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Energy Retrofitting of Social Housing Stock in northern Italy.

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Abstract

This research addresses the issue of energy retrofitting of 1970s social housing stock in northern Italy, still existing estates of multi-storey, concrete prefabricated developments, constructed in diverse Italian cities. The research identifies environmental advantages and limitations in the additional sunspace for the Italian climatic "zone E". Moving from knowledge gained through the analysis of existing examples of solar buildings developed under the U.P.S.E. European demonstration Project (1979-1983), the research explores technological aspects and amenity values of passive solar systems, paying particular attention to maintenance and management aspects which have resulted over time. The methodology framework is based on an analysis, consisting of in-situ fieldwork and thermal simulation of a case study building model, the Orbassano Solar Tower. Using the Energy Indexes reported in the official UPSE documentation, a performance reference level has been set as the basis for retrofitting analysis.
Several alternative retrofitting solutions are evaluated and compared to cost effectiveness parameters.

Keywords: energy retrofitting, sunspace, passive solar design, Italian social housing, building heritage rehabilitation.

1.1 Theoretical Background

Solar Architecture developments in Italy, took place in the civil sector in the wake of the energy crisis of the 1970s. From 1978 to 1983, a generation of studies and applications relating to solar energy was underway. Hence, important examples of multi-storey solar buildings, created in low-cost housing programs were developed in Italy. The I.A.C.P. Programmes in Milan and Lombardy, the U.P.S.E. in Piedmont and Cooperatives of Marostica in Veneto were all building programs that, besides being innovative in terms of technology and applications, were also instrumental in setting up a new relationship between designers, companies, researchers and industries (Pagani, 1986). Analysis conducted by Enea on documented solar building programmes, shows that the progression in solar building practises carried out in the early eighties has been constant in its growth, in part perhaps due to fully state-subsidised experiments.

The Experimental Programme U.P.S.E. (Piedmont Union of Building Developers a consortium of builders of the Piedmont Region), took place with the partial funding of the C.E.R. Housing Committee in 1980 to realize 17 solar buildings in the Piedmont region. In some of these cases, the architectural integration of active (collectors) and passive components were the main objects of research, later evolving into an architectural idiom itself. The CER/UPSE demonstration project was focused on the application of solar-air systems, not yet experimented in buildings at that time. Passive solar configurations such as *Barra-Costantini Systems, Sunspaces, Thrombe walls* and movable boards were integrated into the envelope itself. Active technologies such as solar-air collectors provided pre-heated air in winter via mechanical ventilation plant components integrated into the ceiling. Typical configurations associated with 1970s developments' in urban and suburban areas, as linear, high-rise buildings and row houses were experimented upon in the U.P.S.E demonstration project. Aim of the project were to measure thermal performances of the above mentioned buildings through appropriate monitoring systems, to compare the whole set of

experimental buildings through Energy Saving Indices and prove the effectiveness of the adopted solutions through the economic efficiency compared to conventional fuels (Pagani, 1990).

1.2 Achievements in Passive Solar Systems

With reference to the monitored results of the UPSE demonstration project, the energy performances of most of the experimented buildings receive the expected positive outcome. Whereas; in other cases, the negative impact of the global results were mainly related to human error at some point in the system installation, operation or maintenance but also the occupant attitude, poor basic energy cultural practises and/or other such tampering and miss-use. In some 1970s examples of passive solar systems, there was a lack of widespread culture regarding building details able to ensure both energy efficiency and user friendliness. Codes of practice and a clearer simplification in the management of the systems would have made life easier for the average user.

The encouragement of a reasonable level of passive-intelligence would have been too expensive for social housing developments in the 1970s, whereas today a much more widespread automation in the construction market could result effective for the improvements of some passive solar systems' performances. Looking at comfort and well being as perceived by the occupants in the majority of cases, passive solar buildings enjoy perhaps the influence of radiant exchange between the mass surfaces and the surface of the human skin (Onbasioglu et al, 1982). These features, combined with the real opportunity to enjoy the amenity value of an additional space, have been the main factors behind the sunspace success and diffusion. Sunspace is therefore chosen to be an important strategy to apply solar energy in a refurbishment since the concept helps to solve main renovation problems together with potentially major energy savings. Thus, precedent examples represent today important references for current retrofitting activity.

2.1 Precedent Case Study – Orbassano Solar Tower

One of the most successful passive Solar Buildings carried out by UPSE Demonstration Project has been the Orbassano Solar Tower, completed in 1984 by the firm Gabetti and Isola Architects and located on the outskirts of Turin at the foot of the Chisone Valley, 45° North Latitude. Morphologically the building site is flat, with good solar access, unobstructed by the surrounding developments. The average temperature in summer is about 20°C, with peaks in July reaching 30°C, 2880 degree-days (reference temperature 20°C), and mean daily global horizontal irradiation of 4000 Wh/m^2 (Pagani et al, 1983). The tower is a ten-storey prismatic volume, orientated towards the sun. The sunspace on the southeast and southwest symmetrical façades display a full high curtain wall screen. The plan is composed of four apartment types; two double exposed, organised according to a three bedroom layout, and two characterised by a single orientation respectively one and two bedroom flat. The leading building material used for the structural system was reinforced concrete, cast on-site using metal moulds (coffrage tunnel). In winter, the air is preheated by the air-solar collectors placed on the vertical chamfered front of the building (Figure 1). In summer, the air-flow-rate through the collectors is used only for hot water production. Individual thermostats control the indoor temperature and the system's adjustment is carried out by three-way valves on the two heating loops (Figure 2), the auxiliary energy consumption for space heating is metered for each dwelling unit.

2.2 Measurement Result Display

As resulting from the three-year measurement campaign, a representative week of February 1987 is displayed for winter, and August 1986 for summer. Figure 4 and 5, displays the air temperature monitored in the south-west facing flat, on the exhaust air duct, where air is sufficiently mixed. The thermostat is set at 20° Celsius. The graph shows the temperature trend within the sunspace, the room adjacent to the sunspace, north oriented room and outdoor temperature during a sunny February day.[1] During sunny hours, the sunspace achieves temperatures peaks above 30° Celsius. The concrete wall of 0.15 meters of thickness collects heat in its mass during the daytime. The wall's thermal transmittance placed in between the sunspace and the adjacent room is 0.69 W/m^{2}K and the time of inertia is about 3.5-hours delayed. In mid-season, when the occupant opens the

internal window, the collected heat that is slowly released after the sunny hours, contributes to maintain the internal temperature in comfort. Night time temperature lead a consideration on the comfort conditions that a similar space can provide in the middle season, when the external temperature drops down and the mean radiant temperature, due to the convective heat transferred from the concrete wall, affects the perceived sensation of comfort.

A thermal simulation model has been calibrated according to building construction materials and thicknesses published in the official reports of European Communities Commission, General Directorate Energy – DGXVI, SE/0028/81/IT, UPSE Demonstration Project for Orbassano solar tower. Measurements reported from the monitoring campaign have been used as the main term of comparison with the simulation results to assess the accuracy of the calibration. Assumed input values arose from fieldwork observations and occupant interviews. The operation was carried out through the use of Edsl Tas 9.1.4.1. software.

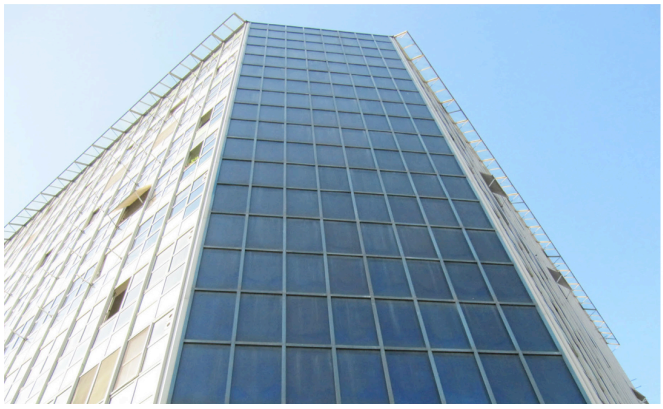
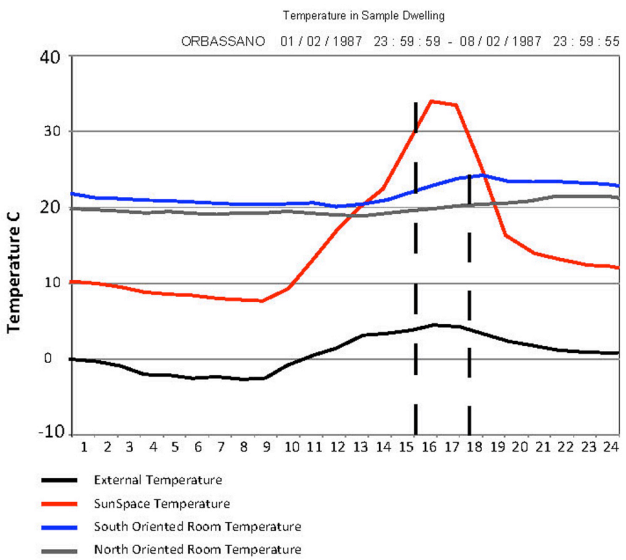


Figure 1. Orbassano Solar Tower, 205 m^2 of solar-air collectors. Figure 2. View from the sunspace. Figure 3. User Management Control System, individual thermostat.



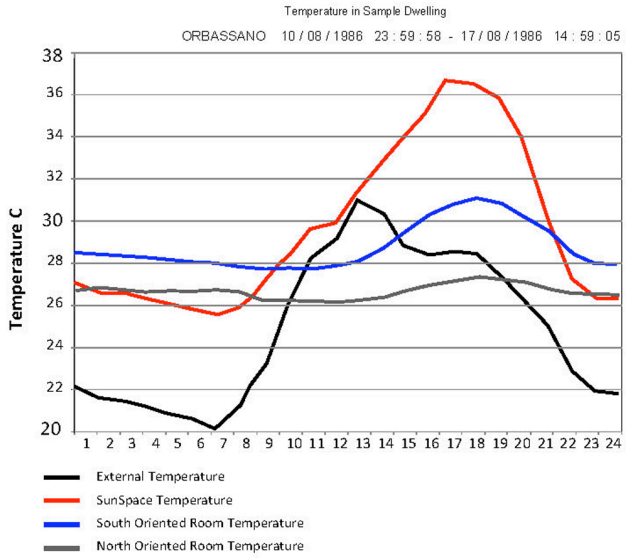


Figure 4. Winter temperature display. Figure 5. Summer temperature display.

2.3 Analysis Results

Evaluation on the sunspace energy contribution carried out in the UPSE demonstration project for the Orbassano case study, can be extended to the Italian “Climatic zone E”, 2100 - 3000 degree days. The sunspace, consisting of a single glazed layer covering the south facing façades, not heated or cooled by mechanical means, enclosed on all sides, attached and accessible from a dwelling, can represent an efficient energy saving solution. In this climate the percentage of space heating covered by the passive system can reach values around 5-7% in December and January, while in

spring and fall it can cover about 90%.

Owing to its highly glazed envelope and lightweight construction, its interior is sensitive to fluctuations in outdoor temperature and sunshine. In turn, the environmental conditions prevailing in the sunspace, can affect the temperatures, ventilation, solar gain and daylight conditions in adjacent spaces. "Accepting its nature as an intermediate space with a variable microclimate, clearly not a suitable space for continuous occupation throughout the year", the sunspace provides, during certain periods of the years, such as sunny winter hours, spring and autumn, the opportunity to extend comfort conditions, contributing to occupant fulfilment in the ability to make choices and control the environment, which is a critical aspect in the satisfaction of users (Isague et al, 2006).

The percentage of space heating consumption covered by the sunspace is directly related to its geometry, material property, orientation but most importantly, the factor which affects the performance level of the system over time is *how occupants use this additional space.* On the one hand, experiences have furnished examples, which indicate that occupants, who are reluctant to accept system control, prefer to renounce maximum efficiency. In other cases, the most successful have demonstrated that energy efficiency and consumer confidence in the system increase over time. Occupant attitude in the management of the system is therefore directly connected to the additional value that the system can provide.

3.1 Energy Retrofitting Hypothesis

Based on official documentation of the UPSE demonstration project, thermal transmittance values of a traditional building used as a benchmark for the standard 373 and the previous construction standards have been set. An analysis of the typical 1970s social housing construction technology has been conducted and it has been possible to set a transmittance value for opaque elements of *0.75 W/m^{2}K*, which has been a reference for the investigations on 1970s buildings and the energy-retrofitting hypothesis. Table 1. shows the set transmittance values, referring to the main envelope characteristics for each regulation phase that has occurred over time in Italy.

Table 1. Set transmittance values in relation to different regulation phases in the Italian national legislation.

	before Act No.373	**Act No.373 of 1976**	**1980 UPSE**	**Act No.311 of 2006**
Opaque Construction Elements	0.75 W/m^{2}K	0.75 W/m^{2}K	0.6 W/m^{2}K	0.3 W/m^{2}K
Transparent Elements	Single Glaze	Double Glaze	Double Glaze + sunspace SG	Double Glaze Low E

One of the most representative of 1970s developments for its traditional social housing characteristics is the Gratosoglio neighbourhood (1963-1971). It was realized on a settlement capacity of 15,000 inhabitants on the extreme outskirts of Milan in a four-year housing plan.[2] Modular dwelling typologies alternate themselves in one- and two-bedrooms apartments. Linear buildings are oriented north-south and east-west. The insulation layer, positioned on the internal side of the prefabricated concrete layer, has allowed the elimination of thermal bridges through the pillars but not at floor level. (D'Amato et al, 2004).

The building transmittance values have been improved according to four different scenarios where retrofitting strategies have been simulated. Traditional retrofitting operations such as the replacement of windows and the addition of insulation coat resulted the most efficient strategies for space heating with 48% reduction of energy consumptions. The two addition strategies (fig 8, 9)

were evaluated considering both the localised sunspace incorporated into the existing balcony and the extended sunspace adjacent to the entire facade. In the addition strategy single glazed windows have not been replaced. A thermal insulation coat has been considered where the sunspace does not cover the facade. The saving percentage on space heating consumption for both sunspace cases is 40%. Higher comfort conditions are achieved in summer when the sunspace covers the whole façade by shading the concrete perimetal wall. In both cases an additional space is provided for the occupants. The thermal simulation did not consider the contributions of winter pre-heating air, which can minimize heat losses due to ventilation in winter.

3.2 Cost Effectiveness Evaluation

The insulation coat is the most profitable and for this the most practical. It seems unnecessary to point out that the economic investment for the construction of an insulation-coat, and in general for the insulation of any high energy building, although substantial, is easily amortized over an average of about 10 years, due to significant energy savings achieved (42 kWh/m^2 year) coupled in Italy with the 55% tax relief provided by recent Finance Acts. The average recouped on cost time for each intervention has been calculated taking into account the price of fuel (fixed quarterly by the Authority), the average cost of each material used (values were calculated per m^2 unit according to the official price list of Lombardy region) and the energy savings achieved.

By dividing the amount of the expenditure for retrofitting with the annual saving value related to the energy cost, it was possible to obtain the number of years required for payback of the investment. The calculation has been updated according to an inflation index of 2%. Percentage impact of each item of retrofitting activity was analysed. Calculation results show that in a period of 20 years (excluding tax benefits) both the costs for retrofitting by using the sunspace incorporated into the balcony and the insulation coat are cushioned. More maintenance costs arise from a traditional building façade than compared to a sunspace, which has demonstrated no need for maintenance cost over a period of 40 years (Orbassano). The strategy of the insulation coat has a higher energy saving but on the other hand requires higher costs for painting and a little maintenance every 10/15 years.

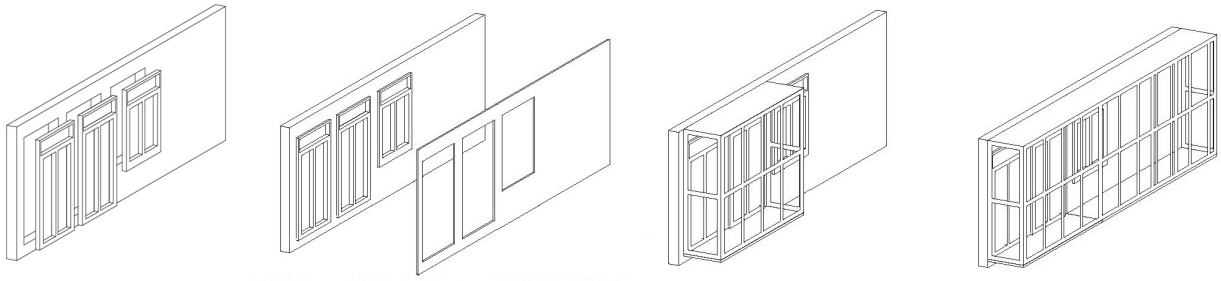


Image 6. Transparent Element Replacement with Double Glazing Low Emissivity - Image 7. Transparent Element Replacement and Insulation Coating. - Image 8. Additional Sunpace on the balcony. - Image 9. Additional semi independent Sunspace on the façade.

Table 2. Heating load reduction in % per each retrofitting strategy.

	Double Glaze + Low E	Glazing and Insulation	Sunspace Balcony	Semi-independ. Sunspace
Heating Loads % saving	33%	48%	40,2%	40,2%

3.3 Conclusion

The retrofitting project aimed at upgrading the energy efficiency of residential buildings has a wide range of possible action. The thermal insulation-coat represents a good cost-effective compromise. Considering the limits of available economical resources compared to the size of social housing building stock to be upgraded, this option is a practical means to remedy the problem.(Di Giorgio et al, 1998). However, in the evaluation of technological solutions used for

energy retrofitting, it should be taken into account not only of the reduction of energy costs due to operational period, but also construction and maintenance costs. The latter aspect is particularly significant in the retrofitting processes since the durability of materials and the impact of technologies used identify the intervention break-even. Demonstration projects underline how occupant's attitude, in the management of the sunspace, was directly connected to the additional value that the space could provide, demonstrating that energy efficiency and consumer confidence in the system increase over time. Moreover the sunspace durability, little or no maintenance, use of conventional building materials, is a reliable, low-costs, and a long system lifetime. The "addition strategy" can improve quality of life of occupants and can involve transformative effects on the building's image (Gaspari, 2010).

Sunspace structural configuration and build-ability therefore need a number of important technological and constructive assessments. The need to preserve the building in the time and the possibility to intervene from the outside when this is occupied by its inhabitants, can be achieved through the sunspace "addition strategy". It is important that sunspace geometry allows occupants to use it, without reducing the amount of natural light and ventilation in the adjacent dwelling spaces. Due to different geometrical characteristics, the incorporation of balconies and loggias in 1970s heritage, do not always guarantee the additional amenity value that Orbassano sunspace could provide. Once urban planning boundary conditions are analysed, and the sunspace can represent an alternative retrofitting, decisions on whether to add a sunspace can be influenced also by distances and obstructions from the closest buildings, however this problem can be solved by splitting the operation into elements of smaller size and distributed in relation to the constraint factors. To improve the envelope stratigraphy and its thermal behaviour, it is therefore possible to operate according to a localised or extended addition strategy.

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