Sets of PnP prefab components for building envelopes

Deliverable D1.1

Deliverable D1.1, issue date on 31 August 2017

P2ENDURE

Plug-and-Play product and process innovation for Energy-efficient building deep renovation

This research project has received funding from the European Union's Programme H2020-EE-2016-PPP under Grant Agreement no 7723391.

P2ENDURE
PLUG & PLAY BUILDING RENOVATION

Sets of PnP prefab components for building envelopes

Deliverable Report D1.1

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Colophon

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Publishable executive summary

P2ENDURE promotes evidence-based innovative solutions for deep renovation based on prefabricated plug and play (PnP) systems. The primary objective of this deliverable report is to provide a critical review of the novel PnP prefab components and systems for deep renovation of building envelopes.
The following PnP technological solutions have been selected to ensure the achievement of the project's goals:

- FC multifunctional panel
- EASEE multifunctional panel
- Smart window
- Rooftop retrofitting
- Folding balcony (commercial product)

The present document describes the work done within task T1.1 and zooms in on the examination of the above mentioned PnP prefab components along with the manufacturing and installation techniques. In the context of the task's objective of optimisation of the solutions, the report addresses also the suitability and possible implementation of these technologies in the renovation process of the demonstration cases.

In addition, the initial performance criteria and requirements in relation to energy, material use, and costs and an optimisation plan for each product are examined. The on-site assembly procedures are also described and preliminary implementation plans for some of the demonstration sites have already been identified.
Based on the requirements pointed out by the building owners during the Technical Workshop in Warsaw, PL on 31 Jan. – 2 Feb. 2017, further follow-up actions will be addressed in the course of the project in order to meet the end-users expectations. The next steps are the creation of BIM models of the proposed products and subsequently, working on a more detailed planning of the assembly process. The combination of these renovation solutions will be analysed within the concept of integrated packages, which will be extensively addressed within D1.2 due at month 36 (August 2019).

List of acronyms and abbreviations

BIM	Building Information Model
EASEE	European project called: Envelope Approach to improve Sustainability and Energy Efficiency in existing multi-storey, multi-owner residential buildings
FC panel	Panel developed by partner Fermacell
FMC	Fermacell
GA	Grant Agreement
HVAC	Heating, Ventilation, and Air Conditioning
IDRP	Innovative deep renovation product
IEQ	Indoor Environmental Quality
KPI	Key performance indicator
kWh	The kilowatt hour
MEP	Mechanical, electrical, and plumbing
PnP	Plug and Play
TES	Timber based Element Systems

Contents

1. Introduction

The P2ENDURE tasks T1.1, T1.2 and T1.3 are focused on analysis and selection of the advanced technologies allowing energy-efficient advanced deep retrofitting of existing buildings. Thus, the tasks are focused on selection, consolidation, optimisation and integration of innovative PnP prefab components (T1.1 and T1.2) that are necessary to achieve the targeted quality and performance in terms of energy-, cost- and time-saving as well as improved Indoor Environmental Quality and reduced disturbance during on-site processes.

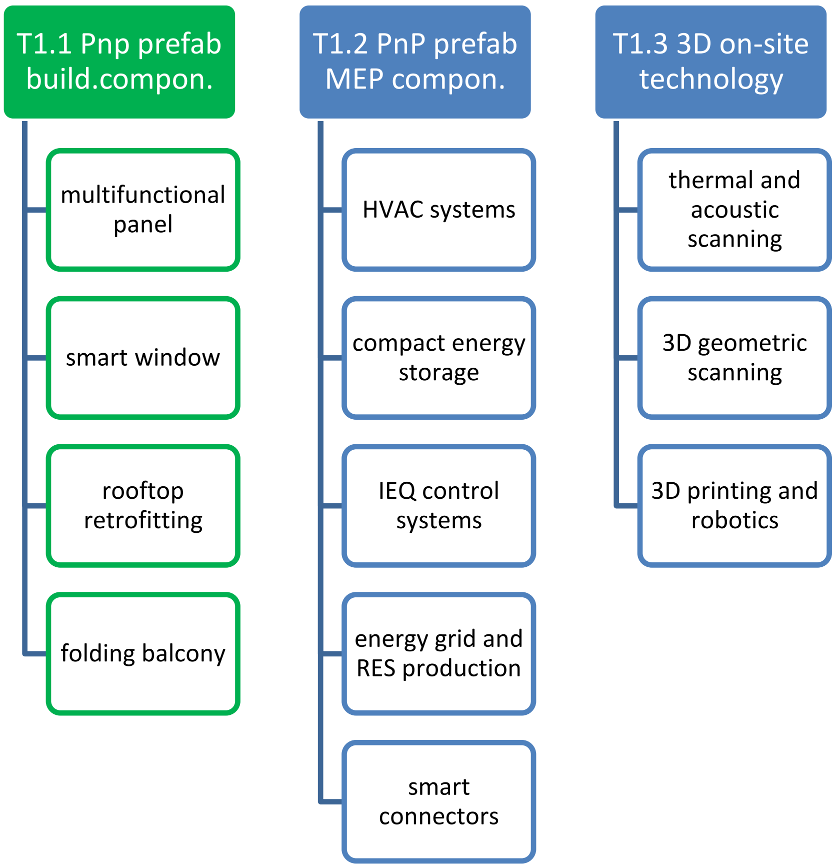


Figure 1: Allocation of the D1.1 inside the Work Package 1

This deliverable report provides a critical review of the novel PnP prefab components and systems for deep renovation of building envelopes. Figure 1 shows the selected products within P2ENDURE corresponding to each of the WP1 tasks.

Regarding the 'multifunctional panel category, in this report there are two multifunctional panels described: 1. the FC panel designed by the consortium partner – Fermacell (FMC) and 2.

the EASEE panel, which is a result of a European research project[1] under GA contract number 285540. The owner and supplier of the EASEE panel is the Italian company Magnetti, also a stakeholder within P2ENDURE, which is represented by the project partner - RINA Consulting (previously D'Appolonia). Secondly, the supplier of the smart windows is project partner - Bergamo Tecnologie (BGTEC).

The design of the rooftop retrofitting module is being addressed by the project partner - PAN+ Architects. This specific solution should be understood more as a service than a product that aims not only to improve the energy efficiency of the building but also to extend the building with an additional floor to increase the usable space.

Last, but not least, the folding balcony is an innovative commercial solution, which does not require further optimization within the project. The product was included in P2ENDURE to show new possibilities in building renovation.

During the Technical Workshop that took place in Warsaw during 31.01-02.02.2017, all solutions were presented to the building owners and their representatives. The proposed solutions were confronted with the needs of the end-users. As a result of various technical meetings and discussions, key issues with regard to the performance and optimisation of these products were identified. This is also in relation to the building owners' expectations on cost and energy effectiveness of the proposed solutions. Thus, the cost, time and energy efficiency were pointed out as the most important KPIs to be addressed in P2ENDURE (Figure 2) when dealing with renovation works and on-site disturbance.

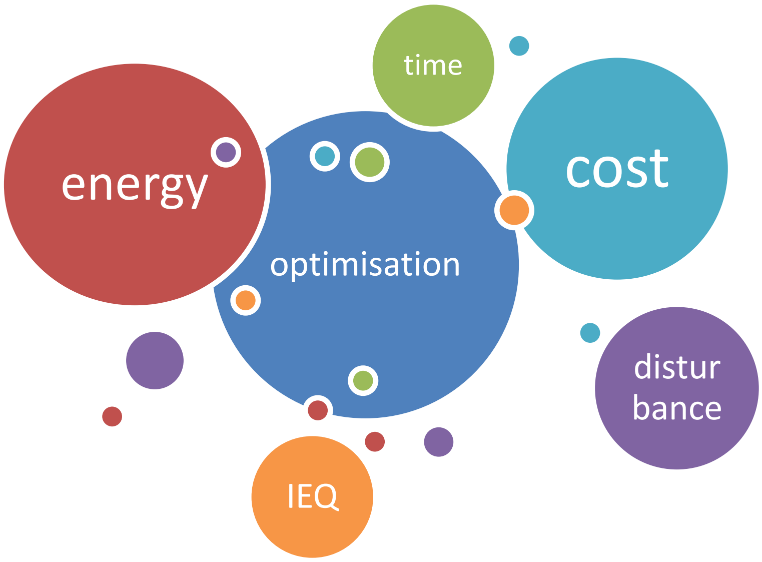


Figure 2: Examples of identified KPIs

[1] http://cordis.europa.eu/project/rcn/102518_en.html

2. PnP prefab components for building envelopes

2.1 FC multifunctional panel

2.1.1 Short description of the product

Within the project P2ENDURE new type of multifunctional façade panels will be developed. Fermacell (the panel developer) is a producer of construction kits for the dry lining industry basing on gypsum fibre or fibre reinforced cementitious boards. The product range comprises wall and ceiling systems and rain screen façades for indoor and external use. Furthermore Fermacell is in many countries the market leader of timber frame constructions i.e. where the cladding – the Fermacell gypsum fibre
or cementitious boards – take over load bearing functions and can replace e.g. chip wood boards as a not inflammable product. The fire safety of construction products is determined through Euroclasses. The Euroclasses were introduced following a resolution of the Commission (2000/147/EEC) from February 2000 to create a common platform for the comparison of the fire properties of construction materials. The materials belonging to class A (Non-combustible – Best performance for both flame spread and penetration) like gypsum or cementitious boards allow to create with wooden substructure façades that have sufficient fire resistance.

Fermacell knowledge and expertise will also allow to integrate different installations (like HVAC) within the façade panel and to perform the design in order to fill the durability, thermal and fire resistance requirements. The goal is to integrate existing on market materials in order to achieve new functionalities of the façade panels:

- Versatility: retrofitting solution applicable to many of the old and un-renovated buildings;
- Quick to install, especially in urban areas with limited space for material, handling devices and storage area;
- Compliance with current building regulations with regard to building physics, comfort and durability;
- Possibility of the implementation of heating, ventilation and air conditioning devices according to local and users' needs;
- Design concept for the horizontal and vertical installation of tubes and ducts either pre-installed or installed on site.

The solution that will be developed is a versatile prefabricated façade panel composed from a wooden substructure that will allow integrating: water ducts and pipes, air supply or/and even ventilation channels, heating and cooling functions.

Fire properties of the materials that can be applied during retrofitting or building construction depend also on the building height. Different European countries have their own national definition of "high rise buildings", for instance for Germany it is a building height of >22m and in case of Poland > 25m or buildings > 4 floors. For those high rise buildings special fire safety requirements need to be fulfilled in order to avoid fire propagation. For high rise buildings use of materials (insulation) with the reaction to fire class of A1 or A2 and the use of steel substructure elements is recommended. For the buildings <22 or <25m wooden substructure can be applied.

Due to the fact that a wooden substructure is relatively ease in fabrication and more cost-efficient, this type of substructure was chosen for the multifunctional façade panel. However - if needed - the wooden substructure can be easily changed to a steel substructure.

Gypsum fire boards are produced by Fermacell according to EN 15283-2 + complementary ETA´s and glass fibre reinforced cement boards according to EN 12467 + complementary ETA´s. In order to make the product "board" applicable and easy to use, Fermacell delivers many construction kits for walls, ceilings, floors, roofs and façades. Within the P2ENDURE project Fermacell will develop a construction kit "versatile Plug&Play façade for renovation" that will be a solution for deep renovation of existing buildings. The construction kit will be mainly a design guideline how to properly design such a Plug&Play façade with the use of wood or steel substructure in combination with gypsum fibre and/or cementitious boards.

At the very beginning of the design process a literature search was made which yielded many results but only two results showed a good match with regard to a Plug&Play approach. The project TES EnergyFaçade[2] focused on the development of methods to modernize existing buildings – with low comfort and thermal performance – with prefabricated timber based solutions (TES = Timber based Element Systems) which are installed on top of the already existing outer shell of the building. The report gives clear indication how supports and connections between the elements have to be correctly designed (Figure 3) and which thicknesses are required in order to match building regulations. Within the project special attention was paid to the planning process of such projects which encompasses the measurements on site, the processing of these data, prefabrication in a factory, the installation method on site and finally the maintenance of such façade elements.

[2] TES Energy Façade – prefabricated timber based building system for improving the energy efficiency of the building envelope. Wood wisdom Net Research Project 2008-2009.

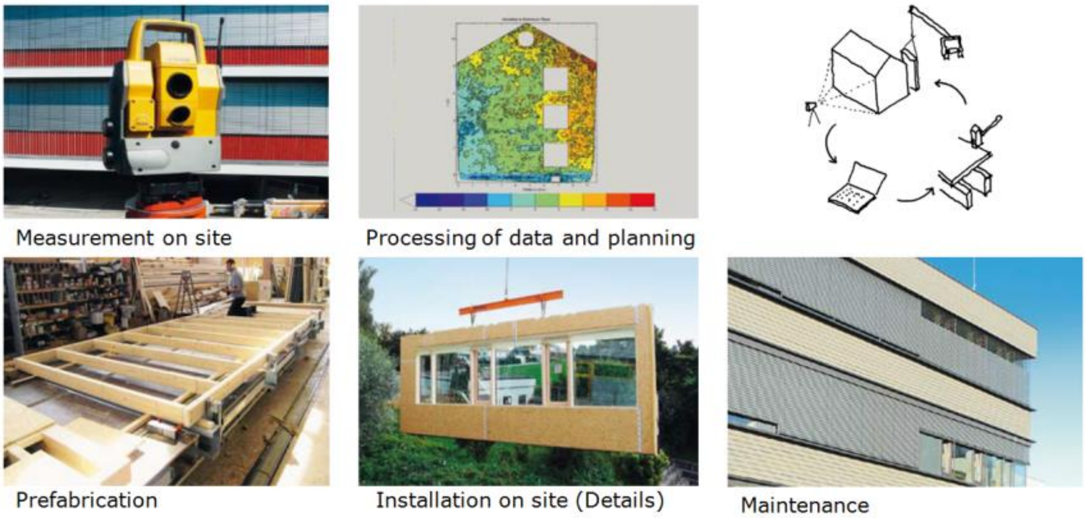


Figure 3: TES-project – scope and implementation

TES project is not dealing with the installation of ducts or vents in real projects, nor with the installation of HVAC devices. A step further goes IEA ECBCS – Annex 50[3]]: Retrofit module design guide which compiles the data from different research projects and which focuses more on installation of ducts in such prefabricated retrofit solutions (Figure 4). It also shows an example how a retrofit solution with a steel substructure could look like. In a nutshell: The Multifunctional façade panel adopts many of the ideas from the before mentioned research projects and is on top a holistic solution with regard to media supply, integration of heating, ventilation and cooling and related energy saving options. The Multifunctional façade panel offer furthermore the possibility to match building regulations with regard to fire safety – especially for multi-story buildings (height <22m in Germany[4])- by using as outer cladding materials with class A.

Figure 4: IEAIEA ECBCS Annex 50 - Prefabricated Systems for Low Energy Renovation of Residential Buildings Retrofit Module Design Guide

[3] René L. Kobler et al.: IEA ECBCS Annex 50 Prefabricated Systems for Low Energy Renovation of ResidentiaL Buildings Retrofit Module Design Guide (March 2011)
[4] Fermacell handbook 2017

As most of the buildings which could be renovated in the framework of the P2ENDURE project are houses with 2 – 3 floors, it was assumed to focus in the first step on a multifunctional façade panel composed of an outer A class cladding (in terms of fire) and a wood base substructure.
In order to obtain all necessary data about the geometry of existing buildings and correctly plan the design process, 3D-scanning methods were used. This approach will allow to correctly plan the prefabrication process and analyses what kind of duct implementation is feasible (vertical or horizontal) and what functionalities of the façade are needed (heating, cooling, ventilation, power supply, etc.).
The design of a multifunctional façade panel as construction kit will allow using of the Fermacell products or components by other companies to produce façades of such kind.

2.1.2 Optimisation plan in P2ENDURE

The results of the literature search and P2ENDURE innovation potential can be sumarized as depicted in Figure 5.

TES	Retrofit module design, IEA	P2Endure -novelties
Wooden substructure	Wooden and steel substructure	Wooden/steel sub.
Prefab	Prefab and site assembly	Prefab or site assembly **(distr. Fact.)**
Supports	Connectors	Connectors, fixations
Planning and installation on site	Not subject	**Digital planning + BIM**
Not subject	Not subject	**Marketing platform**
Not subject	Vertical duct integration	**Vertical and horizontal integration of ducts/media**
Not subject	PV-Panels	**Implementation of HVAC**

Figure 5: Findings of literature search

In order to come closer to the goal of Plug&Play and multifunctianal façade the most important issue that need to be developed and analysed are: the horizontal and vertical integration of all kinds of ducts and the integration of Heating, Ventilation and Air Conditioning devices (HVAC). - Table 1 below shows the actual status of Fermacell façade panels and planned novelties for multifunctional façade panel developed within P2ENDURE project for reftrofitting purposes.

Current features of Fermacell panels	Targeted improvements	P2ENDURE novelties	Planned actions
Wooden substructure with mineral wool infill and A-rated cladding for walls of buildings both load bearing and non load bearing. Low amount of installation, mainly electric supply, randomly distributed. Mostly prefabricated and then transported to the construction site	Façade and walls with defined installation ducts/channels for water, electric supply and air supply. Furthermore integration of heating, cooling and ventilation functions in walls/façades in order to speed up installation process. Digital planning in order to speed up planning process and to enhance precision.	Vertical and horizontal integration of ducts/media and implementation of HVAC. Additionally planning is fully digital using methods like laser scanning and building information modelling (BIM). Centralized prefabrication is not mandatory, also local assembly on site is possible which offers chance to smaller companies to do such jobs.	Step 1: laser scan of implementation projects, eg. For Nursery demo building in Warsaw (Poland) Step 2: development of an adaptable system using A-rated material and integrating ducts/cables and HVAC components in order to create a multifunctional façade panel/wall Step 3: Prototype production and approval by consortium partners Step 4: Adaption of the approved prototype on implementation projects Step 5: Presentation on marketing platform

Table 1: Development of a retrofitting solution from current status to a multifunctional façade panel

2.1.3 Technical performance, specification and cost information of the optimised product

The main key performance indicators for a multifunctional façade panel are:

Reftrofitting costs of 1m² of envelope:

This cost is manly related with the labour cost in different country. Prefabrication is very cost effective in countries with high labour costs (Sweden, Norway, Luxemburg, the Netherlands, Switzerland). The buildings that are the " ideal candidate" for renovation with prefabricated elements are the buildings with architectural design that allows a high grade of standardisation. Within the P2ENDURE project the preeliminary cost analysis of the design with P&P façade elements was performed for theWarsaw demo nursery building. The calculated cost for retrofitting of walls was ~ **115€/m²**.

This calculation does not include tracing the installation ducts, cables and HVAC unit, the calculation was performed base on current price list of Fermacell components in Poland and base on average labout costs in Poland.

Performance with regard to energy:

The possible improvement in terms of energy performance for renovation with the use of multifunctional façade panels should be investigated based on live demonstration projects. The key performance indicators that will be analysed are: heat transfer coefficient of renovated wall and ventilation performance that can be influenced and improved by the multifunctional façade panel.

The heat transmission will be reduced by an improved U-value of the façade. The guidelines in Europe require U-values between 0,28 (Germany) – 0,20 – 0,23W/(m²K)[5] (in Poland for buildings erected after 01/01/2021 U<0,20) for exterior walls. The façade element, approx. 250mm thick, with a 200mm mineral wool filling between 60x200mm timber studs, will reach an U-value of between 0,20 W/(m^{3}*K) and 0,23W/(m^{2}*K) calculated according to EN ISO 6946 including ventilaton devices and ducts (so called "thermal bridges"). The range derives from different possible Lambda values of the mineral wool insulation material and the amount of wooden rips and installtion ducts needed (amount of wooden rips according to static requirements). By increasing the thickness of the façade element even better values can be reached. Current standards in e.g. Germany require for walls

U-values< 0,28[6]

For a Warsaw nursery demo building potential energy savings were calculated according to EN ISO 6946 and they are shown in table below:

Actual not retrofitted envelope energy performance value U [W/(m^2K]	Energy performance after retrofitting with multifunctional façade panels U [W/(m^2K]
1,215	<0,23 (<0,20 if needed)

Table 2: Potencial energy savings for a Warsaw nursery demo building

[5] National guidelines for building construction issued by Ministry of Infrastructure: Dz.U. Nr 75, poz. 690

[6] EnEV 2016 Germany (National guideline for energy saving 2016)

Next step is to assess the possible improvements of energy performance for heat recovery of the ventilation devices (in this case a central ventilation device called Schüco Vento Tec, technical data according to figure 14 or Appendix 1). In the case of the Warsaw demo building, the windows are opened currently (Figure 6) in order to ventilate the rooms (and at the same time the heaters are on). This can be avoided with a ventilation device with heat recovery (approx. 80%). The calculations were performed with the assumption that permanent ventilation is needed (nursery with many children) and that the ventilation device is only needed during the "cold" season between October and March (6 month, 5 days a week and 10h per day). The hourly fresh air requirement for one child has been taken from DIN 13779 (Ventilation for non-residential buildings - Performance requirements for ventilation and room-conditioning systems). The assumptions for the calculation can be found in Appendix 1.

Figure 6: Ventilation process with opening of windows during heating period in Warsaw nursery demo building

Calculated ventilated total energy savings are on the level of 961.750Wh per year. This value means that per "ventilated" child a saving of approx. 192.350Wh per year can be made if for each child a ventilation according to DIN 13779 shall be provided (DIN 13779 requires a hourly fresh air supply of approx. 20m^3/h per child, means that one Vento Tec ventilation device with a maximum flow rate of 100m^3/h can supply 5 children with fresh air). Ventilation by opening the windows is no longer needed, if such ventilation devices will be installed.

A direct comparison with the actual situation is not possible – not even an estimate basing on the measured actual leakiness of the building with a leakage of approx. 3656m^3/h. This is also related with the fact that this value does not consider the opening of windows which provide ventilation.

Embedded energy and recyclability potential:

The embedded energy was calculated on the basis of EPDs (Environmental Product Declarations) in which the embedded energy both for the Fermacell boards and the mineral wool were declared[7]. Minor parts like screws were considered as irrelevant. Wood is treated as the neutral with regard to embedded energy. All declarations base both on ISO 14025 and EN 15804.The values for the different materials from which the multifunctional envelope will be composed can be found
in appendix 1. As wood is treated as neutral the embodied energy can be calculated per sqm for the following cross section from inside to the outside: **20mm mineral wool - 12,5mm gypsum fibre board – 200mm mineral wool filling – 15mm HD board**. Details can be found in figures 14 and 15 with regard to the cross section of the façade panel. The embodied energy shows
a high variation depending on the specific weight of the mineral wool. If a 30kg/m^3 mineral wool is chosen, the embodied energy amounts to approx. **277 MJ/m^2 or referred to a service life[6] of 50 years of approx. 277/50 = 5,55MJ/(m^2*a).**

2.1.4 Off-site manufacturing / prefab procedures

The façade elements should be prefabricated. The prefabrication can take place in a factory and then the elements can be transported to the construction site. Another opportunity is the local production – called “local factory” close to the construction site, Figure 7.

[7] EPD-Fermacell Gypsum Fibre Panel EPD-FC-20-2010-1, EPD-Fermacell HD and Powerpanel 2012211-D-FMC-2012211-DEPD-FMC-2012211-D, EPD-Rockwool EPD-DRW-20120112-IBCZ-DE

Figure 7: Local factory concept

The proposed manufacturing process uses current production techniques – like line production – which is state of art in the prefab timber construction industry. Automated production is not mandatory all the manual work can also be done in ordinary workshops without production lines etc. The system is somewhat adaptable to local needs in terms of automatization of production. The same applies to the different steps of work which are necessary. If the manufacturing of the element was awarded to one company, the works e.g. with regard to the outer rendering can be awarded to another company which is doing this work on site. Full flexibility is thus safeguarded.

2.1.5 On-site assembly procedures

The elements should be produced by first arranging the studs and joining them by screws and then attaching the gypsum fibre board from one side. Subsequently the mineral wool should be filled in. On one side a vapour barrier should be installed either by installing a foil or using special gypsum fibre boards which have a vapour barrier laminated on top. Finally the outer layer – a cementitious board which is more durable with regard to moisture and frost – will be installed.

The next step is the installation of a thin mineral wool layer on the backside of the element which acts as a tolerance offset (the mineral wool is very soft and thus capable to offset tolerances of the building envelope). Furthermore steel brackets can be installed and also the final layer on the outer side – on top of the cementitious board – which could be either a plaster rendering or just paint (see Figure 8 for illustration) or even flexible tiles e.g. with clinker design.

Figure 8: Possible renderings – plaster, paint or klinker bricks

On site only the butt joints should be covered – either by profiles or by painting or plastering. Tubes and cables can be pre-installed and later can be connected by connector systems that is pressed on or simply screwed together. The same applies to ventilation ducts inside the façade which can be joined together either by adhesive tapes or by conventional joining techniques like bolted connections. Example of prefabrication of steel frames elements and on site installation process is shown on Figure 9.

Figure 9: Prefabrication of steel frames and installation[8]

2.1.6 Implementation in P2ENDURE Demonstration case

Multifunctional façade panel is the innovative solution in terms of material and media integration that is developed within the P2ENDURE project. Therefore this solution was not yet implemented and the first implementation will be done within P2ENDURE live demonstration projects.

In order to have a template for a first planning of a prefab façade one of the intended live demonstration projects – the Warsaw nursery – was selected. This project is appropriate for this type of renovation as the

[8] Stahl-Informations-Zentrum Dokumentation 560: Häuser in Stahl-Leichtbauweise

façade has a simple structure and can be accessed by truck, crane and forklift. Furthermore the substructure is concrete or light weight concrete which is ideal for fasteners and supports in terms of mechanical strength. The concept is either to install a ventilation device into the element with a high performance heat recovery (77 – 81% heat recovery) which will replace today´s ineffective ventilation (supported by opening the windows) or to guide air through the façade element by means of ducts with a central ventilation unit – e.g. located on the rooftop or the cellar. Furthermore this concept fits perfectly into the P2ENDURE thinking of Plug&Play. Required cables and ducts will be installed in a vertical (if needed also horizontal) installation duct which is accessible from outside. In order to avoid freezing the shaft is sufficiently insulated, if needed with a vacuum insulation panel. Figure 16 shows the concept of accessibility. Compared to a traditional renovation system – e.g. like external wall insulations systems commonly referred to as "ETICS" (Figure 10) – which are installed layer by layer with a high amounts of manual labour, this system is mainly prefabricated and allows a fast and accurate installation in cases were a certain repetition of equal elements is possible.

Figure 10: View of ETICS system

In combination with laser scanning technologies buildings with a more individual morphology can be cladded with this system as a fast generation of data is possible which can subsequently be used in order to produce tailor made elements. Pre-installation of ventilation devices, cables and ducts contributes to fast and efficient renovation processes because there is no need to demolish indoor walls, beams or other building elements. It may be concluded that application of multifunctional panels allow to keep the building as it is and transfer the supply systems (air, water, electricity, etc.) to the outside into well insulated building layer.

The preliminary installation sequence is shown in Figures 11 and 12. The prefabricated vertical installation shaft can be integrated, which is planned as follows (simplified):

- installation of façade supports/brackets and vertical beams or connection points on existing façade (1,2);
- Positioning of elements (one storey high, width not determined yet) on the supports (3);
- Fixation of element by anchors and screws (4).

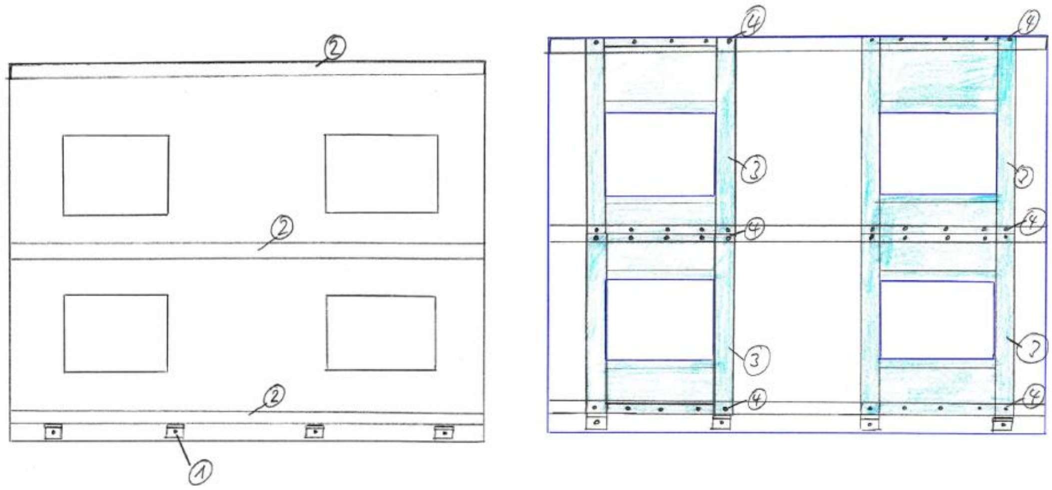


Figure 11: Installation sequence batten/support mounting + façade element installation

Next step is the Installation of ducts and cables and connection with ventilation devices (5, 6, 7). Figure 12 shows the closing of the installation shaft by lid, then the finishing works as corner installation, roof top sheet installation, etc. need to be performed.

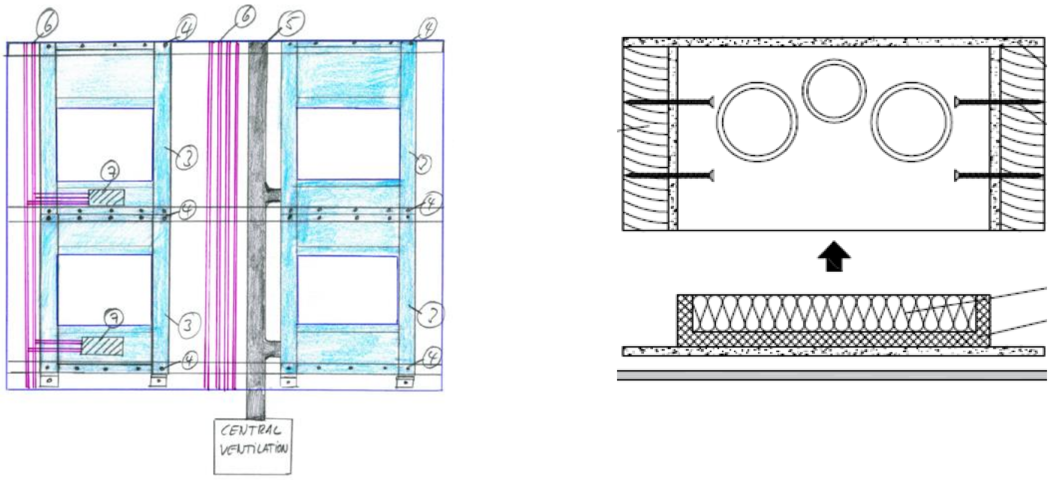
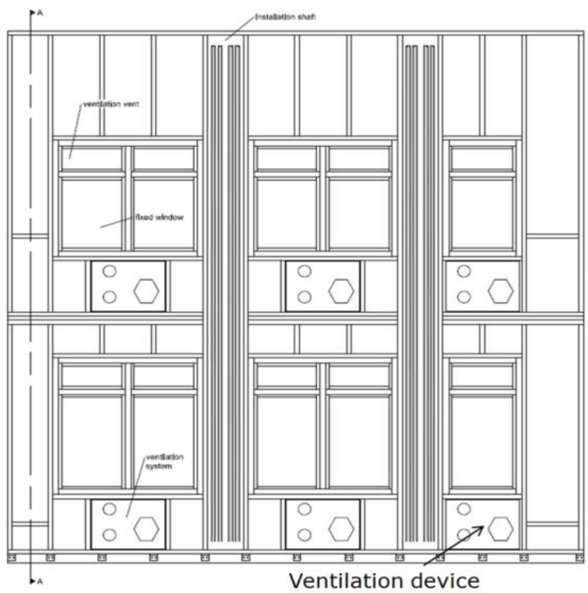


Figure 12: On the left installation of tubes and cables, on the right closing of installation shaft

For the Warsaw nursery demo building a preliminary design for renovation of the building with multifunctional façade panels was performed, see Figure 13. The design contains the localisation of ventilation units that can be installed under windows elements. There is also the possibility to use the ventilation units with heat recovery systems, see Figure 14.

Figure 13: Preliminary design of renovation with multifunctional façade panels (done by Fermacell)



Technical data for Schüco Vento Tec			
Feature	Level 1	Level 2	Level 3
Device dimensions (B x H x T)	860 x 710 x 140 mm		
Volume flow	50m³/h	70m³/h	100m³/h
Level of heat distribution	81%	79%	77%
Sound power level (Lw)	43dB	48dB	55dB
Sound pressure level (Lp)	35dB	40dB	47dB
Operating limits	-15°C to +70°C		
Power consumption	16W	22W	40W
Material class	B2		
Thermal insulation of fan in panel	U = 0,75W/(m²K)		

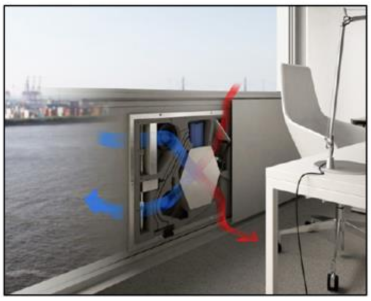


Figure 14: Façade design showing the vertical installation channels for tubes and ducts

In order to assess the feasibility of the structure the next step was to construct a prototype in scale 1:1 in the Fermacell premises in Germany, see Figure 15. This concept was assessed by the consortium partners (including Mostostal and Fasada – companies with expertise in renovation) and will later be optimised and where necessary be changed. The detail description of this construction will be implemented in Deliverable D4.5 "Optimised prototypes of PnP prefab components and integrated packages" (M24).

Figure 15: Prototype of multifunctional façade panel constructed by Fermacell

2.2 EASEE multifunctional panel

2.2.1 Short description of the product

EASEE panel is a product developed by the Italian Company Magnetti Building[9]. Although Magnetti Building is not a member of the P2ENDURE consortium, it agreed to share information on its innovative technologies. The following section has been completed by Rina Consulting and Fasada, which cooperated with Magnetti within the FP7 EU-funded project "EASEE" (Envelope Approach to improve Sustainability and Energy Efficiency in existing multi-storey multi-owner residential buildings, grant agreement no 285540)[10] – from which the name "EASEE panel" comes from.

EASEE panel is a prefabricated insulating panel whose purpose is to reduce the time for retrofitting operations and to guarantee adequate thermal energy savings by reducing the thermal transmittance of the walls. It is composed of two external layers of Textile Reinforced Concrete (1.4 cm each) and an inner insulation layer made of expanded polystyrene (10 cm). The total thickness of the panels is 12.8cm, but it may increase if needed. The widths of the panel ranges between 0.5m-1.5m, while the height between 1.5m – 3.0m. The weight of the panel is around 54 kg/m2.

EASEE panel can be applied to concrete slabs or to brick/cellular concrete blocks, significantly improving their thermal properties: U<0.23 W/m^{2}K for retrofitted wall (this value was validated within the EASEE project). The anchorage system allows for fast installation - 50% shorter than in traditional retrofitting - flexibility and adaptability to different architectonic configurations and building typologies.

Lastly, the panel's high aesthetic properties and several finishing options (due to the material used for the external layer, TRC) make it suitable for application to buildings under cultural heritage protection. The images below show some of these options.

Figure 16: Finishing options for EASEE panels

[9] http://www.magnetti.it
[10] http://www.easee-project.eu/

The images below show the texture that has been used in the EASEE project demonstration buildings in addition to the smooth surface. That the EASEE panels can be manufactured in every kind of colours (within the EASEE project: light gray, gray and charcoal, yellow were used).

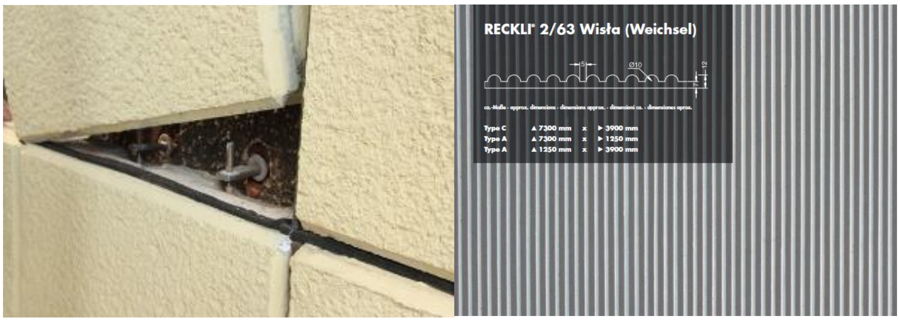


Figure 17: Different panel textures used in the EASEE project

2.2.2 Optimisation plan in P2ENDURE

The quality of the product is high in terms of both the insulating material and the design. Indeed, data and thermal photos from previous research activities have showed that EASEE panel attenuated the heat flux reducing the energy losses and the thermal bridges. In particular, the monitoring campaign performed demonstrated a decrease in U-value by 65%[11]. Moreover, because of the thermal inertia of the panels, the external solution allowed to reduce the indoor ambient air temperature during the summer. Thus, the test façade was able to slow the rate at which the sun heats the indoor space.

Nevertheless, the current version of EASEE panel is not yet definitive, as some improvements are needed in order to make the panel more customizable and to simplify the manufacturing procedure. Particular attention must be paid to the technological aspects that are not handled by MAGNETTI (formwork and hanging). The following table summarizes the improvements targeted within the P2ENDURE project.

Current features of EASEE	Targeted improvements	P2ENDURE novelties	Planned actions
Vertical formwork	Faster and cheaper manufacturing process	Possibility to cast the panel in horizontal formwork	Optimization of manufacturing process that will allow efficient manufacturing with the use of horizontal formwork
Insulation core with thickness of 10 cm of EPS	Better thermal properties of the panel in order to fulfil new requirements	Increase of the thickness of the insulation or use of material with lower thermal	Analysis of the manufacturing process with variable thickness

[11] From the Fp7 project "EASEE" D8.2 – Performance assessment of the 3 demo buildings (public).

	for the walls U<0,2 W/m²K	conductivity coefficient - λ	and material type (base on Italian and Polish thermal requirements fo retrofitted buildings)
Rectangular panel shape	New panel shapes	Possibility to cover the buildings with various panel shapes in order to achieve better architectural appearance	Advancement equipment for the production

Table 3: Optimisation process

2.2.3 Technical performance, specification and cost information of the optimised product

EASEE panel is an insulating panel aimed at reducing the time for retrofitting operations. Therefore, its Key Performance indicators are:

- Energy performance in terms of building physics (possible U value): The goal is to improve the energy performance
  of panels in order to fulfil the coefficient U<0,2 W/m2K for retrofitted wall.
- Estimated manufacturing/production cost per m2: price of the finished panel at full production volume <150 €/m2[12]
- Installation time: The average time of installation of 1 m² of EASEE panels with a size of 0,5 x 1,5m for demonstrator in Gdansk was 25 minutes (**1h = 2,5m²**)[13]. However this installation time is valid for the building wall without the windows opening, this time also does not takes into account corner finishing. In comparison the installation of 1m² of system based on ETICS (manual application of insulation material EPS, mesh and plaster) takes 120 minutes (1h = 0,5 m²) – based on Fasada internal data. The goal is to keep the installation time for small size panel
  at level of 1m² < 60 minutes for the wall with window opening, what results in 50% reduction time of installation in comparison with ETICS.

[12] Cost provided by Magnetti.
[13] From the FP7 project "EASEE" D8.1 EASEE solutions applied to demo buildings (public)

2.2.4 Off-site manufacturing / prefab procedures

The actual manufacturing process is based on the equipment developed by the STAM Tech (consortium partner of EASEE project). Most of the panels manufactured within the EASEE project were casted in a vertical formwork. However it is worth considering that a horizontal layout process also can be used and will be analysed for manufacturing optimization. The main manufacturing steps are:

- The height of the panel to be produced is adjusted, operating the side of the formwork and setting;
- The orthogonal sides, that set the width of the panel, are placed and fixed, as well as anchors and any additional element;
- The demo building grease coating is spread all over the formwork surface;
- The first concrete layer is casted, with the required surface finish level;
- The reinforcement (reinforcement bars or "rebars", plates or fibers) are put in position;
- Another layer of grey concrete is casted;
- The concrete layers are compacted through mechanical vibrations with ranging frequencies;
- The insulating layer (previously shaped) is positioned and fixed;
- The second concrete layer is casted and compacted;
- The panel waits for the curing time, that can be accelerated through moisture and temperature control or with additives in the concrete;
- The formwork's sides are displaced and the panel is extracted.

In order to fully exploit the potentials of this production technique, horizontal formworks can be equipped with lateral and longitudinal elements, such as:

- hydraulic/electric side to set panel height;
- tilting side, to ease the panel extraction after curing;
- tilting structure, used to put the panel in vertical position, for handling and storing, after production;
- magnetic sides, to set the panel width;
- windows and doors sockets
- fixtures for anchors, both for panels handling and on-site installation;
- rubber-steel chamfers;
- solutions for the building's aesthetics (colour and granularity).

2.2.5 On-site assembly procedures

The scheme below provides the installation process of the EASEE panels. The process is divided into 4 main steps: Building relief and anchoring installation, panels' installation, joints installation and finishing works. The main requirement is that skilled and properly trained workers perform the installation procedure.

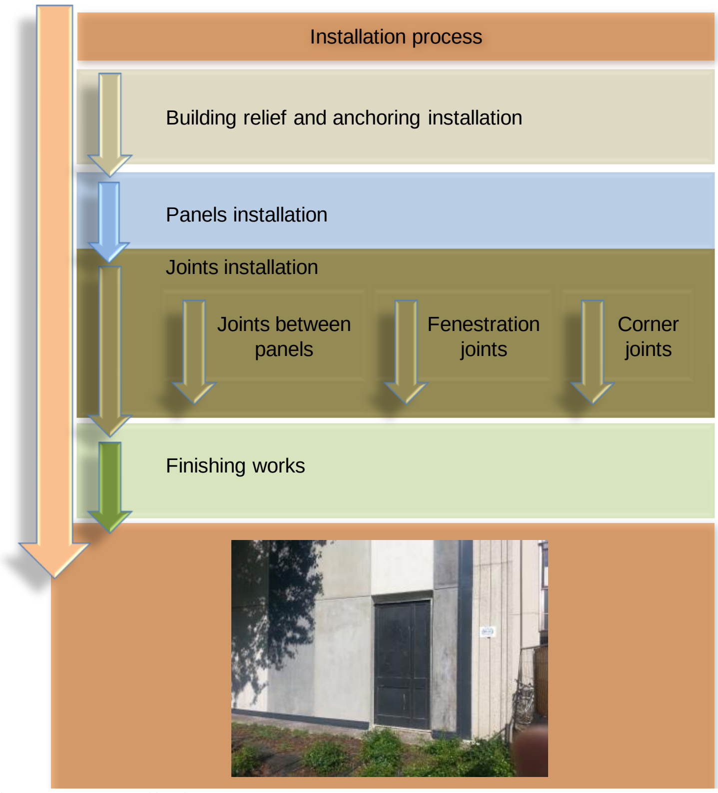
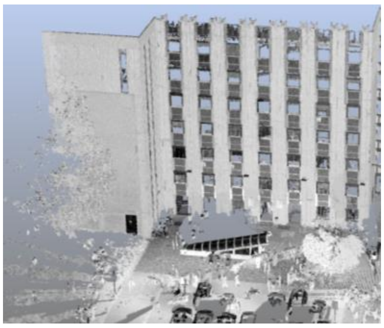
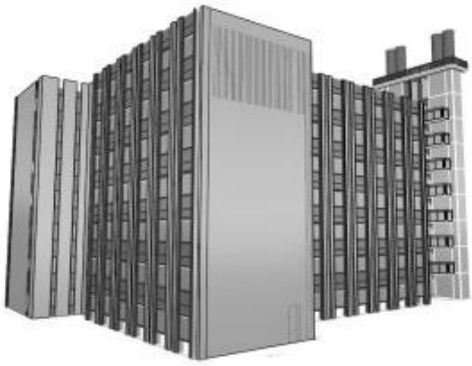
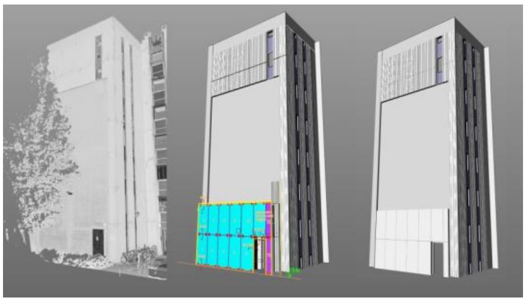


Figure 18: Installation process

The following pages provide an extract from the guidelines for installing the EASEE panels. These guidelines refer to the installation of 13 panels at a test façade at Polytechnics of Milan where the panels are still installed. The same procedure has been adopted for the installation of the panels in other three demo buildings in Italy, Spain and Poland.

Step 1: Building relief and anchoring definition

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 façade 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.	

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 the anchoring.	 
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 staff fixing the anchors operates on special platforms loaders while the panels are moved through, Figure 19.

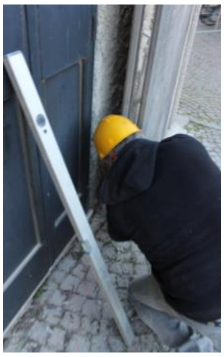
Figure 19: Equipment for panels installation

In the case of a rough existing wall, it is important to smooth the external surface to have a flat plane where to install the anchoring system. Anchoring systems can be mechanical or chemical depending on the condition of building that will be retrofitted,

Figure 20.In order to choose the most optimum anchoring type, the anchor manufacturer – Halfen (consortium partner of EASEE project) should be consulted.

a) b)

Figure 20: Type of anchoring systems according to the available façade (EASEE project)

Step 2: Panels installation	
2.1 Lift the first panel and place it carefully close to the final position. The installation and levelling 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. 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).	

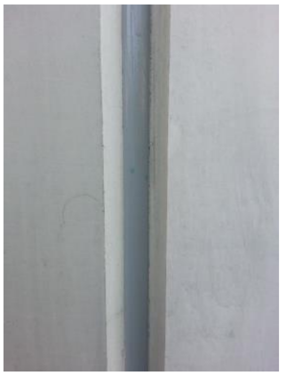
2.4 Adhesive polyurethane based sealing tape lay on the adjacent sides between panels.	 
2.5 Installation and levelling of the panels after the first band.	
2.6 Check the sealing and level (spirit level) of the second row of anchors before installation of the panels of the second row.	

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 of 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:

- EASEE panels have a large surface but relatively low weights (0.54 kN/sm). This advantage reflects on the speed of assembly, since no scaffolding is needed for their installation but only the use of wheeled cranes. Eaves or protruding façade elements may require the use of special sling bars counterbalanced flag, especially for the installation of the panels located at the top of the building. In fact, the use of sling for the installation is the best way to avoid interference or potential damage to the eaves. Additionally, the installation usually starts from the lower to the upper rows.
- The staff required the use of special platforms loaders and crane for the installation.
- The joint between the panels employed a low elastic modulus neutral-curing silicone sealant with outstanding ageing resistance. Silicon was put 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.

Step 3: Joints between panels

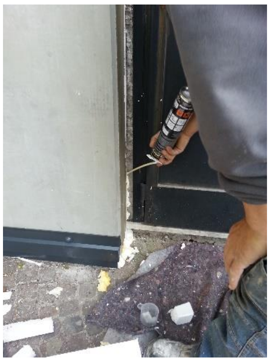
3.1 Laying the polyurethane backfill material between the panels for vertical and horizontal joint.	
3.2 Laying the low elastic modulus neutral-curing silicone sealant with outstanding ageing resistance.	 

Comments:

From a geometric standpoint, the façade misalignments (out of plumb) could be compensated by the tolerances of the anchoring systems. When the misalignment was too marked, multiple ranges of anchoring systems could be used. 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) and can be exposed directly to the weather when compressed between the two elements. It also absorbs vibration and follows the expansions, protects against dirt and cannot be attacked by birds.
It is suitable for concrete, stone, brick, brick, metal, wood, rigid PVC, Plexiglas, drywall, glass, fiberglass and many other materials.

Step 4: Finishing works

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 form on the back of the panels must be sealed or filled.
- 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 the building to ensure air-tightness, water tightness, vapour barrier, thermal insulation, acoustical insulation, elasticity, and aesthetics.

2.2.6 Examples of previous implementation

In the following table, examples of implementation of the EASEE panels are reported. The implementation was made within the demonstration activities of EASEE project in year 2015 in three countries: Italy, Spain and Poland.

Demo building in Italy	
	
Age of construction: 70s Owner: Local Social Housing Agency (ALER) U value before retrofitting: 0,8012 W/m2K	Installation of 186 EASEE panels U value after retrofitting: 0,2377 W/m2K
Demo Building in Spain	
	
Age of construction: 60s Owner: Private - mid-age Spanish family U value before retrofitting: 1,88 W/m2K	Installation of 12 EASEE panels and cavity retrofitting through innovative perlite U value after retrofitting: 0,37 W/m2K
Demo building in Poland	
	

Age of construction: 1950 Owner: Municipality (Building under protection of Cultural Heritage Conservator (CHC)) U value before retrofitting: 1 W/m2K	Installation of 40 EASEE panels (50cm x150cm x12,4cm) U value after retrofitting: 0,33 W/m2K

2.2.7 Implementation in P2ENDURE Demonstration cases

Within the P2ENDURE project the analysis of potential application of EASEE panels in Gdynia demo building was performed.

It is a two storey kindergarten building with the underground basement level, constructed in year 1963 (Figure 21). The building belongs to the Municipality of Gdynia. The building foundation is made from concrete, the external walls are made from full brick and the play rooms' walls are made from reinforced concrete. The partition walls are made from cellular brick. The external walls are not insulated, what has is resulting in high heating cost during winter and low thermal comfort.

Figure 21: Type of anchoring systems according to the available façade (EASEE project)

Within the P2ENDURE project the single storey part of the building will be retrofitted, therefore the draft design of implementation of EASEE panels was performed. In order to cover the building three types of panel dimensions were taken into account: 0,85x,95m; 0,70x0,95m and 0,80x1,50m. The draft design for implementation of EASEE panels in Gdynia demo building was made by Fasada and it is shown on Figure 22.

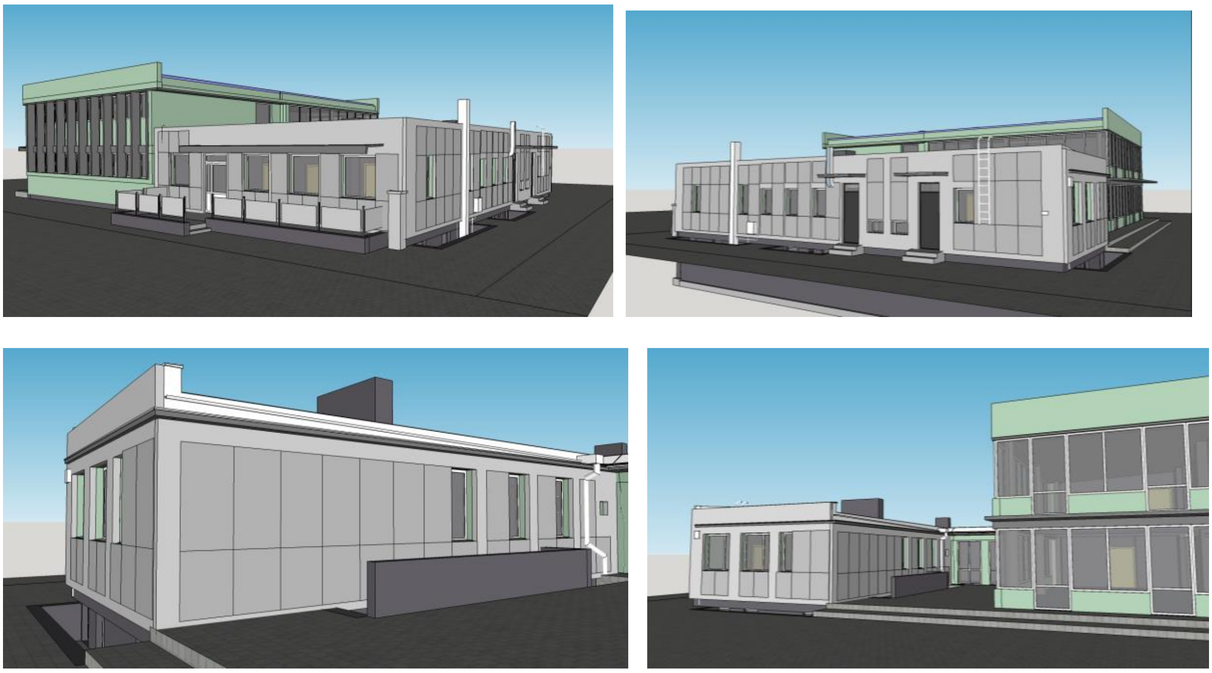


Figure 22: Draft implementation plan of EASEE panels in Gdynia demo building

2.3 Smart Window

2.3.1 Short description of the product

BGTEC is polish SME, active since 1996 in a production of customized windows and fenestration products. Company headquarter is located in Konstantynów Łódzki with specific focus on works for retrofitting and novel energy efficient solutions in construction sector as well as on development of innovative prefabricated solutions integrating winidows. Within P2EDURE project BGTEC company provides novel product which is smart reversible window.

Smart Window technology allows users to rotate the window sash 180° and lock it in the reverse position which can result in reduction of annual energy demand. Each window is fitted with glazing set covered with low-e coating. Due to sash rotation it permits various amounts of solar radiation into the building at different times of the year. Low emissivity (Low-E) coating thanks to rotating sash can be either positioned on the outside of the inner glazing (which maximise solar gain-desirable in winter) or the inside of the outer glazing (which minimise solar gain-desirable in summer).

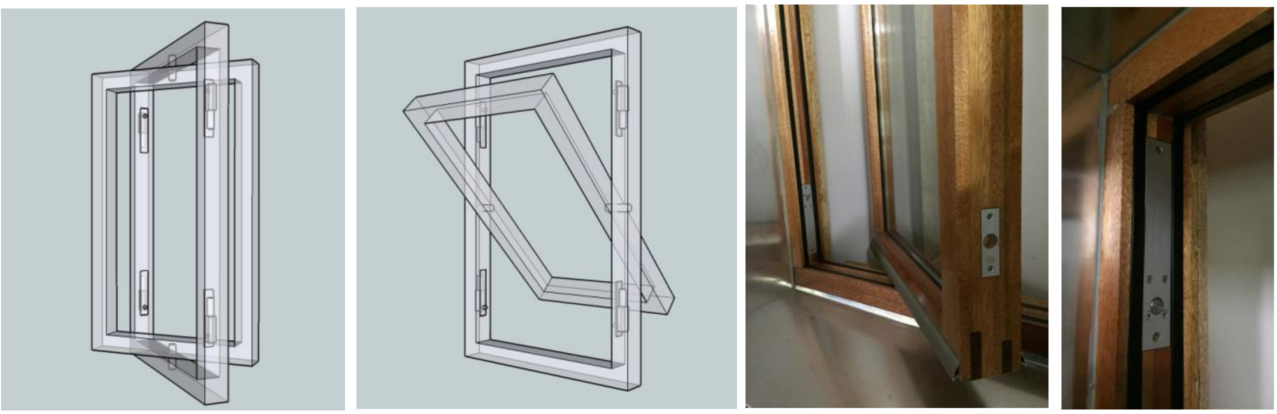


Figure 23: Smart Window design

The sash is supported by two steel pins integrated into the window frame, enabling rotation either on the horizontal or vertical axes, taking into consideration the architectural and customers requirements. Gaskets are a central element of the concept, being operated hydraulically (environmentally-friendly non-freezing liquids). When the position of the solar control glass coating is about to be changed and the sash is in line with the frame, a small pump (or compressor in case of air) activates the seals, removing the fluid from gasket permitting the movement with no degradation and then filling the gasket once again to ensure window tightness. Ventilation is achieved by emptying the gaskets, enabling air to flow through the space between frame and sash, keeping the window locked at the same time. This is achieved thanks to implementation of electromagnetic locks that work independently from sealing system. Locks are hidden inside the window frame and can stay in closed position while opening space between frames and letting the air in. Locks are easyly operated by pushing single button placed on window frame.

Benefits

Potential energy use reduction using a reversible window with different glass configurations has been estimated by performing a sensitivity analysis. The reduction has been calculated as the difference in energy demand with a reversible window and a fixed window in solar protection position.

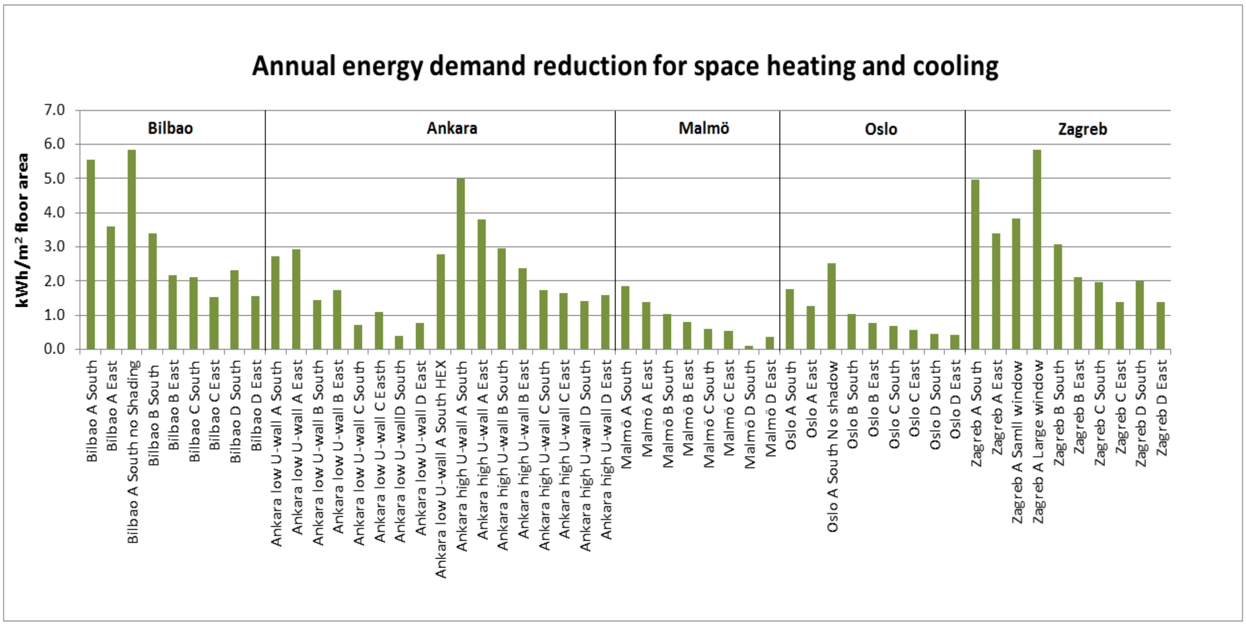


Figure 24: Computer calculations of energy demand reduction

The results proved that in each case and for every type of glazing used we are able to decrease annual energy demand. Obtained maximum reduction of energy demand due to the smart window configuration is 5.8 [kWh/m2 floor area] which corresponds to 17% decrease of needed energy just by changing the position of low-e coating. However speculation is that the potential for the smart window may decrease, if implemented in an already highly retrofitted building where heating season is short and energy demand is already low.

It is important to consider that minimum and maximum dimesnions are connected only with glazing mechanical performance, however generally smaller windows feature worse values of energy demand reduction. This is because glazing area is a crucial part of the system and usually the bigger window the higher glazing to frame area ratio.

What is more, reversible window was designed taking into consideration posssibility to connect with smart house systems. Implementation of electric devices enables full control of window and its remote control. Sealing system as well as locking mechanism has possibility to be operated from distance just by pushing buttons on partable devices.

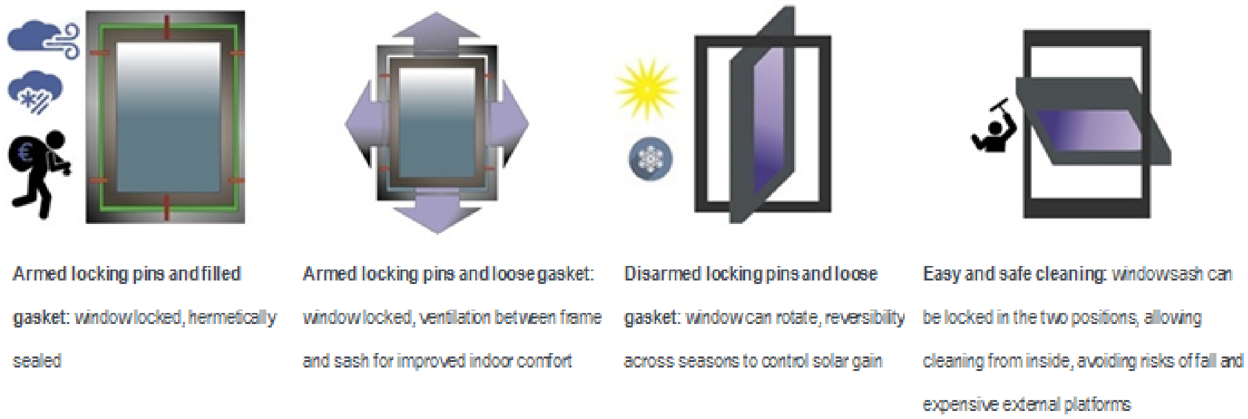


Figure 25: Key features and benefits of the Smart Window

2.3.2 Optimisation plan in P2ENDURE

The current state of the BGTEC'S solution requires electricity as well as an integration of the additional devices (such as metering pump, battery, liquid container) in the technological box installed next to the window.

With regards to customer requirements the refined reversible window design is being developed in the framework of P2ENDURE project. The idea is to simplify the window which shall be equipped with locks and gaskets based on typical systems not requiring electricity to operate. Window will not require integration with additional technical box and will be opened / closed manually. In that way, according to individual retrofitting project, there can be an option to choose between:

- Electromagnetic locks / locking system based on "typical solutions", which are currently used by windows manufacturers;
- Inflatable gasket / sealing system based on typical gaskets.

Current features of BGTEC windows	Targeted improvements	P2ENDURE novelties	Planned actions
Technic box dimensions are 40 x 30 x 17 [cm]	Minimization of technic box (applicable to the solution with electromagnetic locks and inflatable gasket)		To find the smaller substitutes with the required performance at the same time for the components such as: metering pump, battery, liquid container. To develop solution for the technic box to operate more windows at the same time.
Electromagnetic locks	Change of the system from electromagnetic to mechanical.	Locking system based on “typical solution” which is used in the windows currently available on the market, but adjusted in the way that provide cooperation with reversible sash	To perform tests confirming locking system performance and usability.
Inflatable gasket	Change of the system so that metering pomp is not required any more.	Sealing system based on “typical solutions” – solution designed in a way not requiring electricity to be operated	To refine design of the new sealing system. To validate the solution in terms of air permeability and water tightness as well as functionality from the end user perspective.

Table 4: Optimisation process

Cost optimisation

Currently cost optimization can be considered by simplification of window design and implementation of elements not requiring electricity to be operated. Cost of electromagnetic locks as well as inflatable gaskets with all additional devices needed to make seals run are quite costly solutions in comparison to gaskets and locks used in commercially available windows. Cost of sqm of reversible window comprising simplified elements will be lower from sqm cost of reversible window with electric devices.
What is more, increase in quantity of produced windows from prototype level to full scale production and related rise in materials' trade required for window realization and hence greater and better cooperation with the supplier can lower production costs in the future. Consistent production line generates lower costs than the production of single component. This will result in decrease of final costs of Smart Window.

2.3.3 Technical performance, specification and cost information of the optimised product

Three main performance indicators were identified:

1. Costs per sqm:
   Crucial factor, main variable in the price of the window is selected system (from comprising electric devices to fully simplify with standard elements). The price varies also depending on chosen glazing set, its properties and thickness (double/triple glazing): the expected price should range between 400 -650 €/m2 for basic version of window comprising standard elements to 800-900 €/m2 for window with electric devices (applicable for windows of the area ≥1m2)
2. Thermal performance: $U_w \leq 1.1$ W/m2K
   As window is based on wooden frames its overall thermal performance can be controlled and optimised by implementation of double/triple/quadruple glazing sets.
3. Difference in TST for summer and winter glazing position
   Total solar transmittance is dependent on type of glazing and properties of used low-e coating. During hot days it is preferable to have glazing with low TST for best protection from solar heat while during cold periods TST should be as high as possible to enable solar energy to penetrate into the building. That is why chosen glazing set should present features appropriate for climate where windows will be implemented. General rule is: the bigger difference in TST for two positions of low-e coating the higher efficiency of reversible window.
4. Time and easiness of installation

The selected solutions for P2ENDURE project should provide simple and fast installation, which does not require more time and higher level of expertise than during installation of the usual window. However installation time and level of difficulty often depends on conditions met on the construction site and hence on the level of penetration needed into building envelope.

2.3.4 Off-site manufacturing / prefab procedures

Window is a prefabricated element. It is assembled from raw materials received from various production companies and afterwards transported on site. Glazing, wooden profiles, inflatable gaskets are prepared by proper manufacturers and delivered to BGTEC premisies. Then assemble of all elements take places including installation of electromagnetic locks and gaskets inside window frame, preparation of technical box (including metering pump, glycol container, additional battery), putting frame pieces all together and placing glazing within window frame. Window frames are adjusted to implemented systems on CNC machine.

2.3.5 On-site assembly procedures

Smart windows shall be installed in the window opening as the typical window in compliance with the national and local building regulations as well as good engineering practice provided that primary functions such as air and water tightness are achieved at required level.

Regarding window with electric devices, first window with already installed glazing is mounted in window opening. Technical box is installed independently in most suitable place on the wall next to the window opening. Then hoses from inflatabel gaskets and electric wires from eletromagnetic locks coming from bottom part of window frame need to be pluged into technical box. Hoses and electric wires can be hidden in cavities made in wall and afterwards covered with plaster.

Figure 26: Installation of first Smart Window prototype on building in Sweden

Regarding new prototype that is currently under development, window installation will not differ from installation of typical market available window: mountig of window frame in window opening followed by sash installation.

2.3.6 Implementation in P2ENDURE Demonstration cases

Each demo building needs to be considered individually. Implementation of reversible window depends on several features, where the most important is location and shading level of each façade. The greatest impact and highest benefits from implementation of reversible window can be achieved on highly sunlit façades throughout the year. After receiving basic information on location and nearest surrounding of demo buildings it was possible to prepare preliminary proposition on which and how many windows could be replaced with reversible ones.

Gdynia demo building

Building owners are willing to replace windows located on east, west and south façade of the building. However, nursery school in Gdynia is located on one of residential areas. From south it is surrounded by block of flats that can effectively block the sunrays and cast a shadow upon building. What's more, trees round the building can also block energy coming from the sun.

Figure 27: Installation of first Smart Window prototype on building in Sweden

To have more accurate data on this issue we have asked for information on shading level of the building. Received information from Fasada generated from BIM model shows how shades are casted during different time in the year.

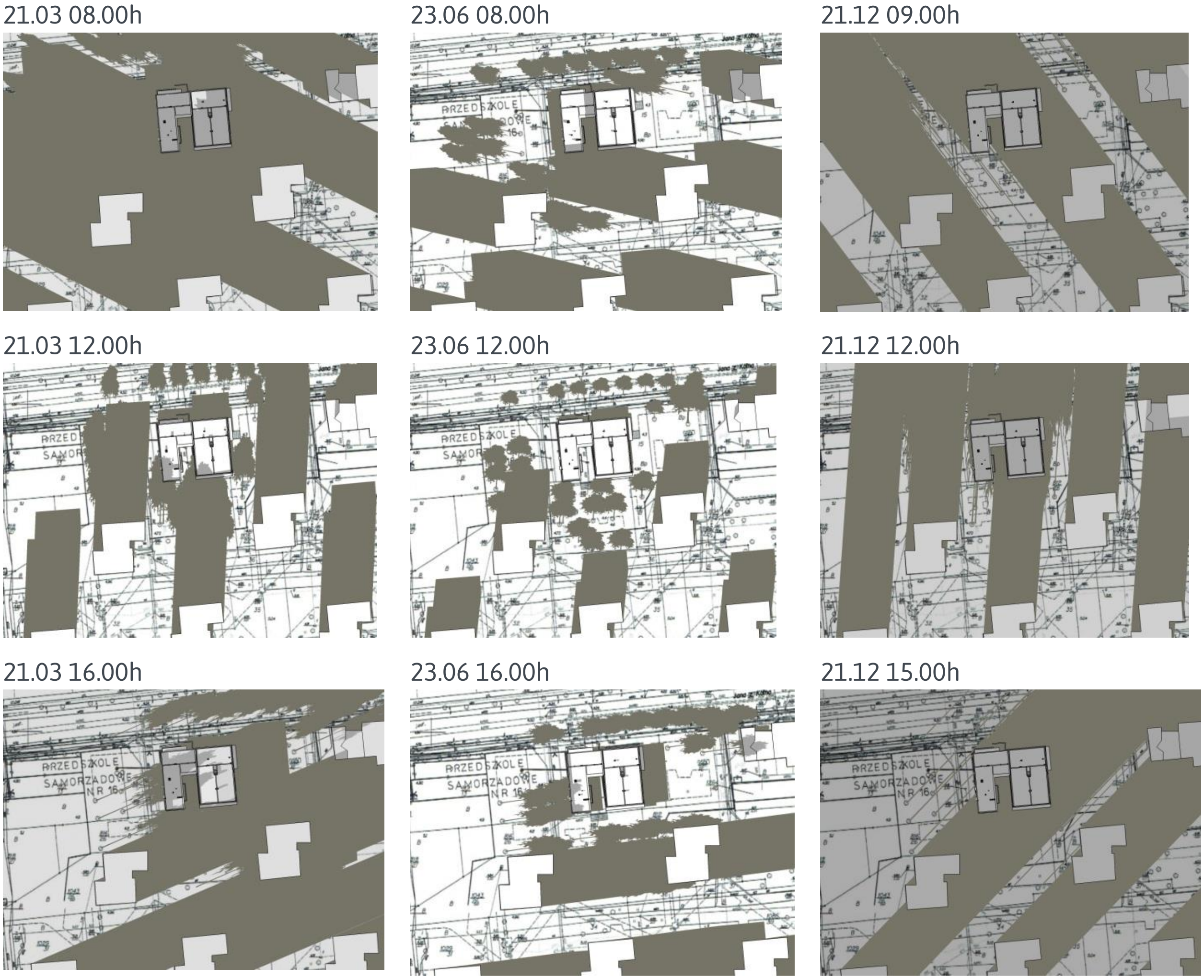


Figure 28: Gdynia demo building shading level

From above pictures it can be observed that building is mainly shaded during winter times. It means that energy gains from sun are also quite low. The level of exposure to sun rays is getting higher when it is getting closer to summer time. In June all three considered façades: east, south and west are highly exposed to sun energy that can get through windows in hottest periods. Although energy gains from the sun during winter could not be very high it would be wise to implement window with low-e coating at least to decrease amount of energy floating out from the building. During summer, it would be good to have solar protective coating to decrease energy floating into the building.

Building orientation, shading level (despite high shading of the building during winter) as well as diverse polish climate with hot summers and very cold winters favours implementation of reversible windows on Gdynia demo building. There may be observed only slight reduction in energy used for heating/cooling but it should significantly influence people comfort inside accommodations. It is proposed to exchange all 13 windows on considered façades. First choice would be usage of glazing set with solar protective coating, it will manage to do both jobs: protect interior from overheating during summer as well as will reflect heat back to the interior during winter. However this will be confirmed and validated throughout thermal calculations.

Figure 29: Gdynia demo building – proposed windows for replacement

Warszawa demo building

Warszawa demo building owners were considering replacement of all windows located on the building. However due to high amount of windows, their size and fact that they are quite new and in overall good condition it was decided between partners that only a few windows will be replaced. Main aim of this approach is to test and validate novel product in real conditions and compare its behaviour with existing commercial windows.

In order to decide which windows would be best to replace building plans and location have been analysed.

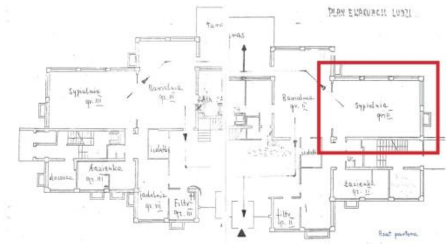
Nursery school in Warsaw is placed on residential area. From east, south and west it is surrounded by block of flats. To have more accurate information on shading level of the building we have received pictures of the building from Mostostal presenting sunlit level of particular façades during the day.

Figure 30: Warsaw demo building location

Figure 31: Warsaw demo building shading level

From the pictures it can be noticed that surrounding buildings do not cast any shadows on the nursery school and south part of the building is well exposed to the sun.

It is proposed to replace 5 windows on south/west corner of the building. This area has a greatest sunlit level and reversible windows will be most effective. Taking also into consideration building plans, the proposition is to replace five windows in one room in south/west corner of the building whether it will be on ground floor or on first floor. The same configuration is on another floor – the same accommodation area, the same window sizes. In this way we can assure same conditions for eventual testing of product in real conditions. Results obtained from testing can show in accurate way differences in both products – between reversible and traditional window.



Ground floor

Figure 32: Warsaw demo building – proposed windows for replacement

First floor

Building can be highly exposed to the sun during summer as well as during winter. For summer period most reasonable solution would be implementation of low-e coating. For summer, on the other hand, for the best protection from overheating it would be preferable to use solar protective coating. It is hard to decide exactly which glazing type would be best in this situation. That is why computer calculations of overall energy demand carried out with both types of glazing should give us an answer which glazing fits best Warsaw demo building.

Genova demo building

Genova demo building owners are considering replacement of all windows on the building. Main façades of the building are facing east and west. What is more, from west side the nursery school is surrounded by high buildings in a very close distance casting shadows on west façade throughout the day. Due to building location and in cooperation with Rina it is proposed to implement 8 reversible windows on east façade of the building.

Figure 33: Genova demo building location

The climate in Genova is rather warm and first choice is to implement windows with solar protective coating. However this should be confirmed by proper thermal calculations.

Apart from works carried out to establish which and how many windows it is reasonable to exchange for reversible ones on each demo building, research have been made on possible types of glazing. Several products were chosen that can work best on our demo buildings. Properties of each type of glazing can be seen in table below:

	LIGHT		SOLAR RADIANT HEAT				GLAZING U VALUE	WINDOW U VALUE
	transmittance	reflectance	direct transmittance	reflectance	absorptance	g-value (total transmittance)		
SUNCOOL 50/25								
double glazing								
summer mode	50	18	24	33	43	27	1,0	1,3
winter mode	50	18	24	33	43	58	1,0	1,3
tripple glazing								
summer mode	45	20	22	33	45	24	0,7	1,0
winter mode	45	20	22	39	39	44	0,7	1,0
OPTITHERM S1								
double glazing								
summer mode	70	21	41	41	18	45	1,0	1,3
winter mode	70	21	41	38	21	51	1,0	1,3
tripple glazing								
summer mode	56	31	30	48	22	32	0,7	1,0
winter mode	56	31	30	44	26	35	0,7	1,0
KGLASS								
tripple glazing								
summer mode	64	24	49	19	32	54	0,9	1,2
winter mode	64	24	49	19	32	59	0,9	1,2

Table 5: Properties of different type of glazing

Plan is to distribute this information to partners responsible for computer calculations and to carry out proper thermal assessment taking into consideration each demo building to determine which type of glazing fits best in each situation.

Generally the smart window can be an energy efficient retrofitting solution in every buidling where replacement of the window is required. The smart window has its advantages in relation to other solar protection devices. Many buildings have historical or cultural value where external sun screening is not possible, then the smart window technology is an optimal solution. Also, architectural interests may not always allow different solutions. Suggested windows are customised and can retain the apperance of existing façade. On the other hand there are architectural limitations which prevent from using the solution: such as columns, shading devices etc. on window rotation route. It is necessary to provide free space outdoor as well as indoor to enable sash rotation.

2.4 Rooftop retrofiting

2.4.1 Short description of the product

PAN+ architectuur is a small innovative architectural firm in the Netherlands. The firm is very active in the field of energy-efficiency and re-destination of buildings, always looking for the integral and smart solution. The experience PAN+ has in the field of rooftop retrofitting has been deployed in the system-solution rooftop-retrofitting.

Rooftop retrofitting is a specific solution not for a problem but for an opportunity. The most important information to determine the success of the rooftop retrofitting solutions is based on added value for exploitation and possibilities regarding the existing building. This means there should be answers to the following three main questions:

- Is building extension interesting (financially and/or other reasons)?
- Is an extension on the ground floor impossible (not desirable)?
- Is the existing building suitable for an extra leightweight rooftopfloor (elevator options, staircase, firesafety, constructon and building physics, allocation plan).

If the answers to these questions are positive the rooftop retrofit solution can be an interesting choice for an project.

2.4.2 Rooftop retrofitting with steel frame construction

The rooftop retrofitting solution is produced with a steel frame construction.
The steel frame construction of the P2ENDURE rooftop solution ensures:

- A lightweight rooftop solution;
- Optimal customization opportunities, efficient design and building process.

2.4.3 Description of design process

Step 1 – Quick scan/ design (mapping/ modelling, first phase)

First step is researching the added value of a potential rooftop retrofitting extension by answering the aforementioned questions. Are these questions positive then a first preliminary design will function as the basis for an integral exploitation calculation. Dependend on the result of this study the project will proceed. (GO/NO-GO)

Step 2 – preliminary design/ research (mapping/modelling, second phase)

The existing building will be researched by architect (possibly also building physics inspector) and structural designer. Through a, special developed, quickscan methodology. This quickscan methodology adresses all important issues systematically. This research must proof the proposed rooftopextension is achievable technically. And if not what are the (financial) implications to make alterations to the building or add construction. Next further calculations can be made for energy - and exploitationcalculations. Dependend on the result of this study the project will proceed. (GO/NO-GO)

Step 3 – engineering (moddelling/making)

The main construction partners (consortium) are choosen. The design will be made definitive by the architect together with the building owner. Then the technical design will be made in a 'Building team' (advisors and constructionindustry working together).
Design development will be very efficient, no needles work will be done with continued budget control.
The steelframeproductioncompany takes the lead in technical engineering (BIM), the architect co-designs.
The HVAC-assembler takes the lead in installations (electrical and services) with BIM, the instalationadvisor(sustainability advisor) co-designs.

Step 4 – permit

The design is production-ready, a building permit will be applied.

Step 5 – production (making)

Production starts after approval of building permit. Without alterations, production will be able to start immidiately. Prefabrication will take place, dependend on the project site, on a central location (lowest transportation costs, labour and other direct costs, preferrebly the productionlocation of steelframes).
Critical time is delivery of installations and windowframes. Consortium collaberation will provide quickness, quality and control. This collabaration will be improved with every project.

Step 6 - Assembling (making)

Mounting elements on site will reduce buildingtime substantially. Production of steelframe constructions is very precise, no measurement flaws will be detected. Working through a BIM model ordering products will be efficient, errors are substantially reduced.

2.4.4 Information requirements project

Information gathering for the first step is crucial to get an overall view off the rooftop retrofitting possibilities for a project.

To answer the three main questions these can be elaborated with the following questions:

Is an extension of the building interesting?

- Need for extra space? (organisation efficient? New technologies a solution? etc)
- Need for adding new function?
- Extra value for existing function?
- Extra value for neighbourhood?
- Condition of rooffinishing/ insulation bad?

Is extending on ground floor not desirable?

- Plot too small?
- Available space in use?
- Ground contaminated?
- Protected trees?
- Possible in allocation plan?
- Monument (and strong insurmountable restrictions)?

Existing building/ site suitable?

- State of construction?
- Connection with existing staircase possible?
- Enough fire escape oppertunities?
- Elevator possitioning possible?

In addition to the answers to these questions the following informaton is needed in the mentioned step.

Step	Structural data/ condition scores. Energy/ TCO/ Exploitation	Legislation/ municipality/ finance	Geometry/ materials
1	**Information needed** Answers to questions above Information about energy usage	**Information needed** **Answers above** Information of location/project (drawings, urban plan, airpicture, pictures)	**Information needed** **Answers above** Pictures of existing situation (possible 360°) Technical drawings of building
2	Ground compilation Structural information Visit and verification of condition and real situation. (using P2ENDURE inspection tool)	Verifing position municipality Check building legislation Research financial possibilities	Thermal images Inspection with P2ENDURE inspection tool (to verify materials and conditions)
3		Possibilities location during construction	3D scan of building (mininal: indoor were rooftop connection is made, external for roofmeasurements and atircase)

Table 6: Information/data needed step-by-step

2.4.5 Technical performance, specification and cost information of the optimised product

The rooftop retrofitting concept comprehends three main Key performance indicator-subjects.

Subjects:

1. Adding a rooftop solution in general enables::

- Reducing energy-usage (roofinsulation and high quality rooftopextension);
- Enhancing functionality (value);
- Re-use of building and extanding lifespan will optimising embedded energy balance;
- Reduction in costs, no need to purchase land.

2. Using steelframe construction for rooftop solution enables:

- Reducing waste of material in production process (production-on-demand);
- Reducing preparation and building time through efficient stock/ production balance (production-on-demand);
- Enhancing recyclability of building materials through 'dry' building;
- Desintegrated building process facilitates clear building sequence and easy installationassebly.

3. Lean Preparation and Building process enables:

- Reducing duration of projectexecution substantially, in comparison with traditional building techniques;
- Reducing unnecessary projectcosts through structured process (higher budgetsecurity for client);
- Reducing building errors substantially (main industrial partners part of the designprocess);
- Conceptual aproach provides best precondition for optimal integral result;
- Possibilty to provide prestation warranty and maintaincecontract. (more security for owner).

2.4.6 On-site assembly procedures

The Rooftop construction of steel frame is produced in 2D façade- and floor components. All holes for ducts are already placed in the steel structure. The frame is finished with the first layer of external plating, insulation and vaper foil. Depended on the accessibility of the ducts after assembling the components on site, the ducts are placed in the components.

On site all necessary adaptations to the existing building are made. Normally a steel construction on the existing roof is used as a foundation. The components are assembled and ducts are 'plugged in'.

Figure 34: Rooftop retrofitting example, only 'dry' building techniques are used; highly prefabricated Project Lage landen (publicatie Bouwen met Staal)

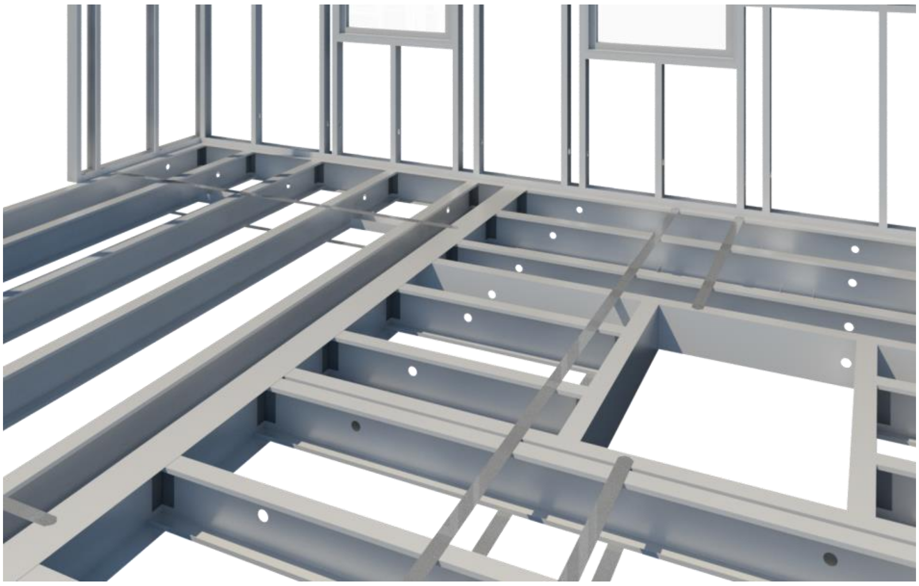


Figure 35: Steel frame construction; extremely customizable

2.4.7 Implementation in P2ENDURE Demonstration case

The first example is an executed rooftop retrofitting extension of social housing in Tilburg. In this case the rooftop retrofitting was not done with steelframe, but its a good example for rooftop retrofitting concept. Two other examples are not executed but are in a design phase and show two diverse possibilities for the implcation of the steelframe rooftop retrofitting solution. The first is a schoolbuilding retrofitting project in the city of Tilburg in the Netherlands. The second is a proposed solutution for rooftop retrofitting of a nurseryschool in the city of Warsaw in Poland. Both cases are very different and show the broad potential of the solution.

Figure 36: School building Abdij van Bernestraat

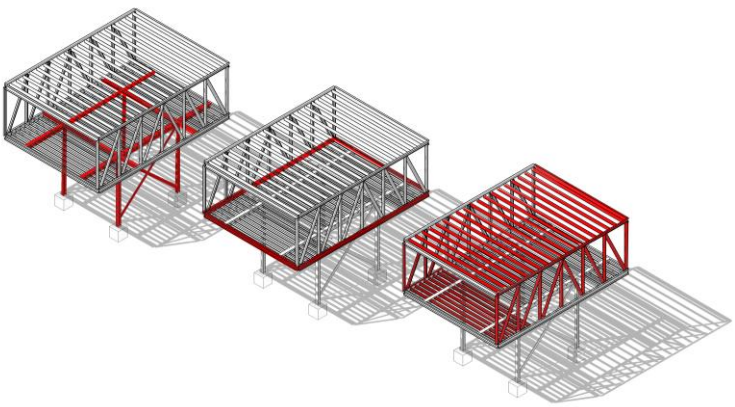


Figure 37: Steel (frame) structure school building Abdij van Bernestraat

Figure 38: Rooftop retrofit solution nursery school Warsaw

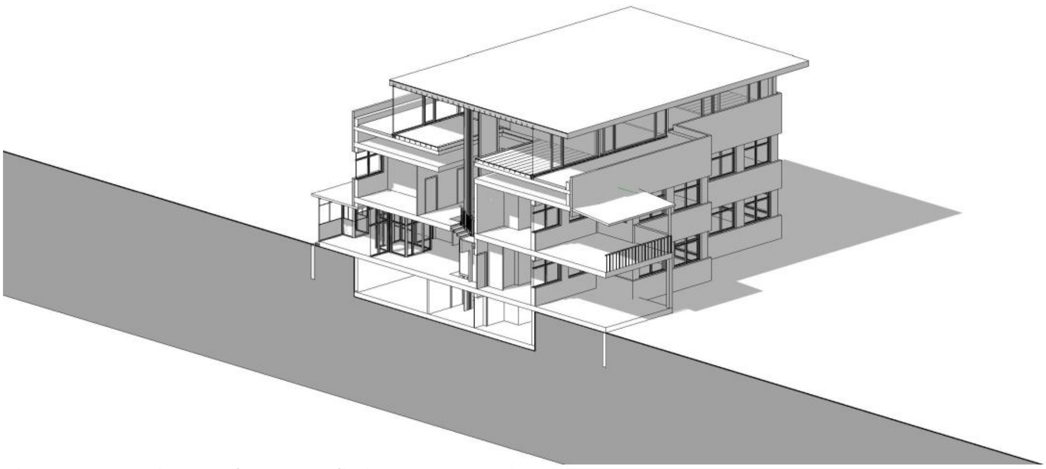


Figure 39: Section rooftop retrofitting nursery school Warsaw

2.5 Folding balcony

Bloomframe® window is designed by Dutch architects HofmanDujardin and engineered by French manufacturer Kawneer France. The innovative window that morphs into a balcony at the touch of a button is a commercial product that is already available on the market. The technology offers inhabitants of apartments, offices and hotels a flexible living environment: an insulated window and a balcony in one, adding vital space to compact interiors and bringing the outdoors in.

Website: http://www.hofmandujardin.nl/bloomframe-window

2.5.1 Short description of the product

The Bloomframe® window looks like an ordinary window at first glance, except the lower part of the frame that consists of an opaque metal panel instead of glass. The window is operated by a remote control. When activated an electric motor drive will extend out the top frame, pushing the lower one down into the balcony's floor. The whole process takes about fifteen seconds to complete, and the result is a real balcony with enough space for two people to sit down at a table and enjoy a cup of coffee. The folding balcony was created especially for spaces where traditional balconies are not possible to be installed, like in case of apartment renovation or warehouse conversions, where regular balcony is not possible or not allowed while residents in congested urban areas demand private outside space to enjoy the weather.

Figure 40: Folding balcony

The French manufacturer Kawneer, global leader for aluminum façades, windows and doors based on Alcoa window system, is responsible for the development, the fabrication and the international sales of the Bloomframe® balcony.
The technology was tested and certified for countries with European building and machinery regulations. The testing considered the three positions:

- Window
- Machine (during opening)
- Balcony

Kawneer France obtained all the necessary certifications to transform the prototype into a safe and affordable building component. Its dimensions, color and materials are all fully adaptable and can be custom-designed to complement the façade of new and existing buildings.

- Weight: 350 kg
- Maximum size: 3000 cm long x 2400 cm high

2.5.2 Technical performance, specification and cost information of the optimised product

- Durable materials: the Bloomframe® window is made of aluminum, glass and panels
- Flexible and adaptable design according to individual wishes (flexible size, material and coloring)

2.5.3 Examples of previous implementation

The engineering of the folding balcont was finished in 2015; the final prototype was presented at the international construction exhibition BATIMAT 2015 in Paris.
The first models were destined for an apartment building in Amsterdam in the Netherlands. This demonstration case proves the functional and aesthetic benefits of the technology and the Bloomframe® window could soon become a familiar solution for building renovation as well as new construction projects where lack of space is often a problem in the modern cityscape.
When a dozens of the folding balconies are installed in a single apartment building, like in the Hofman Dujardin's proposed housing block, the result is a dynamic, constantly changing façade pattern. "In the winter the façade is closed, during spring the façades open like a flourishing flower" say the designers.

Figure 41: Folding balcony

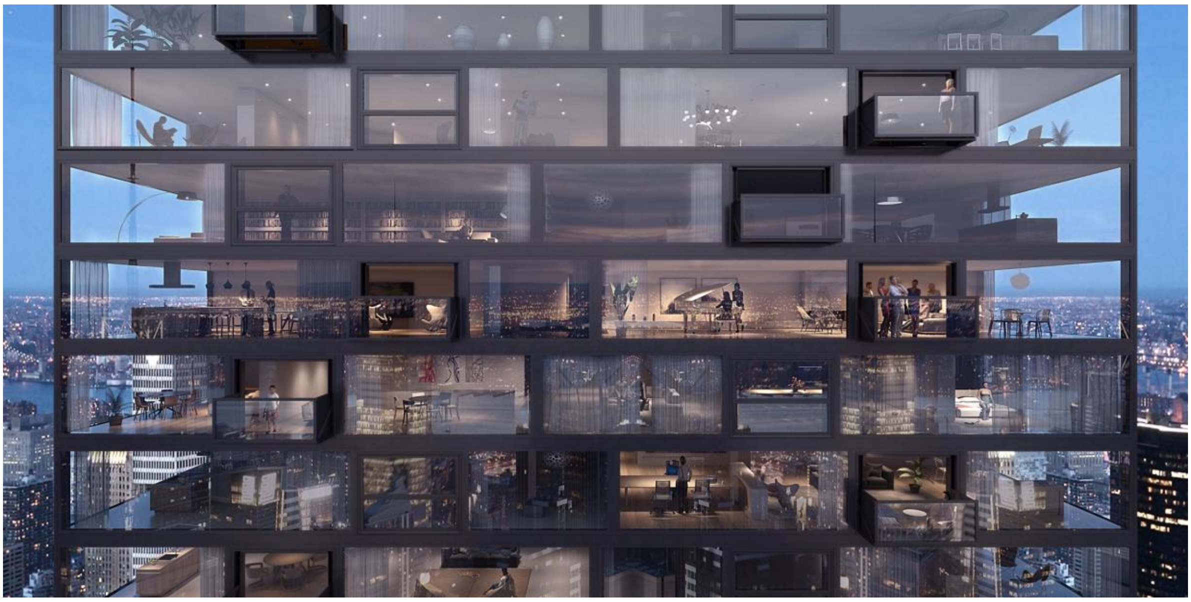


Figure 42: Folding balcony

3. Conclusions

This report described the sets of Plug and Play prefabricated components for building envelopes that have been selected for the P2ENDURE project. All the partners responsible for each of the technological solutions have defined various optimization goals, which fit into the challenges of the project. Regular consultation between the technical partners and end users will remain an ongoing activity throughout the lifetime of the project.

In summary, Fermacell, through designing the new panel, would like to speed up the installation process thanks to the integration of heating, cooling and ventilation functions in façades. End users will still have access to these installations by opening appropriate ducts in the façade. Time savings will also be achieved through usage of digital planning (laser scanning, BIM model) and off-site manufacturing. The possible improvement in terms of energy performance for renovation with the use of multifunctional façade panels should be further investigated based on live demonstration projects. The Key Performance Indicators related to the FC panel that will be analysed are: heat transfer coefficient of renovated wall and ventilation performance that can be influenced and improved by the multifunctional façade panel. The heat transmission will be reduced by an improved U-value of the façade. The possible improvements of energy performance for heat recovery of the ventilation devices (Schüco) will also be investigated.

In case of the EASEE panel, the purpose is to shorten the installation time, especially on the walls that contain a lot of windows and to reduce the weight of its structure. Better energy performance is planned to be achieved through increase of the thickness of the insulation and use of material with lower thermal conductivity.

An important challenge of the optimisation process of the BGTEC smart window is to reduce the technical box, which is applicable to the solution with electromagnetic locks and inflatable gasket. Second challenge is to change the system from electromagnetic to mechanical locks. Thanks to the elimination of the technical box in the proposed alternative solutions, costs savings will be achieved. Regarding the energy performance, this will be improved by using double/triple/quadruple glazing sets.

Rooftop retrofitting is a specific solution that gives the opportunity to extend the user area and can be applied where additional usable area is needed in the building but when land surface is not available. The advantages for this solution are twofold: achievement of energy reduction through roofinsulation and high quality rooftopextension and cost reduction due to no need to purchase additional land surface.

The information described in this report will be used mainly by partners involved in 'Performance validation and optimisation' (WP3) and 'Live demonstration projects' (WP4). Further investigation on the optimization of the solutions and their implementation will be carried out for ensuring that the needs of the end users are met.

Annex 1

Calculation of energy savings related to ventilation units installed in multifunctional façade panels

Warsaw climate: October – March = 6 month average -5°C outside / +20°C inside

Performance ventilation device = 100m³/h over 10h on 5 days

Calculation: 26weeks x 5 days/week x 10h/day x 100m³/h = 130.000m³

According to DIN 13779 this is sufficient for about 4 – 5 Children

Specific density air = 1,2kg/m³

Cp = 1,007KJ/kg

Heat recovery = appox. 80% = 0,8

Power consumption (current) = 40W

Conversion factor current = 2,5 (varies between countries, average value)

Efficiency of heat generation of actual heat generation in nursery Warsaw = 0,85

1 Liter of domestic fuel = 10 KWh = 10.000 Wh

Costs = 0,65 €/dm³ (costs August 2017 for domestic fuel)

Energy saving:

>> 130.000m³/a x 1,2kg/m³ x 1,007KJ/kg*K x 0,278W/KJ x 25K = 1091750 Wh per year

How much domestic fuel is needed to generate this "heat/energy" with the existing heating system?

>> 1.091.750Wh / (10.000Wh/dm³ x 0,85) x 0,8 = approx. 100 dm³ of domestic fuel

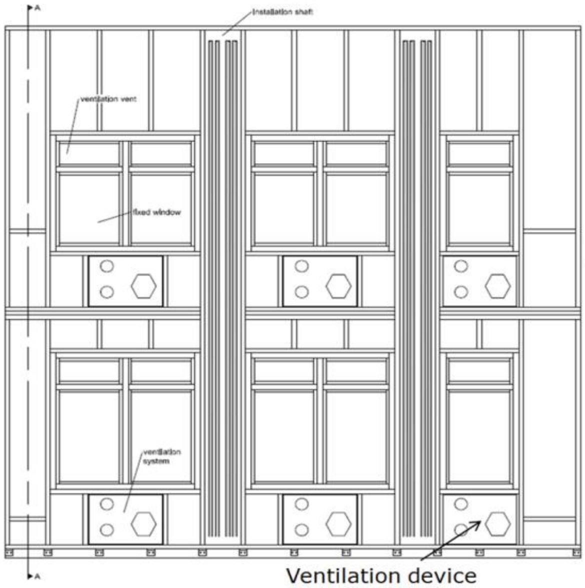
In order to drive the ventilator, current is needed. Current is produced from fossil energy with a conversion factor of approx. 2,5

>> Current ventilator = 40W x 1300h/a = 52000Wh x 2,5 = 130.000Wh per year

The "converted" real primary energy demand can now be considered:

>> Corrected Energy saving = 1091750Wh – 130.000Wh = 961.750Wh per year

Saving per child and year: 961.750Wh/(5Children) = 192.350Wh/(child*a)



Technical data for Schüco Vento Tec			
Feature	Level 1	Level 2	Level 3
Device dimensions (B x H x T)	860 x 710 x 140 mm		
Volume flow	50m³/h	70m³/h	100m³/h
Level of heat distribution	81%	79%	77%
Sound power level (Lw)	43dB	48dB	55dB
Sound pressure level (Lp)	35dB	40dB	47dB
Operating limits	-15°C to +70°C		
Power consumption	16W	22W	40W
Material class	B2		
Thermal insulation of fan in panel	U = 0,75W/(m²K)		

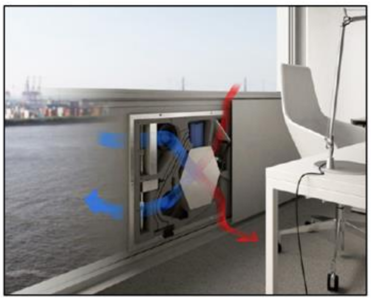


Figure A1-1: technical data of ventilation device

Calculation of embodied energy for multifunctional façade panels

- Gypsum Fibre Board 12,5mm[6] : GFB = 37,33MJ/m^2 MJ/m^2
- Cement Bonded Board 15mm[6]: CBB = 155,79MJ/m^2
- Mineralwool[6] = 1185 MJ/m^3 for a 94kg/m^3mineral wool which is declared in the EPD. Normally for fillings in wood based walls a 30kg/m^3 mineral wool is taken (this means: 30kg/m^3= 380MJ/m^3). According to EPD extrapolation is allowed.
- Wood = renewable = 0 MJ/m^2. Per sqm of façade (thickness of mineral wool = 220mm / 12,5mm GFB inside and 15mm CBB outside) the following values can be calculated with regard to embedded energy:

Values for calculation:
GFB = 37,33MJ/m^2
CBB = 155,79MJ/m^2
Mineral wool 94,1kg/m^3= 0,2m filling plus 0,02m for tolerance offset = 1185MJ/m^3*0,22m = 260MJ/m^2
Mineral wool 30kg/m^3= 0,2m filling plus 0,02m for tolerance offset = 380MJ/m^3*0,22m = 84MJ/m^2 (extrapolated)
From the individual values the total embedded energy can be calculated. If a 30kg/m^3 mineral wool is chosen the embodied energy per sqm façade amounts to approx. = 37,33MJ/m^2+155,79MJ/m^2+84MJ/m^2 = **277 MJ/m^2 or referred to a service life[6] of 50 years of approx. 277/50 = 5,55MJ/(m^2*a)**