P2ENDURE
PLUG & PLAY BUILDING RENOVATION

Baseline report of pre-renovation condition of demonstration cases

Deliverable Report D4.1

Deliverable Report: D4.1, issue date on 18 April 2018

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 723391.

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Baseline report of pre-renovation condition of demonstration cases

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Produced by	Huygen Engineers & Consultants
Main author	MSc Loes Visser
Co-authors	MSc Eric Willems (HIA), Dr Marco Arnesano (UNIVPM), MSc Anna Gralka (DMO), MSc Laura Ferrari (BEQ)
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Colophon

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

Publishable executive summary

In this deliverable, the baselines for the pre-renovation conditions for each demonstrator are devised. The baselines are consolidated on:

- the initial condition assessment;
- the value of the key performance indicators of the primary energy use and the Indoor Environmental Quality (IEQ).

The Work Package 4 ‘Live demonstration projects’ is the heart of the P2ENDURE project. Each demonstration case addresses one or more challenges of deep renovation that should be solved using Plug and Play (PnP) prefab systems. The targeted achievements are threefold: realizing and measuring the success of the pilot deep renovation cases, facilitating cross-learning between different projects and geo-clusters, and securing the broad replication potential at EU level.

The 4M methodology will be applied for all demonstration projects (4M: Mapping-Modelling-Making-Monitoring). The P2ENDURE 4M modular process is a stepwise approach for preparing and implementing the deep renovation, followed by real monitoring of the resulting performance improvements. The main activities within each step are explained in the Chapter 1. For more detailed description of the P2ENDURE 4M methodology please check the Deliverable 2.1 report[1].

This baseline report is the first step of the 4M approach: Mapping. The pre-renovation data is collected and the Key Performance Indicators (KPIs) are calculated for the existing situation. At this stage the initial condition of the demonstrators is evaluated, the expected post-renovation state compared to the pre-renovation state is shown and the improvements compared to the goals of P2ENDURE are pointed out. This deliverable is a starting point and, at the same time, a feasibility study for the further tasks to be carried out in the Work Package 4.

The table below shows the specific KPIs for each demonstration case that are considered, and the deliverable where the results will be reported.

[1] D2.1 available on the P2ENDURE public website: https://www.P2ENDURE-project.eu/en/results/d2-1

KPI	Primary Energy	LCA	Time	LCC	Replicability	Thermal comfort	Acoustics	IAQ	Disturbance
Deliverable **Due date**	D4.1	D3.2 – M42	D3.3 - M24	D3.3 - M24	D 3.4 – M42	D4.1	D4.1	D4.1	D3.5 - M24
Demo Project									
1. Gdynia (PL)	X	X	X	X		X		X	X
2. Warsaw (PL)	X	X	X	X		X		X	X
3. Ancona (IT)	X	X	X	X		X	X	X	X
4. Genova (IT)	X	X	X	X		X	X	X	X
5. Palmanova (IT)	X								
6. Florence (IT)	X		X	X	X	X			X
7. Soest (DE)									
8. Enschede (NL)	X		X	X		X		X	X
9. Tilburg (NL)	X		X	X		X	X	X	X
10. Korsløkken (DK)	X	X	X	X		X		X	X
11. Breda (NL)	X	X	X	X					X

Table: Overview of defined KPIs for P2ENDURE demonstration cases
Legend:
X *Data reported in deliverable by due date*
X *Data reported in update of deliverable, see header of the table (updates: D4.1 by M24 - August 2018,*
D3.3, D3.4, D3.5 by M30 - February 2019 and M36 - August 2019)

Each demonstration case has a different planning schedule. In this deliverable we show the results of the baseline of the demonstration cases that have finished the Mapping stage. The results of the mapping of all the demonstration cases will be updated at Month 24 of the project – in August 2018.

The PnP-solutions are applied as measures for deep renovation. The applied PnP-solutions make the ambition of the targeted KPI-values possible. When there are constrains in performing deep renovation, for example caused by high monumental value of a building, traditional renovation measures are considered. These constraints that restrict applying the PnP solutions are elaborated and a full overview is given in the Chapter 4.

The baseline of the KPIs with according methodology, for Life-Cycle Analysis (LCA), time reduction, Life-Cycle Costs (LCC), replicability, and disturbance, are defined in the Work Package 3 'Performance validation and optimization'.

List of acronyms and abbreviations

4M: Mapping-Modelling-Making-Monitoring
DoA: Description of Action
BIM: Building Information Model
EC: Exploitation Coordinator
GA: General Assembly
HVAC: Heating Ventilation and Air Conditioning
IEQ: Indoor Environmental Quality
IPR: Intellectual Property Right
KPI: Key Performance Indicator
LCA: Life-Cycle Analysis
LCC: Life-Cycle Costs
MEP: Mechanical Electrical Plumbing
PC: Project Coordinator
PnP: Plug and Play
R&D: Research and Development
RES: Renewable Energy Source
SC: Steering Committee
SME: Small and Medium-sized Enterprise
TC: Technical Coordinator
TCP: Technology Commercialization Platform
ToC: Table of Content
TRL: Technology readiness level
WP: Work Package

Contents

1. Introduction

In this deliverable, the baselines for the renovation conditions for each demonstrator will be devised. The baselines are consolidated based on the initial condition assessment and the value of the Key Performance Indicators (KPIs) for primary energy consumption and Indoor Environmental Quality (IEQ) developed in WP1 'Product Innovation' and WP3 'Performance validation and optimization'. Once the initial condition of the demonstrators is known, it is possible to compare the post-renovation state with the pre-renovation state and to point out the improvements in relation to the P2ENDURE goals. This deliverable can be seen as a starting point and feasibility study for the tasks to be carried out in WP4.

1.1 Baseline before renovation

The main goal of P2ENDURE is to provide evidence of benefits achievable by Plug and Play (PnP) prefab systems for deep renovation of building envelope and technical systems, as well as applicable to a wide range of building typologies. P2ENDURE aims to assess and validate PnP prefab systems enabled by 3D printing, laser and thermal scanning integrated with BIM. The aim of this deliverable is to set a baseline for the demonstration cases to be carried out in P2ENDURE. This work package will demonstrate the PnP prefab innovations on TRL8+ allowing direct testing and validation of the technologies by the stakeholders – the solution providers and the owners of deep renovation projects. The final goal is to demonstrate that P2ENDURE solutions and methodology lead to the ***60% of energy saving*** after deep renovation along with ***15% cost saving***, ***50% time saving***, ***improved Indoor Environmental Quality*** and ***reduced disturbance for the occupants***. The P2ENDURE approach will be applicable for building transformation, non-functioning or sub-optimal public and historic buildings into dwellings, and renovation without transformation. Ten demonstration projects were selected to demonstrate the above P2ENDURE goals so to:

- cover 4 geo-clusters;
- apply the same 4M methodology;
- test different combinations of the proposed innovative solutions

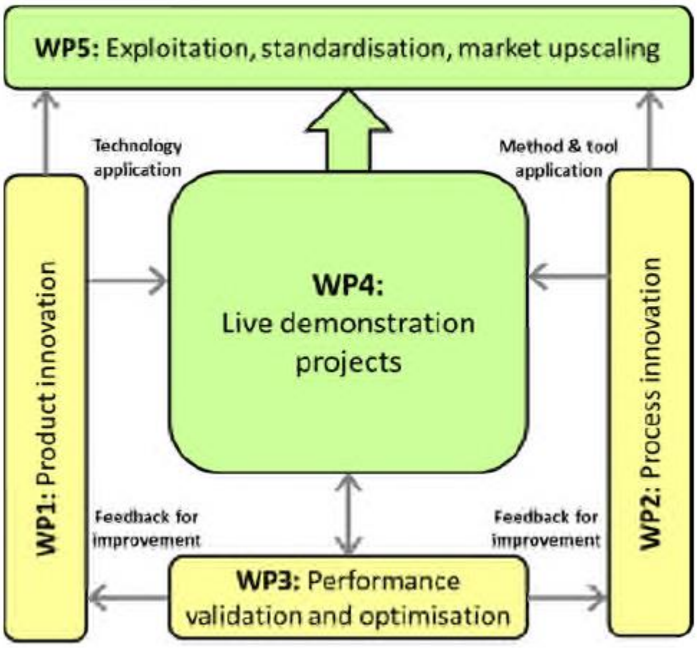


Figure 1: The main contributions of the work packages and the inter-dependencies between them

WP4 'Live demonstration projects' is the heart of the P2ENDURE project. Each project addresses one or more challenges of deep renovation that should be solved using PnP prefab systems. The targeted achievements are threefold: realizing and measuring the success of the pilot deep renovation cases; facilitating cross-learning between different projects and geo-clusters, and securing the broad replication potential at EU level. As commonly acknowledged, managing real demonstration cases in a Research & Development (R&D) project can be very challenging. Therefore, all other WP's are in direct support to WP4, as can be seen in the Figure 1.

1.2 P2ENDURE 4M methodology

The 4M methodology will be applied for all demonstration projects (4M: Mapping-Modelling-Making-Monitoring). Per task of this work package one of the four steps of the 4M approach will be handled. The P2ENDURE 4M modular process is a stepwise approach for preparing and implementing the deep renovation, followed by real monitoring of the resulting performance improvements. The main activities within each step are explained below. More detailed description of the P2ENDURE 4M methodology can be found in the deliverable report D2.1[2].

[2] D2.1 available on the P2ENDURE public website: https://www.P2ENDURE-project.eu/en/results/d2-1

1. Mapping

The purpose of this step is to develop a detailed technical plan and economic feasibility report for deep renovation, as a starting point for the renovation design – including conversion of building function or typology when relevant. The innovative on-site activities are: condition assessment based on self-inspection technology (derived from the H2020 INSITER project); assessment of the functional qualities and potential of improvement of the existing building. Furthermore, the baseline of the Indoor Environmental Quality (IEQ) is measured by the innovative scanning device Comfort Eye. The primary energy is determined by using energy bills.

2. Modelling

The purpose of this step is to develop the deep renovation design ready for execution. This step will result in BIM models of the existing buildings and deep renovation designs with energetic properties, including architectural, structural and Mechanical Electrical Plumbing (MEP) systems and parametric BIM's of the prefab renovation components for manufacturing, local factories (3D printing), and to enrich the digital solution library in the e-Marketplace. Within this step BIM models are created and combined with 3D data capturing and thermal scanning.

3. Making

The purpose of this step is to execute deep renovation activities. This step will result in improved, tested and implemented innovative PnP prefab components for deep renovation; ready for large-scale production and commercialization. Within this step the delivery of components and solution packages ready for assembly are a main item; rapid and low-disturbance building component assembly based on combined product-process information in 3D/4D/5D BIM, and calibration and operating 3D-printing robots.

4. Monitoring

The purpose of this step is to monitor and guarantee the high-quality execution of the construction works, and to monitor the Indoor Environmental Quality (IEQ) and primary energy consumption after deep renovation. This step will result in "as-built" BIM models integrated with sensory systems and software tools for continuous performance monitoring and long-term maintenance and optimization. Within this step IEQ monitoring will also be performed by indoor 3D thermal scanning (Comfort Eye).

1.3 Mapping of demonstration cases

The mapping of the demonstration cases consists of collecting the data for the determination of the base line of the condition assessment and base line of the Key Performance Indicators (KPIs) of the demonstration cases. The baseline is the starting point for the recommended measures and improvement of the KPIs by application of the PnP pre fab solutions.

Work Package 4 (WP4) 'Live Demonstration projects' coordinates and implements all the demonstration actions through the 4M process steps (Mapping-Modelling-Making-Monitoring). Although, each demonstration case has an assigned responsible partner who has the responsibility to:

- Collect data from the building (e.g. point clouds, BIM-models, energy bills, construction plans, restrictions from local legislation, (financial) requirements from the building owner etc.);
- Collect data from the Indoor Environmental Quality by the Comfort Eye;
- Supervise the application of P2ENDURE methodology to the demonstration project (BIM development, monitoring);
- Intermediate the relationship between solution providers and building owner/manager;
- Support the design decision making process.

In the table below, the responsible partner per demonstration case is stated.

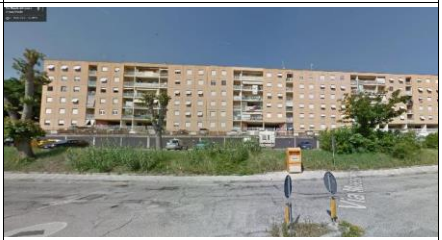
Demo Project	Responsible Partner
1. Gdynia (PL)	FAS
2. Warsaw (PL)	WAW
3. Ancona (IT)	UNIVPM
4. Genova (IT)	RINA
5. Florence (IT)	SGR
6. Soest (DE)	3L
7. Enschede (NL)	TUB, CAM
8. Tilburg (NL)	PAN
9. Korsløkken (DK)	INV
10. Breda (NL)	HIA

Table 1, Responsible partner per demonstration case

Work Package 4 coordinates and implements all the demonstration actions through the 4M process steps (Mapping-Modelling-Making-Monitoring). Thus, all the demo responsible partner activities will be supervised by the Work Package 4 leader, HIA, with the support of:

1.4 Demonstrating cases

Below the 10 demonstration cases are more elaborated explained. A complete overview of the demonstration cases is found in Deliverable 7.2.

Gdynia (PL)	Demonstration building is a two-story kindergarten building, attended by about 130 children. It was constructed in year 1965 and it has the function of kindergarten from the beginning. Building volume is 2712 m^3 and built up area is 464 m^2. The main goal of the demonstration is to minimize the energy consumption especially for heating needs through the retrofitting of the envelope (add insulation layer), implementing new windows and improve aesthetic appearance of envelope. The building is connected to district city network.	
Warsaw (PL)	The building was built in 1983. It is in the southern part of the city, in Ursynów District, and is one of 55 municipal nurseries in Warsaw. It is a place for temporary care to 108 children aged 1-3. The main goal of the demonstration is support Warsaw's climate targets – energy efficiency, CO2 reduction thanks to the opportunity to test innovative solutions.	
Ancona (IT)	This case study is a multi-apartment block, located in Ancona and built in 1980. The building is composed of 100 dwellings, 6 floors and total gross area of 1720 m2. The objective is to demonstrate the energy savings from advanced retrofit solutions (e.g. insulation materials, renewables and MEP, comfort monitoring and improvement)	

Genova (IT)	The nursery school NEMO is located on the second floor of a two-level building, built in 1930s with concrete structure and non-structural brick walls. The building is listed under the Italian Legislative Decree 42/2004, which poses cultural heritage constraints on its conservation. The goal of this project is the reduction of heating consumption through replacement of high performance windows. Additionally, Municipality of Genova has foreseen heating plant substitution and roof renovation has been performed last year.	
Florence (IT)	This historical residential building in Florence is part of the expansion and rehabilitation area implemented in the period from 1864 to 1871 following the project proposed by Giuseppe Poggi for Florence, capital of Italy. Considering the location and architecture typology the building was born with a multifunctional used: commercial / craft on the ground floor, and residential use on the upper floors. The objective is to demonstrate the energy savings from advanced retrofit solutions (e.g. insulation materials, renewables and MEP, comfort monitoring and improvement)	
Soest (DE)	Not yet defined	
Enschede (NL)	This demonstrator is the deep retrofit, redesign and transformation of an abandoned university building, originally built in 1965, into a student hostel and hotel building. The goals are to improve the energy efficiency of the building from energy label G to B (target A) and extend the lifespan of the building. The field demonstration activities will focus on the testing and inspection of new facade panels and parts of the new MEP system.	
Tilburg (NL)	Lidwina monastery is a historical building (1935) used as a temporary guest accommodation. The 5400 m2 building accommodates approximately 60 (potential) rooms. Most parts of the building are well maintained but never been replaced. The objective is to fully renovate the monastery to a new level of comfort, improving energy performance substantially, increasing flexibility of rental situation and modernizing the monastery. The plan is to ad to every room a new bathroom, new ventilation and installation concept, insulate windows and façade and reduce sound comfort of the rooms.	

Breda (NL)	Renovation of row homes for a social housing company to the level of NOM (0 on the meter). Area Kruiskamp is in the city of Den Bosch, Netherlands. The homes to be renovated are built in 1967. Demonstration of applicability of NOM concept, stemming from the Dutch Government program ’ Energiesprong ‘ carried within the regional program SB NOM.	
Korsløkken (DK)	The building no. 34.3 at Korsløkken is a typical Danish 2 floor residential building from the 1970’s. The building is part of one of the biggest residential housings in Odense city. The inhabitants are typical middle and lower class. The overall objective in this building is a total renovation interior and exterior. Furthermore, they would like to have some 3D design and promotion of the whole residential park Korsløkken. The target is to make a 3D design facade faster and with less manpower onsite.	

Figure 1: Overview demonstration cases

In every demonstration case one or multiple PnP solutions are applied. These PnP solutions will ensure more primary energy reduction, cost saving, time saving, a better Indoor Environmental Quality (IEQ) and less disturbance for the occupants compared to traditional methods for deep-renovation. Chapter 3 and 4 will provide more inside on the reason why a renovation is recommended and why a solution is finally chosen by the building owner.
The applicable Key Performance Indicators (KPIs) per demonstration case are described in chapter 2. The baseline of primary energy use and IEQ of the demonstration cases is discussed in Chapter 3, where the full overview of the PnP-solutions applied in all demonstration cases are shown in the conclusion.

Each demonstration case has a different planning schedule. In this deliverable we show the results of the demonstration cases that have finished the mapping stage. The results of the mapping of all the demonstration cases will be updated by M24 (August 2018).

2. P2ENDURE key performance indicators

In P2ENDURE the improvement of the performance of the demonstration cases is expressed by Key Performance Indicators (KPIs). Generic KPIs are defined in the Description of Action (DoA), while detailed project KPIs have been developed at the beginning of the project. Furthermore, calculating the KPIs is done with collected data from the buildings and by the methodology developed in WP3. The collection of the data is part of WP4 and the collaboration with WP3 will be explained in this chapter.

2.1 Key performance indicators and ambition

To reach the final goals of P2ENDURE as stated in section 1.2 and the DoA, these goals are translated in measurable indicators. The improvement of the building through applications of the Plug and Play (PnP) solutions is expressed by the condition assessment and KPIs. These defined indicators are shown in the table below.

The methodologies to determine the value of these KPIs are developed in WP3 and in detailed explained in the according deliverables, also shown in the table below. These methods determine what data needs to be collected from the different demo cases to calculate the KPI in a proper way.

KPIs	Goal	Objective	Deliverable	Input from
Energy				
Energy saving: primary energy	60% reduction	Objective 3	D3.1 (BEQ)	
LCA		Objective 1	D3.2 (HIA)	
Materials -> solution providers + comparison				
Process				
Time				
On-site/empirical approach	50% reduction	Objective 3	D4.5 (FAS)	D3.3 (FAS)
Extend at renovation + scale of the building				
Cost	15% reduction	Objective 3	D4.5 (FAS)	D3.3 (FAS)
LCC				
Renovation costs (art. No 4 EPBD)				
Replicability		Objective 4	D4.5 (FAS)	D3.4 (FAS)
Statistics/questionnaire				
Constraints -> solution providers				

Building typologies				
Indoor environment & disturbance				
Indoor Environmental Quality (IEQ)	Improving	Objective 3	D4.7 (UNIVPM)	D3.6 (UNIVPM)
Thermal comfort				
Acoustics				
Indoor Air Quality (IAQ)				
Disturbance	50% reduction	Objective 2	D4.6 (FAS)	D3.5 (UNIVPM)
Safety of residents				
Noise and vibrations				
Dust emissions (PM2.5-PM10)				
Total time for construction activities outside the building				
Total time for construction activities inside the building				
Surface occupied by the construction activities				
Generation of waste: Waste treatment and disposal				

Table 1: Overview KPIs

In this deliverable we will handle the condition assessment, primary energy consumption and Indoor Environmental Quality. The other KPIs are reported in deliverables from WP3. Nevertheless, they are not listed in this baseline report because they are not relevant for the decision making by the building owner of the deep renovation measures of the demonstration case.

2.2 Optimization of KPIs by PnP-solutions

WP3 'Performance validation and optimization' is closely related to WP4, as expressed in Figure 2. The methodology for calculating the KPIs and the required data is developed and used in WP3.

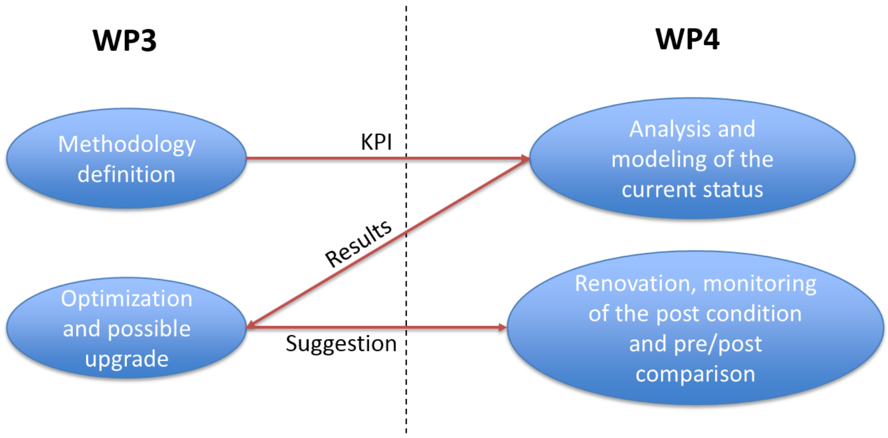


Figure 2: Inter-relationship between WP3 and WP4

The actual data collection will be done in WP4. KPIs are calculated and the results are feedback to WP3, to optimize and upgrade the PnP solutions in WP3 and will be given as input for further recommendations elaborated in WP4.

The execution of the demonstration projects has different time schedules and different PnP-solutions. This implies that next to different timing also the data type collection per KPI differs per demonstration case. Collecting the right data at the right point in time is an important aspect of WP4.

The planning of the demonstration projects can be found in the Deliverable 7.2 as the main guideline to determine the right timing to collect the data from the demonstration cases. The progress of the planned activities is mainly fed by data from the responsible partners. The table below shows an overview of the status of the collection of data needed to calculate the KPIs.

KPI	Primary Energy	LCA	Time	LCC	Replicability	Thermal comfort	Acoustics	IAQ	Disturbance
Deliverable Due date	D4.1	D3.2 – M42	D3.3 - M24	D3.3 - M24	D 3.4 – M42	D4.1	D4.1	D4.1	D3.5 - M24
Demo Project									
12. Gdynia (PL)	X	X	X	X		X		X	X
13. Warsaw (PL)	X	X	X	X		X		X	X
14. Ancona (IT)	X	X	X	X		X	X	X	X
15. Genova (IT)	X	X	X	X		X	X	X	X
16. Palmanova (IT)	X								
17. Florence (IT)	X		X	X	X	X			X
18. Soest (DE)									
19. Enschede (NL)	X		X	X		X		X	X
20. Tilburg (NL)	X		X	X		X	X	X	X
21. Korsløkken (DK)	X	X	X	X		X		X	X
22. Breda (NL)	X	X	X	X					X

Table 2: Overview of defined KPIs for P2ENDURE demonstration cases
Legend:
X *Data reported in deliverable by due date*
X *Data reported in update of deliverable, see header of the table*
(Upcoming updates: D4.1 by M24 - August 2018,
D3.3, D3.4, D3.5 by M30 - February 2019 and M36 - August 2019)

Reporting the KPI's

As stated before, the KPIs for primary energy, thermal comfort, acoustics and Indoor Air Quality (IAQ) are described in this deliverable. Due to the planning of projects not all data is available at the time of the due date of this deliverable. The red crosses indicate the data collection that will be included in the update of this deliverable by M24 (August 2018). The other five KPIs will be discussed in other deliverables that are mostly due in M24 (August 2018).

The KPI concerning replicability will be elaborated at the end of the project and it will be done within a general study, concerning the replicability of the PnP-solutions per building type and per building function. At the end of the project, with the experiences from the demonstration cases, the analysis can be made.

Not all KPIs are applicable to all demonstration cases, as shown in table 2. At this stage of the project the demonstration case in Soest (DE) is not defined yet. In addition, Palmanova (IT) has been cancelled in a very late stadium of the P2ENDURE project and replaced by another project in Florence. Palmanova will remain as a virtual demonstration case in the course of the project.

The Life Cycle Analysis will be performed on PnP solutions and reported in Deliverable 3.2 by M42 (February 2020). This means that the PnP solutions installed in each demonstration case will be compared with traditional renovation solutions. Therefore, only the demonstration cases are considered where P2ENDURE PnP-solutions are applied.

The time reduction by renovating with PnP solutions is discussed in Deliverable 3.3. To conduct this assessment a detailed design of the renovation needs to be ready. By M24 (August 2018) not all demonstration cases are at that phase yet, therefore this deliverable is expected to be updated in M30 (February 2019).

The measurement and assessment of renovation disturbance, compared to traditional renovations, is discussed in Deliverable 3.5. The reduction of the disturbance will be measured by means of questionnaires. These questionnaires will be handed out to construction workers, the building owner(s) and the occupants. This deliverable is also due in M24 (August 2018), and the same applies for this KPI; not all demonstration projects are at the renovation stage yet in M24 (August 2018). Therefore, this deliverable is expected to be updated in M30 (February 2019).

3. Baseline before renovation by mapping

Renovation of the existing buildings is the key to meeting the long-term energy and climate goals within the European Union as most of the buildings that will exist in the year 2050 are already built (Building Renovation Challenge Report – Practical Approaches, Energy efficiency, EASME, EC[3]). In P2ENDURE 10 deep renovation projects were selected to prove the higher performance and better cost-competitiveness of the chosen innovative solutions compared to the existing ones. In order to measure and compare the results of deep renovation of the demonstration buildings it is crucial to generate a detailed technical report to analyse the technical feasibility for deep renovation. In this chapter the baseline of the demonstration cases is explained. First the building condition assessments are performed to show whether there is need for deep-renovation measures. In addition, the current energy consumption is discussed, and the ambition of primary energy consumption is shown. Finally, initial results of Indoor Environmental Quality (IEQ) measurements are elaborated. The combination of these parameters shows that there is a real need for deep-renovation measures because of the poor quality of buildings' condition and performance.

3.1 Pre-renovation condition assessment

The P2ENDURE mobile inspection tool for building condition assessment is used to collect evidence of the building condition before deep renovation. The inspection tool is developed by the consortium partner DEMO Consultants based on the state-of-the-art RE Suite software tool that is already available on the Dutch market and follows the Dutch technical norm for condition assessment, i.e. NEN 2767. The norm was developed based on in-depth research funded by European Commission and conducted by an international consortium (i.e. EU project "Condition Assessment of Buildings and Building Components") and gives clear directions for an effective and efficient condition assessment that can be easily adjusted for application in other European countries.

The mobile inspection tool and methodology used for condition assessment is elaborated in more details in the deliverable report Deliverable 2.3 submitted in M6 (February 2017)[4].

[3] https://ec.europa.eu/easme/sites/easme-site/files/practical_approaches_to_the_buildings_renov_challenge.pdf
[4] D2.3 can be found on the public website of P2ENDURE https://www.P2ENDURE-project.eu/en/results/d2-3

3.1.1 Scale of the condition scores

The condition score is displayed on a six-point scale. Condition score '1' represents the new build state and condition score '6' the worst possible condition. In the table below, brief descriptions of the condition scores are given. Chapter 2 provides a general description of the different condition scores.

Condition score	Description
1	Excellent condition
2	Good condition
3	Reasonable condition
4	Mediocre condition
5	Bad condition
6	Very bad condition

Table 3. Condition scores

3.1.2 Description of the condition scores

- The condition score is determined by the extent, intensity and severity of the defects. The following explanations of the condition scores are general and indicative; the condition score is a result of a NEN2767 methodology to perform a condition assessment of buildings and building components.

Condition score 1 - Excellent condition

- No or very limited deterioration of building components as a result of aging;
- Defects in finishing layers, materials, parts and constructions due to aging do not occur;
- Operational reliability of the installations is guaranteed; utility function of the building is not disrupted due to defects of the installations or building components;
- Defects in the form of slight mechanical damages or of an aesthetic nature may be encountered occasionally;
- Well-executed repairs may occur that restored the building component back to its intended basic quality;
- In general, the building components, construction and installations are in an excellent state, professionally executed.

Condition score 2 - Good condition

- Initial deterioration / aging;
- Defects in building and installation parts in the form of material damage and deterioration of finishing layers, materials, parts and constructions occur rarely;
- Efficiency of the installations, with a few exceptions, is not interrupted; the operational reliability is guaranteed; utility function of the building is hardly disrupted due to defects of the installations or building components;

- Defects of the building components caused by aging or weathering as well as dirt caused by environmental conditions may be locally visible;
- In general, the building components, construction and installations are of a good quality and condition what indicates good design, good detailing, as well as thorough execution and finishing.

Condition score 3 - Reasonable condition

- The deterioration / aging process has started locally;
- Defects of building components and installations' finishing layers, materials, parts and constructions occur occasionally; effects of moisture and draft can be spotted;
- The functioning of the installations may sometimes be disrupted; the defects have no influence on the functioning of the construction or installations; utility function of the building is not interrupted;
- Defects resulted from weathering etc. may occur regularly;
- Regularly executed and durable repairs may be performed; local repairs can also be carried out with less suitable means;
- Building components may show visible signs of aging and dirt caused by environmental conditions on the whole surface;
- In general, the technical condition is qualified as reasonable - the quality of the applied materials and/or drawback in the design, detailing and execution play a significant role.

Condition score 4 - Mediocre condition

- The deterioration / aging process is clearly detectable;
- Defects of the building components and installations' finishing layers, materials, parts and constructions occur regularly;
- The functioning of the installations may be disrupted locally; operational interruptions in a proper performance of the building and installations may occur several times per year; the number of defects that lead to impediments in the buildings' functionality is increasing; security of the operational reliability of the systems is mediocre;
- In general, the building and installations are assessed as poor. This may be partly caused by faults in material choice, poor basic quality and/or execution.

Condition score 5 - Bad condition

- The deterioration / aging process became irreversible;
- Defects of the building components and installations' finishing layers, materials, parts and constructions are considerable;

- The primary functions of the building components that influence proper performance of the building and installations are no longer secured; operational reliability of the systems is no longer guaranteed;
- There may be many (severe) defects that lead to impediments in the buildings' functionality;
- Operational interruptions may take place regularly;
- In general, the condition of building components and installations is very poor because of structural defects in the materials, but also faults in the design and/or the execution.

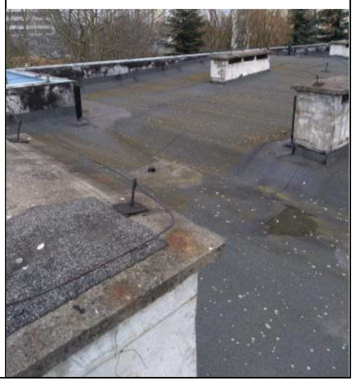
Condition score 6 - Very bad condition

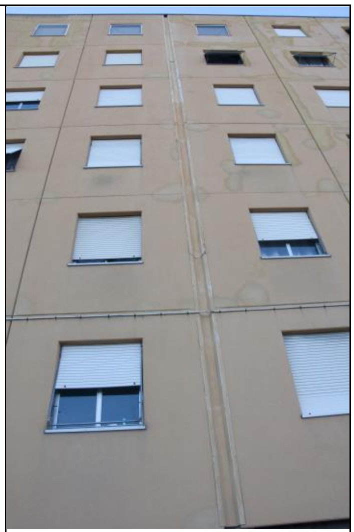
- The condition of the building components is so bad that it can no longer be classified under condition 5;
- Operational performance of the building and installations is continuously disrupted;
- The building and building components may be qualified for demolition.

3.1.3 Results of the condition assessment

Condition assessment with the RE Suite software tool has been performed of five P2ENDURE demonstration cases with completed BIM models for retrieving information on the building components. The condition assessment was performed in these buildings firstly as their scope and planning of the renovation works are progressing in accordance with the project developments and their function remains the same. This will provide a good comparison of the condition before and after the renovation. The complete results of the condition assessments can be found in Appendix I.
The demonstration cases in Soest (DE) and Florence (IT) are not (completely) specified yet. As soon as the commitment of the building owners and the scope of renovation are confirmed, an inventory of the building components will be created, and the condition assessment will be performed.

The overview below gives a global description of the condition of the buildings, based on the condition assessment performed with the mobile inspection tool and by the building owners before the renovation designs. It is separately stated if information is collected by other means that the condition assessment tool.

1. Gdynia (PL)	The kindergarten building was built in 1966. Numerous minor upgrades have been made. The general condition of the building is poor. The general condition of the building components is mediocre (condition score 4). Especially the windows and doors are in bad condition (condition score 5/6): wooden windows have damaged frames, not tight, repeatedly painted; double glazing; they do not meet thermal requirements. Replacement of the wooden windows is strongly recommended. PVC windows are in fair condition. Aluminium doors are in good condition. Without visible damage, they perform their function without reservation. Steel doors are leaky; they are an element with poor thermal properties and they require replacement. The inner doors are in poor technical condition, repeatedly painted without removing the previous layer of paint, with numerous mechanical damages. The internal windows show defects due to the aging process and mechanical damage, also because of incorrect maintenance. Finally, the inner stairs/ramps and concrete floors are strongly corroded, with uneven surfaces and uneven height (condition score 5). Most of the other building components are rated condition score 3 or 4.	 
2. Warsaw (PL)	The building was built in 1983. It is a place for temporary care to 108 children aged 1-3 (6 groups). The building is made of prefabricated concrete elements and cellular concrete wall and comprises two over ground floors and one floor in the basement. Gross covered area is 631 m2. The technical condition of the building is qualified as mediocre (condition score 4). Especially the basement windows and the roof are in bad shape (condition score 5). The thermal performance of the roofs building fabric is insufficient. The cold deck flat roof needs insulation; there are now large heat losses. The basement windows feature single-glazed wooden frame windows, with very high U. After dismantling the windows, they may not be suitable for re-assembly.	 

3. Ancona (IT)	It is a social housing with 100 apartments. Quickly built after a big landslide in the early eighties, the load-bearing structure is composed of concrete prefabricated slabs. The overall condition of the building is poor due, in particular, to the quality of materials, mediocre execution and lacks in maintenance over the years. The general condition of the building components is mediocre (condition score 4). Most of the outer building components have a condition score of 3 or 4 due to weather and ageing. The interior finishing of the walls and ceiling are in a bad condition (condition score 5). The ageing process and the lack of ordinary maintenance made the finishing extremely deteriorate. Because of lacks in ventilation, surface moisture is a primary issue. Such defect regularly occurs in each apartment. In some particularly critical cases (e.g. bathrooms), mold proliferation and the biofouling cover all the walls. Occupants' health is seriously at risk. Finally, the radiators are in really bad condition (condition score 6). The heating system is an extremely old one-pipe system. The undersized radiators do not provide sufficient heat to satisfy the thermal comfort. Many occupants pay expensive bills because they leave the system always on in winter and adopted further device (e.g. heaters) to warm up the rooms. A complete renovation of the system is strongly recommended.	 
4. Genova (IT)	The building is listed under the Italian Legislative Decree 42/2004, which poses cultural heritage constraints on its conservation. The general condition of the building is poor. Although, most buildings components have a condition score of 3 or lower. The windows are in a very bad condition (condition score 6). There is single glazing, damaged glass substituted with temporary panels. Damaged stucco, glass, window frames and missing parts. The corrosion is more advanced on the East facade (inner and outer sides).	 

5. Palmanova (not by condition assessment tool)	Virtual demonstration case; only mapping and modelling are performed. The location is restricted as a national monument; application of renovation is too limited for deep renovation.	No condition assessment is performed because deep renoavation cannot be executed
6. Florence	Not defined yet	
7. Soest	Not defined yet	
8. Enschede (not by condition assessment tool)	The condition assessment of Hogekamp Enschede (NL) was performed by the building owner regarding structural assessment and compulsory check for presence of asbestos. The results of the condition assessment before and after the renovation performed by the mobile inspection tool RE Suite would not be comparable because the function of the building will change, and it was standing empty for years prior the P2ENDURE renovation. This demonstration case was originally designed for its research and educational function as a transitory for the University of Twente and had to be suitable for specific laboratory functions. For many years the building was not in use, and now the building is being renovated and transformed into student housing (75%) and hotel (25%) as demonstration case in P2ENDURE.	
9. Tilburg (NL)	Most of the building components have a condition score of 3 or lower. Especially the windows are in bad condition (condition score 5). There is single glazing and corrosion. Renovation / replacement of the windows is strongly recommended. Sun screens are locally damaged and not working. Finally, the roof shows defects in water drainage and dirt; The slope of the roofs should be adjusted.	 

10. Korsløkken (not by condition assessment tool)	The demonstration case in Korsløkken contains houses from a housing corporation. In a cycle of 25 years regular maintenance is needed. This maintenance is extended with deep renovation activities. There is no need to use a specific assessment tool.	
11. Breda (not by condition assessment tool)	The demonstration case in Breda contains houses from a housing corporation. In a cycle of 25 years regular maintenance is needed. This maintenance is extended with deep renovation activities. There is no need to use a specific assessment tool.	 

Figure 3: Overview condition score of demonstration cases

3.2 Baseline of the primary energy consumption

According to Description of Action (DoA), all the case studies shall put in force appropriate retrofit interventions to achieve a 60% reduction in terms of primary energy needs. P2ENDURE first expected impact is, in fact: 'Net primary energy use reduced by 60% compared to pre-renovation levels'. This is one of the most important Key Performance Indicators (KPIs) as well.
Hence, the achievement of this threshold for all the demo cases shall be validated and possibly monitored, providing all the necessary justifications.

The expected impact of each single intervention applied to the demo case shall be calculated using proper tools, with the unique fundamental constraint that the calculations must be done within a full compliance with the requirements of the European norms (Directive2010/331/EU). Benefits are calculated as the difference of the primary energy requirements in the 'business as usual' scenario (i.e. the Buildings needs before the interventions) and the ones resulting after the deep renovation. The pre-renovation demand is calculated with the 'baseline quantitative method' (detailed calculation in combination with *ceterus paribus* substitution) aiming at the assessment of the primary energy savings of all deep renovation demonstrators.

The overall primary energy demand, both in the pre and the post-renovation scenarios, are then given as the sum of the correspondent primary energy associated to the several end-uses of the demo cases:

- Electricity demand (in most of the cases provided on a monthly basis)
- Thermal demand for heating
- Thermal demand for hot water
- Thermal demand for cooling (in most of the cases referring again to electricity, being the cold produced through compression chillers)
- Ventilation demand

Finally, the shift from the demand associated to each end-use, and its correspondent requirement in terms of primary energy, is made considering both the average national efficiency standards of the pilot countries (*e.g.* to convert electricity into primary demand) and the efficiency of the systems operating in the facilities (*e.g.* boilers, heat pump, cooling systems, *etc*.).

Data collected from literature, surveys and from the reading of the past energy bills, help in refining the theoretical energy assessment and the energy model basing on real consumption data, finally yielding very reliable results. Finally, the results of these activities are presented in Task 3.1 though a handbook of retrofit solutions and good practices. It is important to underline that the research activities related to this topic have been shared between WP3 and WP4, specifically for D 3.1, D 4.1 and D 4.3. This is particularly true, especially for all the partners that have succeeded in running the energy calculations using Building Energy modelling (BEM) software.

The WP inter-operation has been developed according to following research steps:

1st stage:

- WP 3: partners collected the energy data (bills, survey, *etc*.);
- WP 4: implementation of BIM for all the demo cases, in some cases further implemented through BEM.

2nd stage

- WP 4: refining of the BIM models through the input from WP 3 energy data (*e.g.* in the pre-renovation scenarios, energy bills show consumptions lower than the ones computed using BEM, meaning that a consistency check is necessary on the description of the envelope elements and materials, or usage data are not accurate).

- BIM is then implemented and refined thanks to WP3 activities.

3rd stage

- WP 3: energy calculations in the post renovation scenarios using tools 'compliant' to Directive 2010/331/EU;
- WP 4: for each one of the demo cases, completion of very reliable BIM, implemented with libraries of energy database, existing plant layout, information on the thermal characteristics of the envelope elements (transmittance, etc.).

4th stage

- WP 3: report of the energy analyses of the post renovation scenarios, providing at least the benefits in terms of primary energy savings, coming from the application of every single intervention, when possible, using the BIM-BEM (previously optimized thanks to the double check with the pre-renovation energy data/bills). Publication of the handbook of interventions.

The baseline for primary energy consumption is derived from the energy bills and the BEM models. The energy use for natural gas, district heating and electricity is multiplied by a factor, different per country depending on the national figures and national energy mix, to convert the energy consumption into primary energy use. In a final step the primary energy use is divided by the matching floor area to obtain the specific numbers.
The table below shows the baseline for energy consumption for each demonstration case before renovation.

	Baseline	Ambition	
1 Gdynia (PL)	154	-65%	54
2 Warsaw (PL)	166	-80%	33
3 Ancona (IT)	86	-60%	34
4 Genova (IT)	161	-63%	60
5 Palmanova (IT)	-	-	-
6 Soest (DE)	200	-95%	10
7 Enschede (NL)	199	-63%	74
8 Tilburg (NL)	228	-94%	14
9 Korsløkken (DK)	64	-72%	18
10 Breda (NL)	501	-60%	200

Table 4: Baseline and ambition of the primary energy consumption [kWh/m2/y]

3.3 Baseline of the Indoor environmental quality (IEQ)

The P2ENDURE methodology for the IEQ assessment, developed by UNIVPM in the framework of WP3 Performance Validation and Optimization, is based on the EN15251 approach. The methodology provides the evaluation of KPIs and benchmarks according to the buildings classification shown in the next table:

Category	Explanation
I	High level of expectation and is recommended for spaces occupied by very sensitive and fragile persons with special requirements like handicapped, sick, very young children and elderly persons
II	Normal level of expectation and should be used for new buildings and renovations
III	An acceptable, moderate level of expectation and may be used for existing buildings
IV	Values outside the criteria for the above categories. This category should only be accepted for a limited part of the year

Given that P2ENDURE addresses deep renovation, the expected result is that all demo sites will be compliant with the Category II of the EN15251 classification. For each domain (thermal comfort, acoustic, IAQ), a KPI ranging from 0% (worse) to 100% (best) is calculated in function of the level of compliance with Category requirements. Detailed description of the methodology (measurement and calculation) is provided in Appendix III.

	Thermal comfort winter	Target	Thermal comfort summer	Acoustic comfort	Target	Indoor Air Quality winter	Indoor Air Quality summer	Target
1 Warsaw (PL)	PMV = +0,15 ±0,2 100% in cat II; normal	II	NA	NA		100% in cat III; not acceptable	NA	II
3 Ancona (IT)	PMV = -0,8 ±0,3 55% in cat IV; poor	II	NA	40%; poor	70%	NA	NA	II
4 Genova (IT)	PMV = +0,3 ±0,2 23% in cat III; acceptable	II	50% in cat IV; poor	NA		28% in cat IV; poor	98% in cat I; high level	II

Table 5. Baseline and ambition for the IAQ

Each demonstration case has a different planning schedule. In this deliverable we show the results of the demonstration cases that have finished the mapping stage. The results of the mapping of all the demonstration cases will be updated by M24 (August 2018).

4. Feasibility study for deep renovation

From the baseline results from the condition assessment and the baseline of the energy consumption, a list of desired measures is chosen. An overview of the recommended and actual proposed measures is summarized in the tables below, per demo case. When there is deviation from the recommended measures this is commented and the type and nature of the constraints for application I described.

Warsaw

Existing situation	Recommended measures	Applied measurements	Applied PnP-solutions after optimization	Constrains	Comments
Roof: U = 1,126 m2K/W	Roof insulation: U= 0,2 W/m2K				
Walls: U = 1,215 m2K/W	Wall insulation: U= 0,2 W/m2K				
Floors: U = 0,731 m2K/W	Floor insulation: U= 0,2 W/m2K				
Windows: U = 1,5 m2K/W	HR++ glazing				
HVAC-systems: heating from district heating system network, ventilation - natural	Ventilation with heat recovery of demand controlled ventilation				

Measure	(Will be) applied	Comments
3D-scanning	x	
Condition assessment	x	Energy Audit (2015)
BIM-model	x	
BIM to BEM	x	
Comfort eye	x	

At the moment of writing this deliverable the applied measures are not yet defined of the Warsaw demonstration case. However, given the results of Indoor Environmental Quality (IEQ) monitoring, the suggestion of installing a mechanical ventilation system is provided.

Gdynia

Existing situation	Recommeded measures	Applied measurements	Applied PnP-solutions after optimization	Constrains	Comments
Roof: U = 0,18 m2K/W	Roof insulation: U= 0,2 W/m2K	Roof insulation: U= 0,18 m2K/W	(virtual demo of rooftop extention module), in reality no works related to roof will be done		
Walls below ground (basement): U = 1,43 m2K/W	Wall insulation: U= 0,2 W/m2K	Wall insulation: U= 0,19 m2K/W	-		in order to limit energy losses layer of traditional insulation (explanded polystyrene) will be applied
Walls above the ground U = 1,19 m2K/W	Wall insulation: U= 0,2 W/m2K	Walls above the ground U = 0,20 m2K/W	Fermacell facade		
Floor in the basement U = 0,49 m2K/W	Floor insulation: U= 0,2 W/m2K	Floors: U = 0,49 m2K/W	-	Not possible due to contruction and high investment costs	
Windows: U = 3,12 m2K/W	HR++ glazing	Windows: U = 0,9 m2K/W	BG windows		
HVAC-systems: natural & mechanical ventilation	Ventilation with heat recovery of demand controlled ventilation New boiler or heatpump system	No new HVAC-system		Not chosen because of high investment costs	

Measure	(Will be) applied	Comments
3D-scanning	yes	
Condition assessment	yes	
BIM-model	yes	
BIM to BEM	yes	
Comfort eye	yes	two comfort eyes installed before summer 2018

Because of the high investment costs, the owner of the building did not choose to renovate the HVAC system and to insulate the current basement floor.

However, the insulation of the rest of the building envelop will be renovated to a higher level then recommended.

Ancona

Existing situation	Recommended measures	Applied measurements	Applied PnP-solutions after optimization	Constrains	Comments
Roof: U = 0.65 W/m2K	Roof insulation: U= 0,2 W/m2K				
Walls: U = 0.6 W/m2K	Wall insulation: U= 0,2 W/m2K				
Floors: U =1.68 W/m2K	Floor insulation: U= 0,2 W/m2K				
Windows: U = 5.8 W/m2K (frame 7 W/m2K)	HR++ glazing				
HVAC-systems: gas boiler in each apartment, efficiency <0.8	Ventilation with heat recovery of demand controlled ventilation				
	New boiler or heatpump system				
Comfort KPIs: 0%					
Acoustic KPI: 40%					

Measure	(Will be) applied	Comments
3D-scanning		
Condition assessment	X	
BIM-model	X	
BIM to BEM	X	
Comfort eye	X	

The design phase of the Ancona demonstration case is just started and the discussion with the municipality is ongoing regarding the applied measures taken for the Ancona demonstration case. However, given the result of the IEQ monitoring, indoor thermal comfort is very poor, with high humidity levels and low temperatures. The HVAC refurbishment is highly recommended for the renovation, together with envelope insulation.

Genova

Existing situation	Recommended measures	Applied measurements	Applied PnP-solutions after optimization	Constrains	Comments
Roof: U = 0.516 W/m^{2}K	Roof insulation: U= 0,2 W/m2K			Genova demo site is subject to restriction under Cultural and Heritage Office, therefore aesthetic renovation is not allowed.	
Walls: U = 1.3 W/m2K	Wall insulation: U= 0,2 W/m2K				
Floors: U =1.699 W/m2K	Floor insulation: U= 0,2 W/m2K				
Windows: U = 5.9 W/m2K	HR++ glazing				
HVAC-systems: Central Heating system: Traditional Boiler Gas Powered (Efficiency 87%)	Ventilation with heat recovery of demand controlled ventilation and cooling				

Measure	(Will be) applied	Comments
3D-scanning		Not useful because of the simple architecture and accurate DWG drawings present
Condition assessment	X	
BIM-model	X	
BIM to BEM	X	
Comfort eye	X	Comfort eye not ready when monitoring started. Comfort monitoring of the comfort have been performed by using traditional instrumentation (Temp; U%;CO2 level)

The discussion about the measures to be applied is still ongoing and not final for the Genova demonstration case. This demonstration project is under restriction of the Cultural and Heritage regulations and therefore, it is harder to renovate the property with innovative PnP solutions. Furthermore, the IEQ monitoring in winter revealed a poor Indoor Air Quality (IAQ). Thus, a mechanical ventilation system should be suggested according to mapping. Moreover, the poor summer thermal comfort suggests the application of measures to mitigate the situation (air conditioning).

Florence

Existing situation	Recommended measures	Applied measurements	Applied PnP-solutions after optimization	Constrains	Comments
Not insulated roof: U = 1,811 W/m2K	Roof insulation: U= 0,2 W/m2K	Roof insulation: U= (to be defined)			
Not insulated external walls: U = 1,212 W/m2K	Wall insulation: U= 0,2 W/m2K	Wall insulation: U= (to be defined)		No outside changes allowed	
Floors: U = 1,445 W/m2K	Floor insulation: U= 0,2 W/m2K	Floor insulation: U = (to be defined)			
Windows: U = 5,294 W/m2K	HR++ glazing	New window frames: applied			
HVAC-systems: gas boiler in each apartment, efficiency <0.8		HVAC-systems: new ventilation system per room; new central heating			
No sanitary equipment per room		New sanitary to be applied			

Measure	(Will be) applied	Comments
3D-scanning		
Condition assessment	X	
BIM-model	X	
BIM to BEM	X	
Comfort eye	X	

The discussion about the final insulation to be applied are still ongoing and not final for the Florence demonstration case because outside changes are not allowed due to the restriction of the Cultural and Heritage Office. The project was later brought into P2ENDURE; it was therefore not possible to perform 3D-scanning of the building.

Enschede

Existing situation	**Recommended measures**	**Applied measurements**	**Applied PnP-solutions after optimization**	**Constrains**	**Comments**
Roof: U = 0.4 W/m2K	Roof insulation: U= 0,2 W/m2K	Roof insulation: U= 0,16 W/m2K			
Walls: U = 0.4 W/m2K	Wall insulation: U= 0,2 W/m2K	Wall insulation: U= 0,2 W/m2K	Prefab facades		
Floors: U = 0.4 W/m2K	Floor insulation: U= 0,2 W/m2K	Floor insulation: U = 0,16 W/m2K			
Windows: U = 5,1 W/m2K	HR++ glazing	New window frames: applied U = 1,65 W/m2K	integrated in prefab facades		
HVAC-systems: centralized heating system with gas boiler. No ventilation in the rooms. Radiators and piping in bad state. Electricity infrastructure in bad state.	Ventilation with heat recovery of demand controlled ventilation	New ventilation system per room			
	New boiler or heatpump system	New heating with heatpump			
No sanitary equipment per room		New sanitary to be applied	PnP bathroom cabins		

Measure	**(Will be) applied**	**Comments**
3D-scanning	X	
Condition assessment	X	
BIM-model	X	
BIM to BEM	X	
Comfort eye	X	

The renovation of the Enschede demonstration case will be finished in the summer 2018. Almost all renovation measures will be performed with PnP solutions.

Tilburg

Existing situation	**Recommended measurements**	**Applied measurements**	**Applied PnP-solutions after optimization**	**Constrains**	**Comments**
Roof: non insulated	Roof insulation: U= 0,2 W/m2K	Roof insulation: U= 0.14 W/m2K			
Walls: not insulated	Wall insulation: U= 0,2 W/m2K	Wall insulation: U= 0.56 W/m2K (insulating the cavity between inner and outer façade-layer)		Monument, no outside changes allowed	
window frames in bad state, single glazing	Application of new window frames	New window frames applied or renovation of existing		Monument, no outside changes allowed	
Windows: single glazing	HR++ glazing	New HR++ glazing: applied			
Walls internal: brick		New internal wall on one side of the room	PnP wall elements with integrated electricity and wall outlets		
Floors: concrete and wooden non-insulated		new floor heating system with fermacell floor plates	Efficient integrated floorheating and acoustical comfort system		
HVAC-systems: centralized heating system with gas boiler. No ventilation in the rooms. Radiators and piping in bad state. Electricity infrastructure in bad state.	Ventilation with heat recovery of demand controlled ventilation	New ventilation system per room	PnP-engine on ventilation per room		
	New boiler or heatpump system	New heating with collective (3 or 6 rooms combined) heatpump	PnP shaft for new infrastructure		
No sanitary equipment per room		New sanitary to be applied	PnP bathroom cabins		

Measure	**(Will be) applied**	**Comments**
3D-scanning	X	
Heat pictures	X	
Acoustical measurements	X	
Condition assessment	X	
BIM-model	X	
BIM to BEM	X	
Comfort eye	X	

to measure before and after acoustical comfort

The Tilburg demonstration case contains three pilot rooms that will be renovated with almost only PnP solutions, the only constrain is that the outside walls cannot be insulated due to the building being a monument.

Breda

Existing situation	**Recommended measures**	**Applied measurements**	**Applied PnP-solutions after optimization**	**Constrains**	**Comments**
Roof: U = 4,35 m2K/W	Roof insulation: U= 0,2 W/m2K	Roof insulation: U= 0,16 m2K/W	PnP roof		
Walls: U = 1,39 m2K/W	Wall insulation: U= 0,2 W/m2K	Wall insulation: U= 0,2 m2K/W	PnP walls including HVAC installations		
Floors: U = 9,09 m2K/W	Floor insulation: U= 0,2 W/m2K	Floor insulation: U = 0,2 m2K/W			
Windows: U = 5,1 m2K/W	HR++ glazing	New window frames: applied U = 1,1 m2K/W	Windows are included in the facades		
HVAC-systems: HRE 24/28 combination heater, no ventilation	Ventilation with heat recovery of demand controlled ventilation	HVAC-systems: New HVAC engine will be applied	PnP HVAC Engine		

Measure	**(Will be) applied**	**Comments**
3D-scanning		
Condition assessment		
BIM-model	X	
BIM to BEM	X	
Comfort eye		No possibility for comfort eyes, but sensors will be applied for energy use and indoor temperature

The Breda demonstration case will be renovated with almost only PnP solution. The roof, engine and facades will be fabricated in a factory, where after they will be moved to the building site and installed within two days.

Korsløkken

Existing situation	**Recommended measures**	**Applied measurements**	**Applied PnP-solutions after optimization**	**Constrains**	**Comments**
Roof: U = 0,45 m2K/W	Roof insulation: U= 0,2 W/m2K	Roof insulation: U= 0,1 m2K/W	new solution 400mm insulation		
Walls: U = 1,1 m2K/W		Wall insulation: U= 0,81 m2K/W	New window instead of wall		
Gable: U = 0,40 m2K/W	Insulation: U= 0,2 W/m2K	Gable insulation: U= 0,16 m2K/W	New 200mm insulation		
Windows: U = 2,9 m2K/W	HR++ glazing	New windows: U = 0,81 m2K/W	New windows installed		
HVAC-systems: natural	HVAC with heat recovery and/or demand controlled ventilation	HVAC-systems: new central with heat recovery.			

Measure	**(Will be) applied**	**Comments**
3D-scanning		
Condition assessment		
BIM-model	X	
BIM to BEM	X	
Comfort eye	X	

In the Korsløkken demonstration case a robotic technology is used to 3D-print the facades of the apartment complex. The front facades of the apartments are changed into an opaque façade and therefore, of a lower insulation value comparing to a solid facades.

5. Conclusion

In this deliverable, the baselines for the pre-renovation conditions for each demonstrator are devised. The baselines are consolidated on:

- the initial condition assessment;
- the value of the key performance indicators of the primary energy use and the IEQ.

This baseline report is the first step of the 4M approach, representing: Mapping.
The data is collected and the baseline of KPIs is calculated for the pre renovation situation. Now the initial condition of the demonstrators is evaluated, the expected post-renovation state compared to the pre-renovation state is shown and the improvements compared to the goals of P2ENDURE are pointed out. This deliverable can be seen as a starting point and at the same time feasibility study for the further tasks to be carried out in WP4.

Due to the different planning of the projects and progress this deliverable contains only a part of the results from the demonstration cases. This deliverable with the complete results of the baseline of all demonstration cases will be updated by M24 (August 2018). The results for the other KPIs will be reported in the WP3 deliverables.

The table below shows the specific Key Performance Indicator (KPI) for each demonstration case and in which deliverable the results will be reported.

KPI / Deliverable / Due date / Demo Project	Primary Energy D4.1	LCA D3.2 – M42	Time D3.3 - M24	LCC D3.3 - M24	Replicability D 3.4 – M42	Thermal comfort D4.1	Acoustics D4.1	IAQ D4.1	Disturbance D3.5 - M24
23. Gdynia (PL)	X	X	X	X		X		X	X
24. Warsaw (PL)	X	X	X	X		X		X	X
25. Ancona (IT)	X	X	X	X		X	X	X	X
26. Genova (IT)	X	X	X	X		X	X	X	X
27. Palmanova (IT)	X								
28. Florence (IT)	X		X	X	X	X			X
29. Soest (DE)									
30. Enschede (NL)	X		X	X		X		X	X
31. Tilburg (NL)	X		X	X		X	X	X	X
32. Korsløkken (DK)	X	X	X	X		X		X	X
33. Breda (NL)	X	X	X	X					X

Legend:
X *Data reported in deliverable by due date*
X *Data reported in update of deliverable, see header of the table*
(upcoming updates: D4.1 by M24 - August 2018,
D3.3, D3.4, D3.5 by M30 - February 2019 and M36 - August 2019)

Each demonstration case has a different planning schedule. In this deliverable we show the results of the demonstration cases that have finished the mapping stage. The results of the mapping of all the demonstration cases will be updated by M24 (August 2018).

The PnP-solutions are applied as measures for deep renovation. The applied PnP-solutions make the ambition of the targeted KPI-values possible. When there are constrains in performing deep renovation, for example caused by high monumental value of a building, traditional renovation measures are considered. These constraints that restrict applying the PnP solutions are elaborated and a full overview is given in the Chapter 4.

The baseline of the KPIs with according methodology, for Life-Cycle Analysis (LCA), time reduction, Life-Cycle Costs (LCC), replicability, and disturbance, are defined in the Work Package 3 'Performance validation and optimization'.

Annex 1 – Condition assessments

no	Building component	Material	Quantity *(Unit)*	Condition score (NEN)	Short description of the condition
	Name: Kindergarten nr 16, Gdynia PL	—	—	*4*	*The kindergarten building was built in 1966. Numerous minor upgrades have been made. The general condition of the building is poor.*

Inventory list of building components demanding maintenance

(choose applicable components, add new ones if necessary, provide photos of the details and defects)

1. **Facade**

▪ Facade *(excluding outer opening)*	foam concrete	*156m2*	3	No visible cracks or deviation from the vertical. There are mechanical damages on the corners of facades.
▪ Facade cladding (excluding outer opening)	plaster	*156m2*	4	Visible deteriorations of the wall finish. Numerous discoloration, dirt. and splinter.
▪ Other:				
▫ Window sills	steel	*18,6m*	3	Only part of window sills meets thermal requirements.

2. **Openings in the facade**

▪ Windows	*wood/ PVC*	*23,6m2*	6/3	Wooden windows have damaged frames. Not tight, repeatedly painted, with splited. Double glazing. Do not meet thermal requirements. Replacement of the wooden windows is strongly recommended. PVC windows are in fair condition.
▪ Doors	aluminum/ steel	*7,7m2*	2/6	Aluminum doors in good condition. Without visible damage, they perform their function without reservation. Steel doors are leaky, they are an element with poor thermal properties. They require replacement.

3. **Roofs / drainage**

▪ Flat roof finishing	waterproof membrane	*182m2*	1	The flat roof finishing is new. The roof has been insulated several years ago. Mechanical damage is not visible.
▪ Other:				
▫ Gutters and fascias	steel	*59m*	2	Elements have been replaced during the insulation of the roof.
▫ Downspouts	steel	*3,6m*	2	Elements were replaced during ongoing repairs.

4. **Chimneys**

▪ Chimney *(m2 of the brickwork if applicable)*	bricks	*30m2*	3	Chimney in good condition. No cracking visible. Most of ventilation grills require replacement. The building has a noticeable shortage of ventilation air - the installation of automatic or manual window diffusers is required.
▪ Gas flue pipes	steel	*4*	2	Gas pipes in good condition. Tight, corrosion is not visible.
▪ Ventilation pipes	steel	*12*	4	The ventilation ducts need replacing. Corrosion is visible despite maintenance.

5. **Stairs and ramps**

▪ External stairs / ramps	concrete, tiles	*3*	1	Pavements around the building, including stairs and ramps, were renovated during the thermo-modernization of basement walls.
▪ Inner stairs / ramps	concrete	*1*	5	Concrete floors strongly corroded, with uneven surfaces and uneven height.

6. **Other structural elements**

▪ Beams	reinforced concrete	*23m*	2	Beams in good condition, without cracks and other visible deformations.

7. **Inner walls**

▪ Not constructive	hollow brick, plaster board	*138,5m2*	3	The walls are sufficient. No cracks, no biological corrosion.
▪ Constructive	full brick	*26m2*	3	The walls are sufficient. No cracks, no biological corrosion.

▪ Other:

▫ Finishing walls (e.g. plasterwork, tiles)	gypsum plaster, paint, tiles	*330m2*	5	Wall finishing requires leveling and renewal. Old tiles, cracking, arranged in a messy manner that makes it difficult to maintain proper hygiene standards.
▫ Finishing ceilings	gypsum plaster, paint	*162m2*	4	Plastering and painting done in an imprecise manner which increase visible of ageing process.

8. **Internal openings**

▪ Doors	wood	*28,5m2*	6	Doors in poor technical condition, repeatedly painted without removing the previous layer of paint. Numerous mechanical damage.
▪ Internal windows	*wood*	*0,9m2*	6	The aging process and mechanical damage as well as incorrect maintenance led to poor technical condition of the window.

9. **Internal floors**

▪ Not constructive	gypsum screed	*330m2*	3	Uneven floors, visible damage.
▪ Constructive	DMS ceiling	*162m2*	2	Ceilings in a sufficient condition. No distortion or chemical or biological pollution.

▪ Other:

▫ Finishing (e.g. tiles, carpeting)	tiles, PVC flooring	*160m2*	4	Cracked floor tiles, corroded floor drains.

10. **Balustrade and railings**

▪ Handrails	steel, PVC	*3,3m*	4	Painted many times to prevent corrosion. PVC handle bent and damaged.

11. **Paintwork**

▪ External:

▫ Walls	plaster	*156m2*	—	Plaster cracked in some places. Visible dirt and stains.

▪ Internal:

▫ Walls	paint, tiles	*330m2*	—	Old, cracked, uneven tiles. A lot of joints make it difficult to maintain hygiene standards.
▫ Ceilings	paint	*162m2*	—	

12. **Terrain** *(elements demanding maintenance)*

13. **Other**

▫ Other (e.g. radiators)	steel	*14*	2	In sufficient technical condition

no	Building component	Material	Quantity *(Unit)*	Condition score (NEN)	Short description of the condition
	Name: Nursery building in Warsaw	—	1	4	The building was built in 1983. It is a place for temporary care to 108 children aged 1-3 (6 groups). The building is made of prefabricated concrete elements and cellular concrete wall and comprises two over ground floors and one floor in the basement. Gross covered area is 631 m2 The technical condition of the building is qualified as reasonable.

Inventory list of building components demanding maintenance

(choose applicable components, add new ones if necessary, provide photos of the details and defects)

1. **Facade**

▪ Facade *(excluding outer opening)*		*656,93 m2*	4	The thermal performance of the building fabric is insufficient. The walls above ground level needs insulation, heat transfer coefficient (U) of exterior load-bearing wall is 1.215 [W/m2K], exterior aircrete wall os 1.198 [W/m2K].
▪ Facade cladding (excluding outer opening)		*(m2)*		
▪ Other:				
▫ Keystones		*(no. of pieces)*		
▫ Architraves		*(m1)*		
▫ Window sills		*(m1)*		
▫ Finishing (e,g, plasterwork)		*(m2)*		
▫ Lead		*(m1)*		
▫ …				

2. **Openings in the facade**

▪ Windows		*81 pieces, 305,27 m2* *Entrance 21,74 m2*	3 - windows at the story's, 5 - windows in the basement	PVC-framed windows were replaced in 2005 and are in reasonable condition. At the basement level, the building features single-glazed wooden frame windows, with very high U. After dismantling the windows may not be suitable for re-assembly.
▪ Doors		*7 pieces, 19,43 m2*	3	The unheated main-entrance vestibule features a steel-framed insulating glass unit. The exterior doors are aluminum-framed (main door) doors, solid-wooden doors, solid-steel doors, and steel-framed single-glazed doors (on the exterior end walls).

▪ Other:

▫ Roof openings (e.g. skylight)		*(no. of pieces) (size indication: small, medium, large)*		
▫ …				

3. **Roofs / drainage**

▪ Flat roof finishing		*541,74 m2*	5	The thermal performance of the building fabric is insufficient. The cold deck flat roof needs insulation, large heat losses.
▪ Pitched roof finishing		*(m2)*		

▪ Other:

▫ Gutters and fascias		*(m1)*		
▫ Downspouts		*(m1)*		
▫ Coping stones		*(no. of pieces)*		
▫ Lead		*(m1)*		
▫ …				

4. **Chimneys**

▪ Chimney *(m2 of the brickwork if applicable)*		*16 pieces, 101,78 m2*	4	All rooms are naturally ventilated through vertical masonry chimneys extending above the roof with vent terminals. Ventilation is insufficient due to air-tight windows and needs to be improved. Cracks in the chimney walls
▪ Gas flue pipes		*(no. of pieces)*		
▪ Ventilation pipes		*(no. of pieces)*		
▪ …				

5. **Stairs and ramps**

▪ External stairs / ramps		*1 piece, 3 steps*		
▪ Inner stairs / ramps		*(no. of pieces)*		

▪ Other:

▫ Finishing (e.g. tiles, carpeting)		*(m2)*		
▫ …				

▫ …

6. **Other structural elements**

▪ Columns		*74 pieces, 240,50 m2*		
▪ Beams		*89 pieces, 249,02 m2*		
▪ …				

7. **Inner walls**

▪ Not constructive		*909,78 m2*		
▪ Constructive		*556,41 m2*		

▪ Other:

▫ Finishing walls (e.g. plasterwork, tiles)		*(m2)*		
▫ Finishing ceilings		*(m2)*		
▫ …				

8. **Internal openings**

▪ Doors		*138,27 m2*		
▪ Internal windows		*19,53 m2*		
▪ …				

9. **Internal floors**

▪ Not constructive		*(m2)*		
▪ Constructive		*1636,00 m2*		

▪ Other:

▫ Finishing - wooden		*307,00 m2*		
▫ Finishing - Terracotta		*210,00 m2*		
▫ Finishing - PVC		421,00 m2		

10. **Balustrade and railings**

▪ Balustrades		*(m1)*		
▪ Handrails		*(m1)*		
▪ …				

11. **Paintwork**

▪ External:

▫ Walls		*(m2)*	—	
▫ Window/door frames		*(m2 of the whole opening as in no1)*	—	
▫ Other (e.g. fascias, balustrades)		*(depending on the element)*	—	
▫ …			—	

▪ Internal:

▫ Walls		*(m2)*	—	
▫ Ceilings		*(m2)*	—	
▫ Door frames		*(m2 of the whole opening as in no1)*	—	
▫ Other (e.g. handrails)		*(depending on the element)*	—	
▫ …			—	

12. **Terrain** *(elements demanding maintenance)*

▫ Finishing (e.g. gravel, tiles)		*(m2)*		
▫ Other (e.g. lamps)		*(depending on the element)*		
▫ …				

13. **Other**

▫ Combined heat distribution unit		1 unit	2	The heat for the building is supplied by a CH and DHW combined heat distribution unit installed in the basement. The unit is equipped with weather-responsive control and is in a good condition; the equipment and individual valves and gauges have been replaced in recent years.
▫ Source of heat supply		1 unit	2/3	The domestic hot-water supply system was replaced over ten years ago and is in a reasonable condition. The system is made of synthetic non-insulated (vertical and horizontal runs) pipes, with no control system to reduce hot-water circulation.
▫ Central-heating system		1 unit	2/3	The existing system is in a reasonable condition following a retrofit around 2002, which included the installation of synthetic pipes, thermostatic radiator valve bodies, and balancing valves under vertical pipe runs. Most of the old radiators have been left in place, including cast-iron column radiators and plain-wall pipe radiators.

no	Building component	Material	Quantity *(Unit)*	Condition score (NEN)	Short description of the condition
	Name: Social housing (ERAP), Ancona IT	—	—	*4*	*It is a social housing with 100 apartments. Quickly built after a big landslide in the early eighties, the load-bearing structure is composed of concrete prefabricated slabs. The overall condition of the building is poor due, in particular, to the quality of materials, mediocre execution and lacks in maintenance over the years.*

Inventory list of building components demanding maintenance

(choose applicable components, add new ones if necessary, provide photos of the details and defects)

1. **Facade**

▪ Facade *(excluding outer opening)*	concrete, slightly insulated walls without cavity	*~4700 (m2)*	4	Generally deteriorated with visible moisture and cracks
▪ Facade cladding (excluding outer opening)	plaster	*~4700 (m2)*	4	Deteriorations due to ageing process and weather are clearly detectable and diffused along all the surfaces. Deteriorations due to moisture are extremely evident and diffuse.
▪ Other:				
▫ Keystones		*(no. of pieces)*		
▫ Architraves		*(m1)*		
▫ Window sills	steel	*565 (m1)*	2	The steel sills are wall passing, providing a sensible thermal bridge. Their status is quite good but a complete replacement with elements with the thermal break is highly recommended.
▫ Finishing (e.g., plasterwork)	plaster	*~4700 (m2)*	4	Deteriorations due to ageing process and weather are clearly detectable and diffused along all the surfaces. Deteriorations due to moisture are extremely evident and diffuse.
▫ Lead		*(m1)*		
▫ …				

2. **Openings in the facade**

▪ Windows	*steel*	*900(m2) 478 pieces*	3	Single glazing. Metal frame without the thermal break. Little defects due to weather and ageing. Air infiltrations are consistent. Installation of poor quality provide issues in closing. A complete substitution is recommended.
▪ Doors: building entrance	*steel*	*18(m2) 6 pieces*	3	Single glazing. Metal frame without the thermal break. Little defects due to weather and ageing. Installation not often performed well. In some cases, the glass is broken.

▪ Other:

▫ Roof openings (e.g. skylight)		*(no. of pieces) (size indication: small, medium, large)*		
▫Garage shutters	*metal*		3	Pivot shutters manually handling. Corrosions of the materials are visible and weather defects occur regularly.

3. **Roofs / drainage**

▪ Flat roof finishing	waterproof membrane	*1720 (m2)*	?	The access to the roof was not possible.
▪ Pitched roof finishing	\	*(m2)*		
▪ Other:				
▫ Gutters and fascias	*copper, plastic?*	*(m1)*	?	They are probably settled inside the walls. Status not detectable.
▫ Downspouts	*copper, plastic?*	*(m1)*	?	They are probably settled inside the walls. Status not detectable.
▫ Coping stones		*(no. of pieces)*		
▫ Lead		*(m1)*		
▫ …				

4. **Chimneys**

▪ Chimney *(m2 of the brickwork if applicable)*		*(no. of pieces); (m2)*		
▪ Gas flue pipes		*(no. of pieces)*		
▪ Ventilation pipes		*(no. of pieces)*		
▪ …				

5. **Stairs and ramps**

▪ External stairs / ramps		*3*	4	High level of corrosion and cracks, poor stability
▪ Inner stairs / ramps	*concrete*	*6 stairwells*	3	No structural defect is visible. The surface moisture on the concrete is clearly visible and regularly diffuse. The rubber finishing presents cracks regularly, some pieces are missing at all.

▪ Other:

▫ Finishing (e.g. tiles, carpeting)		*(m2)*		
▫ …				

▫ …

6. **Other structural elements**

▪ Columns		*(no. of pieces); (m1)*		
▪ Beams		*(no. of pieces); (m1)*		
▪ …				

7. **Inner walls**

▪ Not constructive	*brick*	*~13400 (m2)*	4	
▪ Constructive	*concrete*	*~13500 (m2)*	4	

▪ Other:

▫ Finishing walls (e.g. plasterwork, tiles)	*gypsum lime plaster*	*~23500 (m2)*	5	The ageing process and the lack of ordinary maintenance made the finishing extremely deteriorate. Because of lacks in ventilation, surface moisture is a primary issue. Such defect regularly occurs in each apartment. In some particularly critical cases (e.g. bathrooms), the mold proliferation and the biofouling cover all the walls. Occupants' health is seriously at risk.
▫ Finishing ceilings	*gypsum lime plaster*	*~8000 (m2)*	5	The ageing process and the lack of ordinary maintenance made the finishing extremely deteriorate. Because of lacks in ventilation, surface moisture is a primary issue. Such defect regularly occurs in each apartment. In some particularly critical cases (e.g. bathrooms), the mold proliferation and the biofouling cover all the ceilings. Occupants' health is seriously at risk.
▫ …				

8. **Internal openings**

▪ Doors: apartments entrance	*wood*	*190(m2) 100 pieces*	4	Single wood panel with a plastic coating. Very high air infiltrations. Installation of poor quality provide issues in closing. Damages of the finishing and the panel are clearly and regularly detectable.
▪ Doors: internal to the apartments	*wood*	*834(m2) 524 pieces*	4	Single wood panel with a plastic coating. Air infiltrations are consistent. Installation of poor quality provide issues in closing. Damages of the finishing and the panel are clearly and regularly detectable.
▪ Internal windows	*(material of the frame)*	*(m2)*		
▪ …				

9. **Internal floors**

▪ Not constructive		*(m2)*		
▪ Constructive	*concrete*	*8600(m2)*	3	

▪ Other:

▫ Finishing (e.g. tiles, carpeting)	*tiles*	*7300(m2)*	2	The overall status is quite good. Defects (e.g. cracks) are localized.
▫ …				

10. **Balustrade and railings**

▪ Balustrades	*metal*	*180(m1)*	3	Material deterioration is clearly visible and diffuse. The surface paint is missing in several parts.
▪ Handrails	*plastic*	*180(m1)*	2	The overall status is quite good. Defects occur rarely.
▪ …				

11. **Paintwork**

▪ External:

▫ Walls	plaster	*~4700 (m2)*	4	Deteriorations due to ageing process and weather are clearly detectable and diffused along all the surfaces. Deterioration due to moisture is extremely evident and diffuse.
▫ Window/door frames		*(m2 of the whole opening as in no1)*	—	
▫ Other (e.g. fascias, balustrades)		*(depending on the element)*	—	
▫ …			—	

▪ Internal:

▫ Walls	*gypsum lime plaster*	*~23500 (m2)*	5	The ageing process and the lack of ordinary maintenance made the finishing extremely deteriorate. Because of lacks in ventilation, surface moisture is a primary issue. Such defect regularly occurs in each apartment. In some particularly critical cases (e.g. bathrooms), the mold proliferation and the biofouling cover all the walls. Occupants' health is seriously at risk.
▫ Ceilings	*gypsum lime plaster*	*~8000 (m2)*	5	The ageing process and the lack of ordinary maintenance made the finishing extremely deteriorate. Because of lacks in ventilation, surface moisture is a primary issue. Such defect regularly occurs in each apartment. In some particularly critical cases (e.g. bathrooms), the mold proliferation and the biofouling cover all the ceilings. Occupants' health is seriously at risk.
▫ Door frames		*(m2 of the whole opening as in no1)*	—	
▫ Other (e.g. handrails)		*(depending on the element)*	—	
▫ …			—	

12. **Terrain** *(elements demanding maintenance)*

▫ Finishing (e.g. gravel, tiles)		*(m2)*		
▫ Other (e.g. lamps)		*(depending on the element)*		
▫ …				

13. **Other**

▫ Radiators	*steel*	*516 pieces*	6	The heating system is an extremely old one-pipe system. The undersized radiators do not provide sufficient heat to satisfy the thermal comfort. Many occupants pay expensive bills because they leave the system always on in winter and adopted further device (e.g. heaters) to warm up the rooms. A complete renovation of the system is strongly recommended.
▫ …				

no	Building component	Material	Quantity*(Unit)*	Condition score (NEN)	Short description of the condition
	Name: Genoa Nursery NEMO	—	—	3	The building is listed under the Italian Legislative Decree 42/2004, which poses cultural heritage constraints on its conservation. The general condition of the building is poor.

Inventory list of building components demanding maintenance

(choose applicable components, add new ones if necessary, provide photos of the details and defects)

1. **Facade**

▪ Facade *(excluding outer opening)*	brick wall with cavity beams (plaster and concrete)	301,8 m2	2	
▪ Facade cladding (excluding outer opening)		*(m2)*		
▪ Other:				
▫ Window sills	concrete	63,5 m1	2	Fractures and cracks. Recommended renovation during window replacement
▫ Architraves	concrete	63,5 m1	2	Fractures and cracks. Recommended renovation during window replacement
▫ Beams	concrete	13 pieces	2	
▫ Finishing (e.g., plasterwork)	plaster	301 m2	3	Discoloration - more advanced on the East facade. Not constructive crack
▫ Lead		*(m1)*		
▫ …				

2. **Openings in the facade**

▪ Windows	steel	26 pieces, 94 m2	6	Single glazing. Damaged glass substituted with temporary panels. Damaged stucco, glass, window frames. Missing parts. Corrosion is more advanced on the East facade (inner and outer sides). Renovation / replacement of the windows is strongly recommended
▪ Doors: main entrance	PVC	2 pieces, 4,4 m2 each	2	Single glazing. Metal frame without thermal break. Air infiltration. The general condition is good
▪ Doors: boiler room and roll-up doors	steel	8 m2	3	Corrosion
▪ Other:				
▫ Roof openings (e.g. skylight)		*(no. of pieces) (size indication: small, medium, large)*		
▫ …				

3. **Roofs / drainage**

▪ Flat roof finishing	waterproof membrane	349 m2	2	
▪ Flat roof finishing: boiler	incl. concrete construction	20 m2	2	
▪ Pitched roof finishing		*(m2)*		
▪ Other:				
▫ Gutters and fascias	rubber fascias	100 m1	2	
▫ Downspouts	PVC	8 m1	2	
▫ Coping stones		*(no. of pieces)*		
▫ Lead		*(m1)*		
▫ …				

4. **Chimneys**

▪ Chimney *(m2 of the brickwork if applicable)*	steel	2 pieces	2	
▪ Gas flue pipes	gas pipes	40 m1	2	
▪ Ventilation pipes		*(no. of pieces)*		
▪ …				

5. **Stairs and ramps**

▪ External stairs / ramps		*(no. of pieces)*		
▪ Inner stairs / ramps		*(no. of pieces)*		
▪ Other:				
▫ Finishing (e.g. tiles, carpeting)		*(m2)*		
▫ …				

▫ …

6. **Other structural elements**

▪ Columns		*(no. of pieces); (m1)*		
▪ Beams		*(no. of pieces); (m1)*		
▪ …				

7. **Inner walls**

▪ Not constructive		*(m2)*		
▪ Constructive		*(m2)*		
▪ Other:				
▫ Finishing walls (e.g. plasterwork, tiles)	plaster	969 m2	2	Fractures and cracks. Moisture in the storage room
▫ Finishing walls: toilets	ceramic tiles	70 m2	2	
▫ Finishing ceilings	plaster	260 m2	2	
▫ …				

8. **Internal openings**

▪ Doors: classrooms	wood	12 pieces, 22 m2	2	
▪ Doors: toilets	wood	6 pieces, 7 m2	2	
▪ Internal windows	*(material of the frame)*	*(m2)*		

▪ …				

9. **Internal floors**

▪ Not constructive		*(m2)*		
▪ Constructive		*(m2)*		

▪ Other:

▫ Finishing (e.g. tiles, carpeting)	stone and mortar mix	244 m2	2	Fractures and cracks.
▫ Finishing: toilets	ceramic tiles	16 m2	2	Fractures and cracks.
▫ …				

10. **Balustrade and railings**

▪ Balustrades: entrance	steel	52 m1	2	
▪ Handrails		*(m1)*		
▪ …				

11. **Paintwork**

▪ External:

▫ Walls	on brick / concrete	*301 m2*	—	
▫ Window frames	on metal	94 m2	—	Renovation / replacement of the windows is strongly recommended
▫ Roll-up door	PVC	9,6 m2	—	
▫ Other (e.g. fascias, balustrades)		*m2*	—	
▫ …			—	

▪ Internal:

▫ Walls	plaster	969 m2	—	
▫ Ceilings	plaster	260 m2	—	
▫ Door frames	wood	29 m2	—	
▫ Other (e.g. handrails)		*(depending on the element)*	—	
▫ …			—	

12. **Terrain** *(elements demanding maintenance)*

▫ Finishing (e.g. gravel, tiles)		*(m2)*		
▫ Emergency lamp main entrance		1 piece		
▫ …				

13. **Other**

▫ Radiators		19 pieces		
▫ …				

no	Building component	Material	Quantity *(Unit)*	Condition score (NEN)	Short description of the condition
	Name: Lidwina monastery, Tilburg NL	__	__	*general building score*	*description of the general building condition*

Inventory list of building components demanding maintenance

(choose applicable components, add new ones if necessary, provide photos of the details and defects)

1. **Facade**

▪ Facade *(excluding outer opening)*	Brick facade	2140 m2	2	Locally visible fractures, cracks and moisture
▪ Facade cladding (excluding outer opening)	Stone (main entrance)	5 m2	1	Dirt. No other visible signs of deterioration
▪ Other:				
▫ Keystones - front side	Stone	234 pieces	2	
▫ Architraves		*(m1)*		
▫ Window sills	Stone	225 m1	3	Fractures and cracks
▫ Finishing (e.g., plasterwork)		*(m2)*		
▫ Lead		*(m1)*		
▫ Terrace wall	Brick	75 m2	2	

2. **Openings in the facade**

▪ Windows	Steel frames incl. wooden screens	206 m2	5	Single glazing. Corrosion. Renovation / replacement of the windows is strongly recommended
▪ Windows - stained glass	Steel frames incl. wooden screens	138 m2	5	Single glazing. Corrosion. Renovation / replacement of the windows is strongly recommended
▪ Windows - stained glass, artwork	Steel	8 m2	3	Single glazing.
▪ Windows - back side, terrace 1st floor	Steel	26 m2	3	
▪ Windows - basement	Steel	15 m2	2	
▪ Doors - front entrance (double door)	Wood	4 pieces, 8 m2	2	
▪ Doors - back side	Steel	12 pieces, 24 m2	2	
▪ Doors - back side (double door)	PVC	14 pieces, 28 m2	2	
▪ Other:				
▫ Skylights		6 pieces, medium size	2	
▫ Window wooden sunscreens	Wood	206 m2	4	Locally damaged, few not working

3. **Roofs / drainage**

▪ Flat roof finishing - front side	Copper	28 m2	3	Corrosion

▪ Flat roof finishing - back side	Bitumen	190 m2	4	Defects in water drainage, dirt. The slope of the roofs should be adjusted.
▪ Pitched roof finishing	Ceramic	1920 m2	2	

▪ Other:

▫ Fascias - back entrance	Stone	9 m1	2	
▫ Fascias - green boards	Wood	220 m1	2	
▫ Gutters with gutter hangers	Zink	200 m1	2	
▫ Downspouts	PVC	85 m1	3	Recommended local spouts replacements
▫ Downspouts	Steel	105 m1	3	
▫ Downspouts	Zink	15 m1	3	
▫ Coping stones	Stone	70 m1	2	Moss
▫ Lead on bitumen roofs (terraces)		77 m1	3	Local damages, missing parts
▫ Lead on the pitched roof		44 m1	2	
▫ Bell tower	Copper	1 piece	2	
▫ Terrace floor	Composite floor on bitumen roof	110 m2	3	

4. **Chimneys**

▪ Chimney *(m2 of the brickwork if applicable)*	Brick	4 pieces, 30 m2	2	
▪ Gas flue pipes	PVC	6 pieces	2	
▪ Ventilation pipes	Steel	2 pieces	2	
▪ …				

5. **Stairs and ramps**

▪ External stairs - front side	Stone	2 pieces	2	Fractures
▪ External stairs - back side	Stone with ceramic tiles	3 pieces, 8 m2 of tiles	3	Fractures and cracks, missing parts
▪ Inner stairs / ramps		*(no. of pieces)*		

▪ Other:

▫ Finishing (e.g. tiles, carpeting)		*(m2)*		
▫ …				

▫ …

6. **Other structural elements**

▪ Columns		*(no. of pieces); (m1)*		
▪ Beams		*(no. of pieces); (m1)*		
▪ …				

7. **Inner walls**

▪ Not constructive		*(m2)*		
▪ Constructive		*(m2)*		

▪ Other:

▫ Finishing walls (e.g. plasterwork, tiles)		*(m2)*		
▫ Finishing ceilings		*(m2)*		
▫ …				

8. **Internal openings**

▪ Doors		*(m2)*		
▪ Internal windows	*(material of the frame)*	*(m2)*		
▪ …				

9. **Internal floors**

▪ Not constructive		*(m2)*		
▪ Constructive		*(m2)*		

▪ Other:

▫ Finishing (e.g. tiles, carpeting)		*(m2)*		
▫ …				

10. **Balustrade and railings**

▪ Coping walls	Brick walls with tiles	40 m1	2	
▪ Handrails	Steel	20 m1	2	
▪ …				

11. **Paintwork**

▪ External:

▫ Walls		*(m2)*	—	
▫ Entrance wooden doors	transparent lacquer on wood	8 m2	—	
▫ Green fascias boards	on wood	220 m2	—	
▫ Steel doors	on steel	24 m2	—	
▫ Steel window frames	on steel	379 m2	—	

▪ Internal:

▫ Walls		*(m2)*	—	
▫ Ceilings		*(m2)*	—	
▫ Door frames		*(m2 of the whole opening as in no1)*	—	
▫ Other (e.g. handrails)		*(depending on the element)*	—	
▫ …			—	

12. **Terrain** *(elements demanding maintenance)*

▫ Entrance terraces, tiles - back side	Stone	(m2)	4	Damaged tiles, visible fractures and cracks, missing parts
▫ Entrance terraces, gravel tiles - back side	Stone	(m2)	4	Damaged tiles, visible fractures and cracks, missing parts

▫ Other (e.g. lamps)		*(depending on the element)*		
▫ …				

13. **Other**

▫ Other (e.g. radiators)		*(depending on the element)*		

Annex 2 - Methodology IEQ

General Approach for IEQ performance assessment

The P2ENDURE methodology for the IEQ assessment, developed by UNIVPM in the framework of WP3 Performance Validation and Optimization, will follow the EN15251 approach. The proposed methodology is based on the evaluation of KPIs and benchmarks according to the buildings classification shown in the next table:

Category	Explanation
I	High level of expectation and is recommended for spaces occupied by very sensitive and fragile persons with special requirements like handicapped, sick, very young children and elderly persons
II	Normal level of expectation and should be used for new buildings and renovations
III	An acceptable, moderate level of expectation and may be used for existing buildings
IV	Values outside the criteria for the above categories. This category should only be accepted for a limited part of the year

Given that P2ENDURE addresses the deep renovation, the expected result is that all demo sites will be compliant with the Category II of the EN15251 classification.
Finally, given the fact that EN15251 does not cover all the IEQ aspects, for specific issues or problems of a demo site, the inclusion of further parameters will be evaluated after the completion of evaluation process of all demo cases, if required.

Indoor Air Quality

Objective

Indoor air quality depends on a variety of sources, such as occupants, finishing materials, cleaning products, equipment and activities carried out in the spaces; these sources emit various types of pollutants that are difficult to forecast and complex to monitor. However, the presence of people inputs CO_2 from breathing, with increasing concentration in the indoor air as the occupants exhaust the available air. The assessment of CO_2 concentration in the air covers the overall air quality, as the air changes required to contain the CO_2 levels guarantee a reduction of the concentration of other, more dangerous, pollutants, increasing the quality of the indoor air and thus providing a healthier environment for the occupants. Basically, a KPI calculated on the CO_2 concentration can provide a comprehensive

and straightforward way to assess and measure improvement in the building ventilation to guarantee the users' health and well-being. This approach underpins the standard ISO15251, where the indoor air quality assessment methodology provides a CO_2 KPI.
Remain the fact that the mere CO_2 could not be fully representative of particular problems that can occur in indoor environments. Other pollutants, relevant for the human health, should be investigated too. The most recognized are:

- Formaldehyde
- VOC (volatile organic components)
- PM (particulate matter)
- BTX (Benzene-Toluene-Xylene)

The possibility to monitor those pollutants should also be considered case-by-case so to face problems specific of the buildings and district under investigation. In fact, the CO_2 represents well the air renovation rate: thus, a poor CO_2 KPI will surely identify also bad conditions from the other pollutants. However, in some cases, there could be the internal emission or outdoor inlet of other pollutants, which cause health problems even if the CO2 is lower than the safety threshold.
P2ENDURE will perform the condition assessment of each demonstration case. The monitoring of the indoor air quality KPI according to ISO15251 will be applied and, where relevant and needed, enhanced with the monitoring of other pollutants, according to the demonstration requirements. For this reason, only the CO_2 monitoring and assessment methodology will be detailed in this phase.

Assessment Methodology

Air quality of a building must be evaluated in areas where people are the main pollution source by measuring the average CO_2 concentration in the building, when the building is fully occupied. This can be done either with representative samples of room air or by measuring the concentration of the exhaust air. Measurements shall be made where occupants are known to spend most of their time, preferably at head level during typical high load conditions. CO_2 measurements should preferably be made under winter conditions, as normally fresh air supply is lowest during the colder months (limited use of operable windows, partly closed facade shutters due to draught risk). In some cases, momentary measurements at 'worst case times' (e.g. end of the morning or end of the afternoon in for example an office or school), might be sufficient. In larger buildings not all rooms need to be evaluated**,** measurements in only 5 or 10% of the rooms (representatively chosen) might be enough. In mechanically ventilated buildings measurement of the amount of fresh air supply is often more practical and precise than the measurement of CO2 concentrations.
The measurement instrumentation used for evaluation of the air supply shall meet the requirements given in EN 12599.

The hourly CO_2 concentration values above outdoor are assessed against a safety threshold to identify the number of hours outside an acceptable comfort range, and the room values are aggregated through a floor-area weighted average.

Note: as the KPI aggregates the values at building level to provide an overall value, it can hide localized discomfort conditions. It is thus recommended to analyse all room values to identify critical issues.

Data requirement

Parameter	Unit
Room CO2 concentration	ppm
Outdoor CO2 concentration	ppm
Start of monitoring period	dd/mm/yy hh:mm
End of monitoring period	dd/mm/yy hh:mm
Occupied hours	h
Room useful floor area	m2
Number of rooms	-

Calculation method

1. Define the start and end times of the analysis period (yearly, heating, cooling, custom);
2. For the selected rooms in the building, calculate the hourly average CO_2 concentration $CO_{2,\,indoor,\,i}$ [ppm] from measured samples. A minimum sample time of 10 minutes is recommended;
3. For every room and hourly value, calculate the room CO_2 concentration above outdoors $CO_{2,\,above,\,i}$ as follows:

$$CO_{2,above,i} = CO_{2,indoor,i} - 360\ [ppm]$$

4. Define the CO_2 limit $CO_{2,lim}$ as follows:
   - Category I. Spaces with special requirements (sensitive and fragile persons, e.g. sick people, very young children, II elderly adults): CO2,lim = 350 ppm
   - Category II. New buildings and renovations: CO2,lim = 500 ppm
   - Category III. Existing buildings: CO2,lim = 800 ppm
   - Category IV. Acceptability for a limited part of the year: CO2,lim > 800 ppm
5. For every room in the building, calculate the number of occupied hours outside range $h_{or,i}$ as the number of hours when $CO_{2,above,i} \geq CO_{2,lim}$;
6. For every room, calculate the percentage of hours outside range POR_i [%] as follows:

$$POR_i = \frac{h_{or,i}}{h_{tot}} * 100\ [\%]$$

   Where h_{tot} = total occupied hours during the analysis period [h]
7. Calculate the average building percentage of hours outside range POR as follows:

$$\Delta T = \frac{\sum_{i=1}^{n} POR_i * S_i}{\sum_{i=1}^{n} S_i}\ [\%]$$

Where:
- n = total number of rooms investigated in the building [-]
- S_i = floor area of i-th room in the building [m^2]

Note: only consider main rooms that are occupied for several hours (e.g. bedrooms, offices, classrooms). Do not consider short-term occupancy and transit areas (e.g. bathrooms, corridors, small storage areas).

Benchmarks

According to EN 15251, an acceptable amount of deviation is 5% of occupied hours. The best performance is achieved when there are no deviations outside the design limit.
To define an assessment scale, a linear interpolation between the minimum (5%) and best performance (0%) is recommended.

Summer Comfort without Cooling System

Objective

In buildings where occupants have easy access to operable windows and can freely adapt their clothing to the thermal conditions, the thermal response differs from that of occupants of buildings with HVAC systems, and depends in part on the outdoor climate. This criterion thus allows to evaluate the thermal quality of the indoor environment and the performance of passive measures to guarantee the users' health and well-being.

Assessment Methodology

The indoor operative temperatures must be monitored and compared to the external running mean temperature, and the difference is assessed against a set limit to identify the number of days outside an acceptable comfort range. Then, the values of monitored rooms are aggregated through a floor-area weighted average.
Note: as the KPI aggregates the values at building level to provide an overall value, it can hide localized discomfort conditions. It is thus recommended to analyse all room values to identify critical issues.

Data requirement

Parameter	Unit
Operative temperature	°C
Start of monitoring period	dd/mm/yy hh:mm
End of monitoring period	dd/mm/yy hh:mm
Occupied days	d
Room useful floor area	m2
Number of rooms	-

Calculation method

1. For every room in the building, calculate the daily average of hourly operative temperatures $T_{o,i}$ [°C];
2. For every day *j* in the cooling season, calculate the running mean of the daily outdoor temperature $T_{rm,j}$ [°C] as follows:

$$T_{rm,j} = \frac{T_{ed-1} + 0{,}8T_{ed-2} + 0{,}6T_{ed-3} + 0{,}5T_{ed-4} + 0{,}4T_{ed-5} + 0{,}3T_{ed-6} + 0{,}2T_{ed-7}}{3{,}8} \ [°C]$$

Where:

- T_{ed-1} is the daily average of hourly external temperatures for the previous day (according to location weather data)
- $T_{ed-2…7}$ are the daily averages of hourly external temperatures for the 2^{nd} … 7^{th} previous days (according to location weather data)

3. For every room and every day, calculate the difference between operative and running mean temperature ΔT_i as follows:

$$\Delta T_i = T_{o,i} - 0{,}33T_{rm,j} - 18{,}8 \ [°C]$$

4. Define the comfort limit ΔT_{lim} as follows:
   - Category I. Spaces with special requirements (sensitive and fragile persons, e.g. sick people, very young children, elderly adults): $\Delta T_{lim} = \pm 2$ °C
   - Category II. New buildings and renovations: $\Delta T_{lim} = \pm 3$ °C
   - Category III. Existing buildings: $\Delta T_{lim} = \pm 4$ °C
   - Category IV. Acceptability for a limited part of the year: $\Delta T_{lim} > \pm 4$ °C
5. For every room in the building, calculate the number of occupied days outside range $d_{or,i}$ as the number of days when $|\Delta T_i| \geq |\Delta T_{lim}|$ and occupancy is above 0;
6. For every room, calculate the percentage of occupied days outside range POR_i [%] as follows:

$$POR_i = \frac{d_{or,i}}{d_{tot}} * 100 \ [\%]$$

Where: d_{tot} = total occupied days during the cooling season [h]

7. Calculate the average building percentage of occupied days outside range *POR* as follows:

$$\Delta T = \frac{\sum_{i=1}^{n} POR_i * S_i}{\sum_{i=1}^{n} S_i} \ [\%]$$

Where:

- n = total number of rooms in the building [-]
- S_i = floor area of i-th room in the building [m^2]

Note: the method is valid only when 15 °C < T_{rm} < 30 °C. Days with T_{rm} values outside this range shall be excluded from the calculation, and the user advised that the outdoor conditions for that day do not allow thermal comfort without mechanical systems.

Note: only consider main rooms that are occupied for several hours (e.g. bedrooms, offices, classrooms). Do not consider short-term occupancy and transit areas (e.g. bathrooms, corridors, small storage areas).

Benchmarks

According to EN 15251, an acceptable amount of deviation is 5% of a year. The best performance is achieved when there are no deviations outside the comfort range.

To define an assessment scale, a linear interpolation between the minimum (5%) and best performance (0%) is recommended.

Thermal Comfort in the Heating Season and Cooling Season (with Cooling System)

Objective

While optimizing the heating/cooling systems is crucial to reduce the energy consumption, the comfort of users must be considered and guaranteed for most of the operative hours of the systems. Several parameters affect user comfort, and the PMV (Predicted Mean Vote) methodology allows to consider through a single parameter both building- and system-related aspects such as the air and mean radiant temperature, the air speed and humidity, and user-related aspects such as clothing and activity types. As the predicted quality of the indoor thermal environment increases, the PMV value gets closer to 0 (neutral thermal environment).

Assessment Methodology

The hourly PMV values must be evaluated against a set limit to identify the number of occupied hours outside an acceptable comfort range, and the room values are aggregated through a floor-area weighted average.

Note: as the KPI aggregates the values at building level to provide an overall value, it can hide localized discomfort conditions. It is thus recommended to analyse all room values to identify critical issues.

Data requirement

Parameter	Unit
PMV value	-
Start of Monitoring period	dd/mm/yy hh:mm
End of Monitoring period	dd/mm/yy hh:mm
Occupied hours	h
Room useful floor area	m2
Number of rooms	-

Calculation method

1. For every room in the building, calculate the hourly PMV $PMV_{h,i}$ [-] according to the EN ISO 7730:2005 methodology;
2. Define the PMV limit PMV_{lim} as follows:
   - Category I. Spaces with special requirements (sensitive and fragile persons, e.g. sick people, very young children, elderly adults): $PMV_{lim} = \pm 0,2$
   - Category II. New buildings and renovations: $PMV_{lim} = \pm 0,5$
   - Category III. Existing buildings: $PMV_{lim} = \pm 0,7$
   - Category IV. Acceptability for a limited part of the year: $PMV_{lim} > \pm 0.7$
3. For every room in the building, calculate the number of occupied hours outside range $h_{or,i}$ as the number of hours when $|PMV_{h,i}| \geq |PMV_{lim}|$ and occupancy is above 0;
4. For every room, calculate the percentage of occupied hours outside range POR_i [%] as follows:

$$POR_i = \frac{h_{or,i}}{h_{tot}} * 100 \; [\%]$$

   Where: h_{tot} = total occupied hours during the heating season [h]
5. Calculate the average building percentage of occupied hours outside range *POR* as follows:

$$\Delta T = \frac{\sum_{i=1}^{n} POR_i * S_i}{\sum_{i=1}^{n} S_i} \; [\%]$$

Where:

- n = total number of rooms in the building [-]
- S_i = floor area of i-th room in the building [m^2]

Note: only consider main rooms that are occupied for several hours (e.g. bedrooms, offices, classrooms). Do not consider short-term occupancy and transit areas (e.g. bathrooms, corridors, small storage areas).

Benchmarks

According to EN 15251, an acceptable amount of deviation is 5% of occupied hours a year. The best performance is achieved when there are no deviations outside the PMV range.
To define an assessment scale, a linear interpolation between the minimum (5%) and best performance (0%) is recommended.

Acoustic Comfort

Objective

High levels of noise inside building have a direct effect on the comfort of inhabitants and users, with possible impacts on their well-being, productivity and health. The building envelope and plants renovation leads to an improvement of the acoustic comfort within the living environments.
Acoustic comfort is estimable through the *indoor A-weighted sound pressure level* [dB(A)]. The building performance assessment is derived from measurement of the indoor and outdoor

sound pressure levels. The EU standard for acoustic assessment of building façades is the EN ISO 16283-3 and the methodology presented in this document fulfil that standard for the measurement approach, while the benchmark methodology follows the EN ISO 15251 approach.

Assessment methodology

Acoustic comfort is assessed with the monitoring of the indoor sound pressure levels of the rooms (bordering to the façade) of the building against a set limit for every room typology (offices, bedrooms, classrooms, restaurants, etc.) in order to identify how far they are from the acceptable comfort value. In the case of large buildings with high number of rooms, the most representative for each façade should be considered.

The indoor and outdoor sound pressure levels and the reverberation time must be measured with a Sound level meter. The sound pressure level, expressed dB, is filtered through a standard frequency weighting known as A-weighting. This filter copies the frequency response of the human ear, so that the resulting sound level closely represents what people actually hear. The reverberation time should be evaluated according to the ISO 3382-2 and ISO 18233.

Data requirement

Parameter	Unit
Internal sound pressure level	dB
Outdoor sound pressure level	dB
Reverberation time	s
Start of monitoring period	dd/mm/yy hh:mm
End of monitoring period	dd/mm/yy hh:mm
Occupied hours	h
Room useful floor area	m2
Number of rooms	-

Calculation method

1. Measure the outdoor sound pressure levels at 2 meters in front of the façade [dB(A)];
2. Measure the indoor sound pressure level for every room under investigation [dB(A)];
3. Calculate the average indoor sound pressure level, weighted on the floor area of each room as follows:

$$\overline{SPL} = \frac{\sum_{i=1}^{n} SPL_i * S_i}{\sum_{i=1}^{n} S_i} \ [dB(A)]$$

Where:

- $\overline{SPL}$ = average A-weighted indoor sound pressure level [dB(A)]
- SPL_i = A-weighted indoor sound pressure level for the i-th room [dB(A)]

- n = total number of rooms under investigation in the building [-]
- S_i = floor area of i-th room in the building [m^2]

Benchmarks

The standard EN 15251 provides a set of A-weighted sound pressure levels for typical buildings categories as reported in the following table extracted from the same standard. The building performance should be evaluated considering the suggested ranges in comparison to the outdoor noise level. A comparison between day and night could even be reported, following the same measurement and calculation approach.

Monitoring and data collection

The monitoring campaign to collect data for KPIs calculation must be performed according to the following procedure/options:

Code	Type	Description	Instrument	When/Duration	Where/Who
M1	Measurement	Monitoring of all the variables required to assess the indoor climate according to ISO7726 and ISO 15251	Mobile measurement system (MMS)	During periods probably more critical: 2-3 weeks in winter and 2-3 weeks in summer. Frequency: 10-20 min (if possible max, min, average and standard deviation values for each time step).	Installation and removal days: point measurements in large part of the building and outdoor CO2 Other days: continuous measurements in one or more representative rooms.
M2	Measurement	Continuous monitoring of the variables required to assess the indoor climate	Comfort Eye (CE) or sensor network (SN)	3 months in winter (December, January, February) and 3 months in summer (June, July, August). Frequency: 10-20 min.	Continuous measurements in 2-3 representative points of the building, in 1-2 critical points of the building and in 1 outdoor point. One day for each month

					measurement of the outdoor CO2
M3	Measurement	Acoustic monitoring	Sound Level Meter	Spot measurements: one weekday and one non-working day during occupied hours. If required, measurements during night hours can be performed. Duration 5 hours during the day (peak hours) and 2 hours during the night.	Daily measurements performed by the technician in each room under investigation. Measurement of outdoor and indoor noise should be done at the same time. The season does not impact the measurement.
Q1	Interview	Indirect (paper form) interview. Simplified questions about sensations, preferences, clothing, activity, individual building control, acoustic comfort and air quality.	Questionnaire	During the days of installation and removal of MMS. 2-3 interviews for each measurement point	To the larger number of occupants: at least the 50% of total occupants, better if more than 20.

The monitoring should be performed according to the following specifications:

Variable	Accuracy		Comments
	Required	Desirable	
Air temperature (ta)	± 0.5°C	± 0.2°C	The air temperature sensor shall be effectively protected from any effects of the thermal radiation.
Mean Radiant Temperature (tr)	± 2°C	± 0.2°C	This shall be measured with globe-thermometer or view factor methodology (requires surfaces temperatures)

Absolute humidity expressed as partial pressure of water vapour	± 0.15 kPa	± 0.15 kPa	This variable can be measured also as relative humidity with required accuracy of ± 5 % and desirable accuracy of ± 3 %
Air velocity (va)	± (0.05+0.05va) m/s	± (0.02+0.07va) m/s	This variable becomes significant for values higher than 0.2 m/s. An indication of the mean value and standard deviation for a period of 3 min is also desirable
CO2	± 50 ppm	± 30 ppm	
Noise	± 1 dB	± 0.7 dB	Required accuracy can be achieved with Class 2 instruments, Desirable accuracy with Class 1 instruments.

Annex 3 - Detailed results monitoring IEQ

Baseline IEQ Ancona

The IEQ monitoring has been performed in 4 different apartments of the building, with different expositions to capture a wider spectrum of performances and investigate the worse condition. The data was collected by UNIVPM students for an investigation which was part of a master's degree thesis[5]. Only data of heating season have been collected for thermal comfort analysis, while for acoustic comfort a simulation tool has been applied. Summer data and IAQ data will be collected before the renovation intervention, to complete the analysis.

Thermal Comfort in Heating Season

Thermal comfort was monitored with a traditional microclimate station, according to standard ISO7726. The microclimate station was positioned in the most representative room of each apartment and data acquired for 2 weeks in winter period (February). The worse condition, among the different apartments, has been taken into consideration for detailed analysis, while the KPI was calculated with weighting factor according to the methodology presented in Appendix II. During the survey, visible problems due to high moisture presence were found (molds, condensing windows and floor), as reported in the following picture.

Figure 1 Mould reported during the survey

The Predictive model of ISO7730 was applied to calculate the comfort index with a clothing insulation of 0.9 clo and metabolic rate equal to 1.2 met. An **average PMV of -0.8** was registered with a standard deviation of 0.3 that can be translated in a general cold sensation, dangerously near to the limit of the acceptability range ±1. The analysis on comfort zones with variability analysis was performed on the measured data confirming the initial assessment of the survey. Results are presented in Figure 3.

[5] Elisa Ribilotta: Studio Analitico - Sperimentale E Riqualificazione Tecnologica Di Un Edificio Multipiano Di Ediliza Popolare: Approfondimento Di Soluzioni Dinamiche In Fase Estiva – DICEA, UNIVPM, 2013

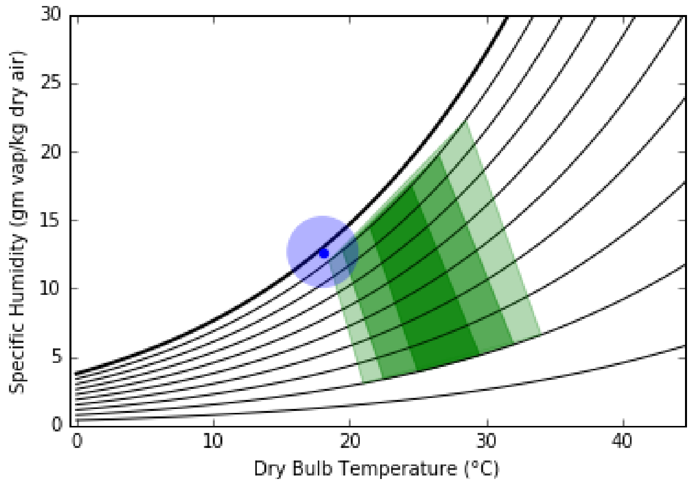


Figure 3: Positioning of the building performance in the comfort zones chart

The average condition (dark blue dot) is located on the upper side of the comfort zones in the psychrometric chart that represents a content of water vapour in the air near to the saturation (relative humidity near to 100%). This aspect in conjunction with the low average air temperature (lower than 18°C) registered, can explain the diffuse mould found in the apartment. The calculation of the percentage of time of building operation within the different Categories is presented in **Error! Reference source not**

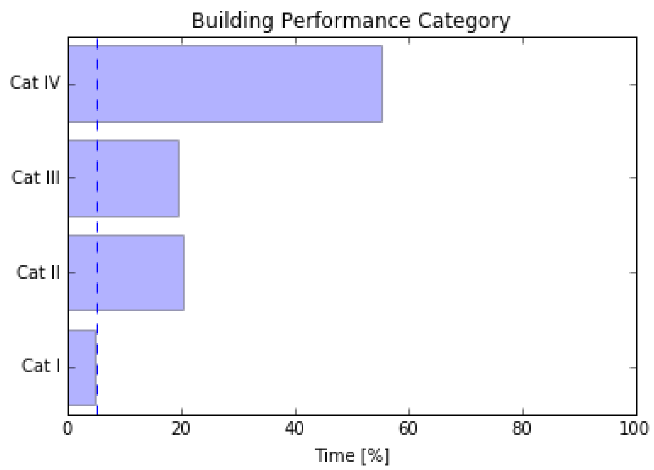


Figure 2: Percentage of operating hours under each building Category according to EN15251 calculated in the demo case of Ancona

ound. 4.

For about 55% of the time, the building operated a Category IV, which indicates a very poor condition, acceptable for a limited time. The KPI calculated as weighted average of the entire monitored apartment turned out to be equal to 0, as expected. The baseline evaluation suggests the need of urgent intervention to improve IEQ building performance.

Acoustic Comfort

The analysis of acoustic comfort was performed by using a simulation tool, which allows the assessment of acoustic quality of the building in current state and after potential renovation scenarios. In particular, the internal acoustic comfort is evaluated through the estimation of the indoor sound pressure level of each room of the building, which is obtained from the measured or predicted sound pressure level in front of each façade and the calculated value of the façade sound level difference, according to the standard EN ISO 12354-3. The final value of the KPI is calculated on the base of single rooms' analyses, which lead to an overall assessment of the acoustic comfort of the building.

The building under analysis is located in an urban area and it is directly exposed to a private road, leading to garages and apartments, but also very closed to a congested road. It is constructed with concrete structure, without insulation layer on external walls, and single glazed window with a float glass of 3 mm thickness and aluminium frame. Data for the acoustic simulation tool were extracted from the BIM model of the demo case. The calculation turned out to provide an **acoustic KPI of 40%** - a value not satisfactory for occupants' well-being and that needs to be addressed by the renovation design.

Baseline IEQ Genova

Thermal Comfort in Heating Season

The thermal comfort in the "Nemo" nursery of Genova has been measured with traditional microclimate station, compliant with ISO7730 and ISO7726, located in two different rooms for one winter month.

Figure 4: Microclimate Station located in the Nemo Nursery - Genova

The detailed analysis of comfort conditions according to ISO7730 is reported in Figure 6.

The Predictive model of ISO7730 was applied to calculate the comfort index with a clothing insulation of 0.9 clo and metabolic rate equal to 1.2 met. The monitoring campaign registered an **average PMV of 0.3** with a standard deviation of ±0.2. The overall thermal sensation is within the optimal comfort range, slightly unbalanced toward warm sensation. In this case there is a condition of bearable overheating that given the low envelope performance, could led to high thermal energy consumption. The calculation of the percentage of time of building operation within the different Categories is presented in Figure 5. For about 23% of the time, the building operated a Category III, which indicates a poor condition. The KPI calculated as weighted average of all the monitored rooms turned out to be equal to 0% for Category II and 100% for Category III. The renovation should target the fulfilment of Category II.

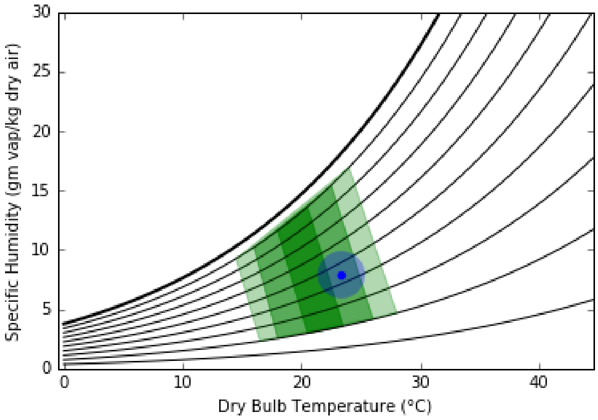


Figure 6: Positioning of the building performance in the comfort zones chart

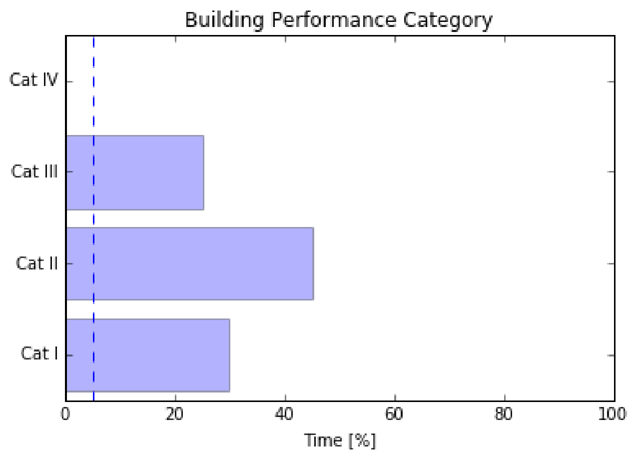


Figure 5: Percentage of operating hours under each building Category according to EN15251 calculated in the demo case of Geneva

Thermal Comfort in Summer Season without Cooling

A survey to investigate children thermal sensation has been specifically created. Given the age of the interviewed persons (from 3 to 5 years old), traditional questionnaires could not be used. Thus, a graphical questionnaire, based on previous research in this field, was prepared together with the teachers. The questions asked to children were related to their feeling (hot/neutral/cold), sensation (happy/sad), thermal preference (colder/neutral/warmer), weather (sunny/cloudy/rainy) and clothing. Each question was asked with a set of images, drawn in function of how children could associate the reply with a representative image (Figure 7)

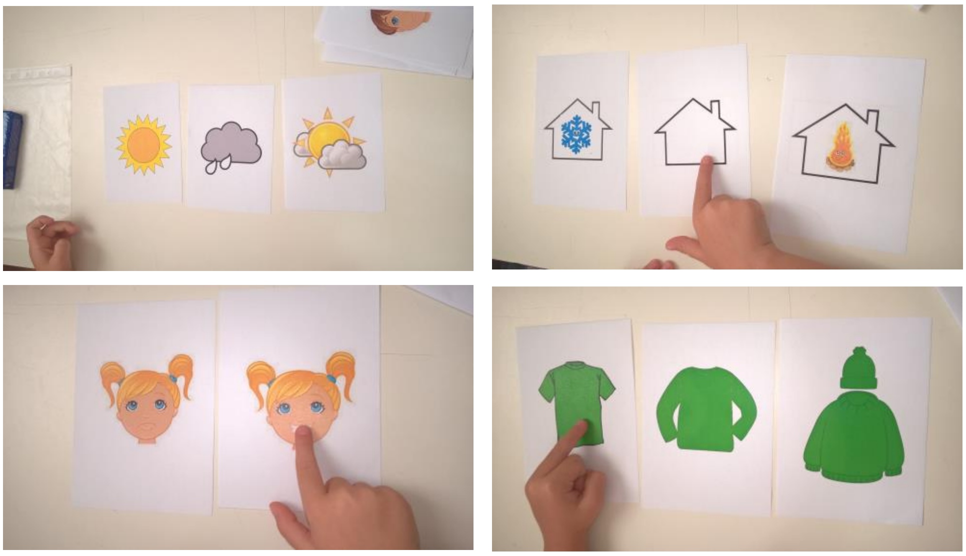


Figure 7: Graphical questions for children interview done in Genova demo case

A total of 127 interviews were conducted during the last month of school activity (June 2017) and analysis of results is reported below.

Q2:how do you think is the classroom today			Q3:When the classroom is (Q2 answ.) how do you feel?		At this moment, would you like to feel..		
hot	not hot neither cold	Cold	sad	happy	warmer	no change	cooler
87	38	3	57	70	20	50	58
69%	30%	2%	45%	55%	16%	39%	46%

From the interviews it is clear that the warm sensation is prevalent, with 69% of replies to the question “How do you think is the classroom today?”. This is also confirmed by the higher percentage of children preferring a cooler feeling. At the same time, the teachers were interviewed about the thermal environment, using traditional questionnaire (thermal sensation, thermal preference and acceptability). The results from adults’ survey revealed a lower acceptability of the thermal

environment. In fact, almost the 100% of the 22 questionnaires reported a very hot sensation, preference of cooler environment and difficulty to accept the thermal environment.
This result demonstrates a higher resilience of children given by a higher adaptation capability. In any case, the survey conducted reveals the necessity of renovation intervention to mitigate the impact of summer condition on the indoor environment.
At the same time the environmental data were acquired to assess thermal comfort using adaptive model for naturally ventilated buildings, according to EN15251 standard. Measured data turned out to provide averaged operating conditions in the Category III comfort zone, with a variability that brought the building also outside that category (see Figure 8).

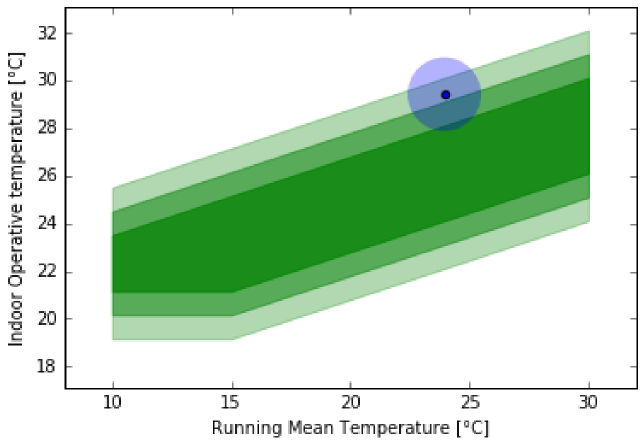


Figure 8: Positioning of the building operation within comfort zones for summer period

Also, in this case, the percentage of the operating hours inside each Category was evaluated as reported in Figure 9. The building operated for about the 50% of the time as Category IV.

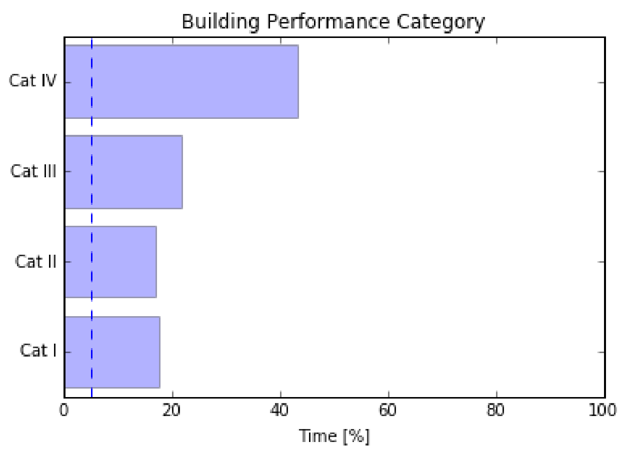


Figure 9: Percentage of operating hours under each building Category according to EN15251 calculated in the demo case of Genova for summer season

Measured data confirmed results obtained with the survey.

Indoor Air Quality

The indoor air quality has been measured and assessed according to the P2ENDURE protocol. One month of CO_2 measurements have been done in both seasons (winter and summer) inside the nursery and spot measurements outside to determine the average external CO_2 level that turned out to be 410 ppm. The data of occupied hours were processed to calculate the KPI.

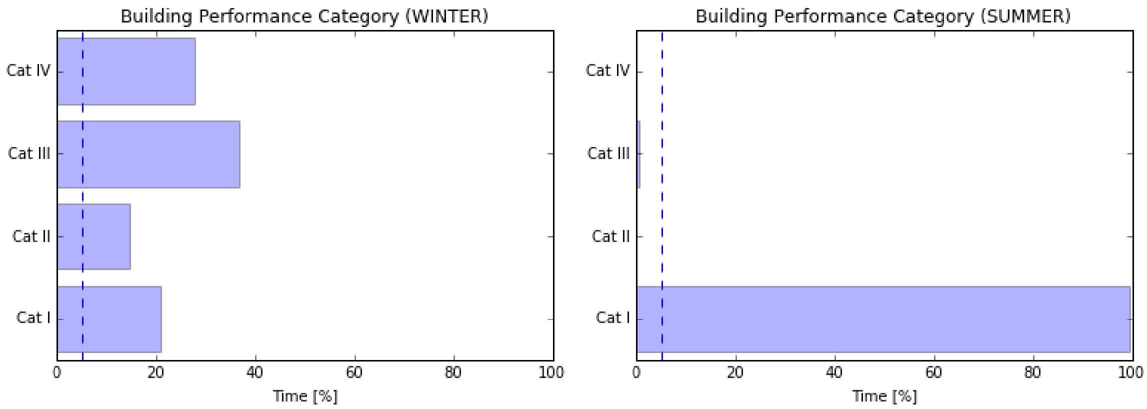


Figure 10: IAQ - Percentage of operating hours under each building Category according to EN15251 calculated in the demo case of Genova for winter and summer season

The results presented in Figure 10a very different behaviour of the building during the two seasons, usual for naturally ventilated buildings. In fact, during winter the windows are mostly kept closed to ensure thermal comfort and the indoor air quality is poor, the nursery operated mostly as Category III and IV. While in summer, the windows were opened and the building presented a very high performance. This result suggests the installation of a mechanical ventilation system with heat recovery to improve the indoor air quality in winter season.

Baseline IEQ Warsaw

The Comfort Eye system was applied to Warsaw for testing the first prototype of the engineered version. The installation was performed in March 2018 for a total IEQ monitoring of 2 days.

Figure 11: Comfort Eye installed in one room of the nursery in Warsaw

The monitoring campaign provided an initial assessment of thermal comfort, IAQ and envelope thermal mapping in winter season.

Figure 12 shows the PMV measured in the room during the test, which turned out to provide an average value of -0.15. The comfort is maintained within the acceptable range, providing a KPI of 100% with the fulfilment of Category II criteria.

The CO2 was measured during the two days of testing, but the room was occupied only during the first day.

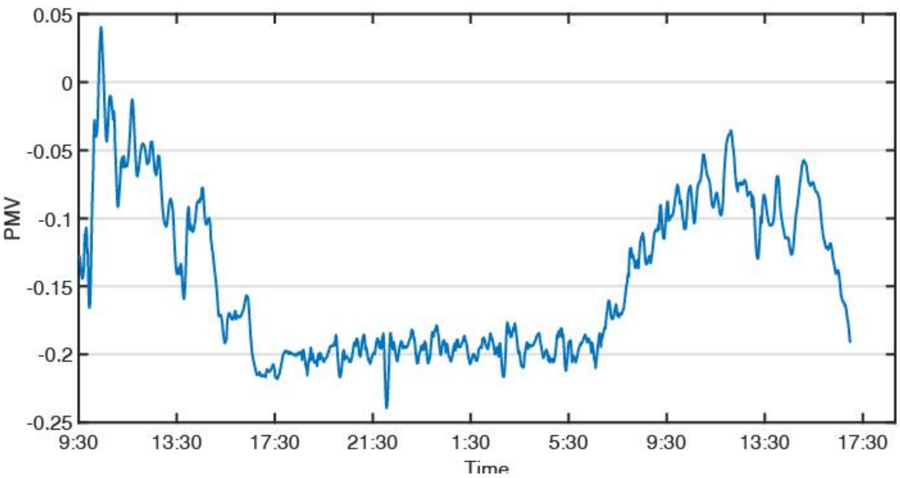


Figure 12: PMV measured during the two days

Figure 13 shows the CO2 trend during the occupied and non-occupied period of the first day. The reference limits for IAQ classification are also provided in the figure. The monitoring turned out to provide a poor level of IAQ during the occupied hours with CO2 concentrations always within the Category III, leading to a KPI equal to 0%. The improvement of ventilation is highly suggested for the renovation design.

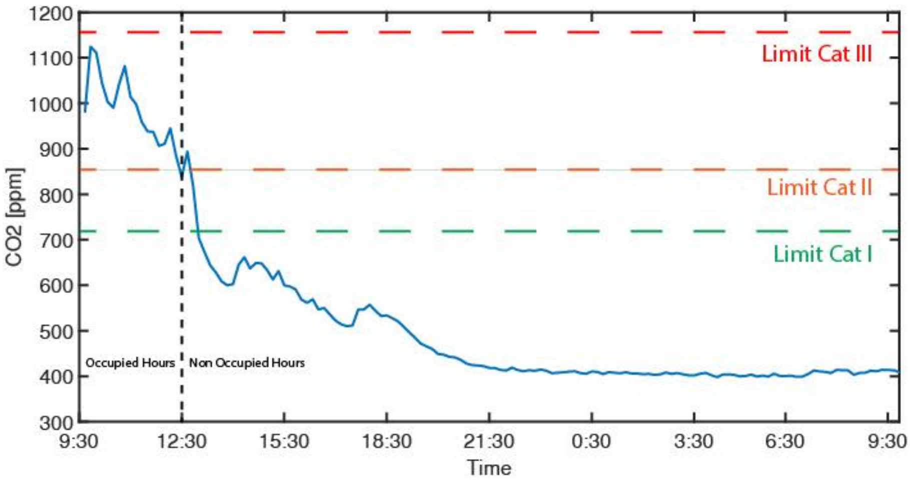


Figure 13: CO2 measurement during the first day

The Comfort Eye thermal mapping feature has been tested in Warsaw. The IR scanning system was used to measure the temperature of indoor walls and to reproduce low-resolution thermal images of the wall exposed to outdoor environment. This is an important feature to investigate the building envelope performance.

Figure 14 shows an example of thermal map where the main elements composing the outer wall of the room. The window area is distinguished by a lower temperature (average of 10°C) with respect to the other parts. In any case the opaque element of the wall registered an average temperature of about 16°C, providing a strong deviation from the average room air temperature (22.8°C). This deviation, together with the low window temperature, had an impact in terms of radiant temperature. In fact, a mean radiant temperature of 17.8°C was measured near the wall (50cm of distance, not in front of the radiator). This initial investigation suggests a non-efficient building performance since, although thermal comfort is kept within requirements, the air temperature is kept high to balance the cooling effect of the building envelope. An improved insulation of both windows and walls could reduce this effect to permit a lower air temperature without reducing thermal comfort, but also improving the building energy efficiency.

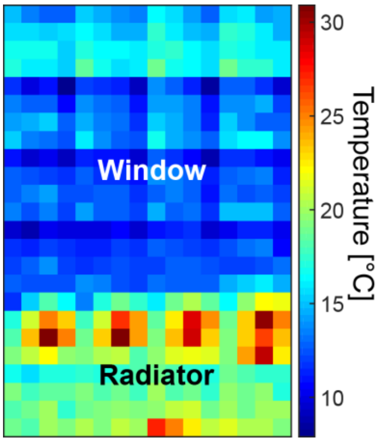


Figure 14: Low-resolution thermal image of the wall exposed to external environment