RE-SKIN

D8.1 - Energy audits and surveys I

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1. Executive summary

This document contains the first release of the detailed survey and energy audit of the first case-study building of RE-SKIN project, located in Milano, Italy. The aim of the document is to provide a comprehensive energy audit of the pre-retrofit state of the building as well as an overall survey of its architectonical and technical systems features.

The first part of the document describes the building site and surrounding context. Chapter 3 illustrates the methodology used for the survey and summarises the main obtained results. Finally, Chapter 4 presents the energy audit report.

It should be mentioned that the deliverable was prepared later than scheduled due to the change of the case-study building by the building owner (Municipality of Milano).

2. Description of the context and the building

This section describes the urban and climatic context of the first demo building of the project.

2.1. Location and urban context

Location: Milan, Italy - Via Amantea No.5
Owner: Municipality of Milan (CDM)
Destination: Community house
Climate: Continental climate
Year of construction/retrofit: 1965/2005

The building is located in the west area of Milan, in the 'Baggio' district, about 7.5 km from the city centre. The neighbourhood is almost residential.

Google maps link: https://goo.gl/maps/ye6WH4XQSgcyPKBX6

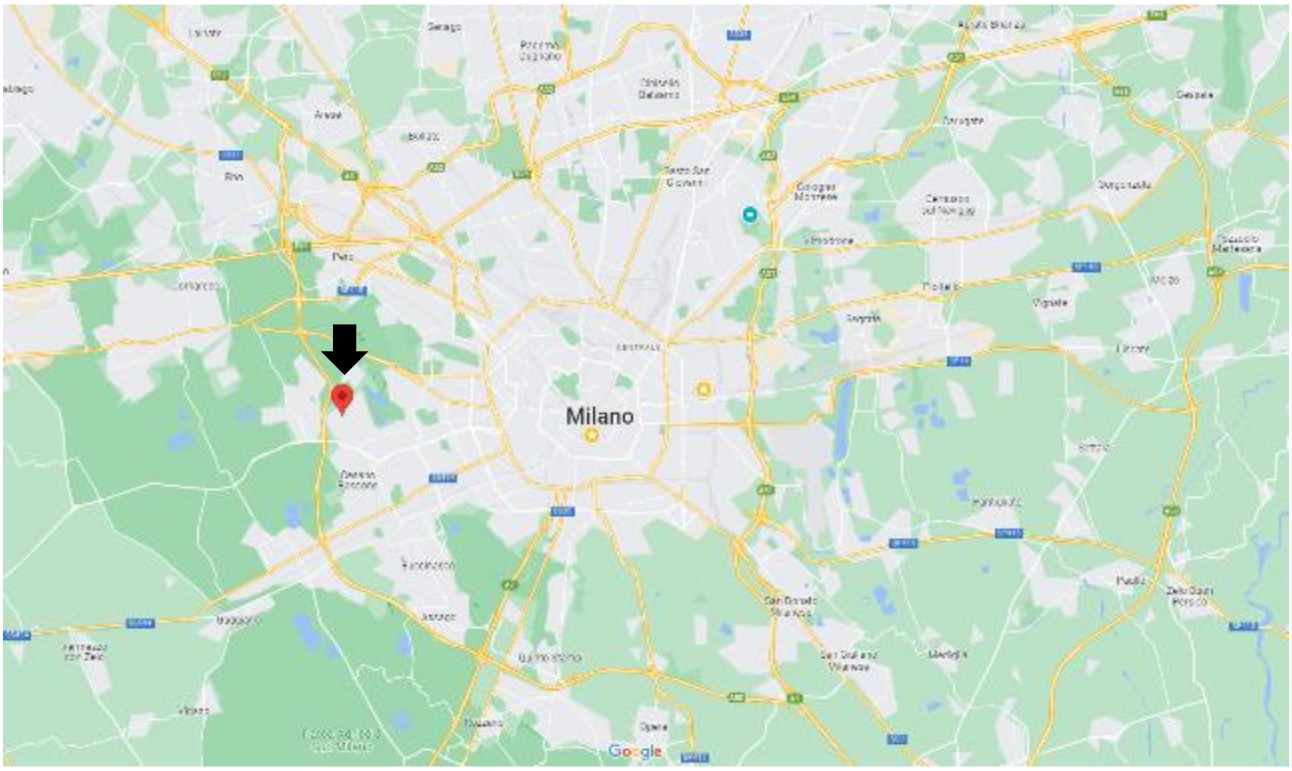


Figure 1. View of the Milan area and location of the building demo case

Baggio is Milan’s typical neighbourhood: it is integrated into the city but has retained its identity as an ancient village. Its historic centre, with old shops, new original commercial shops alternate in the urban building of the district, the old courtyards of the houses and the most characteristic views, feel like you are not in one of Europe's most modern and sprawling metropolises.
The intellectual and social heart of the neighbourhood are the streets around Baggio Park where the Municipal Library, one of the biggest, most active and busiest in Milan, is located.
The Milan case-study building (demo case) is situated near this Library.

Figure 2. View of the Baggio area and where the building is located (Red arrow)

The Milan demo case is a small rectangular building (about 21 x 8 m), oriented approximately along the North-South axis, divided in 2 floors (ground and first floor – approximately 340 m^2 in total), constructed with uninsulated brick walls, double-glazing windows, and 1 tilted roof of around 230 m^2.
In addition, on the east elevation, a supplementary element of the building that contains the staircase to connect the 2 floors is located. The height varies from 8.6 m on the west façade, to 6.5 m on the east façade.

Figure 3. Aereal view of the building

Figure 4. South-West view of the building

2.2. Climatic context

The main climatic parameters of the reference site are reported below.

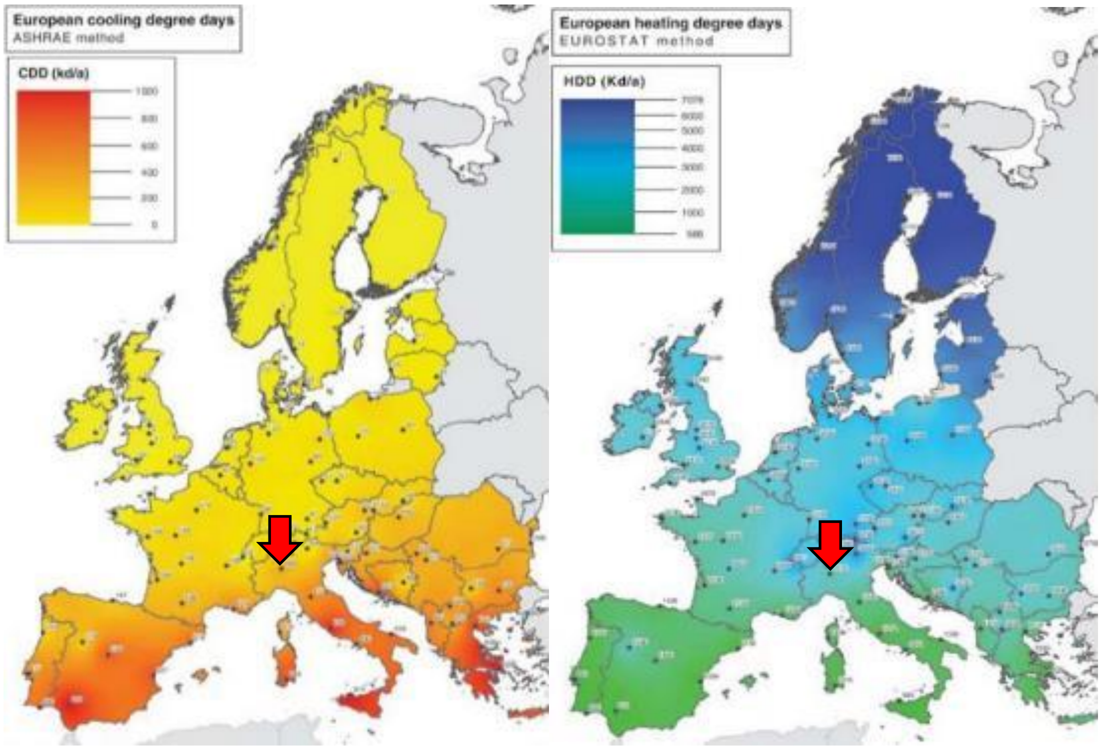


Figure 5. European climatic parameters (HDDs and CDDs) and location of the demo case (red arrow)

Location:	Milano
Latitude:	45° 27’
Longitude:	9° 05’
Height above sea level:	32 m
Climatic zone:	E
Heating degree days (HDD):	2522
Building classification:	E.1
Winter design outdoor temperature:	-4.9 °C
Outdoor summer project temperature:	35.8 °C
Annual solar radiation on the horizontal plane:	1'310 kWh/m^2
Average annual wind speed:	1.3 m/s
Prevailing wind direction:	E
Daily operating period of heating system:	14 hours from 15/10 to 15/04

	Month	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
External Temperature	2021	2.4	7.0	9.8	12.3	16.5	23.8	24.4	23.1	17.2	10.4	5.0	2.1
	2022	4.8	7.1	11.5	15.9	15.9	23.0	27.6	24.0	17.1	14.3	5.1	6.1
	2023	4.1	9.0	11.9	13.6	17.8	23.7	25.4	25.5				

Table 1 - Average monthly temperatures for the analyzed period

3. Architectural survey

This section describes the survey of the architectural features of the building. The first part is focused on the external survey while the second part on the internal environments and elements.

3.1. External survey

3.1.1. Laser scan survey

For the survey of the façades, the Leica HDS7000 scanner was used to ensure the correct 1:50 scale restitution. Twelve scans were made, covering the elevations (Figure 6).
After the necessary alignment of the scans and cleaning (eliminating points not corresponding to the façades) the model in "cloud point" format was exported in *.rcp format.
The rcp point cloud comes from the model made in the Leica Cyclone Register 360 software exported at 4 mm resolution.
The scan positions were organised in Recap so that the 4 elevations and the courtyard area could be selected (switched on/off), which made it easier to use the data (Figure 7).
The cloud point 3D model was imported into AutoCAD and was used as a reference for drawing the 2D elevations (Figure 7 and 8). The only partially occluded portion is that above the porch, inside the courtyard, since it was not possible to position the scanner high enough to cover this portion.
Together with the rendering of the façade for each elevation, it was possible to indicate the position of the trees, entrance gates and boundary walls.

Figure 6. Location of the scans, outside and inside the courtyard of the building. Tool for the work, right view of the model at the end of the data cleaning and alignment operations

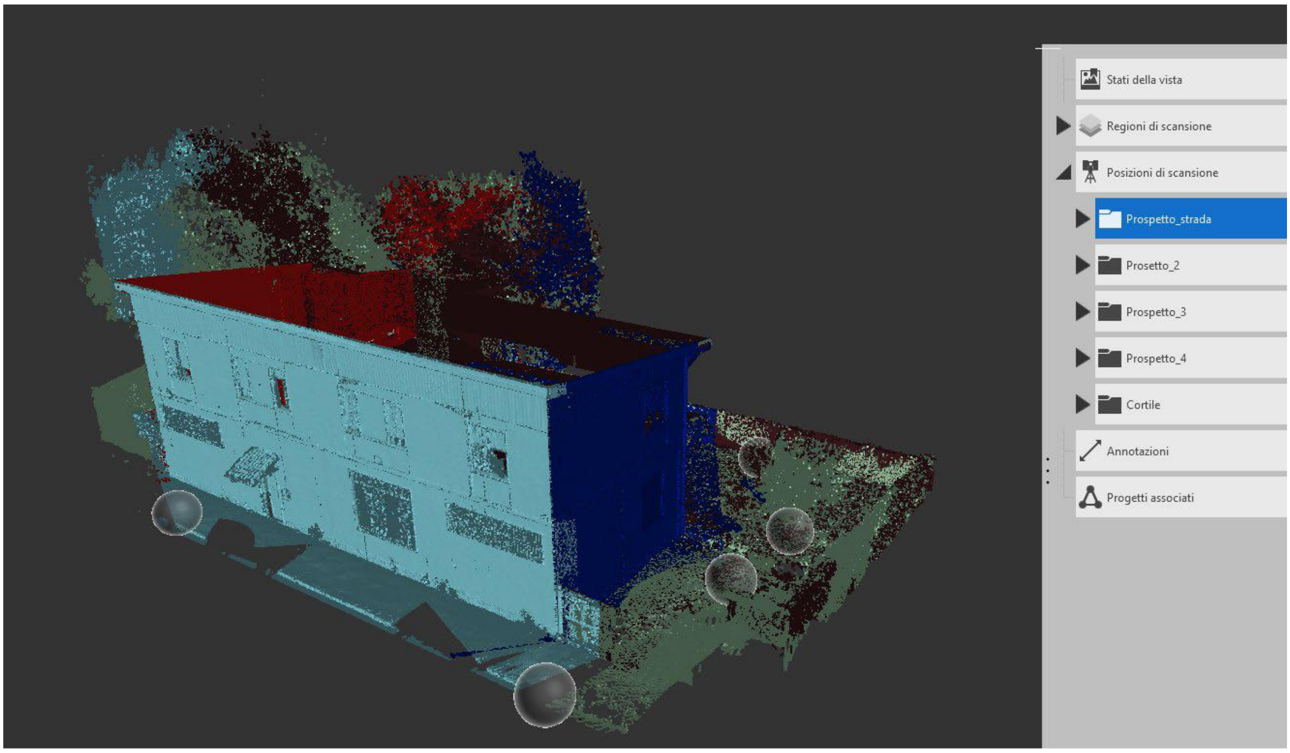


Figure 7. Viewing the point cloud in “Recap”, on the right the division into groups

Figure 8. Elevation drawing phase with AutoCAD

3.1.2. External photographic survey

A precise and accurate photographic survey of the exterior of the building was carried out. In order to provide an overview of the building, below some of the main pictures are reported.

Figure 9. South-East façade

Figure 10. South and North Elevation

3.2. Internal survey

3.2.1. Matterport tool survey

The survey of the interior rooms was carried out with a Matterport 3D surveying tool. Panoramic images were acquired in order to obtain a virtual tour of the two floors. A series of images was linked to the tour, in particular those of the window frames, which are not always visible from the outside due to the presence of gratings and mosquito nets.

At the following link, the final result of the survey is accessible:
https://my.matterport.com/show/?m=Z4fGqzG8Kki

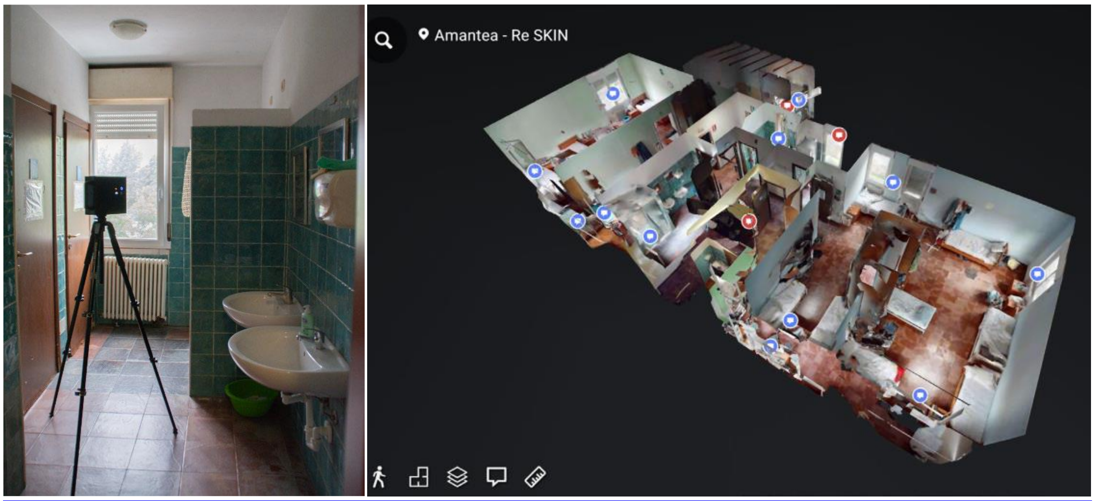


Figure 11. (Left) The tool during the acquisition images phase. (Right) The view of the ground and first floor, location of hotspots with linked images

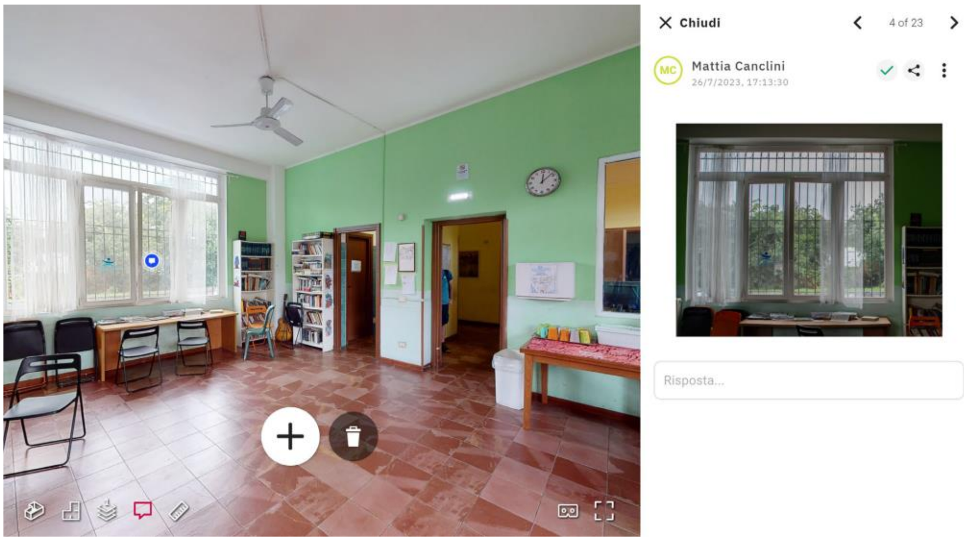


Figure 12. 3D space views from the Matterport and linked image

3.2.2. Internal photographic survey

A precise and accurate photographic survey of the interior rooms was carried out. Below the main images are reported to provide an overview of the spaces.

Figure 13. Ground Floor – Kitchen

Figure 14. Ground Floor – Living room

Figure 15. Ground Floor – TV room

Figure 16. First Floor – Toilet 3

Figure 17. First Floor – Bedroom 4

Figure 18. First Floor – Bedroom 2

3.3. Architectural drawings

On the basis of the outcomes of external and internal survey, it was possible to develop the AutoCAD drawings of the existing building, necessary for the project such as:

1. Ground floor, first floor and roof layouts;
2. North, South, West and East elevations;
3. Sections AA, BB and CC.

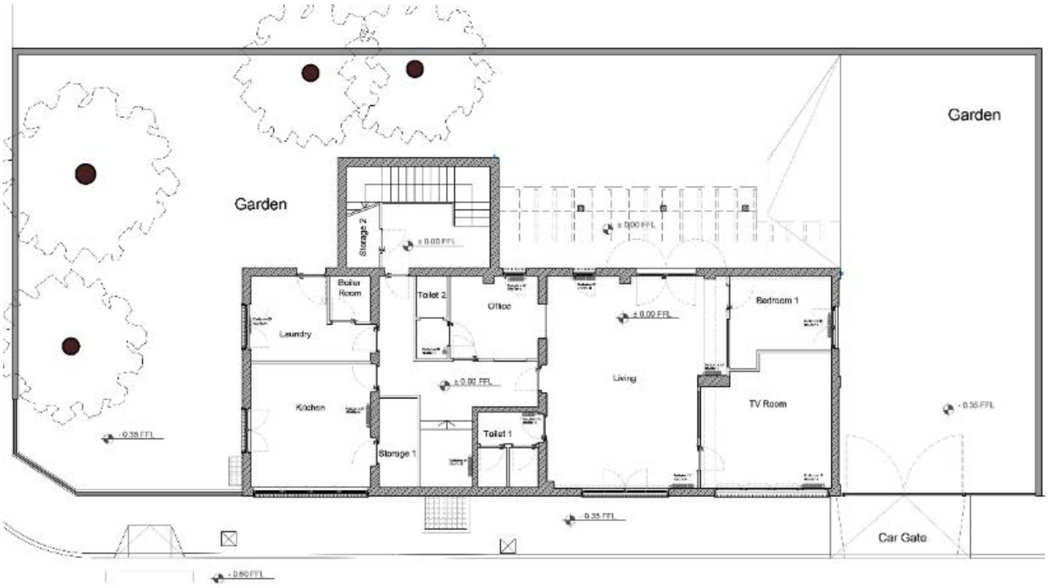


Figure 19. Ground Floor layout

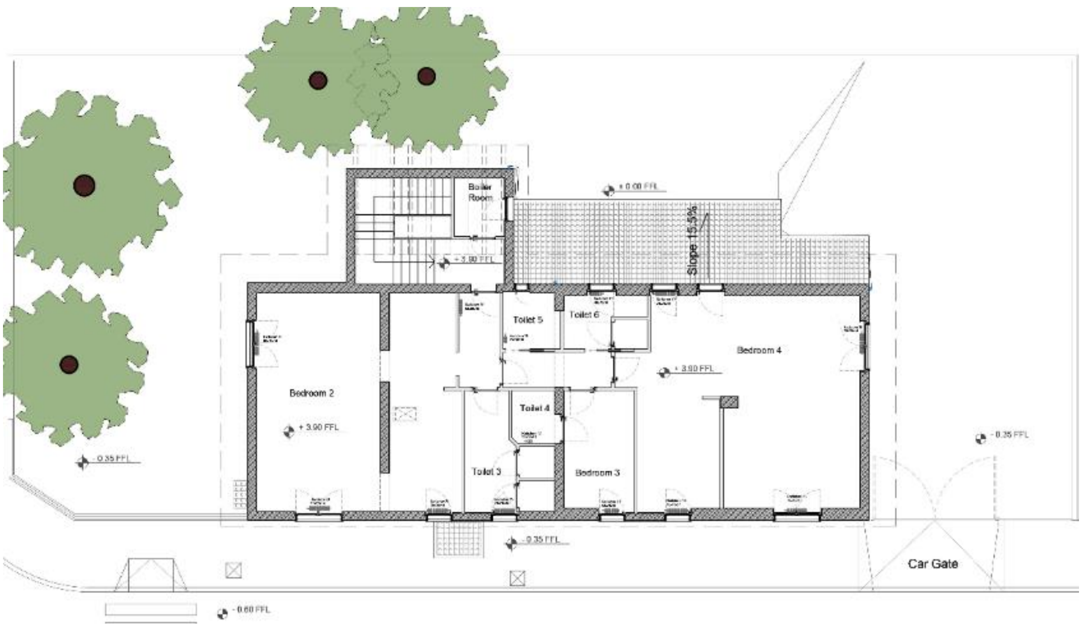


Figure 20. First Floor layout

Figure 21. West elevation

Figure 22. East elevation

Figure 23. North and south elevations

Figure 24. General sections

3.4. Technical systems description

During the site inspections, an analysis of the existing MEP was carried out. MEP includes systems for energy generation, distribution, and water supply.
It has been observed that in the existing state, the heating system and the domestic hot water preparation systems for the ground floor and the first floor are completely independent of each other. More in detail, they are connected to two separate gas boilers.
The first one, installed in a dedicated cabinet in the laundry room on the ground floor, is a traditional wall-mounted boiler with a nominal thermal power of approximately 31 kW and, as mentioned, is exclusively used for the ground floor. It is responsible for managing the heating loads of the ground floor and ensuring the production of domestic hot water for the two sinks in the bathrooms, the kitchen and the laundry.

Figure 25. Ground Floor boiler

On the other hand, the first floor is served by a second boiler, located in a dedicated technical room at the top of the stairs. This is a floor-standing boiler and it is equipped with a domestic hot water storage tank of about 200 l. It exclusively serves the first floor and, compared to the previous one, the production of hot water required by this boiler is higher, as it must serve not only the bathroom sinks but also the six showers, of which, only five are functioning and usable.

Figure 26. Floor-standing boiler located at the first floor

The emission subsystem consists of tubular steel radiators with double or triple columns, with varying heights and numbers of elements. These radiators are installed in the locations specified in Figure 19 and Figure 20.

The distribution of the heat transfer fluid to the radiators is managed through zone collectors highlighted in the following pictures.

The collectors, recessed into the wall behind flush-mounted doors, are traditional brass collectors installed vertically without any pipeline interception. Each collector serves a group of radiators on the floor, with each radiator being supplied by two pipes: one for supply and one for return, both with an outer diameter of approximately 15 mm. The pipes used for the distribution of the heat transfer fluid (water) to individual radiators, as shown in the photo, are made of multilayer PE-X material with insulating sheathing and are most likely in compliance with the current regulations in Italy.

Figure 27. Example of radiator, collector, and type of piping

It's worth considering that, as is the case for most of these types of systems, the setpoint temperature for the heat transfer fluid (water) used for heating hovers is around 65°C. No thermostatic valves have been detected on any radiators to control the flow, based on room temperature, into each terminal for consumption management.

At the time of the survey, no air conditioning system or mechanical ventilation system were installed in the building.

3.5. Summary of building data

In the following table the main data regarding the Milan demo case building are summarized.

Ground Floor – Total Area	190 m^2
Ground Floor - Net Area (excluding perimetral wall)	170 m^2
First Floor - Total Area	190 m^2

First Floor - Net Area (excluding perimetral wall)	170 m^2
Roof - Total Area	230 m^2
Ground Floor - Height	3.65 m
First Floor - Height	2.85 m
Ground Floor – Heating Volume	620 m^3
First Floor – Heating Volume	484 m^3
External wall – Total Area (excluding windows)	450 m^2
Windows - Total Area	55 m^2

Table 2 - Summary building survey

4. Energy audit

This section describes the energy features of the building, starting from the assessment of current energy consumption and then summarizing the main parameters that influence the energy behaviour.

4.1. Building energy consumption

The following sub-sections show the consumption of natural gas and electricity for the building, based on the collected data.

4.1.1. Natural gas consumption

Gas consumption data has been collected since June 2021, as summarized in the following table. Normalized data on actual degree days is also provided.

Heating Season	Natural Gas	Primary Energy	Specific Primary Energy
	[Nm^3]	*[kWh]*	*[kWh/m^2]*
2021-2022	8’587	81’577	240
2022-2023	8’113	77’070	226

Table 3 - Actual consumption of natural gas for heating – Heating season 2021-2023

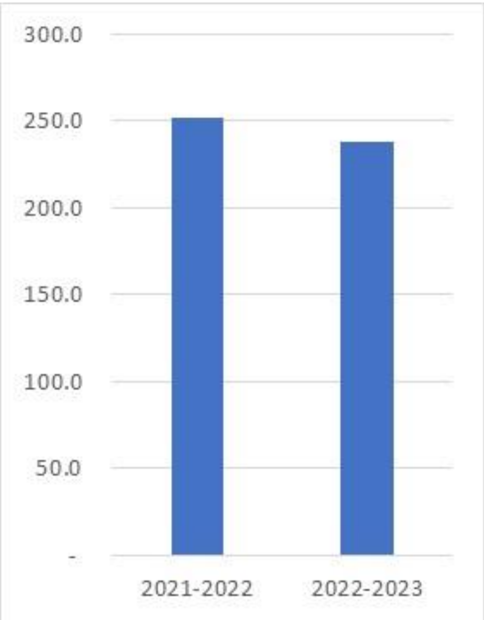


Figure 28. Specific yearly consumption of primary energy (natural gas) [kWh/m^2]

heat season	Natural Gas	Degree Days	Normalized
	[Nm^3]	-	m^3/HDD
2021-2022	8’587	2562	3.35
2022-2023	8’113	2442	3.32

Table 4 - Consumption and normalized consumption

On the basis of the analyzed data, it’s possible to state that the average natural gas consumption of the building is approximately equal to 3.3 m^3/HDD.
The following table and graph also show the consumption per each month. This data is useful for the comparison with the results of energy simulations.

Month	Consumption	Month	Consumption	Month	Consumption
	[Nm^3]		*[Nm^3]*		*[Nm^3]*
-	-	Jan-22	1’782	Jan-23	1’882
-	-	Feb-22	1’376	Feb-23	1’683
-	-	Mar-22	1’265	Mar-23	586
-	-	Apr-22	755	Apr-23	478
-	-	May-22	374	-	-
Jun-21	303	Jun-22	267	-	-
Jul-21	313	Jul-22	250	-	-
Aug-21	313	Aug-22	252	-	-
Sep-21	303	Sep-22	275	-	-
Oct-21	648	Oct-22	459	-	-
Nov-21	1’128	Nov-22	1’190	-	-
Dec-21	1’633	Dec-22	1’835	-	-

Table 5 - Monthly natural gas consumption from 6/2021 to 4/2023

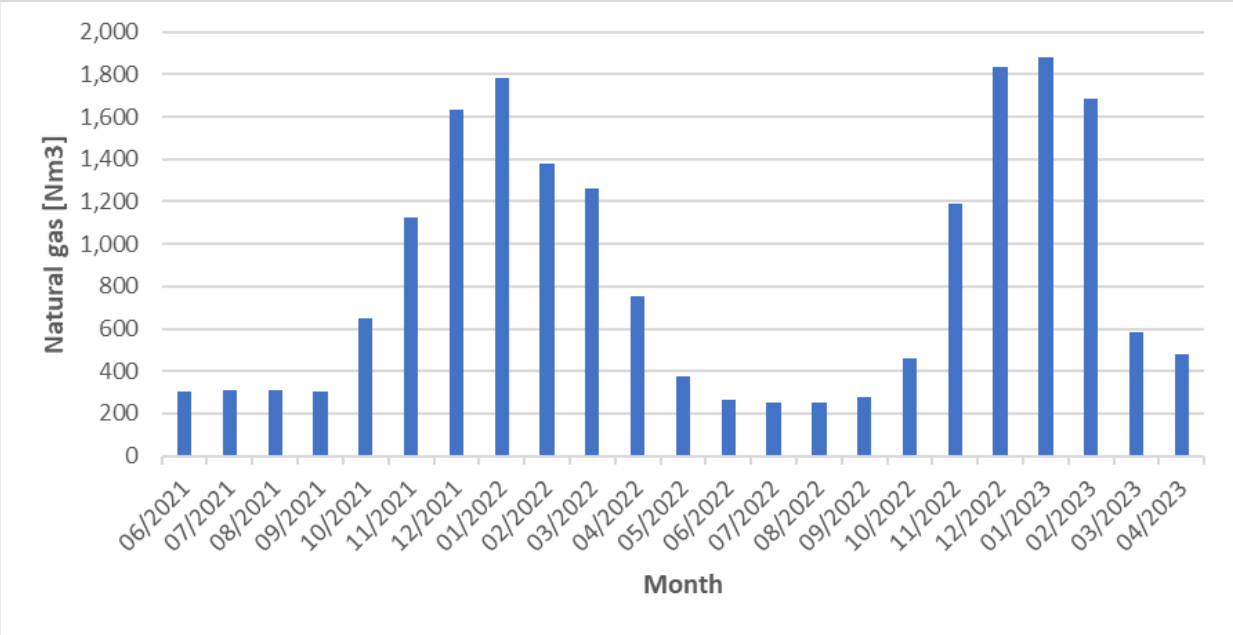


Figure 29. Monthly natural gas consumption from 6/2021 *to* 4/2023

4.1.2. Electricity consumption

The monthly electricity consumption data is reported in the following table and figure.

Date	Total	Date	Total	Date	Total
2021	**[kWh$_{el}$]**	**2022**	**[kWh$_{el}$]**	**2023**	**[kWh$_{el}$]**
-	-	Jan-22	1055	Jan-23	937
-	-	Feb-22	828	Feb-23	859
-	-	Mar-22	917	Mar-23	950
-	-	Apr-22	876	Apr-23	865
May-21	969	May-22	906	May-23	839
Jun-21	1002	Jun-22	1300	Jun-23	1009
Jul-21	1035	Jul-22	1344	-	-
Aug-21	990	Aug-22	1132	-	-
Sep-21	958	Sep-22	1096	-	-
Oct-21	1111	Oct-22	917	-	-
Nov-21	1076	Nov-22	887	-	-
Dec-21	1055	Dec-22	937	-	-

Table 6 - Monthly electricity consumption from 5/2021 to 6/2023

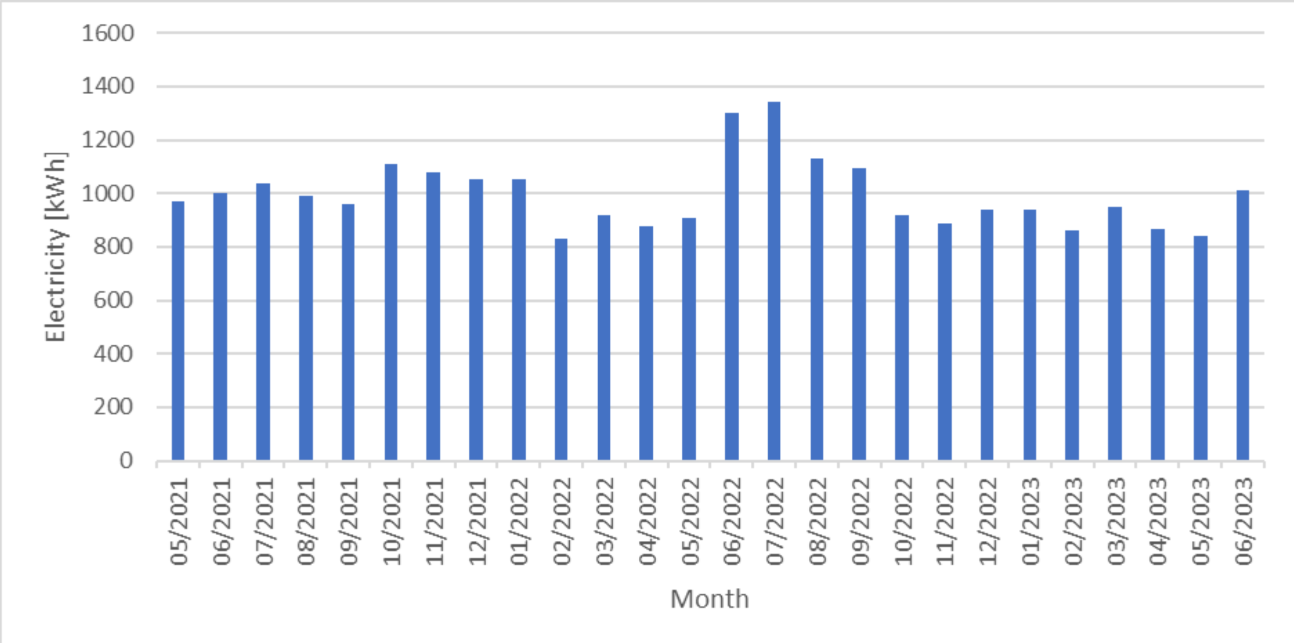


Figure 30. Monthly electricity consumption from 5/2021 to 6/2023

The share of the consumption among the 3 different time slots is reported in the following figure.

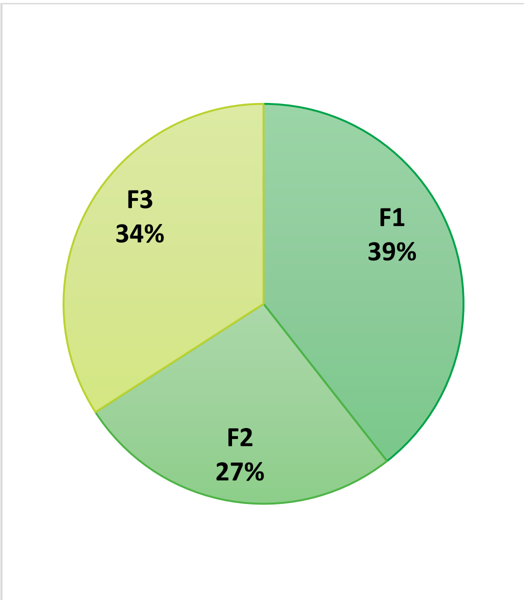


Figure 31. Electric consumption: F1 (peak hours): 8 a.m.-7 p.m. Monday through Friday; F2 (intermediate hours): 7-8 a.m. and 7-11 p.m. Monday through Friday and 7-23 p.m. on Saturdays; F3 (off-peak hours): 11 p.m.-7 p.m. Monday through Saturday and all hours on Sundays and holidays

It is possible to state that the consumption is evenly distributed among time slots, highlighting that there is a quite constant load during daytime and night time.

4.2. Breakdown of energy consumption

At present, no monitoring system is installed to measure the electricity consumption of different appliances, so it is not possible to provide a breakdown of electricity consumption.

Regarding natural gas, instead, from monthly data is possible to state that the average consumption in the summer months is about 270 m^3/month. This quota is that related to DHW preparation and cooking.

Considering that in the building there are on average 16 guests + 2 permanent operators, thus 18 people in total, and considering an average DHW consumption of 80 l/person/day, the natural gas consumption of DHW preparation could be estimated around 200 m^3/month.

The kitchen, on the other hand, has 4 burners of 5.5 kW/each. Assuming to use 2 of them at full power for 2 hours a day, the monthly average consumption for cooking is around 70 m^3.

On a yearly basis, thus, the overall breakdown of natural gas consumption is the following.

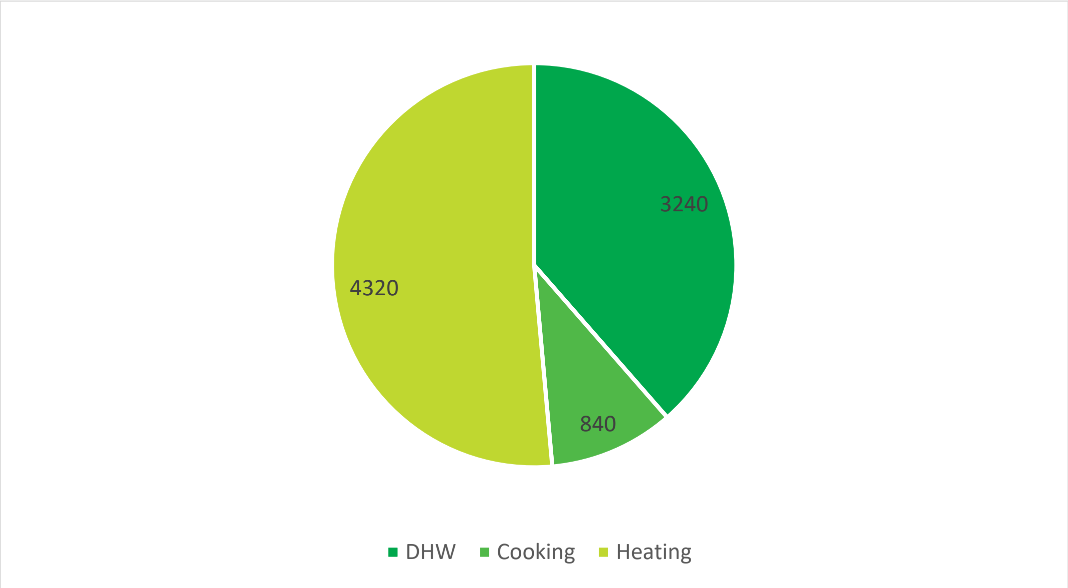


Figure 32. Overall breakdown of natural gas consumption [m^3]

4.3. Temperature and Relative Humidity monitoring

In order to have a first assessment of the temperature and relative humidity in the building, two sensors, with main features and accuracy as reported in the following table, have been installed in two representative rooms.

Instrument model	Measured parameters	Measurement range	Accuracy	Resolution
HOBO MX1101	T	from -20 to +70°C	±0.2°C (0… +50°C)	0.024°C (at 25°C)
	RH	from 1 to 90%	± 2% (10 … 90%)	0.01% (at 25°C)

Table 7 – Main features of the adopted sensor

In the following figures, the distribution for the internal temperature and relative humidity in the monitored rooms, is shown for the first acquisition period (from 29/9/2023 to 09/11/2023).

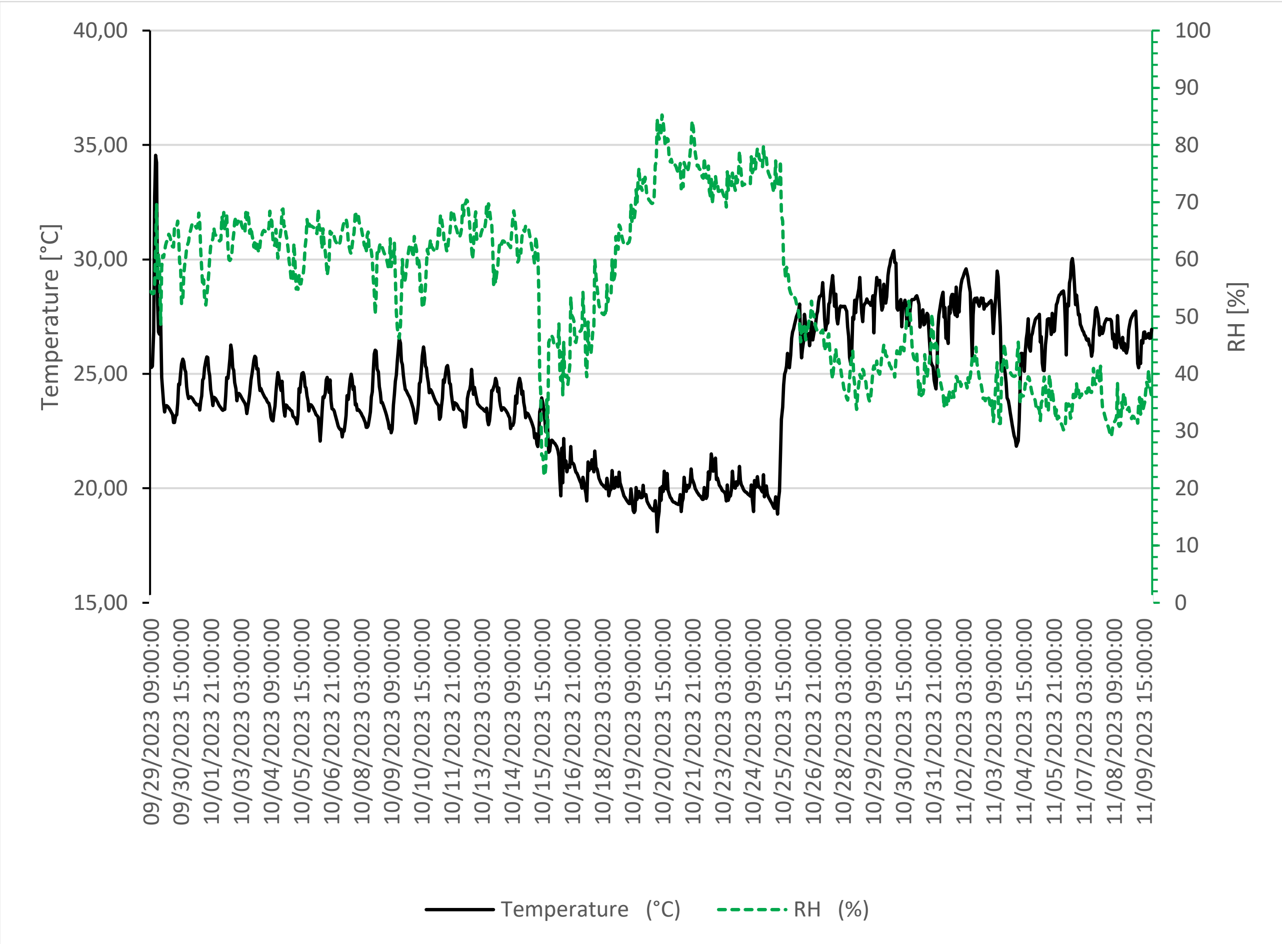


Figure 33. Temperature and relative humidity trend – ground floor

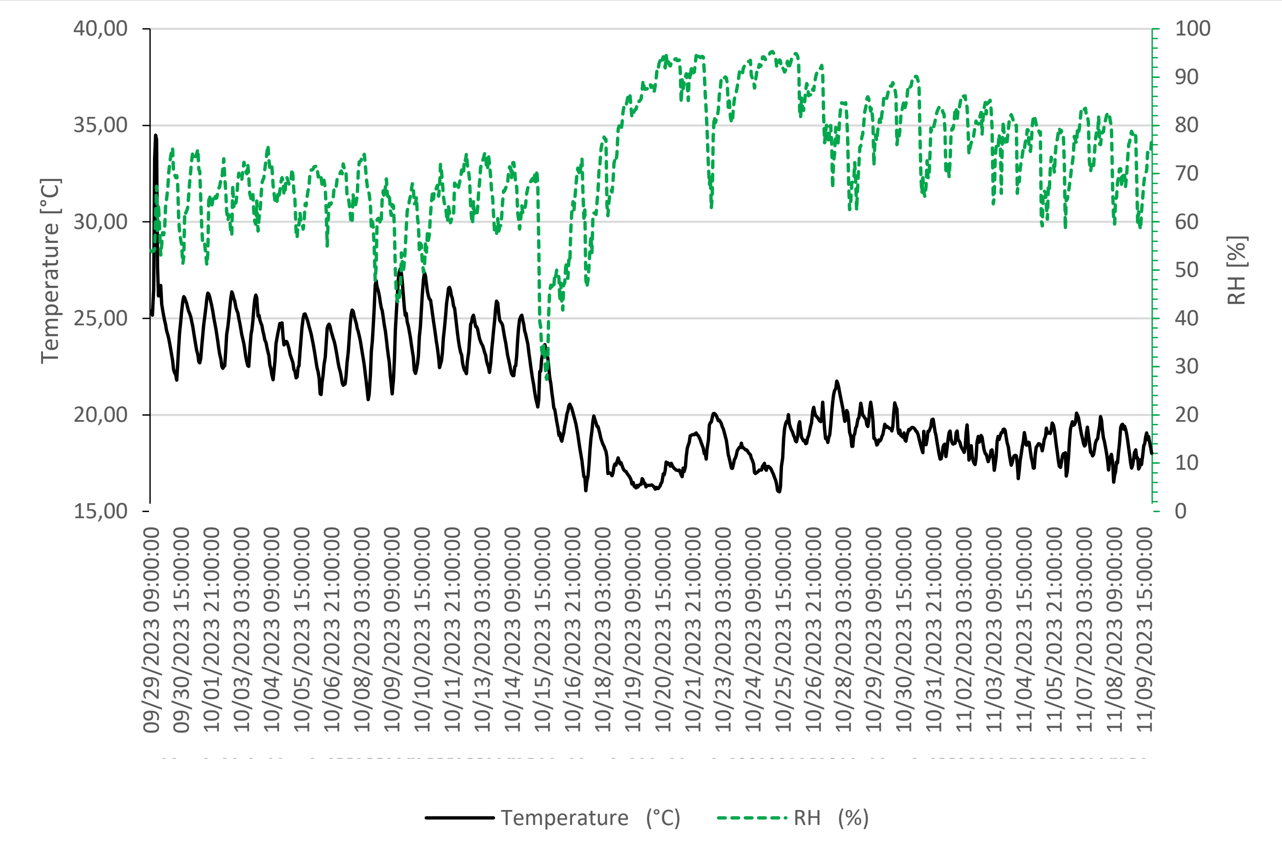


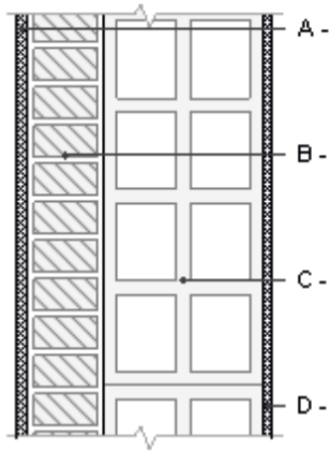
Figure 34. Temperature and relative humidity trend – first floor

Temperatures in the rooms vary on average from 21°C to 26 °C until the mid of October, after that the temperature tend to drop until around 19°C. Starting from the 25th of October, the internal temperature raised again, due to the start of the heating system, and at the ground floor achieved temperatures up to 30°C. In such respect, it is possible to deduce that the control system is not able to set the proper temperature/flow rate of the working fluid.

4.4. Energy features

Hereafter, the thermo-physical proprieties of the main opaque envelope is described. The typology of structures has been retrieved according to the construction year in combination with a visual survey of the stratigraphy of the wall in correspondence of the ventilation hole of the kitchen.

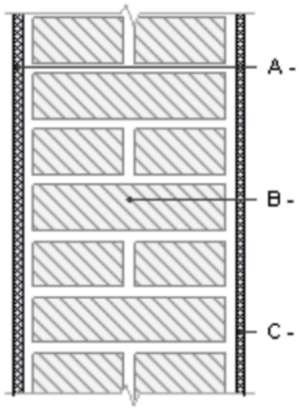
On average the exterior wall, 40 cm thick, is characterized by two rows of bricks, one solid and one hallowed, covered with plaster on both sides, for a total thickness, U value and the superficial mass equal to 40 cm, 0.816 W/m^{2}K and 580 kg/m^2, respectively.



Layer	Thickness	conductivity	Density
	mm	W/mK	kg/m3
A	15	0.7	1400
B	120	0.36	1100
C	250	0.36	1800
D	15	0.9	1800

Figure 35. Outer wall section (40 cm thick)

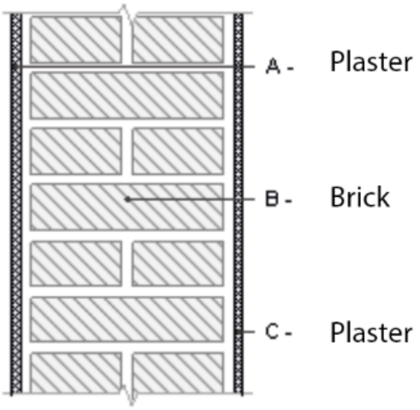
In some portion of the building, the thickness of the wall decreases at around 30 cm, as reported in the following figure. In such respect, the related U value has been calculated equal to 1.09 W/m^2K, while the superficial mass is 275 kg/m^2.



Layer	Thickness	conductivity	Density
	mm	W/mK	kg/m3
A	10	0.7	1400
B	250	0.34	1100
C	10	0.9	1800

Figure 36. Outer wall section (30 cm thick)

The survey, moreover, showed that the walls below the windows are even thinner (18 cm), thus the related U value is equal to 1.55 W/m^2K.



Layer	Thickness	conductivity	Density
	mm	W/mK	kg/m3
A	15	0.7	1400
B	150	0.34	1100
C	15	0.9	1800

Figure 37. Outer wall section (18 cm thick)

Finally, the windows in the building are simple double glazed with plastic frame. The overall U value and solar factor (g) were assumed as 2 W/m^{2}K and 0.7, respectively.

Using the retrieved data related to energy consumption, the energy signature of the building can be applied. It is based on a simple regression, a relationship between outdoor air temperature and thermal power demand.

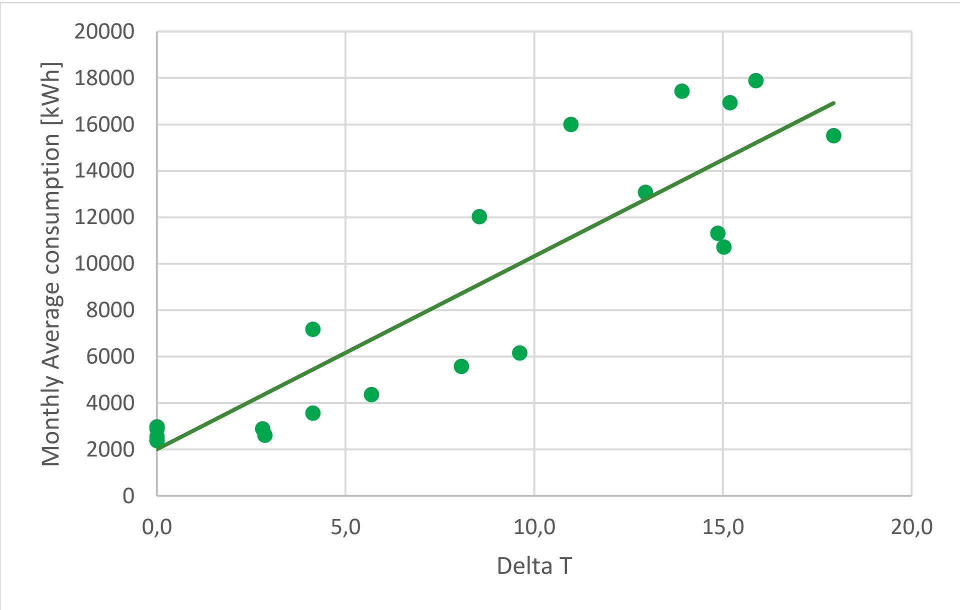


Figure 38. Energy signature

Analysing the graph, some important information can be obtained:

- a slight deviation from the trend line in several points is shown. This is typically caused by the low accuracy of the control system, which is not able to follow the outdoor air temperature trend;

- the intercept with 0 kWh is higher than 20°C of outdoor air temperature. It means that the building is characterized by high internal gains and the control logic is not so accurate;
- Regression line's slope suggests that the building is characterized by an average heat transfer coefficient of around 1.18 kW/K.