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Innovative and adaptable envelopes over existing façades in building refurbishment - Design, economic assessment, logistics and installation guidelines

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Contents

Page

European foreword

This Workshop Agreement has been proposed by the BRESAER consortium (www.bresaer.eu), which is developing a Horizon 2020 project to design, develop and demonstrate an innovative, cost-effective, adaptable and industrialized envelope system for buildings refurbishment including combined active and passive prefabricated solutions integrated in a structural mesh.

This CWA is a technical agreement, developed and approved by an open, independent Workshop structure within the framework of the CEN-CENELEC system, developed in accordance with the CEN-CENELEC Guide 29 "CEN-CENELEC Workshop Agreements" and with the relevant provisions of CEN-CENELEC Internal Regulations – Part 2.

This CWA was agreed on 2019-01-29 through a decision adopted by representatives of interested parties, approved and supported by CEN following a public call for participation made on 2019-02-26. It reflects the agreement only of the registered participants responsible for its content, and it does not necessarily reflect the views of all stakeholders that might have an interest in its subject matter. The secretariat of the CEN Workshop that developed this CWA was the Spanish Association for Standardisation (UNE).

The final text of this CWA was submitted to CEN for publication on 2019-06-03. It was developed and approved by:

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Introduction

The current building stock of the EU has an enormous potential for improvement of the energy efficiency and the application of renewable energy systems, making the transformation of that building stock into energy efficient buildings essential to the climate and energy objectives established in the European 2020 Strategy:

a) 20% target for GHG reductions.

b) 20% of EU energy to be sourced from renewables.

c) 20% reduction in energy use

The industry sector can improve its technological competence, particularly aiming at producing solutions that require less energy. By doing so, the industry sector becomes ready to reach these environmental goals. In addition, this will also contribute to increase the competitiveness of the European construction sector in a global competitive environment. The construction industry however, due to its economic model and long time needed to finish a product and obtain payback, has the particularity that it cannot experiment widely with new technologies. It will do so unless they have been proven, there are guarantees they will perform better than traditional ones in the long term, that they comply with regulations and that there are incentives for their application (reduced costs when compared to traditional technologies).

Since the building envelope (façade and roof) is usually a passive boundary between the indoor and outdoor climate, an 'active' envelope responds to (and anticipates on) changes in indoor and outdoor conditions. Therefore the envelope is key element to address in order to significantly increase the energy efficiency and the use of renewable energy in the building sector.

Standardisation, through CEN/TC 89 and CEN/TC 371, is contributing to reduce the use of non-renewable resources and the emission of CO_2 to the atmosphere in support of the EU Directive on Energy Performance of Buildings (EPBD), developing test methods related to the energy use and thermal performance of buildings. Its scope and the objectives of this workshop are closely related.

Advanced technologies achieve considerable gains concerning the energetic efficiency of building envelopes. This concerns both new buildings and the energetic retrofitting of existing ones. Better insulation of buildings is not only increasing their energy efficiency in cold climates but also in warm and hot regions due to the reduction of cooling (AC) power. The use of renewable energy in the building sector has been traditionally dominated by the application of solar domestic hot water and PV systems in new buildings for single-family houses and small non-residential buildings, omitting the existing building stock. Hence, integrated retrofitting concepts can contribute to take advantage of the potential in the existing stock of both residential and non-residential buildings. Concepts easily implemented and versatile as building envelope to integrate both active and passive solutions using prefabricated and adapted existing technologies, as well as technologies tailored for the building use, are needed.

This workshop is a result of the Horizon 2020 BRESAER project (Breakthrough solutions for adaptable envelopes for building refurbishment), whose general objective is to design, develop and demonstrate an innovative, cost-effective, adaptable and industrialized envelope system for buildings refurbishment including combined active and passive prefabricated solutions integrated in a structural mesh. The BRESAER system has the potential to solve the problem of the construction sector with respect the utilisation of innovative solutions, by using a combination of known and novel technologies, having potential for success when applied in building refurbishment projects.

1 Scope

This CEN Workshop Agreement (CWA) provides orientation for the:

– design process of an innovative and adaptable envelope over existing façades for building refurbishment, describing the possible different technologies and components, and providing guidelines on the selection criteria, limitations for the implementation, estimated costs and payback calculations. This information is intended to help building envelope designers to make informed decisions considering the building particularities.

– production, transport, storage and installation aspects for each system component of an innovative and adaptable envelope for building refurbishment, providing advice for installers on the overall logistics for the real implementation.

– assesment and evaluation of innovative and complex envelope system at building level that is not completely addressed by existing standards. Tests to be selected to feasibly asses an envelope system composed by different components.

This CWA is not designed to support European legislative requirements, such as the Construction Products Regulation 305/2011, or to address issues with significant health and safety implications. CEN and CENELEC are not accountable for its technical content or any possible conflict with national standards or legislation.

2 Normative references

The following documents are referred to in the text in such a way that some or all of their content constitutes requirements of this document. For dated references, only the edition cited applies. For undated references, the latest edition of the referenced document (including any amendments) applies.

EN 10346, *Continuously hot-dip coated steel flat products for cold forming - Technical delivery conditions*

EN 10169, *Continuously organic coated (coil coated) steel flat products - Technical delivery conditions*

3 Terms, definitions and abbreviations

3.1 Terms and definitions

For the purposes of this document, the following terms and definitions apply.

3.1.1
innovative and adaptable envelope
combination of active and passive prefabricated constructive solutions integrated into a structural mesh and installed over an existing façade of a building to improve its energy performance

3.1.2
dynamic window with automated solar blinds
window equipped with blinds capable of auto-adapting to external climate conditions and day-night cycles to improve the energy consumption of a building

3.1.3
multifunctional insulated panel
precast fibre reinforced concrete panel with a layer of thermal insulation capable to receive different finishes, as photovoltaic panels or a combined thermal reflective and photocatalytic functional coating

3.1.4
solar thermal air component
façade or roof solar thermal air collector capable to receive photovoltaic panels as finish

3.1.5
lightweight ventilated façade module
façade cladding based on polymer-concrete panel capable to receive different finishes, as photovoltaic panels or a combined thermal reflective and photocatalytic functional coating

3.1.6
photovoltaic panel
device capable to produce an electrical potential upon exposure to solar radiation designed to be installed over other components of the innovative and adaptable envelope

3.1.7
combined thermal reflective and photocatalytic functional coating
paint with high reflectance, self-cleaning and NOx reducing properties designed to be applied over other components of the innovative and adaptable envelope

3.1.8
Building Energy Management System
BEMS
computer-based control system installed in buildings that monitors and controls the building's mechanical and electrical equipment such as ventilation, lighting, power systems, fire systems, and security systems, opening of windows and operation of blinds

3.2 Abbreviations

For the purposes of this document, the following abbreviations apply.

ACC Avoided capital costs

BEMS Building Energy Management System

CDD Cooling degree days

HDD Heating degree days

IVB Increased value of buildings after retrofit

LCC Life Cycle Cost Analysis

NPV Net Present Value

PB PayBack period

PV Photovoltaic panel

QMS Quality Management System

ROI Return Of Investment

TBR Tenant based revenues

4 Design methodology

4.1 General

The aim of this clause is to give the user a complete guide to comply the design process of an innovative and adaptable envelope system (BRESAER system). The design process is summarized in Figure 1 showing "typical" series of steps that the designers should need to follow in order to filter the wide array of combinations available for an innovative and adaptable envelope system (BRESAER system).

The envelope system described in this design guide (BRESAER system) is an innovative, effective project solution for retrofitting buildings which aim is giving the best possible solution within each different project, condition and situation in terms of energy savings and costs, taking for granted the design will implicitly improve the well-being and comfort of users. Nevertheless, its flexibility gives the designer the opportunity to choose the most suitable solution within different prioritization criteria. The designer can decide which one is important from the variety of criteria, such as design, aesthetics, owners' interests and other factors.

Sometimes the BRESAER solutions described in this design guide are not the best for a very particular situation due to exceptional design conditions, regulations or other conditions. These different situations, when found, correspond to the limitations of BRESAER and where it is not able to be applied. In these supposed cases in which BRESAER cannot be applied in some parts of the envelope, another retrofitting alternatives can be analyzed in order to check if they are compatible with BRESAER solutions under the criteria and responsibility of the designer.

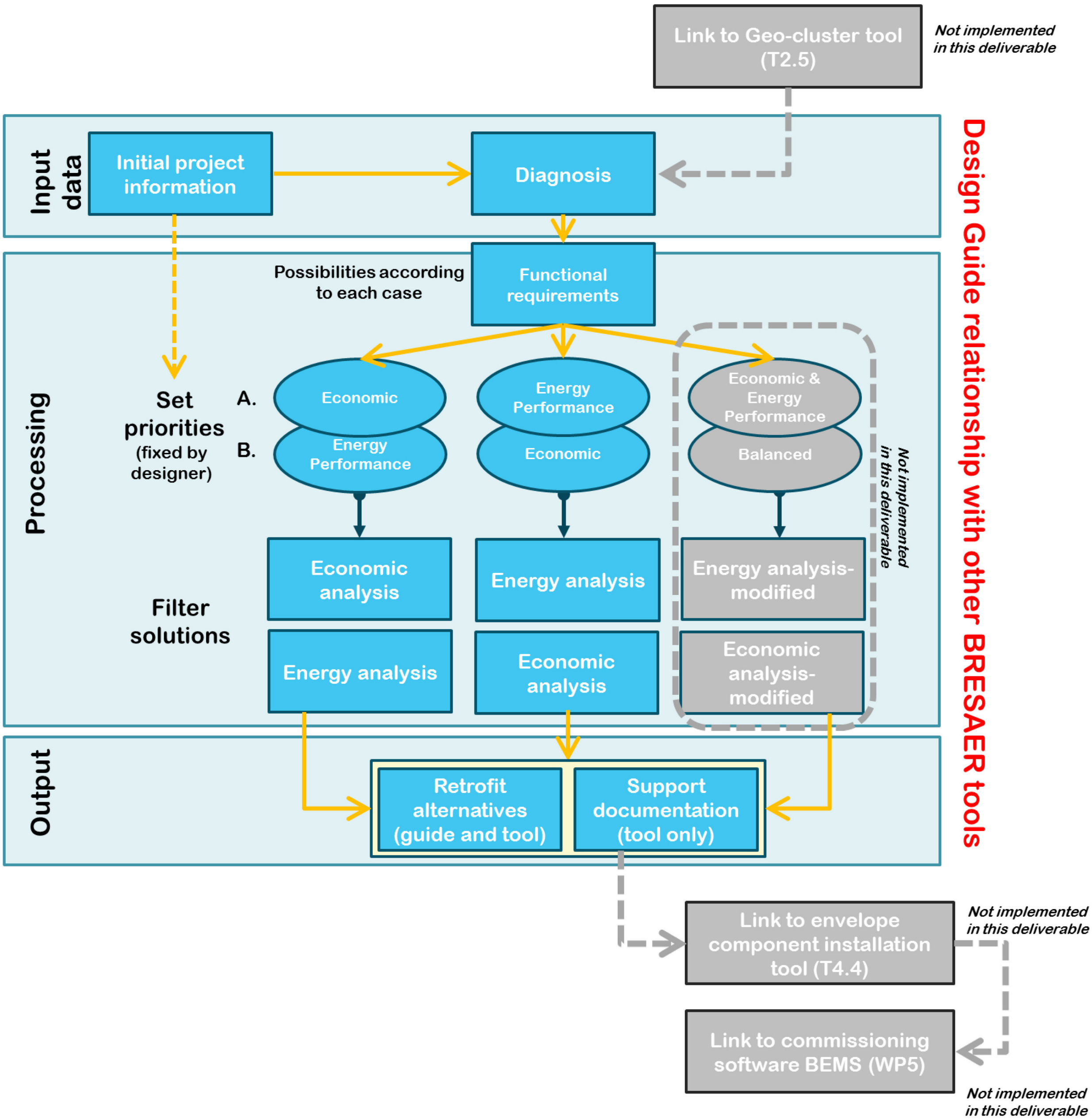


Figure 1 — Synoptic summary of the BRESAER design guide

4.2 Diagnosis

The first step involves the preliminary information that has to be collected by the design team concerning physical, legal and economic aspects that affect directly the construction project. Based on the answers to the questions, the design team can select appropriate courses of action in the constraint analysis and technological delimitation section.

4.2.1 Information gathering

4.2.1.1 General project information

- Project name:
- Project location: City and Country name
- Future usage* of the project: Chosen between Educational, Housing and Office.

  *For mixed-use projects, the analysis has to be separate for each area/floor that has a defined use.

- Analyze the innovative and adaptable envelope solutions (BRESAER solutions): In this step, the proposed technological solutions should be studied in order to identify if all the solutions that are of the interest of the owner and the designer, if not the solution can be delete from the design process.

  The solutions are:

  - Dynamic window with automated solar blinds (DW)
  - Multifunctional insulated panel (IP)
  - Solar thermal air component (SOL)
  - Lightweight ventilated façade module (VF)

  and additionally, according to each situation:

  - Photovoltaic panels integrated in envelope component (PV)
  - Combined thermal reflective and photocatalytic functional coating (COAT)

4.2.1.2 Building Information

- Geometry:
  - Building floors: Exclude basement levels without windows (if not conditioned).
  - Plan dimensions: Specify general dimension of the buildings: plan length (L) and width (W) in meters. Complex plan shapes such as U or L can be simplified for simulation purposes.
  - Height dimensions: General height (H) and average height of each floor (h) in meters.
  - Façade dimensions: Based on the main orientations (North, South, East and West),

    define the total façade areas in meters. Facades can be defined as having a certain

    direction if their maximum tilt is 45 degrees relative to true North.
- Building features: Please note any exceptional corners, entrances, terraces, etc. or if the overall plan is not rectangular or square (e.g. polygonal).

- Identify and analyze building parameters to be solved: These parameters will be solved in the restrictions decision process following the methodology.
    - General façade sides depending on orientation
    - Big wall areas that are more than 1,5 m^2
    - Small wall areas that are less than 1,5 m^2
    - Walls surfaces that are exposed to impacts (Cars, entries...)
    - Glazed areas of the building
    - Flat roofs that are less than 5 degrees
    - Slopped roofs that are more than 5 degrees
    - Wall to wall corners of the building
    - Roof to wall corners of the building
    - Access door
    - Windows and mobile solar shading
    - Canopy or other solar protection element
    - Balcony
    - Loggia or bay window
    - Overhangs
    - Decorative elements
    - Flat roof perimeter wall
    - Sloped roof overhang
    - Rain water gutters
    - Water, gas ducts & rain water downpipes & electrical, telecommunication cables
    - Exhaust stacks
    - Air conditioner units and other HVAC devices

4.2.1.3 Context

- Include climate conditions in building location
- Describe any significant buildings or obstacle shading the project building. (Location, Dimensions, Shade projected, Percentage of shade, Area affected per day hour...): Ask dwellers or relevant people.
- Note open areas and entrances to the buildings: This information is used to find place around the building that can serve to store construction materials and to anticipate problems from construction.

4.2.1.4 Structural conditions

- Construction year of the original building:
- Refurbishments since construction (Years, Modifications): check those that have affected external wall composition or insulation levels, and if possible the level reached.
- Wall composition of the external facades (layers, cm)
- Building materials and their condition:
  - Thickness of the external walls (cm, function): Try to identify load bearing walls.
  - Materials of the external facades: If known, list them from outside to inside.
  - Note degree of deterioration: That would require replacement.
  - Detect possible hidden structural damage: Specialized inspection might be required.

4.2.1.5 Financial requirements

- Project country: Possibly country region, in case there are differentiated tax incentives or labour costs.
- Renovation project:
  - Renovation project cost: % construction budget or fixed amount (euros).
  - Licences: % construction budget or fixed amount (euros).
  - Taxes: % construction budget or fixed amount (euros).
  - Subsidies: (euros).
  - Total retrofitted surface façade area (m^2):
  - Man hour cost (euros/h) (*):
  - Interest rate (%):
- Energy prices of the selected country: electricity energy price (euro/kWh), gas energy price (euro/kWh) (*)
  (*) If no data is introduced by the user, guide average data for the EU 28 countries will be used.

4.2.1.6 Normative

- Investigate local, regional and national regulations concerning:
  - Retrofit of buildings for the area required:
  - Fire, wind and earthquake resistance:
  - Maximum height allowed by normative:
  - Requirements to achieve energy label certification (if this is not mandatory):

4.2.1.7 Priorities

- Set the priorities in the project:
  - o High energy performance: since there are incentives and energy label certification can be achieved.
  - o Lowest cost and high return of investment: It is desired, but still achieving an acceptable energy level reduction.
  - o Design: Criteria of high design performance, this criterion normally increases cost estimations.

4.2.2 Analyzing limitations and restrictions

The innovative and adaptable envelope system (BRESAER system) described in this document is flexible to retrofit buildings with different characteristics. Despite this, due to the intrinsic characteristic of the system, some buildings will be out of the scope of this system retrofitting possibilities because of their technical and non-technical characteristics.

The building's characteristics that could limit the system's implementation are:

1. Complex geometry: Need of installation multiple nonstandard components, the design and implementation will be difficult and costly.
2. Low solar radiation: If there is not sufficiently solar radiation some components could not be use as the PV (permanently shaded by neighbors or obstructions).
3. National regulations: If the implementation is not possible due to national regulations some modifications could be needed, or some solutions will be dismissed.
4. Good energy performing buildings: Buildings for example under Energy Performance of Building Directive (EPBD), here the improvements will not be enough.
5. Historical buildings façades or protected ones: Normally historical buildings (pre-1950 or those featured in heritage listings) are under façade protection. It could be implemented on the roof only, or on facades without any protection feature.
6. Uses that have not been analysed: Such as healthcare, big-box or mall retail, storage, etc, since they have specific energy load and ventilation requirements that need further testing beyond the scope of this innovative and adaptable envelope system.
7. Structural problems: This innovative and adaptable envelope system can only be applied in buildings that are in good structural conditions in the country of application. In each implementation should be checked that the required loads do not exceed the loads considered in the design or rehabilitation. (For example, the heaviest envelope component is the Multifunctional Insulated Panels, which for BRESAER weigh 0,65kN/m^2). In case of problems in the building, these have to be repaired within the country regulations before the application of the innovative and adaptable envelope system (BRESAER). A quantitative analysis before implementation is recommended.
8. Height of the building: This innovative and adaptable envelope system solutions are calculated for an extreme situation of a high building of 30 m in front of the sea, according the CTE-AE Spanish normative, considering a wind load of 1,95 kN/m^2. Building´s height restrictions will be defined more from country regulations restrictions than from wind or height problems.
9. Insufficient space between neighboring buildings: The existing wall separation should be more than the space determined by the thickness of insulation 3 cm to 10 cm.

4.2.3 Identification of functional requirements

Some steps have to be completed before starting the design process. These steps are described to later identify the different interactions among buildings and the innovative and adaptable envelope system (BRESAER system). These steps include the complete geometrical analysis and definition of the building characteristics, but also local regulations.

Following a sequence of the examined building's characteristics, beginning from the most restrictive: those to be decided in the first place affect the rest of the system, or those where a specific technology should be used; and continuing to the most flexible: where several technologies could be used.

The design guide is based on the process defined by five stages that are closely related with the set degrees of flexibility:

- **Stage 0:** Vertical structural profiles and partially horizontal structural profiles.
- **Stage 1:** Grade 1 interactions are identified, and technologies associated with this interaction are implemented.
- **Stage 2:** Grade 2 and 2+ interactions are identified. Energy performance recommendations for that specific climate, orientation and building typology.
- **Stage 3:** Grade 3 and 3+ interactions are identified. Energy performance recommendations for that specific climate, orientation and building typology are checked and a suitable technology is selected and implemented for each situation.
- **Stage 4:** For the selected design (or designs if a single combination is not selected) energy savings are evaluated, and suitable solutions are filtered based on additional criteria such as cost.

The process described next will be followed in order to design the project from more restrictive patterns to more flexible ones, as shown in Figure 2:

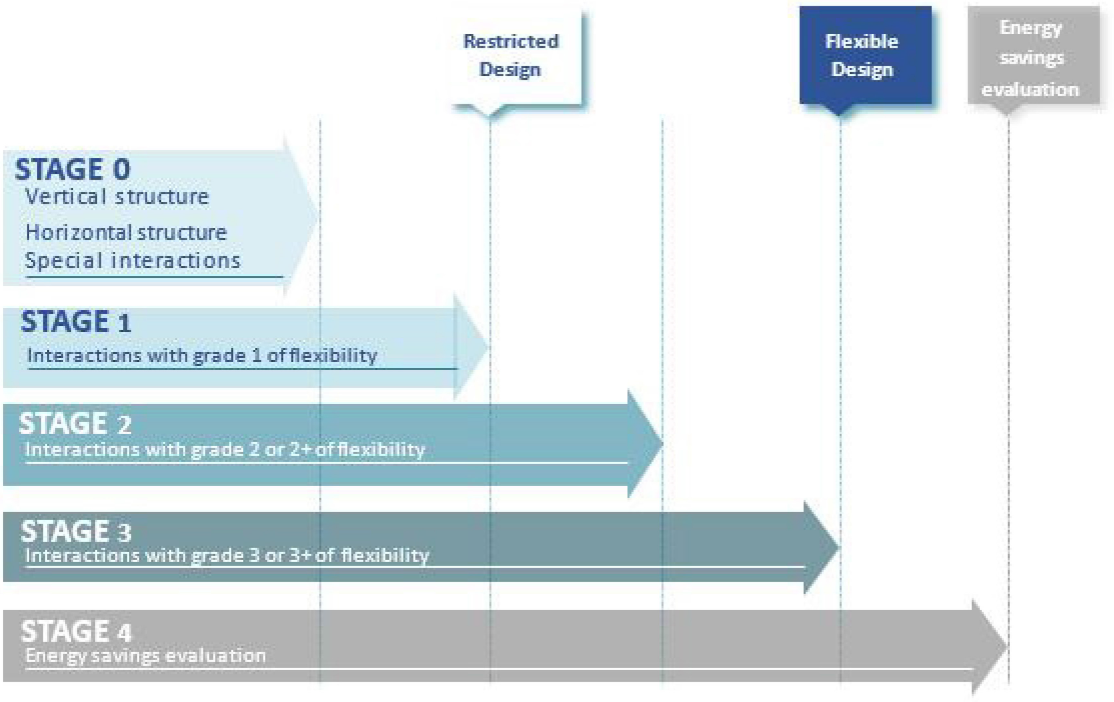


Figure 2 — Stages in the process design

The following steps describe the process to calculate the different solutions and parameters within three prioritization criteria: Economic, Energetic and Design. This innovative and adaptable envelope system (BRESAER system) is prioritized in energetic issues, but in this guide also recommendations in Economic and Design criteria are contemplated. In this case the user should decide which criteria should be followed in each case, as when restrictive decisions appear.

- **Step 0**

  a. General vertical structure: min 25cm – max. 90 cm

  b. Special iterations within (different solutions are identified):
  a. Flat roof (SOL/IP): min. -/50 cm – max. 100/330 cm
  b. Sloped roof (SOL): max. 100 cm
  c. Flat Roof (SOL/VF): min. -/30 cm – max. 100/180 cm
  d. Flat Roof (IP): min. 50cm – max. 330 cm

  c. Horizontal structure: Related to openings, when vertical structure is not continuous.

- **Step 1** At this stage a so called "restricted design" is obtained. This partial design has no flexibility in terms of technology selection and will be the common base for all the customization process.

  a. Walls surfaces that are exposed to impacts (Cars, entrances...)

  b. Access door

  c. Glazed areas / windows of the building / solar shading

  d. Slopped roofs that are more than 5 degrees

  e. Rain water gutters

  f. Downpipes, cables

  g. Air conditioner units and other HVAC devices

- **Step 2**

  a. Overhangs

  b. Small wall areas that are less than 1,5 m^2

  c. Flat roofs that are less than 5 degrees

  d. Wall to wall corners of the building

  e. Roof to wall corners of the building

  f. Decorative elements

  g. Flat roof perimeter wall

  h. Sloped roof overhang

- **Step 3**

  a. Loggia or bay window

  b. Balcony

  c. Big wall areas that are more than 1,5 m^2

  d. Generic wall areas

In step 2 and 3 energy performance recommendations for that specific climate, orientation and building typology are checked and a suitable technology is selected and implemented for each situation. Horizontal structural profiles are defined, and vertical profiles are reviewed.

A summarizing guide to this identification is found in Table 1, relating the next elements of the design process. To fulfil the table the next Table 2, Table 3, Table 4 and Table 5 will be needed in order to have all the complete methodology available to undertake each decision.

Table 1 — Pre-identification of degrees of freedom according to features found in the building

Elements to solve (by each façade orientation)		**Flexible grade**	**ENERGETIC**	**ECONOMIC**	**DESIGN**	**OTHER**
			To choose between solutions: IP, VF, SOL, DW / +COAT, + PV			
STAGE 1 (grade1)	a. Walls exposed to impacts	1				
	b. Access doors	1 (frame)				
	c. Glazed areas/window / solar shading	1+ frame				
	d. Sloped roofs	1				
	e. Rain water gutters	1				
	f. Downpipes, cables	1				
	g. Air conditioning, HVAC	1				
STAGE 2 (grade2,2+)	h. Overhangs	2 + PV in overhang				
	i. Small wall areas that are less than 1,5 m²	2				
	j. Flat roofs that are less than 5 degrees	2*				
	k. Wall to wall corners	2				
	l. Roof to wall corners	2				
	m. Decorative elements	2				
	n. Flat roof perimeter wall	2				
	o. Sloped roof overhang	2				
STAGE 3 (grade 3, 3+)	p. Loggia or bay window	2 + DW + PV above + floor ext.insulation				
	q. Balcony	3 + floor ext. ins. + no PV				
	r. Big wall areas > 1,5 m²	3				
	s. Generic wall areas	3				

The information to complete this decision process is defined in the next sequence of tables, in which the user shall decide over the different technologies with different criteria to fulfil the restriction design process (see Table 1).

Table 2 — Suitable climate and orientation matches for the individual Innovative and adaptable envelope components (BRESAER components)

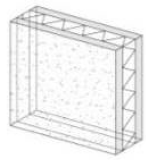
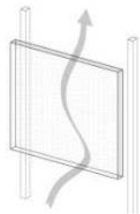
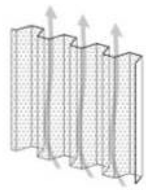
BREASER's climatic zones		Multifunctional insulation panel (STAM panel)	Lightweight ventilated façade (ULMA façade)	Solar thermal air component (Solarwall façade)	Dynamic window (EURECAT window)
					
HOT (D)	**NORTH**	**YES**	**YES**		
	EAST		**+ COAT**	**YES**	**+ COAT**
	SOUTH		**+ PV**	**+ PV**	**+ COAT**
	WEST		**+ COAT**	**YES**	**+ COAT**
HOT SUMMER/ COLD WINTER (C)	**NORTH**	**YES**		**YES**	**YES**
	EAST	**+ COAT**	**+ COAT**		**+ COAT**
	SOUTH		**+ PV**	**+ PV**	**+ COAT**
	WEST	**+ COAT**	**+ COAT**	**YES**	**+ COAT**
TEMPERATE (B)	**NORTH**	**YES**			**YES**
	EAST	**+ COAT**	**+ COAT**		**YES**
	SOUTH	**+ PV**	**+ PV**	**+ PV**	**YES**
	WEST	**+ COAT**	**+ COAT**		**YES**
COLD (A)	**NORTH**	**YES**			**YES**
	EAST	**+ COAT**			**YES**
	SOUTH	**+ PV**	**+ PV**	**+ PV**	**YES**
	WEST	**+ COAT**			**YES**

Table 3 — Envelope location and interaction of the Innovative and adaptable envelope components (BRESAER components)

Envelope locations	Multifunctional insulation panel (STAM panel)		Lightweight ventilated façade (ULMA façade)		Solar thermal air component (Solarwall façade)		Dynamic window (EURECAT window)	
Big wall areas > 1,5 m^2	+ PV	+COAT	+ PV	+COAT	+ PV			
Small wall areas < 1,5 m^2			+ PV	+COAT	+ PV			
Walls exposed to impacts		+COAT						
Glazed areas							+COAT	
Flat roofs <5º	+ PV	+COAT			+ PV*			
Sloped roofs >5º					+ PV			
Wall/wall corners			+ PV	+COAT	+ PV			
Roof/wall corners			YES		YES			

Table 4 — BRESAER integration strategy with visible existing services

Technical appliance	Innovative and adaptable envelope (BRESAER envelope) components
Rain water gutters	Horizontal rain gutters will be integrated in the overhang of slopped roofs. This must guarantee the correct drainage and sealing of rain water.
Water, gas ducts & rain water downpipes & electrical, telecommunication cables	Specific cavities/risers will be located on the envelope to host vertical and horizontal facilities ducts and cables. These cavities/risers will be cladded with Solar Wall or Ventilated Façade envelope components. Gas ducts will be located in independent risers and cladded with Solar Wall metallic sheets with perforations big enough to guarantee good ventilation.
Exhaust stacks	2 options: maintain existing (left) & replace by new one to move location (right)
Air conditioner units and other HVAC devices	Special connectors will be developed to fix the existing Air conditioner units to the innovative and adaptable load bearing structure. A special covering box will be used to integrate these elements.

Table 5 — BREASER integration strategy with visible architectural elements

Architectural element	Innovative and adaptable envelope (BRESAER) interaction/integration strategy
Access door	The building's entrance door will be integrated by including a special frame that will solve the interaction between the opening and the innovative and adaptable envelope to seal the junction between them, anchor the door to the façade and break the possible thermal bridge. The door will be replaced or not depending on its architectural and energy performance quality.
Window	The existing windows will be replaced by the innovative and adaptable envelope Dynamic Window component, which size will be adapted to the previous one. A special frame will solve the junction between the existing wall opening and the new façade. This frame will include the windowsill, header and jamb, glass framing and dynamic blinds' box. The blind's box will be located above the window's opening and cladded by the Lightweight ventilated façade modules or or Solar thermal air components to guarantee the continuity of the envelope overhang.
Canopy or other solar protection element	All existing solar protection devices will be removed as the dynamic window's blinds will replace its shading function.
Balcony	The existing balconies will be refurbished in two different aspects: its floor will be thermally insulated externally with existing market products to break the thermal bridge through this element; the railing will be cladded for its architectural renovation. These cladding components will be done by the innovative and adaptable envelope components as Lightweigth ventilated façade or Solar thermal air component + PV when possible but could be also finished with market products depending on the designers' choice.
Loggia or bay window	Existing loggias will be replaced by Dynamic Windows component and its glazing system. It will include blinds depending on the energetic performance needs. Top and bottom floors will be thermally insulated and cladded with innovative and adaptable envelope components + PV if possible or by market products depending on the designers' choice.
Overhangs	The transition between two façade planes with different overhang will be solved using the most flexible cladding components is sense of dimension and shape. These are the Lightweight ventilated façade and the Solar thermal air component. The last one will just be used as an aesthetical cladding component, not as an active component. Special attention will be taken to the joints to prevent water leakage or thermal bridges.
Decorative elements	Non-regular or non-orthogonal surfaces will be covered by Solar thermal air component. Its metallic sheet cladding allows its adaptation to this kind of volumes. Special attention will be taken to the joints to prevent water leakage or thermal bridges.
Flat roof perimeter wall	The top finishing of flat roof's perimeter wall will be cladded with Solar thermal air component or Lightweigth ventilated façade components because of its light weight and dimensions flexibility. Special attention will be taken to the joints between wall and roof to prevent water leakage or thermal bridges.
Sloped roof overhang	Slopped roof overhangs will be cladded with Solar thermal air components because of its light weight. Drainage opening will be needed as rain will run below this envelope component. Special attention will be taken to the joints between wall, roof and this element to prevent water leakage or thermal bridges.

4.2.4 Energy analysis

After the restrictions decision making process, an energy analysis should be done by using the energy saving estimation methodology and/or simulation results from the project. The steps to follow for the energy analysis are the following:

4.2.4.1 Identification of the climate zone

a. Identify the climate zone: A, B, C, or D according to the climate division map.

Figure 3 — Main climate divisions of Europe and Turkey for the BRESAER project

b. Based on the location, define the climate zone as:

- Cold
- Temperate
- Hot summers and cold winters
- Hot
- High mountain zone (if the project is located in this zone, the analysis cannot continue since it was not examined due to sparse population)

c. Variant to last point (2. Location):

   Use the heating degree days (HDD) and cooling degree days (CDD) division indicated in the same map to define your climate zone according to those limits. (Use this method if the weather characteristics in the project city differ significantly from the divisions on the map).

d. Identify guiding city:

   Representative urban centres were selected for each climate zone. The reference cities are the following:

   ▪ Cold: Prague (Czech Republic)

   ▪ Temperate: Paris (France)

   ▪ Hot summers and cold winters: Bologna (Italy) and Ankara (Turkey)

   ▪ Hot: Athens (Greece)

The city name indicates the results that need to be consulted. A more detailed study for the particular project city will require performing energy simulations. This is recommended for the next stage after choosing the alternatives.

With the main climate zone identified, the designer can review the most suitable energy strategies determined for the climate zone. The designer can match the strategies of the representative city corresponding to the project climate zone. If it is desired to perform a detailed study for the specific location, it can be done by means of software that plots the psychrometric chart using whole-year weather data, such as Climate Consultant or similar.

4.2.4.2 Usage and assumptions

a. The intended future usage of the project defines the internal loads, times of use (months/days/hours), number of occupants, and particular characteristics of the buildings that will affect its energy performance.

b. Assumptions needed to make the estimation:

   o The roof and external walls will have a continuous insulation layer that complies with minimal regulatory values for each reference city. This value has to be verified with the minimum value of the project city, and according to what is implemented in the project.

   o It is important that the constructive process of the retrofit project will address quality control to ensure infiltration reduction that can seriously affect the final performance of the building. This fact should be correctly reflected when using the energy simulations described in the next step.

   o Façade areas that receive permanent shading from neighboring buildings should be covered with the multifunctional insulated panel only. Mutual shading if existing, should be correctly reflected when using the energy simulations described in the next step.

c. Available combinations: Combinations of technologies should be considered by designers according to project’s needs and constraints.

4.2.4.3 Energy estimation and selection of technology combination(s)

In the energy estimation methodology, the total areas to be conditioned should be taken into account as well as the façade areas to be retrofit. It should also be decided if the roof will be used to hold specific technologies.

The estimation of the energy performance and possible savings comparing to the present situation of the buildings should be done using an hourly dynamic simulation model (e.g. Energy Plus, TRNSYS, ESP-r) and EN ISO 52000-1 assesment framework and metholology.

For this purpose, two tests should be carried out: the first is a simulation of the building in its current state and conditions. The second of the building in its state after upgrading, which includes improvements and the chosen technology combination. The simulations should be done in a way that all test data not related to the building upgrade such as operation hours, internal heat loads and number of users, will remain in both tests constant so as not to affect the comparison of the results and their evaluation.

The economic analysis of the studied solution(s) should be done using the method described in Clause 5.

5 Payback calculations

5.1 General

This clause presents an approach of a cost analysis and calculation methodology for evaluating energy-efficient building retrofit alternatives by developing cases studies to evaluate the cost effectiveness of an innovative and adaptable envelopes (hereinafter "envelope system") in building refurbishment of different typologies of buildings in the European building stock. Therefore, to ensure that under present market conditions, that users and manufactures achieve a cost-competitive product across the geographical and usage areas covered by this "envelope system".

The assessment of energy and cost effectiveness in retrofitting buildings is based on the Directive on the Energy Performance of Buildings (EPBD) 2010/31/EU buildings[1] which establishes that Member States must ensure that minimum energy performance requirements are set with a view to achieve the cost optimal level. A cost-optimal level is defined as the energy performance level which leads to the lowest cost during the estimated economic lifecycle.

5.2 Preliminary considerations

The construction sector is considered to be a very traditional sector, characterized by relatively large investments during construction phases, relatively low running costs of buildings, served by a collection of atomized SMEs dealing with particular activities/subsystems in the construction, maintenance, and retrofit process. In many multi-rise building cases, owners are a collection of individuals with different interests, priorities, limited income and asymmetric financial situations, which difficult the decision-making process.

The most frequent obstacle for investing in energy efficiency remains the long payback period and the inability to secure the investments on acceptable terms and also nowadays, the sector has suffered the scarcity of capitals for investment due to the effect of the economic recession.

Grant and subsidies for retrofitting of buildings are generally applied when governments consider that the optimal energy efficient investments cannot be fully supported by the market alone. They can partly help to overcome the upfront cost barrier as they directly fill an immediate financial gap and thus enable a temporary shift in the market.

[1] European Union. 2010. Directive 2010/31/EU of the European Parliament and of the Council of 19 May 2010 on the energy performance of buildings (recast). Official Journal of the European Union, 18 June 2010.

Programs investing in the retrofitting of buildings to make them more energy-efficient can be found in a number of EU countries[2]. These tend to cover private households, but some countries have chosen to finance this kind of retrofitting work in public and industrial buildings as well. Although job creation may not be the primary aim of such initiatives, these programs are recognized as having positive employment effects in a sector which often has been severely affected by the economic crisis (construction). They may also grant social benefits by improving the buildings and thereby the living/working conditions (health, comfort, productivity) of their inhabitants/employees. These social issues also need to be tackled during decision-making process and life cycle sustainability assessment (LCSA) must be included. Although Social LCA is the most recent methodology, the application is still challenging[3].

5.3 Methodology of costs calculation

Calculation methodology for evaluating energy-efficient building retrofit alternatives is used to evaluate the cost effectiveness of an innovative and adaptable envelopes in building refurbishment.

Life Cycle Cost Analysis (LCC) methodology for economic performance evaluation of the refurbishment of buildings is presented in the document EN 16627:2015. Sustainability of construction works - Assessment of economic performance of buildings - Calculation methods, prepared by Technical Committee CEN/TC 350 “Sustainability of construction works”. (http://portailgroupe.afnor.fr/public_espacenormalisation/CENTC350/index.html).

Standard practice considers a cash flow model where, building envelope retrofitting needs to pay back by means of energy savings produced. Figure below presents Cash flow model standard. Other economic benefits such as real state value increase of retrofitted buildings is not considered.

2 BPIE (2011) Europe’s buildings under the microscope: a country-by-country review of the energy performance of buildings, Brussels, Buildings Performance Institute Europe.

3 Touceda I, Richard A, Neila J, Degrez M; Implementation of socioeconomic criteria for the life cycle sustainability assessment of housing retrofit. http://social-lca.cirad.fr/content/download/4277/32060/version/1/file/Thema+2+-+Sess4-3+Touceda+et+al.+2014_4thSocSem_SLCA_Montpellier.pdf

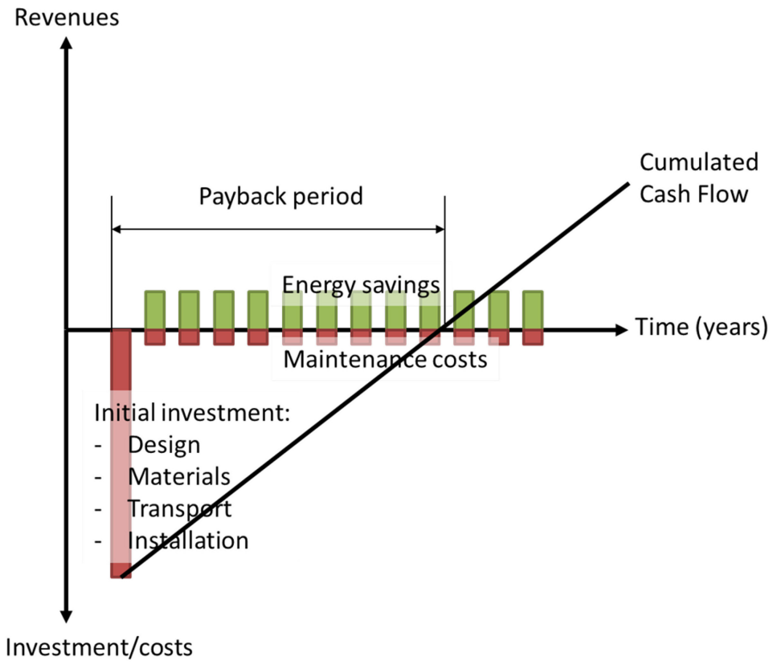


Figure 4 — Cash flow model standard

Energy efficiency delivers energy savings and therefore energy cost savings, as well as direct environmental benefits. Besides, as an indirect effect, it has smaller or larger consequences on other economic values.

Standard practice is to consider only the energy cost saving, which for a deep energy retrofit is not sufficient to have short payback periods. Since the current cash flow model at present does not allow to meet expectations of a short return of investment, an examination is made of relevant intangibles and "green incentives" that increase value through property appreciation and user satisfaction.

In this field, a complete study has been developed by the **Rocky Mountain Institute** (RMI) (2015)[4] where method for capturing the value of deep retrofit processes are proposed. In this document, a wider approach is presented, where the following additional economic revenue streams are considered as avoided capital cost, tenant-based revenues and increased value of buildings, after retrofit. In this same document it is also acknowledged that energy savings by themselves are seldom sufficient to payback for deep retrofit actuations.

All studies in Europe shows the impact of energy efficiency improvements on the value of buildings by increasing its actual value and through the impact on operational costs. Highlights the report the JRC Science for Policy report that[5] reviews current knowledge about the impact of energy efficiency improvements on the value of buildings. In particular, the methodology that can be applied to quantify the increase or decrease of property value linked to the energy performance and sustainability components is explained and different methods are compared. This report also provided an overview of past literature and the impacts found that green value had a positive impact on either the prices or other selling/renting attributes, such as transaction time. The commercial sector was found to see a lot of

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[4] "How To Calculate And Present Deep Retrofit Value" Rocky Mountain Institute, USA, 2015 http://www.rmi.org

[5] "Energy efficiency, the value of buildings and the payment default risk" (2018) Zancanella, P., Bertoldi, P., Boza-Kiss, B.
http://publications.jrc.ec.europa.eu/repository/bitstream/JRC113215/jrc113215_kjna29471enn_v2_ipo_final.pdf

benefits, although not always quantifiable (e.g. through soft impacts). The increase of both the sale price and of the renting rate and both for non-residential and residential (respectively) buildings has been observed in the large majority of the reviewed studies. There seem to be more studies available for the commercial and service segment than for the residential sector. Of the studies examining the impact on sales value, 90% found that the presence of energy/environmental labelling had a positive impact on the sales value (European Commission, 2016). In more recent studies (probably due to more detailed assessments) varied types of impacts were found, e.g. impact depended on the location or on the availability of properties in the neighbourhood. The ranges across countries are difficult to compare, because of the different methodologies and because of the different market structures and label/certification information.

The JRC Science for Policy report indicates that as a rule of thumb an increase of 3%-8% in the price of residential assets as a result of energy efficiency improvements, and an increase of around 3%-5% in residential rents compared to similar properties can be observed. For commercial buildings, the premium seems to be higher, over 10%, and in some studies even over 20% of sales price increase compared to similar properties has been reported. Rental prices of commercial buildings have also been positively affected by 2%-5%. Differences across regions and countries, as well as different property types (e.g. apartments vs. houses) are shown.

Cost analysis for the solutions of the refurbishment of buildings is based on the following items:

- **Capital cost** that includes:

  Retrofit cost:

  Investment cost

  - Cost of the renovation project
  - Cost of products acquisition (product manufacturing (€/m^2)) and product transport to the building to be renovated
  - Cost of products installation: hand work cost to install the component (hour/m^2) and the cost of auxiliary equipment needed to install the component (€/m^2)
  - Maintenance cost that includes: inspection, adjustments, repairs and consumable items during the period of service live. A service live of 30 years has been taken for the building after refurbishment.

  Operational cost, if for example there is an electricity consumption.

  Operating cost savings: Avoided maintenance costs that includes avoided capital costs: Investments in non energy-relate activities. Retrofits that would have been made anyway in the existing façade or roof. For example: repair the façade and paint it.

  Subsidies & incentives: Grants/subsidies that may exist in different countries to overcome barriers to energy renovation of existing buildings.

- **Increased value of buildings after retrofit (IVB):** Increased value is very dependent on the market (tight or not) and location:

  - increase of 3%-8% in the price of residential assets as a result of energy efficiency improvements
  - for commercial buildings, the premium seems to be higher, over 10% to 20% of sales price increase

- **Tenant based revenues after retrofit (TBR):** (only for building rented to third parties)
  - Premium for retrofitted buildings: i.e. rents are increased of around 3%-5% in residential rents
  - an increase of around 2%-5% in commercial buildings
  - For offices: premium offseted by the gain in productivity (2 to 8% mentioned in different studies). REHVA Guidebook no. 6 "Indoor Climate and Productivity in Offices" [Warg 2006] presents a quantitative model that allows one to assess the trade-offs between investments and productivity.
  - Increased occupation rate: Tenants are more willing to settle in "fancy" buildings. Increase in occupation rate by >10% (always <100%)

The methodology presented in this document takes into account Life Cycle Cost Analysis (LCC) methodology for economic performance evaluation of the refurbishment of buildings is presented in the document: EN 16627:2015 and the above cited studies where economic revenue streams are considered as avoided capital cost, tenant-based revenues and increased value of buildings, after retrofit.

Within the LCC studies there are several economic indicators. The economic indicators evaluated depend on the objective of the study, the target audience and the level of accuracy of the required results. Among the main economic indicators, it can be highlighted the following:

- **Net Present Value (NPV):** is the difference between the present value of cash inflows and the present value of cash outflows. NPV is used in capital budgeting to analyse the profitability of a projected investment or project.

$$NPVsl = \sum_{n=1}^{Sl} \frac{\mathrm{Cn}}{(1+d)^n} - I$$

where

Cn = net cash inflow during the period of analysis;

I = total initial investment costs – avoided capital cost;

d = discount rate;

n =is the number of years between the base date and the project service life;

sl = is the period of analysis, the service life.

A positive net present value indicates that the projected earnings generated by a project or investment (in present euros) exceed the anticipated costs (also in present euros).

- **Return Of Investment (ROI):** measures the amount of return on an investment relative to the investment's cost. To calculate ROI, the benefit (or return) of an investment is divided by the cost of the investment, and the result is expressed as a percentage or a ratio.

$$ROIsl = \frac{NPV\ sl}{Inv}\ x\,100$$

where

sl	= is the period of analysis, the service life;
NPV sl	= is the Net Present Value of service life;
Inv	= is the initial investment - avoided capital cost;
d	= discount rate;
n	= is the number of years between the base date and the project service life;
sl	= is the period of analysis, the service life.

- **PayBack period (PB):** is the time it takes to cover investment costs that will be made in the building that will be rehabilitated. It can be calculated from the number of years elapsed between the initial investment, its subsequent operating costs and the time at which cumulative savings offset the investment. Simple payback takes real (non-discounted) values for future monies. Discounted payback uses present values. Payback, in general, ignores all costs and savings that occur after payback has been reached.

The following table presents the calculations to be performed to obtain the Return of Investment (ROI) and the Payback Period (PB), where in the cash flow model has taken into account not only the investment cost but also: the avoided capital cost; the increased value of the building after retrofit (IVB) or the tenant-based revenues (TBR).

Table 6 — Sample calculations to be performed to obtain Return of Investment and Payback Period

		PERIOD					
	n = Year	0	1	2	n	...	SL
	q_n = discount factor	1	$1/(1+d)^{\wedge 1}$	$1/(1+d)^{\wedge 2}$	$1/(1+d)^{\wedge n}$		
	IR_n = inflation factor	1	$(1+i)^{\wedge 1}$	$(1+i)^{\wedge 2}$	$(1+i)^{\wedge n}$		
	ER_n = Energy price rate	1	$(-0{,}0008 \times 1^{\wedge 2}) + (0{,}0311 \times 1) + 0{,}9956$	$(-0{,}0008 \times 2^{\wedge 2}) + (0{,}0311 \times 2) + 0{,}9956$	$(-0{,}0008 \times n^{\wedge 2}) + (0{,}0311 \times n) + 0{,}9956$		
	IVB= Increased Value of the Building		IVB				
	TBR= Tenant Based Revenue		TRB_1	TRB_2	TRB_n		
	MC_n = Maintenance	$MC + t_3$	$(MC + t_3) \times IR_1$	$(MC + t_3) \times IR_2$	$(MC + t_3) \times IR_n$		
	OC_n = Operation	OC	$OC \times IR_1$	$OC \times IR_2$	$OC \times IR_n$		
Energy saving (kwh)	Electricity energy saving	Kwh.e	Kwh.e	Kwh.e	Kwh.e		
	Natural gas enegy saving	kwh.ng	kwh.ng	kwh.ng	kwh.ng		
Energy saving (€) - $\sum Es_n$	Electricity saving cost	kwh.e x €/kwh.e	kwh.e x €.kwh.e x ER_1	kwh.e x €.kwh.e x ER_2	kwh.e x €.kwh.e x ER_n		
	Natural gas saving cost	kwh.ng x €/kwh.ng	kwh.ng x €.kwh.ng x ER_1	kwh.ng x €.kwh.ng x ER_2	kwh.ng x €.kwh.ng x ER_n		
	C_n = Cashflow	- Inv	C_0+ (IVB or TBR_1)+$\sum Es_1 - MC_1 - OC_1$	$C_1 + TBR_2 + \sum Es_2 - MC_2 - OC_2$	$C_{n-1} + TBR_n + \sum Es_n - MC_n$ - Ocn		
	$NetC_n$ = Net Cashflow	$C_0 \times q_0$	$C_1 \times q_1$	$C_2 \times q_2$	$C_n \times q_n$		
	ROI_n	$NPV_0/Inv \times 100$	$NPV_1/Inv \times 100$	$NPV_2/Inv \times 100$	$NPV_n/Inv \times 100$		

input data	
calculation	

where

AC: Adquisition Cost — t1: Adquisition taxes

IC: Installation Cost — t2: Instalation Cost taxes

ACC: is the avoided capital cost

Inv: is the initial investment= AC + t1 + IC +t2- ACC

Cn: is the cost in year n;

q: is the discount factor;

d: is the discount rate;

n: is the number of years between the base date and the project service life;

SL: is the period of analysis, the Service Life.

IVB: is the increased value of the building, after retrofit

TBR: is the tenant based revenue, after retrofit

$$NPV_{SL} = \sum (Cn \times qn) = \sum_{n=1}^{SL} \frac{Cn}{(1+d)^n}$$

$$ROI_{SL} = \frac{NPV_{SL}}{Inv.} \text{ X } 100$$

PB	If NPV > 0, n = PB

The parameters needed to calculate the cost indicators for a refurbishment solution are the following:

- hourly cost[6] (€/h) to calculate the manufacturing, installation and maintenance of each component of the refurbishment solution

- electricity price[7] (€/kW) and gas price[8] (€/kW) to calculate the energy saving after the building refurbishment

- VAT rate[9] (%)

- inflate rate[10] (%)

- discount rate[11] (%)

6 Logistics and installation

6.1 General

Logistics is expressed as: *"The process of planning, implementing, and controlling procedures for the efficient and effective transportation and storage of goods including services, and related information from the point of origin to the point of consumption for the purpose of conforming to customer requirements. This definition includes inbound, outbound, internal, and external movements."* 0

[6] Hourly labour costs per hour for the whole economy in 2017, in euros within the European Union (EU). Source: Eurostat. https://ec.europa.eu/eurostat/statistics-explained/index.php/Hourly_labour_costs

[7] Average European electricity price for household consumers https://ec.europa.eu/eurostat/statistics-explained/index.php/Electricity_price_statistics#Electricity_prices_for_household_consumers

[8] Average European gas price for household consumers https://ec.europa.eu/eurostat/statistics-explained/index.php/Natural_gas_price_statistics#Natural_gas_prices_for_household_consumers

[9] VAT rates applied in the Member States od European Union https://ec.europa.eu/taxation_customs/sites/taxation/files/resources/documents/taxation/vat/how_vat_works/rates/vat_rates_en.pdf

[10] Average European inflation rate according to the European Central Bank´s interest rate. http://appsso.eurostat.ec.europa.eu/nui/setupDownloads.do

[11] European discount rate according to UNE-EN 16627:2016 "Sustainability of construction works - Assessment of economic performance of buildings - Calculation methods". This standard takes the real discount factor of 3% for energy efficiency in building according to the 2010/31/UE European directive.

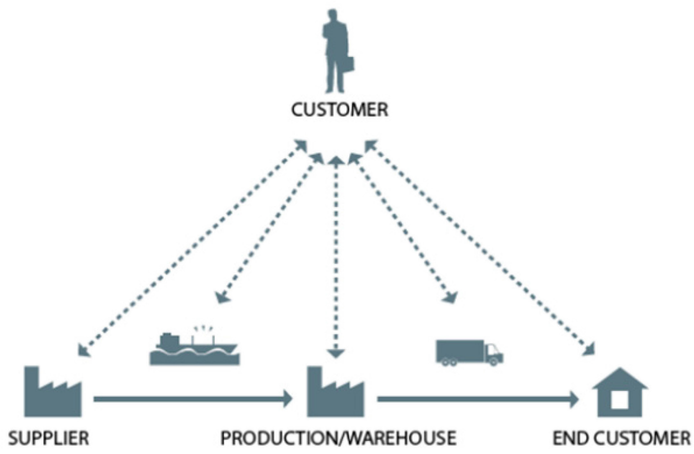

Figure 5 — Logistics Control Tower (UAE Logistics Control Towers, 2007)

It has been recognized that many supply chains do not have the right logistics competence in-house. To improve the efficiency in innovative and adaptable envelopes (BRESAER system) logistics within the supply chain different terms will be analysed though this clause.

Materials supply is an important element of operation of manufacturing and thus a factor that may affects the quality of all construction projects. The level of materials costs reaches up to 70 % of total construction cost estimations in the manufacturing times, therefore any actions towards rationalisation in logistics of size, structure and organisation of material production, workshop and transport are important in terms of project efficiency and require proper management. 0

Firstly the method for evaluating logistics systems should be as generic as possible to be applicable within as many manufacturers as possible. Therefore, a general representation for describing a logistics system is needed. A common way to structure a company from the point of view of manufacturing, from a logistics perspective, is in three main functions - production, workshop and transport.

The scope of logistics goes from the management of raw materials through to the delivery of the final product. Included in this model are also suppliers and customers. Furthermore it demonstrates the materials flow and the requirements information flow in the model. Christopher's (2005) general representation of a logistics system is shown in the Figure 6. 0

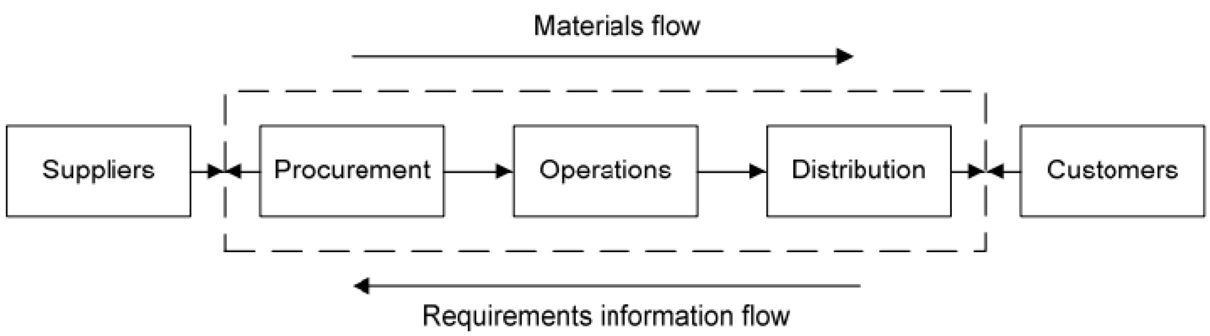

Figure 6 — The scope of logistics (Christopher, 2005)

Therefore, the analysis of internal logistics of the different elements in innovative and adaptable envelopes (BRESAER system) will be divided in the next points within these criteria:

Production

Workshop

Transport

In the field of construction, supply (ordering, transport and storage) and production dominate the logistic processes. Supply and production are often difficult to separate due not only to organisational but also technological reasons. Traditionally, contractors taking part in a project were responsible for their individual supply chains to provide materials and services required within their scope of works. 0

Deciding on project logistics requires a wide knowledge of the building materials market, products, supply chains, times of delivery approaches to supply, and a deep understanding of the logistics impact on the project efficiency in terms of cost, quality and time. It is of great importance to be aware of logistic and their relationship to the innovative and adaptable envelope project (BRESAER system) in order achieve the best performance.

Between the producer and the ultimate customer there are also many intermediaries such as wholesalers, retailers, shipment companies, etc., who, together with the former, constitute a logistic chain. Management of logistic chains is aimed at tightening cooperation between its members, designers, manufacturers... Integration and coordination is to enable using the improvement of each member to the advantage of whole process and optimising the value added by each member of the chain to the good or service offered to the customers according to their expectations.

Extending this philosophy over all functional fields of cooperating enterprises allowed to define the current approach of supply chain. This concept has a broader meaning than logistic chain as the latter focuses mainly on logistic tasks and processes. 0

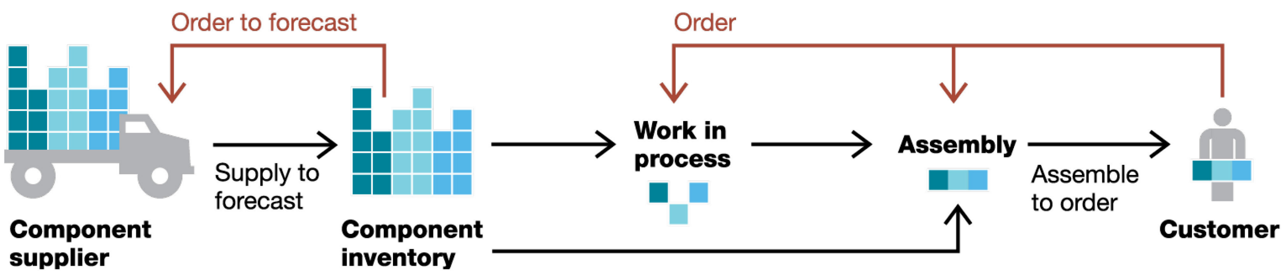

Figure 7 — Process logistics identification

To achieve an efficiency in logistics during the manufacturing also complying within the philosophy of cooperation the different elements that compose an innovative and adaptable envelope, for examplethe BRESAER system, (structure, lightweight ventilated façade module, multifunctional insulated panels, solar thermal air component envelope and dynamic window with automated solar blinds) will be addressed in the next points analysing its production, transport and workshop; also as internal logistics for maintenance and installation. To complete the analysis, commercial information from data sheets of the different elements will be added.

To finalise, the different processes of installation will be resumed, detailed and explained in clause 6.10, where the installation of each element will be detailed following the next structure based in construction processes guides:

- Reception and verification measures
- Health and safety control measures

- Machinery, scaffolding and crafts requirements
- Building preparation measures
- Installation processes
- Revision and cleaning processes

6.2 Structure and substructure

This clause will describe the logistics efficiency and installation analysis of an innovative and adaptable envelope (BRESAER system) structure and substructure.

6.2.1 Production

This clause will develop the logistics efficiency and installation processes and implementation conditions of the substructure developed for an innovative and adaptable envelope (BRESAER project).

The structure and substructure have been designed in aluminium due its lightweight properties and its malleability in the moment of conformation. It is one of the most modern metals, discovered in the XIXth century and due to that fact has been developed really advanced skills through its manufacturing in industrialized processes.

6.2.1.1 Production description

The innovative and adaptable envelope substructure (BRESAER substructure) is made of industrialized aluminium profiles (Aluskit profiles) manufactured by Alu-Stock® S.A. These modular and detachable profiles support all the different cladding systems while connecting to the main structure of different buildings. This system provides a wide variety of components as well as lightweight structure. Moreover, the lateral railways extruded in the aluminium of the Aluskit profiles channels enable a dry and easy mechanical installation procedures, which gives the system a versatile and replicable solutions through the different buildings in which the system could be installed.

The general properties of aluminium are the following:

Table 7 — Aluminium properties

Young module E (MPa)	Transverse elastic modulus G (MPa)	Density (kg/dm^3)	Coefficient of thermal expansion
70 000	27 000	2,7	2,4 x 10-6 K

The aluminium alloy of the vertical profiles is EN AW 6106, having the following properties:

Table 8 — EN AW 6160 alloy structural properties

Elastic limit $R_{p\,0,2}$ (MPa)	Break load R_m (MPa)	Shear break load R_g (MPa)	Elongation break load A_5 (%)	Hardness HB
190	225	140	14	75

The aluminium alloy is EN AW 6106 T6 for the profiles and brackets and EN AW 6063 T6 for the lightweight ventilated façade module (ULMA™ façade) additional components. The certifications of the structure and substructure should be validated with the required specifications coming from the innovative and adaptable envelope project.

Table 9 — Chemical composition

Alloy	Mg	Mn	Fe	Si	Cu	Zn	Cr	Ti	Other elements	Total other	Al
6063	0,45-0,9	≤0,10	≤0,35	0,2-0,6	≤0,10	≤0,10	≤0,10	≤0,10	≤0,05	≤0,15	Rest
6106	0,4-0,8	0,05-0,20	≤0,35	0,3-0,6	≤0,25	≤0,15	≤0,20	≤0,10	≤0,05	≤0,15	Resto

Table 10 — Physical composition

Alloy	E (MPa)	G (MPa)	ν	Fusion interval (Cº)	C_p	α µm m^{-1} K^{-1}	ρ kg m^{-3}	$ρ_{el}$ nΩ m	λ W m^{-1} K^{-1}	CE %IACS
6063	69.500	26.100	0,33	615 - 655	898	23,5	2.700	33,0	201	52,0
6106	69.500	26.100	0,33	610 - 655	897	23,4	2.700	35,0	192	49,5

The maximum height of the standardized aluminium profiles is 6 050 mm with a 15µm natural anodized layer. If requested, these factors can be customized to raw or lacquered finishing and bigger sizes. The main reason for standardized size limits is due to transport difficulties, which could be customized if necessary.

NOTE The final vertical profile chosen for BRESAER system was the Aluskit 150x80 R2 which has double rails in double direction of the façade so as to fix the additional components to reach the finishing material. As this profile is not in the Alu-Stock® catalogues, it has to be specially ordered to extrude the aluminium in the singular shape for BRESAER requests.

6.2.1.2 Definition of elements to be produced

The elements of an innovative and adaptable envelope substructure (BRESAER substructure) are the following:

- **Aluminium brackets** (must be redesigned in each implementation)
- **Vertical aluminium profiles**, Aluskit 150x80 R2.

Dimensions in mm

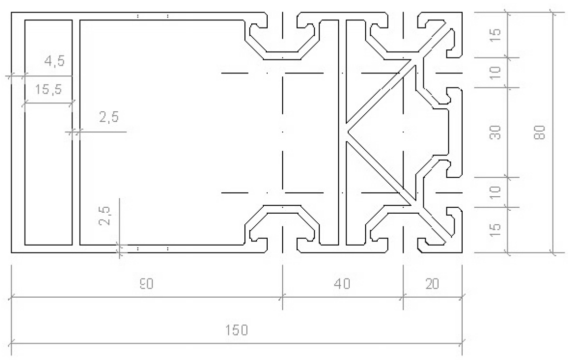

Figure 8 — Aluskit 2015 x 80 R2 customized vertical profile (Aluminium, EN AW 6106 T6)

- **Lightweight ventilated façade module additional components**:

Dimensions in mm

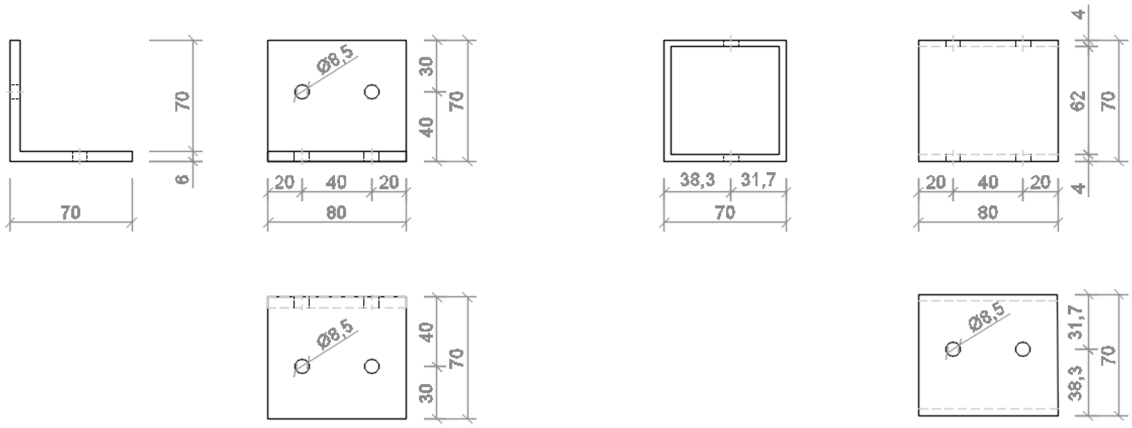

Figure 9 — L70 and lightweight ventilated façade module (ULMA ™) customized connector (Aluminium, EN AW 6063 T3)

- **Multifunctional insulated panel additional components**:
  - o L90.

Dimensions in mm

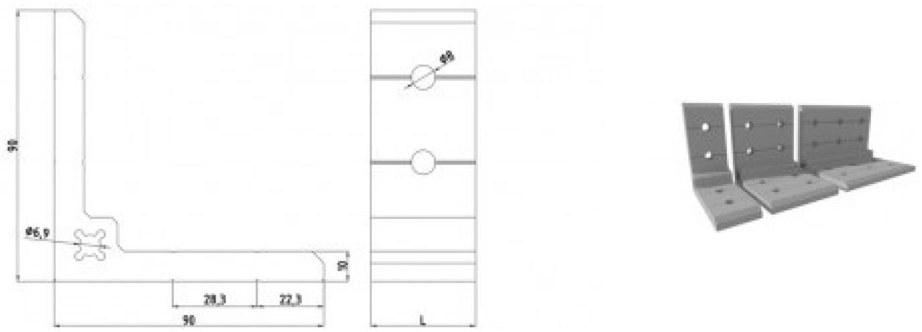

Figure 10 — Alustock® framing square 90 x 90 x 10 (Aluminium, EN AW 6106 T6)

- o Horizontal aluminium profiles, Aluskit 80x80.

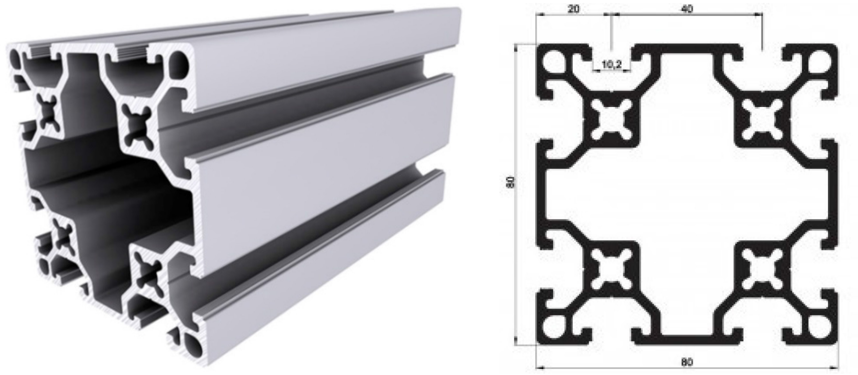

Figure 11 — Aluskit 80 x 80 reinforced square (Aluminium, EN AW6106 T6)

- **Steel hammerhead bolts and nuts.**

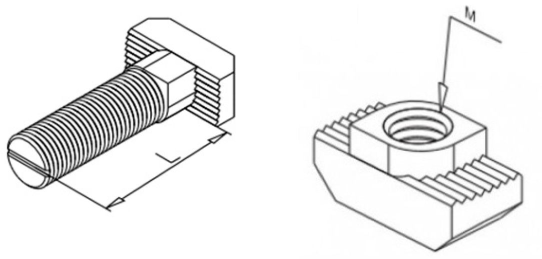

Figure 12 — Aluskit Hammer head bolt and nut (Stainless steel, A4-50)

6.2.1.3 Manufacture timescale

The timescale of the manufacturing will depend on the quantity of the material request as well as the custom-made piece amount.

NOTE For Alustock® vertical profiles 150 x 80 R2 is not in stock and some elements have to be cut in a requested length.

Table 11 — Elements that are not in stock

ELEMENTS	TIME REQUIRED
Extruded profiles	4-6 weeks
Brackets	4-6 weeks
L70 - connector	2-4 weeks

6.2.2 Transport

No special transport requirement is needed, as they are not dangerous products. The components cannot suffer a deterioration in any of the transport phases: loading, transport and unloading.

6.2.2.1 Elements dimensions

As it has been previously mentioned, the standard length of aluminium profiles is 6 050 mm. The standard sizes respond to transport requirements. This dimension can be customized upon request for higher sizes. However, knowing that the vertical profiles have one-storey length (≈3 300 mm), there should not be transport issues.

Dimensions in mm

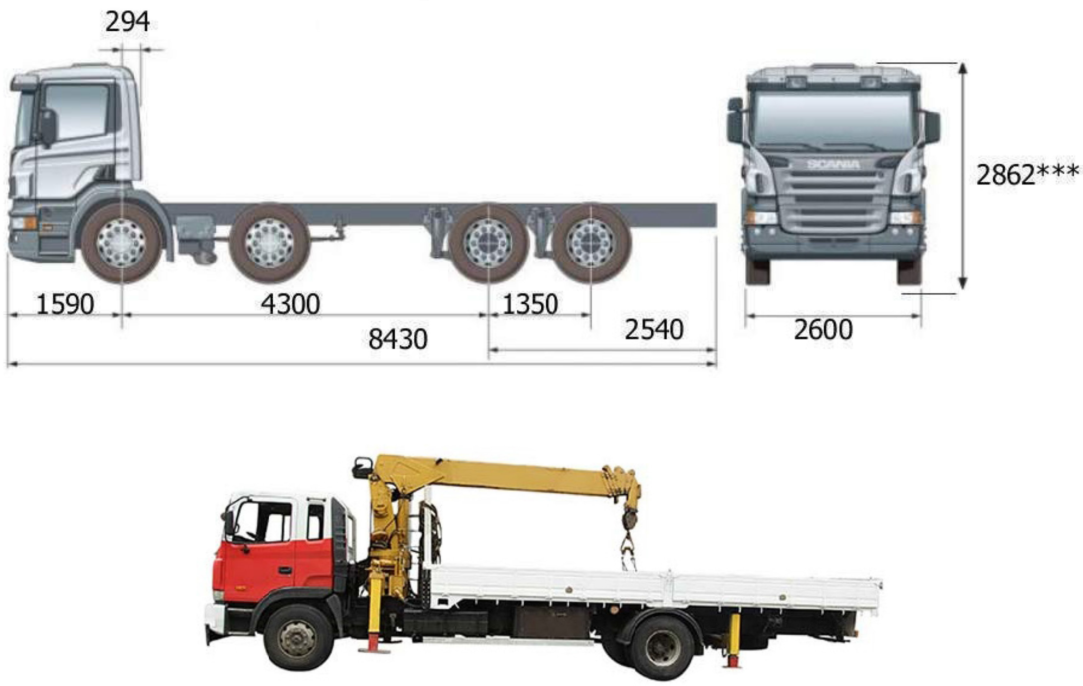

Figure 13 — Type of truck for transportation

6.2.2.2 Logistics

The correct storing, manipulation and transport actions require to meet the current prevention of occupational hazard regulations.

- **Factory**

The aluminium substructure will be collected from the factory (Alu-Stock® factory) or other supplier store in a dry and under-covered place in order to protect the product until the delivery to the building site.

During the storage period, the storing conditions should comply with the control requirements to prevent from imperfections or other misuses before the delivery. For the storing of the components, the packages will be stack in an elevated base covered by an impervious to water and pervious to vapour material. The base for long pieces must guarantee there is no deformation.

Table 12 — Innovative and adaptable envelope structure (BRESAER structure) storage

PACKAGE	PHOTO	INDICATORS
BOX		Max. volume 400 x 400 x 400 mm Max. weight 20 kg/box
PALLET		European pallet 1200 x 800 mm Max. weight 500 kg, 1m height
PROFILES		Adapted pallets for long elements 2/4 reinforcements
	 	Corner protections

- **Workshop**

Storage in building site will be same to factory conditions taking in to account the phase of installation of each material to have them in a proper organization.

6.2.2.3 Delivery control

It should be verified if the delivered products match to the technical specifications and dimensions and provide the correspondent certification. All the components should provide the correspondent certifications that identify the manufactured products.

It is also the client´s responsibility to verify meticulously the quality and control requirements of the delivered products. Facts to be considered:

- Verify there is no material fissure, break or deformation.
- Verify the specifications and certifications of the product correspond to the ones ordered.
- Verify there is no corrosion problem in metallic components.
- Verify the correct package of the components for transport requirements.

6.2.2.4 Inspection

- **Factory**

The factory should meet a Quality Management System control plan requirements to guarantee the correct quality through periodic inspections, for example as defined in EN ISO 9001. The QMS recognizes external quality related requirements in Licenses to Trade, guidelines, specific customer requirements, and the chosen management system standard.

- **On site**

Controls to perform during installation are the following:

Table 13 — Innovative and adaptable envelope structure (BRESAER structure) storage on site control

Process	Control
Verify the correct quality and quantity of the substructure. Accept the delivery if profiles and rest of components meet the requirements.	Supplied material acceptance
Verify storage systems comply with the requirements.	Storing
Verify the installation process complies the installation guide of the system.	Assembling inspection
Verify all equipment and machinery required in the installation comply with the installation guide of the system.	Equipment
Add any incidences to the control sheet on the project.	Incidences
Verify that the substructure installation complies with all Quality Control and Health and Safety Control requirements developed in clause 6.10.	Final inspection

6.2.3 Workshop assembling

Specialized personnel for an innovative and adaptable envelope (BRESAER system) formed by at least two experienced workers must develop the installation of the system.

The required machinery, scaffolding and craft requirements must comply with the functional and quality standards and regulations for the correspondent equipment.

Health and safety control measures are gathered throughout clause 6.10.

6.2.3.1 On-site installation

The main phases of the installation of the elements are summarized in the next points:

- Installation of the Aluskit vertical profiles:
  - Perforations to raise easily the profile. This will help to raise the profile and to place it to the upper fixing point.
  - Perforation for the upper fixing.
  - Secure lifting of the vertical profile.
  - Once the vertical profile is placed it will be proceed to realize the upper fixing of the profile, joining with the U – anchor using stud bolts in the process.
  - Vertical profile alignment or levelling.
  - Interior fixing of the vertical profiles. The bolt will be introduced and tight with the correct tightness.
  - Apply the maximal tightening to the upper fixing.
  - These steps will be realized for the placement and fixation of all vertical profiles.
- Installation of the Aluskit or standard horizontal profiles:
  - Stablish the layout of the horizontal profiles.
  - Fixing of the horizontal profile. The horizontal profile will be placed in its position with the inferior metal L brackets that fix it to the vertical profiles. Once the horizontal profile is fixed from the inferior side we will proceed to fix the upper brackets.
  - For the placement of the rest of horizontal profiles the same process will be done, finalizing with this all the structure and substructure installation.

Further details are explained in the on-site installation guide (see clause 6.10).

6.2.4 Maintenance

One of the aluminium characteristic is that being in contact with the air, the aluminium creates a superficial strong and transparent aluminium oxide layer which protects from corrosion. This feature along with the lightweight properties makes the aluminium a good option for a substructure. This is why no special maintenance is required for the aluminium substructure.

6.3 Lightweight ventilated façade (ULMA façade)

This clause describes the logistics efficiency and installation analysis of ventilated standard panels and PV panels.

6.3.1 Production

6.3.1.1 Production description

Polymer concrete slabs are formed by the consistent mixture of thermoset resins as a binding agent, aggregates of mineral origin, additives and the remainder comprising reactive matter. Lightweight ventilated panels (ULMA panels) are made by moulding after a casting process in which the element acquires the final form. The surface coat, which provides the material its finishing and protective layer, is formed by a consistent mixture of thermoset resins, additives, and colour pastes based on stable pigments.

The slabs are cut to the specific dimensions and grooved on their top and bottom edges, allowing the slabs to be installed by means of aluminium profiles that are inserted in the grooves.

The PV panels are manufactured by assembling them in an aluminium frame around the PV glass. The aluminium frame has analogous grooves as the polymer concrete slabs, allowing the same installation method, what makes easier its installation.

The horizontal support rails are produced from extruded aluminium.

6.3.1.2 Elements to be produced

The elements of the ventilated façade are the following:

- Polymer concrete slabs ULMA
- PV module ULMA.
- PV glass purchased
- Aluminium profiles purchased

Table 14 — ULMA required elements per m²

ELEMENTS	UNIT (SI)	QUANTITY
Polymer concrete slabs	m^2	1
ULMA horizontal profile	unit	1,5
Self-drilling screws	unit	1,5
ULMA component – L70	unit	3
ULMA component – connector	unit	1,5
ULMA component – rod	unit	1,5
ULMA – Hammerhead bolts, nuts & washers	unit	5,9

6.3.1.3 Manufacture timescale

It is expected one month of manufacture for the production of 3 000 m^2.

Table 15 — ULMA calculation of production cost by extrapolation

Time of production	Quantity
1 Labour month	3000m^2
1 Labour week	750m^2

6.3.2 Transport

Standard panels

The panels are delivered to site polyethylene wrapped and banded on wooden pallets. Each pallet bears a label showing the product details such as type, size, quantity and colour.

The panels should be stored vertically and levelled, clearly separated from the ground and undercover to prevent deformation and increase water protection.

The aluminium support rails are delivered to installation site onto a wooden pallet with any items, in separate cardboard boxes.

Packs of rails should be stacked horizontally to prevent distortion. Other components should be stored in a safe weatherproof store.

The panels should be handled with care to avoid damage or breakage during the processes of installation.

Panels should be lifted off, rather than slid across each other, to prevent surface damage. Care is required when handling long lengths of rail, particularly at height.

When handling panels or rails, protective clothing should be worn and all Health and Safety regulations should be followed. In Clause 6.10, are explained safety issues in detail.

PV modules

The panels are delivered to site on wooden or metal pallets. Each pallet should bear a label showing the product details such as type, size, quantity.

6.3.2.1 Elements dimensions

Polymer concrete slabs can have the following dimensions:

- Length (minimum 300 mm and maximum 1 800 mm)
- Height (minimum 300 mm and maximum 900 mm)

Polymer PV modules can have the following dimensions (For 99Wp power with 24 cells)

- Length (minimum 1 090 mm and maximum 1 250 mm)
- Height (minimum 750 mm and maximum 800 mm)

Installation rails have a length of 3 600 mm.

6.3.2.2 Logistics

Factory

- Panels are manufactured and stored in the factory. Logistics within the factory of the final product is made by forklift.
- A pallet can reach maximum weight of 2 000 kg depending on slab sizes.
- Maximum size of pallets depending on slab sizes would be 1x1x1m; 1,5x0,8x1,1m and 1,8x0,8x1,1m. For international shipping an additional wooden exterior frame is attached for additional protection, increasing the total pallet size on 0,20 m.
- It is not allowed to put pallets on top of each other

- The panels are transferred on-site by, sea container and/or truck. For unloading the truck a side unloading truck may be needed, A storage spot should be defined on-site for the storage of the panels, quality-check of the delivered goods, handling,…

6.3.2.3 Delivery control

Upon delivery inspection must be performed so that all the material has arrived with no damage.

All the material has to be received properly labelled to improve the installation times and minimize problems of identification.

It must be checked that all the material covered by the note of delivery has been correctly delivered.

6.3.2.4 Inspection

Factory

Control of the processes includes the following:

Table 16 — Factory control

Process	Control
Preparation of the surface coat. Preparation of the mixture of raw materials with the right dosage.	Weighing ticket of each component with batch traceability.
Manufacturing of the slabs surface coat.	Process settings control
Concrete moulding. Preparation of the slabs by moulding the polymer concrete formedby the consistent mixture of raw materials in the right dosage. Distribution, vibration, compacting and control of the final polymer concrete slab thickness.	Checking of the correct dosage of raw materials.
Polymer concrete curing process Gradual and progressive curing process to achieve the physical and chemical properties of the material.	Curing degree and reactivity control.
Polymer concrete slab mould release and process to ensure slab flatness.	A check is carried out on the thickness, as well as a check on the general finish.
Polymer concrete post-curing process. Final post-curing process in oven at controlled temperature to achieve the final and optimum physical and chemical characteristics of the material.	Control of the temperature of the post-curing process.
Machining process Finishing process for the correct cutting of the slabs at the required dimensions and machining of the anchoring groove.	Machining and dimensional control.

- **On site**

Controls that must be performed during installation:

Table 17 — On site control

Process	Control
Verification of the planarity of the structure	Planarity
Installation of rail profiles	Confirmation of correct installation of self-drilling screws, correct separation between them and planarity of the profiles.
Installation of slabs in the profiles	Verification of correct insertion and no damage to the slabs
Installation of joint separator between slabs	Verification of correct installation
Installation of PV modules	Verification of no damage to the PV module and the correct state of the wiring at the back of the PV modules.

6.3.3 Workshop assembling

All elements can be directly installed by following the different phases described in this document in the clause 6.10 On-site installation guide. Specialized personnel for the innovative and adaptable envelope system (BRESAER system), formed by at least two experienced workers must develop the installation of the system.

6.3.4 On-site installation

As detailed the system comprise two main elements:

A. ULMA polymer concrete slabs or photovoltaic module

B. Guide and support horizontal rails

The polymer concrete slabs are slotted (grooved) on their horizontal edges. The guide and support horizontal rails are inserted in these slots in order to hold the slabs in place for the installation. The photovoltaic module has an aluminium frame with grooves to be hold by the horizontal edges, in the same way as the slabs.

These two elements (slabs and photovoltaic module) will be fixed to the main substructure through the horizontal profiles and form the lightweight industrialized ventilated facade. The fixing points will be placed in the intersection of the guide profiles with the Bresaer substructure by means of the connection profiles. The horizontal spacing between this connection profiles shall be restricted to 90 cm maximum.

Details of the lightweight ventilated façade module can be seen in the following pictures:

1. Polymer concrete slab

2. Horizontal profiles for fixing the polymer concrete slabs

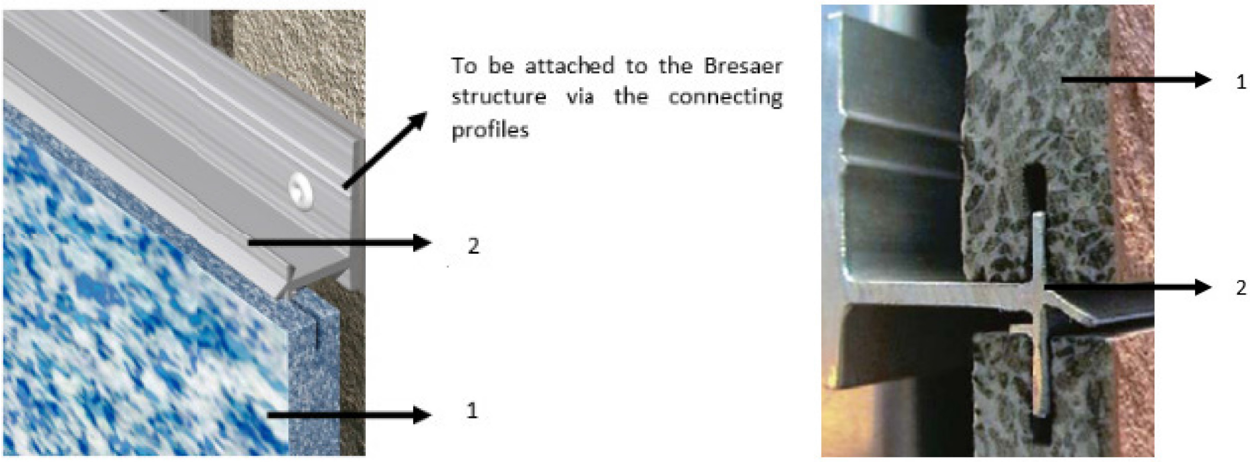

Figure 14 — Lightweight ventilated façade (ULMA façade) details

Installation operators and machinery

Installation operators must be specialized workforce on installing ventilated façade; in addition to this, a minimum of 2-3 days training period is required for installing this system.

Site preparation: Adequate and safe space for storing the pallets and handling the material in a safe way with clean procedures.

Pallets can be handled by a forklift and crane.

Slabs on an individual basis are installed manually, depending on the size may require two people handling the slab. In any case, lifting the equipment is required to move them to the place of installation.

Scaffolding is required for a safe and correct installation. The specialist must define the appropriate way of anchoring the scaffolding depending on the structure of it and the façade system. Different scaffoldings can be used:

- Electric scaffolding
- European scaffolding. In this case electric elevator is required for lifting the slabs to the floor of installation

In the case of high buildings (10 floors or more) the materials should be stored in different floors to facilitate the handling system. Cranes or lifting elements would be required.

On site handling. Security criteria for handling material

When handling the elements, panels or rails, protective clothing should be worn and all Health and Safety regulations should be observed.

The PV modules generate electricity when exposed to sunlight. Even if voltage and current of a single module is low, touching terminals and cables can cause burnings and electrical shock. This risk can increase significantly when more modules are connected and installed together. In order to avoid any risk, turn the front of the module away from the sun or cover it when wiring. Do not connect or disconnect the module under load.

More health and safety concerns are listed in clause 6.10 are explained safety issues in detail.

Installation of slabs

The polymer concrete slabs are hold in place between horizontal profiles, which are screwed in turn to the connectors of the structure.

The horizontal guide profiles must be secured by means of self-drilling screws to the connector, ensuring flatness and horizontality. The vertical separation between these profiles will conform to the dimension height of the slabs up to 900 mm.

To start the installation, the first horizontal support profile shall be installed. The installation of profiles and the polymer concrete slabs will be carried out from bottom to top in successive horizontal rows.

The slabs shall be installed by inserting their lower slotted groove into the horizontal profile wings, forming a continuous anchor. The following horizontal guide rail to be secured shall be installed on the row of previously supported slabs. The installation must be carried out by inserting the new horizontal rail into the upper horizontal groove of the slabs. The insertion shall be carried out without overstraining so as not to compress the profile tab, allowing and verifying the securing and good positioning of the slabs.

Slabs on the same row will thus be maintained between two horizontal profiles which will have been inserted by their top and bottom wings into the grooves envisaged at the horizontal edges of the slabs.

Further details are explained in the on-site installation guide (see clause 6.10).

6.3.5 Maintenance

As the polymer concrete and the surface layer of Gel-Coat are not porous, the maintenance of the Lightweight ventilated façade (ULMA panels) is reduced to periodic cleaning with soap and water. It is recommended to clean the panels after being installed on site, and after that, once a year. If you do not follow this recommendation, it may be harder or even impossible to clean the panels.

It is recommended to clean the façade once the construction work has finished. The Lightweight ventilated façade panels (ULMA panels) should be cleaned with neutral soap and water, using an absorbent cloth or similar cloth, but never with a hard brush or scourer (except for a soft fibre scourer). Rub until the stains disappear, rinse with plenty of water and dry with a clean cloth, to avoid lines. If the stains do not come off after cleaning normally with neutral soap and water, you should not use just any cleaning product because it could contain abrasive materials that could damage the colour of the panels.

6.4 Solar thermal air component envelope (SOLARWALL® Façade)

6.4.1 Production

6.4.1.1 Production description

The solar thermal air component envelope (Solarwall® façade system) consists on a series of metallic components that make up a waterproof air chamber. The majority of the system components are commercial, except the final coating panel whose production and manufacturing process is patented and with exclusive use of Solarwall®.

6.4.1.2 Elements to be produced

Panels: The metal panels are perforated with very small holes or slits and resemble a conventional metal facade.

Panels are available in many colours, including black and dark shades of brown, grey, red, blue and green. They are usually one meter wide overlapping panels of varying lengths and installed to give a continuous appearance along the entire wall. To add structural strength and rigidity, the material is processed through rollers to form corrugations. The corrugations are 35 mm or 39 mm tall and spaced approximately 200 mm apart.

Dimensions in mm

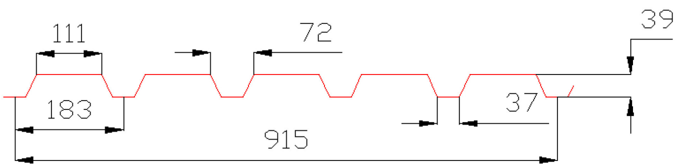

Figure 15 — SolarWall® Panels

The perforated panels are made of either aluminium or galvanized steel. Initially the panels were made from aluminium as there was concern about possible corrosion around the holes if steel was used. Corrosion experts have examined galvanized panels which have been in use since 1989 and found no rust formation. The galvanizing protects the steel from rusting and the air movement through the holes dries any moisture that may exist. As the wall is generally vertical, water runs off the wall and the holes are so small that the surface tension prevents most water from entering the holes.

Material: Galvanized steel S 320 GD, EN 10346

Types:

- Galvanized (EN 10346 P 34310)

- Galvanized and pre-painted EN 10169 XP P 34301)

External side: Hot clip metallic coating upon 95% Zinc and 5% aluminium.

Internal side: galvanized and 10 micron polyester.

Omega profiles: Galvanized Steel

Figure 16 — Omega Profiles

Table 18 — Characteristics of the Omega profiles

CHARACTERISTICS	
CHARACTERISTIC	**NOTES**
MATERIAL	Galvanized Steel
DIMENSIONS	Depending on the cladding element
HORIZONTAL DISTANCE	----
VERTICAL DISTANCE	90 cm maximum
PROTECTION AGAINST CORROSION	• Galvanized steel: Z 275-Z600 • Neoprene: Anticorrosion element between galvanized steel (connection profile) and aluminium. (horizontal profile)

Sandwich Panels:

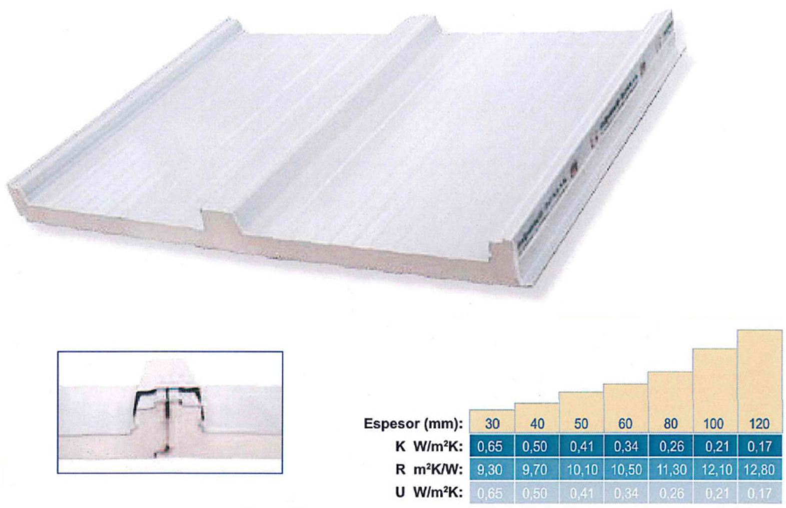

Figure 17 — Sandwich Panels characteristics

External side: Pre-lacquered steel sheet

Internal side: Pre-lacquered steel sheet

Insulation: Polyurethane

6.4.1.3 Manufacture timescale

Table 19 — Manufacturing capacity

Material	Manufacturing capacity
SolarWall® panels	100 m²/day
Omega profiles	50 m -200 m
Commercial structure	According to manufacturer
Special pieces and closing parts	50 m -300 m
Sandwich panels	According to manufacturer

6.4.2 Transport

6.4.2.1 Elements dimensions

Table 20 — Characteristics of the Omega profiles

MATERIAL	Dimensions for delivery	Maximum dimensions
SolarWall® panels	2,3,6 linear m	Width: 1 m Length: Up to 8 m, special orders
Omega profiles	1-3 m	---
Commercial structure	Standard manufacture	---
Special pieces and closing parts	0,5-3 m	Height: 15-60 cm
Sandwich panels	Standard manufacture	Up to 12 longitudinal m

6.4.2.2 Logistics

The transportation of all components will depend on the quantity and dimensions. A conventional truck is enough, preferably with crane to download the material. It is also possible to send in pallets to transport with trolley and facilitate download.

6.4.2.3 Delivery control

In terms of packaging and transportation, quantities, dimensions and destinations determine the procedure. Normally, for large quantities, the panels are protected by a film. On top of each block a standard greased sheet is put, as a protection (see Figure 18). If the system is delivered by boat or road large distances, a frame of protection is usually made in wood. The panels are usually 2 m long, but can be made on request at 2,3,6 m long.

Figure 18 — Sandwich Panels delivery

6.4.2.4 Inspection

- Verify and check the status of the supply. Check also if it has been safely delivered.
- Verify the shipping note analysing if all types and number of each elements match with the requested list.
- In the sandwich panels, horizontal profiles, tubular profiles, corrugated metal sheet and screws, it will be revise that there is not any product with deformations or superficial damage.
- Possible bumps and dents will be visually checked in the panel because it can cause problems in the perfect alignment and levelling over the horizontal fixings. Revise also possible damages in the panels, breaks or fissures. This will be done due to the fragility of them, thus bumps or dents that may cause later breaks or fissures will be checked.
- The dimensions of the profiles and different elements will be checked to verify the components are correct and adequate for the execution of the installation.
- With the corrugated metal sheets it will be taken more care during the storage. Each sheet should be coincident with the upper and bottom one in order to protect them and the plastic of protection.

6.4.3 On-site installation

The main phases of the installation of the elements are resumed in the next points:

- Placement of the main roof sub-structure (Aluskit sub-structure).
  - Drilling holes in the supporting profile for the lifting of it. This will help in the vertical lift of the profile to bring it closer to the attachment point in the roof.
  - Drilling for the upper fastening.
  - Raising of the main substructure.
  - Elastic bands of neoprene or similar will be placed in order to absorb the movements of the structure.
  - When the sub-structure is positioned, the upper fastening of the profile will be carried out, attaching the profile to the support with two aluminium brackets.
  - Levelness of the main substructure profile.
  - Bottom fixing under the main sub-structure.
  - Tighten the top fastening or fixing.
- Placement of the secondary sub-structure.
  - Staying secondary belts.
  - The secondary sub-structure will be on the marks previously made. It will be temporary fixed to the main roof profiles.
  - We will perform the drilling.
  - Once the screws have been fitted, the secondary profile will bel placed on the main profile again and it will be screwed.
- Roof cover with sandwich panels.
  - This system is a commercial one, the instructions of its “guide of use” has to be followed.
- Placement of the second covering layer.
  - Rectangular profiles of steel will be placed on the nerves of the sandwich panels.
  - On these metallic nerves, it will be proceed to place a system of omega straps of steel with the same procedure that we did for the secondary straps. In this case there is no need to perform the holes in the omega to accommodate the screws.
  - Placement of lateral closing elements.

- Placement of the final roof cover.
  - Placement of lateral profiles.
  - Installation of the metal sheet cover. The fixing will be done with self-drilling screws with sealed rubber washer.
  - While advancing with the placement of the metal sheet the sealing parts of the hexagonal ends will be placed.
  - Once all the metal sheets are placed, joints will be sealed with silicone or similar to guarantee the water tightness of the system.

Further details are explained in the on-site installation guide (see clause 6.10).

6.4.4 Maintenance

- The sheets will be checked during the installation process and after to be sure that have not been deformed creating spaces where water infiltrations can appear.
- We will review possible blows and damages that cause loss of protection and its consequent risk of corrosion.
- Check the continuity of the sealing.
- Tests will be done to ensure water tightness of the joints and its sealing.

6.5 Multifunctional Insulated Panels (STAM panels)

6.5.1 Production

6.5.1.1 Production description

The Multifunctional Insulated Panels (STAM panels) should be manufactured in a precast concrete factory. In these factories, Multifunctional Insulated Panels are manufactured according to dimensions provided by architectural drawings for each project. Dimensions of the panels are limited according to the following table.

Table 21 — Suggested dimensional limits of Multifunctional Insulated Panels

	Max (mm)
Height	2 700
Width	1 500

The Multifunctional Insulated Panels are composed by two layers:

- The first one, which stays closer to the existing façade, is made of insulating material, namely a rigid board of polyurethane, or polyisocyanurate, or polystyrene, or others.
- The second one is Fibre-Reinforced Concrete; this layer provides the structural resistance against wind load, weather, and the user customization can be performed on it.

The production of the Multifunctional Insulated Panels is divided into two main steps:

- Preparation of the formwork, including shaping of the insulating material, positioning of the lifting devices, etc.

- Concrete mix preparation and casting.

In the following pictures, the main steps in the manufacturing process are shown.

Figure 19 — Preparation of the formworks, Mixing of the concrete and Concrete casting in the formwork

Figure 20 — Panel extracted and lifted

It is common that for one project, several different panel sizes need to be manufactured. In any case, concrete casting tools are particularized for each panel size. Rails, inserts, etc are performed as part of the casting process. The insulation layer is cut to measure and adhered to the concrete panel.

In small-and medium sized projects, it is common that all panels are stacked in the production plant and delivered in batches to the construction site.

Figure 21 — Example of Panels transportation

Metal parts such as anchors are commonly manufactured by suppliers from the metal industry. Anchors are commonly delivered with standard lengths (e.g. 5 m) and later cut in factory to particular lengths, then holes are made.

6.5.1.2 Elements to be produced

The following elements need to be produced:

- Precast concrete panels, with rear-side insulation
- Anchors

For variants with PV systems, PV systems and fixation systems should be purchased. In this particular case, these products are standardized goods and can be considered as commodities.

Dimensions of the panels are variable, according to architectural project needs, but tentative limits can be established at 1,5 m width and 2,7 m height. Their weight is up to 400 kg with a surface density of 100 kg/m^2.

6.5.1.3 Manufacture timescale

Although it is common that precast panels require up to one day to reach final strength, for manufacturing processes, new panels can be cast every day in the same tooling. Depending on other projects being executed at the same time, up to 50 panels can be cast at the same time. This defines a production rate of around 50-150 m^2/day. Included the days of pre-casting, the production capacity per manufacture line can be assumed at 250 m^2/week.

Table 22 — Calculation of production capacity of Multifunctional Insulated Panels (STAM panels) by extrapolation

Time of production	Quantity
1 Labour week	150 m^2

6.5.2 Storage and transport

The storage of multifunctional panels should be done preferably on racks, keeping the items in a close-to-vertical position (see Figure 22). In fact, the horizontal position should be avoided to save space in the warehouse.

Figure 22 — Example of a concrete sandwich panel stored vertically on a rack

Besides, another advantage of the vertical position is that it facilitates handling operations: as soon as the panel is demoulded, it can be handled vertically with a crane to minimise stresses on the hooks, which are positioned in the thickness of the panel (see Figure 23).

Figure 23 — The panel being demoulded and put in vertical position with the overhead crane

The nominal duration of curing is 28 days: during this period the panels are stored vertically in the outdoor warehouse. After that period, the panels are transported to the installation site.

Figure 24 — Panels ready for transport on a small rack that can be moved with a forklift

Multifunctional Insulated Panels can be transported in assembly. This assembly can be manipulated by pallet truck, forklift trucks or equivalent manipulation means. Special care should be taken for long panels to ensure load stability. The panel should be protected against dust and rain by means of tarpaulin.

6.5.2.1 Elements dimensions

Multifunctional Insulated Panels are delivered stacked in heavy load lorries. Depending on panel size and weight, up to 10 panels per lorry can be delivered.

Although special dimensions can be transported under special transport conditions, Common limitations in this process are the following:

- Longest side: ~4-5 m
- Shortest side: ~2,5 m
- Weight: not very critical to this product
- Stacking: 3-5 units

6.5.2.2 Logistics

Multifunctional Insulated Panels are manufactured and stored in the factory and then transferred on-site by truck. A storage spot should be defined on-site for the storage of Multifunctional Insulated Panels, quality-check of the delivered goods, handling, etc.

Regarding accessibility, truck loading and unloading should be made by means of forklift trucks. This does not imply major requirements to factory layout, but requires that such auxiliary devices are brought to the storage site. It also implies that the area for the unloading and storage of goods is sufficiently flat and firm to allow the continuous passage of heavy machinery.

As the product needs to be installed by means of crane, the storage site should be located within the span of it in order to facilitate panel lifting for the final installation.

Figure 25 — On-site storage and lifting of Multifunctional Insulated Panels

6.5.2.3 Delivery control & Inspection

Quality control should be made by visual inspections. Critical items to be controlled by visual inspection are:

- Planarity of panels
- Cracks (cracked panels should be discarded)
- Broken insulation

6.5.3 Workshop assembling

No actions need to be performed on-site prior to the installation.

6.5.4 On-site installation

The main phases of the installation of the elements are summarised in the next points:

- Anchor layout. The process should start with the identification of the position where the anchors should be installed.
- Screws should be introduced in the prepared holes of the anchors with its respective nuts.
- Anchors should be placed in position with all needed screws in the correct place.
- Elevation and placement of the Multifunctional Insulated Panels. For the elevation or raising of the panel the system contemplated from the manufacturer should be used. With the transport with a truck or similar, the panels should be raised with a crane (also crane truck) and placed over the anchor previously bolted to the structure.
- Once in position, the Multifunctional Insulated Panels should be fixed at its top through the anchors above it.
- Placing of the waterproof sealing. The procedure of installation is easy, its adhesive part should be removed and the tape placed. The joint then expands to completely cover the space of the joint.
- The last three points of the process should be repeated with all panels to be installed in the building.

6.5.5 Maintenance

The Multifunctional Insulated Panels are robust and required minimal maintenance. Its maintenance procedures are similar to almost any other building envelope system constructed in concrete. Junctions and anchor elements should be visually inspected periodically (e.g. every 10 years). For low-rise buildings, visual inspection from ground level can be performed. In higher buildings, where the status of the façade cannot be correctly observed from the ground, visual inspection should be made with appropriate lifting devices.

6.6 Automated and insulated blinds (EURECAT window)

The section below will describe the logistics efficiency and installation analysis of the automated and insulated blinds.

6.6.1 Production

The following section will develop the logistics efficiency and installation processes and implementation conditions of the automated blinds that has been developed within the BRESAER project.

6.6.1.1 Production description

The Automated Blind system is produced in a window/blind assembly line. Within this line, several processes are conducted in a sequential manner:

- Product reception & storage: Components are provided by suppliers, received by the manufacturer and stored for later use.
- Cutting processes: Aluminium profiles.
- Profile assembly: Profiles are assembled in the frame.
- Integration of blinds & mechanical parts over the frame assembled in the previous step.
- Storage & delivery: The finalized product is protected for transport, stored in the finalized product section and awaits transport for final delivery.

Within BRESAER, two possible versions of the automated window system are possible:

- Automated blind section only, to be installed over an existing window, without replacement.
- Integrated component of automated blind & window. The existing window is replaced, and the blind system installed over it. In practical means, these are two different products, window + blind system are manufactured, delivered and installed as individual items.

In both cases, the production process of the components is performed with common Aluminium carpentry processes. Below, cutting tools and handling devices for window manufactures are shown. The assembly & integration process is performed manually due to its complexity.

6.6.1.2 Elements to be produced

The automated blind is composed by the following components:

- Slats
- Frame, comprising, vertical profile, lower profile and blind box.
- Mechanical components

The detailed manufacture process of each element is defined below:

6.6.1.2.1 Frame

The frame is constructed based on commercially available aluminium profiles.

Aluminium profiles are delivered in standardized lengths (e.g. 6 m -10 m). These profiles are latter cut to measure, based on generic details of the system, and architectural drawings of the window blind.

Then blind and window frames are assembled in assembly frames, for ease of manipulation.

The junction of profiles is performed with angled brackets which ensure mechanical strength of the frame. These brackets are tailor-manufactured to fit in the internal voids of the extruded profile.

6.6.1.2.2 Slats

Slats are aluminium extruded profiles. These profiles are filled with thermal insulating foam providing extra thermal resistance.

6.6.1.2.3 Mechanical components

All the components for the rotation mechanism are machined parts and aluminium standard parts.

6.6.1.2.4 Electric components

The movement of the blind slats is powered by an electric motor. This motor is a standard commercial one used in motorized blinds.

6.6.1.3 Manufacture timescale

The manufacture of the automated window is a completely dry process, and no critical machinery is used. The machinery used in the process is quite basic and can be found in almost any retail window supplier in the market. Due to this, the manufacture process is highly scalable, depending on project size and long-term investment options. With this options, times and costs may be reduced to increase productivity by and industrialised manufacturing timescale.

If manual construction means are used, manufacture rates of 4 windows per operator per day (8h) can by handled with ease. With this information, the following weekly rate can be calculated for a crew of 4 pax.

Table 23 — Calculation of production capacity of EURECAT dynamic windows by extrapolation

Time of production	Quantity
1 Labour week	40 blinds ~40-80 m^2

6.6.2 Transport

The product is delivered as a completely panelised assembly conforming a finalized product.

6.6.2.1 Elements dimensions

Final dimensions are highly dependent on the size of the window void to be covered. Estimated dimensions are 2,6x1,2x0,5m for a 2 m high window size.

6.6.2.2 Logistics

The automated blind should be transported in a wooden pallet system completely panelised and assembled, thus may be handled by forklift trucks or equivalent. The elements should be stored in a protected location to avoid unexpected damage. The blind is delivered in a protective plastic +wood envelope. If the envelope is kept closed, it can be stored outside for short periods of time (e.g. <2 weeks).

6.6.2.3 Quality control & Inspection

The assembly should be inspected for unexpected damage during transport and handling. This inspection can be performed by visual means. The following should be checked:

- Integrity of the casing

- Surface finish: Verify that no impacts have resulted in non-planar/straight surfaces.

6.6.2.3.1 Window

In the case of changing the windows in the building when installing BRESAER solution, these new windows will be commercial windows.

The quality control must be done by the window manufacturer according, for example, to EN ISO 9001.

6.6.2.3.2 Blind

6.6.2.3.2.1 Frame

The blind frame is composed mainly by extruded aluminium profiles. These profiles are commercial. By this moment, the manufacturer of the profiles is not determined.

The quality control must be done by the manufacturer according, for example, to EN ISO 9001.

6.6.2.3.2.2 Slats

The main component of the slats is the sandwich panel made of aluminium and phenolic foam. This sandwich is manufactured by an external supplier. The quality control must be done by the manufacturer according, for example, to EN ISO 9001.

6.6.2.3.2.3 Motor and electronics

The quality control must be done by the motor manufacturer.

6.6.2.3.2.4 Assembly

The assembly of all the blind components will be done by an external manufacturer.

The quality control of the complete blind assembled must take into account the following issues:

A. The blind has to be able to rotate the slats without any complication. The slats have to rotate until 90°. Due to the big slats it is necessary to check the movement in each blind.

There are two security switch to control the end of the rotation movement. The correct operation of these switch must be checked in each blind.

B. The external frame of the blind is made by extruded aluminium profiles. It is necessary to check de parallelism between the two vertical profiles. The correct parallelism is important for the sliding of the slats.

6.6.3 Workshop assembling

No on-site assembly process is needed.

6.6.4 On-site installation

The installation of the automated window should be performed before the installation of the façade substructure. The automatic and controlled blind is provided totally assembled as a unit. The actions to be done on site are the following:

A. **Covering the window with insulating**. The blind will be screwed directly to the wall, the insulating is needed to break the thermal bridge between the wall and the blind and provided air and thermal tightness to the building.

   For connecting the electronics to the BEMS of the building is necessary to make a hole to the brick in order let the cables get in the building. This hole has to be insulated.

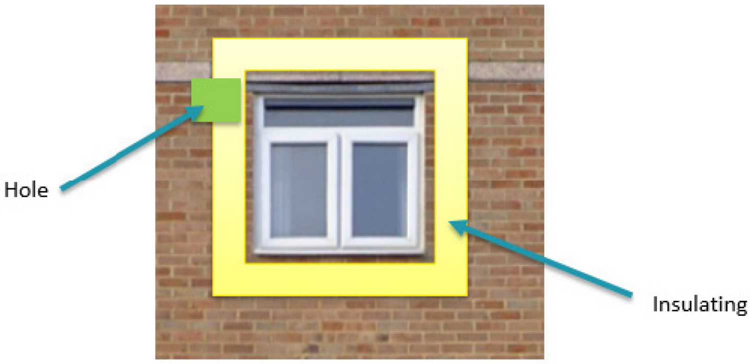

Figure 26 — Blind insulation covering

B. **Screwing the blind to the wall.** The blind has to be fixed directly to the wall through screws. The blind is provided with the screws holes.

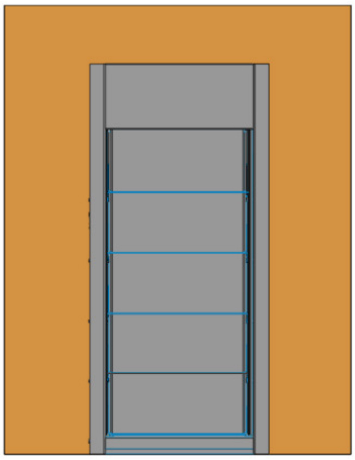

Figure 27 — Blind fixation

C. **Connecting the electronics**. Once the blind is screwed to the wall, all the cables have to be connected the inside of the building.

D. **Fixing the lightweight ventilated façade module profiles (ULMA profiles)**. Horizontal lightweight ventilated façade module profiles can be fixed directly to the blind.

6.6.5 Maintenance

This information will be available after the dynamic windows implementation in the demonstrator building, that will bring valuable lessons learnt.

6.7 PV integration in façades

The design for the overall system must analyse the requirements for electrical connection between PV panels to form the PV arrays. The PV arrays are formed by a specific number of panels (n) in serial arrangement and at the same time the different arrays are connected by parallel connection into a standardised junction box. This junction box permits the connection of batteries controlled by a microcontroller in function of boundary conditions. The electric energy storage systems will be installed, depending on local regulations, feed-in tariffs and the expected mismatch between the electric profiles of the building and its PV production. Since the electric current in PV panels is direct current, an inverter is necessary before connecting to the electric grid and this connection is made at low voltage (230VAC). A general scheme is shown in Figure 27.

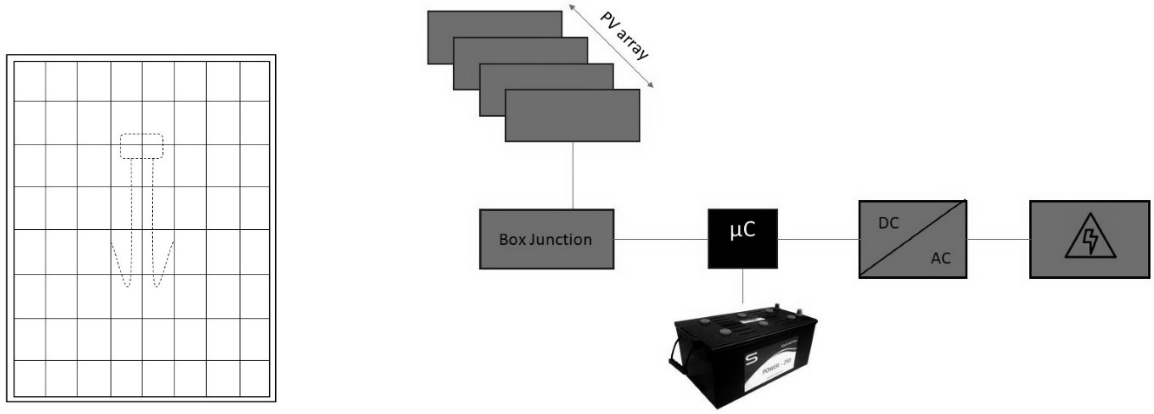

Figure 28 — Electrical connection scheme of the PV array to a low voltage electric grid of a building

Regarding logistics, two main element groups are distinguished:

- Elements installed at façade level:
    - PV panels
    - Support systems
    - Wires
- General electric systems:
    - Switchboards
    - Inverters & batteries

With such division in logistic terms, the façade system should follow the ease of installation, ease of interconnection between panels and the ease of maintenance of the building integrated system.

As for the installation process, a pre-work in the design process is necessary both in the façade system and in the PV panel design. Façade frame may include the corresponding support system that could be rails into the frames or other standardized anchor systems.

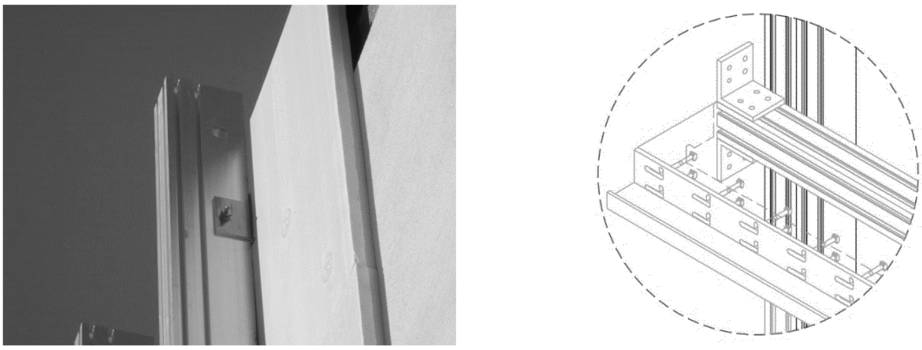

Figure 29 — Support elements fixation for PV panels into the envelope. Source: BRESAER[12]

Wiring in the PV panel system must assure the connection of a new panel to the existing array. The minimum excess wire length for this purpose is 30 cm and the wire length of a panel must reach the border of the adjoining panel.

This way, the panel arrays can be connected horizontally and vertically, varying the necessary wire length in each of the connection modes. In case of horizontal arrays, the junction boxes should be located in the part closest to the next installing panel. This way, if the installation of the horizontal arrays goes from left to the right, the junction box should be directions to the right and vice-versa. For vertical arrays, the junction boxes should be located in the upper part of the panel. In both layout arrays, the connection is made though the rear side of the panel so that, the access to the connection is ensured during the installation phase.

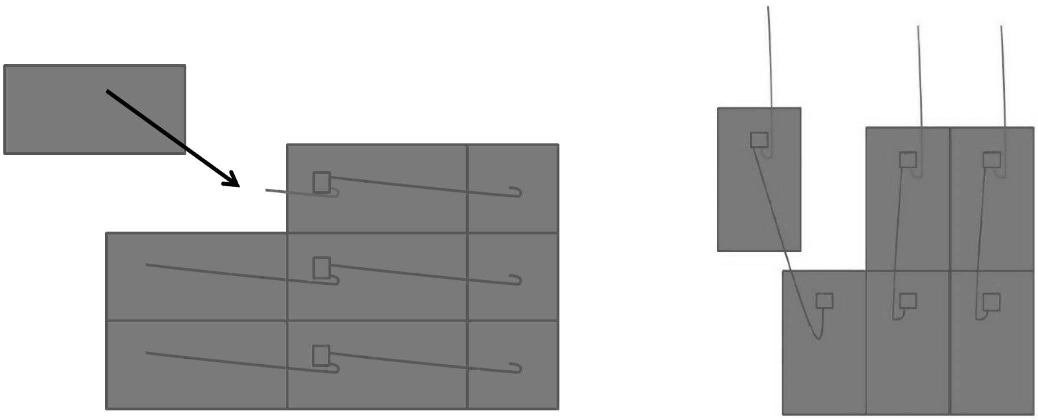

Figure 30 — Horizontal and vertical array layout connection

Finally, and regarding the maintenance of the overall system, the maintenance should be in good standing of the cladding elements. The installation process of the vertical and horizontal arrays described above makes possible the maintenance of one or more than one panel array without affecting the operative procedure of the rest of the arrays. Thus, the demounting process for maintenance may start from the upper collector in vertical arrays and from the part which junction box is the nearest.

[12] BRESAER, Breakthrough Solutions for Adaptable Envelopes in building Refurbishment, http://www.bresaer.eu/

6.8 Air Handling Unit system

The use of an air treatment (handling) unit (AHU) heats the air and also in summer will produce cooling. This unit has a heat pump that depending on the chosen mode will produce heat or cold.

The system includes a set of modular elements that allow the designer to compose air-to-air compact equipment flexibly and perfectly adjusted to their function within the installation.

The system also allows the design of equipment with air flow rates and variable power, used to recirculation installations with mixing or to systems 100% outdoor air, which in this case can be from the solar installation or from the outside, being able to incorporate different types of energy recovery units (static, rotating, etc.).

The proposed equipment offers more flexibility that allows the designer to adjust its performance to the specific needs of the project by means of a modular system based on a common platform. This characteristic is provided by prestigious manufacturers in air-conditioning machines such.

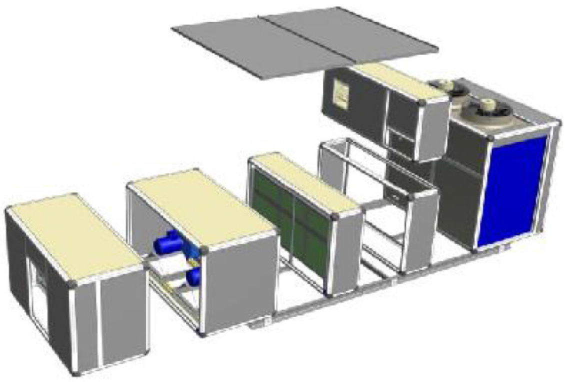

Figure 31 — Main machine cut-out

The system has to be installed by the manufacturer. As it is a modular system form by an aluminium structure it is very flexible and can have in it the next elements depending on the necessities of the client or BRESAER project in each building. Among these elements:

Thermal envelope:

The envelope consists of:

- Structure of aluminium profiles specially designed for the manufacture of this type of units.
- 25 mm thick sandwich panels (optionally 50 mm) formed by two sheets of galvanized steel with high density rock wool core.
- Laminated steel bench.
- Drain trays made of stainless steel.
- Interior spaces in galvanized steel.
- Both the profiles, the bench and the outer face of the panels, are lacquered in the oven.

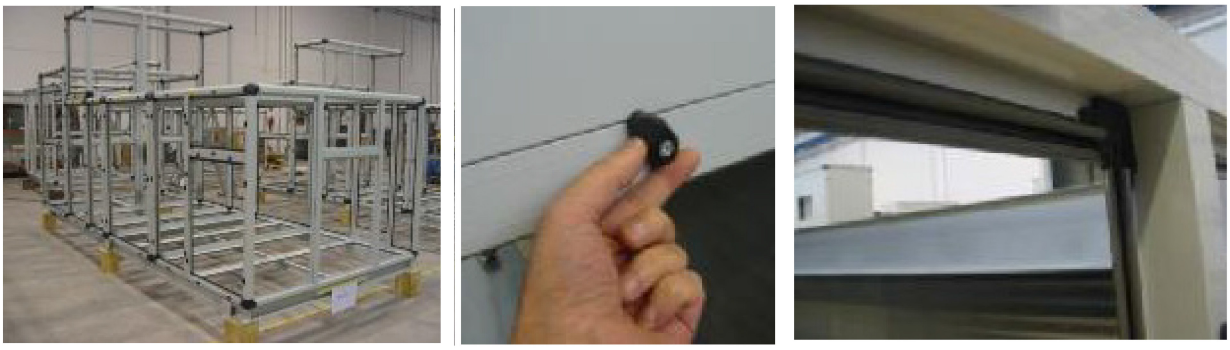

Figure 32 — Surrounding structure

Ventilation train:

The design of the ventilation modules of the equipment always takes into account different possibilities:

1. High or low pressure available.
2. Centrifugal, Plug-fan or Reactive Interior Fans.
3. External axial fans EC with pressure control of condensation by variation of speed.
4. Different power levels depending on the rest of the modules and accessories that incorporate the Machine and may create a pressure drop in the air circuit, for example: due to the distances of the ducts, both suction and discharge.

Filter out:

The possibilities of the equipment, in terms of filtering, are as broad as the options that the market can offer:

1. The filter sections can equip as many filtering stages as desired.
2. The fans are selected per the pressure drop of the filters, in addition to the other elements of the machine, thus ensuring the available pressure required for the ducts.
3. Typical filtering options include G and F filters, HEPA, electronic, activated charcoal, etc.
4. Access to the filter box is quick and easy. Filter modules are standard size.

Refrigerating group:

Possibility of equipping:

1. Compressor inverter group.
2. Electronic expansion valves.
3. Water condensation (single or mixed) for the use of the heat of condensation in the production of hot water at low temperature, if necessary.

To facilitate maintenance and repairs:

1. The batteries can be made of aluminium + copper with acrylic, aluminium-magnesium + copper or copper + copper protection.
2. The internal batteries are removable.

Figure 33 — Pictures refrigerator group

Electric system

It has the following characteristics:

• Frame equipped with manage to thermal protection and circuit breakers for each motor.

• Main board of the control system housed in the frame. Remote control.

• Phase change detector.

• Internal wiring under tube or hose.

• If optionally selected, you can have:

Control system

The control system used will be a conventional data management system

The hardware is widely used for the following applications:

• Coolers and heat pumps

• Air treatment units

• Air conditioning

• Roof-top

• Refrigeration units

• Energy saving management in facilities

• Control of climatic chambers

Figure 34 — Control system

Other features that can be incorporated:

• Housing with thicker panels (50 mm)

• Housing made with stainless steel panels and fasteners.

• Support batteries: hot water, electric, steam.

• Drying rotors.

• Adiabatic cooler.

• Electrode humidifiers, humidifying nozzles ...)

• Disinfection with battery of ultraviolet tubes.

• Voltage different from standard.

• Communication gateways with other control systems (e.g. BACnet, KNX, etc.)

The system has to be transported directly to on-site installation from the manufacturer mounting hall, divided in parts if is its too big for the transportation by truck.

If divided, a pre-mounting must be done on-site before its installation. After that with the help of a crane can be elevated or installed in its position without major problems, always taking into account labour risk management measures.

6.9 BEMS System

As software infrastructure, transportation and storage logistics would not make sense. In contrast, distribution and deployment for the end-users follow the same approach than any commercial software. Therefore, the logistic process differs from the rest of the Innovative and adaptable envelope components (BRESAER components). Hence, BEMS is focused in the final step of the chain (i.e. customer). In this sense, the deployment of software requires an initial set of requirements depending on the environment. It might be installed either in a cloud service or in a local server. But, in both cases, requirements are similar:

- Java Virtual Machine to run the software.
- Postgres database engine.
- Eclipse software development IDE (Integrated Development Environment).
- Internet connectivity.

- Connectivity 24/7 (i.e. Uninterruptible Power Supplies).

Once the aforementioned requirements are ensured either in the server or in the virtual machine, the on-site configuration is required.

1. Data definition in the Postgres database by means of executing the SQL script released in the software. This script would create both the data model structure and insert the initial data (e.g. available sensors, users…).

2. Import the released Java software packages (.jar files) into the Eclipse IDE.

3. Create a run configuration as Equinox running environment where all the previous imported projects are included in the execution environment.

4. Modify the configuration file (under configuration/config.properties) in order to adapt the properties of the specific location (e.g. IP addresses).

5. Run the already-configured execution environment and access the Web site as admin so that new users could be configured for accessibility.

6. Finally, the automatic operation should be configured with the aim of adding new schedulers to automatically run the BEMS processes.

Last but not least, it is highly recommended to periodically check the log files in order to detect errors, bugs or malfunctioning. As well, with the objective of reducing staff handling, it is also recommended to create a start-up script in case the server is rebooted (note that would not be necessary in cloud deployments).

On the other hand, the implementation of the BEMS has followed several standards. Those are explained in the bullets below.

- Sensor networks communication. The monitoring system has been deployed under the LonWorks, which is an open and standard communication protocol under the standard ANSI/CEA-709.1-B with IP (Internet Protocol) capabilities determined in ISO/IEC 14908-4 and ANSI/CEA-852. Besides, Modbsus is also implemented for the communication with the active façade solutions. In this case, Modbus is a de-facto industrial serial standard that makes use of the standard TCP/IP stack.

- Data modelling. As data come from heterogeneous data sources, its harmonisation is crucial for ensuring interoperability. In this sense, BRESAER-BEMS follows the IFC (Industry Foundation Classes), published as standard EN ISO 16739.

- Control elements. Looking at the EN 15232-1 standard on impact of Building Automation, Controls, and Building Management, BRESAER-BEMS may be classified as "Class B" where advanced BACS (Building Automation and Control Systems) and some TBMs (Technical Building Management) rules are included. With respect to the advanced BACS, it is assured by the EnergyPlus-based co-simulation module, as well as the fuzzy decision-making techniques. In the case of the TBMs, some KPIs (Key Performance Indicators) are calculated and alarms are generated to support the building management (malfunctioning, errors…). All of them are focused on the energy performance of building and maximisation of comfort. The automated functions that are included may be summarised in temperature control (set-points), indoor air quality control (air renovation), lighting (corridor), drivers and motors (dynamic blinds), monitoring/technical alarms (integration of sensor network and KPIs) and remote controls (Web-based interface with manual mode).

6.10 On-site installation guide

6.10.1 General

In this clause the different installation phases are explained through enumerations, schemes and graphical information, in order to analyse all the problems, inconveniences and solutions given in the installation phase. These steps of installation may affect through different modifications the design, the costs, the manufacturing time and, of course, its major aim is the reduction of the installation time through quality praxis in each step.

During the installation of each system, the following Health and Safety control measures should be taken into account.

- **Common heathy and safety control measures**

  Some of the risks that may appear and have to be controlled could be among other:

  - Risk of fallings to the same/different height level.
  - Risk of injury from falling parts over people.
  - Accidental impact from objects or tools
  - Cuts from the use of manual mechanic tools
  - Introduction of dust particles into the eyes
  - Over effort
  - Danger of entrapment
  - Risk of falling from the roof.
  - Sinking of the bearing surface
  - Cuts in the handling of the metal corrugated sheets.

  Some prevention measures should be applied in order to minimize these risks:

  - People in charge of making operations will be conscientious and acknowledge of the inherent risks and of the preventive measures to be applied.
  - Installation operators have to be perfectly qualified for the tasks they are going to develop.
  - Diary inspections should be applied before the works start in order to identify possible risks (mainly risk of injury from falling parts over people or risk of falling of auxiliary elements).
  - In case of using a scaffolding, it has to be perfectly fastened and attached to avoid collapse or downfalls.
  - All materials have to be in good conditions before installation, same for machinery and tools.
  - Installation operators should have the safety harness in every moment. The harness has to be always fixed to solid tough elements to avoid possible risk of falling from different level.

- It will be forbidden the presence of people in the ratio of action of the raised or suspended elements or panels in the moment of installation.

- Multifunctional insulated panels (STAM panels) will be raised with the hook of the crane through the use of rocker arms or a similar system.

- Guide cords or cables have to be used by installers to control the movement of the suspended multifunctional insulated panels concrete panels (STAM panels).

- The lifting procedure and steps marked by the manufacturer shall be followed at all times to maintain safety at the precise start of raising the panel.

- The lifting of panels with rain, snow or wind will be suspended when wind speed is above 50 km/h.

- The transport of elements into the roof will be done with the hook of the crane through the use of rocker arms or a similar system. Guide cords or cables have to be used by installers to control the movement of possible big transported elements.

- The assembly of finishing or different roof ends shall be made from a scaffolding or from a lifting platform.

- The lifting of elements as the panel sandwiches, metal sheets or other works in the roof will be suspended with rain, snow or wind when wind speed is above 50 km/h.

To do these tasks special individual protection elements will be use, among them:

- Security helmet.

- Works gloves.

- Security boots.

- Security or safety harness.

- Protection glasses.

- Reflective vest.

6.10.2 Step 0: Disassembly of previous system

The first step and named as “step 0” is to disassembly and remove the previous elements that are interacting with the future innovative and adaptable envelope system (BRESAER system) to be installed or that will not be part of the façade any longer.

- **Elements to be removed or disabled in case of necessity**

  - HVAC Façade system

  - Luminary elements integrated in the façade

  - Machines, electric transformers in the façade

  - Other elements

6.10.3 Step 1: Structural Brackets

- **Reception and verification measures**

  - Verify and check the status of the supply. Check also if it has been safely transported.
  - Verify the shipping note analysing if all types and number of each elements match with the requested list.
  - In the U metal brackets and screws it will be revised that there are all the slots (holes) in its positions, any deviation or possible mistake will affect to the rest of the façade making problems in the system installation. This will create difficulties in the levelness of the main structure.
  - It will be verified that the U anchors maintain angles of 90 degrees and that the distance between the L wings are the same or bigger to the thickness of the vertical profile of Aluskit that will be later in the anchor inserted.
  - The dimensions of the anchors and screws will be revise in order to verify that are the correct and adequate for the execution of the installation.
  - Once the previous steps are already verified all elements have to be pile up for storage. All elements have to be over the ground without direct contact with it. Protection over the elements may be foreseen in order to avoid water accumulation and the consequently degradation. Maintenance should be also done in order to avoid permanent deformations due to the weight of other materials.

- **Machinery, scaffolding and crafts requirements**

  - In this step, scaffolding or lifting platforms will be used for accessing the installation points and make the joints of the different profiles.
  - Electric drill to make perforations in the vertical profiles and to fasten screws and brackets.
  - Ratchet wrenches to tight at maximum bolts and screws.

- **Building preparation measures**

  Before starting the placement of the vertical profile some revisions have to be done:

  - Verify the verticality and the alignment of the façade where the system will be placed.
  - Verify the distance between the horizontal and vertical axes where the anchoring is going to be placed in order to minimize errors.
  - Clean and repair all parts of the façade that may have risk of falling over.
  - Verify anchoring elements and sub-elements are clean, without dust, grit, fat, humidity or any kind of strange substance that will prevent from a perfect joint between elements.
  - Verify the rigidity of the U anchor.
  - Remove any type of obstacle, electric conduits, water pipes, air conditioners, evacuation systems that interfere with the position of the anchorage, as well as the subsequent situation of the main structure.

- **Installation processes**

Once all the preparation tasks are realized, the installation process will start by following the next steps that will define the placement of the insulation panels.

- Layout of the position of the anchor points in the façade. A redefinition of the anchor points in the façade will be carried out, marking the place perfectly with a numeration of the anchor point numeration in case, and in the most exact way possible. This phase is very important since errors can be avoided that may later make difficult the final levelling of the system of façade.

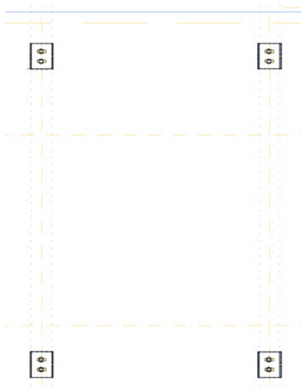

Figure 35 — Layout of the position of the anchor points in the façade

- One the levelness and the points are marked it can be proceeded to make the holes in the support.

- The top anchoring pieces do not carry vertical slot for the screw, so it should be positioned in a proper way before the fixing of the same so as not to confuse the piece and its location to avoid future displacements

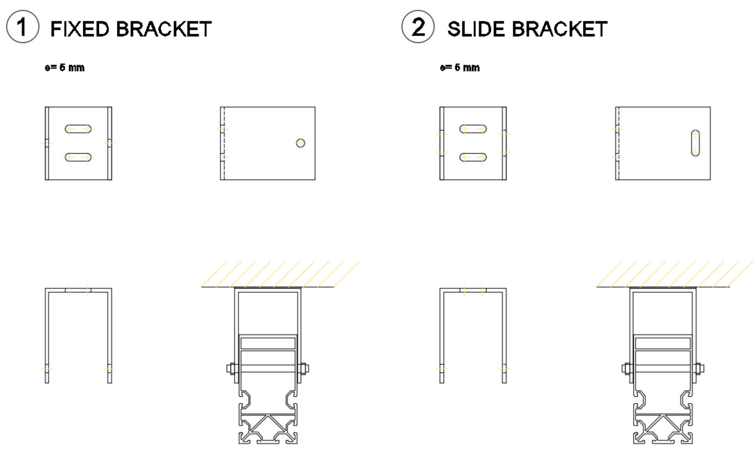

Figure 36 – Anchoring elements

- To place the anchoring piece and fix it with the screws, the piece will be hold in position, avoiding the possible movement or rotation at the moment of the first tightening of the screws.

- Once the first tightening is done, the levelling of the piece will be made by matching its axes with those previously marked in the initial layout made in the façade.

- A final tightening will be done to consolidate the union with the support.

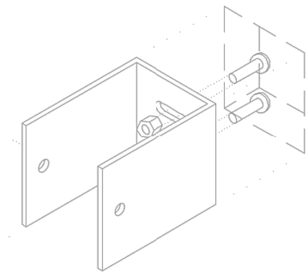

Figure 37 – Anchor fixation

- This procedure will be done with the rest of parts, always ensuring the distance between axes before the last tightening and making corrections any type of deviation with the existing slots in the pieces.

- **Revision and cleaning processes**

  - Once the installation is completed, the joints will be checked. This will be done by verifying that the U - anchors are perfectly aligned and that there is no deviation.

  - Check the distance between the axes and the anchors so that the Aluskit vertical and horizontal profiles to later have the proper tolerances for a correct connection.

  - Verify the rigidity of the U - anchorage, and that the tightening is correct and does not cause deformation in the piece.

6.10.4 Step 2: Insulation installation

- **Reception and verification measures**

  - Verify and check the status of the supply. Check also if it has been safely transported.

  - Verify the shipping note analysing if all types and number of each elements match with the requested list.

  - Insulation panels will be revised to verify that there are not deformations or superficial damage that could compromise the thermal behaviour or the stability after installation.

  - The dimensions of the insulation panels will be revise in order to verify that are the correct and adequate for the execution of the installation. Also the fixing elements (dimensions, correct type, number of elements) and other needed elements for the installation (screws and crafts)

  - Once the previous steps are already verified all elements have to be pile up for storage. All elements have to be over the ground without direct contact with it. Protection over the elements must be foreseen in order to avoid water accumulation and the consequently degradation. Maintenance should be also done in order to avoid permanent deformations due to the weight of other materials.

- **Machinery, scaffolding and crafts requirements**

  - In this step, scaffolding or lifting platforms will be used for accessing the installation points of the insulation.

  - Electric drill to make perforations in the vertical profiles and to fasten screws. It will be used also for the tightness of the clamping system.

  - Cutter to adapt the insulation panels to the innovative and adaptable envelope structure (BRESAER structure). Hammer and other tools to place the insulation and the clamping system.

  Before starting the placement of the vertical profile some revisions have to be done:

  - Verify that there are not possible irregularities, degraded points or elements that will interact with the insulation that were not already removed.

  - Degraded points have to be repaired in case that may affect the integrity, water tightness or infiltrations in the façade. Also the irregularities has to be treated in order to align in a nearly perfect surface all the façade with the objective of avoiding the creation of bellies.

  - A planarity check has to be done before starting the installation in order to identify last irregularities and try to repair them in case of need.

Figure 38 — Façade planarity check

- **Installation processes**

  Once all the preparation tasks are realized, the installation process will start by following the next steps that will define the placement of the insulation panels.

  1. Place the first insulation panel in the lower part of the façade aligned with the edge, taking the consideration that the edge must not have any thermal bridge in the future. The panel has to be sustained by the inferior finishing (see Figure 39). Panels has to be placed counter balanced. (See Figure 40)

  2. If the insulation panel interacts with a U bracket, it must be cut and adapted. Between the U brackets, insulation should be also added to avoid thermal bridges. (See Figure 39)

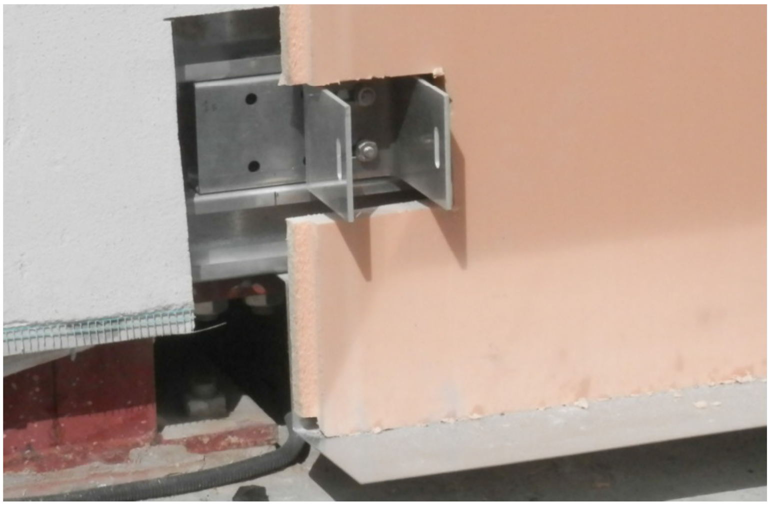

Figure 39 — Hole in the insulation to install the insulation (inside the bracket must be also insulation)

3. Make a perforation with the drilling machine in each corner of the panels (joint edges) into the wall. If the panel is too big maybe more perforations are needed (one in the centre, in the middle of the joints edges…) (see Figure 40)..

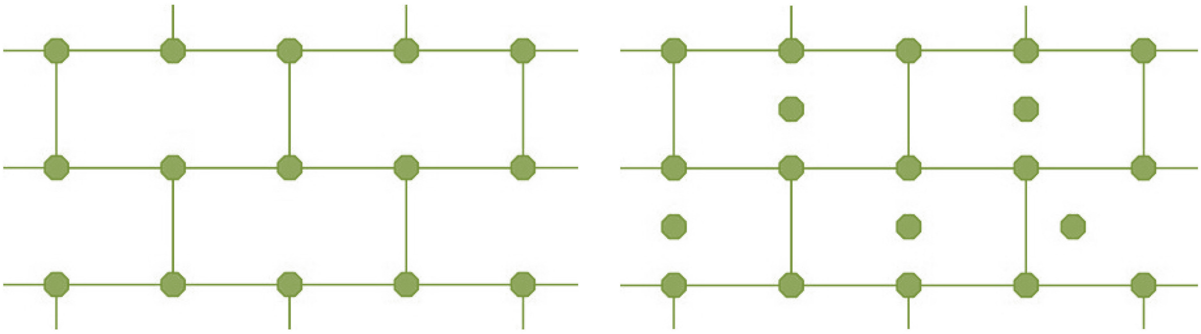

Figure 40 — Position of plugs in the joints (left) and also in the center (right). At least 5 per 1m^2. Counterbalance application

4. Insert in each perforation the fixing elements (plugs) and applicate the special screw inside of it to later proceed to attach it completely with a hammer. There should be at least 5 plugs per each square meter (see Figure 41).

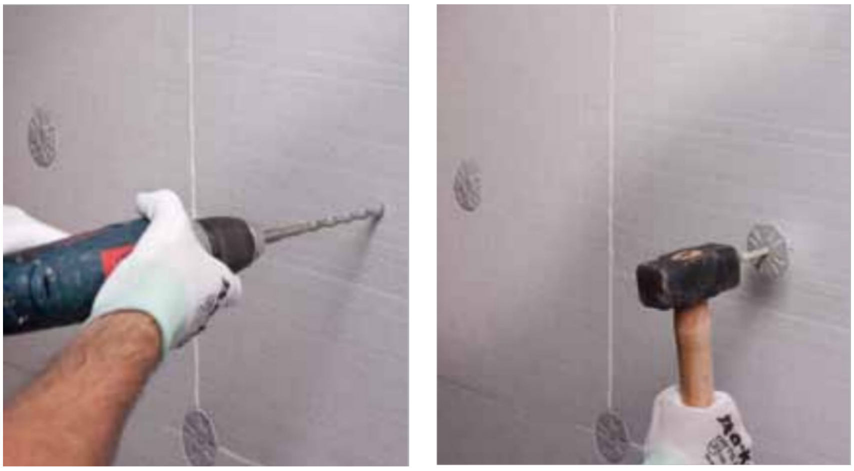

Figure 41 — Drill holes for the plugs and insert them with hammer

5. Repeat the process going to the right and then to the upper part of the façade. Taking specially care in not reproducing bellies in the façade.

6. In the borders a finish element can be integrated in order to give a better aesthetics to the building. In case of integrating these elements the procedure of manufacturers should be followed.

- **Revision and cleaning processes**

  - Cleaning the insulation parts that are not going to be used and the rubbish generated each two installed panels.

  - Once the installation is finished a check of all the insulation joints will be done in order to revise the correct position and that there is not possible thermal bridges because of this.,

  - Clean all possible dirtiness on the U brackets in order to have a perfect joint later with the next of the elements of the innovative and adaptable envelope system (BRESAER system).

  - Revise the perfect alignment and revise the fissures between insulation panels. In case of fissures re-install the panel in order to avoid possible thermal bridges and condensations.

6.10.5 Step 3: Structure and substructure

- **Reception and verification measures**

  - Verify and check the status of the supply. Check also if it has been safely transported.

  - Verify the shipping note analysing if all types and number of each elements match with the requested list.

  - In vertical profiles, horizontal profiles, metal brackets and screws it will be revise that there is any product with deformations or superficial damage that could compromise the structural stability or behaviour or that may affect the process of installation.

  - The dimensions of the profiles and different elements will be revise in order to verify that are the correct and adequate for the execution of the installation.

- Once the previous steps are already verified all elements have to be pile up for storage. All elements have to be over the ground without direct contact with it. Protection over the elements must be foreseen in order to avoid water accumulation and the consequently degradation. Maintenance should be also done in order to avoid permanent deformations due to the weight of other materials.

- **Machinery, scaffolding and crafts requirements**

  - In this step, scaffolding or lifting platforms will be used for accessing the installation points and make the joints of the different profiles.
  - Crane truck or similar for the lifting of the materials to the point of installation.
  - Electric drill to make perforations in the vertical profiles and to fasten screws and brackets.
  - Ratchet wrenches to tight at maximum bolts and screws.

- **Building preparation measures**

  Before starting the placement of the vertical profile some revisions have to be done:

  - Verify that the U - Anchors are perfectly aligned and there is no deviation from its axe.
  - Verify the distance between the anchorage aces in order to dispose of the necessary space for the horizontal profiles that will be installed the next.
  - Verify anchoring elements and sub-elements are clean, without dust, grit, fat, humidity or any King of strange substance that will prevent from a perfect joint between elements.
  - Verify the rigidity of the U anchor.

- **Installation processes**

  Once all the preparation tasks are realized, the installation process will start by following the next steps that will define the placement of the metallic structure.

7. Installation of the aluminium (Aluskit) vertical profiles:

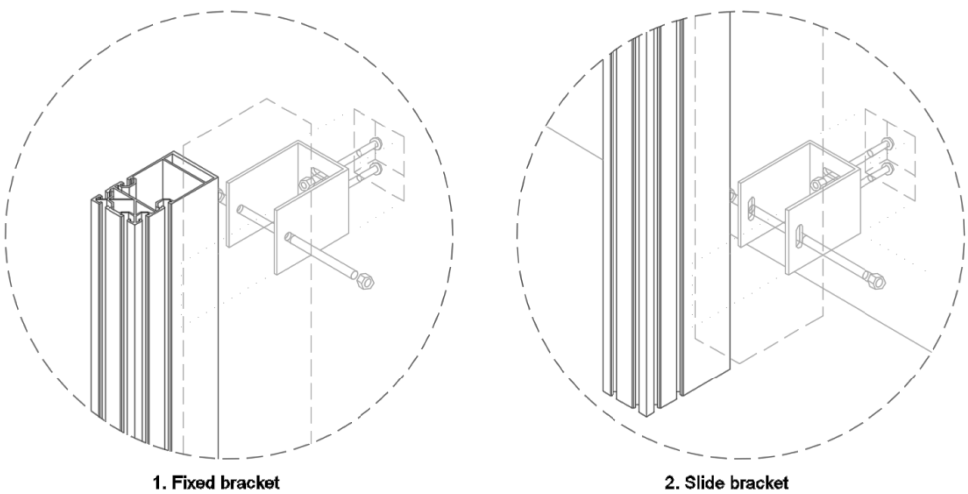

Figure 42 — Vertical profiles fixation

a. Perforations to raise easily the profile. Two perforations will be performed in the upper laterals of the vertical profile, with enough diameter to attach or pass through the hanging chosen system. This will help to raise the profile and to place it to the upper fixing point.

b. Perforation for the upper fixing. Two perforations will be performed with the metric of the bolt to be used.

c. Secure lifting of the vertical profile. This will be done with the help of lifting or crane machines.

d. Once the vertical profile is placed it will be proceed to realize the upper fixing of the profile, joining with the U – anchor using stud bolts in the process. Screwing will be done without the maximal tightening torque giving a few movement.

e. Vertical profile alignment or levelling.

Figure 43 — Upper fixation already placed

f. Interior fixing of the vertical profiles. Once aligned or levelled with the help of a clamping jaw or similar the profile will be fixed to avoid movements. Perforations will be performed in the laterals of the profile, in the middle point of the inferior shaped slots. The bolt will be introduced and tight with the correct tightness.

g. Apply the maximal tightening to the upper fixing.

h. These steps will be realized for the placement and fixation of all vertical profiles.

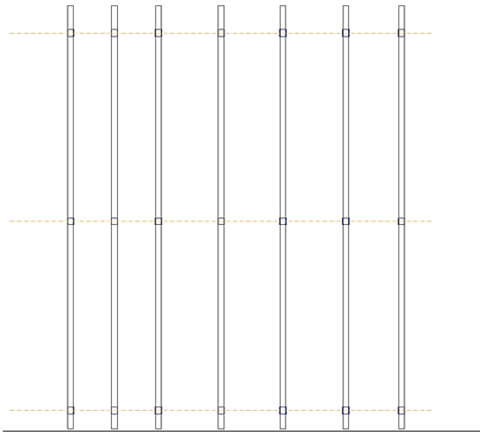

Figure 44 — Vertical profiles already mounted

8. Installation of the aluminium (Aluskit) or standard horizontal profiles:

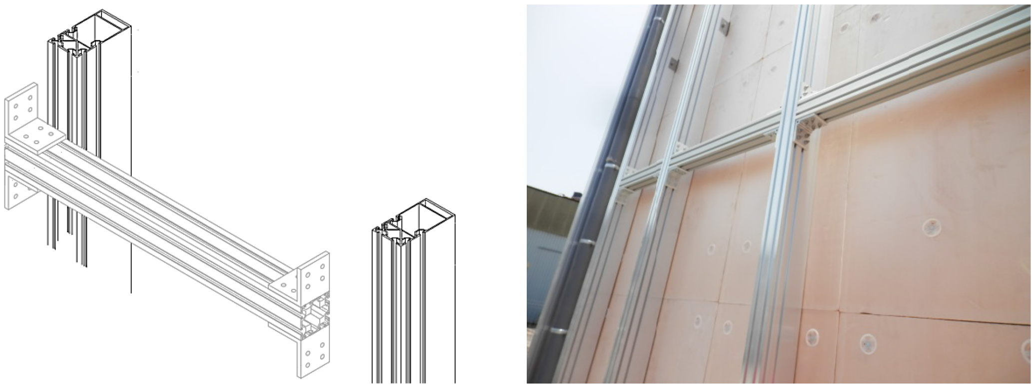

Figure 45 — Horizontal profiles fixation

a. Stablish the layout of the horizontal profiles. Position marks will be were the horizontal profiles will be placed.

b. Fixing of the horizontal profile. The horizontal profile will be placed in its position with the inferior metal L brackets that fix it to the vertical profiles. The brackets will already come with the screws and nuts in the slots. The metal L brackets will be placed introducing the hammer heads in the existing riel of the horizontal profile and in the vertical one. With the help of a screwing electric machine a first tightening has to be done. Once the horizontal profile is fixed from the inferior side it is possible to proceed to fix the upper brackets.

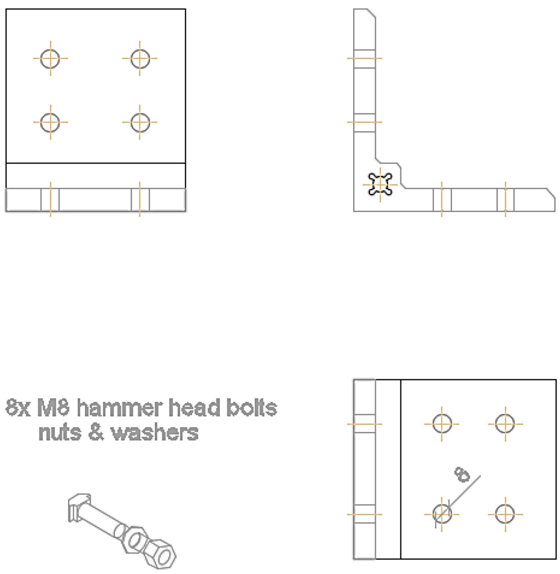

Figure 46 — L brackets

c. For the placement of the rest of horizontal profiles the same process will be done, finalizing with this all the structure and substructure installation.

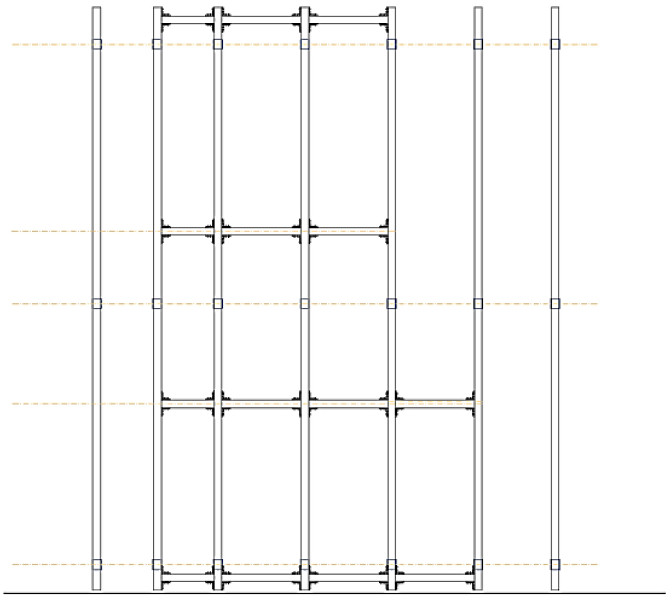

Figure 47 — Structure and substructure

- **Revision and cleaning processes**

  - Once the installation is finished a check of all joints will be done in order to revise the correct tightness torque of each screw, also the joints of the L brackets as the ones between the vertical profiles with the U brackets. The large amount of fixing makes this revision must due to the probability of having some screws without a correct tightness.

  - Clean all possible dirtiness on the frontal of the profiles in order to have a perfect joint later with the next of the elements of the innovative and adaptable system (BRESAER system).

  - Levelness and alignment will be verified in the horizontal and vertical profiles to repair mistakes and minimize future problems.

6.10.6 Step 4: Multifunctional Insulated Panels (STAM panels)

- **Reception and verification measures**

  - Verify and check the status of the supply. Check also if it has been safely transported.

  - Verify the shipping note analysing if all types and number of each elements match with the requested list.

  - Check the anchors that support the panel and screws, check if there is any product with deformations or superficial damage that could compromise the structural stability or behaviour or that may affect the process of installation.

  - Possible bumps and dents should be visually checked in the panel because they can cause problems in the perfect alignment and levelling over the horizontal profiles. Revise also possible damage in the corners of the panel, breaks or cracks in the concrete that may cause structural or falling problems. The insulation should be revised to confirm its continuity in the back side of the panel.

  - The dimensions of the anchors and different elements should be revise in order to verify that are the correct and adequate for the execution of the installation.

- Once the previous steps are verified, all elements should be prepared for storage. All elements should be placed over the ground avoiding direct contact with it. Protection over the elements should be foreseen in order to avoid water accumulation and consequent degradation. Maintenance should be also done in order to avoid permanent deformations due to the weight of other materials.

- **Machinery, scaffolding and crafts requirements**

  - In this step or activity, lifting articulated platforms should be used to help the guide in the raising of the panel to make a correct placement.

  - Crane truck or similar should be used for the lifting of the materials to the point of installation, with rocked arms or similar.

  - Electric screwdrivers should be used to fasten screws in the anchors.

  - Ratchet wrenches should be used to tighten at the required torque bolts and screws.

- **Building preparation measures**

  - Check the structural stability of the different types of joint in order to identify possible problems that may affect the stability of the structure once the panel are installed.

  - Verify that there is no dirt or dust on the sub-structure profiles, in order to have a perfect joint between the anchor and the sub-structure.

  - Verify the superficial continuity of the vertical and horizontal profiles to detect any possible discontinuity that may provoke deformations in the joint with the anchor.

- **Installation processes**

  This system is based on anchors that support the weight of the panels; due to this, the system should be installed from the bottom to the top. Firstly the bottom anchor should be installed, then the panel, and finally the top anchor. This process has to be repeated successively.

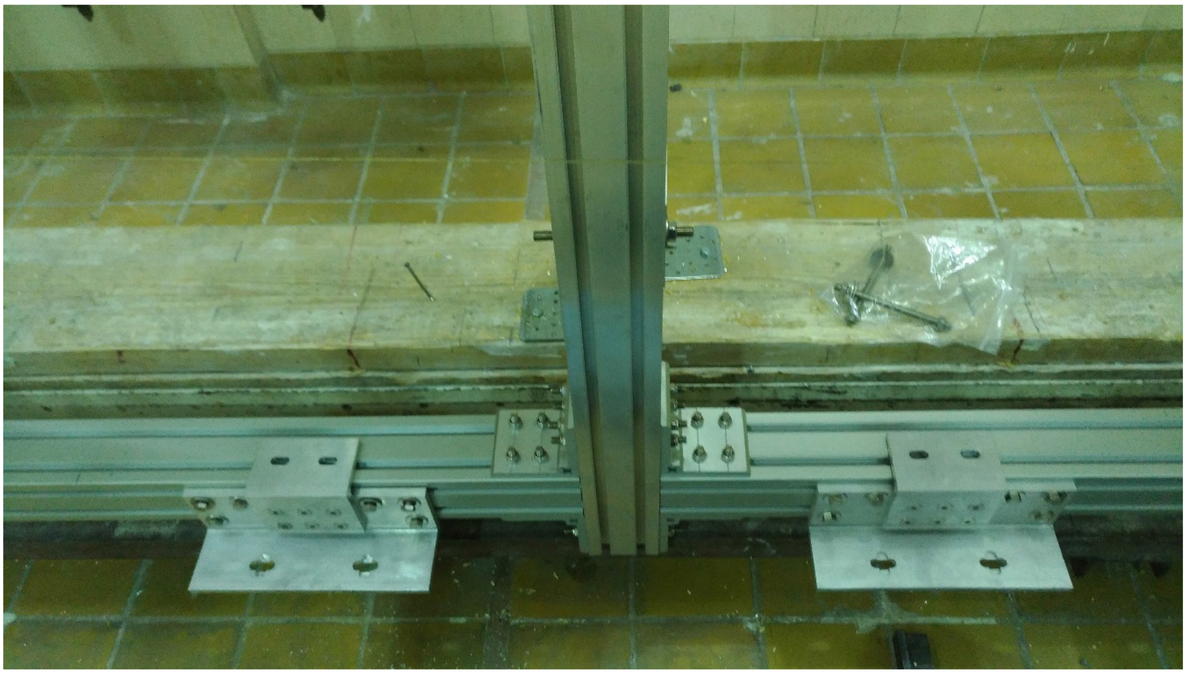

Figure 48— Anchors fixing

1. Anchors layout. The process should start with the identification of the anchors position, marking it on the horizontal profile of the sub-structure.

2. Screws should be placed and tightened to install the bottom anchor. Thanks to the slots and the set screw on top, the anchors can be adjusted vertically. The pin of each anchor should be installed and tightened. Finally, plastic spacers should be placed as washers in the pins.

3. Elevation and placement of the panels. A metal beam should be used for the elevation of panels, connected to the top edge. This way, the panel can be displaced with a crane (also crane truck) and placed over anchors previously installed on the sub-structure. This operation should be performed slowly in order to avoid any damage in the installation of the panel (sockets) on the anchor pins.

4. Once the panel is in position, it should be fixed by two anchors above it. These anchors should be installed by operators in a cherry picker. The panel is secured by installing the pins of the anchors above the panel, tightening them in the nut that is embedded in the panel.

5. The beam used to lift the panel can be removed, only after the top anchors are secured and the panel is completely fixed to the sub-structure.

Figure 49 — Placement of Multifunctional Insulated panels in real case

6. Once the panel is installed and secured, the insulating tape should be applied to its edges, where necessary. To do this, the protection paper should be removed and the tape should be stuck to the panel edges.

7. After this step, operations from 1 to 5 should be repeated to install the adjacent panel.

8. Once the installation procedure is finalized, the joints should be sealed with fire-retardant silicone.

- **Revision and cleaning processes**

  - Once the installation is finished a control of all panels should be performed, verifying that there are no alignment errors.

  - It should be verified that all panels are well anchored and that there are no movements that could generate vibrations.

  - Another control for cracks or imperfections should be performed, to ensure aesthetics in line with expectations.

  - Joints should be checked to verify perfect continuity, closing possible gaps that have remained, to ensure a perfect air and water tightness.

6.10.7 Step 5: Lightweight ventilated façade (ULMA façade)

- **Reception and verification measures**

  - Verify and check the status of the supply. Check also if it has been safely transported.

  - Verify the shipping note analysing if all types and number of each elements match with the requested list.

  - In the L mounting brackets, square aluminium brackets, fixing profiles, panels and screws it will be revise that there is any product with deformations or superficial damage that could compromise the structural stability or behaviour or that may affect the process of installation.

  - Possible bumps and dents will be visually checked in the panel because it can cause problems in the perfect alignment and levelling over the horizontal fixings. Revise also possible damage in the panels, breaks or fissures. This will be done due to the fragility of them, thus bumps or dents that may cause later breaks or fissures will be checked.

  - The dimensions of the fixing profiles and different panel will be revise in order to verify that are the correct and adequate for the execution of the installation.

  - Once the previous steps are already verified all elements have to be pile up for storage. All elements have to be over the ground without direct contact with it. Protection over the elements must be foreseen in order to avoid water accumulation and the consequently degradation. Maintenance should be also done in order to avoid permanent deformations due to the weight of other materials.

  - Special care will be taken as mentioned before in the storage of the lightweight ventilated façade panels (ULMA panels) thus they are very fragile. Between each panel flexible spacers will be placed to avoid bumps, contacts or direct charges. If not possible fissures or broken parts may appear wasting the material.

- **Machinery, scaffolding and crafts requirements**

  - In this step or activity, lifting articulated platforms will be used to help the guide in the raising of the panel to make a correct placement.

  - Crane truck or similar for the lifting of the materials to the point of installation.

  - Electric screwing to make to fasten screws in the mounting brackets and the square profiles. It will be used also in the tightness of self-drilling screws.

  - Ratchet wrenches to tight at maximum bolts and screws in the screws and profiles.

  - Use of radial for possible cuts and adaptation of metallic profiles to the facade.

  - Stone saw for poosssible cuts and adaptation of polymer condrete slabs

  - Drilling machine for the execution of perforations in mounting brackets and square profiles.

- **Building preparation measures**

  - Check the structural stability of the different types of joint in order to identify possible problems that may affect the integral stability of the structure once the ventilated façade panels will entry in tension charge within the sub-structure.

  - Verify that there is no dirtiness on the frontal of the aluminium (i.e. Aluskit) or Standard profiles in order to have a perfect joint later between the square profile and the horizontal profile of the sub-structure of de lightweight ventilated façade (ULMA façade).

  - Verify the superficial continuity of the vertical and horizontal profiles to detect any possible fissure or discontinuity that may provoke deformations in the joint with the square profile and mounting brackets. This problem will create difficulties in the attachment of the panels in the joints, with the possibility of apparition of fissures, ruptures, joint discontinuity or movement problems between panel provoking vibrations.

- **Installation processes**

  This system, in a similar way as Multifunctional Insulated Panels (STAM panels) is based on a series of fixing system profiles that support the weight and avoid the possible rollover of the panels, due to this the system has to be install from the bottom to the top. To place these elements firstly the bottom fixing profile has to be installed, to later place in it the lightweight ventilated façade panels (ULMA panels), after that the top fixing profile has to be install. This process has to be repeated successively.

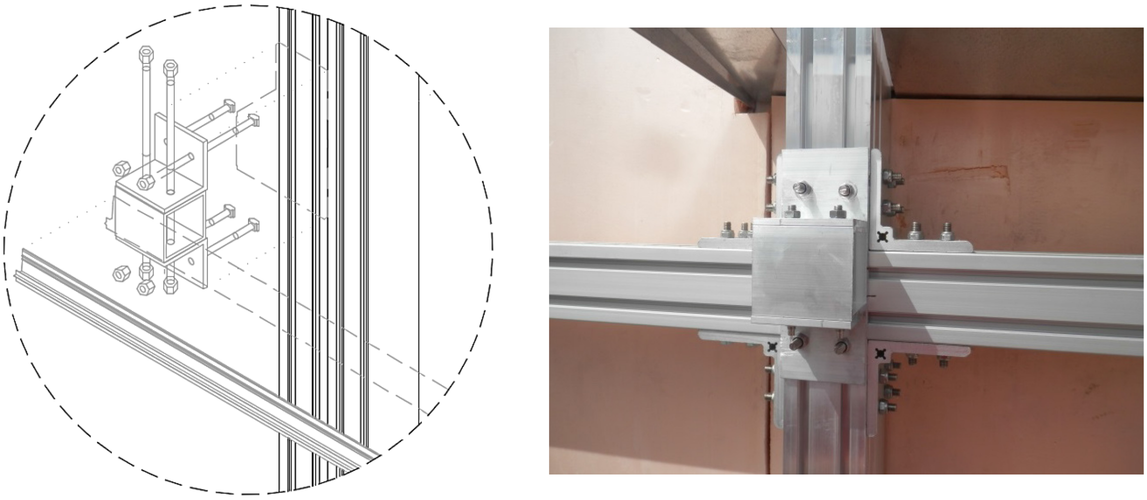

Figure 50 — Base system fixing

1. Square profiles layout. The process will start with the identification of the position where the mounting brackets and the square profiles will be installed, marking the position over the front face of the vertical and horizontal main structure. With this it will be able to identify possible joint points between vertical and horizontal profiles. These profiles will work as the joint between the main structure and the sub structure system that support the lightweight ventilated façade (ULMA façade).

2. Before beginning with the placement and fixing of these profiles and mounting brackets, it will be checked that they have the correct perforations. If they come without them, it will be needed a work table to do them with exactitude, making a prefect coincidence between the two elements. If this is not the case when attaching these pieces to the Aluskit profile structure, the front face of the square profiles will be in a different plane, causing subsequent no surfaces alignment and discontinuities in the termination panels.

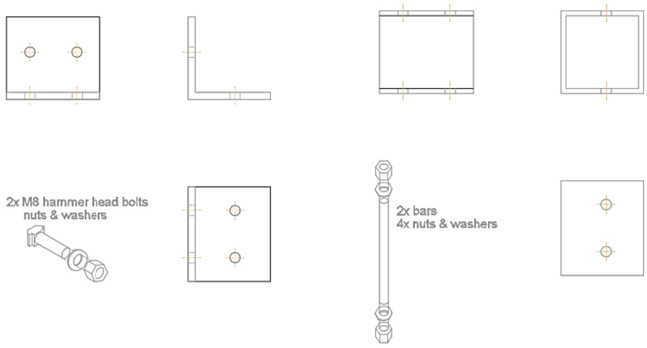

Figure 51 — Fixing of profiles and L profiles

3. The placement of these pieces will follow a similar procedure to the horizontal Aluskit profiles of the main structure. It will begin with the fixing of the bottom square on the marks made in the previous set out or layout, making a first tightening with the electric screwing machine. Subsequently it will be placed the square profile and its upper square, joining them with the vertical long bolts. This joint will not be tighten until the upper bracket is perfectly fixed to the vertical aluminium (Aluskit) profile. The top bracket will be tighten in the same way, making the tightening with the electric screwing machine. The joint will be consolidated with the tightening of the vertical long bolts,

taking special care with the maximum tightening of the same, due it can deform the front of the square profile, where later is going to be fixed the profiles of subjection of the façade panels.

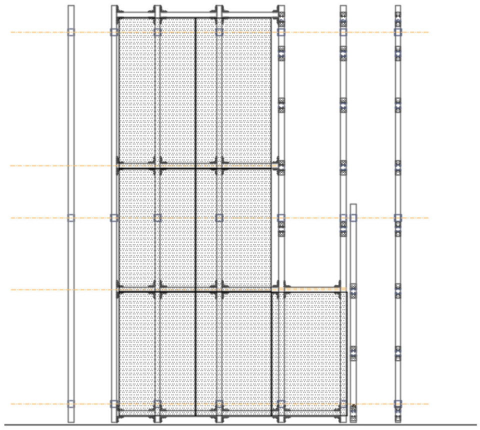

Figure 52 — Placement of tubular profiles and L elements

4. Lay out of the supporting profiles of the lightweight ventilated façade (ULMA panels). For the installation of these profiles it is necessary to perform a lay out of the position of the profiles, this layout will be made by marking on the front surface of the square profiles previously anchored. As the installation procedure goes from bottom to top the positioning will be focused on the bottom part mainly. Corrections should be made after having this perfectly located and levelled.

Figure 53 — Placement of supporting horizontal profiles

5. Placing the bottom profile. This is one of the most important points, therefore it must be ensured that the level of the profile is maintained correctly during the fixing process. To do this the profile will be placed in its position, checking the level and holding it with the help of clamps or sergeants. In this way it will be avoid in the process of screwing possible displacements of the profile. In this connection self-drilling screws are used with the help of an electric screwing machine.

6. Placement of the lightweight ventilated façade panels (ULMA panels). The concrete panel moved by two operators will rest on the previously installed profile of the ventilated façade sub-structure, matching its lower slot to the profile receiving rail. It will be positioned in its exact location and held until the positioning of its upper securing profile to avoid rollover. When installing adjacent panels a

plastic joint between them will be placed to allow for thermal expansion and a ficed metallic one when movement restriction is required

7. Placement of the top securing profile. Having the façade panel attached, the profile will be placed in its correct location, matching the lower anti roll over of the profile to the top slot of the lightweight ventilated façade panel (ULMA panel). The horizontal alignment will be checked with a level and it will be proceed to the screwing of the fastening profile superior to the square profile.

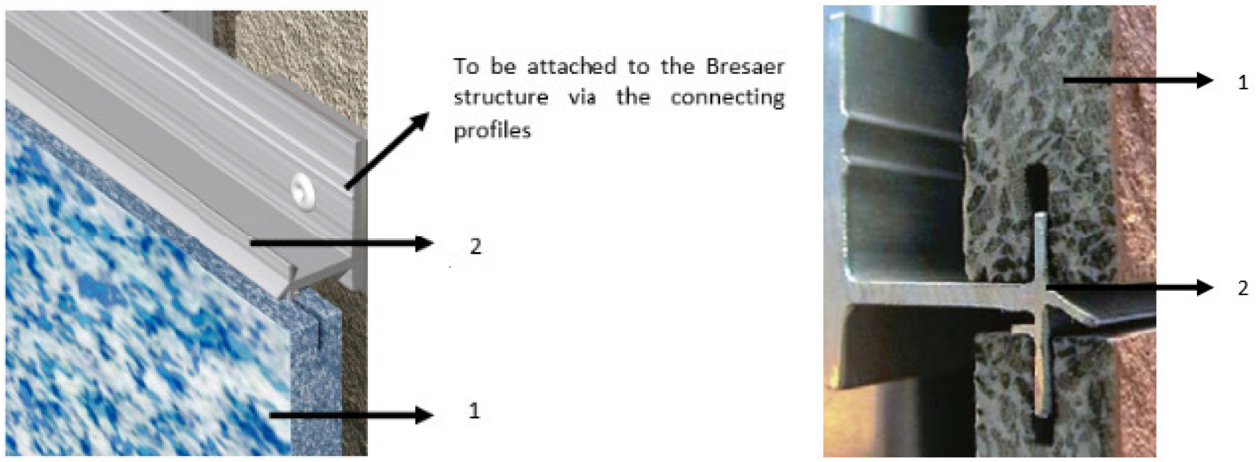

Figure 54 — Lightweight ventilated façade (ULMA façade) details

8. Top façade installation parts. Before continuing with the assembly process of the top panels, side finishing will be placed, which will be hidden under the adjacent panels. These finishing's will block the lateral movement of panels throughout the system.

9. The same procedure of ascending placement (from bottom to the top) will be followed until the top position in the last panel, the top of the structural profile.

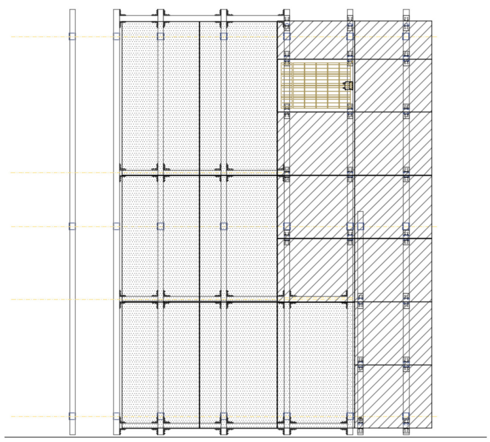

Figure 55 — Placement of finishing profiles

- **Revision and cleaning processes**
  - Once the installation is finished a check of all the panels will be done, checking that there are no excessive alignment differences between their surfaces.

- It will be verified that panels are well anchored and that there are no gaps or small movements that could generate vibrations.

- Check for possible fissures, cracks or imperfections that may have appeared on the panels loading, if not clean superficially maintain good aesthetics in line with expectations.

6.10.8 Step 6: Solar thermal air component roof (SOLARWALL® roof)

- **Reception and verification measures**

  - Verify and check the status of the supply. Check also if it has been safely transported.

  - Verify the shipping note analysing if all types and number of each elements match with the requested list.

  - In the sandwich panels, horizontal profiles, tubular profiles, corrugated metal sheet and screws, it will be revised that there is not any product with deformations or superficial damage that could compromise the structural stability or behaviour or that may affect the process of installation. It will be done special emphasis in the metal sheets because its fragility and ease to deformation and possible perforations.

  - Possible bumps and dents will be visually checked in the panel because it can cause problems in the perfect alignment and levelling over the horizontal fixings. Revise also possible damage in the panels, breaks or fissures. This will be done due to the fragility of them, thus bumps or dents that may cause later breaks or fissures will be checked.

  - The dimensions of the profiles and different elements will be revise in order to verify that are the correct and adequate for the execution of the installation.

  - Once the previous steps are already verified all elements have to be pile up for storage. All elements have to be over the ground without direct contact with it. Protection over the elements may be foreseen in order to avoid water accumulation and the consequently degradation. Maintenance should be also done in order to avoid permanent deformations due to the weight of other materials.

  - With the corrugated metal sheets it will be taken more care during the storage. Each sheet should be coincident with the upper and bottom one in order to protect them and the plastic of protection.

- **Machinery, scaffolding and crafts requirements**

  - In this step, scaffolding or lifting platforms will be used for accessing the installation points and the roof.

  - Lifting platform or scaffolding to execute works in the roof perimeter.

  - Crane truck or similar for the lifting of the materials to the point of installation.

  - Electric drill to make perforations in the vertical profiles and to fasten screws and brackets. It will be used also for the tightness of self-drilling screws for the joints of the metals sheets.

  - Ratchet wrenches to tight at maximum bolts and screws.

  - Use of radial for possible cuts and adaptation of the roof metallic sub-structure.

- Drilling machine for the execution of perforations in mounting brackets and square profiles.

- **Building preparation measures**

  - The inclination and alignment of the support surfaces will be checked, verifying that there are no changes of the surface plane that could generate breaks or damages with the different slopes of the roof.

  - It will check the structural stability of the different supports to detect possible errors or damaged, that may affect the structural stability once the roof is loading its charge.

  - Distances between axes and the leveling of the same one will be checked, to minimize future errors in the pieces or elements to install later.

  - Verify that there is no dirtiness on the supports and joints of the roof substructure in order to have a perfect joint later, avoiding possible deviations in the levelness and alignment.

- **Installation processes**

  Once all the preparation tasks have been completed, the different steps for placing the roof cover will begin.

1. Placement of the main aluminium (Aluskit) roof sub-structure.

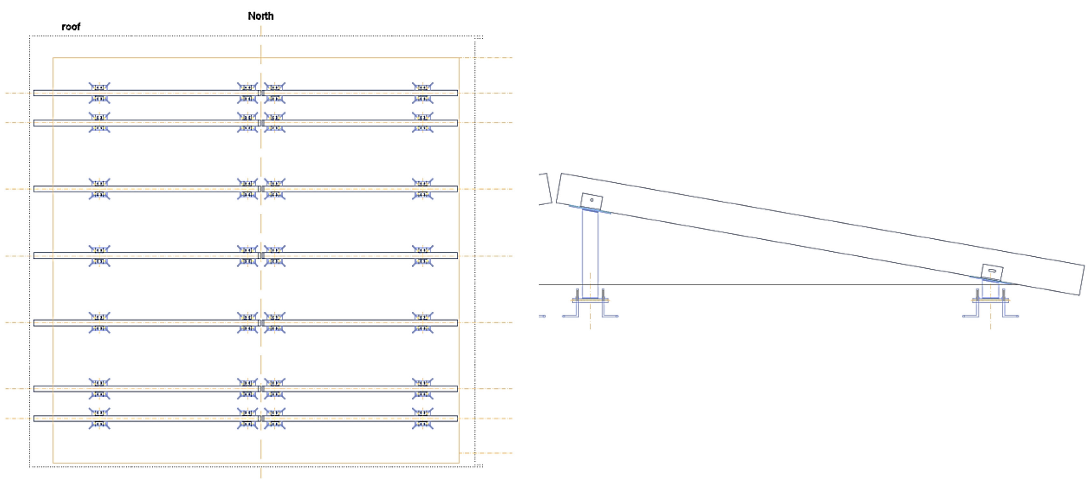

Figure 56 — Installation of the roof sub-structure

   a. Drilling holes in the supporting profile for the lifting of it. Two perforations will be made in the upper sides of the profile, with enough diameter to fast the profile with the chosen system. This will help in the vertical lift of the profile to bring it closer to the attachment point in the roof.

   b. Drilling for the upper fastening. Two lateral perforations will be made with the bolt metric to be used.

   c. Raising of the main substructure. It will be done with the help of lifting machines or cranes.

d. Between the support and the underside of the substructure elastic bands of neoprene or similar will be placed in order to absorb the movements of the structure due to loads or possible thermal dilations.

e. When the sub-structure is positioned, the upper fastening of the profile will be carried out, attaching the profile to the support with two aluminium brackets, placed on the sides of the profile. The attachment of the bracket to the profile will be done with mechanical anchoring. The connection between the brackets and the belt will be made with a threaded bolt through. The screwing will be done but without its maximum tightening.

f. Levelness of the main substructure profile.

g. Bottom fixing under the main sub-structure. Once levelled with the help of a jaw or similar, the profile will be hold to avoid displacements. The sides of the profiles will be at the midpoint of the bottom slot. After this the longer bolt will be inserted with a correct tightening.

h. Tighten the top fastening or fixing.

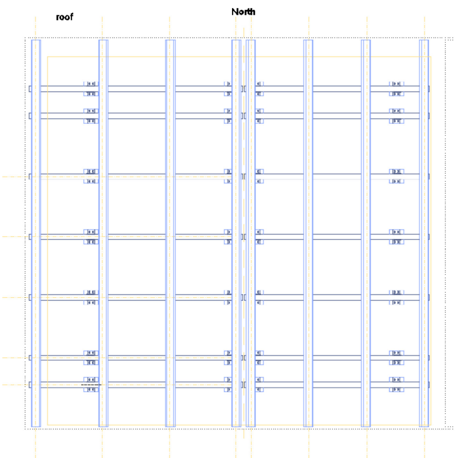

Figure 57 — Placement of primary structure

i. These steps will be done to fix all the main profiles to the supporting elements.

2. Placement of the secondary sub-structure.

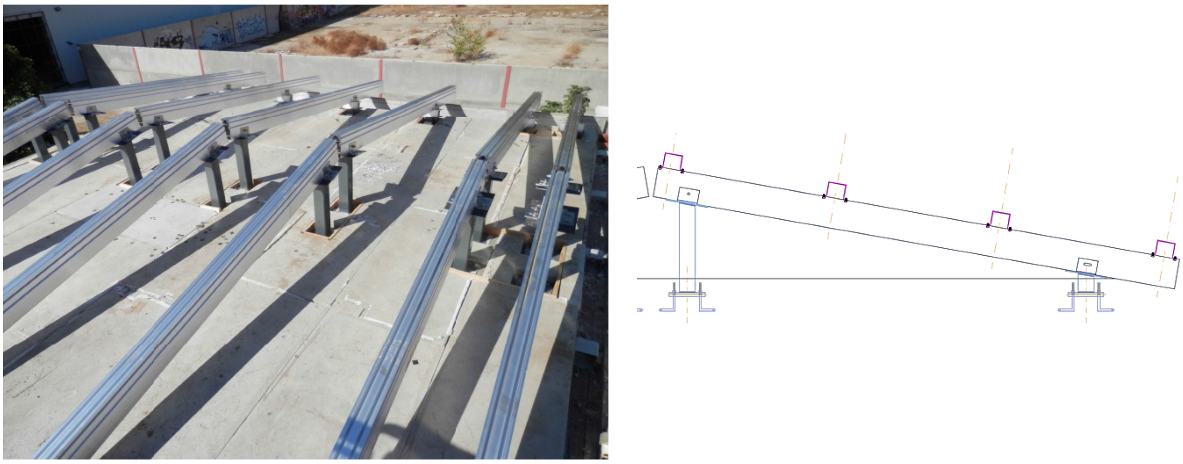

Figure 58 — Placement of secondary substructure

a. Staying secondary belts. We will make a layout marking the position of the elements that will form the secondary sub-structure, consisting of omega profiles of galvanized steel, leaving a mark of position in the top faces of the aluminium (Alsukit) roof structure profile. It will be paid attention to maintaining the axes distance so that the roof loads can be perfectly distributed according to calculations made.

b. The secondary sub-structure will be on the marks previously made. With the help of jaws, it will be temporary fixed to the main roof profiles, avoiding any type of displacement that may cause future problems in the joints.

c. Keeping the sub-profile in its position the points where the holes will be made shall be marked to later be fastened with screws. Once marked, and checking again that there is no movement, we will perform the drilling.

d. The temporary fixing will be removed and the head hammer screws with its corresponding nut will be inserted in the correct holes.

e. Once the screws have been fitted, the secondary profile will bel placed on the main profile again, inserting the screws heads into the corresponding rail. Once the screws are in place, firstly the last ones will be tighten leaving the strap for the later maximum tightness. The tightening will be done with electric drill machine to late tight each of the screws with ratchet wrench.

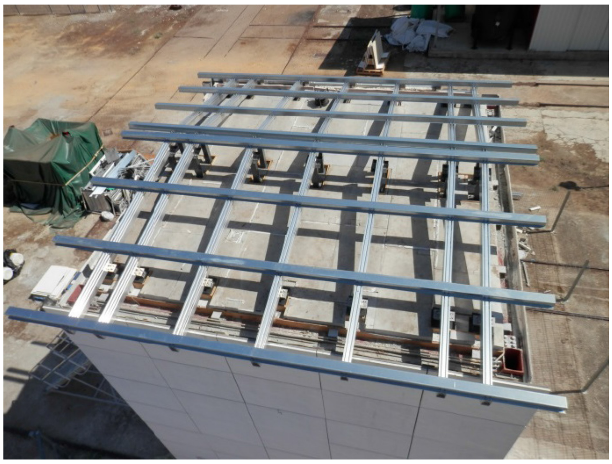

Figure 59 — Structure already placed

f. The same procedure will be followed for the rest of the secondary roof profiles.

3. Roof cover with sandwich panels.

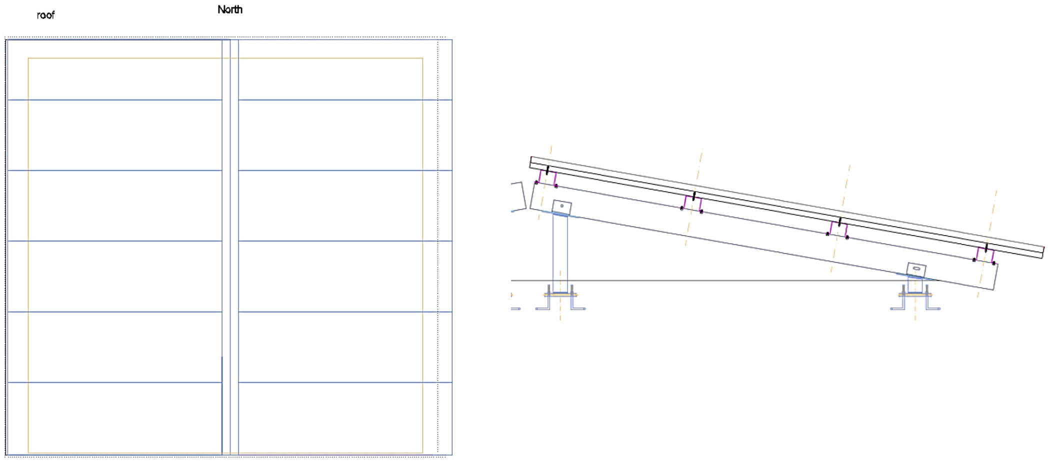

Figure 60 — Sandwich panel installation

a. This system is a commercial one, the instructions of its “guide of use” has to be followed. The beginning of the installation will be on one side, following towards the other side of the roof. We will pay attention to the reframing of the first panel, since with the tongue-and-groove system, could appear errors at the end of the opposite side. The joint between panels will be realized with self-drilling screws fastened to the secondary omega substructure profiles, then the joint will be hidden with a special cover.

Figure 61 — Placement of sandwich panels

4. Placement of the second covering layer.

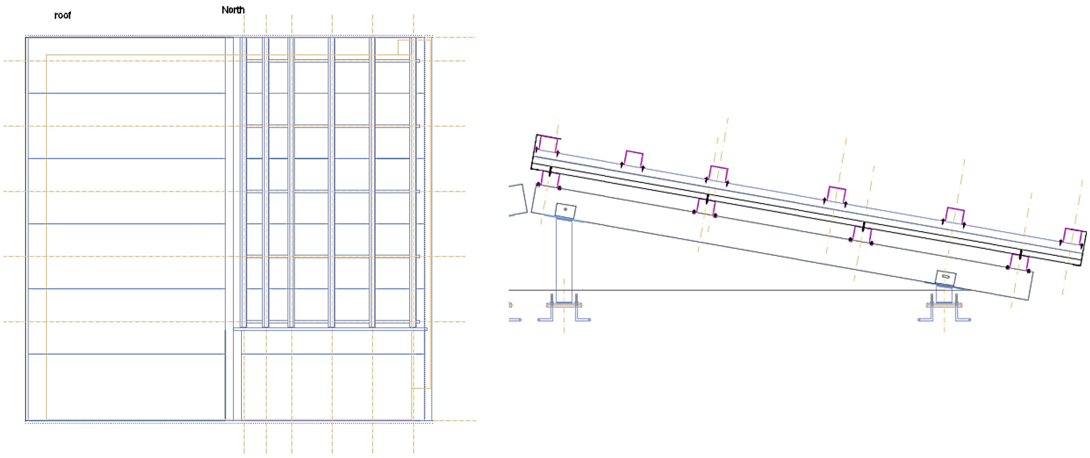

Figure 62 — Installation of second cover roof system

a. In order to generate a chamber with enough thickness, rectangular profiles of steel will be placed on the nerves of the sandwich panels. Profiles should be placed by altering and screwing it through the sandwich panel to the secondary substructure.

b. On these metallic nerves, a system of omega straps of steel will be placed with the same procedure that we did for the secondary straps, in this way it will be completed air chamber according to the needs of the system. The only difference with the previous system is the fixation, which will be done with self-tapping screws instead of hammerhead screws ones. In this case there is no need to perform the holes in the omega to accommodate the screws.

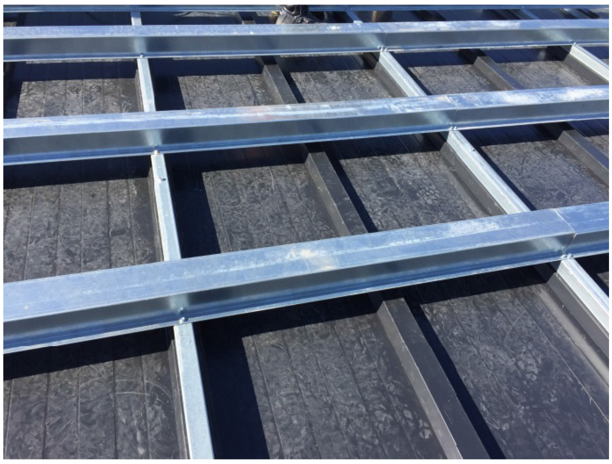

Figure 63 — Second substructure installation

c. Placement of lateral closing elements. Once the chamber has been reached, the whole perimeter will be closed with U-shaped plates to have the required hermetic system.

5. Placement of the final roof cover.

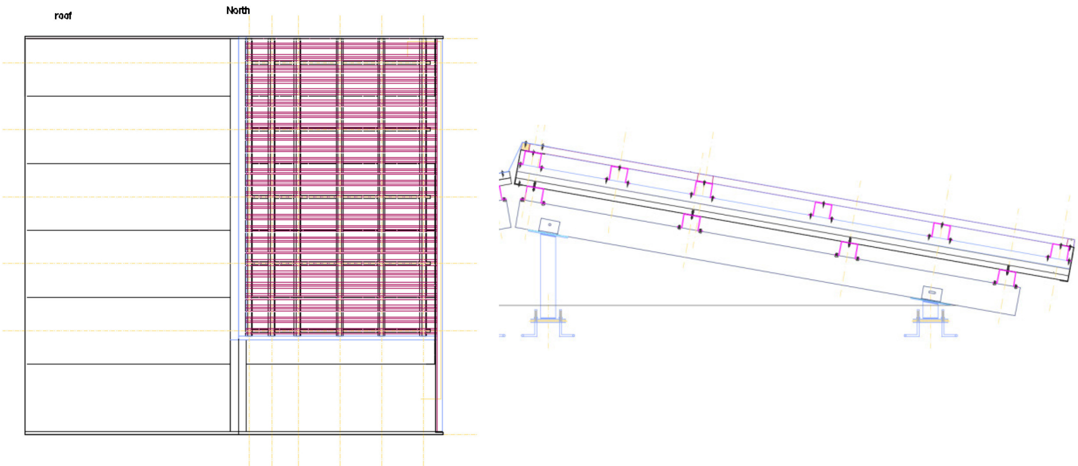

Figure 64 — Final design of the Testcell roof

a. Placement of lateral profiles. Before the start of the installation of the micro perforated metal sheets, the small lateral profiles of closing will be placed, which will seal and close the height air chamber between the two surfaces.

b. Installation of the metal sheet cover. It will begin with the positioning of the first sheet metal, paying great attention that it is in its correct position, because its tongue-and-groove system could generate future errors at the end of the system. The fixing will be done with self-drilling screws with sealed rubber washer.

c. While advancing with the placement of the metal sheet the sealing parts of the hexagonal ends will be placed. These pieces consist of a flexible rubber and a sheet of small thickness with the same shape as the end of the metal sheet. In this way it will be provided air and water tightness in the front and back of the system.

d. Once all the metal sheets are placed, only it will last the placement of the top plates of the roof ridge, joints, eaves and gables. Joints will be sealed with silicone or similar to guarantee the water tightness of the system.

Figure 65 — Final roof installation

e. After the installation, it will be proceeded to remove the protective plastics from the micro perforated metal sheets.

- **Revision and cleaning processes**
  - Check that the inclination of the roof is correct and in line with the project.
  - Verify that there are not problems or bumps in the cover due to the working realized by the operators. These problems may end in possible water accumulation generating infiltrations in building.
  - Check for possible fissures, cracks or imperfections that may have appeared on the surface that could generate corrosion or deteriorate the metal sheet surface.
  - The air and water tightness of the roof will be verified developing test or service trials and the sealing of the joints and finishing's will be revised.
  - Once the installation is finished a check of all the panels will be done, checking that there are no excessive alignment differences between their surfaces.
  - It will be verified that panels are well anchored and that there are no gaps or small movements that could generate vibrations.
  - Check for possible fissures, cracks or imperfections that may have appeared on the panels loading, if not clean superficially maintain good aesthetics in line with expectations.
  - Once the installation is finished a check of all the panels will be done, checking that there are no excessive alignment differences between their surfaces.
  - It will be verified that panels are well anchored and that there are no gaps or small movements that could generate vibrations.
  - Check for possible fissures, cracks or imperfections that may have appeared on the panels loading, if not clean superficially maintain good aesthetics in line with expectations.
  - Joints will be checked to verify the perfect continuity, clogging the possible voids that have remained, to ensure a perfect air and water tightness.

6.10.9 Step 7: Finishes

- **Reception and verification measures**
  - Verify and check the status of the supply. Check also if it has been safely transported.
  - Verify the shipping note analysing if all types and number of each elements match with the requested list.
  - In the vertical and horizontal sheet finishes it should be revised that there is not any product with deformations or superficial damage. This could provoke discontinuities or fissures with future water tightness problems such water infiltrations in façade. Special emphasis should be given in the metal sheets because its fragility to avoid possible deformation and perforations.
  - The dimensions of the profiles and different elements will be revised in order to verify that are the correct and adequate for the execution of the installation.
  - Once the previous steps are already verified all elements have to be pile up for storage. All elements have to be over the ground without direct contact with it. Protection over the elements should be foreseen in order to avoid water accumulation and the consequently degradation.

Maintenance should be also done in order to avoid permanent deformations due to the weight of other materials.

- **Machinery, scaffolding and crafts requirements**
  - In this step, scaffolding or lifting platforms will be used for accessing the installation points and the roof.
  - Crane truck or similar for the lifting of the materials to the point of installation.
  - Electric drill to make perforations in the vertical profiles and to fasten screws and brackets. It will be used also for the tightness of self-drilling screws for the joints of the metal sheets.
  - Use of radial for possible cuts and adaptation of the roof metallic sub-structure.
  - Drilling machine for the execution of perforations in mounting brackets and square profiles.
- **Building preparation measures**
  - Joints were finishing's sheet will be placed must be will checked for a perfect aesthetic solution.
  - The inclinations of the support surfaces will be checked, verifying that there are no changes of plane or alignment that could generate unexpected breaks or perforations in the piece to be installed.
  - It will check that there are no particles or dirt on the fixing surfaces, so there will be no interferences changing the perfect alignment.
- **Installation processes**
  - Initially a slight layout of the measures of the pieces in their place of location will be done in order to visualize possible intersections with the elements to cover. In this way the different cuts in the plates can be perfectly calculate and done.
  - In the lay out it will be also planned the overlaps between the finishing parts, to eliminate water infiltrations in the future.
  - Once the lay out has been completed, the sheet will be marked with the possible adjustment cuts, and then it will be proceeded to make these cuts.
  - The pieces will be raised to their position and hold to avoid movements in the fixing processes. These pieces will be fixed with self-drilling screws to the already installed elements of the facade system.
  - This process will be repeat with the rest of the sheets until the cover of all joints or holes of the system.
  - Sealing of joints. An exhaustive seal in the joints and overlaps of each one of these sheets will be done, ensuring the tightness of the system.
- **Revision and cleaning processes**
  - The sheets will be checked during the installation process and after to be sure that have not been deformed creating spaces where water infiltrations can appear.
  - We will review possible blows and damages that cause loss of protection and its consequent risk of corrosion.
  - Check the continuity of the sealing.

- Tests will be done to ensure water tightness of the joints and its sealing.

7 Testing

7.1 General

The aim of this clause is to give orientation on the main characteristics of the principal innovative and adaptable envelope components described in this document, together the test methods that can be applied for the determination of these characteristics.

7.2 Solar Thermal Air Component

Regarding **Solar Thermal Air Component**, the following parameters are the most important ones:

- External fire performance
- Reaction to fire of steel sheet (both sides)
- Wind load resistance
- Bending strength, modulus of elasticity of the panel
- Pull-through resistance and pull-through resistance under shear load of the panel
- Impact resistance

The **external fire exposure test** of the roof structure should be carried out in accordance with CEN/TS 1187. The **guidance result** (related to all of the four samples) should achieve at least B_{roof}(t1).

The **ignitability test** of steel sheet (both sides) should be carried out according to EN ISO 11925-2 and the reaction to fire classification should be defined according to EN 13501-1. The **guidance result** should achieve at least fire classification E.

The **wind suction test** of the system should be carried out in accordance with section Annex E of EAD 090062-00-0404. The **guidance result** is that the system should work at suction of 3 000 Pa without any failure. At suction of 3000 Pa, the maximum deflection should not be higher than 3,0 mm, and the residual deflection should not be higher than 0,5 mm.

The **bending strength of the panel test** should be carried out in accordance with section 2.2.12.1 of EAD 090062-00-0404 considering EN ISO 7438. The **guidance result** is that the average bending strength should be higher than the value declared by the manufacturer and the calculated design resistance should be higher than the design value of the actions calculated to Eurocode 1 (EN 1991-1-1).

The **pull-through resistance test** should be carried out in accordance with section 2.2.12.4 and 2.2.12.5 of EAD 090062-00-0404. The **guidance result** is that the characteristic values of pull through resistance and the pull-through resistance under shear load should be higher than the value declared by the manufacturer. The calculated design resistances should also be higher than the design value of the actions calculated to Eurocode 1 (EN 1991-1-1).

The soft body and hard body **impact resistance test** of the system should be carried out in accordance with section 2.2.11 of EAD 090062-00-0404 and ISO 7892. The **guidance result** is that the system tested should withstood a soft body impact and a hard body impact of 60 J and 10 J respectively. So the system should achieve at least an impact classification category of III to EAD 090062-00-0404.

7.3 Lightweight Ventilated Façade Module

Regarding **Lightweight Ventilated Façade Module**, the following parameters are the most important ones:

- Wind load resistance
- Mechanical resistance of grooved cladding elements
- Resistance to vertical load
- Impact resistance

The **wind suction test** of the system should be carried out in accordance with section Annex E of EAD 090062-00-0404. The **guidance result** is that the system should work at suction of 3 000 Pa without any failure. At suction of 3 000 Pa, the maximum deflection should not be higher than 3,0 mm, and the residual deflection should not be higher than 0,5 mm.

The **mechanical resistance of grooved cladding elements test** should be carried out in accordance with section 2.2.12.2 of EAD 090062-00-0404. The **guidance result** is that the characteristic value of the failure load should be higher than the value declared by the manufacturer and the calculated design resistance should be higher than the design value of the actions calculated to Eurocode 1 (EN 1991-1-1).

The **resistance of the profile to vertical load test** should be carried out considering section 2.2.12.10 of EAD 090062-00-0404. The **guidance result** is that the failure loads with the corresponding deflections should be higher than the value declared by the manufacturer and the calculated design resistance should be higher than the design value of the actions calculated to Eurocode 1 (EN 1991-1-1).

The soft body and hard body **impact resistance test** of the system should be carried out in accordance with section 2.2.11 of EAD 090062-00-0404 and ISO 7892. The **guidance result** is that the system tested should withstood a soft body impact and a hard body impact of 400 J and 10 J respectively. So the system should achieve at least an impact classification category of I to EAD 090062-00-0404.

7.4 Multifunctional Insulated Panel

Regarding **Multifunctional Insulated Panel**, the following parameters are the most important ones:

- Reaction to fire of the panels and the foam core
- Watertightness of the joints
- Wind load resistance
- Bending strength, modulus of elasticity of the panel
- Resistance to vertical load
- Resistance of grooved cladding elements
- Pull-through resistance of fixings from profiles
- Dimensional check of cladding elements
- Water absorption of cladding elements
- Freeze-thaw resistance of cladding elements
- Mechanical resistance of grooved cladding elements
- Impact resistance

The **reaction to fire test of the panel** should be carried out in accordance with EN ISO 11925-2 (ignitability) and EN 13823 (SBI). The **guidance result** should achieve at least fire class of B-s1, d0 to EN 13501-1.

The **watertightness test** of the panel joints should be carried out in accordance with section 2.2.4 of EAD and EN 12865. The level of pressure just before water penetrated through the panel joint should be at least 150 Pa.

The **wind suction test** of the system should be carried out in accordance with section Annex E of EAD 090062-00-0404. The **guidance result** is that the system should work at suction of 3 000 Pa without any failure. At suction of 3 000 Pa, the maximum deflection should not be higher than 3,0 mm, and the residual deflection should not be higher than 0,5 mm

The **bending strength of the panel test** should be carried out in accordance with section 2.2.12.1 of EAD 090062-00-0404 considering EN 12467. The **guidance result** is that the mean value and the characteristic value of modulus of rupture should be higher than the value declared by the manufacturer (calculation should be based on the formula given in EN 12467). The calculated design resistance should also be higher than the design value of the actions calculated to Eurocode 1 (EN 1991-1-1).

The **resistance of grooved cladding elements test** should be carried out in accordance with section 2.2.12.2 of EAD 090062-00-0404. The **guidance result** is that the mean value and characteristic value of the failure load should be higher than the value declared by the manufacturer. The calculated design resistance should also be higher than the design value of the actions calculated to Eurocode 1 (EN 1991-1-1).

The **resistance to vertical load test** should be carried out considering section 2.2.12.10 of EAD 090062-00-0404. **The guidance result** is that the failure loads should be higher than the value declared by the manufacturer (when supporting profiles with a length of 100 mm and 300 mm is loaded with a vertical load until failure). The calculated design resistance should also be higher than the design value of the actions calculated to Eurocode 1 (EN 1991-1-1).

The **pull-through resistance of fixings from profiles test** should be carried out in accordance with section 2.2.12.11 of EAD 090062-00-0404. The **guidance result** is that the mean value and characteristic value of the failure load should be higher than the value declared by the manufacturer. The calculated design resistance should also be higher than the design value of the actions calculated to Eurocode 1 (EN 1991-1-1).

The soft body and hard body **impact resistance test** of the system should be carried out in accordance with section 2.2.11 of EAD 090062-00-0404 and ISO 7892. The **guidance result** is that the system tested should withstood a soft body impact and a hard body impact of 60 J and 400 J respectively. So the system should achieve at least an impact classification category of I to EAD 090062-00-0404.

The **dimensional check of cladding elements test** should be carried out considering section 5.3 of standard EN 12467. The **guidance result** is that the measured values should be within reasonable tolerances.

The **water absorption of cladding elements test** should be carried out in accordance with section 2.2.5 of EAD 090062-00-0404. The **guidance result** is that the retained characteristic and mean value of modulus of rupture after water immersion should be at least 95% comparing to the reference samples.

The **freeze-thaw resistance of cladding elements test** should be carried out in accordance with section 2.2.15.3 of EAD 090062-00-0404. The **guidance result** is that the retained characteristic and mean value of modulus of rupture after 100 freeze-thaw cycles should be within reasonable tolerances.

7.5 Dynamic Window with Automated Solar Blinds

Regarding **Dynamic Window with Automated Solar Blinds**, the following parameters are the most important ones:

- Thermal conductivity
- Acoustic characteristics
- Wind load resistance

Other characteristics that can optionally be measured are solar factor and light transmittance.

The **thermal conductivity test** of the lamella should be carried out in accordance with EN 12667. The **guidance result** is that the lamella should have an equivalent thermal resistance higher than the value declared by the manufacturer and an equivalent thermal conductivity at an average temperature of 10°C lower than the value given by the manufacturer. For measuring the additional thermal resistance of a complete blind EN 13125 can be used.

The **acoustic test** of the lamella should be carried out in accordance with EN ISO 10140-2:2010. The **guidance result** is that the lamella should have at least an air-borne sound insulation parameter higher than the value declared by the manufacturer.

The **wind load resistance test** of the system should be carried out in accordance with EN 13659:2004+A1:2008 and EN 1932:2013. The **guidance result** is that the system can be classified as Class 5 according EN 13659. Any failures, breakages which can result personal injures should not occurre. Derailment from the fixing and closing structure components should not occurre at the safety pressure load.

At suction of 400 Pa, the maximum deflection should not be higher than 4,4 mm and the maximum permanent deflection should not be higher than 0,7 mm. The non-mobile part of the blind should be designed so that they resist a fixed pressure of 800 Pa (according to EN 13659:2004+A1:2009).

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