BIM models of existing buildings based on 3D scanning

Deliverable Report D4.3

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P2ENDURE
Plug-and-Play product and process innovation for Energy-efficient building deep renovation

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Colophon

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Publishable executive summary

Building Information Model represents one of the more powerful instruments for the optimisation, design and management of projects and processes, facilitating the sharing of information between different actors involved; and P2ENDURE research analyses, specifically, the integration of BIM with 3D laser and thermal scanning

In fact, the possibility of having assistance from this representation process meaningfully increases the potential of analyses of P2ENDURE tools, leading to results that are both scientifically accurate and practically usable by a wide parterre of actors (designers, stake holders, customers, etc.).

This acknowledgment is very clear in the same objectives of Work Package (WP) 4: the Description of Action (DoA) clearly states three important achievements that are expected from P2ENDURE research thanks to BIM:

i) the possibility of realising and measuring the success of the pilot deep renovation cases (BIM models are indispensable),
ii) a facilitation in the cross-learning between different projects and geo-clusters (BIM libraries and data are very helpful in facilitating comparison between different case studies, easing the identification of the key processes and parameters independently from the location), and finally
iii) the certainty of allowing a broad replication potential at EU level of the Project findings.

Hence it is absolutely clear that BIM models are indispensable in the development of the research, it is not by chance that Deliverables of WP4 investigating BIM are central in the same development of the P2ENDURE projects, receiving input from the other Work Packages and continuously yielding output back to them in a sort of iterative process.

This is very clear if we consider the link between BIM-BEM: the modelling in a BIM environment of the case studies requires data from topics previously investigated in other Work Packages (mainly WP1, 2, 3).

This Deliverable provides a description of the typical activities that have been developed by partners and stakeholders to get the BIM models, and the information that needed to be collected: starting from drawings of the building, manual of the MEP, plants, energy networks, architectonical elements, further investigated thanks to survey using photogrammetry, 3D geomatics, and 3D thermal scanning: on Site and off Site investigations have been carries out for all the case studies to collect the data that were necessary for a detailed definition of BIM models.

Chapter 2 –*Methodology* – in particular, illustrates the *technologies* adopted in the preparation of BIM models with an overview of 3D scanning and BIM model procedures and their interoperability; bottleneck encountered, and lesson learnt are described.
Deliverable D4.3 hence, is probably the basic step of the whole WP 4, at least in its modelling section.
Title itself is very clear:
"*BIM models of existing buildings based on 3D scanning*"
The DoA for D4.3 topic, in fact, says: "*Pre-renovation BIM models constructed based on drawings, photogrammetry, 3D geomatics, and 3D thermal scanning depending on needs, practicality and availability*.
According to this requirement, Architectural elements, MEP, other information, e.g. on the usage pattern of the examined facilities, have been surveyed, classified and rearranged in the libraries constituting the backbone of BIM.
D2.2 of WP2 findings suggested detailed process guidelines that have been followed during these activities, finally giving the "integrated BIM platform" useful for storing and providing all required information throughout the entire 4M process.
Unfortunately, some problems have arisen: losses of data and libraries often occurred during the bridging between BIM and BEM. However, this problem has been overcome thanks to the input of WP2 as well (characterization). These problems were somehow predictable since the degree of freedom left in the choice of the software for the energy calculation tools. In any case for all the three selected different approach in the BIM to BEM, used in the research and presented in D3.1, any specific issue of data losses has been considered and solved in this Deliverable, once again demonstrating how tight the links are between specifically D3.1 and D4.3.

Chapter 3 – Demonstration cases– reports for all the case studies the activities that have been put in force to prepare and implement the BIM of the pre-renovation status.
In particular, the chapter describes:

i) the steps adopted in the BIM preparation;
ii) the available input data (drawings, geomatics, 3D surveys, etc.)
iii) the accuracy achieved in the BIM models (completeness of the data sets and of the libraries).

The validated BIM models of all the demonstration cases can be found on the SharePoint, together with all the documentation collected during the on-site and off-site investigations, especially the ones related to the laser scanning surveys, where they have been implemented.

Chapter 4 –*Best practice* and conclusions– presents the remarkable progress achieved regarding the interoperability and the data exchange between 3D scanning and BIM model.

List of acronyms and abbreviations

DoA:	Description of Action
BIM:	Building Information Model
EC:	Exploitation Coordinator
GA:	General Assembly
HVAC:	Heating Ventilation Air Conditioning
IEQ:	Indoor Environment Quality
IPR:	Intellectual Property Right
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-size Enterprise
TC:	Technical Coordinator
TCP:	Technology Commercialisation Platform
ToC:	Table of Content
WP:	Work Package

Contents

1. Introduction

WP4 has a pivotal role in the P2ENDURE project, this is due to many aspects that are approached and practically overcame within it.

Focus of this Work Package are 10 demonstration cases located in different geo-clusters across Europe, representing distinctive typologies, functions and characteristic that will practically test the new approach of PnP prefab innovations both on the products technology and on the process innovation.

Each project addresses one or more challenges of deep renovation that should be solved using PnP prefabricated systems. The outcomes of these demonstration cases will be analysed and used in other WPs to improve the products and the processes innovation and to increase the replicability and scalability of the identified solutions.

The expected results of this WP are:

- to realize and measure the results of the pilot deep renovation cases: the success of the renovation processes has a key role toward the project, it is then fundamental to prove the achievement of the fixed goals and, if not possible, to use this experience for further analysis and projects;
- to facilitate cross-learning between different projects and geo-clusters: the exchange of experience and knowledge with other projects and geo-clusters allows the project to overcome barriers and to focus on the research activity, optimizing the time available for the project;
- to secure the broad replication potential at EU level: the considered demonstration cases represent a wide range of buildings and functions across Europe; this will stimulate the deep renovation interventions increasing the replicability of the project far beyond the demonstration cases considered.

In order to reach the fixed objectives, D4.3 will create BIM model of the demonstration buildings using available information, for instance cad/paper drawing and site inspection, and advanced technologies: 3D thermal and laser scanning and photogrammetry.

These models will be used for different activities: detailed design of deep renovation interventions, definition of BIM models of PnP components for the e-marketplace and governance and optimization of the process from the design to the factories and the end-user.

The first section presents an overview of available methodology in the definition of BIM models with a focus on 3D scanning and its interoperability with BIM software, focusing of bottlenecks encountered and overcame. In this chapter the strong connections of D4.3 with other deliverables within P2ENDURE, in particular with D1.5 'Techniques, protocols and application for 3Dscanning' and D2.2 'BIM parametric modeller', will be underlined.

Core of this deliverable are the demonstration cases: it will be provided a description of the information used in the definition of the pre-renovation scenario, the BIM procedure adopted with direct link to the BIM model on the P2ENDURE Share Point; for each demonstration cases are defined bottlenecks and difficulties encountered.

Every demonstration case has peculiar features: for each of them an accurate preliminary activity has been done for the analysis and collection of the available material and, when necessary and feasible, specific on-site investigations have been conducted; the collected material has been elaborated for the creation of the BIM model.
The responsible partner for each demonstration case had the opportunity to select the most suitable procedure for the creation of the BIM model and a detailed description of the chosen methodology has been reported; the choice not to impose the use of specific software had the double benefit of letting the partners to use software and methodologies they were already confident with and to multiply the effect of the project presenting different solution to the many bottleneck encountered.

Finally, even though it is a specific task of Work Package 3, Deliverable 3.1, and hence it will not be discussed in this deliverable, it is important to underline that a validation process has been carried out for any demonstration cases to be sure that the created BIM model was coherent with its real energy behaviour.
This was necessary since the specific request of the DoA, to achieve reliable "pre-renovation" BIM model
WP3 findings, in fact, have provided a lot of information about plants, energy networks, architectonical elements, *etc*. that have been organized and implemented into the WP 4 BIM models. These BIM models are given back to WP3 in order to run energy analyses in the pre-renovation scenarios. If the findings of these analyses are then compared to the official recording of the historical energy consumptions from bills, etc., allowing an immediate check on the reliability of the BIM model as a representation of the real case study. If the findings of the simulations well match with the real energy requirements, then the model is validated and can be used in the further steps of the research. On the contrary, if the validation fails, D3.1 of WP 3 returns the model to D 4.3 of WP 4 for a further implementation of the BIMs in a iterative procedure that ends only at the full validation of the case studies BIM model.
This "ping-pong" implementation, cited as an example, represents the brightest demonstration of how important are BIM models in P2ENDURE: from the DoA in the expected findings of WP 4: "*The results and analyses of the demonstrators will be used as feedback for the work packages 1, 2, 3 and 5 to adjust and fine-tune the product and process innovation and the supporting tools, services and business models*.".

2. Methodology

2.1 3D scanning

Traditional survey techniques are normally used by professionals and technicians when performing buildings' plants survey; this on-site activity has a significant role in the subsequent design phases as a detailed analysis of state-of-the-art conditions may help the detection of critical issues from the preliminary phase of the project, containing time and costs.

3D scanner is, among the used survey techniques, the most advanced form of measurement of spatial object due to its efficiency and time saving comparing with other traditional survey (total station or portable distance meters).

Principle of working of the laser scanner is based on the deviation of the laser beam, which is the scanning mechanism with integrated measuring system.

Previous investigation made in D 1.5 (please see Chapter 2.2) yield that the conditions needed for the proper execution of the scan are:

- Lack of vibrations
- Lack of dust
- No rainfall
- Temperature 0-40 ˚C
- No moving objects and ordered the scan area
- Access to the scanned areas: the lack of guards, floor boards or scaffolding

The results of the scan, independently from the different type of scanners available, are a point cloud.

The point cloud can be used as reference to model object's geometry with specific software based on the scope of the survey: for P2ENDURE purposes BIM software as Revit and ArchiCAD are used.

2.2 Definition of BIM model – implemented procedure

BIM process offers the possibilities to generate an accurate model of a building (or other built constructions) with the aim of simplifying the exchange of information between all actors involved and to facilitate the processes of decision-making regarding design, construction and maintenance. Due to its key role, it is fundamental that the BIM model includes all the input for the mentioned activities.

With reference to P2ENDURE demonstration cases, where BIM models are used to assess the savings in terms of energy demand and time of intervention, specific input related to geometry, material properties, building systems, site conditions and operating information are required to run the planned simulations. In Figure 1, for instance, are listed the information needed to proceed with the energy analyses.

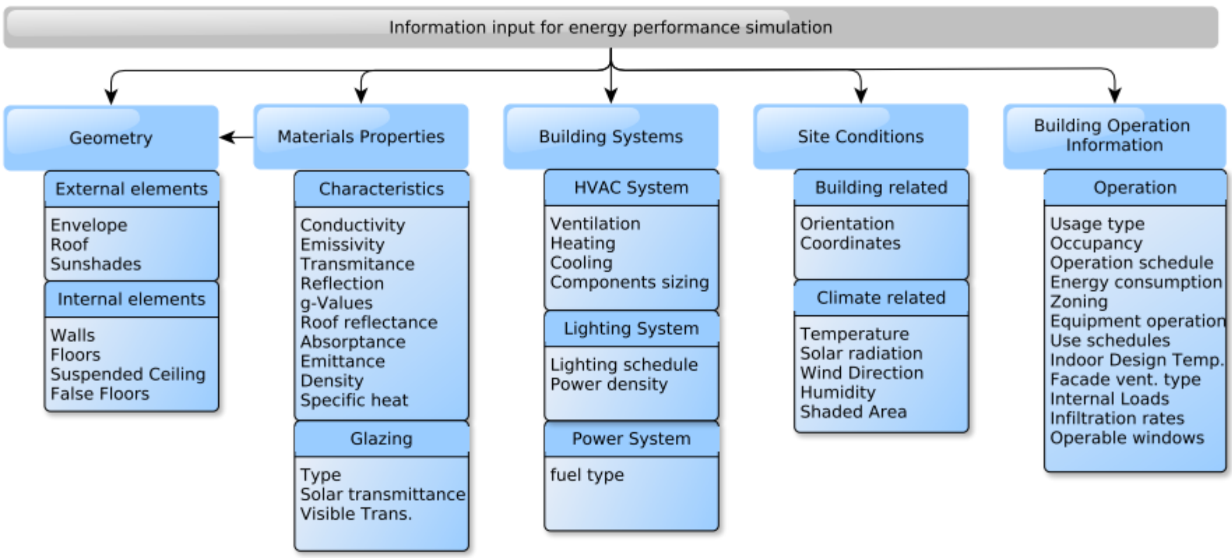


Figure 1: Data to be collected in the BIM model, to run the energy analyses

In order to prove, and verify, the technical integrity of the BIM models and their quality and accuracy, some KPIs have been identified:

KPIs	**Notes**
File size	Considering variables as size of building, number of levels, complexity of design.
Number of objects	Generic and specific objects.
Hours spent modelling	From 2D drawings to complete BIM model.
Point cloud file size	Size of 3D scanning point cloud, if available.
Number of families/objects modelled	Proving the accuracy of the model.

Below there are the most relevant values for the considered demonstration cases:

Menden

KPIs	
File size Number of objects Hours spent modelling Point cloud file size	18.331 MB 534 86
Number of families/objects modelled	WALLS: 161 PILLARS: 8 WINDOWS: 123 DOORS: 31 STAIRS: 3 FLOORS: 31 ROOFS: 26 DOWNSTAND BEAMS: 5

Ancona

KPIs	
File size Number of objects Hours spent modelling Point cloud file size	51.24 MB 5510 450 No laser scanner used
Number of families/objects modelled	WALLS: 12 (4 internal and 8 external) * FLOORS: 4 * STAIRS: 1 * DOORS FAMILIES: 5 (4 internal and 1 external: garage door) WINDOWS FAMILIES: 4 LIGHTING FAMILIES: 7 (5 internal and 2 external) HEATING FAMILIES: 5 (4 radiators and 1 furnace) COOLING FAMILIES: 1 (air conditioning). Tot. libraries: 17 Tot. families: 22

* system families with implementation of parameters about: building physics information and 3D geometry.

Florence

KPIs	
File size	9.91 MB
Number of objects	216
Hours spent modelling	11
Point cloud file size	No laser scanner used
Number of families/objects modelled	3

Genoa

KPIs	
File size	38.36 MB
Number of objects	251
Hours spent modelling	120 h*
Point cloud file size	No laser scanner used
Number of families/objects modelled	17

* The hours refer to the modelling of the BIM model in Revit. All the activities related to the definition of the methodology to simplify and optimize the model for energy simulation are excluded (Compatibility test with other programs, analysis of information loss, etc.)

Gdynia

KPIs	
File size	23.80 Mb
Number of objects	839
Hours spent modelling	1440 h*
Point cloud file size	16 Gb
Number of families/objects modelled	FLOORS: 17 WALLS: 14 ROOF:3 WINDOWS: 3 DOORS: 6 STAIRS: 2 CONSTRUCTION FAMILIES: 8 STRUCTURAL COLUMNS: 3 STRUCTURAL FUNDATIONS: 1

* The hours refer to the modelling of the BIM model in Revit (840 hours) and in SketchUp (600 hours).

Warsaw

KPIs	No laser scanner used
File size	46.30 MB: - 20.30 MB architecture - 15 MB electrical - 11 MB sanitary
Number of objects	16640: - 14179 general construction - 314 electrical - 2147 sanitary
Hours spent modelling	386 h*: - 202 h architecture - 88 h electrical - 96 h sanitary
Point cloud file size	9.16 GB
Number of families/objects modelled	133: - 91 general construction - 8 electrical - 34 sanitary

* this include cleaning point clouds, visits in the demonstration building, drawing, coordination and parameterisation

Tilburg

KPIs	
File size	28 MB building 27 MB demo case
Number of objects	889 building 178 demo case
Hours spent modelling	50 building 40 demo case
Point cloud file size	No laser scanner used
Number of families/objects modelled	FLOORS: 3 (building) 5 (demo case) WALLS: 12 (building) 7 (demo case) ROOF:2 (building) 5 (demo case) WINDOWS: 36 (building) 10 (demo case) DOORS (INTERIOR): 5 (building) 1 (demo case) EXTRAS: 10 (building) 5 (demo case)

* this include cleaning point clouds, visits in the demonstration building, drawing, coordination and parameterisation

2.3 Interoperability 3D-BIM

One of the main issues of this deliverable is, undoubtedly, related to the benefits associated to the possibility of having a 3D laser scanner survey to support the implementation of the BIM model. Many BIM of the demonstration cases, that can be found on the SharePoint, have been created thanks to the 3D laser scanning help, giving a clear picture of the potential of this interoperability (please refer to the SharePoint section for further information).

Converting scan data into BIM models is traditionally a three steps process:

1. multiple scans are captured from Different scanning stations;
2. data from multiple scanning station is stitched together in what is commonly known as the post processing or registration state;
3. BIM software, like Revit and ArchiCAD are used to author object models while referencing the point cloud.

3D laser scanning combined with BIM modelling is suitable for both new buildings and retrofit projects:

- it provides a detailed *point cloud* very quickly and efficiently,
- it produces a high-quality 3D description of plant installations or complex systems of buildings,
- it is used for buildings and buildings sites,
- it improves the creation of BIM model compressing the design process and increasing its accuracy,
- it facilitates the coordination between different actors and stakeholders involved in the process.

In conclusion, the benefits coming from the usage of 3D laser scanning technology in the implementation of the BIM are indisputable. 3D laser scanning always helps in the definition of the very reliable models that are needed to test the energy and time saving requested by P2ENDURE targets.

In the SharePoint there is an extensive presentation of this valuable interoperability. More comments on the lesson learnt and the bottle necks that, unfortunately, sometimes can be experienced can be found in Chapter 4.

3. Demonstration cases

As mentioned in the Introduction, BIM models have been defined after a very deep analysis of the existing buildings, collecting all the available material on them, their consistency (architectural, morphological, technological, *etc.*).

When necessary, these databases have been further implemented thanks to on-site investigations that have been run in order to achieve the highest precision in the buildings description.

In particular, P2ENDURE BIM models are based on the following materials:

OFF-SITE INFORMATION:

- geometric data: 2D paper drawings, 2D digital drawings, 3D digital drawings based on availability;

ON-SITE INFORMATION:

- site inspections and surveys based on photogrammetry, 3D scanning and thermal scanning when needed.

The collection of this information is achieved thanks to offsite and on-site activities aiming to provide a full acknowledgement of:

i) every component of the building (its location, its morphology, its transmittance values and geometrical features, *etc.*),

ii) the existing energy-consuming systems (HVAC, lighting and any other significant device), and

iii) it's the building usage in the terms of it affects the energy demand (*e.g.* operating temperature of air conditioning, when installed, its time pattern, typology of the activities that take place into the indoor spaces, *etc.*)

In the next pages an overview of each demonstration case is illustrated, giving a summary of which preliminary information have been collected and used, of the main input considered for the creation of digital model, finally providing a full description of every BIM, that can be fully explored by connecting to the SharePoint.

3.1 Overview

PRE RENOVATION SCENARIO																				
Country, Partner, Demo case			**Geometric data and modelling**								**Energy and Indoor enviromental data**									**LINK to BIM MODEL on P2ENDURE PORTAL**
			Available information						BIM		transmittance		indoor usage		systems					
			Drawings	Photogrammetry	3D geomatics	3D thermal scanning	stratigraphy	site inspection	completed	validated	envelope	interior	indoor operating temperature	time pattern	HVAC	lighting	power	other	
DE	3L	Menden	Y	N	N	N	N	Y	Y	N	Y	Y	Y	Y	Y	Y	N	-	LINK
DK	INV	Korsløkke	Y	N	N	N	N	Y	Y	Y	N	N	Y	N	N	Y	Y	-	LINK
IT	UNIVPM	Ancona	Y	Y	N	N	Y	Y	Y	N	Y	Y	Y	Y	Y	Y	N	-	LINK
IT	SGR	Florence	Y	N	N	N	N	Y	Y	Y	Y	N	Y	N	N	N	N	-	LINK
IT	RINA	Genoa	Y	N	N	N	Y	N	Y	Y	Y	Y	Y	Y	Y	Y	Y	-	LINK
NL	HIA	Breda																	
NL	CAM	Enschede																	LINK
NL	PAN	Tilburg	Y	Y	N	Y	N	Y	Y	N	Y	Y	Y	Y	Y	N	N	-	LINK
PL	FAS	Gydnia	Y	Y	Y	N	Y	Y	Y	N	Y	Y	Y	Y	Y	Y	N	-	LINK
PL	WAW	Nursery																	LINK

3.2 Denmark, Korsløkken

The building is a typical Danish 2-floor residential building from the 1970's. The construction is brick facade and 20- degree roof made of cembrit wave. The gables have wood frame extra exterior construction only for isolation purpose, closed with plates of cembrit material. This extra gable construction was done 20 years later.

The building is located at one of the biggest residential housing areas in Odense city. The overall total renovation of all these buildings amounts to 1,6 billion DKK. Odense is located on the island Fyn in the middle of Denmark. The inhabitants are typical middle and lower class.

3.2.1 Preliminary information

AVAILABLE INFORMATION - TECHNOLOGIES				
TYPOLOGY		**AVAILABILITY**	**NEED**	**USE**
OFF-SITE	Geometric data (drawings)	Y	Y	Y
ON-SITE	Photogrammetry	N	N	N
	3D geomatics	N	N	N
	3D thermal scanning	N	N	N
	Stratigraphy	N	N	N
	Site inspection	Y	Y	Y

COMPONENTS CHARACTERISTIC			
COMPONENT	**TRANSMITTANCE [W/m2K]**	**THICKNESS/AREA**	**LOCATION**
ENVELOPE			
VERTICAL ELEMENTS			
external opaque elements			
Gable North	0.4	68.4 m2	N
Gable South	0.4	68.4 m2	S
Ceiling	0.45	687 m2	
external transparent elements			
Windows incl. Frame	2.9	120 m2	
Balcony door	2.9	77 m2	
Entrance door	2.9	21 m2	

INDOOR USAGE	
OPERATING TEMPERATURE [°C]	
heating	21°C central heating
cooling	Not present
TIME PATTERN	Fulltime
SYSTEMS	
COMPONENT	**DESCRIPTION/DISTRIBUTION**
HVAC	
ventilation	Individual mechanical in kitchen and bath
heating	Central district heating
cooling	
LIGHTING	Not available
POWER	Not available

3.2.2 Description of BIM procedure

Creation of BIM model for this demonstration case was done by a third party hired by the building owner/ client for that purpose only. Due to privacy constraints it is not possible to share this information within P2ENDURE project.

3.3 Germany, Menden

This live demonstration project is replacing the former "Soest case" as the owner community unfortunately decided to not refurbish the multi-family blocks and the perspective to demonstrate the use of any of the P2ENDURE products was completely lost. The "new" project is located in Menden, Mid-West Germany approx 110 km distance to Cologne and 30 km from Dortmund in a street called Horlecke 46. This demonstration project is an office building with just one storey (+ cellar facilities). The year of erection is not known but following the typology of the building it might have been built before the Second World War in the last century. The new German live demonstration project is part of a large former industrial and storehouse site. The overall size of the site is 5.400 m^2 and the approx. Floor space is 155 m^2. There are no original plans available, so the complete building had to be scanned to deduce 2D and 3D drawings from this action. The energetic standard is very poor compared to new buildings. There are windows with single glazing and exterior walls are not insulated thermally nor are the (flat) roof.

3.3.1 Preliminary information

AVAILABLE INFORMATION - TECHNOLOGIES				
TYPOLOGY		AVAILABILITY	NEED	USE
OFF-SITE	Geometric data (drawings):			
	2D paper	Y	Y	N
	2D digital	Y	Y	Y
	3D digital	Y	Y	Y
ON-SITE	Photogrammetry	N	N	N
	3D geomatics	N	N	N
	3D thermal scanning	N	N	N
	Stratigraphy	N	N	N
	Site inspection	Y	Y	Y

COMPONENTS CHARACTERISTIC			
COMPONENT	TRANSMITTANCE [W/m2K]	THICKNESS [cm]	LOCATION
ENVELOPE			
VERTICAL ELEMENTS			
external opaque elements	2,198	27,5	external walls
external transparent elements	5,706	0,4	external walls
HORIZONTAL ELEMENTS			
external opaque elements	1,501	22	Flat roof
INTERIOR			
VERTICAL ELEMENTS			
Heated/Heated	Not relevant	Not relevant	Not relevant
Heated/Not Heated	Not relevant	Not relevant	Not relevant
HORIZONTAL ELEMENTS			
Heated/Heated	Not relevant	Not relevant	Not relevant
Not Heated/Heated	2,163	27	Basement ceiling
Heated/Not Heated	Not relevant	Not relevant	Not relevant
Not Heated/Not Heated	Not relevant	Not relevant	Not relevant

INDOOR USAGE			
OPERATING TEMPERATURE [°C]			
heating	21°C		
cooling	Not present		
TIME PATTERN			
monday-Friday	7:00 – 16:30		
Saturday	Fulltime		
Sunday	Fulltime		
SYSTEMS			
COMPONENT	**DESCRIPTION/DISTRIBUTION**	**SIZE-POWER DENSITY**	**NUMBER**
HVAC			
ventilation	natural		
heating	Central gas boiler, wall water heaters	Not available	1
cooling	Not present		
LIGHTING			
characteristic	Neon tubes	Not available	Not available
POWER			
distribution	Basic installation in each room	Not available	Not available

3.3.2 Description of BIM procedure

As the building is not very complex and all parts of the building are accessible with conventional measures like laser measurement and folding rule there was no 3D laser measurement performed. Furthermore, it was assumed that the accuracy of the performed conventional geometric measurement is in terms of deduced energy analysis the same or at least nearly the same as a possibly more accurate measurement with 3D laser scanners. The decisive factor in terms of geometry and energy is the area of the envelope of the heated building volume. The measured building was edited in an ArchiCad 3D BIM model and the relevant data of the building parts was processed, calculated and extracted:

- Total heated volume
- Total envelope area
- Different envelope qualities
- Exterior walls assigned to geographic direction (sun orientation)
- Exterior walls assigned to heated neighbour buildings

- Interior floors assigned to unheated basement area
- Heating systems
- other

This data was edited in a professional German software application called “der Energieberater” and the U-Values and the overall energy consumption was calculated.

3.3.3 Outcomes

The energy calculation of old or even historic buildings in terms of used building materials and envelope constructions requires partially some assumptions as not all walls can be entirely tested with non-destructive measuring techniques. Nevertheless, all assumptions taken will represent the real building in an acceptable tolerance. Especially the roof was assumed to be not insulated, as a check of one spot showed that there was no thermal insulation installed.

3.4 Italy, Ancona

The demo case is a social housing composed of 100 apartments. It is located in Ancona (Italy) in a peripheral and mainly residential area of the city. The construction was built after a big landslide (occurred in the early eighties) to quickly provide homes to the survivors. The load-bearing structure consists of concrete prefabricated slabs and the horizontal slabs are in brick-cement. The building has 6 floors above ground and one basement level, with garages and cellars. The ground floor presents 10 apartments, while the other five floors include 18 apartments. Each floor presents the same indoor distribution, characterized by four types of apartments (with different surface area).

Figure 2: The Ancona demo case

The heating systems are composed of boilers and radiators (sheet steel), connected by one-pipe systems. The radiators are undersized and, as a consequence, they do not provide sufficient heat to satisfy the thermal comfort. Complaining about the indoor temperature, many occupants adopt further device (e.g. heaters) to warm up the rooms. Residents are dissatisfied also of the indoor summer conditions but only a few of them installed cooling units (i.e. mono-split air conditioner) to improve the summer thermal comfort and supply further heat during the winter. The mechanical ventilation system is not present. Natural ventilation is performed through windows, which also provide considerable infiltrations.

The overall condition of the building is poor due, in particular, to the quality of the materials, the mediocre execution and the lacks in maintenance over the years. The external facades present deteriorations due to the ageing process, weather and degradations due to moisture. Indoor surfaces are extremely deteriorated. The lack of ordinary maintenance and ventilation made the surface moisture a primary and very critical issue. Such defect regularly occurs in each apartment and, in some particularly serious cases (e.g. bathrooms), the mould proliferation and the biofouling cover all the walls, endangering occupants' health.

3.4.1 Preliminary information

AVAILABLE INFORMATION - TECHNOLOGIES				
TYPOLOGY		**AVAILABILITY**	**NEED**	**USE**
OFF-SITE	Geometric data (drawings)	Y	Y	Y
ON-SITE	Photogrammetry	Y	Y	Y
	3D geomatics	N	N	N
	3D thermal scanning	N	N	N
	Stratigraphy	Y	Y	Y
	Site inspection	Y (partially)	Y	Y

COMPONENTS CHARACTERISTIC			
COMPONENT	**TRANSMITTANCE [W/m2K]**	**THICKNESS [cm]**	**AREA [m2]**
ENVELOPE			
VERTICAL ELEMENTS			
external opaque elements			
M1	0.6	23	2200
M2	0.49	24	1000
M3	0.69	29.5	450
M4	2.35	23	850
M5	2.23	25	400
P1	2.73	23	450

external transparent elements	TRANSMITTANCE glass/frame [W/m2K]	DIMENSIONS width x height [CM]	AREA [m2]
W1(2 casements)	5.8 / 7	150 x 150	550
W3(1 casement_kitchen)	5.8 / 7	90 x 150	140
W3(1 casement)	5.8 / 7	90 x 230	150
W4(2 casements)	5.8 / 7	170 x 230	200
W3(1 casement_bathroom)	5.8 / 7	70 x 150	20
HORIZONTAL ELEMENTS			
external opaque elements			
R1	0.55	32	3300
R3_roof	0.65	34.05	1720
external transparent elements	Not present		
INTERIOR			
VERTICAL ELEMENTS			
Heated/Heated			
P1	2.73	23	3600
P2	0.92	30	100
P3	0.7	30	2200
P4	1.64	10	4600
Not Heated/Not Heated			
P1	2.73	23	600
P3	0.7	30	400
M7	1.91	8	1000
M8	1.47	12	200
HORIZONTAL ELEMENTS			
Heated/Heated			
R2	1.68	28	6600

INDOOR USAGE	
OPERATING TEMPERATURE [°C]	
heating	20°C
cooling	not present
TIME PATTERN	
Everyday_ from 1st November to 15th April	5:00-10:00-->20°C 10:00-16:00-->off 16:00-23:00-->20°C

SYSTEMS			
COMPONENT	**DESCRIPTION/DISTRIBUTION**	**SIZE-POWER DENSITY**	**NUMBER**

HVAC				
ventilation		natural ventilation		
heating		Natural-draft gas boiler FERROLI for heating and DHW	23 kW	100 (one per apartment)
cooling		Not present		
LIGHTING				
	distribution	BT230V		
	BSI 7_A	neon outdoor lights	19 W	12
	BSI 7_B	outdoor dusk lights	40 W	24
	BSI 7_C	outdoor fluorescent lamps	23 W	16
	BSI 8_A	common space lights (stairs)	40 W	36
	BSI 8_B	common space lights (basement)	60 W	6
	BSI 9	indoor lights (neon/spotlights/led)	variable (18/36/6/20 W)	~600

3.4.2 Description of BIM procedure

The creation of the BIM has been performed according to the following steps:

- Acquisition of information and documentation from the municipality (i.e. project owner) and from previous studies performed both in the demo case and in the sister building;
- Creation of the first draft of the BIM which comprises, in particular, geometrical components and stratigraphy;
- Investigation and on-site examination of the demo to check the correctness of the data and to acquire information on the systems and on the actual status of the building;
- Completion of the BIM integrating the information recovered during the survey.

The first phase regards the collection of spatial and geometrical information of the building. The main database refers to the municipality (ERAP Marche) which furnished the technical documentation. It consists of drawings (on the paper) representing the geometrical (i.e. planimetries, plants, sections and, fronts) and stratigraphy features. In past years, the building has been the subject of several studies at UNIVPM. During these investigations, the majority of the technical material was converted in CAD-format.

Moreover, examinations and monitoring provided information on the thermal environment and the status of the geometrical elements

3.4.3 Outcomes

The creation of the BIM has given rise to several issues and bottlenecks. Many of them are strictly connected to the building end-use and to its age. The key points are explained in the following list:

- The private intended use makes more difficult the data acquisition and the on-site investigations since the occupants can deny access to their apartments. The lack of actual information increases the approximations and the assumptions in the model.
- The information dating back to the eighties is not completely reliable since many features could have been modified or the elements could have been substituted during the years. This issue could be solved with actual investigations but, as said before, they are not always possible or allowed.
- Information about not-visible systems (e.g. pipes' path) is extremely difficult to collect. They are not available in the technical documentation and it was not possible to make destructive surveys in the apartments. This lack of data reduces the completeness of the BIM.
- In the software environment, it is very challenging to model old technical systems (e.g. a very old boiler) since the software is mainly targeted for 'new projects'. This decreases the accuracy of the settings in existing buildings.
- Even if the stratigraphy is known, the thermal properties of materials are not the same as when the construction was built. The deterioration due to weather and lack of maintenance cannot be considered when defining the physical properties of the layers in Revit. This leads to an enhancement of the thermal properties of the building which do not reflect the real situation.
- The dimension of the building (i.e. 6 floors and 100 apartments) increases the uncertainty of the model since the assumptions made for one apartment are replicated for those remaining.

3.5 Italy, Florence

The demo case is an historical building located in Florence (Italy). The building 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 building is characterized with 4 main floors (1 under-ground floor and 3 above-ground) connected by one stair and one elevator. Despite this the building in the last decades is abandoned and not used.

Before the renovation the ground floor was characterized by three different units: a commercial activity, a craft business and a storage room. The underground floor was dedicated to storage room for the dwellings and craft business. Instead, the first and second floor was organized with two residential dwellings per floor with different surface area.

From a structural point of view the building is realized adopting load-bearing masonry and wooden floors. The heating systems are composed of boilers and radiators (sheet steel), connected by one-pipe systems. The radiators are undersized and, as a consequence, they do not provide sufficient heat to satisfy the actual Italian winter thermal comfort. Also the summer indoor thermal comfort is inefficient; no cooling units are installed.

Natural ventilation is performed through windows and doors, which also provide considerable infiltrations

3.5.1 Preliminary information

AVAILABLE INFORMATION - TECHNOLOGIES				
TYPOLOGY		**AVAILABILITY**	**NEED**	**USE**
OFF-SITE	Geometric data (drawings) …	Y	Y	Y
ON-SITE	Photogrammetry	N	N	N
	3D geomatics	N	N	N
	3D thermal scanning	N	N	N
	Stratigraphy	Y (partially)	N	N
	Site inspection	Y	Y	Y

COMPONENTS CHARACTERISTIC			
COMPONENT	**TRANSMITTANCE [W/m2K]**	**THICKNESS [cm]**	**AREA [mq]**
ENVELOPE			
VERTICAL ELEMENTS			
external opaque elements			
EW01	1.35	35	249.40
EW02	1.21	40	145.30
EW03	1.74	25	120.00
EW04	2.03	20	10.50
EW05	1.01	50	73.10
EW06	0.93	55	111.60
external transparent elements			
W01	5.29	105x165	17.00
W02	5.29	115x205	24.00
W03	5.29	30x50	2.00
W04	5.29	56x165	0.80
W05	5.29	111x165	1.90
W06	5.29	130x165	2.10
W07	5.29	90x165	1.50

	W08	5.29	160x82	1.32
HORIZONTAL ELEMENTS				
external opaque elements				
	R01	1.50	34	159.10
	EF01	2.61	30	150.03
external transparent elements				
	W09	5.29	160x290	4.65
INTERIOR				
VERTICAL ELEMENTS				
Heated/Heated				
	IW01	1.99	15	112.00
	IW02	2.38	10	115.30
	IW03	1.71	20	49.30
	IW04	1.49	25	35.30
	IW05	1.20	35	11.50
	IW07	0.68	70	12.20
	IW09	2.59	8	39.00
	IW11	1.09	40	26.80
	IW12	2.21	12	9.30
	IW13	2.97	5	5.50
Not Heated/Not Heated				
	IW01	1.99	15	102.00
	IW02	2.38	10	4.00
	IW03	1.71	20	12.90
	IW04	1.49	25	22.40
	IW05	1.20	35	38.70
	IW06	1.33	30	9.40
	IW07	0.68	70	25.00
	IW08	0.86	55	12.00
	IW09	2.59	08	1.50
	IW14	0.92	50	7.70
Heated/Not Heated				
	IW01	1.99	15	74.00
	IW02	2.38	10	8.30
	IW03	1.71	20	12.70
	IW04	1.49	25	0.50
	IW06	1.33	30	9.80
	IW07	0.68	70	13.90
	IW08	0.86	55	18.00
	IW09	2.59	08	2.20
	IW10	1.46	23	31.30

P2ENDURE
PLUG & PLAY BUILDING RENOVATION

HORIZONTAL ELEMENTS				
Heated/Heated				
	IF01	1.89	30	8.10
	IF02	1.23	33	34.40
	IF03	0.71	62	10.10
	IF05	1.49	25	26.80
	IF06	1.14	41	25.80
	IF07	1.15	36	29.20
	IF08	1.14	39	21.00
	IF09	0.62	63	19.20
	IF10	1.35	27	41.90
	IF11	0.67	71	6.20
	IF17	0.55	74	24.20
	IF18	0.98	44	3.20
Not Heated/Heated				
	IF01	1.89	30	73.70
	IF02	1.23	62	4.40
	IF04	1.89	63	4.40
	IF14	2.21	71	2.50
	IF15	0.87	74	15.30
	IF16	0.71	40	26.80
Heated/Not Heated				
	IF01	1.89	30	27.00
	IF02	1.23	33	17.00
	IF04	1.89	20	40.20
	IF14	2.21	15	12.80
	IF15	0.87	49	29.80
	IF16	0.71	57	42.50
Not Heated/Not Heated				
	IF01	1.89	30	2.90
	IF04	1.89	20	3.60
	IF06	1.14	41	1.70
	IF07	1.15	36	12.40
	IF12	0.65	60	3.20
	IF19	0.94	81	4.20

INDOOR USAGE

OPERATING TEMPERATURE [°C]			
heating	20°C		
cooling	Not present		
TIME PATTERN			
Residential	Fulltime		
Commercial	9:00-19:00 Mon-Fri		
SYSTEMS			
COMPONENT	**DESCRIPTION/DISTRIBUTION**	**SIZE-POWER DENSITY**	**NUMBER**
HVAC			
ventilation	Natural ventilation		
heating	Radiators	-	44
cooling	Not present		
LIGHTING			
characteristic	Halogen lamps	-	73

3.5.2 Description of BIM procedure

The model has been created from drawings and historical documentation of the building. Due to a lack of precision of old drawings, some structural elements were reported differently in planimetry of some floors. An analysis of each document and of the state of the art of the building permit has been performed to overcome this discrepancy.

Being the model prepared for energy calculation, the modelling process was carried out with volumetric components, therefore without stratigraphy. For windows and doors, families with standard openings without frame were considered.

At a later stage, through the elaboration of the BIM model in the IFC Builder program, the geometry of the constructive elements as well as their stratigraphy have been included. Through the other programs of the Cypetherm Suite the BIM model was finally implemented with the information necessary to perform the energy assessment of the building.

3.5.3 Outcomes

Some difficulties have been encountered in the definition of the BIM model. The main reason is not related to the software used or to a poor ability of the operator but mainly to a lack of information about the existing building in the pre-renovation scenario. Elements that could not be modelled accurately have been considered as standard to minimise their influence over the project and its energy assessment.

BIM model for energy calculation Is not required to be detailed, as to keep the energy simulation as fluent and simplified as possible; due to this need some simplifications have been made in particular for walled-up openings in ground floor in external partitions (considered as part of the structural elements).

3.6 Italy, Genoa

This demonstration case is a school monumental building under cultural heritage regulations. The building is in a very poor condition and each intervention must be approved by the local Cultural and Heritage Office.

3.6.1 Preliminary information

AVAILABLE INFORMATION - TECHNOLOGIES				
TYPOLOGY		**AVAILABILITY**	**NEED**	**USE**
OFF-SITE	Geometric data (drawings)	Y	Y	Y
	...			
ON-SITE	Photogrammetry	N	N	N
	3D geomatics	N	N	N
	3D thermal scanning	N	N	N
	Stratigraphy	Y (partially)	Y (partially)	Y (partially)
	Site inspection	Y	Y	Y
	...			

COMPONENTS CHARACTERISTIC			
COMPONENT	**TRANSMITTANCE [W/m2K]**	**THICKNESS [cm]**	**AREA [m2]**
ENVELOPE			
VERTICAL ELEMENTS			
external opaque elements			
EW01_THK 45	1.092	45	240.6
EW02_THK 29	1.294	29	100.58
EW03_UPWIN	3.072	29	33.57
EW04_UPWA	1.477	45	22.22
EW05_SHBOX	1.189	45	1.81
external transparent elements			

	W1	5.9/7	180x180	3.24
	W2	5.9/7	216x180	3.89
	W3	5.9/7	324x180	5.83
	W4	5.9/7	196x180	3.53
	W5	5.9/7	196x180	3.53
	W6	5.9/7	196x180	3.53
	W7	5.9/7	196x180	3.53
	W8	5.9/7	196x180	3.53
	W9	5.9/7	196x180	3.53
	W10	5.9/7	287x180	5.17
	W11	5.9/7	287x180	5.17
	W12	5.9/7	180x180	3.24
	W13	5.9/7	100x180	1.80
	W14	5.9/7	216x180	3.89
	W15	5.9/7	324x180	5.83
	W16	5.9/7	167x250	4.21
	W17	5.9/7	167x250	4.21
	W18	5.9/7	217x250	5.47
	W19_ZONE02	5.9/7	167x250	4.21
	W20_ZONE02	5.9/7	167x250	4.21
	W21_ZONE02	5.9/7	180x510	1.35
	W22_ZONE02	5.9/7	180x792	3.89
	W23_ZONE02	5.9/7	100x180	1.80
	W24	5.9/7	180x792	3.89
	W25	5.9/7	100x180	1.80
	GLASSDOOR01_NORTH	5.9/7	180x244	4.39
	GLASSDOOR02_SOUTH	5.9/7	180x244	4.39
HORIZONTAL ELEMENTS				
external opaque elements				
	RF01	0.516	41.4	268.16
	EF01	1.669	27.5	18.79
INTERIOR				
VERTICAL ELEMENTS				
Heated/Heated				
	IW01	few int. wall in the same thermal zone - transmit. not relevant		
HORIZONTAL ELEMENTS				
Heated/Heated				
	IF01	Int. floor between zones with same cond. - transmit. not relevant		

INDOOR USAGE				
OPERATING TEMPERATURE [°C]				
	heating	20-22		
	cooling	not present		
TIME PATTERN				
	monday-Friday	8:00-16:00		
	Saturday	Fulltime		
	Sunday	Fulltime		
SYSTEMS				
COMPONENT		**DESCRIPTION**	**SIZE**	**NUMBER**
HVAC				
	ventilation	Not present (natural ventilation)		
	heating	Boiler - JOANNES ELLEN 2 51 2S	51 kW	1
	cooling	not present		
LIGHTING				
	distribution	BT 230V		
	characteristic	fluorescent lamp		
	power density	10 W/mq		
POWER				
	distribution	GRUNFOS UPSD 32-50 F220	110 W	1

3.6.2 Description of BIM procedure

In Genoa demo case the BIM models have been created using the software Autodesk Revit, on the basis on the document provided by the Genoa Municipality and to the information collected on the onsite inspection.

The main document received has been:

- Building drawings in DWG format. (**Error! Reference source not found.**)
- Datasheet and booklet of the boiler and Layout of the heating system in the technical room.
- Preliminary Energy Audit provided by Genoa Municipality (commissioned before the start of the P2ENDURE project).

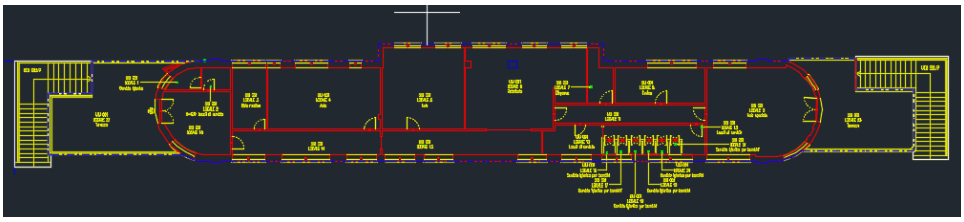


Figure 3: 2D Plant of Nemo nursery school provided by Genoa Municipality.

Using the plant as a starting reference, the measures of each rooms have been verified (perimeter; area; height) as well as the width of the walls and the windows dimensions. The components characteristics, the indoor usage and the systems information, have been collected thanks to onsite inspection and to the information provided by the Genoa municipality, and has been used as input of the BIM models. During the onsite inspection, some in congruence in the information contained in the preliminary Energy Audit provided by the Genova Municipality has been found, consequently it has not been considered in the definition of layers and thermal properties of the building elements.
Two different models have been created: the first is a detailed model containing all the information collected, including geometrical details of the building as well as information on the heating system; the second one is a simplified model optimized for the creation of the Energy model.
The aim of the detailed model is to represent a repository of the main information on the building envelope geometry and thermal performance, as well as of the main information related to the generation system and the emission system (power installed, efficiency, positioning in the building). In the following a brief description of the model is presented:

- Ground floor: it is not part of the nursery school and has been modelled considering only by the external walls, omitting the windows. The only exception is the technical room, which has been modelled in detail and include a model of the gas boiler with power and efficiency of the actual boiler.
- Emission system: it is composed by radiators and has been modelled including information about the power of each element. The distribution system (piping) has not been modelled since no related information was available.
- First floor (Nemo nursery school): it has been modelled in detail including external and internal walls, roof, windows and doors with information on dimension, layers, material used and thermal properties. Aesthetical details such as the windows ledge and the external pillars visible on the facade have been included.

Here below some images about the Revit model realized are shown.

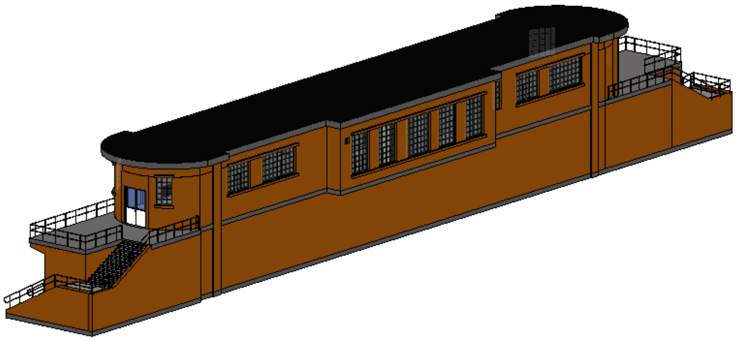


Figure 4: Detailed BIM model of Genoa Demo: external view from south-east

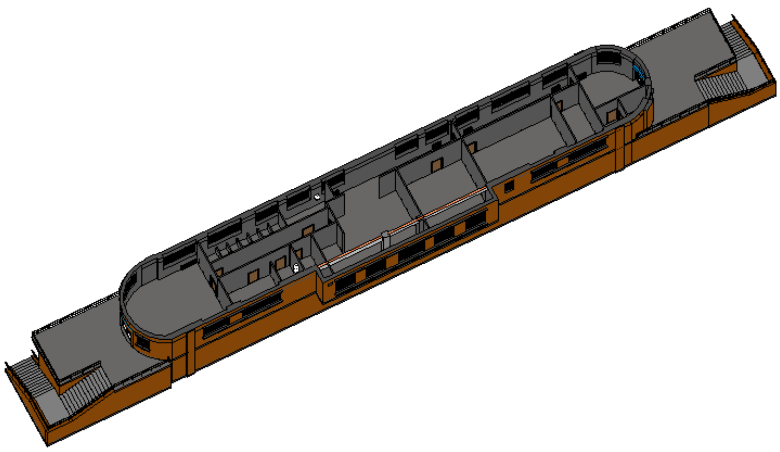


Figure 5: Detailed BIM model of Genoa Demo: view of the internal partition

The simplified model is optimized for energy simulation: the aim is, at the end of the process, to be able to perform accurate energy simulation using the Energy Plus open source software. To do so, an idf (intermediate data format) file should be exported from the BIM model, imported in SketchUp to correct possible geometrical bugs, and then exported again to be used in energy plus. To optimize and fasten the transferring of information among the software involved, it is necessary eliminate all the redundant and useless information from the original BIM model. Two thermal zone has been modelled, one zone including the two classrooms, and one including all the other common areas.

In the following it is described the procedure followed to create the simplified model:

- Horizontal and vertical opaque element: all the opaque elements dividing the heated space from the external environment or from an unheated space have been maintained form the detailed model, while all the elements having no real impact on the envelope thermal performance have been omitted. In order to have correct surfaces and volumes in the Energy plus model, all the elements have been shifted inside of 'half of the element width' with respect to the detailed model. This is due to the fact that the energy model generated by Revit creates for each 3D element an equivalent surface positioned in the centre line of the 3D element. If the offset is not carried out, the volumes and surfaces will be over dimensioned.

- Internal walls: only the walls dividing two different thermal zones have been lest. All the other internal partitions have been deleted.
- Windows and doors: window and doors have not been modified from the detailed model, despite when the model is exported in sketch up all the information about the windows are loosed. Only the total surface and the position of the window are kept in the idf file. All the geometrical and the thermal properties of frame and glass should be inserted later directly in Energy Plus.
- HVAC systems: the systems element like generator and radiators have been omitted in the simplified model because they are not considered by Revit in the energy model, which take into account only the HVAC settings of the thermal zones.

In the following figure the Simplified model is shown:

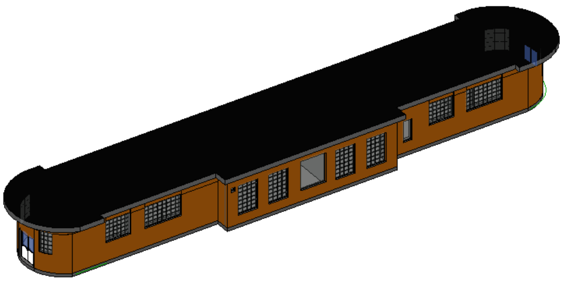
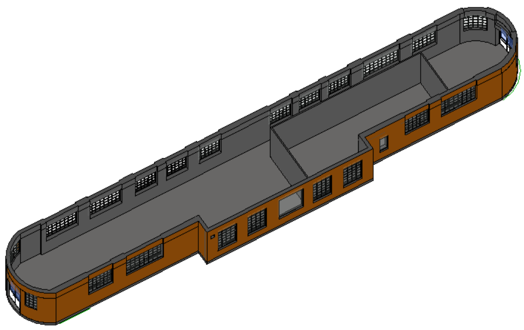


Figure 6: Simplified BIM Model of Genoa Demo: external view form south-east

3.6.3 Outcomes

The creation of the BIM models encountered some difficulties mainly due to the lack of information about the building elements layers and thermal properties. The preliminary energy audit provided by the municipality showed some incongruence with the building typology, so the information about the building elements has been assumed on the basis of the onsite inspection, building typology and age of construction. No destructive surveys have been possible.

Fig. 7: Simplified BIM model of Genoa Demo: view of the internal partition



When it comes to the heating systems, the model of each radiator and of the gas boiler has been included, in order to represent the actual position on the building and give information about powers installed and efficiencies. In this case the problem is that these elements are not considered in the creation of the Revit energy model, which requires the definition of the HVAC system in the thermal zone settings. However, the HVAC configurations available in the zone settings do not comprehend old heating system (e.g. old gas boiler) but have been thought for more recent solutions. In fact, for the energy calculation, the choice of a default HVAC system is needed only to obtain the energy model and so to get the .idf file, but the HVAC system must be more accurately defined after the exportation.

An important outcome of the modelling activity has been the identification of the step needed to optimize the BIM model to create an energy model in Energy Plus, described in the preceding paragraph. This allowed fastening the process to pass from a detailed BIM model to an accurate energy model which can be used in open source software.

3.7 Poland, Gdynia

Demo site in Gdynia (Poland) is a building of a kindergarten no 16 located in a city centre at Jana z Kolna Street 29, see**Error! Reference source not found.**. It is a two-storey building, constructed in year 1965 and attended by around 130 children. Building is divided into two parts: one storey administrative part that will be renovated within P2ENDURE project and 2 storey part where the children are staying (this part will be renovated by City of Gdynia). Exterior walls of the building are not insulated, and in the administrative part of the building there are old wooden windows

3.7.1 Preliminary information

AVAILABLE INFORMATION - TECHNOLOGIES				
TYPOLOGY		**AVAILABILITY**	**NEED**	**USE**
OFF-SITE	Geometric data (drawings)	Y (old drawings from 1965)	Y	Y
ON-SITE	Photogrammetry	Y	Y	Y
	3D geomatics	Y	Y	Y
	3D scanning	Y	Y	Y
	3D thermal scanning	N	N	N
	Stratigraphy	N	N	N
	Site inspection	Y	Y	Y

COMPONENTS CHARACTERISTIC			
COMPONENT	**TRANSMITTANCE [W/m2K]**	**THICKNESS [cm]**	**LOCATION**
ENVELOPE			
VERTICAL ELEMENTS			
external opaque elements	1.19	24	External ground floor walls
	0.19	39	External underground storey walls
external transparent elements	0.21	1	Facades Northen and Estern
	0.28	1	Facades Southern, Estern and Western
HORIZONTAL ELEMENTS			
external opaque elements	0.18	~ 95	Flat roof
	0.49	42	Bacement floor
	0.52	29.5	Floor on the ground
INTERIOR			
VERTICAL ELEMENTS			
Heated/Heated	10.3	6	Not load bearing walls (partition walls)
	3	25	Load bearing walls
HORIZONTAL ELEMENTS			
Heated/Heated	0.71	37	

INDOOR USAGE			
OPERATING TEMPERATURE [°C]			
heating	20°C		
cooling	Not present		
TIME PATTERN			
monday-Friday	6:00 – 17:00		
SYSTEMS			
COMPONENT	**DESCRIPTION/DISTRIBUTION**	**SIZE-POWER DENSITY**	**NUMBER**
HVAC			
ventilation	natural ventilation system		
heating	district central heating and radiartos	85kW	1
cooling	no cooling system		
LIGHTING			
characteristic	fluorescent lamp	15W	6
	fluorescent lamp	30W	14
	light bulb	60W	22

3.7.2 Description of BIM procedure

Demo site in Gdynia (Poland) is a building of a kindergarten no 16 located in a city centre at Jana z Kolna Street 29. It is a two-story building, constructed in year 1965 and attended by around 130 children. Building volume is 2712 m^3 and built up area is 464 m^2, the building has no electrical documentation, only old paper design from year 1965 is available. For correct planning of the demonstration activities there was a need for creation of BIM model of the building. Therefore, first step was to perform the 3D laser scanning, with the use of Faro Focus 3D scanner when the kindergarten was empty (without children and teachers). The result of the 3D scanning was a cloud point model that is shown in following figures.

Figure 8: Point cloud model obtained from laser scanning process for Gdynia demo case.

Next step was the processing of cloud point data, this was done to eliminate information that has been scanned and is not needed (e.g. trees, grass, pavement, etc.). For creation of the BIM model following software were used: SketchUp with Undet plugin and Revit LT. Firstly 3D building model was created base on the imported cloud point from 3D scanning, then the IFC file was upload in the Revit LT and all the requirements and features of the elements were assigned. The BIM model of Gdynia demonstration site is shown in Figure. For activities that were not possible in Revit LT, full trail version of Revit was used.

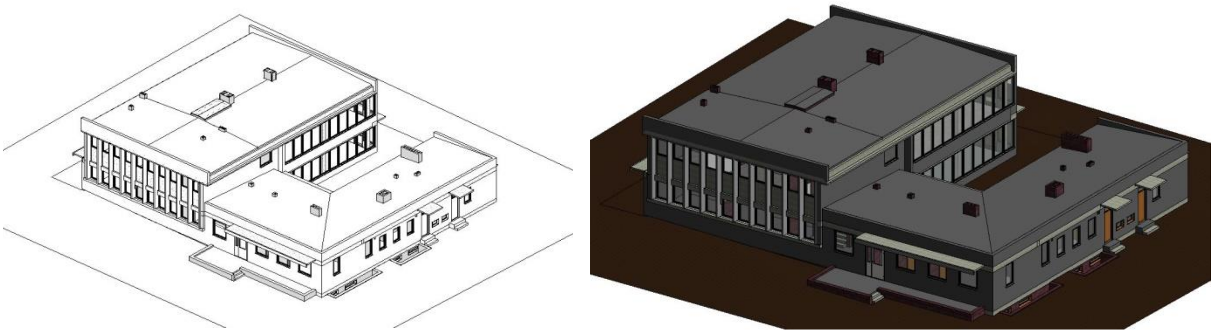


Figure 9: BIM model of Gdynia demonstration site.

The most important features of the used software for creation of BIM model for Gdynia demo site are:

SketchUp software allows to

- import the point cloud with Undet plugin,
- create the 3D model based on the imported point cloud,
- create IFC elements and set its basic properties,
- export and import of the IFC model.

SketchUp doesn't have extended ifc properties functionality. It allows providing only the basic IFC properties, like type, name, basic material. Therefore there was a need to create a model with assigned basic types to elements like IFC Window, IFC Door, IFC Beam, etc. In the name of every element there were entered special keys for later mapping and locating elements in defined layers. Exported IFC file was parsing by our own application made in C# with Xbim open source library. A special dictionary with materials and their properties like Emissivity, Transmittance, Reflection, g-values, Absorptance, Density, Specific Heat, Emittance, etc. (whole from UML model in P2ENDURE specification) was created by FAS team.

Revit LT	
Possibilities	**Limitations**
Creation of a 3D model based on the imported IFC model from SketchUp	No possibilities of editing and modeling the shape of roofs and floors
Definition of the location of the building	No possibility to import a point cloud
Definition of most of the required properties for the IFC model	No possibility to check the interferences
Export and import of the IFC model	No possibility of modelling installation systems
	No possibility to perform area analysis
	No possibility to set heating and cooling loads
	No possibility to model thermal properties of the materials

The required data to create the BIM model of Gdynia demo case were:

- the point cloud
- the construction project of the building
- rebuilding and renovation projects
- photographic inventory
- site visit and general analysis of the building
- organoleptic tests to specify the type of the material
- measurements of the parts of the building which was hidden during scanning 3D

3.7.3 Outcomes

During the modeling instalations (e.g.sanitary, HVAC, rain water systems) there might be some difficulties due to the fact that those installations often are hidden in the other building elements (walls, columns, etc.). Therefore in order to trace them, it is recommended to perform on site survey and make on-site documentation (photos), especially important are ventilation grilles and construction elements that are hidden behind lockers or other furniture. The material of the elements adjacent to the walls and ceilings must be verified to determine whether the element is a construction or interior finishing. The advantage of using the 3D scan is the lack of the need for on-site inventory measurements, this significantly accelerated the work.

3D scanning provides better accuracy of the model and allows verifying the thicknesses of opaque elements such as walls and ceilings. It also allows identifying possible structural defects and technical condition of the building structure. The point cloud allows having “permanent access” to the building - at any time, there is a possibility to check how a part of the building looks like without the need for a visit to the building. Limitations of Revit LT during the creation of BIM model for Gdynia demonstration building are shown in Chapter 4.6.2.

3.8 The Netherland, Tilburg

The building is a monastery located in Lidwina. The current function is a residence for migrant workers. A feasibility study has been made to determine the strategy for a future renovation of the building and to transform the building into a short/long stay residence (same function as it is but broader rental opportunities) and to equip every room with individual sanitary, insulate external wall (possibly) from the inside and find a window solution.

The building is located in a strategic position, close to the city centre of Tilburg and in a good neighbourhood; however, the parking could be a problem.

Because of the building's monumental status, only the interior of the building can be fully renovated. The building's envelope is not considered for deep renovation.

3.8.1 Preliminary information

AVAILABLE INFORMATION - TECHNOLOGIES				
TYPOLOGY		AVAILABILITY	NEED	USE
OFF-SITE	Geometric data (drawings)	Y	Y	Y
	...	Y	Y	Y
ON-SITE	Photogrammetry	N	Y	T.b.d.
	3D geomatics	N	N	N
	3D thermal scanning	Y	Y	Y
	3D scanning	N	T	T.b.d.
	Stratigraphy	N	N	N
	Site inspection	Y	Y	Y
	...			

COMPONENTS CHARACTERISTIC				
COMPONENT	**TRANSMITTANCE [W/m2K]**	**THICKNESS [cm]**	**AREA [m2]**	**LOCATION**
ENVELOPE				
VERTICAL ELEMENTS				
external opaque elements				
walls				
ext wall - with cavity 270 - 100/70/100	0.2700	27	4	
ext wall - with cavity 400 - 220/70/110	0.2934	40	166.5	
ext wall - no cavity 400	1.3450	40	29.5	
ext wall - with cavity 440 - 110/50/110	2.4091	27	10	
floor				

cellar floor	4.6489	22.5	127	
external transparent elements				
Mark A (4 pieces, 1 piece 4,9 m²)	5,7	3	19.6	N
Mark B (1 piece, 1 piece 2,8 m²)	5.7	3	2.8	S
Mark C (1 piece, 1 piece 2,2 m²)	5.7	3	2.2	S
Mark D (2 pieces, 1 piece 4,3 m²)	5.7	3	8.6	N
Mark H (3 pieces, 1 piece 2,5 m²)	5.7	3	7.5	2xN/1xS
HORIZONTAL ELEMENTS				
external opaque elements				
roofs				
roof wood + roof tiles	5.0	15	110	S/N
INTERIOR				
VERTICAL ELEMENTS				
Heated/Heated	2.5	22	90	
HORIZONTAL ELEMENTS				
Heated/Heated				
- Ground floor and first floor (concrete)	4.6	22.5	221.5	
- Second floor (wood)	9.5	5	71	

INDOOR USAGE			
OPERATING TEMPERATURE [°C]			
heating	22°C		
cooling	Not present		
TIME PATTERN			
Monday-Sunday	Fulltime		
SYSTEMS			
COMPONENT	**DESCRIPTION/DISTRIBUTION**	**SIZE-POWER DENSITY**	**NUMBER**
HVAC			
ventilation	Not present (natural ventilation)		
Heating rooms	HR boilers (Remeha Quinto pro in cascade setup)		5
Heating water	Boiler with storage vessel in cellar		1
LIGHTING			
characteristic	Light bulb (2 per room)	40 W	6
	lightning in circulation space (fluorescent lamp)	60 W	1
	lightening basement	40 W	3

3.8.2 Description of BIM procedure

The Lidwina monastery is a complex building due to the fact that it is a historic building and mostly in original state. The building is also reasonably large (measuring 4380 m2). The choice for deep renovation of the whole building is a deep impact decision. Although the building is complex the organisation of the building can be simplified. This is shown in the picture below (left), in this drawing the red colour spaces define the separate rooms. The renovation of the building is divided into a pilot project followed (if this pilot project will be a success) by the renovation of the whole project. For P2ENDURE the active project is the pilot project (containing three rooms, the hallway and the basement (see the red lines in the picture to the right).

For the first step in the permanent decision making and the engineering (the current phase in the project) the BIM model that is used is produced by PAN+ architecture and is drawn with Revit architecture software of Autodesk. The information that is used to generate this BIM model was mostly taken from the original building drawings. These drawings were very precise containing detailing, materials and measurements. Through site inspection the quality of the existing drawings were verified. In the recent years some modifications were done on the building, mostly interior changes. These changes were also laid out in drawings. After inspection it became clear these drawings were also reliable. On-site inspection was done including taking measurements. These measurements were concentrated on the position of the pilot project. Information regarding HVAC installations were gathered using on-site inspection and interviewing the curators and tenant.

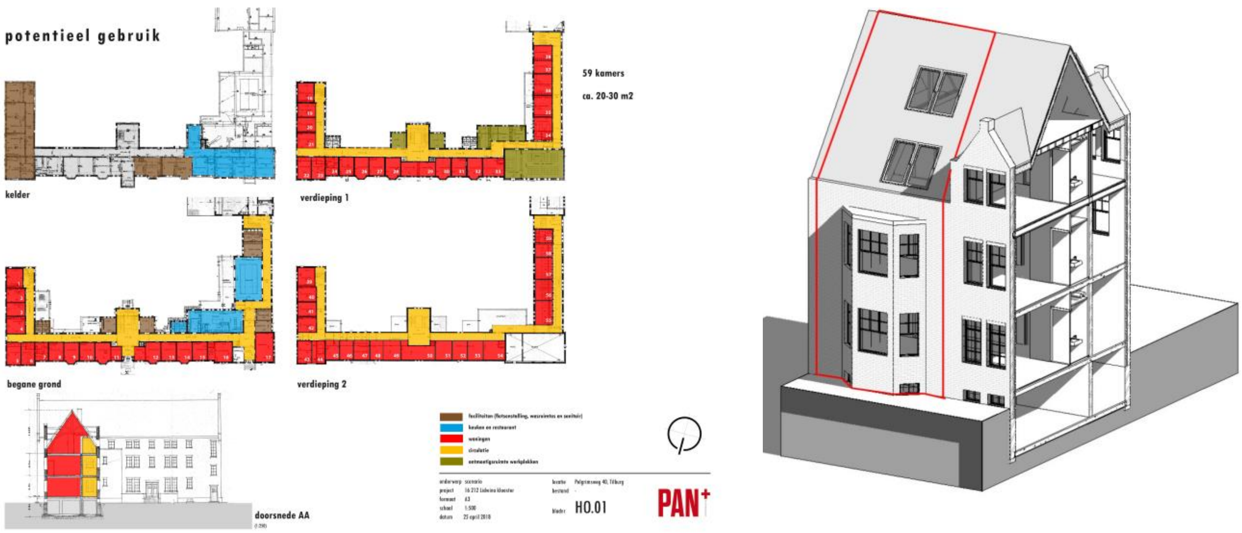


Figure 10: Drawings and 3D model of demonstration case

The next step was modelling the building. For this project two models were produced. First a rougher model of the entire building (see left image below), next a more precise model for the pilot project (see right project).

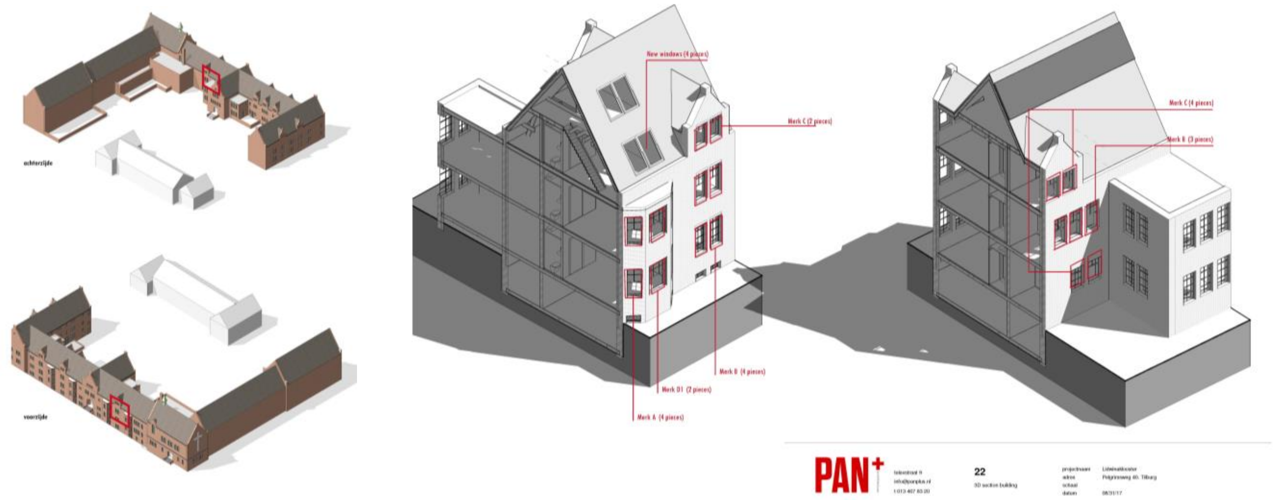


Figure 11: 3D view and sections of demonstration case

This fairly easy process did not result in any problems. The Revit model of the pilot project is used to generate all the building info used for the component characteristics. The Revit model of the entire project is used to present the impact of the project and enlarge the understanding of the building. Existing HVAC components and distributions were not modelled in these models. New HVAC and distribution systems were modelled schematically.

The next step in modelling is 3D scanning the entire building. This will generate valuable information that is first of all useful for the final execution of the pilot project and secondly for the engineering of renovation of the entire building.

3.8.3 Outcomes

With the planning for a project like the Lidwina monastery the scanning and producing a complete and detailed BIM model has not been done in the beginning of the project. At this stage uncertainties concerning execution were too high. The investment is not in proportion. With the current design phase for the Lidwina monastery we are now at point 3D scanning is going to be done.

This will give us valuable information for the placement of all the prefabricated sanitary units and the plan for the new (prefabricated) distribution system for example.

Large downside to this 3D scanning and modelling planning is that the modelling has to been done a second time after the 3D scanning is done. Looking back the complete model of the monastery could have been done even rougher or not at all in the beginning of the project. On the other hand it generated the complete model provided extra insights in the building.
A second lesson to be learned is that the two separate models could have been done in one model. With that methodology the difficulty would have been to draw the pilot project in the full model with separate wall types and separate family types to generate separate information only for the pilot project.
In a most ideal situation 3D scanning and modelling should be done as soon possible in that case it is reasonably certain the renovation measurements that will be executed and/or the value of the 3D model will be awarded by the owner (for example for exploiting the building and maintenance).

For the BIM-BEM modelling and validation the Revit model was used as an information tool to produce the SketchUp model from scratch. This was due to the relative high level of detail in the Revit model of the pilot project. Transforming this model to SketchUp automatically did not work properly (too much errors in the model). Drawing the model roughly from scratch proved to be much more efficient.

4. Best practice and conclusions

4.1 Poland, Gdynia

Lessons learnt

For Gdynia demo site 3D building scanning was used. The main advantage is elimination of the need of time consuming on-site measurement process.

This results in a shorter time for receiving geometry data. The process itself is also easier and more efficient *i.e.* there is no need for axially equipment like scaffolding and ladders in order to reach hard-to-reach places. 3D scanning allows capturing all of the physical measurements of any object, avoiding errors when creating the BIM model.

In specific:

- It provides greater accuracy of the model, allows reading the thicknesses of opaque elements such as walls and ceilings;
- It also allows to identify possible structural defects and technical condition of the building structure;
- The point cloud provides permanent “access” to the building; at any time, you can check any part of the building without visiting it;
- The Point Cloud lower at the minimum any risk of error while working on a building renovation project and possible subsequent work on redesigning the building, being the state of the art reported in the model exactly coinciding with what exist in reality.

In few words, using 3D scan accelerates the work and save time (that is one of the main targets of P2ENDURE as well).

There is hence, the possibility of counting on a much higher reliability and precision to support any possible design task (*e.g.* design, reverse-engineering, performance assessments, *etc.*).

Coming specifically to Gdynia, some bottlenecks occur as well. The main problem that have been encountered is that the building model that result from the 3D scanning is sometime too much complicated, presenting many levels of families of objects that are difficulty processed for instance in the energy analyses.

There is the need of adjusting the BIM to simplify it.

This was the case of Gdynia and Firenze BIM models, even though in the second case, the BIM was not created through a 3D laser scanning procedure.

In Gdynia, the BIM that results from the 3D scanning needed an adjustment to yield a reliable BEM.

4.2 Poland, Warsaw

Lessons learnt

Procedure and outcomes of scan-to-BIM process outcomes and lessons learnt for Warsaw demonstration case have been clearly presented in deliverable 1.5. Please refer to this document (LINK) for further information.