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# Energy Savings in an University Educational Building – the Case of Chemistry Building of Sapienza

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***Abstract*** **–** The commitment for sustainability is a target for the Sustainable Universities Network. Sapienza University of Rome goes in this direction through the energy refurbishment of its building stock, i.e. all the educational buildings. Sapienza campus was built in the 30's and it needs a coherent improvement in terms of energy and environmental performance. Conventional energy retrofitting measures must be within a prioritazion framework to effectively take the most cost-effective strategy. Here, the case of the Chemistry Faculty building is analysed considering the improvement of the building envelope in compliance with the architectural values to be preserved as well as the integration of renewable energy plant. A model of building was used to study it and to create the scenarios and their architectural impact. Furthermore, an energy analysis of the designed refurbishment was carried out to identify the savings.

***Keywords*****:** Existing buildings, Building physics, Energy refurbishment, Energy efficiency.

## 1. Introduction

The adoption of EU legislation in the field of energy and environment call for new urban life quality indices [1] together with more comprehensive building performance metrics [2] for both inland and coastal areas [3]. Building retrofit becomes a hot topic due to its potential to include innovative technologies [4] and comply with urban waste management [4] and energy planning [5]. Energy and environmental retrofit can be tricky in modern architecture [6] if connected to renewable integration [7] and prioritizing the measures is needed [8]. Pushing the adoption of cutting edge technologies at building and urban level [9] should be beneficial in terms of economic [10], environmental benefits [11], thermodynamics [12] and ICT management [13] but conventional and established approaches are often more feasible [14]. Yet, energy planning tools show innovative energy strategies [15] applicable at large environments [16] and involving satellite data [17] to promote a specific renewable energy such as solar [18] or wind [19]. University campuses are between a codified urban level and a building one, comparable with the neighbourhood scale [20] when retrofitting must be planned [21] or GIS tool become suitable [22]. Previous research in this field led to single building retrofitting approach [23] together with testing small scale devices [24], providing cost-benefit analysis [25] and using building performance modelling with in-situ measurements [26] and simplified dynamic tool [27].

Environmental performance is a topic faced from two points of views: environment as indoor and as surroundings. For the first one, comfort analysis and link with energy use is essential [28] while, a wider meaning related to the second point of view entails pollution control and correlation [29] and effects on resource mapping [30]. This paper presents the energy and environmental retrofitting design for a University building located in Rome, Italy. As part of the implementation plan of smart energy solutions by Sapienza University of Rome in its building stock, the study is related to the barriers to overcome when energy refurbishment is designed for historic buildings as well as part of a listed complex due to its architectural values. The University already dealt with energy system improvements [31] or the upgrade of the energy supply [32] when all the building components cannot be modified or even the interior design is listed and neither the heating terminals can be substituted [33]. And, at the same time, where available in other branches the most innovative solutions mapped in other areas [34] are replicated and tested [35]. From the experience of a previous University building refurbishment [36], it is noteworthy to combine single measures for the best mix in terms of energy efficiency, energy flexibility potential [37] and sustainability as well. Sapienza University belongs to the Sustainable Universities Network, committed for improving energy and environmental performance of the campus.

## 2. Building and its history

Chemistry building, one of the largest in the campus, is selected as case study. It was built in 1938 as part of the complex “Citta’ Universitaria” as shown in Figure 1. The target of the Energy Masterplan for that portion of City is to have the so-called energy islands where each building interacts each other in terms of energy flows. This synergy [38] is foreseeable for existing and new buildings [39]. This novelty is beyond the selection of the best materials to retrofit a building even coping with constrained environment [40]. Indeed, more comprehensive analysis and metrics such as Life Cycle Analysis can be integrated to address multiple sustainability aspects [41].

The Chemistry building shows a regular and compact form together with a modular scan of the façade. This is suitable for replicable refurbishment design. Many interventions were already made during its lifespan to restore the injuries of the Second World War, to divide further rooms and adapt laboratories to safety regulations.

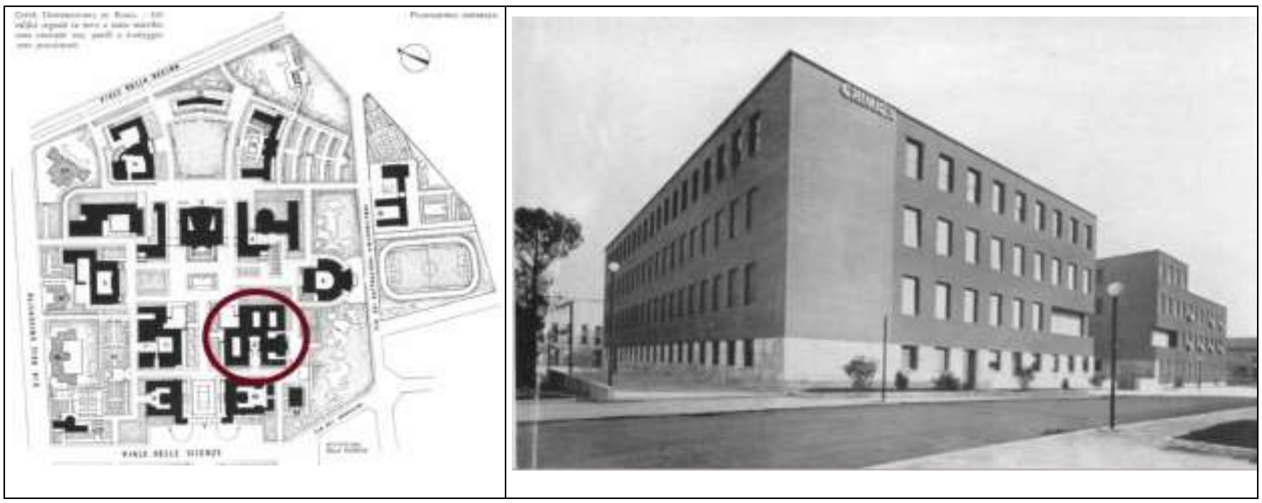


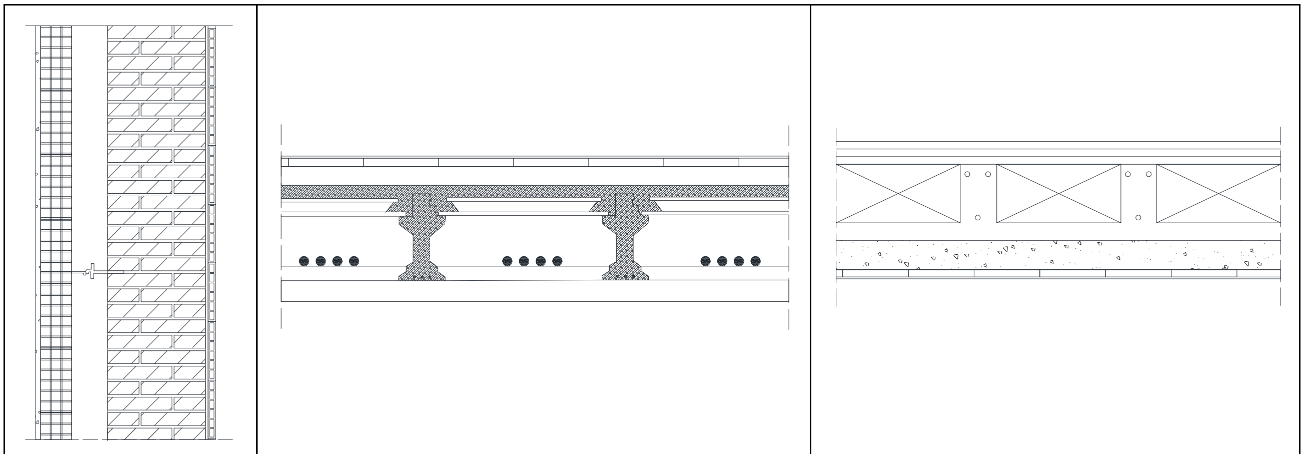
Fig. 1: a) Plan of Città Universitaria; b) Chemistry Building – picture of 1935.

In order to determine the performance of the building, components’ stratification was analysed by means of architectural drawings, archive’s material and in-situ surveys. Then, an abacus of wall, roof and floor structure was built along with the calculation of the equivalent U-value. It is reported in Figure 2.

In detail, the wall is made of three layers, two made of bricks where one is covered by stone and a cavity. While, the partitions are made of a single layer of pumice stone mix with good acoustic insulation. The floor structure is called “Varese” type, with a concrete beams and hollow flooring blocks.

Referring to the windows, they are present both in steel and wood frames. Those latter ones are the main part since wood is less sensitive to the vapour of the chemical reactions occurring in the laboratory rooms as well as no-reactive at magnetic forces. Steel windows are very large and step by step were substituted by aluminium ones.

Figure 3 shows the different mentioned types.



| | | |
|---|---|---|
| **a) U = 1,35 W/m²K** | **b) U = 1,38 W/m²K** | **c) U = 1,30 W/m²K** |

Fig. 2: Abacus of building envelope typologies and their wall construction.

Fig. 3: Windows' typologies.

From an energy point of view, a district heating network is present, supplied by a centralized boiler with 15 MW of thermal power. The water produced by it reaches 130°C. A thermal substation allows the connection between the building and the district heating pipe. Two heat exchangers of 450 kW are installed in it. Constant flow distribution system is there.

Heating terminals are radiators and fan-coils. The regulation system is not present. Cooling supply was not planned and splits with individual units were subsequently installed in the required rooms.

Furthermore, the Hot Water is locally produced in the toilets by installed electric heater. Based on this set of information, a model was built using Stima10-TFM software, which implements the procedures of the UNI 7357/74 for the calculation of winter thermal loads, the Transfer Function Method (TFM) ASHRAE for the calculation of summer thermal loads and calculations of UNI/TS 11300 (UNI EN ISO 13790 national adoption) for the final values of energy needs.

The building model was validated by comparison with the data from energy bills. The current situation is described by Table 1. According to energy label procedure, category D was identified since its fossil primary energy consumption is 99.7 kWh/m$^2$y. The renewable fraction is around 10.5%, calculated considering only the National energy mix from the Power Grid. The primary energy needed for heating purposes is 24.8 kWh/m$^2$y while, the one for cooling purposes is 37.5 kWh/m$^2$y. Furthermore, the average seasonal efficiency of heating system is 48.5%.

Table 1: Primary energy consumptions.

| | | Heating | Cooling | Hot water | Lighting | Total |
|---|---|---|---|---|---|---|
| Renewable | [kWh/y] | 0 | 35,288 | 703 | 177,938 | 213,929 |
| Non-renewable | [kWh/y] | 937,323 | 146,507 | 2,919 | 738,747 | 1,825,496 |
| Total | [kWh/y] | 937,323 | 181,795 | 3,623 | 916,684 | 2,039,425 |
| Renewable fraction | % | 0.0% | 19.4% | 19.4% | 19.4% | 10.5% |

## 2. Retrofitting interventions

Eco-architecture principles can be applied by using local materials [42] together with the analisys of renewable sources available to decarbonize the building supply [43]. Here, main interventions are related to the reduce energy consumption by means of lower U-values for each building component. Since the architectural values must be preserved since it is a listed building, insulation can be integrated in the cavity and not directly in the external façade, energy systems can be modified and the installation of new renewable plants can be done only on the roof. Further interventions possibly attacking this principles must be assessed by risk management matrix [44].

Previous research available for the Italian context provides guidelines for use of materials providing benefits in terms of energy savings [45]. Having said, the wall structure is improved by mean of inserting aerogel panels, a high performance material for tiny cavities. Pavement was further insulted by means of XPS rigid panels while, rock wool is applied to the roof structure to guarantee waterproofing. Finally, as regards the windows, single-glass windows were substituted with double-glass ones and low emissivity characteristics. Table 2 reports the values.

Table 2: U-value of building components.

| Description | Current situation | Proposed measure |
|---|---|---|
| | U [W/m$^2$K] | U [W/m$^2$K] |
| Vertical building envelope | 1.25 | 0.67-0.73 |
| Ground floor | 1.39 | 1.25 |
| Roof | 3.28-5.42 | 1.39 |
| Windows | 2.91-3.16 | 3.28-5.42 |

Referring to the energy system, a regulation system is the first measure to take to efficiently use the energy. Thus, heating terminals will be equipped with thermo-static valves. Then, the distribution system will be improved by allowing variable flow in the hydraulic loop. In terms of final use, the lamps will be changed with LED ones and the lighting control will be automatized as well.

As regards renewable energy sources, solar energy is the most suitable since the supply of the entire campus can be certified with sustainable biomass as studied in [46] to reduce the implications of this large impact decision [47]. So, on the roof a PV plants will be installed with 388 modules of 300 W for a total power of 116.4 kWp. The layout is shown in Figure 4. Considering all the proposed interventions, the achievable energy label is B, with a fossil primary energy equal to 54.6 kWh/m$^2$y, i.e. -50%, and with a renewable fraction of 20.9% deriving from the PV array and the National Grid contribution, as shown in Table 3. It allows reaching further energy flexibility level [48].

The primary energy needed for heating purposes is 8.8 kWh/m$^2$y while, the one for cooling purposes is 36.3 kWh/m$^2$y. Furthermore, the average seasonal efficiency of heating system is 60.4%.

Table 3: Primary energy consumptions.

| | | Heating | Cooling | Hot water | Lighting | Total |
|---|---|---|---|---|---|---|
| Renewable | [kWh/y] | 0 | 51,260 | 703 | 211,640 | 263,603 |
| Non-renewable | [kWh/y] | 399,860 | 110,041 | 2,919 | 486,817 | 999,637 |
| Total | [kWh/y] | 399,860 | 161,301 | 3,623 | 698,457 | 1,263,240 |
| Renewable fraction | % | 0.0% | 31,8% | 19.4% | 30,3% | 20.9% |

Fig. 4: layout of PV array location on the building roof.

## 3. Conclusions

An energy analysis of the Chemistry building was carried out to evaluate current performance and foreseeable values after the refurbishment. The interventions are designed on the building envelope, energy systems and renewable energy integration. Even in a constrained environment as a listed building, there are building technology solutions able to reduce energy consumption, make more efficient use of the available energy and possibility to install Photovoltaics to increase the renewable energy fraction of the consumptions. Within the framework of the Energy Masterplan for the Sapienza University Campus, each building is retrofitted and analysed to explore the reduction in energy use and the opportunities in energy production to contribute to a more sustainable building stock. This case study showed the methodology extended to the other buildings by tailoring the design to the peculiarities of each one.

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