MORE-CONNECT
Development and advanced prefabrication of innovative, multifunctional building envelope elements for MOdular REtrofitting and CONNECTions
(No. 633477)

D5.4 Realization of 5 pilot sites

H2020-EE-2014-1-PPP (EE-01-2014)

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1 Introduction

The objective of work package 5 is the testing, pilot implementations and demonstration in real settings, as well as in industrial settings (demonstration of production), as in practice (demonstration and testing of the developed modular renovation elements both in real settings as in real life learning lab (RLLL) settings. The testing and demonstration in practice will be organised on six locations:

- Czech Republic (RLLL setting for in deep testing)
- Denmark (full real setting)
- Estonia (full real setting)
- Latvia (full real setting)
- The Netherlands (full reals setting and RLLL setting for in deep testing)
- Portugal (partial real setting)

The work package comprises 6 tasks of which this deliverable presents the results of task **5.4 Construction work**, which concerns the actual renovation of the pilot buildings. This may include the partial or total removal of existing structures (facades, roofs, installations), depending on the renovation methodology (total replacement, partial replacement, addition of elements). It also contains the recording and evaluation of the working of the smart plug & play connectors in practice.

Task leader for task 5.4 is Cenergia.

Other participants - knowledge providers: RTU, TUT, Cenergia, UMinho, CVUT

Other participants - industries: BJW, WEBO, LWCC, REF, Matek, ZTC, Invela, Innogie & Darkglobe.

The content of this deliverable is constituted by two parts:

1. A word part which reports the outcome of the tasks. This part hold a country by country report in a standardized format following these headings:
   - Preparation (making the building ready) for the mounting of elements
   - Production of elements – incl. design process and characteristics of elements
   - Mounting of elements – carrying out the renovation
   - After the renovation – showing the final result

2. A PowerPoint part which can be used for the presentation of the results at international and international conferences, workshops and webinars.
   This PowerPoint part can be downloaded from the project website and it is also added as an abbreviated version after the word report as an appendix.

2 Denmark

In Denmark two products/construction concepts have been further developed in the MORE-CONNECT project:

- The company Innogie (new name: Ennogie) has developed a roof consisting of solar cell panels. Innogie is a company specializing in innovative use of solar energy with special attention to power adequacy, design and profitability for the consumer. Within the More-Connect project Innogie has developed several prototypes of its Solar Energy Roof - in particular concerning methods of mounting and flashing details to create a customer and installer driven plug-and-play solution.
- The company Invela has developed a system for finishing and decoration of externally insulated external walls carried out by a robot. Invela has through its work with developing a new solution for prefab manufacturing of façade elements gone from thoughts around the traditional factory prefab solutions using different types of materials herein to the generating of a new company called Robot At Work. Robot At Work aims at getting small intelligent robot solutions on the building site and collaborating with the craftsmen doing the actual work precise and with less hazards involved.

The description below covers the implementation of both these products/systems on the Danish pilot project. As these concepts differ from the prefab building element implemented in the other geo-clusters in the MORE-CONNECT project the content of the description differs somewhat as there is no production of wall elements – so this section is not part of the description for Denmark. And the heading of 3.2 is changed to "Carrying out the renovation".

2.1 Preparation (making the building ready) for the mounting of elements

2.1.1 Innogie

The middle section of the roof of the Danish pilot building was prepared to make it ready for the mounting of the PV-roofing elements.

Fig. 1 The roof on the pilot building – ready for the installation of the PV-roof.

2.1.2 Invela

The gable walls were insulated by Invela with 250 mm mineral wool insulation and then plastered in a traditional way by hand – to make them ready for the robot decoration painting.

Fig. 2 One of the gable walls insulated (left) and plastered (right)

At the same time an artist prepared the logo to be painted on the gable walls.

Fig. 3 The logo of the building association FAB – designed by an artist – to prepare for the robot decoration painting.

2.2 Carrying out the renovation

2.2.1 Innogie

The PV-roofing elements were mounted on the same structure of the roof as the ordinary roof covering. The work is shielded by a movable plastic cover – mounted on a scaffold.

Fig. 4 Mounting of the PV-roof elements – left and middle photo. Micro-inverters have been installed at the top end of each row of PV-roofing elements – right photo.

2.2.2 Invela

The robot was installed onsite with a total working area of $120m^2$ and it performed a precision work on-site painting the logo directly on the gable in 25 minutes.

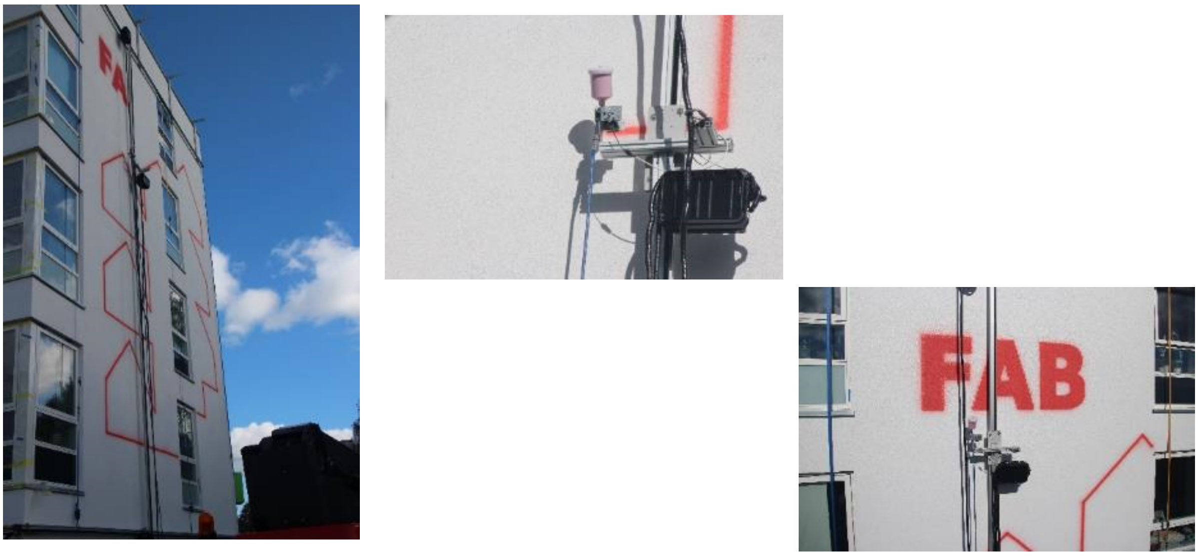


Fig. 5 The modular robot installed on one gable wall to cover the painting in one step (left). Close up of actual painting part (mid and right).

The process was programmed in 20minutes in Fusion360 (Autodesk drawing program) and then the robot onsite was started by the push of one button on the smartphone interface

2.3 After the renovation – showing the final result

2.3.1 Innogie

The approxemately 400 m² PV-roof was installed on the Danish pilot building using 180 person-hours.

Fig. 6 PV-roof on the finished renovated Danish pilot building

Fig. 7 Details showing the flashing around a ventilation outlet.

2.3.2 Invela

The logo design of the building association FAB has been painted by the robot developed by Invela on the vertical gable walls on each end of the building. One end in blue – at the other end in red. The robot was installed onsite with a total working area of 120m² and it performed a precision work on-site painting the logo directly on the gable in 25 minutes.

This process was programmed in 20minutes in Fusion360 (Autodesk drawing program) and then the robot onsite was started by the push of one button on the smartphone interface.

Fig. 8 The gable walls decorated by the scalable robot.

3 Estonia

3.1 Preparation (making the building ready) for the mounting of elements

Estonian pilot building is a 5-story dormitory building with total area 4318 m2, constructed in 1986 and analogous to mass production apartment buildings (series 111-121) from 1960-1990. Existing 250mm concrete panel exterior wall consists of 2 concrete sections and insulation layers: 60mm external reinforced concrete slab + 70mm wood-chip insulation layer + 50mm phenolic foam insulation layer + 70mm internal reinforced concrete slab. The existing flat roof with parapet is covered with bitumen felt and insulated with wood-chip boards. The thermal transmittance of the existing envelopis U=0.9_1.1W/(m2·K).

Preparation of the building before mounting the wall elements consisted mainly of mounting the steel support brackets on the walls. Before that was removed balcony concrete railings as these would be replaced by new wall elements. Each existing concrete wall element external layer was anchored to internal load bearing layer with inclined steel rods/anchors.

For new roof elements was added wooden roof trusses on top of existing horizontal roof. Some difficulty accessible ventilation piping was mounted before new roof.

3.2 Production of elements – incl. design process and characteristics of elements

The building envelope above ground (walls and roof) is planned to be insulated with prefabricated modular panels. Basement walls are planned to be insulated with an external thermal insulation composite system. Prefabricated modular panels consist of a timber frame structure filled with mineral wool. In principle, also other lightweight structures and insulation materials are conceivable. To get accurate information about the unevenness and roughness of the existing surfaces and inhomogeneity of windows location, 3D laser scanning of the envelope was conducted before the design.

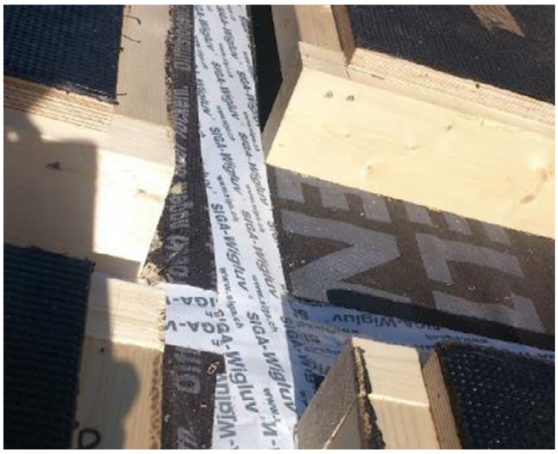
The total thickness of designed modular wall elements is 340-380mm, depending on the surface flatness of the existing wall. The total thickness of the thermal insulation in wall panels is 305-345mm:

30mm wind barrier, 70+195mm insulation between timber frames and 10-50mm light elastic mineral wool to fill the unevenness and roughness of the existing surfaces, U_{wall}=0.11-0.12W/(m^2·K). In the wall panel with dimensions ≈2.7×9m, installed in horizontal direction, are up to three preinstalled windows. To minimize joints between the modules and connections of pipes on site, the panels with ventilation ducts will be installed in vertical direction. According to the structural design of the pilot building, there is no need for additional foundation for the wall module panels. Self-supporting modules will be hanged onto the existing wall surface with the help of designed fixings, allowing adjustment of modules in all directions.
Designed roof elements will be installed on the specially built timber frame because the original roof has an inward slope and parapet. Therefore, under the formed slope roof, in 0.6-1.2m high attic between old and new roof technical appliances are planned to be placed (e.g. heat exchangers, duct dispensers, automatics etc.). The total thickness of the thermal insulation in the roof modules is 340mm, Uroof=0.10W/(m2·K).
To avoid thermal bridges and to minimize the impact of air leakage and convection, smart connectors and innovative fixings, adhesive sealants and elastic polyurethane (PUR) foam will be used in the joints between the modules. All vertical joints between wall modules will be protected with sealing and steel strips under the facade boards. Horizontal joints will be equipped with slits (drip molds) to prevent rain penetration to the insulation. All internal intersections between modules will be sealed and filled with expansive PUR foam. To avoid having to tighten the existing envelope, it is planned to ensure the airtightness of the building with prefabricated highly-insulated modules.
Pre-design (architecture, static calculations, vent., heating, elect., etc.) has been carried out by another company. AS Matek held only design of timber frame elements (external wall and roof). AS Matek's design consists of three stages: AD-approval, ED-elements, MD-montage (assembly). AD- we study customers drawings (in this case pre-design) make necessary adjustments according timber frame element production and approve solution with customer. ED- we design according AD a work drawing for factory production. MD- we design assembly drawings (plans, sections, elevations, details, specifications, etc.) with what the assembly team can assemble elements and finish the building.
There were very large (10x3m) and heavy elements which were unusual to produce. Also, wall construction was not suitable for mass production, especially wind barrier - soft mineral wool board, where we had to use distance bushings to get battens on the same level, very time-consuming. To small façade board joints made assembly (in factory and on-site) difficult and time-consuming. Windows were mounted in the factory as well ventilation pipes inside the elements.

3.3 Mounting of elements – carrying out the renovation

Mounting of wall and roof elements was done simultaneously from both side of the house in sections. Mounting started with wall elements from ground floor up.

As soon as top floor wall was mounted was also mounted roof elements on top of these wall elements to protect mounted elements from the weather. Roof elements joints were quickly closed from outside to get the roof watertight.

Later works regarding walls included mainly sealing walls joints outside and covering horizontal joints with steel sheets and vertical joints with facade boards.


Later roof works consisted of covering the soffit with same facade boards as on the walls. It proved to be very difficult task because of large size and heavy weight.
All outside works were done from big lifts. There were used no scaffolds.

3.4 After the renovation – showing the final result

The preparation and building works on installation of the modular elements were started in June 2017 and ended in August 2017. Thorough inspection and supervision of processes by producer of elements, by main contractor and the owner's supervisory representatives was helping to finish the works on time without any remarkable backstrokes. Some dealys were caused by weather conditions and adjustable support brackets, but no serious complaints from stakeholders were noticed or placed because of quality or technology issues of prefabricated modular elements. The monitoring of the building envelope after the building phase with hourly monitoring system has prooved that hygrothermal performance of the building is in accordance with expectations and tasks formed in the design and/or construction phases.


4 Latvia

4.1 Preparation (making the building ready) for the mounting of elements

Latvian pilot building is typical brick multi apartment building built in 1967. The pilot building is silicate brick residential house with a lateral bearing system. The house has a wooden roof structure with slate covering. The building has simple, rectangular floor plan. It has two floors with similarly designed flats. The house has a hip roof with a number of chimneys. All old wooden windows are replaced by PVC windows 7 – 10 year ago. Building represents typical building constructed in 50ies – 60ies last century. This type of building is very common in rural areas and small cities.
Overall 3D scanning process using drone took less than 5 hours. Scanning process included the following steps:

- Flight planning and preparing - 1 hour
- Flight and capturing images (arrival time to an object is not included): 1 hour and 30 minutes
- Processing photos in ContextCapture Master and searching for control points in Cloud Compare Searching for control points and indication (including control points area editing) - 3 hours and Creating production (reality model) - 2 hours 12 minutes

4.2 Production of elements – incl. design process and characteristics of elements

Based on point cloud creation of BIM model took 16 working hours. Then architectural project was developed within one month. Panel production took 25 days and 5 day were spent for on-site panel mounting. The main lessons learnt are:

- vertical shift up to 5 mm for each panel accrued for each panel led to an overlap between the last panel;
- more precise measurement instruments such as laser levels and crane lifting beams should be used;
- architect should be able to work in BIM in order to insure smooth data transition. Based on public procurement the cheapest offer was selected. Thus, extra effort from project staff was needed to contribute to the development of architectural project in BIM environment.

Fig. 1 Preparation (making the building ready) for the mounting of elements

Preparation (making the building ready) for the mounting of elements included remove of existing window sills, entrance overhang and rain gutters.

Joints sealing tape

Connection groove

Fig. 2 Production of elements

All panels were delivered in one truck.

4.3 Mounting of elements – carrying out the renovation

Fig. 3 Mounting of elements

Wire rope slings were used

Corner junction reinforcement

The prefabricated panels mounting was done using only mechanical level to ensure horizontal and vertical alignment of the panel plane. Due to this inaccurate method a slight vertical shift up to 5 mm accrued for each panel. This led to an overlap between the last panel with the first panel. Based on this experience it is recommended to use theodolite or laser level to insure panel strict vertical placement without any vertical or horizontal shifts.

4.4 After the renovation – showing the final result

Fig. 4 After the renovation

Intermediate results before final sealing

Final result

During the renovation a slight delay occurred due to weather condition. The final sealing was postponed due to limited possibilities to insure smooth gluing of the sealing tapes, surface priming as well as final painting.

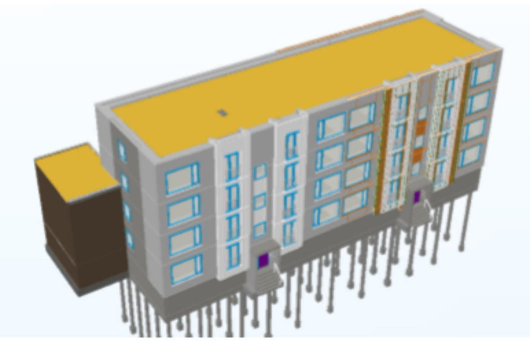
5 The Netherlands

The demonstration project in the Netherlands is situated in the city of Arnhem in the district Presikhaaf. In this demonstration project four porch types residential buildings, each with 16 apartments, from 1963 have been completely renovated, using prefabricated façade elements. After the renovation, the houses have a very nice appearance and completely up-to-date. In addition, they are equipped with new ventilation systems (mechanical ventilation with heat recovery).

Project data:
Initiator: Volkshuisvesting, Bouwnext, Vastbouw
Realized: 2016
Number of homes: 64
Renovation: prefab façade elements, added to the building envelope and roof insulation, air tight building envelope
Building services: new mechanical ventilation systems with heat recovery, counter flow heat exchangers. Renewables: will be added later, by adding PV panels, to make the buildings zero energy.

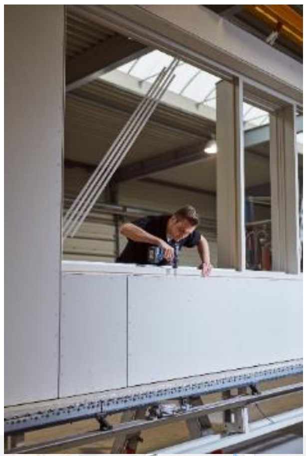
5.1 Preparation (making the building ready) for the mounting of elements

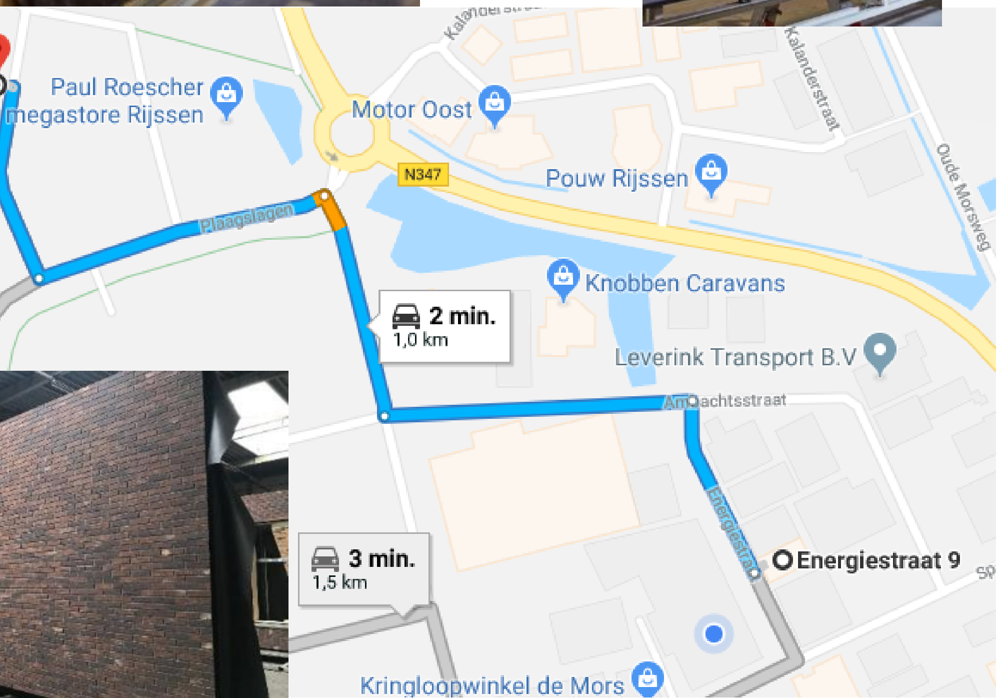
Presikhaaf is a typical example of industrial prefab renovation. An as in every industrial renovation process, industrial building starts with virtual building, or 'bimming'. Virtual collaboration, giving feedback and developing. WEBO uses this phase to ensure that their products are placed in the specific model.
Bimming is a process of co-generation, working together. In this phase the WEBO engineers design the project specific solution and share their BIM library. Insight and knowledge therefore lie ahead. WEBO is building virtually with the IFC model and also use the data in the production processes. Files are read one-to-one in an ERP system. From quotation to delivery.
From incoming goods to deliverable products: virtual building is industrial building.
Fully automated production and assembly: the machines and processes produce directly from the BIM model. The accurate result is there in an instant. WEBO manufactures large and small orders in a minimum time. and deliver ordered products to the construction site as quickly as possible (JIT – just in time).

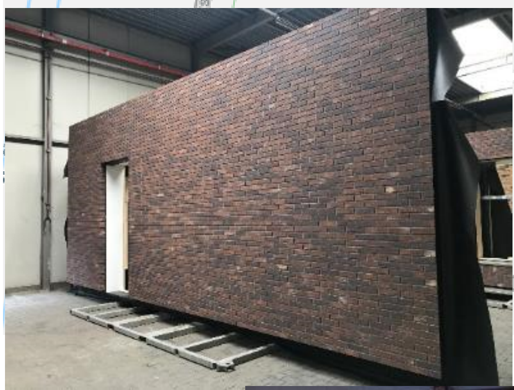



5.2 Production of the elements

The assembly of the prefab elements/ facades is stationed at the HSB production location at the Propaanstraat 7 in Rijssen. Thereafter the elements are transported by forklift truck to the Energiestraat 9 Rijssen. At this location the elements are finishing with outside surface materials.







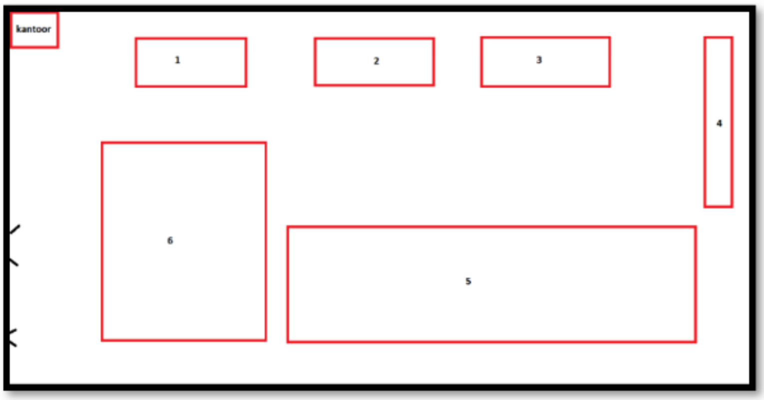
The assembly and finishing of the elements at different locations have several disadvantages:

1. Additional transportation time between location.
2. A lot of communication is required to manage the transportation between the locations.
3. Extra storage is needed as a buffer.

4. Suppliers need to deliver at different locations.
5. No overview of the complete product resulting in possible quality risks.

At the beginning of 2018 WEBO investigated the possibilities to move the assembly of the Steigerloos elements also to the Energiestraat 9. To do so, WEBO faced several challenges. One of them was that the spaces where not large enough anymore to move the elements internal by forklift. Therefore we designed special carts to move the elements with a small mover.

After studying the lean principles and the characteristics of the product we decided to switch from a QRM method, used for low volume and high variety products, to a line production in order to fit the complete production in the facility. At first we started to with a production line with 3 stations, later on we decided to switch to 4 working stations for a better balance.



After the assembly of the elements they are put on the cart toward the station where they are finished with outside surface materials.

Together with a new crane and packaging machine to prepare the elements for transportation we completely renewed the production process. As this process is implemented quiet recently it is at the moment hard to give an exact result of this improvement but the reduction of production hours will be between 15 and 25% and the reduction in lead time between 4-6 days. All the improvements are achieved with a team of co-workers.

5.3 Mounting the elements

WEBO has a unique way of building renovation, the so called scaffoldless renovation methods. Avoiding the use of scaffolds reduces the renovation time as well as the hinderance for the occupants.
In following picture the situation before renovation is shown:

The scaffoldless renovation process is shown if following pictures:

5.4 After the renovation – showing the final result

Following pictures show the final results after renovation:

6 Portugal

6.1 Preparation (making the building ready) for the mounting of elements

Implementation in the Portuguese pilot building is behind schedule. Therefore, preparation of the building so far consists of the planning phase for the mounting of elements. In particular, documentation regarding technical specificities and detailed drawings were prepared (Figure 1 and Figure 2). In addition, a preliminary survey of technical condition of pilot building has been conducted and data on building heat consumption has been analysed. IAQ measurements and airtightness tests were also performed. The building is under continuous monitoring (temperature, CO_2, relative humidity) since March 2016.

Several meetings between the partners of the project (companies, university and the public company owner of the building) are taking place to discuss technical issues of the renovation.

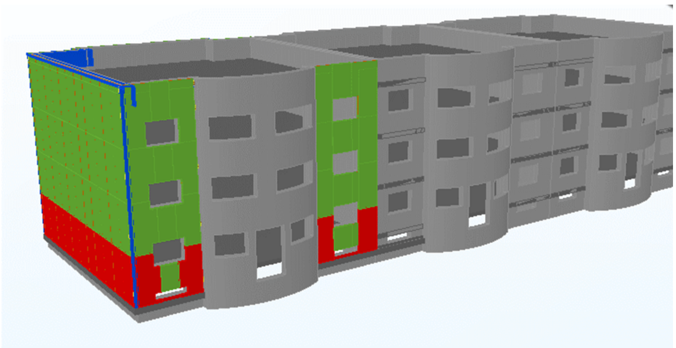


Fig. 1 – Planning of prefabricated panel positioning in the pilot building

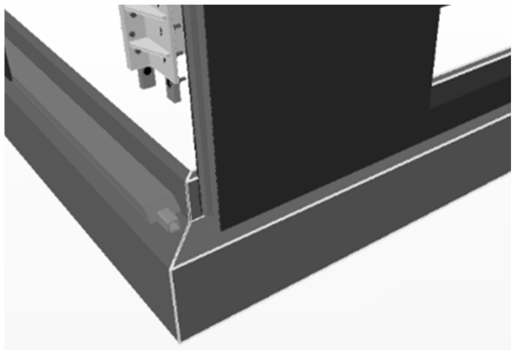


Fig. 2 Detail of lintel to be executed as a preparatory work

6.2 Production of elements – incl. design process and characteristics of elements

At this stage, no elements, besides the prefabricated modules prototypes used for testing, were produced. Start of panel productions is planned to occur until the end of November 2018.

6.3 Mounting of elements – carrying out the renovation

Preparatory works on site are planned for end of February 2019. Mounting of elements is scheduled for March 2019.

6.4 After the renovation – showing the final result

Delivery of completed renovated site is foreseen in March 2019.