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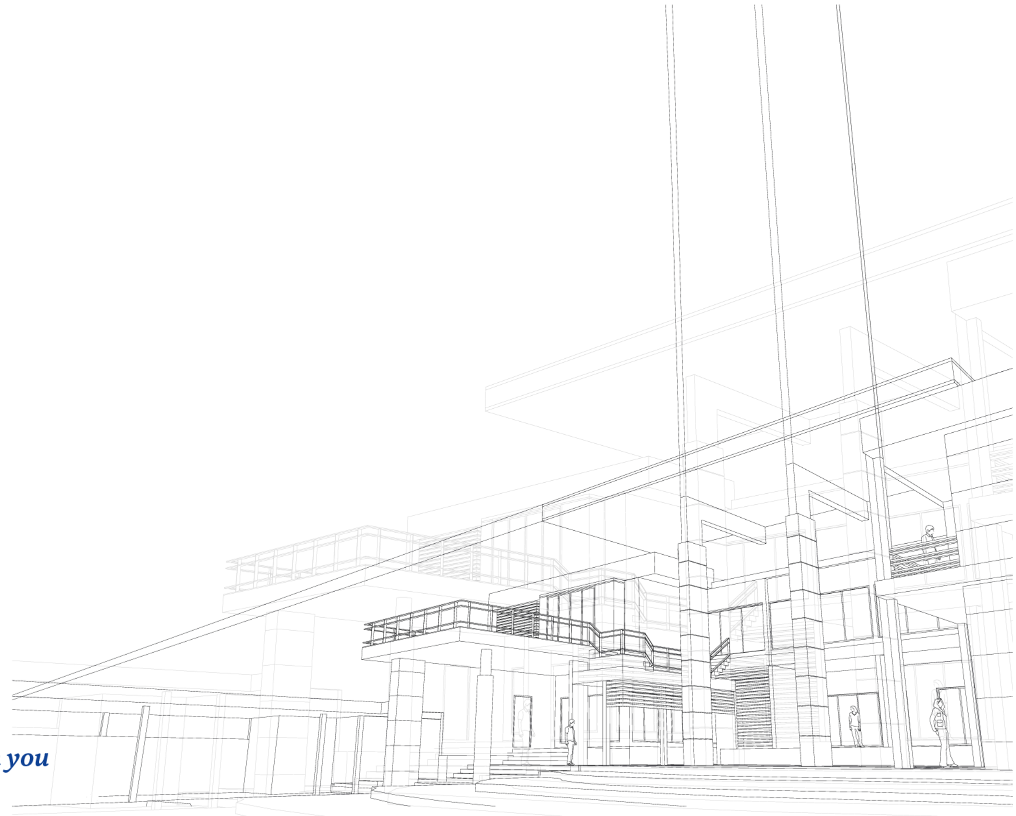

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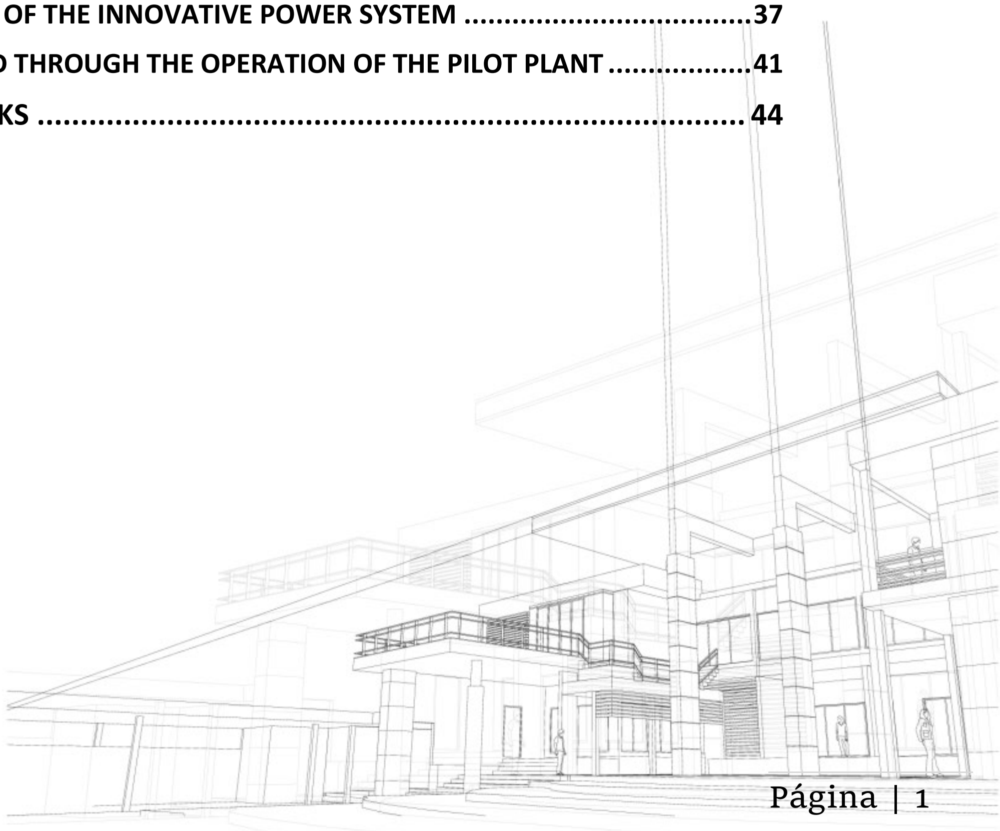
OUTLINE

1. INTRODUCTION 4
2. PILOT PROJECT IN BORDEAUX, FRANCE 5
   2.1 INTRODUCTION 5
   2.2 RENOIR METHODOLOGY 6
   2.3 RESULTS AND RECOMMENDATIONS ARISEN FROM RENOIR TOOL 7
   2.4 RECORES METHODOLOGY 9
   2.5 RESULTS AND RECOMMENDATIONS ARISEN FROM RECORES TOOL 11
3. PILOT PROJECT IN VILA NOVA DE GAIA, PORTUGAL 14
   3.1 INTRODUCTION TO THE CASE STUDY 14
   3.2 MONITORING SYSTEM DESCRIPTION 20
   3.3 DIGITAL TWIN PLATFORM 21
   3.4 RESULTS: RENOVATED VS NON-RENOVATED DWELLINGS 21
4. PILOT PROJECT IN ALPUJARRA DE LA SIERRA, SPAIN 24
   4.1 INTRODUCTION 24
   4.2 ENERGY PERFORMANCE CERTIFICATE BEFORE RENOVATION 26
   4.3 RENOVATION MEASURES, BIM AND MONITORING SYSTEM 28
   4.4 RESULTS OBTAINED FROM THE RENOVATION PROCESS 31
5. PILOT PROJECT IN NOVALES, SPAIN 34
   5.1 INTRODUCTION 34
   5.2 PILOT PLANT DESCRIPTION AND OPERATION 34
   5.3 IMPLEMENTATION OF THE INNOVATIVE POWER SYSTEM 37
   5.4 RESULTS OBTAINED THROUGH THE OPERATION OF THE PILOT PLANT 41
6. CONCLUDING REMARKS 44



LIST OF FIGURES

Figure 1: SUDOE ENERGY PUSH proposal. 5
Figure 2: Energy Push methodology workflow. 7
Figure 3: Renovation strategies performances generated by the optimization algorithm – Impact of the choice of the HVAC package. 8
Figure 4: Impact of the different renovation scenarios on the multi-criteria indicators........ 13
Figure 5: Aerial views of the studied social housing neighborhood. 15
Figure 6: Aerial views of the studied social housing neighborhood 2. 15
Figure 7: Drawings from the ground floor. 16
Figure 8: Drawings from the upper floors........ 16
Figure 9: Studied social housing neighborhood before renovation. 16
Figure 10: Studied social housing neighborhood after renovation. 17
Figure 11: Energy certificate of one studied dwelling /before renovation). 19
Figure 12: Studied dwellings. 20
Figure 13: Scheme of the digitalbuiuldingtwin.fe.up.pt 21
Figure 14: Temperature difference between the indoor environment of the renovated dwelling and the non-renovated dwelling........ 23
Figure 15: Relative humidity difference between the indoor environment of the renovated dwelling and the non-renovated dwelling. 23
Figure 16: Thermal comfort of renovated and non-renovated dwellings using EN 15251. 24
Figure 17: a) Main façade, b) back façade, c) lateral façade and d) inner courtyard of the building. 25
Figure 18: Energy performance certificate before renovation of the building. 27
Figure 19: BIM model of the building in Alpujarra de la Sierra, Granada. 29
Figure 20: Renovation works in the building of Alpujarra de la Sierra, Granada. 30
Figure 21: Electrical panel, sensor and monitoring platform. 31
Figure 22: Energy performance certificate after renovation of the building. 32
Figure 23: Building of Alpujarra de la Sierra, Granada after renovation. 33
Figure 24: Electricity and gas consumptions of Novales' home. 35
Figure 25: Schematic diagram of the pilot plant connected to the social house of Novales (Cantabria, Spain). 35
Figure 26: Plan for the layout of the facilities hut in Novales (Cantabria, Spain) after considering applicable regulations. 38
Figure 27: Housing and installation hut with pilot plant. 38
Figure 28: PV panels (1), PLC and electrical panel (2), inverter (3), battery charge regulator (4) and battery pack (5). 39
Figure 29: Electrolyzer (1), dryer (2), water tank module (3), water purification system (4), high-pressure hydrogen tank (5), hydrogen buffer tank (6), PEM fuel cell (7) and hydrogen compressor (8). 39
Figure 30: Fire extinguishers (1), pressure transducer (2), electrovalve (3), mass flow controller (4), pressure regulator (5), check valve (6), stainless steel piping (7) hydrogen detector and alarm (8). 40
Figure 31: PV panels screen with different energetic values........ 41
Figure 32: a) Use of PV energy production, b) distribution of consumption according to the origin of supply and c) according to the source of consumption. 42

LIST OF TABLES

Table 1: Evaluation grid proposed within RECORES methodology. 10
Table 2: Current construction solutions. 17
Table 3: Renovation solutions... 18
Table 4: Values obtained using the IEQ_v4 during two weeks in the winter. 22
Table 5: Thermal comfort categories explanation from EN 15251... 24
Table 6: KPI's of Alpujarra de la Sierra building prior and after renovation. 33
Table 7: Use of PV energy production. 41
Table 8: Distribution of consumption according to the origin of supply. 42
Table 9: Distribution of consumption according to the source of consumption. 42
Table 10: Primary energy savings, CO_2 emissions avoided and economic savings from January to November 2022... 43
Table 11: Main strengths and future work of every proposed methodology throughout the project. 44

1. INTRODUCTION

The social housing stock in the SUDOE area presents conditions that are far from making it efficient, which adds to the problem of energy poverty and the lack of comprehensive management systems that hinder the implementation of effective energy policies. In the long term, the housing stock will have to be made up of Nearly Zero Energy Buildings (NZEB) or sustainable buildings. Current renovation rates are insufficient, and the citizens affected by energy poverty are the most vulnerable, so the profitability and viability of the actions to be developed must be guaranteed.

Within this framework, the SUDOE ENERGY PUSH (Efficient eNERGY for PUblic Social HOUSING) project proposes an innovative solution for the overall management of social housing located in SUDOE territory, as a reference to increase the energy efficiency of public buildings and improve the quality of life of disadvantaged citizens. Through the combination of passive renovation, BIM methodology, renewable energy sources and novel hydrogen-based technologies, it aims to achieve a double objective: to reduce their consumption and emissions and to improve the comfort of the indoor environment for their inhabitants, overcoming the risks of energy poverty.

Thus, the main product of this project is a decision-making methodology for techno-economic optimization through BIM methodology, as well as an innovative pilot plant to achieve an efficient energy system based on renewable energies and the use of hydrogen as an energy vector. On the one hand, BIM-based methodology will allow the connection of alternatives and renewal scenarios with databases to assess the profitability of these and achieve efficient buildings, as well as their subsequent monitoring. On the other hand, the renewable hydrogen-based pilot plant results obtained from a real experience will serve both to demonstrate its technical feasibility through automation, control and monitoring, and to lay the groundwork for future scaling, where economies of scale will help to reduce the total costs of ownership.

Thus, four different pilot projects have been developed within the SUDOE ENERGY PUSH proposal, which are presented schematically on Figure 1:

1. <u>Pilot project in Bordeaux, France:</u> pilot operation on the ISABELLE residential building, in Le Bouscat, to experiment the RECORES tool for the qualitative analysis of a global rehabilitation project of a building and the RENOIR support approach for the cost-energy optimization of the rehabilitation operation.

2. <u>Pilot project in Vila Nova de Gaia, Portugal:</u> development of a methodology that applies to the operation phase and aims to specify the management and monitoring process that allows interpreting the results of energy renovation actions and relating them to the variables that define the levels of indoor environmental quality (IEQ) and energy efficiency. Hence, Digital Building Twin concept will be applied and the sensors will create and continually update the virtual replica of the real building in Vila Nova de Gaia.

3. Pilot project in Alpujarra de la Sierra, Spain: this pilot activity consists on the implementation of passive refurbishment and renovation measures to enhance the thermal performance of the building thermal envelope, resulting in an improvement of the energy efficiency ranking.

4. Pilot plant in Novales, Spain: a power system combining PV panels and novel hydrogen technologies is proposed to enhance the energy performance and efficiency of the home. The pilot plant is designed to ensure 100% self-sufficiency in terms of electricity for the home throughout the year without needing the utility grid connection or ancillary fossil fuel-based gensets.

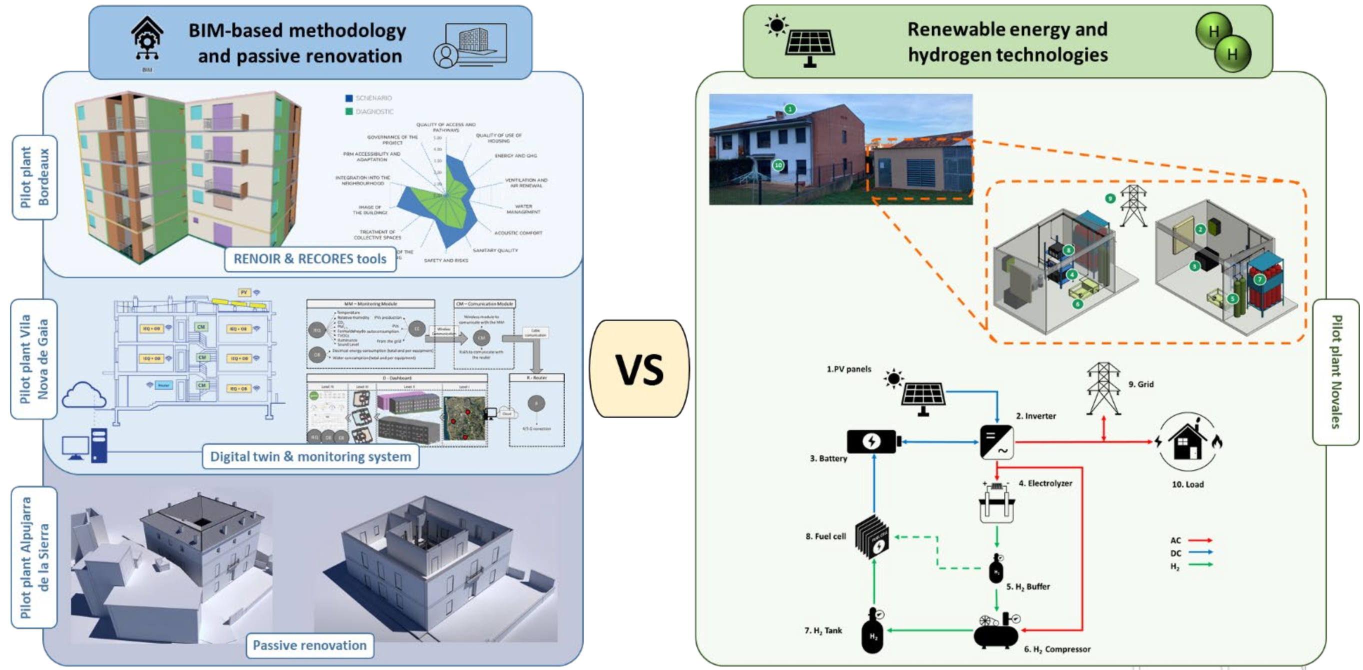


Figure 1: SUDOE ENERGY PUSH proposal.

Main outcomes of the implemented pilot actions previously described will be summarized and compared to assess the main strengths and weaknesses of each one.

2. PILOT PROJECT IN BORDEAUX, FRANCE

2.1 INTRODUCTION

Gironde Habitat is the Public Housing Office (OPH) of the Gironde department. Present in a third of the municipalities in Gironde, it currently manages 19,500 homes.

Because of the presentations made during the local exchange groups, Gironde Habitat expressed its interest in the tools developed by TIPEE, ALEC and CARBONE (French partners of the project). Thus, proposed the realization of a pilot operation on the ISABELLE residential building, in Le Bouscat, to experiment the RECORES tool for the qualitative analysis of a global rehabilitation project of a building and the RENOIR support approach for the cost-energy optimization of the rehabilitation operation.

Based on the energy audit already carried out in 2020 and a site visit, the elements necessary for both tools were collected to carry out an analysis with a more ambitious NZEB objective.

RECORES provided profiles associated with each of the 3 scenarios considered for the 4 buildings of the residence. They highlight the positive aspects of the current situation (such as the «integration into the neighborhood» aspect, for example) and the possible improvements. The approach made it possible to scan all the possible renovation works having an impact on each of the indicators. It thus offers the possibility of extending the analysis to additional issues. For example, in order to improve the «Governance of the project» aspect, it is possible to create a tenants' association, to carry out awareness-raising and information actions on consumption, or to consult the tenants during the presentation of the project.

The RENOIR tool for techno-economic optimization allowed the identification of the best quantitative alternatives for this energy renovation project. From a panel of possible actions in rehabilitation, the digital tools calculated the best strategies in terms of cost and energy performance, taking into account the specificities of each building but also the preferences and possibilities of the client. The tool has been applied to the digital models of the building, bringing a further step in the development of the BIM methodology.

2.2 RENOIR METHODOLOGY

The methodology is organized into three main steps as can be seen on Figure 2:

1. The **description** of the building
2. The **design** phase of the refurbishment
3. The **operation** phase

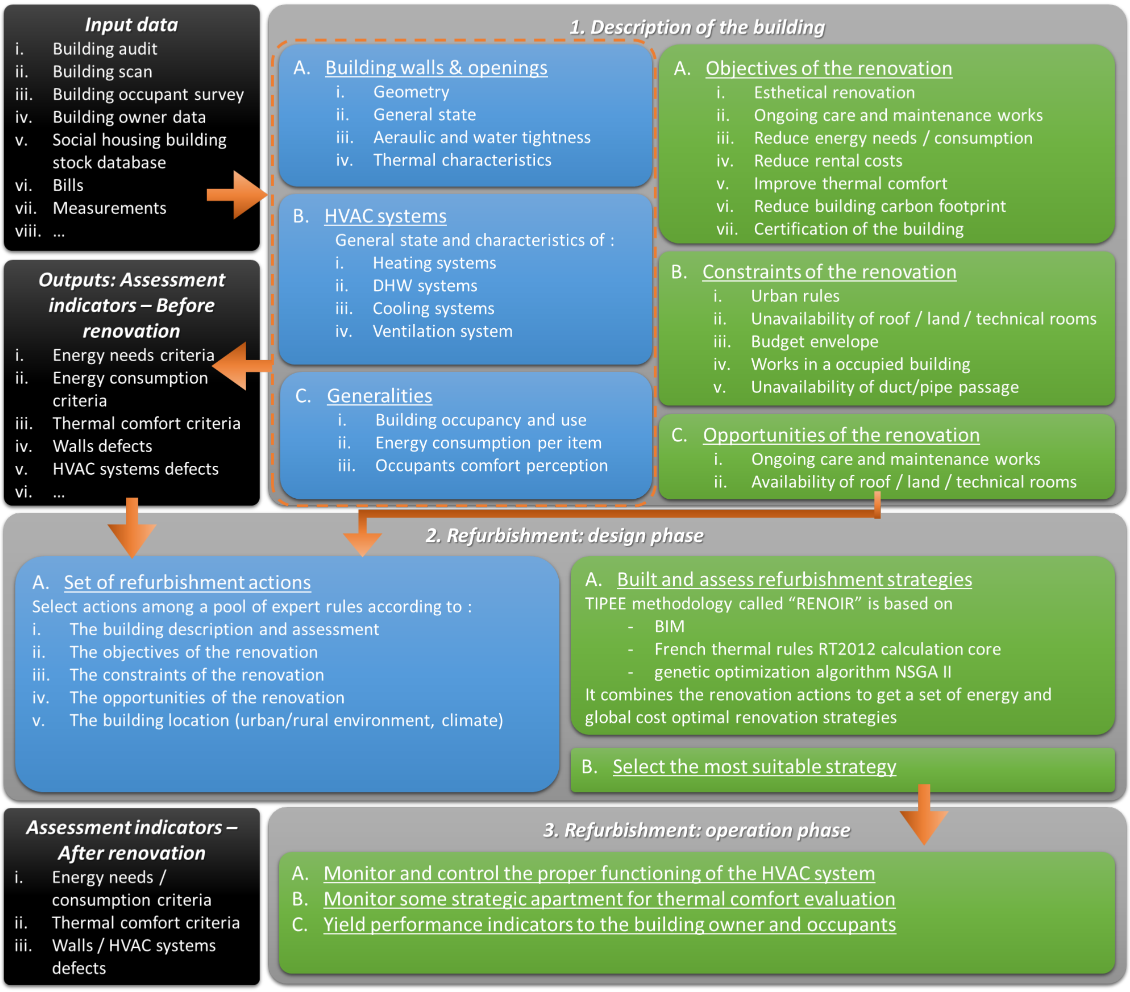


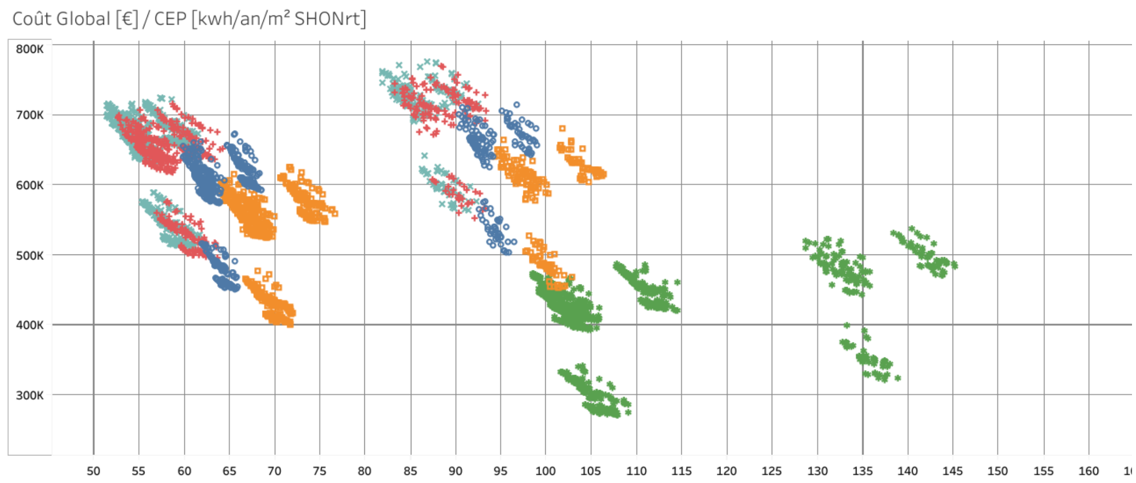
Figure 2: *Energy Push methodology workflow.*

2.3 RESULTS AND RECOMMENDATIONS ARISEN FROM RENOIR TOOL

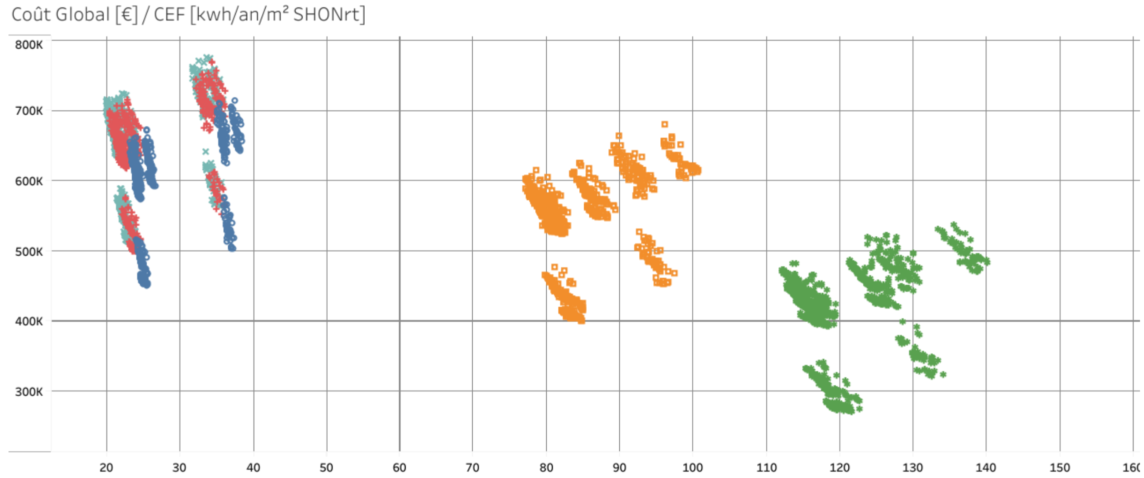
As a result of the aforementioned methodology (explained in more detail in Deliverable 4.1.1), a set of graphs is obtained with reflects several points in different colors, being each point a refurbishment strategy. Each point is positioned in a graph according to its energy consumption and its global cost. Thousands of strategies are assessed by the optimization algorithm. The obtained cloud of points can be used to draw out some trends regarding the renovation actions influence on these two criteria, coloring it according to the different for renovation action. Thus, different refurbishment scenarios have been considered and assessed:

- Choice of the HVAC package.
- Installation or not of PV panels.
- Improvement of the building envelope.
- Choice of the insulation material of the walls, floor and roof.
- Choice of the windows performance.

For instance, Figure 3 represents an example of the performance of different renovation strategies generated by the optimization algorithm with regard to the choice of the HVAC package.



(a) Primary energy consumption (abscissa) versus global cost (ordinate)



(b) Final energy consumption (abscissa) versus global cost (ordinate)

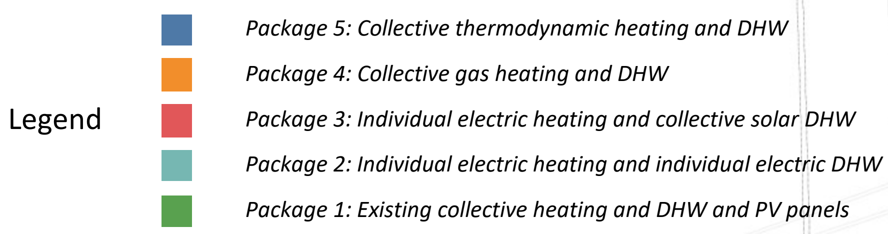


Figure 3: *Renovation strategies performances generated by the optimization algorithm – Impact of the choice of the HVAC package.*

The improvement of the building envelope decreases its energy consumption between 20 to 70 $kWh.m^{-2}.y^{-1}$ and increases its global cost from 30 to 294k€. Even though the energy saving does not balance the investment for the work, the reduction of the building energy needs is required because, as explained before, the constant energy prices is not realistic and the more it rises, the more the most efficient solutions will be economically viable. However, it depends of the building owner budget and the only replacement of the HVAC systems can be an alternative.

Furthermore, there is no clear tendency about the insulation material whatever the kind of surface (roof, wall, and floor). This does not mean that there are all equivalent, but that the energy and global cost are not discriminatory factors. Other could be considered such as the environmental impact, or the ease of works. The EPS is nevertheless the best energy-cost tradeoff for the insulation of the building walls, but this is not significant (the gain is on the same magnitude than the uncertainties of the calculation).

The windows replacement is to be avoided according to energy and cost criteria. The only valuable reason for the window replacement would be for instance a poor air or water tightness. In addition, the possibility of doing the walls insulation work with pre-casting could imply to replace it.

The replacement of the shutters is not energetically and economically relevant but the existing ones are aging on the one hand, and they are a key factor to control the thermal comfort on the other hand. For these reasons, it seems appropriate to change it.

The improvement of the heating and DHW generation is a key aspect of the refurbishment of this building. It offers a good investment-energy gain ratio. If the building is insulated, the combination of electric individual radiator and thermodynamic individual water heaters appears as the best tradeoff. The use of the solar energy to replace the individual water heaters by a collective systems is less expensive and a little bit less performant. It is also probably a better strategy in term of maintenance. If the building is not insulated, the collective Air/Water heat pump is a good strategy.

The replacement of the insulation of the roof could be the opportunity to install this kind of power plant, and around 10 kWp per building seems appropriate. An additional study should be done to size a photovoltaic power plant energetically and economically accurately.

The active cooling has not been studied in this project, but the question of the thermal comfort is of prior importance.

Last, the indoor air quality problem must be solved installing a mechanical simple flux ventilation.

2.4 RECORES METHODOLOGY

The objective of the RECORES 2020 grid is to provide an aid to the client in defining a global rehabilitation strategy for a building or a dwelling. It is composed of questions that are grouped into 38 composite indicators that allow the building to be assessed in its initial situation. The indicators are classified in 14 categories:

1- Quality of access & pathways.
2- Quality of use of buildings.
3- Energy.
4- Ventilation and air renewal.
5- Water management.
6- Acoustics.
7- Sanitary quality.
8- Safety and risks.
9- Sustainability of the work.
10- Collective spaces.
11- Image of the building.
12- Integration into the neighborhood.
13- Accessibility (people with reduced mobility).
14- Project governance.

These questions are then subject to recommendations that will change the indicators. It is then possible to compare the evolution of the building from its initial situation to a situation after work, or to make several scenarios.

For each question, the initial state of the building before the work is assessed on the basis of a qualitative analysis which can sometimes lead to quantitative indicators. To highlight the gains relative to each question, it is proposed to "normalize" the evaluation in a grid established as described in Table 1:

Table 1: *Evaluation grid proposed within RECORES methodology.*

	Not applicable for the building
1	Condition absolutely requiring intervention (regulatory or safety or basic comfort) - Very poor condition
2	Condition requiring intervention for basic quality - Rather poor condition
3	Condition of average obsolescence, RAS - Fair condition
4	Fair condition - Rather satisfactory condition
5	Very good quality, very satisfactory condition

This normative assessment can be a starting point for a rehabilitation project. It does not aim to establish a heritage assessment. It is therefore a question of evaluating the building from the point of view of a probable rehabilitation action to highlight the most important points to be treated. The evaluation of the gains of the rehabilitation project will be done in a first step as a reading of the gains likely to be obtained on each indicator, calculated from the aggregation of the answers to the different questions.

2.5 RESULTS AND RECOMMENDATIONS ARISEN FROM RECORES TOOL

The analyzed building presents clean facades from the outside, the car parks are secure and well-maintained, and the accesses are functional. Local shops and public transport are available on leaving the residence.

From the inside, the common areas are fairly bright, wide and secure. The condition of the wall surfaces is fairly old. Some minor damage has been noted in the common areas. Some common areas, such as the former rubbish chute, are overloaded with various clutter.

The ventilation is of the natural type and is equipped with adapted regulation devices in the roof. However, the vents in the dwellings are clogged, which reduces the quality of ventilation. In addition, this type of ventilation is very energy intensive compared to mechanical extraction.

Energy and water management is the responsibility of the tenants. They have individual gas boilers and individual contracts. The management of the regulation often seems to be ignored by the users. Regarding water quality, the pressure at the taps seems to be sufficient, but the sanitary appliances are not equipped with water saving devices.

The double glazing was renovated 3 years ago and is in a very good condition. But overall, the quality of the insulation is rather poor and leads to thermal bridges in various places (uninsulated common areas, insulation of the building from the inside, etc.). Thus, four different scenarios have been proposed for evaluation:

Scenario 1: the works planned in this scenario are broken down into 12 actions.

1- Electrical safety measures in the dwelling and common areas, addition of PCs in the kitchen and living room.
2- Replacement of landing doors.
3- Replacement of the boilers by boilers with suction cup outlets, room thermostats.
4- Installation of thermostatic valves on radiators.
5- Reinforcing the insulation underneath the top floorboards of the cellars and outside halls.
6- Installation of a low-pressure Hygro B ventilation system connected to unused flue gas ducts (pipework to be done).
7- Replacement of the waterproofing of the roof terrace with 150mm thick insulation, with replacement of the smoke extraction skylight and metal guardrails.
8- Replacement of the lighting fixtures in the common areas with LED fixtures and presence detector.
9- Replacement of entrance hall doors.
10- Repairing the fence on rue Isabelle.
11- Creation of PMR accommodation on the ground floor of building B (62.9m²).

12- Replacement of all sanitary appliances in bathrooms, embellishments, adaptation of some bathrooms on the ground floor.

Scenario 2: the works planned in this scenario considers scenario 1 plus the installation of photovoltaic panels.

Scenario 3: same as scenario 2 with the addition of a lift.

Scenario 4: in this case, passive renovation actions are proposed, consisting in 8 main recommendations:

1- External insulation of the facades (wood cladding finish) + treatment of the junctions.
2- Reinforcement of the insulation of the roof terrace.
3- Replacement of some double glazing with triple glazing (about 30% of the windows).
4- Reinforcing the insulation of low floors on unheated premises.
5- Installation of a collective gas energy production in each of the buildings, coupled with flat modules to distribute DHW and heating water (possible variant in electric radiators and thermodynamic balloons).
6- Installation of decentralized double flow ventilation (room by room).
7- Installation of water-saving taps.
8- Treatment of air tightness.

Thus, Figure 4 gathers the impact of these scenarios in the performance of different indicators:

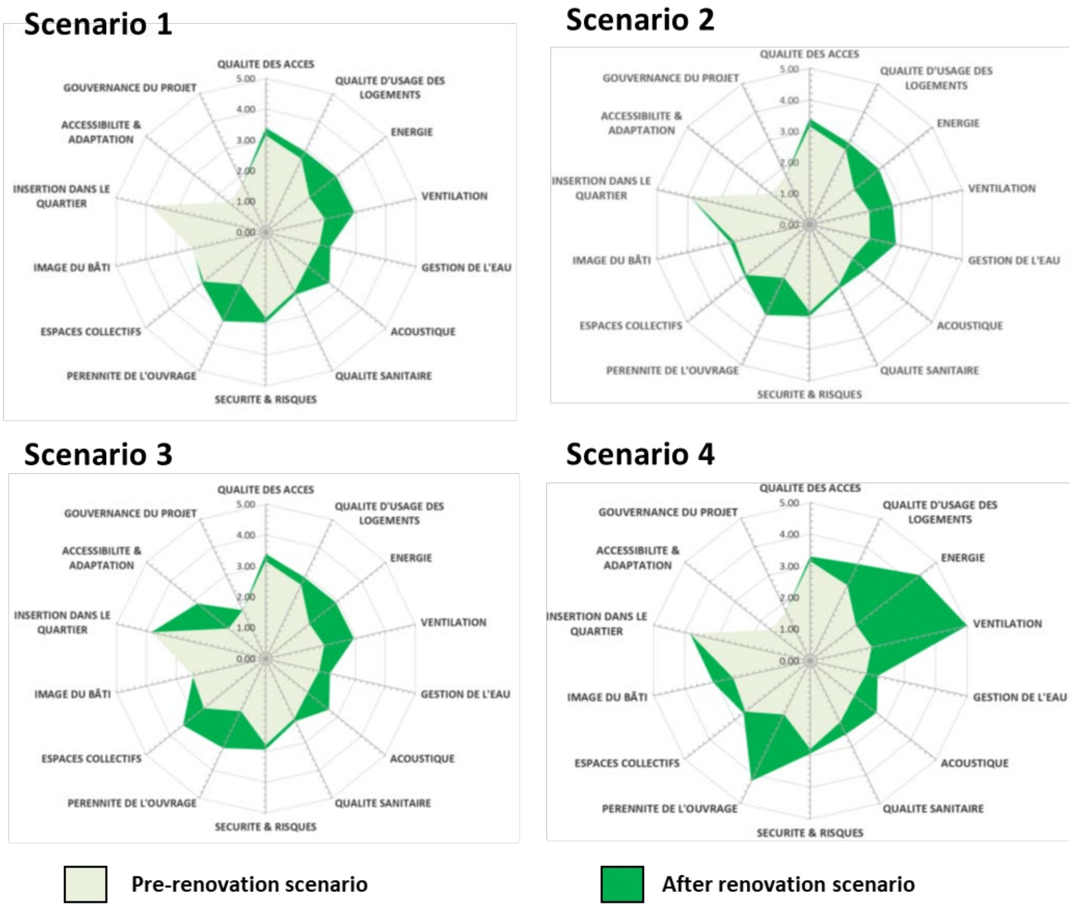


Figure 4: *Impact of the different renovation scenarios on the multi-criteria indicators.*

The RECORES multi-criteria analysis tool was used to provide profiles associated with each of the scenarios envisaged for the 4 buildings of the ISABELLE residence in Bordeaux. They highlight the strong points as they stand (such as the "Integration into the neighbourhood" component, for example) and the possible areas for improvement for each of the indicators. All the works envisaged are thus integrated, and their impacts associated with the various indicators. Thus, it is clear that scenarios 1 and 2 improve the building in the areas of "Energy", "Water quality", "Quality of use", "Ventilation" and "Sustainability of the building". Some aspects are not affected, such as "PRM accessibility", but are addressed by scenario 3 through the creation of lifts.

Secondly, this tool offered the possibility of scanning all the possible renovation works that have an impact on each of the indicators. It thus offers the possibility of pushing the analysis to additional issues. For example, to improve the "Governance of the project" aspect, it is possible to create a tenants' association, to carry out awareness-raising and information actions on consumption, or to consult tenants during the presentation of the project.

A RECORES analysis of the renovation projects and/or of the existing stock allows to provide a simple, detailed and pictorial analysis of their condition and potential.

3. PILOT PROJECT IN VILA NOVA DE GAIA, PORTUGAL

3.1 INTRODUCTION TO THE CASE STUDY

The case study is a Portuguese small social housing neighbourhood in the Municipality of Vila Nova de Gaia (Figure 5, Figure 6, Figure 7, Figure 8 and Figure 9) named Prof. Carlos Alberto Mota Pinto. The neighbourhood, built in 1997, consists of two similar and parallel buildings with three entrances each (Figure 7 and Figure 8). Low-income households occupy all the 35 dwellings. Each building has three floors above the ground. Each entrance gives access to two dwellings per floor (six dwellings per entrance). In each floor, there is a two-bedroom apartment and a three-bedroom apartment (Figure 7 and Figure 8). The façades of both buildings have similar construction solutions (Table 2), with the structure consisting of concrete columns and beams combined with concrete slabs of pre-stressed joists and ceramic blocks. The dwellings rely on natural ventilation and they include vertical ducts in the bathrooms. There is no centralised heating or cooling system installed, and gas heaters produce domestic hot water.

In 2021 the first phase of the planned renovation was completed and focused only on the east building (Figure 10). The intervention covers 18 of the neighbourhood dwellings. By the start of the present project, renovation measures were already defined and approved by the Municipality, aiming to solve the construction anomalies that arose in the buildings, namely condensation and infiltration of rainwater, promoting an architectural requalification, an improvement of the surrounding urban environment, and a reduction in energy consumption and related costs. The planned renovation measures (Table 3) are based in standard procedures, following the regulation requirements.

Before renovation, a dwelling considered as the one with more unfavourable envelope had an energy label of E (Figure 11). After the renovation works, the energy certificate turns to a C. And the global nominal annual primary energy needs reduced from 339.8 kWh_{EP}/m^2.year to 143.2 kWh_{EP}/m^2.year. The ratio of primary energy reduced from 243% to 114%.

After renovation, two dwellings were monitored using the new monitoring system developed in this project and further detailed. The dwellings can be seen in Figure 12.

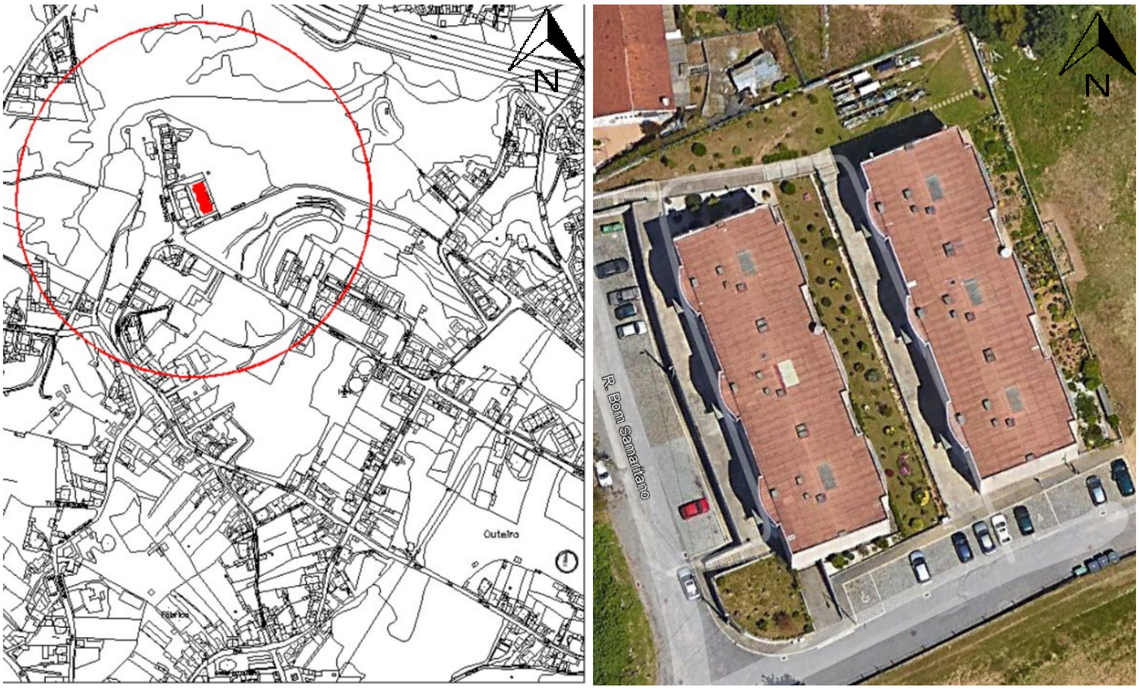


Figure 5: Aerial views of the studied social housing neighborhood.

Figure 6: Aerial views of the studied social housing neighborhood 2.

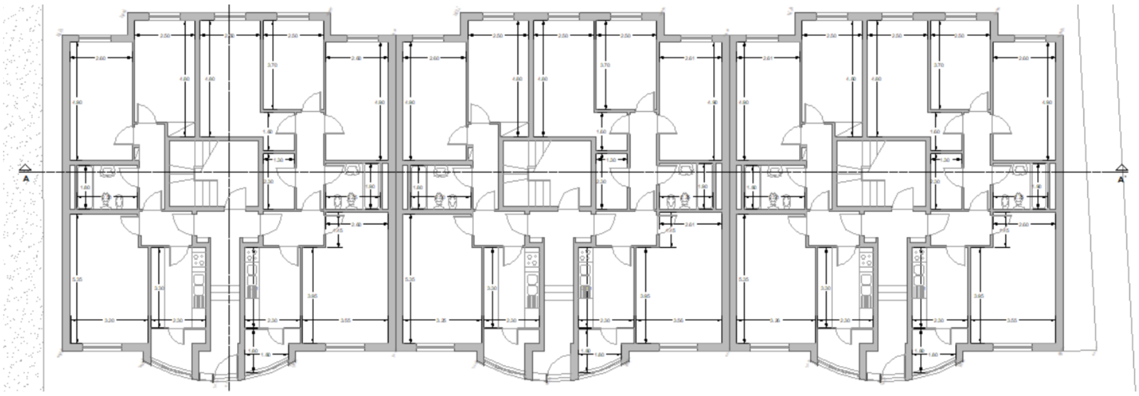


Figure 7: *Drawings from the ground floor.*

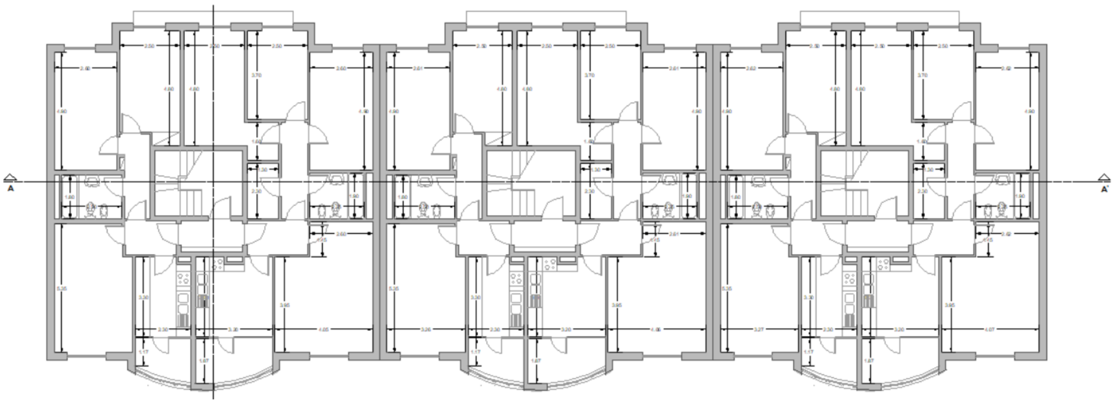


Figure 8: *Drawings from the upper floors.*

Figure 9: *Studied social housing neighborhood before renovation.*

Figure 10: *Studied social housing neighborhood after renovation.*

Table 2: Current construction solutions.

Construction element	Thermal Transmittance Coefficient, U-value (W/ (m².°C))	Construction solution
External walls (0.40 m)	0.96	Double hollow brick masonry wall, 11 cm and 15 cm thick, plastered on the inside and coated with light coloured industrial cementitious mortar , on the outside
Walls that separate apartments from the staircase (0.24 m)	1.16	Simple hollow brick masonry wall coated on the outer face with light coloured industrial cementitious mortar and on the inner face with stucco or ceramic tiles.
Pitched roof	U_{asc}= 1.90 U_{desc}= 1.44	The 2nd floor ceiling slab is a concrete slab of prestressed joists and ceramic blocks with no thermal insulation. The attic is poorly ventilated. The roof slopes are covered with fibre cement sheets.

Ground floor slab (with sanitary air space underneath)	1.18	Concrete slab of prestressed joists and ceramic blocks coated with wood parquet or ceramic tiles.
Windows	3.10	Aluminium frames with clear double-glazing and an outer plastic roller blind of a light colour.

Table 3: Renovation solutions.

Renovation Action Construction Solution U-Value	Renovation Action Construction Solution U-Value	Renovation Action U-Value
Application of thermal insulation on the external walls after cracking repair	ETICS	0.390
Replacement of fibre cement sheets by sandwich panels and application of thermal insulation on the ceiling slab	Sandwich panels as roof covering. Application of 0.10 m of mineral wool on the second-floor ceiling slab.	U_{asc} =0.330 U_{desc}=0.313

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Este certificado apresenta a classificação energética deste edifício ou fração. Esta classificação é calculada comparando o desempenho energético deste edifício nas condições atuais, com o desempenho que este obteria nas condições mínimas (com base em valores de referência ou requisitos aplicáveis para o ano assinalado) a que estão obrigados os edifícios novos. Saiba mais no site da ADENE em www.adene.pt.

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Determinam a classe energética do edifício e a eficiência na utilização de energia, incluindo o contributo de fontes renováveis. São apresentados comparativamente a um valor de referência e calculados em condições padrão.

Aquecimento Ambiente
Referência: 39 kWh/m².ano
Edifício: 115 kWh/m².ano
Renovável - %
191% MENOS eficiente que a referência

Arrefecimento Ambiente
Referência: 3,0 kWh/m².ano
Edifício: 2,5 kWh/m².ano
Renovável - %
16% MAIS eficiente que a referência

Água Quente Sanitária
Referência: 34 kWh/m².ano
Edifício: 47 kWh/m².ano
Renovável - %
39% MENOS eficiente que a referência

CLASSE ENERGÉTICA

Mais eficiente — Julho 2006 | Dez. 2013 | Janeiro 2016

A+ 0% a 25%
A 26% a 50%
B 51% a 75%
B- 76% a 100%
Mínimo: Edifícios Novos
C 101% a 150%
Mínimo: Grandes Intervenções
D 151% a 200%
E 201% a 250%
F Mais de 251%

E 243%

ENERGIA RENOVÁVEL
Contributo de energia renovável no consumo de energia deste edifício.
0%

EMISSÕES DE CO_2
Emissões de CO_2 estimadas devido ao consumo de energia.
3,99 toneladas/ano

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1 de 7

Figure 11: *Energy certificate of one studied dwelling /before renovation).*

Figure 12: *Studied dwellings.*

3.2 MONITORING SYSTEM DESCRIPTION

The final version (version 4) of the IEQ monitoring system had two modules, one with the main IEQ sensors and other just with the temperature and relative humidity sensor. This version contained all the sensors considered:

- Temperature and relative humidity,
- Sound pressure level,
- TVOCs,
- Formaldehyde,
- Illuminance on the vertical and horizontal plane,
- Particulate matter,
- Movement,
- CO_2,
- Anemometer.

The monitoring system also relies on energy and water meters.

NOTE: Due to restrictions related with a patent pending, no pictures or detailed data of this module will be provided.

3.3 DIGITAL TWIN PLATFORM

Based on the monitoring system and using the communication module to place the data in the DIGITALBUILDINGTWIN.FE.UP.PT cloud, it is possible to remotely access the monitored data in real time (Figure 13). The platform collects data from the physical twin and places that data on the BIM model to represent its digital replica. The monitoring system used collects data of water and electricity consumption and makes it possible to know what percentage of consumption corresponds to energy produced by the photovoltaic (PV) panels and provided from the grid. The system also makes it possible to distinguish what percentage of the electrical energy is produced by the PV panels is injected into the network when it is not used in the building. Inside the building, the indoor environmental quality is assessed using temperature, relative humidity, CO_2, PM1.0, PM2.5, PM10, TVOCs, formaldehyde, illuminance, anemometers, motion detection and sound pressure level sensors.

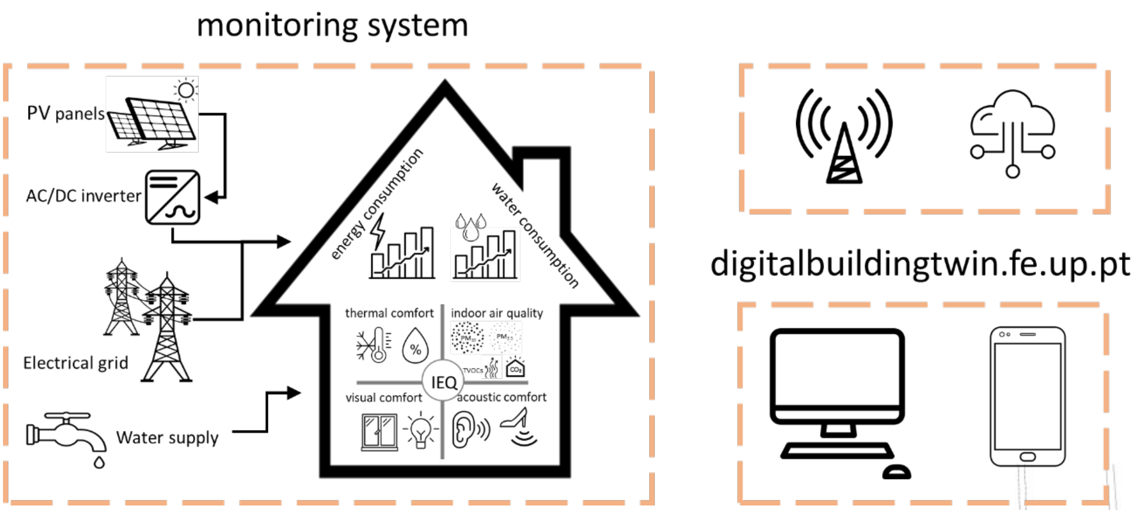

Figure 13: *Scheme of the digitalbuiuldingtwin.fe.up.pt*

3.4 RESULTS: RENOVATED VS NON-RENOVATED DWELLINGS

Due to the renovation works performed and the limited time considered in this analysis (two weeks in winter), the differences between the non-renovated and the renovated dwellings are more preponderant in terms of thermal comfort (Table 4). However, since the monitoring data stated on this report only refers to a few winter weeks, it is expected that the one-year monitoring campaign reveal data that could enable more holistic analysis. The renovated dwelling had in average higher temperature of 1.5°C (Figure 14). The maximum registered difference in temperature was 2.64°C and the minimum was -0.58°C. This period where indoor temperature of the renovated dwelling was below the indoor temperature of the non-renovated dwelling corresponded to the only period where the non-renovated dwelling was heated. The values of relative humidity had the inverse behaviour since the two parameters are inversely correlated (Figure 15).

Table 4: Values obtained using the IEQ_v4 during two weeks in the winter.

		T	RH	CO_2	CH2O	PM1.0	PM2.5	PIR	Sound_P	Lux_V
non-renovated	average	16.87	83.50	696.40	2.91	10.90	19.53	1.00	47.03	6.70
	standard deviation	0.56	2.61	352.51	0.42	10.57	15.58	0.00	5.22	24.59
	maximum	18.75	88.78	2982.21	7.80	65.18	103.78	1.00	96.27	420.72
	minimum	16.01	76.43	395.02	1.40	0.00	0.03	1.00	44.54	-0.59
	percentile 95	17.72	87.80	1428.11	3.60	32.23	50.61	1.00	60.67	24.11
	percentile 5	16.08	79.53	401.54	2.20	0.38	3.90	1.00	44.85	1.62
renovated	average	18.34	75.56	697.37	6.14	6.66	13.04	1.00	58.64	23.43
	standard deviation	0.35	3.43	211.73	2.36	9.17	13.21	0.00	5.66	102.48
	maximum	19.51	83.28	2078.00	26.88	95.91	143.59	1.00	122.29	2526.39
	minimum	17.51	67.26	438.35	2.00	0.00	0.08	1.00	55.69	1.27
	percentile 95	18.82	81.93	1062.31	9.20	25.33	40.49	1.00	70.08	96.48
	percentile 5	17.61	70.65	480.00	3.00	0.00	3.00	1.00	56.17	1.28

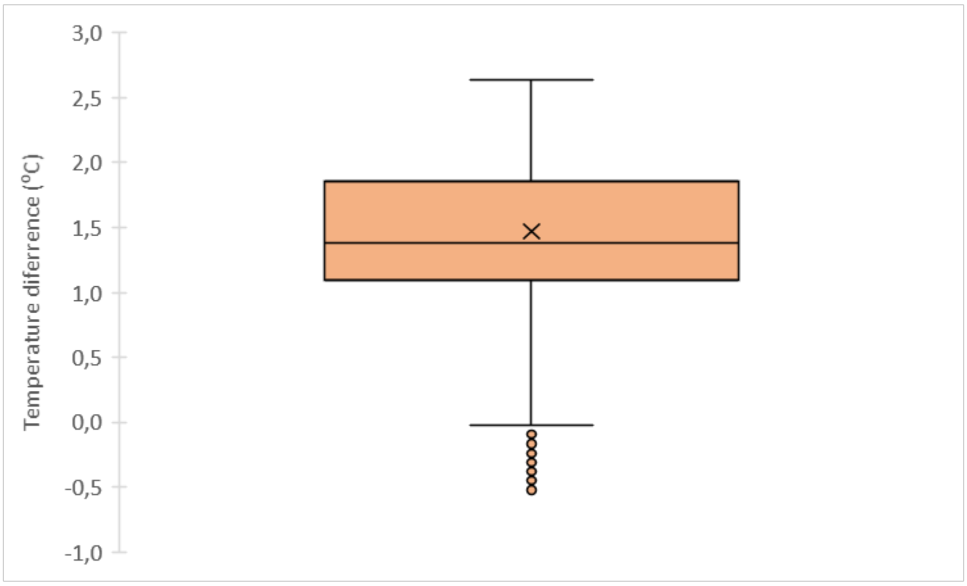

***Figure 14:** Temperature difference between the indoor environment of the renovated dwelling and the non-renovated dwelling.*

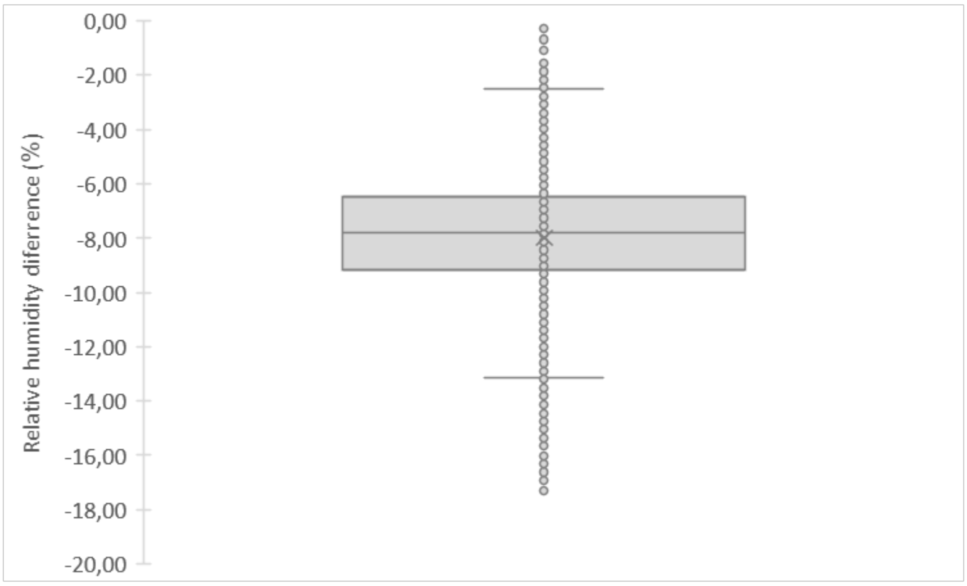

***Figure 15:** Relative humidity difference between the indoor environment of the renovated dwelling and the non-renovated dwelling.*

Considering the standard EN 15215, it was possible to analyse the thermal comfort of the two dwellings, represented in Figure 16. Table 5 shows that dwelling that was renovated had almost all the days within the thermal comfort ranges. The dwelling non-renovated had many moments bellow that threshold. The definition of the categories stated in EN 15251 are presented on Table 5.

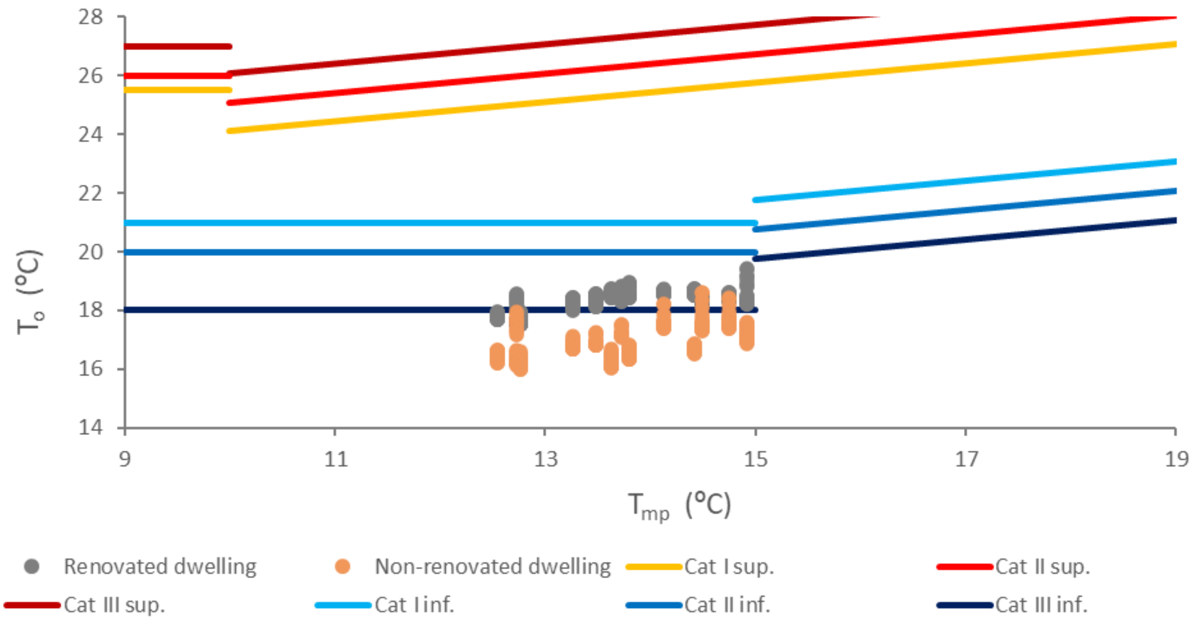

Figure 16: *Thermal comfort of renovated and non-renovated dwellings using EN 15251.*

Table 5: Thermal comfort categories explanation from EN 15251.

Category	Explanation
I	High level of expectation and is recommended for spaces occupied by very sensitive and fragile persons with special requirements like handicapped, sick, very young children and elderly persons
II	Normal level of expectation and should be used for new buildings and renovations
III	An acceptable, moderate level of expectation and may be used for existing buildings

4. PILOT PROJECT IN ALPUJARRA DE LA SIERRA, SPAIN

4.1 INTRODUCTION

The pilot actions carried out in Alpujarra de la Sierra (Granada, Spain), consist on the implementation of passive renovation and refurbishment measures to enhance the energy efficiency and performance of a building. This isolated building consist of three-storey building constructed in 1900, with 10 social rental dwellings, owned by AVRA.

Neoclassical influence building, with a rectangular base, inner courtyard and galleries. Dwellings' access are through galleries as a typology of a courtyard house. The main façade is divided into three bodies, each body include three lintel openings which can be seen in Figure 17.

Figure 17: *a) Main façade, b) back façade, c) lateral façade and d) inner courtyard of the building.*

The project involved the refurbishment of an existing listed building, including common spaces, roof and heating systems. As a historic building, PV panels are not possible to be installed because of the kind of roof and environmental protection. This building has a 354 m^2 area. The budget employed for refurbishment is 152,367.60 € with an estimated durations of 3 months. The main structure of the building consists of:

1. Load-bearing walls in the first division of the building: 75 cm thickness: clinker brick + interior plastering without insulation.
2. Pillars in the inner backyard.
3. One-way floors with wooden joists.
4. Inclined roofs with Arab-style roof tiles.
5. Double exterior carpentry (wood-metallic).
6. Ground and first floors have a height of 4 meters. However, the second floors has a height of 2.45 meters.

Finally, the main pathologies of the building are rising Damps in ground floor walls (outer and interior façade), roof partially unreformed, lack of isolation in roofs and walls, and heating systems problems.

4.2 ENERGY PERFORMANCE CERTIFICATE BEFORE RENOVATION

The energy performance certificate considers different aspects such as the orientation of the building, thermal envelope (opaque enclosures, openings and skylights), thermal systems (heating, refrigeration, domestic hot water), lighting, operating and occupancy conditions, and renewable energies.

After accounting all these parameters, the energy performance of the building before renovation was **47.74 kg CO_2/(m^2 ·$year^1$) "E"** concerning the emissions. Likewise, the energetic performance was **259.47 kWh/(m^2·year) "E",** heating demand performance **132.43 kWh/(m^2·year) "E",** and the refrigeration performance **9.01 kWh/(m^2·year) "C"** as described in Figure 18:

ANEXO II
CALIFICACIÓN ENERGÉTICA DEL EDIFICIO

Zona climática	D3	Uso	CertificacionExistente

1. CALIFICACIÓN ENERGÉTICA DEL EDIFICIO EN EMISIONES

INDICADOR GLOBAL		INDICADORES PARCIALES			
<8.40 A 8.40-13.60 B 13.60-21.10 C 21.10-32.40 D 32.40-66.30 E 66.30-79.60 F =>79.60 G	47,74 E	**CALEFACCIÓN**		**ACS**	
		Emisiones calefacción (kgCO2/m2 año) 40,55	E	*Emisiones ACS (kgCO2/m2 año)* 6,01	G
		REFRIGERACIÓN		**ILUMINACIÓN**	
Emisiones globales (kgCO2/m2 año)1		*Emisiones refrigeración (kgCO2/m2 año)* 1,18	A	*Emisiones iluminación (kgCO2/m2 año)* -	-

La calificación global del edificio se expresa en términos de dióxido de carbono liberado a la atmósfera como consecuencia del consumo energético del mismo.

	kgCO2/m2.año	kgCO2/año
Emisiones CO2 por consumo eléctrico	28,81	31373,40
Emisiones CO2 por combustibles fósiles	18,93	20601,03

2. CALIFICACIÓN ENERGÉTICA DEL EDIFICIO EN CONSUMO DE ENERGÍA PRIMARIA NO RENOVABLE

Por energía primaria no renovable se entiende la energía consumida por el edificio procedente de fuentes no renovables que no ha sufrido ningún proceso de conversión o transformación.

INDICADOR GLOBAL		INDICADORES PARCIALES			
<37.10 A 37.10-60.1 B 60.10-93.20 C 93.20-143.30 D 143.30-298.10 E 298.10-336.80 F =>336.80 G	259,47 E	**CALEFACCIÓN**		**ACS**	
		Energía primaria no renovable calefacción (kWh/m2año) 217,01	E	*Energía primaria no renovable ACS (kWh/m2año)* 35,48	G
		REFRIGERACIÓN		**ILUMINACIÓN**	
Consumo global de energía primaria no renovable (kWh/m2año)1		*Energía primaria no renovable refrigeración (kWh/m2año)* 6,99	B	*Energía primaria no renovable iluminación (kWh/m2año)* 0,00	-

3. CALIFICACIÓN PARCIAL DE LA DEMANDA ENERGÉTICA DE CALEFACCIÓN Y REFRIGERACIÓN

La demanda energética de calefacción y refrigeración es la energía necesaria para mantener las condiciones internas de confort del edificio.

DEMANDA DE CALEFACCIÓN		DEMANDA DE REFRIGERACIÓN	
<11.70 A 11.70-27.0 B 27.00-48.70 C 48.70-81.60 D 81.60-144.10 E 144.10-157.10 F =>157.10 G	132,43 E	<5.50 A 5.50-8.90 B 8.90-13.90 C 13.90-21.30 D 21.30-26.30 E 26.30-32.40 F =>32.40 G	9,01 C
Demanda de calefacción (kWh/m2año)		*Demanda de refrigeración (kWh/m2año)*	

1El indicador global es resultado de la suma de los indicadores parciales más el valor del indicador para consumos auxiliares, si los hubiera (sólo ed. terciarios, ventilación, bombeo, etc…). La energía eléctrica autoconsumida se descuenta únicamente del indicador global, no así de los valores parciales.

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Ref. Catastral 6131401VF8963A Página 6 de 8

Figure 18: *Energy performance certificate before renovation of the building.*

4.3 RENOVATION MEASURES, BIM AND MONITORING SYSTEM

A series of renovation works were planned to improve conservation and energy efficiency performance. It is important to highlight that energy improvements works were carried out with dwellings occupied by tenants (it is an important external factor to be consider in the renovation designing plan). The applied energy efficiency measures are the following ones:

Ground floor:

- Actual heating systems replacement with high quality biomass system (finally, original equipment was replaced by high quality wood stoves are pellets are more expensive than wood stoves).
- Rising damp proof treatment (wall lower part).
- Damp proof treatment (exterior wall).
- Damp proof treatment (interior wall).
- Internal reinforcement with insulation (90mmm rock wool) and external ventilated chamber.

First floor:

- Exterior Thermal Insulation System (SATE) for thermal and acoustical insulation with 80mm rock wool + layer of acrylic mortar (finally, it has been replaced by internal reinforcement without air chamber, as SATE is a rough material that additionally reduces room areas. This solution has a higher thermal transmittance).

Second floor:

- Exterior Thermal Insulation System (SATE) for thermal and acoustical insulation with 80mm rock wool + layer of acrylic mortar (finally, it has been replaced by internal reinforcement without air chamber, as SATE is a rough material that additionally reduces room areas. This solution has a higher thermal transmittance).
- False ceiling filled with thermal insulation.

Roof:

- Better roof insulation and waterproofing.
- Tiles substitution + insulation constructed in multiple reflexive layers + 15 cm of insulation in second floor false ceiling.

These measures were previously analyzed in a BIM model of the building. This model was obtained through laser scanning and data collection from a cloud of points. Figure 19 shows the BIM model and the laser scanned picture.

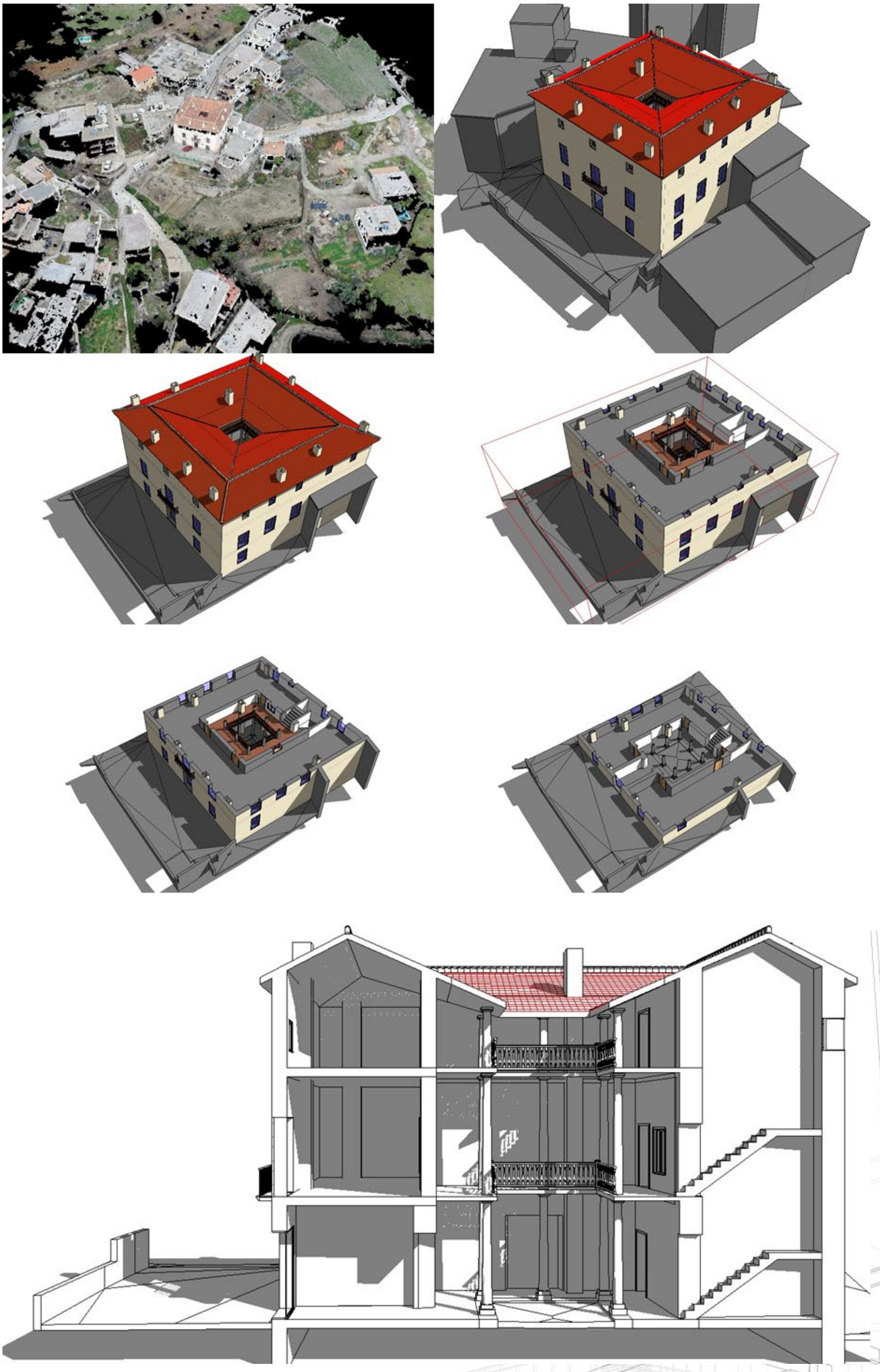


Figure 19: *BIM model of the building in Alpujarra de la Sierra, Granada.*

Following the simulation of the performance obtained with the application of the renovation measures in the BIM model, these were applied in the building subject of study. Hence, Figure 20 gathers different pictures of the refurbishment works:

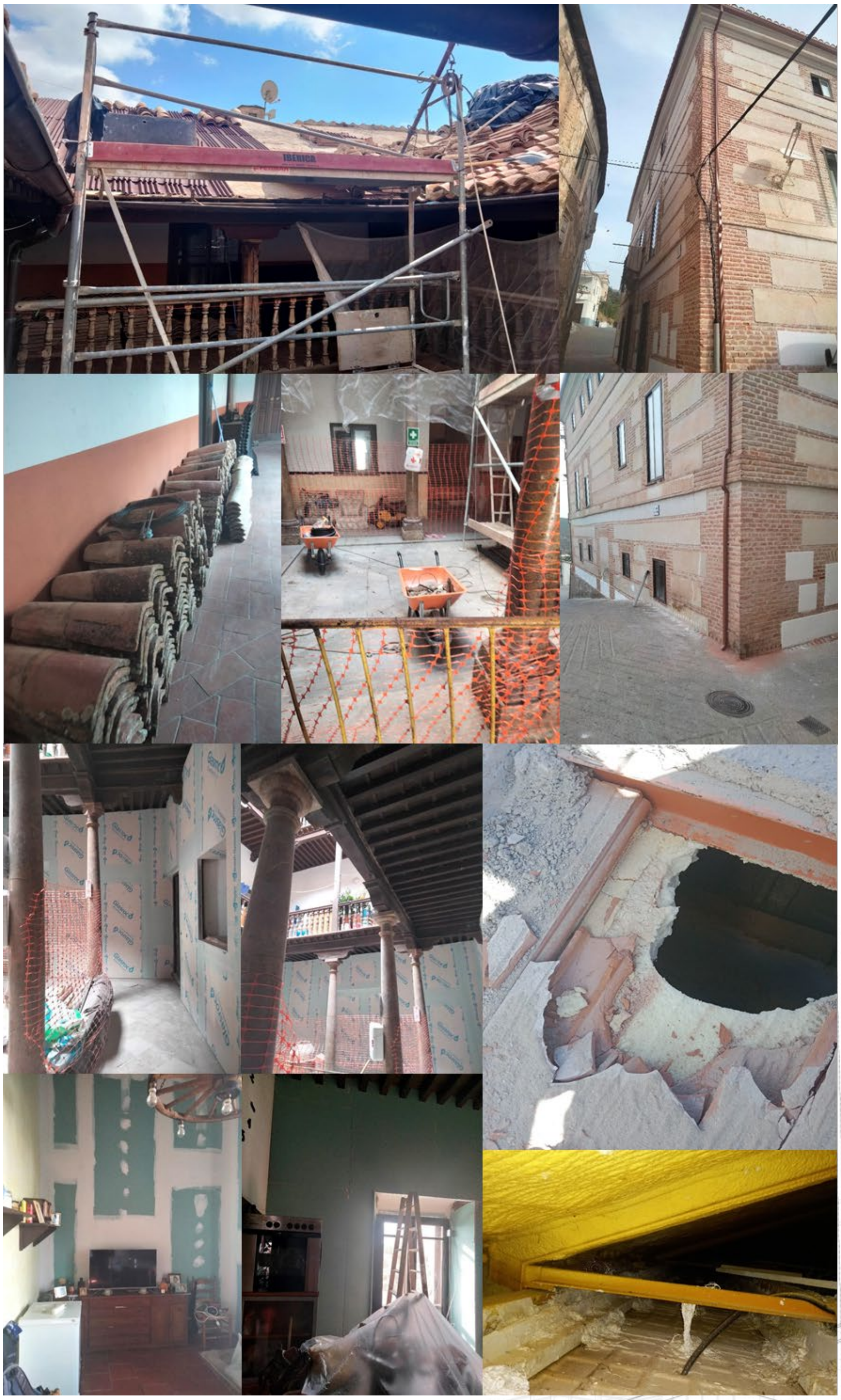


Figure 20: *Renovation works in the building of Alpujarra de la Sierra, Granada.*

Finally, to monitor the performance of the renovated building, different sensors of temperature, relative humidity and CO_2 concentration were installed, along with a management digital platform that can be seen in Figure 21:

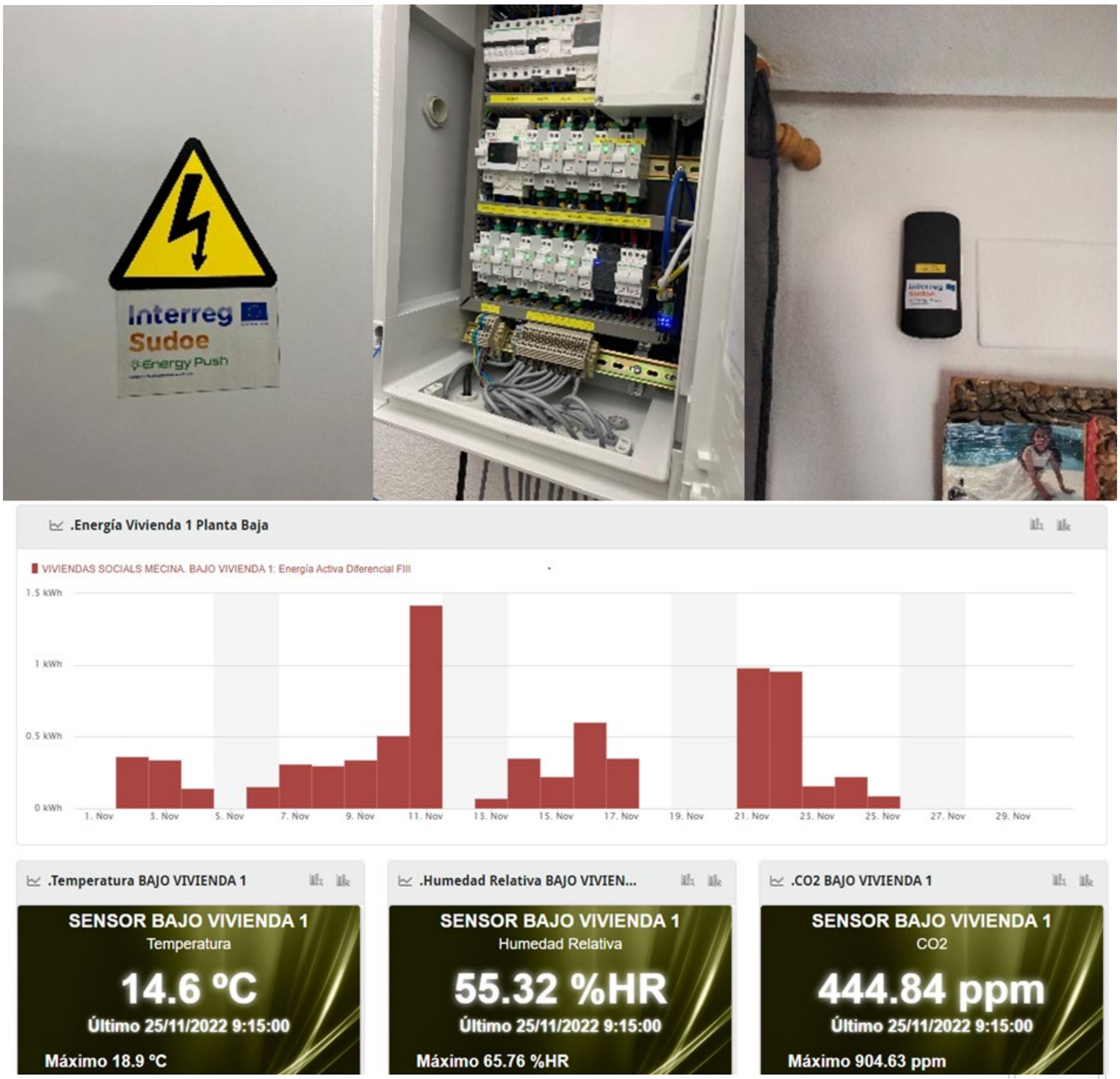
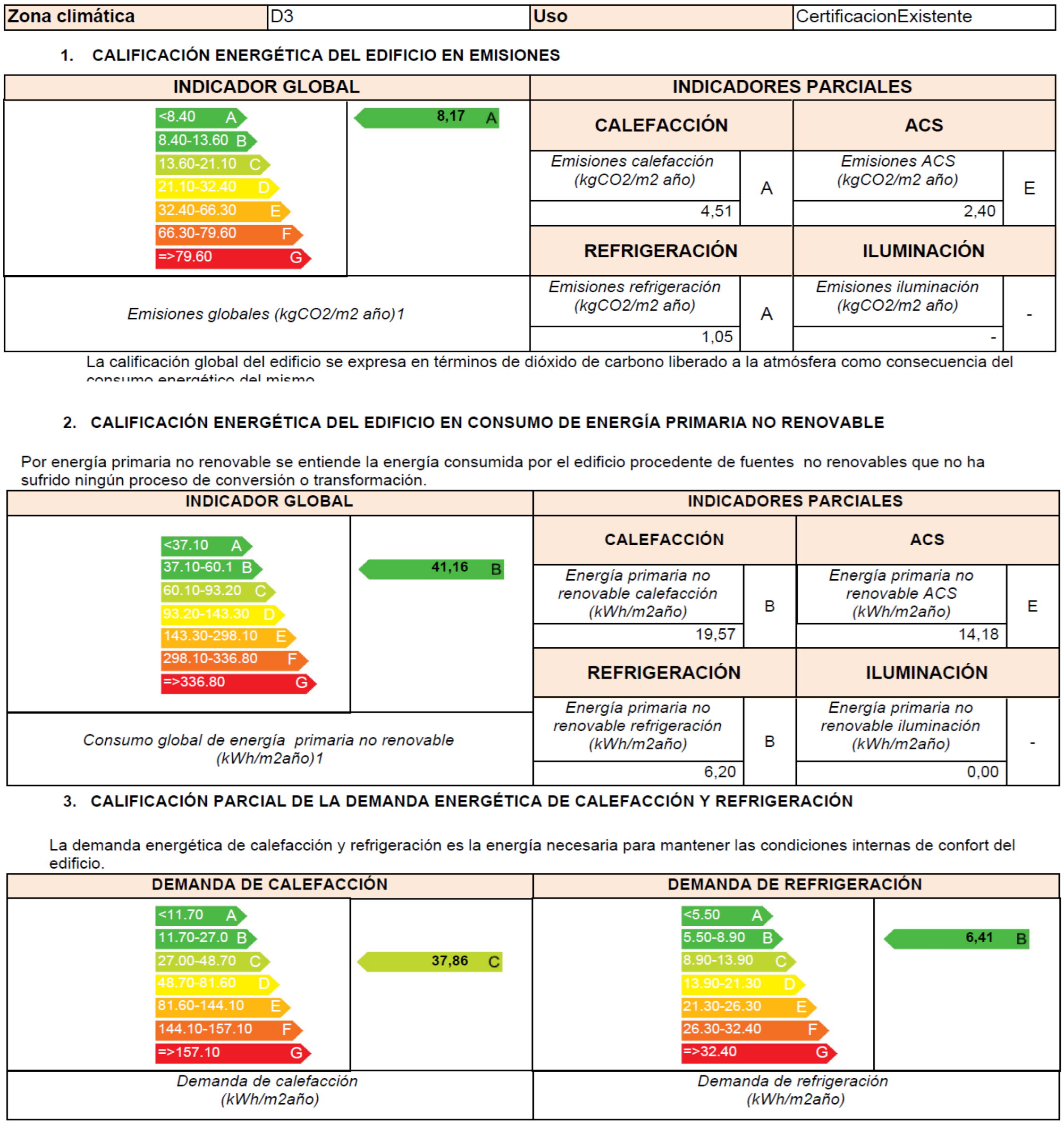


Figure 21: *Electrical panel, sensor and monitoring platform.*

4.4 RESULTS OBTAINED FROM THE RENOVATION PROCESS

After renovating the building, all the energetic indicators have been considerably improved, thus, achieving **8.17 kg CO_2/(m^2 ·year^1) "A"** concerning the emissions, an energetic performance of **41.16 kWh/(m^2·year) "B"**, heating demand performance **37.86 kWh/(m^2·year) "C"**, and the refrigeration performance **6.41 kWh/(m^2·year) "B"** as shown in Figure 22:



Zona climática	D3	Uso	CertificacionExistente

1. CALIFICACIÓN ENERGÉTICA DEL EDIFICIO EN EMISIONES

INDICADOR GLOBAL		INDICADORES PARCIALES			
<8.40 A; 8.40-13.60 B; 13.60-21.10 C; 21.10-32.40 D; 32.40-66.30 E; 66.30-79.60 F; =>79.60 G	8,17 A	CALEFACCIÓN		ACS	
		Emisiones calefacción (kgCO2/m2 año) 4,51	A	Emisiones ACS (kgCO2/m2 año) 2,40	E
		REFRIGERACIÓN		ILUMINACIÓN	
Emisiones globales (kgCO2/m2 año)1		Emisiones refrigeración (kgCO2/m2 año) 1,05	A	Emisiones iluminación (kgCO2/m2 año) -	-

La calificación global del edificio se expresa en términos de dióxido de carbono liberado a la atmósfera como consecuencia del consumo energético del mismo.

2. CALIFICACIÓN ENERGÉTICA DEL EDIFICIO EN CONSUMO DE ENERGÍA PRIMARIA NO RENOVABLE

Por energía primaria no renovable se entiende la energía consumida por el edificio procedente de fuentes no renovables que no ha sufrido ningún proceso de conversión o transformación.

INDICADOR GLOBAL		INDICADORES PARCIALES			
<37.10 A; 37.10-60.1 B; 60.10-93.20 C; 93.20-143.30 D; 143.30-298.10 E; 298.10-336.80 F; =>336.80 G	41,16 B	CALEFACCIÓN		ACS	
		Energía primaria no renovable calefacción (kWh/m2año) 19,57	B	Energía primaria no renovable ACS (kWh/m2año) 14,18	E
		REFRIGERACIÓN		ILUMINACIÓN	
Consumo global de energía primaria no renovable (kWh/m2año)1		Energía primaria no renovable refrigeración (kWh/m2año) 6,20	B	Energía primaria no renovable iluminación (kWh/m2año) 0,00	-

3. CALIFICACIÓN PARCIAL DE LA DEMANDA ENERGÉTICA DE CALEFACCIÓN Y REFRIGERACIÓN

La demanda energética de calefacción y refrigeración es la energía necesaria para mantener las condiciones internas de confort del edificio.

DEMANDA DE CALEFACCIÓN		DEMANDA DE REFRIGERACIÓN	
<11.70 A; 11.70-27.0 B; 27.00-48.70 C; 48.70-81.60 D; 81.60-144.10 E; 144.10-157.10 F; =>157.10 G	37,86 C	<5.50 A; 5.50-8.90 B; 8.90-13.90 C; 13.90-21.30 D; 21.30-26.30 E; 26.30-32.40 F; =>32.40 G	6,41 B
Demanda de calefacción (kWh/m2año)		Demanda de refrigeración (kWh/m2año)	

Figure 22: *Energy performance certificate after renovation of the building.*

Furthermore, these renovation actions can be appreciated in Figure 23:

Figure 23: *Building of Alpujarra de la Sierra, Granada after renovation.*

The total final investment made was 167,604.36 €, 16,760.43 € per dwelling. With this investment, the energy performance has been dramatically enhanced. The main outcomes and the comparison prior and post renovation of the building are presented in Table 6:

Table 6**:** KPI's of Alpujarra de la Sierra building prior and after renovation.

CURRENT ENERGY PERFORMANCE CERTIFICATE		**RENOVATED ENERGY PERFORMANCE CERTIFICATE**	
Total primary non-renewable Energy Consumption (kWh/(m²year))	Cooling and Heating Energy Demand (kWh/(m²year))	Total primary non-renewable Energy Consumption (kWh/(m²year))	Cooling and Heating Energy Demand (kWh/(m²year))
259,47	141,44	41,16	44,27
Heating Energy Demand (kWh/(m²year))	Cooling Energy Demand (kWh/(m²year))	Heating Energy Demand (kWh/(m²year))	Cooling Energy Demand (kWh/(m²year))
132,43	9,01	37,86	6,41
IMPROVEMENTS			
Reductions in total primary non-renewable Energy Consumption		Total primary non-renewable Energy savings Consumption	
218,31 kWh/(m²year)		84,14 %	
Reduction in cooling and heating energy demand		Cooling and heating energy demand savings	
97,17 kWh/(m²year)		68,70 %	
Energy rating initial state		**Energy rating renovated state**	
E		**B**	

5. PILOT PROJECT IN NOVALES, SPAIN

5.1 INTRODUCTION

The main objective of WP4 is to compare the effectiveness of two different solutions to improve the overall efficiency of social housing and to convert them into nearly zero emission buildings (nZEB): efficient envelopes vs energy efficient systems. After a preliminary techno-economic feasibility analysis carried out in Task 3.2, the main objective of Task 4.4 is to evaluate the performance of the designed pilot plant in the location of Novales (Cantabria, Spain). This pilot plant combines renewable energy sources (photovoltaic panels) and novel hydrogen chain technologies with two main objectives:

1- Improve the system efficiency and energy management of the house.
2- Enable a 100% self-sufficient and decarbonized energy supply to the house.

Given the characteristics of the consumption, the use of photovoltaic (PV) panels to supply electricity to the home implies a great energy excess during summer time due to the low demand. In this regard, we have selected hydrogen technologies to store surplus energy seasonally during the year without degradation and cover the demand during winter when solar energy is scarce. Thus, the pilot plant is designed to ensure 100% self-sufficiency in terms of electricity for the home throughout the year without needing the utility grid connection or ancillary fossil fuel-based gensets.

5.2 PILOT PLANT DESCRIPTION AND OPERATION

To achieve the ultimate goal of detaching the social home from the utility grid, the pilot plant has to be designed accordingly. Thus, after performing multiple simulations based on the electricity consumption shown in Figure 24, different equipment and subsystems have been selected and defined. Figure 25 shows the schematic diagram with all the components making up the pilot plant.

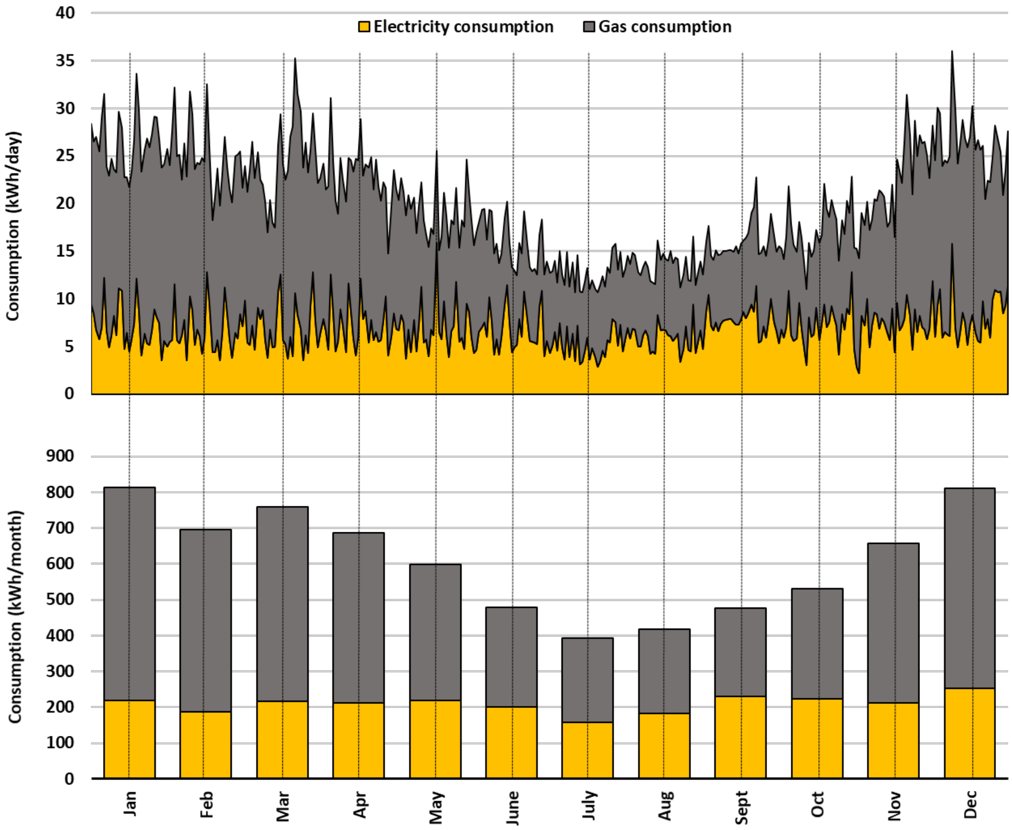


Figure 24: *Electricity and gas consumptions of Novales' home.*

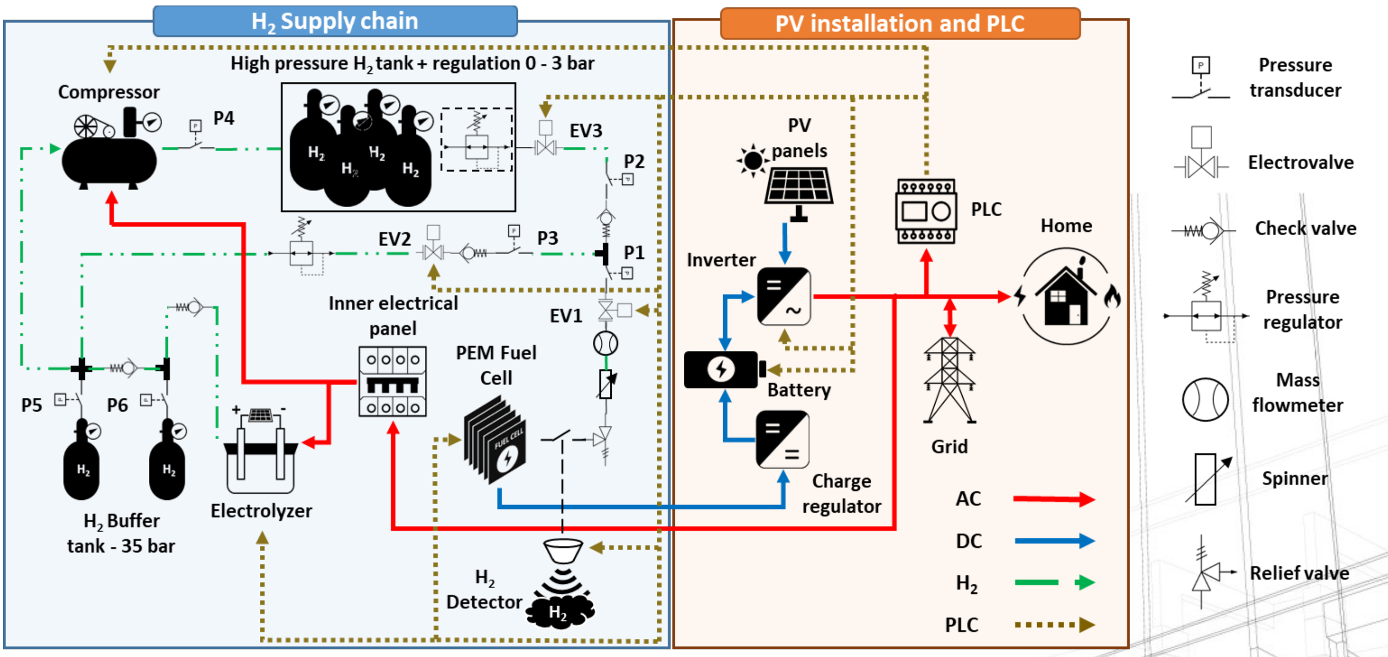


Figure 25: *Schematic diagram of the pilot plant connected to the social house of Novales (Cantabria, Spain).*

The following is a description of the different subsystems and equipment that make up the pilot plant and their characteristics:

PV subsystem

- PV panels.
- Inverter.
- Batteries.
- Battery charge regulator.
- Power meter.
- PLC.

Hydrogen supply chain

- Electrolyzer.
- Dryer.
- Water tank module.
- Water purification system.
- Fuel cell.
- Compressor.
- High-pressure H_2 tank.
- H_2 buffer tank.

Instrumentation

- Pressure transducers.
- Electrovalves.
- Check valves.
- Pressure regulator.
- Mass flowmeter.
- H_2 spinner.
- Relief valve.
- H_2 detector.

The pilot plant previously depicted operates as follows:

1- PV panels are the primary energy source and will supply the load meanwhile solar irradiation is sufficient.

2- When there is excess PV generation, the energy surplus will be stored in the batteries in the first stage.

3- The excess energy that cannot be stored in the batteries will be accumulated in the form of hydrogen generated by means of the electrolyzer.

4- The hydrogen generated will be stored in a first stage in a buffer tank with an intermediate pressure. When the buffer is full, the compressor will be started and the hydrogen will be stored at high pressure in the tank.

5- When the solar irradiation is insufficient to cover the demand of the house, the batteries will supply the necessary energy to the house.

6- If the batteries are discharged, the fuel cell will generate electricity to charge the batteries from the stored hydrogen. As far as possible, the hydrogen stored in the buffer will be used first to avoid the compression stage, thus increasing energy efficiency.

7- The system and the house will be connected to the grid on a self-consumption basis to avoid cutting off the power supply to the house in case of installation failures or maintenance operations. Excess energy that the system is not able to assimilate can also be dumped or tapped for revenue depending on the contract with the utility company.

8- This operation procedure is programmed in the PLC to operate the pilot plant automatically and track it through any computer connected.

5.3 IMPLEMENTATION OF THE INNOVATIVE POWER SYSTEM

Prior to the implementation of the pilot plant and the placement of the equipment in its final location, it is required to provide the installation with the necessary civil infrastructure. In this regard, the European and Spanish legislative framework concerning self-consumption facilities, hydrogen storage and acoustic standards inside the different rooms of the home. In the case of Spain, it has been followed the specific regulation from the Subworking Group of Hydrogen Technologies of Spanish Ministry of Industry, Commerce and Tourism, which is applicable in the case of the pilot plant to be implemented in Novales (Cantabria).

Considering all these regulations and restrictions, it was decided to place the PV panels in the roof of the building for solar energy harvesting and to implement the rest of the components in an installations shed. This shed is located in an adjacent land plot. The available area to deploy it has been obtained after considering all the safety distances to surrounding buildings, public roads, power lines, etc.; and it is depicted in Figure 26. Moreover, Figure 27 displays the final placement of the hut.

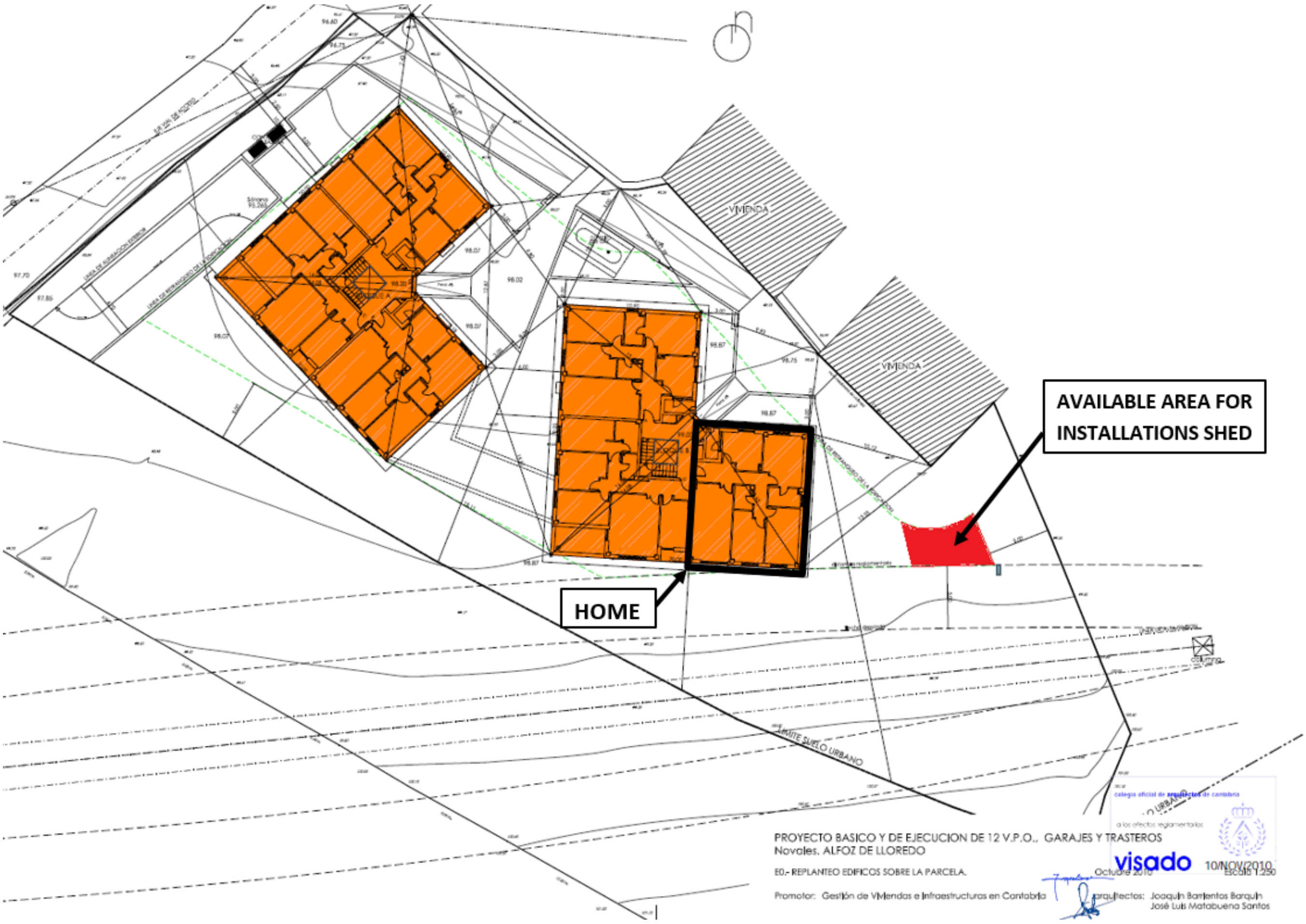


Figure 26: *Plan for the layout of the facilities hut in Novales (Cantabria, Spain) after considering applicable regulations.*

Figure 27: *Housing and installation hut with pilot plant.*

Furthermore, the PV subsystem equipment previously defined are shown in place in Figure 28. Likewise, hydrogen supply chain and instrumentation devices are displayed in Figure 29.

Figure 28: *PV panels (1), PLC and electrical panel (2), inverter (3), battery charge regulator (4) and battery pack (5).*

Figure 29: *Electrolyzer (1), dryer (2), water tank module (3), water purification system (4), high-pressure hydrogen tank (5), hydrogen buffer tank (6), PEM fuel cell (7) and hydrogen compressor (8).*

Finally, Figure 30 shows ancillary equipment required for the interconnection of the different devices as well as for monitoring and safety operation of the pilot plant.

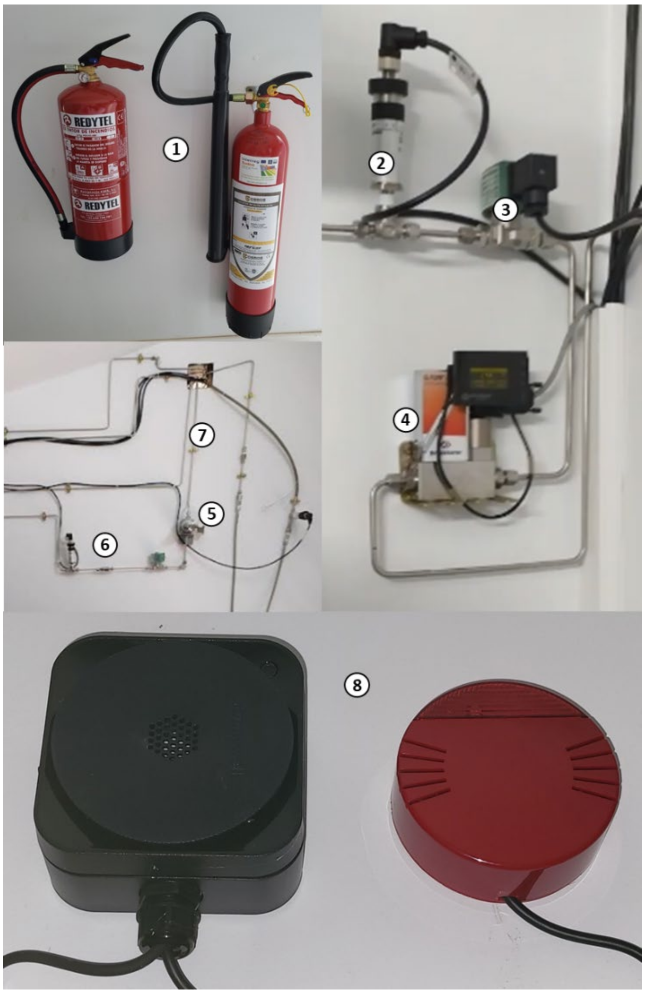


Figure 30: *Fire extinguishers (1), pressure transducer (2), electrovalve (3), mass flow controller (4), pressure regulator (5), check valve (6), stainless steel piping (7) hydrogen detector and alarm (8).*

Moreover, the operation of the pilot plant is automatically controlled thanks to a PLC. It monitors different parameters such as the battery state of charge, PV panels production, home consumption, battery charge and discharge rates, fuel cell output, electrolyzer production, etc. Thus, different screens have been created to monitor and control the installation remotely from the University of Cantabria. For instance, Figure 31 reflects several parameters that can be monitored in PV panels screen:

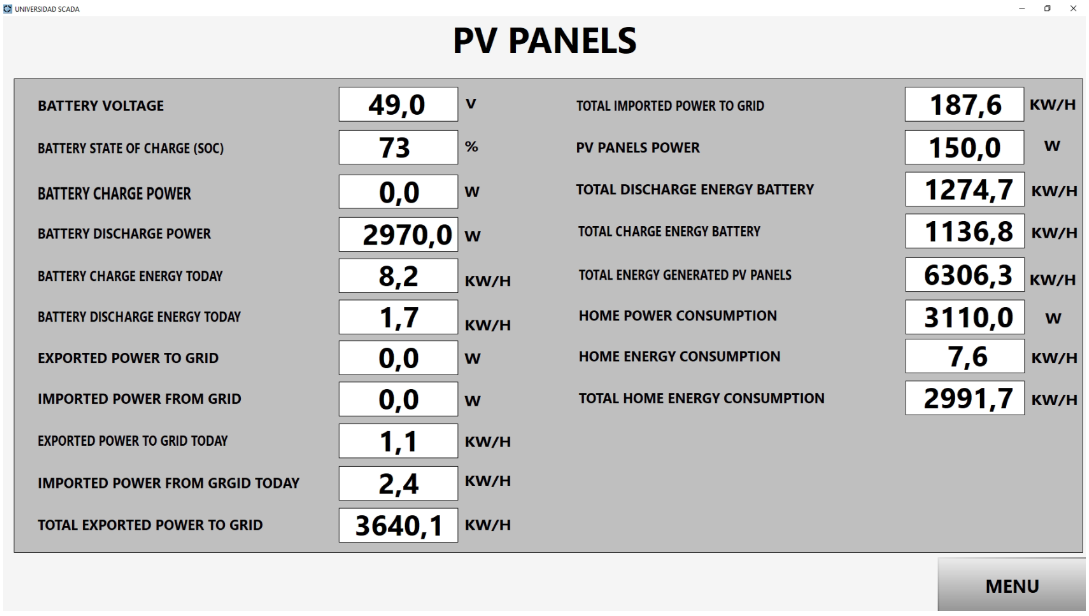


Figure 31: *PV panels screen with different energetic values.*

5.4 RESULTS OBTAINED THROUGH THE OPERATION OF THE PILOT PLANT

Main results derived from the operation of the pilot plant previously described are presented hereafter. The results will be presented both in an annual and monthly basis. It should be noted that the PV subsystem was installed during January, while the self-consumption tariff with surplus compensation was signed in mid-February. On the other hand, the hydrogen supply chain has been operating automatically since August (in the case of the electrolyzer and compressor), whereas the fuel cell has started operating automatically in mid-November. Thus, Table 7 reflects the total energy generated by PV panels and its use, Table 8 accounts the total energy consumption and its distribution according to the equipment covering the demand, and Table 9 ranks this distribution according to the source of consumption. These data belong to a 10-month period from **February to November.** Furthermore, Figure 32 represents all these data.

Table 7: Use of PV energy production.

Description	Energy	Percentage
Total PV generation	6,325 kWh	100%
Total charge energy – Batteries	1,148 kWh	18%
Total exported energy to grid	3,920 kWh	62%
Total direct PV consumption	1,257 kWh	20%

Table 8: Distribution of consumption according to the origin of supply.

Description	Energy	Percentage
Total energy consumption (including home, electrolyzer, compressor and ancillary equipment)	3,025 kWh	100%
Total direct PV consumption	1,257 kWh	42%
Total discharge energy – Batteries	1,294 kWh	43%
Total imported energy from grid	474 kWh	15%

Table 9: Distribution of consumption according to the source of consumption.

Description	Energy	Percentage
Total energy consumption (including home, electrolyzer, compressor and ancillary equipment)	3,025 kWh	100%
Total home consumption	2,575 kWh	85%
Total electrolyzer consumption	276 kWh	9%
Total consumption ancillary equipment (compressor, water purification system, etc.)	174 kWh	6%

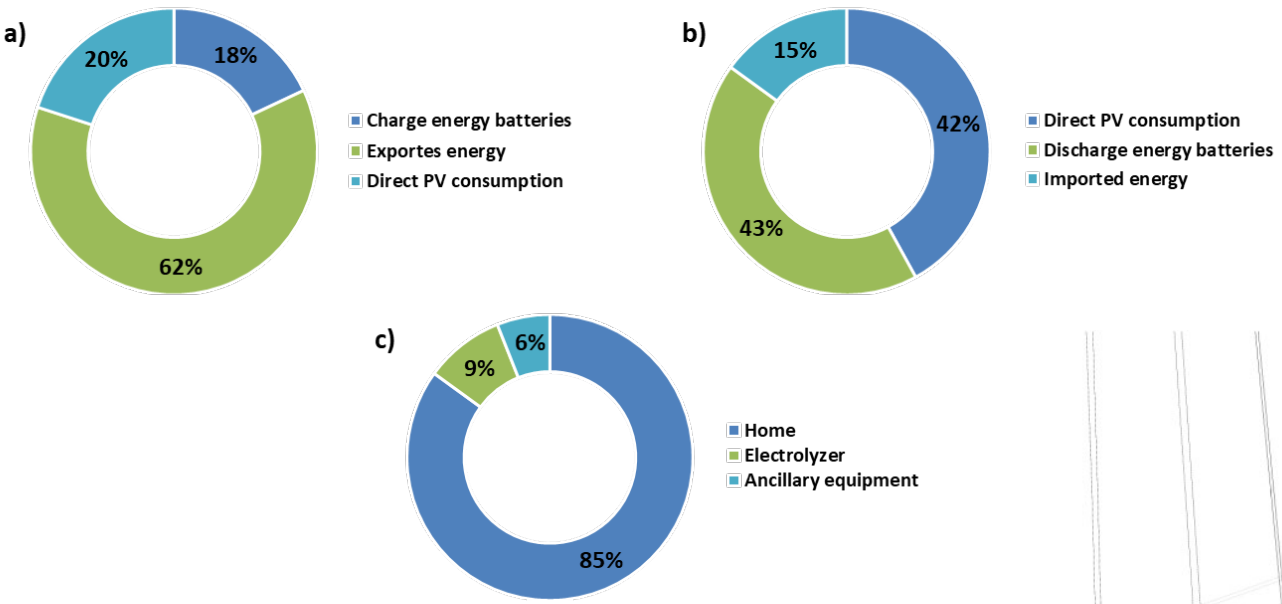


Figure 32: *a) Use of PV energy production, b) distribution of consumption according to the origin of supply and c) according to the source of consumption.*

As it can be seen in Table 7, total PV production in monitoring period (from February to November) is 6,325 kWh, while the simulated production is 8,660 kWh (deliverable WP3.2.1). This represents a 75% of the previously simulated scenario, but it should be noted that there are still 2 months and a half left (PV panels were installed in early February), and that during March a strong haze occurred all over Spain, covering the solar panels with dust that could not be cleaned for weeks. Therefore, we can assert that a good correlation exists between the simulated renewable energy and the real one. The exported energy is high, compared to the home demand due to the period between the start of operation of the solar panels and of the hydrogen chain, which started operating in August. In this regard, this statement is valid for the consumption of energy from the grid (15% of the demand, Table 8). Nevertheless, this demand is still a moderate value assuming that the hydrogen chain did not start the operation until mid-summer. It should be noted as well that the electrolyzer and ancillary equipment consumption is low compared to the home consumption due to their late start of automatic operation but is expected to grow for next year (Table 9).

On the other hand, several techno-economic parameters have been defined to quantify and evaluate the overall performance of the system in terms of economics, energy and environmental impact. Therefore, the KPI's defined in Equations 1, 2, 3 and 4. These current milestones and outcomes are summed up in Table 10.

$$E_{useful,\,n} = \sum (E_{load} + E_{excess,\,year\,n}) \quad (1)$$

$$Primary\ energy\ savings,\ year\ n = 2.403 \cdot \sum(E_{useful,\,n})\ ^{*} \quad (2)$$

$$CO_2\ emissions\ savings,\ year\ n = 0.357 \left[\frac{kg\ CO_2}{kWh}\right] \cdot \sum(E_{useful,\,n})\ ^{*} \quad (3)$$

$$Economic\ savings = 0.317 \frac{€}{kWh} \cdot \sum (E_{PV-load}) \quad (4)$$

* These values have been obtained from the Spanish Regulation of Thermal Installations in Buildings.

Table 10: *Primary energy savings, CO_2 emissions avoided and economic savings from January to November 2022.*

Primary energy savings	~ 4,500 kWh
CO_2 emissions avoided	~ 700 kg CO_2
Economic savings	~ 450 € (Feb 22/Nov 22)

During the first 10 months of operation, the pilot plant has accomplished three main milestones: 4,500 kWh of primary energy saved, 700 kg of CO_2 emissions saved and more than 450€ saved for the most vulnerable citizen in the SUDOE region. Finally, the functioning of the installation will continue to be monitored to see the performance of the pilot plant for a full year without interruption with both PV subsystem and hydrogen chain installed and properly configured.

6. CONCLUDING REMARKS

The heterogeneous social housing stock in the SUDOE region makes it necessary to evaluate specifically in each case the best option to improve the efficiency and energy management of each building. Within the SUDOE ENERGY PUSH project, 4 different solutions have been adopted to solve the energy poverty faced by the most disadvantaged inhabitants, improving the overall performance of the buildings. Thus, through the combination of new digital tools that facilitate the management of passive renovations and allow the optimization of the actions to be carried out, in addition to the adoption of renewable energies and new energy storage technologies such as hydrogen, great progress has been achieved in different areas: reduction of final and primary energy consumption, CO_2 emissions savings, reduction in electricity and gas bills, improvement of indoor thermal comfort, monitoring and tracking of renovations, etc.

All the solutions proposed within the SUDOE ENERGY PUSH project have increased the standards of energy efficiency, management, and overall performance of the social housing. However, there is still potential ahead to further enhance the pilot actions carried out. Therefore, Table 11 collects the main strengths of every proposed methodology as well as the future work and development ahead to improve the adopted solutions.

***Table 11*:** Main strengths and future work of every proposed methodology throughout the project.

Pilot plant	Tool	Strengths	Future work/Bottlenecks
Bordeaux (France)	RENOIR	- Holistic approach, considering at the same time all the opportunities for improvement on both the building envelope and systems. - Considering the global cost and not only the investment cost. - Enable to assess thousands of relevant solutions and therefore to highlights trends of the renovation actions impact in terms of energy and money saving. - Enable to formulate clear recommendations, and to quantify their relevance according to other possible choices. - Can help technical offices to save time	- Based on the French thermal regulation model for the energy calculation. - Need for a lots of technical and economic data. - Complex to use, and complex to explain. - Need several weeks of work to set all the models.
	RECORES	- Easy to use.	- The same person should fill in the table (initial state/after work).

		- A tool for dialogue and consultation to highlight areas for progress. - Modular and adaptable to local contexts and to the evolution of sustainable and urban planning policies.	- Several skills are needed: thermal engineering office and architect at least. - No economic dimensions
Vila Nova de Gaia (Portugal)	Digital twin	- Allows managers of social housing stock to know the state of dwellings concerning indoor environmental quality and energy and water efficiency. - Allows renovation decision-making based on real data collected from buildings candidates for renovation works. - Provides real data about the condition of the dwellings that can be used as a basis for the renovation strategies at the design stage. - Enables the creation of alerts to help occupants operate their homes better.	- The system has operational costs (electrical consumption and internet). - Since the monitoring system is left in the dwellings, there is a risk of damage. - The managers of social housing stock need technical training to understand the data produced by the digital building twin.
Alpujarra de la Sierra (Spain)	BIM and digital energy managment	- Improved communication with stakeholders. - Diminishes the risk of errors. - Increase efficiency in Public Administration.	- Lack of technical training. - It takes a lot of time to implement in a social housing stock. - Upgrading a cloud storage.
Novales (Spain)	Renewables-hydrogen energy system	- Flagship green hydrogen configuration in social housing. - Energy system that ensures 100% electrical self-sufficiency throughout the year. - Zero-emissions implementation with almost zero electricity bills. - Continuous control of monitoring of the consumption, indoor thermal comfort, PV production, hydrogen generation, etc.	- Prototype phase. Scale-up of the system required to analyze cost-competitiveness. - Covering thermal requirements needs further design. - Digitalization of the system to optimize its performance.