e-SAFE

DELIVERABLE REPORT

WP5 Demonstration activities

D5.2

REPORT WITH THE PRELIMINARY CO-DESIGN OUTCOME

Due date

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☐ DEM – Demonstrator
☐ DEC – Websites, patents filling, videos, etc.
☐ OTHER
☐ ETHICS – Ethics requirement
☐ OPRP – Open Research Data Pilot
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EXECUTIVE SUMMARY

The present document is the Deliverable "D5.2 – Report with the preliminary co-design outcome" of the **e-**SAFE project (Grant Agreement No. 893135), funded by the European Commission under its Horizon 2020 Research and Innovation Programme (H2020).

The document describes the preliminary co-design activities that led to the preliminary design of the pilot building in Via Acquicella Porto 27/H in Catania (Italy) within the **e-**SAFE project. The document also reports the outcomes of the co-design process regarding architectural, technological, structural issues, and the thermal systems. **e-**SAFE experts and local stakeholders have contributed to them, each one for their own skills and needs.

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GLOSSARY OF TERMS

ACRONYM	DESCRIPTION
ASHRAE	American Society of Heating, Refrigerating and Air-Conditioning Engineers
CLT	Cross-Laminated Timber
COP	Coefficient of Performance
DHW	Domestic Hot Water
DSS	Decision Support System
IACP	Istituto Autonomo Case Popolari
IWEC	International Weather for Energy Calculation
PC	Project Coordinator
RC	Reinforced Concrete
ToF	Time of Fly
TLS	Terrestrial Laser Scanning
WP	Work Package

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1. INTRODUCTION

This document describes data collection and the preliminary activities aimed to perform the co-design process for the renovation of the pilot building in Catania (Italy). The co-design process, which led to the definition of the preliminary version of the renovation design, involved local stakeholders, i.e. the residents of the pilot building: they provided the primary data for understanding the needs of the building in terms of energy consumption, environmental comfort, perception of safety related to earthquakes, satisfaction for functional performance, level of maintenance and overall architectural aspect.

1.1 Deliverable structure

The deliverable starts with a brief summary of the tools and actions preparatory to the co-design process, partly anticipated in D5.1 "Detailed Survey of the Real Pilot" [1], as described in the section "Preliminary co-design process". The document is organised according to the following specific items that are preliminary to the definition of the joint project:

- the geometric survey after the removal of those elements non-conforming to the original design, which would have interfered with the application of **e-**SAFE technologies;
- the architectural solutions resulting from the validation of the expressive potential of **e-**SAFE technologies and the demands of the stakeholders;
- the preliminary design of the thermal systems;
- the details of **e-** SAFE technologies judged most suitable to the current state of the building and the needs of the inhabitants;
- the choice of structural solutions adapted to the geometric and structural reality of the pilot building.

1.2 Links with other tasks in the project

The results presented in this report are part of the "Demonstration activities" of WP5. They complete the work already presented in Task 5.1 and prepare that of Task 5.3 and Task 5.5.

1.3 Contribution of the partners

UNICT has conducted the coordination activities of the co-design process, starting with the involvement of the participants and their preliminary training. Different research groups participating in the **e-**SAFE project were involved: "Architectural Design" team (Sections 2 and 4); "Building Construction" team (Section 6); "Building Physics" team (Sections 5 and 7). Instead, the second phase of the geometric survey (Section 3) was subcontracted – as well as the first phase – to the Laboratory of Surveying and Representation of Kore University of Enna.
Partner IACP has contributed by actively participating in the co-design phases facilitating accessibility to the premises and contributing to preliminary preparation of the pilot building for subsequent project interventions.

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2. PRELIMINARY CO-DESIGN PROCESS

This section describes the participants, tools and activities preparatory to the co-design process.

2.1 Co-design participants and tools

The activities of the co-design process started with the involvement and participation of local stakeholders, such as: the inhabitants of the pilot building, including owners and tenants; the representatives of the Institute for Social Housing (Istituto Autonomo Case Popolari - IACP) of Catania, academic researchers, local professional associations (engineers and architects), relevant Trade Associations, Trade Unions and municipal administration.

The actions of involvement in the co-design process were conducted both by engaging the specific official participants and also by organizing meetings and public events open to all, citizens and professionals outside the project. This mode has allowed the **e-**SAFE approach to be shared and disseminated as well as refined and adapted to the specific needs of the case study.

Specifically, for the start of the co-design process, the representatives of IACP, which is the owner of 7 out of 10 apartments, played a mediating role. They were immediately willing to actively and concretely participate in the preliminary activities of the co-design process. This has made it easier to overcome some legitimate resistance and mistrust from the remaining owners and tenants. The Trade Associations, Trade Unions and municipal administration, on the other hand, played the role of attentive and interested spectators with respect to the reproducibility of the process and the versatility of the **e-**SAFE technologies. For the lack of immediate and direct interests, their role was only passive.

2.2 Co-design activities

Numerous meetings and campaign of surveys, preparatory to the co-design process, were carried out with the inhabitants of the pilot building to understand the census, the specific living habits and everything else that could have design implications. The bills certifying the electrical consumption have been collected. The technological devices, internal and external, for cooling and heating of the apartments have been recorded and reported on the drawings of the current state. Experts also detected the verandas on the balconies, and the changes made by the residents to the interior and the windows on the facades. All the fixtures and their state of preservation and function were verified and recorded.

With this wealth of data and information, a first phase of debate on the architectural design was started with the organisation of a workshop in which inhabitants of the pilot building participated, together with some local professional associations (engineers and architects). Workgroups comprised both young and experienced designers, inhabitants and owners of the pilot building and academics from UNICT. All phases of the workshop were carried out with the inhabitants who actively participated in the project choices, giving valuable indications, listing preferences, suggesting solutions, indicating criticalities, expressing concerns and advising activities.

To make the sharing of design choices more immediate and easier to understand, we used the tool of the physical model described in Deliverable D2.2 "3D physical and digital models of the real pilot". In addition, to better visualize with inhabitants these ideas we proceeded with photo voice, through which each resident gave voice to his/her aesthetic preference and chose one or more virtual images for the building.

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The workshop activities produced six design solutions realized and shared with all the participants in the process. In particular, with regard to the architectural image and the coating material of the **e-**SAFE panels, for each group the following proposals were produced:

- G1 solution: Perforated aluminium panels (Figures 1a, 1b, 1c, 1d);
- G2 solution: Glass Fiber Reinforced Concrete (GFRC) panels (Figure 2a, 2b, 2c, 2d);
- G3 solution: Wood Plastic Composite (WPC) panels (Figure 3a, 3b, 3c, 3d);
- G4 solution: Folded aluminium panels (Figure 4a, 4b, 4c, 4d);
- G5 solution: Glass Fiber Reinforced Concrete (GFRC) and Bricks (Figure 5a, 5b, 5c, 5d);
- G6 solution: Glass Fiber Reinforced Concrete (GFRC) panels (Figures 6a, 6b, 6c, 6d).

Figure 1a, G1: South elevation

Figure 1b, G1: North elevation

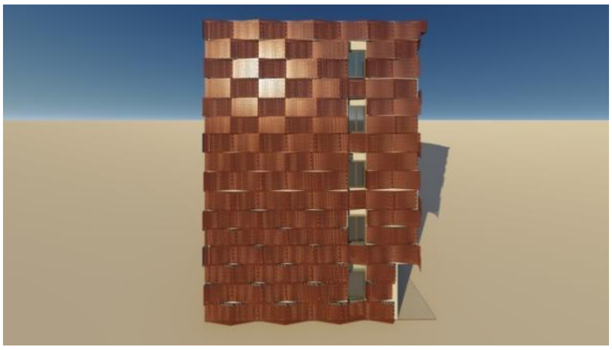

Figure 1c, G1: East elevation

Figure 1d, G1: North-east perspective

Figure 2a, G2: South elevation

Figure 2b, G2: North elevation

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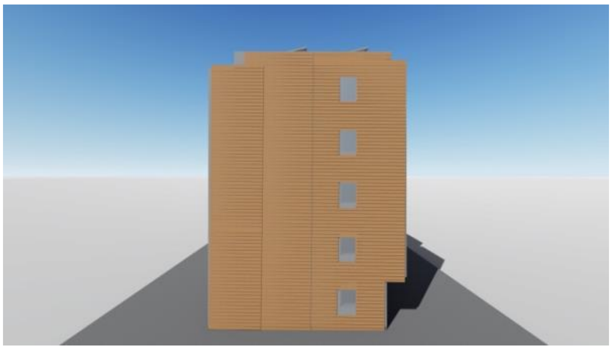

Figure 2c, G2: East elevation

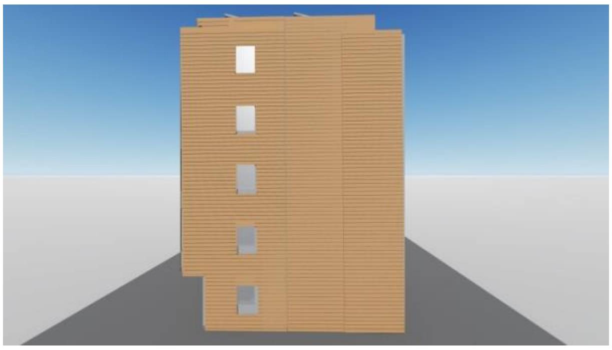

Figure 2d, G2: West elevation

Figure 3a, G3: South elevation

Figure 3b, G3: North elevation

Figure 3c, G3: East elevation

Figure 3d, G3: West elevation

Figure 4a, G4: South elevation

Figure 4b, G4: North elevation

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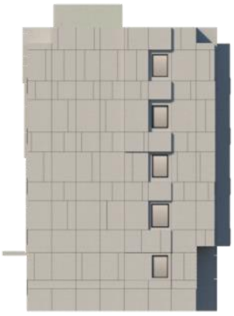

Figure 4c, G4: East elevation

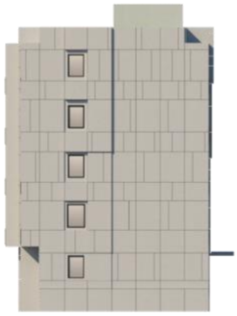

Figure 4d, G4: West elevation

Figure 5a, G5: South elevation

Figure 5b, G5: North elevation

Figure 5c, G5: East elevation

Figure 5d, G5: West elevation

Figure 6a, G6: South elevation

Figure 6b, G6: North elevation

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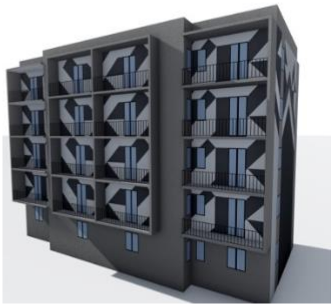

Figure 6d, G6: North-west perspective

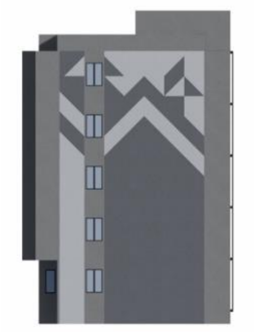

Figure 6d, G6: West elevation

All the design solutions developed during the workshop involve materials that are lightweight, resistant to corrosion and humidity, fire resistant, and have easy cleaning and maintenance, high energy and acoustic performance, high durability, and multiple chromatic possibilities and surface finish. Finally, all the project proposals offer the possibility of organically inserting new verandas. All solutions also show the possibility of inserting on the roof terrace a photovoltaic field for the supply of electricity.

The six project solutions completed at the end of the workshop, although realized in sharing with the inhabitants, have been subjected to a survey among them with the aim of collecting further information on architectural suggestions and technological solutions. They are considered for the subsequent phase of the co-design aimed at the drafting of the final project.

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3. PRELIMINARY CO-DESIGN: THE GEOMETRIC SURVEY

This section aims at describing the second phase of the survey campaign, conducted after the removal of the existing verandas. Thus, the analysis was focused mainly on the south front that had the verandas. The survey of the other fronts, which had no changes, remained the same as already presented in Deliverable D5.1 [1].

3.1 Second phase of survey campaign

As stated in the previous Deliverable 5.1, the second phase of the survey campaign began after the demolition of the existing verandas on the south-facing balconies. To this purpose, using the same approach as in phase I, the survey covered every single balcony on the south front of the pilot building that was affected by the recent changes. This in-situ activity was carried out in April and May 2022.

By merging, registering and updating the new geometric data of the south façade, it was possible to derive a single three-dimensional model, with high density and realistic colour data, of the four fronts of the building. The model was further processed, cleaned up and appropriately oriented, in order to obtain an updated restitution, in CAD environment, of the above-mentioned front.

Below, the images of the updated point cloud, the ortho-projection of the south front of the point cloud, and the corresponding graphic restitution.

Figure 7: 3D views of the updated point cloud model without verandas.

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Figure 8: The south front of the pilot building.

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4. ARCHITECTURAL CO-DESIGN

This section aims at describing the different solutions about the architectural quality of the project declined through the verification of both the expressive potential of **e-**SAFE technology and the demands of the stakeholders.

The section is organized according to the different aspects considered during architectural co-design process: a summary description of the current state; the delineation of a preliminary architectural design; the activities carried out during the last residents' meeting; the definition of the architectural detail design.

4.1 Summary description of the current state

As stated in the previous Deliverable 5.1 "Detailed Survey of the Real Pilot" [1], the Pilot building has a tower structure and borders to the north with via Acquicella Porto; to the west with an adjacent area five meters away; to the south with an inner courtyard; to the east with an adjacent common area.

The tower has five storeys and several projecting balconies. There are two flats per floor for a total of ten apartments. The raised ground floor is more than 1,00 m above ground level. All levels are accessed via a central staircase located on the south side that leads to the terrace floor.

The architectural and physical aspect of the pilot building is very clear: a simple box shape. It consists of a regular and axially symmetrical prism. Thus, to complete the external volume, there are some loggias, namely protruding panels that frame the different floors. Currently, the façade colour tone is very light. Several external fixtures are double-glazed door windows. Shading devices mainly consist of roller shutters. Balcony railings are made of metal and thin bars. The parapet of the roof terrace is on the same plane of the exterior wall. Other elements affecting the appearance of the building are: the external air-conditioning units; some parabolic antennas; the exhaust air extractors; gas pipelines and electrical and telephone wiring.

The two apartments per floor have a similar internal distribution. The stairwell, that corresponds to the entrance to the building, is to the south and located at the centre between them. Each apartment comprises three bedrooms, a kitchen, a living/dining room, a bathroom and a laundry room and three balconies. All balconies are closed on the short sides to form loggias on the long façades of the building, to the north and to the south (from Figure 9 to Figure 16). The raised floor on the northern front, on via Acquicella Porto, has only some windows and there are no balconies. On the short fronts, east and west, there is a column of windows. Before the last geometric survey campaign, the external building image was strongly characterized by the presence of many "verandas" (i.e. a sort of greenhouse that close a balcony creating a sort of bow-window). During the investigation, in order to allow carrying out a more accurate geometric survey and co-design process, the verandas on the southern side were removed. Consequently, several criticalities emerged in this phase are resolved: these criticalities consist of a small misalignment of the windows between one floor and the other; at the ground level the difference between the southern and northern sides and dissimilar floor-to-ceiling heights.

Following the geometric survey conducted as described in Section 3, the laser scanner and photographic technology was able to outline more realistic dimensional characteristics of the pilot: covered area of 2330 m^2, uncovered surface area of 61 m^2; volume (from platform to gutter) equal to 3844 m^3; the height of 17.2 m on the south side and of 16,95 m on the north side; the floor-to-ceiling height equal to 3.11 m maximum and 2.88 m minimum.

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Figure 9: Distribution of ground floor apartments.

Figure 10: Distribution of apartments on the 1st floor.

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Figure 11: Distribution of apartments on the 2nd floor.

Figure 12: Distribution of apartments on the 3rd floor.

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Figure 13: Distribution of apartments on the 4th floor.

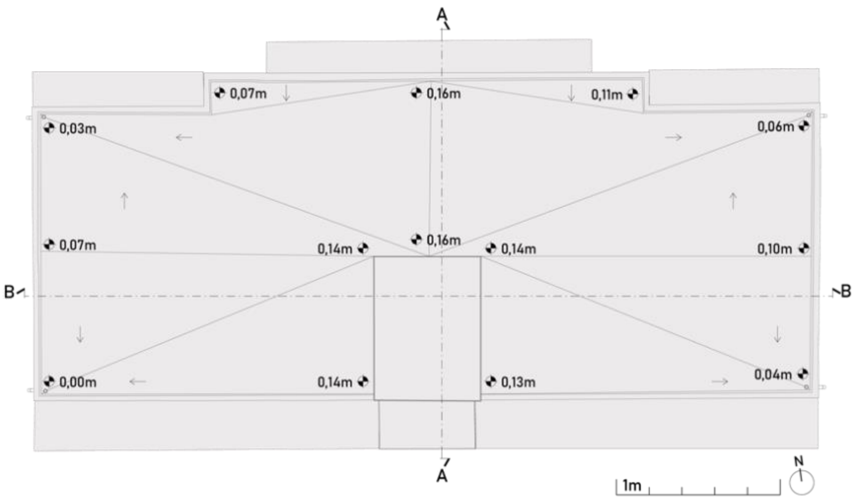

Figure 14: Terrace plan on the top.

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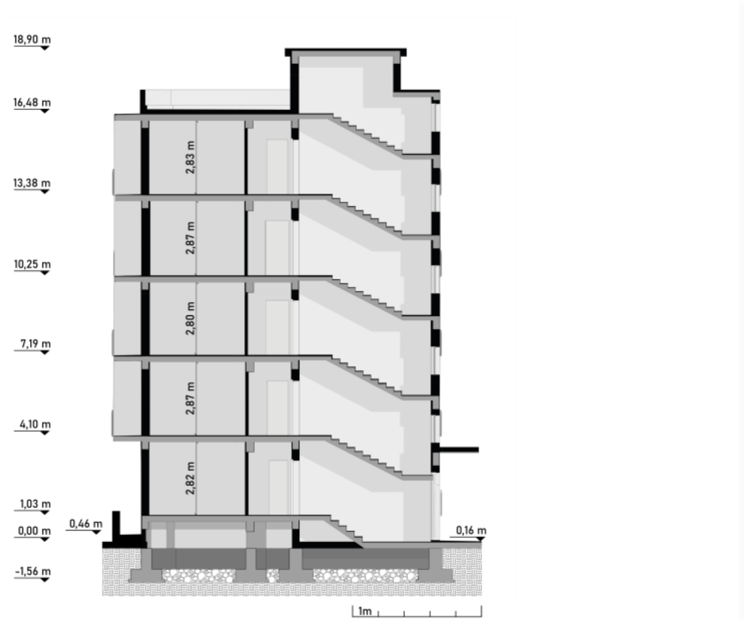

Figure 15: Section A-A.

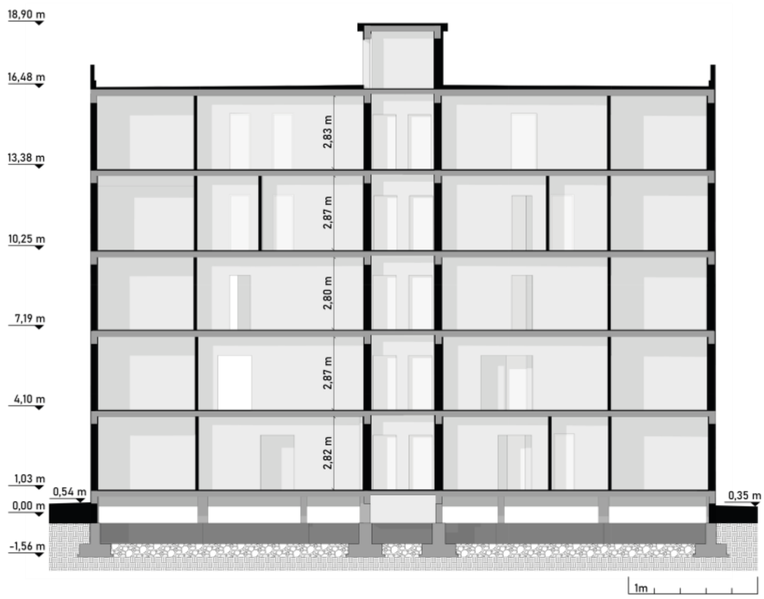

Figure 16: Section B-B.

4.2 Preliminary architectural design

The **e-**SAFE project consists of a deep renovation of the pilot building and aims to the growth of critical awareness in terms of aesthetic value, energy savings, seismic safety and thermal, visual and acoustic comfort for residents.

Essentially, the role of the **e-**SAFE project team at this stage of the co-design process is to respond to the needs of the inhabitants and concurrently resolve all aspects of design. For instance, after the geometric survey conducted with laser-scanner technology, the small misalignment of the existing windows in all façades, the different floor-to-ceiling heights and the difference in ground level between the southern and northern sides have led redefining a new alignment structure for the laying of **e-**CLT and **e-**PANEL.

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After the last residents’ meetings, an additional co-design phase has begun. It is still intermediate, and involves an architectural proposal that has to be further discussed and debated with local residents.

Since the same shape of the pilot volume must be kept, the co-design proposal consists of three essential architectural signs:

1. emphasizing the pre-existing volume of the building by covering it with a neutral coloured material;
2. underlining the subdivision of the five levels by the creation of stringcourses of east and west sides;
3. introducing a different colour for loggias, frames and shading devices. As is known, colour and shapes play a key role in the perception of architecture and emphasize the structure of the building.

Between each stringcourse that participates in the horizontality sign given by the presence of the floors, the vertical rhythm is defined by ceramic panels of several sizes and shades: ceramic is an environmentally-friendly material that ensures a contemporary and aesthetically attractive effect.

This cladding consists of tiles of rectangular shape: they have same height but different widths that are reinforced by underlying support formed by aluminium omega profiles. The shape of these cladding elements provides formal and aesthetic solutions to technical and functional issues. Similarly, the stringcourses on the east and west sides are made of light-coloured ceramic. On top, the parapet is covered with the same coating but on the short fronts, east and west, it is set back from the line of the building. This arrangement accentuates the building form and emphasizes the pilot prismatic volume.

The position and size of the windows on each front have been maintained. Instead, to accentuate the protruding frame of the loggias, we applied a contrasting colour to the neutral background of the ceramic cladding.

The treatment of each front is the same except for the choice of shading and blackout devices. They are not present on the north side, that of Via Acquicella Porto. On the short sides, coloured sheet metal projections frame the perimeter of the windows roughly aligned on one side of the front. On each of these a darkening solution is installed, with an opaque and folding panel screen.

On the south side, which borders the inner courtyard, the shading devices consist of coloured sliding panels, aligned to the edge of the parapets and attached to the respective lower and upper slab floors. Since light conditions change over the course of the day and the seasons, this solution gives the building a different and vibrant appearance depending on the time of day and season.

On top, the roof terrace lends itself to the placement of photovoltaic units for turning sunlight into electricity.

All these elements (neutral ceramic coating; stringcourse; the contrasting colour to paint loggias and shading devices) constitute, at this phase, the invariant elements of the project. Beyond these, we will see in Section 4.3 the variable elements of the project to be submitted to local residents to undertake the final phase of co-design activities.

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4.3 Residents' meeting for the final architectural co-design

Figure 17a: Pictures on resident's meeting event.

Figure 17b: Pictures on resident's meeting event.

Once the invariant elements of the project were defined, as described in the previous section "Preliminary architectural design", it was possible to compare other aspects of the architectural project with local residents and make additional choices together (Figures 17a – 17b). They consist of:

Colours to paint loggias and shading and blackout devices (Figures 18a, 18b, 18c, 18d).

As is known, colour is a significant quality of the project design both to emphasize the presence of certain elements and to influence the perception of the building and its impact on the context. Emerging from the neutrality of the prismatic volume of the pilot building, it was chosen to use colour, a design action at a negligible cost, not as mere decoration, but as an aesthetic expedient to define spaces and to stimulate the perception of the architecture. Four virtual images were submitted to the opinion of residents: one showed the blue paint, another ochre, another red and finally dark grey colour. Each of these colours has determined a different aspect of the building that has aroused different reactions. Grey was not appreciated due to low contrast in comparison with ceramic coating. Most residents preferred a deep colour like red, but the choice of a dark colour for the loggias' frames would also require more attention during the building maintenance phase: indeed, dark colours are more subject to desaturation caused by solar radiation.

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Figure 18: Virtual image on the possible colours to paint loggias and shading and blackout devices. (a) light blue; (b) ochre; (c) dark grey; (d) deep red.

Coplanarity of ceramic tiles coating the prismatic block (Figure 19 and 20).

The existing building appears to be flat. To remediate such inconvenient a ceramic coating was adapted, consisting of rectangular tiles reinforced by a system of omega aluminium profiles. The thickness of these profiles allows perceiving the thickness of the individual ceramic elements. This expedient allowed to distinguish the various architectural items and highlight more remarkable aspects of the building's façade. Thus, the residents were shown two virtual images, namely, two design solutions in comparison: one showed the shape of the prismatic volume, the other emphasized the compositional rhythm of the **e-**SAFE panels and the geometry of the stringcourses on the east and west sides.

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Figure 19: Coplanar ceramic tiles that are all bound together through a rigid substructure.

Figure 20: non-coplanar ceramic tiles that are all bound together through a rigid substructure. This expedient emphasizes the compositional rhythm of the **e**-SAFE panels and the geometry of the stringcourses.

<u>Number of performed sliding panels on the south side</u> (Figure 21 and 22).

Another topic concerned the presence of coloured perforated sliding panels located on the southern side, aligned to the edge of the parapets and attached to the respective lower and upper floors. Designed in perforated metal sheet, these panels contribute to the aesthetic composition of the entire building and serve to shade the windows located on the south side. They are subject to intense sunlight and participate in the aspect of the building if the resident will decide to restore the previous verandas. The virtual images have given to the residents two solutions: the southern front without the presence of shading screens; or with the presence of three sliding panels for each apartment, a total of six per floor. Actually, this design solution was appreciated since it allows responding to individual needs.

Figure 21: Absence of sliding panels in perforated metal sheet on the south side.

Figure 22: Sliding panels in perforated metal sheet on the south side.

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Presence or absence of shelter for the photovoltaic system (Figure 23 and 24).

Another topic concerned the support structure of the photovoltaic system provided on the terrace. This topic was the one that highlighted the most critical issues for the habitants, especially when it comes to the sharing of condominium spaces. The shelter to support the photovoltaic system is a crowning element of the building and contributes to its architectural composition, but also allowing the fruition of the space below. In this way, all residents could benefit and take advantage of the terrace. On the other hand, a photovoltaic system lying on the floor would not allow the same accessibility. Due to internal problems among residents, the initial preference was to opt for a photovoltaic system placed directly on the floor. Then, the open dialogue led, after the stipulation of a house rule for the use of all condominium spaces, to the choice of a solar shelter.

Figure 23: Absence of shelter for the photovoltaic system.

Figure 24: Presence of shelter for the photovoltaic system.

4.4 Final architectural co-design

The final architectural design is the last stage of the architectural co-design process. The final moment of confrontation occurred on an April afternoon in the inner courtyard of the tower of Via Acquicella Porto 27/H. This meeting was indispensable to define the final architectural aspect of the pilot and then complete the final design. During all phases of the co-design process, every decision taken to define the overall architectural image of the pilot derived from answers to questions of aesthetic, functional, technological, productive, seismic safety and environmental sustainability.

The new architectural appearance of the pilot will therefore include the coating of **e-**CLT and **e-**PANEL by means of a structure composed of omega-shaped sheet metal pillars on which rectangular ceramic tiles of different size will be attached. These tiles will be used to cover the façade of the building in two ways: the first concerns the creation of stringcourses that emphasize the presence of the five levels; the second concerns the area between the two stringcourses. Here the arrangement of the ceramic tiles will follow a vertical composition. The different thickness of the support substructure will allow perceiving individual panels as if they were of different thicknesses.

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During the final meeting, the majority of residents considered that this choice made the façade more vibrant. The light colour was also preferred. Consequently, the ceramic cladding will cover the building on all sides, including the stairwell. This choice was made for several reasons:

1. Being the pilot a regular prism, to emphasize the pre-existing shape;
2. Responding to the preference of the inhabitants;
3. Creating a greater contrast with the colouring of shading and darkening devices.

Also contributing to the architectural aspect of the pilot are the shading devices. They are absent on the northern front. On the short sides, they consist of coloured sheet metal projections that frame the windows approximately aligned on one side of the front. On each of these, a darkening solution with an opaque and folding panel screen is adopted.

On the south side, the one that borders the inner courtyard, the shading devices consist of coloured perforated sliding panels, aligned to the edge of the parapets and attached to the respective lower and upper floors, giving raise to an aspect of the facade always changing throughout the day. As to their presence, at first, the inhabitants showed some perplexity. The reasons were due to a lack of knowledge of the advantages of sliding panels as solar screens. They replace the previous sunshades, allow greater flexibility and provide greater privacy. In the end, the choice to include them was then welcomed with enthusiasm leaving to each inhabitant the possibility of distributing them according to their own needs. After some discussion about the usefulness of the sliding panels, this solution was adopted with conviction by the inhabitants.

Moreover, it was agreed that a different colour to paint loggias, frames and shading devices plays a key role in the perception of architecture and emphasizes the structure of the building. Consequently, shading and darkening devices will also have a light colour. In the beginning, the choice fell between a darker colour, a burgundy red, and a lighter colour, ochre. Finally, the colour ochre was preferred, although this detail can be further examined again in proximity of the construction stage.

In conclusion, a shelter at the top will be built as a support element to the photovoltaic system. The inhabitants have understood that the photovoltaic shelter, as well as being the crowning element of the building and contributing to the architectural composition, actually makes the terrace usable. The dialogue with local residents, also in this case constructive and useful, led to the choice by the majority of the solar shelter (Figure 25).

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Figure 25: Final architectural virtual image.

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5. PRELIMINARY CO-DESIGN OF THE THERMAL SYSTEM

This section aims at describing the preliminary configuration for the **e-**THERM system, aimed at heating/cooling and Domestic Hot Water (DHW) preparation as well as electric energy production by a photovoltaic (PV) system.

5.1 e-THERM architecture: general overview

In the existing situation central heating is not available, and thermal needs are covered by autonomous systems in each apartment. As far as cooling is concerned, some dwellings are served by split systems, whose external units are installed on the balconies and the external facades, in non-uniform and disordered positions. The production of domestic hot water is provided by electric boilers (in few cases with a gas boiler), mainly installed in bathrooms or balconies.

The general idea of the **e-**THERM concept consists in installing a centralised thermal plant with decentralised DHW storage, with electric heat pumps connected to a PV system in order to maximize the use of renewable energy sources. Figure 26 shows the hydronic scheme of thermal and DHW production system.

5.1.1 Heating/Cooling system

The heating/cooling system basically consists of a hydronic system where the thermal energy is provided by one air-to-water reversible electric heat pump (EHP) producing hot water for the heating service in winter and cold water for the cooling service in summer. A two-pipe main network connects a buffer tank to the fan-coils installed in the apartments; only in the bathrooms, heated towel rails will be installed in place of the fan-coils, for the only heating service. This solution was discussed and then selected due to the ability of this kind of technical system to provide both heating and cooling service by the same hydronic terminal, while also providing flexibility in use. Moreover, the use of air-to-water heat pumps was motivated by the possibility of using renewable energy sources, namely free thermal energy withdrawn from outdoor air plus electric energy produced by the PV system.

5.1.2 Domestic Hot Water (DHW) production system

The innovative solution proposed in **e-**SAFE concerning the DHW production system consists of a single water storage tank (namely "**e-**TANK") for each dwelling instead of the current single electric or gas boiler. The **e-**TANK temperature is controlled by an internal water coil, served by the technical hot water coming from the centralised heat pump system, during specific periods of the day in order both to reduce thermal losses – like in traditional centralised DHW systems with recirculating pipe loop – and to optimize the use of renewable electric energy produced by the PV system.

The architecture of the proposed DHW system requires a centralised air-to-water EHP working at temperatures up to 60 °C combined with a main water storage tank, and a two-pipe network serving the **e-**TANK for each dwelling. From **e-**TANK, DHW pipelines will serve the terminal units (shower, taps, etc.)

5.1.3 Photovoltaic and electric system

A PV system, which will be installed on the rooftop, is provided for the renewable electric energy production to supply all technical equipment of the central heating systems, like heat pumps, water pumps and control system components. The PV system is meant to be grid connected.

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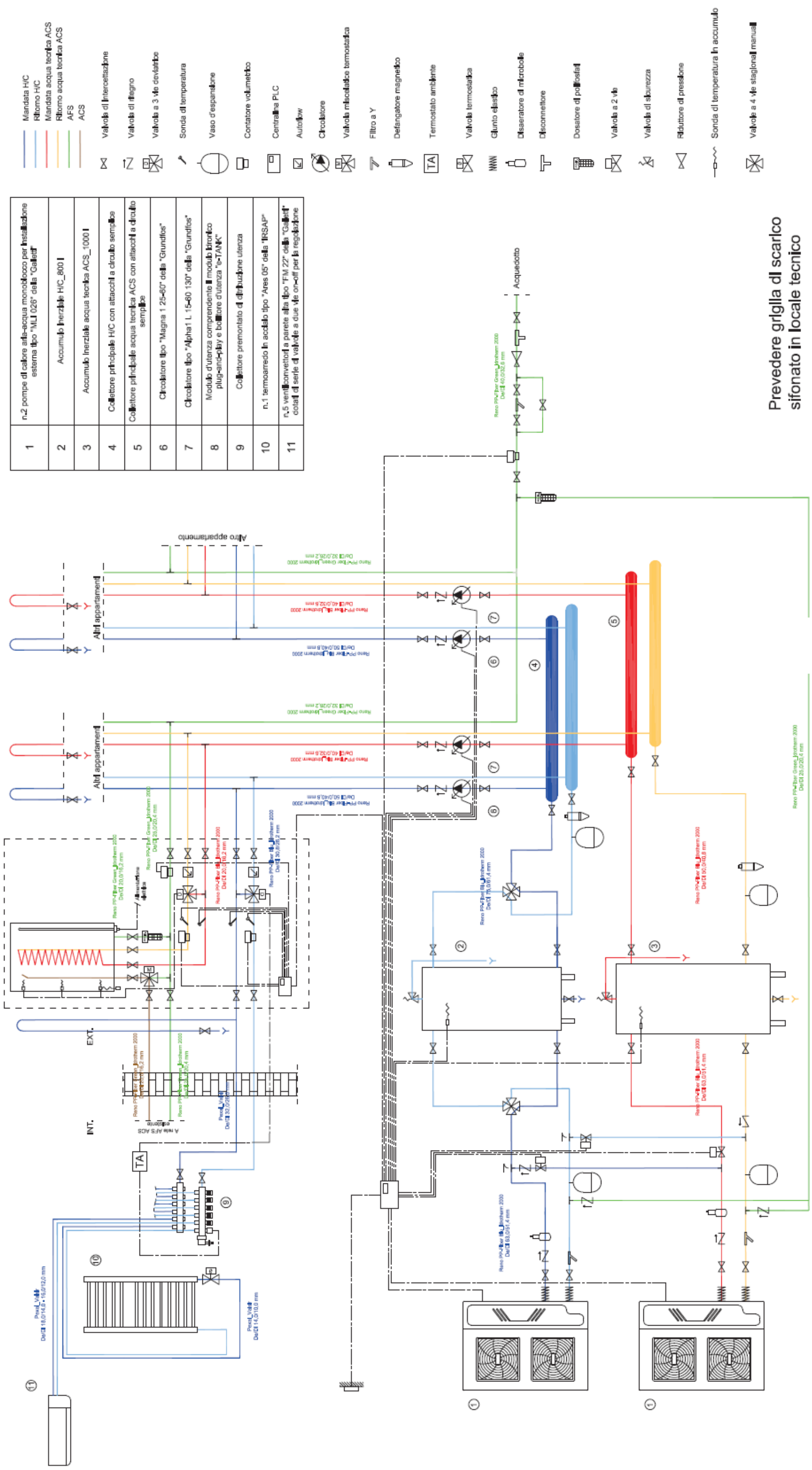

Figure 26: scheme of the hydronic thermal plant and DHW production
(blue/light blue: heating/cooling network; red/orange: DHW network; green: mains water).

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5.2 Preliminary design of the central heating system

The preliminary solution for the central heating system consists of n.2 EHPs installed outdoors – one for the Heating/Cooling services and one for DHW service – and all necessary mechanic and electric equipment that will be installed in a prefabricated cabinet located in the courtyard outside the building and close to the west property border. The choice of this arrangement is due to technical issues and to the requests of the residents.

Concerning the technical aspects, the typology of heat pumps was primarily chosen according to thermal/cooling load profiles and to operating temperatures of technical water. The max cooling load for the whole building is estimated in 34 kW (Carrier method) while the max heating load is 33 kW (EN 12831); the heating capacity required for DHW production is 24 kW. The results of hourly calculations (EN ISO 52016) of thermal loads, and the analysis of load factors distribution during the whole year, allowed to size correctly the number and the capacity of heat pumps: the proposed solution provides two heat pumps of 26 kW each, with a compressor managed by an inverter to modulate the thermal demand. The EHPs will be installed in parallel assuring a redundancy of the thermal power supply for both services and the extra power during periods of maximum load.

As shown in Figure 27, for the space conditioning service, in the winter the EHP will operate with a load factor below 50% for about 90% of the hours, while the maximum thermal power will be required for only 10% of the time. In the summer, the EHP will operate mainly at 50-100% of the full load, while the second EHP can be necessary only during peaks loads (4-5% of hours).

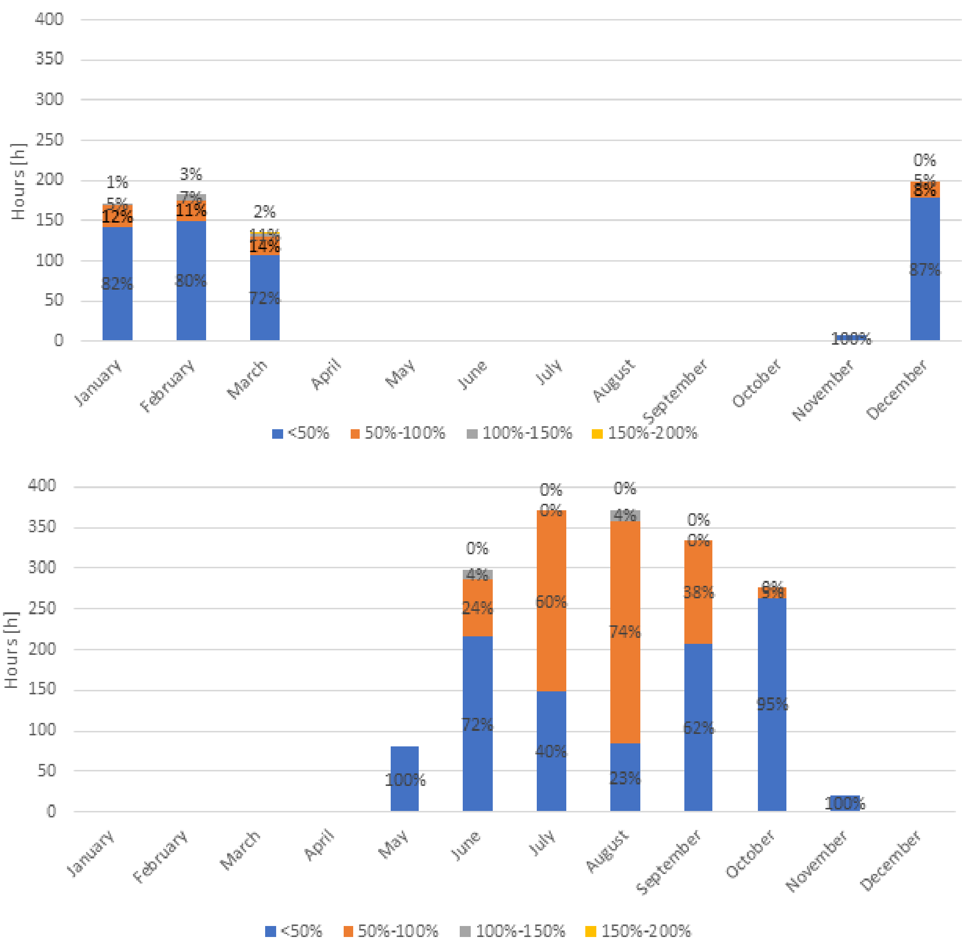

Figure 27: Hourly distribution of heating load factor (top) and cooling load factor (bottom).

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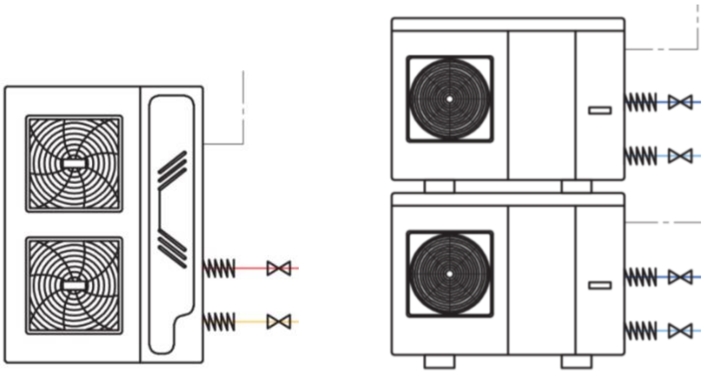

Figure 28: Possible typologies of air-to-water heat pumps.

Depending on market availability and cost of installation, the single heat pump for space heating and cooling can be split in two heat pumps as in Figure 28. The final choice of the heat pumps must also consider environmental sustainability aspects (e.g. using refrigerant gas with low GWP) and noise emission impact. Concerning this last issue, the adopted EHPs must have low sound power level values such as to reduce noise level inside the building according to national standard. The installation will be near the road boarder in order to minimise this impact.

The central heating system also provides the following technical equipment: a buffer tank of 800 l connected to EHP for the heating/cooling service, a storage tank connected to EHP for the DHW service, and all required hydronic components: circulating pumps, expansion tank (closed type), valves, as shown in the diagram of Figure 26. Inside the prefabricated cabinet, an electric panel will be installed for the power to all equipment of the central heating system, together with a panel for the control system and signal transmission lines. The position of this cabinet will allow easy access for the installation and maintenance of all components. A first solution for a possible installation on the rooftop, discussed during on-site inspection, was not considered due to possible structural load problems for the weight of the buffer tanks and due to difficulties for maintenance access, given the lack of a lift.

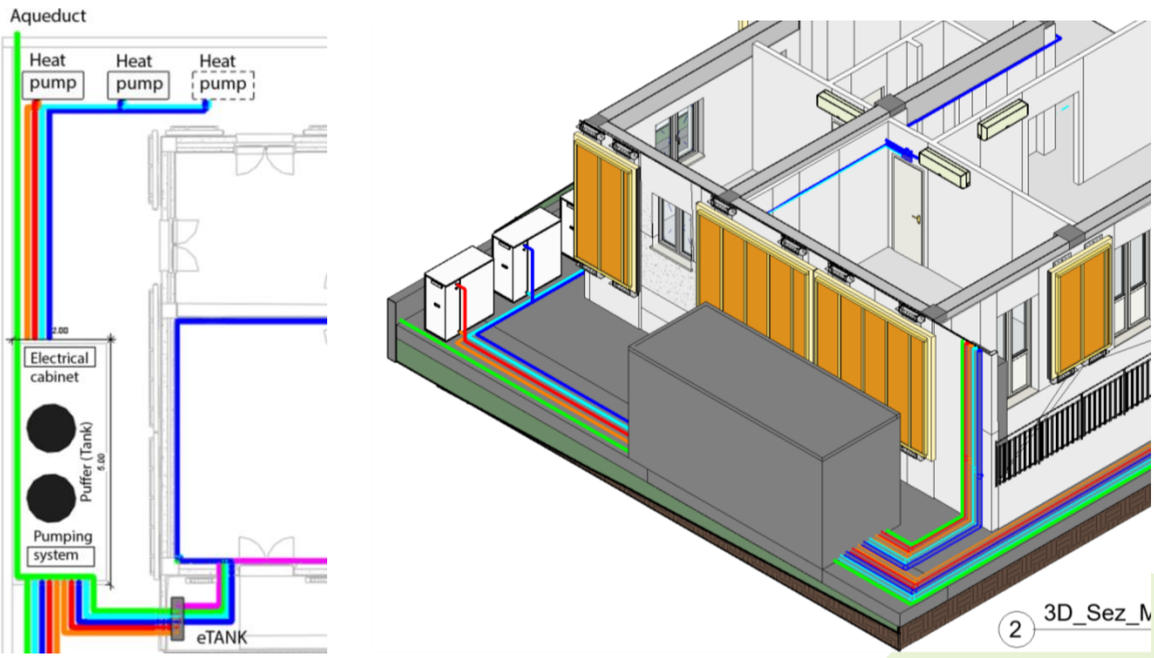

Figure 29: Position of Heat Pumps and the cabinet.

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Figure 29 shows the position of the heat pumps and the cabinet, and a sketch of the pipelines from EHPs to the cabinet and from the cabinet towards the building. EHPs and cabinet must be mounted on a concrete basement. All necessary electric power lines, data bus lines and also drainage pipelines will be provided.

5.3 Pipe distribution and position of the fan-coils

As sketched in Figure 30 and Figure 31, two different pipe distribution lines are provided: the external one, from the cabinet to the **e-**TANK modules – which will be located on south side balconies of each dwelling – and the internal one from the **e-**TANK to the internal units.

The external pipelines include:

a) two-pipe main hydronic network for heating/cooling service, carrying hot water in winter and refrigerated water in summer;
b) two-pipe hydronic network carrying hot water for the **e-**TANK charging;
c) one-pipe hydronic network carrying mains cold water for domestic use from mains.

All those pipes will travel from the cabinet towards the building in underground excavations, and will continue on the external wall of the balconies. The pipes will be thermally insulated and, on the external side, a specific panel will cover and protect them from external damaging factors. Parallel to the pipes a drainage pipe will be also located, and the cables for data transmission. All pipes will be connected to the hydronic module on the lower part of the **e-**TANK (Figure 32) where the energy meters are located – for heating/cooling and DHW energy consumption monitoring.

The Internal pipelines include:

a) two-pipe secondary hydronic network for heating/cooling, serving internal fan-coils, carrying hot water in winter and refrigerated water in summer;
b) one-pipe DHW and one-pipe mains water serving bathroom and kitchen equipment.

In addition, discharge pipes for condensation water and power supply lines of fan-coils are provided. In order to reduce installation costs and to limit the disturbance to the occupants, the internal distribution and positions of pipes will be preferably near the ceiling: in Figure 30 and Figure 31, a possible solution is sketched out. The final solution will be defined after further discussion with residents on the position of fan-coils and any possible constraint. In particular, the presence of concrete beams of great height on external walls and in the central part of the dwellings will determine the need of deviating some pipes and to find a suitable position for the manifold and for air relief valves of hydronic network.

Terminals for heating and cooling were chosen according to the occupants needs (both heating and cooling), to technical aspects and to the desire of limiting resident's disturbance. For this reason, wall mounted fan-coils were preferred, according to the residents, in main rooms – bedrooms and living room – while in the bathrooms heated towel rails will be installed for the only winter heating.

The following pictures show possible pipes distribution and positions of fan-coils and heated towel rails, designed for a first analysis with residents.

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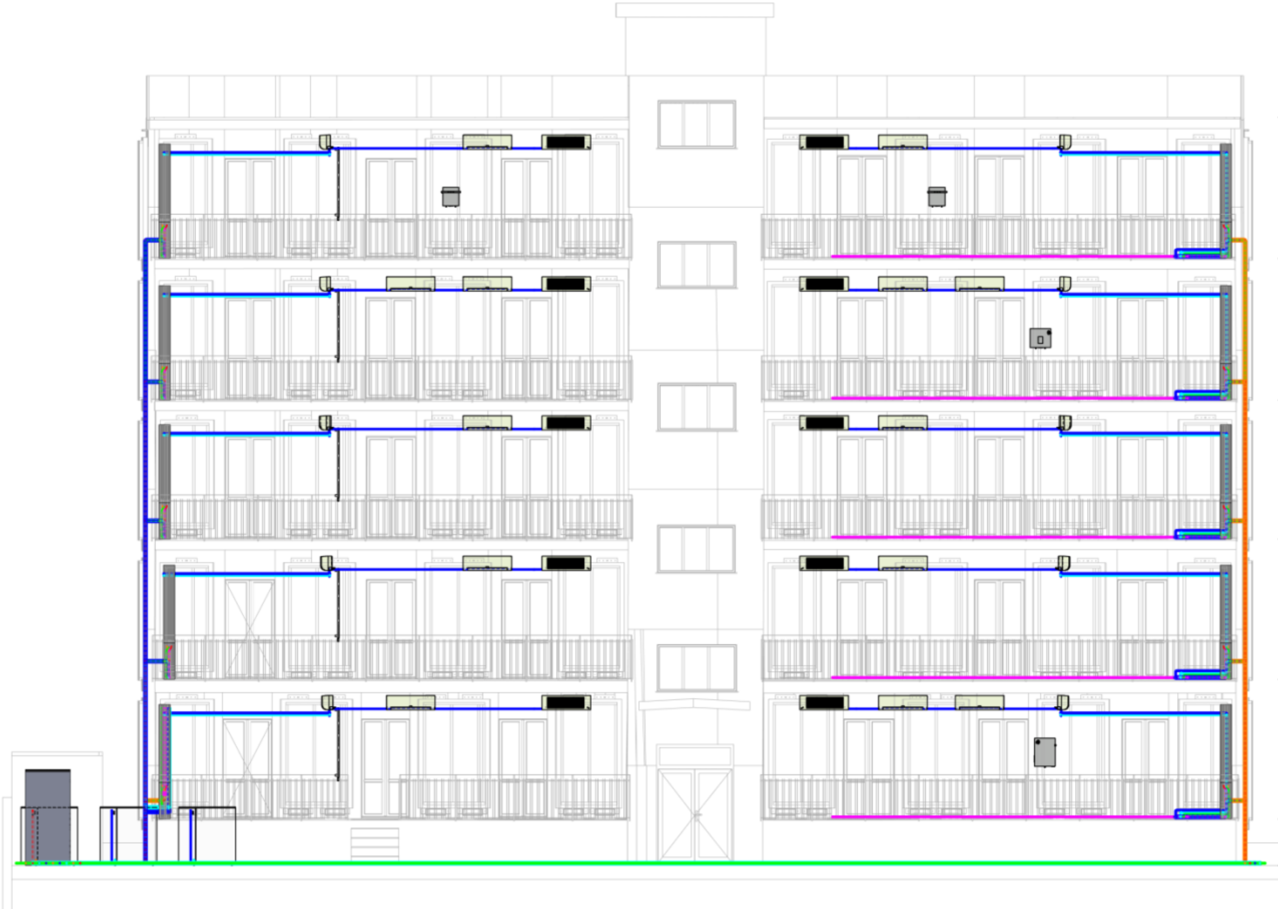

Figure 30: Pipe distribution from the cabinet to internal units: front view of the building.

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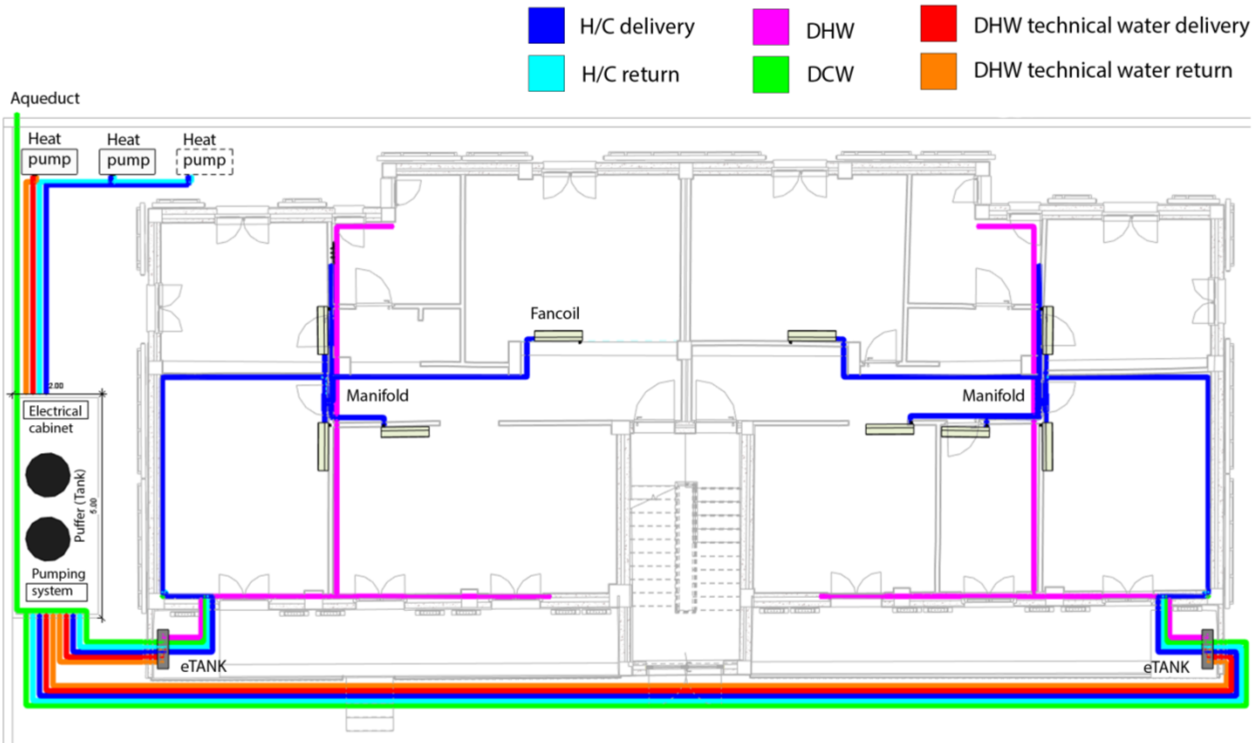

Figure 31: Pipe distribution from the cabinet to the internal units: plan view of a typical floor.

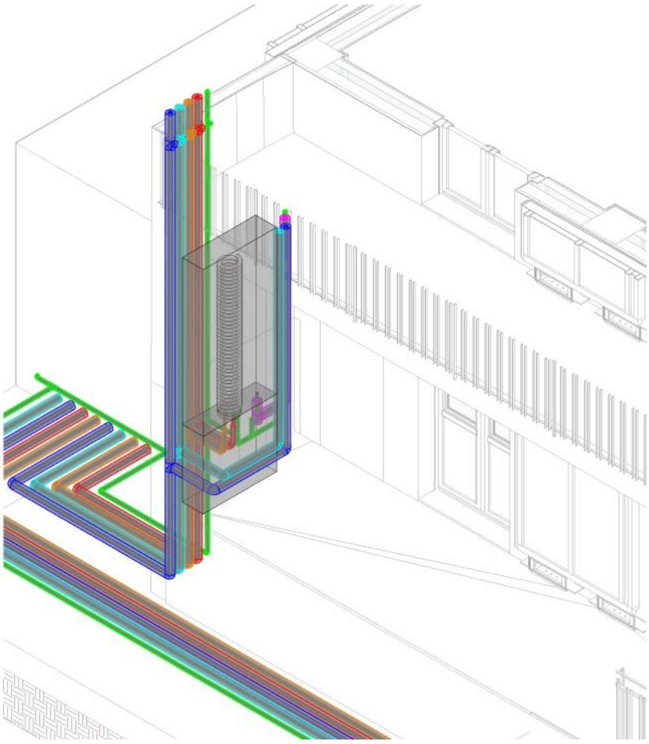

Figure 32: Pipe distribution: connection to **e**-TANK.

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Figures 33-37 report the preferred positions of fan-coils and heated towel rails as expressed by the residents of the various apartments. The floor plans without any indication refer to those apartments whose occupants did not respond to the survey while, for those who did, the various floor plans show the position of fan-coils (red hatches) and heated tower rails (blue hatches). During the detailed design stage, the requests of the residents will be properly taken into account, unless they will not be feasible for technical reasons. In this case, a suitable variant will be proposed and discussed with the residents. In those dwellings where the residents did not express any preference, the design will follow the best technical option.

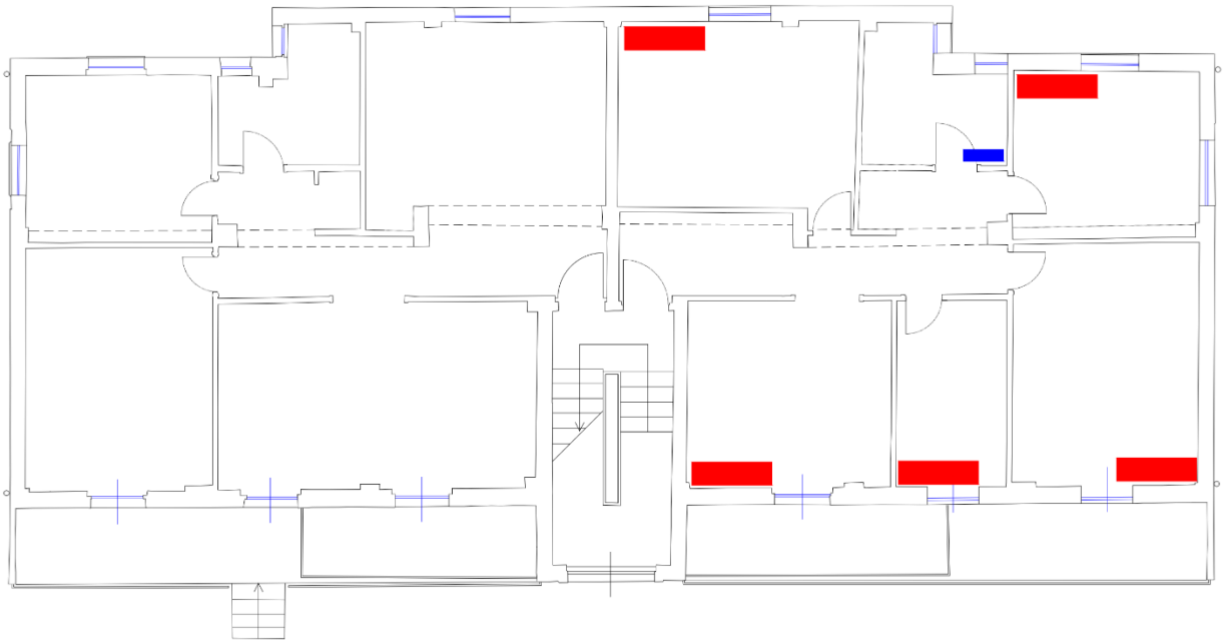

Figure 33: Preferred position of fan-coils (red hatch) and heated towel rails (blue hatch) according to the residents' survey. Ground floor.

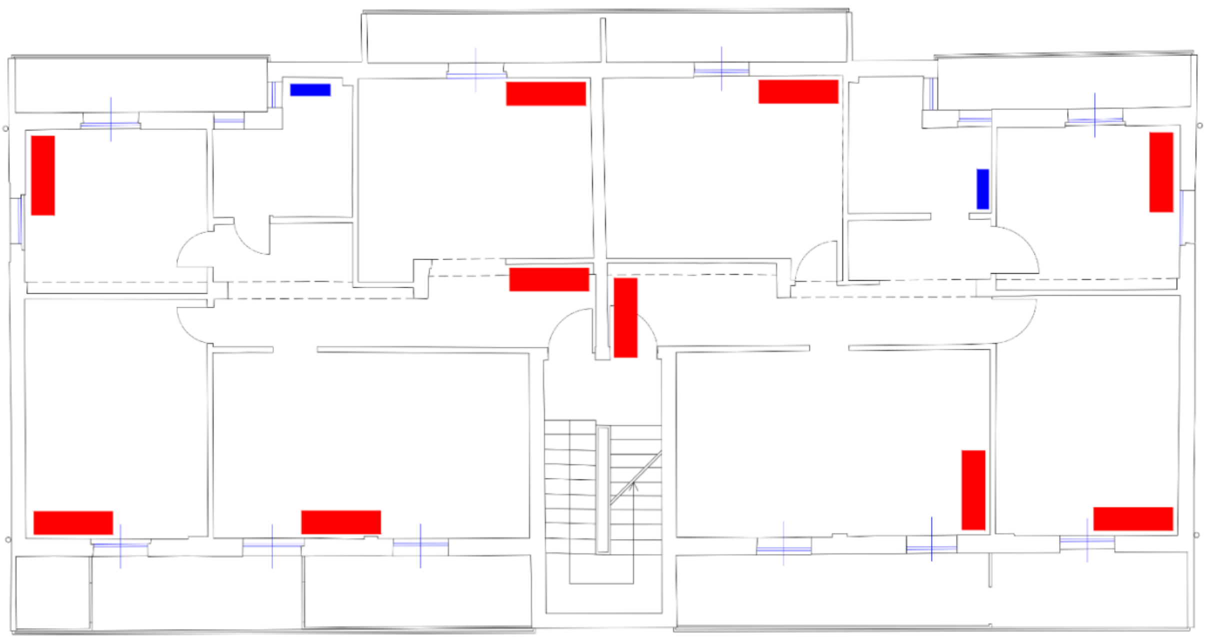

Figure 34: Preferred position of fan-coils (red hatch) and heated towel rails (blue hatch) according to the residents' survey. First floor.

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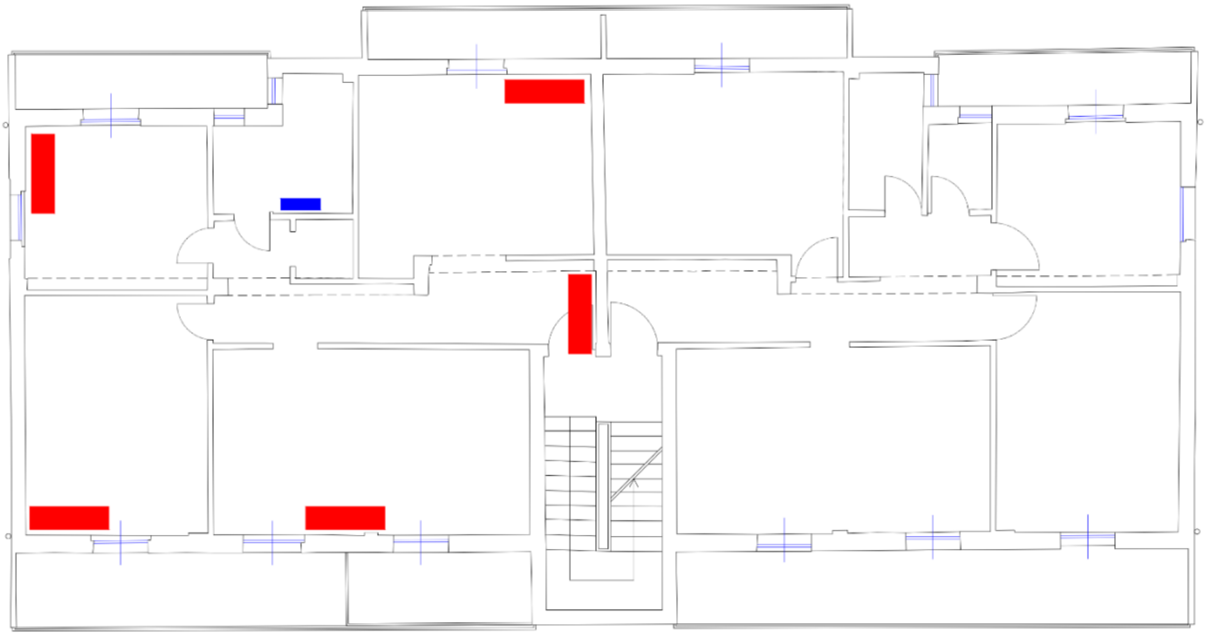

Figure 35: Preferred position of fan-coils (red hatch) and heated towel rails (blue hatch) according to the residents' survey. Second floor.

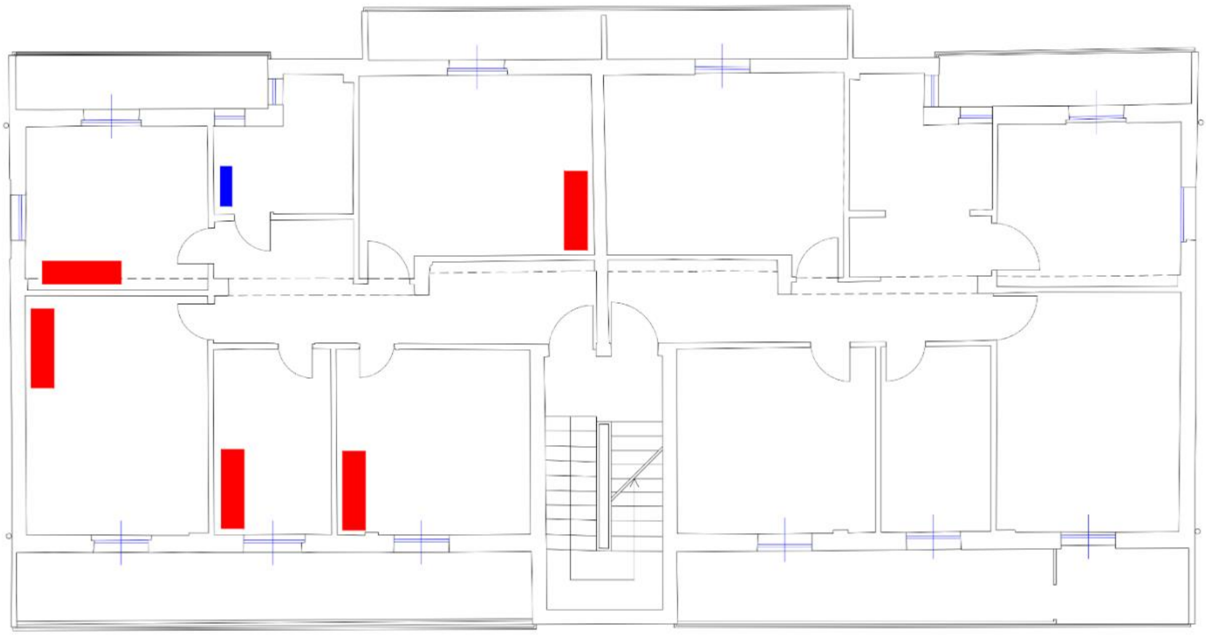

Figure 36: Preferred position of fan-coils (red hatch) and heated towel rails (blue hatch) according to the residents' survey. Third floor.

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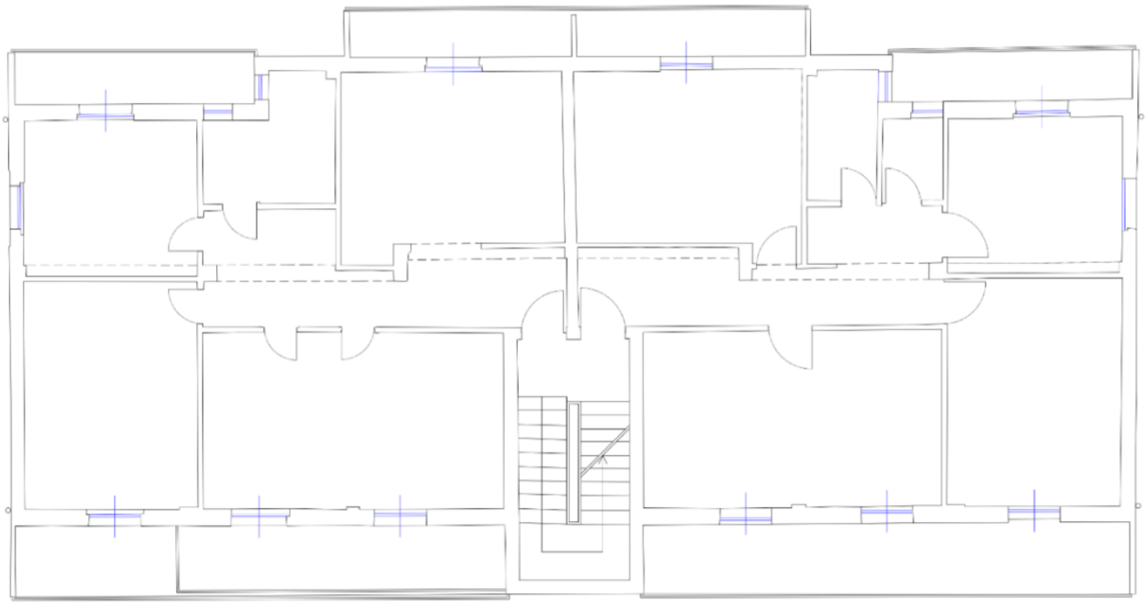

Figure 37: Top floor – Residents did not specify any preferred positions for fan-coils and heated towel rails.

Further meetings will be needed with occupants in order to define final solutions, also evaluating all masonry works required for the installation of fan-coils and pipelines.

5.4 Preliminary assessment of the energy performance

The energy performance of the pilot building can be assessed by comparing the heat losses of the current state with those expected after the renovation through the quasi steady-state calculations carried out with the commercial software Blumatica Energy [2]. This tool is used also for assessing the compliance of the renovation project with Italian regulations. Table 1 reports the overall heat loss coefficient H', and shows that the magnitude of the heat losses after renovation is significantly lower than in the current state. Indeed, the coefficient drops from H' = 1.746 $W \cdot m^{-2} \cdot K^{-1}$ in the current state to H' = 0.592 $W \cdot m^{-2} \cdot K^{-1}$ after renovation: this value complies with the Italian regulation concerning major renovations in climate zone B, which requires H' < 0.63 $W \cdot m^{-2} \cdot K^{-1}$ [3].
Furthermore, Figure 38 suggests that the application of **e-**PANELs and **e-**CLTs – along with the insulation of the roof and the replacement of the windows – slightly reduces the weight of thermal bridges in the overall heat losses of the building from 21.9% to 20.6%. However, the percentage distributions have only minor variations, with the floor slab (i.e. the only uninsulated building envelope component) that has now a larger share (around 9.5% of the total), and the roof and the boxes of the window shutters contributing to a lesser extent.

Table 1: Overall heat loss coefficient per unit surface (H').

FLOOR	APARTMENT	BEFORE RENOVATION	AFTER RENOVATION	VARIATION
Ground floor	West side	1.425 $W \cdot m^{-2} \cdot K^{-1}$	0.582 $W \cdot m^{-2} \cdot K^{-1}$	-59.2%
	East side	1.368 $W \cdot m^{-2} \cdot K^{-1}$	0.567 $W \cdot m^{-2} \cdot K^{-1}$	-58.6%
Intermediate floor	West side	2.051 $W \cdot m^{-2} \cdot K^{-1}$	0.663 $W \cdot m^{-2} \cdot K^{-1}$	-67.7%
	East side	2.051 $W \cdot m^{-2} \cdot K^{-1}$	0.663 $W \cdot m^{-2} \cdot K^{-1}$	-67.7%
Top floor	West side	1.633 $W \cdot m^{-2} \cdot K^{-1}$	0.503 $W \cdot m^{-2} \cdot K^{-1}$	-69.2%
	East side	1.633 $W \cdot m^{-2} \cdot K^{-1}$	0.503 $W \cdot m^{-2} \cdot K^{-1}$	-69.2%
Entire building	-	1.746 $W \cdot m^{-2} \cdot K^{-1}$	0.592 $W \cdot m^{-2} \cdot K^{-1}$	-66.1%

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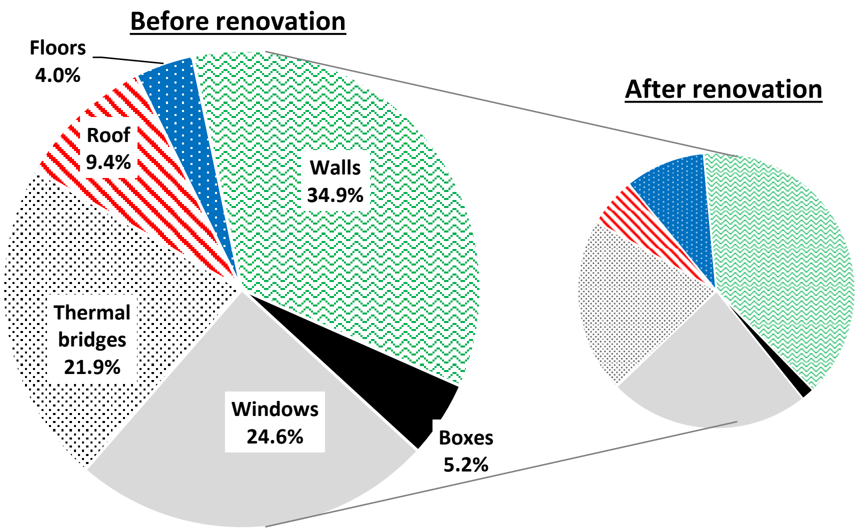

Figure 38: Percentage distribution of the transmission heat losses, before and after renovation.

In addition, detailed energy simulations have been carried out through the transient building energy simulation tool EnergyPlus [4] in order to appraise the heating and cooling energy demand before and after the renovation. The results of these simulations are summarized in Figure 39, with separate plots for the ground, intermediate and top floors, while also including the floor-averaged energy figures of the entire building.

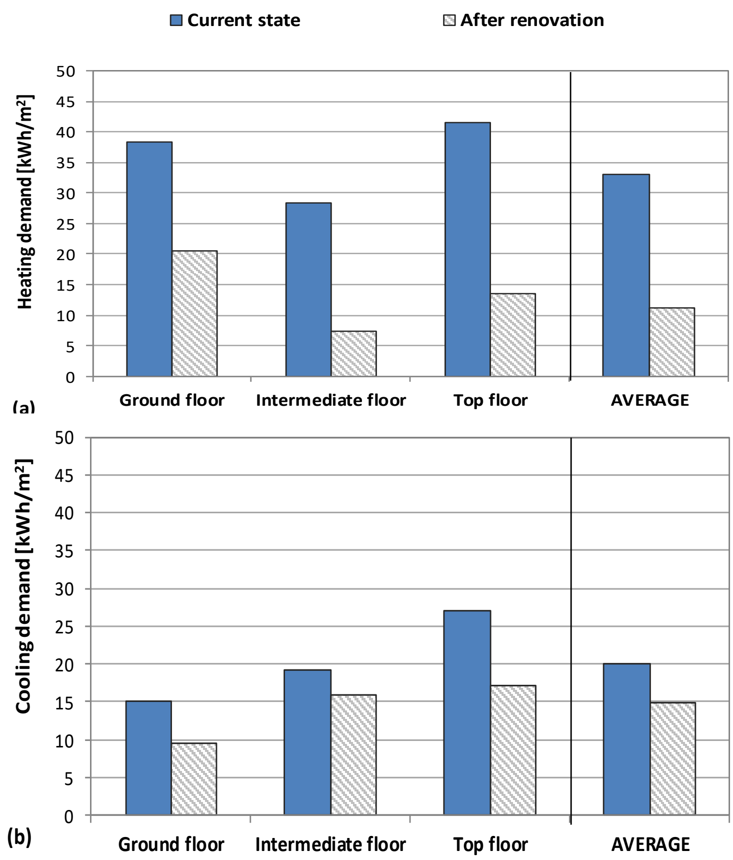

Figure 39: Results of the dynamic energy simulations:
(a) heating demand, (b) cooling demand.

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What first emerges is that, in the current state (solid blue hash), the top floor shows the highest energy demand for both space heating (41.5 kWh·m^{-2}, Figure 39a) and space cooling (27 kWh·m^{-2}, Figure 39b). This mainly stems from a higher dispersing surface compared to the other floors; moreover, in the summer the top floor suffers from the very high solar irradiation hitting the roof. Instead, at the ground floor, the slab is mainly subject to the heat transfer with the unheated underground space, whose temperature is constantly closer to the indoor than the outdoor air temperature. For this reason, the ground floor is favored in the summer, when it shows the lowest cooling demand (15 kWh·m^{-2}), while in the heating season its energy demand (38.3 kWh·m^{-2}) is higher than in the intermediate floor (Figure 39a).

If looking at the retrofit intervention, a drastic overall reduction in the heating energy demand is expected, ranging from 47% in the ground floor to 74% in the intermediate floor (Figure 39a). In the cooling season, the benefit of wall insulation is less evident (Figure 39b), and energy savings are predicted in a range of 17% (intermediate floor) to 36% (both top and ground floors). In the top floors, including the shading effect of the PV modules (installed on the rooftop) would introduce a further 4% reduction in the cooling energy demand.

The average expected reduction in the final energy demand by the pilot building thus amounts to around 66% in the heating season and to about 25% in the cooling season.

5.5 Preliminary sizing of the PV system

The electric energy required by the thermal systems, including the heat pumps and the circulation pumps, is essential to proceed with the sizing of the PV system. To this aim it is important, for a correct design of the PV system, to have an electricity production coherent with the electric energy requested by the final user. If this condition is not met, the user must either withdraw a high amount of energy from the distribution net, or transfer a considerable share into the distribution net, but in both cases the financial performance of the system would be negatively affected.

Table 2 reports the estimated electric energy needs from the **e-**THERM system.

Table 2: Estimated annual electricity consumption from the **e-**THERM system.

SERVICE	VALUE
Space heating (from December to March)	1580 kWh/year
Space cooling (from June to September)	5450 kWh/year
Domestic Hot Water (all year round)	13120 kWh/year
Pumps	850 kWh/year
TOTAL	21000 kWh/year

The PV system has been sized by considering the data reported in Table 3. The PV modules will be placed on a structure 2 m high on the rooftop, and can be considered as being ventilated. The overall estimated initial annual electricity production from the PV system amounts to 22000 kWh/year. However, if one accounts for the degradation of the efficiency with time (estimated at 0.5% per year), the electricity production decreases to 21000 kWh after 10 years of operation, which perfectly fits the requirements from the **e-**THERM system.

Further details about the estimated daily energy consumption and PV production are reported in Figure 40 and Figure 41. The mean initial annual efficiency of the PV system, including the losses in the inverters, is estimated at around 16.6%.

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Table 3: Data regarding the preliminary design of the PV system.

PARAMETER	VALUE
Slope	10°
Azimuth angle	9° East
Type of PV modules	Monocrystalline silicon
Efficiency in Standard Conditions (STC)	20.2%
Size of each PV module	1050 x 1770 x 35 mm
Number of PV modules	36
Overall PV surface	67 m^2
Peak Electric Power (per PV module)	375 W
Peak Electric Power (TOTAL)	13.5 kW

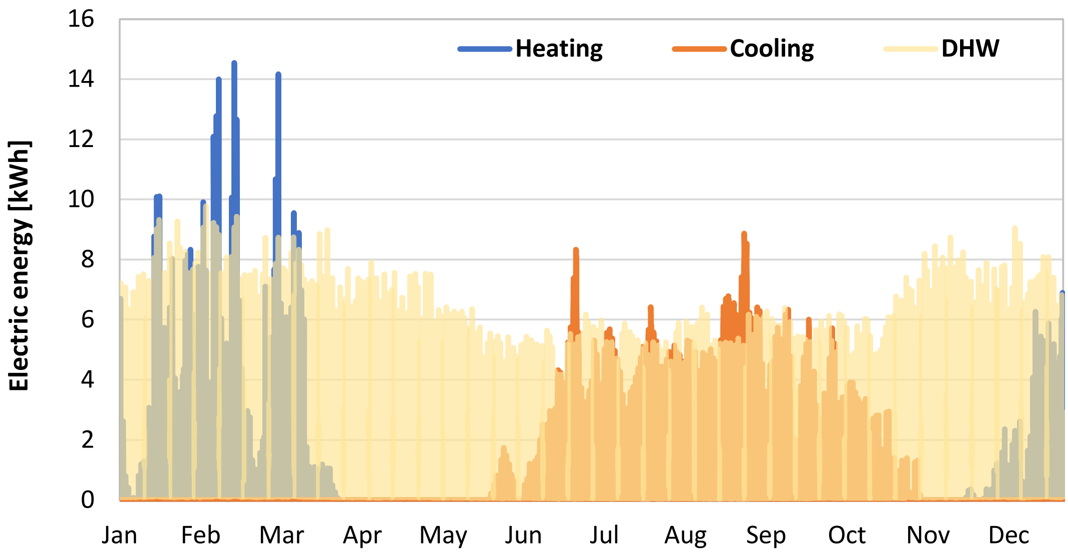

Figure 40: Estimated daily electricity consumption (per service).

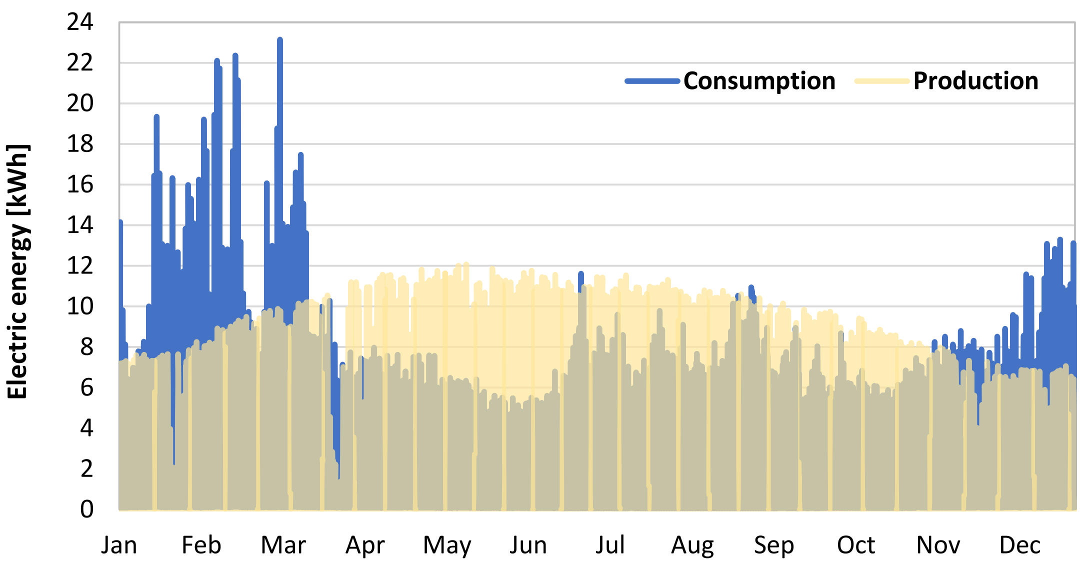

Figure 41: Comparison between the estimated daily electricity consumption and production.

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Finally, the **e-**THERM concept includes batteries for storing the PV electricity when it is not directly consumed by the heat pumps and the auxiliary systems. Batteries allow increasing the self-consumption rate, thus decreasing the electricity withdrawn from the net.

The criteria that have led to the sizing of the batteries are:

- Batteries must be charged daily by the PV electricity that is not self-consumed;
- The electricity stored in the batteries during the day must provide a relevant share of the **e-**THERM consumption at night;
- The price of the selected batteries must be consistent with the budget available in **e-**SAFE.

According to these criteria and to the calculations of the hourly energy fluxes, the choice has fallen on 20 kWh capacity. For instance, a possible product is the one shown in Figure 42: here, four modules (5 kWh each) can be combined to get two 10 kWh separate batteries.

Thanks to the selected batteries, and according to the preliminary calculations, it is reasonable to get an annual self-consumption rate between 70% and 75%.

Figure 42: Possible storage batteries (made of two modules, 5 kWh each).

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6. PRELIMINARY CO-DESIGN OF CONSTRUCTION SYSTEM

This chapter describes the main outcomes of the preliminary design of the **e-**SAFE envelope technology for its application to the pilot building.

This preliminary design phase was aimed at: (i) defining the application criteria of the **e-**CLT and **e-**PANEL solutions to the pilot building; (ii) defining the stratigraphy of the **e-**CLT and **e-**PANEL to ensure them high-quality performance; (iii) analysing the main constructive issues related to the installation of the technology and the architectural integration of each component.

Figure 43 shows proposed distribution of the **e-**CLTs and **e-**PANELs to the outer envelope of the pilot building. According to the concept of the **e-**SAFE technology, the structural **e-**CLTs are applied to the outer blind walls and are connected to the existing RC beams through the novel friction dampers developed within the WP3. Overall, the **e-**CLTs aim at increasing the seismic and dissipative capacity of the existing structure, by exploiting the high mechanical properties of CLT and the additional energy dissipation source, respectively.

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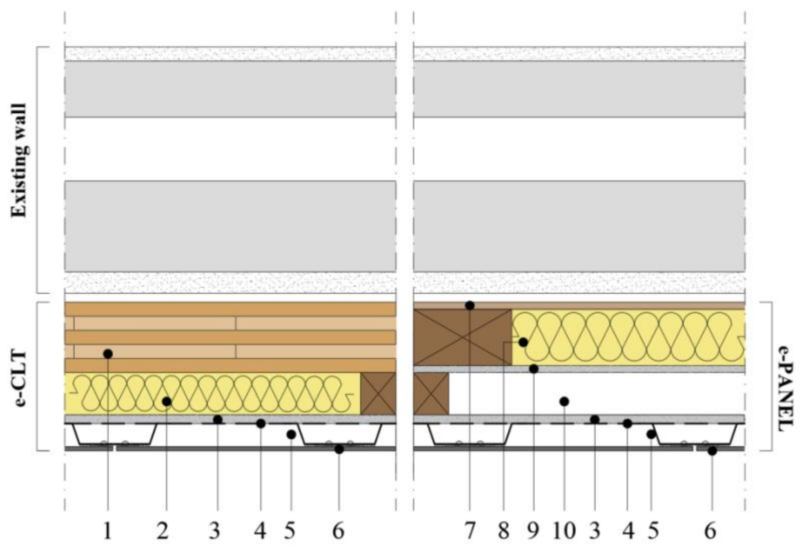
Figure 43: Proposed distribution of **e**-CLT and **e**-PANEL. Top: north-east front; Bottom: south-west front.

Conversely, the non-structural **e-**PANELs are applied to all the windowed walls as well as to the blind walls having a too small width for the application of the structural **e**-CLT. The **e**-PANELs integrate new high-performance windows which replace the existing ones. The new windows are also equipped with new external sun shading systems which aim at reducing indoor overheating in summer, thus increasing indoor thermal comfort. The type of the new windows and shading devices will be selected in next steps according to both technical needs and users' preferences.

The **e-**CLT and **e**-PANEL solutions have been designed with a high level of prefabrication to make their implementation fast and easy. Indeed, the panels will be totally prefabricated off-site and will be installed through mobile lifting equipment from the building outside in order to avoid demolition interventions, minimize waste production and reduce implementation costs and time as well as the occupants' disruption. The activities to be carried out from inside the apartments thus will involve only the removal of the existing windows and the fitting between the existing intrados and the **e-**PANELs.

Figure 44 shows the cross-section proposed for the **e-**CLT and **e-**PANEL. The **e-**CLT is made of 100-mm thick CLT panel and is coupled with 60-mm thick wood fibre insulation layer. The thickness of the CLT panel is coherent with the assumption used for the numerical and experimental activities within the WP3 (Task 3.2). The **e-**PANEL has a wooden-framed structure and integrates 80-mm thick wood fiber insulation layer. These materials reduce the U-value of the existing wall, and comply with the limits set by the current national regulations for the climate zone B (Catania). The **e-**PANEL also has a 60-mm thick non-ventilated air cavity to match the overall **e-**CLT thickness. Cement-based boards are inserted into both panels to ensure adequate fire performance, preventing the wood-based insulating material from contributing to the spread of a possible fire. Moreover, a weatherproof vapour-open membrane protects the main layers of each panel (i.e. insulation materials, CLT panel etc.) from rainwater and reduces condensation issues.



1. CLT panel, 100 mm
2. Wood fiber thermal insulation, 60 mm
3. Cement-based board, 12.5 mm
4. Weatherproof vapour-open membrane
5. Ventilated air cavity + aluminum omega-shaped profiles, 30 mm
6. Cladding layer (porcelain stoneware tiles, 6 mm)
7. Marine plywood board, 10 mm
8. Wood fiber thermal insulation, 80 mm
9. Cement-based board, 10 mm
10. Non-ventilated air cavity, 60 mm

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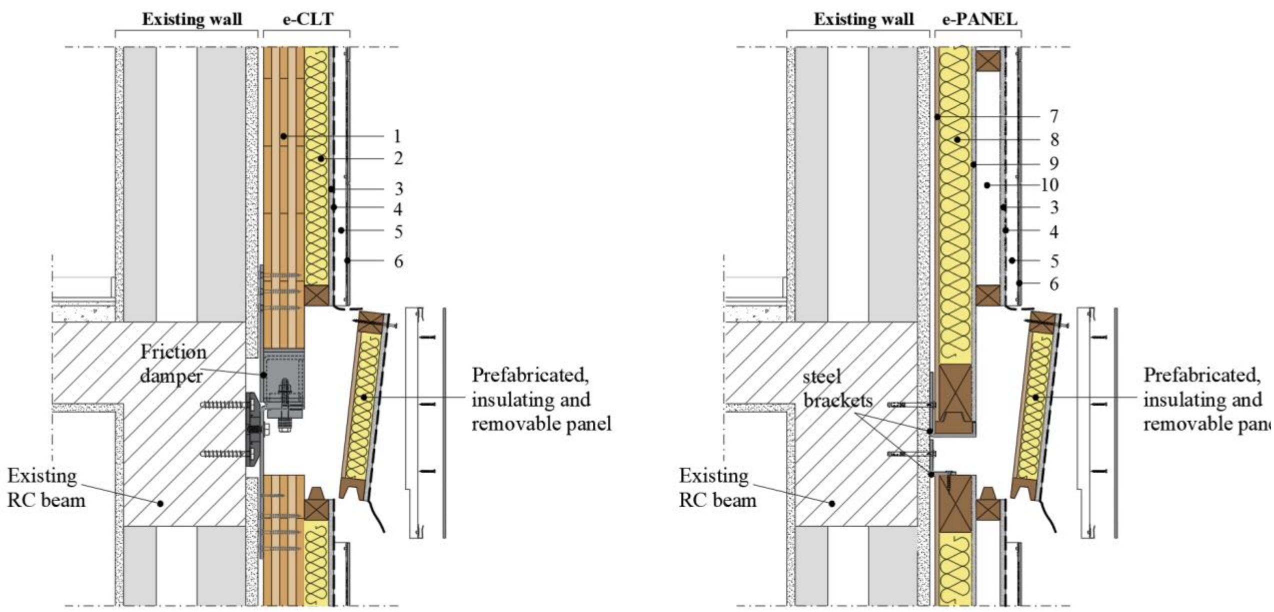
Figure 44: Horizontal cross section of **e**-CLT and **e**-PANEL solutions.

Then, a ventilated air cavity of at least 30-mm thick is provided between the insulation and the cladding layers: this contributes to avoiding summer overheating in the insulation material, while also drying possible rainwater infiltration or winter moisture. Different architectural solutions on the building façades can be also obtained by varying the thickness of the ventilated air cavities in the two kinds of panels. According to the above-described stratifications, and by assuming a cladding layer made of 6 mm-thick porcelain stoneware tiles that are glued to aluminum omega-shaped profiles, the total panels thickness is 208 mm.

Once the **e-**CLTs and **e-**PANELs are installed, cladding solutions that cover the dampers are required. The main technical requirements for these solutions are the ease of installation and removal to ensure the damper inspection and maintenance. They also need to be integrated with thermal insulation solutions to reduce the thermal bridges at the beams level.

Figure 45 reports a potential solution based on the use of further timber-based prefabricated panels. The panel has a wooden frame and integrates insulation material. It is screwed to the **e-**CLT of the upper storey, while it is put on the **e-**CLT of the bottom storey by means of a tongue and groove joint. Then, the cladding substructure and the cladding layer are installed on-site. In particular, the porcelain stoneware tiles can be fixed - and also removed - through standard clips systems.

The above insulating and removable panel can be used also to connect two consecutive **e-**PANELs, thus ensuring architectural uniformity in façade. Indeed, unlike the **e-**CLTs, the **e-**PANELs are not equipped with friction dampers since they have no structural role. Conversely, they are connected to the existing RC structure through steel brackets and anchors having seismic resistance properties.



1. CLT panel, 100 mm
2. Wood fiber thermal insulation, 60 mm
3. Cement-based board, 12.5 mm
4. Weatherproof vapour-open membrane
5. Ventilated air cavity + aluminum omega-shaped profiles, 30 mm
6. Cladding layer (porcelain stoneware tiles, 6 mm)
7. Marine plywood board, 10 mm
8. Wood fiber thermal insulation, 80 mm
9. Cement-based board, 10 mm
10. Non-ventilated air cavity, 60 mm

Figure 45: Vertical cross section of the **e**-CLT and **e**-PANEL solutions.

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7. USING THE E-DSS IN THE CO-DESIGN PROCESS

The firs release of the **e-**DSS was completed in January 2022, and then tested internally through a detailed debugging process. In March 2022 it was fully functioning and could be finally used in the preliminary co-design process.

Thus, UNICT personnel acted as a "technician" in the co-design process: they created a new-project in the **e-**DSS, named "Progetto Pilota", and compiled all fields to determine the performance of the pilot building in the current state. Then, they started a new renovation process: by specifying all the features of the pilot building and its surroundings, and after answering a series of questions, the **e-**DSS notified that both **e-**EXOS and **e-**CLT solutions can be applied to the pilot building. The choice is that **e-**CLT will be demonstrated in the pilot, of course together with a renovation of the technical systems (e-THERM).

After choosing thickness and type of thermal insulation, as well as the features of the energy systems (size of the heat pump, number of fan-coils, PV surface and type), the **e-**DSS provided the comparison between current and future energy performance, together with a preliminary estimation of renovation costs and environmental benefits. These results were then shown to the residents and to the building manager, who could appreciate the importance of the savings they are expected to get.

The next pages report the screenshots of the various datasheet in the **e-**DSS, and the final results. We must here remind that the **e-**DSS is a tool used in a preliminary design stage: its main scopes are:

- assisting the technician in the decision-making process towards the most suitable **e-**SAFE renovation solutions;
- helping him/her in showing and discussing the decisions with the residents.

Then, the technical details of the renovation solution, as well as the final results, cannot be regarded as conclusive information, and will be further refined during the design stage in Task 5.3.

Moreover, from the discussion arisen with the residents, we understood that they would like to have further information on how the operating costs (i.e. the electricity bills) will be distributed amongst the various dwellings, according to their use of the thermal systems. This cannot emerge from the **e-**DSS, so in an upcoming meeting with the residents we will provide further details about energy metering and criteria for costs distribution.

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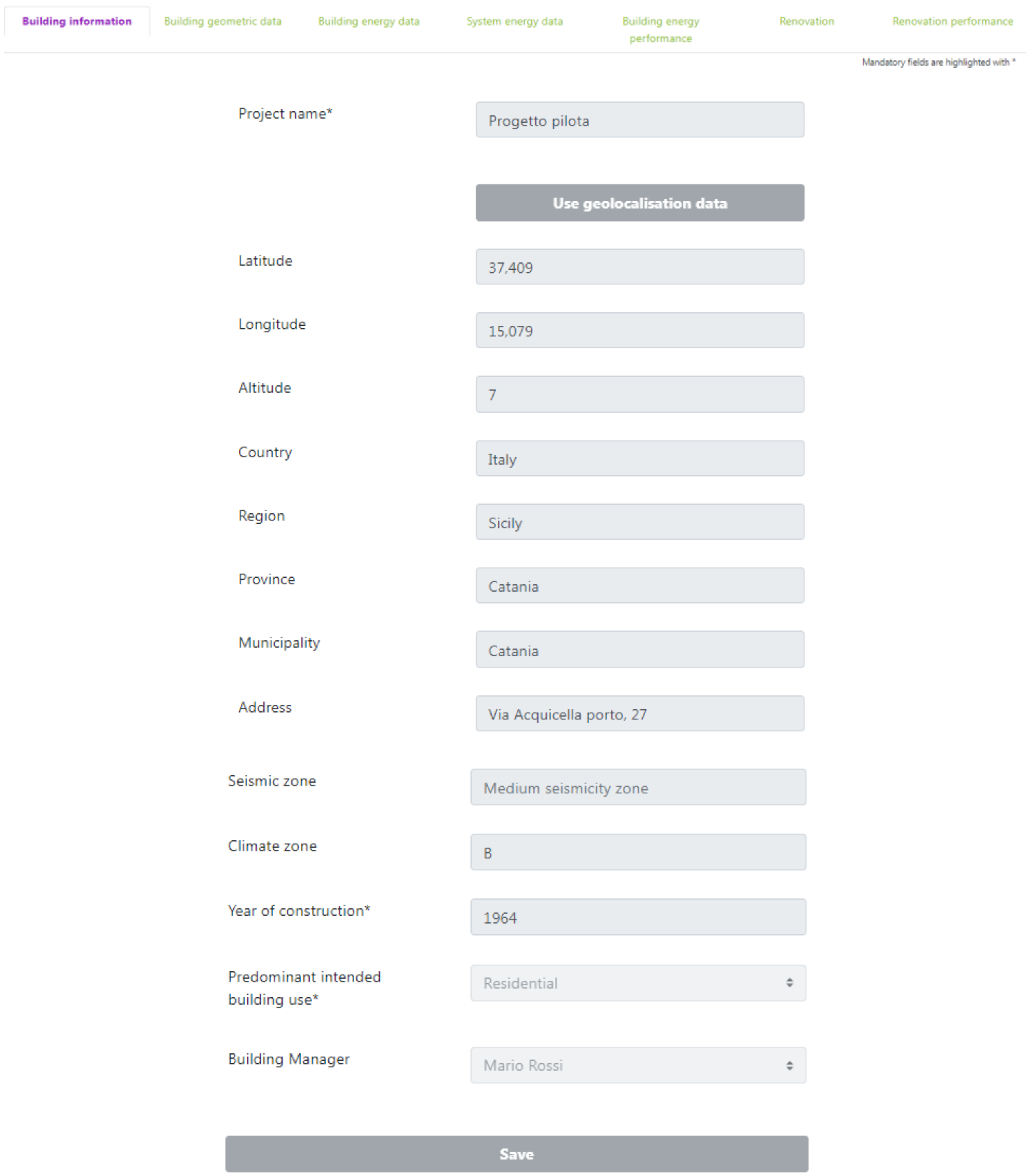
7.1 Datasheet "Building Information"



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7.2 Datasheet "Building Geometric Data"

Overall number of floors above the ground*	5
Number of heated floors*	5
Building height (m)*	16,9
Gross surface of the ground floor (m^2)*	208
Overall gross heated volume (m^3)*	3307
Overall net heated volume (m^3)*	2680

Number of floors in the adjacent buildings

North	0	North-East	0
East	0	South-East	0
South	0	South-West	0
West	0	North-West	0

Length of the facades (m)

North	24	North-East	0
East	10	South-East	0
South	24	South-West	0
West	10	North-West	0

Total windows surface (m^2)

North	51.2	North-East	0
East	10.2	South-East	0
South	83	South-West	0
West	10.2	North-West	0

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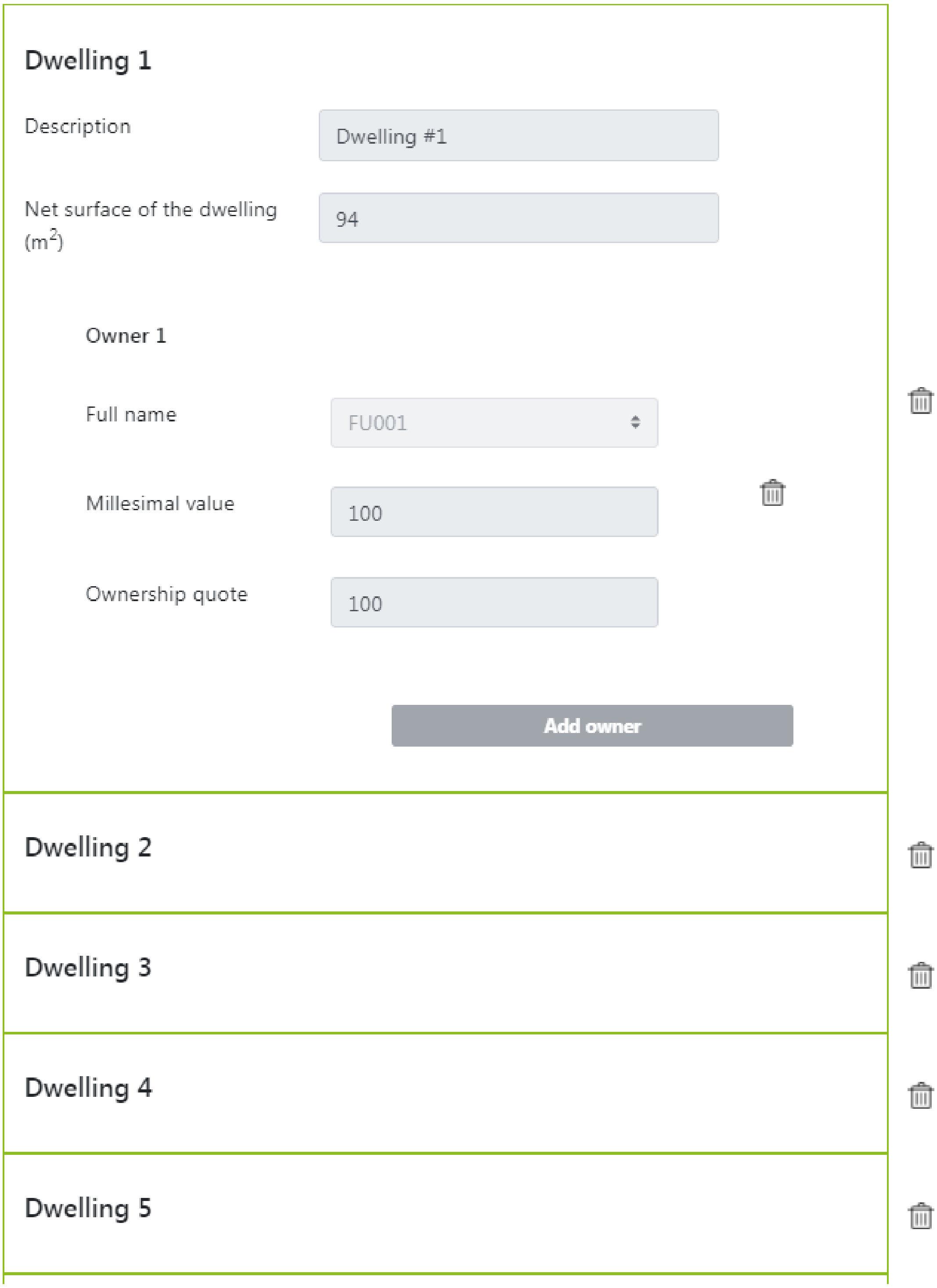
7.3 Datasheet “Dwellings”



Notes: the ten dwellings have the same features as Dwelling #1, apart from the name of the owner

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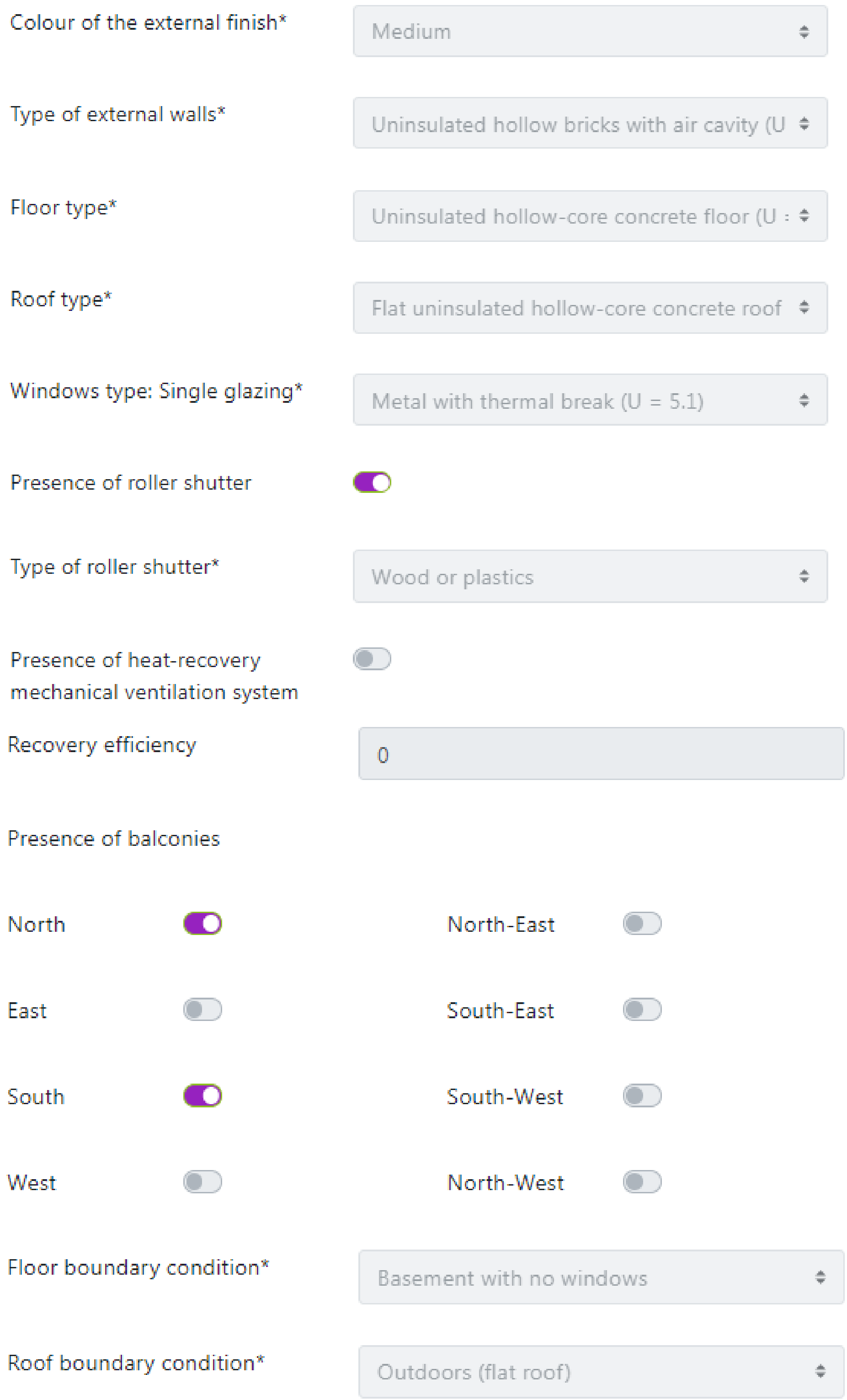
7.4 Datasheet "Building Energy Data"



Notes: some dwellings have different windows than those reported in the **e-**DSS. This cannot be simulated with the **e-**DSS, which considers the most frequent type of windows.

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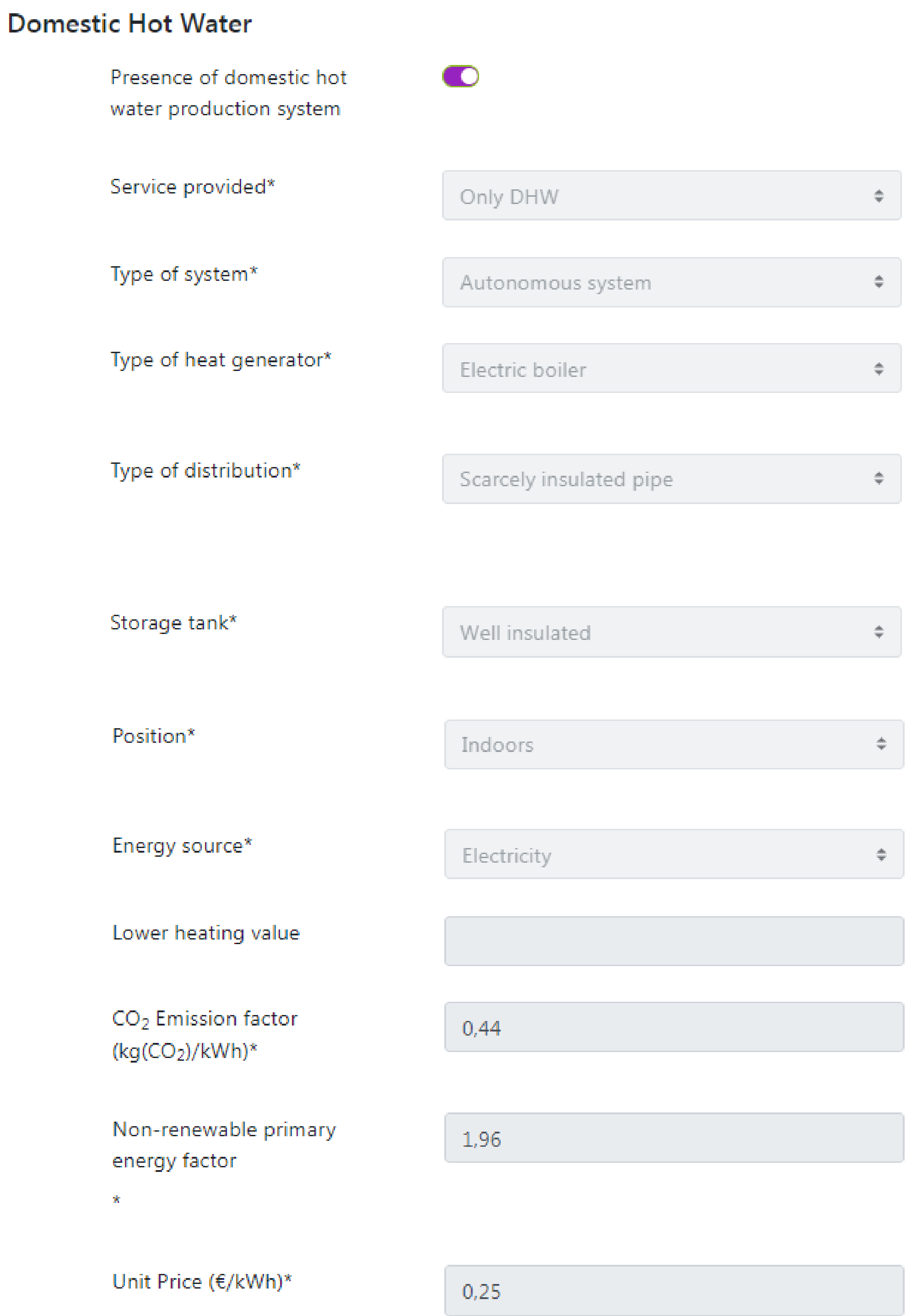
7.5 Datasheet "System Energy Data"



All other data, regarding "Space heating systems", "Space cooling systems", "PV systems" and "Solar thermal systems", were not included. Indeed, as highlighted in Deliverable D5.1 [1], no solar systems are currently available; furthermore, the few split units detected in the pilot during the survey are used seldom, and just for cooling purposes during some exceptional hot spells; some of them are even out-of-order. In such circumstances, the **e-**DSS considers a fictitious heating system consisting of a gas-fired boiler (thermal efficiency = 0.70). As for the cooling system, the **e-**DSS considers old split systems with poor energy performance (default COP = 2.2).

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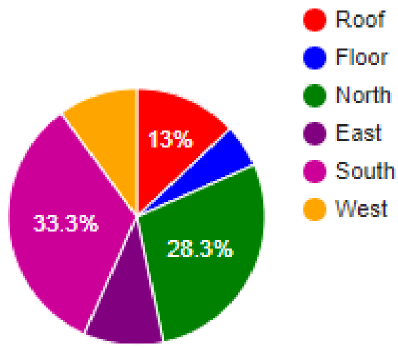
This choice derives from the need of showing to the residents the benefits (energy savings and reduction in the bill) provided by **e-**SAFE: otherwise, since at the moment most of them do not require heating and cooling, the renovation process would be perceived as just an increase to their electric energy bills.

7.6 Datasheet "Building Energy Performance"

Overall heat transfer coefficient	1.69
S/V Ratio	0.47
Annual energy demand for space heating (kWh/year)	49548.86
Annual energy demand for space cooling (kWh/year)	23907.28
Heat losses – distribution	

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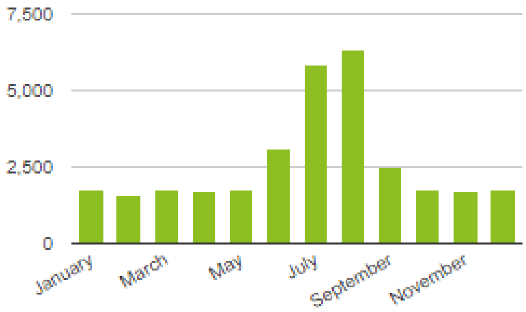
Monthly net electric energy consumption (kWh/month)



Annual net electric energy consumption (kWh/year)	31716.11
Annual gas fuel consumption (m^3/year)	7222.86
Annual liquid or solid fuel consumption (kg/year)	0.00
Non-renewable primary energy (kWh/year)	136486.85
Total CO_2 emissions ($kgCO_2$/year)	28400.82
Total operating costs (€/year)	13707.32
Operating costs for each dwelling	Details

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7.7 Datasheet "Renovation"

Selection of the solution

The building is in High/Average Seismicity Zone: please consider also seismic renovation

Energy retrofit | **Combined seismic and energy retrofit**

Is there sufficient operation space for the crane around the building? **Yes** No

Are there any constraints (cultural heritage, local regulations) that forbid altering the outer appearance of the building? Yes **No**

In the ground floor, openings, doors and door-windows occupy more than 60% of the perimeter? Yes **No**

How many facades are attached to other buildings? (Confirm

Are there at least 3m of free space around the building, without trespassing the property's boundaries? **Yes** No

You can use either **e**-CLT or **e**-EXOS to renovate this building! Which solution do you want to try? **e-CLT** e-EXOS Cancel

Fine, it seems that you want to try the effectiveness of **e**-CLT. However, before proceeding with the next steps you should answer a few more questions

Please specify the surface that will be covered with **e**-PANEL in each facade.

Surfaces for **e**-PANEL (m^2)

North	139
East	36
South	114
West	36

Is the existing structure (reinforced concrete frame) degraded? The structures are just slightly degraded

If looking at a typical floor, what is the percentage of the perimeter occupied by balconies? between 30% and 50%

Confirm

Ok, it seems that **e**-CLT is a good choice

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Update of energy data - envelope

e-CLT thickness (cm) | 10

External cladding layer | Gres (porcelain stoneware)

Insulating material | Wooden fibre

What is the target U-value that you want to reach in the vertical opaque surfaces? Following the local regulations, the suggested value is 0.4 (W/m^{2}K) | 0,34

Calculate the minimum insulation thickness

You should adopt at least 6 cm of insulation. Please confirm or change this value | 6

The calculated average wall thermal transmittance (including **e** -CLT and **e** -PANEL) is 0.32 W/m^{2}K

Confirm

Windows choice

Coming to the windows, do you want to install a specific commercial solution? | Yes | No

Please specify the type of glazing and frame that you want to choose | Aluminium with thermal break

Confirm

Refurbishment of the existing roof

Do you want to refurbish the existing roof? | Yes | No

Insulating material | Cork

Thickness of the insulating material (cm) | 10

Do you want to replace also the pavement/tiles? | Yes | No

Possible roof tiles | Clay tile

Do you also envisage replacing the weather-protection membrane? | Yes | No

Confirm

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Replacement of technical systems

Do you want to replace your technical systems with the more efficient **e**-THERM solutions?	Yes / No
Type of heat pump	Air-to-water
COP (value in standard conditions: 3.8)	4.000
SEER (value in standard conditions: 2.7)	2.700
Size of heat pump (kW)	54
Number of fan coils in each apartment	5
Type of PV modules	Monocrystalline silicon
PV surface installed (m^2)	67.000
Type of PV installation	Roof mounted (with supporting frame)
Orientation of PV modules	South

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7.8 Datasheet "Renovation Performance"

Energy savings and environmental benefits

Electricity savings (kWh/year)	29089.86
Gas fuel savings (m^3/year)	7222.86
Liquid or solid fuel savings (kg/year)	0.00
Non-renewable PE saving (kWh/year)	131339.41
CO_2 emissions savings ($kgCO_2$/year)	27245.27

Savings in the operating costs

Annual savings on the energy bill (€/year)	13050.76

Total costs for the e-SAFE renovation

Overall installation costs for the entire building (€)	948369.45

Total time for the e-SAFE renovation

Time for installation (weeks)	33.42

Time of Return of the investment

Time (years)	72.67
Renovation costs for each dwelling	Details

Renovation costs for each dwelling

Dwelling description	Renovation costs (€/year)	Owners
Dwelling #1	94836.945	FU001
Dwelling #2	94836.945	VR002
Dwelling #3	94836.945	CV003
Dwelling #4	94836.945	CG004
Dwelling #5	94836.945	SM005
Dwelling #6	94836.945	DS006
Dwelling #7	94836.945	SN007
Dwelling #8	94836.945	AU008
Dwelling #9	94836.945	DL009
Dwelling #10	94836.945	CG010

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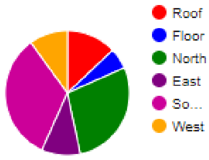
Comparison pre- vs post-renovation

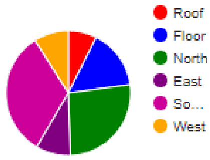
	Pre-renovation	Post-renovation
Overall heat transfer coefficient	1.69	0.59
Annual energy demand for space heating (kWh/year)	49548.86	13088.05
Annual energy demand for space cooling (kWh/year)	23907.28	16975.37

Heat losses – distribution

Pre-renovation:



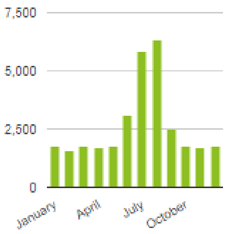
Post-renovation:



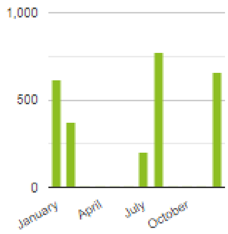
	Pre-renovation	Post-renovation
Annual electricity production from PV (kWh/year)	0.00	20275.14

Monthly net electric energy consumption (kWh/month)

Pre-renovation:



Post-renovation:



	Pre-renovation	Post-renovation
Annual net electric energy consumption (kWh/year)	31716.11	2626.25
Annual gas fuel consumption (m^3/year)	7222.86	0.00
Annual liquid or solid fuel consumption (kg/year)	0.00	0.00
Non-renewable primary energy (kWh/year)	136486.85	5147.45
Total CO_2 emissions ($kgCO_2$/year)	28400.82	1155.55
Total operating costs (€/year)	13707.32	656.56

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Operating costs for each dwelling

Dwelling description	Operating costs pre renovation (€/year)	Operating costs post renovation (€/year)	Owners
Dwelling #1	1370.73	65.656	FU001
Dwelling #2	1370.73	65.656	VR002
Dwelling #3	1370.73	65.656	CV003
Dwelling #4	1370.73	65.656	CG004
Dwelling #5	1370.73	65.656	SM005
Dwelling #6	1370.73	65.656	DS006
Dwelling #7	1370.73	65.656	SN007
Dwelling #8	1370.73	65.656	AU008
Dwelling #9	1370.73	65.656	DL009
Dwelling #10	1370.73	65.656	CG010

Notes: the comparison between pre-renovation and post-renovation suggests that the energy bill for each dwelling would be reduced by around 95%, for a same given level of thermal comfort. No fossil fuel consumption will be needed, and a very high share of the electricity consumed by the centralized **e-**THERM system will be covered by PV electricity.

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8. CONCLUSION AND CRITICAL ISSUES

The document describes the actions and the first results of the co-design process aimed at drafting the preliminary project of the pilot building located in Catania, which will be renovated in the framework of the demonstration activities in **e-**SAFE.

The first preliminary action of the co-design process was the involvement of the occupants, in order to share the most convenient technologies and ensure the acceptance and the satisfaction of the future users. The thermal systems and the positions of all the components for heating/cooling purposes were thus discussed and finally defined. The application of the **e-**CLT and **e-**PANEL panels and their distribution on the four sides of the building have also been carefully explained to the participants, thus increasing their awareness of the reasons for the choices made and their impact in terms of architectural image, security, and energy savings.

Finally, the **e-**DSS tool guided the choices of **e-**SAFE experts participating in the co-design process, who could verify the applicability of two different technological solutions (**e-**EXOS and **e-**CLT) to the pilot building.

As a conclusion, two types of critical issues have emerged. The first type of criticality is due to the implementation of the co-design process and the type of actions itself, which sometimes tends to generate new problems. The second type of criticality is instead due to the satisfaction of the stakeholders demands in relation to the budget, that is limited. Nevertheless, all the preliminary actions to the definition of the pilot project have constructively contributed to the solutions so far suggested.

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ACKNOWLEDGEMENTS

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REFERENCES

Internal references

[1] **e-**SAFE, Deliverable D5.1 “e-SAFE D4.1 Renovation Space Representational Model”.

External references

[2] BLUMATICA ENERGY v.6.2.3.2 software. Available from: https://www.blumatica.it/software-certificazione-energetica-degli-edifici-ape-ed-aqe/ [Accessed 15.09.2021].

[3] Inter-Ministerial Decree 26/06/2015. Applicazione delle Metodologie di Calcolo delle Prestazioni Energetiche e Definizione delle Prescrizioni e dei Requisiti Minimi degli Edifici. Ministero dello Sviluppo Economico (in Italian).

[4] EnergyPlus v.9.0 software. Available from: https://energyplus.net/.

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