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Project acronym: EASEE

Project title: Envelope Approach to improve Sustainability and Energy efficiency in Existing multi-storey multi-owner residential buildings

Funding scheme: Collaborative Project

Thematic Priority: EeB.NMP.2011-3 - Energy saving technologies for buildings envelope retrofitting

Starting date of project: 1st of March, 2012

Duration: 48 months

D6.5 – Guidelines and protocols for the flexible moulding and for the installation of anchoring systems and joints

Due date of deliverable: 31 March 2015
Actual submission date: 30 April 2015

Organisation name of lead contractor for this deliverable: *DAPP*

Dissemination Level		
PU	Public	X
PP	Restricted to other programme participants (including the Commission Services)	
RE	Restricted to a group specified by the consortium (including the Commission Services)	
CO	Confidential, only for members of the consortium (including the Commission Services)	

Table of Contents

1 Introduction

The present document constitutes Deliverable 6.5 “Guidelines and protocols for the flexible moulding and for the installation of anchoring systems and joints” in the framework of the EASEE project.
This deliverable reports the activities carried out within Work Package 6, and specifically within Task 6.4 “Application Guidelines”. The description of this Task in the DoW is reported below:

“The preparation of protocols and guidelines for each developed application will be a key task in the work programme. Indeed, the base requirement for all the components to be developed is the utilisation ease: this specification will increase the industrial exploitation of the product. Protocols and guidelines will be written in the form of ***technical reports*** *and* ***checklist****, but* ***detailed troubleshooting*** *tables will be prepared as well. As the control system of the* ***reconfigurable system*** *will be deeply integrated with the* ***Pattern Generation tool****, the large part of required operations are performed autonomously, and only few checks are expected by the human operator. Guidelines for the use of the* ***software tool*** *will be prepared, as well as protocols for the manufacturing of envelope elements by means of the* ***flexible tool****. Although* ***anchoring*** *are well known elements for construction manpower, protocols for their installations will be prepared showing the installation upon the building’s envelope through the laser projection system. Particular attention will be paid at the preparation of* ***installation protocols*** *for* ***fenestration joints****, where the correct installation is crucial for final performances. Visual directives such as pictures and/or video samples will be provided to help the user. These activities will be carried out by DAPP, in collaboration with all the end-users (construction) SMEs in the consortium.”*

Thus, the document mainly focuses on the following main project results:

- Design Tool, developed in Task 5.3 “Component construction guidelines module”
- Adjustable formwork for panels manufacturing, developed within WP6 “Processes and application guidelines”
- Panels anchoring systems, developed in Task 6.3 “Development of anchoring systems and joints”, together with the panels for the exterior retrofitting finalization
- Panels joints, investigated within WP2 and strictly linked also to WP6 activities

To achieve the Task goals, the document has been mainly structured into **2 main sections**:

- **Section 1** aims at providing technical data sheets of the above mentioned project results and identifying the main end-users, altogether with their needs, in order to valorize how the innovative aspects of each result is going to address those needs.
- **Section 2**, which is the core of the document, aims at providing guidelines for each project result used (with a detailed description of the steps to be performed also with the help of screen shoots and checklists). Trouble shooting tables are included within this section, thus could constituting a stand-alone document to be potentially attached and sold together with each project result, in order to increase their industrial exploitation value.

2 EASEE project retrofitting process

The EASEE project aims at providing an innovative building retrofitting process based on high level prefabrication of components, characterized already at the manufacturing stage by the final appearance, without additional finishing on site. The first step of the retrofitting process consists in the careful assessment of the envelope from a structural and energetic point of view, as well as in terms of other non technical parameters that will be useful for the planning of the retrofitting intervention. The structural and physical conditions of the building is thus evaluated through **3D laser scanning** allowing to acquire a very detailed model and geometrical relief of the building. The detailed model and the geometrical relief is finally respectively elaborated through the **Design Tool and Retrofitting Planner** that have many-fold functions.

From one side, the **Retrofitting Planner** provides an assessment of the current energetic performances of the building, taking into account also complementary information on the HVAC status, roof and basement situation, energetic signature of the building with the purpose of clearly evaluating and freezing the building baseline to define the best combination of retrofitting solutions for all or single parts of the envelope. In this respect, the Retrofitting Planner also simulates energy performance of the building with different retrofitting combinations, providing a ranking of the available options also taking into account non technical parameters as cost, expected service life, maintenance, installation and return of investment.

On the other side, if external retrofitting is needed, the **Design Tool**, through pattern recognition techniques, provides the design specifications for the off-site production of the prefabricated components, minimising the number of shapes required, and evidencing the critical points where specific solutions for the joints have to be adopted.

Thus, the Retrofitting Planner communicates to the design tool the technical specification of the external retrofitting panels to be manufactured, installed to guarantee the expected building energy saving. The Design Tool evaluates the correct positioning of such retrofitting solution, taking into account possible window/piping interfaces. Once the panels number and sizes are optimized and their position is validated also under the structural point of view, the insulating panels, having the final appearance of the façade, are produced through a dedicated formwork, able to produce different panels sizes and textures.

The correct positioning of the modular elements could is ensured for instance by **projecting laser dots** onto the façade for the correct placement of the anchoring system. Proper **anchoring systems and specific joints selection** complete the building external retrofitting.

Vertical platforms, suspended cradles or cherry pickers are then used to install the panels avoiding in this a way the installation of fixed scaffoldings.

The following scheme represents the above explained building external retrofitting process.

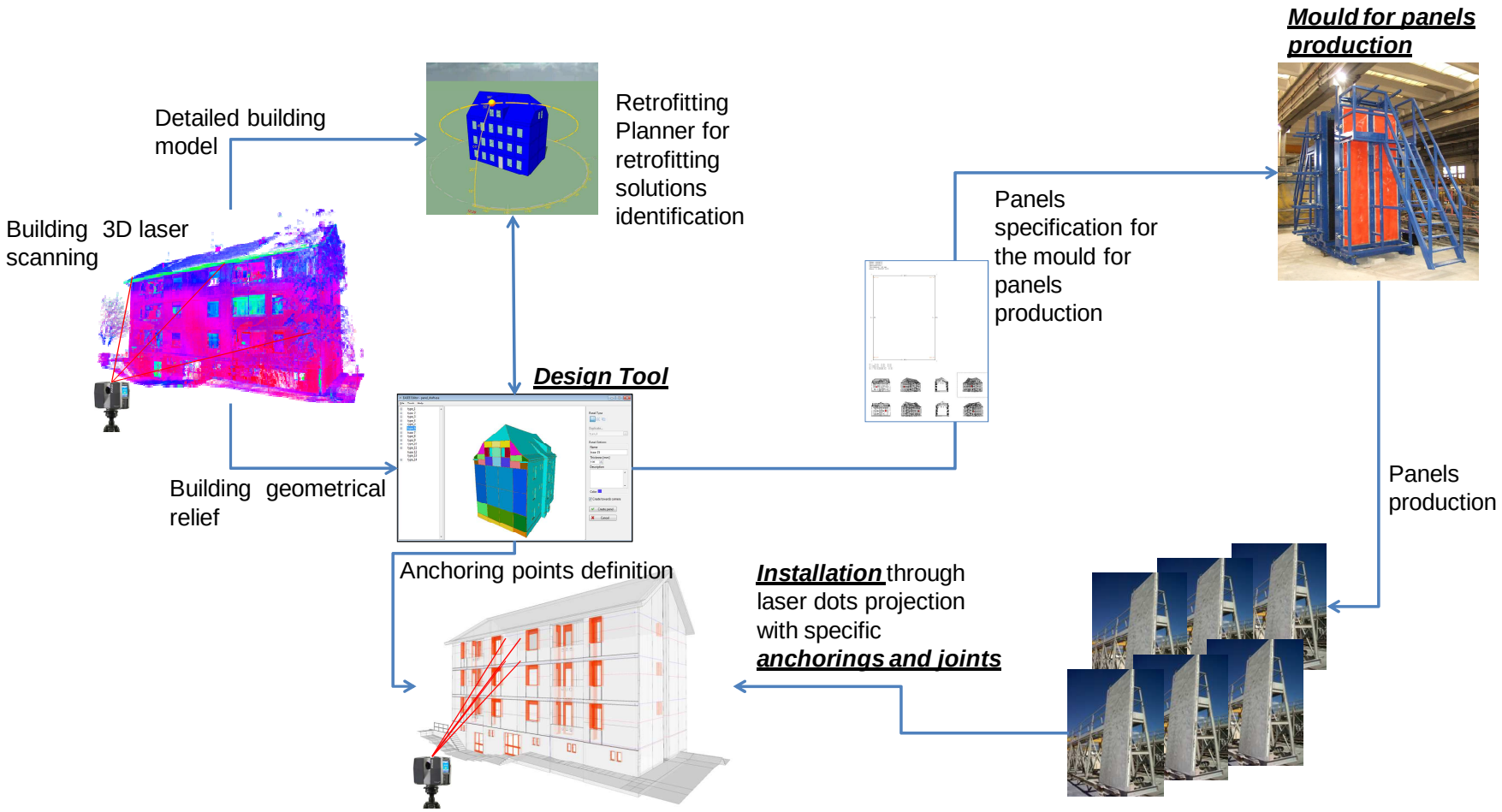
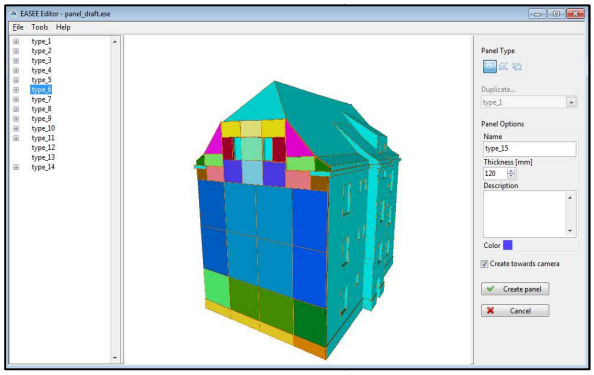


Figure 1: Building External Retrofitting Process

2.1 Design Tool

DESIGN TOOL

DESCRIPTION



The Design Tool is an integrated part of the Retrofitting Process developed during EASEE Project. Together with EASEE novel insulation systems, the building owner (or administrator/manager) gets a set of tools and services, which includes assessing building geometry, thermal simulation, planning of panels design.
Design Tool is an application dedicated for construction purposes, allowing to place virtual panels on the buildings surface in 3D space. The panels are created using a grid generated by corners and edges of the building and other panels; therefore it is easy to control their size and the way they fit. Panels could be then exported into documentation allowing to manufacture them and to mount them correctly on the real building.

REQUIREMENTS:

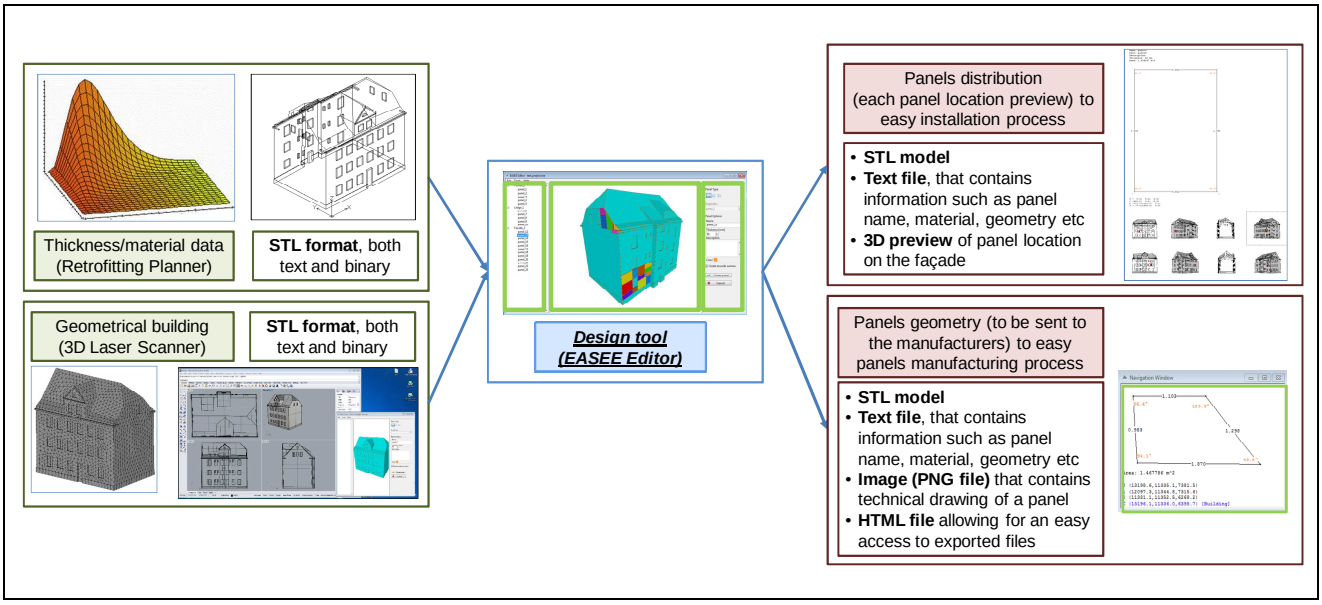
Hardware: there is no particular requirements regarding computer for the software; typical office PC computer is sufficient.
Software: Windows XP or higher is recommended. Additionally, Design Tool utilizes National Instruments LABVIEW Runtime Environment, which is provided with the software, free of charge.

END USERS:
Planning a panel distribution on the façade is not an easy task, various different constrains exist:

- *Architectural details* – panels distribution needs to be planned with respect to aesthetic and technical facade features that affect building final appearance
- *Mechanical strength* – panels size and distribution shall take into account building structure and therefore different limits of load per square meter of wall
- *Anchoring* systems – maximum size of panel and optimum anchors location on the façade have to be chosen wisely according to building material and construction type
- *Tolerances* – panels distribution shall take into account mounting process (joints, etc) to avoid inaccuracies or problems during installation
- *Manufacturing constraints* – manufacturing techniques constraints (limited shapes, etc) shall be taken into account to find the best trade-off between costs and panels number

Due to the complexity of the task (planning panel distribution on the facade), actual end-user of the software should be an architect or structural engineer responsible for the whole retrofitting process.

BLOCK DIAGRAM



2.2 Formwork for panels manufacturing

ADJUSTABLE FORMWORK

DESCRIPTION

The adjustable formwork is a dedicated technological equipment designed for the manufacturing of the multi-layer panels for the building external envelope retrofitting. Indeed, the formwork is able to manufacture the sandwich prefabricated panels developed within the project with different sizes and geometries, aiming at the best trade-off between system's flexibility (possibility to produce different geometries) and stress resistance while customizing the process to increase the automation level.

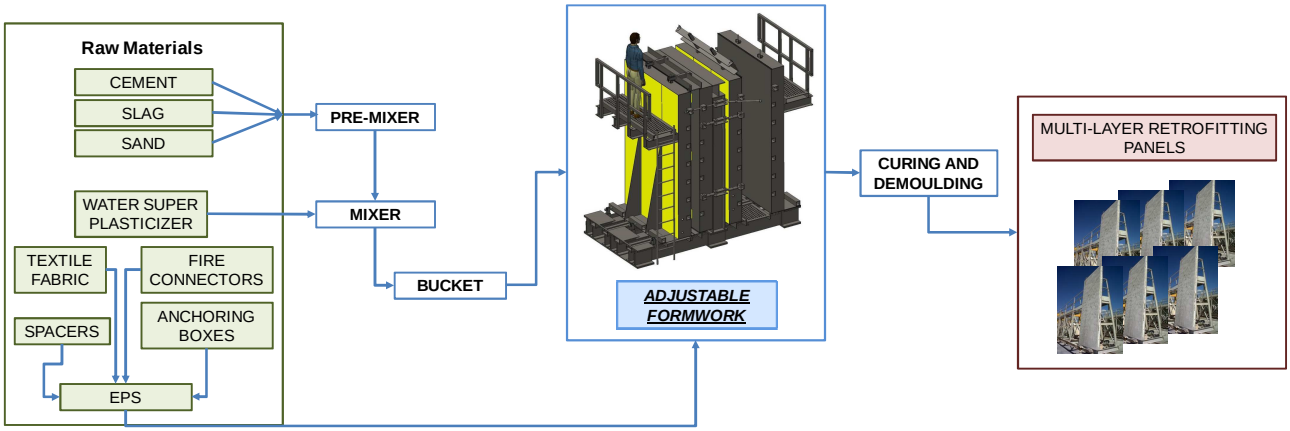
REQUIREMENTS:

- The formwork has to be accurately brushed and cleaned between each use, in order to avoid that mortar remainders and dirt accumulate on junctions.
- Counter-moulds to decorate the external side of the building shall be bonded to the main surface of the formwork, so there is no need for fastening details (such as holes, sockets, etc.). On the contrary, EPS blocks have to be securely fastened within the formwork at the correct distance, as the TRM layers thickness depend on this precise position. This can be done either with slight interference between the sides of the cavity or with fasteners.
- The top side shuttering must be removable in order to extract the panel and lift it with the overhead crane.
- Each movable wall of the formwork has to withstand the curing pressure and they have to also be connected each other; this shall be done through highly resistant connectors that can be easily unclamped when the panel is extracted.
- The formwork has to be equipped with a proper bucket for the mortar pouring.
- As both some clamping elements and the venting valves are placed close to the top shuttering, the upper part of the formwork must be safely reachable with a walkway. This will be useful also for panel de-moulding operations (eyebolts installation in their holes in dedicated boxes, spreader beam hooking, etc.).
- The panel have to cure for about at least 8-10 h, depending on the environmental conditions of the plant (mainly temperature and humidity). In order to increase the productivity, the formwork will be equipped with accelerated curing devices to warm the cavities and keep them in temperature.

END USERS:

- Retrofitting panels manufacturers
- Precast companies and construction companies active in the retrofitting market

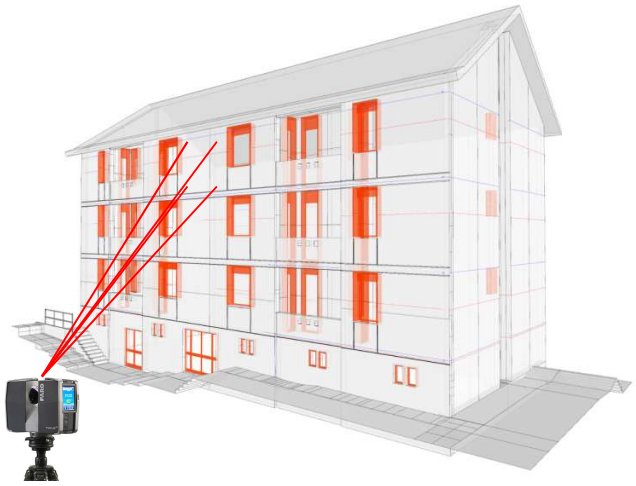
BLOCK DIAGRAM



2.3 Installation process

INSTALLATION PROCESS

DESCRIPTION



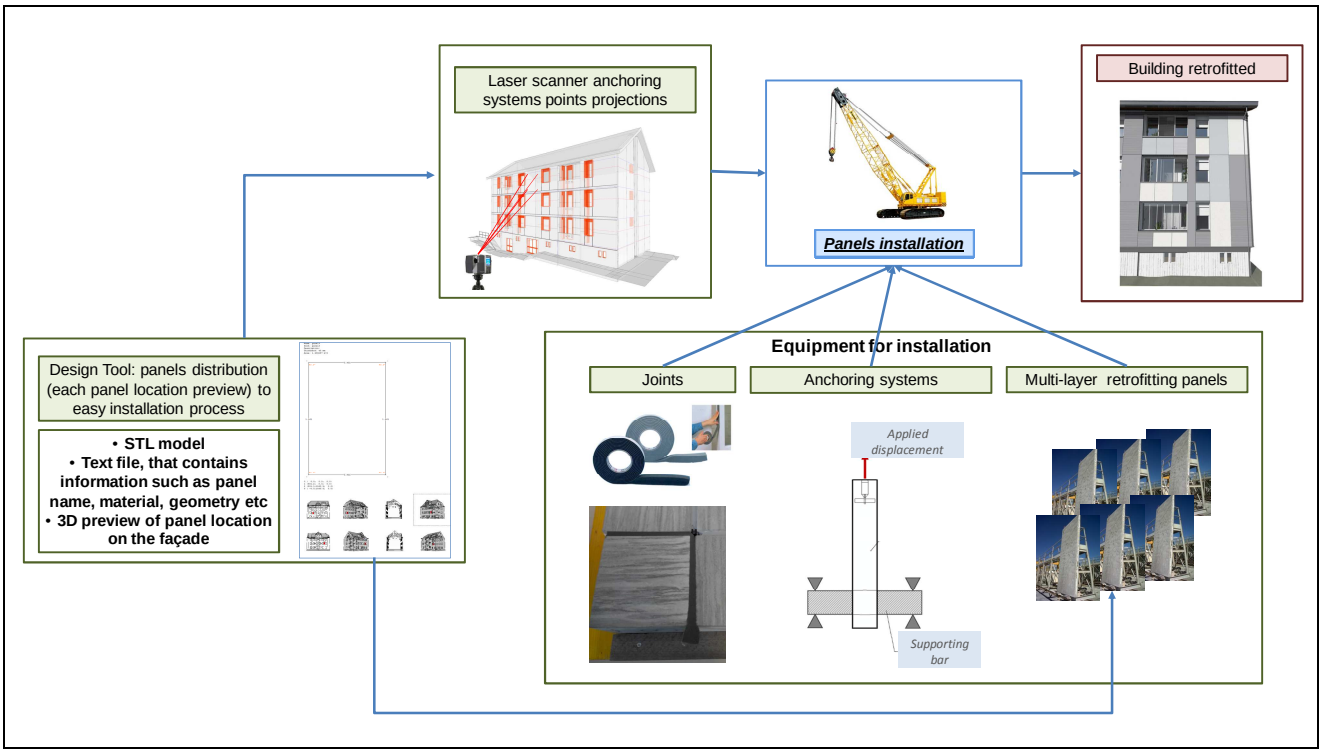
Based on the 3D model of the building and user's guideline, the Design Tool provides the design specifications for the off-site production of the prefabricated components, minimising the number of shapes required and evidencing the critical points where specific solutions for the joints have to be adopted. According to the selected retrofitting solution and considering possible window/piping interfaces, insulating prefabricated panels having the final appearance of the façade are thus produced using the related manufacturing process. The correct positioning of the modular elements is then ensured through a dedicated installation technique of projecting laser dots onto the façade for the correct placement of the anchoring systems. Vertical platforms, suspended cradles or cherry pickers are used to install the panels; the lack of human intensive on-site activities and of wet processes do not require the installation of fixed scaffolds.

REQUIREMENTS:

Skilled people properly trained on the installation technique.

END USERS:
Skilled and trained workers of construction companies (mainly SME)

BLOCK DIAGRAM



3 Guidelines and troubleshooting tables

This section aims at valorising the products (Design Tool) and the processes (panels' manufacturing and installation) described in the previous paragraphs by means of their technical fact-sheets, by providing the dedicated guidelines to be attached and sold together. Troubleshooting tables are also developed, highlighting the main problems that might occur while following the provided guidelines (while using the Design Tool or while manufacturing the panels as well as installing them).

The guidelines aim to streamline processes, namely to guide the Design Tool users and to train the prefabricated insulating panels manufacturers and installers, according to a set routine or sound practice. By definition, following a guideline is never mandatory. Guidelines are not binding and thus are not mandatory enforced. These guidelines have been written down based on the experience acquired from the project activities performed. Guidelines are provided in a synthetic but exhaustive way (step by step), and each step is correlated with one or more pictures that should be as much as possible self explaining. Thus the following guidelines are provided:

- Guideline for using Design Tool
- Guideline for prefabricated insulating panels manufacturing
- Guidelines for prefabricated insulating panels installation

Also videos will be/have been provided, in particular:

- Demo on the use of the Design Tool, as a “Help” function and as a side tool for the user. (soon on the website).
- Video of the prefabricated panels manufacturing to be used by the future panels manufacturers interested in purchasing the panels formwork (soon on the website).
- Video of the prefabricated panels installation to be used during training courses for installers and workers of SMEs interested in acquiring this new skill and expertise (on the website).

3.1 Design Tool

First step to use the Design Tool is the installation of the software tool. To do this, the following steps shall be performed:

- Copy all provided files to your hard drive.
- Install LabView runtime environment, by double clicking executable file (LVRTE2009_SP1f4std.exe) provided with the installation files. Follow installation instructions provided within the wizard (Figure 2)

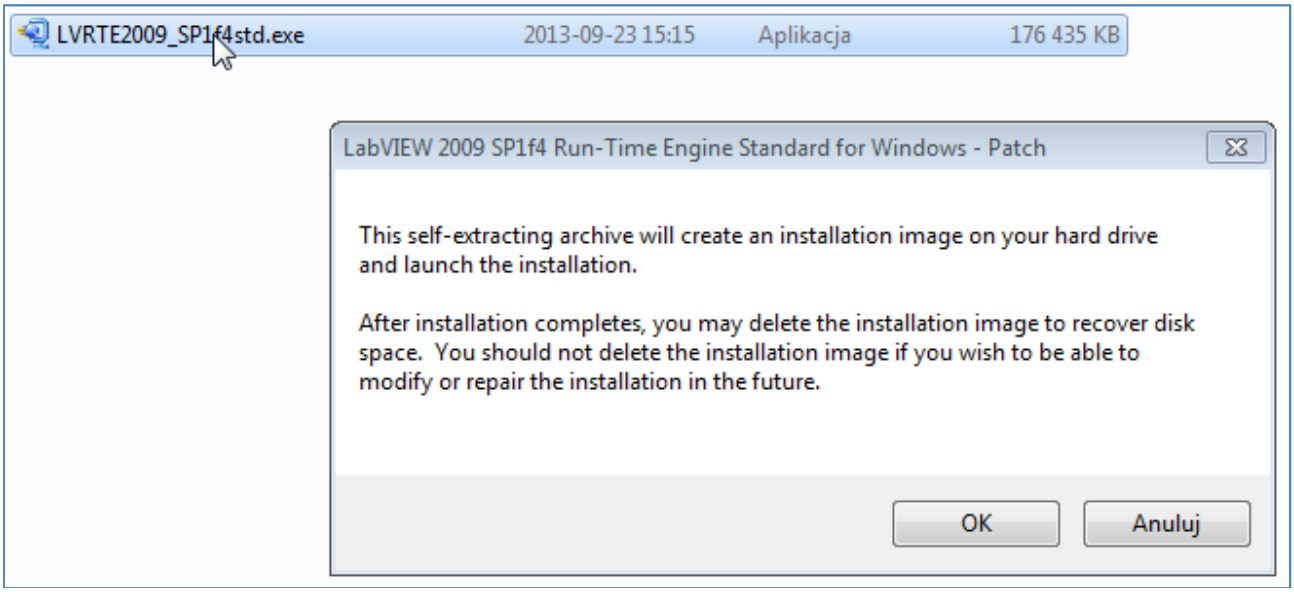


Figure 2: Installing runtime environment

- Run Design Tool by double clicking “EASEE Editor.exe” file, in the EASEE Editor folder provided with the installation files (Figure 3)

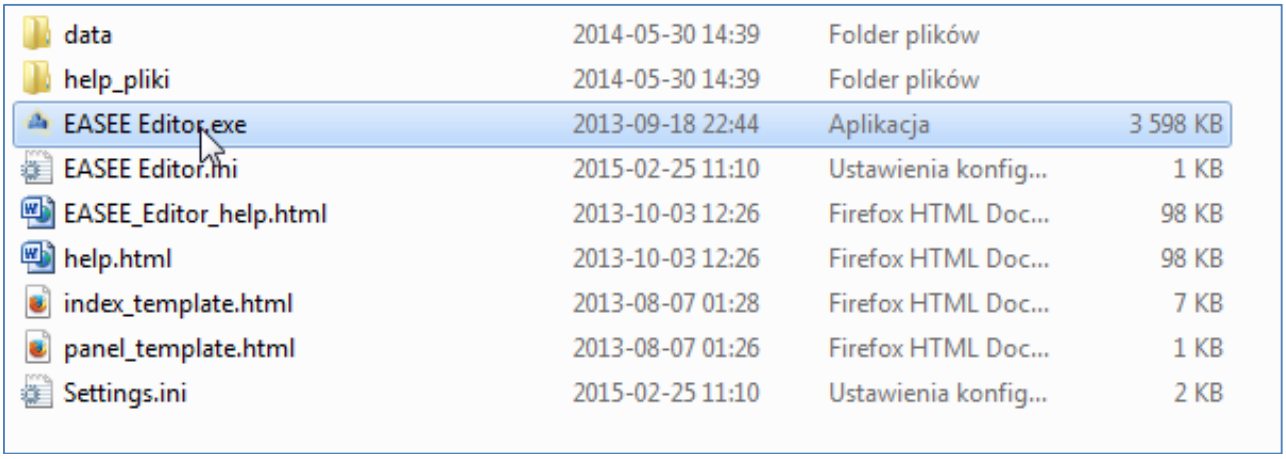


Figure 3:Running Design Tool

- (OPTIONAL) You can access help files by double clicking help.html file that can be found in the main provided folder (Figure 4)

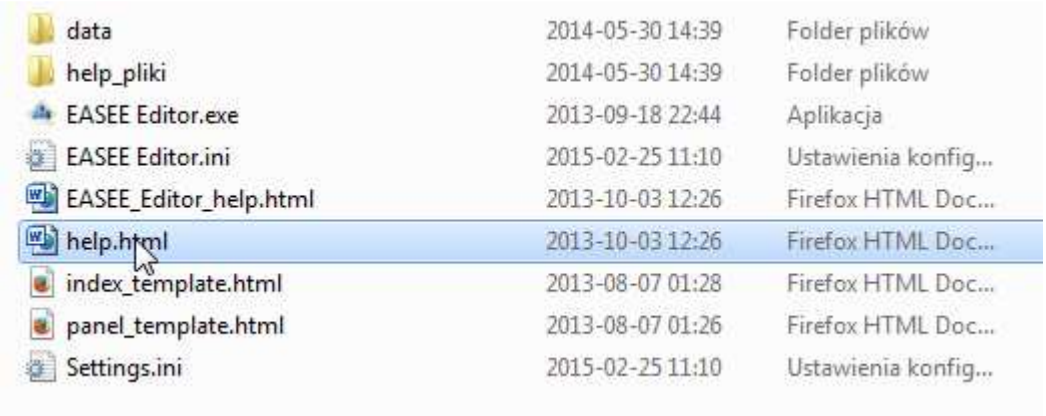


Figure 4: Running help

Once the software has been installed, the user can start using it by creating a new project. To create a new project the user shall enter the main application window (Figure 5). The main application window is divided into three parts:

- Panel tree, in which the user can organize the created panels into a multilayer and hierarchic structure;
- 3D view of the panels and building models;
- Panel creation controller.

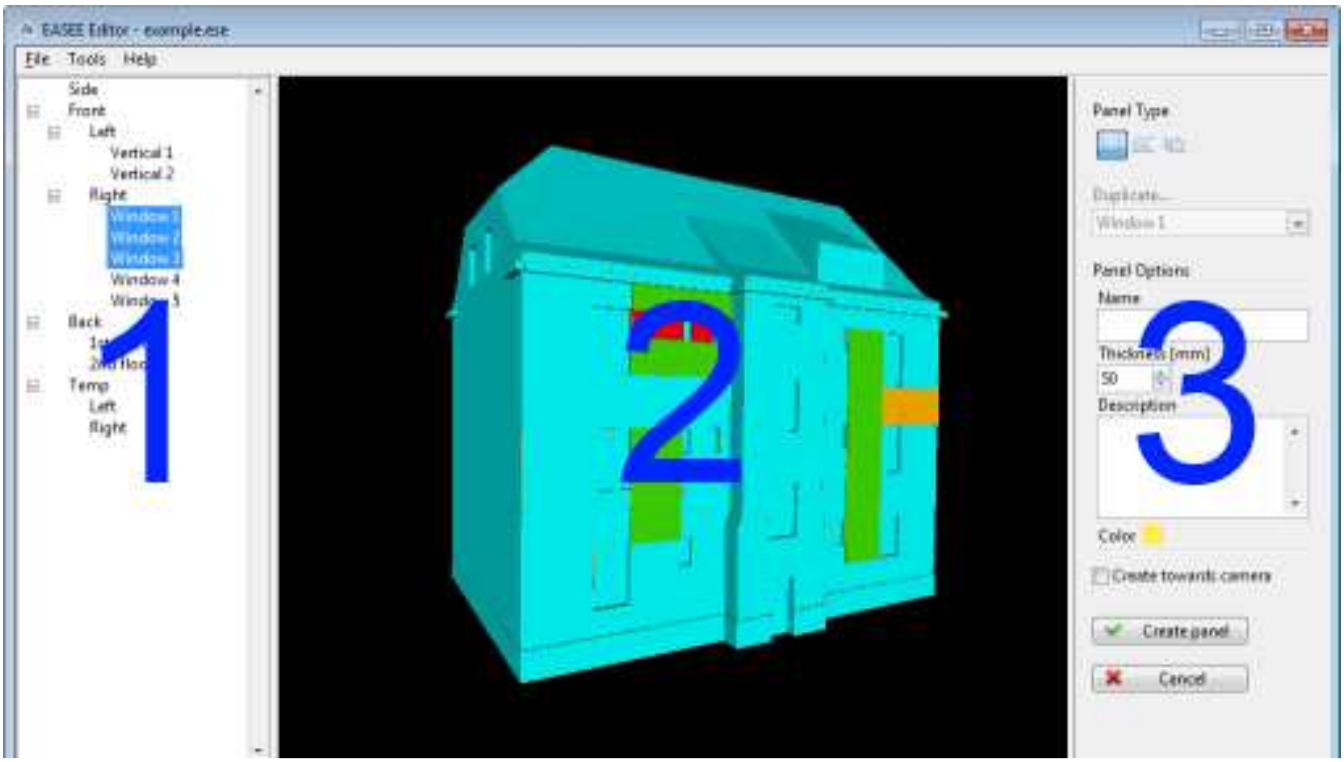


Figure 5: Main application window

After importing the model, the user can navigate 3D space using keyboard and mouse using the following combinations:

- Sliding the mouse with the left mouse button pressed – turning the camera around the building
- Ctrl + sliding the mouse with the left mouse button pressed – sliding the camera to the sides
- Shift + Sliding the mouse with the left mouse button pressed – zooming in/ zooming out.

After clicking the right mouse button on the 3D view an Autofocus option is enabled, switching to default camera view. An experimental zoom in/out option is also available (switched off by default) using mouse wheel. To activate it change the value of the key Mouse Wheel Zoom Factor in the Settings.ini file to a non-zero value e.g. 100. After restarting the application you are able to zoom in and out using mouse wheel.

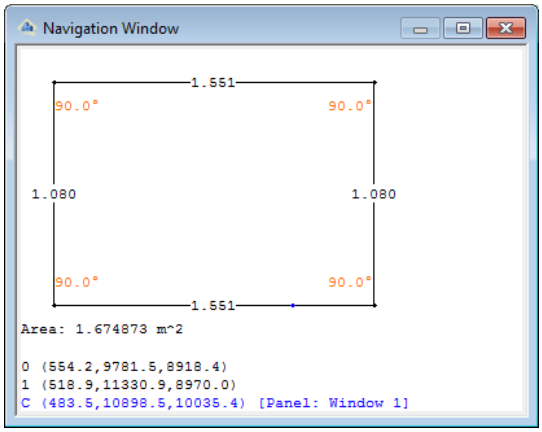


Figure 6: The navigation window

The user is thus able to open and navigate the main window by selecting from the menu "*Tools -> Navigation Window*". The navigation window simplifies the creation of panels by drawing a preview of the panel that is being created and allows to make measurements of length (in meters), angles and surface. Additionally the information of the existing control points layout is displayed, placement of the cursor (XYZ in millimetres) and the object on which the cursor is currently placed.

Note: Panel contour visible in the Navigation Window may in fact be its mirror image reflected vertically

The scheme below represents the main steps to be performed in order to use the tool for the panels design and positioning.

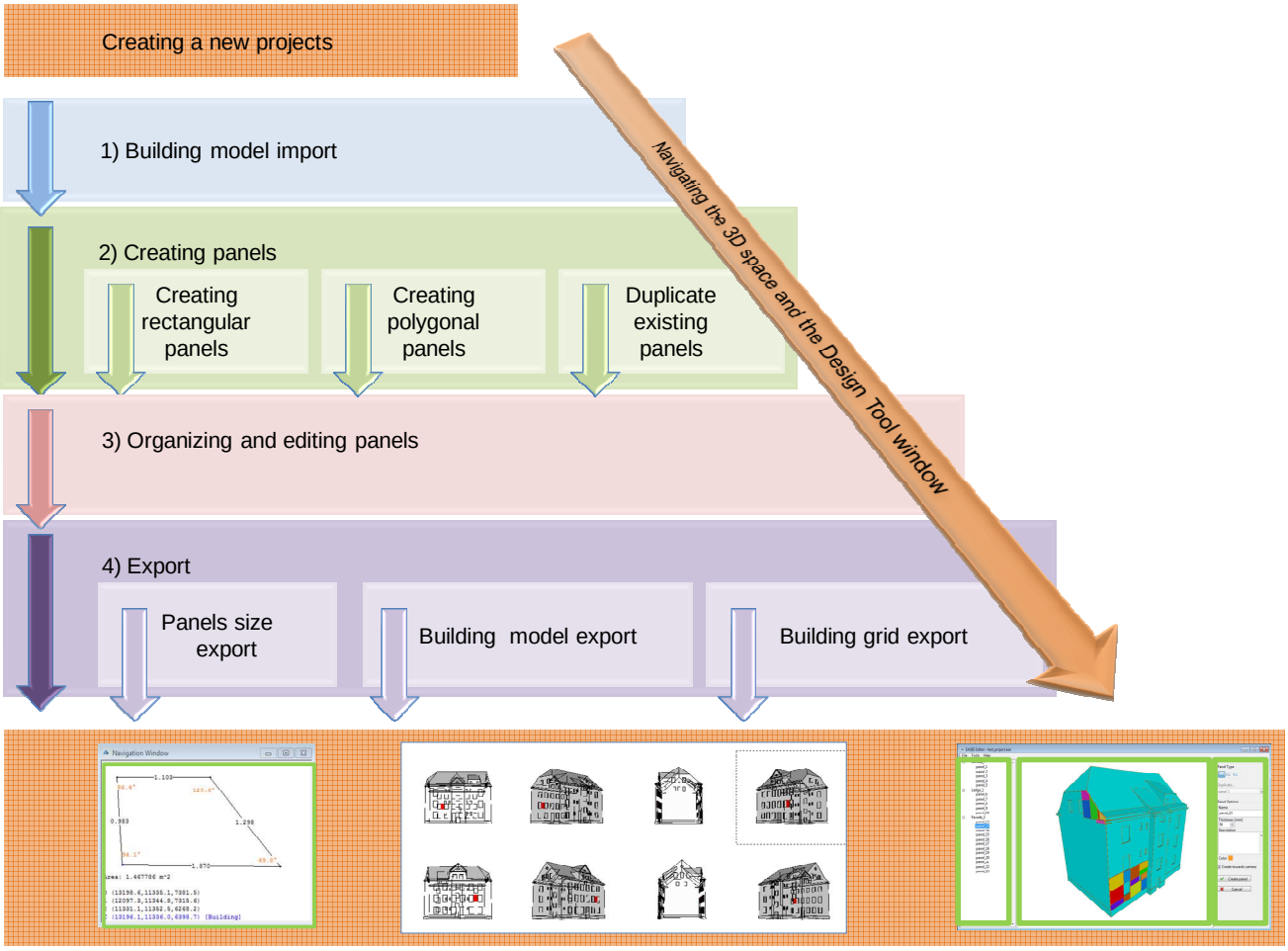


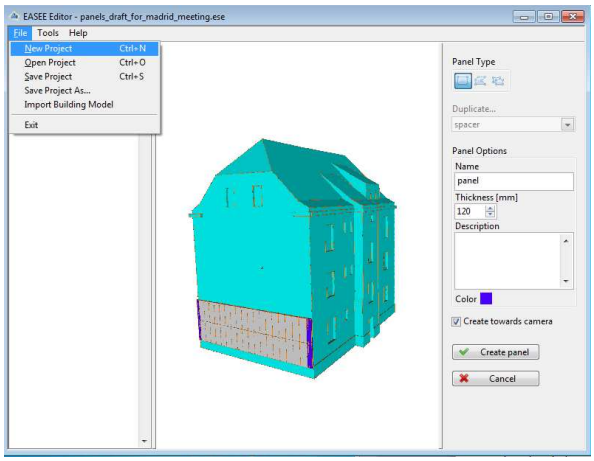
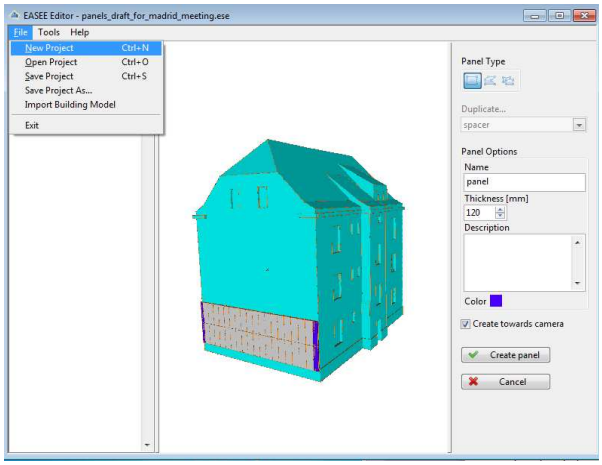
Figure 7: Guidelines blocks flow scheme for Design Tool use

3.1.1 Glossary

The description of user settings contained in the "*Settings.ini*" file located in the main application folder is provided in the following items.
To change these settings, it is necessary to close the application, edit the file and then run the application again. The values given in brackets are default values.
To reset all settings to default values it is necessary to delete the "*Settings.ini*" file and the application will create a new file while starting with default settings values.

- *Grid Plane Threshold:* Parameter of the grid generation algorithm. If the dihedral angle between two triangle is less than this value (in degrees), then their joint side becomes the grid edge (179)).
- *Grid Edge Threshold:* Parameter of the grid generation algorithm. If the angle between two model edges is greater than this value (in degrees) the edges are then connected into one (179).
- *Control Point Size:* The size of a control point in millimeters (100). .
- *Grid Edge Snap Distance:* The distance of snap to the grid edge in millimeters (50).
- *Grid Node Snap Distance:* The distance of snap to the grid nodes in millimeters (50).
- *Grid Edge Radius:* The radius of the cylinder that creates the edge of the grid (in millimeters). This value should be less that *Grid Edge Snap Distance* and *Grid Node Snap Distance*. In other case the attraction to the grid will not be possible (5).
- *Grid Node Radius:* The radius of the sphere that creates the grid node (in millimeters)(10). This value should be less that the value of *Grid Edge Snap Distance* and *Grid Node Snap Distance*. Otherwise the attraction to the grid will not be possible.
- *Cursor Size:* The size of the cursor in millimeters (100).
- *Plane Tolerance:* Maximum allowed distance between the point and the plane, so that the point is considered as laying on the plane in millimeters. This parameter is used on the Navigation Window (1).
- *Exported Image Width:* The width of the exported PNG image in pixels (800).
- *Exported Font Name:* The name of the font used during exporting for the description of the length of sides and panel angle values (Courier New).
- *Exported Font Size:* The size of the font used during exporting for the description of the length of sides and panel angle (14).
- *Overview Positions:* The number of miniatures attached to exported PNG images showing the location of the panels (8).
- *Overview Image Size:* The Size (length and width) of the miniatures with panel location in pixels (200).
- *Overview Distance:* The distance between the building and the camera while creating miniatures with panel location in meters (50).
- *Overview Height:* The height camera is set on while creating miniatures with panel location in meters (2).
- *Overview FOV:* The camera angle while creating miniatures with panel location in degrees (30).
- *Mouse Wheel Zoom Factor:* The parameter controlling the camera zoom in/out degree while using the mouse wheel. This function is experimental, that is why it is turned off by default (hence the value 0). When a + value is input the camera zooms out when turning the mouse wheel to the front. When a – value is input the effect is reversed. The value module defines the degree of camera shift per one click of the mouse wheel. Adjusting this parameter to your needs you can define the starting value as 100. The mouse wheel is inactive by default (0).

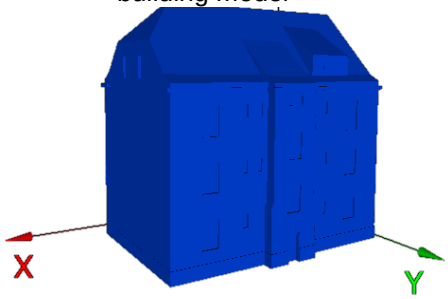
3.1.2 Guidelines for the Design Tool user

1. Building model import	
Steps:	Pictures:
1.1 Create a new project: select from menu "*File -> New Project".*	
1.2 Import the building model in an STL file format: select from menu "*File -> Import Building Model".*	

Comments:

Import can be long process, but it is performed once for one model. During import, a mesh that allows the placement of panels is created on the basis of the building model. To allow an appropriate import of the building model, the model has to be saved in a text or binary STL file in which the coordinates of triangle corners are in millimetres. It is recommended that the base of the building is on the XY plain, one of its corners is placed at the beginning of the coordinate system, Z axis is pointing up and the front or rear façade is heading towards the Y axis (as shown in **Error! Reference source not found.**)

Figure 8: Recommended orientation of building model



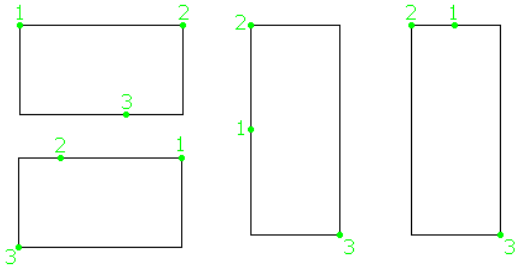
2. Creating panels

Steps:

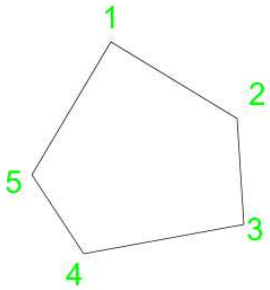
Pictures:

2.1 Create panels surface: panels' creation is done by placing control points on the surface of the building (or other panels) that define the placement of the panel corners and surface on which it is to be placed. To insert a control point click on the building holding "*Ctrl+Shift*". To create a panel at least three control points are required. First three control points always define the surface on which the panel is to be placed. The user is able to create rectangular (**2.1.a**) or polygonal (**2.1.b**) panels by choosing the related button.

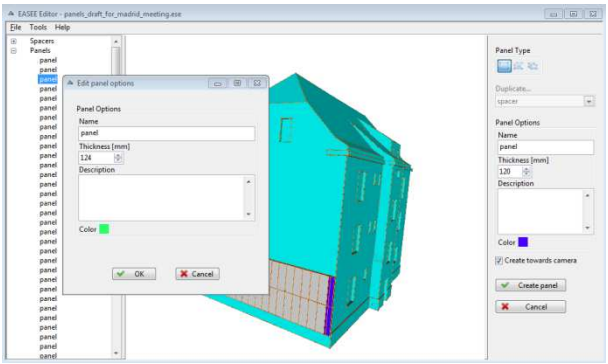
2.1.a In the case of rectangular panels, first two control points define the line on which one of the edges is placed, the third point defines the length of the second edged (as a distance from the first line) and the placement of the corners. Rectangular panels are created automatically after inserting the third control point.



2.1.b In the case of polygonal type of panels the control points in any number define the placement of the panel corners.



2.2 Characterize panels *Double click on panel name*: to rename it, the user shall change thickness, colour and description for the newly created panel.



2.3 Select and duplicate existing panels: select form the menu "*Duplicate panels*". The first control point defines the place where the first control point form the duplicated panel will be placed. The second point will define the line on which the second point will be placed. The third point along with the first two defines the surface on which the duplicate will be placed. The panels are created automatically after inserting the third point.

Comments:

- The option "*Create towards camera"* controls the heading of the created panel. Since in most cases user observes building from the outside, panel is usually created heading towards the camera. However, in some special applications other heading may be required. It is possible to create zero-thickness panels. It is useful for creating temporary "positioning panels" or to increase the ergonomics during the creation of ad joint panels or to have easier access to grid nodes – after creating a panel set you can assign their designated thickness (Figure 9).

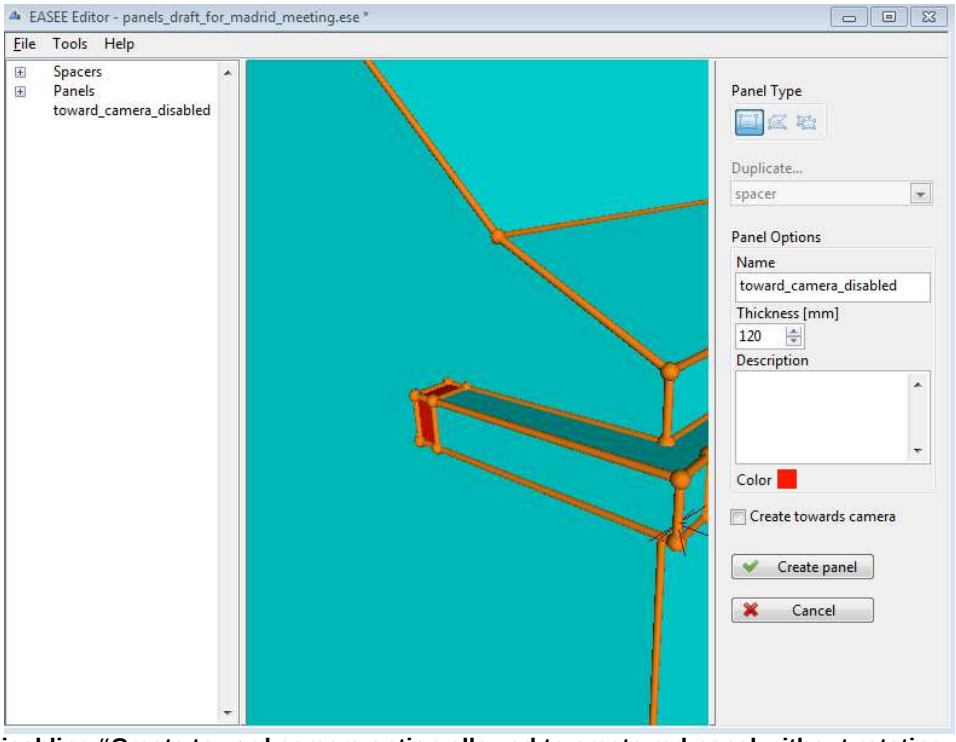


Figure 9: Disabling "Create toward camera option allowed to create red panel without rotating a model

- Using the panels duplication method the user can create panels which are exact copies of the original or its symmetrical reflections. Figure 10 presents the pattern panel (blue), the order of its control points and its four duplicates (green) along with marking of the placement of their control points. The user shall keep in mind that the first point of each duplicate has a defined placement, but the second control point can be placed in any point along the appropriate half line, and the third point can be placed in any place on the

appropriate half plain.

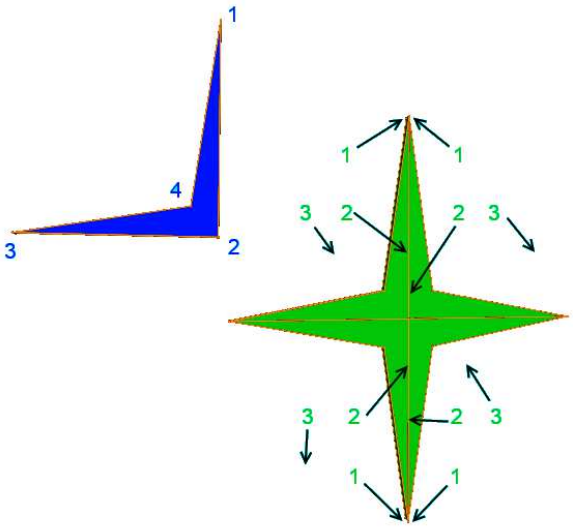


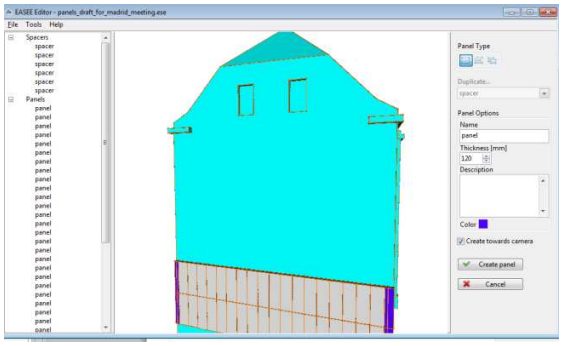
Figure 10: Original panel and its duplicates

Creation of duplicates requires from the user a certain skill and consistency, because there is no way to display the numbers of control points of existing panels. The user has to know (check), which point of the pattern panel is to be considered.

3. Organizing and editing panels

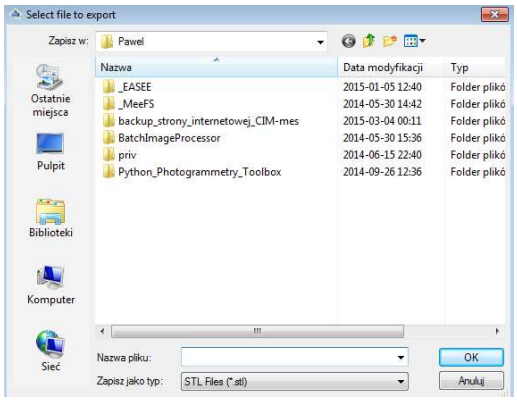
Steps:	Pictures:

3.1 Create hierarchic tree structure to organize panels: to add a new tree, click with the right mouse button on the control on the left side of the menu called "*New Category*").

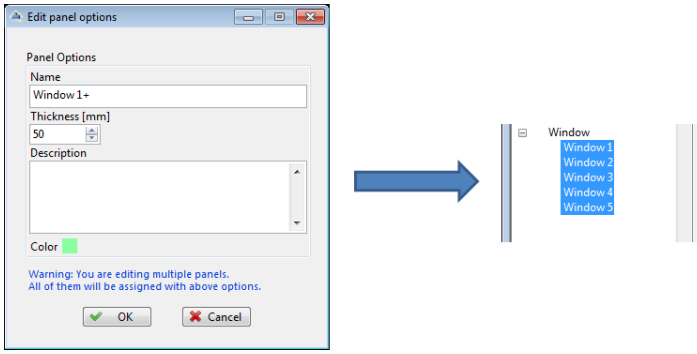


3.2 Select panels: "*shift*" to select the panel scope and/or *"Ctrl"* to select panels that are not placed next to one another and drag them into a newly created category.

3.3 Create subcategories using the same method dragging one category into another one: double click on a category allows to rename it.



3.4 Edit existing panels: select them and then using the tree context menu select "*Edit Selected Panels".* In case of editing several panels the user can use automatic numbering of panel names. In order to do that, use the shape counter in the panel name <number>+ or <number>-. For the next panels the counter will be substituted with numbers starting from the one given and increasing or decreasing by 1, depending on whether you used + or -.



Comments:
The order of panel selection makes a difference. i.e.: if the user shift and select panels from top to bottom, they will be numbered the same way. If the user select them from bottom to the top the numbering will be reversed (5,4,3,2,1). The user can delete panels or categories selecting from the context tree menu the option "*Delete -> Selected Item"*. Deletion of category does not delete the panels or subcategories within it. All elements within a deleted category are moved to the top branch of the tree.

4. Export

Steps:

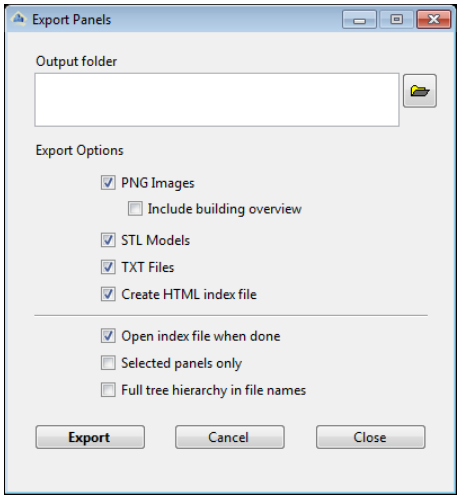
The Design Tool provides the possibility to export panels sizes (**4.a**), building model (**4.b**) and building grid for anchoring systems tracking (**4.c**).

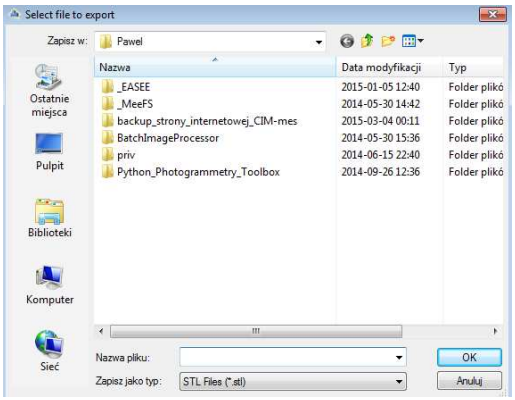
4.a To export panels select from "*Tools -> Export Panels"*. The panel export window will appear and the user can select a designated catalogue along with export options.

4.b To export the building model contained in the project into a STL file: select "*Tools -> Export Building Model"* and input the desired path for the STL file.

4.c To export the building grid to a text file: select from menu "*Tools -> Export Building Grid"* and input the desired path for the text file. The first row of the outcome file contains the number of grid nodes, the second – the number of grid edges, next is the list of the grid nodes coordinates in the form of X;Y;Z and then a list of edges (start – end) of the grid in the form of X;Y;Z X;Y;Z.

Pictures:






```
41                                                          <- number of nodes
84                                                          <- number of edges
15219.450;1785.057;-0.020                                   |
15388.760;1668.680;9620.423                                 |- number of nodes
653.360;6567.825;14698.220                                  |
(...)
653.360;6567.825;14698.220   8012.012;1718.601;14459.500    |
653.360;6567.825;14698.220   12844.540;6499.950;14699.180   |- number of edges
8012.012;1718.601;14459.500  12844.540;6499.950;14699.180   |
(...)
```

Comments:

Panels can be exported to a form of STL models, PNG files containing information about the panel along with its contour (similar to the one in The Navigation Window) and/or TXT files containing information about the panels in text format. Selecting the option "*Include building overview"* adds a miniatures panel to the image, showing the building along with highlighting of the panels position on the wall. Generating of miniatures can take some time and can use up a significant amount of RAM.

Additionally it is possible to create a HTML file allowing for an easy access to exported files. To do that, the user shall select the option "*Create HTML index file"*. The user can adjust the way that the HTML file looks to your needs, editing "*files index_template.html"* and "*panel_template.html"* placed in the main application catalogue. Figure 11 shows a part of an example HTML file and a panel exported to a PNG file. The graph contains the information about the panel, its concept drawing describing the shape of the panel (the length of the sides in meters and the measure of the angle is in degrees) along with the set of miniatures showing the placement of the panel on the wall. The miniature on which the panel is closest to the camera is marked with a frame.

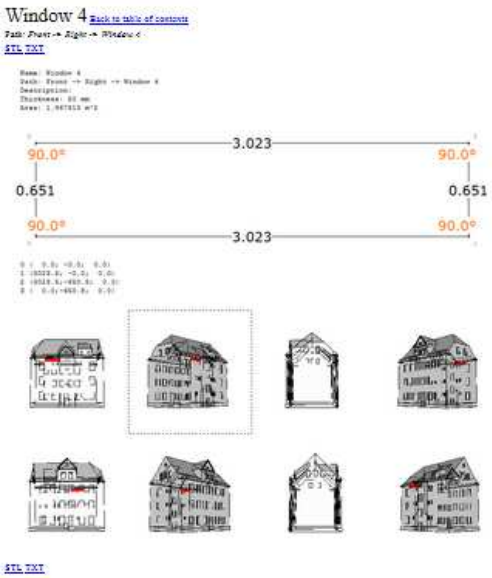


Figure 11: The panel exported into a PNG image

Planning patterns distribution constraints

- Panels shall be placed on the wall with 1 cm dilatation joint (in horizontal and vertical directions) between each other.
- Minimum dimension of the panel is 0,5 x 1,5 m.
- Maximum dimension of the panel is 1,5 x 3,3 m.
- Rectangular panels' shapes are strongly advised. Non-rectangular panels can be manufactured, but such process is more complicated.
- In general, walls should be covered with panels having as wide as possible dimensions – it allows to increase the speed of the insulation process and to decrease number of anchors required. Although, depending on the transport costs / mechanical strength of building / internal regulations, for different countries and on different buildings other strategies are allowed.
- Number of panels' types to be manufactured for one building should be minimized.
- If the texture for a panel is selected, it is important that its depth (largest distance between the top and the bottom of textures profile) should be below 10 millimetres.
- In general, panels should be placed evenly, with respect to the architectural features – lines of the dilatations should in most cases remain straight, horizontal and vertical.
- All criteria described above should be applied with a respect to the structural constraints, which takes into account architectural and mechanical features of the building, like for example steel construction, high performance concrete reinforcements etc.

Table below provides the troubleshooting table in order to help the user in case problems occur while using the Design Tool.

Table 1: Design Tool troubleshooting table

Problems	Possible causes	Contingency
Building model does not look good after import to the Design Tool	STL model created in the cloud processing software is somehow incorrect	The user can try to use external software (for instance MeshLab), to display and fix STL mesh. If the user encounters problems with edge detection (EASEE Editor will not detect edges between two walls), Open Settings.ini file (in the installation folder) with a text editor shall be opened and following parameters adjusted: • Grid Plane; • Grid Edge Threshold.
It takes very long time to import building model	STL mesh on the model is very dense	Up to some point, it is normal. After successful import, the user shall always save your project. However, when exporting STL from the external software, the user can try modifying export settings to avoid unnecessary density increase.
Cursor does not snap to panel edges/corners, and as result panels connectivity is not as desired	Graphics picking tolerance is not adjusted to your display resolution.	The user shall open Settings.ini file (in the installation folder) with a text editor, and adjust following parameters: • Grid Edge Snap Distance • Grid Node Snap Distance • Grid Edge Radius • Grid Node Radius After that, the user shall restart EASEE Editor.

3.2 Prefabricated insulating panels manufacturing

The scheme below is representing the main steps to be performed in order to manufacture the prefabricated insulating panels for external envelope retrofitting developed and designed within the EASEE project.

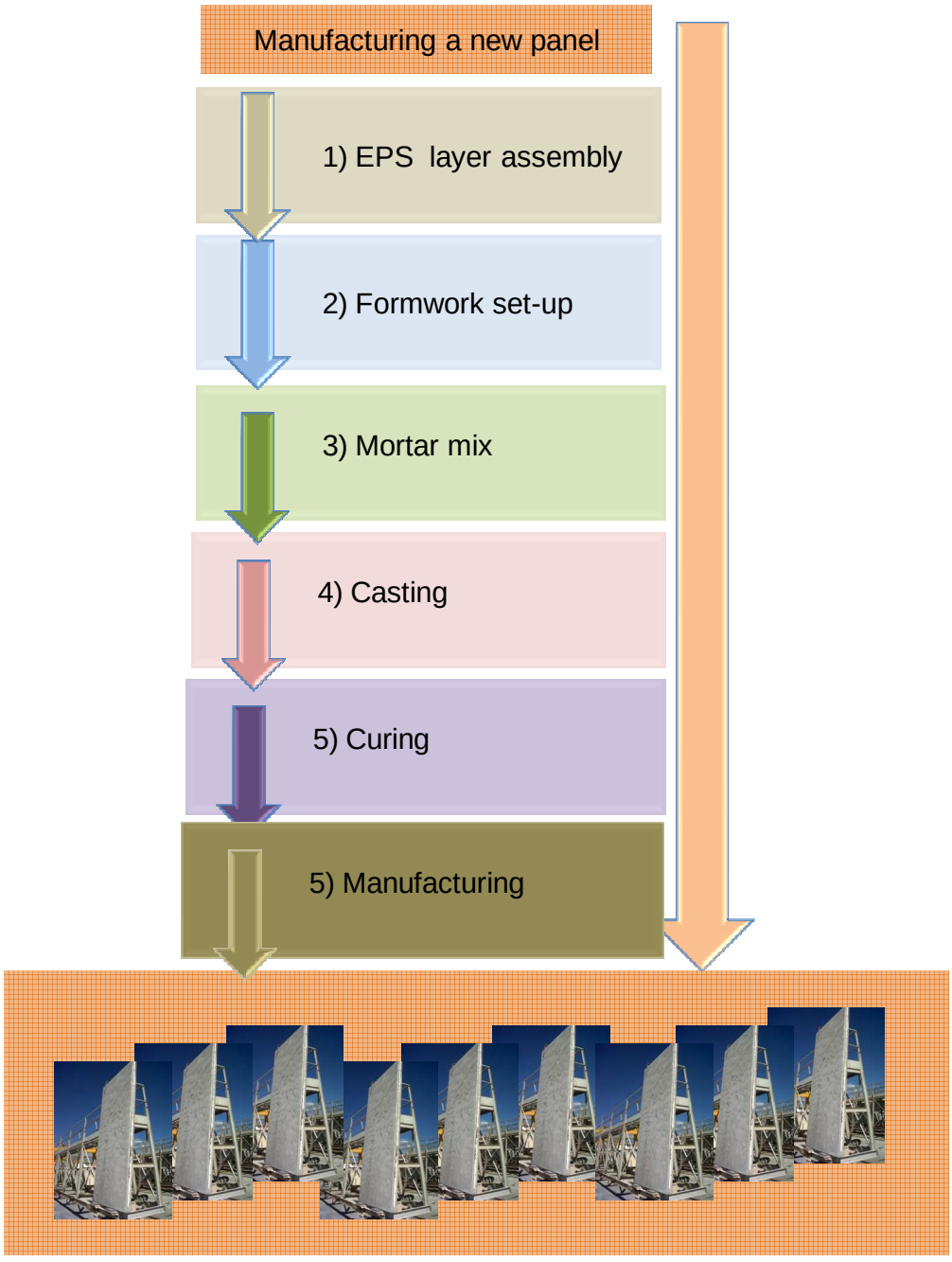


Figure 12: Guidelines blocks flow scheme for prefabricated panels manufacturing

3.2.1 Glossary

Below is the description of the main systems (materials and components) needed for the prefabricated panels manufacturing.

- *Spacers:* Proper spacers have been designed in order to keep constant the layer thickness during the sandwich panel casting at both sides of the EPS. Moreover, the spacers can help the exceeding air to exit and avoid discrepancies in the panels finishing texture.
- *Fire connectors:* An ad hoc serpentine folded steel wire is used in order to ensure a proper fire resistance to the panel.
- *Formwork:* dedicated technological equipment designed for the manufacturing of the multi-layer panels for the building external envelope retrofitting with different sizes (see dedicated datasheet at Paragraph 2.2).
- *Counter-moulds:* Several sheet-like counter-moulds for a bas-relief pattern is used for those panels reproducing an external facade different from a smooth one. The counter-moulds is glued to one of the sides of the formwork (the one which reproduces the external facade). The counter-moulds thickness and the texture reproduced could be different.
- *Bucket:* dedicated buckets of different dimensions could be used for the mortar pouring into the formwork. Thus, bucket is used as a hopper and can be opened to spread its content on the formwork.
- *Eyebolt*: two eyebolts are installed only in the top surface of the panels, because the product is relatively light. Thanks to the spreader beam, the panel can be easily attached to the crane and moved to the warehouse.
- *Overhead crane:* an overhead crane, commonly called a bridge crane, is a type of crane found in industrial environments. An overhead crane consists of parallel runways with a travelling bridge spanning the gap. A hoist, the lifting component of a crane, travels along the bridge. If the bridge is rigidly supported on two or more legs running on a fixed rail at ground level, the crane is called a goliath crane.
- *Spreader beam:* the spreader beam is used in order to extract the panels and handle them. A spreader beam consists of a rigid beam connected to the overhead crane hook with chains. Besides, the beam is equipped with a number of hooks that are connected to the eyebolts, installed on the panel after casting.

3.2.2 Guidelines

1. EPS layer assembly	
Steps:	Pictures:
1.1 Lay the EPS on the proper position in order to assemble it. The EPS is supplied already of the needed size and properly cut.**Error! Reference source not found.**	
1.2 Install the AR glass fabrics: the AR glass fabric shall be installed with horizontal and vertical warp on both side of the EPS modules.	
1.3 Anchoring boxes installation: the anchoring systems have to be inserted in their dedicated sockets.	Photo not available for confidentiality reasons
1.4 Insert spacer in the EPS in order to keep constant the mortar thickness during the panel casting at both sides of the EPS. The proper number and distance of the spacers shall be duly taken into account.	

1.5 Fire connectors installation: EPS is properly cut to insert the fire connector represented by a serpentine folded steel wire.

Comments:

Due to the challenging thickness of the two layer of mortars finding out the suitable spacers able to fulfil their function as well as guaranteeing the panel's aesthetic was a very difficult task. Moreover, the smooth panels and the panels with particular finishing textures have different requirements with respect to their production process. Thus, the choice of the most suitable spacer is of utmost importance for the panels manufacturing.

Time required to perform this phase is approximately 90 minutes. 2 workers needed.

2. Formwork set-up

Steps:	Pictures:
2.1 Set-up of the proper width and height of the formwork: the setting shall be done according to the panels thickness and height/length through the proper positioning of the formwork lateral and inferior shutterings.	
2.2 Clean the formwork in order to avoid obstacles to mortar pouring and ensure good aesthetic of the panels.	
2.3 Apply/spray the demoulding agent on its lateral surface in order to create a form of physical barrier between the formwork side and the mortar layer of the panel and facilitate its proper separation in the demoulding phase.	
2.4 Position of the counter-moulds/finishing layer to decorate the external side (if required by the specific panel design).	

2.5 Position of additional shuttering (i.e. specific shuttering systems for balconies, windows, doors or any other façade singularity that must be replicated by the panel. These devices will be assembled separately and fastened to the formwork's fixed front side thanks to magnetic couplings.

Photo still not available since the production of this kind of particular panels shall be still done

2.6 Set the EPS block assembled in step 1, properly shaped. The formwork is designed so that a mistake-proof (poka-yoke) insertion of EPS places it at the correct distance from the fixed front side.

2.7 Set the different shuttering: in particular set the movable side shuttering, the movable front side, the top side shuttering.

2.8 Close and fasten the formwork, through the following steps:

- All tie-rods must be put in operation thanks to their large pitch bolts.
- All the locking screws on the base of the movable front sides must be tightened.
- All the locking screws of the top side shuttering must be tightened.

Comments:

- Since the mortar pouring to produce façade panels is made at once, all steps related to components positioning are made before closing the formwork. As a consequence, a key role is played by the EPS insulating layer, on which all devices will be applied and fixed so that they will be embedded in the mortar matrix. As soon as these operations are performed, the formwork is ready for fastening and mortar pouring. Since, as stated above, mortar must be poured in a limited range of time after mixing, the time schedule of mixing and formwork setup must be properly calibrated.
- In order to provide a nice panels with respect to an aesthetical point of view) different solutions for avoiding deficiencies/imperfections on the external side of the panels are under investigations (see trouble-shooting table).
- Several movable side/top/bottom shuttering shall be also foreseen for the formwork equipment in order to ensure the needed customizability for the panels production.

Time required to perform this phase is quite difficult to estimate since there are several variables to take into account according to the typology of panels that have to be produced (size, finishing, etc). Approximately 30 minutes are needed in order to prepare the formwork for standard production (smooth panels) while the whole day could be necessary to prepare the formwork for a non-standard panel (panel with different size and particular counter-mould for the texture). 2 workers are needed.

3. Mortar mix	
Steps:	Pictures:

3.1 Set the materials needed and mix them in the planetary mixer to correctly blend constituents.

3.2 Send the mortar mix to formwork through flying bucket.

Comments:

Thorough mixing is essential for the production of uniform, high quality concrete/mortar. For this reason, equipment and methods should be capable of effectively mixing concrete materials containing the largest specified aggregate to produce uniform mixtures of the lowest slump practical for the work. In the EASEE case, this aspect is facilitated by the very small dimension of aggregates, that makes the mixture fall in the mortar case, instead of the concrete one.

In order to correctly mix the mortar of the prefabricated insulating panels, any standard method can be used, from very basic ones (with drill mixers) to large industrial equipment. In the specific case the EASEE project, the production process of the prefabricated insulating panels is hold at MAGNETTI's premises, who owns equipment typical of large prefabrication plants.

After mixing the mortar components, it is immediately transported close to the formwork, through a flying bucket for concrete delivery. The mixer must be promptly washed with high pressure water to clean the mortar from containers and mechanisms, before it hardens.

Time required to perform this phase is approximately 30 minutes. 2 workers needed.

4. Casting	
Steps:	Pictures:
4.1 Pour the mortar mix: as soon as the mortar is delivered by the flying bucket for concrete to the hopper above the formwork, the mortar pouring can start. The flow rate should follow a ramp from low values up to about 12 l/min, when the level of mortar poured has reached that of the valve and there is no free flow of liquid within the formwork.	Photo not available
4.2 Mortar pouring stopped when formwork is filled and cleaning of equipment used (hopper, etc)	Photo not available

Comments:
The selected pouring technique is still to be improved in order set-up a more automatic manufacturing process and thus producing panels that are high-quality, double-sided, tightly dimensioned elements.

Time required to perform this phase is approximately 30 minutes. 2 workers needed.

5. Curing	
Steps:	Pictures:
5.1 Curing of the panels (see comments)	Photo not available

Comments:
The prefabricated insulating retrofitting panel must cure for about 12-14 h, depending on the environmental conditions of the plant (mainly temperature and humidity). In order to increase the productivity, the formwork has been equipped with a dedicated finned piping system. Low-pressure steam curing adds moisture and increases the temperature, which are important factors that accelerate the curing process: both result in an increased rate of hydration. Low-pressure steam curing can be performed in an enclosed permanent structure or in a temporary enclosure formed by a heavy sheeting. To achieve the best results when steam curing:

- Apply elevated temperatures after the initial set of the fresh concrete. This is usually a period of 2 to 4 hours.
- Apply a gradual temperature rise of no more than 4°C per hour, up to a maximum temperature between 50 and 60°C.
- Maintain a relative humidity between 75-90%
- Gradually lower the temperature at a rate not to exceed 6.5°C per hour, to avoid any thermal shock. Moisture evaporates very quickly from a hot surface and the durability to weathering and atmosphere will be detrimentally affected. Too rapid evaporation rate at low humidity will cause the surface to dry out and produce a concrete structure that has a permeable, poorly cured surface with relatively poor durability.
- Continue moist curing after steaming, as needed.

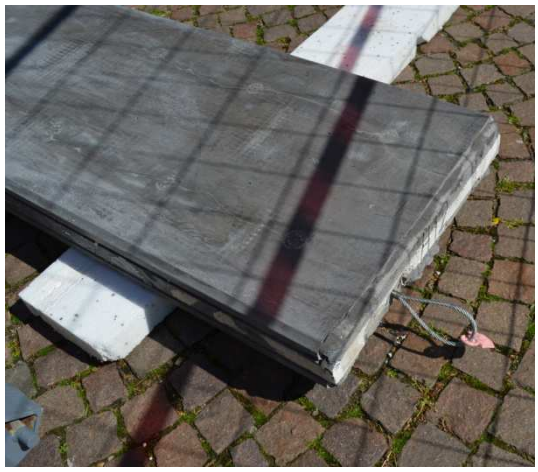
6. Handling

Steps:

Pictures:

6.1 Unfasten the formwork by untightening the large pitch bolts of tie-rods, the locking screws on the base of the movable front sides and on the top side shuttering.

6.2 Install the lifting eye bolts: the eyebolts are installed in their holes in the dedicated boxes. The overhead crane is approached to the formwork and the hooks on the spreader beam are connected to the eyebolts. By doing so, the panel will not fall down when opening the front sides.



6.3 Remove the movable side shutterings. In particular, the movable front sides are displaced to open the formwork. The special shuttering systems for doors, windows, etc. are removed as well.

6.4 Extract the panel with overhead crane. Once secured, the panel is slowly extracted from the formwork, first in vertical. With enough clearance, the overhead crane simply moves the element from its vertical position in the form, to the storage area.

6.4 Clean the formwork.

Comments:
After a trade-off analysis, the formwork was designed in order to cast the panel in vertical position (lying on its bottom surface). The main reason that drove the decision was the fewer (virtually none) tilting operations required, that strongly decrease the risk of damaging the panel during handling and transport operations.
The prefabricated insulating retrofitting panel production process also eases material handling: the anchors for the crane generates less stress on the freshly cast element. In fact often producers add reinforcements just for the initial pick from a horizontal to vertical position.

Time required to perform this phase is approximately 30 minutes. 2 workers needed.

Table below provides the trouble shooting table in order to help the user in case of problems occur while using the Design Tool.

Table 2: Panels' manufacturing process troubleshooting table

Problems	Possible causes	Contingency
Problems of cracking found in the panels of the maximum size.	The main cause is the phenomenon of shrinkage of the mortar.	The shrinkage of the mortar is essentially due to the intrinsic characteristics of the material and to the very thin thickness of mortar. The contingency plan is under finalization. The use suitable expansives is currently implemented.
Not so good aesthetics of the panels	Potential causes could be: • The sensibility of the mortar to the outside temperature • The sensibility of the mortar to the formwork front side material • The spacers used • The crackings above mentioned	Potential contingency plans are under finalization. The use of polycarbonate sheet to be used in place of the counter-mould (for a smooth exterior finishing of the panel) and glued to one of the sides of the formwork (the one which reproduces the external facade) is under discussion in order to ensure a perfectly smooth texture. Also the use of other kind of synthetic based membranes to be embedded within the formwork front side is under investigation.

3.3 Installation process

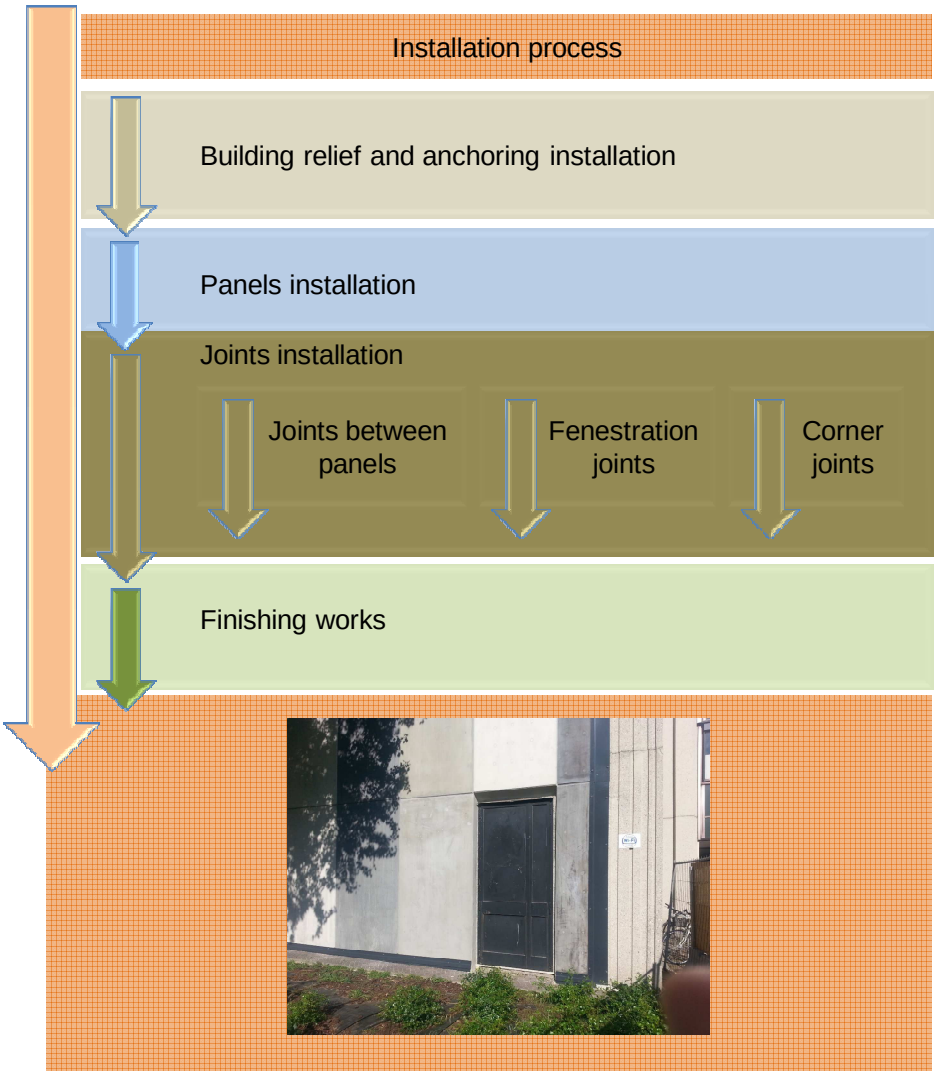
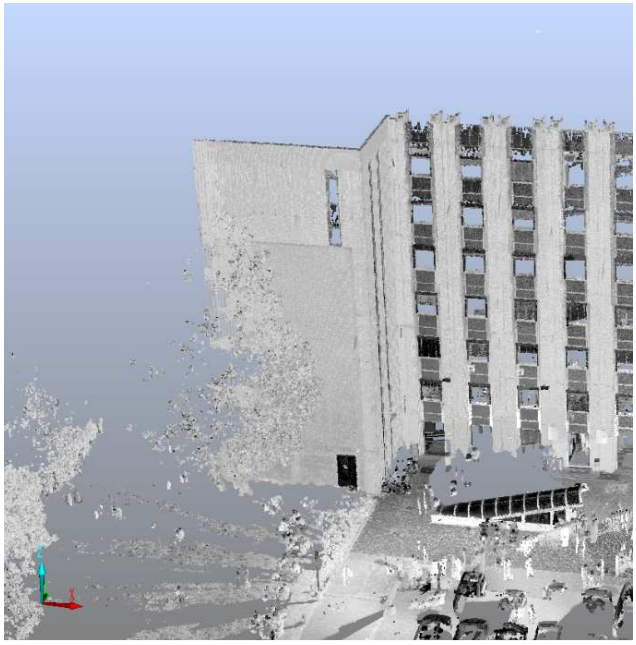
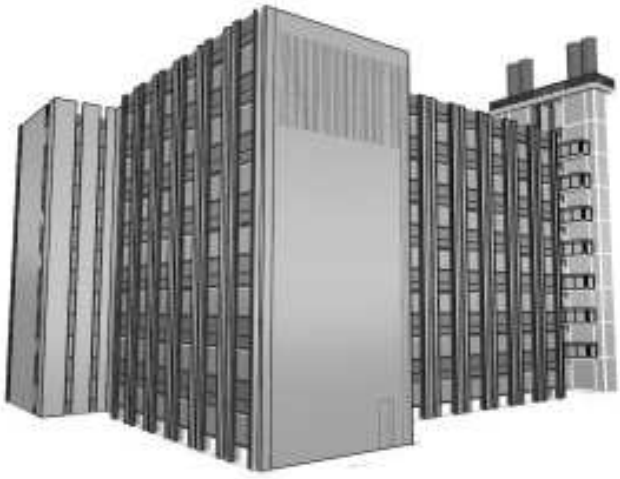
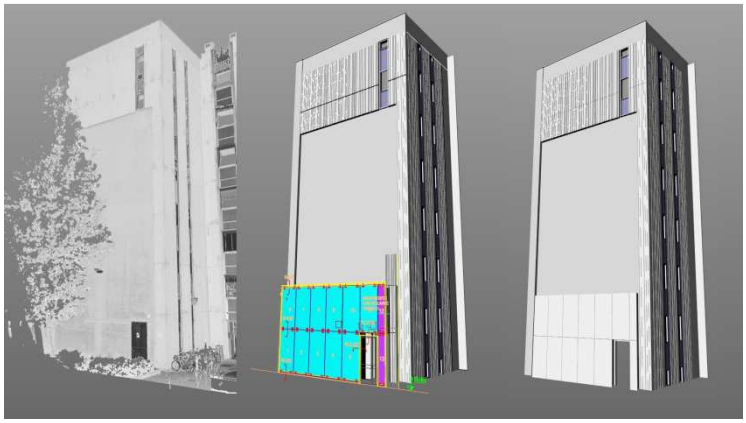


Figure 13: Guidelines blocks flow scheme for panels installation

3.3.1 Guidelines

1. Building relief and anchoring definition	
Steps:	Pictures:
1.1 Survey of the existing building by scanning laser technique. The advantages of this technique are rapid acquisition of the data, the extreme precision, non-invasive, non-dependence on the complexity of the work detected and digitization of all data acquired.	
1.2 Definition and verification of the anchoring points within the developed building 3D model through the correct georeferencing of the executive 2D design. The correct laser-survey of the three-dimensional surface enables to identify and locate discontinuities, projections and out of plumb of the facade and facilitates the correct positioning of the anchoring location.	

1.3 Three-dimensional **data conversion** into text files in order to be acquired by the total station.



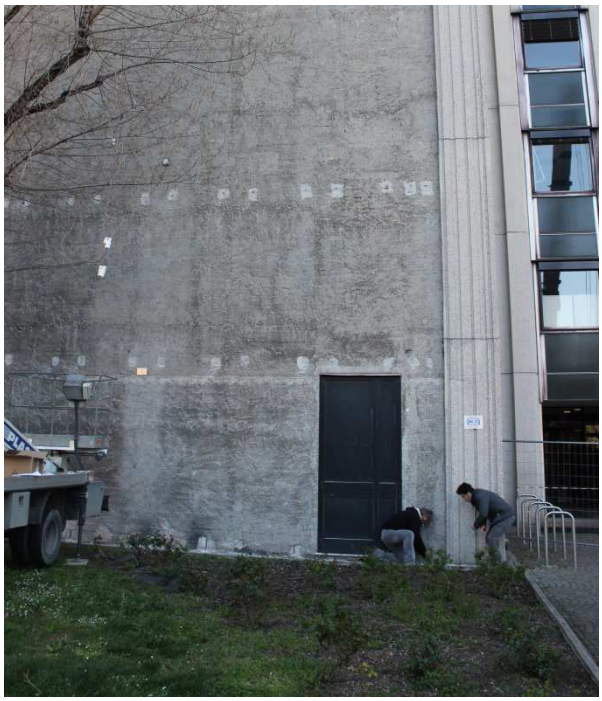
1.4 Definition of lead-off with subsequent determination of the appropriate anchors panel fixing, based on the Design Tool output.

1.5 Tracking on the wall properly prepared for installation of the panels by means of the total station.

1.6 Marking and realization of the holes, always by means of laser technology, for the anchoring points once verified the vertical and horizontal axes of the identified points.

1.7 Laying, installing and centering the bubble (spirit level) of Halfen anchorings.

1.8 Verification of horizontality by centering the bubble (spirit level) of the overall perimeter defined by the points of the anchoring at the four edges in order to ensure a further verification of the entire anchoring system proper set-up.



1.9 Preparation, verification and control of possible production deficiencies of the panels stocked on site prior proceeding with their installation.

Comments:

- The required staff for the fixing of the anchors operate on special platforms loaders while the panels are moved through a crane.

Figure 14: Equipment for panels installation

- In the case of a rough existing wall it is important to smooth the external surface to have a flat plane on which to install the anchoring system. Anchoring systems will be mechanical (Figure 15, c)) in the case of reinforced concrete substructures or chemical substructures (see Figure 15 a), b)) in the case of clay wall. The perfect verticality of the wall mounted is assured by the tolerances inherent in anchoring systems.

a) b) c)

Figure 15: Type of anchoring systems according to the available facade

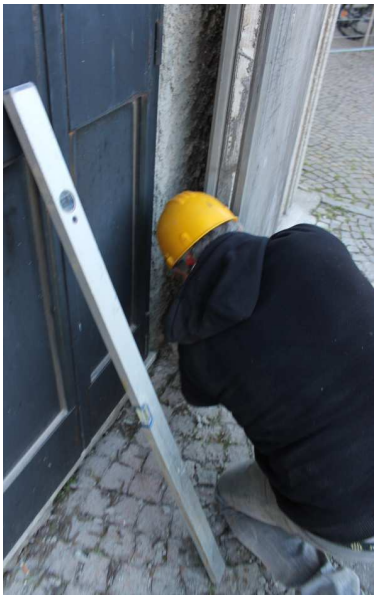
- To keep as a reference the manual for anchoring installation provided by the anchoring suppliers (HALFEN guidelines according to the type of anchoring provided) shall be consulted.

2. Panels installation

Steps:

Pictures:

2.1 Lift the first panel and place it carefully close to the final position. The installation and leveling of the panel No. 1 on the first row of anchors installed is crucial for the correct installation of the subsequent panels.



2.2 Proper placement of the anchoring within the boxes of the panels. Move the panel up to the anchors and match the anchoring boxes of the panels with the lower couple of the anchoring systems. Than fix the panel to the wall using the upper boxes and anchor system. It is important to check that the anchoring are working properly at shear and that are positioned on the saucer and not on the screw. In the case, lengthen the screw and the distance from the screwing / unscrewing the pin).

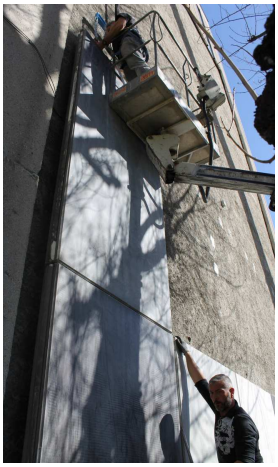
2.3 Check the gap between wall and panel as designed (distance from the wall to the inside edge of the 4 panel berths).

2.4 Adhesive polyurethane based sealing tape lay on the adjacent sides between panels.

2.5 Installation and leveling of the panels after the first band.

2.6 Check the sealing and level (spirit level) of the second row of anchors before installation of the panels of the second row.

2.7 Installing the second row of panels and positioning of a filler to enhance the thermal and energy capacity and avoid thermal bridges. The proper installation o f the first panel determines the correct positioning of subsequent panels.



2.8 Concluding the installation of the second row panels after verification of the sealing and the levelling of the superior anchoring systems of the first band.

Comments:

- The panels have large areas but relatively low weights (0.54 kN/sm). This advantage is reflected on the speed of assembly, since no scaffolding is needed for their installation but only the use of wheeled cranes is foreseen. In the case of eaves projecting the use of special sling bars counterbalanced flag will be foreseen for the assembly of panels, especially those located in the top. In fact, in order not to interfere with potential eaves, and then to avoid possible damage of the same, it is assumed to use such a sling for the installation of all the panels. For simplicity, the assembly of the panels will gradually from the lower row to the top ones.
- The staff required for the fixing of the panels will operate on special platforms loaders and crane as already mentioned.
- The joint between the panels has been made using a low elastic modulus neutral-curing silicone sealant with outstanding ageing resistance. The silicon has been placed on polyurethane backfill material in order to reduce the danger of cracking. The elasticity remains constant at temperatures ranging from -50°C to +100°C. The high resistance to UV rays and atmospheric agents foresees that after 20 years of service under normal conditions, the joints shows no trace of superficial cracks.
- In case of more rows of panels, perform again procedures from step 2.5 on.

3. Joints between panels	
Steps:	Pictures:
3.1 Laying the polyurethane backfill material between the panels for vertical and horizontal joint.	
3.2 Laying the low elastic modulus neutral-curing silicone sealant with outstanding ageing resistance.	 
3.3 Laying the polyurethane sealant foam over the whole perimeter.	

Comments:

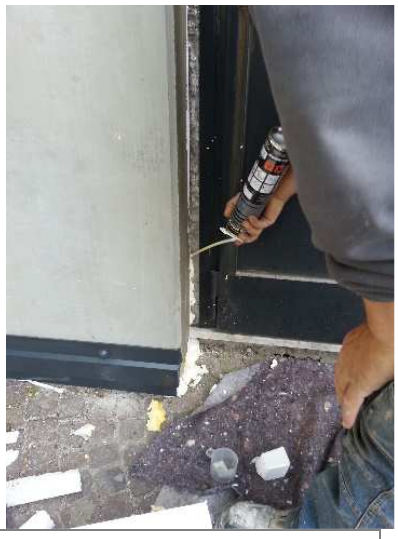
- Under the geometrical aspect, the facade misalignments (out of plumb) shall be compensated by the tolerances of the anchoring systems, or in case the misalignments were very marked, using multiple ranges of anchoring systems.
- In the corners, the miter cutting of panels (cut at 45 °) allows the aesthetic homogeneity of the façade, although it requires a much more complex processing of the panels. By contrast, the 90 ° angle is much simpler but requires an additional processing on one of the two panels accidents in order to mask the vertical section open.
- Regarding corner joints, WKP Plus sealing tape is suitable for sealing expansion joints in building construction such as precast walls and wooden clinker. Thermal insulation and waterproof seal between the prefabricated components, between window frame and the wall, etc. The WKP tape is water noise and dust proof (ensure sealing against heavy rain), it can be exposed directly to the weather when compressed between the two elements. Absorbs vibration and follows the expansions. Protects against dirt and is not attacked by birds. Suitable for concrete, stone, brick, brick, metal, wood, rigid PVC, Plexiglas, drywall, glass, fiberglass and many other materials.

Tape color	Gray and black
Composition	Polyurethane foam with a fine, open cell structure, bitumen free and after installation silicone free. The tape is provided with a self-adhesive side based on an acrylic carrier.
Volume weight	110 kg/m^3 (±10%)
Impregnation	Acrylate polymer dispersion
Temperature resistance	-30 +90 °C
Thermal conductivity	0.05 W/mK
Water vapour diffusion	μ≤100 as per DIN 18542
Fire behavior	Flame retardant – Class B1
Expansion times in the joint	0°C up to 10 days 10°C 48 hours 20°C 3 hours 30 °C 10 minutes
Elasticity	Long-term elasticity is ensured for many years
Resistance	UV-resistant, weather-resistant, resistant to mold and bacteria
Shelf life	2 years at +5 °C to +25°C
Application temperature	Day from +5°C

4. Finishing works	
Steps:	Pictures:
4.1 Flashing installation over the whole perimeter – lower side	 
4.2 Flashing installation over the whole perimeter –upper side	 
4.3 Flashing installation over the whole perimeter –left side	 

4.4 Flashing installation over the whole perimeter –right side

4.5 Door frame finishing with insulation, Fiberglass net and plaster



Comments:

- Air knives that can then create on the back of the panels, in order not to create a worsening of the energy balance, must be separated as by means of seals or fills so as to prevent movements of air.
- After the installation of the panels, the workers shall proceed with the installation of the elements in proximity of the openings (windows and / or doors) and at the top and bottom elements of closure of the building if required. These elements shall ensure air tightness, water tightness, vapour retarder, thermal insulation, acoustical insulation, elasticity, aesthetics.

Figure 16: Test facade installed

Table below provides the troubleshooting table in order to help the user in case of problems occur while using the Design Tool.

Issues	Possible causes	Fixes
Surface roughness of the wall	Retrofitting process is usually performed in order to enhance the energetic behavior as well as the aesthetic of old buildings, whose external walls are usually not very smooth and not very nice.	To prepare a proper wall surface for laying the anchoring systems
Difficulties in the correct leveling of the first row of anchors	It is mainly due to the fact that installers are working on an existing building.	For installers it is enough to have as a reference the first row and the outermost points of each side of the facade in order to verify if the panels are compliant with the centering the bubble (or to pull the wires)
Difficulties in the installation of the first raw of panels	Danger of crushing hands for workers	Set-up of a sort of shelf to guarantee panels horizontal level while safeguarding workers hands.

4 Conclusions

This report constitutes Deliverable 6.5 “Guidelines and protocols for the flexible molding and for the installation of anchoring systems and joints” and presented the associated work that has been done within Task 6.4 “Application Guidelines”. Indeed, the document provides specific guidelines for the project developed applications (namely the Design Tool, the formwork for panels manufacturing as well as the prefabricated panels installation process). Guidelines are based on the activities performed towards the design and the installation of the prefabricated insulating panels on the test facade. Guidelines have been provided in a practical and synthetic way and have been supported by pictures of each steps to be taken, taking into account the target of end-users per each result. Technical datasheets have been set-up, and trouble shooting tables are included, in order to support the end-users in solving the main problems that might occur. The intent of the document is thus to constitute a stand-alone document, to be attached and sold together with each project result, in order to increase their industrial exploitation value.