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AiCARR
Via Melchiorre Gioia 168
20125 Milano MI
Tel. 0267479270
Fax 0267479262
e-mail: info@aicarr.org
sito web: www.aicarr.org
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Upgrading 20th Century Historic Buildings in Accordance to Principles of Energy Efficiency
Riqualificazione energetica dell'edilizia residenziale storica del Novecento

FRANCESCO MANCINI[1] – SIMONA SALVO[2] – ROSA TOSCANO[3]

[1] Dipartimento di Pianificazione, Design, Tecnologia dell'Architettura, Università La Sapienza, RM
[2] Dipartimento di Storia, disegno e restauro dell'architettura, Università La Sapienza, RM
[3] Architetto libero professionista, RM

SUMMARY

Upgrading historic 20th century buildings in accordance to principles of energy efficiency implies careful examination that goes beyond their historic and artistic value. It is important to critically analyse the scope of interventions by evaluating the energy efficiency of the building envelope where not only preservation and restoration are a concern, but the need to reuse and maintain them sustainably and in step with the times also comes into play.

This study examines potential interventions necessary to improve and upgrade the energy efficiency of the buildings in the Olympic Village in Rome, built in 1958-1960 by the then INCIS (National Institute for Civil Servant Housing) for residential use. It develops a range of intervention proposals defined according to energy conservation and sustainability criteria, and fosters an approach that favours the solution to problems concerning public housing where homogeneous building and construction design is flanked by high maintenance – regular and additional – property management.

The interventions presented in this work describe how to improve the energy efficiency of the buildings by providing proper insulation to the horizontal and vertical surfaces, replacing the windows, and upgrading the installed supply systems. These interventions must be carried out according to a clear set of guidelines that indicate the necessary course of actions.

The implementation of and compliance with technical instalment methods and solutions illustrate how to attain significant results in improving the energy efficiency of the building envelope; maintain the historic values of the buildings; and establish a progressive cycle between energy efficiency retrofit and the preservation of historic heritage.

RIASSUNTO

La riqualificazione energetica del patrimonio architettonico di valore storico riconosciuto implica importanti riflessioni che vanno oltre la valutazione degli aspetti storici

e artistici. È, infatti, indispensabile analizzare in maniera critica le possibilità d'intervento, valutando l'equilibrio energetico dell'involucro architettonico quale operazione attorno alla quale non giocano soltanto questioni di conservazione e restauro ma anche il necessario riuso e mantenimento in un circuito di fruizione sostenibile e al passo coi tempi.

In questo studio, sono stati presi in esame gli interventi potenzialmente eseguibili sugli edifici a scopo residenziale del Villaggio Olimpico di Roma, costruiti nel 1958-1960 dall'allora INCIS. Proporre una gamma di possibili interventi opportunamente definiti secondo criteri conservativi ma, anche, sostenibili, rappresenta un buon approccio per risolvere questioni relative ad edifici di edilizia residenziale pubblica dove ad una tipologia edilizia e costruttiva omogenea si affianca una manutenzione - ordinaria e straordinaria - di difficile gestione.

Gli interventi di riqualificazione proposti individuano nell'isolamento delle strutture opache verticali e orizzontali e nella sostituzione di infissi e impianti, alcune soluzioni adatte a migliorare le prestazioni energetiche dell'edificio. Tutto ciò presuppone che gli interventi siano correlati da linee guida che stabiliscano i giusti presupposti alla realizzazione degli stessi.

L'applicazione e il rispetto di indicazioni di metodo e di soluzioni di carattere tecnico-impiantistico dimostra come si possano raggiungere risultati rilevanti sia dal punto di vista delle prestazioni energetiche dell'involucro edilizio, sia nella conservazione delle valenze storico-artistiche dei manufatti, stabilendo in tal modo un circolo virtuoso tra *retrofit* energetico e tutela del patrimonio storico-architettonico.

Keywords: modern architecture, upgrade, architectural conservation, energy efficiency.

Parole chiave: architettura moderna, riqualificazione, restauro, equilibrio energetico

1. INTRODUCTION

Recent statistics on energy consumption indicate that in Italy (but not only), the highest percentage of primary energy consumption is attributed to the real estate sector (residential and service sector) (Figure 1). In this sector, unlike the industrial and transportation sectors, there has been a constant rise in energy consumption consistent with data from previous years: the level of energy consumption (approx. 48 MTEP) is equal to a high level of pollution emissions.

The level of consumption is due to the age of Italy's architectural heritage which was constructed, for the most part, without taking into consideration the energy and environmental impact it would have. Awareness of these issues has risen in the recent past in the wake of the first policies on energy savings that emerged in the second half of the 1970s.

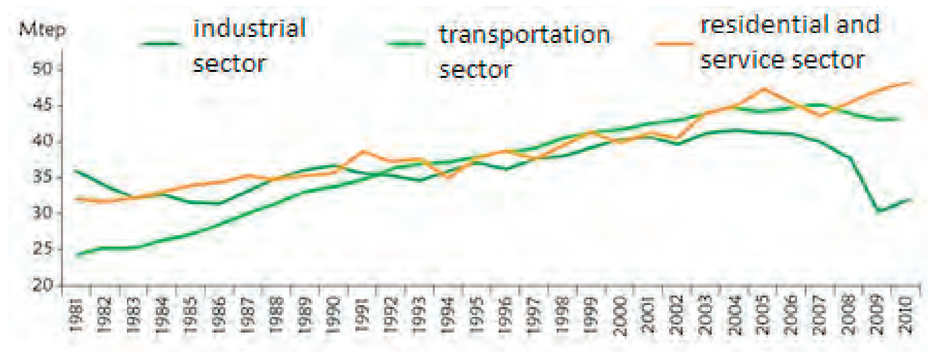


Figure 1 – Primary energy consumption per sector – Processed by CRESME on data from MI.S.E. and ENEA

Furthermore, most of Italy's architectural heritage was built during the economic and real estate boom that took place during the 1960s and 1970s, (Figure 2). During this growth in building construction, politicians and public administration focused mainly on the quantity rather than the quality of construction.

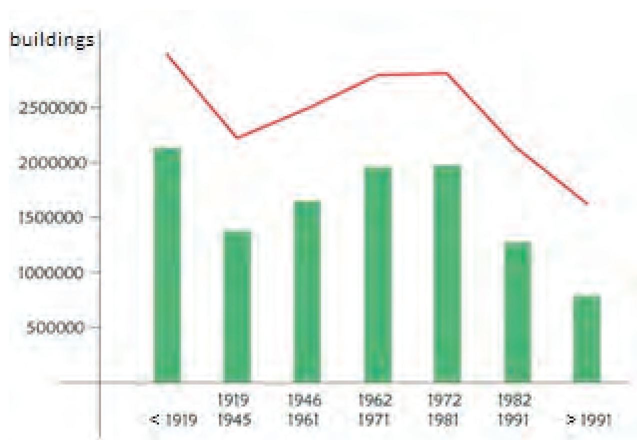


Figure 2 – Years of building property construction - Data by ISTAT Census 2001

It is nonetheless important to distinguish between "new construction" and buildings classified as "modern architecture" that have architectural or historic value and have been recognized as "cultural assets" in compliance with the laws regulating the preservation of historic heritage (Cultural Heritage and Landscape Code, Legislative Decree 42/2004). However, the European Union Directive n. 2012/27/UE states that "*Member States may decide not to set or apply the requirements* for energy performance *to the following categories of buildings: buildings officially protected as part of a designated environment, or because of their special architectural or historical merit, in so far as compliance with certain minimum energy performance requirements would unacceptably alter their character or appearance.*"

The purpose of this study is to illustrate that, in compliance with the Italian laws that regulate the protection and conservation of cultural heritage, and in the spirit of the aforementioned EU Directive, energy efficiency improvements on historic buildings must be studied *ad hoc*. Therefore, various and different types of interventions must be taken into consideration that will allow the building owners and managers to adapt the interventions according to their specific needs with the aim of creating a balance between the improvement of energy performance and the conservation of the historic and architectural value of the building.

2. THE OLYMPIC VILLAGE IN ROME: LIMITATIONS AND SUGGESTIONS FOR INTERVENTION

2.1. History and current situation

The Olympic Village (Figure 3) was built in 1958-59 for the XVII Olympic Games held in Rome in 1960. The site chosen was along the plain between the Villa Glori Hill and the Tiber River, an area owned by the city that had been designated for residential building after World War II.

Figure 3 – Recent aerial photograph of the Olympic Village in Rome

The aim was to build a neighbourhood that would temporarily house the athletes and then after the Games would become comfortable, modern, affordable and functional housing for civil servants (Salvo S., 2010). It was designed by Luigi Moretti, Adalberto Libera, Vittorio Cafiero, Amedeo Luccichenti and Vincenzo Monaco; some of the greatest and most admired architects of the time.

The architects wanted to give the village a unique, organic and urban unity and found inspiration from the bastions of modern architecture for the design of the free façade, the flat roof, the ribbon windows and the *pilotis* that support the housing blocks. They used the same brickwork throughout the cladding and the same materials for all the windows. (Salvo S., 2012). Adalberto Libera eloquently described the village as, "*…urbanly varied even though, from an architectural point of view, it may erroneously seem monotonous. The consistency of its architectural style, applied to the entire structure, is essentially made up of the following elements: grey concrete, golden pink brickwork exterior, white steel windows united in their size.*"

Today, however, the changes that have been made during the past six decades – without rule or regulation – have considerably damaged the original architectural style conceived by the architects who designed the Olympic Village.

Closing off the balconies to acquire extra living space (Figure 4); the use of different kinds of shades for protection against harsh sunlight; changing the colours and materials of the window blinds; installing different types of independent heating systems, and external air conditioning units are the most common elements that "disturb" the façade. Additional modifications include elevators in the stairwells, painting the *pilotis* and changing the floor plans of the apartments.

Figure 4 – Closed off balconies with different types of windows (left) and the addition of air conditioners

The modifications that were made – and continue to be made – often sprung from the need to improve the problems connected to the construction methods of the time in which they were built, and to keep in step with current standards of environmental comfort. Nevertheless, without a suitable overall redevelopment project, each intervention could compromise the historic and architectural value of the Olympic Village.

2.2. Guidelines for energy efficient improvements

In light of these observations, a study to determine guidelines that indicate how to carry out energy efficient improvements and upgrade the historic buildings of the Olympic Village is necessary.

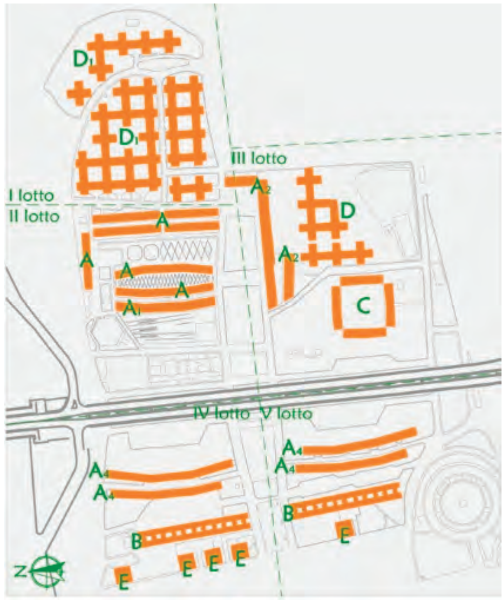


Figure 5 – Olympic Village in Rome: separated by type

Respecting the historic and architectural value of a structure means, above all, the preservation of the original architectural and constructive elements that define the value of the buildings. In the case of the Olympic Village in Rome, it would entail preserving the following:

- the external brickwork cladding;
- the modularity and thickness of the parts of the ribbon windows;
- maintaining the open-beamed *pilotis* facet;
- maintaining the "empty and full" details of the perspective.

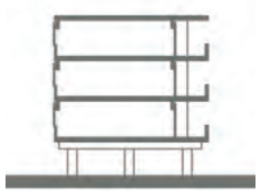
In the hypothesis of an energy efficient renovation, it is necessary to take into consideration the various types of buildings characteristic to the neighbourhood, and find technical solutions suitable for the upgrade interventions in each specific situation. For example, the possibility of installing solar power and/or photovoltaic power supply must be adapted and divided according to the five building types (Figure 5), and interventions that are or are not feasible and effective in preserving the value of the buildings must be identified.

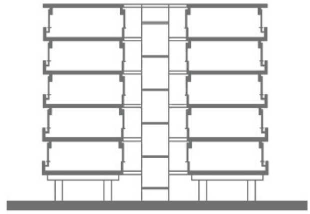
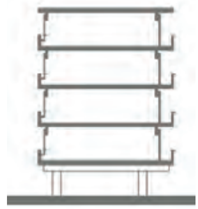
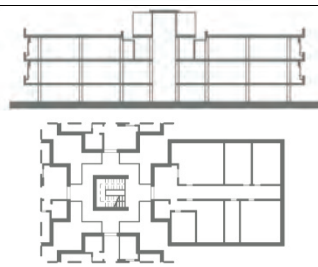
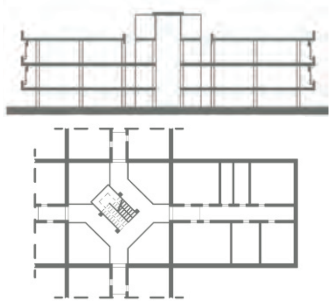
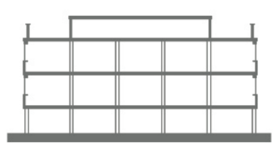
Table 1 illustrates the five main interventions (Toscano R., 2013):

1. insulation of the external horizontal structures, permitted only for the roofing;
2. insulation of the internal vertical and horizontal structures;
3. replacement of the windows, only if the frame is the same size (with a 2 cm margin), shape and colour of the current one;
4. replacement of the heating systems with more efficient ones placed on the roof or in areas not visible from the outside;

5. installation of photovoltaic panels on the roof or in areas not visible from the outside.

Table I – Intervention limitations and feasibility

			External insulation	Internal insulation	Replacement of windows	Replacement of installed systems	Photovoltaic power supply system
TYPE A			✗	✓	✓	✓	✗
TYPE A1			✗	✓	✓	✓	✗
TYPE A_2			✗	✓	✓	✓	✗
TYPE A_4			✗	✓	✓	✓	✗

TYPE B			X	V	V	V	V
TYPE C			X	V	V	V	X
TYPE D			X	V	V	V	V
TYPE D_1			X	V	V	V	V
TYPE E			X	V	V	V	V

Compliance with the guidelines as well as simple maintenance work, would give back the "architectural style" that has been lost through the years due to continuous and unregulated additions and changes to the neighbourhood.

After focusing attention on the historic and architectural elements, it is important to analyse the compatibility of the interventions with the technological materials and solutions used in the buildings.

3. TECHNOLOGICAL AND THERMO-HYGROMETRIC ANALYSIS OF CURRENT STATE: BUILDING IN VIA UNIONE SOVIETICA

In order to quantify the positive effects of feasible interventions, a standard building type was studied (Figure 6). The structure is 150 metres long, 10 meters wide and has a north-south exposure. The building has a load-bearing structure in reinforced concrete; it is five storeys high, elevated "on *pilotis*" and features eight stairwells which did not originally house elevators. Each stairwell serves two apartments (with double orientation) per floor, for a total of 64 apartments with floor space ranging from 80 to 90 m^2.

Figure 6 – Building via Unione Sovietica

A survey and analysis of the use of materials and the construction features of the building envelope was based on a first-hand study and close analyses of the accessible parts of the building. Moreover, the current data collected was compared with references from the original 1958-60 designs housed at Rome's National Archive ('Luigi Moretti' foundation) (Toscano R., 2013). In fact, the thickness of the vertical partitions – external and internal – are of different sizes and in many cases the actual building does not correspond to the original project design.

Based on the survey, the building envelope is made up of:

1. *external walls*: hollow cavity wall framework in perforated and solid brickwork covered externally by 2 cm-thick detailed brickwork and internally by 1.5 cm lime-based plasterwork for a total thickness of 33 cm;

2. *internal walls between stairwell and apartment (Type 1)*: hollow cavity wall framework in perforated brickwork covered by 1.5 cm-thick lime-based plasterwork per side for a total of 28 cm;
3. *internal walls between stairwell and apartment (Type 2)*: solid brickwork covered by 1.5 cm-thick lime-based plasterwork per side for a total thickness of 16.5 cm;
4. *floor on pilotis and the space between floors:* ribbed slab floor in brick-concrete covered internally in granulated tiles and 1.5 cm lime-based plasterwork externally for a total thickness of 25.5 cm;
5. *rooftop*: ribbed slab floor in brick-concrete insulated externally by various layers of blacktop and tar paper protected by reinforced concrete for a total thickness of 29.8 cm.

The survey also showed that many of the original windows have been replaced by windows made from different materials, and in different shapes and colours.

Figure 7 – Examples of windows

The original windows, some of which are still *in situ*, are made of ready-made self-contained systems in zinc-coated steel, painted white. The frames are very thin, without glazing, and the glass is only 2 millimetres thick. The long ribbon windows on the west side are double-leaf or bottom-pivoting hopper casement (figure 7) that alternate and form repetitive three-unit modules along the entire façade. The façade facing east is characterized by one or two-leafed panels, and one or two-leafed French doors (Figure 7) that open onto the balconies.

Every window has roll-down blinds that were originally made of yellow painted wood. They are housed in zinc-coated steel blind boxes and secured directly to the reinforced concrete curb without insulation (Figure 8).

The newer roll-down blinds that replaced the original ones are mainly made of plastic in colours similar to the original ones.

Figure 8 – Detail of the box and roll-down blinds

Based on the survey, a calculated module was developed on certified software to evaluate the energy efficiency of the current state and to assess the quality of the building envelope.

Table II – Transmittance, cavity and surface condensation of current situation

Building	Transmittance [W/(m^{2}K)]	Cavity condensation	Surface condensation
External walls	1.217	No	No
Internal walls dividing apartments and stairwells	1.186	No	No
Internal walls dividing apartments and stairwells	1.877	No	No
Floor on Pilotis storey	1.408	No	No
Rooftop	1.673	Yes (it evaporates in summer)	No
Windows	5.86		No

According to the calculations, the energy performance of every apartment (regardless of the storey or exposure) is classified as G due primarily to the poor quality of the building envelope (Table 3).

4. HYPOTHESIS FOR INTERVENTIONS AND RESULTS

When developing a hypothesis for a large-scale improvement project for energy efficiency performance (De Santoli L., Mancini F., Cecconi M., 2009 and 2010), it is important to bear in mind that every single intervention will affect different parts of the building depending on its position and exposure within the structure as a whole, and it will also affect the individual subjects (in this case families) that have different social and cultural backgrounds and different financial resources. In light of intergenerational transfers in recent years, there is a high probability of finding new families living in the apartments, and therefore more open to change, and families made up of elderly people. It is very important to consider both the prospects of permanent stay in the apartments that would imply a return on investments in the future, and the financial conditions of the individual subjects (Salvo, 2010).

In view of these aspects, the table below illustrates various phases of intervention where each individual case can choose the intervention that best meets its needs, and will not have an impact on the historic and architectural value of the building (Figure 9, Table 3) (Mancini F., Caruso G., Ceci A., 2010).

With reference to the laws that regulate the minimum standards for building envelopes and installed systems (Legislative Decree 192/2005), five hypothetical interventions regarding the position and exposure of the apartments have been developed:

A. insulation of the opaque vertical structures, the rooftop (where necessary), the *pilotis* floors (where necessary);
B. replacement of all the windows with more efficient ones;
C. insulation of the opaque vertical structures, the rooftop (where necessary), the *pilotis* floors (where necessary), and replacement of all the windows with more efficient ones;
D. insulation of the opaque vertical structures, the rooftop (where necessary), the *pilotis* floors (where necessary), replacement of all the windows, installation of a aerothermal heat pump system, radiant heating floor panels, fan coil units, and an AC accumulator tank;
E. insulation of the opaque vertical structures, the rooftop (where necessary), the *pilotis* floors (where necessary), replacement only of the windows facing east, minimal interventions on windows facing west: addition of glazing and insulation to blind boxes, and installation of a pump system as described in intervention D.

Figure 9 – Division of apartments by position and exposure (south: on the left, east-west: in the middle, north: on the right)

Table III – Analyses of the energy performance of the apartments based on the exposure, position and type of intervention - EP_{CI} [kWh/(m^{2}a)] (Energy classification)

Exposure	South facing apartments			East-west facing apartments			North facing apartments		
Storeys	I	II-III	IV	I	II-III	IV	I	II-III	IV
Current state	272.9 (G)	186.1 (G)	277.7 (G)	269.1 (G)	161.1 (G)	266 (G)	281.7 (G)	198 (G)	287.1 (G)
Intervention A	127 (F)	108 (E)	120.3 (E)	108 (E)	108.9 (E)	108.9 (E)	199.7 (G)	108.9 (E)	121.1 (E)
Intervention B	203.1 (G)	114.3 (E)	200.5 (G)	200.3 (G)	91.8 (E)	191.5 (G)	208.5 (G)	119.4 (E)	203.8 (G)
Intervention C	67.6 (C)	57.1 (C)	70.7 (C)	64.3 (C)	56 (C)	66.1 (C)	68.2 (C)	57.9 (C)	70.7 (C)
Intervention D	45.2 (B)	40.3 (B)	46.1 (B)	46 (B)	43 (B)	46.8 (B)	45.4 (B)	41.1 (B)	48.2 (B)
Intervention E	57.5 (C)	52.2 (B)	58.1 (C)	58.9 (C)	54.1 (B)	59.7 (C)	56.3 (C)	53.1 (B)	57.1 (C)

The results of the calculations carried out on the envisaged *post operum*, clearly illustrate the effectiveness of the interventions on the building envelope (on both opaque and transparent parts). A complete upgrade (intervention 'D') would reduce primary energy consumption for each apartment by 85% compared to the current state.

5. TECHNOLOGICAL SOLUTIONS ADOPTED AND A PROJECT FOR THE SYSTEMS: ANALYSES OF A "PROTOTYPE" CASE

The following case study is relevant to a type 'E' intervention where the ribbon windows are not replaced on the western orientation in order to best preserve one of the main architectural features of the façades.

The apartment chosen to examine the described procedures more closely is a residential unit on the last storey with northern exposure because it poses the worst energy performance (Table 3).

In reference to the technological elements that make up the envelope, the following procedure was applied:

1. <u>insulation of the external walls</u> by filling the cavity with a sandwich panel (8 cm thick) of expanded polyiso foam coated on both sides by a thin layer of saturated glass, U= 0,266 W/m^{2}K;
2. <u>insulation of internal dividing walls (Type 1)</u> between the apartment and the stairwell by filling the cavity with a sandwich panel (9 cm thick) of expanded polyiso foam coated on both sides by a thin layer of saturated glass, U= 0,240 W/m^{2}K;
3. <u>insulation of internal dividing walls (Type 2)</u> between the apartment and the stairwell using a panel (1 cm thick) in formless nanotechnological insulation gel silicone coupled with a transpiring membrane in polypropylene reinforced with glass fibres, U= 0,85 W/m^{2}K;

4. insulation of space between floors using thermal (3.2 cm total thickness) radiant heating floor panels, U= 0,66 W/m^{2}K;
5. insulation of the rooftop by placing a layer of tar paper blacktop on top of the existing structure, covered by a panel of insulating expanded polysio foam coated on both sides with saturated glass (8 cm thick), and protected by a layer of waterproof slate, U= 0,268 W/m^{2}K.

Regarding the original windows on the west facing side, it is necessary to insulate the blind boxes using two isolating sheets that adjust to the existing structure (U= 0,6 W/m^{2}K). Furthermore, according to the solutions, double paned windows in wood replace the windows facing east with the same thickness as the existing ones, and with improved performance, U= 1,5÷1,8 W/m^{2}K, g = 0,59.

Table IV – Aerothermal heat pump technical data

Cooling capacity	14 kW
Energy absorption capacity	3.68 kW
EER	3.8
Thermal power	12 kW
Energy absorption	2.79 kW
COP	4,3
Heating: Temp. water 30°C/35°C Temp. external air 7°C B.S./6°C B.U. Cooling: Temp. water 23°C/18°C Temp. external air 35°C B.S./24°C B.U.	

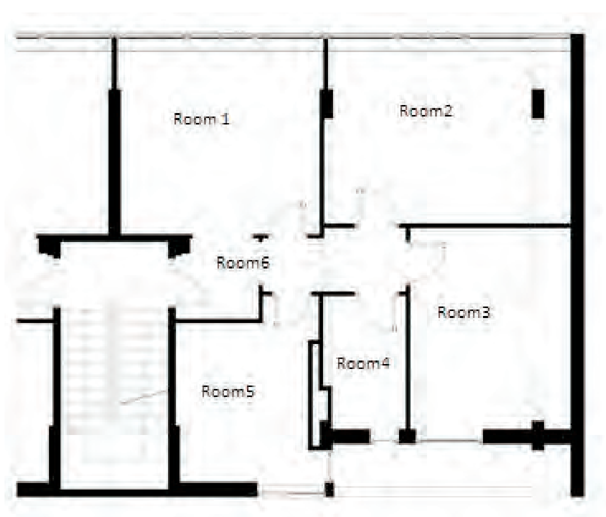


Figure 10 – Plan of the apartment

Table V – Thermal loads and equipment

	Surface	Winter heat load		Summer cooling load		Radiant heating floor panels	Fan-coil unit
	[m^2]	[W]	[W/m^2]	[W]	[W/m^2]		
Room 1	21,5	1677	78	3498	163	✓	✓
Room 2	25,6	1807	71	3686	144	✓	✓
Room 3	16,5	775	47	2163	131	✓	✗
Room 4	5	206	41	1113	223	✓	✗
Room 5	14	630	45	2177	156	✓	✗
Room 6	8,3	162	20	1240	149	✓	✗

Regarding the installed systems, the intervention proposes the replacement of the gas heaters with a aerothermal heat pump (Table 4), radiant heating floor panels, fan coil units (integrated where necessary), and an accumulator tank for domestic use of hot water. This would result in using renewable aerothermal resources in compliance with Legislative Decree 28/2011. An additional improvement that would lead to an even higher energy classification, but is not foreseen in the guidelines for this specific case, is the installation of photovoltaic panels on the roof.

CONCLUSIONS

Tackling the issues of making energy efficient improvements on historic residential buildings raises many questions regarding which intervention best meets the requirements for improved energy consumption while respecting the architectural features of the structure. In the case of the buildings of the Olympic Village in Rome, a careful examination of the historic and architectural features, the urban layout of the building complex, and the problems inherent to the construction techniques have led to the development of guidelines that identify interventions on some of the features with various costs and advantages that would solve the problem efficiently and on different levels.

Although the solutions proposed may not represent the best possible solutions available in terms of energy efficiency improvements, it has been proven that preserving the peculiar characteristics of a building is not an obstacle in the quest for optimum performance.

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