D7.4b - Renovated Case Studies, Madrid

Development of Systemic Packages for Deep Energy Renovation of Residential and Tertiary Buildings including Envelope and Systems

iNSPiRe

Project Title: Development of Systemic Packages for Deep Energy Renovation of Residential and Tertiary Buildings including Envelope and Systems

Project Acronym: iNSPiRe

Deliverable Title: D7.4b – Renovated Case Studies, Madrid

Dissemination Level: PU

Lead beneficiary: Gruppo Industriale Tosoni

Santiago Antolin, EMVS

Diego Romera, ACCIONA

Roberto Fedrizzi. EURAC

Diego Bertesina, MANENS TIFS

Date: 30 March 2016

This document has been produced in the context of the iNSPiRe Project.

The research leading to these results has received funding from the European Community's Seventh Framework Programme (FP7/2007-2013) under grant agreement n° 314461. All information in this document is provided "as is" and no guarantee or warranty is given that the information is fit for any particular purpose. The user thereof uses the information at its sole risk and liability. For the avoidance of all doubts, the European Commission has no liability in respect of this document, which is merely representing the authors view.

Table of Contents

1 Executive Summary

The building selected by EMVS as a demonstration of project iNSPiRe practices is located at 47, Canción del Olvido street, Ciudad De Los Angeles in Madrid.

This building was commissioned in 1960 and its foundations were partially renovated back in 2003. This property is located in the area for integral Renovation of *Ciudad De Los Angeles* since 2008.

The condition of this property prior to the renovation jobs showed a number of defects, in particular foundation problems derived from the structure's differential settlement, which caused significant cracks on the building facade. Besides, the building envelope lacked any kind of insulation and the roof's insulation and waterproofing consisted of what is known as '*Catalonian roofing',* traditional Spanish construction technique consisting of an aired/ventilated chamber providing both insulation and waterproofing.

Figure 1 - North façade

Figure 2 – South facing façade

At this point it is worth mentioning that the income levels of both landlords and inhabitants of this building are quite limited, making unfeasible a fully-fledged renovation project out of their own financial resources. As such, they were selected as beneficiaries of EMVS Renovation Plan as well as new installations thanks to Project iNSPiRe at no extra cost.

Given the level of deterioration observed in the building, the property owners were left with no option but to explore the different alternatives: either renovate or even demolish and rebuild.

Finally the owner's association decided not to demolish it and carry out a complete renovation including new features as a lift shaft attached to the external building envelope improving access to the properties, redesigning the stairway from two flights to a single one, rebuilding the stairwell. All of these works were carried out with the occupiers remaining in premises throughout the duration of the project.

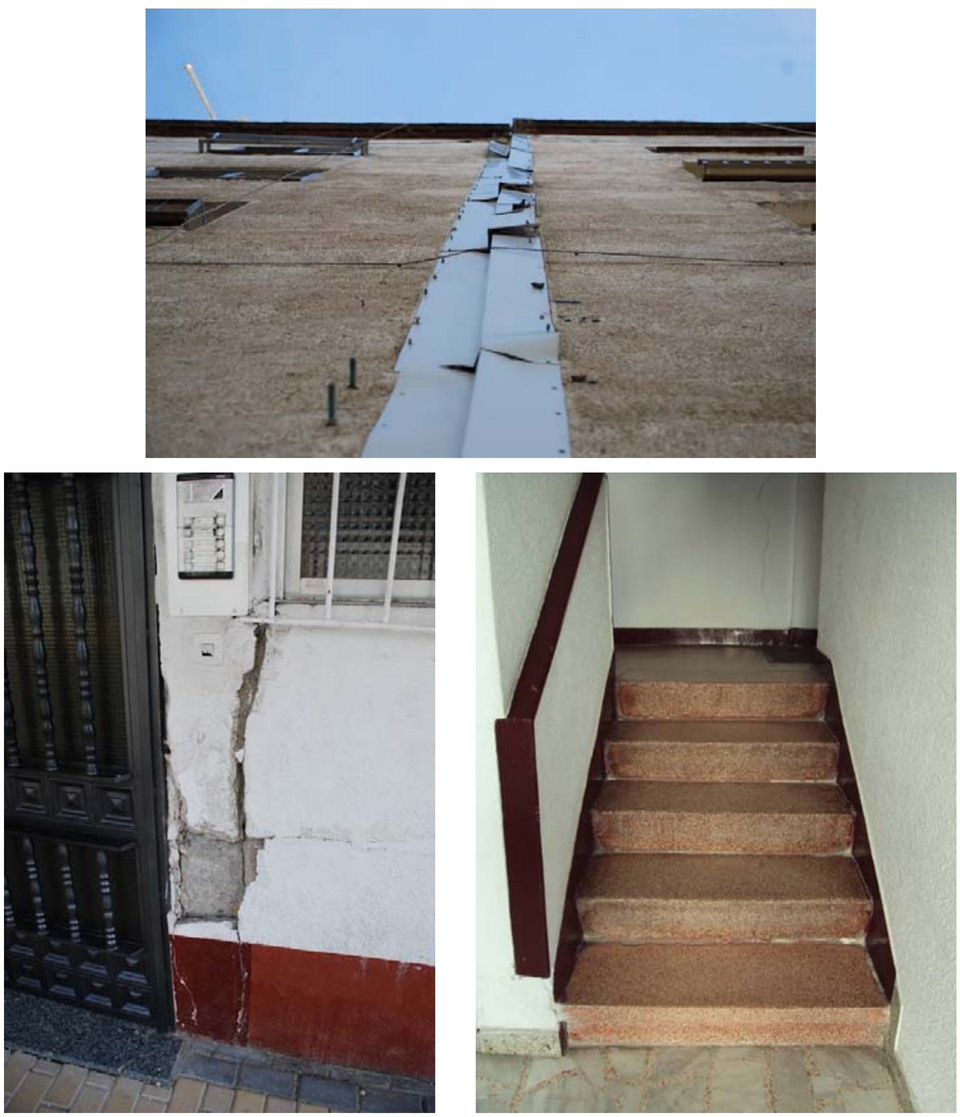

Figure 3 – Cracks assessed during audits

Two of the kits developed were implemented in this demo site. The first Kit is the Energy Management System composed of a number of Energy Hubs distributed within the new centralise heating and cooling systems, and of one energy Manager installed in the technical room of the building.

The second Kit is the integration between the aluminium radiant ceiling panel and recessed luminaires.

Opposite to the demo site in Germany, here the Kits are used to setup the new centralised heating and cooling system, while commercial solutions are used to retrofit envelope and windows.

Also in this case, the planning phase of the Kits and market available solutions requested a long time within the research program timeframe, while the installation stage has been relatively fast.

This is due to the need of coordination among different working teams, with different backgrounds and expertise. Moreover, the ownership of the building considered in this document is diffused (one owner per dwelling): project partners EMVS and ACCIONA participated in the retrofit design phase and, in parallel, acted as facilitators of the rehabilitation process towards the inhabitants. This non-technical activity took most of the effort of the partners, in the first 2 years of the iNSPiRe project elaboration.

The building is now retrofitted, while monitoring is ongoing. The commercial solutions employed and the radiant ceiling + recessed luminaire Kit are ready for direct replication in similar applications.

On the other hand, some more work is needed to industrialise the Energy Hub solution, including the CE accreditation of the thermal energy metering units included.

The main lesson learned is that coordinating the design, together with gathering the needed agreement by the owners, were the most challenging tasks, far behind the development of the technical solutions.

2 Building Status before Renovation

The building has rectangular shape, with sides of 16,34m x 7,55m and a central projection on the main façade 7m x 0,78 whereby the access to the main entrance is located.

Figure 4 - Building vertical view

The use of the building is fully residential. It contains ten dwellings distributed on five floors, being the main entrance of the building at the same level of the two dwellings of the ground floor.

The useful area of each dwelling is 50 m^2 with a free height of 2,48m, shared among three bedrooms, one bathroom, one living-dining room and one kitchen. The inner distribution of each dwelling is shown in the plan of Figure 5.

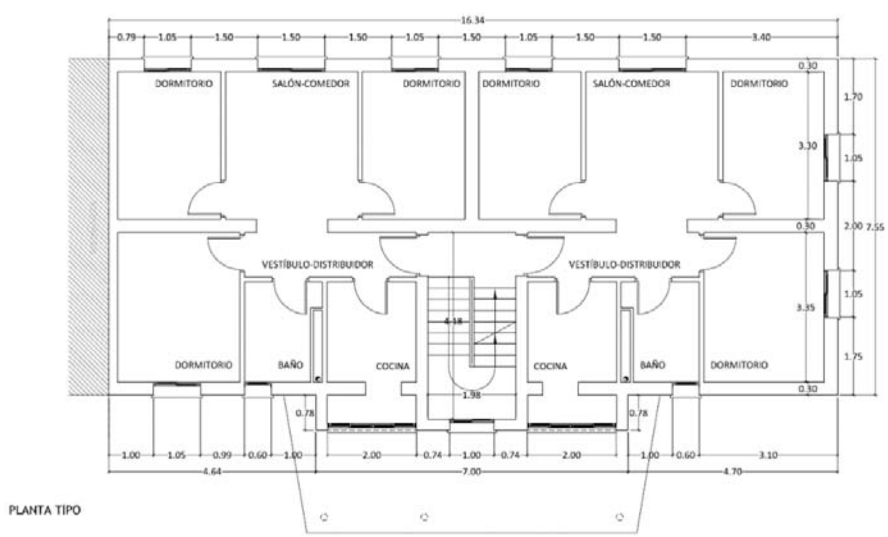

Figure 5 Building floor plan

The gas piping distribution as well as the phone lines and electricity wiring are located along the façade.

The stairs that gave access to the dwellings of each floor were U-stairs with half landing. In the fourth floor, the last flight of stairs, gave access to the roof.

The roof was accessible but used only for maintenance works. The small technical room located on the roof housed the electrical meters of the ten dwellings.

Figure 6 - Gas piping

Figure 7 - Telephone lines

Figure 8 - Electricity wiring

The windows existing installed can be divided in two groups:

1. Single window, single clear glazing 6mm.

   Aluminium window frame (no thermal break)

   u value estimated equal to 5.8

2. Double window with air cavity 10 cm. Single clear glazing 6mm per window.

   Aluminium window frames (no break)

   u value estimated equal to 3.1

Almost all the bedrooms and dining rooms of the dwellings were provided with white roller blinds to avoid overheating in summer, sunlight during the day and exterior artificial light during nights. In all cases, the mechanism is manual.

Some windows facing west orientation were also provided with textile awnings.

Figure 9 - Blind 1

Figure 10 - Blind 2

Figure 11 - Overhangs

Figure 12 - Electric heater

Figure 13 - Gas boiler

Figure 14 - Electric radiator

Figure 15 - Butane heater

Figure 16 - Radiator

Figure 17 - A/C split

Each dwelling had its own HVAC system setup. All dwellings are setup with a DHW and space heating system. Most commonly, natural gas or electric boilers were used; in some cases however, butane gas boilers were still used.

The dwellings set up with gas boilers had also radiators installed, while independent electric radiators or butane heaters were installed in the remaining apartments.

Just three dwellings were setup with cooling via single split units.

No ventilation was present in the dwellings.

3 Integral building renovation

As already mentioned the general condition of this building was poor and deteriorated, showing significant cracks on structure and envelope, damaged fittings, fixtures and joinery, construction flaws as well as unfinished renovation works which did not improve the building condition.

Part of the initial building survey consisted in finding what was the level of completion of the partial renovation carried out in 2003, the quality and condition of those works, as well as all other identified defects.

Another section of this initial phase consisted of the identification of requirements for obtaining a new energy rating for the property in order to apply for public funding aids from EMVS.

The planning permission stage aimed at both renovating the building inferring to it a sustainable character as well as improving accessibility by means of an external lift attached to the main building facade.

A geotechnical survey was carried out in order to analyse and determine the best course of action for foundation renovation, which had already been identified as a major task in this project.

Figure 18 – Cracks inside sleeping room

The renovation process went through a number of actions, starting from the structural reinforcement of the building, the thermal insulation of the envelope and the installation of a centralised heating and cooling system.

The structural works can be summarised as follows:

1. Execution of micropiles and caps, planned back in 2001 but not carried out during the previous renovation works in 2003, which would complete thereafter all foundation works and their interconnection. More precisely those micropiles on traversal walls supporting stairways and short facades.
2. The existing caps from 2001 are built in 9 different sections and are not interconnected. By means of the new caps and mechanical-chemical bindings all existing and new sections have been interconnected providing a solid foundation.
3. Double bracing at building joint using steel adjustable tension stringers and brackets attached to concrete walls. These have been replaced at a final stage with metallic squares anchored to concrete walls.
4. Construction of lift shaft with concrete walls, which contributes to the overall building stability acting as a buttress.

5. In order to build the new lift shaft, the existing stairwell had to be demolished and a new one put in place. It is worth to keep in mind that during all this process the building was inhabited by owner-occupiers.
6. Construction of a new roof structure by means of a metallic ring structure braced with steel stringers and connected to the new lift shaft structure. The former has been finally replaced by a permanent concrete slab attached to structural walls.
7. Repair facade cracks, eliminate external artefacts (aerials, satellite dishes, etc...) and consolidate boiler exhausts and vents in order to increase the aesthetical value of the property.

Figure 19 – Lift shaft during installation and at the end of the retrofit

The buildings façade has been coated with an external thermal insulation system in order to improve the thermal behaviour and meet existing regulations in Spain.

New double glazed windows have been setup, as well as passive protection lattices where appropriate.

The heat generation system is a reversible 20 kW air to water double circuit heat pump: one circuit is always turned in heating mode and connected to a 500 litres hot water storage for domestic hot water preparation, the other is turned in heating mode in winter and in cooling mode in summer. A 22 m^2 solar thermal plant feeding an 800 litres thermal storage is the main system for DHW production.

The distribution system is a four pipes system allowing to distribute contemporarily DHW, and heating or cooling. All the pipes from the technical room on the roof to the dwelling's hydraulic stations have been placed under the facade insulation, on the external side of the walls.

In the dwellings, the heating and cooling system is distributed by means of radiant ceilings. Pipes distributing water from the mains to the dwellings have been installed in the false ceiling on the staircase and in the main corridor of each dwelling.

4 Renovation measures adopted – an insight

The envelope solutions adopted for this retrofit are fully commercial, and have been planned and setup in parallel to the iNSPiRe project measures.

The iNSPiRe renovation mainly regarded the installation of the new centralised heating and cooling system. With this respect, the energy hubs developed have been used to hydraulically connect all the heating and cooling units, and the technical room to the single dwellings' DHW and space heating distribution system.

The distribution Kit integrating recessed luminaires in a radiant ceiling panel has been used in the latter case.

4.1 Envelope solutions

It has been mentioned already that the building was in a bad status of conservation before retrofit start: the building had a conventional foundation, which was partially micropiled in 2003 to try a first structural recovery. Despite this, depth and status of the existing base were not known.

For this reason, before implementing energy efficiency measures, it was necessary to proceed with the structural stabilisation of the property.

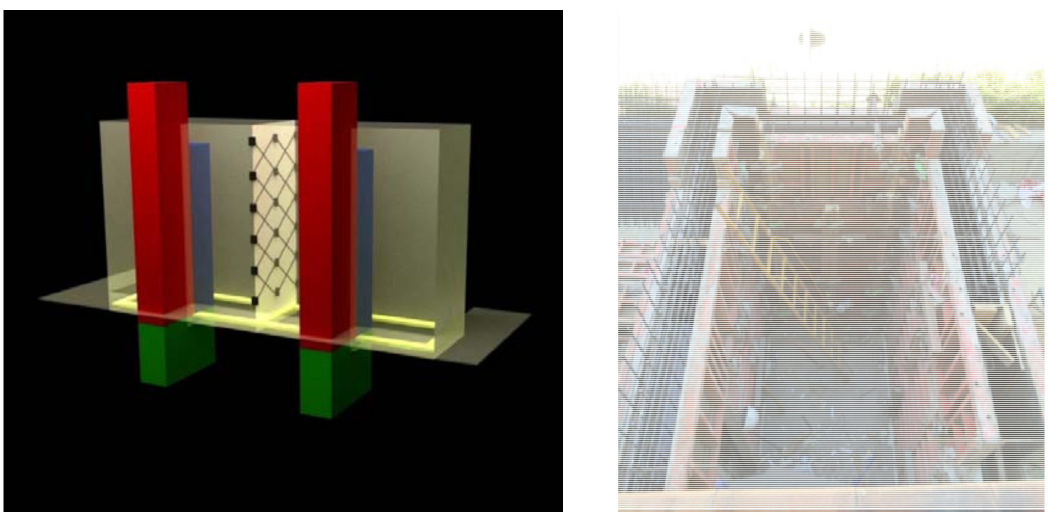

Figure 20 – 3D preliminary analysis (left) and lift shaft foundation (right)

Thirteen grade slabs, installed in front and partially below the existing stairway, constitute the new foundation that distributes evenly the vertical and lateral loads of the building on the ground (green in Figure 20). To this purpose, a steel structure is interposed between grade slabs and the ground floor of the building.

The new lift shaft - manufactured with three concrete walls and beams that join it to the concrete façade of the building - is based on six new piles.

The horizontal structure of the building is made of concrete beams and slabs. The existing structure has a thickness of 22 cm including the pavement. The horizontal structure was not altered except in the stairwell and the connection with the new lift shaft. The existing stairway was completely substituted with a new metal one. This is welded to anchor plates screwed onto the concrete slabs of each floor.

Windows with vertical opening installed on the north side of the lift shaft allow for a better illumination and night-ventilation at summertime of the common areas.

Figure 21 – Steel structure in the foundation reinforcing the existing bearing piles (left) and anchor plates (right)

Figure 22 – Newly setup staircase during and after installation completion

The existing facades are made out of concrete cavity walls without insulation. In order to comply with the of the national regulations, a new external insulation was installed made out of 10 cm thick rock wool panels anchored to the concrete walls. A coating with fiberglass mesh and acrylic coloured mortar protects the façade solution.

Figure 23 – Mineral wool insulation

Figure 24 – new windows installed (left) and polyurethane insulation installed in the basement (right)

New windows were installed from the outside on top of the existing ones, without entering the apartments. The existing roller shutters were also left in place minimising the discomfort for the inhabitants.

The 4/10/4 mm, double pane, low-emissivity glass, dark grey lacquered aluminium windows are flux mounted onto the new insulation.

Under the south façade windows, perforated metal sheet shading elements installed allow to dry cloths maintaining privacy.

The building has no garage nor lumber rooms below the ground floor dwelling. An empty gap with a height of about 1.4 m separated first apartment from grade. Polyurethane foam with a thickness of about 5 cm and density 35 kg/m^3 was sprayed onto the lower surface, to insulate and to partially cut thermal bridges (Figure 24 right).

Figure 25 – Flat roof before and after water proof coating deposition

Figure 26 – XPS roof insulation

The exiting "catalan" cover was dismantled and the remaining structure was reinforced with an added concrete structure, to avoid any future structural failures. The water proof insulation was guaranteed with a geotextile polyester foil (300 g/m²) covered with a 1.2 mm PVC-P coating reinforced with fiberglass.

A 60 mm XPS insulation was the installed, again protected with geotextile protection and gravel.

Figure 27 – North façade after retrofit

4.2 Centralised space heating, cooling and DHW preparation system

The heat generation system is a reversible 20 kW air to water double circuit heat pump: one circuit is always turned in heating mode and connected to a 500 litres hot water storage for domestic hot water preparation, the other is turned in heating mode in winter and in cooling mode in summer. One energy Hub connects the heat pump to the storage tank.

In summer the heat pump produces contemporarily cooling and heating: the rejected heat from the HP is recycled to produce DHW if needed, instead of being rejected in the environment.

The heat pump is located externally on the roof, next to the east wall of the technical room. A concrete bench was specifically built to support the overloading of the unit. The external pipelines connecting the heat pump with the DHW and heating/cooling circuits have been properly isolated and protected with an aluminium layer.

An 800 litres storage is connected in series to the 500 litres one fed by the heat pump. This is due on the one hand to the lack of height in the technical room for the installation of a unique 1300 litres tank, on the other to the Spanish regulations, which forbid a backup heater directly installed on the solar circuit storage tank.

Figure 28 – Heat pump setup on the roof

Figure 29 – Solar field installation on the south facing parapet

A 24 m^2 solar thermal plant feeds in fact the large thermal storage through an internal heat exchanger. Due to space and aesthetic constraints (the collectors are aligned with to windows on the same façade), 8 solar collectors are installed in parallel on the south facing parapet of the building, while other 2 collectors were installed on the wall of the technical room.

In addition, in order to allow maintenance directly from the roof, solar collectors were installed with a gap of 200 mm from each other and distance of 200 mm between bottom connections and roof surface. An anchoring structure made out of "c-shape" profiles with the same width of the solar collectors was designed on purpose in order to bear collectors' weight and eventual wind loads.

Solar field pipelines are made out of copper and covered with 2 inches elastomer insulation. An aluminium layer protects insulation from degradation due to UV rays. Pipes with not easy access were covered with a special paint.

One Energy hub connects the solar field to the 800 litres storage tank.

The solar field is designed and controlled as to avoid stagnation also during summer. However, eventual stagnation due to unforeseeable conditions is prevented thanks to a dissipation unit in parallel to the solar circuit, which is set on when temperature higher than 95°C are detected.

Figure 30 – South-facing façade with solar collectors installed

Figure 31 – paint protection on hardly accessible pipes (left) and heat dissipation unit (right)

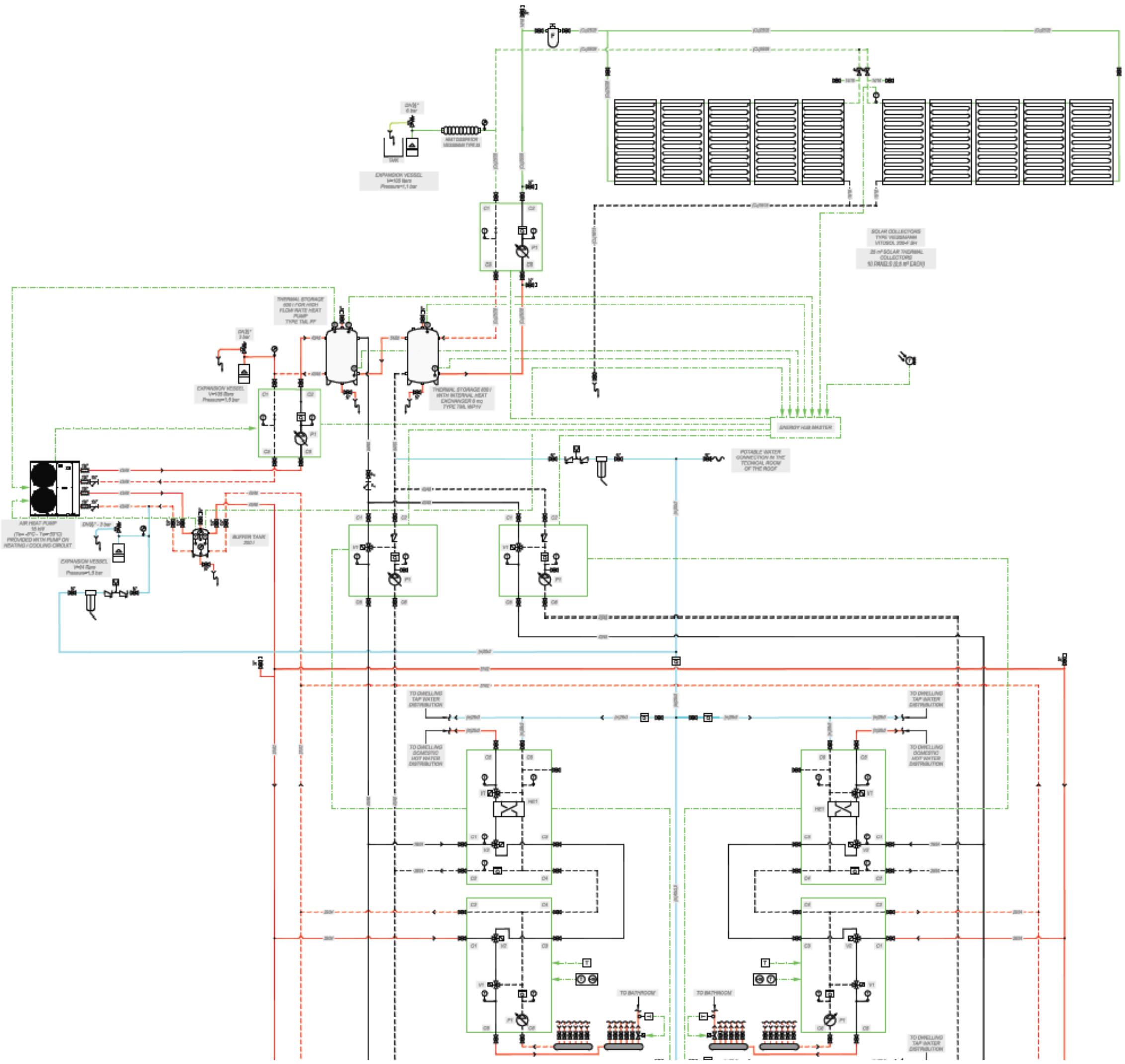

Figure 32 – Schematic of the hydraulic system. Energy hubs highlighted in the green boxes

The distribution system is a four pipes one, two for heating or cooling (in red in Figure 32), two only for DHW production (in black in Figure 32). Two Energy Hubs distribute water for DHW preparation to the west and east dwellings respectively. The temperature of the primary distribution system is set to a value independent of the storages by using mixing valves in the two modules.

The heat pump is connected directly to a hydraulic junction (200 litres) before distributing heating/cooling water to the apartments. This is useful both to provide a thermal buffer to eventual de-icing cycles operated by inverting the heat pump thermodynamic cycle and to decouple the generation flow from the users. The latter guarantees that the unit works smoothly, avoiding continuous on-off cycles when building loads are lower than the minimum part load operation (around 30% of the rated thermal capacity).

To fill the system, two mains have been installed, one for the DHW line and one for the Heating/cooling and solar lines. Moreover, it has been designed a setup suitable to the mix propylene glycol to water needed for the solar circuit, and anticorrosive fluid to water for the heating/cooling circuit.

Figure 33 – thermal storage tanks and the four Energy Hubs

Figure 34 - Mixing system

An electric cabinet was designed and installed to hold the electric devices required for the operation of the installation. It hosts:

- Protection devices: Thermal circuit breaker, Residual current circuit breaker, to protect the units against power surge or electrical shunts
- Electric Meters: One three-phase meter to measure the HP consumption and three one-phase meters to measure the consumption of the rest of the equipment installed.
- Relays and contactors: Activated by the EM, to control the operation of HP and some units with motor (heat dissipation unit, motor valves, etc.)
- 24V Power Supply Unit

All the EH are supplied with 24V and are connected to each other and to and Energy Manager through a ModBus network. In addition, the EHs provided with a pump, are powered with 230V.

Once, all the connections were checked, all the wires were properly covered and secured with a metallic wire way.

Figure 35 - Electric cabinet and Energy Manager

The vertical lines connect and supply heating/ cooling water and DHW from the tanks located in the technical room directly to the Energy Hubs located on each floor.

They are disposed in two groups feeding water to the dwellings of each side of the building (right and left). Each of the two group consists of two verticals for the DHW and two verticals for the heating/cooling.

On the right side and separated by the others, it was located the tap water pipe, while on the left side, it was setup the sink pipe from the technical room.

Polypropylene (PPR) pipes were used in all cases, allowing for a cheaper and faster installation. The construction process has been the following:

- Firstly, anchoring structure holding the pipelines was fixed to the concrete facade of the lift shaft. In addition, at each floor, four extra profiles were added in order to support the EH.
- The PPR pipes were attached to the external metal profiles by screwed clamps
- The shaft was closed from the outside with and structural insulated panel.
- Finally the Energy Hubs distributing water to the dwellings were fixed to the metal profiles and connected to the pipelines. Here multi-layer pipes were used to ease the setup of complex junctions.

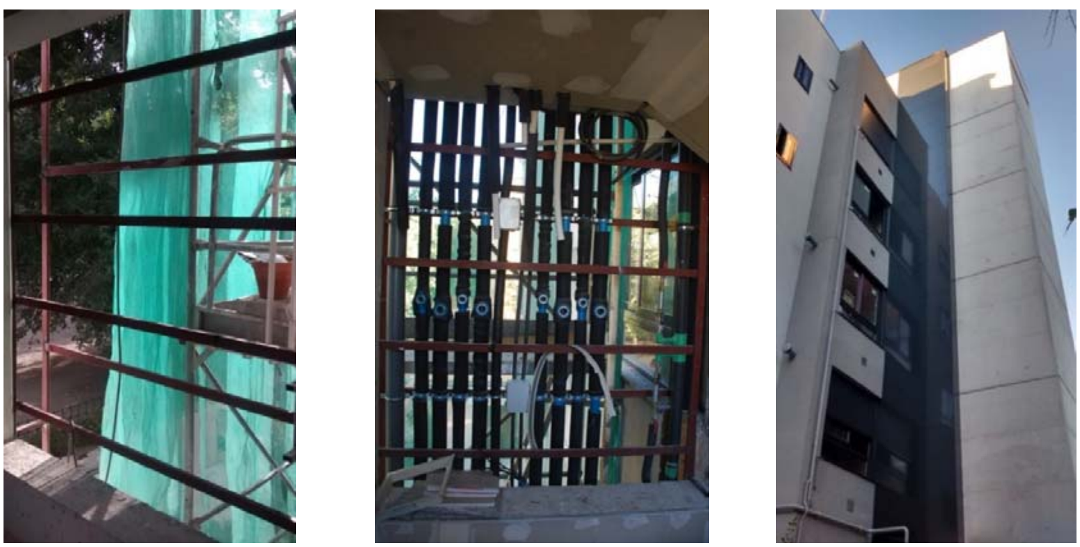

Figure 36 - Vertical pipelines construction

Two Energy Hubs are installed for each dwelling, one for heating and cooling distribution domestic and the other for domestic hot water preparation.

The DHW Hub is fed with hot water from thermal storages. The primary hot water circuit and domestic hot water circuit are separated by a plate heat exchanger. This results in the instantaneous production of DHW, avoiding any legionella disease ingeneration even if the primary circuit is fed with 40-45 °C water. This on the other hand allows to reduce significantly the thermal losses through the pipelines, with respect to systems fed with 60-70°C warm water.

The distribution one is fed by the 200 litres buffer tank. The two are also connected to each other, so as to allow using excess solar thermal energy with respect to DHW needs for space heating in the mid-season. This also permits contemporary space heating in some apartments and space cooling in other.

A security door was added, to protect the Energy Hubs and to separate the pipes shaft from the lift hall, in compliance with fire safety regulations.

At the bottom part of the shaft, an emptying system has been foreseen for the evacuation of water of the whole system.

Figure 37 – Energy Hubs connections

Figure 38 Safety door on the hallway and emptying system of the verticals lines

The horizontal piping from the Energy hubs to the dwellings was executed through the fall ceiling setup, once it the new stairway was build.

The heating/cooling pipes enter into the dwelling above the entrance door, while the DHW enter through the closed terrace of the kitchen.

Air vents were install along the pipelines before entering the dwellings (that is the most elevated position on each floor).

Figure 39 - Horizontal pipelines installation process

The heating and cooling system in the dwellings is a radiant ceilings one: radiant ceiling works as heating system in winter and cooling system in summer, when heat pump is turned in cooling mode.

A main programmable thermostat in the corridor acts on the pump of the distribution station when heating or cooling is required. In addition, a thermo-hygrostat was installed allowing to control inner conditions and to avoid moisture condensation on the radiant ceilings in summer, by proper control of the supply temperature from the Energy Hub.

Each dwelling was designed independently in terms of radiant panels positioning. The owners were asked about their preferences for the location of the radiant panels, integration of luminaires in the panels, piping covers, etc. The position of the furniture were a key factor in order to choose the best panels' distribution in the dwelling. Aesthetics was a critical issue for the social acceptance of the system.

Another design driver was that the central internal partition is a load bearing wall, that greatly hampered drilling holes to install pipes to certain rooms.

Initially the manifold was planned to be installed outside the dwelling. However, in order to reduce the number of holes above the main entrance, it was located in the corridor. Ball valves were left at the outside of the dwelling allowing to close the water supply to the dwelling.


Figure 40 - Piping distribution in the corridor of the dwellings


Figure 41 - Anchoring system of the ceiling panels (left) and flexible metal hose

The pipes used are multi-layer without insulation installed. The anchoring system of the panels is made out of four hook-shaped, metal profiles, complementary to the ones installed on the radiant panels. This system allows the easy installation and future maintenance.

A metal hose with fast fitting connections was used to join the multi-layer pipe to the aluminium pipes inside the radiant panel, which is long and flexible enough to ease this operation.

All corridors were covered with plasterboards for aesthetical reasons. Different solutions were adopted to cover the pipes in the rest of the rooms, following the requests of the inhabitants.

In one dwelling, the whole ceiling was covered with plaster boards. In this case, none of the radiant panels integrate luminaires, as they will be placed next to the wall to ease maintenance. The rest of the dwellings chose the "island" option: all the panel are located in the middle of the room and incorporate the luminaires needed for a proper illumination of the room. In these cases, the pipes were hidden by covers supplied by TRIPAN, and plaster moulding, depending on the owners requests.

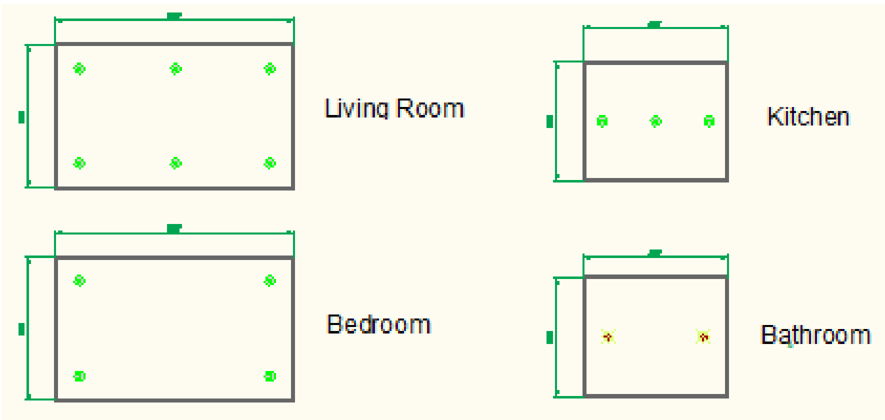

Figure 42 - Luminaires distribution on the radiant panels

Figure 43 - Radiant panels installed

5 Lessons Learned

The level of disruption was acceptable for the residents during the construction process. Besides the lift shaft erection and staircase renovation, and with reference to the iNSPiRe measures adopted, the highest level of disruption was caused by the installation of the ducts inside the property, which required good coordination with the residents.

The erection of the pipelines shaft, technical room and Energy Hubs was unproblematic to the inhabitants.

The main lesson learned is that gathering the needed agreement by the owners, were the most challenging tasks. Project partners EMVS and ACCIONA participated in the retrofit design phase and, in parallel, acted as facilitators of the rehabilitation process towards the inhabitants.

An improvement for the future would be to clarify exactly the scope and the investment costs of the retrofit project at the beginning of the planning phase, in a way to get the owners agreement and a signed framework program from the beginning.

With such a complex planning and installation process, it is essential that the share of work and responsibilities of the partners involved in the different phases, and responsible persons are identified initially. This also allows also minimising the volume of documentation exchange and facilitates the communication. The main coordination role was kept by the architect. The conceptual planning was carried out within the research partners of iNSPiRe, whereas the detailed plans and approval were carried out by the architect and the professionals responsible for the installations.

Two of the kits developed were implemented in this demo site. Professionals are not aware of how to optimally use and install such systems: as such, the setup phase has taken longer than expected and technical issues have been solved on site as far as the installation was proceeding, with unexpected additional effort needed.

In future demonstration projects, time should be spent to hire professionals in an early stage of the planning phase, and to train them before the installation phase begins. During commercialisation, significant effort has to be placed by manufacturers on creating a network of trained professionals that could be employed for the installation and maintenance of own systems.

Finally, a deep rehabilitation process does not only involve the implementation of energy efficiency measures. It usually accounts for structural reinforcement of the building and update to the latest regulations, for instance eliminating architectural barriers, updating electric wiring and water pipelines, etc. The structures devoted to the implementation of energy efficiency measures often facilitate such an update.

Consequently, after the renovation, the property has not only higher energy efficient but also higher economic value and longer lifetime. This is hardly accounted for when evaluating the payback time of the energy efficiency measures adopted. Specific property value estimation should however be carried out, as a value proposition of the retrofit action undertaken, showing the overall financial picture to owners and public/private investors.