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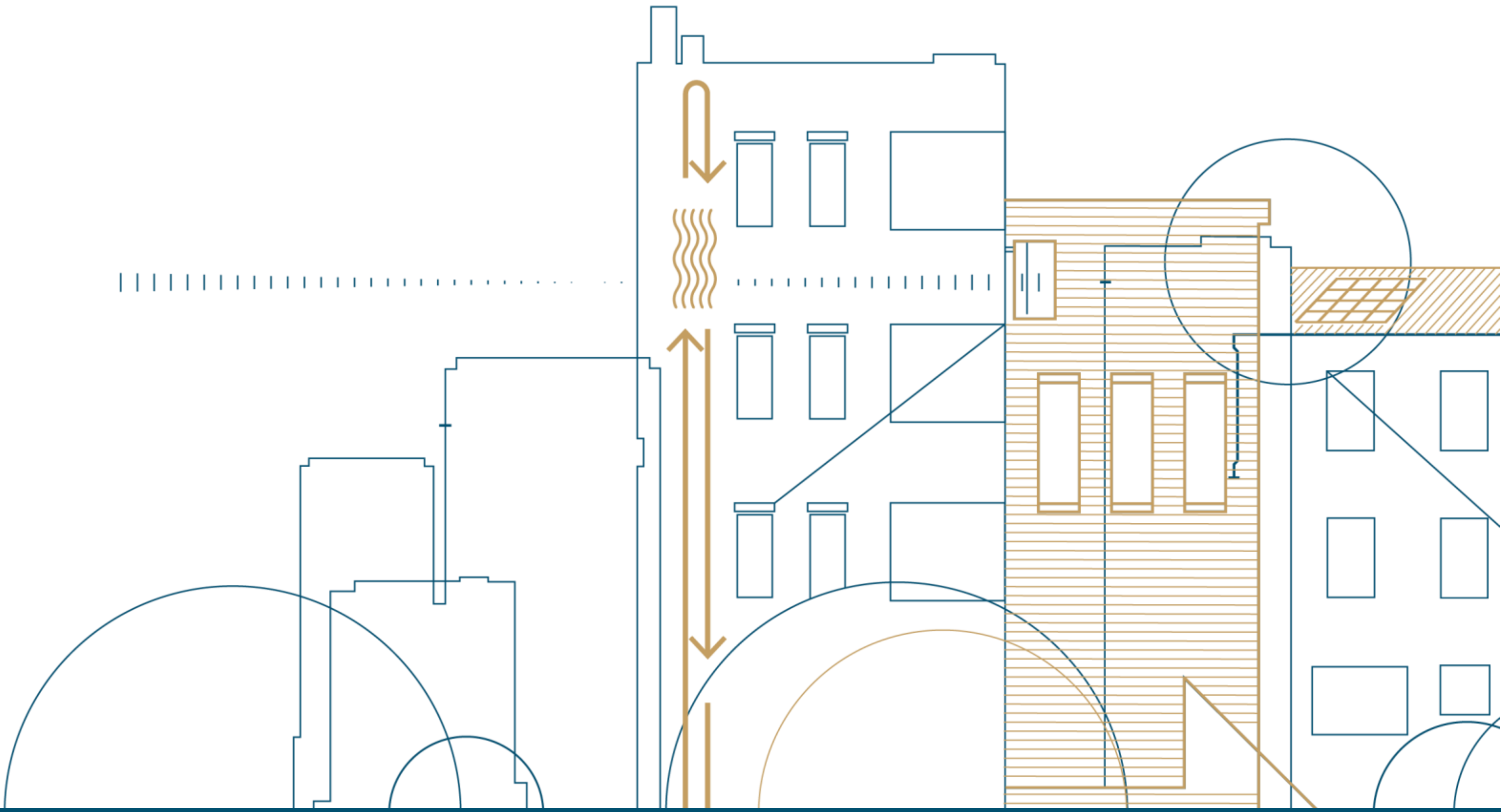
REHOUSE



D4.2

Technical diagnosis (SRI, energy performance, air quality) initial status

Co-funded by the European Union

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Associated Task	Task 4.2: DIAGNOSIS - Technical diagnosis (baseline) of current buildings status and energy systems
Deliverable Lead Partner	CEA
Contributors	CAR, CERTH, DUTH, RENEL, NTUA, PSYCTO, AMS, ENEA, RINA-C, UNIBAS, WOODS, PLAT, FCHURCH, NBK, UNIBAS, TERA
Author(s)	CEA (Christian ORGIAZZI, Fabrice CLAUDON), ENEA (Patrizia AVERSA, Elena CANDIGLIOTA, Antonio DI MICCO, Francesca HUGONY, Vincenza Anna Maria LUPRANO, Giuseppe MARGHELLA, Anna MARZO, Monica MISCEO, Valerio PFISTER, Salvatore TAMBURRINO, Angelo TATÌ, Concetta TRIPEPI), UNIBAS (Giuseppe SANTARSIERO, Giuseppe VENTURA, Angelo MASI, Vincenzo MANFREDI, Antonio D'ANGOLA), RINA-C (Cristina VACCARELLA, Andrea WELTI), FCHURCH (Pál Lehofer, Dr. Gábor Mondovics, Kinga Takács), CERTH (Christos Tsaknakis, Dimitris Vamvakas, Christos Korkas), DUTH (Adamantios Papatsounis, Konstantinos Lymperopoulos, Athanasios Papavasileiou, Niki Efstratiou), WOODS (Zoltán Pásztory), NTUA (Ioannis Atsonios, Manos Katsigiannis), AMS (Constantinos Tsoutis, Sofia Papadopoulou), PSYCTO (Apostolos Gkountas, Pantelis Bakalis), TERA (Andrea Cavallaro, Farideh Soheyli, Ivan Tartaro)
Reviewer(s)	CERTH (Dimitris Vamvakas, Christos Korkas), NBK (Aurélien Henon), CARTIF (Jonatan Viejo, Javier Antolín)
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DOCUMENT HISTORY

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V0	09/01/2024	Table of Content	CEA
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V9	27/03	Document ready for the review process	CEA
V9.1	8/04	Review of the document	CARTIF, CERTH, NBK
V10	12/04	Finalization of the document	CEA
V11	12/04	Final document	CARTIF

EXECUTIVE SUMMARY

Deliverable 4.2 presents the results of Task 4.2 "DIAGNOSIS - Technical diagnosis (baseline) of current buildings status and energy systems" from Work Package 4 "Demonstration of the 8 renovation packages (TRL7)" in the Horizon Europe project REHOUSE. All the WP4 tasks works towards the aim to demonstrate the 8 Renovation Packages innovative solutions at TRL7 in the 4 demo-sites, from the deployment of a digital building logbook (T4.1), continuing with the process of the diagnosis of the buildings (T4.2), the design and preparation phases (T4.3), the construction phase (T4.4), the operational phase (T4.5) and by ending with the evaluation of the performance of the solutions under real conditions (T4.6).

More specifically, D4.2, entitled "Technical diagnosis (SRI, energy performance, air quality) initial status", presents the starting point of the four demo-sites of the REHOUSE project before the retrofit and it defines the baseline situation for the four demo-sites, so that the evaluation of the final performance, as defined in WP3 "Measurement, Evaluation and Learning methodology, impact assessment and platform specifications", can be implemented.

The document is structured in 8 chapters. After the introduction in chapter 1, chapter 2 presents the link with measurement and evaluation methodology as defined in WP3 in which T3.2 "Establishment of the REHOUSE set of indicators" identified and defined the project KPIs and T3.4 "Monitoring programmes/plans" which defined the monitoring programs for each demo-site, including the baseline monitoring needs. Detailed information about the previous tasks (T3.2 and T3.4) outcomes can be found under D3.2 "REHOUSE set of indicators selected for the impact assessment" and D3.4 "Monitoring programmes for the 4 demos". The other chapters define the initial conditions of the demo-sites throughout different axes. Chapter 3 gives a global assessment of the buildings for each demo-site regarding the existing conditions, facilities and infrastructures collected through a defined questionnaire. Chapter 4 presents the assessment of the SRI initial level for each site. Chapter 5 and Chapter 6 present the energy performance and thermal comfort and indoor air quality initial status respectively for each demo-site. Finally, Chapter 7 presents the methodology followed by the Italian demo-site for the building structural diagnosis due to their seismic implications. In the Annex of the report it is possible to see the results of the application of the methodology presented in Chapter 7 to the Italian demo-site and the Questionnaire used for the data collection and the analysis shown in Chapter 3.

Keywords: Diagnosis, Energy, Building, Baseline, Systems

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LIST OF ABBREVIATIONS

ACRONYM	DESCRIPTION
BIM	Building Information Modelling
CO	Carbone Monoxide
D	Deliverable
DHW	Domestic Hot Water
EU	European Union
EV	Electric vehicle
HUF	Hungarian Forint
KPI	Key Performance Indicator
PM	Particulate Matter
PMV	Predicted Mean Vote
PV	Photovoltaic
RES	Renewable Energy Systems
RP	Renovation Package
RPi	Raspberry Pi
SRI	Smart Readiness Indicator
T	Task
TRL	Technology Readiness Level
TVOC	Total Volatile Organic Compounds
USB	Universal Serial Bus
VOC	Volatile Organic Compounds
WP	Work Package

1 INTRODUCTION

1.1 PURPOSE AND SCOPE OF THE DOCUMENT

This document defines the starting point of the buildings, the baseline, for the four demosites, so that the evaluation of the final performance (as defined in WP3 "Measurement, Evaluation and Learning methodology, Impact assessment and Platform specifications") of the demo-sites once the Renovation Packages are installed on them can be deployed comparing both situations (baseline vs retrofitting).

The document is organized in five main parts that describe the baseline situation of the building:

- Assessment of general information from the current status of the building collected through a questionnaire which aimed to assess existing conditions, facilities and infrastructure of the pilot site.
- SRI initial level: definition of the initial SRI-level following the SRI methodology (Heating, DHW, Cooling, Controlled Ventilation, Lighting, Building Envelope, Electricity, EV chargers and Monitoring and Control).
- Energy performance initial status: definition of a complete and fixed picture of the current situation of the building in the architectural, energy and environmental fields.
- Thermal comfort and Air quality current status: definition of the current status of the thermal comfort and indoor air quality conditions, considering the different building users' typology. In the scope of this status definition, sensors were installed.
- An additional part, specific to the Italian demo-site seismic implications, describing a structural assessment methodology that was defined and its application to the Italian demo-site.

1.2 CONTRIBUTION OF PARTNERS

The contribution of the partners to the Deliverable 4.2 is shown in Table 1.

Table 1: Partners' contribution to T4.2

PARTICIPANT	CONTRIBUTIONS
CEA	Leader of the document, contribution in all the sections
ENEA	Contribution to section 3, 4, 5, 6, 7
CARTIF	Reviewer of the document
UNIBAS	Contribution to section 3, 5, 6, 7
CERTH	Reviewer of the document Contribution to section 3, 4, 5, 6
FCHURCH	Contribution to section 3, 4, 5, 6

PARTICIPANT	CONTRIBUTIONS
ARCA	Contribution to section 3, 4, 7
DUTH	Contribution to section 3, 5
RINA	Contribution to section 3, 5, 6, 7
TERA	Contribution to section 3, 5, 6, 7
NBK	Reviewer of the document

1.3 RELATION TO OTHER ACTIVITIES IN THE PROJECT

The main inputs are the results of the Tasks 3.2 "Establishment of the REHOUSE set of indicators" and 3.4 "Monitoring programmes/plans" that respectively define the choice of KPIs and the definition of the monitoring program.

The outputs of this report will be completed by the baseline monitoring data that will occur until the initiation of the construction phase of the demo-sites. Finally, baseline monitoring data will be used in Task 4.6 "Evaluation – Impact assessment and evaluation of performance" to assess the different KPIs that will quantify the performance gap due to the RPs implemented on the demosites.

Table 2: Relation of T4.2/D4.2 with other activities in the project

ACTIVITY (DELIVERABLE NUMBER)	DESCRIPTION
ST1.1.2 Local social context (D1.2)	This report complements the social situation of the 4 local contexts by providing the technical part and therefore giving the overall picture of the demo-sites.
T3.2 REHOUSE set of indicators (D3.2)	The baseline definition of the demo-sites need to consider the set of KPIs selected for the REHOUSE project in order to be able to collect all the needed information for their later calculation.
T3.4 Monitoring programs (D3.4)	The monitoring programs define the needs for the baseline monitoring programs.
T3.5/T4.1 Digital Building Logbook	Although this report defines the initial situation of the buildings, additional baseline monitoring data will be collected until the initiation of the construction stage thanks to the installation of specific monitoring systems in the demo-sites that are currently collecting data. Baseline monitoring data will be initially stored in local platforms and then stored in the project Digital Building Logbook once deployed.
T4.6 (D4.9) Impact assessment	Baseline monitoring will be use for the calculation of the Baseline KPIs for the deployment of the final impact activities by comparing baseline KPIs vs reporting KPIs.

Figure 1 presents the work-flow for different tasks of WP4.

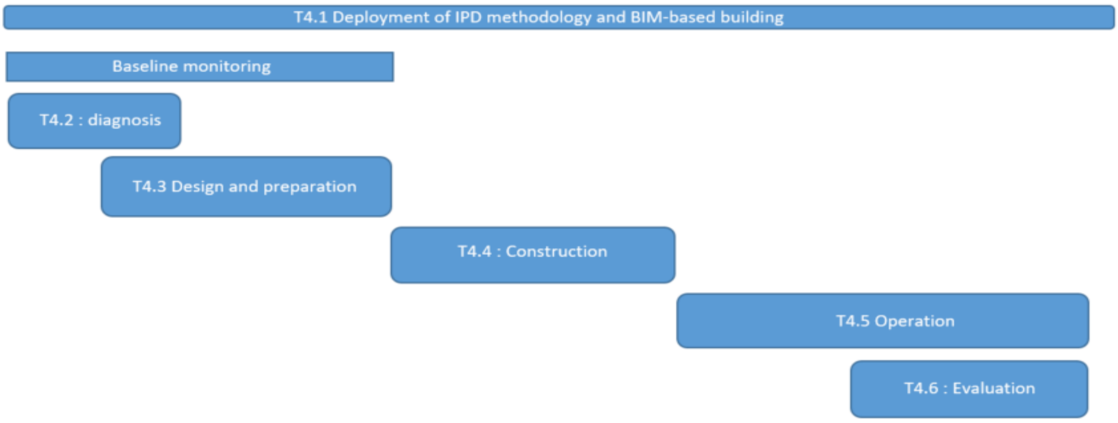


Figure 1: Work-flow of WP4 tasks

2 BASELINE MONITORING PROGRAMME

2.1 ROLE OF THE BASELINE MONITORING PROGRAMME

The building operation monitoring program (described in D3.4 "Monitoring programs for the 4 demos") is the reference document containing all the information about parameters to be measured and associated measurement devices needed to evaluate the KPIs selected and defined in the D3.2 "REHOUSE set of indicators selected for the impact assessment" together with additional information about data acquisition systems and monitoring periods. The roles and responsibilities of partners involved in each demo-site into monitoring activities are also defined in the respective monitoring programs.

References will be made to D3.4 and D3.2 throughout this document for example about the monitoring period and the demo-site KPIs. The following sub-sections present the synthesis of baseline KPIs for the four demo-sites and the monitoring period for the four demo-sites.

2.2 BASELINE PERIOD OF THE FOUR DEMOSITES

The baseline period is the period of time chosen to represent the operation of the facility or system before the REHOUSE retrofit.

This report defines the initial situation of the demo-sites previous to the retrofitting actions but the baseline monitoring period will continue until the beginning of the renovation and construction works in each demo-site thanks to the installation of monitoring devices as it is appreciated in Figure 2. The results obtained through this report will be complemented with the additional monitoring data collected until the initiation of the construction period. Baseline monitoring data will be used for the later calculation of reference KPIs to be used during the impact assessment activities in Task 4.6.

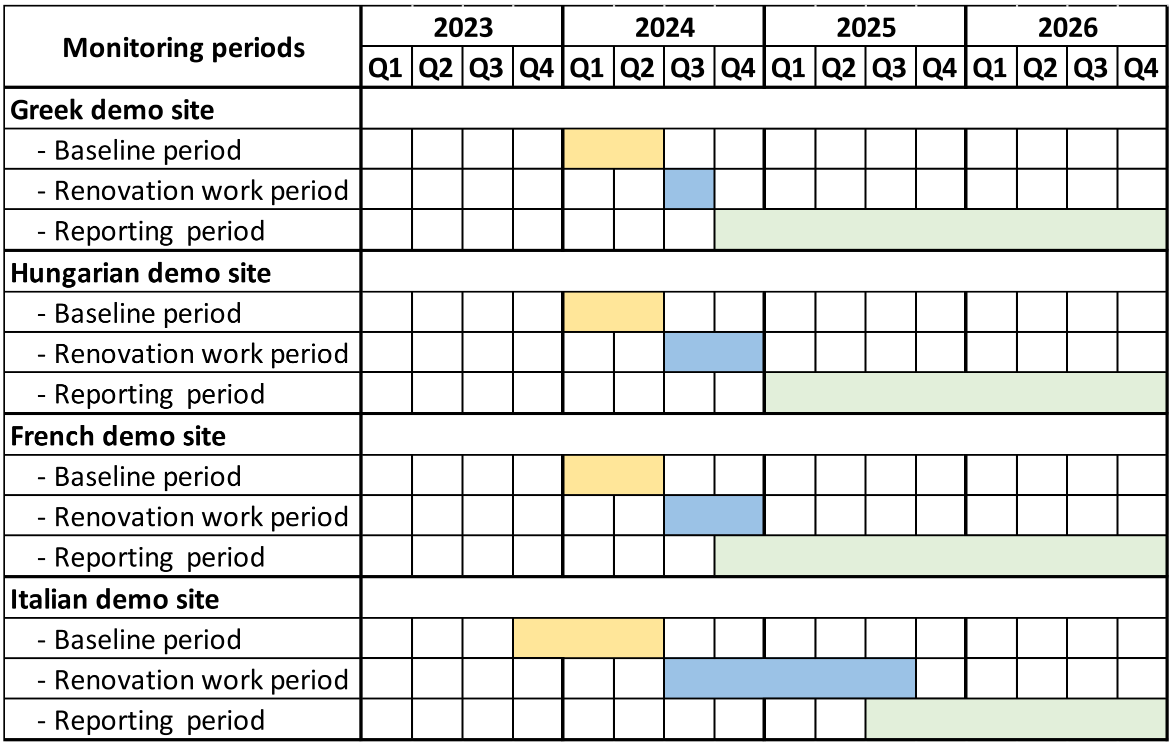


Figure 2: Baseline monitoring periods from D3.4

2.3 SYNTHESIS OF BASELINE KPIS FOR THE FOUR DEMOSITES

The baseline KPIs synthesis table is presented below. It indicates the different KPIs applicable for each of the four demo-sites and the specific section in this document in which the information for their later calculation is referred .

Table 3: Summary table of KPIs applicable to the baseline period coming from D3.2

KPI Nº	Key performance indicator title [unit]	Reference Section	Demo site			
			Greek	*Hungarian*	*French*	*Italian*
KPI01	Thermal resistance of façade walls R value	5				
KPI02	Final energy use for systems of building – Demo site level – [kWh/yr.]	5				
	Final energy use for systems of building – Dwelling level –[kWh/yr.]	5				
KPI03	Electrical peak power demand reduction from the grid [kW]	5				
KPI04	Primary energy use stage energy performance [kWh/m2/yr.] of building	5				
KPI05	Non-renewable primary energy consumption [kWhep/m²/yr.]	5				
KPI06	SRI score [%] of the whole demo site building	4				
KPI10	Final energy savings [% and kWh/m2*year]	5				
KPI11	Primary energy savings [%]	5				
KPI12	Building Energy rating	3				
RP-KPI12	Energy demand reduction [%]	5				
RP-KPI16	Increase of RES power at demo site level [kWp]	5				
KPI14	Lighting and visual comfort [lux]	6				
KPI15	Improvement of ambient thermal comfort in dwellings	6				
RP-KPI04	Reduction in the Predicted Percentage of Dissatisfied people during occupancy hours [%]	6				
RP-KPI05	Improvement in terms of PMV [Predicted Mean Vote]	6				
RP-KPI06	Reduction in the Sound pressure level in occupied spaces [%]	6				
RP-KPI08	Reduction in the average Formaldehyde and VOCs concentration [%]	6				
RP-KPI09	Reduction in the TVOC concentration (Total Volatile Organic Compound) [%]	6				
RP-KPI10	Reduction in CO, PM concentration [%]	6				
KPI21	Lifetime income [€]	5				
KPI26	Operational CO_2 emissions [kgCO_2eq/year]	5				
KPI27	Lifetime CO_2 emissions savings [kgCO_2eq, kgCO_2eq/year]	5				

3 ASESSMENT OF THE EXISTING CONDITIONS, FACILITIES AND INFRASTRUCTURE OF THE PILOT SITE

3.1 ASSESSMENT METHODOLOGY - QUESTIONNAIRE

The first step in approaching a building for renovation is to obtain general information to assess existing conditions, facilities and infrastructures. In addition, it is important to have information about the building's inhabitants, their consumptions and needs.

To obtain this information, two questionnaires were prepared: one to be submitted to the **tenants** (WP1: D1.3 Report of Social requirements identified in the elicitation activities-Annex 1 Questionnaire) and one to be submitted to the **building owner** (WP4 Questionnaire).

The first one aims to capture and discover both stakeholders and end users' needs and expectations (owners, renters, tenants) for the TRL6 demonstration of the technologies, defining what features are essential for these users. The questionnaire was the first step of the methodology proposed in the D1.3. It bases on a "participatory design approach" that combines the expertise of the system designers and researchers, and with the perceptions and needs of people who are affected by the energy renovation changes. It was divided in four sessions: demography, energy behaviour, building requirements, life quality and neighboured and final consideration. The results of the questionnaire have been inserted in a matrix: it is a tool to match the users' requirements with the design phases and the construction phase of the project.

The concept of the matrix is the following: match the items of the interviews with the WPs as the activities to be performed. Concerning WP4, the information collected is about social housing users' behaviour on opening windows or switching on/off heating management system, that can be useful for the Task 4.2 energy audit phase.

In the second one are collected all the information on the building, General psychographic questions, Current energy performance, Structural analysis of the building, Renewable Energy Sources and other information available (plans, BIM etc). The following sub sections contain summaries of the results of the WP4 questionnaire for each demosite. The entire questionnaires can be found in Annex 1 of this report.

3.2 Greek demo-site

PILOT SITE	KIMMERIA, XANTHI, GREECE
Organization	*Democritus University of Thrace (DUTH)*
Building	*Residential, Multi Apartment, No monumental, The use of the basement is for storage room, the building is isolated*
Period of construction	*1981-2000*
Period of	*1981-2000*

PILOT SITE	KIMMERIA, XANTHI, GREECE
design	
General psychographic questions	*More than 60 dwellings in the building, no indoor air quality assessment devices installed in the apartments*
Current energy performance	*No energy audit available before the start of the project*
Structural analysis of the building	*Load-bearing structure in concrete, mineral insulation material, the building envelop is poor, double glazed, there are defects on the building envelope like plaster swelling, leaks, detachment and/or damage to the claddings, not available design of technical documentation, no structural intervention over the years has been done, NO change of use over the years has been done*
Renewable Energy Sources	*Energy generation system [Photovoltaic systems (50kWp), Biomass (1,1 MW central heating), Solar heating (1 MW central heating)], energy storage very often monitored with digital meter and website for on-site generated renewable electricity with batteries: ≈10 (kW), 544 (kWh), communication protocol used is MBus, electric vehicle (EV) charging spots*
Other information	*No BIM model of the building, floor plans of the pilot site available in DWG PDF and paper*

3.3 Hungarian demo-site

PILOT SITE	BUDAPEST, HUNGARY
Organization	*FCHURCH*
Building	*Residential, Multi Apartment, No monumental (but the building has a historical character), The use of the basement is storage room and gas furnace, the use of the attic residential, The building is isolated*
Period of construction	*<1900*
Period of design	*<1900*
General psychographic	*In total 39 rooms (14 rooms for boys, 25 rooms for girls), they are rooms with shared shower rooms, kitchens and laundries in the building, No indoor*

PILOT SITE	BUDAPEST, HUNGARY
questions	*air quality assessment devices installed in the apartments*
Current energy performance	*No energy audit available before the start of the project.* *Energy class and the indicated energy consumption has been calculated during the REHOUSE Project* - *Energy Class: __C__* - *Energy consumption (kWh/m²/year): _113,73_*
Structural analysis of the building	*Load-bearing structure in concrete and brick, No insulation material, the building envelop is poor, In the apartments there are double glazed, there are defects on the building envelope like water/oil rising, detachment and/or damage to the claddings a few place, it is available design technical documentation (reproduced drawings, floor plan and facades), No structural intervention over the years were done, No seismic improvement has been done, The building had an industrial function and was converted into a dormitory, No subjected to structural works*
Renewable Energy Sources	*No energy generation system (i.e. solar panels), No energy storage technology, no electric vehicle (EV) charging spots*
Other information	*No BIM model of the building, floor plans of the pilot site available in PDF*

3.4 French demo-site

PILOT SITE	SAINT-DIÉ-DES-VOSGES, FRANCE
Organization	*CEA*
Building	*Residential, multi Apartment, no monumental, no attic, the use of the basement is Residential, the building location is isolated*
Period of construction	*1941-1960*
Period of design	*1941-1960*
General psychographic questions	*More than 20 dwellings in the building, no indoor air quality assessment devices installed in the apartments*

PILOT SITE	SAINT-DIÉ-DES-VOSGES, FRANCE
Current energy performance	*The estimation is an energy class D which correspond to an energy consumption between 151 and 230 kWh/m²/year*
Structural analysis of the building	*Load-bearing structure in concrete, no insulation, the condition of the building envelope is sufficient, double glazed windows in the apartment, there are minor airtightness defects on the building envelope, design technical documentation is available, no structural intervention over the years, no seismic improvement after the construction, no change of use of the building over the years, no events which required structural works*
Renewable Energy Sources	*No renewable energy generation system installed, no electric vehicle charging spots*
Other information	*No BIM model available, floor plans are available in PDF*

3.5 Italian demo-site

PILOT SITE	MARGHERITA DI SAVOIA, ITALY
Organization	*ARCA*
Building	*Residential, Multi Apartment, No monumental, The use of the basement is residential, the use of the attic is for storage room, The building is isolated*
Period of construction	*1981-2000*
Period of design	*1981-2000*
General psychographic questions	*8 dwellings in the building, No indoor air quality assessment devices installed in the apartments*
Current energy performance	*No energy audit available before the start of the project.* *Energy class and the indicated energy consumption has been calculated during the REHOUSE Project* - *Energy Class: G* - *Energy consumption (kWh/m^{2}year): 222.83*

PILOT SITE	MARGHERITA DI SAVOIA, ITALY
Structural analysis of the building	*Load-bearing structure in concrete, no insulation material (air cavity), the building envelop is sufficient, in 3 apartments there are double glazed and the other single glazed, there are defects on the building envelope like plaster swelling, visible reinforcements, leaks, water rising, detachment and/or damage to the claddings, it is available design technical documentation, no structural intervention over the years were been done, Only in one apartment (n. 5) seismic improvement has been done, NO change of use over the years has been done, one apartment has been subjected to fire and then was subjected to structural works*
Renewable Energy Sources	*No energy generation system (i.e. solar panels), no energy storage technology, no electric vehicle (EV) charging spots,*
Other information	*No BIM model of the building, floor plans of the pilot site available in paper*

4 SRI INITIAL LEVEL

4.1 SRI methodology

The SRI methodology is based on the multi-criteria assessment method defined in Commission Delegated Regulation (EU) 2020/2155 of 14 October 2020. After considering the building systems and services already present in the pilot buildings, the assessor can define the preferred approach to calculating the SRI level. In the "Building Information" tab, the user can select the preferred weightings, services catalogues and domains that are present in the building, and fill out essential building information such as the building owner, type and address (Figure 3). There are two preferred services catalogues, "A" and "B", the assessor can choose from. The former constitutes a simplified method which contains a simplified list of services, while the latter constitutes a more detailed method, with a detailed list of available systems and services. For the weightings, the assessor can choose between pre-defined, default weights, assigned to different EU regions, and custom weights, defined specifically for the building to be assessed.

GENERAL BUILDING INFORMATION

Building type	residential
Building usage	residential - other
Location	Greece
Climate zone:	*South Europe*
Total useful floor area of the building	1.000 - 10.000 m²
Year of construction	1990 - 2010
Building state	Original
Please provide a brief description of the building	Student residences in the DUTh Kimmeria Campus, Xanthi
Address:	Foititikes Esties Kimmerion
	Kimmeria, Xanthi, Greece
	67100

METHODOLOGY SELECTION

Preferred weightings	Default
Preferred services catalogue	B

Domains present

Are the following technical building systems present in your building?
If not, are they mandatory for new constructions in your country of residence?
1 - This domain is present; 2 - This domain is absent but mandatory; 0 - This domain is absent and not mandatory

Heating	1
Domestic hot water	1
Cooling	0
Ventilation	0
Lighting	0
Dynamic building envelope	0
Electricity	1
Electric vehicle charging	0
Monitoring and control	1

ASSESSMENT DATE

Year	2023
Month	10
Day	12

Figure 3: Building Information Tab of Greek Pilot SRI Calculation Sheet

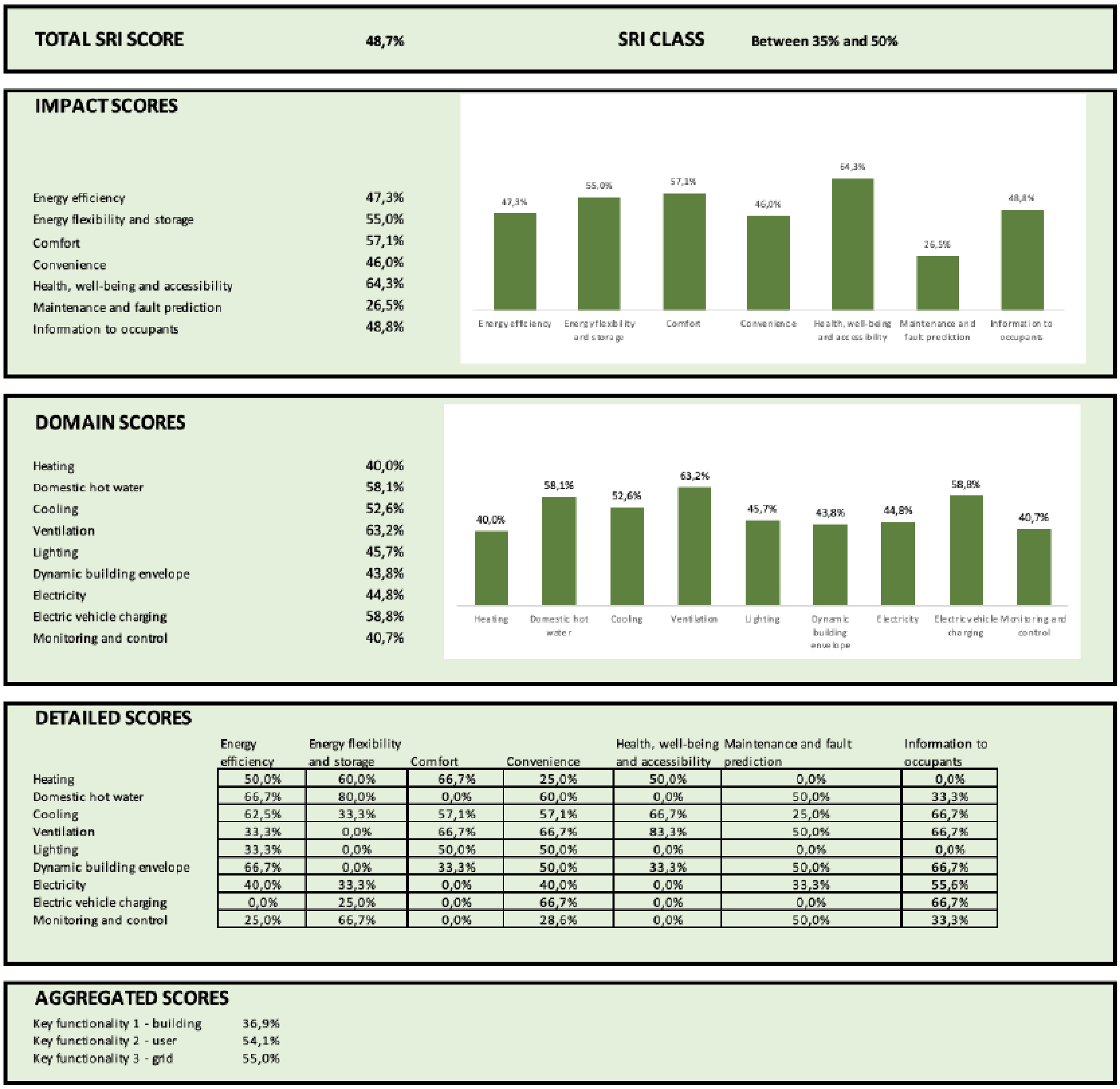
After completing the “Building Information” tab, the assessor can view the existing services in the “Overview_of_Services” tab. In the “Calculation Sheet” the actual assessment takes place. Every line in this sheet represents a service of the services catalogue (Figure 4). The assessor indicates the importance of a service and its functionality level, by choosing the appropriate numerical value in the corresponding columns (Figure 5). After the SRI assessment has been concluded, the results can be viewed in the “Results” tab, where a percentage of the SRI value and detailed scores for each domain will be displayed (Figure 6).

Domain	Code	Service group	Smart ready service	Functionality level 0 (as non-smart default)	Functionality level 1	Functionality level 2	Functionality level 3
Heating	H-1a	Heat control - demand side	Heat emission control	No automatic control	Central automatic control (e.g. central thermostat)	Individual room control (e.g. thermostatic valves, or electronic controller)	Individual room control with communication between controllers and to BACS
Heating	H-1b	Heat control - demand side	Emission control for TABS (heating mode)	No automatic control	Central automatic control	Advanced central automatic control	Advanced central automatic control with intermittent operation and/or room temperature feedback control
Heating	H-1c	Heat control - demand side	Control of distribution fluid temperature (supply or return air flow or water flow) - Similar function can be applied to the control of direct electric heating networks	No automatic control	Outside temperature compensated control	Demand based control	
Heating	H-1d	Heat control - demand side	Control of distribution pumps in networks	No automatic control	On off control	Multi-Stage control	Variable speed pump control (pump unit (internal) estimations)
Heating	H-1f	Heat control - demand side	Thermal Energy Storage (TES) for building heating (excluding TABS)	Continuous storage operation	Time-scheduled storage operation	Load prediction based storage operation	Heat storage capable of flexible control through grid signals (e.g. DSM)
Heating	H-2a	Control heat production facilities	Heat generator control (all except heat pumps)	Constant temperature control	Variable temperature control depending on outdoor temperature	Variable temperature control depending on the load (e.g. depending on supply water temperature set point)	

Figure 4: Example portion of "Overview of Services" tab

Code	Service group	Smart ready service	Service included in the selected method (A/B/custom): 0 - not included, 1 - included	1 - This domain is present; 2 - This domain is absent but mandatory; 0 - This domain is absent and not mandatory	TRIAGE: 1 - This service affects maximum obtainable score, even if service is not applicable in this building; 0 - This service does not affect maximum obtainable score when not present in building	Service applicable in your building? - to be assessed by the assessor: 1 - applicable; 0 - not applicable	Main functionality level as inspected by SRI assessor	share (default = 100% means applicable throughout the building)	Optional: additional functionality level in part of the building	Share of additional functionality level	Warnings	Functionality level 0 (as non-smart default)	Functionality level 1	Functionality level 2	Functionality level 3
H-1a	Heat control - demand side	Heat emission control	1	1	0	1	1	100%		0%		No automatic control	Central automatic control (e.g. central thermostat)	Individual room control (e.g. thermostatic valves, or electronic controller)	Individual room control with communication between controllers and to BACS
H-1b	Heat control - demand side	Emission control for TABS (heating mode)	1	1	0	1	1	100%		0%		No automatic control	Central automatic control	Advanced central automatic control	Advanced central automatic control with intermittent operation and/or room temperature feedback control
H-1c	Heat control - demand side	Control of distribution fluid temperature (supply or return air flow or water flow) - Similar function can be applied to the control of direct electric heating networks	1	1	0	1	1	100%		0%		No automatic control	Outside temperature compensated control	Demand based control	
H-1d	Heat control - demand side	Control of distribution pumps in networks	1	1	0	1	1	100%		0%		No automatic control	On off control	Multi-Stage control	Variable speed pump control (pump unit (internal) estimations)

Figure 5: Example portion of "Calculation Sheet" tab



TOTAL SRI SCORE	48,7%	SRI CLASS	Between 35% and 50%

IMPACT SCORES

Energy efficiency	47,3%
Energy flexibility and storage	55,0%
Comfort	57,1%
Convenience	46,0%
Health, well-being and accessibility	64,3%
Maintenance and fault prediction	26,5%
Information to occupants	48,8%

DOMAIN SCORES

Heating	40,0%
Domestic hot water	58,1%
Cooling	52,6%
Ventilation	63,2%
Lighting	45,7%
Dynamic building envelope	43,8%
Electricity	44,8%
Electric vehicle charging	58,8%
Monitoring and control	40,7%

DETAILED SCORES

	Energy efficiency	Energy flexibility and storage	Comfort	Convenience	Health, well-being and accessibility	Maintenance and fault prediction	Information to occupants
Heating	50,0%	60,0%	66,7%	25,0%	50,0%	0,0%	0,0%
Domestic hot water	66,7%	80,0%	0,0%	60,0%	0,0%	50,0%	33,3%
Cooling	62,5%	33,3%	57,1%	57,1%	66,7%	25,0%	66,7%
Ventilation	33,3%	0,0%	66,7%	66,7%	83,3%	50,0%	66,7%
Lighting	33,3%	0,0%	50,0%	50,0%	0,0%	0,0%	0,0%
Dynamic building envelope	66,7%	0,0%	33,3%	50,0%	33,3%	50,0%	66,7%
Electricity	40,0%	33,3%	0,0%	40,0%	0,0%	33,3%	55,6%
Electric vehicle charging	0,0%	25,0%	0,0%	66,7%	0,0%	0,0%	66,7%
Monitoring and control	25,0%	66,7%	0,0%	28,6%	0,0%	50,0%	33,3%

AGGREGATED SCORES

Key functionality 1 - building	36,9%
Key functionality 2 - user	54,1%
Key functionality 3 - grid	55,0%

Figure 6: Example of SRI calculation results as presented in the "Results" tab

4.2 Greek demo-site

In this section the reported SRI is referring to the Greek demo-site. The SRI calculation took place on the 12th of October 2023, the preferred services catalogue was “B” and the existing services at the time were “Heating”, “Domestic Hot Water”, “Electricity” and “Monitoring and Control”. The “Default” weightings referring to Southern Europe have been chosen.

GENERAL BUILDING INFORMATION

Building type	residential
Building usage	residential - other
Location	Greece
Climate zone:	*South Europe*
Total useful floor area of the building	1.000 - 10.000 m²
Year of construction	1990 - 2010
Building state	Original
Please provide a brief description of the building	Student residences in the DUTh Kimmeria Campus, Xanthi
Address:	Foititikes Esties Kimmerion Kimmeria, Xanthi, Greece 67100

METHODOLOGY SELECTION

Preferred weightings	Default
Preferred services catalogue	B

Domains present

Are the following technical building systems present in your building?
If not, are they mandatory for new constructions in your country of residence?
1 - This domain is present; 2 - This domain is absent but mandatory; 0 - This domain is absent and not mandatory

Heating	1
Domestic hot water	1
Cooling	0
Ventilation	0
Lighting	0
Dynamic building envelope	0
Electricity	1
Electric vehicle charging	0
Monitoring and control	1

ASSESSMENT DATE

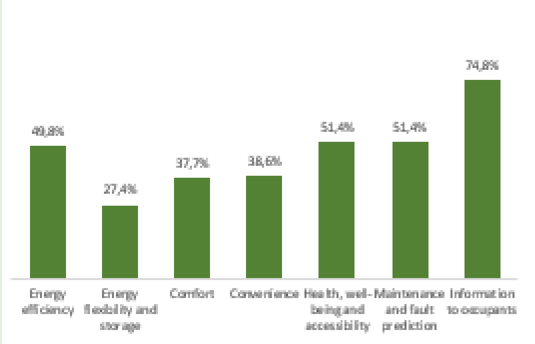
Year	2023
Month	10
Day	12

Figure 7: Building Information Tab of Greek Pilot SRI Calculation Sheet

TOTAL SRI SCORE	42,9%	SRI CLAS Between 35% and 50%

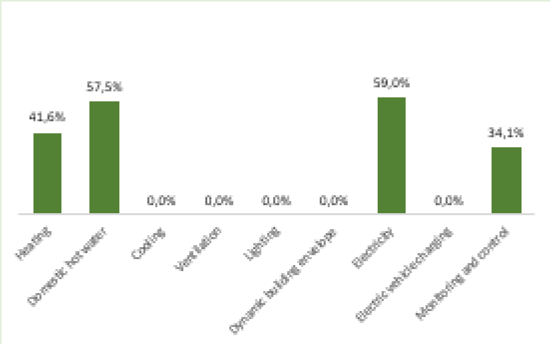
IMPACT SCORES

Energy efficiency	49,8%
Energy flexibility and storage	27,4%
Comfort	37,7%
Convenience	38,6%
Health, well being and accessibility	51,4%
Maintenance and fault prediction	51,4%
Information to occupants	74,8%



DOMAIN SCORES

Heating	41,6%
Domestic hot water	57,5%
Cooling	0,0%
Ventilation	0,0%
Lighting	0,0%
Dynamic building envelope	0,0%
Electricity	59,0%
Electric vehicle charging	0,0%
Monitoring and control	34,1%



DETAILED SCORES

	Energy efficiency	Energy flexibility and storage	Comfort	Convenience	Health, well-being and accessibility	Maintenance and fault prediction	Information to occupants
Heating	52,4%	18,2%	41,7%	45,5%	40,0%	60,0%	75,0%
Domestic hot water	54,5%	27,3%	0,0%	57,1%	0,0%	100,0%	100,0%
Cooling	0,0%	0,0%	0,0%	0,0%	0,0%	0,0%	0,0%
Ventilation	0,0%	0,0%	0,0%	0,0%	0,0%	0,0%	0,0%
Lighting	0,0%	0,0%	0,0%	0,0%	0,0%	0,0%	0,0%
Dynamic building envelope	0,0%	0,0%	0,0%	0,0%	0,0%	0,0%	0,0%
Electricity	57,1%	36,4%	0,0%	63,6%	0,0%	83,3%	100,0%
Electric vehicle charging	0,0%	0,0%	0,0%	0,0%	0,0%	0,0%	0,0%
Monitoring and control	20,0%	42,9%	0,0%	21,4%	66,7%	27,3%	55,6%

AGGREGATED SCORES

Key functionality 1 - building	50,6%
Key functionality 2 - user	50,6%
Key functionality 3 - grid	27,4%

Figure 8: Results Tab of Greek Pilot SRI Calculation Sheet

The calculation results reported (Figure 8) indicate a 42.9% SRI, considering that most domains involved in the calculation present hold functionality levels 1 and above (in some cases functionality levels 4 and 5). The impact criteria scores are moderately high, the highest being “Information to occupants” at 74.8%. In the DHW, Cooling, Ventilation and Dynamic Building Envelope domains, we shall see an increase in their relative scores after the renovations are finished, due to RPs #1, #2 and #3.

4.3 Hungarian demo-site

The Smart Readiness Indicator assessment had been done in the Hungarian Demo building, although this old building could not reach a high score in this evaluation. That proves the necessity of the retrofit. General data can be seen in Figure 9.

GENERAL BUILDING INFORMATION

Building type	residential
Building usage	residential - other
Location	Hungary
Climate zone:	*South-East Europe*
Total useful floor area of the building	1.000 - 10.000 m²
Year of construction	< 1960
Building state	Original
Please provide a brief description of the building	Dormitory for about a 70 students
Address:	69 Gyömrői
	Budapest
	Hungary

METHODOLOGY SELECTION

Preferred weightings	User-defined
Preferred services catalogue	B

Domains present

Are the following technical building systems present in your building?
If not, are they mandatory for new constructions in your country of residence?
1 - This domain is present; 2 - This domain is absent but mandatory; 0 - This domain is absent and not mandatory

Heating	1
Domestic hot water	1
Cooling	0
Ventilation	0
Lighting	1
Dynamic building envelope	0
Electricity	1
Electric vehicle charging	0
Monitoring and control	0

ASSESSMENT DATE

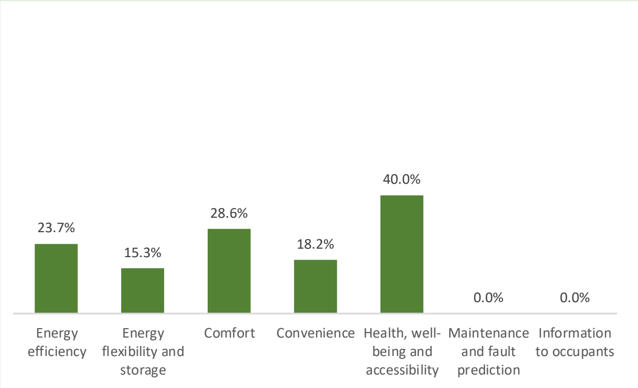
Year	2024
Month	1
Day	20

Figure 9: Building Information Tab of Hungarian Pilot SRI Calculation Sheet

TOTAL SRI SCORE	**16.3%**	**SRI CLAS!**	**Lower than 20%**

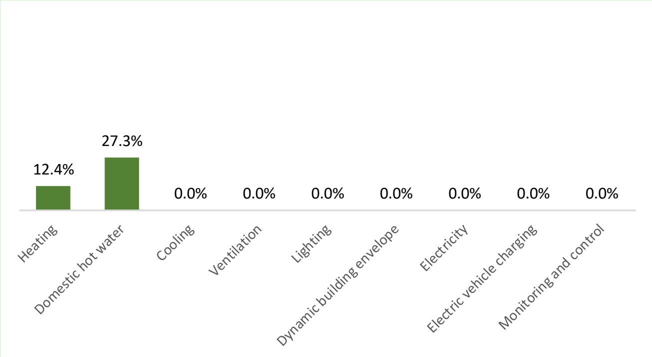
IMPACT SCORES

Energy efficiency	23.7%
Energy flexibility and storage	15.3%
Comfort	28.6%
Convenience	18.2%
Health, well-being and accessibility	40.0%
Maintenance and fault prediction	0.0%
Information to occupants	0.0%



DOMAIN SCORES

Heating	12.4%
Domestic hot water	27.3%
Cooling	0.0%
Ventilation	0.0%
Lighting	0.0%
Dynamic building envelope	0.0%
Electricity	0.0%
Electric vehicle charging	0.0%
Monitoring and control	0.0%



DETAILED SCORES

	Energy efficiency	Energy flexibility and storage	Comfort	Convenience	Health, well-being and accessibility	Maintenance and fault prediction	Information to occupants
Heating	30.0%	0.0%	28.6%	20.0%	40.0%	0.0%	0.0%
Domestic hot water	50.0%	33.3%	0.0%	40.0%	0.0%	0.0%	0.0%
Cooling	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
Ventilation	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
Lighting	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
Dynamic building envelope	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
Electricity	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
Electric vehicle charging	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
Monitoring and control	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%

AGGREGATED SCORES

Key functionality 1 - building	11.8%
Key functionality 2 - user	21.7%
Key functionality 3 - grid	15.3%

Figure 10: Results Tab of Hungarian Pilot SRI Calculation Sheet

The basic technical equipment are available, but the ones that provides a higher comfort are missing, that is why the building evaluation is quite poor. For example, there is a heating system, (necessary for the winter season), but cooling and ventilation systems are absolutely missing. There are no thermal energy storage and no control system for optimizing the energy consumption.

The results reflects the conditions of the building. On the one side the structure of the building was built more than hundred years ago and no structural damage can be seen (no cracks or other damages). The building was definitely well structured and designed to last over time. However, the technical level is far behind the levels that can be achieved nowadays.

Results shows there are missing basic technical elements for Health and wellbeing and also for energy optimization such as ventilation, energy storage, etc. The energy source is 100% non-renewable, the technical equipment represents technical levels dating back a decade or, in some cases, more than a decade. The retrofit should significantly change the SRI assessment of Hungarian Demo building.

4.4 French demo-site

The French demo-site SRI calculation was assessed the 16th of January 2024. The following figures present the general building information, the methodology and the results.

The "A" preferred services catalogue was selected with the existing services :"Heating", "Domestic Hot Water", "Ventilation", "Lighting", "Dynamic building envelope", "Electric vehicle charging", "Electricity" and "Monitoring and Control". The "Default" weightings is referring to West Europe.

GENERAL BUILDING INFORMATION

Building type	Résidentiel
Building usage	Résidentiel - grand collectif
Total useful floor area of the building	1 730 m²
Year of construction	1959
Building state	Initial
Please provide a brief description of the	
Address:	Saint-Dié des vosges
e-mail address du contact	

METHODOLOGY SELECTION

Preferred weightings	Par défaut
Preferred services catalogue	A

Domains present

Are the following technical building systems present in your building?

Les domaines figés à 1 ont un caractère obligatoire et impacteront le résusltat SRI même s'ils ne sont réellement pas présents

1 - This domain is present; 2 - This domain is absent but mandatory; 0 - This domain is absent and not mandatory

Heating		1
Domestic hot water		1
Cooling		0
Ventilation		1
Lighting		1
Dynamic building envelope		1
Electricity		1
Electric vehicle charging		
→Places de parking disponible?	Oui	1
Monitoring and control		1

ASSESSMENT DATE

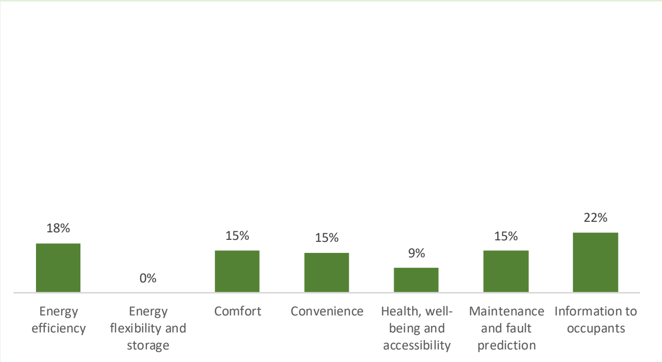
Year	2024
Month	1
Day	16

Figure 11: Building Information Tab of French Pilot SRI Calculation Sheet

TOTAL SRI SCORE	14%	SRI CLASS	D

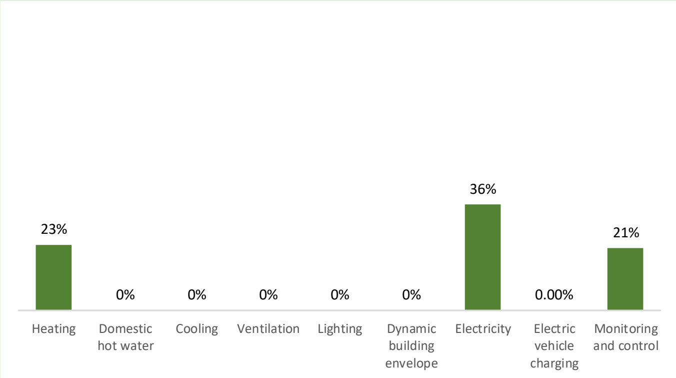
IMPACT SCORES

Energy efficiency	18%
Energy flexibility and storage	0%
Comfort	15%
Convenience	15%
Health, well-being and accessibility	9%
Maintenance and fault prediction	15%
Information to occupants	22%



DOMAIN SCORES

Heating	23%
Domestic hot water	0%
Cooling	0%
Ventilation	0%
Lighting	0%
Dynamic building envelope	0%
Electricity	36%
Electric vehicle charging	0.00%
Monitoring and control	21%



DETAILED SCORES

	Energy efficiency	Energy flexibility and storage	Comfort	Convenience	Health, well-being and accessibility	Maintenance and fault prediction	Information to occupants
Heating	25%	0%	40%	40%	50%	0%	0%
Domestic hot water	0%	0%	0%	0%	0%	0%	0%
Cooling	0%	0%	0%	0%	0%	0%	0%
Ventilation	0%	0%	0%	0%	0%	0%	0%
Lighting	0%	0%	0%	0%	0%	0%	0%
Dynamic building envelope	0%	0%	0%	0%	0%	0%	0%
Electricity	50%	0%	0%	0%	0%	25%	67%
Electric vehicle charging	0%	-50%	0%	0%	0%	0%	0%
Monitoring and control	25%	0%	0%	29%	0%	50%	33%

AGGREGATED SCORES

Key functionality 1 - building	17%
Key functionality 2 - user	15%
Key functionality 3 - grid	0%

	Key functionality 1 - building	Key functionality 2 - user	Key functionality 3 - grid
Heating	13%	33%	0%
Domestic hot water	0%	0%	0%
Cooling	0%	0%	0%
Ventilation	0%	0%	0%
Lighting	0%	0%	0%
Dynamic building envelope	0%	0%	0%
Electricity	38%	33%	0%
Electric vehicle charging	0%	0%	-50%
Monitoring and control	38%	31%	0%

Figure 12: Results Tab of French Pilot SRI Calculation Sheet

The calculation results in Figure 12 present a 14% score corresponding to the D class. This result is due to the fact that most of the domains involved in the calculation present a low functionality level of service (level 0 and level 1 mainly, sometimes level 2). The impact criteria scores are quite balanced except for the energy flexibility and storage (no functionality). The retrofit will increase the SRI score by increasing the functionality level in the different domains.

4.5 Italian demo-site

In this chapter the information listed in Chapter 4.1 is reported referring to the Italian demo. It is worth to highlight that the SRI calculation has been based on the method A and the baseline scenario include the domains Heating, Domestic Hot Water, Lighting and Electricity.

GENERAL BUILDING INFORMATION

Building type	residential
Building usage	residential - small multi-family house
Location	Italy
Climate zone:	*South Europe*
Total useful floor area of the building	500 - 1.000 m²
Year of construction	1960 - 1990
Building state	Original
Please provide a brief description of the building	Social housing building (880 m2, 1986) located in Margherita di Savoia, province of Barletta-Andria-Trani
Address:	Via Salinis, 8
	Margherita di Savoia, Barletta-Andria-Trani, Itlay
	76016

Figure 13: “Building Information“ Tab of Italian Pilot SRI Calculation Sheet

METHODOLOGY SELECTION

Preferred weightings	Default
Preferred services catalogue	A

Domains present

Are the following technical building systems present in your building?
If not, are they mandatory for new constructions in your country of residence?
1 - This domain is present; 2 - This domain is absent but mandatory; 0 - This domain is absent and not mandatory

Heating	1
Domestic hot water	1
Cooling	0
Ventilation	0
Lighting	1
Dynamic building envelope	0
Electricity	1
Electric vehicle charging	0
Monitoring and control	0

ASSESSMENT DATE

Year	2022
Month	1
Day	16

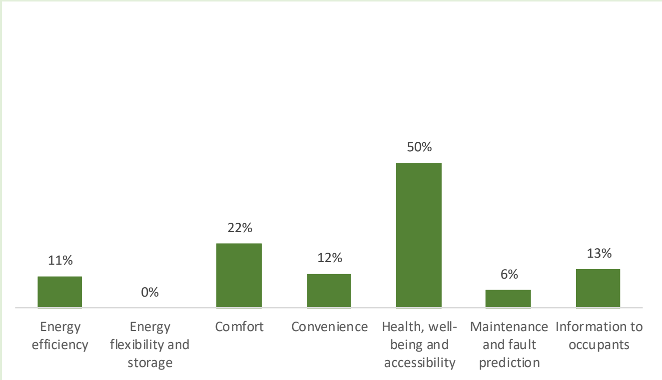
Figure 14: "Building Information" Tab of Italian Pilot SRI Calculation Sheet

The calculation results are reported in Figure 15. It is worth to see that the SRI is very low (the score is 8% and the class is the G) considering that almost all the domains involved in the calculation present a smart readiness level of each smart readiness service that are low (those related to Domestic hot water are even the lowest possible and for this reason the domain score is equal to 0%). Finally, also the impact criteria scores are low for each criterion except for "Health, well-being and accessibility" (i.e., 50%); however, this score is almost the minimum possible and is linked to the presence of an heating system presenting almost the lowest levels possible of the smart readiness services linked to the "Heating" domain.

TOTAL SRI SCORE	8%	SRI CLASS	G

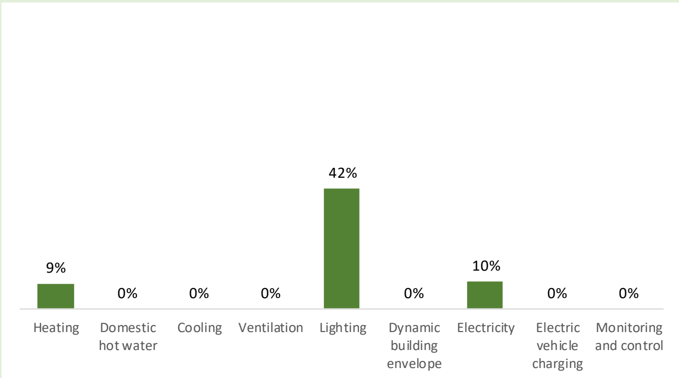
IMPACT SCORES

Energy efficiency	11%
Energy flexibility and storage	0%
Comfort	22%
Convenience	12%
Health, well-being and accessibility	50%
Maintenance and fault prediction	6%
Information to occupants	13%



DOMAIN SCORES

Heating	9%
Domestic hot water	0%
Cooling	0%
Ventilation	0%
Lighting	42%
Dynamic building envelope	0%
Electricity	10%
Electric vehicle charging	0%
Monitoring and control	0%



DETAILED SCORES

	Energy efficiency	Energy flexibility and storage	Comfort	Convenience	Health, well-being and accessibility	Maintenance and fault prediction	Information to occupants
Heating	10%	0%	14%	20%	50%	0%	0%
Domestic hot water	0%	0%	0%	0%	0%	0%	0%
Cooling	0%	0%	0%	0%	0%	0%	0%
Ventilation	0%	0%	0%	0%	0%	0%	0%
Lighting	33%	0%	50%	50%	0%	0%	0%
Dynamic building envelope	0%	0%	0%	0%	0%	0%	0%
Electricity	20%	0%	0%	0%	0%	17%	22%
Electric vehicle charging	0%	0%	0%	0%	0%	0%	0%
Monitoring and control	0%	0%	0%	0%	0%	0%	0%

AGGREGATED SCORES

Key functionality 1 - building	9%
Key functionality 2 - user	24%
Key functionality 3 - grid	0%

Figure 15: SRI calculation results of Italian Pilot as presented in the "Results" tab

5 ENERGY PERFORMANCE INITIAL STATUS

5.1 Greek demo-site

5.1.1 DESCRIPTION OF THE BUILDING

The Greek demo site is located in the Kimmeria campus of Democritus University of Thrace (DUTH), in Xanthi, Greece. The campus holds 8 residential buildings for student housing. The ‘Building C2’ is the selected REHOUSE demo building and it was constructed in 1997. It has a gross total area of 1,371 m^2 and since its construction it has not undergone any kind of renovation. The selected building has 62 rooms, as well as common areas such shared kitchen and shared living room.

It should be noted that there is no Energy Performance Certificate available for the building.

The building C2 was constructed according to the Thermal Insulation Regulation of Greece that was in forced the construction period, which means that it has a building envelope consisting of poorly insulated walls and aluminium double-glazed windows with poor airtightness. There is an inclined tile roof that is also insulated according to the Greek regulations. It has to be mentioned that their increased number of thermal bridges that increase the thermal losses and thus reduce the energy efficiency of the building. As seen from the figures below, Building C2 is not surrounded by other buildings, while there are also few trees and a parking lot located in the north façade. Therefore, the shading of the demo building is only slightly affected by other elements and is not significant.

Figure 16: General view and aerial view of the Greek demo-site

5.1.2 DESCRIPTION OF THE ENERGY SYSTEM

The C2 building is heated by the central hybrid biomass/solar thermal system that is responsible for all 8 buildings at DUTH's campus. The hybrid biomass/solar thermal system consists of a solar thermal system of flat plate selective collectors of 1,873m^2 working together with a biomass boiler (pellets) of 1.15 MW$_{th}$. A short-term thermal energy storage of 40m^3 is also part of this central heating system. An extensive piping network is used to deliver heat from the central heating system to the buildings of the campus. C2 building, along with C1 building is directly connected to the central heating system and a specific pump is used to circulate hot water to/from the building. To deliver heat to each area of the C2 building, a piping network is installed, equipped with circulation pumps (two zones).

It should be mentioned that the central heating system includes two heating oil boilers that are installed in parallel with the biomass boiler and being used as a back-up system.

The domestic hot water needs are covered by a DHW tank of 2,000 lt, which installed at the basement of C2 building. The DHW tank is equipped with an internal heat exchanger and an electric heater of 8kW. The internal heat exchanger is connected with the central heating system of the campus, while the electric heater is covered by the installed rooftop autonomous PV system of 51.48kWp. The PV system has a battery storage (Lead Acid Batteries) system of 11.34kAh and besides the DHW tank is also covers specific electrical loads of the building.

The C2 building is connected to the main Grid, as part of the central connection of the campus (in Medium Voltage of national Grid, 20kV).

It should be mentioned that there is no cooling system installed in C2 building.

5.1.3 BASELINE MONITORING PLAN FOR ENERGY PERFORMANCE INITIAL STATUS

In D3.2 "REHOUSE set of indicators selected for the impact assessment" the KPIs were defined for the REHOUSE project, and in D3.4 "Monitoring programs for the 4 demos (construction, building operation, LCA, LCC)" the selection of each KPI for the Greek case took place, resulting in the following table.

Table 4: Parameters to be measured in Greek demo-site building for KPIs calculation

PARAMETERS TO BE MEASURED	RELATED TO KPI №[1]	SENSOR OR MEASUREMENT DEVICE	BOUNDARIES	COMMENTS
Building Envelop parameters				
Surface temperature on wall surfaces	KPI01, RP-KPI02	Surface temperature sensor	On the outdoor and indoor surfaces of walls	Sensor or measurement device installed in the demo-site
Air temperature near the walls	KPI01, RP-KPI02	Air temperature sensor	Outdoor and indoor air temperature measurements near the walls to be evaluated	Sensor or measurement device installed in the demo-site
Resource use				
Electrical energy and power consumption	KPI02-a, KPI03, KPI04, KPI05, KPI10, KPI11, RP-KPI12, KPI26	Electric energy and power meters/demo site building	1 meter per whole building consumption	Sensor or measurement device installed in the demo-site
			1 meter per heating system	Sensor or measurement device installed in the demo-site
			1 meter per lighting system	Sensor or measurement device installed in the demo-site
	KPI07, KPI08, RP-KPI13, RP-KPI16, KPI26		1 meter per PV system production	Sensor or measurement device installed in the demo-site

[1] The numbers of KPIs from the D3.2. REHOUSE set of indicators selected for the impact assessment

PARAMETERS TO BE MEASURED	RELATED TO KPI №[1]	SENSOR OR MEASUREMENT DEVICE	BOUNDARIES	COMMENTS
	KPI07, KPI08, KPI26		1 meter per PV energy exported to the grid	
	KPI02-b	Electric energy and power meters/dwelling	1 meter per consumption of whole dwelling	Sensor or measurement device installed in the demo-site
			1 meter per lighting system	Sensor or measurement device installed in the demo-site
Thermal energy production	KPI09	Thermal energy meter	1 meter per demo site building	Sensor or measurement device installed in the demo-site
Thermal energy consumption	KPI09, KPI10, KPI11		1 meter per demo site building	Sensor or measurement device installed in the demo-site
Indoor environmental/comfort conditions				
Ambient temperature and indoor relative humidity	KPI15	Temperature and relative humidity sensor	1 sensor per dwelling or 1 sensor per room (living room and 1 bedroom)	Sensor or measurement device installed in the demo-site
CO_2 concentration	KPI15	CO_2 sensor	1 sensor per dwelling	Sensor or measurement device installed in the demo-site
Formaldehyde and VOCs concentration	RP-KPI08	VOC sensor	Several sensors per demo site building	Sensor or measurement device installed in the demo-site
TVOC concentration	RP-KPI09	TVOC sensor	Several sensors per demo site building	Sensor or measurement device installed

PARAMETERS TO BE MEASURED	RELATED TO KPI №[1]	SENSOR OR MEASUREMENT DEVICE	BOUNDARIES	COMMENTS
				in the demo-site
CO, PM concentration	RP-KPI10	PM / CO sensor	Several sensors per demo site building	Sensor or measurement device installed in the demo-site
Luminosity	KPI14	Luxmeter	1 sensor per dwelling	Sensor or measurement device installed in the demo-site
Environmental data and other parameters impacting data analysis				
Global inclined solar radiation		Pyranometer	In the vicinity of demo-site location	The weather station should be installed in a location free of shadow and free of influencing environment
Outdoor temperature		Weather station including all the relevant sensors		
Outdoor humidity				
Wind velocity				
Rain intensity				
Number of occupants		Occupancy sensors	Number of occupants in demo site building	Sensor or measurement device installed in the demo-site

D3.4 additionally contains information on the measurement devices used to evaluate the respective KPIs defined in D3.2 in each pilot. A detailed explanation and analysis of the placed sensors and systems on 'Building C2' can be found in Section 6 of D3.4.

5.1.4 ENERGY DIAGNOSTIC

As stated, C2 building has no valid Energy Performance Certificate, nevertheless, according to an energy audit performed by DUTh's research team, its energy classification is considered to be "E". This section includes evidence of this statement through analytical description of the energy performance of the building.

The building envelope is considered as the main reason for the reduced energy performance of the building, since it consists of poorly insulated walls and roof, as well as low energy performance windows. Therefore, the thermal energy losses of the building are high and calculated at approximately 150W/m^2. This also results in increased thermal energy consumption for heating of the building. Nevertheless, DUTh, as the owner of the buildings' complex operates the central heating system with specific schedule which is divided into three two-hour periods per day during the heating season (15th of October to 15th of April). Specifically, heating is operating from 7:00 to 9:00, from 14:00 to 16:00, and from 20:00 to 22:00. On the contrary, DHW is always in operation, since DHW is constantly maintained at approximately 45°C in the tank, either heated by the central heating system or by the electric heater. To achieve this, the electric heater which is fully supplied by the autonomous rooftop PV system, operates with a time schedule that includes three hours of operation in the morning (9:00 – 12:00) and three hours of operation in the afternoon (19:00 – 22:00) every day.

The heating system of the building includes two circulation pumps of very low energy performance that divide the heating distribution network of the building into two zones. It also includes a specific circulation pump connected to the heat exchanger of the DHW tank. There is no central thermostat installed in building, however, 20 out of 62 rooms have a specific thermostat that controls a specific solenoid valve. To deliver heat in the buildings' rooms and common areas, the building is equipped with conventional AKAN type radiators. In addition, the piping network consists of uninsulated steel pipes. This results, in very low efficiency of the heating distribution system.

As far as DHW is concerned, the use of the installed PV system supports the low primary energy consumption required for the production of hot water. However, it should be noted that the DHW network is considered to be extensive and consists of uninsulated steel pipes, thus resulting in significant energy losses. Also, the absence of recirculation of DHW results in increased water consumption.

No cooling system is installed in the building. Additionally, no mechanical ventilation is installed in the building. Therefore, the thermal comfort of the users is not considered as optimal.

The electrical loads of the building include lighting and appliances. Lighting of the building is of low energy performance, since it consists of fluorescent lamps. Part of the electrical loads are covered by an autonomous rooftop PV system of 51.48kWp with a battery storage capacity of 11.34kAh. The PV system covers the electrical needs of the DHW, as well as the lighting needs of the common areas of the C2 building. The estimated renewable energy consumed is approximately 30 MWh/year.

Although almost 100% of heating needs and small portion of the electrical are covered by RES technologies, the energy performance of the C2 building is generally considered to be low, due to two main reasons. The buildings' envelope is of very low efficiency resulting in increased final energy consumption and the heating system's operation is of low efficiency resulting in increased energy consumption. Therefore, there is room for energy renovation to increased energy performance and increased RES utilization.

5.1.5 ANALYSIS OF THE ENERGY BILLS

End-users of Greek demo site are mainly students and staff of University campus, as well as visitors. Renewable generation is owned by the University. For the remaining electricity required, the campus is connected to the main grid. There is no demand response program applied. In terms of electricity from the main grid, flat rate tariffs are used. Smart meters are installed both at the room level and at the building level.

Data regarding energy bills of C2 building are available for electric energy consumption along with price per KWh_e and heating energy consumption along with price per KWh_{th}. Data regarding energy bills are collected both by DUTH's MediLab research team and the administration of DUTH. Both electrical and heating energy consumption data of C2 building are collected by DUTH's MediLab research team's smart energy meters, while energy prices are acquired by DUTH's administration.

Data collected from DUTH's MediLab research team electrical energy meters, show the course of C2 building's electrical energy consumption in Table 5 and Figure 17, Figure 18 and Figure 19.

Table 5: C2 building electrical energy consumption regarding the years 2022 and 2023

DATE & TIME (DD/MM/YYYY & MM:SS)	TOTAL CONSUMPTION (KWH_E)	YEARLYCONSUMPTION (KWH_E)
01/01/2022, 00:00	83,395	-
31/12/2022, 23:45	185,518	102,123
31/12/2023, 23:45	283,372	97,854

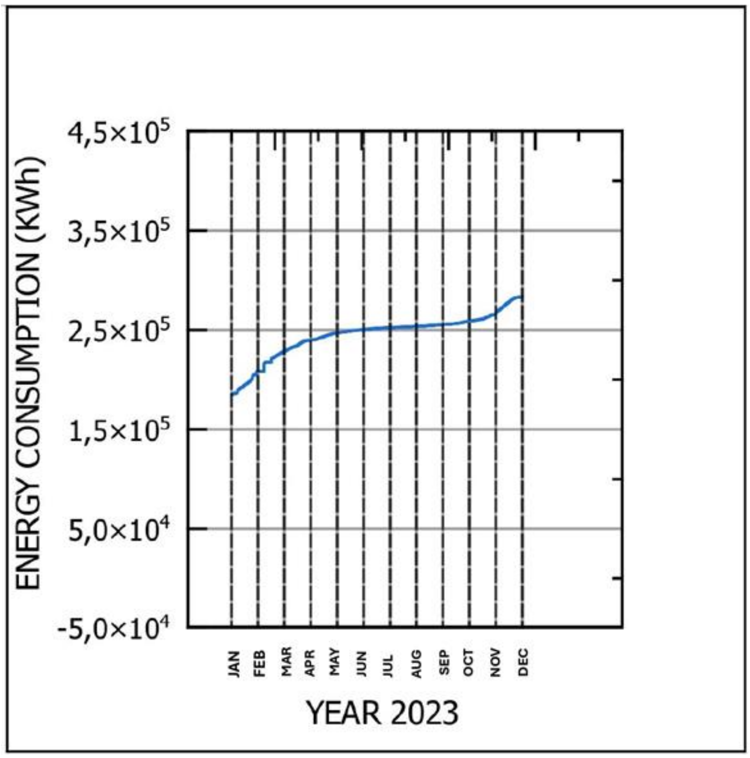


Figure 17: C2 building's electrical energy consumption plot regarding the year 2023

ID	G2 building Active Energy (KWh)	Date
11513901	283372.00	2023-12-31 23:45:00

Figure 18: C2 building's electrical energy consumption in the end of the year 2023

ID	G2 building Active Energy (KWh)	Date
264675	185518.00	2022-12-31 23:45:00

Figure 19: C2 building's electrical energy consumption in the end of the year 2022

Given the fact that the total building complex consumed 748,125.6 total KWh_e in year 2023, C2 consumed 13 % of total electrical energy in the building's complex in 2023. The cost of electric energy approximated at 0.30 euro/KWh_e due to the dynamic nature of this variable defined within the National Grid contracts. It is concluded that for year 2022 and 2023, the cost of electric energy was 30,630 euro and 29,400 euro respectively.

The baseline annual thermal energy consumption (biomass/pellets and solar thermal) is estimated at 57 MW_h/yr. (2022-2023) and in terms of energy cost is estimated at 2,500 euros, considering the cost of pellet in metric ton scale to be 200 euro. In order, to supply 57 MWh/yr. to C2 building 12,500 kg of pellet are required as well as 24MWh/yr. solar thermal energy from solar thermal field.

The campus heating season ranges from 130 to 140 days per year (mid-October to late March). Oil boilers which are available as backup equipment, covered around 20-40 days per year of heating due to technical issues effecting pellet boiler's operation and/or weather conditions e.g. heavy cloud cover effecting the operation of the solar thermal.

5.2 Hungarian demo-site

5.2.1 DESCRIPTION OF THE BUILDING

The Hungarian Demo Site is a two-story building with an additional third attic floor, and works as student dormitory for a university in the capital city of Hungary. Originally was built around 1900s, and the planned function was industrial building.

Figure 20: The Hungarian demo building - View from the street front, From south-southwest.

Figure 21: The Hungarian demo building - View from the courtyard, looking east.

Nowadays the building provides a living area for about 65 students which number can vary according the fluctuation of students. In the three floors are common bathroom kitchen and laundry rooms beside the dormitory rooms. The rooms depending on the size has one or two occupant(s). In the last decade, the building was formed to a dormitory which meant also a moderate renovation mostly in the rooms separation and the utility system including the water and electricity systems. That time the heating system was renewed, but no RES system was built in and the energy source is still natural gas for domestic hot water and heating. No cooling and ventilation system was prepared and the building was not insulated at all.

The walls are made of small size solid brick as the technology made it possible a century ago. However, the wall thickness is slightly thicker than that of the building today; thermal resistance of the wall is not considerable. The windows were changed but only for the type was prescribed that time with a U value of 1.2 W/m^2K.

5.2.2 DESCRIPTION OF THE ENERGY SYSTEM

The only heating source of the building is natural gas. This is used for heating of the building and for producing domestic hot water. On the cellar there are two 45 kW gas furnaces working together, connected in parallel; for the case one could not provide enough energy amount. The age of the furnaces is about 10 years, and they are regularly maintained. There is an installed gas meter for measuring the consumption, although this gauge is not the base of billing, because the demo site is belonging to the group of building inside the park. From the aspect of the project, it is an outstanding advantage to be able to measure the building natural gas consumption.

To minimize the peak loads of heating, and the dynamic consumption of domestic hot water there were settled warm water storage tanks. The water is warmed up by the furnace and the tank can store the heat for a daily cycle. This system helps also to minimize switching on and off the furnaces and run them on higher efficiency. The heating of the rooms is done by means of heating bodies with an older type (radiator), and there is no ventilation or any other type of heating or fresh air inlet.

The regulation of the heating is done by valve on the heating bodies; thus, every room can be regulated separately and the set temperature varies according to the occupant demand. The floor does not contain own heating body, because the floor is in the middle of the building and the rooms “protect” them, consequently almost no cooling outside surface exists.

Domestic hot water can be used only in the kitchens and the bathrooms.

The second energy source of the building is the electricity supplied by the electric grid. Recently no solar panels nor wind turbines have been settled that is why 100% of the consumption comes from non-renewable sources. The electric consumption is not typical of a normal residential home, because the occupants are students and the consumption concentrated on the morning and the evening.

The electric system was designed to be optimal to the dormitory that is why the separated measurement is impossible, no separated electric circuit was formed.

The lighting system is a mixed version of LED and traditional lighting bodies.

5.2.3 BASELINE MONITORING PLAN FOR ENERGY PERFORMANCE INITIAL STATUS

The project results will be measured by means of different indicators comparing the original or initial data to the measured ones after renovation. The selected indicators are described in D3.2 (REHOUSE set of indicators selected for the impact assessment) the monitoring solutions are detailed in D3.4 Monitoring programs for the 4 demos (construction, building operation, LCA, LCC) reports.

The exact and manifested sensor type and location and architecture described here below:

Table 6: Sensor types and locations in Hungarian Demo building

Sensor type	Floor	Measurement	RPi	ID	Power source
Multisensor	1	Hallway	3	3	RPi
	1	Hallway	2	4	RPi
	2	Hallway	4	5	RPi
	3	Hallway	6	2	RPi
	1	Bathroom	2	7	Battery
	1	Kitchen	2	6	RPi
	3	Room 300	7	3	RPi
	3	Room 311	6	4	Adapter
	3	Room 302	7	4	Battery
	2	Room 211	4	6	Adapter
	2	Room 200	5	3	Adapter
	2	Room 204	5	5	Battery
	1	Room 113	2	8	Battery
	1	Room 104	3	7	Battery
	1	Room 103	3	6	Adapter
		Outdoor	3	8	Adapter
CO_2 VOC	1	Hallway	3	4	RPi
	1	Hallway	2	3	RPi
	2	Hallway	4	4	RPi
	3	Hallway	6	3	RPi
	1	Kitchen	2	5	RPi
	3	Room 311	6	5	RPi
	3	Room 300	7	2	Adapter

Sensor type	Floor	Measurement	RPi	ID	Power source
	2	Room 211	4	7	Adapter
	2	Room 200	5	4	Adapter
	1	Room 103	3	5	Adapter
		Outdoor	3	9	Adapter
Electrical energy 3-phase	Basement	Main power	3	10	Distribution box
	To be done	Solar generation	To be done		
Water meter (It will be installed in the near future)	Basement	Basement	8	-	RPi
Gas meter	Basement	Basement	8	-	RPi
Weather Station	Roof		1	-	Solar

The backbone of the local monitoring system is Raspberry Pi (called RPi) system net connected to the wireless network of the building. The RPi well equipped local Linux based computer with a very high operational reliability. Beside the RPi unit has a wire and wireless communication ability there can be connected sensors directly via USB port or transmitters. In the case of the Hungarian Demo building there were two methodologies to connect the sensors to the net. The first one when the sensor was settled very close to the RPi, in this case the USB cable connection were used. The advantage of this type of connection is the sensor get the supply via the cable and do not need a battery or an electric grid connection. The second connection when the sensors were farer than the length of the cable. In this cases a Z-wave system were used for the communication of the sensors and the RPi. For this reason, such a sensor type were chosen which were prepared the Z-wave communication, and the sensor itself was able automatically connect this communication network. To the RPi was not integrated such a communication unit that is why had to use a Z-wave communication sticker. The sticker can have connected simply to USB slot of RPi and the sensor was revived by this connection protocol from the given RPi.

Sensors are able to communicate via Z-wave:

- Multisensor data (temperature, humidity, sound pressure, light).
- CO_2 and VOC (carbon-dioxide, volatile organic compounds, total volatile organic compounds).
- Electric energy 3-phase sensor (current in 3 phase, voltage in 3 phases).
- Weather station (outdoor humidity, temperature, solar radiation, wind speed).

Gas meter and water meter were equipped with impulse sensor. The existing gas meter was able to connect an impulse sensor and this impulse sensor was connected to the RPi, by means of an intelligent microcontroller circuit.

5.2.4 ENERGY DIAGNOSTIC

Recently no energy diagnostic system is functioning, and no measurement was done excluding the gas consumption. Even the electricity is not measured separately, being part of a group of buildings. After the formation of industrial building to dormitory an energy calculation had been done resulted a 43 kW winter heat loss performance. This value is high comparing the valid requirements, and the carbon footprint is also outstanding.

Co-funded by the European Union

5.2.5 HUMIDITY

Similarly, the older buildings could not meet the up to date requirement such as airing and ventilation, heat bridge effects, etc.

On the first visual investigation was already recognized the strong heat bridge effect of the walls and the lack of regular ventilation. The old brick wall without an insulation provides not a considerable thermal resistance and the insight surface temperature can be low enough to reach the condensation temperature so called dew point on the wall. This phenomenon causes a dramatic problem in the bathrooms, where the humidity usually high easily reach the 100%. The lack of ventilation results in the bathroom molds on the wall surface especially in the corners. The room cannot be dried, because of the regular humidity munition of showering. For seeing the real data, a multisensory was installed to one of the bathroom in the building.

It is expected the thermal insulation will help a lot for minimizing or eliminating the heat bridge effect, but the 100% relative humidity is a dew point itself. This could be terminated only by overall or local ventilation of the building.

It should be taken into consideration the high energy content of the vapor over the higher temperature of the bathroom air. The traditional ventilation would have caused a significant energy wasting, by ventilating out the bathroom air without heat exchanger. To gain back this energy the usage of a heat exchanger should be recommended.

Figure 22: Wall watering in the corridor

Figure 23: Molds on the wall surface especially in the corners in the bathroom

Figure 24: Defect on the exterior brick façade. Original bricks are missing in several places

5.2.6 ANALYSIS OF THE ENERGY BILLS

Below is some basic information about the equipment that supplies gas and electricity.

Steel hot water storage 5 x 500L, indirect gas boiler heating primary priority, insulated by polyurethane foam coating thickness 50mm.

Only one gas furnace supplies the heating system and the hot water system in the same time. The efficiency is about 90%.

Heating demand is 43 kW, unfortunately no data is available for annual heating demand in kWh.

The building has not a system for cooling.

Table 7: Hungarian Demo building equipment

DOMESTIC HOT WATER	
Specific domestic hot water (DHW) demand (L/day/person)	80
Temperature of the hot water (ºC)	45
Mean temperature of the cold water from the grid (ºC)	14
Natural gas boiler efficiency for DHW (%)	90
Distribution thermal losses for DHW (%)	40
Natural gas boiler	
Lower heating value of the used natural gas (kJ/kg)	34 MJ/m^3
Natural gas boiler efficiency (%)	90
Distribution of thermal losses of the heating system (%)	15
Boiler capacity (kW)	90

The table below shows the energy bills for recent years. The data for 2022 and 2023 will hopefully be available in the near future, when we will expand the table.

The basic and total amount to be paid per month; the unit price per kWh; and the amount of consumption per month.

Invoices always show the amount of consumption of the previous month. One or two 'settlement' bills are also sent out each year. In addition to the monthly bills, there are also "settlement" bills at the end of the year, which is why there are not only 12 bills in a year.

The amount in euro is calculated using an exchange rate of 394 HUF (Hungarian Forint), which is today's daily mid-rate. Unfortunately, the HUF/EUR exchange rate varies significantly from day to day, so we are unfortunately not able to forecast exact amounts for costs in EUR.

Table 8: Electricity bills for the last few years

Electricity

HUF/month total	EUR/month	HUF/kWh	Consumption/month	Basic fee/month
Year 2020				
249,471	633	27.17	5,598	152,071.35
543,278	1,379	27.17	11,530	313,215.91
462,443	1,174	27.17	9,431	256,195.94
328,091	833	27.17	6,109	165,952.82
133,328	338	27.17	2,082	56,558.15
74,196	188	27.17	1,312	35,640.87
96,603	245	27.17	1,307	35,505.05
164,414	417	27.17	2,530	68,728.21
173,039	439	27.17	3,283	89,183.68
166,082	422	27.17	2,474	67,206.95
277,945	705	27.17	4,937	134,115.09
355,980	904	27.17	6,864	186,462.62
3,024,870	**7,677**		**57,457**	-
Year 2021				
348,204	884	27.17	7,483	203,277.94
425,584	1,080	27.17	8,821	239,625.11
329,604	837	27.17	6,871	186,652.78
167,789	426	27.17	3,004	81,604.56
144,673	367	27.17	2,414	65,577.03
116,469	296	27.17	1,647	44,741.25
345,544	877	27.17	6,621	179,861.45
600,722	1,525	27.17	13,674	371,458.31
207,755	527	27.17	3,394	92,199.03
119,138	302	27.17	1,877	50,989.27
206,668	525	27.17	4,170	113,279.30
3,012,150	**7,645**	**-**	**59,976**	-

Table 9: Natural gas consumption bills for recent years

Natural gas

m^3/month	Total HUF/month	Total EUR/month	MJ/month	price 1. HUF	MJ/month	price 2. HUF	price 1. /month	price 2. /month	Basic fee HUF/month	Total MJ/month
Year 2020										
867	139,940	355	23,434	4.36626	7,738	3.75539	102,319	29,059	131,378	31,172
423	66,321	168	10,410	4.36626	4,294	3.75539	45,453	16,126	61,578	14,704
423	66,594	169	11,217	4.36626	3,486	3.75539	48,976	13,091	62,068	14,703
423	66,732	169	11,442	4.36626	3,261	3.75539	49,959	12,246	62,205	14,703
423	66,594	169	11,217	4.36626	3,486	3.75539	48,976	13,091	62,068	14,703
423	66,664	169	11,330	4.36626	3,373	3.75539	49,470	12,667	62,137	14,703
423	66,594	169	11,217	4.36626	3,486	3.75539	48,976	13,091	62,068	14,703

m^3/month	Total HUF/month	Total EUR/ month	MJ/ month	price 1. HUF	MJ/ month	price 2. HUF	price 1. /month	price 2. /month	Basic fee HUF/month	Total MJ/month
423	66,664	169	11,330	4,36626	3,373	3.75539	49,473	12,667	62,140	14,703
423	66,594	169	11,217	4,36626	3,486	3.75539	48,976	13,091	62,068	14,703
6,059	953,934	2,421	-	4,36626	39,888	3.75539	-	149,795	149,795	39,888
10,310	**1,626,631**	**4,129**	**329,457**	**4,36626**	**39,888**	**3.75539**	**1,438,495**	**149,795**	**1,588,290**	**369,345**
Year 2021										
788	125,911	320	23,181	4.36626	4,273	3.75539	101,214	16,047	117,261	27,454
788	125,063	317	23,968	4.36626	3,486	3.75539	104,651	13,091	117,742	27,454
788	125,270	318	24,306	4.36626	3,148	3.75539	106,126	11,822	117,948	27,454
788	125,063	317	23,968	4.36626	3,486	3.75539	104,651	13,091	117,742	27,454
788	125,132	318	24,081	4.36626	3,373	3.75539	105,144	12,667	117,811	27,454
788	125,063	317	23,968	4.36626	3,486	3.75539	104,651	13,091	117,742	27,454
788	125,132	318	24,081	4.36626	3,373	3.75539	105,144	12,667	117,811	27,454
788	125,063	317	23,968	4.36626	3,486	3.75539	104,651	13,091	117,742	27,454
698	114,588	291	15,012	4.36626	9,877	3.75539	65,546	37,092	102,638	24,889
788	127,892	325	23,968	4.36626	3,486	3.75539	104,651	13,091	117,742	27,454
788	125,132	318	24,081	4.36626	3,373	3.75539	105,144	12,667	117,811	27,454
788	125,063	317	23,968	4.36626	3,486	3.75539	104,651	13,091	117,742	27,454
1,637	259,750	659		4.36626		3.75539	-	-	-	-
11,003	**1,754,122**	**4,452**	**278,550**	**4.36626**	**48,333**	**3.75539**	**1,216,222**	**181,509**	**1,397,731**	**326,883**

Because of Hungary's climate, the main period of energy consumption is winter and, before that, late autumn and then early spring. Most of the consumption is for heating, with cooling playing a much smaller role.

5.3 French demo-site

5.3.1 DESCRIPTION OF THE BUILDING

The French Demosite is a social housing with an area of 2,260 m², located in the town of Saint-Dié-des-Vosges, in the North East of France. The building is composed of 20 apartments; 34 people live in, with an average age of 55-60 years old. It was built in 1959 and since its construction has only undergone an energy renovation with the replacement of the windows. The building has an East – West orientation and a rendered masonry façade. Initially, the building was equipped with an oil-fired boiler before switching to natural gas. The demonstrator is generally very poorly insulated (around 3 cm of glass wool in roof) which justifies a global renovation beyond the facades (#RP6). As we can see in the figure below, the demo-site (at the centre of the aerial view) is surrounded by a parking, small houses and the road. As a result, the shading on the façade is not significant.

Figure 25: General view and aerial view of the French demo-site

5.3.2 DESCRIPTION OF THE ENERGY SYSTEM

All the apartments have static ventilation (air ducts) but no mechanical ventilation system. As a result, people open the windows additionally, for very short periods in winter, longer in summer. All tenants have an individual gas boiler for the production of heating and DHW. Boilers are about 20 years old (no low-temperature, no condensation, 80% efficiency). A thermostat is available to set the temperature. The vast majority of tenants heat their homes to 19.5°C and are extremely careful to limit their energy consumption to reduce expenses. All households have LED lamps and appliances in class A. No air conditioning system (individual or collective) is present in the building.

5.3.3 BASELINE MONITORING PLAN FOR ENERGY PERFORMANCE INITIAL STATUS

The following table gives the KPIs regarding the energy performance initial status that have been selected for the French demo-site with the associated measurement and devices. This table is extracted from the building operation monitoring programme (D3.4). The KPIs are defined in D3.2.

Table 10: Energy Performance initial status KPIs

Parameters to be measured	Related to KPI №[2]	Sensor or measurement device	Boundaries	Comments
Building Envelop parameters				
Heat flux	KPI01, RP-KPI02	Heat flux meters or systems for walls' transmittance/ resistance measurements	On the renovated façade walls	North façade
Resource use				

2 The numbers of KPIs from the D3.2. REHOUSE set of indicators selected for the impact assessment

Parameters to be measured	Related to KPI №2	Sensor or measurement device	Boundaries	Comments
Electrical energy and power consumption	KPI02-a, KPI03, KPI04, KPI05, KPI10, KPI11, RP-KPI12, KPI26	Electric energy and power meters/demo site building	1 meter per whole building consumption	Electricity consumption of common areas (lighting, heat pump, etc.)
			1 meter per ventilation system	DF ventilation
			1 meter per heating system	Collective system, to be defined if some apartments can be monitored
			1 meter per domestic hot water system	Collective system, to be defined if some apartments can be monitored

5.3.4 ENERGY DIAGNOSTIC

The energy and environmental performance rate of the French DPE is a D rate; it means that the primary energy consumption value is between 151 and 230 kWh/m²/year. This estimate is given by the project owner but no diagnostics were carried out (apart from airtightness tests in the following section 5.3.5). However, a dynamic thermal simulation (Design Builder) was also carried out based on the existing situation (subsection 5.3.7) following the consumption analysis of the building (subsection 5.3.6). The results presented below corresponds to the project owner estimation of an energy and environmental performance D rate of the French DPE.

5.3.5 AIRTIGHTNESS REPORT

The Airtightness report was conducted the 02/08/2023. Sampling was carried out in accordance with the FD P 50 784 supplementing the NF EN ISO 9972 standard, i.e. 3 dwellings, one on each level, selected according to tenants' availability.

The results obtained are already relatively good Q4 = 1.57 $m^3/h/m^2$. The main parasitic air inlets identified are in the following areas:

- PVC joinery, whose seals and closing systems are sometimes no longer sufficiently effective, and roller shutter boxes and their mechanical closing systems,
- Technical columns and their separation by light panels in WCs, or even bathrooms,
- Electrical feed-throughs in entrances, and, to a lesser extent, pipe feed-throughs between levels in ceilings, floors and service columns.

In addition, natural air intakes in wet rooms (kitchen (2), WC (2), bathroom (1)) must be sealed and their connections to the walls treated. The same applies to gas ducts in kitchens and old chimney flues in other rooms. Effective treatment of these main defects should make it possible to reduce leakage rates by a factor of at least 2.

Below the detailed photos of the main air inlets revealed are presented.

Figure 26: deformation of the sash on the living room French window, creating a gap that the seal no longer covers. joinery seal between living room window and French window

Figure 27: leak at connection in living room. A hole in roller shutter box. Leak in the roller shutter mechanism

Figure 28: air inlet at wall frame connection.

Figure 29: Air intake at top/bottom sash connection. Two windows no longer close properly

Figure 30: bushings, fittings, natural air extraction

Figure 31: natural air inlet grilles and boiler smoke exhaust

5.3.6 ANALYSIS OF THE ENERGY BILLS

Classically, it is necessary to collect as many invoices as possible in order to estimate the building's consumption, which is often long and complicated. On buildings of a certain size (for data protection reasons), it is possible thanks to a GRDF (the company that distributes gas in France) service to collect all invoices without coming into contact with the tenants of the building. In this case, this service is extremely useful to have an overall vision of the demonstrator's gas consumption before the retrofit operation.

We were unable to access the tenants' electricity consumption. In any case, the implementation of #RP6 will only affect the heating consumption of the dwelling.

Table 11: Occupied apartments, gas consumption and CO_2 emissions for year 2020, 2021 and 2022

	Occupied apartments			Gas consumption (MWh/y)		
YEAR	**2020**	**2021**	**2022**	**2020**	**2021**	**2022**
	18	20	20	206	250	213
CO_2 EMISSIONS (TEQ CO_2)				46.76	56.75	48.35
HEATING DEGREE DAYS					2,880.1	2,546.1

The calculation of Heating Degree Days (HDD) is given for the city of Nancy (https://www.infoclimat.fr/); located 80 km northwest of Saint-Dié, where the demonstrator is located. Nancy is the city with the closest climate with complete data for the years 2021 and 2022 (2020 is not considered because not all the accommodations were occupied).

In order to distribute the total consumption between the different uses, the following table describes the assumptions used for estimating domestic hot water needs and gas consumption for cooking. The gas boilers installed in the accommodation are of the medium/high temperature type aged around 20 years. Their efficiency is estimated at 80%.

Table 12: Distribution of the total consumption between the different uses

	Assumption	Total value
DOMESTIC HOT WATER	Method ESM 2.0+3°C*	27.58 to 46.79 MWh/y
GAS CONSUMPTION FOR COOKING	315.5 kWh/y for 1.7 persons (average occupancy per apartment)	6.31 MWh/y
HEATING NEEDS	Year 2021	196.9 to 219.11 MWh/y

* The esm 2.0 method is the standard method for calculating hot water needs and calculating solar hot water production. It is adapted by the TECSOL engineering office taking into account feedback from monitored installations. In the calculation, only the domestic heat requirement part is used given that production is ensured by gas boilers. Regarding the hypotheses of water consumption (at 60°C), the lower hypothesis being 33 litter/day/person (TECSOL) to 56 litter/day/person (national method for energy diagnostics).

5.3.7 DYNAMIC THERMAL SIMULATION

A dynamic thermal simulation (Design Builder) was also carried out based on the existing situation, given that there were no energy diagnostics carried out on the demonstrator (apart from airtightness tests). The weather file considered is also that of Nancy. The HDDs on this file are 2,814.02 over the year.

The building is equipped with air inlet systems (hygro A type) and ventilation columns in the technical areas but there are no fan motors, it is a static ventilation. Regarding the modelling assumptions, they are described in the following table:

Table 13: Dynamic thermal simulation main parameters

Technical detail	Value
Heating set point	19.5°C **
Heating set point reduction	16°C **
Ventilation rate	0.2 vol/h
Windows opening every morning 10 minutes	4 vol/h
Ventilation due to airtightness defects	1.57 $m^3/h/m^2$
Window type	PVC, double glazing (4/6/4, no low emissivity coating)
Roof insulation	Glass wool (3cm)
Walls	No insulation, concrete block for non-load-bearing walls and shuttered concrete for load-bearing walls
Basement	No insulation

** Retired people (11 people) are still present during the day. Students, school children and employees (17 people) are absent from 8 a.m. to 6 p.m. Unemployed people (6) are present from 8:00 a.m. to 2:00 p.m.

Taking into account the same boiler efficiency (80%) and taking into account the slight difference between the HDDs, gas consumption relative to heating needs reaches 196.57 MWh/y. This result is entirely relevant compared to the estimate made via gas bills. Given the uncertainties involved, notably concerning the overall airtightness of the demo site, this difference is quite acceptable.

5.4 Italian demo-site

5.4.1 DESCRIPTION OF THE BUILDING

The Italian demonstration site is situated in Margherita di Savoia, an Adriatic coastal municipality within the Apulia region of Italy. The demo building is part of a cluster of similar structures, all sharing common issues of physical degradation and social vulnerability. The assignees of this public housing stock are notably frail and vulnerable. Over the past two years, regional policies have been introduced for the requalification of poor areas.

The demo building has a rectangular footprint, and it is built in a reinforced concrete frame with poor insulation. The building has four floors above ground plus a floor on the roof dedicated to storage rooms. Each floor consists of two units of 80m^2 and 93m^2, respectively, for a total of eight apartments. The building, built in the mid-1980s, has a reinforced concrete structure with perforated brick closures and metal window frames without thermal break and with single glazing, except for three apartment units where the glazed surfaces have been replaced by PVC elements and double-glazing.

As we can see in the figure below, the demo-site (at the centre of the aerial view) is surrounded by a parking, small trees and the road. As a result, the shading on the façade is not significant.

Figure 32: Picture of Italian Pilot Building

5.4.2 DESCRIPTION OF THE ENERGY SYSTEM

All apartments are equipped with an independent heating system. Five dwellings have a condensing boiler (Apartment (Ap.)1, Ap.2, Ap. 5, Ap. 7, Ap. 8), while the remaining units have a standard boiler. Three apartments related to Aps 4, 5, and 8, respectively, have an air conditioning system with Heat Pump. It can also be used as heating system.

No thermostats or building automation and control devices are present. The unique device is a switch to turn the heating on and off.

Furthermore, no mechanical ventilation systems are present. It is difficult to define the energy class of the household appliances because, excluding the apartment int. 5, which was recently renovated (major renovation).

The EPC (energy performance certificate) of the entire building is G, with a primary total energy requirement of 250.33 kWh/m²/year.

The following figures present the results for INT. 5 (representing the typical apartment,), regarding the primary energy demand, for winter and summer air conditioning and DHW production. A similar analysis was reported in D2.3 "Detailed models of the 8 RPs".

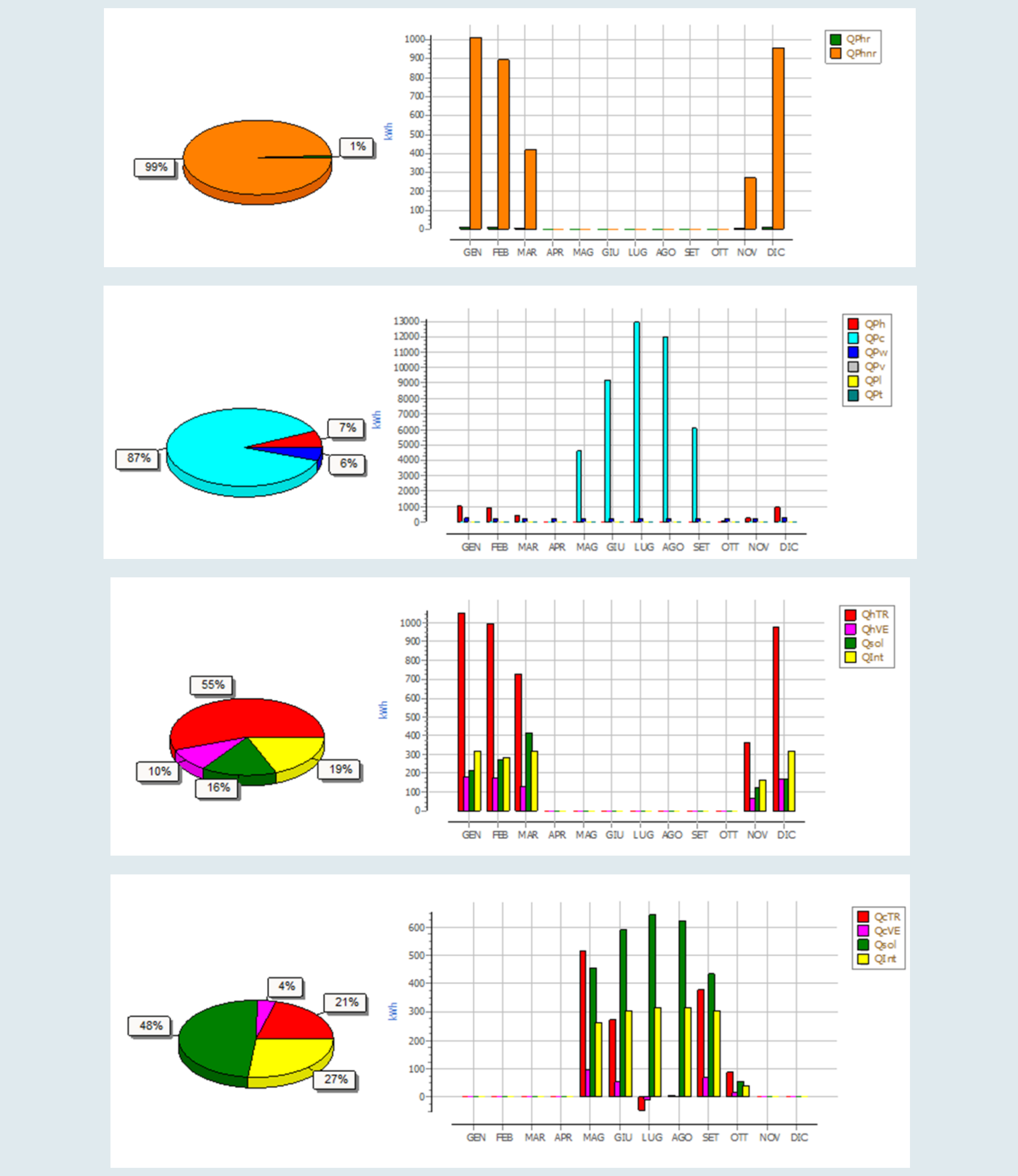


Figure 33: Primary energy demand of int. 5

5.4.3 BASELINE MONITORING PLAN FOR ENERGY PERFORMANCE INITIAL STATUS

The energy performance initial status has been evaluated thanks to the collection of the energy bills, as described in the following paragraph. Both electric and thermal bills has been collected by owners and thanks to the consultation of Electric energy and Natural Gas company providers.

A thermofluximetric analysis was foreseen in February 2024. However, the owner of the apartment 4, where the analysis was foreseen, was injured, and so the winter monitoring has been postponed.

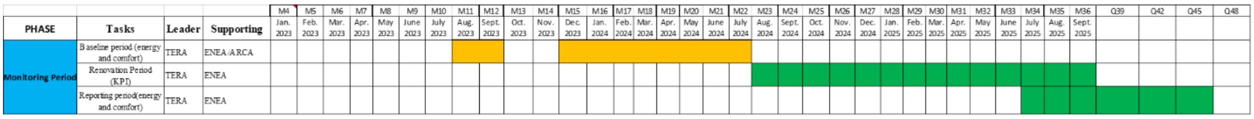


Figure 34: monitoring plan

The Italian demo site is a social housing building located at Margherita di Savoia consisting of 8 dwellings where no instrumentation was initially present in the building.

The baseline monitoring plan, as already anticipated in D3.2 and D3.4, has foreseen the definition of an ex-ante pre-monitoring baseline one for the summertime period from 10th August till the 10th September 2023 – labelled as **Pre-monitoring Period #1** – and one fort he wintertime period from the 14th December 2023 – labelled as **Pre-monitoring Period #2** – and still ongoing at the moment we are editing this report.

Regarding the setup of the **Pre-monitoring Period #2 baselines,** four dwellings were considered in the research activity, but different units were involved (namely units 1, 5, 6, and 8).

The instrumentation used for the definition of **Pre-monitoring Period #2** (started on 14th December 2023 and still ongoing at the time we are editing this report) consists of the provisioning of four **SMART INFO+ from ENEL** that act as electrical fiscal reader meter (one for each dwelling) whom data can be collected by the data acquisition system provided by TERA and described in Section 6.4.3.

Table 14: List of variables

Read variable	Unit	localisation	quantity	Brand	Reference	Communication protocol
Active Energy	W	1 for dwelling	4	ENEL	SMART INFO+	Power Line Communication (PLC)
Reactive Energy	W	1 for dwelling	4	ENEL	SMART INFO+	Power Line Communication (PLC)

Furthermore, a set of up three **Smart Switch 6 from AEOTEC** were distributed and assigned across each dwelling for measuring electrical loads from white goods and/or smart appliances with the aim at supporting the profiling of electrical energy consumption.

Measured variable	Unit	localisation	quantity	Brand	Reference	Communication protocol
Energy Load	W	Living room / Bedroom #1 / Bedroom #2 / Kitchen	Up to	AEO TEC	SMART SWITCH 6	Zwave

Monitored or read data from the **Pre-monitoring Period #2** is not available yet.

5.4.4 ENERGY DIAGNOSTIC

The energy audit was carried out through an analysis of the actual consumption of the actual state of the building-plant system. The objective is to define a baseline consumption, to be used for the evaluation of the energy improvement interventions. In this way, actions on the envelope and actions on thermal and electrical systems can be defined. These actions can be completed with monitoring systems and integrated with renewable sources.
The energy audit has been realized using TerMus BIM tool, a commercial software produced by ACCA software S.p.A..
The starting point was the creation of the BIM model of the DEMO building in Margherita di Savoia (south of Italy).
In Figure 35, the three-dimensional model created is shown.

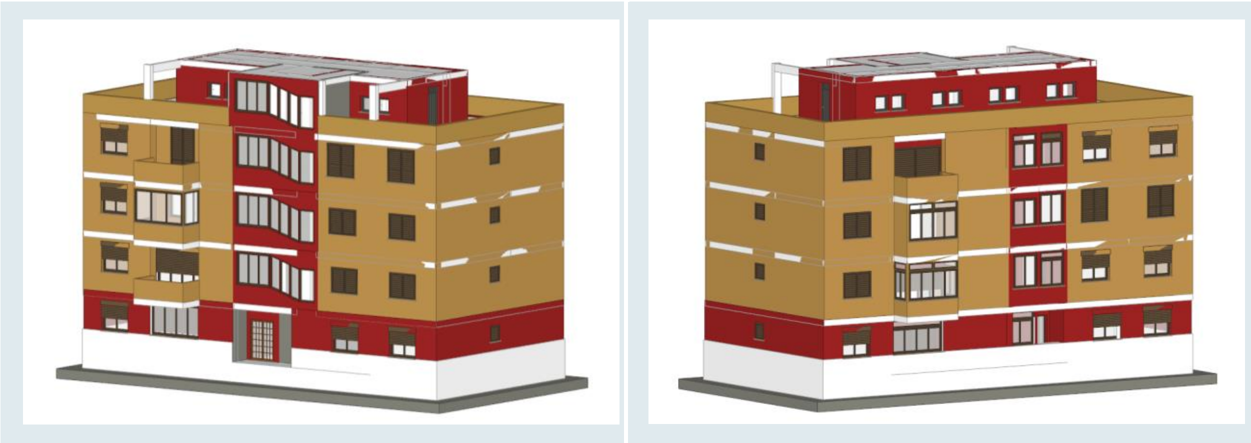


Figure 35: the three-dimensional model

In the software was inserted the energy consumption calculated using the energy bill, as described in the previous paragraph.

The transmittance, used in the simulation software, was calculated from the results of coring tests performed on the wall package.

In the picture (Figure 36) two wall packages are putting in evidence

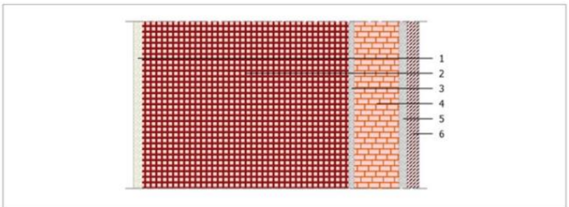
Figure 36: Results of the coring tests

The stratigraphy is visible from the coring tests, and four layers were considered and modelled in TeRMUS software. The results are reported in the following diagrams:

Titolo: Parete perimetrale zona rivestimento Marmo
Descrizione:

STRATIGRAFIA

Strato	Descrizione	Spessore [mm]	Conduttività [W/mK]	Conduttanza [W/m²K]	Massa superficiale [kg/m²]	Resistenza al vapore [-]	Calore specifico [J/kgK]	Resistenza [m²K/W]
	Adduttanza interna	0		7.7000				0.1299
1	Intonaco interno	15	0.7000	46.6667	21.00	10.7222	1´000	0.0214
2	Blocco laterizio forato (370*250*250)	370		0.9434	248.00	9.3826	840	1.0600
3	Malta di cemento	10	1.4000	140.0000	20.00	22.7059	1´000	0.0071
4	Mattoni pieni, forati, leggeri - densità 800	80	0.2970	3.7125	64.00	5.7733	840	0.2694
5	Malta di cemento	15	1.4000	93.3333	30.00	22.7059	1´000	0.0107
6	Marmo	20	3.5000	175.0000	56.00	10´000.0000	1´000	0.0057
	Adduttanza esterna	0		25.0000				0.0400

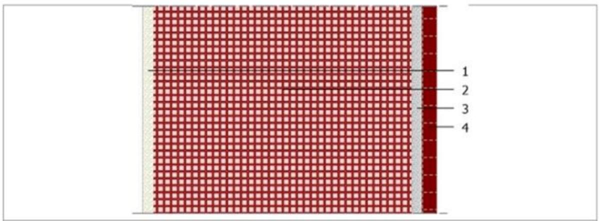


Spessore totale = 510 [mm]
Trasmittanza termica globale = 0.6476 [W/m²K]
Resistenza termica globale = 1.5442 [m²K/W]
Massa superficiale globale = 418.00 [kg/m²]
Capacità termica areica = 45.382[kJ/m2K]
Trasmittanza termica periodica = 0.10[W/m2K]
Fattore di attenuazione = 0.16[-]
Sfasamento = 14.21[h]

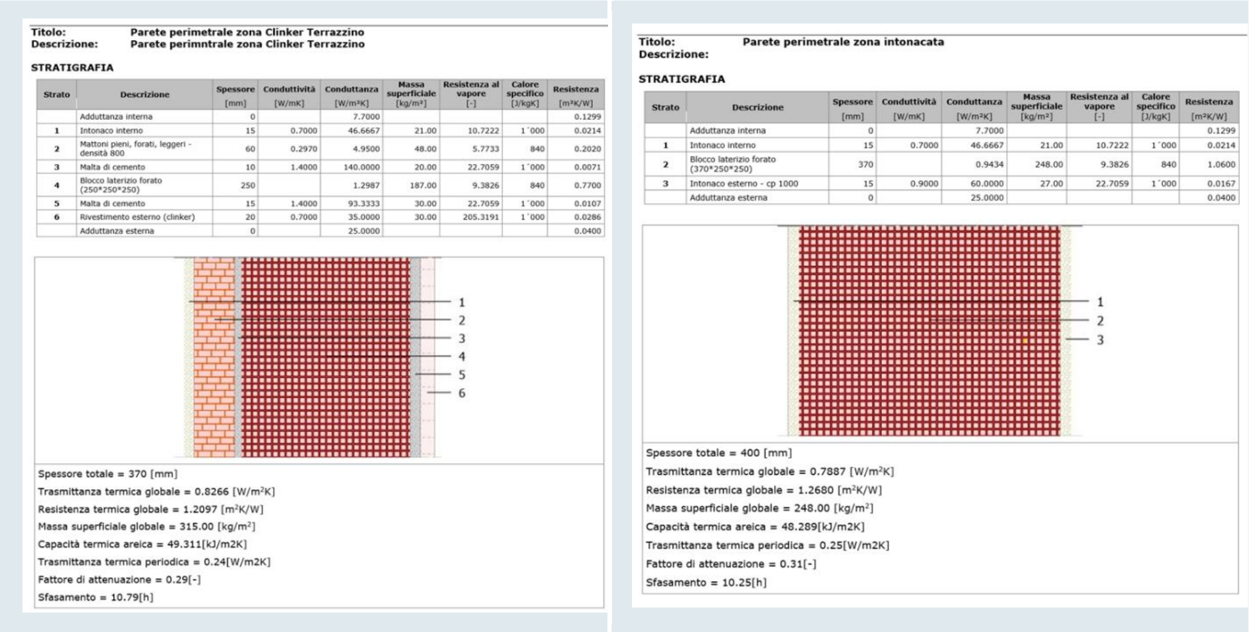
Titolo: Parete perimetrale zona Clinker
Descrizione:

STRATIGRAFIA

Strato	Descrizione	Spessore [mm]	Conduttività [W/mK]	Conduttanza [W/m²K]	Massa superficiale [kg/m²]	Resistenza al vapore [-]	Calore specifico [J/kgK]	Resistenza [m²K/W]
	Adduttanza interna	0		7.7000				0.1299
1	Intonaco interno	15	0.7000	46.6667	21.00	10.7222	1´000	0.0214
2	Blocco laterizio forato (370*250*250)	370		0.9434	248.00	9.3826	840	1.0600
3	Malta di cemento	15	1.4000	93.3333	30.00	22.7059	1´000	0.0107
4	Rivestimento esterno (clinker)	20	0.7000	35.0000	30.00	205.3191	1´000	0.0286
	Adduttanza esterna	0		25.0000				0.0400



Spessore totale = 420 [mm]
Trasmittanza termica globale = 0.7748 [W/m²K]
Resistenza termica globale = 1.2906 [m²K/W]
Massa superficiale globale = 308.00 [kg/m²]
Capacità termica areica = 47.836[kJ/m2K]
Trasmittanza termica periodica = 0.22[W/m2K]
Fattore di attenuazione = 0.29[-]
Sfasamento = 10.95[h]



Titolo: Parete perimetrale zona Clinker Terrazzino
Descrizione: Parete perimntrale zona Clinker Terrazzino

STRATIGRAFIA

Strato	Descrizione	Spessore [mm]	Conduttività [W/mK]	Conduttanza [W/m²K]	Massa superficiale [kg/m²]	Resistenza al vapore [-]	Calore specifico [J/kgK]	Resistenza [m²K/W]
	Adduttanza interna	0		7.7000				0.1299
1	Intonaco interno	15	0.7000	46.6667	21.00	10.7222	1´000	0.0214
2	Mattoni pieni, forati, leggeri - densità 800	60	0.2970	4.9500	48.00	5.7733	840	0.2020
3	Malta di cemento	10	1.4000	140.0000	20.00	22.7059	1´000	0.0071
4	Blocco laterizio forato (250*250*250)	250		1.2987	187.00	9.3826	840	0.7700
5	Malta di cemento	15	1.4000	93.3333	30.00	22.7059	1´000	0.0107
6	Rivestimento esterno (clinker)	20	0.7000	35.0000	30.00	205.3191	1´000	0.0286
	Adduttanza esterna	0		25.0000				0.0400

Spessore totale = 370 [mm]
Trasmittanza termica globale = 0.8266 [W/m²K]
Resistenza termica globale = 1.2097 [m²K/W]
Massa superficiale globale = 315.00 [kg/m²]
Capacità termica areica = 49.311[kJ/m2K]
Trasmittanza termica periodica = 0.24[W/m2K]
Fattore di attenuazione = 0.29[-]
Sfasamento = 10.79[h]

Titolo: Parete perimetrale zona intonacata
Descrizione:

STRATIGRAFIA

Strato	Descrizione	Spessore [mm]	Conduttività [W/mK]	Conduttanza [W/m²K]	Massa superficiale [kg/m²]	Resistenza al vapore [-]	Calore specifico [J/kgK]	Resistenza [m²K/W]
	Adduttanza interna	0		7.7000				0.1299
1	Intonaco interno	15	0.7000	46.6667	21.00	10.7222	1´000	0.0214
2	Blocco laterizio forato (370*250*250)	370		0.9434	248.00	9.3826	840	1.0600
3	Intonaco esterno - cp 1000	15	0.9000	60.0000	27.00	22.7059	1´000	0.0167
	Adduttanza esterna	0		25.0000				0.0400

Spessore totale = 400 [mm]
Trasmittanza termica globale = 0.7887 [W/m²K]
Resistenza termica globale = 1.2680 [m²K/W]
Massa superficiale globale = 248.00 [kg/m²]
Capacità termica areica = 48.289[kJ/m2K]
Trasmittanza termica periodica = 0.25[W/m2K]
Fattore di attenuazione = 0.31[-]
Sfasamento = 10.25[h]

Figure 37: Stratigraphy model

5.4.5 ANALYSIS OF THE ENERGY BILLS

Some difficulties were encountered in collecting electricity and gas consumption bills from tenants. Therefore, data were obtained through the customer service of local distributors, in particular for electricity we received data from Enel Distribuzione and for natural gas from Italgas.

Table 15 summarizes natural gas consumption from January 2022 to May 2023, and Table 16 shows electricity consumption, for the same time period.

Table 15: Natural Gas Consumption (methane) [smc]

	Apartment 1 (Smc)	Apartment 2 (Smc)	Apartment 3 (Smc)	Apartment 4 (Smc)	Apartment 5 (Smc)	Apartment 6 (Smc)	Apartment 7 (Smc)	Apartment 8 (Smc)
gen-22	89	57	117	1	156	130	101	194
feb-22	83	45	90	1	102	99	61	138
mar-22	76	48	82	6	98	112	74	177
apr-22	32	16	36	15	35	47	39	67
mag-22	2	11	5	5	13	24	29	19
giu-22	7	2	1	1	10	18	17	15
lug-22	4	11	0	1	10	18	14	14
ago-22	6	7	6	1	8	18	15	14
set-22	7	6	0	0	10	21	18	13
ott-22	12	6	0	1	13	25	28	10
nov-22	17	8	31	0	35	48	37	55
dic-22	27	22	69	1	45	99	53	94
gen-23	38	225	98	6	144	117	91	146
feb-23	44	132	90	3	81	116	77	141
mar-23	25	81	59	2	61	75	47	87

	Apartment 1 (Smc)	Apartment 2 (Smc)	Apartment 3 (Smc)	Apartment 4 (Smc)	Apartment 5 (Smc)	Apartment 6 (Smc)	Apartment 7 (Smc)	Apartment 8 (Smc)
apr-23	21	56	41	3	50	49	44	55
mag-23	19	14	12	1	15	36	35	15

Table 16: Electricity consumption (kW/h)

	Apartment 1 (kW/h)	Apartment 2 (kW/h)	Apartment 3 (kW/h)	Apartment 4 (kW/h)	Apartment 5 (kW/h)	Apartment 6 (kW/h)	Apartment 7 (kW/h)	Apartment 8 (kW/h)
gen-22	62.325	173.8	131.96	73.089	189.09	193.04	250.724	133.406
feb-22	49.466	150.03	107.91	66.485	197.84	179.87	201.277	119.035
mar-22	47.886	187.89	111.39	82.391	145.34	138.39	242.457	138.474
apr-22	33.968	95.84	109.775	145.925	136.785	158.16	169.93	118.36
mag-22	22.586	65.83	91.68	121.064	140.9	175.77	131.49	140.587
giu-22	68.23	46.27	126.73	185.743	180.88	164.19	125.88	246.288
lug-22	79.511	81.96	134.84	296.454	218.8	181.91	119.66	323.98
ago-22	96.195	81.92	166.82	355.508	174.51	191.39	122.26	248.257
set-22	70.999	54.01	110.54	110.318	130.97	169.98	99.87	123.507
ott-22	81.635	58.4	100.29	100.635	137.67	168.27	107.08	122.995
nov-22	81.266	76.56	77.01	76.575	164.18	156.26	268.05	118.477
dic-22	85.733	166.82	83.23	76.277	194.38	185	231.73	164.85
gen-23	76.657	181.8	85.73	84.693	177.27	186.66	278.33	177.731
feb-23	73.978	170.91	68.28	69.198	165.76	185.64	269.27	142.58
mar-23	78.051	124.57	67.69	90.633	168.74	202.8	220.52	145.144
apr-23	72.701	91.44	86.26	76.262	172.76	194.25	181	135.14
mag-23	87.643	77.99	73.56	95.291	163.85	213.45	6.26	107.37

In the tables, it is evidencing a difference and a deviation for the AP. 4 for electricity and gas consumptions. The tenant's interviews of D1.4 "Design of social activities tailored to the local contexts" and the methodologies of D1.3 "Report of social requirements identified in the elicitation activities" will be used to better understand the reasons and find solutions for the operative phase of renovation of the building.

A thermographic investigation was also done on the building, which allowed the detection of thermal bridges in the software. In the picture an example of the investigation.

Figure 38: Thermography of the prospectus done by Studio Tiziano Bibò

ENEA (Patrizia Aversa) has done two thermographic campaigns, to evaluate the indoor quality of apartments and thermal bridges.

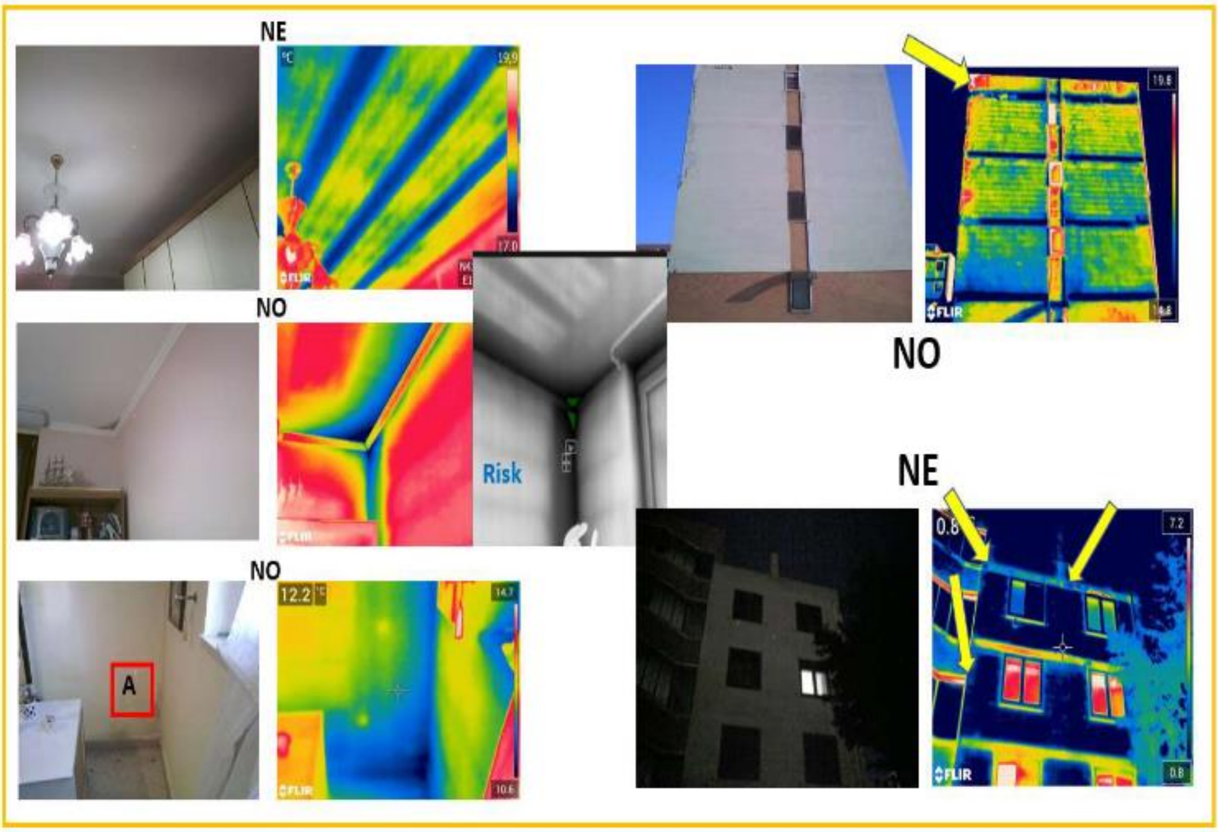


Figure 39: Thermographic analysis indoor and outdoor side NO and NW

In Figure 39, there are thermal bridges, mainly at the terrace slab, at the abutments and at the junction of terrace slab - stairwell parapet. These thermal bridges and infiltration increased heat loss in favour of indoor health issues due to presence of mold and/or condensation

5.4.6 THERMAL MODEL CALIBRATION

Actual consumption obtained from the websites of electricity and gas local distributors (as mentioned in the previous paragraph) was entered into the calculation model (Figure 40).

This procedure required the validation of the numerical model since the actual consumption was not aligned with those estimated by the software according to the current regulations.

This aspect is due to the fact that the regulations, for climate zone C, stipulate an on-time period for heating that runs from November 15 to March 31 and an on-time period for cooling that runs from June 10 to September 4, while in reality, based on the information provided by the tenants, the operation periods do not coincide with those in the regulations but are related to the habits of the tenants.

Figure 40: consumption obtained from the websites of electricity and gas local distributors

Therefore, to calibrate the model, a consumption analysis was carried out, acting on the turn-on period of the winter and summer air conditioning systems, as in Figure 41.

Figure 41: Consumption analysis

In Figure 42, the positive validation of the calculation model is shown, with a congruity factor of 0.979.

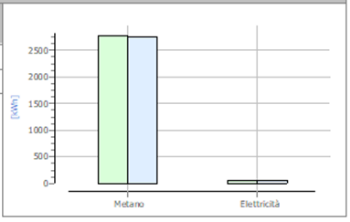
VALIDAZIONE DEL MODELLO DI CALCOLO

Fattore di congruità	0.979 (congruità: ALTA)		Modello validato

Legenda
Fattore di congruità = rapporto fra i consumi di energia reale desunti dalle bollette e i consumi energetici valutati con il calcolo semistazionario.

COMBUSTIBILI [kWh]

Nome	Consumo reale	Consumo stimato	Fattore congruità
Metano	2783.025	2757.160	1.009
Elettricità	60.640	58.603	1.035



SERVIZI [kWh]

Nome	Consumo reale	Consumo stimato	Fattore congruità
RSC	212.557	210.476	1.010
ACS	2631.108	2605.287	1.010

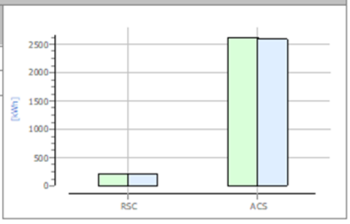


Figure 42: Validation of calculation model

The next steps are to verify the energy saving and costs saving thanks to the RP4 and RP5.

In March, the plant model will be studied. In the model, this will be added to the value of the final transmittance of the muti facade of RP5. The designer is choosing the air conditioning system and other equipment useful for the plant.

For the mentioned reasons, at the moment we have only an evaluation of the heating demand reduction of 75.2% thanks to the thermal insulation provided by RP5 with in addition those of completion on floors, fixtures and boxes.

					Heating demands		
EX ANTE	Eph,nd	Area netta	Eph,nd	EX POST	Eph,nd	Area netta	Eph,nd
	kWh/m²a	m²	kWh/a		kWh/m²a	m²	kWh/a
Ap. 1	47,08	82,32	3875,87	Ap. 1	14,08	84,18	1185,51
Ap. 2	49,57	94,24	4671,10	Ap. 2	21,48	94,23	2024,14
Ap. 3	26,59	82,01	2180,56	Ap. 3	10,26	84,09	862,79
Ap. 4	37,24	93,42	3479,33	Ap. 4	9,31	95,39	888,12
Ap. 5	19,28	85,15	1641,35	Ap. 5	4,91	85,53	420,29
Ap. 6	35,26	95,09	3352,97	Ap. 6	5,86	95,30	558,17
Ap. 7	71,62	83,76	5998,89	Ap. 7	10,87	83,93	912,21
Ap. 8	69,88	92,56	6468,37	Ap. 8	11,48	94,57	1085,92
TOTALE EX ANTE	44,69	708,55	31668,45	TOTALE EX POST	11,07	717,22	7937,14

Figure 43: Heating demands in a provisional phase

5.5 Reference value

The concept of reference value and building makes it possible to determine for each demonstrator the minimum insulation level imposed by the regulations of each country. Each type of envelope element is thus specified (this makes it possible to carry out renovations with real energy efficiency, in general, these minimum values make it possible to obtain state aid). As part of the REHOUSE project, we will be able to compare the results (simulations and consumption measurements) of each demosite with the reference buildings. This will make it possible to characterize the improvements of #RP in relation to the regulations of each country.

Table 17: Reference values for standard renovations for each site

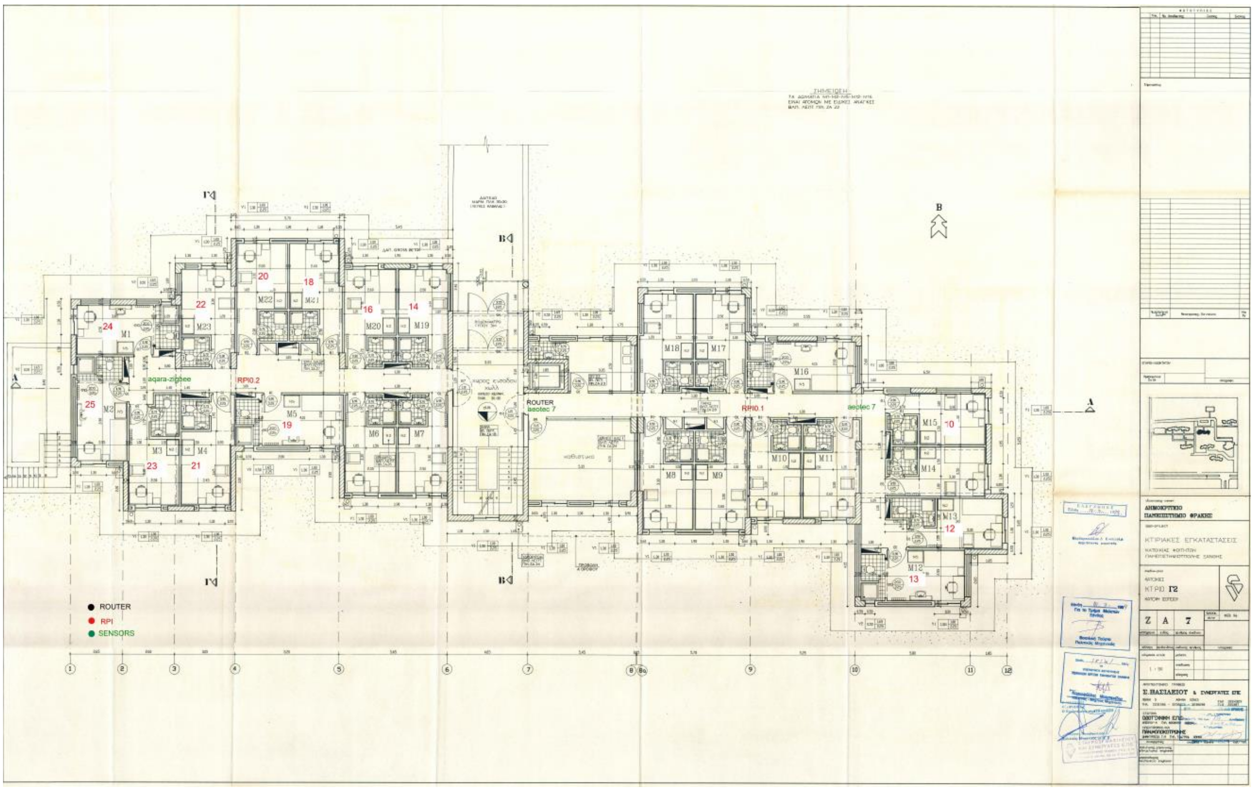
Reference value for a standard renovation	
Greece	The minimum requirement for thermal resistance to have the state aids are : • R = 0,32 (m^2.K/W) (U=3,1 W/m^2 K) • R = 0,95 (m^2.K/W) (U=1,05 W/m^2 K) • R = 0,8 (m^2.K/W) (U=1,25 W/m^2 K)
Hungary	The minimum requirement for thermal resistance are : • Walls R = 1.166 m^2.K/W • Windows R = 0.91 m^2.K/W • Roof R = 5.88 m^2.K/W
France	The minimum requirement for thermal resistance to have the state aids are : • R = 3.0 m^2.K/W for low floors over basements, over crawl spaces or open passageways, • R = 3.7 m^2.K/W for facade or gable walls, • R = 7.0 m^2.K/W for attic floors.
Italy	The minimum thermal resistance requirement for the type of structure - climate zone C : • Vertical opaque structures: R = 2.778 m^2.K/W • Horizontal or inclined opaque roofing structures: R = 3.125 m^2.K/W • Windows: R = 0.5 m^2 K/W

6 THERMAL COMFORT AND INDOOR AIR QUALITY INITIAL STATUS

6.1 Greek demo-site

6.1.1 BASELINE MONITORING PLAN FOR THERMAL COMFORT AND INDOOR AIR QUALITY STATUS

Thermal comfort of the occupants of the Greek demo site was provided by radiators in each room. All occupants can control the temperature setpoints depending on current environmental characteristics and occupant needs. The baseline monitoring plan, showcased in D3.2 and D3.4, defines two pre-monitoring baseline periods. Pre-monitoring Period #1 is ongoing from February 1st till April 30th 2024. Pre-monitoring Period #2 will begin in May 1st and continue till the 31st of July 2024. Detailed schematics with the floor plans of Building C2 and the installation of sensors and routers can be seen in the following figures.



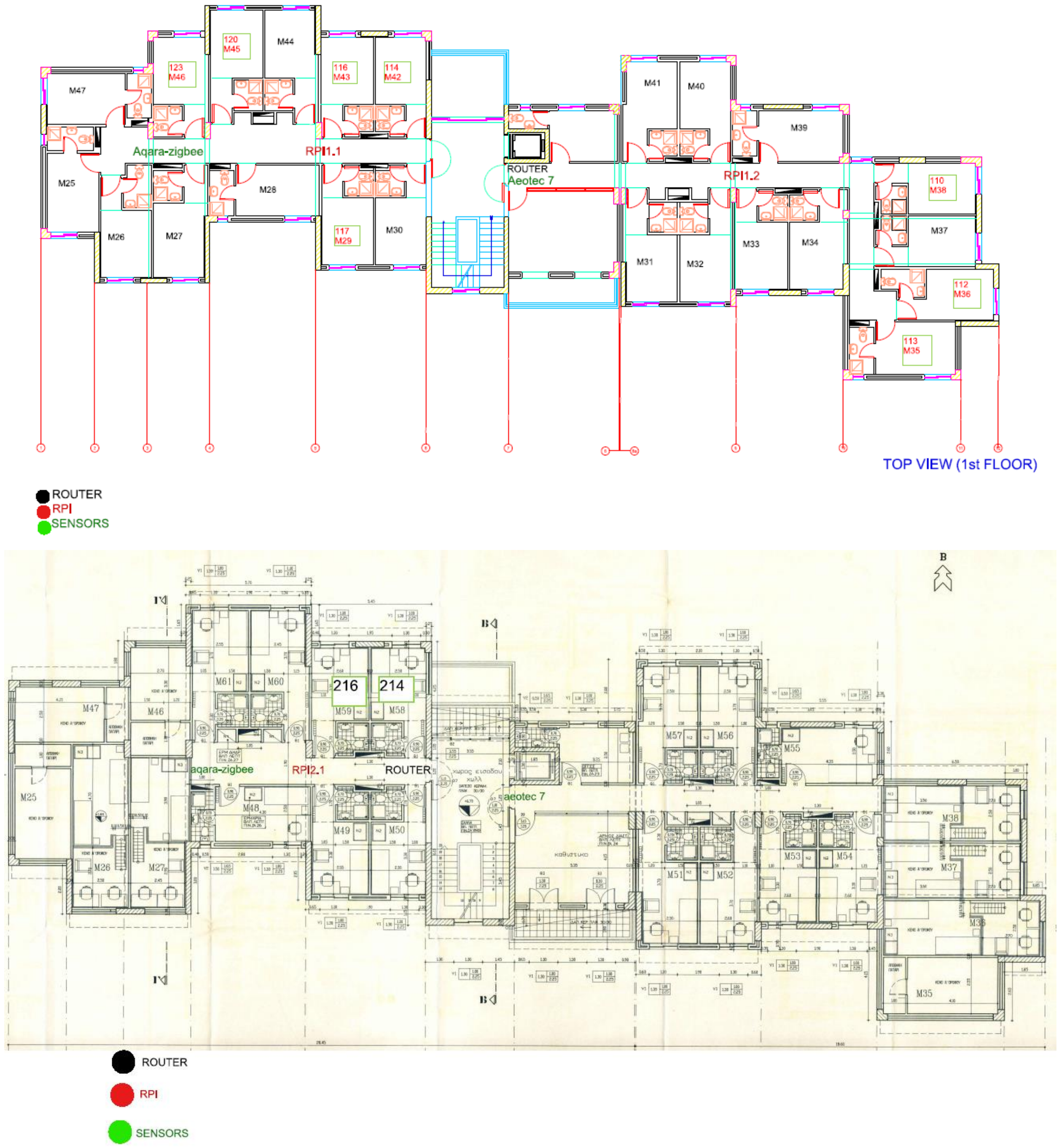


Figure 44: Floor plans of the Greek demo-site. Ground floor, 1st floor and 2nd floor seen from top to bottom

6.1.2 DESCRIPTION OF THE INSTRUMENTATION

In the pursuit of enhancing residential living standards and promoting energy efficiency, a comprehensive sensor deployment system has been implemented within a residential building. This innovative system incorporates advanced technology, primarily consisting of 5 Raspberry Pi units strategically positioned throughout the premises. Two Raspberry Pi units have been placed at the ground floor, two more at the first floor of the building and the last unit is located at the second floor. These Raspberry Pi units serve as the backbone of the sensor network, facilitating data collection, analysis, and communication across various floors of the building.

To ensure comprehensive environmental monitoring, a total of 19 z-wave Multisensor 7 Aotec devices have been deployed, meticulously placed to cover key areas within each floor. These sensors provide accurate and real-time measurements of temperature and humidity levels, enabling precise climate control and optimization of indoor comfort conditions.

Additionally, the integration of 3 z-wave MCO home CO_2 sensors offer invaluable insights into indoor air quality, monitoring CO_2 levels to mitigate potential health risks associated with poor ventilation. Complementing this setup, 5 Tuya CO_2 sensors further bolster the monitoring capabilities, ensuring a holistic approach towards maintaining optimal air quality standards throughout the building.

Furthermore, energy consumption management is a focal point of this initiative, facilitated by the installation of 7 z-wave Qubino 3-phase smart meters in some rooms of the building. These meters enable granular monitoring of electricity usage, empowering residents and building management with actionable insights to drive efficiency and reduce wastage.

In tandem with environmental monitoring, the implementation of 3 Aqara Zigbee multisensors contributes additional layers of data on temperature and humidity, further enriching the understanding of indoor environmental dynamics.

Table 18: Thermal comfort and IAQ Instrumentation for the Greek demo-site

Quantity	Device
Five (5)	*Raspberry Pi*
Three (3)	*Router*
One (1)	*Splitter*
Nineteen (19)	*Multisensor 7 aeotec*
Five (5)	*Aeotec 7 zwave stick*
Four (4)	*Sonoff Zigbee Stick*
Three (3)	*Mco CO_2 sensor*
Seven (7)	*Qubino 3 phase smart meter*
Five (5)	*Tuya CO_2 Sensor*
Three (3)	Aqara zigbee multisensor

Moreover, to ensure seamless connectivity and data transmission, routers have been strategically placed on each floor, facilitating uninterrupted internet access for the sensor and raspberry pi network. Additionally, safety measures have been incorporated, with fuses installed at the electrical panel on each floor, reinforcing the integrity and reliability of the electrical infrastructure.

In conclusion, the deployment of this sophisticated sensor network underscores a commitment to innovation, sustainability, and enhanced quality of life within this residential environment. By harnessing the power of advanced technology and data-driven insights, we aim to create smarter, more efficient living spaces that prioritize occupant comfort, safety, and resource optimization.

Figure 45: Fuses at the Electrical Panel(RH), Raspberry Pi and Router installation

6.1.3 DATA ACQUISITION SYSTEM

In order to achieve comprehensive data acquisition and management, the Orion Context Broker, implemented through FIWARE, plays a pivotal role in aggregating and orchestrating data streams from diverse sources within the residential building. This open-source framework enables efficient handling of context information, allowing for real-time processing and seamless integration with various IoT devices and sensors.

Through the utilization of Python scripts, the collected data, encompassing temperature, humidity, CO_2 levels, and energy consumption readings from the deployed sensors, are seamlessly transmitted to the Orion Context Broker. This intermediary serves as a central hub for data management and distribution, facilitating the flow of information between the sensor network and downstream applications.

Subsequently, leveraging the capabilities of CrateDB, a distributed SQL database management system, the aggregated sensor data is persistently stored and organized for further analysis and retrieval. CrateDB's scalability and performance ensure reliable storage and retrieval of large volumes of time-series data, effectively supporting the demands of real-time IoT applications.

To visualize and analyse the acquired data in a user-friendly manner, Grafana, an open-source analytics and monitoring platform, is employed. Grafana enables the creation of customizable dashboards, allowing stakeholders to gain actionable insights into various aspects of the residential environment, including temperature trends, humidity fluctuations, CO_2 levels, and energy consumption patterns. By leveraging Grafana's intuitive interface and powerful visualization capabilities, stakeholders can make informed decisions regarding climate control, resource optimization, and overall building management.

Grafana, CrateDB and Orion Context Broker are all installed through docker and are running continuously, forming a robust pipeline that enables seamless data acquisition, storage, analysis and visualization.

Figure 46: Visualization of Temperature ,Humidity and CO_2 levels at Hallway 1 with Grafana

6.1.4 RESULTS ANALYSIS

The monitoring will run until the construction initiation date. The results analysis of the monitoring baseline data will be possible at the end of this period. This analysis will be presented in Task 4.6 “Impact assessment and evaluation of the performance”.

			M11	M12	M13	M14	M15	M16	M17	M18	M19	M20	M21	M22
Tasks	**Leader**	Supporting	Sept. 2023	Oct. 2023	Nov. 2023	Dec. 2023	Jan. 2024	Febr. 2024	Mar. 2024	Apr. 2024	May. 2024	June. 2024	July 2024	Aug. 2024
Material Orders	CERTH													
Material Purchase Installation	CERTH	DUTH												
Gateway Integration and Testing	CERTH													
Interconnectivity Integration and testing (correspoding to Task 3.4)	CERTH													
Monitoring (corresponding to Task 3.4)	CERTH													

Figure 47: Gantt Chart for the Baseline Monitoring Period, with the completed and ongoing tasks

6.1.5 CALCULATED BASELINE KPIS

The first analysis and calculation are presented in the following table. For the other baseline KPIs (In process), the end of the monitoring period is needed for the calculation. The complete table will be presented in Task 4.6.

Table 19: Calculated baseline KPI values for the Greek demo-site

KPI Nº	Key performance indicator title [unit]	Baseline Result
KPI01	Thermal resistance of façade walls R value	In process
KPI02	Final energy use for systems of building – Demo site level	185 MWh/yr.

KPI Nº	Key performance indicator title [unit]	Baseline Result
KPI03	Electrical peak power demand reduction from the grid [kW]	In process
KPI04	Primary energy use stage energy performance [kWh/m2/yr.] of building	In process
KPI05	Non-renewable primary energy consumption [kWhep/m²/yr.]	In process
KPI06	SRI score [%] of the whole demo site building	48.7 %
KPI10	Final energy savings [% and kWh/m2*year]	In process
KPI11	Primary energy savings [%]	In process
KPI12	Building Energy rating	In process
RP-KPI12	Energy demand reduction [%]	In process
RP-KPI16	Increase of RES power at demo site level [kWp]	In process
KPI14	Lighting and visual comfort [lux]	In process
KPI15	Improvement of ambient thermal comfort in dwellings	In process
RP-KPI04	Reduction in the Predicted Percentage of Dissatisfied people during occupancy hours [%]	In process
RP-KPI05	Improvement in terms of PMV [Predicted Mean Vote]	In process
RP-KPI06	Reduction in the Sound pressure level in occupied spaces [%]	In process
RP-KPI08	Reduction in the average Formaldehyde and VOCs concentration [%]	In process
RP-KPI09	Reduction in the TVOC concentration (Total Volatile Organic Compound) [%]	In process
KPI21	Lifetime income [€]	In process
KPI26	Operational CO_2 emissions [$kgCO_2eq$/year]	30,204 $kgCO_2eq$
KPI27	Lifetime CO_2 emissions savings [$kgCO_2eq$, $kgCO_2eq$/year]	In process

6.2 Hungarian demo-site

The originally situation of the building is really simple (see the former chapters concerning Hungarian Demo building). Firstly, thermal comfort cannot be high, because of the low thermal resistance of the walls, secondly the indoor air quality is also weak. The reasons of these weakness are the lack of cooling system. During the previous decades the peak temperatures were not as high then as during the last years, and the expectation was also lower. In addition, no commercialized technical solution was available. The second main reason of low air quality is the lack of ventilation. In the former buildings the natural ventilation provided the fresh air manifested by the leakages of the windows. The newer windows are equipped with sealing strips blocking the air from moving between indoor and outdoor sites. These facts resulted in the need to open the window for ventilation unless the air quality getting worse.

There were explored a critical point also in bathroom where the main claim for ventilation was the extreme high relative humidity. The regularly high RH combined with a low thermal wall conditions resulted firm mold growth. The molds are not just the symptom of inadequate structural and technical situation, but could cause further health problem for several persons.

The air quality including temperature humidity VOC etc. was not measured before.

6.2.1 BASELINE MONITORING PLAN FOR THERMAL COMFORT AND INDOOR AIR QUALITY STATUS

Hungarian Demo building is partially renovated industrial building from the early 1900s. As it was described earlier the building has no thermal insulation on the outer wall at all. However, the wall thickness is slightly thicker than that of the newer brick buildings, but the other side the brick was used for building is solid without an insulation air space inside. Thermal loss of the building was calculated 43 kW in heating period, this high value was supplied by 2 times 45 kW natural gas furnaces. The fossil fuel consumption is considerable high, resulting high cost and carbon dioxide consumption. Thermal comfort of the occupants was provided individually regulated heating bodies. The system makes possible to set different temperature room by room, and all occupant could regulate it according to the momentary demand. During the expectation of the demo building it was experienced the temperature were set in higher value than it is normal in a residential home. The supposed reason is that the occupant wanted to compensate the low radiation by the lower surface temperature of the outer walls.

The structure and the parts of the monitoring system is the same as it is described in chapter 5.2.3. Raspberry Pi system collect the data from the sensors and transfer them via VPN system to the CERTH server for logging.

6.2.2 DESCRIPTION OF THE INSTRUMENTATION

Instrumentation of the monitoring system was installed mostly in end of January 2024 and the data collection could start on February, because of some connection problems. There are still some improvements required in the case of several sensors such as gas and water meter and the weather station. These settings are in progress. The table below shows the type and quantity of the built-in sensors the location can be seen in the formerly presented table in chapter 5.2.3.

Table 20: Sensor types and sensor quantities in Hungarian Demo building

Sensor	Measurements	Feature	Pieces
Energy measurement tool	Current & total power measurement, reactive energy measurement, PHI power factor and voltage measurement	Smart ZigBee Energy Meter Single Phase 80A Din Rail	5
Multi sensor	Motion, Vibration, Light, Ultraviolet, Temperature, Humidity Sensors	Aeotec MultiSensor 7	16
Air Quality Sensor	CO_2, VOC, Temperature and Humidity Sensors	MCO Home CO_2 Sensor 12VDC/230VAC	12
Water meter	Consumed water	Flow meter (It will be installed in the near future.)	1
Raspberry Pi 4 KIT	Local data logger and fulfil the function of gateway	Kit=RPi+Supply+Case+Heatsink+SD; Minimum: 4GB RAM, 16GB microSD	7

Sensor	Measurements	Feature	Pieces
Z-Wave stick	Connection	Aeotec Z-Stick	7
Router	Network connection	TP-LINK ER605	1
Natural gas	Consumed gas amount	Flow meter, with impulse counter	1
Weather station	Temperature, humidity, wind speed, solar radiation	Z-Wave	1

In the table can be seen the connection protocol of the sensors. The original solution was RPi net connected to Wi-Fi, and the sensors connected to the RPis either directly or by Z-wave wireless connection protocol.

6.2.3 DATA ACQUISITION SYSTEM

The acquisition of the building data for the Hungarian demo-site is realized by CERTH. This subsection refer directly to the Greek demo-site (subsection 6.1.2).

6.2.4 RESULTS ANALYSIS

The measurement started only in February 2024 and not enough data for a reliable baseline are available for now. For the KPI values of the demo site, we will use partly the bill data of the past years (mainly gas and electricity) and partly the results measured by the meters installed this year. Since the gas meter was only installed properly during the previous weeks to deliver this report (it was installed earlier but did not work well), we will unfortunately only be able to look back at winter gas consumption (which is the most important energy use) from the bills, not from the measurements. The other data will be extracted from the measurements.

Since the measurements will be continuous from now on, we will be able to provide the data from the measurements after the renovation in Task 4.6 “Impacts assessment and evaluation of performance”. Of course, for verification purposes, it will be possible to compare the data with the data from the accounts.

The sensor list and plan with current data is presented below.

Table 21: Sensor list and plan

	SENSOR	WHAT MEASURES?	WHERE?	CODE	RPI	ID	PLACE
Electric 3 Phase	1	Daytime supply	basement electrical cabinet	3/10	3	10	supply cabinet
	2	Night supply	basement electrical cabinet	NO	-	-	NO
	3	Heating, hot water supply	basement electrical cabinet	NO	-	-	NO
	4	RESERVE	-	-	-	-	-
	5	Solar panel production	LATER	-	-	-	-
Multi-sensor	1	Ground floor corridor	Rpi	3/3	3	3	Gr. Fl. corridor

	SENSOR	WHAT MEASURES?	WHERE?	CODE	RPI	ID	PLACE
	2	Ground floor corridor	Rpi	2/4	2	4	Gr. Fl. corri-dor
	3	Upstairs corridor	Rpi	4/5	4	5	Upst. corri-dor
	4	Attic corridor	Rpi	6/2	6	2	Att. corridor
	5	Bath	battery	2/7	2	7	Gr. Fl. Bath
	6	Kitchen	Rpi	2/6	2	6	Gr. Fl. Kitchen
	7	attic room	Rpi	7/3	7	3	300 room
	8	attic room	CO_2 common plug II	6/4	6	4	311 room
	9	attic room	battery	7/4	7	4	302 room
	10	room upstairs	CO_2 common plug II	4/6	4	6	211 room
	11	room upstairs	CO_2 common plug II	5/3	5	3	200 room
	12	room upstairs	battery	5/5	5	5	204 room
	13	room ground floor	Rpi	2/8	2	8	113 room
	14	room ground floor	CO_2 common plug II	3/7	3	7	104 room
	15	room ground floor	battery	3/6	3	6	103 room
	16	Outside	CO_2 common plug II	3/8	3	8	Outside
CO_2 VOC	1	Ground floor corridor	Rpi	3/4	3	4	Gr. Fl. corri-dor
	2	Ground floor corridor	Rpi	2/3	2	3	Gr. Fl. corri-dor
	3	Upstairs corridor	Rpi	4/4	4	4	Upst. corri-dor
	4	Attic corridor	Rpi	6/3	6	3	Att. corridor
	5	Kitchen	Rpi	2/5	2	5	Gr. Fl. Kitchen
	6	attic room	Rpi	6/5	6	5	311 room
	7	attic room	Multi common plug II	7/2	7	2	300 room
	8	room upstairs	Multi common plug II	4/7	4	7	211 room
	9	room upstairs	Multi common plug II	5/4	5	4	200 room
	10	room ground floor	Rpi	None			None
	11	room ground floor	Multi common plug II	3/5	3	5	103 szoba
	12	Outside	Multi common plug II	3/9	3	9	Outside
Water	1	Water	Cellar - LATER	-	-	-	-
Gas	1	Gas	Cellar - LATER	-	-	-	-

	SENSOR	WHAT MEASURES?	WHERE?	CODE	RPI	ID	PLACE
Weather	1	Temperature, humidity, wind, etc.	Roof	-	-	-	-

Figure 48: Some photos of sensors and measuring instruments.

6.2.5 CALCULATED BASELINE KPIS

The first analysis and calculation are presented in the following table. For the other baseline KPIs (In process), the end of the monitoring period is needed for the calculation. The complete table will be presented in Task 4.6.

Table 22: Calculated baseline KPI values for the Hungarian demo-site

KPI Nº	Key performance indicator title [unit]	Baseline Result
KPI01	Thermal resistance of façade walls R value	In process
KPI02	Final energy use for systems of building – Demo site level	163 MWh/yr.
KPI03	Electrical peak power demand reduction from the grid [kW]	In process
KPI04	Primary energy use stage energy performance [kWh/m2/yr.] of building	In process
KPI05	Non-renewable primary energy consumption [kWhep/m²/yr.]	In process
KPI06	SRI score [%] of the whole demo site building	16.3 %
KPI10	Final energy savings [% and kWh/m2*year]	In process
KPI11	Primary energy savings [%]	In process

KPI Nº	Key performance indicator title [unit]	Baseline Result
KPI12	Building Energy rating	In process
RP-KPI12	Energy demand reduction [%]	In process
RP-KPI16	Increase of RES power at demo site level [kWp]	0 kW. We do not have a renewable energy source now, but will have one after the renovation (PV).
KPI14	Lighting and visual comfort [lux]	In process
KPI15	Improvement of ambient thermal comfort in dwellings	In process
RP-KPI04	Reduction in the Predicted Percentage of Dissatisfied people during occupancy hours [%]	In process
RP-KPI05	Improvement in terms of PMV [Predicted Mean Vote]	In process
RP-KPI06	Reduction in the Sound pressure level in occupied spaces [%]	In process
RP-KPI08	Reduction in the average Formaldehyde and VOCs concentration [%]	In process
RP-KPI09	Reduction in the TVOC concentration (Total Volatile Organic Compound) [%]	In process
KPI21	Lifetime income [€]	In process
KPI26	Operational CO_2 emissions [kgCO_2eq/year]	38,967 kgCO_2eq
KPI27	Lifetime CO_2 emissions savings [kgCO_2eq, kgCO_2eq/year]	In process

6.3 French demo-site

6.3.1 BASELINE MONITORING PLAN FOR THERMAL COMFORT AND INDOOR AIR QUALITY STATUS

The following table gives the KPIs regarding the thermal comfort and air quality initial status that have been selected for the French demo-site with the associated measurement and devices. This table is extracted from the building operation monitoring programme (D3.4). The KPIs are defined in D3.2.

Table 23: Thermal comfort and air quality initial status KPIs for the French demo-site

Indoor environmental/comfort conditions				
Ambient temperature and indoor relative humidity	KPI15	Temperature and relative humidity sensor	1 sensor per dwelling or 1 sensor per room (living room and 1 bedroom)	Only in 3 dwellings (to be defined with the building owner)
CO_2 concentration	KPI15	CO_2 sensor	1 sensor per dwelling	Only in 3 dwellings (to be defined with the building owner)

Indoor environmental/comfort conditions				
TVOC concentration	RP-KPI09	TVOC sensor	Several sensors per demo site building	Only in 3 dwellings (to be defined with the building owner)
CO, PM concentration	RP-KPI10	PM sensor	Several sensors per demo site building	Only in 3 dwellings (to be defined with the building owner)
Luminosity	KPI14	Luxmeter	1 sensor per dwelling	Only in 3 dwellings (to be defined with the building owner)
Acoustic performance	RP-KPI06	Noise meter	Several sensors per demo site building	Only in 3 dwellings (to be defined with the building owner)

6.3.2 DESCRIPTION OF THE INSTRUMENTATION

No instrumentation was initially in the building. The sampling of monitored apartments has been defined to three instrumented dwellings. The following table gives the description of the instrumentation that have been defined in this task for the installation.

Table 24: Description of the instrumentation for the French demo-site

MEASURED VARIABLE	UNIT	LOCALISATION	QUANTITY	BRAND	REFERENCE	COMMUNICATION PROTOCOL
Temperature	°C	Living room / Bedroom	2	Nano Sense	EP5000	ENOCEAN
Humidity	RH %	Living room / Bedroom	2	Nano Sense	EP5000	ENOCEAN
CO_2	ppm	Living room / Bedroom	2	Nano Sense	EP5000	ENOCEAN
VOC (totals)	µ·g/m3	Living room / Bedroom	2	Nano Sense	EP5000	ENOCEAN

MEASURED VARIABLE	UNIT	LOCALISATION	QUANTITY	BRAND	REFERENCE	COMMUNICATION PROTOCOL
PM 10, 2,5 1 (CO)	ppm	Living room / Bedroom	2	Nano Sense	EP5000	ENOCEAN
Luminosity	lux	Living room / Bedroom	2	Nano Sense	EP5000	ENOCEAN
Acoustic performance	dB	Living room / Bedroom	2	Nano Sense	EP5000	ENOCEAN
Window opening detection sensor		Living room / Bedroom / Kitchen	3	Fibaro	Opening detector	Z-Wave+

6.3.3 DATA ACQUISITION SYSTEM

Regarding the digital acquisition, the sensors are connected to a specific data acquisition system/gateway, based on a mini-PC system (Jeedom type) and TP link to transmit data to CEA servers.

The analogical sensors are connected to a central acquisition unit (Agilent type). The central acquisition is also connected to mini-PC system like a Jeedom and a TP link. The following figure describes the general architecture.

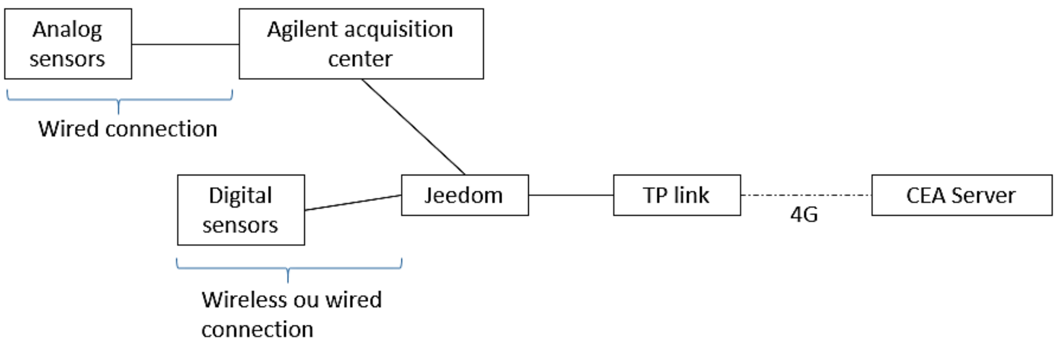


Figure 49: Data acquisition architecture at the French demo site

The gateway collect the data of sensors and meters and send it to software gateway platform situated at a private IP address and to Digital Building Logbook of the REHOUSE project once it is deployed. The specifications of the Digital Building Logbook will be defined into the D3.5. Open Specifications framework for the definition of Building logbook, BIM models, Digital Twins and the Building Renovation Passports. The data from this platform (if available) could be exported at the next file extensions: *.csv

6.3.4 RESULT ANALYSIS

The equipment installation is under finalization. From April 2024, the monitoring will run until the construction initiation date, which is now planned for September 2024. The results analysis of the monitoring baseline data will be possible at the end of this period. This analysis will be presented in Task 4.6.

Tasks	M16 Febr. 2024	M17 Mar. 2024	M18 Apr. 2024	M19 May. 2024	M20 June. 2024	M21 July 2024	M22 Aug. 2024	M23 Sept. 2024
Material installation								
Monitoring								
Construction initiation								

Figure 50: Monitoring baseline period

6.3.5 CALCULATED BASELINE KPIS

The first analysis and calculation are presented in the following table. For the other baseline KPIs (In process), the end of the monitoring period is needed for the calculation. The complete table will be presented in Task 4.6.

Table 25: Calculated baseline KPI values for the French demo-site

KPI Nº	Key performance indicator title [unit]	Baseline Result
KPI01	Thermal resistance of façade walls R value	Baseline: 1,339 W/m²K (from simulation)
KPI02	Final energy use for systems of building – Demo site level – [kWh/yr.]	Gas: 250,000 kWh (year 2021)
	Final energy use for systems of building – Dwelling level – [kWh/yr.]	Gas: 12,500 kWh (year 2021)
KPI04	Primary energy use stage energy performance [kWh/m²/yr.] of building	Heating, DHW, cooking: 185.2 kWh/m2/yr.
KPI06	SRI score [%] of the whole demo site building	15 %
KPI12	Building Energy rating	Class D (estimated from the building consumption)
KPI14	Lighting and visual comfort [lux]	In process
KPI15	Improvement of ambient thermal comfort in dwellings	In process
RP-KPI04	Reduction in the Predicted Percentage of Dissatisfied people during occupancy hours [%]	In process
RP-KPI05	Improvement in terms of PMV [Predicted Mean Vote]	In process
RP-KPI06	Reduction in the Sound pressure level in occupied spaces [%]	In process

KPI Nº	Key performance indicator title [unit]	Baseline Result
RP-KPI08	Reduction in the average Formaldehyde and VOCs concentration [%]	In process
RP-KPI09	Reduction in the TVOC concentration (Total Volatile Organic Compound) [%]	In process
RP-KPI10	Reduction in CO, PM concentration [%]	In process
KPI26	Operational CO_2 emissions [kgCO_2eq/year]	56,750 kgCO_2eq (year 2021)

6.4 Italian demo-site

6.4.1 BASELINE MONITORING PLAN FOR THERMAL COMFORT AND INDOOR AIR QUALITY STATUS

The Italian demo site is a social housing building located at Margherita di Savoia consisting of 8 dwellings where no instrumentation was initially present in the building.

The baseline monitoring plan, as already anticipated in D3.2 and D3.4, has foreseen the definition of an ex-ante pre-monitoring baseline one for the summertime period from 10th August till the 10th September 2023 – labelled as **Pre-monitoring Period #1** – and one fort he wintertime period from the 14th December 2023 – labelled as **Pre-monitoring Period #2** – and still ongoing at the moment we are editing this report.

With reference to **Pre-monitoring Period #1** baseline only four dwellings (namely units 2, 4, 5, and 8) were included for the baseline creation (see Figure 51, Figure 52, Figure 53, and Figure 54 below).

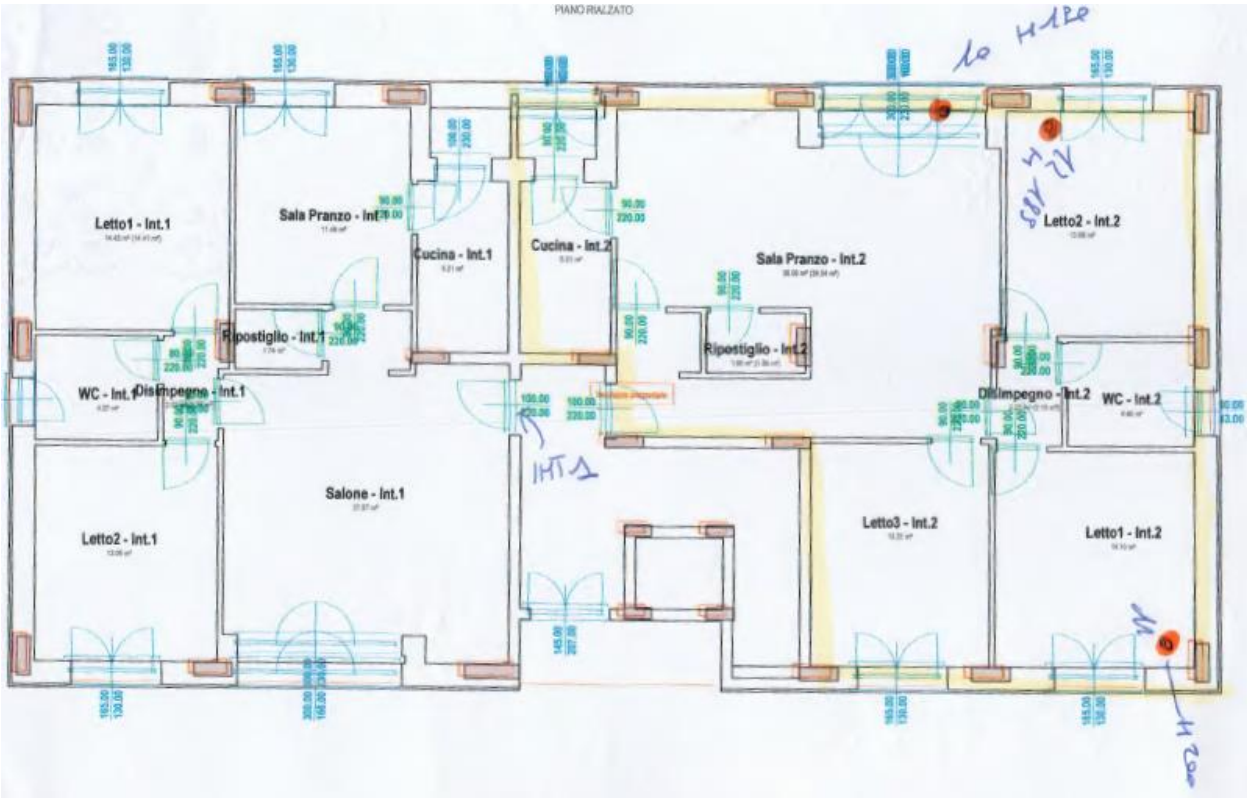


Figure 51 - Pre-monitoring Period #1 - Unit 2

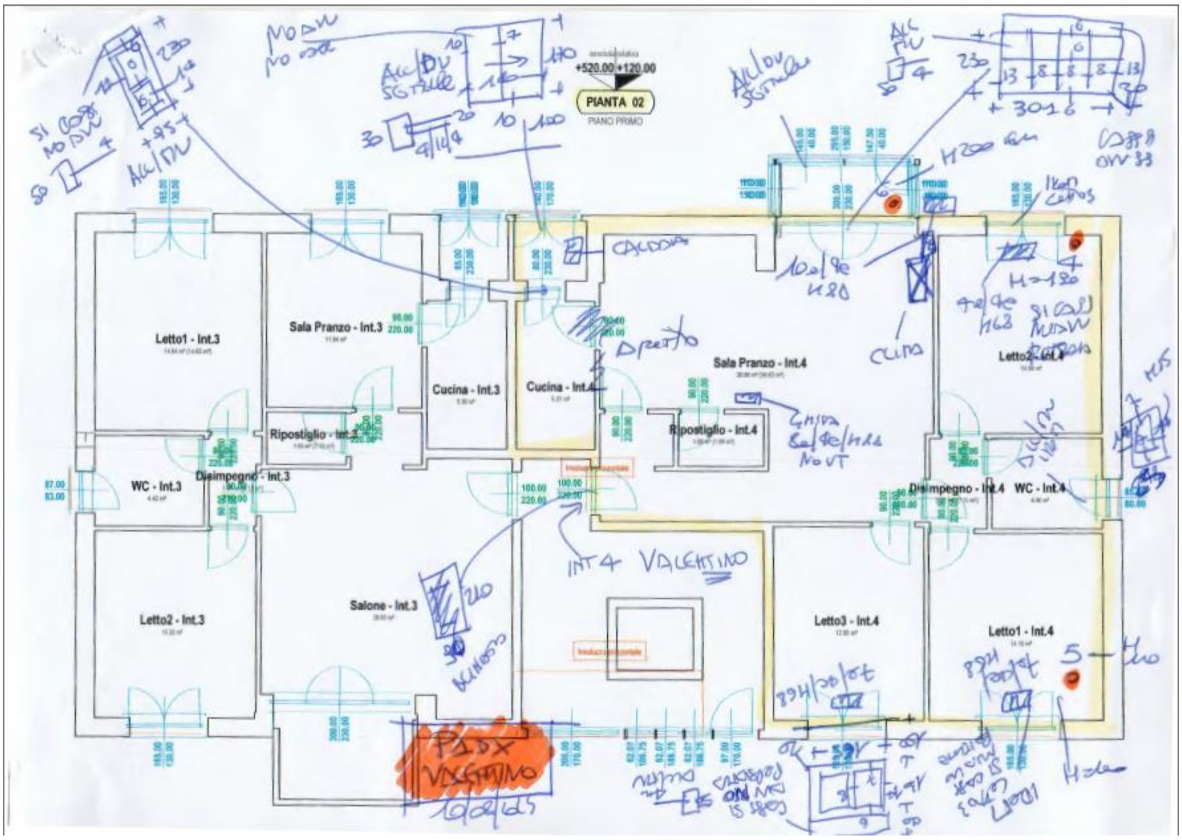


Figure 52 - Pre-monitoring Period #1 - Unit 4

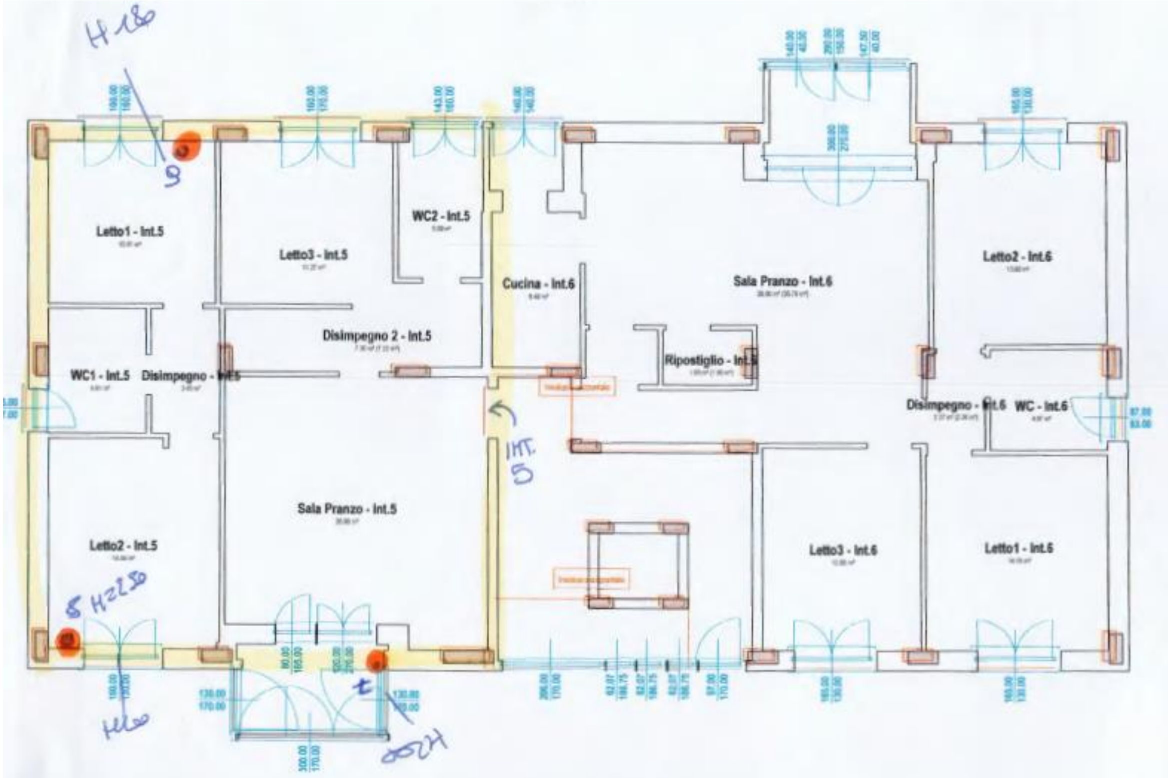


Figure 53 - Pre-monitoring Period #1 - Unit 5

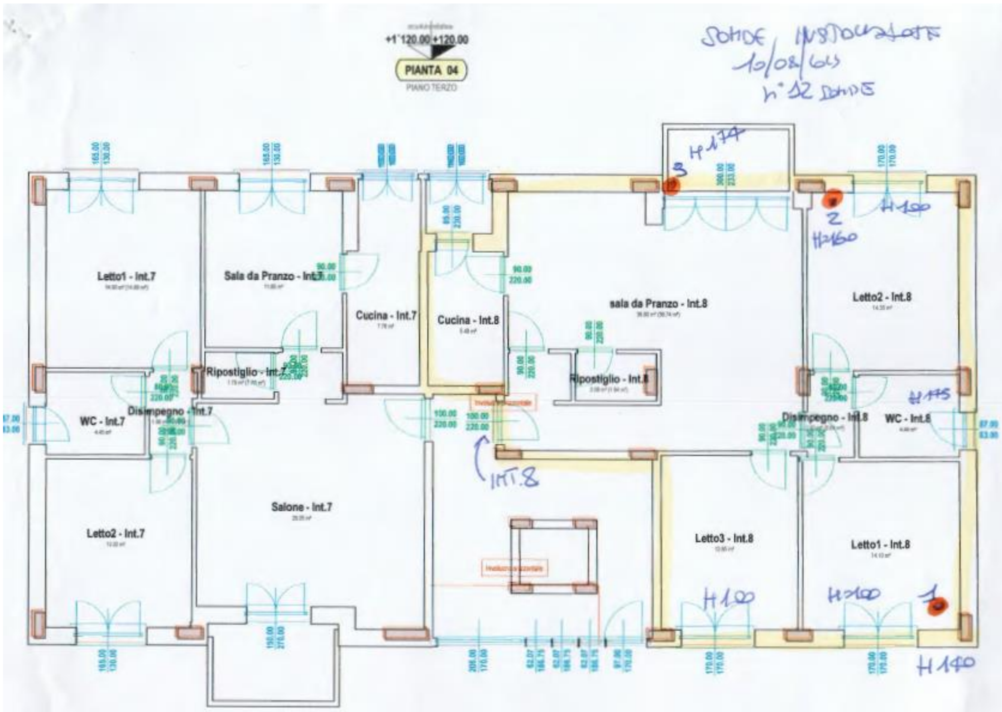


Figure 54 - Pre-monitoring Period #1 - Unit 8

Regarding the setup of the **Pre-monitoring Period #2 baselines,** still four dwellings were considered in the research activity, but different units were involved at this time (namely units 1, 5, 6, and 8) as shown in Figure 55, Figure 56, Figure 57, and Figure 58.

Figure 55 - Pre-monitoring Period #2 - Unit 1

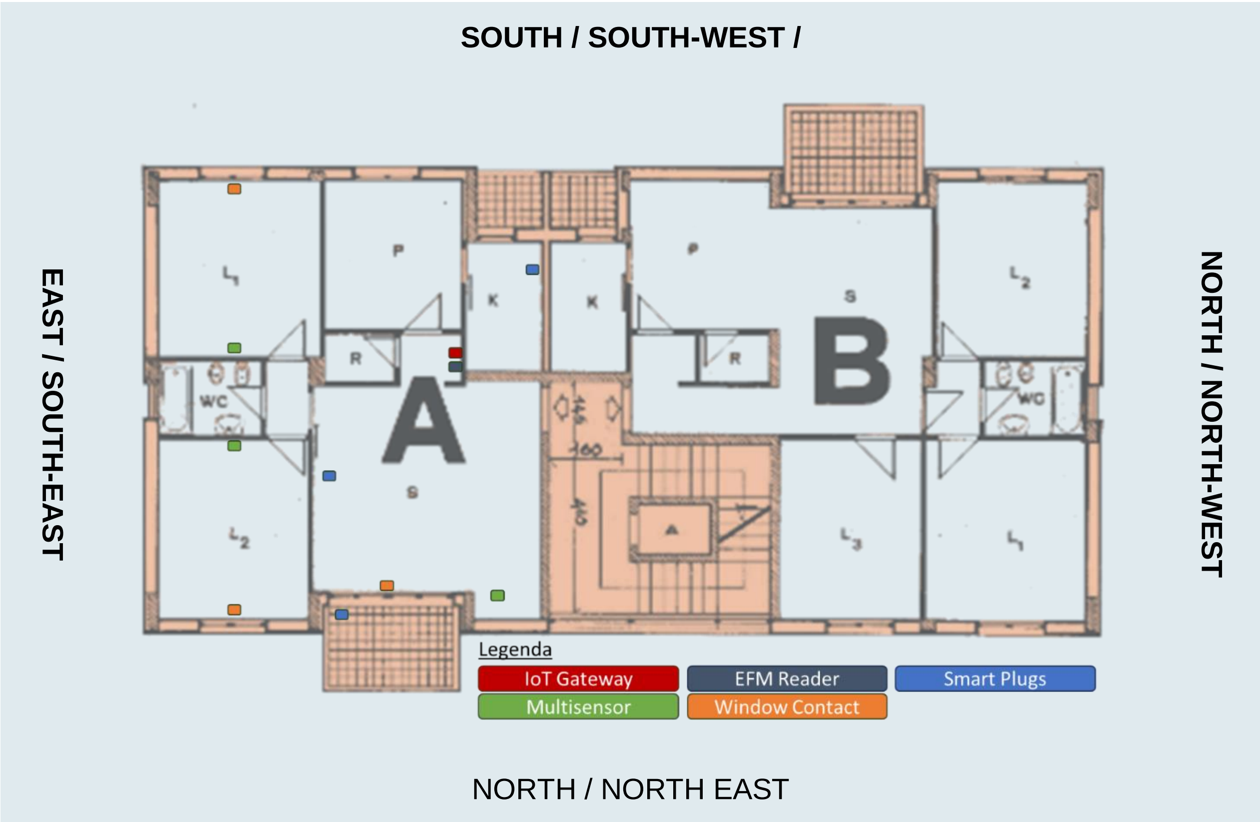


Figure 56 - Pre-monitoring Period #2 - Unit 5

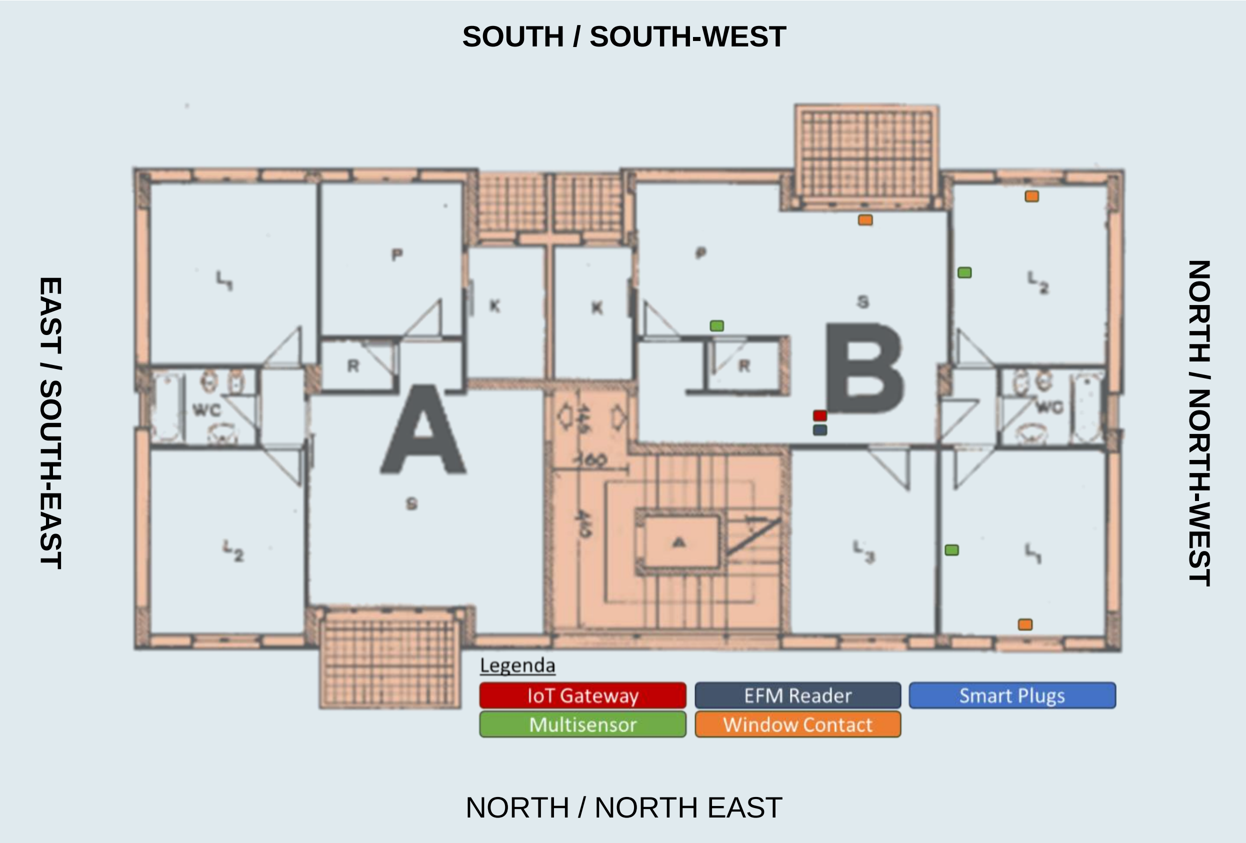


Figure 57 - Pre-monitoring Period #2 - Unit 6

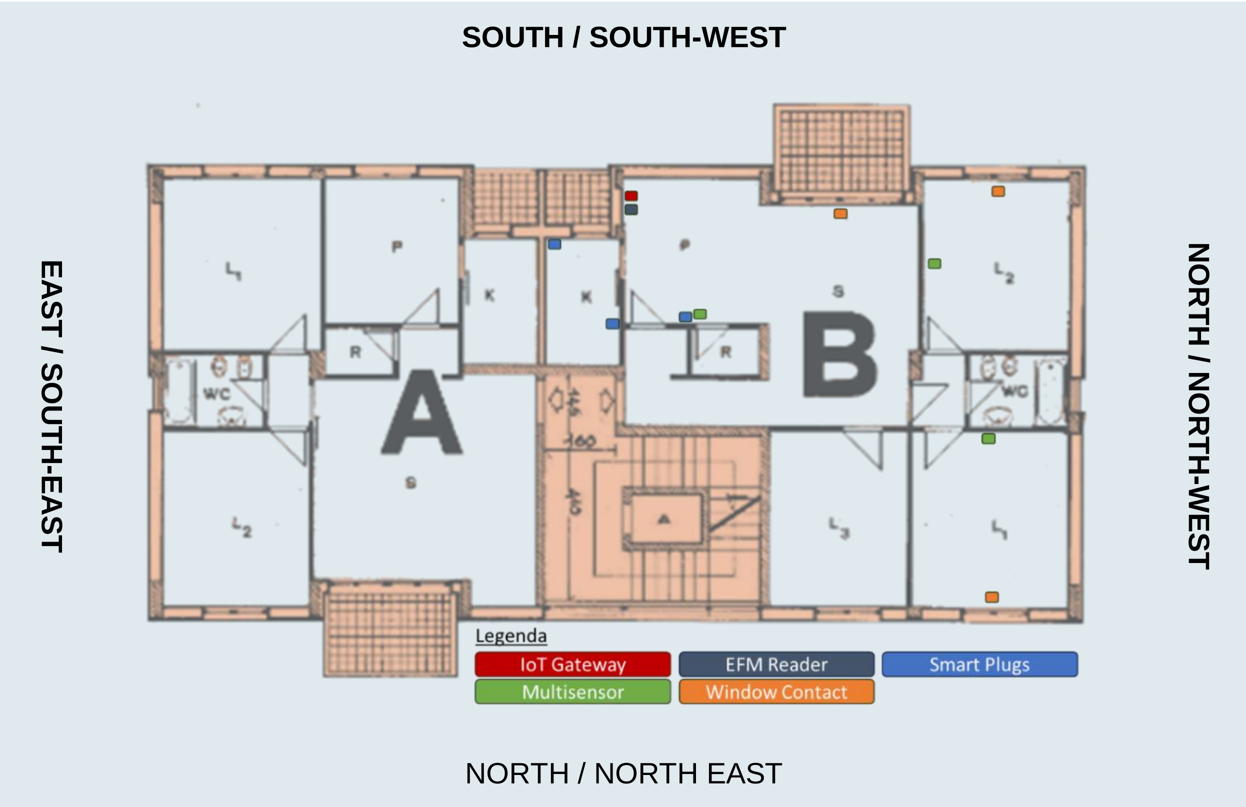


Figure 58 - Pre-monitoring Period #2 - Unit 8

6.4.2 DESCRIPTION OF THE INSTRUMENTATION

The instrumentation used for the definition of **Pre-monitoring Period #1** consists of the provisioning of twelve TROTEC BL30 serving four dwellings (three probes were installed in each unit). The BL30 climate data logger reliably measures and documents air temperature and humidity and can be used to collect up to 32,000 measuring values in intervals and cycles selected by the users. This specific instrumentation – and the data gathered by such data logger - was provided to REHOUSE by an external organisation subcontracted by TERA specifically for supporting the project in the definition of a valuable and usable summertime period baseline.

The measured variables, as it can easily retrieved from what stated above an summarised in table below, are temperature (°C) and relative humidity (RH%) collected from two indoor spaces (living room and bedroom) and one outdoor space (balcony) at each of the four dwellings selected and involved in this phase of the project.

Table 26: Measured variables for the Italian demo-site

MEASURED VARIABLE	UNIT	LOCALISATION	QUANTITY	BRAND	REFERENCE	COMMUNICATION PROTOCOL
Temperature	°C	Living room / Bedroom #1 / Outdoor (Balcony)	4	TROTEC	BL30	n/a (standalone datalogger)
Humidity	RH %	Living room / Bedroom #1 /Outdoor (Balcony)	4	TROTEC	BL30	n/a (standalone datalogger)

The definition of the wintertime baseline – useful to support also the definition of the renovation baseline that will commence in July 2024- as seen the identification and following installation of a valuable set of interoperable Wi-Fi sensors – to be efficiently connected to the data acquisition system – aiming at reducing disruption and discomfort for social housing users while guaranteeing a reliable monitoring system. The list of sensors consisting of the **Environment Multi-sensor (temperature, relative humidity, movement, brightness, UV and vibration) from Aeotec** and the **door/window sensor from FIBARO** is summarised in table below.

Table 27: Description of the instrumentation for the Italian demo-site

MEASURED VARIABLE	UNIT	LOCALISATION	QUANTITY	BRAND	REFERENCE	COMMUNICATION PROTOCOL
Temperature	°C	Living room / Bedroom #1 / Bedroom #2 / Kitchen	Up to 4	AEOTEC	ZW100-C	Zwave
Humidity	RH %	Living room / Bedroom #1 / Bedroom #2 / Kitchen	Up to 4	AEOTEC	ZW100-C	Zwave
Luminosity	lux	Living room / Bedroom #1 / Bedroom #2 / Kitchen	Up to 4	AEOTEC	ZW100-C	Zwave
Ultraviolet	UV	Living room / Bedroom #1 / Bedroom #2 / Kitchen	Up to 4	AEOTEC	ZW100-C	Zwave

Window opening detection sensor		Installed in a subset locations from the group above	Up to 4	FIBARO	FGDW-002 ZW5	Zwave+

The positioning and commissioning of the above sensors, dated 14th December 2023, are further detailed including ID/MAC address of each device (considering also the IoT gateway used as data acquisition module, the electrical fiscal meter reader, and few smart plugs used for measuring electrical loads from white goods and/or appliances), exact location in the dwelling, and height from the floor (expressed in [cm]) as for the reporting tables below.

Unit: n. #1 (A) | Floor: #1 | Number of Resident(s): #2 | POD: IT001E72089283

Table 28: Description of the instrumentation – Dwelling 1A

Device Type/Model	ID | MAC Address	Room	Height from the floor [cm]
Gateway/datalogger: Beeta™ Box	1 | MAC: 6737B7	S	30 (behind TV)
Electrical Fiscal Meter Reader: SMART INFO P520	17SMI5FC3000006 34	S	30 (behind TV)
Multisensor #1	MULM_1A | #10	L2	145
Multisensor #2	MULM_1B | #11	-	-
Multisensor #3	MULM_1C | #12	-	-
Multisensor #4	MULM_1D | #13	-	-
SmartPlug #1	SM_1A | #14	P	10 (fridge)
SmartPlug #2	SM_1C | #15	K	145 (washing machine)
SmartPlug #3	SM_1B | #16	-	-
Window contact sensor #1	CON_1A | #17	L2	210
Window contact sensor #2	CON_1B | #18	L1	210
Window contact sensor #3	CON_1C | #19	-	-
Positioning and commissioning performed by:			**Andrea Cavallaro**
Date and Time			**14/12/2023 at 12:30**

Unit: n. #5 (A) | Floor: #3 | Number of Resident(s): #2 | POD: IT001E72089053

Table 29: Description of the instrumentation – Dwelling 5A

Device Type/Model	ID | MAC Address	Room	Height from the floor [cm]
Gateway/datalogger: Beeta™ Box	3 | MAC: 673855	P	20
Electrical Fiscal meter reader: SMART INFO P520	17SMI5FC3000057 56	P	20
Multisensor #1	MULM_3A | #08	L1	150

Device Type/Model	ID | MAC Address	Room	Height from the floor [cm]
Multisensor #2	MULM_3B | #09	P	160
Multisensor #3	MULM_3C | #10	-	-
Multisensor #4	MULM_3D | #11	L2	160
SmartPlug #1	SM_3A | #12	S	120 (oven)
SmartPlug #2	SM_3C | #13	S	180 (dryer)
SmartPlug #3	SM_3B | #14	K	120 (washing machine)
Window contact sensor #1	CON_3A | #15	L1	210
Window contact sensor #2	CON_3B | #16	L2	210
Window contact sensor #3	CON_3C | #17	S	210
Positioning and commissioning performed by:			**Andrea Cavallaro**
Date and Time			**14/12/2023 at 14:40**

Unit: n. #6 (B) | Floor: #3 | Number of Resident(s): #4 | POD: IT001E72089052

Table 30: Description of the instrumentation – Dwelling 6B

Device Type/Model	ID | MAC Address	Room	Height from the floor [cm]
Gateway/datalogger: Beeta™ Box	4 | MAC: 673756	S	70
Electrical Fiscal meter reader: SMART INFO P520	17SMI5FC3000060 43	S	100
Multisensor #1	MULM_4A | #11	L1	150
Multisensor #2	MULM_4B | #12	P	160
Multisensor #3	MULM_4C | #13	L2	160
Multisensor #4	MULM_4D | #14	-	-
SmartPlug #1	SM_4A | #15	-	-
SmartPlug #2	SM_4C | #16	-	-
SmartPlug #3	SM_4B | #17	-	-
1	CON_4A | #18	S	210
Window contact sensor #2	CON_4B | #19	L2	210
Window contact sensor #3	CON_4C | #20	L1	210
Positioning and commissioning performed by:			**Andrea Cavallaro**
Date and Time			**14/12/2023 at 13:20**

Unit: n. #8 (B) | Floor: #4 | Number of Resident(s): #2 | POD: IT001E72089050

Table 31: Description of the instrumentation – Dwelling 8B

Device Type/Model	ID | MAC Address	Room	Height from the floor [cm]
Gateway/datalogger: Beeta™ Box	5 | MAC: 6737AF	P	30 (behind TV)
Electrical Fiscal meter reader: SMART INFO P520	17SMI5FC3000048 07	P	30 (behind TV)
Multisensor #1	MULM_5A | #11	P	160
Multisensor #2	MULM_5B | #12	L2	160
Multisensor #3	MULM_5C | #13	-	-
Multisensor #4	MULM_5D | #14	L1	170
SmartPlug #1	SM_5A | #16	K	170 (washing machine)
SmartPlug #2	SM_5C | #17	K	10 (fridge)
SmartPlug #3	SM_5B | #18	P	30 (portable heater)
Window contact sensor #1	CON_5A | #19	L1	210
Window contact sensor #2	CON_5B | #20	L2	210
Window contact sensor #3	CON_5C | #21	S	210
Positioning and commissioning performed by:			**Andrea Cavallaro**
Date and Time			**14/12/2023 at 14:10**

6.4.3 DATA ACQUISITION SYSTEM

The need to create a valuable and long-lasting winter baseline plus the creation of a renovation baseline, as seen a strong effort put in place by TERA to support the Italian demo ecosystem. With this regard, and anticipating some technical enhancement of their own IoT edge computer planned for the second half of the project, TERA as designed, developed, and released a new functionality consisting on a data logger feature.

The Wi-Fi sensors have been connected to a specific data acquisition system/gateway, BeetaTM Box (hereinafter BeetaBox) that is an edge computer designed for indoor IoT ecosystems. It is based on LINUX Embedded platform, which allows implementing software solutions which can run in a standalone mode or interfaced to remote web services. The use of standardized protocols and communication interfaces makes this electronic control unit an unprecedented multi-protocol gateway and allows full configurability, modularity, and scalability of BeetaBox, whose embedded SW can be upgraded remotely (OTA). This feature is of great value for the maintenance and upgrading of the BeetaBox to ensure that the number of devices and protocols supported are compatible and aligned with the market evolutions.

It can be used in combination with third party software platforms/tools/frameworks for the implementation of an integrated management and control systems, in applications like Smart Home (Behind the meter), Smart Metering, asset management, (Building/Energy Management System), Smart Grid services, security, automation.

BeetaBox is an edge computer characterised by a range of factures, performances and communication interfaces that is one of a kind, being however able to be customise for different applications, configuring its equipment from the top of the range up to ad-hoc versions (outfitting).

BeetaBox is based on ARM Cortex A7 processor, with several embedded IoT wireless modules (Wi-Fi, 802.15.4, Bluetooth, Z-wave, WM-Bus 169MHz, NB-IoT or 868MHz LoRaWAN) and wired connectivity like RS485 (e.g., Modbus, Sunspec and others for photovoltaic/battery management inverters etc.), Gigabit Ethernet (Bacnet, Modbus, KNX, Daikin, etc.), USB, S0 and dedicated I/O (Dry Contact, Open Collector).

Moreover additional 3 USB ports cab be used to easily expand the BeetaBox to include modules like GPRS/UMTS/4G, etc… The available I/Os, make it possible also to get data from smart meter directly or to drive load or boiler through relay modules.

BeetaBox has also internal devices such as sensors for Temperature, Rh and air pressure, microphones, speakers and an optional Trusted Platform Module (TPM 1.2) soldered chip; sensors can be used in combination to visual and acoustic embedded actuators for smart feedback to the users.

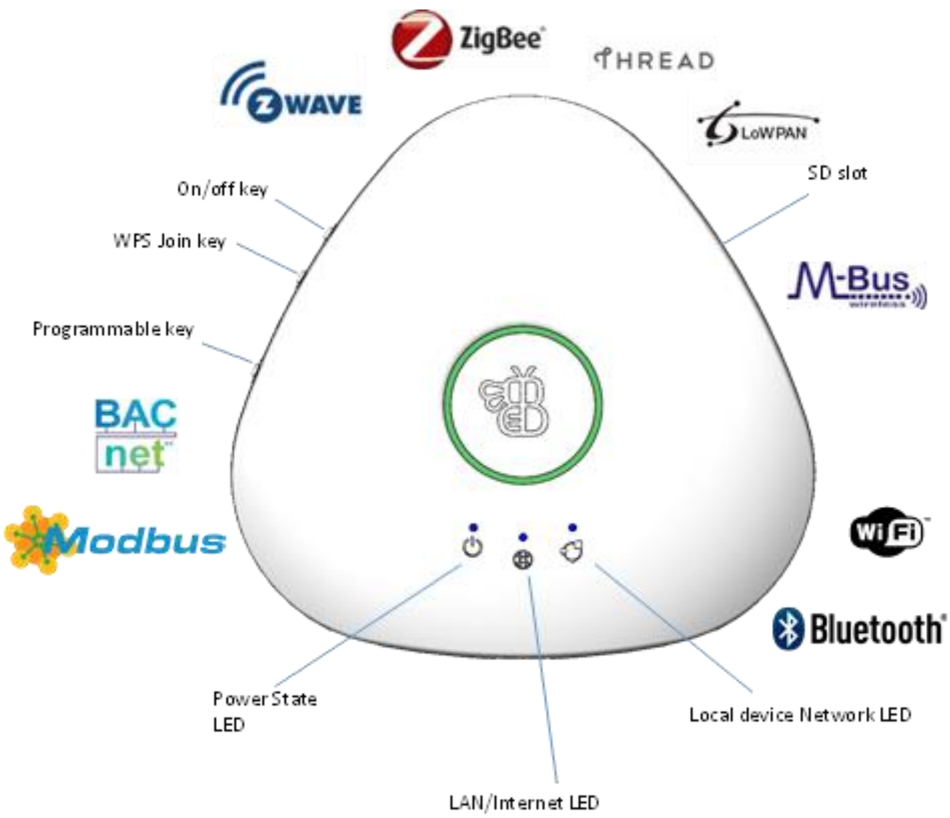


Figure 59 - BeetaBox IoT edge computing gateway front face

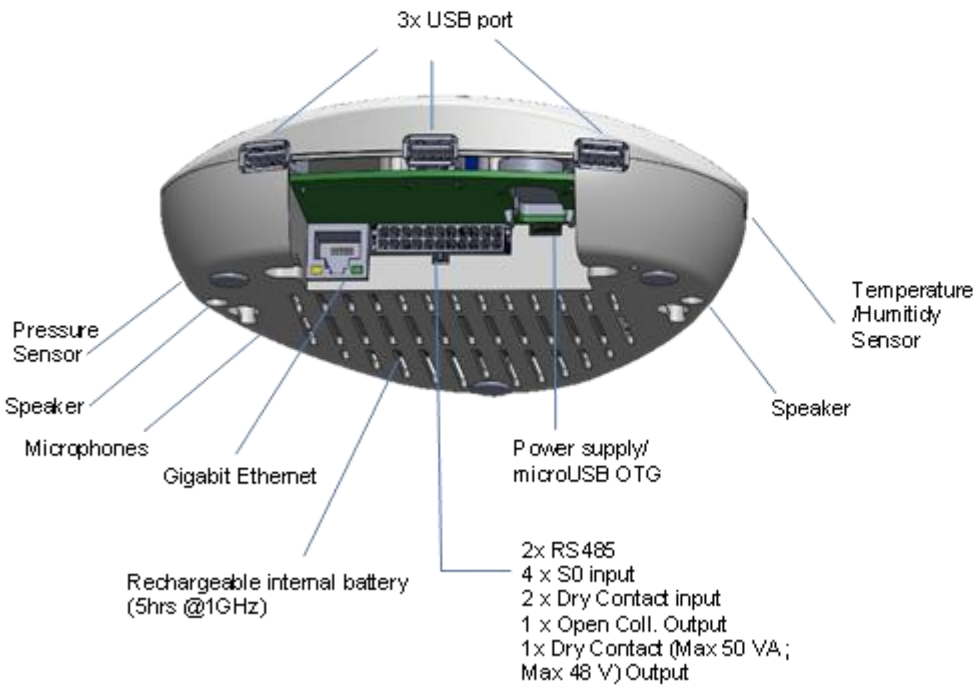


Figure 60 - BeetaBox IoT edge computing gateway rear face

The BeetaBox is able to receive and store the data provided by the smart meters “1G” and “2G” installed in by e-Distribuzione (the main Distributor in Italian electricity grid and in some other countries) via Power Line, connected via USB port:

- in "A" band, when connected to devices such as the e-distribution "Smart Info" (or other devices equipped with an e-distribution "MOME" card, such as the Beeta Power in the MOME version), communicating with the first-generation counters (also called "1G", for example GEM, GEMIS) or even with 2G generation meters (2.1), enabled to send data on band "A";
- in band "C", when connected with devices such as the Beeta Power "2G" version, in this case communicates only with the "second generation" meters, or "2.0 electronic meters" or "smart meter 2.0", or simply "2G" (e.g., models CEG2, CE2G, "gen2"); it should be noted that, for those of the second generation, new features will be activated which are currently being tested.

As a powerful edge computer, there are several options in using BeetaBox:

a. without SW: customer/partner installs Linux and other SW tools;
b. equipped with pre-installed Linux arranged and tuned by us (ArmBian); several open-source software tools and frameworks can be used, like NodeRed, Home Assistant etc.
c. equipped with pre-installed Linux arranged and tuned by us (ArmBian) plus a middleware (OSGI compliant) customized by TERA and some "drivers" developed by TERA;
d. equipped with pre-installed Linux arranged and optimized by us (ArmBian) plus some middleware (OSGI compliant) customized by TERA and some "drivers" developed by Tera, including MQTT configured to send data to an MQTT broker (a sort of "IoT" platform " that some potential partners have);
e. equipped with pre-installed Linux arranged and optimized by us (ArmBian) **plus “FIN FRAMEWORK” (by J2 Innovation- A Siemens Company);** thanks to FIN framework is compliant with the open-source initiative Project Haystack to streamline working with data from the Internet of Things.

In this initial Pre-monitoring - Period #2, the gateway will only act as a data logger – a dedicated feature designed for REHOUSE project purposes since no internet connectivity is available at both building and dwelling level – retrieving and collecting the data of sensors and meters and store it inside its 128 GB microSDHC internal memory. The acquired data from the IoT gateway acting as a data logger could be exported at the next file extensions: *.json. To facilitate project partners data manipulation, TERA will develop a software module for parsing *.json data file to *.csv or *.xlsx file.

6.4.4 RESULTS ANALYSIS

6.4.4.1 PRE-MONITORING PERIOD #1

The monitored data - from each of the four-dwelling involved at the stage of the project - has been acquired at the sample rate of 180 seconds during **Pre-monitoring Period #1** and stored in the data logger. The data from units 2, 4, 5, and 8 has been clustered at unit level and presented in sections below.

6.4.4.1.1 UNIT: N. #2 (B) | FLOOR: #1 | NUMBER OF RESIDENT(S): #1

Room: L1

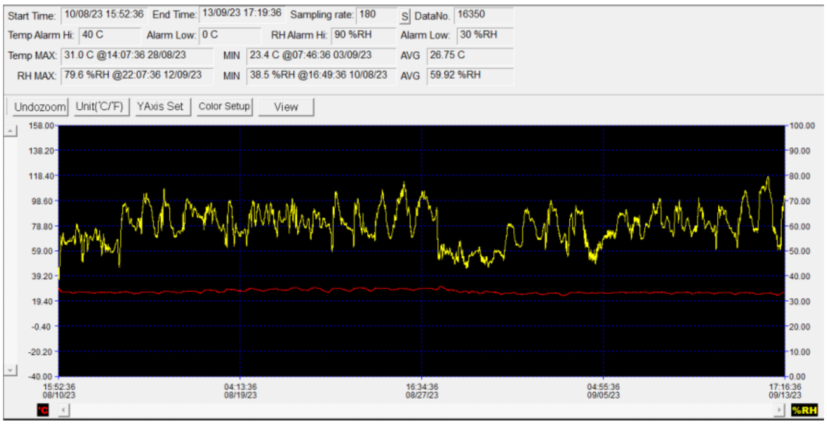


Figure 61 - Pre-Monitoring Period #1 - Temp&RH Unit #2, Room L1

Room: L2

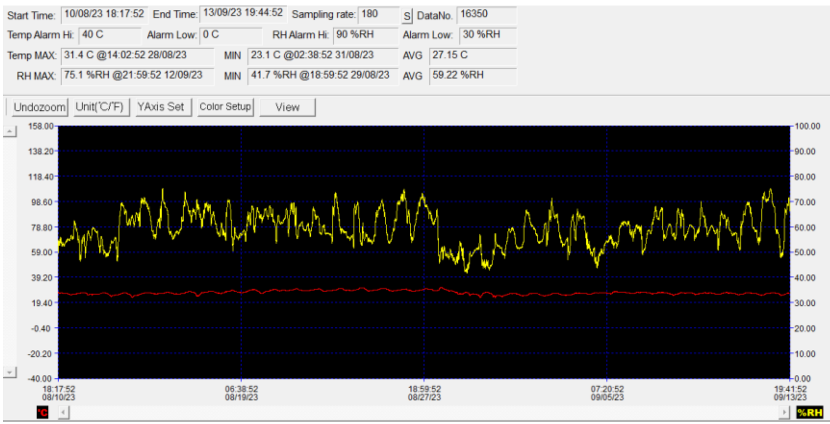


Figure 62 - Pre-Monitoring Period #1 - Temp&RH Unit #2, Room L2

Room: Outdoor (Balcony – K)

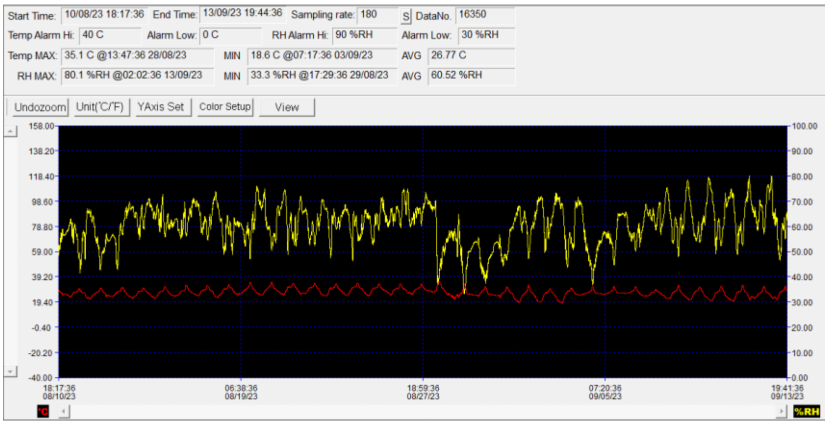


Figure 63 - Pre-Monitoring Period #1 - Temp&RH Unit #2, Room Balcony (K)

Final Consideration about Unit #2

The maximum indoor temperature recorded in this unit is about 31.4 °C, while the minimum indoor temperature recorded is 23.1 °C, with an average temperature of about 26.95 °C. This latter is about 0.2 °C higerthan the average outdoor temperature recorded in the period and equal to 26.77 °C.

With respect to the relative humidity, the maximum indoor RH% recorded in the period is about 79.6%, while the minimum RH% is 38.5%, with an average RH% of about 59.57% recorded in the period. This latter is 1% lower than the average outdoor RH% recorded for the same period.

6.4.4.1.2 UNIT: N. #4 (B) | FLOOR: #2 | NUMBER OF RESIDENT(S): N/A

Room: L1

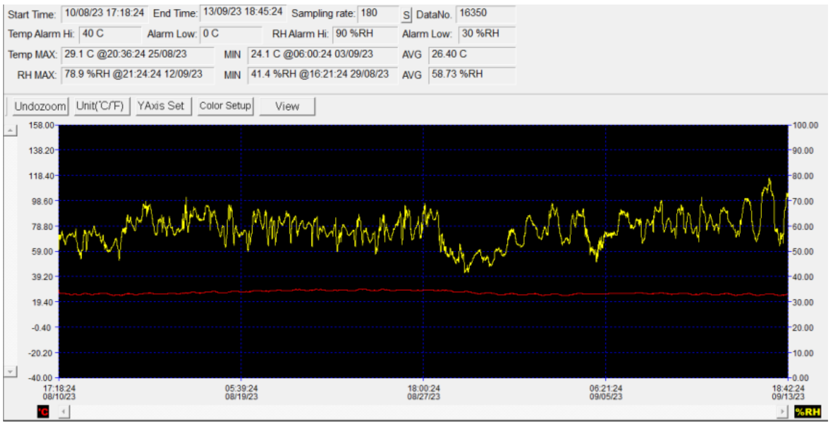


Figure 64 - Pre-Monitoring Period #1 - Temp&RH Unit #4, Room L1

Room: L2

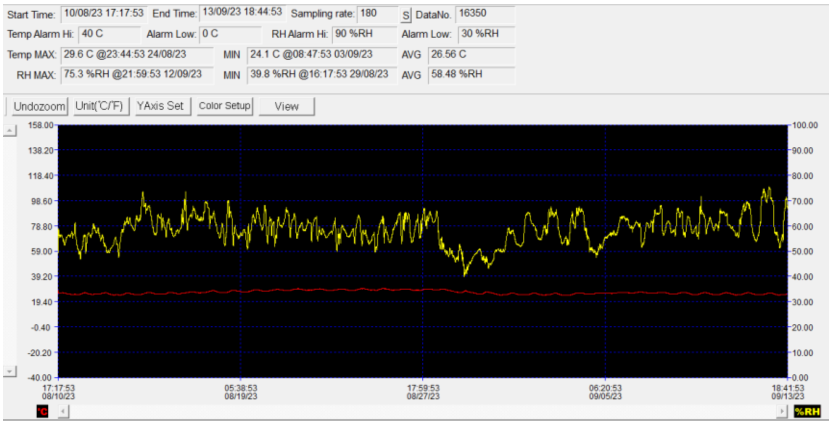


Figure 65 - Pre-Monitoring Period #1 - Temp&RH Unit #4, Room L2

Room: Outdoor (Balcony – K)

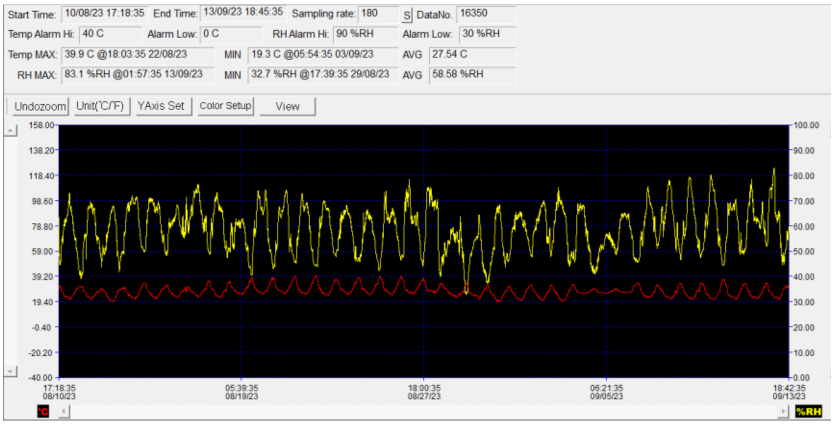


Figure 66 - Pre-Monitoring Period #1 - Temp&RH Unit #2, Room Balcony (K)

Final Consideration about Unit #4

The maximum indoor temperature recorded in this unit is about 29.6 °C, while the minimum indoor temperature recorded is 24.1 °C (the same in both bedrooms), with an average temperature of about 26.48 °C. This latter is about 1 °C lower than the average outdoor temperature recorded in the period and equal to 27.54 °C.

With respect to the relative humidity, the maximum indoor RH% recorded in the period is about 78.9%, while the minimum RH% is 38.9%, with an average RH% of about 58.61% recorded in the period. This latter is almost equal to the average outdoor RH% recorded for the same period.

6.4.4.1.3 UNIT: N. #5 (B) | FLOOR: #2 | NUMBER OF RESIDENT(S): #2

Room: L1

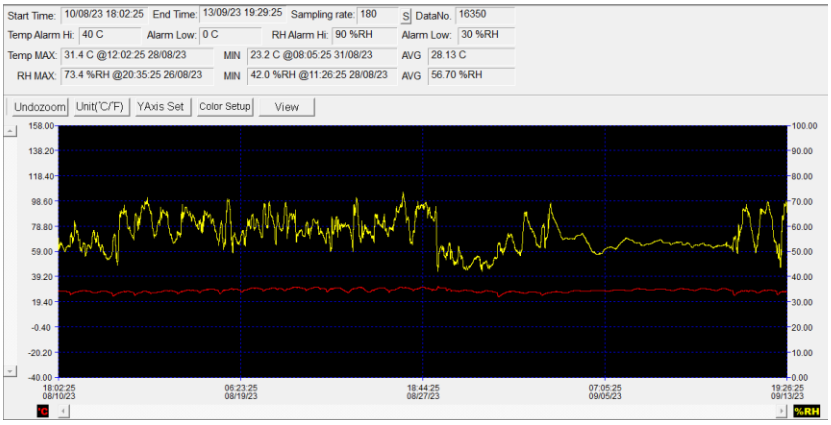


Figure 67 - Pre-Monitoring Period #1 - Temp&RH Unit #5, Room L1

Room: L2

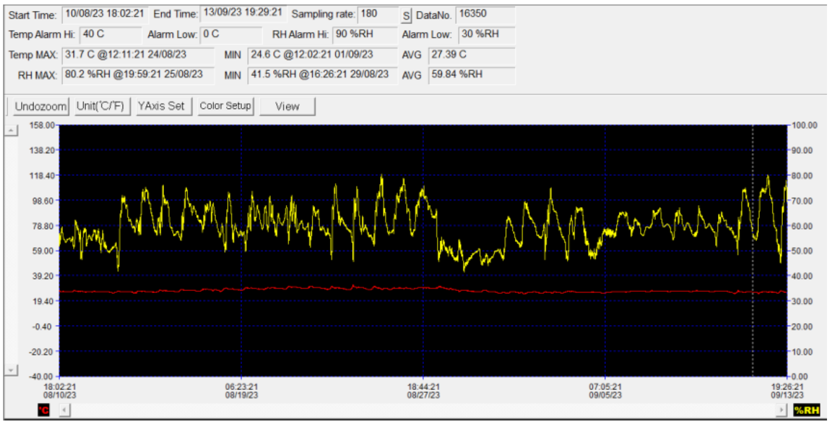


Figure 68 - Pre-Monitoring Period #1 - Temp&RH Unit #5, Room L2

Room: Outdoor (Balcony – K)

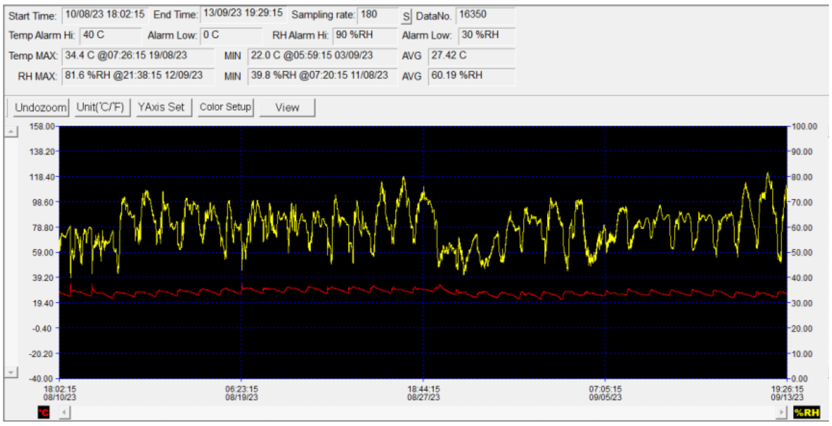


Figure 69 - Pre-Monitoring Period #1 - Temp&RH Unit #5, Room Balcony (K)

Final Consideration about Unit #5

The maximum indoor temperature recorded in this unit is about 31.7 °C, while the minimum indoor temperature recorded is 23.2 °C, with an average temperature of about 27.76 °C. This latter is about 0,3 °C higher than the average outdoor temperature recorded in the period and equal to 27.54 °C.

With respect to the relative humidity, the maximum indoor RH% recorded in the period is about 80.2%, while the minimum RH% is 41.5%, with an average RH% of about 58.27% recorded in the period. This latter is about 2% lower than the average outdoor RH% recorded for the same period.

6.4.4.1.4 UNIT: N. #8 (B) | FLOOR: #4 | NUMBER OF RESIDENT(S): #2

Room: L1

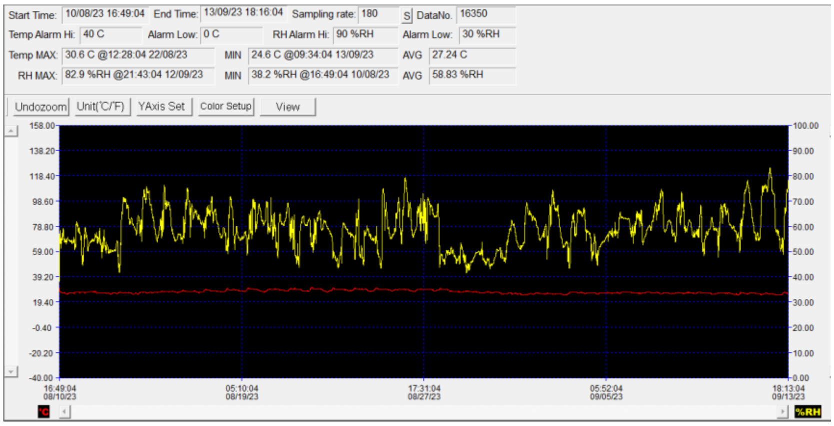


Figure 70 - Pre-Monitoring Period #1 - Temp&RH Unit #8, Room L1

Room: L2

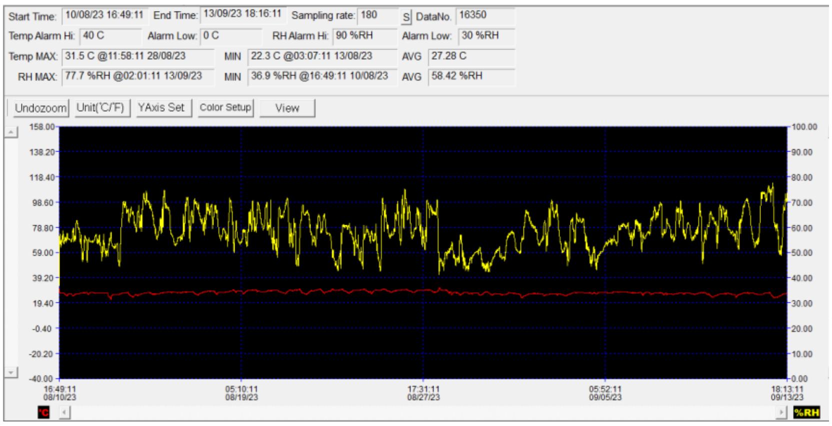


Figure 71 - Pre-Monitoring Period #1 - Temp&RH Unit #8, Room L2

Room: Outdoor (Balcony – K)

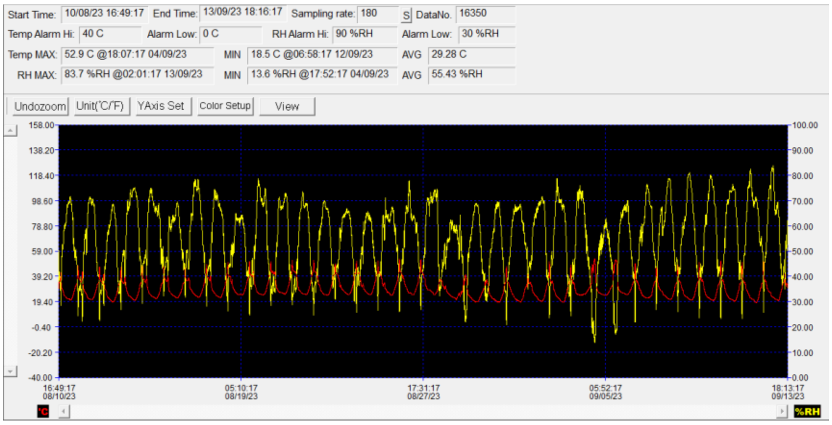


Figure 72 - Pre-Monitoring Period #1 - Temp&RH Unit #8, Room Balcony (K)

Final Consideration about Unit #8

The maximum indoor temperature recorded in this unit – located at the top floor of the building demo site - is about 31.5 °C, while the minimum indoor temperature recorded is 22.3 °C, with an average temperature of about 27.26 °C. This latter is about 2 °C lower than the average outdoor temperature recorded in the period and equal to 29.28 °C.

With respect to the relative humidity, the maximum indoor RH% recorded in the period is about 82.9%, while the minimum RH% is 36.9%, with an average RH% of about 58.62% recorded in the period. This latter is about 3% higher than the average outdoor RH% recorded for the same period.

6.4.4.2 PRE-MONITORING PERIOD #2

At this stage of the project, it is worth to mention that read and monitored data from the **Pre-monitoring Period #2** is not available yet since the acquisition is still ongoing. The analysis will be presented in task 4.6.

6.4.5 CACLCULATED BASELINE KPIS

The first analysis and calculation are presented in the following table. For the other baseline KPIs (In process), the end of the monitoring period is needed for the calculation. The complete table will be presented in task 4.6.

Table 32: Calculated baseline KPI values for the Italian demo-site

KPI Nº	Key performance indicator title [unit]	Baseline KPI
KPI01	Thermal resistance of façade walls R value	0.65 W/m² °C
KPI02	Final energy use for systems of building – Demo site level – [kWh/yr.]	NG: 59769 kWh/yr. Electricity: 18,400 kWh/yr. Total: 78,169 kWh/yr.

KPI Nº	Key performance indicator title [unit]	Baseline KPI
	Final energy use for systems of building – Dwelling level –[kWh/yr.]	
KPI03	Electrical peak power demand reduction from the grid [kW]	In process
KPI04	Primary energy use stage energy performance [kWh/m²/yr.] of building	NG: 65,746 kWh/yr. Electricity: 36,800 kWh/yr. Total: 102,546 kWh/yr.
KPI05	Non-renewable primary energy consumption [kWhep/m²/yr.]	NG: 65,746 kWh/yr. Electricity: 25,760 kWh/yr. Total: 91,506 kWh/yr.
KPI06	SRI score [%] of the whole demo site building	8 %
KPI10	Final energy savings [% and kWh/m2*year]	In process
KPI11	Primary energy savings [%]	In process
KPI12	Building Energy rating	G
RP-KPI12	Energy demand reduction [%]	In process
RP-KPI16	Increase of RES power at demo site level [kWp]	48 kWp
KPI14	Lighting and visual comfort [lux]	In process
KPI15	Improvement of ambient thermal comfort in dwellings	In process
RP-KPI04	Reduction in the Predicted Percentage of Dissatisfied people during occupancy hours [%]	In process
RP-KPI05	Improvement in terms of PMV [Predicted Mean Vote]	In process
RP-KPI06	Reduction in the Sound pressure level in occupied spaces [%]	In process
RP-KPI08	Reduction in the average Formaldehyde and VOCs concentration [%]	In process
RP-KPI09	Reduction in the TVOC concentration (Total Volatile Organic Compound) [%]	In process
RP-KPI10	Reduction in CO, PM concentration [%]	In process
KPI21	Lifetime income [€]	In process
KPI26	Operational CO_2 emissions [$kgCO_2eq$/year]	Evaluate using the emission factor
KPI27	Lifetime CO_2 emissions savings [$kgCO_2eq$, $kgCO_2eq$/year]	In process

7 SPECIFICITY OF THE ITALIAN DEMO SITE: STRUCTURAL DIAGNOSIS

7.1 REHOUSE INTEGRATED METHODOLOGY

For the Italian DEMO SITE an integrated methodology devoted to retrieving information about the three main aspects to be investigated during the assessment of a building (social, structural and energy efficiency) has been set up. The methodology considers the three aspects in an integrated manner since they interact with each other. The importance of writing down the methodology developed lies in the fact that after the REHOUSE project, it can be available to other public or private bodies under the form of guidelines. This should allow a faster, standardized, and more economically efficient assessment of their building portfolios. The following sub sections show the methodological approach followed by ENEA and UNIBAS. Annex 1 - Section 10.1 shows how this methodological approach was applied to the Italian demo-site and the results obtained.

7.1.1 INTRODUCTION OF SEISMIC STRUCTURAL ASSESSMENT OF THE BUILDING BEFORE ENERGY RENOVATION

Existing building requalification, sustainable design, and community involvement are three topics that frequently come together today, demonstrating that the design sensitivity required for intervening in the recovery of existing heritage cannot be expressed separately from continuous dialogue with inhabitants, in the search for solutions that can adapt old buildings to new living needs. Interventions on the building envelope, structure, and systems improve both the building's performance and residents' comfort. In Europe, in recent years, there has been a growing number of old buildings' requalification following such an approach. In particular, there has been an increasing sensitivity to the theme of sustainable requalification, almost always associated with strategies for reducing energy consumption, mainly through the use of renewable energies and eco-compatible materials. However, it should be noted that reinforced concrete constructions represent a large part of the existing building heritage, mainly built during the second half of the twentieth century. These buildings have reached the end of their service life (50-60 years according to current regulatory standards) and show serious deficiencies from both a structural and energy standpoint. In this context, issues related to the structural deficiencies of buildings are often overlooked, although in some cases, they are severe and evident. The damages caused by recent earthquakes have shown that the structural strengthening is important to avoid huge damage to measures aimed solely at energy and architectural requalification.

In the face of this scenario, the attempt must be to create moments of synthesis (with citizens) and integration of knowledge (among designers) in the structural, energy, and functional fields, resulting in proposals for coordinated and "integrated" interventions capable of combining energy efficiency, architectural restyling, and improvement of structural performance (static and seismic). However, expressing a judgment of energy-structural vulnerability on an existing building of a certain age (for example, 30-40-50 years) proves to be a complex task because it is strongly conditioned by the limited "knowledge" of the envelope properties and structural features. This document, in compliance with Italian and European Technical Standards, aims to provide indications on the criteria to be adopted to acquire information about the geometry, construction details, and properties of materials based on the level of knowledge intended to be achieved for the existing building while minimizing impact and disruption to tenants. Surveys are fundamental for the technician if they intend to first carry out the evaluation and then the project of the "integrated" intervention.

In this initial context, building information modelling (BIM) is used to get all involved designers sharing the acquired information more quickly and effectively to optimize intervention solutions. By using a process based on "intelligent" 3D models, the project team can efficiently collaborate in the structural energy evaluation phase, make more informed design decisions, automate model construction, and produce more achievable projects.

7.1.2 HISTORICAL CRITICAL ANALYSIS OF THE BUILDING

For the correct identification of the existing structural system and its state of stress, it is important to retrieve information on the design and construction process and subsequent modifications undergone by the structure over time, as well as the events that have affected it (e.g. earthquakes). This "preliminary" investigation, in addition to identifying the structural geometry, aims to verify the existence of any pathological situations, describe their nature, and provide an initial assessment regarding possible effects on performance, residual life, and structural safety. In particular, original design documents or any documentation acquired after construction, which allows tracing back to the construction period(s), are useful. These documents help characterize the building through construction techniques of the era or, for more recent buildings, the regulations in force at the time of construction. Through the design documents, it is also possible to identify any modification carried out on the building not foreseen in the original project. The collection of original project documents must be carried out at the competent local authorities (Municipality, Civil Engineering Authority, Public Works Authority, etc.). Reconstructing the building history will also allow verifying possible earthquakes experienced by the structures, eventual damage and related repair interventions.

The quantity and quality of acquired data (Table 33) determine the analysis method and the values of confidence factors to apply to the material properties used in safety verifications. Therefore, it is fundamental to assume various pieces of information, obtainable by retrieving the original design documents or a copy of it, in order to assess the building's construction age and establishing whether the building was designed with seismic criteria or not.

Table 33: Historical Critical Analysis: Sources and Information

SOURCES	• Project documents with specific reference to geological, geotechnical, and structural reports, as well as structural graphical elaborations. • Documentation acquired after the construction phase. • In situ and laboratory tests during construction phases or following previous interventions. • Acts related to the static testing of structures.
Information	• Identification of the structural system. • Identification of foundation structures. • Information on the geometric dimensions of structural elements, quantities of reinforcements, mechanical properties of materials, and connections. • Information on potential defects in construction details (such as reinforcement details, beam-column eccentricity, column-column eccentricity, beam-column and column-foundation connections, etc.).

- Information on the standards used in the original design, including the value of any seismic design actions.
- Reassessment of the service class for variable loads, based on any changes in the intended use.
- Information on the nature and extent of any previous damage and repairs performed.

7.1.3 DEFINITION OF THE LEVEL OF KNOWLEDGE TO BE ACHIEVED

The major difficulty in the assessment activities on existing structures lies in the lack of knowledge about materials and details and uncertainty regarding eventual damage or degradation phenomena. In order to guarantee a reliable safety assessment, the role played by the identification of the structure as a whole is therefore of fundamental importance.

Based on the previous considerations, the level of knowledge acquired about the structure determines the method of analysis and the confidence factors to be applied to the mechanical properties of the materials used in the calculation. Technical standards [1, 2] identify three levels of achievable knowledge (KL1, KL2, KL3), which require the use of appropriate confidence factors defined considering the level of knowledge attained (or level of depth of the investigations) and the reliability of the available information:

- **KL1: limited knowledge;**
- **KL2: normal knowledge;**
- **KL3: full knowledge.**

Based on the previous classification, the higher the level of knowledge of the construction, the lower the corresponding value of the confidence factor (CF). In general, it is preferable to achieve, through on-site investigations, a sufficiently high level of knowledge so as not to excessively penalize, with the use of more costly confidence factors, the verifications to be carried out. In economic terms, this causes a greater financial expense needed to conduct a broader campaign of in-situ investigations. The aspects that define knowledge levels are:

a) Geometry

- Structural layout of the building through original carpentry drawings or surveys of the existing condition, particularly the geometric characteristics of the structural elements (cross-section, span/height of beams and columns, thickness and arrangement of slabs, overhang arrangement, type of foundations, etc.);
- Any original carpentry drawings must always be verified with the actual condition through visual and dimensional surveys to ascertain the presence of any undocumented modifications (extensions, expansions) made after the completion of the building.

b) Structural Details

- The quantities and arrangement of longitudinal reinforcements, anchoring, spacing of stirrups, and their closure for reinforced concrete structures, etc.
- Connections for steel structures.
- Connections between different structural elements.
- The consistency of non-structural collaborating elements.

c) Structural Materials

- Mechanical properties of materials identifiable from the original design documents but always to be verified through investigations on structures in situ (core drilling and sampling of reinforcements):
- Compressive strength of in-situ concrete.
- Tensile strength of in-situ concrete.
- Tensile strength of steel, etc.

The level of acquired knowledge determines the method of analysis and the values of confidence factors to be applied to the properties of materials, as indicated Table 34 [3].

Table 34: Level of acquired knowledge.

KNOWLEDGE LEVEL	GEOMETRY	DETAILS	MATERIALS	ANALYSIS	CF
KL1		Simulated design in accordance with relevant practice and from limited in-situ inspection	Default values in accordance with standards of the time of construction and from limited in-situ testing	Static or dynamic linear analysis	1.35
KL2	From original outline construction drawings with sample visual survey or from full survey	From incomplete original detailed construction drawings with limited in-situ inspection or from extended in-situ inspection	From original design specifications with limited in-situ testing or from extended in-situ testing	All	1.20
KL3		From original detailed construction drawings with limited in-situ inspection or from comprehensive in-situ inspection	From original test reports with limited in-situ testing or from comprehensive in-situ testing	All	1.00

The simulated design serves, in the absence of original construction or execution drawings, to define the quantity and arrangement of reinforcement in all elements with structural function. It must be carried out based on the current technical standards and the construction practice characteristic of the time of construction.

Limited in-situ checks are used to verify the correspondence between the reinforcement actually present and that reported in the construction drawings or obtained through the simulated project. They require that checks be carried out on at least 15% of the primary structural elements for each type of element (beams, columns, walls, etc.).

Extended in-situ checks are used when the original construction drawings are not available as an alternative to the simulated project followed by limited checks, or when the original construction drawings are incomplete. They require that checks be carried out on at least 35% of the primary structural elements for each type of element (beams, columns, walls).

Exhaustive in-situ checks are used when the original construction drawings are not available, and a high level of accurate knowledge (KL3) is desired. They require that checks be carried out on at least 50% of the primary structural elements for each type of element (beams, columns, walls).

In-situ checks will be carried out on an appropriate percentage of the primary structural elements for each type of element, with a preference for elements that play a more critical role in the structure, such as columns.

The elective mode of assessing material properties in situ is based on direct tests, generally of a destructive nature. The measurement of the mechanical characteristics of concrete is obtained by extracting samples (core drilling) and conducting compression tests until failure.

For the concrete material tests, it is permitted to replace some destructive tests, no more than 50%, with a larger number, at least triple, of non-destructive tests, single or combined, calibrated on the destructive tests;

The measurement of the mechanical characteristics of steel bars is obtained by extracting samples and conducting tensile tests until failure, determining yield strength and ultimate strength and deformation, unless test certificates of compliant magnitude are available, as required for new constructions in the regulations of the time.

For further details related to the investigations needed to achieve a certain Knowledge Level, please see references [1, 2, 3].

References of Section 7.1.3

1. Ministero delle infrastrutture e dei trasporti NTC, “Norme Tecniche per le Costruzioni. DM 17/1/2018,” 2018.
2. EN 1998-3 (2005): Eurocode 8: Design of structures for earthquake resistance – Part 3: Assessment and retrofitting of buildings.
3. Circolare Esplicativa 7, 2019. Ministero delle Infrastrutture e dei Trasporti, Circ. C.S.LI.Pp. No. 7 del 21/01/2019.

7.1.4 PRELIMINARY INSPECTIONS

The characterization of materials and structural elements represents a problem in the case of inhabited buildings in which it is not possible or difficult to carry out destructive tests but also non-destructive tests due to the difficulty sometimes in accessing the elements to be tested but also due to the impossibility to remove plaster or coverings. So, a methodology has been developed that meets these needs.

Below is described a methodology which aims to significantly reduce the in situ destructive tests in inhabited buildings and to limit as much as possible the invasiveness of the tests carried out, including non-destructive ones, as well as reducing the number of visits to disturb the tenants as little as possible.

The diagram in Figure 73 summarizes the operations necessary for a preliminary knowledge of the building in order to plan the test campaign on the structural and non-structural elements for more detailed knowledge. The three blocks in the diagram are non-consequential operations, for which the procedures can also be carried out at the same time.

First block relates to the outside survey, which involves visual inspection and survey with laser scanner and other diagnostic techniques (thermographic, pacometric, georadar measurements) to be compared to the project drawings. The thermographic inspection, in particular, allows the identification of any discontinuities or deteriorations, structural or otherwise, of the building envelope due to the presence of columns, beams, collapse of floors, infiltrations of walls and superficial cracks.

Second block involves the survey operations carried out inside. Among these, in order to obtain further information, it is important to be able to conduct hygrometric measurements since these allow without affecting the concrete to verify the presence and/or distribution of moisture up to a depth of 30 cm and to determine whether it is a temporary or persistent phenomenon on masonry materials and packages also affected by hygroscopic moisture phenomena.

The last block of the diagram referred to the social analysis developed in WP1. As mentioned before, the integrated methodology includes the involvement of the tenants in a co-design approach (D1.3). It is a participatory design approach, where the expertise of the system designers and researchers are combined with needs of tenants affected by the renovation changes. Tenants become key actors of the design process. Professionals, thanks to the support of the social facilitator, meet tenants and inform them on the whole renovation process: tests, design, and construction phases. It is a way also to give them pills of knowledge on energy and seismic issues. This block includes obtaining information relating to energy consumption (e.g. electricity, gas bills).

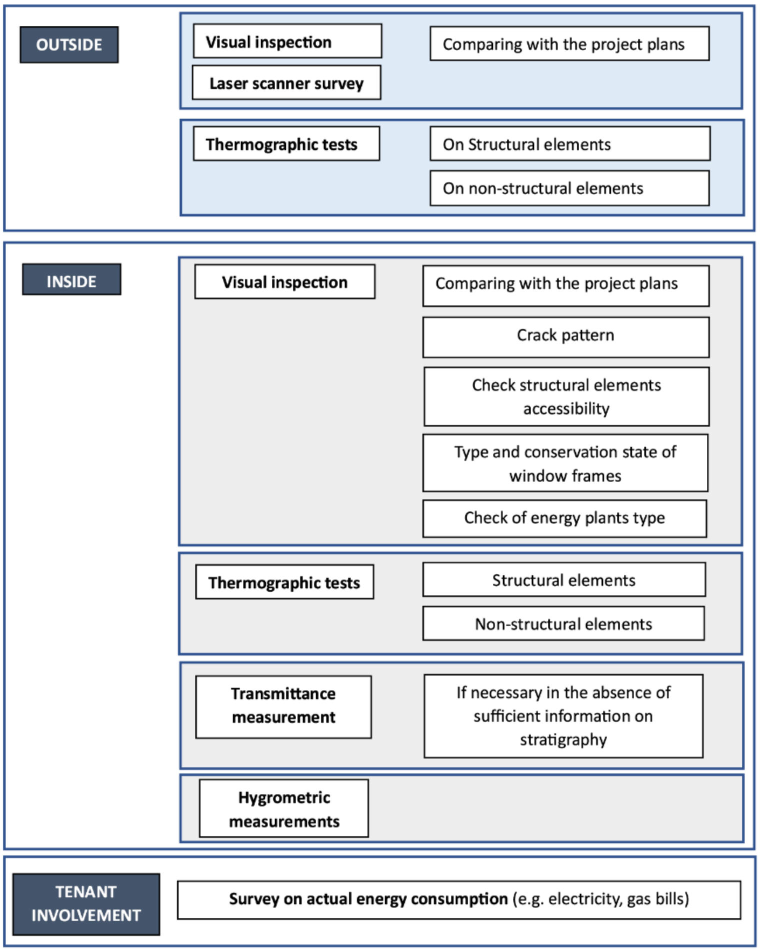


Figure 73: survey and inspection of the building.

7.1.5 RAPID ASSESSMENT OF STRUCTURAL CRITICALITIES USING THE ENEA APP "CONDOMINI+ 4.0"

A preliminary structural assessment of the building is performed through the ENEA application "Condomini +4.0" [1]. The aim of this point of the REHOUSE Methodology is to highlight possible structural issues which can be recognized on the basis of the documentary evidence and of a visual inspection, following a guided procedure in the form of an App. This procedure, which can be defined expeditious and qualitative, is not based on FEM numerical simulations and/or instrumental tests and, therefore, it doesn't provide a Vulnerability Assessment under the Rules. However, resting on some structural deficiencies and on well-known seismic effects, it leads to a preliminary estimation of the expected level of intervention. On one side it strictly depends on previous points of the Methodology, where all existing documentation is collected and a detailed visual inspection is performed. On the other side, working on this data, it allows for bringing out some criticalities which need to be examined in deep and provides some useful elements for the successive points of the structural assessment.

Below the questions faced on the structural survey of the "Condomini+ 4.0" procedure are briefly introduced.

1. Section 1: the **Intrinsic Vulnerability** of the building is inspected, which means that the building life, from its birth, is pieced together in order to establish Rules followed at the design stage and in case of subsequent modifications and transformations. In other words, at this step it must be ensured if the building was constructed taking into account the

seismic load, if it was subsequently seismically improved or vice-versa if, during its life, it underwent changes which may have worsened its behaviour.

2. Section 2: the **Organization of the Resistant System** is analysed in terms of the building's capacity to successfully oppose acting loads both in vertical and horizontal directions. Evident structural anomalies must be reported, if any.
3. Section 3: the **Quality of Structures** is inspected by detecting the material properties and the laying in work through a non-instrumental survey.
4. Section 4: the safety condition of **Foundations** is evaluated on the basis of soil-structure behaviour described in the design documents (i.e. type of foundation structure, type of ground, etc…).
5. Section 5: the **Horizontal Resistant System** ability of effectively transmitting loads to the vertical resistant system is evaluated by checking the in-plane stiffness and the connections between parts.
6. Section 6: the **In-Plan Regularity** evaluation consists in detecting the possible triggering of torsional effects, which could lead to high demand for ductility especially on the outside columns. Both the centre of masse and centre of stiffness are here roughly determined, moreover the effects of elongated shape and the presence of protruding appendices are taken into account.
7. Section 7: the **In-Elevation Regularity** evaluation consists in detecting the possible triggering of unusual dynamic responses causing stress concentration along the height of the building. Variation of geometry, mass and stiffness from floor to floor is recorded paying particular attention to the absence of infill walls.
8. Section 8: the presence of **Critical Elements**, that is elements which have not the ability to deform in the plastic range, is investigated. In this regard stocky columns, which are characterized by fragile mechanisms, are reported here.
9. Section 9: stability of **Non-Structural Elements** is checked since their detachment during an earthquake could involve people injuring, obstruction of escape routes and, in general, damages.
10. Section 10: the evaluation of **Condition of Things** consists on reporting the presence of cracks, deteriorations and conditions of imminent danger which require an immediate safety action.

In each Section, all parameters requested by application must be inserted. That done, the evaluation of the Partial Level of Intervention, due to the criticalities resulting in that Section, is given back from the device on a scale of 1 to 3 or sometime of 1 to 4. Finally, the result of each Section is weighted and a synthetic index is computed which provides an increasing global Level of Intervention on a scale of 1 to 6, where 6 corresponds to the highest structural criticalities.

References of Section 7.1.5

1. G.Buffarini, N.Calabrese, A. Carderi, P.Clemente, C.Lavinia, A.Marzo, C.Tripepi (2018). App ENEA "Condomini +4.0" (available online at https://www.efficienzaenergetica.enea.it/vi-segnaliamo/condomini-4-0-l-app-enea-per-gli-edifici-condominiali.html)

7.1.6 DESIGN OF DESTRUCTIVE INVESTIGATION PROGRAM

The implementation of a campaign of diagnostic tests devoted to the structural and seismic assessment of reinforced concrete building is standardisable for every context, but must be designed for each individual building in order to choose the most suitable investigation techniques. In most cases, the joint use of destructive and non-destructive tests represents the best compromise, since the reduction of building disruption is one of the main requirements. At the same time, the investigation program will therefore be calibrated based on the minimum information needed for the safety evaluation and the degree of complexity and importance of the building [1], accounting for the invasiveness and cost of the tests. Consequently, the most delicate aspect is the choice of the locations of the tests or samples (sampling) and the type of test to be carried out. Below are some key points for designing a "correct" campaign of destructive tests in relation to the chosen depth level, trying to contain the expense and invasiveness of the investigations:

a) For an inhabited building, investigations on structures and tests on non-structural elements, although difficult, should be reduced as much as possible in number in order to limit disturbance and restoration costs, especially in residential areas;
b) The choice of points to be investigated should be shared among the different involved designers (structural, energy, etc.) in order to investigate a limited number of points and at the same time obtain more information for energy and structural analyses (e.g., visual tests near the columns allow both the survey of structural elements and the survey of the stratigraphy of the infill);
c) Rely on critical study of the available documentation to capture the most critical aspects (considering interference with systems, water and gas pipes as well as electricity or telecommunication ducts) that could influence the position of the investigation points;
d) Where concrete appears degraded the tests should have some priority. However, to standardize this aspect, non-destructive tests can effectively reveal groups of structural elements having a sort of material homogeneity, allowing to choose sampling points evenly distributed in those groups. In this regard, ultrasonic (or sonic) investigations, hygrometric measurements, can be used in selecting sampling points (see section 7.1.7); Moreover, a preliminary structural model could allow recognizing the most stresses elements, giving further guidance for the sampling points;
e) It is advisable to group the structural elements into typologically groups (as an example, for vertical element, distinguish shear walls and columns) or based on their position and role in the structural system. Even though for both columns and beams it is appropriate to investigate both some central position and some in an external position, dealing with medium to small size social housing building, to reduce invasiveness, it is suggested to perform core drillings and steel rebar extractions from outside, on the external frames. The necessary sampling inside the building could be performed inside the staircase, on the elevator case, therefore avoiding dwellings;
f) Whenever possible, in general, it is suggested replacing as many destructive tests (max 50%) with non-destructive tests;
g) When accessible, prefer basement, semi-basement, or attic floors where disturbance of investigations is reduced;
h) Already in the preparation phase of the sampling program, it may be useful to collaborate with a materials testing laboratory experienced in the field and equipped to operate outside the building (e.g., a laboratory not equipped to work at heights would condition the technician who would be forced to choose sampling points inside the houses, causing obvious inconvenience to the occupants);
i) Regarding the columns, the ideal sampling zone is the middle of the element, where flexural stresses are lower;
j) Similarly, for stiff beams (those having depth higher than the slab), it is suggested taking

the sample on the side of the beams between 1/4 and 1/5 of the clear span and approximately at half depth;

k) Where it is necessary to detect some important details (such as the closure of stirrups, the length of overlap of longitudinal bars, or the diameter of longitudinal bar stirrups), it is advisable to carry out visual inspection (by removing the concrete cover) at the sampling points always preferring areas outside the dwellings.

References of Section 7.1.6

1. EN 1998-3 (2005): Eurocode 8: Design of structures for earthquake resistance – Part 3: Assessment and retrofitting of buildings.

7.1.7 NON-DESTRUCTIVE INVESTIGATIONS AND ANALYSIS

For the structural assessment of existing concrete structures, as shown in section 7.1.3 - Definition of the level of knowledge to be achieved - it is important to know the strength of different elements.

Assessment of the compressive strength of structures can be done by (i) destructive coring tests in varying amounts (sect. 7.1.6) and (ii) calibrated indirect methods, combining destructive coring with non- or semi-destructive techniques. The use of coring is a time- and labour-intensive method that weakens the existing concrete structure, leaving a lasting impression on it. Alternatively, several non- and semi-destructive techniques are available for in situ determination of compressive strength that must be appropriately correlated with destructive testing.

In order, also, to minimize disruption to tenants/owners, a wide use of Non-Destructive Testing (NDT) techniques are used. It is worth noting that the RILEM TC 249-ISC [1,2] has recently published some Recommendations on NDT in situ strength assessment of concrete introducing a new methodology to reduce the errors in the technical assessment following the UNI EN 13791:2019 standard [3]. The RILEM methodology is easy to apply and can give results (mean strength estimates, local strength estimates) equivalent or more accurate than those provided by previous approaches; mostly can save a significant number of destructive testing (which are mandatory anyway), through the conditional coring option, without any additional cost.

Below is a summary of the operations to be performed to act in accordance with the RILEM Recommendations adapted for a regular building, such as the Italian Demo Building of Margherita di Savoia, in which the inhabitants living in the apartments and all the apartments are plastered.

1. Definition of tests number on materials and structural elements characterization according to the current European and Italian/Local Technical Standard in order to achieve a Knowledge Level as defined in section 7.1.3 .
2. In compliance with the RILEM TC 249-ISC Recommendations, definition of the prescribed minimum number of cores on the basis of prior knowledge about the range of concrete properties (section 7.1.6).
3. Execution of a wide campaign of ND tests on the columns of the building in order to evaluate the effectiveness and feasibility of implementing the methodology developed under RILEM TC 249-ISC to reduce the error in the technical assessment following the standard UNI EN 13791:2019. The information from this extensive test campaign, conducted on the results of the data collection obtained in the preliminary inspection (section 7.1.4), is necessary to define the columns on which to carry out the measurements. is. At the beginning of the test campaign it is important to identify the position of the column reinforcing bars using a pacometer and/or a georadar. After these mandatory inspections, it is possible to carry out a campaign of ultrasonic

measurements on the inspected columns using the direct method, for columns accessible from opposite sides, and/or the indirect method, for columns accessible from one side only.

4. Data analysis starting from the results of the ND test campaign in order to identify the columns from which to extract the cores on which to perform compression- and ultrasonic- tests for the characterization of the concrete. The same data analysis process allows evaluating the reduction in the number of cores.

References of Section 7.1.7

1. Breysse, D., Balayssac, J.-P., Biondi, S., Corbett, D., Goncalves, A., Grantham, M., Luprano, V.A.M., Masi, A., Monteiro, A.V., Sbartai, Z.M. 'Recommendation of RILEM TC249-ISC on non-destructive in situ strength assessment of concrete' (2019) Materials and Structures/Materiaux et Constructions, 52 (4), art. no. 71,
2. In-Situ Strength Assessment of Concrete: Detailed Guidelines In book: Non-Destructive In Situ Strength Assessment of Concrete, Practical Application of the RILEM TC 249-ISC Recommendations (April 2021). DOI: 10.1007/978-3-030-64900-5_1
3. UNI EN 13791:2019. Valutazione della resistenza a compressione in sito nelle strutture e nei componenti prefabbricati di calcestruzzo / Assessment of in-situ compressive strength in structures and precast concrete components.

7.1.8 PERFORMING OF DESTRUCTIVE INVESTIGATIONS

7.1.8.1 CONCRETE

The measurement of the mechanical properties of concrete is obtained by extracting samples (cores) and conducting compression tests until failure. As mentioned earlier, the results of such tests can be used either alone or to calibrate the results obtained with non-destructive indirect methods. Coring is certainly the most widespread destructive method, as it allows determining the concrete's resistance in a manner similar to that adopted for cubes. However, coring execution is a rather complex and delicate operation, both due to possible difficulties in access and positioning the drilling equipment, and to the damage that may occur to the structure (in addition to the disturbance caused to the building occupants). The in-situ coring is regulated by the standard UNI EN 12504-1:2021 [1], which outlines the execution methods aimed at minimizing sample damage during extraction operations.

The resistance measured on the cores fc_{ar} is influenced by numerous factors that differentiate it from the in-situ concrete strength fc_{is} :

- the position of the sampling within the structural element (e.g., at the base or head of a column, parallel or orthogonal to the casting direction);
- the disturbance following the sampling operations (in addition, although generally to a lesser extent, to subsequent preparation operations performed to obtain a suitable specimen for testing);
- the dimensions of the cores (micro-cores or cores with an Height/Diameter ratio different from 2);
- the presence of any included reinforcements.

These factors generally usually lead to underestimate the strength measured on the cores compared to fc_{is}, although the effect of some of them can be eliminated or reduced by accurately conducting sampling and preparation operations. To convert fc_{ar} into the corresponding fc_{is} , corrective coefficients properly calibrated can be used.

7.1.8.2 REINFORCING STEEL

In the case of reinforcing steel, mechanical properties cannot be evaluated in situ with a sufficient precision as the non-destructive procedures (e.g. hardness test) is not considered enough reliable. Therefore, the steel strength estimation generally requires the sampling of reinforcement pieces to be subsequently tested in the laboratory. These reinforcement pieces must be sampled in such a way as not to compromise the integrity of the structural element, minimizing the resulting damage. The sampled reinforcement pieces must undergo the standard tensile test to estimate yield strength, ultimate tensile strength, and elongation at fracture. The execution methods and interpretation of the results of this test do not differ from those used in the case of new structures. Attention should be paid to identifying the possible presence of bar corrosion processes, which may compromise their current or future load-bearing capacity. This condition, in addition to potentially reducing the cross-sectional area of the steel bars, can negatively and significantly affect the steel-concrete bond. The presence of corrosion should be investigated with particular attention if the depth of carbonation exceeds the average cover thickness. To reduce the number of samplings, consider that steel is an industrial product, therefore with a rather limited variability in terms of mechanical properties. In most cases, reinforcing steel type can be identified by a simple visual inspection and some confirmation can be obtained considering the reinforced concrete constructions' standards in force at the time of construction.

7.1.8.3 VISUAL INSPECTION

A visual inspection on reinforced concrete structural elements is carried out by removing the concrete cover thickness to directly detect the position, diameter, and type of reinforcement bars (smooth or ribbed), as well as construction details such as the bending of stirrups. In the case of columns, the test should be extended for a length of at least 30 cm along the axis of the element. The test is usually carried out at mid-height of the element, although performing it starting from 60-70 cm from the base of the columns would allow evaluating the overlapping device in sections adjacent to the slabs. In the case of beams, especially for stiff ones, tests will be carried out only on the intrados at the supports and at mid-span for a length along the axis of the element of at least 30 cm (to also reveal the spacing of the stirrups). Tests on floor slabs will be carried out to determine the layout (if not detected in any other way, e.g., using a thermal camera) and the type of slabs, the dimensions of the ribs, and lightweight elements. In addition, the quantity and size of bars placed at the bottom (intrados) will be recorded both at mid-span and at the supports. Tests can also be used to identify the type of infill (e.g., double lining) and the characteristics of the components (perforated bricks, solid bricks, concrete blocks, etc.), as well as the thickness of the linings and any cavity. In this case, the tests consist of small perforations combined with endoscopic investigation. The procedure involves drilling approximately 2 centimetres in diameter, through which the flexible endoscope cable, equipped with a video camera, is inserted. Video recording and acquisition of still images can be performed at various depths to document different stratifications or internal cavities. This technique is essential for investigating inaccessible areas of the building such as attics, floors, foundations, technical spaces, etc.
To maximize the results of this activity, where possible, it is advisable to categorize the structural elements into typologically similar groups (columns, flat beams, stiff beams, walls, etc.) so that tests are only conducted on a limited number of them, and the results can be extended to similar ones.

References of Section 7.1.8

1. UNI EN 12504-1:2019. Prove sul calcestruzzo nelle strutture - Parte 1: Carote - Prelievo, esame e prova di compressione. / Testing concrete in structures - Part 1: Cored specimens - Taking, examining and testing in compression.

7.1.9 DETAILED STRUCTURAL ANALYSIS AND SEISMIC VULNERABILITY ASSESSMENT

7.1.9.1 DEFINITION OF SEISMIC ACTION

To proceed with the assessment, it is necessary to define the seismic design spectrum and determine the soil category and the topographic category since they affect the shape of the acceleration spectrum. This must be done according to the Italian building code [1], as briefly summarized in the following. Geological/geotechnical surveys and investigations should be conducted to obtain the soil and topographic classification according to the categories foreseen by the code, and then calculate the design spectra parameters dependent on them for the different limit states.

The elastic response spectrum in acceleration is expressed by a spectral shape (normalized spectrum) referred to a conventional damping of 5%, multiplied by the value of the maximum horizontal acceleration a_g on a horizontal rigid reference site. Both the spectral shape and the value of ag vary with the return period T_R.

For each limit state, which corresponds to a different return period (T_R), all the necessary parameters are determined to define the elastic response spectrum of the horizontal components S_e(T) based on the site where the building is located, the soil class and the topographic condition. In the case of linear analysis, for life safety limit state SLV, and design or assess structures, the dissipative capacities can be taken into account conventionally by reducing the elastic forces, through the so called “behaviour factor” *q*, which introduces in a simplified way the inelastic dissipative behaviour of the structure, its overstrength, and the increase of its natural period following the formation of plastic hinges. In this case, the design spectrum to be used S_d(T) is the corresponding elastic response spectrum, referred to the considered return period, with ordinates reduced by the *q* factor [1].

7.1.9.2 ANALYSIS METHODS

The choice of the analysis method to assess the seismic safety of existing structures must comply with the technical standards [2]. In particular, linear analysis methods (where the nonlinearity of the response under seismic action is not explicitly modelled) or nonlinear methods (vice versa) can be adopted, depending on what emerges from the building's knowledge phase and its structural characteristics. Additionally, it should be noted that in existing reinforced concrete buildings, unlike newly designed buildings, it is common to find elements whose expected behavior is governed by brittle failure mechanisms (e.g., shear). The possible presence of such elements significantly influences the definition and choice of the analysis method to be adopted.

- Linear Analysis

Even though a linear analysis could also be of static type (consisting in applying equivalent horizontal static forces), due to their limitations, dynamic analysis are now the standard. This latter takes into account the effects of multiple modes of vibration, which are combined to obtain the seismic response of the structure, in addition to the first mode, is considered, and their contributions to the effects of interest are combined using statistical rules.

Great importance must be given to the choice of the behaviour factor (q factor) that reduces the elastic spectrum representing the seismic action. The behaviour factor should not exceed *q*=3 and could be higher for constructions designed with seismic rules, while, for buildings designed only with respect to gravity loads, a lower *q* values should be adopted [2].

- Nonlinear Analysis

The evaluation of seismic action effects can be conducted with either static or dynamic analysis. However, static (pushover) analyses are the most used. Nonlinear analysis usually provides a more reliable seismic evaluation even though it is more complex than linear analysis, needing a refined definition of the nonlinear behaviour of structural members. It should be noted that when fragile failures are expected in the buildings (buildings designed to old standards without seismic criteria) linear and nonlinear analysis methods do not provide so different results. Therefore, it is preferable using linear method being simpler and faster to apply.

It should also be noted that nonlinear analysis methods can be used for reinforced concrete structures only if KL is at least KL2 [2]. This limitation aims conceptually to allow the use of more sophisticated methods, which require much more complex modelling, only in cases where the achieved knowledge allows sufficient reliability.

7.1.9.3 CAPACITY MODELS

The assessment of Capacity to compare with Demand to determine the seismic safety level specializes for the specific SL under consideration. For reinforced concrete buildings, at the SLD, checks can be made in terms of stiffness, aimed at limiting the damage to non-structural elements (e.g., infills) by controlling interstory drifts, evaluating the interstory drifts d_r from a structural model without the stiffening and resisting contribution of infills (Demand), and verifying that they are less than 0.5% of the interstory height (H) (Capacity). Greater deformation limits (0.75% or 1% of H) may be allowed with increasing displacement capacity in the plane of the infill. For existing buildings, [2] also defines deformation limits for structural elements corresponding to their yielding, or formulations expressing chord rotation at yielding, θ_y. It is worth noting that verifying compliance with such deformation limits conceptually corresponds to what the standard defines, for newly designed buildings, as a "strength" check – understood as a "non-yielding" check.

- Checks at the SLV must be carried out in accordance with what is explicitly stated in [2] with specific reference to existing buildings. It is emphasized that "ductile" mechanisms (beams, columns, and walls with and without axial force) must be verified by comparing Demand and corresponding Capacity in terms of deformation or strength depending on the analysis method used. Conversely, "brittle" mechanisms (shear mechanisms in beams, columns, walls, and joints) must be verified by comparing Demand and corresponding Capacity always in terms of strength. Furthermore, in evaluating Capacity (both in terms of strength and deformation), the average properties of existing materials, obtained from specific investigations, must be reduced:
- for ductile elements/mechanisms: by the confidence factor (CF) related to the reached knowledge level (KL).
- for brittle elements/mechanisms: by the corresponding partial safety coefficient of the material (γM) and by the confidence factor (CF) corresponding to the reached knowledge level (KL).

It is emphasized that safety checks must involve all elements that may contribute to reaching a given limit state (SL). Therefore, with reference, for example, to beam-column joints of reinforced concrete structures, such elements must always be subject to safety checks regardless of the structural typology (i.e., frames, frames and walls, walls, etc.) and the reinforcement technique possibly used.

- **Ductile Mechanisms: Beams and Columns**

The Capacity at the SLV of beams and columns with and without axial force must be evaluated in terms of:

– resisting moment, if a force-based analysis method is used;

– rotational capacity at the chord, if a displacement-based analysis method is used.

The resisting moment should be estimated based on the principles of Structural Engineering, considering the section bent or near-bent in its Ultimate Limit State. For this purpose, concrete can be characterized alternatively by an elastic-plastic constitutive relationship, parabola-rectangle, or stress-block; steel can be modelled with an elastic-plastic or elastic-hardening relationship.

The rotational capacity at the chord (given by the ratio between the relative displacement between the end section and the section characterized by null bending moment and their distance, equal to the shear span), can be assessed using numerical models that adequately account for the contributions of concrete, steel, and steel-concrete bond, or through formulas of proven validity [2]. Regardless of the formulation used for θu, the rotational capacity at the SLV should be evaluated as 3/4 of that θu.

- **Brittle Mechanisms: Beams and Columns**

For evaluating the ultimate strengths of beams and columns against shear stresses due to gravity loads only, what is indicated for non-seismic conditions applies. The variable angle truss model is applied for determining the resisting shear V_R.

For seismic actions, the reduction in shear strength under cyclic conditions based on the ductility demand on the element, for the considered action level, should be considered. In this case, shear strength can be evaluated based on three contributions due to the normal force N, to the shear resistant mechanisms of concrete, and to transverse reinforcement. The value of shear strength must always be limited to the value of shear-compression strength, assessed as for non-seismic conditions [1] assuming θ=45°.

- **Brittle Mechanisms: Joints**

The verification of joints must be carried out for joints not entirely confined [1], both in diagonal tension and diagonal compression. The verification approach reported in [2] involves comparing the principal tensile stress demanded at the joint (Demand) with the Capacity in tension (expressed as 0.3 times the square root of the compression strength used for the verification) or the principal compression stress demanded at the joint (Demand) with the Capacity in compression (expressed as 0.5 times the compression strength used for the verification). The principal tensile and compression stresses can be assessed (alternatively to the more conservative values obtained with calculation software) according to the basic principles of Structural Mechanics considering that the joint panel is subjected to the normal force of the upper column and the joint shear. The latter is the algebraic sum of the tension actions transmitted by the converging beams in the joint and the column shear.

7.1.9.4 SAFETY VERIFICATIONS

The assessment of the safety level of an existing building for the generic limit state - and the generic mechanism, given the limit state - must be made in terms of peak ground acceleration (PGA) or return period (T_R). For each limit state, it is possible to associate the value of "capable ground acceleration" (PGA_C) corresponding to its occurrence. Essentially, PGA_C corresponds to the zero-period point (anchored to the ordinate axis) of the "capable spectrum" in pseudoacceleration ($S_{e,c}$), under which all D/C ratios of the performed checks are at most equal to 1. Where PGA is understood as acceleration on rigid ground (a_g) amplified by the effects of stratigraphic and topographic amplification (S).

Since the trend of horizontal acceleration on rigid ground a_g is monotonic with increasing return period, it is possible to determine the return period $T_{R,C}$ associated with PGA_C: it represents the capacity, expressed through the return period, of the relevant limit state.

Very rarely, for the generic verification limit state, the "capable spectrum" coincides with one of the 9 spectra (30 years, 50 years, 72 years, 101 years, 140 years, 201 years, 475 years, 975 years, 2475 years) provided by the technical standards [1]. For this reason, it is generally necessary to search for the capable T_R and the corresponding capable PGA through logarithmic interpolation on the parameters that uniquely define a spectrum (a_g, F_0, Tc*) between the last spectrum (of the 9 provided by the standard) for which all verifications are satisfied (T_{R1}) and the first spectrum (of the 9 provided by the standard) for which there is at least one unsatisfied verification (T_{R2}).

The ratio ζ=C/D is defined [2] as the safety (or vulnerability) index and can be defined in terms of acceleration, where for each significant limit state and mechanism of interest, it is expressed as the ratio between PGA_C/PGA_D. However, values of the index less than unity indicate an unsatisfied verification.

Very often, the condition for ζ<1 does not refer to the first activated mechanism (ductile or brittle) but rather to a series of mechanisms or multiple elements not verified.

The assessment of structural safety cannot disregard an analysis under "static" conditions, therefore it is essential to evaluate the index ζ = C/D, where the demand is defined by gravitational loads, particularly the variable loads related to the current use of the building.

References of Section 7.1.9

1. Ministero delle infrastrutture e dei trasporti NTC, “Norme Tecniche per le Costruzioni. DM 17/1/2018,” 2018.
2. Circolare Esplicativa 7, 2019. Ministero delle Infrastrutture e dei Trasporti, Circ. C.S.LI.Pp. No. 7 del 21/01/2019.

7.1.10 TENDER

The design of the renovation works and the selection of the best solutions to achieve all the objectives defined in the project, it is a very crucial phase, as well as the involvement of householders in the design of the retrofit.

The retrofit of the building has to start from the three-analysis set up by the project partners: the energy audit, the structural assessment and the social analysis. Therefore, the final project, should at first overcome all the technical criticalities highlighted by the building analysis and the designers, who will be committed for the retrofit, shall cover specific technical skills of anti-seismic design and building energy efficiency, both for the envelope and for the technical building systems. To meet these needs, specifically requirements are mandatory for the selection of the designers, and the public tender shall collect all requirements.

In building retrofits, several aspects are to take into account: the safety regulation for construction site, the fire safety regulation, acoustic requirements set by law, geologic configuration of the soil, in case of installing geothermal pump, even aspects dealing with building automation systems (BACS). BACs are useful to be applied for an automatic regulation of the technical building systems, as it is demonstrated it increases the efficiency of the building/heating and Colling system.

In order to cover all mentioned issues, in the Italian Pilot of Margherita di Savoia it is preferable to rely on a group of designers, composed by professionals covering all the requested competences, able to work by mutually integrating their respective skills.

For Margherita di Savoia another type of professional is fundamental to guarantee the success of the project: a “social facilitator” for enabling a constructive dialogue with the householders and who can facilitate the communication between professionals and final users.

8 CONCLUSION

The primary objective of this document was to assess the existing conditions of the buildings at the four demo-sites prior to their retrofitting. General information about the buildings' conditions, facilities, and infrastructure was gathered through questionnaire responses provided by demo-site representatives. Subsequently, the Smart Readiness Indicator (SRI) of each building was evaluated to determine its level of intelligence before the integration of innovative solutions.

Furthermore, comprehensive assessments of energy performance and thermal comfort, as well as indoor air quality, were conducted to establish the initial status of the demo-sites in these aspects. The energy performance assessment included descriptions of the current energy systems, baseline monitoring plans, energy diagnostics, and analyses of energy consumption. Similarly, the thermal comfort and indoor air quality assessments outlined baseline monitoring plans, instrumentation details, data acquisition systems, and preliminary analysis of key performance indicators (KPIs). It is important to note that the complete set of baseline data will enable the calculation of all KPIs at a later stage of the project.

Additionally, a detailed methodology for building structural assessment was described, tailored to meet the specific seismic requirements of the Italian demo-site. This methodology was applied to the Italian site, with the results presented in the Annex of this document.

- SRI Initial status

The SRI indicator, which evaluates the intelligence potential of buildings based on energy saving, energy flexibility, and occupant comfort, revealed varying scores among the demo-sites. The Greek demo-site exhibited a higher score, around 40%, while the other three sites scored considerably lower, around 15% or less. The implementation of Renovation Packages is expected to significantly enhance this indicator, and a reassessment will be conducted after the renovation work.

- Energy performance initial status

The energy performance assessments indicated considerable potential for improvement across the demo-sites. Issues such as poor insulation and low-efficiency energy systems were identified as significant contributors to high energy consumption. It is anticipated that the deployment of Renovation Packages will lead to substantial improvements in energy efficiency at the demo-sites.

In the following table is shown a summary of the energy performance initial status per each demo-site.

Table 35: Energy performance initial status per each demo-site.

	Consumption (final energy)	Energy sources (final energy)	Emissions
Greek Demosite	185 MWh/yr.	97,854 kWh/yr. electrical energy (all uses, without PV production) 30 MWh/yr. (self-consummated PV estimation) 57 MWh/yr. thermal energy	28,818 $kgCO_2eq$ (electricity) 1,386 $kgCO_2eq$ (wood pellets)
Hungarian Demosite	163 MWh/yr.	59,976 kWh electrical energy 102,595 kWh natural gas	15,678 $kgCO_2eq$ (electricity) 23,289 $kgCO_2eq$ (natural gas)
French Demosite	250 MWh/yr.	Natural gas (Heating, DHW, cooking)	56,750 $kgCO_2eq$
Italian Demosite	78 MWh/yr.	18,400 kWh/yr. electrical energy 59,769 kWh/yr. natural gas	6,146 $kgCO_2eq$ (electricity) 13,568 $kgCO_2eq$ (natural gas)

- Thermal comfort and thermal air quality status

Monitoring of indoor comfort and air quality will continue until the commencement of renovation and construction works. While initial results and qualitative feedback have been presented in this deliverable, a comprehensive evaluation report will be presented in Task 4.6.

In conclusion, the findings presented in this document serve as a crucial foundation for the subsequent phases of the project, particularly the implementation of Renovation Packages and the assessment of their impact on the demo-sites. The insights gained from these assessments will inform the development of effective strategies for enhancing energy efficiency, indoor comfort, and overall building intelligence.

9 REFERENCES

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10 ANNEX

10.1 APPLICATION OF THE REHOUSE INTEGRATED METHODOLOGY TO THE ITALIAN DEMO SITE

10.1.1 INTRODUCTION SEISMIC STRUCTURAL ASSESSMENT OF THE BUILDING BEFORE ENERGY RENOVATION

The demo building, named "Building A" (Figure 76 and 77), is part of a residential complex of reinforced concrete social housing units designed in the mid-1980s. The aim is to provide an assessment of the seismic vulnerability of the structure that is useful in defining subsequent intervention strategies. The reconstruction of the structural entity from a geometric standpoint, the properties of the materials used, and the quantities of reinforcement arranged are based on the information gathered from the documentation on the building made available by ARCA Puglia Centrale.

Figure 74: Location of the building of the italian demo site.

In order to assess safety, the investigative phase of the structures is of fundamental importance, planned to provide a sufficiently comprehensive and representative overview of the structure under examination. The Italian demo site structural assessment has been carried out with reference to recent literature and matching the Italian building code by following the main steps here reported:

1. Historical critical analysis of the building;
2. Definition of the knowledge level to be achieved;
3. Preliminary inspections: geometric and structural survey also using diagnostic techniques;
4. Destructive and non-destructive investigation planning and performing;
5. Detailed structural analysis and seismic vulnerability assessment;
6. BIM structural modelling.

10.1.2 HISTORICAL CRITICAL ANALYSIS OF THE BUILDING

This phase consists in collecting and analysing all the available design documents that can provide valuable information about the building structure. It was possible to retrieve the architectonic design documents, structural design drawings, final testing and approval of the structure. The building has a rectangular layout (22×11m^2) and is built on four levels outside with a 3m interstory. The foundations are made by a RC plate stiffened by beams, while on the accessible roof, there are compartments used as storage spaces. The load-bearing structure is made of reinforced concrete with frames arranged in the two main directions of the structure and floor slabs of cementitious screed type. An elevator shaft is positioned along the long side of the building and adjacent to the staircase.

The main information about the structure is as follows:

Age

- Structural design year: 1984
- Static testing at completion year: 1986
- Seismic classification of the municipality of Margherita di Savoia (Italy): year 1981

Structural Typology

- Reinforced concrete framed structure
- Envelope made of masonry infills
- Frames in two plan directions
- Prevalence of wide beams (depth lower that width)
- 5 storeys (4 ordinary + roof storey)
- Floor area 220 m^2
- Inter-storey height 3 m
- Reinforced concrete ribbed plate foundation

Materials

- R'bk 250 concrete
- FeB 44K reinforcing steel

No information about any structural intervention during building life was found in the collected documents.

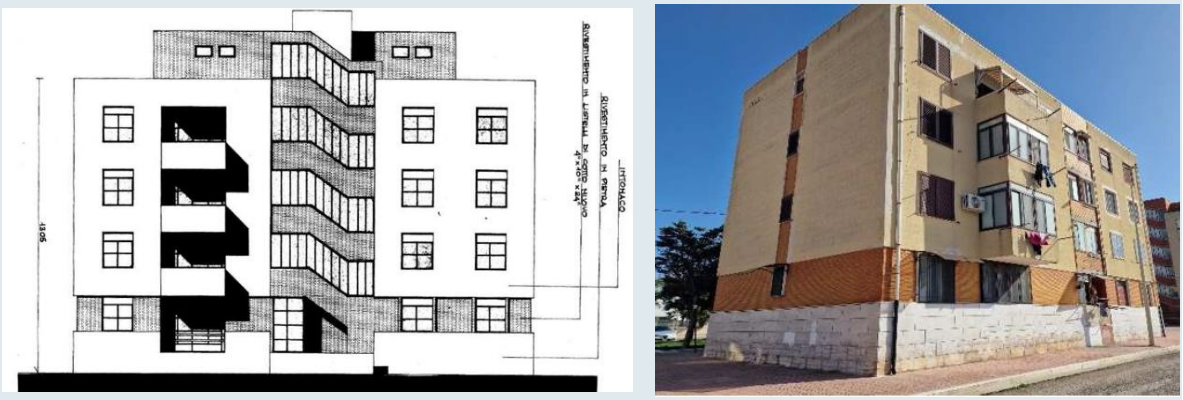


Figure 75: The demo building of Margherita di Savoia.

In this phase and based on the design drawings collected, a preliminary finite element model of the building has been set up (Figure 76), serving to the calculation of the fundamental vibration periods T1x and T2y for the two plan directions, through dynamic modal analysis.

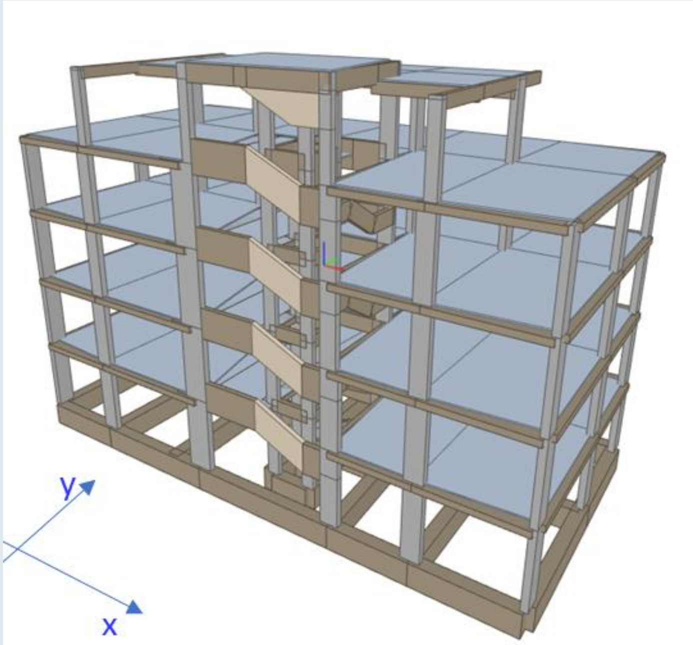


Figure 76: Preliminary fe model of the building.

The fundamental periods have been used to calculate the seismic action according to design code in force at the time of design (1984) and seismic action currently in force, according to the present Italian building code. As can be seen from Figure 77, the ratio between these two seismic action values is 0.35, and this means that older design seismic actions are 35% of the current ones and this represents a sort of preliminary seismic assessment.

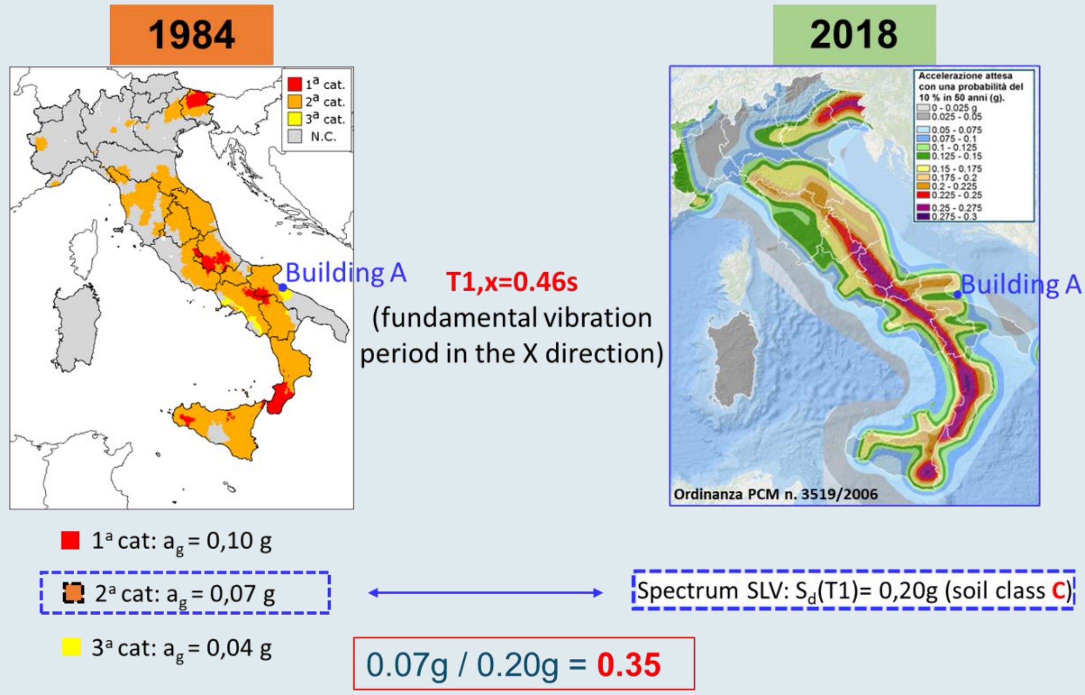


Figure 77: Comparison of design seismic actions and current assessment seismic actions.

10.1.3 DEFINITION OF THE LEVEL OF KNOWLEDGE TO BE ACHIEVED

The level of knowledge represents the accuracy of the information related to the building for the structural assessment and this affect the Confidence Factor (FC) that should be used to reduce the material strength values. There are three possible levels of knowledge according to the Italian building code:

- KL1 lowest level of knowledge corresponding to FC=1.35
- KL2 intermediate level of knowledge corresponding to FC=1.2
- KL3 maximum level of knowledge corresponding to FC=1.0

It could be desirable to obtain KL3 even tough is more expensive since it needs a large number of investigations being also invasive due to the concrete cover demolitions that have to be made to perform all the needed surveys. In order to balance the need for a detailed knowledge and that related to reducing invasiveness of the structural investigations, in agreement with the building owner (ARCA) the selected knowledge level is the intermediate one, i.e. KL2, relating with a confidence factor FC=1.2. Once the knowledge level is assumed, the number and type of destructive and non-destructive investigation can be evaluated in order to make a detailed investigation plan, which should be preceded by preliminary inspections.

According to the Italian building code, in order to get a knowledge level KL2 (Table 36) the geometry must be known from one of the two following options: (i) original design drawings + visual survey or (ii) complete dimensional survey. In this case the option (i) has been used, considering that design drawing are available. This is achieved by the preliminary inspections.

The structural details must be known according to the two following options: (i) incomplete design documents + limited in-situ investigations or (ii) extended in situ investigations. Option (i) has been adopted.

Material properties must be known according to the two following options: (i) original design specifications + limited investigations or (ii) extended investigations.

Therefore, whenever possible, limited investigations have been conducted in order to limit the invasiveness and disruption created by the assessment procedure.

Table 36: Investigations according tot he kl (extracted from the italian building code).

Knowledge level	Geometry	Structural details	Material properties	Analysis methods	FC (*)
KL1	From design drawings and visual sample survey or complete survey	Simulated design and limited tests	Usual values and limited tests	Linear analyses static or dynamic	1,35
KL2		From incomplete design documents and limited tests, or with extended tests	From original design specifications and limited tests, or with extended tests	All	1,20
KL3		From design documents and limited tests, or with exhaustive tests	Original testing documents o design specifications with extended tests or exhaustive tests	All	1,00

10.1.4 PRELIMINARY INSPECTIONS

10.1.4.1 OUTSIDE

Preliminary inspections are necessary to get in touch with the building and for the verification of the main information collected through the previous phase. In this step, general building dimensions are checked as well as those related to structural elements like beam and columns. Thanks to thermographic tests, it was possible to identify the load-bearing beams along the perimeter of the building (Figure 78) and inside the apartments without needing for visual inspections (Figure 79). Moreover, some non-destructive investigations are performed with the aim of verifying the presence and type of some structural elements as for example for the elevator case. Using the Ground Penetrating Radar scanning technique (GPR) it was possible to prove that the elevator case was made of RC columns and beams instead of walls.

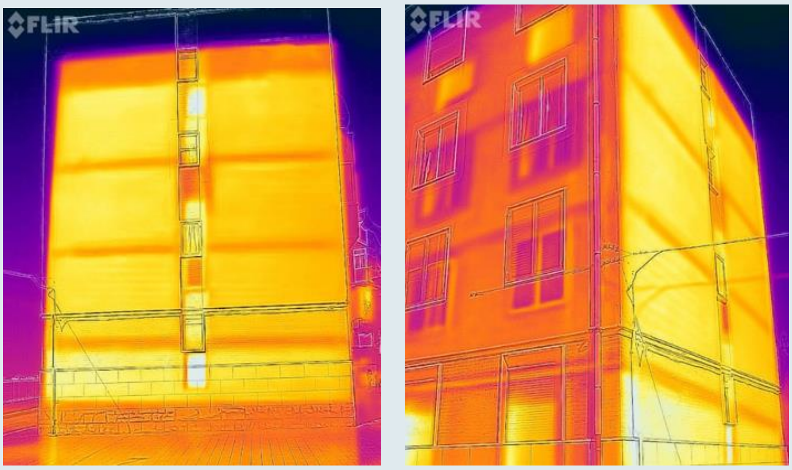


Figure 78: Thermographic tests.

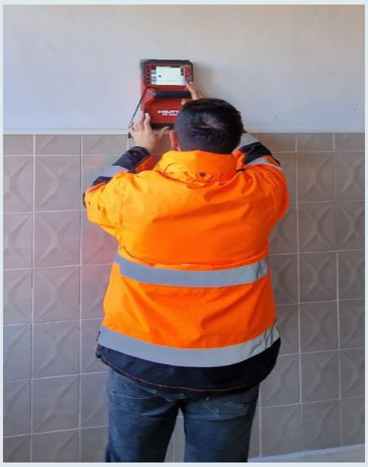


Figure 79: GPR scanning on the elevator case.

Thermographic and thermo-hygrometric inspections on the Italian Demo Site building, both during the day and at night [1], made it possible to highlight and limit critical issues and possible causes of heat loss in the building in consideration of its characteristics, intended use and the air conditioning technology used. The thermographic investigations also made it possible to verify the compliance with the planimetric tables of the arrangement of columns and beams.

The thermographic investigations highlighted the presence of infiltration mainly from the junction between the slab and the vertical wall and from the railing along the vertical and horizontal axis in which the columns stand.

From these investigations, qualitative information is obtained through the thermal image of the analysed area and dimensional information of the degradations detected on the "thermal map" of the anomalous areas. Specifically, from the outside it was possible to evaluate, on the columns, the hygroscopic impact linked to capillary filtrations due to deterioration of the external facade (Figure 80).

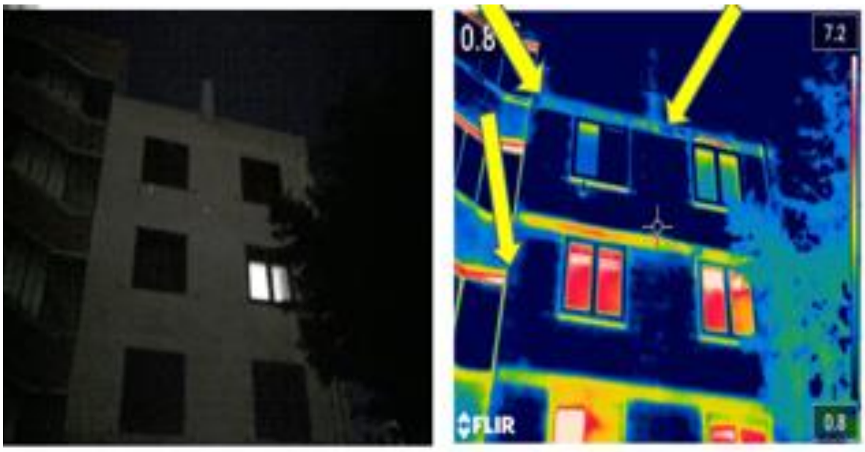


Figure 80: photography and thermographic survey of the north-east facade of the Italian Demo Site building.

Visual inspections, combined with instrumental surveys on the external envelope, have allowed to identify some structural elements where the degradation process of concrete and corrosion of reinforcements is in a rather advanced stage (Figure 81).

Figure 81: Degradation of concrete and corrosion of the reinforcements.

Thanks to these preliminary inspections, it was possible to update the finite element model created in the previous step in order refine the evaluations in view of the destructive investigation aimed at extracting material samples (concrete and steel) from the building structure.

10.1.4.2 INSIDE

Two surveys campaigns were carried out in December 2022, one aimed at identifying the structural elements on which to perform non-destructive concrete characterization tests and the other aimed at verifying the conservation and degradation state of the structural elements through thermographic analysis.

The data collected are reported in special sheets for collecting as much information as possible in a single inspection to reduce the number of visits to the apartments to a minimum. A sheet has been developed in which for each element the suitability to be subjected to testing is noted after checking the accessibility on each side and noting the surface treatment. For each floor, the structural elements that can be subjected to non-destructive testing are highlighted in the plan, following all the assessments carried out during the surveys (Figure 82).

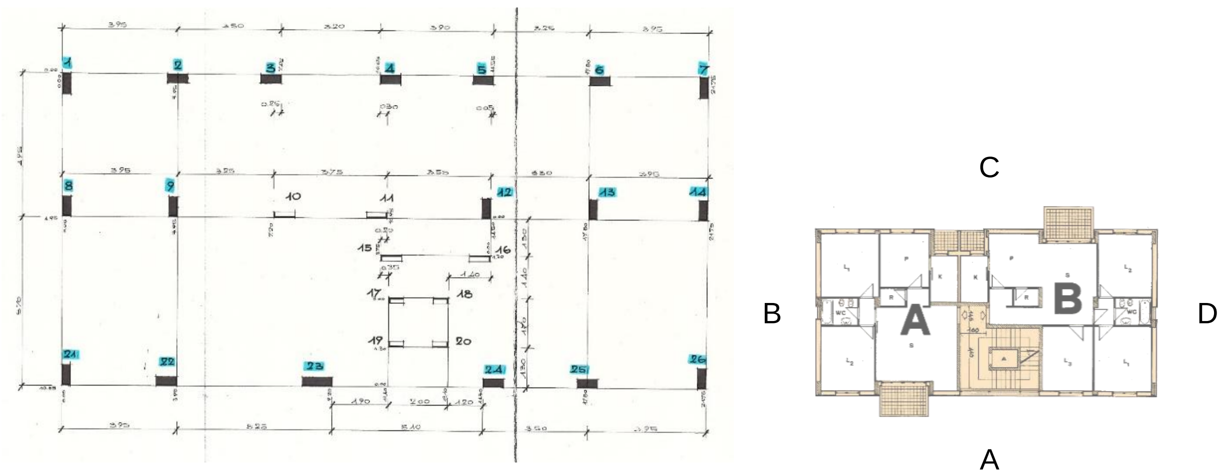


Figure 82: Floor plan (left) with columns numbering and (right) denomination of the

building sides (A, B, C, D) to identify the side of the element subjected to testing.

Also, for thermographic tests, a special form has been developed indicating the structural elements and surfaces investigated and reporting the photographic survey points.

The data collected led to the drafting of a non-destructive tests plan scheduled for February 2023. They allowed to get an overview about the conservation state of the building. The preliminary surveys carried out allowed the identification of the elements to be subjected to endoscopic tests and the elements from which to extract concrete cores and reinforcing bars for laboratory tests. All aimed at reducing the number of destructive tests, more invasive, to a minimum.

10.1.4.2.1 VISUAL INSPECTION TO IDENTIFY STRUCTURAL ELEMENTS FOR NON-DESTRUCTIVE TESTS

Below, the structural elements on which it is possible to carry out non-destructive tests, for each floor, verified during the survey, are identified on drawings made available by ARCA.

The upper ground floor is called R, the levels from the first to the third floor are marked with the corresponding numbers 1, 2, 3.

A summary sheet has been developed for the visual inspection (Figure 83). For each element the suitability to be subjected to testing is noted, after having verified its accessibility on each side and the surface treatment noted. Photographic surveys were carried out during the inspections (Figure 84).

The inspection objective was to identify possible structural elements for carrying out the tests in order to characterize the building and in particular the reinforced concrete columns. For this purpose, the outside building, the apartments and the attic floor were viewed also using of a thermal image to determine the columns exact position. Information was collected from the tenants and by people who participated in the building construction.

The tests points, sonic and ultrasonic analyses, for the concrete characterization, were chosen for minimizing the impact on the apartments tenants and to reduce as much as possible any restoration works to be carried out following the tests.

The inspection made it possible to determine some building characteristics that were not clear on the available design documentation and to verify the correspondence between project and built. In particular, it was possible to establish that:

- the basement is not accessible;
- the columns 10, 11, 15 and 16 have a thickness about 10 cm less than of the other columns;
- the lift shaft is not accessible from the inside; therefore, it was not possible to examine the columns indicated with numbers 17, 18, 19 and 20;
- the beams are made in thickness;
- the perimeter columns are made approximately 8-10 cm inside the floors;
- the window openings are made flush with the upper floor ceiling;
- the cladding of the upper ground floor is made flush with the columns and consists in stone slabs at the bottom and tiles, approximately 1 cm thick, at the windows level;
- on the upper floors the covering is made of plaster flush with the floors.

Below a sheet is shown as an example used for each element with the sides of the element on which the test can be performed highlighted.

pilastro (n°)	appartamento	Dimensioni elemento(cmxcm)	Superfici ndagabili PND (lato)				Superfici intonacate				Superfici con rivestimento				Elemento prelievo carota				prelievo barre d'armatura (lato)				Superficie di prova (cm x cm)	NOTE (annotare anche presenza di eventuali lesioni)
1-01	A		A	B	C	D	A	B	C	D	A	B	C	D	AC	CA	BD	DB	A	B	C	D		
1-02	A		A	B	C	D	A	B	C	D	A	B	C	D	AC	CA	BD	DB	A	B	C	D		
1-03	A		A	B	C	D	A	B	C	D	A	B	C	D	AC	CA	BD	DB	A	B	C	D		Ft 4317-8
1-04	B		A	B	C	D	A	B	C	D	A	B	C	D	AC	CA	BD	DB	A	B	C	D		Esame ext
1-05	B		A	B	C	D	A	B	C	D	A	B	C	D	AC	CA	BD	DB	A	B	C	D		Esame ext
1-06	B		A	B	C	D	A	B	C	D	A	B	C	D	AC	CA	BD	DB	A	B	C	D		Esame ext
1-07	B		A	B	C	D	A	B	C	D	A	B	C	D	AC	CA	BD	DB	A	B	C	D		Esame ext
1-08	A		A	B	C	D	A	B	C	D	A	B	C	D	AC	CA	BD	DB	A	B	C	D		
1-09	A		A	B	C	D	A	B	C	D	A	B	C	D	AC	CA	BD	DB	A	B	C	D	NDT	Foto 4319
1-10			A	B	C	D	A	B	C	D	A	B	C	D	AC	CA	BD	DB	A	B	C	D		Muro port.
1-11			A	B	C	D	A	B	C	D	A	B	C	D	AC	CA	BD	DB	A	B	C	D		Muro port.
1-12	B		A	B	C	D	A	B	C	D	A	B	C	D	AC	CA	BD	DB	A	B	C	D		No esame
1-13	B		A	B	C	D	A	B	C	D	A	B	C	D	AC	CA	BD	DB	A	B	C	D		No esame
1-14	B		A	B	C	D	A	B	C	D	A	B	C	D	AC	CA	BD	DB	A	B	C	D		No esame
1-15			A	B	C	D	A	B	C	D	A	B	C	D	AC	CA	BD	DB	A	B	C	D		Vano asc.
1-16			A	B	C	D	A	B	C	D	A	B	C	D	AC	CA	BD	DB	A	B	C	D		Vano asc.
1-17			A	B	C	D	A	B	C	D	A	B	C	D	AC	CA	BD	DB	A	B	C	D		Vano asc.
1-18			A	B	C	D	A	B	C	D	A	B	C	D	AC	CA	BD	DB	A	B	C	D		Vano asc.
1-19			A	B	C	D	A	B	C	D	A	B	C	D	AC	CA	BD	DB	A	B	C	D		Vano asc.
1-20			A	B	C	D	A	B	C	D	A	B	C	D	AC	CA	BD	DB	A	B	C	D		Vano asc.
1-21	A		A	B	C	D	A	B	C	D	A	B	C	D	AC	CA	BD	DB	A	B	C	D		
1-22	A		A	B	C	D	A	B	C	D	A	B	C	D	AC	CA	BD	DB	A	B	C	D		Esame ext
1-23	A		A	B	C	D	A	B	C	D	A	B	C	D	AC	CA	BD	DB	A	B	C	D		
1-24	B		A	B	C	D	A	B	C	D	A	B	C	D	AC	CA	BD	DB	A	B	C	D		Esame ext
1-25	B		A	B	C	D	A	B	C	D	A	B	C	D	AC	CA	BD	DB	A	B	C	D		Esame ext
1-26	B		A	B	C	D	A	B	C	D	A	B	C	D	AC	CA	BD	DB	A	B	C	D		Esame ext

Figure 83: Visual inspection sheet - first floor - with the investigated elements and sides highlighted.

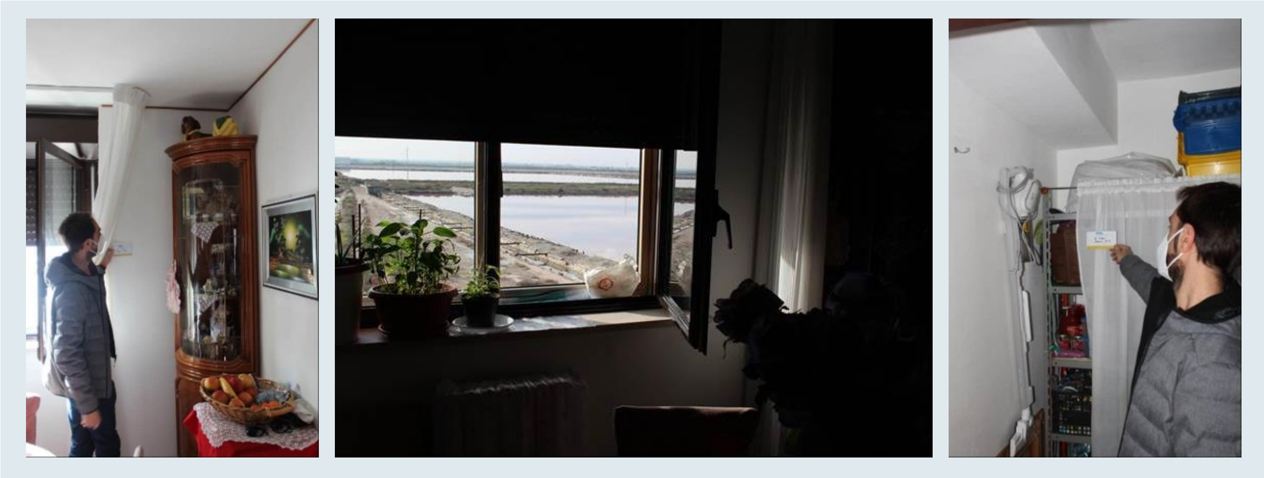


Figure 84: Column 1-03 (photo 1 and 2) and column 1-09 (photo 3).

Special sheets were used for the thermographic survey and the thermographic images for each of the two apartments on each floor (apartment A and apartment B). Below, only some images are showed as examples (Figure 85 and Figure 86).

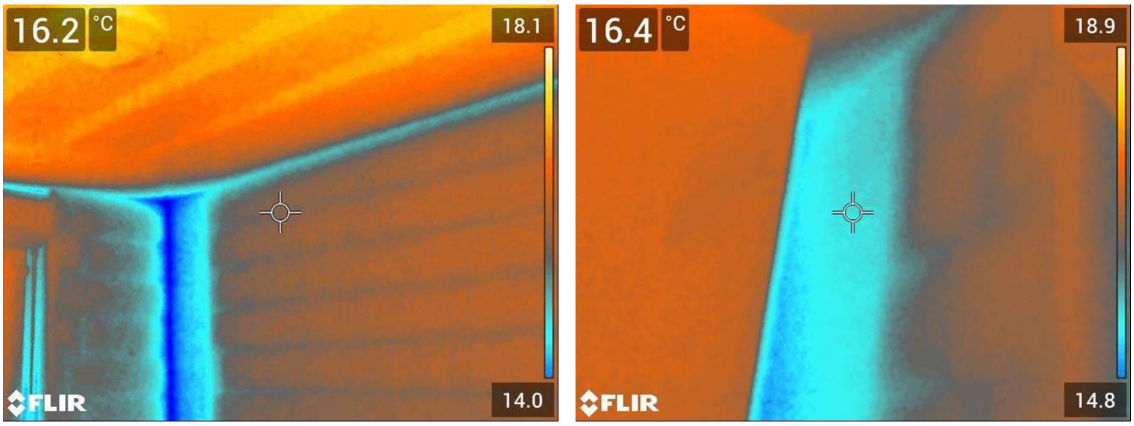


Figure 85: Upper ground floor plan, apartment A, room 5. Thermographic images T2575 e T2639.

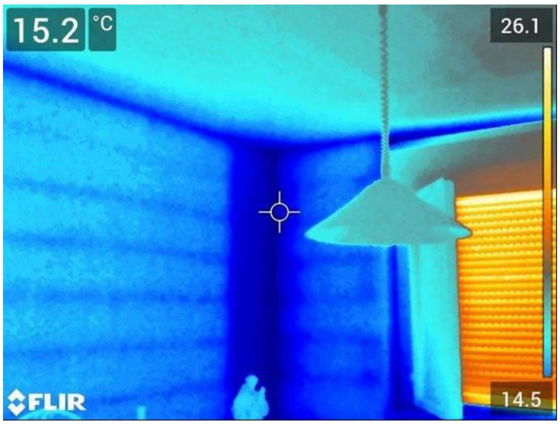


Figure 86: Upper ground floor plan, apartment A, room 6. Thermographic image T2576.

At a later stage, the hygrometric measurements allowed to confirm the infiltration phenomena by analysing, from the inside, the wall structures, the columns (Figure 87) and finally by carrying out measurements on the extracted cores (Figure 88).

Figure 87: Wall and column thermo-hygrometric measurements

Figure 88: Thermohygrometric measurements on core.

The thermo-hygrometric measurements also provided information on the conditions of the walls, making the impact on the indoor environment predictable.

10.1.4.2.2 ELEMENTS TO TEST FOR CONCRETE CHARACTERIZATION

The columns that can be subjected to non-destructive testing (Figure 89), following the assessments carried out during the inspections, are highlighted in each floor plan. It was not possible to inspect apartment B in floor 1, that has been inspected during the subsequent survey campaign in February 2023.

Accessibility to the columns for carrying out the tests is penalized by the presence of external cladding, in particular on the upper floors where, as the perimeter columns are built inside the slab, their external surfaces are covered with tiles approximately 5 cm thick and, probably, with a polystyrene insulating panel. This configuration does not allow direct ultrasonic tests to be carried out, except in some columns inside the apartments (n. 9, 12 and 13 in the floor plan) which are only covered with plaster.

Therefore, the greatest number of ultrasonic tests should be carried out with indirect method, operating on the same column face for both impulse transmission and reception.

As an alternative, some tests at upper ground floor will be to carried out. On the outside, the covering with 1 cm thick tiles is well adhered to the columns and it should not significantly influence the ultrasonic measurement.

Similarly, for core drilling and the removal of reinforcing bars, the tests on the upper ground floor presents notable advantages, such as being able to operate without use platforms, having reduced costs for restoration and carrying out the tests in correspondence of the ultrasonic ones in order to correlate the data.

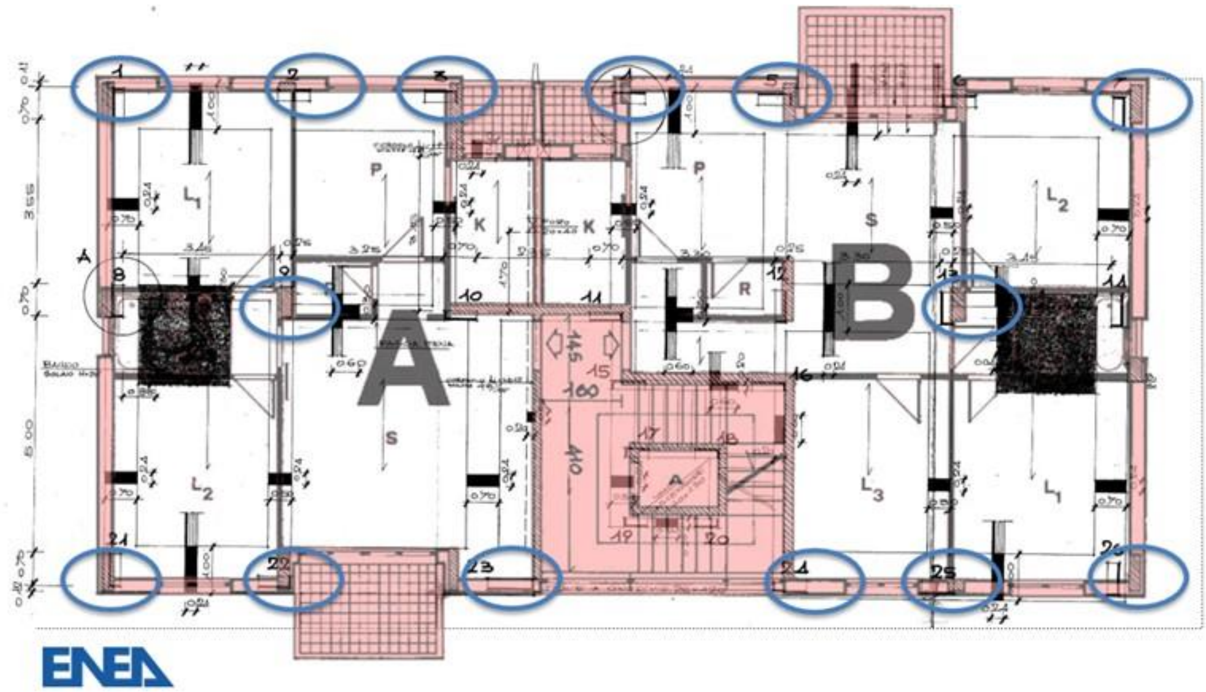


Figure 89: Upper ground floor plan. Identification of the elements that can be subjected to non-destructive testing.

References of Section 10.1.4

1. ‘Campagna di misure termografiche e termoigrometriche presso la Palazzina “A” di via Salinis 8, Margherita di Savoia’, Technical Report ENEA/2023/54059/SSPT-PROMAS, available on **Hermod at https://hermod.cartif.es/** (Technical Report nr. 4).

10.1.5 RAPID ASSESSMENT OF STRUCTURAL CRITICALITIES USING THE ENEA APP “CONDOMINI+ 4.0”

According to the methodology developed by ENEA and UNIBAS, at this point of the structural diagnosis the rapid assessment of the structural criticalities of Italian Demo Site Building, located at number 8 Via Salinis in Margherita di Savoia (FG), was performed using the ENEA APP “Condomini+4.0” [1].

As previously mentioned (see Section 7.1.5), the procedure implemented within the APP is not based on numerical simulations (FEM) and/or instrumental tests and, therefore, it doesn’t provide a Vulnerability Assessment under the Rules. This fast method, which rests on some evident structural deficiencies and on well-known seismic effects, leads to a preliminary estimation of the expected level of intervention from the structural point of view.

As required by procedure, the result here reported is based on the technical documentation (made available by the Project) and on a visual inspection (conducted by ENEA on 16th of February 2023).

In particular, this paragraph picks up the structure of the report generated by the Device, as document of output of the investigation carried out through the App. Having placed the seismic hazard of the area, the 10 sections dealing with the main elements of vulnerability investigated are reported. Each section is structured as follows: a brief description of that element of vulnerability, the data sheet on which the assessment was based, a brief description of the Level of Intervention reached for that element of vulnerability. For the sake of brevity full description of levels reachable for each section has been here omitted, please refer to the Report [2] for details. Finally, conveniently weighting the (partial) Levels of Intervention due to the criticalities resulting in each Section, a synthetic index is computed by the device to provide a global Level of Intervention (increasing on a scale of 1 to 6). The lower the safety level is, the higher the level of intervention needed.

10.1.5.1 SEISMIC HAZARD OF THE AREA

In this section information concerning seismic hazard of the municipality where the building is located is provided in terms of Seismic Zone. In case geological information is available, Site Class and Topography Class defined according to NTC (Italian Technical Standards for Constructions) are here recorded.

Data Sheet

Seismic Zone	Zone 2			
Is there geological information available?	YES		NO	X[3]
Site Class	-			
Topography Class	-			

The fast nature of this analysis doesn't include investigations aimed at predicting the potential of liquefaction which must be adequately investigated during Seismic Vulnerability evaluation according to the current Standard.

[3] Since the Site Class according to the current NTC requires the knowledge of the velocity of propagation of the shear waves, and we don't have this information, we had checked "NO" as far as the geological information availability. As a result, in the device the boxes for data entry related to Site Class and Topography Class are locked and, consistently they are not filled in this Data Sheet. However, Topography Class can be easily assigned, since the land develops on a flat surface (=T1).

10.1.5.2 ANALYSIS OF THE ELEMENTS OF VULNERABILITY

SECT 1: INTRINSIC VULNERABILITY

In this section the Level of Intervention due to the intrinsic vulnerability of the building (growing from 1 to 4) is computed based on Regulations followed at the design step and for subsequent renovation works (if any). The Level achieved depends on the availability of the technical documentation from which information about seismic behaviour can be deduced (e.g.: presence of prefabricated structure, change of use, functional changes of spaces and transformations).

Data Sheet

Regulations followed at the design step	-				
Regulations followed for renovation works (if any)	-				
Is the time of design documented with certainty and is the design printout report of building available? Are reports about renovation works available (if any)?		YES		NO	X[4]
Design documentation	-				
Renovation works documentation	-				
Is this a prefabricated structure?		YES		NO	X
Has the building been subjected to change of use or functional changes of spaces (which led a load increment) or transformations (e.g.: works, enlargements, raisings)?		YES		NO	X
Kind of change or kind of modification	-				
Date of the modification	-				

Result = Level 4[5]

Cases where design printout reports are not available, or cases where the building doesn't follow anti seismic Regulations and has a prefabricated structure (or in general all cases where the building doesn't fit with previous levels) fall into this category.

Level 4

[4] This section provides for the insertion of the only information documented with certainty and data sheet has been filled based on the documentation available at the time of writing this report. Since among the documentation the design printout report is missing, we selected "NO" for this answer. Then, some boxes were locked by device and, consistently, they are not filled in this Data Sheet.

[5] The Level 4 has been reached since, among the available technical documentation, the design printout report is missing.

SECT 2: ORGANIZATION OF THE RESISTANT SYSTEM

In this section the organization of the resistant system is evaluated (with a safety level which decreases from 1 to 3 and, accordingly, a level of intervention which increases from 1 to 3) based on the overall behaviour of the structure against the acting loads. A good organization is achieved when support frames are oriented in both directions whereas the presence of structural abnormalities is considered damaging. The belonging of the building to an aggregate entails different effects based on its position with respect to the other adjacent buildings.

Data Sheet

Are the support frames oriented in both directions?	YES	X	NO	
Is there any structural abnormality? (e.g.: columns which don't discharge loads to the ground, cantilevers having a span over two meters, columns having a side lower than 30 cm and other macroscopic abnormalities)	YES	X[6]	NO	
Is the building part of a structural aggregate?	YES		NO	X
If so, in what position?	-			

Result = Level 3

Presence of structural abnormalities (e.g..: columns which don't discharge loads to the ground, cantilevers having a span over two meters, columns having a side lower than 30 cm and other macroscopic abnormalities).

Level 3

SECT 3: QUALITY OF STRUCTURES

In this section the quality of structures is evaluated (with a safety level which decreases from 1 to 3) based on the characteristics of materials and on their laying. The points which mainly contribute to this evaluation are the concrete's consistence and quality, the modality of execution of the concrete castings resumes, the layout of the steel reinforcement and its covering.

Data Sheet

Can the concrete be considered of good consistence and quality?	YES	X	NO	
Are the concrete castings resumes barely visible and well-executed?	YES		NO	
Are the steel reinforcements well-arranged and well coated?	YES		NO	X
Does available information exclude the possibility of poor methods of execution and/or incorrect procedures or design decisions?	YES	X	NO	

Result = Level 2[7]

Buildings which do not fall in Level 1 or 3[8]

Level 2

[6] The kind of structural abnormalities which has been found based on the available documentation [3] is the presence of columns having a side lower than 30 cm

[7] According to this expeditious method, the concrete was considered of good consistency and quality within the limits of characteristics verifiable through the non-instrumental visual inspection conducted by ENEA on 16th of February 2023. During this visual inspection the steel reinforcements, in some areas, appeared not to be well coated whereas it was not possible to check the quality of recoveries between concrete castings.

[8] Please refer to Report [2] for details about description of Level 1 and Level 3.

SECT 4: FOUNDATIONS

In this section an evaluation of the safety level of foundations is reported (decreasing from 1 to 3) based on the behaviour of both soil and structure. The type of soil and the type of foundations are the main factors contributing to the level computation. Staggered plans of foundations are considered as a detrimental condition.

Data Sheet

Are tests and/or geotechnical documents available?		YES	X[9]	NO	
Type of soil (rocky or granular soil)	Granular soil				
Type of foundation	Slab				
Are the foundations placed at different depths?		YES		NO	X

Result = Level 1

Buildings built on rocky ground or on granular soil without foundations at different depths or buildings built on rocky grounds with foundations at different depths if foundations have a documented solidity (deduced from design documents and tests).

Level 1

SECT 5: HORIZONTAL RESISTANT SYSTEM

In this section an evaluation of the safety level of the horizontal resistant system is reported (decreasing from 1 to 3) based on the characteristics of the structural elements (it is taken into account the difference between prefabricated joists and slabs cast-in-place together with beams). Horizontal Slabs placed at different heights are considered as a negative condition since they affect the in-plane stiffness.

Data Sheet

Are there horizontal slabs placed at different heights?		YES		NO	X
Joists type	Cast-in-place together with beams[10]				

Result = Level 1

Buildings without horizontal slabs placed at different heights having slabs cast-in-place together with beams

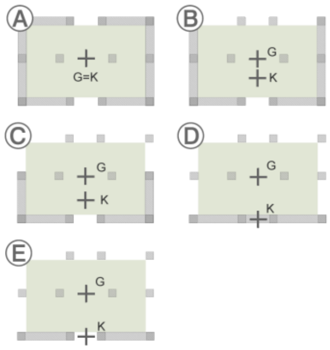
Level 1

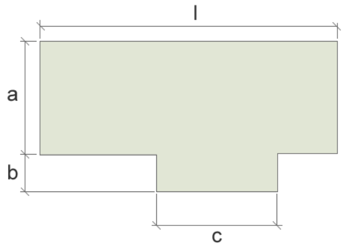
[9] Information here reported is taken from documents made available ([4] and [5])
[10] The type of joists was taken from documents made available [6]

SECT 6: IN PLAN REGULARITY

In this section an evaluation of the safety level (decreasing from 1 to 3) arising from the layout plan of the building is reported. This layout can have a negative impact on the building behaviour triggering torsional effects and high demand for ductility. In the assessment the distance between centre of mass and centre of stiffness, the shape of the building and the presence of protrusions come into play.

Data Sheet





Configuration that best approximates the building	B			
Smaller side of the rectangle circumscribed to the building's planform *a*	10.65	m		
Longer side of the rectangle circumscribed to the building's planform *l*	21.75	m		
Are there any protrusion with respect to the rectangular shape?	YES		NO	X
Width of protrusion (if any) *c*	-	m		
Dimension of the protrusion outside the rectangle (if any) *b*	-	m		

Result = Level 1

IT IS DEFINED AS REGULAR THE PLAN OF A BUILDING WHICH MEETS ALL THE FOLLOWING REQUIREMENTS:

AS REGARDS MASS AND STIFFNESS DISTRIBUTIONS Β1 < 0,2.

THE RATIO Β2 > 0,4.

AS REGARDS THE SHAPE OF BUILDING THERE ARE ONE OR MORE PROTRUSIONS WITH Β3 > 0,5 OR THERE ARE NONE.

LEVEL 1

Where the ratio □1=e/d is the maximum one, where "e" is the distance between centre of mass and centre of stiffness in the direction considered and "d" is the plan dimension of the building in the same direction. Some reference values of the ratio β1 = e/d are fixed for the exemplifying geometries in figure: A=0, B=0,08, C=0,28, D=0,40 and E=0,43.

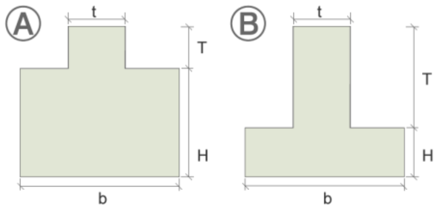
The ratio between smaller side "a" and longer side "l" in plan is defined as β2.

The dimension of protrusions is evaluated through the ratio β3 = c/b

SECT 7: IN ELEVATION REGULARITY

In this section an evaluation of the safety level (decreasing from 1 to 4) arising from in elevation configuration is reported. This configuration may result in irregular dynamic behaviours and in stress concentration in some areas of the building which are affected by changes along the height. The assessment depends on changes of geometry, of mass and of stiffness among the floors and on the Soft Story (if any).

Data Sheet



Is there any change of geometry, of mass or of stiffness among floors?	YES	X	NO	
How much is the percentage change of the area among the floors?	60[11]	%		
Is there a floor without infill walls (Soft Story)?	YES		NO	X

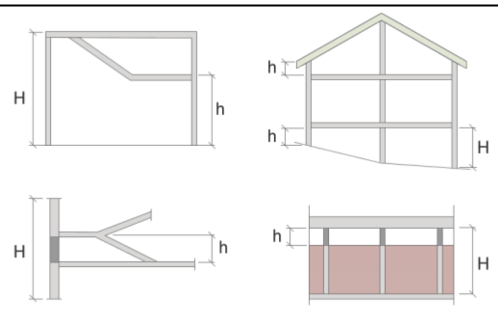
Result = Level 4

Buildings having area, mass and stiffness which change among floors more than 50%.
Level 4

SECT 8: CRITICAL ELEMENTS

In this section an evaluation of the safety level (decreasing from 1 to 3), resulting from the presence of elements having low ductility, is reported. These elements don't have a significant plastic deformation capacity and then they can lead to the activation of fragile mechanisms. To evaluate this issue, the height of the shortest element is compared with the other ones in order to pinpoint stocky elements.

Data Sheet



Height of the shortest element h	1.30[12]	m
Height of the other elements H	2.7	m

Result = Level 2

Buildings where H/4 < h ≤ H/2
Level 2

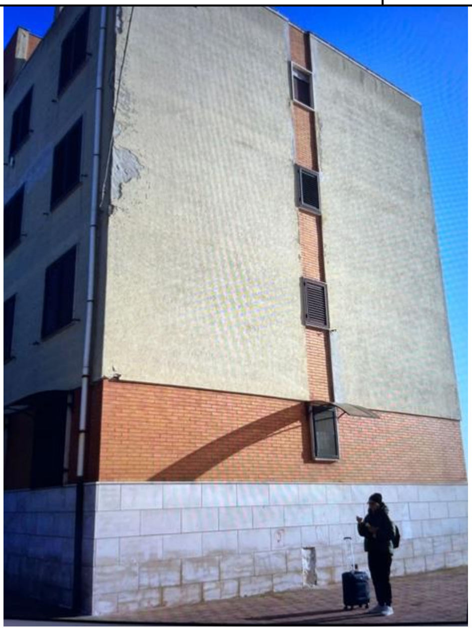
---

[11] The percentage change of the area among the floors here reported refers to the last floor (where the store rooms are located)
[12] The shortest elements here considered are the columns of the stairs

SECT 9: NON-STRUCTURAL ELEMENTS

In this section an evaluation of the safety level (decreasing from 1 to 3) resulting from the presence of non-structural elements is reported. These elements, in case of seismic events, can lead to a condemned building even without structural damages. To keep into account this, issue the percentage of these elements and their stability over seismic actions is evaluated.

Data Sheet

Are there external non-structural elements?	YES	X	NO	
Are the external non-structural elements stable over seismic actions?	YES		NO	X
Percentage of the non-structural elements with respect to the building perimeter.	70[13]		%	
Are there internal non-structural elements?	YES	X	NO	
Are the internal non-structural elements adequately connected or are they stable over seismic actions?	YES		NO	X
Percentage of the non-structural elements with respect to the internal surface area of the building.	60[14]		%	
Picture				

Result = Level 3

NON-STRUCTURAL ELEMENTS NOT EFFECTIVELY CONNECTED WHICH DISTRIBUTE ON MORE THAN 30 % OF THE EXTERNAL PERIMETER AND ON MORE THAN 30% OF THE TOTAL INTERNAL SURFACE AREA.

LEVEL 3

[13] The external non-structural elements here considered are the infill walls. They cannot be regarded as stable over seismic actions since a suitable connection system between them and the structural frames were not required by rules at the time of construction.

[14] The internal non-structural elements here considered are partition walls, furniture, objects hanging from the ceiling or from partition walls which, analogously, cannot be regarded as stable over seismic action

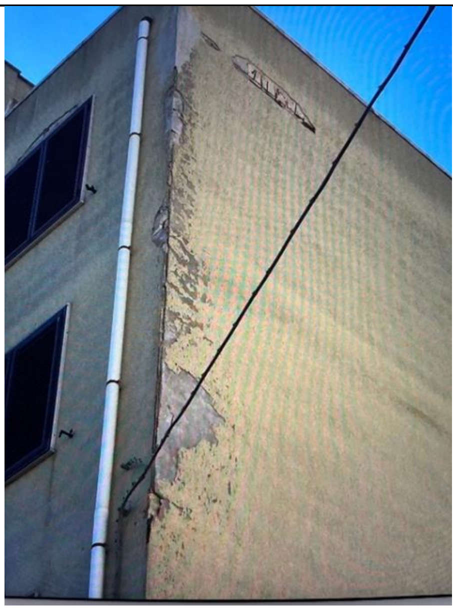
SECT 10: CONDITION OF THINGS

In this section the evaluation of the safety level (decreasing from 1 to 4) resulting from the condition of things of the building is reported. The assessment is carried out by detecting the presence of cracks and deteriorations on the building and of signs of problems at foundations. Previous earthquakes which may have been incurred by the building, of the same intensity as the design value, is considered representative of an experimentally tested behaviour.

Data Sheet

<table>
<tr><td colspan="2">Presence of cracks in the structural elements</td><td colspan="4">Absent</td></tr>
<tr><td colspan="2">Presence of deteriorations (corrosion, carbonation, swelling etc.)</td><td colspan="4">Present</td></tr>
<tr><td colspan="2">Are there any effect due to exceptional loads or due to an earthquake equivalent to the one of design?</td><td>YES</td><td></td><td>NO</td><td>X</td></tr>
<tr><td colspan="2">Are there any sign of foundations problems?</td><td>YES</td><td></td><td>NO</td><td>X</td></tr>
<tr><td colspan="2">Are there any problem (on structural or on non-structural elements) which require immediate safety measures?</td><td>YES</td><td>X</td><td>NO</td><td></td></tr>
<tr><td>Types of problems observed and immediate safety measures proposed</td><td colspan="5">Main problems requiring immediate safety measures are:
• Presence of portions of plaster detached from the facades of the building.
• Expulsion of concrete covering from reinforcing steel of beams and columns.

It is suggested to remove falling parts and refurbish damaged and/or deteriorated areas.</td></tr>
<tr><td colspan="2">Are there any sign of problems concerning gravity loads? (e.g.: evidence of high deformability and “breakthrough” of the floor slabs, loss of shape in the vaults)</td><td>YES</td><td></td><td>NO</td><td>X</td></tr>
</table>

Pictures	 

Result = Level 2[15]

Presence of small signals of degradation in the structural elements at sight, but without signals of structural cracks. This level is also assigned to the buildings more than 70 years old even if they appear to be in good condition. Absence of foundation problems and absence of problems concerning gravity loads.

Level 2

10.1.5.3 LEVEL OF INTERVENTION

In the Table 36 the (partial) Levels of Intervention, obtained for each Element of Vulnerability as previously detailed, are summarised.

[15] Evaluations regarding the conditions of things are derived from visual inspection conducted by ENEA on 16th of February 2023

Table 37: Summary of (partial) levels of intervention

ELEMENT OF VULNERABILITY		LEVEL
SECT 1	INTRINSIC VULNERABILITY	4
SECT 2	ORGANIZATION OF THE RESISTANT SYSTEM	3
SECT 3	QUALITY OF STRUCTURE	2
SECT 4	FOUNDATIONS	1
SECT 5	HORIZONTAL RESISTANT SYSTEM	1
SECT 6	IN PLAN REGULARITY	1
SECT 7	IN ELEVATION REGULARITY	4
SECT 8	CRITICAL ELEMENTS	2
SECT 9	NON-STRUCTURAL ELEMENTS	3
SECT 10	CONDITION OF THINGS	2

Adequately weighting the (partial) Levels of Intervention above, the device computed a synthetic Level of Intervention equal to 4 (medium-high) (Figure 90).

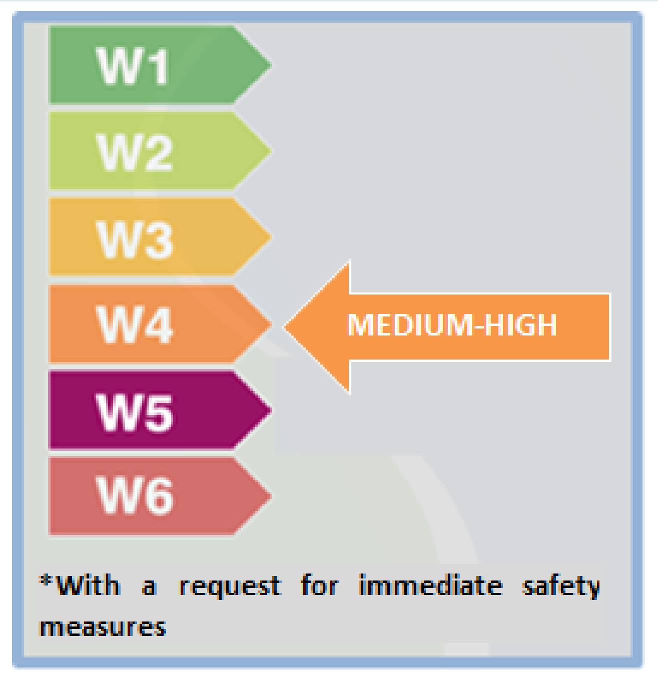


Figure 90: Level of intervention evaluated through the app enea

According to the qualitative and expeditious assessment performed at this step of the structural diagnosis through the ENEA App, the main criticalities that emerged are summarised below.

1) Among the technical documentation the design printout report was lacking, which means that important information is missing and an in-depth analysis on the seismic capacity of the building is needed.

2) Some columns have a side lower than 30 cm, which represents a structural abnormality with possible consequences in terms of resistance and deformability.
3) Within the limits of characteristics verifiable through the non-instrumental visual inspection conducted by ENEA on 16th of February 2023, the concrete was considered of good consistency and quality whereas in some areas the steel reinforcements appeared not well coated. It was not possible to check the recoveries between concrete castings.
4) As concerns aspects related to the regularity, it was found that there is a significant percentage change of the area among the last floor (where the store rooms are located) and the lower ones whereas the building appears to have an almost regular plan configuration. However, the effects of the presence and of the arrangement of the knee beams between floors should be explored more deeply through a numerical analysis (FEM).
5) It has emerged that there are some critical elements. Most likely these elements don't have a significant plastic deformation capacity and then they can lead to the activation of fragile mechanisms. We are talking about the columns of stairs which are stocky elements which could be prone to shear failure.
6) Particular attention should be paid to the non-structural elements in terms of connections to the structural ones and in terms of stability over seismic actions. We are talking about elements at risk of falling outward (e.g. infill walls) and elements at risk of falling inward (e.g. furniture, objects hanging from the ceiling or from partition walls) whose fall can injure people and/or can cause damage and/or can block escape routes in case of emergency.
7) The condition of things was evaluated during the visual inspection conducted by ENEA on 16th of February 2023, from which some clear signs of deterioration emerged. Particularly it was noted the presence of portions of plaster detached from the facades of the building and, in some cases, the expulsion of concrete covering from the reinforcing steel of beams and columns with consequent oxidation of the reinforcement. Some immediate safety measures are required aimed at removing falling parts and at refurbishing damaged and/or deteriorated areas.

During the next steps of the structural diagnosis it is suggested to:
- performed destructive and non-destructive testing aimed at deepening the knowledge of materials and elements;
- performed the Seismic Vulnerability Assessment under the Rules aimed at identifying all the necessary interventions.

References of Section 10.1.5

1. G.Buffarini, N.Calabrese, A. Carderi, P.Clemente, C.Lavinia, A.Marzo, C.Tripepi (2018). App ENEA "Condomini +4.0". https://www.efficienzaenergetica.enea.it/vi-segnaliamo/condomini-4-0-l-app-enea-per-gli-edifici-condominiali.html
2. 'Valutazione speditiva delle criticità strutturali della Palazzina "A", Margherita di Savoia, attraverso l'App ENEA "Condomini+ 4.0"', Technical Report ENEA/2023/54010/SSPT-MET-DISPREV, available on Hermod at https://hermod.cartif.es/ (Technical Report nr. 1).
3. Panel of Design n.4 "Carpenteria 1° e 2° Piano Pal. A" signed by Eng. Mario Maggio, deposited with "Ufficio del Genio Civile di Foggia". Date 28/09/1984.
4. Report "Studio geologico – tecnico sui terreni di fondazione delle case popolari da costruirsi in Comune di Margherita di Savoia ai sensi della Legge 457 – III biennio 82-83 completamento" signed by Geologist Giulio Suzzi. Opinion issued by Technical Committee. Date 16/04/1984.
5. Panel of Design n.2 "Carpenteria Fondazioni Pal.A" signed by Eng Mario Maggio, deposited with "Ufficio del Genio Civile di Foggia". Date 05/11/1984.
6. Panel of Design n.7 "Carpenteria […] Cantinole Pal.A" signed by Eng. Mario Maggio,

deposited with “Ufficio del Genio Civile di Foggia”. Date 28/09/1984.

10.1.6 DESIGN OF DESTRUCTIVE INVESTIGATION PROGRAM

It is worth noting that the preliminary rapid assessment conducted using the “CONDOMINI+ 4.0” app (see Section 10.1.5) allowed to highlight some criticalities that indicate a possible poor seismic performance of the building at hand. In particular, the above-mentioned assessment evidenced, among other issues, the existence of short and stiff elements in the staircase, which can fail through fragile mechanisms, the presence of elevation irregularities (store level) due to floor plan surface variation. Therefore, an immediate detailed assessment is necessary to carefully evaluate the structural and seismic vulnerability of the building. To do so, it is first necessary to plan destructive investigations able to provide the needed information about material properties, structural details and geometry, which can allow performing a detailed assessment according to the rules of the Italian building code.
As already mentioned in section 7.1.6, the design of the surveys is crucial both to confirm hypotheses formulated during preliminary phases and to obtain a realistic estimate of the physical and mechanical parameters to be used in structural verifications. In the case at hand, considering that the building is fully occupied, the survey program to achieve the knowledge level KL2 was designed to minimize the invasiveness of the tests. Except for the concrete cores, the survey points were chosen following a careful analysis of the information gathered, the preliminary study of the building, and the site inspection carried out inside each apartment. Concerning the concrete cores, the investigation points were chosen using the valuable information provided by the sonic measurements carried out by ENEA, also in section 10.1.7.
According to the code definition of “limited tests”, 15% of structural members must verified and 1 concrete + 1 steel rebar sample should be extracted from the building. This means that the following total investigations must be conducted.

- 37 GPR scans and endoscopy test to check the number of rebars inside column and beams;
- 2 visual inspections to check reinforcement layouts (by concrete cover removal);
- 1 visual inspection on infill walls;
- 2 endoscopy inspections to check the foundation typology;
- Extraction of 8 cores from column member to assess the concrete strength. It was not possible to extract core from beams since they have the same thickness as the slab and therefore are not suitable for this purpose;
- Extraction of 6 steel rebars from columns and roof storey beam members.

The details related to the destructive tests’ execution are reported in section 10.1.8.

10.1.7 NON-DESTRUCTIVE INVESTIGATIONS AND ANALYSIS

10.1.7.1 AIM OF THE MEASUREMENTS CAMPAIGN

The non-destructive testing campaign is dedicated to the evaluation of the condition of the concrete columns of the social housing building. The assessment was conducted through the following sub-activities:

- collection of basic information and field investigations, in particular regarding structural aspects, in order to obtain as detailed and truthful description of the building [1].
- planning and execution of in situ non-destructive tests [2]. In particular, pacometric,

ultrasonic and sonic tests were carried out on the columns of the building in order to test the effectiveness and possibility of implementing the methodology developed within RILEM TC 249-ISC [3,4] on 'NDT in situ strength assessment of concrete' to minimise the error in the technical assessment following the standard UNI EN 13791:2019 [5].

The importance of developing an effective methodology, as non-destructive as possible, for the assessment of concrete strength also has the aim of minimising inconvenience to tenants.

The characterisation tests of the materials and structural elements were carried out in accordance with the European and Italian technical regulations in force, in order to achieve a Knowledge Level of at least KL2 (section 10.1.3). In situ and laboratory tests were subsequently carried out by GIEPI S.r.l. of Foggia, an authorised laboratory for this type of testing.

This deliverable only reports the results of the measurement campaign carried out with sonic velocity measurements because they were the non-destructive measurements on which the selection of the points on which the cores were then based.

10.1.7.2 SONIC VELOCITY MEASUREMENTS: SET-UP

THE SONIC VELOCITY TEST TECHNIQUE IS BASED ON THE GENERATION OF MECHANICAL IMPULSES WITH FREQUENCIES IN THE SOUND FIELD. THE SOUND WAVE IS GENERATED ON THE ELEMENT, THE COLUMN IN THE SPECIFIC CASE OF THIS MEASUREMENT CAMPAIGN, BY IMPACTING WITH AN INSTRUMENTED HAMMER, AND IS RECEIVED BY A SENSOR (PIEZOELECTRIC ACCELERATOR) PLACED AT A DIFFERENT POINT ON THE ELEMENT. TO CALCULATE SONIC VELOCITY, IT IS NECESSARY TO MEASURE THE TRAVEL TIME OF A SONIC SIGNAL THROUGH A SURFACE. IN OUR CASE INDIRECT MEASUREMENTS WERE CARRIED OUT PLACING THE IMPACT POINT OF THE INSTRUMENTED HAMMER AND THE RECEIVING ACCELERATOR ON THE SAME FACE OF THE COLUMN AS REPORTED IN FIGURE 91.

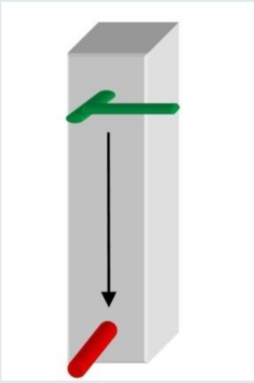


Figure 91: Scheme of indirect measures.

Measurements were carried out by Level 3 personnel trained according to UNI/PdR 56:2019 [6].

The signal processing and measurement acquisition part was handled with the IMG 5200 CSD instrument (device on the left in Figure 92), which is a digital low-frequency equipment for the control of inhomogeneous materials, equipped with a touchscreen, with multiple functions such as the storage of oscillograms (A-Scan) and relative calibration parameters.

An instrumented hammer with an accelerometer sensor (Figure 93) for measuring sonic velocities was connected to the IMG 5200 CSD.

Figure 92: Img 5200 csd device.

Figure 93: Sonic velocity instrumentation (instrumented hammer for measuring sonic velocity).

Both devices are connected to a signal amplifier and an analogue-to-digital converter for visualisation and data recording on a laptop computer.

The processing of the data consists of determining the flight times (expressed in microseconds): the read values represent the time the sound emitted by the hammer takes to reach the end of the element in which the accelerometer sensor is positioned. The crossing velocity of the investigated element, generally expressed in m/s, is obtained from these values, knowing the distance between the point of impact of the hammer and the position of the receiver, as well as the dimensions – cross section - of the column.

For each measurement setting on the column, at least 3 distinct measurements are generally carried out and their signals recorded: the velocity at the column is the average value of the 3 measurement values.

10.1.7.3 MEASUREMENT CAMPAIGN DATA

The measurement campaign was focused on the columns of Italian Demo Site in Margherita di Savoia (FG) as part of the REHOUSE Project.

At the same time as the measurements were taken, photographic surveys were carried out at the columns subject to the measurement activities.

Figure 94 shows a plan of the building, highlighting the columns that were the subject, on at least one of the 4 floors, of sonic velocity measurements.

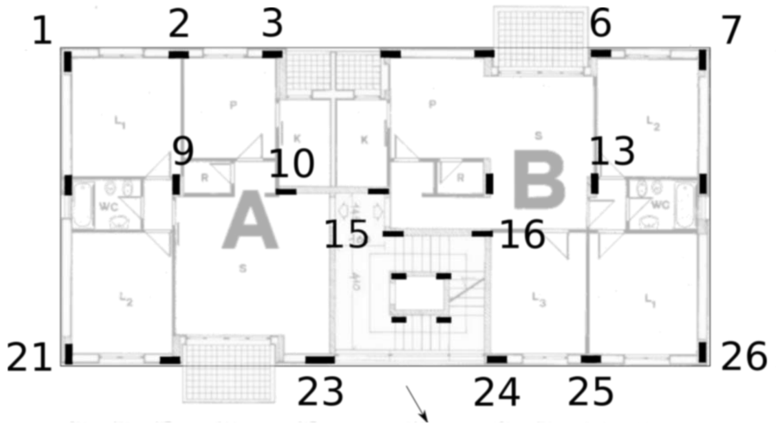


Figure 94: Floor plan highlighting the columns and indicating the column identifiers with at least one sound velocity measurement on one of the 4 floors.

The investigation plan led to reducing the lot of columns actually candidates for core drilling to those accessible from outside the apartments. In this way, the core extraction operations are less invasive (process water, dust and debris, noise, restoration of surfaces, moving apartment furniture) for the tenants and quicker to carry out for the operators.

For this reason, columns of interest were considered to be those with a side facing outside of the building or facing the stairwell. Since the operators of the NDT tests could not access two opposite side of the column, it was decided to perform the tests in the indirect configuration.

On the first day of the measurement campaign, inspections were carried out with GIEPI S.r.l.'s georadar instrumentation and pacometer in order to identify the position of the reinforcement bars in some of the columns of the building.

The surveys took place both inside the building (in the flats, Figure 95, and in the stairwell, Figure 96) and externally.

However, this survey could not cover all the columns of Building A on which non-destructive inspections were to be carried out and was completed for the columns that were not inspected in the following days using a pacometer provided by ENEA.

The positions of the bars, both longitudinal (vertical) and transversal, or stirrups, were marked from time to time with adhesive paper tape, Figure 96, in order to leave fewer residual traces on the flat walls, or with chalk (on the outside).

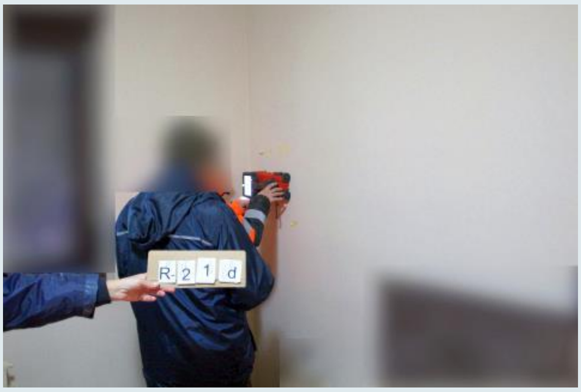


Figure 95: Georadar survey of reinforcement bars at column 21 on the upper ground floor, flat interior.

Figure 96: Labelling of reinforcement bars at column 15 on the second floor, stairwell side.

10.1.7.4 INDIRECT SONIC TESTS CAMPAIGN

Indirect NDT measurements were performed to assist technicians in selecting the columns from which to extract the cores.

The execution of the tests on the columns required careful time planning to agree on the co-presence of the tenants without whom it would not have been possible to access the apartments. Previous inspections (section 10.1.4) made it possible to optimize intervention times by not considering the columns that did not have a clear surface: in many situations it would have been impossible, or extremely complicated, to move the furnishing elements.

IT IS WORTH REMEMBERING THAT FOR CORRECT EXECUTION OF SONIC TESTS IT IS NECESSARY TO HAVE BOTH A FREE COLUMN SURFACE BUT ALSO A SUFFICIENTLY LARGE SPACE IN FRONT OF IT SO THAT THE INSTRUMENTED HAMMER CAN HAVE THE CORRECT EXCURSION TO IMPACT THE COLUMN WITH ENERGY SUITABLE FOR THE PROPAGATION OF THE SONIC IMPULSE.

TAKING THESE LIMITATIONS INTO ACCOUNT, IT WAS STILL POSSIBLE TO CONDUCT A LARGE SERIES OF INDIRECT SONIC MEASUREMENTS WHICH WERE PERFORMED BY POSITIONING THE POINT OF IMPACT OF THE INSTRUMENTED HAMMER ON THE COLUMN AT A HEIGHT OF 2 M FROM THE FLOOR AND, WITH ALIGNMENT ON THE VERTICAL, THE ACCELEROMETER AT A DISTANCE OF 15 CM FROM THE FLOOR (FIGURE 97).

Figure 97: Execution of sonic test.

Table 38 shows the velocities calculated on the flight time measurements, sorting the data first based on the ascending column identifier, then by ascending floor.

Table 38: Indirect sonic velocity measurements to support structural analysis on the italian demo site building.

		INDIRECT SONIC VELOCITY [M/S]				INDIRECT SONIC VELOCITY [M/S]	
column	floor	mean value	std. dev.	column	floor	mean value	std. dev.
1	U.G.	3696.8	79.1	21	U.G.	3939.7	116.3
1	1	3080.5	84.6	21	1	3095.4	12.9
1	3	3690.5	34.3	21	3	3403.1	28.0
2	U.G.	3064.9	31.1	23	1	3601.8	28.4
3	3	3550.9	5.6	23	3	3762.8	22.0
6	2	2889.4	72.6	24	1	4186.2	53.7
7	U.G.	3810.2	119.3	24	2	2896.5	62.0
7	1	3679.6	123.5	25	2	3425.9	9.0
7	2	3085.5	37.8	25	3	4103.2	71.1
15	U.G.	3895.2	41.0	26	U.G.	4171.8	145.5
15	1	3967.3	28.1	26	1	3769.7	83.4
15	2	3629.9	133.5	26	2	3522.0	40.6
15	3	3157.6	42.1				

10.1.7.5 DATA ANALYSIS

The mean values of the indirect sonic velocity measurements, summarized in Table 38, refer to the columns identified for the possible core samples in Section 10.1.6.

The distribution of the measurements is shown in Figure 98 and the average values of the sonic velocity measurements have a normal distribution for values between 3350 m/s and 4100 m/s whereas there are concentrations for both low sonic speed values and high values.

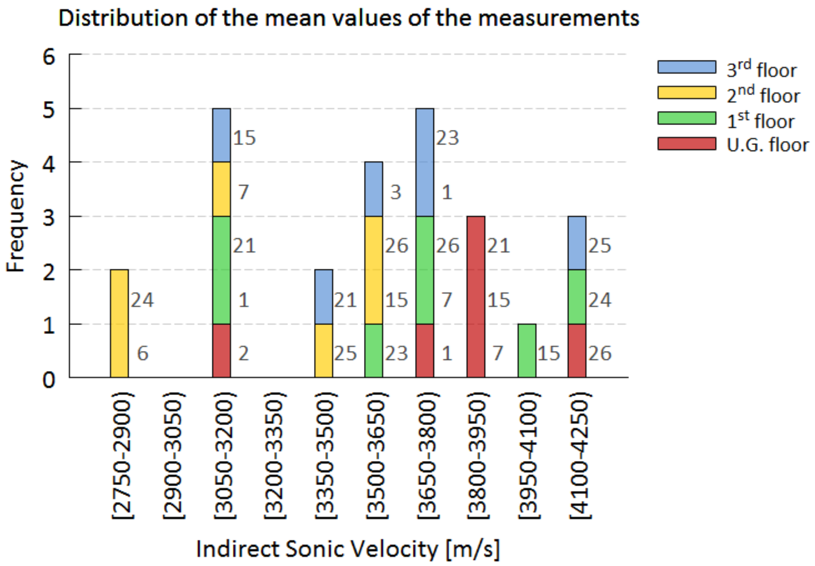


Figure 98: Distribution of indirect sonic measurements.

In section 10.1.6 were assessed 8 samples of cores to be extracted - according to the regulations and guidelines for a KL2 level of knowledge appropriate to the situation of the building in via Salinis - it was planned to extract no more than 2 cores per floor (on different columns) and no more than 2 cores per column (on different floors).

Keeping these indications in mind it was suggested to follow the approach indicated by RILEM TC 249-ISC using the information collected in the performed indirect ND measurement campaign: that is, to choose the positions from which to extract the cores so that the corresponding values of the sonic velocity measurements previously detected are distributed over the entire range.

To support this course of action it was agreed that ENEA would contribute by proposing up to 7 positions from which to extract the core samples.

To provide more effective graphic feedback, the entire series of sonic velocity measurements, sorted by increasing value, is shown in Figure 99, on the left, and the 7 positions where core drilling was proposed are highlighted by black triangles. The right chart of the Figure 99 shows the actual dispersion of the indirect sonic velocity measurements corresponding to the proposed coring positions.

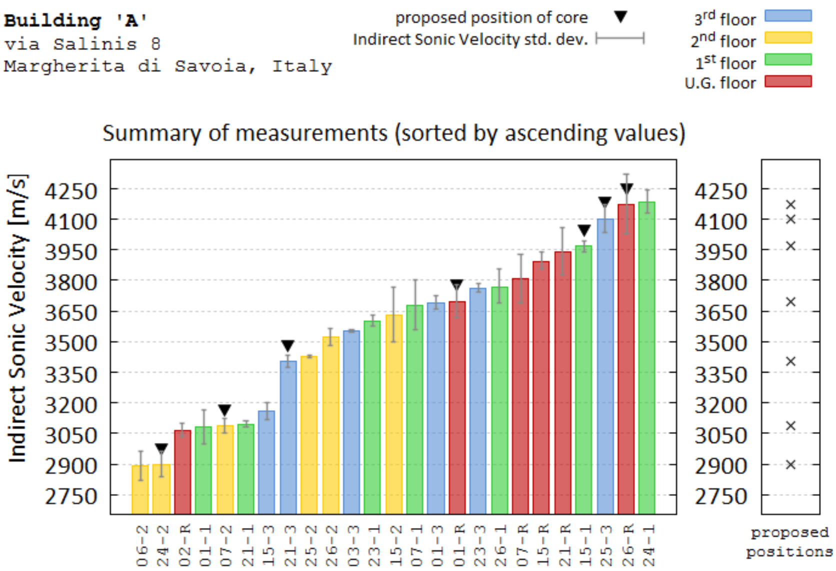


Figure 99: Sonic measurements and highlighting of proposed positions for core extraction.

References of Section 10.1.7

1. 'Progettazione preliminare ed esecuzione di indagini non distruttive presso la Palazzina "A" di via Salinis 8, Margherita di Savoia', Technical Report ENEA/2023/54056/SSPT-PROMAS-MATAS, available on Hermod at https://hermod.cartif.es/ (Technical Report nr. 2).
2. 'Campagna di misure non distruttive (13-17 febbraio 2023) presso la Palazzina "A" di via Salinis 8, Margherita di Savoia', Technical Report ENEA/2023/54057/SSPT-PROMAS-MATAS, available on Hermod at https://hermod.cartif.es/ (Technical Report nr. 3).
3. Breysse, D., Balayssac, J.-P., Biondi, S., Corbett, D., Goncalves, A., Grantham, M., Luprano, V.A.M., Masi, A., Monteiro, A.V., Sbartai, Z.M. 'Recommendation of RILEM TC249-ISC on non destructive in situ strength assessment of concrete' (2019) Materials and Structures/Materiaux et Constructions, 52 (4), art. no. 71.
4. In-Situ Strength Assessment of Concrete: Detailed Guidelines In book: Non-Destructive In Situ Strength Assessment of Concrete, Practical Application of the RILEM TC 249-ISC Recommendations (April 2021). DOI: 10.1007/978-3-030-64900-5_1 .
5. UNI EN 13791:2019. Valutazione della resistenza a compressione in sito nelle strutture e nei componenti prefabbricati di calcestruzzo / Assessment of in-situ compressive strength in structures and precast concrete components.
6. UNI/PdR 56:2019, Prassi di riferimento 'Certificazione del personale tecnico addetto alle prove non distruttive nel campo dell'ingegneria civile' / Reference Practice for the 'Certification of Technical Personnel for Non-Destructive Testing in Civil Engineering'.

10.1.8 PERFORMING OF DESTRUCTIVE INVESTIGATIONS

Visual inspections

Visual inspections (Figure 100) of reinforcement details (type, diameter, and quantity of bars actually present) were conducted by means of seven exploratory tests distributed across various floors between beams and columns, utilizing the extraction points of the reinforcement samples. Each test allowed to see longitudinal reinforcements for a length greater than the spacing of the stirrups. Preliminary pacometric investigations allowed for the identification of the number and position of the reinforcement bars. Regarding the external column elements, given the typological homogeneity, it was sufficient to carry out only one test at the first storey. The exploratory test on infills and cladding elements was made through a hole, combined with endoscopic investigation, to recognize the stratigraphy and transverse thickness of the panel. Two additional endoscopic investigations were carried out at the foundation beams around the perimeter of the building to detect areas inaccessible beneath the ground floor slab. In particular, the foundation level, the type of foundation system, and the presence of water were recorded.

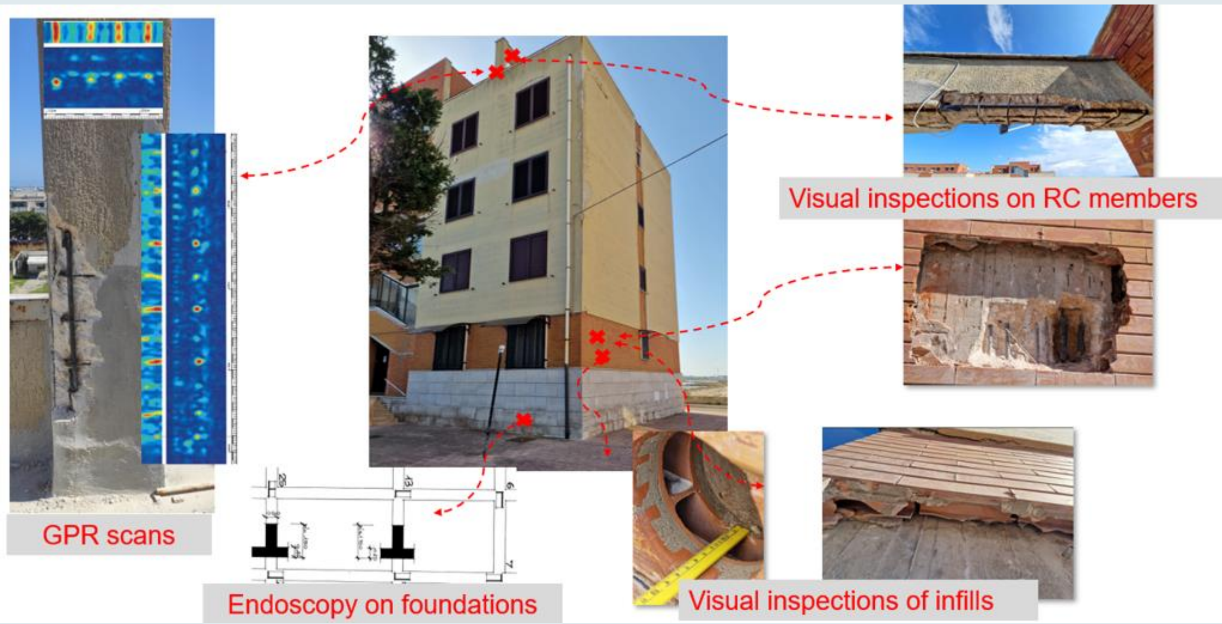


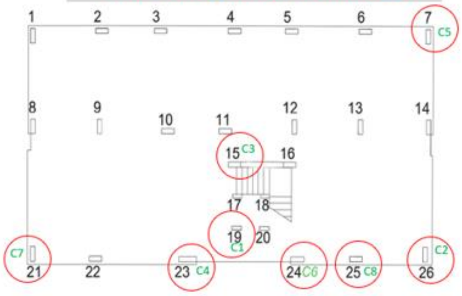
Figure 100: Overview of inspections and investigations.

Coring tests

The building has a floor area of approximately 220m^2 per floor. To achieve knowledge level KL2, a total of eight cores were extracted (two per floor). Considering the difficulty of extracting samples from wide beams, coring activities focused only on the columns. Each core has a diameter of 10 cm and a length of approximately 13 cm. To identify concrete areas without reinforcement, pacometric surveys were conducted. Each sample was taken at approximately half the height of the columns, on the side with larger dimensions. After each extraction, prompt and careful closure of the hole and restoration of finishes (cladding and plaster) were carried out. Out of the eight total extracted cores, two targeted internal columns and six targeted external columns, where the use of an aerial platform was indispensable (Figure 101).

During this phase, the cladding of the external columns was recorded. At ground level, the cladding consists of Apricena stone slabs, terracotta strips, and a layer of plaster, with a thickness of 6.5cm. On upper floors, there is a cladding with a thickness of 13.5cm, defined by a layer of plaster, perforated bricks, and an air gap.

Plan distribution of cores



Some extracted cores

Storey distribution of cores

Core	Storey
C1	5
C2	1
C3	2
C4	2
C5	3
C6	3
C7	4
C8	4

Coring by the outside

Figure 101: Summary of material sampling.

The extracted specimens underwent compression testing according to the provisions outlined in the standard UNI EN 12504-1:2021. The strength of the cores taken, denoted as $f_{car,i}$, was converted to the corresponding in-situ concrete strength, $f_{cis,i}$, before being utilized in verification calculations. To reassess the strengths, the following relationship, as proposed by [2], was employed:

$$f_{cis,i} = (C_{h/D} \times C_{dia} \times C_a \times C_d) \times f_{car,i}$$

where:

- $C_{h/D} = 2/(1.5 + D/h)$ is the corrective coefficient for h/D ratios different from 2;
- C_{dia} is the corrective coefficient related to the diameter: assumed to be 1 for D=100 mm;
- C_a is the corrective coefficient related to the presence of included reinforcements: assumed to be 1 in this specific case because there are no bars inside the cores;
- C_d is the corrective coefficient to account for the disturbance caused to the core during extraction and preparation operations: assumed to be 1.30 for f_{car} < 10 Mpa or 1.20 for 10 < f_{car} < 20 MPa.

Extraction of rebars

Given the steel design specifications and considering the operational difficulties in extracting reinforcement samples from the beams, the extraction of the six steel bars only involved the columns at specified levels. Each reinforcement sample was taken in a way to minimize the impact on structural elements' integrity and damage due to extraction. After each extraction, the initial load-bearing capacity of the structural element was restored by replacing the extracted rebar with one of equal diameter and strength, ensuring the continuity of existing/new reinforcement through a proper welding.

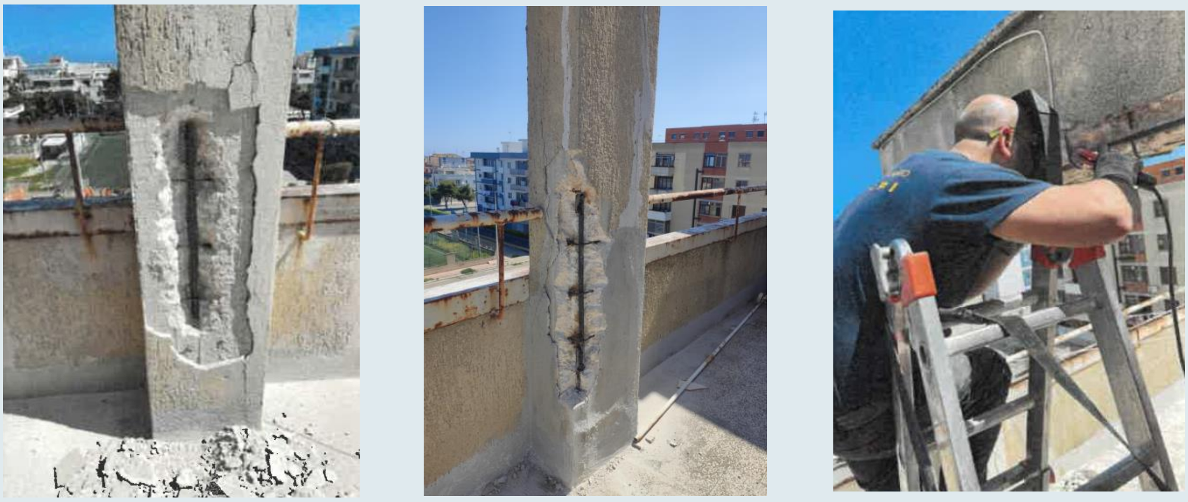


Figure 102: Overview of inspections and investigations.

The reinforcement sections, with a length of approximately 60 cm (Figure 102), underwent tensile strength testing in accordance with the standard UNI EN ISO 6892-1:2020.

As a result of the structural investigations, the following material properties have been assumed in the subsequent calculations and it was possible to finalize the finite element model to conduct the structural and seismic assessment.

- Mean concrete compressive strength f_{cm} = 26.8 MPa
- Mean steel tensile strength f_{ym} = 430 Mpa

References of Section 10.1.8

1. Ministero delle infrastrutture e dei trasporti NTC, "Norme Tecniche per le Costruzioni. DM 17/1/2018," 2018.
2. Masi, Angelo. (2005). La stima della resistenza del calcestruzzo in situ mediante prove distruttive e non distruttive. Il Giornale Delle Prove Non Distruttive, 1-2005.

10.1.9 DETAILED STRUCTURAL ANALYSIS AND SEISMIC VULNERABILITY ASSESSMENT

As already mentioned, the structural assessment and seismic evaluation is made by finite element analysis using a commercial software package, according to the Italian building code.

The assessment procedure foresees the following steps:

- Structural analysis under gravity loads (service conditions): it is devoted to assessing the capacity of structural members under gravity loads verifying that flexure and shear capacities are sufficient with respect to the loads prescribed by the current Italian building code.
- Damage limitation state seismic assessment: it is a seismic assessment under frequent earthquake devoted to verifying that interstorey drift values do not exceed a threshold value (0.5% of the interstorey height) to protect infill walls and systems from excessive damage and consequent losses.
- Life safety assessment: it provides safety checks of structural members under a less frequent earthquake in order to protect the structure with respect to possible life loss.

Static loads

Reinforced concrete self-weight γ= 25 kN/m^3

Residential floor slabs variable load Qf = 2 kN/m^2

Balcony and stairs variable load Qb = 4 kN/m^2

Infill walls self-weight γ = 8 kN/m^3

Seismic analysis method and input modelling

The selected seismic analysis method is dynamic linear (modal). This method is foreseen by the Italian seismic code and consists of modal decomposition of the structure motion, calculating effects for each mode and finally the superposition of modal effects allow obtaining the whole effects on individual structural members. The seismic action is modelled by design spectra as mentioned earlier.

All seismic data are reported in the following:

- Building coordinates LAT (ED50): 41.3797493 [°], LON (ED50): 16.1428204 [°]
- Intended use: residential
- Use class 2 (ordinary buildings)
- Use coefficient Cu=1
- Nominal life duration Vn=50 years
- Reference period Vr= Cu*Vn = 50 years
- Soil type = C
- Topographic coefficient = T1 (flat)
- Life safety (LS) return period Tr = 475 years
- Damage limitation (SLD) return period Tr = 50 years
- Life safety (LS) Seismic design acceleration a_g = 0.195 g
- Damage limitation (SLD) Seismic design acceleration a_g = 0.076 g

Analysis result under gravity loads

Figure 103 shows the results of gravity loads verifications under flexure and shear of column and beam members. Colormaps report the demand/capacity ratio of structural members which is always lower that 1.0 meaning that no members reach the full strength exploitation under gravity loads. This indicates that the gravity load verification is fully satisfied. Therefore, the capacity/demand ratio (safety factor) is higher 1.0 (C/D= 1.03 for flexure and 1.11 for shear).

The red elements reported in the right side of Figure 103 are those the reach first the limit condition represented by the achievement of the stress equal to strength at section level.

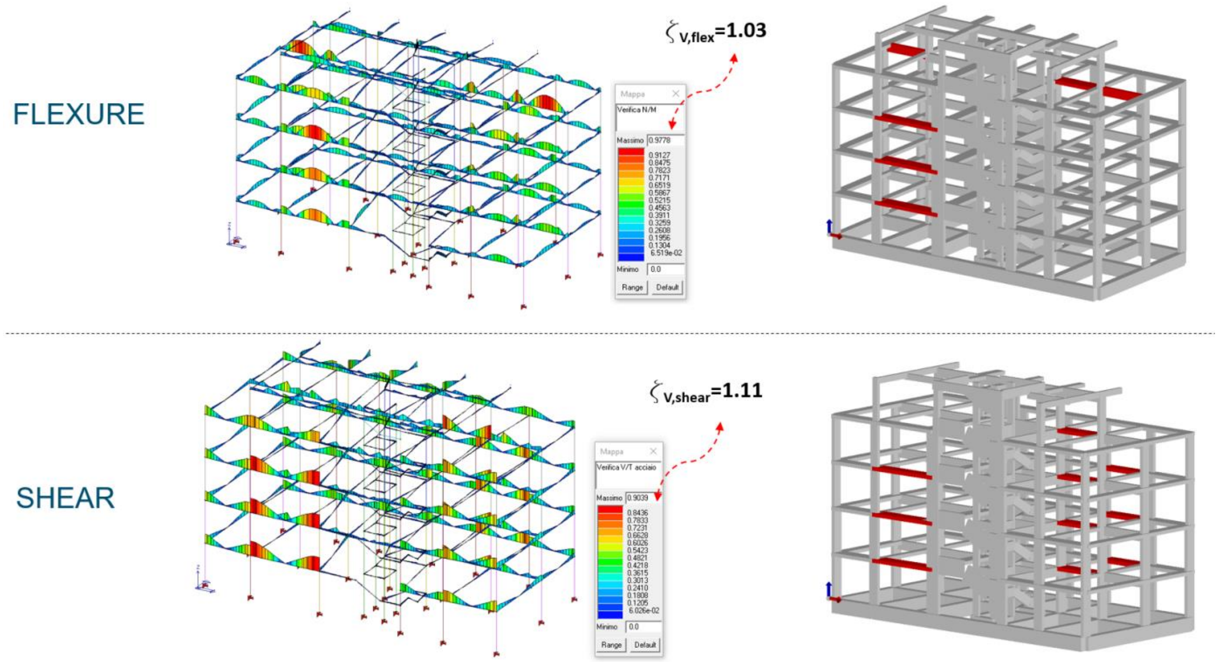


Figure 103: Gravity loads verification.

<u>Seismic analysis results at damage limitation limit state (SLD)</u>

As already mentioned, the damage limitation verification is only based on checking that the maximum intestorey displacement does not exceed a predefined threshold aimed at protecting the integrity of non-structural elements like infill walls and systems in the as-built condition and, more importantly, in the post-intervention condition. In fact, the realization of renovation packages which foresees the installation of new heat pump systems and related piping and a multipurpose façade made of photovoltaic panels and insulation panels. The integrity of this latter in strictly related to the interstorey drift values attained during seismic excitations.

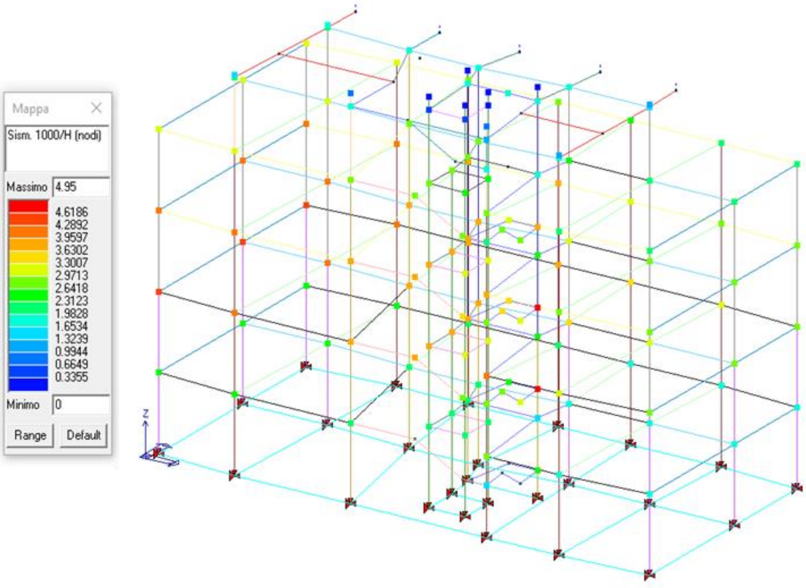


Figure 104: Indication of joint with colormap of interstorey drift values (as ‰ of interstorey height).

As can be seen, the highest drift values are achieved by joints placed along the structure's perimeter due to some torsion effects that are related to the presence of the staircase which generates eccentricity between the centre of mass and the centre of stiffnesses.

These effects can be better seen in Figure 105 showing the absolute displacements, where the rotational effects can be observed.

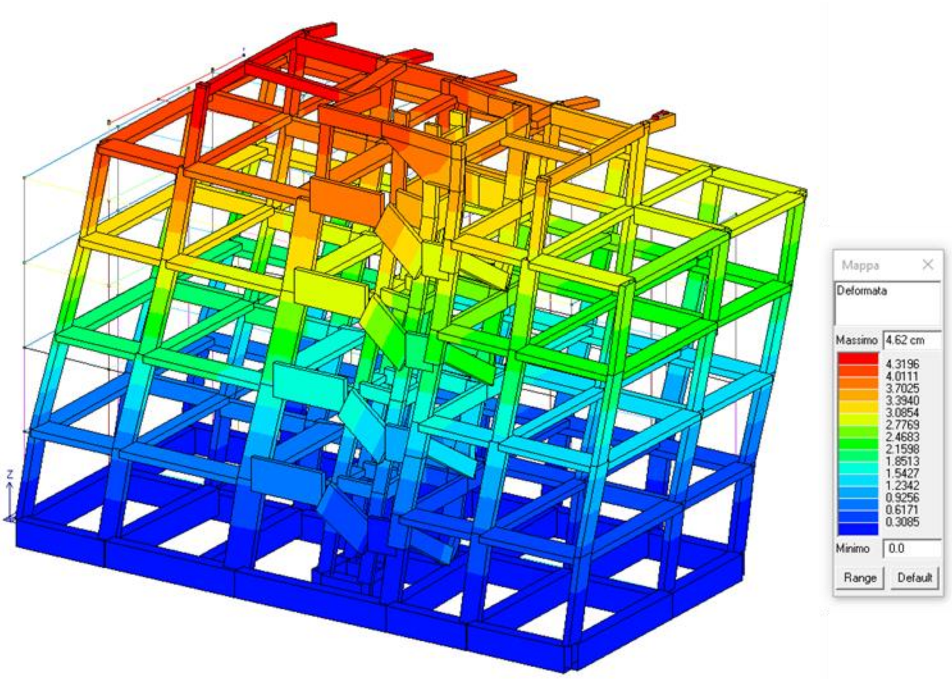


Figure 105: Absolute displacements at SLD limit state.

<u>Seismic analysis results at life safety (LS) limit state</u>

Framed reinforced concrete buildings designed according to outdated codes are often subjected to fragile collapse due insufficient capacity under shear stresses, affecting beam-column joints, beams and columns. This does not allow buildings to exploit their capacity under flexure mechanism because of the preceding shear failures.

The LS verification has been carried out by gradually increasing the seismic action (ground acceleration) until the first fragile crisis appeared. Technical literature allows to make several assumptions of what failure condition is determining the SL state, especially regarding the number of failed elements. In terms strictly normative, when the first element fails the LS limit state is reached. However, during the gradual seismic input intensity increase, often more elements reach the failure simultaneously and the results is that the LS state is almost always represented by the presence of a group of elements not verified (failed). In this case, the building seismic vulnerability is influenced by beam-column joints.

Safety checks of these elements must be performed according to expressions (1) and (2) reported in Figure 106 where f_{yd} is the steel yielding stress, A_{s1} is the top beam reinforcement area and A_{s2} in the bottom beam reinforcement area. V_c is the shear force acting on the column and □$_{rd}$ is a safety factor. V_{jbd} is the joint shear stress.

Due to the fragility of joints, the top reinforcement A_{s1} will not reach the yielding and considering f_{yd} stress is useless and too conservative in terms of resulting shear stress on the joint panel. Therefore, in place of f_{yd}, the real tensile stress □$_s$ acting in the top beam reinforcement may be used (which is much lower), according to equation (3).

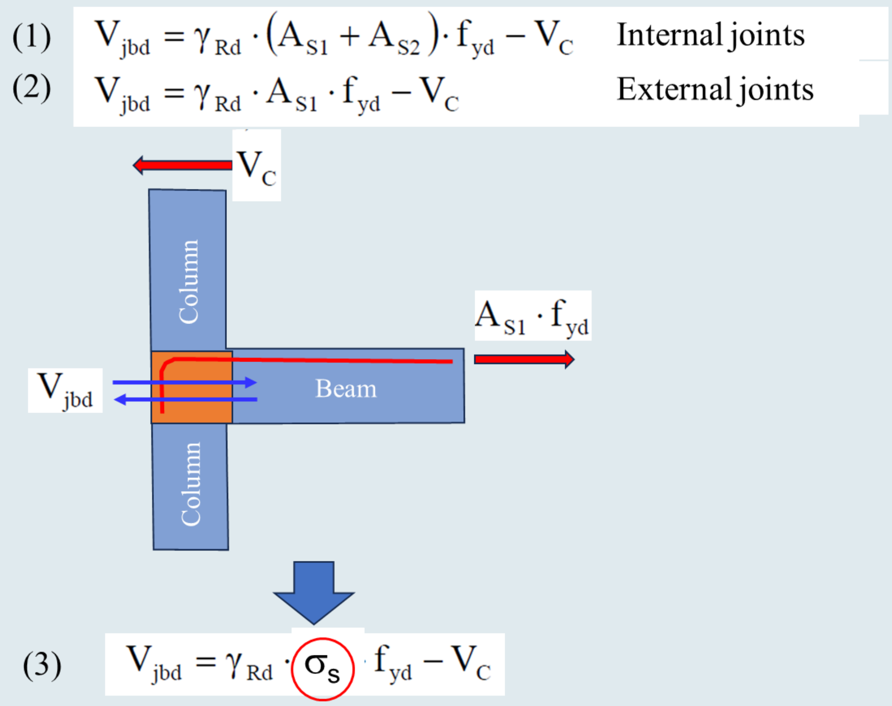


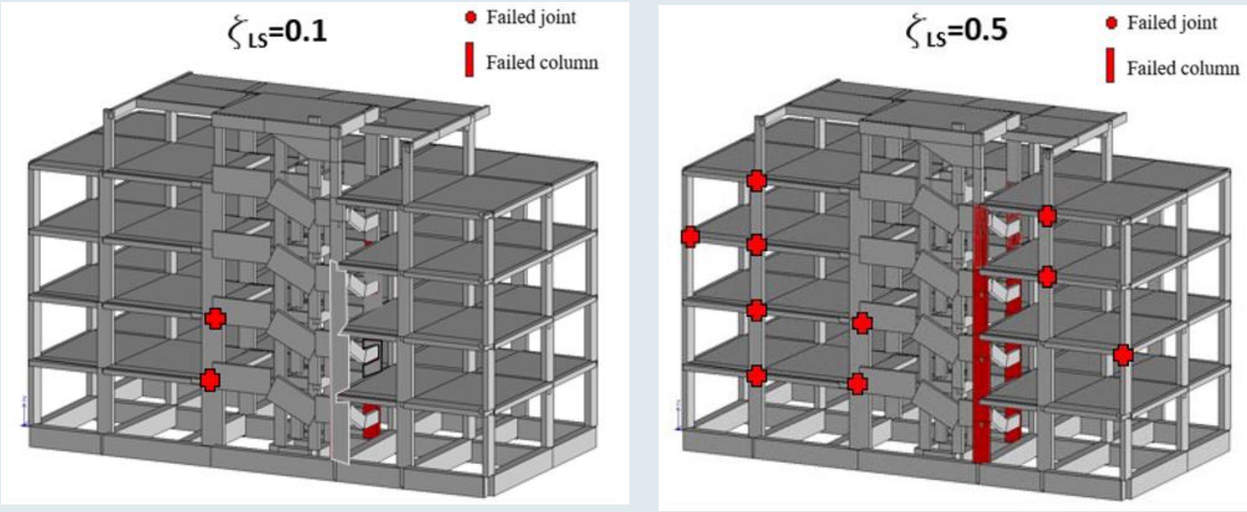
Figure 106: Safety checks of beam-column joints.

This allows to avoid overconservative joints' evaluation which could lead to invasive interventions on joint throughout the building, forcing the users to abandon the building during works.

Following this procedure, the LS limit state seismic acceleration has been found and the safety index has been calculated as reported in Figure 107.a.

In fact, □□$_{LS}$ = 0.1 indicates that the building structure in the as-built condition is able to sustain 10% of the design seismic action. Fully code conforming structure should have such index equal to at least 1.0. At that stage, two beam column joints and one column member fail under shear.

Increasing the seismic action till 50% of the seismic design value, there are 17 joints and 6 column elements failed under shear, as can be seen from Figure 107.b. Beyond this value of the seismic safety index, the flexure failure of beam and column start to happen and more intrusive and impacting interventions would be needed. Therefore, □$_{LS}$ = 0.5 is clearly the threshold of the seismic safety index that can be reached making interventions only on beam-column joints. Moreover, all the failed joints are placed on the building façade, thus allowing the structural interventions made by the outside, without forcing the users to leave the building.



A) B)

Figure 107: Safety checks of beam-column joints at □$_{LS}$ = 0.1 (a) and □$_{LS}$ = 0.5 (b).

Regarding the slab structural capacity, a portion of the floor slab located on the 3rd floor (Figure 108) was chosen to perform a static load test by the application of a point load simulating a distributed load, which in this specific case, is 2.00 kN/m^2. The load is applied through several incremental steps until the service load is reached, continuously measuring displacements through transducers placed in contact with the soffit of the 2nd floor. This test gave a positive result, given that measured deflections were lower than expected from calculations and the deflection was almost totally recovered after unloading, indicating a good structural health of the slab.

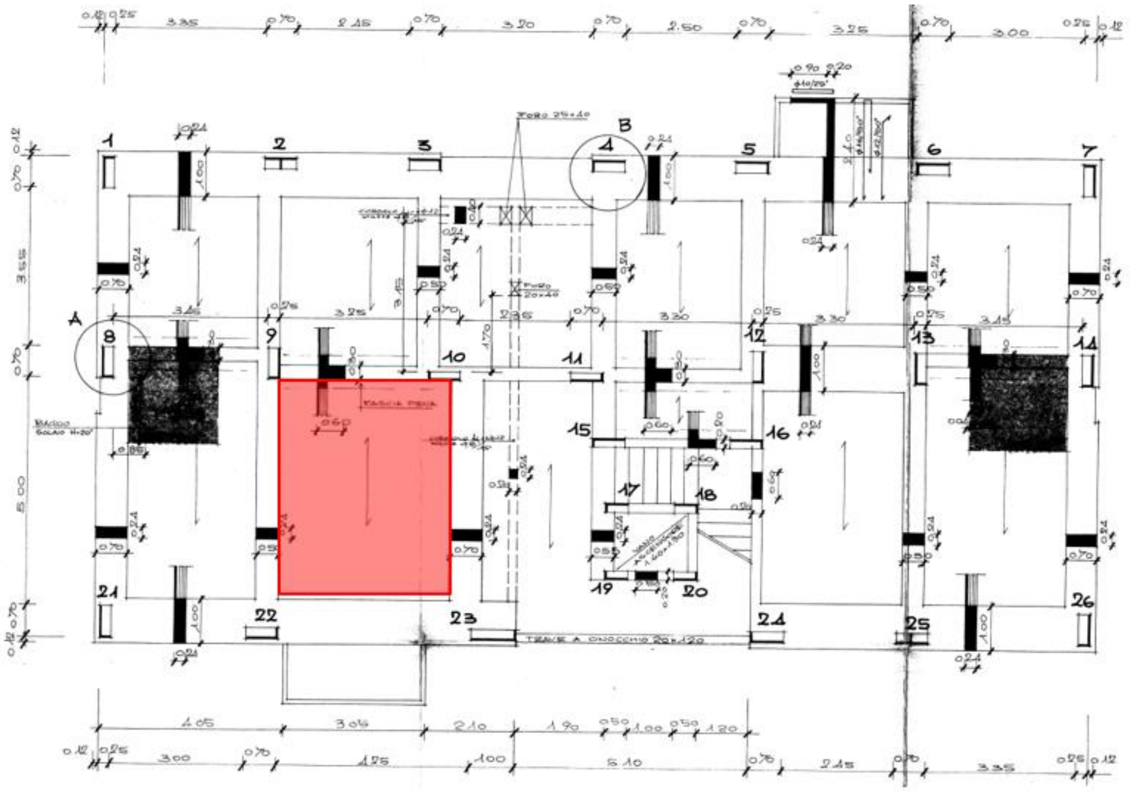


Figure 108: The 3rd-floor framework with indication of the investigated floor slab section.

Final remarks

In can be concluded that the Margherita di Savoia demo building has sufficient capacity under service loads (gravity loads) and with respect to seismic actions related to frequent earthquakes at the damage limitation state (SLD). On the other hand, with reference to seismic capacity against less frequent and stronger earthquakes related to life safety limit state (SLV), the building is highly vulnerable and can be seriously damaged due to fragility of joints and columns placed in the staircase, being very vulnerable because of the presence of short members. This agrees with the result of the "Condomini+ 4.0" app preliminary evaluation, which underscored some criticalities from the seismic behaviour standpoint (section 10.1.5).

Finally, a structural load test on a slab portion gave positive results indicating in general that horizontal structures have sufficient capacity.

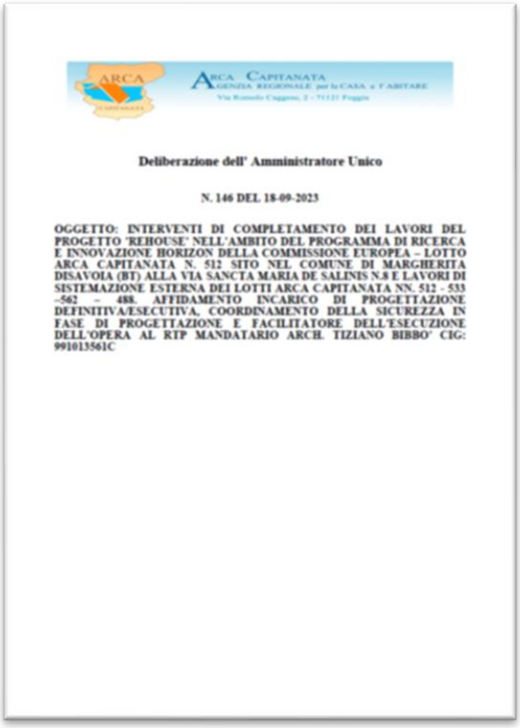
10.1.10 TENDER

Taking advantages from REHOUSE project, ARCA Capitanata, with the support of ENEA, decided to set up an innovative tender for the selection of project designers. The public tender, defined as "expressions of interest concerning the procedure for the assignment of architectural and engineering services relating to the energy upgrading and seismic improvement of Public Residential buildings", was opened to a single operator but also to a consortia or temporary groupings of economic operators established or being established. It defines a group of minimum requirements concerning technical and soft skills (useful for co-design actions with tenants). In this way the committed professionals should assure the compliance with the multiple requirements included in the tender and therefore to cover all the necessary skills to overcome technical and social barriers.

In particular the professional skills required in the public tender were:

- Safety skills of work site during designing phase;
- Knowledge in the sustainability of the building retrofit according to the UNI CEI EN ISO/IEC 17024
- Certification as "BIM manager" or "BIM coordinator" according to an Italian standard UNI 11337-7
- For the facilitator role, crucial for the success of the retrofit project, the requirements included in the tender are the followings:
    - relations with householders in order to guarantee optimal collaboration with all the professionals and companies involved in the design, execution, processing and management;
    - assistance in the operational, technical and administrative management of the works and/or installation;
    - training manager of building retrofit workers, as well as end-users;
    - assistance for all the activities needed after the renovation, including the end of the contract with ARCA Capitanata;
    - assistance in the preparation of documentation containing instructions and management control tools for use by staff, including forms and operating procedures;
    - assistance in setting up document flows and documentation archiving methods;
    - management of the plan of technical controls including inspections to monitor the regular progress of the work;
    - organisation and management of "As Built" documentation.

The tender was published on 31st May 2023 and on 28th of July the selected team has been presented to the REHOUSE partner of Italian demo site. Several meetings between the designers' team with RP5 and RP4 partners have been organized to share problem solutions and to facilitate the integration of traditional aspects of energy efficiency solutions and the most innovative technologies of RP#.



ARCA CAPITANATA
AGENZIA REGIONALE per la CASA e l'ABITARE
Via Romolo Caggese, 2 - 71121 Foggia

Deliberazione dell' Amministratore Unico

N. 146 DEL 18-09-2023

OGGETTO: INTERVENTI DI COMPLETAMENTO DEI LAVORI DEL PROGETTO 'REHOUSE' NELL'AMBITO DEL PROGRAMMA DI RICERCA E INNOVAZIONE HORIZON DELLA COMMISSIONE EUROPEA – LOTTO ARCA CAPITANATA N. 512 SITO NEL COMUNE DI MARGHERITA DISAVOIA (BT) ALLA VIA SANCTA MARIA DE SALINIS N.8 E LAVORI DI SISTEMAZIONE ESTERNA DEI LOTTI ARCA CAPITANATA NN. 512 - 533 –562 – 488. AFFIDAMENTO INCARICO DI PROGETTAZIONE DEFINITIVA/ESECUTIVA, COORDINAMENTO DELLA SICUREZZA IN FASE DI PROGETTAZIONE E FACILITATORE DELL'ESECUZIONE DELL'OPERA AL RTP MANDATARIO ARCH. TIZIANO BIBBO' CIG: 991013561C

Figure 109: Public tender front page.

10.2 QUESTIONNAIRE TO ASSESS EXISTING CONDITIONS, FACILITIES, AND INFRASTRUCTURE OF THE PILOT SITE

10.2.1 GREEK DEMO-SITE QUESTIONNAIRE

Pilot site: Kimmeria, Xanthi, Greece

Author(s): Professor Pantelis N. Botsaris Organization: Democritus University of Thrace

The questionnaire should be fill out by a technician with the building owner. "Participation in this questionnaire is voluntary. All answers will be anonymized"

Building

1. What is the type of the building?

- **Residential**
- Office
- Business
- Other: ____________________

2. If it is residential, what is the type?
- Single family
- **Multi apartment**

3. Does it have a status of the monument?
- Yes
- **No**

4. What is the year of construction?
- < 1900
- 1901-1920
- 1921-1940
- 1941-1960
- 1961-1980
- **1981-2000**
- 2001-2020

5. What is design era?

- **< 1900**
- 1901-1920
- 1921-1940
- 1941-1960
- 1961-1980
- 1981-2000
- 2001-2020

6. What is the use of the basement?
- No basement
- Residential
- **Storage room**
- Office

7. What is the use of the attic?
- **No attic**
- Residential
- Storage room
- Office

8. What is the building location?
- **Isolated**
- Adjacent
- Seismically joined
- In aggregate

General psychographic questions

9. What is the number of dwellings in the building?
- 1-3
- 4-7
- 8-12
- **12 or more**

Well-being and indoor comfort rating

10. Are indoor air quality assessment devices installed in the apartments?

- Yes
- **No**

Current energy performance

11. Is an Energy Performance Certification (EPC) available for the pilot building?
- Yes
- **No**

12. If an EPC is available, please provide the energy class and the indicated energy consumption
- Energy Class: ____________
- Energy consumption (kWh/m^2/year): ____________

13. Were Energy Audits conducted on the pilot building?
- Yes
- **No**

Structural analysis of the building

14. What is the material of your load-bearing structure?
- **Concrete**
- Brick
- Wood
- Composite steel
- Masonry
- Other: ________________

15. What type of exterior wall insulation is used in your apartment?
- **Mineral (rockwool, glass wool…)**
- Synthetic (Styrofoam, XPS…)
- Natural (wood fibre…)
- Other: _______________

16. What is the condition of the building envelope?

- good
- sufficient
- **poor**

17. What kind of glazing is there in the apartment?
- Single glazed
- **Double glazed**
- Triple
- Other: ______________

18. Are there any maintenance defects on the building envelope?

- **plaster swelling**
- visible reinforcements
- **leaks**
- water rising
- **detachment and/or damage to the claddings**
- Other:_______________________

19. Is its available design technical documentation? In case of affirmative answer please provide it.

- Yes
- **No**

20. Has the building been subject to structural intervention over the years? In case of affirmative answer please If yes, please specify the timeframe (to determine the applicable technical standards used) and provide all technical documentation available.

- **No**
- Expansion
- Raising
- Seismic retrofitting
- Seismic improvement
- Local reinforcement
- Other:______________

21. After the construction of building, has some seismic improvement been done? In case of affirmative answer please provide all technical documentation available.

- **No**
- Steel bracings
- Concrete walls
- Wrapping of columns for example through Fibre Reinforced Polymer (FRP)
- Foundations reinforcement
- Other____________

22. Has the building been subject to change of use over the years? In case of

affirmative answer please provide all technical documentation available.

- **No**
- Change of use from residential building to offices
- Other:_______________

23. Has the building been subject to events which required structural works? In case of affirmative answer please provide all technical documentation available.

- **No**
- Fire
- Flood
- Demolition
- Other:_______________

Renewable Energy Sources

24. Does the building have an energy generation system (i.e. solar panels) installed?
- **Yes**
- No

25. If yes, please select the RES technology. If more than one, please selects all that apply. Please provide the nominal power of each one.
- **Photovoltaic systems (50kWp)**
- Wind Energy
- **Biomass (1,1 MW central heating)**
- CHP (Combined Heat and Power)
- **Solar heating(1 MW central heating)**
- Geothermal energy
- Other: _______________

26. How do you monitor the generated and stored energy of your building?
- **Digital meter**
- **Website**
- Mobile App
- Other: _______________

27. How often do you monitor the energy generation in your building/household?
- **Very often**
- Often
- Regularly
- Almost never
- Never

28. Does the building have an energy storage for on-site generated renewable electricity?
- **Yes**

- No

If yes please select the energy storage technology, if more than one please selects all that apply. Please provide also the nominal power (kW) and the capacity (kWh) for each one.

- **Batteries:** __≈10 (kW)_,544 (kWh)_______
- Supercapacitors: __________
- Compressed air: __________
- Flywheel: __________

Communication protocol

29. Please select all the communication protocols used for the devices installed.

- **Wi-Fi**
- Zigbee
- Z-Wave
- Cellular (3G/4G/5G)
- Bluetooth
- RFID
- Other: ______________

Electrical vehicle

30. Please define whether there are electric vehicle (EV) charging spots in your building

- **Yes**
- No

Other

31. Is there a BIM model of the pilot site available?

- Yes
- **No**

32. Are there floor plans of the pilot site available?

- **Yes**
- No

33. If yes, in which form are they available?

- **DWG**
- **PDF**
- **Paper**
- Other: ___________

34. Are there any other sources of information that could be used?

- Energy audit reports
- Destructive and non-destructive testing reports
- Other reports
- **Other: _____NO_______**

10.2.2 HUNGARIAN DEMO-SITE QUESTIONNAIRE

Pilot site: Budapest, Hungary

Author(s): Miklós Doleschall Zoltán, Pásztory Organization: FCHURCH , WOODS

The questionnaire should be filled out by a technician with the building owner. "Participation in this questionnaire is voluntary. All answers will be anonymized"

Building

16. What is the type of the building?
- **Residential**
- Office
- Business
- Other: *dormitory*

17. If it is residential, what is the type?
- Single family
- **Multi apartment**

18. Does it have a status of the monument?
- Yes
- **No** but the building has a historical character

19. What is the year of construction?
- **< 1900**
- 1901-1920
- 1921-1940
- 1941-1960
- 1961-1980
- 1981-2000
- 2001-2020

20. What is design era?
- **< 1900**
- 1901-1920
- 1921-1940
- 1941-1960
- 1961-1980
- 1981-2000
- 2001-2020

21. What is the use of the basement?
- No basement
- Residential
- **Storage room** and gas furnace

- Office

22. What is the use of the attic?
- No attic
- **Residential**
- Storage room
- Office

23. What is the building location?
- **Isolated**, the building stands on a church and university campus surrounded by a fence
- Adjacent
- Seismically joined
- In aggregate

General psychographic questions

24. What is the number of dwellings in the building?
- 1-3
- 4-7
- 8-12
- **12 or more**, they are rooms with shared shower rooms, kitchens and laundries

Well-being and indoor comfort rating

25. Are indoor air quality assessment devices installed in the apartments?

- Yes
- **No** and it will be needed because the building envelop will seal the natural ventilation, (the newly installed monitoring system comply air quality sensors)

Current energy performance

26. Is an Energy Performance Certification (EPC) available for the pilot building?
- **Yes**
- No

27. If an EPC is available, please provide the energy class and the indicated energy consumption
- Energy Class: **C**
- Energy consumption (kWh/m^2/year): **25.8 MWh/year + 91.0 MWh/year ÷ 1 027 m^2 = 113.73 kWh/m2/year**

28. Were Energy Audits conducted on the pilot building?
- Yes
- **No**

Structural analysis of the building

29. What is the material of your load-bearing structure?
- **Concrete**
- **Brick**
- Wood
- Composite steel
- Masonry
- Other: _______________

30. What type of exterior wall insulation is used in your apartment?
- Mineral (rockwool, glass wool…)
- Synthetic (Styrofoam, XPS…)
- Natural (wood fibre…)
- **None**
- Other: ______________

16. What is the condition of the building envelope?
- good
- sufficient
- **poor**

18. What kind of glazing is there in the apartment?
- Single glazed
- **Double glazed**
- Triple
- Other: ______________

18. Are there any maintenance defects on the building envelope?
- plaster swelling
- visible reinforcements
- leaks
- water rising
- **detachment and/or damage to the claddings**, only a few
- Other:_______________________

19. Is its available design technical documentation? In case of an affirmative answer please provide it.
- **Yes,** reproduced drawings, floor plan and facades
- No

20. Has the building been subject to structural intervention over the years? In case of an affirmative answer, please specify the timeframe (to determine the applicable technical standards used) and provide all technical documentation available.

- **No**
- Expansion
- Raising
- Seismic retrofitting
- Seismic improvement
- Local reinforcement
- Other:_______________

21. After the construction of the building, has some seismic improvement been done? In case of an affirmative answer, please provide all technical documentation available.

- **No**
- Steel bracings
- Concrete walls
- Wrapping of columns for example through Fibre Reinforced Polymer (FRP)
- Foundations reinforcement
- Other_____________

22. Has the building been subject to change of use over the years? In case of an affirmative answer, please provide all technical documentation available.

- No
- Change of use from residential building to offices
- **Other: The building had an industrial function and was converted into a dormitory**

23. Has the building been subject to events which required structural works? In case of an affirmative answer, please provide all technical documentation available.

- **No**
- Fire
- Flood
- Demolition
- Other:_______________

Renewable Energy Sources

35. Does the building have an energy generation system (i.e. solar panels) installed?

- Yes
- **No**

36. If yes, please select the RES technology. If more than one, please selects all that apply. Please provide the nominal power of each one.

- Photovoltaic systems

- Wind Energy
- Biomass
- CHP (Combined Heat and Power)
- Solar heating
- Geothermal energy
- Other: ______________

37. How do you monitor the generated and stored energy of your building?

- Digital meter
- Website
- Mobile App
- Other: **No generated energy**

38. How often do you monitor the energy generation in your building/household?

- Very often
- Often
- Regularly
- Almost never
- **Never**, because it not generated energy at all

39. Does the building have an energy storage for on-site generated renewable electricity?

- Yes
- **No**

If yes please select the energy storage technology, if more than one please selects all that apply. Please provide also the nominal power (kW) and the capacity (kWh) for each one.

- Batteries: __________
- Supercapacitors: __________
- Compressed air: __________
- Flywheel: __________

Communication protocol

40. Please select all the communication protocols used for the devices installed.

- **Wi-Fi**
- Zigbee
- **Z-Wave**
- Cellular (3G/4G/5G)
- Bluetooth
- RFID
- Other: ______________

Electrical vehicle

41. Please define whether there are electric vehicle (EV) charging spots in your building

- Yes
- **No**

Other

42. Is there a BIM model of the pilot site available?
- Yes
- **No**

43. Are there floor plans of the pilot site available?
- **Yes**
- No

44. If yes, in which form are they available?
- DWG
- **PDF**
- Paper
- Other: ___________

45. Are there any other sources of information that could be used?
- Energy audit reports
- Destructive and non-destructive testing reports
- Other reports
- Other: **No**

10.2.3 FRENCH DEMO-SITE QUESTIONNAIRE

Pilot site: French Demosite

Organization: CEA

The questionnaire should be fill out by a technician with the building owner.

Building

1. What is the type of the building?
- **Residential**
- Office
- Business
- Other: ____________________

2. If it is residential, what is the type?
- Single family
- **Multi apartment**

3. Does it have a status of the monument?
- Yes

- **No**

4. What is the year of construction?
- < 1900
- 1901-1920
- 1921-1940
- **1941-1960**
- 1961-1980
- 1981-2000
- 2001-2020

5. What is design era?
- < 1900
- 1901-1920
- 1921-1940
- **1941-1960**
- 1961-1980
- 1981-2000
- 2001-2020

6. What is the use of the basement?
- No basement
- **Residential**
- Storage room
- Office

7. What is the use of the attic?
- **No attic**
- Residential
- Storage room
- Office

8. What is the building location?
- **Isolated**
- Adjacent
- Seismically joined
- In aggregate

General psychographic questions

9. What is the number of dwellings in the building?

- 1-3
- 4-7
- 8-12
- **12 or more**

Well-being and indoor comfort rating

10. Are indoor air quality assessment devices installed in the apartments?

- Yes
- **No**

Current energy performance

11. Is an Energy Performance Certification (EPC) available for the pilot building?

- Yes
- **No**

12. If an EPC is available, please provide the energy class and the indicated energy consumption

- Energy Class: D (estimation)
- Energy consumption (kWh/m^2/year): between 151 and 230 kWh/m²/year

13. Were Energy Audits conducted on the pilot building?

- **Yes**
- No

Structural analysis of the building

14. What is the material of your load-bearing structure?

- **Concrete**
- Brick
- Wood
- Composite steel
- Masonry

15. Other: _______________What type of exterior wall insulation is used in your apartment?

- Mineral (rockwool, glass wool…)

- Synthetic (Styrofoam, XPS…)
- Natural (wood fibre…)
- **Other: no insulation**

16. What is the condition of the building envelope?
- good
- **sufficient**
- poor

17. What kind of glazing is there in the apartment?
- Single glazed
- **Double glazed**
- Triple
- Other: _______________

18. Are there any maintenance defects on the building envelope?
- plaster swelling
- visible reinforcements
- leaks
- water rising
- detachment and/or damage to the claddings
- **Other: minor airtightness defects**

19. Is its available design technical documentation? In case of affirmative answer please provide it.
- **Yes**
- No

20. Has the building been subject to structural intervention over the years? In case of affirmative answer please If yes, please specify the timeframe (to determine the applicable technical standards used) and provide all technical documentation available.
- **No**
- Expansion
- Raising
- Seismic retrofitting
- Seismic improvement
- Local reinforcement
- Other:_______________

21. After the construction of building, has some seismic improvement been done? In case of affirmative answer please provide all technical documentation available.
- **No**

- Steel bracings
- Concrete walls
- Wrapping of columns for example through Fibre Reinforced Polymer (FRP)
- Foundations reinforcement
- Other____________

22. Has the building been subject to change of use over the years? In case of affirmative answer please provide all technical documentation available.

- **No**
- Change of use from residential building to offices
- Other:______________

23. Has the building been subject to events which required structural works? In case of affirmative answer please provide all technical documentation available.

- **No**
- Fire
- Flood
- Demolition
- Other:______________

Renewable Energy Sources

24. Does the building have an energy generation system (i.e. solar panels) installed?

- Yes
- **No**

25. If yes, please select the RES technology. If more than one, please selects all that apply. Please provide the nominal power of each one.

- Photovoltaic systems
- Wind Energy
- Biomass
- CHP (Combined Heat and Power)
- Solar heating
- Geothermal energy
- Other: ______________

26. How do you monitor the generated and stored energy of your building?

- Digital meter
- Website
- Mobile App
- Other: ______________

27. How often do you monitor the energy generation in your building/household?

- Very often
- Often
- Regularly
- Almost never
- Never

28. Does the building have an energy storage for on-site generated renewable electricity?

- Yes
- No

If yes please select the energy storage technology, if more than one please selects all that apply. Please provide also the nominal power (kW) and the capacity (kWh) for each one.

- Batteries: __________
- Supercapacitors: __________
- Compressed air: __________
- Flywheel: __________

Communication protocol

29. Please select all the communication protocols used for the devices installed.

- Wi-Fi
- Zigbee
- Z-Wave
- Cellular (3G/4G/5G)
- Bluetooth
- RFID
- Other: ______________

Electrical vehicle

30. Please define whether there are electric vehicle (EV) charging spots in your building

- Yes
- **No**

Other

31. Is there a BIM model of the pilot site available?

- Yes
- **No**

32. Are there floor plans of the pilot site available?

- **Yes**
- No

33. If yes, in which form are they available?
- DWG
- **PDF**
- Paper
- Other: ___________

34. Are there any other sources of information that could be used?
- Energy audit reports
- Destructive and non-destructive testing reports
- **Other reports**
- Other: ____________

10.2.4 ITALIAN DEMO-SITE QUESTIONNAIRE

Pilot site: Margherita di Savoia (IT) – Via Salinis 8

Author(s) Gennaro Di Tella, Armando De Santis, Vincenzo DeDevitis   Organization_ARCA__

The questionnaire should be fill out by a technician with the building owner. "Participation in this questionnaire is voluntary. All answers will be anonymized"

Building

31. What is the type of the building?
- **Residential**
- Office
- Business
- Other: ____________________

32. If it is residential, what is the type?
- Single family
- **Multi apartment**

33. Does it have a status of the monument?
- Yes
- **No**

34. What is the year of construction?
- < 1900
- 1901-1920
- 1921-1940
- 1941-1960
- 1961-1980
- **1981-2000**
- 2001-2020

35. What is design era?

- < 1900
- 1901-1920
- 1921-1940
- 1941-1960
- 1961-1980
- **1981-2000**
- 2001-2020

36. What is the use of the basement?

- No basement
- **Residential**
- Storage room
- Office

37. What is the use of the attic?

- No attic
- Residential
- **Storage room**
- Office

38. What is the building location?

- **Isolated**
- Adjacent
- Seismically joined
- In aggregate

General psychographic questions

39. What is the number of dwellings in the building?

- 1-3
- 4-7
- **8-12**
- 12 or more

Well-being and indoor comfort rating

40. Are indoor air quality assessment devices installed in the apartments?

- Yes
- **No**

Current energy performance

41. Is an Energy Performance Certification (EPC) available for the pilot building?
- Yes
- **No, but it has been calculated in the initial energy building evaluation (energy audit)**

42. If an EPC is available, please provide the energy class and the indicated energy consumption
- Energy Class: __**G**__
- Energy consumption (kWh/m^{2}year): _**222,83**__________

43. Were Energy Audits conducted on the pilot building?
- Yes
- **No**

Structural analysis of the building

44. What is the material of your load-bearing structure?
- **Concrete**
- Brick
- Wood
- Composite steel
- Masonry
- Other: _______________

45. What type of exterior wall insulation is used in your apartment?
- Mineral (rockwool, glass wool…)
- Synthetic (Styrofoam, XPS…)
- Natural (wood fibre…)
- Other: __**No insulation (air cavity)**

16. What is the condition of the building envelope?
- good
- **sufficient**
- poor

19. What kind of glazing is there in the apartment?
- Single glazed
- Double glazed
- Triple
- Other: **In 3 apartments there are double glazed and in the other single glazed**_______________

18. Are there any maintenance defects on the building envelope?

- **plaster swelling**
- **visible reinforcements**
- **leaks**
- **water rising**
- **detachment and/or damage to the claddings**
- Other:_______________________

19. Is its available design technical documentation? In case of affirmative answer please provide it.

- **Yes**
- No

20. Has the building been subject to structural intervention over the years? In case of affirmative answer please If yes, please specify the timeframe (to determine the applicable technical standards used) and provide all technical documentation available.

- No
- Expansion
- Raising
- Seismic retrofitting
- Seismic improvement
- Local reinforcement
- Other**:** **Only in one apartment (n. 5)** __________

21. After the construction of building, has some seismic improvement been done? In case of affirmative answer please provide all technical documentation available.

- **No**
- Steel bracings
- Concrete walls
- Wrapping of columns for example through Fibre Reinforced Polymer (FRP)
- Foundations reinforcement
- Other____________

22. Has the building been subject to change of use over the years? In case of affirmative answer please provide all technical documentation available.

- **No**
- Change of use from residential building to offices
- Other:______________

23. Has the building been subject to events which required structural works? In case of affirmative answer please provide all technical documentation available.

- No
- **Fire**

- Flood
- Demolition
- Other:______________

Renewable Energy Sources

46. Does the building have an energy generation system (i.e. solar panels) installed?
- Yes
- **No**

47. If yes, please select the RES technology. If more than one, please selects all that apply. Please provide the nominal power of each one.
- Photovoltaic systems
- Wind Energy
- Biomass
- CHP (Combined Heat and Power)
- Solar heating
- Geothermal energy
- Other: ______________

48. How do you monitor the generated and stored energy of your building?
- Digital meter
- Website
- Mobile App
- Other: ______________

49. How often do you monitor the energy generation in your building/household?
- Very often
- Often
- Regularly
- Almost never
- **Never**

50. Does the building have an energy storage for on-site generated renewable electricity?
- Yes
- **No**

If yes please select the energy storage technology, if more than one please selects all that apply. Please provide also the nominal power (kW) and the capacity (kWh) for each one.

- Batteries: __________
- Supercapacitors: __________
- Compressed air: __________
- Flywheel: __________

Communication protocol

51. Please select all the communication protocols used for the devices installed.
- Wi-Fi
- Zigbee
- Z-Wave
- Cellular (3G/4G/5G)
- Bluetooth
- RFID
- Other: _______________

Electrical vehicle

52. Please define whether there are electric vehicle (EV) charging spots in your building
- Yes
- **No**

Other

53. Is there a BIM model of the pilot site available?
- Yes
- **No**

54. Are there floor plans of the pilot site available?
- **Yes**
- No

55. If yes, in which form are they available?
- DWG
- PDF
- **Paper**
- Other: ____________

56. Are there any other sources of information that could be used?
- Energy audit reports
- Destructive and non-destructive testing reports
- Other reports
- Other: _____________