THE SCHOOL OF MATHEMATICS AT ROME'S UNIVERSITY CAMPUS

GIO PONTI, 1935

Edited by Simona Salvo | Sapienza University of Rome

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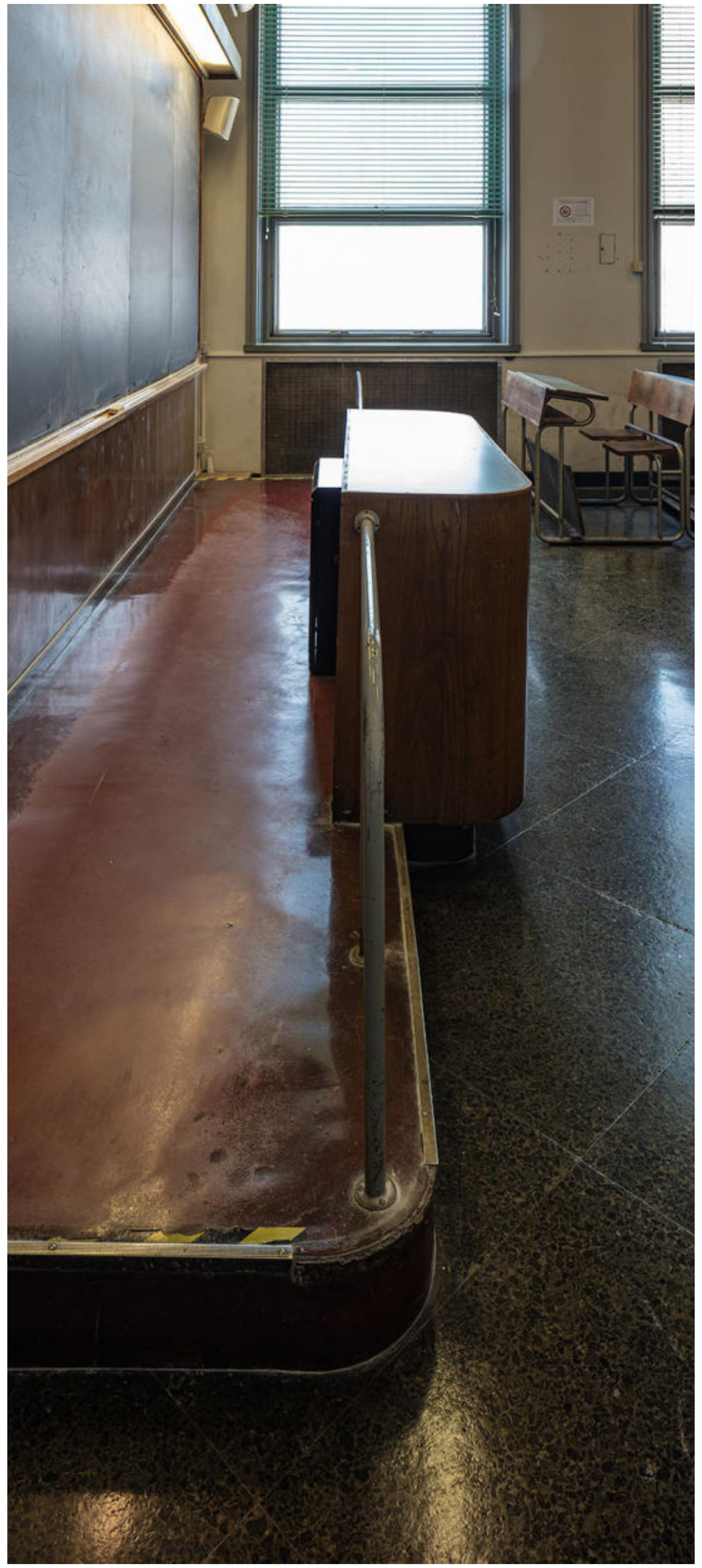

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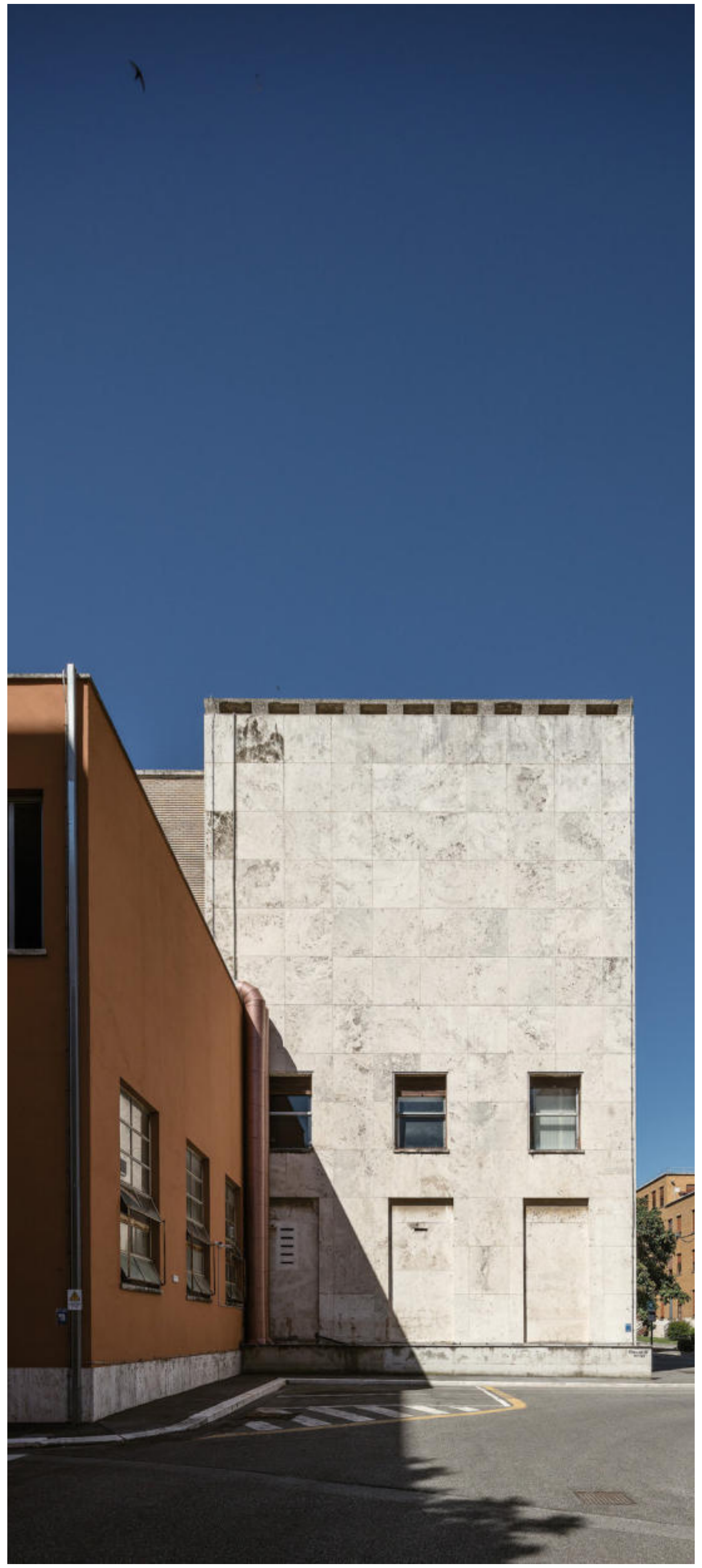

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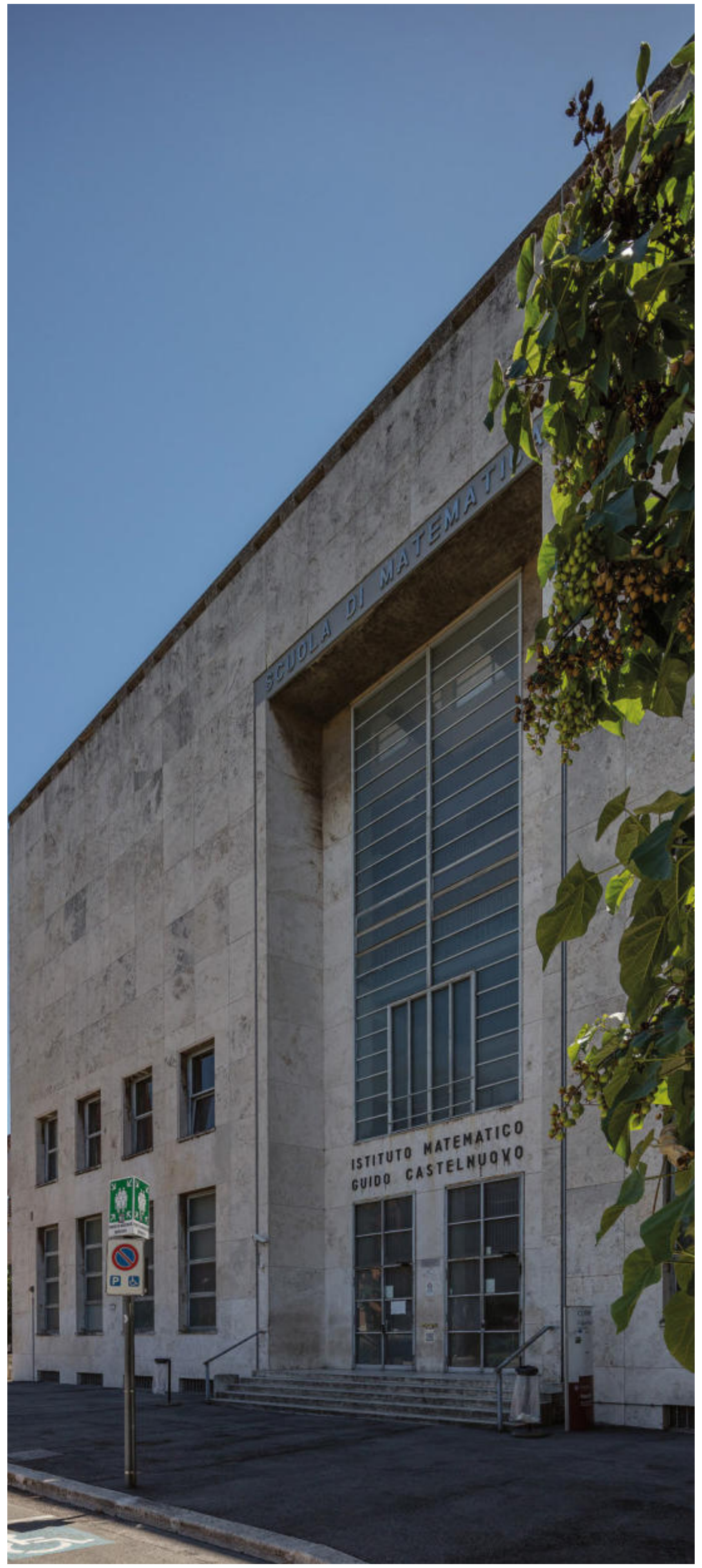

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TECHNICAL ISSUES, COMFORT AND ENERGY EFFICIENCY

Francesco Mancini, Giada Romano, Maria Rosso

BASIC BUILDING SYSTEMS

The study of the building has highlighted a crucial symbiosis between the architectural design and the layout of the plant system. Such intimate integration between apparently diverse aspects derives from the capacity to merge a deep knowledge of the building's thermal behaviour and the ability to design its volumetric development accordingly. In Gio Ponti's project, the 'integrated' design of the different aspects gave rise to an admirable combination of architecture and environmental comfort.

The architectural development may be compared to that of an amphitheatre, where the planimetric layout around an "unhinged semicircle'" develops in planimetry and in elevation. The void of the internal courtyard arranges in fact three main different bodies: the front building, the curved wings and the tower of the classrooms.

This research has proved that specific architectural and plant solutions were designed for each of the buildings, in order to achieve both environmental comfort and Indoor Environmental Quality (IEQ) according to the various different activities carried out in each.

The study of the different buildings has therefore been discussed separately, in full coherence with the original design concept in distinct bodies, in order to explain the synergic relationship between architecture and plant systems that originally rendered the interior spaces particularly pleasant and functional.

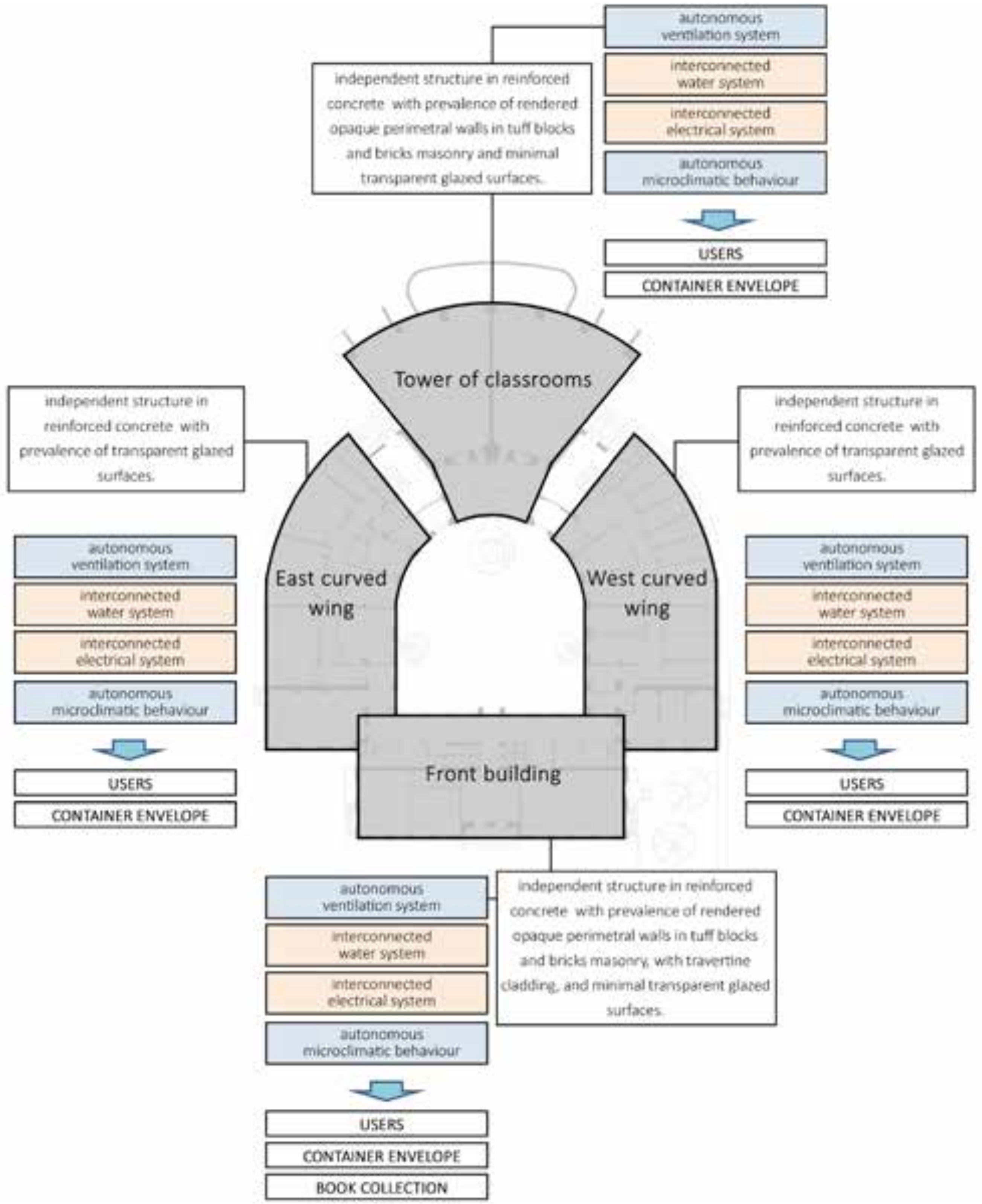
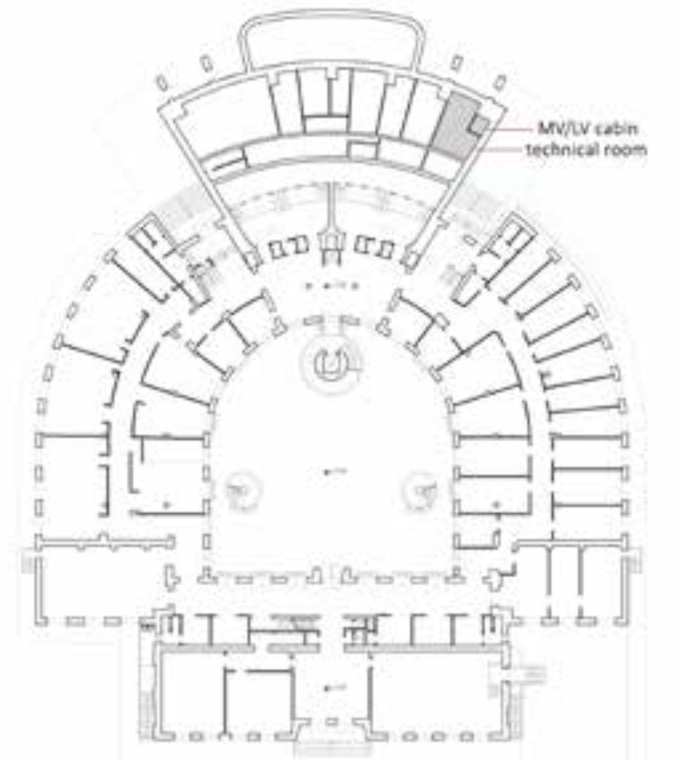


Figure 1 - Technical plant engineering and architectural features according to the main bodies of the building (© Mancini, Romano, Rosso 2020)

The School of Mathematics is equipped with essential technological systems, which satisfy functional needs and achieve environmental comfort. More specifically, the building is equipped with electrical systems for the supply of motive power and lighting, with heating systems serving the entire building, with cooling systems serving some parts of the building and in some case single rooms, with mechanical ventilation serving some parts of the building and with domestic hot water systems. Electricity necessary for the operation of the building is supplied through a Medium Voltage/ Low voltage (MV/LV) transformer substation, located in its original location (since 1935) at the ground floor of the Tower of classrooms, with access from the outside.

The distribution pipes that feed the area panels start from the General Low Voltage Switchboard (QGBT) and branch off through appropriate ducts in the shaft or under the pavements. The connections for the power supply of motive power and lighting depart from the area panels.



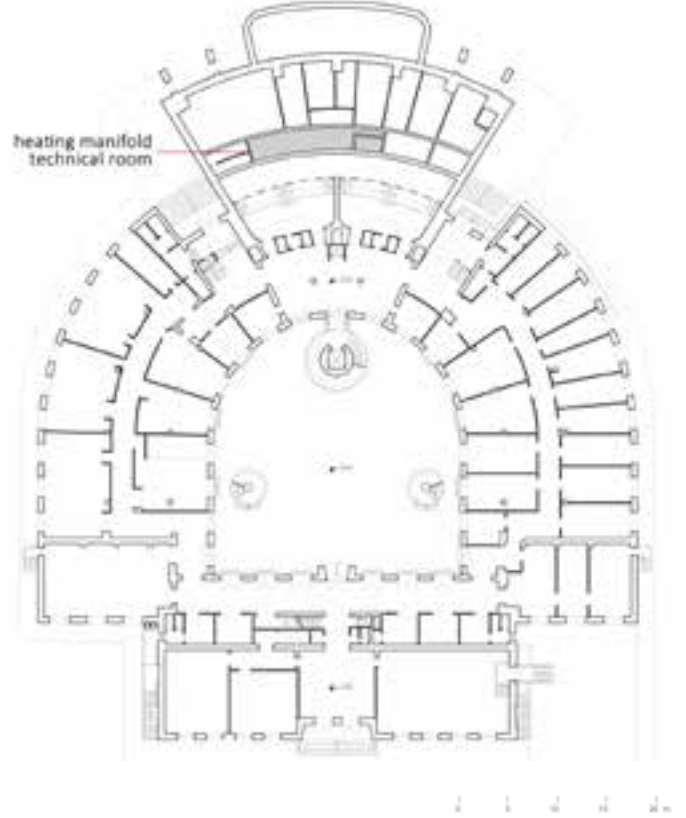


Figure 2 - Location of the Medium Voltage/Low Voltage cabin, in grey (© Rosso 2020)

Figure 3 - Location of the heating manifold technical room, in grey (© Rosso 2020)

Figure 4 a/b - Original equipment and signage of the heating manifold technical room (© Salvo 2021)

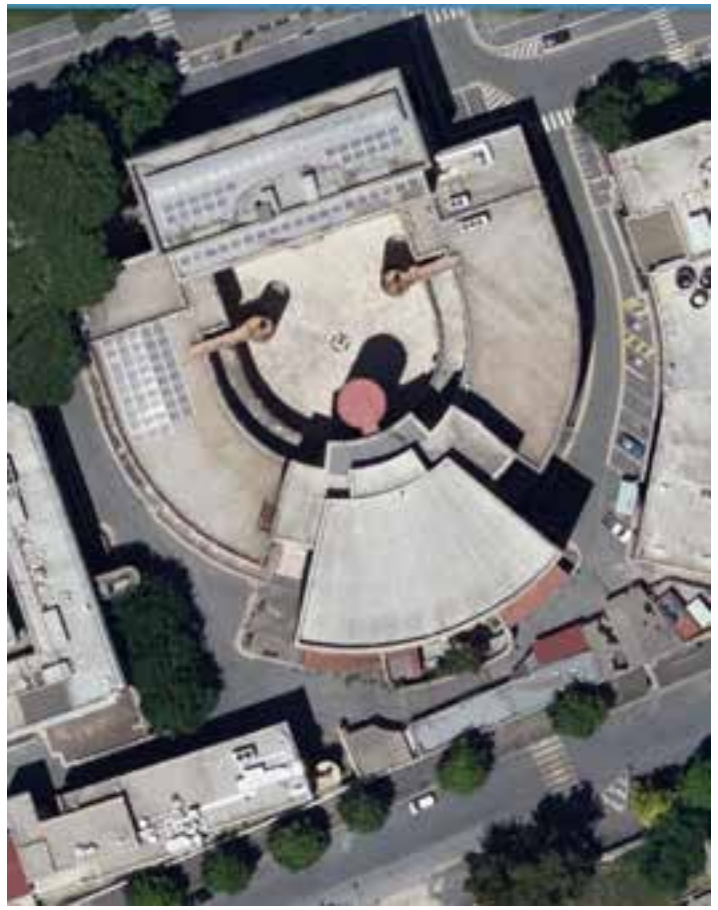


Figure 5 a/b - One of the zone switchboards and a cable duct (© Mancini 2020)

Figure 6 a/b - Original integrated ceiling lights in the tiered lecture halls and non-original ones (© Salvo 2021)

Figure 7 - Aerial view of the PV system (https://g3w-suite.cittametropolitanaroma.it/it/map/inquadramento-territoriale/, 2022)

A photovoltaic system has been recently installed on the roofs of the Front building and of the east curved wing in an integrated way with an azimuth orientation of- 22° south and an inclination of 10°. This grid connected system operates in parallel with the low voltage electricity network of the university campus and in an on-site exchange regime with the Municipal medium voltage distribution network (ACEA). This is part of a higher scale system implemented throughout the entire campus, which allows to cover the energy needs of the School of Mathematics and of other campus buildings, although only in part. The general system consists of two subsections: one dedicated to the building of the Rectorate and placed on its roof (on the roof of the Rectorate); another dedicated to the buildings of Arts and Humanities, and to the School of Mathematics.

In regard to the heating system, the building is connected to the university District Heating Network, through a secondary branch that starts from the substation of the nearby Institute of Pharmaceutical Chemistry and arrives in a technical room located at the foot of the Tower of classrooms; from here the distribution backbones branches off, housed in underground rooms of the nearby buildings through a distribution manifold.

Figure 8 - The PV system on the rooftop of the front building (© Salvo 2021)

HEATING, COOLING AND VENTILATION SYSTEMS

The front building consists of a parallelepiped that develops on three levels, plus a basement: the ground floor is divided into three sections and consists of an atrium and side classrooms; the first and second floors are occupied by offices and by the library, with reading hall, study rooms, deposits for storage of books, archive offices and services, all distributed by staircases within the same library. The orientation of this body in north /south, since all the windows face north and overlook the main aisle of the campus, or south and overlook the courtyard.

The classrooms, offices and halls of the front building are heated by radiators, most of which are still positioned in their original location- i.e. the one established in 1935- due to the few plan changes that have taken place in this part of the building over time. The original position is easy to detect as radiators are housed inside niches obtained in the walls, and protected by metal grates, so to appear perfectly integrated into the architectural system. Air exchange takes place through natural ventilation, thanks to the presence of windows in every room.
Ventilation and heating systems of the library have also been worked out with specific attention to the architectural configuration of this space, and to its specific activities. The two systems are closely linked and have therefore been detected in close reference. The main reading hall of the library consists of one single volume, naturally lit through a wide skylight that covers the entire longitudinal length of the space and by a large vertical window positioned on the central axis of the façade, crossing the entire height of the block, which therefore sheds light in the interior and beyond, reaching the rooms placed on the other side of the building. Air exchange originally took place mainly through the windows that flank the above skylight, while a strong circulation of air originally was guaranteed by the interconnection of spaces from level to level and from side to side.

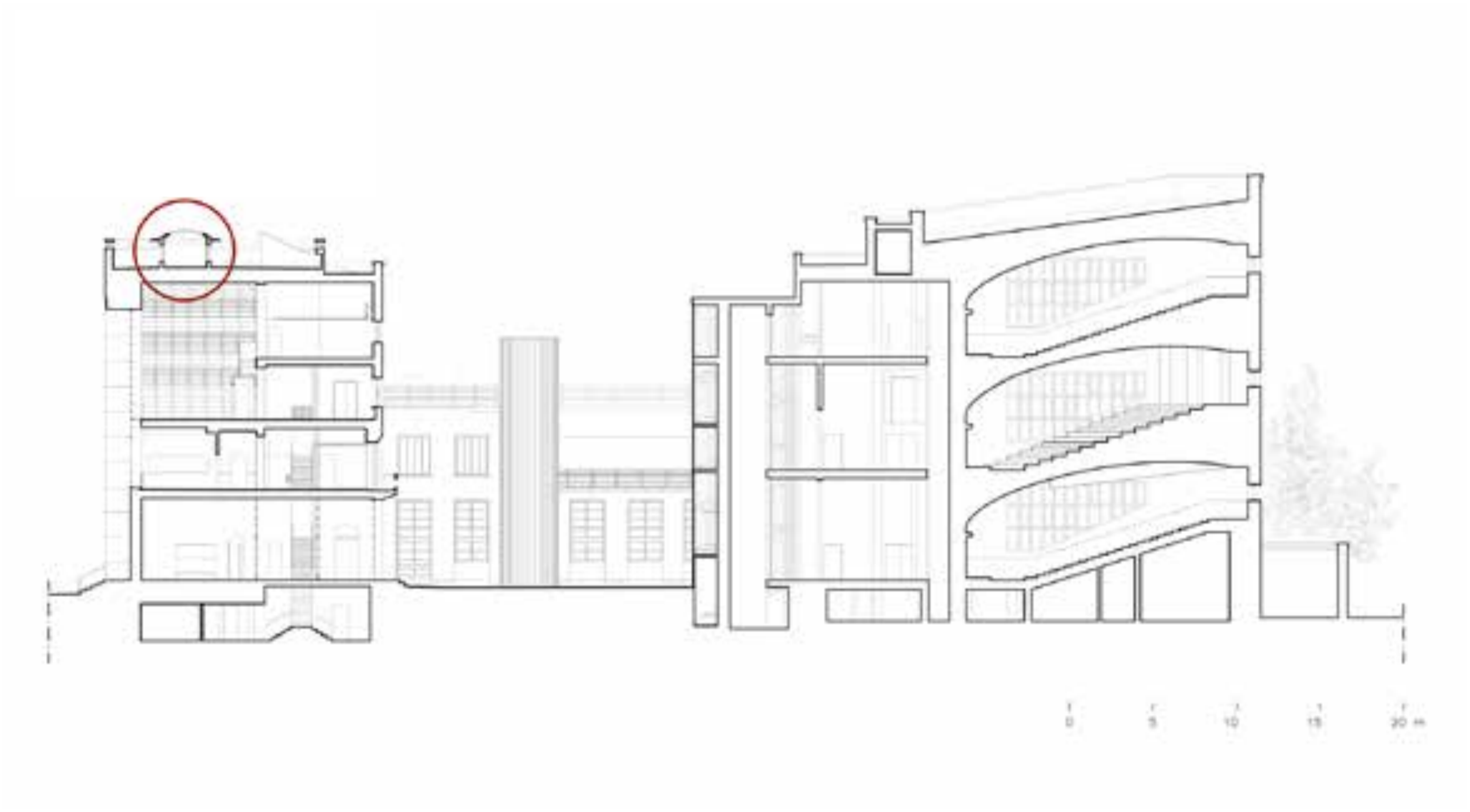


Figure 9 a/b - a) location of the skylights above the library; b) view from the rooftop (© Salvo 2021)

Figure 10 - A radiator of the front building (© Salvo 2021)

Today the opening system of these windows cannot be operated easily as they can be opened only from the outside, accessing on the roof terrace; in addition, recent maintenance works have laid varnish on hinges and fixtures, which are now stuck in the closed position. Since there is no evident system that can operate these windows from inside the library, it is probable that these were meant to be kept constantly open, to guarantee air exchange in the reading room where operable windows are absent. This hypothesis is supported by the jutting cement cornice of the skylight, which was probably designed to protect the pivoting windows in the open position in order to protect them from the rain.

The refrigeration units for the management of the cooling system of the library are positioned on the rooftop of the east curved wing, flanked by another Air Handling Unit (AHU) positioned next to each dedicated refrigeration unit, which serve the rooms at the basement level of the building.

The two curved wings that embrace the central courtyard are symmetrical and connect front block and tower through a central corridor. To date, the situation of the installations in the two symmetric bodies is different in consequence to the different use of the two, as one is destined to offices and classrooms, and the other is only in part dedicated to offices and hosts IndAm on the upper level, which is organized and managed apart. The original drawing classrooms, consisting of large open spaces, have been subdivided in order to optimise their use due to the change in academic courses and programs, and to the high increase of the number of students. This fragmentation of the original open space has not only altered the functional and architectural organization of this part of the building but has also affected the internal microclimatic balance among the rooms, significantly worsening the indoor environmental quality, or comfort. The cross current air that once allowed natural air circulation and a full air replacement in the rooms, is today impeded by the

Figure 11 a/b - a) View of the refrigeration unit with Air Handling Unit dedicated to the library rooms placed on the rooftops (© Salvo 2021) and detail (b) (© Mancini 2020)

Figure 12 - Detail of the Air Handling Unit (AHU) (© Mancini 2020)

presence of the corridor and of the many partitions along the entire length of the wings.

However, natural light is guaranteed in each classroom by the presence of wide windows, while heating is also guaranteed by the presence of radiators. The current situation is rather different from the original especially at the ground floor, where full-height windows have been reduced by one third, and rest on travertine sills under which the radiators are located. The presence of such wide glazing in all rooms, versus the scarce natural air circulation, renders microclimatic discomfort perceived more in the summer season, and for this reason HVACs systems have been installed in many rooms for cooling.

The Tower of classrooms consists of an amphitheatre-like body, which develops its curvilinear side towards south, with very few openings, and is wedged into the courtyard with a semi glazed façade, overlooking north. Lighting fronts are concentrated to the sides facing east and west, with large, contoured windows that allow a sufficient level of natural lighting for the use of these large halls during the day. While the building envelope is pierced by a limited number of openings compared to the imposing continuity of the outer wall- probably also dictated by the need to limit wind pressure on fragile surfaces- it is evident that the shape of this body was conceived to accommodate the tiered lecture halls.

Electrical heating, cooling and ventilation systems
The original electrical system of the School of Mathematics has undergone significant changes to comply to the constantly evolving legislation and to the changing needs of the academic community. Classrooms have increased in number and decreased in dimensions throughout the subdivision of the original halls. The demand for motive power for various uses has also changed and increased in general with the introduction of several systems for summer cooling (HVAC), which in many cases serve individual rooms. All these

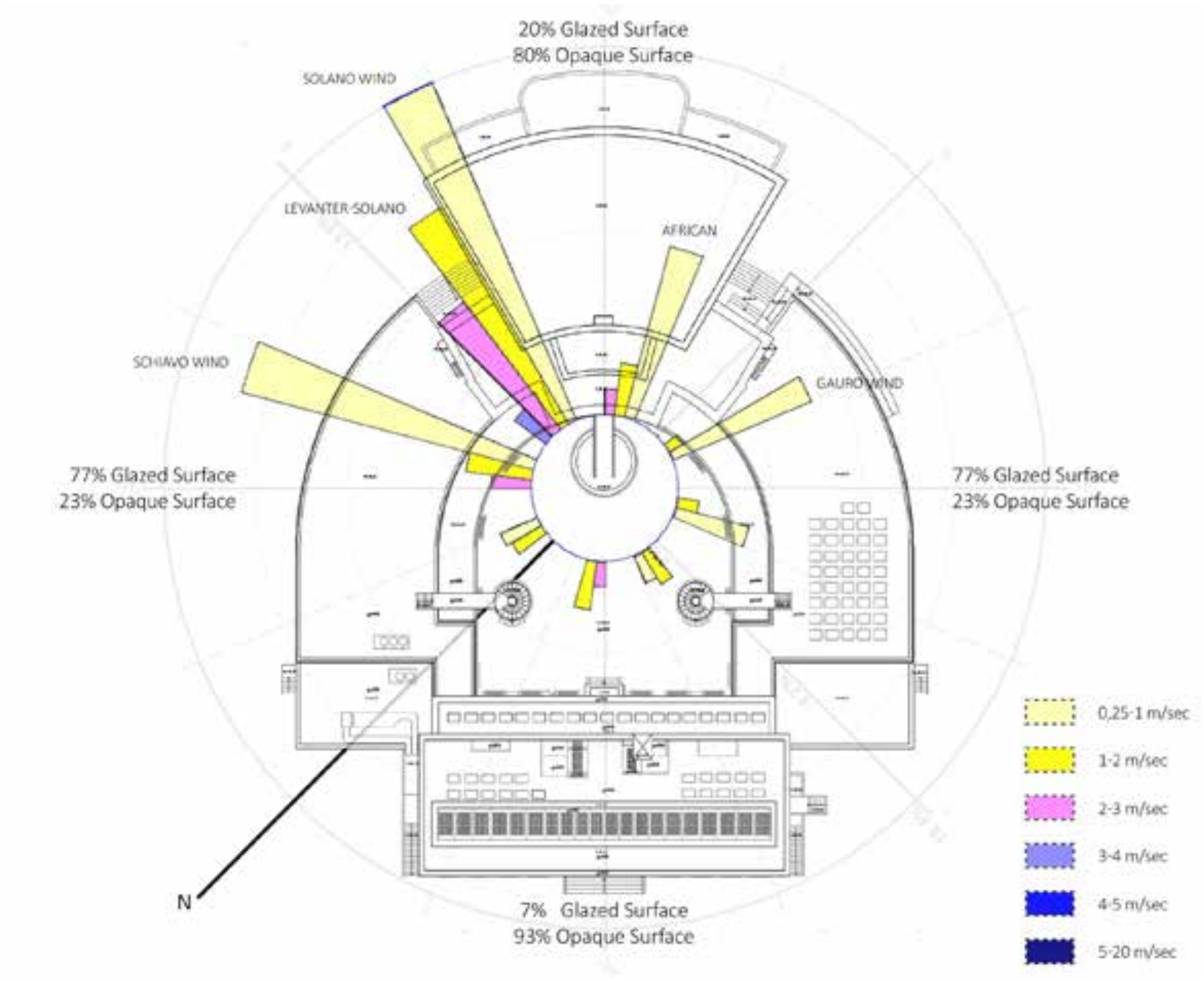


Figure 13 - Orientation diagram of the building, with percentage of opaque and glazed surfaces and prevailing compass wind rose (source of climatic data: http://www.arsial.it/portalearsial/agrometeo/E2_5.asp year 2020)

changes have implied the passage of new cables and ducts, and the installation of new ceiling lights, also altering or replacing the original fixtures. The electrical substation has been instead kept in the original position, as evidenced by the plate positioned above the manifolds, which tells the name of the original supplier of the heating system, the Florentine firm "Giuseppe De Micheli & Co". Cold water distribution lines for toilets and for other building's uses depart from this same room, while domestic hot water for the toilets is produced using local electric boilers. Observing the cross section of the front building, the original ventilation system, which guaranteed circulation and supply of fresh air in a semi closed room recurring to a rather brilliant architectural solution, appears evident.

Due to the heating effect, a vertical convective motion of rising warm air is generated, thus allowing the exchange of air induced by the ribbon windows on the sides of the skylight. At the level of the study tables, instead, a horizontal circulation is guaranteed by the presence of aligned entrances, openings and windows, all placed one in front of the other.

The all glass vertical window on the front façade - which lost its decorated stained-glass work during World War II and was reinstated thereafter with common transparent glazing – has altered its lighting function today due to the drastic changes in the space organization of this part of the building: the insertion of a slab between the once called 'professors' atrium' and the reading hall of the library has in fact interrupted much of the air and light flow from level to level, thereby also limiting air currents produced by an excessive ascent speed given by the notable height of the library reading hall.

The original location of the heating terminals – or radiators – in this part of the building appears in the few historical photographs of the newly built library, designed in perfect harmony with the function of the space, the furniture and the overall architectural

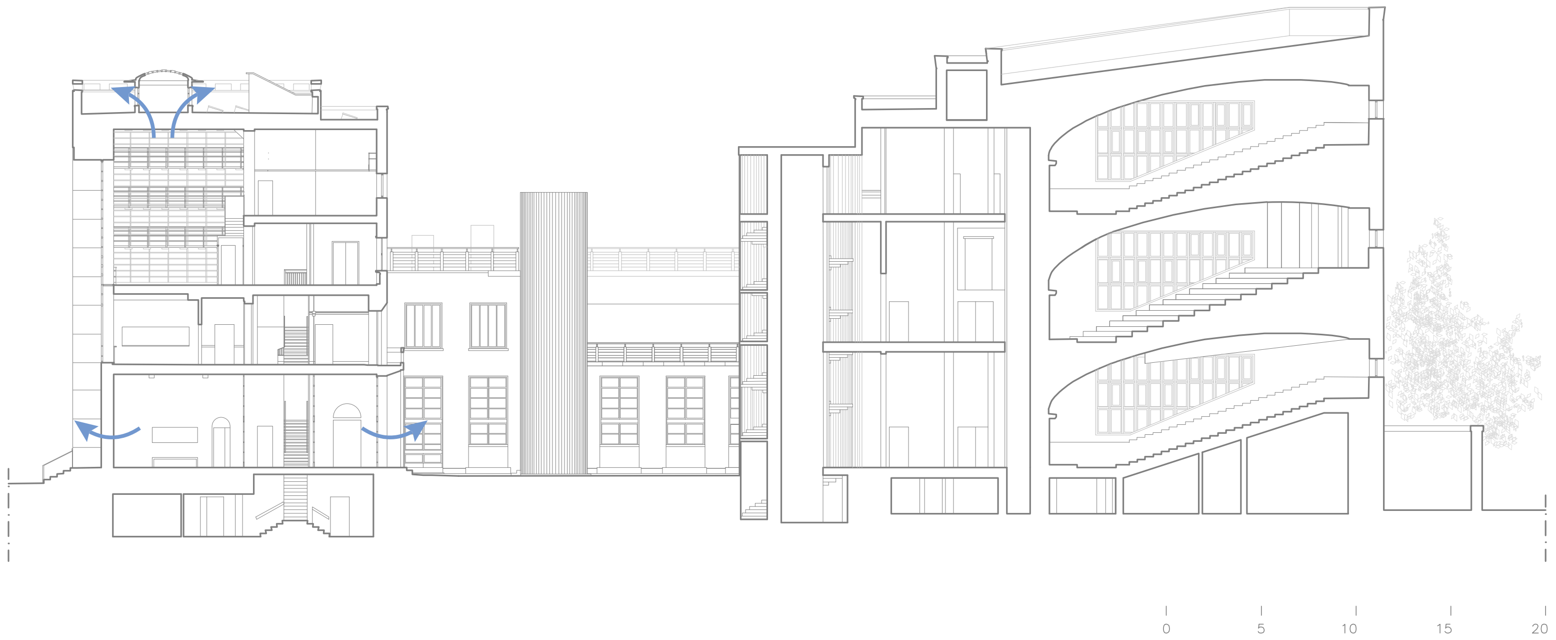


Figure 14 - Detail of air flow in the library reading hall in the original situation (ACS_pht_30)

Figure 15 a/c - Details of opening systems to operate windows out of direct reach (© Rosso 2020)

Figure 16 - Section of the front building with direction of air flow in the library reading hall in the original situation (© Rosso 2020)

space. On the first floor, as in most rooms, radiators were positioned near the windows. In the reading hall of the library, given the huge space to heat and in absence of traditional windows, radiators had been integrated in the body of the study tables, as a further demonstration of an integrated design between architecture, furnishings and installations. Therefore, a battery of continuous radiators heated the room longitudinally, very near to the users, which received immediate comfort. The entire space was therefore well heated at least for 150 centimetres of height, except for the area between the vertical window and the main entrance. Such careful and clever positioning of glazed elements (windows) and of radiators allowed the users to benefit from the natural lighting of the skylight without being affected by temperature gradients and by glare produced by the huge window. In addition, the location of the radiators in the centre of the room was- and still is- also functional to the conservation of the books on the shelves along the entire perimeter walls of the room.

Probably, after the subdivision of the triple height, and in consequence to the locking of the windows on the skylight, radiators were replaced with fan coils in order to cool the room during the summer. This alteration may be also linked to the rise in temperatures due to the reduction in air circulation produced by the same alteration and by the closing of originally open passages with doors and partitions. However, the combination of alterations has led to a decisive worsening of the environmental comfort in the winter season, and probably to a more dangerous microclimate for the conservation of the book collection[1]. More specifically, the presence of radiators and cooling systems may produce the deterioration of the book collection due to the rising of hot air currents, which are forced by the action of the fan coils and channelled through the narrow section that has been created above the study tables.

Figure 17 a/b - a) The library in 1935 (BBL_pht_30); b) the library in 2020 (© Romano 2020)

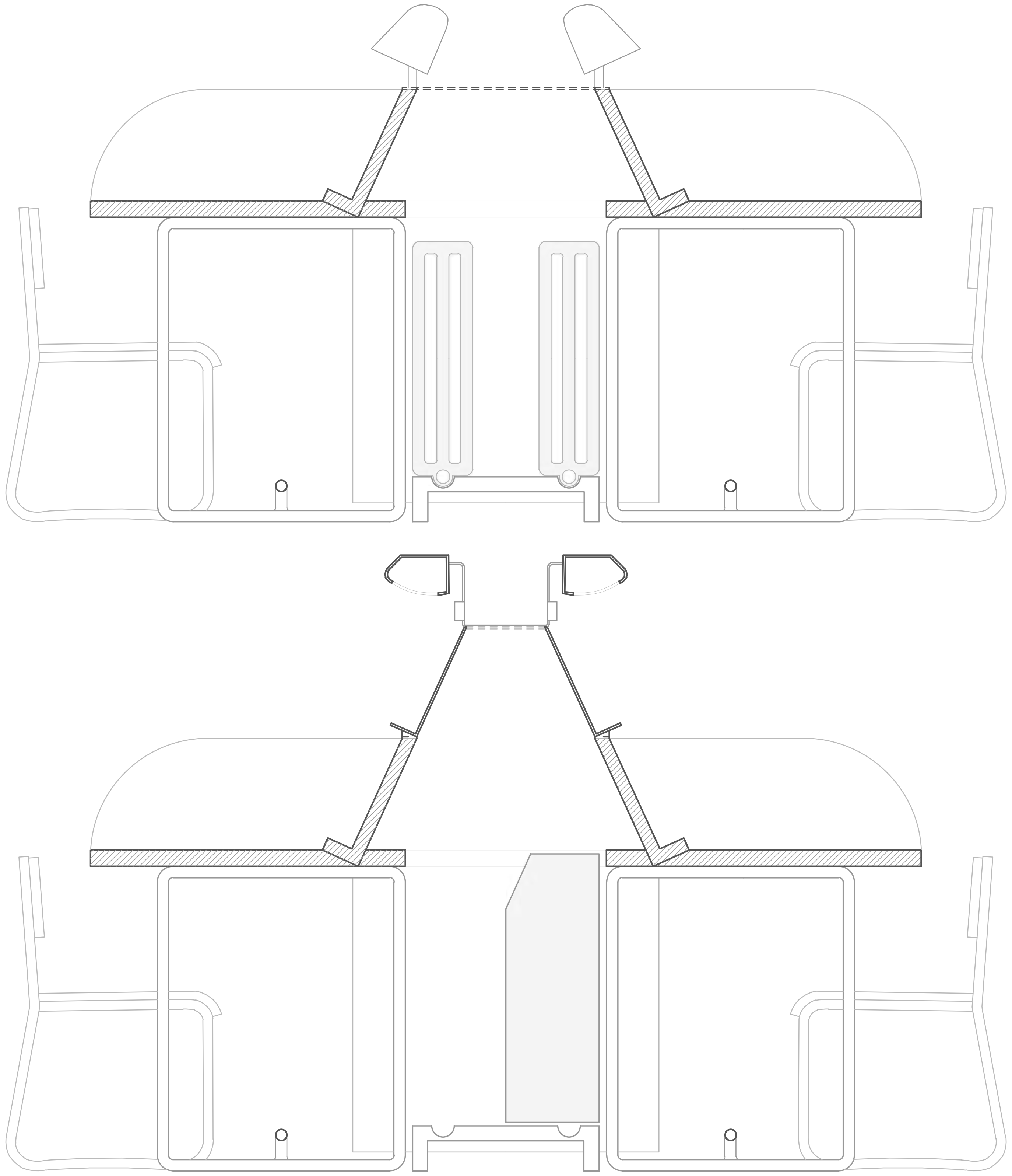


Figure 18 a/b - Reconstruction of the original situation and current condition with modifications due to the change of the lighting fixtures and the embedded radiators with fan coils (© Cortesi 2021)

The situation, both for users and collection, is different during the summer, when comfort is significantly improved thanks to the fan coils that have also been installed in the rooms adjacent to the rooms intended for books storage.

As the curved wings are semi-symmetric in respect to a north/south axe, they are both oriented east/west; yet, thanks to their curvilinear conformation, they collect natural light also from the south. The percentage of transparent surfaces of the building envelope is higher here than in the other blocks.

The original configuration allowed the optimal use these classrooms for technical drawing, which in fact needed maximum daylight. Large, glazed surfaces on both sides of the halls (full height glazing on the outer wall and ribbon glazing on top of the corridor wall) at the ground floor allowed for considerable natural lighting and adequate ventilation of the rooms, as well as access to the room both from the internal courtyard and from outside the building. At the first floor instead, again full height ribbon windows on both sides of the classrooms were set to shed natural light on the tables and for natural ventilation of the rooms.

Figure 19 - The reading tables of the library with evidence of subsequent modifications due to the change of the lighting fixtures and of the embedded radiators with fan coils (© Petraroia 2020)

Figure 20 - View of the curved wings in the original configuration (ACS_pht_10)

Figure 21 a/b - The original configuration of the drawing classrooms at ground and first floor (ACS_pht_15, ACS_pht_14)

Cleverly positioned radiators under or near the windows allowed the classrooms to be heated avoiding air currents, especially in such large rooms, both at the ground level and at the upper floor, according to the different position of the few opaque surfaces.

Unfortunately, these rooms have undergone thorough changes over the years: the inner space of the west wing has been fragmented as early as 1939, while the east wing was radically altered in the late 1970s. In both cases the wide, open spaces have been fragmented to obtain smaller offices and classrooms, thereby disrupting the very fine- and fragile- balance established by Ponti's design among natural lighting, heating, and ventilation.
Ventilation of the tiered lecture halls stacked in the tower was instead produced mechanically, given the high level of crowding for which these halls were intended and given the difficulty in managing natural ventilation. For this reason, in these halls the huge windows on the side walls were not all operable except a few, plus the ones in the rear wall, probably due to guarantee safety. However, they were not sufficient to ensure correct air exchange.

The boilers serving the heating system of these halls are located at the foot of the Tower, together with the heat transfer fluid distribution centre. The boilers are since long obsolete and no longer in use, but are still in their original position. They consist of two parallel fans for delivery and expulsion of heated air, and of dampers to regulate the air flow to the different distribution channels.

Figure 22 - One of the columns incorporated in the walls added to fragment the drawing rooms at the first level of the curved wings (© Salvo 2021)

Figure 23 - The main tiered lecture hall at the third level, in the original condition (ACS_pht_18)

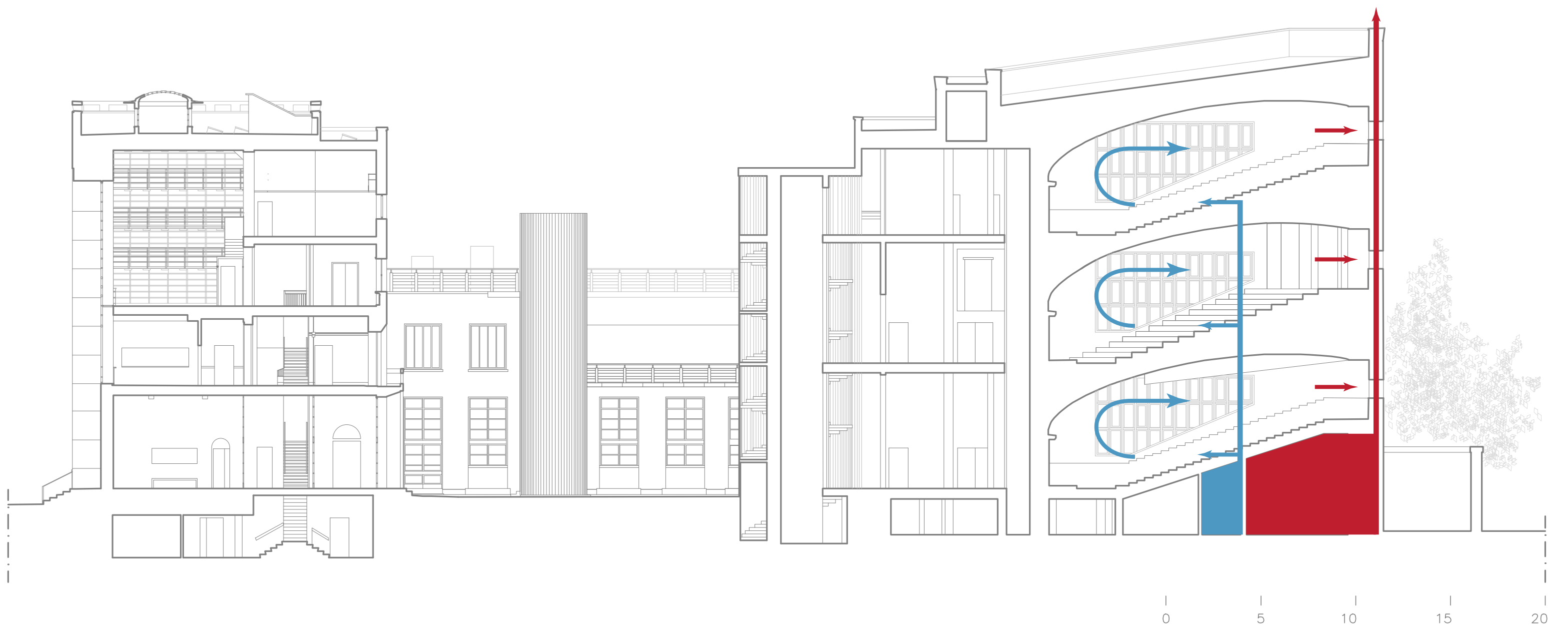


Figure 24 a/b - Diagram of hot air circulation system in the tiered lecture halls: blue arrows indicate the delivery section of air, red expulsion (© Mancini 2020), and an image of the tower of the 1930s where the chimney is still visible (ASS_pht_05)

Figure 25 - Technical rooms at the foot of the Tower of classrooms where fans for delivery and expulsion of heated air are locate, on the right (© Salvo 2020)

Figure 26 a/c - The delivery section of the heating system of the Tower: (a) heating coil, (b) humidification coil, (c) regulation damper (© Romano 2020)

Since it is not possible to directly survey the path of the heating ducts, it can be assumed that the ducts reach the cavity between ceiling and slabs, which worked as a “distribution plenum” to deliver warm air into the rooms through vents that were integrated with the steps of the tiered halls, which are still visible today. Air was then expelled through recovery grids positioned in the upper part of the back wall of the halls. To improve the heating of the classroom, radiators were also positioned in the lower part of the side walls, which have unfortunately been replaced with fan coils.

Figure 27 - Scheme of airflow in the tower of classrooms, assuming that the cavity between ceiling and slab works as distribution plenum (© Mancini 2020)

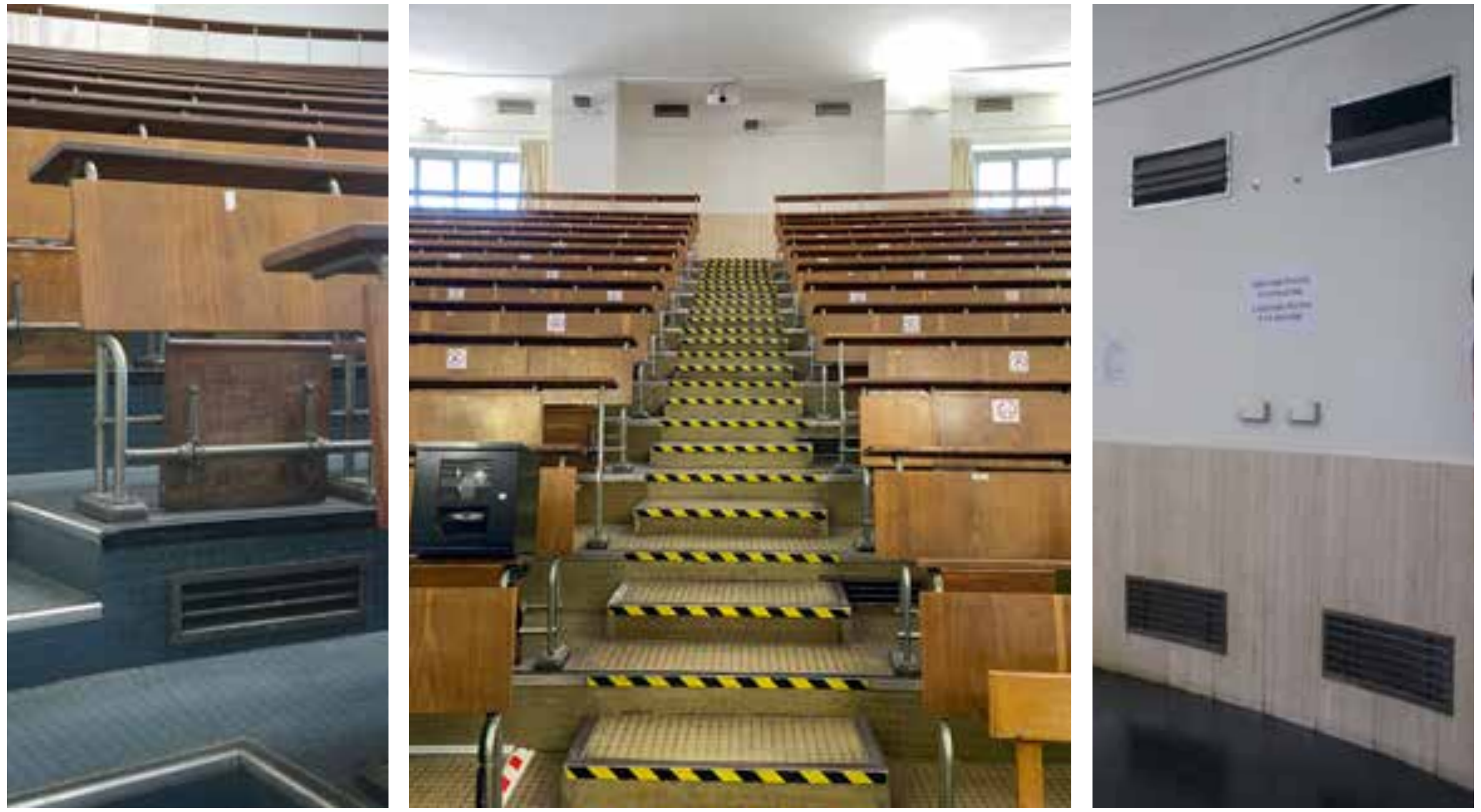


Figure 28 a/c - Original delivery vents (a), return grids (b) and radiators (c) in the tiered lecture halls of the tower (© Salvo 2021)

THE GLAZED SURFACES

One of the main features of this building relates to its windows and to the glazed surfaces of the building envelope. These are not only architectural features but also means for technical management of the interior comfort, or discomfort. Windows are therefore a critical element where functional instances clash with the preservation of heritage values. Therefore, a closer investigation around the system of window fixtures in the building is essential to understand values at stake and limits of intervention.

This analysis was again implemented in strict consideration of the different characteristics of the three bodies of the building, therefore following the tripartition in front building, curved wings and tower. The results of this investigation were therefore necessary to value the microclimate in each body and elaborate hypothesis of indoor microclimate improvement.

An abacus of the window fixtures has been collected, to report basic materials (wood /metal) of the window frames, window typology, type of opening, presence of gaskets, putty and sealings, type of windowsill, and type of glazed surfaces; this analysis has been repeated for all 151 windows present in the building, providing a complete catalogue of the situation in 2020.

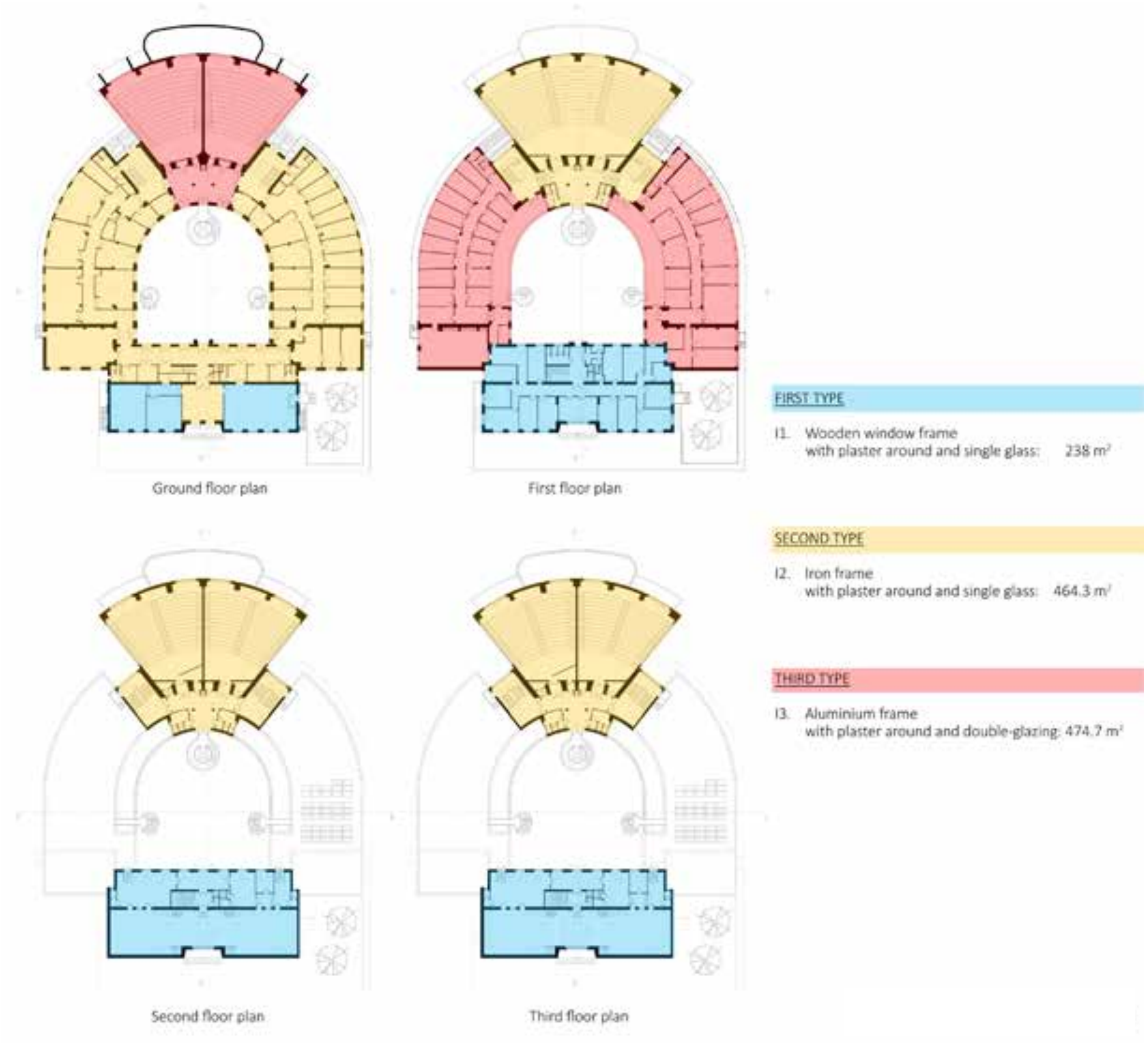


Figure 29 - Mapping of types of window frames in wood, iron and aluminum (© Romano 2020)

Following, a more detailed elaboration of the information has been reported directly on the survey drawings of each level of the building. A description of each window frame is provided describing three main variables- general information, window identification and specific features- each associated to alphanumeric codes: mapping allows to position information of each window for a synthetic reading of the overall situation.

This coding system has allowed mapping on the four main levels of the building, and for all three blocks: front building, wings and tower of classrooms, according to their orientation. Following, in addition to this first synthetic coding system assigned to each frame, more detailed information has been added:

> I- general information concerning block and room (A – Front building, B – Tower of classrooms, C1-C2 East and West curved wings), and orientation;
>
> II – position within the corresponding façade in view of microclimatic investigation;
>
> III – description of opening system, material of frame, type of glazing, type of putty, and material of windowsill.

This mapping system has produced a total of 18 sheets: four providing synthetic overall information of the fixtures for each floor; four technical sheets for each of the three bodies of the building (front, wings, tower), to which more detailing sheets were added to provide information of fixtures that were not included in the coding. Each summary sheet instead indicates: location (block front block / tower / wings); orientation (north, south, east, west); description of the technical characteristics; an image and the identification code.

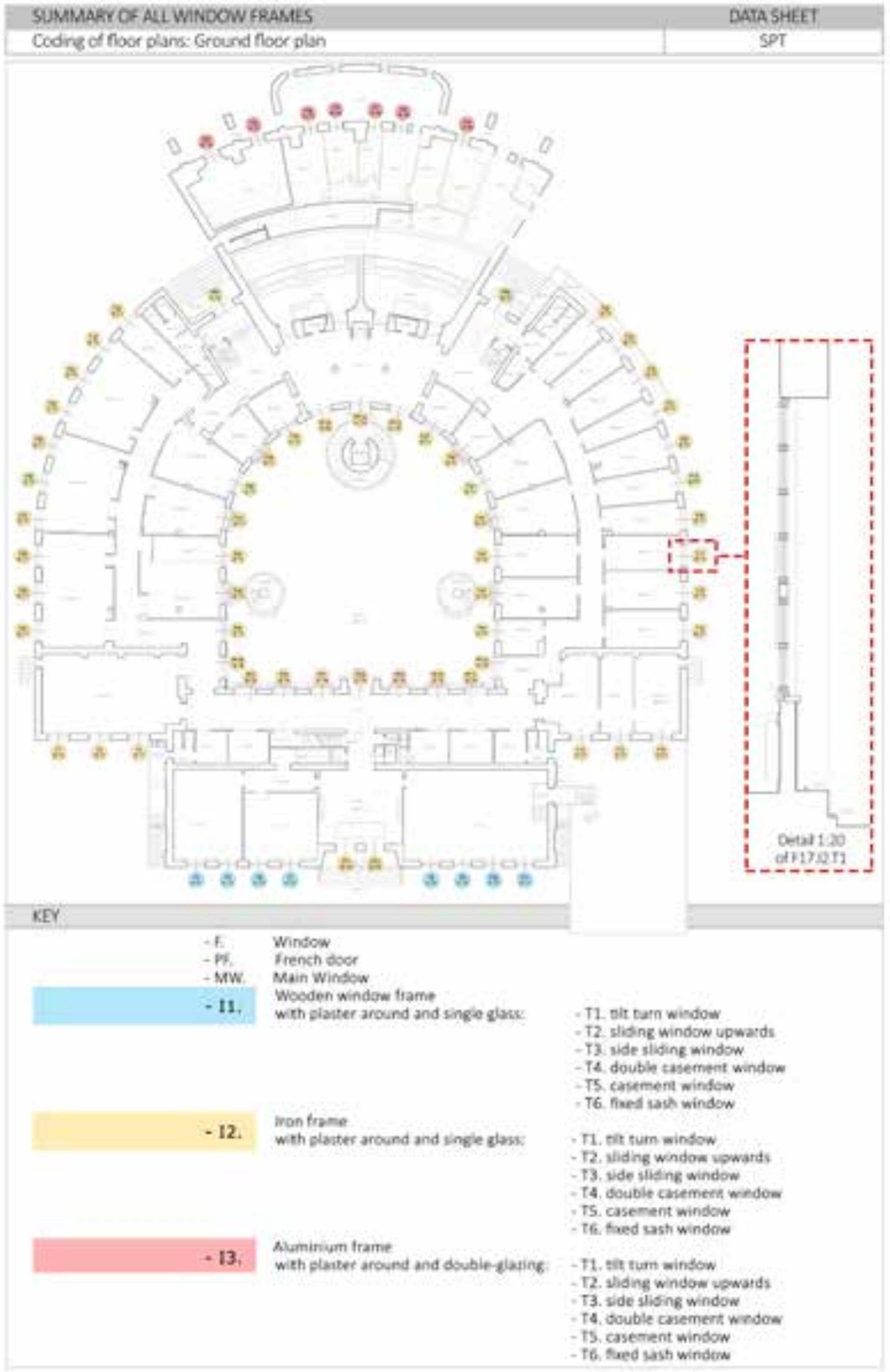
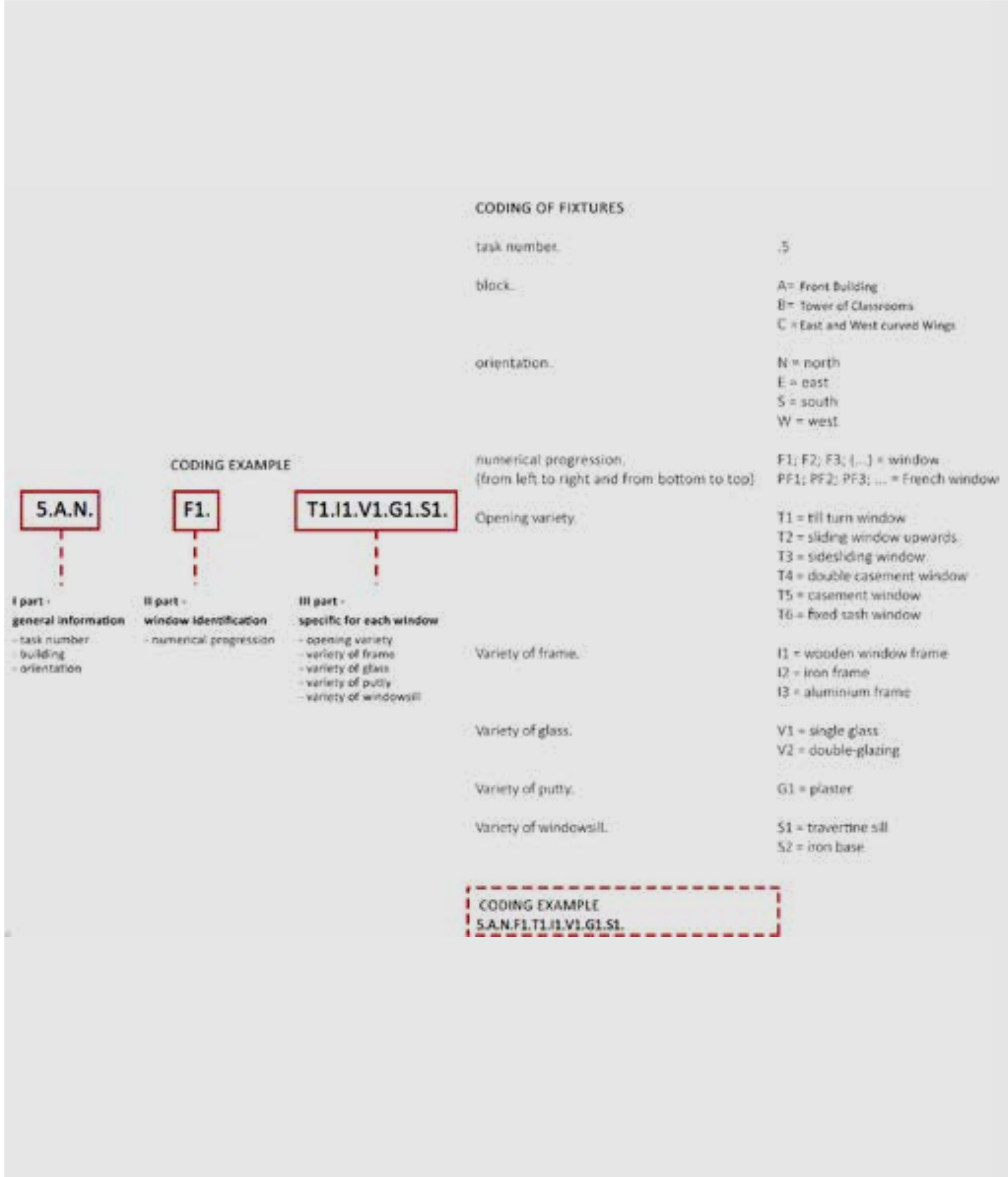


Figure 30 - Sample of window mapping at the ground floor, with detail of one type of window (© Romano 2020)



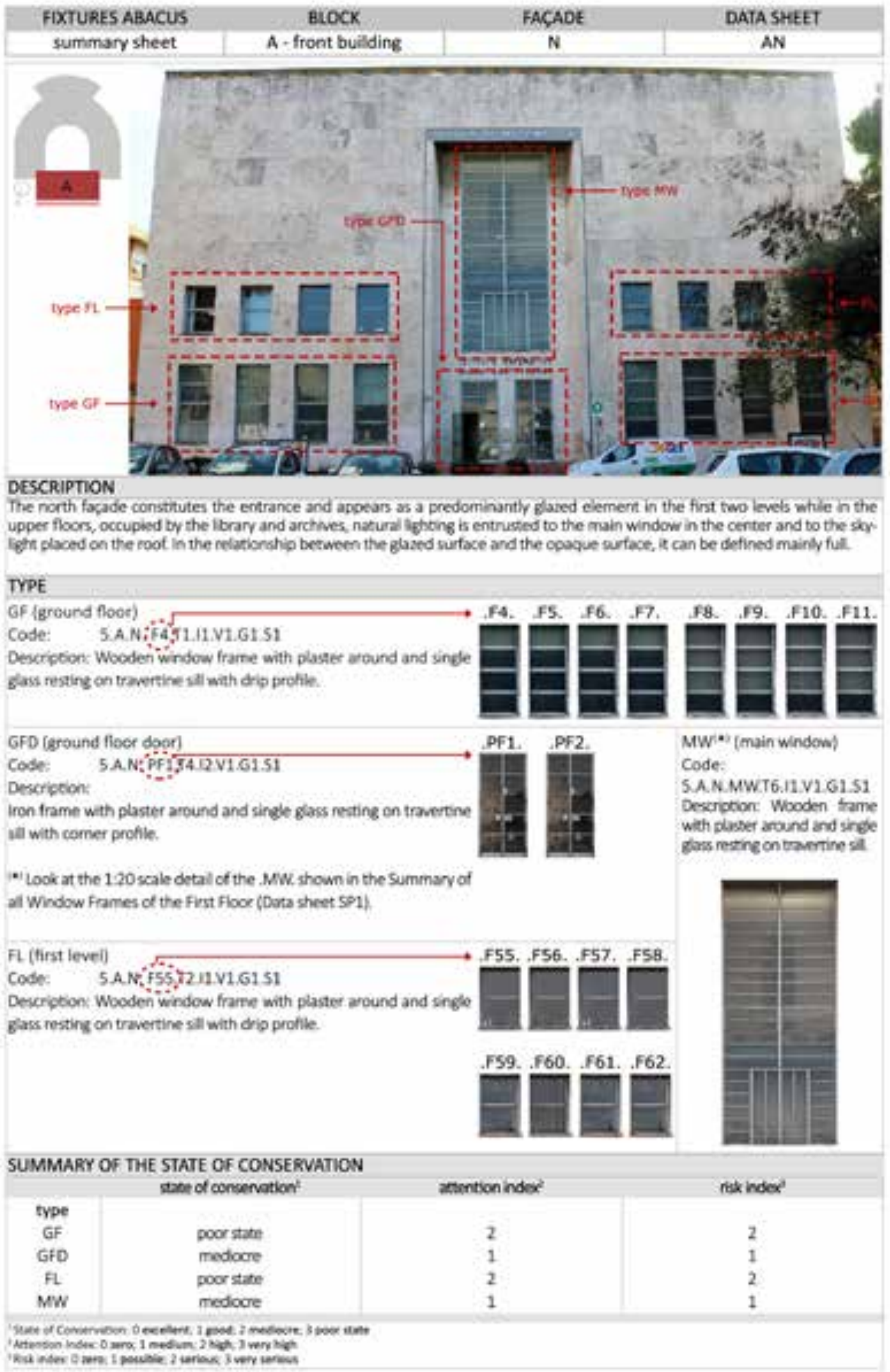


Figure 31 - Coding scheme of window fixtures (© Rosso, Romano 2020)

Figure 32 - Sample of the summary sheets which provide a general abacus of the window fixtures, referred to the windows on the north façade of the front building (© Romano 2020)

The evaluation of the state of conservation of the window fixtures has been developed providing indexes based on the severity of the decay process; this was estimated through a risk index (RI) associated to an attention index (AI) as shown below:

- (0) excellent state of conservation = zero attention index; currently, the situation does not require checks or instrumental investigations;
- (1) good state of conservation = medium attention index: the situation requires checks over time, even if at the moment there are no signs of danger;
- (2) average state of conservation = high attention index: further investigations may be necessary;
- (3) poor state of conservation = very high attention index; interventions must be immediate given the criticality of the situation.

As the attention index increases, risk index condition obviously also increases according to the following progression:

- 0 = zero risk;
- 1 = possible risk: mitigation/attenuation interventions are recommended;
- 2 = serious risk: attenuation interventions are recommended;
- 3 = very serious risk: urgent interventions are recommended.

Figure 33 - Sample of analysis sheets of fixture types (© Romano 2020)

PLANT SYSTEM INVESTIGATIONS

The overall result of the above-mentioned investigations highlighted the fact that the entire building is equipped with plant systems dedicated to its “basic” use, while its different bodies (front, wings and tower) are characterized with specific technical solutions and plant engineering, to achieve specific environmental comfort and, more in general, Indoor Environmental Quality (IEQ) in close consideration of the different activities carried out in each. These specificities consist in the very careful characterization of the building envelope, in the fine tuning of the ratio between opaque and glazed surfaces in order to maximise the positive effects of natural lighting and natural ventilation, with integration of systems mechanical ventilation where necessary.

INDOOR ENVIRONMENTAL QUALITY MEASUREMENTS

In order to assess the Indoor Environmental Quality (IEQ) of the building, seasonal measurements of temperature, relative humidity and air quality have been carried out throughout. Monitoring campaign took place in summer, autumn, and winter[2]. A direct measurement method was used, recurring to specific instrumental analysis techniques, carried out during several days of inspections, and by integrating the collected information with data provided by the “Regional Environmental Protection Agency” (ARPA) of the Lazio Region referred to the same days. Comfort values assumed are:

- a temperature of 20°C in the winter season and of 26°C in the summer season, with a deviation of ± 1°C;
- a relative humidity of 50% with a deviation of ± 5% in both seasons.

The set of pollutants monitored to assess Indoor Air Quality (IAQ) allow us to describe both indoor and outdoor air quality. Table 1 shows a breakdown of air quality classes according to the concentration values of the pollutants.

Classes	CO_2 [ppm]	TVOC [ppm]	PM_{10} [μg/m^3]
Hazardous	1,501 ÷ 5,000	0.431 ÷ 3000	141 ÷ 750
Unhealthy	1,001 ÷ 1,500	0.262 ÷ 0.430	91 ÷ 140
Moderate	601 ÷ 1,000	0.088 ÷ 0.261	31 ÷ 90
Good	340 ÷ 600	0.000 ÷ 0.087	0 ÷ 30

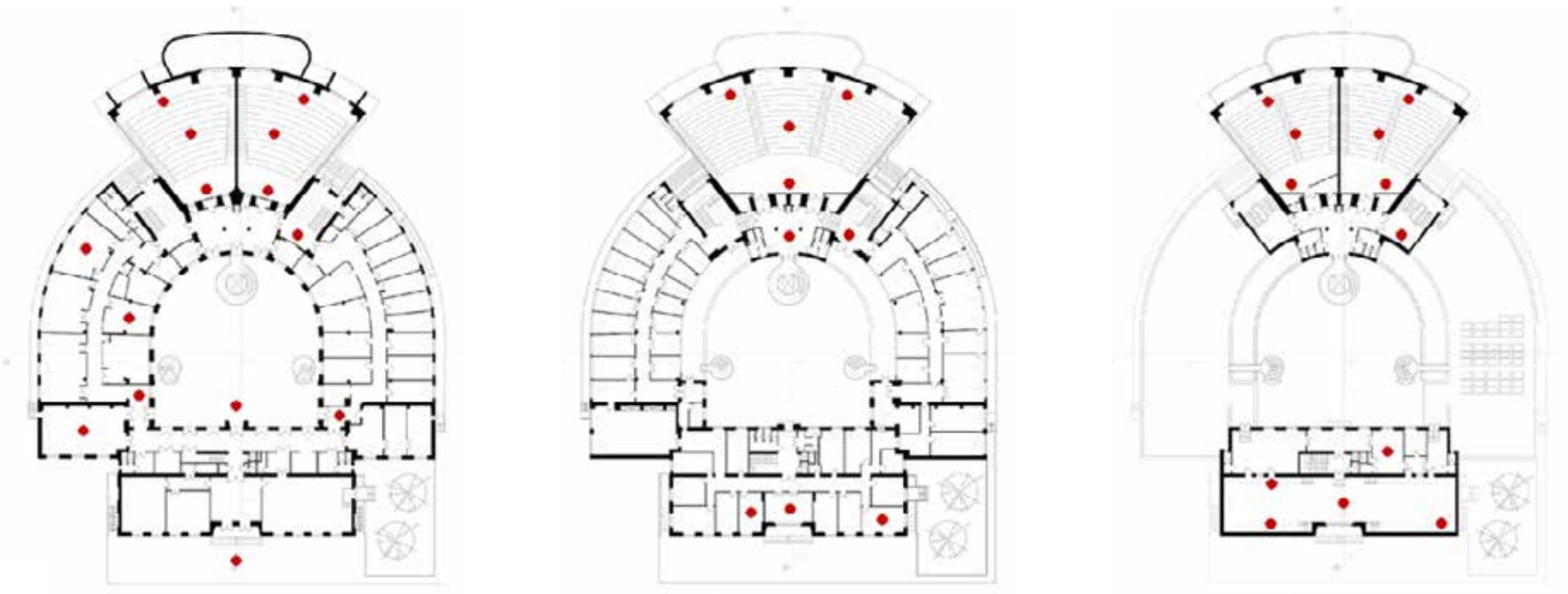
Table 1 - Concentration values of pollutants and classification of air quality (© Mancini 2020)

THE PROTOCOL

As monitoring of IAQ is the goal of this part of the research, hourly average values were collected by carrying out samples of short duration, 30 minutes each. The reference timing was fixed from 10 am to 4 pm. During the reference period, sampling of the monitored parameters (VOC, PM10, CO2) was carried out with closed windows and by positioning the samplers in the centre of the room at a height of 150 centimetres for a 30-minute time lapse. All probes for thermo-hygrometric characterization have been fixed at a height of 100 centimetres from the floor; the equipment used to determine IAQ parameters has been positioned at a height corresponding to the average height of human upper respiratory tract, for the entire duration of the sampling. In order to identify the contribution of the external environment to the indoor concentration levels of monitored pollutants, measurements of the same pollutants have been carried out almost simultaneously in order to acquire information about the extent of the external contribution.

Concerning the front block, specific attention has been paid to the library, aiming at a closer investigation of levels of pollution with respect to human perception but also of the prestigious book collections stored on open air bookshelves, in the book deposit and in adjacent rooms. In addition to the central part of the library reading hall, monitoring therefore took place at different heights- 210 / 420 / 630 centimetres from the pavement- starting from the entrance and in correspondence of the bookshelves; the offices and study rooms adjacent to the main reading hall of the library have also been analysed.

Concerning the curved wings, one among the many classrooms has been chosen in the east curved wing at the ground floor to monitor the situation of pollutants. Concerning the tower of classrooms, measurements have been concentrated in the tiered lecture halls I, III, V at the three different levels of this building; in this case, the significant difference in height of each hall - 420 meters distance between the first seat and the last step- has required many different measurements within the same rooms.



Ground floor plan *First floor plan* *Second floor plan*

Figure 34 - Positioning of measuring points for IAQ sampling at the three levels of the building (© Mancini, Romano 2020)

OUTCOMES

Summer monitoring campaign has taken place in presence of very few students and teachers and/or in almost empty classrooms. The cooling system was generally off. No significant difference between indoor and outdoor values has been noticed. CO2 values, as well as VOCs measured indoor and outdoor indicate good quality levels (blue band of the graphs), while the PM10 values are at predominantly of moderate quality (green band). Overall, all three pollutants detected are in acceptable quality classes, both for human health and for the proper maintenance of the book collections conserved in the library. Conditions of thermo-hygrometric comfort are instead lacking in the rooms, as expected in absence of a suitable cooling system.

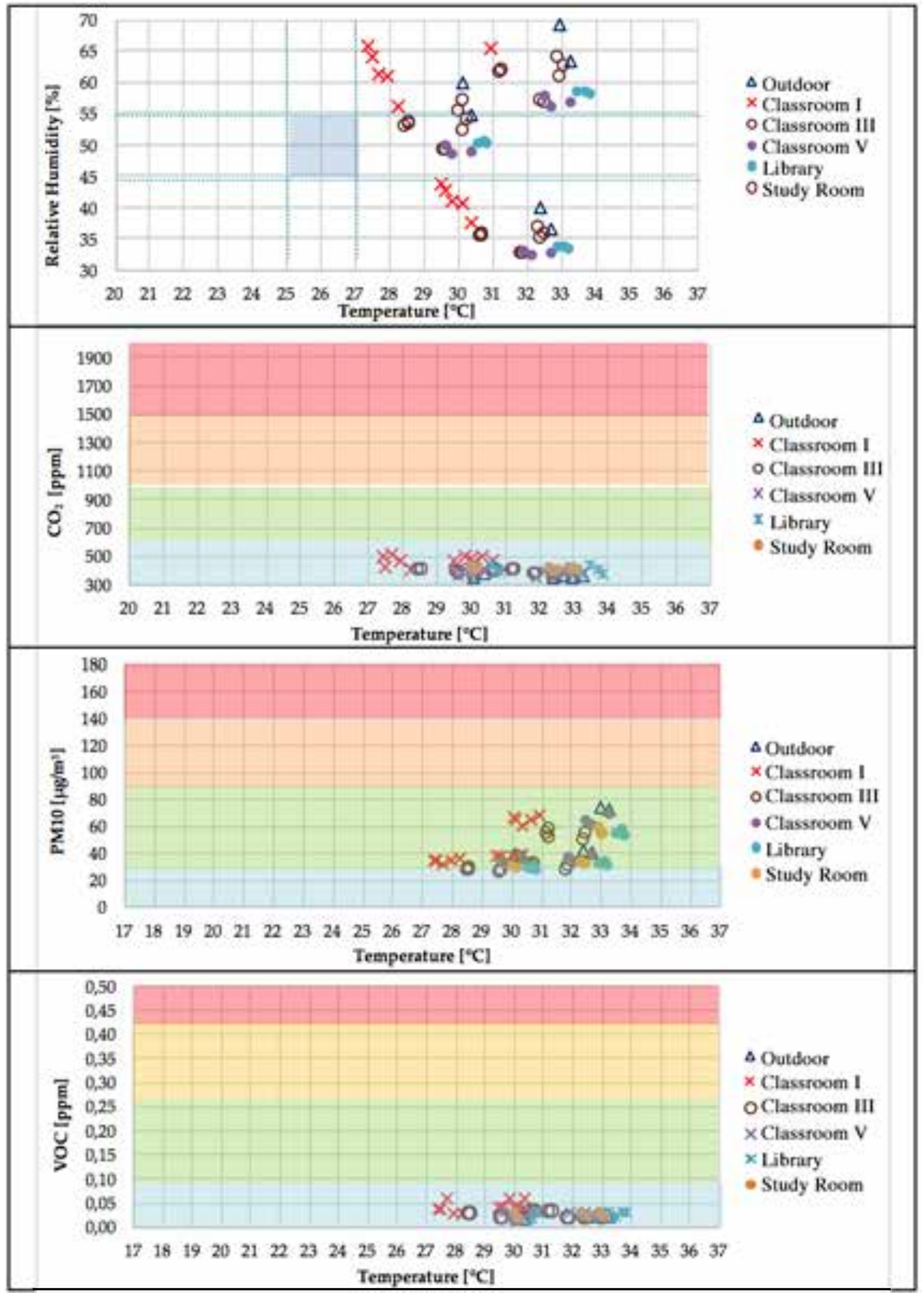


Table 2 - Results of measurements in the summer season (© Mancini, Romano 2020)

Autumn monitoring campaign has taken place as the air conditioning system was turned off and classrooms were half full, given the start of the academic year in the month of September. Also in this case, similar parameters emerged from the outdoor and indoor surveys. The CO2 values have been found halfway between good and moderate (blue-green band), PM10 values within the moderate values level (green band), while VOCs have been observed at a good level of quality (blue band). The parameters measured during the autumn season are slightly worse than in the summer, but still acceptable, and guarantee human health and the correct maintenance of the book collections. The expectations for the spring season are roughly the same, being the two seasons both of transition between summer and winter conditions.

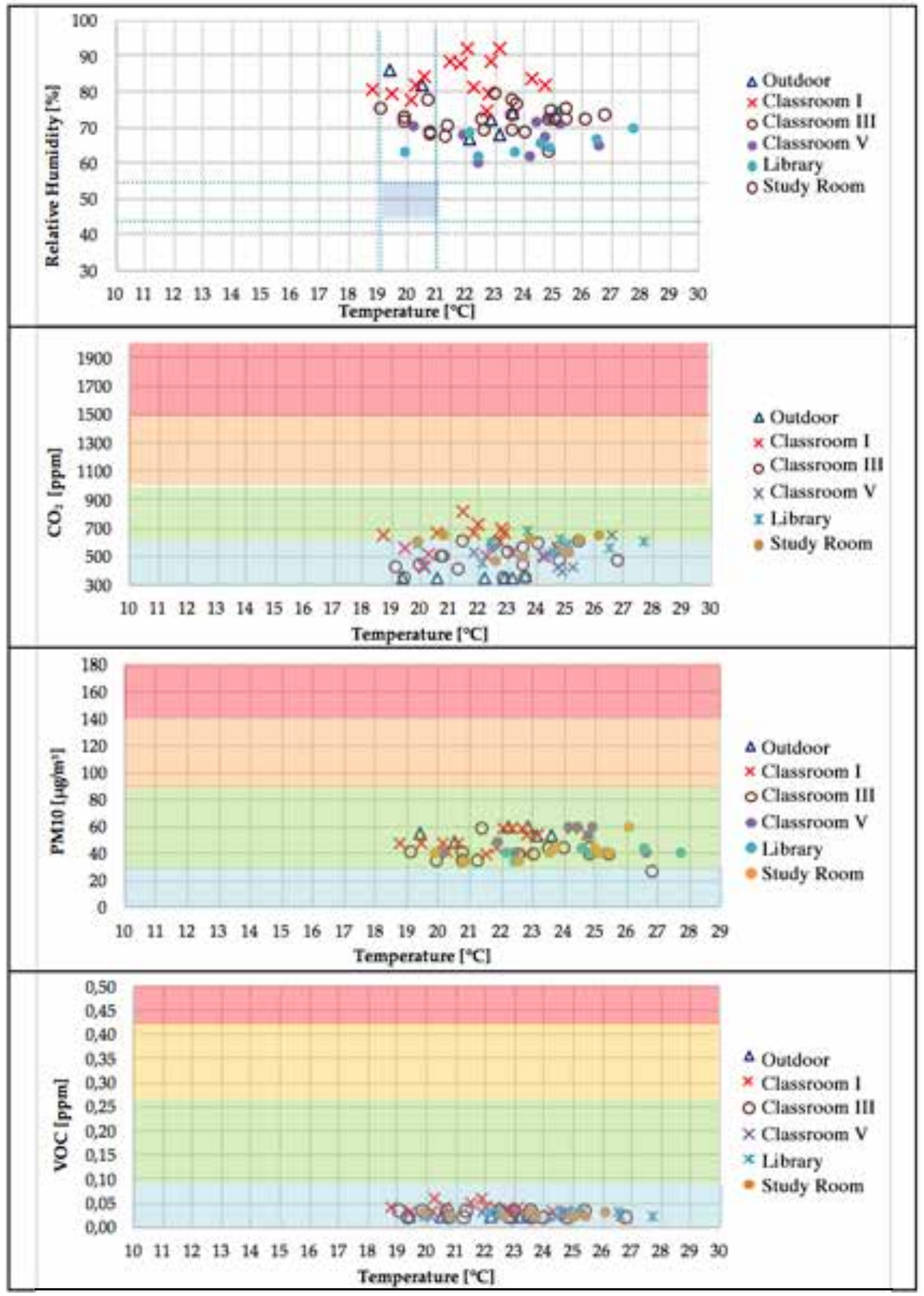


Table 3 - Results of measurements in the autumn season (© Mancini, Romano 2020)

The winter monitoring campaign has taken place as the air conditioning systems was on and the classrooms were half full. CO2 levels surveyed correspond to unhealthy quality class (orange band) in the study room, which was the only one full of students (80-90 people present during the monitoring campaign), while the quality resulted average good (blue-green band) in other environments. PM10 values fall between moderate and unhealthy levels for all environments (green-orange band), while VOC levels fall once again in the good range (blue band of the graph).

It is closer to the conditions of thermo-hygrometric comfort in all rooms, except for the library, where the conditions are acceptable. In general, the slight deterioration of the quality classes of the pollutants detected in this period of the year- which in any case remains at acceptable levels – may be explained with the fact that more people were present in the rooms, the windows were closed, and the air conditioning system was switched on.

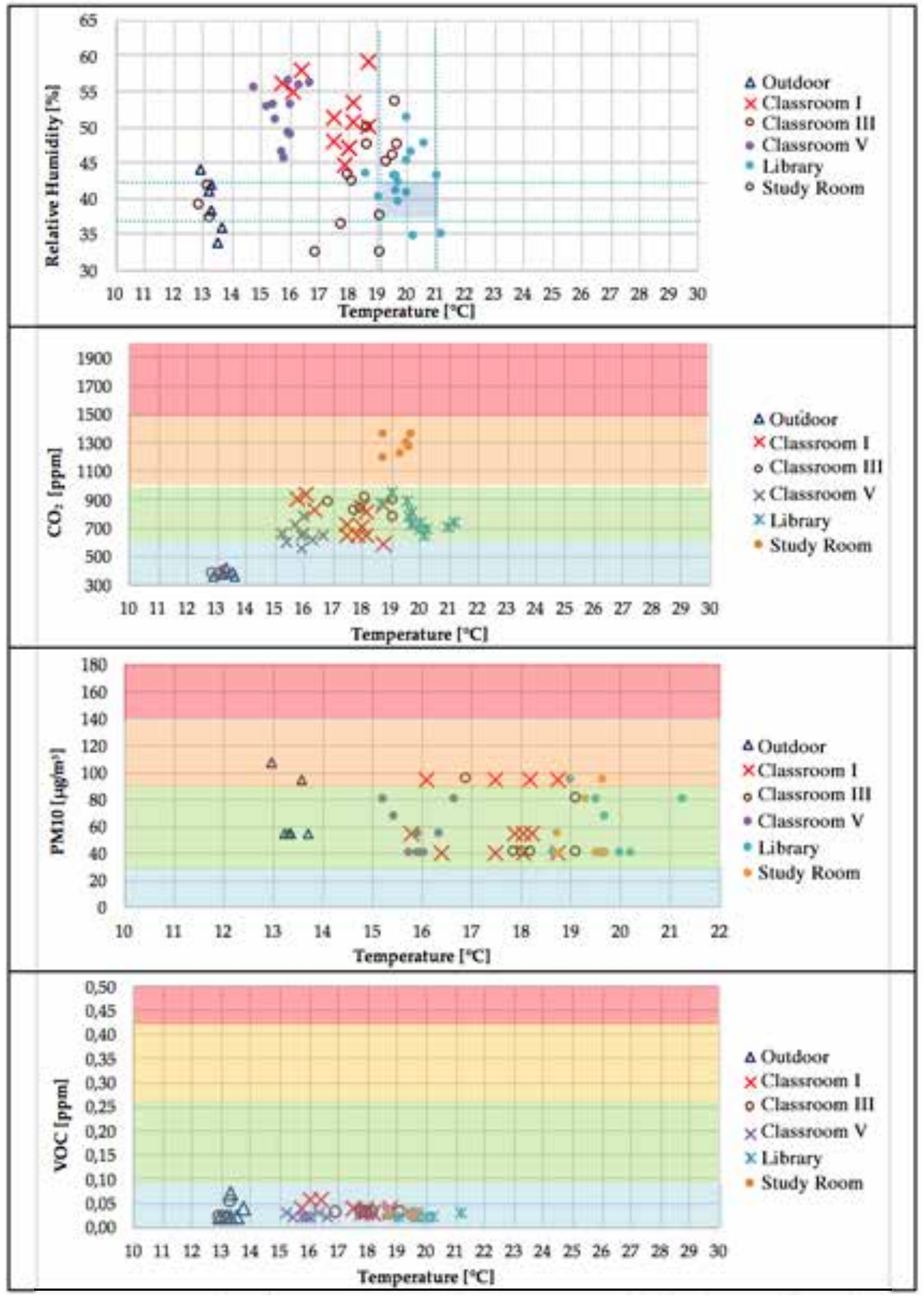


Table 4 - Results of measurements in the winter season (© Mancini, Romano 2020)

ENERGY PERFORMANCE CERTIFICATION

Energy Performance Certification (APE) is a document required by the Italian law that provides a framework of information about the energy performance of the building envelope and of its installations. To this kind of certification is tied much of the late tax credit in case of building requalification- which is granted only if the work guarantees improvement of two grades of energy performance. Requalification works supported with a tax credit system guaranteed by the State have received enormous impulse after the pandemic, as European financing system is based on climate change, sustainability and energy sparing, which explains the overall importance of this certification in Italy, today. Beyond this, Energy certification, described as follows, represents the Italian official system of measuring buildings' energy performance[3].

Current Italian legislation (Inter-Ministerial Decree of 26 June 2015, adaptation of national guidelines for the Energy Certification of Buildings) provides for the calculation of energy performance in buildings, the use of national technical standards UNI/TS 11300. These standards define the procedures for the Italian application of UNI EN ISO 13790:2008 and are aimed at all possible applications herby envisaged: design rating, energy assessment of buildings through the calculation of standard conditions (asset rating) or in specific climatic and operating conditions (tailored rating).
The School of Mathematics has therefore been analysed in its entirety, but also according to 4 thermal zones- front building / curved wing east / curved wing west / tower of Classrooms- to investigate the energy performance of each in detail, in respect of Article 6 of Legislative Decree 192/2005. Energy services considered in the evaluation of the energy performance of the building are:

- winter air conditioning;
- production of domestic hot water (DHW);
- lighting and transport of people or things.

The intended use of the building corresponds to "E.7-School buildings of all levels and similar", (i.e. primary, secondary, high schools and universities) according to Presidential Decree 412/93. More specifically, the calculation of the energy performance of the building allows to determine:

- global non-renewable energy performance index EPgl,nren, which determines the energy class of the building (alphabetical indicator for classes G-F-E-D-C-B-A1-A2-A3-A4, where the letter G represents the highest consumption class and, therefore, the worst energy performance) obtained in comparison to a reference building (identical in terms of location and geometry, but equipped with standard walls and systems);
- energy performance index (winter and summer) of the building envelope as a ratio between the useful needs (winter and summer) and the distribution of the building.

A synthesis of the elements analysed and the results obtained within each block is found in the next pages.

ENERGY PERFORMANCE CERTIFICATION IN THE CURRENT CONDITION

Front building

To simulate energy behaviour of the building envelope of the front building implemented with dedicated software, reference has been made to the results of the investigations carried out by contextual research - dedicated to historical matter, structural understanding, construction techniques, study of functions and uses over time and to value assessment- and to information collected during inspections. Listing of opaque structures includes floors, which have been modeled as brick-concrete elements of variable thickness, between 35 and 40 cm, and perimeter walls, which have been modelled as tuff blocks alternating with parallel rows of red bricks, plastered with lime mortar, with the exception of the main and rear façade, which are cladded with travertine slabs and Litoceramics, with an overall thickness of about 80 cm. Transparent surfaces are all single glazed, mostly windows with wooden frames, resting on travertine sills and without solar shading systems.

Energy services considered in the calculation of the energy performance of this part of the building are winter air conditioning, production of domestic hot water (DHW), lighting and transport of people or things.

The heating system of these spaces is connected to the university campus district heating network, through a secondary branch starting from a substation which reaches a technical room from which the backbones branch off through a distribution manifold and heat exchangers. Distribution boxes are housed in the basement near the block. The production of domestic hot water (DHW) for the toilets is produced locally using local electric boilers. Lighting fixtures in this part of the building are equipped with tubular fluorescent lighting lamps with an average diameter of 38 mm while the transport of people or things is entrusted to an electric lift, whose motor is at the top of the shaft, with automatic scrolling cabin doors.

In light of the information acquired the calculation of the energy performance of the front building, at present, has resulted in a non-renewable global energy performance index EPgl,nren = 87.6 kWh/m2 year, thanks to which the energy class of the building has been defined as corresponding to the E class. The winter energy performance index is of low quality, while the summer performance is of medium quality, based on the analysis of the parameters described above.

Curved wings

For the simulation of the energy behaviour of the building envelope of the curved wings implemented with dedicated software, reference has been made to the results of the investigations carried out by Tasks 1-3-4-6, and to the information collected during the inspections. Listing of opaque structures is not different from the Front building.

Transparent surfaces are all single glazed, with aluminium or iron window frames except for the first floor where they are double-glazed with aluminium frames, resting on travertine sills and with solar shading consisting of Venetian blinds placed inside classrooms and offices. The energy services considered in the calculation of the energy performance of the building are winter air conditioning, production of domestic hot water (DHW), lighting and transport of people or things.

The heating system of these spaces is connected to the university campus district heating network, through a secondary branch that starts from a substation, and arrives in a technical room from which the backbones branch off through a distribution manifold and heat exchangers. Distribution boxes are housed in the basement near the block. The production of domestic hot water (DHW) for the toilets is produced locally using local electric boilers.

In light of the information acquired, the calculation of the energy performance of the Curved wings C1 and C2, at present, has resulted in a non-renewable global energy performance index EPgl,nren = 141,8 kWh/m2 year, thanks to which the energy class of the building has been defined as corresponding to Figure 35.

Tower of classrooms

For the simulation of the energy behaviour of the building envelope of the Tower of classrooms implemented with dedicated software, reference has been made to the results of the investigations carried out by Tasks 1-3-4-6, and to the information collected during the inspections. Listing of opaque structures is not different from the Front building. Transparent surfaces are all single glazed, with aluminium or iron window frames, resting on travertine sills and with solar shading consisting of fabric curtains placed inside the classrooms.

The energy services considered in the calculation of the energy performance of the building are winter air conditioning, production of domestic hot water (DHW), lighting and transport of people or things. The heating system of these spaces is connected to the university campus district heating network, through a secondary branch that starts from a substation, and arrives in a technical room from which the backbones branch off through a distribution manifold and heat exchangers. Distribution boxes are housed in the basement near the block. The production of domestic hot water (DHW) for the toilets is produced locally using local electric boilers.

In light of the information acquired, the calculation of the energy performance of the Tower of classrooms B, at present, has resulted in a non-renewable global energy performance index EPgl,nren = 123,7 kWh/m2 year, thanks to which the energy class of the building has been defined as corresponding to F class. Both the winter energy performance index and the summer performance index are of low quality.

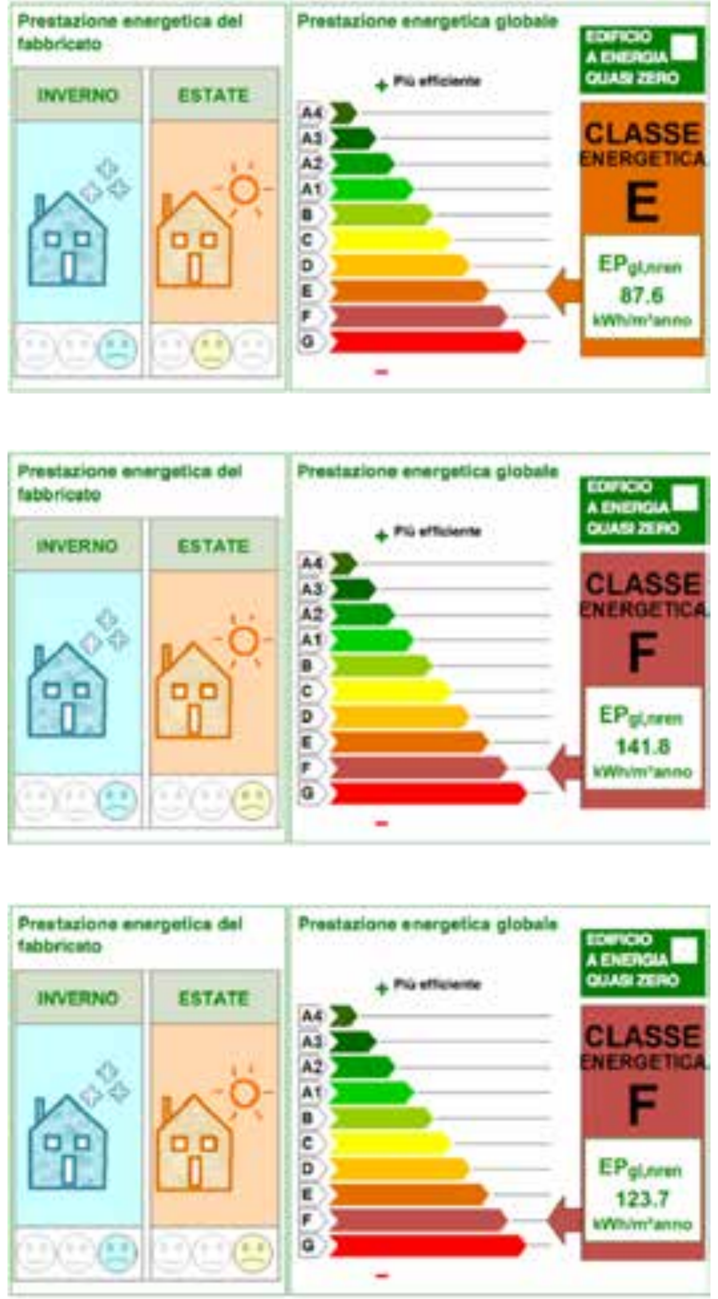


Figure 35 a/c - Energy Performance Certification of the front building, curved wings and tower of classrooms in the current condition (© Mancini, Romano, Rosso 2020)

CONSIDERATIONS ABOUT THE GLAZED SURFACES

The common feature of all the window fixtures in the building, and especially in the front body, consists in having a single glass, including the huge window of the library facing north, which was once decorated with stained-glass and today carries plain white transparent glazing. The state of conservation of the window fixtures is not good, in general, especially in the case of the wooden window frames. Therefore, replacement of single glazing with new double-glazing- and in some cases of the entire window fixture, including frames- would significantly increase the comfort of the interiors, but would affect the overall value of the building as these mostly authentic original pieces.

Assuming the historicity of these elements as a prevailing instance, especially in regards of the main window of the library, focusing on more conservative interventions, such as the insertion of air curtains or the integration of a double frame on the existing one appears to be necessary.

Concerning the curved wings, recently replaced glazing, installed in a disorderly manner and without any coordination, clearly disfigure the façades of the building.

Instead, in the tower of classrooms, the ventilation system is to date insufficient to ensure a complete air exchange of the tiered lecture halls, and its regulation according to the presence of students. However, since the halls are wide and spacious and have large single-glazed windows on the sides, no discomfort situations have been detected according to the measurements performed by this research. Nevertheless, the design of a new air conditioning system would help to significantly improve the internal conditions.

ENERGY PERFORMANCE CERTIFICATION ACCORDING TO REQUALIFICATION HYPOTHESIS

Front building

To identify which are the most effective strategies for improving the energy behaviour of each block, a further simulation has been made recurring to the software used for Energy performance Certification, simulating a post requalification situation. Keeping the opaque elements of the building envelope unchanged, the situation after replacement of the existing window fixtures, with thermal-break, open joint and low-emission double glazing and solar shading systems, but maintaining the original frame where possible, is simulated. In the case of the main window, where the preservation of the original window frame is undisputed, the insertion of a glazed counter wall with a PVC frame may be a possible solution.

Energy services considered in the calculation of the energy performance of the fornt building are winter air conditioning, production of domestic hot water (DHW), lighting and lifting of people or things. As far as the heating system is concerned, the building remains connected to the university campus district heating network, while high-efficiency silenced heat pumps are proposed to generate heat, which also allow almost costless production of domestic hot water (DHW) for the toilets. Furthermore, about the distribution subsystem, the installation of thermostatic valves coupled to electronic thermostatic heads is proposed for each heating radiator, to regulate the inflow of hot water according to the temperature of each room.

Concerning the electrical system, the implementation of the existing photovoltaic system placed on the roof is suggested, being this the only way to acquire adequate energy performance; yet, the current PI system displayed on the roof top is not sufficient to gain a substantial increase of the energy class, and is aesthetically disturbing considering the view of the rooftops from other buildings.

Concerning the lighting system, the replacement of bulbs with energy-saving LED elements is proposed and the insertion of timers for automatic switch-off of lights at pre-set times, differentiated by areas, while the lifting of people or things remain unvaried.
Considering the proposed requalification solutions for the front building, the calculation of energy performance results in a non-renewable global energy performance index EPgl,nren = 74.8 kWh/m2 year, thanks to which the energy class could increase to level A1, significantly higher than the initial one. The winter energy performance index is of high quality, while that of the summer performance remains of medium quality, based on the analysis of the parameters described above.

East and west curved wings

As in the previous case, opaque elements of the building envelope remain unchanged, while the replacement of the existing window fixtures, with thermal-break, open joint and low-emission double glazing and solar shading systems, but maintaining the original frame where possible, is simulated.

Energy services considered in the calculation of the energy performance of these buildings are winter air conditioning, production of domestic hot water (DHW), lighting and lifting of people and things.
As far as the heating system is concerned, the building remains connected to the university campus district heating network, while high-efficiency silenced heat pumps are proposed to generate heat, which also allow almost costless production of domestic hot water (DHW) for the toilets. Furthermore, about the distribution subsystem, the installation of thermostatic valves coupled to electronic thermostatic heads is proposed for each heating radiator, to regulate the inflow of hot water according to the temperature of each room.

Similar measures as in the previous case may be adopted for the electrical system, bulbs and timers for the automatic switch-off of the lights at pre-set times differentiated by areas.

Considering the proposed requalification solutions for the front building, the calculation of energy performance results in a non-renewable global energy performance index EPgl,nren = 57,3 kWh/m2 year, thanks to which the energy class could increase to level C, which is higher than the initial one. The winter energy performance index is of high quality, while that of the summer performance remains of medium quality.

Tower of classrooms

As in the case of the front building, the opaque elements of the building envelope remain unchanged, while replacement of existing window fixtures should be considered with due attention, as in the previous case. Same considerations are referred to the heating and electrical system, and to the installation of energy sparing devices.

Considering the proposed requalification solutions for the front building, the calculation of energy performance results in a non-renewable global energy performance index EPgl,nren = 74.8 kWh/m2 year, thanks to which the energy class of the building as corresponding to level C, higher than the initial one but lower than the front building. A due to summer air conditioning and the share of renewable energy sources from which it is served. Both the winter energy performance index and the summer performance index are of high quality, based on the analysis of the parameters described above.

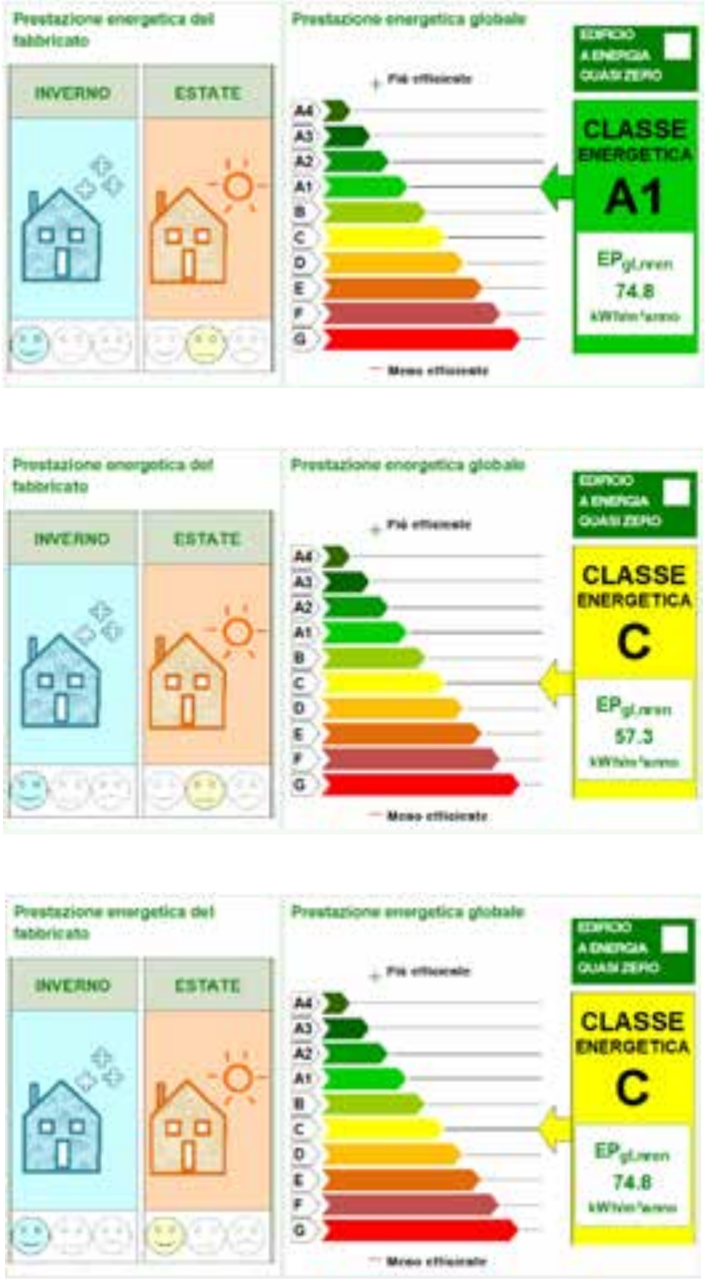


Figure 36 a/c - Energy Performance of the front building, curved wings and tower of classrooms after requalification (© Mancini, Rosso, Romano 2020)

Further interventions following the simulation of energy requalification, assessments and analyses carried out may consist in:

Conservation and improvement of the building envelope:

a. No specific intervention on the masonry structures, except for periodic maintenance;
b. Implementation of (internal) mitigation systems for window frames belonging to those environments where it is necessary to improve the microclimate;
c. Replacement of mechanical window opening systems where necessary;
d. More specifically, as the main window in the library is imbued with historical value, it is advisable to:
  i. add an internal glazed counter-wall with PVC frame;
  ii. replace glass only, leaving the original frame;
  iii. insert an air destratifier.

Improvement of the air conditioning systems:

a. Front Building:
  iv. Installation of thermostatic valves on all radiators;
  v. Library: creation of a horizontal barrier to limit rising air currents in the central area of the reading tables during the winter season;
b. Curved Wings:
  vi. Installation of thermostatic valves on all radiators;
  vii. Study rooms: replacement of current systems serving individual rooms with a centralised heating/cooling system.
c. Tower of Classrooms:
  viii. Installation of thermostatic valves on all radiators;
  ix. Tiered lecture halls: requalification of the original thermo-ventilation system, especially taking into account its historical value;

Improvement of electrical system:

a. implementation of PV systems to support the existing electrical system;
b. scheduled replacement of bulbs with LED lamps;
c. insertion of timers for automatic switching-off of lights according to pre-established times and functions differentiated for external areas, common areas such as corridors, lobbies and classrooms.

NOTES

1. The book deposit, which is adjacent and in special continuity with reading hall, stores books of minor and major value; yet, the ancient book collection, with pieces dating back to the XV century, has been moved to another room of the library, closed and with a separate management for safety and security reasons.
2. Survey during spring was not possible due to the pandemic, which has precluded access to the campus for months.
3. This explains why the sheets hereby presented in this study report measurements and outcomes in Italian, as they have been processed with official software approved by the Italian government.

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