P2ENDURE

Plug-and-Play innovative products for energy efficient, cost effective and high-quality deep renovation of buildings embedded in a stepwise fully BIM supported development process

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

What is P2ENDURE?

The project aims to improve the availability and performance of **energy saving solutions for deep renovation** and transformation of vacant, obsolete, or sub-optimal public buildings into dwellings promoting 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 **9 real projects**, **2 virtual demonstrators** in 4 geo-clusters with EU-wide replication potentials.

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Suggested for digital use

This booklet is a living document, and it presents the main innovations, outcomes and lessons learnt from P2ENDURE.
This version of the document is launched in the last phase of the project.

P2ENDURE *Factsheet*

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

DK: Invela

DE: 3L-Plan Lenze-Luig Architects, Fermacell GmbH, Technische Universität Berlin,

NL: DEMO Consultants, Huygen Installatie Adviseurs, PANplus Architectuur, Excalibur

PL: Bergamo Technologie Spzoo, Fasada, Mostostal Warszawa, Miasto Stołeczne Warszawa,

IT: Berquerel Elactric, SGR Servizi, RINA Consulting, Università Politecnica delle Marche.

[1] with an extension of 6 months due to Covid-19 outbreak

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Problem Statement

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Almost 90% of 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 (TRLs)

3

However, there are several barriers for large-scale deep renovation in Europe:

- Financial barriers: renovation costs, access to finance, (temporarily) low energy price
- Technical barriers: lack of affordable technical solutions and know-how 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

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

Hypothesis

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

- PnP renovation goes beyond *modular building units*.
- 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 innovation vision?

Project objectives:

- To **optimize**, **integrate and validate** state-of-the-art prototypes and commercially available packages of **PnP prefab solutions** for deep renovation;
- To **demonstrate** and **promote innovative on-site processes** for fast deep renovation projects with low disturbance for the residents, and significantly improved indoor environment quality (IEQ) after completion;
- To **measure**, **monitor** and **validate P2Endure** products and process innovations based on live **demonstration projects** of deep renovation, virtual simulation and prototyping;
- To provide **solid empirical evidence** of the performance and quality of P2Endure solutions while ensuring their **scalability and replicability** at district, city, region, country and EU level;
- To ensure the **market uptake** and **upscaling** of P2Endure innovations during and immediately after the project by directly involving 'launch customers', value-chain and distribution network partners, and other stakeholders at local, regional, and EU level;
- To **disseminate** and **valorise knowledge and results** from P2Endure along with establishing and strengthening synergies with other EU and national innovation activities.

Technical goals:

- To implement a new **methodology for PnP deep renovation**;
- To ensure the **readiness of PnP solutions** (Building Envelope and Technical Systems retrofits);
- To configure and use **supporting ICT tools** (BIM, BEM, software tools);
- To **demonstrate** in real deep renovation projects.

Measurable indicators of achievement:

- At least **60% energy saving** (more energy-efficient compared to before renovation) through:
  - Implementation of PnP prefab solutions to 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) through:
  - Major labour cost reduction through PnP prefab 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) through:
  - 50% faster from production to on-site assembly
  - PnP prefab solutions ready to be implemented without structural changes of the existing building

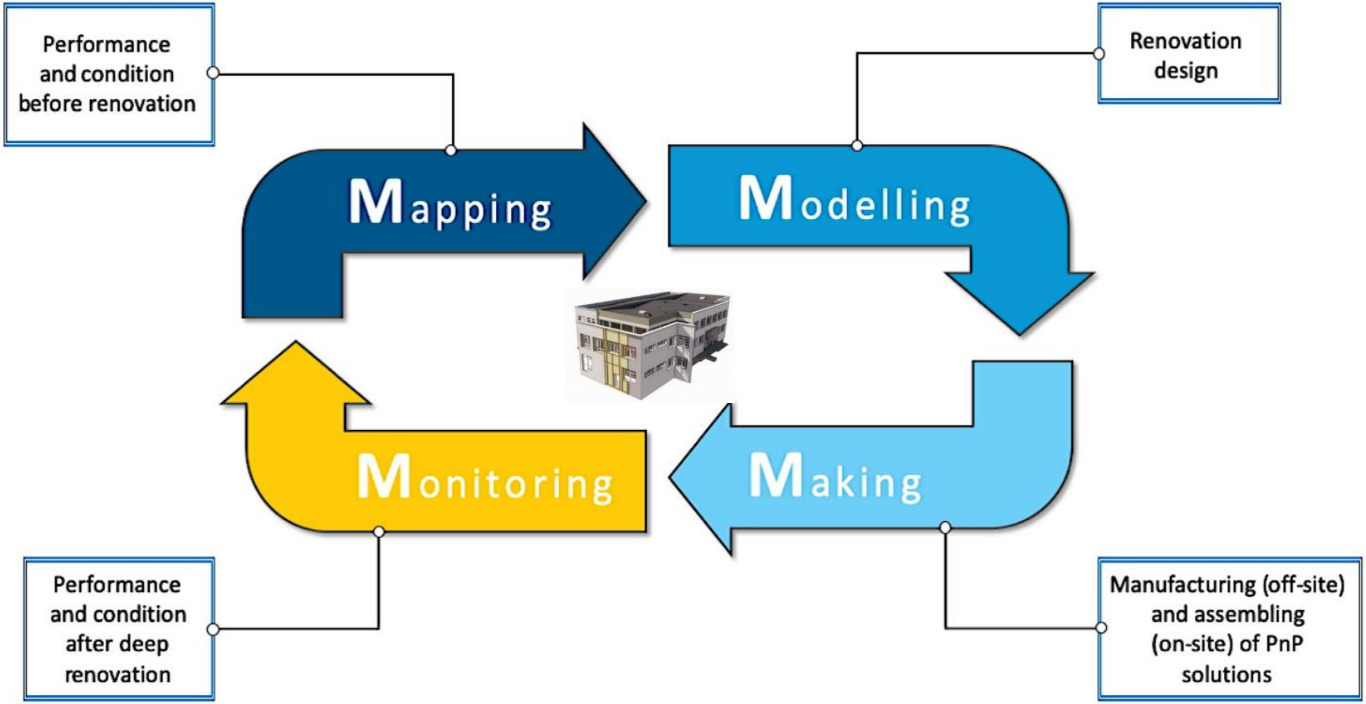
P2Endure KPIs:

- Reduced Net Primary Energy
- Lowered Embodied Energy
- Reduced renovation costs
- Reduced renovation times
- Reduced disturbance during renovation
- Improved indoor environmental quality
- Replicability and scalability

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 a starting point for the renovation design.*

<u>'3D scan to BIM' process:</u>

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

<u>Off-site activities:</u>

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

<u>On-site activities:</u>

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

<u>Online interactions processes between on-site and off-site processes:</u>

- Comparative analysis.

Point cloud of the Warsaw demonstration case, obtained after 3D laser scanning

Modelling

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

<u>'BIM to BEM' process:</u>

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.

<u>Off-site activities:</u>

- BIM creation
- e-Marketplace

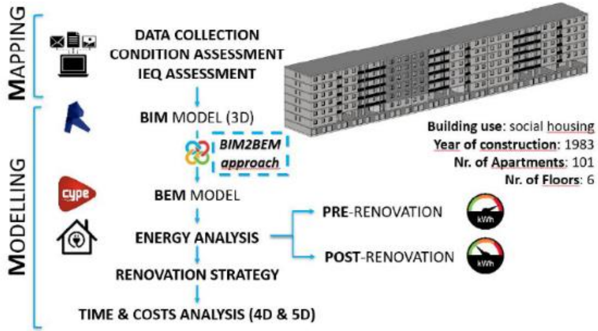
<u>On-site activities:</u>

- 3D Data capturing and thermal scanning.

<u>Online interactions processes between on-site and off-site processes:</u>

- Performance simulations of innovative P2ENDURE solutions.

BIM model and analytical model of Ancona demonstration case



Making

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).

On-site panels installation in Gdynia demonstration case

Production of the Cocoonz façade elements for Lekkerkerk demonstration case

Monitoring

Purpose: to monitor and guarantee the high-quality execution of the construction works and 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.

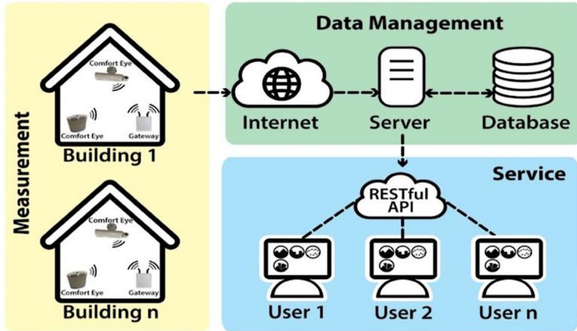
On-site activities:

- 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 and built for maintenance and facility management,
- BIM based Life Cycle management planning & total cost of ownership
- Managing feedback loop for systematic improvements of prefab components.

Monitoring the indoor environmental quality in demo cases



P2ENDURE solutions technologies tools

PnP prefab components for building envelopes:

- Prefab facade
    - Fermacell Multifunctional Façade Panel
    - Beam Façade
    - Cocoonz Frameless Prefab Façade developed by NBU innovatie bv
    - Aluminium Façade Component
    - RenoZEB Unit
- Smart Energy-Efficient Window
- Flat Energy Rooftop Extension Module

On-site 3D technologies:

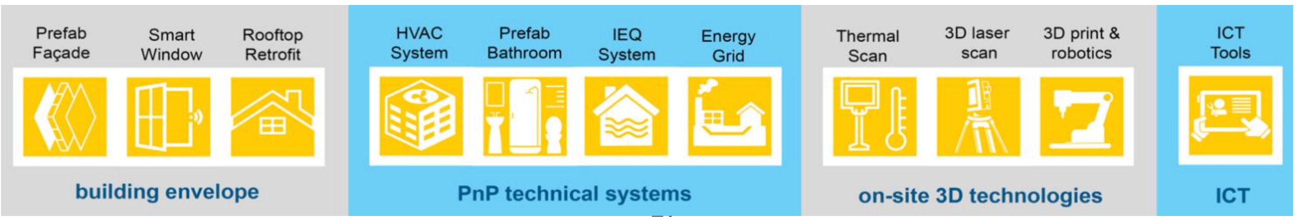
- Thermal and acoustic scanning technologies
- 3D scanning (geomatics) – laser and photogrammetry
- 3D printing robotics

PnP prefab technical systems:

- HVAC System
- Prefabricated Bathroom Module
- Comfort EYE – IEQ Control System
- Connection to energy grid and RES production

ICT tools for deep renovation:

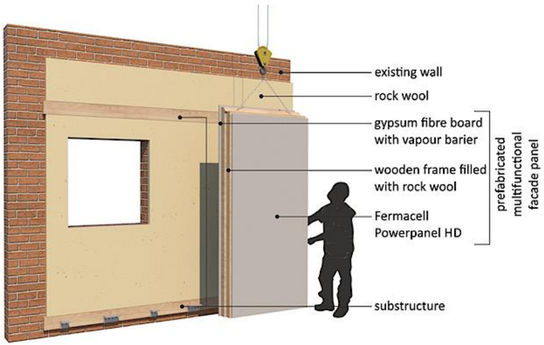
- RE Suite

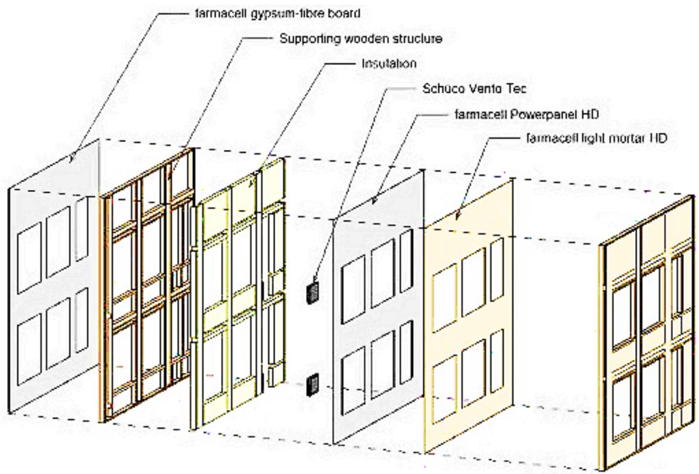


PnP prefab components for building envelopes

Fermacell Multifunctional façade panel

- Prefabricated highly insulating panel – substructure wood or steel – with a cementitious board on the outer and 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





Beam Prefab Façade

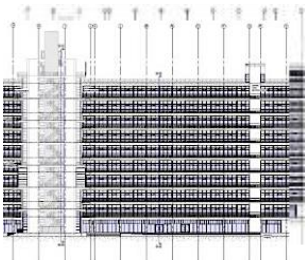
- Standardised insulation materials and window frames.
- Highly customised finishing
- Renovation can be performed while the building is occupied and it takes about one week
- The components are assembled on site, no need for storage of construction or waste depot

Cocoonz 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 uninsulated façade
- Fully industrialised production process
- Reduction of assembling and mounting time on-site as well as of costs
- Cocoonz facade is frameless therefore without thermal bridges in the component
- further development for robotized production

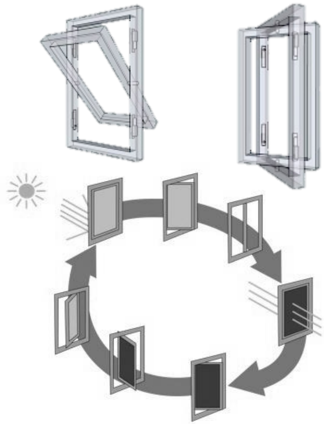
Aluminium Façade Component

- Equipped with a façade identification system (FIS), connected to 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 risk of mistakes
- Inspection before and after placement can be stored in the BIM model based on the unique identification of the façade element



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/m^2 of floor area] – corresponding to 39 [kWh/m^2 of glass area])
- Reduced costs for heating and cooling
- Reduced CO_2 emissions thanks to energy savings
- Comfortable indoor climate and conditions the all year round
- Possibility of shading integration.

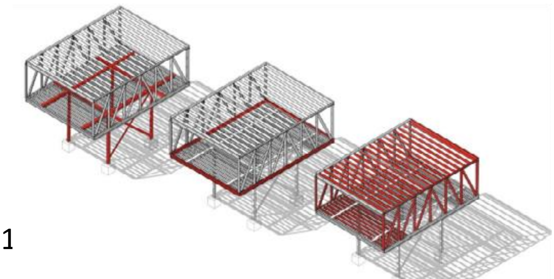


RenoZEB Unit (integrating solutions available in the market)

- Demonstrating the potential of integrating plug & play solutions that are available in the market
- PnP component developed within the RenoZEB project (GA No. 768718).
- Prefabricated units composed by a steel frame and several types of layers
- 8 typologies of units have been developed to fulfil different building requirements

Flat Energy Rooftop 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



PnP prefab technical systems

HVAC System

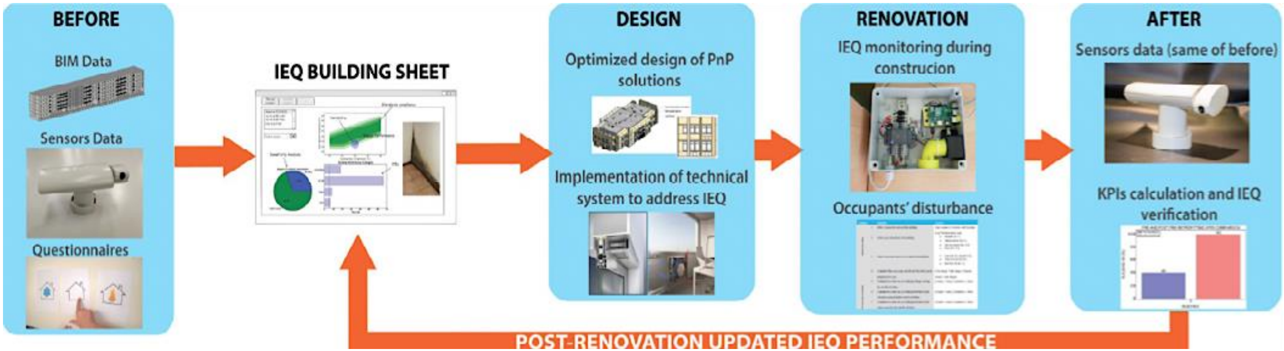
- Complete PnP MEP/HVAC engine for deep renovation
- It includes: air-heat pump, storage capacity for domestic hot water (DHW), mechanical ventilation system, expansion barrel, and control systems
- The total cost of retrofitting installations is reduced by 40% due to efficient manufacturing and efficient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

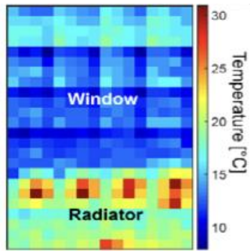
Prefabricated Bathroom Module

- Fabricated in a factory, only needs to be mounted and connected to piping on site in the building
- All piping and ducting is already prepared in the building, which makes PnP 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 environmental and IAQ parameters
- The system can perform continuous measurements of PMV and Mean Radiant Temperature (ISO 7730), together with IAQ
- These data are used for KPI estimation, for long-term monitoring or real-time HVAC control



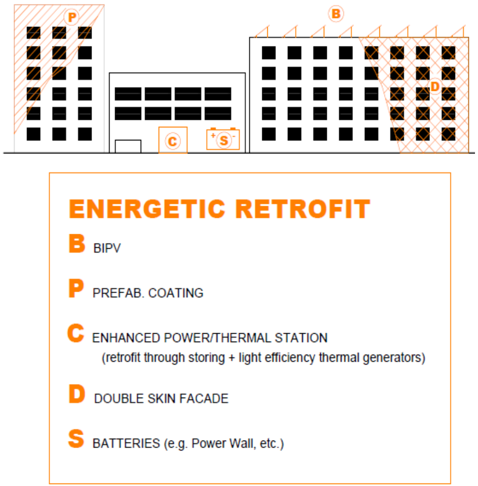


Connection to energy grid and RES production

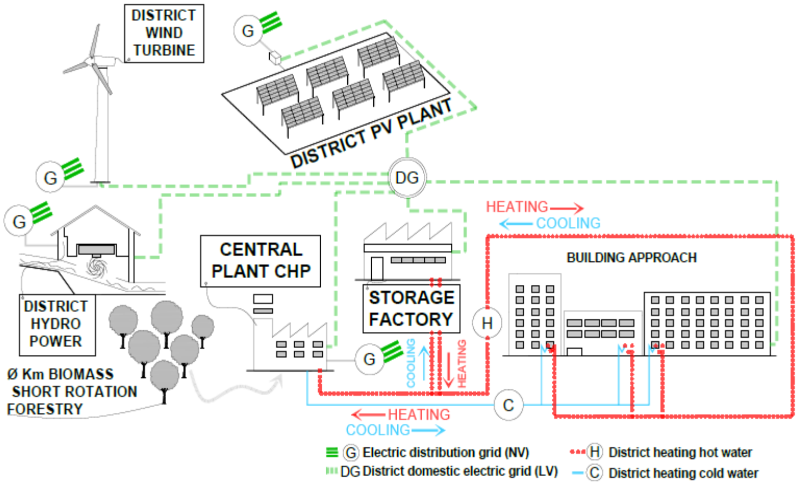
Three-steps approach:

- To pursue the best utilisation of sustainable portions of the building envelope to lodge the RES production, in order to optimise the direct use of the electricity/heat self-produces 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 centralised 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

BUILDING APPROACH



DISTRICT APPROACH



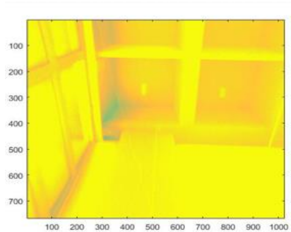
On-site 3D technologies

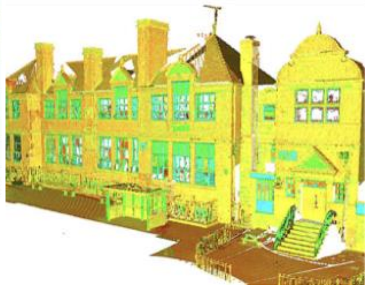
3D scanning (geomatics) – laser and photogrammetry

- P2ENDURE has implemented 3D laser scanning in several demonstration cases

Thermal and acoustic scanning technologies

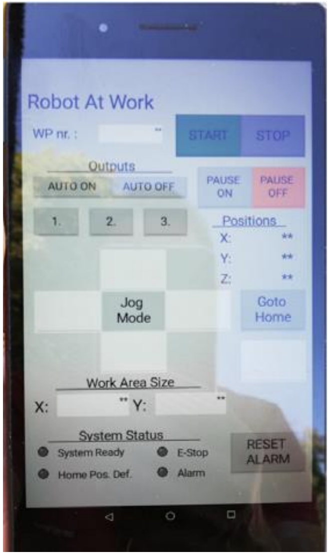
- Quality controls for prefab panels to eliminate or reduce the quality gap between the design and construction phases through self-inspection and self-instruction techniques
- Thermal bridges detection
- Thermal transmittance degree
- Structural integrity diagnosis
- Acoustic leakages detection
- 3D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

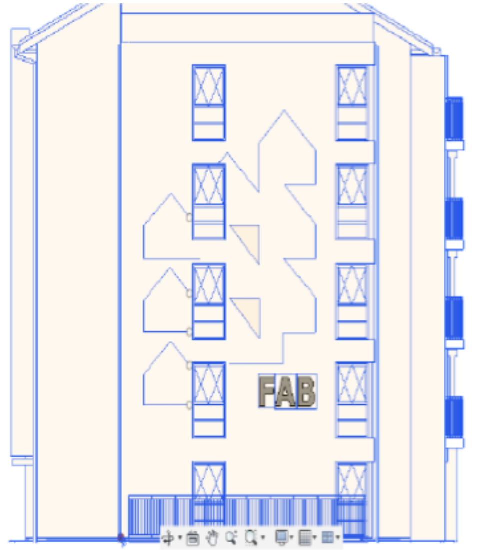




3D printing and robotics

- The modular robot platform can work from 1m^2 to 60m^2 (or more) on site
- It has a multifunctional use and can be integrated in different tasks on site
- It can operate with different kinds of tools for example: spray-painting, spraying mortar/ putz for rendering, milling, 3D printing on ground or façade with any material and it can move and lift materials
- A platform was developed that communicates to the robot directly

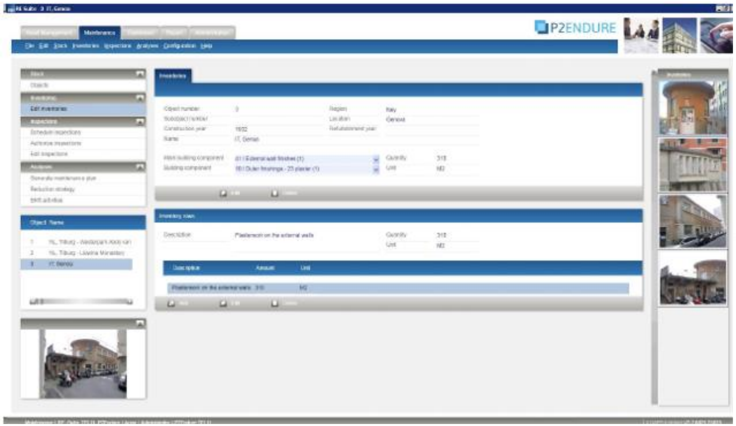




ICT tools for deep renovation

<u>RE Suite</u>

- 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

List of pilot projects

Transformation of public or historic buildings:

- **Reggio Emilia** (IT) – transformation of a historic hotel into office building
- **Enschede** (NL) – transformation of an unused university building into student hostel/hotel
- Tilburg (NL) – virtual demonstration case: transformation of a historic monastery into short stay facility

Deep renovation of public buildings

- **Warsaw** (PL) – refurbishment of a nursery building
- **Gdynia** (PL) – deep renovation of kindergarten
- **Menden** (DE) – refurbishment of an office building

Deep renovation of residential buildings or/and districts

- **Genova** (IT) – refurbishment of a historic nursery building
- **Korsløkkeparken** (DK) – refurbishment of a social housing district
- **Lekkerkerk** (NL) – refurbishment of social housing in residential district
- **Utrecht** (NL) – refurbishment of low houses (10 single family dwellings)
- Ancona (IT) – virtual demonstration case: refurbishment of a residential block

List of pilot projects, implemented solutions, and the KPIs

Pilot site	Solutions, technologies, tools	Reduced Net Primary Energy	Lowered Embodied Energy	Reduced renovation costs	Reduced renovation times	Reduced disturbance during renovation	Improved indoor environmental quality
Tilburg	Building envelope, Smart window, HVAC system, Prefab bathroom, Thermal scan, RE Suite	71%	NA	20%	NA	NA	NA
Reggio Emilia	Building envelope, HVAC system, Grid connection, IEQ system	90%	NA	Globally	10%	NA	Questio-nnaire 50% Before: 50% After: 100%
Enschede	Building envelope, HVAC system, Thermal scan, Prefab bathroom	62%	NA	Globally	56%	NA	CE 75% After: 75%
Warsaw	Building envelope, Grid connection, Rooftop module, IEQ system, 3D scanning	60%	2%	15%	52%	NA	CE Netatmo 60% Before: 40% After: 100%
Gdynia	Building envelope, Rooftop module, IEQ system, 3D scanning	67%	5%	15%	50%	91%	CE 50% Before: 25% After: 75%
Menden	Building envelope, HVAC system, IEQ system	61%	44%	YES	YES	87%	NA
Ancona	Building envelope, IEQ system, RE Suite, HVAC system	68%	10%	NO	90%	NA	Before: 0% Measured only before the renovation
Genova	IEQ system, Smart window, RE Suite	60%	NA	15%	NA	100%	CE 50% Before: 0% After: 50%
Korsløkke	3D printing	39%	NA	NA	NA	NA	NA
Lekkerkerk	Building envelope, Thermal scan	46%	0%	YES	55%	85%	Sensi 50% Before: 50% After: 100%
Utrecht	Building envelope, HVAC system	66%	37%	NA	49%	YES	NA

Legend

CE= Implementation of Comfort Eye
SENSI= Implementation of indoor sensor SENSI
Netatmo= implementation of Netatmo sensor network
After= IEQ percentage After renovation
Before= IEQ Before renovation
NA= Not applicable

Reduced disturbance during renovation	The higher the percentage the better reduction in the disturbance
Improved indoor environmental quality	The higher the percentage the better more improvement in IEQ

Replicability and scalability

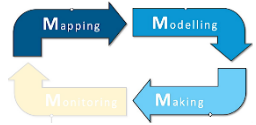
The performance of the P2Endure solutions was assessed also through the replication potential to other buildings that are located in different European countries. The idea is to support potential investors and designers and to show them what are the technical, legal, financial, and social constraints when applying the P2ENDURE solutions. Specific attention should be paid to:

- The implementation of a PnP façade solution is more effective on the buildings with modular and regular building geometry, regular windows openings, and details.
- 3D printing technology is highly relevant for the buildings that have façade ornaments, and their original façade appearance needs to be preserved.
- Solutions that can be applied widely are 3D scanning, based on which as-built Building Information Model can be performed or Comfort EYE that is a tool developed in the project for indoor air quality monitoring.

It is estimated that for this moment P2Endure solutions can be implemented in the following number of residential buildings:

- 794 282 buildings in Poland,
- 549 200 in the Netherlands,
- 664 209 in Norway,
- 4 930 000 in Germany and
- 1 139 549 in Italy.

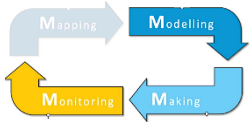
In addition, it is estimated that approximately 526 educational buildings in Warsaw and Gdynia, the P2ENDURE solutions can be implemented in a short timeframe (i.e., within 3 years).



Transformation of public or historic buildings

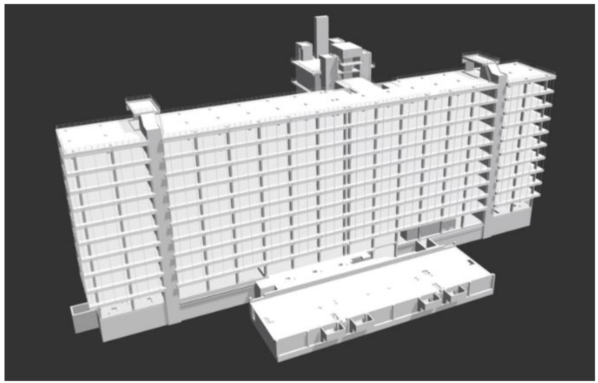
Reggio Emilia (IT) – transformation of a historic hotel into office building

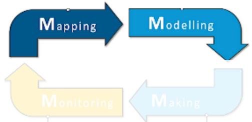
- Built in the Middle Ages and refurbished in the early 1900s, now abandoned.
- Deep renovation of 300 m2 to get an energy efficient building, preserving the historical elements.
- Use of prefab products on the building envelope and use of technical systems (HVAC engine, control systems, thermal sensor, grid connection: heat pump fed by electricity produced thanks to PV systems and local hydropower plant).



Enschede (NL) – transformation of an unused university building into student hostel/hotel

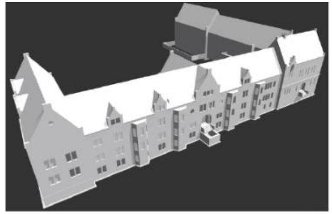
- Abandoned building of the University of Twente campus.
- Installation of a new building shell together with a new HVAC system is expected to provide an energy saving of 70% in comparison to the original state.
- Prefab solutions applied on this project should allow to reach 50% savings in the renovation time.

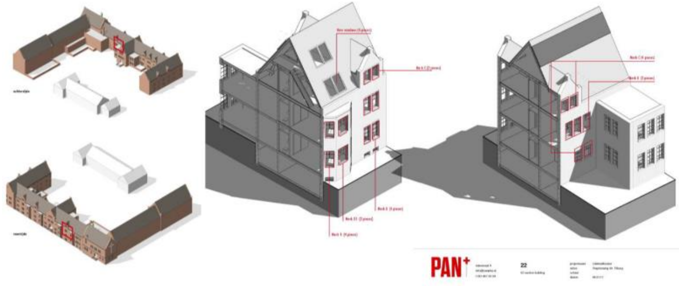


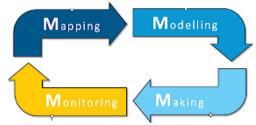


Tilburg (NL) –transformation of a historic monastery into short stay facility

- Build in 1935, well maintained but never renovated.
- 5.400 m^3 with approximately 60 rooms.
- The objective of the deep renovation was to fully renovate the monastery to a new level of comfort and to improve its energy performance.
- Addition to every room were a PnP-bathroom unit, a new heating by HVAC-engines, application of 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.







Deep renovation of public buildings

Warsaw (PL) – refurbishment of a nursery building

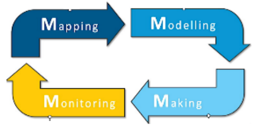
- Built in 1983 in the southern part of the city (Ursynów district). It is one of the 64 municipal nurseries in Warsaw.
- The building is made of prefabricated concrete elements and cellular wall. It comprises two above-ground floors and one floor in the basement; its gross covered area is 631 m^2.
-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

Solution 1:
Envelope of the building: multifunctional panels by Fermacell

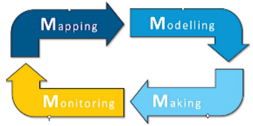
Solution 2:
Smart reversible windows by Bergamo Tecnologie

Solution 3:
Rooftop retroffiting module design by PAN+ Architektuur

Gdynia (PL) – renovation of the kindergarten building



- Built in 1970, used as a nursery school.
- The built-up area is 464 m^2.
- The City of Gdynia decided to finance insulation of the walls under the ground level, change of old wooden windows and perform preparatory works for P2ENDURE renovation activities.
- Renovation works include the use of Multifunctional façade panels and monitoring of the indoor air quality before and after the renovation with two comfort eyes. Rooftop retrofitting module was design and analysis of the energy production from renewables was performed.



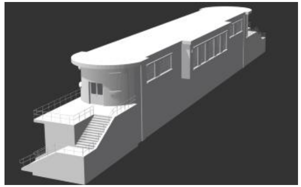
Menden (DE) – refurbishment of an office building

- It is a 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 approximate office floor space is 155 m^2.
- Prefab deep renovation solutions: adding prefabricated façade elements, prefabricated HVAC installation, Comfort EYE technology.
- Energy saving target after deep renovation: <u>100 kWh/m^2a (German Energieeffizienzklasse C-D)</u>

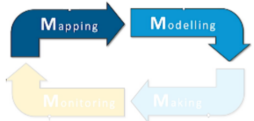
Deep renovation of residential buildings and/or districts

Genoa (IT) - refurbishment of a historic nursery building

- Located in an urban context at the 1st floor of a 1900s building.
- Net surface area of 267 m^2.
- Renovation objective is to improve the energy efficiency and the internal thermal comfort of the school. Especially during summer.
- Due to the historical constrains 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 façade.

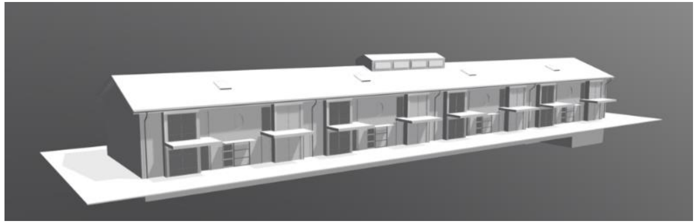


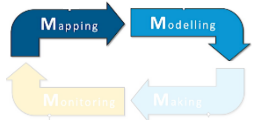
Window locked, hermetically sealed | Ventilation between frame and sash for improved indoor comfort | Reversibility across seasons to control solar gain | Easy and safe cleaning: cleaning from inside



Korsløkkeparken (DK) – refurbishment of a social housing district

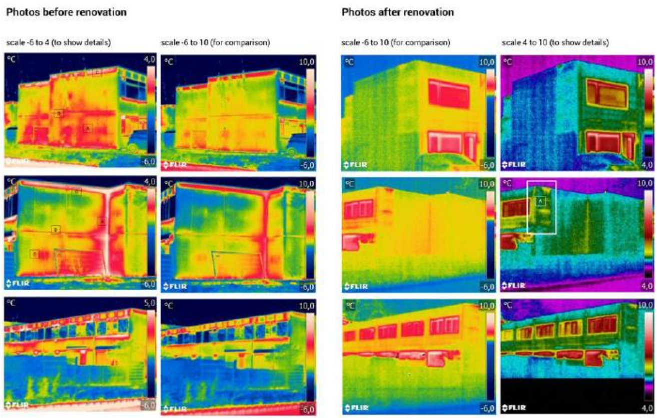
- The residential district Korsløkken was constructed in the years 1958 – 78 and is one of the biggest in Odense City.
- Total area for deep renovation is 73.707 m^2.
- The overall objective is a total exterior and interior deep renovation.
- The main exterior work is a new thermal insulation with a climate shell, and a renewal of the ventilation system.
- Innovation: application of advanced 3D printing technologies with robot for façade renovation.





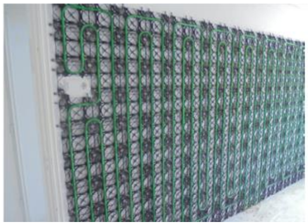
Lekkerkerk (NL) – refurbishment of social housing in residential district

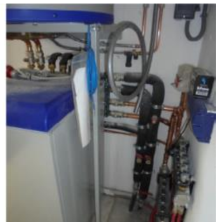
- The dwellings were built in 1975 and owned by a social housing cooperation consisting of 78 dwellings.
- The dwellings morphology contains a concrete façade finished with concrete panels, concrete floor and roof.
- The dwellings are renovated in a habited condition using prefabricated façade elements.
- The elements already contain door, windows and exterior and interior finishing's and are mounted in 1 day.
- Energy savings are expected to be 60% compared to the pre-renovation situation.

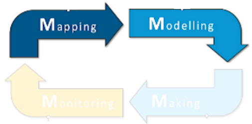


Utrecht (NL) – refurbishment of low houses (10 single family dwellings)

- Built in 1960s.
- Dutch energy label G; building physical quality of the façade is very poor. Energy savings after deem renovation expected higher than 60%
- Building Morphology: Concrete bearing partition walls and floors. Light facades 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.

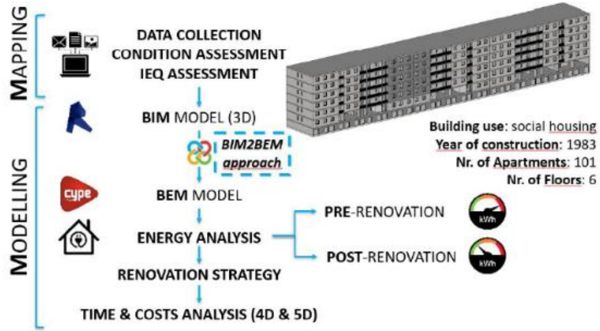


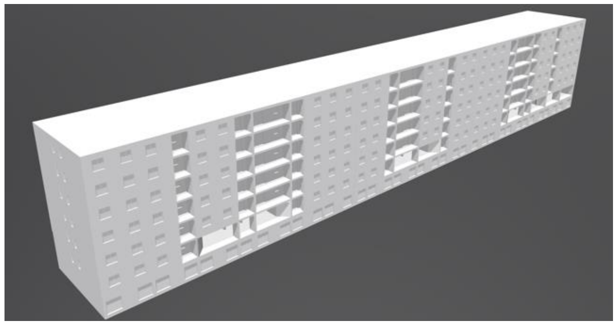




Ancona (IT) – virtual demonstration case: refurbishment of a residential block

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





P2ENDURE lessons learnt

4M approach & PnP solutions

Lessons learnt from the demonstration case in Reggio Emilia

4M process

MAPPING	• Collection of some bills and records from the past users; Hard to collect data form occupants about the use of the building; difficulties in determining the typology of materials of the building envelope since the historic and architectonic constraints and issues in their BIM modeling
MODELING	• BIM to BEM gives the possibility for accurate prediction for the energy use and thermal comfort • Clash control by BIM preventing from trial-and-error design • Necessity of considering input from the Architectural Superintendence and the related restraints
MAKING	• Necessity of planning a careful making of the robotic milling of the floor to adjust the zig-zag radiant elements in their best configuration in terms of cuttings, grooves and distance of slits. Prepare the planning carefully of the mounting because windows are heavy • Perform quality control at the highest level since the architectural value of the existing building elements.
MONITORING	• Measuring the benefits to develop guidelines for new replicating construction Interviews before and after to communicate about the benefits of the renovation with the occupants of the building are much useful

PnP solutions:

1. PnP solutions are difficult to implement in historic buildings but it they are definitely feasible and could have a considerable market in Europe, PnP RES application at district level needs an approach that goes beyond the mere building, e.g. hydro power plant to feed heat pump is "elsewhere" from the local surrounding but electricity is the ideal vector to perform efficiency

Lessons learnt from the demonstration case in Enschede

4M process

MAPPING	• Accuracy is key, especially in large project. The accuracy of the mapping determines the outcomes of the whole renovation process
MODELING	• Need for library of PnP-products to evaluate the best solution per project • Due to the large project and risks, only market ready solutions were chosen • Involve all stakeholders form the beginning of the project, including the contractors. After the modelling nothing can be changed without high costs
MAKING	_
MONITORING	_

PnP solutions

1. Decide to use PnP solution 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.

Lessons learnt from the demonstration case in Warsaw

<u>4M process</u>

MAPPING	• Public building’s owner [City of Warsaw] is very interested in the monitoring process with Comfort EYE, including monitoring of PM 2.5 and PM 10. This is related to the very low air quality in Poland. • The building has only old and not actual paper documentation. 3D scanning allows to create quite fast BIM model which is a basis for coordination between designers and can be used for further analysis. • Small architectural offices do not always work in BIM.
MODELING	• Clash detection allows to detect design errors before the start renovation works. • Architects prefer use proven products and are afraid of innovative solutions.
MAKING	• Renovation companies afraid of innovative solutions. • Augmented reality helps easy to check correctness of the work performed with the project.
MONITORING	• Monitoring of Indoor air quality comfort before and after renovation is useful to check the results of renovation works. • BIM model for the analysis of against the spread of COVID-19 to check the safety procedures.

Lessons learnt from the demonstration case in Gdynia

4M process

MAPPING	• Public buildings' owner [City of Gdynia] is very interested in the monitoring process with Comfort EYE, including monitoring of PM 2.5 and PM 10. This is related to the very low air quality in Poland. Public owners pay more and more attention to Indoor Air Quality in their buildings • The building has only old and not actual paper documentation, 3D scanning and BIM model allowed to create reliable as-built model which is a basis for further analysis
MODELING	• Reliable energy analysis allows to find the most optimum renovation solution
MAKING	• High efficiency because the engineering and blue-collar workers form the same company FASADA • Make replication grade as high as possible • Develop guidelines for new replicating construction techniques
MONITORING	• Monitoring of IAQ before and after renovation with comfort eye • Use of BIM model for the analysis of the safety procedure against the spread of COVID-19

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.

Lessons learnt from the demonstration case in Menden

4M process

MAPPING	• Mapping is crucial and complex at the same time, as the criteria that are most important in modelling and making are not precisely defined • Create a partnership with the user of the building
MODELING	• Modelling needs a special expertise in order to realise BIM / BEM connection properly
MAKING	_
MONITORING	_

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 analysed and developed to realise 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.

Lessons learnt from the demonstration case in Genova

4M process

MAPPING	• Adapt mapping questionnaires to the occupants, e.g. pictures for children of a nursery • Raise awareness of the collaboration with the occupants to make the renovation process smoother
MODELING	• BIM models create insight and helps the communication on the aesthetic impact • BIM helps to evaluate alternative solutions. • Not automated parts (e.g. inoperable data) are still time consuming in the process
MAKING	• Prepare the planning carefully of the mounting because windows are heavy. 2. Perform quality control at the factory as much as possible
MONITORING	• Monitoring before and after to communicate about the benefits of the renovation with the occupants of the building

PnP solutions

1. The preassembling of all the main components at the factory (including the technology box) would allow to perform high quality check at the factory and fasten the on-field works.
2. Smart window PnP solution proved high adaptability. The original design has been modified in order to allow its applicability also in a Historical building, but keeping the high thermal performance and the innovative feature of the windows.

Lessons learnt from the demonstration case in Lekkerkerk

4M process

MAPPING	• High resolution 3D scanning with GoPro camera to locate 3D-pictures easily • Perform 3D scanning and BIM modelling by the same company
MODELING	• 3D-scanning is basis for the prefabricated panels • Involve tenants and inform them by visualisations (made easy by 3D and BIM rendering) • Creating parametrical elements of the façade components reduce engineering time.
MAKING	• Develop new quality control procedures for this new process • Increase the quality and reduce time to develop robotised manufacturing in future. Reduces costs and make prefabrication economic more feasible • Make detailed transportation plan from the factory to the construction site, especially when the travelling takes multiple hours and risks of traffic jams
MONITORING	• Monitor energy and IEQ before renovation to compare with results afterwards • Communication in a simple and direct way with the tenants

PnP solutions

1. PnP solution should be fully incorporated/ adopted by a contractor. For complex prefabricated components the engineering, production and after-service should be fully integrated in the specific project.
2. In the case of Cocoonz façade the fact that the main contractor was the product developer of the PnP façade made an efficient mapped, engineered and executed project possible.
3. A quick and predictable execution with a minimal amount of nuisance is an important key performance in a large residential project.
4. Reducing costs in production needs upscaling of production or a flexible production facility. In case of Cocoonz façade the latter is the case. The factory is able to produce a set of PnP products all based on the composite material, the Cocoonz façade panel is one of those products.

Lessons learnt from the demonstration case in Utrecht

4M process

MAPPING	• Involve the occupant with the mapping to create awareness about the quality they perceive
MODELING	• Prepare using BIM in the chain of companies you want to work with. One weak partner makes the total strength, quality, and functionality
MAKING	• Train contractors and blue-collar workers for new pre-fab products. It is not self-explaining as it might be for the designers • PnP is not a competitive market; prices remain high
MONITORING	• Inform occupants with results of the RoI based on real costs, show deviations from the original plan to gain confidence and show transparency

PnP solutions

1. Industrialisation is not about building factories, but is looking for a way to reach as many people and possible in an efficient way. So PnP 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 product that fulfil a specific function).

Lessons learnt from the virtual demonstration case in Ancona

4M process

MAPPING	• Data collection when building in use is difficult • Hard to collect data form occupants about the use of the building
MODELING	• No standardized and automated procedure for BIM to BEM modelling, which made it time consuming • Collaborative design could made possible by freeware-approach
MAKING	_
MONITORING	_

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 simplified BIM highly increases the difficulties in integrating the PnP HVAC solutions in BIM, which can include a very simplified MEP or not include it at all.

Conclusions & recommendations

Related to the initial objectives and promised achievements.

Objective 1: To optimize, integrate and validate state-of-the-art prototypes and commercially available packages of PnP prefab solutions for deep renovation.

- In 11 demonstration cases, spread over Europe, 7 PnP prefab state-of-the-art prototype solutions supported with 3 onsite 3D technologies and ICT tools have been applied.
- During the 4,5 years duration of the P2Endure project these solutions, technologies and tools have been optimized to a level up to TRL8+ to be applied for holistic deep renovation

Objective 2: To demonstrate and promote innovative on-site processes for fast deep renovation projects with low disturbance for the residents, and significantly improved indoor environment quality (IEQ) after completion.

- (Impact 4) In the demonstration cases the running time from order to final delivery of deep renovation products is reduced to 50%, compared to a traditional approach, due to more efficient design/engineer solutions and reduction of the production time.
- (Impact 4) The time of disturbance for residents, related to on site assembly, is reduced to days instead of weeks or months, compared to current practices of deep renovation.
- (Impact 1) The net primary energy after renovation is reduced to at least 60% in most demonstration cases (9 of 11), resulting in considerable improvement of the indoor environment quality

Objective 3: To measure, monitor and validate P2Endure product and process innovations based on live demonstration projects of deep renovation, virtual simulation and prototyping.

- Quantitative evaluations are executed by application of monitoring tools like the the Comfort Eye giving proof of the improved indoor environment quality and reduced disturbance for residents

- By utilizing BIM-based Augmented Reality (BIM AR) for self-instruction and self-inspection following standardised protocols for prefab solutions, quality gaps between the off-site designed/manufactured and on-site realised/assembled PnP prefab solutions have been prevented
- In order to maintain the optimal lifecycle performance after deep renovation, the renovated buildings are equipped with BIM-based smart monitoring systems
- (Impact 2) Life Cycle Cost (LCC) using PnP solutions is 15% less than the traditional comparative cost of deep renovation due to Integration of PnP components and on-site technologies with BIM, better and more accurate design in terms conflict interference and collision detection, more efficient and faster renovation works thanks to prefabrication and off-site manufacturing and lower need for skilled blue-collar workers
- (Impact 6) Reduction of the embodied energy compared to traditional

Objective 4: To provide solid empirical evidence of the performance and quality of P2Endure solutions while ensuring their scalability and replicability at district, city, region, country and EU level

- The real impacts of the promoted deep renovation solutions across different geo-clusters is shown in 11 live demonstration projects, involving all local stakeholders proving the practical viability of P2Endure results

Objective 5: To ensure the market uptake and upscaling of P2Endure innovations during and immediately after the project by directly involving 'launch customers', value-chain and distribution network partners, and other stakeholders at local, regional, and EU level.

- During the duration of the project a wide range of activities (scientific and practice publications, presentations, workshops, conferences etc) have been applied in order disseminate the P2Endure outcomes among real-estate clients, end-users, policy makers and industrial partners to facilitate and stimulate value-chain integration of P2Endure innovation.

- Within P2ENDURE, the wider impacts on replication and market upscaling were guaranteed by a Technology Commercialization Platform (TCP). The TCP is composed by a group of members from different EU countries representing the different stakeholders interested in applying or marketing the P2ENDURE results.

Objective 6: To disseminate and valorise knowledge and results from P2Endure along with establishing and strengthening synergies with other EU and national innovation activities.

Related to the e-MarketPlace

- The local factory concept supported by district oriented e-Marketplaces will allow innovative talents across Europe to start their own business around deep renovation activities within their districts. The developed design configurator (available as Open Source Software) can serve as the basis for developing and providing such dedicated e-Marketplaces.

e-MarketPlace on Github

e-MarketPlace on YouTube

About possible integration of complementary PnP solutions

- In the demonstration cases a selection of P2Endure solutions, technologies and tools have been applied. If all solutions, technologies and tools are applied, the positive impact in terms of cost and disturbance reduction, energy savings, shortening of production time etc will be higher than what is shown in the actual P2Endure demonstration cases.

For more information visit:

www.p2endure-project.eu/en

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P2ENDURE Horizon 2020

Contact:

Project coordinator: Ir. André van Delft (DEMO Consultants B.V.)
andre@demobv.nl

Technical coordinator: Prof. Gian Marco Revel (Università Politecnica delle Marche)
gm.revel@staff.univpm.it