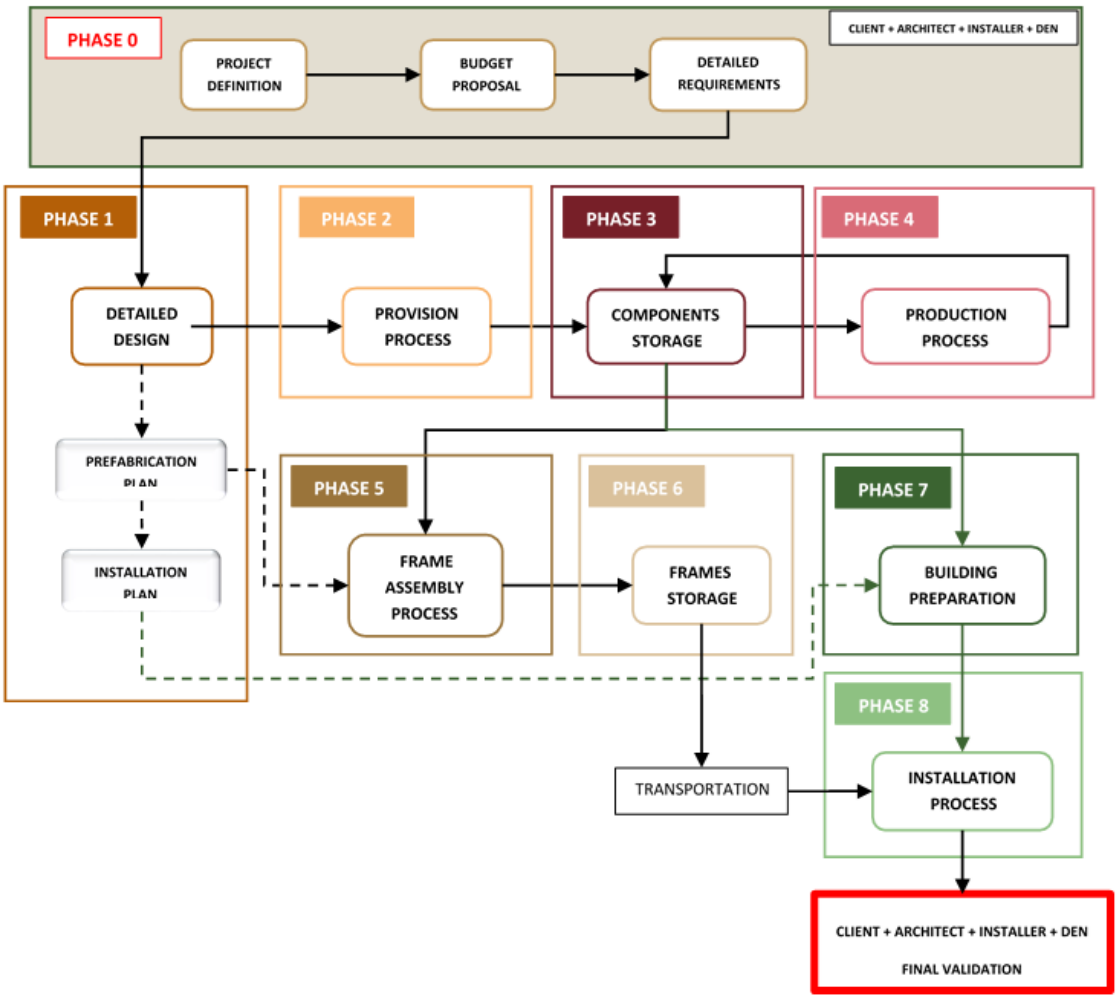


FIGURE 21: HYBRID WALL PERT MANUFACTURING METHODOLOGY

Subject of the current report are Phases 1 to 6, while Phase 7 and 8 related to the installation and in-situ validation methodologies will be presented in other reports of WP6.

3.2 Manufacturing methodology per Working Station

The manufacturing strategy applies not only to the actual PnU kit production but also to the overall project's phases, due to their interdependency and requirements.

3.2.1 *Phase 1: Detailed Design*

It is important to point out that the detailed design phase is consisting by translating the actual design into a list of components as defined by the commercial and technical department in collaboration with architects, the installer, and the customer. This process will provide all the necessary information required to accomplish the fabrication. In other words, the detailed Design is considered as the "digital manufacturing", which is necessary to:

- Define the components to be assembled as Denvelops is not a producer company, is an assembly line factory.
- Perform the initial tests of what will be assembled as per Factory quality procedures via its digitalization.

This phase is in fact a "virtual assembly process" necessary to validate that the PnU kits proposed, can be fabricated and via the FQPs results to proceed in the generation of the total quantities of the components required to fabricate them.

Nowadays, thanks to informatics is possible to check, test and validate with a high degree of accuracy the viability of all manufacturing steps and their assembly press. The key link of this phase is related in the next Table 7:

Factory Quality Procedures (F.Q.P.)	
COMPONENT	**FACTOR QUALITY PROCEDURES**
Detailed design plans production	VALIDATE CRITICAL DATA WITH DOUBLE CHECK: • Check that there are not interferences between components. • Generate a "pre-vision" (estimation), regarding the size and the weight of the components and all the pre-assembly processes that will be required, in order to check the space (storage) availability of the plant. • Check and revise the overall process (metrics, position …), as beyond this process every manufacturing mistake might occur will not be digital, but in some case irreversible reality. • Proposition of small samples / mockup / tests to validate the viability of a particular assembly proposed.

	Generate and define all components in 3d format files. Reduction at the minimum required types of the total number of different components.

TABLE 7: DETAILED DESIGN FQP

In terms of Lean production strategy the Detailed Design phase is executed in one (1) workstation (WS) as *Figure 22* illustrates:

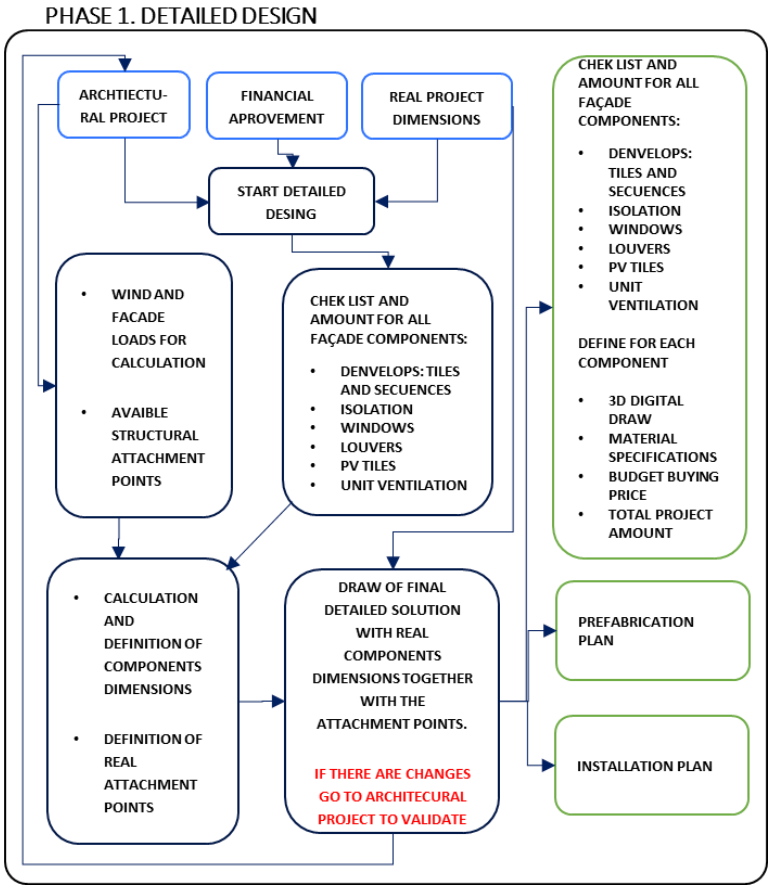


FIGURE 22: WS DETAILED DESIGN

This workstation is situated in the plant's offices, and is aiming to review the initial requirements and finally develop the detailed solutions by assembling in 3d models the entire project. In case of some point at the overall process the proposed architectural initial design cannot be viable, a new solution is drawn, validated with the architects into an over looping process until all criteria will be met and satisfied.

The manufacturing objective of this work executed in WS1, is to analyze and finally generate a check list of all components -and their quantities- required to do the project.

Figure 22 analyses the basic operational steps of the on discussion WS, their interoperability and dependencies among them, as well as *the "cut-off"* points where the "*100% Inspection Method*" is applied and clearly indicates the looping actions among them.

This workstation operational requirements are summarized in *Table 8*:

Step Description	WS / Detailed Design
ESTIMATE TASK DURATION	TWO WEEKS
EQUIPMENT	3d informatics programs like AutoCAD, inventor, Solidworks, etc.
AUXILIARY EQUIPMENTS	• Offices • Ventilation
SPECIFIC TECHNIQUES	3d drawing, small mockup / tests.
ENEREGY REQUIERED	Power supply 240V
POSSIBLE FAILURES	As per F.Q.P
CUT OFF POINT	New changes that need phase 1 approvals.

TABLE 8: DETAILED DESIGN RESOURCES

3.2.2 *Phase 2: Components Provision*

The involved processes in Phase 2 undertaking the tasks of ordering all the elements that have been designed in the detailed design phase and their delivery at the plant's factory facilities, by the means of interpreting the 3D components model files into actual (real) components. For the Hybrid Wall systems required many types of components, by a series of different providers and fabrication processes.

In this phase Denvelops has the responsibility to choose the correct producer and ensure that each component will be able to fulfil the requirements and the specifications for what it has been designed in Phase 1.

It must be noted that is not Denvelops objective to be aware on how each component has been produced as relies on the expertise and specifications given by their manufacturers. E.g., has no sense to attempt to do a revision on how screws and rivets are fabricated and produced. However, for other less standardized components, like the assemblies needed e.g. for windows or the PV tiles or the windows

roller guides, there is a closer collaboration with the manufacturers as some important technical points must be clarified and controlled to ensure the best results during PnU kits fabrication.

Being aware that HybridWall is made by the addition of different components in a variable assembly production chain and it is important to rely on the each component's manufacturer expertise to provide the best solutions under the umbrella of their own quality control process.

If the first important goal of this phase is to obtain the required components, the second more important goal is to know when they will be delivered in the plant, since this information will affect the production scheduling.

This phase has three clear actions:

a. Send the required information (needed by the provider) to each provider to receive the required components.
b. Receive budget and fabrication time.
c. Control and validate the components and its associated data when they finally arrive to the factory for their storage.

The key points of this phase are presented in *Table 9*:

Factory Quality Procedures (F.Q.P.)	
COMPONENT	**FACTOR QUALITY PROCEDURES**
Components provision process	Choose the providers and have clear way to transfer the components information. Double check for the list components and formalize the order Follow the sending and establish a clear production time Received elements validation: • Mass • Element codification/ Labelling • Weight • Dimensions • Certifications • Holes /metric

TABLE 9: PROVISION PROCESS FQP

NOTE: In activity 1.3 are described the production and quality certification of the Denvelops materials and components providers.

The Components Provision Process is mainly executed in one (1) workstation (WS) as *Figure 23* illustrates:

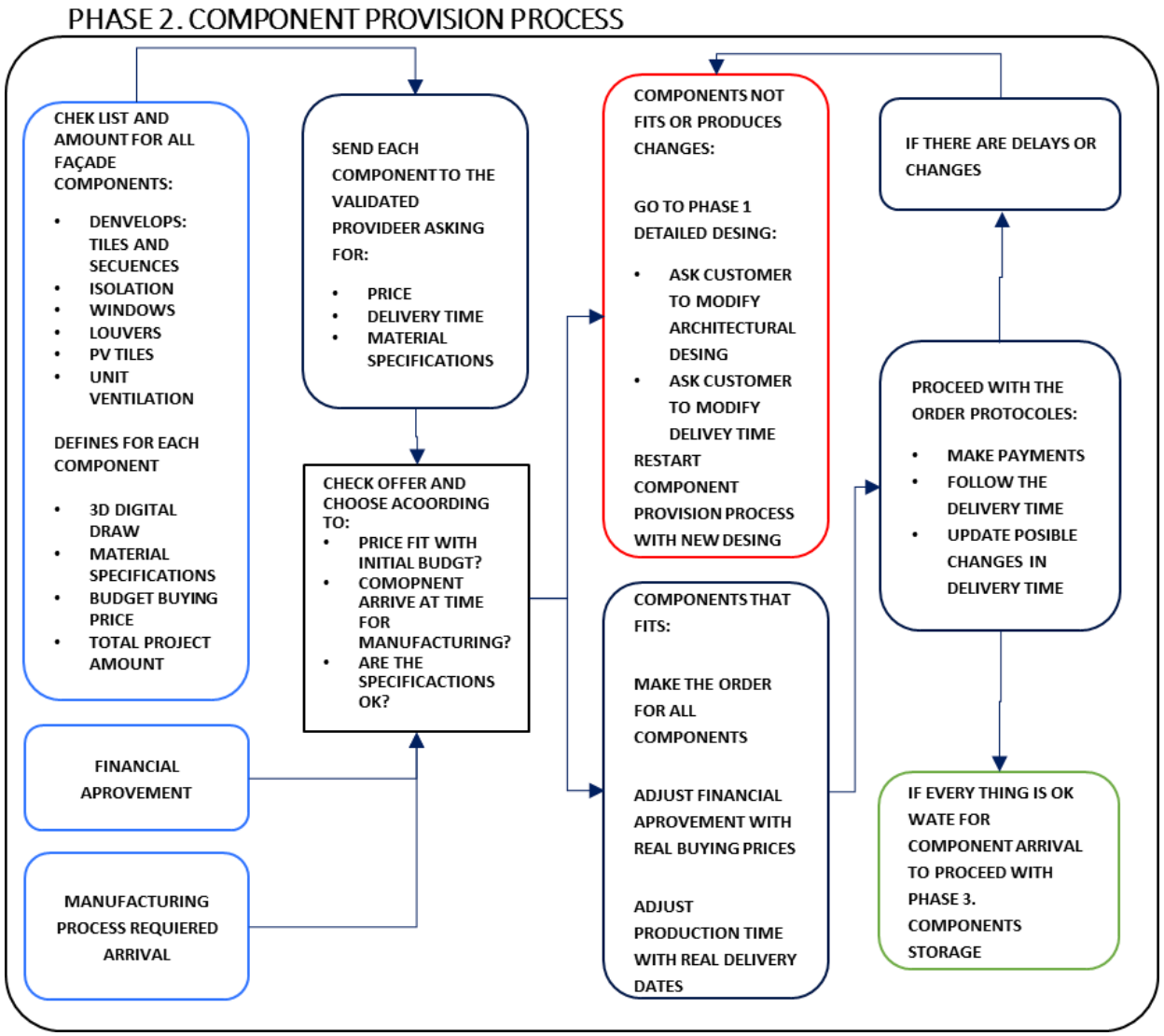


FIGURE 23: WS COMPONENTS PROVISION PROCESS

This workstation operational requirements can be summarized as per *Table 10* description:

Step Description	WS / Components Provision Process
Estimate task duration	• Weeks for standard components production • 8 weeks for functional components like windows or unit ventilation

Equipment	• Office and management PC programs • Standards ordering sheet for the commands. • Standards sheets to follow the state of the command. • Tools for take measurements, and standards sheets for components reception.
Auxiliary equipment	• Offices • Crane • Ventilation
Specific techniques	• Management of provision components. • Quality control procedures to check the produced components at their reception.
Energy required	Power supply 240V
Possible failures	As per F.Q.P
Cut off point	Delay in arrival of components

TABLE 10: PROVISION PROCESS RESOURCES

3.2.3 *Phase 3: Components Storage*

The storage phase is consisting by six (6) sub-tasks:

- Storage's area optimization.
- Time reduction components transportation from entrance/storage place/ assembly place
- Storage area ambient and safety conditions.
- Constantly update storage's data.
- Classification of components by industry and fabrication process.
- Storage of components to be ready for assembly.

Every factory has its own type of storage area which is mainly related to the type of products they manufacture. In Denvelops case, it is a factory more related to the assembly process and components focused on a chain production scheme. Besides that, in Devenlops plant tailor made solutions are developed and fabricated to every façade dimension, which means that components will rapidly be used for production and their storage time will be minimized during production.

According to Devenlops Assembly Process*, (see section 3.2.5)* the chain production is defined in four (4) big areas or assembly points:

a. Components assembled in horizontal position
b. Components assembled in vertical position,
c. Preassembly Louver and
d. Preassembly window.

However it has to be added, that an additional area exists, where the insulation is processed, as described in paragraph *3.2.4 Components production process* of the current report.

According to the plant's manufacturing concept, storage elements ought to be close to the assembly or production areas where they will be used, and / or to their surrounding area in order to be easy to be found and use them in the assembly process.

In case that some of the components will be arriving prior production commencement, or while another project is being at the time of their arrival manufactured, they are stored behind the area that will be used to free up space and not interfere the manufacturing processes. At the end of the manufacturing process, it will be necessary to store the leftover components, at the designated storage area.

Finally, the ambient conditions of the storage area the assembly line, should be controlled and not be aggressive or prejudicial for the components in use or stored. Measurement are taken to reduce the risk of acid environments, high humidity, iron contamination, dust,etc.

Table 11 presents the key activities of the current manufacturing phase:

Factory Quality Procedures (F.Q.P.)	
COMPONENT	**FACTOR QUALITY PROCEDURES**
Storage	• Informatics program and use of barcodes to know on real time where and from when are materials storage. • Easy and safety factory entry and pavement to ensure components are well treat all the time. • Safety and as many of required machines to move the different types of components with total guarantee. • Storage area space: Reduces distances of components. Storage next to assembly operation • Ambient conditions: Safety for components and workers • Basic functionalities: Cleaning, ease of access, ease of operations.

TABLE 11: STORAGE FQP

The Components Storage is mainly executed as per *Figure 24* illustration:

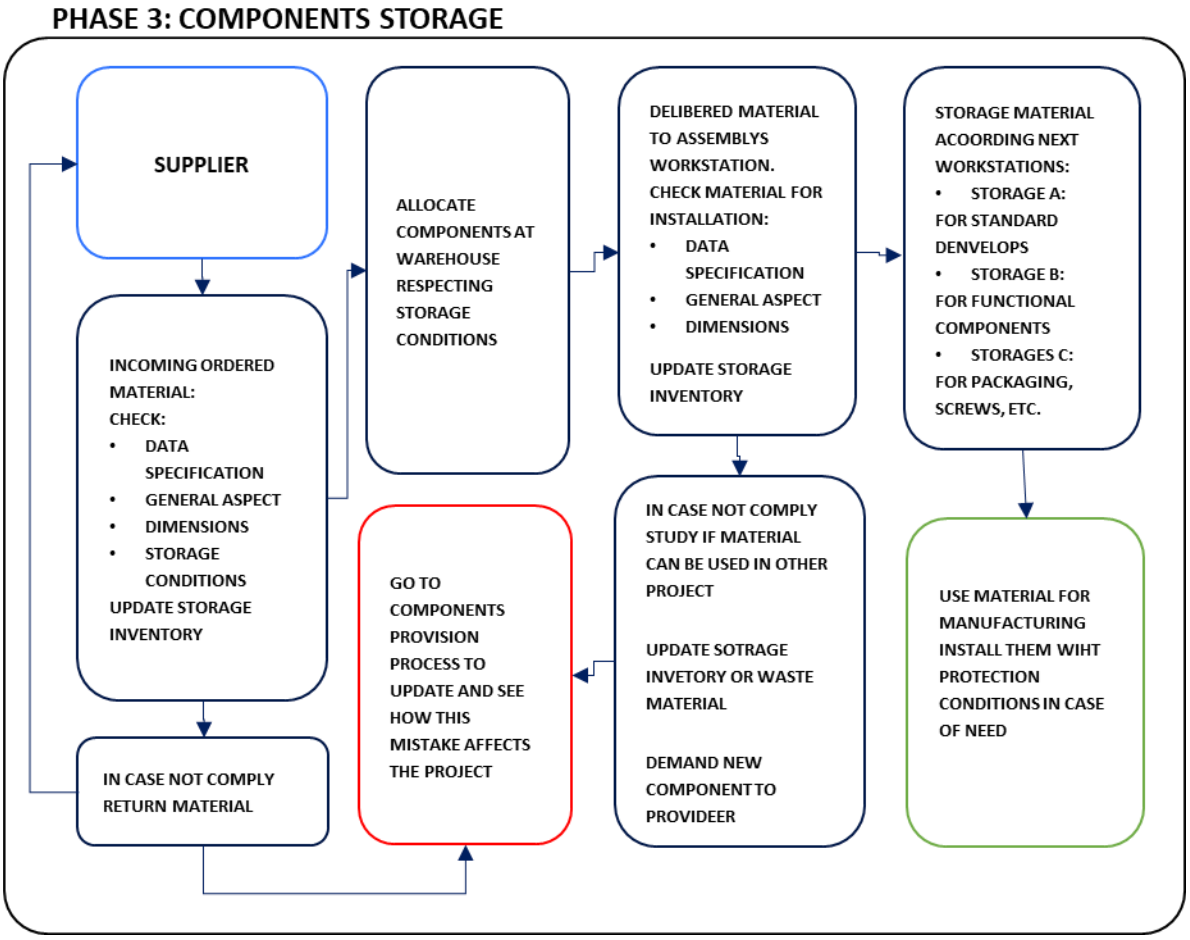


FIGURE 24: WS COMPONENTS STORAGE

This operational requirements for the current manufacturing sub-task are summarized in *Table 12:*

Step Description	WS / Components Storage
Estimate task duration	FOUR WEEKS (same time coincidence with components provision process)
Equipment	• Forklift had pallet truck. • Barcode reader • Foam or wood protectors • Wood pallets
Auxiliary equipment	• Offices • Crane

	• Storage auxiliary furniture • Ventilation
Specific techniques	Storage informatic programs.
Energy required	Power supply 240V
Possible failures	As per F.Q.P
Cut off point	Damages of components storage

TABLE 12: STORAGE RESOURCES

3.2.4 *Phase 4: Components Production*

The Hybrid Wall manufacturing has been designed focusing onto a chain assembly production line system, aiming to reduce production's operational tasks, as this type of manufacturing process generates wastes which have to be recycled according the Spanish National Regulations.

Additionally, working with pre-fabricated components tailor-made to the Hybrid Wall system made by the providers, ensures that the assembly process will flow with the maximum possible efficiency. However, there are some components, e.g. the insulations panels that need shaping into size at the assembly line as cannot be bought in Hybrid Wall's custom made dimensions.

The shaping and treatment of the insulation materials need to be executed in a designated area of the plant to ensure waste minimization and shaping optimization. This particular sub-process will be defined during Phase 1, where the total number of panels required, their dimensions and specifications, as well as their shaping conditions will be defined and all relevant data will be handed to the involved workers.

Following the provided data, the insulator's shaping sub-process will be executed on appropriate benches, marking the relevant holes and cutting edges with a specific cutter. Each panel's codification will be written in the insulation with over a non-removable marker. Once completed it will be transported to the assembly storage area, with the other Hybrid Wall components.

The key points of this phase are presented in *Table 13*:

Factory Quality Procedures (F.Q.P.)	
COMPONENT	**FACTOR QUALITY PROCEDURES**
Components produce process	• Use of safety components for workers and tools. • Reduction of number of operations and different types of combined components. • Only one (1) operation per worker. Double works produces mistakes.

	• Standardization of operations. More repetitions more speed. • Easy and clear information of the process. • Special area for each process in where only the tools will be needed, not more to give chance to do mistakes. • Use reasonable timing to calculate duration tasks. • Respect the data and codification of all process. • Respect codification of all panels

TABLE 13: COMPONENTS PRODUCTION FQP

The overall sub-process of the Components Assembly is presented in *Figure 25* as following:

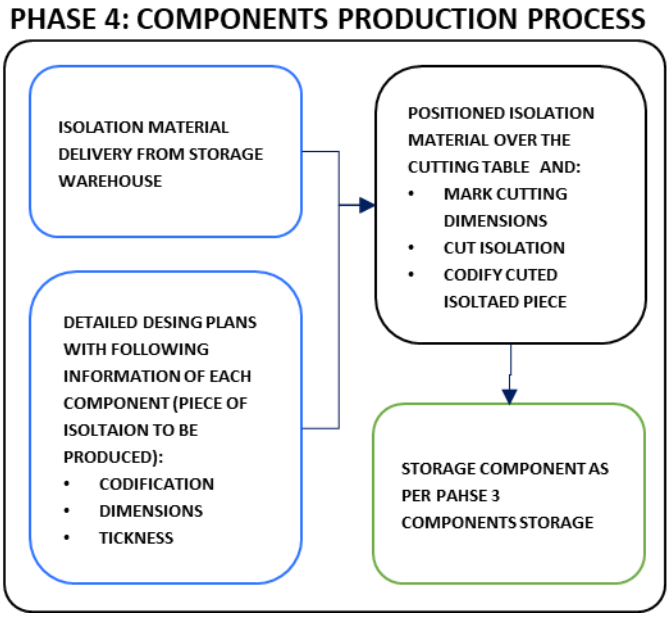


FIGURE 25: WS COMPONENTS PRODUCTION PROCESS

The operational requirements for the components' assembly sub-task are shown in *Table 14*:

Step Description	WS / Components Production Process
Estimate task duration	10 minutes for each isolation required panel
Equipment	• Forklift • Wood pallets • Table, cutter, measuring tape • Gloves, hand protector • Cutting Table

Auxiliary equipment	• Offices • Crane • Production plan • Packaging tools • Ventilation
Specific techniques	Cut isolation panels
Energy required	Power supply 240V
Possible failures	As per F.Q.P
Cut off point	Mistake in result (dimensions or codifies

TABLE 14: COMPONENTS PRODUCTION RESOURCES

3.2.5 *Phase 5: Frame Assembly*

Once all HybridWall's components are placed on the designated areas for manufacturing, the prefabrication process and all digital data have been delivered by the Assembly points then the PnU kits prefabrication commences. This process includes the frame assembly of all Hybrid Wall's frames according to the codification system produced in Phase 1.

Prior any works commencement each Assembly's Point responsible crosschecks:

- The digital files received by the design department,
- The specification of each frame, and
- The storage data to confirm no component is missing.

The frame assembly process is divided in 4 workstations:

- *WS 1 Assembly stage A:* The main parts of every frame is manufactured. Furthermore, all components necessary for the frame assembly are installed according to the digital files produced.
- *WS 2 Assembly stage B:* Due to the complexity of the frames parts executed in WS3 and WS4, are gathered and the final assembly of the frame is conducted.
- *WS 3 Louver assembly:* Louvers assembly point feeding WS2 with the required components.
- *WS 4 Window assembly:* Similar to WS3 windows are assembled and transported in WS2 for the final Assembly of Hybrid Wall.

Assembly Stage A:

Table 15 thoroughly describes the relevant actions of Assembly Stage A:

Factory Quality Procedures (F.Q.P.) - Assembly Stage A:	
Place Lines	Check codification versus order codifications inside the frame.
Install Wind bridges	a. Check rivets to be well installed. b. Check that distance between line is the same as the frame plan
Sort and place connectors	Check that the disposition of the connectors with the frame plan.
Attach connectors	Every union between line and connector must touch to ensure the union is finish.
Install Hinges	Check rivets are well installed.
Install load guides	a. Check rivets to be well installed. b. Check the load guide is well oriented to the back facade
Install load windows	a. Check rivets to be well installed. b. Check the load window is well oriented to the back façade
Install insulation knives	a. Check rivets to be well installed. b. Check the knives situation is the same as the frame plan
Install Plural lov 1480 down + louver rail and wheels	a. Check all required attachment points are placed. No torque is required but there no must be space between the nut and the window frame anchoring point of connection to the temporal anchor. b. Check that the nuts between the lover rail and the 1480 down has been placed. c. Check that the wheels move easily with no interruptions.
Install UV temporal anchor	Check that all required attachment points are placed. No torque is required but there no must be space between the nut and the window frame anchoring point of connection to the temporal anchor.
Install the louver rail and wheels in the window top area	Check that all required attachment points are placed. No torque is required but there no must be space between the nut and the window frame anchoring point of connection to the temporal anchor.
Install louver assembly D	a. Check all required attachment point are placed. No torque is required but there no must be space between the nut and the window frame anchoring point of connection to the temporal anchor. There are many louvers to install. *BEAWARE*: b. Check that the chosen louver assembly is the same as the one described in the frame plane. c. Check that the first louvers is attached with the first pair of wheels.

Install UV	a. Check the nuts of all the temporal anchors are installed. No torque is required but there no must be space between the nut and the UV anchoring point of connection. b. Check that the position of the UV is the closest to the lines to reduce the thickness of the frame during its factory storage and later transportation.
Install PV anchors to the Lines	No torque is required but there no must be space between the nut cartel and the lines point of connection.
Install PV tiles	a. Check that all the PV tiles of the frame plane has been installed b. Check that the special washer has been well installed. No torque is required but there no must be space between the nut cartel and the PV tiles point of connection.
Connect PV tiles	Check that all the connections of the frame plane has been connected.
Install insulation layer	Check that the perimeter of the isolation fits with the perimeter of the lines like is drawn in the frame plane.
Install exopalet	Check that there are flanges every 50 cm of line

TABLE 15: FRAME ASSEMBLY FOR STAGE "A" FQP

Assembly Stage B:

By the outcome of *Task 4.4 – PnU kits addressing the 3 demo sites requirements,* as well as by Denvelops internal process of chain production line improvement, it was evident that Assembly Stage B could be integrated with the Phase 6 "Frames storage".

This integration results on time earnings as if stage B manufacturing could be executed over the pallet prior their storage, could be integrated at the same time that the frame is produced. In this sense, the actions of Phase 6 are transformed only to pallet's movement and transportation.

Similarly to Assembly Stage A, *Table 16* describes the sub-tasks involved at Assembly Stage B:

Factory Quality Procedures (F.Q.P.) - Assembly Stage A:	
Move the frame from the stage A workstation to the frame pallet.	• Check that the strap is well fixed. • Before remove the strap checks the frame is well attached to the pallet. • Control codification data of the frame and the pallet

Install window assembly C (Described in table C)	• Check the nuts of al the temporal anchors are installed. No torque is required but there no must be space between the nut and the window frame anchoring point of connection to the temporal anchor. • Check the position of the window is the closest to the lines to reduce the thickness of the frame during its factory storage and later transportation.
Pre-attach Window finishing	• Check the codification of the components, • Check that the pre-attachment does not make vibrations when is touched. It has to resist the vibrations of a transportation way.
Final pallet packaging	• Check the data stick corresponds to the codifications of the frames of the pallet.

TABLE 16: FRAME ASSEMBLY - STAGE "B" FQP

The Frame's Assembly Process is graphically illustrated in *Figures 26 and 27*:

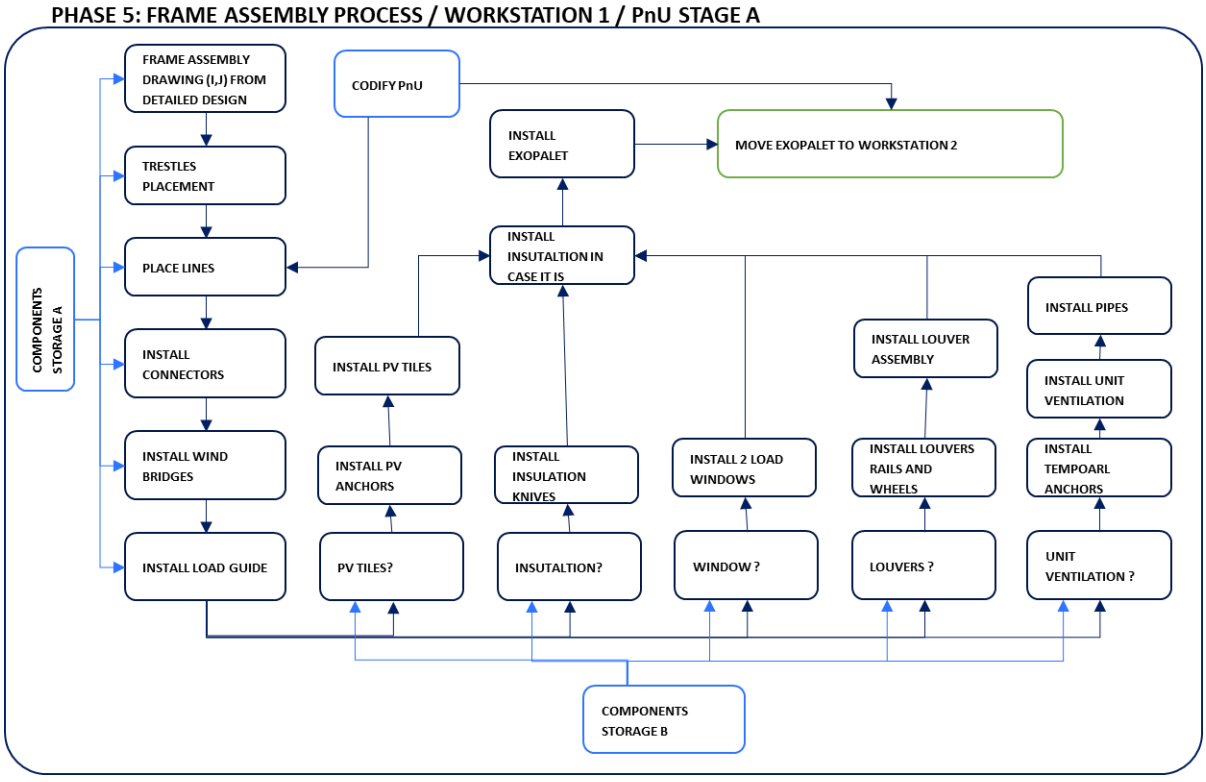


FIGURE 26: WS1 FRAME ASSEMBLY PROCESS STAGE A

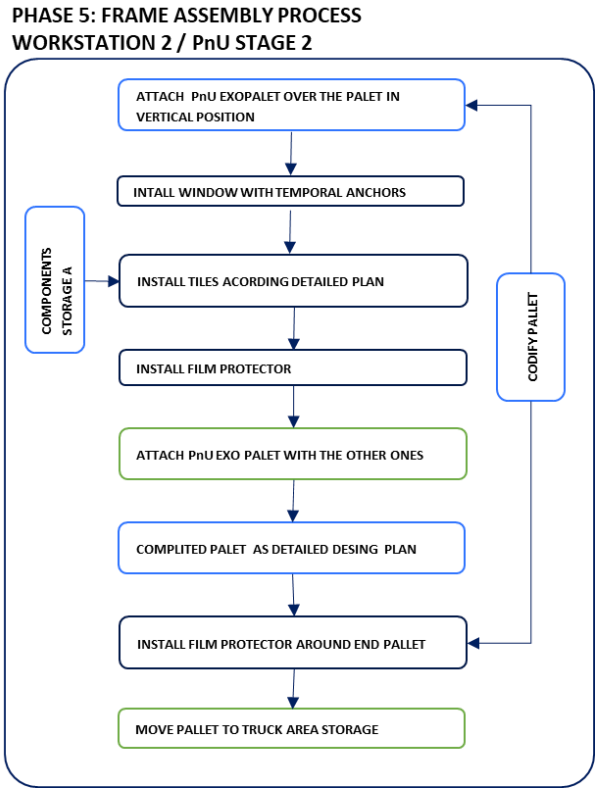


FIGURE 27: WS2 FRAME ASSEMBLY PROCESS - STAGE B

Furthermore, there are two more workstations involved in the overall Assembly preassembling processes:

- Louvers and
- Windows

as per *Tables 17 & 18* description.

Louvers preassembly

Component	Factor Quality Procedures / Louver
Place Lines	Check codification versus other codifications inside the frame.
Install Wind bridges	a. Check rivets are well installed. b. Check that distance between line is the same as the frame plan
Sort and place connectors	Check that the disposition of the connectors with the frame plan.
Attach connectors	Every union between line and connector must touch to ensure the union is finish.

Install Hinges	Check rivets are well installed.
Install final tiles cladding	a. Check that the disposition and colours of the tiles frames is the same detailed on the frame plane. b. Check all pieces are horizontal aligned, which means all of them have been inserted correctly to the connectors.

TABLE 17: LOUVERS PREASSEMBLY FQP

The louvers preassembly process is graphically illustrated in *Figure 28*:

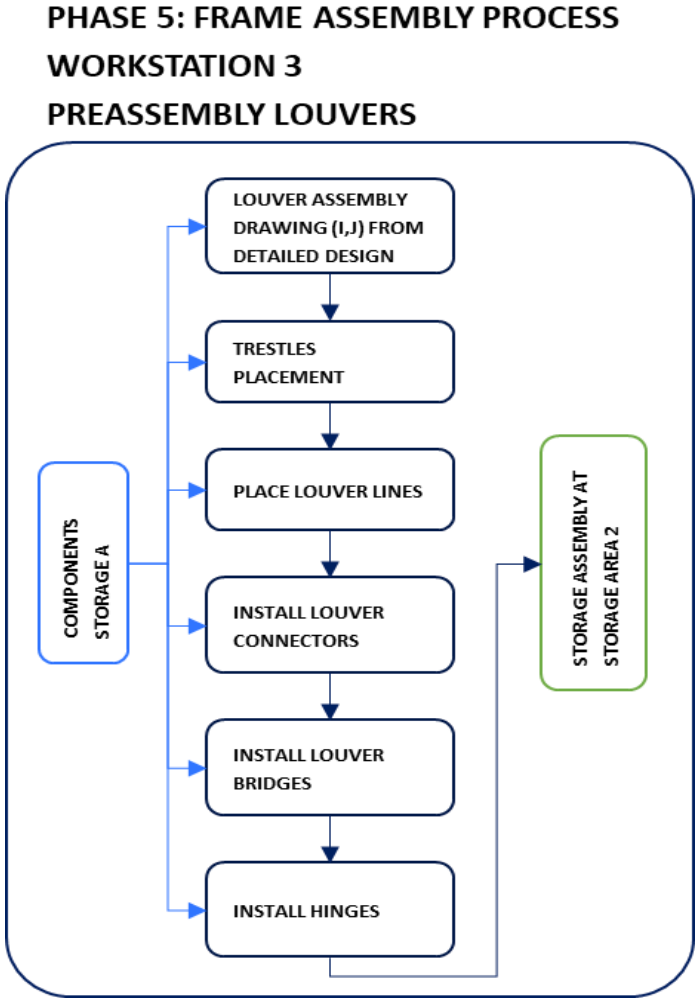


FIGURE 28: WS PREASSEMBLY OF LOUVERS

***Preassembly of louvers, anchors, and louver tiles.*

Windows preassembly

COMPONENT	FACTOR QUALITY PROCEDURES
Install the window temporary anchors over the window	a. Check all the fixing points has been attached. No torque is required but there no must be space between the nut cartel and the PV tiles point of connection. b. Check the codification of the window.

TABLE 18: WINDOWS' PREASSEMBLY FQP

The louvers preassembly process is graphically illustrated in *Figure 29*:

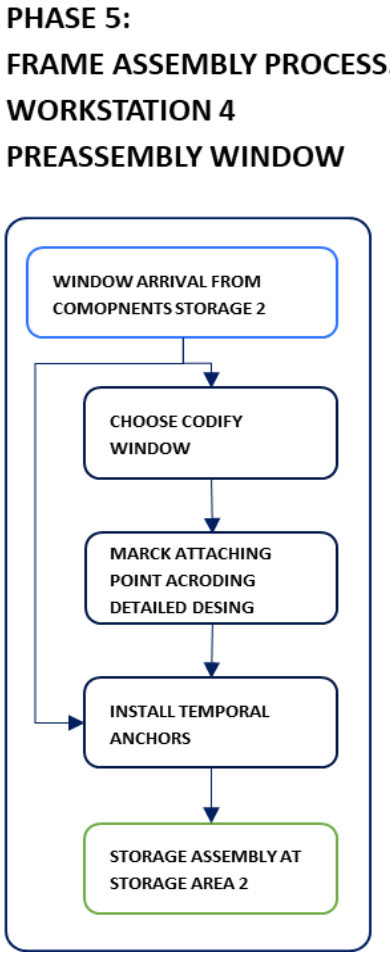


FIGURE 29: WS PREASSEMBLY WINDOW

**Preassembly WINDOW/WINDOW FRAME/WINDOW TA*

Table 19 presents the key activities of Frame's Assembly Process:

Step Description	WS / Frame Assembly Process
Estimate task duration	ASSEMBLY STAGE A: 6 hours ASSEMBLY STAGE B: 30 min PREASSEMBLY LOUVERS: 120 min PREASSEMBLY WINDOWS: 60 min
Equipment	• Various hand tools
Auxiliary equipment	• Factory • Crane • Forklift • Production plan • Ventilation
Specific techniques	Production program (To indicate the operation is done).
Energy required	Power supply 240V
Possible failures	As per F.Q.P
Cut off point	Fins some components do not fit or that gets damaged. Go again to components provision process.

TABLE 19: FRAME'S ASSEMBLY RESOURCES

3.2.6 *Phase 6: Frame Storage*

Once Phase 5 is completed frames needs to be stored in a designated area where will be protected with a specific type of packaging, protecting them for their transportation and future installation. Storage orientation, plays a significant role as most of the Hybrid Wall systems include fragile components such as windows, PVs, UVs etc., therefore are all stored in a vertical position.

The most important equipment during this assembly phase are the packaging components and transportation pallets. Though it has to be underlined that pallets need to be optimized in such a way to fit in a container's truck, but at the same time to fit as many as possible systems within it.

Important parameter is considered to be their transportation within the plant as due to their mass and weight all pallets need to be moved and transferred with the aid of a forklift or crane.

Table 20 presents the FQPs involved at the Storage Process, while *Table 21* presents the key resources required for the Storage Process.

Component	Factory Quality Procedures
Final pallet packaging	a. Check the data stick corresponds to the codifications of the frames of the pallet. b. Check that pallet is strong done.

TABLE 20: STORAGE FQP

Step Description	Ws / Frames Storage
Estimated task duration	20 minuts
Equipment	• Various hand tools
Auxiliary equipment	• Factory • Crane • Forklift • Production plan • Ventilation
Specific techniques	• Production program (To indicate the operation is done). • Storage program. (To fill where it is)
Energy required	Power supply 240V
Possible failures	As per F.Q.P.
Cut off point	Find some components do not fit or that gets damaged. Go again to components provision process

TABLE 21: STORAGE RESOURCES

3.3 PERT diagram

From the analysis of the PERT diagram *(Figure 30)* and the description of the manufacturing methodology developed for the Hybrid Wall, there are a series of critical points in every fabrication phase that could modify the sequence and duration of the Hybrid Wall manufacturing process.

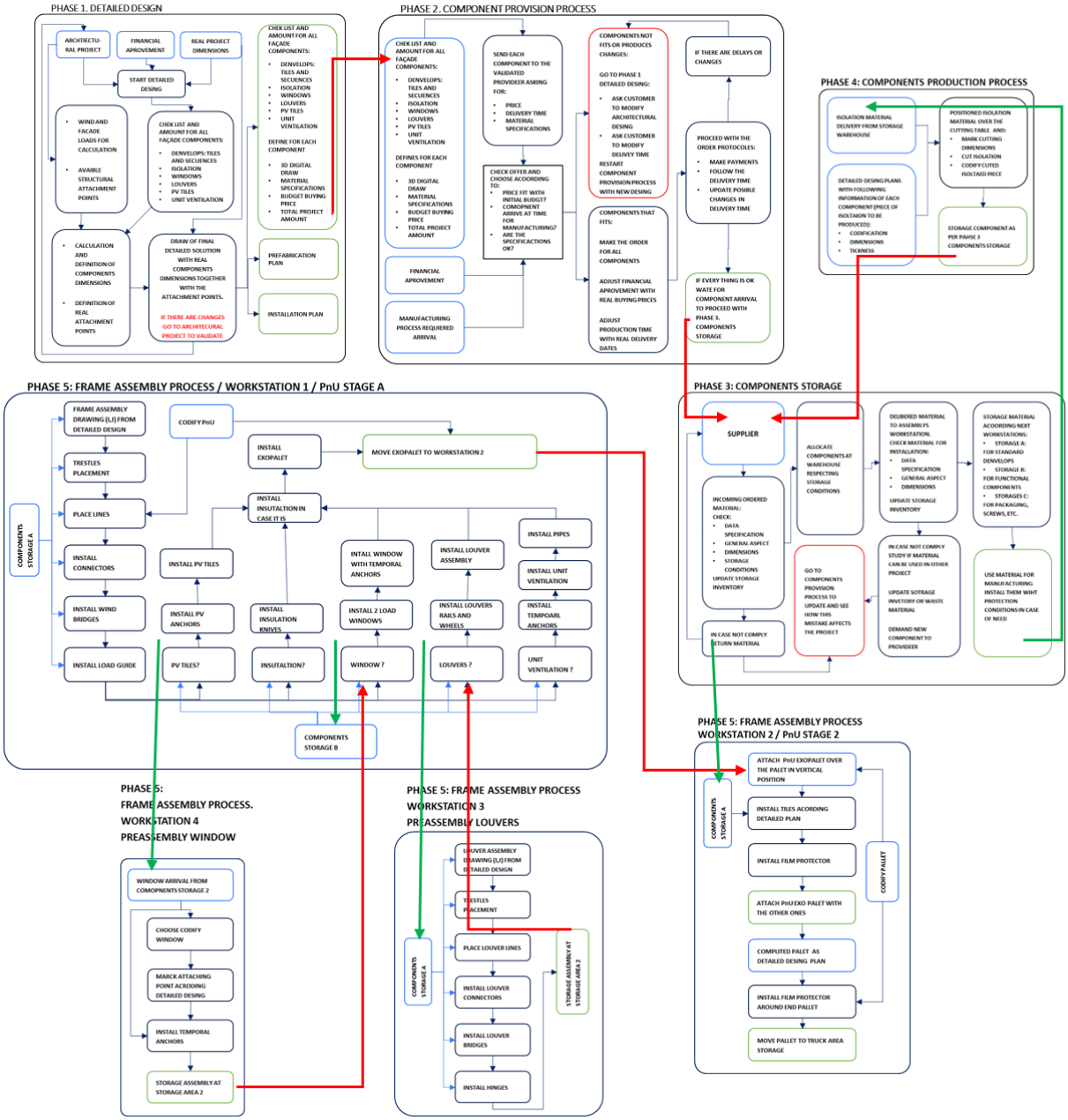


FIGURE 30: HYBRIDWALL PERT MANUFACTURING METHODOLOGY

Tables 22 – 27 summarise the most important aspects of the risks involved per manufacturing phase, as those occurred by the interpretation of PERT diagram:

Phase 1: Detailed Design		
Critical point	**Associated risk**	**Maximum delay & time provision**
Architectural project needs the aprovement of the customer. In PLURAL's case, the architectural project is not 100% aprobed by AHC.	Until project is 100% approved by the owner, Hybrid Wall components cannot be produced. Final approval from AHC is expected to be done at the end of November. This action delays the tendering process, which once completed installation will be completed by June 2023.	1 month
Building permits • From City Hall • From Roads' Department	Until project is 100% approved by the owner, Hybrid Wall components cannot be produced. Fabrication should not start until relevant permissions are obtained, due to the changes on design might occur. Permission can be granted by submitting a preliminary design, therefore any delays are minimised.	3 months
Financial issues	Changes of raw material prices could generate delays.	1 month
Lack of information	For the detailed sedign of the components a detaied survey is requiered. The detailed survey is expected to be concluded by January 23.	2 weeks

TABLE 22: PHASE 1 - DETAILED DESIGN CRITICAL POINTS

Phase 2: Components provision process		
Critical point	**Associated risk**	**Maximum delay & time provision**
Complex functional components like, photovoltaics, unit ventilation or windows.	If delays will occur on their provision, some parts of the Hybrid Wall would not be able to be manufactured. This issue would not directly affect the overall duration of manufacturing process, since frames could be manufactured and install them at a later stage.	2 months

TABLE 23: PHASE 2 - COMPONENTS PROVISION CRITICAL POINTS

Phase 3: Components storage		
Critical point	**Associated risk**	**Maximum delay & time provision**
Damage on components while storage	Reordering damaged components if not on plant's stock	1 month

TABLE 24: PHASE 3 - STORAGE CRITICAL POINTS

Phase 4: Components production process		
Critical point	**Associated risk**	**Maximum delay & time provision**
Mistakes, defaults or omission during their production	Reordering damaged components if not on plant's stock	1 month

TABLE 25: PHASE 4 - PRODUCTION PROCESS CRITICAL POINTS

Phase 5: Frame assembly process		
Critical point	**Associated risk**	**Maximum delay & time provision**
Mistakes, defaults or omission on their design.	Reordering damaged components if not on plant's stock	1 month for simple components. 3 months for complex functional components

TABLE 26: PHASE 5 - FRAME ASSEMBLY CRITICAL POINTS

Phase 6: Frame storage		
Critical point	**Associated risk**	**Maximum delay & time provision**
Damages In pallet due to internal or external causes.	Re-fabrication of the damaged panels	2 months

TABLE 27: PHASE 6 - STORAGE CRITICAL POINTS

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

It has to be noted that the aforementioned tables, do not define and describe the "daily and small" problems that might occur during the daily operation of each workstation. Those kind of "problems and risks" could not be considered as critical issues but daily operational issues. Due to the experience gained all those years that Devenlops operates, it is well known to the plant managers how to deal with them and minimize any possible risk might occur by the "daily" problems, and in every case should be considered as "very low risks" with minimum impact to overall manufacturing process.

Furthermore, a detailed analysis of all risks, mistakes, omissions, defaults etc., will be presented in the *Deliverable D6.3 – Quality assurance plan – manufacturing / assembly*.

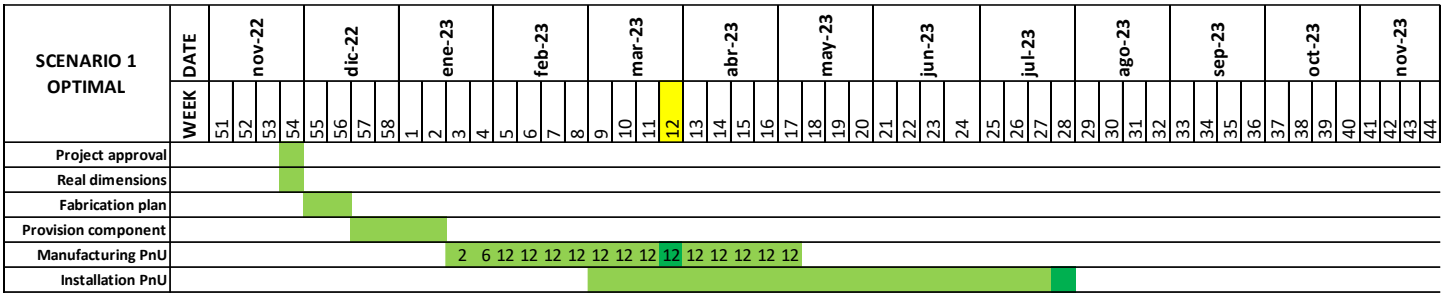
3.4 Production Plan scenarios

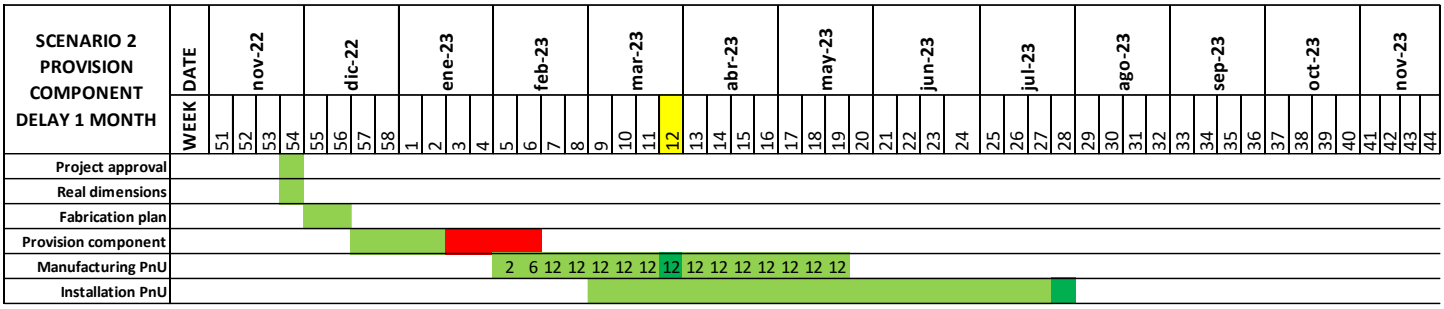
According Denvelops' plant's capacity the standard production duration for the Hybrid Wall components has been estimated to be produced twelve (12) frames per working week. However, according Devnlops experience, all projects do not have the same production duration, even if the components need to be assembled are the same or with minor modifications. Usually, at the beginning of the manufacturing process the manufacturing efficiency might be decreased down to 25%, gradually increase when the workstation getting familiar with the Hybrid Wall components and at the end of the manufacturing process might be even faster than the target of twelve (12) frames per week.

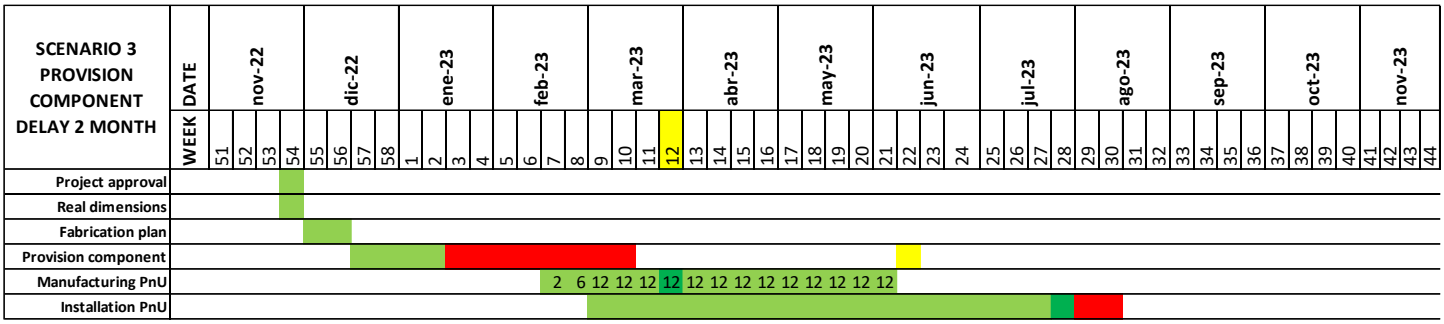
Taking into consideration that for PLURAL project need to be manufactured one hundred sixty four (164) frames, under the optimal manufacturing conditions, without any delays on the provision of materials the overall manufacturing duration is estimated at three and half months. To this manufacturing duration estimation, should be added two extra weeks prior manufacturing commencement for personnel training to familiarize with Hybrid Wall system in order to reduce manufacturing mistakes, omissions and possible delays. Moreover, one additional month should be added for the "Provision Components Phase", and two more weeks to complete the "Detailed Design Phase" once everything is authorized and validated.

The Gant diagrams in *Table 28* illustrate the four different scenarios that Denvelops considers as the most possible to happen according of what has been described in the previous *paragraph 3.3 - Pert Diagram.*

1. The first one is the *"As planned production"*, while,
2. The second is taking into consideration delays of thirty (30) days occurring by the components provision delay and similarly
3. The third is taking into consideration delays of the provision of the components of sixty (60) days.
4. Finally, the fourth scenario is dealing with the worst case manufacturing duration delays that might slow down the manufacturing process.







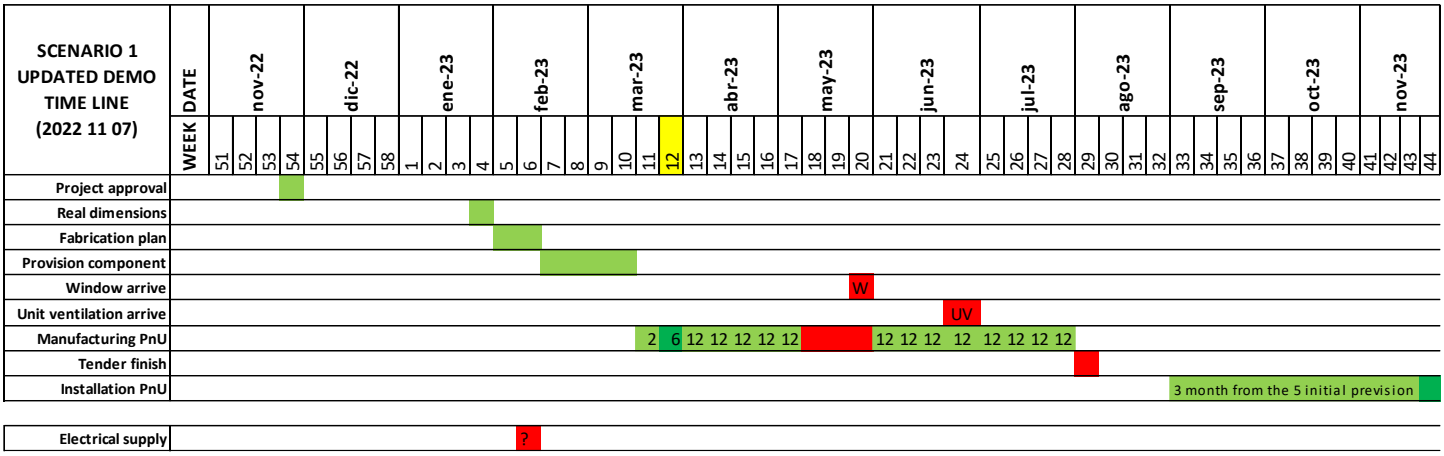


TABLE 28: PRODUCTION PLAN SCENARIOS

3.4.1 *Planned production*

This scenario takes into consideration the best timeline which under the current (at the time that this report was written) conditions seems to be feasible and possible. In brief, the production of Hybrid Wall systems could commence at week 3 (January 23) and finished in week 17 (May 23) in a total of 15 weeks duration, without counting the necessity, of the as described on the above six (6) weeks required for the "Detailed Design" and to do fabrication plans and "Components Provision".

According this scenario the original target date set at the beginning of the project (end of March 223) will not be achieved. In any case, this five (5) weeks delay would not affect the overall project's activities, since the activities of *Task 7.3 - Installation of PLURAL system in Terrassa-Barcelona*, despite the fact that would start earlier, would be dealing with all pre-requisite's to Hybrid Wall installations on site and the overall installation is expected to be completed on time, by the end of July 2023.

However, this scenario doesn't confront any possible delays and/or problems might occur during the manufacturing process, and in case of their occurrence the alternative plans described in *3.4.5. – Alternative Plans paragraph* should be adopted.

In any case according this scenario, the manufacturing process ends three (3) months prior the on-site installation is scheduled to be completed, therefore upon its implementation, no further actions would be required.

3.4.2 *Delay on materials provision (+ 30 Days)*

According to this scenario additional thirty (30) days are added on the *"As planned"* scenario, allocated in the provision of materials. Under this condition, manufacturing would not start as scheduled, but once components would start arriving in the plant, and by Devenlops experience the total delay to finish the manufacturing would be two weeks from last scenario.

This scenario would extend the manufacturing process by two weeks, resulting to manufacturing commencement at week five (5 - February 2023) and completed in week seventeen (17 - May 2023), corresponding at total duration of nineteen (19) weeks.

Similarly to the *"As planned"* scenario, also this scenario doesn't confront any possible delays and/or problems might occur during the manufacturing process, and in case of their occurrence the alternative plans described in *3.4.5. – Alternative Plans paragraph* should be adopted.

Taking into consideration the same comments as on the above paragraph, regarding the completion of manufacturing time related to the on-site installation no further actions would be required.

3.4.3 *Delay on materials provision (+ 60 Days)*

This scenario is dealing with materials and components delay provision of sixty (60) days, which according Devenlops experience might be considered as an extreme and "unlikely to happen" condition. This delay is mainly focused on the provision of the complex / functional components, like windows, unit ventilation of PV tiles.

In such a case and similarly to *paragraph 3.4.2 - Delay on materials provision (+30 days)*, the production could start once the first elements would be arrived in the plant and/or to start the assembly process without the missing components, reducing the possible completion delay to thirty (30) days.

According this scenario, the manufacturing duration would be extended by four (4) weeks, resulting to manufacturing commencement at week seven (7 - February 2023) and completed in week twenty one (21 - June 2023).

Similarly to the *"As planned"* scenario, also this scenario doesn't confront any possible delays and/or problems might occur during the manufacturing process and possibly some additional actions might be required such as weekend or double shifts might need to be considered.

Analyzing this scenario in more detail, depending on the delayed components some remedial actions could be applied during manufacturing process:

- Delay of ventilations units: Would affect only some frames and in such a case the ventilation units could be installed at a later production stage or even at the building site by the traditional construction way.
- Delay of PV panels: Similar comments as on previous point.
- Delay of windows: No remedial actions apart their installation on site with the traditional construction way.

3.4.4 *Worst case scenario (Updated at 15.11.2022)*

According to this scenario, further delays are taken into consideration, mainly in terms of the final design process completion as will be approved by the owner, which under the current conditions is expected to be completed by the last week of January 2023.

This delay could affect:

a. the manufacturing of the windows, since their final dimensions are required for their production and
b. the ventilation unit (which in any case would be delivered in June 2023.

According to this scenario delay of thirty (30) days on the provision of the functional components is considered during the manufacturing process, while at the same time is simulated the requirement to stop the manufacturing process due to the non-delivery of windows.

In such a case, as described in the previous *paragraph 3.4.3 – Delay on material provision (+60 days)*, most of the assembly could start without the windows, corresponding to an actual delay that should not exceed thirty (30) calendar days.

Following this scenario, the manufacturing commencement is estimated at week eleven (11 - March 2023) and should be completed in week twenty eight (28 - July 2023).

Furthermore, if on this scenario will be added the required tendering time for the Spanish demo building, seems that the actual commencement installation date for the Hybrid Wall installation could start at August or September 2023.

This scenario would probably produce four (4) weeks of delay to the finish date of the Hybrid Wall installation in the demo building, and for this case alternative plans have been investigated as *per 3..4.5 – Alternative Plans paragraph*.

3.4.5 ***Alternative Plans***

In order to anticipate all the aforementioned scenarios that could possibly generate delays and to reduce the manufacturing time, some additional remedial actions could be introduced:

- Work at extended and/or double shifts.
  In such a case the manufacturing time could be reduced by three (3) to seven (7) weeks.
- Increase manpower.
  Due to the space limitations on the working stations of the plant, manpower could be increased by only 25%, corresponding to a reduction of three (3) to four (4) weeks.
- Extent working days (weekend work), corresponding to three (3) to four (4) weeks on time production gain.
- Reduce the waiting time for the approval of the final design by the owner.
  Depending on the time reduction up to two (2) months could be gained.

Though, as described in the Smart Wall alternative plans solutions, it has to be noticed that all aforementioned actions are only indicative and not all of them are applicable to every condition might occur. The necessary actions will be chosen to be applied will be selected for each case in particular, depending the nature of delay, its severity and its related cost.

3.5 DEN's Health & Safety Plan

3.5.1 *Company Details*

- Company: DENVELOPS TEXTILES, S.L.
- Address: C/ LUXEMBURG, 9
- Locality: IGUALADA
- Province: Barcelona
- Included in Annex I: No
- C.I.F. B-67162370
- Activity: Metal carpentry
- C.N.A.E.(s): 2512 - Manufacture of metalwork
- Evaluated Work Center: FIXED CENTER – INDUSTRIAL WAREHOUSE + OFFICES
- Address: C/ LUXEMBURG, 9
- Locality: IGUALADA
- Province: Barcelona
- Person in charge: Pere Riba
- Teléfono1: 609 643153

3.5.2 *General Characteristics*

As workplaces, mechanical workshops must be maintained in proper conditions of order and cleanliness and comply with the requirements on temperature, humidity, ventilation, lighting and noise set out in the following legal texts:

- ✓ Royal Decree 486/1997, of 14 April, on workplaces.
- ✓ Royal Decree 286/2006, of 10 March, on noise.
- ✓ Royal Decree 485/1997, of 14 April, on signage.

To define the different environmental conditions that mechanical workshops must meet in accordance with the provisions of the legal provisions in force, the activities carried out in the different areas of work of the Department have been considered on the documentary basis of the actions carried out in said Department by the Occupational Risk Prevention Service of Calvia 2000, supported by visits to the various facilities. In this regard, the following work activities can be considered:

- ✓ Administration and training tasks
- ✓ Control, verification and maintenance operations of Work Equipment
- ✓ Activities typical of mechanical workshops, such as wheel balancing, tire change, etc.

3.5.2..1 Order and cleanliness

Order and cleanliness must be intrinsic to the work. Below, we present specific guidelines for the type of premises that concern us, in this case the mechanical workshops:

- ✓ Keep the workstation clean, preventing dirt, dust, or metal debris from accumulating, especially around machines with moving members. Also, floors must remain clean and free of spills to avoid slipping.
- ✓ Collect, clean and store in the storage areas the tools and work utensils, once their use ends.
- ✓ Clean and maintain properly the machines and work equipment, in accordance with the established maintenance programs.
- ✓ Repair damaged tools or report the fault to the corresponding supervisor, avoiding tests if the corresponding authorization is not available.
- ✓ Do not overload shelves, containers and storage areas.
- ✓ Do not leave objects lying on the floor and avoid spilling liquids.
- ✓ Always place waste and garbage in suitable containers and containers.
- ✓ Arrange instruction manuals and general utensils in a place in the workplace that is easily accessible, that can be used without saturating it and without hiding the tools of habitual use.
- ✓ Always keep the stairs and passage areas clean, free of obstacles and properly signposted.
- ✓ Do not block fire extinguishers, hoses and firefighting elements in general, with boxes or furniture.

3.5.2..2 Temperature, humidity, and ventilation

The exposure of workers to the environmental conditions of mechanical workshops must not pose a risk to their safety and health, nor should it be a source of discomfort or discomfort, avoiding:

- ✓ Humidity and extreme temperatures.
- ✓ Sudden changes in temperature.
- ✓ Annoying drafts.
- ✓ Unpleasant odors.

In addition, the thermal insulation of closed premises must be adapted to the climatic conditions of the site.

3.5.2..3 Lighting

The lighting of the mechanical workshops must be adapted to the characteristics of the activity carried out in them, according to the provisions of Annex IV of Royal Decree 486/1997, of April 14, which establishes the minimum safety and health provisions in work rooms, taking into account:

- ✓ The risks to the safety and health of workers, depending on the conditions of visibility.
- ✓ The visual demands of the tasks carried out.

The different types of lighting will be used according to the circumstances, i.e.:

- ✓ Whenever possible, mechanical workshops should preferably have natural lighting.
- ✓ Artificial lighting should complement natural lighting.
- ✓ Localized lighting will be used in specific areas that require high levels of lighting.

It should be noted that, according to the activity carried out, the minimum lighting requirements in these premises, included in the aforementioned annex IV of Royal Decree 486/1997, of April 14

These minimum levels should be doubled when:

- ✓ There are appreciable risks of falls, collisions or other accidents in general purpose premises and on traffic routes.
- ✓ Given the possibility of visual appreciation errors, dangers are generated for the worker who executes the tasks or for third parties.
- ✓ The contrast of luminance or color between the object to be displayed and the background on which it is located is very weak.

The distribution of lighting levels must be uniform, avoiding sudden variations in luminance within the work area and between it and its surroundings. Also, we must avoid glare:

- ✓ Directions: produced by sunlight or by high-luminance artificial light sources.
- ✓ Indirect: caused by reflective surfaces located in or near the operating area.

No systems or light sources should be used that impair the perception of contrasts, depth or distance between objects within the work area. In addition, these lighting systems must not be a source of electrical, ignition or explosion hazards.

Emergency evacuation and safety lighting should be installed in places where a failure of normal lighting poses a risk to the safety of workers.

3.5.2..4 Noise

Noise levels in mechanical workshops must comply with the provisions of Royal Decree 286/2006, of March 10, on the protection of the health and safety of workers against risks related to exposure to noise. Within the framework of Law 31/1995, on the Prevention of Occupational Risks, the aforementioned Royal Decree establishes that the risks derived from exposure to noise must be eliminated at source or reduced to the lowest possible level, taking into account technical advances. Risk reduction shall take into account:

- ✓ Other working methods involving less exposure to noise
- ✓ The choice of work equipment that generates the lowest possible noise level
- ✓ The design and layout of places and places of work
- ✓ Appropriate information and training to teach workers how to use work equipment correctly with a view to reducing their exposure to noise
- ✓ Technical noise reduction, by means of enclosures, coatings and screens of acoustically absorbent material or by means of damping and insulation that avoid noise transmitted by solid bodies
- ✓ Appropriate maintenance programs for equipment, locations and workstations
- ✓ The organization of work by limiting the duration and intensity of exposure and by properly ordering work.

Based on the risk assessment, a program of technical and organizational measures to be integrated into the planning of the preventive activity of the undertaking shall be drawn up and implemented in order to reduce exposure to noise. Likewise, workplaces where noise levels are reached that exceed the upper exposure values that give rise to an action, must be adequately signaled, in accordance with the provisions of Royal Decree 485/1997, of April 14 (see section 1.2.3 of this manual).

Royal Decree 286/2006 establishes the following exposure values :

- ✓ Exposure limit values, taking into account the attenuation provided by the individual hearing protectors used. LAeq,d = 87 dB(A) Lpico = 140 dB(C)
- ✓ Higher exposure values that result in action, regardless of the attenuation of individual hearing protectors. LAeq,d = 85 dB(A) Lpico = 137 dB(C)
- ✓ Lower exposure values that result in action, regardless of the attenuation provided by hearing protectors. LAeq,d = 80 dB(A) Lpico = 135 dB(C)

In accordance with the provisions of article 6 of Royal Decree 286/2006, of March 10, an evaluation will be carried out based on the measurement of the noise levels to which workers are exposed, within the framework of the provisions of article 16 of Law 31/1995. Similarly, in accordance with the provisions of Article 23 of the Law and Article 7 of Royal Decree 39/1997, the data obtained from the evaluation, as well as the measurements, will be kept in such a way as to allow subsequent consultation.

A representative sampling of the personal exposure of workers may be used for the assessment and measurement of noise and the equipment used must be checked beforehand and after measurements using an acoustic calibrator. Likewise, the evaluation and measurement of noise will be carried out by qualified personnel, in accordance with the provisions of articles 36 and 37 of Royal Decree 39/1997, of January 17.

Every effort should be made to ensure that hearing protectors are used, encouraging their use where this is not compulsory and ensuring that they are used when they are not mandatory.

Under no circumstances shall the exposure of the worker exceed the exposure limit values. If, despite the measures taken, exposures above the exposure limit values are found, the following shall be:

- ✓ Take immediate action to reduce exposure below limit values
- ✓ Determine the reasons for overexposure
- ✓ Correct prevention and protection measures to prevent a recurrence
- ✓ Inform prevention delegates of such circumstances

Persons exposed at their workplace to a noise level equal to or greater than the lower exposure values giving rise to an action and their representatives shall be provided with, inter alia, adequate information and training on, the nature of such risks and the measures taken to prevent them.

Workers whose exposure to noise is greater than the higher exposure values giving rise to an action shall have the right to have their hearing function monitored. Workers whose exposure exceeds the lower exposure values giving rise to an action shall also have the right to preventive audiometric monitoring, where the assessment and measurement reveal a risk to their health. Where the monitoring of hearing function reveals that a worker is suffering from a diagnosable injury, the doctor responsible for health monitoring shall assess whether the injury may be caused by exposure to noise.

- Signage

In workplaces in general and in mechanical workshops in particular, signage helps to indicate those risks that by their nature and characteristics have not been eliminated. Considering the most frequent risks in these premises, the signs to consider are the following:

3.5.2..1 Warning signs of a hazard

They have a triangular shape and the black pictogram on a yellow background. The most frequently used are:

- ✓ Flammable materials. In this type of premises, solvents and paints that respond to this type of risk are often used, using the indicated signal.
- ✓ Electrical risk. This sign must be placed on all cabinets and electrical panels in the workshop.
- ✓ Laser radiation. It shall be used whenever verification and control equipment based on this form of radiation is handled. He has been accompanying the aforementioned teams. If these are fixed, it is advisable to put the sign at the entrance of the enclosure where they are located.

- ✓ Risk of falls at the same level. When obstacles on the ground are difficult to avoid, the corresponding sign shall be placed in a clearly visible place.

When in the workshop there are slopes, obstacles or other elements that may cause risks of people falling, collisions or blows likely to cause injury, or it is necessary to delimit those areas of the work premises to which the worker has to access and in which these risks occur, signage consisting of alternating yellow and black stripes may be used. The bands must have an inclination of about 45º and respond to the following model:

3.5.2..2 Prohibition signs

Round in shape with black pictogram on white background. They have the edge of the contour and a descending transverse band from left to right of red, forming this with the horizontal an angle of 45º.

- Whenever flammable materials are used, the triangular warning sign of this danger must be accompanied by the sign expressly indicating the prohibition of smoking and lighting fires, shown below:

3.5.2..3 Signs of obligation

They are also round in shape. They have the white pictogram on a blue background. Depending on the type of risk they seek to protect, the following should be noted as the most frequent in these establishments:

- ✓ Mandatory vision protection: It will be used as long as there is a risk of projection of particles into the eyes, in operations with grinders, radiales, etc.
- ✓ Mandatory ear protection. This signal will be placed in those work areas where the equivalent noise level or 137 dB(C) peak are exceeded, in accordance with the provisions of article 7 of Royal Decree 286/2006, of March 10.
- ✓ Mandatory foot protection. Of use in those cases in which there is a risk of falling heavy objects, likely to cause injuries of greater or lesser consideration in the feet and the use of safety footwear is necessary.
- ✓ Mandatory hand protection. This signal should be displayed in workplaces where operations involving risks of hand injury (cuts, contact dermatitis, etc.) are performed and high tactile sensitivity is not required for its development.
- ✓ Mandatory head protection: To be used whenever there is a risk of blows to the head or falling objects from an elevated position. It is used, for example, in work under lifting bridges or in pits.

3.5.2..4 Signs relating to fire-fighting equipment

They are rectangular or square in shape. They have the white pictogram on a red background. The most frequent in mechanical workshops are those that indicate the location of fire extinguishers and hoses, that is:

3.5.2..5 Other signs

Depending on the characteristics of the premises and considering its specific risks, the

Mechanical workshops must display other signs warning of the existence of such risks.

In addition, it is worth remembering the obligation to delimit the storage and passage areas, both for vehicles and people, as well as emergency exits and first aid items (first aid kit, emergency showers, eyewashes, etc.).

- Lifting and handling of loads

Work in mechanical workshops sometimes requires maneuvering with heavy parts that involve lifting operations and general handling of loads. Lifting operations are usually carried out with hoists, while handling can be done manually, if the parts are not very heavy, or by mechanical equipment, when they are.

In this section we will review both types of maneuvers, indicating the precautions to be taken into account for their correct performance.

3.5.2..1.1 Polyps and other lifting equipment

They are elementary lifting and lowering work equipment that does not need for their operation more than the effort of the person who has to handle it, although some of this equipment have electric motors for the operations they perform, especially those of lifting and lowering. Moving through a guide is usually done manually.

Next, the general minimum safety requirements contained in Royal Decree 1215/1997, of July 18, which these work teams must meet, whose compliance contributes to preventing the most frequent risks arising from their

Manipulation and that basically are: fall of the load and entrapment between the mobile organs of the equipment.

3.5.2..1.2 Drive devices

If the equipment has an electric motor, its service organs must be clearly visible and identifiable and, if necessary, be labelled appropriately. The indicative colors of these organs are:

- Commissioning or in tension: WHITE / VERDE.
- Stop or start out of tension: RED.
- Emergency stop: RED.

They shall be located in the vicinity of the command post and outside the danger zone.

3.5.2..1.3 Start-up of the equipment

Where the equipment has an electric motor, the start-up must be the result of a voluntary action by the operator on a drive panel set up for that purpose.

After a power failure, its subsequent resumption must not result in the dangerous parts of the equipment being put into operation. In any case, the start-up bodies must be located abroad.

3.5.2..1.4 Stop

The stop order must take precedence over all others. The control organ that allows to obtain this function of emergency stop must be red and placed on a yellow background. The installation of an emergency stop device only makes sense if the stopping time it allows to be obtained is significantly shorter than that obtained with the normal stop, which requires effective braking.

3.5.2..1.5 Risks arising from the handling of hoists

The most frequent risk arising from the manipulation of these work equipment is that of falls and projections of objects.

The possible fall of objects due to both the operation of the equipment and accidental circumstances must be prevented. The preventive measures to be taken shall be designed to protect not only operators but also any other person who may be exposed to these hazards. To this end, the following precautions shall be taken:

- ✓ • The lifting elements, such as the chains, will be checked before being put into service.
- ✓ • When the links suffer excessive wear, have been bent or cracked, they will be cut and replaced immediately.

- ✓ • They shall be wound only on drums, shafts or pulleys which are fitted with grooves to prevent coiling without kinks.
- ✓ • The hooks shall also be of wrought iron and shall be fitted with latches or other devices to prevent the load from falling.

3.5.2..1.6 Maintenance

- ✓ The conditions of use of this equipment, as recommended by the manufacturers, shall be respected.
- ✓ Cleaning and repairs will be carried out with the equipment stopped. As for specific repairs, they will only be carried out by specialized and duly authorized personnel.

3.5.2..1.7 Moving Parts

Two types are distinguished:

Moving transmission elements: Transmission shafts, pulleys, cables and belts are included in this group.

It is generally not necessary during normal operation of the equipment to access these organs, being necessary to prevent them from being reached. To this end, protective devices shall be fittedto completely isolate dangerous elements. All hazardous mechanical elements such as gears, pulleys, cables, winding drums, etc., must have effective protective housings that avoid the risk of entrapment.

Mobile work elements: They are those that exert a direct action on the material and develop their action in operation. The equipment shall be fitted with fixed protectors in parts where access is required only exceptionally or with little frequency.

3.5.2..1.8 Separation of energy sources

With regard to electrical energy and in those cases in which the hoist has a motor driven by this energy source, separation can be ensured by:

- Parade arrow.
- Maneuvering cut-off wrench.

3.5.2..1.9 Signage and warning

There will be a clearly visible maximum load sign in Kg., being strictly forbidden to exceed said load. Also, the up and down buttons will be correctly identified.

The route of the loads must be monitored, both during the elevation and in the descent, as well as in the displacements and must go in such a way as to avoid landslides.

3.5.2..1.10 Other considerations

Any hoist must bear its corresponding CE marking. If its acquisition has been prior to 1995 and lacks such marking, it will be brought into conformity, in accordance with the provisions of Royal Decree 1215/1997, of July 18.

All equipment will have the corresponding instruction manual and maintenance book and revisions in Spanish provided by the manufacturer.

3.5.2..1.11 Cargo handling

Load handling is a frequent activity in mechanical workshops. As a general rule, whenever possible, the handling of loads shall be carried out by appropriate and safe mechanical means.

However, when, due to the characteristics of the work, it must be carried out manually, the prescriptions established in Royal Decree487/1997, of 14 April, will be taken into account. The aforementioned legal text requires assessing the risk considering the following factors:

- ✓ Characteristics of the load
- ✓ Physical effort required
- ✓ Characteristics of the working environment
- ✓ Requirements of the activity
- ✓ Individual characteristics of the worker

In addition to assessing the risk, appropriate measures must be taken to carry out the work safely and adequate health surveillance of the workers concerned shall be ensured.

Likewise, information and training will be provided to workers on the correct way to handle loads and their participation in the proposal of improvements aimed at handling them in the safest possible way will be encouraged.

Techniques of standup will be used whose basic principle is to keep the back straight and to make the effort with the legs, namely:

- ✓ Support your feet firmly
- ✓ Separate the feet at approximately 50 cm from each other
- ✓ Bend the hips and knees to catch the load well attached to the body

- ✓ Keep your back straight and use leg strength
- ✓ If the load is too heavy or bulky, use the help of mechanical means or lift it between several people.

- Hand tools and portable machines

Both hand tools and portable machines are elements of special relevance in the daily work of mechanical workshops. Although for a better knowledge of the risks arising from handling and the measures to be taken to avoid or minimize them, it is possible to resort to the corresponding manual, its importance and frequency of use in this type of workplace, it is advisable to pay them a brief attention in this document, highlighting some of the essential aspects to be considered.

3.5.2..1 Hand tools

The handling of tools such as hammers, screwdrivers, pliers, various wrenches, etc., is common in the workshops considered, because many of the operations carried out in these premises can only be carried out manually.

Although apparently harmless, when used improperly they can cause injuries (injuries and bruises, mainly) that occasionally have some consideration, to the point that 7% of all accidents and 4% of those classified as serious, have their origin in the manipulation of a manual tool.

Although the causes of these accidents are very diverse, the following can be cited as more significant:

- ✓ Poor quality of tools.
- ✓ Improper use for the work done with them.
- ✓ Lack of experience in its handling by the worker.
- ✓ Insufficient maintenance, as well as incorrect transport and siting.

In accordance with these considerations, the general recommendations for the correct use of hand tools, to avoid accidents that may originate are the following:

- ✓ Conservation of tools in good condition of use.
- ✓ Use of the appropriate tools for each type of work to be done.
- ✓ Appropriate training of workers in the handling of these work items.
- ✓ Transport them safely, protecting the edges and tips and keep them tidy, clean and in good condition, in the place intended for this purpose.

3.5.2..2 Portable machines

These elements play an increasingly important role in mechanical workshops, as they spare the worker the fatigue involved in the use of hand tools, providing enough energy to carry out the work faster and more efficiently.

The causes of accidents with this type of machines are very similar to those indicated for hand tools, that is, poor quality of the machine; improper use; lack of experience in handling, and insufficient maintenance, if in portable machines must also be added, those derived from the energy source that moves them: electrical, pneumatic, and hydraulic. It should also be noted that accidents involving this type of machinery are usually more serious than those caused by hand tools.

Although the risks caused by portable and prevention machines are studied in greater depth in the corresponding manual, it has been considered appropriate to review here the most frequent, that is:

- ✓ The ions produced by the tool, both by direct contact and by breakage of said element.
- ✓ Injuries caused by the power supply, i.e. those derived from electrical contacts, breaks or leaks from compressed air pipes or hydraulic fluid, leaks of high-pressure fluids, etc.
- ✓ Injuries caused by the projection of particles at high speed, especially ocular ones.
- ✓ Alterations of hearing function, because of the noise they generate.
- ✓ Osteoarticular injuries derived from the vibrations they produce.

- General work teams

The machines and work equipment used in mechanical workshops must comply with legal requirements that guarantee the safety of the workers who handle them, as well as the patrimonial assets of the company. These requirements are set out in two legal texts, namely:

- ✓ Royal Decree 1435/1992, of 27 November, of approximation of the legislations of the States members on machines, modified by the Royal Decree 56/1995, of 20 January.
- ✓ Royal decree 1215/1997, of 18 July, by which establish the minimum dispositions of security and health for the utilization by the workers of los teams of work.

The first of these texts requires, in general terms, that all new machinery and work equipment must bear the CE marking and an EC declaration of conformity. This requirement always applies:

- ✓ To all new machines, even if they do not present any risk to the safety of users
- ✓ To all those that are of own manufacture, even if they are not marketed
- ✓ In cases where machines or parts of machinery of different origins are assembled

The above requirement shall not apply where interchangeable equipment is attached to machinery or tractor.

The EC declaration of conformity certifies that the machinery or work equipment satisfies the essential safety requirements, and its signature is possible for the affixing of the CE mark to the machinery or equipment concerned.

As for equipment and machines manufactured before 1 January 1995 that do not have a CE marking, they must be brought into conformity in accordance with the provisions of Royal Decree 1215/1997, of 18 July.

One way to address the legal problems generated by machines and work equipment is to make an inventory that allows us to know exactly the existing deficiencies.

- Chemical storage and handling

Chemicals such as oils, drills, fuels, paints and solvents are frequently used in mechanical workshops. Some of these products can be dangerous, being classified as harmful, easily flammable, irritating, etc.

3.5.2..1 Identification

For their correct handling and storage, it is essential that the user knows how to identify the different dangerous products through the signage established by Royal Decree363/1995, of March 10, which approves the Regulation on the declaration of new substances and classification, packaging and labeling of dangerous substances. This legal text has undergone numerous modifications, the last of which has been given rise by Royal Decree 99/2003, of 24 January.

To make it easier for the user to identify these substances, the Regulation has made it compulsory to put on the label symbols (pictograms) drawn in black on a yellow-orange background, which represent the danger of each type of product.

3.5.2..2 Storage Plan

For its correct storage, an adequate plan must be established that allows, in case of leak, spill or fire, to know accurately and quickly the nature of the stored products, their characteristics, quantities and location, to act in sequence. It is also advisable to distribute the surface of the warehouse in different areas clearly marked by letters or numbers, which facilitate its identification.

The data that a storage plan must contain are:

- ✓ Daily updated inventory of stored products, indicating the maximum permissible quantity of the total set.
- ✓ Maximum permissible quantity of each class of products.
- ✓ Areas of the warehouse where the different types of products are located.
- ✓ Actual stored quantity of each product.
- ✓ Control of warehouse inputs and outputs, which allows to know, always, the movements of the different products. It should be carried out by means of a computer application, outlining the product type, quantity, date of entry, date of departure and particular observations.

Also, to achieve a safe storage of dangerous products there are two basic types of measures to be taken:

- ✓ Storage in separate premises
- ✓ Sufficient separation of stored products

Dangerous substances and preparations should be grouped by class, avoiding the joint storage of incompatible products and maximum quantities.

It should be pointed out that, because of their intrinsic characteristics, certain classes of products are incompatible and can react violently with each other and should therefore not be stored together, from certain quantities.

It should be borne in mind that in case of leakage or fire, packaging may be damaged and, consequently, incompatible products may come into contact leading to dangerous reactions. By way of example, combustible and oxidizing products should not be stored because their contact causes very violent exothermic reactions which can cause fires. Toxic products with oxidizing or flammable products should also not be stored.

As additional security measures must be taken into account those that are

Oriented to the prevention of fires, among which it is worth noting:

- ✓ Smoking ban.
- ✓ Prohibition of using open flames or ignition sources.
- ✓ Use only authorized electrical equipment.
- ✓ Prohibition of unauthorized vehicles entering the warehouse.
- ✓ Do not carry out work in the warehouse that produces sparks or that generates grinding, welding, grinding. If, exceptionally, any of these works must be carried out, it must be authorized by the person in charge of the warehouse and establish all the necessary security measures to carry out the work properly.

3.5.2..3 Chemical handling

In order to carry out the storage operations themselves and others related to them that involve the handling of the products (packaging, transfer, connection and disconnection of tubes for filling containers and containers, sampling, etc.) work instructions must be established.

These instructions may relate both to a specific product and to a class of products with similar characteristics. Thus, the work instructions should include the following aspects:

- ✓ Work area and activity developed.
- ✓ Identification of the hazardous substance.
- ✓ Risks to humans and the environment.
- ✓ Protective measures and behavior patterns.
- ✓ Storage incompatibilities.
- ✓ Action in case of danger.
- ✓ First aid to be applied in case of accident.
- ✓ Conditions for disposal and disposal of waste

Where it is necessary to transfer a chemical, whatever its nature, from a container to a smaller container, it shall be carried out with due precautions:

- ✓ If the original container has a tap, it will be done by gravity by opening it slowly.
- ✓ If the original container does not have a tap, a vacuum pump specially designed for this purpose will be used, being strictly forbidden to suck with the mouth to make the vacuum through a tube.
- ✓ Once the product has been transferred to the destination container, it must be labelled in the same way as the original packaging.
- ✓ In the event of an accidental spill or spill, the following procedure shall be carried out in general terms:
- ✓ If it is a solid, it will be collected by aspiration, avoiding sweeping, since it could cause the dispersion of the product through the atmosphere of the premises.
- ✓ If it is a liquid, the drains will be protected, treated with absorbent materials (such as diatomaceous earth) and deposited in suitable containers to remove it as waste. When necessary, before treating it with absorbent, it will be inertisized, for which the corresponding safety data sheet will be consulted and in case of doubt, it will be treated with the supplier.

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3.5.2..4 Gas cylinder handling

The handling of gas cylinders shall be carried out only by persons duly trained for this purpose. The use of these elements by inexperienced workers can pose serious risks, such as leaks of toxic and toxic gases, fires and explosions.

Before using a bottle, the label should be read to ensure that it is the one you intend to use. In case of doubt about its content or form of use, consult the supplier. Likewise, any bottle that has expired the date of the periodic test, as established by the Regulation of Pressure Equipment, will be returned to the supplier.

The taps of the bottles will open slowly and progressively. In the event of any difficulty in opening, it shall be returned to the supplier, without forcing or using it.

Any tool, since there is a risk of breakage of the tap, with the consequent escape of the pressurized gas. Bottle taps should not be greased, as some gases, such as oxygen, react violently with greases, producing explosions.

For the transfer of the bottles to the different points of use, bottle trucks will be used, being completely prohibited their dragging or rolling, since dents and deterioration may occur in the walls, reducing their mechanical resistance. However, for small movements, it can be moved by turning it along its base, once it has been slightly tilted. In all cases, gloves and safety footwear will be used, which must be free of grease or oil for the reason given above.

If, as a result of an accidental blow, a bottle is damaged, marked or has a slit or cut, it shall be immediately returned to the gas supplier, even if it has not been used.

Once the bottle has been placed at the place of use, it must be properly fixed, for example with chains, thus avoiding the risk of falling, which could cause injury to persons or gas leaks due to broken connections. This operation must be adequately supervised.

Gas cylinders must never be used as a support for striking pieces, priming arches and soldering on them. The effects that such actions produce on the bottle can decrease its mechanical strength, with the following risk of leakage and explosion.

When a gas cylinder has to be opened, the exit of the tap in an open position to the worker shall be arranged and in no case shall it be directed towards persons in the vicinity. In this way, projections of pressurized gas or accessory elements are avoided, in the event of failure or breakage.

The transfer between bottles is an extremely dangerous operation and must be expressly prohibited.

Where it is necessary to use gas flow rates greater than the cylinder can supply, several parallel connected cylinders or cylinder blocks shall be used. In no case will methods such as heating be used, as this practice poses a danger of explosion.

Once the work with the bottle is finished, the regulation screw and the pressure reducer will be loosened, and the tap will be closed.

Gas cylinders should not be used in enclosed or confined spaces without ensuring adequate ventilation. The exhaust or accumulation of gas has been the cause of serious accidents. Carrying out such operations requires obtaining a work permit.

In no case, the user should paint the gas cylinders, much less alter or change their colors. The color of the bottle is an important element of security, which quickly informs about its contents.

In the event of a leak in a gas cylinder, it will be necessary to intervene quickly, following the steps indicated:

- ✓ Identify the gas.
- ✓ Stock up on the necessary equipment, which for toxic, harmful or corrosive gases must be an autonomous breathing apparatus.

3.5.2..5 Waste management

The handling of chemical products often involves the generation of waste that needs to be properly treated. In this regard, the European Union defines the lines of action to be followed and which are basically three, namely:

- ✓ Minimize the generation of waste at its source. It involves intervening preventively, preventing them from occurring. It is necessary to act on consumption, trying to use only the amount of product required for the work to be developed.
- ✓ Recycling. It aims to reuse the waste generated, in the same or another process, as raw material.
- ✓ Safe disposal of non-recoverable waste. It must be carried out in accordance with the indications in the safety data sheet or, in case of doubt, the manufacturer's instructions and always through an authorized manager. As a step prior to disposal, it is essential that the waste is sorted, segregated, and deposited in appropriate containers.

3.5.2..6 Safety data sheets

Where it is necessary to prepare work instructions for the correct handling of chemicals or whenever information is required on the products available in the warehouse and in work areas in general, so-called safety data sheets should be used. Therefore, the existence of an updated inventory of the products in use allows to carry out a strict control of such documents that in turn, offer the necessary information to properly handle the products.

The legal obligation to deliver these sheets to the user of chemical products, by the manufacturer or importer of such products, is established in Royal Decree 255/2003, of February 28, which approves the Regulation on classification, packaging and labeling of dangerous preparations. In accordance with the provisions of Article 13 of the aforementioned Regulation, the safety sheet must be drawn up, at least, in the official Spanish language of the State, including the following 16 headings:

1. Identification of the preparation and the person responsible for its marketing.
2. Composition/information about the components.
3. Identification of hazards.
4. First aid.
5. Fire-fighting measures.
6. Measures to be taken in case of accidental spillage.
7. Handling and storage.
8. Exposure/personal protection controls.
9. Physical and chemical properties.
10. Stability and reactivity.
11. Toxicological information.
12. Ecological information.
13. Disposal considerations.
14. Information relating to transport.
15. Regulatory information.
16. Other information.

3.5.3 ***Specific Activities***

- Special work teams

Depending on the activity they carry out, mechanical workshops require machines and work equipment specially designed to perform the usual operations. Among such equipment and machines, the following are described in this manual:

3.5.3..1 Machine tools

Non-portable motor-driven machines intended for metal machining, understood as the set of cold forming operations with chip removal, by means of which the shape and dimensions of a metal part are modified. These machines give the tool and the part to be formed the precise movements, so that the required shape and dimensions are reached. Among the machine tools, some stand outas: lathes, drilling machines, boring machines, milling machines, broaching machines, grinding machines and others that perform operations derived from the ones.

The following describes the minimum general safety requirements contained in Royal Decree 1215/1997, of July 18, already mentioned, which must be met by machine tools, whose compliance contributes to preventing the most frequent risks arising from the handling of this equipment and that basically They are: ACCI dental contact with the moving tool or part; entrapment with the machine's motion organs; projection of the working piece or tool, and dermatitis due to contact with cutting fluids used as coolants.

3.5.3..1.1 Action Organs:

The service organs of such machinery must be clearly visible and identifiable and, if necessary, be appropriately labelled. The indicative colors of these organs are:

- ✓ Commissioning or in tension: WHITE.
- ✓ Stop or put out of tension: BLACK.
- ✓ Emergency stop: RED.
- ✓ Suppression of abnormal conditions: YELLOW.
- ✓ Rearmament: BLUE.
- ✓ Command organs may be of the following types:
- ✓ Pushbutton: Except for the stop button, they must be embedded.
- ✓ Pedal: Protected against involuntary drives.
- ✓ Parallel bar: According to current regulations it should not be used.
- ✓ Two-hand control: It will be push-button type. It must have synchronism and be effective against mockery.

They shall be in the vicinity of the command post and outside the danger zone, with the exception of the emergency stop zone. Likewise, from the command post the entire area of operation will be dominated. Otherwise, the start-up will be preceded by an acoustic warning signal or warning.

3.5.3..1.2 Commissioning

It must be the result of a voluntary action by the operator on a drive device placed for that purpose.

After a power failure (electrical, pneumatic, hydraulic), its subsequent resumption must not lead to the start-up of the dangerous parts of the machinery.

A machine tool must be prevented from starting:

- ✓ By the closure of a guard with interlocking device.
- ✓ When a person withdraws from an area covered by a sensitive device, such as an immaterial barrier.
- ✓ By maneuvering an operating mode selector.
- ✓ By unlocking an emergency stop button.
- ✓ For the rearmament of a thermal protection device.

The stop order must take precedence over all others. The following are considered:

3.5.3..1.3 Types of stops:

- ✓ General stop: Every machine tool must have a category 0 stop, i.e. immediate suppression of energy from the machine actuators.
- ✓ Stop from the workstation: This is intended to allow an operator to stop the machine when he has to intervene in a dangerous area for a specific operation. In turn, this type of stop can be:
  a. Category 1, so that when the stop function is sorted, it occurs when the machinery is in a safe position
  b. Category 2, so that when ordering the stop function the machine stops at that moment, but keeps its energy sources activated.
- ✓ Emergency stop: Operated by a device that must allow the machine to stop in the best possible conditions, by means of an optimal deceleration of the moving parts. This stop can be category 0 or category 1.

The control organ that allows to obtain this function of emergency stop (button of hand, cable, bar, etc.) must be red and placed on a yellow background. The installation of an emergency stop device only makes sense if the stopping time it allows to be obtained is significantly shorter than that obtained with the normal stop, which requires effective braking.

3.5.3..1.4 Falls and projections of objects

Chip spraying and splashing of cutting fluids and the possible fall of objects due to both the proper operation of the machine and accidental circumstances must be prevented.

The preventive measures to be taken shall be designed to protect not only operators but also any other person who may be exposed to these hazards. They shall consist essentially of equipping machinery with fixed or movable guards of adequate strength and of placing obstacles or any other means to prevent persons close to them from being exposed to these risks.

3.5.3..1.5 Emission of gases, vapors, liquids, and dusts

Where there may be a risk of emission of some of these elements (e.g. cutting fluid mists) in a machine tool, care should be taken to capture them at their own source by means of a localised extraction device, integrated in the shelters or housings. The type of emission produced will be studied in each case and the extractor element will be designed according to its characteristics.

- ✓ The conditions of use of these machines as recommended by the manufacturers must be complied with.
- ✓ Careful care will be taken to maintenance, especially when it is not possible to place effective protectors and a correct adjustment will be made.
- ✓ Cleaning and repairs will be carried out with the machine stopped. As for specific repairs, they will only be carried out by specialized and duly authorized personnel.

3.5.3..1.6 Mobile Parts

In general, two types of mobile elements are distinguished, whose description coincides with those addressed in section 1.3.1 referring to Hoists.

3.5.3..1.7 Separation of energy sources

With regard to electrical energy, separation can be ensured by:

- ✓ A switch-isolator.
- ✓ A circuit breaker that has the sectioning function.
- ✓ An outlet for an intensity less than or equal to 16 amps and a total power of less than 3 KW.

Separation devices must provide every guarantee that each position (open/closed) of the organ of the device corresponds immutably to the position (open/closed) of the contacts.

3.5.3..1.8 Signage and warning

In the case of machinery which, after adapting appropriate protective measures, a residual risk persists, it must be adequately marked by standardized indicators.

The machine shall be located in a level and firm place. Likewise, the location area will be clean, dry and ventilated.

It will have an electrical service headed by an adequate differential with its corresponding circuit breaker and watertight type connection belt, in accordance with the provisions of the Low Voltage Electrotechnical Regulation. Machines shall not be in places that may give rise to a risk of falling from height.

Personnel handling this type of machinery shall be duly authorized and specifically trained.

The machinery must be fixed in such a way that there is no undesirable movement caused by vibration.

Before starting a machine, it will be checked that no one is handling it.

3.5.3..1.9 Other considerations:

Any machine tool must bear its corresponding CE marking. If it was acquired prior to 1995 and does not have such a marking, it shall be brought into conformity.

All machines will have the corresponding instruction manual and maintenance book and revisions in Spanish provided by the manufacturer.

- Welding and oxyfuel operations

Welding can be considered a process with heat input, by which two metal pieces are joined, and may or may not intervene another substance or material foreign to the pieces, or of the same nature.

This type of operation is usually frequent in mechanical workshops and despite its apparent simplicity, it should never be forgotten that energy sources capable of reaching temperatures around 3000 °C are handled, constituting ignition sources that can cause fires, explosions, burns and injuries of various considerations, as well as the generation of fumes of varied nature, inhalation of which may affect the health of exposed persons.

These possible risks require a deep knowledge on the part of the users, both correct functioning of the equipment, and of the circumstances of the environment that may lead to more or less serious accidents. Although for a better knowledge of the risks arising from welding operations and the measures to be

taken to mitigate them, it is possible to resort to the corresponding manual, its importance and frequency of use in these workplaces, it is advisable topay due attention to them in this manual.

Depending on the heat source, welding can be electric, when it uses this type of energy or autogenous, when the heat comes from the combustion of a gas. In turn, electric welding can be by resistance or arc.

3.5.3..1 Welding of electronic and electrical material

The welding used for this application is usually known as resistance welding, based on the JOULE effect, by which the heat needed to melt the metals involved in the operation (usually tin) comes from the heat produced by heating an electrode that acts as an electrical resistance when passing a certain intensity of current:

Q = I2 . R . t . 0,24

This type of welding presents few risks (mainly thermal and electrical contacts) although it is convenient to take into account some general recommendations, namely:

- ✓ Before starting the work, check that the electrical equipment and instruments are in perfect conditions of use. When finished, do not remove the plug from your plug by pulling the cable, but from the plug itself.
- ✓ Arrange the resistance soldering iron in a suitable support, orienting the electrode in the opposite direction to where the operator is and while it is hot should not be left on the work table.
- ✓ Do not store the soldering iron until the electrode is at room temperature.
- ✓ Avoid inhalation of fumes that occur in welding, especially when using flux resins.

3.5.3..2 Arc welding

In this type of welding, the heat source comes from the electric arc that is produced by approaching two metal elements in tension.

The most frequent risks arising from this type of welding are basically:

- ✓ Electrical contact
- ✓ Thermal contact
- ✓ Fire
- ✓ Smoke inhalation

In turn, the precautions to take into account to avoid these risks are the following:

3.5.3..3 Handling and transporting equipment

- ✓ All conductors, both those supplying power to the group and welding, must be protected during transport or use, against possible mechanical damage.
- ✓ Connection cables to the network, as well as welding cables, must be wound to be transported and will never be pulled to move the machine .
- ✓ If any damaged cable or element is observed, it must be notified and repaired immediately, and should not be used under any circumstances.

Secure connection of the equipment to be welded

- ✓ The connection terminals of the supply circuits must be isolated and protected. In addition, the outer surface of the electrode holders must be insulated in contact with the hand.
- ✓ The dough or return clamp must be rigidly fixed to the piece to be welded, and the distance between the point to be welded and the clamp must be minimized.
- ✓ Never use the metal structures of buildings, pipes, etc., as return conductors, when these are not the piece to be welded.

Indoor welding

- ✓ When working in narrow places or small enclosures, fresh air, never oxygen, shall be continuously breathed in to remove gases, vapors and fumes.
- ✓ If it is not possible to ensure good ventilation, respiratory protective equipment with air supply should be used.
- ✓ Use both inner and outer clothing that is hardly flammable.
- ✓ If welding work is carried out in highly conductive places (boilers, metal pipes, tunnels, etc.) voltages exceeding 50 v shall not be used, and the welding equipment must remain outside the premises where the worker operates.

Personal protective equipment

- ✓ For arc welding, personal protective equipment shall consist of the following elements:
- ✓ Face and eye protection screen.
- ✓ Long leather gloves.
- ✓ Leather apron.
- ✓ Quick-opening gaiters, with pants above.
- ✓ Insulating safety footwear.

General precautions

- ✓ Welding in places where flammable products are stored should be avoided. If necessary, the room shall be ventilated until there are no traces of substances in the indoor atmosphere which may give rise to a risk of fire or explosion.

- ✓ Since electric arc welding reaches very high temperatures, a large amount of smoke is often generated, which should be avoided as much as possible. For this, the use of welding tables provided with localized extraction is used and if the parts to be welded are large, mobile extraction mouths are used. These precautions should be taken when welding operations are carried out on galvanized or painted parts with lead chromate or coated with antioxidant primers of minimum. If it is not possible to use this type of general protection, the use of individual respiratory protection should be used.

3.5.3..4 Autogenous welding and oxyfuel operations

In this type of welding, as well as in oxyfuel, the heat source comes from the combustion of a gas, in many cases acetylene.

The most frequent risks arising from this type of operation are very similar to those of electric arc welding, with some exceptions, namely:

- ✓ Thermal contact
- ✓ Fire
- ✓ Smoke inhalation
- ✓ Falling bottles

According to these considerations, the precautions to be considered to avoid such risks are:

3.5.3..4.1 Bottles

- ✓ Gas cylinders must be adequately protected to prevent falls, either by clamps on the wall or fixed to forklifts in case of mobile equipment.
- ✓ Check the last official test date, which must be in the period of validity.
- ✓ Acetylene valves without a flywheel must always be fitted with the corresponding key for handling in an emergency.

3.5.3..4.2 General security conditions

- ✓
- ✓ it should be checked that neither gas cylinders nor the equipment attached to them are leaking.
- ✓ Protect bottles against dangerous shocks and heating.

- ✓ Before attaching the pressure reducing valve, the bottle valve should be opened for a short period of time to remove dirt.
- ✓ The hoses must be in perfect condition and admit the maximum working pressure for which they have been designed.
- ✓ All hose joints must be fixed by clamps, to prevent accidental disconnection.
- ✓ All connections must be completely watertight. The check should be done by neutral soap solution. An open flame should never be used.
- ✓ The gas outlet should not be checked by keeping the torch directed against parts of the body, as the gas-air mixture can ignite by scattered sparks and cause severe burns.
- ✓ The torch must operate correctly at the working pressures and flow rates indicated by the supplier.
- ✓ Upon completion of the work, the valve of the cloth should be closed and the pressure reducing valve purged. In addition, appliances and pipes must not be stored in closed cabinets or toolboxes.
- ✓ As in electric arc welding, in autogenous welding and oxyfuel very high temperatures are reached, producing many fumes. In order to avoid this problem, you can resort to the use of welding tables provided with localized extraction or moving extraction mouths, if the parts to be welded are large. These precautions should be taken when welding galvanized or coated parts with lead or minimum chromate. If it is not possible to use this type of general protection, the use of individual respiratory protection should be used.

3.5.3..4.3 Personal protective equipment

The personal protective equipment to perform autogenous welding and oxyfuel operations is very similar to that used in electric welding and basically consists of:

- ✓ Adequate protective glasses.
- ✓ Long leather gloves.
- ✓ Leather apron.
- ✓ Quick-opening gaiters, with pants above.
- ✓ Insulating safety footwear.

- Compressed air circuits

Compressed air has many applications in mechanical workshops, including:

- ✓ Tire inflation

- ✓ Feeding certain tools
- ✓ Distribution of fats and oils
- ✓ Airbrush painting

The main risks presented by these installations are compressor explosion; hearing loss caused by the noise generated by the compressors; projection of particles from blower nozzles and direct exposure to compressed air jet.

The essential element of a compressed air installation is the compressor, whose tank is subject to the regulations affecting pressure vessels, and must also:

- ✓ Periodically check the functioning of the control and safety organs and in particular the pressure gauge and the safety valve.
- ✓ Perform inspections and regulatory tests of the air tank.
- ✓ Clean the inside of the compressed air containers every year, to remove the remains of oil and char that they may contain.

Compressors must be soundproofed or placed in enclosed areas and separated from the rest of the workshop.

As far as blowing nozzles are concerned, they can be dangerous because of their ability to disperse dust particles and liquids in the form of aerosols. General protective measures are recommended:

- ✓ Feed them with a pressure of less than 2,5 bar, using a reducer if the inlet pressure is higher.
- ✓ Use models equipped with diffuser, to reduce the projection of solid matter.

In either case, appropriate eye protection should be worn and if the noise level generated is above 87 dB(A), hearing protection should also be worn, and the indications given in Table III should be followed.

The use of blower nozzles should be prohibited in the following cases:

- ✓ Drying of parts after a degreasing operation with solvents. Drying should be carried out under a suction hood.
- ✓ Cleaning of elements and parts with high dust content, since the dispersion of particles occurs through the atmosphere of the workshop.
- ✓ Drying or blowing of work clothes. This bad practice, quite common in workshops, can cause serious injuries to the eyes, such as insertion of foreign bodies and retinal detachment, as well as in the ears. If compressed air penetrates under the skin through small wounds, it can cause sudden swelling and if it penetrates a vein it can lead to a gas embolism, leading to death.

- Work with high pressure fluids

The handling of liquids or gases at high pressure gives rise to a characteristic risk consisting of accidental injection of the fluid into human tissues.

There are several types of fluids that can be handled at high pressure, especially in the operations listed below:

- ✓ Washing of components and parts with hot or cold water, containing additives (detergents, antifouling, plasticizers, etc.) which are projected at a pressure of about 100 or 150 bar.
- ✓ Greasing of components with high pressure gun, performing the operation at about 250 or 300 bar.
- ✓ The preventive measures to be taken when working with high-pressure fluids are as follows:
- ✓ Periodically check the safety devices of the generator sets (pressure gauges, safety valves, emergency stop devices, etc.).
- ✓ Check the firing device maintained on all guns.
- ✓ Check the condition of hoses and flexible tubes and avoid contact with sharp edges and edges during use.
- ✓ Never place your hand in front of the gun, a valve or an injector, even when protected with a cloth or gloves, when the installation to which they are connected is under pressure.
- ✓ Never disassemble a piece of equipment, without making sure that the pressure has been canceled.

- Washing, cleaning, and degreasing

Two fundamental types of cleaning are carried out in mechanical workshops:

- ✓ Washing of components by machines that work with water at different pressures and temperatures, and to which various products such as detergents, waxes and brighteners are added.
- ✓ Cleaning of disassembled parts or subassemblies, consisting of removing dust, degreasing and washing, before making any repair.
- ✓ The risks arising from these operations are basically:
  Projection of foreign bodies (mud, gravel, dust...) by dynamic effect of the water or air jet, when compressed air nozzles are used.
- ✓ Wounds caused by the impact of the jet of pressurized liquid.
- ✓ Burns caused by contact with the jet of hot water or steam, or by contact with the washing lance.

- ✓ Respiratory disorders due to inhalation of vapors containing the indicated additives and dermatitis, due to contact with these products.
- ✓ Falls to the same level due to slips on wet ground.
- ✓ The preventive measures to be taken against these risks are:
- ✓ Use glasses, gloves, boots, and waterproof apron.
- ✓ Organize the workstation so that workers circulating in the vicinity of the washing area cannot be reached by the jet.
- ✓ Ensure the good condition of the electrical installation and the grounding of all equipment.
- ✓ Cover the floor of the washing areas with a non-slip material or paint.
- ✓ Have good ventilation of the washing area when the operation is carried out inside a building.
- ✓ Do not use flammable products for washing parts.
- ✓ If parts are cleaned or degreased in bathrooms, use facilities equipped with localized extraction and articulated covers.
- ✓ Avoid the use of solvents for hand washing as they can cause contact dermatitis and other conditions by absorption through the skin.

- Battery work

It is a very frequent activity in mechanical workshops, which involves the following

Main risks:

- ✓ Detachment of hydrogen and oxygen, weakly when the battery is at rest, and in considerable quantity when it is in charge, which can generate explosive atmospheres.
- ✓ Possibility of burns if the electric arc occurs when a metal part or tool puts both terminals in contact.
- ✓ Splash sulfuric acid.

Measures to prevent them include:

- ✓ Do not smoke and avoid the presence of open flames, ignition sources or sparks, as well as welding operations, in the vicinity of battery storages, as well as in cargo areas.
- ✓ Loading areas must be independent of the workshop and adequately ventilated. In addition, they must have explosion-proof lighting.
- ✓ Loosen the plugs of the vessels to facilitate the evacuation of gases, avoiding overpressures that can lead to blowouts.
- ✓ Work with fully insulating tools, avoiding depositing metal elements on top of the battery that can cause short circuits.
- ✓ Disconnect them begin with it by the negative (-).

- ✓ When it is necessary to start a vehicle that has the battery discharged, using the battery of another, two cables of different colors must be used, connecting the poles of the same sign. When performing the operation, the connection will first be established on the charged battery and later, contact will be made on the other battery.
- ✓ When handling sulphuric acid, the acid should be poured into the water and never the other way around, to avoid dangerous projections.
- ✓ Before discarding traces of excess acid, it must be diluted with water and chemically neutralized, and a lime slurry may be used.
- ✓ The personal protective equipment for handling this product is glasses or screen for handling chemical products, antacid gloves and boots.
- ✓ Near the battery charging room, an eyewash device and an emergency shower should be installed.

3.5.4 *Actions In Case Of Emergency - First Aid*

Rapid action in the event of an accident can save a person's life or prevent the worsening of possible injuries. Therefore, it is important to know the basic actions of immediate attention in case an accident occurs during the development of the work. In addition, it is necessary to place in a clearly visible place, the telephone number for emergencies.

- General tips

STAY CALM to act with serenity and speed, giving tranquility and confidence to the fans.

(go EVALUATE THE SITUATION before acting, carrying out a rapid inspection of the situation and its environment that allows to start the so-called PAS behavior (protect, warn, help):

PROTECT the injured person by ensuring that both he and the person who helps him are out of danger. This is especially important when the atmosphere is not breathable, a fire has occurred, there is electrical contact, or a machine is running.

Immediately notify both the health services, so that they go to the scene of the accident to provide their specialized help. The notice should be clear, concise, indicating the exact place where the emergency occurred and first impressions about the symptoms of the affected person or persons.

HELP the injured person or persons starting with a primary evaluation. Are you conscious? Do you breathe? Do you have a pulse? A person who is unconscious, does not breathe and has no pulse should undergo Cardio-Pulmonary Resuscitation (CPR).

DO NOT MOVE the injured person.

DO NOT GIVE DRINK OR MEDICATE to the injured.

- How to act in case of bleeding?

A hemorrhage is the outflow of blood from blood vessels:

- ✓ Arteries (bright red blood gushing out)
- ✓ Veins (dark red blood that comes out continuously).

The severity of a bleed depends on the amount of blood coming out in the unit of time and how long it lasts.

3.5.4..1 If the injured person bleeds profusely from injury to a limb:

- ✓ Place a dressing or clean gauze over the bleeding spot.
- ✓ Perform a direct compression with your hand on the dressing or gauze for at least 5 minutes.
- ✓ If the bleeding does not stop, place several gauzes on the first dressing and apply a compressive bandage.
- ✓ If the bleeding does not stop, press your fingers on the root artery of the bleeding limb:
    a. For hemorrhages in the arm, place the hand below the arm and look with your fingers for the pulse of the brachial artery (at the inner edge of the biceps) and compress strongly against the humerus bone raising the arm above the level of the heart.
    b. For bleeding in the leg, place the edge of the hand over the groin and press hard down to compress the femoral artery, raising the foot above the level of the heart.
- ✓ If, despite the above actions, the hemorrhage continues to endanger the life of the injured person, a tourniquet should be placed at the root of the limb as a last resort. For this, a wide and long tie of knotted cloth (a large, folded handkerchief) will be used on which a stick (a pen) will be turned until the blood stops flowing through the wound.

3.5.4..2 Nosebleeds (epistaxis):

- ✓ Place the person seated and with the head tilted forward.
- ✓ Compress the nostrils with your fingers for 2 to 5 minutes and lift the compression to see if the bleeding has stopped.
- ✓ If it does not yield with compression, make a plug, introducing into the nose a rolled gauze soaked in hydrogen peroxide.

3.5.4..3 Ear hemorrhages (otorrhagia):

Do not try to stop an ear bleed from appearing after a blow to the head. Place the person lying down and immediately notify the health services.

3.5.4..4 Intern hemorrhages as:

They occur when a blood vessel inside the body, mainly the abdomen, ruptures because of great trauma or diseases of the stomach or intestine.

It can be suspected of its existence when a person who has suffered an intense blow to the abdomen, after a few minutes begins to feel bad, becomes pale, sweaty, and even loses consciousness.

3.5.4..5 How to act in case of injuries?

According to their mechanism of production, wounds can be classified into:

- ✓ Blunt: Produced by blunt objects with irregular edges. They are very painful and bleed little.
- ✓ Incisas: Produced by sharp objects. Of separated edges and profuse hemorrhage.
- ✓ Sharps: Produced by sharp objects. They are little painful, deep but with minimally separated edges.
- ✓ Tears: Produced by entrapment and traction. They produce variable pain and bleeding.

In the event of a wound in general, you should:

- ✓ Extreme cleaning and disinfection measures. Washing hands
- ✓ Try to contain bleeding and consider other associated injuries
- ✓ Wash the wound with plenty of water, soap and water, or hydrogen peroxide
- ✓ Place a sterile dressing or gauze, and a compressive bandage on it
- ✓ Waiting for specialized healthcare
- ✓ Do not attempt to remove interlocked foreign bodies or dig into the wound.

If the wound is deep, puncture or with irregular or widely separated edges, place a sterile dressing on it and go to the doctor.

3.5.4..6 How to act in case of burns?

Burns in workshops can be caused by:

- ✓ Contact with a high-temperature bulb: a flame, a hot surface or a liquid or hot steam

- ✓ Contact with corrosive chemicals
- ✓ Contact with electricity

Its severity depends on its depth and extent.

In the event of a superficial burn of little extension, it is due:

- ✓ Remove the affected person from the caloric agent
- ✓ Wash the affected area thoroughly under a stream of clean water
- ✓ Assess the severity of the burn
- ✓ Place a sterile dressing and refer to the doctor

In case of electrical burns, of great depth, or extensive burns or that affect the face, seek medical assistance.

3.5.4..7 How to act in case of fractures?

According to their mechanism of production, fractures are classified into:

- ✓ Direct: When the bone is broken in the place where the trauma has occurred, by a strong blow or by crushing.
- ✓ Indirect: When the trauma and fracture do not coincide in their location. A fall to the ground on a hand can give a fracture below the elbow or even in the arm or shoulder.

A fracture usually occurs:

- ✓ With previous trauma
- ✓ Characteristic clicking or noise
- ✓ Deformity or wound
- ✓ Impossibility of abnormal movement or movement
- ✓ Pain

Fractures are most severe when they are complicated (open or affected structures other than bone) or when they affect the spine and head.

The general action before a fracture is:

- ✓ Do not move the injured person, especially if abdominal fracture, spine, etc.) is suspected.)
- ✓ Look for possible associated injuries (other fractures, trauma). Do not touch the focus of fracture or attempt to mobilize the affected limb.
- ✓ Wait for the arrival of healthcare.

3.5.4..8 How to act in case of foreign bodies in the eyes?

In the workshop, the projection of particles into the eyes in the course of various tasks carried out without protection is very frequent.

The general action when a projection occurs will be:

- ✓ Prevent the affected person from rubbing his or her eye
- ✓ Perform an open eye wash with an eyewash shower or under the flow of clean water
- ✓ Whether the foreign body has been removed with washing, or remains interlocked, cover the eye with a sterile dressing and refer to the doctor.
- ✓ If the projection has been caused by caustic acids or alkalis, wash the eye abundantly in the eyewash shower or under the flow of clean water, maintaining irrigation for 10 minutes. Cover the eye with a sterile dressing and refer to the doctor.

3.5.4..9 How to act in case of poisoning?

The causes that cause poisoning in a workshop are basically:

a. Inhalation or skin contact of toxic chemicals.
b. The inhalation of carbon monoxide produced by incomplete combustion of fuel in the engine.

The general action against inhalation poisoning will be:

- ✓ Notify healthcare
- ✓ Aerate and ventilate the area, before approaching to help
- ✓ Stop the engines and prevent the formation of sparks
- ✓ Separate the affected person from the area where the poison is breathing
- ✓ Assess the state of vital signs
- ✓ Start cardio-pulmonary resuscitation maneuvers if necessary

3.5.5 ***Fire Prevention and Extinction***

- Types of fire and extinguishing agents

One of the risks to which it is necessary to pay greater attention in mechanical workshops is that of fire. People who may be affected by a fire are subject to the following factors:

- ✓ Hot fumes and gases

- ✓ Insufficient oxygen
- ✓ Heat
- ✓ Risk of burns
- ✓ Panic

Depending on the nature of the fuel that generates a fire, there are different types of fire, namely:

- ✓ Class A: Fire of solid materials (wood, cardboard, paper, fabric)
- ✓ Class B: Fire of liquids or liquefied solids (waxes, paraffins, fats, alcohol, gasoline)
- ✓ Class C: Gas fire (acetylene, methane, propane, butane, natural gas)
- ✓ Class D: Metal fire (sodium, potassium, magnesium, aluminum powder)

In mechanical workshops, the most frequent are class B, for the handling of liquid fuels, such as gasoline and especially diesel. Class C should also be taken into account due to the improper handling of comb unstable gas cylinders used in welding and oxyfuel operations. Finally, class A can occur in those cases where pallets, dirty rags or cardboard accumulate.

The mechanisms by which a fire starts in mechanical workshops can be varied, the most frequent being sparks released in a welding, oxyfuel or radial cutting operation; a short circuit in a defective electrical installation, or the auto-ignition of grease-impregnated rags that have been used to clean machines, equipment, and tools. in general. This phenomenon, although not very common, responds to an exothermic chemical reaction of oxidation-reduction between the fat and the oxygen of the air itself, favored in the summer season by the high temperatures of the environment. Its spontaneous nature makes it especially dangerous when at night or on holidays there are no people who can detect combustion in its beginnings and extinguish it.

In the event of an outbreak, initial action should be aimed at trying to control and extinguish the fire quickly, using the appropriate extinguishing agents.

The choice of an extinguishing agent and its form of application depend on different variables among which it is worth highlighting:

- ✓ The type of fire
- ✓ The necessary speed of action
- ✓ The magnitude of the risk
- ✓ The location of risk factors
- ✓ The damage that the possible extinguishing agent may cause in the facilities
- ✓ The cost of extinguishing equipment

Depending on the extinguishing agent, fire extinguishers can be:

- ✓ Water
- ✓ Foam
- ✓ Powder
- ✓ Carbon dioxide (carbon dioxide)
- ✓ Of halogenated hydrocarbons (halons)
- ✓ Specific for metal fire

Considering the types of fire that can most often occur in mechanical workshops and taking into account the types of existing installations, the following extinguishing agents are recommended:

- ✓ Carbon dioxide (carbon dioxide): In engine laboratories, engine test benches, research areas and in general, where liquid fuels are handled and there are orders, control equipment and precision electronic devices.
- ✓ Multipurpose powder: In the rest of workshops and areas of administration and training.

- Use of portable fire extinguishers

Those fire extinguishers designed to be carried and used by hand and who's mass is less than 20 kg are known as portable fire extinguishers. For the location of these fire extinguishers in workplaces, the following factors will be taken into account:

- ✓ Location close to the points where there is a greater probability of starting a fire, including equipment with special risk, such as transformers, boilers, electric motors, control panels and in the vicinity of evacuation exits
- ✓ That they are easily visible and accessible, appropriately signposted, as indicated in section 1.2 of this manual.
- ✓ Fastening preferably on supports fixed to vertical walls or pillars, so that the upper part of the extinguisher does not exceed the height of 1.70 m from the ground.

It should be borne in mind that the extinguishing agent of a portable computer is consumed in 20 seconds, therefore, if the fire outbreak is not extinguished, the difficulties of extinction and losses increase. For these reasons it is recommended to read the labels of fire extinguishers and consider the following general rules of use in case of fire:

- ✓ Pick up the extinguisher closest and most appropriate to the type of fire, holding it or by the handle or fixed handle, and place it on the ground in an upright position.
- ✓ Grasp the nozzle of the fire extinguisher hose and check, if any, that the valve or safety disc is in a position without risk to the user. Remove the grill or security seal by pulling its ring out.
- ✓ Press the lever of the fire extinguisher head and, if it exists, tighten the nozzle lever performing a small check discharge.

- ✓ Direct the jet to the base of the flames with sweeping motion. In case of liquid fire, project the extinguishing agent superficially, so that the impulse pressure does not disperse the burning liquid. Slowly approach the fire to a maximum of 1m.

- Preventive measures

Although this information is useful in case of fire, to avoid this type of accident it is necessary, above all, to take into account the following preventive measures:

- ✓ Store only the essential combustible material for the working day or shift at the workstations.
- ✓ Do not throw grease-impregnated rags on the ground or in the corners, especially if flammable materials are present in the vicinity.
- ✓ Collect and remove waste periodically in appropriate containers.
- ✓ Provision of collection trays for spillage of flammable liquids, and localized suction of combustible vapors.
- ✓ Carry out transfers of flammable liquids safely.
- ✓ Periodically check the electrical installations.
- ✓ Regulate smoking bans in at-risk areas, including warehouses.
- ✓ Strictly inspect manufacturing or maintenance work that requires the use of flames and cutting and welding equipment.
- ✓ Control the existence of static electricity sources.
- ✓ Keep all valves closed on fuel gas cylinders and installations when not in use.
- ✓ Check the tightness of the connections between combustible gas ducts, with soapy water.
- ✓ Extreme order and cleanliness to avoid the accumulation of easily burning materials and spread of fire.
- ✓ Inform workers about fire risk factors in their work area.

3.5.6 *Summary of Good Practices to Observe In Mechanical Workshops*

- ✓ Keep the workplace clean and tidy, avoiding or, where appropriate, collecting any spills and spills of products used, as well as shavings that may have fallen to the ground. Keep machines and tools in good working order and prevent cables and accessories from invading the floor and passage areas.
- ✓ Prevent bumps, falls, and trips.
- ✓ Do not remove safety devices while the engines are running.
- ✓ All machines must have:
- ✓ Marked CE

- ✓ Instruction manual
- ✓ Maintenance book
- ✓ The control devices of the machinery must be clearly visible and well identified.
- ✓ Respect safety signage.
- ✓ No smoking inside the cabins.
- ✓ Avoid direct skin contact with engine coolants. In cases where it cannot be avoided, use gloves or barrier creams.
- ✓ Do not perform welding work or use open flames or ignition sources, in places close to the storage of flammable products, engine test benches, etc.
- ✓ Gas and compressed air installations must be subject to periodic maintenance, solely and exclusively by authorized entities.
- ✓ Have good general ventilation in this type of workshops.

4 eWHC - ConExWall Manufacturing Methodology

4.1 ConExWall manufacturing methodology

This report describes processes involved during the PnU kit eWHC- ConExWall system development, from the initial stage till the panels production, briefly adumbrating the subsequent on-site stage. The following stages can be identified during the process:

- Stage 1: Information and requirements gathering – collecting all the data related to the Czech demo construction site Kasava, customer requirements, authority and standard requirements, possibilities of incorporating auxiliary systems (ventilation, PV, heating, control); structural survey and 3D scan by NTUA.
- Stage 2: ConExWall design – involving of all parties of the design process (customer, architect, structural engineer, specialists, manufacturer, ...), considering technical requirements of incorporated systems, possibilities of the manufacturer, transportation limits, etc.;
- Stage 3: Drawing documentation production – 2D and 3D initial drawings are created and continuously updated, in loop with stage 2 if not complying requirements or adjusted, leading to a final 2D and 3D production documentation in the end;
- Stage 4: Material and components order – based on production documentation;
- Stage 5: ConExWall panels production – assembly of the panels at the manufacturer plant, including the quality control;
- Stage 6: Storage – short-time storage of the already assembled panels until all panels are completed;
- Stage 7: Transportation – once all the panels are finished, transportation of the completed PnU kit to the construction site;
- Stage 8: On-site installation – installation on the Czech demo building Kasava, requires some preliminary on-site preparation and works in advance.

The overview of the proposed ConExWall manufacturing methodology is shown in Figure 31.

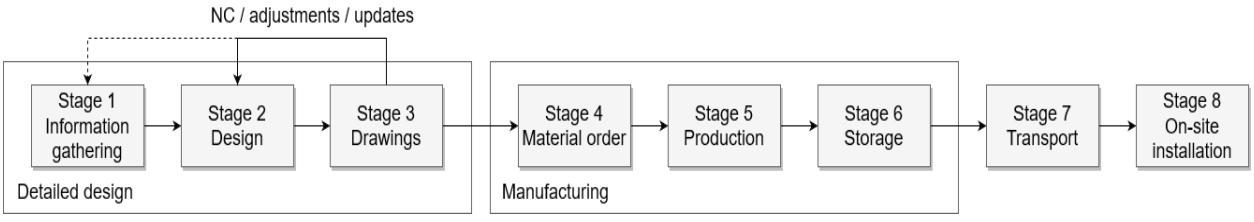

FIGURE 31: EWHC - CONEXWALL MANUFACTURING METHODOLOGY

Processes are described in detail in chapter 4.2. Stages 1 to 3 comprise a detailed design process described in chapter 4.2.1. Stages 4 to 6 belongs to manufacturing processes described in chapters 4.2.2 to 4.2.6.

4.2 Manufacturing methodology per Working Stations

Before manufacturing process starts, the detailed design phase has to be completed. Production drawings are a prerequisite for material and component ordering and inclusion into the production plan. Manufacturing processes including production assignment to individual working stations are shown in Figure 32. For more detailed successions and time dependencies of the processes, and production plan scenario developed see chapters 4.3 and 4.4.

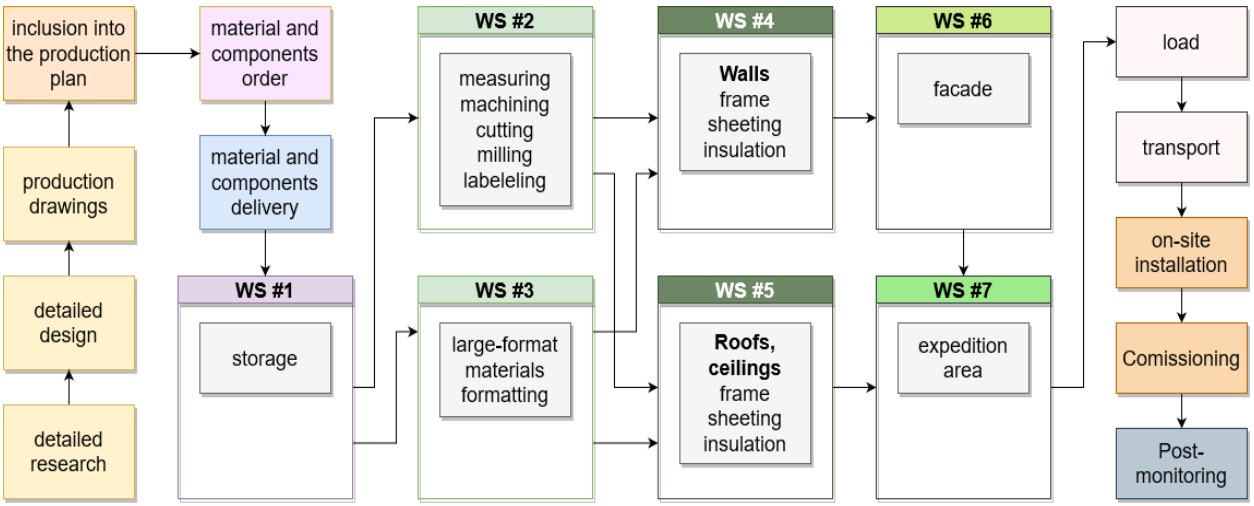

FIGURE 32: SCHEMATIC OVERVIEW OF CONEXWALL MANUFACTURING PROCESSES

4.2.1 *Detailed design*

The existing Kasava building has been 3D scanned and structural survey has been completed from the point of view of structure quality, anchoring possibilities, and bearing capacity for the additional load by the panels. This determined the design boundary conditions and limitations.

The ConExWall will be manufactured by RDR company. The goal was to incorporate the ConExWall into the standard manufacturing process in maximum extent, with minimum processes adjustments to maximize production efficiency. The Manufacturer works with standardized set of 10 dimensions of wooden elements, therefore, the ConExWall detailed design lead off those standardized formats used in manufacturer's plant.

The maximum overall size of the panels is limited by manipulation possibilities during manufacturing and transportation limits. Frames are designed with respect to the thermal insulation formats to minimize its cutting and amount of waste.

The basic wooden panel incorporates additional elements – windows/doors, system heating layer, ventilation unit etc. An RDR's designer has designed the panels in cooperation with producers of those additional elements. Based on the Czech demo mock-ups feedback, final design was established. Structural design was made by RDR engineer in cooperation with architect and CTU structural engineer, respecting the standardized set of wooden elements used by the manufacturer. Anchors are designed by CTU and will be produced by one of the RDR's suppliers based on the drawing documentation. The project architect implements the final building look into the panel design process. All components (windows, doors, ventilation units, PV, wiring or small equipment) dimensions and their fixing specifications and requirements are defined in advance by individual producers and incorporated into the final documentation.

Meanwhile, the official authority statement and building permit processes are launched, using a simplified documentation. That processes, leading to a building permission, are necessary for finalizing the documentation and final approval by the customer.

The final ConExWall design is then transferred into the production documentation, necessary for proceeding to the next stage.

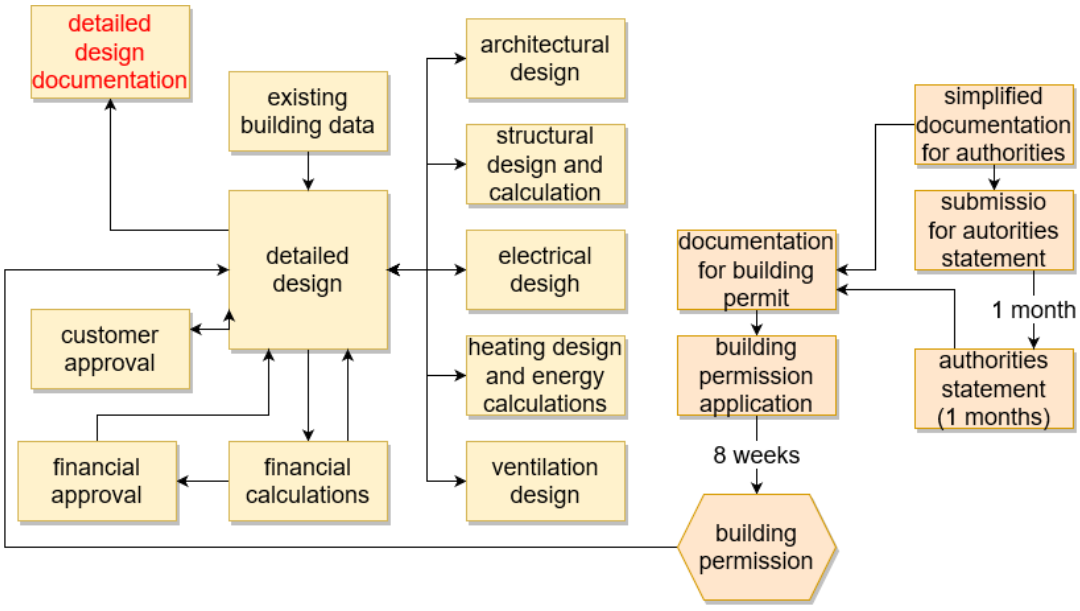

FIGURE 33: DETAILED DESIGN PROCESSES

Step description	Resources
Final design duration	1 year of discussions, examinations and planning
Software equipment	AutoCAD, Archicad, Revit, AXIS VM, Excel, Tepelná technika Energie, cadwork, etc.
Specific techniques and outputs	2D and 3D drawings, 2 small mock-ups
Possible failures	inaccuracies in 3D scanning and its incorporating into the final manufacturing design, off-size structures' flatness, installation tolerances higher than expected

TABLE 29: DETAILED DESIGN RESOURCES

4.2.2 *Manufacturing Stage #1 (Frame)*

The manufacturer RDR takes wood from his settled suppliers. For the ConExWall frame, mainly KVH and construction timbers are used. All the material and components are ordered and to be delivered and stored prior the production stage start.

Once the production starts, material is shifted from storage (Working station (WS) #1) to formatting centres (WS#2 and WS#3). At WS#2, timbers are machined, cut, milled and labeled. At WS#3 large-format materials (boards etc.) are formatted. Then formatted material is shifted to WS#4 and WS#5 for assembly. See Figure 34.

WS#4 is devoted to wall panels assembly, WS#5 serves for roof and ceiling panels assembly. Based on current workload at the time of manufacturing stage, one or two working stations can be devoted to wall panels assembly (WS#4a, WS#4b). At WS#4 and WS#5, on the assembly table, on the basis of the production documentation, timbers are (manually) put together to desired position, temporarily fixed and connected using fasteners (usually nails or steel sheets).

Spatial measurement of the assembled frame is performed by a quality responsible person and the dimensions are checked against the documentation (for quality control see D4.4: PnU kit prototypes and D6.3: Quality Assurance Pan- manufacturing /assembly to be submitted in M36).

The frame is then provided with the gypsum wood-fibre board (Fermacell) cladding, fixed with staples, and a vapour barrier foil (where relevant) with sufficient overlaps for further joint on construction site. Fixing of the cladding ensures the spatial stability of the frame. Based on the type of panel, additional frame is installed (e.g. wall panel 2, see D2.7, chapter 4.1).

Textile slings (producer Mipas) for hanging onto a crane are attached, based on the structural engineer's design.

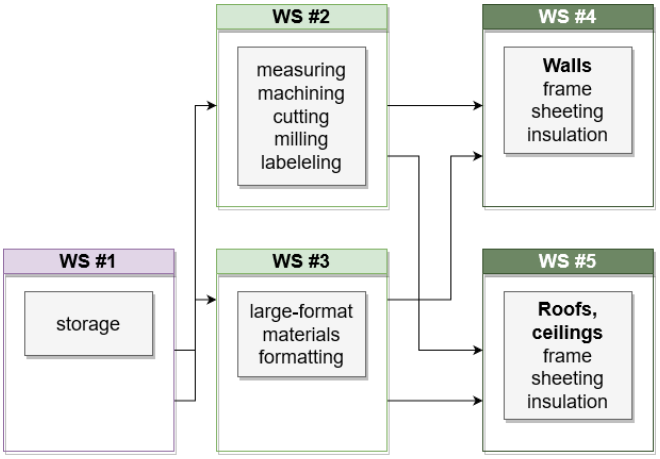

FIGURE 34: MANUFACTURING STAGE #1 (FRAME) STEPS PER WORKING STATION

The RDR manufacturing process is largely automated. Manipulation is mostly based on automation for timber prefabricated elements, such as multifunctional bridges, pre-cat automation centers, turn-over tables, automated sliders etc. For material manipulation from/to storage and loading/unloading, a forklift or a bridge crane is used. Manual manipulation is limited to timber positioning, forming the frame structure, insulating, and some atypical components installation (e.g. heating layer).

Step description	Resources
Frame assembly duration	40 minutes / 1 frame
Equipment	Automation for timber prefabricated elements: multifunctional bridges, pre-cat automation centre, turn-over tables, automated slider etc. Material manipulation from/to storage: forklift or a bridge crane Manual manipulation: timber positioning forming the frame
Number of workers at WS	4 workers at each WS#1 4 workers at each WS#2 and WS#3 4 workers at each WS#4 and WS#5

TABLE 30: MANUFACTURING STAGE #1 (FRAME) RESOURCES

4.2.3 *Manufacturing Stage #2 (Components installation)*

Components installation and preparation takes place at WS#4 (walls) and at WS#5 (roofs).

The wall panels may contain the following components:

- heating layer with insulation and heating pipes;
- window(s) or door(s);
- ventilation unit(s);

- wiring and cable protection pipes.

Roof panels contain:

- PV installation/anchors and preparation for PV installation;
- wiring and cable protection pipes for cables.

The opening for the window/door/ventilation unit is cut out once the panel is sheeted. However, the component itself is installed and fixed only after complete cladding and insulation of the panel.

Window/door is installed as a whole (the frame and the wing together) and must be fitted with connection profiles, prepared by the supplier in advance, to fix the window/door into the frame. Ventilation unit is installed after the window. The process of component installation is automated and driven by the production documentation. Airtight tapes are used to seal widow-to-opening connection.

Precision of the component installation is ensured by automated machined-based processes on the basis of production drawings. After complete component installation, quality is checked by a responsible person against the drawings (for quality control see D4.4: PnU kit prototypes and D6.3: Quality Assurance Pan-manufacturing /assembly to be submitted in M36).

Step description	Resources
Component installation duration	10 minutes / 1 typical window/door
Equipment	Automation: multifunctional bridges, turn-over tables, automated slider etc.
Number of workers at working station	4 workers at each WS#4 and WS#5

TABLE 31: MANUFACTURING STAGE #2 (COMPONENTS INSTALLATION) RESOURCES

4.2.4 *Manufacturing Stage #3 (Insulators installation)*

Frames are design with respect to the thermal insulation formats, therefore, only a minimum cutting is needed and is mainly limited to the side panel fields. Both, the potential insulation formatting as well as insulation installation takes place at the WS#4 (walls) and WS#5 (roofs, ceilings).

At wall panel 1 (see Figure 35), after interior cladding and vapour foil fixing, the panel is turned upside down and the insulator is manually inserted between timbers. Subsequently, additional facade thermal insulation is laid, weathering membrane is added, and those fixed by screwed facade laths. Heating layer soft insulation layer is inserted within the heating component installation (see chapter 4.2.5).

At wall panel 2 (see Figure 35), interior frame substituting existing wall is insulated and completed first, then the panel is turned, and the same procedure follows as in wall panel 1 case.

Roof panel (see Figure 35) is insulated between timber frame first, then a water vapour barrier is inserted on which interior thermal insulation layer is installed, covered by gypsum wood-fibre board fixed with staples. The panel is then turned upside down and exterior insulation is installed and, after laying a weathering membrane, fixed by screwed laths that forms an air gap layer.

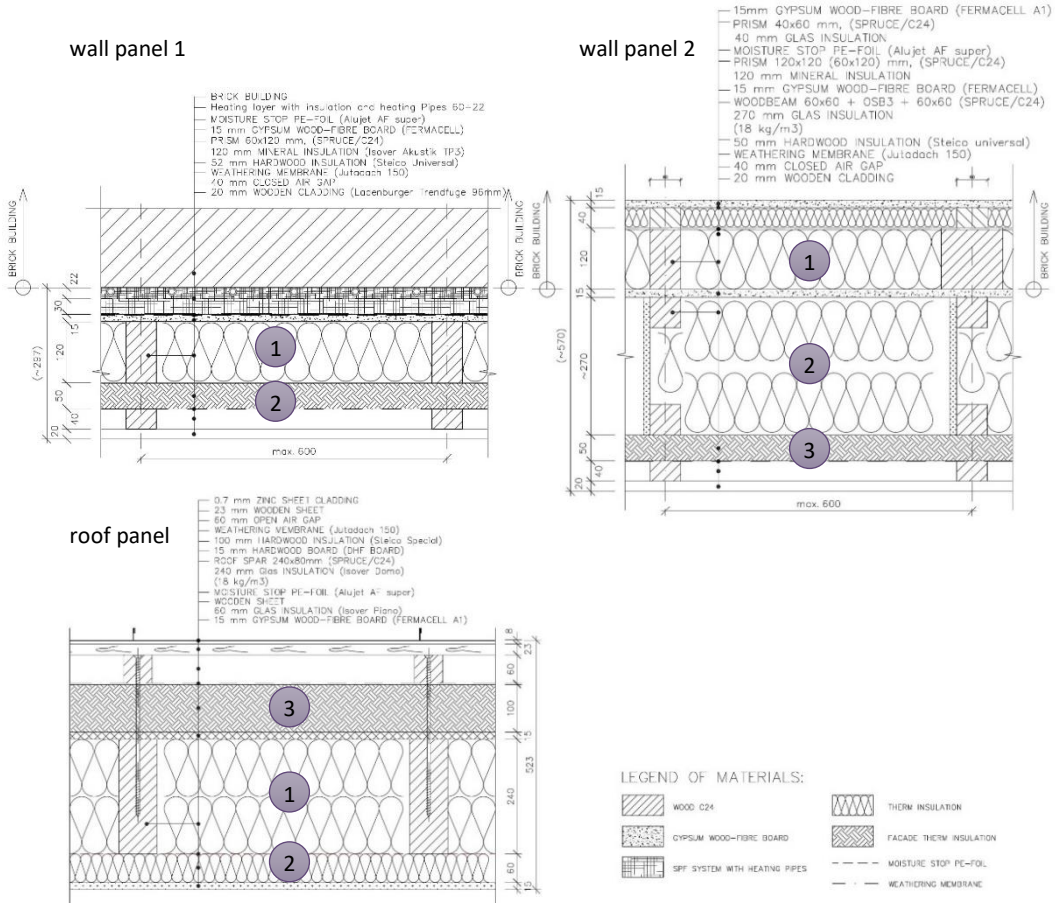

FIGURE 35: MANUFACTURING STAGE #3 (INSULATORS INSTALLATION)

Step description	Resources
Component installation duration	2 hours / 1 average panel
Equipment	Automation: multifunctional bridges, turn-over tables, automated slider etc. Manual manipulation: inserting the insulator
Number of workers at WS	4 workers at each WS#4 and WS#5

TABLE 32: MANUFACTURING STAGE #3 (INSULATORS INSTALLATION) RESOURCES

4.2.5 *Manufacturing Stage #4 (E/M components installation)*

E/M components consist of:

- heating layer with insulation and heating pipes (wall panels);
- ventilation units (wall panels);
- PV installation/preparation for PV installation (south roof panels);
- wiring and plastic protecting tubes (both walls and roof panels).

All the E/M components installation related works take place at the WS#4 and WS#5 for walls and roofs, respectively. The E/M components dimensions and their fixing specifications and requirements are incorporated in the production documentation. On its basis the openings for the components are cut in cladding (similar to windows) where relevant.

For transportation and safety reasons, anchors for PV will only be installed as a part of the prefabricated roof panels. Anchors' positions come from the PV panel dimensions and producer's and structural design requirements and are indicated in the production documentation. Anchors' installation will be subject to the quality control. The PV panels will be installed on-site only after the roof panels installation is completed.

Wiring is needed mainly for sensors installed in the heating layer, window inter-glazing blinds, and for PV. Wiring for ventilation unit leads through an existing wall or a window reveal. For wiring a plastic protecting tubes are manually installed at the position indicated in the production documentation, fixed and sealed where needed. The final wiring is made only at the construction site to prevent its damage during panels transportation and installation.

Heating system layers: on the gypsum wood-fibre board cladding with the water vapour barrier, a soft insulation layer is put and fixed (the soft insulation layer ensures the panel fit tightly onto the existing brick wall). A milled particleboard (the mill out is prepared by the heating system producer) is laid. Thin steel/aluminium sheet formed for heating pipes installation is then inserted to the particleboard grooves and pipes are subsequently installed. The heating system layer composition is then fixed with stripes screwed into the frame. Heating layers installation is illustrated in Figure 36.

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

FIGURE 36: MANUFACTURING STAGE #4 (E/M COMPONENTS INSTALLATION) – HEATING LAYER WITH INSULATION AND HEATING PIPES

Step description	Resources
Component installation duration	2 hours / E/M components for a single panel in average
Equipment	Automation: multifunctional bridges, automated slider Manual manipulation: drills, screwdrivers, hammer
Number of workers at WS	4 workers at each WS#4 and WS#5

TABLE 33: MANUFACTURING STAGE #4 (E/M COMPONENTS INSTALLATION) RESOURCES

4.2.6 *Manufacturing Stage #5 (Finishes installation)*

Completed and insulated wall panel fitted with all components is shifted to WS#6 where, in vertical position, a facade wooden cladding is installed. At some parts, facade is omitted to ensure on-site access to panel anchoring, vapour barrier foil joining, and access to the channel for the sake of heating pipes interconnection. These facade parts will be completed on-site once all the anchoring and joints are completed.

Wooden cladding is being ordered in required colour, hence there is no painting-related activity in case of ConExWall manufacturing process.

The pursuit of maximum extent of prefabrication, including the facade finishing, entails the following disadvantages:

- increase of facade cladding incision and thus decrease of material utilization efficiency due to its formatting to a panel's dimensions;
- visual appearance – visible panel joints need not to be of desire for a customer/architect in general.

Completed panels are shifted to a pickup area in the expedition hall (WS#7). Once all the panels are finished and collected, they are transported to the construction site (usually the day following the production completion). The panels load order comes from the requested unload order on the construction site. To facilitate and minimize amount of manipulation, the manufacturing order preferably follow the needs of loading order, too.

4.3 PERT diagram

From the PERT diagram (see Figure 37) and ConExWall manufacturing methodology analysis, a set of critical points was identified that can lead to delays during the manufacturing process.

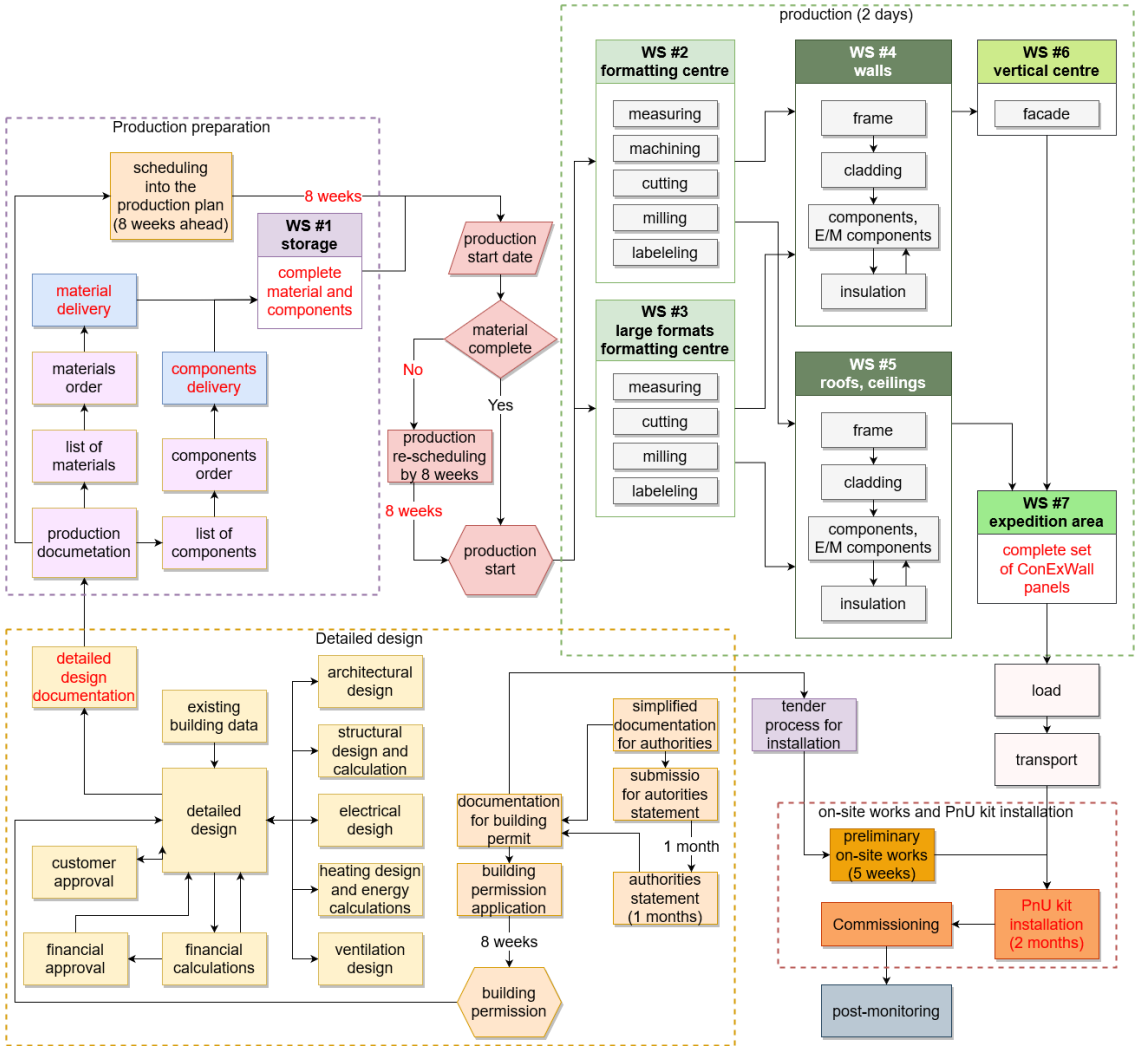

FIGURE 37: CONEXWALL PERT MANUFACTURING METHODOLOGY

Typically, design activities, having character of loop iterative process, tend to be of increased risk of extended duration than expected. Especially in case of a new system with amount of new technical details involved, such as PnU kit development, it is crucial not to underestimate the complexity of the design and work in higher design detail to verify design assumptions in connection with new technologies or techniques as soon as possible.

Certain delay may also occur within the building permit process. In case the building authority requests further documentation or statements, or enjoin some changes, it may delay the expected typical 2-month period of gaining the building permit or take additional time for incorporating the requested changes. Since the building authority may request some changes as a condition for the permission, the final documentation will only be finished and transferred into production documentation when the building permit is issued. Therefore, the building permit related issue is also understood as the activity being on a critical path since it delays the whole subsequent process if retarded.

Another critical point is the production preparation phase. Once the production documentation is completed, the manufacturer incorporates the ConExWall production into the production plan, scheduling the production start date 8 weeks ahead, and order all material and components. Within those eight weeks, all the material and components have to be delivered to meet the scheduled production start. In case the supplies are delayed and complete material and components are not available at the start date, the production is rescheduled by 8 weeks which significantly delays the whole subsequent process.

The production duration is quite short compared to other activities – it is estimated by the manufacturer to 2 days. Although there are some new components the workers are not familiar with, which may lead to decreased production speed, potential delay in manufacturing procedures would not affect significantly the overall time plan. However, for safe side of planning, the total production time is supposed to be one week for time planning and production scenarios purposes.

Certain risk can be identified in the PnU installation stage. The installation company is not yet tendered and it will depend on skills and experience of the workers and on-site manager how they cope with the new techniques brought by the ConExWall. Further, the installation technology is not verified in such a scale, therefore, possible delays can occur during the installation if expectations based on previous testing mock-ups installation do not meet the reality of the Czech demo Kasava.

The aforementioned cases belong to potential risks of higher significance and impact on the whole processes' timetable. Additionally, some small issues may occur on a daily basis which, however, does not influence the course of the project significantly as all the parties involved (especially manufacturer and architects and design specialist) are experienced enough to be able to solve those on-the-daily-bases issues effectively.

The most critical risks that may occur during the project are analysed and elaborated into the production plan scenarios, described in chapter4.4, to quantify potential impact on the time plan.

4.4 Production Plan scenarios

At the end of 2022, the Czech demo Kasava project is to be submitted for official statements of concerned authorities. Receiving the statements typically takes 1 month, therefore, it is expected to be gained at the end of January. Within the period of waiting for the statements, the project will be completed (for the statement application, a simplified version of the project is sufficient). When all the statements are received, an application for a building permit will be submitted, i.e. expected at the beginning of February. There is an official period for issuing a building permission which is 2 months, i.e. the building permission is expected at the end of March. Within those two months, the project will be elaborated into the detail necessary for transferring the ConExWall project to the production documentation. Elaborating the production documentation of common commission of similar size typically takes about 1 week, however, with respect to number of atypical components and details, the production documentation duration for the ConExWall case has been considered as 3 weeks to have reserve to potential details resolving and approvals.

In parallel, a tender process for installation company will be launched to have the selected company contracted in time and involved in the detailed project elaboration, if possible, to get familiar with the technology and potentially adjust based on the company's scope.

According to manufacturer's capacity, the expected production duration of all ConExWall panels is 2 days. Considering the fact that there are parts and components the workers are not familiar with from their standard production routine (heating system layers, ventilation unit), at the beginning of the assembly process it may take more time to complete a panel. Therefore, the overall production time is rounded up to 1 week for planning purposes.

The manufacturer incorporates the ConExWall production into the production plan only after the production documentation is completed. The production start is typically scheduled in 8 weeks ahead. Within those 8 weeks, the material and components are ordered.

On the construction site, preparation for the ConExWall installation will take 4 to 5 weeks, depending on the construction company capacities. The preparation phase will be scheduled right prior the ConExWall installation to avoid idle time.

The duration of the on-site installation of the ConExWall is expected to be 2 months.

Development, manufacturing, and installation of a completely new product is always accompanied by uncertainties. Further, there is a shortage in sources (raw material, electronics) on both global and local

markets that may affect delivery time or availability of material and components needed for manufacturing. Production plan scenarios try to take the uncertainties into account in a form of a time reserve for unexpected occurrence already included in the activity duration where reasonable.

With respect to the possible uncertainties and subsequent delay occurrence, the following scenarios have been considered and analysed:

- Planned production;
- Delayed final detailed documentation (4 weeks);
- Delayed production start (8 weeks);
- Worst-case scenario.

Overview of the aforementioned scenarios is shown in Figure 38. The scenarios are described in detail further in the text.

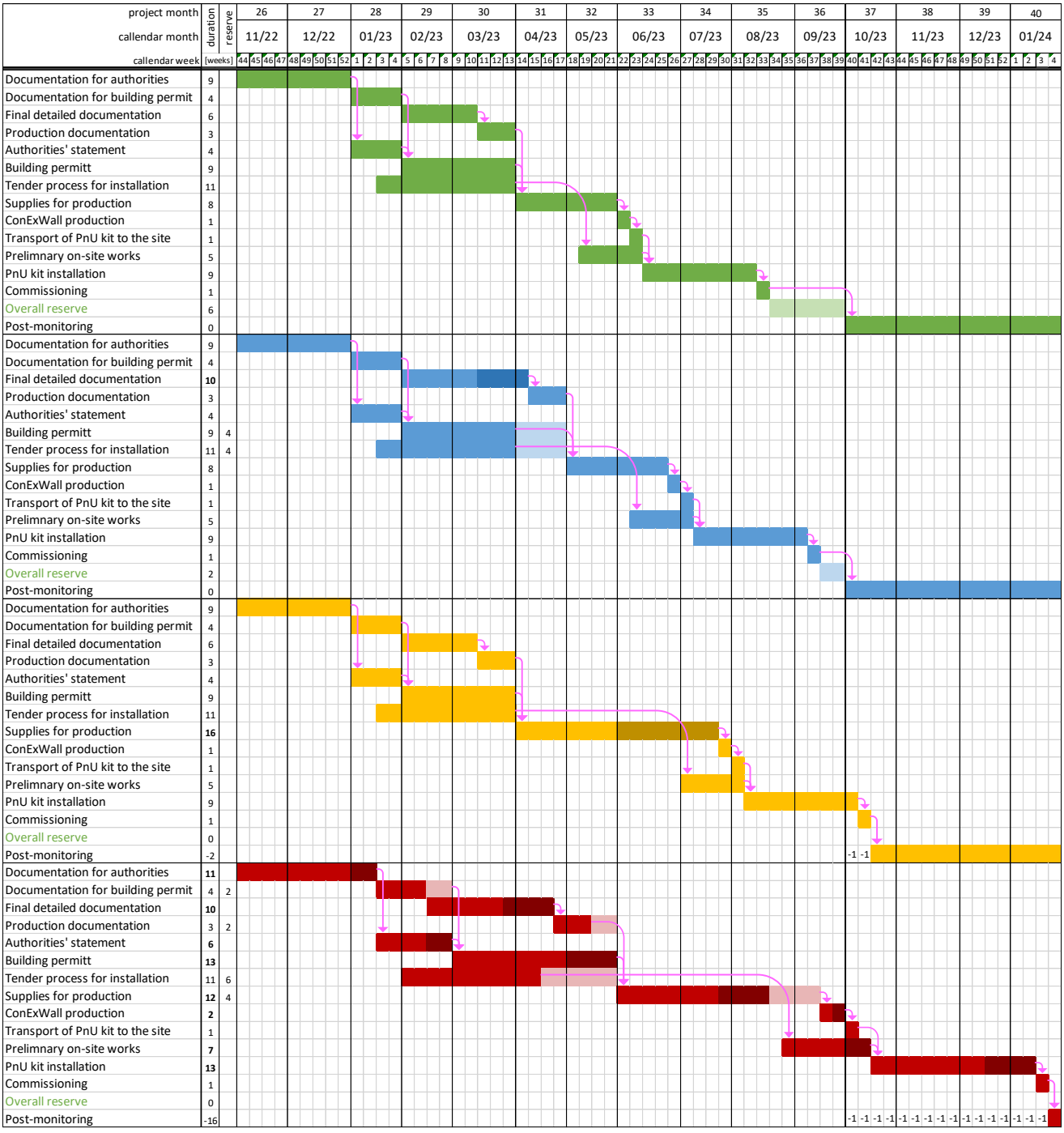

FIGURE 38: PRODUCTION PLAN SCENARIOS (DARK SHADES = DELAY, LIGHT SHADES = RESERVE)

4.4.1 *Planned production*

This plan assumes the best possible course when all durations will be met as expected, i.e. there will be no delay on the critical path. The duration of individual task has been estimated to be feasible under the current conditions (at the time of this report being written) and supplemented with a proportionate reserve where reasonable.

This scenario provides 6-week reserve after the Czech demo Kasava commissioning, considering the requested 12-month post-monitoring period (expected to start in October 2023).

4.4.2 *Delayed final detailed documentation (4 weeks)*

This scenario assumes one of the most common delay reasons which is the final detailed documentation duration extension. This scenario is of high probability as in case of new system being developed within the project, with many parties involved, bringing it into a conclusion can take more discussion and time in the end.

The 4 weeks more at the design phase introduces reserve into a building permit and tender process activities, since the material is only ordered when the production documentation is finished.

This scenario causes extension by 4 weeks in comparison to as-planned production but still provides a 2-week reserve within the whole period, considering the requested 12-month post-monitoring phase after the Czech demo Kasava commissioning.

4.4.3 *Delayed production start (8 weeks)*

Once the ConExWall is scheduled in the manufacturer's production plane, it assumes start of production in 8 weeks. Within those eight weeks, the material and components are ordered and expected to be delivered to the manufacturer's plant. In case there is a delay in supplies and some of the material or component is not available by the scheduled production start date (even delayed by a single day), the production is cancelled and rescheduled for 8 weeks later (the manufacturer works with eight-week planning periods, which means there are other jobs already scheduled for the next eight weeks). The cancelled production also brings financial consequences for the manufacturer as the already booked days for the ConExWall production can hardly be filled in by another job since production and related material delivery is scheduled for eight following weeks. Therefore, plant idle time is imminent in such a case.

Considering a general shortage in sources on both global and local markets, this scenario is of certain likelihood. The manufacturer cooperates with settled material suppliers having a stable position on the market; therefore, higher risk lies on delivery of non-standard components of the ConExWall system.

This scenario causes 8-week delay which means the post-monitoring duration gets reduced by 2 weeks.

4.4.4 *Worst-case scenario*

The Worst-case scenario works with an assumption that almost all actions on the critical path will be delayed as follows:

- submission for authorities' statement – by 2 weeks
- authorities' statements – by 2 weeks
- building permission – by 4 weeks
- final detailed documentation – by 4 weeks
- material delivery – by 4 weeks
- production start – by 8 weeks (due to material delivery delay)
- production – by 1 week
- preliminary on-site works – by 2 weeks
- on-site installation – by 4 weeks

This is quite pessimistic scenario attempting to estimate the largest possible delay of the project, identify the decisive milestones and prepare for potential adoption of alternative plans. The scenario is, however, unlikely to occur in its full extent.

At certain points, delay of some activity brings reserve into another activity situated on a non-critical path at that moment. More time is thus available for building permit documentation, production documentation, or tender process. Further, even the four-week delayed material delivery can get delayed more without additional effect as the time step of the production start rescheduling is eight weeks.

All these delays combined into the subsequent causal chain will result in 22-week delay in total compared to the as-planed scenario. This would lead to the post-monitoring period condensed by 16 weeks.

4.4.5 *Alternative Plans*

Once a delay on a critical path arises or become likely, certain alternative plans can be taken into consideration.

Most critical, and being likely to some extent at the same time, is a combination of the delayed final documentation and material delivery.

To forestall delay in documentation finalization or to reduce the delay when already occurred, it is generally recommended to:

- gather all the detailed technical documentation of the components to be included into the panels already now,
- elaborate the documentation to a high degree of detail as soon as possible to prevent late incompatibility discovery, forcing additional changes,

- compress the time for the customer approval of the design by concurrent discussion and preliminary approvals to parts already settled,
- in case of the production documentation delay, a manpower increase is of recommendation.

To forestall material or components delivery delay, a preliminary verification of source accessibility may identify possible risk in advance and adopt effective decision where possible. Further, pre-selection of alternative material or components of minimum effect on the overall system design in advance may be of help if some sources shortage becomes imminent.

On the other hand, the ConExWall production itself, with respect to the manufacturer's capacity, occupies rather short period within the whole span and, at the same time, contains about triple reserve already in the as-planned scenario. Therefore, it is not assumed the manpower increase or extending shifts or working days devoted to the project would be needed or bring significant improvement; moreover, the manufacturer is already operates on a three-shift operation (see chapter 4.5.1) thus it would be hard to increase its capacity, anyway.

4.5 Health & Safety Plan

Manufacturer's Health & Safety Plan (HSP) is created by an external company which also supervises its observing during manufacturing processes. Since ConExWall production does not introduce any new processes or activities into the manufacturing procedures, the standard manufacturer's HSP applies for ConExWall production as well.

Based on risks identified in HPS, all employees undergo Health & Safety (HS) trainings, regularly repeated. Specialized trainings are required for specific equipment operation such as:

- forklifts,
- cranes,
- multifunctional bridges,
- pre-cat automation centre,
- turn-over tables,
- automated slider,
- and all other kind of automation for timber prefabricated elements.

HSP also defines personal protective equipment (PPE) required for each working station and/or activity. HSP further describes safety distances and various zone access restrictions.

4.5.1 *Overall production management*

The manufacturer's operation involves 1- to 3-shift operation, depending on type of activity, to maximize production capacity:

- expedition – 2-shift operation,
- production – timber preparation for framing – 2-shift operation,
- production – panels assembly and prefabrication – 3-shift operation,
- administration – 1-shift operation.

4.5.2 *Traffic & Delivery Management*

Material delivery and final product transportation is organized to ensure safety of all persons involved. Within the whole plant area, speed limit of 30 km/h applies. Separate zones and paths are defined for:

- trucks,
- car parking,
- crane operation area with restricted access,
- pedestrians.

Main storage is situated accessible from outside and close to first working station. Local storage areas by individual working stations are kept well organized to eliminate risk of injuries due to difficult access or passing through. Expedition area is close to last working station and accessible from outside for loading the final components for transportation to a site. Traffic between outside and inside is ensured by bridge crane or forklifts.

An emergency services (ambulance, fire units, etc.) uses the access for trucks.

4.5.3 *Working at Height*

There are no works at height needed during the ConExWall production.

4.5.4 *Storage of materials*

There is a main storage area in the plant, accessible from outside and operated by bridge crane and forklifts. The storage area is organized with designated area to each type of materials to secure safety and easy access to all types of materials stored. For hazardous materials (petrol, chemicals, etc.) a separated area is designated, fulfilling safety requirements and national regulations.

Local storage areas by individual working stations are kept well organized to ensure easy access and passing through.

Material is generally ordered based on planned production to prevent excess of material and overflowed storage.

4.5.5 *Storage of Waste Materials*

Waste is stored and disposed in accordance with manufacturer's internal directive of waste management and current national regulations. Packaging and communal waste material is sorted. Remainders of timbers and boards are sold for further use.

4.5.6 *Manual Handling*

Since most of the manufacturing procedures is automated (bridge crane, forklift, multifunctional bridge), manual handling is limited to small number of activities such as:

- timber handling and positioning while forming the frame,
- inserting insulators,
- special components installation, such as heating layers,
- manipulation with remainders after formatting.

HSP determines the maximum load which a person may carry and rules for manual handling. Respecting the rules is observed by an external HS manager.

4.5.7 *Live Services*

All equipment is regularly scrutinized by a responsible person based on the Live service plan. Only authorizes persons with respective training and approval are allowed to manipulate and check the electrical equipment. Operating companies or external technicians are involved in equipment inspections where needed. Any suspicious cases are overhauled. No use of equipment being of hazardous use or not fulfilling the safety regulations is allowed.

4.5.8 *Use of and Contact with Power Tools*

In general, use of and contact with power tools is subject to Czech safety regulations and standards. Workers can only use the tools they are approved to use based on HS training and use them in accordance with the tool producer's manuals and instructions.

Some of the large equipment have an automatic safety fuse – if a person enters a protected are, the machine automatically stops.

4.5.9 *Control of Lifting Operations*

There are bridge cranes and forklift available in the plant. Only persons with appropriate training are allowed to operate them. Typically, there are 3 persons authorized for crane operation and 5 forklift operators at each work shift.

4.5.10 *Noise and Dust*

Works emitting noise is limited to indoor areas (halls). Employees working at noise environment are equipped with earplugs throughout their work shift. Further, based on the HSP, acoustic breaks are prescribed in which the machines have to be switched off.

Dust is minimized by regular cleaning in the plant spaces, including the production area, and does not exceed limits. There is no personal protective equipment needed and used in relation to dust. Fire inspections are carried out on a medium-term basis to check the fire risk in relation to dust.

4.5.11 *Hot Works*

There are no hot works in the plant.

4.5.12 *Spills*

There is no risk of spills during the common operation. Potential accidents (spilled drinking water) are to be solved by common cleaning equipment. Accidentally spilled chemicals are to be cleaned and treated in a prescribed way. Wet floor prevention during a rainy weather is ensured by doormats.

4.5.13 *Exposure to UV Radiation*

All works take place in indoor environment with no exposure to UV radiation. The only outside activity is loading/unloading materials and products from/to trucks, which is a short-term activity with no need of protective measures.

4.6 Safe Working Procedures during Production

4.6.1 *Method Statements and Risk Assessments*

There is a common Health & Safety Plan (HSP) elaborated for all the activities within manufacturer's production, including risk assessments, and is regularly inspected by a safety manager. Since production of ConExWall does not introduce any new activities, the HSP applies with no need of additional documents or actions.

All the documents related to HS (HSP, training protocols, certifications and approvals) are stored in a designated folders in an administration office.

4.6.2 *Personal Protective Equipment (PEE)*

Based on the HSP, the following PEE are prescribed and used for production activities:

- Safety footwear – to be worn at all spaces of the production plant throughout the work shift, the type of footwear is prescribed based on the activities carried out by a worker and spaces he moves at during his work shift.

- Work gloves – to be worn throughout the work shift unless the activity risk assessment specifies differently.
- Safety goggles – to be worn throughout the work shift at any activity where the risk assessment prescribes.
- Earplugs – to be used at working stations with increased noise level, or incessant equipment or machine noise emissions.
- Reflective vest – to be worn during activities where the increased visibility of a person is of request or recommendation, such as persons involved in loading products, or activities with higher identified risks due to visibility.

The PEE is secured by the manufacturer and provided to all employees and are available/to pick up in the production hall or designated storerooms.

4.6.3 *Safety signs*

There are several types of signs at the plant identifying a hazard or risk or notifying a rule:

- traffic signs,
- permanent marking of specific conditions or area (crane or equipment space delimitation, lowered soffit, etc.),
- information signs,
- emergency situation related signs (exits, fire extinguishers, first aid, etc.)
- operation labels on the equipment (warnings and rules given by the equipment provider).

Standardized colours and shapes are used for signs and marking.

In case of accident or occasion occurred, an occasional labelling is used to indicate possible hazard and secure safety.

4.6.4 *Emergency Procedures during Pilot Production*

The manufacturer has a general emergency plan describing potential emergency events or foreseeable incidents. Since ConExWall pilot production does not introduce any new activities, the existing emergency plan applies with no need of additions. The plan mainly contains:

- identification of possible risk and their level of seriousness and probability,
- establishing procedures to follow in case of emergency situation or event, such as using alarms, shutting of power supply, fire procedures, evacuation rules, first aiders, responsible persons, etc.,
- plant plans with identification and marking of emergency exits and routs,
- plant plans with positions of all emergency equipment, such as first aid kit, fire extinguisher, total stop button, alarms, etc.

Emergency plan is provided in written to all employees. Signs of emergency routs, exits and emergency equipment positions are visibly placed in the plant areas.

4.6.4..1 Control Measures

Accessibility of all paths and safety of all equipment is regularly supervised by a safety manager.

4.6.4..2 Actions

Trainings of emergency procedures are carried out, including special training for those with special responsibilities.

- Health

There is a contracted company doctor in Rýmařov (RDR) and regular medical examinations of employees are prescribed to prevent health issues.

- Reporting accidents

In a case an injury occurs, it is noted into the Book of injuries with the details about injured person, witnesses, reason/cause, and measures to prevent further injuries.

- First aid

There are at least 2 people trained in first aid at each work shift. First aid kits are placed in the production hall, visibly marked and easy to access.

Minor injuries are treated using the first aid kit and trained people at plant. In case of a more serious accident, the injured person is transported to medical emergency in Rýmařov (RDR) or a nearest hospital in Bruntál (distant about 20 km), or an ambulance is called by phone number 155.

4.6.5 ***Welfare arrangements***

The manufacturer is aware of importance of care for the welfare of the employees and its effect of increasing the overall safety and productivity.

The following welfare facilities are available in the plant area:

- rest place in production hall area with a calm sitting place equipped with food and drink automat,
- canteen serving hot food,
- separate dressing rooms for men and women,
- separate toilets for men and women,
- designated areas for smokers (smoking is prohibited in the production hall),
- drinking filtered tap water,

- regular cleaning service and toiletries replenishing.

4.6.6 *Unforeseen Eventualities*

Unforeseen eventualities during any project stage including production phase may affect project run and schedule. Decision about necessary schedule changes in reaction to an unforeseen situation is under responsibility of Production manager.

Potential unforeseen health & safety issues will be dealt with by HS manager in cooperation with Production manager.

5 Conclusions

D6.1 described the steps that will be followed for the manufacturing of the three core PnU kits to be used for the deep renovation of the three demonstration sites of the PLURAL project. The reported LEAN management approach for each PnU kit of the PLURAL project can be summarized as follows:

a) Manufacturing methodology description, analyzing the manufacturing processes' actions per each PLURAL kit.

b) PERT analysis of the manufacturing process, indicating and analyzing the manufacturing tasks' critical path and their inter-dependencies.

c) Working stations diagram, indicating per working station: the performing tasks, manpower in use, the duration of each task, the materials and equipment in use, as well as any auxiliary actions & processes might have direct impact to its operations.

d) Manufacturing contingency plan (P.B.P. - Production Back-Up Plan)

e) Remedial actions for the defaults might occur during PLURAL kits manufacturing.

f) Health & Safety Plan (H.S. P.) related to the manufacturing process.

g) Overall manufacturing time schedule, taking in consideration all local circumstances per demo building, e.g. climatic conditions, occupants' availability, transportation etc. Each manufacturer of PnU kit (DEN, BGTC, RDR) is responsible for the description of its own manufacturing time plan. Input and technical data will be provided by the developers (AMS, CVUT, SPF, ITeC, PA, RECUAIR) to be included in the manufacturing methodology.

By using the LEAN management system, a toolbox of interactive looping actions is created among different tasks of the manufacturing process where the outcome of each task is developed, evaluated, corrected (if necessary), redesigned and redeveloped in a constant loop. Following this method, the performance and efficiency of the manufacturing process is constantly under control, while at each looping action is optimized and gradually becomes more efficient and productive.

The implementation of the LEAN manufacturing methodology for the PnU kits will reduce investment, time and effort leading to significant overall reduction in time and cost for prefabrication, this justifying its choice.

The deliverable D6.1 is public as it can serve as a guideline for future similar approaches, i.e LEAN manufacturing of off-site prefabricated hybrid (including active and passive systems) façade kits.