The energy retrofit of a multifamily building in Madrid

At 47 Calle de la Canción del Olvido in Madrid, last winter owners have heated their apartments with electric heaters and gas boilers. Since June they can count on a more efficient heating and cooling system based on a smart hydronic unit developed within the FP7 project iNSPiRe.

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The retrofit of a vast portion of the European building stock is becoming a stringent requirement from the structural, functional and the energy perspectives, following European Commission Directives, deterioration of the buildings and eldering of the population.

EMVS (Empresa Municipal de la Vivienda y Suelo de Madrid) selected the multifamily house located at 47 Calle de la Canción del Olvido in Madrid as a demonstration building to be fully retrofitted in the framework of the FP7 project iNSPiRe.

This building was commissioned in 1960's, and prior to renovation the property showed a number of defects, in particular foundations problems produced by the structure's uneven settlement, which caused significant cracks on the building façade and inner walls (see **Figure 1**). Besides, the building envelope lacked any kind of insulation.

The renovation process has undergone several actions, starting from the structural reinforcement of the building, the thermal insulation of the envelope and

Figure 1. The apartment building before retrofit and cracks assessed during audits.

the installation of a centralised heating and cooling system.

Looking at the structural works, micropiles have been installed under the façade bearing the staircase and the short façades of the building. All micropiles' caps have been interconnected mechanically resulting in a solid foundation. Steel adjustable tension stringers and brackets have been used to embrace the building, and to connect building's concrete walls to the new foundations.

A concrete walls shaft has been raised in front of the existing staircase, with the double objective of incrementing the structural stability and providing the building with a new elevator. To do this, the existing stairwell has been demolished and replaced with a prefabricated one (see **Figure 2**).

This measure has been extremely significant, not only from the technical perspective but also for the owners, mostly retired people, who had started to perceive the missing elevator as a barrier to a comfortable lifestyle.

The high degree of prefabrication allowed the owners to leave in their homes during the entire process.

The existing façades are made from concrete cavity walls without insulation. In order to comply with the national regulations, a new external insulation has been installed with 10 cm thick rock wool panels. A coating with fiberglass mesh and acrylic coloured mortar protects the insulation.

4/10/4 mm double pane, low-emissivity glass, aluminium frame windows have been flux mounted onto the new insulation outside the existing ones, which have been left in place. The existing roller shutters have also been conserved minimising the discomfort for the inhabitants.

An empty gap with a height of about 1.4 m separates ground floor apartments from grade. Polyurethane foam with a thickness of about 5 cm has been sprayed onto the lower surface, to insulate and to partially cut thermal bridges.

The exiting roof cover has been dismantled and the remaining structure has been reinforced with an added concrete structure to avoid any future structural failures. A geotextile polyester foil covered with 60 mm XPS insulation and a 1.2 mm PVC-P coating reinforced with fiberglass guarantees waterproof insulation.

Centralised space heating, cooling and DHW preparation system

A technical room was not present before building renovation since single dwelling electric heaters and gas boilers where used for both space heating and DHW preparation. Due to the narrow gap, available underneath the building, it has not been possible to place the technical room at ground level.

To this purpose, the elevator shaft has demonstrated to be most useful: the structural reinforcement provided has permitted to install on the roof a new, relatively heavy, centralised heating and cooling system.

Figure 2. Lift shaft during installation and at the end of the retrofit.

The plant installed is based on a reversible 20 kWth air-to-water double circuit heat pump: one circuit is always turned in heating mode and connected to a 500 litres thermal storage for domestic hot water preparation; the other is turned in heating mode in winter and in cooling mode in summer. In summer the heat pump can produce contemporarily cooling and heating: the rejected heat from cooling 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 in order to be shaded during hottest hours of summer days (see **Figure 3**).

22 m² solar thermal collectors mounted vertically on the south-oriented façade also contribute to the DHW preparation. An 800 litres storage with internal heat exchanger has been set up to harvest the solar energy. The latter storage is connected in series to the 500 litres fed by the heat pump, due to the lack of space in the technical room for the installation of a unique 1300 litres tank.

Due to space and aesthetic constraints (the collectors are aligned with to windows on the same façade), 8 solar collectors have been installed on the parapet of the building, while other 2 collectors have been installed on the wall of the technical room. In order to allow maintenance directly from the roof, the solar collectors have been installed with a gap of 200 mm one from another and with a distance of 200 mm between bottom connections and roof surface. An anchoring structure made with "c-shape" profiles has been used to bear collectors' weight and wind loads.

The distribution system is a four pipes one: two pipes are used for space heating or cooling, and two for DHW delivery. Polypropylene (PPR) pipes have been used, allowing for a cheaper and faster installation.

Figure 3. Heat pump and solar thermal field installation on the south facing parapet.

Once again, the newly raised shaft has been used to set up the vertical mains connecting the technical room to the single dwellings. As shown in **Figure 4**, they have been arranged into two groups, each feeding one column of apartments on the two sides of the staircase.

Lastly, space heating and cooling are delivered to dwellings through radiant ceiling panels set up during retrofit.

The design of such a system is challenging to many small energy-consulting offices, and the installation is not expected to be a competence of the plumbers, due to the strong integration needed among all the units set up (heat pump, solar collectors, storages), where optimal renewable energy harvest and minimum thermal energy losses are required.

For this purpose, the project partners have collaborated to develop a modular technology facilitating the installation of this complex heating and cooling systems in small- and medium-sized residential buildings. The solution is based on a plug-and-play hydronic unit (Energy Hub - EH) including the needed pumps and valves, designed to connect hydraulically to the components of a heating and cooling system, and electronically to a central controller (Energy Manager - EM).

Compared to most of the modules available on the market that enable hydronic integration of the system components and metering of the energy uses, the EHs are smart elements allowing also continuous monitoring and management of the plant. To this end, the EHs are all connected via Modbus to the EM.

Figure 4. Vertical pipelines construction.

The latter is used to manage the EHs in the network and provides to the users and to the system manager supervision, control and monitoring functions, via a graphical human-to-machine interface. This feature supports a continuous commission of the systems through its lifetime preventing long-lasting malfunctioning and allowing to optimise its operation during the first months after setup.

Figure 5 shows the EHs in the technical room, used to connect heat pump and solar collectors to the storage tanks and to distribute water into the building; the 4 EHs that are installed on each floor to provide DHW, and space heating and cooling to the dwellings.

Lessons Learned

The level of disruption introduced during retrofit has been acceptable to the residents. Thanks to prefabrication, setting up the pipelines, technical room and Energy Hubs has been unproblematic, although the design phase has been longer compared to traditional processes and required well-structured coordination among all the actors involved.

Despite the use of prefabricated solutions, the electric/electronic integration and commissioning of the Energy Hubs has still resulted complex to the installer. This shows that training of the professionals must always follow the introduction on the market of new enabling technologies.

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.

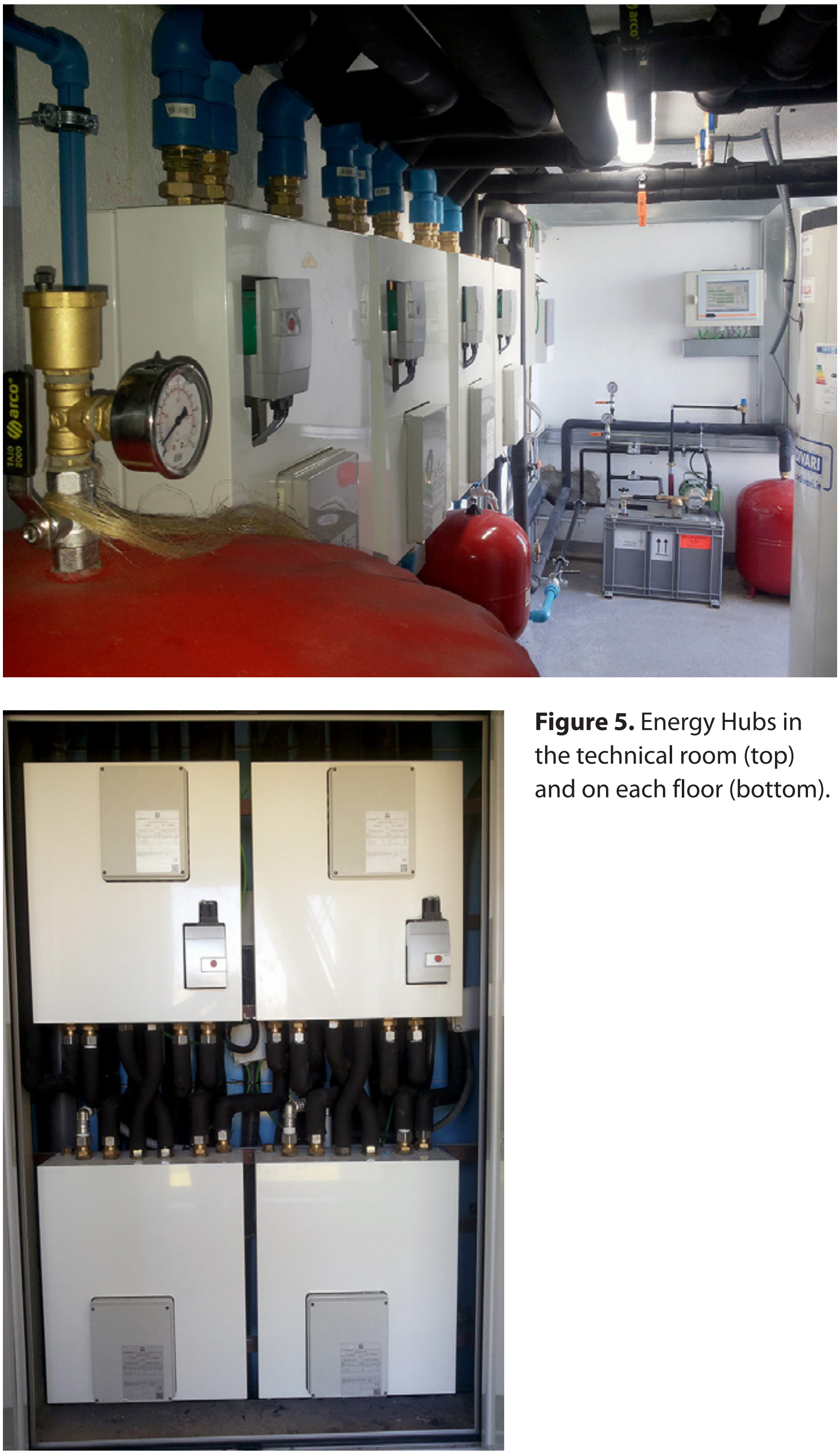

Figure 5. Energy Hubs in the technical room (top) and on each floor (bottom).

Consequently, after renovation, the property has not only higher energy efficiency but also higher value and longer lifetime. This is not accounted for when evaluating the payback based on the energy savings achieved: a specific property value estimation – before and after renovation – should be carried out, as a value proposition of the retrofit undertaken, showing the overall financial picture to owners and public/private investors. ■