BIM4EEB

BIM based fast toolkit for
Efficient rEnovation in Buildings

D8.3 Report on demonstration in Poland

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D8.3 Report on demonstration in Poland

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EXECUTIVE SUMMARY

The following report describes the demonstration of BIM-based fast toolkit for Efficient rEnovation of residential Buildings (BIM4EEB), which is a set of dedicated tools for the effective renovation process, on the Polish pilot site in the Chorzow city.

Provided demonstration process, according to the Grant Agreement no. 820660 (part B, 1.3.2.3, table 2) concerned the following set of tools: Management system (BIMMS platform), Tool 1 - Fast mapping of buildings (fast mapping toolkit), Tool 3 - Human machine interface (BIM4Occupants), Tool 4 – HVAC Design, Operation and Efficiency Management (BIMcpd).

The report contains the results of the Key Performance Indicators (KPIs) evaluation for individual tools, to the extent defined in deliverable D8.1 Report on management of real Best Practice Examples. Verification process was based on D3.5 Measurement and Verification protocol.

Document contains a detailed description and characteristics of the pilot building. The report also presents the process of metering residential premises, whose residents have voluntarily agreed to participate in the BIM4EBB project, into devices monitoring the internal parameters of usable areas and apartments energy consumption.

Report D8.3 contains the most important conclusion in relation to the demonstration process itself, the evaluation of the Key Performance Indicators (KPIs) for the BIM4EBB toolkit, and the description of the experience gained.

Demonstration of selected tools form BIM4EBB toolkit presented the following results. Relative to traditional approach, BIM-based retrofitting process supported by BIM4EEB toolset is able to reduce the time and costs. Using Fast mapping toolkit during inventory stage, with laser scanning for point clouds generation, can provide a reduction in measurement time up to 80%. Renovation supported by BIM-based approach in engineering phase with BIMMS platform as a Common Data Environment and BIMcpd for improving design solutions, can reduce the time by more than a quarter (27%). In relation to this, significant cost reduction for the design stage was also estimated (19%). Within residential premises, comfort level indicators have been successfully estimated using BIMcpd and BIM4Ocupants platform, which provided detailed information on apartments' internal conditions and inhabitants' preferences. During social indicators' evaluation, assisted by surveys, it was shown that the use of BIM4EBB toolkit caused a positive reaction of end users.

PUBLISHING SUMMARY

Report D8.3 presents demonstration of BIM-based fast toolkit for Efficient rEnovation of residential Buildings, which contains innovative tools created and developed as part of the BIM4EEB project.

Demonstration activities were carried out in the demo building in Poland. Pilot site provide a reference example of residential facility from the Central Europe climate zone. The research program involved residents from 5 apartments of the pilot building, who voluntarily agreed to participate in the BIM4EEB research project.

The demonstration process concerned the following set of tools from BIM4EEB package: BIMMS platform, Fast mapping toolkit, BIM4Occupants, BIMcpd.

Demonstration on the Polish pilot site presented the potential of the toolkit in increasing the efficiency of the renovation process. Fast mapping of buildings in the inventory phase with laser scanning, to produce point clouds, showed the time reduction of measurements up to 80%, relative to traditional approach. Renovation supported by BIM-based approach in engineering phase with BIMMS platform as a Common Data Environment and BIMcpd for improving design solutions, presented the possibility to reduce the time of the processes by more than a quarter (27%). In conjunction with this significant cost reduction 19%, was estimated. Tools as BIMcpd and BIM4Ocupants provide comfort level indicators' estimation, which preserve detailed information about inhabitants' preferences related with thermal and visual conditions inside the studied apartments. BIM4EEB toolkit demonstration provide positive feedback by end-users stated in dedicated surveys.

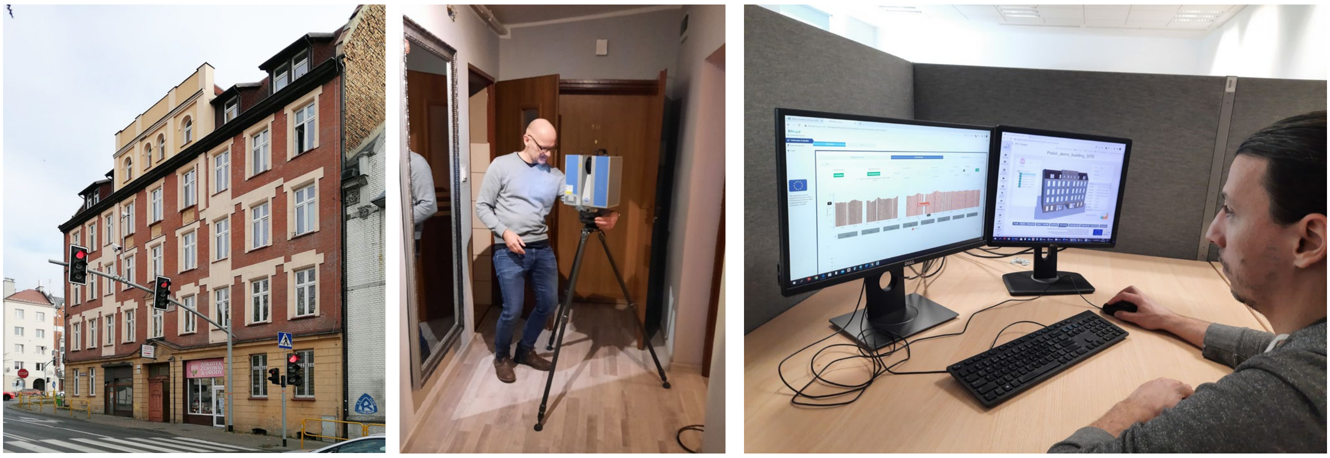

Figure 1 Polish pilot site BIM4EEB toolkit demonstration

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1. Introduction

This document describes the demonstration process of the BIM4EEB, which is BIM-based toolkit supporting the building renovation processes. The demonstration activities, described in the following report, were carried out on the pilot building in Poland. The activities were focused on the demonstration of BIM4EBB-toolkit in particular, according to Grant Agreement no. 820660 (part B, 1.3.2.3, table 2), concerned the following set of tools: Management system (BIMMS platform), Tool 1 - Fast mapping of buildings (fast mapping toolkit), Tool 3 - Human machine interface (BIM4Occupants), Tool 4 – HVAC Design, Operation and Efficiency Management (BIMcpd). The major topic of this report was the assessment of Key Performance Indicators (KPIs) defined as part of the main assumptions for the WP8 (work package 8). Demonstration activities carried out on the Polish pilot site focused on the initial phases of the building's retrofitting process, in particular the inventory phase and the design process.

All activities described in this document drew from the results of work developed in related work packages. The methodology of tools testing was based on the material developed in the document D8.1 Report on management of real Best Practice Examples [8]. To demonstrate BIM4EBB toolkit against the renovation scenarios the following deliverables were considered: D2.1 Definition of relevant activities and involved stakeholders in actual and efficient renovation processes [1] and D2.2 List of Designers' Needs and Requirements for BIM-Based Renovation Processes[2].

List of Key Performance Indicators (KPIs), the range of data necessary to examine the individual indicators with definitions of baseline values were based on the results presented in the document D3.5 Measurement and Verification protocol [3]. Performance characteristics for selected tools used in the demonstration process described in the report use the results contained in the report D4.10 Testing and validation results on demonstration sites [5]. The assessment of the performance indicators was based on specification and results developed by the tools owners, among others: D4.9 Tested version of the platform, D5.5 technical report on testing and validation results [4], D6.3 Tool for constraint checking BAC topologies VS building codes – including, D6.4 Tool for connecting BIM and BAC and, D6.5 Database Management system [7].

Demonstration activities at the Polish pilot site in Chorzow city have shown that the use of BIM4EBB toolkit during the BIM-based renovation is able to reduce the time and costs in individual phases of the process. Fast mapping toolkit during the inventory stage, with laser scanning for point clouds generation can provide a reduction in measurement time up to 80% relative to the traditional approach. Application BIM-based approach for engineering phase of retrofitting with BIMMS platform as a Common Data Environment and BIMcpd for improving design solutions, can reduce the time by more than a quarter (27%) also resulting in the associated cost reduction (19%). In addition, within residential premises, comfort level indicators, have been successfully estimated using BIMcpd and BIM4Ocupants platform, preserve detailed information about inhabitants' indoor preferences. The demonstration in Poland has shown that the implementation of modern IT solutions such as BIMMS platforms requires certain investment outlays but it's able to provide a large increase in work efficiency. Annual cost savings could be up to 30%. As part of the evaluation relative to social indicators, it was shown that the use of BIM4EBB toolkit caused a positive reaction of end users.

The document in its structure consists of 9 chapters and related subsections. Chapter 1 describes objectives, relation with other task and structure of document. Chapter 2 defines the referentiality of the demo site in relation to the geographical and national location, also contains the precise description of the Polish pilot building. This part presents a detailed description of the sensors and meters installation process, in selected residential premises. The chapter describe methodology and a scheme for the testing procedure along with the key performance indicators list to be evaluated. This part applies a detailed demonstration procedure for each of the tools demonstrated on the Polish demo case. Chapters 4 and 5 provide a detailed analysis and evaluation of key performance indicators designated for use in the Polish case on the basis of the main assumptions of the project included in D8.1 and D3.5.

The remaining chapters of the report include, among others, conclusions with lesson learnt, which is a summary of demonstration activities using BIM-based fast toolkit for Efficient rEnovation of residential Buildings at Polish demo site. The limitations of demonstration activities that had appeared in the process independently and due to the restrictions related to the COVID-19 pandemic was also described in this part.

2. Description of the Polish pilot

The Polish pilot site is located in the city of Chorzow, Dabrowskiego 1 street, in the Silesian district. The building was built in 1902, making it the oldest of the BIM4EEB pilot facilities. At the same time providing excellent references for the typical historical residential buildings located in city centres that urgently require the implementation of renovation processes in order to increase their energy coefficients and ensure the improvement of the comfort for the inhabitants. The pilot building takes the form of a 5-storey residential building containing 12 apartments and 3 commercial premises on the ground floor (figure 2). Most of the apartments in the building are equipped with an individual heat source used for the space heating powered by gas from the external installation.

Figure 2 Polish pilot site street view

Figure 3 Common space in the Polish pilot building

In the central part of the building there is a main staircase housing technical shafts with electric energy consumption meters. Gas consumption meters are located at the entrances to individual apartments (figure 3). Chorzow residential building under the ground level has a basement, which contain storage compartments and the main technical room with all the necessary technical services.

Voluntary willingness to participate in the BIM4EBB project was expressed by the residents of 5 apartments inside the building. All activities were carried out on the basis of the informed consent of individual residents who agreed to join the BIM4EEB project, after prior familiarization with the nature and scope of demonstration activities. The building administrator was designated to contact with demo partners (PROCHEM) by the building owner (SOLINTEL). He supported demonstration activities to the extent required.

2.1. Sensors set up

Demonstration activities for selected tools of BIM4EEB tool-kit, in particular the BIM4Occupant and BIMcpd platform, required the installation of a set of devices monitoring detailed internal parameters of usable areas inside selected apartments in the demo building.

Installation activities on the Polish pilot site were based on the adopted solutions included in the report D8.1 Report on management of real Best Practice Examples [8]. Some original assumptions in the above-mentioned document, regarding the installation of sensors have been partially modified due to the initial lack of access to residential premises and the availability of monitoring devices resulting from the interruption of the supply chain related to the development of the Covid-19 pandemic. The number of apartments monitored has remained five. However, due to the concerns of residents, in several cases there was a change of the typed apartment to a reference premises. In addition, there was a quantitative correction of the installed equipment in individual commercial premises due to technical conditions and the final preferences of residents regarding the detailed arrangement of devices. In relation to the change in the configuration of gas meters by the building administration during the demonstration process, which resulted in a lack of technical possibilities, the installation of devices monitoring current gas consumption was abandoned. In order to provide data on quantitative consumption for heating purposes, as part of a replacement solution, the demo partners (PROCHEM) kept readings of the current energy consumption for heating and domestic hot water of individual residential premises, using dedicated meters installed by the administrator.

Installations of monitoring devices, sensors and meters, on the Polish demo case were based on a central unit for communication equipped with a dedicated system Samsung SmartThings. The system of devices installed by demo partners (PROCHEM) on the Polish pilot site included the following components:

Samsung SmartThign's central control device:

The HUB	
	Name: SmartThings V3 Hub Product Weight: 156.8g Product Dimensions:127x29x126mm Connectivity: 802.11a/b/g/n/ac Power supply: AC

To measure in selected rooms: Temperature (^{0}C), Relative humidity (%), Occupancy, Illuminance (ppm):

Multisensor A	
	Name: Multi-sensor 6 Product Weight: 65 g Product Dimensions: 47 x 47 x 38 mm Z-Wave Plus Certified: Yes Power supply: battery power (2×CR123A batteries, 3V, 1500mAh).

To measure in selected rooms: Temperature(^{0}C), Relative humidity (%), CO^2 (ppm):

Multisensor B	
	Name: Netatmo Healthy Home Coach Product Weight: 153 g Product Dimensions: 45x 45 x 155 mm Power supply: AC Connectivity technology: Wireless

To measure the current consumption of electricity based on the readings of existing meters following devices were used:

Electric Energy meter	
	Name: NorthQ power Product Dimensions: 93x 75 x 38 mm Connectivity technology: Wireless Power supply: battery power (2×AA).

As part of the final setup the following installation schema was used (figure 4). The main communication was based on the central unit connected to monitoring devices. Samsung SmartThings API integration with the BIMMS platform was provided by WP4 partners to retrieve data from sensors installed in individual apartments.

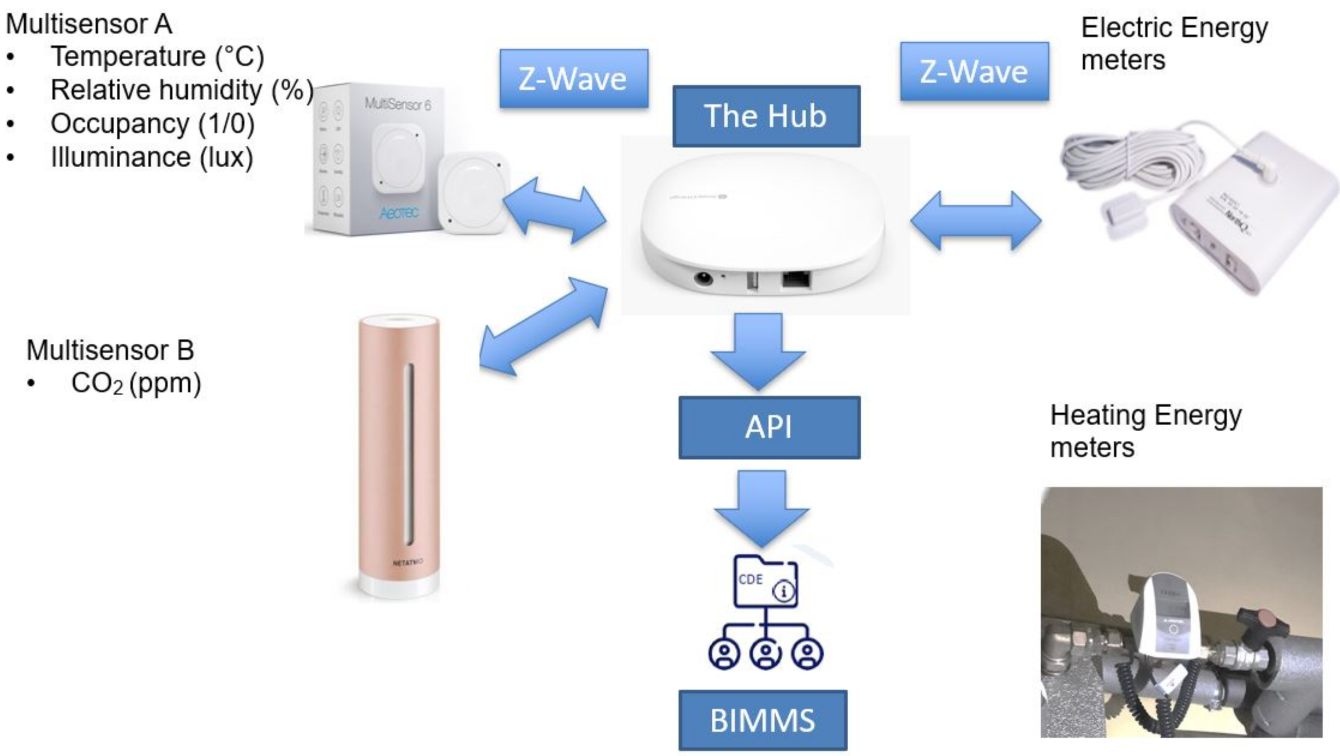


Figure 4 Polish sensors' setup

During the installation of monitoring devices inside individual rooms, to gain the most appropriate reading resulting, most of the sensors were placed on walls perpendicular to the external walls in the middle of the length of rooms. Partners responsible for equipment installation (PROCHEM), had to take into account the constraints related to the location of the furniture and the position of the power points and, in some cases, the special preferences of individual owners (figure 5).

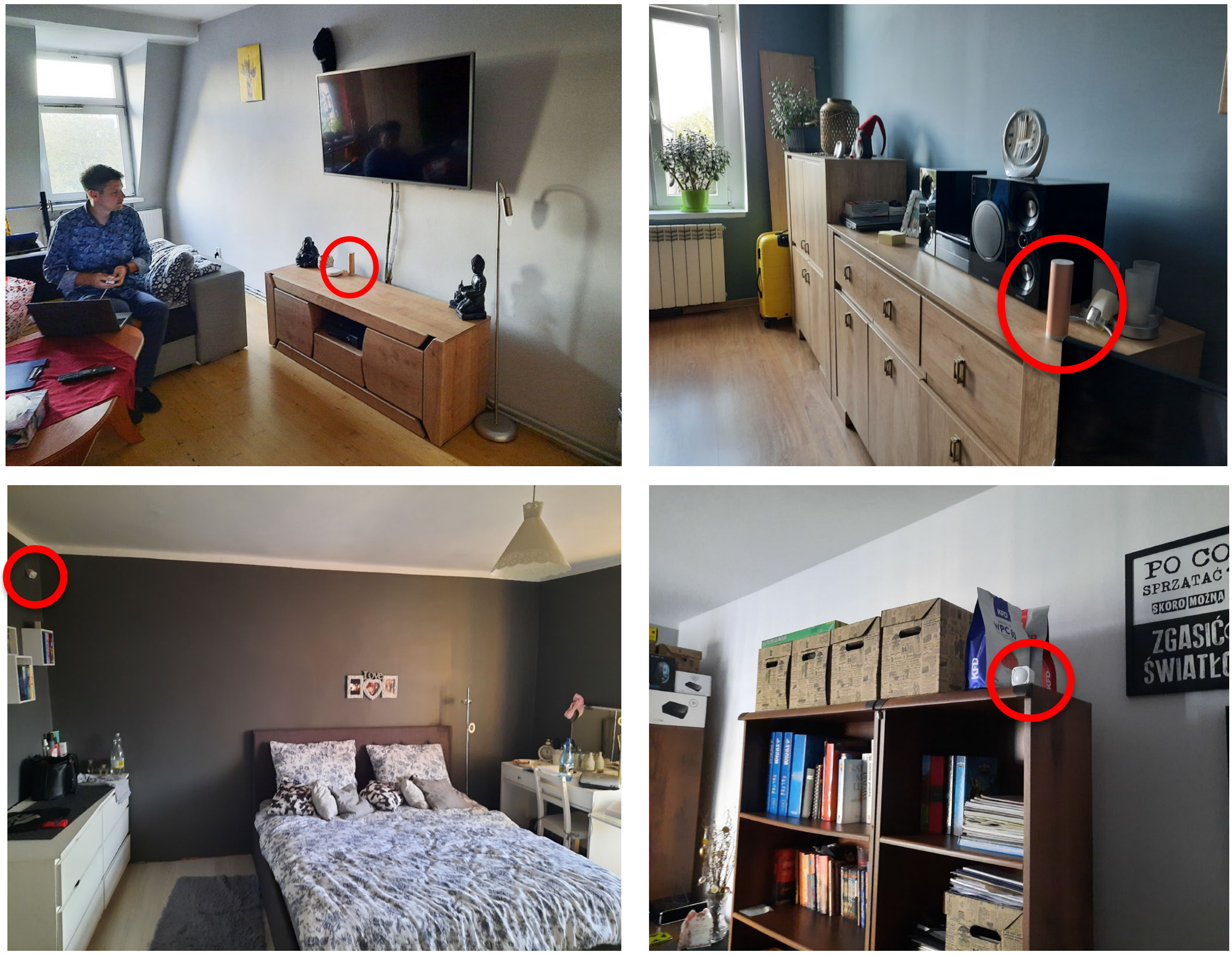


Figure 5 Installation of sensors inside apartments

As part of the detailed configuration Multisensors B were installed in living rooms, while Multisensors A were installed in bedrooms (figure 5). In addition, dedicated meters for the current electricity consumption had been provided in the technical shaft on the main staircase (figure 3). All the above devices communicated via the Samsung SmartThings platform, with the use of additional dedicated scripts for data purpose integration. The central units were installed in the common space of the building within the main staircase.

Due to the fact that devices included in the system required access to the Internet for communication, demo partners (PROCHEM) provided in the common space, a dedicated Internet network using a main router and, in the case of a significant distance from the central unit, also signal amplifiers (repeaters).

In order to obtain the most averaged results, sensors were installed in the reference residential premises within the ground floor, 1st floor, 3rd floor and the 4rd floor. Table 1 is presenting the final setup of sensors monitoring internal factors inside individual apartments in relation to the selected spaces.

Table 1 Polish site sensors' setup

		APARTMENTS							
		apartment A (GF)	**apartment B (floor 1)**	**apartment C (floor 1)**		**apartment D (floor 3)**		**apartment E (floor 4)**	
DEVICES		living room	living room	living room	bedroom	living room	bedroom	living room	bedroom
Multi-sensor	Temp	x	x	x	-	x	x	x	x
	Humidity	x	x	x	-	x	x	x	x
	Occupancy	-	x	-	-	-	x	-	x
	Luminance	-	x	-	-	-	x	-	x
IAQ Sensor	CO2	x	-	x	-	x	-	x	-
	PM2.5	-	-	-	-	-	-	-	-
	PM10	-	-	-	-	-	-	-	-
	VOC	-	-	-	-	-	-	-	-
Electric power meter		-	-	x		x		x	
GAS meter		-	-	-		-		-	
Heat cost allocator		x	x	x		x		x	
HUB		x	x	x		x		x	
Internet connection		x	x	x		x		x	

3. Evaluation of the pilot

The BIM4EEB toolkit demonstration activities on the Polish demo case have provided an assessment of dedicated Key Performance Indicators (KPIs). The detailed scope of activities was based on the guidelines included in D8.1 Report on management of real Best Practice Examples [8] and D3.5 Measurement and Verification protocol [3]. The final KPIs list that has been evaluated on the Polish pilot site, in relation to individual tools is presented in annex I. The schedule contains updates in terms of coefficients that were not available for evaluation due to lack of implementation related functions in the final versions of the software and inability of purchasing dedicated monitoring devices caused by Covid-19 pandemic supply chain disruption.

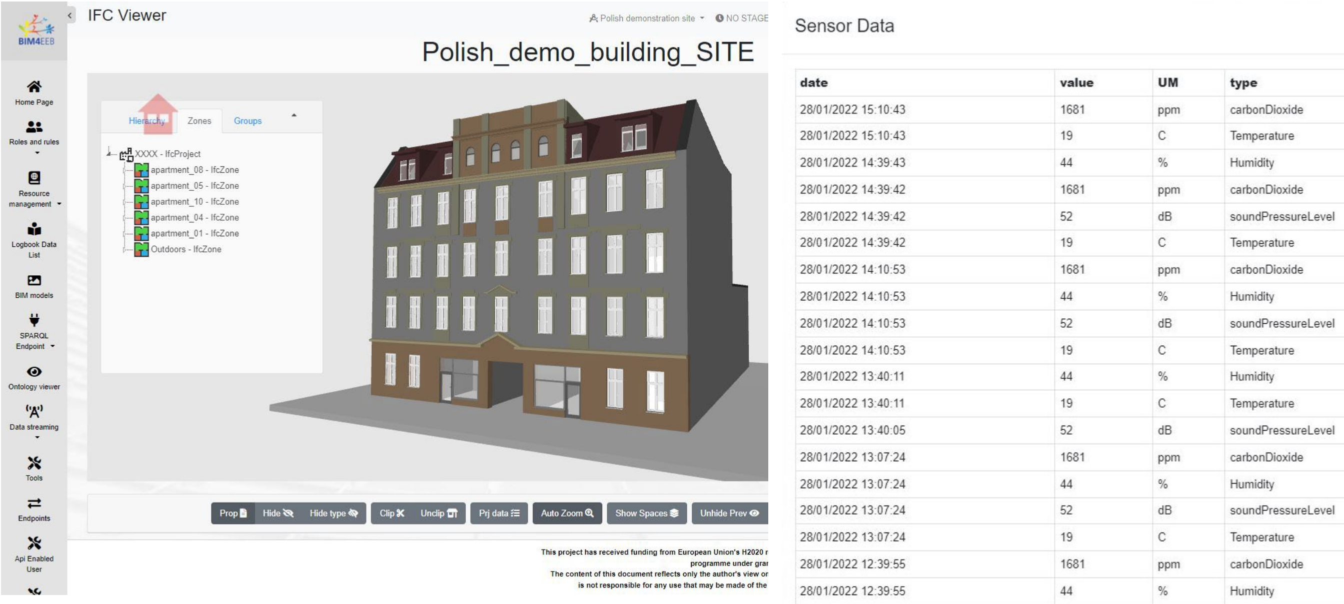
3.1. Tools demonstration process

General demonstration process of the BIM4EBB toolkit was developed in the field of activities of work package 8 (WP8). Final scheme of activities was aimed at defining the necessary steps needed to carry out the most effective tool validation process. Process has been prepared with reference to the D8.1 Report on management of real Best Practice Examples [8]. General scheme served as the guideline for the demonstration process. According to assumptions the activities were divided into two main areas. In the first stage, the process was focused to the demonstration part of individual tools (Tool Demonstration). In the second part the scheme defined activities necessary to assess dedicated indicators (KPIs Demonstration).

General tools demonstration process was performed as follows. During first step tools owners specified the data that would be necessary to carry out the demonstration. In the second stage, demo partners made the necessary actions to provide the required data. Thanks to the data collected by the demo site, the tool owner was able to perform the initial settings of the tool. Before the tools were demonstrated by end users, among others by inhabitants, designers and building administrator, dedicated Workshops were performed. In the next step, the end users practised tools operating with the support of tool developers and demo partners. This phase was followed by an analysis of the data collected by demo partners. The final step was the assessment of the individual Key Performance Indicators (KPIs).

3.1.1. BIMMS platform demonstration

The demonstration process of the BIMMS platform, the tool provided as a result of WP4 (work package 4), included a number of activities that formed the basis for this task by the partners responsible for the process on the Polish demo case (PROCHEM). First step was to create a BIM model in IFC format based on archival documentation provided by the site owner (SOLINTEL). Test model was provided with LOD 200 accuracy according to Level of Development (LOD) Specification Guide [13]. Next step was to create a dedicated accounts inside BIMMS platform, in accordance with the applicable registration procedure contain in D4.9 (table 25) [4]. The main user account received the role of Project administrator, giving broader management rights. After a dedicated account was created, the previously created IFC file of the Polish demo building was loaded into BIMMS platform. For this purpose, the Resource Management module was used, in a particular new resource feature, along with the subsequent stages of the process. After loading the test model, the object and its structure were traced using the BIM Models module. Test model in addition to the geometry of the building covered the structure of the spaces for residential premises that have joined the BIM4EBB research project. During next step the tool owner (OneTeam) carried out the process of integrating sensor and meters readings installed on the Polish demo case, inside the BIMMS platform. The Samsung SmartThings platform API was used for data streaming integration (figure 6).



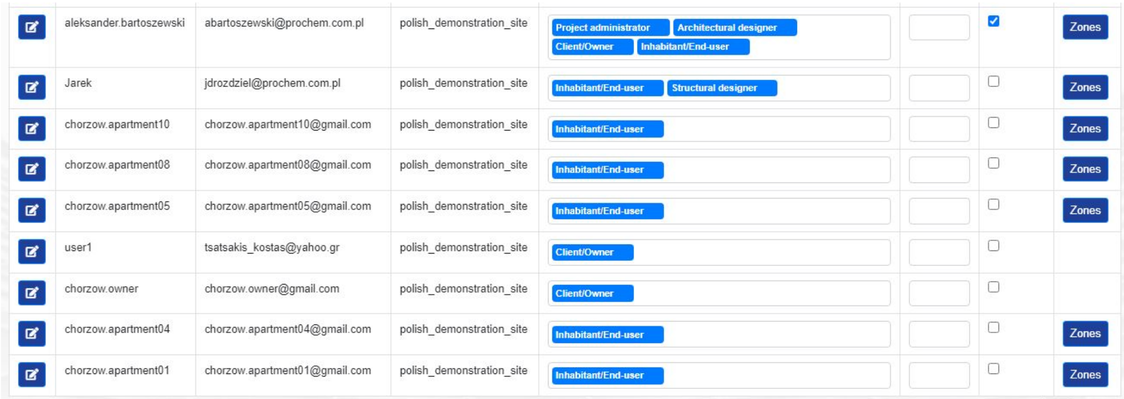
date	value	UM	type
28/01/2022 15:10:43	1681	ppm	carbonDioxide
28/01/2022 15:10:43	19	C	Temperature
28/01/2022 14:39:43	44	%	Humidity
28/01/2022 14:39:42	1681	ppm	carbonDioxide
28/01/2022 14:39:42	52	dB	soundPressureLevel
28/01/2022 14:39:42	19	C	Temperature
28/01/2022 14:10:53	1681	ppm	carbonDioxide
28/01/2022 14:10:53	44	%	Humidity
28/01/2022 14:10:53	52	dB	soundPressureLevel
28/01/2022 14:10:53	19	C	Temperature
28/01/2022 13:40:11	44	%	Humidity
28/01/2022 13:40:11	19	C	Temperature
28/01/2022 13:40:05	52	dB	soundPressureLevel
28/01/2022 13:07:24	1681	ppm	carbonDioxide
28/01/2022 13:07:24	44	%	Humidity
28/01/2022 13:07:24	52	dB	soundPressureLevel
28/01/2022 13:07:24	19	C	Temperature
28/01/2022 12:39:55	1681	ppm	carbonDioxide
28/01/2022 12:39:55	44	%	Humidity

Figure 6 BIMMS platform - polish demo building 3D model with sensors' data integration

During the initial step of the demonstration process as part of the training activities for the BIMMS platform, a dedicated workshop (on-line meeting) conducted by OneTeam took place on November 22th, 2021. The workshop was attended by PROCHEM team, consisting of representatives for the architectural, structural, and HVAC departments. The workshop demonstrated how to use the BIMMS in typical professional context focusing on the main functionalities to manage documents, BIM models, Linked data, and sensors data streaming. A set of example procedures were presented to describe the most common use cases supported by the platform:

- connect and login with BIMMS, invite and assign roles and permissions to users;
- create, edit, delete and share document and linked data resources;
- manage the IFC spatial and hierarchy data through the creation of new IfcZones;
- retrieve existing IfcZones, IfcSpaces, IfcGroups to define work locations in BIM models;
- manage activities, alerts, and sensor measurements;
- collect the data using the BIMMS SPARQL Endpoint.

After the completion of the sensor integration and the training activities, dedicated accounts were created at BIMMS platform for end users, including each of the residential premises participating in the project, demo partners and building administrator (figure 7)



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chorzow.apartment05	chorzow.apartment05@gmail.com	polish_demonstration_site	Inhabitant/End-user	☐	Zones
user1	tsatsakis_kostas@yahoo.gr	polish_demonstration_site	Client/Owner	☐	
chorzow.owner	chorzow.owner@gmail.com	polish_demonstration_site	Client/Owner	☐	
chorzow.apartment04	chorzow.apartment04@gmail.com	polish_demonstration_site	Inhabitant/End-user	☐	Zones
chorzow.apartment01	chorzow.apartment01@gmail.com	polish_demonstration_site	Inhabitant/End-user	☐	Zones

Figure 7 BIMMS platform users management module

As part of the demonstration activities, at the Polish demo site BIMMS platform was assessed according to key performance indicators (KPIs), in particular related to the renovation process (REP), economic (ECON) and social (SOC) aspects. The evaluation of the tool during the renovation process was based on the renovation scenarios developed and reported in the deliverables D2.1 and D2.2.

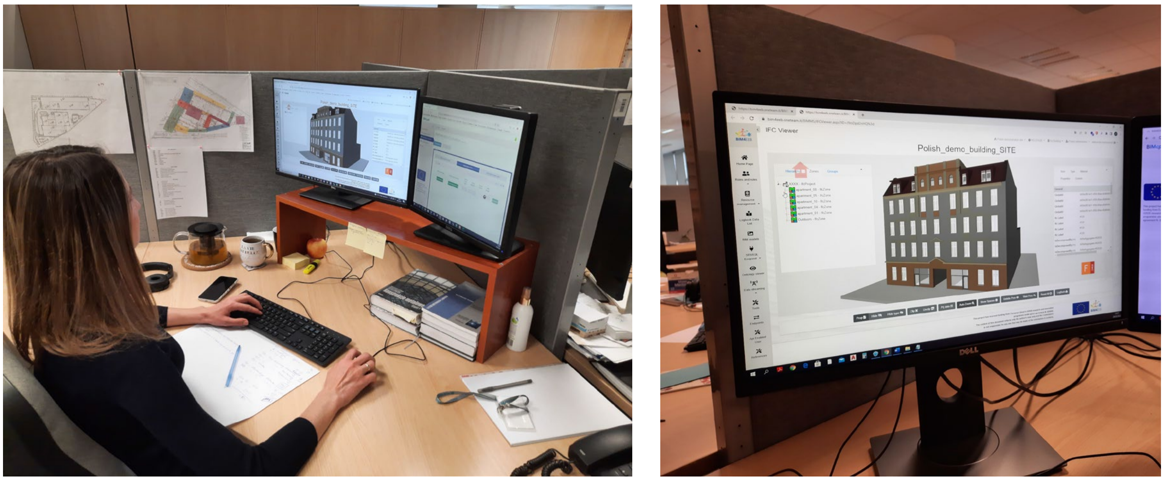

Figure 8 BIMMS platform demonstration by end users (structural engineer)

3.1.2. Fast mapping demonstration

Fast mapping toolkit demonstration activities took place at Polish pilot site at Chorzow on 1st and 2nd February 2022. The demonstration activities were carried out in one of the apartments, whose inhabitants joined the BIM4EEB research program. The apartment that was selected for the test activities, is a typical reference of premises in the pilot building. It is located on the third floor of the building. The apartment has a usable area of approximately 90 m^2, contain living room, 2 bedrooms, kitchen, bathroom and the corridor.

The demonstration activities were attended by: toolkit owner (RISE), demo partners (PROCHEM) and apartment's owner. During the tool demonstration, WP5 partners provided training for apartment owners and demo partners.

February 1, 2022

In the first stage of toolkit demonstration, laser scanning of all rooms within the apartment was carried out. As a result of these activities, a point cloud was generated.

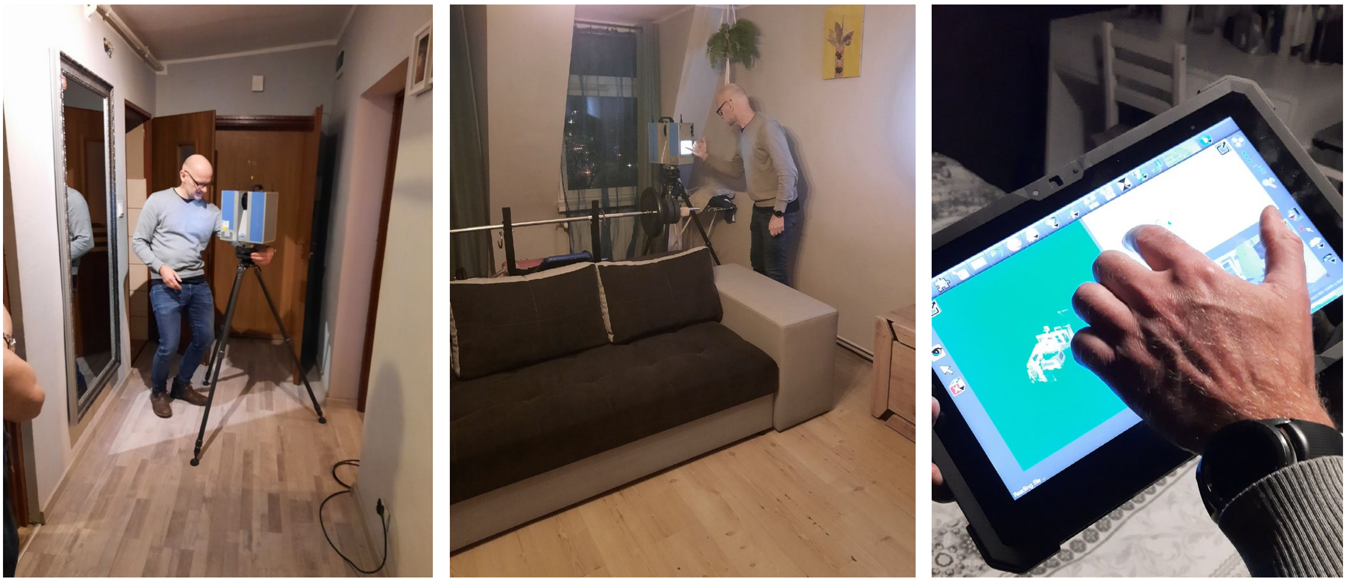

Figure 9 Fast mapping toolkit demonstration

The fast mapping procedure in the first stage was as follows:

1. Set up the laser scanner quality. The survey was carried out with a medium coverage set up
2. Survey of the whole apartment with the laser scanner
3. Reproduction of point cloud within the software released by the laser scanner producer
4. Merge together the different developed points cloud

February 2, 2022

During the second day of the tool demonstration, a points cloud was imported through Unity 3D application in order to properly position it using Hololens. Once this process was complete, it was possible to create several 3D objects inside Hololens based on the points cloud. In the next step, in one of the rooms, a prototype of senor stick device was used. After completing this procedure, a test IFC file was generated and saved.

The second stage of fast mapping demonstration was as follow:

1. Import and download of the point cloud in the PC
2. HoloLens based activity - import of the point cloud in 3D unity.
3. With HoloLens capability to rotate objects, the point cloud was positioned according to real objects
5. Inside HoloLens 3d objects were created to survey imported point cloud.
4. Survey test with sensor stick to detect electric wires, plumbing etc.
6. IFC file was generated and saved through fast mapping toolkit software.

During Fast mapping toolkit demonstration, the approximate time of each activity was recorded throught WP8 representatives to check assesment of the indicators related with the toolkit.

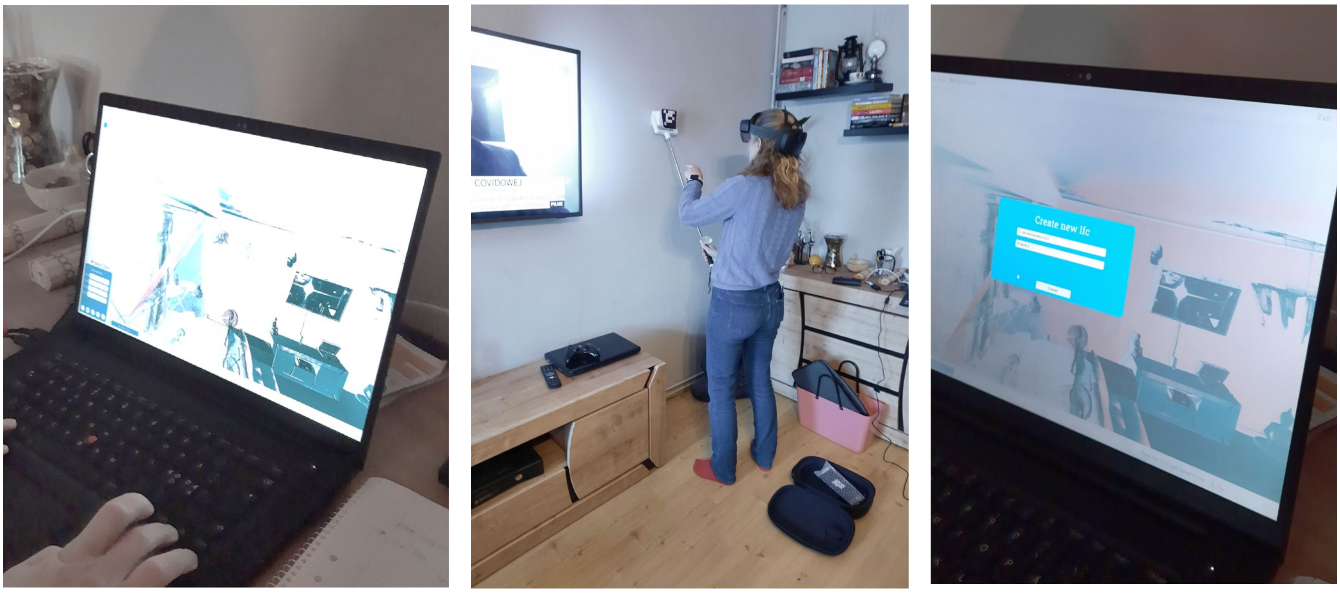

Figure 10 Fast mapping toolkit demonstration

3.1.3. BIM4Occupants demonstration

The demonstration process of the BIM4Occupants tool at the Polish site at Chorzow consisted of several stages necessary to carry out on-site activities. In the first stage, an on-line meeting was conducted by the tool owner (Suite5) aimed at presenting the final BIM4Occupants platform for the demo side (PROCHEM). As part of the presentation, the final version of the tool was presented with all available functionalities. The developed user interface was discussed in detail. In addition, it was also presented how to create new accounts for end users with all necessary login procedure details (considering also users' registration in BIMMS platform).
In the initial stage, dedicated user accounts were created on the BIMMS platform for each apartment and the building administrator. During the second step, dedicated accounts were created on the BIM4Occupants platform using dedicated Token codes (Figure 11) from BIMMS platform.

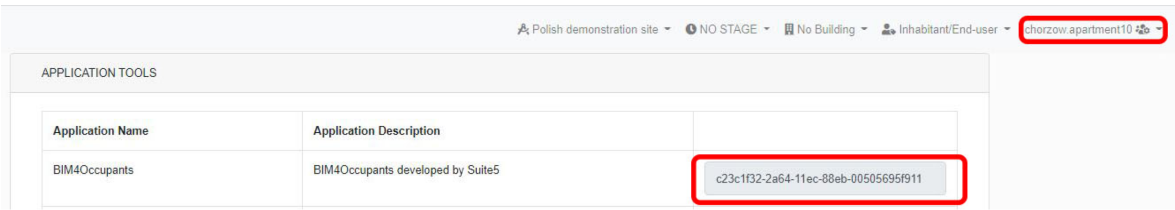

Figure 11 BIMMS platform Application Tools tab – token code

As part of the second stage of the process, the demo partners (PROCHEM) according to the tool specification developed by the owner (Suite5) created dedicated users' manuals translated in Polish for residents of premises participating in the BIM4EEB program and the building administrator. On November 22, 2021 at the Polish pilot site a dedicated workshop for the building administrator and inhabitants was provided by the demo partners (PROCHEM) and the tool developer (Suite5) (figure 11). During on-line presentation, user interface and all available features of the BIM4Occupants platform were discussed. The presentation part took place in English and it was translated to Polish (by PROCHEM) to the workshop participants. General part was followed by detailed meetings with residents to discuss in detail the platform's user interface and available features.

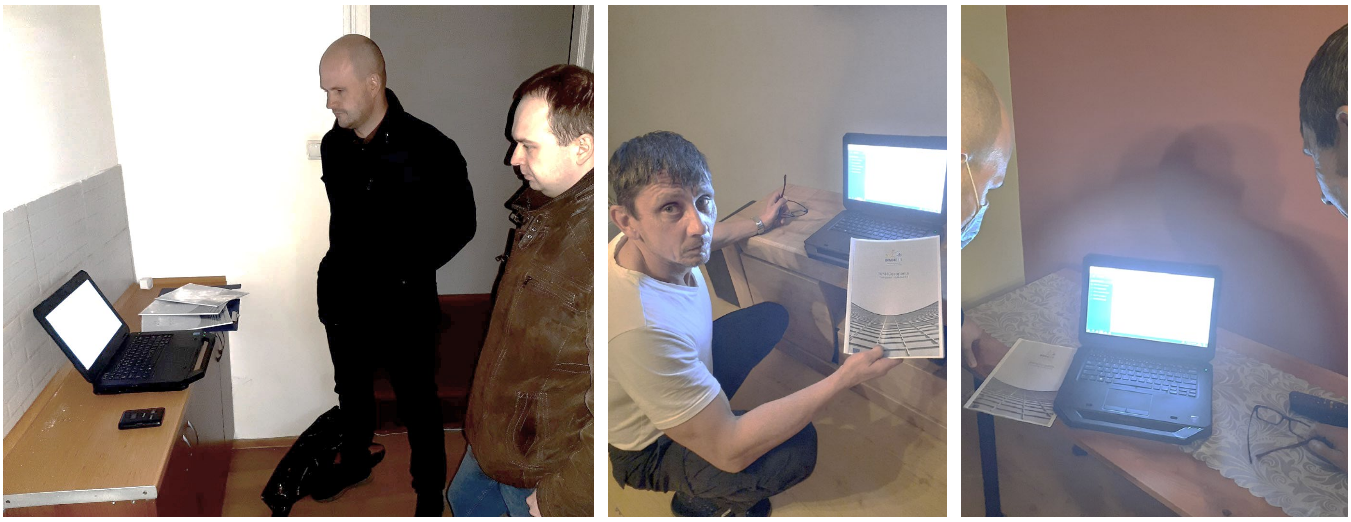

Figure 12 BIM4Occupants workshop

The demonstration process of the BIM4Occupants platform on the Polish pilot was as follows. At the beginning, BIM4Occupants users were encouraged to provide information about gender and age of each inhabitant to be introduced in the user profile tab (figure 13). It was explicitly stated that this information is optional.

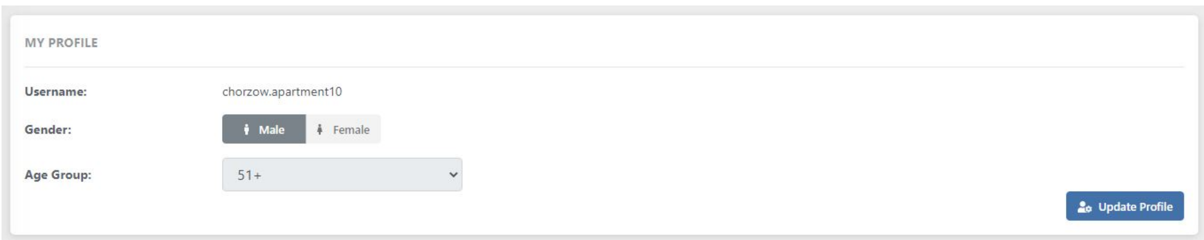

Figure 13 BIM4Occupants my profile feature

In the second stage, demo partners get a quick overview of "determine hourly occupancy schedules" functionality (figure 14). The users were encouraged to provide their feedback in order to be able to provide a more accurate estimation of occupancy profiling information that is further useful for the operational management of building activities.

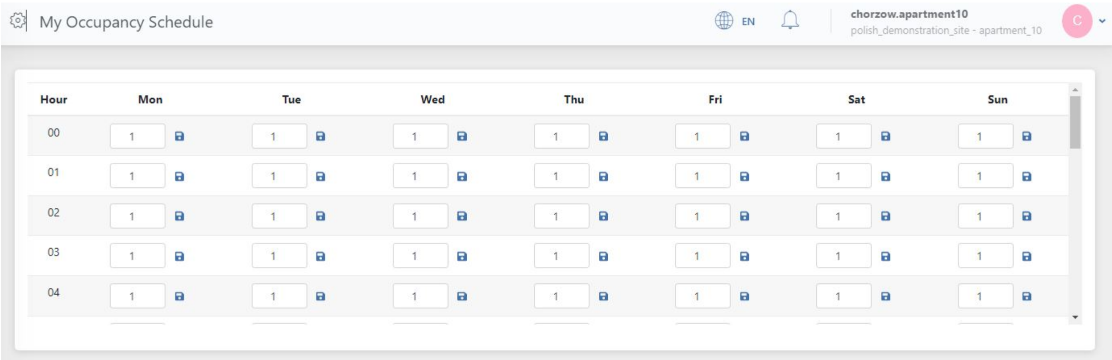

Figure 14 BIM4Occupants occupancy schedule feature

In the next phase, inhabitants were prompted to provide feedback about their thermal sensation and visual comfort preferences inside the BIM4Occupant application with a weekly frequency, using the available user interface (figure 15). This feedback is very useful for the extraction of typical thermal and visual comfort boundaries of the users.

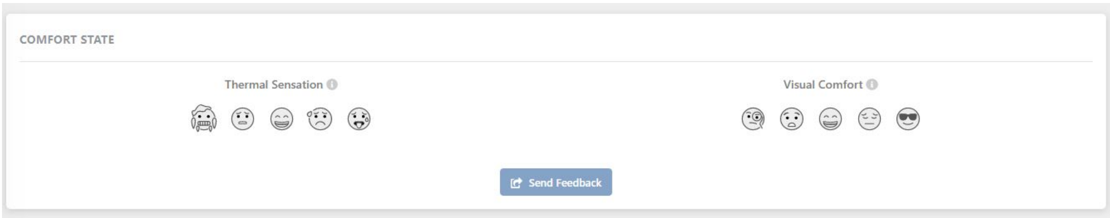

Figure 15 BIM4Occupants comfort state feature

Thanks to the integration of data stream from installed and on-line measurements from the nearest meteorological stations inside the BIM4Occupants platform, inhabitants obtained real-time information about basic temperature, humidity, illuminance and CO_2 concentration level inside the apartment and outdoors (figure 16).

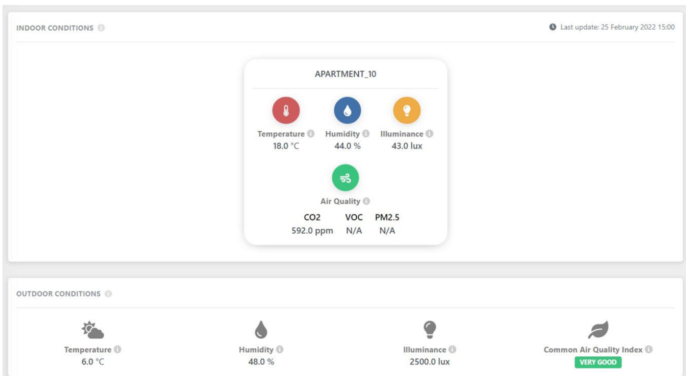

Figure 16 BIM4Occupants indoor conditions tab

End users were demonstrated the functionality of getting access to real ambient conditions about temperature, humidity and illuminance. Constant measurements of real-time electricity consumption are available on the BIM4Occupants platform.

Demonstration process of the BIM4Occupants platform, due to the advanced age of some users and difficulties with the operation of broadly understood IT tools, was supported by the demo partners (PROCHEM) to the extent necessary for the proper demonstration of the tool.

3.1.4. BIMcpd demonstration

The demonstration of the BIMcpd platform on the Polish demo case was preceded with the installation of sensors in selected apartments. Firstly, the sensors' data stream has been integrated into BIMMS platform and in the next step inside BIMcpd platform by the tool owner (UCC). In the initial phase the tool owner (UCC) created a dedicated account for the demo partners (PROCHEM). All demonstration activities performed by end-users were supported by the tool owner. As part of the training activities in relation with BIMcpd, UCC conduted a dedicated workshop (on-line meeting) at November 24th. The workshop was attended by the demo partners - PROCHEM team, consisting of HVAC designers, architectural and structural department representatives (figure 17).

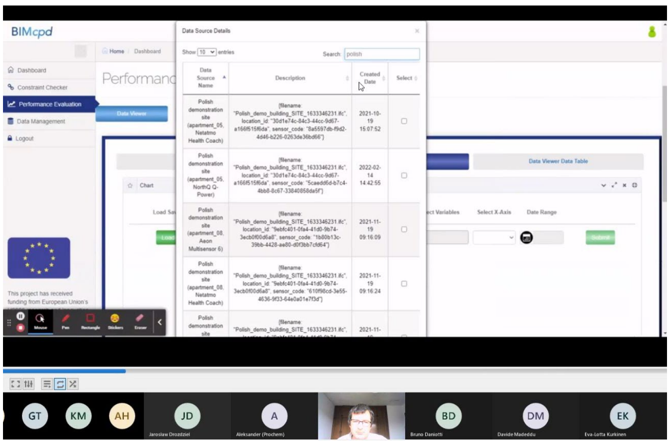

Figure 17 BIMcpd workshop

The demonstration of BIMcpd platform on the Polish pilot site focused on the initial phases of the renovation process. A renovation scenario developed in D2.1 and D2.2 was adopted.

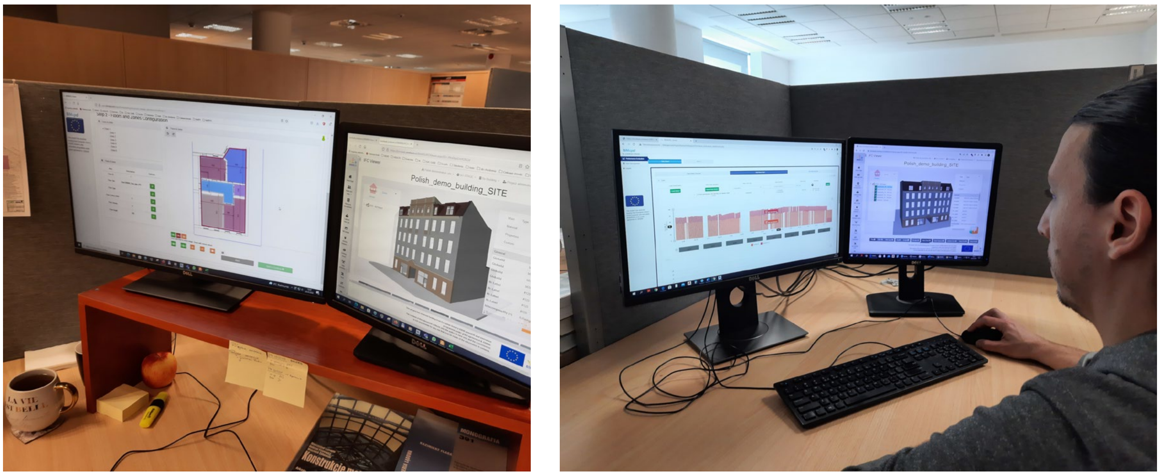

Figure 18 BIMcpd demonstration by end-users (HVAC designer)

3.2. Polish site Final Workshop

In order to summarize the demonstration activities in Poland, on the February 15, 2022, partners responsible for the demonstration of BIM4EEB toolkit on the Chorzow demo case carried out the final workshop. The meeting was provided as an on-line event for a wide audience. In addition to the BIM4EEB consortium members, the workshop was attended by engineers, designers, Polish building administrator and the Polish member of the Advisory Board.

WORKSHOP AGENDA:

- February 2, 2022 (14-16 CET)

Start	End		Presenter
14:00	14:20	**1. Welcome, introduction to the project**	Aleksander Bartoszewski (PROCHEM)
14:20	14:30	**2. Polish pilot site presentation**	Aleksander Bartoszewski (PROCHEM)
		3. Demonstrated tools presentation:	
14:30	14:50	• BIMMS platform	Davide Madeddu (One Team)
14:50	15:10	• Fast mapping toolkit	Eva-Lotta Kurkinen (Rise)
15:10	15:30	• BIM4Occupants	Kostas Tsatsakis (Suite5)
15:30	15:50	• BIMcpd	Eoin O'Leidhin (UCC)
15:50	15:55	**4. Surveys collection**	
15:55	16:00	**5. Conclusions**	

Figure 19 Final Workshop in Poland

As part of the dedicated workshop, the background of the BIM4EEB project was presented in the introduction. Additionally, the exact characteristics of the Polish pilot site and the sensors' installation inside residential premises were presented. In the second part, a detail presentation provided by the owners of the tools demonstrated on the Polish demo case took place.

4. Primary KPIs Assessment

As part of the demonstration activities on the Polish demo case, the following primary indicators were examined in relation to individual BIM4EBB tools.

4.1. Renovation process indicators

4.1.1. REP 1 Renovation Time Reduction

According to D3.5 REP1 is defined as the time savings performed during the renovation process based on better management of the renovation activities, compared to the baseline/planned process[3]. At the Polish demo case the reduction of the time during renovation process was demonstrated with BIMMS platform, Fast mapping toolkit and BIMcpd tool. Activities on the Polish pilot building were focused on the initial stage of the renovation process: the inventory phase and the engineering phase.

In order to evaluate time reduction in relation to selected BIM4EBB tools demonstration, the time of analogous activities during the renovation process performed in a traditional way were first estimated. Tables 2 presents (according to Grant Agreement) following times for the renovation schedule in the Polish demo case.

Table 2 Traditional estimated schedule for the renovation in the Polish pilot site

Polish demo building		Time of renovation divided into common steps (in weeks)			Total
Type	Size(m^2)	Inventory	Engineering	Renovation	Time
Private	1330	**4**	**16**	48	68

<u>Inventory phase:</u>

The assessment of the renovation time reduction rate in the inventory phase was based on demonstration of the Fast mapping toolkit. The demonstration of the tool in the Polish demo case took place in relation to a certain range of building structure inside one of the typical apartment. The Fast mapping toolkit was demonstrated in the flat with 90sq meters usable area, consist of living room, kitchen, 2 bedrooms, bathroom and hallway. All activities performed are shown in table 4. Figure 21 presents point cloud generated for the demonstrated flat.

In order to determine the time needed for inventory of the apartment using the traditional approuch, few activities were performed according to table 3 for one of the 6 rooms included in the apartment. The following results have been assessed:

- floor plan inventory inside room by 2 people - approx. 20 minutes.
- inventory of the basic buildings' elements inside room by 2 people – approx. 25 minutes
- time for the possible measurement of missing elements – approx. 5 minutes

The total time needed for the inventory of one room (figure 20) by 2 people was about 50 minutes. The estimated time needed for the inventory of the entire apartment by 2 people was: 50 minutes x 6 rooms = approx. 300 minutes = 5 hours.

Table 3 Traditional inventory process inside demonstrated apartment

No	Baseline inventory activities	Person /Activity time (approx.)
1	Floor plan inventory	2 workers / 2 hours
2	Measuring each room building components	2 workers /2.5 hours
3	Measurement of the missing parts, if needed	2 workers / 0.5 hour
4	Identification of the position of electrical systems and other constraints from site survey*	not possible to be fully estimated
5	Gas and heating distribution systems identification measurements of each system component *	not possible to be fully estimated
6	Inspection activities dedicated to create of technical assessment	Not applicable

* This activity require open-pit work, wasn't possible to perform on the demo site

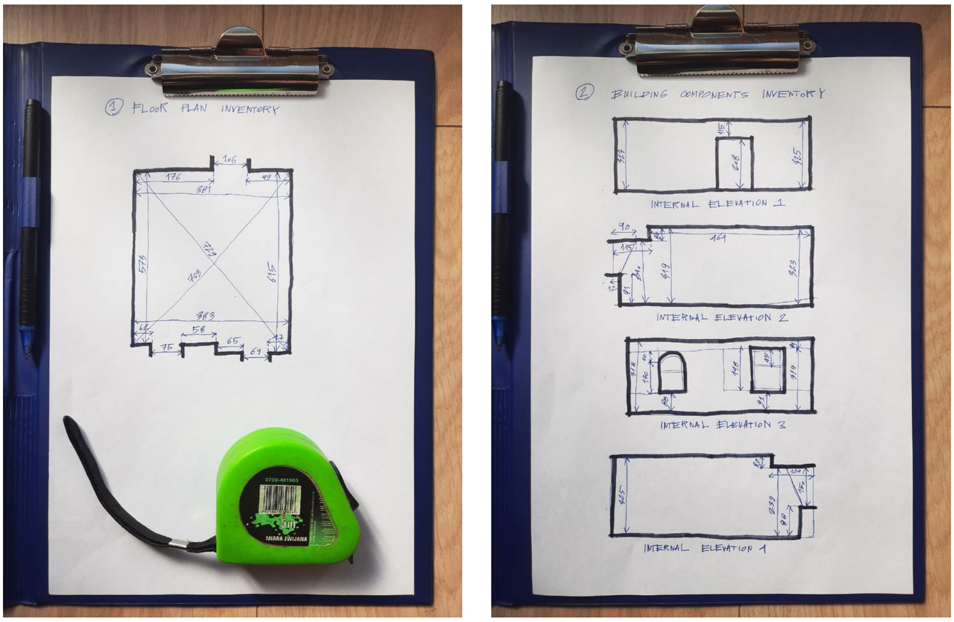

Figure 20 Typical room floor plan and building elements inventory basic sketches

Table 4 Fast mapping process inside demonstrated apartment

No	Fast mapping toolkit process	Person /Activity time
1	• Set up the laser scanner quality. The survey was carried out with a medium coverage set up • Survey of the whole apartment with the laser scanner • Reproduction of point cloud within the software released by the laser scanner producer • Merge together the different developed points cloud	1 worker / approx. 2 hours (coloured version of point cloud) 1 worker / approx. 1 hour (not coloured point cloud – process is at least twice fast)
2**	• Import and download of the point cloud in the PC • HoloLens based activity - import of the point cloud in 3D unity. • With HoloLens capability to rotate objects, imported point cloud was positioned according to real objects • Inside HoloLens some 3d object was created to survey imported point cloud. • Survey test with sensor stick to detect electric wires, plumbing • IFC file was generated and saved through fast mapping toolkit software	1 worker / 2 hours

** This stage is considered as engineering phase of renovation process related to BIM model creation base time during traditional inventory process

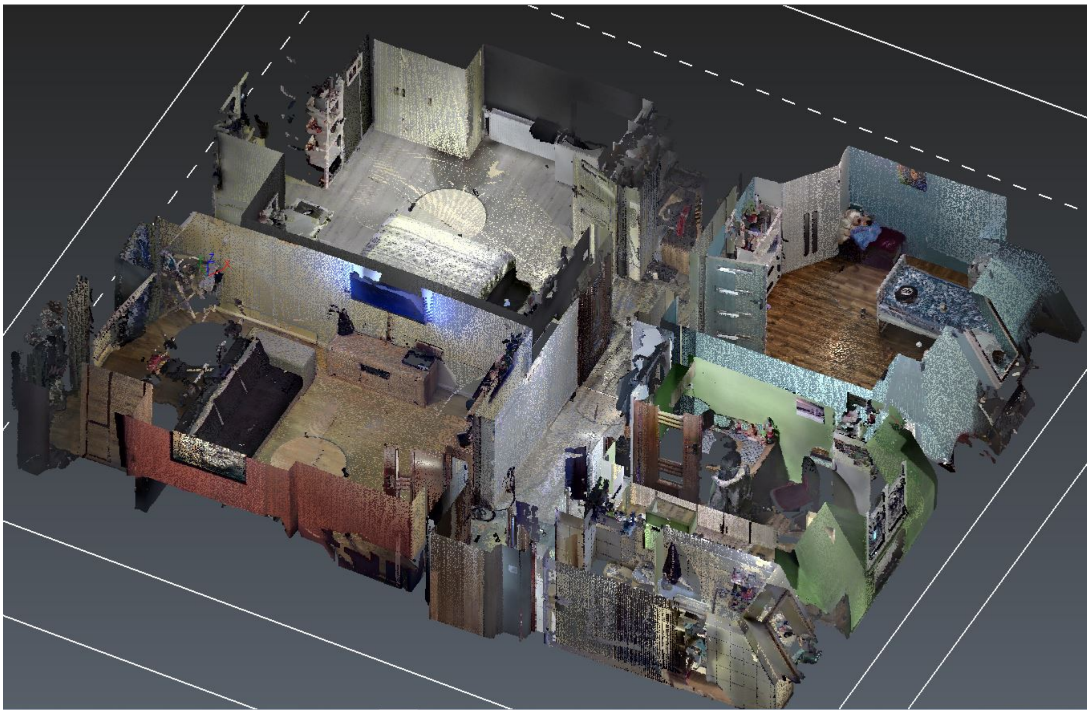

Figure 21 Point cloud generated for the demonstrated apartment

Determining the time reduction in the case of the other activities performed in the inventory process, using Fast mapping toolkit, was impossible due to the lack of technical possibilities to determine baselines. The sensor stick functionality that gives the ability to detect installations running in walls is a specific added value to the inventory process. This process is not possible to perform in a standard approach without open pits and even then, this verification is only possible to a small extent. The final functionality of the Fast-mapping toolkit, after the end of the prototype phase, can be a very high added value in this respect and strongly deepening the range of data obtained during the inventory process.

The final results of time reduction for inventory activities with the Fast-mapping toolkit in relation to traditional approach are as follows:

- The average time of traditional inventory process for demonstrated apartment by 2 person - approx. 5 hours.
- Laser scanning time of apartment by one person - point cloud (no coloured) approx.1 hour

The estimated average time reduction for inventor phase using laser scanning was approximately 80%.

Engineering phase:

The assessment of the time reduction rate in the design phase using the BIM4EBB toolkit was based on following tools demonstration: Fast mapping toolkit in the field of creating a 3D building structure model in IFC format, data flow management process using the BIMMS platform (Common Data Environment), and BIMcpd platform in the field of supporting the initial design. The diagram bellow (figure 22) presents the demonstration workflow of the tools for the Polish pilot building.

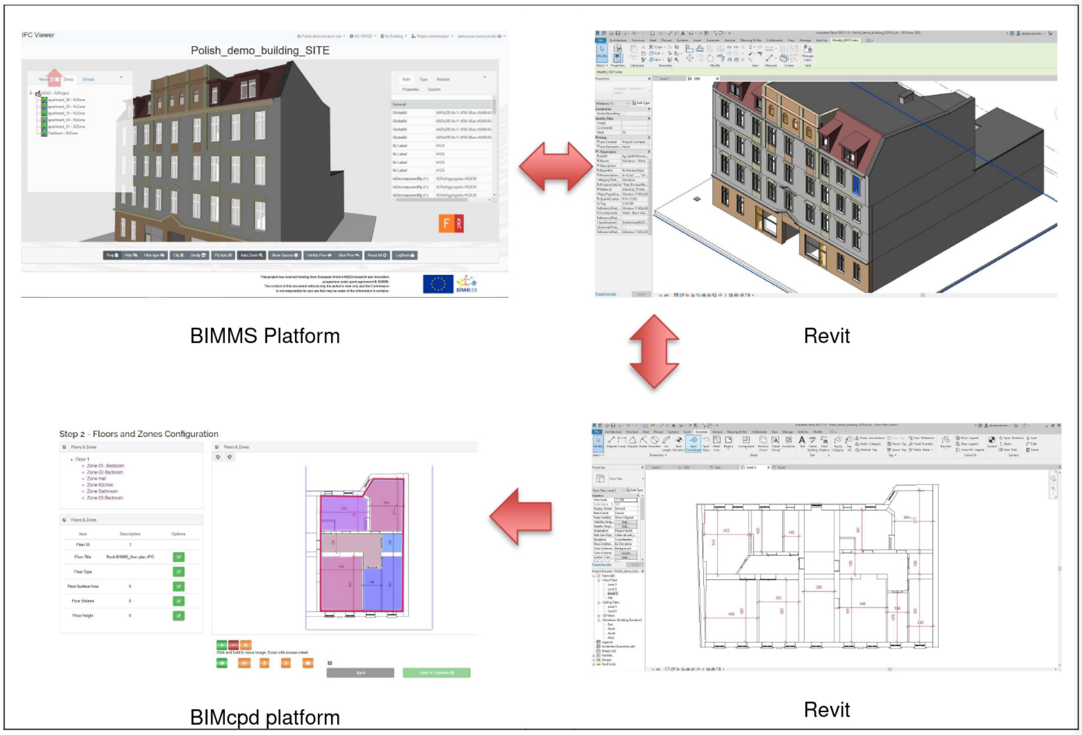

Figure 22 Engineering phase toolkit demonstration workflow

Fast-mapping toolkit:

Fast-mapping toolkit on the Polish pilot site was demonstrated with the current prototype functionality of the tool. The process is described in detail in deliverable D5.5[6] . At this stage of the tool development, there was no time reduction associated with the generation of the IFC model. For comparison, the traditional method based on building a 3D model using an authoring tool, e.g. Revit according to inventory measurements in CAD files has been taken into account. Analysis of the renovation, using the fast-mapping toolkit in relation to the traditional approach according to renovation scenarios contained in D2.2 [2] is provided in Annex II.

BIMMS platform:

The time reduction associated with the demonstration of BIMMS platform as a (CDE) Common Data Environment were based on the results contained in D4.9 [4] and D4.10 [5] The BIMMS works mainly as a central platform to store, share and manage files. In order to calculate the time reduction within the activity of the renovation process the tool owner (OneTeam) made a comparison of the following workflows.

BIMMS platform workflow:

A designer, or a user in another professional role, logins to the BIMMS, upload a BIM file, set permissions to his\her team to collaborate, use the BIMMS' BIM viewer to view and check the model, upload and download changes to the BIMMS using the IFC model as reference or directly using the native model in the authoring tool of choice.

Context and environment: The BIM Model is about 50Mb.

The internet connection is a 20MBit\s

Is expected a cycle of editing and model updates of 10 times

Duration of activities in total was 565 seconds

BIMMS Workflow

Time in seconds

activity	Time to complete	Run at once or multiple times	Total time	Time affected mostly by	Additional description
1) Login to BIMMS	5	1	5	User	
2) Create resource	60	1	60	User	
3) Upload file for resource	20	1	20	Internet connection	
4) Set permissions	30	1	30	User	
5) Conversion time (BIM Models)	300	1	300	Server	
6) Download BIM Model	20	1	20	Internet connection	
7) Visualize on Viewer (BIM Models)	5	10	50	Server	
8) Update BIM Model in the BIMMS (POST)	1	10	10	Server	
9) Update BIM Model in the Authoring Tool (GET)	1	10	10	Server	
10) Change Revision \ Status	60	1	60	User	
TOTAL			565		

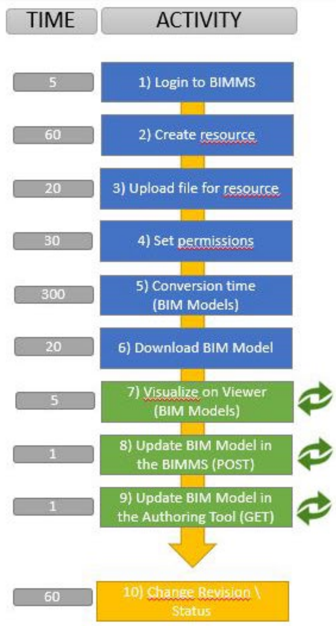

Figure 23 BIMMS platform workflow results

Typical traditional workflow:

A designer or other professional role login to the file sharing platform, upload a BIM file, set permissions to his\her team to collaborate.

As the most file sharing system do not have an embedded BIM viewer, the user uses software viewers installed in his\her device.

In the traditional workflow, the documents are shared multiple times uploading and downloading the updated versions.

Context and environment:

The BIM Model is about 50Mb.

The internet connection is a 20MBit\s

Is expected a cycle of editing and model updates of 10 times

Duration of activities in total was 2055 seconds

Traditional Workflow

Time in seconds

activity	Time to complete	Run at once or multiple times	Total time	Time affected mostly by	Additional description
1) Login to filesharing	5	1	5	User	
2) Create resource	40	1	40	User	
3) Upload file for resource	20	1	20	Internet connection	
4) Set permissions	30	1	30	User	
5) Download BIM Model from the filesharing service	20	10	200	Internet connection	
6) Conversion time (BIM Models)	120	10	1200	Device	
7) Visualize on Viewer (BIM Models)	30	10	300	Device	
8) Upload BIM Model in the filesharing service	20	10	200	Internet connection	
9) Change Revision \ Status	60	1	60	User	
TOTAL			2055		

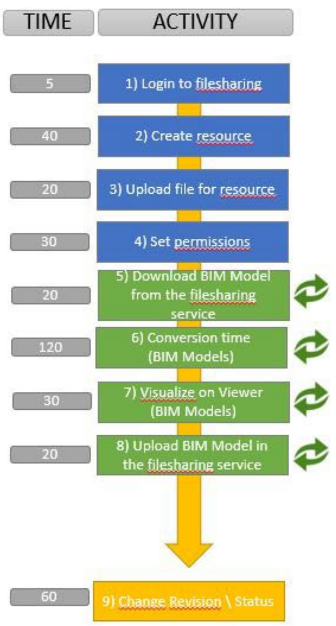

Figure 24 Traditional workflow results

Reduciton of time in renovation activities related to storing, sharing and managing files was estimated as follows: (565 - 2055) / 2055 = 72.5%.

Detail analysis in relation to renovation scenarios is provided in Annex II.

BIMcpd

The BIMcpd platform has been demonstrated as a supporting tool in the initial phase of design process. The evaluation was made in relation to demonstration of the Performance Evaluation tool, in particular Data Viewer to obtain data from sensors installed in selected apartments of demo building. Demonstration of the Constrain Checker tool was also provided. Analysis of the process in relation to the renovation scenarios is presented in Annex II.

Conclusions:

Evaluation of the design process based on renovation scenarios (annex II) by the demo partners (PROCHEM) design team, in the field of BIM-based workflow using a multi-discipline 3D model, and design data exchange as an IFC model, showed possible time reduction at the level of 20%, against to the traditional approach realized with 2D drawings. Resources management part was estimated at 10% of the total design cycle. The use of Common Data Environment (BIMMS platform) to store, share and manage files gave the opportunity to reduce this phase in the ridges by 72.5% (figure 23).

The demonstration of the Fast-mapping toolkit, at this stage of development, did not show a time reduction in IFC model creation. The use of the BIMcpd tool showed a potential for supporting a deeper analysis of internal conditions inside monitored apartments undergoing renovation in the preliminarily design phases. The demonstration also presented the potential to support HVAC equipment design concepts. Construction phase of the renovation was not examined during demonstration activities on the Polish pilot site.

Overall time reduction in relation to demonstration of BIM4EEB toolkit in inventory phase was estimated at 80%, and in the engineering phase at 27%.

4.1.2. REP 2 Renovation Cost Reduction

The cost saving performed during the renovation process based on the better management of the renovation activities; compared to the baseline/traditional process [3].

The result considered the engineering phase activities done by an architect leading renovation works, as a lead architect, who is supported by structural enginner and services designers. Retrofitting process was simulated as BIM-base workflow with CDE (BIMMS platform) to be used. To estimate the overall cost reduction of the design phase, it was assumed that the cost retalted to personal effort is 70%. Remaining part is the practice additonal expenses: software, indirect costs e.t.c.

The KPI is calculated assuming that the costs savings can be related directly with the reduction of time.

- 17 euros as average hourly charge for an architect employed Poland (1)
- 13 euros as average hourly charge for a technologist (1)
- A reduction time percentage estimated around 27%, considering BIM-based renovation process with CDE (BIMMS platform).
- Engineering phase activities baseline 80 days (16 weeks)
- Estimated design team: lead architect (1person) + structural enginner(1 person) + services designers (2 person)

Sources:
(1)THE ARCHITECTURAL PROFESSION IN EUROPE 2020 A SECTOR STUDY, Table 3-5, pag.42 [10]

Baseline costs
Average baseline 80 days (16 weeks) per project engineering phase

- [1x(17€ * 8hr) + 3x(13€ * 8hr)]* 80 days = 35840€

Cost savings
Average baseline 80 days per project * 27% reduction time = 22 days saved

- [1x(17€ * 8hr) + 3x(13€ * 8hr)]* 22 days = 9856€

Cost savings retalted to personal effort = (1-25984/35840)*100 = 27%

Total cost savings, taking into account indirect costs: 19%

The estimated costs of engineering phase, related to Polish demo building, are 7.5% of the investment value, in accordance with the guidelines of the Association of Architects of the Republic of Poland [12]. Due to the nature of the building, the 4th degree of complexity was assumed.

The main cost reduction of renovation could occurs at the stage of construction works. This phase was not included in the scope of demonstration activities on the Polish pilot site.

4.2. Comfort level indicators

4.2.1. COM 7 Occupancy Profiling Accuracy

In this section the impact on occupancy profiling accuracy is extracted. A brief presentation of the methodology is provided and then the calculation of the KPI is performed.

Indicator characteristic

The KPI Occupancy profiling accuracy measures deviations related to actual and predicted occupancy [3].

In the context of the project, planned occupancy is defined as the occupancy related to the design phase of the building where predefined schedules (as stated also in the standardization) are considered. On the other hand, actual occupancy reflects the actual situation in the building environment.

It is evident that one size does not fit all and thus the predefined schedules, though representative enough at an average level, cannot capture the particularities of each scenario (building environment).

Towards this direction, the main innovation and actual contribution of the BIM4Occupants framework is to facilitate a more accurate estimation of the occupancy level (planned value in the building environment). There are two main processes considered in the project:

a) End users through the BIM4Occupants are prompted to provide their feedback about the occupancy level at the building environment. This configuration process reflects the actual situation in the building environment and thus the users are able to properly define the occupancy states. Temporal deviations over time (e.g., seasonality patterns, etc.) are also addressed by the tool as we are able to track the history of information provided by the users

b) Complementary to the BIM4Occupants occupancy logging process, occupancy measurement data are also considered in the analysis (in case occupancy related data are available). As reported in D6.7, occupancy presence data are cross correlated with the manually defined profiles in order to extract fine grained occupancy profiles for each building area. We have to point out that the second approach is applied in the project to a representative number of building zones (once again considering the installation of sensors and the log capabilities of the sensing equipment available in place).

By taking into account the aforementioned values, the KPI calculation is performed.

Baseline calculation

As stated in the previous section, a preliminary step of the methodology is the definition of baseline values – planned occupancy. The reference occupancy schedule parameters for the Polish demo site are provided by the demo partner as part of the preparatory activities of the project (reflecting the configurations provided at building simulation tools- the extrapolation of this data to the selected building apartments is performed and thus the indicative occupancy schedules are presented).

<table>
<tr><th>Apartment ID</th><th>No of Occupants</th><th>Occupancy Configuration
(60% presence)</th></tr>
<tr><td>apartment C</td><td>1</td><td rowspan="5">Average occupancy per apartment: 2.0

Occupancy time schedule:

08:00 – 16:00 absence

16:00 – 08.00 presence</td></tr>
<tr><td>apartment D</td><td>3</td></tr>
<tr><td>apartment E</td><td>2</td></tr>
<tr><td>apartment B</td><td>1</td></tr>
<tr><td>apartment A</td><td>2</td></tr>
</table>

Table 5 Occupancy Baseline Configuration

Actual occupancy calculation

Then, input data as provided by the occupants to the app were considered in order to fine tune the information about occupancy at building premises. During the demonstration period at the Polish demo site, there were minor updates provided by the occupants on the occupancy profile mainly reflecting the number of occupants and not the actual time of presence at the residential premises. The indicative results of this user configuration are presented in the following figure for 2 apartments (apartment B/5 and apartment D/10). The selection of the apartments for representation is based on the availability of occupancy/presence sensors.

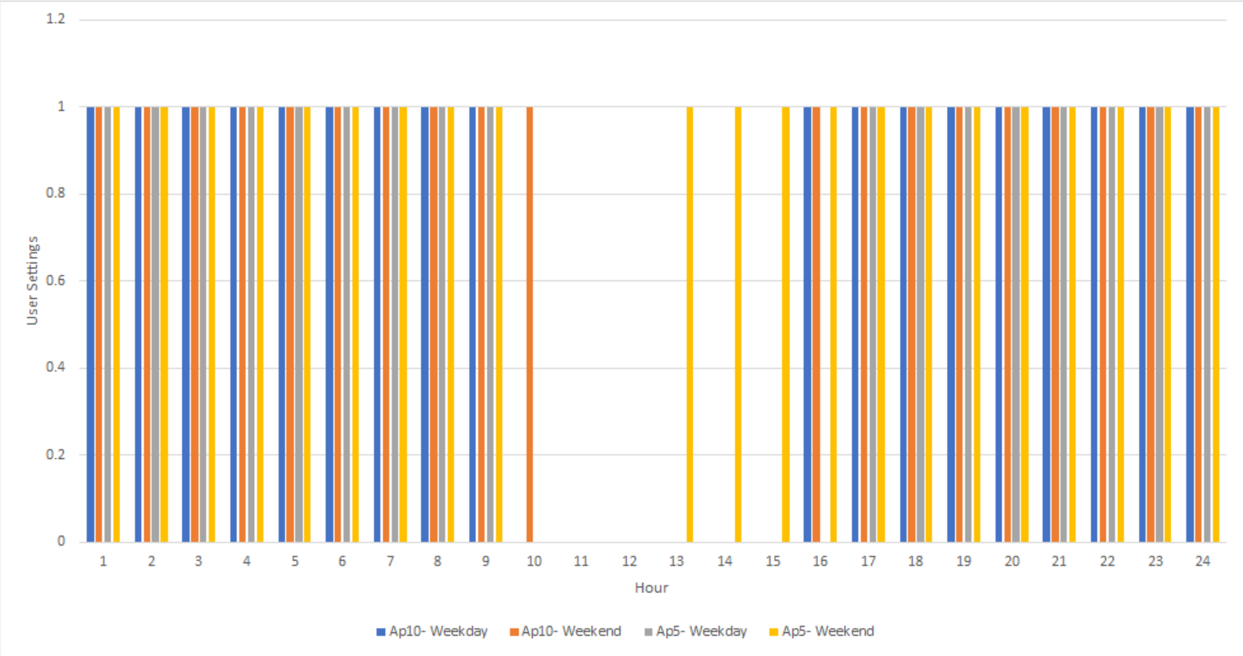

Figure 25 Occupancy sensing profile – user settings

Last but not least, the accuracy of input settings by building occupants are validated. Presence data was available from 2 building apartments (apartment B and apartment D) and thus further analysis was performed over motion events in order to extract the actual occupancy schedules. A statistical analysis over the even data (resampling of the event data) applies (transformation of occupancy events to occupancy timeseries data) and then statistics over the data streams are performed in order to extract the typical occupancy presence profile (at hourly level) during weekdays/weekends. The results of this analysis are presented in the following figure (Apart10, Apart 5).

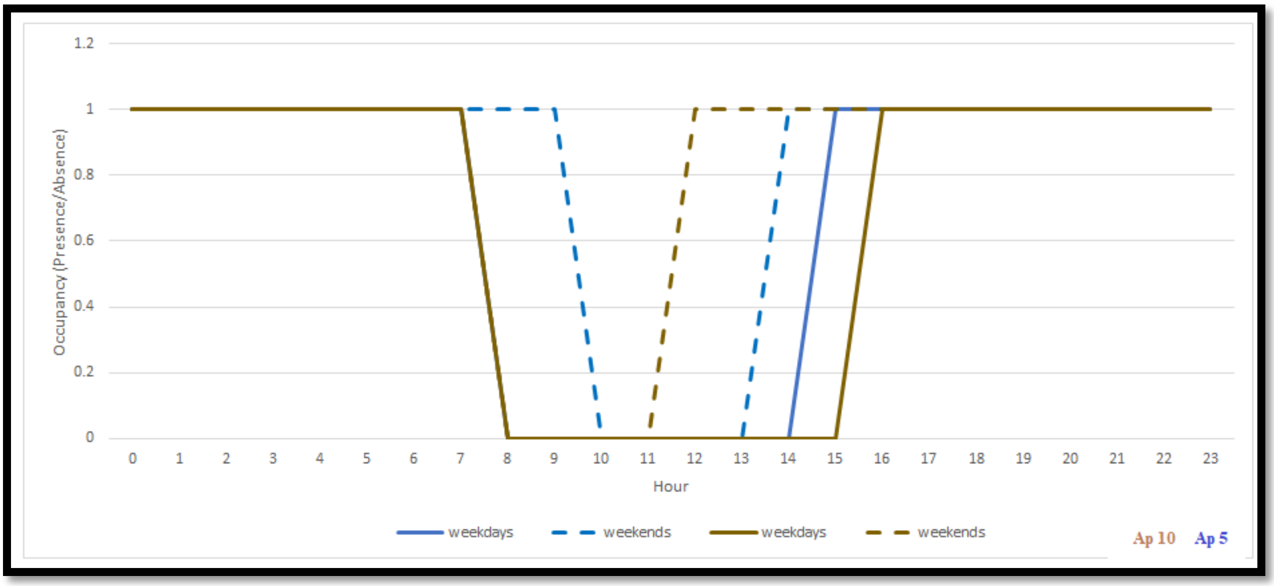

Figure 26 Occupancy sensing profile – actual data

Indicator assessment

Last but not least, the KPI Occupancy profiling is calculated at the Polish demo site for the demo premises where actual metering data are available. Overall, the accuracy level is **~ 91.5%** (from **85.2** % with baseline data counting only the active hours of the day during the validation – excluding from the analysis night hours where the occupancy profile in residential premises is rather static) considering that the building occupants were motivated to fine tune occupancy related information at the dedicated application.

It is evident that user's feedback may considered as the way to fine tune the static occupancy profiles in order to have a better representation of occupancy (especially in cases where there is a high volatility or in cases where there is a different use of the building). In addition, we have to point out that the measurements from occupancy sensors may be also considered for a more accurate estimation of the occupancy level in premises.

4.3. Energy performance indicators

4.3.1. ENE 3 Primary energy savings

The KPI Primary energy savings calculates the percentage difference between measured and baseline primary energy consumption data within a predefined period [3].

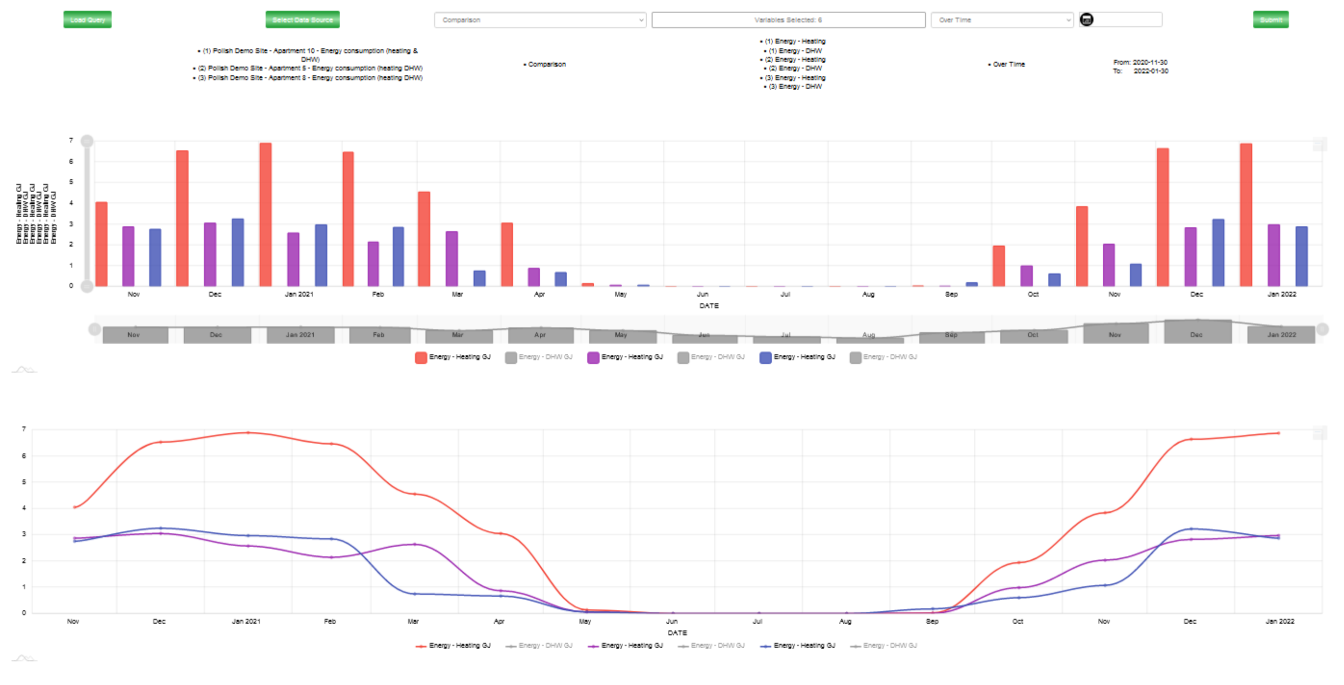

Figure 27 BIMcpd heating + DHW consumption data

A reduced winter Nov-Feb heating season was considered for the evaluations. Indicator assessment was presented as apartment base approach, due to the lack of technical possibilities to read the gas consumption for the entire building. For this case 3 of 5 metered apartments have been chosen for the assessment. Indicator is defined as a percentage difference between and baseline primary energy consumption data within a predefined period. The gas heat consumption was measured according to 5.4.1. and electric energy form bills. Consumption data was converted to primary energy using Polish conversion factors. Conversion factors of 1,1 was used for gas heating and 3 for electricity.

The results are shown in table 7.

Table 6 primary energy saving

	gas heat (kWh)	electricity (kWh)	total (kWh)	saving percentage
primary baseline	15486	3780	19226	18.1 %
primary renovated	12155	3590	15745	

4.4. Social indicators

The assessment of the indicators took place on the basis of surveys containing dedicated questions, developed as part of the document D3.5 Measurement and Verification protocol [3].

4.4.1. SOC 8 Improved monitoring/access on information during renovation works

The extent to which BIM4EEB provides improved monitoring capabilities of the renovation works for Construction Companies, FMs and Occupants.

''With BIM4EEB I can monitor easily the construction works during the renovation, compared to a traditional renovation approach.''

4.4.2. SOC 9 Increased easiness in information exchange and tracking (data accessibility)

The extent to which BIM4EEB improves tracking and information exchange among its various stakeholders (i.e. Construction Companies, Designer, FMs, Occupants).

''BIM4EEB makes it easier for me to exchange/track information with other stakeholders.''

4.4.3. SOC 10 Modular design and development of the BMS platform

The extent to which BIM4EEB can be expanded to address additional types of requirements from the business actors (i.e. Construction Companies, Designer, FMs, Occupants)

''The modular design of BIM4EEB makes it easier to address other types of requirements from the various business actors''

4.4.4. SOC 11 Interoperability and data storage capability of BMS platform

The extent to which BIM4EEB incorporates standards-based data models to ensure interoperability among the different tools and data reusability of the platform to large scale applications

''I find that the BIMMS platform offers increased data interoperability among the provided tools and data storage/reusability capabilities.''

4.4.5. SOC 12 Use of BIM in renovation business

The extent to which BIM utilisation in the renovation industry can alleviate typical process, financial and technical barriers by reducing costs of building information acquisition and generate more accurate energy savings forecasts, as declared by the BIM4EEB stakeholders involved or Advisory Board (construction / renovation companies, /service companies)

''I believe that utilising BIM in renovation projects, provides the means to overcome typical barriers (e.g. financial, technical) identified in the traditional process, as well as produce more accurate energy savings estimates through simulation tools.''

4.4.6. SOC 15 Development of digital logbooks for renovated building; management of as-built data in operational BIM models

The extent to which use of enriched BIM model with detailed as-built data orderly stored in digital logbooks can accelerate the market uptake of BIM; as declared by involved stakeholders (designers, construction/renovation companies, inhabitants, clients, service companies)

''I find that the use of a digital logbook, enables better management of the building information and generally can boost the renovation market uptake.''

4.4.7. Results of assessment for Primary social KPIs

Assessment of primary social KPI divided by target group (figure 28 and 29)

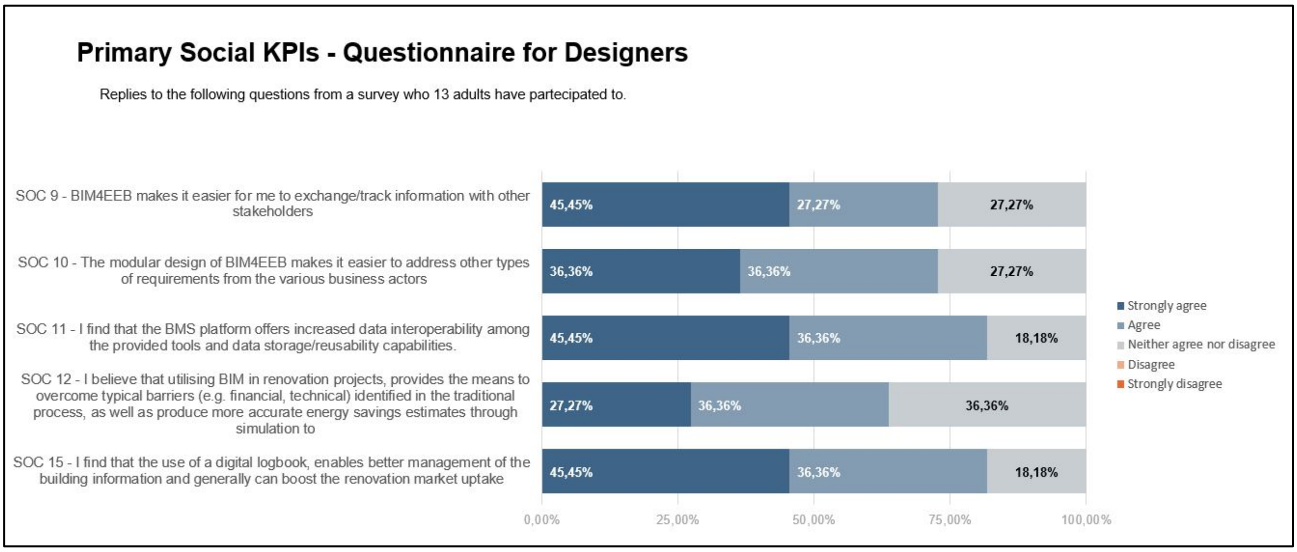

Figure 29 Questionnaire replies to primary social KPIs by Designers

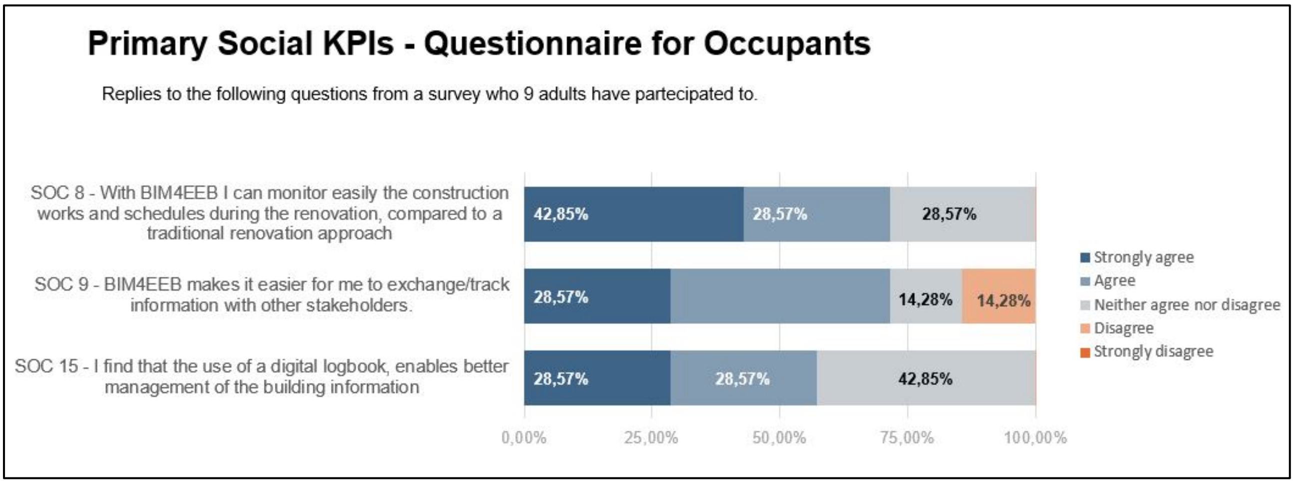

Figure 28 Questionnaire replies to primary social KPIs by Occupants

5. Secondary KPIs assessment

5.1. Renovation process indicators

5.1.1. REP 3 Actual/planned conformance – time

Better accuracy of the renovation process time considering the design phase; compared to the baseline/traditional process [3].

The design phase of the renovation carried out using the traditional method for Polish pilot site was estimated at 16 weeks (80 working days). There was initially assumed 4 weeks (20 working days) time reduction related with BIM-based BIM4EEB toolkit implementation. The planned duration of the design phase was 60 days. As a result of the analyses carried out as part of the T8.3 task, the possible reduction of time in the design phase was estimated at 27%, i.e. reducing the time by 22 working days. The actual time of the design phase was 58 days. Using the above data in the calculation, the following were obtained:

REP 3 = 97%

5.2. Comfort level indicators

5.2.1. COM 1 Adaptive Predicted Mean Vote (PMV)

Adaptive PMV (based on PMV) predicts the mean value of the overall thermal sensation of a person as a function of environmental parameters: air temperature, mean radiant temperature, air velocity, and air humidity[3]. Indicator and assessment process was detailed described in deliverable D8.2 [9].

PMV inside BIMcpd platform is calculated on hourly basis, it is not advisable to provide a single value as a representative KPI for the project. It was chosen to plot only a few average PMV values, evaluated for representative apartments to show the variability of the climatic conditions inside the monitored spaces (table 8).

Table 7 PMV values for 3 sample apartments (BIMcpd)

Apartment	Floor	Sensor	Date From	Date To	Temperature	Humidity	Average PMV	Max PMV	Min PMV
C	1	Multisensor B	21/02/22	28/02/22	21.5	38	-0.56	-0.19	-1.19
C	1	Multisensor B	24/12/21	31/12/21	20	36	-0.97	-0.10	-1.78
C	1	Multisensor B	24/10/21	31/10/21	21.5	44	-0.52	0.29	-0.91
D	3	Multisensor B	21/02/22	28/02/22	17.5	50	-1.55	-0.61	-1.98
D	3	Multisensor B	24/12/21	31/12/21	16.5	50	-1.82	-1.28	-2.78
D	3	Multisensor B	24/10/21	31/10/21	19	56	-1.11	-0.44	-1.82
E	4	Multisensor B	21/02/22	28/02/22	19	45	-1.17	-0.91	-1.44

E	4	Multisensor B	24/12/21	31/12/21	18.5	44	-1.31	-0.91	-1.57
E	4	Multisensor B	24/10/21	31/10/21	19.5	56	-0.98	-0.58	-1.52

5.2.2. COM 2 Predicted Percentage of dissatisfaction (PPD)

Percentage of the people who felt more than slightly warm or slightly cold [3]. Assessment process was detailed described in deliverable D8.2 [9].

Few average PPD values were chosen to plot from BIMcpd platform, evaluated for representative apartments to show the variability of the climatic conditions inside the monitored spaces (table 9)

Table 8 PPD values for 3 sample apartments (BIMcpd)

Apartment	Floor	Sensor	Date From	Date To	Temperature	Humidity	Average PPD	Max PPD	Min PPD
C	1	Multisensor B	21/02/22	28/02/22	21.5	38	12	6	35
C	1	Multisensor B	24/12/21	31/12/21	20	36	25	5	66
C	1	Multisensor B	24/10/21	31/10/21	21.5	44	11	7	22
D	3	Multisensor B	21/02/22	28/02/22	17.5	50	53	13	76
D	3	Multisensor B	24/12/21	31/12/21	16.5	50	68	39	98
D	3	Multisensor B	24/10/21	31/10/21	19	56	31	9	68
E	4	Multisensor B	21/02/22	28/02/22	19	45	34	23	47
E	4	Multisensor B	24/12/21	31/12/21	18.5	44	41	23	55
E	4	Multisensor B	24/10/21	31/10/21	19.5	56	25	12	52

5.2.3. COM 3 Thermal discomfort factor

Assessing the people's satisfaction with the thermal environment [3].
The scope of this section is to provide the results of validation activities performed at the Polish demo site. Starting with thermal comfort validation, special reference to the calculation of the thermal discomfort indicator taking into account users' feedback from the BIM4Occupants application. An overview of the environmental conditions (temperature, humidity) is provided in the following figure for a single apartment (apartment C) for a reference period (1.5-month period, October- November).

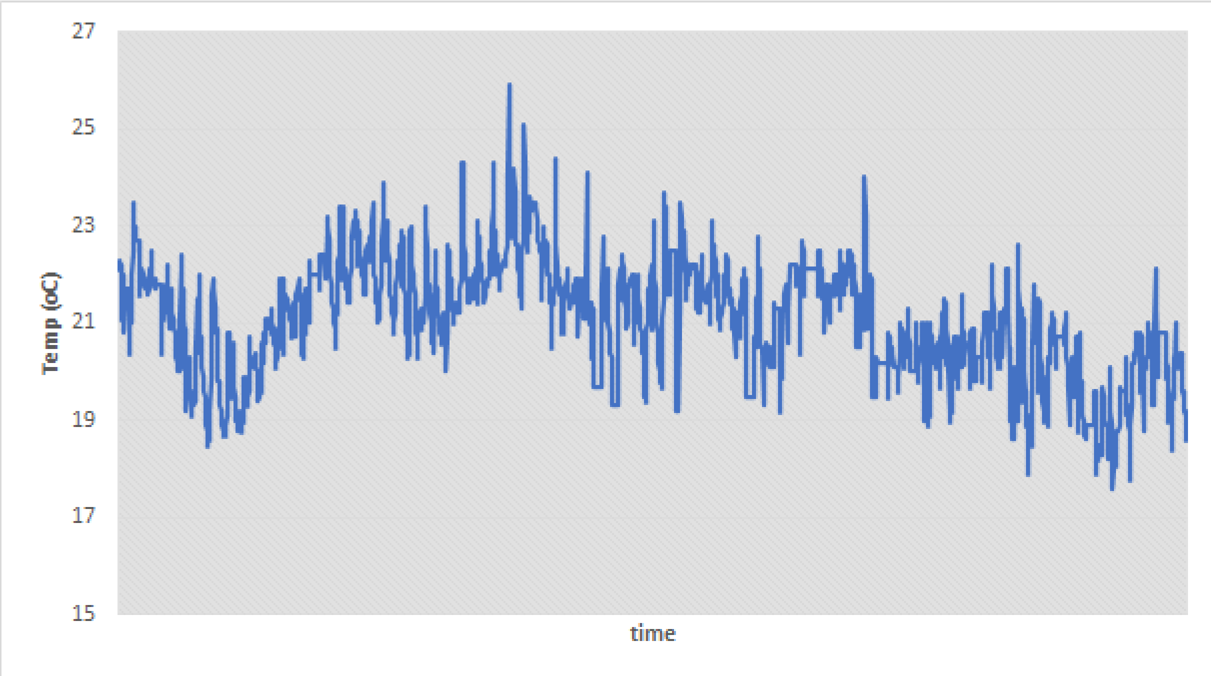

Figure 30 Indoor temperature conditions

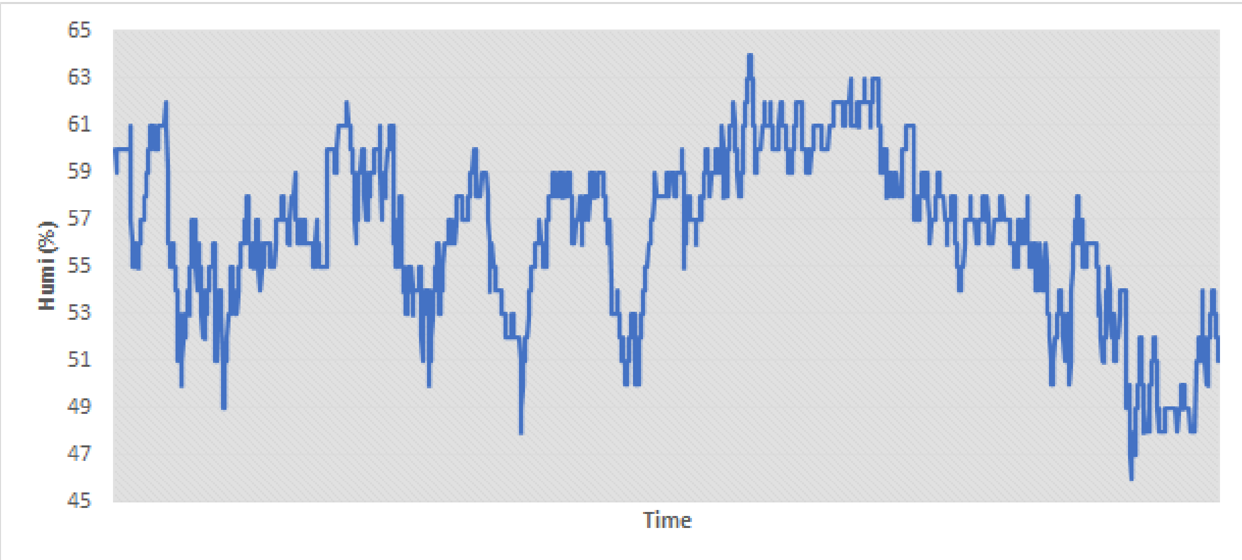

Figure 31 Indoor humidity conditions

In addition to the aforementioned KPIs, the thermal discomfort factor is calculated as an index assessing the people's satisfaction within the building environment at each specific environmental condition (by applying ML based techniques over data streams). By taking into account users' interaction (user settings via the application and sensing/measurement data), the thermal discomfort profiles for the different apartments are defined. The percentage values extracted represent the quantification of the level of comfort a user feels under specific conditions (100% max comfort, 0 % max discomfort). Then, post processing of these values applies to extract the values of max comfort as well as comfort boundaries (based on the statistics analysis performed over the data). Details about the KPIs are presented in D3.5 while the analytics techniques details in D6.7.

A summary of the KPIs calculated is presented in the following table:

Apartment	Indicator	Max Comfort	Comfort Boundary
apartment C	Thermal	21.5 °C	19.8 °C
apartment D	Thermal	23.0 °C	21.0 °C
apartment E	Thermal	22.0 °C	20.2 °C
apartment B	Thermal	22.5 °C	20.0 °C
apartment A	Thermal	22.0 °C	20.0 °C

Figure 32 Thermal discomfort indicator

Note: For thermal comfort boundary we present only the low comfort boundary level, considering that the demonstration was performed during the winter period (and thus feedback about non comfort conditions was provided for low temperature conditions).

5.2.4. COM 4 Operative Illuminance

Assessing the people's satisfaction in terms of illuminance compared to a reference value [3].
Results according to 5.3.5.

5.2.5. COM 5 Visual discomfort factor

Identifying the feeling of visual discomfort defined from sensing and actuation data [3].

An overview of the environmental conditions (illuminance) is provided in the following figure for apartment B for a reference period (1.5-month period, October- November). Once again to point out that luminance data were available only for 3 apartments in PL demo site.

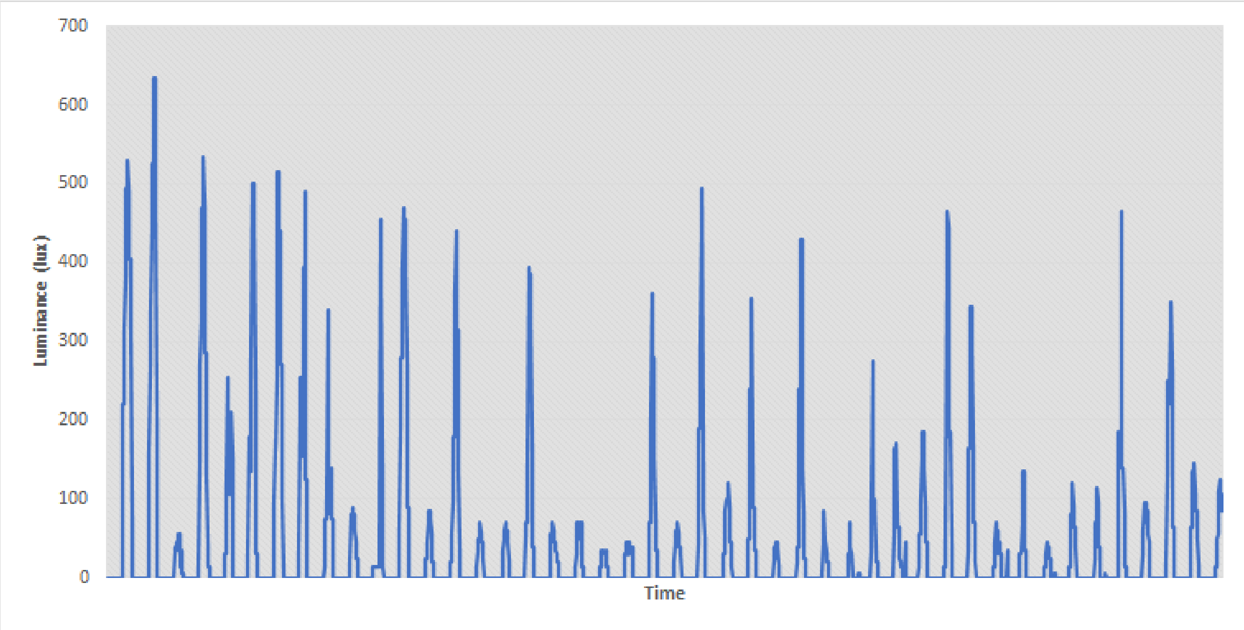

Figure 33 Indoor luminance conditions

The results of the KPI analysis by taking into account the measurements (luminance) are presented in the following table:

Apartment	Indicator	Illuminance Level
apartment C	Avg. Illuminance	N/A
apartment D	Avg. Illuminance	130 lux
apartment E	Avg. Illuminance	110 lux
apartment B	Avg. Illuminance	130 lux
apartment A	Avg. Illuminance	N/A

Table 9 Visual performance indicators

The visual discomfort factor is calculated assessing the people's satisfaction within the building environment by applying ML based techniques over data streams. By taking into account users' interaction (user settings via the application and sensing/measurement data), the visual discomfort profiles for building occupants are extracted. Details about the KPIs are presented in D3.5 while the analytics techniques details in D6.7.

A summary of the KPIs calculated is presented in the following table:

Apartment	Indicator	Max Comfort	Comfort Boundary
apartment E	Visual	130 lux	70 lux
apartment D	Visual	150 lux	100 lux
apartment C	Visual	N/A	N/A
apartment B	Visual	140 lux	100 lux
apartment A	Visual	N/A	N/A

Table 10 Visual discomfort indicator

5.3. Economic indicators

Calculations based on Annex III – BIMMS – cost to implement

5.3.1. ECON 1 Annual Cost Savings

Definition is a reduction of cost due to the renovation activities; compared to the baseline values.
The KPI ECON1 - Annual Cost Saving is calculated considering the cost saved by the time reduction occurred during the renovation phases. The result considered the activities done by an architecture practice leading a renovation work, as lead architect that supervise the design phases.

The KPI is calculated assuming that the costs savings can be related directly with the reduction time.

- 17 euros as average hourly charge for an architect employed in Poland (1)
- A reduction time percentage estimated around 30%, considering the different kind of activities that involves the architect.
- Architect activities baseline 80 days (16 weeks – engineering phase)

Sources:
(1) THE ARCHITECTURAL PROFESSION IN EUROPE 2020 A SECTOR STUDY, Table 3-5, pag.42 [10]

Baseline costs
Average baseline 80 days (16 weeks) per project engineering phase

- 17€ Avg hourly charge in Poland * 8hr * 80 days = 10880€

Cost savings
Average baseline 80 days per project * 30% reduction rime = 24 days saved per renovation project

- 17€ Avg hourly charge in Poland * 8hr * 24 days = 3264€

Cost savings = (1-7616/10880)*100 = 30%

5.3.2. ECON 2 Net Present Value (NPV)

Calculated based on nominal costs and discount rate based on the projected actual future costs to be paid, including general inflation and deflation [3].

NPV calculation related to BIMMS implementation, depending on the number of users required for the project, over a 5-year period.

Table 11 NPV calculation

Mid-Range Server - NPV for **practice 6 to 10 staff**		Low-Range Server – NPV for **practice 6 to 10 staff**	
Data	**Description**	**Data**	**Description**
0,01	Annual discount rate	0,01	Annual discount rate
-12000	01.01.2022	-9000	01.01.2022
1088	31.12.2022	1088	31.12.2022
-2500	01.01.2023	-2500	01.01.2023
1088	31.12.2023	1088	31.12.2023
-2500	01.01.2024	-2500	01.01.2024
1088	31.12.2024	1088	31.12.2024
-2500	01.01.2025	-2500	01.01.2025
1088	31.12.2025	1088	31.12.2025
-2500	01.01.2026	-2500	01.01.2026
1088	31.12.2026	1088	31.12.2026
Formula	**Description**	**Formula**	**Description**
-16 474 €	Net present value of this investment	-13 474€	Net present value of this investment
Mid-Range Server - NPV for **practice 2 to 5 staff**		Low-Range Server – NPV for **practice 2 to 5 staff**	
Data	**Description**	**Data**	**Description**
0,01	Annual discount rate	0,01	Annual discount rate
-12000	01.01.2022	-9000	01.01.2022
924	31.12.2022	924	31.12.2022
-2500	01.01.2023	-2500	01.01.2023
924	31.12.2023	924	31.12.2023
-2500	01.01.2024	-2500	01.01.2024
924	31.12.2024	924	31.12.2024
-2500	01.01.2025	-2500	01.01.2025
924	31.12.2025	924	31.12.2025

-2500	01.01.2026	-2500	01.01.2026
924	31.12.2026	924	31.12.2026
Formula	**Description**	**Formula**	**Description**
-17 270 €	Net present value of this investment	-14 270 €	Net present value of this investment

Demonstration at Polish demo site adopted renovation scenario performed by practice 2 to 5 staff with Low-Range Server setting.

ECON 2 = -14 270 €

5.3.3. ECON 3 Pay-back Period

Pay-back Time is the period of time required to recover the funds spent in an investment. In other words, the pay-back period is the time required for an investment reaches a breakeven point. [3].

The KPI ECON3 – Pay-back period can be calculated considering the investment in IT by the practice, considering as data

- the average practice revenue (1)
- the average practice profits (2)
- the average percentage of investment in IT (3)
- the cost to implement the BIMMS in 5 years.
- the EU discount rate 2021 = 0.0% (approx. 0,0001)

Sources:

(1) THE ARCHITECTURAL PROFESSION IN EUROPE 2020 A SECTOR STUDY, Paragraph 3.3, pag. 36 [10]
(2) THE ARCHITECTURAL PROFESSION IN EUROPE 2018 A SECTOR STUDY, Paragraph 3.6, pag.41 [11]
(3) THE ARCHITECTURAL PROFESSION IN EUROPE 2020 A SECTOR STUDY, Table 3-4, pag.41 [10]

Poland - the average practice revenue (1)

- 3 to 5 staff = 112801 €/yr
- 6 to 10 staff = 132786 €/yr

Average practice profits percentage (2)

- 3 to 5 staff = 41%
- 6 to 10 staff = 41%

Poland - the average practice profits

- 3 to 5 staff = 112801 €/yr x 41% profit percentage = 46248 €/yr
- 6 to 10 staff = 132786 €/yr x 41% profit percentage = 54442 €/yr

Percentage of investment in IT = 2% (media retail) (3)

- 3 to 5 staff = 46248 €/yr avg practive profits * 2% investment in IT = 924 €/yr
- 6 to 10 staff = 54442 €/yr avg practive profits * 2% investment in IT = 1088 €/yr

Payback time

- Mid-Range Server - Payback for practice (2 to 5 staff) = 22000/924 = 23,8yr
- Mid-Range Server - Payback for practice (6 to 10 staff) = 22000/1088 = 20,2yr
- Low-Range Server - Payback for practice (2 to 5 staff) = 14000/924 = 15,1yr
- Low-Range Server - Payback for practice (6 to 10 staff) = 14000/1088 = 12,9yr

Demonstration at Polish demo site adopted renovation scenario performed by practice 2 to 5 staff with Low-Range Server setting.

ECON 3 = 15,1 yr

5.4. Energy performance indicators

5.4.1. ENE 1 Energy Savings

Calculating the percentage difference between measured and baseline consumption data within a predefined period [3].

Baseline:

Indicator assessment was presented as apartment base approach, due to the lack of technical possibilities to read the gas consumption for the entire building. For this case 3 of 5 apartments have been chosen for the assessment. The baseline measured gas consumption for a winter heating season for apartments C,D,E **Nov 2020-Feb 2021** before renovation was selected to present the baseline (table 12). The value for **ER_E is 14079 kWh**.

Table 12 Energy consumption baseline (heating + DHW) - kWh

Reference period	Apartament E	Apartament D	Apartament C
2021-February	1915	896	665
2021-Januray	2041	932	781
2020-December	1941	1010	918
2020-November	1243	872	865
Sum	**7140**	**3710**	**3229**
Total	**14079**		

Measured value:

During the assessment renovation phase of retrofitting process wasn't examine. The reference residential building measurements were taken for calculations. The apartments after typical renovation with reference parameters were taken into account. The corresponding gas consumption is taken from the measurement period **Nov 2021- Feb 2022** (table 13). The value for **ES_C is 11050 kWh**.

Table 13 Energy consumption reference (heating + DHW) - kWh

Reference period	Apartament E*	Apartament D*	Apartament C*
2022-February	1330	732	582
2022-Januray	1464	832	653

2021-December	1405	875	702
2021-November	987	743	745
Sum	5186	3182	2682
Total	**11050**		

ENE 1 Energy savings = 22%

5.4.2. ENE 5 Total Use of Primary Energy

User of primary energy expressed as the indicator Cumulative Energy Demand during the lifecycle of the project (considering the different phases) [3].

Estimated energy consumption was produce based on data gathered form inspected apartments in relation to building structure. Additional data should have required to complete more accurate analysis.

Fuel source	Consumption (kWh)	PEF (-)	Primary energy (Year) (kWh)	Primary energy (25 Years) (MWh)
Natural Gas	77,368	1.1	85,105	2,127
Electricity	33,250	3.0	48,600	1,215

5.5. Social indicators

The assessment of the indicators took place on the basis of surveys containing dedicated questions, developed as part of the document D3.5 Measurement and Verification protocol [3].

5.5.1. SOC 1 Ease of use for end users of the solution

It provides the means for assessing the acceptability of the framework from BIM4EEB end user (i.e. Construction Companies, Designer, FMs, Occupants).

"I believe that BIM4EEB solutions offer clear advantages in the renovation process (e.g. Increased comfort, quality, etc)"

5.5.2. SOC 2 Beneficial for end-users

The extent to which BIM4EEB offers clear advantages for end users (i.e. Construction Companies, Designers, FMs, Occupants). Advantages can vary from cost savings, improved quality and increased comfort. It is presumed that solutions which have a higher level of advantages to end users will be more likely to be adopted than solutions which have negative or no advantages.

"I believe that BIM4EEB solutions offer clear advantages in the renovation process (e.g. cost/time savings)"

5.5.3. SOC 3 Occupants active involvement in the renovation phase

The extent to which occupants have been involved in the renovation process.

''With BIM4EEB, it was easier for me to be involved in the renovation process, compared to a traditional renovation approach.''

5.5.4. SOC 4 Productivity improvement

The extent to which BIM4EEB improves the productivity of its users (i.e. Construction Companies, Designer, FMs), during the various stages of the renovation.

''I believe that by using BIM4EEB I become more productive.''

5.5.5. SOC 5 Improvement in collaboration among teams

The extent to which BIM4EEB can improve the collaborations among its stakeholders (i.e. Construction Companies, Designer, FMs, Owners)

''Through BIM4EEB it's easier for me to exchange information and collaborate with other stakeholders.'' (Occupants)
''I think that BIM4EEB promotes a more collaborative work environment.(Designers)''

5.5.6. SOC 6 Improvement in safety at construction site

The extent to which BIM4EEB can improve the H&S on site during the renovation works for Construction companies, FMs and Occupants.

''Using BIM4EEB makes me feel safer around the construction site.''

5.5.7. SOC 7 Level of intuitiveness in user applications

How the users (i.e. Construction Companies, Designer, FMs, Occupants) of the BIM4EEB find the design of the system/toolkits understandable and easy to use.

''I find that the User Interface of BIM4EEB and its user applications have intuitive design.''

5.5.8. Results of assessment for Secondary social KPIs

Assessment of primary social KPI divided by target group (figure 22 and 23)

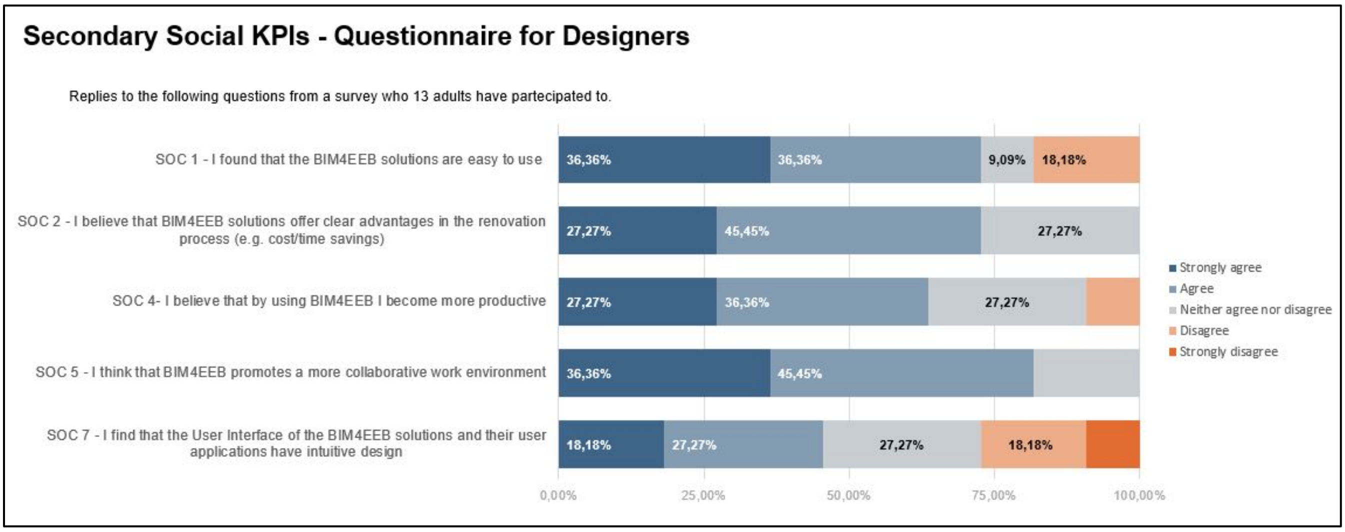

Figure 34 Questionnaire replies to secondary social KPIs by Designers

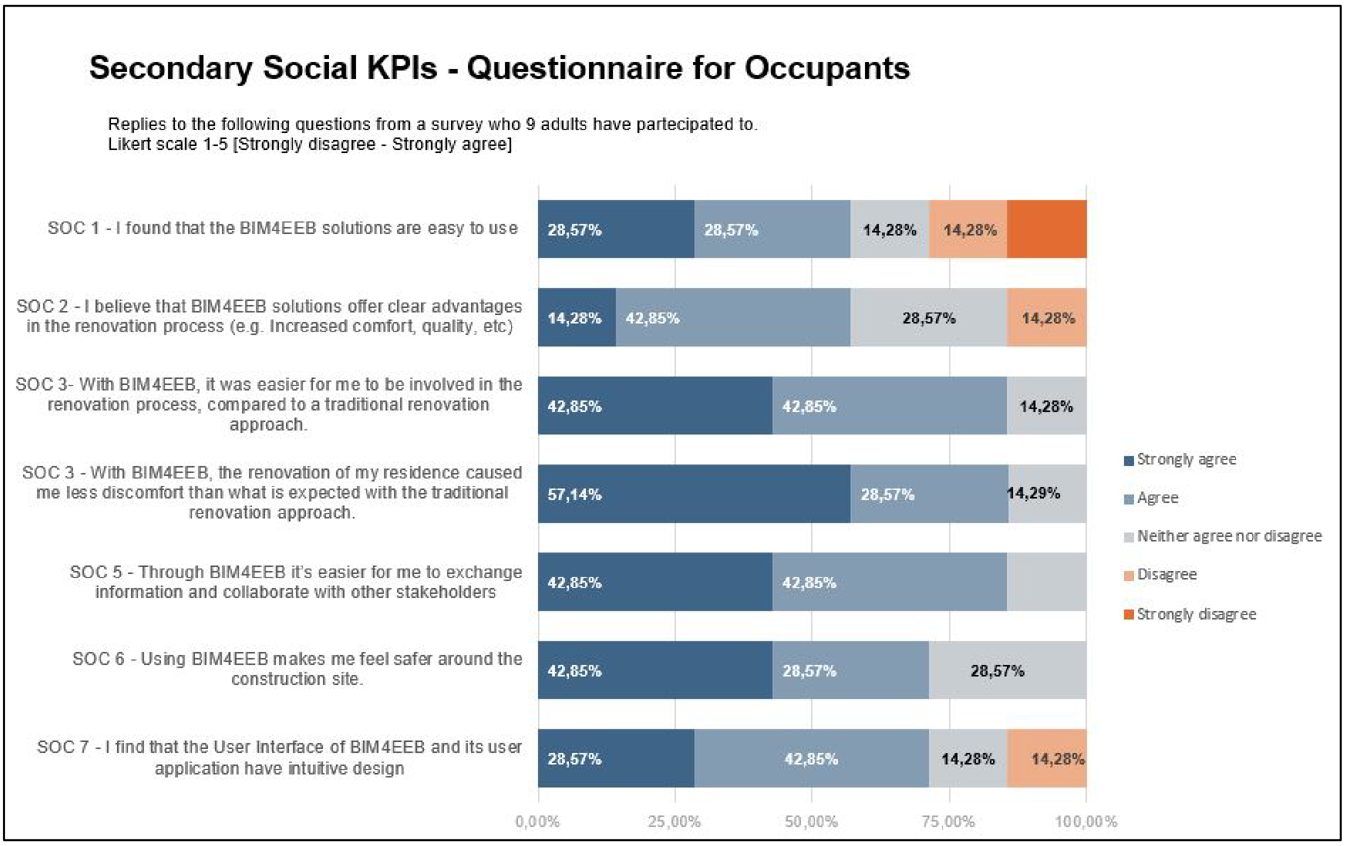

Figure 35 Questionnaire replies to secondary social KPIs by Occupants

5.6. Environmental and safety indicators

5.6.1. ENV 1 CO2/CO compounds reduction

Assessing the level of pollutant emissions (CO2 in the project) compared to a reference value is the process considered in the project. The long-term IAQ evaluation vector of CO_2 concentrations KPI for a monitored space i and for a time-period T is performed by evaluating the specific average value over the time [3].

Then, the reference value for the pollutant is defined taking into account the standardization (Note: Thresholds as defined in the literature analysis performed in D3.5).

In the following, IAQ (CO2) indicative screenshots of the measurements are provided in order to show the variation of the values during a reference period (1.5 period Oct-Nov 2021) for building E (where IAQ sensor is installed).

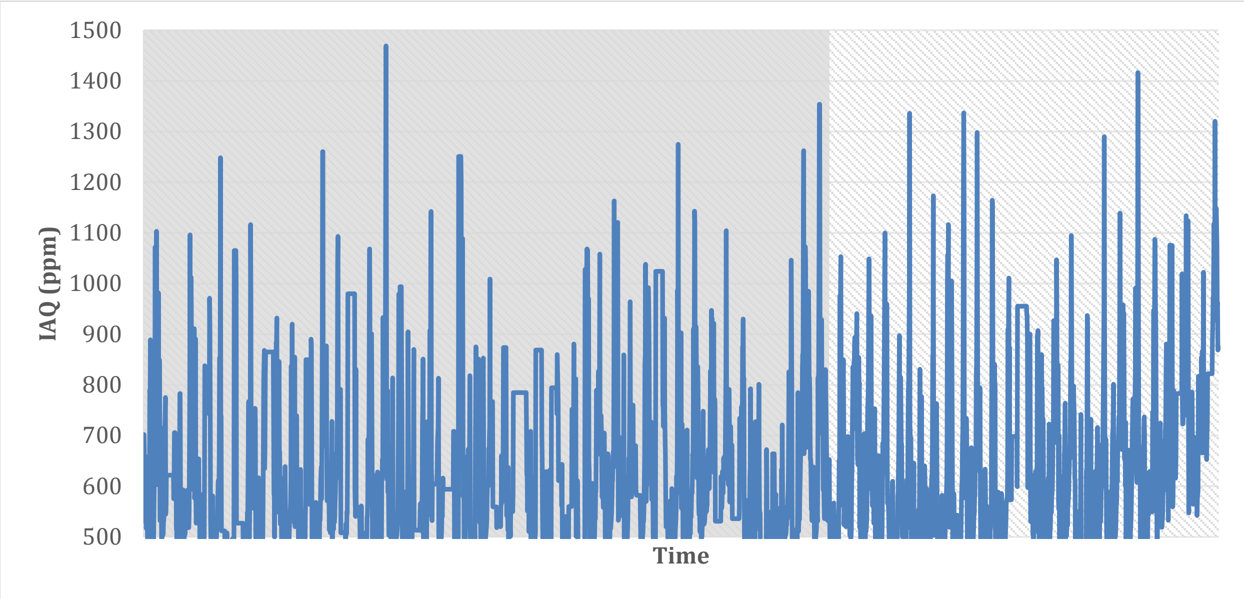

Figure 36 Indoor CO2 conditions

Then, in relation to the sensors measurements as retrieved from the demonstration period, the typical statistics over IAQ conditions are performed to extract the relevant indicators.

Apartment	Indicator	Average	% above threshold
apartment C	IAQ	735 ppm	10.81 %
apartment D	IAQ	631 ppm	3.63 %
apartment E	IAQ	850 ppm	32.65 %
apartment B	IAQ	N/A	N/A
apartment A	IAQ	650 ppm	3.87 %

Table 14 IAQ performance indicator

We have to point out some outliers on the IAQ conditions. These are mainly affected by specific conditions in the building environment (smoking, lack of ventilation). By having the information available, then additional counter measurements may take place in order to increase the level of quality in IAQ conditions.

6. Conclusions

This deliverable was aimed to present in detail the demonstration process of selected BIM4EEB tools, i.e., BIMMS platform, Fast mapping toolkit, BIMcpd tool and BIM4Occupants platform. Activities were carried out on the Polish pilot site as a reference for Central European climate conditions. All demonstration activities were supported at every stage by the toolkit owners according to the workflows developed as part of the work package 8 (WP8).

The demonstration at the Polish demo case has presented the potential to increase the efficiency of residential buildings' renovation processes with BIM4EBB toolkit implementation. Detailed assessment has been based on the use of selected BIM-based tools within the individual phases of the retrofitting. The impact of this process, mapped with detail renovation scenarios, has been assessed by key performance indicators.

During the first step of activities five apartments, whose owners have voluntarily agreed to join BIM4EEB research project, have been equipped with sensors monitoring the internal parameters and electric energy consumption. The data collected from the sensors has been used by BIM4Occupants and BIMCpd platforms, to evaluate directly performance indicators, and additionally has been integrated inside the BIMMS platform (CDE).

The major focus of the demonstration was to apply a selected BIM4EBB tools, i.e. BIMMS platforms, BIMcpd, and Fast mapping toolkit to the inventory and engineering phase of renovation process. The assessment of Key Performance Indicators (KPI's) allows the following conclusions to be drawn. During the demonstration activities with the use of selected BIM4EBB tools, the time reduction for the inventory phase was estimated around 80% and the engineering phase at approx. 27%, which meets the assumptions made in the Grand Agreement No. 820660. Part B paragraph 2.1.1.1. The cost reduction of the design phase was estimated at around 19%. Thanks to the BIM4Occupants platform, comfort indicators related to indoor conditions have been successfully identified for apartments that were equipped with appropriate sensors, such as: Thermal discomfort factor, Operative Illuminance and Visual discomfort factor. Also, the level of pollutant emissions was assessed. The results of the CO2 concentration in all apartments monitored are above threshold (table 14). With BIMcpd platform, for selected apartments, comfort indicators such as Adaptive Predicted Mean Vote (PMV), Predicted Percentage of dissatisfaction (PPD) (table 7,8) were measured. The obtained results signalled that unfavourable temperature conditions prevail in most of the usable areas. The cost analysis of the BIMMS platform implementation during the design process was examined using economic indicators. Annual Cost Savings related to renovation process supported by BIM-based approach with Common Data Environment are positive and reach up to 30%. Pay-back period calculated a consideration the investment in IT by the practice in Poland varies according to the size of the practise and the software plan implementation chosen. With the help of dedicated questionnaires social indicators were assessed. The overall evaluation of BIM4EEB toolkit by end users is positive. The results in relation to specific indicators are shown using charts (figure 28,29) and (figure 34,35). As there was no construction phase of renovation in the building in Chorzow, the estimation of economy indicators was based on the reference object, to the possible extent.

The general conclusions regarding the demonstration of individual BIM4EEB tools on the Polish pilot site can be summarized as follows:

The reduction of time needed to perform inventory measurements, using a component element of the fast-mapping toolkit, in the form of laser scanning has been noticed. Developed tool shows the potential of use in the inventory phase and early design phase. However, a fast-mapping toolkit, occurring in the prototype phase, requires further development that it would lead to improved functionality and give a chance for commercial use.

The BIMMS platform as a Common Data Environment, has shown potential to reduce the time of renovation thanks to a more efficient data exchange management process. Due to the platform supports the IFC format in the field of files exchanges and build up model viewer, it can be used in building renovation processes supported by BIM-based approach, which gives the significant potential to increase efficiency compared to the traditional process.

BIMcpd platform has presented the potential to support the early stage of the design process, mainly by access to environmental data inside residential premises (Performance Evaluation tool). Platform also supports the initial design phase by automatically determining the most favourable course of HVAC and electrical installations (Constraint Checker tool).

During the BIM4Occupants demonstration, it was found that the platform offers great potential in determining the inhabitants' preferences related to the internal conditions inside the apartments before and during the renovation. It also creates the right place to better manage the process, taking into account the needs of residents.

Demonstration activities were carried out in the course of the ongoing Covid-19 pandemic, which had a significant impact on the manner of conducting individual activities. During all activities, demo partners (PROCHEM) had to take into account the safety of inhabitants and other stakeholders participating in the BIM4EEB research project.

6.1. Lesson learnt

Since all the tools demonstrated are not commercial solutions, the demonstration activities required, taking into account the limitations resulting from this fact. An effective demonstration process of the BIM4EBB toolkit forced in-depth analysis of the individual platforms' functionality. During the demonstration activities on the Polish pilot site, barriers related with the efficient handling of solutions appeared. Some of the tools, among others, Fast mapping toolkit, BIMcpd as a specialized solutions require at least intermediate training. For the efficient use of BIMMS and BIM4Ocuupants platforms basic training should be enough.

During the demonstration activities on the Polish pilot site, there were problems with the use of IT tools by inhabitants, who joined the BIM4EEB project, especially the elderly person. The whole process of demonstration in relation to residents had to be supported by demo partners (PROCHEM). Voluntary participation in the project made it necessary to constantly encourage demonstration activities.

In the course of activities on the Polish demo case using selected BIM4EBB tools, major potential was observed to support renovation process with BIM-based approach. The increase in the efficiency of the toolkit largely depends on the further development of individual platforms lead to commercialization as well as the level of training for the end users.

The greatest challenge in the future development of BIM4EEB tools, in order to commercialize them, is to focus on increasing their efficiency by simplifying use by end users and implementing dedicated training plans.

7. Bibliography

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8. Annex I – List of the KPIs

Table 16 Indicators for the Polish pilot. (Adapted from D8.1 table 27)

Table 15 KPIs to be measured in Polish pilot site according to the tools.

Category of KPI	kpi	Name of the KPI	Description of the KPI and formula	Unit	Polish site: BIMMS	Polish site: Tool 1	Polish site: Tool 3	Polish site: Tool 4
Renovation process	**REP 1**	Renovation Time Reduction	This is the time saving performed during the renovation process based on the better management of the renovation activities, compared to the baseline/traditional process. A multi-vectoral analysis should be considered addressing the different steps of the renovation process (e.g. audit time, data retrieval, renovation actions etc.,)	%	X	X		X
Renovation process	**REP 2**	Renovation Cost Reduction	This is the cost saving performed during the renovation process based on the better management of the renovation activities, compared to the baseline/traditional process	%	X			
Renovation process	**REP 3**	Actual/planned conformance - **time**	Better accuracy of the renovation process **time** considering the design phase, compared to the baseline/traditional process	%		X		
Comfort	**COM 1**	Adaptive Predicted Mean Vote (PMV)	Adaptive PMV (based on PMV) predicts the mean value of the overall thermal sensation of a person as a function of environmental parameters: air temperature, mean radiant temperature, air velocity, and air humidity	Numerical (-3 to +3)			X	X
Comfort	**COM 2**	Predicted Percentage of dissatisfaction (PPD)	Percentage of the people who felt more than slightly warm or slightly cold	%			X	X
Comfort	**COM 3**	Thermal discomfort factor	Assessing the people's satisfaction with the thermal environment	Probability (0-1)			X	
Comfort	**COM 4**	Operative Illuminance	Assessing the people's satisfaction in terms of illuminance compared to a reference value.	lux			X	
Comfort	**COM 5**	Visual discomfort factor	Identifying the feeling of visual discomfort defined from sensing and actuation data.	Probability (0-1)			X	
Comfort	**COM 7**	Occupancy Profiling Accuracy	Deviations about real and predicted occupancy schedules	%			X	
Economic	**ECON 1**	Annual Cost Savings	Reduction of cost due to the renovation activities; compared to the baseline values	%	X			
Economic	**ECON 2**	Net Present Value (NPV)	Calculated based on nominal costs and discount rate based on the projected actual future costs to be paid, including general inflation and deflation.	€	X			
Economic	**ECON 3**	Pay-back Period	The period required to recover the funds expended in an investment on renovation.	Time (years)	X			

Energy	**ENE 1**	Energy Savings	Calculating the percentage difference between measured and baseline consumption data within a predefined period	%				X
	ENE 3	Primary Energy Savings	Calculating the percentage difference between measured and baseline primary energy consumption data within a predefined period	%				X
	ENE 5	Total Use of Primary Energy	User of primary energy expressed as the indicator Cumulative Energy Demand during the lifecycle of the project (considering the different phases)	MJ or %				X
Social	**SOC 1**	Ease of use for end users of the solution	It provides the means for assessing the acceptability of the framework from BIM4EEB end user (i.e. Construction Companies, Designer, FMs, Occupants).	Likert scale (1-5)	X	X	X	X
	SOC 2	Beneficial for end-users	The extent to which BIM4EEB offers clear advantages for end users (i.e. Construction Companies, Designers, FMs, Occupants). Advantages can vary from cost savings, improved quality and increased comfort. It is presumed that solutions which have a higher level of advantages to end users will be more likely to be adopted than solutions which have negative or no advantages.	Likert scale (1-5)	X	X	X	X
	SOC 3	Occupants active involvement in the renovation phase	The extent to which occupants have been involved in the renovation process.	Likert scale (1-5)			X	
	SOC 4	Productivity improvement	The extent to which BIM4EEB improves the productivity of its users (i.e. Construction Companies, Designer, FMs), during the various stages of the renovation.	Likert scale (1-5)	X		X	X
	SOC 5	Improvement in collaboration among teams	The extent to which BIM4EEB can improve the collaborations among its stakeholders (i.e. Construction Companies, Designer, FMs, Owners)	Likert scale (1-5)	X		X	
	SOC 6	Improvement in safety at construction site	The extent to which BIM4EEB can improve the H&S on site during the renovation works for Construction companies, FMs and Occupants.	Likert scale (1-5)	X		X	
	SOC 7	Level of intuitiveness in user applications	How the users (i.e. Construction Companies, Designer, FMs, Occupants) of the BIM4EEB find the design of the system/toolkits understandable and easy to use.	Likert scale (1-5)	X	X	X	X
	SOC 8	Improved monitoring/access on information during renovation works	The extent to which BIM4EEB provides improved monitoring capabilities of the renovation works for Construction Companies, FMs and Occupants.	Likert scale (1-5)	X	X	X	
	SOC 9	Increased easiness in information exchange and tracking (data accessibility)	The extent to which BIM4EEB improves tracking and information exchange among its various stakeholders (i.e. Construction Companies, Designer, FMs, Occupants)	Likert scale (1-5)	X	X		X
	SOC 10	Modular design and development of the BMS platform	The extent to which BIM4EEB can be expanded to address additional types of requirements from the business actors (i.e. Construction Companies, Designer, FMs, Occupants)	Likert scale (1-5)	X			

	SOC 11	Interoperability and data storage capability of BMS platform	The extent to which BIM4EEB incorporates standards-based data models to ensure interoperability among the different tools and data reusability of the platform to large scale applications	Likert scale (1-5)	**X**			
	SOC 12	Use of BIM in renovation business	The extent to which BIM utilisation in the renovation industry can alleviate typical process, financial and technical barriers by reducing costs of building information acquisition and generate more accurate energy savings forecasts, as declared by the BIM4EEB stakeholders involved or Advisory Board (construction / renovation companies, /service companies)	Likert scale (1-5)		**X**		
	SOC 15	Development of digital logbooks for renovated building; management of as-built data in operational BIM models	The extent to which use of enriched BIM model with detailed as built data orderly stored in digital logbooks can accelerate the market uptake of BIM; as declared by involved stakeholders (designers, construction/renovation companies, inhabitants, clients, service companies)	Likert scale (1-5)	**X**			
Environmental/safety	**ENV 1**	CO2/ CO compounds reduction	Assessing the level of pollutant emissions (CO2/CO) compared to a reference value	ppm			**X**	**X**

9. Annex II – Developed time and cost analysis

BIMMS platform:

BIMMS time and cost saving evaluation (ref. Table 3 D2.2)

BIMMS method	Baseline (how it is done in the business-as-usual renovation?)	How the improvement due to BIMMS is measured?
Use Case 0 Initiative: Preliminary decision for the renovation (go / no go desicion)		
• The data required in Use Case 0 can be stored and shared in the BIMMS' CDE a) requirements can be shared as resource documensts b) sensors data streaming can be available in the BIMMS for the monitored apartments c) If cost and saving databases are available as Linked Data sources, they can be queried with the BIMMS' SPARQL Endpoint d) The BIMMS can store the OPR	• Data exchanged by email with document attachments • No digital copy of the resources • No historical energy performance data available	• As data is stored in the BIMMS' CDE, it can be easely shared with stakeholders: o time saved thanks to reduced time to upload\download resources o indirect costs saved thanks to the reduced risk of data loss, data redundancy
Use Case 1 Initiation: Renovation project initiation		
• The data required in Use Case 1 can be stored and shared in the BIMMS' CDE. • sensors data streaming (occupant's behaviour and indoor air quality) can be available in the BIMMS for the monitored apartments	• Data exchanged by email with document attachments • No occupant's and comfort data available • No indoor air quality available • No historical energy performance data available • Initial geometry information is shared using CAD drawings instead BIM models	• As data is stored in the BIMMS' CDE, it can be easely shared with stakeholders: o time saved thanks to reduced time to upload\download resources o indirect costs saved thanks to the reduced risk of data loss, data redundancy o model updates can be done via REST APIs reducing times to export\upload\download\import
Use Case 2.1 Concept Design: Quick calculation to find the design alternatives at conceptual level		
• The data required in Use Case 2.1 can be stored and shared in the BIMMS' CDE. • sensors data streaming (occupant's behaviour and indoor air quality) can be available in the BIMMS for the monitored apartments • The BIMMS can store the OPR. OPR results are available via SPARQL Endpoint • The BIMMS allows to manage the resources in compliancy with the ISO 19650 BIM Standard: versioning, status, classification	• Data exchanged by email with document attachments • No occupant's and comfort data available • No indoor air quality available • No historical energy performance data available • geometry information is shared using CAD drawings	• As data is stored in the BIMMS' CDE, it can be easely shared with stakeholders: o time saved thanks to reduced time to upload\download resources o indirect costs saved thanks to the reduced risk of data loss, data redundancy • model updates can be done via REST APIs reducing times to export\upload\download\import
Use Case 2.2 Preliminary Design: Preliminary energy simulations of the design alternatives		
• The data required in Use Case 2.2 can be stored and shared in the BIMMS' CDE. • sensors data streaming (occupant's behaviour and indoor air quality) can be available in the BIMMS for the monitored apartments • The BIMMS can store the OPR. OPR results are available via SPARQL Endpoint • The BIMMS allows to manage the resources in compliancy with the ISO 19650 BIM Standard: versioning, status, classification •	• Data exchanged by email with document attachments • No occupant's and comfort data available • No indoor air quality available • No historical energy performance data available • geometry information is shared using CAD drawings instead BIM models	• As data is stored in the BIMMS' CDE, it can be easely shared with stakeholders: o time saved thanks to reduced time to upload\download resources o indirect costs saved thanks to the reduced risk of data loss, data redundancy model updates can be done via REST APIs reducing times to export\upload\download\import
Use Case 2.3 Developed Design: More detailed energy simulation of the design alternatives		
• The data required in Use Case 2.3 can be stored and shared in the BIMMS' CDE.	• Data exchanged by email with document attachments	• As data is stored in the BIMMS' CDE, it can be easely shared with stakeholders:

• sensors data streaming (occupant's behaviour and indoor air quality) can be available in the BIMMS for the monitored apartments • The BIMMS can store the OPR. OPR results are available via SPARQL Endpoint • The BIMMS allows to manage the resources in compliancy with the ISO 19650 BIM Standard: versioning, status, classification •	• No occupant's and comfort data available • No indoor air quality available • No historical energy performance data available • Initial geometry information is shared using CAD drawings instead BIM models	○ time saved thanks to reduced time to upload\download resources ○ indirect costs saved thanks to the reduced risk of data loss, data redundancy model updates can be done via REST APIs reducing times to export\upload\download\import
Use Case 2.4 Detailed Design: More detailed simulation of the design alternatives		
• The data required in Use Case 2.4 can be stored and shared in the BIMMS' CDE. • sensors data streaming (occupant's behaviour and indoor air quality) can be available in the BIMMS for the monitored apartments • The BIMMS can store the OPR. OPR results are available via SPARQL Endpoint • The BIMMS allows to manage the resources in compliancy with the ISO 19650 BIM Standard: versioning, status, classification	• Data exchanged by email with document attachments • No occupant's and comfort data available • No indoor air quality available • No historical energy performance data available • Initial geometry information is shared using CAD drawings instead BIM models	• As data is stored in the BIMMS' CDE, it can be easely shared with stakeholders: ○ time saved thanks to reduced time to upload\download resources ○ indirect costs saved thanks to the reduced risk of data loss, data redundancy model updates can be done via REST APIs reducing times to export\upload\download\import
Use Case 3 Construction: Implementation of the planned renovation measures		
• The data required in Use Case 3 can be stored and shared in the BIMMS' CDE. • sensors data streaming (occupant's behaviour and indoor air quality) can be available in the BIMMS for the monitored apartments • The BIMMS can store the OPR. OPR results are available via SPARQL Endpoint • BIM Models, CAD drawings, reports and other construction documents can be stored, shared and managed in the BIMMS • Resources can be linked (i.e. model entity with drawings\reports\specifications	• Data exchanged by email with document attachments • No occupant's and comfort data available • No indoor air quality available • No historical energy performance data available • geometry information is shared using CAD drawings instead BIM models	• As data is stored in the BIMMS' CDE, it can be easely shared with stakeholders: ○ time saved thanks to reduced time to upload\download resources ○ indirect costs saved thanks to the reduced risk of data loss, data redundancy model updates can be done via REST APIs reducing times to export\upload\download\import

BIMcpd :

Use cases and relevant requirement vs renovation process (ref. Table 3 D2.2)

Activities based on D2.2 table 3 that are relevant for BIMcpd	**BIMcpd method**	**Baseline (how it is done in the business-as-usual renovation?)**
Use Case 0 Initiative: Preliminary decision for the renovation (go / no go decision)		
• Monitored historical energy performance data.	• Provides data analysis, M&V and data management tools • The acquisition and structured analysis of energy performance data	• Collecting of energy certificates approximately **1 week**. • Collection of gas bills and electric energy bill from database. The time required to obtain the data from the plant operator is approximately **30 days**. Historical consumption is considered in the evaluation • Reelaboration of data in digital format (e.g. excel file) for consumption distribution calculation Centralized heating, domestic hot water gas and electricity consumption are constantly monitored as they are linked to the expenses that are charged to tenants. Gas and electricity consumption is billed once every two months. The time needed to get the annual data from the administrative offices is approximately **2 weeks**. • Saving of excel files in database (from energy audits) Database extraction approximately **2 hours**
Use Case 1 Initiation: Renovation project initiation		
• Helps to view current occupant's behaviour and comfort metrics and set related targets • Analyse current indoor air quality levels and set related targets • Analyse historical energy performance data and set related targets	• Provides several tools for recommending the location of HVAC, lighting, fire and other sensors • Provides an M&V tool for establishing a baseline and reporting period with non-routine adjustments • Analyse of energy performance data and comfort data.	• Collection of feedbacks from inhabitants about comfort through the environmental interview The evaluation that leads to the decision to carry out maintenance is referenced to the available resources.
Use Case 2.1 Concept Design: Quick calculation to find the design alternatives at conceptual level		
• Each designer (HVAC, lighting, structural, electrical etc.) provides list of alternative measures at concept level • Project manager communicates renovation alternatives with the building owner	• BIMcpd can be used in the first design session with the MEP company and the client to provide early recommended locations for approval from the client. • BIMcpd provides the ability to receive an IFC and other required information from BIMMS • National fire safety and building codes are updated. • Different scenarios for the layouts of	• Concept architectural design • Concept design of HVAC and electrical system using architectural assumptions • Pre-dimensioning of the system • Assessment of the number of devices to be installed • E-mail communication through design team • Comparison with national standard and normative requirements The Lead Designer with Project manager, communicates the renovations alternatives to the building owner with evaluation of cost with relation with scope of work. Approximately time for this activity is **10 days.**

	HVAC, fire and electrical systems are presented with BIMcpd • This can also help speed up and provide approximate costs for the quantity surveying of the renovation.	
Use Case 2.2 **Preliminary Design:** Preliminary energy simulations of the design alternatives		
• The design team prepares a set of available design alternatives • The renovation alternative approved by the owner is selected.	• See 2.1 above	• Drafting of the architectural design alternatives • Dimensioning of the systems (HVAC and electrical) on updated drawings • E-mail communication through design team • Constraint checking with architectural preliminary design • Definition of preliminary draft of system design The estimated time for this activity is **10 days**.
Use Case 2.3 Developed Design: More detailed energy simulation of the design alternatives		
• Model coordinator ensures that the latest information is included in the BIM • The energy expert refines the simulation	• BIMcpd includes a tool for verifying the "presence" of the various BIM objects (via the ontologies from WP3) and provide a report to the user • This can help ensure consistency in BIM projects	• Development of the final architectural design for the building • Development of the systems (HVAC and electrical) detail design for the building using the updated architectural design. • Constraint checking with architectural design • Communication through e-mail with designers The estimated time for this activity is **30 days**.
Use Case 2.4 Detailed Design: More detailed simulation of the design alternatives		
• M&V expert can evaluate the potential energy savings	• By uploading simulated data associated with the detailed design, an M&V expert can evaluate this data (reporting period) against the pre-renovation baseline data to give the client an early indication of potential energy savings and reduced costs.	• Drafting of the project relating to the tender specifications, technical specifications and cost calculation. • Calculation of energy savings according to the pre-intervention baseline Definition of baseline energy consumption values • Calculation of energy certificates The estimated time for this activity is **15 days**.
Use Case 3 Construction: Implementation of the planned renovation measures		
• M&V expert can validate the actual versus the simulated potential energy savings	See Use Case 2.4 above – but this time real data will begin to come in as the renovation progresses So replacing the simulation data with this real data will help validate the potential savings made previously (in 2.1)	• On-site detail design conducted in parallel with renovation approximately **20 days**.

Fast mapping toolkit:

Use cases nd relevant requirement vs renovation process (ref. Table 3 D2.2)

Activities based on D2.1 tables that are relevant for Fast Mapping Toolkit	Fast Mapping Toolkit method	Baseline (how it is done in the business-as-usual renovation?)
Use Case 1 Initiation: Renovation project initiation		
• Measured Surveys (site survey), measuring each room in order to return a geometrical representation of the building to be renovated. • Measured Surveys (site survey), measuring each room building component (i.e. Window system) in order to return a geometrical representation of the building to be renovated. • Condition Surveys of existing structures • Identification of causes of past, or ongoing, deterioration and issues that need attention to prevent serious damages (and Photo collection) • Identification of HVAC distribution and size of each building service component (and Photo collection) • Identification of materials and classification according to environmental issues (and Photo collection)	• The toolkit helps to provide a visualization of the existing building. The geometric data are obtaind by a lacer scan. The lacer scan result in a point cloud of the considerd rum. • The point cloud are downloaded to the companion app in order to make it visible in the HoloLens2 • Once the point cloud is in the HoloLens 2, its possibly to define the walls, window, doors etc. All objects are defined as boxes. • By using the sensor stick, it is possibly to detect capacitance, inductance, electricity and temperature in the walls. Depending on the purpose with the mapping these properties are possibly to present in the HoloLens2 by boxes	• On-site inventory. Measurements can be estimate by each typical average apartment/ space Approximately: 1 apartment (average size) 2 workers = **2-3 hours** The estimated total time for the building is **60 hours**. • measuring each room building components Approximately: 1 apartment (average size) 2 workers = **2-3 hours** The estimated total time for the building is **60 hours** • Inspection activities dedicated to create of technical assessment Approximately: 1 apartment (average size) 1 worker = **2 hours** The estimated total time for the building is **30 hours** • Measurement of the missing parts, if needed Approximately: 1 apartment (average size) 2 workers = **1-2 hours** The estimated total time for the building is **15 hours**
Use Case 2.1 Concept Design: Quick calculation to find the design alternatives at conceptual level		
• Architectural designer prepares graphic presentations of the project for discussions with the client and other interested parties • Architectural designer produces a set of preliminary design drawings at an appropriate scale (typically 1:200-1:100) with floor plans, sections, elevations and 3d modelling • Architectural designer produces technical reports to explain design options • Architectural designer produces architectural plans and documentation describing the project to a level of detail as required for Planning or Building permit applications (based on the approved design)	• The visualisation can help to understand how the different options will look like • The fast mapping gives in first place information about exixting construction. But its possibly to add boxes on other places. What is difficult is to remowe things.	• Creating CAD drawing from the measurements, activity can be estimate by average size apartment Approximately: 1 apartment (average size) 1 worker = **4-8 hours** The estimated total time for the building **90 hours**
Use Case 3 Construction: Implementation of the planned renovation measures		
• Identify existing geometry of a room or a whole building • To the geometry add installations etc. • Visualize existing building in 3D	• Identify existing geometry by a lacer scaning that is transferd to the toolkit • Define walls, window and doors • Use the sensor stick to add installations to the digetal geometry • The tool visualize existing building in 3D	• Site inspection analysing presence of building services, Installation components etc. This activity is impossible to reach with inside wall Services. Approximately: 1 apartment (average size) 2 workers = **2-3 hours** The estimated total time for the building is **30 hours** • Documenting presence of systems in CAD drawings estimate by average size apartment 1 apartment (average size)1 worker = **4-6h**

10. Annex III – BIMMS - Costs to implement

The ECON KPIs can be calculated considering the costs and the values of the implementation of the BIMMS in a mid-size organization with a team composed by professional figures with competencies in the building sector and renovation works, like architects and engineers.
The BIMMS implementation consider the deployment in the organization premises with a deployment in a existing organization's IT infrastructure. The deployment can be also done in a cloud service, but due to high variability in the services offered on the marked, and to simplify the baseline definition, was considered only the deployment on premises.
The costs considered are the sum of hardware, software licenses, and the IT maintenance and implementation services. The costs are calculated as average of the current availability and can be subject to changes not dependent by the authors.

		BIMMS - Costs to implement (prices in euros)	Mid-range	Low-range
Hardware	a	Server	6000	3000
Software	b	Microsoft Windows Server Standard	2000	2000
Software	c	Openlink Virtuoso Server Workgroup	1000	1000
Services	d	Configuration, Maintenance, Other (1st year)	3000	3000
Services	e	Maintenance	1500	1500
Total	F	a+b+c+d	12000	9000
Total for 5 years	G	F+(c+e)*5yr	22000	14000
Cost per year*	H	G / 5yr	4400	2800

The server configuration is able to support up to 50 users (mid-range) or 30 users (low-range), and differs in CPU, RAM and Disk space availability. The BIMMS is considered in use at least for 5 years, without major updates in hardware configurations. The total cost for 5 years considered the total costs for the first year (with server, software, and full implementation services) and a year ownership fee composed by the software license subscription (Openlink Virtuoso for 1000 euros) with a reduced service maintenance fee that consider only IT maintenance (esteemed in 1500 euros).
As reference, other CDE platforms available on the market offers monthly and yearly SaaS solutions. The functionalities, features and tool included can differ significally from the BIMMS. The costs do not include discount prices.

Users per year(s)	Autodesk BIM 360 Docs	Kroqi (CSTB) Enterprise	Comparison with BIMMS MID-Range Server
1 user \ 1 year	530	12	n.a.
20 users \ 1 year	10600	2880	2800 (low-range)
30 users \ 1 year	15900	4320	4400 (mid-range)
1 user for 5 years	2650	60	n.a.
20 users for 5 years	53000	14400	14000
30 users for 5 years	79500	21600	22000
			Prices in euros