ENSNARE - ENvelope meSh aNd digitAl framework for building Renovation

D7.1 - Architectural construction projects for demo buildings

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Revision Table

Version	Date	Modified Page/Section	Author	Comments
0	12.08.2022	TOC	ABUD	
0.01	12.09.2022	TOC + Outlined content	ABUD	
0.02	12.10.2022	Contributions from pilot leaders	ABUD, TARTU, COAF, BAL	Content provided by pilot leaders to be structured in the next version
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1.0	12.12.2022	First complete DRAFT version	ABUD	
2.0	16.01.2023	Second version	ABUD	Content ready for 2nd Review
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4.0	31.01.2023	Final version	ABUD	Reviewed version ready for submission
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Content

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Summary

The ENSNARE project main goal is increasing and supporting the implementation of NZEB renovation packages through the development of two key structures to accomplish this objective: an industrialized envelope mesh and a digital platform that will interconnect all ENSNARE's solutions.

This report is related to the concept design of 3 demo buildings and 3 virtual demos based on the specifications defined in the previous WPs in the combination of the architectural and energetic approaches. In WP7, the architectural plans for the entire solution (based on information from all digital and physical WPs) for demo buildings (residential typology) are developed. The primary outcome will be the definition of the architectural projects of the pilots, conceived by the consideration of integration of the most convenient products for each element and section of the pilot building and data from the different digital tools developed in the project. The information included in this Deliverable 7.1 is the result of the work carried out in Task 7.1 *Building Concept design – Architectural construction projects*.

The report is subdivided into the following sections:

- *Introduction*. The introduction will present the ENSNARE project, as well as its aims and goals. In addition, the purpose of this report and its relationship with the other activities of the WP7 will be further clarified in the following paragraphs.
- *Description of the Demo and Virtual Buildings.* This section will introduce the characteristics of the buildings which will be retrofitted in Europe in the framework of the ENSNARE project. The site and general information on chosen buildings as well as existing architectural, structural, mechanical and electrical systems will be overviewed based on the information provided by the partners in relevant locations. These inputs will be part of section 3 Building concept of the pilot buildings.
- *Diagnosis report - Current status of the building.* This section will identify the demo building condition of the load-bearing structures, and fencing structures of the building, and the possibilities for reconstruction before the optimal renovation concept. Once all the information about the partner's technologies and diagnosis reports are collected, outline specifications (technical and logistical) will be developed and proposed to the client as part of the concept design phase.
- *Renovation Measures.* After describing the initial information on the current buildings' condition and the overall framework of the renovation process, some measures that are needed before an actual

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execution will be defined. This section will mainly include a description of the preliminary concept design for each case study including analysis of the technologies, solar studies, evaluation of structural systems, feasibility study and expected impact of the renovation strategies. Additionally, it will be described the planning strategies, including the development of schedules for the transportation of materials, and construction considering the climatic specifications of each region.

- *The next steps and considerations* section summarizes the actions to be carried out once the primary renovation process is defined. Relevant limitations of projects will be outlined for consideration in later design stages.
- *Conclusions.* The main findings of the report and the overall process/methodology will be synthesized.

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List of Abbreviation

BIM	Building Information Modelling
BMS	Building Management System
BOS	Balance Of the System
BSS	Building services system
D5.1	Deliverable 5.1
D7.1	Deliverable 7.1
DHW	Domestic Hot Water
DoA	Document of Agreement
DP4ER	Digital Platform for Envelope Retrofitting
EBC	Electron Bean Curing
EDF	Exterior grade, Heavy duty or severe use, Flame-retardant grade
EDST	Early Decision Support Tool
ENSNARE	ENvelope meSh aNd digitAl framework for building REnovation
ETICS	External Thermal Insulation Composite System
GHG	Greenhouse gases
H2020	Horizon 2020
HB	Heat Batteries
HVAC	Heating, Ventilation, and Air Conditioning
IDP	Integrated Design Process
LCA	Life Cycle Assessment
LMN	Thermal insulation of mineral wool board
NZEB	Nearly Zero-Energy Buildings
OSM	OpenStreetMaps

PCM	Phase Change Material
PEFs	Primary Energy Factors
PV	Photovoltaic
PVT	Photovoltaic Thermal Collectors
R&I	Research and Innovation
SCOP	Seasonal Coefficient of Performance
SEER	Seasonal Energy Efficiency Ratio
ST	Solar Thermal (Collectors)
T7.1	Task 7.1
TEC	Tecnalia
WP	Work Package

1. Introduction

1.1. Context. ENSNARE project, WP7 and T7.1

Building Design Concept

ENSNARE (ENvelope meSh aNd digitAl framework for building Renovation) is a European funded research project under the H2020 Programme – Grant Agreement Number: 958445. The project will run between 2021 and 2025, by a Consortium comprised of 19 European partners from 12 countries.

The main goal of the ENSNARE project is to boost the implementation of Nearly Zero-Energy Buildings (NZEB) renovation packages in Europe, with a focus on residential buildings. To accomplish this objective, the project develops two key structures that interconnect all building components: an envelope mesh and a digital platform. The envelope mesh is fully modular and facilitates the mechanical assembly and interconnection of all components and energy/data networks. The Digital Platform is aimed at providing stakeholders with a clear structure and access to a wide range of technologies for deep renovation of buildings. It supports all stages of the renovation process, from early decision making and data acquisition to the manufacturing, construction works, and the operation and maintenance of the implemented system. The platform makes use of a digital toolbox (an open collection of modular tools) which is closely linked to a digital model of the building. The approach conceived in this project consists in continuously updating this model, starting with a simple and basic concept, which as the process evolves increases in complexity and interaction potentialities. In its final stage, the model is a Digital Twin that allows real-time control, simulation, and operation of all building components.

<u>According to the Document of Agreement (DoA):</u>

In Work Package (WP) 7, the architectural plans for the entire solution (based on information from all digital and physical WPs) for demo buildings (residential typology) are developed. Three demos will be refurbished with the system: one in Estonia (Nordic Climate), another in Bulgaria (Continental climate) and the last one in Italy (Mediterranean climate). Apart from this, the used technology from the project is implemented in 3 virtual demos in Glasgow, Netherlands and Italy with different configurations to compare the data with reality.

Task 7.1

The task includes the design of the final concept of the building (construction projects with all the details) according to the requirements of customers (WP1)

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and the alternatives of the materials and systems developed in previous WPs. The pilot's architectural project is done in combination with their Digital Twin in parallel with WP4 to combine the architectural and energetic approaches. The seven Essential Requirements (Construction Products Regulation) are to be fulfilled during the design process:

1. Structural and mechanical - checking any possible problems related to the connections and behaviour of the different components, improvement of the use of the different materials and systems developed;
2. Safety about Fire - considering the characteristics based on the testing of the different materials and components developed;
3. Hygiene, health and the environment - control of the influence of the components on the interior of building, analysis of the traceability of the different materials;
4. Safety and accessibility in use - compliance with the specific requirements of the demo buildings;
5. Protection against noise – verification of the behaviour related to vibrations and noise transmission of all the elements and design concepts. As prediction models, the methods of ISO 12354:2017 and the ISO 10848:2010 are used;
6. Energy economy and heat retention (using tools developed in WP4) - verification with the requirements of the project and an Energy Positive Building, obtaining a NZEB;
7. Sustainable use of natural resources – study of the connection of the data of the components developed in previous WPs with the digital twins of the pilots and its influence.

The architectural project will consider the integration of the most convenient products for each element and section of the pilot building.

Task 7.2

The task is to validate the research results in the real scenario (North of Europe - Tartu, Estonia) with the participation of all the partners involved in the development of the systems. The partner responsible for providing construction and units elements is also in charge of transporting them into the construction demonstration site in respect to the construction timing deadlines. Once the architectural project is technically and economically validated, the system project’s definitive implementation is carried out in both buildings.

Task 7.3

After the validation of the architectural project for the building (Continental Europe - Sofia, Bulgaria), the system is implemented on the demo building. The process

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of installation is the analogous to the North demo building considering a completely different configuration. The same components are to be used with some modifications to the new configuration, to demonstrate the feasibility of the concept.

Task 7.4

The installation process is the same with the other two demo buildings taking into account that the configurations are different from each other. The building which is going to be retrofitted is located in the south of Europe (Sassa Scalo, L'Aquila, Italy). All the components are going to be the same but adapted to this new configuration, in order to demonstrate the feasibility of the concept. When the architectural project is validated, the system project's definitive implementation is carried out in the demo.

Task 7.5

Along with verification of real demo buildings, three virtual demos are also used to check the performance of the ENSNARE system. They are connected to several hundred machine-generated virtual demos in three different climatic regions. The same process that was used for real demos is also followed for these virtual demos to be able to compare the results of the system in buildings with higher surfaces than the ones implemented in the real demos.

1.2. Purpose

According to DoA:

In the framework of ENSNARE project, the general objective of ABUD in WP7 is to demonstrate and validate the system performance in three real pilots in different climates: Nordic, Continental and Mediterranean. The partial objectives are:

- To demonstrate the behaviour of the system and compare with traditional ones
- To identify limitations and problems
- To validate the fulfilment of the objectives of the project
- To assess the performance of the integrated system
- To validate the system for three European climates
- To validate on-site cost advantages of the new system

The task of the ABUD is to design the final concept of the building (construction projects with all the details) based on the requirements from customers defined in WP1 and the alternative options of the materials and systems developed in previous WPs. To develop the final concept, the architectural project of the pilots and their Digital Twin will be combined, merging the architectural and energetic approaches.

As part of the work, the architectural project will consider the integration of the most convenient products for each element and section of the pilot building. The final Construction Project for the demonstration building will give an important output concerning the type and number of materials used and construction elements manufacturing. All this work will be done considering the data from the different digital tools developed in the project (DP4ER, building acquisition modules, EDST and Digital Twins)

1.3. Methodology

1.3.1. Integrated Design Process (IDP)

The traditional design, which is usually defined as a linear process from the client's request to design and construction, is unable to integrate an opportunity for maximum optimization of processes on each level. The usual conventional design may have only limited exploitation of the potential advantages of the physical environment that the building is located in, on the other hand, IDP maximizes the benefits of the renovation process.

The integrated design suggests an iterative design approach with effective involvement of all the actors of the project and allows its optimization during the design, and execution processes. It is a multi-disciplinary design, that aims to involve the surrounding social, ecological and economic communities. IDP can be applied to any design project due to its flexibility and opportunity to be adjusted to different goals and environments. The project execution contains the same main steps and actors of the linear approach, however, to attain the advantages of integrative design the design facilitator is introduced to ensure the iterative design of the projects in compliance with the set-out goals. So, the integrative design process is based on the linear backbone of the traditional approach to design with a few essential components which expand the design with iteration loops (Figure 1).

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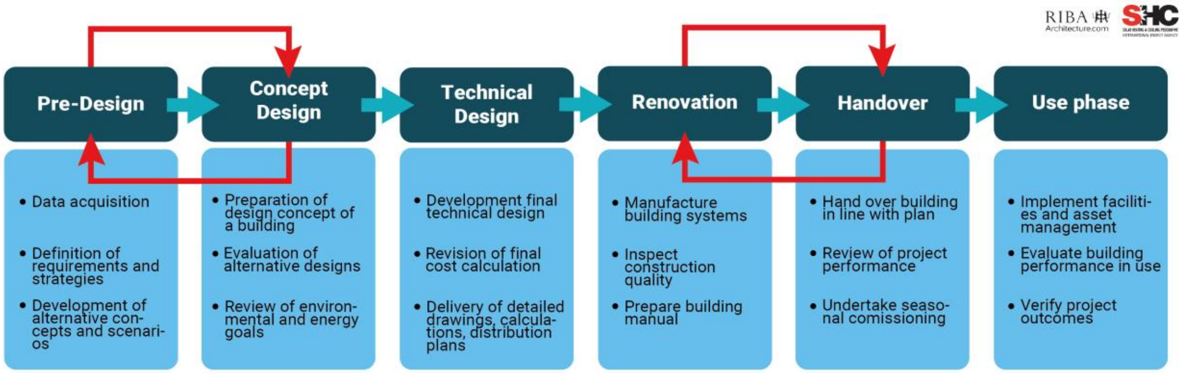

Figure 1. The design process (Author: ABUD)

Integrative design links ecology and economics through the synergy of competency and skills throughout the process. This allows the client to reduce investments and operating costs while at the same time reaching a high level of performance. The added feedback loops keep the team engaged, evaluate and challenge each decision to reinforce the effectiveness of the process.

The actors in projects efficiently cooperate with each other from the early stages of the design with a vision for far-reaching goals and iteration of the processes in order to solve the rising issues and find an optimal solution between various specialists. The composition of the design team and their communication is adapted to every project. The core members work on the project throughout the whole process, whereas the additional members may be brought for the duration of the project or for a few workshops.

The design facilitator/manager is appointed to manage the Integrated Design Process. The member must possess some knowledge of green design principles, ensure participation of all members of the design team in the process and align their vision to a common vision.

The sources of the methodology include the Grant Agreement of the project and the Integrated Design Process Guideline developed by the International Energy Agency (Günter Löhnert, 2003).

1.3.2. Concept Design

The Concept Design stage of the process is identified as a crucial step towards achieving an optimized building design. It investigates the alternatives in the design, continuously checking them with the requirements and project goals with other actors (Riba, 2020).

During the previous pre-design stage, the ideas of the project are translated into the structure, where various scenarios are developed in relation to the building's site opportunities, programmatic requirements, performance criteria, costs, schedule, and benchmarks. Then, the options are checked against the goals and objectives of the project.

The concept development establishes the performance targets for a broad range of parameters and develops preliminary strategies, which help to avoid the sub-optimal solutions. Considering the skills of engineers and consultants to be involved in the early stages ensures an efficient definition of the concept of the whole renovation process in macro.

During the concept design, the preliminary energy and financial analysis is made to assess the available options and strategies. Life cycle assessment (LCA) is conducted to see the alternatives associated with long-term costs and savings.

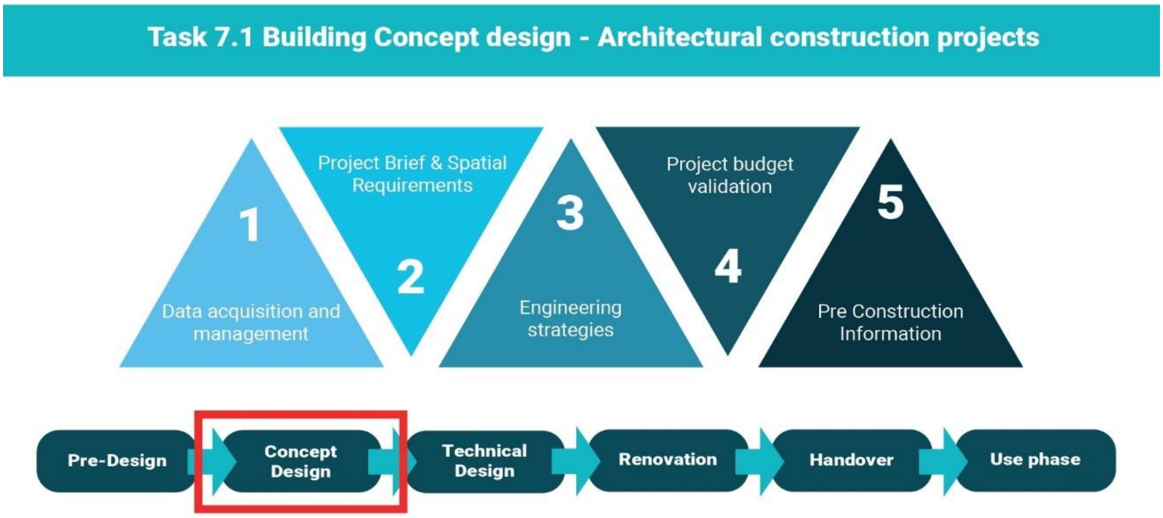

Figure 2. Concept design tasks (Author: ABUD)

As shown in Figure 2, the five main objectives are set for the concept design phase:

- *Data acquisition and management – collecting previously developed components and systems*
- *Project brief and spatial requirements – development of drawings and analysis of context*
- *Engineering strategies – definition of building services (civil and structural)*
- *Project budget validation – including initial costs and quantities*
- *Pre-construction information – according to relevant developed design*

As for the limitations of the integrated design process, the length of the planning phase may take longer in comparison with the conventional design due to the needed cooperation between members and the structure of the design phase. A continuous collaboration may also result in conflicts during the decision-making, due to the involvement of many specialists from the beginning with different

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interests and priorities. Hence, the design process requires conflict management to keep a common vision of the team and enhance the quality of communication.

The renovation design also has some points to consider, which can affect the timing and the strategy. The system manufacturing process, transportation, and changing seasons may affect the implementation timing and schedules. All these factors must be considered in planning phase.

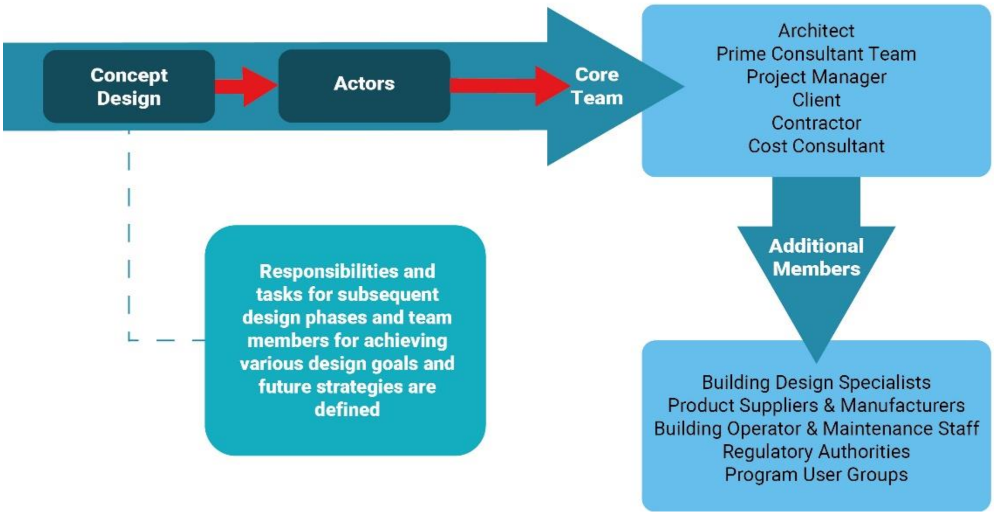

Figure 3. Members involved in the concept design stage (Author: ABUD)

As it was mentioned above, the team consists of core and additional members (Figure 3). The core team includes architect, prime consultant team, project manager, client, contractor, and cost consultant. The core team invites additional members as needed depending on the project type, expertise of the core team, and client preferences. On the other hand, the additional members may consist of building design specialists, product suppliers, manufacturers, building operator, utilities, maintenance staff regulatory authorities and program user groups (BUSBY PERKINS+WILL STANTEC CONSULTING, 2007).

1.4. Relation with other activities

<u>According to DoA:</u>

The workflow of ENSNARE is developed in a such a way, where a sequence of stages, each of which involves different set of activities, ensures achieving the requested objectives.

Relation with WP1. The project starts from the development of the framework of the project (WP1), considering the stakeholders and their interaction at

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different stages (CORDIS, 2022). This allows for connecting the virtual models with developed technologies and components.

The analysis of the six pilot buildings, 3 of them being renovated in reality and the other 3 acting as "virtual demos", will allow to consider the application of the digital platform in different stages of the renovation process. This exercise will provide feedback to the development of the digital tool, and therefore, to readapt and optimize the platform according to those recommendations.

Relation with WP2 and WP3. Initially, the first contacts between the owner/promoter and the architect/designer are made, and valuation methods and alternatives are studied. Provided basic information about the building (general dimensions, location, consumption, orientation, etc.) is used in the creation of a model with Level of Detail 4 (WP2) and several alternatives, which are analyzed by the Early Decision Support Tool (WP3) and reduced to the most relevant ones. The feasibility study based on the results is made including the initial concept, potential possibilities, technologies, and costs. It is essential to collect enough information to make it possible to come to the decision about the execution of the potential renovation.

If the contract is signed, the process of development starts again but with more details and precision. The real status of the building is identified using the ENSNARE onsite automated measurement system of the façade (WP2) by using the so-called April-Tags and OpenCV. The final renovation project (WP3) is selected based on the carried-out simulations and modular approach conceived by the ENSNARE façade mesh.

Relation with WP5 and WP6. The process till this point is done mainly using digital tools and virtual models, but after the design is completed, the effective renovation intervention is started in a real environment (WP5, WP6). Now, when components are defined in a virtual model, their manufacturing is upscaled.

In WP5 and WP6 physical technologies have been developed and tested. Different limitations and attributes have been noted during the development and testing process which are ought to be followed with the main purpose of optimal placement of the technologies or modules on the three pilot buildings. For that, three baseline scenarios have been formulated - one for each pilot building, with the aim of placing as many modules with active technology as possible on the building façade. The outcomes of the baseline modulation exercises are described in detail in the relevant pilot buildings sections. Nevertheless, it should be recognized that the results produced during the preliminary modulation exercise may change as the design advances.

Relation with WP4. As the last step of process, the Digital-Twin model (WP4) supports the management and effective operation of completely renovated buildings. This phase requires interaction between the renovation team, building owners and managers to provide a right exploitation during the life cycle of the buildings.

Along with the main processes of design and implementation, a specific management methodology is used, that includes 4 main iterative steps:

- *Definition of requirements. The system requirements and performance indicators are defined through analysis of context and trends in the industry.*
- *Development. Definition of the BIM model of the architecture of the system.*
- *Implementation and prototyping.*
- *Performance evaluation. The design of testing to verify the performance characteristics. Validation of the pilot buildings.*

The iterative method guarantees a satisfactory solution, due to the iterative design and development of the optimal technology. The strategy of the project adapts throughout the project according to feedback from the market, stakeholders and customers.

In addition, the developed modules and envelope systems are taken through highly focused monitoring activities in experimental buildings and virtual buildings, in order to execute the full assessment of performance in different setups and climatic conditions. An intermediate stage towards full integration in real buildings Six demonstrators (WP7) shows the replication possibilities (3 real Demo and 3 Virtual buildings) of the project, in terms of advanced and improved retrofitting activities.

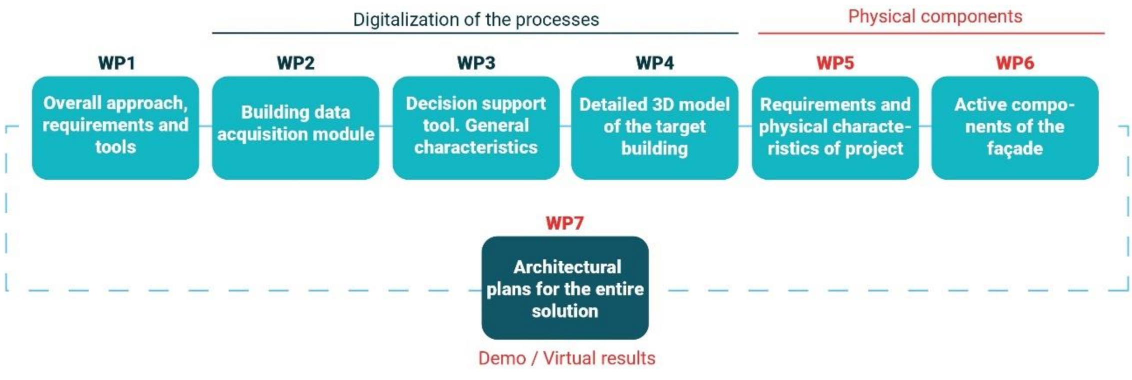

Figure 4. Relation of WP7 with other WPs (Author: ABUD)

1.5. Integrated Design Process (IDP) activities in WP7

The IDP approach to the ENSNARE project works towards a multi-disciplinary solution involving all the actors from the earliest steps of design. ABUD aims to design the final concepts of the demo buildings and act as a design facilitator/manager.

1.5.1. Pre-design

- The data acquisition starts with the basic information on the structure, location, systems, and drawings of buildings.

The pre-design step of the project involves the direct participation of partners from WP2, WP3, WP5, and WP6 along with representatives of demo buildings. Through continuous meetings once in two weeks, the core team of actors ensures that the essential data for further design is acquired, and all the stakeholders of the projects are introduced.

ABUD maintains effective information exchange and planning between the partners and finds the building limitations and challenges, the actors in terms of the configuration of modules, their placement, and their connection. This leads to finding new solutions but also may result in the delay of delivery results.

These processes of data acquisition and development of alternative concepts look like continuous interaction with partners and clients through meetings on a weekly basis. First, early designs are worked out in the 1st modulation exercises on a 2D level. This step allows all actors to understand how the ENSNARE system can be implemented in each demo and what limitations and additional requirements are needed.

The data management is taking place on the EMDESK platform, however, at the same time, external sources are used to coordinate the data. The information is stored according to each pilot and each phase to make the process of finding the necessary data easy and accessible to every WP though the links. The table is updated regularly on each step of the design process of the project. The complete table for all the pilots can be found in Appendix C: Planning.

1.5.2. Concept design

The main process in the concept design phase is a continuation of meetings in order to gather the needed information and engage all the stakeholders. Communication between the partners is helping towards the effective achievement of each step of the design process, including the important decision-making process. The data acquired is going to be a part of WP 7.2, 7.3 and 7.4, the technical phases of each of the demos.

- Data acquisition: the categorization of incoming data continues from the pre-design stage onwards. The nature of data goes more into detail, for the

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development of alternative strategies due to the individual specialty of each member, every WP requires its own set of data, which is also requested from the buildings´ representatives.

- Project brief & spatial requirements: due to the six different climates and different requirements of pilots, it is important to the decision-making process to make meetings separately, especially at this phase. The complete meetings schedule where the requirements and limitations are discussed can be found in Appendix C: Planning,1. Meeting schedule.
- Engineering strategies: the design and proposals are developed by technical partners, WP3 and WP5, for each case study. ABUD acts as a bridge between pilots and technical partners.
- Project budget validation: depending on the final decisions on the systems of the buildings, the cost is considered later by stakeholders depending on the technical elements of each case study. The costs of renovations will vary and not be the same. This step is closely related to the 3rd step of engineering strategies.
- Pre-construction information: summary of building renovation technical guidelines is delivered with the status of pilots and further steps of the project. In addition, the schedules of renovation for each pilot are developed considering each case study, country and regulations. The individual regulations and renovation project phases are explained in Appendix A, section 1.1 and section 2.3.

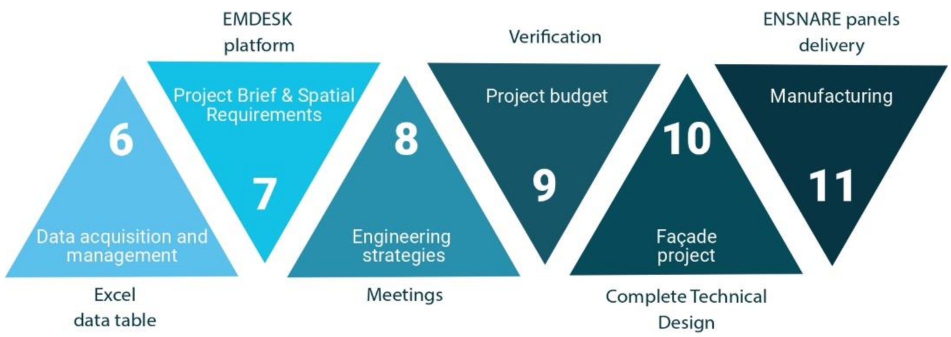

Figure 5. Used tools during the Concept Design (Author: ABUD)

The main outcome of the concept design is the initial project schedule for each pilot building. The scheduling improves the coordination and communication between the partners and the pilot leaders by tracking the progress of the activities, bottlenecks and status. It also provides a guide for the partners to identify their activities' inputs and outputs. Determination of the critical actions and milestones in case of progress delay enables one to focus on critical tasks in timely completion and identify which activity has a total float. Some main considerations should take into account the production of all the modules for the

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building (coordination of the initial works, production and delivery), new regulations and bureaucratic procedures (difficult to estimate the time of obtaining them), the times necessary for design, production and assembly (require special time and planning for manufacturers), and accessibility of the renovation for the performance in different seasons.

The schedule is going to be modified according to the activities performed in the next years. The modifications will take place in line with the needs of partners and pilot leaders, creating many versions of the schedule. The final schedule will be essential for detailed design of Pilot cases, which will be developed on M28 (April 2022) in WP7.

The meetings are carried out between the representatives of WPs and clients individually at each stage on a periodic basis.

The following three steps of concept design are carried out in each demo building:

1. Renovation report: assigned architects create a report based on current condition of a building, from which the limitations and new opportunities are explored.

2. Evaluation: the partners design alternative solutions based on new up-to-date inputs with more detailing.

3. Review: the solution is overviewed in the framework of project´s environmental and technological goals.

More complete information on the development of each model can be found in chapters of Programme and phasing for each pilot.

1.5.3. Technical design

The developed building concepts allows Tasks 7.2, 7.3, 7.4 to start in the period of M25 to M34 of ENSNARE project, which are led by 3 pilots.

The final detailed design of ENSNARE system is developed based on the previous options. All the information regarding the renovation process, including the detailed drawings, calculations and plans are delivered for each building. The final cost calculations are revised.

These next steps will be considered later in the design process, next year with the rest of the tasks with each pilot individually. ABUD will continue with the coordination and organization of activities and decision-making process with previously acquired data management on the EMDESK platform.

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1.5.4. Renovation

The renovation takes place when all relevant drawings and documents are provided to the actors and continuously updated. For TARTU, SOFIA and SASSO SCALO pilot buildings the documentation will be prepared in future Tasks 7.2, 7.3, and 7.4, respectively. Supervision is done by persons fully instructed by the designers with an understanding of structures and environmental issues. Quality control also will take place to ensure that the initial design goal and predicted performance are achieved. Renovation is continuously controlled and assisted. The specific control and management system is integrated, which collects data for optimization of the real-time performance of the envelope.

1.5.5. Hand – over

Before the start of the operation of the buildings, the interaction between the renovation team and the building owners and/or managers takes place. Any defects must be eliminated before the handover of the building. Upon completion, the updated design information must be provided to facility management. Validation and monitoring of energy and environmental performance through tests and re-adjustments are essential to not hinder the building's operation.

1.5.6. Use phase

The performance characteristics, data and feedback, are generated. The highly focused monitoring activities will be able to fully assess the performance of the ENSNARE system in different climatic conditions and setups. The system behaviour will be continuously evaluated according to the initial goals of the project. The operation is going to be fully supported by the Digital Twin model (WP4). Previously developed documentation serves as a basis for later renovation projects. Periodic re-commissioning and user surveys should be scheduled to evaluate the performance.

2. Description of ENSNARE system in the Demo Buildings and Virtual Buildings

2.1. General description of the ENSNARE SYSTEM

The description of the system according to the current level of development can be resumed in Figure 6. The modular façade developed in ENSNARE is an aluminum-based solution combining two main LAYERS; the inner layer and the technological external layer. The combination of both layers in an offsite industrialized solution represents the MODULE, that describes the modular façade concept.

When installed in the building, the module represents an over cladding solution that is attached to the façade to be renovated and it is anchored by means of two anchor points in the top part of the module using a hanging concept. This structural design implies a bottom-up assembly process on site to allow the accessibility to the anchoring elements during the implementation process. The module is suspended from the upper anchorage and stabilized in the lower anchorage. As a matter of principle for the ENSNARE concept of the system, the anchorages should provide a correct position for the module.

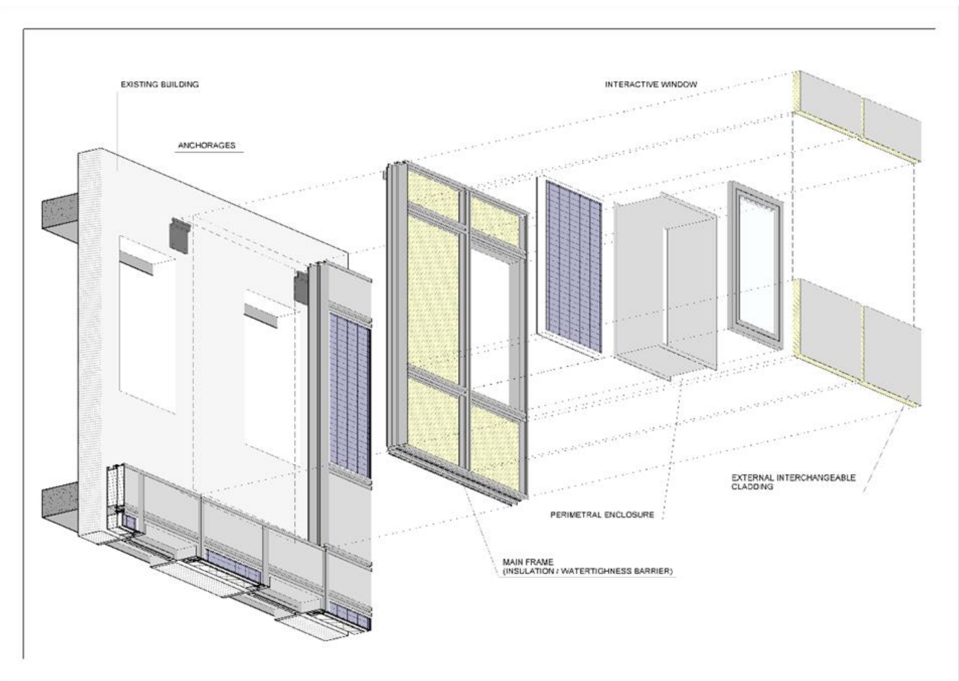

Figure 6. ENSNARE's modular façade concept (Source: RIVENTI)

The inner layer contains the structural aluminium profiles, the main frame of the module and the insulation, as well as the watertightness membrane. This internal

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layer generates the main covering skin of the building providing the main functionalities (structural, insulation, water tightness, etc.).

The second layer is the technological layer and is made up of a series of independent PANELS attached to the main (inner) structure by means of secondary profiles. The independence of each panel facilitates its replacement and maintenance tasks. It is an external interchangeable cladding designed to incorporate active technologies, such as photovoltaic, solar thermal and hybrid panels, but that can also include finishing panels and material such as Trespa phenolic boards or other types of materials, renders and systems (ceramic, glass, stone, etc.).

SOLAR THERMAL PANELS BASED ON ROLL BOND TECHNOLOGY (ST): solar absorbers of these panels have been improved due to the roll bond design, which allows to add two coatings in the roll bond channels to enhance the stability and performance of the ST panels.

PHOTOVOLTAIC THERMAL PANELS (PVT): this hybrid technology combines the PV effect with the thermal panels. The heat produced in PV panels is used by the solar collector to generate more thermal power. At the same time, the roll bond design helps to keep cool the PV cells for a better working.

PHOTOVOLTAIC PANELS BASED ON DIFFERENT SUBSTRATES (PV+STONE & PV+AL): standard BIPV panels have been modified to study and analyse new ways in order to integrate them in buildings. In this project, we have replaced the rear glass/backsheet of the PV panels by two substrates: synthetic stone (STONE) and ALUMINIUM (AL). Each substrate provides different properties to the PV panels.

- **PV + STONE** adds more aesthetic value in comparison with standard BIPV modules. This fact implies that we can offer a lot of possibilities to the clients for any building.
- **PV + AL** is a cheap, light-weight solution. Therefore, this might be the perfect choice for specific buildings with a reduced budget.

Additionally, the ACTIVE WINDOW is a complementary component that is attached to the inner layer, generating an opening that passes through both, the inner and the technological layers, by means of a perimetral enclosure that generates the support to hold the window. The active concept implies the incorporation of a heat exchanger to renovate the air in the inside room and the element is aligned with the system's tightness line.

Complementarily, another key element associated with active solar technologies are the REGISTRATION AREAS. These are panels that can be opened allowing the access to these specific zones where the main services associated to the solar

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technologies are integrated, implying pipes and wires for energy distribution, connections, control, monitoring and security devices, etc. These registration areas are arranged as part of the external technical layer of the module and are also in the outside part of the water tightness line. These registration areas need to be arranged one next to the other, providing an interconnection that gives the required continuity of the electrical and thermal network with the necessary accessibility. In the standard version of the module, the registration areas are made up of a folding Trespa panel.

Summarizing, the combination of different panels, windows and registration areas following the approach of a double layer implies to configure multiple and alternative modular designs, with different dimensions and compositions. This concept gives a high level of flexibility to generate a cladding that can be geometrically accommodated for alternative façade renovation scenarios, with different characteristics, technologies, and energy requirement levels.

The design process of the ENSNARE system is linked to different strategies that feed the design iteratively.

First, the design has been developed based on the basic requirements determined in task 5.1. Several calculations and simulations have been carried out to verify compliance with the requirements. In addition, RIVENTI has led the study of the integration of all the technologies within the system so that manufacturing, handling and installation are feasible.

At this point, full-scale prototypes have started to be manufactured for laboratory testing. The proposed tests are:

- Fire tests:

  o SBI: 5 tests. Performance of each technology under reaction to fire test. Fire load 30 kW. Conducted.

  o ISO: 2 tests. Each prototype 6.2 m^2. and includes all technologies, combined in different ways. Fire load 300 kW. In progress.

- Environmental tests:

  o Test under ventilated façade standard: 1 prototype of 12 m^2. All the technologies included. Wind and impact resistance test. In progress.

  o Test under curtain wall standard. 1 prototype of 17.6 m^2. Cladding layer is made of Trespa panel and a window is included. Tested for air permeability, watertightness, wind and impact resistance. In progress.

In parallel, within the framework of WP6, an experimental campaign is also being carried out to monitor and measure the energy generated by each of the active technologies offered by the ENSNARE system under real environmental conditions. 2 m^2 of each active technologies (PVT, ST, PV+AL, PV+ Stone) have been installed on a test bench at TECNALIA's facilities.

The information obtained from each of these tests' feeds into the design review and incorporates modifications to improve the performance of the ENSNARE system if necessary.

The details of the laboratory tests are presented in D5.5 v4.0 submitted in July 2022. The results and conclusions will be included in D5.6.

The details and results of the energy rating test will be included in D6.6.

Figure 7. Full-scaled prototype located in the Fire Test Bench. 6,2 m^2 (Source: TECNALIA)

Figure 8. ISO Fire test being conducted (Source: TECNALIA)

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3. Building Concept of the Pilot buildings

The characteristics of the buildings which will be retrofitted in Europe can be seen in the images below. Once the architectural project has been technically and economically validated, the system project's definitive implementation will be carried out in the demo buildings. It is also worthy to mention here that the roofs of the pilot buildings are excluded from the scope of the ENSNARE project and the intervention will be restricted to façades only.

3.1. Demo Building 1: TARTU, Estonia

3.1.1. Building General Description

Demo Building 1: Tartu
The demo building 1 has the following characteristics:

Table 1: Characteristics of demo building 1 (Source: Tartu)

Location	Tartu, Estonia
Year of construction	1947
Storeys number	2
Typology	Residential
Number of dwellings	Up to 15 (after renovation)
Current occupancy	30

Figure 9. Picture of the location of the demo building in Tartu (Source: Tartu)

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3.1.1.1. Location

The demo building is located in Tartu, Estonia. The following photos of the location are provided by Estonian partner, Tartu on the 29th of November 2022. More photos can be found on EMDESK platform in folder WP7, Pre-design of TARTU building.

Figure 10. Side view of the demo building in Tartu (Source: Tartu)

3.1.1.2. Building History

The year of initial commissioning of the building is indicated as the year of initial introduction in 1933. The residential building under consideration is located at Tartu County, Tartu City. The building was established on the former Anne manor areas. The manor was built by 1865 and has perished by 2006. The manor linden alley and park are still in use and under protection.

The building has been used has a care home and is currently in use as a rehabilitation center for former inmates.

3.1.1.3. Architecture and structural system

The building has the following structural system details:

Table 2: Structural system details of demo building 1: Tartu (Source: Tartu) (RIVENTI Nuria Jorge, Guillermo Rilova, Hugo Bergado, 2021)

Structure typology	Timber framing
Distance between slabs (floors) [m]	2,42 to 2,82
Slab structure thickness [m]	0,37 to 0,49
Slab material properties	Timber beams
Height [m]	6,09; 10 to top of chimney
Floor dimensions (length x width) [m]	3,06 x 10,56

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3.1.1.4. Construction and building envelope information

Table 3: Construction/Building envelope: Tartu (Source: Tartu)

External wall	Plaster, wood walls, wood structure, wood walls, plaster. U-value: N/A
Internal partition	Plaster, wood structure, plaster. U-value: N/A
Internal ceiling / floor	Plaster ceiling, wood structure, wood floors. U-value: N/A
Ground floor/ roof	Wood structure on ground and ceiling. Pltwood surface with linoleum, carpet or plaster on the ceiling
Window %, type and frame	Double glazed; plastic frame. More than 10 years ago. U-value: N/A
Infiltration rate - Property air tightness (poor, basic, good)	Very poor air tightness. No tests done.
Infiltration rate - External Vents	Natural ventilation

3.1.1.5. Mechanical and electrical systems

The building is currently equipped with the following building system services (BSS):

- ***Heating system installed:*** Wood-burning stove in every room. The heat from the fire warms the stove and the air in the room. The smoke from the fire is drawn out of the house through the stove's chimney. The damper allows the user to control the airflow to the stove, which affects how large the fire grows and how much heat it emits.
- ***Domestic hot water (DHW) system:*** Communal hygiene room with water from electric boiler.
- ***Air-conditioning system:*** Not available.
- ***Mechanical ventilation system:*** Not available.

Available low carbon technologies:

- ***Renewable heat generation source:*** Not available.
- ***Renewable electricity generation source:*** Not available.

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3.1.1.6. Floor plans

The floor plans are provided by the Tartu partner in December 2022. Plans of other floors are found in in Appendix A: Demo Buildings, Additional plans.

Figure 11. Floor 1 plan (Source: Tartu)

3.1.1.7. Sections

The sections of the building in Tartu are seen below, received in December 2022.

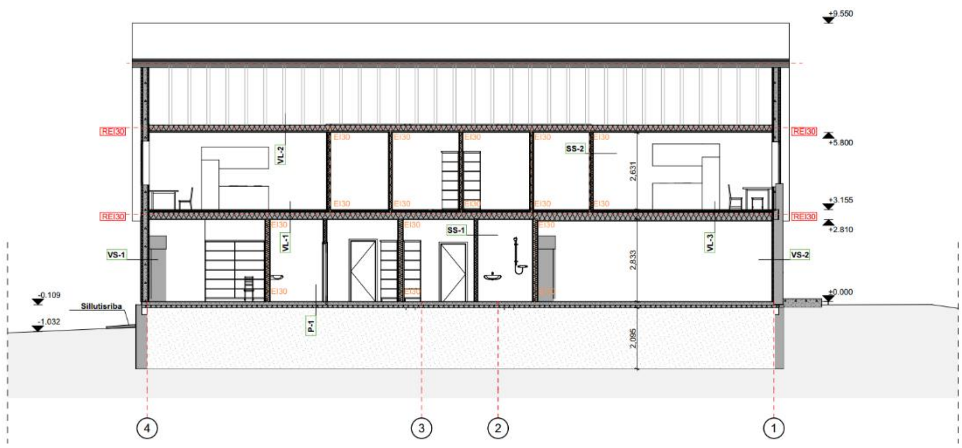

Figure 12. Section A-A Tartu building. (Source: Tartu)

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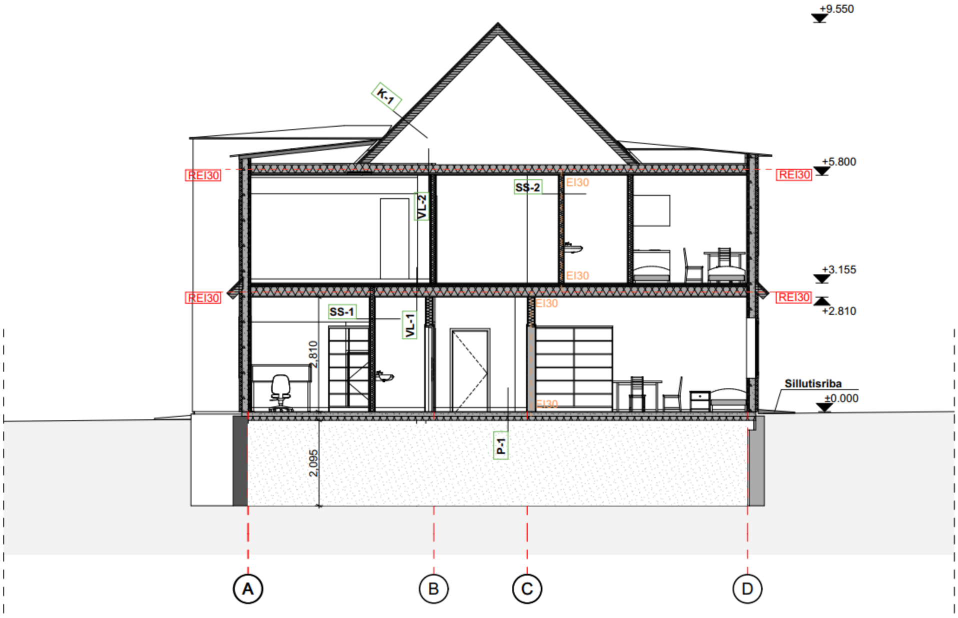

Figure 13. Section B-B Tartu building. (Source: Tartu)

3.1.1.8. Elevations

The envelope composition of the building in Tartu is categorised as a medium-height structure adaptable for PV modules. The most windows are on the west (14 windows) and east side (7 windows), while on the north and south façades two windows are located one on each of them.

A preliminary analysis indicated the outputs and the estimation of PV energy production, to clarify the scenarios in the building (See D5.1 (RIVENTI Nuria Jorge, Guillermo Rilova, Hugo Bergado, 2021)). The elevations are described as follows, received in December 2022 (south and east elevations are to be found in in Appendix A: Demo Buildings, Additional plans):

Figure 14. West façade, Tartu (Source: Tartu)

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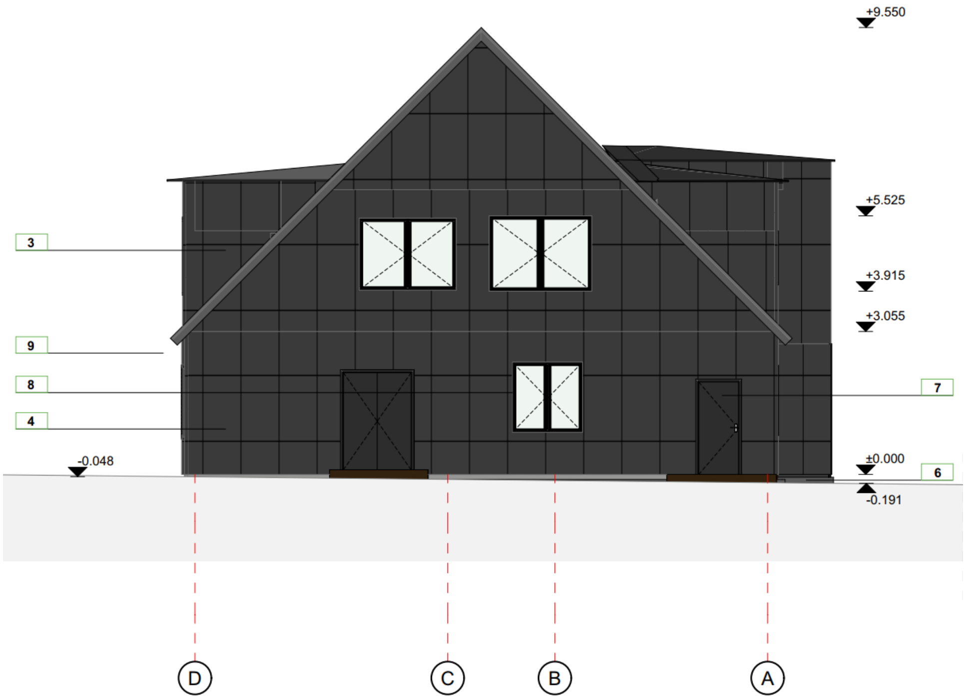

Figure 15. North façade, Tartu (Source : Ribbon Consult – Tartu)

3.1.1.9. 3D Visualizations or models

The 3D model of a building, provided on the 6th of May 2021 is seen below:

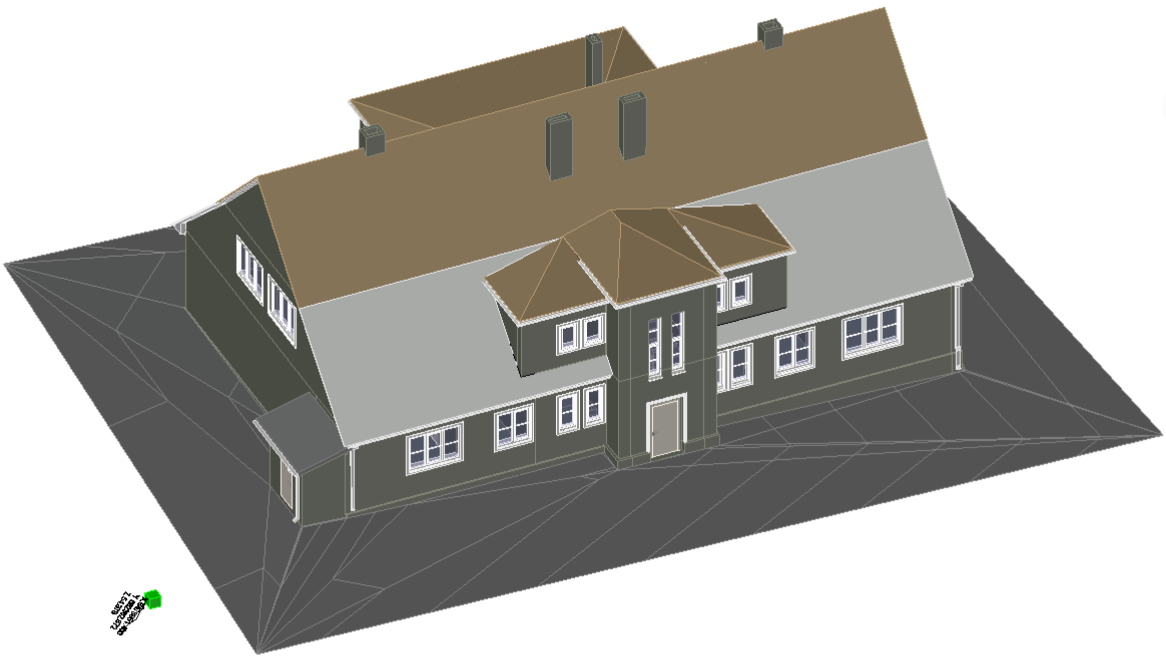

Figure 16. 3D model REVIT version : View from North-West (Source : Ribbon Consult – Tartu)

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3.1.1.10. Existing information and communications technology (ICT) structure

There is no existing BMS and control system in the building.

3.1.2. Diagnosis Report – Current status of the building

3.1.2.1. Objectives of diagnosis

The aim of diagnosis report is to visually assess the condition of the load-bearing structures, and fencing structures of the building, and the possibilities for reconstruction.

3.1.2.2. General nature of the building

The residential building with the register code 104018038, commissioned in 1947. The building, measuring 23.9 x 12.9 m and 10.0 m high, has two storeys, a gable roof, and a partial basement. Its main purpose is to serve as a residential building with three or more apartments.

3.1.2.3. Current structural condition of the building

A visual inspection by TARTU team was conducted on October 1, 2021, followed by a more thorough inspection involving the opening of structures and drilling on October 19, 2021.

- The **external walls** of the building have a double truss structure with potential local damage. The floor joists have suffered moisture damage due to the lack of a moisture barrier and need replacing, which is difficult due to the dowel-type connection with the base beam. The walls lack modern insulation and should be additionally insulated during reconstruction.

a) b) c)

Figure 17. Current situation of the pilot building in Tartu: External walls a) opening in the outer wall, b) an open socket in the façade, c) the underlay of the wall (Source: Tartu)

- The **internal walls** are constructed of vertical wooden planks, plastered solid boards, wool, and plasterboard. The staircase walls are made of silicate bricks. All walls are in good condition. During reconstruction, removal of some internal walls should consider potential subsidence of the wooden intermediate floor.

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- The first and second-**floor ceilings** of the building are in poor condition, with significant unevenness and potential sinking of load-bearing beams. The second-floor ceiling beams show signs of moisture damage. Large-scale openings are needed to assess the extent of damage and the possibility of retaining existing beams.
- The **ground floor**, built on soil-supported wooden planks, has suffered moisture damage due to lack of insulation, resulting in poor condition. Reconstruction should involve demolishing the existing floor structure, removing the soil, installing construction sand and insulation, and pouring new reinforced concrete floors. If the basement is to be utilized, a water barrier and reinforced concrete floor are necessary; otherwise, it should be filled with construction sand.

Figure 18. Current situation of the pilot building in Tartu: PERIMETER of the building (Source: Tartu)

- The **roof structures**, while visually in good condition, do not meet modern standards. The rafters and ties have inadequate load capacity, and the gutters under the roof tile have a large step and narrow cross-section. It is recommended to remove existing roofing and gutters, add additional rafters, and install an underlay with correct cross-section and step.
- The **plinth wall and foundation** show moisture damage from poor drainage and a missing paving strip. Despite this, the foundation shows no subsidence. The reconstruction should include a paving strip, proper soil
- slope, rainwater discharge, and waterproofing and insulation of the foundation wall. Due to the foundation's positioning, horizontal perimeter insulation should also be added.

3.1.2.4. Conclusion

In general, the load-bearing structures of the building are in satisfactory condition. If reconstructed, fire safety class TP2 and fire resistance requirement R30 must be adhered to. The building should be energy efficient to reduce future operational costs.

3.1.3. Renovation Measures

3.1.3.1. Preliminary system approach

3.1.3.1.1. Initial pilot building requirements

The decision on the aesthetic value of the building is usually made by the architect of the building, who has also been issued a corresponding professional certificate.

The suitability of the urban space is confirmed by the city architect of Tartu, who has the right to veto the corresponding solution, if the corresponding solution as a whole does not fit into the environment of the given urban space or the ensemble of buildings.

In advance, based on the size of the financial resources, the customer can give guidelines to the architect of the building to choose the appropriate direction, whether to use stronger and more extravagant solutions or more modest ones. In this case, as the customer, we would have proposed to the architects to use materials with a decent lower level of cost, which are dignified and long-lasting at the same time, from plaster façade to lower cost composite boards.

There are no requirements according to aesthetic aspects as well as the cultural heritage of building.

3.1.3.1.2. Preliminary Concept Design of ENSNARE system in TARTU demo building

3.1.3.1.2.1. ENSNARE technologies

To carry out the pre-design of the pilots, a similar analysis process has been carried out in all cases. In the first place, the layout of the slabs and the different singular elements of the façade are analyzed, such as windows or protruding elements, such as plinths and cornices. These elements condition the layout of the envelope mesh axes.

In the case of Tartu, the characteristics of the building structure and the insolation conditions have determined the layout of the ENSNARE system on the ground floor of the south and west façades only.

The horizontal axes are determined by the need to establish the different elements of the system by bands. Firstly, a horizontal and continuous registration area that runs along the façade, then a strip of height equal to the height necessary to distribute active panels with rollbond absorbers, and finally a lower strip that can accommodate photovoltaic panels. The vertical axes are distributed responding to the dimensions of the different panels and the existing windows.

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In the first proposals for the pre-design, the possibility of installing larger panels was contemplated, however, as the development of technologies has progressed, it has been found that it is preferable to install panels of smaller dimensions. This process has given rise to various pre-designs until reaching the final one.

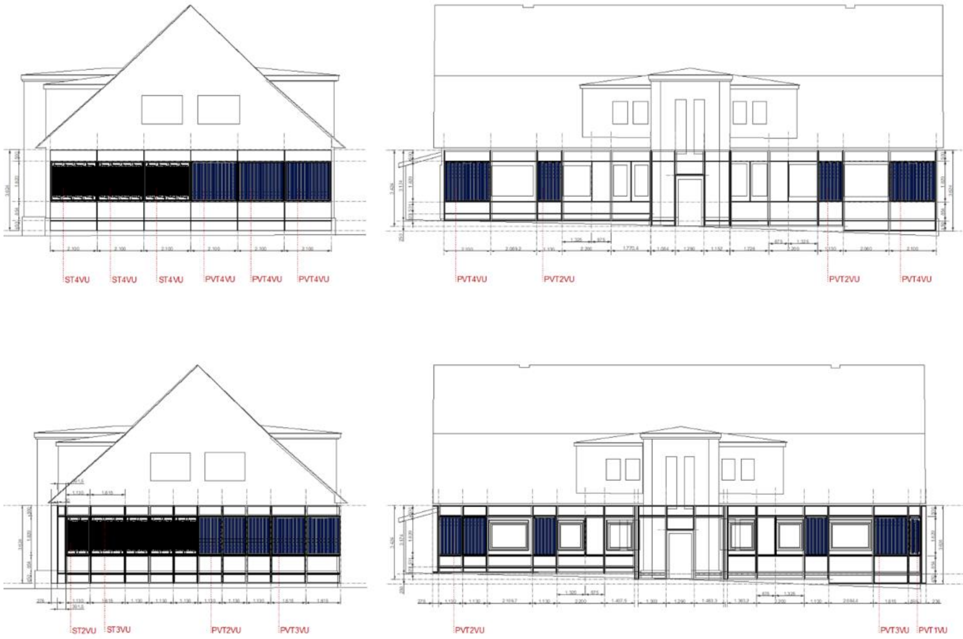

Figure 19. ENSNARE system proposals for Tartu – west and south façades (Source: RIVENTI)

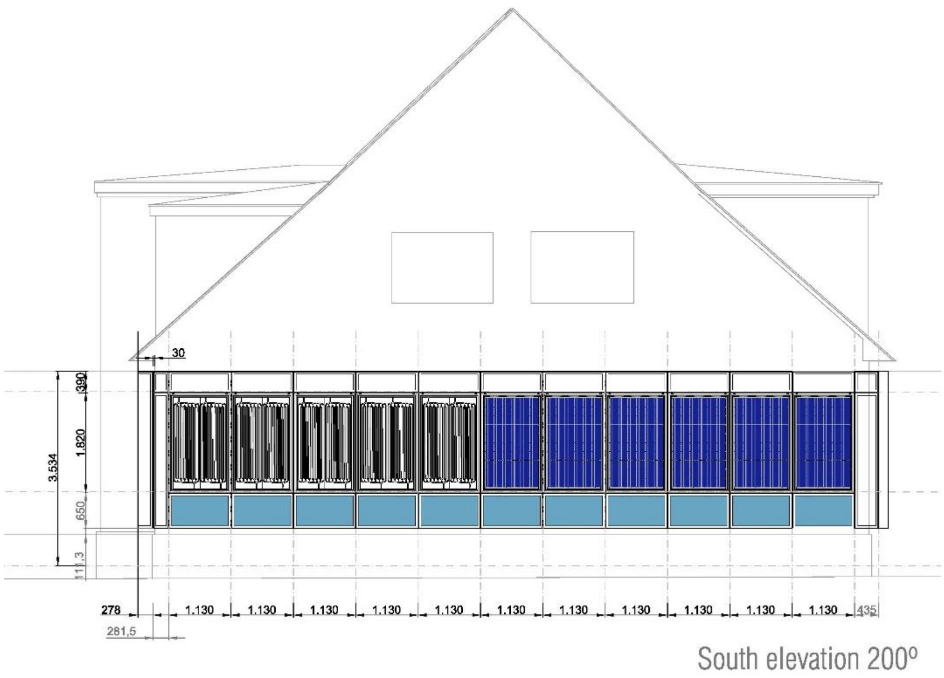

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Figure 20. ENSNARE system final predesign in Tartu (Source: RIVENTI)

The summary of the area covered by active modules is in the Table 4.

Table 4: Modulation design, Tartu (Source: RIVENTI)

Tartu Pilot - Modulation Design					
Category	**South**	**North**	**West**	**East**	**Total**
Façade area [m²]	103	92	84	86	365
Windows area [m²]	5	5	20	21	51
Active area [m²]	25.78	0	31.15	0	56.93

3.1.3.1.2.2. Preliminary concept design with 3D parametrization

By using the semi-automated tools developed in Task 2.1, the Tartu demo-building was modelled by TUM as presented in the next picture.

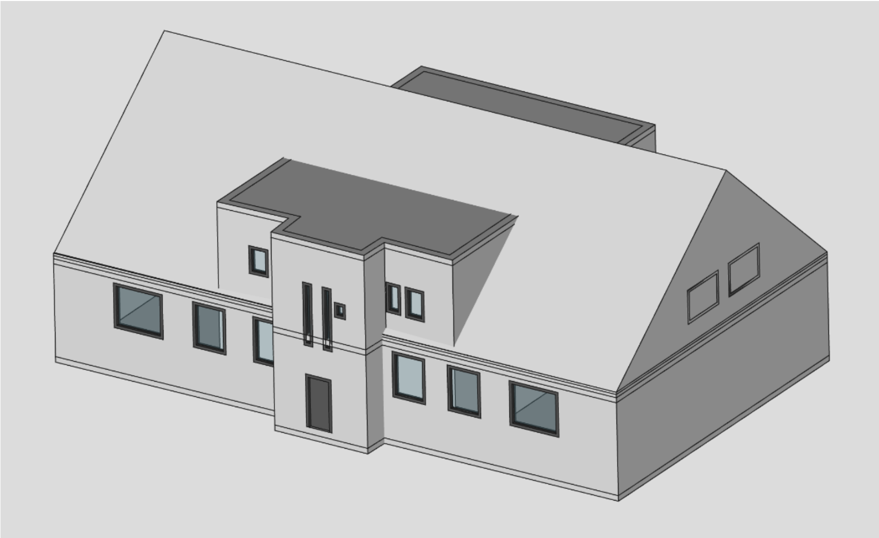

Figure 21. Model of TARTU demo building, Free CAD version. (Source: TUM)

This model was accomplished only with the pictures of the building and the OSM file with the ground floor shape. The time for modelling this building was about 25 minutes by a trained person with architectural knowledge.

With this model, the initial façade modelling was generated, following the algorithms developed in Task 2.1 by TUM, as shown in the next pictures.

Figure 22. Initial west façade modeling of TARTU demo building, Free CAD version. (Source: TUM)

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Figure 23. Initial east façade modeling of TARTU demo building, Free CAD version. (Source: TUM)

The modulation was achieved in less than 5 minutes by a trained person without architectural knowledge.

The calculation of the solar panels and the total disponible area was also calculated by TUM, as some examples show it in the pictures in Appendix A: Demo Buildings, 1.2.

3.1.3.1.2.3. Solar radiation analysis

A preliminary solar analysis was carried out by ONYX in the initial stage of the project. The power output has been worked out per day and m^2. Then, kWh/year was analyzed to make initial decisions. All façades and roofs were studied regardless of the shadows generated by trees or buildings. The results are presented in D5.1. In case of Tartu, the most suitable façades in terms of energy production are West, East and South façades (7872 Kwh/year, 10637 kWh/year and 12482 kWh/year respectively). However, taking into account the solar study made by ABUD, East façade is not feasible to install ENSNARE system. Therefore, West and South façade are the chosen ones.

To guide the modulation design, a detailed solar radiation study has also been conducted for the pilot building. For this purpose, the 3D model of the Tartu pilot building is used along with the site map to incorporate the surroundings as well. In Rhinoceros 3D, Ladybug within Grasshopper is used for the analysis. Although it has been tried to emulate the site conditions as close to reality as possible, the trees modelled in the software may have some deviations from the actual trees present on the site in terms of their height, circumference, transmissivity extent of solar radiations through the distance from buildings. Therefore, slight deviations can be expected but this study provides adequate information to make the decision of choosing façades for placement of active modules and non-active panels.

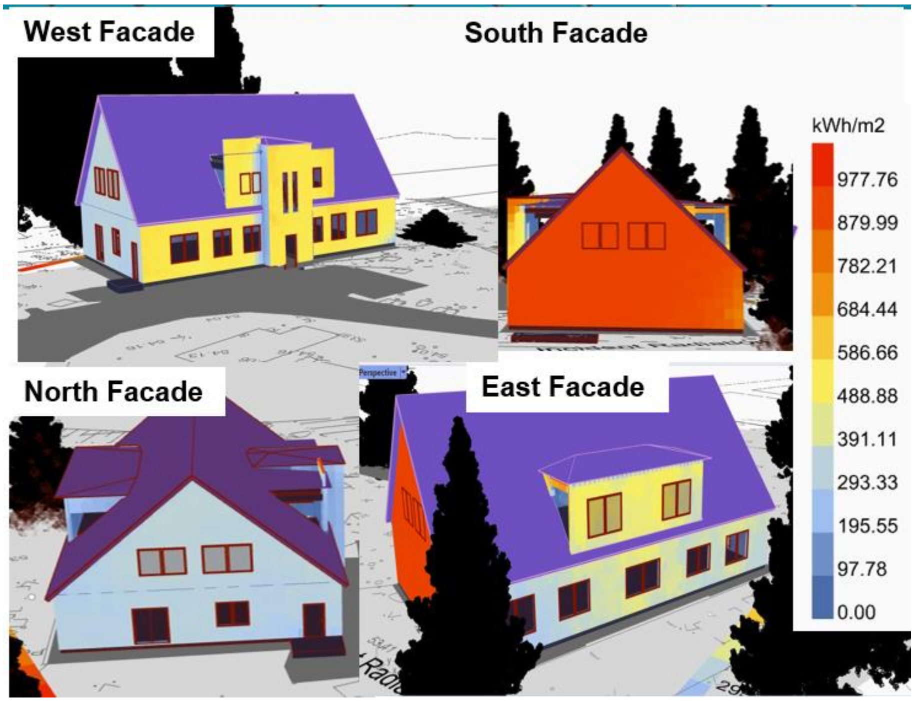

Figure 24. Solar study of TARTU demo building (Source: ABUD)

It is deduced that the South and West façades are most appropriate for the placement of active technology while the East and North façade would host Trespa panels.

3.1.3.1.2.4. Concept design of non-active Façade (Trespa panels)

The non-active façade will be executed with a ventilated façade system with thermal insulation and Trespa Meteon panels as finishing material by means of a visible fastening system with rivets.

The composition of the ventilated façade solution shall have the following basic elements:

- Exterior cladding with 8 mm thick EDF Trespa® Meteon® FR panels - fire classification B s1 d0, colour and texture to be defined by DF within the manufacturer's colour chart, produced with thermosetting resins that do not contain Urea-Formaldehyde, homogeneously reinforced with natural fibres with EBC (Electron Bean Curing) surface colour, non-melamine, and anti-graffiti properties throughout its lifetime. Its resistance to ultraviolet radiation according to EN 438-29 and the Florida Test shall not be less than 4-5, contrasting both standards with the grey scale of ISO 105 A2.
- 3 cm ventilated air chamber

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- Thermal insulation of mineral wool board (LMN), hydrophobic, coated on one side with black glass fleece, according to (EN13162), 100 mm thick, thermal resistance 2.90 m²K/W, thermal conductivity 0.034 W/(mK), butted to avoid thermal bridges, mechanically fixed to existing façade.
- Visible mechanical fastenings by rivets to the aluminium substructure
- Aluminium substructure with mechanical fastening system TS700 in accordance with DIT 473p/22 and ETA 20/1265 by means of a vertical grid of T- and L-shaped aluminium profiles, fixed to the wall by means of load and suction brackets, and ventilated cavity ≥ 30 mm Supporting and retaining brackets for load transmission from the substructure to the support by means of anchors.
- Anchoring of brackets to the support
- Various accessories for the treatment of single points

The defined façade solution consists of a composition with parts in a metallic premium finish so that several shades of the same colour can be seen on the façade.

a) b)

Figure 25. Façade solutions for TARTU demo building: a) south elevation b) east elevation (Source: TRESPA)

a) b)

Figure 26. Façade solutions for TARTU demo building: a) north elevation b) west elevation (Source: TRESPA)

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At the transition points between the technology and the fv, a transition bar tack of the following type will be used:

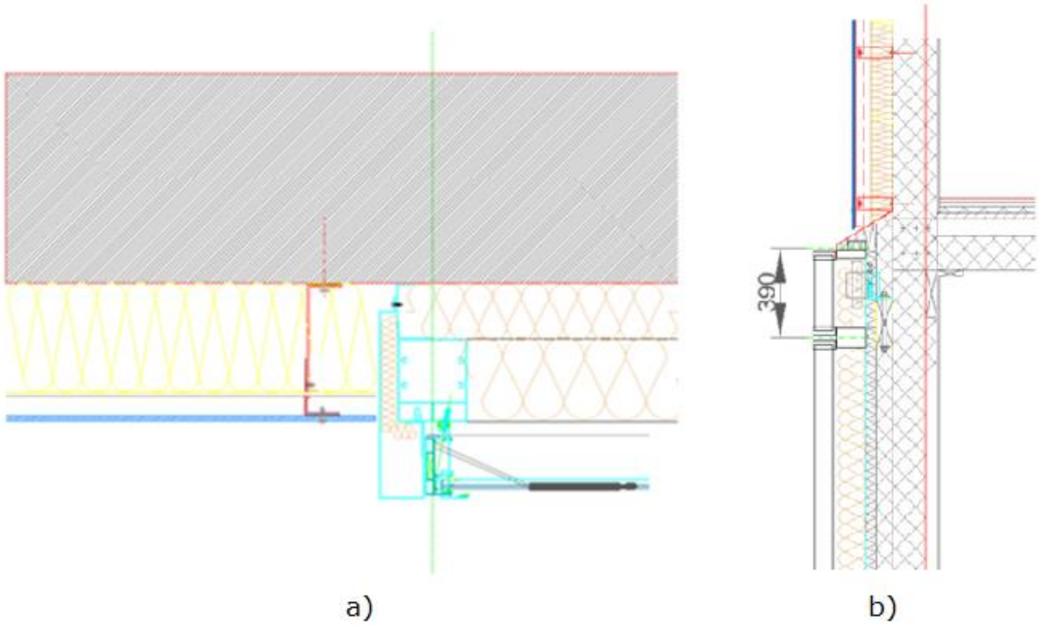

Figure 27. Transition joints of TARTU demo building façade: a) vertical joint b) horizontal joint (Source: TRESPA)

3.1.3.1.3. Evaluation of structural systems

Once it was agreed that the ENSNARE module system would be hung from the top anchor and that the modules would only be placed on the ground floor (South and West elevation), work was done to indicate the possible position of the anchor system (3D adjustable anchor) on the new beam placed for this purpose (200 x 75 mm timber frame). The lower stabilization system was also shown.

The capacity of the new beams to support the self-weight of the ENSNARE modules was also verified. For this purpose, a self-weight of 44 kg/m^2 was considered.

This value was calculated considering a reference ENSNARE module of the Tartu demo-building configuration. The type of technologies and geometrical characteristics of this module are shown in the picture below. The photovoltaic panel represented in the drawing corresponds to BIPV with aluminum substrate.

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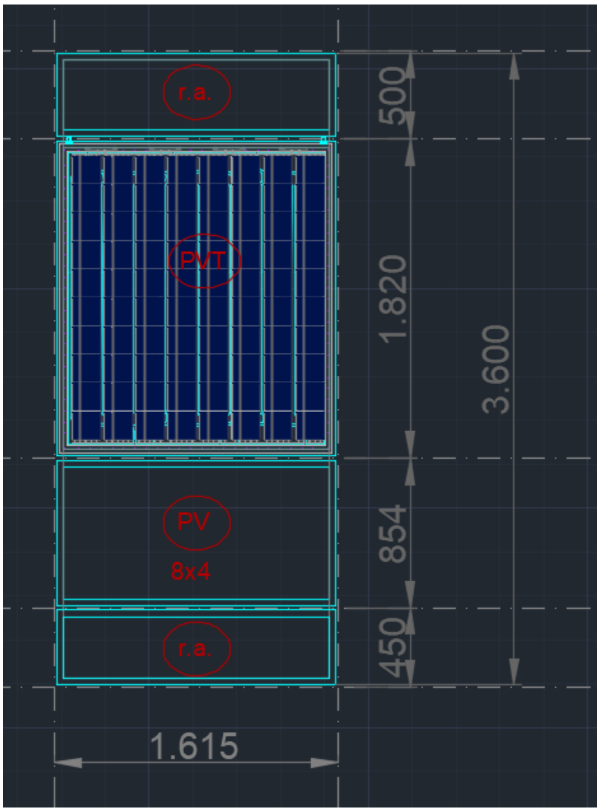

Figure 28. Configuration and dimensions of the reference module for calculating the weight per square meter of the ENSNARE façade system (Source: RIVENTI)

The characteristics of the materials taken into account for the calculation are included in the table below.

Table 5. Characteristics of the materials considered for the calculation of the self-weight of ENSNARE façade (Source: TEC)

Material	Density (kg/m^3)	Weight (kg/m^2)
Aluminum	2700	
Trespa Meteon (8 mm)		11.2
Glass	2500	
Insulation	70	
Water*	1000	

Note*: For the calculation it has been considered that the thermal technologies are filled with water.

At the same time the position of the continuous watertightness barrier (WATERPROOFING + THERMAL INSULATION) was specified, including the watertightness of the ENSNARE façade modules themselves and the joints with the typical building envelope in the ventilated façade part.

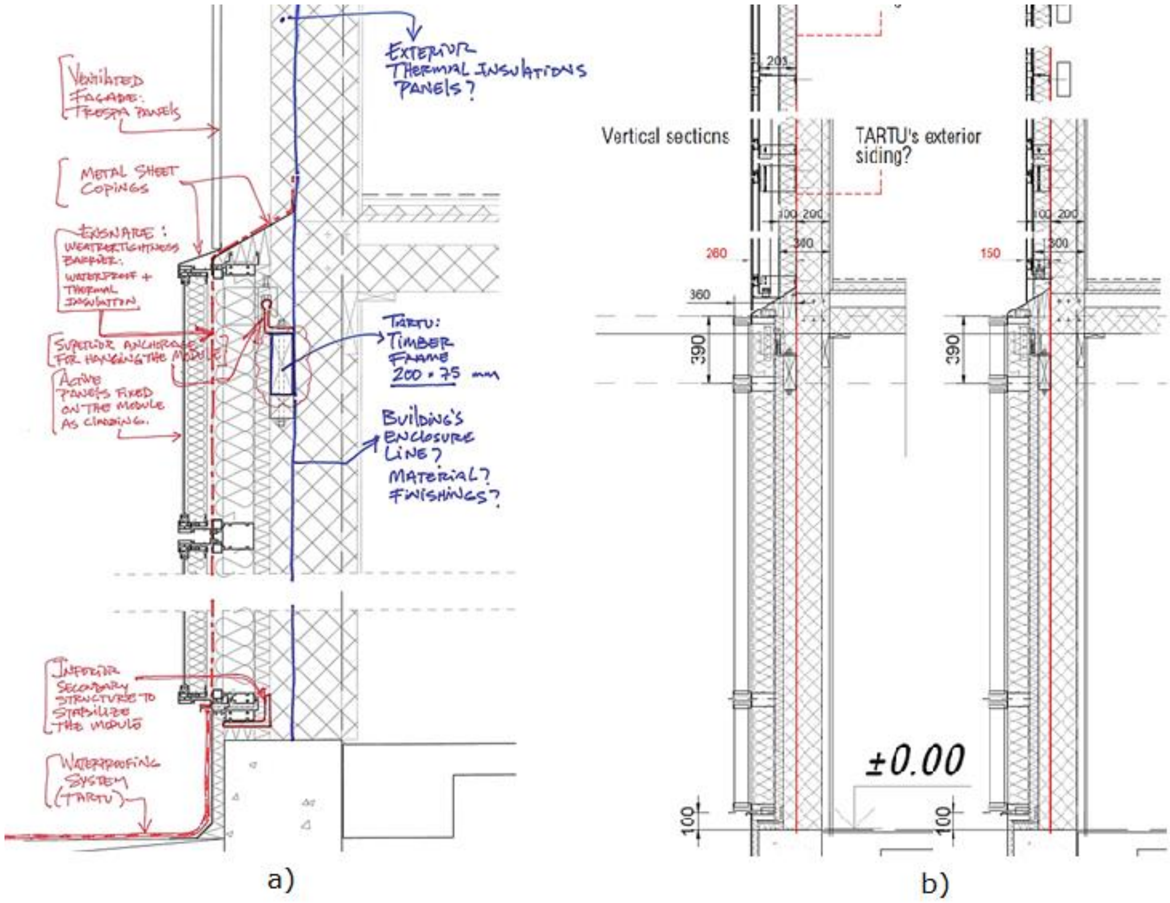

Figure 29. a) Anchor placed on new Timber frame beam. Definition of the position of the weathertightness of the façade in ENSNARE System. b) Joint between ENSNARE System and ventilated façade (Source: ENAR)

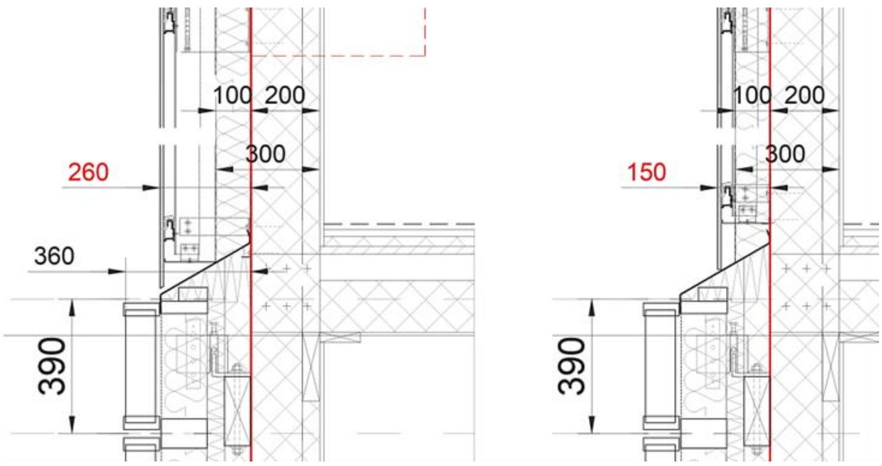

Figure 30. Dimension of the ventilated cavity (Source: ENAR)

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3.1.3.1.4. Potential major engineered systems

The summary of the situation pre- and post-intervention for the HVAC and DHW equipment is as follows:

Table 6. HVAC and DHW equipment for the situation pre- and post-intervention (Source: TEC)

Item	Pre-intervention	Post-intervention
SH generation system	Individual wood stoves	~30% solar thermal output / Geothermal pump
SH distribution system	None	Heated floors
Ventilation system	None	Heat recovery ventilation (SFPv ≤ 1.8 kW/(m^3/s))
Temperature level for the production of SH	None	38/33°C (water based)
DHW system	Electric boiler	~70% solar thermal output / Geothermal pump
Temperature level for the production of DHW	60ºC	60ºC

Electric batteries and water tanks will be included to store the production peaks.

3.1.3.2. Planning strategies

3.1.3.2.1. Expected timeline for design, implementation and feedback loops

Table 7: Design stages of a case study: TARTU (Source: ABUD)

	Pre-Design	Concept Design	Technical Design
Involved partners	ABUD, TEC, RIVENTI, ONYX	ABUD, TEC, RIVENTI, ONYX	
Status	Basic Data acquisition. Partners introduced the technologies	Meetings with core team (architect) exploring the alternative designs, individual limitations, resolving questions regarding the connection of modules, level of detailing, ventilation	Task 7.2

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		solutions. The design is in the development.	

Table 7 outlines the current progress of each stage for the TARTU demo building. The complete meeting schedule and data collected are available in Appendix C: Planning, Meeting Schedule. The technical renovation schedule is prepared according to country-specific requirements. In addition to the technical renovation schedule, a timetable that combines other partners' activities is developed. The current version is available in Appendix C: Planning, Data Management and Planning for Tartu Demo Building. This schedule is subject to further changes. Scheduling is a dynamic process with monitored limitations and corresponding date adjustments. Therefore, Deliverable 7.1 may serve as a reference tool during the design and renovation stages.

Currently, the renovation permit acquisition process is underway. Dates are tailored to each pilot based on country regulations, collected data, and other considerations. The schedule for the next five months is presented in Chapter 3.1.3.2.3: Programme and Phasing.

3.1.3.2.2. Feasibility study for TARTU demo building

The feasibility study proposed in Deliverable 5.1 (RIVENTI Nuria Jorge, Guillermo Rilova, Hugo Bergado, 2021) is updated in this paragraph, with new costs and conditions for the pilot under consideration. The aim of this analysis is to estimate an average cost of the façade retrofit considering the active panels area and production planned within the demo building under consideration. The analysis has been carried out considering two economic future scenarios: 1) the costs are assumed from EUROSTAT (Eurostat, n.d.) and partners based on the pre-pandemic condition, and 2) the costs are assumed based on the last data available by EUROSTAT (Eurostat, n.d.) for the first semester 2022. The second scenario is included to provide further information on the effect of actual socio-economic condition. Nonetheless, it is worth noticing that the highly variable prices of 2022 can heavily affect the interpretation of results. The additional following assumptions are considered for the TARTU demo building:

1. Heating, Domestic Hot Water (DHW), and electric consumption are assumed from average Estonia values (EUROSTAT (Eurostat, n.d.)) and are listed in Table 8. An area of 438 m² and 6 dwellings are assumed. According to pre 2020 costs and the previous assumption, the estimated annual cost for electricity (due to the electric DHW boiler and electric consumption) is around 3800 €/y, which is in line with the real cost of 4000 €/y.
2. The active area, considered totally as PV, is 25.5 m² on the South façade (900 kWh/(m² y) of solar radiation), and 28.3 m² on the West façade (530 kWh/(m² y) solar irradiation). The total electric production from ENSNARE active technologies in this case is 5700 kWh/y. The remaining surface is considered insulated.

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3. The retrofitted building is supplied with an electric heat pump for heating and DHW (COP 3.5 and 3, respectively).
4. Four scenarios are presented regarding the space heating (SH) consumption reduction after the retrofit: 40% SH reduction (S-1), 60% SH reduction (S-2), 80% SH reduction (S-3), 90% SH reduction (S-4).

Table 8: Cost and energy assumptions for TARTU demo building (Source: UNIDP)

Heating demand [kWh/(m² y)]	DHW demand [kWh/(m² y)]	Electric consumption per dwelling [kWh/y]
180.8	29.3	2759.0
Electricity price pre 2020 [€/kWh]	**Gas price pre 2020 [€/kWh]**	**Discount rate [%]**
0.043	0.130	3.0
Electricity price first semester 2022 [€/kWh]	**Gas price first semester 2022 [€/kWh]**	**Discount rate [%]**
0.111	0.206	5.0

According to the listed assumptions, the building's annual energy consumption and costs saving results are shown in Table 9. Since a Heat Pump is considered for both SH and DHW, the whole building is served by electric systems, resulting in an annual electric energy consumption between 34407 kWh and 23094 kWh depending on the SH saving (S-1-4). With this condition, it is likely that the whole PV production from ENSNARE systems (5692 kWh) is consumed on-site. The annual cost saving considering pre-pandemic economic conditions is in the range of 3493 – 4963 € (S-1-4). On the contrary the higher energy prices during the first semester of 2022 increase the possible future cost savings with ENSNARE system installation. In the latter, the saving results are between 8929 and 11259 €.

Table 9: Energy and cost saving results (Source: UNIDP)

	S-1	S-2	S-3	S-4
Annual electricity consumption [kWh-e]	34407	29882	25357	23094
Annual PV self-consumption [kWh-e]	5692	5692	5692	5692
Annual net cost for electricity [€] pre-2020	3733	3145	2556	2262
Annual cost saving [€] pre 2020	3493	4081	4669	4963
Annual net cost for electricity [€] first semester 2022	5915	4983	4051	3585
Annual cost savings [€] first semester 2022	8929	9861	10793	11259

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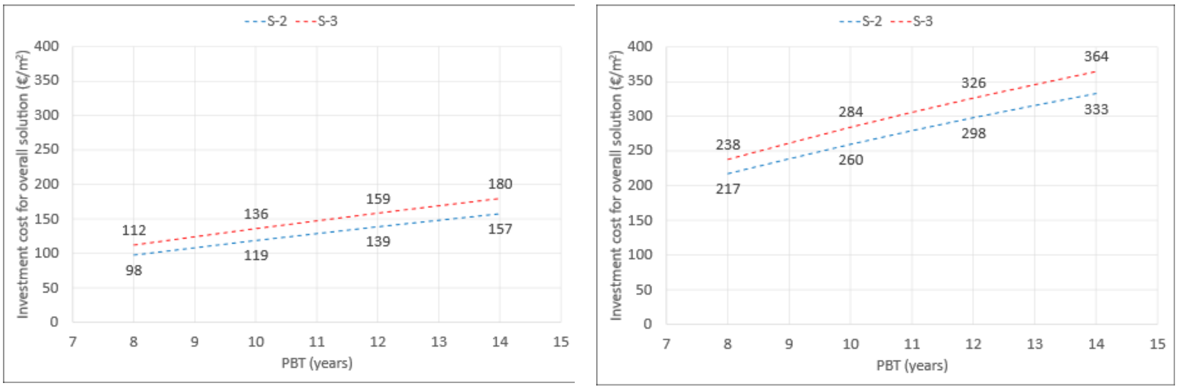
Considering the discount rate assumed in Table 10, the following table provides the investment cost that is suitable considering different pay back periods, i.e. 8, 10, 12, 14 years, namely S-8-14.

Table 10: Target investment cost for active façade [€] (Source: UNIDP)

Payback time (y)	S-1	S-2	S-3	S-4
(pre 2020) S-8	24,517	28,647	32,776	34,841
(pre 2020) S-10	29,793	34,811	39,829	42,338
(pre 2020) S-12	34,765	40,621	46,477	49,405
(pre 2020) S-14	39,453	46,098	52,743	56,066
(first semester 2022) S-8	57,708	63,733	69,758	72,770
(first semester 2022) S-10	68,945	76,143	83,341	86,940
(first semester 2022) S-12	79,137	87,399	95,661	99,792
(first semester 2022) S-14	88,382	97,609	106,836	111,450

The resulting specific investment cost for the overall façade is display in Figure 31, both for pre 2020 and 2022 prices. The effect of the higher energy cost is a clear economic advantage for ENSNARE systems, even if it is still difficult to define a trend of energy prices in the next future.



(a) (b)

Figure 31. Specific cost for the overall solution in case of 60% (S-2) and 80% (S-3) SH consumption reduction [€/m2]: (a) pre 2020 costs, (b) first semester 2022 costs (Source: UNIDP)

3.1.3.2.3. Programme and phasing

- Currently, the TARTU demo building is in the process of acquisition of construction permit.
- Further steps include the technical design of façade and its manufacturing.
- The Table 11 gives an overview of the activities of demo building TARTU and partners for the next 5 months.

Table 11: Summary schedule of renovation process: TARTU (Source: ABUD)

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WP7 PILOT BUILDING - TARTU					
ID	ACTIVITY	PARTNER	START	DAYS	END
1	**Approval of façade configuration**				
1.3	Laboratory test results	TEC	23/01/2023	15	10/02/2023
1.4	Permit process	TARTU	01/01/2023	22	31/01/2023
1.5	Construction permit based on LOD200 (priority)	TARTU	01/01/2023	22	31/01/2023
1.6	Construction permit based on LOD300 (if needed)	TARTU	01/01/2023	22	31/01/2023
1.7	First results of energy rating test	TEC	01/03/2023	18	24/03/2023
2	**Façade project**				
2.1	Survey of the exact geometry of the façades of the building	TARTU	09/01/2023	5	13/01/2023
2.2	Façade project	ENAR, TRESPA (Ventilated façade)	09/01/2023	20	03/02/2023
2.3	Equipment and hydraulic & electrical infrastructure definition	TEC, Onyx	16/01/2023	15	03/02/2023
2.4	Monitoring & Control infrastructure definition	IES	16/01/2023	15	03/02/2023
3	**Manufacture of façade modules**				
3.1	*Manufacturing of technologies and modules*				
3.1.1	PV+STONE & supply to RIV	ONYX	23/01/2023	20	17/02/2023
3.1.2	PV+Al & supply to RIV	ONYX	01/03/2023	23	31/03/2023
3.1.3	PVT & supply to RIV	ONYX	13/02/2023	25	17/03/2023
3.1.4	Absorbers-PVT supply to ONYX	KAMEL	09/01/2023	25	10/02/2023
3.1.5	Absorbers-ST supply to RIV	KAMEL	09/01/2023	25	10/02/2023
3.1.6	TRESPA & supply to RIV	TRESPA	23/01/2023	50	31/03/2023
3.1.7	Insulation for ENS modules supply to RIV	TRESPA	30/01/2023	15	17/02/2023
3.1.8	Trespa ventilated façade, insulation included (supply directly to the building site, 3.2)	TRESPA	30/01/2023	45	31/03/2023
3.2	*Assembly of modules at RIV*				
3.2.1	Modules	RIV	06/02/2023	60	28/04/2023
3.2.2	Anchoring system	RIV	06/02/2023	15	24/02/2023
3.2.3	Finishing manufacturing	RIV/TARTU	10/04/2023	15	28/04/2023
4	**Material Shipment and stocking in Demo-site**				
4.1	Ensnare Façade Modules + finishing	RIV	01/05/2023	20	26/05/2023
4.2	Trespa ventilated façade + finishing	TRESPA	03/04/2023	15	21/04/2023
4.3	Electrical and hydraulic infrastructure	TECN, ONYX	01/05/2023	20	26/05/2023
4.4	Monitoring & Control infrastructure	IES	01/05/2023	20	26/05/2023
5	**Ensnare implementation in Demo Building & start-up**				

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5.1	Construction procurement	TARTU	31/01/2023	44	31/03/2023
5.2	Construction	TARTU	31/03/2023	195	31/12/2023
5.4	TRESPA ventilated façade (Trespa VF)	TARTU/ TRESPA	03/04/2023	85	28/06/2023

3.1.3.2.4. Buildability and construction logistics

During the next months, after the agreement on the design, construction logistics planning will take place before the execution.

3.1.3.2.5. Sustainability assessment

The construction company has to take care of the waste management. Waste will be handled in accordance with the waste management regulations of Tartu municipality. Construction waste must be sorted and collected in a construction waste container and stored and transported by a licensed company. The construction company is responsible for correct disposal.

Before applying for a house use safety permit, the owner of the house has to sign appropriate contracts for regular household waste disposal.

In the building after renovation, it is highly recommended to collect waste separately, i.e. bio, paper, packaging and household waste.

According to the designer, the reconstruction works included in the project does not have a major negative environmental impact.

3.1.3.2.6. Risk assessment

According to the Occupational Safety Act in Estonia, the general contractor/construction company is responsible for occupational safety when carrying out construction work. It is their task is to ensure that all necessary safety measures are taken during the construction of the building and that personal protective equipment is used when the construction work is in progress.

At the beginning of construction work, workers are informed of safety measures, including the appointment of a person responsible for safety at work, who is competent in providing first aid and is aware of the means of first aid (location).

In addition, there is also monitoring of the introduction and compliance with safety measures. During the demolition work, the task of the site manager is to organize and coordinate occupational safety activities on the site.

3.1.3.2.7. Considerations

Communicating and scheduling with multiple partners. The decision-making process is longer than usual due to the factor of many partners. Regulations between countries are different and need more time to make sure that all partners are aware of each state´s regulations.

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The integrated design process extended the overall workflow, primarily due to detailed discussions, extensive information sharing, team collaboration, coordination, and thorough evaluations required. This process spanned over a three-month period to deliver a more comprehensive output for the subsequent phases. It has also enabled avoiding errors and mistakes that could arise at a later stage, thus requiring substantially larger resources for their rectification. Also, quick on-spot decisions, conflict-resolution, consensus building, and approvals allowed partners to avoid unnecessary delays and redundant to and forth emails. It has also facilitated developing in-depth understanding of the complete process and expectations of the partners. Many pivotal decisions were taken during the scheduled meetings with inputs from all partners which made the whole process beneficial and supportive.

3.1.3.3. Impact of expected renovation strategies

<u>Insulation of the envelope with ENSNARE panels</u>

To estimate the energy savings thanks to the insulation of the building, the simulation model prepared with DesignBuilder is as follows:

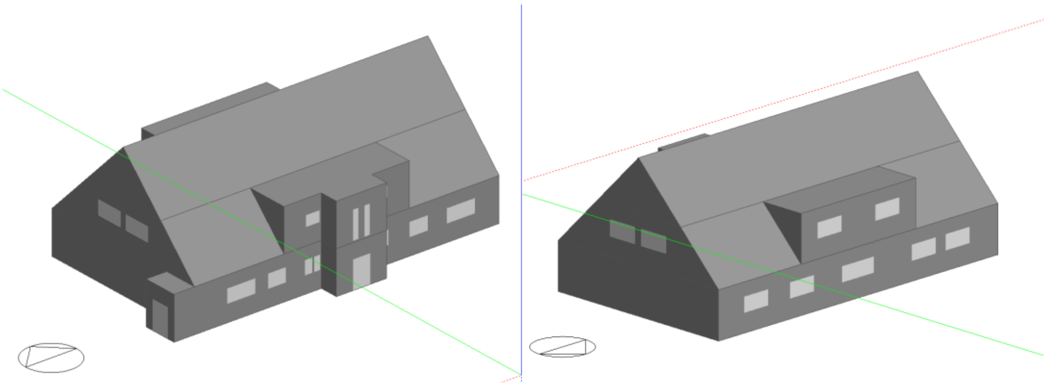

Figure 32. 3D virtual models for Tartu (Source: TEC)

Thanks to the electricity bills provided by the demo coordinators, the calibration and final validation of the model were possible, with the following outcomes:

Table 12: Monthly electric consumption of the Tartu building according to electric bills (left column) and simulation (right column) (Source: TEC)

Period	Electricity consumption according to bills [kWh]	Electricity consumption according to simulation [kWh]
January	1188	1084
February	1040	979
March	1094	1083
April	990	1050

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May	969	1083
June	898	1048
July	1010	1085
August	1029	1083
September	1074	1049
October	1219	1084
November	1171	1048
December	1210	1085
TOTAL	12,891	12,758

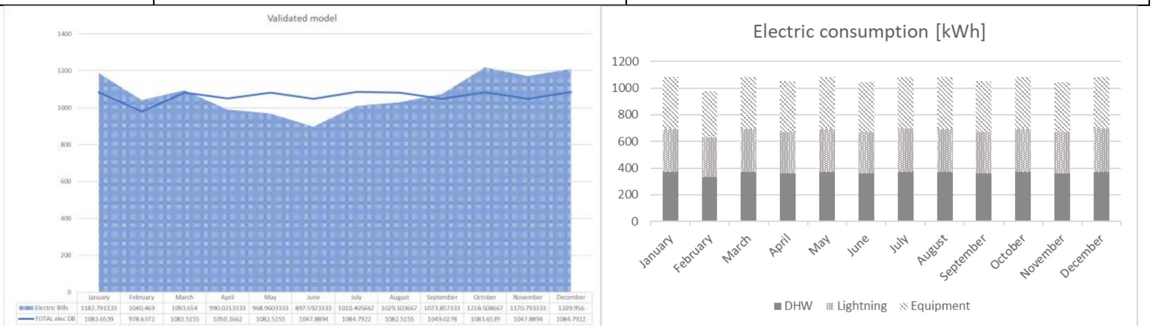

Figure 33. Aggregated electric consumption based on bills and simulation (left); and disaggregation (Source: TEC)

It can be observed how the DHW consumption represents approximately 400 kWh/month, calculated as 28 liters/person·day, with an occupancy of 25 people→ 625 liters/day. In spite of being thermal demand, it is completely covered by electricity and thus is considered as electric demand for the validation.

For the specific estimation of the thermal demand, the simulation models reflect the following outcomes:

Table 13: Monthly thermal demand of the Tartu building according to simulation (Source: TEC)

Period	SH and DHW demand pre-intervention according to simulation [kWh]	SH and DHW demand post-intervention according to simulation [kWh]
January	7,942	5.432
February	6,855	4.716
March	6,020	4.386
April	3,541	2.936

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May	1,469	1.813
June	348	1.239
July	334	1.276
August	319	1.272
September	1,356	1.598
October	3,248	2.671
November	5,865	4.161
December	7,164	4.863
TOTAL	44,461	36,363

This allows a saving in final energy of 8,098kWh/year regarding demand.

Installation of ENSNARE active panels

For Tartu, several configurations were considered taking into account different combinations of the three types of active panels. The two most suitable combinations are:

FIRST OPTION

Table 14: First configuration for Tartu demo building (Source: TEC)

Technology	Units	Solar thermal area [m²]	PV area [m²]	Electric peak power [kWh]
ST	South: 6 West: 3	South:10.46 West: 5.15	NA	South: 2,298 West: 3,90
PVT	South: 5 West: 3	South: 8.67 West: 5.20	South: 8.67 West: 5.20	
PV	South: 11 West: 16	NA	South: 6.65 West: 20.80	

This will ensure the following production:

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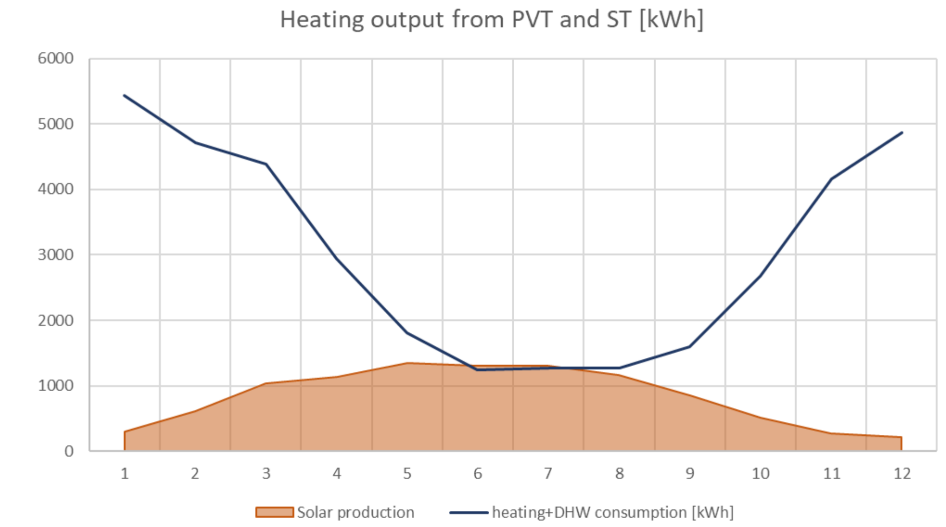

Figure 34. Heating output of first configuration for TARTU demo building (Source: TEC)

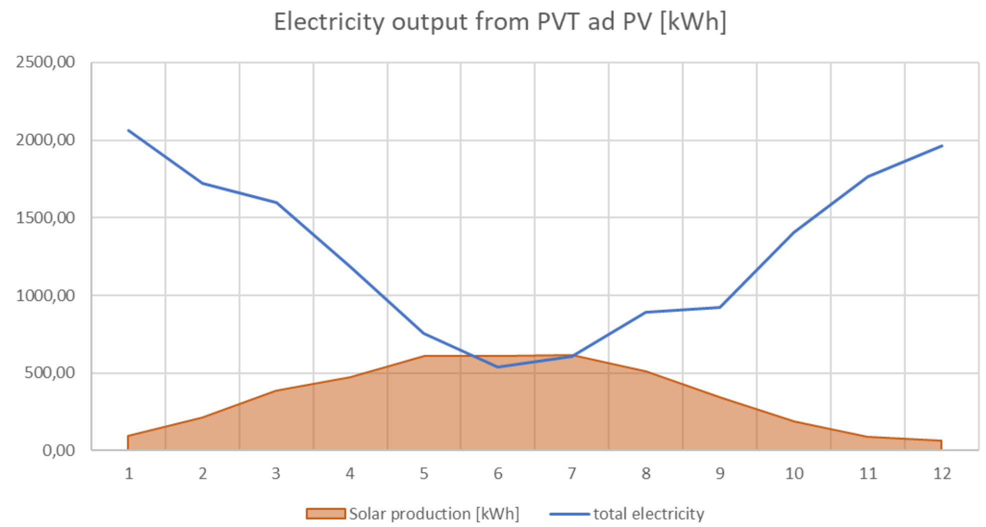

Figure 35. Electricity output of first configuration for TARTU demo building (Source: TEC)

This option has surplus of energy for both electricity and heating during the sunniest months of the year.

The estimated energy output of this configuration is:

- Electric output: 4,209 kWhe.
- Thermal output: 10,066 kWht.

<u>SECOND OPTION</u>

Table 15: Second configuration for Tartu demo building (Source: TEC)

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Technology	Units	Solar thermal area [m²]	PV area [m²]	Electric peak power [kWh]
ST	South: 8 West: 4	South:13.95 West: 6.89	NA	South: 1,827 West: 3,675
PVT	South: 3 West: 2	South: 5.2 West: 3.47	South: 5.2 West: 3.47	
PV	South: 11 West: 16	NA	South: 6.64 West: 20.20	

This will ensure the following production:

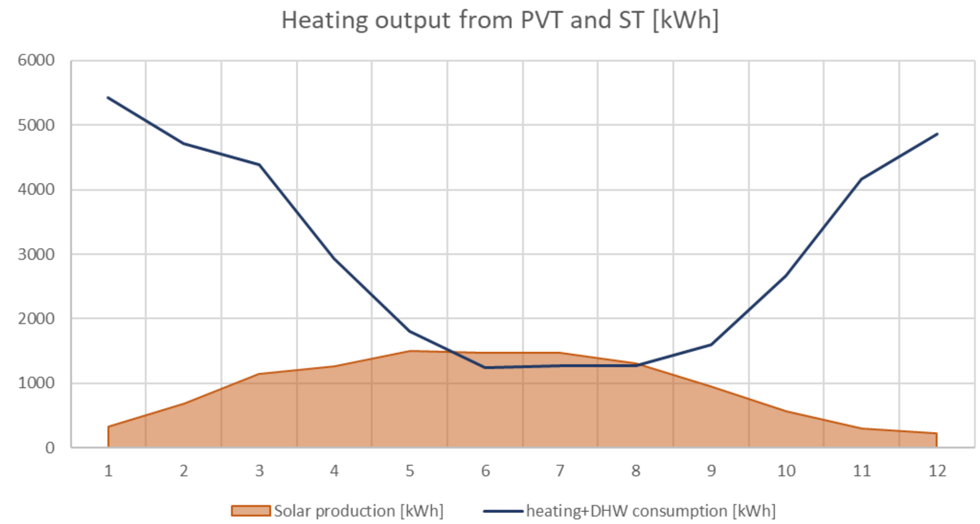

Figure 36. Heating output of second configuration for TARTU demo building (Source: TEC)

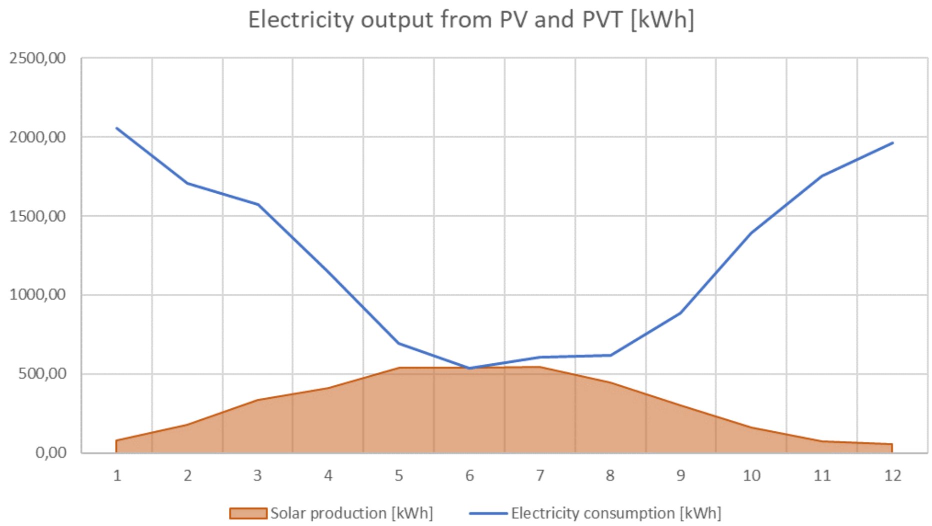

Figure 37. Electricity output of second configuration for TARTU demo building (Source: TEC)

This option has surplus of heating energy during the sunniest months of the year.

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The estimated energy output of this configuration is:

- Electric output: 3,675 kWhe.
- Thermal output: 11,250 kWht.

The preferred option by the demo coordinators was the second option to avoid energy surplus of electricity. From now on, only this option is considered for the calculations.

Primary energy and GHG total savings

For the GHG savings, the methodology used was the one suggested in the Tool to support the calculation of GHG emission avoidance from renewable electricity, renewable cooling and renewable heating projects under the Innovation Fund (v2.0 - 24.03.2021). This methodology gives the following factors:

- Emission factor for combustion of biomass: 0 tonnes CO_2e / MWh.
- Emissions of electricity production in 2030: 0.150 tonnes CO_2e / MWh.

Primary Energy Factors (PEFs) for both heat production and electric consumption were obtained from standard practice:

- PEF of heat production by solid biomass: 1.2 kWh/kWh.
- PEF of electricity production: 2 kWh/kWh.

Regarding the HVAC characteristics considered for the calculation:

- Geothermal pump has a SCOP of 4.4.
- Wood stoves have an efficiency of 0.85.
- Electric boiler has an efficiency of 0.85.
- Refrigeration is neglected as its value is <1kWh/m^2·year.

The final energy savings estimated in previous sections together with the factors lead to the calculation of primary energy and GHG savings.

Table 16. Summary of the annual savings obtained for Tartu (Source: TEC)

Savings	Final energy [kWh/year]	Primary energy [kWh/year]	GHG savings [kg/year]
a) Consumption of the stoves	46.660	55.992	-
b) Consumption of the DHW boiler	5.647	11.294	847
c) Consumption of the geothermal pump	7.195	14.390	1.079
d) Electricity produced by the active panels	3.675	3.675	-

e) Heating produced by the active panels	11.250	11.250	-
Total [a+b-(c+d+e)]	30.187	37.971	-232

The electricity consumption non-heating related, this is, devoted to lighting, equipment etc. remains the same for the situation post-intervention with 7,244kWh of final energy consumption (see Table 12).

Regarding the consideration of the building as NZEB, the following estimations are obtained:

- Final energy consumption (kWh/m^2·year) = 4.54
- Primary energy consumption (kWh/m^2·year) = 9.09

Electric storage

The analysis of the energy from the panels installed suggest that:

- there would be few hours of the year with surplus electricity available for either storage or injection on the grid.
- There would be surplus of heating produced by the solar and hybrid panels during summer period, where the irradiation is at its maximum and heating demand at its minimum. The surplus of heating during winter is expected to be very close to zero.

Different thermal storage has been considered based on the maximum surplus energy available. Due to the wide range of products and solutions, the specific size, and number of units is also something with a high degree of flexibility. There are also multiple combination possibilities thanks to the modular approach of these components. PCM thermal storage has been considered as preferred option; the following assumptions are considered:

- A PCM thermal storage unit with 13.5 kWh of capacity has the following dimensions: 600 x 500 x 250 mm (based on commercial modules).
- Some additional space requirements for components, pipes, valves… needs also be considered.
- Depending on the autonomy that can be covered for DHW needs for different periods and low-level irradiation days, the following outcomes are obtained for PCM thermal storage batteries:

Table 17: PCM thermal storage batteries (Source: TEC)

Daily consumption of DHW [litres/day]	Autonomy [days]	Thermal Capacity [kWh]	Number of units	Surface needed [m^2]
625	1	26	2	0.69

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1250	2	52.6	4	1.36
1875	3	79	6	2.04
2500	4	105	8	2.72
3125	5	131.6	10	3.4

- If a standard water tank is used, the floor surface required will be 20% lower. But the idea in ENSNARE is to test the PCM battery.

Regarding electrical storage associated to the PV panels, the following table provides associated energy storing capacity with space requirement of commercial batteries.

Table 18: Estimation of the batteries (Source: TEC)

Electrical Capacity [kWh]	Surface needed [m^2]
5	0.2
10	0.29
15	0.4
20	0.48
30	0.56

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3.2. Demo Building 2: Sofia, Bulgaria

3.2.1. Building General Description

Demo Building 2: Sofia
The demo building Sofia has the following characteristics:

Table 19: Characteristics of demo building 2: Sofia (Source: BAL)

Location	Republic of Bulgaria, Sofia
Year of construction	1965
Storeys number	5
Typology	Residential
Number of dwellings	1
Current occupancy	9

Figure 38. Side view of the demo building in Sofia, Bulgaria (Source: BAL)

3.2.1.1. Location

The demo building is located in Sofia, Bulgaria. The following photos of location are provided by Bulgarian partner, BAL on 7th of July 2022.

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Figure 39. Location of the demo building in Sofia (Source: BAL)

Figure 40. Side view of the demo building in Sofia (Source: BAL)

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3.2.1.2. Building History

The building is located in quarter 22, according to the cadastral map of the city of Sofia, Boyana quarter, Vitosha district. The initial commissioning took place in 1965.

In 1985 construction was carried out to expand and overbuild the western half of the building by constructing an additional reinforced concrete bridge structure.

In 2015 renovation of the building was carried out by covering the façade of the building with 10 cm thermal insulation materials. PVC frames and double-glazed windows have been installed. Photovoltaic panels are installed on the roof.

3.2.1.3. Architecture and structural system

The demo building Sofia has the following structural system details:

Table 20: Structural system details of demo building 2: Sofia (Source: BAL)

Structure typology	Construction of concrete floors and pillars
Distance between slabs (floors)[m]	2,75
Slab structure thickness [m]	0,20
Slab material properties	C20/25 fck = 30 Mpa, B500B fyk = 500 Mpa
Height [m]	14.45
Floor dimensions (length x width)[m]	19.90 x 11,40

3.2.1.4. Construction and building envelope information

Table 21: Construction/Building envelope: Sofia (Source: BAL)

External wall	250 mm brick masonry with 50 mm EPS insulation panels and plaster. U=0.55 W/m^2K
Internal partition	120 mm brick masonry with plaster on each side. U=1.5W/m^2K
Internal ceiling/floor	150 mm concrete slabs with 50 mm cement screed. U=2 W/m^2K
Ground floor/ roof	150 mm concrete slabs with 50 mm cement screed. U=1.2 W/m^2K
Window %, type and frame	PVC Double glazed windows with 15% frame
Infiltration rate - Property air tightness (poor, basic, good)	Unknown
Infiltration rate - Any External Vents Present?	Unknown

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3.2.1.5. Mechanical and electrical systems

The demo building Sofia is currently equipped with the following building services system (BSS):

- ***Heating system installed:*** Material, also called Heat Batteries (HB), is installed in the vicinity of the heat pump unit. After the heat pump unit, two thermal loops are formed: one to the heat batteries and the other one to the heating system. Circulation to the thermal circuit for the thermal batteries is performed via a circulation pump (P1). Circulation to the heating circuit is achieved by means of a second circulation pump (P2). Only one circulating pump works at a time. Priority is given to heating up the heat batteries through a circulator pump (P1). During the heating season, after the heating batteries have been charged, the circulation pump (P1) will shut off and a circulator pump (P2) is turned on.

Information has been provided about this heat pump as an additional attachment by BAL. Also, they have attached a file about the number and type of radiators in the individual rooms in the building.

- ***Domestic hot water (DHW) system:*** BAL has attached (as an additional attachment) a scheme for the method of domestic water heating.
- ***Air-conditioning system:*** The building has 7 (seven) standard air conditioners powered by electricity.
- ***Mechanical ventilation system:*** No. The building does not have a ventilation system.

Available low carbon technologies:

- ***Renewable heat generation source:*** N/A
- ***Renewable electricity generation source:*** The Solar PV system is a 12.54 kW peak capacity comprising of 42 x LG 340N1K-V5 Modules. 33 modules are mounted on the south-east facing sloped roof and 9 modules are mounted on the flat roof areas using Renusol mounting clamps, and A-frames and fixed using hanger bolts secured to the roof sub-structure. The area occupied by the photovoltaic panels is 71,4 m^2. All data on the electricity produced (as well as consumed) by the photovoltaic system can be seen on the SolarEdge Monitoring Platform.

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3.2.1.6. Floor plans

The following floor plans are provided by the BAL partner on the 7th of July 2022. See Appendix A: Demo Buildings, 2.4. Additional plans for plans of other floors and site plan.

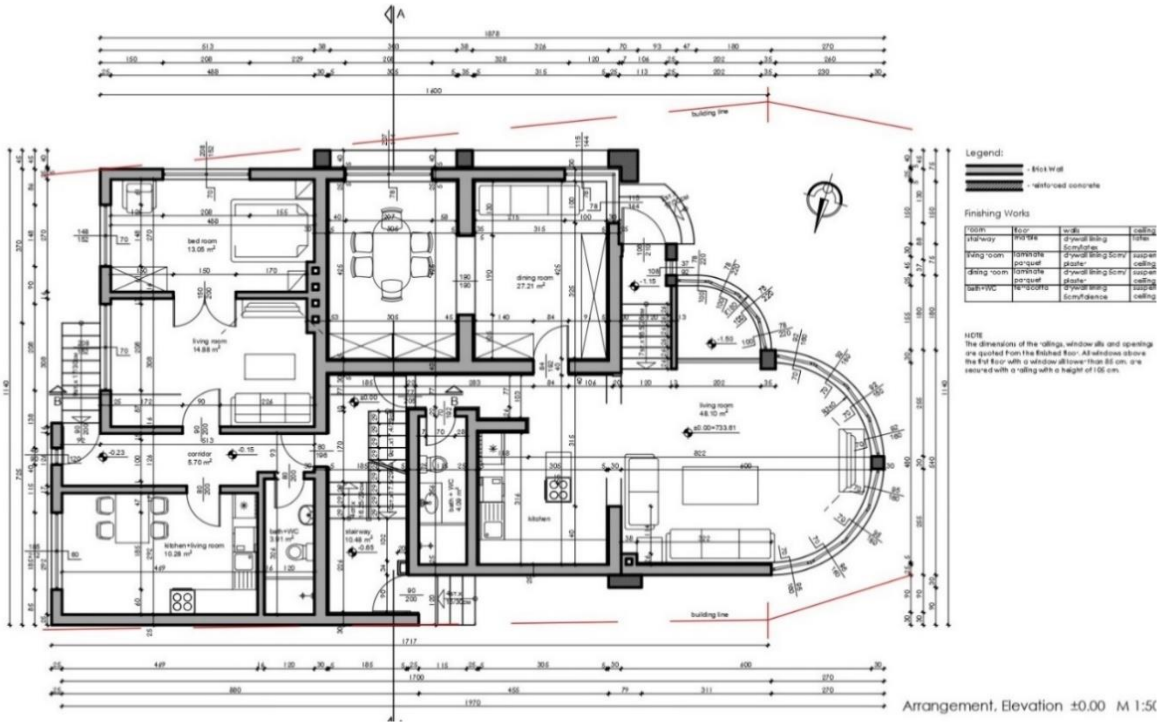

Figure 41. Ground floor plan (Source: BAL)

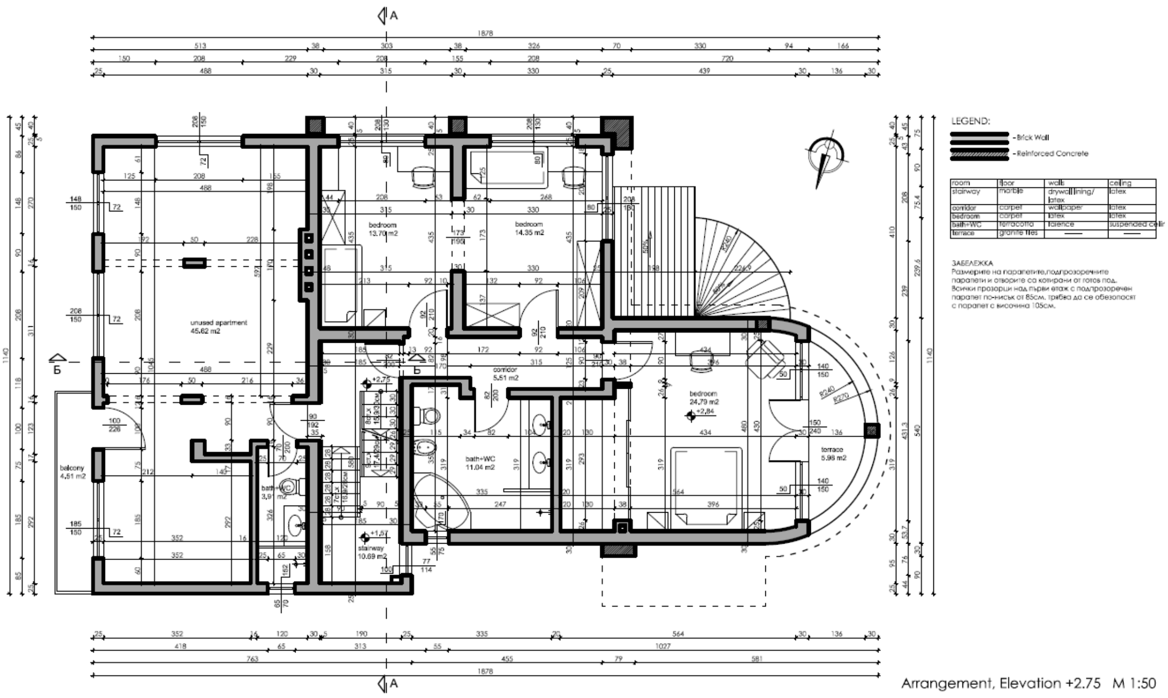

Figure 42. Floor 1 plan (Source: BAL)

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3.2.1.7. Sections

The sections of the demo building Sofia are seen below, received on the 1st of December 2021.

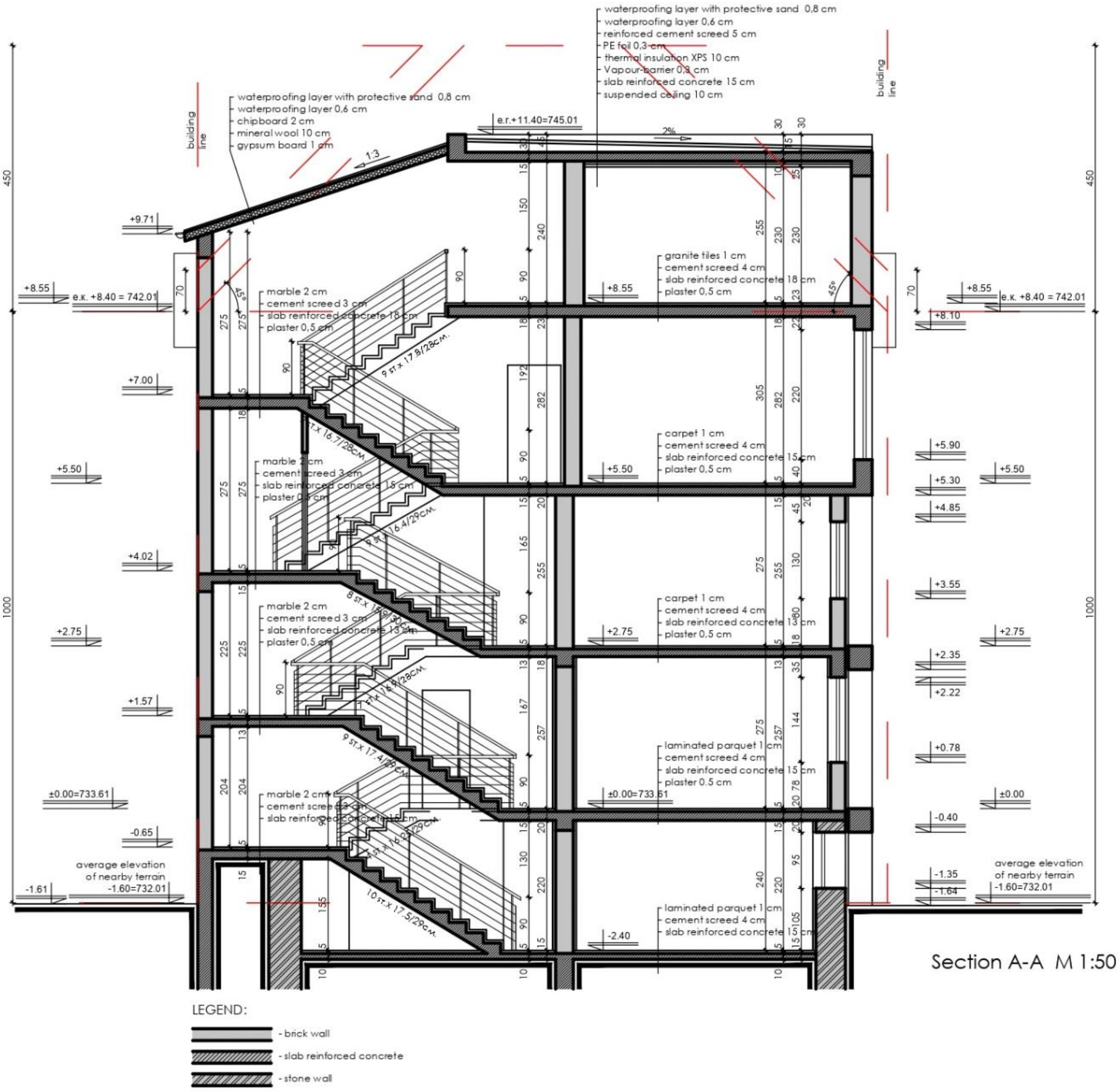

Figure 43. Cross section: View A-A (Source: BAL)

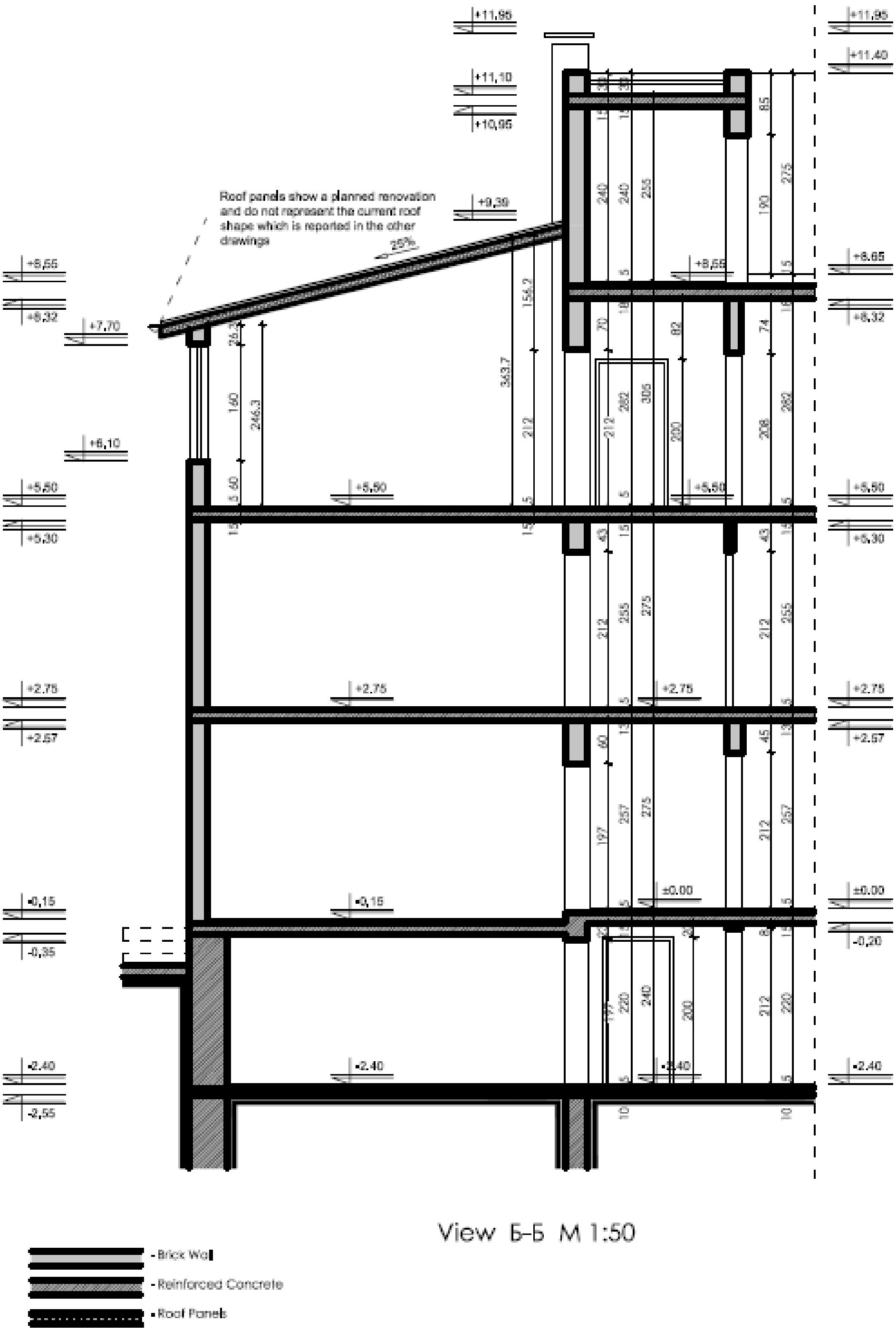

Figure 44. Partial Cross-section, Roof panels, 25% (Source: BAL)

3.2.1.8. Elevations

The facades of the demo building Sofia are seen below, received on the 7th of July 2022. See Appendix A: Demo Buildings, 2.4. Additional plans for other façade of the building.

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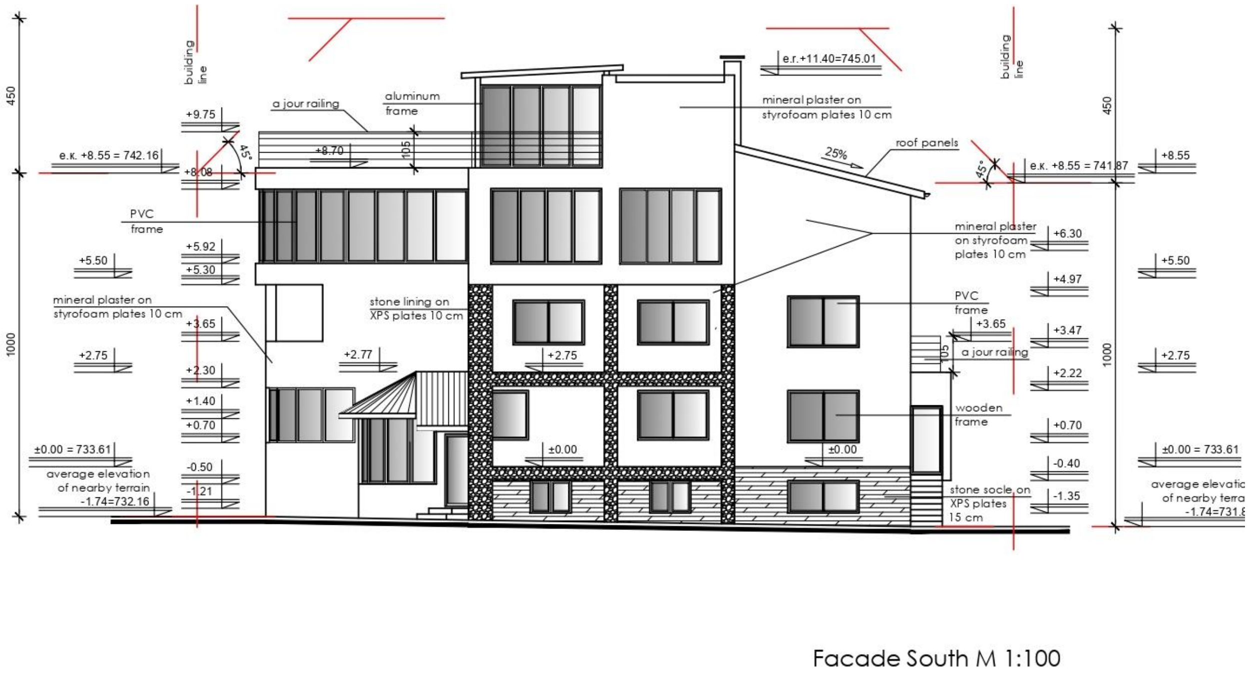

Figure 45. South façade, Sofia (Source: BAL)

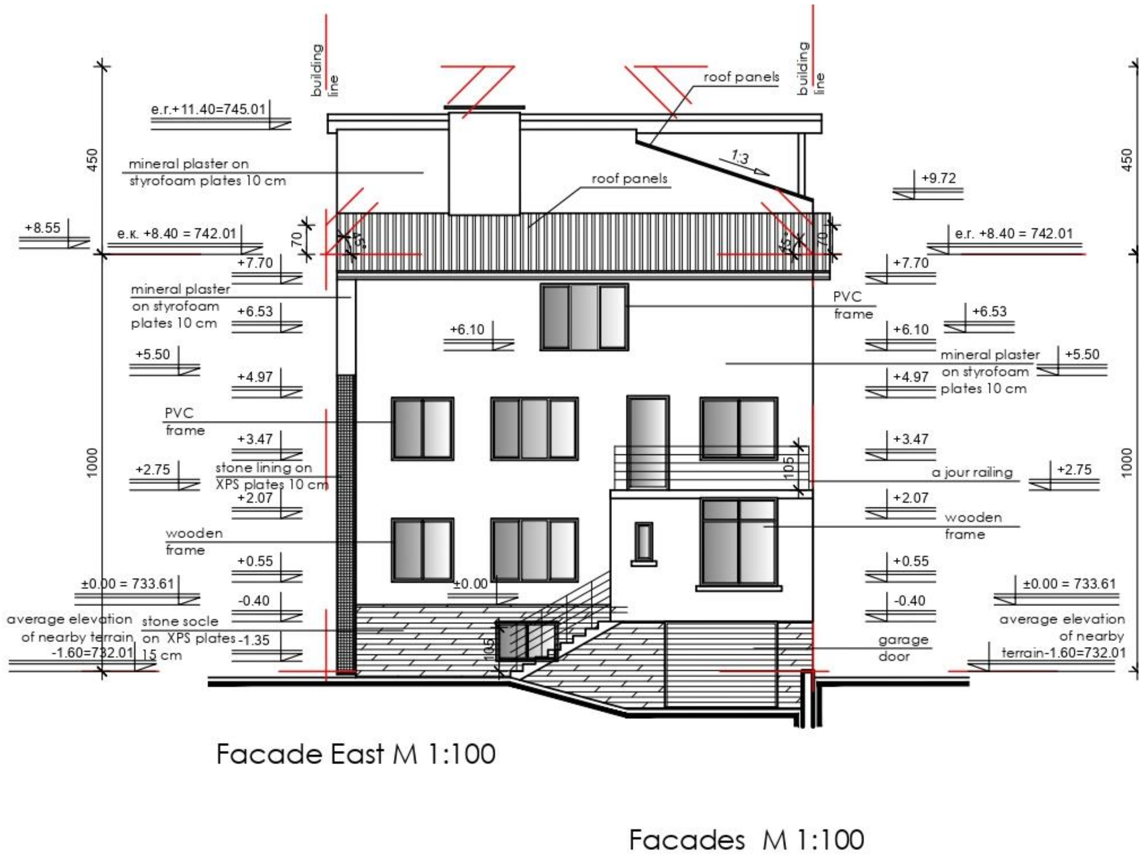

Figure 46. East façade, Sofia (Source: BAL)

3.2.1.9. 3D Visualisations of models

The 3D model of a building, provided on the 7th of July 2022 is seen below.

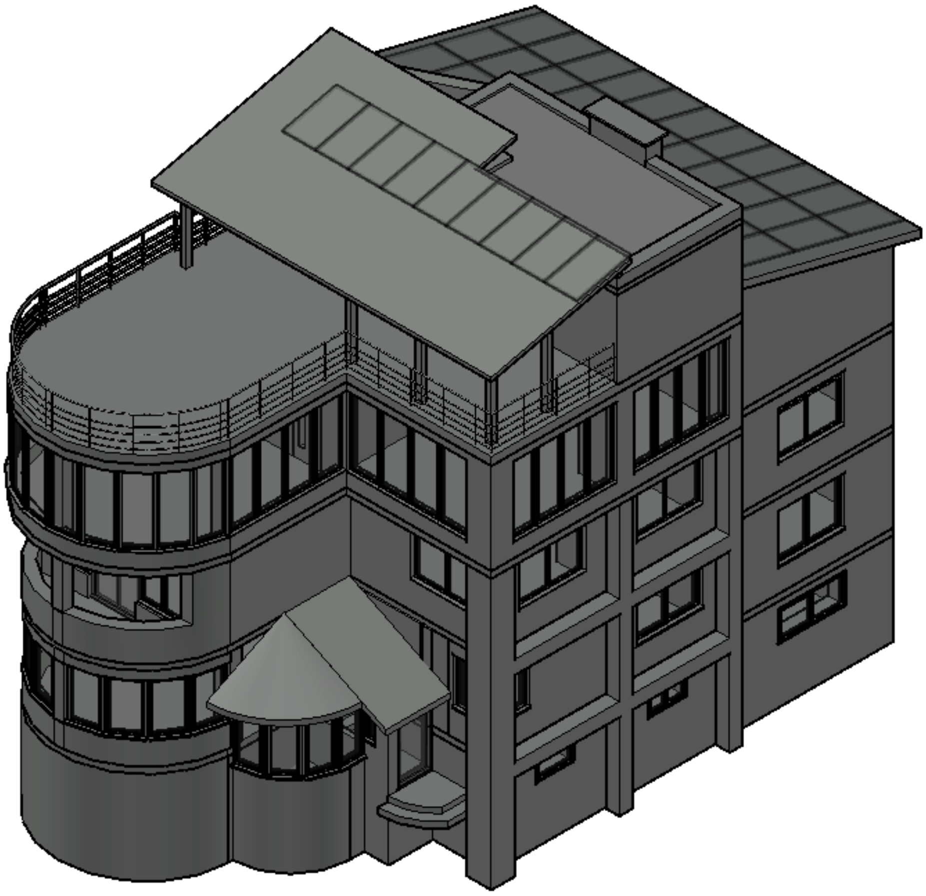

Figure 47. 3D model, Sofia: View from South-West, AutoCAD. (Source: BAL)

3.2.1.10. Existing information and communications technology (ICT) structure

There is no existing BMS and control system in the building.

3.2.2. Diagnosis Report – Actual stage of the building

3.2.2.1. Objectives of diagnosis

The aim of diagnosis report is to visually assess the condition of the load-bearing structures, and fencing structures of the building, and the possibilities for reconstruction.

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3.2.2.2. General nature of the building

The building has dimensions of 18.78 x 11.40 m and a height of 11.40 m.

The building has a semi basement floor, a ground floor, a first residential floor, a second residential floor, a third residential floor and an attic floor with a flat roof.

3.2.2.3. Current structural condition of the building

A visual inspection by BAL team was conducted in November, 2021.

- The main building features stone masonry foundations, solid ceramic brick walls, and reinforced concrete slabs between floors. The western part was upgraded with a **reinforced concrete bridge structure**, a second residential floor, and an attic floor with a flat roof. An oval-reinforced concrete structure and ceramic brick walls were added on the west side.
- The semi-basement floor's **external walls** are 40 cm thick stone masonry, while the upper floors use 24 cm thick ceramic bricks. All exterior walls are covered with 10 cm thick Styrofoam for thermal insulation.
- The **internal walls** are constructed from 12 cm thick ceramic bricks and are covered with plasterboard on both sides.

Figure 48. External wall conditions (Source: BAL)

- The **ceilings** are lined with plasterboard.
- The **floors** are adorned with terracotta tiles.

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- The flat **roof construction** consists of a 15 cm thick reinforced concrete slab, topped with 10 cm XPS, a 5 cm concrete screed for slope, and two layers of bituminous waterproofing. The slats are made of a wooden structure covered with 2 cm chipboard, underneath which is 10 cm mineral wool and 10 cm plasterboard. The chipboard is further topped with two-layer bitumen waterproofing.
- The **basement wall and foundation**, also known as the plinth wall, are covered with 10 cm thick Styrofoam for thermal insulation.

3.2.2.4. Conclusion
In general, the load-bearing structures of the building are in a stable condition and comply with the current load-bearing capacity requirements.

The roof structure is in good condition and complies with the current requirements for hydro and thermal insulation.

The entire building has good thermal and hydro protection.

3.2.3. Renovation Measures

3.2.3.1. Preliminary system approach

3.2.3.1.1. Initial pilot building requirements
The ventilated façade of the SOFIA demo building is made of non-combustible materials. The color of the new part of the façade must be consistent with the color of the rest of the building.

For this specific case, a suspended façade can be used. The structure of the building is able to bear an additional load of the new elements. The new elements of the suspended façade will be anchored combined: in the axis of the reinforced concrete slabs and in the first row of bricks above the slabs. This system concept will be confirmed according to further decisions during the renovation phase. See section 3.2.3.1.3. Evaluation of structural systems:

There are no requirements according to aesthetic aspects as well as the cultural heritage of building.

3.2.3.1.2. Preliminary Concept Design of ENSNARE system in SOFIA demo building

3.2.3.1.2.1. ENSNARE technologies
In the case of the Sofia pilot, the geometric characteristics of the building and the insolation conditions have determined the arrangement of the ENSNARE system only in the upper and right part of the south façade and the upper part of the east façade.

The horizontal axes are determined by the position of the slabs and the height of

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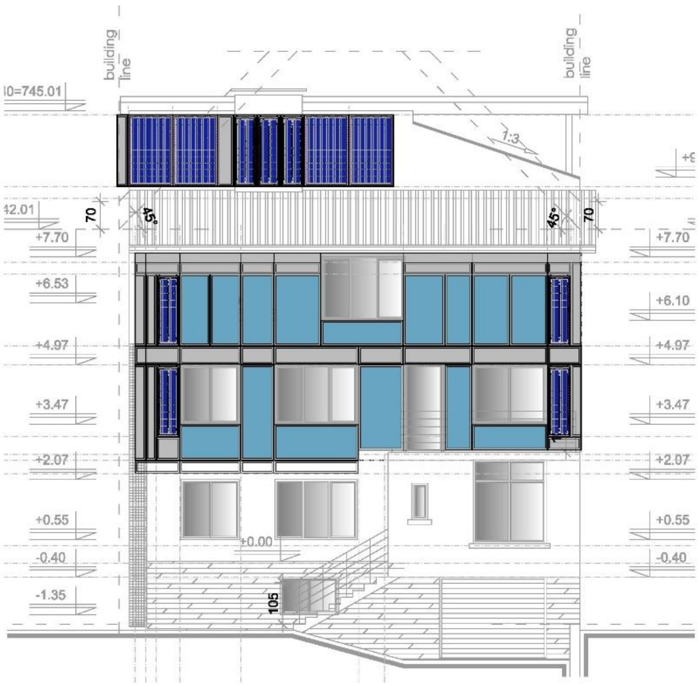
the windows. As in the case of Tartu, it is necessary to establish strips that order the arrangement of the panels. In the first place, horizontal and continuous registration areas on each floor up to the vertical registration area that includes all of them. Then a central strip that adapts in each case to the size of the windows, the panels with rollbond absorbers or the photovoltaic panels (with blue pattern). The vertical axes are distributed responding to the dimensions of the different panels and the existing windows. The predesign of the solution to be adopted is shown below.

South elevation



East elevation

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Figure 49. ENSNARE system predesign in Sofia (Source: RIVENTI)

The summary of the area covered by active modules are in the Table 22.

Table 22: Modulation design, Sofia (Source: RIVENTI)

Sofia - Modulation design					
Category	**South**	**North**	**West**	**East**	**Total**
Façade area [m²]	145	146	92	88	471
Windows area [m²]	45	14	37	24	120
Active area [m²]	23.31	0	0	35.83	59.14

3.2.3.1.2.2. Preliminary concept design with 3D parametrization

The lack of good quality, workable pictures and perspective makes it difficult to develop the 3D model for the subsequent modulation.

3.2.3.1.2.3. Solar radiation analysis

ONYX carried out a preliminary solar analysis in the earlier phase of the project. The power output has been worked out per day and m^2. Then, kWh/year was analyzed to make initial decisions. All façades and roofs were studied regardless of the shadows generated by trees or buildings. The results are presented in D.1. In the case of the Sofia pilot, the most suitable façades in terms of energy production are the West, East and South façades (5211 Kwh/year, 8893 kWh/year and 9880 kWh/year respectively). However, the West façade was discarded due to the curved shape preventing the ENSNARE system's installation.

For a detailed analysis and assessment of solar insolation, a more in-depth study is made. It was observed that the neighboring elements of the Sofia pilot building obstruct the sun from reaching a major area of the building surface, which is further substantiated by the solar insolation investigation in Grasshopper (Rhinoceros 3D) using the Ladybug plugin. The adjacent elements and the pilot building have been modelled with the aid of online maps (Google Maps and OpenStreetMap), pictures, Point Cloud and a 3D building model provided by BAL. The heights and circumference of trees are estimated from the Point Cloud. The EnergyPlus Weather File of Sofia city has been used to supply the weather data. The adjoining building is developed in the form of a block by extruding its layout from the Openstreetmap file to match the original height – which is confirmed through Point Cloud.

The analysis provides a sufficient idea with a conservative approach to comprehend the shading impact on the pilot building of the trees and the adjacent building, especially on the east façade. This information is of vital importance for determining the location where technological panels should be placed to maximize the solar energy potential since the west façade cannot host the standard ENSNARE system because of its curved shape and excessive shading.

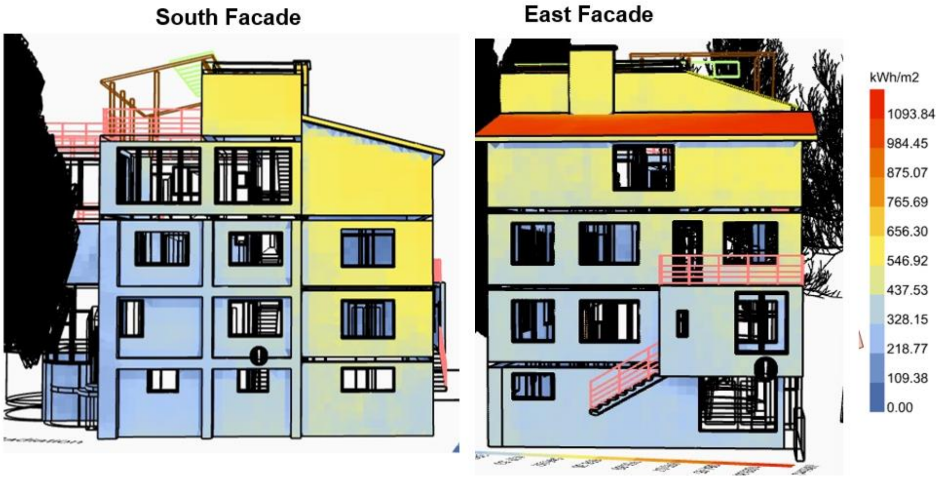

Figure 50. Solar study of SOFIA demo building (Source: ABUD)

Despite the roof receiving a large volume of solar radiation, it is not considered in the scope of the ENSNARE project, which is limited to façades of buildings only. However, this portion of the roof is not left idle at all, it is already covered with solar panels by the property owners.

3.2.3.1.2.4. Concept design of non-active Façade (Trespa panels)

In this building there is a recent refurbishment with a 100 mm thick ETICS (External Thermal Insulation Composite System) where the insulation of the building in general was improved. It is to be assessed whether to maintain or install a ventilated façade. The design of Trespa panels installation is still in progress.

3.2.3.1.3. Evaluation of structural systems

In the Sofia building, it is found that the thickness of the reinforced concrete slab, 150mm, initially raises doubts about its structural capacity to support the ENSNARE system modules. The thickness of the slab would imply having anchors in reinforced concrete and anchors in the brick walls.

This issue was discussed with Hilti's technical engineer in Bulgaria. However, no conclusion was reached on the fixing of the anchors, as there is no security on the brick wall and the Hilti software does not work with these slab thicknesses.

In this regard, BAL will evaluate three options proposed by ENSNARE to validate the anchoring system to be used to hang the system modules.

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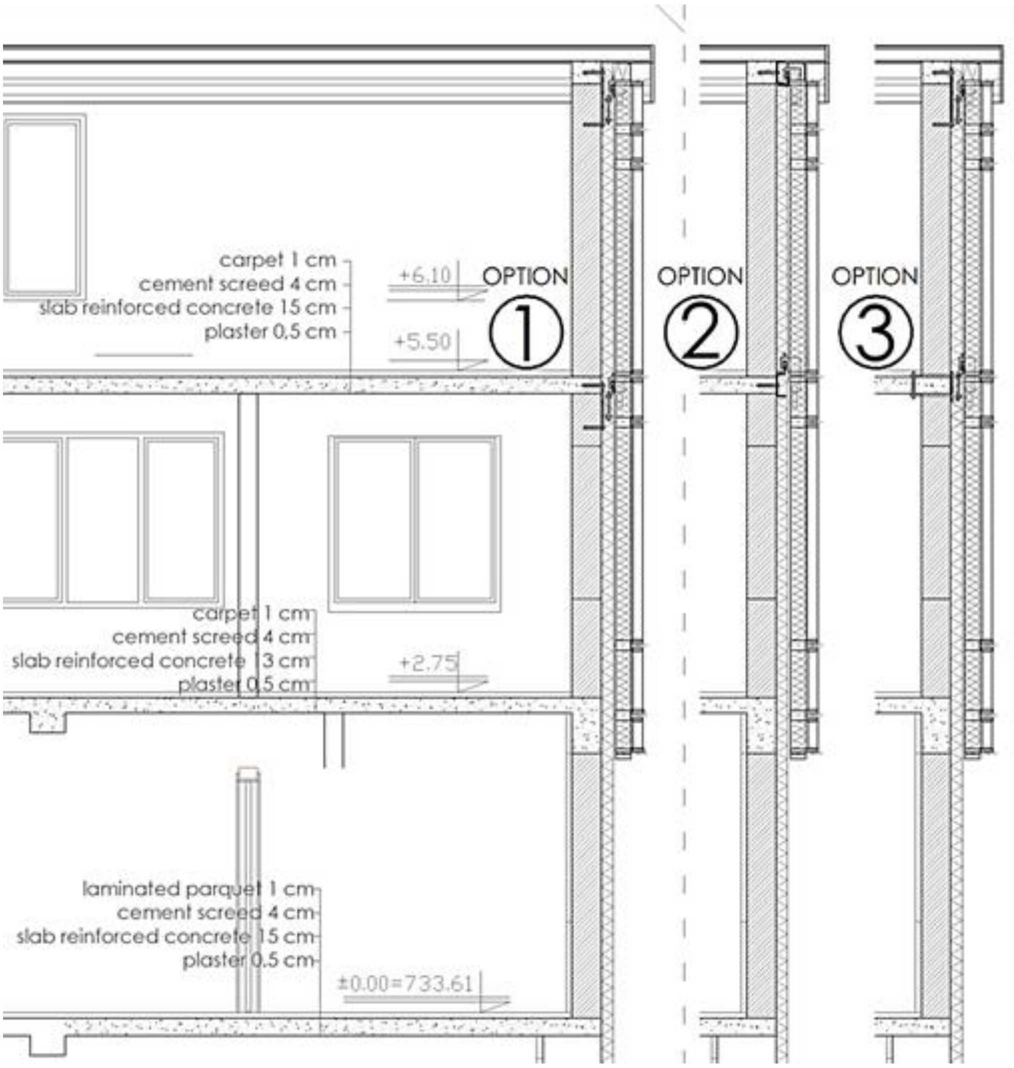
The loads that the ENSNARE system would transmit to the main structure of the building have also been provided.

An important aspect to be taken into account in the installation of the ENSNARE system in the Sofia building (3.2.3.1.2.4. Concept design of non-active Façade (Trespa panels)) is the existing 100 mm thick ETICS , which was recently installed and is in good condition. It was agreed to maintain the ETICS, with only occasional interventions on the ETICS to install the anchor plates.



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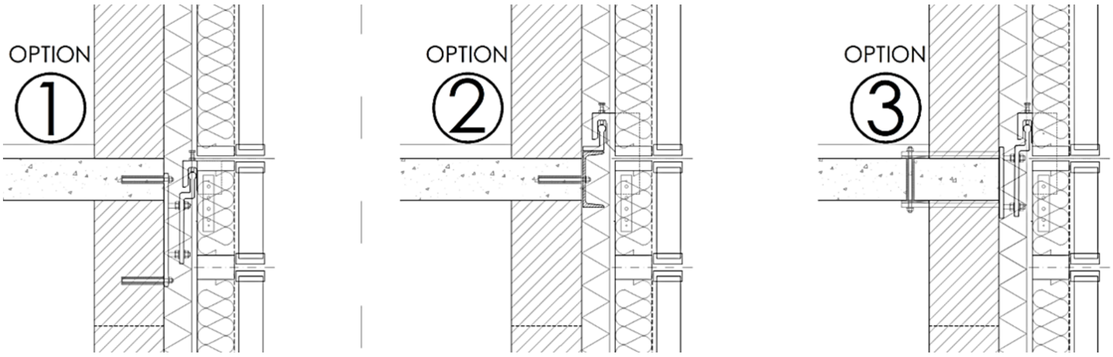

Figure 51. Anchorage system. Options due to low thickness slab (Source: ENAR)

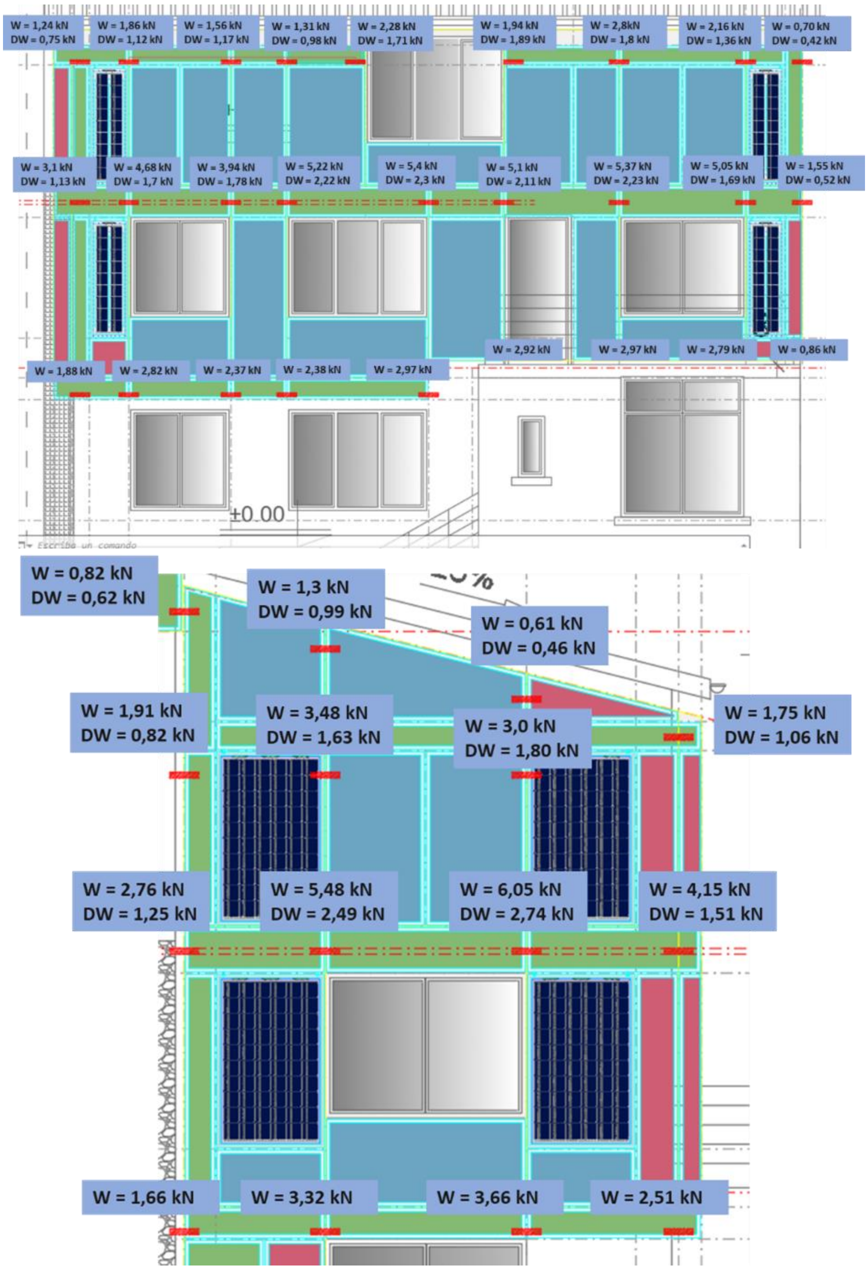

Figure 52. Load on each anchor - south and east façades (Source: ENAR)

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3.2.3.1.4. Potential major engineered systems

The situation pre- and post-intervention is the same for the Sofia demo building:

- Electric batteries and water tanks will not be included as production peaks are note expected.

3.2.3.2. Planning strategies

3.2.3.2.1. Expected timeline for design, implementation and feedback loops

Table 23. Design stages of a case study, Sofia (Source: ABUD)

	Pre-Design	Concept Design	Technical Design
Involved partners	ABUD, TEC, RIVENTI, ONYX	ABUD, TEC, RIVENTI, ONYX	
Status	The building is currently occupied, building was renovated from original drawings.	Discovering that only one façade can be considered for the design. Limitations with the involved architect. Connection is only with management of building. The design is not ready.	Task 7.3

Table 23 displays the current progress of each stage for the SOFIA demo building. A complete schedule of meetings and the table of acquired data can be found in Appendix C: Planning, Meeting schedule. The technical schedule for the renovation process has been created according to country specifications, as detailed in section 2.3.2.3. Programme and phasing. In addition to the technical renovation schedule for the pilot, a combined schedule incorporating the activities of other partners has also been developed. The current schedule is available in Appendix C: Planning, Data management and planning for the Sofia demo building. Please note that this schedule may change in future steps.

Scheduling is an ongoing process where constraints are monitored, and dates are adjusted accordingly. Consequently, this deliverable 7.1 could be used as a reference tool in future design and renovation stages. At the moment, we are in the process of acquiring the renovation permit. The schedules are adapted to each pilot individually, based on country regulations, collected data, and other considerations.

The schedule for the next five months is outlined in section 3.2.3.2.3. Programme and phasing.

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3.2.3.2.2. Feasibility study for SOFIA demo building

The feasibility study proposed in Deliverable 5.1 (RIVENTI Nuria Jorge, Guillermo Rilova, Hugo Bergado, 2021) is updated in this paragraph, with new costs and conditions for the pilot under consideration. The aim of this analysis is to estimate an average cost of the façade retrofit considering the active panels area and production planned within the demo building under consideration. The analysis has been carried out considering the last costs provided from BAL. The additional following assumption are considered for the SOFIA demo building:

1. Heating, Domestic Hot Water (DHW), and electric consumption are assumed from average Bulgaria values (EUROSTAT (Eurostat, n.d.)) and are listed in Table 24. An area of 562 m² and 3 dwellings are assumed. According to costs and the previous assumption, the estimated annual cost for electricity (due to the electric SH/DHW boiler and electric consumption) is around 1340 €/y, which is in line with the real cost of 1260 €/y.
2. The active area, considered totally as PV, is 21.7 m² on the South façade (530 kWh/(m² y) of solar radiation), and 36.3 m² on the East façade (450 kWh/(m² y) solar irradiation). The total electric production from ENSNARE active technologies in this case is 4177 kWh/y. The remaining surface is considered insulated.
3. The retrofitted building is supply with an electric heat pump for heating and DHW (COP 3.5 and 3, respectively).
4. Four scenarios are presented regarding the space heating (SH) consumption reduction after the retrofit: 40% SH reduction (S-1), 60% SH reduction (S-2), 80% SH reduction (S-3), 90% SH reduction (S-4).
5. The analysis does not consider the electric energy produced by the already installed PV system.

Table 24: Cost and energy assumptions for SOFIA demo building (Source: UNIDP)

Heating demand [kWh/(m² y)]	DHW demand [kWh/(m² y)]	Electric consumption per dwelling [kWh/y]
78.2	26.6	3667.0
Electricity price from BAL [€/kWh]	**Gas price from BAL [€/kWh]**	**Discount rate [%]**
0.113	0.179	5.0

According to the listed assumptions, the building annual energy consumption and costs saving results are shown in Table 25. Since a Heat Pump is considered for both SH and DHW, the whole building is served by electric systems, resulting in an annual electric energy consumption between 23518 kWh and 17240 kWh depending on the SH saving (S-1-4). With this condition, it is likely that the whole PV production from ENSNARE systems (4178 kWh) is consumed on site. The annual cost saving is in the range 4464 – 5173 € (S-1-4).

Table 25: Energy and cost saving results (Source: UNIDP)

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	S-1	S-2	S-3	S-4
Annual electricity consumption [kWh-e]	23518	21007	18495	17240
Annual PV self-consumption [kWh-e]	4178	4178	4178	4178
Annual net cost for electricity [€]	2185	1902	1618	1476
Annual cost saving [€]	4464	4748	5031	5173

Considering the discount rate assumed in Table 24, the following table provides the investment cost that is suitable considering different pay back periods, i.e. 8, 10, 12, 14 years, namely S-8-14.

Table 26: Target investment cost for active façade [€] (Source: UNIDP)

Payback time (y)	S-1	S-2	S-3	S-4
S-8	28,851	30,685	32,520	33,437
S-10	34,469	36,661	38,852	39,947
S-12	39,565	42,080	44,595	45,853
S-14	44,187	46,996	49,805	51,209

The resulting specific investment cost for the overall façade is display in Figure 5353. In this demo building the low grid electricity costs and the low active technologies production (due a small available area and shading effects around building) results in a small feasible investment cost.

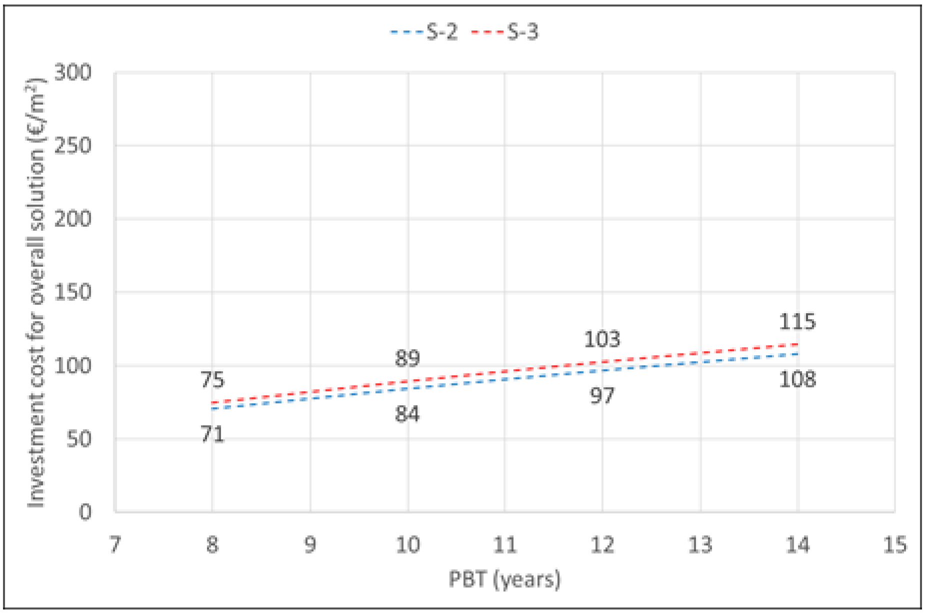

Figure 53. Specific cost for the overall solution in case of 60% (S-2) and 80% (S-3) SH consumption reduction [€/m²] (Source: UNIDP)

3.2.3.2.3. Programme and phasing

- Currently, the SOFIA demo building is in the process of acquisition of construction permit.
- Further steps include the technical design of façade and its manufacturing.

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- The Table 27 gives an overview of the activities of demo building SOFIA and partners for the next 5 months.

Table 27: Schedule of renovation process: SOFIA (Source: ABUD)

WP7 PILOT BUILDING					
ID	ACTIVITY	PARTNER	START	DAYS	END
0	**Pre-Design**				
0.1	Technical assignment for reconstruction of the building	BAL	02/01/2023	22	31/01/2023
1	**Approval of façade configuration**				
1.1	Laboratory test results	TEC	23/01/2023	15	10/02/2023
1.2	Design visa and approval the visa by the approving authorities	BAL	01/02/2023	20	28/02/2023
1.3	Design insurance	BAL	31/03/2023	1	31/03/2023
1.4	Concept design for the reconstruction of the building	BAL	03/04/2023	20	28/04/2023
1.5	Detailed design for the reconstruction of the building	BAL	01/05/2023	89	31/08/2023
1.6	First results of energy rating test	TEC	01/03/2023	18	24/03/2023
2	**Façade project**				
2.1	Survey of the exact geometry of the façades of the building	TARTU	09/01/2023	5	13/01/2023
2.2	Façade project	ENAR, TRESPA (Ventilated façade)	09/01/2023	20	03/02/2023
2.3	Equipments and hydraulic & electrical infrastructure definition	TEC, ONYX	16/01/2023	15	03/02/2023
2.4	Monitoring & Control infrastructure definition	IES	16/01/2023	15	03/02/2023
3	**Manufacture of façade modules**				
3.1	*Manufacturing of technologies and modules*				
3.1.1	PV+STONE & supply to RIV	ONYX	23/01/2023	20	17/02/2023
3.1.2	PV+Al & supply to RIV	ONYX	01/03/2023	23	31/03/2023
3.1.3	PVT & supply to RIV	ONYX	13/02/2023	25	17/03/2023
3.1.4	Absorbers-PVT supply to ONYX	KAMEL	09/01/2023	25	10/02/2023
3.1.5	Absorbers-ST supply to RIV	KAMEL	09/01/2023	25	10/02/2023
3.1.6	TRESPA & supply to RIV	TRESPA	23/01/2023	50	31/03/2023
3.1.7	Insulation for ENS modules supply to RIV	TRESPA	30/01/2023	15	17/02/2023
3.1.8	Trespa ventilated façade, insulation included (supply directly to the building site, 3.2)	TRESPA	30/01/2023	45	31/03/2023
3.2	*Assembly of modules at RIV*				
3.2.1	Modules	RIV	06/02/2023	60	28/04/2023
3.2.2	Anchoring system	RIV	06/02/2023	15	24/02/2023
3.2.3	Finishing manufacturing	RIV/TARTU	10/04/2023	15	28/04/2023
4	**Material Shipment and stocking in Demo-site**				
4.1	Ensnare Façade Modules + finishing	RIV	01/05/2023	20	26/05/2023
4.2	Trespa ventilated façade + finishing	TRESPA	03/04/2023	15	21/04/2023

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4.3	Electrical and hydraulic infrastructure	TECN, ONYX	01/05/2023	20	26/05/2023
4.4	Monitoring & Control infrastructure	IES	01/05/2023	20	26/05/2023
5	**Ensnare implementation in Demo Building & start-up**				
5.4	TRESPA ventilated façade (Trespa VF)	TARTU/TRESPA	03/04/2023	85	28/06/2023

3.2.3.2.4. Buildability and construction logistics

There is nothing on the terrain on the east side. This part can be used to store building materials and install machinery for construction purposes. This part of the property is accessed from the street entrance. The property is bordered by a street that connects the property with the southern arc of the ring road of the city of Sofia. Access to the eastern part of the yard is through a narrow passage through which a car, minibus, small truck or small crane can pass.

3.2.3.2.5. Sustainability assessment

For the waste management, a construction waste container will be provided during construction processes. The waste will be sent to a landfill for construction waste in the district of the city of Sofia.

The area is densely populated. Hence, it is not recommended to perform noisy activities in the period from 14:00 to 16:00 in the afternoon.

3.2.3.2.6. Risk assessment

The construction activities will be carried out in accordance with the regulation for safe and healthy working conditions during construction.

Construction is supervised by a licensed and experienced company.

The designer of building structures will give an official opinion on the bearing capacity of the building under the new loads. The supervision during the execution of the construction will be carried out by the designer.

3.2.3.2.7. Considerations

The integrated design process meetings provided an impetus to facilitate the collaboration. Although the process was not as fast as expected, the objectives were met at the end and required details were sorted out. Demonstrating the capacity of the structure to support the modules took longer, however, it was resolved after a consensus was reached between different partners and their teams.

3.2.3.3. Impact of expected renovation strategies

<u>Insulation of the envelope with ENSNARE panels</u>

The simulation model prepared with DesignBuilder is as follows:

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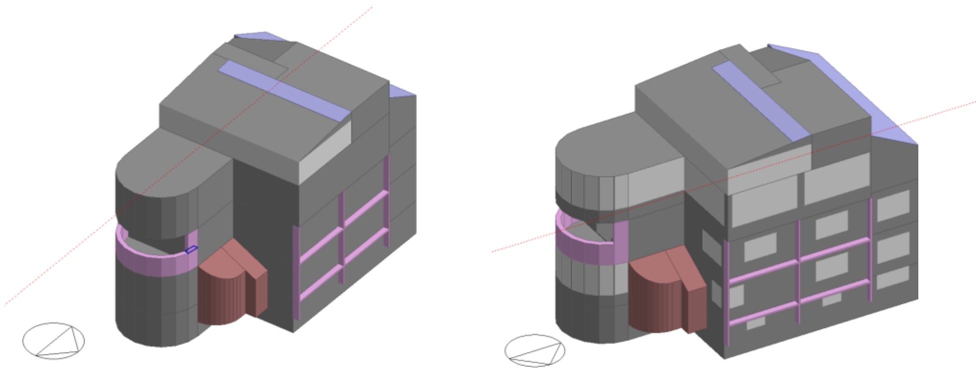

Figure 54. 3D virtual models for Sofia (Source: TEC)

This demo site had already 10 cms of insulation, which can be considered as proper insulation and it has been decided to keep the existing insulation intact instead of dismantling and wasting it. Although the substitution of this insulation for the one provided by ENSNARE panels could provide further savings, it must be assessed if the energy savings are substantial. The model allows to estimate these savings with the following outcomes:

Table 28: Monthly electric consumption of the Sofia building according to simulation: electric (left column) and gas consumption (right column) (Source: TEC)

Period	Electricity consumption according to simulation [kWh]	Gas consumption according to simulation [kWh]
January	2387	6436
February	2172	5114
March	2434	2191
April	2436	263
May	3159	16
June	5097	0
July	5550	0
August	5578	0
September	3523	0
October	2645	441
November	2336	3180
December	2406	6132
TOTAL	39,723	23,773

If the 10 cms of insulation is modified with 15 cms, the following results are obtained:

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Table 29: Monthly electric consumption of the Sofia building according to simulation: electric (left column) and gas consumption (right column) (Source: TEC)

Period	Gas consumption according to simulation [kWh]
January	5957
February	4692
March	1914
April	201
May	11
June	0
July	0
August	0
September	0
October	355
November	2860
December	5664
TOTAL	21,655

It can be observed how the consumption decreases in 8.9%. This low value does not justify the substitution of a relative new insulation for the insulation included in the ENSNARE panels. Therefore, only active panels are to be installed without any insulation.

Installation of ENSNARE active panels

For Sofia, several configurations were considered taking into account different combinations of the three types of active panels. The maximum production from the total available area was analyzed for each of the systems, being the following the result of this analysis:

Table 30: Proposed configuration for Sofia demo building (Source: TEC)

Technology	Units	Solar thermal area [m^2]	PV area [m^2]	Electric peak power [kWh]
ST	South: 3 East: 4	South:6.95 East: 7	NA	South: 2,340 West: 4,170
PVT	South: 4 West: 7	South: 5.2 West: 5.7	South: 5.2 West: 5.7	
PV	South: 10 West: 15	NA	South: 10.4 West: 22.1	

Those configurations would have the following production compared to the annual consumption from the grid and/or local systems.

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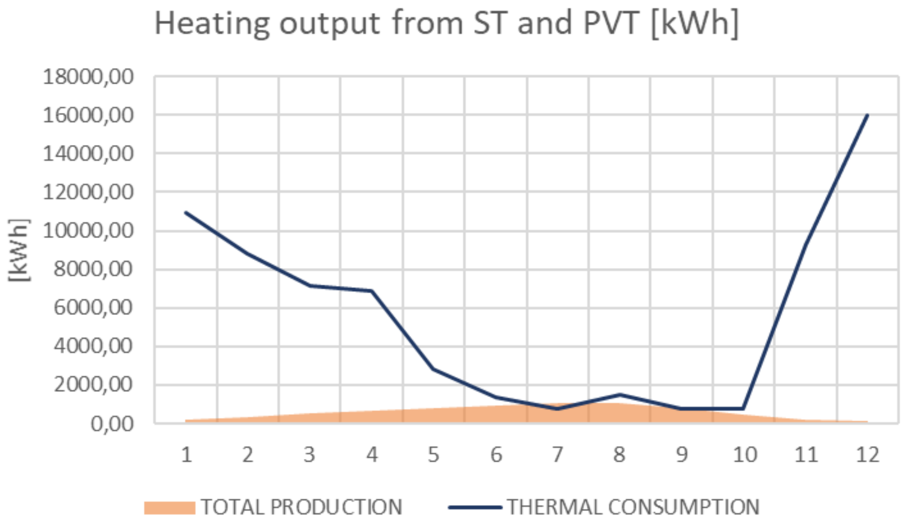

Figure 55. Heating output of the proposed configuration for Sofia demo building (Source: TEC)

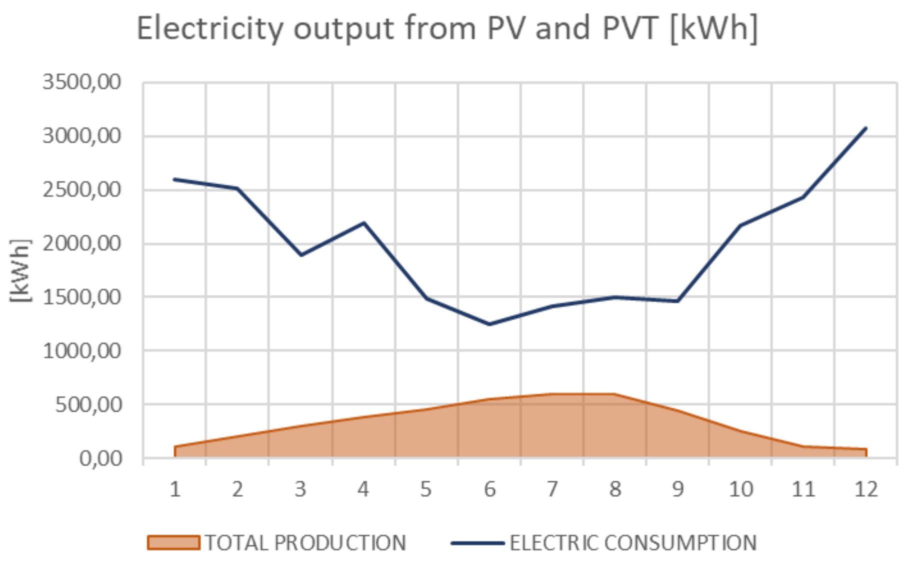

Figure 56. Electricity output of the proposed configuration for Sofia demo building (Source: TEC)

This consumption (thermal and electric) is the one billed by the energy company, and therefore is net imported, not overall consumption. This means that the PV production from the pre-existing panels is already subtracted from the panels. As it can be seen in the figures, the proposed configuration has surplus of heating energy during the sunniest months of the year; moreover, the electricity generation of both the PV and PVT is below the electricity consumption of the building during the whole year.

The estimated energy output of this configuration is:

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- Electric output: 4,097 kWhe.
- Thermal output: 7,178 kWht.

Primary energy and GHG total savings

For the GHG savings, the methodology used was the one suggested in the Tool to support the calculation of GHG emission avoidance from renewable electricity, renewable cooling and renewable heating projects under the Innovation Fund (v2.0 - 24.03.2021). This methodology gives the following factors:

- Emission factor for combustion of gas: 0.202 tonnes CO_2e / MWh.
- Emissions of electricity production in 2030: 0.150 tonnes CO_2e / MWh.

Primary Energy Factors (PEFs) for both heat production and electric consumption were obtained from standard practice:

- PEF of heat production by gas: 1.2 kWh/kWh.
- PEF of electricity production: 2 kWh/kWh.

The final energy savings estimated in previous sections together with the factors lead to the calculation of primary energy and GHG savings.

Table 31. Summary of the annual savings obtained for Tartu (Source: TEC)

Savings	Final energy (kWh/year)	Primary energy (kWh/year)	GHG savings (kg/year)
a) Consumption of the electricity	23,981	47,962	3,597
b) Consumption of gas for heating	66,972	80,367	13,528
c) Electricity produced by the active panels	4,097	4,097	-
d) Heating produced by the active panels	7,178	7,178	-

The electricity consumption reduces its impact on 7,118kWh of final energy, 14,356 kWh of primary energy, and 1,077 kgs of CO_2 per year. Regarding the heating consumption, it reduces its impact on 4,097kWh of final energy, 4,916 kWh of primary energy, and 828 kgs of CO_2 per year.

Regarding the consideration of the building as NZEB, the following estimations are obtained:

- Final energy consumption (kWh/m^2·year) = 136.37
- Primary energy consumption (kWh/m^2·year) = 200.34

Energy storage

Due to the low energy surplus of energy expected, there is not foreseen any energy storage.

3.3. Demo Building 3: Sassa Scalo, Italy

3.3.1. Building General Description

Demo Building 3: Sassa Scalo

The demo building Sassa Scalo has the following characteristics:

Table 32: Characteristics of demo building 3: L'Aquila (Source: COAF)

Location	Sassa Scalo, L'Aquila, Italy
Year of construction	1978
Storeys number	3
Typology	Residential
Number of dwellings	2
Current occupancy	max 20

Figure 57. Side view of the demo building in Sassa Scalo (Source: COAF)

Figure 58. View of the demo building in Sassa Scalo (Source: COAF)

3.3.1.1. Location

The demo building is located in Sassa Scalo, Italy. The following photos of the location are provided by Italian partner COAF on the 31st of May 2022.

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Figure 59. Aerial view of the demo building in Sassa Scalo (Source: COAF)

3.3.1.2. Building History

The building was built 1974 and had the intended use of homes for two families. After the 2009 earthquake there were some renovations, especially on the roof but it did not suffer structural damage. Today, it is used in part for offices and the other has remained a home.

3.3.1.3. Architecture and structural system

The building Sassa Scalo has the following structural system details:

Table 33: Structural system details of demo building 3: Sassa Scalo (Source: COAF) (RIVENTI Nuria Jorge, Guillermo Rilova, Hugo Bergado, 2021)

Structure typology	Construction of concrete floors and pillars
Distance between slabs (floors) [m]	3,00
Slab structure thickness [m]	0,30
Slab material properties	Reinforced concrete
Height [m]	9,00
Floor dimensions (length x width) [m]	20,00 x 15,00

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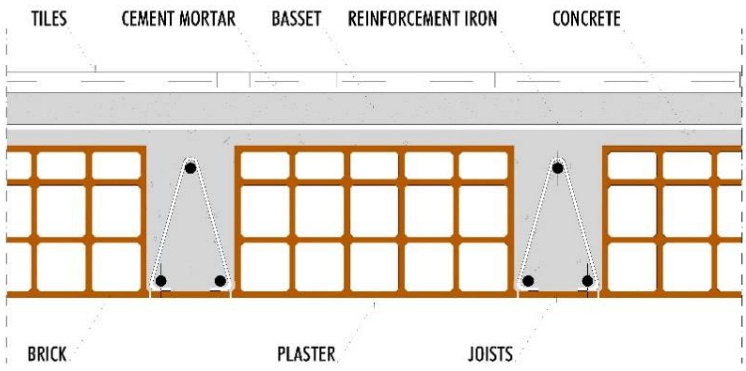

Figure 60. Italian pilot structural scheme (Source: COAF)

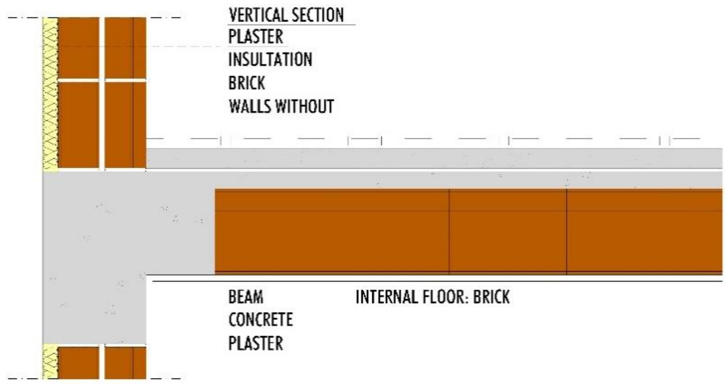

Figure 61. Italian pilot structural detail (Source: COAF)

3.3.1.4. Construction and building envelope information

Table 34: Construction/Building envelope: COAF (Source: COAF)

External wall	Plaster, brick, cavity, brick, plaster
Internal partition	Plaster, brick, plaster
Internal ceiling/floor	Plaster, brick, concrete, tiles
Ground floor/ roof	Plaster, brick, concrete, tiles
Window %, type and frame	Wooden, single glass
Infiltration rate - Property air tightness (poor, basic, good)	Poor
Infiltration rate - Any External Vents Present?	Yes

3.3.1.5. Mechanical and electrical systems

The building Sassa Scalo is currently equipped with the following building system services (BSS):

- ***Heating system installed:*** Hydraulic central heating system: gas-fired condensing boiler and radiators consisting of assembled cast-iron heating elements: there is one boiler for each of the two building units.

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- ***Domestic hot water (DHW) system:*** The DHW system is fed by the same condensing boiler that provides hot water distribution to the radiant heating system.
- ***Air-conditioning system:*** Not available.
- ***Mechanical ventilation system:*** Not available.

Available low carbon technologies:

- ***Renewable heat generation source:*** Not available.
- ***Renewable electricity generation source:*** Not available.

3.3.1.6. Floor plans

The following floor plans were provided by the COAF partner on the 31st of May 2022. See Appendix A: Demo Buildings, Additional plans for plans of other floors.

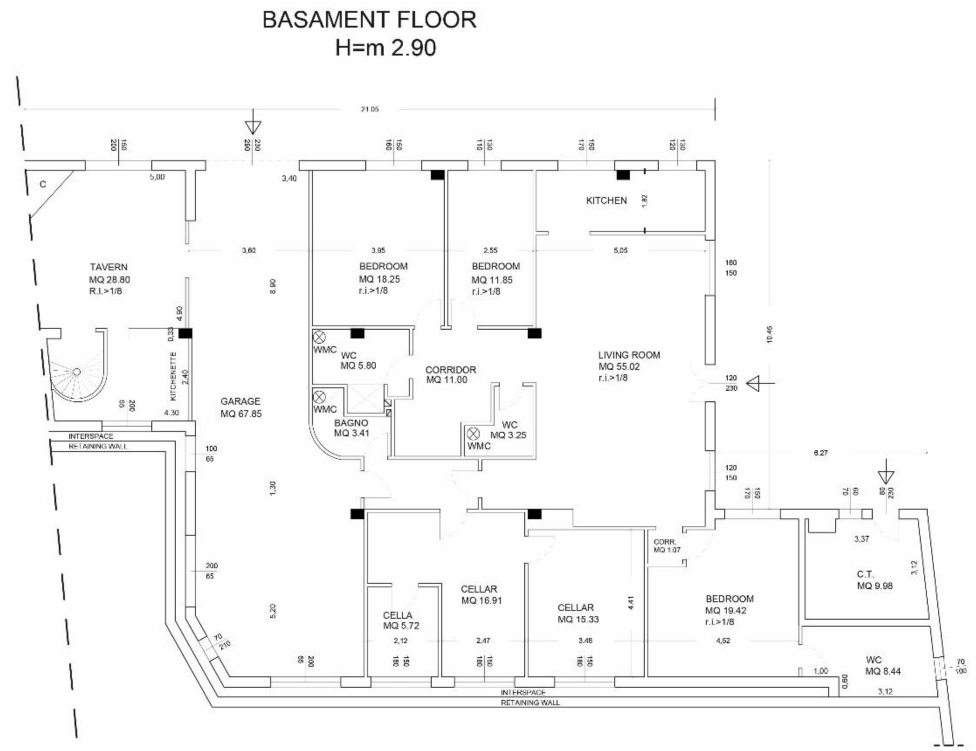

Figure 62. Ground floor plan (Source: COAF)

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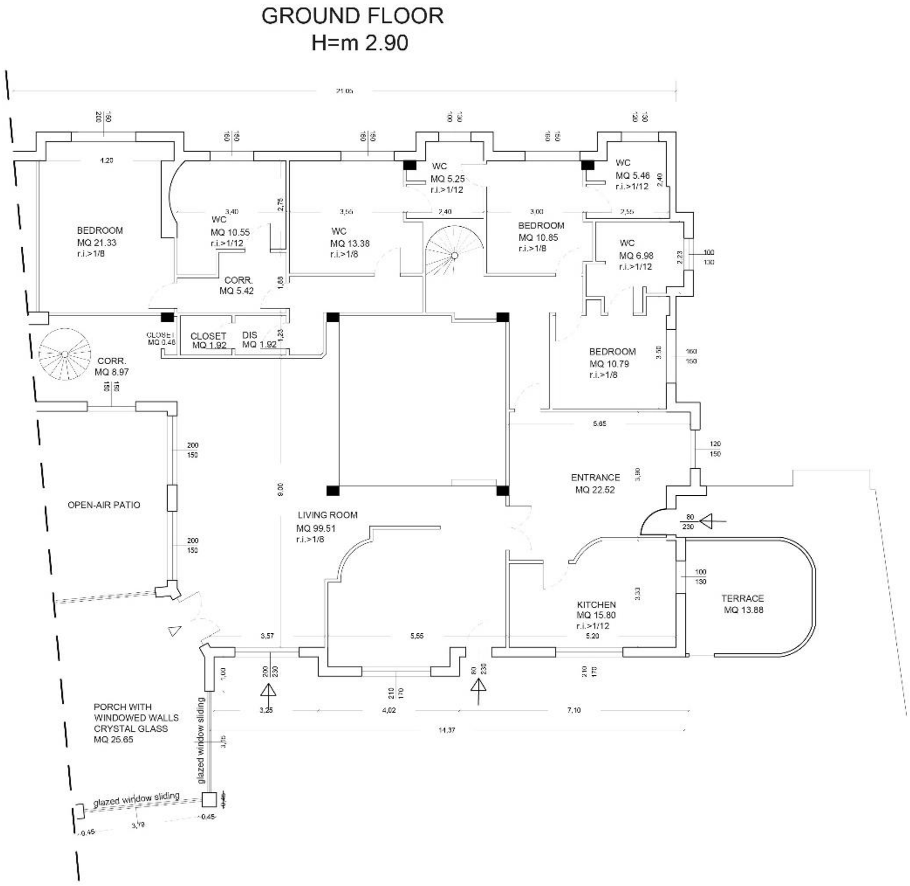

Figure 63. Floor 1 plan (Source: COAF)

3.3.1.7. Sections

For the demo building Sassa Scalo, a section can be seen below:

Figure 64. Section A-A Villa Irti, Sassa Scalo, Italy (Source: COAF)

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3.3.1.8. Elevations

The envelope composition of the building Sassa Scalo is categorised as a medium-height structure adaptable for PV modules. Most windows are in the north (26 windows), while there are 6 windows on the south façade, 7 on the west façade, 6 on the east façade and 4 at the roof.

A preliminary analysis indicated the outputs and the estimation of PV energy production, to clarify the scenarios in the Sassa Scalo building (RIVENTI Nuria Jorge, Guillermo Rilova, Hugo Bergado, 2021). The elevations are described as follows:

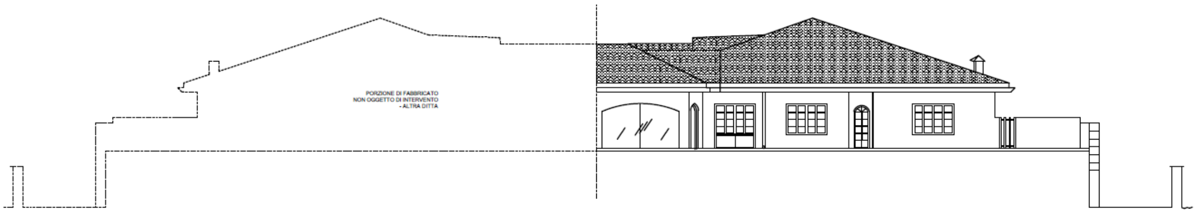

Figure 65. South elevation, Villa Irti, Italy (Source: COAF)

Figure 66. Side elevation, Villa Irti, Italy (Source: COAF)

3.3.1.9. 3D Visualizations or models

The 3D model of the building was provided on November 17, 2022, and it is shown below in the Figure 67.

Figure 67. 3D model, Sassa Scalo: View from North-West, REVIT (Source: COAF)

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3.3.1.10. Existing information and communications technology (ICT) structure

There is no existing BMS and control system in the building.

3.3.2. Diagnosis Report – Actual stage of the building

The villa is in good condition even if it shows some degradation on the outside due to the lack of renovations in recent years.

3.3.2.1. Objectives of diagnosis

The aim of diagnosis report is to visually assess the condition of the load-bearing structures, and fencing structures of the building, and the possibilities for reconstruction.

3.3.2.2. General nature of the building

The structure is in reinforced concrete and has a reinforced concrete retaining wall.

3.3.2.3. Current structural condition of the building

A visual inspection by COAF team was conducted in November, 2021.

- The building is structurally sound and has required no reinforcements, even after the 2009 earthquake.
- The **external walls** remain undamaged, though we observe isolated instances of plaster detachment.

Figure 68. Current state of the demo building in Sassa Scalo from left to right: entrance door, window, and rear entrance façade (Source: COAF)

- The **internal walls** are in pristine condition with no signs of damage.

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- The **structure's ceiling** is coated with a layer of plaster and notably, the building does not feature any suspended ceilings.
- The apartments are located across **two floors**. There is an additional floor below the roof, but it's not suitable for living.
- The building is equipped with a hip-and-valley **roof** structure.

a)

b)

Figure 69. View of the side elevations a) northwest side b) northeast side (Source: COAF)

Figure 70. View of the secondary elevation (rear entrance) (Source: COAF)

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- The **foundation** of the building is engineered as a shallow foundation, reinforced with a plinth beam for added stability.
- The **building's facade features** a plastered surface exhibiting occasional instances of detachment, and the doors and windows are crafted from wood.

3.3.2.4. Conclusion

The building's layout could be improved. The main facade, home to the primary entrance, is just one level above ground, and the vegetation limits internal lighting. The north facade has considerable space but isn't ideally positioned. However, the side facades are promising, with a good amount of surface area and better orientation.

3.3.3. Renovation Measures

3.3.3.1. Preliminary system approach

3.3.3.1.1. Initial pilot building requirements

According to the local requirement about aesthetic aspects of the building, the existing building is one of the most beautiful garden villas in the area and will become a residence for the elderly. It is essential to combine aesthetic choices, the wishes of the owners, and technological requirements. As for the Code for the cultural heritage of the building, there no requirements.

3.3.3.1.2. Preliminary Concept Design of ENSNARE system in SASSO SCALO demo building

3.3.3.1.2.1. ENSNARE technologies

In the case of the Sassa Scalo pilot, the geometric characteristics of the building and the insolation conditions have determined the arrangement of the ENSNARE system only on the east and west façades, mainly. In addition, the option of creating an auxiliary structure that offers continuous and regular support to the system has been considered, since the existing building has multiple protruding elements that would otherwise make it difficult to install the system.

The horizontal axes are determined by the position of the beams of the main structure and slabs of the building, as well as by the height and position of the windows. As in the previous cases, it is necessary to establish strips that order the arrangement of the panels.

First, there are horizontal and continuous registration areas up to the area where the service room is located, then a central strip that adapts to the panels with rollbond absorbers, and finally, a lower strip for the location of photovoltaic panels. The vertical axes are distributed responding to the dimensions of the different panels and the position of the existing windows.

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Below is the pre-design of the solution to adopt.

Figure 71. ENSNARE system predesigns in Sasso Scalo (Source: RIVENTI)

The summary of the area covered by active modules is in the Table 35.

Table 35: Modulation Design, Sasso Scalo (Source: RIVENTI)

Sassa Scalo - Modulation Outcomes					
Category	**South**	**North**	**West**	**East**	**Total**
Façade Area [m²]	118.4	337	98.6	98.6	652.6
Windows Area [m²]	45.24	68.6	22.3	22.3	158.44
Active area [m²]	0	0	29.72	29.72	59.44

3.3.3.1.2.2. Preliminary concept design with 3D parametrization

The lack of good quality, workable pictures and perspective makes it difficult to develop the 3D model for the subsequent modulation.

3.3.3.1.2.3. Solar radiation analysis

Initially, a preliminary solar analysis was carried out by ONYX. The power output has been worked out per day and m^2. Then, kWh/year was analyzed to make initial decisions. All façades and roofs were studied regardless of the shadows generated by trees or buildings. The results are presented in D5.1 (RIVENTI Nuria Jorge, Guillermo Rilova, Hugo Bergado, 2021). In case of Sassa Scalo pilot, the most suitable façades in terms of energy production are West, East and South façades (18994 Kwh/year, 22940 kWh/year and 48307 kWh/year respectively). Nevertheless, South façade is not an option due the structure of the building. Therefore, West and East façades were chosen to install active technologies.

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For facilitating the modulation design, a detailed solar insolation study has been carried out for Sassa Scalo pilot building with the consideration of its spatial characteristics. For that purpose, the 3D model provided by COAF, building pictures and Google Maps have been utilized in Rhinoceros 3D and Grasshopper.

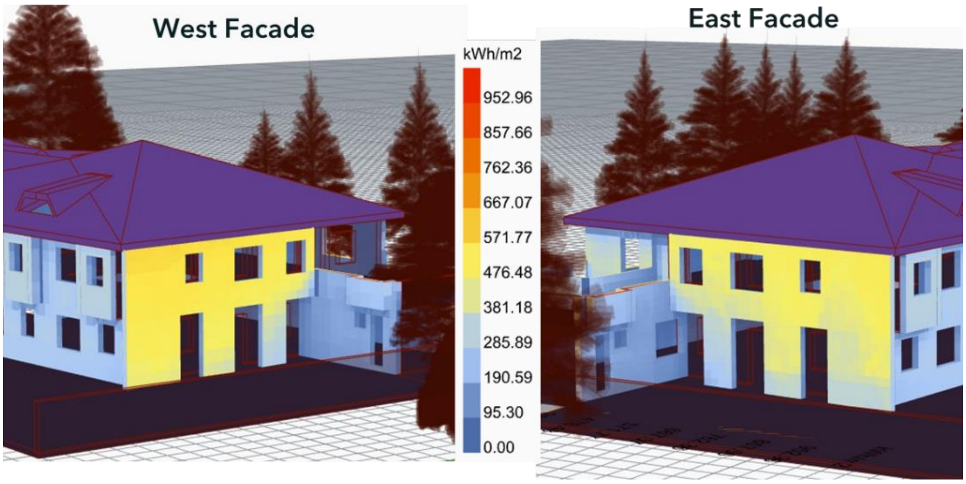

Figure 72. Solar Insolation Study for SASSA SCALO demo building (Source: ABUD)

The analysis demonstrates that the panels at the level of first floor will receive more radiation than the lower level. Also, some parts of the façade closer to the perpendicular wall receive less solar radiation.

3.3.3.1.2.4. Concept design of non-active Façade (Trespa panels)

Trespa Meteon façade panels can be adapted to existing volume differences or new façade planes can be created to harmonize the façade.

The non-active façade will be executed with a ventilated façade system with thermal insulation and Trespa Meteon panels as finishing material by means of a visible fastening system with rivets.

The composition of the ventilated façade solution shall have the following basic elements:

- Exterior cladding with 8 mm thick EDF Trespa® Meteon® FR panels - fire classification B s1 d0, colour and texture to be defined by DF within the manufacturer's colour chart, produced with thermosetting resins that do not contain Urea-Formaldehyde, homogeneously reinforced with natural fibres with EBC (Electron Bean Curing) surface colour, non-melamine, and anti-graffiti properties throughout its lifetime. Its resistance to ultraviolet radiation according to EN 438-29 and the Florida Test shall not be less than 4-5, contrasting both standards with the grey scale of ISO 105 A2.
- 3 cm ventilated air chamber
- Thermal insulation of mineral wool board (LMN), hydrophobic, coated on one side with black glass fleece, according to (EN13162), 100 mm thick,

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thermal resistance 2.90 m²K/W, thermal conductivity 0.034 W/(mK), butted to avoid thermal bridges, mechanically fixed to existing façade.
- Visible mechanical fastenings by rivets to the aluminium substructure
- Aluminium substructure with mechanical fastening system TS700 in accordance with DIT 473p/22 and ETA 20/1265 by means of a vertical grid of T- and L-shaped aluminium profiles, fixed to the wall by means of load and suction brackets, and ventilated cavity ≥ 30 mm Supporting and retaining brackets for load transmission from the substructure to the support by means of anchors.
- Anchoring of brackets to the support
- Various accessories for the treatment of single points

3.3.3.1.3. Evaluation of structural systems

Following the analysis of the building's various façades, the pilot owner COAF and the ENSNARE partners (RIVENTI, ENAR, TECNALIA, ONYX, CAMEL, ABUD) agreed that the only feasible façades for the ENSNARE system installation were the east and west façades.

These façades have the problem of the overhanging volumes on the first floor with respect to the ground floor. This, in addition to the roof overhang, would cause excessive shadows that would affect the good performance of the active panels.

The proposal for this building is to place the ENSNARE system on a single vertical plane flush with the first-floor balconies. In this way, the building would have a system similar to a double skin façade.

a)

b)

Figure 73. View of the side elevations a) northwest side b) northeast side (Source: ENAR)

- **Structural decisions or remarks for the SASSO SCALO pilot**

Initially there were doubts about the existing structure, especially about the structure at the roof eaves, which had to be clarified by the COAF team.

COAF confirmed that there is indeed a reinforced concrete slab in the eaves on which the anchorages of the new modules could be fixed.

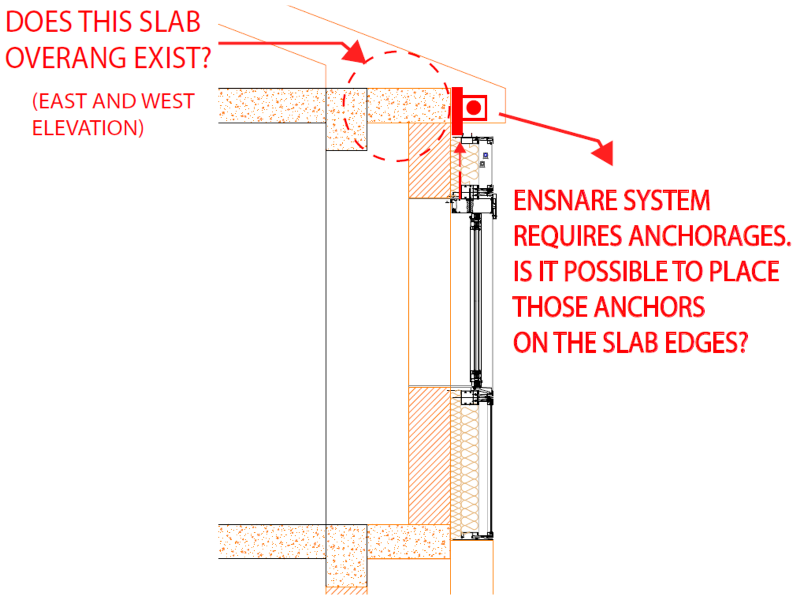

Figure 74. Doubts on reinforced concrete slab - anchorages fixed to the edge of the slab (Source: ENAR)

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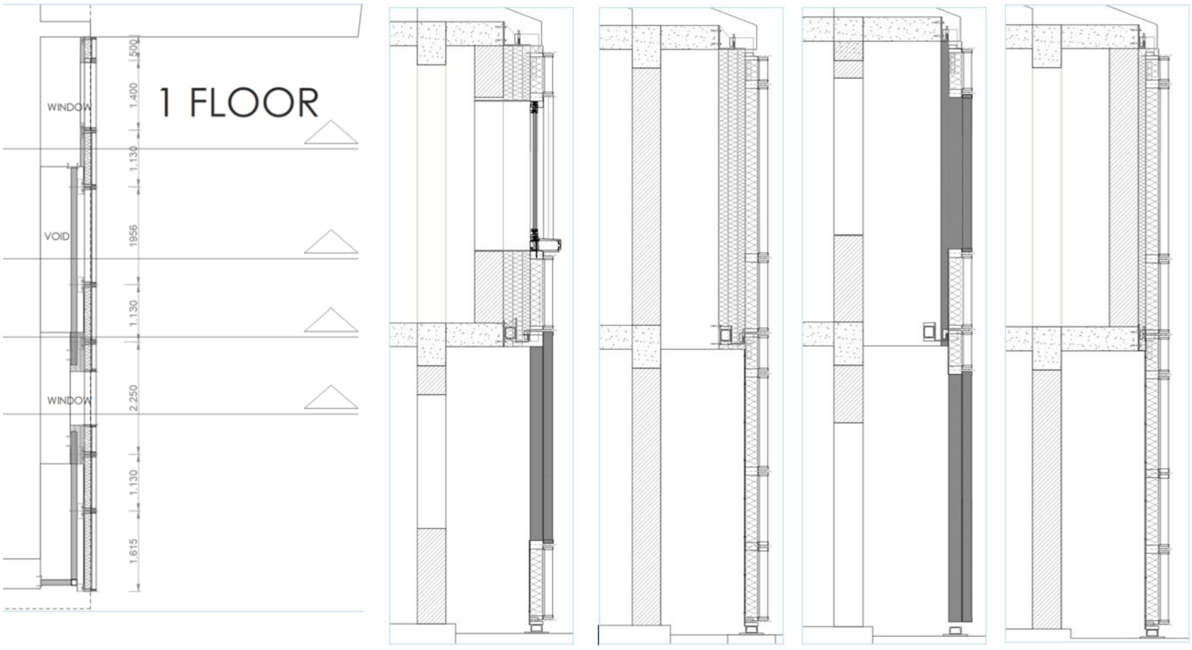

a) b)

Figure 75. a) First floor plan and b) Vertical sections (Source: ENAR)

3.3.3.1.4. Potential major engineered systems

Due to the lack of resources and information, the development of potential major engineered systems is still in process.

3.3.3.2. Planning strategies

3.3.3.2.1. Expected timeline for design, implementation and feedback loops

Table 36. Design stages of a case study, Sasso Scalo (Source: ABUD)

	Pre-Design	Concept Design	Technical Design
Involved partners	ABUD, TEC, RIVENTI, ONYX	ABUD, TEC, RIVENTI, ONYX	
Status	The building is currently occupied. The architecture has a local style and surrounded by nature.	Limitations with the involved architect and protruding elements, may need additional substructures. The proposal is ready.	Task 7.4

Table 36 displays the current progress of each stage for the SASSO SCALO demo building. A complete schedule of meetings and a table of acquired data are available in Appendix C: Planning, Meeting schedule. The technical schedule for the renovation process has been created based on country-specific specifications, as outlined in 3.3.2.3. Programme and phasing.

In addition to the technical renovation schedule, a comprehensive schedule incorporating activities from other partners has been developed. The current

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version of this schedule is located in Appendix C: Planning, Section 4. Data management and planning for the Sasso Scalo demo building. This schedule may be subject to changes going forward.

Scheduling is an ongoing process. Limitations are monitored and dates are adjusted accordingly. Therefore, Deliverable 7.1 can be used as a support tool during the design and renovation stages. Currently, the renovation permit acquisition process is underway. Depending on country regulations, collected data, and other factors, dates are adapted individually for each pilot. The schedule for the next five months is presented in Chapter 3.3.3.2.3, "Programme and Phasing."

3.3.3.2.2. Feasibility study for SASSO SCALO demo building

The feasibility study proposed in Deliverable 5.1 (RIVENTI Nuria Jorge, Guillermo Rilova, Hugo Bergado, 2021) is updated in this paragraph, with new costs and conditions for the pilot under consideration. The aim of this analysis is to estimate an average cost of the façade retrofit considering the active panels area and production planned within the demo building under consideration. The analysis has been carried out considering two economic future scenarios: 1) the costs are assumed from EUROSTAT (Eurostat, n.d.) and partners based on the pre-pandemic condition, and 2) the costs are assumed based on the last data available by EUROSTAT (Eurostat, n.d.) for the first semester 2022. The second scenario is included to provide further information on the effect of actual socio-economic condition. Nonetheless, it is worth noticing that the highly variable prices of 2022 can heavily affect the interpretation of results. The additional following assumption are considered for the SASSA SCALO demo building:

1. Heating, Domestic Hot Water (DHW), and electric consumption are assumed from average Italy values (EUROSTAT (Eurostat, n.d.)) and are listed in Table 37. An area of 820 m² and 7 dwellings are assumed. According to pre 2020 costs and the previous assumption, the estimated annual cost for electricity and natural gas is around 4040 €/y and 10 400 €/y, respectively, which is in line with the real costs of 3800 €/y for electricity and 10 800 €/y for natural gas.
2. The active area, considered totally as PV, is 24.1 m² on the East façade (1423 kWh/(m² y) of solar radiation), and 24.1 m² on the West façade (985 kWh/(m² y) solar irradiation). The total electric production from ENSNARE active technologies in this case is 8720 kWh/y. The remaining surface is considered insulated.
3. The retrofitted building is supply with an electric heat pump for heating and DHW (COP 3.5 and 3, respectively).
4. Four scenarios are presented regarding the space heating (SH) consumption reduction after the retrofit: 40% SH reduction (S-1), 60% SH reduction (S-2), 80% SH reduction (S-3), 90% SH reduction (S-4).

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Table 37: Cost and energy assumptions for SASSA SCALO demo building (Source: UNIDP)

Heating demand [kWh/(m² y)]	DHW demand [kWh/(m² y)]	Electric consumption per dwelling [kWh/y]
128.4	23.9	2623.0
Electricity price pre 2020 [€/kWh]	**Gas price pre 2020 [€/kWh]**	**Discount rate [%]**
0.083	0.22	3.0
Electricity price first semester 2022 [€/kWh]	**Gas price first semester 2022 [€/kWh]**	**Discount rate [%]**
0.099	0.31	5.0

According to the listed assumptions, the building annual energy consumption and costs saving results are shown in Table 38. Since a Heat Pump is considered for both SH and DHW, the whole building is served by electric systems, resulting in an annual electric energy consumption between 42943 kWh and 27902 kWh depending on the SH saving (S-1-4). With this condition, it is likely that the whole PV production from ENSNARE systems (8719 kWh) is consumed on site. The annual cost saving considering pre pandemic economic conditions is in the range 6876 – 10 185 € (S-1-4). On the contrary the higher energy prices during the first semester of 2022 increase the possible future cost savings with ENSNARE system installation. In the latter, the saving results in between 7415 and 12 107 €.

Table 38: Energy and cost saving results (Source: UNIDP)

	S-1	S-2	S-3	S-4
Annual electricity consumption [kWh-e]	42943	36927	30910	27902
Annual PV self-consumption [kWh-e]	8719	8719	8719	8719
Annual net cost for electricity [€] pre-2020	7529	6206	4882	4220
Annual cost saving [€] pre 2020	6876	8199	9523	10185
Annual net cost for electricity [€] first semester 2022	10678	8801	6924	5985
Annual cost savings [€] first semester 2022	7415	9292	11169	12107

Considering the discount rate assumed in Table 39, the following table provides the investment cost that is suitable considering different pay back periods, i.e. 8, 10, 12, 14 years, namely S-8-14.

Table 39: Target investment cost for active façade [€] (Source: UNIDP)

Payback time (y)	S-1	S-2	S-3	S-4
(pre 2020) S-8	48,266	57,557	66,848	71,494
(pre 2020) S-10	58,652	69,942	81,233	86,878
(pre 2020) S-12	68,441	81,617	94,792	101,380
(pre 2020) S-14	77,669	92,621	107,572	115,048

(first semester 2022) S-8	47,922	60,054	72,187	78,253
(first semester 2022) S-10	57,253	71,748	86,243	93,490
(first semester 2022) S-12	65,717	82,355	98,992	107,311
(first semester 2022) S-14	73,394	91,975	110,556	119,847

The resulting specific investment cost for the overall façade is display in Figure 76, both for pre 2020 and 2022 prices. The effect of the higher energy cost result in a slight economic advantage for ENSNARE systems. The result is less emphasized than TARTU building due to a different effect of higher prices and higher discount rate.

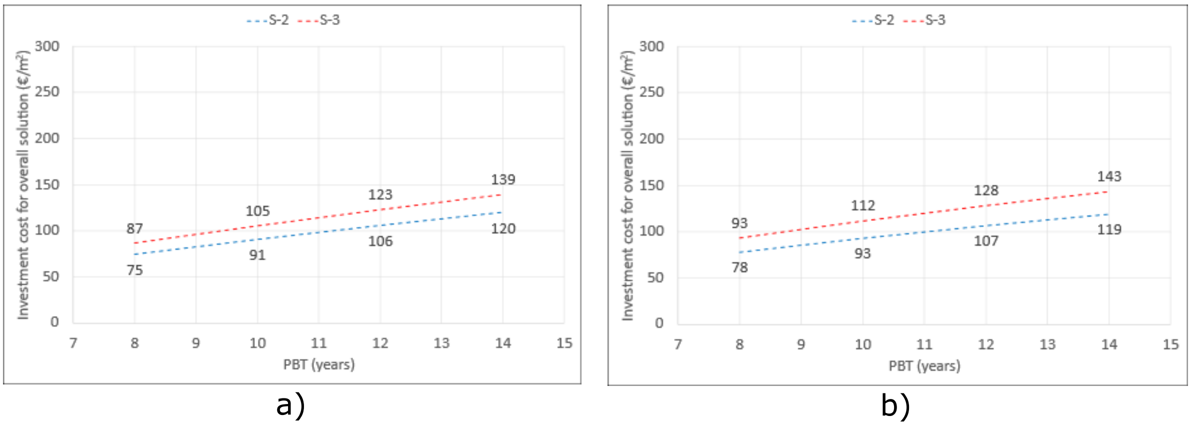

Figure 76. Specific cost for the overall solution in case of 60% (S-2) and 80% (S-3) SH consumption reduction [€/m2]: a) pre 2020 costs, b) first semester 2022 costs (Source: UNIDP)

3.3.3.2.3. Programme and phasing

- Currently, the SASSO SCALO demo building is in the process of acquisition of construction permit.
- Further steps include the technical design of façade and its manufacturing.
- The Table 40 gives an overview of the activities of demo building SASSO SCALO and partners for the next 5 months.

Table 40: Schedule of renovation process: Sasso Scalo (Source: ABUD)

WP7 PILOT BUILDING					
ID	ACTIVITY	PARTNER	START	DAYS	END
0	**Pre-Design**				
0.1	Arch.design terms and conditions (permit process)	COAF	01/06/2022	175	04/02/2023
0.2	Main project (LOD 300-350)	COAF	01/01/2023	22	01/02/2023
1	**Approval of façade configuration**				
1.1	Laboratory test results	TEC	23/01/2023	15	10/02/2023
1.2	First results of energy ratting test	TEC	01/03/2023	18	24/03/2023

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2	**Façade project**				
2.1	Survey of the exact geometry of the façades of the building	TARTU	09/01/2023	5	13/01/2023
2.2	Façade project	ENAR, TRESPA (Ventilated façade)	09/01/2023	20	03/02/2023
2.3	Equipments and hidraulic & electrical infrastructure definition	TEC, ONYX	16/01/2023	15	03/02/2023
2.4	Monitoring & Control infrastructure definition	IES	16/01/2023	15	03/02/2023
3	**Manufacture of façade modules**				
3.1	*Manufacturing of technologies and modules*				
3.1.1	PV+STONE & supply to RIV	ONYX	23/01/2023	20	17/02/2023
3.1.2	PV+Al & supply to RIV	ONYX	01/03/2023	23	31/03/2023
3.1.3	PVT & supply to RIV	ONYX	13/02/2023	25	17/03/2023
3.1.4	Absorbers-PVT supply to ONYX	KAMEL	09/01/2023	25	10/02/2023
3.1.5	Absorbers-ST supply to RIV	KAMEL	09/01/2023	25	10/02/2023
3.1.6	TRESPA & supply to RIV	TRESPA	23/01/2023	50	31/03/2023
3.1.7	Insulation for ENS modules supply to RIV	TRESPA	30/01/2023	15	17/02/2023
3.1.8	Trespa ventilated façade, insulation included (supply directly to the building site, 3.2)	TRESPA	30/01/2023	45	31/03/2023
3.2	*Assembly of modules at RIV*				
3.2.1	Modules	RIV	06/02/2023	60	28/04/2023
3.2.2	Anchoring system	RIV	06/02/2023	15	24/02/2023
3.2.3	Finishing manufacturing	RIV/TARTU	06/02/2023	15	28/04/2023
4	**Material Shipment and stocking in Demo-site**				
4.1	Ensnare Façade Modules + finishing	RIV	01/05/2023	20	26/05/2023
4.2	Trespa ventilated façade + finishing	TRESPA	03/04/2023	15	21/04/2023
4.3	Electrical and hydraulic infrastructure	TECN, ONYX	01/05/2023	20	26/05/2023
4.4	Monitoring & Control infrastructure	IES	01/05/2023	20	26/05/2023
5	**Ensnare implementation in Demo Building & start-up**				
5.1	Construction procurement	COAF	30/01/2023	45	31/03/2023
5.2	Construction	COAF	01/01/2023	195	31/12/2023
5.4	TRESPA ventilated façade (Trespa VF)	TARTU/TRESPA	03/04/2023	260	28/06/2023

3.3.3.2.4. Buildability and construction logistics

The Buildability and construction logistics for the Sassa Scalo pilot will be defined later during the technical and pre-renovation phases. The concept design explained in previous sections will be considered according to the client's need.

3.3.3.2.5. Sustainability assessment

The sustainability requirements and assessment of the Sassa Scalo pilot will be defined later during the technical and pre-renovation phases. The concept design explained in previous sections will be considered according to the client's needs.

3.3.3.2.6. Risk assessment

The risk assessment specifications of the Sassa Scalo pilot will be defined later during the technical and pre-renovation phases. The concept design explained in previous sections will be considered according to the client's needs.

3.3.3.2.7. Considerations

Similar integrated design approach has been used for the Sassa Scalo pilot building just like other pilot buildings. Although the project posited many constraints in terms of irregular façade, a unique and specific approach of overlaying the existing façade with a secondary planar façade was developed to facilitate the installation of active panels.

3.3.3.3. Impact of expected renovation strategies

Due to the lack of resources and information, the estimation of the impact of expected renovation strategies is still in process.

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4. Description of the Virtual Buildings

In general, the workflow that the virtual pilots will not deploy the ENSNARE technologies and a renovation plan in this project, a different approach is foreseen for these pilot sites. This general workflow can be seen in the image below.

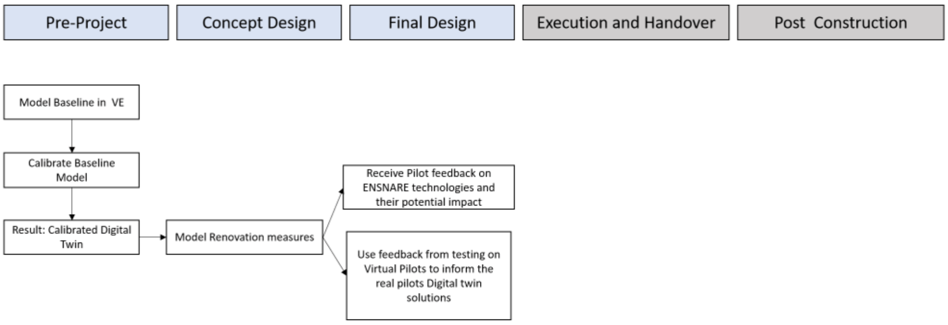

Figure 77. General workflow for virtual buildings in the ENSNARE process (Source: IES)

The buildings will be modelled virtually in the IES VE software and calibrated with the baseline performance with historical bills procured from the pilot leaders. This is important as the calibration process increases the confidence in the robustness of the building model before the renovation takes place. Once we have these calibrated models, different renovation scenarios will be defined, based on the technologies developed in the project. For instance, different combinations of renovation technologies and surface areas where the technologies are applied will be tested. The virtual pilots could also act as testing cases for the developments in other work packages, as detailed below.

Table 41: Contribution of Virtual Pilots process to the following WPs (Source: TUDELFT, TUM, TEC, IES, RIVENTI, ONYX, ABUD)

WP1	Testing the methodology with the pilot leaders and end users
WP2	Based on the developments of Task 2.1, the Virtual Buildings were modeled, and the façade layout was generated with the semi-automated tools. Some buildings presented more difficulties than others as explained next.
WP3	The virtual pilots will be adopted as use cases to help the development of the Early Decision Support Tool, and also for validating the process and outputs of the tool as part of Task 3.5.
WP4	Requirements of dashboards to be tested with the feedback of the virtual pilots. Additionally, the development of digital twin may require testing on control and optimisation logic, and the virtual digital twins can be utilised for the same.

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WP5	The analysis of the pilot buildings and the generation of the most appropriate scenarios offer valuable data on the requirements that the system must meet to respond to the needs of each case.
WP6	The calibration process and the generation of scenarios help to select the type and the quantity of each technology, which are developed in WP6, needed for the pilot, accelerating the design stage.
WP7	ABUD to be spearheading the process of analyzing the performance of the ENSNARE system by actively engaging with all the partners and contributing to the development of different scenarios to test the performance and robustness of the modulation.

4.1. Virtual Demo 1: Glasgow, UK

4.1.1. Building General Description

Virtual Building 1: Glasgow

The virtual building 1 in Glasgow (Helix building) has the following characteristics:

Table 42: Characteristics of virtual building 1: Glasgow (Source: IES)

Location	Glasgow, Scotland
Year of construction	About 2002
Storeys number	2
Typology	Non-residential/Office
Number of dwellings	N/A
Current occupancy	N/A

Figure 78. Front view of the Helix building, Glasgow (UK) (Source: IES)

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Figure 79. Rear view of the Helix building, Glasgow (UK) (Source: IES)

4.1.1.1. Location

Helix Building is located in Glasgow, United Kingdom, G20 0SP Kelvin Campus.

Figure 80. Location of the Helix building, Glasgow (UK) (Source: IES)

4.1.1.3. Architecture and structural system

The Glasgow building has the following structural system details:

Table 43: Structural system details of virtual building 1: Glasgow (Source: IES) (RIVENTI Nuria Jorge, Guillermo Rilova, Hugo Bergado, 2021)

Structure typology	Structure of concrete floors and pillars
Distance between slabs (floors)	2.5 m + 1.2 m void ceiling
Slab structure thickness	15 cm
Slab material properties	Mainly dense concrete

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Height	20 cm
Floor dimensions (length x width)	The wings: 26.9 m x 30.3 m, 18.9 x 8.6 the core

4.1.1.4. Construction and building envelope information

Table 44: Construction/Building envelope: Glasgow (Source: IES)

External wall	Cement bonded particle board with 8cm of insulation, U=0.260 W/m²K
Internal partition	U=1.798 W/m²K
Internal ceiling/floor	U=2.502 W/m²K
Ground floor/ roof	Concrete masonry with 8 cm insulation, U=0.397 W/m²K / Insulated seam standing roof U=0.155 W/m²K
Window %, type and frame	WWR 16%, Double glazed with 10% of metal frame, U=0.16 W/m²K
Infiltration rate - Property air tightness (poor, basic, good)	0.25 ach - good
Infiltration rate - Any External Vents Present?	-

4.1.1.5. Mechanical and electrical systems

The Glasgow building is currently equipped with the following building system services:

- ***Heating system installed:*** Natural gas LTHW boiler with seasonal efficiency of 0.95. Heat distributed through radiators. Heating setpoint of 21 °C in office spaces and 18 °C elsewhere.
- ***Domestic hot water (DHW) system:*** Yes.
- ***Air-conditioning system:*** No
- ***Mechanical ventilation system:*** Two spaces have mechanical supply at 1.8 W/(l/s) supply specific fan power each. Three spaces have mechanical exhaust at 0.6 W/(l/s) exhaust specific fan power and 10 ac/hr extract flow rate. All office space and some other spaces have natural ventilation only.

Available low carbon technologies:

- ***Renewable heat generation source:*** Not available
- ***Renewable electricity generation source:*** Not available

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4.1.1.6. Floor plans

The following floor plans were provided by the IES partner on the 22nd of July 2021.

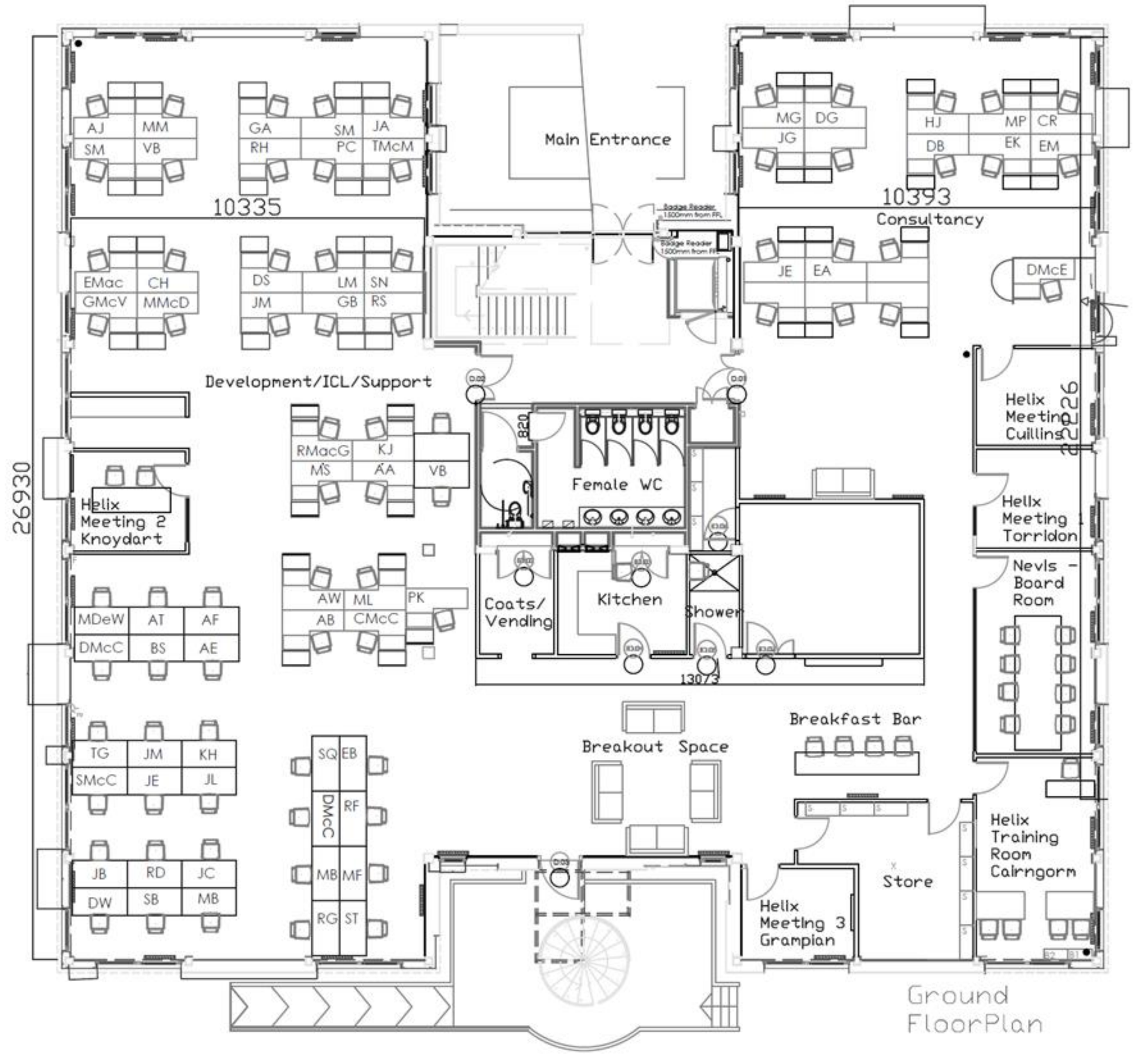

Figure 81. Ground floor plan of the Helix building in Glasgow (Source: IES)

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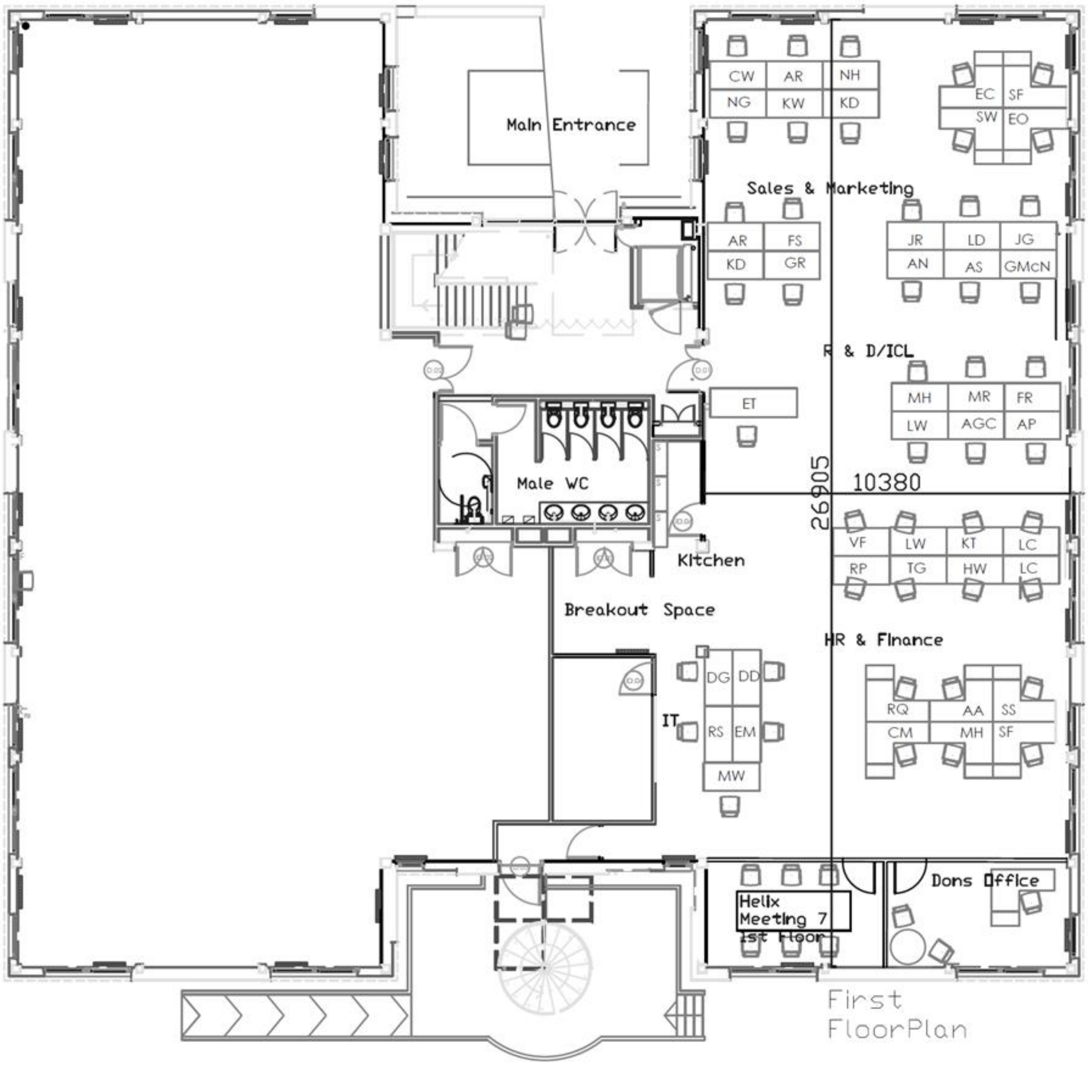

Figure 82. First floor plan of the Helix building, Glasgow (UK) (Source: IES)

4.1.1.7. Sections

Two sections of the Helix building are shown below:

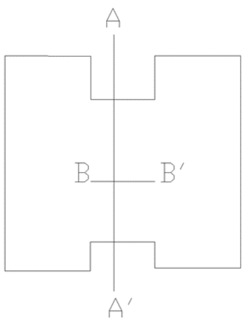

Figure 83. Sketch Sections - Helix building (Source: IES)

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- **Section AA'**

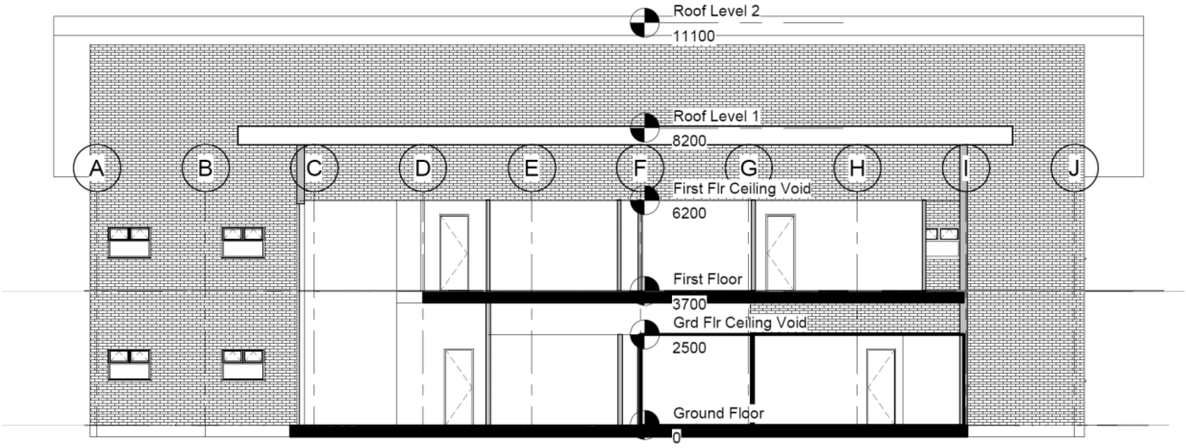

Figure 84. Section AA' - Helix building (Source: IES)

- **Section BB'**

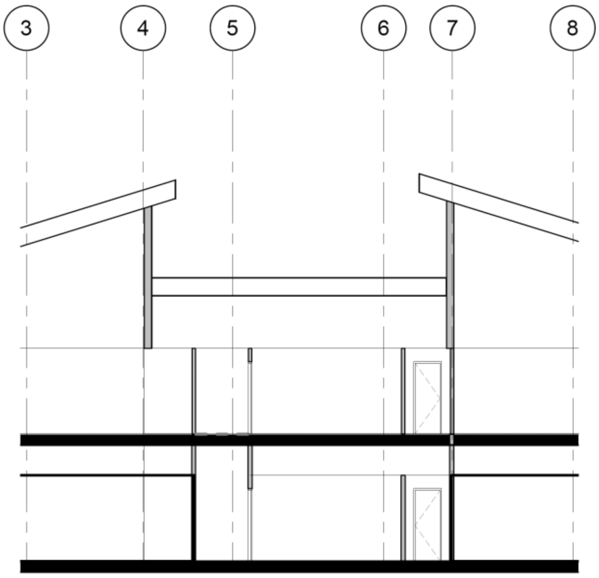

Figure 85. Section BB' - Helix building (Source: IES)

4.1.1.8. Elevations

The envelope composition of the building in Glasgow is categorised as a medium-height structure adaptable for PV modules. Most windows are in the west (20 windows) and east side (15 windows), while on the north façade there are 8 (+ 1 bigger) windows and on the south façade 8 windows.

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A preliminary analysis indicated the outputs and the estimation of PV energy production, to clarify the scenarios in Glasgow building (See D5.1 (RIVENTI Nuria Jorge, Guillermo Rilova, Hugo Bergado, 2021)).

North and east façade of the Helix building can be found in Appendix B: Virtual Buildings, Additional plans.

Figure 86. West Elevation - Helix Building, Glasgow (UK) (Source: IES)

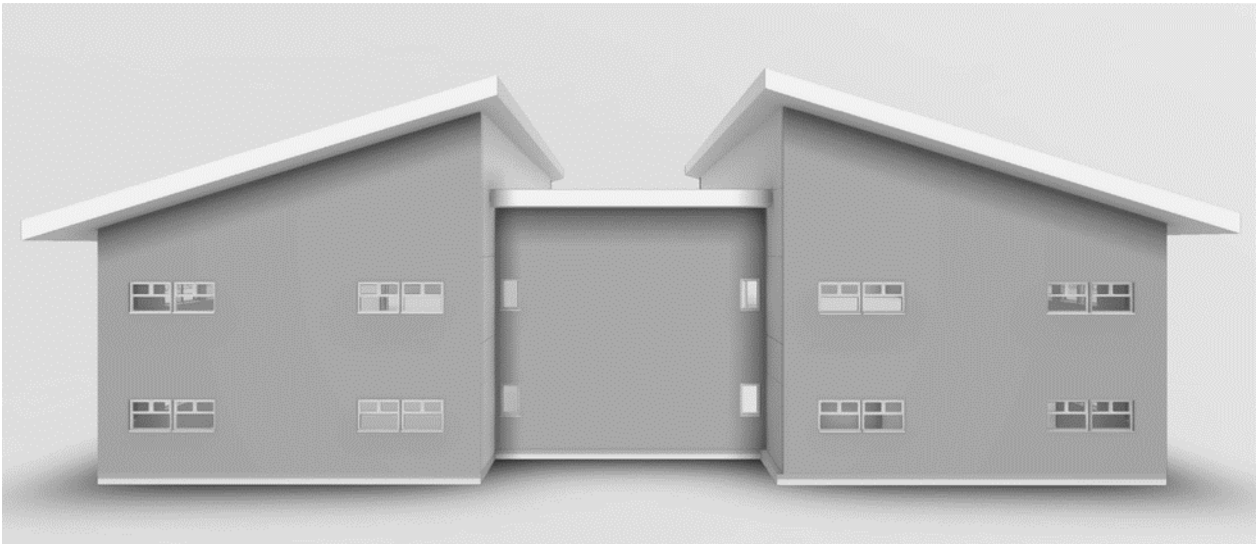

Figure 87. South Elevation - Helix Building, Glasgow (UK) (Source: IES)

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4.1.1.9. 3D Visualisations or models

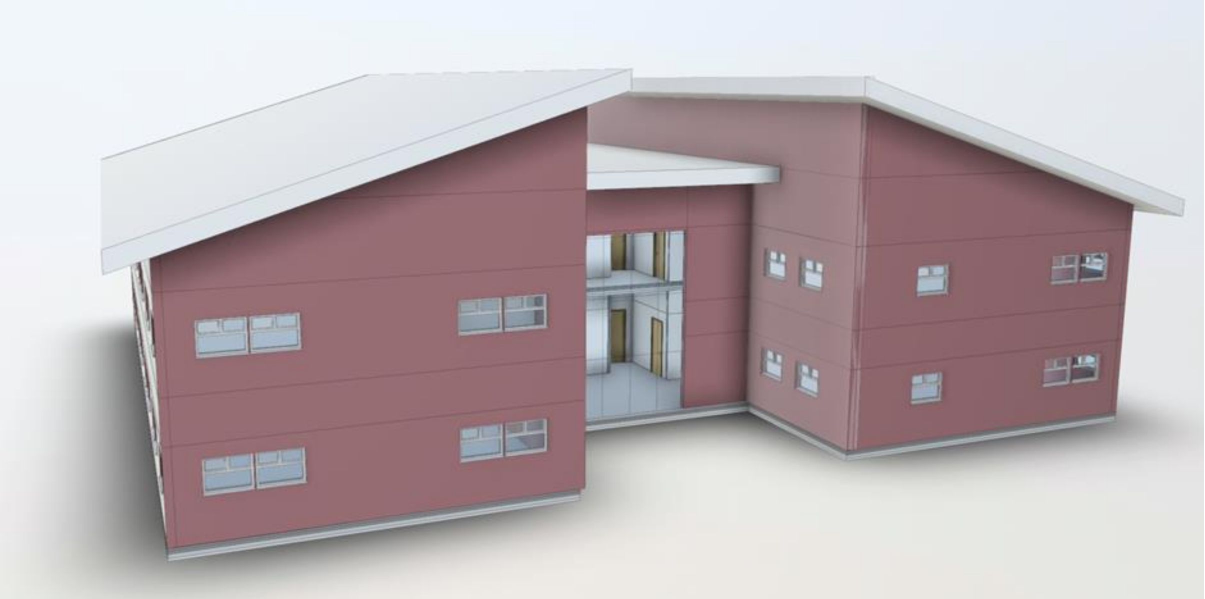

Figure 88. 3D model of the Helix building in Glasgow (Source: IES)

4.1.1.10. Preliminary Semi-automated Modulation Design

The Virtual demo Building in Glasgow was modeled with the semi-automated online tools developed in Task 2.1, as shown in the next picture.

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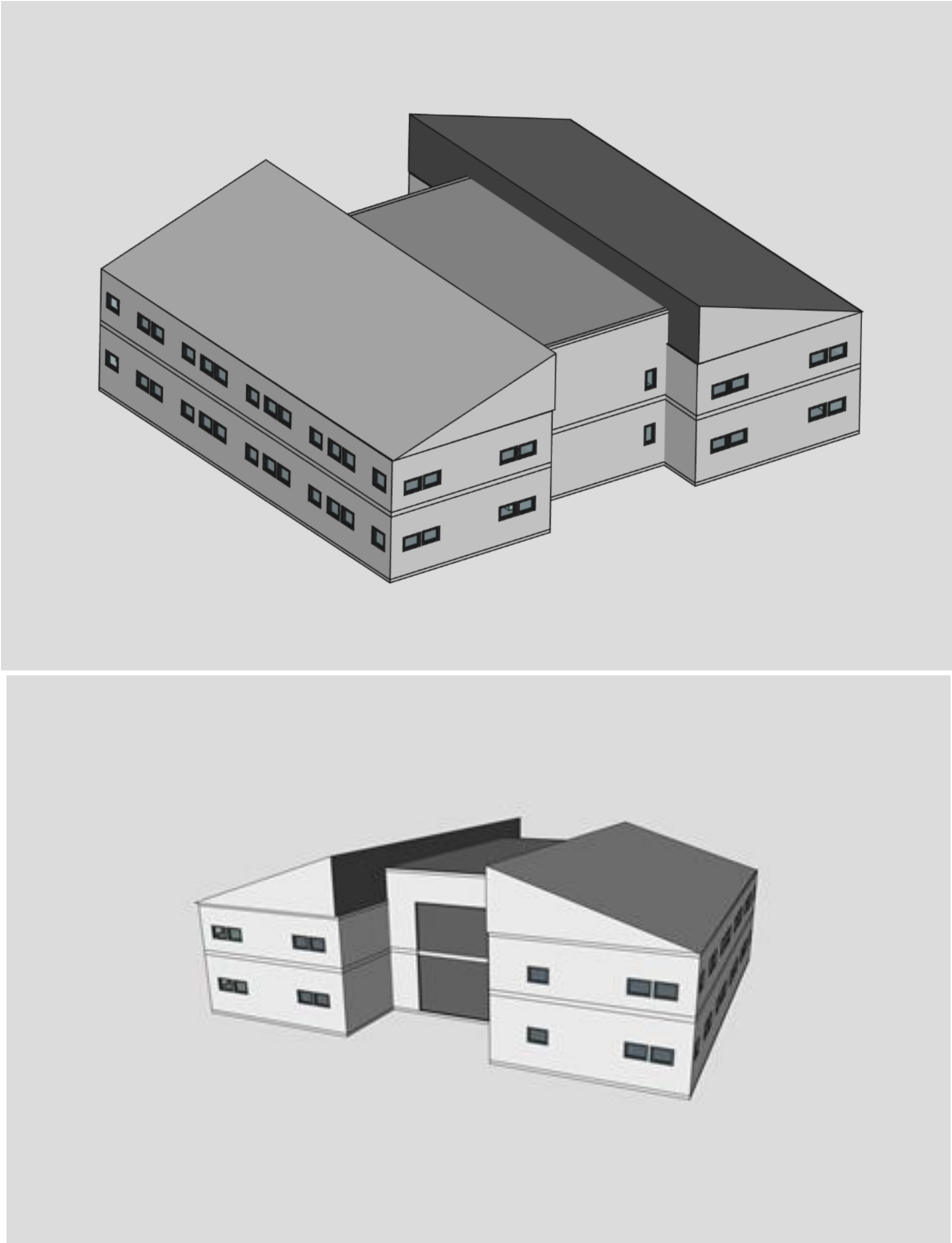

Figure 89. Model of the virtual demo building in Glasgow (Source: TUM)

With this building model, it was possible to generate the layout of the prefabricated façade modules by optimizing the area of the solar panels as shown in the next picture.

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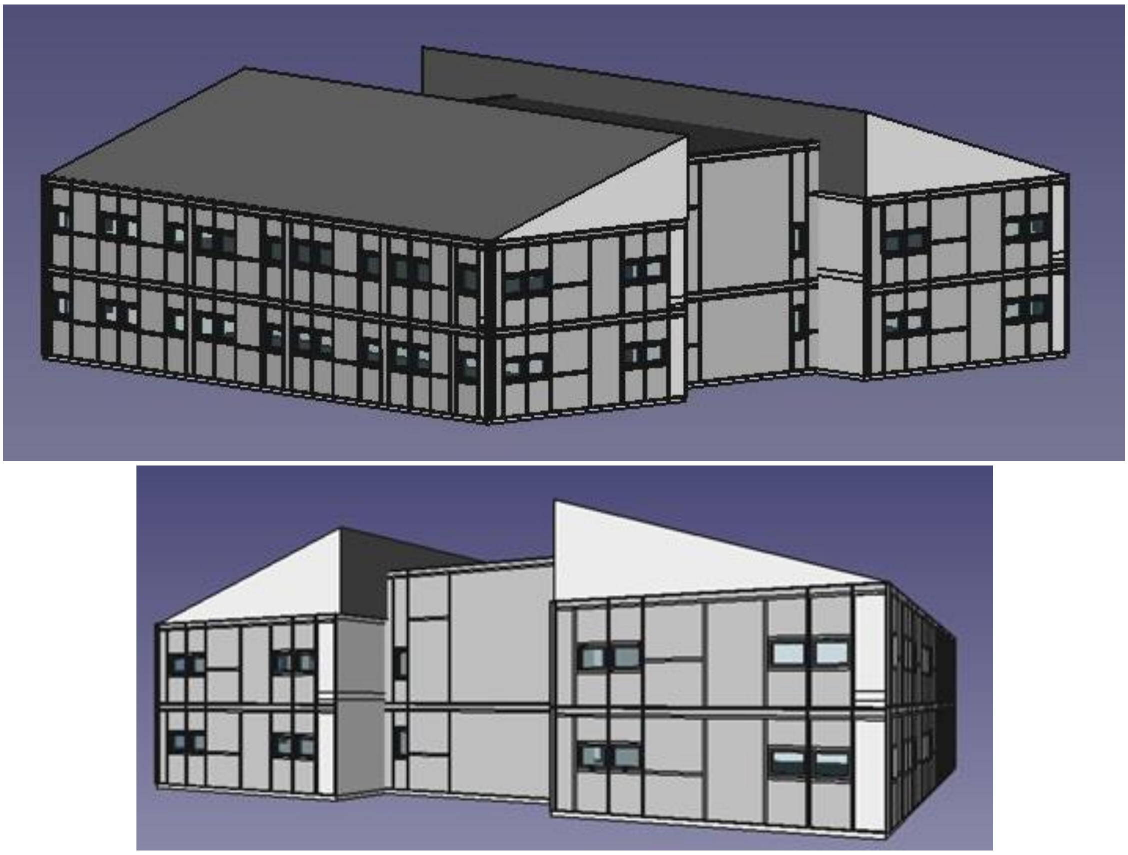

Figure 90. The layout of prefabricated façade modules in the virtual demo building in Glasgow (Source: TUM)

Both building modelling and layout definition was achieved in less than 30 minutes.

The calculation of the solar panels and the total disponible area was also calculated by TUM, as some examples show in the 4. Description of the Virtual BuildingsAppendix B: Virtual Buildings, Additional plans.

4.1.2. Preliminary Baseline Model

The Helix building's model has been created in the IESVE software. The inputs of the building have been assigned as follows:

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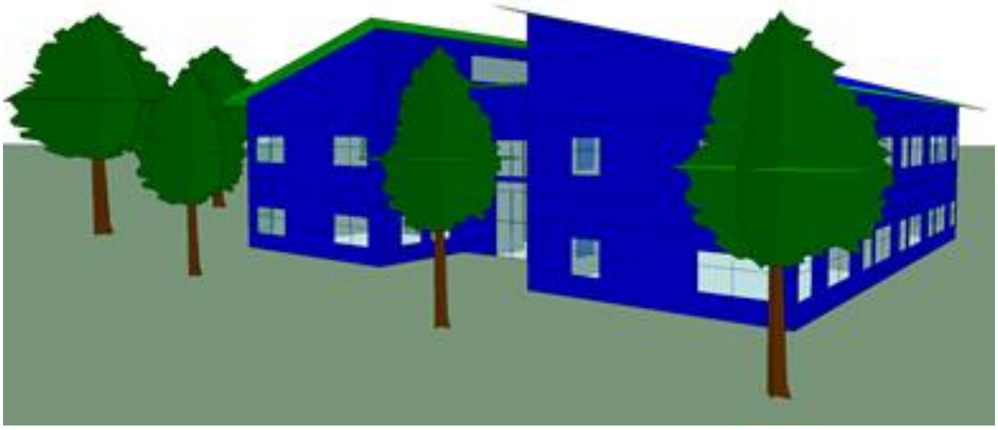

Figure 91. Model the virtual demo building in Glasgow (Source: IES)

- Room types

Figure 92. The ground floor of the virtual demo building in Glasgow (Source: IES)

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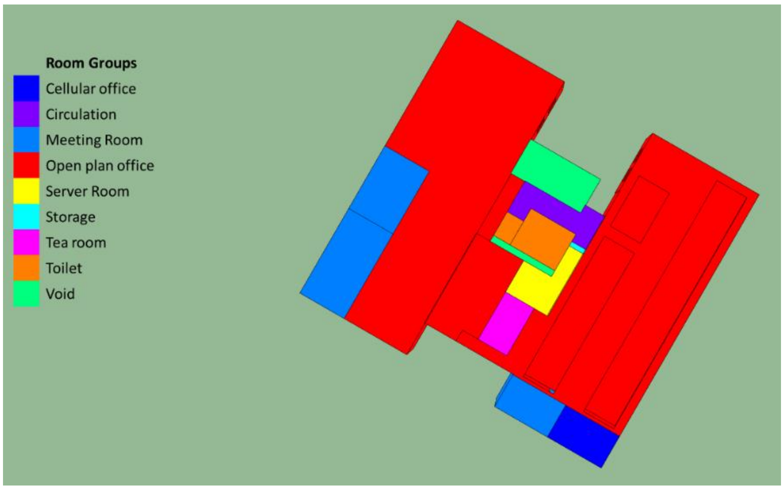

Figure 93. The first floor of the virtual demo building in Glasgow (Source: IES)

Based on this initial baseline model which has already been calibrated with metered data, we have the annual total electricity consumption X and heating consumption as X. This calibrated model has been made available prior to this project; thus, it would not need to undergo calibration again.

It is important to note that the building is located in a shaded area, especially on the south façade, which would affect the efficacy of solar technologies on the façade.

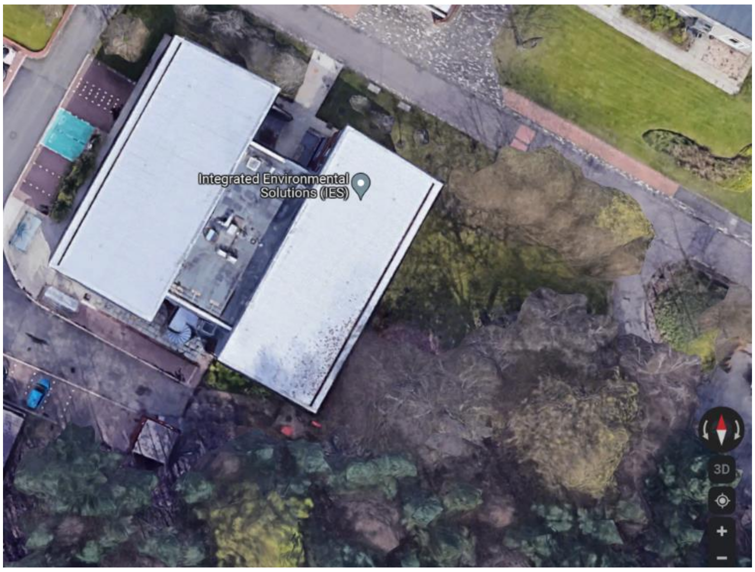

Figure 94. The location of the virtual demo building in Glasgow (Source: IES)

Additionally, as this is a commercial office space rather than residential space as in other pilots, there may be differences in how the operational strategies are approached in this pilot.

4.2. Virtual Demo 2: Amsterdam, Netherlands

4.2.1. Building General Description

Virtual Building 2: Amsterdam

The virtual building 2 in Amsterdam has the following characteristics:

Table 45: Characteristics of virtual building 2, Amsterdam (Source: TUDELFT)

Location	Reigersbos, Amsterdam, the Netherlands
Year of construction	1985
Storeys number	4
Typology	Residential (1,2,3 floors); commercial (ground floor)
Number of dwellings	30
Current occupancy	N/A

Figure 95. Virtual building in Amsterdam (Source: TUDELFT)

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Figure 96. View of the virtual building in Amsterdam (Source: TUDELFT)

4.2.1.1. Location

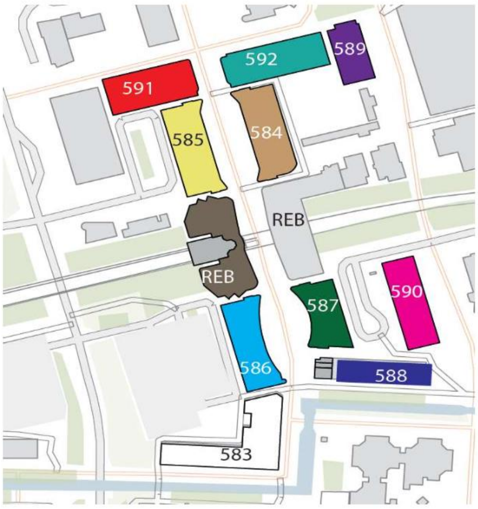

Figure 97. Location information of the virtual building in Amsterdam (Source: TUDELFT)

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4.2.1.2. Building History

Reigersbos is a residential area in the Amsterdam district of Gaasperdam, built in the 1970s and 1980s to offer Amsterdammers affordable living space. The district also consists of the residential areas of Holendrecht, Nellestein and Gein. Reigersbos consists of a shopping center and four residential areas that differ from each other in terms of layout. The administrative designation as a development neighborhood, which recognizes the urgency to improve Reigersbos, was the reason for drawing up the policy memorandum. The memorandum is the first product of the Plaberum and is a (first phase) exploration of the social and physical measures.

Reigersbos is part of Gaasperdam and was completed between 1980 and 1984. The district is on its way to its fortieth anniversary. It is a green and pleasant neighbourhood. But there are also many things that could be improved. The neighborhood is outdated in a number of respects. For example, the public space, public green areas and some sports and play facilities need to be replaced. Some places in the area do not feel safe, such as around the tunnels and in the parking areas along the avenues. And there are not enough homes and facilities, especially for the young and the elderly. Reigersbos is therefore in need of renewal. The municipality of Amsterdam will carry out this renovation step by step in the coming years.

Reigersbos is one of the 32 neighborhoods in Noord, Nieuw-West and Zuidoost that have been designated as a Development Area. This means that the Municipal Executive invests heavily in these neighborhoods. In each neighborhood, residents, housing corporations and other parties are looking at what needs to be done in the neighborhood and how we can best do this.

4.2.1.3. Architecture and structural system

The Amsterdam building has the following structural system details:

Table 46: Structural system details of virtual building 2, Amsterdam (Source: TUDELFT) (RIVENTI Nuria Jorge, Guillermo Rilova, Hugo Bergado, 2021)

Structure typology	Bearing walls and columns
Distance between slabs (floors) [m]	2,52
Slab structure thickness [m]	0,27
Slab material properties	Concrete
Height [m]	2,52
Floor dimensions (length x width) [m]	65,44 x 11,38

4.2.1.4. Construction and building envelope

Table 47: Construction/Building envelope, Amsterdam (Source: TUDELFT)

External wall	North and south façade

	- Concrete wall (Thickness [m]: 0.2; Conductivity [W/mK]: 0.4-0.7) - Brick wall (Thickness [m]: 0.12; Conductivity [W/mK]: 0.6-1.0) <u>West and East façade</u> - Double glass with aluminum frames, including ventilation grilles on top (Thickness [m]: 0.1; Conductivity [W/mK]: Aluminum: 121; Glass: 0.96) - Non-insulated trespa (HLP) plate (under the windows) (Thickness [m]: 0.01; Conductivity [W/mK]: 0.2) - Asbestos cladding (Thickness [m]: 0.01; Conductivity [W/mK]: 0.15)
Internal partition	Building brick (Thickness [m]: 0.07; Conductivity [W/mK]: 0.6-1.0)
Internal ceiling/floor	Concrete slab (Thickness [m]: 0.275; Conductivity [W/mK]: 0.4-0.7)
Ground floor/ roof	<u>Ground floor:</u> Concrete slab (Thickness [m]: 0.295; Conductivity [W/mK]: 1.0-1.8); <u>Flat roof covered with asphalt roofing</u>: Concrete slab (Thickness [m]: 0.275; Conductivity [W/mK]: 0.4-0.7); Asphalt layer: (thickness [m]: 0.16; Conductivity [W/mK]: 0.75)
Window %, type and frame	Double glass with aluminum frames, including ventilation grilles on top
Infiltration rate - Property air tightness (poor, basic, good)	Poor
Infiltration rate - Any External Vents Present?	Ventilation grilles (manually operated) are included in the frames

4.2.1.5. Mechanical and electrical systems

The Amsterdam building is currently equipped with the following building system services:

- ***Heating system installed:*** The heating consists of an individual central heating system per house (CH boiler), with flue gas discharge per house on the façade. Depending on the layout of the house, the central heating boiler is located at the front of the house, with flue gas outlet above the gallery, just outside the rising façade, or at the rear, with flue gas outlet above the balconies. Radiators for heating
- ***Domestic hot water (DHW) system:*** CH boiler/ water heater

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- *Air-conditioning system:* Not available. Natural ventilation for both cooling and IAQ.
- ***Mechanical ventilation system:*** The apartments are ventilated by exhaust air via joint ducts with roof ventilator per shaft. The air supply is via window grilles in the front and rear (it is expected that these are often closed). As a result, there are many damp complaints in the homes.

Available low carbon technologies:

- ***Renewable heat generation source:*** Not available.
- ***Renewable electricity generation source:*** Not available.

4.2.1.6. Floor plans

All the information for Buildings A1-A8, regarding floor plans, sections and elevations are available in the scanned drawings. Below an example of the information for Building A5 is provided. See Appendix B: Virtual Buildings, Additional plans for plans of other floors.

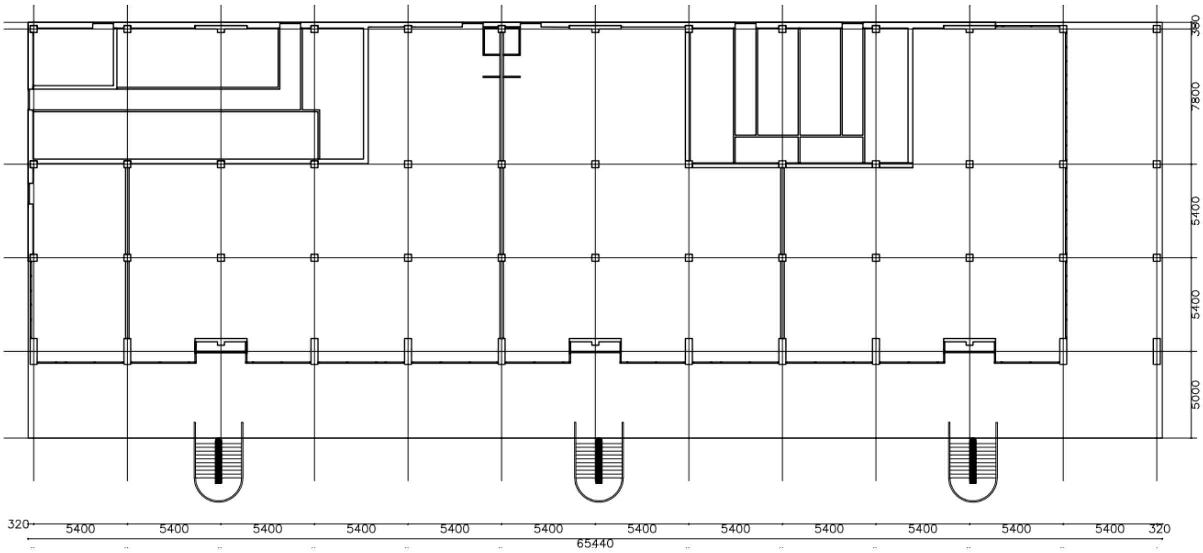

Figure 98. Ground floor plan, Building A5, Reigersbos, Amsterdam (Source: TUDELFT)

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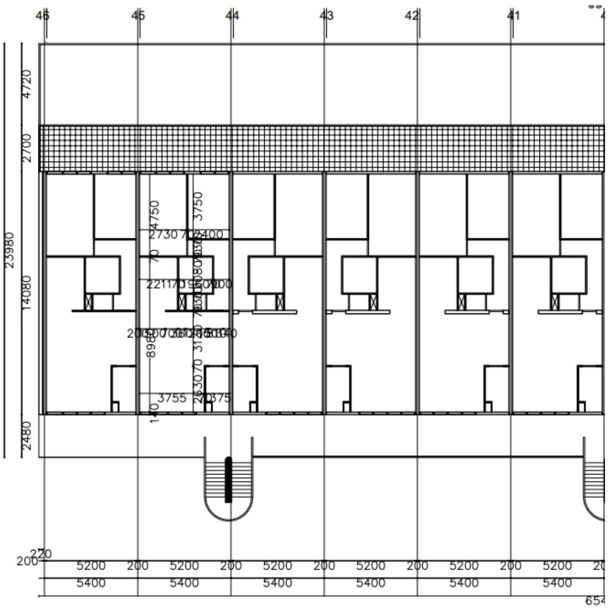

Figure 99. First floor plan, Building A5, Reigersbos, Amsterdam (Source: TUDELFT)

4.2.1.7. Sections

See Appendix B: Virtual Buildings, Additional plans for plans of other sections of the building.

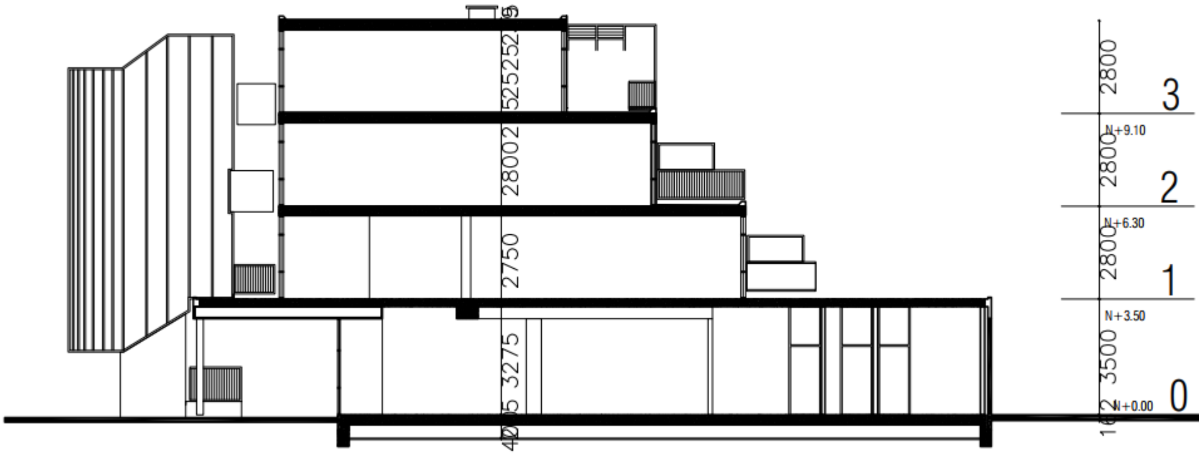

Figure 100. Section a-a, Building A5, Reigersbos, Amsterdam (Source: TUDELFT)

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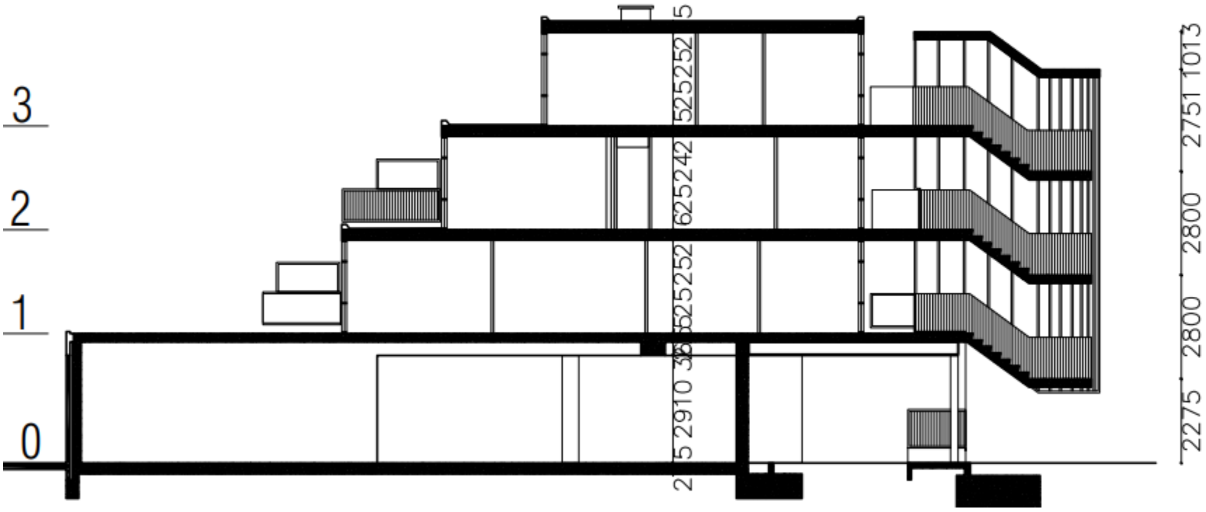

Figure 101. Section b-b, Building A5, Reigersbos, Amsterdam (Source: TUDELFT)

4.2.1.8. Elevations

The envelope composition of the building in Amsterdam is categorised as a medium-height structure adaptable for PV modules. Most windows are in the west (213 windows) and east side (216 windows), while on north façade there are 3 windows and on the south façade 10 windows.

A preliminary analysis indicated the outputs and the estimation of PV energy production, to clarify the scenarios in Amsterdam building (See D5.1 (RIVENTI Nuria Jorge, Guillermo Rilova, Hugo Bergado, 2021)).

See Appendix B: Virtual Buildings, Additional plans for west and north façade.

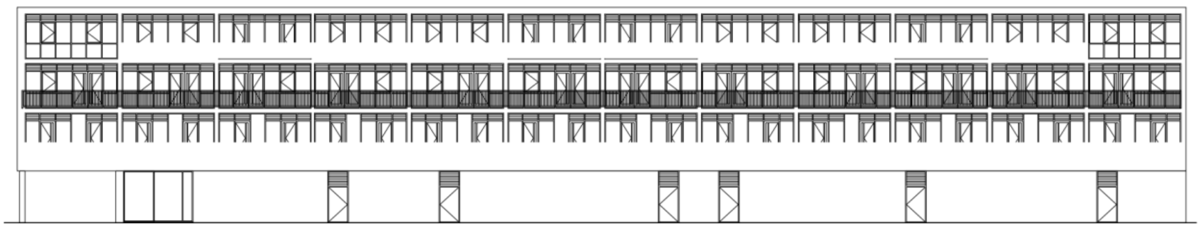

Figure 102. East façade, Building A5, Reigersbos, Amsterdam (Source: TUDELFT)

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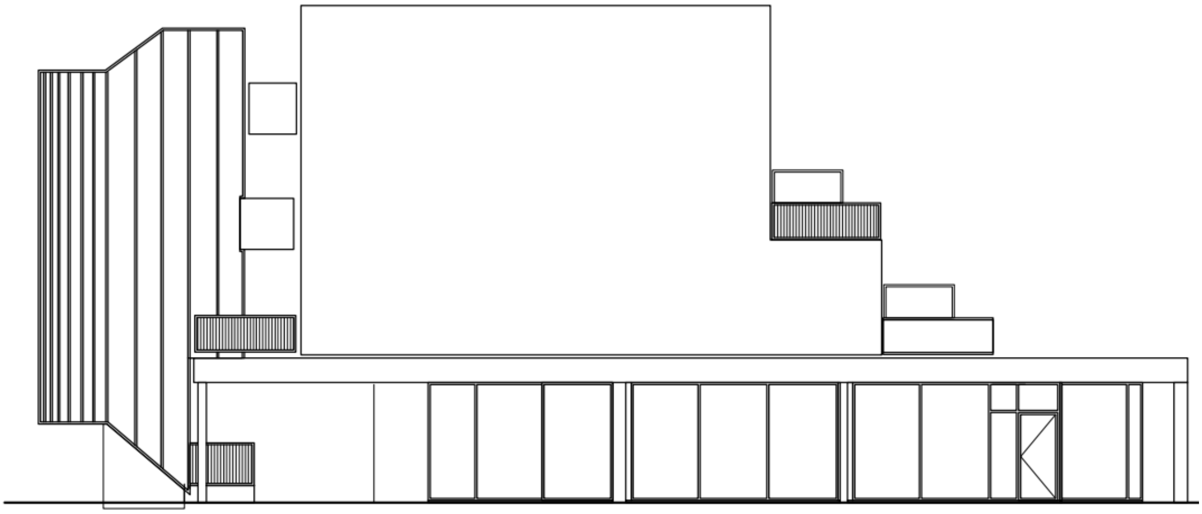

Figure 103. South façade, Building A5, Reigersbos, Amsterdam (Source: TUDELFT)

Similar information is available for all buildings from A1 to A8 in Reigersbos, Amsterdam.

4.2.1.9. 3D Visualizations or models

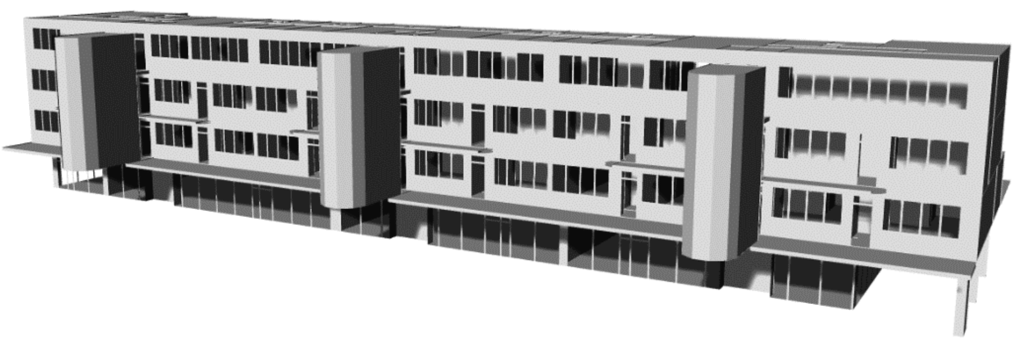

Figure 104. 3D visualization, Amsterdam (Source: TUDELFT)

4.2.1.10. Preliminary Semi-Automated Modulation Design

The Virtual demo Building in Amsterdam was modeled with the semi-automated online tools developed in Task 2.1, as shown in the next picture.

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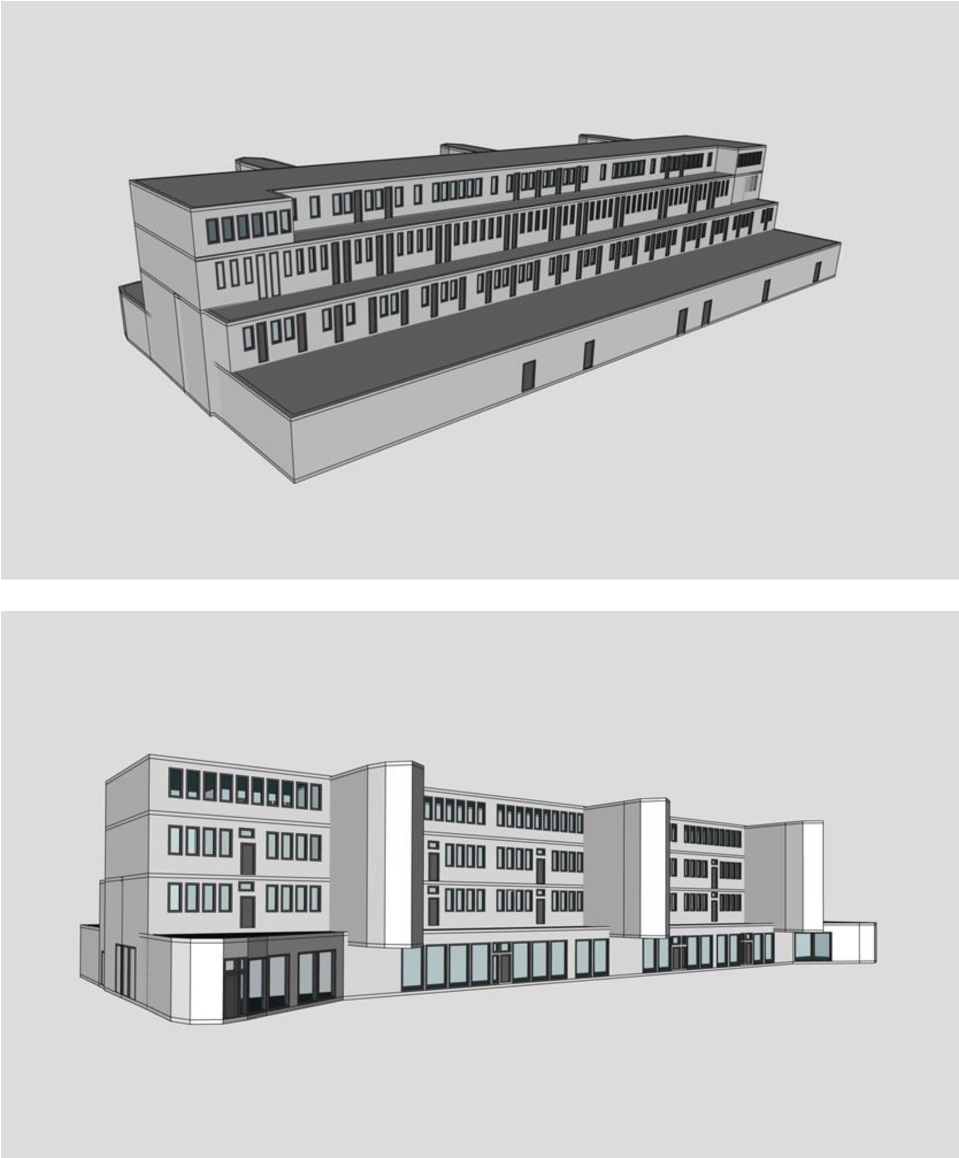

Figure 105. Model of the virtual demo building in Amsterdam (Source: TUM)

With this building model, it was possible to generate the layout of the prefabricated façade modules by optimizing the area of the solar panels.

The layout definition, calculation of the solar panels and the total disponible area are still in progress.

4.2.2. Preliminary Baseline Model

The Amsterdam pilot is modelled in the IES VE software as above and is a multi-family residential property. The following images summarise the characteristics of the model:

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Figure 106. The model of the virtual demo building in Amsterdam (Source: IES)

- Room types

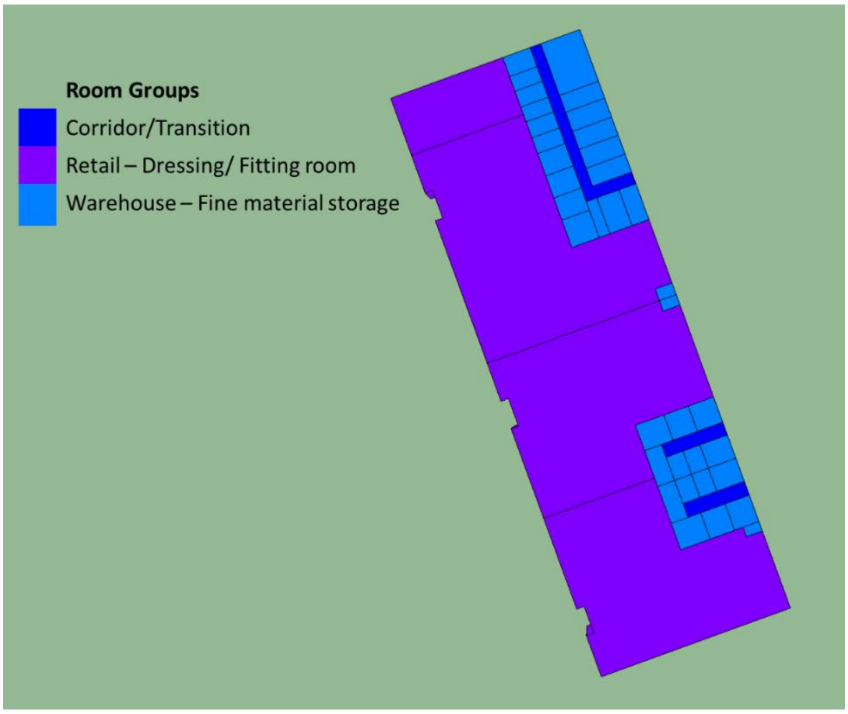

Figure 107. The ground floor of the virtual demo building in Amsterdam (Source: IES)

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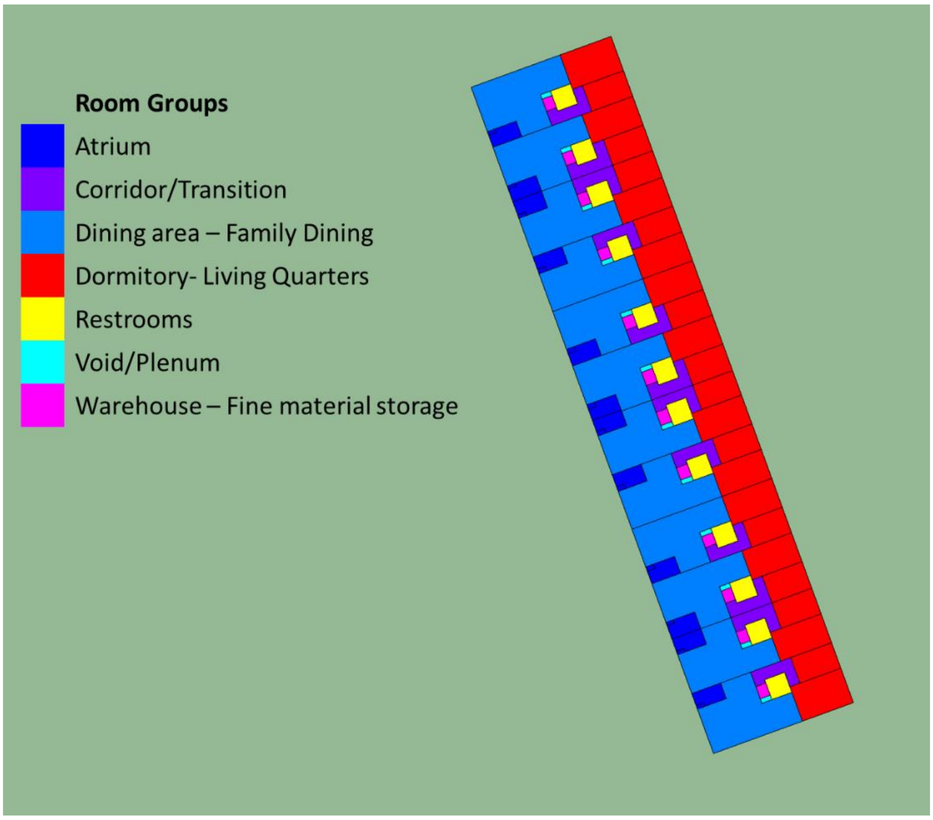

Figure 108. The first floor of the virtual demo building in Amsterdam (Source: IES)

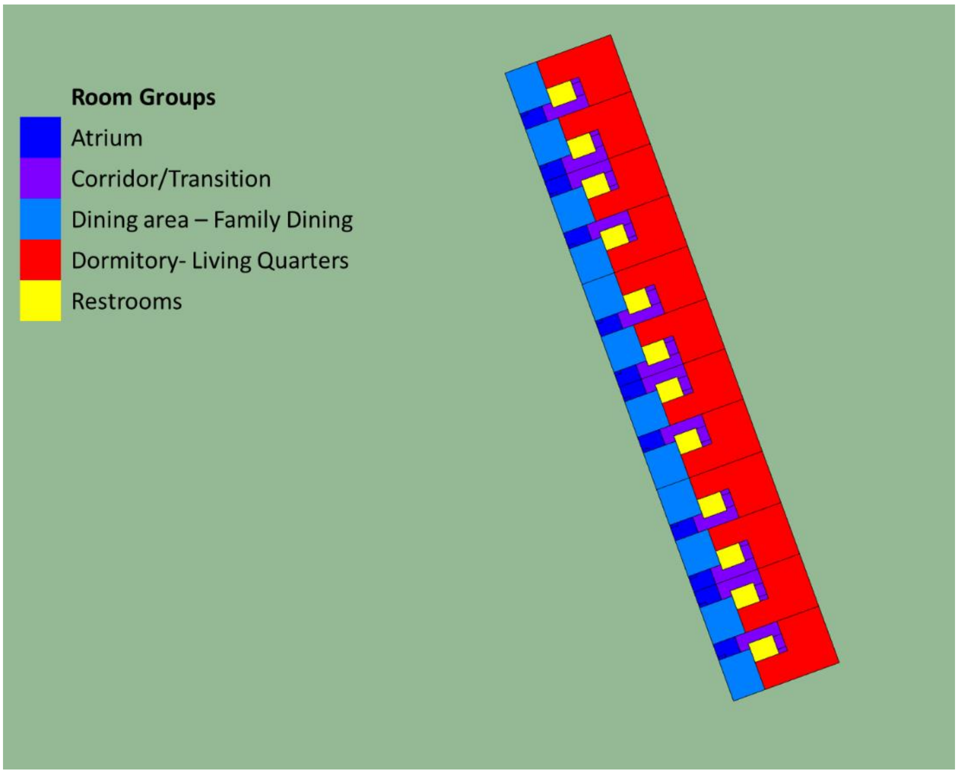

Figure 109. The second floor of the virtual demo building in Amsterdam (Source: IES)

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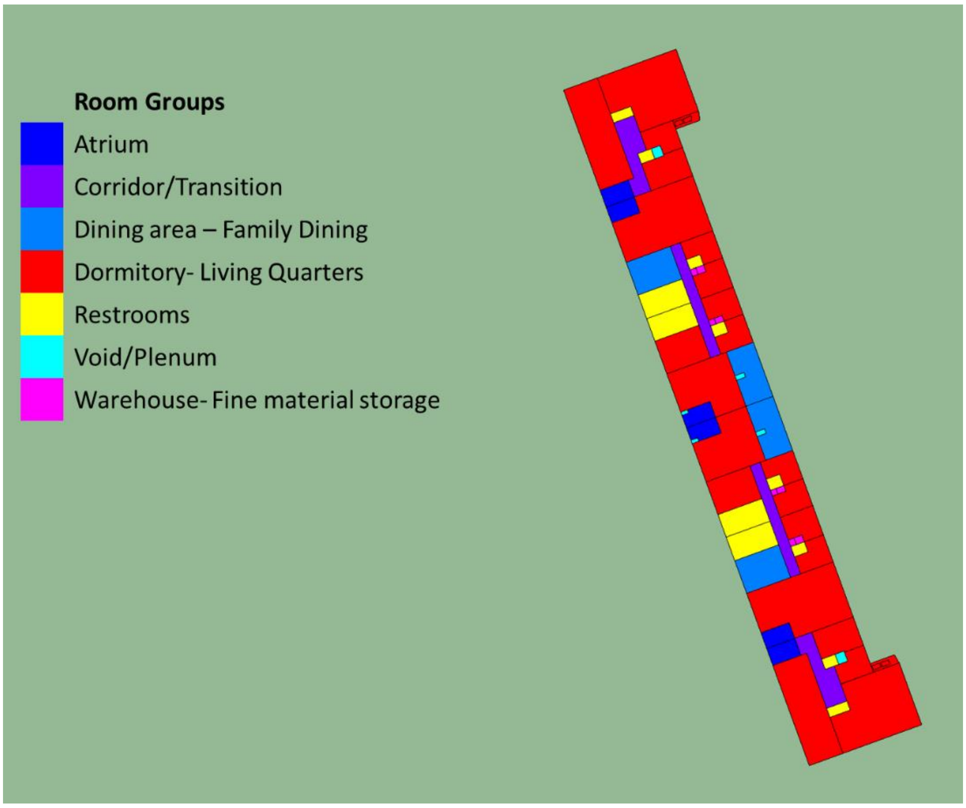

Figure 110. The third floor of the virtual demo building in Amsterdam (Source: IES)

As this is a multi-family building, it will be complex to be able to receive energy bills at a building level to assist in calibration, as this will be divided per home. Additionally, it is equally challenging to receive energy bills per home and calibrate at an individual home level. The approach taken for calibration here will be to receive at least one energy bill per home, and generalise it across the building, to be able to estimate a building level energy consumption.

4.3.1. Building General Description

Virtual Building 3: Milano

The virtual building 3 in Milano has the following characteristics:

Table 48: Characteristics of virtual building 3: Milano (Source: CIVIESCO)

Location	Via Valsesia, Milano, Italy
Year of construction	1970
Storeys number	Block A (7 storeys), Block B (8 storeys), Block C (10 storeys), Block D (11 storeys)
Typology	Residential
Number of dwellings	36
Current occupancy	About 140 residents

Figure 111. Milano virtual buildings, Via Valsesia. (Source: CIVIESCO)

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4.3.1.1. Location

Figure 112. Dollhouse view and virtual tour navigation mode (Source: R2M Solution)

4.3.1.2. Building History

The building is part of a residential complex of tower buildings located in Milan, in the west suburban area of the city. The complex has been built in the 70's and includes 14 buildings of which 9 (including the building selected for ENSNARE project) have the same characteristics in terms of geometry, structure, and energy performances. Some buildings have been renovated, through interventions of energy efficiency and seismic retrofitting; few retrofits are ongoing, while other are planned but not yet started, as in the case of the ENSNARE building.

4.3.1.3. Architecture and structural system

The Milano building has the following structural system details:

Table 49: Structural system details of virtual building 3, Milan (Source: CIVIESCO)

Structure typology	Structure of concrete floors and pillars
Distance between slabs (floors) [m]	2,90
Slab structure thickness [m]	0,30
Slab material properties	N/A
Height [m]	42,90
Floor dimensions (length x width) [m]	10,00 x 10,00

4.3.1.4. Construction and building envelope information

Table 50: Construction/Building envelope, Milan (Source: CIVIESCO)

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External wall	Ventilated brick wall with 80 mm brick layer, 200 mm air cavity, 120 mm brick layer. U-Value 1,061 W/mqK
Internal partition	80 mm brick layer. U-value 1,64 W/mqK
Internal ceiling/floor	350 mm concrete-brick slab. U-value 1,18 W/mqK
Ground floor/ roof	Ground floor/roof 350 mm concrete-brick slab. U-value 1,347 W/mqK
Window %, type and frame	Different types of windows for each apartment (double or single glass, wooden or aluminum or pvc frame)
Infiltration rate - Property air tightness (poor, basic, good)	Poor
Infiltration rate - Any External Vents Present?	No

All the above characteristics have been produced through an energy audit carried out in March 2022 by the construction company Teicos Group company.

3.3.1.5. Mechanical and electrical systems

The Milano building is currently equipped with the following building system services:

- ***Heating system installed:*** There is a central heating system with three generators: one has power of 1163 kW, the others two have a power of 628 kW. The three boilers serve the complex of 2 condos. The energy carrier used is methane gas.
- ***Heating type, fuel, and system age:*** Radiators and water heater.
- ***Seasonal efficiency (sCOP):*** about 90% of nominal power.
- ***Domestic hot water (DHW) system****:* The production of domestic hot water is autonomous for each apartment. The source is gas.
- ***Air-conditioning system:*** Some apartments have an air conditioning system. The system consists of an outdoor unit and split. Natural ventilation for both cooling and IAQ.
- ***Cooling type and system age:*** air conditioning or none.
- ***Seasonal energy efficiency ratio (SEER):*** different for each apartment.
- ***Mechanical ventilation system****:* Not available.

Low carbon technologies:

- ***Renewable heat generation source:*** Not available.
- ***Renewable electricity generation source:*** Not available.

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4.3.1.6. Floor plans

See Appendix B: Virtual Buildings, 3.2. Additional plans for plans of other floors.

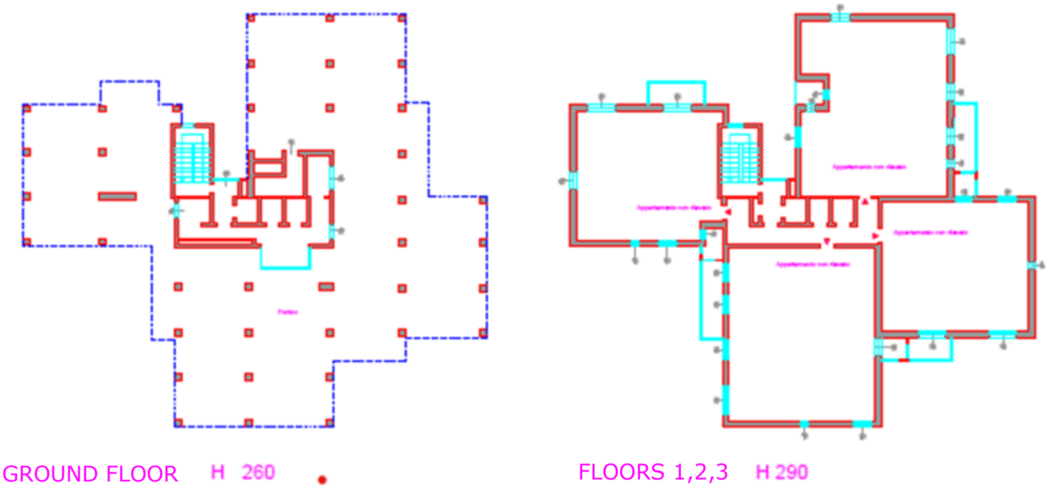

Figure 113. Ground floor and 1-3 floor plans, Via Valsesia, Milano, Italy (Source: CIVIESCO)

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Figure 114. Detailed floor plan, Via Valsesia, Milano, Italy (Source: CIVIESCO)

4.3.1.7. Elevations

The envelope composition of the building in Milano is categorised as a medium height-structure adaptable for PV modules. Most windows are in the south-east (73 windows) and in the north-west side (61 windows), while on the south-west and north-east façades, they are distributed (54 and 42 windows, respectively).

A preliminary analysis indicated the outputs and the estimation of PV energy production to clarify the scenarios in the Milano building (See D5.1 (RIVENTI Nuria Jorge, Guillermo Rilova, Hugo Bergado, 2021)).

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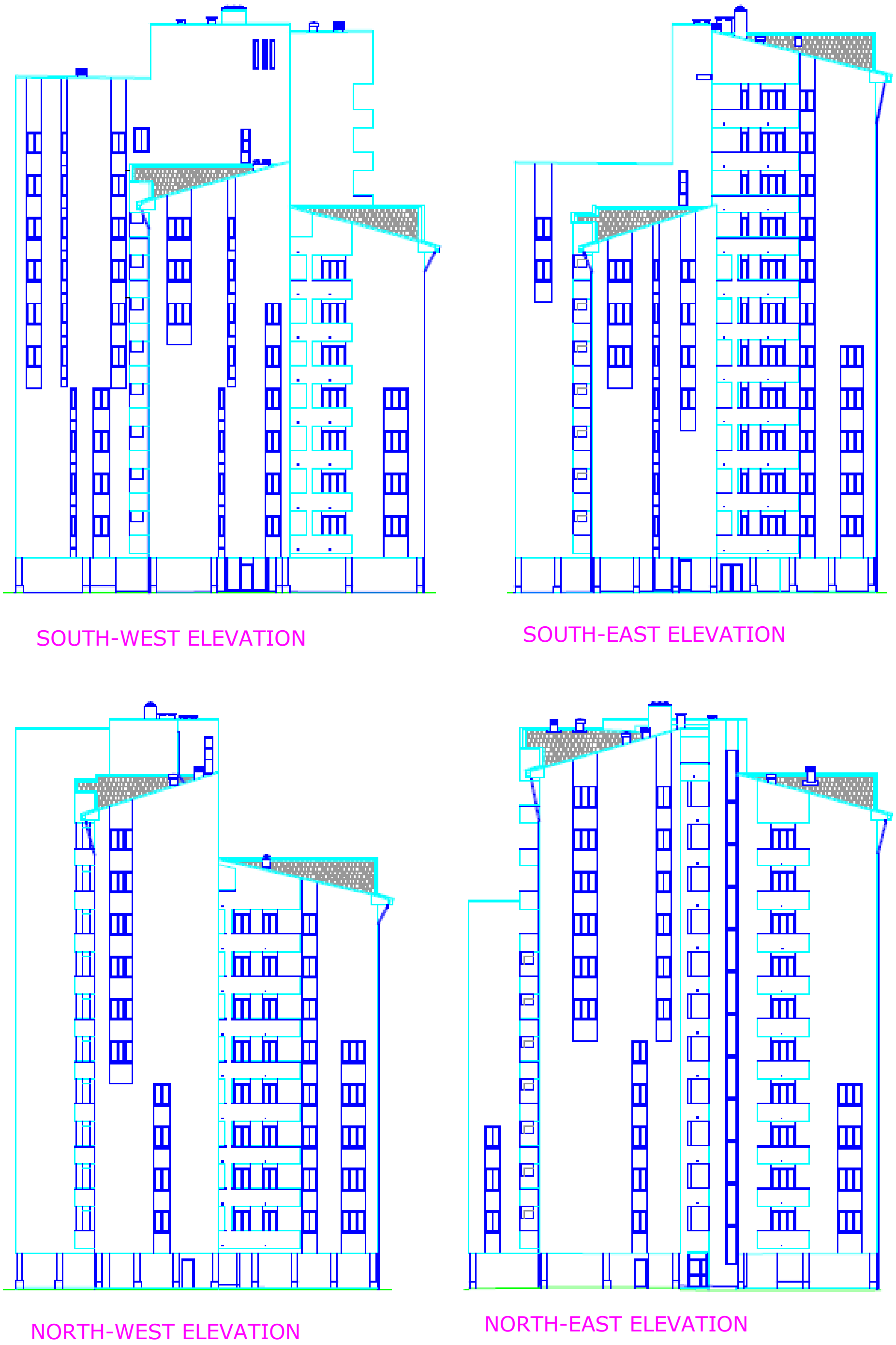

Figure 115. Elevations, Via Valsesia, Milano, Italy (Source: CIVIESCO)

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4.3.1.8. 3D Visualizations or models

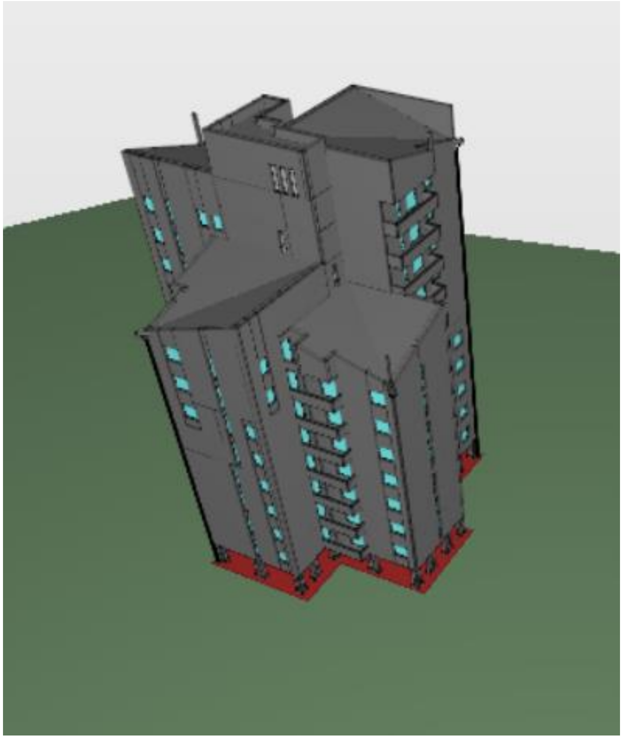

Figure 116. 3D model, Via Valsesia, Milano, Italy (Source: CIVIESCO)

4.3.1.9. Preliminary semi-automated Modulation Design

The Virtual demo Building in Milan was modeled with the semi-automated online tools developed in Task 2.1, as shown in the next picture.

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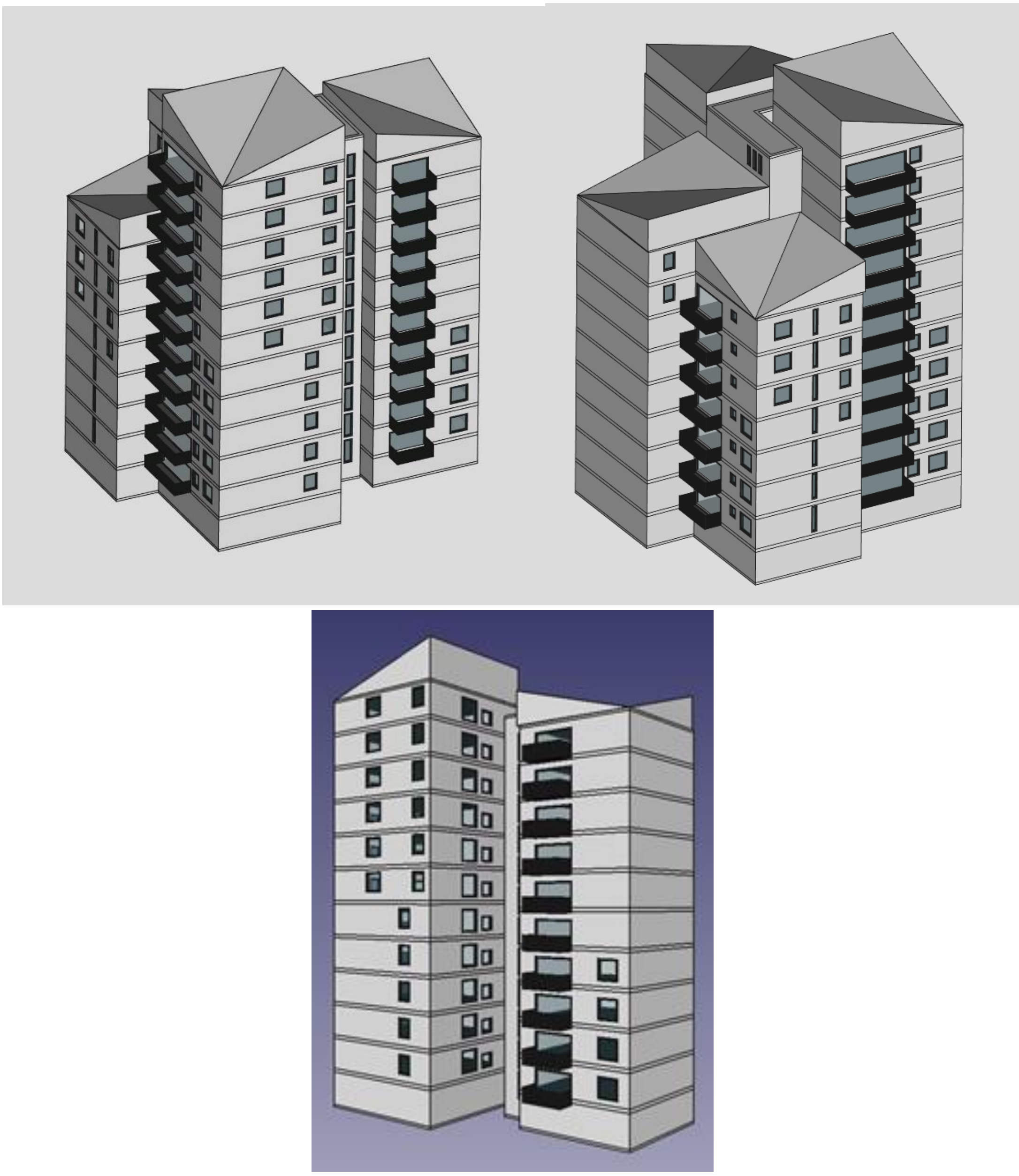

Figure 117. Model of the virtual demo building in Milan (Source: TUM)

With this building model, it was possible to generate the layout of the prefabricated façade modules by optimizing the area of the solar panels as shown in the next picture.

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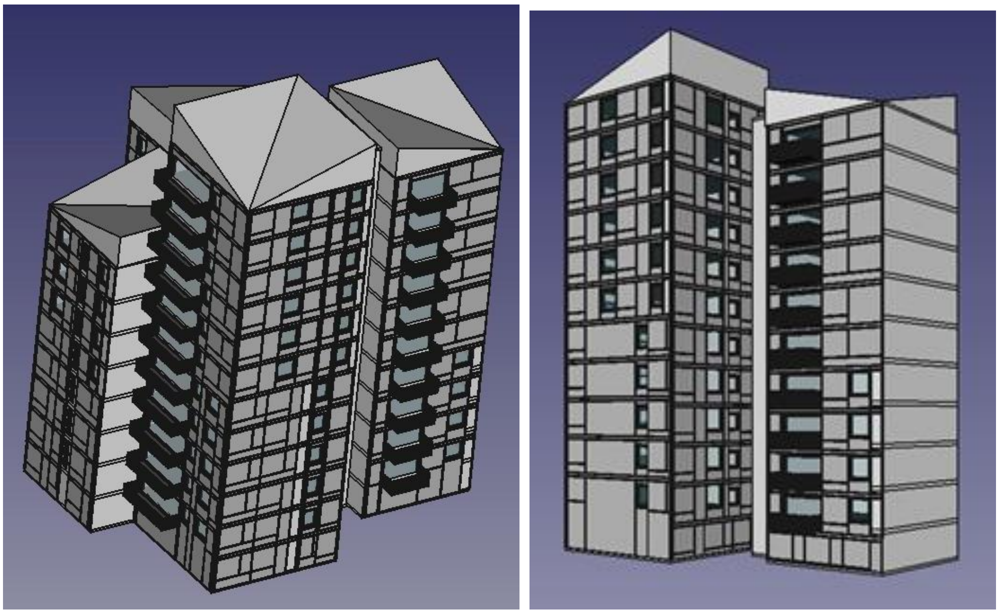

Figure 118. The layout of prefabricated façade modules in the virtual demo building in Milan (Source: TUM)

Both building modelling and layout definition was achieved in less than 30 minutes.

The calculation of the solar panels and the total disponible area was also calculated by TUM, as some examples show in the Appendix B: Virtual Buildings, 3.2. Automated Modulation Design.

4.3.2. Preliminary Baseline Model

A preliminary baseline model has been developed by IES with the space types on the basis of space use and boundary condition. The details of the spaces are shown in the following pictures.

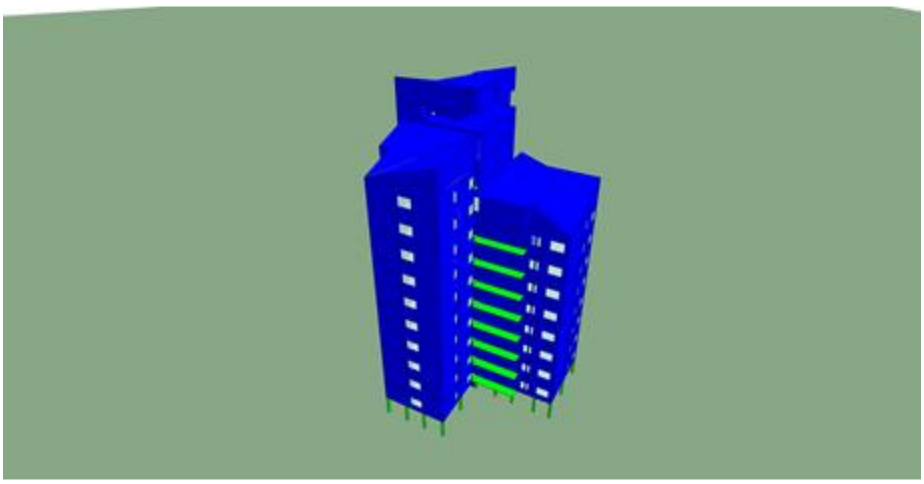

Figure 119. The model of the virtual demo building in Milan (Source: IES)

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Room types:

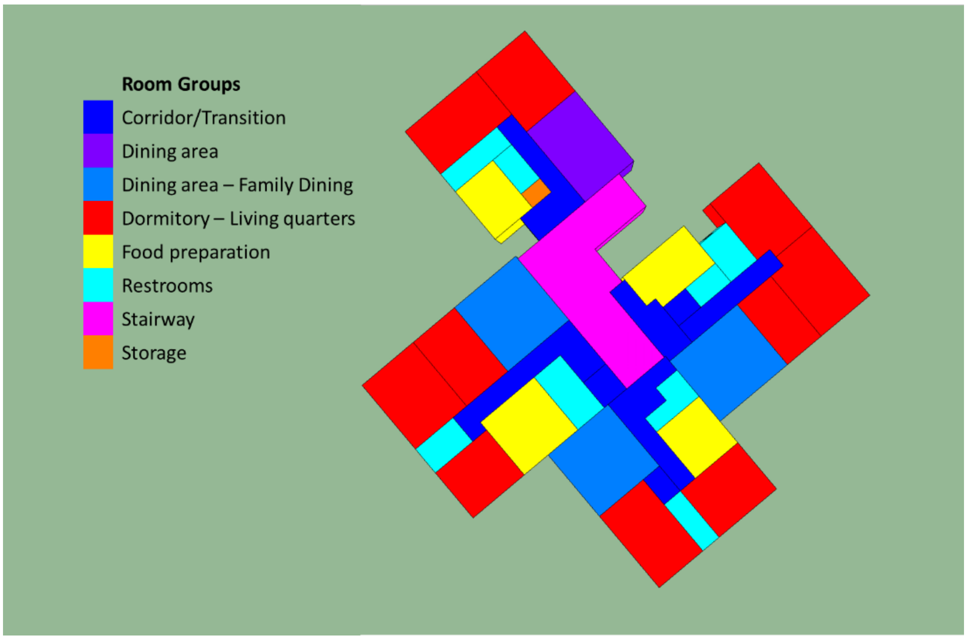

Figure 120. The room types in the virtual demo building in Milan (Source: IES)

HVAC groups:

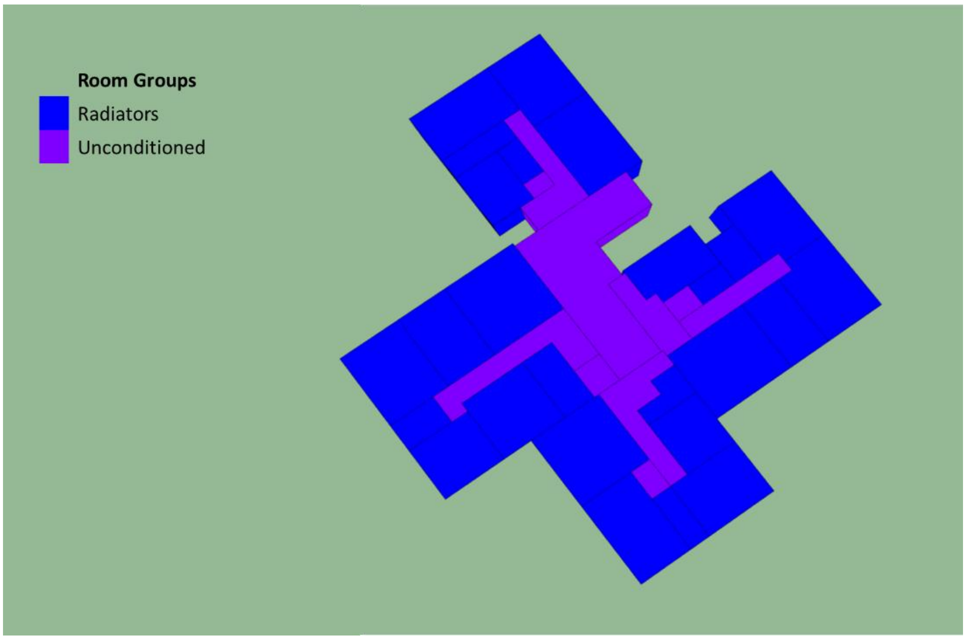

Figure 121. The HVAC groups in the virtual demo building in Milan (Source: IES)

In the coming phases, the models will be calibrated, and different scenarios will be created to determine the performance of the ENSNARE system based on the flexibility the virtual pilot renders. It is envisaged to create various scenarios, which are yet to be decided, with discrete use types, locations and different combinations of ENSNARE panel in order to “play” with the model and determine the behavior of the model to different conditions.

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5. Next Steps

5.1 Further research and definition of Technologies

WP1: The development of T7.1 will help to define the strategies to execute T1.5 "Validation of the Digital Platform DP4ER" in terms of the decision making process and communication protocols with the different stakeholders at the different stages.

WP2: Apart from the semi-automated online tools, the on-site accurate measurement novel technologies must be tested in WP7 in the next stages.

WP3: For the development stage of the Early Decision Support Tool (EDST), the project pilots provide example cases that are useful for testing the functionality of the tool, the suitability of the proposed renovation options, and the plausibility of the obtained results. At validation stage, project pilots will provide data that will allow comparison with the predicted values (e.g. temperature, energy consumption, energy expenditure), providing feedback that could lead to improvements in the EDST. The weather and energy data monitored at the pilot buildings can also be used to calibrate the parameters of the building energy models of the EDST.

WP4: The pilots will aim to be calibrated at the baseline level and improved with more data as it is available. Basic renovation models will be created with ENSNARE technologies. Once the renovation strategy is clear for all demo pilots, the 'renovated' models will be improvised and further detailed to reach to an operational model of the demonstration pilots. After the buildings renovation is completed and sufficient data is available for recalibration, recalibration will be achieved and this should provide a base for an operational digital twin, where optimisation service and active control will be implemented in the later stages of the project. In the virtual pilots, the calibrated baseline models can be tested for what-if renovation scenarios including the use of ENSNARE technologies, optimization and control use cases etc. This feedback will be provided to pilots for potential real application in the buildings. Further, feedback will be received from the pilots on the work done in the demo pilots for e.g. in terms of Operational Digital Twin Dashboards.

WP5: From the WP5 work package, the different proposals for the pilot buildings are studied and analyzed, seeking the best adaptation of the system in each case and through an iterative process, the requirements of the façade system are verified.

Decisions made in WP7 on the design of the building pilots affect task 5.5 of WP5 since this task is the manufacturing of the system and assembly all technologies

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to be installed in the pilots. Therefore, all the square meters of the façades needed for each pilot will be defined in WP7 and manufactured in WP5.

WP6: Decisions made in Task 7.1 on the design of the building pilots affect task 6.5 of WP6 since this task is the manufacturing of all technologies to be installed in the pilots. Therefore, all the square meters of each technology needed for each pilot will be defined in WP7 and manufactured in WP6.

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Conclusions

The integrated design process has been the main driver of the concept design. An integrated and well-coordinated approach has expedited the design process. During the conceptual design, detailed assessments of pilot buildings were carried out. The building diagnostic reports aided in understanding the overall condition of the pilot buildings and analyzing the suitability of structures to host ENSNARE panels. Although different challenges have arisen in different pilot buildings, the close collaboration of partners and pilot leaders has allowed for addressing these issues. Several tests and evaluations have been made on the developed technologies depending on each client and building needs. The results of these tests meet the project expectations during the concept phase. Impact evaluation of ENSNARE interventions demonstrates considerable improvements in the pilot buildings' energy performance as well as the production of solar energy. Furthermore, the digital modulation approach applied to the pilot buildings and demo buildings has also exhibited promising prospects in facilitating renovation projects. The interlinkage of ICT and physical technologies via digital twins will also take place in the next stages to leverage fully the potential of digital technologies in tandem with physical devices. To appraise the potential of ENSNARE technologies with differing approaches, discrete scenarios will be generated for virtual pilot buildings once connected with the digital twin. These scenarios will be advantageous in checking out the optimal combination of technologies with building operations. The ENSNARE solutions developed are envisaged to be further developed and refined during the technical and renovation phase.

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RIVENTI Nuria Jorge, Guillermo Rilova, Hugo Bergado. (2021). *D5.1 Deliverable titleProducts design requirements.*

Appendix A: Demo Buildings

1. Demo Building 1, Tartu

1.1. National building regulations - Safety in case of fire

For the building in Tartu, the following information is provided:

It is necessary to follow the rules of all the Estonian fire safety documents and rules. The project has accepted all these norms and standards and requirements and has been confirmed by the south Estonia department of fire safety institution (given a few samples of the regulations).

The reconstructing building is located in its former location. The expansion of the building is not planned (the dimensions of the building will increase only in the form of insulation of the outer walls and plinth).

The required fire safety distance of 8 meters with surrounding buildings is ensured. The nearest building on the same property is more than 12 meters away.

The load-bearing and stiffening structures of the building must comply with fire resistance R30. Fire resistances of fire sections: ground floors, attic - EI30, basement - EI60, walls and doors of apartments divided into accommodation rooms - EI15.

In the building, separate fire protection sections meeting the requirements of EI30 must be formed from the evacuation staircase, the ventilation room, the ground floors and the attic.

The presence of two scattered evacuation accesses must be provided from each floor. The main evacuation is organized through the evacuation stairwell. The construction of a second evacuation access should be planned for the second floor. On the first floor, a second evacuation access is ensured through the external door built into the kitchen.

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1.2. Additional plans

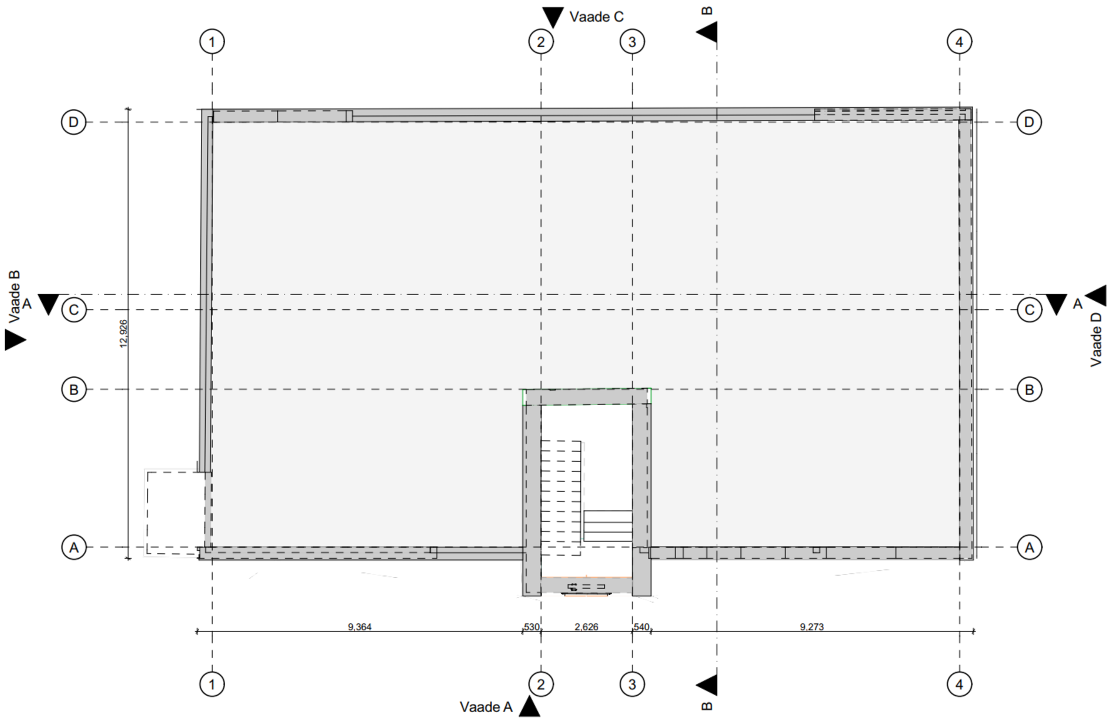

Figure 1. Foundation plan (Source: TARTU)

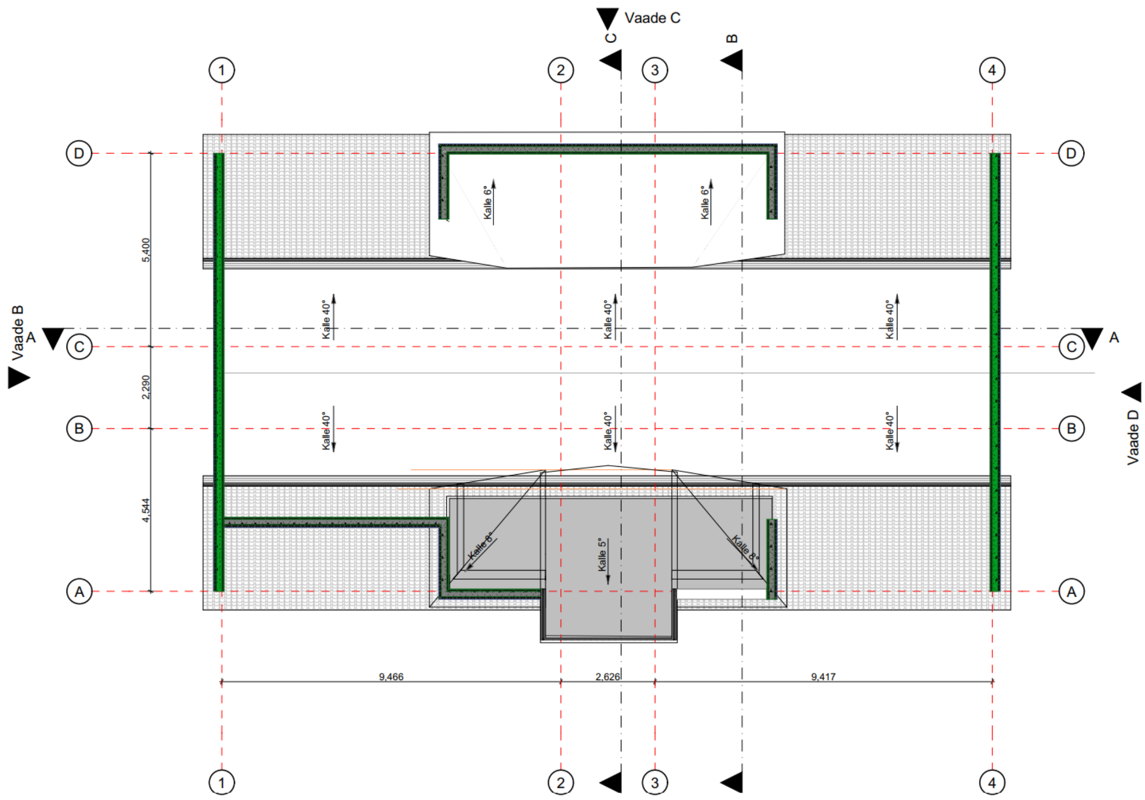

Figure 2. Attic plan (Source: TARTU)

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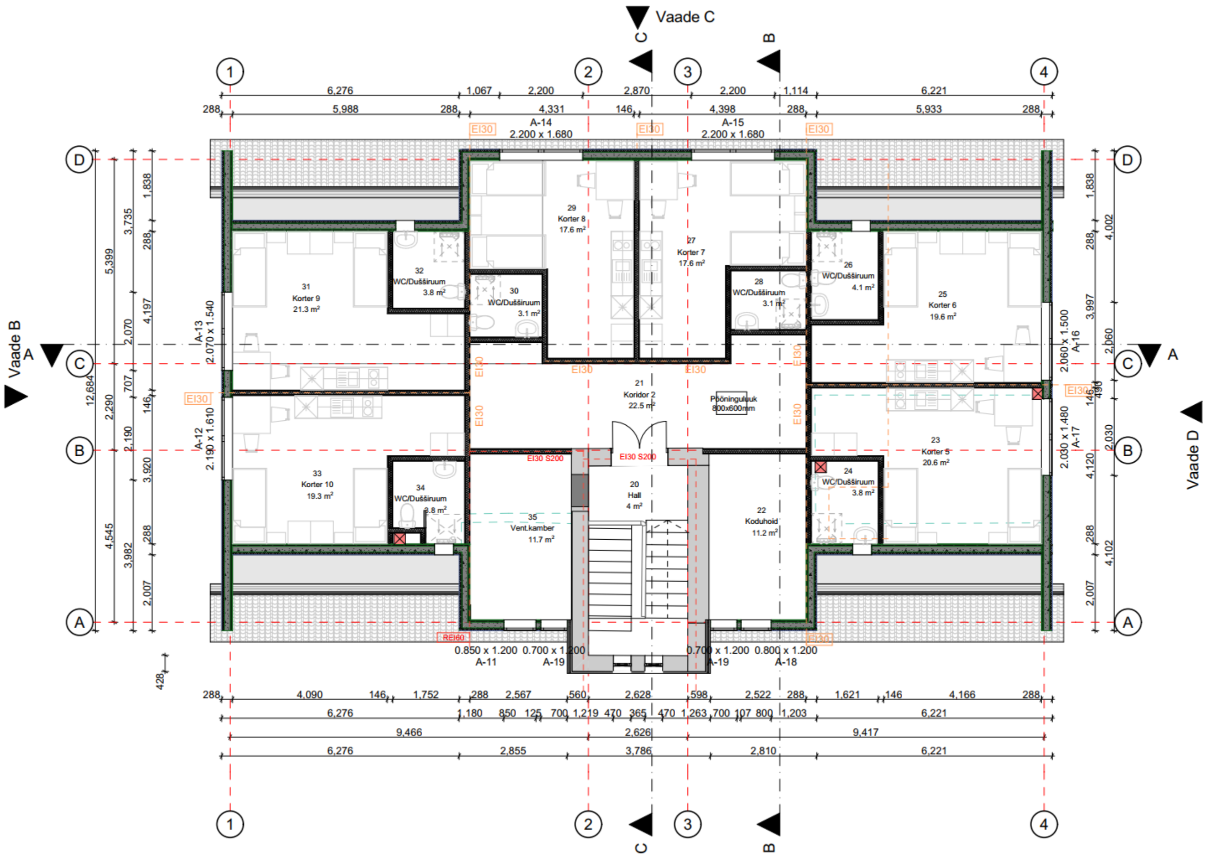

Figure 3. Floor 2 plan (Source: TARTU)

Figure 4. East façade, Tartu (Source: TARTU)

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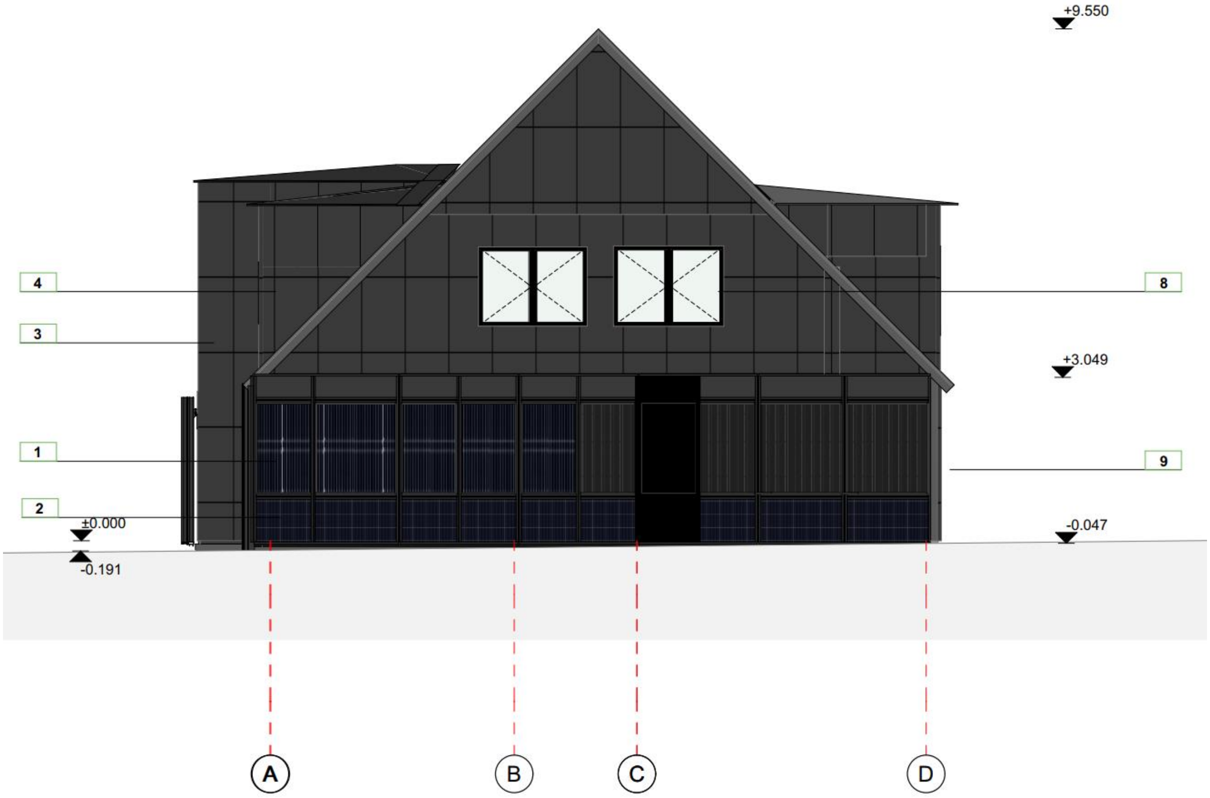
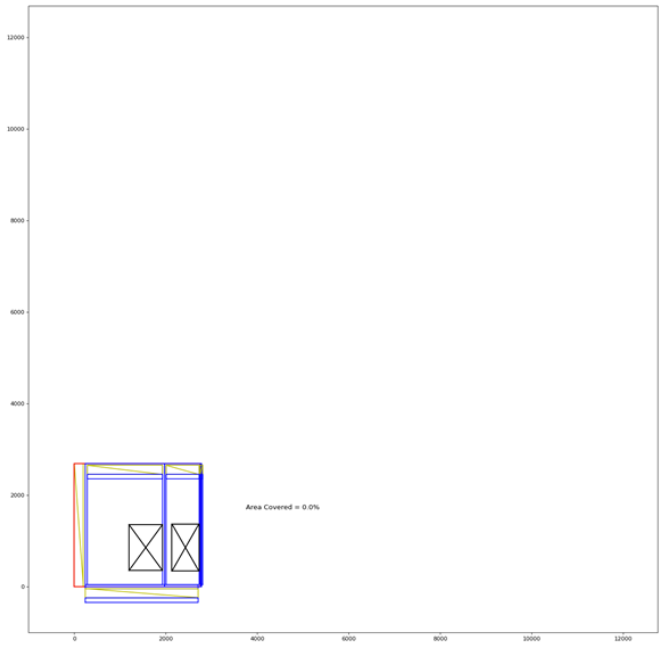
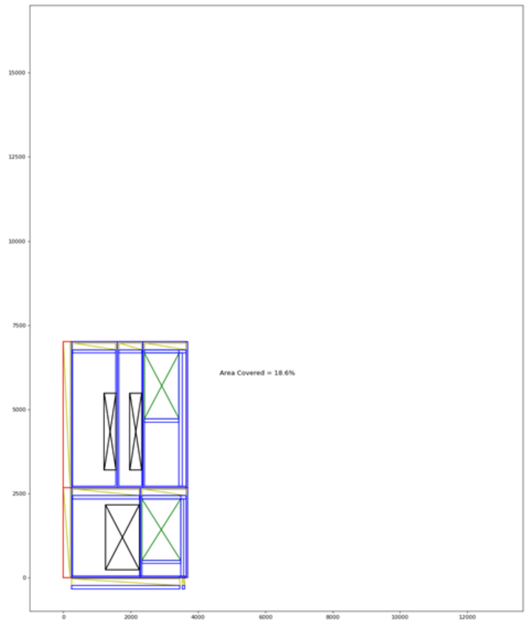


Figure 5. South façade, Tartu (Source: TARTU)

1.2. Automated Modulation Design





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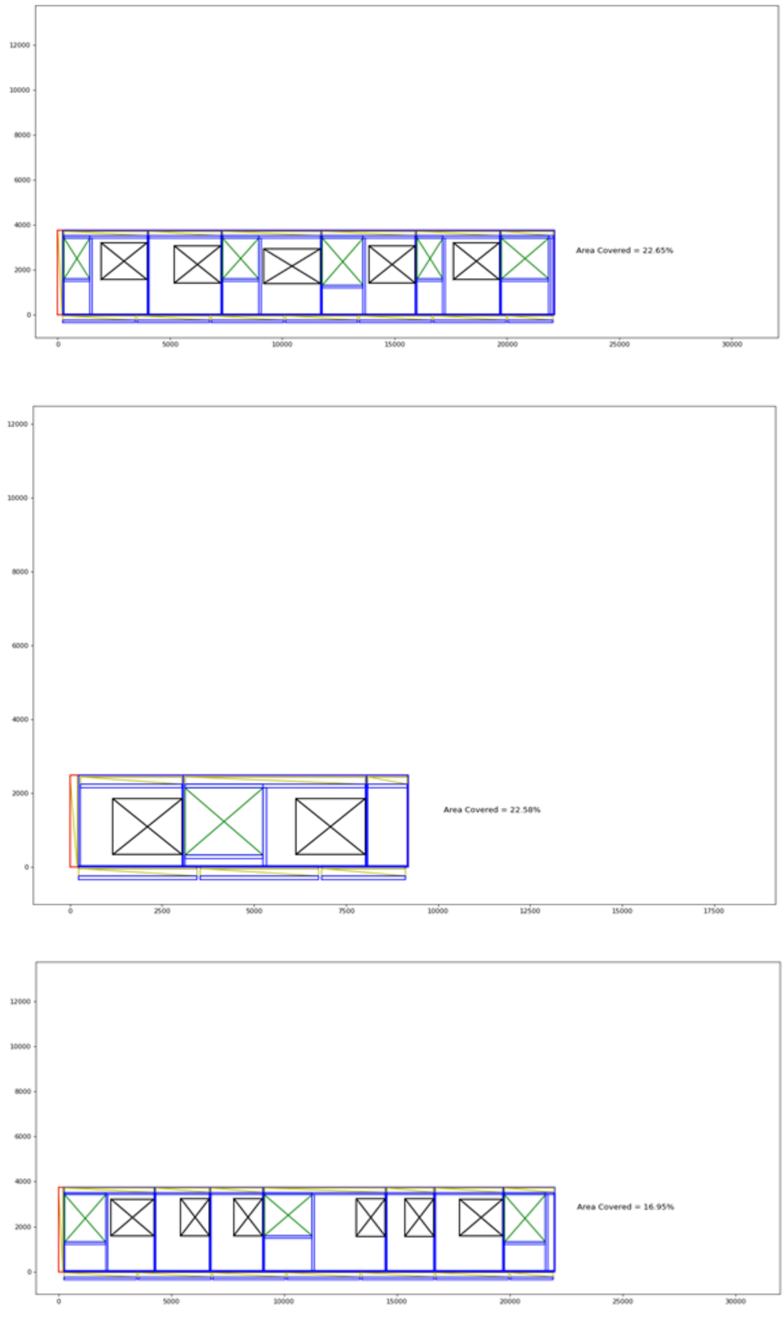

Figure 6. Automated Modulation and total area for solar panels (Source: TUM)

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2. Demo Building 2, Sofia

2.1. Thermal characteristics

Table 1: Thermal characteristics of the envelope, Sofia (Source: BAL)

Layer	Layer 1	Layer 2	Layer 3	Layer 4	Layer 5
Façade 01					
Material name	plaster	brick wall	EPS thermal	exterior plaster	-
Thickness [m]	0.01	0.25	0.1	0.02	-
Conductivity [W/mK]	0.7	0.52	0.035	0.35	-
Façade 02					
Material name	plaster	brick wall	EPS thermal	exterior plaster	-
Thickness [m]	0.01	0.25	0.1	0.02	-
Conductivity [W/mK]	0.7	0.52	0.035	0.35	-
Façade 03					
Material name	plaster	brick wall	EPS thermal	exterior plaster	-
Thickness [m]	0.01	0.25	0.1	0.02	-
Conductivity [W/mK]	0.7	0.52	0.035	0.35	-
Façade 04					
Material name	plaster	brick wall	EPS thermal	exterior plaster	-
Thickness [m]	0.01	0.25	0.1	0.02	-
Conductivity [W/mK]	0.7	0.52	0.035	0.35	-
Roof					
Material name	bitumen waterproofing	cement screed	XPS thermal insulation	reinforced concrete slab	plaster
Thickness [m]	0.005	0.08	0.1	0.15	0.02
Conductivity [W/mK]	0.19	0.93	0.035	1.63	0.7

- **Energy parameters**

Table 2: Energy parameters, Sofia (Source: BAL)

ENERGY	
Energy consumption for heating [kWh/m² year]	-
Energy consumption for cooling [kWh/m² year]	-
Total energy consumption for electrical appliances [kWh/year]	-

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Air-Conditioned Floor Surface [m²]	562,47
Air-Conditioned Volume [m³]	1444
Façade Total surface [m²]	885.77
Windows no.	51
Window-To-Wall ratio [%]	163.3
Energy Cost (Gas & Electricity) [€/year]	Gas: 401,24
	Electricity: 1 264,03
Clearance height overhead [m]	0.8
Climatic zone	6
Compactness: Volume/External Surface V/A [m³/m²]	-

- **Envelope characteristics**

Table 3: Envelope characteristics, Sofia (Source: BAL)

	Façade 01	Façade 02	Façade 03	Façade 04	Roof
Orientation	East	West	North	-	South
Degrees*	75º	255º	345º	165º	0º /14º/45º
Structure (Light-Medium-Heavy)	Medium	Medium	Medium	Medium	Heavy/Light
External or Internal	External	External	External	External	External
Surface [m²]	152	190.53	181.2	173.74	188.3
Windows no.	11	16	9	14	1
Window-To-Wall ratio [%]	29.13	71.75	5.2	46.1	11.12
U value [W/(m² K)]	0.285	0.285	0.285	0.285	0.32
g factor [-]	0.5	0.5	0.5	0.5	0.6
Shaded by other buildings? (YES or NOT)	NO	NO	NO	YES	NO
Average size of windows. Width by Height [m]	The windows are of different sizes (AutoCAD Plant 3D)	The windows are of different sizes (AutoCAD Plant 3D)	The windows are of different sizes (AutoCAD Plant 3D)	The windows are of different sizes (AutoCAD Plant 3D)	The windows are of different sizes (AutoCAD Plant 3D)

***Degrees. Not only indicate north, south, east and west, but also consider the degrees. According to this scale; 0º for north, 90 east, 180º south, 270º west.**

2.2. Building services system (BSS)

Table 4: Building services system, Sofia (Source: BAL)

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BUILDING SERVICES SYSTEM	
The heating system	Circulation to the thermal circuit for the thermal batteries is performed via a circulation pump (P1). Circulation to the heating circuit is achieved by means of second circulation pump (P2). Only one circulating pump works at a time.
The domestic hot water (DHW) system	The scheme for the method of domestic water heating is attached
The air-conditioning system	The building has 7 standard air conditioners powered by electricity
The ventilation system	None
The renewable heat generation source	None
The renewable electricity generation source	The Solar PV system is 12.54kW peak capacity comprising of 42 x LG 340N1K-V5 Modules. The area occupied by the photovoltaic panels is: 71,4 m^2.

2.3. National building regulations

2.3.1. Safety in case of fire

For the building in Sofia, the following information is provided:

Table 5: National building regulations (Sofia, Bulgaria): Security in case of fire (Source: BAL)

SECURITY IN CASE OF FIRE	Ordinance № Iz-1971 on construction and technical rules and norms for ensuring fire safety	Minimum fire resistance of the wall (minutes)	60
	Ordinance № Iz-1971 on construction and technical rules and norms for ensuring fire safety	Spread of fire	s2, d1
	Ordinance № Iz-1971 on construction and technical rules and norms for ensuring fire safety	Reaction to fire	C

2.3.2. Safety and accessibility in use

For the building in Sofia, the following information is provided:

Table 6: National building regulations (Sofia, Bulgaria): Structural requirements (Source: BAL)

STRUCTURE	ORDINANCE № 3 on the basic provisions for the design of the structures of the constructions and on the impacts on them	wind load (without increasing)	0.43kN/m^2
	ORDINANCE № 3 on the basic provisions for the design of the structures of the constructions and on the impacts on them	seismic load (without increasing)	ag=0.23*g

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2.3.3. Protection against noise

For the building in Sofia, the following information is provided:

Table 7: National building regulations (Sofia, Bulgaria): Acoustics requirements (Source: BAL)

ACOUSTICS (noise)	ORDINANCE № 6 OF 26.06.2006 ON ENVIRONMENTAL NOISE INDICATORS TAKING INTO ACCOUNT THE DEGREE OF DISCOMFORT	Minimum airborne sound insulation (dB)	30dB

2.3.4. Energy, economy and heat retention

For the building in Sofia, the following information is provided:

- **Energy saving:**

Table 8: National building regulations (Sofia, Bulgaria): Energy saving requirements (Source: BAL)

ENERGY SAVE (e.g. Building regulation Part L in the UK, EnEV in Germany)	ORDINANCE № 7 ON ENERGY EFFICIENCY OF BUILDINGS	U-value of the external wall [W/(m² K)]	0.28
	ORDINANCE № 7 ON ENERGY EFFICIENCY OF BUILDINGS	Limit value for air permeability of holes in the thermal envelope [m³/h·m²]	2 n50
		Non-renewable primary energy consumption [kW·h/m²year]	no
	ORDINANCE № 7 ON ENERGY EFFICIENCY OF BUILDINGS	Total primary energy consumption [kW·h/m²year]	190
		Minimum contribution of renewable energy to cover the domestic hot water demand	no
		Minimum generation of electrical energy	no
		Limit value of the solar control parameter. qsol;jul,lim [kWh/m²·month]	no

- **Indoor air quality:**

Table 9: National building regulations (Sofia, Bulgaria): Indoor air quality requirements (Source: BAL)

INDOOR AIR QUALITY	Ventilation rates	no

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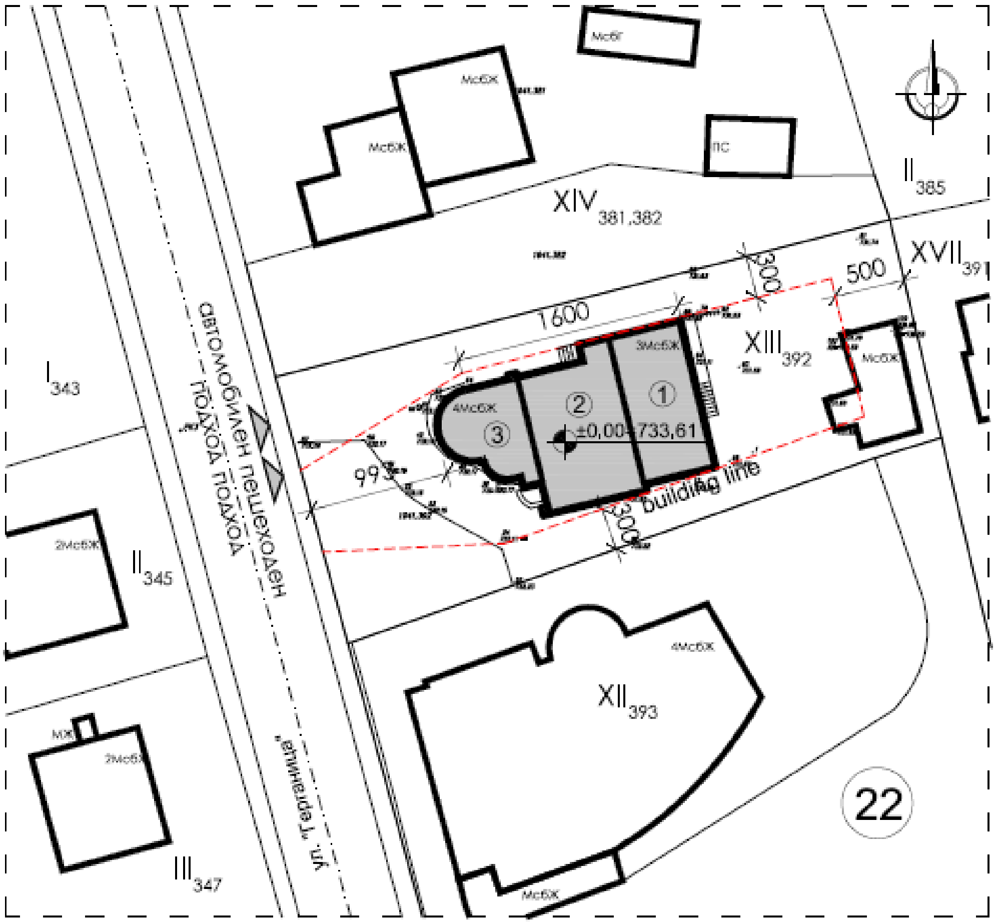
2.4. Additional plans



Постигнати показатели:

Regulated Estate Area - 785,5 кв.м
Density- 22,0%
Construction Intensity - 0.71
Greening Coeff. - 70%

Технически показатели:

Zoning according to
Public Building Plan - Жм2
Density - 30%
Construction Intensity - 1
Greening Coeff. - 60%

Legend:

1.Old part of the building
2.Superstructure
3.Extention

Figure 7. Site layout (Source: BAL)

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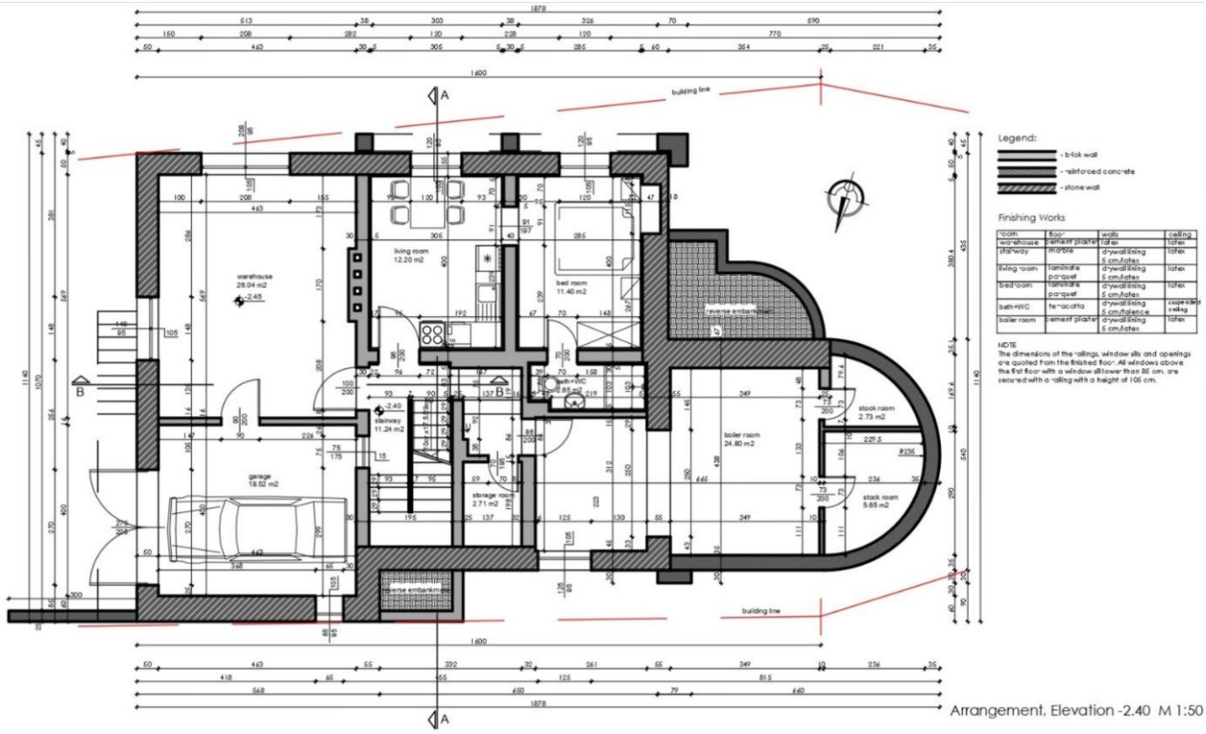

Figure 8. Basement plan (Source: BAL)

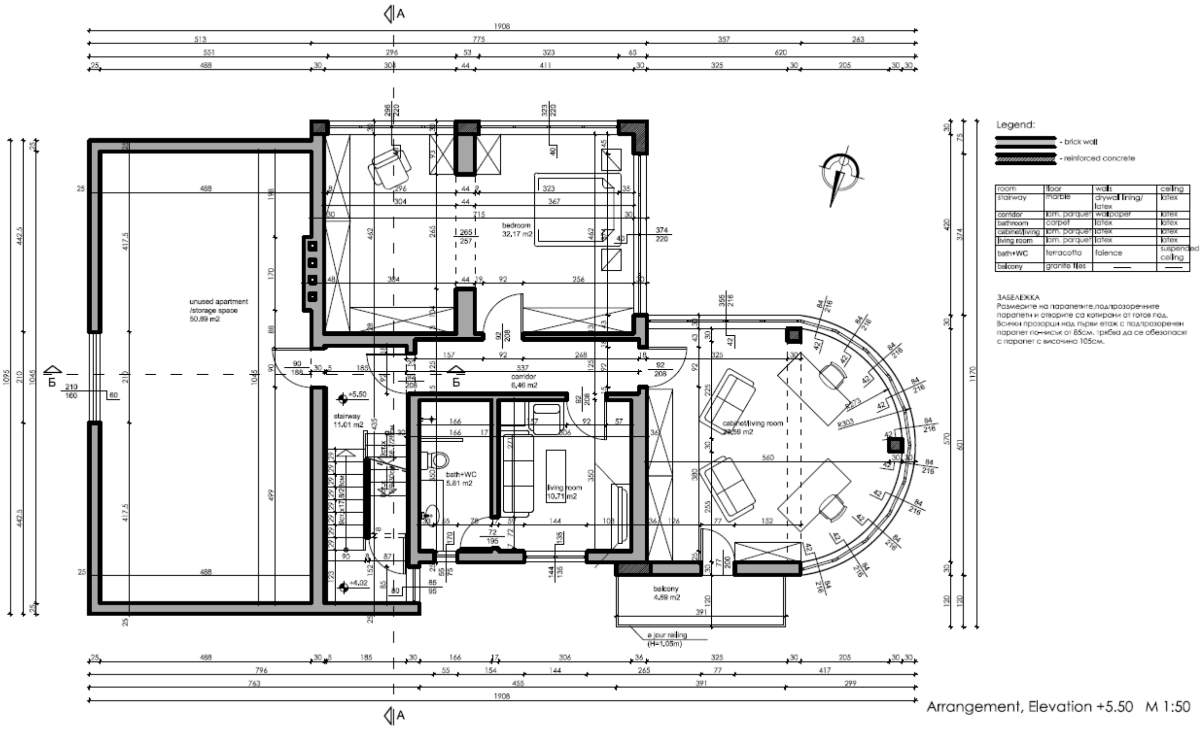

Figure 9. Floor 2 plan (Source: BAL)

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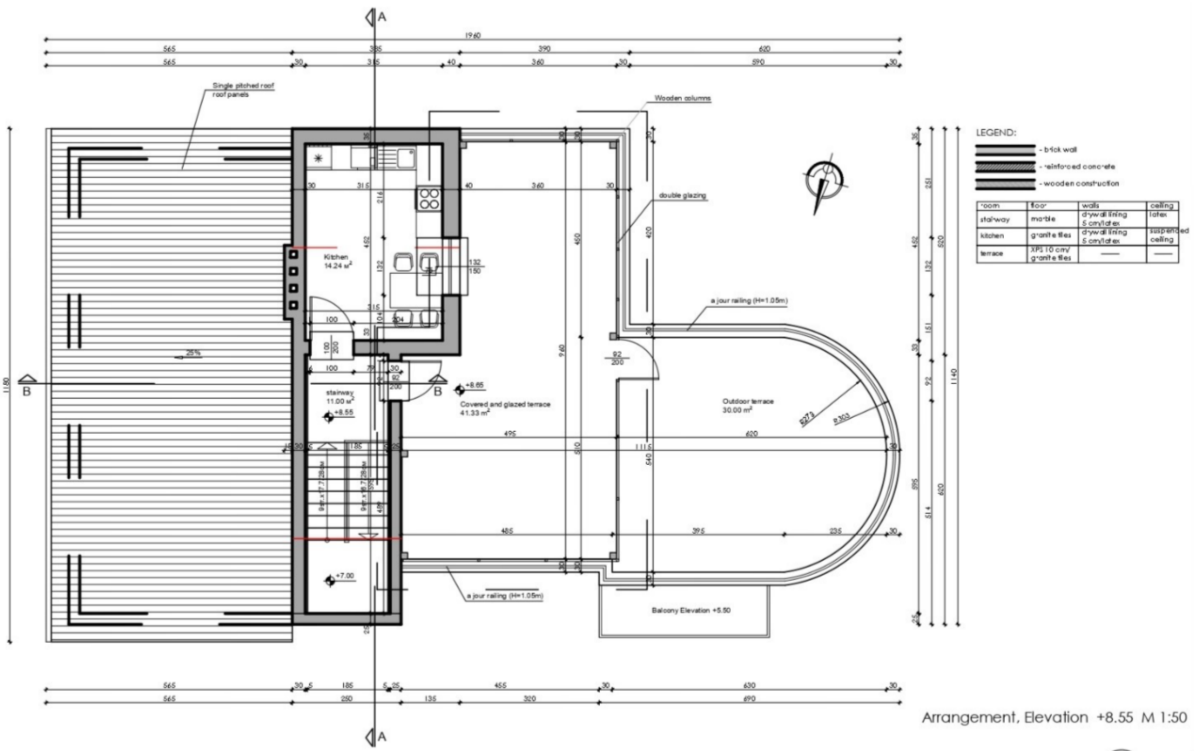

Figure 10. Floor 3 plan (Source: BAL)

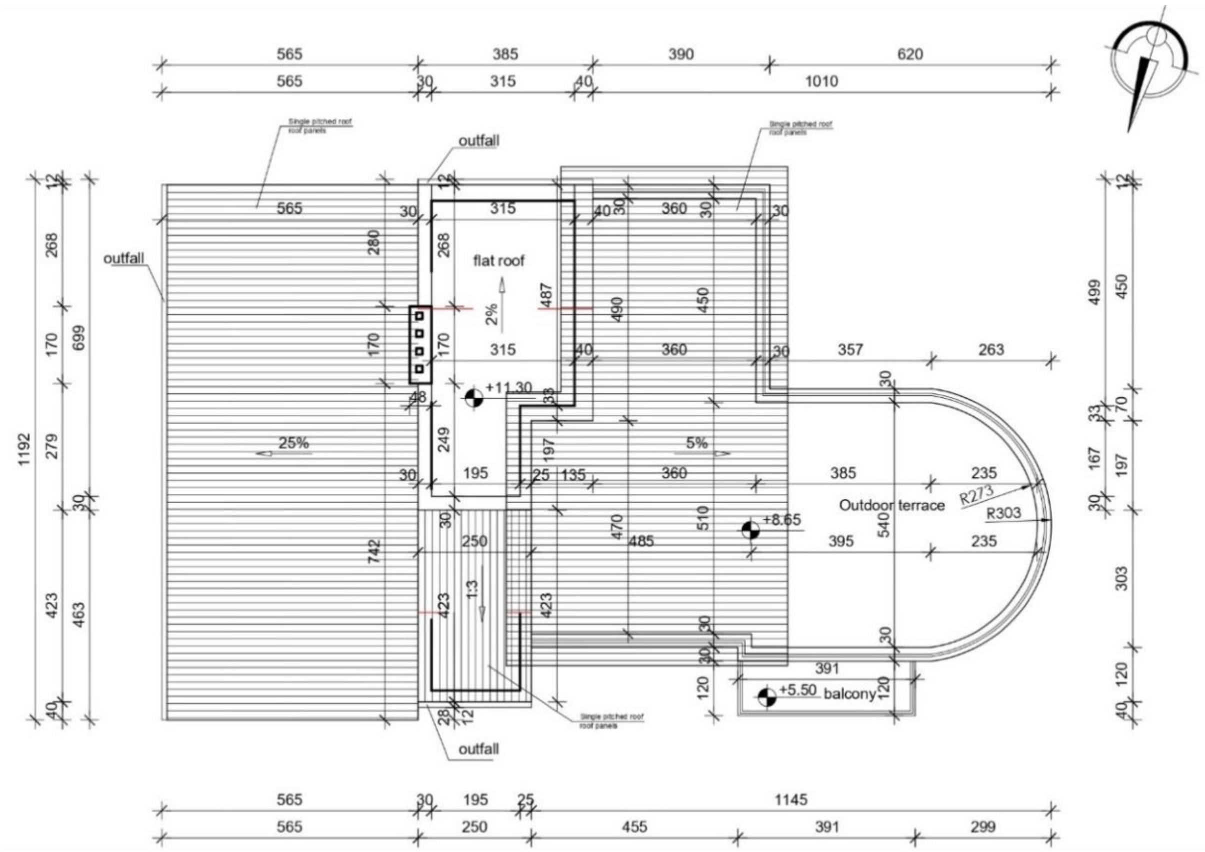

Figure 11. Roof plan (Source: BAL)

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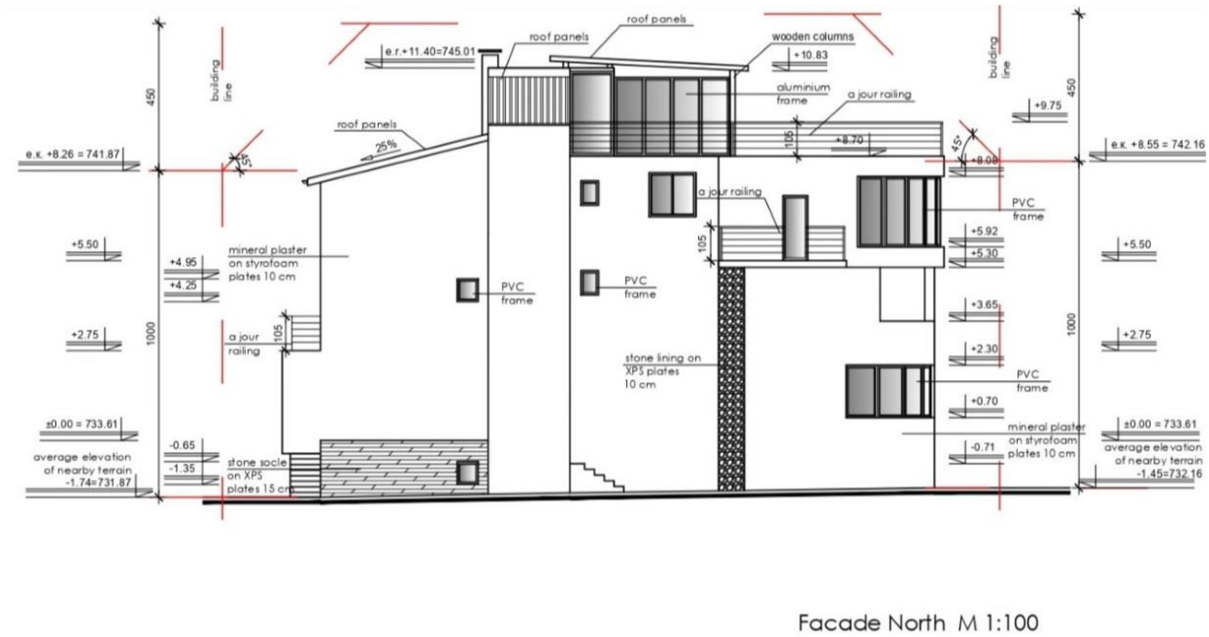

Figure 12. North façade, Sofia (Source: BAL)

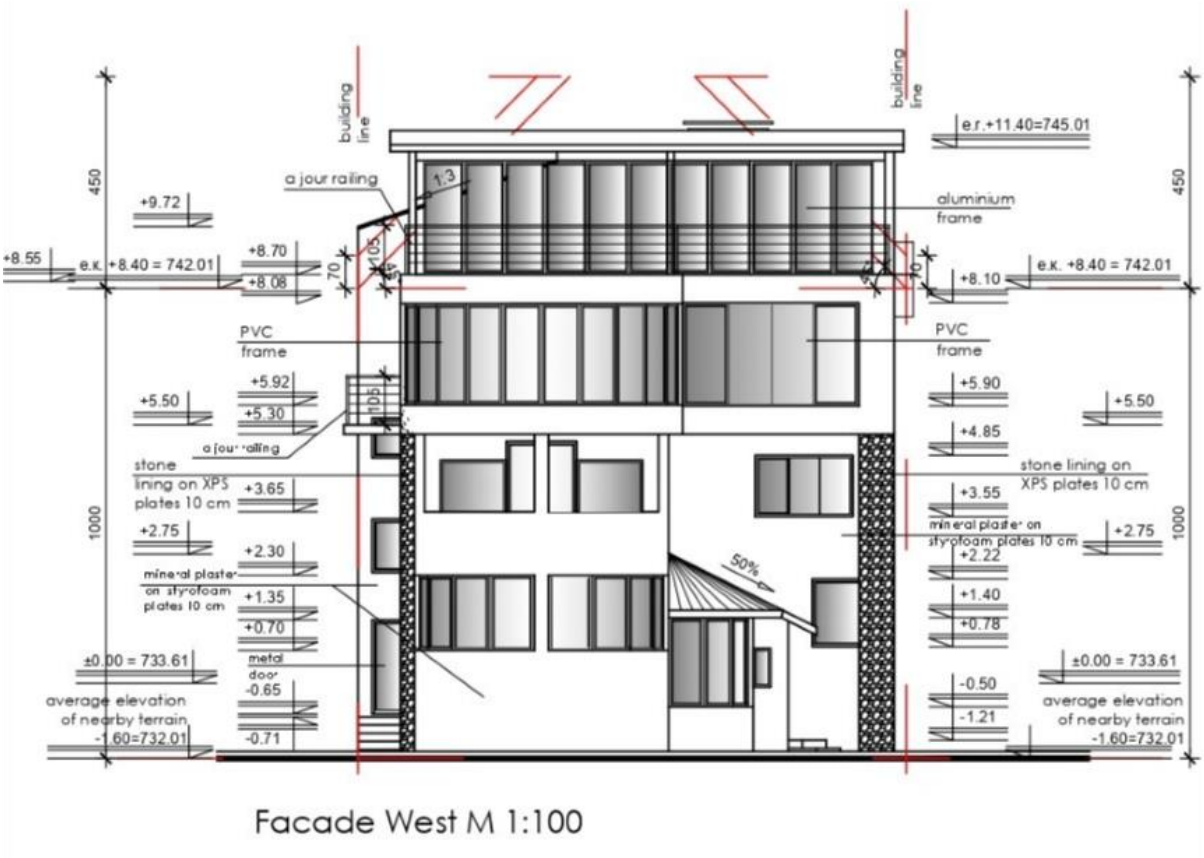

Figure 13. West façade, Sofia (Source: BAL)

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3. Demo Building 3, Sassa Scalo

3.1. Additional plans

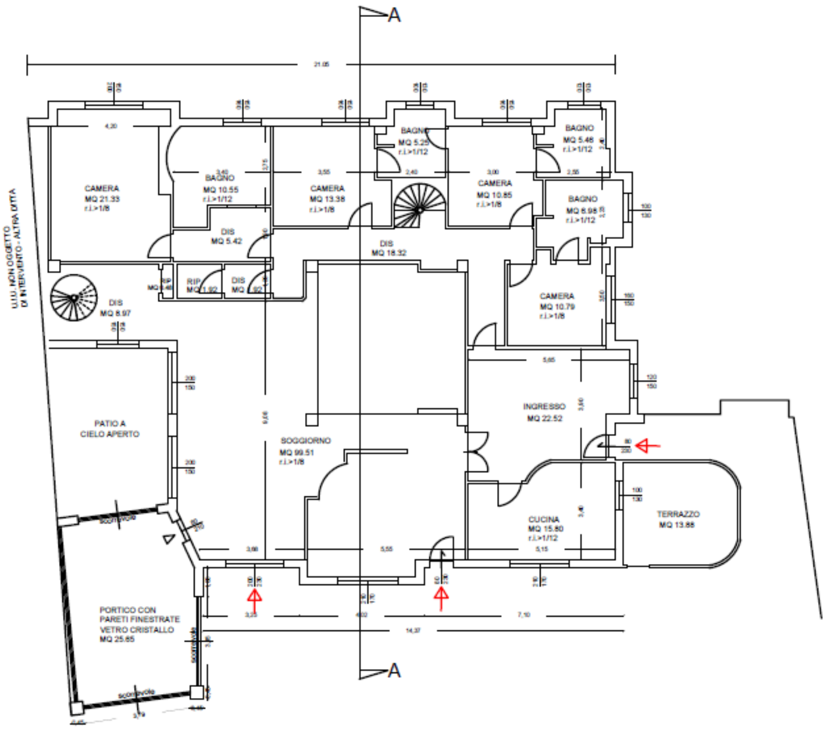

Figure 14. Floor 1 plan (Source: COAF)

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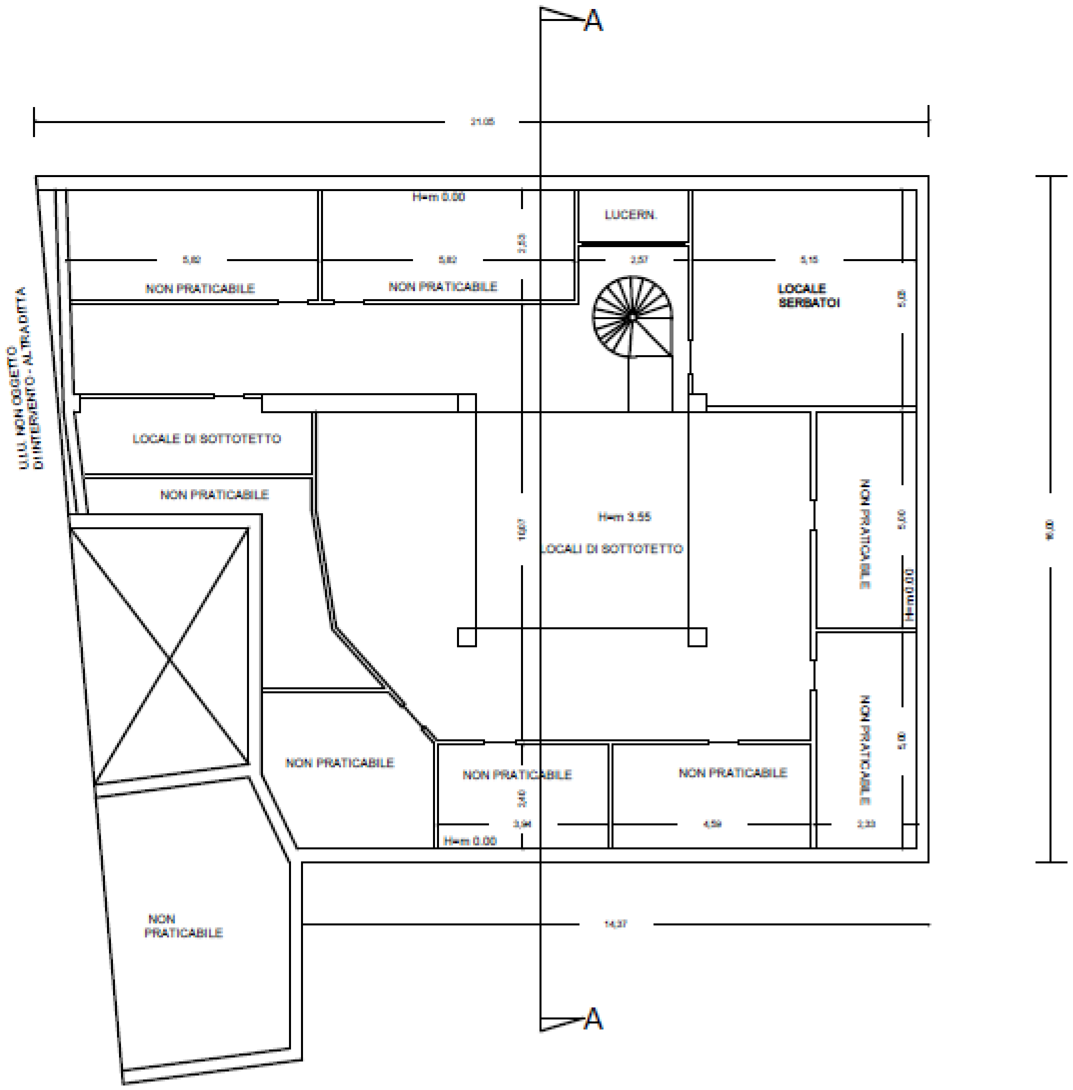

Figure 15. Attic plan (Source: COAF)

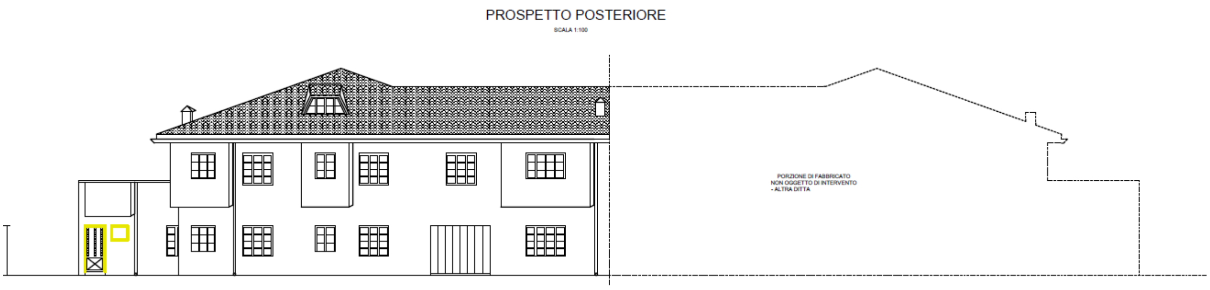

Figure 16. North elevation, Villa Irti, Italy (Source: COAF)

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Appendix B: Virtual Buildings

1. Virtual Building 1, Glasgow

1.1. Additional plans

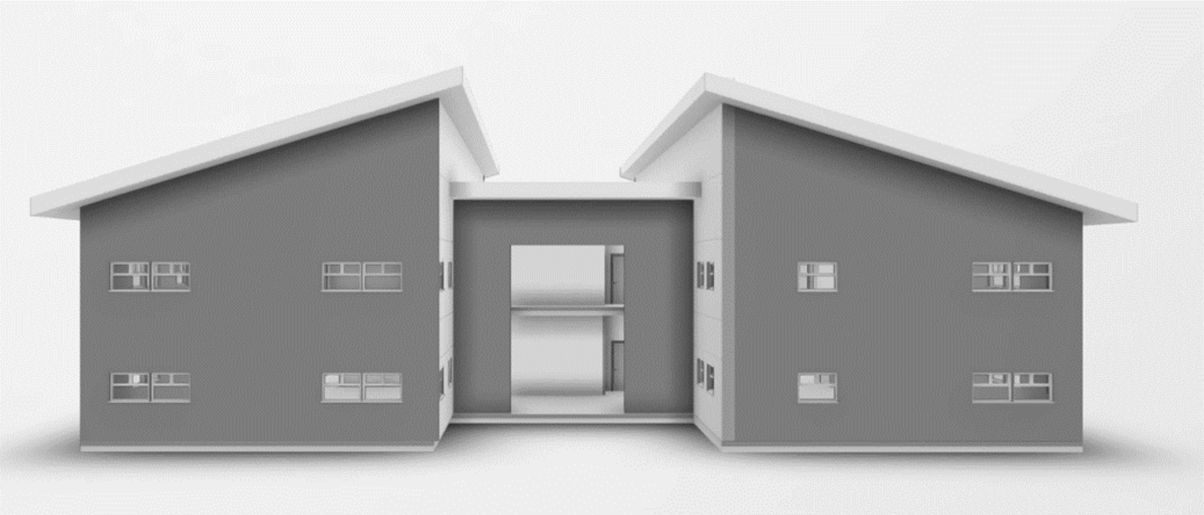

Figure 1. North Elevation - Helix Building, Glasgow (UK) (Source: IES)

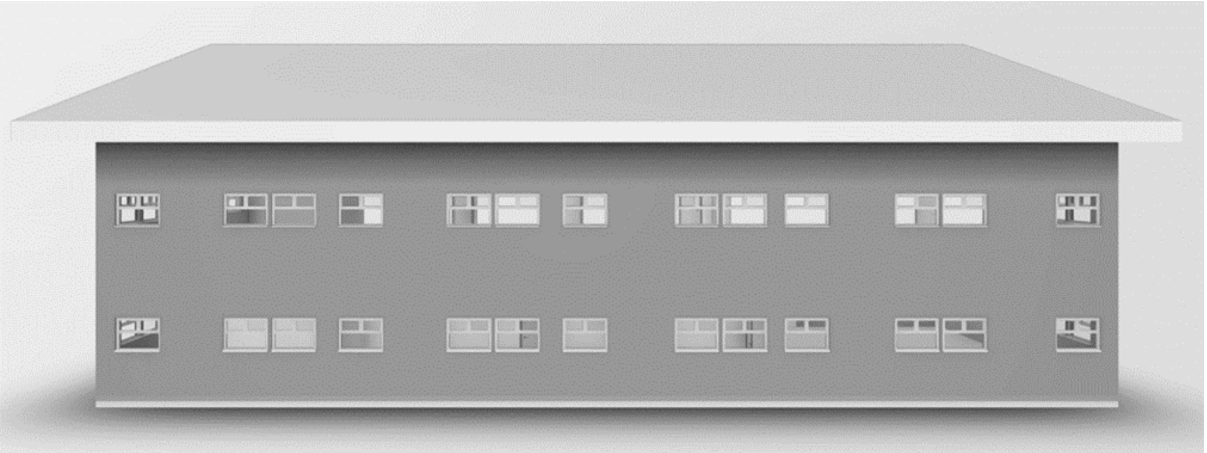

Figure 2. East Elevation - Helix Building, Glasgow (UK) (Source: IES)

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1.2. Automated Modulation Design

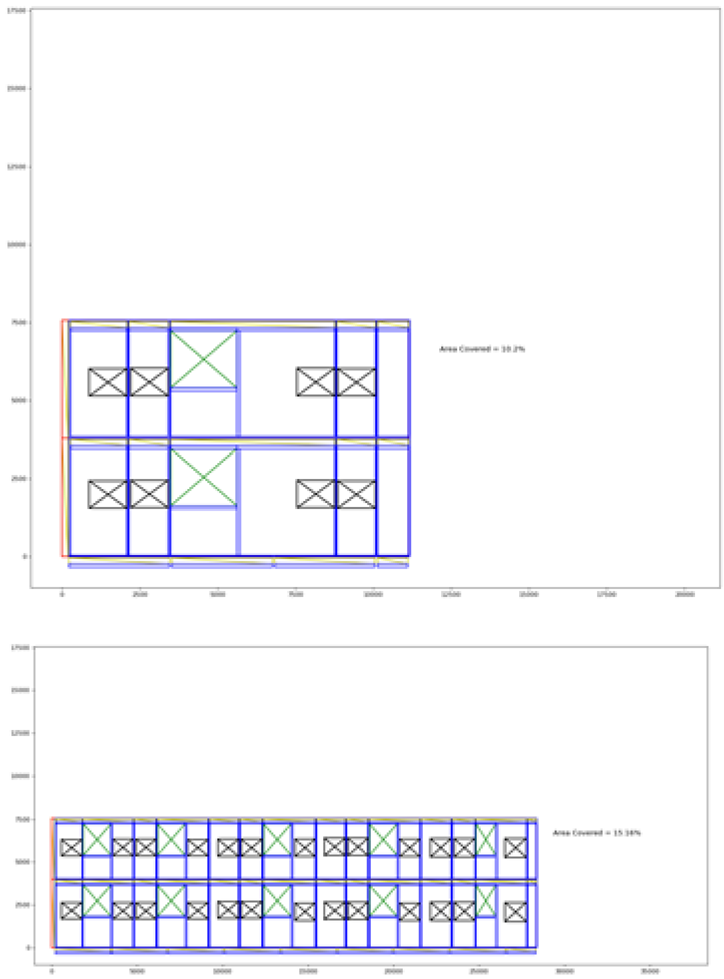

Figure 3. Automated modulation and total area for solar panels (Source: TUM)

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2. Virtual Building 2, Amsterdam

2.1. Additional plans

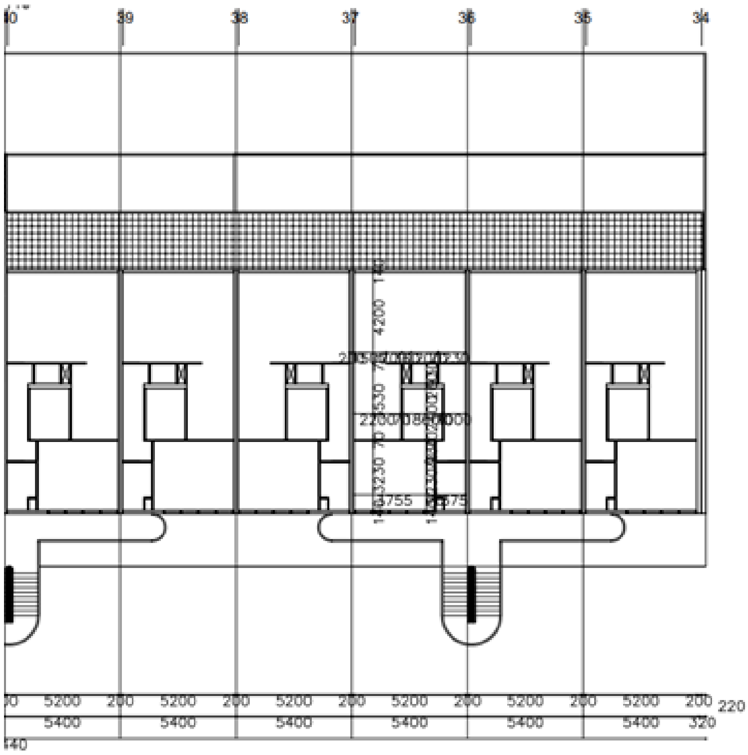

Figure 4. Second floor plan, Building A5, Reigersbos, Amsterdam (Source: TUDELFT)

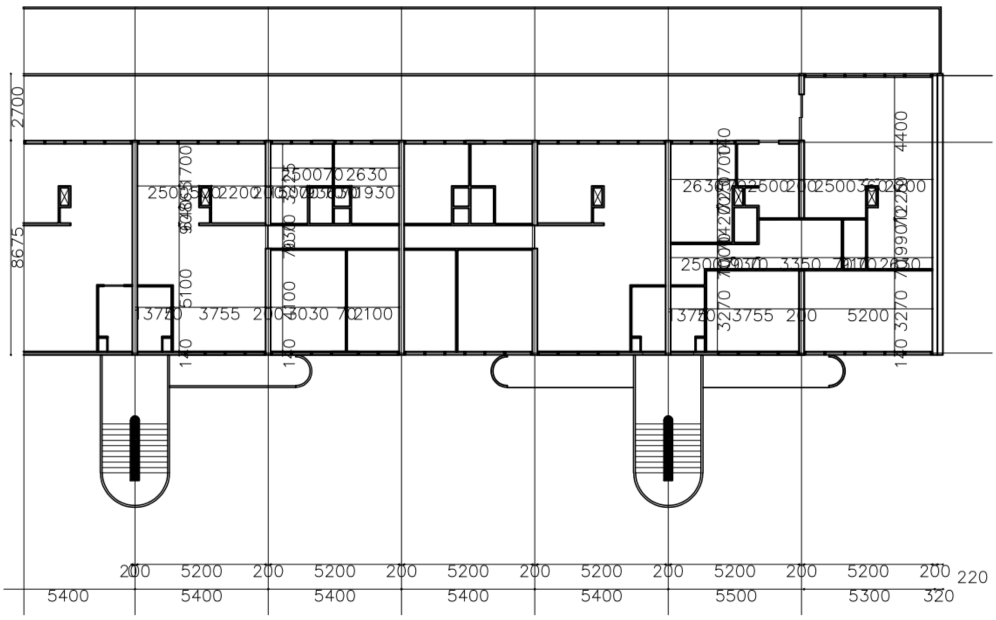

Figure 5. Third floor plan, Building A5, Reigersbos, Amsterdam (Source: TUDELFT)

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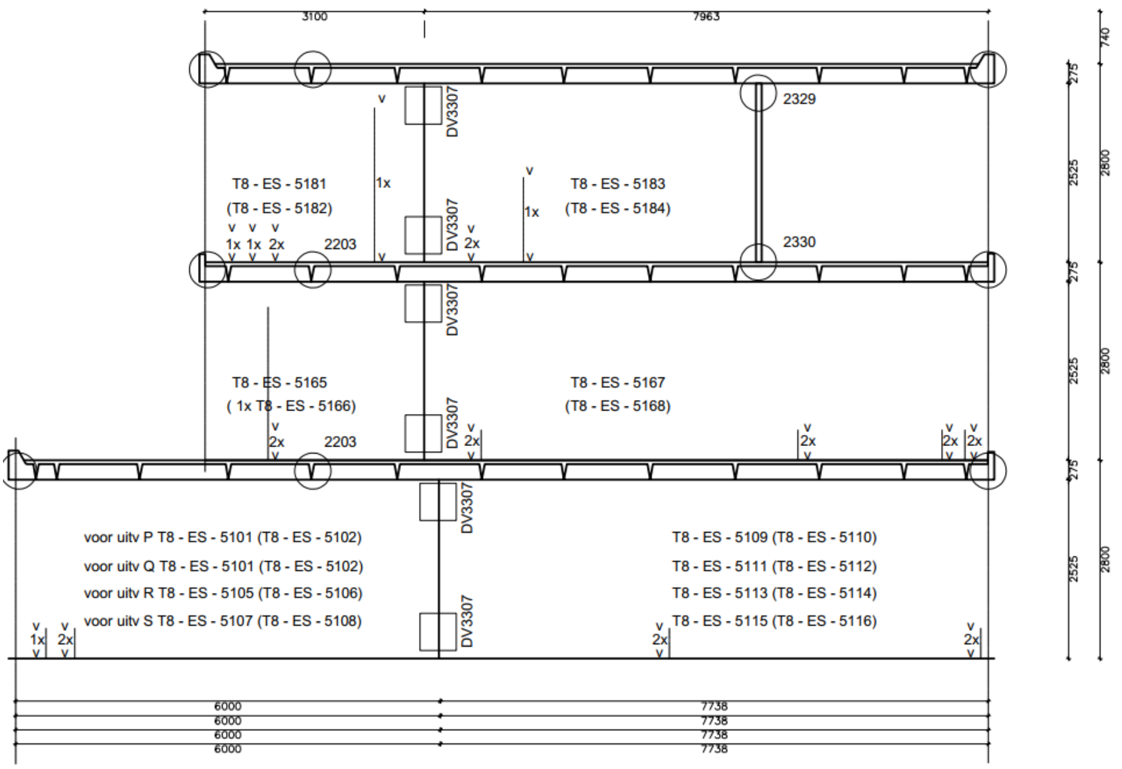

Figure 6. Section (other): End wall of all blocks, Amsterdam (Source: TUDELFT)

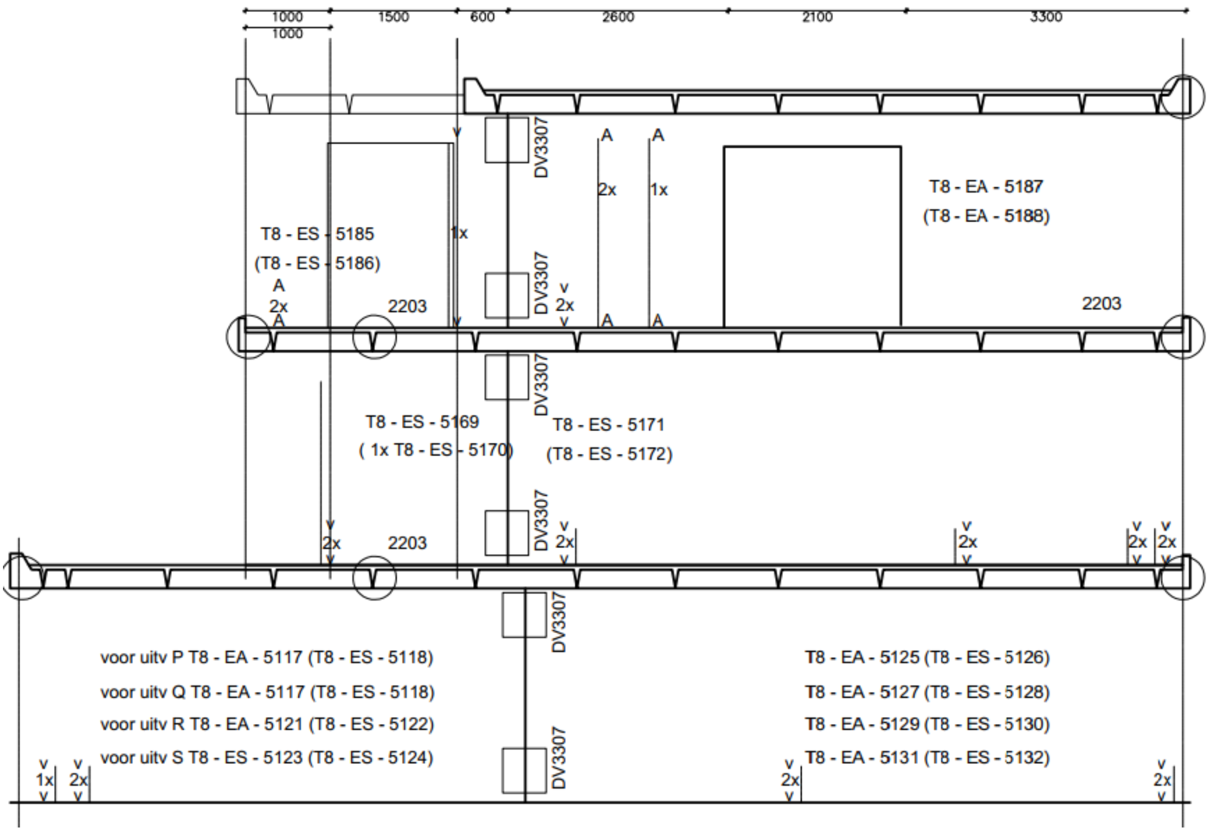

Figure 7. Section (other): Partition wall, Amsterdam (Source: TUDELFT)

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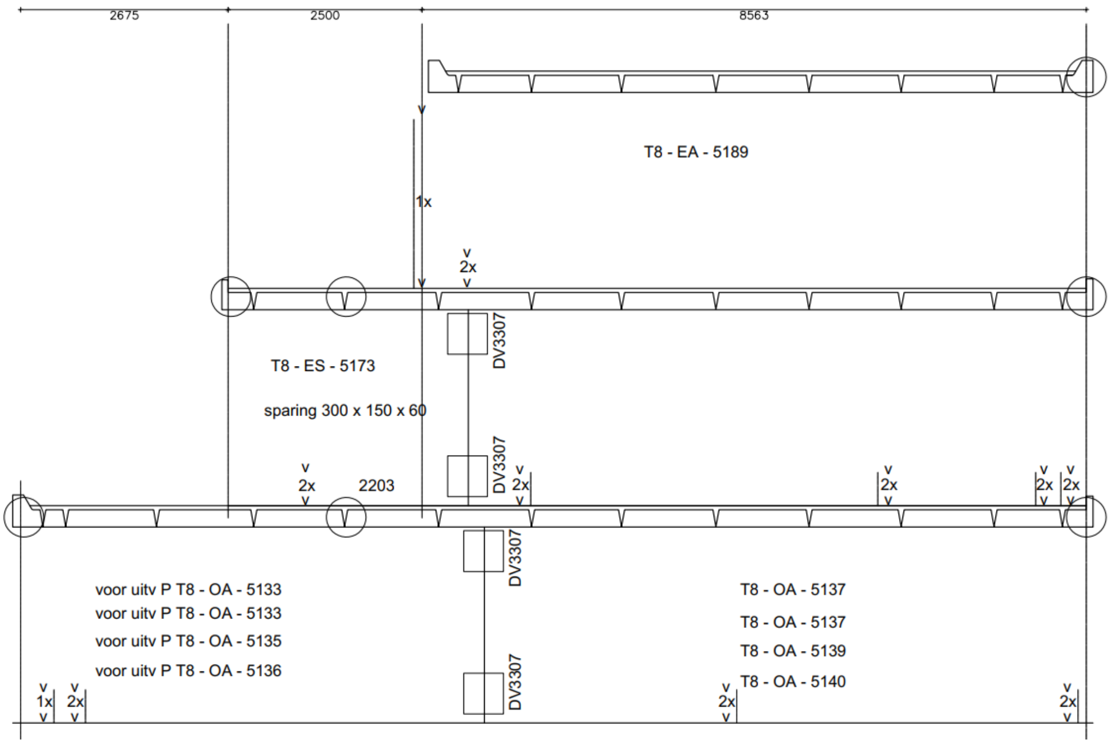

Figure 8. Section (other): Composition cross section, Amsterdam (Source: TUDELFT)

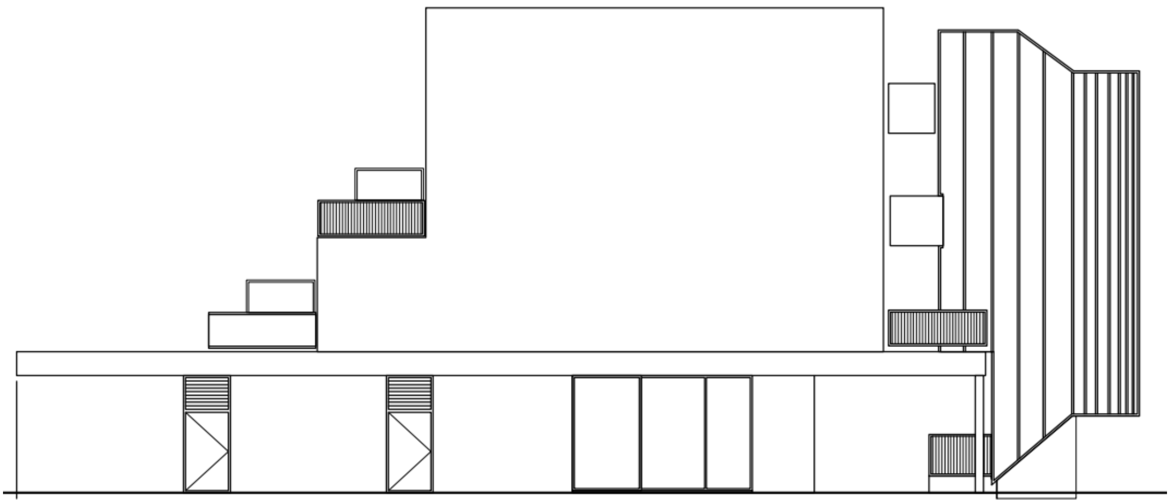

Figure 9. North façade, Building A5, Reigersbos, Amsterdam (Source: TUDELFT)

Figure 10. West façade, Building A5, Reigersbos, Amsterdam (Source: TUDELFT)

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3. Virtual Building 3, Milano

3.1. Thermal characteristics

The façade layout of the Milano building is composed of (1) plaster, (2) brick masonry, (3) cavity, (4) brick masonry, and (5) plaster.

Furthermore, the roof layout consists of (1) plaster, (2) brick slab, and (3) mat.

Table 1: Thermal characteristics of the envelope, Milano, Italy (Source: CIVIESCO)

Layer	Layer 1	Layer 2	Layer 3	Layer 4	Layer 5
Façade 01					
Material name	plaster	brick masonry	cavity	brick masonry	plaster
Thickness [m]	0.020	0.080	0.200	0.120	0.020
Conductivity [W/mK]	0.400	0.400	1.111	0.387	0.900
Façade 02					
Material name	plaster	brick masonry	cavity	brick masonry	plaster
Thickness [m]	0.020	0.080	0.200	0.120	0.020
Conductivity [W/mK]	0.400	0.400	1.111	0.387	0.900
Façade 03					
Material name	plaster	brick masonry	cavity	brick masonry	plaster
Thickness [m]	0.020	0.080	0.200	0.120	0.020
Conductivity [W/mK]	0.400	0.400	1.111	0.387	0.900
Façade 04					
Material name	plaster	brick masonry	cavity	brick masonry	plaster
Thickness [m]	0.015	0.080	0.200	0.120	0.015
Conductivity [W/mK]	0.400	0.400	1.111	0.387	0.900
Roof					
Material name	plaster	brick slab	mat		
Thickness [m]	0.010	0.200	0.080		
Conductivity [W/mK]	0.900	0.660	0.300		

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- **Energy parameters**

Table 2: Energy parameters, Milano, Italy (Source: CIVIESCO)

ENERGY PARAMETERS	
Energy consumption [kWh/m² year]	185.22
Air-Conditioned Floor Surface [m²]	3706
Air-Conditioned Volume [m³]	11118
Façade Total surface [m²]	3380
Windows no.	245
Window-To-Wall ratio [%]	16%
Energy Cost (Gas & Electricity) [€/year]	Gas: € 30,000.00
	Electricity
Clearance height overhead [m]	42.9
Climatic zone	E
Compactness. V/A [m³/m²]	**2.49**

***Data of Table 2 are based on assumptions made through the analysis of previous energy retrofit interventions carried out on other buildings of the complex with the same characteristics. These data will be verified through an additional energy modelling that will be carried out in the following months.**

- **Envelope characteristics**

Table 3: Envelope characteristics and estimation of the energy generated, Milano, Italy (Source: CIVIESCO)

	Façade 01	Façade 02	Façade 03	Façade 04	Roof
Orientation	North-East	Nord-West	South-East	South-West	
Degrees	45	315	135	225	
Structure (Light-Medium-Heavy)	Medium	Medium	Medium	Medium	Medium
External or Internal	External	External	External	External	Internal
Surface [m²]	939	1056	815	826	410
PV Surface [m²]	798.15	929.28	684.6	677.32	
Windows no.	42	61	73	54	
Window-To-Wall ratio	15%	12%	16%	18%	0%
U value [W/(m² K)]	1.054	1.054	1.054	1.054	1.848
g factor [-]					

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Shaded by other buildings? (YES or NOT)	NO	YES	YES	NO	
Average size of windows. Width by Height [m]	1,3 x 2,05	1,3 x 2,05	1,3 x 2,05	1,3 x 2,05	
Energy generated [kWh/year] PV	91307	105837	45999	45239	
Energy generated [kWh/year] Solar Thermal	244.04	246.66	389.21	402.81	613.92
Energy generated [kWh/year] PVT	181.77	190.61	257.15	275.55	388.65

***Data of Table 3 are based on assumptions made through the analysis of previous energy retrofit interventions carried out on other buildings of the complex with the same characteristics. These data will be verified through an additional energy modelling that will be carried out in the following months.**

Degrees. Not only indicate north, south, east and west, but also consider the degrees. According to this scale; 0º for north, 90 east, 180º south, 270º west.

Notes:

All data from Kamel Solar are based on software T*SOL 2018, regarding the weather conditions from Meteo Syn for Milano, Italy with yearly solar radiation of 1125.699 kWh/m2.

On the roof the panels are south oriented on 35 degrees angle.

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3.2. Additional plans

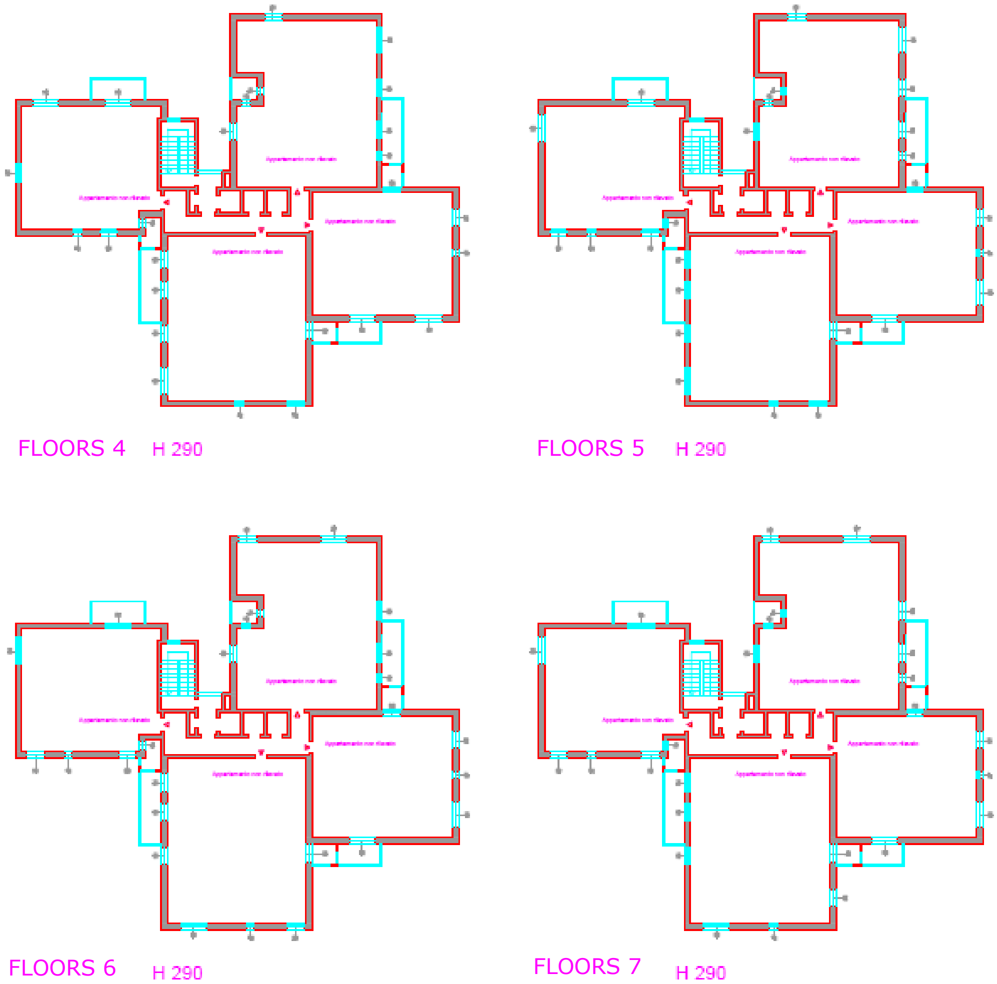

Figure 11. 4-7 floor and roof plans, Via Valsesia, Milano, Italy (Source: CIVIESCO)

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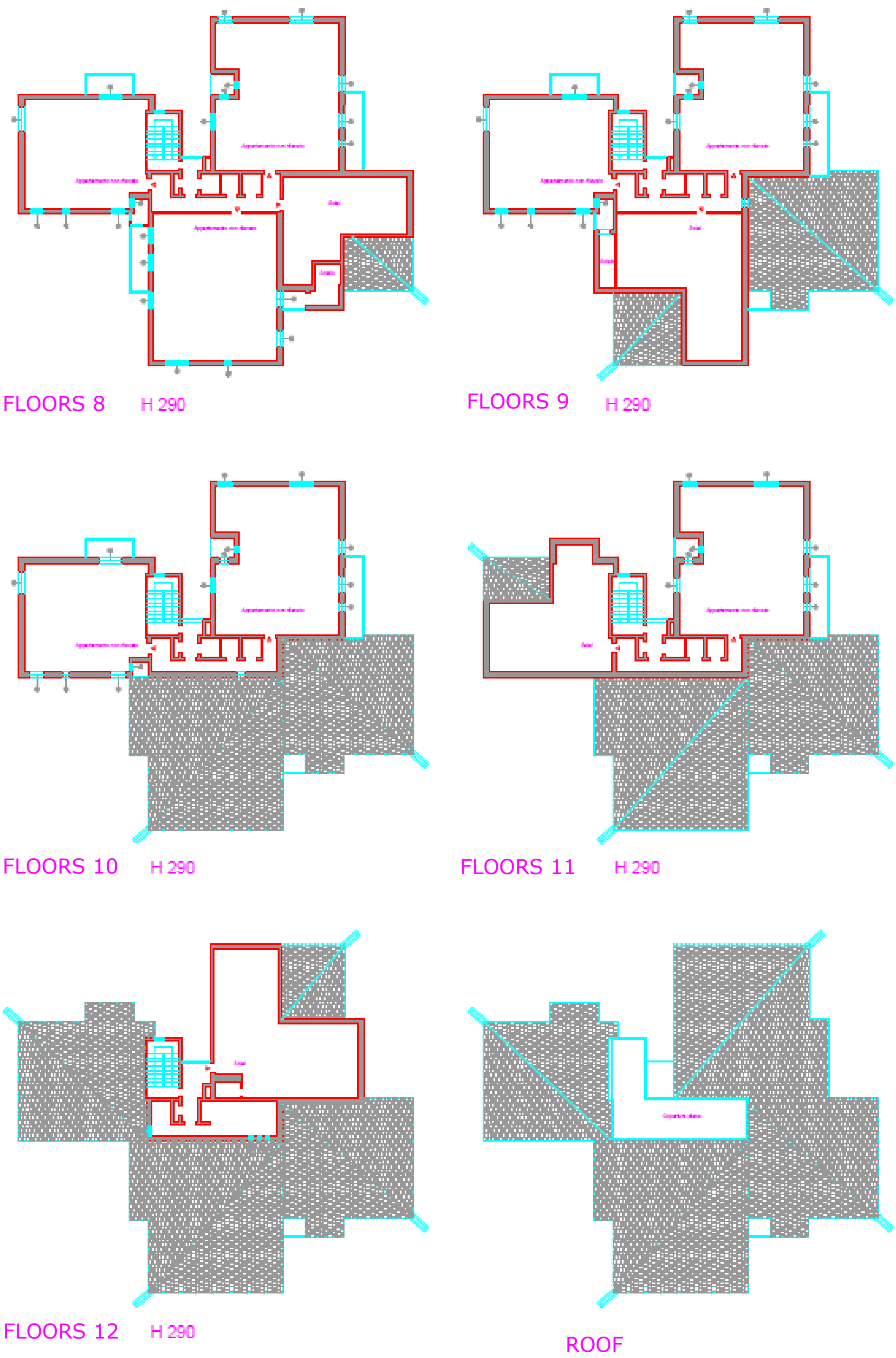

Figure 12. 8-12 floor plans and roof, Via Valsesia, 50, Milano, Italy (Source: CIVIESCO)

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research and innovation programme under grant agreement n° 958445

3.2. Automated Modulation Design

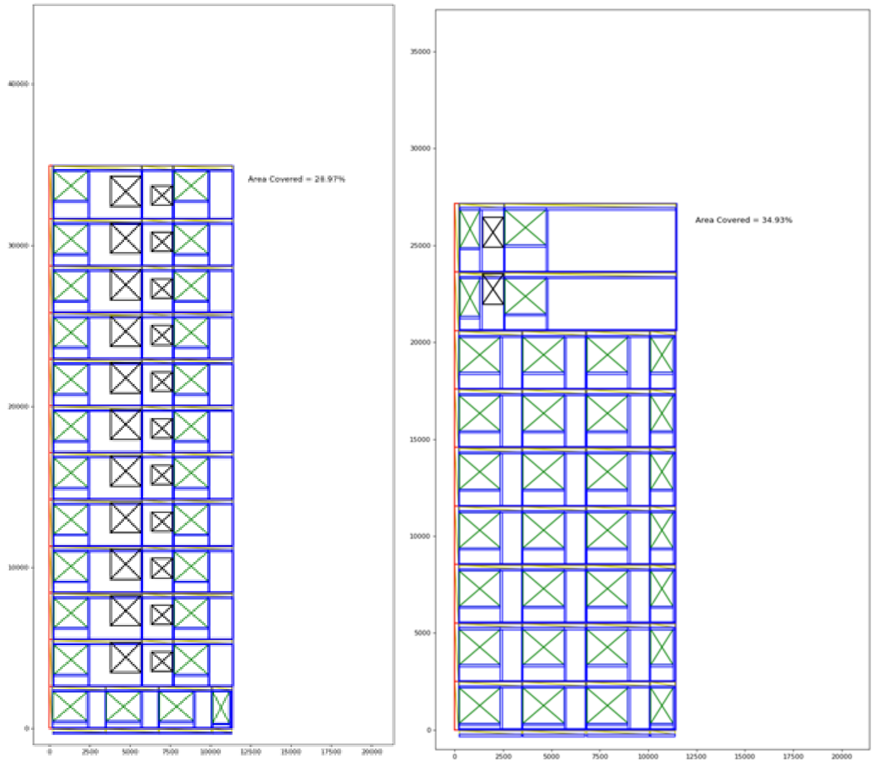

Figure 13. Automated modulation and total area for solar panels (Source: TUM)

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Appendix C: Planning

1. Meeting schedule

DEMO & VIRTUAL MEETINGS SCHEDULE 2022

TYPE	PARTNER	TOPIC	TASK	MEMBERS	WEEK - DAY	02/14	02/15	02/21	02/28	03/07	03/14	03/21	03/28	04/04	04/11	04/18	04/25	05/02	05/09	05/16	05/23	05/30	06/06	06/13	06/20	06/27	07/07	07/17	07/27
DEMO	TARTU	DEMO BUILDING UPDATE	T7.1	ABUD,IESS, TEC, RIVENTI,ONYX, TARTU	WEDNESDAY	Official				03/09	03/16	03/23	03/30	04/06	04/13	04/20	04/27	05/04	05/11	05/18	05/25	06/01	06/08	06/15	06/22	06/29	07/07	07/15	07/22
													M		M		M		M		M		B		B		M		B
					HOUR								10:30		10:30		10:30		10:30		10:30						13:00		
	SOFIA	DEMO BUILDING UPDATE	T7.1	ABUD,IESS,TEC, RIVENTI,ONYX, BAL	WEDNESDAY	02/24		03/03	03/06	03/10	03/17	03/24	03/31	04/07	04/14	04/21	04/28	05/05	05/12	05/19	05/26	06/02	06/09	06/16	06/23	06/30	07/07	07/14	07/22
						M		M		M			M		M		M		M		M		B		B		M		B
					HOUR	11:00		11:00		11:00			10:30		10:30		10:30		10:30		10:30						13:00		
	SASSA SCALO	DEMO BUILDING UPDATE	T7.1	ABUD,IESS,TEC, RIVENTI,ONYX, COAF	WEDNESDAY					03/10	03/17	03/24	03/31	04/07	04/14	04/21	04/28	05/05	05/12	05/19	05/26	06/02	06/09	06/16	06/23	06/30	07/07	07/14	07/22
													M		M		M		M		M		B		B		M		B
					HOUR								10:30		10:30		10:30		10:30		10:30						13:00		

PARTNER	WEEK - DAY	08/06	08/16	08/26	09/05	09/15	09/25	10/05	10/15	10/25	10/15	10/25	11/04	11/14	11/24	11/24	12/04	12/04	12/14	12/14	12/24	12/24	01/03	01/03	01/13	01/13
TARTU	WEDNESDAY	07/30	08/05	08/13	08/21	08/29	09/06	09/14	09/28	10/06	10/06	10/12	10/19	10/26		11/03	11/10	11/17	11/16	11/23	11/24	12/01	12/08	12/10	12/13	12/15
			M		B		B		M		M		M			M			M		MP		MP		MP	
	HOUR		10:00						11:00		10:00		10:00			14:00			GA						D7.1	
SOFIA	WEDNESDAY	07/29	08/05	08/12	08/19	08/26	09/02	09/09	09/28	10/05	10/12	10/14	10/19	10/22	10/26	10/29	11/10	11/17	11/16	11/23	11/24	12/01	12/08	12/10	12/13	12/15
			B		B		B		M		NA		M		M		M		M		MP		MP		MP	
	HOUR								11:00				11:00		10:00		10:00		GA						D7.1	
SASSA SCALO	WEDNESDAY	07/29	08/05	08/12	08/19	08/26	09/02	09/09	09/16	09/23	10/13	10/15	10/17	10/19	10/26	10/28	11/09	11/16	11/16	11/23	11/24	12/01	12/08	12/10	12/13	12/15
			B		B		B		NA		M				M		M		M		MP		MP		MP	
	HOUR										###				11:00		11:00		GA						D7.1	

M	MEETING DONE
MP	MEETING PLANNED
NM	NO ATTENDANCE
B	SUMMER BREAK
GA	GENERAL ASSEMBLY

Figure 1. Demo & Virtual Meetings Schedule 2022 (Source: ABUD)

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2. Data management and planning for Tartu demo building

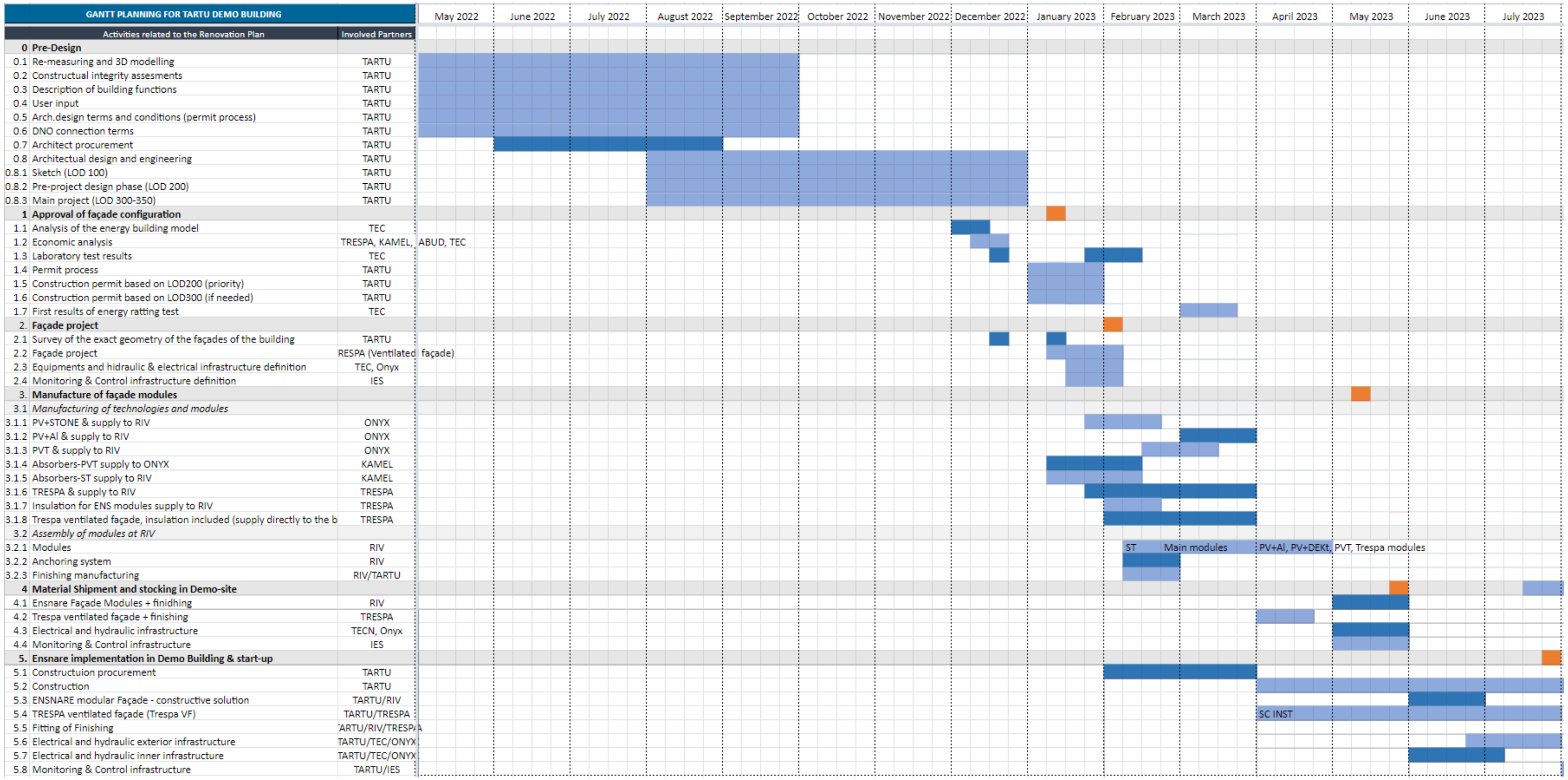

Figure 2. GANTT Planning for TARTU demo building (Source: ABUD - TECNALIA)

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DEMO & VIRTUAL BUILDINGS													
PARTNER	PHASE	FOLDER	VP TASK	File name	Description	LINK	SUBFOLDER	LINK	RECEIVER	VHEN	DEADLINE	STATUS	NOTE
CONCEPT PHASE													
TARTU	CONCEPT DESIGN	Diagnosis Report	WP7_T7.1_ABUD	DESIGN PHASES	Design Phases schedule of the renovation process	https://docs.google.com/spreadsheets/d/13L4cQ15uqq20b-PCf62vj3rrB50XZQIEJuszzDOF			WP7_ABUD	07.06.2022	10.12.2022	COMPLETE	To upload the last version to emdesk by Ainur
				DIAGNOSIS REPORT	Status of the buidling. Including presentation with actual photos and drawings .	https://emdesk.eu/cms/?p=334&hash=c9sZGVyOzQ0MzQ1cmVkaXJIY3Q7Zma			WP7, WP3, WP5	30.04.2022	09.09.2023	COMPLETE	The report includes the description of the building and pictures of the internal and external walls
		Prelimnary Design_WP3_WP5	WP3_TEC	Table of requirements for the pilots	Wall layers, slab distance, Beam perimeter	https://emdesk.eu/cms/?p=334&hash=3vYWQ7bGF0ZXN0OzMzMDM2NAlIZG93bmxd	2D_Section	https://emdesk.eu/cms/?p=334&hash=5OzMzMDU2OOnnZG93bmxyY	WP7, WP3, WP6	30.04.2022	10.07.2022	COMPLETE	
			WP5_RIVENTI	FAÇADE DETAILS	2D drawings and strcutural details		Technical System Parameters for all pilots by RIVENTI	https://emdesk.eu/cms/?p=334&hash=17bGF0ZXN0OzMzNTIxOOIIZG93bm	WP7, WP3,WP5	30.04.2022	01.08.2022	COMPLETE	Same inputs for all the pilots
				Preliminary Modulation Design	Preliminary design of the façade modulation. The system development includes the exercise of modulation made by RIVENTI and ENAR	https://emdesk.eu/cms/?p=334&hash=em9sZGVyOzQ1MDk1cmVkaXJIY3Q7Z3	Updated version	https://emdesk.eu/cms/?p=334&hash=1F0ZXN0OzMzNTMwNwnnZG93bmxyYWQ7bGd	WP7, WP3,WP6, WP2	30.04.2022		COMPLETE	Not an updated version
			WP7_ABUD	Solar analysis				https://emdesk.eu/cms/?p=334&hash=bF0ZXN0Oz		01.11.2022		COMPLETE	
		Building system_WP4	WP4_IESS	Building system requirements	Inputs required by IESS	https://emdesk.eu/cms/?p=334&hash=6GF0ZXN0OzMzMzgwNgnnZG93bmxyYWQ7bf				19.10.2022		IN PROGRESS	
		2D_3D FILES	TARTU ARCHITECTS	Plans and available drawings	Autocad drawings, PDF and 3D model	https://emdesk.eu/cms/?p=334&hash=7ZXN0OzMzMzc5MQnnZG93bmxyYWQ7bGF04				07.11.2022		COMPLETE	

Figure 3. Data management during Concept phase for TARTU demo building (Source: ABUD)

This project has received funding from European Union's Horizon 2020 research and innovation programme under grant agreement n° 958445

3. Data management and planning for Sofia demo building

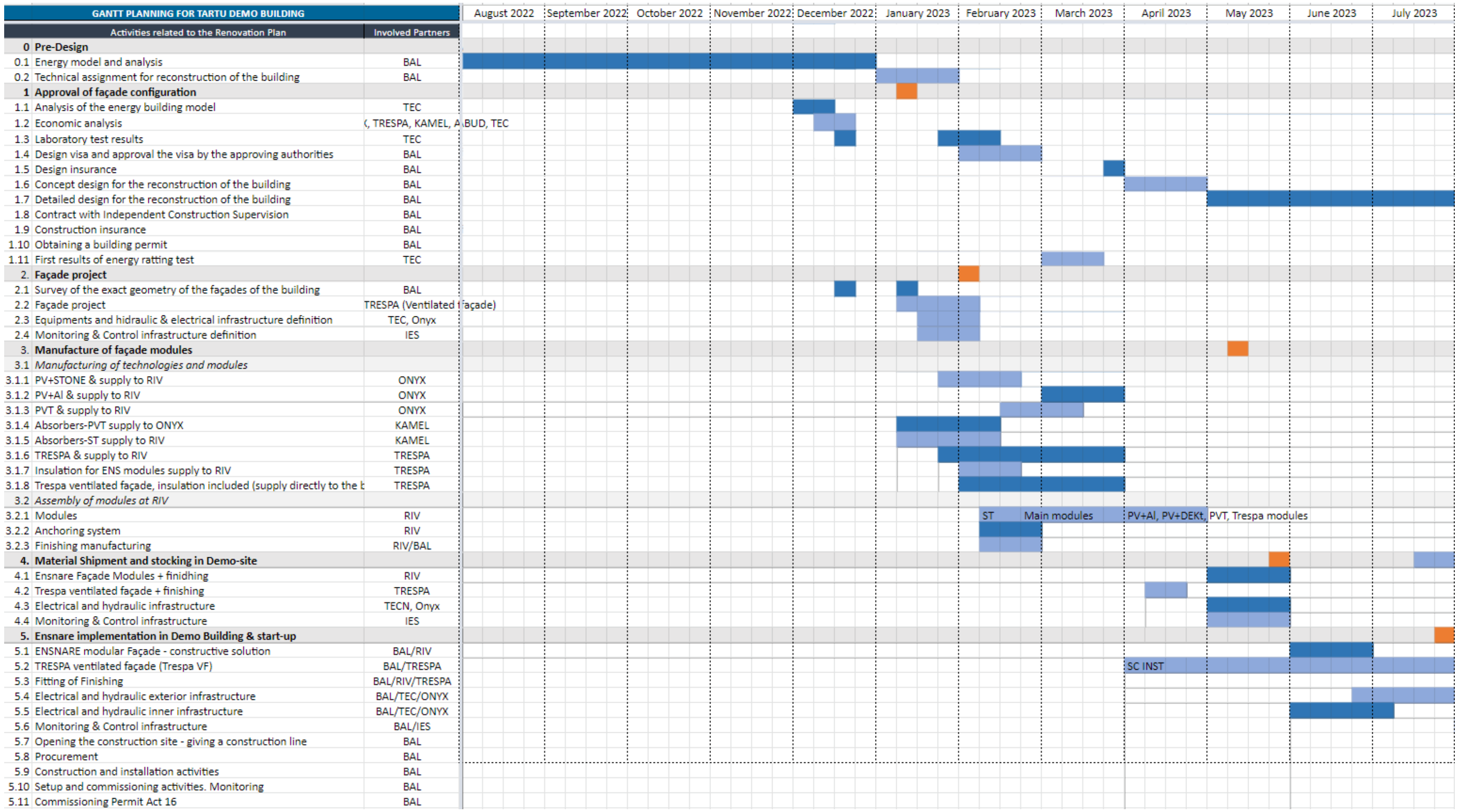

Figure 4. GANTT Planning for SOFIA demo building (Source: ABUD - TECNALIA)

This project has received funding from European Union's Horizon 2020 research and innovation programme under grant agreement n° 958445

	PARTNER	PHASE	FOLDER	WP TASK	File name	Description	LINK	SUBFOLDER	LINK	RECEIVER	WHEN	DEADLINE	STATUS	NOTE
							DEMO & VIRTUAL BUILDINGS							
DEMO	BAL	CONCEPT DESIGN	Diagnosis Report	WP7_T7.1_ABUD	DESIGN PHASES	Design Phases schedule of the renovation process	https://docs.google.com/spreadsheets/d/13L4cQ15uqq20b-PCf62vj3rrB50XZQIEJuszzDOF9rc/edit#gid=595216935			WP7_ABUD	07.06.2022	10.12.2022	COMPLETE	To upload the last version to emdesk by Ainur
					DIAGNOSIS REPORT	Status of the buidling. Including presentation with actual photos and drawings . (PART 1 AND PART 2)	https://emdesk.eu/cms/?p=334&hash=9MzMDQ3NAnnZG93bmxvYWQ7bGF0ZXN0Oz1			WP7, WP3, WP5	07.07.2022	09.09.2022	COMPLETE	The report includes the description of the building and pictures of the internal and external walls.
							https://emdesk.eu/cms/?p=334&hash=d7bGF0ZXN0OzMzMDQ3NgnnZG93bmxvYWQd			WP7, WP3,WP3	07.07.2022	09.09.2022	COMPLETE	The report includes the description of the building and pictures of the internal and external walls.
			Prelimnary Design_WP3_WP5	WP3_TEC	Table of requirements for the pilots	Wall layers, slab distance, Beam perimeter	https://emdesk.eu/cms/?p=334&hash=fXN0OzMzMDc3OAIlZG93bmxvYWQ7bGF0Za			WP7, WP3,WP5	07.07.2022	01.08.2022	COMPLETE	
				WP7_ABUD	Solar analysis		https://emdesk.eu/cms/?p=334&hash=e0OzMzMzUwMA--ZG93bmxvYWQ7bGF0ZXNe		https://emdesk.eu	WP7, WP3,WP5	26.11.2022		COMPLETE	
				WP5 _RIVENTI	FAÇADE DETAILS	2D drawings and structural details. Higher level of detail.	https://emdesk.eu/cms/?p=334&hash=4GF0ZXN0OzMzMDQ2NAIlZG93bmxvYWQ7ba		https://emdesk.eu/cms/?p=334&hash=e7bGF0ZXN0OzMzNTI4NQ--	WP7, WP3,WP5	07.07.2022	01.08.2022	COMPLETE	
					Preliminary Modulation Design	Preliminary design of the façade modulation. Modulation Exercise by ABUD	https://emdesk.eu/cms/?p=334&hash=2vYWQ7bGF0ZXN0OzMzMDU4MgnnZG93bmxf		https://emdesk.eu	WP7, WP3,WP6	06.06.2022	01.08.2022	COMPLETE	
			Building system_WP4	WP4_IESS	Building system requirements	Inputs required by IESS_2021	https://emdesk.eu/cms/?p=334&hash=dZGVyOzQ0OTUzcmVkaXJIY3Q7Zm9sf	INPUTS_2022		WP4,WP5	07.11.2022		IN PROGRESS	
			2D_3D FILES	BAL ARCHITECTS	Plans and available drawings	Autocad drawings_Sections	https://emdesk.eu/cms/?p=334&hash=bXN0OzMzMzg5MAIlZG93bmxvYWQ7bGF0Z2	Google drive link_2D and 3D point cloud	https://drive.google.com/drive/folders/1aGNimPEkY5Lz9-uFWUA1LFqD_4qr	WP3,WP5,WP2,WP7	07.11.2022		COMPLETE	Completed 3D laser scan of the house in Boyana, Sofia.

Figure 5. Data management during Concept phase for SOFIA demo building (Source: ABUD)

This project has received funding from European Union's Horizon 2020 research and innovation programme under grant agreement n° 958445

4. Data management and planning for Sasso Scalo demo building

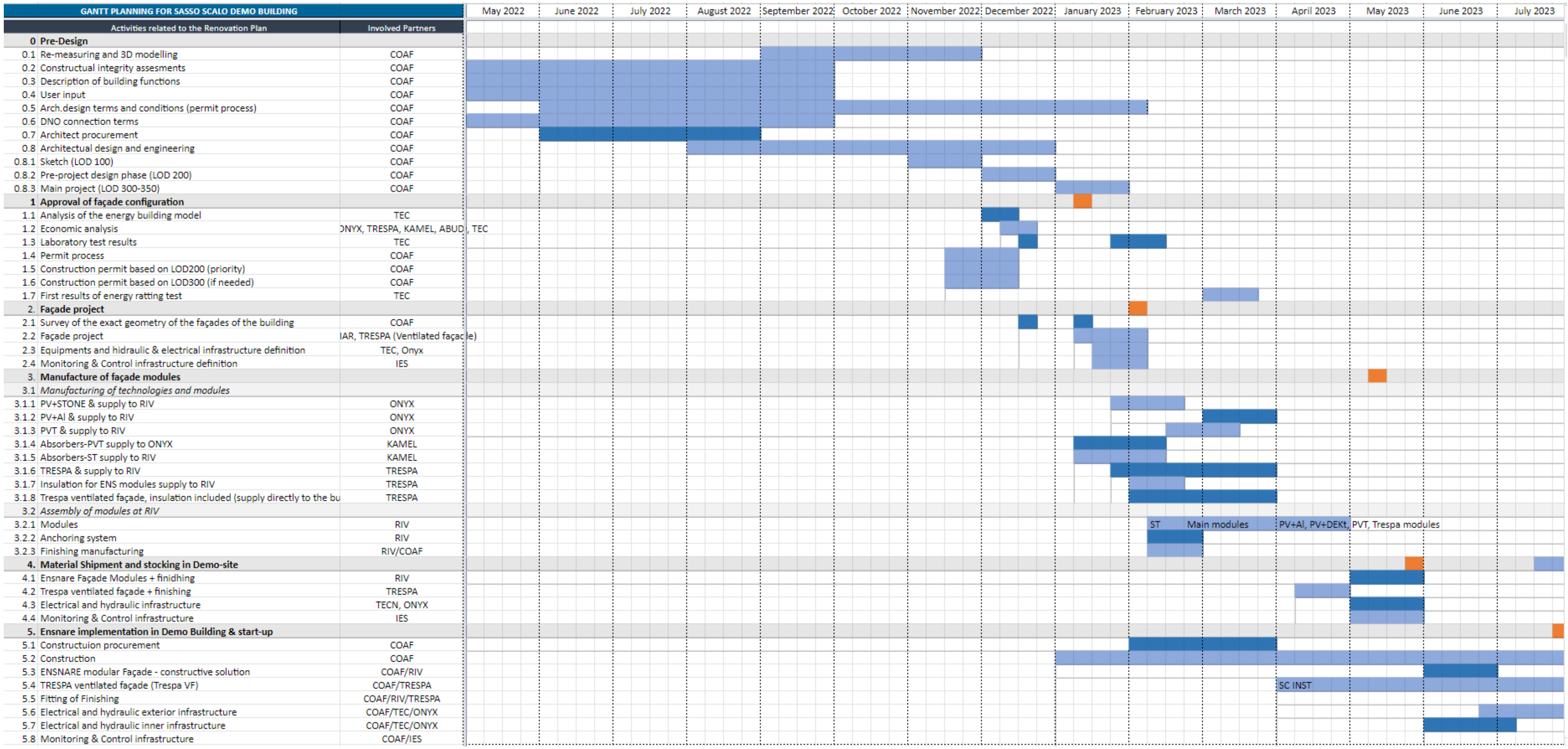

Figure 6. GANTT Planning for SASSO SCALO demo building (Source: ABUD - TECNALIA)

This project has received funding from European Union's Horizon 2020 research and innovation programme under grant agreement n° 958445

DEMO & VIRTUAL BUILDINGS														
	PARTNER	PHASE	FOLDER	VP TASK	File name	Description	LINK	SUBFOLDER	LINK	RECEIVER	VHEN	DEADLINE	STATUS	NOTE
DEMO	COAF	CONCEPT DESIGN	Diagnosis Report	WP7_T7.1_ABUD	DESIGN PHASES	Design Phases schedule of the renovation process	https://docs.google.com/spreadsheets/d/13L4cQ15uqq20b-PCf62vi3rrB50YZQIE_JuszzDQE			WP7_ABUD	07.06.2022	10.12.2022	COMPLETE	To upload the last version to emdesk by Ainur
					DIAGNOSIS REPORT	Status of the buidling. Including presentation with actual photos	https://emdesk.eu/cms/?p=334&hash=1bmxvYWQ7bGF0ZXN0OzMzMDQ4MqlIZG935			WP7, WP3, WP5	5,2022	09.09.2022	COMPLETE	The report includes the description of the building and pictures of the internal and
			Prelimnary Design_WP3_WP5	WP3_TEC	Table of requirements for the pilots	Wall layers, slab distance, Beam perimeter	https://emdesk.eu/cms/?p=334&hash=4GF0ZXN0OzMzMDU0MAnnZG93bmxvYWQ7b4				30.04.2022	10.07.2022	COMPLETE	
				WP5 _RIVENTI	FAÇADE DETAILS	2D drawings and strcutural details. Higher level of detail.		Wall Details	https://emdesk.eu/cms/?p=334&hash=0F0ZXN0OzMzMD	WP7, WP3,WP5	07.07.2022	01.08.2022	COMPLETE	
						Façade clarifications and questions provided by RIVENTI	https://emdesk.eu/cms/?p=334&hash=1GF0ZXN0OzMzMDQ5NAllZG93bmxvYWQ7bc		https://emdesk.eu/cms/?p=334&hash=aQ7bGF0ZXN0Oz		07.07.2022	01.08.2022	COMPLETE	
					Preliminary Modulation Design	Preliminary design of the façade modulation. Modulation Exercise by ABUD	https://emdesk.eu/cms/?p=334&hash=6GF0ZXN0OzMzMzMxNwllZG93bmxvYWQ7b9		https://emdesk.eu	WP7, WP3,WP6	26.10.2022		COMPLETE	
					Design Option_ENAR	Design Option 1	https://emdesk.eu/cms/?p=334&hash=87bGF0ZXN0OzMzMzM4NA--ZG93bmxvYWQ8	Model version	https://emdesk.eu/cms/?p=334&hash=amxvYWQ7b				COMPLETE	https://emdesk.eu/cms/?p=334&hash=eOzMzNTI3OQnnZG93bmxvYWQ7bGF0ZXN06
				WP7_ABUD	Solar analysis		https://emdesk.eu/cms/?p=334&hash=eXN0OzMzNDk3NgnnZG93bmxvYWQ7bGF0Z8						COMPLETE	
			Building system_WP4	WP4_IESS	Building system requirements	Inputs required by IESS	https://emdesk.eu/cms/?p=334&hash=0lY3Q7Zm9sZGVyOzQ1MTAxcmVkaXJ8			WP3,WP4	26.10.2023		IN PROGRESS	
			2D_3D FILES	COAF ARCHITECTS	Plans and available drawings	Autocad drawings, PDF and 3D model	https://emdesk.eu/cms/?p=334&hash=67Zm9sZGVyOzQ1MTExcmVkaXJlY3Qe		https://emdesk.eu/cms/?p=334&hash=9XN0OzMzN	WP3,WP5,WP7	26.10.2023		COMPLETE	

Figure 7. Data management during Concept phase for SASSO SCALO demo building (Source: ABUD)

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