P2ENDURE

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

Factsheet

Start date:	1 September 2016
Duration:	48 months
Project Coordinator:	DEMO Consultants
Scientific Coordinator:	Universitá Politecnica delle Marche
Partners:	16 (8 SME, 5 IND, 2 HES/RES, 1 PUB)

DK : Invela

DE : Lenze-Luig 3-L-Plan, James Hardie Europe, Technische Universitaet Berlin

NL : DEMO Consultants, Huygen Installatie Adviseurs, PANplus Architektuur, Camelot Vastgoed

PL : Bergamo Tecnologie, Fasada, Mostostal Warszawa, Miasto Stoleczne Warszawa

IT : Becquerel Electric, SGR Servizi, RINA Consulting, Universitá Politecnica delle Marche

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Contents

Version 1.0

This booklet is a living document and presents the main innovations and outcomes of P2Endure. An updated version of this living document will be launched before the end of the project.

Introduction

Problem Statement

1

Almost 90% of the existing building stock in the EU is older than 30 years, but the rate of renovation is only 1-2% each year, and within this only 5% of the renovated buildings achieve >60% energy saving

(source: European Parliament, 2016, Boosting Building Renovation: What potential and value for Europe?)

2

This fact is hard to accept since:

- Advanced renovation solutions (products and services) are available
- Sustainability policies and financial benefits encourage energy-efficient buildings
- Research in deep renovation have achieved a high Technology Readiness Level

3

There are several barriers for large-scale deep renovation in Europe

(source: European Parliament, 2016, Boosting Building Renovation: What potential and value for Europe?)

- Financial barriers: renovation cost, access to finance, [temporarily] low energy price
- Technical barriers: lack of affordable technical solutions and knowhow of professionals
- Process barriers: fragmentation in supply-chain and high complexity for owners/occupants
- Regulatory barriers: varying performance requirements and definition of (deep) renovation
- Awareness barriers: insufficient insights in renovation benefits and increased user comfort

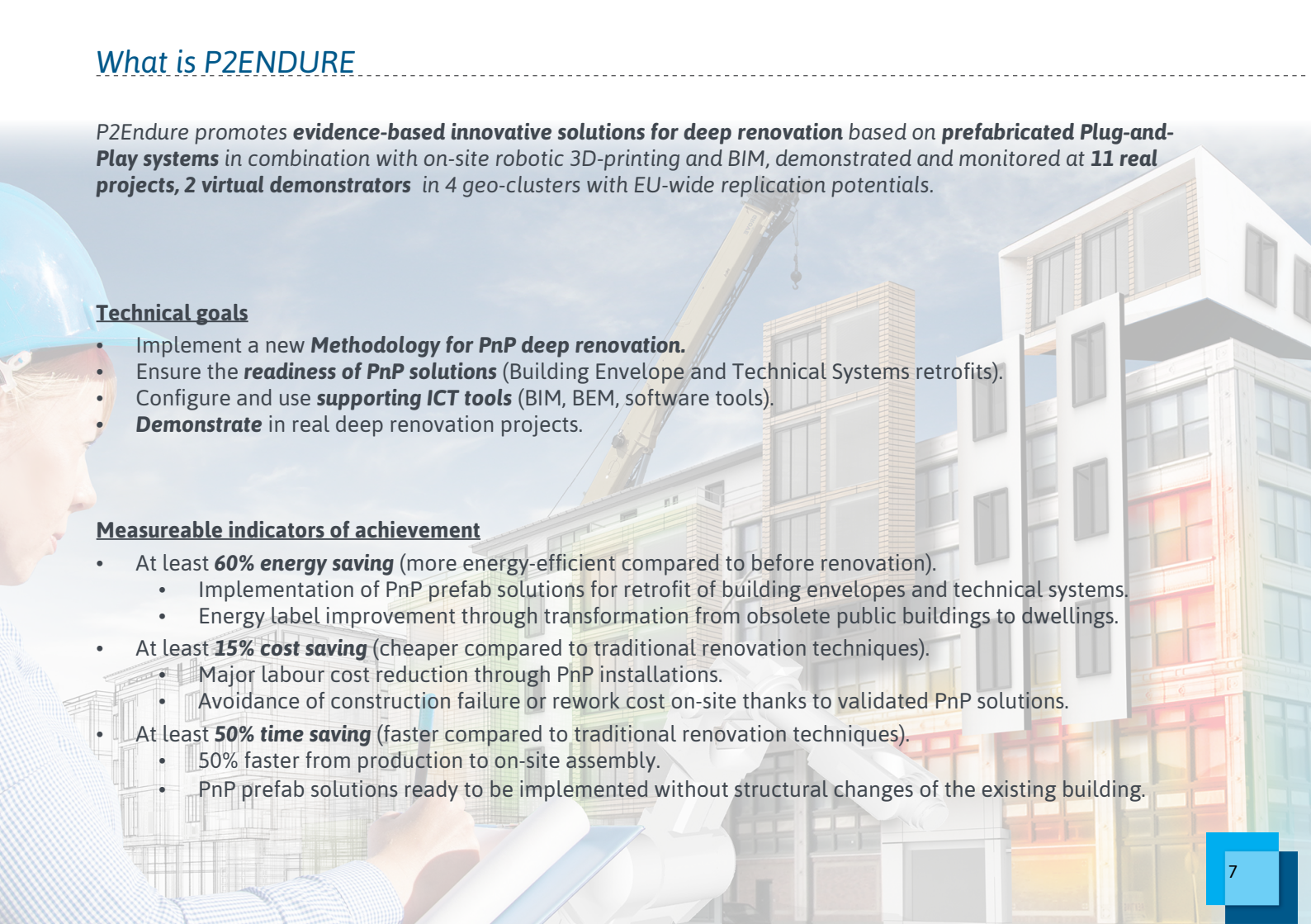
Hypothesis

Plug-and-Play (PnP) *concept is key to large-scale deep renovation:*

- PnP deep renovation goes beyond 'modular building units'.
- Plug-and-Play (PnP) solutions can break through the current renovation barriers.
- Scan-to-BIM-to-BEM is essential for PnP product and process integration.
- Upgrading building's smartness through deep renovation can be facilitated by PnP updates.

What is P2ENDURE

P2Endure promotes ***evidence-based innovative solutions for deep renovation*** *based on* ***prefabricated Plug-and-Play systems*** *in combination with on-site robotic 3D-printing and BIM, demonstrated and monitored at* ***11 real projects, 2 virtual demonstrators*** *in 4 geo-clusters with EU-wide replication potentials.*



Technical goals

- Implement a new ***Methodology for PnP deep renovation.***
- Ensure the ***readiness of PnP solutions*** (Building Envelope and Technical Systems retrofits).
- Configure and use ***supporting ICT tools*** (BIM, BEM, software tools).
- ***Demonstrate*** in real deep renovation projects.

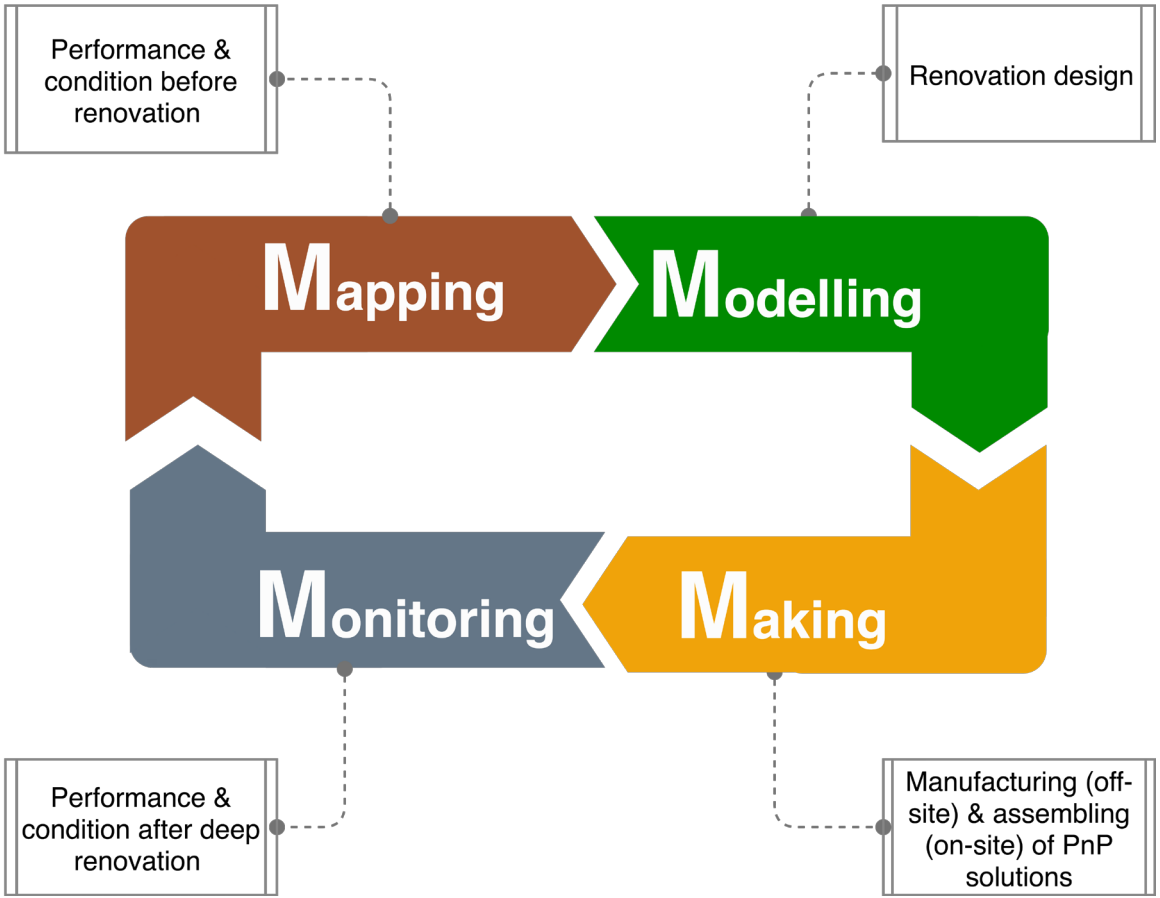
Measureable indicators of achievement

- At least ***60% energy saving*** (more energy-efficient compared to before renovation).
  - Implementation of PnP prefab solutions for retrofit of building envelopes and technical systems.
  - Energy label improvement through transformation from obsolete public buildings to dwellings.
- At least ***15% cost saving*** (cheaper compared to traditional renovation techniques).
  - Major labour cost reduction through PnP installations.
  - Avoidance of construction failure or rework cost on-site thanks to validated PnP solutions.
- At least ***50% time saving*** (faster compared to traditional renovation techniques).
  - 50% faster from production to on-site assembly.
  - PnP prefab solutions ready to be implemented without structural changes of the existing building.

The 4M process

for cost effective and time-efficient deep renovation

The 4M process

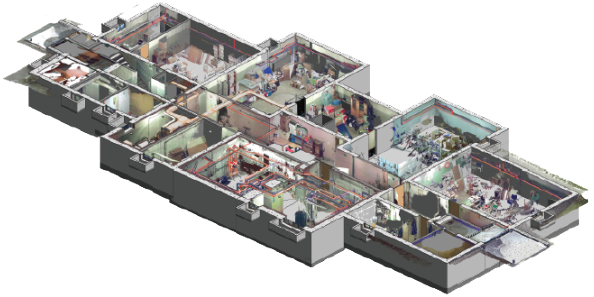


Mapping

Purpose: to develop a detailed technical plan and economic feasibility report for deep renovation, as starting point for the renovation design.

'3D scan to BIM' process:

1. Collection of the existing as-built documentation of the building, to define the most optimal protocol for 3D data acquisition through laser & thermal scanning.
2. Creation of the As-Built BIM model.
3. Usage of the As-Built BIM model in software tools for building condition assessment.



Off-site activities

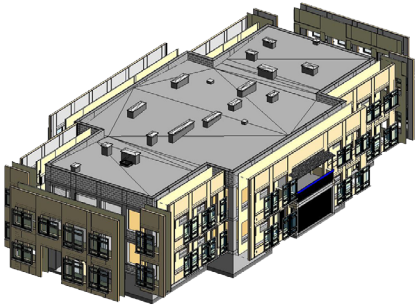
- Real estate valuation and investment appraisal of existing building.
- Economic feasibility study based on Total Cost of Ownership.
- Holistic scenario development.

On-site activities

- Condition assessment based on self-inspection - technology.
- Assessment of the functional qualities and potential of the existing building.

Online interactions processes between on-site and off-site processes

- Comparative analysis.



Modelling

Purpose: to develop the deep renovation design ready for execution.

'BIM to BEM' process:

1. BIM Parametric Modeler tool to make configurations of suitable renovation solutions and to present the impact of various renovation options.
2. Building Energy Modelling (BEM) for the estimation of energy performance.

Off-site activities

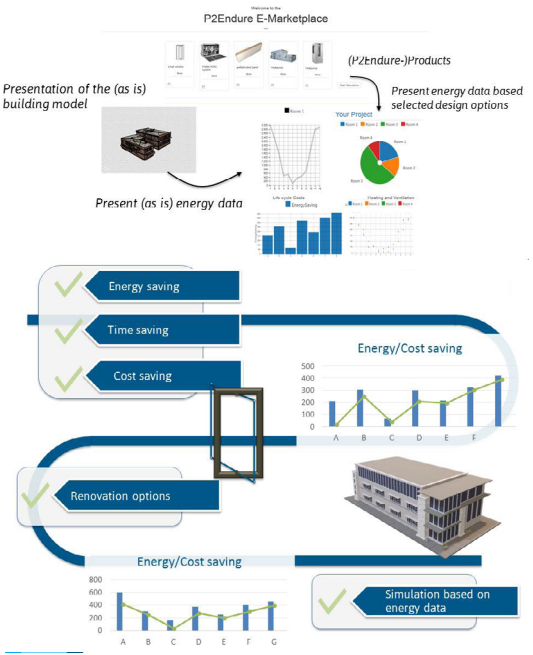
- BIM creation.
- E-Marketplace.

On-site activities

- 3D data capturing and thermal scanning.

Online interactions processes between on-site and off-site processes

- Performance simulations of innovative P2Endure solutions.



STEP 1
Creation of the BASELINE energy model

STEP 2
VALIDATION
of the baseline with the energy meters and bills

STEP 3
Creation of the POST-RENOVATION MODEL

STEP 4
Evaluation of the PERFORMANCE of the renovation

Analysis of FURTHER ACTIONS to achieve the 60% energy saving

Purpose: to improve, test and implement PnP prefab components for deep renovation and to execute deep renovation activities.

Off-site activities

- Just In Time and lean factory production process
- Information in 3D/4D/5D BIM (cost and time).
- Manufacturer and supplier engagement.
- Coordination through E-Marketplace.

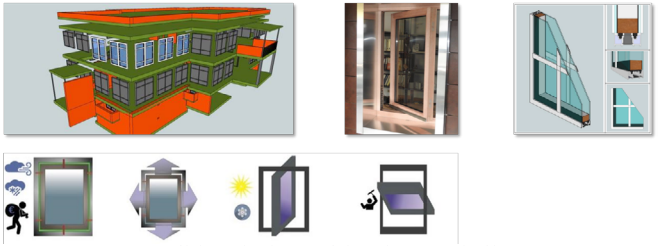
On-site activities

- Delivery of PnP components and solutions.
- Rapid and low disturbance building component assembly.
- Assembly using self-instruction and self-inspection system for construction actors.
- Calibration and operating 3D-printing robots.
- For district renovation setting up local assembly factory.

Online interactions processes between on-site and off-site processes

- Brokerage platform for suppliers, skills and labour force (local employment and training).
- Development of an optimised logistics and assembly plan (reducing transport).

Collaborative robot for façade retrofitting by on-site 3D rendering and milling



Reversible window with advanced climate and energy properties

Monitoring

Purpose: to monitor and guarantee the high-quality execution of the construction works, and to monitor the Indoor Environmental Quality and Energy Performance after deep renovation.

Off-site activities

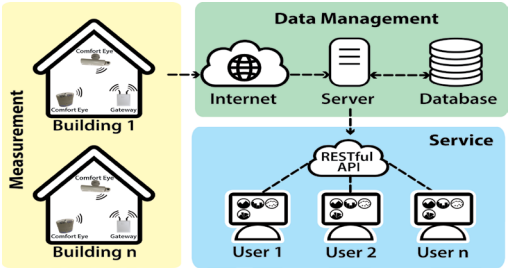
- Contracts for performance guarantee.
- Best practices.
- Description of user evaluations of manufacturers, suppliers and contractors available in E-Marketplace.

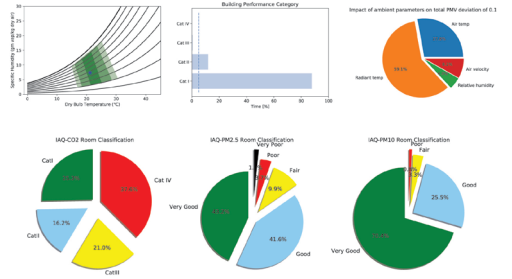
On-site activities

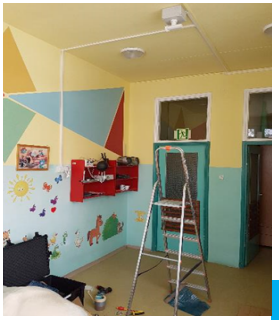
- Indoor Environmental Quality monitoring.
- BIM based self inspection by end-users.
- Self-instruction for optimal use of renovated building.

Online interactions processes between on-site and off-site processes

- 3D laser scanning and thermal imaging connected to BIM for real time quality control.
- Real time / online AR process tracking (webcam).
- Update BIM as built for maintenance and Facility Management.
- BIM based Life Cycle management planning and Total Cost of Ownership.
- Managing feedback loop for systematic improvements of prefab components.







P2Endure lessons learnt
4M approach & PnP-solutions

Lesson learnt from Gdynia demonstration case

4M Process

1. Public buildings owner - City of Gdynia - is very interesed in the monitoring process with Comfort EYE, including monitoring of PM 2.5 and PM 10. This is related with the very low air quality in Poland. Public owners pay more and more attention to Indoor Air Quality in their buildings.

2. 4D time scheduling helps to better plan on site renovation works.

PnP-solutions

1. It is challenging to adjust prefab panels to not typical and repeatable building envelopes.

2. When using new PnP building solutions, it is good to have technical adviser who can help during the design and support the contractor.

3. The key issue with PnP envelope solutions is the possibility to adjust the thermal properties to national standards (FC multifunctional panels give that possibility).

Lesson learnt from Menden demonstration case

4M Process

1. Mapping is crucial and complex at the same time as the criteria that are most important in modelling and making are not precisely defined.

2. Modelling needs a special expertise in order to realize the BIM/BEM connection appropriately.

3. Making is closely related to the applicatino of single solutions for constructive and MEP/HVAC building holistic realization offer. The decision making process in order to optimize the holistic offer cannot easily supported at different experts' level.

PnP-solutions

1. PnP solutions are successfully implemented as a single product but the combination of PnP solutions is not providing a PnP systemic solution automatically.

2. The points of junction have to be analyzed and developed to realize at the highest level.

3. Some of the products are not applicable in different demonstrators based on country specific demands. Therefore, even for PnP solutions adjustments processes are needed.

Lesson learnt from Enschede demonstration case

4M Process

1. To be sure that decision are made on the right parameters, mapping becomes more and more important.
2. Modelling a library of available and qualified products to be able to predict impact is crucial.
3. Monitoring needs to be decided and set up in the design process to avoid unwanted impact during implementation phase (esthetical). And also to make sure it can be used during the lifetime cycles to support decisions in the (near) future.

PnP-solutions

1. Decide to use PnP solutions at start of the development phase.
2. Use proven concepts when you are working on a large scale (try experiments / innovation on small scale projects to avoid risks).
3. Incorporate producer and constructor in the design process at start.

Lesson learnt from Ancona demonstration case

4M Process

1. The limitation, a lack of information and not accurate information limits the accuracy of modelling and decision making, as a concequence, on the overall results.
2. BIM to BEM has lots of limitations in transferring data which still leeds to a lot of double work.

PnP-solutions

1. Wide variety of PnP solutions and numbers are increasing.
2. Simplifications and approximations can have a great impact on the decision making and on the definition of the renovation strategies.
3. Lack of documentation and information about the HVAC systems and the simplified BIM highly increases the difficulties in integrating the PnP HVAC solutions in the BIM, which can include a very simplified MEP or not include it at all.

Lesson learnt from Utrecht demonstration case

4M Process

1. Mapping of the entire building stock reduces 7.5 million homes in 9 types of roofs, 7 types of facades and 5 types of spaces. It is key to our approach of the market.

2. BIM provides solutions but is difficult to implement when the market is just small and not fully convinced of the advantages of BIM.

3. It is necessary to make a difference in the process between the PnP solutions and individual custom works.

PnP-solutions

1. Industrialisation is not about building factories, but is looking for a way to reach as much people as possible, in an efficient way. So plug and play still allows for labour at the site.

2. PnP solutions need to have boundaries, and comprise just a part of the building and not a complete building. The solutions need to incorporate quality. Therefore the scale should be on the component level (combined products that fulfil a specific function).

P2Endure Solutions

PnP prefab components for building envelopes

- Fermacell multifunctional panel
- Alliantie+ prefab BEAM façade
- Energy efficient aluminium façade element
- RenoZEB Units for building envelopes
- Cocoonz frameless prefab façade
- Smart energy efficient window
- Rooftop retrofitting / extension module

PnP prefab technical systems

- HVAC system
- Prefab bathroom
- Comfort EYE - IEQ control system
- Connection to energy grid and RES production

On-site 3D technologies

- Thermal and acoustic scanning technologies
- 3D scanning (geomatics) - laser and photogrammetry
- 3D printing and robotics

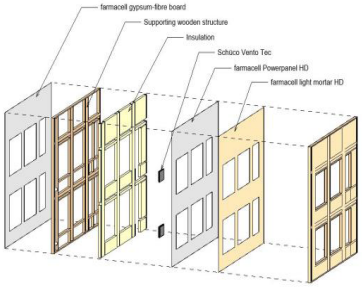
ICT tools for deep renovation

- RE Suite

PnP prefab components for building envelopes

Fermacell multifunctional panel

- Prefabricated highly insulating panel – substructure wood or steel – with a cementitious board on the outer and a gypsum fibre board on the inner face.
- Different installations and HVAC systems can be integrated within the façade panel.
- Renovations can quickly be done without major installation works inside the building.
- Competitive solution when labour costs are high and a building must be completely renovated including all supply ducts, heating/cooling units and cabling.




facade panel with central air supply (left side with ventilation ducts) and electric + water supply (right side)

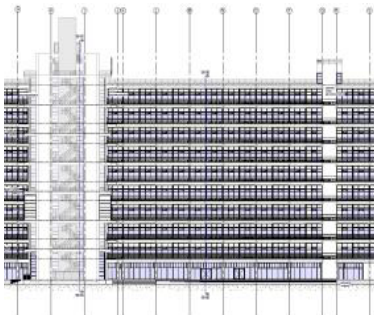
Alliantie+ prefab BEAM façade

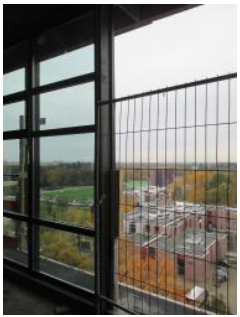
- Standardardised insulation materials and window frames.
- Highly customised finishings.
- Renovation can be performed while the building is occupied and it takes about one week.
- The components are assembled on site, no need for storage of construction or a waste depot.

PnP prefab components for building envelopes

Energy efficient aluminium façade element

- Equipped with a façade identification system (FIS), connected to the BIM model and based on IFC.
- FIS facilitate the identification of the element and the exact position where it should be placed.
- FIS reduces mounting time and decreases the risks of mistakes.
- Inspection before and after placement can be stored in the BIM model based on the unique identification of the facade element.



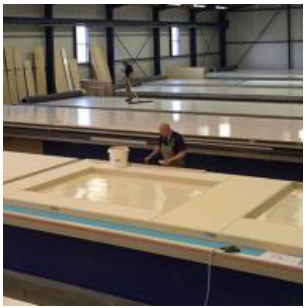


RenoZEB Units for building envelopes

- Prefabricated units composed by a steel frame and several types of layers.
- 8 typologies of units have been developed to fulfil different building requirements.
- PnP component developed within the RenoZEB project (GA No. 768718).

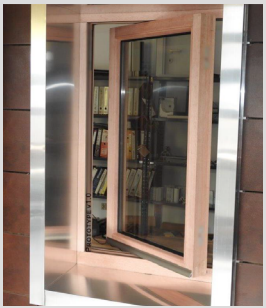
Cocoonz´s frameless prefab façade

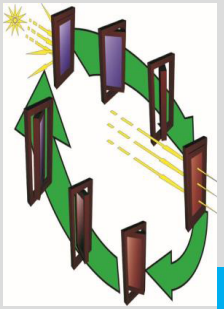
- Polyester layer with a PU-insulation layer, an outer finishing of a 'thin brick layer', wood covering, plaster or other finishing material or product.
- Integration of installations in the façade is possible.
- The element can be placed in addition to an existing thermal unisolated façade.
- Fully industrialised production process.
- Reduction of assembling and mounting time on-site, as well as of costs.



Smart energy efficient window

- Reversible sash (turning 180/360), closing in the reverse position.
- Possibility to change Low-E coating position (expected annual energy savings max. 5.8 [kWh/m2 floor area] corresponding to 39 [kWh/m2 glass area).
- Reduced costs for heating and cooling.
- Reduced CO2 emissions thanks to the energy savings.
- Comfortable indoor climate and conditions the whole year round.
- Possibility of shading integration.

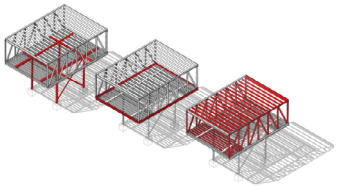




PnP prefab components for building envelopes & technical systems

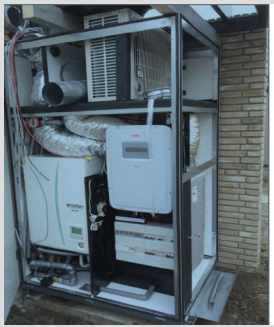
Rooftop retrofitting / extension module

- Fast, lightweight, dimensionally stable solution for adding a new floor to an existing building.
- Hollow walls easily facilitate pre-installed installations and ducts.
- Demonstrated in several pilot projects within the EU IEE project SuRE-FIT.



HVAC system

- Complete PnP MEP/HVAC engine for deep renovation.
- It includes: air- heat pump, storage capacity for domestic hot water (DHW), mechanical ventilation system, expansion barrel, and control systems.
- The total cost of retrofitting installations is reduced by 40% due to efficient manufacturing and efficient use of labour.
- Quick assembly time of just 0.5 day to place engine, connect pipes/ducts, and then operate with predictable predefined performance.



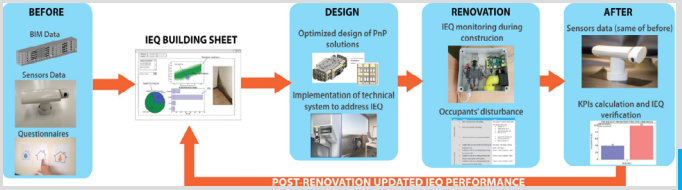
PnP prefab technical systems

Prefab bathroom

- Fabricated in a factory and only need to be mounted and connected to piping on site in the building.
- All piping and ducting is already prepared in the building, which makes Plug-and-Play assembling possible.

Comfort EYE - IEQ control system

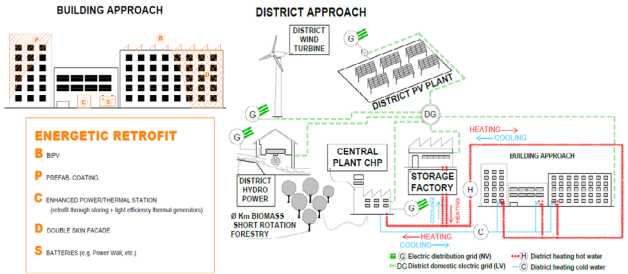
- Innovative system for the Indoor Environmental Quality monitoring.
- Composed by a ceiling mounted device that scans the room's surfaces temperature and by a desk node for environamental and IAQ parameters.
- The system can perform continuos measurements of PMV and Mean Radiant Temperature (ISO 7730), together with IAQ. This data can be used for long-term monitoring or real-time HVAC control.



Connection to energy grid and RES production

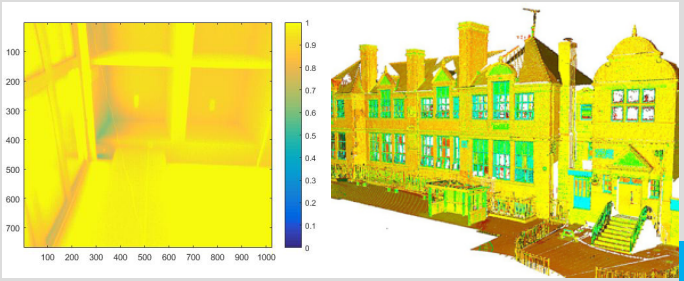
Three-step approach:

- to pursue the best utilization of suitable portions of the building envelope to lodge the RES production, in order to optimis e the direct use of the electricity/heat self-produced by these devices;
- to promote the best utilisation of PnP compact energy storage systems at building level;
- to promote the development and deployment of combined heat and power (CHP) plants, associated to centralized storage systems, within neighbour/district configurations, assisted by control systems, to enhance their potential of lowering the shift between RES production and end-user demand.



Thermal and acoustic scanning technologies

- Quality controls for prefab panels to eliminate or reduce the quality gap between the design and construction phases through self-inspection and self-instruction techniques.
- Thermal bridges detection.
- Thermal transmittance degree.
- Structural integrity diagnosis.
- Acoustic leakages detection.
- 3D geometric scanning and reconstruction.



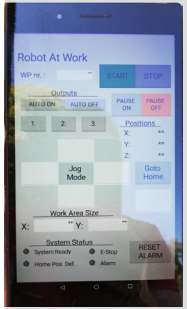
On-site 3D technologies

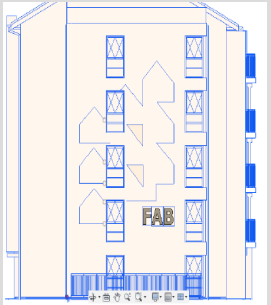
3D scanning (geomatics) - laser and photogrammetry

- P2Endure has implemented 3D laser scanning in several demonstration cases.

3D printing and robotics

- The modular robot platform can work from 1m² to 60m² (or more) on-site.
- Has a multifunctional use and can be integrated in different tasks on-site.
- It can operate with different kinds of tool for example: spray-painting, spraying mortar/ putz for rendering, milling, 3D printing on ground or facade with any material and it can move and lift materials.
- A platform was developed that communicates to the robot directly.





RE Suite

- Software solution that supports collecting, structuring, analysing and disseminating information of buildings and civil infrastructure.
- Supports the entire life-cycle of real estate and information management.
- Condition assessment tool for building renovation and for life-cycle cost analysis and asset management.

P2Endure Demonstration cases

Transformation of public or historic buildings

- **Palmanova (IT) -** Virtual demo case
From historic hospital into dwellings
- **Tilburg (NL) -** Virtual demo case
From historic monastery into short stay facility
- **Reggio Emilia (IT)**
From historic hotel into office
- **Enschede (NL)**
From university building into student hostel / hotel
- **Gdynia (PL)**
From nursery school into apartments

Deep renovation of public buildings

- **Warsaw (PL)**
Refurbishment of a Nursery building
- **Menden (DE)**
Refurbishment of an office building
- **Genova (IT)**
Refurbishment of historic nursery building

Transformation of public or historic buildings

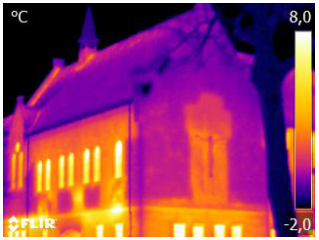
Deep renovation of residential buildings and districts

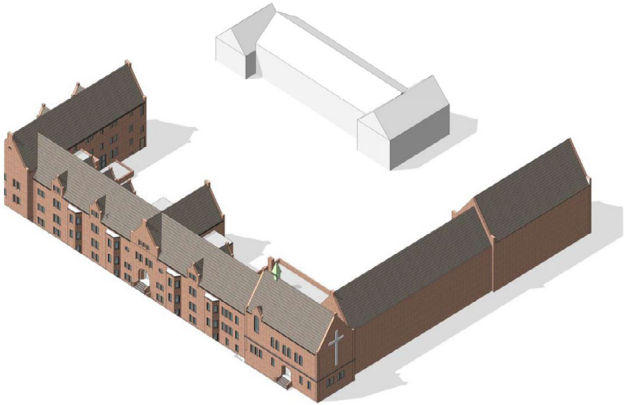
- **Ancona (IT)**
Refurbishment of residential block
- **Florence (IT)**
Refurbishment of historic residential building
- **Korsløkkeparken (DK)**
Refurbishment of a residential district
- **Lekkerkerk (NL)**
Refurbishment of a residential district
- **Utrecht (NL)**
Refurbishment of 10 single family dwellings

Palmanova, IT - from historic hospital to dwellings

- Built in early 1900s, refurbished several times up to 1995, now abandoned.
- Deep renovation would include the restoration of the historical parts (8.500 $m^{3)}$ and the demolition and replacement of the damaged and degradated volumes (27.400 m^3).
- The project has been temporarily stopped in 2018. It remains a virtual demonstration case for P2Endure. Surveys have been completed and virtual analyses are performed with specific reference to the application of RES system and their benefits at district level.

Tilburg, NL - from historic hospital to dwellings





- Built in 1935, well maintained but never renovated.
- 5.400 m^2 with approximately 60 rooms.
- Deep renovation objective was to fully renovate the monastery to a new level of comfort, improve energy performance.
- Addition to every room a PnP-bathroom unit, new heating by HVAC-engines, applying HR++ glazing, PV-panels in the back side of the building and increasing the sound insulation between rooms.
- The project has been stopped and remains a virtual demonstration case for P2Endure.

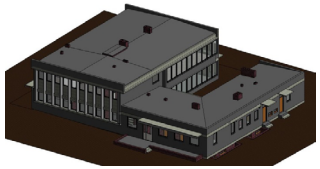
Reggio Emilia, IT - from historic hotel to offices

- Built in the Middle Age and refurbished in the early 1900, now abandoned.
- Deep renovation of 300 m^2 to get an energy efficient building, preserving the historical elements.
- Use of prefab products on the building envelope and use of technical systems (HVAC engine, control systems, thermal sensor, grid connection: heat pump fed by electricity produced thanks to PV systems and a local hydropower plant).

Enschede, NL - from university building to dwellings

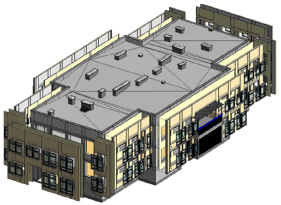
- Abandoned building on the University of Twente campus.
- Installation of a new building shell together with a new HVAC system will provide an energy saving of close to 70% compared to the current building.
- Prefab solutions will be applied on this project this will allow to reach the 50% savings in renovation time.

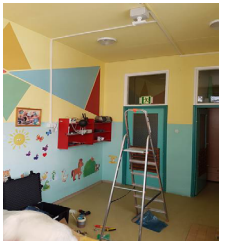
Gdynia, PL - from nursery school to dwellings



- Built in 1970, used first as orphanage, and currently houses a nursery school.
- The built up area is 464 m^{2}.
- The City of Gdynia decided to finance insulation of the walls under ground level and perform preparatory works for P2ENDURE renovation activities.
- Renovation includes the use of Multifunctional façade panels, the installation of 13 smart windows and rooftop retrofitting module.

Warsaw, PL - nursery building





- Built in 1983 in the southern part of the city, in Ursynów District. It is one of 64 municipal nurseries in Warsaw.
- The building is made of prefabricated concrete elements and cellular concrete wall and comprises two over ground floors and one floor in the basement; its gross covered area is 631 m^2.
- Retrofit solutions consist of the use of prefab modules on the building envelope, smart reversible windows, and rooftop retrofitting module.

Deep renovation of public buildings

Menden, DE - office building

- It is part of a large former industrial and storehouse site built before 1940. The overall size of the site is 5.400 m^2 and the approx. office floor space is 155 m^2.
- Prefab deep renovation solutions: Adding prefabricated façade elements, prefabricated integrated HVAC installation, Comfort EYE technology.
- Energy saving target after deep renovation: 100 kWh/m^2a (German Energieeffizienzklasse C-D).

Genoa, IT - historic nursery building

- Located in an urban context at the 1st floor of a 1930s building. Net surface area of 267 m^2.
- Renovation objective is to improve the energy efficiency and the internal thermal comfort of the school, specially during the summer.
- Due to the historical constraints of the façades and the actual state of the windows the most convenient P2ENDURE solution is the Smart Window which requires careful design in order to comply with the original windows and the external aspects of the facade.

Ancona, IT - residential block

- Built in 1980, 100 dwellings, 6 floors and total gross area of 1720 m^2.
- The load bearing structure is realized with precast reinforced concrete bearing walls.
- The balconies are prefabricated concrete panels are replaced by a wall of perforated brick (12cm thick) with a total thermal transmittance U = 0.55 W/m2K.
- The glazed surface are made with insulating glazing and metal frames without thermal break (U=3.28 W/m2K).

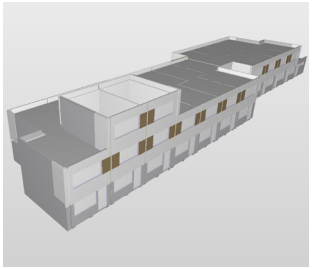
Florence, IT - residential building

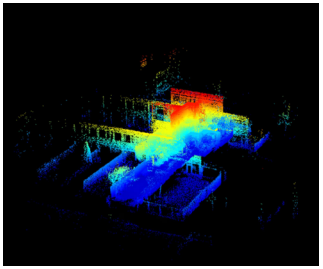
- The building is part of the expansion and rehabilitation area implemented in the period from 1864 to 1871.
- Multifunctional use: commercial / craft on the ground floor, and residential use on the upper floors.
- Deep renovation solutions: high performance insulation of the roof, new windows with U-value of 1,4 W/m2K, new ventilation system per room and new floor heating system with high efficiency condensing boiler, Comfort EYE.

Korsløkkeparken, DK - residential district

- The residential district constructed in the years 1958-78 and is one of the biggest in Odense City.
- Total area m^2 for deep renovation: 73707m^2.
- The overall objective is a total exterior and interior deep renovation. The main exterior work is a new thermal insulation and climate shell and renewal of the ventilation system.
- Innovation: Application of advanced 3D printing technologies with robot for façade renovation.

Lekkerkerk, NL - residential district





- The dwellings are built in 1975 and owned by a social housing cooperation.
- The dwelling morphology contains a concrete façade finished with concrete panels, concrete floor and roof.
- The dwellings are renovated in a habited condition using fully prefabricated façade elements.
- The elements already contain the doors, windows and exterior and interior finishing's and are mounted in 1 day.
- Energy savings are expected to be 60% compared to the pre-renovated situation.

Utrecht, NL - block of 10 single family dwellings

- Built in 1960.
- Dutch Energy label G; building physical quality of the façade is very poor. Energy savings after deep renovation expected higher that 60%.
- Building Morphology: Concrete bearing partition walls and floors. Light façades with poor insulation and single glazing in sleeping rooms.
- The components for roof, façade, floor, installation and interior are combined to reach the ambition Net-Zero energy use.