RINNO

RINNO PROJECT

Report

An augmented intelligence-enabled stimulating framework for deep energy renovation delivering occupant-centred innovations

Deliverable 3.2: Building-As-Is Capturing and Mapping Tools (Final Version)

Work Package 3: RINNO Toolkits for Improving the

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Executive Summary

This deliverable is part of the task T3.1 Immersive Building Capturing & Mapping. This deliverable detail the BIM modelling created for the three demo cases. The 4th demo in Denmark was not created using scans as the project already had an existing BIM model. The D3.2 also details BIM model done after renovation for the French et the Greek demo. Danish and Polish demo are also set to have BIM models after renovation, after the end of the Rinno project, by the end of 2025.

Scans of the buildings were conducted on the outside and the inside imposing minimum disruption to the building occupants. Once the building scan was completed, it was updated with the envelope's thermophysical properties.

Several tools were used to capture, analyse, and model the existing buildings: drones, 3D cameras, infrared camera. The purpose is to achieve a precise capturing and modelling to represent the real dimensions and geometry of the building.

On the other hand, thermophysical properties (U-value…) were manually integrated to create the BIM model which was then simulated for their energy consumption in the T3.2.

This deliverable is the direct sequel of the D3.1, which focussed more on the process of the Bim's creation. It adds the post renovation's BIM of French et Greek demo. It also contains feedback of the uses of the BIMs models during the project.

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1. Introduction

The present report is a public deliverable (Deliverable D3.2 “Building-As-Is Capturing and Mapping Tools (Final Version)”) of the RINNO H2020 funded European project (GA 892071)

1.1 Scope and Objectives

The main aim of this report is to provide a detailed description of the activities conducted to deliver the BIM model of the demonstrator buildings.

For existing buildings, especially if there are no existing plans, developing a Building Information Modeling (BIM model) can make it easier for designers and owners to make changes to the existing building. It is very useful nowadays to enhance the design, to accelerate the manufacturing phase and finally to optimize the construction work on an occupied site.

A 3D scan was required to model the existing buildings, via a cloud of points to generate a detailed BIM Model. This included the existing building showing the elevations, sections and 3D view of the building. This BIM model will be used to simulate the energy consumption for different scenarios and to choose the best one based on economic, technical, and environmental assessments. Each partner has the responsibility to scan a building and generate a detailed BIM model.

1.2 Structure of the Deliverable

This deliverable has been divided into two sections. The first describes how the Building Immersive Model were been created, and the second part explains how it was done on each of the demo case.

1.3 Relation to other Tasks and Deliverables

Once the BIM Model is generated, thermal properties of the building envelop were established based on the materials used on the existing building. This was used by task 3.2 to create a digital twin, which is another tool in WP3 to complete energy simulations. The aim is to generate a complete model and assess the best scenario from an energy, environmental and economical point of view by task T3.3.

In workpackage4, task 4.4, the 3D model can be used as the base for the digital twin and be integrated to the AR/VR learning module. In the same WP, task 4.2 can use the 3D model where the progress of a construction project can also be visually monitored at distance by linking building elements to the project planning. This type of interactions already exists in the market.

In WP4, task 4.1, the BIM model could also be used to control/supervise the façade insulation process, especially in the case of a robotic process. It is possible in the future to link the cloud of points to the robot that is being developed to print the exterior insulation on the façade. The robot has been tested on the French demo but did not use cloud of points, indeed, for renovation it is a complicate thing to do, to achieve few results. It will be necessary to evaluate if the existing data are sufficient or if a new scan is necessary to meet the technical specifications of this process.

IN WP5, task 5.3 the BIM will be used to visualize the building and to link the sensors to the building spaces.

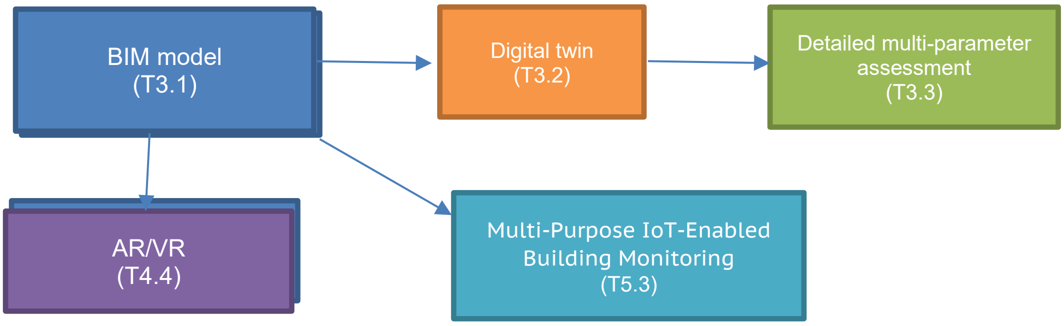

Figure 1: Interactions of the RINNO Renovation Optimiser and Planner with the rest of the RINNO tasks and WPs

1.4 Delays in submitting deliverable

This deliverable was supposed to be submitted M36 but was delayed due to delays in the construction site leading to delays in the making of the newly BIM models

2. Creating an immersive environment through 3D scanning

The growing adoption of BIM over the past decades has significantly contributed to the digital transformation of the AEC sector. As a collective platform, it facilitates exchanges between the various stakeholders throughout the building lifecycle. The digital model plays a central role in this approach; with the reliability of the information it contains being a major challenge.

A BIM model can be created either using 2-D plans or with the help of a 3D scan. Scanning-to-BIM is a process where the geometry of an existing building is digitalized to create a virtual model of the building. To create a BIM model the building is scanned to create a cloud of points that is then used to obtain the internal and external geometry of the building.

3D laser scanners capture a high-density of points of a physical building which is analysed via some intelligent algorithms to define the geometry and the shape of the building and its envelope. As a result, a BIM model will digitize, represent, and show the existing building.

The captured 3D building model serves as a unique and detailed 360°model that includes all the building elements with high accuracy for the design team. It serves as a 3D geometry audit.

2.1 Scanning a building

The first step, data capture, is now well-mastered thanks to the advent of faster scanners adapted to various use cases (new construction or renovation projects). There are three types of scanners: TLS (terrestrial laser scanning), MLS (mobile laser scanning), and ALS (aerial laser scanning). While the first emphasizes precision, the latter two offer rapid capture and greater adaptability to their environments. One important point to highlight is drone regulation, which varies from country to country. In France, regulation is relatively strict, which can lead to long delays or even flight refusals.
There are mobile and stationary equipment used to scan buildings. Stationary scans can be machines mounted on a tripod or a mobile application. For mobile units, drones are used to reach heights that are not accessible using stationary type of scanners. In some cases, a hybrid version, stationary and mobile scanners are used together to build a better cloud of points for taller buildings.

First the external part of the building is scanned. This included the facades (ground up to the top floor), roofs, windows, and external doors. It is important to scan the surrounding trees, other building, and any other exiting objects to take into consideration the shadow effect on the building during the solar and thermal calculations/simulations.

The internal geometry audit can be established using existing plans or questionnaires and with on-site survey to localize: the technical rooms, the existing heating emitters (radiators), the main electrical and thermal system elements (electric panel, ventilation units, meters, DHW, etc.) and centralized or decentralized Heating and Cooling generators.

But now with the help of scanning equipment, and occupants that are willing to allow access to their apartments, more accurate details can be obtained. A mobile 360° camera can scan the interior of the building with a good accuracy close to +/-2 cm for the design and cost estimation phase and +/-5 mm for the manufacturing phase.

When performing a scan, the first step is to establish markers on the ground that help the different scans realign and merge smoothly together. This is done by identifying several points on the ground that are then picked up by the stationary and mobile scan units. When the scans are merged the intelligence of the system proposes the built-up space of the building. This is then validated by the person performing the scan.

During the validation of the merged cloud of points, critical points such as vertical and horizontal alignments, edges of facades, roofs and windows, the exact location of the openings (windows, doors, etc…) and the external elements such as balconies, pipes, ledges, individual ventilation units and holes are analyzed and checked carefully.

It is also important to confirm while the scans are being done that trees, canopies, other buildings, access road width, electrical cabinet, etc which are part of the built environment around are correctly integrated into the cloud of points.

The scans can eliminate humans, animas or cars that are mobile and not part of the built environment especially if these have moved during the scanning process. There is nevertheless a human component that is important to make sure that items that do not belong to the built environment are deleted out of the scan.

2.2 Cloud of points

A point cloud is a collection of data points defined by a given coordinates system. These points are not linked like a 3D Mesh. The point cloud includes no surfaces or geometry. Once merged it helps to create a building. It involves cleaning unnecessary data using specific software provided by manufacturers (Leica, Trimble, Faro). This step is crucial because point clouds are increasingly large in volume, and to use them effectively, it is necessary to reduce them and keep only the essential parts. In addition, cleaning and assembling software enables the export of point clouds in standardized formats such as E57 or LAS.

A scan will include several file formats to create a cloud of points. Some are specific to 3D Scanner manufacturer (FLS for Faro, PTX/PTG/LGS for Leïca). The most common is E57 (standard ASTM E28073) which may be imported in all software to process the data (for example, Autodesk Recap, Cloud Compare, Leïca Cyclone 3DR etc…).

Point clouds are obtained using a LIDAR Scanner (for instance 3D Scanner using laser for laser geometry) and pictures (photogrammetry). Acquisition maybe static or dynamic. In the case of static 3D Scanner, each scanned position results in an “isolated” point cloud. All isolated point clouds will be gathered in one unique “unified” point cloud, it is the process of geometric assembly and reconstruction.

For easy understanding and exploitation of a cloud of points it is highly recommended that the different types of points are identified with a different color and pictures are integrated to the 360° spatial construction.

When there are interferences during the scanning it is important to clean these out manually. For example, a mirror in an apartment can create an additional space due to reflection. Thus, human intervention to identify the error and to delete the extra mirror image is required.

The precision and the density of the cloud of points will govern the quality of the BIM that is that is generated. We recommend retrieving the cloud of points in E57/LAS/RCP file formats.

2.3 BIM Model

Building Information Modeling (BIM) can be generated in different ways to help planning, designing and decision-making process fluid and easy in the building construction industry. For new building design the BIM is often developed by a BIM manager using the 2D plans developed by the design team. The combination of architectural, mechanical, and electrical plans with their physical and technical characteristics of each trade helps builds this virtual building that can then be manipulated to enhance a design efficiently.

For existing buildings, we can use the cloud of points to develop a BIM of the building. Currently a BIM manager is required at to perform this as the transition from a cloud of points to an exploitable BIM format. In the near future, this process can be automatized by generating rules and methodology of this transition by inspiring from what the BIM manager is performing today and with the lessons learnt on renovating existing buildings. Automating this process remains a major technological challenge. The emergence of robotics could facilitate data capture, while artificial intelligence and computer vision make it possible to accelerate the processing and conversion of the point cloud into usable data (plans, 3D models, or BIM). The automated method requires more steps. It includes data generation (capture + assembly), pre-processing (data cleaning), processing (segmentation and labeling), and modeling (creating links, BIM formatting).

Autodesk software like Revit, ReCap and AutoCAD to manage the BIM Models and the cloud of points. Revit needs a .rcp or .rcs file made with Autodesk ReCap. The RAW file format for the point cloud shall be one of them supported by ReCap.

It is important to note that there is an important difference between the building that is built with the scan of points and the building that is extracted from this to a BIM. The scan of points are locations on site and a BIM model is an extraction of this point of a virtual building.

2.4 Application for BIM

A BIM model can be used to plan and change the aesthetics of a building, planning of construction work and planning, establish a bill of quantities, perform energy simulations, heat island effect and many other functionalities.

When moving from a cloud of points to a BIM it is important to first understand the final use of the BIM that is being developed to be able to best aggregate the meta data.

A BIM manager prepares a BIM model from a cloud of points it is important to identify the different building elements. Once the building elements/components have been identified properties can be assigned based on built and/or renovated materials used.

For an energy modelling comparison of before and after a minor difference in the location of the floor would not influence the end results. Having the building model helps study the multiple kits or solutions to help identify the best for the project.

3. Developing the BIM files of the RINNO demo buildings

3.1 French demo case

The 4-level building located in Lille, includes 29 small (size T1) apartments. It has a ground floor, first, second, third and fourth floor and no basement.

Figure 1 Project Sarrazins located in Lille, France before renovation

Scanning the building

For the 3D scan of the French demo site, Bouygues Construction decided to combine the scanning with photogrammetry for the buildings envelop. A team of three people were required to do the scan; one person handling the stationary scanner and moving it from point to point and two people handling the drone. To coordinate the scans coming from the stationary units and the drone several target points were identified on the floor as shown in figure 2.

Figure 2 – Reference point located on the ground for merging scans (reference points)

Drone Phantom 4 RTK (figure3) was used with GPS RTK (figure 4) to place reference targets for georeferencing with centimetric correction by Orpheon network.

For the interior space a laser grammetry was used using static LIDAR scanner (Leïca BLK360).

The BLK360 was chosen for several reasons. First, because it is easy to handle as its compact and light (165mmx100mm for 1kg), and as its user friendly and easy to use as a non-expert can manipulate it to obtain easy and fast results. The acquisition time per station is relatively short (on average 4min per station) and no leveling of scanning head is required. The scanner can be moved from point A to B with ease and flexibility as it is randomly selected. The maximum space between laser locations was no more than 3m.

In the context of scanning in an occupied environment, it is important to be as unobtrusive as possible for the tenants and for the shortest possible time. The average time to scan an apartment is 18 minutes.

The accuracy of 4mm at 10m and the range of 6 m radius are more than sufficient and satisfactory for the typology of the project. In addition to the point cloud, the BLK360 takes 360° horizontal and 300° vertical photo spheric images, as well as 360° horizontal and 70° vertical thermal images, using the different sensors embedded in it (3 photographic sensors of 15MP and 1 FLIR sensor).

It took us twelve hours to scan all the common areas, the roof, the exterior all around the building and 60% of the individual apartments using the BLK360, and 3 hours for the building envelop with the drone. Roughly a period of three days was taken to complete the scans and obtain an exploitable cloud of points.

Figure 3 Drone use on the French demo

Figure 4 - Building interior using Standard LIDAR

Cloud of points

The BLK 360 was moved to the different locations identified by the red dots on figure 5. BLK360 LIDAR works with an iPad and the Cyclone Field 360 Software. Advantage of that is when the operator is on site for data acquisition, he has live image and scanned data streaming, live data viewing and editing on the iPad. Point Cloud is “pre-assembled” as the scan progress using intelligent algorithms which proceed to geometric analysis between two positions.

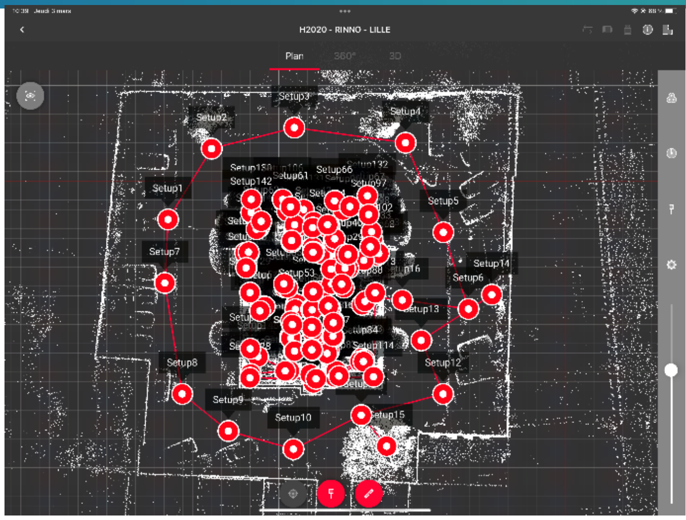

Figure 5 – French cloud of points overview “Site Map”

For each station, operator can control and correct the assembly between last and previous scan stations. As seen here in figure 6, the points read from one point is in blue and the next one is in brown. When the second location is scanned and the connection is made with the two scans, the scanner on site able to confirm and validate if the points merge and do not have any clashes and represents the real space.

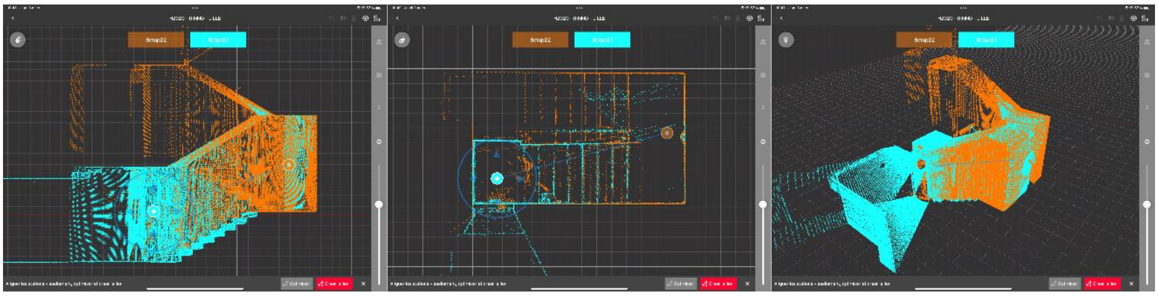

Figure 6 – Automated controls for pre-assembling point cloud between each position

BIM Model pre-renovation

After scanning and assembling the point cloud was automatically exported in RCP format with an assembly report in PDF to be provided to the BIM modeler. This report specifies coverage and overlays quality between “isolated” stations, strength of links created between stations. The cloud of points is then sent to the BIM manager who then converts this to a BIM model (figure 7).

As the scan is a 3D version of the building complete inside and outside the building it is also possible to obtain section through the building (figure 8).

The model is governed by a strict quality chart, that every stakeholder involved in the BIM development follows.

Figure 7 French BIM model version 2

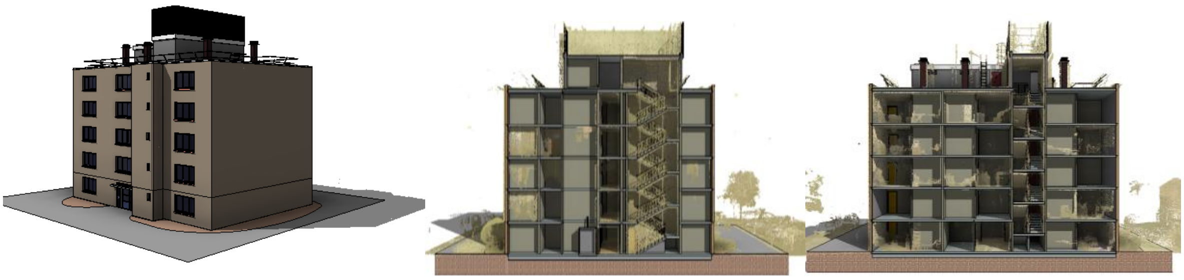

Figure 8: French BIM model – Section

BIM Model post-renovation

During the design phase, the model was used to present the studies conducted and to ensure the coherence of the various works to be carried out. Thus, it was updated and refined at each design phase, preliminary design, detailed design, and final design. For the handover of work and resolution of issues, the model was utilized in Dalux a BIM web platform to specify the location of the issues, monitor their progress and facilitate cooperation.

Figure 9: French BIM model post renovation – Section

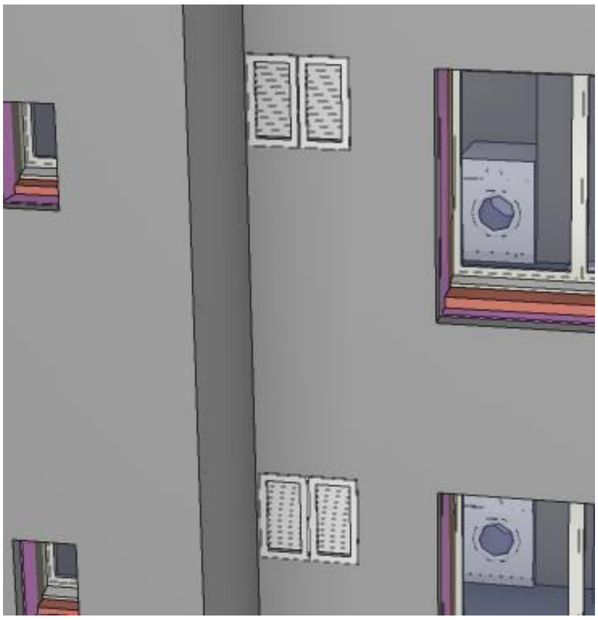

Figure 10: Inventilate from outside

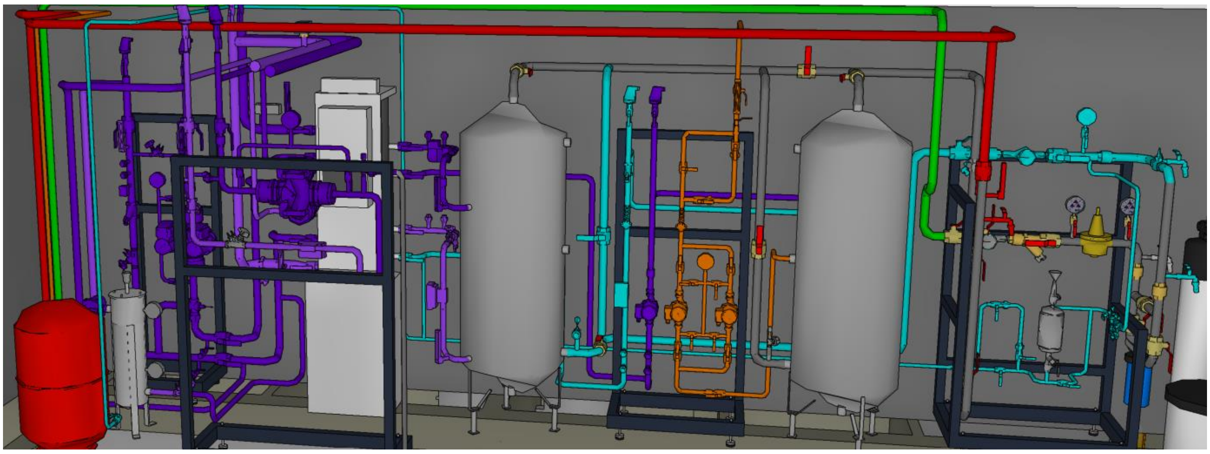

Figure 11: Technical room

This model does not include the technical details and the technical system of the Inventilate solution.

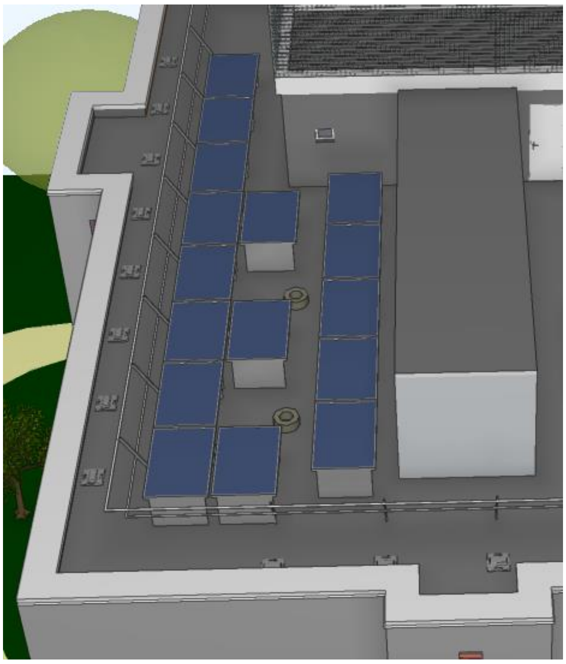

Figure 12: New PV panels on the roof

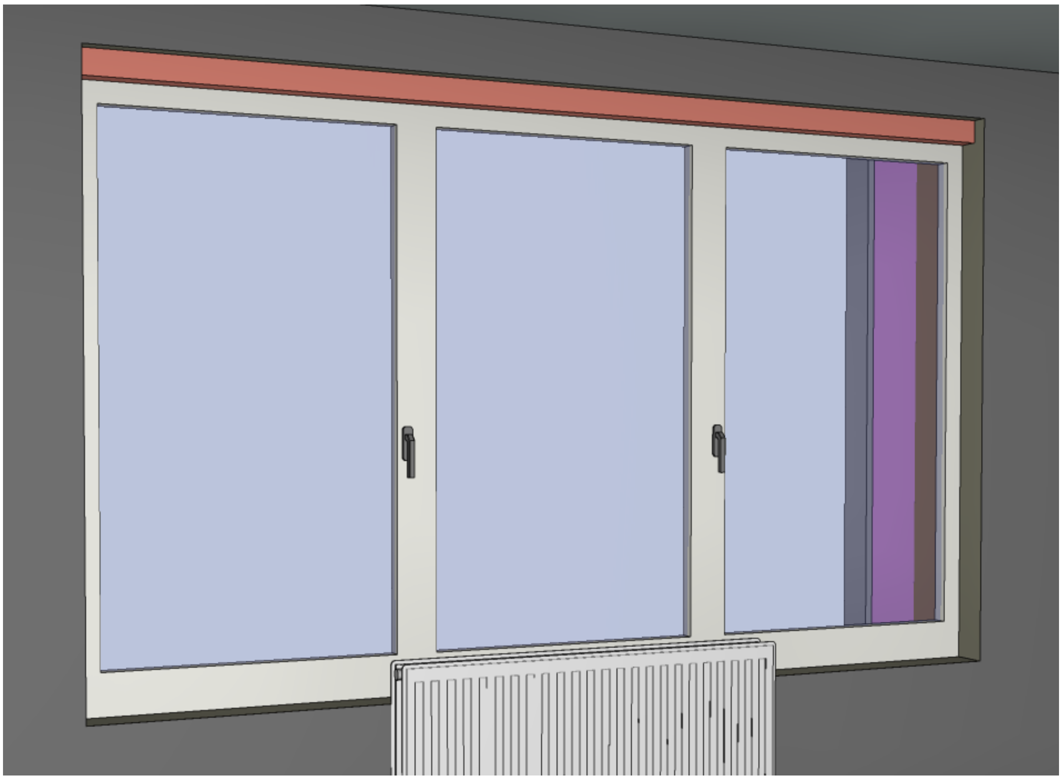

Figure 13: New windows with high-performance double glazing and roller shutters

Figure 14: The 2 layers of isolation, in pink

3.2 Greek demo case

The Greek demo is a four-floor building (a ground floor, first, second and third floor and a basement) (Figure 9). Each floor has two mirrored apartments. In total, the building has eight apartments with the same area of approximately 75m2.

Figure 15 Greek Demo Building in Athens

3D Scanning

The 3D scanning of the Greek building was conducted with the use of the FARO FOCUS S150 laser scanner (Figure 10). The FARO Laser Scanner is a high-speed three-dimensional laser scanner for detailed measurement and documentation using laser technology to produce exceedingly detailed three-dimensional images of complex environments and geometries in a few minutes. The resulting images are an assembly of millions of 3D measurement points. Specifications of the FARO FOCUS S150 are provided below.

- Range: 0.6 – 150m
- High Dynamic Range (HDR) Photo Recording 2x/3x/5x
- Measurement Speed: up to 976,000 points/second
- Ranging Error: ± 1mm
- On-site Compensation
- Accessory Bay
- Angular Accuracy: 19 arc sec for vertical/horizontal angles
- Integrated Color Camera: Up to 165 mio. Pixel
- Laser Class: Laser class 1
- Multi-Sensor: GPS, Compass, Height Sensor, Dual Axis Compensator

Figure 16 Faro scanner focus S150

To succeed a flawless point cloud registration, FARO FOCUS provides artificial targets such as white spheres with magnetic attachment (Figure 11) that should be placed in a vertical range of -50° to +50° from the scanner. Thus, the targets were placed in places visible from the scanner like the door thresholds or the stair railings. During the scanning process these targets were moved accordingly to follow the scanner from point to point and get an all-around capture of the building. When moving the scanner from one point to the other, care was taken so as to leave 1-2 targets static to be used as reference points for seamless image collation.

Figure 17 Artificial Target of FARO FOCUS

The 3D scanning of the demo building was conducted over a period of three consecutive days between 12 – 14 July 2021. During the first day, external scanning was conducted to capture the surroundings of the building as well as internal scanning of the ground floor corridors and stairs. On the second day, the apartments, and hallways of the first and second floor were scanned whilst during the last day, the apartments, and hallways of the third floor, as well as (part of) the basement were scanned. No scanning was conducted on the roof due to lack of safe access, see Figure 12. In total, approximately eight scans per apartment were conducted, two to three scans per staircase, six scans at the basement and eight scans for the external surroundings.

Figure 18 Access to the roof for pilot

Cloud of point

Having conducted the scanning of the Greek demo building, the next step in the process of the BIM development is the generation of the point cloud data. For this, the FARO SCENE software (Figure 13) was used. FARO SCENE is a comprehensive 3D point cloud processing and managing software tool for the professional user. It is specially designed for viewing, administration, and working with extensive 3D scan data obtained from high resolution 3Dlaser scanners such as the FARO Focus. FARO SCENE offers various services such as simple measuring to 3D visualization through to meshing and exporting scan data into various point cloud and CAD formats (RCP/RCS). The software allows automatic target recognition of artificial (spheres etc.) or natural reference points (corner points etc.), scan registration and validation and it generates high-quality data in full colour by incorporating images from automated targetless and target-based scan positioning. Additional functionalities include the use of filters such as filters for additional noise reduction and the removal of unwanted objects from registered scan data that moved through a scene while it was being scanned.

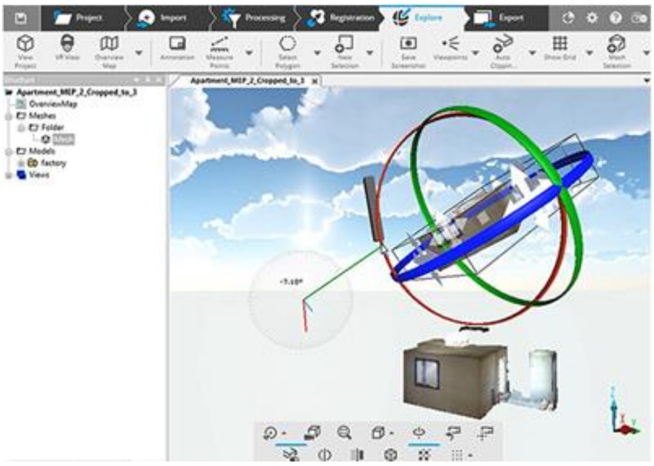

Figure 19 Faro scene software

BIM Model pre-renovation

Similar to the the French BIM, after CERTH completed the scan, Bouygues used this to create the BIM model of the building.

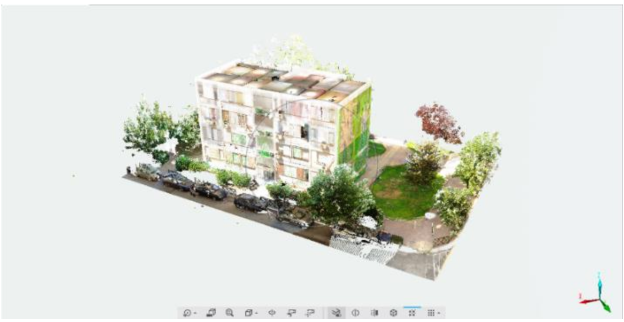

Figure 20 Greek BIM model Version 1

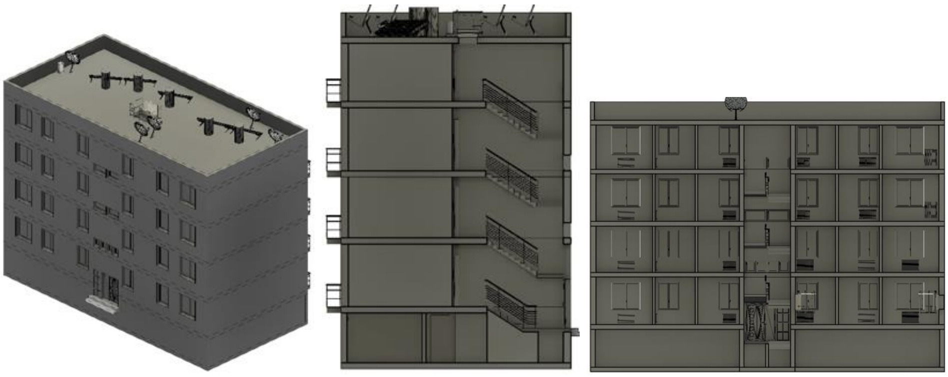

Figure 21 Greek BIM model

BIM Model post-renovation

The BIM model of the Greek demo building was updated to include the renovation measures installed. These include:

- External insulation on walls (8cm K-FLEX biobased panels)
- External insulation on the roof (20cm EPS)

- Insulation on the unheated basement (3cm EPS)
- Installation of solar thermal panels on all flats
- Triple glazing on the ground floor, first floor and one flat on the second floor
- Triple glazing with thermochromic pane on the windows
- Rooftop PV system
- BIPV system from GREENSTRUCT

It should be noted that the installation of the rooftop of the PV system and the BIOV panels from GREENSTRUCT had not been completed at the time that the BIM was updated. Furthermore, there was no access to the roof of the building. For this reason, the exact location of the systems was based on drawings provided by HPHI.

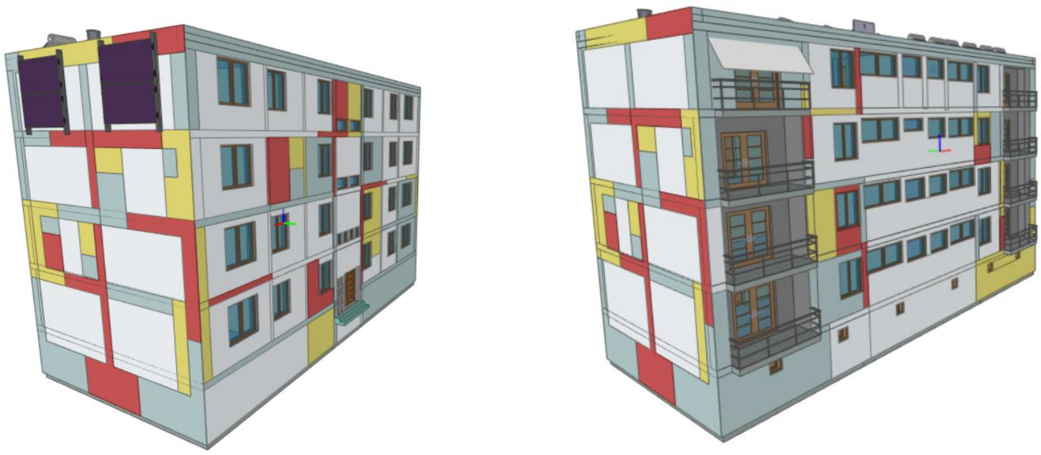

Figure 22 Updated BIM model of the Greek pilot – external views

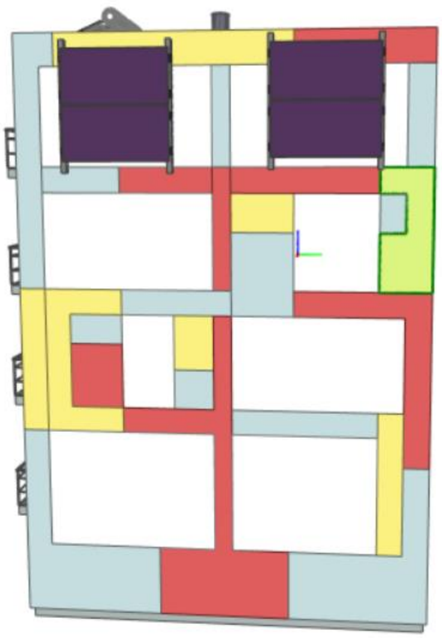

Figure 23 Close-up of the BIPV panel on the south-west facade of the building

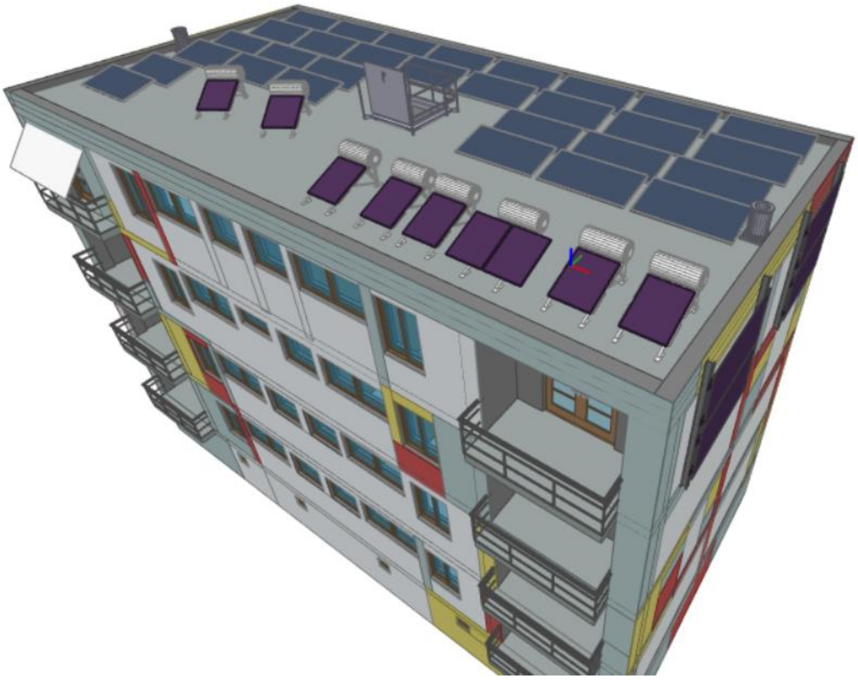

Figure 24 Close-up of the PV and the solar thermal systems installed on the roof

3.3 Polish demo case

The Polish demo has 3 floors above ground (ground floor, 1st floor and2nd floor) with a partial basement from the northern side. The building has one staircase with direct entrances to the premises. It is low-rise building with a traditional brick structure with a wooden roof covered with metal sheet. The total usable area of the building is 313,43 m², with a maximum height of 12m and has 5 flats.

Figure 16 Poland demo building: Masovia Voivodship in Rajszew

In the Polish demo, the 3D scanning has been conducted by a sub-contractor of K-FLEX. K-FLEX conducted thermal imaging survey of the building under cold weather conditions to identify thermal bridges.

3D scanning of the Polish demo building was conducted with the use of Faro Focus S70. 3D scanning consists in spatial measurement, registering several dozen points during the measurement in a few minutes.

The designed scanner stations are positioned to see every detail of the inventoried object. In this case, colour scans were made, which, based on the built-in camera, additionally added the photorealistic effect of the point cloud. In the interiors, the settings of 1/5 of the resolution with the quality parameter at level 3 were used. The elevations were measured with an increased resolution of 1/4 with the quality parameter at level 3. As a rule, the scanner positions did not exceed 5 m in relation to the next one.

The BIM model was developed as IFC4 format and contained information about components.

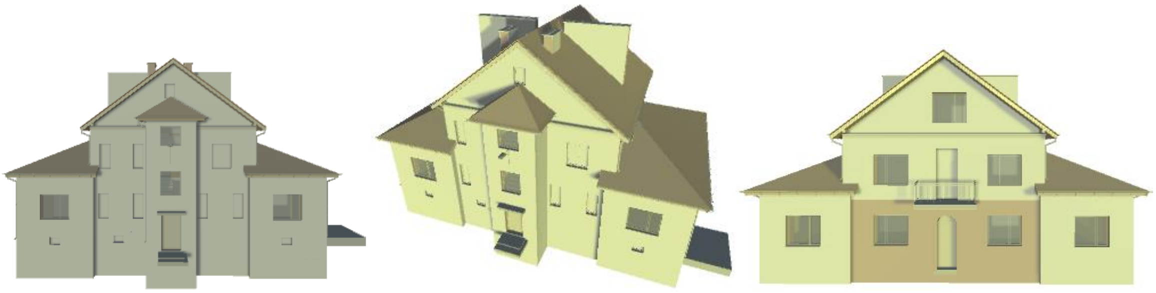

Figure 17 Elevation of the Polish BIM Model

Polish demo does not have a post renovation BIM because the renovation work is ongoing.

3.4 Danish demo case

The Danish demo case had an existing BIM model and thus there was no scan or new BIM created for the Danish demo building.

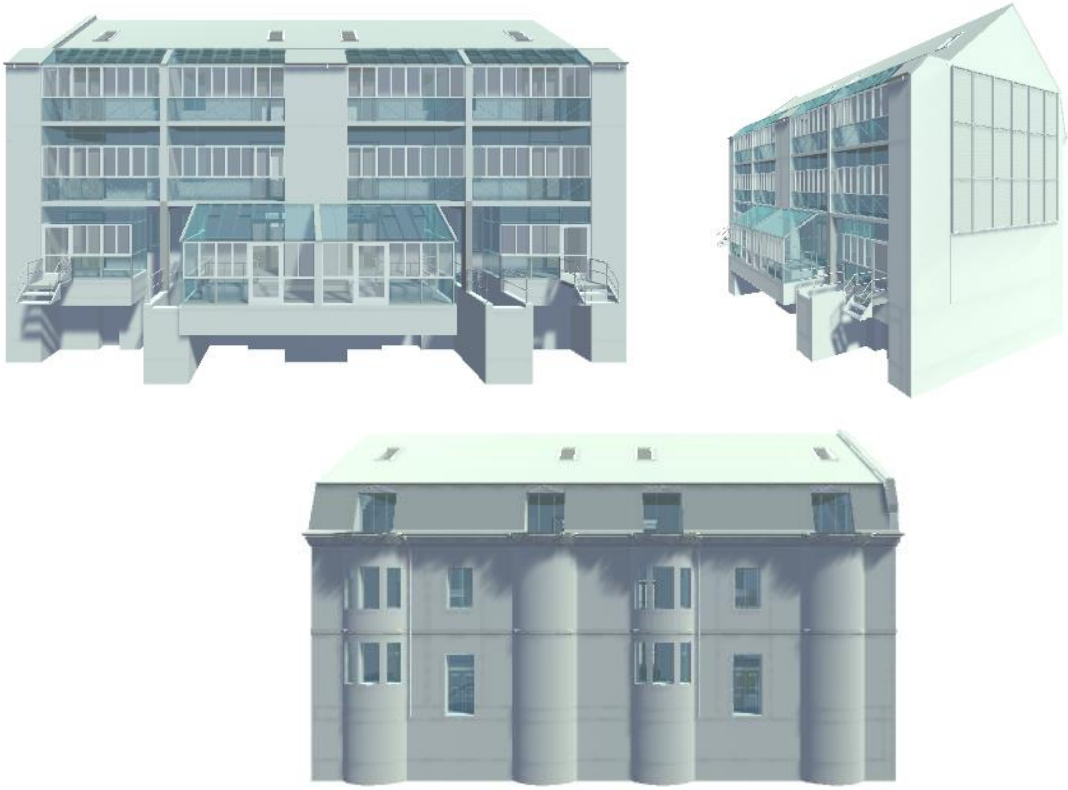

Figure 18 Elevation of the Danish BIM Model

Danish demo does not have a post renovation BIM because the renovation work just ended.

4. Conclusion

The scans have been successfully completed for the three demo sites in France, Greece and Poland. The BIM model for the Danish demo existed so no scan was done on this. The 3D models have been provided to the contractors on site and the objective was to use it to create a BOQ and integrate the new renovation details onto the BIM provided. BIM model developed in IFC format that includes all information on geometry, surrounding area, BIM component properties, Bill of Quantities, type and location of building energy systems and delivery units.

New limitations have emerged with the research into fully automated processes. The uniqueness of each building complicates the creation of a universal workflow, the quality of point clouds affects both accuracy and computation time, there is often a lack of integration between components, and insufficient data is available for certain types of structures to train machine learning algorithms. Moreover, human verification is still required at every stage. But the gain of this process is significant, because with Scan-to-BIM we can reduce both cost and time, ensure data consistency between the physical and digital models, add value throughout the building lifecycle, and move toward an industrialized process. At Bouygues Construction, thanks to the experience gained during the Rinno project, the first results have been achieved using AI and computer vision. A complete automated BIM modeling process has been implemented and tested on preliminary datasets for an internal project, CRHOS BYWALL.

ABOUT RINNO

RINNO is a four-year EU-funded research project that aspires to deliver greener, bio-based, less energy-intensive from a life cycle perspective and easily applicable building renovation elements and energy systems that will reduce the time and cost required for deep energy renovation, while improving the building energy performance. Its ultimate goal is to develop, validate and demonstrate an operational interface with augmented intelligence and an occupant-centered approach that will streamline and facilitate the whole lifecycle of building renovation.

For more information, please visit https://rinno-h2020.eu/

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